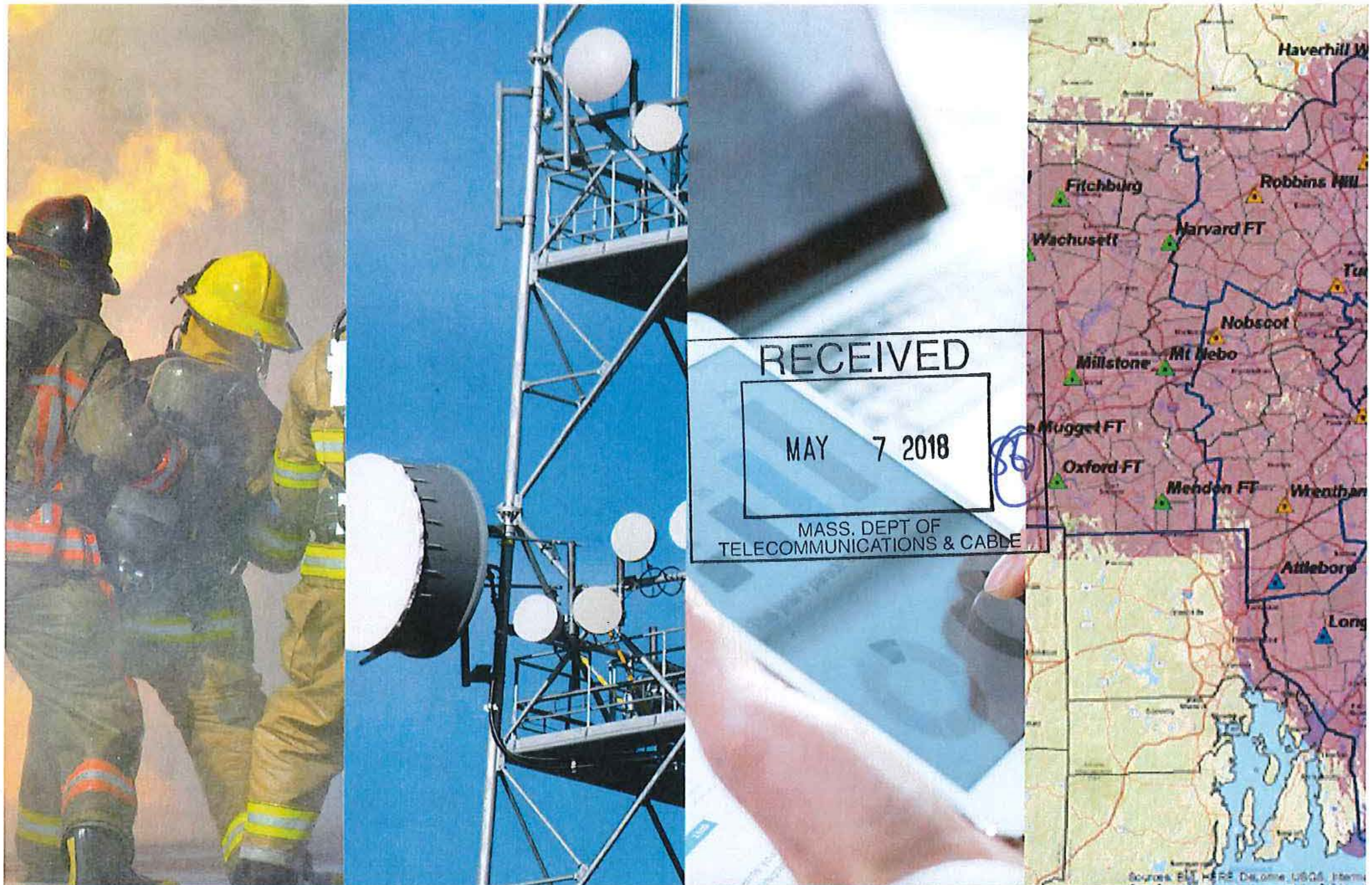

Commonwealth of Massachusetts Interoperable Radio System (CoMIRS)

2 Current State Assessment and Key Findings

Version 1.0 (May 2017)

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2 CURRENT STATE ASSESSMENT AND KEY FINDINGS

The ability of first responders and others reliably to communicate in real-time is critical to the public safety and security of the Commonwealth. This section of the Radio Strategy Document describes and evaluates the current state of public safety Land Mobile Radio (LMR) communications in Massachusetts. The focus of this analysis is the Department of State Police Radio Network (MSP Radio Network), since this network is currently the only fully statewide radio network and serves as the primary statewide interoperability platform for public safety in the Commonwealth. This section also evaluates how the MSP Radio Network serves as the primary operable communications platform for the Department of State Police and others.

Due to the mission of the Department of State Police not only to monitor and police the state highway system but also to serve as a primary law enforcement agency throughout the Commonwealth, the MSP Radio Network's coverage spans the Commonwealth. As the largest law enforcement agency in New England, the MSP stations its approximately 2,300 officers across the Commonwealth in 40 barracks organized into seven troops. As a function of its traffic regulation and criminal justice enforcement duties, the troopers and civilians of the MSP must be able to communicate statewide in real-time.

Figure 2-1: MSP Troop Map

Over the past two decades, the use of the MSP Radio Network has expanded to include multiple other state and local agencies. With this expanded usage, the network has come to be known as the Commonwealth of Massachusetts Interoperable Radio System (CoMIRS). Throughout this document, the terms "CoMIRS" and "MSP Radio Network" are used interchangeably.

This review focuses on the current state of operability for the individual users of the statewide radio network and the interoperability of users that communicate on a day-to-day basis on another network or a subnetwork within the statewide radio network. For this review, operable communications is defined as the ability of public safety users to establish and sustain communications in support of day-to-day mission objectives. These operable communications tend to be *within* a single jurisdiction, discipline, and/or organization. Interoperable communications is the ability for public safety professionals to communicate *across* jurisdictions, disciplines, and/or levels of government when the need arises and as authorized. System operability is a required prerequisite for system interoperability.

To assess the current network and identify recommendations for improving the network, the project team conducted discussions with over 20 stakeholder organizations currently using the radio network operably or interoperably. These discussions provided a detailed understanding of the various systems that comprise public safety communications within Massachusetts and the needs of the users of these networks. The project team facilitated discussions with the following organizations:

Barnstable County Sheriff's Office	Boston Area Police Emergency Radio Network (BAPERN)	City of Boston	City of Cambridge	City of Worcester
Department of Conservation and Recreation (DCR)	Executive Office of Public Safety and Security (EOPSS)	Massachusetts Emergency Management Agency (MEMA)	Massachusetts Department of State Police (MSP)	
Massachusetts Department of Transportation (MassDOT)	Western MA Law Enforcement Council (WMLEC)	Multiple local fire departments	Multiple local police departments	

Figure 2-2: Agencies Interviewed

An analysis of these systems and their underlying technologies has resulted in the identification of the four immediate needs and eleven longer-term key findings presented in Table 2-1 and Table 2-2, respectively. These key findings are the basis for the recommendations for a future vision of the network. See Section 4 of this document for more details on the Future Vision.

Together, these 15 key findings lay out the primary issues that the Commonwealth must address over the course of the next few years to assure the continuity and reliability of statewide public safety radio communications. The Commonwealth must address several of these issues immediately. Major components of the network must be replaced or upgraded, and significant funding will be required to address these issues. Once completed, the Commonwealth will have a reliable communications platform with expanded coverage, capacity, and capabilities for its current users and potentially for additional user agencies in the years to come.

The follow four key findings represent immediate needs and should be addressed during the Commonwealth's fiscal year 2018:

Key Finding	Urgency	Cost
Key Finding #1: State Police dispatch console systems are no longer supported by the network software and must be replaced.	**Immediate Need**	$$

Twenty-nine of the consoles in operation at eight State Police locations are from the Motorola Gold Elite family of console systems. The Motorola Gold Elite family of console systems are no longer supported by the manufacturer. These Gold Elite Console Systems are incompatible with the most recent system software release and must be replaced prior to the release upgrade. Manufacturers support for Gold Elite components ends in 2018.

Key Finding	Urgency	Cost
Key Finding #2: Important backhaul components need to be replaced to assure continued radio communications.	**Immediate Need**	$$

The MSP trunked subsystems of CoMIRS rely heavily on wireless microwave point-to-point links to backhaul communications from radio tower sites. Many of these important links are beyond manufacturer support and some are experiencing performance issues due to path obstructions that cannot be resolved. When point-to-point links fail, radio communications from sites at the end of the path are lost to the network creating large coverage "holes".

Key Finding	Urgency	Cost
Key Finding #3: The oldest time and frequency reference clocks cannot be repaired and are in need of immediate replacement.	**Immediate Need**	$

The analog portion of the CoMIRS network includes four simulcast sites. Highly accurate and dependable reference clocks are required to maintain the functioning of these simulcast sites. The reference clocks at some of these analog sites are outdated and need immediate replacement. Failure to upgrade these clocks threatens the voice communications in important areas of these simulcast sites.

Key Finding #4: Analog radios do not meet the operational needs of current users and must be replaced to operate on a digital network.	Urgency	Cost
	Immediate Need	**$$$**
The CoMIRS network is presently a mix of analog and digital subsystems without full statewide coverage in either technology. Agencies with statewide jurisdiction should be equipped with radios that can operate on both analog and digital systems to maximize coverage availability. Additionally, when users on different types of systems (analog and digital) interact, they often cannot communicate with one another until a system administrator patches their channels together. After communications are established, there is often also a significant degradation in the quality of voice communications across the two platforms. *Priority should be given to updating the MSP radio fleet so that all MSP radios can operate across the analog and digital systems comprising CoMIRS.*		

Table 2-1: Summary of Immediate Needs Key Findings

The Commonwealth should address these additional eleven key findings within the next two to five fiscal years:

Key Finding #5: Many of the backhaul circuits to radio tower sites will not be supported in future releases of the radio network software.	Urgency	Cost
	2 to 3 years	**$$**
Backhaul allows a radio site to communicate with the rest of the network. Without it, all the users in that area are disconnected from communications on the radio network. Much of the existing CoMIRS backhaul network uses old, circuit-switched backhaul technology. The telecommunications industry has moved away from circuit-switched technology to Ethernet packet based transmission protocols as a more bandwidth efficient and flexible method for point-to-point communications. *The circuit-switched backhaul technology that is in use in much of the existing CoMIRS backhaul network will not be supported by the CoMIRS radio software by 2019 (Motorola System Release 7.19). Backhaul from radio sites using this old technology will not work when the software release is applied and therefore radio communications relying on those radio sites will not work.*		

Key Finding #6: The current CoMIRS network is old, and it relies on unsupported analog radio components.	Urgency	Cost
	2 to 5 years	**$$**
The current CoMIRS network is reliant on out of date and often unsupported analog equipment that is at the end of its life and must be replaced in order for the network to continue to provide the level of communications service required for first responders across the Commonwealth.		

Key Finding #7: The current CoMIRS network does not meet stated goals for statewide coverage.	Urgency	Cost
	2 to 5 years	$$$

CoMIRS consist of a mix of regional analog and P25 digital trunked systems. No complete statewide coverage exists through either the analog systems or the P25 digital systems alone.

Key Finding #8: The reliance on analog technology precludes the use of important advanced radio features.	Urgency	Cost
	2 to 5 years	$$$

Advanced radio features used within the P25 segments of CoMIRS have improved user safety and efficiency. These features are not available in the analog networks.

Key Finding #9: CoMIRS should adopt P25 TDMA as its broadcast standard to significantly improve spectrum efficiency and capacity.	Urgency	Cost
	2 to 5 years	$$$

The telecommunications industry has generally moved from analog to digital based communications. One of the drivers for the move is improving the efficiency of how limited available spectrum is used. CoMIRS P25 TDMA subsystems are 4 times more frequency efficient than CoMIRS analog subsystems.

Key Finding #10: Critical, aging components of the CoMIRS infrastructure require continued attention and support to assure network availability.	Urgency	Cost
	2 to 5 years	$

MSP and EOPSS administer a maintenance contract with an outside vendor for preventative maintenance and repair of the analog and P25 digital components of the CoMIRS radio network. The contract includes a system release upgrade every two years for the P25 digital components of the network. It is anticipated that issues involving aging analog components will only worsen as CoMIRS continues to rely on its analog subsystems. Sufficient funding should be made available to support emergency repair needs for the aging analog network.

Key Finding #11: Consistent and sufficient annual operational and capital funding is needed to support, maintain, and grow the network.	Urgency	Cost
	2 to 5 years	$$$

CoMIRS capital funding has been sporadic, and, in many years, there is little or no capital reinvestment in the radio network. Operational funding has been largely level, but additional operational funding will be needed to properly support the network in the coming years.

Key Finding #12: CoMIRS needs a clearly defined decision-making structure that supports operable and interoperable users.	Urgency	Cost
	2 to 5 years	$

Governance and administration for the CoMIRS network is performed primarily today by EOPSS and MSP, respectively. Additionally, the SIEC provides advisory guidance on certain interoperability matters involving the network. It is not currently well-understood universally which organization is responsible for the different aspects of governance and administration, including policy decision making, financing, administration, spectrum management, and standards development. CoMIRS needs a clearly defined governance structure that can address governance issues that affect the operable use of CoMIRS (by groups like MSP and Barnstable County) and/or the interoperable use of CoMIRS (by agencies throughout the Commonwealth).

Key Finding #13: There needs to be clear standards for all users on the CoMIRS network and clear standards of service for subnetworks.	Urgency	Cost
	2 to 5 years	text

Due largely to the federated nature of the CoMIRS network, where individual agencies or regional groups are responsible for large subnetworks and the provision of their own radio devices, there is inconsistency in the nature and promulgation of system standards and standard operating procedures (SOPs). Not all subnetworks on CoMIRS need to behave the same. There should, however, be an understanding across agencies, and approval when needed, when deviations in SOPs are implemented on the network. Additionally, there needs to be clear expectations for the levels of service and the standards for maintenance of all of the subsystems of CoMIRS.

Key Finding #14: There is an uneven level of user knowledge on how to properly use CoMIRS interoperability channels.	Urgency	Cost
	2 to 5 years	$

A radio network is only as effective as the users on the network. There are standards and best practices that, when universally understood, enhance the value of the network as a whole. Currently, decisions on the nature, content, and timing of radio training is left to each individual agency on the network. This can result in confusion and inefficiency when interjurisdictional communications are required.

Key Finding #15: CoMIRS will likely require additional spectrum at least during the transition from analog to digital.	Urgency	Cost
	2 to 5 years	$
The expanded use of radio frequencies cannot be accommodated overnight. Rather, potential future demands for frequencies must be planned for years in advance. CoMIRS will likely need additional frequencies to provide adequate bandwidth as agencies move from analog to digital radio. Additionally, after CoMIRS transitions fully to a digital network, other user may seek to use the network to address their frequency or financial concerns. CoMIRS administrators should gauge future interest in the network now, so that capacity can be properly planned and implemented during the digital transition.		

Table 2-2: Summary of Longer-Term Key Findings

2.1 Overview of Statewide Public Safety Communications in Massachusetts

This section presents the state of public safety radio communications in Massachusetts. It provides an overview of the history of the public safety communications industry, explains the historical background for the development of CoMIRS, and describes the current user base and uses of the network.

2.1.1 History of Public Safety Radio Communications

Land mobile radio (LMR) systems are terrestrially-based, wireless communications systems commonly used by federal, state, local, tribal, and territorial emergency responders, public works companies, and even the military to support voice and low-speed data communications.[1] LMR has been in use in the United States by public safety organizations since the 1930s to support mission-critical voice communications. Analog trunked radio technology, like that still used by large portions of the CoMIRS network, has been widely used in the United States since the mid-1980s. The development of this technology for public safety by multiple manufacturers resulted in proprietary systems from each of the manufacturers. While the Association of Public Safety Communications Officials (APCO) International recommended certain public safety features and standards for inclusion in radio systems, the inclusion of these features and standards was not mandatory. The result is that analog trunked systems remain to this day proprietary to the original manufacturer.

