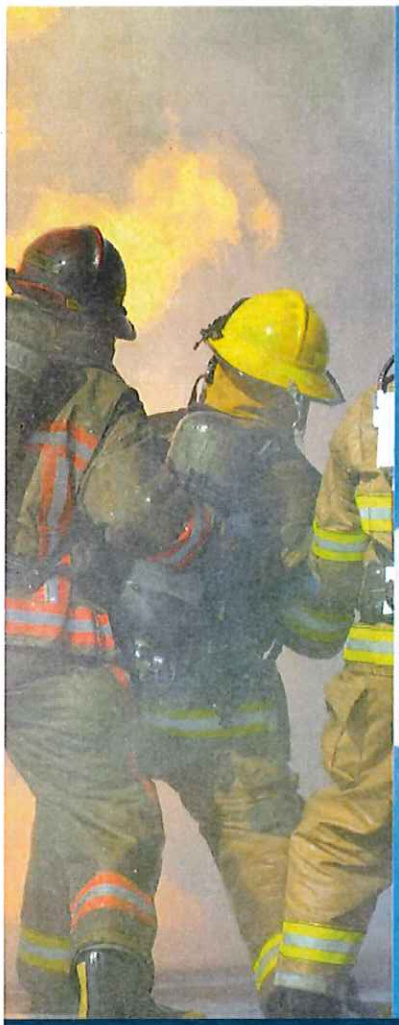

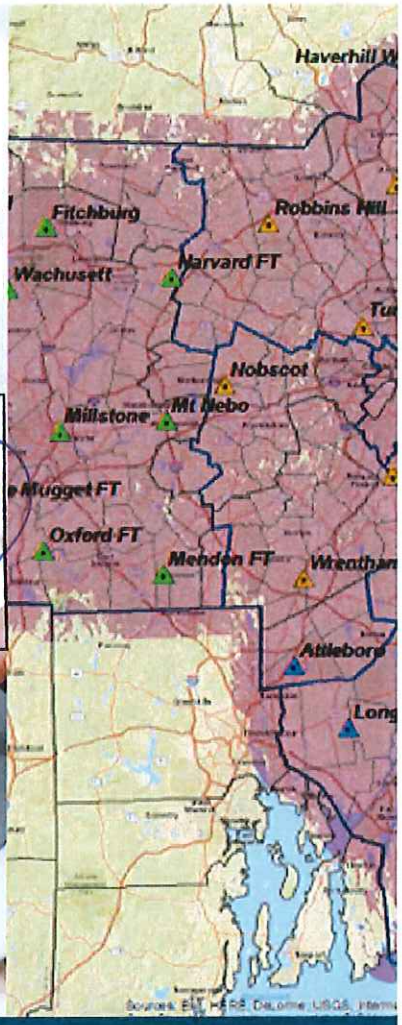

Commonwealth of Massachusetts Interoperable Radio System (CoMIRS)

3 CoMIRS Market Analysis

Version 1.0 (May 2017)

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3 MARKET ANALYSIS

It is critical for state, local, tribal, and federal public safety personnel across the Commonwealth of Massachusetts to have radio communications systems that meet their daily and emergency needs. The objective of this market analysis is to examine how other states similar to the Commonwealth in numerous ways have implemented statewide public safety radio networks.

3.1 Assessment

3.1.1 Overview

To determine how similar states have implemented statewide public safety radio networks, 16 candidate states were identified in consultation with the Massachusetts Executive Office of Public Safety and Security (EOPSS) and the Massachusetts State Police (MSP). These comparison states were assessed on a variety of criteria to determine the likelihood that their experiences would be applicable to Massachusetts. This initial assessment led to the selection of four states deemed most similar to the Commonwealth. The radio communication systems of these four states were then evaluated in greater detail.

Figure 3-1 highlights the states used for comparison in this report. Together, the 12 states shaded in blue and the four states shaded in yellow represent the 16 comparison states. The pinned yellow states are the ones selected for the more detailed analysis including:

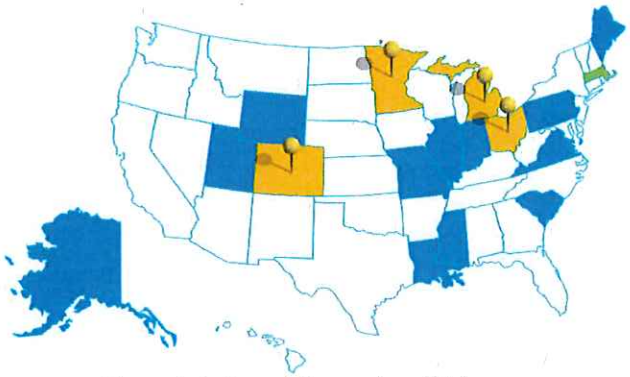

Figure 3-1: Map of Comparison States

- Colorado
- Michigan
- Minnesota
- Ohio

3.1.2 Methodology

The 16 candidate states represent a cross section of states, including those with statewide P25 digital networks in place. The selected states were evaluated against key baseline criteria to determine their similarity to the Commonwealth, including criteria pertaining to:

- Home Rule
- Geography
- Population

3.1.2.1 Home Rule

Massachusetts is a Home Rule state, which has significant implications for how projects can be planned, financed, managed, and implemented. According to the American City County Exchange, "Home Rule charters permit local governments to conservatively pass ordinances as they see fit, provided they abide by the state laws and constitutions." (Russell & Bostrom, 2016). States were selected for further analysis on the basis that they too were Home Rule states.

See the following publication for additional information on the implementation of Home Rule in Massachusetts: http://www.mass.gov/dor/docs/dls/mdmstuf/technical-assistance/best-practices/homerule.pdf.

3.1.2.2 Geography

A key component affecting the size of a radio network is the amount of landmass covered. This is a direct driver for infrastructure costs, such as tower locations. Moreover, if the network covers a wide variety of terrain, such as coastlines and mountains, each terrain type can create its own challenges for providing adequate radio coverage. The table below shows a cross section of both geographic and population details used to narrow the comparative field. A description of the fields and their relevance to the analysis immediately follows.

