Minnesota
VHF/UHF Interoperability Infrastructure Planning Project
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FINAL REPORT

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"Unleashing the Power of Technology"

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Executive Summary

Minnesota's Statewide Communications Interoperability Plan (SCIP) identified a need for the state to develop a plan to provide an interoperability infrastructure linking existing and future public safety radio systems within and adjacent to Minnesota. The primary public safety, interoperability radio system in Minnesota is the Allied Radio Matrix for Emergency Response (ARMER). ARMER is a 700/800 MHz, Project 25 (P25) standards-based radio system that ultimately offers the highest level of interoperability possible to state, local and regional radio users in Minnesota. The SCIP also recognizes that not all local or regional radio users will join ARMER and envisions leveraging the investment in ARMER by utilizing the ARMER backbone to support additional interoperability infrastructure. This interoperability infrastructure will be one facet of the plans used to address interoperability between disparate systems in the state and adjacent jurisdictions.

The Department of Homeland Security, through the SAFECOM program, lists five basic technical approaches to achieve communications interoperability ranging from basic (Level 1) to advanced (Level 5) solutions. These are:

- Level 1 - Swap radios
- Level 2 - Gateways
- Level 3 - Shared channels
- Level 4 - Proprietary shared systems
- Level 5 - Standards-based shared systems

The State of Minnesota contracted Federal Engineering (***FE***) to assess the options for providing the highest practicable level of interoperability throughout the state. In this report, ***FE*** outlines several conceptual approaches, shown in Table 1, to provide an interoperability infrastructure in Minnesota. ***FE*** met with the Statewide Radio Board Interoperability Committee (SRBIC), the six regional radio advisory committees (RACs) and the Metropolitan Emergency Services Board (MESB) Technical and Operations Committee (TOC) to review these approaches and to elicit feedback and comments from radio system users regarding the attributes of each conceptual approach.

Table 1 – Interoperability infrastructure solutions

Approach	Description	Interoperability Level[1]
Donor radios	**ARMER radios installed in local dispatch centers**	**1-2**
Dedicated connections	**Direct audio connections between dispatch centers**	**2**
Radio over IP (RoIP)	**Voice over IP systems connecting existing radio channels**	**2**
Interoperability overlay	**Common, dedicated interoperability channels statewide**	**3**
Hybrid	**A combination of two or more of the above**	**1-3**

Based on feedback from these meetings, interoperability plans already in place and conversations with staff from the Division of Emergency Communication Networks and the Department of Transportation, ***FE*** recommends a hybrid solution using two of these approaches to provide a supplemental cross spectrum interoperable infrastructure to ARMER. The state can implement a hybrid solution in a phased manner while also meeting a majority of the interoperability needs of the state. The recommended hybrid solution includes the following primary components operating in the two predominant radio bands, VHF (150-174 MHz) and 800 (806-854 MHz), in use within and adjacent to Minnesota:

1. ARMER donor radios
2. VHF/800 MHz interoperability channel overlay

The ARMER donor radios provide dedicated radios to local dispatch centers to allow ARMER users to communicate directly with local dispatchers and users that remain on local VHF systems. This approach can provide Level 2 interoperability (gateway) between ARMER users and local VHF radio system users when donor radios are integrated into local radio dispatch consoles and when the ARMER and local VHF radio system users are within the coverage areas of their respective systems.

[1] As defined in the SAFECOM interoperability continuum.

A VHF/800 interoperability overlay resolves interoperability issues between VHF and ARMER system users within the state and in adjacent states and provinces. The VHF/800 interoperability overlay, comprised of a limited number of common radio channels deployed at strategic locations throughout the state, provides a communications safety net or lifeline allowing conventional VHF or conventional 800 MHz radio users traveling outside the coverage of their primary radio systems to contact local and state dispatch centers.

These solutions could be implemented independent of the other. However, finalizing the plan for deployment of these interoperable solutions as an integrated system would be more effective and would minimize the potential for stranded investments that could occur without such a plan. An initial deployment strategy that incorporates the capabilities of both solutions at a system level may allow for reduction in costs and a reduction in the operational complexity by eliminating or reducing the need for ancillary equipment required to integrate the two components retroactively.

FE further recommends the following steps be included in the plan of action to provide an interoperability infrastructure in Minnesota.

1. The deployment of ARMER donor radios to local dispatch centers should continue in order to address day-to-day interoperability issues that exist between agencies that remain on VHF systems that still need to communicate with ARMER trunked radio system users.
2. Work should commence immediately on the design and deployment of the VHF/800 interoperability overlay to address incident based interoperability issues for conventional VHF or conventional 800 MHz radio users traveling outside the coverage of their primary radio systems within the state.
3. The state should implement the hybrid solution as a pilot project in the ARMER phase 3 region (23 counties of central and southeastern Minnesota) to test and refine the design prior to deployment in ARMER phases 4, 5 and 6.

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1. Introduction

In 2007, the Minnesota Department of Public Safety, Division of Emergency Communication Networks (DPS) coordinated the development of a State Communication Interoperability Plan (SCIP) consistent with criteria adopted by the U.S. Department of Homeland Security (DHS). The SCIP provided an overview of the status of interoperability in Minnesota and outlined several steps toward enhancing interoperability throughout the state.

The foundation for public safety radio interoperability in Minnesota is the Allied Radio Matrix for Emergency Response (ARMER). ARMER is a 700/800 MHz, trunked, P25 standards-based shared radio system that ultimately offers the highest level of interoperability state, local and regional agencies in Minnesota that join ARMER. Over $150 million in state and local funds was originally invested in the ARMER project for the Twin Cities metropolitan area. In 2005, an additional $45 million was appropriated to expand ARMER into 23 counties of central and southeastern Minnesota. In 2007, the legislature appropriated another $186 million to fund the continued expansion of ARMER to the remaining counties in the state with a projected completion date of late 2012. Recognizing that not all local or regional radio users will join ARMER, the SCIP also laid out the vision to leverage the investment in the ARMER system by utilizing the backbone to support additional interoperability infrastructure. This additional interoperability infrastructure would be one facet in the state's overall plans to address interoperability between legacy systems in the state and adjacent jurisdictions (primarily VHF) and between legacy systems and ARMER system users.

2. Interoperability basics

As shown in Exhibit 1, the Interoperability Continuum developed by SAFECOM indicates that an agency's level of interoperability improves as they address five key criteria. Interoperability improves as an agency or group of agencies makes progress on each of these criteria or "lanes" as defined by SAFECOM. These interoperability lanes are characterized as follows.

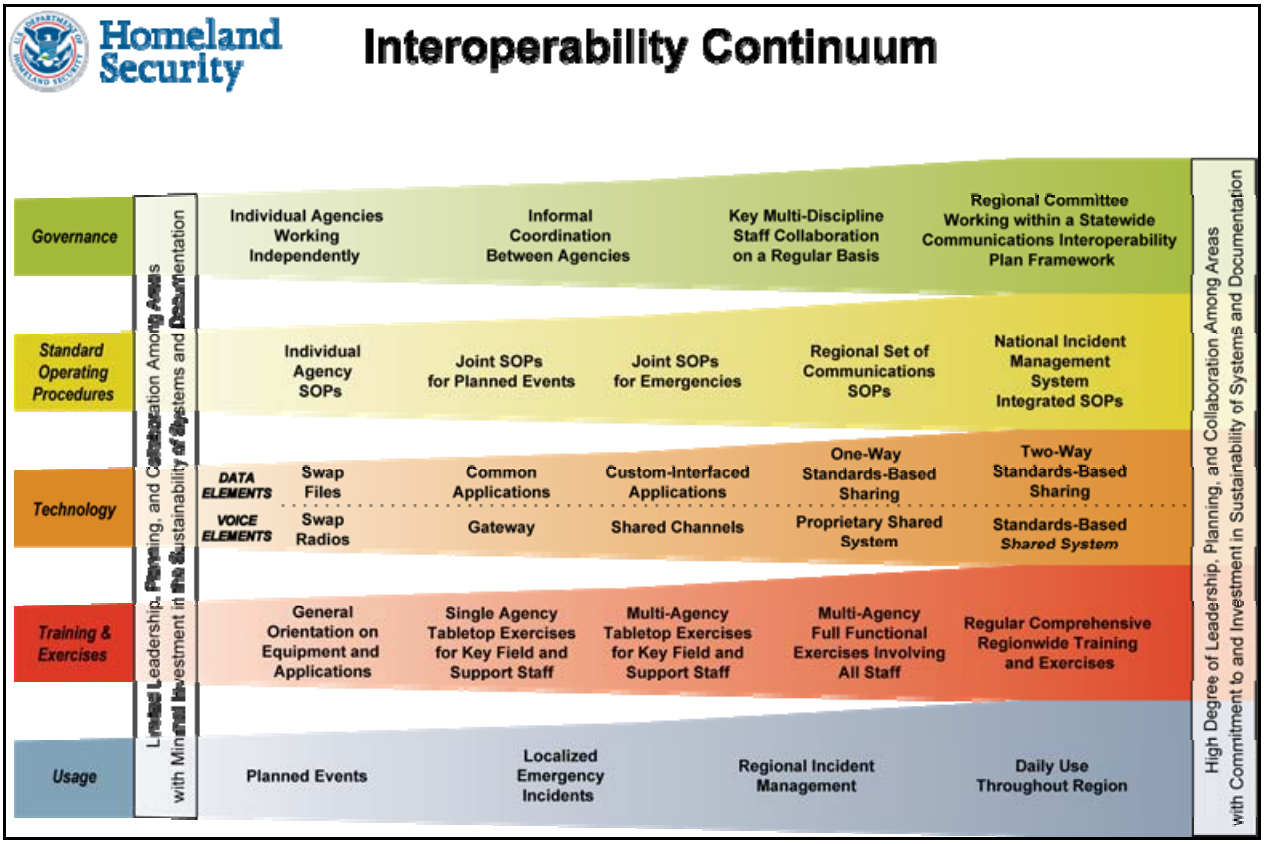

Exhibit 1 - SAFECOM Interoperability Continuum[2]

<u>Governance</u>

Interoperability improves as structured coordination and collaboration between agencies and disciplines improve. A formal governance structure is key to the success of

[2] http://www.safecomprogram.gov/NR/rdonlyres/54F0C2DE-FA70-48DD-A56E-3A72A8F35066/0/Interoperability_Continuum_Brochure_2.pdf

interoperable communications projects and the structure should include local, tribal, state, and federal entities from all pertinent public safety disciplines within the region.

Standard operating procedures

Interoperability is enhanced by the development of standard operating procedures (SOPs) governing the use of interoperable resources in day-to-day operations and emergency incident management. This becomes especially important when interoperable resources are available on a regional or statewide basis. Ultimately, these SOPs should also be consistent with the procedures detailed in the National Incident Management System (NIMS).

Training and exercises

The successful use of interoperability solutions requires training in the proper utilization of those resources and then testing of that training through regular local, regional and state exercises.

