Zone systems are similar to multicast except that receive only sites are distributed in the zones by frequency where they are most needed. The system designer is required to know the service area of individual agencies in the county or state and will adjust the transmit and receive sites accordingly.

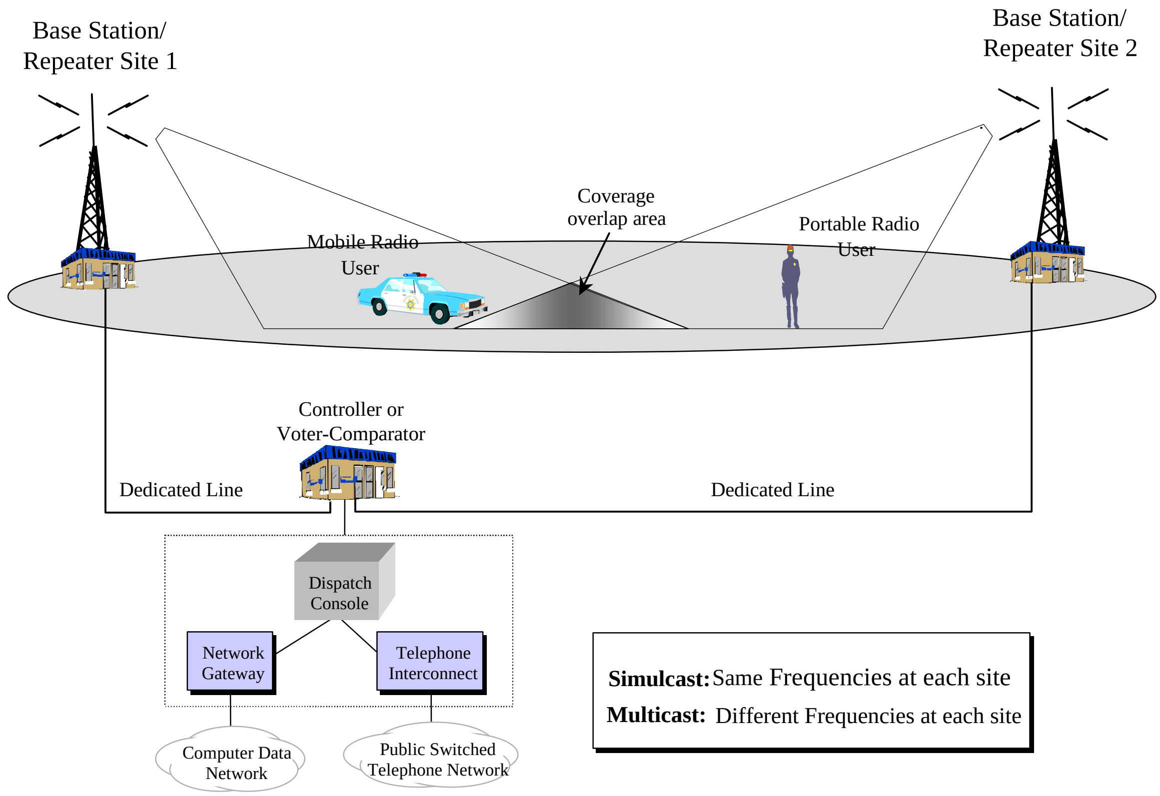


Figure 6.2 – Typical Two-Site Transmitter System (Source PSWN)

6.1.4 Trunking Systems

Since radio frequency spectrum is a limited resource and can be costly to obtain, radio equipment manufacturers developed trunking systems to optimize the use of available licensed channels. In general terms, trunking is the commonly accepted term for computer controlled sharing of a relatively small number of communications channels among a relatively large number of users. In contrast to a conventional LMR system in which users communicate over a dedicated channel, a trunked system uses a computer-driven controller to dynamically assign a channel to a user or group of users on a call-by-call basis. When a user presses the push-to-talk button, the system controller checks the ID of the talkgroup with which the radio user wants to communicate, checks for a vacant channel, and sends channel assignment instructions on the control channel to all of the radio units presently selected (turned on) for that talk group. After a channel is assigned, the identified users have private use of that channel for the duration of the call. If no channels are free, the request is sent to a queue where it remains until a channel is available. The controller can assign preference to the members of this group to complete their conversation through the use of a "message trunking" feature or software algorithm. Once the conversation is complete, the channel is returned to the pool of channels where it is available to other users.