State	Population (15 est)	Pop Density	Sq. Miles	Coastal	Metro	Mountains	Significant Snow	Similarity	Lane Miles	Major Metro Areas	Home Rule	SW Network or PS
Alaska	738,432	1.1	665,384	Yes	No	Yes	Yes	High	31,618	Anchorage, Fairbanks, Juneau	Yes	No
Colorado	5,456,574	52.4	104,094	No	Yes	Yes	Yes	High	184,289	Denver	Yes	No
Illinois	12,859,995	222.1	57,914	No	Yes	No	No	Low	305,872	Chicago	Yes	Maybe
Indiana	6,619,680	181.8	36,420	No	Yes	No	No	Low	203,569	Indianapolis, Fort Wayne	Limited (Dillon's rule)	Yes
Louisiana	4,670,724	89.2	52,378	Yes	Yes	No	No	Medium	130,038	New Orleans, Shreveport, Baton Rouge, Lafayette	Yes	No
Maine	1,329,328	37.6	35,380	Yes	No	Yes	Yes	High	46,879	Portland	Yes	Yes
Massachusetts	6,794,422	643.8	10,554	Yes	Yes	Yes	Yes		76,852	Boston, Springfield	Yes	
Michigan	9,922,576	102.6	96,714	Yes	Yes	No	Yes	High	256,806	Detroit	Yes	Yes
Minnesota	5,489,594	63.1	86,936	No	Yes	No	Yes	Medium	285,084	Minneapolis	Yes	Yes
Mississippi	2,992,333	61.8	48,432	Yes	Yes	No	No	Medium	156,999	Jackson	No	No
Missouri	6,083,672	87.3	69,707	No	Yes	No	No	Low	273,589	St Louis	Yes	Maybe
Ohio	11,613,423	259.1	44,826	Yes	Yes	No	Yes	High	262,851	Cleveland, Cinncinati, Akron, Columbus,	Yes	Yes
Pennsylvania	12,802,503	278.0	46,055	No	Yes	Yes	Yes	High	250,199	Philidelphia, Pittsburgh	Yes	Yes
South Carolina	4,896,146	152.9	32,020	Yes	No	No	No	Low	140,106	Greenville, Columbia,	Limited	Yes
Utah	2,995,919	35.3	84,897	No	Yes	Yes	Yes	Medium	97,448	Salt Lake City	Limited	No
Virginia	8,382,993	196.0	42,775	Yes	Yes	Yes	No	High	161,914	DC, Virginia Beach	No	Yes
Wyoming	586,107	6.0	97,813	No	No	Yes	Yes	Medium	60,454	Casper	No	Yes

Table 3-1: Comparison of States

- **Population**: Based on 2015 estimate, a larger population typically means more over the air traffic.

- **Population Density**: Calculated as population per square mile, a higher population density typically requires more first responders in that area.
- **Sq. Miles**: The total area, including land and water, in square miles.
- **Coastal**: Signifies if the state has significant coastal area on large bodies of water (e.g., oceans, Great Lakes, etc.) which can present different challenges for providing coverage.
- **Metro**: Indicates if the state has a large metropolitan area. Large metropolitan areas typically require a higher population of first responders and increased radio traffic.
- **Mountains**: Signifies whether the state has mountainous geographic areas. Mountainous areas have an impact on the transmission of radio waves.
- **Significant Snow**: Indicates whether the state receives a significant amount of snowfall. Snowfall often increases the demands of first responders and other public safety radio users, such as the Department of Transportation.
- **Similarity**: An assigned rating of potential similarity based meeting a combination of the various criteria in the table.
- **Lane Miles**: The total number of road miles within the state. The number of lane miles is an indication of the expected traffic volume across the state.
- **Major Metro Areas:** A listing of the largest metropolitan areas within the state.
- **Home Rule**: An indication of whether the state uses Home Rule (or some variation). This has an impact on the way in which the state may establish statewide regulations and commissions.
- **SW Network or PS**: Signifies whether the state has implemented a statewide public safety (or equivalent) radio network.

3.1.2.3 Population

A network that serves a larger population can be expected to have a proportionately higher number of first responders and other public personnel requiring radio communications. For network planning, population density is important for two reasons:

1. **In Building Coverage**: A highly dense population requires urban environments. Urban environments create demand for better quality of in-building radio coverage and create corresponding challenges in providing the coverage.
2. **Demand for Channels**: Dense population centers require more public services in smaller areas. With greater density, demand for additional radio channels makes spectrum management, message prioritization, and infrastructure management more challenging.

Among the 17 states considered, including Massachusetts, the greatest areas of disparity pertained to geographic size and population density. Massachusetts is the smallest landmass of the sample set, but is the fifteenth most populated state. This gives the Commonwealth a greater population density than

the states we sampled. This density difference does not invalidate further comparison. It does mean, however, that when comparing Massachusetts to other states, Massachusetts' higher population density may result in a higher density of first responders, state activities, and local governments. ***All else being equal, Massachusetts will need to plan for higher channel density and more stringent frequency management than the peer states analyzed.***

3.2 States Matching the Commonwealth

After further analysis, considering home role, geographic similarities, population, size, and technology usage, Massachusetts was found to be a reasonable match with Ohio (OH), Michigan (MI), and Minnesota (MN). Minnesota was added to the analysis after public safety radio managers in Ohio and Michigan recommended that Minnesota be considered because of their unique governance structure and their progress on building out their network. All comparison states selected use Home Rule, have between five and 12 million residents, are and between 10,000 and 105,000 square miles.

Characteristics of States Selected for Comparison:

- Home Rule
- Geographic similarities
- 5M – 12M residents
- 10K – 105K square miles

From a technology perspective, all four of the selected states chose to build their network around a modern set of radio technologies. In all four cases, the statewide network was built on P25 compliant digital trunked radio technology in the 700 and 800 MHz frequency band. Massachusetts adopted P25 digital trunked technology in 2005. Systems build out since then in Massachusetts have utilized P25 technology. The Commonwealth network also operates in the 700 and 800 MHz frequency band.

Another major comparison consideration regarding technology usage is whether the radio system is used for daily operations and/or for interoperability and mutual aid. In the selected four states, the statewide network provided both operational and interoperable capabilities to its users, although new users are often charged an extra fee for placing heavier usage needs on the network. The existing Massachusetts network provides daily operational use for multiple state, county, and local agencies as well as the capacity for interoperability and mutual aid. As the Commonwealth plans to upgrade its network and possibly expand the usage to other agencies, both operational and interoperation use need to be considered in the near future.

Many of these comparison states have made a significant amount of information available publically that we leveraged for this analysis. The publically available documentation is itemized in the References section of this report. To gather more detailed information and to fill in gaps not addressed with publically available information, we conducted interviews with key personnel involved in the radio networks in the focus states. The interviews averaged 90 minutes in length and used a standard list of questions to build a consistent baseline for comparison across the sample set. During the interviews, information about the origin and roll out of the statewide systems, the technology in use, the governance structure in place to support the networks, and the business model used to purchase and fund ongoing operations was discussed. See the Appendix for a list of interview questions.

