Minnesota Public Safety Interoperable Wireless Data Feasibility Study

Deliverable #11: Final Report

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Prepared by:

"Unleashing the Power of Technology"

Federal Engineering®

Federal Engineering, Inc.
10600 Arrowhead Dr, Suite 160
Fairfax, VA 22030
703-359-8200

Executive Summary

FE was tasked by the state of Minnesota to conduct a Public Safety Interoperable Wireless Data Feasibility Study (WDFS). The purpose of the study is to provide the Minnesota Department of Public Safety (DPS) and the Minnesota Statewide Radio Board (SRB) with a comprehensive assessment of the current state of wireless public safety data technology and of alternatives upon which to develop a comprehensive strategy for interoperable public safety data (including local, regional or statewide) within the state of Minnesota. In a series of deliverables leading up to this final report, ***FE*** examined in excess of 20 potential wireless data technologies considered appropriate for implementation of a public safety interoperable Mobile Data System (MDS) leveraging the state's investment in Minnesota's Allied Radio Matrix for Emergency Response (ARMER) Project 25 (P25) voice radio system infrastructure.

Given the relatively large capital investment required to implement a state owned (or private) mobile data system, the state should first consider the use of established commercial mobile data services. As described in Section 1, commercial mobile data services were assessed early in this project[1]. This final report provides a thorough assessment of the strengths and weaknesses of the implementation of a state owned dedicated public safety mobile data system should a public/private partnership with a commercial carrier not be achievable or practical.

Following a full evaluation of the alternatives available[2], the following four stand alone MDS technologies were selected to be examined in depth in this report:

- Association of Public Safety Communications Officials (APCO) P25 Integrated Voice and Data (IV&D), with the ability to switch to a broadband network or commercial service
- Motorola High Performance Data (HPD), with the ability to switch to a broadband network or commercial service
- CalAmp Dataradio, with the ability to switch to a broadband network or commercial service
- Worldwide Interoperability for Microwave Access (WiMAX) broadband

Having completed a full and thorough evaluation of these four technologies, ***FE*** recommends that if the state is to adopt a comprehensive strategy based upon the listed technologies, the state consider a hybrid approach to support the hypothetical requirements used as the basis of this report. This hybrid approach would involve

[1] Wireless Data Technology and Commercial Service Assessment (WDFS Deliverable 3), Appendix C
[2] Commercial services were not incorporated into the full evaluation of alternatives.

implementing a wide-area technology that can provide a minimum of a Tier 2 service, (defined as having a throughput of 96 Kbps) and gradually supplement that system with broadband 'hot spots' to support higher speed Tier 3 and Tier 4 services in more populated areas of the state. Higher levels of service that can support Tier 3 or Tier 4 applications over a large portion of the state would be ideal, but would not be practical or financially feasible. Detailed descriptions of the application tier levels can be found in Section 1.3 of this report.

Each wide-area technology assessed in this report has their own advantages and disadvantages, but the ideal choice becomes clearer as one considers two key factors, data throughput rate and capital cost. Based on these factors, ***FE*** recommends that a deployment of the Dataradio platform for a wide-area mobile data network, which is capable of supporting Tier 2 services, should be the basis of the state's comprehensive strategy for an MDS.

After exploring WiMAX broadband technology in detail, ***FE*** finds it to be a feasible solution for localized 'hot spot' Tier 3 and Tier 4 services throughout the state, in population centers of 25,000 people or more. Other 'hot spot' technologies such as WiFi already in place may be very feasible and cost effective supplementary services. ***FE*** recommends that the state strategy include the implementation of software-based switch (or 'middleware') in each mobile client laptop that automatically selects the appropriate service and enables applications within a Tier appropriate for the available service level.

It is important to note that the availability of 700 MHz 50 kHz data channels are pending the FCC's decision on the 700 MHz 'D-Block'[3], which includes a discussion of a national public safety data network. Technologies that use 50 kHz channels will provide higher data throughput rates; however, development of products and technologies for those channels are currently on hold as vendors await a final determination of the D-Block. Currently, only 25 kHz channels are available.

FE recommends that the state perform a full evaluation of commercial services available, similar to the analysis of the state owned options provided in this report. This evaluation should measure the available commercial services to the functional requirements established, compare data throughput rates, interoperability, technology update intervals and service priority. The state should also develop a cost benefit analysis comparing the long-term costs (capital and recurring) associated with private/state-owned versus commercial wireless solutions. At a minimum, the analysis

[3] Minnesota Public Safety Interoperable Wireless Data Feasibility Study-FCC D-Block Report and Assessment, (Deliverable 4), Appendix D of this report

should compare the return on investment of a private mobile data system to the recurring costs associated with leasing airtime on a commercial mobile data system.

Commercial systems are established, in place, and operational with system owners responsible for the maintenance. With commercial systems, there are no overhead costs associated with system maintenance, no capital funds required for infrastructure replacement, and the consistent recurring monthly costs are easily projected. The only foreseeable capital cost required is the procurement of the mobile client equipment. However, the state would have minimal control and decision making authority because the state would not own the system.

To counter the potential lack of control, the state should consider the possibility of entering into a public/private partnership with a commercial wireless carrier. This may give the state more control and decision making authority regarding the operation of the network. For example, the state could offer the use of their ARMER infrastructure such as towers and shelters in return for discounted and/or priority use of the carrier's system, thus saving the state the relatively large capital investment required to implement a state owned (or private) mobile data system. These relationships have the potential to be mutually beneficial and ***FE*** would strongly recommend any resulting agreement explicitly define the responsibilities and expectations of both parties.

Above all, ***FE*** recommends that the state perform a more detailed analysis of the applications and functional requirements required by agencies that are likely to use the MDS. A Tier 2 system may be more than adequate to support the loading defined in the hypothetical functional requirements. Broadband solutions or other alternatives should only be considered if it is determined that a network capable of supporting Tier 3 and 4 applications is actually required.

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1. Introduction

This document constitutes ***FE***'s final report of the Minnesota DPS Interoperable Wireless Data Feasibility Study (WDFS). The following section provides project background and details of each task leading up to this final report.

1.1 Current public safety communications in Minnesota

The state of Minnesota implementation of a statewide public safety radio communications system is known as the Allied Radio Matrix for Emergency Response (ARMER). It is a 700/800 megahertz (MHz) trunked communication system using the Project 25 technology for voice communications. The backbone for the ARMER system was initially constructed in 2001 in nine counties (Anoka, Carver, Chisago, Dakota, Hennepin, Isanti, Ramsey, Scott, and Washington) in the Minneapolis/St. Paul metropolitan area. The cities of Minneapolis and Richfield and the counties of Carver and Hennepin added infrastructure to provide additional capacity and coverage for local agencies. Following the initial implementation, the counties of Anoka, Ramsey, Dakota, and Washington integrated their local public safety communication operations on to the ARMER system. Scott County will integrate its public safety communications operations on to the ARMER system in 2009.

In 2005, the Minnesota legislature provided funding for the continued implementation of the ARMER system into 23 counties of central and southeastern Minnesota. That implementation is currently underway and will be completed in 2009. In 2007, the Legislature authorized implementation of the ARMER system in the remaining 55 counties of the state. The Minnesota Department of Transportation (MnDOT) has completed the detail design for that implementation with completion of the statewide implementation anticipated by the end of 2012. The ARMER backbone network consists of radio sites and microwave links (also known as 'backhaul'). Excess capacity of these infrastructure components could be used by systems other than the ARMER voice radio system.

In 2007, the Minnesota Department of Public Safety (DPS), Division of Emergency Communication Networks (ECN) coordinated the development of a Statewide Communication Interoperability Plan (SCIP) consistent with the SAFECOM program criteria adopted by the U.S. Department of Homeland Security (DHS) and U.S. Department of Commerce (DOC). SAFECOM is a public safety communication interoperability program operated by DHS and information on that program and the

criteria can found at http://www.safecomprogram.gov/SAFECOM/. As part of the SCIP, Minnesota articulated its strategy for the implementation of interoperable public safety data. A review of existing public safety mobile data networks demonstrated the following three approaches:

- Regional Enhancements – The Metropolitan Emergency Services Board (also referred to as the MESB is a subordinate regional radio board covering the metropolitan area) is working with Hennepin County to implement a region-wide wireless public safety data network over the ARMER system in the metropolitan area, using the ARMER backbone. Hennepin County was the recipient of a Community Oriented Policing Services (COPS) grant, which provided funding for this implementation as a regional enhancement to the ARMER system. The radio component of the data network is distinctly separate from the radio component of the voice network, but they are compatible systems that might be integrated into one voice and data network in the future.
- Minnesota State Patrol Data System – The Minnesota State Patrol has a mobile data system across major portions of the state, utilizing towers and microwave capacity that are or will be part of the ARMER infrastructure. As it exists, that system is not capable of providing significant wireless Internet Protocol (IP) connectivity for a broad category of public safety users, but may provide a foundation for the evolution of wireless data as part of Minnesota's broader wireless interoperable data initiatives to strengthen information sharing and collaboration capabilities..
- Local Data Systems – A number of counties have implemented local wireless data systems and in some cases, those local data systems have been implemented on a regional or multiple county basis.

In addition to these approaches, a number of law enforcement agencies in the Minneapolis/St. Paul metropolitan area use commercial wireless data networks provided by cellular telecommunication providers.

The DPS has coordinated a comprehensive program for the integration and sharing of public safety databases throughout the state. The CriMNet program operated by the Bureau of Criminal Apprehension (BCA) seeks to broadly coordinate the integration of information between local, regional, and state government agencies and to make that information available to public safety officials when and where it is needed. Developing a strategy for the provision of wireless mobile data across the state would clearly support the objectives of the CriMNet program by providing broader access to public safety data to public safety officials.

The Minnesota Office of Enterprise Technology (OET) provides a secure intranet environment for the state's public safety community of agencies. This statewide network

has a 15-year history of leveraging private sector telecommunications facilities and services to deliver a common, secure, reliable, and high-capacity IP network services to over 400 locations within the state's public safety community. This includes all of Minnesota's 87 county government centers including county sheriff offices, numerous city police offices, several tribal governments, departments of Public Safety, Health, Corrections, Transportation, Natural Resources, Pollution Control, Agriculture, Military Affairs, and State Courts, the Office of Governor, and the Legislature.

The OET architecture provides Multi-Protocol Label Switching (MPLS) IP network services using a high-speed backbone network that consists of transmission facilities leased from telephone companies, cable companies, and utility companies. This network has been in service since 1993. The backbone network consists of a mesh of environmentally hardened network hubs and regional aggregation points. These hubs aggregate IP traffic locally and regionally and route traffic to its destination.

Currently, the network has 30 hubs and aggregation points interconnected by OC3, OC12, 100Mpbs, and Gigabit Ethernet transmission facilities. The converged IP voice, video, and data network utilizes Quality of Service (QoS) techniques to guarantee delivery of time-sensitive and critical network applications. It provides access to the Internet, Internet2, National Lambda Rail Network[4], and several private provider networks.

Minnesota has been monitoring the progress of the Federal Communication Commissioner (FCC) 700 MHz D-Block auction and the Public Safety Spectrum Trust. Based upon the results of the first auction and the current outlook for the continued development of a nationwide public safety data network in the 700 MHz spectrum, the state should:

- Perform a broader assessment of the current state of the wireless data technology
- Monitor the development of standards necessary to assure interoperability
- Investigate strategies and alternatives that might be adopted by the state and local governments to provide wireless data

In 2004, the Minnesota Legislature created the Statewide Radio Board (SRB) to provide operational and technical oversight for the implementation of the ARMER system. The Legislature designated the SRB as the State Interoperability Executive Committee (SIEC) and expanded its role to provide broader coordination of public safety

[4] National Lambda Rail Network is a unique nationwide network infrastructure that is owned and controlled by the nation's research community to support experimental and production networks, foster networking research, promote next-generation applications, and facilitate interconnectivity among high-performance research and education networks. See www.nlr.net/about/

communication throughout the state. In addition to the SRB, seven Regional Radio Boards (RRBs) have been established throughout the state to support regional participation and planning on public safety communication issues. This governance structure provides the basis for statewide and regional planning necessary for the development of various approaches to public safety data.

1.2 Minnesota wireless data feasibility study project background

Early in this project, ***FE*** developed a list of potential wireless data technologies considered appropriate for implementation of a public safety wireless data network utilizing Minnesota's ARMER P25 voice radio system backbone. These technologies were grouped into 4 categories:

- Low Speed (Integrated Voice and Data) - Integrated Voice and Data (IV&D) technologies are advantageous when voice is required and only low speed data applications such as CAD, text messaging and low volume report writing are anticipated; an IV&D solution can be economical in that respect. If higher data rates are required, a stand-alone data system would be more suitable.
- High Speed (VHF/UHF/700/800/900 MHz Stand-Alone Data) - High speed, or stand-alone, data systems operate in the same bands as the IV&D systems. These systems, however, transmit data only, with all bandwidth and resources dedicated to data, thus providing higher data rates. This 'high speed' market has created a niche filled by vendor proprietary (not open standard) products.
- Broadband – Broadband technologies utilize wider or 'broader' channels (or frequencies); these broader channels allow for greater data rates. Mobile data technologies available in the broadband spectrum may be proprietary or based on an open standard.
- Commercial services - ***FE*** also created a list of potential commercial service providers with wireless data networks operating within Minnesota which may be suitable to provide wireless public safety data services.

FE developed a high-level report '*List of ARMER-based Wireless Data Technologies and Commercial Services*', listing the potential technologies and commercial services. This report also provided high-level system descriptions and technical information such as the technology protocol (or type), frequency band availability and data rates offered. From this list, ***FE*** and the Minnesota DPS chose 10 technologies to further assess:

- APCO P25 IV&D
- M/A-COM OpenSky
- Motorola HPD
- Dataradio
- WiMAX

- TD-CDMA
- Long Term Evolution (LTE)
- Verizon (Commercial Wireless Service Provider)
- AT&T (Commercial Wireless Service Provider)
- A Better Wireless (Proposed Commercial Wireless Service)

FE then developed a second report '*Wireless Data Technology and Commercial Services Assessment Report*' providing more detailed system technical information such as data transport mechanism(s), coverage, application, equipment, implementation, expandability/scalability, backhaul requirements and standards adaptability. This report also included assessments from agencies currently utilizing these technologies including their user's perspective. The information contained in the report assisted the state of Minnesota in selecting the most viable mobile data technologies for further analyses.

The assessment of commercial services provided above was limited to information available from the vendor. Those services were not included for further assessment based upon the limited ability to evaluate the commercial services against the functional requirements at different levels. From a broad perspective, the state of Minnesota has indicated an interest in the continued consideration of the potential to include commercial services as an element of any mobile date system solution and may be interested in pursuing a public/private partnership for the purpose to expand commercial data service coverage in underserved portions of the state.

Based on the detailed information provided in the second report and as noted above, the list of technologies was 'shortlisted' to the following four solutions:

- APCO P25 IV&D, with the ability to switch to a broadband network or commercial service
- Motorola HPD, with the ability to switch to a broadband network or commercial service
- Dataradio, with the ability to switch to a broadband network or commercial service
- WiMAX

FE subsequently developed a broad list of high-level functional requirements for a county, regional, and statewide mobile data system (MDS) implementation based on industry experience and on functional portions of technical specifications found in request for proposals (RFPs) from existing mobile data systems procured by competitive bids. Beltrami County and the Northwest Region were chosen as models for the requirements and subsequent solution assessments. To assess these four

solutions, ***FE*** developed proposals representing each of these four solutions responding to the defined functional requirements. This report contains the full assessment of each solution, including point-by-point responses to each of the functional requirements.

Note that these functional requirements only address the system layer; deployed applications will require a separate set of functional requirements that match the mobile data system's capabilities. ***FE*** recommends that the state thoroughly research potential mobile data applications to ensure compatibility with a selected MDS solution.

1.3 Mobile data application tiers

This section contains a listing of potential Minnesota public safety mobile data applications. Subsequent sections of this report address the technologies and identify the set of applications that each can support. Each technology discussed provides a maximum throughput rate and each public safety application requires a minimum throughput rate, measured in bits per seconds (bps). In this section, we have classified potential public safety applications into tiers according to the throughput required for the application to operate satisfactorily. Each application Tier is determined by a data rate range and has an associated set of example applications. The following defines each Tier, the associated data rates, and potential applications under that Tier.

Tier 1 - 'Text' Applications (Up to 19.2 kbps)

- Messaging
- Dispatch (CAD)
- Text messaging
- Query Databases
- Driver's license
- License plates
- Warrants
- Low cadence AVL

Tier 2 – 'Still Image' Applications (Up to 96 kbps, 25 kHz channels)

- Includes Tier 1
- Field Reporting
- Still Image Transfer
- Mug Shots
- High Cadence AVL
- Fingerprints (Inbound only)
- Intranet

Tier 3 – 'Browser' Application (Up to 230 kbps, 50 kHz channels)

- Includes Tier 1&2
- Internet Access
- Images (Tx/Rx)
- Video (low bandwidth)

Tier 4 – 'Multimedia' Applications (Megabits)

- Includes Tier 1-3
- Desktop applications
- Video (full motion)
- Multimedia

1.4 Purpose of this report

As mentioned, this document contains high-level hypothetical proposals for an MDS based on the four solutions described above. Based upon the high-level functional requirements developed earlier in the project, ***FE*** developed these proposals to represent implementations in a single county, single region and throughout the state. ***FE*** and the state of Minnesota DPS chose Beltrami County as the county model and the counties represented by the Northwest Regional Radio Board (NW-RRB) as the regional model for the WDFS. This scalable plan will serve as a template for other counties or regions. Beltrami County and the NW-RRB were chosen to exemplify the viability and impact of implementing any of the technologies selected.

These proposals include system descriptions and the capabilities provided within the county, region and state. The proposals also provide descriptions of the implementations and rough order-of-magnitude (ROM) cost estimates for consideration. In addition to these items, each proposal provides an assessment of the following:

- How well the implementation addresses the functional requirements
- The benefits and disadvantages of the technology over other technologies and any limitations upon the use of the technology
- Whether the technology is adaptable to any recognized interoperability standards
- Any other attributes or issues generally considered relevant to the implementation and use of the technology

FE views the development of these proposals as one of the most critical tasks of this project. These proposals are essentially the business cases for each technology.

Information contained in this report will assist the state of Minnesota in developing a statewide MDS strategy that will potentially leverage the infrastructure of the ARMER P25 voice radio system.

Many MDS functional requirements developed are based on different applications assigned to various 'Tiers' described above. The application requirement is the most prominent factor in determining whether a viable MDS solution addresses the needs for an agency or group of agencies. The responses to the functional requirements in these proposals will consider the state of Minnesota's application requirements according to these Tiers.

1.5 Overview of this document

Section 1 provides an introduction and overview of this document. This section provides backgrounds of both the current status of public safety communications in Minnesota and the Minnesota Public Safety Interoperability Wireless Data Feasibility Study project. It contains a listing of potential public safety mobile data applications and the typical data transmission rates each of these applications require.

Section 2, 3, 4 and 5 contain the hypothetical proposals for P25 IV&D, HPD, Dataradio and WiMAX, respectively. Each proposal contains a system description and system implementation information relevant to the proposed MDS for Beltrami County, the Northwest Region, and the state of Minnesota. These proposals also identify any interoperability standards that these technologies may satisfy, system capabilities by addressing the functional requirements noted above, and discuss the advantages and disadvantages of each technology compared to the other technologies under consideration. The final sections provide a ROM cost estimate for each of the proposed systems for Beltrami County, the 14-county Northwest Region and the state of Minnesota.

Section 6 provides ***FE***'s conclusions and recommendations for the Minnesota WDFS.

Several appendices are included:

- Appendix A – Glossary
- Appendix B – Index
- Appendix C – Wireless Data Technology and Commercial Services Assessment Report (Deliverable 3)
- Appendix D – FCC D-Block Report and Assessment (Deliverable 4)

2. APCO Project 25 IV&D

2.1 System description

The proposed Motorola P25 IV&D MDS expands Motorola's P25 mission critical platform by adding data capabilities to the existing Project 25-based ARMER system. As such, it provides a scalable interoperable multi-agency network that will:

- Provide reliable mobile data communications leveraging the existing P25 ARMER system, sites and equipment
- Provide a migration path to a standards based, open-architecture platform
- Be capable of supporting multiple data networks such as Motorola HPD and High-Speed Data (HSD), WiFi, WiMAX and other private and/or public networks with the ability to roam between networks using mobile router/switching technology
- Be capable of expanding the service area as other agencies, counties and/or regions are added to the system
- Operate in public safety licensed spectrum

The P25 IV&D overlay system provides a raw data rate of 9.6 kbps and delivers an approximate data throughput of 4.8 to 7.2 kbps, depending on the application and data message type. This system will provide connectivity for Tier 1 applications, as defined in section 1 of this document.

The proposed P25 IV&D MDS can be implemented as a 'layer' over the state of Minnesota's Allied Radio Matrix for Emergency Response (ARMER) P25 voice radio system; the coverage of this MDS would be similar to the ARMER P25 voice radio system. These systems can share backhaul and infrastructure facilities as well as core switching equipment, as these components are designed to be fully integrated and essentially are the same system.

The P25 IV&D system can operate in both the 700 MHz and 800 MHz spectrum utilizing standard 12.5 kHz channel spacing. It is based on open standards, such as TIA-102 (P25), Internet Protocol (IP) and Transmission Control Protocol (TCP) to ensure ongoing compatibility with current and future equipment and software. The over-the-air protocol, that allows the wireless communications between the mobile client and the base station, is also standardized under the P25 suite of standards.

Motorola P25 IV&D systems are expandable and scalable to the extent of the agency's needs. Additional radio sites should not be required as the P25 IV&D coverage will be

the same as the existing ARMER P25 voice radio system coverage. Additional channels can be added to the system to meet the anticipated capacity requirements. These channels would expand the capacity of the system for both voice and data traffic.

The proposed P25 IV&D systems contain many of the familiar components of a traditional wireline data network. Motorola would supplement, as required, the Ethernet local area network (LAN) at the master and base sites, which will connect to the state of Minnesota backhaul network, providing connectivity between the master and base sites. Figure 1 below is a high-level system diagram depicting the major components of the proposed P25 IV&D MDS fixed equipment.

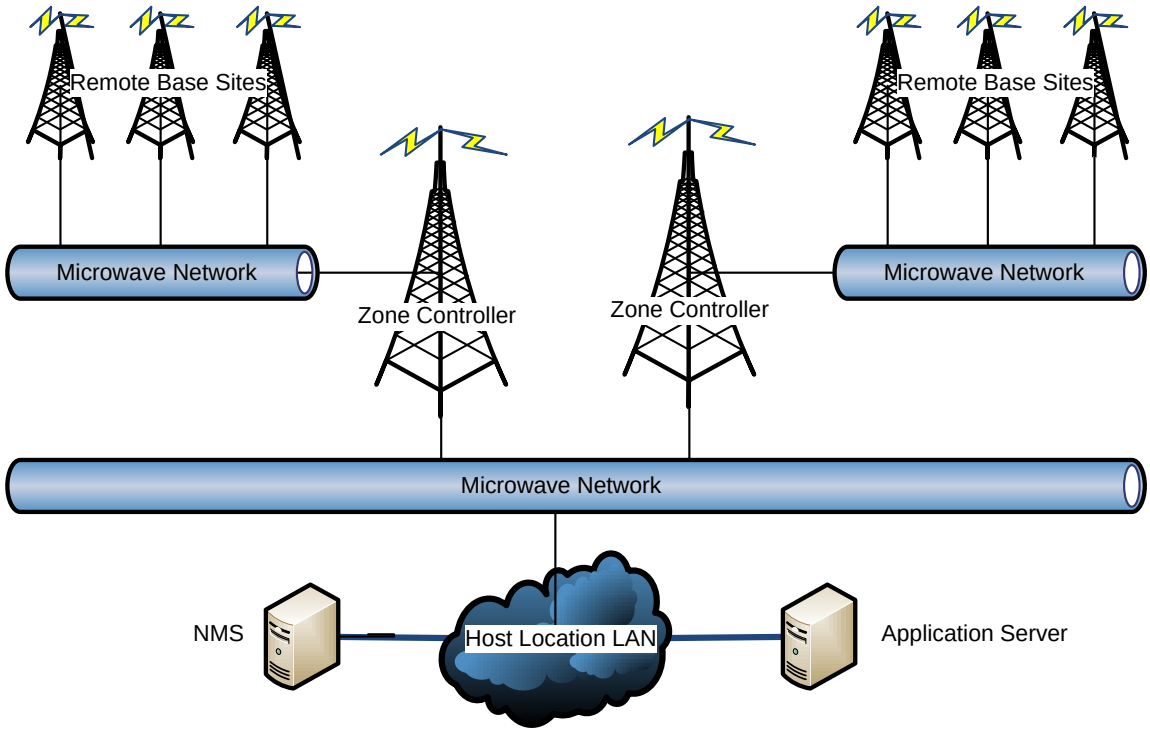

Figure 1 – P25 IV&D MDS fixed equipment system diagram

Applications on the mobile client will use a software-based switch compatible with Microsoft Windows XP, Windows 2000, Windows 98 and Windows Mobile to switch between the MDS supporting Tier 1 (and possibly Tier 2) applications and the MDS supporting Tier 2 and above applications as they become available. This switch controls connections to multiple wireless data networks, such as HPD, WiFi, and WiMAX. The switch is configured for each MDS, enabling the mobile client to roam between the different networks with no user intervention.

The mobile client switch automatically limits the use of an application over certain network types, preventing applications that require higher bandwidth (e.g., Tier 2 and above) from using the low bandwidth (Tier 1) MDS. The switch sets up a virtual private network (VPN) session enabling mobile client applications access to databases and other services on the host LAN. Since the switch retains logon information for each MDS, users do not have to log on each time the mobile client connects to a new network. The switch maintains VPN connectivity after a user roams between MDSs. Even after roaming to another MDS, the switch maintains an application's connection to databases and other services on the host LAN. Server-based network administration software, residing on the host LAN, provides remote control and management of the mobile client switch software. The VPN also provides data security and encryption services.

Implementation of a P25 IV&D MDS is similar to other private MDSs. However, since the proposed P25 IV&D MDS can be implemented as a 'layer' over the ARMER P25 voice radio system, leveraging the ARMER network. Core system infrastructure will be shared between systems and the coverage footprint would be the same as the ARMER P25 voice radio system; the channels and sites will be shared between systems.

Below are the high-level steps to implement a P25 IV&D MDS:

1. Develop a detailed design for the P25 IV&D MDS
2. Acquire spectrum
3. Upgrade the backhaul network if necessary
4. Prepare and release a Request for Proposal (RFP) if necessary
5. Update the radio site infrastructure as necessary
6. Install and test the P25 IV&D MDS fixed and mobile equipment
7. Perform system cutover and testing of user radio equipment
8. Complete acceptance testing for the P25 IV&D MDS

The schedule and timeframe for implementation are dependent upon the number of radio sites, and the cutover strategy (phased regional deployments or a single statewide deployment) to be utilized. The P25 IV&D MDS may be implemented at local, regional, or statewide levels; if necessary, regions may be deployed one-by-one and connected together in a phased approach in order to accomplish a statewide implementation.

This proposal considers implementation scenarios at the county (Beltrami), regional (NW-RRB) and statewide levels. Section 2.6 of this document provides ROM costs for each implementation.

2.2 System implementation

This section provides descriptions of county, regional and statewide MDS implementations. The information outlines system coverage, system architecture, network interface, and backhaul for each of the implementations.

2.2.1 County implementation – Beltrami County

2.2.1.1 Overview

The implementation for Beltrami County includes a basic P25 IV&D MDS with the flexibility to be expanded to higher data rates in the future. The proposed design includes one Packet Data Gateway to be located at the ARMER regional zone controller and two P25 IV&D base stations to be located at each of the seven radio sites proposed for coverage in the county from the ARMER P25 voice radio system. As the P25 IV&D data overlay shares base stations and sites with the ARMER P25 voice system, the proposed P25 IV&D MDS footprint will match that of the ARMER P25 voice radio system coverage.

The proposed P25 IV&D MDS design requires 14 700 MHz and/or 800 MHz 12.5 kHz channels (or frequency pairs), with two channels at each of the seven ARMER sites in the county. This proposed P25 IV&D MDS is designed to support 58 concurrent active mobile clients[5], with a 10% growth factor of additional users per the functional requirements.

2.2.1.2 Network interfaces

The proposed MDS can support the required three[6] host application connections; this is the connectivity point for external host application systems, such as computer aided dispatch (CAD), records management systems (RMS), etc., for data transmitted and

[5] Total user counts are based on two units for every 1,000 population, for a given geographic area; 66% of each count will be assumed for total concurrent system users. Counts used are based on estimated 2007 census data, with a statewide population of 5,197,621.
[6] Three host connections are required for each county.

received over the network infrastructure. Expansion is possible with the appropriate additional routing equipment.

The connection between the host application network and the P25 IV&D network is IP over Ethernet. The end-to-end IP network transports user data and control information between host computers to and from the mobile clients in the field. RS-232 connections are available on the P25 IV&D radio modem allowing mobile clients access to the network through a point-to-point protocol (PPP) interface.

2.2.1.3 Backhaul

It shall be the responsibility of the state of Minnesota to provide the necessary backhaul between sites. The network backhaul must meet the minimum required specifications as indicated in Table 1 provided in the point-by-point response section of this proposal.

A backhaul network is required to facilitate communication between the zone controller and each remote base site. The P25 IV&D MDS demarcation points will be the core routers at the zone controller and the routers at the remote base sites.

To provide connectivity to the additional base stations at each site, a minimum of one DS0 per channel is required from each remote base site to interconnect to the zone controller. Therefore, seven circuits containing two DS0's, that meet the specifications noted above, are required for connectivity to the seven remote base sites located in Beltrami County.

The proposed P25 IV&D platform uses a non-proprietary IP open-architecture utilizing standardized IEEE 802.3 Ethernet 10/100Base-T protocols in a LAN environment. Motorola proprietary routers and network switches are employed within the existing ARMER P25 network and will support the P25 IV&D overlay. Interconnection between base stations and the network currently utilize T1 connectivity. If Ethernet circuits are used for backhaul, they can be connected directly to the base station. If a T1 or DS0 circuit is used, then a router will have to be used to translate the T1 or DS0 circuit to Ethernet.

2.2.2 Regional implementation - Northwest Region

2.2.2.1 Overview

The implementation for the Northwest Region of state of Minnesota includes a basic P25 IV&D MDS with the flexibility to migrate to higher data rates in the future. The proposed design includes one packet data gateway, to be located at the ARMER regional zone controller and two P25 IV&D base stations to be located at each of the 57 radio sites proposed for the ARMER P25 voice radio system. As the P25 IV&D data overlay shares base stations and sites with the ARMER P25 voice system, the proposed P25 IV&D MDS footprint will match that of the ARMER P25 voice radio system coverage.

The proposed P25 IV&D MDS design requires approximately 114 700 MHz and/or 800 MHz 12.5 kHz channels, with two channels at each of the 57 site. This does not mean, however, that 114 frequencies are required. Frequencies can be used at two or more radio sites as long as there is adequate separation between sites. If sites are too close, using the same frequency for a channel will cause interference. Based on information provided by Motorola, the minimum number of frequencies that may be required for a Northwest Region implementation is 14. A detailed design, however, may indicate that more frequencies are needed. The system architecture theoretically requires a minimum of a 14-channel reuse pattern (assuming two channels at each site). When terrain and high antenna mounting heights are factored in, many more frequencies may be required before any reuse pattern can be established.

This proposed P25 IV&D MDS is designed to support 333 concurrent active mobile clients[7], with a 10% growth factor of additional users per the functional requirements.

2.2.2.2 Network interfaces

The proposed MDS can support a minimum of three[8] host application connections per county; this is the connectivity point for external host application systems, such as computer aided dispatch (CAD), records management systems (RMS), etc., for data transmitted and received over the network infrastructure. Expansion is possible with the appropriate additional routing equipment.

[7] Total user counts are based on two units for every 1,000 population, for a given geographic area; 66% of each count will be assumed for total concurrent system users. Counts used are based on estimated 2007 census data, with a statewide population of 5,197,621.
[8] Three host connections are required for each county.

The connection between the host application network and the P25 IV&D network is IP over Ethernet. The end-to-end IP network transports user data and control information between host computers to and from the mobile clients in the field. RS-232 connections are available on the P25 IV&D modem allowing mobile clients access to the network through a PPP interface.

2.2.2.3 Backhaul

It shall be the responsibility of the state of Minnesota to provide the necessary backhaul between sites. The network backhaul must meet the minimum required specifications as indicated in Table 1 provided in the point-by-point response section of this proposal.

A backhaul network is required to facilitate communication between the zone controller and each remote base site. The P25 IV&D MDS demarcation points will be the core routers at each zone controller and the routers at the remote base sites.

To provide connectivity to the additional base stations at each site, a minimum of one DS0 per channel is required from each remote base site to interconnect to the appropriate zone controller. For example, a remote base site equipped with two additional channels would require requires two additional DS0's. Therefore, 57 circuits containing two DS0's, that meet the specifications noted above, are required for connectivity to the 57 sites located throughout the region.

The proposed P25 IV&D platform uses a non-proprietary IP open-architecture utilizing standardized IEEE 802.3 Ethernet 10/100Base-T protocols in a LAN environment. Motorola proprietary routers and network switches are shared with the ARMER P25 network. Interconnection between base stations and the network currently utilize T1 connectivity. If Ethernet circuits are used for backhaul, they can be connected directly to the base station. If a T1 or DS0 circuit is used, then a router will have to be used to translate the T1 or DS0 circuit to Ethernet.

2.2.3 Statewide implementation

2.2.3.1 Overview

The statewide implementation includes a basic P25 IV&D MDS with the flexibility to migrate to higher data rates in the future to serve the entire state. The proposed design includes six packet data gateways, one to be located at each of the six ARMER regional

zone controllers, and two P25 IV&D base stations to be located at each of the 320 radio sites proposed for the ARMER P25 voice radio system. As the P25 IV&D data overlay shares base stations and sites with the ARMER P25 voice system, the proposed P25 IV&D MDS footprint will match that of the ARMER P25 voice radio system coverage.

The proposed P25 IV&D MDS design requires 640 700 MHz and/or 800 MHz 12.5 kHz channels, with two channels at each of the 320 sites. This does not mean, however, that 640 frequencies are required. Frequencies can be used at two or more radio sites as long as there is adequate separation between sites. If sites are too close, using the same frequency for a channel will cause interference. Per Motorola, the minimum number of frequencies that may be required for a statewide implementation is 14. A detailed design, however, may indicate that more frequencies are needed. The system architecture theoretically requires a minimum of a 14-channel reuse pattern (assuming two channels at each site). When terrain and high antenna mounting heights are factored in, many more frequencies may be required before any reuse pattern can be established.

This proposed P25 IV&D MDS is designed to support 6,860 concurrent active mobile clients[9], with a 10% growth factor of additional users per the functional requirements.

2.2.3.2 Network interfaces

The proposed MDS can support a minimum of three[10] host application connections per county; this is the connectivity point for external host application systems such as computer aided dispatch (CAD), records management systems (RMS), etc. to transmit and receive data over the network infrastructure. Expansion is possible with the appropriate additional routing equipment.

The connection between the host application network and the P25 IV&D network is IP over Ethernet. The end-to-end IP network transports user data and control information between host computers to and from the mobile clients in the field. RS-232 connections are available on the P25 IV&D radio modem allowing mobile clients access to the network through a PPP interface.

[9] Total user counts are based on two units for every 1,000 population, for a given geographic area; 66% of each count will be assumed for total concurrent system users. Counts used are based on estimated 2007 census data, with a statewide population of 5,197,621.
[10] Three host connections are required for each county.

2.2.3.3 Backhaul

It shall be the responsibility of the state of Minnesota to provide the necessary backhaul between sites. The network backhaul must meet the minimum required specifications as indicated in Table 1 provided in the point-by-point response section of this proposal.

A backhaul network is required to facilitate communication between each respective zone controller and the remote base sites under its control. The P25 IV&D MDS demarcation points will be the core routers at the zone controller and the routers at the remote sites.

To provide connectivity to the additional base stations at each site, a minimum of one DS0 per channel is required from each remote base site to interconnect to the zone controller. Therefore, 320 circuits containing two DS0's, that meet the specifications noted above, are required for connectivity to the 320 sites located throughout the state.

The proposed P25 IV&D platform uses a non-proprietary IP open-architecture utilizing standardized IEEE 802.3 Ethernet 10/100Base-T protocols in a LAN environment. Motorola proprietary routers and network switches are shared with the ARMER P25 voice network. Interconnection between base stations and the network currently utilize T1 connectivity. If Ethernet circuits are used for backhaul, they can be connected directly to the base station. If a T1 or DS0 circuit is used, then a router will have to be used to translate the T1 or DS0 circuit to Ethernet.

2.3 Interoperability standards

The P25 IV&D radio modem supports interoperability for basic data IP bearer services in compliance with the Project 25 interoperability modes. These modes for the data interoperability channel include radio-to-radio, radio to repeater and radio to fixed network equipment (FNE). Mobile client users manually switch between P25 IV&D channels to the data interoperability 'mutual aid' type channel.

The P25 IV&D over-the-air protocol is standardized under Project 25, additionally the backhaul connectivity and peripheral equipment interfaces are IP standards-based. This complies with National Information Exchange Model (NIEM) and guidance set by SAFECOM.

2.3.1 Data transport

There are three areas of data transport: over-the-air, peripheral interface and backhaul interface. The P25 IV&D over-the-air transport mechanism is TIA-102 (P25) protocol. The backhaul interface connects the base stations to the console and the network as a whole. Although the backhaul interface is IP-based, interconnection between base stations and the network currently utilizes T1 connectivity. The peripheral interface is the connection between the radios and the mobile client or other devices in the vehicle. The peripheral interface use standard IP protocols.

2.3.2 Equipment

The Motorola P25 IV&D equipment platform uses standardized IEEE 802.3 Ethernet 10/100Base-T protocols and interfaces to connect to the dispatch/control center from the radio sites. Standardized IEEE 802.3 Ethernet 10/100Base-T protocols and interfaces are utilized between the modem and peripheral devices within the vehicle. P25 standardized C4FM/CQPSK modulation and air interface protocol is used over-the-air from the modems to the base stations.

2.4 System capabilities

This section provides a point-by- point response to Section 3.0 of the state of *Minnesota Public Safety Interoperable Wireless Data Feasibility Study Deliverable for Tasks 8 and 9: High Level Wireless Data Functional Requirements* document. The functional requirements defined in this deliverable are re-stated here in *blue italics* with the response immediately following.

2.4.1 General requirements

The MDS shall meet the following general requirements:

- *Provide mobile public safety connectivity for at a minimum, police, fire, and EMS*
- *Operate in licensed land mobile radio frequency bands, except in the very high frequency (VHF) band for Tier 1 applications*
- *Use technologies in the unlicensed or licensed public safety bands, in conjunction with the Institute of Electrical and Electronics Engineers (IEEE) 802.11 for fixed 'hot spot' technology for, at a minimum, Tier 2 and Tier 3 applications*

- *Provide service to mobile units operating at street level at speeds up to posted speed limits*
- *Provide connectivity to approximately 100 public safety answering points (PSAPs)*
- *The system shall utilize existing ARMER tower sites, the state of Minnesota's Office of Enterprise Technology (OET) network, and backhaul equipment, to the maximum extent possible*
- *The overall architecture of the system shall provide for scalability, maintainability, disaster recovery, state-of-the-art equipment and software, future expansion potential to support additional services and be cost effective*

Complies. Specifics can be found in the P25 IV&D system description and in subsequent responses.

2.4.1.1 General specifications

2.4.1.1.1 Protocols

Data transmitted over the system shall be formatted in accordance with Internet Protocol (IP) version 4 (IPv4) or better.

Complies. The P25 IV&D MDS uses industry standard IPv6 routing. The use of IP suite complies with the user-driven Project 25 standards for data systems.

2.4.1.1.2 Standards

Quality of service (QoS) and virtual local area network (VLAN) tagging should be in accordance with IEEE 802.1p, 802.1q, and request for comments (RFC) 791.

Radio frequency (RF) links shall comply with applicable Federal Communication Commission (FCC) rules and guidelines.

Does not comply. The proposed P25 IV&D MDS is not able to determine Quality of Service (QoS) metrics.

Complies with FCC rules and guidelines.

2.4.1.1.3 Spectrum

The spectrum may include licensed and unlicensed frequencies in all bands except VHF. If unlicensed frequencies are proposed, the vendor must provide an interference risk mitigation plan to assure the state of the usefulness of the unlicensed spectrum.

Complies. The proposed MDS will operate in the licensed 700 MHz and/or 800 MHz band.

It is the understanding that the state of Minnesota will provide properly licensed frequencies for use with all proposed equipment for all sites. This proposed P25 IV&D system design is based on utilizing frequencies with a minimal frequency separation of 250 kHz.

2.4.1.2 Codes and standards

The equipment, application software, and components, as well as their installation, integration, and testing, shall be in accordance with reasonable best industry standards. All materials, equipment, supplies, installation, and testing shall Complies with the project requirements, the latest editions of standards, as applicable, and all other applicable standards and requirements.

The MDS shall adhere to appropriate codes and standards from the following standards bodies:

- *ANSI American National Standards Institute*
- *ASME American Society of Mechanical Engineers*
- *ASTM American Society for Testing and Materials*
- *EIA Electronic Industries Association*
- *FCC Federal Communications Commission*
- *IEEE Institute of Electrical and Electronic Engineers*
- *ISO International Standards Organization*
- *NEC National Electric Code*
- *NEMA National Electrical Manufacturers Association*
- *NFPA National Fire Protection Association*
- *OSHA Occupational Safety and Health Administration*
- *UL Underwriters Laboratory*

Complies

2.4.2 Functional requirements

2.4.2.1 System overview

The MDS shall offer a high degree of scalability, expandability, and upgradeability with minimal hardware obsolescence risk. The following system attributes are among those of most interest to the state of Minnesota:

- *Data throughput performance*
- *Channel bandwidths*
- *Over-the-air data speeds*
- *Over-the-air technology*
- *Fixed infrastructure topology (sites and frequencies)*
- *Networking*

The MDS shall support Tier 1 applications for all users. The MDS shall support Tier 2 and Tier 3 applications for 100% of all users.

The intent of the MDS is to provide seamless data coverage and roaming capabilities for data operations throughout the defined coverage area (county, region or state). The MDS shall leverage existing ARMER towers, sites, and backhaul equipment and potentially integrate into the OET Multi-Protocol Label Switching (MPLS) IP network, to the maximum extent possible. The state envisions the MDS to provide data services at the IP address level and utilizing open architecture and off-the-shelf equipment wherever possible.

Complies. The proposed P25 IV&D MDS is flexible and scalable; please refer to the system description.

Due to the data throughput limitations of the P25 protocol and the 12.5 kHz radio channels, the P25 IV&D system is most appropriate for Tier 1 applications only. Tier 2 and Tier 3 applications should be supported on alternative transports medium, such as HPD/HSD, carrier networks, or broadband networks. The interconnection of these networks can be made seamless to the end user and applications through the use of appropriate IP routing middleware solutions.

The P25 IV&D MDS is designed for deployment as a citywide system, countywide system, statewide system, or country-wide systems by utilizing a 'zone concept' that allows systems to be networked together to form a larger system requiring no intervention by the end-user as they traverse 'zones'. The system can roam from site to site, transparent to the user.

2.4.2.2 System architecture

The MDS architecture shall be open, IP-based, scalable, and expandable. The MDS shall take advantage of existing ARMER tower sites and OET backhaul capabilities and, to the extent possible, leverage other existing equipment and infrastructure. The MDS shall utilize state-of-the-art equipment and software with future expansion capabilities to support additional services.

Complies. The P25 IV&D MDS is fully compliant with theTIA-102 standard.

The MDS shall support Tier 1 applications with the ability to interface and switch to at least Tier 2 and Tier 3 applications in certain 'hot spot' locations. All applications shall reside on a single user's mobile data computer.

Complies. The P25 IV&D MDS satisfies Tier 1 application requirements. Applications are transparent to the P25 IV&D network; all applications can reside on a single mobile client, provided it has the capacity for the applications. Tier 2 and Tier 3 applications can be transported by one of many alternative systems.

The MDS must be capable of interfacing to the state of Minnesota Justice Information System (MNJIS) through local Computer Aided Dispatch (CAD) system interfaces or directly to the MNJIS via IP using a web browser.

Complies

The MDS shall be equipped to address each mobile client device on an individual, group or all-call basis.

Does not comply. The proposed P25 IV&D MDS does not support RF broadcast or group call communications. The P25 IV&D MDS supports single-threaded over-the-air communication between the mobile client and the P25 IV&D system. Typically, the host application or a middleware application can be used to support this type of functionality.

The MDS shall be able to provide Tier 1 applications within the same coverage footprint as the ARMER P25 voice radio system. Tier 2 level and higher applications may use a separate system potentially requiring an additional user mobile data modem.

Complies. The proposed P25 IV&D MDS coverage footprint will match that of the ARMER P25 voice radio system coverage.

2.4.2.3 RF spectrum

The MDS shall operate in licensed land mobile radio frequency bands, except in the very high frequency (VHF) band for Tier 1 applications. The MDS shall operate in the unlicensed or licensed public safety bands, in conjunction with the Institute of Electrical and Electronics Engineers (IEEE) 802.11 and/or 802.16 standards for fixed 'hot spot' technology for Tier 2 and above applications. The MDS shall have the ability to add channels, if needed, as RF spectrum becomes available.

Complies. The proposed P25 IV&D MDS will operate in the licensed 700 MHz and/or 800 MHz band. The P25 IV&D MDS can be upgraded to support additional sites and channels if required.

2.4.2.4 Coverage

The MDS coverage design, implementation, and testing must adhere to the Telecommunications Industry Association (TIA) Telecommunications Systems Bulletin (TSB) #88 'Wireless Communications Systems Performance in Noise-Limited Situations' Parts 1, 2 & 3 (TIA TSB-88.1 & 2 & 3). These parts are as follows:

- *Part 1 - Recommended methods for technology independent performance modeling*
- *Part 2 - Propagation and noise*

- *Part 3 - Performance verification*

The TIA TSB-88 document addresses items including but not limited to: channel performance criterion (CPC), CPC reliability design target, terrain profile extraction method, interference calculation method, metaphors to describe the plane of the service area, required service area reliability, adjacent channel drift confidence factor, conformance test confidence level, sampling error allowance, pass/fail criterion, and treatment of inaccessible grids.

Coverage is broken down into coverage area and coverage reliability. Coverage area pertains to the physical 'footprint' of the system's transmission and reception area. Coverage reliability pertains to the probability of receiving and/or transmitting good data packets at any point in time, at any location within the specified coverage area.

Complies. Motorola adheres to TSB-88.

2.4.2.4.1 Coverage area

The Tier 1 MDS coverage area shall meet the same coverage area requirements of the ARMER P25 voice radio system. In-building coverage is not a requirement.

The required coverage area based on application Tiers is as follows:

- *The MDS providing Tier 1 applications shall provide 95% mobile coverage by county. This is the same coverage area requirement for the ARMER system*
- *The MDS providing Tier 2 and Tier 3 applications shall provide 'best effort' coverage as they may be commercially owned systems; it is expected that all users will obtain an unspecified variable bit rate and delivery time, dependent upon current traffic load*

Users shall be able to roam seamlessly between sites within one mobile data technology throughout a coverage area.

Complies. The proposed P25 IV&D MDS coverage footprint will match that of the ARMER P25 voice radio system coverage, providing Tier 1 support.

2.4.2.4.2 Coverage reliability

The MDS design shall provide adequate signal strength and forward error correction to accommodate areas obstructed by a foliage canopy, buildings and other structures, or topography, etc. in order to meet specified coverage reliability requirements.

The MDS shall achieve a minimum message success rate within 95% of the specified coverage area for 95% of the time.

Complies

2.4.2.4.3 Message success rate

Message success rate (MSR) is defined as the number of packet retries where the data equipment, as opposed to the software application, generated the original transmission and any subsequent re-transmissions.

The required message success rate based on system type (tier) shall be as follows:

- *Tier 1 systems shall have no more than three automatic re-transmissions on any attempted data transmission*
- *Tier 2 and higher tier systems shall have no more than 10% automatic retransmissions in any given timeframe*

The MDS must achieve this MSR while vehicles travel at posted speed limits.

Complies for Tier 1.

Tier 2 and higher will be handled by alternative transport methods and are not covered under this P25 IV&D proposal.

2.4.2.5 Mobile client roaming

2.4.2.5.1 Intrasystem

The system shall allow mobile data clients to roam across different collocated or non-collocated access points within the same wireless network from both an inactive or

active client session. Roaming between different access points shall minimally impact client units. The system shall allow for roaming threshold to be configurable system-wide on an individual client basis by the data system administrator.

Complies

2.4.2.5.2 Regional

The MDS shall be able to be shared, with the same level of functionality, with other regional sub-systems. Networking or interfacing in this case means the linking of systems at the highest possible level to allow roaming (assuming the same frequency band and protocol) and equivalent functionality between regions. The system shall not preclude the networking of separate wireless data systems being procured separately, but shall enhance these designs wherever possible.

Complies

2.4.2.5.3 Multi-network

The MDS shall be equipped to allow the mobile data clients to switch between dissimilar wireless networks, such as IEEE 802.11 or those of commercial service providers, to provide access to Tiers 1, 2 and 3 applications.

Complies. The proposed P25 IV&D MDS allows clients to roam from site to site and zone to zone.

Applications on the mobile client will use a software-based switch compatible with Microsoft Windows XP, Windows 2000, Windows 98 and Windows Mobile to switch between the MDS supporting Tier 1 (and possibly Tier 2) applications and the MDS supporting Tier 2 and above applications as they become available. This switch controls connections to multiple wireless data networks, such as HPD, WiFi, and WiMAX. The switch is configured for each MDS, enabling the mobile client to roam between the different networks with no user intervention.

The mobile client switch automatically limits the use of an application over certain network types, preventing applications that require higher bandwidth (e.g., Tier 2 and above) from using the low bandwidth (Tier 1) MDS. The switch sets up a virtual private network (VPN) session enabling mobile client applications access to databases and other services on the host LAN. Since the switch retains logon information for each MDS, users do not have to log on each time the mobile client connects to a new network. The switch maintains VPN connectivity after a user roams between MDSs. Even after roaming to another MDS, the switch maintains an application's connection to databases and other services on the host LAN. Server-based network administration software, residing on the host LAN, provides remote control and management of the mobile client switch software. The VPN also provides data security and encryption services.

2.4.2.6 Data throughput

Data throughput (or capacity) is highly dependent on the applications, frequency of use of the applications, and the number of users. Other variables include application header size requirements, voice traffic priority, and the variety of applications in use.

Potential MDS vendors shall provide a detailed throughput study. This study shall include the required number of channels for the given geographical user distribution to support Tier 1 applications. It shall also include provisions for overhead associated with the following:

- *Automatic RF acknowledgment transmissions for all inbound and outbound messages*
- *Retries*
- *Automatic roaming*
- *Message packetization*
- *Error correction and error detection*

Capacity and throughput are dependent on many performance factors such as message load profiles of all applications running on mobile clients in the wireless network, network protocol TCP/IP or user datagram protocol (UDP)/IP) used, network traffic load and coverage reliability. Performance is optimized if the mobile application software has been written specifically for and successfully implemented in a wireless environment.

2.4.2.6.1 Data rate

The MDS shall have a minimum over-the-air data rate of 9,600 bps for Tier 1 applications; the MDS shall have a minimum over-the-air data rate of 64,000 bps for Tier 2 and Tier 3 applications.

Complies with clarification.

The proposed P25 IV&D system provides an over-the-air data rates of 9600 bps, with throughputs of approximately 4800 to 7200 bps depending on message type.

Tier 2 and Tier 3 applications will be handled by the software-based switch described in the *mobile client roaming* section above.

2.4.2.6.2 Geographical user distribution

2.4.2.6.2.1 Beltrami County

Beltrami County shall be used as a countywide model for MDS system. Beltrami County encompasses 3,056 square miles, of which 550 square miles is water. The population of the county is 43,609.[11]

The ARMER system is planned for approximately 320 sites of which 7 sites are planned for the Beltrami County. The ARMER coverage plan calls for 95% coverage in each county. It is expected that the Tier 1 MDS system footprint will closely match the ARMER P25 voice radio system coverage.

For Beltrami County, the MDS shall support a minimum of 58 concurrent active mobile client units[12] *and interface to a minimum of one CAD system to support the PSAP in the region.*

[11] 2007 estimated US census data
[12] Total user counts are based on two units for every 1,000 population, for a given geographic area; 66% of each count will be assumed for total concurrent system users. Counts used are based on estimated 2007 census data, with a statewide population of 5,197,621.

Complies. Please refer to the system description for details.

2.4.2.6.2.2 Northwest region

The Northwest Region of the state of Minnesota shall be used as a regional model for the MDS system. This region consists of 14 of the 87 counties in the state.

This region encompasses 17,055 square miles and includes these three medium-sized cities.

These cities have a combined population of 129,152, with the total population of the NW region being 251,994. The state of Minnesota population is 5,197,621. In comparison to the state, the Northwest Region represents 21% of the total square miles and 5% of the population.[13]

The ARMER system is planned for approximately 320 sites of which 57 sites are planned for the Northwest Region. The ARMER coverage plan calls for 95% coverage in each county. It is expected that the Tier 1 MDS system footprint will closely match the ARMER P25 voice radio system coverage.

For the Northwest Region, the MDS shall support a minimum of 333 concurrent active mobile client units and interface to a minimum of 14 CAD systems to support the 14 PSAP's in the region.

Complies. Please refer to the system description for details.

