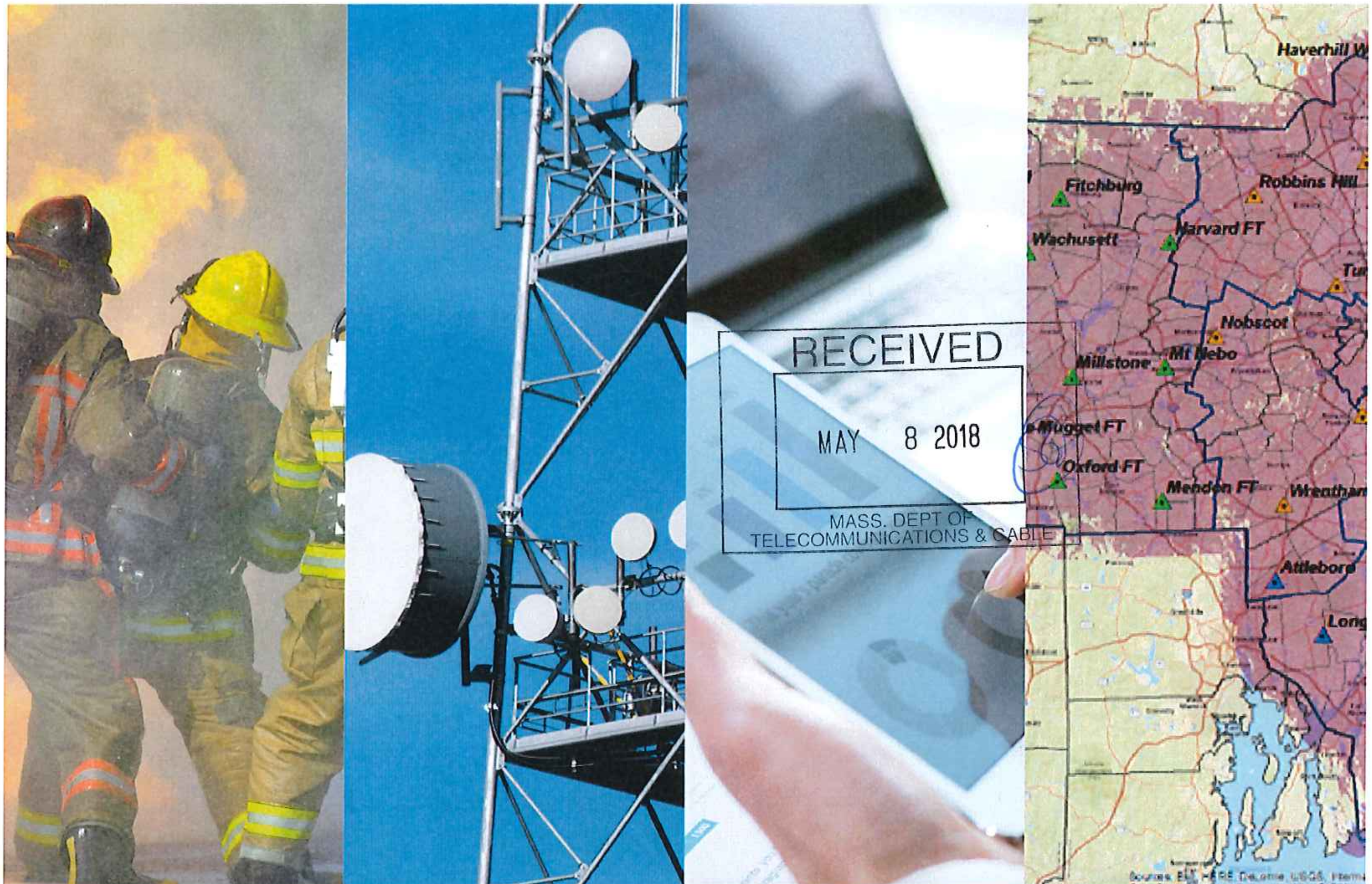


Commonwealth of Massachusetts Interoperable Radio System (CoMIRS)

4 Future Vision

May 2017

EOPSS DRAFT

Table of Contents

TABLE OF FIGURES

TABLE OF TABLES

This section of the Strategy Report is largely unchanged from the version submitted by the Radio Strategy Team as part of the strategic planning project. The future vision for the network should be revisited and this section revised after key decisions on funding, usage, and governance are made. This section should be read understanding those considerations.

4 FUTURE VISION

The purpose of this section is to outline a potential recommended Future State or "To Be" Model of the Commonwealth of Massachusetts Interoperable Radio System (CoMIRS) that will address current and future first responder communication requirements. This Future State Vision was developed via a requirements-prioritization approach, evaluation of the current network posture, and a predictive traffic model.

4.1 Introduction

The following Future State vision is recommended for the Commonwealth of Massachusetts. The Future State is defined by three areas of prioritization (see Figure 1), further elaboration and details on which are detailed in the subsequent sections:

Future Vision Phase 1: Immediate Needs

Future Vision Phase 2: Other Agency Adoption

Future Vision Phase 3: Regional and T-Band Alternative

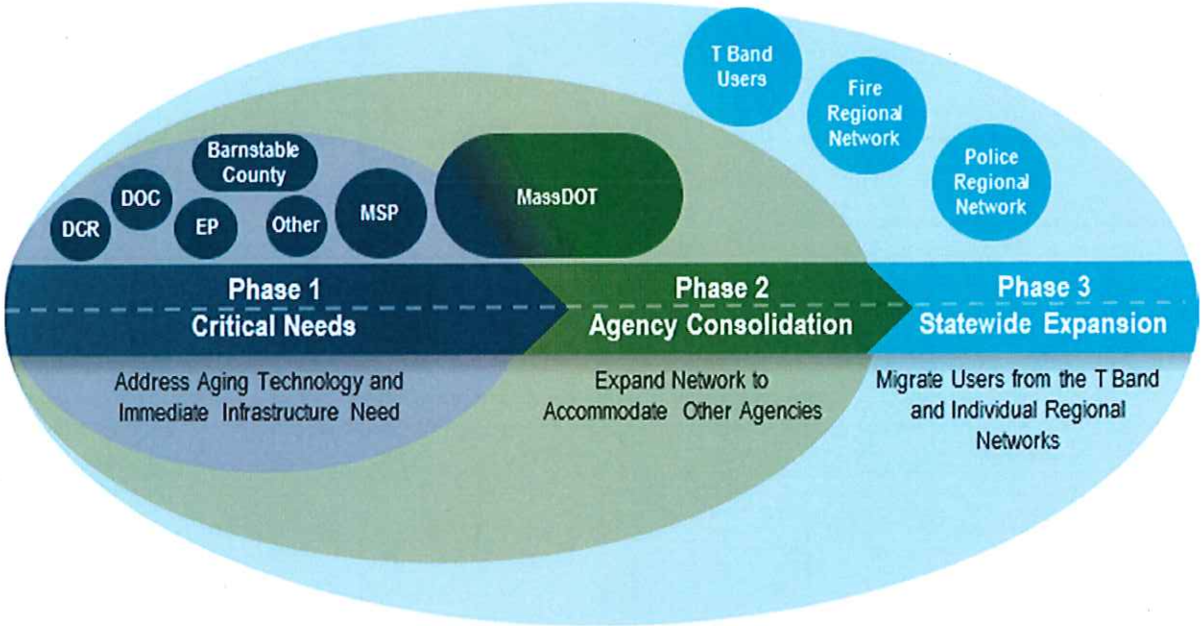


Figure 4-1: Three Potential Phases of the Commonwealth Future State Radio Network

This Recommended Future State addresses multiple upgrades and requirements including; immediate critical needs, additional user voice traffic loads for new users, incorporation of new agencies, and a more comprehensive interoperable communications capability for the Commonwealth's first responder communities.

Future Vision One: **Critical Need**. Replaces obsolete technology, addresses the immediate needs of the current user base of the public safety radio network, and migrates to a P25 digital system. This phase represents the bare minimum improvements required of the CoMIRS. These upgrades are absolutely needed in the near term.