This process takes advantage of the fact that not all channels (or talk groups) are used simultaneously, thus employing available bandwidth more efficiently than conventional system technology. Typical channel use statistics are very supportive of this conclusion. For example, on a 10-channel conventional system, a total of approximately 500 – 1,000 public safety users can be served, whereas those 10 channels on a trunked system could serve roughly 1,200 – 1,800 users. The very largest 28 channel trunking systems can accommodate 6,000 or more users in public safety service depending on the agency mix. Additionally, the assignment of channels in a trunked system is completely transparent to the user. Figure 6.3 illustrates an example of how a typical trunked radio system may allocate channels.

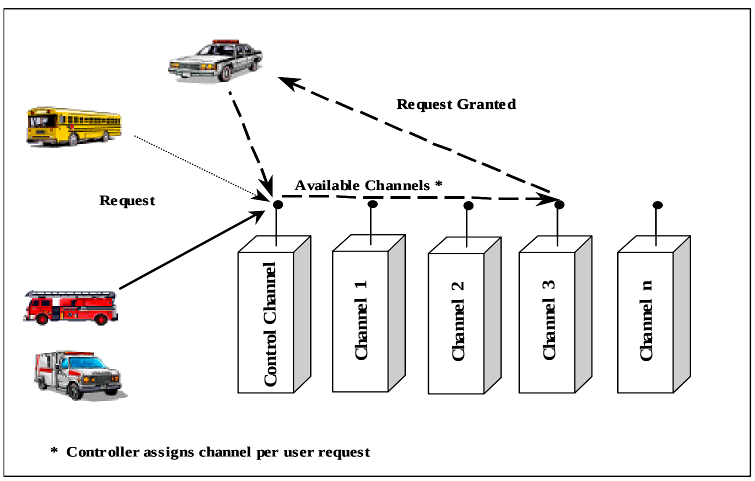


Figure 6.3 – Typical Trunking System

What is the primary difference between conventional and trunking technology? A trunked radio system allows a group of users to share a set of available frequencies. These groups of users are commonly referred to as talk groups. A talk group is a preprogrammed, predetermined basic organizational group of land mobile radio (LMR) users. In a trunked system, each subscriber unit has a unique address that corresponds to a talk group. Radio users on a trunked system have the ability to switch between talk groups by physically turning the knob on their subscriber unit to a different number. Typically, users that have similar operational, functional, and technical requirements are divided into larger segments called announcement groups. For instance, law enforcement, fire, and emergency medical services personnel are generally organized into a common announcement group and then sub-divided into functional talk groups. However, extensive planning and organizing is required to develop an effective talk group plan. If designed and implemented properly, an effective talk group plan will enhance existing system capabilities and provide flexibility over the long term.

The public safety radio communications network architectural elements and sub-systems presented thus far are summarized in Table 6.1 below.

Element/sub-system	Remarks
Base Station	Basic conventional system building block. Single frequency license.
Repeater	Two frequency (Pair) licensed station.
Receiver Voting	Multiple receiver sites to improve portable radio coverage.
Simulcast Transmit	Multiple synchronized transmit sites on same frequency to improve all radio coverage. Also includes receiver voting.
Multicast Transmit	Multiple transmit sites on different frequencies to improve all radio coverage. Also includes receiver voting.
Zone Transmit	Similar to Multicast, but with less voting receivers.
Trunking	Two or more frequency pairs with radio frequency assignments controlled by computer. More spectrally efficient than conventional. Trunking system design can utilize any of the above elements/sub-systems.

Table 6.1 – Summary of System Architectural Elements

6.2 Infrastructure Equipment Vendors

The common equipment necessary to design the sub-systems outlined in Table 6.1 is the base station/repeater. In this sub-section we will survey the public safety marketplace for equipment offerings from various vendors. Our intention is not an exhaustive review, but to include major vendors with their current station products. We will compare vendors with interoperability features such as Project 25 digital and narrowband capability and type of trunking protocol available. This information is summarized in Table 6.2 to follow.

Product offerings from six key vendors are included. Significant progress in the acceptance of the Project 25 digital standard for conventional operation can be noted as four of the six vendors have shipping product today. A fifth vendor, Tait Electronics Ltd., has committed to delivery of P25 conventional stations by yearend. Additionally, all of the vendor products have narrowband 12.5 KHz capability, and one repeater - the STR 3000 from Motorola, is digital narrowband only – no analog.