The proposed P25 IV&D MDS can only provide one 'IP tunnel' to one host per mobile client at any given time however, multiple applications can be accessed from one host. In addition, the mobile client can utilize a software-based switch, described in the system description, giving it the ability to access multiple hosts at one time.

2.4.2.6.2.3 State of Minnesota

[13] 2007 estimated US census data

The state of Minnesota encompasses 87,014 square miles and the population with a population of 5,197,621.[14]

For the state, the MDS shall support a minimum of 6860 concurrent active mobile client units and interface to a minimum of 100 CAD systems to support the PSAP's in the state according to the following:

- *In a defined rural environment, the MDS shall support a minimum of 10 concurrent active mobile client units interfacing two CAD systems on a per site basis*
- *In a defined urban environment, where Tier 2 and higher application services are available, the MDS shall be equipped to support a minimum of 20 concurrent active mobile client units interfacing three CAD systems on a per site basis*

Complies with clarification.

Tier 2 and higher applications will be handled by the software-based switch described in the system description.

The proposed P25 IV&D MDS can only provide one 'IP tunnel' to one host per mobile client at any given time however, multiple applications can be accessed from one host. In addition, the mobile client can utilize the software-based switch, giving it the ability to access multiple hosts at one time.

2.4.2.6.3 Message load profile

A projected message load profile is an estimate of the number of bytes transmitted and/or received per application transaction. Transactions may include Law Enforcement Message System (LEMS) queries and hot files to the state of Minnesota Justice Information Services (MNJIS) and the Federal Bureau of Investigation (FBI) Criminal Justice Information Services (CJIS) and National Crime Information Center (NCIC) databases, as well as motor vehicle, driver and warrant queries.

The predicted user message load profile (Table 1 of the functional requirements document) shall serve as a benchmark for the MDS and be used in data throughput calculations. The Tier 1 MDS shall handle a peak Tier 1 message load profile of the

[14] 2007 estimated US census data

peak number of units (2/3 of the total units) during the peak busy hour. This load profile shall be considered consistent throughout the state of Minnesota.

Complies. The proposed MDS system has two channels at each site to support the required message load profile assuming 2/3 of the total users concurrently on the system at peak usage time. The total number of channels required system-wide is based on the ability to reuse frequencies at different sites. These sites must be adequately separated. The diagram I Figure 1 below depicts an example frequency reuse pattern showing frequencies reused at sites located one site away from each other. Please refer to the P25 IV&D system implementation sections for the potential number of channels and frequencies required for each implementation.

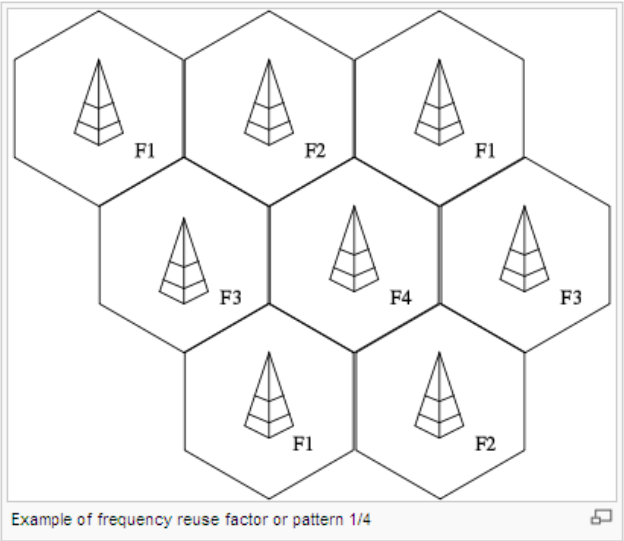

Figure 2 – Frequency Reuse Pattern

The predicted performance is based on the following assumptions:

- **The RF coverage area in the analysis is equal to the size of the ARMER P25 voice radio system**
- **All mobile clients in the simulation are distributed uniformly across the coverage area**
- **Additional UDP/IP headers are added to the length of the RFP profile message. Internet messages are associated with TCP/IP messages with additional overheads to support typical TCP and Internet access protocol.**

- **The message acknowledgment delay is the time elapsed between the initiation of the message and the return of corresponding acknowledgment after the message has been successfully delivered (excluding delays associated with host/client applications)**

2.4.2.6.4 Large file transfer

The MDS shall be capable of configuring the system to allow for large file transfers, where Tier 2 and higher data speeds are accessible. The MDS will integrate wireless broadband 'hot spots' with capacity able to handle large wireless file transfers where backhaul capacity is capable of providing the appropriate network connectivity.

Complies with clarification.

Tier 2 and higher applications will be handled by the software-based switch described in the system description.

2.4.2.6.5 Future growth

The MDS shall meet the system requirements specified in this document plus an additional 10% of users for future growth.

Complies. The proposed P25 IV&D MDS is designed for an additional 10% of users.

2.4.2.7 Security

The system must have security capabilities that control system access and protects data integrity, such as encryption. The system shall employ security on multiple layers in compliance with Federal Information Processing Standards (FIPS) 140-2.

Complies

2.4.2.7.1 Encryption

The MDS shall support over-the-air, data link layer encryption. Over-the-air encryption shall have minimal impact to overhead data. Encryption schemes must be non-proprietary for 'hot spots' and follow federally recommended encryption standards.

Over-the-air encryption should be limited such that regular data transmissions are not adversely affected.

Partially Complies. Encryption is provided at the application layer; the proposed P25 IV&D MDS does not offer 'hard' encryptions keys built in to the modems.

2.4.2.7.2 User authentication

The MDS shall authenticate individual users on the network with a login and password combination that is unique to each individual user.

Partially complies. The P25 IV&D system would not perform this task, this would be performed at the application level. The system does perform device authentication, see below.

2.4.2.7.3 Device authentication

The MDS shall authenticate access by an authorized mobile client and deny access to an unauthorized mobile client. Any device being used to access the network must be authenticated to the network by an identifier that is unique to the device before access is granted.

Complies

2.4.2.8 Interfaces

2.4.2.8.1 System host interfaces

The MDS shall support a minimum of three host interfaces per county with the ability to add host interfaces up to a maximum of five per county.

Complies. Please refer to the system description for details.

2.4.2.8.2 Database interfaces

The MDS shall support access to MNJIS, FBI CJIS, NCIC and Law Enforcement Message System (LEMS) databases.

Complies. Please refer to the system description for details.

2.4.2.8.3 Physical interfaces

The vendor shall describe the physical (DB-9, RJ-45, USB, etc.) and logical (serial, Ethernet, etc.) interfaces used for, but not limited to, the following:

- *The transmission and reception of mobile client/host application data*
- *Control of the base station features and functions*
- *Equipment monitoring/diagnostic*

For every site, and for each interface, the vendor shall state the transmission media that will interconnect the base stations to the system controller equipment or monitoring/diagnostic systems.

At each site where the existing digital microwave system will be used as the transmission media, the vendor shall describe the amount of bandwidth required for each interface.

Motorola has included equipment to support customer host interfaces, customer network interface barriers (CNIBs). The CNIB is a connectivity point for the State of Minnesota external host system to the secure P25 IV&D network infrastructure. These are the connection points for host applications such as computer aided dispatch (CAD), records management systems (RMS), etc.

The connection between the state of Minnesota Host network and the P25 IV&D network is IP over Ethernet. The end-to-end IP network transports user data and control information between LAN-based computers and wireless computers in the field. RS-232 connections are available with Motorola's P25 IV&D modem allowing wireless computers to access the network through a PPP interface.

Physical and logical demarcation points

Motorola's physical demarcation point on the host end will be the border router's WAN port that provides a physical connection point for the state of Minnesota customer enterprise network (CEN). The state of Minnesota must connect their CEN using a network switch or router to the border router WAN port. All equipment required to faciliate this connection will be provided by the state of Minnesota.

The network interface barrier (NIB) will be Motorola's logical demarcation point on the host end. First, core security components such as the firewall, intrusion detection sensor and core security management server (CSMS) will manage access to the P25 IV&D network from the CNIB. If access is permitted, the packet data gateway (PDG) will establish secure VPN tunnels to perform IP packet routing to and from the CEN. For example, it will forward mobile authentication requests to the authentication server in the state of Minnesota's host network. In order for host and mobile traffic to flow across the CNIB, all software applications must be written to a standard TCP/IP or UDP/IP interface. They also must fall into the policies estalished in the CSMS.

Total bandwidth required is specified in the backhaul response.

2.4.2.8.3.1Data ports

The Owner may wish to add additional mobile computing devices such as optical readers, fingerprint scanners, printers, digital video recorders, etc., as they become ready for deployment. It is envisioned that these devices will be interconnected in such a manner as to create a vehicular local area network with the mobile modem being offered.

The vendor shall describe the manner(s) by which you propose to network these devices.

These additional devices may be connected to the mobile client laptop. There is a physical RS-232 demarcation point on the mobile client end. For the logical network interface, the mobile application software must be capable of communicating to the P25 IV&D modem through a PPP interface. The mobile application software must be written to a standard IP communication stack for transport across the P25 IV&D network.

2.4.2.9 Network management and control

The MDS shall include a network management and control subsystem (NMCS) as an integral component of the system. There may be one NMCS for Tier 1 application support and a separate NMCS for Tier 2 and Tier 3 application support; or there may be one NMCS for Tiers 1-3 application support.

Each NMCS shall be IP-based and function as the interface between the wireless network and the wire-line network utilizing simple network management protocol (SNMP), Telnet, and support higher-level network management system protocols. The NMCS shall be responsible, at a minimum, for the configuration and management of mobile clients, wireless network resources, and capable of all general administrative, diagnostic, monitoring, and reporting functions.

The NMCS shall be of current production and shall be capable of withstanding the harsh operating environment heavy usage associated with the delivery of public safety services. It shall provide features and functions compatible with existing and new fixed and mobile equipment. The NMCS shall be comprised of hardware, software, cabling, and associated accessories utilizing standard commercial-off-the-shelf (COTS) equipment wherever possible.

In addition, user/client prioritization is a desirable feature, but is an optional requirement at this time.

The NMCS will encompass administrative and maintenance functions necessary for proper installation, setup, and maintenance of the MDS.

Partially Complies. The proposed P25 IV&D MDS does not offer a NMCS product that provides real-time utilization and performance history. However, Motorola's FullVision integrated network manager (INM) offers a simple network management protocol (SNMP) trap message forwarding capability to pass fault information to a higher level, 'enterprise' network manager.

The network management and control system (NMCS) is comprised of three major subsystems. Each of these subsystems supports certain specific functions or management applications. These three subsystems are:

- **User configuration subsystem (UCS)**
- **Zone manager (OZM)**
- **FullVision integrated network manager (INM)**

All three subsystems reside on the zone controller/zone manager local area network (LAN). Access to network management applications is through network management terminals.

The NMCS can be viewed as a set of software applications or tools used to manage the zone controller and its constituent components. These tools are intended to maximize the available resources and minimize system downtime and maintenance costs.

The NMCS supports the following services:

- **Fault management – Applications are included for monitoring the status of the transport network and the individual infrastructure components; displaying status information; forwarding alert information; and performing diagnostic procedures.**
- **Configuration Management – Facilities are provided for entering and maintaining the operational parameters of the infrastructure components and user devices.**
- **Accounting management– NMCS supports the tracking of data radio usage of the system by providing an optional interface to third-party accounting and/or billing applications.**

- **Security management – NMCS includes features for setting user privileges and controlling their access to view and/or modify information contained in the configuration databases.**

The user interface of the network manager includes menus to select objects and screens to enter data. The screens have a message area and help screens to inform and instruct the user on the entry of information and the use of the network manager. A graphical user interface (GUI) for the network manager allows for a multiple window, mouse-driven application that contains a pictorial representation of the zone level equipment. Each managed system component (i.e. site, controller, etc.) is represented by a pictorial icon that allows the user to access the current status of the component via a pull-down menu. Fault indications (alerts and alarms) on classes of components (i.e. repeaters, site controllers, etc.) can also be displayed. The user entry for the configuration of system components and subscriber information is simplified with the GUI. In general, the GUI provides a more visually intuitive interface.

2.4.2.9.1 Unique identifier

A unique ID must identify all fixed or mobile MDS terminal devices.

Complies

2.4.2.9.2 Device management, monitoring, and alarms

The NMCS shall provide real-time utilization, performance, status, health, and fault alarm information of all MDS system components including, but not limited to, network servers, networking devices, data base stations, mobile clients, and others.

The NMCS shall provide the following minimum features:

- *Remote management and upgrade of client devices*
- *Event logs*
- *Report generation*
- *Performance statistics such as link quality, network delays, etc.*
- *Secured remote access by typical client devices from authorized maintenance personnel*

The NMCS shall also be capable of reporting information of a historical nature and in a manner suitable for network planning purposes. At a minimum, the NMCS shall report bi-directional performance statistics on both the wireless and wireline portions of the network including each mobile client device, each radio base station, and the composite of all radio base stations.

The NMCS shall be equipped with the functionality capable of delivering alert text and/or email messages to radio pagers or cellular phones in the event of a detected fault condition. At a minimum, the text message shall contain fault specific information regarding the affected equipment and the location of the fault.

Partially Complies. The proposed P25 IV&D MDS does not offer a NMCS product that provides real-time utilization and performance history. However, Motorola's FullVision INM offers a simple network management protocol (SNMP) trap message forwarding capability to pass fault information to a higher level, 'Enterprise' network manager. Faults and interpretive messages may be forwarded to a service technician's alphanumeric pager via a compatible dial-up, commercial paging service.

Please also refer to the description above.

2.4.2.9.3 Management partitioning

The MDS shall allow for partitioning of the system as it relates to administrative functions, system configurations, and client programming. The NMCS shall allow designated users permission to accomplish the following:

- *User groups permission to add or delete their client units from the system*
- *Maintenance personnel to verify device configuration and status*
- *Administrative personnel access to real time and historical reports*

Complies

2.4.2.9.4 Load balancing

Dependent upon the systems available within the user's current location, the MDS shall be able to balance low and high data payloads from different applications. For example, if a user is located in a rural environment for which only Tier 1 services exist, Tier 2 and higher applications shall not be allowed to transmit or receive data until the user has physically moved within range of a Tier 2 or higher radio site location. The load balancing thresholds shall be configurable by the data system administrator.

Complies. The proposed P25 IV&D MDS mobile clients can be configured with a third party middleware that intelligently switches between various services when available to the mobile client. Please refer to the system description for more detail.

2.4.2.9.5 Remote access

The NMCS shall be equipped to enable full functional access from IP-based networked workstations and utilize standardized internet applications (e.g. HTML, etc) for browser interface, by authorized personnel within the private network, or over encrypted connections, such as VPNs, for access from remote networks.

Complies

2.4.2.9.6 Programming and configuration

The NMCS shall allow for programming and configuration of the system base stations and mobile units from a system based network location by authorized users.

Partially Complies. The proposed P25 IV&D MDS overlays on the existing base stations and fixed network devices and allows for the same level of remote programming and configuration as exists from the ARMER P25 voice network. Programming of mobile client devices can be performed over the air through the implementation of the 'programming over P25' (POP25) feature. The POP25 feature will enable over the air programming for both IV&D as well as appropriately enabled voice units.

2.4.2.9.7 Information repository

The NMCS shall provide a database repository of system device and network connectivity information for use in configuration, programming, testing, and troubleshooting of system equipment and connections. Data shall include, but not be limited to, the following:

- *Network architecture diagram and description of hardware and software*
- *Base station and mobile device model and serial numbers, including configuration options and program settings*
- *Redundant carrier and redundant path description for telecom services that support the remote monitoring systems*
- *Network monitoring procedures*
- *Classification of support issues with corresponding escalation procedures and response times.*

All pertinent MDS data shall reside on a common network and be accessible from any location within the network by authorized personnel.

Partially Complies. This information will be provided for storage and access on the customer's enterprise network.

2.4.2.10 Scalability, expandability, and redundancy

The MDS shall be deployable on a single site, multi-site, regional, or wide area basis capable of servicing any area within the state of Minnesota where ARMER or OET infrastructure exists. In addition, the network should provide for full automatic and seamless operation to mobile client users, while utilizing simple management and administrative functions.

The state shall be able to expand the MDS by adding sites for increased coverage, base stations for larger capacity, or network applications to improve efficiencies. In all cases, the MDS shall employ a high level of system redundancy (no single point of failure).

The MDS may initially be deployed on a regional or smaller basis, with the expectation to migrate to statewide use.

Complies. Please see responses below.

2.4.2.10.1 Expansion

The MDS shall be modular and scalable, utilizing hardware and software designs such that the system may be expanded, rather than replaced, to meet future requirements. The scalability of the system shall permit easy expansion, at a minimum, in these major areas:

- *Number of clients*
- *Radio frequencies*
- *Tower sites*
- *Host interfaces*
- *Network management interfaces*

Complies. The number of clients, radio frequencies, tower sites, host and management interfaces are all expandable.

2.4.2.10.2 Redundancy

Due to the critical nature of the MDS services, a high degree of reliability is required. Redundancy and reliability shall meet or exceed ARMER P25 voice radio system requirements. All components that encompass the MDS, including the NMCS, shall be viewed as critical elements of the network. Therefore, a network topology utilizing fault tolerance shall be incorporated to the greatest extent possible through a distributed and/or redundant architecture.

Complies. The proposed P25 IV&D MDS is based on and integrated into the Motorola's mission-critical P25 infrastructure currently supporting the ARMER P25 voice radio system.

2.4.2.10.3 System scan

The system shall be equipped to allow mobile clients to automatically scan for another RF channel in the event of loss of their primary RF channel.

Complies

2.4.2.10.4 Failure modes

The system shall be equipped with multiple failure modes to allow use of the MDS on limited data throughput basis rather than full system shut down.

Does not comply. The proposed P25 IV&D MDS provides limited 'scaled-back' failure modes. The P25 IV&D overlay system relies on the ARMER P25 trunked network and connectivity to the packet data gateways. It must be noted, that redundancy is built-in or inherent to critical system points such as redundant core fixed network equipment and the trunked design of the base stations at each remote base site.

2.4.2.11 Backhaul

The MDS shall utilize existing ARMER and OET networks for backhaul connectivity. MDS physical and protocol interfaces (e.g., DS0, T1, or Ethernet) shall Complies with ARMER and OET site-specific connectivity requirements. Bandwidth requirements of the MDS shall consider the available capacity of the ARMER and OET network.

Complies. It shall be responsibility of the state of Minnesota to provide operational interconnect facilities to provide connection points for Motorola installed fixed end equipment. The network backbone must meet the minimum required specifications as indicated below:

Table 1 - Minimum required T1 specifications

T1 SPECIFICATIONS	
Bit error rate – BER	**1×10^{-6}**
Stratum level	**2 or better**
Max. delay	**5 milliseconds (ms)**
Availability	**99.999 %**
Line coding	**B8ZS (bit 8 zero substitution)**
Signaling	**Clear channel**
Compression	**None**

T1 SPECIFICATIONS	
Framing	**ESF (extended super frame)**
Pulse amplitude	**0 dBdsx (3.0V +/- 0.3V or 6V P-P)**
Dry or wet	**Dry, no voltage (-48 VDC or other) present**

A minimum of one DS0 per channel is required from each remote site to interconnect to its respective zone controller. For example, a P25 IV&D site equipped with two additional channels will require two additional DS0's over the existing connectivity.

Please refer to the backhaul requirements detailed in the system description for each implementation.

2.4.2.12 Radio equipment requirements

2.4.2.12.1 Site infrastructure

The MDS shall utilize the state's existing ARMER site locations, available site equipment, infrastructure, and tower space to the greatest extent possible.

RF subsystem equipment (e.g., Heliax®, antennas, and lightning and surge protection) shall be supplied for each site. Equipment shall connect to the state's existing microwave, fiber, and leased-line transport backhaul infrastructure.

Complies

2.4.2.12.1.1 Security

Gates, door locks, and passcode entrances shall physically secure MDS transmitter sites, database locations, and limited access terminals, where permissible.

Complies

2.4.2.12.1.2 Installation

Equipment shall be installed in existing equipment room spaces where available. Equipment shall be housed in suitable indoor-type cabinets or relay racks. These cabinets or racks shall be installed with ease of accessibility. Equipment shall be arranged and installed so its intended function will not be impaired due to weather, temperature, adjacent equipment, or other factors. Sufficient space and clearance shall be provided such that service and maintenance can be readily performed.

Renovations, designs, and installations at the site shall conform to the following guides:

- *Industry best practices*
- *Commercial Building Standard for Telecommunications Pathways and Spaces, TIA/EIA-569*
- *Commercial Building Telecommunications Wiring Standard, TIA/EIA-568*
- *Occupational Safety and Health Administration's recommended approved practices*
- *National Electric Code practices, including grounding and lightning suppression*
- *All applicable local, county, state building and life-safety codes*

Upon completion of the installation, all systems and equipment shall operate in accordance with applicable standards for operation.

Complies. All installations will comply with Motorola's R56 standards.

2.4.2.12.1.3 Power

System hardware installed at the transmitter sites shall be equipped with an uninterruptible power supply. Power losses, restorations, surges, sags, and/or brownouts shall not alter the operating parameters of MDS components. Other than total power loss or lethal surges, all components shall remain fully operational within the specifications of its design while experiencing any of these occurrences.

Complies

2.4.2.12.2 Base station radio

The base radio system shall be rated for and capable of continuous duty operations with required automatic station identifiers. The fixed equipment proposed shall be modular in design using 19' rack mountable units.

Complies

2.4.2.12.2.1 Programming and software upgrades

The base station radio shall allow for remote network based programming and/or software upgrades.

Complies

2.4.2.12.2.2 Security

Any MDS base station radio must authenticate any person utilizing the device via user login and password and/or biometrics.

Partially complies. As stated above, the proposed P25 IV&D MDS can support this, but authentication is handled at the application layer.

2.4.2.12.2.3 IP

Each base station radio shall be equipped with an IP address (dynamic or static).

Complies. Within the proposed P25 IV&D MDS, each network device can operate with a static or dynamic IP address.

2.4.2.12.2.4 Unique modem identifier

Each base station radio must be uniquely identifiable by its static IP address or modem MAC address.

Complies

2.4.2.12.3 Mobile radio modem

The mobile radio modem shall provide an interface between the mobile computing device and the wireless data fixed network equipment. The mobile modem shall be a rugged, factory integrated vehicular radio modem product designed to provide optimal data transmission performance for mobile data applications.

Mobile units shall include a 'smart switch' to determine the most efficient data transfer technology to use. The MDS modem shall default to the high-speed network when available; otherwise, it will switch to the existing low-speed network. This 'switching' capability may be hardware of software integrated.

Complies. The proposed P25 IV&D MDS mobile clients can be configured with a third- party middleware that intelligently switches between various services when available to the mobile client. Please refer to the system description for more detail.

2.4.2.12.3.1 Programming and software upgrades

The mobile client shall allow for over-the-air-programming (OTAP) and/or software upgrades.

Complies. The proposed P25 IV&D MDS is capable of OTAP with the addition of Motorola's POP25 feature.

2.4.2.12.3.2 Security

Any MDS client device must authenticate any person utilizing the device via user login and password and/or biometrics.

Partially complies. As stated above, the proposed P25 IV&D MDS can support this, but authentication is handled at the application layer.

2.4.2.12.3.3 Multiple receive

The modem shall simultaneously decode two incoming message streams for increased message reliability.

Does not comply. The proposed P25 IV&D MDS modem is not capable of multiple receive.

2.4.2.12.3.4 GPS

The mobile radio modem shall either incorporate global positioning system (GPS) receiver or be capable of receiving a GPS data from an external source.

Complies. The proposed P25 IV&D MDS mobile clients are capable of interfacing to a GPS receiver.

2.4.2.12.3.5 Internet Protocol

Each radio modem shall be equipped with an IP address (dynamic or static).

Complies. Within the proposed P25 IV&D MDS, each network device can operate with a static or dynamic IP address.

2.4.2.12.3.6 Unique modem identifier

Each modem must be uniquely identifiable by its static IP address or modem MAC address.

Complies

2.4.2.12.3.7 Broadcast mode addressing

Modems must support individual group broadcast addressing by IP multicast and directed subnet broadcast.

Partially complies. The proposed P25 IV&D MDS does not support RF broadcast or group call communications. The P25 IV&D MDS supports single-threaded over-

the-air communication between the mobile client and the P25 IV&D system. Typically, host applications can be used to support this type of functionality.

2.4.2.12.3.8 Positive acknowledge

Modems shall be capable of sending a positive acknowledgment to the originating base station radio upon receipt of successfully received and corrected messages.

Complies

2.4.2.12.3.9 Client Interface

Modems shall interface to a mobile data computer installed within a vehicle's passenger compartment.

- *Tier 1 modems shall interface via a 10/100Base-T or USB or serial DB9 connection, and*
- *Tier 2 and higher modems shall interface via a 10/100Base-T connection and employ advanced technology to allow higher performance operation, to allow for future modem upgrades or enhancements, and to allow the greatest degree of mobile hardware flexibility*

Complies. The proposed P25 IV&D MDS modem interfaces to the mobile client via RS-232.

2.5 Advantages and disadvantages

The Motorola P25 IV&D platform is designed specifically to integrate voice and data on one network, unlike other MDSs which require the creation of a parallel network. P25 IV&D also allows mobile data to utilize existing infrastructure, base stations, channels, sites and backhaul that exist for a voice radio system.

Motorola's mobile data systems have been installed in various configurations (local and wide area) and optimized for different user types including public safety, public works, utilities, and transportation agencies. Motorola's P25 IV&D product line includes devices capable of both 700 and 800 MHz frequency bands at 12.5 kHz bandwidth.

The backhaul and peripheral device wireline interface of this system is a standards-based IEEE 802.3 IP-based protocol and Ethernet 10/100Base-T interconnection. An IP

standards based backhaul provides a semi-distributed architecture, increasing system redundancy and reducing the possibility of single point failures. A centralized system controller handles the P25 IV&D data traffic and may be configured for redundant operation.

Below are strengths and weaknesses of Motorola P25 IV&D platform as compared to other technologies:

Strengths:

- P25 IV&D is a completely integrated voice and data overlay, not a parallel mobile data network
- P25 IV&D is overlaid on the P25 voice system, using the same sites, channel, stations, and backhaul system
- P25 IV&D can support low bandwidth data applications without requiring a second radio unit in the vehicle
- User radio modems can operate on both 700 MHz and 800 MHz frequency bands.
- P25 IV&D coverage and capacity is available wherever P25 trunked voice service exists, even without the implementation of additional base stations or sites
- Other than operations and maintenance, there are no recurring costs

Weaknesses:

- Data throughput is only acceptable for Tier 1 applications
- User must have authorization to use or ownership of appropriate spectrum
- The system uses proprietary routers and network switches
- Use of a centralized system controller creates a potential single point of failure
- Some applications (Tier 2 and higher) will require access to a second, higher bandwidth data network

2.6 Rough order-of-magnitude (ROM) cost estimates

This section provides high-level, ROM estimates for each implementation – county, regional and statewide - discussed in this proposal. Please note that these estimates are ROM only, and a detailed design would be required for a more accurate estimate.

Capital outlay costs associated with deploying this technology include the site mobile data equipment and user radio modems. There are no recurring fees other than regular operations and maintenance. Please note other assumptions and notes following the cost tables.

2.6.1 County implementation

	Qty	Cost	Total
Zone controller	1	$1,500,000	$1,500,000
Remote site	7	$240,000	$1,680,000
Mobile client and modem	87	$8,000	$696,000
Switching middleware (per mobile client)	87	$1,000	$87,000
Infrastructure Sub-total			$3,963,000
Project management / engineering		included	$0
TOTAL ROM COST			**$3,963,000**

2.6.2 Regional implementation

	Qty	Cost	Total
Zone controller	1	$1,500,000	$1,500,000
Remote site	57	$240,000	$13,680,000
Mobile client and modem	504	$8,000	$4,032,000
Switching middleware (per mobile client)	504	$1,000	$504,000
Infrastructure Sub-total			$19,716,000
Project management / engineering		included	0%
TOTAL ROM COST			**$19,716,000**

2.6.3 Statewide implementation

	Qty	Cost	Total
Zone controller	6	$1,500,000	$9,000,000
Remote site	320	$240,000	$76,800,000
Mobile client and modem	10,395	$8,000	$83,160,000
Switching middleware (per mobile client)	10,395	$1,000	$10,395,000
Infrastructure Sub-total			$179,355,000
Project management / engineering		included	$0
TOTAL ROM COST			**$179,355,000**

Notes:

1. Cost to add data capability to existing zone controller is $1.3M to $1.5M

2. Regional ARMER zone controllers utilized to reduce costs. Zone controller costs include the addition of a Packet Data Gateway.
3. Remote site cost = $211K to $240K
4. Site costs include two 700/800 MHz base stations at each site
5. Costs include site and mobile equipment installation
6. Costs include site and mobile antenna systems
7. All tower sites include $5,000 for structural analysis of existing tower structures
8. Costs do not include backhaul costs and may require additional capacity
9. Costs include one year warranty and software updates
10. Discounts are not included

3. High Performance Data (HPD) system

3.1 System description

The proposed HPD MDS compliments Motorola's P25 mission critical platform and provides a scalable interoperable multi-agency network. HPD will:

- Provide a migration path to a standards based, open-architecture platform
- Be upgradeable to support future 700 MHz wide band data technologies
- Be capable of switching to other data networks such as WiFi, WiMAX and other private and/or public networks using software-based mobile router/switching technology
- Be capable of expanding the service area as other agencies, counties and/or regions are added to the system
- Operate in public safety licensed spectrum

HPD provides 32 kbps to 96 kbps raw data throughput, depending on the MDS signal level at the mobile client. The data throughput performance of the system reaches 96 kbps when in close proximity to communications sites and throttles down to 32 kbps at the fringe of the coverage footprint. This system will provide connectivity for Tier 1 and Tier 2 applications, as defined in the introduction of this report.

The proposed HPD MDS can be implemented as a 'layer' over the state of Minnesota's ARMER P25 voice radio system; the coverage of this MDS would be similar to the ARMER P25 voice radio system. These systems can share backhaul and infrastructure facilities as well as core switching equipment, as these components are designed to work together.

HPD operates in both the 700 and 800 MHz spectrum utilizing standard 25 kHz channels. It is based on open standards (such as IP and TCP) to ensure ongoing compatibility with current and future equipment and software. The over-the-air protocol of HPD, that allows the wireless communications between the mobile client and the base station, however, is proprietary.

HPD provides a future migration path to Motorola's next generation data system, High Speed Data (HSD) with data rates up to 230 kbps. HSD, however, requires 50 kHz channels to support the increased data rate. Motorola is currently awaiting the outcome of the Federal Communication Commission's (FCC) D-Block auction in order to deploy 50 kHz channels using 700 MHz D-Block spectrum. When (and if) the D-Block frequencies become available, Motorola anticipates that it will take approximately 12

months to provide the software upgrades for the modems, base stations and controller. There may also be a hardware upgrade required for the base stations. It is important to note that the state of Minnesota would need to acquire 50 kHz 700 MHz channels in order to deploy HSD.

Motorola HPD systems are expandable and scalable; as agency needs grow, the system can be expanded to provide additional coverage and capacity.

HPD systems contain many of the familiar components of a traditional wireline data network. An Ethernet local area network (LAN) connects the master and remote base sites. This LAN then connects to the state of Minnesota backhaul network, providing connectivity between the master and base sites. Below is a high-level system diagram depicting the major components of the proposed HPD MDS fixed equipment.

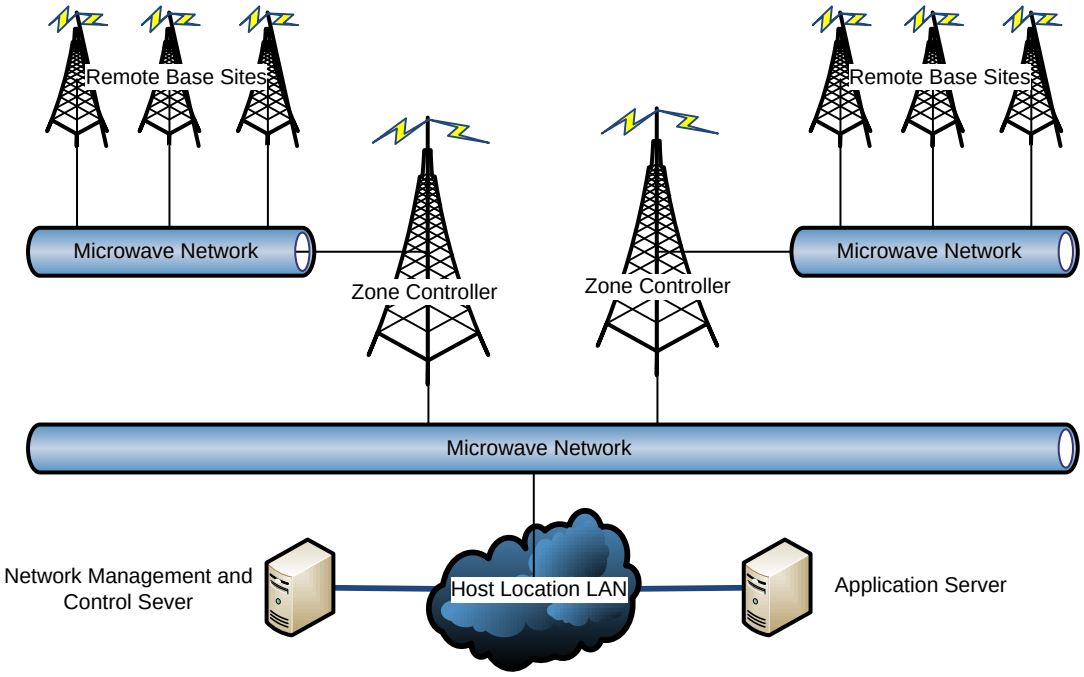

Figure 3 – HPD MDS Fixed Equipment Diagram

Applications on the mobile client will use a software-based switch compatible with Microsoft Windows XP, Windows 2000, Windows 98 and Windows Mobile to switch between the MDS supporting Tier 1 (and possibly Tier 2) applications and the MDS supporting Tier 2 and above applications as they become available. This switch controls connections to multiple wireless data networks, such as WiFi and WiMAX. The switch is

configured for each MDS, enabling the mobile client to roam between the different networks with no user intervention.

The mobile client switch automatically limits the use of an application over certain network types, preventing applications that require higher bandwidth (e.g., Tier 2 and above) from using the low bandwidth (Tier 1) MDS. The switch sets up a virtual private network (VPN) session enabling mobile client applications access to databases and other services on the host LAN. Since the switch retains logon information for each MDS, users do not have to log on each time the mobile client connects to a new network. The switch maintains VPN connectivity after a user roams between MDSs. Even after roaming to another MDS, the switch maintains an application's connection to databases and other services on the host LAN. Server-based network administration software, residing on the host LAN, provides remote control and management of the mobile client switch software. The VPN also provides data security and encryption services.

Implementation of a HPD MDS is similar to other private MDSs. However, the proposed HPD MDS can be implemented as a 'layer' over the ARMER P25 voice radio system, leveraging the ARMER network (and possibly the Metro Regional/Hennepin County MDS) resources to reduce the steps necessary for implementation. Core system infrastructure can be shared between systems, and with the coverage footprint similar to the ARMER P25 voice radio system, the MDS may be able to use the same sites as ARMER.

Below are the high-level next steps of the implementation of the HPD MDS:

1. Develop a detailed design for the HPD MDS
2. Acquire spectrum
3. Upgrade the backhaul network if necessary
4. Prepare and release a Request for Proposal (RFP) if necessary
5. Update the radio site infrastructure as necessary
6. Install and test the HPD MDS fixed and mobile equipment
7. Perform system cutover and testing of user radio equipment
8. Complete acceptance testing for the HPD MDS

The schedule for implementation is dependent upon the availability of radio sties and frequencies, number of radio sites, and cutover strategy (phased county/regional deployments or a single statewide deployment). The HPD MDS may be implemented at local, regional, or statewide levels; if necessary, regions may be deployed one-by-one and connected together in a phased approach in order to accomplish a statewide implementation.

This proposal considers implementation scenarios at the county (Beltrami), regional (NW-RRB) and statewide levels. Section 3.6 of this document provides ROM costs for each implementation.

3.2 System implementation

This section provides descriptions of county, regional and statewide HPD MDS implementations. The information outlines system coverage, system architecture, network interface, and backhaul for each of the implementations.

3.2.1 County implementation – Beltrami County

3.2.1.1 Overview

The implementation for Beltrami County includes a basic HPD MDS with the flexibility to migrate to a HSD solution in the future. The proposed design includes one zone controller and six remote HPD base sites to provide 95% county coverage; site count and site locations are identical to the seven sites proposed for the ARMER P25 voice radio system. By using the same sites, the proposed HPD MDS footprint will closely match that of the ARMER P25 voice radio system coverage as well as maximize cost savings. If the existing Metro Regional/Hennepin County zone controller is used, and/or the existing region's Motorola SmartZone (Detroit Lakes) controller is upgraded to support HPD, costs can be reduced even more by leveraging these investments. These savings are illustrated in the ROM costing in Section 3.6.

The proposed county HPD MDS design requires 14 700 MHz channels (or frequency pairs), with two channels at each of the seven ARMER sites in the county. The MDS can support a maximum of 96 remote base sites with each base site supporting up to five channels each. This proposed HPD MDS is designed to support 58 concurrent

active mobile clients[15], with a 10% growth factor of additional users per the functional requirements.

3.2.1.2 Network interfaces

The proposed HPD MDS can support a minimum of three[16] host application connections per county; this is the connectivity point for external host application systems, such as computer aided dispatch (CAD), records management systems (RMS), etc., for data transmitted and received over the HPD network infrastructure. Expansion is possible with the appropriate additional routing equipment.

The connection between the host application network and the HPD network is IP over Ethernet. The end-to-end IP network transports user data and control information between host computers to and from the mobile clients in the field. Both universal serial bus (USB) and Ethernet connections are available on the HPD modem allowing mobile clients access to the network through a PPP interface.

3.2.1.3 Backhaul

Minnesota will provide the necessary backhaul between sites. The network backhaul must meet the minimum required specifications as indicated in Table 1 provided in the point-by-point responses of this proposal.

A backhaul network is required to facilitate communication between the zone controller and each remote base site. The HPD MDS demarcation points will be the core routers at the zone controller and routers at the remote sites.

A minimum of two DS0's per site or one DS0 per channel (whichever is greater) is required from each remote base site to interconnect to the zone controller. For example, a remote base site equipped with four channels requires four DS0's; a single channel site will require two DS0's. Therefore, seven circuits containing two DS0's, that meet the specifications noted above, are required for connectivity to the seven remote base sites located in Beltrami County. If the state of Minnesota chooses to use a zone controller outside of the Metro Regional/Hennepin County MDS, provisions will need to be made on the backhaul network in order to route those circuits to that location.

[15] Total user counts are based on two units for every 1,000 population, for a given geographic area; 66% of each count will be assumed for total concurrent system users. Counts used are based on estimated 2007 census data, with a statewide population of 5,197,621.
[16] Three host connections are required for each county.

The proposed HPD backhaul platform uses a non-proprietary IP open architecture utilizing standardized IEEE 802.3 Ethernet 10/100Base-T protocols in a LAN environment. Motorola proprietary routers and network switches are employed within the HPD network. Interconnection between base stations and the network currently utilize T1 connectivity. If Ethernet circuits are used for backhaul, they can be connected directly to the base station. If a T1 or DS0 circuit is used, then a router will have to be used to translate the T1 or DS0 circuit to Ethernet.

3.2.2 Regional implementation - Northwest Region

3.2.2.1 Overview

The implementation for the Northwest Region of the state of Minnesota includes a basic HPD MDS with the flexibility to migrate to a HSD solution in the future. The proposed design includes one zone controller and 56 remote base sites to provide 95% regional coverage; site count and site locations are identical to the 57 sites proposed for the ARMER P25 voice radio system. By using the same sites, the proposed HPD MDS footprint will closely match that of the ARMER P25 voice radio system coverage and maximize cost savings. If the existing Metro Regional/Hennepin County zone controller is used, and/or the existing region's Motorola SmartZone (Detroit Lakes) controller is upgraded to support HPD, costs can be reduced even more. These savings are illustrated in the ROM costing in Section 3.6.

The proposed regional HPD MDS design requires approximately 114 700 MHz channels with two channels at each of the 57 sites. This does not mean, however, that 114 frequencies are required. Frequencies can be used at two or more radio sites as long as there is adequate separation between sites. If sites are too close, using the same frequency for a channel will cause interference. Per Motorola, the minimum number of frequencies that may be required for a Northwest Region implementation is 14. A detailed design, however, may indicate that more frequencies are needed. The HPD architecture theoretically requires a minimum of a 14-channel reuse pattern (assuming two channels at each site). When terrain and high antenna mounting heights are factored in, many more frequencies may be required before any reuse pattern can be established. A final channel count will be determined during the detailed design phase.

The MDS can support maximum of 96 remote HPD base sites with each base site supporting up to five channels each. This proposed HPD MDS is designed to support

333 concurrent active mobile clients[17], with a 10% growth factor of additional users per the functional requirements.

3.2.2.2 Network interfaces

Please refer to network interfaces described in the county implementation section above.

3.2.2.3 Backhaul

It shall be the responsibility of the state of Minnesota to provide the necessary backhaul between sites. The network backhaul must meet the minimum required specifications as indicated in Table 1 provided in the point-by-point responses of this proposal.

A backhaul network is required to facilitate communication between the Zone controller and each remote base site. The HPD MDS demarcation points will be the core routers at the zone controller and routers at the remote sites.

A minimum of two DS0's per site or one DS0 per channel (whichever is greater) is required from each remote base site to interconnect to the zone controller. For example, a remote base site equipped with four channels requires four DS0's; a single channel site will require two DS0's. Therefore, 57 circuits containing two DS0's, that meet the specifications noted above, are required for connectivity to the 57 sites located throughout the region. If the state of Minnesota chooses to use a zone controller outside of the Northwest Region (Metro Regional/Hennepin County MDS), provisions will need to be made on the backhaul network in order to route those circuits to that location.

The proposed HPD backhaul platform uses a non-proprietary IP open-architecture utilizing standardized IEEE 802.3 Ethernet 10/100Base-T protocols in a LAN environment. Motorola proprietary routers and network switches are employed within the HPD network. Interconnection between base stations and the network currently utilize T1 connectivity. If Ethernet circuits are used for backhaul, they can be connected directly to the base station. If a T1 or DS0 circuit is used, then a router will have to be used to translate the T1 or DS0 circuit to Ethernet.

[17] Total user counts are based on two units for every 1,000 population, for a given geographic area; 66% of each count will be assumed for total concurrent system users. Counts used are based on estimated 2007 census data, with a statewide population of 5,197,621.

3.2.3 Statewide implementation

3.2.3.1 Overview

The statewide HPD MDS implementation includes a basic HPD MDS with the flexibility to migrate to a HSD solution in the future to serve the entire state. The proposed design includes four zone controllers and 316 remote base sites to provide 95% statewide coverage; site count and site locations are identical to the 320 sites proposed for the ARMER P25 voice radio system. By using the same sites, the proposed HPD MDS footprint will closely match that of the ARMER P25 voice radio system coverage and maximize cost savings. If the existing Metro Regional/Hennepin County zone controller is used, and/or the existing region's Motorola SmartZone (Detroit Lakes) controller is upgraded to support HPD, costs can be reduced even more. These savings are illustrated in the ROM costing in section 3.6 of this document.

The proposed statewide HPD MDS design requires approximately 640 700 MHz channels, with two channels at each of the 320 sites. This does not mean, however, that 640 frequencies are required. Frequencies can be used at two or more radio sites as long as there is adequate separation between sites. If sites are too close, using the same frequency for a channel will cause interference. Per Motorola, the minimum number of frequencies that may be required for a statewide implementation is 14. A detailed design, however, may indicate that more frequencies are needed. The HPD architecture theoretically requires a minimum of a 14-channel reuse pattern (assuming two channels at each site). When terrain and high antenna mounting heights are factored in, many more frequencies may be required before any reuse pattern can be established.

The MDS can support maximum of 384 remote HPD base sites (96 per zone controller) with each base site supporting up to five channels each. This proposed HPD MDS is designed to support 6,860 concurrent active mobile clients[18], with a 10% growth factor of additional users per the functional requirements.

3.2.3.2 Network interfaces

Please refer to network interfaces described in the county implementation section above.

[18] Total user counts are based on two units for every 1,000 population, for a given geographic area; 66% of each count will be assumed for total concurrent system users. Counts used are based on estimated 2007 census data, with a statewide population of 5,197,621.

3.2.3.3 Backhaul

It shall be the responsibility of the state of Minnesota to provide the necessary backhaul between sites. The network backhaul must meet the minimum required specifications as indicated in Table 1 provided in the point-by-point responses of this proposal.

A backhaul network is required to facilitate communication between the Zone controller and each remote base site. The HPD MDS demarcation points will be the core routers at the zone controller and routers at the remote sites.

A minimum of two DS0's per site or one DS0 per channel (whichever is greater) is required from each remote base site to interconnect to its zone controller. For example, a remote base site equipped with four channels requires four DS0's; a single channel site will require two DS0's. Therefore, 320 circuits containing two DS0's, that meet the specifications noted above, are required for connectivity to the 320 sites located throughout the state.

The proposed HPD backhaul platform uses a non-proprietary IP open-architecture utilizing standardized IEEE 802.3 Ethernet 10/100Base-T protocols in a LAN environment. Motorola proprietary routers and network switches are employed within the HPD network. Interconnection between base stations and the network currently utilize T1 connectivity. If Ethernet circuits are used for backhaul, they can be connected directly to the base station. If a T1 or DS0 circuit is used, then a router will have to be used to translate the T1 or DS0 circuit to Ethernet.

3.3 Interoperability standards

When operating in the 700 MHz frequency band, the HPD modem supports interoperability for basic data IP bearer services in compliance with the Project 25 interoperability modes. These modes for the data interoperability channel include radio-to-radio, radio to repeater and radio to Fixed Network Equipment (FNE). Mobile client users manually switch between HPD channels and the data interoperability 'mutual aid' type channel.

Although the HPD over-the-air protocol is proprietary, backhaul connectivity and peripheral equipment interfaces are IP standards-based. This complies with National Information Exchange Model (NIEM) and guidance set by SAFECOM.

As mentioned, HPD has a migration path to higher speed data speeds. The state of Minnesota would be able to leverage an initial HPD system investment by migrating to HSD, and thereby to 50 kHz channels that are TIA-902 standard compliant.

3.3.1 Data transport

There are three areas of data transport: over-the-air, peripheral interface and backhaul interface. The HPD over-the-air transport mechanism is a Motorola proprietary protocol. The backhaul interface connects the base stations to the console and the network as a whole. Although the backhaul interface is IP-based, interconnection between base stations and the network currently utilizes T1 connectivity. The peripheral interface is the connection between the radios and the mobile client or other devices in the vehicle. The peripheral interface use standard IP protocols.

3.3.2 Equipment

The Motorola HPD equipment platform uses standardized IEEE 802.3 Ethernet 10/100Base-T protocols and interfaces to connect to the dispatch/control center from the radio sites. Standardized IEEE 802.3 Ethernet 10/100Base-T protocols and interfaces are utilized between the modem and peripheral devices within the vehicle. A proprietary half-duplex modified scalable amplitude modulation (SAM) protocol is used over-the-air from the modems to the base stations.

3.4 System capabilities

This section provides a point-by- point response to Section 3.0 of the state of *Minnesota Public Safety Interoperable Wireless Data Feasibility Study Deliverable for Tasks 8 and 9: High Level Wireless Data Functional Requirements* document. The functional requirements defined in this deliverable are re-stated here in *blue italics* with the response immediately following.

3.4.1 General requirements

The MDS shall meet the following general requirements:

- *Provide mobile public safety connectivity for at a minimum, police, fire, and EMS*

- *Operate in licensed land mobile radio frequency bands, except in the very high frequency (VHF) band for Tier 1 applications*
- *Use technologies in the unlicensed or licensed public safety bands, in conjunction with the Institute of Electrical and Electronics Engineers (IEEE) 802.11 for fixed 'hot spot' technology for, at a minimum, Tier 2 and Tier 3 applications*
- *Provide service to mobile units operating at street level at speeds up to posted speed limits*
- *Provide connectivity to approximately 100 public safety answering points (PSAPs)*
- *The system shall utilize existing ARMER tower sites, the state of Minnesota's Office of Enterprise Technology (OET) network, and backhaul equipment, to the maximum extent possible*
- *The overall architecture of the system shall provide for scalability, maintainability, disaster recovery, state-of-the-art equipment and software, future expansion potential to support additional services and be cost effective*

Complies. Specifics can be found in the HPD MDS system description and in subsequent responses.

3.4.1.1 General specifications

3.4.1.1.1 Protocols

Data transmitted over the system shall be formatted in accordance with Internet Protocol (IP) version 4 (IPv4) or better.

Complies. The HPD MDS uses industry standard IPv6 routing. The use of IP suite complies with the user-driven Project 25 standards for data systems.

3.4.1.1.2 Standards

Quality of Service (QoS) and virtual local area network (VLAN) tagging should be in accordance with IEEE 802.1p, 802.1q, and request for comments (RFC) 791.

Radio frequency (RF) links shall comply with applicable Federal Communication Commission (FCC) rules and guidelines.

Complies

3.4.1.1.3 Spectrum

The spectrum may include licensed and unlicensed frequencies in all bands except VHF. If unlicensed frequencies are proposed, the vendor must provide an interference risk mitigation plan to assure the state of the usefulness of the unlicensed spectrum.

Complies. The proposed MDS will operate in the licensed 700 MHz band.

It is the understanding that the state of Minnesota will provide properly licensed frequencies for use with all proposed equipment for all sites. This proposed HPD system design is based on utilizing frequencies with a minimal frequency separation of 250 kHz.

3.4.1.2 Codes and standards

The equipment, application software, and components, as well as their installation, integration, and testing, shall be in accordance with reasonable best industry standards. All materials, equipment, supplies, installation, and testing shall comply with the project requirements, the latest editions of standards, as applicable, and all other applicable standards and requirements.

The MDS shall adhere to appropriate codes and standards from the following standards bodies:

- *ANSI American National Standards Institute*
- *ASME American Society of Mechanical Engineers*
- *ASTM American Society for Testing and Materials*
- *EIA Electronic Industries Association*
- *FCC Federal Communications Commission*
- *IEEE Institute of Electrical and Electronic Engineers*
- *ISO International Standards Organization*
- *NEC National Electric Code*
- *NEMA National Electrical Manufacturers Association*
- *NFPA National Fire Protection Association*

- *OSHA Occupational Safety and Health Administration*
- *UL Underwriters Laboratory*

Complies

3.4.2 Functional requirements

3.4.2.1 System overview

The MDS shall offer a high degree of scalability, expandability, and upgradeability with minimal hardware obsolescence risk. The following system attributes are among those of most interest to the state of Minnesota:

- *Data throughput performance*
- *Channel bandwidths*
- *Over-the-air data speeds*
- *Over-the-air technology*
- *Fixed infrastructure topology (sites and frequencies)*
- *Networking*

The MDS shall support Tier 1 applications for all users. The MDS shall support Tier 2 and Tier 3 applications for 100% of all users.

The intent of the MDS is to provide seamless data coverage and roaming capabilities for data operations throughout the defined coverage area (county, region or state). The MDS shall leverage existing ARMER towers, sites, and backhaul equipment and potentially integrate into the OET Multi-Protocol Label Switching (MPLS) IP network, to the maximum extent possible. The state envisions the MDS to provide data services at the IP address level and utilizing open architecture and off-the-shelf equipment wherever possible.

Complies. The proposed HPD MDS is flexible and scalable; please refer to the system description.

The HPD MDS is designed for deployment as a citywide system, countywide system, statewide system, or country-wide systems by utilizing a 'zone concept' that allows systems to be networked together to form a larger system requiring

no intervention by the end-user as they traverse 'zones'. The users can roam from site to site, which is transparent to them.

3.4.2.2 System architecture

The MDS architecture shall be open, IP-based, scalable, and expandable. The MDS shall take advantage of existing ARMER tower sites and OET backhaul capabilities and, to the extent possible, leverage other existing equipment and infrastructure. The MDS shall utilize state-of-the-art equipment and software with future expansion capabilities to support additional services.

Partially complies. The TIA-902 standard was used as a base for HPD; the HSD MDS is fully compliant. The TIA-902 standard was developed for the 50 kHz technologies; since HPD is a 25 kHz technology, it technically does not comply in this area.

The MDS shall support Tier 1 applications with the ability to interface and switch to at least Tier 2 and Tier 3 applications in certain 'hot spot' locations. All applications shall reside on a single user's mobile data computer.

Complies. The HPD MDS satisfies Tier 1 and Tier 2 application requirements. Applications are transparent to the HPD network; all applications can reside on a single mobile client, provided it has the capacity for the applications.

The MDS must be capable of interfacing to the state of Minnesota Justice Information System (MNJIS) through local Computer Aided Dispatch (CAD) system interfaces or directly to the MNJIS via IP using a web browser.

Complies

The MDS shall be equipped to address each mobile client device on an individual, group or all-call basis.

Exception. The proposed HPD MDS does not support RF broadcast or group call communications. The HPD MDS supports single-threaded over-the-air communication between the mobile client and the HPD system. Host applications may support this type of functionality.

The MDS shall be able to provide Tier 1 applications within the same coverage footprint as the ARMER P25 voice radio system. Tier 2 level and higher applications may use a separate system potentially requiring an additional user mobile data modem.

Complies. The proposed HPD MDS coverage footprint will closely match that of the ARMER P25 voice radio system coverage.