Future Vision Two: **Agency Consolidation**. Begins to consolidate the separate networks within the state by fully incorporating other statewide networks' infrastructure, funding, and remaining users into a single statewide network. Consolidation introduces and establishes operational and fiscal efficiencies (and is effectively cheaper) across state agencies that utilize the same technologies but reside on separately funded and managed radio networks.

Future Vision Three: **Regional and T-Band Alternative**. Addresses the inherent limitations and constraints of radio spectrum availability in the Commonwealth and the public safety ramifications of the planned loss of the T-Band communications channels. In the next five years, first responders across the Commonwealth will lose access to the T-Band spectrum that are to be auctioned off by the federal government. Many municipalities will be left with few options to provide emergency communications at the necessary level of service. This phase also considers a single statewide interoperable radio network to address the future communication requirements of the Commonwealth.

A predictive traffic modeling approach (predictive traffic modeling assumes a targeted grade of service can be achieved by a certain number of RF (Radio Frequency) talk paths supporting a certain amount of voice traffic presented to the system during a defined length of time). This approach has been used to address the new technological innovations and the incorporation of enhanced geographic coverage, municipalities, and user communities. Additional information about this predictive traffic modeling approach is found later in this section.

4.2 Future Vision One: Critical Need

This section outlines the first phase within the Future State Vision, moving current users of the CoMIRS radio network including – Department of State Police (MSP), Environmental Police (EP), Department of Corrections (DOC), Department of Conservation and Recreation DCR), Massachusetts Emergency Management Agency (MEMA), Department of Fire Services (DFS) and others from the current mixed analog/digital system to a full P25 digital architecture. Future Vision One replaces obsolete technology, addresses the immediate needs of the current user base of the public safety radio network, and assures mission-critical voice communications. The current state architecture addresses seven key infrastructure recommendations to implement the immediate needs of CoMIRS. Please refer to the "Current State" section of this document for further information.

4.2.1 Users

Future Vision One of the CoMIRS addresses the immediate concerns for the current user base of the existing radio network. Specifically, the users require uninterrupted communications to respond to daily and emergency communications needs throughout the state on the MSP radio network. The existing users of the current MSP radio network include EOPSS-based agencies as well as a mix of other state agencies and regional/local users.

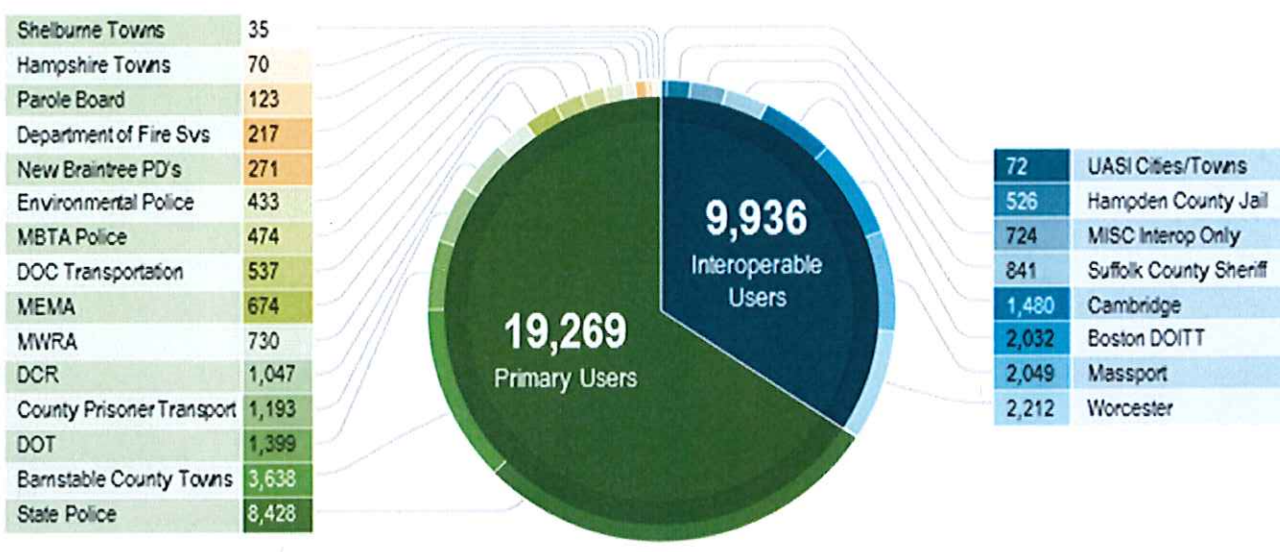


Figure 4-2 - User Base by Agency

The current network has an operating area that spans the entire state, with almost 25,000 radio subscribers. Figure 2 shows the estimated numbers of subscribers by agency currently using the MSP radio network. Many of these users are also relying on soon to be retired analog equipment. Analog systems are being replaced nationwide by advanced P25 digital systems.

In order to efficiently move to the P25 digital standard, Future Vision One focuses on users who currently use the MSP network daily. Across the state users currently rely on a digital component in Western Mass (MSP Troop B) and in the Boston Area (the Metro Overlay) while the remainder of the state is analog. There are approximately 16,000 analog radio users across the Commonwealth network. These analog-only radios will need to be replaced as the network is upgraded.

Currently, some users have the ability to span both digital and analog areas, using newer subscriber radios providing connectivity to both architectures. However, the majority of analog network users cannot cross into the digital area without physically switching to different radios.

Figure 3 below illustrates the current existing sites and the proposed additional sites required to upgrade the CoMIRS to a P25 digital network. The green dots represent current P25 digital network sites/components within the network, whereas the red dots illustrate where the outdated analog sites/components will be upgraded to a P25 digital network.

4.2.2 Technology

There are two basic types of radio networks, analog and digital. Analog radio networks have been in use for decades and the technology has become obsolete in many first responder communities. In comparison to digital radios, analog radios do not provide any encryption capabilities on the voice network. All conversations are unencrypted and can be heard by anyone tuned into the channel.

Digital systems have far more capabilities as compared to analog system:

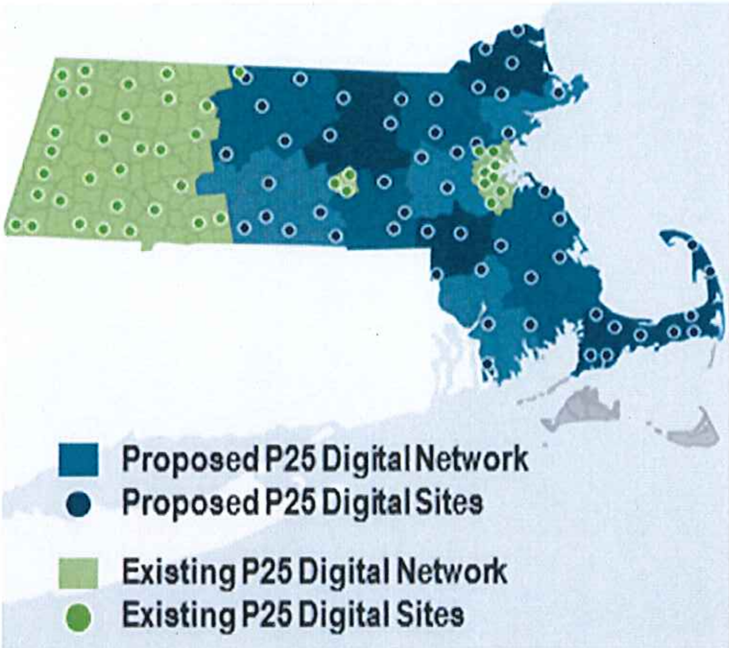


Figure 4-3 - Proposed P25 Digital Network Sites

Increased capacity through improved band usage - The Time Division Multiple Access (TDMA) technology provides two talk paths per frequency pair, effectively doubling the capacity for each 12.5 kHz wide frequency pair licensed by the FCC. In addition, the move to a digital TDMA system also conforms to FCC mandates of 6.25 kHz bandwidth talk paths. Analog systems are noncompliant with this mandate.

Improved voice quality - Current digital voice algorithms use forward error correction (FEC) which both increase range and maintain high quality voice by intelligently decoding severely faded receiver RF levels. Analog radios exhibit receive noise and severely degraded voice quality long before digital radios.