Progress toward implementing P25 trunking capability, however, is much more limited. Only Motorola offers infrastructure equipment that supports the basic P25 trunking standard. The remaining vendors are continuing to offer their traditional trunking system protocols. This situation exists, in our opinion, because of the huge product engineering investment required to develop a full LMR digital trunking product line to include simulcast transmitters, voting receivers, comparators, switches, and controllers. All of these systems products are necessary to properly address the coverage and communications requirements of the public safety marketplace.

		Base Station/Repeater Interoperability Analysis Considerations										
								Encryption Specifications		TIA 102 Standards		
Vendor	Product	Frequency bands Available	Channel Spacing	Analog/ P25 Digital Capable	Transmitter Deviations Available	Emissions Designators	Conventional/ Trunking Support	Encryption Capable	OTAR Support	CAI	IMBE	DES Encryption
Daniels Electronics LTD.	VT-4 & VR-4, UT-4 & UR-4	VHF, UHF, UHF-T	12.5/25 kHz	Analog and Digital		16K0F3E, 11K0F3E,8K10F1E, 11K0F2D, 11K0F1D, 15K0F2D	Conventional Only					
EFJohnson	2600 Series	VHF, UHF, UHF-T	12.5/15/25/30 kHz	Analog and Digital		16K0F3E, 11K0F3E,8K10F1E	Conventional & Trunking (MultiNet)					
Kenwood	TKR-7400 & 8400 Series	VHF, UHF, UHF-T	12.5/15/25/30 kHz	Analog Only	+/-2.5/5	16K0F3E, 11K0F3E	Conventional Only	No	No	No	No	No
M/A-COM, Inc.	MASTR III P25	VHF, UHF, UHF-T, 800	12.5/25/30 kHz	Analog and Digital	+/-2.5/5		Conventional & Trunking (EDACS, ProVoice)	Yes	Yes			
M/A-COM Inc.	MASTR III	VHF, UHF, UHF-T, 800	12.5/25/30 kHz	Analog Only	+/-2.5/5	16K0F1D, 16K0F1E, 16K0F3E, 15K0F1D, 15K0F1E, 14K0F3E,	Conventional & Trunking (EDACS, ProVoice)					
M/A-COM, Inc.	SkyMASTR	700, 800 MHz	12.5/25 kHz	Analog and Digital			Conventional & Trunking (OpenSky)	Yes	Yes		No - AMBE	No - AES
Motorola, Inc.	Quantar	VHF, UHF, UHF-T, 800	12.5/25/30 kHz	Analog and Digital	+/- 2.5/3.6/5 kHz	16K0F3E, 16K0F1D, 20K0F1E, 11K0F3E, 8K10F1E, 10K0F1D	Conventional & Trunking (SMARTNET II, SmartZone, & ASTRO 25)	Yes	Yes	Yes	Yes	Yes
Motorola, Inc	STR 3000	700, 800 MHz	12.5 kHz	P25 Only		8K70F1E, 8K70D1W	Conventional & Trunking (ASTRO 25 Only)	Yes	Yes	Yes	Yes	Yes
Tait Electronics	8000 Series	VHF, UHF, UHF-T	12.5/20/25 kHz	Yes (end of 2004)			Conventional & Trunking (MPT 1327)					
Tait Electronics	T800 Series II	VHF, 220, UHF, UHF-T, 800	12.5/20/25/30 kHz	Analog Only	+/- 2.5/5 kHz		Conventional & Trunking (MPT 1327)					