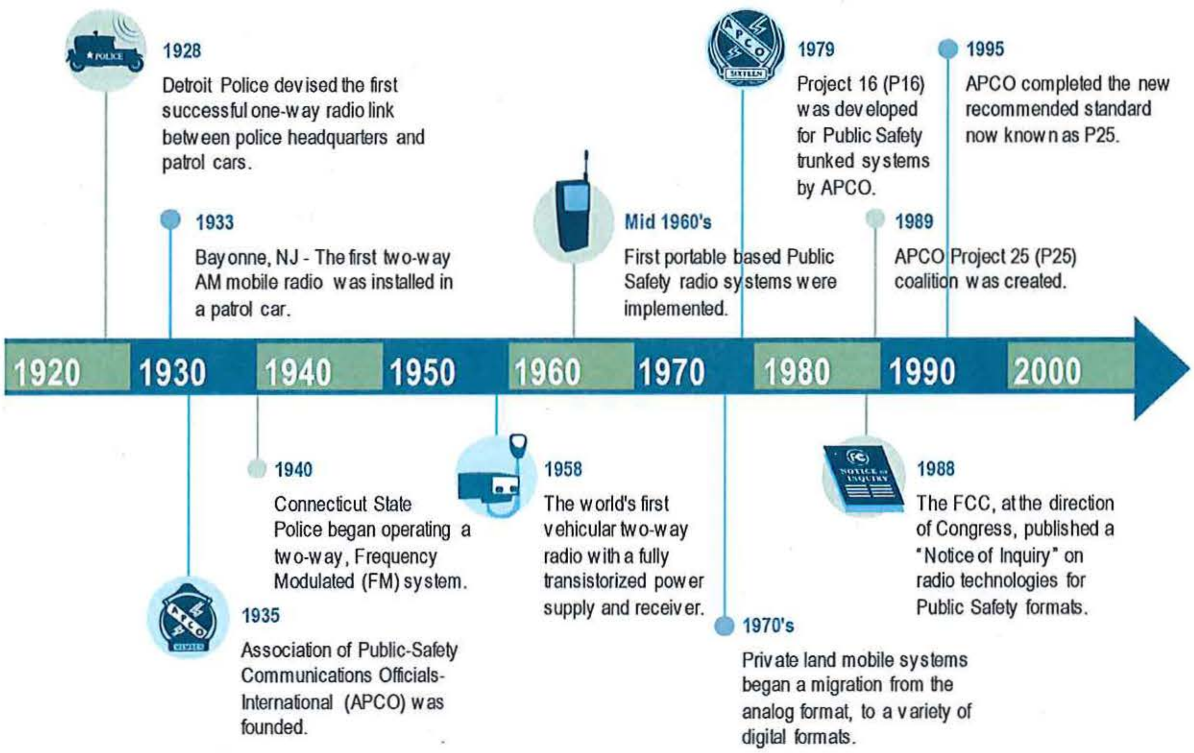


Figure 2-3: Public Safety Radio Communications Key Milestones

[1] https://www.dhs.gov/sites/default/files/publications/LMR%20101_508FINAL.pdf

Two vendors have supplied proprietary trunked radio systems in Massachusetts – Motorola Solutions (Motorola) and Harris Critical Networks (Harris). Harris is the supplier for the Massachusetts Bay Transportation Authority (MBTA) bus and rail trunked system discussed later in this document. Motorola is the supplier for all other major public analog trunked systems in place within Massachusetts today, including the MSP Radio Network.

Most manufacturers, including Harris and Motorola, have discontinued production of proprietary analog systems and components in favor of new standards-based digital technologies. Due to the proprietary nature of analog systems, the majority of the analog mobile and portable radios operating on CoMIRS are Motorola devices. E.F. Johnson, now a division of JVCKENWOOD Group, is the only radio manufacturer licensed by Motorola to produce and market radios compatible with the proprietary Motorola analog trunked system. Users in Barnstable County recently purchased E.F. Johnson radios for use on the analog system in southeast Massachusetts.

observation

Major radio manufacturers have moved away from proprietary analog systems toward standards-based digital radio systems. Many analog radio components are no longer supported.

Development of digital standards for public safety radio systems began in 1989 by APCO International under Project 25 (P25). APCO is an American National Standards Institute (ANSI) accredited standards developer (ASD). The P25 (TIA-102) digital standard was created to promote:

- frequency efficiency,
- voice security,
- consistent voice quality over the coverage area,
- combined voice and data communications,
- feasible equipment migration from analog to digital, and
- enhanced, interoperable public safety communications in the digital world[2].

The published P25 standards are administered by the Telecommunications Industry Association (TIA) in their Mobile and Personal Private Radio Standards Committee (TR-8).

The P25 standard is continually being updated and improved. The first digital common air interface (Phase 1) utilized Frequency Division Multiple Access (FDMA) to improve frequency efficiency by reducing the required frequency bandwidth for a single 800 MHz radio call from 25 kHz to 12.5 kHz. This standard effectively doubled the capacity of the 800 MHz spectrum. P25 FDMA compliant radio system deployment in the United States began in the late 1990s.

The P25 standard promotes a multi-vendor environment that is widely used in the U.S. and abroad. Massachusetts utilized the P25 standard for the build out of its digital trunked systems in western

[2] https://www.apcointl.org/spectrum-management/resources/interoperability/p25.html

Massachusetts in 2011. While the P25 standard is not mandated by FCC rules, new standards for narrowband (12.5 kHz and 6.25 kHz) frequency efficiency promote digital technology. P25 is the most widely used digital technology by public safety agencies across the nation and has been adopted by many Federal Government users. To encourage the adoption of the P25 standard by public safety agencies in the United States, federal grants for interoperable communications are available to states and local communities for the use of P25 standards in new or expanded systems.

In 2010, APCO adopted P25 Phase 2, which utilizes Time Division Multiple Access (TDMA) technology. P25 TDMA allows two simultaneous radio calls per 12.5 kHz base station. This further improves the efficiency of channel utilization and reduces the number of base stations required for implementation, when compared to the prior digital standard, P25 FDMA (Phase 1). The first commercially available P25 TDMA systems shipped to the marketplace in 2011.

Currently, the following states have implemented statewide or significant TDMA systems:

- Connecticut
- Illinois
- Mississippi
- New Jersey
- Ohio
- Oregon
- Tennessee
- Several major counties in California

observation

Systems using spectrum-efficient P25 TDMA (Phase 2) standards have been in operation since 2011. TDMA systems are four-times as spectrum efficient when compared to analog systems, like CoMIRS.

Several other states are in the process of implementing TDMA systems as replacements for older analog and FDMA radio systems.

2.1.2 History of CoMIRS

CoMIRS is a network of radio systems that have been pieced together over the years as the Massachusetts State Police and other state and regional radio partners have added radio infrastructure and expanded coverage to create the current statewide communications network. This expansion has been sporadic and often driven by immediate regional communications needs and the availability of scarce funding resources.

The network origins trace back to the Metropolitan District Commission (MDC) Police 3-site 800 MHz simulcast trunk network originally installed in 1987. Figure 2-4 below shows the key events of the history of CoMIRS.

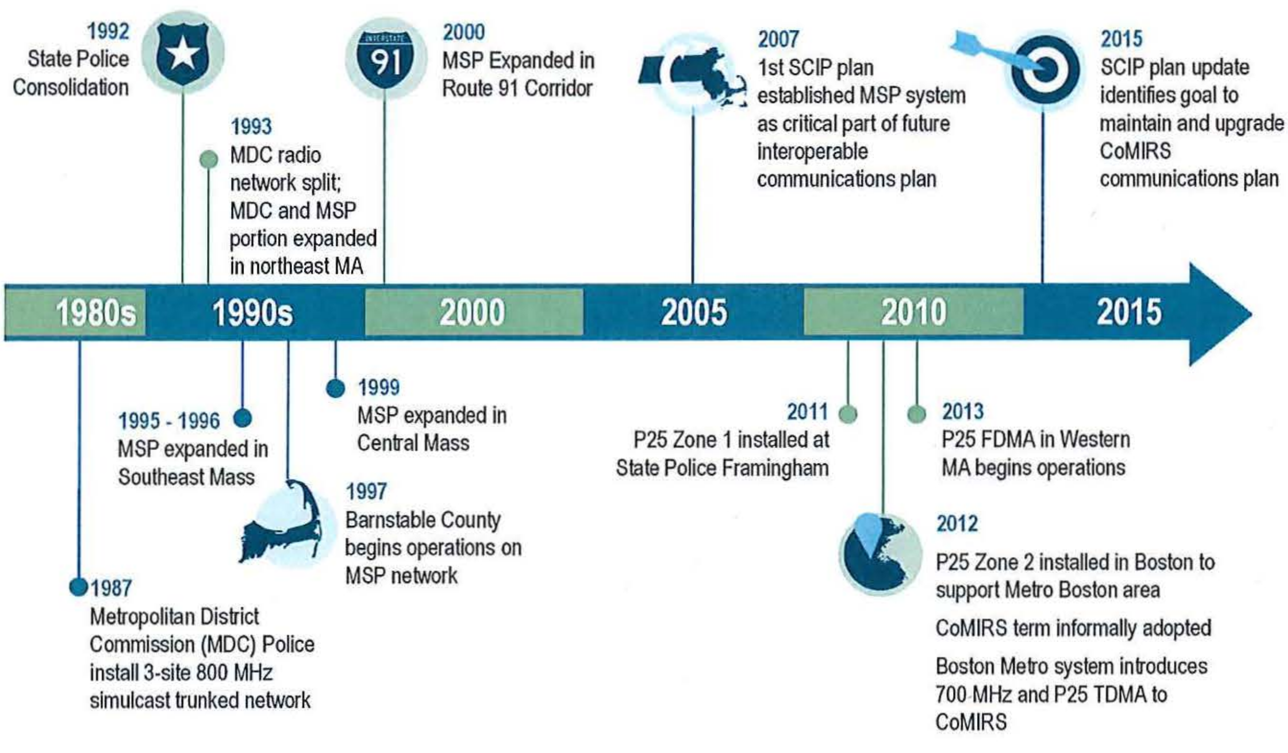


Figure 2-4: CoMIRS Key Milestones

In 1992, the Commonwealth merged several state law enforcement agencies per Chapter 412 of the Massachusetts Acts of 1991 to form the current Department of State Police. This merger included the State Police, the Metropolitan District Commission Police, the Registry Police, and the Capitol Police. In 1993, the original MDC radio system was split into two networks – one to support the operations of the MDC and the Massachusetts Water Resources Authority (MWRA) in metropolitan Boston and one to support MSP Troops A and H operations in Suffolk, Essex, Middlesex, and Norfolk Counties. The MSP portion of the radio network expanded from three to nine radio sites.

In 1995 and 1996, the MSP added analog trunked systems in Bristol, Plymouth, and Barnstable Counties to serve MSP Troop D. During this period, Barnstable County also began operational use of the network. Over the next few years, the network expanded and added capacity to support additional troops across the state.

observation

ANALOG

Despite the industry move to digital for radio communications, CoMIRS is still heavily reliant on aging, outdated, and often unsupported analog technology.

In 2007, the Department of Homeland Security required states to publish a Statewide Communications Interoperability Plan (SCIP). The SCIP outlined the state's accomplishments and challenges as well as defined the strategic direction for inoperability across the Commonwealth.[3]

In 2011, the MSP installed the network's first Zone Controller at MSP Headquarters in Framingham. Among other functions, the Zone Controller handles the call processing for a region within the radio network. MSP installed this initial Zone Controller to support the P25 radio network installation in western Massachusetts.

In 2012, a second Zone Controller was added to the MSP Radio Network to expand the capacity of the network and support new interoperable P25 systems and dispatch consoles in the metropolitan Boston area. The second Zone Controller is located at Boston Police Headquarters at One Schroeder Plaza.

Also in 2012, the City of Boston installed a digital interoperable P25 based 700 MHz system overlaying the City of Boston and Suffolk County. This system utilizes both P25 FDMA and P25 TDMA standards. Further expanding the network's digital footprint, a P25 FDMA digital project began in western Massachusetts. This project provided 800 MHz P25 radio service in Berkshire, Hampden, Hampshire, and Franklin Counties to support MSP Troop B and other users.

observation

UPGRADE

Several CoMIRS partners have already implemented digital upgrades to their networks. These partners cannot move forward with annual software upgrades without a major upgrade to CoMIRS.

Currently the CoMIRS Zone Controllers are operating on release 7.15 of the Motorola ASTRO 25 operating software, which was release in 2015. As an integrated radio network, all sub-systems of the radio network must be upgraded simulatenously. This includes those operated by the MSP, as well as

[3]https://www.dhs.gov/statewide-communication-interoperability-plans

those operated by its partners in the Cities of Boston, Worcester, and elsewhere. This software is due to be upgraded to firmware release 7.17 this calendar year. Several of the critical, aging analog components still in use on CoMIRS will not be supported by this release.

Current Network Coverage

Shown below are three views of the current state of radio coverage across Massachusetts. The first two show the analog network, which comprises the majority of the central and eastern portion of the state. Figure 2-5 shows the expected coverage for portable or hand-held radios typically used by responders on the ground.

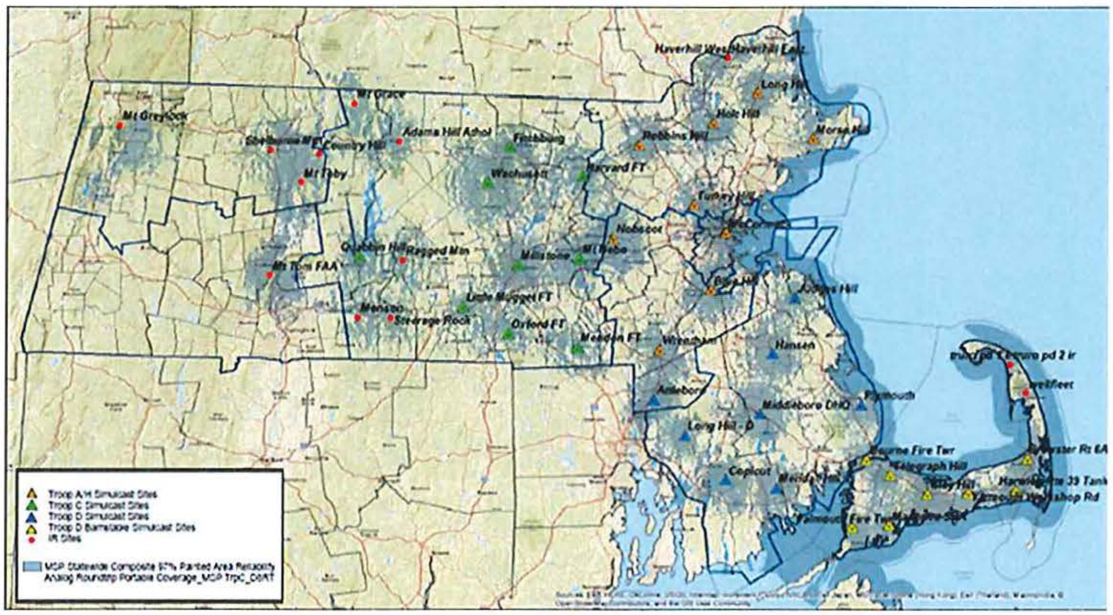


Figure 2-5: Analog Portable Coverage

Figure 2-6 shows the current analog network mobile radio coverage for the MSP network. Mobile coverage is the typical coverage expected for radio communications using a higher-powered vehicle-mounted radio. Mobile coverage tends to have a larger coverage area than portable coverage, due largely to the power of the user's radio.

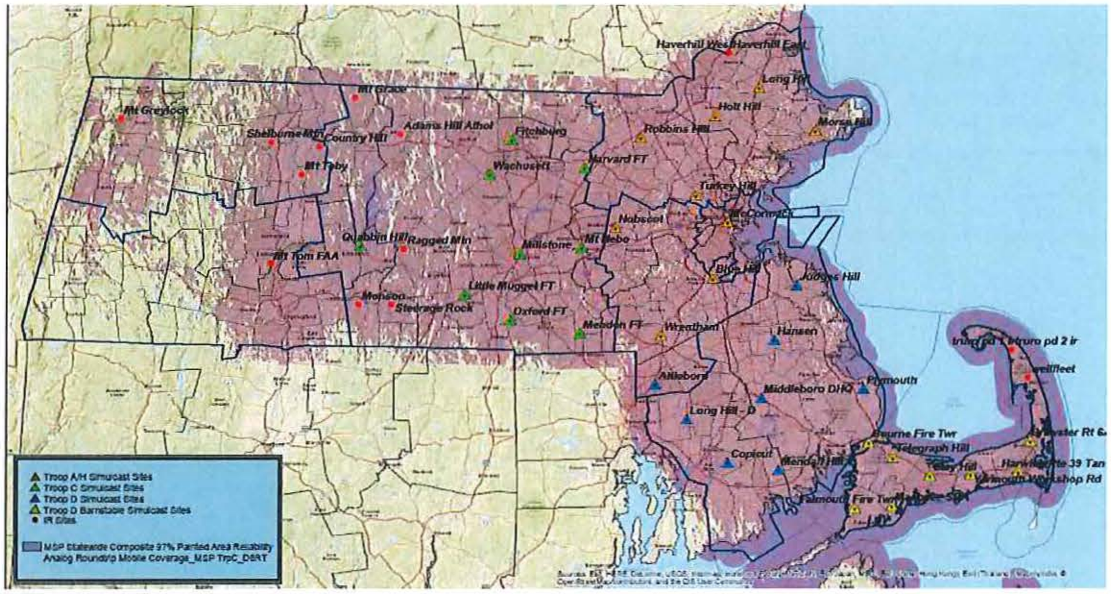


Figure 2-6: Analog Mobile Coverage

Figure 2-7 shows the current digital mobile coverage provided by the Troop B P25 FDMA system installed in 2012. This FDMA system provides mobile coverage for large parts of Berkshire, Franklin, Hampshire, and Hampden Counties.