Remote radio management – Due to the digital nature of the voice traffic and total subscriber control via the control channel, data can be interleaved with subscriber channel assignment commands. This data can do things such as - control when a subscriber Push-To-Talk (PTT) is permitted by the system, change encryption keys, change the radio configuration, enable and disable individual radios, etc. Analog radios are unable to perform any of these functions.

Text messaging - Text messaging is a digital service and can only be enabled on a digital radio system.

Call privacy through encryption - Encryption is a technique where digital voice packet bits are scrambled per a numerical key and decoded at its destination via a numerical key. Digital systems leverage encryption standards such as Advanced Encryption Standard (AES) to ensure the highest level of encryption. Analog systems do not support this encryption.

Improved range - A transition from analog to digital system normally allows a 6 dB increase in link budget performance for the same occupied bandwidth of the modulated RF signal due to FEC techniques.

P25 digital is the industry standard replacement for obsolete analog technology. Digital has some of the same capabilities as cellular phones such as text messaging, privacy, and increased reliability. Digital systems have been engineered to also use the new 700 MHz spectrum. Unlike analog systems, which transmit only voice, digital transmissions can also relay data thus enabling multiple modes of communication.

Recommendation FV1-T1: Adopt TDMA as the future digital architecture for CoMIRS

TDMA architecture is preferred over FDMA. TDMA has many more voice and data channel options than FDMA, resulting in much better call capacity

In moving to a P25 network, the Commonwealth must determine whether it should invest in Frequency Division Multiple Access (FDMA) or Time Division Multiple Access (TDMA) architecture.

TDMA uses the full 12.5 kHz channel and splits it into two time slots supporting two simultaneous messages. By splitting the band, more users can transmit on one channel, sending and receiving messages in succession based on time. Moving directly to Future Vision Two reliably supports more users and allows the Commonwealth to handle comfortably future call volumes.

Recommendation FV1-T2: Organize the P25 TDMA Deployment in Regional Simulcasts

The P25 digital deployment should be organized in smaller regional simulcast so system resources can be assigned based on operational requirements. This means that network resources can be allocated more efficiently and the network can accommodate more users.

The existing analog infrastructure relies heavily on four large simulcast systems to provide radio coverage over large geographic areas. This topology promotes inefficient use of the network because service can only be assigned to users within these large cells. For example, a user with an Essex

County jurisdiction must be assigned service on a simulcast cell that covers the geographic area spanning from the New Hampshire and Rhode Island borders. With this smaller cell design, the Essex County user referenced in the earlier example could be assigned resources only in the required cell, and not reserve unneeded resources in adjoining cells.

The concept presented here is analogous to cellular systems where reducing the coverage areas of cell sites allows for additional cell sites to address system capacity thus avoiding overloading a particular cell site. With smaller coverage areas, the system can efficiently leverage frequency reuse within the same geographical area thus addressing the communications needs of a community without impacting the adjacent community users. The system does not bring resources on the air in areas where it is not required for user community communication. TDMA, by its nature, provides enough talk paths per frequency pair to enable this concept.

The Future State Vision One model output based on user distribution traffic model and its migration to a TDMA P25 digital network is shown in Table 1 below. This model was developed from current system reports (GenWatch) and has a new topology with additional site resources. This model includes a 20% increase in capacity to accommodate additional talkgroups.

Site Name	Number of Talkpaths	Probability a Call Will be Queued (GoS)	Probability a Call Will not be Queued	Average Delay (Seconds)
1021 P25 Vent 1	4	167.58%	-67.58%	9.64
1024 P25 B North	5	0.97%	99.03%	0.03
1025 P25 B South	5	0.23%	99.77%	0.01
1026 P25 Mt Grace	4	1.41%	98.59%	0.04
1027 P25 Wilbraham	4	1.41%	98.59%	0.04
1028 P25 Stockbridge	4	1.41%	98.59%	0.04
1029 P25 Williamsburg	4	1.41%	98.59%	0.04
1030 P25 Greylock HS	4	1.41%	98.59%	0.04
1031 P25 Sandisfield	4	1.41%	98.59%	0.04
1032 P25 Tolland	4	4.42%	95.58%	0.15
1033 P25 Chester Rte. 20	4	1.41%	98.59%	0.04
1035 P25 Massport	144	0.00%	100.00%	0.00
1036 P25 Worcester	13	0.00%	100.00%	0.00
1038 P25 Essexx North	10	0.00%	100.00%	0.00
1039 P25 Essex South	10	0.00%	100.00%	0.00
1040 P25 Middlesex	10	0.01%	99.99%	0.00
1041 P25 Norfolk	10	0.00%	100.00%	0.00
1042 P25 Bristol	10	0.00%	100.00%	0.00
1043 P25 Plymouth	10	0.32%	99.68%	0.01
1044 P25 Barnmstable	12	0.63%	99.37%	0.02
1045 P25 Worcester NW	10	0.00%	100.00%	0.00
1046 P25 Worcester SW	10	0.00%	100.00%	0.00
1047 P25 Worcester NE	10	0.00%	100.00%	0.00
1048 P25 Worcester SE	10	0.00%	100.00%	0.00
1070 P25 HCJ	4	0.09%	99.91%	0.00
1071 P25 DOC Norfolk	4			
2001 P25 Cambridge	11	0.00%	100.00%	0.00
2002 P25 Metro Boston	15	0.02%	99.98%	0.00

Increase in traffic by 20% affects the GoS for eight highlighted sights on the radio network.

Table 1 - Future Vision One Traffic Model

The Commonwealth must determine the level of coverage required for the new P25 digital systems. The digital system in western Massachusetts is designed to provide coverage for mobile radios throughout the service area. The analog systems provide fairly reliable mobile coverage although some areas need improvement in the new deployment. Portable coverage on the analog system is simply determined by the proximity of the user to the nearest radio site as demonstrated in the coverage prediction maps provided by Motorola.

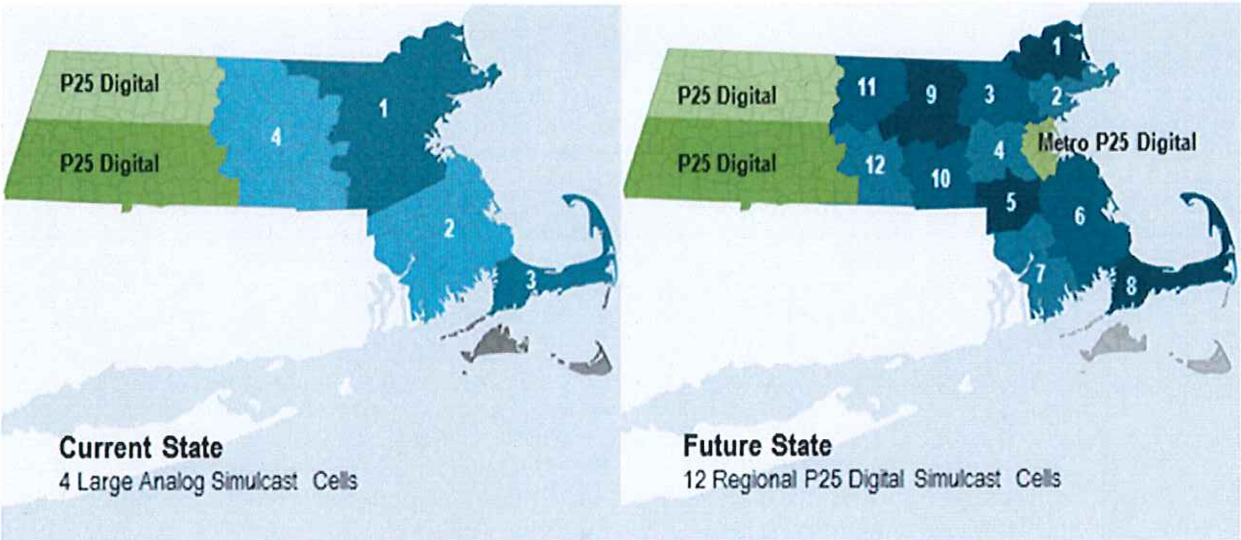


Figure 4-4: Comparison of Analog vs Digital Simulcast Cells

As previously stated, the analog portion of the existing MSP radio network is comprised mainly of 4 large simulcast cells. These cells vary in capacity:

- Troop A/H simulcast – 9 voice paths
- Troop D simulcast – 7 voice paths
- Troop C simulcast – 7 voice paths
- Barnstable simulcast – 10 voice paths

A large percentage of radio calls on the system require channel assignments on more than one of these systems to reach all members of the talkgroup. If a user is on a talkgroup that spans multiple simulcast sites in a given geography, anytime that user listens on that talkgroup he occupies a channel on each site, hence reducing the overall capacity of the system.