Figure 3-2, compares the four states and Massachusetts in five important areas including 1) the size of the state in square miles, 2) the overall population, 3) the population density, 4) the number of member

agencies on the networks, and 5) the number of active subscribers currently using the network. As Massachusetts does not currently operate a true statewide radio network, the number of active subscribers in Massachusetts is less than the comparison states operating a statewide network. The table shows the range in subscriber counts in the comparison states who have a relatively similar population to Massachusetts. The number of active users ranges from 72,000 in Ohio to 92,000 active users in Colorado.

	Size (miles^2)	Population	Pop Density	Member Agencies	Acitve Subscriber IDs
Colorado	104,094	5,456,574	52.4	1000	92,000
Michigan	96,714	9,922,576	102.6	1500	75,000
Minnesota	86,936	5,489,594	63.1	83 (Counties)	89,000
Ohio	44,826	11,613,423	259.1	1200	72,000
Massachusetts	10,554	6,794,422	643.8	n/a	16,000

Figure 3-2: Overview of Comparison Networks

3.2.1 Overview of Focus States

Understanding which services are provided is central to the discussion of costs and adoption as more modern capabilities require expensive upgrades of both infrastructure and end-user equipment. Expensive equipment requirements, particularly for smaller municipalities or agencies with limited budgets, can be a major deterrent to joining a statewide network. On the other hand, more modern services offered by a large network, and underwritten by the state or a larger body of users, can also be a significant draw for agencies to join the network. This is particularly true if the initial cost of equipment acquisition can be partially offset thereby reducing total cost of ownership.

The basic trunked radio technology is the central element of the services offered. Some states have additional services as well. Michigan offers firefighters an 800 MHz digital paging service to replace their traditional VHF paging. Ohio adds mobile data and computer aided dispatch. While these features can be useful to a subset of users, it is clear that the real draw of a statewide network is geographical reach and the ability to communicate with a large number of other users on the same system.

When building out their systems, some states have taken an incremental approach to driving adoption, such as designing capabilities into their system to allow connectivity with legacy technologies. For example, both Minnesota and Colorado have substantial amounts of conventional VHF radio networks connected to their statewide network. This allows agencies still operating VHF end user equipment to benefit from the statewide system – and ultimately fully migrate to it as their older equipment ages out. An overview of each of the four states, including the services available, is provided below.

3.2.1.1 Colorado Overview

Colorado's statewide radio network, the Public Safety Communications Network Digital Trunked Radio System (DTRS), is managed by the Consolidated Communications Network of Colorado, Inc. (CCNC), which is a non-profit 501(c)(3) corporation.

CCNC's primary role in managing the state radio system is in coordinating cooperative agreements that bind user agencies. These agreements address equipment usage and programming, infrastructure management, and required upgrades and maintenance. As an example, if an agency chooses to join CCNC and connect to the network with their own infrastructure, CCNC requires the agency to sign an agreement stipulating that their system software will be upgraded to maintain compatibility with the broader statewide system.

CCNC Inc.
Consolidated Communications Network of Colorado

Supports 757 agencies as primary users and 289 as secondary users. This list includes federal, state, and local agencies as well as EMS, fire, public works, tribal entities, and utilities

Membership is optional. Users opt-in to membership with CCNC by signing an operating agreement and paying a nominal fee

Services provided:

- P25 compliant trunked communications system
- 700/800 MHz frequency band
- Daily dispatch and operational use
- Interoperability and mutual aid channels

Figure 3-3: Colorado Highlights

Through these agreements, CCNC maintains a state network that is essentially a loose federation of statewide infrastructure and compatible equipment from local user agencies that goes far beyond traditional public safety radio users.

3.2.1.2 Michigan Overview

Beginning in the mid-1990s, the State of Michigan made a significant investment to develop the Michigan Public Safety Communications System (MPSCS), which provides statewide radio communication for first responders. While MPSCS was first implemented to serve the Michigan State Police, the scope expanded to include over a thousand state and local agencies. In recent years, the Departments of Natural Resources and Transportation have also become reliant on the system.

MPSCS
Michigan's Public Safety Communications System

Supports 1494 federal, state, and local public safety agencies

Membership is optional. Michigan markets the capabilities to users who choose to opt in

Services provided:

- P25 compliant trunked communications system
- 800/700 MHz frequency band
- Dispatch redundancy for member agencies
- Two-tone fire paging as well as 800 alert paging
- Daily operations as well as interop and mutual aid

Figure 3-4: Michigan Highlights

MPSCS operates as a division of Michigan's Department of Technology, Management, and Budget. MPSCS provides a stable, secure framework for interoperable communications among local, state, federal, tribal, and private first responders and supplies a public safety communication resource for citizens.

MPSCS handles the second-largest trunked communication system in the world, including administration of a statewide 700/800 MHz digital

trunked radio communication network spanning 59,415 square miles and including more than 246 radio towers and 74,000 radios.

3.2.1.3 Minnesota Overview

Minnesota's statewide radio network is called the Allied Radio Matrix for Emergency Response (ARMER). ARMER is one of Minnesota's Emergency Communications Networks (ECNs) and operates under the authority of the Minnesota Department of Public Safety.

Minnesota established the ARMER Program in 2004. It is administered in coordination with the Statewide Emergency Communications Board and manages the implementation of the 800 megahertz shared, digital trunked radio communication system.

The ARMER backbone is owned and operated by the Minnesota Department of Transportation (MNDOT). It is a robust, scalable, state-of-the-art system capable of serving the radio communications needs of every city, county, state agency, tribal government, and non-government public safety entity in the state.

Supports 83 of 86 counties across the state. Users federal, state, and local agencies; tribal governments; and non-government public safety users

Membership is optional. Members must opt-in and submit a comprehensive participation plan in order to join ARMER

Services provided:

- P25 compliant trunked communications system
- 800 MHz frequency band
- Daily dispatch and operational use
- Interoperability and mutual aid channels
- VHF overlay network for interoperability and usage by members with older equipment

Figure 3-5: Minnesota Highlights

3.2.1.4 Ohio Overview

The Ohio Multi-Agency Radio Communication System (MARCS) is a 700/800 MHz radio and data network that utilizes state-of-the-art trunked technology to provide statewide interoperability in digital clarity to its subscribers throughout Ohio as well as a 10-mile radius outside of Ohio. The MARCS system provides statewide, secure, reliable public service wireless communication for public safety and first responders.