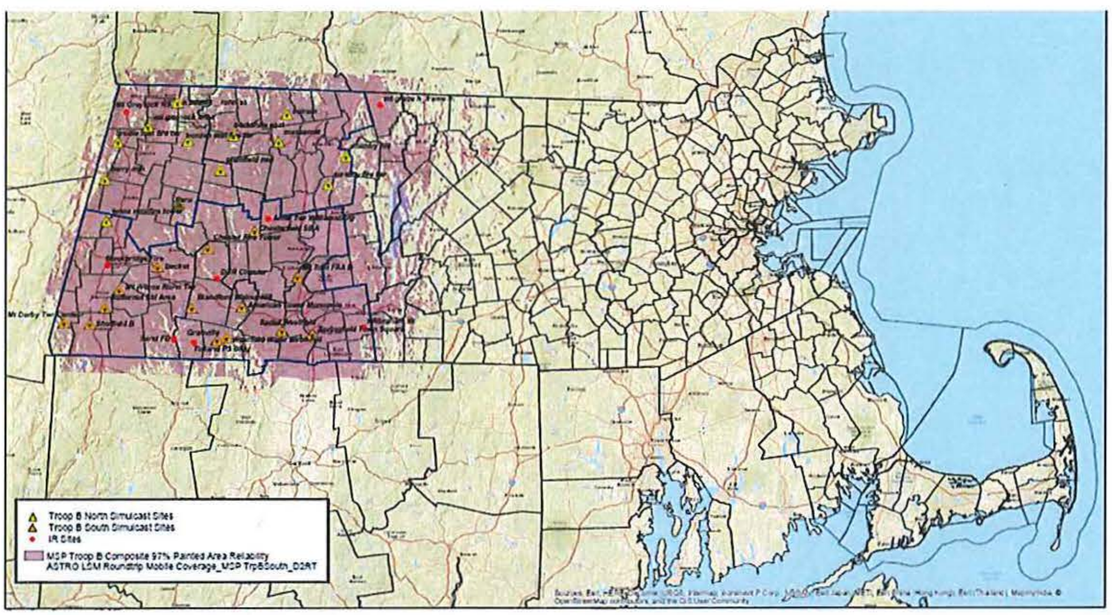


Figure 2-7: Digital P25 Mobile Coverage

2.1.3 Who Uses CoMIRS

The CoMIRS user base is a large cross section of the first responder community in Massachusetts. Like the network itself, the CoMIRS user base has grown significantly over the past 25 years. What began as a police radio system in the metropolitan Boston area now supports nearly 30,000 active radio devices statewide. The CoMIRS user base includes operable users that use the network to support daily operations, as well as interoperable users that depend on the network when needed to facilitate interagency communications during multi-agency responses and events.

Figure 2-8 below shows the breakdown of devices used by primary users for day-to-day operations and those that primarily use the system for interoperable communications. The State Police (8,428 devices) and Barnstable County (3,638 devices) are the largest operable users of the network. Massport (2,049 devices) and the cities of Worcester (2,212 devices), Boston (2,032 devices), and Cambridge (1,480 devices) are the largest interoperable users.

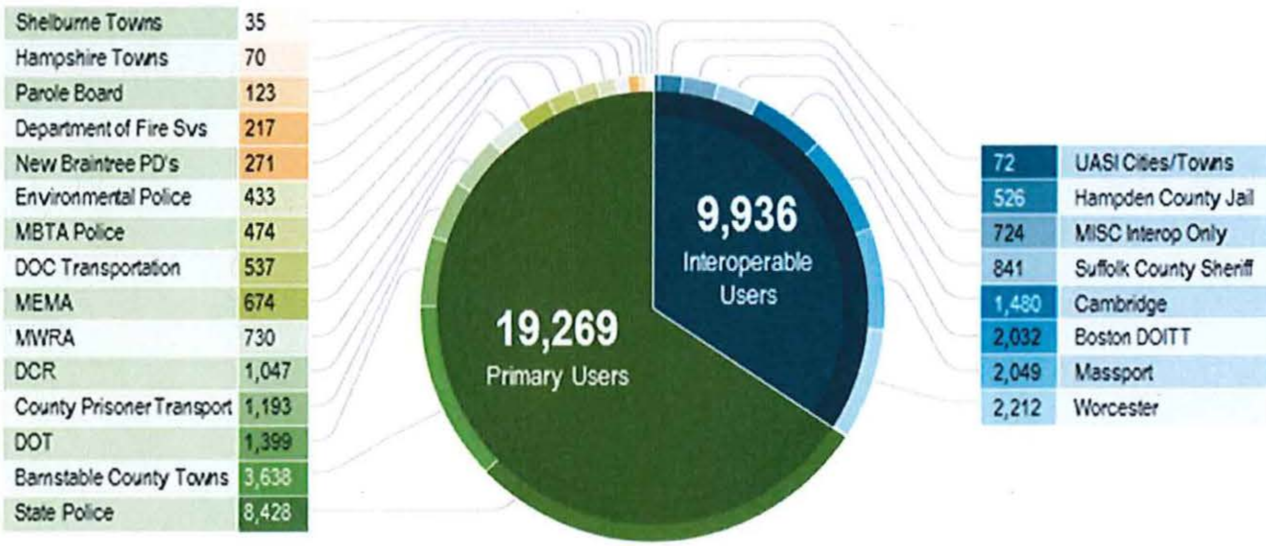


Figure 2-8: User Base by Agency

The Commonwealth also operates and maintains a conventional analog interoperable network called TAC Stacks, described later in this document. TAC Stacks utilizes nationwide interoperability channels (8TAC, UTAC and VTAC) in the 800 MHz, UHF, and VHF bands. Massachusetts regularly utilizes interoperable talkgroups and TAC Stacks channels for special events, disaster response, training, and other events where multi-agency communication is required. Multiagency participation in recurring events such as the Boston Marathon, the Fourth of July celebrations, and parades is an indicator that a broad base of users need to know how to connect to and use the statewide network for interoperability on a regular basis. Figure

Figure 2-9: Marathon Bombing Response Interoperability

2-9 represents the interoperability radio assets used during the 2013 Marathon bombing response to coordinate multiple agencies' activities.

Operational users of the network all operate in the 800 MHz frequency band. To facilitate interagency or interoperable communications within the network, interoperability talkgroups were established. A talkgroup is a digitally defined and programmed grouping of users. Interoperability talkgroups are shared talkgroups created in the system for use by all system users. The network includes eighteen interoperability talkgroups, ten Local Public Safety talkgroups (LPS 1- LPS 10), and eight Event talkgroups (Event 1 – Event 8). All system users have these common talkgroups programmed into their radios and/or dispatch consoles.

Most local public safety agencies in the Commonwealth operate on different frequency bands: T-Band (470-512 MHz), UHF (450-470 MHz), or VHF (150-174 MHz). Most radios in their fleets are not capable of operation in the 700/800 MHz bands. To enable direct communications between the CoMIRS network and other system users when required, network dispatch consoles "patch" or bridge the network interoperability talkgroups with Boston Area Police Emergency Radio Network (BAPERN), Western Massachusetts Law Enforcement Council (WMLEC), Metrofire, or other common operating frequencies available through network Core connected dispatch consoles. A summary of network operational and interoperability users are included in Table 2-3 below.

Agency	Operational Use	Interoperability Use	Network Radio Count	Core Connected Console(s)	Core Connected Trunked System
Barnstable County Cities and Towns	X	X	3700		
Barnstable Sheriff	X	X	207		
Boston Area Police Emergency Radio Network (BAPERN) – UHF patch to CoMIRS		X			
City of Boston		X	2032	X	X
City of Cambridge		X	1,480	X	X
City of Worcester		X	2212	X	X
County Jails Prisoner Transportation	X	X	1,700	X	
Department of Conservation and Recreation	X	X	1,050	X	X
Department of Correction (Transport)	X	X	537		X
Department of Fire Services	X	X	217		
Department of Transportation	X	X	1400	X	X
Fire District 6 Westford		X		X	
Fire District 7 -VHF patch to CoMIRS		X			
Fire District 8 -UHF patch to CoMIRS		X			
Fire District 14 Ashland		X		X	
Fire District 15 North Andover		X		X	
Hampden County HOC		X	526	X	X
Harvard University Police		X		X	
Local agency interoperability radios		X	724		
Massachusetts Emergency Management Agency	X	X	674	X	
Massachusetts Environmental Police	X	X	433	X	
Massachusetts METROFIRE-UHF patch to CoMIRS		X			
Massachusetts Port Authority		X	2,049	X	X
Massachusetts State Police	X	X	6600	X	X
MBTA Police	X	X	474	X	
MWRA	X	X	730		
New Braintree E-911 Towns	X	X	271	X	
Northampton E-911 Towns	X	X	70	X	
Parole Board	X	X	123		
Plymouth County Sheriff		X		X	
Regional Communications Center Middleton		X		X	
Shelburne E-911 Towns	X	X	35	X	
Springfield Police and Fire		X		X	
Suffolk County Jail and HOC		X	841	X	
UASI Cities and Towns		X	72	X	
Western Mass Law Enforcement Council (WMLEC) – UHF patch to CoMIRS		X			
Total Network Radio Count			28,157		

Table 2-3: CoMIRS Usage by Agency

2.1.4 How CoMIRS is Used

The CoMIRS network is more than a communications system for state troopers. CoMIRS serves a vital role in daily local law enforcement, fire services, correctional services, and other public safety activities throughout the Commonwealth. Additionally, CoMIRS serves a vital role in 911 dispatch, and it provides needed backhaul for local public safety communications needs. Figure 2-10 provides an overview of usage of CoMIRS, including the calls processed in a year (over 42 million) and the number of talkgroups (686) in use.

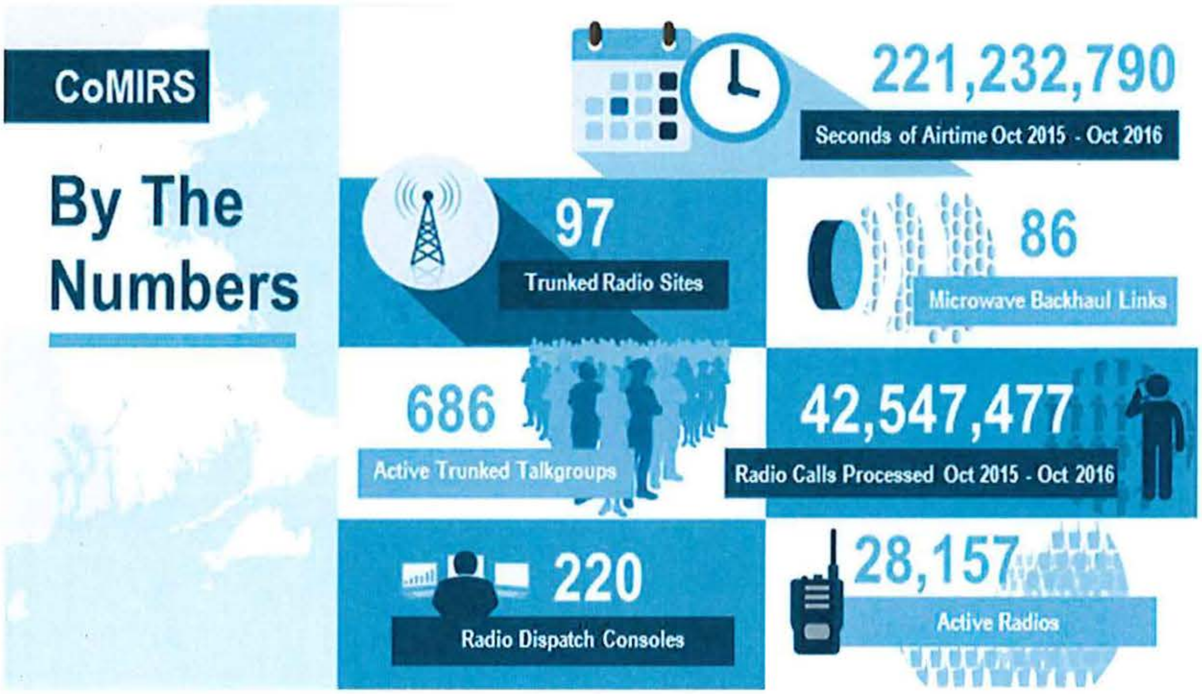


Figure 2-10: CoMIRS by the Numbers

The following are different types of users that the CoMIRS system supports throughout Massachusetts:

Console Users

Dispatch consoles are a common point of communications within the CoMIRS network. MSP handles approximately 1.5 million 911 calls per year through General Headquarters (GHQ) alone. The MSP also provides E-911 call taking and dispatching services to 52 communities from the Northampton, New Braintree, and Shelburne Falls E-911 centers. Currently, console operators using obsolete Motorola Gold Elite dispatch consoles process most of these calls.

Mobile Users

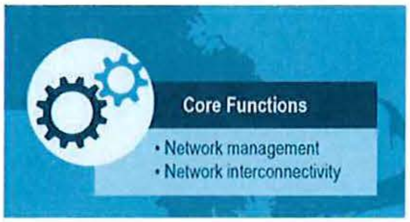
Mobile radios (or mobiles) are wireless communications devices that tend to be mounted in public safety vehicles and that share the vehicle's power supply. Because of this external power source, mobiles tend to have greater power output levels portable radios. Therefore, they have larger coverage areas than portable radios. Users typically use mobiles to respond to dispatch calls while in transit from one place to another. In addition to the MSP use of mobiles in their vehicles, local law enforcement, fire services, correctional institutions, and transportation organizations all use mobile radios on CoMIRS.

Portable Users

Portable radios are wireless communications devices carried by an individual user. First responders and others use these radios for group and emergency communications, as well as for reporting and general communications in the field. During special events, users of portable radios are often required to communicate with users from other jurisdictions. Therefore, these devices must be interoperable across agencies and jurisdictions. During incidents, commanders communicate with responders on the ground using these devices. There are tens of thousands of portable radios on CoMIRS.

Radio Infrastructure Users

Agencies also use the CoMIRS infrastructure to create backhaul links to other networks or to extend service areas for groups that need to communicate outside their immediate range of operations. This shared infrastructure usage allows individual agencies or groups to leverage CoMIRS resources and reduce the need to duplicate communications infrastructure across the Commonwealth.



Core Functions

CoMIRS provides authorized users with Core functions, such as network management and network interconnectivity, throughout the Commonwealth. Network management systems provide for the central management, alarming, and control of remote network components. The MSP administers the network management system. Certain administrator rights are granted to private system owners, such as Cambridge, Boston, Worcester, Massport, and DCR, as well as large fleet administrators like Barnstable County and Department of Correction. In addition, the Core provides the means for connected dispatch centers to provide some level of redundancy across dispatch centers.

2.2 Review of the CoMIRS Network

Beginning with the split of the MDC radio network in 1993, the Massachusetts Department of State Police has held primary responsibility for the construction, operation, and oversight of the 800 MHz statewide trunked radio network. Initially focused on supporting the operational needs of the MSP, this radio network has expanded over time to support the operational needs of a number of other state, county, and local public safety agencies. These other users, commonly referred to as "partners" or "stakeholders," operate under the guidelines established by the Department of State Police, as the principle steward of the network. The Executive Office of Public Safety and Security (EOPSS) and the Department of State Police fund the radio network's operations, maintenance, expansion, and enhancement through a number of fixed and ad hoc funding sources. Included in this financial support is funding for an annual vendor maintenance contract to support the upkeep of the MSP network.

Below is a summary of the end of lifecycle timelines for critical CoMIRS radio equipment and components.