3.4.2.3 RF spectrum

The MDS shall operate in licensed land mobile radio frequency bands, except in the very high frequency (VHF) band for Tier 1 applications. The MDS shall operate in the unlicensed or licensed public safety bands, in conjunction with the Institute of Electrical and Electronics Engineers (IEEE) 802.11 and/or 802.16 standards for fixed 'hot spot' technology for Tier 2 and above applications. The MDS shall have the ability to add channels, if needed, as RF spectrum becomes available.

Complies. The proposed HPD MDS will operate in the licensed 700 MHz band. The HPD MDS can be upgraded to support additional sites and channels if required.

3.4.2.4 Coverage

The MDS coverage design, implementation, and testing must adhere to the Telecommunications Industry Association (TIA) Telecommunications Systems Bulletin (TSB) #88 'Wireless Communications Systems Performance in Noise-Limited Situations' Parts 1, 2 & 3 (TIA TSB-88.1 & 2 & 3). These parts are as follows:

- *Part 1 - Recommended methods for technology independent performance modeling*
- *Part 2 - Propagation and noise*
- *Part 3 - Performance verification*

The TIA TSB-88 document addresses items including but not limited to: channel performance criterion (CPC), CPC reliability design target, terrain profile extraction method, interference calculation method, metaphors to describe the plane of the service area, required service area reliability, adjacent channel drift confidence factor, conformance test confidence level, sampling error allowance, pass/fail criterion, and treatment of inaccessible grids.

Coverage is broken down into coverage area and coverage reliability. Coverage area pertains to the physical 'footprint' of the system's transmission and reception area. Coverage reliability pertains to the probability of receiving and/or transmitting good data packets at any point in time, at any location within the specified coverage area.

Complies. Motorola adheres to TSB-88.

3.4.2.4.1 Coverage area

The Tier 1 MDS coverage area shall meet the same coverage area requirements of the ARMER P25 voice radio system. In-building coverage is not a requirement.

The required coverage area based on application Tiers is as follows:

- *The MDS providing Tier 1 applications shall provide 95% mobile coverage by county. This is the same coverage area requirement for the ARMER system*
- *The MDS providing Tier 2 and Tier 3 applications shall provide 'best effort' coverage as they may be commercially owned systems; it is expected that all users will obtain an unspecified variable bit rate and delivery time, dependent upon current traffic load*

Users shall be able to roam seamlessly between sites within one mobile data technology throughout a coverage area.

Complies. The proposed HPD MDS coverage footprint will closely match that of the ARMER P25 voice radio system coverage, providing Tier 1 & 2 support.

3.4.2.4.2 Coverage reliability

The MDS design shall provide adequate signal strength and forward error correction to accommodate areas obstructed by a foliage canopy, buildings and other structures, or topography, etc. in order to meet specified coverage reliability requirements.

The MDS shall achieve a minimum message success rate within 95% of the specified coverage area for 95% of the time.

Complies

3.4.2.4.3 Message success rate

Message success rate (MSR) is defined as the number of packet retries where the data equipment, as opposed to the software application, generated the original transmission and any subsequent re-transmissions.

The required message success rate based on system type (tier) shall be as follows:

- *Tier 1 systems shall have no more than three automatic re-transmissions on any attempted data transmission*
- *Tier 2 and higher tier systems shall have no more than 10% automatic retransmissions in any given timeframe*

The MDS must achieve this MSR while vehicles travel at posted speed limits.

Complies

3.4.2.5 Mobile client roaming

3.4.2.5.1 Intersystem

The system shall allow mobile data clients to roam across different collocated or non-collocated access points within the same wireless network from both an inactive or active client session. Roaming between different access points shall minimally impact client units. The system shall allow for roaming threshold to be configurable system-wide on an individual client basis by the data system administrator.

3.4.2.5.2 Regional

The MDS shall be able to be shared, with the same level of functionality, with other regional sub-systems. Networking or interfacing in this case means the linking of systems at the highest possible level to allow roaming (assuming the same frequency band and protocol) and equivalent functionality between regions. The system shall not preclude the networking of separate wireless data systems being procured separately, but shall enhance these designs wherever possible.

3.4.2.5.3 Multi-network

The MDS shall be equipped to allow the mobile data clients to switch between dissimilar wireless networks, such as IEEE 802.11 or those of commercial service providers, to provide access to Tiers 1, 2 and 3 applications.

Complies.

Applications on the mobile client will use a software-based switch compatible with Microsoft Windows XP, Windows 2000, Windows 98 and Windows Mobile to switch between the MDS supporting Tier 1 (and possibly Tier 2) applications and the MDS supporting Tier 2 and above applications as they become available. This switch controls connections to multiple wireless data networks, such as WiFi and WiMAX. The switch is configured for each MDS, enabling the mobile client to roam between the different networks with no user intervention.

The mobile client switch automatically limits the use of an application over certain network types, preventing applications that require higher bandwidth (e.g., Tier 2 and above) from using the low bandwidth (Tier 1) MDS. The switch sets up a virtual private network (VPN) session enabling mobile client applications access to databases and other services on the host LAN. Since the switch retains logon information for each MDS, users do not have to log on each time the mobile client connects to a new network. The switch maintains VPN connectivity after a user roams between MDSs. Even after roaming to another MDS, the switch maintains an application's connection to databases and other services on the host LAN. Server-based network administration software, residing on the host LAN, provides remote control and management of the mobile

client switch software. The VPN also provides data security and encryption services.

3.4.2.6 Data throughput

Data throughput (or capacity) is highly dependent on the applications, frequency of use of the applications, and the number of users. Other variables include application header size requirements, voice traffic priority, and the variety of applications in use.

Potential MDS vendors shall provide a detailed throughput study. This study shall include the required number of channels for the given geographical user distribution to support Tier 1 applications. It shall also include provisions for overhead associated with the following:

- *Automatic RF acknowledgment transmissions for all inbound and outbound messages*
- *Retries*
- *Automatic roaming*
- *Message packetization*
- *Error correction and error detection*

Capacity and throughput are dependent on many performance factors such as message load profiles of all applications running on mobile clients in the wireless network, network protocol (TCP/IP or UDP/IP) used, network traffic load and coverage reliability. Performance is optimized if the mobile application software has been written specifically for and successfully implemented in a wireless environment.

The HPD MDS can support up to five transmit/receive HPD channels per site in a typical system with up to 1,000,000 messages per hour per system. The number of channels per zone is limited to 300. Message throughput may vary depending on system configuration.

3.4.2.6.1 Data rate

The MDS shall have a minimum over-the-air data rate of 9,600 bps for Tier 1 applications; the MDS shall have a minimum over-the-air data rate of 64,000 bps for Tier 2 and Tier 3 applications.

Complies. The proposed HPD system provides data rates from 32 kbps to 96 kbps (depending on the distance to a site) over the coverage area.

3.4.2.6.2 Geographical user distribution

3.4.2.6.2.1 Beltrami County

Beltrami County shall be used as a countywide model for MDS system. Beltrami County encompasses 3,056 square miles, of which 550 square miles is water. The population of the county is 43,609.[19]

The ARMER system is planned for approximately 320 sites of which 7 sites are planned for the Beltrami County. The ARMER coverage plan calls for 95% coverage in each county. It is expected that the Tier 1 MDS system footprint will closely match the ARMER P25 voice radio system coverage.

For Beltrami County, the MDS shall support a minimum of 58 concurrent active mobile client units[20] *and interface to a minimum of one CAD system to support the PSAP in the region.*

Complies. Please refer to the system description for details.

3.4.2.6.2.2 Northwest Region

The Northwest Region of the state of Minnesota shall be used as a regional model for the MDS system. This region consists of 14 of the 87 counties in the state.

[19] 2007 estimated US census data
[20] Total user counts are based on two units for every 1,000 population, for a given geographic area; 66% of each count will be assumed for total concurrent system users. Counts used are based on estimated 2007 census data, with a statewide population of 5,197,621.

This region encompasses 17,055 square miles and includes these three medium-sized cities.

These cities have a combined population of 129,152, with the total population of the NW region being 251,994. The state of Minnesota population is 5,197,621. In comparison to the state, the Northwest Region represents 21% of the total square miles and 5% of the population.[21]

The ARMER system is planned for approximately 320 sites of which 57 sites are planned for the Northwest Region.NR The ARMER coverage plan calls for 95% coverage in each county. It is expected that the Tier 1 MDS system footprint will closely match the ARMER P25 voice radio system coverage.

For the Northwest Region, the MDS shall support a minimum of 333 concurrent active mobile client units and interface to a minimum of 14 CAD systems to support the 14 PSAPs in the region.

Complies. Please refer to the system description for details.

The proposed HPD MDS can only provide one 'IP tunnel' to one host per client at any given time. Multiple applications can be accessed from one host, however. In addition, the mobile client can use switching middleware, giving it the ability to access multiple hosts at one time via one or more networks.

3.4.2.6.2.3 State of Minnesota

The state of Minnesota encompasses 87,014 square miles and the population with a population of 5,197,621.[22]

For the state, the MDS shall support a minimum of 6860 concurrent active mobile client units and interface to a minimum of 100 CAD systems to support the PSAP's in the state according to the following:

[21] 2007 estimated US census data
[22] 2007 estimated US census data

- *In a defined rural environment, the MDS shall support a minimum of 10 concurrent active mobile client units interfacing two CAD systems on a per site basis*
- *In a defined urban environment, where Tier 2 and higher application services are available, the MDS shall be equipped to support a minimum of 20 concurrent active mobile client units interfacing three CAD systems on a per site basis*

Complies. Please refer to the system description for details.

The proposed HPD MDS can only provide one 'IP tunnel' to one host per client at any given time. Multiple applications can be accessed from one host. In addition, the mobile client can use switching middleware, giving it the ability to access multiple hosts at one time via one or more networks.

3.4.2.6.3 Message load profile

A projected message load profile is an estimate of the number of bytes transmitted and/or received per application transaction. Transactions may include Law Enforcement Message System (LEMS) queries and hot files to the state of Minnesota Justice Information Services (MNJIS) and the Federal Bureau of Investigation (FBI) Criminal Justice Information Services (CJIS) and National Crime Information Center (NCIC) databases, as well as motor vehicle, driver and warrant queries.

The predicted user message load profile (Table 1 in the Minnesota Public Safety Interoperable Wireless Data Feasibility Study Deliverable for Tasks 8 and Task 9: High Level Wireless Data Functional Requirements *document) shall serve as a benchmark for the MDS and be used in data throughput calculations. The Tier 1 MDS shall handle a peak Tier 1 message load profile of the peak number of units (2/3 of the total units) during the peak busy hour. This load profile shall be considered consistent throughout the state of Minnesota.*

Complies. The proposed HPD MDS system has two channels at each site to support the required message load profile assuming 2/3 of the total users concurrently on the system at peak usage time. The total number of channels required system-wide is based on the ability to reuse frequencies at different sites. These sites must be adequately separated. The diagram below depicts an example frequency reuse pattern showing frequencies reused at sites located

one site away from each other. Please refer to the implementation sections for the potential number of channels and frequencies required for each implementation.

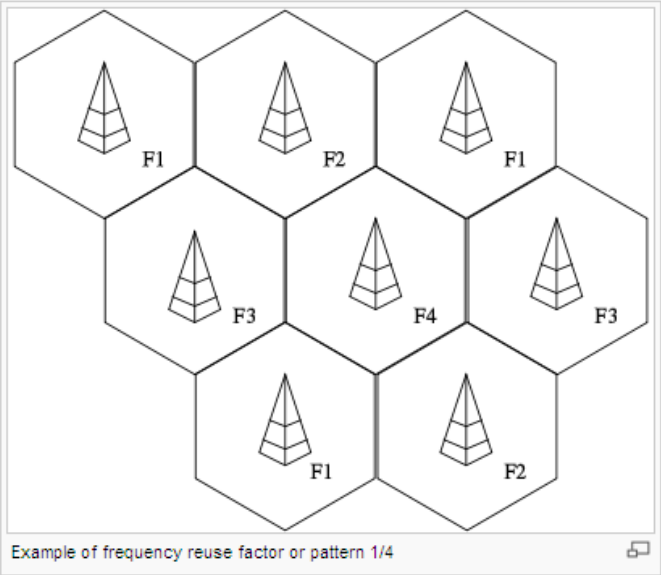

Figure 4 – Frequency Reuse Pattern

The predicted performance is based on the following assumptions:

- **The RF coverage area in the analysis is equivalent to the size of the ARMER P25 voice radio system**
- **All mobile clients in the simulation are distributed uniformly across the coverage area**
- **Additional UDP/IP headers are added to the length of the RFP profile message. Internet messages are associated with TCP/IP messages with additional overheads to support typical TCP and Internet access protocol.**
- **The message acknowledgment delay is the time elapsed between the initiation of the message and the return of corresponding acknowledgment after the message has been successfully delivered (excluding delays associated with host/client applications)**

3.4.2.6.4 Large file transfer

The MDS shall be capable of configuring the system to allow for large file transfers, where Tier 2 and higher data speeds are accessible. The MDS will integrate wireless

broadband 'hot spots' with capacity able to handle large wireless file transfers where backhaul capacity is capable of providing the appropriate network connectivity.

Complies. The proposed HPD MDS mobile clients can be configured with a third party middleware that intelligently switches between various services when available to the mobile client. Please refer to system description for more detail.

3.4.2.6.5 Future growth

The MDS shall meet the system requirements specified in this document plus an additional 10% of users for future growth.

Complies. The proposed HPD MDS is designed for an additional 10% of users.

3.4.2.7 Security

The system must have security capabilities that control system access and protects data integrity, such as encryption. The system shall employ security on multiple layers in compliance with Federal Information Processing Standards (FIPS) 140-2.

Complies

3.4.2.7.1 Encryption

The MDS shall support over-the-air, data link layer encryption. Over-the-air encryption shall have minimal impact to overhead data. Encryption schemes must be non-proprietary for 'hot spots' and follow Federal recommended encryption standards.

Over-the-air encryption should be limited such that regular data transmissions are not adversely affected.

Partially Complies. Encryption is provided at the application layer; the proposed HPD MDS does not offer 'hard' encryptions keys built in to the modems.

3.4.2.7.2 User authentication

The MDS shall authenticate individual users on the network with a login and password combination that is unique to each individual user.

Partially complies. The HPD system would not perform this task. It must be performed at the application level.

3.4.2.7.3 Device authentication

The MDS shall authenticate access by an authorized mobile client and deny access to an unauthorized mobile client. Any device being used to access the network must be authenticated to the network by an identifier that is unique to the device before access is granted.

Complies

3.4.2.8 Interfaces

3.4.2.8.1 System host interfaces

The MDS shall support a minimum of three host interfaces per county with the ability to add host interfaces up to a maximum of five per county.

Complies. Please refer to the system description for details.

3.4.2.8.2 Database interfaces

The MDS shall support access to MNJIS, FBI CJIS, NCIC and Law Enforcement Message System (LEMS) databases.

Complies. Please refer to the system description for details.

3.4.2.8.3 Physical Interfaces

The vendor shall describe the physical (DB-9, RJ-45, USB, etc.) and logical (serial, Ethernet, etc.) interfaces used for, but not limited to, the following:

- *The transmission and reception of mobile client/host application data*
- *Control of the base station features and functions*
- *Equipment monitoring/diagnostic*

For every site, and for each interface, the vendor shall state the transmission media that will interconnect the base stations to the system controller equipment or monitoring/diagnostic systems.

At each site where the existing digital microwave system will be used as the transmission media, the vendor shall describe the amount of bandwidth required for each interface.

Motorola has included equipment to support customer host interfaces, customer network interface barriers (CNIBs). The CNIB is a connectivity point for the state of Minnesota external host system to the secure HPD network infrastructure. These are the connection points for host applications such as computer aided dispatch (CAD), records management systems (RMS), etc.

The connection between the state of Minnesota host network and the HPD network is IP over Ethernet. The end-to-end IP network transports user data and control information between LAN-based computers and wireless computers in the field. Both USB and Ethernet connections are available with Motorola's HPD modem allowing wireless computers to access the network through a PPP interface.

Physical and logical demarcation points

Motorola's physical demarcation point on the host end will be the border router's WAN port that provides a physical connection point for the state of Minnesota customer enterprise network (CEN). The state of Minnesota must connect their CEN using a network switch or router to the border router WAN port. All

equipment required to faciliate this connection will be provided by the state of Minnesota.

The network interface barrier (NIB) will be Motorola's logical demarcation point on the host end. First, Core security components such as the firewall, intrusion detection sensor and core security management server (CSMS) will manage access to the HPD network from the CNIB. If access is permitted, the GGSN (gateway general packet radio service (GPRS) support node) will establish secure VPN tunnels to perform IP packet routing to and from the CEN. For example, it will forward mobile authentication requests to the authentication server in the state of Minnesota's host network. In order for host and mobile traffic to flow across the CNIB, all software applications must be written to a standard TCP/IP or UDP/IP interface. They also must fall into the policies estalished in the CSMS.

Total bandwidth required is specified in the backhaul response.

3.4.2.8.3.1 Data ports

The Owner may wish to add additional mobile computing devices such as optical readers, fingerprint scanners, printers, digital video recorders, etc., as they become ready for deployment. It is envisioned that these devices will be interconnected in such a manner as to create a vehicular local area network with the mobile modem being offered.

The vendor shall describe the manner(s) by which you propose to network these devices.

There are two physical demarcation points on the mobile client end. The first is the HPD modem Ethernet or USB port on the mobile client. The second is the global positioning system (GPS) serial COM port on the mobile client.

For the logical network interface, the mobile application software must be capable of communicating to the HPD modem through a PPP interface. The mobile application software must be written to a standard IP communication stack for transport across the HPD network.

3.4.2.9 Network management and control

The MDS shall include a network management and control subsystem (NMCS) as an integral component of the system. There may be one NMCS for Tier 1 application support and a separate NMCS for Tier 2 and Tier 3 application support; or there may be one NMCS for Tiers 1-3 application support.

Each NMCS shall be IP-based and function as the interface between the wireless network and the wire-line network utilizing simple network management protocol (SNMP), Telnet, and support higher-level network management system protocols. The NMCS shall be responsible, at a minimum, for the configuration and management of mobile clients, wireless network resources, and capable of all general administrative, diagnostic, monitoring, and reporting functions.

The NMCS shall be of current production and shall be capable of withstanding the harsh operating environment heavy usage associated with the delivery of public safety services. It shall provide features and functions compatible with existing and new fixed and mobile equipment. The NMCS shall be comprised of hardware, software, cabling, and associated accessories utilizing standard commercial-off-the-shelf (COTS) equipment wherever possible.

In addition, user/client prioritization is a desirable feature, but is an optional requirement at this time.

The NMCS will encompass administrative and maintenance functions necessary for proper installation, setup, and maintenance of the MDS.

Partially complies. The proposed HPD MDS does not offer a NMCS product that provides real-time utilization and performance history. However, Motorola's FullVision integrated network manager (INM) offers a simple network management protocol (SNMP) trap message forwarding capability to pass fault information to a higher level, 'enterprise' network manager. Faults and interpretive messages may be forwarded to a service technician's alphanumeric pager via a compatible dial-up, commercial paging service.

The network management control subsystem (NMCS) is comprised of three major subsystems. Each of these subsystems supports certain specific functions or management applications. These three subsystems are:

- **User configuration subsystem (UCS)**
- **Zone manager (OZM)**
- **FullVision integrated network manager (INM)**

All three subsystems reside on the zone controller/zone manager local area network (LAN). Access to network management applications is through network management terminals.

The NMCS can be viewed as a set of software applications or tools used to manage the zone controller and its constituent components. These tools are intended to maximize the available resources and minimize system downtime and maintenance costs.

The NMCS supports the following services:

- **Fault management – Applications are included for monitoring the status of the transport network and the individual infrastructure components; displaying status information; forwarding alert information; and performing diagnostic procedures.**
- **Configuration management – Facilities are provided for entering and maintaining the operational parameters of the infrastructure components and user devices.**
- **Accounting management– NMCS supports the tracking of data radio usage of the system by providing an optional interface to third-party accounting and/or billing applications.**
- **Security management – NMCS includes features for setting user privileges and controlling their access to view and/or modify information contained in the configuration databases.**

The user interface of the network manager includes menus to select objects and screens to enter data. The screens have a message area and help screens to inform and instruct the user on the entry of information and the use of the network manager. A graphical user interface (GUI) for the network manager allows for a multiple window, mouse-driven application that contains a pictorial representation of the zone level equipment. Each managed system component (i.e. site, controller, etc.) is represented by a pictorial icon that allows the user to access the status of the component via a pull-down menu. Fault indications

(alerts and alarms) on classes of components (i.e. repeaters, site controllers, etc.) can also be displayed. The user entry for the configuration of system components and subscriber information is simplified with the GUI. In general, the GUI provides a more visually intuitive interface.

3.4.2.9.1 Unique identifier

A unique ID must identify all fixed or mobile MDS terminal devices.

Complies

3.4.2.9.2 Device management, monitoring, and alarms

The NMCS shall provide real-time utilization, performance, status, health, and fault alarm information of all MDS system components including, but not limited to, network servers, networking devices, data base stations, mobile clients, and others.

The NMCS shall provide the following minimum features:

- *Remote management and upgrade of client devices*
- *Event logs*
- *Report generation*
- *Performance statistics such as link quality, network delays, etc.*
- *Secured remote access by typical client devices from authorized maintenance personnel*

The NMCS shall also be capable of reporting information of a historical nature and in a manner suitable for network planning purposes. At a minimum, the NMCS shall report bi-directional performance statistics on both the wireless and wireline portions of the network including each mobile client device, each radio base station, and the composite of all radio base stations.

The NMCS shall be equipped with the functionality capable of delivering alert text and/or email messages to radio pagers or cellular phones in the event of a detected fault condition. At a minimum, the text message shall contain fault specific information regarding the affected equipment and the location of the fault.

Partially complies. The proposed HPD MDS does not offer a NMCS product that provides real-time utilization and performance history. However, Motorola's FullVision INM offers a simple network management protocol (SNMP) trap message forwarding capability to pass fault information to a higher level, 'enterprise' network manager. Faults and interpretive messages may be forwarded to a service technician.

Please also refer to the description above.

3.4.2.9.3 Management partitioning

The MDS shall allow for partitioning of the system as it relates to administrative functions, system configurations, and client programming. The NMCS shall allow designated users permission to accomplish the following:

- *User groups permission to add or delete their client units from the system*
- *Maintenance personnel to verify device configuration and status*
- *Administrative personnel access to real time and historical reports*

Complies

3.4.2.9.4 Load balancing

Dependent upon the systems available within the user's current location, the MDS shall be able to balance low and high data payloads from different applications. For example, if a user is located in a rural environment for which only Tier 1 services exist, Tier 2 and higher applications shall not be allowed to transmit or receive data until the user has physically moved within range of a Tier 2 or higher radio site location. The load balancing thresholds shall be configurable by the data system administrator.

Complies. The proposed HPD MDS mobile clients can be configured with a third party middleware that intelligently switches between various services when available to the mobile client. Please refer to the system description for more detail.

3.4.2.9.5 Remote access

The NMCS shall be equipped to enable full functional access from IP-based networked workstations and utilize standardized internet applications (e.g. HTML, etc) for browser interface, by authorized personnel within the private network, or over encrypted connections, such as VPNs, for access from remote networks.

Complies

3.4.2.9.6 Programming and configuration

The NMCS shall allow for programming and configuration of the system base stations and mobile units from a system based network location by authorized users.

Partially complies. The proposed HPD MDS allows for remote programming and configuration for base stations and fixed network devices. Motorola takes exception to mobile client device programming, this cannot be performed over the air.

3.4.2.9.7 Information repository

The NMCS shall provide a database repository of system device and network connectivity information for use in configuration, programming, testing, and troubleshooting of system equipment and connections. Data shall include, but not be limited to, the following:

- *Network architecture diagram and description of hardware and software*
- *Base station and mobile device model and serial numbers, including configuration options and program settings*
- *Redundant carrier and redundant path description for telecom services that support the remote monitoring systems*
- *Network monitoring procedures*
- *Classification of support issues with corresponding escalation procedures and response times.*

All pertinent MDS data shall reside on a common network and be accessible from any location within the network by authorized personnel.

Partially complies. This information will be provided for storage and access on the customer's enterprise network.

3.4.2.10 Scalability, expandability, and redundancy

The MDS shall be deployable on a single site, multi-site, regional, or wide area basis capable of servicing any area within the state of Minnesota where ARMER or OET infrastructure exists. In addition, the network should provide for full automatic and seamless operation to mobile client users, while utilizing simple management and administrative functions.

The state shall be able to expand the MDS by adding sites for increased coverage, base stations for larger capacity, or network applications to improve efficiencies. In all cases, the MDS shall employ a high level of system redundancy (no single point of failure).

The MDS may initially be deployed on a regional or smaller basis, with the expectation to migrate to statewide use.

Complies. Please see responses below.

3.4.2.10.1 Expansion

The MDS shall be modular and scalable, utilizing hardware and software designs such that the system may be expanded, rather than replaced, to meet future requirements. The scalability of the system shall permit easy expansion, at a minimum, in these major areas:

- *Number of clients*
- *Radio frequencies*
- *Tower sites*
- *Host interfaces*
- *Network management interfaces*

Complies. The number of clients, radio frequencies, tower sites, hosts and management interfaces are all expandable.

3.4.2.10.2 Redundancy

Due to the critical nature of the MDS services, a high degree of reliability is required. Redundancy and reliability shall meet or exceed ARMER P25 voice radio system requirements. All components that encompass the MDS, including the NMCS, shall be viewed as critical elements of the network. Therefore, a network topology utilizing fault tolerance shall be incorporated to the greatest extent possible through a distributed and/or redundant architecture.

Complies. The proposed HPD MDS is based on Motorola's mission-critical P25 infrastructure.

3.4.2.10.3 System scan

The system shall be equipped to allow mobile clients to automatically scan for another RF channel in the event of loss of their primary RF channel.

Complies

3.4.2.10.4 Failure modes

The system shall be equipped with multiple failure modes to allow use of the MDS on limited data throughput basis rather than full system shut down.

Does not comply. The proposed HPD MDS does not provide limited 'scaled-back' failure modes; it works or it does not. It must be noted that redundancy is built-in or inherent to critical system points such as redundant core fixed network equipment (FNE) at zone controllers and the design requiring two base stations at each site.

3.4.2.11 Backhaul

The MDS shall utilize existing ARMER and OET networks for backhaul connectivity. MDS physical and protocol interfaces (e.g., DS0, T1, or Ethernet) shall comply with

ARMER and OET site-specific connectivity requirements. Bandwidth requirements of the MDS shall consider the available capacity of the ARMER and OET network.

Complies. It shall be responsibility of the state of Minnesota to provide operational interconnect facilities to provide connection points for Motorola installed fixed end equipment. The network backbone must meet the minimum required specifications as indicated in Table 1:

Table 2 - Minimum required T1 specifications

T1 SPECIFICATIONS	
Bit error rate – BER	**1×10^{-6}**
Stratum level	**2 or better**
Max. delay	**5 milliseconds (ms)**
Availability	**99.999 %**
Line coding	**B8ZS (bit 8 zero substitution)**
Signaling	**Clear channel**
Compression	**None**
Framing	**ESF (extended super frame)**
Pulse amplitude	**0 dBdsx (3.0V +/- 0.3V or 6V P-P)**
Dry or wet	**Dry, no voltage (-48 VDC or other) present**

A minimum of two DS0's per site or one DS0 per channel (whichever is greater) is required from each remote site to interconnect to the zone controller. For example, an HPD site equipped with four channels requires four DS0's; a single channel site will require two DS0's.

Please refer to the backhaul requirements detailed in the system description for each implementation.

3.4.2.12 Radio equipment requirements

3.4.2.12.1 Site infrastructure

The MDS shall utilize the state's existing ARMER site locations, available site equipment, infrastructure, and tower space to the greatest extent possible.

RF subsystem equipment (e.g., Heliax, antennas, and lightning and surge protection) shall be supplied for each site. Equipment shall connect to the state's existing microwave, fiber, and leased-line transport backhaul infrastructure.

Complies

3.4.2.12.1.1 Security

Gates, door locks, and passcode entrances shall physically secure MDS transmitter sites, database locations, and limited access terminals, where permissible.

Complies

3.4.2.12.1.2 Installation

Equipment shall be installed in existing equipment room spaces where available. Equipment shall be housed in suitable indoor-type cabinets or relay racks. These cabinets or racks shall be installed with ease of accessibility. Equipment shall be arranged and installed so its intended function will not be impaired due to weather, temperature, adjacent equipment, or other factors. Sufficient space and clearance shall be provided such that service and maintenance can be readily performed.

Renovations, designs, and installations at the site shall conform to the following guides:

- *Industry best practices*
- *Commercial Building Standard for Telecommunications Pathways and Spaces, TIA/EIA-569*
- *Commercial Building Telecommunications Wiring Standard, TIA/EIA-568*
- *Occupational Safety and Health Administration's recommended approved practices*
- *National Electric Code practices, including grounding and lightning suppression*
- *All applicable local, county, state building and life-safety codes*

Upon completion of the installation, all systems and equipment shall operate in accordance with applicable standards for operation.

Complies. All installations will comply with Motorola's R56 standards.

3.4.2.12.1.3 Power

System hardware installed at the transmitter sites shall be equipped with an uninterruptible power supply. Power losses, restorations, surges, sags, and/or brownouts shall not alter the operating parameters of MDS components. Other than total power loss or lethal surges, all components shall remain fully operational within the specifications of its design while experiencing any of these occurrences.

Complies

3.4.2.12.1.4 Base station radio

The base radio system shall be rated for and capable of continuous duty operations with required automatic station identifiers. The fixed equipment proposed shall be modular in design using 19" rack mountable units.

Complies

3.4.2.12.1.5 Programming and software upgrades

The base station radio shall allow for remote network based programming and/or software upgrades.

Complies

3.4.2.12.1.6 Security

Any MDS base station radio must authenticate any person utilizing the device via user login and password and/or biometrics.

Partially complies. As stated above, the proposed HPD MDS can support this, but authentication is handled at the application layer.

3.4.2.12.1.7 Internet Protocol

Each base station radio shall be equipped with an IP address (dynamic or static).

Complies. Within the proposed HPD MDS, each network device can operate with a static or dynamic IP address.

3.4.2.12.1.8 Unique modem identifier

Each base station radio must be uniquely identifiable by its static IP address or modem MAC address.

Complies

3.4.2.12.2 Mobile radio modem

The mobile radio modem shall provide an interface between the mobile computing device and the wireless data fixed network equipment. The mobile modem shall be a rugged, factory integrated vehicular radio modem product designed to provide optimal data transmission performance for mobile data applications.

Mobile units shall include a "smart switch" to determine the most efficient data transfer technology to use. The MDS modem shall default to the high-speed network when available; otherwise, it will switch to the existing low-speed network. This 'switching' capability may be hardware of software integrated.

Complies. The proposed HPD MDS mobile clients can be configured with a third party middleware that intelligently switches between various services when available to the mobile client. Please refer to the system description for more detail.

3.4.2.12.2.1 Programming and software upgrades

The mobile client shall allow for over-the-air-programming (OTAP) and/or software upgrades.

Does not comply. The proposed HPD MDS is not capable of OTAP.

3.4.2.12.2.2 Security

Any MDS client device must authenticate any person utilizing the device via user login and password and/or biometrics.

Partially complies. As stated above, the proposed HPD MDS can support this, but authentication is handled at the application layer.

3.4.2.12.2.3 Multiple receive

The modem shall simultaneously decode two incoming message streams for increased message reliability.

Does not comply. The proposed HPD MDS modem is not capable of multiple receive.

3.4.2.12.2.4 GPS

The mobile radio modem shall either incorporate global positioning system (GPS) receiver or be capable of receiving a GPS data from an external source.

Complies. The proposed HDP MDS utilizes Trimble Placer 450 GPS receivers. They integrate GPS and protocol support onto a single board enclosed in a low profile and ruggedized housing. The compact Trimble Placer 450 GPS unit includes two serial ports for connection to the mobile client. The Trimble Placer 450 GPS receivers incorporate a sophisticated 8-channel GPS receiver capable of tracking up to eight satellites. The GPS receiver calculates a new position once every second. Position accuracy is specified at 25 meters spherical error probability (SEP) and speed and heading accuracy is specified at 0.1 meters per second without selective availability.

3.4.2.12.2.5 Internet Protocol

Each radio modem shall be equipped with an IP address (dynamic or static).

Complies. Within the proposed HPD MDS, each network device can operate with a static or dynamic IP address.

3.4.2.12.2.6 Unique modem identifier

Each modem must be uniquely identifiable by its static IP address or modem MAC address.

Complies

3.4.2.12.2.7 Broadcast mode addressing

Modems must support individual group broadcast addressing by IP multicast and directed subnet broadcast.

Partially complies. The proposed HPD MDS does not support RF broadcast or group call communications. The HPD MDS supports single-threaded over-the-air communication between the mobile client and the HPD system. Typically, host applications can be used to support this type of functionality.

3.4.2.12.2.8 Positive acknowledge

Modems shall be capable of sending a positive acknowledgment to the originating base station radio upon receipt of successfully received and corrected messages.

Complies

3.4.2.12.2.9 Client Interface

Modems shall interface to a mobile data computer installed within a vehicle's passenger compartment.

- *Tier 1 modems shall interface via a 10/100Base-T or USB or serial DB9 connection, and*
- *Tier 2 and higher modems shall interface via a 10/100Base-T connection and employ advanced technology to allow higher performance operation, to allow for*

future modem upgrades or enhancements, and to allow the greatest degree of mobile hardware flexibility

Complies. The proposed HPD MDS modem interfaces to the mobile client via USB or COM connection.

3.5 Advantages and disadvantages

The Motorola HPD platform is designed specifically for a mobile data environment, unlike integrated voice and data systems (IV&D) which are optimized for voice. Of importance to the state of Minnesota, an HPD MDS can leverage existing and planned ARMER P25 voice radio system infrastructure including remote base sites, backhaul and core zone controller equipment. Motorola's mobile data systems have been installed in various configurations (local and wide area) and optimized for different user types including public safety, public works, utilities, and transportation agencies. Motorola's HPD product line includes devices capable of both 700 and 800 MHz frequency bands at 25 kHz bandwidth.

The backhaul and peripheral device wireline interface of this system is a standards-based IEEE 802.3 IP-based protocol and Ethernet 10/100Base-T interconnection. An IP standards based backhaul provides a semi-distributed architecture, increasing system redundancy and reducing the possibility of single point failures. A centralized system controller handles the HPD data traffic and may be configured for redundant operation.

Below are strengths and weaknesses of Motorola HPD platform as compared to other technologies:

Strengths:

- HPD is a stand-alone mobile data system solution, thereby providing higher data speeds than an IV&D solution
- HPD can be overlaid on any voice system, using the same sites and backhaul system. In particular, HPD can be overlaid on the ARMER network leveraging the existing ARMER sites, backhaul and some zone controller equipment.
- User radio modems can operate on both 700 and 800 MHz frequency bands
- Radio sites are deployed only where the HPD coverage and capacity are required
- Other than operations and maintenance, there are no recurring costs

Weaknesses:

- HPD is a stand-alone mobile data system solution, thereby requiring two mobile radios, two base stations, two network controllers, etc. for users who require both voice and data operations
- User must have authorization to use or ownership of appropriate spectrum
- Implementation of a network requires real estate site leases and/or site acquisition
- The system uses proprietary routers and network switches
- Use of a centralized system controller creates a potential single point of failure
- Migration to HSD requires 700 MHz 50 kHz channels

3.6 Rough order-of-magnitude (ROM) cost estimates

This section provides high-level, ROM estimates for each implementation – county, regional and statewide - discussed in this proposal. Please note that these estimates are ROM only, and a detailed design would be required for a more accurate estimate.

Capital outlay costs are associated with deploying this technology for the site mobile data equipment and user radio modems. There are no recurring fees other than regular operations and maintenance. Please note other assumptions and notes following the cost tables.

3.6.1 County implementation

	Qty	Cost	Total
Zone controller (see Note 1)	1	$0	$0
Remote site (see Note 3)	7	$841,000	$5,887,000
Mobile client modem	87	$8,500	$739,500
Switching middleware (per mobile client)	87	$1,000	$87,000
Infrastructure Sub-total			$6,713,500
Project management / engineering		included	$0
TOTAL ROM COST			**$6,713,500**

3.6.2 Regional implementation

	Qty	Cost	Total
Zone controller (see Note 1)	1	$0	$0
Remote site (see Note 3)	57	$841,000	$47,937,000
Mobile client modem	504	$8,500	$4,284,000
Switching middleware (per mobile client)	504	$1,000	$504,000
Infrastructure Sub-total			$52,725,000
Project management / engineering		included	$0
TOTAL ROM COST			**$52,725,000**

3.6.3 Statewide implementation

	Qty	Cost	Total
Zone controller (see Note 1)	1	$0	$0
Zone controller (see Note 2)	3	$1,500,000	$4,500,000
Remote site (see Note 3)	316	$841,000	$265,756,000
Mobile client modem	10,395	$8,500	$88,357,500
Switching middleware (per mobile client)	10,395	$1,000	$10,395,000
Infrastructure Sub-total			$369,008,500
Project management / engineering		included	$0
TOTAL ROM COST			**$369,008,500**

Notes:

1. Assumes use of the Metro Regional/Hennepin County zone controller (New zone controller cost = $7.1M to $8.1M.)
2. Cost to add data capability to existing zone controller is $1.3M to $1.5M
3. Remote site cost = $740K to $841K
4. Site costs include two 700 MHz base stations at each site
5. Costs include site and mobile equipment installation
6. Costs include site and mobile antenna systems
7. All tower sites include $5,000 for structural analysis of existing tower structures
8. Costs do not include backhaul costs and may require additional capacity
9. Costs include one year warranty and software updates
10. Discounts are not included

4. CalAmp Dataradio MDS

4.1 System Description

The proposed CalAmp Dataradio MDS will serve as a platform for a scalable interoperable multi-agency MDS network. It will:

- Be upgradeable to support future 700 MHz wide band data technologies
- Be capable of supporting multiple data networks such as WiFi, WiMAX and other private and/or public networks with the ability to roam between networks using mobile router/switching technology
- Be capable of expanding the service area as other agencies, counties and/or regions are added to the system
- Operate in public safety licensed spectrum

CalAmp's Dataradio public safety product line includes the Gemini mobile radio modems paired with Paragon digital base stations. This equipment employs CalAmp's proprietary digital over-the-air protocol, which allows the wireless communications between the mobile client and the base station. These products are developed specifically for those intending to deploy a dedicated public safety MDS.

The proposed Dataradio MDS will be implemented in the 700 MHz frequency band with an over-the-air data rate of 64 to 128 kbps. The base stations do not dynamically switch between data rates, each base station is set at a specific data rate. For the proposed Dataradio MDS to provide data rates in the range of 64 to 128 kbps, one base station will be configured for 64 kbps and another at 128 kbps; as the proposed design calls for two channels or base stations at each site. The purpose of this multi-data rate design is to provide a larger coverage footprint at the lower speed to more closely match the coverage footprint of the ARMER P25 voice radio system; the base station configured for 64 kbps will provide a larger coverage area, more closely matching to that of the ARMER coverage. Applications from Tiers 1, 2, and 3 may be effectively deployed on this infrastructure.

The wireless application will interface to the radio network using IP. IP connectivity allows a variety of mobile data applications to operate over the Dataradio infrastructure. Dataradio's IP implementation reduces unnecessary IP overhead, provides compression for efficient delivery, and encrypts to provide security.

The wireless connection between mobile clients and the base sites will be implemented using Dataradio's enhanced dynamic bandwidth allocation (E-DBA) radio link protocol.

E-DBA is Dataradio's highest performance over-the-air protocol specifically optimized for transactions found in applications requiring short and long inbound and outbound transmissions. The E-DBA protocol for over-the-air data transmission provides the greatest throughput and the fastest response times available on a private mobile data network. E-DBA, because of its ability to quickly deliver large packets, error handling algorithms and contention resolution protocols, provides tremendous efficiencies in the bandwidth constrained RF environment.

E-DBA supports these transactions by providing many advanced features not available from any other wireless vendor. Some of these features include:

- Out-Of-Band (OOB) Signaling – Allows transmission of GPS information without consuming bandwidth for user data.
- Hyper-Code Forward Error Correction – A high efficiency error correction technique that corrects for errors due to fades in the mobile environment.

These enhancements allow Dataradio to provide networks with higher capacity and throughput rates than those from competitive private radio networks.

Figure 5 shows an overall diagram of the proposed Dataradio MDS. The customer-provided application server, the network management information server (NMIS) and the Paragon base station radios will reside on the state's ARMER network. These devices must reside either on the same sub-net or they must have a routable path between each other. Each mobile in the fleet will be assigned a static IP address on a separate wireless subnet.

The proposed Dataradio MDS will use routers just as the wired network currently does. All mobile users will be segregated onto a separate wireless subnet. System security on the wired side of the LAN remains the state of Minnesota's responsibility.

When the application server has a message to send to a mobile, it sends it to an IP address, just as if it were sending to a workstation connected to the LAN. Essentially, the state of Minnesota's wired infrastructure relays the message through router(s). The router then delivers the message to the proper tower. The message will be delivered to the proper tower through the state of Minnesota's LAN. Once received at the base site, it is sent over-the-air to the mobile client.

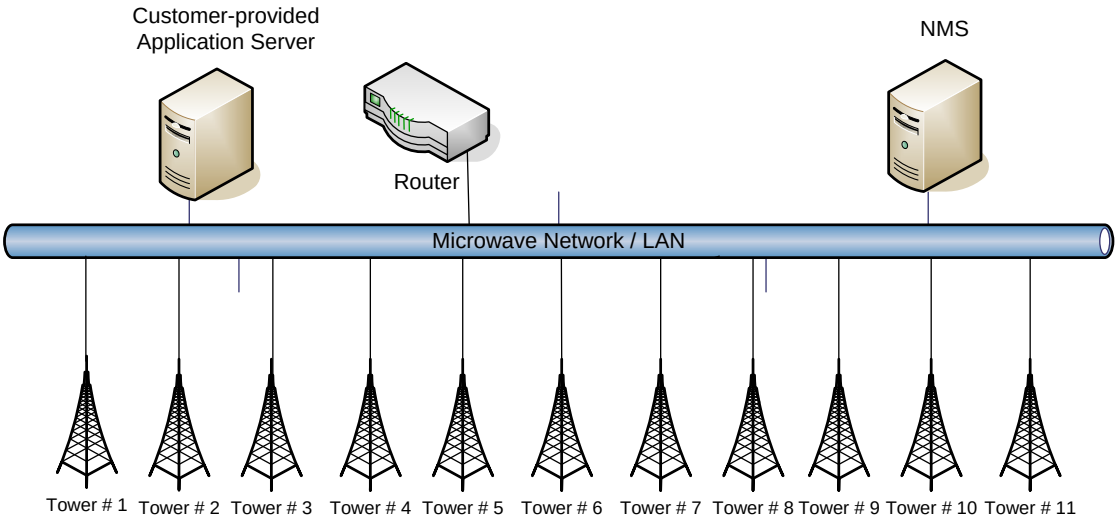

Figure 5 – CalAmp DataRadio MDS Base Radio Sites

A block diagram of the equipment to be placed at each tower site can be found in Figure 6. Each base site will be connected to Minnesota's Ethernet LAN.

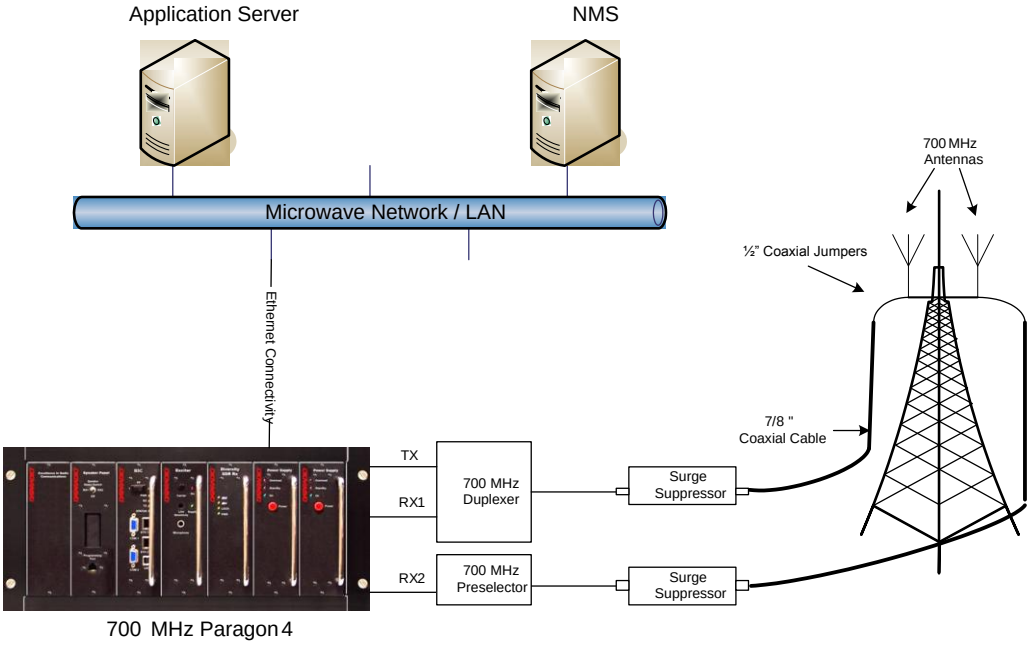

Figure 6 – DataRadio MDS remote site block diagram

The proposed Dataradio MDS will be designed to maximize RF coverage and capacity. Each site uses an antenna network designed to provide maximum system performance. One antenna will be for a transceiver and the other antenna will be for a secondary receiver only. Two antennas horizontally spaced are the minimum needed in a parallel decode system. The Paragon base station is connected to the customer-provided application server via the state of Minnesota's LAN. The Paragon base station radios operate in a full-duplex mode. The Dataradio proposal includes all necessary RF equipment to outfit the sites for data operation.

Applications on the mobile client will use a software-based switch compatible with Microsoft Windows XP, Windows 2000, Windows 98 and Windows Mobile to switch between the MDS supporting Tier 1 (and possibly Tier 2) applications and the MDS supporting Tier 2 and above applications as they become available. This switch controls connections to multiple wireless data networks, such as HPD, WiFi, and WiMAX. The switch is configured for each MDS, enabling the mobile client to roam between the different networks with no user intervention.

The mobile client switch automatically limits the use of an application over certain network types, preventing applications that require higher bandwidth (e.g., Tier 2 and above) from using the low bandwidth (Tier 1) MDS. The switch sets up a virtual private network (VPN) session enabling mobile client applications access to databases and other services on the host LAN. Since the switch retains logon information for each MDS, users do not have to log on each time the mobile client connects to a new network. The switch maintains VPN connectivity after a user roams between MDSs. Even after roaming to another MDS, the switch maintains an application's connection to databases and other services on the host LAN. Server-based network administration software, residing on the host LAN, provides remote access and management of the mobile client switch software. The VPN also provides data security and encryption services.

Implementation of a Dataradio MDS is similar to other private mobile data systems. The proposed Dataradio MDS will be implemented as a 'layer' over the ARMER P25 voice radio system. With the proposed multi-data rate design described above, the coverage footprint will be similar to the ARMER P25 voice radio system and the sites will be identical between systems.

Below are the high-level steps to implement a P25 IV&D MDS:

- Develop a detailed design for the Dataradio MDS

- Acquire spectrum
- Upgrade the backhaul network if necessary
- Prepare and release a Request for Proposal (RFP) if necessary
- Update the radio site infrastructure as necessary
- Install and test the Dataradio MDS fixed and mobile equipment
- Perform system cutover, installation, and testing of user radio equipment
- Complete acceptance testing for the Dataradio MDS

The schedule and timeframe for implementation are dependent upon the availability of radio sites and frequencies, number of radio sites, and cutover strategy (phased regional deployments or a single statewide deployment). The Dataradio MDS may be implemented at local (county), regional, or statewide levels. If necessary, regions may be deployed one-by-one and connected together in a phased approach in order to accomplish a statewide implementation.

This proposal considers implementation scenarios at the county (Beltrami), regional (NW-RRB) and statewide levels. Section 4.6 of this document provides ROM cost for each implementation.

4.2 System implementation

This section provides a description of the implementation of the MDS at a county, regional or state level. The information outlines the requirements for system coverage, system architecture, network interface, and backhaul for each of the implementations as envisioned by DPS.

4.2.1 County implementation – Beltrami County

4.2.1.1 Overview

The proposed Dataradio MDS county design includes seven sites to provide 95% county coverage; site count and site locations are identical to the seven sites proposed for the ARMER P25 voice radio system. By using the same sites, the proposed Dataradio MDS coverage will closely match that of the ARMER P25 voice radio system coverage and contribute to overall cost savings.

The proposed Dataradio MDS county design requires 14 700 MHz channels, providing two channels at each site (ideally one 25 kHz and one 50 kHz channel at each site, if available). This proposed Dataradio MDS is designed to support 58 concurrent active

mobile clients[23], with a 10% growth factor of additional users per the functional requirements.

4.2.1.2 Network interfaces

The proposed Dataradio MDS can support the required three (per the functional requirements) host application connections; this is the connectivity point for external host application systems, such as computer aided dispatch (CAD), records management systems (RMS), etc., for data transmitted and received over the network infrastructure. Expansion is possible with the appropriate additional routing equipment.

The connection between the host application network and the Dataradio network is IP over Ethernet. The end-to-end IP network transports user data and control information between host computers to and from the mobile clients in the field. Ethernet connections are available on the Dataradio modem allowing mobile clients access to the network through a PPP interface.

4.2.1.3 Backhaul

The state of Minnesota will be responsible to provide the necessary backhaul between sites. The network backhaul must meet the minimum required specifications as indicated in Table 1 provided in the point-by-point responses of this proposal.

The Gemini/Paragon equipment platform uses a non-proprietary IP open-architecture utilizing standardized IEEE 802.3 Ethernet 10/100Base-T protocols in a LAN environment. Commercial off-the-shelf routers and network switches are employed in the network design for ease of training and maintenance. Any backhaul architecture (microwave, fiber, or leased lines) capable of transporting IP traffic may be used for the Dataradio network. If Ethernet circuits are used for backhaul, they can be connected directly to the base station. If a T1 or DS0 circuit is used, then a router will have to be used to translate the T1 or DS0 circuit to Ethernet.

Backhaul network connectivity must be available and either have available capacity or the ability to upgrade in order to meet the state of Minnesota's growth requirements. In the case of the Gemini/Paragon equipment, standardized IEEE 802.3 Ethernet

[23] Total user counts are based on two units for every 1,000 population, for a given geographic area; 66% of each count will be assumed for total concurrent system users. Counts used are based on estimated 2007 census data, with a statewide population of 5,197,621.

10/100Base-T protocols and interfaces allow interconnection from the radio base stations via the agency's network.

A backhaul network is required to facilitate communication between sites. The Dataradio MDS demarcation points will be the routers at the sites. A minimum of 256 kbps of backhaul bandwidth is required for each base station. Based on the proposed two-channel design, 512 kbps of backhaul bandwidth will be required for each site.

4.2.2 Regional implementation - Northwest Region

4.2.2.1 Overview

The proposed Dataradio MDS regional design includes 57 sites to provide 95% regional coverage. The site count and site locations are identical to the 57 sites proposed for the ARMER P25 voice radio system. By using the same sites, the proposed Dataradio MDS footprint will closely match that of the ARMER P25 voice radio system coverage and contribute to overall cost savings.

The proposed Dataradio MDS regional design requires 114 700 MHz channels, providing two channels at each site (ideally one 25 kHz and one 50 kHz channel at each site, if available). This does not mean, however, that 114 frequencies are required. Frequencies can be used at two or more radio sites as long as there is adequate separation between sites. If sites are too close, using the same frequency for a channel will cause interference. In a similar implementation, Motorola has indicated, the minimum number of frequencies that may be required for a Northwest Region implementation is 14. A detailed design, however, may indicate that more frequencies are needed. The technology architecture theoretically requires a minimum of a 14-channel reuse pattern (assuming two channels at each site). When terrain and high antenna mounting heights are factored in, many more frequencies may be required before any reuse pattern can be established.

This proposed Dataradio MDS is designed to support 333 concurrent active mobile clients[24], with a 10% growth factor of additional users per the functional requirements.

[24] Total user counts are based on two units for every 1,000 population, for a given geographic area; 66% of each count will be assumed for total concurrent system users. Counts used are based on estimated 2007 census data, with a statewide population of 5,197,621.

4.2.2.2 Network interfaces

The proposed Dataradio MDS can support a minimum of three (per the functional requirements) host application connections per county; this is the connectivity point for external host application systems, such as computer aided dispatch (CAD), records management systems (RMS), etc., for data transmitted and received over the network infrastructure. Expansion is possible with the appropriate additional routing equipment.

The connection between the host application network and the Dataradio network is IP over Ethernet. The end-to-end IP network transports user data and control information between host computers to and from the mobile clients in the field. Ethernet connections are available on the Dataradio modem allowing mobile clients access to the network through a PPP interface.

4.2.2.3 Backhaul

The state of Minnesota will be responsible to provide the necessary backhaul between sites. The network backhaul must meet the minimum required specifications as indicated in Table 1 provided in the point-by-point responses of this proposal.

The Gemini/Paragon equipment platform uses a non-proprietary IP open-architecture utilizing standardized IEEE 802.3 Ethernet 10/100Base-T protocols in a LAN environment. Commercial off-the-shelf routers and network switches are employed in the network design for ease of training and maintenance. Any backhaul architecture (microwave, fiber, or leased lines) capable of transporting IP traffic may be used for the Dataradio network. If Ethernet circuits are used for backhaul, they can be connected directly to the base station. If a T1 or DS0 circuit is used, then a router will have to be used to translate the T1 or DS0 circuit to Ethernet.