Usage

The highest level of interoperability is achieved when interoperable resources can be easily accessed and are utilized on a day-to-day basis.

Technology

This project is focused upon the technology lane that specifies five basic technology approaches to achieve communications interoperability ranging from basic (Level 1) to advanced (Level 5) solutions. Those approaches are:

- Level 1 - Swap radios
- Level 2 - Gateways
- Level 3 - Shared channels
- Level 4 - Proprietary shared systems
- Level 5 - Standards-based shared systems

While technology is integral to achieving improved interoperability, a successful solution must also address the following criteria:

- Needs of the end users
- Communications environments in different regions

- Capabilities of existing support infrastructure
- Cost of the technology versus the improved interoperability it would provide
- Sustainability and maintainability of the technology
- Scalability to support day-to-day incidents as well as larger, multiple agency incidents
- Security and access management

The ARMER system, a P25 standards-based shared radio system, offers the highest technical level of interoperability infrastructure to state, local and regional radio users in the state of Minnesota. However, there is a recognition that a number of public safety agencies have made prior, significant investments in non-ARMER resources and that many local or regional radio users are not currently prepared to join ARMER. Furthermore, ARMER does not inherently improve interoperability with adjacent states and provinces. Therefore, Minnesota is committed to consider approaches that address interoperability between legacy systems in the state and adjacent jurisdictions (primarily VHF) and between legacy systems and ARMER. A similar interest in adopting a final interoperability approach or solution that leverages or builds upon the investment in ARMER to the maximum extent possible is also a primary consideration. The following sections outline several conceptual approaches presented and considered for Minnesota to develop a strategy for development of an interoperable infrastructure that meets these requirements.

3. Donor radio connections to ARMER

In this approach, shown in Figure 1, local or regional systems use fixed ARMER 700/800 MHz radio control stations installed in local or regional public safety answering points (PSAPs) or dispatch centers to communicate with ARMER users on a trunked talk group or groups. The fixed radio control stations, if integrated into local or regional dispatch console systems, also provide the option of connecting or patching ARMER talk groups to local or regional radio resources.

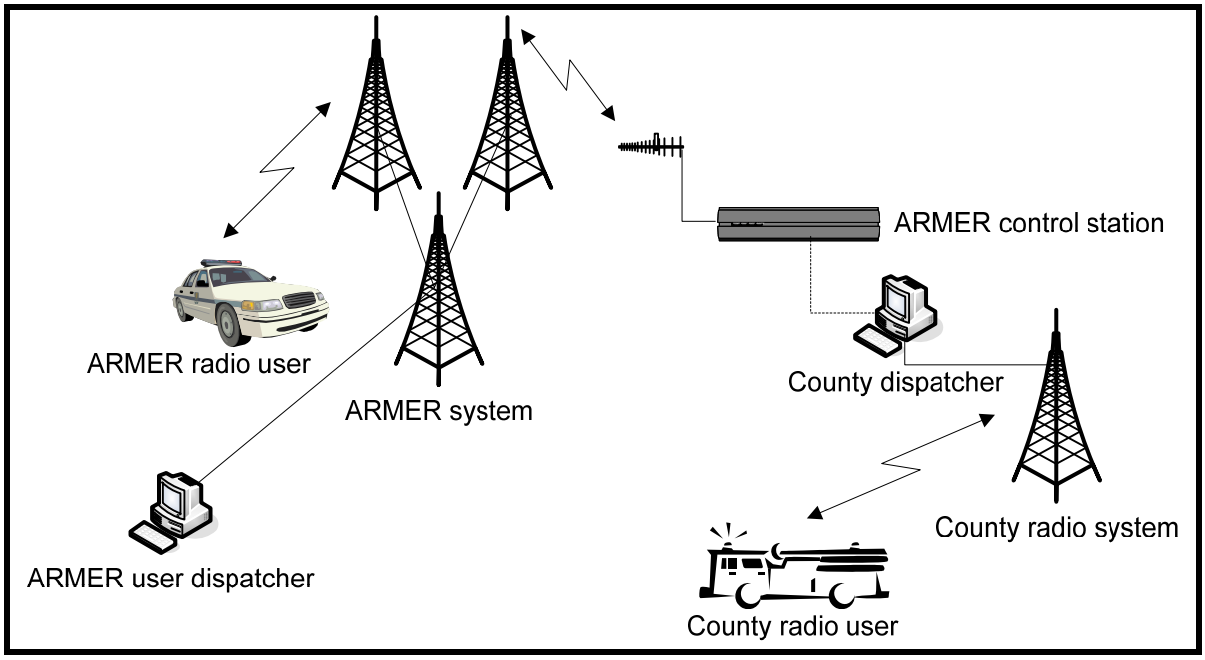

Figure 1 - Donor radio connection to ARMER

Local and regional users have a single interoperable communications path per radio control station to ARMER users and a dispatcher must relay information or patch radio traffic together for this approach to be effective. Since this solution does not add separate radio channels or capacity to the statewide, regional or local user's primary radio system, it adds traffic to these existing systems if they interconnect through console patches or other gateways. The use of compatible radios and dispatch console equipment may also allow the use of additional radio features such as access to multiple modes or scanning though scanning may be of limited operational value in this configuration.

The donor radio approach provides basic Level 1 (swap radios) interoperability in the SAFECOM interoperability continuum. Level 2 (gateway) interoperability is possible

when the ARMER control station is patched to a local radio resource via a dispatch console or gateway.

3.1 Characteristics of the donor radio approach

Talk group programming in the ARMER control stations would be the primary issue to be resolved during implementation of the donor radio approach. A consistent method for programming is required so that all radio users and dispatchers can receive uniform training in the proper use of the resources. For instance, each locality or region could have a separate talk group on the ARMER system so that ARMER users would be able to quickly contact a local or regional dispatcher by selecting the appropriate talk group though this may create ARMER system loading issues. Another approach would be to establish interoperability talk groups on a regional or statewide basis or to use existing ARMER interoperability talk groups but restrict the conditions under which a local or regional dispatcher can access them.

The primary advantage to the donor radio approach is simplicity but this may also be its biggest disadvantage since it offers only limited interconnection between users in separate frequency bands or radio systems. Some of the other advantages and disadvantages of this approach are as follows.

<u>Advantages</u>

- Additional end user subscriber programming may not be required since current channels and/or trunked talk group resources may be used.
- This approach does not require significant capital and maintenance costs to implement and maintain.
- The dispatcher serves as a built in access control or gateway point.
- Additional transport (microwave, fiber, leased lines) is not required.
- Current state plans include this approach and funds are available to execute this solution.
- Standard operational policies (SOPs) for use of this approach would be relatively simple to develop.

Disadvantages

- Connections from local systems to and from ARMER are limited.
- The potential exists for overloading conventional channels or trunked talk groups when ARMER radios are patched to local, regional or state system resources, due to the added traffic.
- This solution requires a dispatcher to relay information or patch traffic together depending on local or regional implementation.
- Differences in coverage between ARMER and local radio systems are not addressed.
- This approach does not address interoperability with neighboring states and provinces.
- This solution provides limited interoperability between non-ARMER systems or users.
- It is not easily scalable and does not provide interoperable connections to non-traditional land mobile radio (LMR) systems (e.g., commercial wireless systems, telephone, unlicensed wireless, etc.).

3.2 Example of the donor radio approach

Pennsylvania Statewide Radio Network (PA-STARNET)

The Commonwealth of Pennsylvania provides a dedicated 800 MHz talk group for each county on the statewide radio system (PA-STARNET) as well as a dedicated PA-STARNET control station for each PSAP. Local PSAPS have the option of connecting this control station directly into their normal dispatch console systems through a remote control adapter and the majority of the PSAPs in the Commonwealth have done this.

Link to PA-STARNET information:

- http://www.outreach.psu.edu/programs/interop/files/Breakout6.pdf

4. Dedicated audio connections to ARMER

In this solution, shown in Figure 2, state, local and regional dispatch centers would be connected together using dedicated microwave or optical fiber communication links to enable console patching between dispatch centers and disparate radio systems. The dedicated links between dispatch centers can patch radio resources available in separate dispatch centers together. For instance, when requested, an ARMER user's dispatch center might connect an ARMER talk group to Interop link 1. A county dispatcher would connect a local county radio channel to Interop link 1. Once the incident or need for communications is over, each dispatch center would take down the patches to Interop link 1.

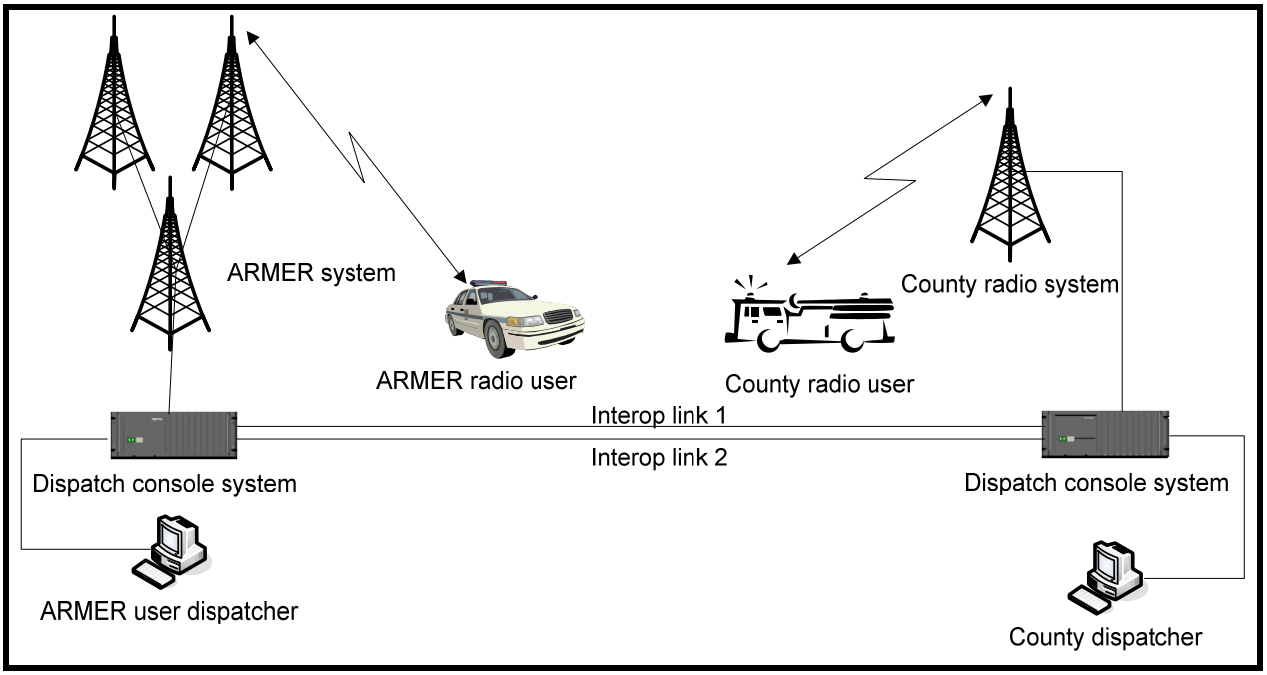

Figure 2 - Dedicated audio connections

This approach provides Level 2 (gateway) interoperability in the SAFECOM interoperability continuum.