Table 6.2 – Infrastructure Equipment Vendor Comparison

		Portable Radio Interoperability Analysis Considerations													
							Encryption Specifications				Scanning Specifications		TIA 102 Standards		
Vendor	Product	Freq. bands Available	Channel Spacing	Analog/ P25 Digital Capable	Cross/ Multi-Band Support	Conventional/ Trunking Support	Encryption Capable	OTAR Support	Over-the-Air Programming	Radio-to-Radio Cloning Support	User Defined	Between Systems/Modes	CAI	IMBE	DES Encryption
Datron	Guardian G25RPV100	VHF	12.5, 25 KHz in 2.5 KHz steps	Analog & Digital	No	Conventional Only	Yes	Yes		Yes			Yes	Yes	Yes
EFJohnson	5100 Series	VHF, UHF, UHF-T, 800	12.5, 25, 30 KHz	Analog & Digital	No	Conventional & Trunking (SMARTNET II, SmartZone, ASTRO 25, and Multi-Net)	Yes (SecureNet DES, DES-XL)	Yes			Yes	Yes	Yes	Yes	Optional
EFJohnson	7700 Series		25, 30 KHz	Analog Only	No	Conventional & Trunking (SMARTNET II, SmartZone, and Multi-Net)	No	No					No	No	No
Kenwood	TK-290 & 390 Series	VHF, UHF	12.5, 15, 25, 30 KHz	Analog Only	No	Conventional Only	Yes				Yes		No	No	No
Kenwood	TK-5400	800 MHz	12.5, 25 KHz	Analog & Digital	No	Conventional & Trunking (ASTRO 25)	Yes				Yes		Yes	Yes	
M/A-COM	P7200 Series	700, 800 MHz	12.5, 25 KHz	Analog & Digital	No	Conventional & Trunking (EDACS, ProVoice, OpenSky)	Yes - DES, AES	Yes			Yes		Yes	Yes	Yes
M/A-COM	P7100IP Series	VHF, 380, UHF, UHF-T, 800	12.5, 25 KHz	Analog & Digital	No	Conventional & Trunking (EDACS, ProVoice)	Yes	Yes	Yes		Yes		Yes	Yes	Yes
M/A-COM	Jaguar 725P	VHF, UHF		Analog & Digital	No	Conventional & Trunking (EDACS, ProVoice)	No	No					Yes	Yes	No
Motorola	MTS2000	VHF, UHF, UHF-T, 800	12.5, 20, 25, 30 KHz	Analog Only	No	Conventional & Trunking (SMARTNET II & SmartZone)	Yes	No	No	Yes		Yes	No	No	Yes
Motorola	XTS5000	VHF, 380, UHF, UHF-T, 700, 800	12.5, 25, 30 KHz	Analog & Digital	No	Conventional & Trunking (SMARTNET II, SmartZone, & ASTRO 25)	Yes	Yes	No	Yes	Yes	Yes (End of 2004)	Yes	Yes	Yes
Motorola	XTS3000	VHF, UHF, UHF-T, 800	12.5, 25, 30 KHz	Analog & Digital	No	Conventional & Trunking (SMARTNET II, SmartZone, & ASTRO)	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Motorola	XTS2500	VHF, UHF, UHF-T, 700, 800	12.5, 25, 30 KHz	Analog & Digital	No	Conventional & Trunking (SMARTNET II, SmartZone, & ASTRO 25)	Yes (ADP Only)	Yes	No	Yes		Yes (End of 2004)	Yes	Yes	No
Motorola	XTS1500	700, 800	12.5, 25 KHz	Analog & Digital	No	Conventional & Trunking (SMARTNET II, SmartZone & ASTRO 25)	No	No	No	Yes	Yes	No	Yes	Yes	No
Tait	5000 Series	MB, VHF, 225,380,UHF, UHF-T,800, 900	7.5, 12.5,20, 25 KHz	Analog Only (P25 by end of 2004)	No	Conventional & Trunking (MPT-1327)	No				Yes		No	No	No
THALES	Thales25	VHF	12.5, 20, 25, 30 KHz	Analog & Digital	No	Conventional Only	Yes	Yes			Yes	Yes	Yes	Yes	Yes