The Minnesota, Michigan, Colorado and Ohio systems referenced in the Market Assessment section of this report reflect the geographic and demographic characteristics of those states (large rural landmasses with comparatively lower population densities) and were designed for mobile coverage throughout the state with portable coverage in certain urban areas.

Recommendation FV1-T3: Configure Cells with Consistent Voice Paths

The inconsistent number of available voice paths across the systems causes queuing in some cases. This queuing will be minimized with consistent capacity across all the simulcast cells in the new P25 deployment, minimizing communications delays.

To maintain consistent capacity across the network, each digital simulcast cell should have at least 10 available talk paths. The number of talk paths was predicated by a reasonable interpretation of the grade of service models. They are also driven by the incremental increase of equipment. One equipment rack services 6 channels. It is better to estimate based on what is needed with one rack of equipment rather than two, considering the impact on things such as floor space, HVAC, power, cost, etc.

If TDMA is deployed, this means 6 discrete channels will be required for each simulcast cell. If FDMA is deployed, 11 discrete channels are required for each cell. Simulcast channel requirement numbers are predicated by Grade of Service models. Simulcast channel requirement numbers are predicated by the Grade of Service models. TDMA provides for a more effective usage of simulcast channels, which correlates to a more efficient usage of radio equipment. TDMA requires approximately half the equipment rack space to provide the same 10 voice paths per simulcast cell than the comparable FDMA simulcast cell.

Spectrum Constraint

Additonal 700 or 800 mhz spectrum is required to migrate from analog to digital.

The analog network presently utilizes spectrum in the 800 MHz band. A new 700 MHz band is presently available for use by digital radio systems that meet the Federal spectrum efficiency requirements. There are currently 12 state licenses for this 700 MHz band, including the interoperable Metro Boston simulcast cell. The Metro Boston digital simulcast cell (frequently referred to as the "Metro Overlay") essentially duplicates the coverage of the interoperable analog system. The digital system overlays the analog system to give users time to migrate old analog radios to new digital radios over a period of years. When all users have migrated to the new digital system, the analog system will be decommissioned.

TOP 13 URBAN AREAS

- Boston
- Worcester
- Springfield
- Lowell
- Cambridge
- New Bedford
- Brockton

A similar strategy will be required to migrate the State network from analog to digital. Old analog systems will need to stay in place while replacement digital systems are constructed, tested and populated with users. The analog and digital systems cannot both occupy the same frequencies during this extended cutover period. Digital systems should be constructed on new 700 MHz channels to allow the analog system to continue operation on 800 MHz channels. When the cutover of all existing users is complete, analog systems should be decommissioned and the 800 MHz channels can be used to expand the capacity of the new digital network for additional users, repurposed by another licensee in Massachusetts or returned to the Federal Communications Commission for reassignment. Post decommissioning, the licenses will be terminated and frequencies returned to the FCC for reassignment. If the Commonwealth of Massachusetts decides to reuse the 800MHz channels to expand capacity, the state's licensing department will need to submit a new application and justification to the FCC.

Many of the interoperable P25 systems currently integrated with the network provide reliable P25 digital portable radio coverage in urban areas of the Commonwealth. These systems are managed by the system owners for the benefit of their current subscriber base.

Recommendation FV1-T3: Expand the Subscriber Base by Adding State Network Users

The subscriber base can be expanded to include state network users with appropriate governance agreements and required capacity expansion. Agreements to share these systems would eliminate the need for the state to construct new systems in these areas.

The City of Boston, City of Worcester, City of Cambridge and Mass Port Authority are already integrated with the Commonwealth CORE. Nantucket operates a compatible P25 digital system on the island without a connection to the CORE. These systems currently provide portable radio coverage in 5 of the 13 urban areas of the Commonwealth identified as candidates for portable coverage (Boston, Worcester, Cambridge, Quincy and Somerville).

Recommendation FV1-T4: Improve Mobile Coverage throughout the Commonwealth

The Commonwealth should seek to improve mobile coverage through the new P25 coverage areas and design for portable coverage in the highest population urban areas where demands for portable service are greatest.

To ensure that voice audio quality meets the needs of the first responder community, a Delivered Audio Quality (DAQ) rating of 3.4 should be required throughout the mobile and portable service areas. The Telecommunications Industry Association Bulletin, TIA TSB 88.1-C, cites a DAQ of 3.4 for public safety communications. A DAQ of 3.4 refers to a carrier to noise ratio (C/N) that provides a perceived audio quality that meets public safety requirements. The Commonwealth requires 6 TDMA channels to support the current mix of users for the Future Vision One rollout.

Most Massachusetts stakeholders prefer a portable coverage network over a mobile coverage network but designing for portable coverage across the state would be cost prohibitive due to the requirement for a significant increase in the number of required radio tower sites. Portable networks require a much denser distribution of radio tower sites than mobile networks. Radio networks, like Cellular, are inherently uplink limited and would require more radio sites to provide portable coverage everywhere. The transmit power of a portable radio is much less than the transmit power of a mobile radio.

Recommendation FV1-T5: Establish a 1% Grade of Service

The current Grade of Service (GoS) for the existing State Police radio network is 2%. A GoS of 1% is recommended for a public safety network.

Based on Grade of Service (GoS) analysis conducted on the existing analog system, there is sufficient capacity to support a 2% GoS with the present user base and channel distribution. The 2% GoS standard presently used by the State Police in managing the network would be considered high for a public safety network. A 1% GoS is a better target for a network of this type. In a shared network, a 1% GoS means that no more than 1% of calls are placed in queue waiting for an available channel during the time of busiest system use. The queue of wait time can vary and the State Police consider three seconds or more to be an unacceptable wait time. These queued calls with wait time of more than three seconds are used to calculate the GoS.

Capacity to support additional users can be supplemented either through additional channels or by converting existing channels from Future Vision One FDMA to Future Vision Two TDMA. Conversion to TDMA will provide additional channels thus increasing system capacity, without degradation of GoS. Both Boston and Worcester currently utilize both formats.

4.3 Future Vision Two: Agency Consolidation

This section outlines the second phase within the Future State Vision, to be built upon the completed first phase, by incorporating additional state agencies and their users onto the P25 digital radio network. The major addition of new users during this phase will be from the Massachusetts Department of Transportation (MassDOT).

Incorporation and consolidation introduces and establishes efficiencies across state agencies that utilize the same technologies but reside on separately funded and managed radio networks. Candidates for system consolidation include; Master, Prime, and Remote Sites, Shelters, Backhaul Facilities, Radio Frequencies, Equipment Spares, and Maintenance Contracts. This will result in cost saving via network efficiencies, as well as streamline funding and acquisition costs. The goal of this phase is to achieve economies of scale for radio communications across Commonwealth agencies and save money on on-going maintenance and other costs.

4.3.1 Users

Future Vision Two offers opportunities for significant efficiency and cost-saving for the Commonwealth. Like EOPSS, MassDOT is a statewide agency that currently uses and depends upon radio communications for daily operations, emergency response, and public safety. MassDOT has thousands of users traveling across the state. MassDOT includes 4 agencies within the department: Highway, Transit (MBTA), Registry of Motor Vehicles (RMV), and Aeronautics. Specific attention was focused on Highway and MBTA as they have the bulk of the potential users to include in the CoMIRS.

Currently, MassDOT region 6 regularly operates on the CoMIRS, with 1869 active users on the network. Upgrading the CoMIRS to P25 provides the Highway department with an opportunity to bring all users onto a single cohesive network.

The MBTA operates bus, subway, commuter rail, and ferries within the Boston Metro area, carrying over 1.3 million riders a week.