4.1 Characteristics of the dedicated audio connection approach

The primary advantage to this approach is that it allows local, state and regional dispatchers to continue to use the same equipment that they use every day to create

interoperability talk paths. It works best when the dispatch centers use similar dispatch console equipment. Gateway type solutions can only work when the interconnected users are within the respective coverage areas of their interconnected systems. The following are some additional characteristics inherent in this approach.

Advantages:

- Dedicated links provide a high degree of flexibility to dispatch operators.
- Reprogramming of existing subscribers is not required.
- This solution may be less costly than overlay and Radio over Internet Protocol (RoIP) solutions to deploy and maintain.

Disadvantages:

- These links can easily be overloaded.
- Use of the system requires a high degree of cooperation to be effective.
- This solution requires additional transport between dispatch centers.
- Gateway systems do not address coverage or capacity issues inherent in the interconnected networks.
- Only linked systems or users experience improved interoperability.
- Connecting too many systems or channels together can actually inhibit communications.
- The system is not easily scalable and may not provide interoperable connections to non-traditional LMR systems (e.g., commercial wireless systems, telephone, unlicensed wireless, etc.).
- This approach is most practical in an urban environment where local systems provide significant overlapping coverage.

4.2 Example of dedicated audio connection approach

Seattle, WA Tri-County Interoperability System (TRIS)

The TRIS directly ties six major public safety radio systems together using microwave or fiber circuits to provide dispatcher-to-dispatcher connectivity on the King County, city of Tacoma, Snohomish County and Port of Seattle 800 MHZ trunked radio systems as well as the VHF systems operated by the Washington State Patrol and the federal Integrated Wireless Network (IWN). Each dispatch center has one or more dedicated links to each of the other primary dispatch centers that can be patched to a trunked or conventional

resource in the primary system. A coordination intercom function is also present on these consoles allowing all participating centers to coordinate activities on a common “party line” basis. Additionally, VHF, and UHF (450-4760 MHz) radio control stations are tied into a shared dispatch console central electronics bank so that out-of-band, out-of-area radio users can communicate via radio with users on the King County, city of Tacoma, Snohomish County and Port of Seattle 800 MHz systems.

5. Radio over Internet Protocol connections to ARMER

This approach, as depicted in Figure 3, would utilize a Radio over Internet Protocol (RoIP) system or systems to connect ARMER users and infrastructure to other state, local and regional users and radio systems. RoIP is an expansion of the use of Voice over Internet Protocol (VoIP) with additional control functions needed in land mobile radio systems such as push to talk (PTT). VoIP employs session control protocols to control the set-up and teardown of calls as well as specialized audio coding and decoding to enable transmission of audio over an IP network. In order to deploy an RoIP system or systems, existing transport networks would have to be expanded and/or enhanced utilizing RoIP routers and gateways to transmit audio data packets over statewide, local and regional networks.

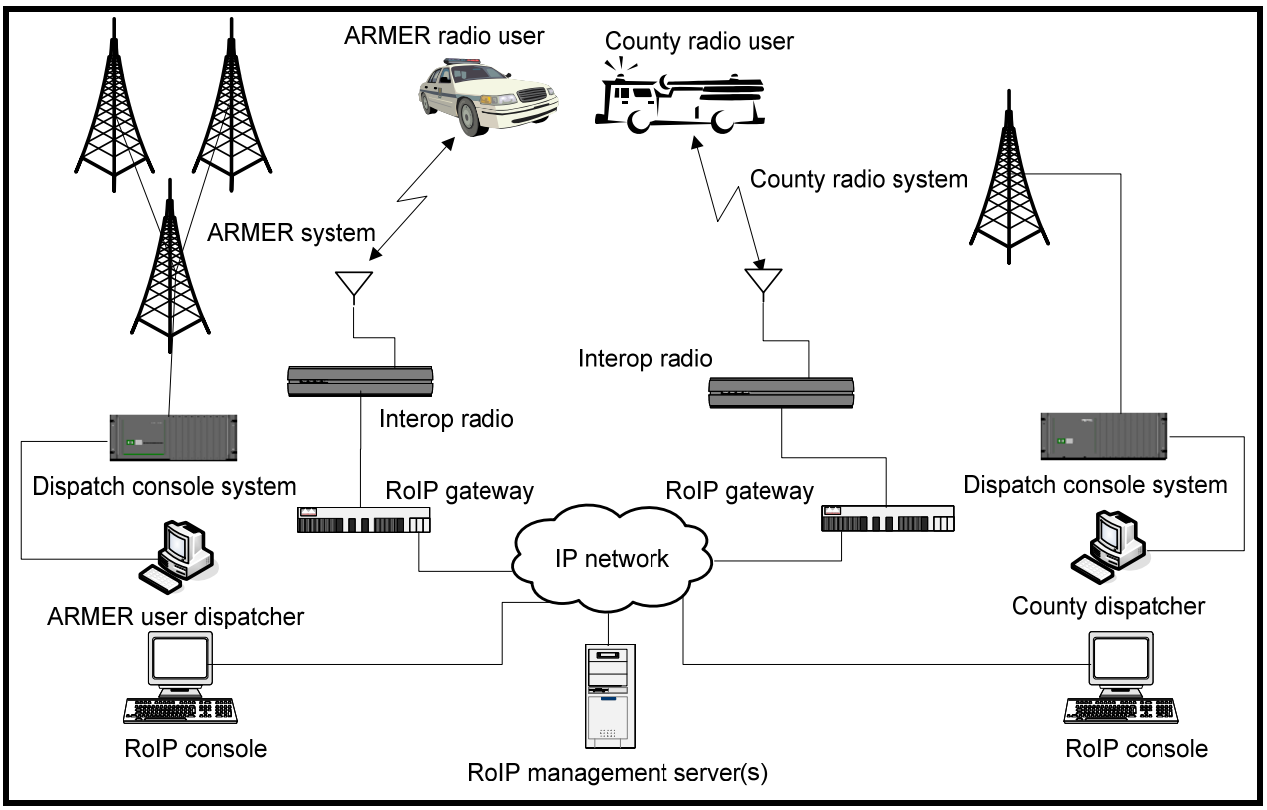

Figure 3 - RoIP connections

The interoperability radios connected to the RoIP system may be new radios installed strictly for interoperability purposes, existing local or regional interoperability channels, existing primary local or regional radio channels or any combination thereof.

The use of RoIP interoperability solutions continues to expand as the underlying technologies mature and as the land mobile radio market in general continues to move towards convergence with more traditional voice and data networks.

RoIP connections would provide Level 2 (gateway) interoperability in the SAFECOM interoperability continuum albeit with greater flexibility than more traditional gateway connections, such as console-based patches.

5.1 Characteristics of the RoIP approach

While RoIP systems can significantly enhance interoperability, understanding the underlying technology as well as the specific capabilities and drawbacks of a particular vendor solution is essential for planning and deploying these systems. RoIP systems are less spectrally efficient than the use of a shared system and require additional ancillary equipment at the dispatch centers, increasing training requirements and other ongoing support. Just as with other gateway type solutions, RoIP systems provide true interoperability only when the interconnected users are within the respective coverage areas of their interconnected systems. Some of the other advantages and disadvantages of this approach are as follows.

Advantages

- RoIP systems are scalable and can provide interoperable connections to non-traditional LMR systems (e.g., commercial wireless, telephone, unlicensed wireless, etc.).
- The nature of these systems can also enable limited PC-based access to land mobile radio channels and networks.
- Reprogramming of existing subscribers is not required.
- Use of a RoIP system does not necessarily require immediate investment in legacy radio systems.
- This solution may be used to improve interoperability between non-ARMER systems and users.
- Given the increasing potential for convergence of public safety IP networks (911, radio and data systems), the use and expansion of existing IP networks for radio interoperability may result in cost savings versus more traditional land mobile radio site interconnection methods.

Disadvantages

- RoIP systems do not address coverage or capacity issues inherent in the interconnected networks.
- Like other gateway solutions, RoIP does not use spectrum efficiently because it requires the broadcasting of identical communications over two or more different frequencies or systems.
- Linked systems or users experience true interoperability only when the interconnected users are within the respective coverage areas of their interconnected systems.
- Most traditional land mobile radio transport networks were not originally designed to support IP communications.
- Total cost to implement and maintain can be significant.
- Use of advanced subscriber radio features, such as emergency alarms and user identification, is limited.
- RoIP systems from different vendors may have proprietary features.
- Supporting transport and IP networks must be designed to provide the quality of service and reliability needed for public safety communications systems.
- Complexity and capabilities of RoIP result in more effort needed to develop effective SOPs, training guidelines and security safeguards.
- Connecting too many systems or channels together can actually inhibit communications or create a “ping pong” effect disrupting necessary communications.
- Work to define standards for communications interfaces between different RoIP systems is still ongoing[3].

5.2 Examples of RoIP systems

Florida Interoperability Network (FIN)

The FIN utilizes an RoIP system (Motorola Motobridge) to interconnect an overlay of VHF, UHF and 800 MHz interoperability channels to the 800 MHz Statewide Law Enforcement Radio System (SLERS) utilized by state law enforcement officers and 225 SLERS and local dispatch centers. All FIN-connected dispatch centers are currently fed by T1 circuits but the state is evaluating scaling some sites back to fractional T1 service depending on the number of local interoperability resources in that area.

[3] http://www.safecomprogram.gov/SAFECOM/currentprojects/voip/

Links to FIN information:

- http://dms.myflorida.com/suncom/public_safety/radio_communications/florida_interoperability_network_fin
- http://www.motorola.com/Business/US-EN/Business+Solutions/Product+Solutions/Incident+Scene+and+Event+Management/MOTOBRIDGE+IP+Interoperability+Solution_US-EN

Virginia Commonwealth's Link to Interoperable Communications (COMLINC)

The COMLINC project leverages several different RoIP systems to allow disparate radio systems to communicate within Virginia and to interface with the Statewide Agencies Radio System (STARS) network. The STARS project team reviews regional and local interoperability projects, working in conjunction with the Commonwealth Interoperability Coordinator, State Interoperability Executive Committee, and the Virginia Information Technologies Agency (VITA) to ensure that all RoIP technologies considered for COMLINC meet certain technical and functional requirements. Currently COMLINC uses three different vendor solutions. These are:

- Cisco IPICS
- Motorola Motobridge
- SyTech RIOS

Links to COMLINC information:

- http://www.interoperability.virginia.gov/CommunicationSystems/COMLINC.cfm
- http://www.cisco.com/en/US/prod/collateral/ps6712/ps6718/prod_brochure0900aecd80352c7e.html
- http://www.motorola.com/Business/US-EN/Business+Solutions/Product+Solutions/Incident+Scene+and+Event+Management/MOTOBRIDGE+IP+Interoperability+Solution_US-EN
- http://sytechcorp.com/new_site/SytechCorp/SyTechCorpXY/CDR02.asp

Olympic Public Safety Communications Alliance Network (OPSCAN)

OPSCAN uses an RoIP system installed by an integrator (ARINC with Twisted Pair servers/software and Cisco gateways) to connect users from disparate radio systems amongst a consortium of 43 local, state, federal, non-governmental, tribal, and transit agencies. A shared microwave backbone around the entire Olympic Peninsula of Washington State and a network of interoperability gateways, routers and servers

supports OPSCAN. The OPSCAN network also incorporates some of the national interoperability (VTAC and UTAC) channels through 11 cross band repeater sites.