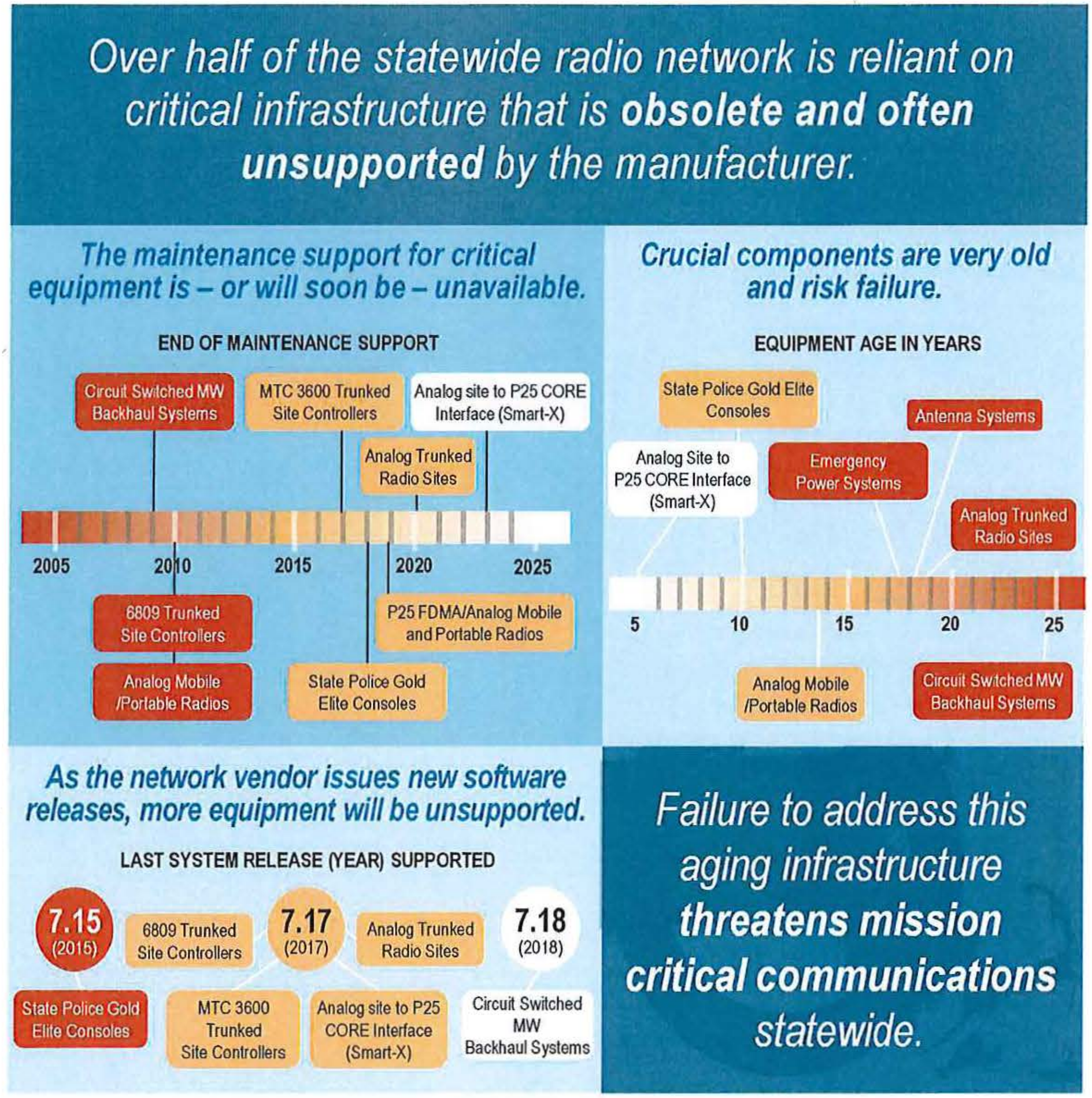


Figure 2-11: CoMIRS Aged Analog Equipment in Use

Following the recommendations of the 9/11 Commission Report, the states and the Federal government focused greater attention and effort on improving inter-agency communications amongst first responders. As a condition of Federal Homeland Security grant funding, the Department of Homeland Security charged each state with the responsibility to create a Statewide Communications Interoperability Plan (SCIP). The SCIP established a baseline plan to improve inter-agency communications and effectiveness within that jurisdiction. The Massachusetts SCIP recognized the importance of the MSP Radio Network as a statewide platform to enhance first responder effectiveness in the years ahead.

observation

Consistent with the Massachusetts SCIP, CoMIRS has become the backbone for public safety interoperable communications throughout the Commonwealth (serving 245 current agencies).

Consistent with the strategic direction documented in the 2007 Massachusetts SCIP, the MSP Radio Network has continued to expand its user base and its role in improving interoperable communications statewide. Supported by the MSP and EOPSS, additional agencies are using the MSP Radio Network as the conduit to interconnect agency dispatch centers, new P25 trunked systems, and regional networks operating in other radio bands (VHF, UHF, and T-Band). In recognition of this expanded role, the network designation informally changed from the "MSP Radio Network" to the Commonwealth of Massachusetts Interoperable Radio Network (CoMIRS). Today, CoMIRS is a collection of individually managed radio systems and dispatch console networks all interconnected through the MSP network to improve radio intercommunication amongst different agencies.

This section of this radio strategy reports introduces the sub-networks that comprise CoMIRS, the technology that supports CoMIRS, and analyzes its current coverage and capacity statewide.

2.2.1 CoMIRS Subnetworks

Currently, CoMIRS is comprised of four EOPSS agency radio subnetworks and numerous interoperable associated radio subnetworks. These subnetworks, which consist of a mix of old regional proprietary analog trunked systems and newer standards-based P25 digital trunked systems, are interconnected and managed by the CoMIRS network Core. This interconnection allows users on the various radio subnetworks to communicate seamlessly across subnetworks, when needed.

Figure 2-12 shows an outline of the important systems integrated with the Commonwealth of Massachusetts Interoperable Radio System.

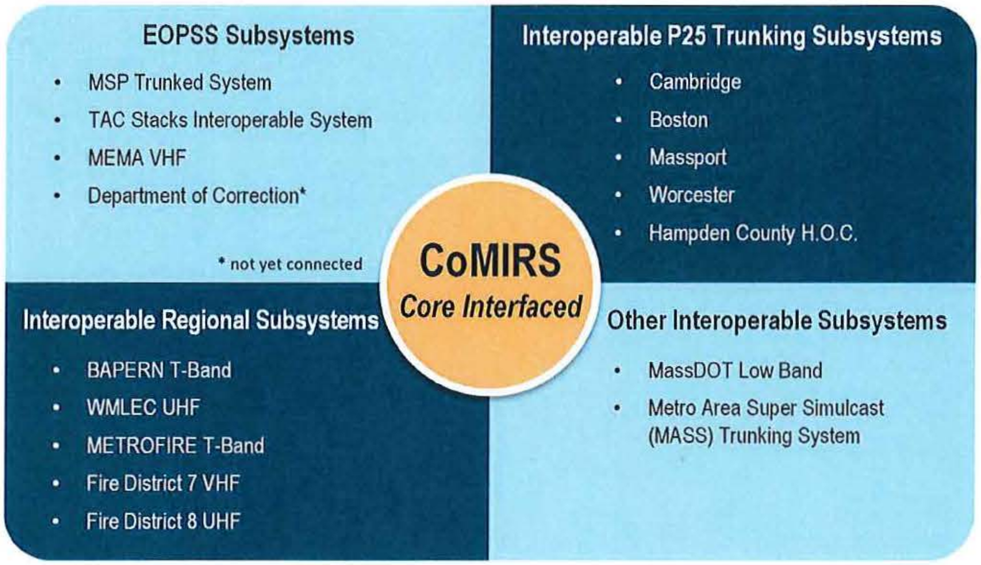


Figure 2-12: CoMIRS Subsystems

2.2.1.1 EOPSS Radio Subsystems on CoMIRS

Among the many subnetworks that comprise CoMIRS are four EOPSS radio subsystems. These include:

- Massachusetts State Police Trunked Radio Subsystem
- TAC Stacks Subsystem
- MEMA VHF Subsystem
- Department of Correction Systems (not yet connected to CoMIRS)

While managed by their respective EOPSS departments or agencies, each of these subnetworks falls under the auspices of EOPSS. Below are overviews of each of these EOPSS subsystems.

Massachusetts State Police Trunked Radio Subsystem

The first and most important of the four EOPSS subsystems is the MSP Trunked Radio System. This MSP Radio Network is a high-performance trunked system that operates primarily in analog mode in the 800 MHz frequency band. The network includes a combination of legacy 800 MHz analog transmitter sites (constructed between 1989 and 2010) and 800 MHz P25 digital transmitter sites (constructed since 2013 using P25 Phase 1 digital standards). All radio sites in the network interface with one of the two CoMIRS Zone Controllers. Zone Controller 1 and the CoMIRS Core are located at MSP General Headquarters in Framingham. Zone Controller 2 is located at Boston Police Headquarters in Roxbury.

The MSP Radio Network is a combination of simulcast and multicast topology to maximize radio coverage, system capacity, and frequency efficiency. "Simulcast" broadcasting refers to a system configuration in which multiple transmitter sites (e.g., radio towers) broadcast over a large area using the same radio frequencies simultaneously. Radio networks include simulcast broadcasts to make the most efficient use of limited radio frequencies. For the MSP Radio Network, there are four analog simulcast sites and two P25 digital simulcast sites in service.

"Multicast" broadcasting refers to a system configuration in which each transmitter site has its own discrete set of radio frequencies. Radio system planners typically use this type of broadcast to fill in small areas where coverage improvements are needed and there may be overlapping radio transmission zones. There are 13 analog multicast sites and 8 P25 digital multicast sites on the MSP Radio Network. Figure 2-13 depicts a representation of the frequency efficiency of simulcast vs. multicast sites.

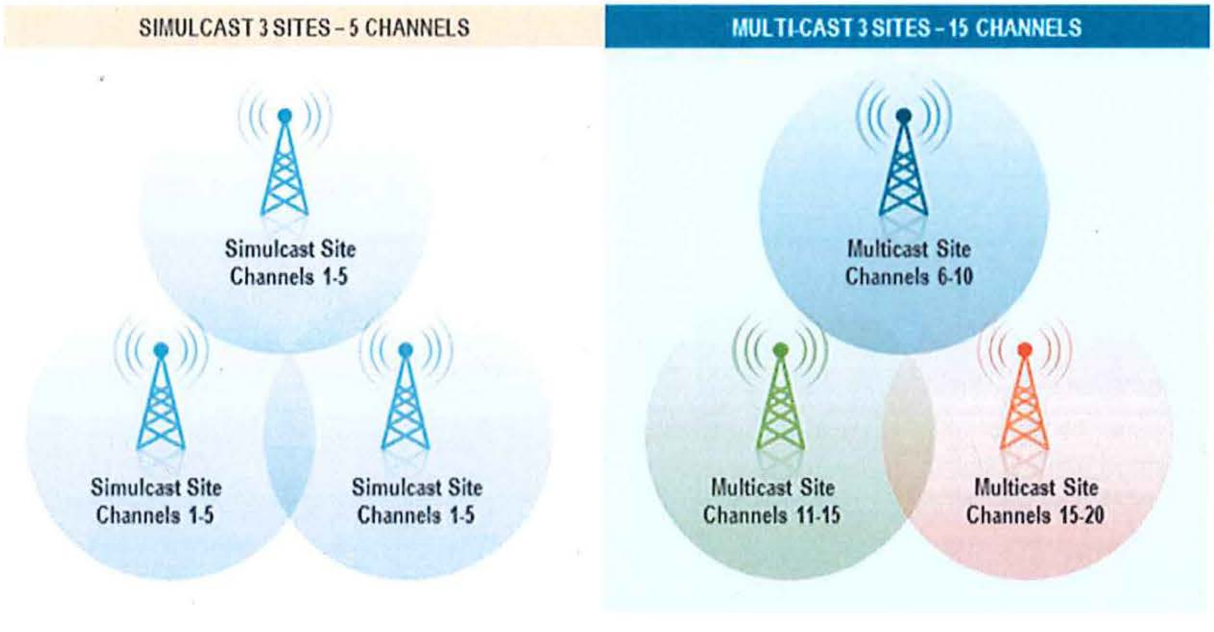


Figure 2-13: Simulcast vs Multicast Frequency Requirements

A trunked radio system is a complex type of computer-controlled two-way radio system that allows sharing of relatively few radio frequency channels among a large group of users. Instead of assigning, for example, a radio channel to one particular organization at a time, a trunked radio system administrator assigns users to a logical grouping, known as a talkgroup. Radio network administrators often assign operational users to dedicated talkgroups to support their daily operations. These talkgroups tend to have a limited number of users with shared operational responsibilities. Examples of operational talkgroups on CoMIRS include:

- 80002073 (A PTL 1) Assigned to Mass State Police as the primary dispatch and car-car channel for Troop A operations
- 80002447 (MEP 1) Assigned to Mass Environmental Police as the primary dispatch and car-car channel for MEP statewide
- 80003329 (MBTA Zone A) Assigned to MBTA Police as the primary and car-car channel for MBTA Police operations

Table 2-4 below shows a summary of the count of active talkgroups assigned to operational system users.

Agency	Operational Talkgroups Assigned on Network
Department of Correction	144
Massachusetts State Police	74
Barnstable County Cities and Towns	47
Other	28
Department of Transportation	21
MBTA Police	8
County Sheriffs	6
Department of Conservation and Recreation	6
Massachusetts Emergency Management Agency	4
Massachusetts Environmental Police	4
New Braintree Dispatch Towns	4
Northampton Dispatch Towns	4
Parole Board	4
Department of Fire Services	2
Shelburne Dispatch Towns	2
Massachusetts Water Resources Authority	1
Total	359

Table 2-4: CoMIRS Operational Talkgroup Summary

TAC Stacks Subsystem

The second largest and one of the most broadly used EOPSS subsystems in CoMIRS is the Tactical Stacks (TAC Stacks) subsystem. TAC Stacks is a network of conventional (non-trunked) repeaters/stations across the state that support interoperable communications amongst public safety users. A network administrator must activate these repeaters/stations when needed. They are not available for day-to-day operational use.

The FCC allocates specific conventional channels in all bands for exclusive interoperability use nationwide. The Commonwealth implemented the TAC Stacks "on-demand" network of conventional stations and repeaters on the following analog interoperability frequencies:

- VHF (150 MHz-174 MHz)
- UHF (450 MHz-470 MHz)
- 800 MHz bands

The Department of State Police implemented the TAC Stacks system at 62 transmitter sites across the Commonwealth. Additionally, the MSP is responsible for the management and maintenance of the system. The State Police and the Massachusetts Emergency Management Agency (MEMA) share activation and control responsibilities for the TAC Stacks system.

Any first responder can activate a TAC Stacks repeater or site by contacting either the MSP or MEMA. If a TAC Stacks site is equipped with VHF, UHF, and 800 MHz stations, it can support cross-band communications in all three bands. Thirty sites are equipped with stations in multiple bands; thirty-two are equipped with 800 MHz stations only. The Commonwealth maintains mobile TAC Stacks sites that can be transported anywhere service is required. The map below (Figure 2-14) depicts the distribution of TAC Stacks repeaters across the Commonwealth.

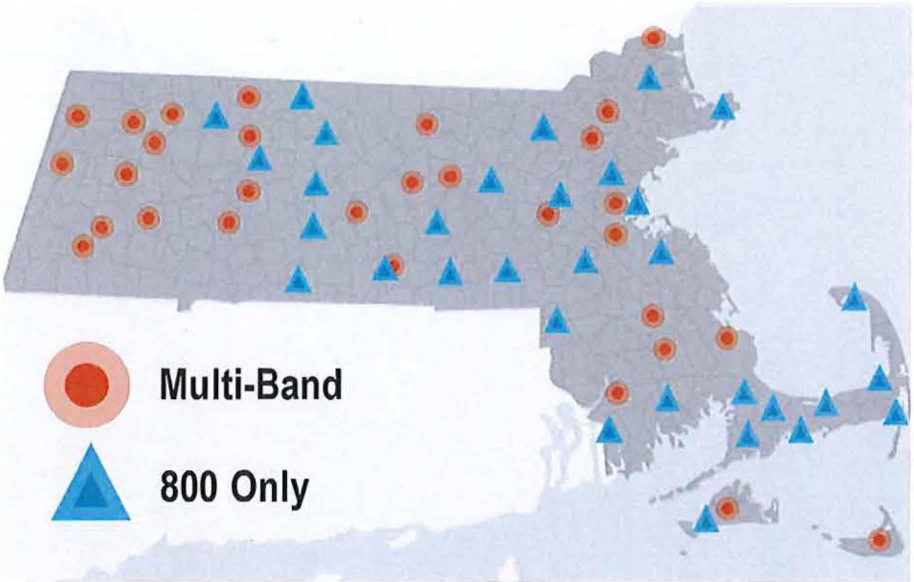


Figure 2-14: TAC Stacks Locations

MEMA VHF Subsystem

The third EOPSS radio subsystem in CoMIRS is a statewide network of VHF repeaters operated by the Massachusetts Emergency Management Agency (MEMA). MEMA operates a VHF radio network at nine tower sites across the Commonwealth. The MEMA VHS subsystem utilizes three VHF (151 -157 MHz) frequency pairs organized by MEMA region. One frequency pair is in Region 1, another is for Region 2, and the third is for Regions 3 and 4. Figure 2-15 below shows MEMA's operating regions.