The MARCS development contract required 97.5% mobile voice and data in street coverage. Aggregate voice coverage of 99.71% was realized and 98.13% aggregate data coverage was achieved. This allows maximum statewide interoperability and enhanced safety and protection for public safety service providers through secure digital transmissions.

Supports more than 1200 public safety/public service agencies statewide. This includes local, state and federal agencies

Membership is optional. Ohio markets the capabilities to users who choose to opt in. Several cities maintain their own networks for operations and use MARCS for interoperability

Services provided:

- P25 compliant trunked communications system
- 800/700 MHz frequency band
- Dispatch redundancy for member agencies
- Mobile data
- Computer aided dispatch including GPS enable vehicle location

Figure 3-6: Ohio Highlights

3.3 Detailed Findings

This section includes the detailed findings of the market analysis of the four comparison states. The findings are presented in four categories: Users, Technology, Governance and Administration, and Finance. A high-level summary is provided followed by the information for each state.

3.3.1 User Findings

During our interviews, we asked our target states which users they allowed on the system. In most cases, the interviewees stated that they generally let anyone on the system who fulfills all of the equipment and regulatory requirements. Specifically, all four of the states interviewed allow membership from any government entity that requests access, with the primary emphasis placed on the public safety community. All four states approached the statewide network from the perspective of providing a capability that would be attractive to new users and allowing them to opt-in rather than making usage mandatory.

Usage rights across the networks vary, and all four states allowed a remarkably wide variety of state and local government agencies to use the network. Beyond the traditional police, fire, EMS, and transportation users – we found users from tribal entities, local schools, parks, and recreation.

The statewide networks of the target states generally began at the grassroots level as regional networks providing interoperability primarily to users at police and fire departments. Regional networks then began to proliferate as other parts of the state decided they needed similar levels of communication and started creating islands of interoperability across the state. Notably, this evolution tended to leave sparsely populated parts of the state isolated from the larger networks.

In most cases, the first statewide network users were state police. In the four states interviewed, the existing state police network became the superstructure upon which the new state system was built. Starting with the existing state police network, our four target states began to build out capability in one of two ways, either by connecting infrastructure from other agencies that wanted to join the network or by adding new towers and radios to extend coverage.

3.3.1.1 Colorado Users

In Colorado, membership is open to any law enforcement groups, fire department, school districts, and any other city, county, state, tribal, or federal agency able to meet FCC Regulation 90.20. Currently, Colorado's network includes over 1,000 user agencies. Membership is broken into two categories: Primary Members and Associate Members. Primary Members are members that use the DTRS as their primary means of voice communications. Associate Members are those users that do not use the DTRS as their primary means of voice communications. Associate Members may participate in governance activities but cannot vote or hold office.

In Colorado, private companies may also receive consideration to use the system if they meet the following conditions:

- Must be contracted to perform services for a governmental agency approved to use the system.
- Must be sponsored by the governmental agency.

- Must be conducting business pursuant to the contracted services with the governmental agency.
- May not have talkgroups on the system to conduct their day-to-day business, not associated with their contracted services.

3.3.1.2 Michigan Users

Michigan currently has 63 of their 83 counties on their network. This includes approximately 1,500 agencies and over 75,000 subscribers. Michigan projects a 9% growth in the user base for the next six months.

3.3.1.3 Minnesota Users

To date, 78 of the 87 Minnesota counties have migrated to ARMER. Seven additional counties have or will be creating a participation plan to assess the feasibility of migrating to ARMER within the next few years.

3.3.1.4 Ohio Users

Over 1,200 public safety/public service agencies use Ohio's state network. This includes local, state, and federal agencies. The largest member agencies include the State Highway Patrol, the Ohio Department of Transportation, and the Department of Natural Resources. The larger cities in Ohio have their own networks, but they use MARCS for interoperability. There are over 47,500 voice units and over 1,800 mobile data units on Ohio's MARCS system.

3.3.2 Technology Findings

The four selected states have unique systems and their technical parameters are different. This section compares the states across various technical parameters and provides a description of the respective systems. Table 3-2 Technical Specification Summary below provides a quick glance reference of the comparison systems.

Technical	Colorado	Michigan	Minnesota	Ohio
Vendor	Motorola	Motorola	Motorola	Motorola
P25	Yes	Yes	Yes	Yes
Version	Unavailable	7.13	7.15	7.15
Trunked	Yes	n/a	Yes	Unavailable
700 MHz	Yes	Yes	No	Yes
800 MHz	Yes	Yes	Yes	Yes
Sites	220	247	326	Unavailable
PSAPS	400	Unavailable	113	Unavailable
Phase II	Unavailable	Yes, not deployed	No	Unavailable
Coverage	90%	97%	95% Mobile	99%

Technical	Colorado	Michigan	Minnesota	Ohio
Fire Pagers	Unavailable	Unication	No	Unication
Zone Controllers	5	Unavailable	6	Unavailable
Simulcast	Yes	Yes	Unavailable	Yes
Multi-Cast	Yes	Yes	Unavailable	Yes
In-Building	No	Unavailable	Yes	Unavailable
Technical	Colorado	Michigan	Minnesota	Ohio
ADP encryption	Yes	Yes	Yes	Yes
AES encryption	Yes	Yes	Yes	Yes
Subscriber standards	Yes	Yes	Unavailable	Yes
Codeplug	By Agency	Unavailable	By Agency	Unavailable
Mutual Aid Channels	Required	Unavailable	VHF and 800	Unavailable
Training	Centralized	Unavailable	Centralized	Unavailable
Call Volume	8,000,000 / month	Unavailable	Unavailable	95 million PTT (2012)
Busy queues	1 - 2 seconds	< 3 Seconds	Unavailable	Unavailable
VHF	Yes	Unavailable	Yes (109 Sites)	Unavailable
UHF	Yes	Unavailable	Unavailable	Unavailable
Consoles	Unavailable	272 Console Positions	MCC7500	Unavailable
Fiber Backhaul	Unavailable	Unavailable	n/a	Yes
Microwave Backhaul	Unavailable	Yes	Yes	Yes
# of Towers	Unavailable	Unavailable	105	218

Table 3-2: Technical Specification Summary

3.3.2.1 Colorado Technology

The State of Colorado's radio network supports over 1,000 agencies and 92,000 user IDs with a Motorola, P25 trunked system operating in the 700 and 800 MHz bands. The system is comprised of 220 sites and 400 PSAPs connected by five zone controllers. The network provides statewide radio coverage to 64 counties.

In addition to Motorola subscribers, some agencies choose to purchase equipment from other vendors such as Harris, Tait, Kenwood, and RELM Wireless. Technical and operational testing is required of

each model to ensure that system standards are met. The radio models that pass and are accepted for use are published in a list provided to state agencies.