With thousands of radio subscribers currently in use in the Boston area, additional radio network capacity will be necessary should MBTA use COMIRs. Refer to user distribution in figure 7 below.

MBTA dispatches to all their subscribers on a more frequent basis then most of the current users on the system. They will continue to operate in the same fashion should they join the Commonwealth network, as their needs are different then dispatching first responders.

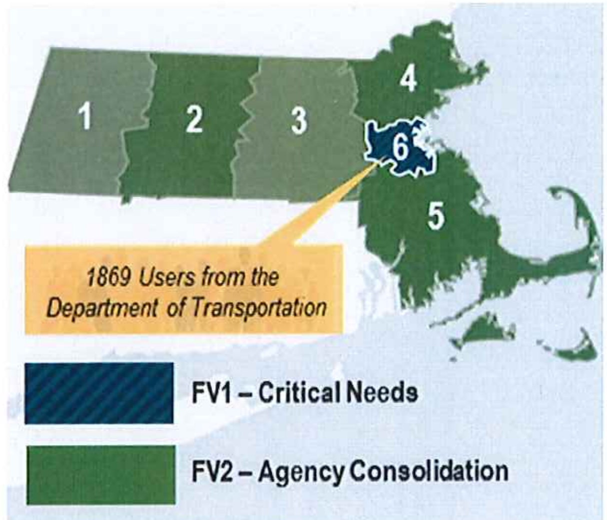


Figure 4-5: MassDOT Regions

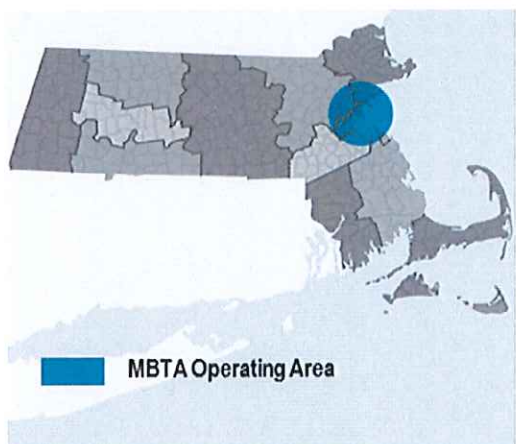


Figure 4-6: MBTA Operating Area

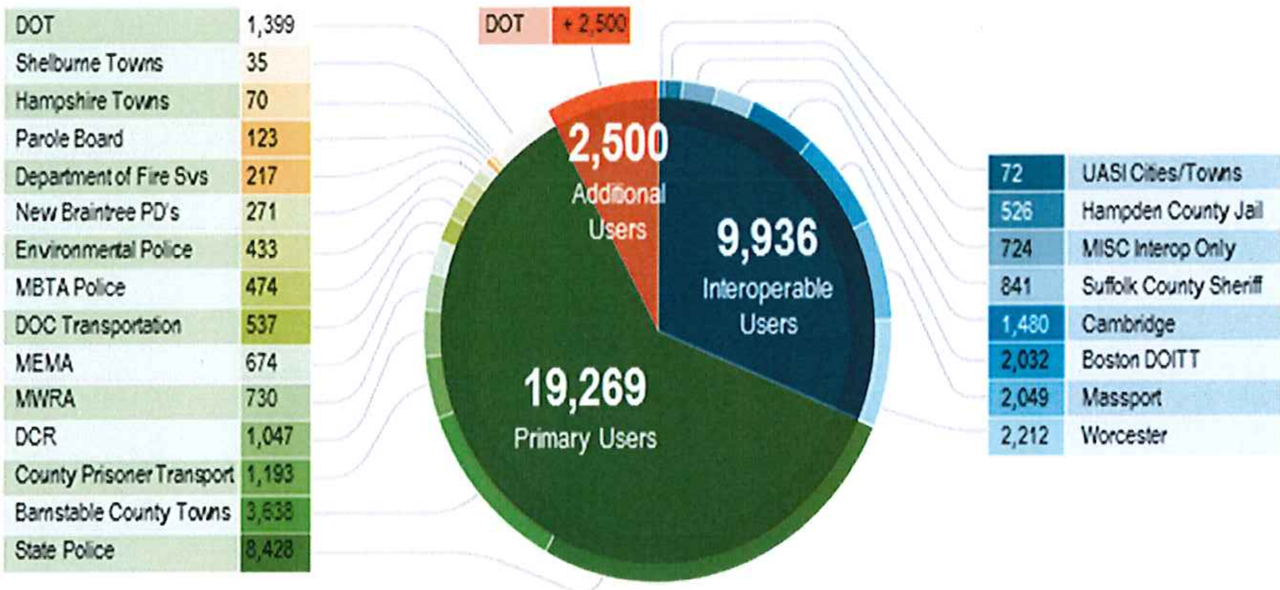


Figure 4-7: Future Vision Two User Count by Agency

4.3.2 Technology

The Future Vision Two model output based on user distribution and migration to P25 digital network is outlined below. This model uses the Future Vision One traffic as the baseline and increases the traffic loading by adding additional MassDOT traffic on the system. With the increase in user traffic, the P25 TDMA architecture will be required to provide the additional bandwidth.

The traffic model for Future Vision Two accounts for all the inputs for Future Vision One plus the additional MassDOT user distribution, their operating area, subscriber counts and other requirements to determine the overall load on the current system.

Site Name	Number of Talkpaths	Probability a Call Will be Queued (GoS)	Probability a Call Will not be Queued	Average Delay (Seconds)
1021 P25 Vent 1	4	168%	-68%	9.64
1024 P25 B North	9	0%	100%	0.01
1025 P25 B South	8	1%	99%	0.02
1026 P25 Mt Grace	8	1%	99%	0.02
1027 P25 Wilbraham	8	1%	99%	0.02
1028 P25 Stockbridge	6	1%	99%	0.03
1029 P25 Williamsburg	6	1%	99%	0.03
1030 P25 Greylock HS	6	1%	99%	0.03
1031 P25 Sandisfield	6	1%	99%	0.03
1032 P25 Tolland	7	1%	99%	0.02
1033 P25 Chester Rte. 20	6	1%	99%	0.03
1035 P25 Massport	14	0%	100%	0.00
1036 P25 Worcester	13	0%	100%	0.00
1038 P25 Essexx North	10	0%	100%	0.00
1039 P25 Essex South	10	0%	100%	0.00
1040 P25 Middlesex	10	1%	99%	0.02
1041 P25 Norfolk	10	0%	100%	0.00
1042 P25 Bristol	10	0%	100%	0.00
1043 P25 Plymouth	11	1%	99%	0.01
1044 P25 Barnmstable	13	1%	99%	0.02
1045 P25 Worcester NW	10	0%	100%	0.00
1046 P25 Worcester SW	10	0%	100%	0.00
1047 P25 Worcester NE	10	0%	100%	0.00
1048 P25 Worcester SE	10	0%	100%	0.00
1070 P25 HCJ	4	0%	100%	0.00
1071 P25 DOC Norfolk	4			
2001 P25 Cambridge	11	0%	100%	0.00
2002 P25 Metro Boston	15	0%	100%	0.00

Proposed New P25 digital sites (10) to address the Future traffic needs of the system. The new sites are 1038 to 1048 within this table

Table 4-1: Future Vision Phase Two Traffic Model

There are 10 new digital sites proposed to support the Future Vision One and Future Vision Two. The model, shown above, identifies the system capacity and the traffic loading placed on the individual sites. The model helps to identify the over-loaded system components. In addition, the model shows that the new sites (1038-1048 in the table above) can accommodate the expected traffic increase with a GoS of 1%.

Recommendation FV2-T1: Implement Highway Tunnel Coverage

Highway Tunnel Coverage can be addressed by the 700 MHz overlay, and by the DOT 700 MHz radios. This eliminates the need to spend money on new infrastructure.

Primary Highway Tunnel Coverage is accomplished using a distributed antenna system (DAS) supplied and maintained by MassDOT. The DAS currently operates with the 800 MHz analog network. It should be modified to operate with the 700 MHz Digital Metro Boston system bringing digital coverage into the tunnel network. The DAS serves all system users.

Recommendation FV2-T2: Incorporation of Other Spectrum

Reuse 800 MHz spectrum licensed to the Commonwealth for analog systems operation.