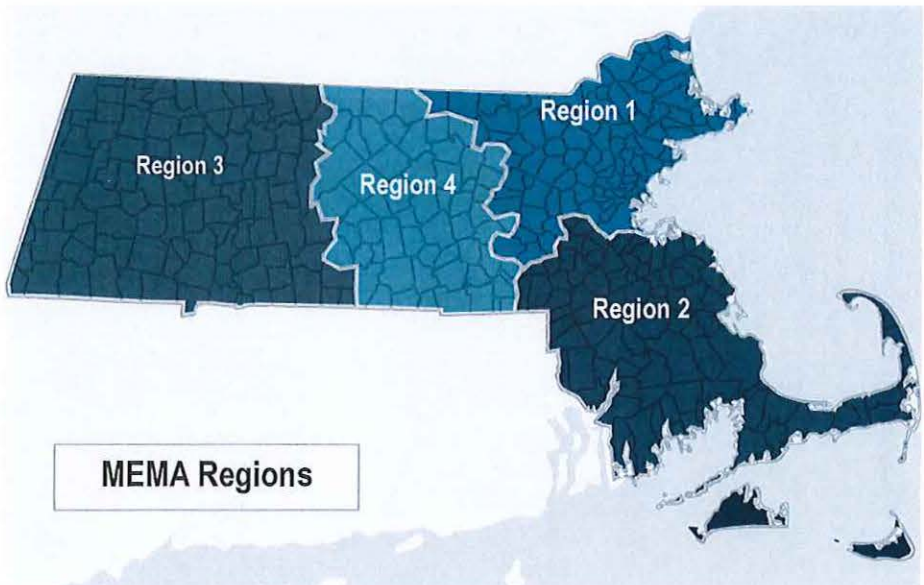


Figure 2-15: MEMA Regions and Frequency Pairings

The MEMA VHF subsystem operates in both the analog and P25 digital modes. MEMA utilizes MCC-7500 dispatch consoles, located at MEMA headquarters in Framingham, to manage communications on the VHF network. The consoles and radio sites are interfaced to the CoMIRS at Zone 1 in Framingham. MEMA can link or "patch" its VHF network with CoMIRS trunked talkgroups or TAC Stacks stations, as required.

Department of Correction Systems (not yet connected to CoMIRS)

The fourth EOPSS radio system is a group of 800 MHz systems operated by the Department of Correction (DOC). The DOC operates two standalone 800 MHz Motorola analog trunked systems (at Bridgewater and Shirley) and two standalone 800 MHz Motorola P25 digital trunked systems (at Framingham and Norfolk) to support campus operations at large correctional facilities. Figure 2-16 below depicts the locations of the four DOC trunked radio systems.

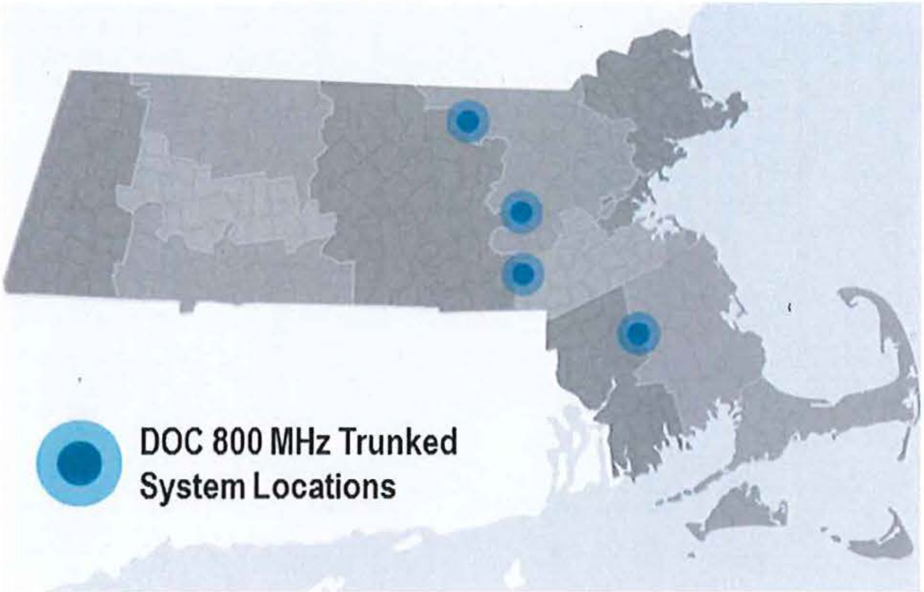


Figure 2-16: DOC 800 MHz Trunked System Locations

At smaller facilities (like Gardner and Concord), 800 MHz conventional systems are installed to support DOC operations. None of these DOC radio systems is linked through the Core to other CoMIRS assets. Therefore, each DOC radio system operates as its own independent system and not as an integrated subsystem of CoMIRS. The separate nature of these systems limits the ability of correctional staff to communicate between facilities and manage all of the systems from a central location. The DOC operates approximately 2,000 radios within these 800 MHz trunked and conventional systems.

In addition to the radios operated within the correctional facilities, the DOC Transportation Department and Special Operations divisions operate over 500 radios on the MSP trunked network. These divisions generally operate outside DOC facilities and require the wide area coverage provided by the MSP network to perform their duties.

2.2.1.2 Other Radio Subsystems on CoMIRS

In addition to EOPSS agency radio subsystems, CoMIRS also includes radio subsystems and radio consoles operated by other agencies throughout the Commonwealth. These radio systems interface with CoMIRS for interoperability through one of the two CoMIRS Zone Controllers.

In addition to the MSP-constructed P25 digital system in western Massachusetts serving MSP Troop B and others in western Massachusetts, the Cities of Boston, Cambridge, and Worcester, as well as the organizations of Massport and the Hampden County Sheriff's Office, have implemented P25 700 or 800 MHz digital trunked systems to support their operational needs. These systems interface to the CoMIRS' Core to promote interoperability with others in the first responder community. These systems provide portable radio "in-building" coverage within their respective service areas.

In 2013, Nantucket implemented a P25 800 MHz digital trunked system to serve local government operational needs on the island. While this system is not interfaced to the CoMIRS Core, it could be with a backhaul connection between the island of Nantucket and either CoMIRS Zone Controller in Framingham or Boston.

Of the seven other public safety P25 trunked systems in the Commonwealth, five of them operate in the P25 FDMA (Phase 1) mode and two operate in mixed mode of P25 FDMA and P25 TDMA (Phase 2). Table 2-5 shows details about these other agency interoperable P25 trunked systems in Massachusetts.

System Owner	Frequency Band	Phase 1 or Phase 2	# of Frequencies	Core Connected
City of Boston	700 MHz	Mix	8-Phase 1 4-Phase 2	Yes
City of Cambridge	800 MHz	Phase 1	12	Yes
Massport	800 MHz	Phase 1	15	Yes
Hampden County Jail	800 MHz	Phase 1	5	Yes
DOC Norfolk	800 MHz	Phase 1	5	No
City of Worcester	800 MHz	Mix	10-Phase 1 2-Phase 2	Yes
Nantucket	800 MHz	Phase 1	4	No

Table 2-5: Other P25 Digital Trunked Systems in Massachusetts

Subject to sharing agreements and available channel capacity, these local systems could be utilized to expand the P25 digital service area of the network for all operational users. Integration of these systems with the network would expand the coverage footprint for digital users without the need to construct new tower sites or backhaul connectivity. Additional channels and/or migration from P25 Phase 1 to P25 Phase 2 may be required to increase the capacity of the systems for more operational users.

2.2.1.3 Other Interoperable Radio Networks Connected to CoMIRS

The public service radio environment in Massachusetts includes a number of other important single user and interoperable systems. These systems largely operate independently of CoMIRS but interface with the CoMIRS Core at Zone 1 or Zone 2 to allow direct radio-radio interoperability between users when required. For example, the interface between the MSP Radio Network and the BAPERN system allows a MSP 800 MHz trunked radio to interoperate with a BAPERN member agency UHF radio.

Six large regional networks interface with CoMIRS to promote interoperability across disciplines and jurisdictional boundaries. These systems operate on various frequency bands, including UHF, low band, and 800 MHz. Their interfaces are managed through the CoMIRS Core and can be modified quickly as required by operational needs and management agreements between system operators. Table 2-6 provides a summary of these six regional networks below. The sections that follow describe each of these in more detail.

Radio System	Operating Area	Frequency Band	Interoperable with Commonwealth Network
BAPERN	Eastern Massachusetts	UHF T-Band	Yes
WMLEC	Western Massachusetts	UHF	Yes
MassDOT Highway	Statewide except Metro Boston	Low Band	Yes
MassDOT Transit (MBTA)	Metro Boston	800 MHz	Limited
MassMetrofire	Metro Boston	UHF T-Band	Yes
MASS Simulcast	Metro Boston	800 MHz	Yes

Table 2-6: Summary of Other Interoperable Radio Networks

Boston Area Police Emergency Radio Network (BAPERN)

BAPERN is a regional police radio network deployed throughout eastern Massachusetts. The Greater Boston Police Council, Inc. owns and operates the radio network on behalf of its 166 member agencies. Together, these agencies operate 11,000 radios that utilize BAPERN for regional interoperability.

BAPERN consists of two area-wide channels, six district channels, and four P25 digital district tactical channels. The BAPERN area-wide channels operate across all districts, and district channels operate within each district shown in Figure 2-17.

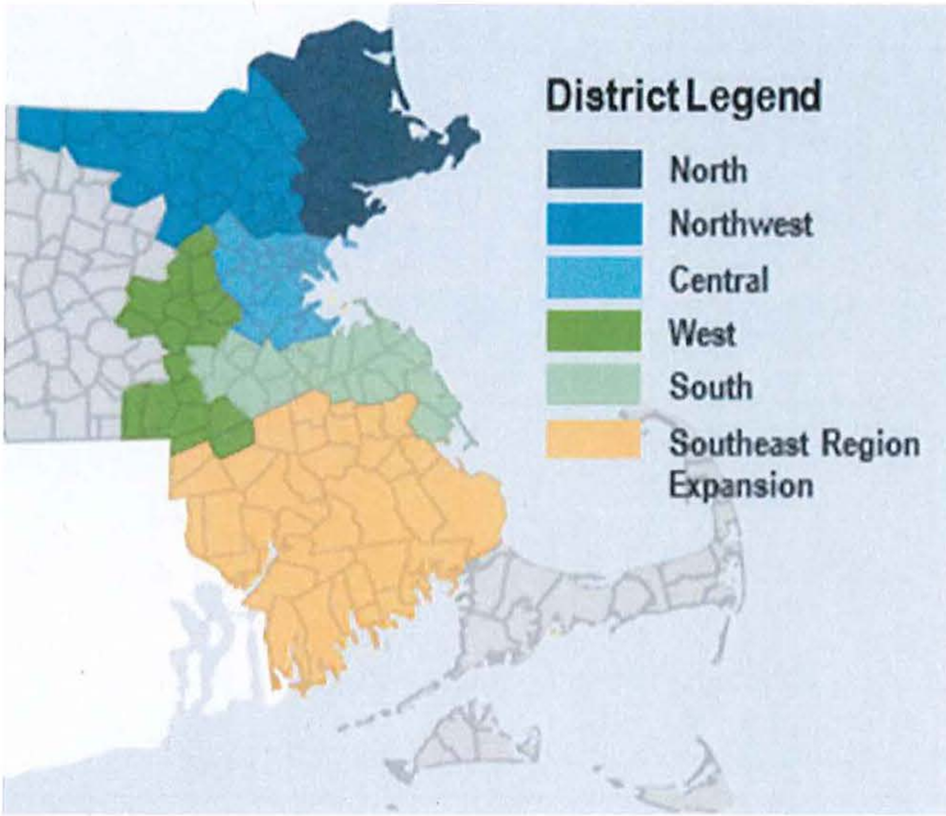


Figure 2-17: BAPERN Districts

BAPERN members each operate their own radio network within their primary jurisdiction and use the shared BAPERN channels for interoperability when required. The BAPERN network operates in UHF T-Band (470 MHz-512 MHz) as do most of the individual networks operated by BAPERN members. As a provision of the Middle Class Tax Relief and Job Creation Act of 2012, public safety users of this band are required to vacate the band in or around 2022.

Some city and town BAPERN members are included in the Urban Areas Security Initiative (UASI) region and operate CoMIRS interfaced radio control consoles at dispatch centers interfaced to CoMIRS at Zone 2. CoMIRS interfaces to BAPERN through Zone 2 located at Boston Police Headquarters.

Western Massachusetts Law Enforcement Council (WMLEC)

WMLEC is a 2-channel UHF (450 MHz-470 MHz) regional radio network in western Massachusetts. WMLEC members operate within the WMLEC service area shown in Figure 2-18.

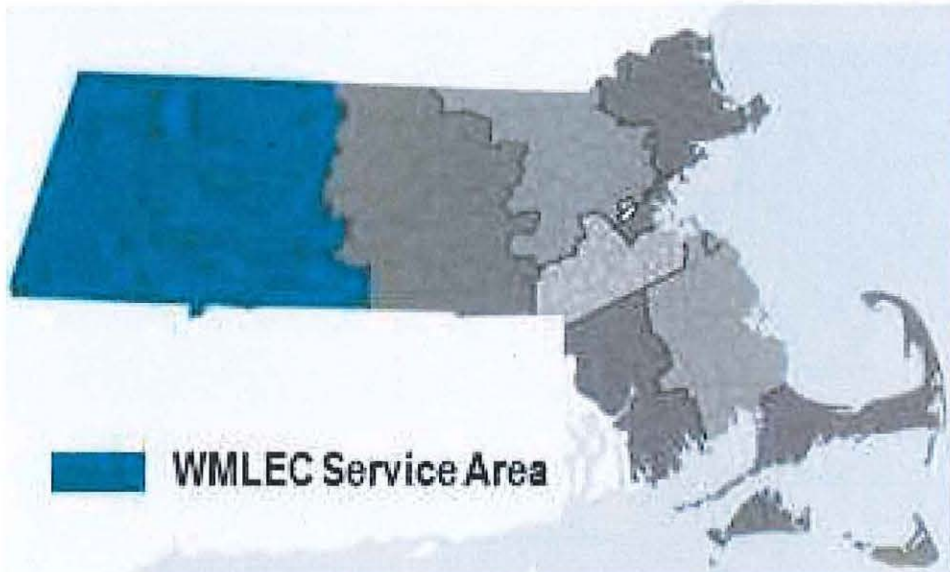


Figure 2-18: WMLEC Service Area

WMLEC channel 1 is a police interoperability channel and WMLEC channel 2 is a Fire/EMS interoperability channel. WMLEC members each operate their own radio network within their primary jurisdiction for day-to-day operations. Most WMLEC member systems operate in the UHF band. CoMIRS interfaces to WMLEC through Zone 1 located at MSP Headquarters in Framingham.

Massachusetts Department of Transportation (MassDOT) – Highway Division

The Highway Division of MassDOT operates district wide low band (47 MHz) radio systems in Districts 1 through 5. In District 6 (Metro Boston), the Highway Division operates on CoMIRS through the MSP trunked network. Figure 2-19 below depicts the MassDOT operating districts.