Link to OPSCAN information:

- http://www.twistpair.com/index/case-opscan

6. Interoperability channel overlay for ARMER

An interoperability channel overlay, as depicted in Figure 4, would include the build-out of new interoperability channels or the incorporation of existing interoperability channels in multiple bands. Typically, interoperability channel overlay systems include one or more VHF channels, one or more UHF channels and one or more 700/800 MHz national interoperability channels statewide or by region. The number and band of the interoperability channels deployed may be based on the number and types of radio users in each band in that particular state and/or region but are often also restricted by the transport capacity of the statewide radio system. Interoperability overlays do not provide the same levels of coverage or capacity as a primary statewide radio system but do provide a resource for command and control functions or a “lifeline” to local and regional radio users who are outside the coverage of their primary radio systems.

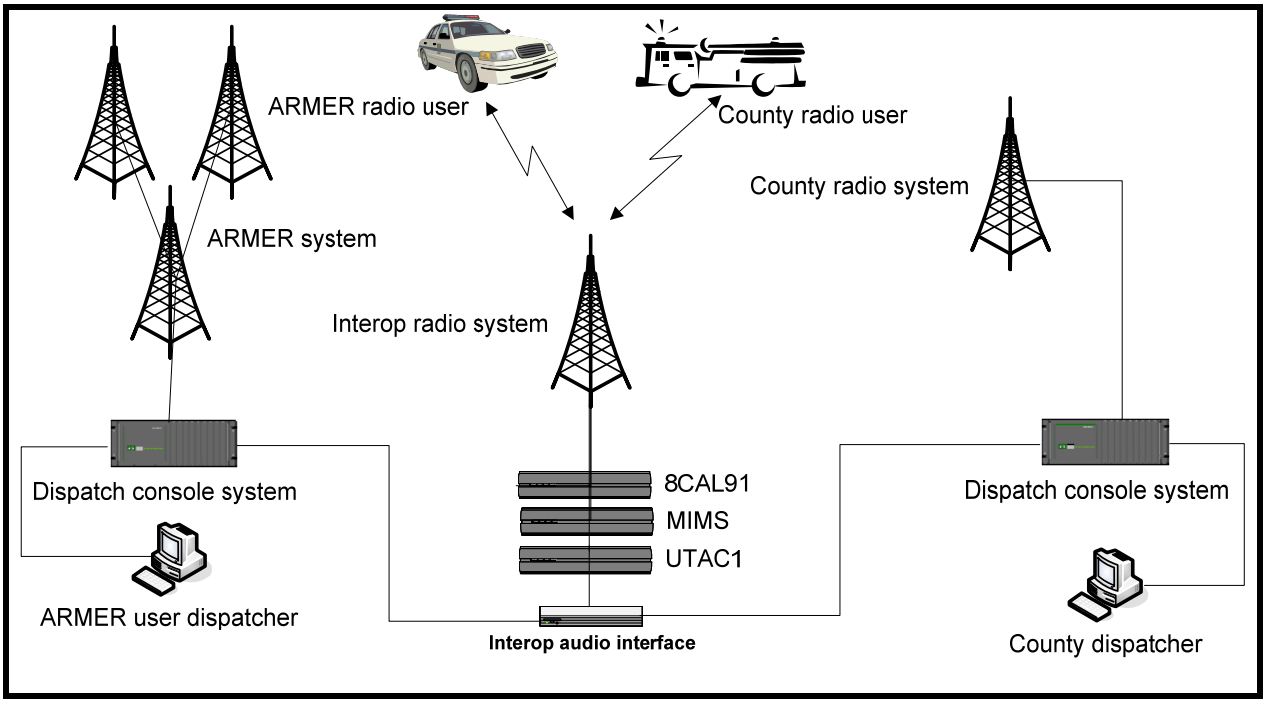

Figure 4 - Interoperability channel overlay

The use of a small number of conventional channels (VHF) for interoperability is part of the original conceptual plan for ARMER and estimated bandwidth requirements for this are included in the overall ARMER transport network design. Conventional

interoperability channels can also be retrofitted into the current ARMER network and included in the design of ARMER phases still being deployed.

The interoperability channel overlay provides state, local and regional users a set of common channels for use during events requiring responses from multiple public safety/service disciplines but may become overloaded if not managed properly. Since the overlay infrastructure utilizes radio channels that are separate from the state, region or local user's primary radio system it does not add traffic to these systems unless the overlay channels connect to them through console patches and/or gateways.

This approach provides Level 3 (shared channels) interoperability in the SAFECOM interoperability continuum.

6.1 Characteristics of the interoperability channel overlay approach

The primary issues with deploying an interoperability channel overlay all relate to spectrum. Finding new unused channels or identifying existing channels to utilize in an overlay network can be extremely challenging especially in congested bands like VHF. Border states like Minnesota must also coordinate the use of certain channels with Canada, particularly in areas above what is referred to as "Line A" , as shown in Figure 5, which further reduces the pool of potential channels.

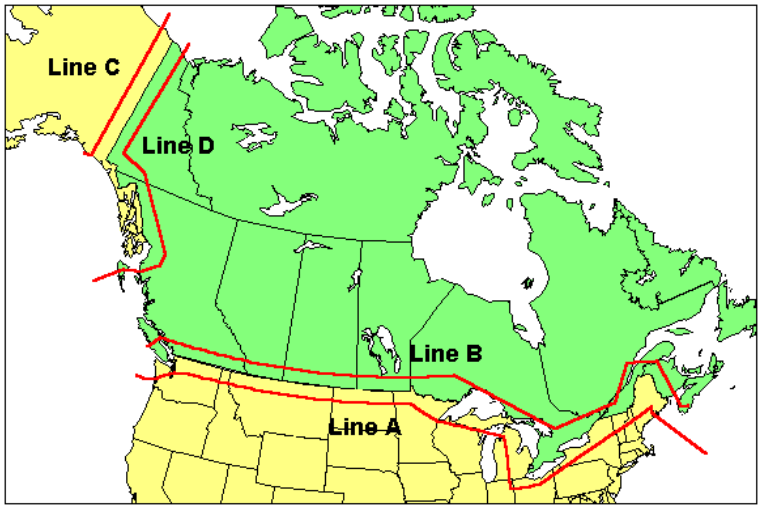

Figure 5 - Line A

Adding further complexity to these challenges are several spectrum related initiatives mandated by the Federal Communications Commission (FCC). In the VHF and UHF

bands, the FCC has mandated that all wideband (25 kHz) channels operating below 512 MHz (VHF and UHF) must move to narrowband (12.5 kHz) channels by January 1, 2013. The 800 MHz band is in the midst of a process called rebanding which will separate public safety radio channels from those used by commercial wireless carriers.

In a previous report provided to DPS, ***FE*** identified 36 narrowband frequencies that may have the potential for use on a statewide basis for interoperable communications.

Some of the other advantages and disadvantages of this approach are as follows.

Advantages

- This approach improves interoperability between both ARMER and non-ARMER systems and radio users.
- A common set of channels across multiple bands provides at least one common channel for programming into any users' radio.
- Costs to maintain this solution are relatively low when combined with existing statewide radio system infrastructure.
- The overlay does not necessarily require a dispatcher to activate or participate in a call depending upon the specific system implementation.
- Being an "always on" solution, it can be relatively simple to use in a day-to-day or emergency situation.
- The overlay system can provide a separate and potentially redundant communication system for use during catastrophic failures of local or regional systems although limitations in capacity quickly become an issue.

Disadvantages

- If radio traffic is not controlled the overlay system will be overloaded quite easily.
- Cost to implement can be significant.
- Additional channels may need to be programmed into all subscriber radios.
- Development of standard channel naming and SOPs for effective use is required.
- Separate channels in different frequency bands do not provide consistent coverage across bands and are not usually consistent with the coverage provided by the primary state, regional or local system.
- Monitoring and/or recording of these overlay channels may require additional resources.

- Providing balanced or equivalent coverage in all bands deployed for interoperability becomes more difficult due to differences in propagation characteristics between bands.
- Integrating existing state, local or regional radio resources can be problematic (varying levels of maintenance, coverage, accessibility, etc.).
- An overlay system is not easily scalable and does not provide interoperable connections to non-traditional LMR systems, (e.g., commercial wireless, telephone, unlicensed wireless, etc.).

6.2 Examples of interoperability channel overlay systems

Florida Interoperability Network (FIN)

The FIN includes an overlay of VHF, UHF and 800 MHz interoperability channels deployed across 93 sites statewide that enhance and expand the capabilities of the 800 MHz Statewide Law Enforcement Radio System (SLERS) utilized by state law enforcement officers. The interoperability overlay connects to SLERS and local dispatch centers via a Radio over IP (RoIP) system (Motorola Motobridge).

Arizona Interoperability Radio System (AIRS)

AIRS is a system of VHF, UHF and 800 MHz interoperability channels deployed at approximately 32 sites statewide. The channels at each site interconnect in a back-to-back manner using four-wire audio bridges and are tone remote controlled over a single four-wire circuit. Each site connects to regional dispatch centers via the state's Department of Public Safety statewide microwave system.

Pennsylvania Statewide Radio Network (PA-STARNET)

Pennsylvania has installed VHF and UHF overlay systems. The VHF system uses the National Emergency Police Frequency (NEPF), which is available to all public safety agencies in the Commonwealth. The state installed 50 base stations on this simplex, carrier squelch channel. The state is also in the process of deploying a UHF overlay system with approximately 50 base stations/repeaters on the national UHF interoperability channels (UCALL, UTACS). In both cases, the VHF and UHF overlay channels connect to a Harris Network First device at each site and interface into the PA-STARNET system on dedicated talk groups.

7. Hybrid approach

As indicated in several previous examples, statewide or regional interoperability systems are often deployed as or migrate to a hybrid approach that includes some aspect, if not all, of the approaches described previously. Several factors cause this to occur including budgetary constraints at the state, local and regional levels, the maturation of underlying communications technologies, and variability in state, local or regional needs. In some cases, interoperability solutions deployed to meet a short term or immediate need are also later incorporated into a more robust or widespread solution. Hybrid approaches often develop when there is insufficient transport or other technological issues that restrict deployment of the preferred or standard interoperability solution in a particular area or region.