Backhaul network connectivity must be available and either have available capacity or the ability to upgrade in order to meet the state Minnesota's growth requirements. In the case of the Gemini/Paragon equipment, standardized IEEE 802.3 Ethernet 10/100Base-T protocols and interfaces allow interconnection from the radio base stations via the agency's LAN.

A backhaul network is required to facilitate communication between sites. The Dataradio MDS demarcation points will be the routers at the sites. A minimum of 256 kbps of backhaul bandwidth is required for each base station. Based on the proposed two-channel design, 512 kbps of backhaul bandwidth will be required for each site.

4.2.3 Statewide Implementation

4.2.3.1 Overview

The proposed Dataradio MDS statewide design includes 320 sites to provide 95% statewide coverage; site count and site locations are identical to the 320 sites proposed for the ARMER P25 voice radio system. By using the same sites, the proposed Dataradio MDS footprint will closely match that of the ARMER P25 voice radio system coverage and contribute to cost savings.

The proposed Dataradio MDS statewide design requires 640 700 MHz channels, providing two channels at each site (ideally one 25 kHz and one 50 kHz channel at each site, if available). This does not mean, however, that 640 frequencies are required. Frequencies can be used at two or more radio sites as long as there is adequate separation between sites. If sites are too close, using the same frequency for a channel will cause interference. In a similar implementation Motorola estimated, the minimum number of frequencies that may be required for a statewide implementation is 14. A detailed design, however, may indicate that more frequencies are needed. The system architecture theoretically requires a minimum of a 14-channel reuse pattern (assuming two channels at each site). When terrain and high antenna mounting heights are factored in, many more frequencies may be required before any reuse pattern can be established.

This proposed Dataradio MDS is designed to support 6,860 concurrent active mobile clients[25], with a 10% growth factor of additional users considered per the functional requirements.

4.2.3.2 Network Interfaces

The proposed Dataradio MDS can support a minimum of three (per the functional requirements) host application connections per county; this is the connectivity point for external host application systems such as computer aided dispatch (CAD), records management systems (RMS), etc. to transmit and receive data over the network infrastructure. Expansion is possible with the appropriate additional routing equipment.

[25] Total user counts are based on two units for every 1,000 population, for a given geographic area; 66% of each count will be assumed for total concurrent system users. Counts used are based on estimated 2007 census data, with a statewide population of 5,197,621.

The connection between the host application network and the Dataradio network is IP over Ethernet. The end-to-end IP network transports user data and control information between host computers to and from the mobile clients in the field. Ethernet connections are available on the Dataradio modem allowing mobile clients access to the network through a PPP interface.

4.2.3.3 Backhaul

The state of Minnesota will be responsible to provide the necessary backhaul between sites. The network backhaul must meet the minimum required specifications as indicated in Table 1 provided in the point-by-point responses of this proposal.

The Gemini/Paragon equipment platform uses a non-proprietary IP open-architecture utilizing standardized IEEE 802.3 Ethernet 10/100Base-T protocols in a LAN environment. Commercial off-the-shelf routers and network switches are employed in the network design for ease of training and maintenance. Any backhaul architecture (microwave, fiber, or leased lines) capable of transporting IP traffic may be used for the Dataradio network. If Ethernet circuits are used for backhaul, they can be connected directly to the base station. If a T1 or DS0 circuit is used, then a router will have to be used to translate the T1 or DS0 circuit to Ethernet.

Backhaul network connectivity must be available and either have available capacity or the ability to upgrade in order to meet the state of Minnesota's growth requirements. In the case of the Gemini/Paragon equipment, standardized IEEE 802.3 Ethernet 10/100Base-T protocols and interfaces allow interconnection from the radio base stations via the agency's LAN.

A backhaul network is required to facilitate communication between sites. The Dataradio MDS demarcation points will be the routers at the sites. A minimum or 256 kbps of backhaul bandwidth are required for each base station. Based on the proposed two-channel design, 512 kbps of backhaul bandwidth will be required for each site.

4.3 Interoperability standards

Although the CalAmp over-the-air protocol is proprietary, their Gemini modem and Paragon base station adhere to standards defined by IEEE 802.3 for backhaul and peripheral interconnectivity. A non-proprietary backhaul allows for interface into various agency systems, meeting Department of Homeland Security (DHS) interoperability

requirements and complies with National Information Exchange Model (NIEM) and guidance set by SAFECOM.

4.3.1 Data transport

There are three areas of data transport: over-the-air, peripheral interface and backhaul interface. The CalAmp Dataradio public safety systems employ a proprietary over-the-air half-duplex E-DBA protocol developed by CalAmp Dataradio specific for the mobile data environment. E-DBA is a scheduled air-link protocol (that is, packets are scheduled to go out over-the-air according to priority as opposed to being sent immediately) whose algorithms were designed to favor throughput over latency. To achieve that goal, the air-link uses adaptive timeslots called cycles to schedule traffic. These cycles dynamically vary in length (typically, between 200 to 1500 milliseconds) based on various factors, including network load. Each packet of data transiting through an E-DBA network must therefore be scheduled for transmission. This scheme provides for an efficient way to provide higher data rates.

4.3.2 Equipment

The Gemini/Paragon equipment platform uses standardized IEEE 802.3 Ethernet 10/100Base-T protocols and interfaces to connect the dispatch/control center with the radio sites. The same protocols and interfaces are utilized between the modem and peripheral devices within the vehicle. Proprietary E-DBA with OOB automatic vehicle location support is the over-the-air protocol between the modems and the base stations.

4.4 System capabilities

This section provides a point-by-point response to Section 3.0 of the state of *Minnesota Public Safety Interoperable Wireless Data Feasibility Study Deliverable for Tasks 8 and 9: High Level Wireless Data Functional Requirements* document. The functional requirements defined in this deliverable are re-stated here in *blue italics* with the response immediately following.

4.4.1 General requirements

The MDS shall meet the following general requirements:

- *Provide mobile public safety connectivity for at a minimum, police, fire, and EMS*
- *Operate in licensed land mobile radio frequency bands, except in the very high frequency (VHF) band for Tier 1 applications*
- *Use technologies in the unlicensed or licensed public safety bands, in conjunction with the Institute of Electrical and Electronics Engineers (IEEE) 802.11 for fixed 'hot spot' technology for, at a minimum, Tier 2 and Tier 3 applications*
- *Provide service to mobile units operating at street level at speeds up to posted speed limits*
- *Provide connectivity to approximately 100 public safety answering points (PSAPs)*
- *The system shall utilize existing ARMER tower sites, the state of Minnesota's Office of Enterprise Technology (OET) network, and backhaul equipment, to the maximum extent possible*
- *The overall architecture of the system shall provide for scalability, maintainability, disaster recovery, state-of-the-art equipment and software, future expansion potential to support additional services and be cost effective*

Complies. The proposed Dataradio RF Infrastructure will operate in the 700 MHz frequency band and can operate on both 25 kHz and 50 kHz channels at data rates of 64 kbps and 128 kbps respectively[26]. This proposed infrastructure supports Tier 1, Tier 2 and Tier 3 applications. The Dataradio solution also supports roaming from the proposed 700 MHz private network to 802.11 networks via Radio-IP multi-roaming software. This allows the MDS to automatically switch to the customer's 802.11 client WiFi adapter when in range of a WiFi access point or 'hot spot'.

4.4.1.1 General specifications

4.4.1.1.1 Protocols

Data transmitted over the system shall be formatted in accordance with Internet Protocol (IP) version 4 (IPv4) or better.

Complies

4.4.1.1.2 Standards

[26] Currently awaiting the FCCs ruling of the 700 MHz 'D-Block' for 50 kHz channel availability.

Quality of service (QoS) and virtual local area network (VLAN) tagging should be in accordance with IEEE 802.1p, 802.1q, and request for comments (RFC) 791.

Radio frequency (RF) links shall Complies with applicable Federal Communication Commission (FCC) rules and guidelines.

Complies

4.4.1.1.3 Spectrum

The spectrum may include licensed and unlicensed frequencies in all bands except VHF. If unlicensed frequencies are proposed, the vendor must provide an interference risk mitigation plan to assure the state of the usefulness of the unlicensed spectrum.

Complies. The Dataradio proposed RF Infrastructure will operate in the licensed 700 MHz frequency band on a 50 kHz channel.

4.4.1.2 Codes and standards

The equipment, application software, and components, as well as their installation, integration, and testing, shall be in accordance with reasonable best industry standards. All materials, equipment, supplies, installation, and testing shall Complies with the project requirements, the latest editions of standards, as applicable, and all other applicable standards and requirements.

The MDS shall adhere to appropriate codes and standards from the following standards bodies:

- *ANSI American National Standards Institute*
- *ASME American Society of Mechanical Engineers*
- *ASTM American Society for Testing and Materials*
- *EIA Electronic Industries Association*
- *FCC Federal Communications Commission*
- *IEEE Institute of Electrical and Electronic Engineers*
- *ISO International Standards Organization*
- *NEC National Electric Code*

- *NEMA National Electrical Manufacturers Association*
- *NFPA National Fire Protection Association*
- *OSHA Occupational Safety and Health Administration*
- *UL Underwriters Laboratory*

Complies. The proposed mobile data radios complies with applicable FCC and Industry Canada (IC) standards.

4.4.2 Functional requirements

4.4.2.1 System overview

The MDS shall offer a high degree of scalability, expandability, and upgradeability with minimal hardware obsolescence risk. The following system attributes are among those of most interest to the state of Minnesota:

- *Data throughput performance*
- *Channel bandwidths*
- *Over-the-air data speeds*
- *Over-the-air technology*
- *Fixed infrastructure topology (sites and frequencies)*
- *Networking*

The MDS shall support Tier 1 applications for all users. The MDS shall support Tier 2 and Tier 3 applications for 100% of all users.

The intent of the MDS is to provide seamless data coverage and roaming capabilities for data operations throughout the defined coverage area (county, region or state). The MDS shall leverage existing ARMER towers, sites, and backhaul equipment and potentially integrate into the OET Multi-Protocol Label Switching (MPLS) IP network, to the maximum extent possible. The state envisions the MDS to provide data services at the IP address level and utilizing open architecture and off-the-shelf equipment wherever possible.

Complies. The proposed Dataradio RF Infrastructure offers scalability, expandability and upgradeability with minimal hardware obsolescence risk. The proposed Dataradio RF Infrastructure supports Tier 1, Tier 2 and Tier 3 applications for all users at a maximum data rate of 128 kbps.

4.4.2.2 System architecture

The MDS architecture shall be open, IP-based, scalable, and expandable. The MDS shall take advantage of existing ARMER tower sites and OET backhaul capabilities and, to the extent possible, leverage other existing equipment and infrastructure. The MDS shall utilize state-of-the-art equipment and software with future expansion capabilities to support additional services.

Partially Complies. The proposed Dataradio RF infrastructure is an open, IP-based, scalable, and expandable architecture, which uses state-of the art equipment with future expansion capabilities to support the needs of the customer. The Dataradio RF infrastructure will interface to the state of Minnesota Justice Information System via IP.

The MDS shall support Tier 1 applications with the ability to interface and switch to at least Tier 2 and Tier 3 applications in certain 'hot spot' locations. All applications shall reside on a single user's mobile data computer.

Complies. The Dataradio MDS satisfies Tier 1 and Tier 2 application requirements (and Tier 3 if 50 kHz channels are used). Applications are transparent to the network; all applications can reside on a single mobile client, provided it has the capacity for the applications.

The MDS must be capable of interfacing to the state of Minnesota Justice Information System (MNJIS) through local computer aided dispatch (CAD) system interfaces or directly to the MNJIS via IP using a web browser.

Complies

The MDS shall be equipped to address each mobile client device on an individual, group or all-call basis.

Complies

The MDS shall be able to provide Tier 1 applications within the same coverage footprint as the ARMER P25 voice radio system. Tier 2 level and higher applications may use a separate system potentially requiring an additional user mobile data modem.

Dataradio can only commit to the coverage footprint outlined in the plots accompanying a Dataradio RF coverage study for the proposed system.

4.4.2.3 RF spectrum

The MDS shall operate in licensed land mobile radio frequency bands, except in the very high frequency (VHF) band for Tier 1 applications. The MDS shall operate in the unlicensed or licensed public safety bands, in conjunction with the Institute of Electrical and Electronics Engineers (IEEE) 802.11 and/or 802.16 standards for fixed 'hot spot' technology for Tier 2 and above applications. The MDS shall have the ability to add channels, if needed, as RF spectrum becomes available.

Complies. The Dataradio proposed RF Infrastructure will operate in the licensed 700 MHz frequency band on a 50 kHz channel at a maximum data rate of 128 kbps.

4.4.2.4 Coverage

The MDS coverage design, implementation, and testing must adhere to the Telecommunications Industry Association (TIA) Telecommunications Systems Bulletin (TSB) #88 'Wireless Communications Systems Performance in Noise-Limited Situations' Parts 1, 2 & 3 (TIA TSB-88.1 & 2 & 3). These parts are as follows:

- *Part 1 - Recommended methods for technology independent performance modeling*
- *Part 2 - Propagation and noise*
- *Part 3 - Performance verification*

The TIA TSB-88 document addresses items including but not limited to: channel performance criterion (CPC), CPC reliability design target, terrain profile extraction method, interference calculation method, metaphors to describe the plane of the service area, required service area reliability, adjacent channel drift confidence factor,

conformance test confidence level, sampling error allowance, pass/fail criterion, and treatment of inaccessible grids.

Coverage is broken down into coverage area and coverage reliability. Coverage area pertains to the physical 'footprint' of the system's transmission and reception area. Coverage reliability pertains to the probability of receiving and/or transmitting good data packets at any point in time, at any location within the specified coverage area.

Complies. Dataradio adheres to TSB-88.

4.4.2.4.1 Coverage area

The Tier 1 MDS coverage area shall meet the same coverage area requirements of the ARMER P25 voice radio system. In-building coverage is not a requirement.

The required coverage area based on application Tiers is as follows:

- *The MDS providing Tier 1 applications shall provide 95% mobile coverage by county. This is the same coverage area requirement for the ARMER system*
- *The MDS providing Tier 2 and Tier 3 applications shall provide 'best effort' coverage as they may be commercially owned systems; it is expected that all users will obtain an unspecified variable bit rate and delivery time, dependent upon current traffic load*

Users shall be able to roam seamlessly between sites within one mobile data technology throughout a coverage area.

Partially complies. Dataradio will make every effort to meet the coverage requirements of the state of Minnesota Public Safety MDS. Essentially, Dataradio will design an MDS that will provide for 95% reliability in the predicted coverage footprint as per the results of RF coverage analysis conducted by Dataradio.

Dataradio can only commit to the coverage footprint outlined in the plots accompanying a Dataradio RF coverage study for the proposed system.

4.4.2.4.2 Coverage reliability

The MDS design shall provide adequate signal strength and forward error correction to accommodate areas obstructed by a foliage canopy, buildings and other structures, or topography, etc. in order to meet specified coverage reliability requirements.

The MDS shall achieve a minimum message success rate within 95% of the specified coverage area for 95% of the time.

Partially Complies. The proposed Dataradio MDS is designed to achieve a minimum message success rate within 95% of the specified coverage area for 95% of the time. An RF Coverage Verification test will be performed after system deployment as part of the acceptance testing and the actual reliability will be determined from the results of the test.

4.4.2.4.3 Message success rate

Message success rate (MSR) is defined as the number of packet retries where the data equipment, as opposed to the software application, generated the original transmission and any subsequent re-transmissions.

The required message success rate based on system type (tier) shall be as follows:

- *Tier 1 systems shall have no more than three automatic re-transmissions on any attempted data transmission*
- *Tier 2 and higher tier systems shall have no more than 10% automatic retransmissions in any given timeframe*

The MDS must achieve this MSR while vehicles travel at posted speed limits.

Complies. While the number of RF retries on the proposed 700 MHz private system can be limited to three, this may not necessarily be optimal for any given system.

4.4.2.5 Mobile client roaming

4.4.2.5.1 Intrasystem

The system shall allow mobile data clients to roam across different collocated or non-collocated access points within the same wireless network from both an inactive or active client session. Roaming between different access points shall minimally impact client units. The system shall allow for roaming threshold to be configurable system-wide on an individual client basis by the data system administrator.

Complies. While the proposed system consists of the 700 MHz, 50 kHz private mobile data offering, the Dataradio solution also supports roaming from the proposed 700 MHz private network to 802.11 networks via Radio-IP multi-roaming software. This allows the MDS to automatically switch to the customer's 802.11 client WiFi adapter when in range of a WiFi access point or 'hot spot'.

4.4.2.5.2 Regional

The MDS shall be able to be shared, with the same level of functionality, with other regional sub-systems. Networking or interfacing in this case means the linking of systems at the highest possible level to allow roaming (assuming the same frequency band and protocol) and equivalent functionality between regions. The system shall not preclude the networking of separate wireless data systems being procured separately, but shall enhance these designs wherever possible.

Complies

4.4.2.5.3 Multi-network

The MDS shall be equipped to allow the mobile data clients to switch between dissimilar wireless networks, such as IEEE 802.11 or those of commercial service providers, to provide access to Tiers 1, 2 and 3 applications

Complies. The proposed Dataradio RF Infrastructure includes Radio IP that provides for seamless and automatic wireless network roaming between an unlimited number of wireless networks. Radio IP supports wireless roaming over TCP/IP networks, private RF networks and/or UDP/IP networks.

Applications on the mobile client will use a software-based switch compatible with Microsoft Windows XP, Windows 2000, Windows 98 and Windows Mobile to switch between the MDS supporting Tier 1 (and possibly Tier 2) applications and the MDS supporting Tier 2 and above applications as they become available. This switch controls connections to multiple wireless data networks, such as HPD, WiFi, and WiMAX. The switch is configured for each MDS, enabling the mobile client to roam between the different networks with no user intervention.

The mobile client switch automatically limits the use of an application over certain network types, preventing applications that require higher bandwidth (e.g., Tier 2 and above) from using the low bandwidth (Tier 1) MDS. The switch sets up a virtual private network (VPN) session enabling mobile client applications access to databases and other services on the host LAN. Since the switch retains logon information for each MDS, users do not have to log on each time the mobile client connects to a new network. The switch maintains VPN connectivity after a user roams between MDSs. Even after roaming to another MDS, the switch maintains an application's connection to databases and other services on the host LAN. Server-based network administration software, residing on the host LAN, provides remote control and management of the mobile client switch software. The VPN also provides data security and encryption services.

4.4.2.6 Data throughput

Data throughput (or capacity) is highly dependent on the applications, frequency of use of the applications, and the number of users. Other variables include application header size requirements, voice traffic priority, and the variety of applications in use.

Potential MDS vendors shall provide a detailed throughput study. This study shall include the required number of channels for the given geographical user distribution to support Tier 1 applications. It shall also include provisions for overhead associated with the following:

- *Automatic RF acknowledgment transmissions for all inbound and outbound messages*
- *Retries*
- *Automatic roaming*

- *Message packetization*
- *Error correction and error detection*

Capacity and throughput are dependent on many performance factors such as message load profiles of all applications running on mobile clients in the wireless network, network protocol (TCP/IP or UDP/IP) used, network traffic load and coverage reliability. Performance is optimized if the mobile application software has been written specifically for and successfully implemented in a wireless environment.

For budgetary purposes, a two-channel system is anticipated. Dataradio will perform a throughput analysis based on the user message load profile in (Table 1 of the functional requirements document) during the detailed design phase. This analysis will yield the number of users per channel that can be supported on the proposed RF infrastructure.

4.4.2.6.1 Data rate

The MDS shall have a minimum over-the-air data rate of 9,600 bps for Tier 1 applications; the MDS shall have a minimum over-the-air data rate of 64,000 bps for Tier 2 and Tier 3 applications.

Complies. The proposed Dataradio RF Infrastructure will operate with an over-the-air data rate of up to 128 Kbps in the 700 MHz frequency band on a 50 kHz channel.

4.4.2.6.2 Geographical user distribution

4.4.2.6.2.1 Beltrami County

Beltrami County shall be used as a countywide model for MDS system. Beltrami County encompasses 3,056 square miles, of which 550 square miles is water. The population of the county is 43,609.[27]

[27] 2007 estimated US census data

The ARMER system is planned for approximately 320 sites of which 7 sites are planned for the Beltrami County. The ARMER coverage plan calls for 95% coverage in each county. It is expected that the Tier 1 MDS system footprint will closely match the ARMER P25 voice radio system coverage.

For Beltrami County, the MDS shall support a minimum of 58 concurrent active mobile client units[28] and interface to a minimum of one CAD system to support the PSAP in the region.

Complies. Please refer to the system description for details.

Dataradio will perform a throughput analysis based on the user message load profile (Table 1 of the functional requirements document) to determine the number of concurrent active mobile client units that can be supported per channel on the proposed Dataradio MDS infrastructure. Dataradio will make every effort to meet the desired number of client users outlined above.

Dataradio will only commit to the coverage footprint outlined in the plots accompanying a Dataradio MDS coverage study for the proposed system.

4.4.2.6.2.2 Northwest region

The northwest region of the state of Minnesota shall be used as a regional model for the MDS system. This region consists of 14 of the 87 counties in the state.

This region encompasses 17,055 square miles and includes these three medium-sized cities.

These cities have a combined population of 129,152, with the total population of the NW region being 251,994. The state of Minnesota population is 5,197,621. In comparison to

[28] Total user counts are based on two units for every 1,000 population, for a given geographic area; 66% of each count will be assumed for total concurrent system users. Counts used are based on estimated 2007 census data, with a statewide population of 5,197,621.

the state, the northwest region represents 21% of the total square miles and 5% of the population.[29]

The ARMER system is planned for approximately 320 sites of which 57 sites are planned for the northwest region. The ARMER coverage plan calls for 95% coverage in each county. It is expected that the Tier 1 MDS system footprint will closely match the ARMER P25 voice radio system coverage.

For the Northwest region, the MDS shall support a minimum of 333 concurrent active mobile client units and interface to a minimum of 14 CAD systems to support the 14 PSAP's in the region.

Complies. Please refer to the system description for details.

4.4.2.6.2.3 State of Minnesota

The state of Minnesota encompasses 87,014 square miles and the population with a population of 5,197,621.[30]

For the state, the MDS shall support a minimum of 6860 concurrent active mobile client units and interface to a minimum of 100 CAD systems to support the PSAP's in the state according to the following:

- *In a defined rural environment, the MDS shall support a minimum of 10 concurrent active mobile client units interfacing two CAD systems on a per site basis*
- *In a defined urban environment, where Tier 2 and higher application services are available, the MDS shall be equipped to support a minimum of 20 concurrent active mobile client units interfacing three CAD systems on a per site basis*

Complies. Please refer to the system description for details.

4.4.2.6.3 Message load profile

[29] 2007 estimated US census data
[30] 2007 estimated US census data

A projected message load profile is an estimate of the number of bytes transmitted and/or received per application transaction. Transactions may include Law Enforcement Message System (LEMS) queries and hot files to the state of Minnesota Justice Information Services (MNJIS) and the Federal Bureau of Investigation (FBI) Criminal Justice Information Services (CJIS) and National Crime Information Center (NCIC) databases, as well as motor vehicle, driver and warrant queries.

The predicted user message load profile (Table 1 of the functional requirements document) shall serve as a benchmark for the MDS and be used in data throughput calculations. The Tier 1 MDS shall handle a peak Tier 1 message load profile of the peak number of units (2/3 of the total units) during the peak busy hour. This load profile shall be considered consistent throughout the state of Minnesota.

Complies. Dataradio will use the predicted user message load profile (Table 1 of the functional requirements document) above and will use it as a benchmark for the proposed Dataradio RF Infrastructure. Dataradio will take into account the predicted user message load profile (Table 1 of the functional requirements document) when performing a throughput analysis during detailed design.

4.4.2.6.4 Large file transfer

The MDS shall be capable of configuring the system to allow for large file transfers, where Tier 2 and higher data speeds are accessible. The MDS will integrate wireless broadband 'hot spots' with capacity able to handle large wireless file transfers where backhaul capacity is capable of providing the appropriate network connectivity.

Complies. The proposed Dataradio RF infrastructure employs enhanced dynamic bandwidth allocation (E-DBA). E-DBA is Dataradio's highest performance over-the-air protocol specifically optimized for transactions found in applications requiring short inbound and long outbound transmissions.

The Dataradio solution also supports roaming from the proposed 700 MHz private network to 802.11 networks via Radio-IP multi-roaming software. This allows the MDS to automatically switch to the customer's 802.11 client WiFi adapter when in range of a WiFi access point or 'hot spot'.

4.4.2.6.5 Future growth

The MDS shall meet the system requirements specified in this document plus an additional 10% of users for future growth.

Complies. Dataradio will work with the state Minnesota Department of Public Safety to achieve the system requirements specified in this document plus an additional 10% of users for future growth. The proposed Dataradio RF Infrastructure is modular by design and is capable of expansion to meet the changing needs of the customer.

4.4.2.7 Security

The system must have security capabilities that control system access and protects data integrity, such as encryption. The system shall employ security on multiple layers in compliance with Federal Information Processing Standards (FIPS) 140-2.

Complies

4.4.2.7.1 Encryption

The MDS shall support over-the-air, data link layer encryption. Over-the-air encryption shall have minimal impact to overhead data. Encryption schemes must be non-proprietary for 'hot spots' and follow Federal recommended encryption standards.

Over-the-air encryption should be limited such that regular data transmissions are not adversely affected.

Complies. The proposed Dataradio Paragon base station and Gemini mobile radio modem utilize AES 128-bit encryption.

4.4.2.7.2 User Authentication

The MDS shall authenticate individual users on the network with a login and password combination that is unique to each individual user.

Partially complies. The Dataradio MDS would not perform this task; this would be performed at the application level. The system does perform device authentication, see below.

4.4.2.7.3 Device Authentication

The MDS shall authenticate access by an authorized mobile client and deny access to an unauthorized mobile client. Any device being used to access the network must be authenticated to the network by an identifier that is unique to the device before access is granted.

Complies. All base stations feature a limited authorized/unauthorized access list.

4.4.2.8 Interfaces

4.4.2.8.1 System host interfaces

The MDS shall support a minimum of three host interfaces per county with the ability to add host interfaces up to a maximum of five per county.

Complies. Please refer to the system description for details.

4.4.2.8.2 Database interfaces

The MDS shall support access to MNJIS, FBI CJIS, NCIC and Law Enforcement Message System (LEMS) databases.

Complies. The proposed Dataradio solution is designed to support IP-based application software (Ethernet IEEE 802.3).

4.4.2.8.3 Physical Interfaces

The vendor shall describe the physical (DB-9, RJ-45, USB, etc.) and logical (serial, Ethernet, etc.) interfaces used for, but not limited to, the following:

- *The transmission and reception of mobile client/host application data*
- *Control of the base station features and functions*
- *Equipment monitoring/diagnostic*

For every site, and for each interface, the vendor shall state the transmission media that will interconnect the base stations to the system controller equipment or monitoring/diagnostic systems.

At each site where the existing digital microwave system will be used as the transmission media, the vendor shall describe the amount of bandwidth required for each interface.

Complies. The proposed Dataradio Paragon base station is equipped with a built-in standard IP router and two Ethernet RJ-45 Auto-MDIX 10/100Base-T interfaces, replacing the need for proprietary controller equipment. Additionally, the Paragon3 base station has two RS-232 DB-9F serial ports configured as terminal servers.

Where backhaul facilities are concerned, the required bandwidth per Paragon base station is 256 kbps.

4.4.2.8.3.1 Data Ports

The Owner may wish to add additional mobile computing devices such as optical readers, fingerprint scanners, printers, digital video recorders, etc., as they become ready for deployment. It is envisioned that these devices will be interconnected in such a manner as to create a vehicular local area network with the mobile modem being offered.

The vendor shall describe the manner(s) by which you propose to network these devices.

Complies. The proposed Dataradio Gemini mobile comes standard with a built-in router, an Ethernet 10/100Base-T interface and two RS-232 ports configured as terminal servers. Additional devices such as optical readers, fingerprint scanners, printers, and digital video recorders can be connected to the network by using an in-car hub or switch.

4.4.2.9 Network management and control

The MDS shall include a network management and control subsystem (NMCS) as an integral component of the system. There may be one NMCS for Tier 1 application support and a separate NMCS for Tier 2 and Tier 3 application support; or there may be one NMCS for Tiers 1-3 application support.

Each NMCS shall be IP-based and function as the interface between the wireless network and the wire-line network utilizing simple network management protocol (SNMP), Telnet, and support higher-level network management system protocols. The NMCS shall be responsible, at a minimum, for the configuration and management of mobile clients, wireless network resources, and capable of all general administrative, diagnostic, monitoring, and reporting functions.

The NMCS shall be of current production and shall be capable of withstanding the harsh operating environment heavy usage associated with the delivery of public safety services. It shall provide features and functions compatible with existing and new fixed and mobile equipment. The NMCS shall be comprised of hardware, software, cabling, and associated accessories utilizing standard commercial-off-the-shelf (COTS) equipment wherever possible.

In addition, user/client prioritization is a desirable feature, but is an optional requirement at this time.

The NMCS will encompass administrative and maintenance functions necessary for proper installation, setup, and maintenance of the MDS.

Complies. Dataradio's network management and control system (NMCS) provides a proactive simple network management protocol (SNMP) based system

management tool for data network administrators. A Dataradio supplied management information base (MIB) is used to collect mobile and base station status information and channel loading statistics.

Using a SNMP-capable manager, key information on the Dataradio network can be collected. The information can be used to analyze system operation and perform initial troubleshooting diagnostics in case of a component failure in the system. Channel loading can be monitored to insure the radio network is not overloaded with traffic. Any changes to software can be analyzed to determine the loading affect on the network. System expansion can be planned well in advance as loading requirements increase before the system is overloaded.

4.4.2.9.1 Unique identifier

A unique ID must identify all fixed or mobile MDS terminal devices.

Complies

4.4.2.9.2 Device management, monitoring, and alarms

The NMCS shall provide real-time utilization, performance, status, health, and fault alarm information of all MDS system components including, but not limited to, network servers, networking devices, data base stations, mobile clients, and others.

The NMCS shall provide the following minimum features:

- *Remote management and upgrade of client devices*
- *Event logs*
- *Report generation*
- *Performance statistics such as link quality, network delays, etc.*
- *Secured remote access by typical client devices from authorized maintenance personnel*

The NMCS shall also be capable of reporting information of a historical nature and in a manner suitable for network planning purposes. At a minimum, the NMCS shall report bi-directional performance statistics on both the wireless and wireline portions of the

network including each mobile client device, each radio base station, and the composite of all radio base stations.

The NMCS shall be equipped with the functionality capable of delivering alert text and/or email messages to radio pagers or cellular phones in the event of a detected fault condition. At a minimum, the text message shall contain fault specific information regarding the affected equipment and the location of the fault.

Partially Complies. The proposed NMCS provides real-time information for the base stations. Although it can also do the same for mobiles, it is not normally done as it consumes substantial bandwidth and thus not practical. Mobile-related information is typically gathered at the respective base stations and forwarded along with the base station information.

The NMCS can also provide real-time information for network servers, network devices, etc. as long as these devices are SNMP-compliant and their MIBs support the required information.

While the proposed NMCS does allow for remote access, it does not support the upgrading of client devices.

The NMCS reports bi-directional performance statistics on the Dataradio wireless portion of the network including each mobile client device, each radio base station, and the total of all radio base stations.

The NMCS however does not report any performance statistics on the wire-line portion. This can be achieved via the use of suitable publicly available MIBs.

4.4.2.9.3 Management partitioning

The MDS shall allow for partitioning of the system as it relates to administrative functions, system configurations, and client programming. The NMCS shall allow designated users permission to accomplish the following:

- *User groups permission to add or delete their client units from the system*

- *Maintenance personnel to verify device configuration and status*
- *Administrative personnel access to real time and historical reports*

Complies. While all of the above are possible functions of the proposed system, there is only one level of password protection on Paragon and Gemini. Access to the NMCS comprises authentication at its respective components.

4.4.2.9.4 Load balancing

Dependent upon the systems available within the user's current location, the MDS shall be able to balance low and high data payloads from different applications. For example, if a user is located in a rural environment for which only Tier 1 services exist, Tier 2 and higher applications shall not be allowed to transmit or receive data until the user has physically moved within range of a Tier 2 or higher radio site location. The load balancing thresholds shall be configurable by the data system administrator.

Complies. The proposed Dataradio MDS mobile clients can be configured with a third party middleware that intelligently switches between various services when available to the mobile client. Please refer to the system description for more detail.

4.4.2.9.5 Remote access

The NMCS shall be equipped to enable full functional access from IP-based networked workstations and utilize standardized internet applications (e.g. HTML, etc) for browser interface, by authorized personnel within the private network, or over encrypted connections, such as VPNs, for access from remote networks.

Complies. Remote access can be achieved through user authentication on the machine hosting the NMCS. This can be performed over remote networks via VPN (customer provided) or over the local network through applications such as remote desktop.

4.4.2.9.6 Programming and configuration

The NMCS shall allow for programming and configuration of the system base stations and mobile units from a system based network location by authorized users.

Complies. System base stations and mobile units may be configured by authorized users via Dataradio web interface through any web-based browser. Base station and mobile configuration is also accessible from the Dataradio NMCS. Please note that in this context, it is understood that programming and configuration are synonymous.

4.4.2.9.7 Information repository

The NMCS shall provide a database repository of system device and network connectivity information for use in configuration, programming, testing, and troubleshooting of system equipment and connections. Data shall include, but not be limited to, the following:

- *Network architecture diagram and description of hardware and software*
- *Base station and mobile device model and serial numbers, including configuration options and program settings*
- *Redundant carrier and redundant path description for telecom services that support the remote monitoring systems*
- *Network monitoring procedures*
- *Classification of support issues with corresponding escalation procedures and response times.*

All pertinent MDS data shall reside on a common network and be accessible from any location within the network by authorized personnel.

Partially Complies. This information will be provided for storage and access on the customer's enterprise network.

The information described above consists of documentation and is not an NMCS function per se. A documentation package that is usually supplied as part of a system typically includes Dataradio technical manuals, applicable diagrams, troubleshooting procedures, configuration files, base station and mobile device serial numbers. The documentation package is normally provided in electronic format. It is left to the customer to decide where to place this information, how it can be retrieved and who will have authorized access.

4.4.2.10 Scalability, expandability, and redundancy

The MDS shall be deployable on a single site, multi-site, regional, or wide area basis capable of servicing any area within the state of Minnesota where ARMER or OET infrastructure exists. In addition, the network should provide for full automatic and seamless operation to mobile client users, while utilizing simple management and administrative functions.

The state shall be able to expand the MDS by adding sites for increased coverage, base stations for larger capacity, or network applications to improve efficiencies. In all cases, the MDS shall employ a high level of system redundancy (no single point of failure).

The MDS may initially be deployed on a regional or smaller basis, with the expectation to migrate to statewide use.

Complies. The proposed Dataradio MDS is expandable and scalable to the extent of agency's needs. Radio sites may be added whenever and wherever the agency requires additional coverage; additional channels may be added to the system to meet any increased capacity requirements. A private mobile data system is inherently able to provide the coverage and capacity where and when the agency requires it.

4.4.2.10.1 Expansion

The MDS shall be modular and scalable, utilizing hardware and software designs such that the system may be expanded, rather than replaced, to meet future requirements. The scalability of the system shall permit easy expansion, at a minimum, in these major areas:

- *Number of clients*
- *Radio frequencies*
- *Tower sites*
- *Host interfaces*
- *Network management interfaces*

Complies. The proposed Dataradio RF Infrastructure is modular and scalable, utilizing hardware designs such that the system may be expanded, rather than replaced to meet future requirements.

4.4.2.10.2 Redundancy

Due to the critical nature of the MDS services, a high degree of reliability is required. Redundancy and reliability shall meet or exceed ARMER P25 voice radio system requirements. All components that encompass the MDS, including the NMCS, shall be viewed as critical elements of the network. Therefore, a network topology utilizing fault tolerance shall be incorporated to the greatest extent possible through a distributed and/or redundant architecture.

Complies. The proposed Dataradio RF Infrastructure can include additional routers (hot or cold standby) which will provide redundancy to the network. It is understood that the NMCS is NOT a critical element of the network.

4.4.2.10.3 System scan

The system shall be equipped to allow mobile clients to automatically scan for another RF channel in the event of loss of their primary RF channel.

Complies

4.4.2.10.4 Failure modes

The system shall be equipped with multiple failure modes to allow use of the MDS on limited data throughput basis rather than full system shut down.

Does not comply. The proposed Dataradio MDS does not provide limited 'scaled-back' failure modes; it works or it does not. It must be noted that redundancy is built-in or inherent to critical system points such as redundant core routing equipment and the design requiring two base stations at each site.

4.4.2.11 Backhaul

The MDS shall utilize existing ARMER and OET networks for backhaul connectivity. MDS physical and protocol interfaces (e.g., DS0, T1, or Ethernet) shall comply with ARMER and OET site-specific connectivity requirements. Bandwidth requirements of the MDS shall consider the available capacity of the ARMER and OET network.

Complies. Where backhaul facilities are concerned, the required bandwidth per Paragon base station is 256 kbps.

Table 3 - Minimum required T1 specifications

T1 SPECIFICATIONS	
Bit error rate – BER	**1×10^{-6}**
Stratum level	**2 or better**
Max. delay	**5 milliseconds (ms)**
Availability	**99.999 %**
Line coding	**B8ZS (bit 8 zero substitution)**
Signaling	**Clear channel**
Compression	**None**
Framing	**ESF (extended super frame)**
Pulse amplitude	**0 dBdsx (3.0V +/- 0.3V or 6V P-P)**
Dry or wet	**Dry, no voltage (-48 VDC or other) present**

4.4.2.12 Radio equipment requirements

4.4.2.12.1 Site infrastructure

The MDS shall utilize the state's existing ARMER site locations, available site equipment, infrastructure, and tower space to the greatest extent possible.

RF subsystem equipment (e.g., Heliax, antennas, and lightning and surge protection) shall be supplied for each site. Equipment shall connect to the state's existing microwave, fiber, and leased-line transport backhaul infrastructure.

Complies. Dataradio will take into account the state's existing ARMER site locations, available site equipment, infrastructure and tower space to the greatest extent possible during the MDS design. However, pursuant to a site survey, if it is not feasible to incorporate existing components, Dataradio must use new components to ensure the proposed system will operate properly.

4.4.2.12.1.1 Security

Gates, door locks, and passcode entrances shall physically secure MDS transmitter sites, database locations, and limited access terminals, where permissible.

Complies

4.4.2.12.1.2 Installation

Equipment shall be installed in existing equipment room spaces where available. Equipment shall be housed in suitable indoor-type cabinets or relay racks. These cabinets or racks shall be installed with ease of accessibility. Equipment shall be arranged and installed so its intended function will not be impaired due to weather, temperature, adjacent equipment, or other factors. Sufficient space and clearance shall be provided such that service and maintenance can be readily performed.

Renovations, designs, and installations at the site shall conform to the following guides:

- *Industry best practices*
- *Commercial Building Standard for Telecommunications Pathways and Spaces, TIA/EIA-569*
- *Commercial Building Telecommunications Wiring Standard, TIA/EIA-568*
- *Occupational Safety and Health Administration's recommended approved practices*
- *National Electric Code practices, including grounding and lightning suppression*
- *All applicable local, county, state building and life-safety codes*

Upon completion of the installation, all systems and equipment shall operate in accordance with applicable standards for operation.

Partially Complies. The proposed Paragon base station is supplied in a rack mount configuration. The Paragon base will be installed in either a standard 19-inch rack mount cabinet or a standard 19-inch open rack.

Design and renovation of sites is not within the scope of work for the proposed system. Installation at the sites will conform to industry best practices and applicable standards.

4.4.2.12.1.3 Power

System hardware installed at the transmitter sites shall be equipped with an uninterruptible power supply. Power losses, restorations, surges, sags, and/or brownouts shall not alter the operating parameters of MDS components. Other than total power loss or lethal surges, all components shall remain fully operational within the specifications of its design while experiencing any of these occurrences.

Complies

4.4.2.12.2 Base station radio

The base radio system shall be rated for and capable of continuous duty operations with required automatic station identifiers. The fixed equipment proposed shall be modular in design using 19' rack mountable units.

Complies

4.4.2.12.2.1 Programming and software upgrades

The base station radio shall allow for remote network based programming and/or software upgrades.

Complies. The proposed Paragon Base Station can be completely reprogrammed remotely through the state of Minnesota's LAN and backhaul lines.

4.4.2.12.2.2 Security

Any MDS base station radio must authenticate any person utilizing the device via user login and password and/or biometrics.

Partially complies. As stated above, the Dataradio can support this, but user authentication is handled at the application layer.

4.4.2.12.2.3 Internet Protocol

Each base station radio shall be equipped with an IP address (dynamic or static).

Complies. Each network device can operate with a static or dynamic IP address.

4.4.2.12.2.4 Unique modem identifier

Each base station radio must be uniquely identifiable by its static IP address or modem MAC address.

Complies

4.4.2.12.3 Mobile radio modem

The mobile radio modem shall provide an interface between the mobile computing device and the wireless data fixed network equipment. The mobile modem shall be a rugged, factory integrated vehicular radio modem product designed to provide optimal data transmission performance for mobile data applications.

Mobile units shall include a 'smart switch' to determine the most efficient data transfer technology to use. The MDS modem shall default to the high-speed network when available; otherwise, it will switch to the existing low-speed network. This 'switching' capability may be hardware of software integrated.

Complies. The proposed Dataradio RF Infrastructure includes the Gemini Agile Dual Band (ADB) capable mobile data modem. The Gemini ADB-capable mobile data modem provides an interface between the mobile computing device and the wireless data fixed network equipment. The Gemini ADB-capable mobile automatically adapts to the speed of the Paragon base station.

The Dataradio solution also supports roaming from the proposed 700 MHz private network to 802.11 networks via Radio-IP multi-roaming software. This allows the MDS to automatically switch to the customer's 802.11 client WiFi adapter when in range of a WiFi access point or 'hot spot'.

Figure 73 shows a diagram of the mobile installation. Each mobile will be outfitted with a Gemini mobile radio modem, which is typically mounted in the trunk. The Gemini communicates with the mobile laptop (or client) via a 20-foot long CAT5 cable. Gemini modems come pre-configured from the factory ready to use.

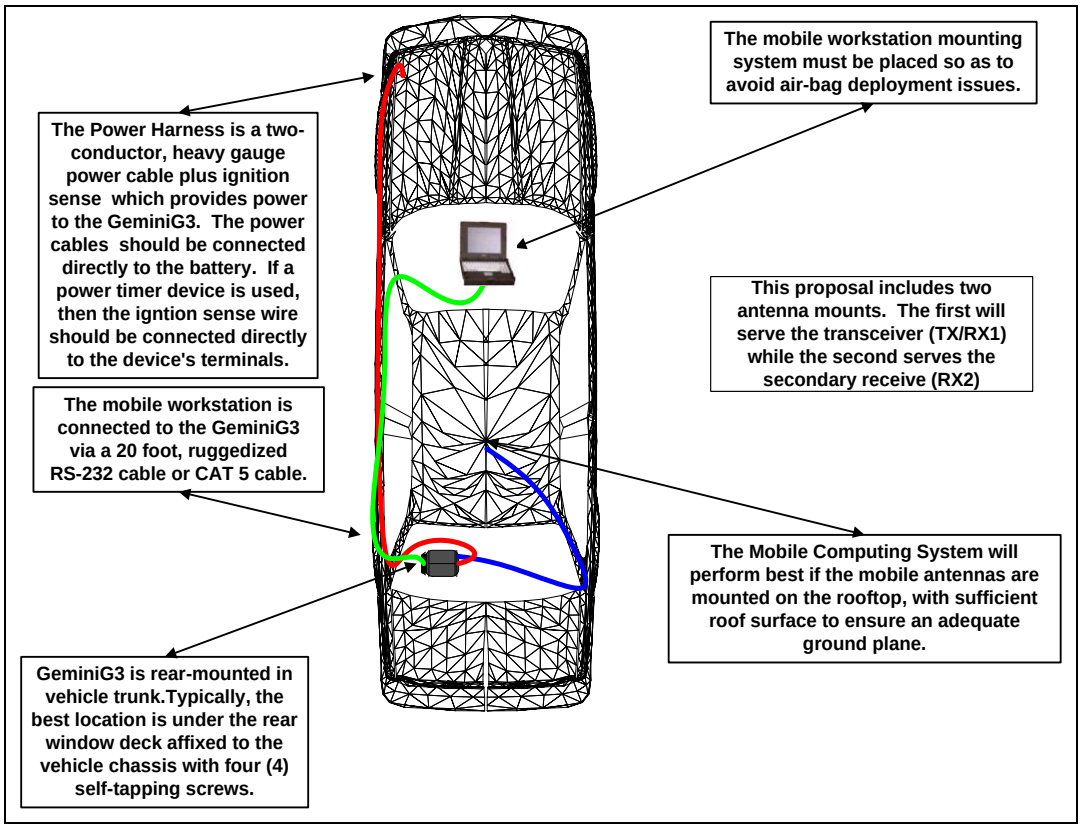

Figure 7 – DataRadio proposed mobile installation

The Gemini modem will interface the client application in each vehicle to the radio network. Each vehicle will be equipped with a Gemini mobile radio modem, two 700 MHz antennas and a global positioning system (GPS) antenna. The Gemini contains a GPS receiver that is capable of accepting differential or wide area augmentation system (WAAS) corrections. The modems will employ the E-DBA protocol in communicating with the tower sites and IP or RS-232 to communicate with the application software.

4.4.2.12.3.1 Programming and software upgrades

The mobile client shall allow for over-the-air-programming (OTAP) and/or software upgrades.

Partially Complies. While the proposed Gemini ADB-capable mobile data modem is capable of having parameters reconfigured over-the-air, upgrading the firmware over-the-air is impractical and should be done locally.

4.4.2.12.3.2 Security

Any MDS client device must authenticate any person utilizing the device via user login and password and/or biometrics.

Complies

4.4.2.12.3.3 Multiple receive

The modem shall simultaneously decode two incoming message streams for increased message reliability.

Complies

4.4.2.12.3.4 GPS

The mobile radio modem shall either incorporate global positioning system (GPS) receiver or be capable of receiving a GPS data from an external source.

Complies. The proposed Dataradio RF Infrastructure includes the Gemini ADB capable mobile data modem. The Gemini comes equipped with an internal 12-channel WAAS capable GPS receiver, providing position, speed and heading data for the vehicle. This information can then be reported locally to the attached mobile data computer and/or to a remote GPS host.

4.4.2.12.3.5 IP

Each radio modem shall be equipped with an IP address (dynamic or static).

Complies. Each network device can operate with a static or dynamic IP address.

4.4.2.12.3.6 Unique modem identifier

Each modem must be uniquely identifiable by its static IP address or modem MAC address.

Complies

4.4.2.12.3.7 Broadcast mode addressing

Modems must support individual group broadcast addressing by IP multicast and directed subnet broadcast.

Complies

4.4.2.12.3.8 Positive acknowledge

Modems shall be capable of sending a positive acknowledgment to the originating base station radio upon receipt of successfully received and corrected messages.

Complies

4.4.2.12.3.9 Client Interface

Modems shall interface to a mobile data computer installed within a vehicle's passenger compartment.

- *Tier 1 modems shall interface via a 10/100BaseT or USB or serial DB9 connection, and*
- *Tier 2 and higher modems shall interface via a 10/100BaseT connection and employ advanced technology to allow higher performance operation, to allow for future modem upgrades or enhancements, and to allow the greatest degree of mobile hardware flexibility*

Complies. The proposed Dataradio RF Infrastructure includes the Gemini ADB capable mobile data modem. The Gemini interfaces to the mobile data computer installed within a vehicle's passenger compartment via a 10/100Base-T connection.

4.5 Advantages and disadvantages

CalAmp's Dataradio platform is designed specifically for mobile data and is not an overlay on a voice system. CalAmp's mobile data systems have been installed and optimized in single site local area and multi-site wide area configurations for public safety, public works, utilities, and transportation markets. Additionally, the CalAmp product line includes devices capable of both 700 and 800 MHz frequency bands at bandwidths variations from 25 kHz, 50 kHz, and greater.

The backhaul and peripheral device wireline interface of this system is an IP standards based IEEE 802.3 protocol and Ethernet 10/100Base-T interconnection. An IP standards based backhaul not only allows for use of commercial-off-the-shelf equipment, but also provides a distributed architecture, increasing system redundancy and reducing the possibility of single point failures.

CalAmp's proprietary over-the-air interface E-DBA was developed specifically for the mobile data environment. Additionally, normal data transactions provide advanced features including:

- OOB Signaling – Allows transmission of GPS without consuming bandwidth for user data
- Hyper-Code Forward Error Correction – A high efficiency error correction technique that detects and corrects errors due to fades in the mobile environment

The following are strengths and weaknesses of CalAmp's Dataradio platform as compared to other technologies:

Strengths:

- The system is designed specifically for mobile data, it is not a voice system with a data overlay
- The technology is more mature than P25 IV&D and Motorola HPD
- User radio modems can migrate from 25 kHz, 50 kHz, and greater bandwidths, as they become available
- The system uses commercial off-the-shelf routers and network switches
- Radio sites are deployed where coverage is required
- The system is scalable, being able to meet capacity requirements as needed
- The system has dedicated throughput capabilities
- Other than operations and maintenance, there are no recurring costs

Weaknesses:

- Implementation requires a significant capital outlay due to infrastructure and user radio procurement
- User must have authorization to use or ownership of appropriate spectrum
- Implementation of a network requires real estate site leases and/or site acquisition

4.6 Rough order-of-magnitude (ROM) cost estimates

This section provides high-level, ROM estimates for each implementation – county, regional and statewide - discussed in this proposal. Please note that these estimates are ROM only, and a detailed design would be required for a more accurate estimate.

Capital outlay costs are associated with deploying this technology for the site mobile data equipment and user radio modems. There are no recurring fees other than regular operations and maintenance. Please note other assumptions and notes following the cost tables.

4.6.1 County implementation

	Qty	Cost	Total
Host site	1	$15,000	$15,000
Remote site	7	$125,000	$875,000
Mobile client and modem	87	$7,000	$609,000
Switching middleware (per mobile client)	87	$1,000	$87,000
Infrastructure Sub-total			$1,586,000
Project management / engineering		20%	$317,200
TOTAL ROM COST			**$1,903,200**

4.6.2 Regional implementation

	Qty	Cost	Total
Host site	14	$15,000	$210,000
Remote site	57	$125,000	$7,125,000
Mobile client and modem	504	$7,000	$3,528,000
Switching middleware (per mobile client)	504	$1,000	$504,000
Infrastructure Sub-total			$11,367,000
Project management / engineering		20%	$2,273,400
TOTAL ROM COST			**$13,640,400**

4.6.3 Statewide implementation

	Qty	Cost	Total
Host site	100	$15,000	$1,500,000
Remote site	320	$125,000	$40,000,000
Mobile client and modem	10,395	$7,000	$72,765,000
Switching middleware (per mobile client)	10,395	$1,000	$10,395,000
Infrastructure Sub-total			$124,660,000
Project management / engineering		20%	$24,932,000
TOTAL ROM COST			**$149,592,000**

Notes:

- Costs reflect one host location per county and includes 3 connections at that location, per the functional requirements
- Site costs include two 700 MHz base stations at each site
- Costs include site and mobile equipment installation
- Costs include site and mobile antenna systems
- All tower sites include $5,000 for structural analysis of existing tower structures
- Costs do not include backhaul costs and may require additional capacity
- Costs include one year warranty and software updates
- Discounts are not included

5. WiMAX

5.1 System description

The proposed WiMAX MDS will provide high-speed broadband data access to mobile clients within covered areas and can also supplement a lower speed MDS. The WiMAX technology provides 'best effort' localized ('hot spot') coverage. Ubiquitous or near-ubiquitous coverage is not feasible because of the small coverage footprint for a given base station;; this is inherent to higher frequency, wider bandwidth (broadband) technologies. WiMAX requires the use of many base stations, and therefore prohibitively higher costs to cover a large area.

WiMAX operates in the 2.5 GHz band and Minnesota would need to acquire licenses in this band to deploy WiMAX. WiMAX operates within five MHz channels in this band and can reliably provide one Mbps to five Mbps to the mobile client. Therefore, this system will provide adequate throughput for all four tiers of applications as defined in the introduction.

A WiMAX MDS consists of a minimum of one WiMAX base station and one WiMAX access controller. An access controller can typically support 250 base stations. The access controller can be located anywhere in Minnesota's ARMER core network, or anywhere that has IP connectivity back to the ARMER network; it controls access and configuration of the base stations. The controller also handles subscriber routing and mobile client system access on the network. Before access is granted to a mobile client, the following authentication is performed:

1. Each client device has a unique identifier, or Electronic Serial Number (ESN), that must be recognized by the access controller to allow access to the network
2. Each user on the system must enter log on information that must be verified by Minnesota's authentication servers

Each base station provides coverage approximately from a half-mile to a two-mile radius, depending on factors such as terrain, foliage density, buildings and other structures. This would cover an area 0.8 square miles to 12.5 square miles. A base station can support hundreds of concurrent client device connections and allows client devices to seamlessly roam between base stations. There are several vendors offering WiMAX base stations, including Alcatel-Lucent, Motorola and Alvarion and Motorola.

Base stations are typically implemented with three sector antennas. Depending on the amount of spectrum available, each sector may have its own channel. Mobile clients connected to that sector use the same channel; each client does not require its own channel. This is possible through the use of WiMAX's Time Division Duplex (TDD) technology. Time slots are given to each client in the same channel; no two clients are transmitting at the same time to the same sector. The blocks in the 2.5 GHz Educational Broadband Service / Broadband Radio Service (EBS/BRS) spectrum have four to six MHz channels available.