The existing CoMIRS analog systems all operate in the 800 MHz band. This band is contiguous with the 700 MHz band proposed for use in the new P25 digital system. During the build-out of the digital system, the analog system must remain in place while existing users "cutover" to the new system. During the buildout of the digital system, analog channels can be decommissioned over time as users convert to digital radios. The Commonwealth should begin the planning process to incorporate the decommissioned 800 MHz channels into the digital system for additional capacity that will be required in Future Vision 3 when more regional and local users join the network.

The Commonwealth holds over 60 800 MHz FCC licenses to support the CoMIRS. There are at least 90 800 MHz frequencies in eastern Massachusetts included in these licenses. In addition, the MBTA holds an FCC license for 20 800 MHz frequencies to support their existing 800 MHz analog trunked system. This 800 MHz spectrum resource is extremely important to the long-term viability of an expanded CoMIRS and planning for its deployment in Future Vision 3 is an important step.

4.4 Future Vision Three: Regional and T-Band Alternative

This section outlines steps within the Future State Vision Three. It covers the potential incorporation of users migrating from T-band and the incorporation of additional regional networks onto the P25 digital radio network. The proposed architecture shall support the capacity, coverage and spectrum requirements based on the anticipated increase in user traffic long-term.

Future Vision Three incorporates the Future Vision One and Two enhancements, and adds T-Band users, and other user groups from individual regional networks. These additional subscriber counts and other requirements are used to determine the overall load on the system.

Current Federal Communication Commission (FCC) rules require that T-Band users vacate the frequencies they currently use by 2021. This creates a significant technical challenge for T-Band users because the FCC did not identify any replacement spectrum in a similar band for displaced T-Band users. In Massachusetts, T-Band frequencies were available within 50 miles of the center of Boston. As one of the top urban areas in the United States, demand for radio frequencies is very high in the Boston area and finding replacement frequencies will be challenging. T-Band frequencies are used for both the BAPERN Regional Police System and METROFIRE regional systems and by 149 BAPERN member agencies and 34 METROFIRE member agencies.

The Commonwealth is in a unique position to assist the T-Band impacted users with the technical challenges associated with relocating the individual and regional systems. BAPERN and METROFIRE regional system functionality can readily be replaced with the 700 MHz P25 system that is the object of this report. To replace individual systems operated T-Band agencies the Commonwealth can offer two options:

1. Utilize CoMIRS 700 MHz P25 trunked system with individually assigned talkgroups. This report recommends that new P25 systems be designed for statewide mobile radio coverage and "in-street" portable coverage in 13 urban areas within the state. Subject to this coverage standard, individual user agencies could purchase new subscriber radios, join CoMIRS, and share system capacity with other users. The user agency would not require an individual FCC license and CoMIRS would replace BAPERN and METROFIRE regional functionality.

2. Construct private systems with new individually licensed channel(s). The agency would move operations from T-Band to another band, replacing the T-Band fixed network and subscriber radios. While VHF, UHF, 700 or 800 MHz bands could be used for replacement systems, 700 or 800 would be preferable due to frequency availability and compatibility with CoMIRS. In this case, the user agency would use the private system for operational needs and switch to CoMIRS as the regional network. With this option, the user agency has the advantage of designing operational coverage for individual needs.

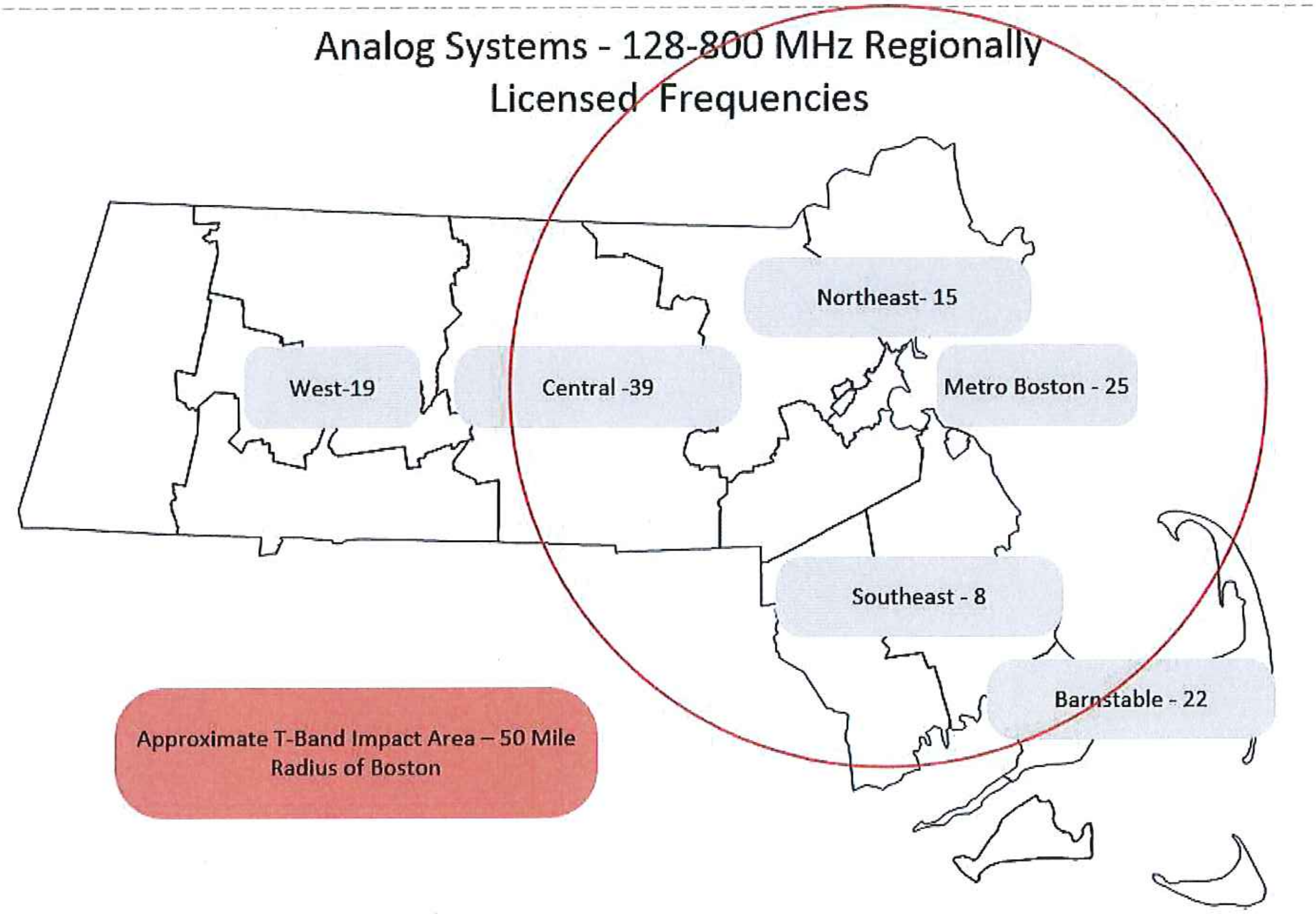
Both these methods are currently deployed within CoMIRS on Barnstable County. Most agencies use CoMIRS for day-to-day operations and regional interoperability. Some agencies (Falmouth PD, Sandwich PD, Bourne PD and Yarmouth PD) operate private 800 MHz systems for day-to-day operations and utilize CoMIRS for regional interoperability.

The new P25 digital systems recommended for deployment in CoMIRS will operate in the 700 MHz band. 700 MHz was chosen because the new system must be constructed as an overlay of the existing 800 MHz analog systems so both systems can be operational until cutover 3-4 years from project start.

The Commonwealth has FCC licenses or interagency agreements for 128 regionally assigned 800 MHz frequencies used in the operation of the analog systems. When the 700 MHz P25 system is fully constructed, these 800 MHz channels can be reallocated to support T-Band users displaced by FCC rules or any other user seeking to join CoMIRS in the future. With sufficient planning time, these frequencies can be used to enhance capacity of CoMIRS or support individual systems operated by individual users.