The system uses simulcast and multi-site designs to provide 90% on-street coverage and is not designed for in-building coverage. ADP and AES encryption are used by various agencies across the state as needed, with ADP being the predominate type due to cost.

Codeplug development, or programming within the subscriber unit, is handled by each agency. Users are allowed to program their own scan list. However, mutual aid channels are required in all radios. The non-profit that manages the network maintains its own training subcommittee.

The system processes around eight million calls per month and busy queues are one to two seconds in length. UHF and VHF are still in use across the state.

3.3.2.2 Michigan Technology

The State of Michigan's radio network was originally designed to provide coverage along major roadways. Today, the system has been expanded to provide enhanced coverage for users beyond the roadways. The system is a 247 site, P25, Motorola 7.13 system operating in the 800 MHz band. Currently, 700 MHz channels are being added as needed.

The system uses both simulcast and multicast technology. However, counties are covered by 10 separate simulcast systems of varying channel density. While 18 channels are typical, a large city like Detroit has 30 channels. More channels are associated with locations with more population density due to the probability of system loading. The system is Phase II TDMA capable, but has not been employed.

Overall, the system affords 97% coverage statewide in all weather conditions. Fifteen hundred agencies operate on the system and make up 70,000 users. Unication pagers are used for fire service. The network and 272 console positions are connected by seven cores across the state.

The system uses both ADP and AES encryption. Encryption is employed on certain select talk groups across the state to manage and somewhat alleviate problems with disparate keys. The system's backhaul is composed of microwave, which is affected by fog off nearby lakes in many areas.

The system is locked down and the system-key is closely controlled for programming and is not shared. Michigan encourages the use of radio brands that meet the agencies' budgets. However, no radio is allowed onto the network until it undergoes technical and operational testing.

The system is realizing 9% growth every six months, with most busy queues lasting less than three seconds.

3.3.2.3 Minnesota Technology

Minnesota operates a Motorola P25 Phase 1, 800 MHz trunked radio system called ARMER. ARMER is a Release 7.15 system, which is currently undergoing an upgrade to 7.17 with hardware installation to support a future transition to 7.19. The system is composed of 326 radio sites to provided mobile radio coverage at a 95% reliability level. The 700 MHz spectrum is not used.

ARMER is deployed in a six-zone configuration with microwave backbone providing all system backhaul. ARMER includes 104 primary PSAPs answering 911 calls and five secondary PSAPs. They operate three PSAPs for State Patrol and the University of Minnesota Twin Cities campus.

The Minnesota Department of Transportation (MNDOT) provides most of the maintenance on the network with minor support provided by outside contractors when required.

The system operates in conjunction with interoperability talk groups on a county, region, and statewide level. Local agencies participating in the system and seeking to enhance the coverage in their local area have added approximately 150 tower sites to the network. Local agencies that supply additional radio sites to enhance coverage are responsible for backhaul to system Zone Controllers with guidance from the governance organization. Local agencies are responsible for maintenance and software upgrades of locally owned fixed infrastructure equipment, with coordination and input from MNDOT and the governance organization.

The ARMER governance body has approved 115,225 radios to operate on the network. As of the date of this report, 91,596 radios are registered on the system. All radios on the 800 network are required to have 800 MHz National Interop Channels.

User agencies are responsible for maintenance and software support on subscriber radios operated on the network. The ARMER governance organization dictates standards for the programming and configuration of user radios to ensure that all interoperability provisions are applied universally across the network. Local agencies are authorized to program radios on the network once training requirements have been met. Training is provided at the state level or by Motorola as the prime contractor.

Encryption of both ADP and AES are used on the system by agencies that require privacy for sensitive radio traffic.

3.3.2.4 Ohio Technology

The State of Ohio is comprised of 88 counties and uses a Motorola Release 7.15 P25 network operating within the 700 and 800 MHz bands. The system uses a combination of simulcast and multicast technology to provide 99% mobile coverage to users. More heavily populated areas use simulcast and areas that are more rural use multicast.

The system operates approximately 8,000 talk groups and 72,000 subscribers of which approximately 50,000 units are billable. The system assigns 1.1 million push-to-talks per day. For fire services, Unication pagers are used over the trunked system.

Encryption is used as needed for sensitive radio traffic and some users use ADP. However, AES was recognized by the interviewees for interoperability with federal agencies. Frequencies of 700 and 800 MHz are acquired as needed and they do not realize interference for other users within the band.

The system's backhaul is a combination of fiber and diversity microwave for redundancy. State agencies are the top users on the network - some of which include the Ohio State Police, the Department of Transportation, and the Department of Natural Resources.

Motorola APX, XTS, XTL are the primary subscriber products operating on the system. There is, however, other vendors' equipment operating on the system such as Kenwood, Harris, Tait, RELM Wireless, and EFJohnson. Before any P25 radio is to the network, the radio must undergo technical and operational testing to ensure it is compatible on the state's network.

3.3.3 Finance Findings

In this section of the analysis, we examine each of the four focus states in terms of the cost to build and maintain their radio system and the funding sources utilized to cover the costs.

Financial approaches across the states varied, as illustrated in Figure 3-7. Methods of funding network construction and operations included grant funding, bond issuance, 911 surcharge, user fees (by subscriber or by agency), and general fund appropriation. In a few cases, a significant amount of the cost of the network is born by local users who provide some of the infrastructure that comprises the network.

State	Cost in millions	Grants	State Appropriations	Subscriber Fee	911 Fee	Locally Funded	Membership Fee	Bonds	Activation Fee
Michigan	230		x	x				x	x
Minnesota	236	x			x			x	
Colorado	135			x	x	x	x		
Ohio	272					x			

Figure 3-7: Financial Comparison of States

3.3.3.1 Colorado Finances

Costs

While Colorado invested in new infrastructure in the mid 1990's, they did not build out a complete statewide network as one project in the same way that Michigan, Ohio, and Minnesota did. This is because Colorado's network is less of a true state system and more of a federation of local agencies and users who opt-in to a set of common operating standards to create a mesh that covers the entire state.

The costs for Colorado's build out totaled to $135 million dollars in 1995. These costs included:

- Backbone equipment: $105,000,000
- Subscriber equipment (10k units): $27,400,000
- Fixed equipment (state level only): $2,910,000

Since costs are scattered across hundreds of user agencies, Colorado's federated network model creates challenges in estimating the maintenance cost necessary to keep the equipment running properly. In 2010, Colorado commissioned a consulting firm to research and report on the total costs of their statewide radio network. That report concluded that Colorado would pay $11 million per year from 2010-2014 as recurring maintenance cost, and would additionally need to invest between $6 million and $15 million to replace aging equipment already in use across the network.