Applications on the mobile client use a software-based switch compatible with Microsoft Windows XP, Windows 2000, Windows 98 and Windows Mobile to switch between the MDS supporting Tier 1 (and possibly Tier 2) applications and WiMAX, as it is available. This switch controls connections to multiple wireless data networks, such as HPD, WiFi, and WiMAX. The switch is configured for each MDS, enabling the mobile client to roam between the different networks with no user intervention.

The mobile client switch automatically limits the use of an application over certain network types, preventing applications that require higher bandwidth (e.g., Tier 2 and above) from using the low bandwidth (Tier 1) MDS. The switch sets up a virtual private network (VPN) session enabling mobile client applications access to databases and other services on the host LAN. Since the switch retains logon information for each MDS, users do not have to log on each time the mobile client connects to a new network. The switch maintains VPN connectivity after a user roams between MDSs. Even after roaming to another MDS, the switch maintains an application's connection to databases and other services on the host LAN. Server-based network administration software, residing on the host LAN, provides remote control and management of the mobile client switch software. The VPN also provides data security and encryption services.

Figure 8 shows how the mobile client devices wirelessly connect to the WiMAX base stations. The base stations are connected to the core network with high capacity backhaul where they communicate with the Access Service Node – Gateway (ASN-GW). The ASN-GW forwards all mobile client requests for authentication to the Authentication, Authorization and Accounting (AAA) server, which will allow access if the logon information matches the AAA database, or deny access if it is not. When a user is granted access by the AAA server, the user can then access services on the network and the Internet (if it is connected to the network).

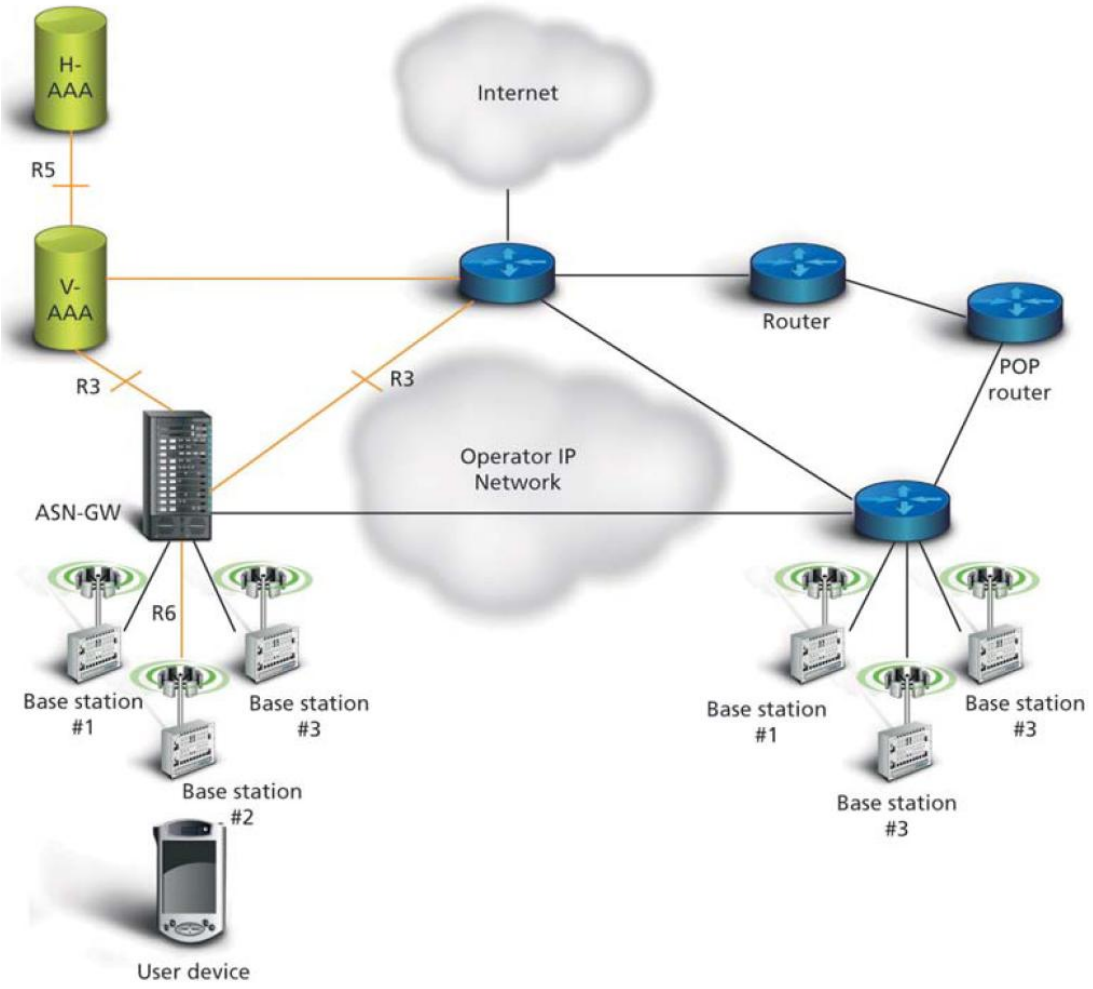

Figure 8 - Topology of a WiMAX network

Substantial backhaul capacity is required for each WiMAX base station to support high bandwidth applications. The existing ARMER public safety voice network provides a robust network for public safety communications in Minnesota and may have the necessary capacity to support these base stations. In areas where the ARMER backhaul is not sufficient, additional backhaul will be required. A baseline for backhaul requirements is 1 Mbps per user on each base station or 15 Mbps, whichever is greater. This is the equivalent to 10 T1 connections.

This proposal considers implementation scenarios at the county (Beltrami), regional (NW-RRB) and statewide levels. Section 5.6 of this document provides ROM costs for each implementation.

5.2 System implementation

This section provides descriptions of county, regional and statewide WiMAX MDS implementations. The information outlines system coverage, system architecture, network interface, and backhaul for each of the implementations.

5.2.1 County implementation – Beltrami County

5.2.1.1 Overview

Coverage areas will vary and average approximately a 1.5 mile radius from the base station; as mentioned above, this would cover an area of seven square miles. The coverage areas will be localized and offered in more populated areas. The highest populated area in Beltrami County is the town of Bemidji, with a population of 13,519[31]. Given the area covered by one base station, with the antenna at approximately 150' above ground level (AGL), and Bemidji covering 13 square miles, two base stations could cover the area.

If an ARMER tower site is in a good location to provide the WiMAX coverage, the WiMAX MDS can leverage the ARMER site and backhaul resources. If the ARMER site is not in a good location to provide coverage for Bemidji, an additional tower site or building rooftop in the area will be needed to house the WiMAX base station; backhaul to the new location will also be required.

5.2.1.2 Network interfaces

The proposed WiMAX MDS can support the required three[32] host application connections; this is the connectivity point for external host application systems, such as computer aided dispatch (CAD), records management systems (RMS), etc., for data transmitted and received over the WiMAX network infrastructure. Expansion is possible as long as there is enough backhaul to support the additional applications. The connection between the host application network and the WiMAX network is IP over Ethernet. The end-to-end IP network transports user data and control information between host computers to and from the mobile clients in the field.

[31] 2000 census data.
[32] Three host connections are required for each county.

USB-connected laptop cards are available for connecting the mobile clients to the WiMAX network. Currently, the client devices are not external modems similar to the low speed, wide-area networks; they are very similar to a Sprint or Verizon laptop card. The WiMAX card plugs directly into the laptop. There are no external parts to the system. The radio and antenna are integrated into the card.

5.2.1.2.1 Backhaul

The WiMAX system will require a supporting IP based backhaul infrastructure with a minimum bandwidth capacity to support the peak number of users. The total number of users in Beltrami County is 87, with 58 peak users[33]. Since the WiMAX system only covers a small portion of the region, backhaul is not needed for 58 users, only for users in the proximity of a WiMAX base station in Bemidji. A recommended minimum amount of backhaul for the county should be one Mb per user, or 15 Mbps per base station, whichever is greater. With a population of 13,419 in Bemidji and an estimated number of 18 peak concurrent users (27 total) in the area (based on the calculations used above), the WiMAX MDS for the County will require 15 Mbps to each base station.

5.2.2 Regional implementation – Northwest Region

5.2.2.1 Overview

Implementation in the Northwest Region is similar in size and scale to the Beltrami implementation above. By providing WiMAX in areas with a population of 25,000 or more, the town of Fargo-Moorhead will be the only city in the Northwest Region covered. With an area of 13 square miles[34], it could be covered with two base stations.

The ARMER infrastructure, including towers and backhaul, will be priority and utilized where possible, as noted above.

5.2.2.2 Network interfaces

Please refer to network interfaces described in the county implementation section above.

[33] Total user counts are based on two units for every 1,000 population, for a given geographic area; 66% of each count will be assumed for total concurrent system users. Counts used are based on estimated 2007 census data, with a statewide population of 5,197,621.
[34] 2000 census data.

5.2.2.3 Backhaul

The WiMAX system will require a supporting IP based backhaul infrastructure with a minimum bandwidth capacity to support the peak number of users. The total number of users in the NW-RRB region is 504, with 333 peak users (based on calculations used above). Since the WiMAX system only covers a small portion of the region, backhaul is not needed for 333 users, only for users in the proximity of a base station in Fargo-Moorhead. A recommended minimum amount of backhaul per base station should be 1 Mb per user, or 15 Mbps, whichever is greater. With a population of 38,346 in Fargo-Moorhead and an estimated number of 51 peak concurrent users (77 total) in the area (based on the calculations used above), the WiMAX MDS for the region will require 26 Mbps to each base station.

5.2.3 Statewide implementation

5.2.3.1 Overview

Coverage areas will vary and average approximately a 1.5 mile radius from the base station, as noted above; this would cover an area of 7 square miles. The coverage areas will not be ubiquitous over a large area, providing coverage in more populated areas. By providing WiMAX in areas with a population of 25,000 or more, 33 cities[35] will require coverage, totaling 867 square miles in Minnesota. Based on coverage area of 7 square miles as described above, Minnesota will need approximately 124 base stations to cover these cities. Although 1 controller could handle these base stations, 2 controllers are recommended for redundancy and ease of backhaul routing across the state.

The ARMER infrastructure, including towers and backhaul, will be priority and utilized where possible, as noted above.

5.2.3.2 Network interfaces

Please refer to network interfaces described in the county implementation section above.

[35] City is defined as a population of 25,000 or more.

5.2.3.3 Backhaul

The WiMAX system will require a supporting IP based backhaul infrastructure with a minimum bandwidth capacity to support the peak number of users. The total number of users for Minnesota is 10,395, with 6,860 being peak users. Since the WiMAX system only covers a small portion of the state, backhaul is not needed for all peak users in Minnesota, but for all peak users in the proximity of the WiMAX base station. A recommended minimum amount of backhaul per base station should be 1 Mb per user, or 15 Mbps, whichever is greater. In this scenario, the WiMAX MDS should have a minimum of 22 Mbps to each base station, based on an estimated 2,689[36] concurrent peak users (4075 total) within the 33 cities.

5.3 Interoperability standards

All aspects of the WiMAX system are based on open and recognizable standards. WiMAX technology is completely based on the work of the fully open IEEE 802.16 standards group. The IEEE continues to make advancements to 802.16; as an example, work has begun for a follow-on standard to 802.16e called 802.16m to make improvements for increased throughput at mobile speeds to match that of LTE-Advanced (1 Gb/s for fixed, 100 Mb/s for high mobility).

WiMAX also utilizes an all-IP architecture for the base stations and access controllers, which is another example of how the overall network is easily interoperable and utilizes open standards. Any WiMAX-certified mobile client device can be used to access to the WiMAX MDS; mobile client device equipment from a variety of vendors will work on the WiMAX MDS.

5.4 System capabilities

This section provides a point-by- point response to Section 3.0 of the state of *Minnesota Public Safety Interoperable Wireless Data Feasibility Study Deliverable for Tasks 8 and 9: High Level Wireless Data Functional Requirements* document. The functional requirements defined in this deliverable are restated here in *blue italics* with the response immediately following.

In this particular assessment, it is assumed that the WiMAX hotspots have been integrated with another implementation providing at least Tier 1 data capability

[36] Based on 2007 estimated census population of 2,037,566 for the 33 cities. Total user counts are based on two units for every 1,000 population, for a given geographic area; 66% of each count will be assumed for total concurrent system users.

throughout the state. As previously noted, a statewide WiMAX implementation would not be practical given the limited range of WiMAX base radio sites. Where compliance is indicated it is assumed that the WiMAX alternative is part of a broader hybrid approach built around another technology which may include commercial services.

5.4.1 General requirements

The MDS shall meet the following general requirements:

- *Provide mobile public safety connectivity for at a minimum, police, fire, and EMS*
- *Operate in licensed land mobile radio frequency bands, except in the very high frequency (VHF) band for Tier 1 applications*
- *Use technologies in the unlicensed or licensed public safety bands, in conjunction with the Institute of Electrical and Electronics Engineers (IEEE) 802.11 for fixed 'hot spot' technology for, at a minimum, Tier 2 and Tier 3 applications*
- *Provide service to mobile units operating at street level at speeds up to posted speed limits*
- *Provide connectivity to approximately 100 public safety answering points (PSAPs)*
- *The system shall utilize existing ARMER tower sites, the state of Minnesota's Office of Enterprise Technology (OET) network, and backhaul equipment, to the maximum extent possible*
- *The overall architecture of the system shall provide for scalability, maintainability, disaster recovery, state-of-the-art equipment and software, future expansion potential to support additional services and be cost effective*

Complies. Specifics can be found in the system description and in subsequent responses.

5.4.1.1 General specifications

5.4.1.1.1 Protocols

Data transmitted over the system shall be formatted in accordance with Internet Protocol (IP) version 4 (IPv4) or better.

Complies. WiMAX uses industry standard IP version 4 and version 6 routing.

5.4.1.1.2 Standards

Quality of Service (QoS) and virtual local area network (VLAN) tagging should be in accordance with IEEE 802.1p, 802.1q, and request for comments (RFC) 791.

Radio frequency (RF) links shall comply with applicable Federal Communication Commission (FCC) rules and guidelines.

Complies

5.4.1.1.3 Spectrum

The spectrum may include licensed and unlicensed frequencies in all bands except VHF. If unlicensed frequencies are proposed, the vendor must provide an interference risk mitigation plan to assure the state of the usefulness of the unlicensed spectrum.

Complies. The proposed MDS will operate in the licensed 2.5 GHz band.

It is the understanding that the state of Minnesota will provide properly licensed frequencies for use with all proposed equipment for all sites.

5.4.1.2 Codes and standards

The equipment, application software, and components, as well as their installation, integration, and testing, shall be in accordance with reasonable best industry standards. All materials, equipment, supplies, installation, and testing shall comply with the project requirements, the latest editions of standards, as applicable, and all other applicable standards and requirements.

The MDS shall adhere to appropriate codes and standards from the following standards bodies:

- *ANSI American National Standards Institute*
- *ASME American Society of Mechanical Engineers*

- *ASTM American Society for Testing and Materials*
- *EIA Electronic Industries Association*
- *FCC Federal Communications Commission*
- *IEEE Institute of Electrical and Electronic Engineers*
- *ISO International Standards Organization*
- *NEC National Electric Code*
- *NEMA National Electrical Manufacturers Association*
- *NFPA National Fire Protection Association*
- *OSHA Occupational Safety and Health Administration*
- *UL Underwriters Laboratory*

Complies

5.4.2 Functional requirements

5.4.2.1 System overview

The MDS shall offer a high degree of scalability, expandability, and upgradeability with minimal hardware obsolescence risk. The following system attributes are among those of most interest to the state of Minnesota:

- *Data throughput performance*
- *Channel bandwidths*
- *Over-the-air data speeds*
- *Over-the-air technology*
- *Fixed infrastructure topology (sites and frequencies)*
- *Networking*

The MDS shall support Tier 1 applications for all users. The MDS shall support Tier 2 and Tier 3 applications for 100% of all users.

The intent of the MDS is to provide seamless data coverage and roaming capabilities for data operations throughout the defined coverage area (county, region or state). The MDS shall leverage existing ARMER towers, sites, and backhaul equipment and potentially integrate into the OET Multi-Protocol Label Switching (MPLS) IP network, to the maximum extent possible. The state envisions the MDS to provide data services at the IP address level and utilizing open architecture and off-the-shelf equipment wherever possible.

Complies. The proposed WiMAX system is flexible and scalable; please refer to the system description.

5.4.2.2 System architecture

The MDS architecture shall be open, IP-based, scalable, and expandable. The MDS shall take advantage of existing ARMER tower sites and OET backhaul capabilities and, to the extent possible, leverage other existing equipment and infrastructure. The MDS shall utilize state-of-the-art equipment and software with future expansion capabilities to support additional services.

Complies

The MDS shall support Tier 1 applications with the ability to interface and switch to at least Tier 2 and Tier 3 applications in certain 'hot spot' locations. All applications shall reside on a single user's mobile data computer.

Complies. The WiMAX system satisfies all tiers of application requirements. Applications are transparent to the WiMAX network; all applications can reside on a single mobile client, provided it has the capacity for the applications.

The MDS must be capable of interfacing to the state of Minnesota Justice Information System (MNJIS) through local Computer Aided Dispatch (CAD) system interfaces or directly to the MNJIS via IP using a web browser.

Complies

The MDS shall be equipped to address each mobile client device on an individual, group or all-call basis.

Partially complies. The native transport technology (WiMAX) does not offer the functionality, but it doesn't preclude the application layer from providing this capability. The proposed WiMAX system does not support RF broadcast or group call communication; the WiMAX technology supports single-threaded over-the-air

communication between the mobile client and the WiMAX base station. Host applications may support this type of functionality.

The MDS shall be able to provide Tier 1 applications within the same coverage footprint as the ARMER P25 voice radio system. Tier 2 level and higher applications may use a separate system potentially requiring an additional user mobile data modem.

Not applicable. The proposed WiMAX system coverage footprint will be in certain 'hotspot' areas for opportunistic, not ubiquitous coverage.

5.4.2.3 RF spectrum

The MDS shall operate in licensed land mobile radio frequency bands, except in the very high frequency (VHF) band for Tier 1 applications. The MDS shall operate in the unlicensed or licensed public safety bands, in conjunction with the Institute of Electrical and Electronics Engineers (IEEE) 802.11 and/or 802.16 standards for fixed 'hot spot' technology for Tier 2 and above applications. The MDS shall have the ability to add channels, if needed, as RF spectrum becomes available.

Complies

5.4.2.4 Coverage

The MDS coverage design, implementation, and testing must adhere to the Telecommunications Industry Association (TIA) Telecommunications Systems Bulletin (TSB) #88 'Wireless Communications Systems Performance in Noise-Limited Situations' Parts 1, 2 & 3 (TIA TSB-88.1 & 2 & 3). These parts are as follows:

- *Part 1 - Recommended methods for technology independent performance modeling*
- *Part 2 - Propagation and noise*
- *Part 3 - Performance verification*

The TIA TSB-88 document addresses items including but not limited to: channel performance criterion (CPC), CPC reliability design target, terrain profile extraction method, interference calculation method, metaphors to describe the plane of the service

area, required service area reliability, adjacent channel drift confidence factor, conformance test confidence level, sampling error allowance, pass/fail criterion, and treatment of inaccessible grids.

Coverage is broken down into coverage area and coverage reliability. Coverage area pertains to the physical 'footprint' of the system's transmission and reception area. Coverage reliability pertains to the probability of receiving and/or transmitting good data packets at any point in time, at any location within the specified coverage area.

Complies

5.4.2.4.1 Coverage area

The Tier 1 MDS coverage area shall meet the same coverage area requirements of the ARMER P25 voice radio system. In-building coverage is not a requirement.

The required coverage area based on application Tiers is as follows:

- *The MDS providing Tier 1 applications shall provide 95% mobile coverage by county. This is the same coverage area requirement for the ARMER system*
- *The MDS providing Tier 2 and Tier 3 applications shall provide 'best effort' coverage as they may be commercially owned systems; it is expected that all users will obtain an unspecified variable bit rate and delivery time, dependent upon current traffic load*

Users shall be able to roam seamlessly between sites within one mobile data technology throughout a coverage area.

Not applicable. The proposed WiMAX system coverage footprint will be in certain 'hotspot' areas for opportunistic, not ubiquitous coverage.

5.4.2.4.2 Coverage reliability

The MDS design shall provide adequate signal strength and forward error correction to accommodate areas obstructed by a foliage canopy, buildings and other structures, or topography, etc. in order to meet specified coverage reliability requirements.

The MDS shall achieve a minimum message success rate within 95% of the specified coverage area for 95% of the time.

Complies for the 'hot spot' coverage it will provide.

5.4.2.4.3 Message success rate

Message success rate (MSR) is defined as the number of packet retries where the data equipment, as opposed to the software application, generated the original transmission and any subsequent re-transmissions.

The required message success rate based on system type (tier) shall be as follows:

- *Tier 1 systems shall have no more than three automatic re-transmissions on any attempted data transmission*
- *Tier 2 and higher tier systems shall have no more than 10% automatic retransmissions in any given timeframe*

The MDS must achieve this MSR while vehicles travel at posted speed limits.

Complies

5.4.2.5 Mobile client roaming

5.4.2.5.1 Intersystem

The system shall allow mobile data clients to roam across different collocated or non-collocated access points within the same wireless network from both an inactive or active client session. Roaming between different access points shall minimally impact client units. The system shall allow for roaming threshold to be configurable system-wide on an individual client basis by the data system administrator.

5.4.2.5.2 Regional

The MDS shall be able to be shared, with the same level of functionality, with other regional sub-systems. Networking or interfacing in this case means the linking of systems at the highest possible level to allow roaming (assuming the same frequency band and protocol) and equivalent functionality between regions. The system shall not preclude the networking of separate wireless data systems being procured separately, but shall enhance these designs wherever possible.

5.4.2.5.3 Multi-network

The MDS shall be equipped to allow the mobile data clients to switch between dissimilar wireless networks, such as IEEE 802.11 or those of commercial service providers, to provide access to Tiers 1, 2 and 3 applications.

Complies.

Applications on the mobile client will use a software-based switch compatible with Microsoft Windows XP, Windows 2000, Windows 98 and Windows Mobile to switch between the MDS supporting Tier 1 (and possibly Tier 2) applications and the MDS supporting Tier 2 and above applications as they become available. This switch controls connections to multiple wireless data networks, such as HPD, WiFi, and WiMAX. The switch is configured for each MDS, enabling the mobile client to roam between the different networks with no user intervention.

The mobile client switch automatically limits the use of an application over certain network types, preventing applications that require higher bandwidth (e.g., Tier 2 and above) from using the low bandwidth (Tier 1) MDS. The switch sets up a virtual private network (VPN) session enabling mobile client applications access to databases and other services on the host LAN. Since the switch retains logon information for each MDS, users do not have to log on each time the mobile client connects to a new network. The switch maintains VPN connectivity after a user roams between MDSs. Even after roaming to another MDS, the switch maintains an application's connection to databases and other services on the host LAN. Server-based network administration software, residing on the host LAN, provides remote control and management of the mobile client switch software. The VPN also provides data security and encryption services.

5.4.2.6 Data throughput

Data throughput (or capacity) is highly dependent on the applications, frequency of use of the applications, and the number of users. Other variables include application header size requirements, voice traffic priority, and the variety of applications in use.

Potential MDS vendors shall provide a detailed throughput study. This study shall include the required number of channels for the given geographical user distribution to support Tier 1 applications. It shall also include provisions for overhead associated with the following:

- *Automatic RF acknowledgment transmissions for all inbound and outbound messages*
- *Retries*
- *Automatic roaming*
- *Message packetization*
- *Error correction and error detection*

Capacity and throughput are dependent on many performance factors such as message load profiles of all applications running on mobile clients in the wireless network, network protocol used (TCP or UDP), network traffic load and coverage reliability. Performance is optimized if the mobile application software has been written specifically for and successfully implemented in a wireless environment.

Complies. The WiMAX system supports RF acknowledgments, retries, roaming, message packetization and error detection/correction.

5.4.2.6.1 Data rate

The MDS shall have a minimum over-the-air data rate of 9,600 bps for Tier 1 applications; the MDS shall have a minimum over-the-air data rate of 64,000 bps for Tier 2 and Tier 3 applications.

Complies. The proposed WiMAX system provides data rates from 1 Mbps to 5 Mbps depending on the distance to a base station and signal conditions over the coverage area.

5.4.2.6.2 Geographical user distribution

5.4.2.6.2.1 Beltrami County

Beltrami County shall be used as a countywide model for MDS system. Beltrami County encompasses 3,056 square miles, of which 550 square miles is water. The population of the county is 43,609.[37]

The ARMER system is planned for approximately 320 sites of which 7 sites are planned for the Beltrami County. The ARMER coverage plan calls for 95% coverage in each county. It is expected that the Tier 1 MDS system footprint will closely match the ARMER P25 voice radio system coverage.

For Beltrami County, the MDS shall support a minimum of 58 concurrent active mobile client units[38] *and interface to a minimum of one CAD system to support the PSAP in the region.*

Not applicable. It is understood that the WiMAX MDS will not provide 95% coverage and will supplement a wide-area MDS.

5.4.2.6.2.2 Northwest Region

The Northwest Region of the state of Minnesota shall be used as a regional model for the MDS system. This region consists of 14 of the 87 counties in the state.

This region encompasses 17,055 square miles and includes these three medium-sized cities.

These cities have a combined population of 129,152, with the total population of the NW region being 251,994. The state of Minnesota population is 5,197,621. In comparison to

[37] 2007 estimated US census data
[38] Total user counts are based on two units for every 1,000 population, for a given geographic area; 66% of each count will be assumed for total concurrent system users. Counts used are based on estimated 2007 census data, with a statewide population of 5,197,621.

the state, the Northwest Region represents 21% of the total square miles and 5% of the population.[39]

The ARMER system is planned for approximately 320 sites of which 57 sites are planned for the Northwest Region.NR The ARMER coverage plan calls for 95% coverage in each county. It is expected that the Tier 1 MDS system footprint will closely match the ARMER P25 voice radio system coverage.

For the Northwest Region, the MDS shall support a minimum of 333 concurrent active mobile client units and interface to a minimum of 14 CAD systems to support the 14 PSAP's in the region.

Not applicable. It is understood that the WiMAX MDS will not provide 95% coverage and will supplement a wide-area MDS.

5.4.2.6.2.3 State of Minnesota

The state of Minnesota encompasses 87,014 square miles and the population with a population of 5,197,621.[40]

For the state, the MDS shall support a minimum of 6860 concurrent active mobile client units and interface to a minimum of 100 CAD systems to support the PSAP's in the state according to the following:

- *In a defined rural environment, the MDS shall support a minimum of 10 concurrent active mobile client units interfacing two CAD systems on a per site basis*
- *In a defined urban environment, where Tier 2 and higher application services are available, the MDS shall be equipped to support a minimum of 20 concurrent active mobile client units interfacing three CAD systems on a per site basis*

Complies. WiMAX will support the number of anticipated users and applications in its given coverage area.

[39] 2007 estimated US census data
[40] 2007 estimated US census data

5.4.2.6.3 Message load profile

A projected message load profile is an estimate of the number of bytes transmitted and/or received per application transaction. Transactions may include Law Enforcement Message System (LEMS) queries and hot files to the state of Minnesota Justice Information Services (MNJIS) and the Federal Bureau of Investigation (FBI) Criminal Justice Information Services (CJIS) and National Crime Information Center (NCIC) databases, as well as motor vehicle, driver and warrant queries.

The predicted user message load profile (Table 1 in the Minnesota Public Safety Interoperable Wireless Data Feasibility Study Deliverable for Tasks 8 and 9: High Level Wireless Data Functional Requirements document) shall serve as a benchmark for the MDS and be used in data throughput calculations. The Tier 1 MDS shall handle a peak Tier 1 message load profile of the peak number of units (2/3 of the total units) during the peak busy hour. This load profile shall be considered consistent throughout the state of Minnesota.

Complies. The proposed WIMAX system has two channels at each site to support the required message load profile. The total number of channels required system-wide is based on the ability to reuse frequencies at different sites. These sites must be adequately separated. The diagram below depicts an example frequency reuse pattern showing frequencies reused at sites located one site away from each other. Please refer to the implementation sections for the potential number of channels and frequencies required for each implementation.

Frequency re-use – 3 channels **Frequency re-use – 1 channel**

Figure 4 - Frequency Re-use

The predicted performance is based on the following assumptions:

All mobile clients in the simulation are distributed uniformly across the coverage area.

Additional UDP/IP headers are added to the length of the RFP profile message. Internet messages are associated with TCP/IP messages with additional overheads to support typical TCP and Internet access protocol.

The message acknowledgment delay is the time elapsed between the initiation of the message and the return of corresponding acknowledgment after the message has been successfully delivered (excluding delays associated with host/client applications)

5.4.2.6.4 Large file transfer

The MDS shall be capable of configuring the system to allow for large file transfers, where Tier 2 and higher data speeds are accessible. The MDS will integrate wireless broadband 'hot spots' with capacity able to handle large wireless file transfers where backhaul capacity is capable of providing the appropriate network connectivity.

Complies. WiMAX is a broadband service.

5.4.2.6.5 Future growth

The MDS shall meet the system requirements specified in this document plus an additional 10% of users for future growth.

Complies

5.4.2.7 Security

The system must have security capabilities that control system access and protects data integrity, such as encryption. The system shall employ security on multiple layers in compliance with Federal Information Processing Standards (FIPS) 140-2.

Complies

5.4.2.7.1 Encryption

The MDS shall support over-the-air, data link layer encryption. Over-the-air encryption shall have minimal impact to overhead data. Encryption schemes must be non-proprietary for 'hot spots' and follow Federal recommended encryption standards.

Over-the-air encryption should be limited such that regular data transmissions are not adversely affected.

Complies

5.4.2.7.2 User authentication

The MDS shall authenticate individual users on the network with a login and password combination that is unique to each individual user.

Complies

5.4.2.7.3 Device authentication

The MDS shall authenticate access by an authorized mobile client and deny access to an unauthorized mobile client. Any device being used to access the network must be authenticated to the network by an identifier that is unique to the device before access is granted.

Complies

5.4.2.8 Interfaces

5.4.2.8.1 System host interfaces

The MDS shall support a minimum of three host interfaces per county with the ability to add host interfaces up to a maximum of five per county.

Complies

5.4.2.8.2 Database interfaces

The MDS shall support access to MNJIS, FBI CJIS, NCIC and Law Enforcement Message System (LEMS) databases.

Complies

5.4.2.8.3 Physical Interfaces

The vendor shall describe the physical (DB-9, RJ-45, USB, etc.) and logical (serial, Ethernet, etc.) interfaces used for, but not limited to, the following:

- *The transmission and reception of mobile client/host application data*
- *Control of the base station features and functions*
- *Equipment monitoring/diagnostic*

For every site, and for each interface, the vendor shall state the transmission media that will interconnect the base stations to the system controller equipment or monitoring/diagnostic systems.

At each site where the existing digital microwave system will be used as the transmission media, the vendor shall describe the amount of bandwidth required for each interface.

The mobile client receives Ethernet data over USB connection to the modem. The base station will be controlled and monitored via Ethernet. The base station will interconnect to the router/switch via RJ-45 that is connected to the microwave system.

Physical and logical demarcation points

The WiMAX system's physical demarcation point on the host end will be the base station's WAN port that provides a physical connection point for the state of Minnesota customer enterprise network (CEN). The state of Minnesota must connect their CEN using a network switch or router to the base station WAN port. All equipment required to faciliate this connection will be provided by the state of Minnesota.

The controller will be the logical demarcation point on the host end. First, core security components such as the firewall, intrusion detection sensor and access controller will manage access to the WiMAX network. For example, the base station will forward mobile authentication requests to the access controller, which in turn queries the authentication server in the state of Minnesota's host network. In order for host and mobile traffic to flow across the network, all software applications must be written to a standard TCP/IP or UDP/IP interface. They also must fall into the policies estalished in the CSMS.

Please refer to the backhaul requirements detailed in the system description for each implementation.

5.4.2.8.3.1 Data ports

The Owner may wish to add additional mobile computing devices such as optical readers, fingerprint scanners, printers, digital video recorders, etc., as they become ready for deployment. It is envisioned that these devices will be interconnected in such a manner as to create a vehicular local area network with the mobile modem being offered.

The vendor shall describe the manner(s) by which you propose to network these devices.

There is one physical demarcation point on the mobile client end, a USB connection. All peripheral devices will need to be connected directly to the client laptop for interface to the WiMAX MDS.

5.4.2.9 Network management and control

The MDS shall include a network management and control subsystem (NMCS) as an integral component of the system. There may be one NMCS for Tier 1 application support and a separate NMCS for Tier 2 and Tier 3 application support; or there may be one NMCS for Tiers 1-3 application support.

Each NMCS shall be IP-based and function as the interface between the wireless network and the wire-line network utilizing simple network management protocol (SNMP), Telnet, and support higher-level network management system protocols. The NMCS shall be responsible, at a minimum, for the configuration and management of mobile clients, wireless network resources, and capable of all general administrative, diagnostic, monitoring, and reporting functions.

The NMCS shall be of current production and shall be capable of withstanding the harsh operating environment heavy usage associated with the delivery of public safety services. It shall provide features and functions compatible with existing and new fixed and mobile equipment. The NMCS shall be comprised of hardware, software, cabling, and associated accessories utilizing standard commercial-off-the-shelf (COTS) equipment wherever possible.

In addition, user/client prioritization is a desirable feature, but is an optional requirement at this time.

The NMCS will encompass administrative and maintenance functions necessary for proper installation, setup, and maintenance of the MDS.

Complies

5.4.2.9.1 Unique identifier

A unique ID must identify all fixed or mobile MDS terminal devices.

Complies

5.4.2.9.2 Device management, monitoring, and alarms

The NMCS shall provide real-time utilization, performance, status, health, and fault alarm information of all MDS system components including, but not limited to, network servers, networking devices, data base stations, mobile clients, and others.

The NMCS shall provide the following minimum features:

- *Remote management and upgrade of client devices*
- *Event logs*
- *Report generation*
- *Performance statistics such as link quality, network delays, etc.*
- *Secured remote access by typical client devices from authorized maintenance personnel*

The NMCS shall also be capable of reporting information of a historical nature and in a manner suitable for network planning purposes. At a minimum, the NMCS shall report bi-directional performance statistics on both the wireless and wireline portions of the network including each mobile client device, each radio base station, and the composite of all radio base stations.

The NMCS shall be equipped with the functionality capable of delivering alert text and/or email messages to radio pagers or cellular phones in the event of a detected fault condition. At a minimum, the text message shall contain fault specific information regarding the affected equipment and the location of the fault.

Complies

5.4.2.9.3 Management partitioning

The MDS shall allow for partitioning of the system as it relates to administrative functions, system configurations, and client programming. The NMCS shall allow designated users permission to accomplish the following:

- *User groups permission to add or delete their client units from the system*
- *Maintenance personnel to verify device configuration and status*
- *Administrative personnel access to real time and historical reports*

Complies

5.4.2.9.4 Load balancing

Dependent upon the systems available within the user's current location, the MDS shall be able to balance low and high data payloads from different applications. For example, if a user is located in a rural environment for which only Tier 1 services exist, Tier 2 and higher applications shall not be allowed to transmit or receive data until the user has physically moved within range of a Tier 2 or higher radio site location. The load balancing thresholds shall be configurable by the data system administrator.

Complies. The proposed mobile clients can be configured with a third party middleware that intelligently switches between various services when available to the mobile client. Please refer to the system description for more detail.

5.4.2.9.5 Remote access

The NMCS shall be equipped to enable full functional access from IP-based networked workstations and utilize standardized internet applications (e.g. HTML, etc) for browser interface, by authorized personnel within the private network, or over encrypted connections, such as VPNs, for access from remote networks.

Complies

5.4.2.9.6 Programming and configuration

The NMCS shall allow for programming and configuration of the system base stations and mobile units from a system based network location by authorized users.

Partially complies. The proposed WiMAX system allows for remote programming and configuration for base stations and fixed network devices. Mobile clients cannot be configured over the air.

5.4.2.9.7 Information repository

The NMCS shall provide a database repository of system device and network connectivity information for use in configuration, programming, testing, and troubleshooting of system equipment and connections. Data shall include, but not be limited to, the following:

- *Network architecture diagram and description of hardware and software*
- *Base station and mobile device model and serial numbers, including configuration options and program settings*
- *Redundant carrier and redundant path description for telecom services that support the remote monitoring systems*
- *Network monitoring procedures*
- *Classification of support issues with corresponding escalation procedures and response times.*

All pertinent MDS data shall reside on a common network and be accessible from any location within the network by authorized personnel.

Complies

5.4.2.10 Scalability, expandability, and redundancy

The MDS shall be deployable on a single site, multi-site, regional, or wide area basis capable of servicing any area within the state of Minnesota where ARMER or OET infrastructure exists. In addition, the network should provide for full automatic and seamless operation to mobile client users, while utilizing simple management and administrative functions.

The state shall be able to expand the MDS by adding sites for increased coverage, base stations for larger capacity, or network applications to improve efficiencies. In all cases, the MDS shall employ a high level of system redundancy (no single point of failure).

The MDS may initially be deployed on a regional or smaller basis, with the expectation to migrate to statewide use.

Complies

5.4.2.10.1 Expansion

The MDS shall be modular and scalable, utilizing hardware and software designs such that the system may be expanded, rather than replaced, to meet future requirements. The scalability of the system shall permit easy expansion, at a minimum, in these major areas:

- *Number of clients*
- *Radio frequencies*
- *Tower sites*
- *Host interfaces*
- *Network management interfaces*

Complies. The quantities of clients, radio frequencies, tower sites, hosts and management interfaces can all be scaled easily.

5.4.2.10.2 Redundancy

Due to the critical nature of the MDS services, a high degree of reliability is required. Redundancy and reliability shall meet or exceed ARMER P25 voice radio system requirements. All components that encompass the MDS, including the NMCS, shall be viewed as critical elements of the network. Therefore, a network topology utilizing fault tolerance shall be incorporated to the greatest extent possible through a distributed and/or redundant architecture.

Complies. All network equipment can be installed in a redundant topology.

5.4.2.10.3 System scan

The system shall be equipped to allow mobile clients to automatically scan for another RF channel in the event of loss of their primary RF channel.

Complies

5.4.2.10.4 Failure modes

The system shall be equipped with multiple failure modes to allow use of the MDS on limited data throughput basis rather than full system shut down.

Complies. The mobile WiMAX client will change modulation rates to adapt to degrading signal conditions which will allow for lower data throughputs. When a connection fails and the system is no longer available, third party middleware can be used to connect to another available network.

5.4.2.11 Backhaul

The MDS shall utilize existing ARMER and OET networks for backhaul connectivity. MDS physical and protocol interfaces (e.g., DS0, T1, or Ethernet) shall comply with ARMER and OET site-specific connectivity requirements. Bandwidth requirements of the MDS shall consider the available capacity of the ARMER and OET network.

Complies. The state is to provide operational interconnect facilities to provide connection points for the WiMAX base station equipment. The network backbone must be able to support 1 Mbps per user on the system or 15 Mbps, whichever is greater. If the ARMER site does not have the available capacity for the WiMAX system, then Ethernet backhaul should be provided to the site via Ethernet microwave radios or leased services (optical fiber, multiple T1-circuits, DS3-circuits).

Please refer to the backhaul requirements detailed in the system description for each implementation.

5.4.2.12 Radio equipment requirements

5.4.2.12.1 Site infrastructure

The MDS shall utilize the state's existing ARMER site locations, available site equipment, infrastructure, and tower space to the greatest extent possible.

RF subsystem equipment (e.g., Heliax, antennas, and lightning and surge protection) shall be supplied for each site. Equipment shall connect to the state's existing microwave, fiber, and leased-line transport backhaul infrastructure.

Complies

5.4.2.12.1.1 Security

Gates, door locks, and passcode entrances shall physically secure MDS transmitter sites, database locations, and limited access terminals, where permissible.

Complies

5.4.2.12.1.2 Installation

Equipment shall be installed in existing equipment room spaces where available. Equipment shall be housed in suitable indoor-type cabinets or relay racks. These cabinets or racks shall be installed with ease of accessibility. Equipment shall be arranged and installed so its intended function will not be impaired due to weather, temperature, adjacent equipment, or other factors. Sufficient space and clearance shall be provided such that service and maintenance can be readily performed.

Renovations, designs, and installations at the site shall conform to the following guides:

- *Industry best practices*
- *Commercial Building Standard for Telecommunications Pathways and Spaces, TIA/EIA-569*
- *Commercial Building Telecommunications Wiring Standard, TIA/EIA-568*
- *Occupational Safety and Health Administration's recommended approved practices*
- *National Electric Code practices, including grounding and lightning suppression*
- *All applicable local, county, state building and life-safety codes*

Upon completion of the installation, all systems and equipment shall operate in accordance with applicable standards for operation.

Complies

5.4.2.12.1.3 Power

System hardware installed at the transmitter sites shall be equipped with an uninterruptible power supply. Power losses, restorations, surges, sags, and/or brownouts shall not alter the operating parameters of MDS components. Other than total power loss or lethal surges, all components shall remain fully operational within the specifications of its design while experiencing any of these occurrences.

Complies

5.4.2.12.2 Base station radio

The base radio system shall be rated for and capable of continuous duty operations with required automatic station identifiers. The fixed equipment proposed shall be modular in design using 19' rack mountable units.

Complies

5.4.2.12.2.1 Programming and software upgrades

The base station radio shall allow for remote network based programming and/or software upgrades.

Complies

5.4.2.12.2.2 Security

Any MDS base station radio must authenticate any person utilizing the device via user login and password and/or biometrics.

Partially complies. As stated above, the proposed WiMAX system can provide the medium on which the authentication takes place, but the authentication of a user is handled at the application layer.

5.4.2.12.2.3 IP

Each base station radio shall be equipped with an IP address (dynamic or static).

Complies

5.4.2.12.2.4 Unique modem identifier

Each base station radio must be uniquely identifiable by its static IP address or modem MAC address.

Complies

5.4.2.12.3 Mobile radio modem

The mobile radio modem shall provide an interface between the mobile computing device and the wireless data fixed network equipment. The mobile modem shall be a rugged, factory integrated vehicular radio modem product designed to provide optimal data transmission performance for mobile data applications.

Mobile units shall include a 'smart switch' to determine the most efficient data transfer technology to use. The MDS modem shall default to the high-speed network when available; otherwise, it will switch to the existing low-speed network. This 'switching' capability may be hardware of software integrated.

Does not comply. The WiMAX mobile modem is not vehicular integrated, but is connected directly to the mobile client laptop. The mobile client laptop can be configured with a third party middleware that intelligently switches between various services when available to the mobile client, the WiMAX modem does not support this. Please refer to system description for more detail.

5.4.2.12.3.1 Programming and software upgrades

The mobile client shall allow for over-the-air-programming (OTAP) and/or software upgrades.

Does not comply. The proposed WiMAX mobile client is not capable of OTAP.

5.4.2.12.3.2 Security

Any MDS client device must authenticate any person utilizing the device via user login and password and/or biometrics.

Partially complies. As stated above, the proposed WiMAX system can provide the medium on which the authentication takes place, but the authentication of a user is handled at the application layer.

5.4.2.12.3.3 Multiple receive

The modem shall simultaneously decode two incoming message streams for increased message reliability.

Does not comply. The proposed WiMAX modem is not capable of multiple receive.

5.4.2.12.3.4 GPS

The mobile radio modem shall either incorporate global positioning system (GPS) receiver or be capable of receiving a GPS data from an external source.

Does not comply. The WiMAX modem does not have a built-in GPS receiver and does not have an external connection for a GPS receiver. A GPS would generally connect to the mobile client laptop or wide-area MDS modem.

5.4.2.12.3.5 Internet Protocol

Each radio modem shall be equipped with an IP address (dynamic or static).

Complies. Within the proposed WIMAX MDS, each network device can operate with a static or dynamic IP address.

5.4.2.12.3.6 Unique modem identifier

Each modem must be uniquely identifiable by its static IP address or modem MAC address.

Complies

5.4.2.12.3.7 Broadcast mode addressing

Modems must support individual group broadcast addressing by IP multicast and directed subnet broadcast.

Complies. The WiMAX system support IP and all IP multicast functions.

5.4.2.12.3.8 Positive acknowledge

Modems shall be capable of sending a positive acknowledgment to the originating base station radio upon receipt of successfully received and corrected messages.

Complies

5.4.2.12.3.9 Client Interface

Modems shall interface to a mobile data computer installed within a vehicle's passenger compartment.

- *Tier 1 modems shall interface via a 10/100BaseT or USB or serial DB9 connection, and*
- *Tier 2 and higher modems shall interface via a 10/100BaseT connection and employ advanced technology to allow higher performance operation, to allow for future modem upgrades or enhancements, and to allow the greatest degree of mobile hardware flexibility*

Complies. The proposed WiMAX modem interfaces to the mobile client via USB.

5.5 Advantages and disadvantages

Below are strengths and weaknesses of WiMAX as compared to other technologies:

Strengths:

- The high transmitter power allowance makes WiMAX an excellent candidate for rural applications, especially if fixed end-user devices with high-gain antennas are used
- WiMAX operates in licensed 2.5 GHz spectrum, unlike Wi-Fi
- WiMAX technology is more mature than LTE and is available today
- A wide range of WMF-Certified client devices are commercially available, which LTE does not have
- WiMAX was designed from the ground up as an all-IP system, which is not the case for cellular and 3G
- Quality of Service (QoS) was designed in from the beginning and was one of the main goals of the technology. The protocols in WiMAX are much more capable of enabling QoS compared to Wi-Fi
- The cellular-like base station control and flexibility give subscribers access to the wireless medium and enables excellent granularity of service and optimization of the scarce wireless airtime, an advantage over Wi-Fi
- A significant ecosystem (chipset vendors, laptop card makers, WiMAX modem vendors, base station vendors, backhaul vendors) has built up around WiMAX over the last several years
- WiMAX technology supports higher throughput capabilities than 3G and cellular data

Weaknesses:

- WiMAX is still unproven on a large scale, especially with mobility
- Mobility was an add-on to 802.16 in the 802.16e amendment. 802.16 was originally a fixed standard
- There are different frequency bands and different profiles in different countries around the world, unlike Wi-Fi. This has led to some product dispersion among vendors, for example, to focus on the European market more than the USA market.
- High-volume equipment and economies of scale are not readily available compared to Wi-Fi and 3G

5.6 Rough order-of-magnitude (ROM) cost estimates

This section provides high-level, ROM estimates for each implementation – county, regional and statewide - discussed in this proposal. Please note that these estimates are ROM only, and a detailed design would be required for a more accurate estimate.

Capital outlay costs are associated with deploying this technology for the site mobile data equipment and user radio modems. There are no recurring fees other than regular operations and maintenance; if the spectrum is leased, there will be a recurring cost associated with that. Please note other assumptions and notes following the cost tables.

5.6.1 County implementation

Costs below depict a localized implementation of WiMAX for the City of Bemidji only; this must be integrated with another technology to provide county-wide coverage.

	Qty	Cost	Total
Base Station	2	$125,000	$250,000
Client device modem	27	$500	$13,500
Access controller	1	$500,000	$500,000
Infrastructure sub-total			$763,500
Project management/engineering		Included	$0
TOTAL ROM COST			**$763,500**

5.6.2 Regional implementation

Costs below depict a localized implementation of WiMAX for the City of Fargo-Moorhead only; this must be integrated with another technology to provide region-wide coverage.

	Qty	Cost	Total
Base Station	2	$125,000	$250,000
Client device modem	77	$500	$38,500
Access controller	1	$500,000	$500,000
Infrastructure sub-total			$788,500
Project management/engineering		Included	$0
TOTAL ROM COST			**$788,500**

5.6.3 State implementation

Costs below depict localized implementations of WiMAX in populated areas in excess of 25,000 people; this must be integrated with another technology to provide state-wide coverage.

	Qty	Cost	Total
Base Station	124	$125,000	$15,500,000
Client device modem	4,075	$500	$2,037,500
Access controller	2	$500,000	$1,000,000
Infrastructure sub-total			$18,537,500
Project management/engineering		Included	$0
TOTAL ROM COST			**$18,537,500**

Notes:

- Mobile client laptop and middleware costs are not included and are assumed to be provided by the wide-area MDS
- Costs include site and mobile equipment installation
- Costs include site and mobile antenna systems

- All tower sites include $5,000 for structural analysis of existing tower structures
- Costs do not include backhaul costs and may require additional capacity
- Costs include one year warranty and software updates
- Discounts are not included
- These estimated do not reflect any capital or recurring costs associated with sites- towers, shelters, real estate, etc.; it is assumed that existing ARMER sites will be utilized

6. Conclusions and recommendations

Minnesota has viable options available for a local, county, regional and statewide implementation of a public safety mobile data system. More importantly, these options can potentially leverage the existing and planned ARMER infrastructure investment to save cost and increase efficiencies. This Wireless Data Feasibility Study began with an expansive list of potential technologies for assessment. The list was narrowed down to following four potential solutions (three wide-area, lower speed technologies and one localized, high-speed broadband technology):

1. APCO P25 IV&D
2. Motorola HPD
3. Dataradio
4. WiMAX broadband

P25 IV&D, HPD and Dataradio were examined and assessed in this report as wide-area solutions, with the ability to switch to a broadband network or commercial service. WiMAX was examined as one of the broadband technologies that P25 IV&D, HPD or Dataradio users would automatically switch to, when available, for high speed applications such as large file transfers and video. This switching functionality is available regardless of the technology chosen. It is performed by third party switching software that resides on the mobile client laptop. This software controls the connections to multiple wireless data networks, such as HPD, WiFi, and WiMAX. The switch is configured for each MDS, enabling the mobile client to roam between the different networks and enable applications based upon the network without user intervention.

FE has examined the compliance of each technology to the functional requirements. In this section we discuss the results of this examination, paying particular attention to coverage, data rate, cost and interoperability. We have included our recommendations based on the result of this assessment as well as additional recommendations regarding broadband and the potential of using commercial wireless services.

6.1 Functional requirements compliance

The following table summarizes each technology's compliance to the defined MDS functional requirements. Although WiMAX is considered a supplementary network and

not considered an option for Minnesota's 'base' wide-area MDS, it is listed in the table for comparison as if coupled with one of the other wide-area approaches.

Section #	Description	P25 IV&D	HDP	Dataradio	WiMAX
x.1	General requirements	Comply	Comply	Comply	Comply
x.1.1.1	Protocols	Comply	Comply	Comply	Comply
x.1.1.2	Standards	Partially	Comply	Comply	Comply
x.1.1.3	Spectrum	Comply	Comply	Comply	Comply
x.1.2	Codes and standards	Comply	Comply	Comply	Comply
x.2	Functional requirements				
x.2.1	System overview	Comply	Comply	Comply	Comply
x.2.2a	System architecture, misc	Comply	Partially	Comply	Comply
x.2.2b	System architecture, tiers	Comply	Comply	Comply	Comply
x.2.2c	System architecture, interface	Comply	Comply	Comply	Comply
x.2.2d	System architecture, all-call	Partially	Partially	Comply	Partially
x.2.2e	System architecture, footprint	Comply	Comply	Comply	N/A
x.2.3	RF spectrum	Comply	Comply	Comply	Comply
x.2.4	Coverage	Comply	Comply	Comply	Comply
x.2.4.1	Coverage area	Comply	Comply	Partially	N/A
x.2.4.2	Coverage reliability	Comply	Comply	Comply	Comply
x.2.4.3	Message success rate	Comply	Comply	Comply	Comply
x.2.5	Mobile client roaming	Comply	Comply	Comply	Comply
x.2.6	Data throughput	Comply	Comply	Comply	Comply
x.2.6.1	Data rate	Comply	Comply	Comply	Comply
x.2.6.2	Geographical user dist.	Comply	Comply	Comply	N/A
x.2.6.3	Message load profile	Comply	Comply	Comply	Comply
x.2.6.4	Large file transfer	Comply	Comply	Comply	Comply
x.2.6.5	Future growth	Comply	Comply	Comply	Comply
x.2.7	Security	Partially	Partially	Partially	Partially
x.2.7.1	Encryption	Partially	Partially	Comply	Comply
x.2.7.2	User authentication	Partially	Partially	Partially	Comply
x.2.7.3	Device authentication	Comply	Comply	Comply	Comply
x.2.8.1	System host interfaces	Comply	Comply	Comply	Comply
x.2.8.2	Database interfaces	Comply	Comply	Comply	Comply
x.2.8.3	Physical interfaces	Comply	Comply	Comply	Comply
x.2.8.3.1	Data ports	Comply	Comply	Comply	Comply
x.2.9	Network management & control	Partially	Partially	Comply	Comply
x.2.9.1	Unique identifier	Comply	Comply	Comply	Comply
x.2.9.2	Device management, monitoring &	Partially	Partially	Partially	Comply

Section #	Description	P25 IV&D	HDP	Dataradio	WiMAX
	alarms				
x.2.9.3	Management partitioning	Comply	Comply	Comply	Comply
x.2.9.4	Load balancing	Comply	Comply	Comply	Comply
x.2.9.5	Remote access	Comply	Comply	Comply	Comply
x.2.9.6	Programming & configuration	Partially	Partially	Comply	Comply
x.2.9.7	Information repository	Partially	Partially	Partially	Partially
x.2.10	Scalability, expandability & redundancy	Comply	Comply	Comply	Comply
x.2.10.1	Expansion	Comply	Comply	Comply	Comply
x.2.10.2	Redundancy	Comply	Comply	Comply	Comply
x.2.10.3	System scan	Comply	Comply	Comply	Comply
x.2.10.4	Failure modes	Does not	Does not	Does not	Comply
x.2.11	Backhaul	Comply	Comply	Comply	Comply
x.2.12	Radio equipment requirements				
x.2.12.1	Site infrastructure	Comply	Comply	Comply	Comply
x.2.12.1.1	Security	Comply	Comply	Comply	Comply
x.2.12.1.2	Installation	Comply	Comply	Comply	Comply
x.2.12.1.3	Power	Comply	Comply	Comply	Comply
x.2.12.2	Base station radio	Comply	Comply	Comply	Comply
x.2.12.2.1	Programming & software upgrades	Comply	Comply	Comply	Comply
x.2.12.2.2	Security	Partially	Partially	Partially	Partially
x.2.12.2.3	IP	Comply	Comply	Comply	Comply
x.2.12.2.4	Unique modem identifier	Comply	Comply	Comply	Comply
x.2.12.3	Mobile radio modem	Comply	Comply	Comply	Does not
x.2.12.3.1	Programming & software upgrades	Comply	Does not	Partially	Does not
x.2.12.3.2	Security	Partially	Partially	Comply	Partially
x.2.12.3.3	Multiple receive	Does not	Does not	Comply	Does not
x.2.12.3.4	GPS	Comply	Comply	Comply	Does not
x.2.12.3.5	IP	Comply	Comply	Comply	Comply
x.2.12.3.6	Unique modem identifier	Comply	Comply	Comply	Comply
x.2.12.3.7	Broadcast mode addressing	Partially	Partially	Comply	Comply
x.2.12.3.8	Positive acknowledge	Comply	Comply	Comply	Comply
x.2.12.3.9	Client interface	Comply	Comply	Comply	Comply

All four technologies comply with the majority of the functional requirements and all have an equivalent level of compliance. Items 'partially complying' such as encryption, user authentication and broadcast (or all-call) are addressed at the applications layer. Also related is the information repository capability which can be provided for each

technology, but is not offered as an inherent feature of the systems analyzed in this study. The information repository database would be setup on a server on the customer's network, much like an application would be setup.