Planning for reuse of 800 MHz analog system channels should be complete by 2019 – Licensing can take 18 months or more

---



Among the critical issues that will require resolution is the redistribution of state provided funding that is allocated to the various agencies that currently have budgetary responsibility for radios and infrastructure. As the governing body for the network, financial concerns including maintenance, infrastructure purchases, and other expenditures will become critical for the success of the network. The need for subscriber units will continue to be an agency specific requirement, with guidance by the radio governing body to ensure radio purchases are in step with the technology refresh plans of the network.

4.4.1 Users

This section outlines the user composition across the entire state, where any approved Public Safety user can join the network for interoperable communications. As such, the user composition for Phase Three incorporates the user bases of Future Vision One and the additional regional and municipal users discussed below.

Recommendation FV3-T1: Plan for the Incorporation of T-Band Users

By statute, the FCC must reallocate the T-Band spectrum, which is currently used by public safety organizations. By 2021, these current T-Band licensees will no longer have access to those frequencies.

By 2021, the current T-Band licensees will no longer have access to those frequencies and may choose to join the Commonwealth Radio Network. This Spectrum is the narrow banding at VHF, 450-470, 700 MHz that groups using shared systems like BAPERN and METROFIRE, and individual licensees (i.e. Chelsea PD, Chelsea FD) are currently using. The intent is to plan for the potential inclusion and incorporation of these users in Future Vision Three.

These licensees are a large community of users that will require a new mode of communication once T-Band has been reallocated. Within BAPERN, there are over 11,000 police officers with access to the network, covering 2,000 square miles. There are over 130 local police agencies, 17 college police agencies, and 2 hospital police agencies within the BAPERN community. Most of these users do not have the funding or capacity to replace their infrastructure and subscriber units for first responders. The Commonwealth should plan for this possibility now.

Recommendation FV3-T2: Incorporation of Other Licensees

Plan for the potential incorporation of other band licensees using shared systems (WMLEC, Fire Districts, etc.) and other individual licensees are possible users of a statewide network.

In addition to the T-Band users, other band licensees using shared systems (WMLEC, Fire Districts, etc.) and other individual licensees are potential interoperable users of the statewide network. The user base for a statewide radio network could also include community or pubic entities that are currently managing their own communications network.

As was found in the researched states, the interest in a centrally managed statewide public safety network is very high.

Colorado, over 92,000 active subscribers use the network

Michigan, over 75,000 user rely on their system

Minnesota has over 89,000 subscribers

Ohio has over 72,000 subscribers

Each of these systems is open to any locality within the states. In comparison, Massachusetts has about 26,000 current subscribers on the MSP network. Based on the numbers seen in other states, Massachusetts can expect a substantial increase in its user base when the system is offered to users across the Commonwealth.

4.5 Engineering Methodology and Predictive Modeling

This section outlines and details the engineering methodology and resulting predictive modeling utilized to derive our analysis and develop our recommendations. Furthermore, a description and explanation of the tool sets and analytics is provided to confer details into the processes and mechanics behind this evaluation.

A statistical prediction model based on the Poisson[1] distribution of traffic based upon Erlang C [2] was selected due to its long-proven accuracy and its repeatability. This model presents offered load scenarios with predicted Grade of Service (GoS) levels for radio sites as the system topology changes to address new user traffic needs. The number of users and coverage requirements were utilized in the modeling and the resulting solutions were used to identify gaps within the current state of the radio network. Modeling was utilized to properly identify the required technology and level of service required for each phase of the future state.

This modeling effort starts with a "baseline model" reflecting the existing systems offered load based on the system busy hour report from the GenWatch[3] (traffic reporting system), and the existing system topology and capacity. As the future state scenarios progress through Phase Three (outlined in the subsequent section), the statewide radio system was modeled with an appropriate topology, capacity, and user offered traffic load to predict service level performance as user traffic transitions to higher offered loads, including traffic distribution to additional radio sites. This additional traffic with its distribution constraints will drive and validate the technology approach for the highest service levels. In turn, the technology approach will dictate CAPEX obligations, monies used for the physical improvement of the network such as new equipment purchases, and OPEX obligations, monies used in the operations and running of the network, and the user experience and governance model. Figure 2 below illustrates our iterative predictive model

[1] Named after French mathematician Siméon Denis Poisson, a probability density function that is often used as a mathematical model of the number of outcomes obtained in a suitable interval of time and space, that has its mean equal to its variance, that is used as an approximation to the binomial distribution

[2] Erlang C is a traffic modeling formula used in call center scheduling to calculate delays or predict waiting times for callers. Erlang C bases its formula on three factors: the number of reps providing service; the number of callers waiting; and the average amount of time it takes to serve each caller. Erlang C can also calculate the resources that will be needed to keep wait times within the call center's target limits. This method assumes that there are no lost calls or busy signals, and therefore may overestimate the staff that is required.

[3] GenWatch3® empowers system administrators to monitor, manage, and report on Motorola voice and data systems for commercial, private and public safety agencies. One integrated tool pulls together all system-wide data to display real-time activity, send critical notifications, and archive data for forensic reporting and comprehensive analysis

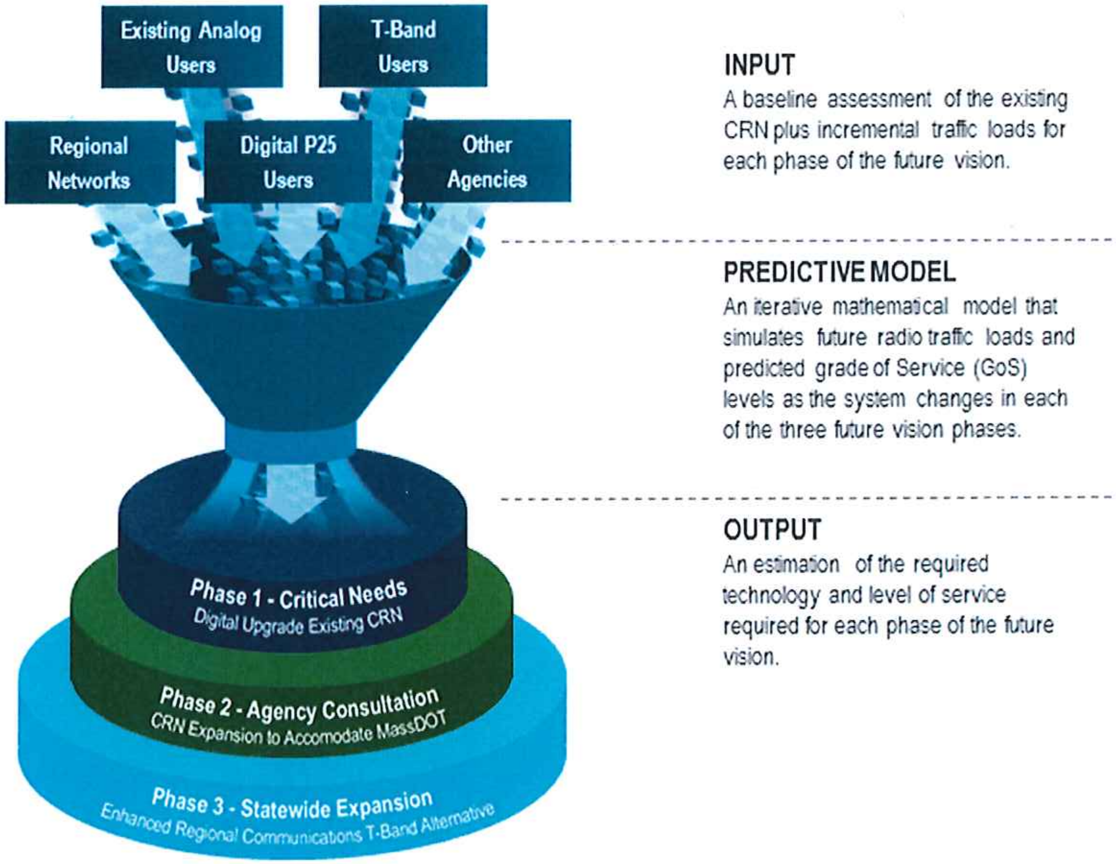


Figure 4-8: Statistical Traffic Prediction Model

A prediction model was used to extrapolate future conditions; including existing traffic loads for a particular coverage area and differing radio system topologies that serve users.