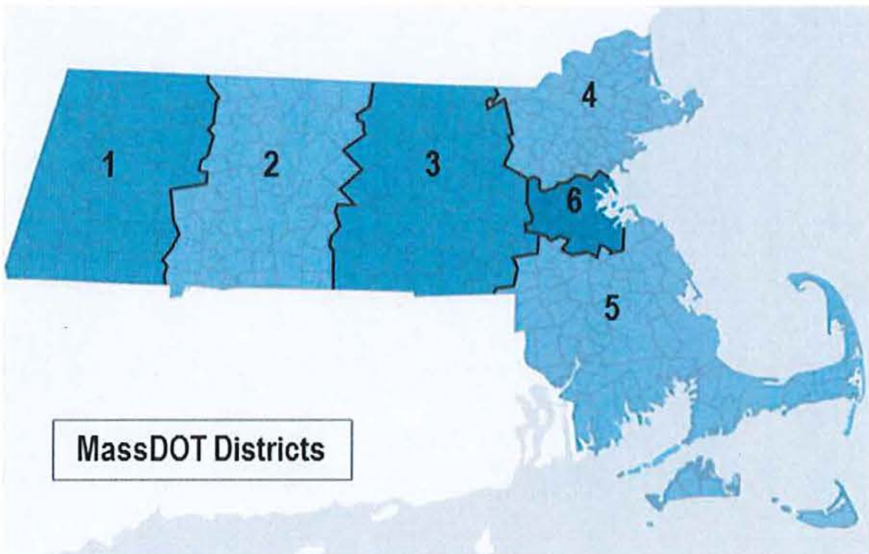


Figure 2-19: MassDOT Districts

To provide for radio communications within the highway tunnel system in Boston, MassDOT operates and maintains a Distributed Antenna System (DAS) that rebroadcasts 800 MHz signals from the Troop A/H analog system inside the underground tunnel area. MassDOT also operates and maintains an analog trunked multi-cast site within the Central Artery Tunnel to provide communications inside the Central Artery Tunnel in the event of a failure in the DAS network.

MassDOT operates with CoMIRS interfaced consoles in Boston and Weston. These consoles have the ability to bridge or "patch" low band channels to MassDOT talkgroups on the MSP trunked system.

Massachusetts Department of Transportation – Transit Division (MBTA)

The MBTA operate a three site 800 MHz Harris EDACS digital trunked simulcast system to support its bus and rail operations within the approximate service area shown in Figure 2-20. This proprietary digital system is not interfaced to CoMIRS except by the radio patch available through the CoMIRS interfaced MBTA police radio console in Boston.

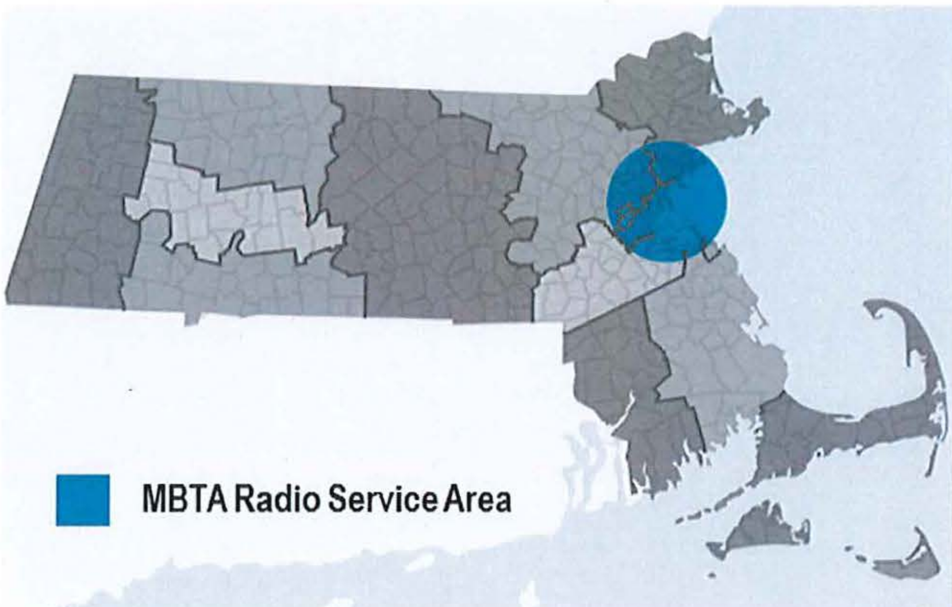


Figure 2-20: MBTA Radio Service Area (approximate)

To provide radio communications in the underground MBTA tunnel network, the MBTA owns and manages a DAS that rebroadcast signals from the above ground MBTA system into the tunnels. In 2014, the DAS was expanded to include 800 MHz channels from the MSP Troop A/H 800 MHz analog trunked radio system. This expansion provides communication for any CoMIRS user operating on the Troop A/H subsystem.

MassMetrofire[4]

MassMetrofire is an association of thirty-four fire departments in the metropolitan Boston area. MassMetrofire operates an interoperable and integrated radio network in the UHF T-Band (470 MHz-512 MHz). Figure 2-21 shows the approximate service areas for MassMetrofire member communities.

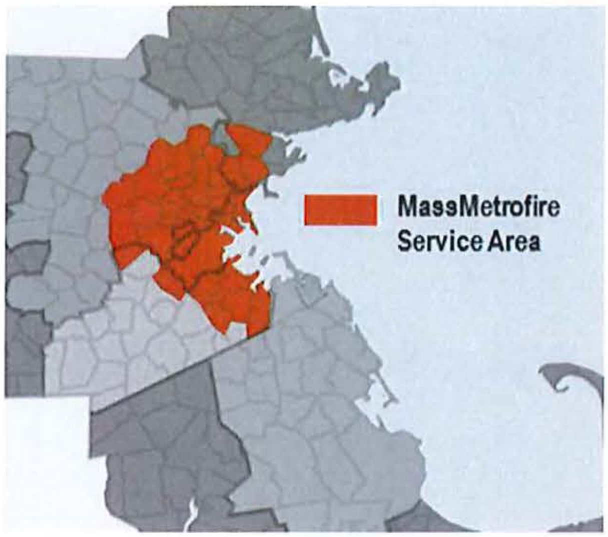


Figure 2-21: MassMetrofire Service Area (approximate)

Member agencies each operate their own radio networks to support internal operations within their primary jurisdiction. Most operate in the UHF T-Band. The City of Cambridge, a MassMetrofire member, operates an 800 MHz P25 trunked system for all city departments. To facilitate direct communication between all member communities, CoMIRS maintains a bridge (or patch) at Zone 2 between MassMetrofire UHF channels and the trunked talkgroups assigned to MassMetrofire.

[4] http://www.massmetrofire.org/

Metro Area Super Simulcast (MASS)

Historically, the City of Boston and the Department of Conservation and Recreation (DCR) each independently operate three site 800 MHz Motorola analog systems in the greater Boston area to support their operations. The DCR system integrated with the network Core at Zone 1, while the Boston system operated as a standalone system. In 2013, the city and the department agreed to consolidate the two systems into one six-site 13-channel system and integrate with the CoMIRS Core for interoperability. Currently, this system operates with five of the six sites in service. This radio network supports nearly 4,000 radios from the City of Boston's public service agencies, as well as DCR's and the Massachusetts Water Resources Authority's operations in the greater Boston area.

The P25 digital system operated by the City of Boston (Metro Boston System) completely overlaps the coverage area provided by the Metro Area Super Simulcast (MASS) system. The City of Boston has been migrating operations from the MASS analog system to the Metro Boston System as they decommission older analog radios and purchase new P25 radios.

Figure 2-22 shows the approximate coverage area for the MASS system.

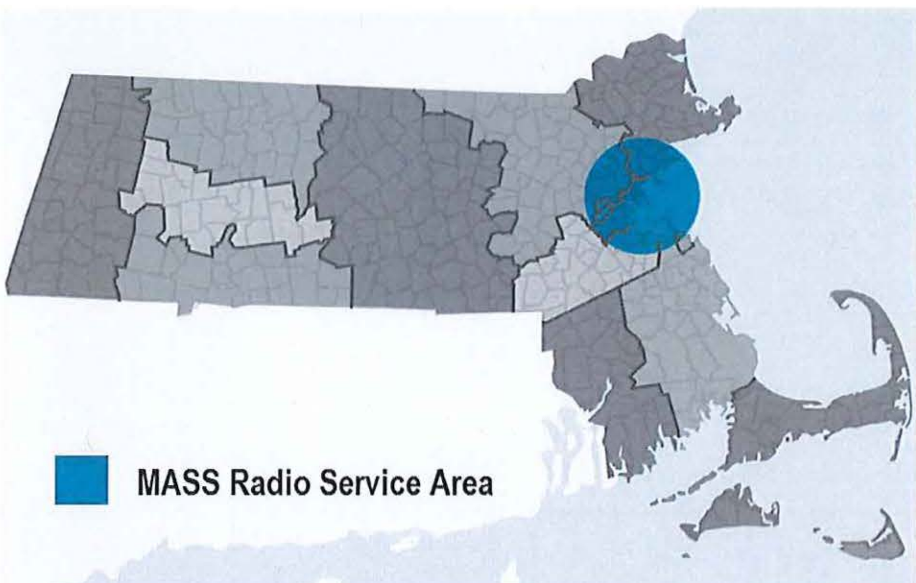


Figure 2-22: MASS Service Area (approximate)

2.2.2 CoMIRS Technology

Land mobile radio systems, like CoMIRS, typically consist of five main categories of equipment and software. These include:

- **Site Equipment**: Site equipment includes the structures and technology needed to establish a radio frequency (RF) broadcast at a fixed location. Site equipment typically includes site towers, site shelters, antennas, emergency power, and backhaul equipment. Additionally, trunked RF sites include specialized trunked site equipment that helps the system coordinate radio broadcasts over shared frequencies. *Site equipment is the "eyes and ears" of the radio network, allowing remote users to be heard by other remote users.*

- **Backhaul Equipment**: Backhaul is the means of getting voice and data from a site tower or radio location to a point from which it can be distributed over a network. Backhaul equipment for LMR networks are the intermediary links required to connect the various RF sites to the common communications system. Without backhaul, there would be no communications with the radio site tower and all users of that tower would be disconnected from communications with others on the radio network. *Backhaul, in a sense, is the "arteries" of the radio network, allowing communications to flow between radio sites.*

- **Network Management**: Network management is a general category for the software and hardware that control the operations of a land mobile radio network. This includes Zone Controllers, the network Core, and the software that manages the provisioning and use of the radio network. *The Core and the Zone Controllers together form the "brain" of the radio system, controlling access to network and dictating how that network functions.*

- **Mobile and Portable Radios**: Mobile and portable radios are end-user devices that permit individuals to communicate over a land mobile radio network. Handheld portable radios are carried by public safety personnel and tend to have a limited transmission range. Mobile radios are often located in vehicles and use the vehicle's power supply and a larger antenna, providing a greater transmission range than handheld portable radios. *They comprise the "voice" of the network.*

- **Dispatch Consoles**: Dispatch consoles are computer software and hardware that are typically used for dispatch, command, and control activities. Consoles are typically wired equipment located in a public safety answering point (PSAP) or in an agency's communications or emergency operations center. Consoles allow an authorized user to monitor communications over multiple radio channels, patch separate channels together for shared communications, and broadcast important information to users of the radio network. *Dispatch consoles, in a sense, are "vital organs" that coordinate the functions of the different organ systems, making sure that timely communications are made across disciplines and organizations.*

The interconnection of these CoMIRS LMR components is depicted below and each category is explained in greater detail in the sections that follow.

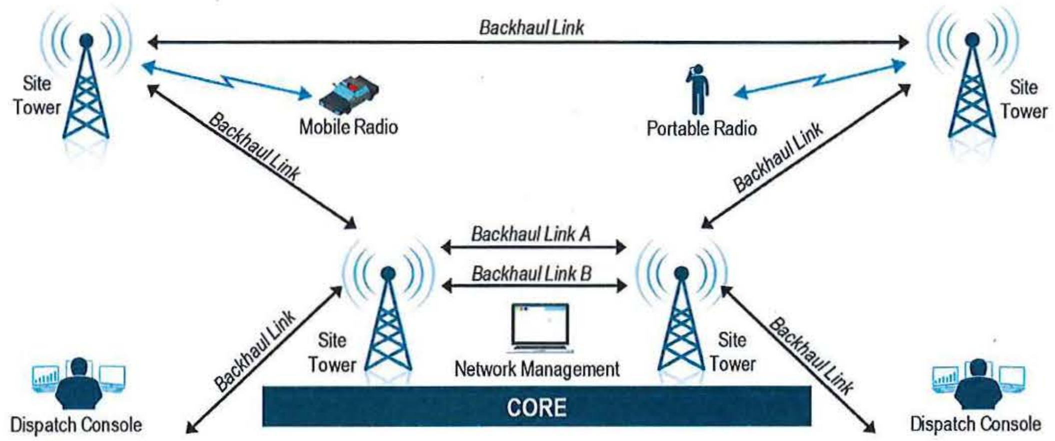


Figure 2-23: Network Building Block Diagram

2.2.2.1 Site Equipment

Site equipment is a critical component of a land mobile radio network. Radio sites allow the network to broadcast radio communications with users throughout the broadcast area. Without radio sites, the wireless network does not function. Each site typically includes a site tower, a site shelter, backhaul equipment, and emergency power. In addition, specialized site equipment is included for trunked radio sites. This diagram shows the basic site equipment, which is described in detail below.

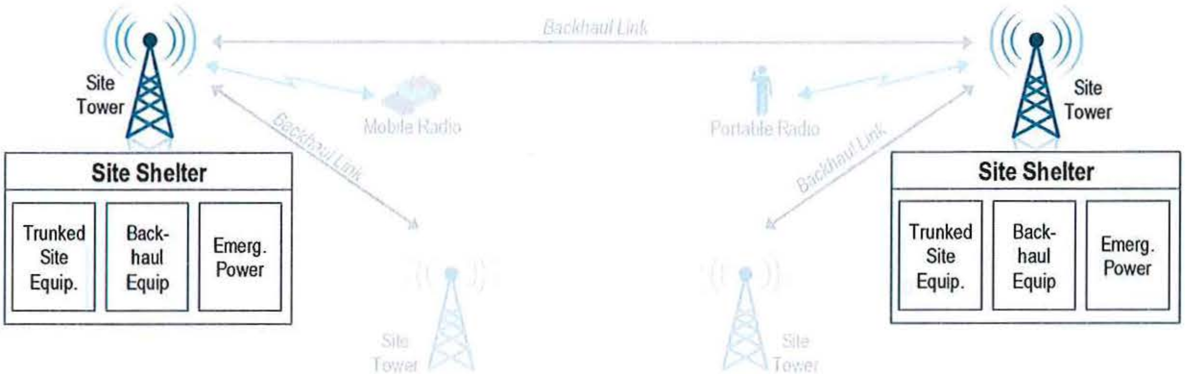


Figure 2-24: Site Equipment

Site Towers

Radio site antennas and microwave backhaul antenna systems mount to site towers, buildings, or other antenna structures. The CoMIRS network uses state owned tower sites where possible and leases other public agency tower space and commercial tower space to complete the constellation of tower sites currently in place.

Currently, the MSP trunked analog and digital systems utilize 82 site towers. Figure 2-25 shows the types of towers in use by CoMIRS. The selection of a tower is dependent upon the tower's height and ability to support antenna equipment in conjunction with current building codes that consider wind, ice, seismic and other loading factors appropriate for the region.

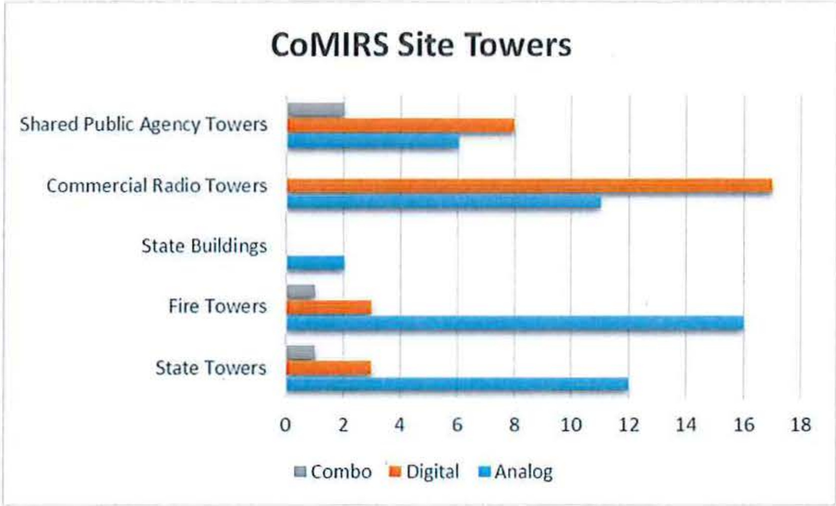


Figure 2-25: CoMIRS Site Towers

CoMIRS currently uses 20 fire towers as radio sites for its digital and analog networks. Fire towers generally are sub-optimal as radio tower sites due to their limited height and structural characteristics. These towers were generally not built initially to support antennas and other communications equipment. Rather, these older structures have been retrofitted to house communications equipment based on the needs for radio broadcasting in their vicinity.