Other requirements not fully met by the technologies are network management, device management, programming, failure modes and multiple receive. While these are listed requirements, they are not considered key features of the proposed MDS. ***FE*** feels that non-compliance with these requirements should not be considered grounds to exclude the technology from consideration.

6.1.1 Coverage

One functional requirement worth noting is coverage. The proposed MDS coverage must match the ARMER P25 voice radio system coverage. P25 IV&D and HPD closely address this requirement, as they are designed by Motorola to match the coverage of the ARMER system. Dataradio, on the other hand, is a standalone system using a different type of technology, which is detailed in its respective proposal. The Dataradio technology does not dynamically decrease the data rate as the user moves away from a transmission site like the HPD technology does; this methodology essentially provides a larger coverage footprint. Dataradio base stations are programmed for one data rate only.

To provide a coverage footprint closer to that of the ARMER P25 voice radio system, Dataradio suggests that one base station be programmed for the higher rate and the second be programmed for the lower data rate, which will provide a broader coverage footprint. It is anticipated that Dataradio would provide comparable coverage by implementing the system in this fashion. Another factor in determining coverage is the frequency band. As the Dataradio MDS would be implemented in the same band as the ARMER P25 voice system, the coverage footprint would be comparable.

6.1.2 Data rate

According to the functional requirement, the proposed wide-area MDS shall support Tier 1 applications at a minimum and a 'hot spot' solution shall support Tier 3 applications at a minimum; please refer to Section 1 for a description of these tiers.

The P25 IV&D technology offers a data rate of 9600 bps. This would satisfy most of the applications in Tier 1.

HPD and Dataradio's data rates are essentially equivalent. As described above, HPD dynamically adjusts the data rate delivered to the user based on their distance from a transmission site; Dataradio's data rate is constant. HPD's raw data rate range for a 25 kHz channel is 32-96 Kbps; Dataradio's raw data rate is 64 Kbps. For a 50 kHz channel, Motorola's High Speed Data (HSD) product will deliver a raw data rate of 76-230 Kbps and Dataradio will deliver a raw data rate of 128 Kbps, according to the respective manufacturers. Both HPD and Dataradio 25 kHz technologies can support Tier 2 applications, while their respective 50 kHz technologies could support Tier 3 applications.

It is important to note that the availability of 50 kHz channels are pending the FCC's decision on the 700 MHz 'D-Block'. Further development of these technologies are currently on hold by vendors, awaiting the final determination of the D-Block. Please refer to our report '*FCC D-Block Report and Assessment'* provided in Appendix C for more detail. Currently, only 25 kHz channels are available.

If the state is to adopt a comprehensive strategy based upon this evaluation of the four listed approaches, ***FE*** recommends the state consider a hybrid approach; implementing a wide-area technology that can provide a minimum of a Tier 2 service and gradually supplement that system with broadband hot spots in more populated areas. A system that could support Tier 4 applications over 95% of the state may be ideal, but would not be practical or financially feasible.

Based on this recommendation, a P25 IV&D MDS is excluded. P25 IV&D barely meets the requirements for Tier 1 applications. P25 IV&D data can, at the most, support simple messaging, CAD and low cadence AVL applications. P25 IV&D does not currently have a migration path to higher data rates and the state would be 'capped' at 9600bps[41]. The P25 suite of standards is continually developing. Phase II of the P25 standard is on the horizon which will include the added development of standards for communications between disparate systems and standards for a Time Division Multiple Access (TDMA) based system. It should be noted that current Phase I systems (i.e., ARMER) will be able to communicate with Phase II systems. This is mandatory in the standards providing for interoperability. As of this writing, APCO has not released the new data rate for P25 Phase II. However, ***FE*** does not anticipate the P25 Phase II data rates to substantially increase.

[41] Phase II P25 IV&D standards are currently under development

6.2 Cost

The following table summarizes the ROM costs provided in the proposals in Sections 3, 4 and 5. (WiMAX costs are not included for comparison as it is considered a supplement for P25 IV&D, HPD and Dataradio.) For each implementation (county, region and state), the lowest cost is indicated by green with the highest cost indicated by red.

Table 1 – ROM capital cost summary

		Cost	Comparison to Dataradio
County	**P25 IV&D**	$3,963,000	108% more
	HPD	$6,713,500	253% more
	Dataradio	$1,903,200	Base
Region	**P25 IV&D**	$19,716,000	45% more
	HPD	$52,725,000	287% more
	Dataradio	$13,640,400	Base
Statewide	**P25 IV&D**	$179,355,000	20% more
	HPD	$369,008,500	147% more
	Dataradio	$149,592,000	Base

These ROM costs represent very high-level, budgetary figures that do not consider discounts which the vendor may offer for economies of scale. The same metrics used for Beltrami County were also used to calculate the regional and statewide system. If the state chose to implement a regional, multi-regional or statewide MDS, vendors may offer a discount off of their list prices (20% or more are common). Although ***FE*** consulted the equipment manufacturers for these ROM costs, ***FE*** strongly cautions the use of these figures. Only after a detailed design and formal response from the vendor would the state obtain an accurate cost. Recurring operational costs or cost of ownership are not known or included in this assessment and will require additional evaluation.

In all scenarios, Dataradio is the least expensive, followed by P25 IV&D then HPD. One may initially think that enabling data on the ARMER P25 voice radio system would be the most cost effective, but it is not. Based on this conclusion in concert with the data rate recommendation above, ***FE*** recommends that Minnesota not consider P25 IV&D as an option for its MDS. HPD and Dataradio data rates are equivalent; Dataradio,

however, is a more economical choice, based upon acquisition costs. If Minnesota chose Dataradio, it would introduce another vendor to Minnesota's communications 'palette', thus diversifying its reliance on vendors.

By implementing a standalone MDS such as Dataradio, the MDS may realize additional reliability and redundancies. When the ARMER P25 voice system is out of service, planned or unplanned, a standalone MDS will still remain operational. It must be noted, however, that in the proposed approach, the Dataradio MDS may leverage existing ARMER sites and backhaul. In this case, if an ARMER site lost power or a microwave link went 'down', both the ARMER P25 voice radio system and the MDS would be out of service.

6.3 Interoperability

Of the four technologies explored in this report, P25 and WiMAX are open standard technologies and HPD and Dataradio are proprietary. Open standard technologies allow for greater interoperability. A user possessing a P25 or WiMAX radio, regardless of the manufacturer, should be able to access other P25 and WiMAX systems respectively, assuming that they are on the same frequency band and user authentication is granted at the application layer. A user with an HPD or Dataradio mobile client can only access Motorola HPD or CalAmp Dataradio systems respectively.

Each technology, however, cannot communicate directly with another technology. For example, P25 cannot communicate with Dataradio. System and interoperability between networks is achieved by deploying the software-based switching technology discussed at length in this report. Measured to SAFECOMs Interoperability Continuum[42], this middleware serves as a gateway on the mobile client end, allowing seamless communications on multiple systems. Interoperability at the radio system level is described in detail for each technology in their subsequent sections in this report.

Interoperability at the application layer is an important consideration. All of the systems defined in this report are IP based and therefore support IP applications, transparent to the user. As an illustration, an application that runs on HPD can also run on Dataradio since both systems employ IP as the transport mechanism. This is similar to a residential user running a particular browser to access the Internet via a digital subscriber line (DSL), and another user running the same browser to access the Internet via cable. Each employs different access technologies, but each may access

[42] http://www.safecomprogram.gov/SAFECOM/interoperability/default.htm

via the same application. This difference in access technologies is transparent to the users and the interoperability 'enabler' is IP.

6.4 Broadband

After exploring WiMAX broadband technology in detail, ***FE*** finds it to be a feasible solution for localized 'hot spot' Tier 3 and Tier 4 services throughout the state, in population centers of 25,000 people or more. Implementing WiMAX technology is an opportunity for the state to construct and own broadband 'hot spots'. As discussed in the commercial services section above, further analysis is required to fully understand and compare the cost benefits of 'owning' vs. 'leasing'.

Other 'hot spot' technologies such as WiFi already in place may be very feasible and cost effective supplementary services. ***FE*** recommends that the state strategy include the implementation of software-based switch (or 'middleware') in each mobile client laptop that automatically selects the appropriate service and enables applications within a Tier appropriate for the available service level.

It is important to note that the availability of 700 MHz 50 KHz data channels are pending the FCC's decision on the 700 MHz 'D-Block', which includes a discussion of a national public safety data network. Technologies that use 50 KHz channels provide higher data rates; further development of these technologies is currently on hold by vendors, awaiting the final determination of the D-Block. Please refer to our report '*FCC D-Block Report and Assessment'* provided in Appendix D for more detail. Currently, only 25 KHz channels are available.

6.5 Commercial services

Given the relatively large capital investment required to implement a state owned (or private) system, the state may wish to further consider the use of established commercial mobile data services. As described in the introduction, commercial services were assessed early in this project, See: Appendix C '*Wireless Data Technology and Commercial Services Assessment Report (Deliverable 3)'* for this preliminary report. Recognizing that a public/private partnership with a commercial carrier should be fully explored as it could yield benefits for both the state and the carrier, for this final report, it was decided to focus on state owned options, to thoroughly assess the strengths and weaknesses for the state to implement a dedicated private system and to use that information to compare and contrast state owed infrastructure versus a commercial service.

FE recommends that the state perform a full evaluation of commercial services available, similar to the analysis of the state owned options provided in this report. This evaluation should measure the available commercial services to the functional requirements established, compare data throughput rates, interoperability, technology update intervals and service priority. The state should also develop a cost benefit analysis comparing the long-term costs (capital and recurring) associated with private/state-owned versus commercial wireless solutions. At a minimum, the analysis should compare the return on investment of a private mobile data system to the recurring costs associated with leasing airtime on a commercial mobile data system.

Commercial systems are established, in place, and operational with system owners responsible for the maintenance. With commercial systems, there are no overhead costs associated with system maintenance, no capital funds required for infrastructure replacement, and the consistent recurring monthly costs are easily projected. The only foreseeable capital cost required is the procurement of the mobile client equipment.

It is important to note that the development of mobile data technologies in the 700 MHz band has been suspended by private data system vendors due to the 'moving target' of the D-Block (please refer to our report '*FCC D-Block Report and Assessment'* provided in Appendix D for more detail); the availability of spectrum in the D-Block would enable these vendors to increase the data rate of their systems. Due to this factor, there is risk in making a large investment in a private system (e.g. HPD or Dataradio) at this point in time. In contrast, commercial system upgrades may be more frequent and less costly than a privately held system, dependent upon the owner's business model and, potentially, other users of the system.

However, since the state would not own the commercial system(s), the state would have minimal control or decision-making ability to impact system functionality or reliability to meet their requirements; that is, the state will have less control of the deployment, coverage, capacity, operations and future of a commercial network. Expansion of mobile data services or coverage area with a commercial carrier may be difficult. Commercial system coverage design is not typical for public safety use as it is limited to areas that produce the highest revenue for the particular carrier. Also, a commercial carrier may not guarantee priority of system resources for a certain agency during emergencies and congested hours.

The first systems to fail or overload during an emergency are typically commercial systems. These systems are designed for investment return and not for high availability. A private system specifically designed and hardened for critical use and limited to non-

public access would continue to operate through storms, emergencies, power outages, cable cuts, public events and other common disruptions.

To counter some of these drawbacks, the state may consider the possibility of entering into a public/private partnership with a commercial wireless carrier. This may give the state more control and decision making authority regarding the operation of the network. For example, the state could offer the use of their ARMER infrastructure such as towers and shelters in return for discounted and/or priority use of the carrier's system. These relationships can be mutually beneficial and ***FE*** would strongly recommend any resulting agreement explicitly define the responsibilities and expectations of both parties.

The hybrid approach described above could also be implemented with a commercial service; a commercial service could be complemented by essentially any other network, commercial or private. Instead of looking at a commercial service as supplementary or as a 'hot spot' technology, it could be regarded as the primary system supplemented by a private dedicated system (e.g. Dataradio) in areas not covered by the commercial service.

6.6 Applications

Above all, ***FE*** recommends that the state perform a more detailed analysis of the applications and functional requirements required by agencies that are likely to use the MDS. A Tier 2 system may be more than adequate to support the basic Message Load Profile (MLP) defined in the hypothetical functional requirements. Broadband solutions or other alternatives should only be considered if it is determined that a network capable of supporting Tier 3 and 4 applications is actually required.

Appendix A – Glossary of acronyms and industry terms

AAA	Authentication, Authorization, and Accounting
ADB	Agile Dual-Band
ANSI	American National Standards Institute
APCO	Association of Public Safety Communications Officials
ARMER	Allied Radio Matrix for Emergency Response
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
Auto-MDIX	Automatic Medium-Dependent Interface crossover
AVL	Automatic Vehicle Location
Backbone	The core of a communications network, i.e., the part that provides high-capacity links over long distances between major nodes.
Backhaul	The transporting of radio communications traffic between distributed sites (typically access points) and more centralized points of presence
Bandwidth	A measure of the width of a range of frequencies, measured in hertz
BCA	Bureau of Criminal Apprehension
BER	Bit Error Rate
Biometrics	Methods for uniquely recognizing humans based upon one or more intrinsic physical or behavioral traits. In information technology, in particular, biometrics is used as a form of identity access management and access control
Bit Rate	The number of binary digits that are conveyed or processed per unit of time
bps	Bits per second
Broadband	Refers to a signaling method that includes or handles a relatively wide range of frequencies, which may be divided into channels or frequency bins. Broadband is always a relative term, understood according to its context. The wider the bandwidth, the greater the information-carrying capacity
Browser	A user interface on a computer that allows navigation of objects
BRS	Broadband Radio Service

CAD	Computer Aided Dispatch
Card	A digitally coded electronic device that controls access to a wireless network
CEN	Customer Enterprise Network
Channel	The route through which a message is sent
CJIS	Criminal Justice Information Services
CNIB	Customer Network Interface Barrier
COM	Communications
Connectivity	The complete path between two terminals
COPS	Community Oriented Policing Services
COTS	Commercial-Off-The-Shelf
Coverage	The geographic area where the user can communicate also sometimes referred to as the service area
CPC	Channel performance criterion
CriMNet	a state-level program that works with Minnesota state and local agencies to make accurate and comprehensive criminal justice information available to criminal justice professionals in law enforcement, the courts and corrections
CSMS	Core Security Management Server
Cutover	The planned migration from one radio communication system to another
Data throughput	The average rate of successful message delivery over a communication channel
Demarcation	The point at which a network ends
DHS	Department of Homeland Security
DOC	Department of Commerce
DPS	Department of Public Safety
DS0	Digital Signal 0 - A basic digital signaling rate of 64 kbit/s, corresponding to the capacity of one voice-frequency-equivalent channel. The DS0 rate, and its equivalents E0 and J0, form the basis for the digital multiplex transmission hierarchy in telecommunications systems used in North America, The DS0 rate was introduced to carry a single digitized voice call.
EBS	Educational Broadband Service

ECN	Emergency Communications Networks
E-DBA	Enhanced dynamic bandwidth allocation
EIA	Electronic Industries Association
EMS	Emergency Medical Services
Encryption	The reversible transformation of data from the original (plain text) to a difficult to interpret format as a mechanism for protecting its confidentiality, integrity and sometimes its authenticity. Encryption uses an encryption algorithm and one or more encryption keys
Error correction	A code in which each data signal conforms to specific rules of construction such that departures from that construction in the received signal can be automatically detected and corrected
Error detection	Extra data added to a message for the purposes of error detection.
Ethernet	A number of wiring and signaling standards providing a means of network access and a common addressing format. Ethernet is standardized as IEEE 802.3. Ethernet also refers to the combination of the twisted pair versions of Ethernet for connecting end systems to the network, along with the fiber optic versions for site backbones, is the most widespread, wired LAN technology.
FBI	Federal Bureau of Investigation
FCC	Federal Communication Commission
FCC D-Block auction	The FCC's plan to auction off the public safety portion of the 700 MHz band
FIPS	Federal Information Processing Standards
Firewall	Part of a computer system or network that is designed to block unauthorized access while permitting outward communication. It is a device or set of devices configured to permit, deny, encrypt, decrypt, or proxy all computer traffic between different security domains based upon a set of rules and other criteria
FNE	Fixed network equipment
Footprint	A way of describing the RF coverage area or anticipated coverage area mapping
Forward Error Correction	A system of error control for data transmission, whereby the sender adds redundant data to its messages, also known as an error correction code. The advantage of forward error correction is that a back-channel is not required, or that retransmission of data can often be avoided, at the cost of higher bandwidth requirements on average. FEC is therefore applied in situations where retransmissions are relatively costly or impossible.

Frequency Reuse Pattern	A method of arranging RF transmission sites such that frequencies may be reused without interference from other sites using the same frequency.
General Packet Radio Service	A second-generation telephony standard that allows a transition to third generation (3G), the GPRS standard is generally classified as 2.5G. GPRS extends the architecture of the GSM standard to allow packet data transfers with theoretical data rates on the order of 171.2 Kbit/s (up to 114 Kbit/s, in practice). Because of its packet transfer mode, data transmissions only use the network when necessary. The GPRS standard therefore allows the user to be billed by volume of data rather than by the duration of the connection, which means, in particular, that the user can remain connected at no extra cost.
GGSN	Gateway general support node - a main component of the GPRS network. The GGSN is responsible for the interworking between the GPRS network and external packet switched networks
GPRS	General packet radio service - a packet oriented mobile data service available to users of the 2G cellular communication systems global system for mobile communications (GSM), as well as in the 3G systems. In the 2G systems, GPRS provides data rates of 56-114 kbit/s. GPRS data transfer is typically charged per megabyte of traffic transferred, while data communication via traditional circuit switching is billed per minute of connection time, independent of whether the user actually is using the capacity or is in an idle state. GPRS is a best-effort packet switched service, as opposed to circuit switching, where a certain quality of service (QoS) is guaranteed during the connection for non-mobile users.
GPS	Global positioning system
GUI	Graphic user interface
High cadence AVL	Automatic vehicle location with a high poling rate, therefore increasing the data usage
Host Interfaces	Means used by a memory adapter to connect to a computer or any other external device
Hot files	A database or data file that is currently being heavily accessed by users. In a hierarchical storage management system (HSM), file I/O may be constantly monitored in order to migrate the hot files to the fastest storage devices or to internal memory for better performance.
Hot spot	A region of high or special activity within a larger area of low or normal activity. A WiFi access point or area, in particular for connecting to the internet
HPD	High Performance Data
HSD	High Speed Data
HSP	High Speed Data

HTML	Hyper Text Markup Language
Hyper-Code Forward Error Correction	A system of error control for data transmission, whereby the sender adds redundant data to its messages, also known as an error correction code. The advantage of forward error correction is that a back-channel is not required, or that retransmission of data can often be avoided, at the cost of higher bandwidth requirements on average. FEC is therefore applied in situations where retransmissions are relatively costly or impossible.
IEEE	Institute of Electrical and Electronics Engineers
Infrastructure	Dedicated telecommunications networks
INM	Integrated network manager
Interface	A point of interconnection between a terminal and a network or between two networks
Interference	An unwanted disturbance that affects a transmitted signal due to either electromagnetic conduction or electromagnetic radiation emitted from an external source. The disturbance may interrupt, obstruct, or otherwise degrade or limit the effective performance of the transmitter.
Interoperability	A property referring to the ability of diverse systems and organizations to work together (inter-operate)
Intranet	A private computer network that uses Internet technologies to securely share any part of an organization's information or operational systems with its employees.
IP	Internet protocol
IP tunnel	A method of connecting two disjoint Internet Protocol (IP) networks that do not have a native routing path to each other, via a communications channel (the IP tunnel) that uses encapsulation technologies across an intermediate network.
IPTV	Internet Protocol Television
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
ISO	International Standards Organization
IV&D	Integrated Voice and Data
LAN	Local Area Network
LEMS	Law Enforcement Message System
LMR	Land Mobile Radio

Load balancing	Distributes the processing and traffic of data evenly across a network, making sure no single device is overwhelmed
Login	The process by which individual access to a computer system is controlled by identification of the user using credentials provided by the user
Low cadence AVL	Automatic vehicle location with a low polling rate, therefore lowing data usage
Management partitioning	The division of management tasks for a network between specific users
MDS	Mobile Data System
Megabits	1 megabit = 10^6 bits = 1000000bits
MLP	Message Load Profile - The configuration of electronic messages that maximizes the efficiency of the network
Message packetization	A technique whereby some of the phases that are involved in setting up a command request and data transfer are combined, making more efficient use of the network.
MIB	Management Information Base
Microwave	Frequencies between 0.3 GHz and 300 GHz.
Middleware	Computer software that connects software components or applications
MnDOT	Minnesota Department of Transportation
MNJIS	Minnesota Justice Information System
Mobile Data Computer	An in vehicle integrated computer system
Mobile radio modem	A modem used to transmit data over a voice radio system
Modem	A device that modulates an analog carrier signal to encode digital information, and also demodulates such a carrier signal to decode the transmitted information.
Modem MAC address	A Media Access Control address (MAC address) is a unique identifier assigned to most network adapters or network interface cards (NICs) by the manufacturer for identification, and used in the Media Access Control protocol sub layer. If assigned by the manufacturer, a MAC address usually encodes the manufacturer's registered identification number. It may also be known as an Ethernet Hardware Address (EHA), hardware address, adapter address, or physical address.

Modulation and air interface protocol	A set of rules governing communication between tags (transceivers) and interrogators (readers). These standards cover modulation, bit-encoding rules, anti-collision protocol, commands for reading, writing, amending and locking data, and in some cases commands to kill the tag.
MPLS	Multi-Protocol Label Switching
MSR	Message Success Rate
National Lambda Rail Network	A high-speed national computer network infrastructure in the United States that runs over optical fiber lines, and is the first transcontinental Ethernet network.
NCIC	National Crime Information Center
NEC	National Electric Code
NEMA	National Electrical Manufacturers Association
Network interface	The point of interconnection between a user terminal and a private or public network
Network Management Information Server	A computer server that collects network information in real time and uses the information to report on the status of the network
NFPA	National Fire Protection Association
NIB	Network Interface Barrier
NIEM	National Information Exchange Model
NMCS	Network Management and Control Subsystem
NMIS	Network Management Information Server
NMCS	Network Management and Control System
OET	Office of Enterprise Technology
Open-architecture platform	An operating system that enables processes residing on multiple processors and operating systems to communicate with each other seamlessly. This enables system designers and users to customize system capabilities with specific features and functionalities.
OSHA	Occupational Safety and Health Administration
OTAP	Over-The-Air-Programming
OOB	Out Of Band - Communications which occur outside of a previously established communications method or channel
OZM	Zone Manager

P25	Project 25
Packet	A formatted block of data carried by a packet mode computer network
Packet data gateway	Controls the flow of packetized data between the home packet data network and a visited packet data network
Passcode	A numerical authentication method
Platform	Hardware architecture or software framework (including application frameworks), that allows software to run. Typical platforms include a computer's architecture, operating system, programming languages and related runtime libraries or graphical user interface.
PPP	Point-to-Point Protocol - A data link protocol commonly used to establish a direct connection between two networking nodes. It can provide connection authentication, transmission encryption privacy, and compression.
POP25	A programming feature of Project 25 technology that allows subscriber radios to be accessed and updated over the air without interference with the user's ability to communicate
Project 25 (P25) or APCO-25	Refers to a suite of standards for digital radio communications for use by federal, state/province and local public safety agencies in North America to enable them to communicate with other agencies and mutual aid response teams in emergencies
Propagation	A term used to explain how radio waves behave when they are transmitted, or are propagated from one point on the earth to another. Like light waves, radio waves are affected by the phenomena of reflection, refraction, diffraction, absorption and scattering.
PSAPs	Public Safety Answering Points
QoS	Quality of Service
R-56	A set of standards and guidelines for the construction of communications sites
Redundancy	The duplication of critical components of a system with the intention of increasing reliability of the system, usually in the case of a backup or fail-safe
Repeater	An electronic device that receives a signal and retransmits it at a higher level and/or higher power, or onto the other side of an obstruction
RF	Radio Frequency
RFC	Request For Comments
RFP	Request For Proposal

RMS	Records Management Systems
Roam	The ability of a mobile communications unit to travel from one coverage area to another with continued connectivity or communication
ROM	Rough Order-of-Magnitude
Router	A networking device whose software and hardware are usually tailored to the tasks of routing and forwarding information
RS-232	A standard for serial binary data signals connecting between a DTE (Data Terminal Equipment) and a DCE (Data Circuit-terminating Equipment). It is commonly used in computer serial ports.
SAFECOM	A communications program of the Department of Homeland Security. SAFECOM provides research, development, testing and evaluation, guidance, tools, and templates on interoperable communications-related issues to local, tribal, state, and federal emergency response agencies.
Sampling error allowance	The number of samples which may be corrupted due to the improper timing of the sampling of target data
SCIP	Statewide Communications Interoperability Plan
SEP	Spherical Error Probability - A probability that a percentage of three-dimension measurements will lie within a sphere of given radius, with the sphere centered at truth or mean of the measurements
Server	Carrier-grade computing platform for communications networks
SIEC	State Interoperability Executive Committee
Single-thread	In computer programming a thread of execution results from a fork of a computer program into two or more concurrently running tasks. A single-thread execution does not fork and performs only a single task at a time.
SNMP	Simple Network Management Protocol
Spectrum	Any signal that can be decomposed into frequency components
SRB	State Radio Board
Surge protection	An appliance designed to protect electrical devices from voltage spikes. A surge protector attempts to regulate the voltage supplied to an electric device by either blocking or by shorting to ground voltages above a safe threshold.
T1	Signaling scheme standard in telecommunications in North America and Japan to transmit voice and data between devices
TCP	Transmission Control Protocol

TD-CDMA	Time Division Code Division Multiple Access - A channel access method that uses synchronous spread spectrum across multiple time slots
Telecom	Assisted communication over a distance (as by telephone)
TIA	Telecommunications Industry Association
Topography	The study or description of the surface shape and features of Earth or an area, especially their depiction in maps
Topology	The study of qualitative properties of certain objects (called topological spaces) that are invariant under certain kind of transformations
Transmission Control Protocol (TCP)	One of the core protocols of the Internet Protocol Suite, TCP was one of the two original components. The entire suite is commonly referred to as TCP/IP. Whereas IP handles lower-level transmissions from computer to computer as a message makes its way across the Internet, TCP operates at a higher level, concerned only with the two end systems, for example, a Web browser and a Web server. In particular, TCP provides reliable, ordered delivery of a stream of bytes from a program on one computer to another program on another computer. Besides the Web, other common applications of TCP include e-mail and file transfer. Among its other management tasks, TCP controls message size, the rate at which messages are exchanged, and network traffic congestion.
Transparent	Features or components that interoperate in a manner such that any disparity is not detectable to the user
Trunked	A complex type of computer-controlled radio system that uses a few channels (the actual frequencies), and can have virtually unlimited talkgroups. The control channel computer sends packets of data to enable one talkgroup to talk together, regardless of frequency. The primary purpose of this type of system is efficiency; many people can carry on many conversations over only a few distinct frequencies. Trunking is used by many government entities to provide two-way communication for fire departments, police and other municipal services, who all share spectrum allocated to a city, county, or other entity.
TSB	Telecommunications Systems Bulletin
UCS	User Configuration Subsystem
UCS or UCM	User Configuration Subsystem/User Configuration Management - The User Configuration Manager report window allows the user to generate data summaries to view information from the database in a Web browser or to export the information as a file
UDP	User Datagram Protocol

UHF	A frequency range with a short antenna(band) of electromagnetic waves with frequencies between 300 MHz and 3 GHz
UL	Underwriters Laboratory
UPS	Uninterruptible Power Supply
USB	Universal Serial Bus
VHF	Very High Frequency - The radio frequency range from 30 MHz to 300 MHz.
VLAN	Virtual Local Area Network
VoIP	Voice over Internet Protocol is a general term for a family of transmission technologies for delivery of voice communications over IP networks such as the Internet or other packet-switched networks
VPN	Virtual Private Network - a computer network in which some of the links between nodes are carried by open connections or virtual circuits in some larger networks, such as the Internet, as opposed to running across a single private network
WAAS	Wide Area Augmentation System
WAN	Wide Area Network
WDFS	Wireless Data Feasibility Study
WDS	Wireless Data System
Wide band data technology	Technology that enables live wide-area wireless mobile video, voice and Intranet/Internet data transmissions for public-safety applications
WiFi	A trademark of the Wi-Fi Alliance for certified products based on the IEEE 802.11 standards. This certification warrants interoperability between different wireless devices
WiMAX	Worldwide Interoperability for Microwave Access, is a telecommunications technology that provides wireless transmission of data using a variety of transmission modes, from point-to-multipoint links to portable and fully mobile internet access
Zone controller	A master computer that keeps track of every radio in use, what site it is using (from the zone controller perspective, each entire simulcast sub-system (no matter how many remote sites it has) is called a site and treated as one site), and what talk group that radio is switched to.
Zone Manager (OZM)	Operational software that manages a zone and the signaling systems in that zone, responsible for database and connection management functions in the zone

Appendix B – Index

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Appendix C - Wireless Data Technology and Commercial Services Assessment Report (Deliverable 3)

Appendix D – FCC D-Block Report and Assessment (Deliverable 4)

Minnesota Public Safety Interoperable Wireless Data Feasibility Study

Deliverable #3: Wireless Data Technology and Commercial Services Assessment Report

March 20, 2009

"Unleashing the Power of Technology"
Federal Engineering®

Federal Engineering, Inc.
10600 Arrowhead Dr, Suite 160
Fairfax, VA 22030
703-359-8200

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1.0 Introduction

1.1 Purpose

This report constitutes the deliverable for Task 3 of the Minnesota DPS Interoperable Wireless Data Feasibility Study. The report details each of the ten technologies identified as potential candidates for a statewide mobile data system for Minnesota. The information contained in the report will assist the state of Minnesota in selecting the most favorable mobile data technology to satisfy its requirements.

1.2 Overview of this report

Section 1 provides an overview of the Minnesota Public Safety Interoperability Wireless Data Feasibility Study project. It also provides a description of actions undertaken by the state to improve public safety voice and data communications. Section 2 contains a listing of potential public safety mobile data applications and the typical data transmission rates these applications require. Section 3 addresses the technologies suitable for creating a mobile data system dedicated to the public safety community. The section provides descriptions of the technologies and a discussion of the strengths and weaknesses of each. Section 4 discusses commercial services that may be applicable to provide wireless data to governmental services. Sections 3 and 4 also identify the set of applications that each technology or commercial service can support. Section 5 provides a summary and comparison of the technologies.

1.3 Current public safety communications in Minnesota

The state of Minnesota implementation of a statewide public safety radio communications system is known as the Allied Radio Matrix for Emergency Response (ARMER). It is a 700/800 megahertz (MHz) trunked communication system using the Project 25 technology (see Section 3.1.1) for voice communications. The backbone for the ARMER system was initially constructed in 2001 in nine counties (Anoka, Carver, Chisago, Dakota, Hennepin, Isanti, Ramsey, Scott, and Washington) in the Minneapolis/St. Paul metropolitan area. The cities of Minneapolis and Richfield and the counties of Carver and Hennepin added infrastructure to provide additional capacity and coverage for local agencies. Following the initial implementation, the counties of Anoka, Ramsey, Dakota, and Washington integrated their local public safety communication needs into the ARMER system. Scott County plans to integrate their public safety communications on the ARMER network in 2009.

In 2005, the Minnesota legislature provided funding for the continued implementation of the ARMER system into 23 counties of central and southeastern Minnesota. That

implementation is currently underway and will be completed in the second half of the year in 2009. In 2007, the Legislature authorized implementation in the remaining 55 counties of the state. The Minnesota Department of Transportation (MnDOT) has completed the detail design for that implementation with completion of the statewide implementation anticipated by the end of 2012. The ARMER backbone network consists of radio sites and microwave links (also known as "backhaul"), and these infrastructure components can be used by systems other than the ARMER voice radio system.

In 2007, the Minnesota Department of Public Safety (DPS), Division of Emergency Communication Networks (ECN) coordinated the development of a Statewide Communication Interoperability Plan (SCIP) consistent with the SAFECOM program criteria adopted by the U.S. Department of Homeland Security (DHS) and U.S. Department of Commerce (DOC). SAFECOM is a public safety communication interoperability program operated by DHS and information on that program and the criteria can found at http://www.safecomprogram.gov/SAFECOM/. As part of the SCIP, Minnesota articulated its strategy for the implementation of interoperable public safety data. A review of existing public safety data networks demonstrated the following three approaches:

- Regional Enhancements – The Metropolitan Emergency Services Board (subordinate regional radio board covering the metropolitan area) is working with Hennepin County to implement a region-wide wireless public safety data network over the ARMER system in the metropolitan area, using the ARMER backbone. Hennepin County was the recipient of a Community Oriented Policing Services (COPS) grant, which provided funding for this implementation as a regional enhancement to the ARMER system. The radio component of the data network is distinctly separate from the radio component of the voice network, but they are compatible systems that might be integrated into one voice and data network at some future point.

- Minnesota State Patrol Data System – The Minnesota State Patrol has a mobile data system across major portions of the state, utilizing towers and microwave capacity that are or will be part of the ARMER infrastructure. As it exists, that system is not capable of providing significant wireless IP (Internet Protocol) connectivity for a broad category of public safety users, but may provide a foundation for the evolution of wireless data as part of Minnesota's broader wireless interoperable data initiatives to strengthen information sharing and collaboration capabilities. The funding for the ARMER system build-out requires a study of how the transport of data can be integrated into the ARMER system design.

- Local Data Systems – A number of counties have implemented local wireless data systems and in some cases, those local data systems have been implemented on a regional or multiple county basis.

- In addition to these approaches, a number of law enforcement agencies in the Minneapolis/St. Paul metropolitan area use commercial wireless data networks provided by cellular telecommunication providers.

The DPS has coordinated a comprehensive program for the integration and sharing of public safety databases throughout the state. The CriMNet program operated by the Bureau of Criminal Apprehension (BCA) seeks to broadly coordinate the integration of information between local, regional, and state government agencies and to make that information available to public safety officials when and where it is needed. Developing a strategy for the provision of wireless mobile data across the state would clearly support the objectives of the CriMNet program by providing broader access to public safety data to public safety officials.

The Minnesota Office of Enterprise Technology (OET) provides a secure intranet environment for the state's public safety community of agencies. This statewide network has a 15-year history of leveraging private sector telecommunications facilities and services to deliver a common, secure, reliable, and high-capacity IP network services to over 400 locations within the state's public safety community. This includes all of Minnesota's 87 county government centers including county sheriff offices, numerous city police offices, several tribal governments, departments of Public Safety, Health, Corrections, Transportation, Natural Resources, Pollution Control, Agriculture, Military Affairs, and State Courts, the Office of Governor, and the Legislature.

The OET architecture provides Multi-Protocol Label Switching (MPLS) IP network services using a leased-line high-speed backbone network that consists of transmission capacity procured from telephone companies, cable companies, and utility companies. This network has been in service since 1993. The backbone network consists of a mesh of environmentally hardened network hubs and regional aggregation points. These hubs aggregate IP traffic locally and regionally and route traffic to its destination.

Currently, the network has 30 hubs and aggregation points interconnected by OC3, OC12, 100Mpbs, and Gigabit Ethernet transmission facilities. The converged IP voice, video, and data network deploys Quality of Service (QoS) techniques to guarantee delivery of time-sensitive and critical network applications. It provides access to the

Internet, Internet2, National Lambda Rail Network[1], and several private provider networks.

Minnesota has been monitoring the progress of the Federal Communication Commissioner (FCC) 700 MHz D-Block auction and the Public Safety Spectrum Trust. Based upon the results of the first auction and the current outlook for the continued development of a nationwide public safety data network in the 700 MHz spectrum, the state should:

- perform a broader assessment of the current state of the wireless data technology,
- monitor the development of standards necessary to assure interoperability, and,
- investigate strategies and alternatives that might be adopted by the state and local governments to provide wireless data.

In 2004, the Minnesota Legislature created the Statewide Radio Board (SRB) to provide operational and technical oversight for the implementation of the ARMER system. The Legislature designated the SRB as the State Interoperability Executive Committee (SIEC) and expanded its role to provide broader coordination of public safety communication throughout the state. In addition to the SRB, seven Regional Radio Boards (RRBs) have been established throughout the state to support regional participation and planning on public safety communication issues. This governance structure provides the basis for statewide and regional planning necessary for the development of various approaches to public safety data.

[1] National Lambda Rail Network is a unique nationwide network infrastructure that is owned and controlled by the nation's research community to support experimental and production networks, foster networking research, promote next-generation applications, and facilitate interconnectivity among high-performance research and education networks. See www.nlr.net/about/

2.0 Mobile data applications

This section contains a listing of potential Minnesota public safety mobile data applications. Subsequent sections of this report address the technologies and commercial services and identify the set of applications that each can support. Each technology or commercial service discussed provides a maximum throughput rate and each public safety application requires a certain throughput rate, measured in bits per seconds (bps). In this section, we have classified potential public safety applications into tiers according to the throughput required for the application to operate satisfactorily.

We recommend that Minnesota determine the highest application tier required in each specific area or region of Minnesota to help determine which technology, or combination of technologies, would provide the best mobile data solution for the state.

Tier 1 - “Text” applications (Up to 19,200 bps, or 19.2 kbps)

- Messaging
- Dispatch (CAD)
- Text messaging
- Query databases
  - Driver’s license
  - License plates
  - Warrants
- Low cadence automatic vehicle location (AVL)

Tier 2 - “Still Image” applications (Up to 96 kbps, 25 kHz channels)

- Includes Tier 1
- Field reporting
- Still image transfer
  - Mug shots
- High cadence AVL
- Fingerprints (Inbound only)
- Intranet

Tier 3 - “Browser” application (Up to 230 kbps, 50 kHz channels)

- Includes Tiers 1 and 2
- Internet access
- Images (transmit and receive)
- Video (low speed)

Tier 4 - “Multimedia” applications (megabits (millions of bits per second, or Mbps))

- Includes Tiers 1-3
- Desktop computer applications
- Video (full motion)
- VoIP (voice over IP)
- IPTV (internet protocol television)
- Multimedia

3.0 Wireless data technology assessments

3.1 Low speed (integrated voice and data)

Integrated voice and data ("IV&D") systems provide low speed mobile data solutions. These systems will only support Tier 1 and, at best, some Tier 2 applications. If this is all an area or region requires, and the area or region already has a voice infrastructure in place that can support a mobile data overlay, then an integrated voice and data system would be a viable, cost-effective solution.

3.1.1 APCO Project 25 (P25)

3.1.1.1 Overview

The Association of Public Safety Communications Officials (APCO) Project 25 (P25) is an open digital radio standard developed for public safety Land Mobile Radio (LMR) systems. The primary purpose of the standard is to promote interoperability among various radio system infrastructure and subscriber (user radios) manufacturers. The P25 standard developed primarily for voice interoperability provides standardized data formats and protocols. The data capability is integrated with the voice system and only requires the addition of some data processing equipment and the user terminal to be functional in any P25 system.

P25 technology is available from multiple manufacturers in various frequency bands allowing the use of various manufacturers' user radios to interface with any other manufacturer's P25 infrastructure. The technology requires a channel of 12.5 kHz bandwidth. P25 Phase I utilizes frequency division multiple access (FDMA) for voice, data, and network control. P25 Phase II is backwards compatible to Phase I and accommodates provisions for time division multiple access (TDMA) allowing two talk paths within a single 12.5 kHz channel, thus doubling the amount of voice or data traffic over a single 12.5 kHz channel.

Manufacturer	Various
Protocol	Non-proprietary APCO Project 25 (P25) open standard. Phase I: FDMA Phase II: TDMA and FDMA

Frequency band availability	Licensed Spectrum: VHF, UHF, 700/800 MHz
Data rates by bandwidth	9.6 kbps at 12.5 kHz
Coverage design	Equivalent to Project 25 voice; local or wide area; single site, multi-site, multi-cast, simulcast.
Integrated voice & data capable	Yes
Backhaul interface protocol/physical port	**Phase I:** DS0 circuit based; RJ45 **Phase II:** Institute of Electrical and Electronics Engineers (IEEE) 802.3 (Internet Control Message Protocol (ICMP), Internet Group Management Protocol (IGMP), Transmission Control Protocol (TCP), User Datagram Protocol (UDP); Ethernet 10/100 BaseT
Backhaul capacity requirements	2x64 kbps per channel
Built-in GPS receiver	Dependent upon manufacturer
Modem peripheral interface protocol/physical port	**Phase I:** RS-232; DB9 **Phase II:** Serial line IP (SLIP) or Point-to-Point (PTP); Ethernet 10/100 BaseT or RS-232 or USB 2.0.

3.1.1.2 Data transport mechanism(s)

P25 uses standard IP protocols within the P25 infrastructure network; the IP packets are encapsulated within the Common Air Interface (CAI) over the air between the infrastructure and the user radio units.

There are three areas of data transport: over-the-air, peripheral interface (interface between the mobile data terminal (MDT), and the radio modem) and backhaul interface. P25 radio systems employ a non-proprietary CAI developed by the standards committee to ensure interoperability between various manufacturers' user radio radios and P25 system infrastructure for the over-the-air interface. The backhaul interface

connects the base stations at the sites to the console and the network as a whole. The backhaul interface for P25 is IP-based. The physical interconnection between the base stations and the network is manufacturer dependent with some manufacturers connecting the base stations and network equipment with a T1 line. The peripheral interface is the connection between the radios and any laptops or other devices in the vehicle. The peripheral interface also uses standard IP protocols.

3.1.1.3 Coverage

The coverage of the mobile data portion of a P25 system matches that of the voice P25 radio system. Coverage and capacity are designed to meet agency voice requirements throughout the service area; data capacity requirements must fit within the voice design. General coverage design parameters are dependent upon the frequency band employed, physical terrain limitations, antenna height above average terrain, and transmit power and receive sensitivity of the mobile and base station radio.

If the state chooses to implement mobile data over the ARMER network, the state should request Motorola to run coverage maps for inbound and outbound data for each of the sites. Although the claim for P25 is that the mobile data's coverage matches that of voice, the state should understand that the potential exists for more errors at the outer edges of a site's coverage contour. The mobile data coverage maps should include this information.

3.1.1.4 Applications

Any applications in Tier 1 may be effectively deployed on this infrastructure. Possible applications may include, but are not limited to, the following:

- Messaging
- Dispatch (CAD)
- Text messaging
- Query Databases
- Driver's license
- License plates
- Warrants
- Low cadence AVL

Mid to high bandwidth applications like streaming video are not recommended on a P25 system.

3.1.1.5 Equipment

The P25 mobile radio acts as a data modem and interfaces to a laptop computer or other MDT device in the vehicle via an IP session connection. A single mobile radio can provide both voice and data conversations. If large amounts of data transactions are anticipated, however, then a dedicated radio may be recommended for data use.

3.1.1.6 Implementation

Implementation of a P25 radio system is similar to any other private radio system; it is dependent upon the agency's budget and staffing constraints. The full-scale implementation strategy includes FCC license acquisition or modification (if frequencies do not already exist), radio site acquisition, modification or design and procurement of the backhaul network, and design and procurement of the mobile data radio system. P25 radio systems are implemented for their voice design, with mobile data considered as a secondary system that is available if necessary.

The state of Minnesota is currently implementing the ARMER P25 system. If the state does not require data applications above Tier 1, adding mobile data to the ARMER system would be a viable solution. Many of the existing P25 user radios already have mobile data capabilities. The state or end user would need to purchase mobile data terminals and application software. The state may also have to add some data infrastructure components.

The P25 standards committee is currently developing the specifications for P25 Phase II with an expected completion date in 2009. Equipment for Phase II P25 would most likely be available in late 2010. Agencies deploying Phase II products should verify that they meet the final open standards requirements.

A deployment strategy for adding mobile data to the ARMER system may include the following steps:

1. Develop user-specific coverage and capacity requirements.
2. Develop a conceptual design for the mobile data system.
3. Update the radio site infrastructure as necessary.
4. Install and test the backhaul network, the mobile data radio equipment, and software.
5. Perform preliminary testing of user equipment and mobile data applications.
6. Complete acceptance testing for the voice and mobile data radio system.
7. Perform system cutover.
8. Install and test the user equipment.

The schedule/timeframe depends upon the applications selected and the vendors' implementation and cutover strategies (phased regional deployments or a single wide area deployment).

Mobile data on a P25 radio system may be implemented on a local, regional, or statewide level. Regions may be deployed one-by-one and connected together using a phased approach in order to accomplish a statewide implementation.

User assessments

The following agencies employ standards-based P25 radio systems:

Agency	**Frequency band/channel bandwidth**	**Approximate number of tower sites**
State of Wyoming "WyoLink" Department of Transportation	VHF at 25 kHz	50 sites
Alaska Department of Administration	VHF at 25 kHz	80 sites
State of Kansas Department of Transportation	800 MHz at 25 kHz	82 sites

The following tables provide contact information and/or interview information for these systems

Technology	P25 IV&D
Agency	State of Wyoming DOT ("WyoLink")
Contact name	Bob Symons
Contact title	Administrative Support
Contact phone/e-mail	307-777-5065; bsymon@wyo.gov
System description	
Wide area VHF P25 IV&D System with two areas using 800 MHz P25 tied in; expect total of over 50 sites statewide; still in the process of adding sites due to delays in site leasing/acquisition process (about 40 sites are on the air today). Approximately 100 agencies have signed membership agreements to use the system - "build it and they will come." Users and dispatch centers are being added into the system as the system becomes available in the different areas of the state. Approximately 200-300 radios are currently on the system. Data is being tested for AVL use and they expect to use it for sending data to highway signs.	
Recommendation to Minnesota	

System meets expectations; portable coverage is better than expected. Please visit WyoLink website at http://wyolink.state.wy.us/ for all documentation, current system status, and contact information.

Technology	P25 IV&D
Agency	Alaska Department of Administration
Contact name	Jim Kohler
Contact title	ALMR Program Manager
Contact phone/e-mail	907-269-4744; jim.kohler@alaska.gov
No interview was conducted with the Alaska Department of Administration.	

Technology	P25 IV&D
Agency	State of Kansas DOT
Contact name	Edwin Geer
Contact title	Communication System Administrator
Contact phone/e-mail	785-296-5948; geer@ksdot.org
System description	
800 MHz P25 IV&D system; total of 80 sites of which about 40 sites are conventional analog that have not yet been upgraded to trunking due to funding. P25 system works well and meets expectations. Total of 6000 radios. Motorola Premier MDC application is used for mobile data and seems to perform as expected. There are plans to add other data applications, more towards public works and transit applications.	
Recommendation to Minnesota	
State of Kansas DOT recommends P25 IV&D; requests that any agencies considering P25 to understand the expectations and limitations of the data throughput. Recommend a thorough review of mobile data applications in conjunction with the technology being acquired. For additional discussion, in particular to mobile data implementation and applications, contact: Captain Randy Moon, Communications Commander, 785-827-3065	

3.1.1.7 Expandability/scalability

P25 radio systems are expandable and scalable to the extent of the agency's needs. Agencies can install additional radio sites whenever and wherever needed for additional coverage; additional channels may be added to increase system capacity. A private radio system is inherently able to provide required coverage and capacity as needed by the agency.

Backhaul network connectivity must be available and either have available capacity or the ability to upgrade in order to meet the agency's growth requirements. Standardized IEEE 802.3 Ethernet 10/100 BaseT protocols and interfaces allow interconnection from the radio base stations via the agency's network. Microwave, fiber, or leased line systems must either have capacity or be able to upgrade to meet future capacity needs.

3.1.1.8 Backhaul

The P25 platform uses a non-proprietary IP open-architecture utilizing standardized IEEE 802.3 Ethernet 10/100 BaseT protocols in a LAN environment. Commercial off-the-shelf (COTS) routers and network switches are employed in the network design for ease of training and maintenance. Any backhaul architecture (microwave, fiber, or leased lines) capable of transporting IP traffic may be used for the P25 system.

3.1.1.9 Technology comparison

The P25 platform is optimized for voice and allows mobile data to utilize the same infrastructure. P25 radio systems have been installed in various configurations, from single site local area to statewide multi-site wide area, with each configuration optimized for different user types such as public safety, public works, utilities, and transportation agencies. Additionally, P25-capable equipment is available in VHF, UHF, and 700/800 MHz frequency bands.

As mentioned, the backhaul interface of this system is an IP standards-based IEEE 802.3 protocol and Ethernet 10/100 BaseT interconnection. An IP standards-based backhaul not only allows for use of commercial-off-the-shelf equipment, but also provides a distributed architecture, increasing system redundancy and reducing the possibility of single point failures. This distributes the system control and intelligence throughout the system instead of having master control points that may become points of failure.

Below are strengths and weaknesses of the P25 platform as compared to other technologies, with respect to mobile data:

Strengths:

- Voice and data are available over the same infrastructure.
- Minnesota's ARMER system uses this technology.
- Radio sites can be deployed where coverage is required.
- P25 is available in several public safety frequency bands.
- The agency owns and controls the system.
- There are no recurring monthly costs other than operations and maintenance.

Weaknesses:

- System design is specifically for voice, with mobile data as a secondary overlay.
- Data standards are not yet finalized for Phase II.
- There is a high initial capital outlay for infrastructure and user equipment procurement.
- Appropriate and exclusive spectrum needs licensure.
- It requires real estate site leases and/or site acquisition,

3.1.1.10 Standards adaptability

P25 is a non-proprietary standard created for equipment and system interoperability. The non-proprietary, over-the-air Common Air Interface (CAI) between the infrastructure and the user units is part of the P25 standard that defines both the voice and the mobile data protocol for a P25 system. The P25 Phase II standard will address system level interfaces between agency systems while also addressing the FCC's future 6.25 kHz channel equivalency requirements by using TDMA. Backhaul and peripheral equipment interfaces are also standards-based.

A P25 system provides a basis for achieving higher levels on the Department of Homeland Security's (DHS's) SAFECOM Interoperability Continuum, thus providing higher levels of interoperability among all system users.

3.1.1.11 Costs associated with build-out

Up-front capital costs are required for deploying P25 site infrastructure, backhaul network, mobile data equipment, and user radio modems. Once a system is deployed and operational, there are no recurring fees other than regular operations and maintenance.

Costs associated with P25 systems should be slightly lower than M/A-COM OpenSky systems. P25 systems are not comparable to CalAmp's Dataradio or Motorola's HPD system.

3.1.1.12 Other relevant attributes/considerations

Overall, P25 radio systems are primarily installed for voice with a minimal capability data overlay. P25 systems provide text messaging and basic queries to field units throughout the same coverage area as the voice system, ensuring coverage reliability where it is needed. It is not recommended that a P25 system be implemented for its data component. Rather, P25 systems implemented as an integrated voice and data system provide a reliable means of low-speed data.

The bandwidth requirements of desired applications will drive the infrastructure being implemented. A P25 system employs low-data speed and is restricted to Tier 1 applications. Federal Engineering (***FE)*** does not recommend implementation of a P25 system for its data capabilities. Users can take advantage of the coverage reliability of a P25 voice system to ensure text and queries are reliably delivered throughout the agency's service area.

As with all private radio systems, of primary concern is the spectrum available for use. The frequency band and channel bandwidth will determine the available product line, and its associated data speeds. Additionally, it is necessary to determine the applications intended for use on the mobile data system.

3.1.2 M/A-COM OpenSky

3.1.2.1 Overview

OpenSky is a proprietary platform developed and manufactured by Tyco Electronics Corporation, M/A-COM Division, for land mobile radio services. The OpenSky platform uses time division multiple access (TDMA) to carry up to four voice conversations on one 25 kHz channel and is therefore compliant with anticipated 6.25 kHz FCC equivalency requirements.

The system is capable of transporting data on a voice channel, allowing both voice and data communications to be provided by a single OpenSky user radio. If heavy system data usage is expected, dedicated data channels should be allocated. The aggregate data rate per 25 kHz channel is 19,200 bps; however, only three-fourths of the channel can be applied to data services at any one time.