The hybrid approach provides Level 1 (swap radios) to Level 3 (shared channels) interoperability in the SAFECOM interoperability continuum depending on the solution deployed in a particular area or region. One hybrid approach, as depicted in Figure 6, would utilize three of the conceptual approaches presented previously – donor radios, RoIP systems and an interoperability overlay.

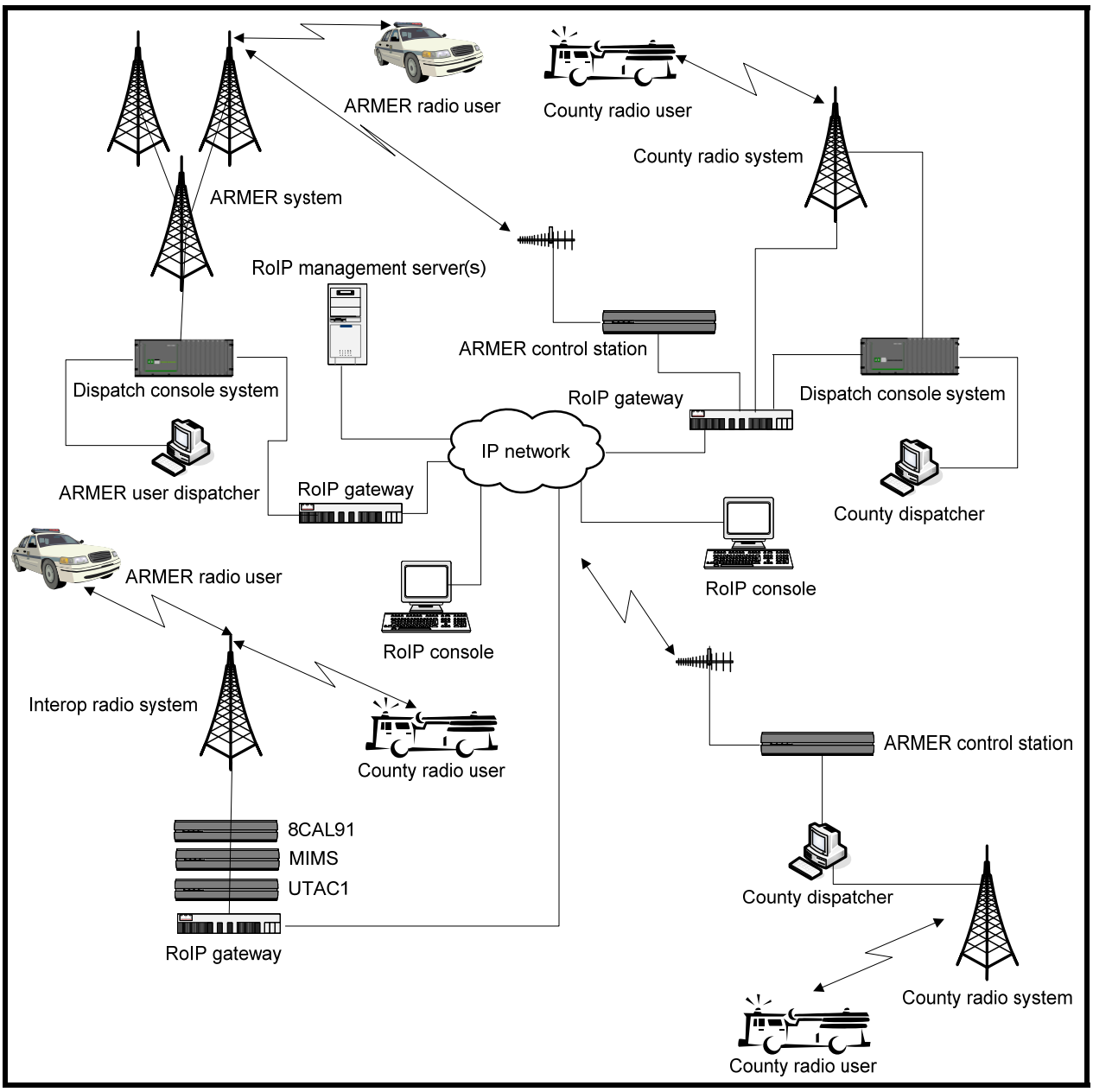

Figure 6 - Hybrid approach

7.1 Characteristics of the hybrid approach

The predominant issue with the hybrid approach is that it does not provide the same level of interoperability system wide or for all potential users. This increases the need for training and exercises so that all users know what interoperability resources are

available in a particular area and how to use them. It also means that SOPs and incident management plans must take into account these variables as well. Additionally, the hybrid approach has all the advantages and disadvantages of the interoperability solutions that it utilizes in the areas where those distinct solutions exist. Management and maintenance of the hybrid approach is also more complicated due to the variability in the solution although it does also provide the highest degree of flexibility of all the approaches presented.

7.2 Examples of the hybrid approach

Florida Interoperability Network (FIN)

The FIN includes an overlay of VHF, UHF and 800 MHz interoperability channels deployed across 93 sites statewide and connected to state and local dispatch centers via a RoIP system (Motorola Motobridge).

Pennsylvania Statewide Radio Network (PA-STARNET)

Pennsylvania has installed VHF and UHF overlay systems that connect to a Harris Network First RoIP system and interface into the PA-STARNET system on dedicated talk groups. Additionally, the Commonwealth provides a dedicated 800 MHz talk group for each county on the statewide radio system, PA-STARNET, as well as a dedicated PA-STARNET control station for each PSAP.

Olympic Public Safety Communications Alliance Network (OPSCAN)

OPSCAN uses an RoIP system installed by an integrator (ARINC with Twisted Pair servers/software and Cisco gateways) to connect users from disparate radio systems among a consortium of 43 local, state, federal, non-governmental, tribal, and transit agencies. The OPSCAN network utilizes the national VTAC and UTAC channels through 11 cross band repeater sites.

8. Project assumptions and guidelines

The overall goal of this project is to assist the State in collaboratively developing the best course of action to maximize interoperability throughout the state for public safety agencies (including federal, state, tribal and local governments) and with bordering states and provinces.

In order to achieve this goal, ***FE*** first reviewed the current plans for interoperability in Minnesota as defined in the SCIP, the ARMER project plan as well as the fiscal year 2007 Public Safety Interoperable Communication (PSIC) investment justifications. These documents clearly indicate that there are two primary visions in the state's plans to provide interoperable communications in Minnesota. First, integrate local public safety entities into ARMER whenever possible in order to achieve the highest level of interoperability. Second, leverage the state's significant investment in ARMER by utilizing the underlying network of towers and transport systems within the ARMER network as a "system of systems" to provide cross spectrum interoperability for users that do not join ARMER.

During subsequent follow up discussions with staff from the Division of Emergency Communication Networks, ***FE*** further refined our understanding of the desired characteristics of the final interoperability solution as follows:

- The proposed solution should not significantly increase ARMER operating costs or create a separate stand-alone interoperability network.
- The proposed interoperability solution should not be a substitute for ARMER since integration of public safety entities into ARMER provides the highest level of interoperability possible at Level 5 (Standards-based shared systems) in the SAFECOM interoperability continuum.
- The primary focus for the cross-spectrum interoperability solution should be to provide a "lifeline" level of radio coverage for radio users traveling outside the coverage of their primary radio systems, enabling them to contact a state, local or regional dispatch center to request assistance or information.

8.1 Regional feedback on conceptual approaches

In the next phase of this project, ***FE*** researched and outlined several conceptual approaches used to provide interoperability infrastructure in other states and regions and described how these solutions might be utilized in Minnesota. ***FE*** then presented these approaches to the SRBIC, the RACs and the MESB TOC to elicit feedback and comments regarding the attributes of each conceptual approach from radio system

operators and users. Table 2 lists the conceptual approaches presented to these groups.

Table 2 – Interoperability infrastructure solutions

Approach	Description	Interoperability Level[4]
Donor radios	**ARMER radios installed in local dispatch centers**	**1-2**
Dedicated connections	**Direct audio connections between dispatch centers**	**2**
Radio over IP (RoIP)	**Voice over IP systems connecting existing radio channels**	**2**
Interoperability overlay	**Common, dedicated interoperability channels statewide**	**3**
Hybrid	**A combination of two or more of the above**	**1-3**

During these meetings, ***FE*** polled the attendees to determine, at a summary level, the perceived interoperability needs and concerns that any proposed interoperability solution should attempt to address. Several common themes and concerns emerged during these meetings as detailed below.

- The solution should address communications between radio users in the state who remain on local VHF systems that still need to communicate with ARMER users and vice – versa.
- The solution should provide a common mechanism to address communications between radio users within Minnesota, without regard to whether those entities operate on ARMER or local VHF systems, as well as users in radio users in adjacent states and provinces (primarily VHF).
- The solution should be relatively simple to use and should not create a significant additional burden on radio users or dispatchers.
- The solution must be cost effective from both a state and local perspective.

[4] As defined in the SAFECOM interoperability continuum.

9. Strategy for a statewide interoperable infrastructure

In May through September of 2009, ***FE*** conducted meetings and reviewed the conceptual approaches for providing a statewide interoperability infrastructure presented in this report with the SRBIC, the RACs and the MESB TOC.

Based on feedback from these meetings, interoperability plans already in place and conversations with staff from the Division of Emergency Communication Networks (DECN) and the Department of Transportation (MnDOT), ***FE*** recommends a hybrid solution using two of these approaches to provide a supplemental interoperable infrastructure to ARMER. The state can implement a hybrid solution in a phased manner while also meeting a majority of the interoperability needs of the state. The recommended hybrid solution includes the following primary components operating in the two predominant radio bands, VHF (150-174 MHz) and 800 (806-854 MHz), in use within and adjacent to Minnesota:

1. ARMER donor radios
2. VHF/800 MHz interoperability channel overlay

During discussions of the various interoperability approaches with the regional radio advisory committees, there was little interest in the dedicated audio connection approach. This is not surprising since this solution would have its greatest impact in urban areas where multiple public safety communication systems have significant overlapping coverage. Given this and the technical issues associated with attempting to utilize this approach statewide or even over a large region, this approach is not considered as a viable option for a statewide interoperable infrastructure.

RoIP was not selected as a primary component in a statewide interoperability infrastructure primarily due to concerns related to the cost of a full-scale statewide system implementation. A more limited use of RoIP as part of an interoperability support system deployed as an integrated subsystem within the existing ARMER transport system is possible. This limited RoIP interoperability backbone would connect, transport and provide for management of the VHF/800 interoperability overlay within a region and allow for additional flexibility and scalability in adapting the interoperability system to specific local and regional needs. A RoIP interoperability backbone would also provide ARMER network support staff with additional tools for managing and supporting the ARMER 700/800 MHz radio system as well as the transition of existing VHF users to ARMER. Further evaluation of the capital and recurring costs of this type of deployment in conjunction with the VHF/800 MHz interoperability channel overlay and

ARMER donor radio approach is needed to determine the extent to which RoIP can be integrated into the recommended hybrid solution.