Table 6.3 – Portable Radio Vendor Comparison

Vendor	Product	Mobile Radio Interoperability Analysis Considerations													
		Freq. bands Available	Channel Spacing	Analog/ P25 Digital Capable	Cross/ Multi-Band Support	Conventional/ Trunking Support	Encryption Specifications		Over-the-Air Programming	Radio-to-Radio Cloning Support	Scanning Specifications		TIA 102 Standards		
							Encryption Capable	OTAR Support			User Defined	Systems/ Modes	CAI	IMBE	DES Encryption
Datron	Guardian G25RMV100	VHF	12.5, 25 KHz	Analog & Digital	No	Conventional Only	Yes	Yes		Yes			Yes	Yes	Yes
EFJohnson	5300 Series	VHF, UHF, 800	12.5, 15, 25, 30 KHz	Analog & Digital	No	Conventional & Trunking (SMARTNET II, SmartZone, ASTRO 25, and Multi-Net)	Yes				Yes	Yes	Yes	Yes	Yes
Kenwood	TK-690, 790, 890 Series	LB, VHF, UHF, UHF-T	12.5, 15, 25, 30	Analog Only	Yes	Conventional Only	Yes				Yes		No	No	No
M/A-COM	M7100 IP Series	VHF, UHF, UHF-T, 800	12.5, 25 kHz	Analog & Digital	No	Conventional & Trunking (EDACS, ProVoice)	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes
M/A-COM	M7200 Series	700, 800 MHz	12.5, 25 kHz	Analog & Digital	No	Conventional & Trunking (EDACS, ProVoice, Open Sky)	Yes	Yes			Yes		Yes	Yes	Yes
Motorola	XTL5000	VHF, 380, UHF, UHF-T, 700, 800	12.5, 25, 30 KHz	Analog & Digital	No	Conventional & Trunking (SMARTNET II, SmartZone, & ASTRO 25)	Yes	Yes	No	Yes	Yes	Yes (end of 2004)	Yes	Yes	Yes
Motorola	XTL2500	VHF, 380, UHF, UHF-T, 700, 800	12.5, 25, 30 KHz	Analog & Digital	No	Conventional & Trunking (SMARTNET II, SmartZone, & ASTRO 25)	Yes (ADP Only)	Yes	No	Yes	Yes	Yes (end of 2004)	Yes	Yes	No
Motorola	ASTRO Spectra Plus	VHF, 380, UHF, UHF-T, 700, 800	12.5, 25, 30 KHz	Analog & Digital	No	Conventional & Trunking (SMARTNET II, SmartZone, & ASTRO 25)	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Tait	T2000 Series	MB, VHF, 225,380,UHF, UHF-T,800,	12.5, 20, 25 KHz	Analog Only	No	Conventional & Trunking (MPT-1327)	Yes						No	No	No
Tait	TM8000 Series	VHF, 225,UHF, UHF-T	12.5, 20, 25 KHz	Analog Only (P25 end of 2004)	No	Conventional & Trunking (MPT-1327)	No				Yes		No	No	No

Table 6.4 – Mobile Radio Vendor Comparison

6.3 Subscriber Radio Vendors

An interoperability comparison of the major subscriber vendors can be found in Tables 6.3 and 6.4 above. Again, the information included is a relative sampling of major public safety marketplace providers. Six of the seven vendors listed have at least one digital narrowband offering and the seventh, Tait Electronics, will have a P25 portable for delivery by the end of 2004. It is obvious that the vendors foresee an increasing business in Project 25 capable radios. As a result, public safety agencies have a number of choices for radios to be used with conventional P25 communications systems.

Additionally, the competitive situation with subscriber radios is improved for P25 trunking systems. Both EF Johnson and Kenwood deliver a portable radio that operates on the Motorola ASTRO 25 trunking system. EF Johnson also ships a P25 compliant mobile radio for trunking. However, an agency must be very careful to require the vendor to thoroughly explain radio capabilities before purchase. For instance, a vendor's radio may be capable of operation on a legacy trunking system or a new Project 25 trunking system, but not simultaneously. Reprogramming of the radio may be required for operation on various types of systems and different bands.

7 Analysis of Cellular System Capabilities

The cellular revolution continues unabated in the United States with 88 Million units sold last year. This growth is sparked by the rollout of new innovative system and handset features. For instance more camera cell phones (24 Million) than digital cameras were purchased last year in America. The infrastructure migration to digital technologies is complete to the extent that the analog backbone will be turned off in most states this year. It is understandable that many public safety agencies look to the use of cell phones to help resolve wireless voice & data interoperability issues. NEXTEL indicates that about 20% of the company's new sales are to public safety and government markets. But agencies must understand what portable radio public safety features may be given up with the use of a cell phone.

The table below compares the availability of a number of public safety radio features among the five leading cellular service providers in the Wisconsin region. These network and portable radio features can be taken for granted by private communications system users. However, they are very important in life and death situations. From Table 7 – 1, NEXTEL comes the closest to meeting our public safety criteria, so we will focus on this carrier in the next few paragraphs to better understand how this came about.

Public Safety Features	Cingular Wireless	NEXTEL	Verizon Wireless	Sprint	AT&T Wireless
NETWORK:					
Reliability		Yes - Metrics	Yes - Metrics		
Capacity	2 % GOS	1 - 2 % GOS	2 % GOS	2 % GOS	2 % GOS
Coverage	Interstates & Major Cities	Interstates & Major Cities	Interstates & Major Cities	Interstates & Major Cities	Interstates & Major Cities
Priority Levels		Yes – Voice & Data			Yes - Data
Data	Yes	Yes	Yes	Yes	Yes - EDGE
Dispatch RF Control		Yes – Radio & Deskset			
Emergency Back-up Sites		Yes - SatCOW			