For the agencies that use the system, their costs are based upon the equipment they have in the system. As an example, the Glendale Police Department is a small user agency and they budget about

$10,000 per year for maintenance. They also have a replacement cycle for equipment that on average is $45,000 per year. This is one small example of an agency's costs not provided for in the state budget.

Administrative costs in Colorado are minimal at the state level. CCNC Inc. is a volunteer organization, which operates on a budget of $100,000 annually. This cost covers a contracted administrative assistant and other minor operations necessary to manage the policies and cooperative user agreements that govern activity on the network.

Funding

There are no sustainable funding streams at this time for the entire system, except what can be appropriated in agency budgets to maintain their portions of the infrastructure. Funding has been, and still is, a large issue that Colorado is trying to address. The Public Safety Communications Network in the state government charges a $50 fee to others in state government for the radios.

The majority of funding for the Colorado network comes from the individual agencies, even at the State level. This results in a wide variety of approaches across the state. Some of the county governments in Colorado recoup costs by charging a fee, usually around $25-$50 per radio. Other county 911 authority boards allow for the use of 911 funds for radio equipment, which has been authorized by statute. These funds are not sufficient to cover the higher costs of infrastructure maintenance, but they do help offset radio programming costs.

CCNC charges an annual membership fee of $100 per agency, however there is no active collection by CCNC. CCNC is dependent on the member agency's good faith to pay the assessed fee.

3.3.3.2 Michigan Finances

Cost

The build out of Michigan's MPSCS took ten years from concept to full operational capacity. Motorola was selected as the infrastructure vendor and the initial contract to provide 180 P25 capable sites with microwave backhaul links was priced at $187 million. Subsequent change orders increased this contract value to $230 million.

The annual budget for maintenance, sustainment, and administration of the network is $39 million. Of this figure, $4.1 million is earmarked for system upgrade maintenance. Another $10.2 million of the annual budget is used to cover labor costs for state employees who administer and maintain the system.

Funding

The MPSCS was primarily funded through a combination of limited general fund appropriation and bonds. The majority of these bonds were non-taxable.

MPSCS is a state level system that is made available to other agencies. Non-state users are required to pay a subscriber fee. The subscriber fee was initially set at $350 per radio, per year. This fee proved to be too high for many of the smaller users and MPSCS adjusted the subscriber fee to one based on the number of talk groups. This also proved to be unworkable. Currently MPSCS has a

much simplified cost structure – a one-time activation fee per radio of $250. When interviewed, the director of the MPSCS stated that the activation fees collected do not provide a significant source of funding, but they continue to collect it because of state mandates. While Michigan charges additional set-up fees for data users, consoles, and 800 MHz fire paging, these are one-time charges.

3.3.3.3 Minnesota Finances

Cost

The ARMER Project Status Report for the reporting period June 1, 2016 through July 1, 2016 provides detailed cost reporting on this project. The capital cost of the state's portion of the network was $236,652,831.

The annual maintenance budget for ARMER is $9.6 million and covers only state-owned infrastructure, not local enhancements. Additionally, Minnesota spends approximately $500,000 annually for administration and support labor. This provides a dedicated 24x7x365 call center at the state level as well as technicians in the field at regional MNDOT centers. These technicians conduct equipment replacement and routine system maintenance when necessary.

ARMER provides a baseline set of capabilities and features to users across Minnesota. For local users who have specific needs in addition to this baseline, or need to add infrastructure to enhance coverage in their region, the costs of additional equipment to provide these capabilities are funded locally. These costs are not included in the ARMER budget.

Funding

The ARMER network's upfront costs were covered by a $236 million state bond. The cost of ongoing maintenance, administration, and servicing the debt on the bond for ARMER are all paid by 911 fees assessed by the state and programmed into the state's annual budget. Transition costs for local users who wished to migrate onto ARMER from their own local networks were subsidized by the state's allocation of federal grant money that was available after September 11, 2001. This grant money covered 44.78% of transition costs for local users. While this source of funds is no longer available, Minnesota continues to subsidize this same percentage of transition costs for users migrating to ARMER as an incentive to join the statewide network.

3.3.3.4 Ohio Finances

Cost

The build out of the MARCS network took place between 1999 and 2004. The year 2002 marked the first wide area usage of the system, and by December of 2004 county by county testing was completed. This project cost Ohio $272 million.

Funding

The original MARCS concept was to facilitate communication between 10 state agencies that would bear the cost of the system. Since then, the system has evolved into an interstate multi-jurisdictional, interoperable service with a more complicated user base and funding model.

MARCS' annual operating budget is just under $11.1 million. The Ohio Revised Code currently provides funding for MARCS from user fees collected and distributed by three different intermediaries.

Section 4501.16 provides for a MARCS maintenance fund which, "shall consist of moneys received by the state highway patrol from users of the multi-agency radio communications system (MARCS). The funds shall be used to provide maintenance for MARCS-related equipment located at both the MARCS facilities and tower sites."

Section 4501.28 provides for a MARCS operations fund which, "shall consist of moneys received by the emergency management agency established under section 5502.22 of the Revised Code from users of the multi-agency radio communications system (MARCS)."

Section 4501.29 provides an administration fund directing the Department of Administrative Services to "collect user fees from participants in the multi-agency radio communications system (MARCS)."

MARCs operates on a tiered membership system whereby user agencies (non-state) pay for access to the system. The five membership tiers are:

- Tier 1 – Basic Subscriber: Purchase radios, pay annual maintenance fees ($240 per radio)
- Tier 2 – Enhanced Local Infrastructure
    - Local partner funds used to enhance capacity and coverage required for the given area
    - MARCS rebates 50% of costs via user fee rebate
- Tier 3 – Connecting P-25 Zone Controllers: Lucas & Butler Counties only
- Tier 4 – Sharing Core Resources: County/Regional tower farms connected to MARCS Zone Controller – generates cost avoidance through sharing of resources
- Tier 5 – Shared Zone Controllers

The table below shows the annual budget for the MARCS network for FY15, FY16, and FY17