- Supports addition of new users for an existing coverage area
- Addresses requirements for existing users to have a different coverage area
- Addresses requirements for new users located in a new coverage area
- Rearranges talkgroup to site user traffic for site resource control

The Poisson Erlang C model helps to predict how these user needs will drive the radio system geographic topology and site resource level, which are not without caveats and need to be understood prior to actual equipment procurement. The GenWatch call record analysis tool, currently in place, illustrates a variance between real grade of service for the offered load in a particular time interval and the statistical calculation for that same load. This illustrates the challenge of modeling changing radio systems and user offered loads. Real user traffic for a group of users is never the same for each time interval. The actual user demand for services for a particular time interval (Erlangs) can be exactly the same for two units of time but one unit of time interval will show no queueing and the other interval will have queueing. This is the nature of real user traffic as the arrival times of the user PTTs (Push-To-

Talk), the number of PTTs, and message lengths differ between the two scenarios but have the same Erlangs.

A model is locked into average user hold times with PTT arrival times driving the model statistical engine and will never represent actual system traffic. In addition, the model does vary from real traffic by the "Affiliation Factor". GenWatch registers talkgroup activity on a site even if it is a short period of time within the GenWatch report time interval; when in actuality, that site talkgroup affiliation is quickly dropped, as when traveling down the highway or through a tunnel. The model will register the talkgroup on the site for the entire time interval stipulated in the model parameters and the GenWatch report interval, in this case one hour. It is important that the results of the model be tempered with the reason of institutional knowledge of the mobility of users in and out of site coverage areas. A case in point for this example is VENT 1 (Site 1025 P25 Vent 1) in table 3 Future Vision Two Traffic Model, an existing site in the MSP radio network that serves tunnels. The users are affiliated on this site for an extremely short time relative to the model time interval but the model is reporting that they are staying in the site coverage area for one hour, which is unreasonable during normal operation. The "Affiliation Factor" is not a factor if users stay in the same site coverage areas during the model time interval but becomes more important as users move. Therefore, the VENT 1 case is ignored, and talk path adjustment will rely on real time GenWatch reports. The model is conservative by design and systems deployed that adhere strictly to the model prediction are underutilized but have enough traffic headroom to accommodate unexpected spikes in user offered loads as when first responder communication needs increase in multiple incidents. The grade of service (GoS) results for a particular site resource availability, as presented by the model, are rationally interpreted for attribution in this report for the system future visions.

With the preceding overview of the nature of this kind of modeling, it is incumbent upon the participants of the modeling effort to be accurate in the gathering of existing system call record data and carefully apply these traffic offered loads to modeling scenarios for new system requirements. As such, the model is based on the following assumptions and constraints –

- The Model takes the GenWatch calculated GoS on real traffic and shows comparison with the Poisson model
- The Poisson statistical model internal mathematical assumptions are generally more conservative than real traffic experiences.
- The Model assumes a message length that is constant
- The Model assumes message arrival times statically
- With real traffic, identical Erlangs of offered load are variable and may result in traffic queuing or no queuing from one day to the next.
- Message lengths and arrival times generated by the Poisson statistical model are not exactly the same as to what is experienced by actual users and frequently result in a conservative GoS

To that end, four separate models were built to model more precisely the current and anticipated future states of the Commonwealth Radio Network.

- <u>Model Number One:</u> This model reflects the radio system with the busy hour traffic as received from the GenWatch reports and distributed to the existing topology and site resources as they exist today. This model is the baseline from which all other models were built and the basis for grade of service calculations in GenWatch. This modeling step provides the State Police with confidence that the follow-on modeling steps will provide valid insight for adjusting the system topology and sizing the buildout of equipment.

- Model Number Two: This Model is called "Future 1" and will reflect the addition of new users and new coverage areas. The baseline model will be adjusted to include new sites, the elimination of legacy sites, the minimum requirements for equipment buildout, and estimates of new user offered loads. This model will help to provide understanding of how the transition of radio system topology and user offered loads impacts grade of service and can help in verifying a roadmap in the system transition steps. This model corresponds to Future Vision 2, Agency Consolidation
- Model Number Three: This Model is called "Future 2" and will reflect the buildout of a TDMA (Time Division Multiple Access) solution for the topology that was established in the "Future 1" model. This model will include additional traffic offered loads projected by the State Police and other user agencies of the radio system. The purpose of this final model is to give confidence that the headroom of the system is sufficient for future user requirements. This model corresponds to Future Vision 3, T-Band Alternative.

Site Name	Number of Talkpaths	Probability a Call Will be Queued (GoS)	Probabi0.00li ty a Call Will not be Queued	Average Delay (Seconds)
1001 Metro simulcast	12	0.00%	100.00%	0.00
1003 D Simulcast	7	4.06%	95.94%	0.12
1004 Cape Simulcast	10	1.20%	98.80%	0.03
1005 AH Simulcast	9	0.01%	99.99%	0.00
1006 Truro	5	1.86%	98.14%	0.06
1007 Mt. Greylock	2	1.34%	98.66%	0.05
1008 C Simulcast	7	0.07%	99.93%	0.00
1009 Ragged Hill	5	0.09%	99.91%	0.00
1010 Athol	4	0.33%	99.67%	0.01
1011 Wellfleet	4	13.00%	87.00%	0.56
1013 Steerage	4	0.08%	99.92%	0.00
1014 Monson	4	0.79%	99.21%	0.05
1015 Mt. Grace	4	0.04%	99.96%	0.00
1016 Shelburn Mt.	4	0.23%	99.77%	0.01
1017 Mt. Toby	5	0.19%	99.81%	0.01
1018 Mt. Tom	4	0.17%	99.83%	0.00
1019 Country Hill	4	0.12%	99.88%	0.00
1020 Haverhill	4	0.30%	99.70%	0.01
1021 Vent 1	5	0.28%	99.72%	0.01
1024 P25 B North	5	0.09%	99.91%	0.00
1025 P25 B South	4	0.01%	99.99%	0.00
1026 P25 Mt Grace	4	0.00%	100.00%	0.00
1027 P25 Wilbraham	4	0.07%	99.93%	0.00
1028 P25 Stockbridge	4	0.00%	100.00%	0.00
1029 P25 Williamsburg	4	0.00%	100.00%	0.00
1030 P25 Greylock HS	4	0.00%	100.00%	0.00
1031 P25 Sandisfield	4	0.00%	100.00%	0.00
1032 P25 Tolland	4	0.00%	100.00%	0.00
1033 P25 Chester Rte. 20	4	0.00%	100.00%	0.00
1035 P25 Massport	14	0.00%	100.00%	0.00
1036 P25 Worcester	13	0.00%	100.00%	0.00
1070 P25 HCJ	4	0.01%	99.99%	0.00
1071 P25 DOC Norfolk	4			
2001 P25 Cambridge	11	0.00%	100.00%	0.00
2002 P25 Metro Boston	15	0. 00%	100.00%	0.00

Five highlighted sites on the current system do not meet the GoS of 1%

Table 4-2: Baseline Traffic Model

This model represents the busy hour traffic as received from the GenWatch reports and distributed to the existing topology and site resources, as they exist today.

- Site Name: This information stipulates the Zone, Site ID, and the Site Alias
  - The first digit of the number is the Zone
  - The last three digits of the number is the SiteID
  - The text is the Site Alias
- Number of Talkpaths: This is the number of concurrent radio audio conversations that can be held on this site.
- Probability a Call Will Be Queued (GoS): This is the statistical probability that a call will be put into busy queue of the traffic that is presented to the Erlang C statistical calculation and ranges from 0 to 1. This calculation contains the results of the probability that a call will be blocked along with consideration for queuing with the constraints for maximum time that the call will remain in the busy queue. This is the grade of service and can be multiplied by 100 for a percentage representation. The criteria for pass in this model is .01 or 1% GoS.
- Probability a Call Will Not Be Queued: This is the inverse of "Probability a Call Will Be Queued (GoS)" column. This value can be presented as percent by multiplying by 100.
- Average Delay (Seconds): This is the calculated average delay of a call in busy queue and is specified to be under one second in this model for a pass (all calls pass).