In addition to the 20 fire tower sites, CoMIRS uses public agency tower sites for an additional 34 radio tower sites. This includes 16 state-owned towers, 2 antenna locations attached to state buildings, and 16 shared public agency towers. The remaining 28 radio sites are leased from commercial tower owners.

In general, the older analog radio sites rely on fire and state towers for radio sites (16 fire tower sites and 12 state tower sites). The more recently installed digital radio sites predominantly use commercial radio tower (17 tower sites) and shared public agency towers (8 tower sites).

The typical tower standard specified under current building codes is American National Standard Institute/Telecommunications Industry of America (ANSI/TIA) 222 Revision G (ANSI/TIA 222 Rev G). This standard is used both in the construction of new towers and the modification of existing towers before new antenna are installed. This standard is typically reviewed every five years, and tower owners and managers must be aware of changing standards and addenda as they are released. ANSI/TIA 222 Rev H is planned for release late in 2017. Revisions to the standard can result in different results for PASS/FAIL structural analysis performed on existing towers, as the requirements tend to be more stringent with each revision. In other words, a tower that currently meets structural standards under ANSI/TIA 222 Rev G may not meet the comparable standard with the release of ANSI/TIA 222 Rev H later this year.

Tower loading standards are developed to ensure the structural integrity of the tower under loads and environmental conditional typical to the region. Towers that do not meet current standards are at increased risk of failure that can cause loss of life and property at the site and loss of emergency radio communications for extended periods of time.

Figure 2-26 shows typical considerations for construction of new tower structures.

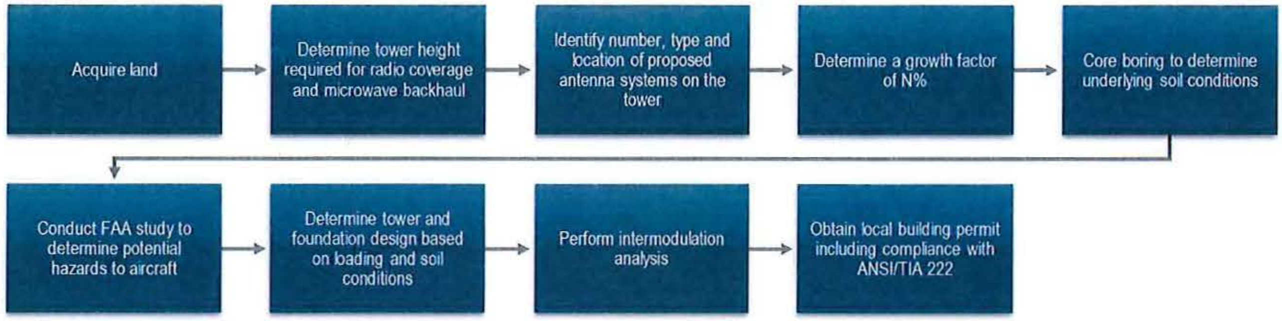


Figure 2-26: Tower Construction Process

Figure 2-27 shows considerations for mounting new antennas to an existing site.

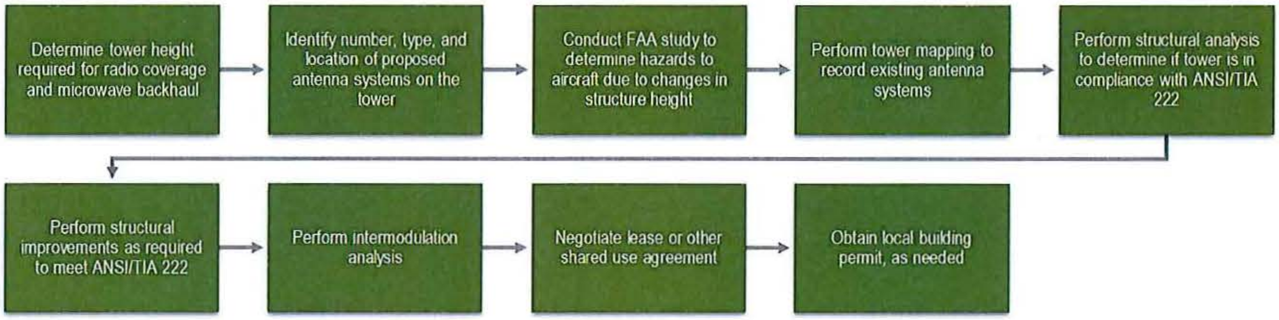


Figure 2-27: Antenna Mounting Process

Tower space is a precious commodity. When locating antenna systems on an existing structure not only does the coverage objective need to be met, but also there must be sufficient separation from other antenna systems on the tower to avoid interference and intermodulation. This is most challenging at the fire tower sites. Fire tower locations are selected because they are always located at elevations higher than surrounding terrain.

Fire towers are typically 65-70 feet tall including the cabin at the top. **Error! Reference source not found.** shows a fire tower set up for radio use. Radio antennas must be mounted at the four corners of the cabin resulting in no vertical separation and limited horizontal separation. The typical 800 MHz trunked site requires three radio antennas, each 15-18' long. Microwave antennas, which are typically 6-8' dish antennas, are mounted at the base of the cabin so they do not interfere with view from the cabin. This means the centerline of the microwave dishes are only 45-50' above the ground, at or below the level of surrounding trees. Where possible local tree growth is restricted by cutting. At many locations, however, the tree growth is on land not owned or controlled by the state or miles from the tower in the middle of the path to the next site.

Figure 2-28: Typical Fire Tower

The decision to build new towers or lease existing towers is based on many factors. The initial costs to build a tower can cost up to $500,000 or more depending on the cost of land acquisition, site access requirements, and type of tower. Commercial tower space leases can range from $2,500/Month to $5,000/Month or more based on the number and type of antenna systems placed at the site and the location of the site. Urban areas tend to be more costly than rural areas. Costs for shared public agency sites are typically satisfied by an agreement to include mutually beneficial equipment and/or services in exchange for use of an agency tower. For example, a tower-owning agency may agree to provide antenna space on the tower to a second agency. In exchange, that second agency covers the costs for space and emergency power for radio equipment used by both agencies.

The decision to construct new radio towers or lease commercially available tower space is based on some of the choices shown below:

Construct New Tower	vs	Lease Commercial Tower Space
High capital cost	✓	High operating costs
Build period 12-24 months	✓	Build period – 4-8 months
Requires active management/maintenance	✓	Management/maintenance by others
Potential revenue stream from tenants	✓	Commercial site ownership can change
Retain control for future state needs	✓	MSP subject to space available on tower
Built to meet specific requirements of state	✓	Limit unforeseen costs
Unanticipated risks or repairs	✓	Flexibility to end agreement

Figure 2-29: Considerations for Constructing or Leasing Tower Space

Site acquisition is a process by which system engineering identifies a set of radio sites or towers that would meet the coverage objectives. A formal site acquisition process was undertaken for the western Massachusetts P25 digital system. The coverage area was determined first, and then sites were acquired to meet the coverage goal. Site acquisition for the analog systems was a more informal process in which available state sites were identified first and coverage was optimized as best it could be from those sites.

Generally, greater antenna height over average surrounding terrain results in a larger coverage area. Height over average surrounding terrain is achieved by either building very large towers (500' or more) or building smaller towers (180') on hilltops.

A tower of 180' typically provides enough mounting space to install required radio antennas and microwave backhaul dishes above any local obstructions such as trees and provides the vertical separation between antennas for optimal performance. Towers that are under 200' do not usually require lighting or other Federal Aviation Authority (FAA) or Federal Communications Commission (FCC) markings.

observation

Many of the radio tower sites – especially fire towers – used for the CoMIRS analog trunked network are old and sub-optimal. These towers should be replaced as part of the broader network improvement effort.

Most fire towers in Massachusetts are under the control of the Department of Conservation and Recreation (DCR) and are all located on high ground but are only 65-70' high. Construction of commercial grade radio towers at DCR fire tower locations would result in improvement of radio coverage and reliability of microwave backhaul connecting the sites.

DCR does not own the underlying land at some fire tower sites, and in some cases, there are title restrictions on land that may preclude the use of the land for any other purpose. It is unclear which of the fire tower sites may open for the construction of radio towers to support the CoMIRS network but an effort to cooperate on the construction of towers between EOPSS and DCR might result in some new possibilities for effective state owned tower sites.

Site Shelters

Equipment required for the operation of the network is installed in secure, environmentally controlled equipment shelters. Site shelters house the radio site transmitters, trunked site controllers, backhaul microwave radios, antenna combining systems, emergency power systems, and other ancillary equipment. As part of the site assessment process, engineers survey shelter space to ensure it meets the basic requirement of space availability, accessibility (24x7), security, power, environmental control, backhaul availability, and overall construction feasibility.

Shelter configurations vary at CoMIRS radio sites as determined by:

- Existing secure shelter or equipment room availability at the site
- Ground space available for new shelters and generators
- Site access (can a prefabricated shelter be transported to the site or is "on-site" assembly required)
- Potential for future growth of communications system usage on site
- Potential for use by other public agencies
- Generator location (indoor or outdoor)

- Shelter and perimeter security
- Year-round site access for system maintenance and generator refueling

Site security is vitally important at most radio sites because they are typically in remote areas with no regular activity. Vandalism and theft are a constant reality at communications sites. Whenever possible, equipment shelters consist of precast concrete structure, reinforced doors, and perimeter fencing. Door and environmental alarms are the only security measures in place at site shelters and these measures do not directly detect vandalism and theft that occur outside the shelter. MSP has experienced theft of copper components from antenna systems that are mounted on the exterior of shelters and on tower structures. This theft is only detected through radio system alarms that detect faults in the antenna system. Motion sensors within the perimeter fencing and/or video cameras can be employed to enhance site security.

observation

Site shelter security could be enhanced with additional use of motion sensors and video cameras.

For the analog systems, equipment shelters are often deployed with outdoor generators. The more recently installed P25 digital systems in western Massachusetts often included larger (12' x 26') equipment shelters and indoor generators. At sites where ground space is extremely limited, outdoor cabinets are often used to house radio equipment. Figure 2-30 shows the breakdown of the 82 shelters used in CoMIRS by ownership. The Department of State Police or the Commonwealth of Massachusetts owns four out of five site shelters. Only 9% are commercially owned.

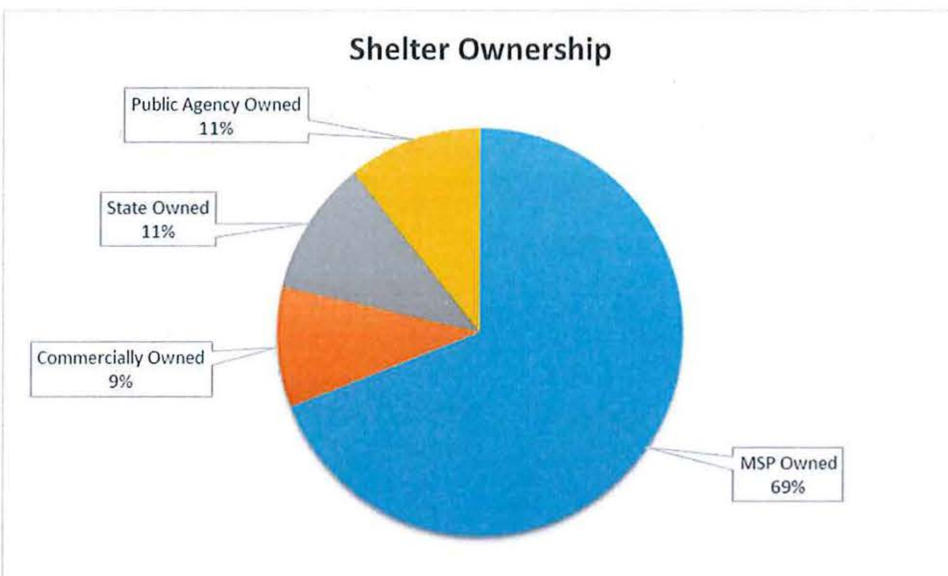


Figure 2-30: CoMIRS Shelter Ownership

All site shelters include heating, ventilating, and air conditioning (HVAC) systems to control the environment within the shelter or equipment room. Maintaining an ambient temperature range of 68° to

75°F (20° to 24°C) is optimal for system reliability of electronic equipment in a data center environment. While there are various equipment types housed in the shelter with varying temperature limits (e.g., radio, microwave, channel banks, routers, switches, etc.), this temperature range satisfies all equipment specifications. HVAC systems are maintained under the MSP maintenance contract for all MSP owned shelters. Others may maintain HVAC systems at site shelters/equipment rooms utilized by MSP, but proper operation is critical to the reliability of the MSP radio networks.

An evaluation of existing site shelters should be undertaken as part of any future digital system design process to determine the feasibility of using existing analog site shelters for the digital expansion. Digital systems will need to cohabit in the site shelters or equipment rooms with analog equipment during the migration from analog to digital. It is unknown if sufficient equipment space, HVAC, or emergency power capacity exists to support both systems simultaneously.

observation

As CoMIRS transitions from analog to digital service, existing analog site shelters should be evaluated to determine if they can concurrently support P25 digital equipment during the system cutover period.

Some site shelters are already in immediate need of improvement. Athol is an analog system radio site and a planned site in the current CoMIRS upgrade plan. The State Police recently acquired ownership of this site. The equipment shelter and generator currently in use are in critical need of replacement due to environmental conditions. Access to the site is limited which makes resupply of liquid propane fuel for the generator very challenging in the winter months. A new shelter would provide much better protection of the equipment and a new generator using diesel fuel could be resupplied with smaller delivery vehicles. Failure to address this current site shelter issue could risk the loss of radio communications for all users in the Athol area of Worcester County.

Trunked Site Equipment

Trunked radio site equipment consists of radio repeaters, trunked site controllers, antenna combining systems, and antenna systems. Radio site equipment operates in either the analog or the digital mode and provides radio coverage over wide areas, dependingon antenna height above the average terrain. The site shelter houses this equipment.

The MSP trunked network includes both proprietary analog and standards based P25 digital trunked radio systems. To enable cross communications between the analog and digital systems, both are interfaced to the system Core. All analog trunked systems are interfaced at Zone 1 in Framingham. This interface enables direct communications between an analog radio operating on the analog trunked system and a P25 digital radio operating on a P25 digital trunked system.

Analog trunked system equipment is no longer being produced in favor of digital systems that offer:

- Improved voice quality over wider coverage areas
- Increased frequency efficiency
- Voice and data communications
- Voice encryption
- Radio location services
- Over-the-air radio programming
- Improved remote management

observation

Critical analog system equipment is old and is no longer being manufactured. Repairing and replacing parts is becoming increasingly expensive and time-consuming.

While all radio equipment within the MSP network is included in a maintenance contract, some major components of the system are old and beyond the manufacturer support period. Being beyond the manufacturer support period results in:

- No guarantee of repair
- Extended repair times
- Limited or no spare parts available from the manufacturer
- No board repair from the manufacturer
- Limited technical support from the manufacturer

Some of the major components of the analog system that are presently beyond the manufacturer support period are:

- Prime and remote site controllers
- Microwave backhaul systems
- Simulcast site rubidium time synchronization clocks
- Radio transmitter and associated equipment (manufacturer support will end in 2020)

Part of the system maintenance contract includes provisions to keep the software and firmware in the network current. The analog system software/firmware is currently at Z release, meaning that the manufacturer is not producing any updates or enhancements. The P25 digital system is currently operating with Motorola System Release (SR) 7.15. System releases impact all current Motorola equipment interfaced to the Core, including:

- P25 Zone 1 Master Site
- P25 Zone 2 Master Site
- P25 Trunked systems (MSP, Cambridge, Boston, Hampden HOC, Massport, DOC, Worcester)
- MCC 7500/7100 Consoles at all locations

observation

Simulcast site standards are critical to the operation of the simulcast radio subsystems on CoMIRS. Unsupported, aging GPS clocks require immediate replacement.

- Network Management Terminals at all locations

All CoMIRS stakeholders on the network must be at the same Motorola System Release. The MSP maintenance and software update contract does not include equipment owned by other stakeholders. Some stakeholders have executed contracts similar to MSP but some have not. This can be problematic and can cause delays in executing software updates. No formal user agreements have been executed between the stakeholders at this time. User agreements are an appropriate vehicle for defining stakeholder maintenance and software release requirements.