	FY15 Budget	FY16 Budget	FY17 Budget
Payroll, Including Overtime	$ 2,851,845	$ 3,024,948	$ 3,519,277
Purchased Personal Services & Other	$ 216,420	$ 612,156	$ 75,100
Supplies, Materials & Minor Expenditures	$ 7,192	$ 8,000	$ 14,400
Motor Vehicles	$ 26,910	$ 60,000	$ 60,000
Travel	$ 8,015	$ 16,000	$ 16,000
Communications	$ 2,755,304	$ 1,732,485	$ 2,250,711
Fuels & Utilities	$ 589,991	$ 626,203	$ 621,000
Maintenance & Repairs	$ 4,764,299	$ 5,365,563	$ 5,219,684
Rentals & Leases	$ 1,016,038	$ 1,031,549	$ 1,050,000
General & Other Expenses	$ 2,054,095	$ 2,299,208	$ 1,881,522
Other Equipment	$ 221,919	$ 164,600	$ 245,613
Subtotal	$ 14,512,028	$ 14,940,712	$ 14,953,307
Actual Budget Request (Approved)	**$ 14,512,028**	**$ 14,940,712**	**$ 14,953,307**

Table 3-3: MARCS Budget FY15 - FY17

3.3.4 Governance & Administration Findings

There is a fair degree of variety in the governance approaches used to manage statewide networks across the states evaluated. On one end of the spectrum, Michigan and Ohio manage their networks, which are government owned and operated, as a part of the state government. At the other end, Colorado has created a private company, CCNC Inc., to manage their network and users. Occupying the center of the spectrum, Minnesota has created a hybrid model that proactively engages stakeholders from across the state to ensure the network reflects the needs of all their users. The state of Minnesota model offers the most value as a potential adoptive policy for Massachusetts, both for rollout and for ongoing governance.

3.3.4.1 Colorado Governance and Administration

The State of Colorado began discussions with local governments in 1992 on a wide area system that users could utilize for primary communications or for inter-agency communications. Today's DTRS has its origins in 2001 where it grew from a shared system between two counties.

In April 2008, the Colorado State Legislature funded a multi-million dollar upgrade to the DTRS network. This upgrade included a significant hardware and software replacement affecting twenty-eight local and state public safety dispatch centers statewide as well equipment at all system sites. Additionally, the Pikes Peak Regional Communications Network (PPRCN) became part of CCNC in July 2009 and its Zone Controller was upgraded and integrated into the DTRS.

The Statewide Digital Trunked Radio System today is a standard based (APCO Project 25) radio system and currently has several different manufacturers producing tiered radio solutions for the user community.

The State of Colorado, through the Communication Services team, has maintained an integral partnership with all levels of government and system users. The State also functions as the primary entity providing system engineering and support. Upgrade benefits include transition to an IP-based network environment, space to add IP-based and hard-wired dispatch consoles, as well as a supported platform for growth with future Project 25 (P25) technologies.

By way of governance structures, there are two different boards within CCNC. The main Board of Directors is comprised of 39 directors who meet monthly. The Executive Board of Directors consists of 13 directors that represent each region. As a matter of practical execution, the Executive Board of Directors oversees most day-to-day decision making which is handled by the three officers of the organization. Major decisions are presented to the main board for formal decision. CCNC has a limited budget and is heavily reliant upon volunteer labor, particularly for board members to represent their regions.

3.3.4.2 Michigan Governance and Administration

To maintain effective operations and communications, MPSCS developed policies and procedures to support emergency first responders across Michigan. These policies and procedures are publically available on the MPSCS website and cover a wide variety of information. This includes approved vendor equipment lists, user fee structures, acceptable use, and equipment co-location.

The Michigan Public Safety Communications Interoperability Board (MPSCIB) focuses on providing statewide interoperability to public safety agencies throughout the state, while adopting procedures governing the organization and operation of the Michigan Public Safety Communications System (MPSCS). Interoperability efforts throughout the state are led by the MPSCIB as the Statewide Interoperability Governing Body (SIGB). The MPSCIB consists of 16 members, nine of whom are appointed by the Governor. The Director of the MPSCS, also recognized as the Statewide Interoperability Coordinator (SWIC), is responsible for execution of the MPSCIB's actions.

Regional interoperability committees are active throughout Michigan's seven emergency management regions and coordinate regularly with members of the MPSCIB. In addition, the MPSCIB hosts information sharing meetings quarterly with Illinois, Indiana, and Ohio, and also coordinates interoperability efforts with Canadian counterparts at each of the state's international border crossings. It is anticipated that the MPSCIB will evolve into the Michigan Emergency Communications Commission (MECC) and act as the primary organization overseeing all interoperable and emergency communications activities.

3.3.4.3 Minnesota Governance and Administration

Minnesota has a strong statewide governance structure created by 2004 legislation establishing the Statewide Emergency Communications Board (SECB). The SECB was originally charged with creating and managing a Statewide Interoperable Public Safety Radio Plan and developing a project plan for the ARMER System. The SECB consists of 20 board members. Six board members are appointed by the Governor including:

- Commissioner of Public Safety
- Commissioner of Transportation

- State Chief Information Officer (CIO)
- Commissioner of Natural Resources
- Chief of the Minnesota State Patrol
- Chair of the Metropolitan Council

Fourteen board members are appointed by associations or groups comprised of State and Local public safety disciplines including:

- League of MN Cities (2)
- Association on MN Counties (2)
- MN Sheriffs Association (2)
- MN Chiefs of Police (2)
- MN Fire Chiefs (2)
- MN Ambulance Association (2)
- Chair Metro Emergency Services Board (1)
- Regional Emergency Services Board (1)

Within the SECB, one-third of the seats are reserved for members from the greater MN (local) public responder agencies (small towns and communities). One-third of the seats are reserved for representatives from the first responder community in major metro areas. The remaining one-third of the seats is reserved for state agencies. This structure provides a balance of interests between the key stakeholders in managing the network.

The composition of the SECB was modified in 2005, 2006, and 2013. Oversight was expanded to include plans, standards, and best practices for Next Generation 911 (NG911), Integrated Public Alerting and Warning Systems (IPAWS) and FirstNet Nationwide Public Safety Broadband Network (NPSBN) as well as ARMER.

The Minnesota legislature and the SECB identified seven emergency service/communications regions of the state and empowered these regions to create governance structures.

The regional boards' mission is to fill the interoperability gaps on a regional level, manage local migration to the ARMER system, and to create and decide on regional emergency communications policy. The Regional Advisory

In Minnesota

- All 87 counties, all major cities and some small and medium cities are participating
- The boards are joint powers entities legally recognized under Minnesota law
- The board's members are elected county commissioner's or city council members
- The regional boundaries were developed locally not mandated

Committees and Regional Radio Boards are the core of Minnesota's governance structure. Currently all 87 counties and a number of cities and tribal governments are participating in these regional governance structures. These legally recognized joint powers boards are made up of elected county commissioners and city council members.