Manufacturer	M/A-COM, a division of Tyco Electronics
Protocol	Proprietary TDMA
Frequency band availability	Licensed spectrum: 700/800, 900 MHz
Data rates by bandwidth	up to 19.2 kbps at 25 kHz
Coverage design	Equivalent to voice; local or wide area; single site, multi-site, multi-cast.
Integrated voice & data capable	Yes
Backhaul interface protocol/physical port	IEEE 802.3 (ICMP, IGMP, TCP, UDP); Ethernet 10/100 BaseT
Backhaul capacity requirements	2x64 kbps per channel
Built-in GPS receiver	Optional
Modem peripheral interface protocol/physical port	Serial line IP (SLIP) or point-to-point (PTP); RS-232 DB9

3.1.2.2 Data transport mechanism(s)

M/A-COM OpenSky uses standard IP protocols within the infrastructure network but employs a proprietary over-the-air protocol. There are three areas of data transport: over-the-air, peripheral interface, and backhaul interface. The backhaul interface connects the base stations to the console and the network as a whole. The backhaul interface is IP-based and is capable of connecting directly to an agency's local area network (LAN). The peripheral interface is the connection between the radios and any laptops or other devices in the vehicle. The peripheral interface uses standard IP protocols and allows the transport of data over the same infrastructure as voice.

3.1.2.3 Coverage

The coverage design of the data system matches that of the voice system and is specific to the public safety agency's integrated voice and data requirements. General coverage design parameters are dependent upon a variety of factors. These factors include the frequency band employed, physical terrain limitations, antenna height above average terrain, and transmit power and receive sensitivity of the mobile and base station radios.

3.1.2.4 Applications

Applications suitable for a low speed (up to 19.2 kbps) environment may operate on this infrastructure. Possible applications from Tier 1 may include:

- Messaging
- Dispatch (CAD)
- Text messaging
- Query databases
- Driver's license
- License plates
- Warrants
- Low cadence AVL

High bandwidth applications like streaming video are not recommended for OpenSky.

3.1.2.5 Equipment

The OpenSky equipment uses standardized IEEE 802.3 Ethernet 10/100 BaseT protocols and interfaces to connect the dispatch/control center with the radio sites. Standardized IEEE 802.3 Ethernet 10/100 BaseT protocols and interfaces are utilized between the modem and peripheral devices within the vehicle. It uses proprietary TDMA data over-the-air from the modems to the base stations.

To send and receive mobile data transactions, an OpenSky mobile radio acts as a modem and interfaces to a laptop computer or other MDT device in the vehicle via an IP session connection. A single mobile radio can provide both voice and data conversations, however if a large amount of data transactions are anticipated, then a dedicated radio may be recommended for data use.

3.1.2.6 Implementation

Implementation of an OpenSky data system is similar to any other private radio network; it is dependent upon the agency's budget and staffing constraints. The full-scale implementation strategy includes the FCC license acquisition or modification (if frequencies do not already exist), radio site acquisition, modification or design and procurement of the backhaul network, and design and procurement of the mobile data radio system.

Deployment strategy recommendations:

1. Develop user-specific coverage and capacity requirements.
2. Develop a conceptual design for the voice and mobile data system.
3. Determine the site locations and channel allocations needed to support the network.
4. Acquire the necessary real estate by site lease and/or site acquisition.
5. Acquire spectrum based on site acquisition and capacity requirements
6. Upgrade the backhaul network if necessary; prepare and release a request for proposal (RFP) if necessary.
7. Prepare and release a request for proposal (RFP) for the procurement of a voice and mobile data radio system.
8. Update the radio site infrastructure as necessary.
9. Install and test the backhaul network and mobile data radio equipment.
10. Perform preliminary testing of user equipment and mobile data applications.
11. Complete acceptance testing for the voice and mobile data radio system.
12. Perform system cutover, installation, and testing of subscriber equipment.

The schedule/timeframe is dependent upon the availability of radio sites and frequencies, number of radio sites, and cutover strategy (phased regional deployments or a single wide area deployment). It is also dependent upon the applications chosen and the application vendor's implementation and deployment schedule.

The OpenSky radio system may be implemented on a local, regional, or statewide level. Regions may be deployed one at a time and connected together using a phased approach in order to accomplish a statewide implementation.

3.1.2.7 User assessment

The following agencies employ M/A-COM OpenSky systems:

Agency	**Frequency band/channel bandwidth**	**Approximate number of tower sites**
Commonwealth of Pennsylvania	800 MHz	500 (mixture of high and low profile sites)
Lincoln Police Department	800 MHz	? (data only)

Contact information and/or interview information are provided in the following tables.

Technology	M/A-COM OpenSky
Agency	Commonwealth of Pennsylvania
Contact name	Charles Brennan
Contact title	Deputy Secretary of Administration
Contact phone/e-mail	717-772-8006; chabrennan@state.pa.us
System description	
800 MHz OpenSky, approximately 13,000 voice users and 1,300 mobile data users. Seventeen (17) state agencies are using the system with various types of users including PennDOT, Pennsylvania State Police, Capital Police, Attorney General, and others. Mobile data operates well for AVL, state database queries, CAD, low resolution photos, and text-based applications. System is actually a data system providing voice over internet protocol (VOIP) for voice communications. The system continues to be updated with latest versions. Excellent data performance for its throughput.	
Recommendation to Minnesota	
OpenSky works well for expected data throughput of 19.2 kbps. Would not recommend a phased regional build out for system implementation. Highly recommend visiting or talking directly to other state agencies to gather “lessons learned” advice for a statewide build-out.	

Technology	M/A-COM OpenSky (data) and EDACS (voice)
Agency	Lincoln Police Department, Nebraska
Contact name	Todd Beam
Contact title	Sergeant of Technical Resources
Contact phone/e-mail	402-441-6012; contact692@earthlink.net
System description	
800 MHz EDACS system has been augmented with OpenSky to provide mobile data services to 130 vehicles. No plans for future expansion at this time. Data throughput is as expected for 19.2 kbps. Coverage meets requirements. Unsure if they will use OpenSky for voice when they migrate from EDACS.	
Recommendation to Minnesota	
Recommend use of OpenSky to any agency, as long as applications will work within 19.2 kbps constraint.	

3.1.2.8 Expandability/scalability

The OpenSky systems are expandable and scalable to the extent of agency's needs. Radio sites may be added whenever and wherever the agency requires additional coverage; additional channels may be added to the system to meet any increased capacity requirements. A private mobile data system is inherently able to provide the coverage and capacity, where and when the agency requires it.

Backhaul network connectivity must be available and either have available capacity or the ability to upgrade in order to meet the agency's growth requirements. Standardized IEEE 802.3 Ethernet 10/100 BaseT protocols and interfaces allow interconnection from the radio base stations via the agency's LAN. Microwave or leased line systems must either have capacity or be able to upgrade to meet future capacity needs.

3.1.2.9 Backhaul requirements

The OpenSky infrastructure equipment uses a non-proprietary IP open-architecture utilizing standardized IEEE 802.3 Ethernet 10/100 BaseT protocols in a LAN environment. Commercial off-the-shelf routers and network switches are employed in the network design for ease of training and maintenance.

3.1.2.10 Technology comparison

M/A-COM's OpenSky platform is designed as an integrated voice and data environment. As with other private two-way radio systems, OpenSky systems are optimized for voice with a mobile data overlay which uses the same infrastructure and/or functionality. OpenSky systems have been installed in various configurations (single site local area) and statewide (multi-site wide area) optimized for different user types including public safety, public works, utilities, and transportation agencies.

The backhaul and peripheral device wireline interface of this system is an IP standards-based IEEE 802.3 protocol and Ethernet 10/100 BaseT interconnection. An IP standards-based backhaul not only allows for use of commercial-off-the-shelf equipment, but also provides a distributed architecture, increasing system redundancy and reducing the possibility of single point failures.

Below are strengths and weaknesses of the OpenSky radio platform as compared to other technologies:

Strengths:

- System is designed for integrated voice and data.
- Radio sites may be deployed where the coverage is required.
- Capacity can be provided where it is required.
- The system has dedicated throughput capabilities.
- There are no recurring monthly costs other than operations and maintenance.

Weaknesses:

- Protocol is not yet mature.
- There is a high capital outlay due to infrastructure and user radio procurement.
- Appropriate and exclusive spectrum needs licensure.
- It requires real estate site leases and/or site acquisition.

3.1.2.11 Standards adaptability

Although M/A-COM's OpenSky over-the-air protocol is proprietary, their backhaul and peripheral equipment interfaces adhere to open standards. A non-proprietary backhaul allows for interface into various agency systems, meeting Department of Homeland Security (DHS) interoperability requirements.

OpenSky adheres to standards defined by IEEE 802.3 for both backhaul and peripheral interconnectivity.

3.1.2.12 Costs associated with build-out

Capital outlay costs are associated with deploying this technology for the site infrastructure, backhaul network, mobile data equipment, and user radio modems. There are no recurring fees other than regular operations and maintenance.

Overall, an OpenSky system is generally a higher cost solution than a P25 solution. Motorola HPD or CalAmp's Dataradio systems are not comparable since they are primarily installed for data only use and not for integrated voice and data.

3.1.2.13 Other relevant attributes and considerations

The bandwidth requirements of desired applications will drive the infrastructure being implemented. An OpenSky system employs low-data speed and can carry Tier 1 and possibly some Tier 2 applications; it is not capable of broadband type applications like full motion video or true internet connectivity. Federal Engineering (***FE)*** does not recommended the implementation of an OpenSky system for its data capabilities, but rather to take advantage of the coverage reliability of the OpenSky voice system to ensure text and queries delivery throughout the agency's service area.

As with all private radio systems, of primary concern is the spectrum available for use. Additionally, it is necessary to determine the applications intended for use on the mobile data system.

3.2 High speed (VHF/UHF/700/800/900 MHz stand-alone data)

High speed mobile data systems will support Tier 1 and Tier 2 applications. These systems are "stand-alone" in that they do not require a voice (or other) infrastructure to support operation and are not IV&D.

3.2.1 Motorola High Performance Data (HPD)

3.2.1.1 Overview

Motorola's High Performance Data (HPD) is a technology developed specifically for a mobile data environment. HPD provides mid-tier level data throughput rates within existing 25 kHz channel bandwidth environments. The HPD system can act as a standalone dedicated data network or be overlayed onto a land mobile voice network, including a Motorola ASTRO 25 (P25) voice network.

HPD can provide up to 96 kbps of data over a wide area network. It operates in both the 700 and 800 MHz spectrum utilizing standard 25 kHz channel spacing. It is based on open standards (such as IP and TCP) to ensure ongoing compatibility with current and future equipment and software. The over-the-air protocol, however, is proprietary.

HPD has a future migration path to Motorola's next generation data system, High Speed Data (HSD) with data rates up to 230 kbps. HSD, however, requires 50 kHz channels to support the increased data rate. Motorola is currently awaiting the outcome of the D-Block auction in order to deploy 50 kHz channels in the 700 MHz D-Block spectrum. When (and if) the D-Block frequencies become available, Motorola will take approximately 12 months to provide the software upgrades for the modems, base stations and controller. There may also be a hardware upgrade for the base stations. It is important to note that the state of Minnesota would need to acquire 50 kHz 700 MHz channels to deploy HSD.

Manufacturer	Motorola
Protocol	Proprietary
Frequency band availability	Licensed Spectrum: 700 and 800 MHz
Data rates by bandwidth	96 kbps at 25 kHz **Next Generation:** High Speed Data (HSD) 230 kbps at 50 kHz

Coverage design	Equivalent to ASTRO 25 voice; local or wide area; single site, multi-site, multi-cast.
Integrated voice & data capable	No
Backhaul interface protocol/physical port	IEEE 802.3 (ICMP, IGMP, TCP, UDP); Ethernet 10/100 BaseT
Backhaul capacity requirements	2x64 kbps per channel
Built-in GPS receiver	Optional
Modem peripheral interface protocol/physical port	IEEE 802.3 (ICMP, IGMP, TCP, UDP); Ethernet 10/100 BaseT and SLIP

3.2.1.2 Data transport mechanism(s)

There are three areas of data transport: over-the-air, peripheral interface, and backhaul interface. The over-the-air transport mechanism is a Motorola proprietary protocol. The backhaul interface connects the base stations to the console and the network as a whole. Although the backhaul interface is IP-based, interconnection between base stations and the network currently utilizes T1 connectivity. Future releases will be capable of interfacing directly into the agency's LAN system. The peripheral interface is the connection between the radios and any laptops or other devices in the vehicle. The peripheral interface use standard IP protocols.

3.2.1.3 Coverage

The coverage of this mobile data system is similar to Motorola's ASTRO voice radio system designs. Motorola system engineers design coverage area and capacity specific to agency's user requirements. General coverage design parameters are dependent upon the frequency band employed, physical terrain limitations, antenna height above average terrain, and transmit power and receive sensitivity of the mobile and base station radios.

If the state chooses to overlay HPD mobile data over the ARMER ASTRO network, the state should request Motorola to run coverage maps for inbound and outbound data for each of the sites. Although the claim is that the mobile data's coverage matches that of voice, the state should understand that the potential exists for more errors at the outer

edges of a site's coverage contour. The mobile data coverage maps should include this information. Coverage information for HSD is not yet available.

3.2.1.4 Applications

HPD will support Tier 1 and Tier 2 applications. Possible applications may include, but are not limited to, the following:

- Messaging
- Dispatch (CAD)
- Text messaging
- Query databases
- Driver's license
- License plates
- Warrants
- Low cadence AVL
- Field reporting
- Still Image transfer
- Mug shots
- High cadence AVL
- Fingerprints (inbound only)
- Intranet

High bandwidth applications like streaming video are not recommended for the HPD private data environment, although modified applications could be tested for use.

3.2.1.5 Equipment

The Motorola HPD equipment platform uses standardized IEEE 802.3 Ethernet 10/100 BaseT protocols and interfaces to connect to the dispatch/control center from the radio sites. Standardized IEEE 802.3 Ethernet 10/100 BaseT protocols and interfaces are utilized between the modem and peripheral devices within the vehicle. A proprietary half-duplex modified scalable amplitude modulation (SAM) protocol is used over-the-air from the modems to the base stations.

3.2.1.6 Implementation

Implementation of a Motorola HPD mobile data system is similar to any other private mobile data network; it is dependent upon the agency's budget and staffing constraints.

Motorola HPD can be overlaid onto a Motorola ASTRO system. Since the state is currently deploying a Motorola ASTRO system, a full-scale implementation strategy would not be required.

Deployment strategy steps:

1. Develop user-specific coverage and capacity requirements.
2. Develop a conceptual design for the voice and mobile data system.
3. Determine the site locations and channel allocations needed to support the network.
4. Acquire the necessary real estate by site lease and/or site acquisition.
5. Acquire spectrum based on site acquisition and capacity requirements
6. Upgrade the backhaul network if necessary; prepare and release a Request for Proposal (RFP) if necessary.
13. Prepare and release a
14.
15.
7. RFP for the procurement of a mobile data radio system.
8. Update the radio site infrastructure as necessary.
9. Install and test the backhaul network and mobile data radio equipment.
10. Perform preliminary testing of user radio equipment and mobile data applications.
11. Complete acceptance testing for the mobile data radio system.
12. Perform system cutover, installation, and testing of user radio equipment.

The schedule/timeframe is dependent upon the availability of radio sties and frequencies, number of radio sites, and cutover strategy (phased regional deployments or a single statewide deployment).

The Motorola HPD system may be implemented at local, regional, or statewide levels. Regions may be deployed one-by-one and connected together in a phased approach in order to accomplish a statewide implementation.

3.2.1.7 User assessments

The following agencies employ Motorola HPD system:

Agency	Frequency band/channel bandwidth	Approximate number of tower sites
Arkansas Wireless	700/800 MHz at 25 kHz	2 sites

Information Network (AWIN)		
Hennepin County	700 MHz at 25 kHz	18 sites
County of San Diego, California	700 MHz at 50 kHz	29 sites

Contact and/or interview information are provided in the following tables.

Technology	Motorola HPD (data) and P25 (voice)
Agency	Arkansas Wireless Information Network (AWIN)
Contact name	Dale Saffold
Contact title	Captain
Contact phone/e-mail	501-618-8219; dale.saffold@arkansas.gov
System description	
700/800 MHz Motorola P25 statewide radio system, 101 sites and 13,000 users; 2 sites overlaid with HPD to cover Little Rock and Ft. Smith. HPD is not heavily used due to cost of HPD modems. Agency is also using commercial broadband air cards in many areas due to capital versus recurring costs. The state has recently begun to work on IV&D in one county; this has been slow due to non-standardized encryption/security requirements from the state and with P25.	
Recommendation to Minnesota	
Cost analysis from AWIN has pushed them to rely on broadband air cards rather than deploying a private mobile data network on all areas. AWIN considers data secondary to voice during emergencies; coverage is sufficient in most areas.	

Technology	Motorola HPD
Agency	Hennepin County, Minnesota
Contact name	King Fung
Contact title	Senior Professional Engineer
Contact phone/e-mail	612-596-1923; king.fung@co.hennepin.mn.us
System description	
700 MHz Motorola HDP system using 25 kHz channels; about 9 agencies are using the system. Applications include CAD, text based queries, AVL, and mug shots (set up specifically for use on HPD system). NetMotion software was added to switch between HPD and WiFi hot spots. HPD coverage is very reliable. Hennepin County contracted with Motorola for an upgrade to an HSD system and is awaiting the release of 700 MHz 50 kHz channels.	

Recommendation to Minnesota
Hennepin recommends HPD as long as desired application will run on 96 kbps. Recommends including NetMotion or other application when using both HPD and WiFi (or other Broadband access). Integration of disparate vendor products and applications is difficult, but possible.

Technology	Motorola HPD
Agency	County of San Diego, California
Contact name	Ashish Kakkad
Contact title	Senior IT Engineer
Contact phone/e-mail	858-692-9089; ashish.kakkad@sdsheriff.org
System description	
800 MHz Motorola HPD system overlaid on Motorola SmartZone system. Current applications running on system include CAD and mobile photos and mug shots and they will be deploying records access. Performance within the 64-96 kbps range has been good. There are no plans to overlay broadband or WiFi at this time. During installation and testing, they found they needed RadioIP software, which increased the cost. Coverage meets user requirements, especially for rural locations where no other data service is available. San Diego County contracted with Motorola for an upgrade to an HSD system and is awaiting the release of 700 MHz 50 kHz channels.	
Recommendation to Minnesota	
San Diego County recommends HPD as long as desired application will run on 96 kbps.	

3.2.1.8 Expandability/scalability

The Motorola HPD systems are expandable and scalable to the extent of the agency's needs. Radio sites may be added whenever and wherever the agency requires additional coverage; additional channels may be added to the system to meet any increased capacity requirements. A private mobile data system is inherently able to provide the coverage and capacity as the agency requires it.

Backhaul network connectivity must be available with sufficient capacity or the ability to upgrade in order to meet the agency's growth requirements. The standardized IEEE 802.3 Ethernet 10/100 BaseT protocols and interfaces allow interconnection from the radio base stations via the agency's LAN. Microwave or leased line systems must either have sufficient capacity or be able to upgrade to meet future capacity needs.

3.2.1.9 Backhaul requirements

The HPD platform uses a non-proprietary IP open-architecture utilizing standardized IEEE 802.3 Ethernet 10/100 BaseT protocols in a LAN environment. Motorola proprietary routers and network switches are employed within the HPD network. Interconnection between base stations and the network currently utilize T1 connectivity; future releases will be capable of interfacing directly into the agency's LAN system.

3.2.1.10 Technology comparison

The Motorola HPD platform is designed specifically for a mobile data environment. Unlike other private two-way radio systems such as P25 and OpenSky is optimized for voice and allows mobile data to utilize existing infrastructure, HPD is a separate system that could potentially use the sites and backhaul that exist for a voice radio system. Motorola's mobile data systems have been installed in various configurations (single site local area) and statewide (multi-site wide area) optimized for different user types including public safety, public works, utilities, and transportation agencies. Motorola's HPD product line includes devices capable of both 700 and 800 MHz frequency bands at 25 kHz bandwidth.

The backhaul and peripheral device wireline interface of this system is a standards-based IEEE 802.3 IP-based protocol and Ethernet 10/100 BaseT interconnection. An IP standards based backhaul provides a semi-distributed architecture, increasing system redundancy and reducing the possibility of single point failures. A centralized system controller handles the HPD data traffic and may be configured for redundant operation.

Below are strengths and weaknesses of Motorola HPD platform as compared to other technologies:

Strengths:

- HPD is specifically for mobile data, not voice with a data overlay.
- HPD can be overlaid on any voice system, using the same sites and backhaul system.
- User radio modems can operate on both 700 and 800 MHz frequency bands.
- Radio sites are deployed only where the HPD coverage and capacity are required.
- Other than operations and maintenance, there are no recurring costs.

Weaknesses:

- Implementation requires a significant capital outlay due to infrastructure and user equipment procurement.
- User must have authorization to use or ownership of appropriate spectrum
- Implementation of a network requires real estate site leases and/or site acquisition.
- The system uses proprietary routers and network switches.
- Use of a centralized system controller creates a potential single point of failure.
- Migration to HSD requires 700 MHz 50 kHz channels.

3.2.1.11 Standards adaptability

Although the Motorola HPD over-the-air protocol is proprietary, their backhaul connectivity and peripheral equipment interfaces are standards based. This complies with National Information Exchange Model (NIEM) and guidance set by SAFECOM.

3.2.1.12 Costs associated with build-out

Capital outlay costs are associated with deploying this technology for the site infrastructure, backhaul network, mobile data equipment, and user radio modems. For the state of Minnesota, however, since the ARMER infrastructure exists or will exist, HPD can be overlaid on the ARMER system. There are no other recurring fees besides regular operations and maintenance.

Within the stand-alone data system category, Motorola HPD systems are generally a higher cost solution than a comparable CalAmp Dataradio system.

3.2.1.13 Other relevant attributes/considerations

The bandwidth requirements of desired applications will drive the infrastructure implementation. Motorola HPD systems utilize a mid-level data speed that is not capable of carrying broadband applications like full motion video or true internet connectivity but has been shown to work well with Tier 1 and Tier 2 applications.

It is possible to build out an HPD system utilizing multi-protocol modems such that multiple data layers may be accessed dependent upon the required application. This helps to ensure guaranteed coverage and capacity when augmented with broadband cellular where available. For example, a police officer may use the Motorola HPD system to look up driver's license or license plate and for Computer Aided Dispatch communications while driving. When that officer wishes to file reports, they can go to a location that supports broadband and transmit lengthy reports over that faster broadband network.

As with all private radio systems, spectrum availability is a primary concern and possibly more so with HPD due to the migration to HSD requiring 700 MHz 50 kHz channels. The frequency band and channel bandwidth will determine the available product line and its associated data speeds.

3.2.2 CalAmp Dataradio

3.2.2.1 Overview

CalAmp's Dataradio product line includes public safety mobile data devices at varying bandwidths, in various licensed frequency bands, using proprietary over-the-air protocols, and either proprietary or standardized wireline protocol formats. Additionally, CalAmp provides mobile data modems for cellular based networks and for unlicensed 900 MHz channels.

CalAmp's primary public safety product line includes the GeminiG3 and Gemini PD+ mobile radio modems paired with the Paragon3 and Paragon PD+ digital base stations. This equipment employs CalAmp's proprietary digital over-the-air protocol. These products and the Dataradio system have been developed specifically for a dedicated public safety mobile data radio system.

Manufacturer	CalAmp
Protocol	Proprietary: Enhanced dynamic bandwidth allocation (E-DBA) with out-of-band AVL support
Frequency band availability	Licensed Spectrum: UHF, 700, 800, 900 MHz
Data rates by bandwidth	**GeminiG3/Paragon3:** 64 kbps in 25 kHz at UHF, 800, or NPSTC 128 kbps in 50 kHz at 700 MHz only **Gemini/ParagonPD+ UHF, 800, 900 MHz:** 43.2 kbps in 25 kHz 22 kbps in 12.5 kHz 24 kbps in NPSPAC
Coverage design	Local or wide area; single or multi-site. Multiple channels may be programmed for automatic roaming.
Integrated voice & data capable	No

Backhaul interface protocol/physical port	**ParagonG3:** IEEE 802.3 (ICMP, IGMP, TCP, UDP); Ethernet 10/100 BaseT **ParagonPD+:** DS0 circuit based; RJ45
Backhaul capacity requirements	2x64 kbps per channel
Built-in GPS receiver	Yes
Modem peripheral interface protocol/physical port	**GeminiG3:** IEEE 802.3 (ICMP, IGMP, TCP, UDP); Ethernet 10/100 BaseT **GeminiPD+:** RS232; DB9

3.2.2.2 Data transport mechanism(s)

There are three areas of data transport: over-the-air, peripheral interface, and backhaul interface. The CalAmp Dataradio public safety systems employ a proprietary over-the-air half-duplex enhanced dynamic bandwidth allocation (E-DBA) protocol developed by CalAmp Dataradio specific for the mobile data environment. E-DBA is a scheduled air-link protocol (that is, packets are scheduled to go out over-the-air according to priority as opposed to being sent immediately) whose algorithms were designed to favor throughput over latency. To achieve that goal, the air-link uses adaptive timeslots called cycles to schedule traffic. These cycles dynamically vary in length (typically, between 200 to 1500 milliseconds) based on various factors, including network load. Each packet of data transiting through an E-DBA network must therefore be scheduled for transmission. This scheme provides for an efficient way to provide higher data rates.

The GeminiG3/Paragon3 equipment platform uses standardized IEEE 802.3 Ethernet 10/100 BaseT protocols and interfaces to connect to both peripheral equipment and to the backhaul network.

The Gemini/Paragon PD+ equipment platform uses standardized serial RS232 protocols and DB9 interfaces to connect to peripheral equipment and circuit based DS0 protocols to the backhaul network.

3.2.2.3 Coverage

The coverage design of this mobile data system is specific to the public safety agency's user requirements. CalAmp system engineers design coverage area and capacity specific to stated requirements. General coverage design parameters are dependent

upon the frequency band employed, physical terrain limitations, antenna height above average terrain, and transmit power and receive sensitivity of the mobile and base station radio.

3.2.2.4 Applications

Any applications from Tiers 1, 2, and 3 may be effectively deployed on this infrastructure. Possible applications may include:

- Messaging
- Dispatch (CAD)
- Text messaging
- Query databases
- Driver's license
- License plates
- Warrants
- Low cadence AVL
- Field deporting
- Still image transfer
- Mug shots
- High cadence AVL
- Fingerprints
- Intranet
- Internet access
- Images (Tx/Rx)
- Video (low bandwidth)

High bandwidth applications like streaming video are not recommended for the CalAmp private data environment, although modified applications could be tested for use.

3.2.2.5 Equipment

The Gemini/Paragon G3 equipment platform uses standardized IEEE 802.3 Ethernet 10/100 BaseT protocols and interfaces to connect the dispatch/control center with the radio sites. The same protocols and interfaces are utilized between the modem and peripheral devices within the vehicle. Proprietary enhanced dynamic bandwidth allocation (E-DBA) with out-of-band (OOB) AVL support is the over-the-air protocol between the modems and the base stations.

The Gemini/Paragon PD+ equipment platform uses proprietary serial RS232 protocols and DS0 interfaces to connect to the dispatch/control center from the radio sites. Standardized serial RS232 protocols and DB9 interfaces are utilized between the modem and peripheral devices within the vehicle. Proprietary enhanced dynamic bandwidth allocation (E-DBA) with OOB AVL support is the over-the-air protocol between the modems and the base stations.

3.2.2.6 Implementation

Implementation of a CalAmp mobile data system is similar to any other private mobile data network; it is dependent upon the agency's budget and staffing constraints. The full-scale implementation strategy includes the FCC license acquisition or modification (if frequencies do not already exist), radio site acquisition, modification or design and procurement of the backhaul network, and design and procurement of the mobile data radio system.

Deployment strategy steps include the following:

1. Develop user-specific coverage and capacity requirements.
2. Develop a conceptual design mobile data system.
3. Determine the site locations and channel allocations needed to support the network.
4. Acquire the necessary real estate by site lease and/or site acquisition.
5. Acquire spectrum based on site acquisition and capacity requirements
6. Upgrade the backhaul network if necessary; prepare and release a request for proposal if necessary.
7. Prepare and release a request for proposal for the procurement of a mobile data radio system.
8. Update the radio site infrastructure as necessary.
9. Install and test the backhaul network and mobile data radio equipment.
10. Perform preliminary testing of user radio equipment and mobile data applications.
11. Complete acceptance testing for the mobile data radio system.
12. Perform system cutover, installation, and testing of user radio equipment.

The schedule/timeframe is dependent upon the availability of radio sites and frequencies, number of radio sites, and cutover strategy (phased regional deployments or a single wide area deployment).

The CalAmp Dataradio system may be implemented in a local, regional, or state level. Regions may be deployed one-by-one and connected together in a phased approach in order to accomplish a statewide implementation.

3.2.2.7 User assessment

The following agencies employ CalAmp's Dataradio systems:

Agency	Frequency band/channel bandwidth	Approximate number of tower sites	Approximate number of users
Post Falls, Idaho	700 MHz at 50 kHz	1 site	50
Mower County, Minnesota	800MHz at 25 kHz	2 sites	50
City and County of Denver, Colorado	800MHz at NPSPAC and 25 kHz	5 sites	500
City of Shreveport/Caddo Parish, Louisiana	800MHz at 25 kHz	8 sites	700
Arizona Department of Public Safety	800MHz at NPSPAC and 25 kHz	26 sites	900

Contact and/or interview information are provided in the following tables.

Technology	CalAmp Dataradio
Agency	Post Falls Idaho
Contact name	Scot Haug
Contact title	**
Contact Phone/e-mail	208-773-6366

Technology	CalAmp Dataradio
Agency	Mower County, Minnesota
Contact name	Terese Amazi
Contact title	Sheriff
Contact phone/e-mail	507-437-9400; tmamaz@co.mower.mn.us
Contact name	Marlys Sorlie
Contact title	Dispatch Supervisor
Contact phone/e-mail	507-437-9400; masorl@co.mower.mn.us
System description	
800 MHz CalAmp Dataradio for mobile data; VHF for voice system. Dataradio system has been installed and tested but it is not yet fully operational due to issues with Positron console integration.	
Recommendation to Minnesota	
Recommend to confirm that the application vendor software has been tested with the	

system. Dataradio system operates as expected.

Technology	CalAmp Dataradio
Agency	City and County of Denver, Colorado
Contact name	Myron Kissinger
Contact title	Engineer Supervisor
Contact phone/e-mail	303-295-4381; Myron.kissinger@denvergov.org
System description	
800 MHz and NPSPAC CalAmp Dataradio system using one NPSPAC channel at 5 sites and one 800 MHz channel at 1 site. System works as expected. Applications recently deployed include thumbnail mug shots and e-mail between cars. There are plans to add digital dispatch and AVL soon. Three vendors were shortlisted for mobile data system. CalAmp Dataradio was the only one capable of running within a NPSPAC bandwidth. System was installed on time and within budget with a short deadline. There are also plans to expand the system to integrate WiFi access points through a Tropos/CalAmp partnership.	
Recommendation to Minnesota	
System runs well; data throughput and coverage area meet the agency's needs. Consulting services aided RFP and implementation process.	

Technology	CalAmp Dataradio
Agency	City of Shreveport/Caddo Parish, Louisiana
Contact name	Martha Carter
Contact title	**
Contact phone/e-mail	318-675-2222

Technology	CalAmp Dataradio
Agency	Arizona Department of Public Safety
Contact name	Kevin Rogers
Contact title	Manager, Wireless Systems Bureau
Contact phone/e-mail	KARogers@azdps.gov

3.2.2.8 Expandability/scalability

The CalAmp Dataradio systems are expandable and scalable to the extent of agency's needs. Radio sites may be added whenever and wherever the agency requires

additional coverage; additional channels may be added to the system to meet any increased capacity requirements. A private mobile data system is inherently able to provide the coverage and capacity where and when the agency requires it.

Backhaul network connectivity must be available and either have available capacity or the ability to upgrade in order to meet the agency's growth requirements. In the case of the Gemini/Paragon G3 equipment, standardized IEEE 802.3 Ethernet 10/100 BaseT protocols and interfaces allow interconnection from the radio base stations via the agency's LAN. The Gemini/Paragon PD+ equipment uses proprietary serial RS232 protocols and requires circuit switched DS0 interfaces to connect from the radio sites. Microwave or leased line systems must either have sufficient capacity or be able to be upgraded to meet future capacity needs.

3.2.2.9 Backhaul

The Gemini/Paragon G3 equipment platform uses a non-proprietary IP open-architecture utilizing standardized IEEE 802.3 Ethernet 10/100 BaseT protocols in a LAN environment. Commercial off-the-shelf routers and network switches are employed in the network design for ease of training and maintenance. Any backhaul architecture (microwave, fiber, or leased lines) capable of transporting IP traffic may be used for the Dataradio network.

The Gemini/Paragon PD+ equipment platform uses proprietary serial RS232 protocols and DS0 interfaces to connect the dispatch/control center with the radio sites. T1 to Ethernet converters would be necessary if a Local Area Network (LAN) provides connectivity.

3.2.2.10 Technology comparison

CalAmp's Dataradio platform is designed specifically for mobile data and is not an overlay on a voice system. CalAmp's mobile data systems have been installed in various configurations (single site local area) and statewide (multi-site wide area) optimized for different user types including public safety, public works, utilities, and transportation markets. Additionally, the CalAmp product line includes devices capable of both 700 and 800 MHz frequency bands at bandwidths variations from NPSPAC, 25 kHz, 50 kHz, and greater.

The backhaul and peripheral device wireline interface of this system is an IP standards based IEEE 802.3 protocol and Ethernet 10/100 BaseT interconnection. An IP standards based backhaul not only allows for use of commercial-off-the-shelf

equipment, but also provides a distributed architecture, increasing system redundancy and reducing the possibility of single point failures.

CalAmp's proprietary over-the-air interface enhanced dynamic bandwidth allocation (E-DBA) was developed specifically for the mobile data environment. Additionally, normal data transactions provide advanced features including:

- OOB Signaling – Allows transmission of GPS without consuming bandwidth for user data.
- Hyper-Code Forward Error Correction – A high efficiency error correction technique that detects and corrects errors due to fades in the mobile environment.

The following are strengths and weaknesses of CalAmp's Dataradio platform as compared to other technologies:

Strengths:

- The system is designed specifically for mobile data, not voice with a data overlay.
- The technology is more mature than P25, M/A-COM OpenSky, and Motorola HPD.
- User radio modems can migrate from NPSPAC, 25 kHz, 50 kHz, and greater bandwidths, as they become available.
- The system uses commercial off-the-shelf routers and network switches.
- Radio sites are deployed where coverage is required.
- The system is scalable, being able to meet capacity requirements as needed.
- The system has dedicated throughput capabilities.
- Other than operations and maintenance, there are no recurring costs.

Weaknesses:

- Implementation requires a significant capital outlay due to infrastructure and user radio procurement.
- User must have authorization to use or ownership of appropriate spectrum.
- Implementation of a network requires real estate site leases and/or site acquisition.

3.2.2.11 Standards adaptability

Although the CalAmp over-the-air protocol is proprietary, their backhaul and peripheral equipment interface is standards based. A non-proprietary backhaul allows for interface into various agency systems, meeting Department of Homeland Security (DHS)

interoperability requirements and complies with National Information Exchange Model (NIEM) and guidance set by SAFECOM.

CalAmp's GeminiG3 mobile radio and Paragon3 base station adhere to standards defined by IEEE 802.3 for backhaul and peripheral interconnectivity.

3.2.2.12 Costs associated with build-out

Capital outlay costs are associated with deploying this technology for the site infrastructure, backhaul network, mobile data equipment, and user radio modems. There are no recurring fees other than regular operations and maintenance.

Overall, CalAmp Dataradio systems are generally a lower cost solution as compared to Motorola HPD.

3.2.2.13 Other relevant attributes/considerations

Application throughput requirements will drive the infrastructure implementation. The CalAmp Dataradio systems utilize a mid-band data speed that is not capable of carrying broadband type applications like full motion video or true internet connectivity. Yet, it is possible to build out a CalAmp Dataradio system utilizing multi-protocol modems such that multiple data layers may be accessed dependent upon the required application, thereby ensuring guaranteed coverage and capacity, with augmented broadband or cellular ability where available. As mentioned previously, this would allow users to run lower speed or less data intensive applications over the Dataradio system and then proceed to broadband or cellular fixed locations to run applications requiring higher data speeds. This keeps the Dataradio system from being bogged down.

As with all private radio systems, spectrum availability is a primary concern. The frequency band and channel bandwidth will determine the available product line and its associated data speeds.

3.3 Broadband

Broadband systems and technologies will support Tier 1, 2 and 3 applications. These systems are “stand-alone” in that they do not require a voice (or other) infrastructure to support operation.

3.3.1 WiMAX

3.3.1.1 Overview

Worldwide Interoperability for Microwave Access (WiMAX) is a brand name for the technology that utilizes the IEEE 802.16 standard. The IEEE is an open standards body and has created a wide family of standards over the last 30 years, including Ethernet (802.3) and Wi-Fi (802.11). The IEEE 802.16 committee has created multiple standards over the past 10 years, the most important of those being 802.16d for fixed communications and 802.16e for mobile communications. Most equipment providers and large operators (e.g., Clearwire) are building and deploying equipment based on the 802.16e standard.

Like many pure standards, 802.16 has numerous options, and an industry group named the WiMAX Forum (WMF) (www.wimaxforum.org) was organized to create interoperable specifications using a subset of the overall features and parameters of the 802.16 standard and certify compliant equipment.

The goal of the WMF is interoperable multi-vendor broadband wireless access worldwide. Many products from earlier in this decade were similar to WiMAX, but were proprietary (e.g., Motorola Canopy, Alvarion BreezeAccess, and many others). With WiMAX-certified equipment, vendor products can be mixed with the base station made by one vendor and the client device made by another vendor, and no single-vendor lock-in occurs. Further, WiMAX runs using transmission control protocol/Internet protocol (TCP/IP) such that it will fit well into the worldwide overall data network.

As a technology goal, the aim of WiMAX is to utilize spectrum more efficiently than many previous cellular data methods and even Wi-Fi. Another important goal was the inclusion of Quality of Service (QoS) from the inception of the standard. Many large WiMAX players want to see WiMAX become the mobile broadband technology of choice, supplanting 3G and future 4G technologies, such as LTE.

Mobile WiMAX technology targets throughput of 40 Mb/s in a 10 MHz channel for both downlink and uplink (shared among all users in a cell), with mobility capability up to 60 mph. It should be noted that with higher mobility the maximum possible throughput would be reduced.

The IEEE 802.16e standard was completed in 2005, and the WMF began certifying mobile WiMAX equipment in 2007. Clearwire (with major joint partner Sprint) has 46 pre-WiMAX networks along with two new markets deployed with WiMAX-compliant equipment in the licensed 2.5 GHz spectrum. There is no official word about how many additional market areas will be deployed during 2009, although speculation is that between six and ten markets.

3.3.1.2 Data transport mechanism(s)

WiMAX utilizes orthogonal frequency division multiplexing (OFDM) for the downstream and orthogonal frequency division multiplexing access (OFDMA) for the upstream. In the downstream, multiple users' data is transmitted at the same time and each user pulls out their specific information. In the upstream, each user transmits on specific assigned sub-channels to reduce the total amount of power required compared to a situation where they would be transmitting on all OFDM sub-channels.

Quality of Service (QoS) was designed into WiMAX from the beginning and was one of the main goals of the technology. Quality of Service (QoS) is the ability to prioritize different types of traffic based on level of importance on a network as the network reaches capacity. QoS ensures that certain types of traffic can be prioritized to get through the network in favor of less important traffic. An example of this on IP networks is prioritizing voice traffic (VoIP) over standard web browsing (HTTP) traffic. The prioritization is typically done on routers and base stations, and has to be done on subsequent routers etc. throughout the network to maintain the prioritization. Some radio equipment for IP networks have the ability to apply QoS to the radio interface, but most cannot prioritize traffic until it reaches the base station.

3.3.1.3 Coverage

The typical cell size for a WiMAX deployment very much depends on physical factors such as terrain and desired throughput. Some of the "hype" around WiMAX claims 70 Mbps at distances over 30 miles, but that is not expected in real-world conditions. Based on our own deployment experiences, we expect that in rural applications, cell sizes may range from 3-10 miles, while in urban environments the cell sizes may be 0.5 miles or less in size. This is because of the increased number of obstructions and higher user density. Cell sizes may need to be even smaller if higher-throughput applications such as video are to be supported. Such environmental and application considerations are true with any broadband technology, in terms of the environment and applications.

3.3.1.4 Applications

All four tiers of the applications described in Section 2 can operate over this network.

3.3.1.5 Equipment

A WiMAX network consists of multiple base stations and some form of a backhaul network to interconnect those base stations. On the client side, a mobile modem such as a WiMAX laptop card or other client device is required.

3.3.1.6 Implementation

Implementation timelines of client devices in areas that a WiMAX operator does not currently have coverage will likely be very long, if at all, since the operator's network build-out is not influenced by the state of Minnesota. The operator will control the deployment of subscribers on and expansion of its network.

A deployment schedule of client devices in the areas where an operator already has coverage should be relatively short since the infrastructure is already in place and only client devices need to be deployed by the state.

WiMAX has potential for implementation across the entire United States since the spectrum allocation spans the country. Clearwire (www.clearwire.com) is the largest license holder and service provider in the USA. They are a joint venture with Sprint and received an investment of over $3 billion from Google, Comcast, and Intel in November 2008 [3]. However, as with any technology, it will take many years, if not decades, for full ubiquity. In areas where Clearwire does not have a license, they will need to work with other operators to have regional or statewide roaming, but given the open standards base of IP networking in WiMAX, this is quite a viable option.

A recent Informa report claims several hundred WiMAX “deployments” around the world, but many of these are trials [4], and this number also includes fixed deployments. The total number of WiMAX subscribers in the USA numbers in the hundreds of thousands, mostly using pre-WiMAX equipment. True mobile WMF-certified deployments are still in an early stage, but the increasing number of certified devices, market maturity, and Clearwire markets under construction means that wider commercial deployment is closer to reality.

In Minnesota, Clearwire’s service is available in areas around Duluth and St. Cloud [5]; however, these are using non-certified pre-WiMAX equipment. Clearwire has launched service to Baltimore and Portland within the last 6 months as their first markets with true WMF-Certified equipment [6].

3.3.1.7 User assessment

No agencies within Minnesota are known to be using WiMAX technology at this time. It is unknown if any public safety organizations nationwide are using WiMAX technology.

3.3.1.8 Expandability/scalability

Initial services by WiMAX service providers typically focus on specific metropolitan areas. Network coverage often can start with providing broadband capability to major population areas and main thoroughfares, and then later fill in the residential neighborhoods and less populated areas. Public safety officials need to understand the intended rollout and coverage expansion plans of the service provider, as the service provider is the party expanding the system.

As the network grows in terms of subscribers and applications, additional capacity is typically needed. Additional base stations can be installed to handle the increased throughput demand from end-user WiMAX devices. The service provider is the party that performs these actions with little or no input from the state of Minnesota.

3.3.1.9 Backhaul

The backhaul for the whole network can be upgraded by increasing the amount of bandwidth available. The service provider is the party that performs these actions with little to no input from the state of Minnesota.

3.3.1.10 Technology comparison

Below are strengths and weaknesses of WiMAX as compared to other technologies:

Strengths:

- The high transmitter power allowance makes WiMAX an excellent candidate for rural applications, especially if fixed end-user devices with high-gain antennas are used.
- There is a nationwide unencumbered footprint of licensed 2.5 GHz WiMAX spectrum, mostly owned by one entity (Clearwire).
- WiMAX technology is more mature than LTE and is available today.
- A wide range of WMF-Certified client devices is commercially available [1], which LTE does not have.
- WiMAX was designed from the ground up as an all-IP system, which is not the case for cellular and 3G.
- Quality of Service (QoS) was designed in from the beginning and was one of the main goals of the technology. The protocols in WiMAX are much more capable of enabling QoS compared to Wi-Fi.

- The cellular-like base station control and flexibility give subscribers access to the wireless medium and enables excellent granularity of service and optimization of the scarce wireless airtime, an advantage over Wi-Fi.
- A significant ecosystem (chipset vendors, laptop card makers, WiMAX modem vendors, base station vendors, backhaul vendors) has built up around WiMAX over the last several years.
- Clearwire has many significant investment partners, including Google, Comcast, and Intel.
- WiMAX technology supports higher throughput capabilities than 3G and cellular data.

Weaknesses:

- Clearwire is a small firm when compared to Verizon or AT&T.
- Clearwire has significant and increasing operational losses.
- WiMAX is still unproven on a large scale, especially with mobility.
- Mobility was an add-on to 802.16 in the 802.16e amendment. 802.16 was originally a fixed standard.
- There are different frequency bands and different profiles in different countries around the world, unlike Wi-Fi. This has led to some product dispersion among vendors, for example, to focus on the European market more than the USA market.
- High-volume equipment and economies of scale are not as readily available compared to Wi-Fi and 3G.

3.3.1.11 Standards adaptability

WiMAX technology is completely based on the work of the fully open IEEE 802.16 standards group. The large attendee group of 802.16 allows for numerous future innovations in multiple areas of the standard. The IEEE continues to make advancements to 802.16; as an example, work has begun for a follow-on standard to 802.16e called 802.16m to make improvements for increased throughput at mobile speeds to match that of LTE-Advanced (1 Gb/s for fixed, 100 Mb/s for high mobility).

WiMAX also utilizes an all-IP architecture, which is another example of how the overall network is easily interoperable and utilizes open standards.

3.3.1.12 Costs associated with build-out

The costs associated with deploying this technology are limited to deployment of the client device and the monthly recurring service charges. Since deployment does not require an infrastructure build, large capital expenditures are avoided.

3.3.1.13 Other relevant attributes/considerations

Both licensed and unlicensed band usage have been discussed for WiMAX. With regard to the USA and specifically Minnesota, the primary frequency bands considered are the following:

Licensed 2.5 GHz spectrum (up to 190 MHz of spectrum available)

Clearwire is the primary owner of this spectrum (some portions of the spectrum may be owned by different entities in specific markets). Clearwire service using pre-WiMAX technology is currently available in areas near Duluth and St. Cloud [5]. They are building more markets, but their nationwide plans will certainly take several years to fruition.

Lightly licensed 3.65 GHz spectrum (50 MHz of spectrum)

The FCC released 50 MHz of spectrum between 3.65-3.7 GHz in 2005 [8], and issued further clarification on many of the rules in 2007 [9]. The “lightly licensed” nature of the spectrum refers to the fact that anyone can install a base station if they file a simple application with the FCC. There is potential interference to WiMAX in the upper 25 MHz of the spectrum (where Wi-Fi can operate), while the lower 25 MHz is very amenable to WiMAX. There are not yet many operators in this spectrum. The WiMAX Forum [10] has certified a few devices.

Unlicensed 5.4 GHz (up to 200 MHz) and 5.7 GHz (100 MHz) U-NII spectrum

The potential for external interference from other users is high in this band. Many Wi-Fi systems operate in the 5 GHz spectrum, as well as point-to-multipoint systems based on proprietary technologies that are like WiMAX protocols, but do not interoperate with WiMAX. Given this wide range of systems that may be present in a geographic area, there is a high likelihood of coexistence issues with the use of WiMAX in this band.

Licensed 700 MHz spectrum auctioned by the FCC in 2008

The band plan for the 700 MHz auction is shown in [11], and a list of auction winners can be found in [12]. Across the nation, the main winners of spectrum were AT&T and Verizon. In Minnesota, outside of Minneapolis-St. Paul, a number of smaller entities (e.g., Frontier, CenturyTel) were the winners, and thus a single statewide operator may be difficult to achieve.

As this auction closed within the last year, there has only begun to be activity in this band. The WiMAX Forum has recently developed profiles for 700 MHz and

chipset providers have begun to create the products [13]. However, this technology is years away from commercial availability, and both Verizon and AT&T have publicly stated they intend to use LTE in this band [14].

WiMAX could potentially be used in the D block of the 700 MHz band. However, given the failure of the auction in 2008 to achieve an acceptable price for the FCC and rules uncertainty, it is not clear when any technology could be viable for the D block.

As the entire 700 MHz spectrum is licensed, the potential for external interference is low.

Licensed 4.9 GHz band (50 MHz) for public safety

There has not been much activity to date with WiMAX in the 4.9 GHz band.

References:

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3.3.2 Time Division - Code Division Multiple Access (TD-CDMA)

3.3.2.1 Overview

TD-CDMA is a Universal Mobile Telecommunications System (UMTS) protocol and part of the 3rd Generation Partnership Project (3GPP) group of international mobile standards. It is very similar to CDMA and wideband code division multiple access (W-CDMA) that cellular carriers have deployed on other networks. Currently, the most significant implementation of TD-CDMA is in New York City. After 9/11, NYC committed to build a dedicated network for public safety. As a result, the city partnered with Northrop Grumman to provide a wireless public safety data network. Northrop Grumman chose the TD-CDMA technology by IP Wireless (a broadband solution provider) for this network because it was so closely parallel to the proven technologies deployed by the major cellular carriers.

The IP Wireless equipment is built using a software defined radio (SDR) architecture, and according to IP Wireless may support LTE and WiMAX via a software upgrade in the future. TD-CDMA can operate in a relatively narrow 10 MHz channel of spectrum and is very spectrally efficient.

TD-CDMA is ideal for mobile applications since the technologies that it was derived from and the standards it is based on are designed for mobile use. Currently, there is only one vendor offering this equipment.

3.3.2.2 Data transport mechanism(s)

TD-CDMA is a UMTS protocol set by the 3GPP. It is very similar to CDMA and W-CDMA that cellular carriers have deployed on their networks.

3.3.2.3 Coverage

TD-CDMA is deployed in a cellular architecture much like other 3G and 4G technologies. Because of this, individual coverage areas are typically small, with the need for many tower sites.

3.3.2.4 Applications

All four tiers of applications listed above can operate over this network.

3.3.2.5 Equipment

A TD-CDMA network from IP Wireless would consist of multiple base stations and microwave backhaul to interconnect those base stations. On the client side, a mobile device would be used, such as a TD-CDMA laptop card or other client device.

3.3.2.6 Implementation

Deployment schedules will be relatively slow since many base stations would be needed for the ubiquitous coverage that would be required for public safety use. It would likely take many years for the state to provide statewide coverage. Factors such as lease negotiations, tower construction, base station installation, and network integration will all affect deployment timelines. It took NYC over a year to deploy its TD-CDMA network citywide.

TD-CDMA has the potential to be implemented by the state on a local, regional, or state level. Local or regional “best effort” deployments would be the most cost effective. Statewide coverage, and even regional ubiquitous coverage, would most likely be cost prohibitive due to the dense amount of base stations that would be required for ubiquitous coverage.

3.3.2.7 User assessment

No agencies within Minnesota are using TD-CDMA technology at this time.

In 2007, New York City deployed its own TD-CDMA wireless data network operating in the 2.5 GHz Emergency Broadcast System (EBS) spectrum initially for public safety use. Initially the network saw 10 Mbps down and 2 Mbps up for data throughput, and is now said to be operating on average at 15 Mbps down and 5 Mbps up. Now the network supports many levels of municipal government use.

3.3.2.8 Expandability/scalability

As the needs of public safety entities grow, expansion of the network will be mostly under the control of the state. In areas that a need for expansion has been identified, the state only has to add a base station site to increase geographic coverage, or upgrade the backhaul bandwidth to an existing base station site.

A few factors that may delay any addition of base stations are site acquisition and lease agreements. Lease agreement negotiations could take anywhere from three to 12 months. If a new tower has to be constructed, construction time must also be considered. Construction time for a new tower installation is also a consideration.

Capacity can be increased at any time by the state of Minnesota by adding more base stations or increasing the amount of bandwidth available on the backhaul.

3.3.2.9 Backhaul

Some form of a backhaul network will be needed to support the deployment of this technology.

3.3.2.10 Technology comparison

TD-CDMA is ideal for mobile applications since it is inherently designed for mobile use and high data rates. It has the ability to operate in small amounts of spectrum to achieve high data rates, compared to other broadband technologies.

One shortfall of TD-CDMA is that it has not benefited from economies of scale. Even though it is a parallel technology to many of the currently deployed cellular standards, few manufacturers make equipment that is compatible with TD-CDMA, causing it to be nearly cost prohibitive.

3.3.2.11 Standards adaptability

TD-CDMA adheres to standards defined by the 3GPP and falls specifically under the UMTS standard. Currently there is only one vendor that makes TD-CDMA base station equipment, but since TD-CDMA is so closely tied to other standards that are widely used today, such as W-CDMA and CDMA, by cellular service providers, existing client device manufacturers could easily begin making TD-CDMA client devices if the market requires it.

3.3.2.12 Costs associated with build-out

A typical build-out per base station is approximately $200,000. This number is for base station equipment and installation only. Other types of costs involved are lease agreements for tower sites, the amount of work needed to upgrade existing towers, and new tower builds. New towers can range anywhere from $50,000 to $150,000, depending on the size and height of the tower.

For a sense of how this scales, NYC spent around $500 million just for its citywide TD-CDMA network. This is typical of the costs that cellular service providers incur during the build-out of their networks.

Client devices can vary widely in cost depending on the type of client device. Client devices can be anything from handheld devices to vehicle mounted client devices. For example, a typical USB card for a laptop is approximately $300 - $400.

3.3.2.13 Other relevant attributes/issues

One of the factors to consider is in what frequency to operate the network. The technology needs at least 10 MHz of spectrum, and this is not always available in traditional public safety frequency allocations. One option is to lease 2.5 EBS/BRS spectrum from educational entities within the state. EBS/BRS spectrum was licensed to educational entities in geographic service areas of a 35-mile radius from the license center. These were originally allocated for educational broadcast television, but have

since been re-allocated to be used for data communications. Most educational entities do not use this spectrum and lease it out. Several licenses within Minnesota area are already leased out to companies like Sprint/Nextel and Clearwire, but many are still available.