9.1 ARMER donor radio deployment

As shown in Figure 7, the ARMER donor radio approach for Minnesota would include two ARMER donor radios installed in each PSAP in counties that do not join ARMER. One ARMER donor radio would be set up on a local or regional PSAP talk group and monitored by the local PSAP dispatcher directly or through integration into the local dispatch console. The second ARMER donor radio would have specific selectable talk groups including statewide or regional interoperability talk groups or perhaps even state agency operational talk groups if approved by the appropriate state agency. The local PSAP dispatcher would also monitor the second ARMER donor radio either directly or through integration into the local dispatch console. Under normal circumstances, the local or regional PSAP talk group would not be cross-patched to another local resource unless there was a compelling operational reason to do so and the appropriate regional radio boards had previously authorized such operations. Should the need arise to patch local resources to ARMER talk groups, this would be done primarily through the second ARMER radio using interoperability or state agency talk groups to ensure that the local or regional PSAP talk groups would remain available for initial hailing or calling uses.

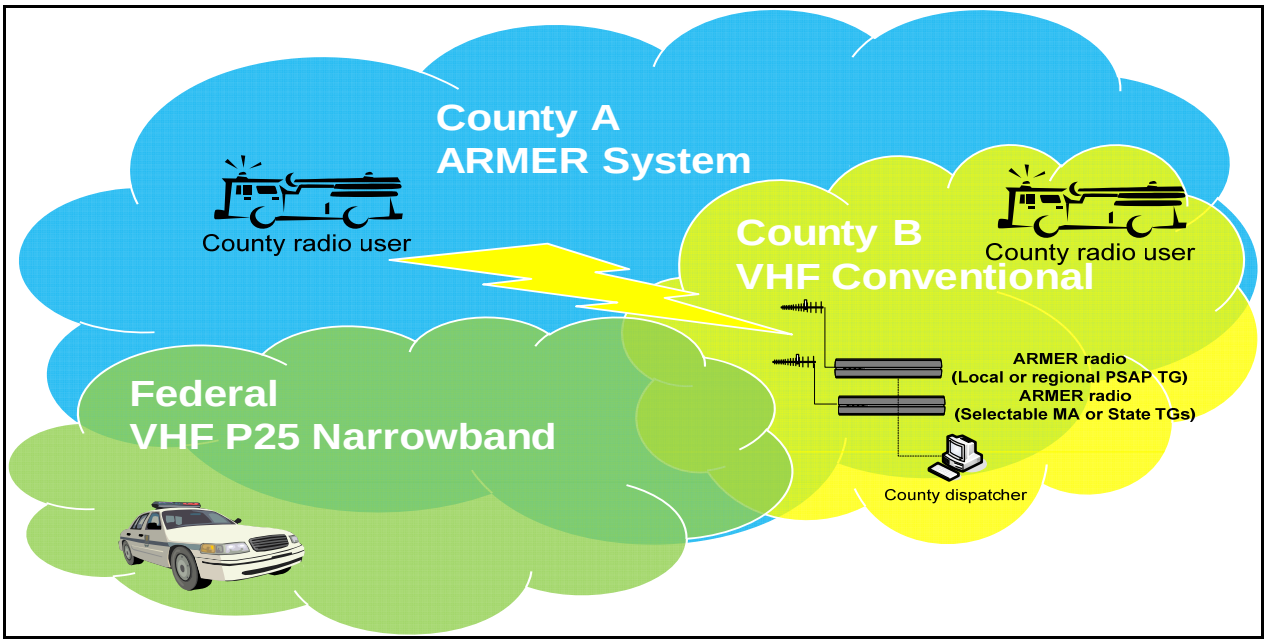

Figure 7 - Donor radio operations

An ARMER user traveling into County B would hail or call a local PSAP on one of the radio control stations over one of the local or regional PSAP talk group. During this call, the local dispatcher and ARMER user would determine if a patch between a local resource and ARMER resources is required. If so, the local dispatcher would direct the ARMER user to the selected regional or agency specific talk group and patch this talk group to a local radio resource or resources.

Should the County B dispatcher need to hail or call County A, they could also use the local or regional PSAP talk group to accomplish this. As part of this initial call the dispatchers would determine whether the event necessitating the call required prolonged coordination or communications. If so, this coordination between counties could continue on a selected regional or agency specific talk group.

This strategy of deploying ARMER donor radios is currently underway in Minnesota and provides Level 2 interoperability (gateway) between ARMER users and local VHF radio system users when:

1. The ARMER donor radio is connected to and controlled by the local dispatch center console and can be patched to local radio resources and;
2. The ARMER radio users and local VHF radio system users are within the coverage areas of their respective systems.

The solution only provides Level 1 interoperability (swap radios) if the ARMER donor radios are not integrated into local dispatch consoles.

Again, as shown in Figure 7, once the County B radio user moves out of their local radio system coverage they would not have any capability to communicate directly with the ARMER radio user. The donor radio approach does not resolve interoperability issues with any radio system users not dispatched by a local PSAP such as federal or tribal entities. However, it may also be possible to install ARMER donor radios at federal or tribal sites to achieve a similar level of interoperability with those agencies if funding is available. This approach does not provide a mechanism by which state or local agencies can achieve interoperability with entities in adjacent states or provinces.

The use of ARMER donor radios is consistent with the SCIP in that it utilizes one of the key capabilities inherent in ARMER, statewide mobile radio coverage, to provide a communications link between non-ARMER and ARMER users. Furthermore, this method of providing interoperable communications is included in the 2007 PSIC grants that allocated $1.75 million to provide ARMER donor radios to establish this level of interoperability in PSAPs in Phases 3-6 of the ARMER deployment plan.

The donor radio approach is a practical, straightforward solution for resolving many interoperability issues between ARMER users and local VHF systems in the State. The basic capabilities of the solution would be relatively simple to integrate into statewide and regional interoperability plans and procedures. An added benefit to this approach is that is does not necessarily require additional transport capacity on the ARMER backbone. During discussions of the various interoperability approaches with the regional radio advisory committees, there was considerable interest in the donor radio approach due to its relative simplicity, ease of implementation and relatively low cost.

9.2 VHF/800 interoperability channel overlay

As depicted in Figure 8 below, the VHF/800 interoperability channel overlay would include statewide deployment of the national interoperability calling channels in the VHF (VCALL10) and 800 MHz (8CALL90) bands. Optionally, local or regional deployment of one of the national interoperability tactical channels in VHF (VTAC11-14) and 800 MHZ (8TAC91-94) would provide additional flexibility in managing ongoing incidents if deployment of these channels were possible within budgetary constraints. Deployment of additional tactical interoperability channels would also mirror the capabilities of the ARMER donor radio approach providing two talk paths for VHF and 800 MHz communications. The VHF/800 interoperability overlay would provide a communications safety net or lifeline for conventional VHF or 800 MHz users traveling outside the normal overage area of their primary systems to reach local and state dispatch centers. The interoperability overlay channels would provide shared, common channels in a narrowband analog mode for the two primary radio bands of operation in the state of Minnesota for many local, tribal and federal entities that do not operate on the ARMER system and for users in adjacent states and provinces.

The use of the national interoperability channels provides common interoperability channels unencumbered by previously established protocols, procedures and history of usage within the state. Alternatively, in the VHF band, the use of existing VHF interoperability channels (MIMS, MINSEF, and SW FIRE) is possible although a special exemption from the FCC for non-discipline specific use of these channels would be required and overcoming long-standing patterns of use will be difficult. Deployment and coverage on these existing VHF interoperability channels varies significantly from county to county as does the age of the base station equipment. Furthermore, these existing VHF interoperability channels will also have to be replaced or modified to meet the 2013 narrow banding deadline. Variability in the age and condition of existing base stations was reported as a significant integration issue in the interoperability networks deployed in Washington and Florida. Another option would be to attempt to license

completely new VHF channels specifically for use in Minnesota from the pool of channels previously identified in ***FE***'s *"Task Five Deliverable: Final Written Report for Tasks 4-8 of the Minnesota VHF/UHF Interoperability Frequency Planning Project".*

The local PSAP dispatcher would monitor the VCALL10 and 8CALL90 channel and, optionally, the locally deployed VTAC/8TAC channel(s). An approach that links the local VCALL10/8CALL90 channels from each tower or group of towers to a local or regional PSAP talk group on the ARMER system may also be used to reduce the need for additional last mile transport from the ARMER system to the local PSAP.

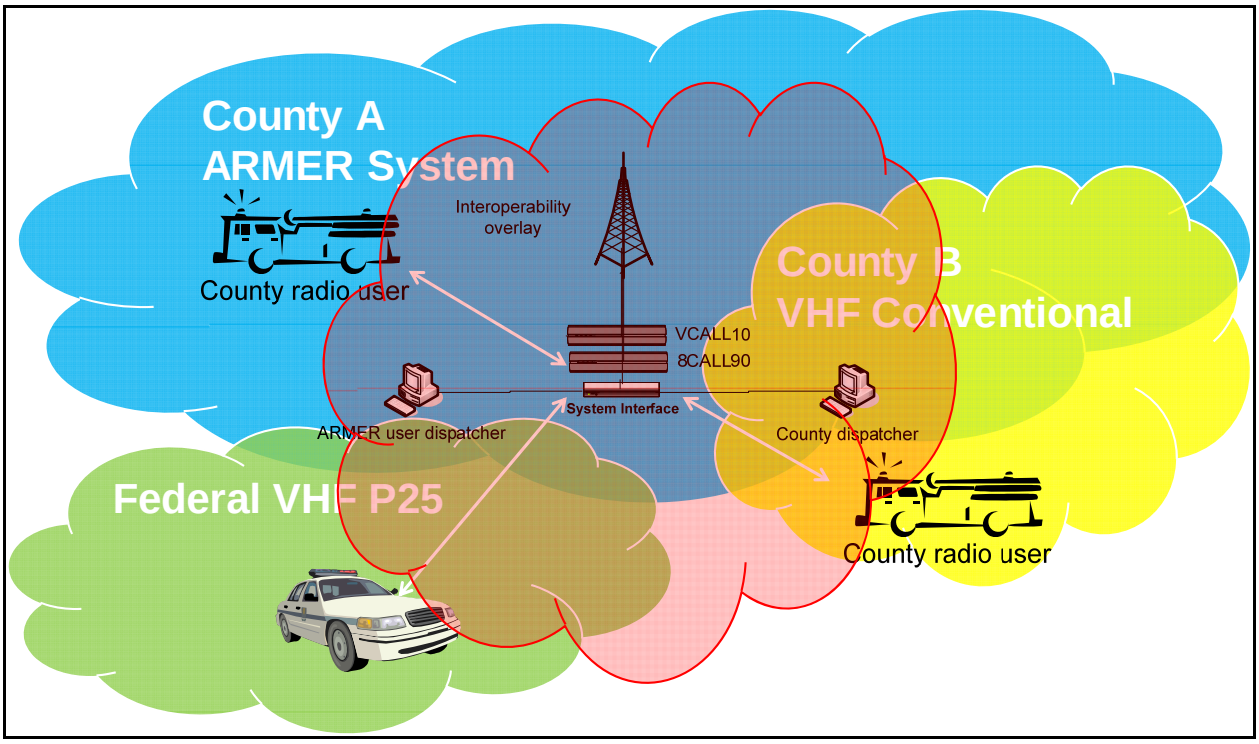

Figure 8 - VHF interoperability overlay operations

A VHF or conventional 800 MHz user traveling into County A (ARMER system participant) could hail or call the local PSAP on the VCALL10 or 8CALL90 channel. A VHF or conventional 800 MHz user traveling into County B could also hail or call the local PSAP on the local VCALL10 or 8CALL90 channel.