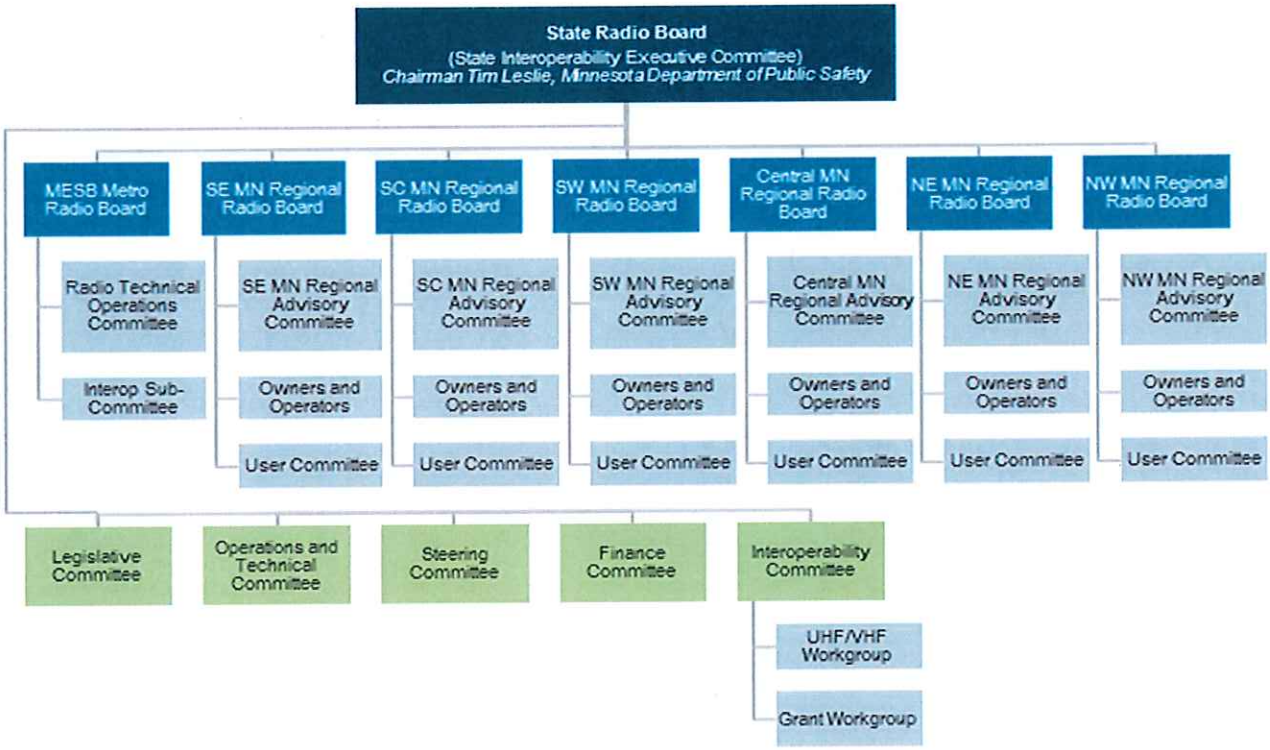

Figure 3-8: Minnesota Governance Structure

Design and rollout of the ARMER network was initially focused on major metro areas and then incrementally rolled out county by county. Currently ARMER is in active use in all but three of Minnesota's eighty-seven counties. Local agencies and communities enroll in the ARMER network by working through their county. ARMER has specifically designed a process where as the small communities work through their local counties and the counties make the request to the agency on behalf of smaller communities.

During the build out of the ARMER network, agencies that chose to opt-in to the network were given the option of tying in previously owned infrastructure. Agencies who contribute infrastructure maintain operational and administration control of that equipment. Also, the administration of that equipment is done at the local level.

3.3.4.4 Ohio Governance and Administration

Ohio's statewide radio network, the Multi-Agency Radio Communication System (MARCS), is a program area of the Office of Information Technology (OIT), which is a division of the Department of Administrative Services.

The MARCS program manager reports to the Chief Operating Officer. The Deputy Director of OIT; supervises two managers and leads approximately two dozen staff members. The MARCS Steering Committee consists of designees of the Directors of the Office of Information Technology, Public Safety, Natural Resources, Transportation, Rehabilitation and Correction, and Budget and Management. The Director of the Office of Information Technology or the Director's designee chairs the Committee.

The Committee is chartered to assist the Director of the Office of Information Technology for effective and efficient implementation of the MARCS system as well as to develop polices for ongoing management of the system. The MARCS Steering Committees report to the Directors on the progress of the MARCS implementation and the development of polices related to the system.

The MARCS Steering Committee handles major changes that would affect the entire network. Ohio's Governor signed an executive order in 2013 that established the State Interoperability Executive Committee (SIEC) – which meets quarterly and has representatives from eight DHS security regions in the state.

3.4 Summary

Each of the states interviewed had multiple obstacles to overcome in developing a statewide public safety radio network, and each state went about it differently. The end result for each state was the implementation of a system that fit their requirements and was both politically and financially acceptable. What this comparative analysis **shows is that it is possible to create a P25 digital public safety radio network that can be shared by both state and local agencies**.

3.4.1 Users

Within each of the targeted states, the overall user base for the radio system reached a larger audience than the current user base in Massachusetts. Users ranged from the state police to small localities, to federal agencies in all states.

3.4.2 Technology

Each of the states reviewed have implemented a Motorola based 800 MHz P25 digital network. In two of the states (Michigan and Ohio), the system also includes the use of Unication P25 digital pagers for use by fire departments. All states leveraged both ADP and AES encryption. States took different approaches to in building coverage, codeplug, backhaul, and more.

3.4.3 Financial

Each state utilized different options for funding the initial deployment and ongoing maintenance and enhancement of the network. In many instances, states use multiple funding approaches, including a combination of state, local, and federal funding sources, as well as both one time and ongoing funding streams. Whatever approach they utilize, each state recognizes the importance of addressing both upfront and ongoing costs to maintain, enhance, and expand the network.

3.4.4 Governance & Administration

Governance in each state depends upon political and statutory requirements of the particular state. A few key consistencies across the states include:

- the importance of establishing a governance board – including determining its working relationships with existing boards like the SEIC – to prevent overlap and duplication of efforts;
- the need to developing operating procedures to formalize processes for providing input into, making, and communicating decisions;
- the value of a fair process to identify and, where necessary reevaluate, membership of the governing board(s) to ensure that all types and levels of entities are represented, including small, local entities.