Software release upgrades of the Motorola Astro 25 Trunking System are contracted by MSP for execution every two years. The initial P25 digital systems were delivered at SR 7.9, and subsequent releases 7.11, 7.13 and 7.15 periodically since then. SR 7.15 is the last system release that supports the Gold Elite Dispatch Console Systems. Gold Elite Dispatch Consoles are in use at 29 operator positions at 8 MSP dispatch locations. The next scheduled SR upgrade is to SR 7.17. This SR is scheduled for 2017. SR 7.17 cannot be applied unless MSP replaces the Gold Elite Console Systems in use at these eight MSP locations.

observation

Software upgrades to CoMIRS subsystems must be coordinated and performed simultaneously. No CoMIRS partner can apply the next standard system upgrade because of MSP's continued use of the outdated Gold Elite Console System.

System releases introduce new APCO Project 25 suites of features, such as P25 TDMA, as the standards body completes them and the manufacture incorporates the standards. These releases also include new manufacturer specific features, such as options for conventional talkgroups. System releases can also include hardware changes to proactively change out hardware components that are moving out of life cycle (e.g., migrating from Juniper Firewall to Fortinet Firewall).

Antenna combining systems installed at trunked radio sites reduce the number of antenna required by combining transmit and receive antenna ports onto a single antenna. Each base station includes two antenna ports, one for the transmitter and a second for the receiver. At radio sites where multiple base stations operating in the same band are present, an antenna combining system is employed. The combining system has two components: a transmit combiner and a receiver multi-coupler. The base station transmit antenna port is connected to the transmit combiner and the receive antenna port is connected to the receiver multi-coupler. The receive multi-coupler is then attached to a single antenna on the tower. This antenna serves all the base stations in the trunked site. The base station transmit antenna port is connected to the transmit combiner and the combiner is connected to a single antenna on the tower. In this way, a trunked site with 10 base stations can be deployed with only two antennas on the tower. The specific frequencies deployed at the site may require more than one transmit combiner for proper filtering and interference reduction. At most simulcast analog sites in the MSP system, two transmit combiners are required resulting in three antenna on the tower (two transmit antennas and one receive antenna).

MSP is seeking frequencies in the 700 MHz band for the new P25 system. MSP has requested frequencies in the 700 MHz band that will allow the use of a single transmit combiner and a single receive multi-coupler. This will minimize the number of antennas required and the resulting loading on selected towers. New antenna models are available that will allow both 700 and 800 MHz systems to share the same antenna systems. The Metro Boston 700 MHz P25 digital system employs this antenna configuration to minimize the number of antenna needed to support the 800 MHz analog system and 700 MHz digital system at shared tower sites.

observation

EOPSS should consider acquiring new antenna models that support broadcasting off both 700 and 800 MHz from the same antenna, minimizing the number of antennas needed for planned coverage.

Emergency Power

Every network site is equipped with emergency power systems that activate in the event of loss of commercial power. Emergency power systems consist of an emergency generator and an Uninterruptable Power Supply (UPS) or 48 Volt (VDC) battery systems. The UPS and 48 VDC battery systems bridge the momentary gap in time between loss of commercial power and generator start up. Generally on CoMIRS, the more modern digital radio sites utilize 48 VDC battery systems and the older analog radio sites are equipped with UPS systems.

The MSP inventory of generators includes 64 MSP owned generators across its analog and digital networks. The inventory does not identify fuel systems used at each site or the age of each generator. With proper maintenance, a high quality generator should last indefinitely. All MSP owned generators are regularly serviced under the radio system maintenance contract. Generator alarm points are monitored through the network alarm system so faults are detected remotely and passed to appropriate personnel at MSP and its service vendor, Motorola.

Generators used at MSP sites use either diesel or propane fuel supplies. Since many of the MSP radio sites are accessed by unimproved roads, it is difficult to resupply propane tanks. For this reason, diesel fuel systems are preferred. Diesel fuel can be delivered to the most remote radio sites in a number of ways, including off road vehicles owned by MSP when required.

Generators are used in both indoor and outdoor configurations. At many of the most remote western Massachusetts radio sites, generators are housed in a generator room inside the site shelter to protect the generator from the environment, including deep snow conditions. At most other radio sites, generators are housed in outdoor housings near the site shelter. Indoor generator mounting is preferred to extend the service life of the equipment. Building codes and space availability within the site compound in most cases will dictate the configuration and placement of the shelter, generator, and generator fuel supply.

Battery systems and associated electronics racks are mounted inside the site shelter. Early battery system configurations included two independent systems:

- 24 Volt DC systems for microwave radios, usually mounted in a single rack, and
- 110 Volt AC UPS system for radio equipment and site controllers, usually mounted in two cabinets.

Newer radio equipment including the P25 digital system in western Massachusetts, uses 48 VDC power rather than 110 Volt AC power. This allows consolidation of emergency battery power systems into a single 48 VDC power system for the site. All system components, including microwave radio, use the same battery system, which is all contained in a single rack. This configuration reduces the maintenance effort and saves valuable floor space in the site shelter. This conservation of available space will be critical at sites that need to support both analog and digital radio systems.

observation

48 VDC battery systems can be deployed on all P25 digital sites to power all site equipment. These battery systems are smaller and more efficient than UPS systems.

Figure 2-31 shows the distribution of the 82 sites between 48 VDC and 110 VDC within CoMIRS.

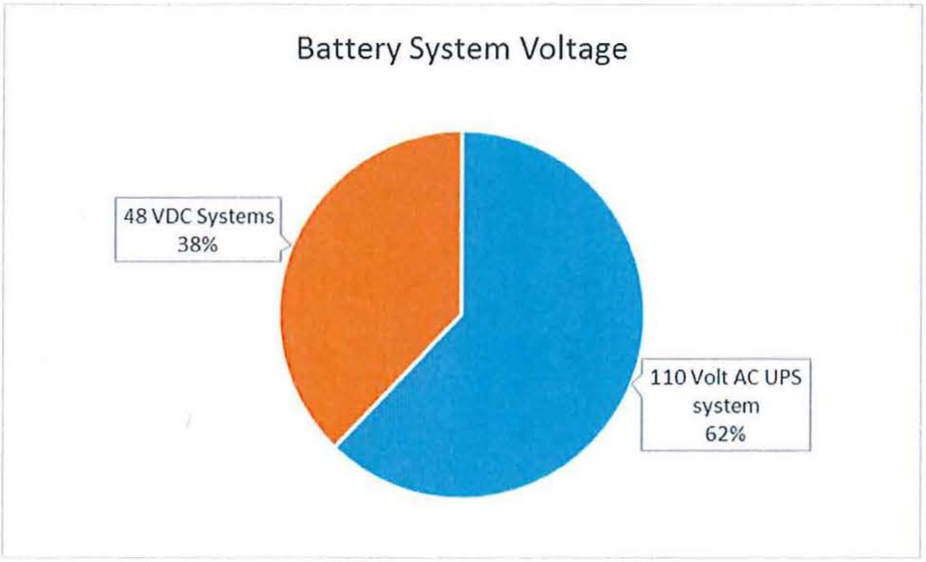


Figure 2-31: Battery System Voltage

UPS and battery system alarm points are monitored through the network alarm system so faults are detected remotely and passed to appropriate personnel at MSP and Motorola.

2.2.2.2 Backhaul Equipment

System backhaul connects the various radio sites into logical radio subsystems and connects radio subsystems and dispatch consoles to the CoMIRS Core through either Zone 1 or Zone 2. Without backhaul, each of the radio sites is disconnected from the network and all of the users connecting to that radio site are cut off from voice communications. In total, there are nearly 200 backhaul connections supporting the analog and P25 portions of the CoMIRS network. Network backhaul consists of:

- 90 connections deployed with wireless microwave radio point to point systems from seven different vendors
- 108 connections deployed with wired connections sourced through private fiber optic cable, commercial Ethernet providers, or Verizon

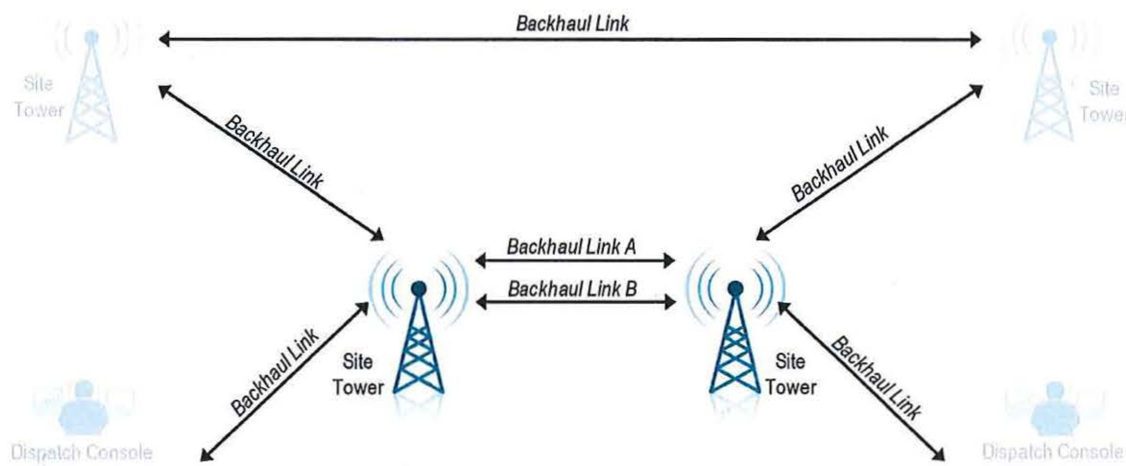


Figure 2-32: Backhaul Equipment

Figure 2-33 details the various uses of the backhaul equipment across CoMIRS. Backhaul connections are designed as circuit switched or packet switched Ethernet protocols. Generally speaking, older connections are circuit switched and newer connections are packet switched.

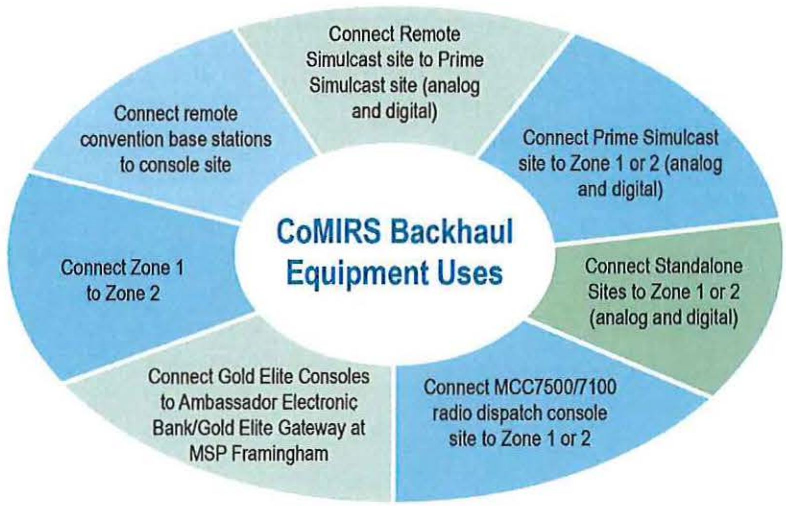


Figure 2-33: CoMIRS Backhaul Uses

Circuit-Switched Backhaul

Circuit-switched backhaul require a single dedicated circuit for each base station or audio path in the system. Each circuit is used only for the base station or audio path it is assigned, even if it is not in use. A trunked radio site with five channels, therefore, requires five audio paths through the backhaul even if there are no radio calls taking place at the site.

Circuit-switched backhaul within CoMIRS is formatted in two ways:

- DS-1 service is a point-to-point, full-duplex, digital private line T1 service. The T1 is broken down into 24 individual circuits through a channel bank. T1 service is used where multiple circuits are required between two points (e.g., from a trunked site to a Zone Controller)
- Tie Line (TL) service is a point-to-point, full-duplex, single private line service. TL circuits are utilized in the system where single remote base stations are controlled from a console site (e.g., Huntington Fire Base Station to Northampton RECC console site)

Verizon is the supplier for all wired T1 and TL circuits in use on CoMIRS. Some CoMIRS stakeholders have reported that Verizon is moving away from support for these services, but to date no official announcement has been made by the vendor.

In packet switched systems, all messages are converted to data, broken down into small packets, and routed through the network based on destination addresses. Using packet switching, the same connection can be shared by multiple users much more efficiently and using less bandwidth.

Modern communications systems are all moving toward packet switched systems and CoMIRS is no exception. METRO Boston, Cambridge, Worcester, and DOC P25 trunked systems are all deployed using packet switched backhaul. Massport is converting from circuit switched to packet switched backhaul, and most new MCC7500/7100 consoles are using packet switched backhaul.

observation

CoMIRS is still a circuit switched network. Circuit switching will soon be unsupported by the CoMIRS operating software. Several CoMIRS partners have already moved to packet switched backhaul.

All MSP trunked systems are using circuit switched backhaul. Motorola has notified MSP that System Release 7.18 is the last system release that will support circuit switched backhaul.

Figure 2-34 below shows the types of circuits currently in use on CoMIRS.

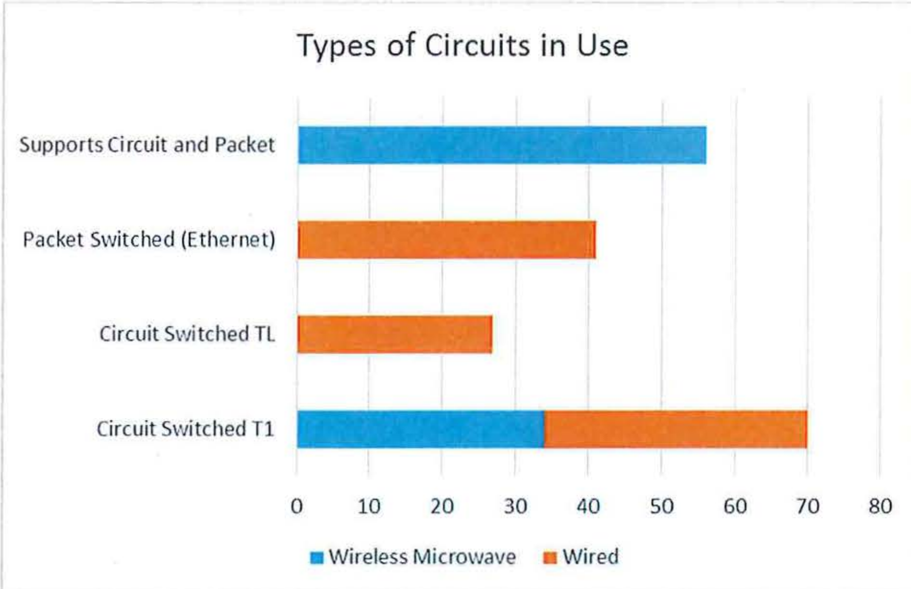


Figure 2-34: Types of Circuits

Microwave Link Backhaul

The MSP trunked radio subsystems utilize 84 microwave backhaul links. Twenty-three of these links are 16 years of age or older. Table 2-7 below summarizes the microwave links in use by the MSP trunked radio subsystems and the age in years of these backhaul links.

MSP Trunked Microwave Links (Count)	Age in Years
Telesciences systems (7)	22 years
Microwave Network Inc. systems (13)	19-22 years
California Microwave system (1)	22 years
GE MDS systems (3)	16 years
Harris Constellation systems (9)	11 years
Harris True Point systems (2)	8 years
Aviat (formerly Harris) systems (37)	4-5 years
Cambium systems (12)	2-4 years

Table 2-7: Type, Count, and Age of CoMIRS Microwave Links

All Telesciences, Microwave Networks Inc. and California Microwave systems are beyond the manufacturers support period, so parts availability and board repair is being performed on a "best effort" basis by the MSP maintenance contractor, Motorola.

Oxford Fire Tower: Three of the Microwave Networks Inc. systems in central Massachusetts are experiencing regular outages due to path obstructions caused by tree growth. The fire tower in Oxford used to support the microwave and radio antennas is only 65' high, which is not high enough to overcome tree growth. Oxford is a microwave hub for radio sites at Charlton, Mendon, and Worcester. To overcome these path issues, either a new higher tower (180') must be constructed at Oxford or the site must be relocated to a new site with a higher tower. The State Police have identified an alternate commercial tower site in Webster that could replace the Oxford site. Failure to address this backhaul issue can affect CoMIRS users throughout central Massachusetts and Fire District 7 and risks the loss of wide area communications.

observation

CoMIRS relies heavily on wireless microwave point-to-point links for its backhaul communications. Many of these links are beyond manufacturer support and others have obstructed paths.

Southeastern Massachusetts Communications: Similarly, there are existing backhaul communications issues involving three microwave links in use in southeastern Massachusetts. These old microwave links support the analog system through the radio towers at Pine Hill (Plymouth),