Use of the VHF and 800 national interoperability overlay channels also provides VHF and 800 MHz radio users with separate interoperability channels for communicating with other adjacent VHF or 800 MHz radios users without necessarily moving incident related traffic onto primary local VHF or 800 MHz radio systems. The VHF/800

interoperability overlay provides Level 2 interoperability (gateway) when ARMER users and VHF radio users are patched together and Level 3 interoperability (shared channels) when utilized by two or more conventional VHF or conventional 800 MHz users or entities.

If the County A radio user moves out of range of the ARMER network they would have the capability to communicate directly with the local VHF radio user or system through the 8CALL90 channel or on ARMER talk groups if the ARMER donor radios were also integrated into the local PSAP dispatch consoles.

The VHF/800 interoperability overlay also addresses communications issues with other VHF radio system users not dispatched by a local PSAP or state agency, such as federal and tribal entities, since these entities could program the interoperability channels into their radios as well. Additionally, it provides a mechanism by which state or local agencies can achieve interoperability with entities in adjacent states or provinces that also operate in the VHF or 800 MHz radio bands as they could program these channels into their radios.

The VHF/800 interoperability overlay approach is a very practical although technically more challenging and expensive solution for resolving interoperability issues between VHF and 800 MHz systems and users in the state and ARMER users. The capabilities of the solution would initially be more difficult to integrate into statewide and regional interoperability plans and procedures but once established should be relatively easy to manage.

Some of the additional complexities involved in implementing this solution are as follows:

- Additional transport in the ARMER network may be required to interface these interoperability channels to the appropriate regional and local dispatch centers but this approach is consistent with the original ARMER plans for deployment of a small number of interoperability channels within the ARMER network.
- Significant engineering and planning is required to determine the best approach for deployment of these channels. For example, maximizing coverage with a high power/high antenna/ low site density approach must be balanced against providing excessive signal overlap that may lead to unintended traffic being heard in and from adjacent counties, states and provinces.
- An analysis of how participating dispatch centers will connect to and monitor the VHF/800 interoperability overlay network in a manner that would minimize

recurring costs and provide the most consistent user interface at the local level is required. As noted previously, an approach such as implementing a RoIP interoperability backbone that links the local VCALL10/8CALL90 channels to a local or regional PSAP talk group on the ARMER system may be used to reduce the need for additional last mile transport from the ARMER system to the local PSAPs. A similar approach of linking a statewide conventional interoperability channel to a local trunked talk group was implemented in Pennsylvania.

- The national interoperability channels will be deployed in a narrowband format since all radio users must migrate to narrowband channels by 2013 per FCC rules. In areas where radio users do not have narrowband capabilities (primarily VHF radios) it may be necessary for local systems to maintain existing wideband VHF channels (MIMS, MINSEF) until VHF users in the state have migrated to narrowband operations.
- It is possible that not all of the national interoperability channels will be usable in all of the areas along the Canadian border. Additional research and analysis is required to determine if use of these channels are precluded along the border in which case other VHF or 800 MHz frequencies may have to be utilized in these areas.

The implementation of a small number of dedicated VHF interoperability channels within the ARMER network was part of the original ARMER project plan and is consistent with the interoperability plans outlined in the SCIP. The ARMER project plan allocates approximately $4.9 million and the 2007 PSIC grants included $3 million to provide this type of interoperability in the state.

During discussions of the various interoperability approaches with the regional radio advisory committees, there was considerable interest in having a mechanism for VHF users to continue to be able to contact local PSAPS when they are traveling outside their normal coverage areas. Furthermore, many entities expressed a desire for increased interoperability with VHF entities in adjacent states and provinces as well as federal and tribal entities. The VHF/800 interoperability overlay would provide additional capabilities in this area. Use of the national interoperability channels may also allow for greater compatibility with existing radio caches and tactical interoperability plans that will likely utilize or reference these channels along with other national interoperability channels. The deployment of 800 MHz national interoperability channels within the VHF/800 overlay will also assist the state in administering deployment of these channels where trunked systems utilize 800 MHz frequencies in the portion of that band managed through the 800 MHz regional planning process. Further details on this

requirement are outlined in the National Public Safety Planning Advisory (NPSPAC) Region 22 plan for Minnesota[5].

9.3 RoIP systems

RoIP is an infrastructure enhancement that facilitates interoperable connections rather than being an interoperable radio system in and of itself. RoIP provide new capabilities by linking existing or new radio systems and channels together but does not add subscriber radio coverage or features that did not already exist in the linked systems.

One of the primary drawbacks to RoIP deployments is the bandwidth required for a local dispatch center to access the full capabilities of the solution. In interviews with vendors and operators of deployed systems, a full or fractional T1 is often required to support a local RoIP dispatch console with full operational capabilities. This recurring cost for connectivity, ranging from approximately $500-1200 per month, is often cited as a detractor to full or continued use of the RoIP system in areas where such systems have been deployed, especially for smaller dispatch centers or rural entities. Additionally, operation and maintenance costs for full featured, large-scale RoIP systems including system support, software updates and maintenance, can be significant.

The state of Florida spent approximately $15 million implementing a statewide RoIP system and spends another $3.5 million annually to support that system and a statewide network of interoperability channels. Given these factors, a RoIP system was not specifically selected as part of the recommended hybrid solution although a more limited implementation of a RoIP interoperability backbone may prove beneficial in deploying and managing both the VHF/800 interoperability overlay and the ARMER donor radio approach.

A RoIP interoperability backbone could be deployed as an integrated subsystem within the existing ARMER transport system that would connect, transport and provide for management of the VHF/800 interoperability overlay within a region. Radio gateways would connect the overlay radios to an IP backbone to allow the patching of the overlay channels to interoperability talk groups on the ARMER system.

Local dispatch centers might have the option of deploying RoIP dispatch consoles and gateways that are compatible with an ARMER RoIP subsystem. Locally deployed consoles and gateways could also incorporate additional local interoperability resources

[5] http://www.srb.state.mn.us/pdf/REGION%2022%20Ammended%20plan%202009.pdf

such as access to schools, utilities and other local radio channels. Dispatch centers not opting to deploy full RoIP consoles would have more limited access to the RoIP interoperability backbone perhaps being restricted to the capabilities included in the ARMER donor radio approach. However, the local ARMER donor radios could also be cross-patched to the hailing or calling channels in the VHF/800 interoperability overlay.

A RoIP interoperability backbone could also allow for additional flexibility and scalability in adapting the interoperability system to specific local and regional needs and would provide ARMER network support staff with additional tools for managing and supporting the ARMER 800 MHz radio system as well as the transition of existing VHF users to ARMER.

Implementing a RoIP interoperability backbone is a very technically challenging and potentially expensive solution for resolving interoperability issues that cannot be resolved with the ARMER donor radios or the VHF/800 interoperability overlay. It does however provide a level of scalability and flexibility that the other two approaches lack. The capabilities of the solution would initially be significantly more difficult to integrate into statewide and regional interoperability plans and procedures as well as requiring substantial training and recurring exercises to ensure successful use during a significant event.

Additional items that must be addressed if a RoIP interoperability backbone is deployed are as follows:

- The selected RoIP solution selected should be compatible with the Bridging Systems Interface developed by the Public Safety VoIP working group.
- A complete analysis and determination of how full participants (installed RoIP consoles) and partial participants (no installed RoIP consoles) may connect to the RoIP network that includes the initial and recurring costs of these connections is still needed.
- The backbone should be a fully redundant IP based system utilizing a distributed architecture minimizing the potential for single points of failure.
- Dispatcher, incident commander and systems management training should be included in the initial system deployment and integrated into recurring training schedules.
- RoIP network security and connection policies at the local, regional and state levels must be well defined and adhered to.

During the regional discussions of the various interoperability approaches, numerous entities reported interoperability concerns with local entities such as mining operations, schools, port authorities, private security firms and ambulance services. While these examples tend to present predominantly local interoperability challenges, they can quickly become larger, regional issues as incidents escalate in size and scope. A RoIP interoperability backbone may provide flexibility and scalability beyond the capabilities of the ARMER donor radios or the VHF/800 interoperability overlay network to address these issues if sufficient capital and recurring funds are available to implement such a system.

9.4 MnDOT interoperability proposal

In May 2009, MnDOT presented a high-level proposal for an interoperability system to the working group of the Statewide Radio Board Interoperability Committee. The proposed system would be based on a RoIP solution and utilize a network of low power radio control stations in different frequency bands to provide a frequency agile (selectable frequency) interoperability overlay as shown in Figure 9.