3.3.3 Long Term Evolution (LTE)

3.3.3.1 Overview

Long Term Evolution is the next generation cellular technology undergoing standardization by 3GPP[2]. LTE is the next step in the evolution of the Global System for Mobile communication (GSM) family of standards, which currently account for 86% of mobile phone connections worldwide [1].

In the United States, AT&T wireless and T-Mobile are the major mobile carriers using a GSM-based cellular technology. In contrast, Verizon Wireless and Sprint use a different type of technology in their networks based on Qualcomm CDMA. This has led to incompatibility of devices manufactured for different cellular operators and the inability to roam between their networks. However, this incompatibility appears to be all but over in the near future as Verizon Wireless has already announced that its next generation network is going to be based on LTE [2] and Clearwire, Sprint's WiMAX partner, has recently noted the possibility of switching to LTE in the future [3]. The LTE end-user devices will conform to the LTE standard, and will thus be able to operate in any of these provider's networks as well as roam between them.

The LTE architecture relies on a data-centric, IP core network and thus provides support for IP-based traffic. The IP architecture ensures interoperability with the majority of other network types and access technologies in use today and enables LTE to provide IP-based services such as end-to-end QoS. LTE targets up to 100 Mbps downlink and 50 Mbps uplink data rates over a 20 MHz spectrum (shared among all users within a cell), and mobility rates of up to 210 mph (350 km/h) though at a maximum of 25% of the peak performance [4]. The high throughput and interoperable architecture of LTE enable it to support Tier 4 applications such as streaming video, and time-sensitive applications such as VoIP and IPTV.

In the United States, LTE deployments will use the 700 MHz spectrum auctioned by the FCC in January 2008 [5]. This spectrum was previously used for analog television broadcasting, which is scheduled to shut down on June 12, 2009. The biggest winners in the 700 MHz auction were Verizon Wireless and AT&T, both of which intend to use the spectrum for LTE deployment. The 700 MHz spectrum allows for better coverage than spectrum used for WiMAX or Wi-Fi-based technologies, which have to be deployed in higher frequency bands, e.g., 2.5 GHz for WiMAX, and 2.4 and 5 GHz unlicensed bands for Wi-Fi.

[2] http://www.3gpp.org

The 3GPP forum started work on LTE in November 2004 and is planning to release the LTE specification (document Rel-8) in March 2009 [6]. On February 18, 2009, Verizon announced they will start to roll out their LTE network in two cities in the United States in late 2009, and then commercially launch in 25 to 30 markets in 2010 [7]. AT&T [8] and T-Mobile [13] have announced they will not deploy their LTE commercial networks until 2011.

This technology may also be deployed, owned and operated by the state using a system integrator and therefore not have to involve a commercial service provider (see Section 3.3.3.6).

3.3.3.2 Data transport mechanism(s)

At the network level, LTE relies on the TCP/IP protocol family, and can carry any TCP/IP traffic, which is the underlying network access method for the vast majority of data traffic and applications in use today.

At the radio access level, LTE's aggressive performance requirements rely on high performance physical layer technologies such as orthogonal frequency division multiplexing (OFDM), multiple-input multiple-output (MIMO) systems, and smart antennas to achieve these targets.

3.3.3.3 Coverage

The achievable coverage of an LTE base station in the United States is projected to be better than existing cellular technologies. LTE base stations are also projected to achieve better coverage than WiMAX and Wi-Fi technologies due to the lower frequencies available for use by LTE (700 MHz for LTE vs. 800 MHz and above for cellular networks, 2.5 GHz for WiMAX, and 2.4 GHz and above for Wi-Fi).

Theoretically, cell sizes are expected to be around three miles and possibly range up to 18 miles and even 62 miles but with performance degradation for larger cell sizes [9]. Actual deployment experience may reveal that cell sizes need to be smaller to achieve peak throughput, especially in urban areas.

3.3.3.4 Applications

All four tiers of applications listed above can operate over this network.

3.3.3.5 Equipment

An LTE network will consist of multiple base stations, microwave backhaul to interconnect those base stations, and core network server systems. Client mobile devices will include an LTE laptop card and a ruggedized mobile data terminal.

3.3.3.6 Implementation

The state may want to consider partnering with a systems integrator to handle the design and implementation of an LTE network. Deployment timelines will be affected by factors such as lease negotiations, tower construction, base station install, and network integration. Initial implementation would be of the core network server systems to prioritize and route the user traffic. Once that is in place, base stations can begin being deployed. The state will decide which base stations to deploy first, depending on where coverage is needed.

Once the network is installed, the state will have control over upgrading bandwidth capacity and coverage areas as needed. Either the state will maintain and operate the network or the state will outsource these tasks.

3.3.3.7 User assessment

No agencies within Minnesota are known to be using LTE technology at this time. No public safety organizations nationwide are currently using LTE technology.

Several cities, counties, and states nationwide are looking to deploy their own LTE networks for public safety and other agency use. Many of these will be built with Alcatel-Lucent LTE equipment since they are the largest of the vendors with LTE equipment available. The City of Boston is one of the cities looking to accomplish this. Boston is currently working with Alcatel-Lucent to design and implement an LTE network throughout the city. The city has currently applied for a waiver from the FCC to be able to use the 700 MHz D-Block spectrum for this build out. This would mean that Boston would own and operate the network without having to rely on a service provider to build out the infrastructure. Current estimates show that just six base station sites will cover the city. Public safety and other city agencies will initially be using the network for broadband data. The city will consider leveraging the network for voice in the future.

3.3.3.8 Expandability/scalability

As the network grows in terms of subscribers and applications, additional capacity is typically needed. LTE is a cellular technology and scales relatively easily. Additional base stations can be installed to handle the increased throughput demand from end-user LTE devices. These added base stations can put a greater load onto the core network systems servers, but these servers are designed to handle hundreds of base stations so no upgrades should be needed.

3.3.3.9 Backhaul

The backhaul for any part of the network can be upgraded by increasing the amount of bandwidth. Bandwidth can be added to individual sites by increasing capacity on existing microwave links or fiber infrastructure. Additionally, bandwidth can be increased by adding microwave links or adding fiber infrastructure to existing backhaul infrastructure.

3.3.3.10 Technology comparison

The following are strengths and weaknesses of LTE as compared to other technologies:

Strengths:

- LTE deployments target ubiquitous coverage within the United States. LTE is deployed by major U.S. carriers with nationwide cellular footprints, unlike proprietary technologies, such as Wi-Fi meshes, pre-WiMAX equipment, or unlicensed spectrum standards-based equipment (e.g., 802.11n), which are deployed in a piecemeal fashion by small or medium operators for specific applications in relatively small areas, such as airports and downtown city areas.
- LTE can support high-bandwidth applications such as streaming video. LTE provides 2 to 4 times higher bandwidths than even the most advanced cellular technologies in deployment today, including WiMAX, and while it has lower bandwidth than 802.11n (the highest throughput Wi-Fi technology), it has better coverage and higher throughput at high vehicular speeds. The Wi-Fi family of standards did not specifically target highly mobile applications.
- LTE will benefit from the economies of scale enjoyed by the GSM family of standards. New LTE devices, services, and applications will be developed faster and cheaper due to the fact that LTE is a standards-based technology and due to the world-wide footprint of GSM deployments (covering 86% of mobile phone connections worldwide), which will gradually upgrade to LTE.

Weaknesses:

- Achieving ubiquitous LTE coverage within the United States will take time. Unlike technologies such as Wi-Fi, and even WiMAX, LTE is normally deployed on a large scale by major carriers, who are the ones to decide when and where to deploy next.
- LTE spectrum may be shared with non-public safety devices. Performance will be affected when there are many users in the same area. However, the technology is capable of providing QoS and should thus be able to provide performance guarantees for public safety applications.

3.3.3.11 Standards adaptability

LTE is a standards-based technology and all LTE end-user devices (e.g., phones, laptops) should be able to use any LTE network (pending subscription for services with the relevant service providers).

In addition, LTE has an all-IP core network, which enables the efficient forwarding of TCP/IP traffic, IP-based services (e.g., end-to-end QoS), and allows different types of access technologies (wireless or wired) to be connected to the core network.

3.3.3.12 Costs associated with build-out

There are several costs associated with a tower site build out. Tower costs, site lease, and backhaul considerations can vary widely. The cost for a base station, antennas, and ancillary equipment is estimated to cost $500k. The cost for initial core network server systems is estimated to be $1.5 million, but is typically only a one-time cost. As more service providers, cities, and states deploy this equipment throughout the United States and the world, hardware costs will continue to decrease.

3.3.3.13 Other relevant attributes/issues

LTE does not have to deal with issues of co-existence with other technologies because the LTE spectrum is licensed and is fully controlled by the respective spectrum owners.

LTE is part of the GSM family of standards that cover 86% of mobile phone connections worldwide and is thus expected to be deployed in the same footprint or a bigger footprint than GSM-based technologies. As a result, its continued evolution is of significant importance to the major mobile carriers and equipment manufacturers around the world.

3GPP has already begun work on the next generation LTE, called LTE-Advanced, and plans to submit it to the ITU (International Telecommunications Union) as a proposal for fourth generation mobile technology (4G) in 2010 [12]. The target uplink data rates are 100 Mbit/s uplink for high mobility (350 km/h), and 1 Gbit/s for low mobility, and half those for downlink speeds. Immediate extensions of LTE include additional features and enhancements to support emergency services, location services, and broadcast services.

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4.0 Commercial service assessments

This section provides assessments of three commercial service providers, Verizon, AT&T, and A Better Wireless, based on their potential to provide public safety mobile data communication services to the state of Minnesota. Applications from Tiers 1, 2, and 3 can be deployed on these networks.

4.1 Verizon

4.1.1.1 Overview

Verizon currently operates a 3G mobile data network within the state of Minnesota and is expanding its network to offer advanced 4G services in some regions of the state. There are several differences between 3G and 4G services, with the main one being that 4G uses an IP only protocol for both voice and data. Because of this, much higher data transfer rates and high levels of QoS are possible. For 3G, Verizon uses technologies based on the CDMA2000 family of 3GPP2 standards. The 3GPP2 is the international set of mobile standards by which many major mobile providers operate throughout the world. CDMA2000 is a standard that has evolved from the cdmaOne standard defined by Qualcomm and is backward compatible with that standard. Universal Mobile Telecommunications System (UMTS) is a competing 3G standard to CDMA2000, and is the technology employed throughout the United States by AT&T. UMTS has become the dominant standard internationally, winning out over CDMA2000 in most countries.

3G technologies are based on code division multiple access (CDMA), a channel access method built by Qualcomm throughout the 1980's. In CDMA, voice transmission is circuit-switched while data transmission is packet-switched. Circuit switched communications are ones in which the base station sets up a specified channel with a client device, and only that client device can use that channel until it is released by the base station. Packet switched communications are ones in which the base station allows a client to use all channels at once, but for only an allotted amount of time. CDMA is a robust communications interface that is based upon spread spectrum technology and is inherently resilient to jamming and errors on the wireless medium. Like other technologies based on spread spectrum, CDMA occupies much more bandwidth than necessary to send data and uses a code to synchronize a subscriber to a tower. This effectively makes the technology resilient to errors, but not terribly efficient in terms of spectral efficiency. This code used in CDMA is different for each subscriber and is independent of the data that is being sent. Since each user has a different code, this allows multiple users to access the same frequency at the same time. CDMA has long been used by the military because it is suitable for encrypted transmissions and its

inherent immunity to interference and jamming. CDMA also allows for better subscriber handoffs between base stations since subscribers are capable of communication with multiple base stations at the same time.

Considering the need for public safety organizations to roam across regions and often to cross-jurisdictional boundaries, CDMA2000 networks are extremely favorable due to their ability to support roaming across large geographical areas. Cellular networks are typically arranged in an architecture where 7-8 base stations connect to a single Mobile Switching Office (MSO). The MSO then connects the cellular network to the Public Switched Telephone Network (PSTN). The cell site base stations typically connect to the MSO via a 1.4 Mbps T1 line, multiple T1 lines, or microwave radio links, depending on the location and subscriber density of each cell site. Over time, as cellular providers upgrade the capacity of the cell sites, backhaul tends to shift away from T-circuits and more towards microwave backhaul and higher capacity fiber based circuits. Cell site base stations use protocols that allow for hand-offs of a subscriber between cell sites, allowing subscribers to be mobile throughout a large network.

Currently, the network only supports equipment procured through Verizon. Verizon offers a variety of devices, including handsets, laptop cards, and a limited selection of vehicle mounted devices such as the Sierra Wireless modem.

In areas where the Verizon 3G service is available, the network typically offers download data rates of 1.4 Mbps. In real world scenarios, the actual throughput speeds are typically much slower and are based on a variety of factors such as distance from the tower, the application, radio characteristics of the client device, load of the base station, and utilization of the backhaul circuit that supports the base station.

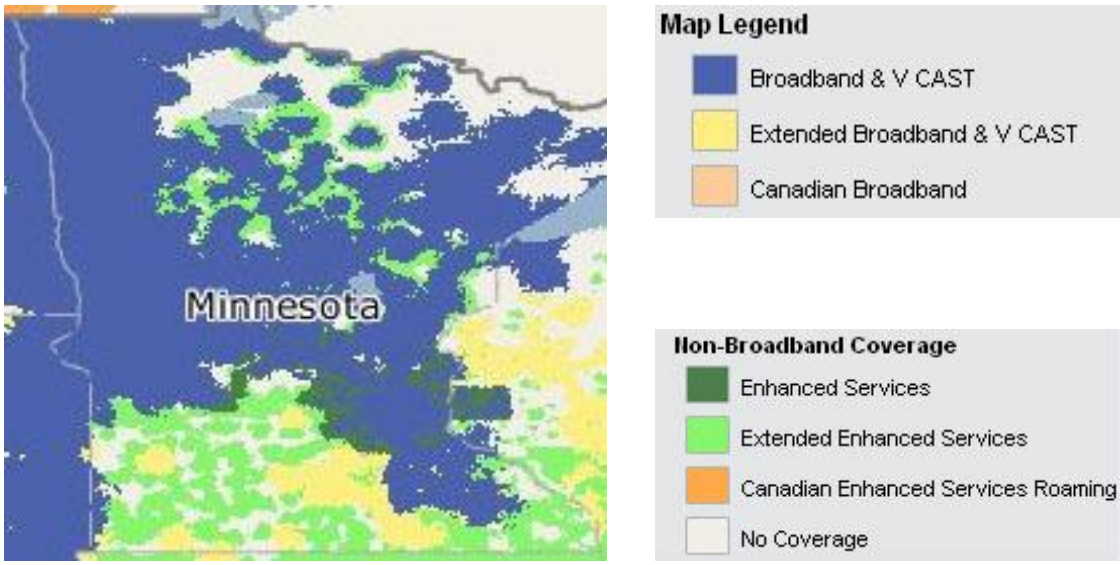
Verizon advertises the 4G network as having the potential to offer up to 20 Mbps downloads to subscribers. Like the advertised speeds of 3G services, the actual real world scenarios typically yield much different results than advertised speeds.

4.1.1.2 Data transport mechanism(s)

Verizon uses the 3GPP2 standard Evolution Data Optimized (EvDO) and EvDO Rev A (which increases the peak data transmission download speed to 3.1 Mbps, the peak upload speed to 1.8 Mbps, and enables telephony-based services such as voice, push-to-talk, and video telephony over a wireless IP network) for its 3G data network. The 4G data network is based upon the 3GPP standard for Long Term Evolution (LTE).

4.1.1.3 Coverage

Verizon has large areas of mobile broadband coverage throughout the state of Minnesota. The areas in and around Minneapolis and St. Paul, along the interstates, the central and western areas of the state support 3G, and some limited 4G, broadband services. Many rural areas of the state have very limited to no mobile broadband data coverage. Most rural areas of Minnesota will have limited data coverage and will typically only support basic SMS text messaging and e-mail services.



4.1.1.4 Applications

Applications from tiers 1, 2, and 3 can operate on this network.

4.1.1.5 Equipment

The state of Minnesota will need to have Verizon specific client devices in the form of laptop cards or handheld devices.

4.1.1.6 Implementation

Implementation timelines of client devices in areas that Verizon does not currently have coverage will likely be very long, if at all, since Verizon's network build-out is not influenced by the state of Minnesota. Verizon will control the deployment of subscribers onto the network and any expansion of its network.

A deployment schedule of client devices in the areas where Verizon already has coverage should be relatively short since the infrastructure is already in place and only client devices need to be implemented by the State.

Mobile broadband data services using Verizon client devices can be implemented quite easily by the state on a local and even regional level. Statewide implementation will be more difficult since Verizon does not offer mobile broadband services in all areas of the state. Verizon's network is designed to maximize subscribers rather than be robust and ubiquitous.

4.1.1.7 User assessment

It is unknown at this time if any agencies within Minnesota are using Verizon's mobile data services.

4.1.1.8 Expandability/scalability

Expansion of mobile data services with Verizon will be difficult. More client devices can be added at any time for users in existing coverage areas, but if geographic coverage needs to be expanded or more capacity added to existing base stations, this is totally under the control of the service provider and not the state.

As the network grows in terms of subscribers and applications, additional capacity is typically needed. Additional base stations can be installed to handle the increased throughput demand from end-user devices. The service provider is the party that performs these actions with little to no input from the state of Minnesota.

4.1.1.9 Backhaul

The backhaul for the whole network can be upgraded by increasing the amount of bandwidth available. The service provider is the party that performs these actions with little to no input from the state of Minnesota.

4.1.1.10 Technology comparison

Verizon's networks are well suited for low-bandwidth mobile users since the architecture of the network is designed specifically for mobility and roaming. This has a significant advantage over most other kinds of broadband data networks that have limited geographic range (Wi-Fi, WIMAX, and others).

The disadvantage of the Verizon data network compared to other broadband technologies is a less robust design, consistency of coverage, and network capacity. The state will also have less control of the deployment, coverage, capacity, operations and future of a Verizon network.

4.1.1.11 Standards adaptability

EvDO is a 3G technology standard defined by the 3GPP2 standards group under the CDMA2000 standard. EvDO is a CDMA technology with typical data rates around 1.4 Mbps. EvDO Rev A is an enhancement to the EvDO standard that allows for higher data rates. The coverage area of each EvDO version is approximately the same.

4.1.1.12 Costs associated with build-out

The costs associated with deploying this technology are limited to deployment of the initial client device and the monthly recurring service charges. Since deployment does not require an infrastructure build, large capital expenditures are avoided.

4.2 AT&T

4.2.1.1 Overview

AT&T currently operates a 3G mobile broadband data network within the state of Minnesota. AT&T uses technologies based on the UMTS family of 3GPP standards. The 3GPP is the international set of mobile standards by which many major mobile providers operate throughout the world. Universal Mobile Telecommunications System (UMTS) is a competing 3G standard to CDMA2000 and is the technology employed throughout the United States by AT&T. UMTS has become the dominant standard internationally, winning out over CDMA2000 in most countries.

The design of the AT&T network is similar to the Verizon network.

Currently, the network only supports equipment procured through AT&T. AT&T offers a variety of devices, including handsets, laptop cards, and a limited selection of vehicle mounted devices such as the Sierra Wireless modem.

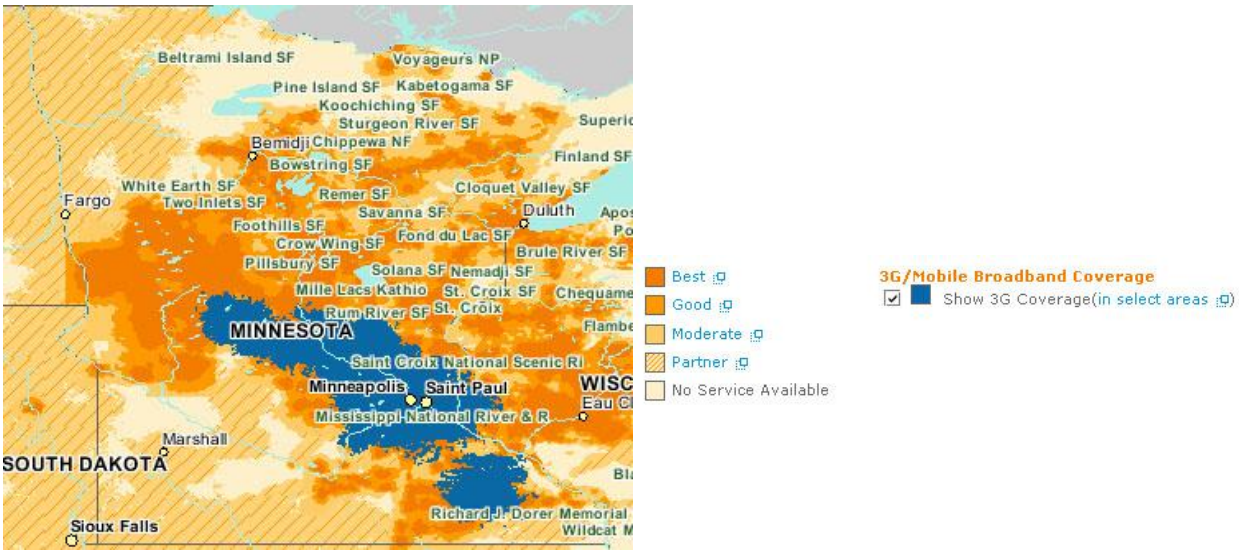
In areas where the AT&T 3G service is available, the network typically offers download data rates of 1.7 Mbps. In real world scenarios, the actual throughput speeds of the service are typically much slower and are based on a variety of factors such as distance from the tower, the application, radio characteristics of the client device, load of the base station, and utilization of the backhaul circuit that supports the base station.

4.2.1.2 Data transport mechanism(s)

AT&T uses the 3GPP standard High Speed Downlink Packet Access (HSDPA) for its 3G data network. HSDPA falls under the UMTS family of standards utilizing W-CDMA technology.

4.2.1.3 Coverage

AT&T has few areas of mobile broadband coverage throughout the state of Minnesota. The areas in and around Minneapolis and St. Paul and along portions of the interstates have mobile broadband coverage. Many rural areas of the state have very limited to no mobile broadband data coverage. Most rural areas of Minnesota will have limited data coverage and will typically only support basic SMS text messaging and e-mail services.



4.2.1.4 Applications

Applications from Tiers 1, 2 and 3 can operate on this network.

4.2.1.5 Equipment

The state of Minnesota will need to have AT&T specific client devices in the form of laptop cards or handheld devices.

4.2.1.6 Implementation

Implementation timelines of client devices in areas that AT&T does not currently have coverage will likely be very long, if at all, since AT&T's network build-out is not influenced by the state of Minnesota. AT&T will control the deployment of subscribers on and expansion of its network.

A deployment schedule of client devices in areas that AT&T already has coverage should be relatively short since the infrastructure is already in place and only client devices need to be implemented by the state.

Mobile broadband data services using AT&T client devices can be implemented quite easily by the state on a local and even regional level. Statewide implementation will be more difficult since AT&T does not offer mobile broadband services in all areas of the state. AT&T's network is designed to maximize subscribers rather than be robust and ubiquitous.

4.2.1.7 User assessment

It is unknown at this time if any agencies within Minnesota are using AT&T's mobile data services.

4.2.1.8 Expandability/scalability

Expansion of mobile data services with AT&T will be difficult. More client devices can be added at any time for users in existing coverage areas, but if geographic coverage needs to be expanded or more capacity added to existing base stations, this is totally under the control of the service provider and not the State.

As the network grows in terms of subscribers and applications, additional capacity is typically needed. Additional base stations can be installed to handle the increased throughput demand from end-user devices. The service provider is the party that performs these actions with little to no input from the State of Minnesota.

4.2.1.9 Backhaul

The backhaul for the whole network can be upgraded by increasing the amount of bandwidth available. The service provider is the party that performs these actions with little to no input from the state of Minnesota.

4.2.1.10 Technology comparison

AT&T's networks are well suited for low-bandwidth mobile users since the architecture of the network is designed specifically for mobility and roaming. This has a significant advantage over most other kinds of broadband data networks that have limited geographic range (Wi-Fi, WIMAX, others).

The disadvantage of the AT&T data network compared to other broadband technologies is a less robust design, consistency of coverage, and network capacity. The state will also have less control of the deployment, coverage, capacity, operations and future of an AT&T network.

4.2.1.11 Standards adaptability

UMTS is a standard defined by the 3GPP. HSDPA and HSUPA fall under UMTS and are considered 3.5G services, providing higher data rates than Enhanced Data rates for Global Evolution (EDGE) networks. These technologies are being deployed alongside EDGE networks, and deployments in the US are still underway and are not as widely deployed as EvDO Rev A networks.

4.2.1.12 Costs associated with build-out

The costs associated with deploying this technology are limited to deployment of the initial client device and the monthly recurring service charges. Since deployment does not require an infrastructure build, large capital expenditures are avoided.

4.3 A Better Wireless, NISP, LLC

4.3.1.1 Overview

A Better Wireless is a company providing wireless data services for residences, businesses, and public safety users to areas in and around Otter Tail County, Minnesota. Their data services are currently using unlicensed frequencies in the 900 MHz and 2.4 GHz bands. Their three current tower sites have 6 Mbps wireless backhaul links. All future tower sites will have 150 Mbps backhaul circuits, with 400 Mbps microwave links for redundancy.

A Better Wireless has indicated that they have secured financing to expand their network, and they are looking to start their initial expansion to the north of Otter Tail County. As part of their expansion, they are adding services in the 760 MHz to 780 MHz frequency range for public safety use only. It is unknown if they plan to use licensed or unlicensed frequencies. According to company officials, data rates are expected to be, at a minimum, 1.6 to 1.8 Mbps. They expect to build one to four towers in 2009, and add approximately four towers per year, for a maximum of 18 towers statewide.

For security, A Better Wireless uses a three-tier authentication of client devices onto their network, in conjunction with a specific agency's security schemes, such as virtual private network (VPN) and remote authentication dial-in user service (RADIUS).

4.3.1.2 Data transport mechanism(s)

A Better Wireless uses IEEE 802.11 protocols and IP protocols on their network. Both are standard protocols that have been in use for many years. The IEEE 802.11 protocol is a contention based protocol, meaning all subscribers are competing simultaneously for access to the base station.

4.3.1.3 Coverage

Currently, service is only available in and around Otter Tail County. They expect to extend service covering up to 91% of the state of Minnesota. They expect that this expansion will be complete by 2015. This current 900 MHz deployment is showing approximately 200 square miles covered per tower. Future deployments with 700 MHz are expected to see approximately 5500 square miles covered per tower, as indicated by preliminary field-testing of equipment and RF modeling.

4.3.1.4 Applications

Applications from all four tiers listed above can operate on this network.

4.3.1.5 Equipment

A Better Wireless provides in-vehicle client devices. These devices are designed to connect directly to a laptop or MDT via Ethernet. Since A Better Wireless owns the network infrastructure, no other devices are needed. A Better Wireless uses various off the shelf parts, such as mini-pci cards and industrial grade motherboards, to construct their own hardware platform.

4.3.1.6 Implementation

A Better Wireless owns the network infrastructure. Therefore, the company will control the implementation of its data services as well as the deployment of subscriber user radios on its network. The state would need to work with A Better Wireless to determine if a cooperative strategy for the design, deployment, and maintenance of a local, regional, or statewide public safety network and subscriber equipment could be achieved.

The state would also need to work with A Better Wireless to determine if a cooperative strategy for A Better Wireless to provide adequate and reliable coverage to required areas could be reached. A Better Wireless has indicated that they are open to input on these subjects from the state of Minnesota.

Once a deployment strategy is established, the implementation schedule should be relatively short since the infrastructure is owned by the service provider and the only thing that needs to be implemented by the State is client devices obtained through the service provider.

Currently, the state would only be able to deploy this technology locally, in Otter Tail County, where current infrastructure exists. The technology has the potential of offering regional or statewide coverage once A Better Wireless expands their network infrastructure.

4.3.1.7 User assessment

For the last three years, the City of Henning has been and is currently using the A Better Wireless 900 MHz data service in two of their patrol cars for report filing and access of online state resources. They are currently using Panasonic Toughbooks in their patrol cars connected to A Better Wireless device via Ethernet. The only issue they are having at this time is with their VPN timing out.

4.3.1.8 Expandability/scalability

As public safety needs increase, it will be up to the service provider to expand the network. A Better Wireless controls the build-out of additional wireless base stations to

increase coverage areas and the addition of transport capacity to each base station site. A Better Wireless has indicated that they are open to input from the state of Minnesota about the expansion of their network.

As the network grows in terms of subscribers and applications, additional capacity is typically needed. Additional base stations can be installed to handle the increased throughput demand from end-user devices. The service provider is the party that performs these actions and is open to input from the state of Minnesota.

4.3.1.9 Backhaul

The backhaul for the whole network can be upgraded by increasing the amount of bandwidth available. The service provider is the party that performs these actions and is open to input from the state of Minnesota.

4.3.1.10 Technology comparison

The technology that A Better Wireless currently uses offers higher data rates and lower latency (the amount of time it takes the information to get from one endpoint to another) than technologies offered by cellular service providers. Low latency is necessary for applications such as streaming video and voice. In addition, A Better Wireless is based in Minnesota and has indicated that their priority for the network is public safety usage.

Lacking in A Better Wireless' network are coverage area and licensed frequencies. Cellular service providers will cover a much larger geographic area than A Better Wireless' current implementation. If A Better Wireless were to use licensed frequencies, they could better control and address any interference issues that may arise in more urban areas.

Future build-outs by A Better Wireless promise to address the lack of geographic coverage area of their network, but will not be complete for at least five years. A Better Wireless plans to expand their network in phases by adding approximately four towers per year, but they do not yet know in which areas and in what order the deployment will occur.

4.3.1.11 Standards adaptability

A Better Wireless uses the IEEE 802.11 industry standard on their network. Any off the shelf equipment adhering to IEEE 802.11 protocols and operating in the 900 MHz or 2.4 GHz frequencies, such as WiFi laptop cards, should be able to attach to the network, after coordinating with A Better Wireless to meet their security scheme. This means that other agencies coming into A Better Wireless' coverage area could be able to access the network in times of emergency. Performance will most likely be reduced if using

client devices other than A Better Wireless' equipment since their equipment has been optimized for mobile in-car use on their network.

4.3.1.12 Costs associated with build-out

The costs associated with deploying this technology are limited mostly to deployment of the initial client device and the monthly recurring service charges. Since deployment does not require an infrastructure build, large capital expenditures are avoided. Client devices will have to be either purchased or leased, depending on the agreement worked out between the state of Minnesota and A Better Wireless. Initial cost estimates of client devices are approximately $1600 per vehicle. Monthly service charges are unknown at this time.

4.3.1.13 Other relevant attributes/issues

There are no spectrum or regulatory issues preventing the state of Minnesota from using A Better Wireless service. The fact that A Better Wireless is currently using unlicensed frequencies could pose some problems with interference and can potentially reduce the quality of service available by using this service. A Better Wireless' future network expansion seeks to address these interference issues by using frequencies in the 700 MHz band that are reserved for public safety use only, but this infrastructure is not built yet and the 700 MHz D-block, which is currently the block reserved for public safety use, has not been auctioned off for use yet.

5.0 Summary of characteristics

The following table summarizes key characteristics for each technology, including a high-level cost (initial capital and recurring) category for each.

Technology/ carrier	Spectrum	Data rate	App's	User or subscriber equipment	Open or proprietary	Architecture	Cost
Private systems							
Project 25	VHF, UHF, 700/800 MHz	up to 9600 kbps	Some Tier 1	LMR portables and mobiles	Open, many vendors	Local or wide area; single site, multi-site, multi-cast	Low (voice net-work in place)
M/A-COM OpenSky	700/800, 900 MHz	up to 19.2 kbps	Tier 1	LMR portables and mobiles	Proprietary	Cellular	Med
Motorola High Performance Data	700/800 MHz	up to 96 kbps	Tiers 1, 2	Mobile devices	Proprietary	Local or wide area; single site, multi-site, multi-cast	Med
CalAmp Dataradio	UHF, 700/800, 900 MHz	up to 128 kbps	Tiers 1, 2	Mobile devices	Proprietary	Local or wide area; single site, multi-site, multi-cast.	Low
WiMAX	10 MHz in the 2.5 GHz band	Up to 40 Mbps	Tiers 1, 2, 3, 4	Laptop cards or handheld devices	Open; currently very few vendors	Cellular; multiple base stations each with high capacity backhaul	Med
TD-CDMA	10 MHz in the 2.5 GHz and 700 MHz bands	Up to 15 Mbps	Tiers 1, 2, 3, 4	Laptop cards or handheld devices	Open; currently only 1 vendor	Cellular; multiple base stations each with high capacity backhaul	High
LTE	20 MHz in the 700 MHz band	Up to 50 Mbps	Tiers 1, 2, 3, 4	Laptop cards or handheld devices	Open; currently very vendors	Cellular; multiple base stations each with high capacity backhaul	Med

Commercial services						Minnesota coverage	
Verizon	Licensed	Up to 1.4 Mbps	Tiers 1, 2, 3	Provider specific laptop card		Regional; populated areas, some rural areas and Interstate highways	Med
AT&T	Licensed	Up to 1.7 Mbps	Tiers 1, 2, 3	Provider specific laptop card		Regional; populated areas and Interstate highways	Med
A Better Wireless	Unlicensed	Up to 5 Mbps	Tiers 1, 2, 3, 4	Provider specific car mounted client device		Local; currently Ottertail County	Med

The following table compares the strengths and weaknesses associated with each of the alternatives in this report for each characteristic.

Characteristic	Project 25	M/A-Com OpenSky	Motorola HPD	CalAmp Dataradio	WIMAX	TD-CDMA	LTE	Verizon	AT&T	A Better Wireless
	S = Strength W = Weakness									
Spectrum	S	S	S	S	W	W	S	S	S	W
Data Rate	W	W	W	S	S	S	S	S	S	S
Application Tier	W	W	W	W	S	S	S	S	S	S
User or subscriber equipment	S	S	S	S	S	S	S	S	S	W
Open or proprietary	S	W	W	W	S	S	S	W	W	W
Architecture	S	W	S	S	W	W	W	W	W	W

Minnesota Public Safety Interoperable Wireless Data Feasibility Study

FCC D-Block Report and Assessment

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1.0 Introduction

1.1 Overview

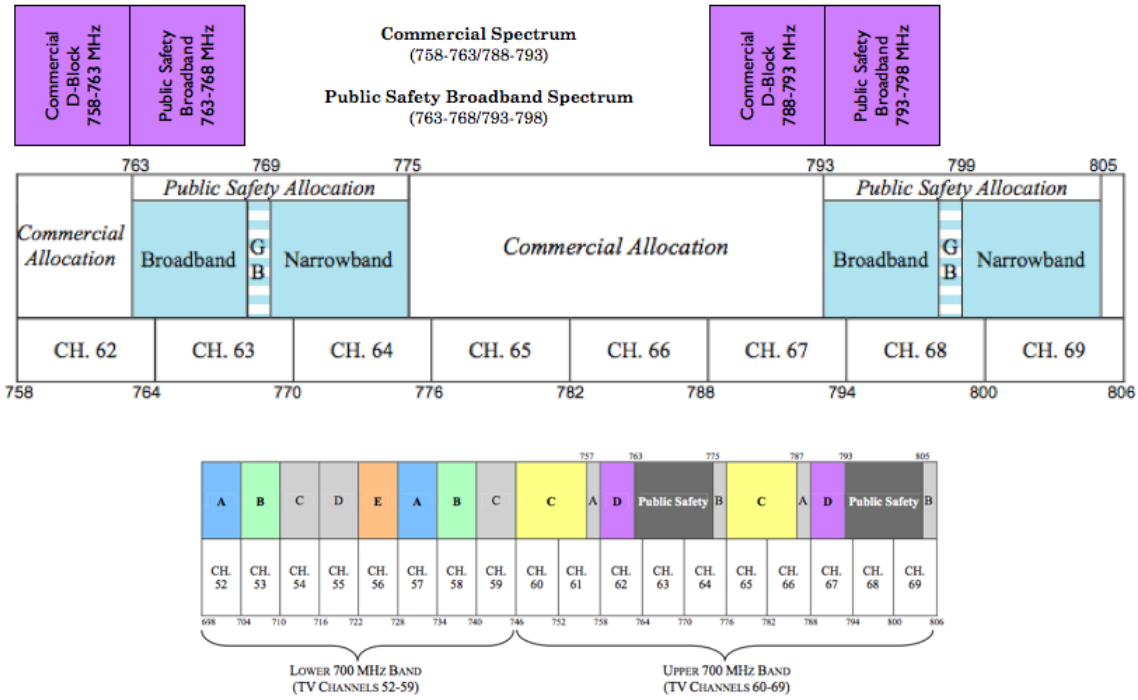
The "700 MHz D-Block" is spectrum that is a part of the "Upper 700 MHz band." The 700 MHz D-Block was part of Federal Communications Commission (FCC) Auction 73, which was a result of Senate Bill 1932, Title 3, *The Digital Television Transition and Public Safety Act of 2005*.

The following is an excerpt from the Federal Communications Commission's (FCC) Auction 73 website:

> *This spectrum is part of the 698-806 MHz band ("700 MHz Band"), which has been occupied by television broadcasters and is being made available for new commercial and public safety services as a result of the digital television (DTV) transition. In prior proceedings, the Commission considered the 700 MHz Band in two parts, 698-746 MHz (the "Lower 700 MHz Band") and 746-806 MHz (the "Upper 700 MHz Band"). The Commission previously assigned licenses for the Lower 700 MHz Band C and D Blocks (Auctions 44, 49, and 60) and for the Upper 700 MHz Band A and B Blocks (Auctions 33 and 38). The Commission previously announced and later postponed the auction of licenses for the remaining blocks (see Auctions 31 and 44). Licenses for the remaining blocks — the Lower 700 MHz Band A, B, and E Blocks, and the Upper 700 MHz Band C and D Blocks — will be offered in Auction 73.*
>
> *Auction 73 includes 1,099 licenses in the 700 MHz Band: 176 Economic Area (EA) licenses in the A Block, 734 Cellular Market Area (CMA) licenses in the B Block, 176 EA licenses in the E Block, 12 Regional Economic Area Groupings (REAG) licenses in the C Block, and 1 nationwide license, to be used as part of the 700 MHz Public/Private Partnership, in the D Block.*

Figure 1 below shows the allocation of spectrum for the 700 MHz D-Block. There are two allocations within the D-Block: 10 MHz for commercial use and 10 MHz for public safety use.

Figure 1 - 700 MHz D-Block spectrum allocation



1.2 History

Several significant events contributed to the formation of the 700 MHz D-Block and the associated public safety spectrum. Most importantly, the events of September 11, 2001, highlighted the need for a nationwide, interoperable public safety network. This need was formalized in the *9/11 Commission Report*, which was published on July 22, 2004. On August 29, 2005, the events of Hurricane Katrina and the subsequent failure of the New Orleans levee system highlighted this need further, as public safety communications systems were found to be insufficient during rescue and disaster recovery. Just a few months later, the U.S. Senate passed Senate Bill 1932, Title 3, *The Digital Television Transition and Public Safety Act of 2005*. This Senate Bill mandated the nationwide transition to digital television and the allocation of new spectrum for public safety use. On

August 10, 2007, the FCC released the *Second Report & Order* (*Second R&O*) which established new service rules for the 698-806 MHz bands (Channels 52-69 of the vacated analog TV channels).

The FCC *Second R&O* specified the new band plan, commercial build-out requirements, and some service rules specific for certain bands (such as the open access provisions for the Upper 700 MHz C-Block). Specific to the D-Block, a Network Sharing Agreement (NSA) framework for a public/private partnership between a commercial licensee and a public non-profit organization, known as the Public Safety Spectrum Trust (PSST), was established. This order established a spectrum auction date to begin on or before January 28, 2008, entitled "Auction 73." The *Second R&O* was adopted on July 31, 2007.

According to the FCC, the goals of the *Second R&O* were the following:

1. To facilitate next generation wireless broadband services in both urban and rural areas;
2. To establish a public/private partnership to deploy a wireless broadband network for public safety that will address the interoperability problems of today's system; and,
3. To provide a more open wireless platform that will facilitate innovation and investment.

Commissioner Kevin J. Martin was a strong advocate for the D-Block, and believed that the public/private partnership was the appropriate solution to "address the interoperability problems of today's system." As defined in the *Second R&O*, the FCC required that the nationwide public safety system be interoperable and based on a single, nationwide licensing scheme. This licensing scheme was a deviation from the regional approaches typically employed by the FCC. Additionally, although no single technology was mandated in the *Second R&O*, it generally required a modern, "IP-based system architecture" that would provide sufficient capacity, reliability, security, and quality of service consistent with public safety operations.

The FCC defined three population-based build-out benchmarks as a requirement of the *Second R&O*. Table 1 shows these build-out requirements.

Table 1 - FCC defined build-out requirements, *Second R&O*

Year of the build-out	Population coverage requirements
Year 4	75%
Year 7	95%
Year 10	99.3%

These build-out requirements defined the most aggressive build-out specification for a wireless network ever considered.

1.2.1 Auction 73

As a basis to set reserve prices for Auction 73, the FCC used the previous Advanced Wireless Services (AWS-1) auction (Auction 66) as a guide. Auction 66 occurred in late 2006. The AWS-1 spectrum consists of the 1710-1755 MHz and 2110-2155 MHz bands. In Auction 66, 104 bidders won 1087 licenses for a total net of $13,700,267,150.

Auction 73 commenced on January 24, 2008, and closed on March 18, 2008. It raised a total of $19,120,378,000 in winning bids for the A, B, C, and E blocks with each exceeding the minimum reserve price. A total of 101 bidders won 1090 licenses. However, the single bidder for the Upper D-Block did not meet the $1.33-billion reserve price, and thus there was not a winning bid. The only bid for the Upper D-Block was from Qualcomm at $472,042,000. The D-Block was the only unsuccessful spectrum block of Auction 73.

1.2.2 Post auction investigations

The FCC drew much criticism from industry analysts due to the failure of the D-Block to meet the FCC reserve price. Specific allegations led to two separate investigations by the Office of Inspector General (OIG).

Investigation #1

The first OIG investigation began on March 20, 2008, and was based on allegations that Cyren Call Communications Corporation, the representative for the PSST, discouraged potential bidders from participating in the D-Block Auction

(Auction 73) by openly discussing terms of the Network Sharing Agreement. The original allegations surfaced in online blogs and newspapers and led to a formal letter sent to the FCC by Harold Feld, Senior Vice President of the Media Access Project (MAP) and a representative of the Public Interest Spectrum Coalition (PISC), requesting the FCC to investigate these allegations.

The Harold Feld letter alleged that Cyren Call discussed lease payments with potential bidders, including Frontline and Verizon. The letter specifically called into question "a purported meeting between Frontline Wireless (Frontline), its financial backers, and Morgan O'Brien of Cyren Call that may have had the effect of preventing Frontline from attracting needed capital and discouraging other bidders."

On April 25, 2008, the initial OIG report was released. This report concluded that the lease payments discussed at the Frontline and Verizon meetings ($50M to $55M per year over 10 years) were only one contributing factor of many as to why the D-Block bid did not meet the minimum reserve price. Frontline Wireless, as well as other bidders, claimed that other issues significantly contributed to the decision to not bid on the spectrum. These issues included the aggressive build out schedule and related costs, unclear negotiation framework with the PSST, and the lack of clarity regarding default payment requirements if negotiations failed.

This OIG report cleared Cyren Call of any wrongdoing.

Investigation #2

The second investigation began on May 23, 2008, and included a request by the U.S. House of Representatives Committee on Energy and Commerce to investigate whether the relationship between Cyren Call and the PSST was consistent with the Commission rule which prohibits entities from holding commercial interests in the Public Safety Broadband Licensee (PSBL). The request for investigation also asked whether "any future, post-auction plans by Cyren Call...including any plans to create or be involved with a mobile virtual network operator...would violate the [rule's] prohibition."

The OIG has not concluded this second investigation.

2.0 Further Notice of Proposed Rulemaking

Because of the failed 700 MHz D-Block auction, the FCC released the *Second Further Notice of Proposed Rulemaking* on May 14, 2008. The FCC sought public comment on how the Commission should proceed with the re-auction and licensing of the 700 MHz D-Block spectrum while maximizing the public safety and commercial benefits of a nationwide, interoperable broadband network.

A public comment period was open until June 20, 2008. On September 25, 2008, the FCC released the *Third Further Notice of Proposed Rulemaking* identifying new revisions for the public/private partnership for a nationwide interoperable public safety network. The modified service rules and framework of the public/private partnership includes the following:

- Significantly relaxed build-out requirements.
- More flexible frequency allocations between the commercial segment and the public safety segment. Operators may use the aggregate spectrum as a shared resource.
- Eligibility is not restricted, and there is no set reserve price beyond the opening bid.
- The rules clarified default payment liability and included a provision that the licensee will not be liable for default payments if:
    - The FCC does not approve the Network Sharing Agreement (NSA) because of any other party's failure to execute the NSA; or,
    - The Commission concludes that there is no acceptable resolution to a dispute regarding terms to be included in the NSA.
- The rules provide that an award can go to the second highest bidder in the event that the highest bidder cannot enter in to a NSA or for any other reason.

The *Third Further Notice of Proposed Rulemaking* calls for three simultaneous auctions to be held mid-2009 as follows:

1. A single nationwide license.

2. A nationwide set of Public Safety Region (PSR) licenses for 58 regions conditioned on the use of Long Term Evolution (LTE) technology. PSRs will mirror the geographic boundaries of the existing 700 MHz Regional Planning Committees.

3. A nationwide set of PSR licenses for 58 regions conditioned on the use of Worldwide Interoperability for Microwave Access (WiMAX) technology.

(Long Term Evolution is the next generation cellular technology undergoing standardization. LTE is the next step in the evolution of the Global System for Mobile communication (GSM) family of standards, which currently account for 86% of mobile phone connections worldwide. Worldwide Interoperability for Microwave Access (WiMAX) is a brand name for the technology that utilizes the Institute of Electrical and Electronics Engineers (IEEE) 802.16 standard.)

If there is a winner for the nationwide auction, that winner will choose the technology to be used and will be issued the license covering all areas of the country. If there is not a winner for the nationwide license, the regional bids will be evaluated. Whichever auction has a sufficient number of bids on enough regions will win the auction, that auction's technology (LTE or WiMAX) will be selected, and the remaining regions will be auctioned again (for that technology) to find winning bidders.

The 58 geographic regions will mirror the 55 Regional Planning Committees for 700 MHz (Figure 2) plus three additional areas as follows:

1. Gulf of Mexico

2. Guam and the Mariana Islands

3. American Samoa

The winning scenario will offer the greatest aggregate population coverage. In the event that multiple bids cover the same aggregate population, the spectrum will be awarded to the highest bidder.

Figure 2 - 700 MHz Regional planning committees map

The FCC significantly reduced population-based build-out benchmarks in the *Third Further Notice of Proposed Rulemaking*. These can be compared against the *Second Further Notice of Proposed Rulemaking* in Table 2.

Table 2 - FCC defined build-out requirements comparison

Year of the build-out	Population coverage requirement (*Second Further Notice*)	Population coverage requirement (*Third Further Notice*)
Year 4	75%	40%
Year 7	95%	No Year 7 requirement
Year 10	99.3 %	75%
Year 15	No Year 15 requirement	Less than100 people per square mile = 90% 100-500 people per square mile

		= 95% Greater than 500 people per square mile = 98%

3.0 Potential

The upcoming auction of the 700 MHz D-Block is likely to end with one of the following four scenarios:

1. Nationwide license with LTE
2. Nationwide license with WiMAX
3. 58 Regional licenses with LTE (with each region potentially licensed by a different bidder)
4. 58 Regional licenses with WiMAX (with each region potentially licensed by a different bidder)

Congress recently delayed the Digital Television Transition from February 17, 2009, to June 12, 2009. The delay is to eliminate problems with the Commerce Department's DTV converter box coupon program. The delay of the DTV transition will likely have little to no additional impact on the deployment timeline of a nationwide public safety broadband network.

3.1 Data transport mechanism(s)

The FCC has proposed that the winning bidder(s) implement a NSA that would define the technology standard and its technical specifications. The FCC has indicated that the standard used be either WiMAX or LTE.

3.2 Coverage

The 700 MHz D-Block is expected to be implemented in a cellular architecture. Coverage areas are expected to be larger than current cellular coverage areas for 3G networks, needing fewer towers for geographic coverage based on the longer propagation characteristics of 700 MHz as compared with higher frequency 3G systems. Cell sizes may need to be smaller in more densely populated urban and suburban areas to accommodate more subscribers where higher capacity cells are required.

3.3 Applications

Both WiMAX and LTE are IP-based systems, which will accommodate all ‘Tiers’ of potential public safety applications.

Tier 1 - “Text” applications (Up to 19,200 bps, or 19.2 kbps)

- Messaging
- Dispatch (CAD)
- Text messaging
- Query databases
  - Driver’s license
  - License plates
  - Warrants
- Low cadence automatic vehicle location (AVL)

Tier 2 - “Still Image” applications (Up to 96 kbps, 25 kHz channels)

- Includes Tier 1
- Field reporting
- Still image transfer
  - Mug shots
- High cadence AVL
- Fingerprints (Inbound only)
- Intranet

Tier 3 - “Browser” application (Up to 230 kbps, 50 kHz channels)

- Includes Tiers 1 and 2
- Internet access
- Images (transmit and receive)
- Video (low speed)

Tier 4 - “Multimedia” applications (megabits (millions of bits per second, or Mbps))

- Includes Tiers 1-3
- Desktop computer applications
- Video (full motion)
- VoIP (voice over IP)
- IPTV (internet protocol television)
- Multimedia

3.4 Equipment

Both LTE and WiMAX network architectures would consist of multiple base stations and microwave/fiber backhaul to interconnect them. On the client side, a mobile device would be used, such as an integrated handset, laptop card, mobile consumer premises equipment, scanner, or other LTE or WiMAX enabled device.

3.5 Implementation

Implementation of the 700 MHz D-Block network will be the responsibility of the winning bidder(s), per the terms of the public/private partnership. Deployment schedules may vary since many base stations will be needed for the ubiquitous coverage required for public safety use. Factors such as lease negotiations, tower construction, base station installation, and network integration will all affect deployment timelines. Due to the FCC build-out requirements, it is likely that installation in the most populous areas will have priority over less populous areas.

3.6 Current technology user assessment

Since 700 MHz is a newly allocated spectrum for broadband use, no agency is currently using broadband technologies in the 700 MHz spectrum. Currently, Verizon is deploying LTE in the 700 MHz A-Block using Alcatel-Lucent base stations for their 4G network services. AT&T Mobility also has plans to deploy LTE for their 4G network services.

3.7 Expandability/Scalability

3.7.1 Coverage

As the needs of public safety entities grow, expansion of the network will be subject to the terms of the NSA/public/private partnership. Although services in the D-Block will be administered by a private sector, commercial entity, the interest of public safety should be well represented through the PSST. Although the specific rules of the NSA are not yet established, it is assumed that the PSST would have the ability to identify coverage gaps and request that the network operator add base stations to increase geographic coverage.

A D-Block LTE/WiMAX base station will achieve better radio coverage than existing cellular and Wi-Fi technologies due to the lower frequencies to be used (i.e., 700 MHz for D-block as compared to 800 MHz and above for cellular networks, 2.5 GHz for WiMax, and 2.4 GHz and above for Wi-Fi).

Theoretically, cell sizes are expected to be around 3 miles, with possible speeds up to 18 miles and even 60 miles (in ideal situations) but with performance degradation for larger cell sizes. Actual deployment experience may reveal that cell sizes need to be smaller to achieve peak throughput, especially in urban areas.

3.7.2 Capacity

Capacity can be increased according to the terms of the public/private partnership by increasing the amount of backhaul bandwidth available to the base stations and/or the core network.

3.7.3 Backhaul

The backhaul for these networks will be terrestrial fiber optics high-capacity microwave, which are the most commonly available networks for this purpose.

3.8 Technology comparison

The 700 MHz D-Block is ideal for mobile applications since carriers will deploy either LTE or WiMAX, both of which are designed for mobile use and high data rates. Since 700 MHz is a lower frequency band than the frequencies used for most high bandwidth systems, propagation will be better, allowing for better building penetration and creating more ubiquitous coverage areas.

Currently there are only a few vendors, such as Alcatel-Lucent, that make equipment for LTE or WiMAX in the 700 MHz band. More equipment options are expected later in the year.

3.9 Standards adaptability

The equipment operating in 700 MHz will most likely adhere to standards defined by the 3rd Generation Partnership Project (3GPP) for LTE or the Institute of Electrical and Electronics Engineers (IEEE) for WiMAX.

3.10 Costs associated with build-out

Equipment costs for 700 MHz D-Block systems have not yet been established, yet typical base station costs are presumed to be in the range of $500k, based on current cellular equipment. This number is for base station equipment and installation only. Other types of costs involved are lease agreements for tower sites, the amount of work needed to upgrade existing towers, new tower builds, and other associated costs such as shelters, back-up, power, interconnection, etc. New towers can range anywhere from $50k to $150k, depending on the size and height of the tower.

Client devices can vary widely in cost depending on the device type. Client devices can be anything from handheld devices to vehicle mounted client devices. For example, a typical USB card for a laptop could range from approximately $100 - $500, equivalent to current handheld 3G devices.

3.11 Other relevant attributes/considerations

The 700 MHz D-Block has not yet been successfully auctioned. The FCC is planning another auction with revised terms for mid-2009, but no date has been set. No build-outs using this spectrum can begin until the spectrum has been successfully auctioned off and the proper agreements in place, such as the Network Sharing Agreement.