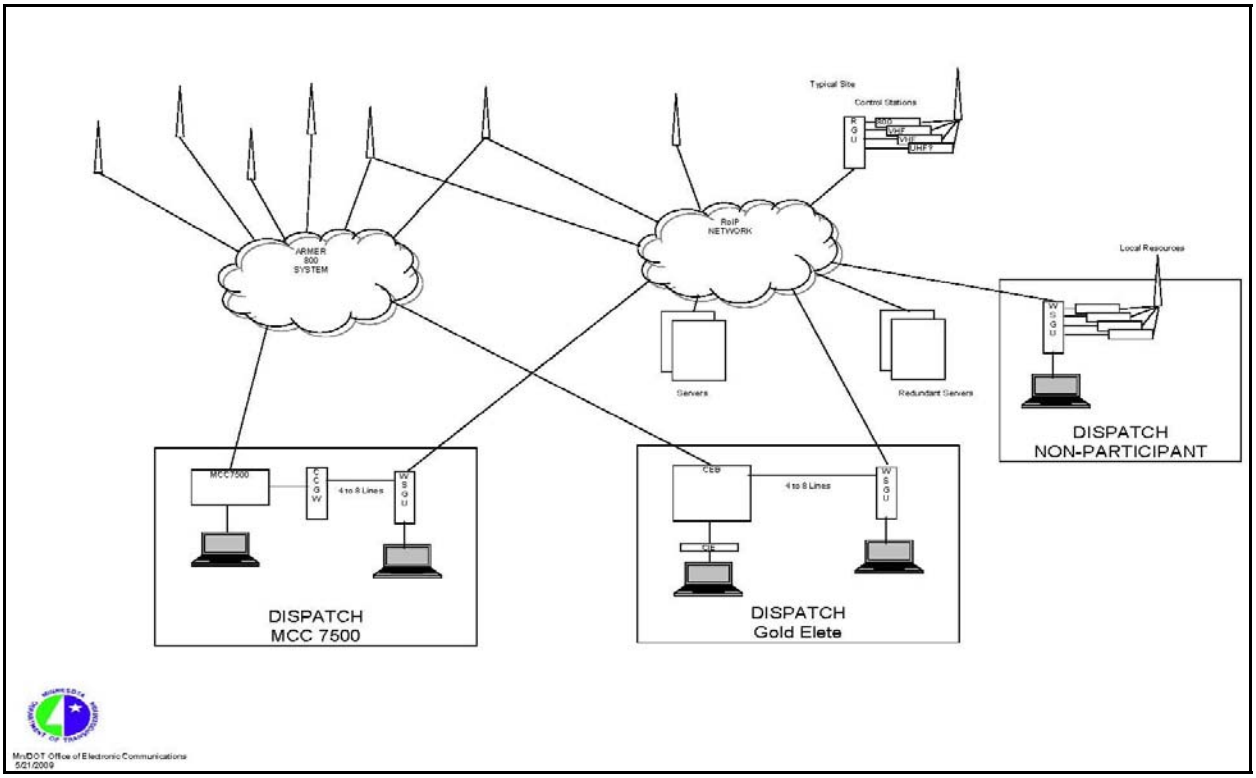

Figure 9 - MnDOT interoperability recommendation

Portions of the ARMER transport systems would be configured to carry RoIP based traffic from remote radio gateway units at ARMER sites to RoIP workstations at state and possibly local dispatch centers. Authorized users could utilize these workstations to link or patch interoperability radios in different bands to ARMER talk groups or to local radio resources available at the local dispatch center. Figure 10 is an example of a typical interoperability configuration at a remote site.

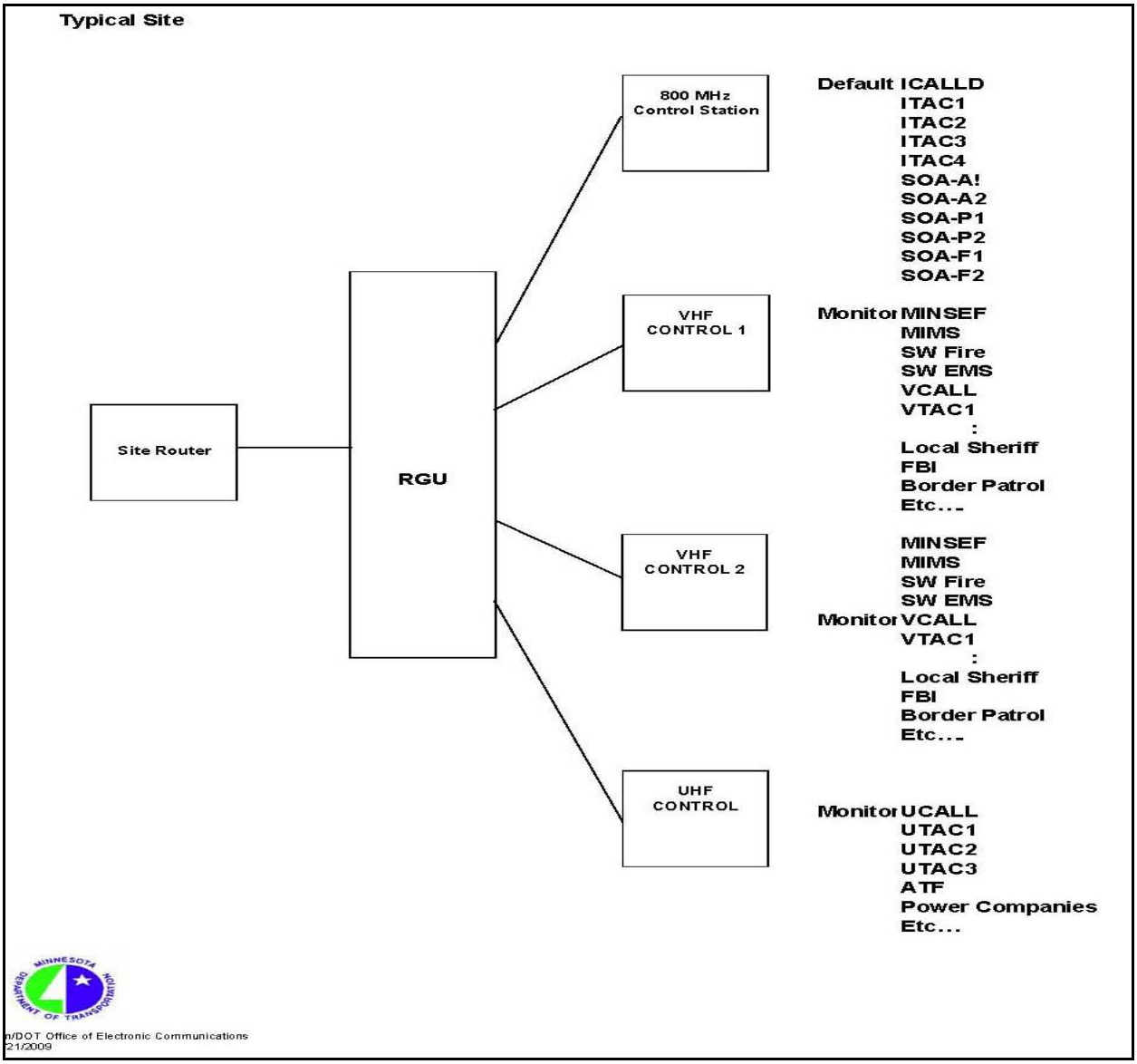

Figure 10 - Typical interoperability remote site

There are several factors specific to the use of Motorola RoIP equipment that may enhance the proposed MnDOT solution. Implementing a Motorola Motobridge system would likely minimize the time needed to implement the solution since system components and services may be included or easily added to existing contracts between Motorola and MnDOT. The use of Motorola radio control stations as part of the overlay network in conjunction with Motobridge provides more remote control capabilities than might be offered in some other RoIP solutions. Motorola's Motobridge product also offers receiver voting and transmitter steering capabilities that would require additional ancillary equipment to duplicate in other RoIP systems. However, the operational limitations associated with the implementation of these features should be researched further to determine the value these capabilities might add in MnDOT's proposed configuration.

The deployment of low power, frequency agile radio control stations in the overlay network significantly increases the amount of channel reuse possible in a region due to the smaller coverage area providing by each station and allows greater operational flexibility by enabling the same resources to be used on different radio channels during different incidents. However, this also increases the number of interoperability resources that a dispatcher or supervisor must monitor and manage which increases the complexity of the solution. A more manageable approach might be to provide higher-powered fixed hailing or calling channels monitored by selected dispatch centers and supplementing those channels with a mixture of low power, frequency selectable resources that can be activated as needed.

The use of RoIP systems was not specifically included in the original ARMER plans but the use of RoIP is consistent with the goals outlined in the SCIP, which directed the state to investigate, develop and test specific technical and operational plans on how existing VHF and UHF interoperable resources might be organized and integrated into public safety communication systems. The ARMER project plan allocates approximately $4.9 million and the 2007 PSIC grants included $3 million to provide this type of interoperability in the state.

As detailed earlier in the report, the addition of a RoIP interoperability backbone could also provide ARMER network support staff with enhanced tools for managing and supporting the ARMER 700/800 MHz radio system as well as the transition of existing VHF users to ARMER. ***FE*** recommends further evaluation of the capital and recurring costs as well as the technical and operational aspects of this type of solution be performed to determine the extent to which RoIP capabilities can be integrated into the recommended hybrid solution.

10. Conclusion and next steps

This revised draft final report expands upon the conceptual approaches for implementing interoperability infrastructure solutions within the state and presents a high-level strategy to provide a supplemental interoperable infrastructure to ARMER. This multi-level deployment uses two types of solutions as components of the interoperability network. The ultimate result of the strategy, if fully deployed, would be a hybrid solution capable of implementation in a phased manner that meets a majority of the identified interoperability needs of the state. The strategy includes the following primary components:

1. ARMER donor radios
2. VHF/800 interoperability channel overlay

The ARMER donor radios provide dedicated radios to local dispatch centers to allow ARMER users to communicate directly with local dispatchers and users that remain on local VHF systems. This approach can provide Level 2 interoperability (gateway) between ARMER users and local VHF radio system users when donor radios are integrated into local radio dispatch consoles and when the ARMER and local VHF radio system users are within the coverage areas of their respective systems.

A VHF/800 interoperability overlay resolves interoperability issues between VHF and ARMER system users within the state and in adjacent states and provinces. The VHF/800 interoperability overlay, comprised of a limited number of common radio channels deployed at strategic locations throughout the state, provides a communications safety net or lifeline for conventional VHF or conventional 800 MHz radio users traveling outside the coverage of their primary radio systems to contact local and state dispatch centers. The VHF/800 interoperability overlay provides Level 2 interoperability (gateway) when ARMER users and VHF radio users are patched together and Level 3 interoperability (shared channels) when utilized by two or more VHF or 800 MHz users or entities.

FE further recommends the following steps be included in the plan of action to provide an interoperability infrastructure in Minnesota.

1. The deployment of ARMER donor radios to local dispatch centers should continue in order to address day-to-day interoperability issues that exist between agencies that remain on VHF systems that still need to communicate with ARMER trunked radio system users.

2. Work should commence immediately on the development of a conceptual design for the VHF/800 interoperability overlay to address incident based interoperability issues between conventional VHF or conventional 800 MHz radio users traveling outside the coverage of their primary radio systems within the state. The conceptual design development work should include the following:
    a. Site selection and coverage analysis based on mobile radios operating primarily in a fixed incident environment.
    b. Analysis of frequency licensing requirements and the suitability of the national interoperability channels for use along state and Canadian borders.
    c. The selection of interoperability channels for short-term (wideband) and long-term (narrowband) use within the overlay.
    d. Traffic analysis for the addition of the overlay channels to the ARMER transport systems.
    e. Evaluation of the options for connecting and monitoring the overlay channels by the appropriate state and local dispatch centers.
    f. Further evaluation of the capital and recurring costs as well as the technical and operational aspects of RoIP solutions to determine to the extent to which RoIP capabilities can be integrated into the recommended hybrid solution.
3. The state should implement the hybrid solution as a pilot project in the ARMER phase 3 region (23 counties of central and southeastern Minnesota). This will allow radio users to test the technical and operational aspects of the hybrid solution and the state to refine the conceptual design prior to deployment in phases 4, 5 and 6. The pilot project would be implemented using existing ARMER funds allocated for interoperability in this region.

The ARMER donor radio and VHF/800 overlay approaches could be implemented independent of each other however, finalizing the plan for deployment of these interoperable solutions as an integrated system would be more effective and minimize stranded investments that might occur without such a plan. An initial deployment strategy that incorporates the capabilities of these solutions at a system level may allow for reduction in costs and operational complexity by eliminating or reducing the need for ancillary equipment needed to integrate the components retroactively.