Public Safety Features	Cingular Wireless	NEXTEL	Verizon Wireless	Sprint	AT&T Wireless
HANDSET:					
Emergency Button		Yes			
Push-to-talk		Yes – Direct Connect™	Yes – SE WI Only		
Group Call		Yes - Group Connect™	Yes – SE WI Only		
Talk Around		Yes – New in 2004			
GPS Location	Yes	Yes	Yes	Yes	Yes
Encryption		Yes			Yes
Data	Yes	Yes	Yes	Yes	Yes
Mil Std 810 compliance		Yes - Model r750plus			

Table 7-1 Important Public Safety Features

The cellular wireless communication industry began in 1974 with the initial authorization from the FCC. At about the same time, the FCC created the Specialized Mobile Radio (SMR) Services. SMR was intended to be a commercial wireless service that primarily provided businesses with mobile dispatch communications. The first SMR became operational in 1977 and early systems utilized the Motorola, Inc. trunking architecture on 800 MHz frequencies.

As both the cellular and SMR services evolved during the 1980s the users demanded more features than just talk-and-listen. In order to meet these user needs, vendors eventually developed features based on more sophisticated digital technology. For SMR operators the digital system platform was referred to as ESMR or Enhanced SMR and was based on Motorola's Integrated Dispatch Enhanced Network (iDEN) TDMA technology.

NEXTEL began life in 1987 as an SMR operator named FleetCall. For the next ten years NEXTEL would merge with or purchase many SMR operators throughout the United States. Through this process the company came to own radio sites and 800 MHz frequencies from coast to coast in the same spectrum with public safety. By migrating to the digital ESMR trunking technology NEXTEL was able to implement wide-area systems with cellular telephony features. Today their integrated voice and data trunking system will support nationwide Direct Connect™ push-to-talk.

To complete the picture we must also know that Motorola adapted the SMR technology for public safety use in the early 1980s through the company's introduction of SmartNet trunking systems. SmartNet was the first trunking system that connected directly to a console for dispatcher control. Thus, the software evolved through the years in the separate markets meeting different standards, but with similar features. For instance, Direct Connect is equivalent to private call on a public safety trunking system.

Through this evolution the NEXTEL network today is capable of providing most, if not all, of the necessary features desired by public safety agencies. The other wireless carriers listed in Table –1 are also slowly enabling these desirable features. The critical areas for agencies in Wisconsin to focus on are network capacity, reliability, and coverage. At the present time, FE does not see adequate capabilities from any of the carriers to be able to recommend any of the services as a primary Public Safety Mobile Radio solution.

Generally speaking, since wireless carriers are in business for profit, they will make network enhancements with an eye toward return on investment. Stations will not be added to cells until the Grade of Service (GOS) is measured worse than 2 percent. Infrastructure reliability and up-time metrics are collected by some wireless carriers today. However, only key sites will have battery and generator back-up in case of power failure. Cell sites will be installed in areas where customers are located not necessarily in locations where emergencies can occur. And of course, since the network is designed to be operating typically at the capacity limit for voice calls, it can quickly overload during a major disaster. While some carriers indicate that there is a prioritization plan that would favor Public Safety subscribers in crisis situations, neither the processes nor the ability of the systems to provide this prioritization have been tested in most cases.

A less risky approach would be to utilize cellular service providers for alternative communications needs, as an adjunct to the PSMR radio system. An agency could off load some of its non-priority voice and data traffic. But these activities should be controlled through the dispatch center and properly tracked with the CAD system and voice recorders.

8 Computer Controller Interoperability System Approaches

One very successful method of providing interoperability to public safety radio communications systems is to link separate systems by deploying a computer controlled capability that receives a transmission on one radio system and retransmits it on a different radio system (often on a different frequency band). This strategy can be implemented without significant additional infrastructure, and without significant modifications to the radio systems being linked. The disadvantage of this approach is that it requires a frequency (channel) to be tied up for each different radio system when in use that is part of the link. Given the relatively low cost of retransmission devices (compared to implementation of a new shared system), and the fact devices that rebroadcast can be installed with minor changes to the existing radio systems, this approach has significant potential, particularly as a near-term solution or as part of a transitional strategy. These gateway approaches can be separated into three general categories; console patch, baseband analog audio, and baseband digital audio.

8.1 Traditional Console Patch

The radio dispatch console is the central integrating element of a modern public safety communications center. Its primary purpose through the years has been to facilitate timely and accurate dispatching of emergency resources. The console provides the means by which one or more dispatchers can effectively control and communicate with field units over multiple radios. Additionally, the dispatch console seamlessly interconnects base stations, auxiliary receivers, telephones, logging recorders, paging encoders, tone encoders & decoders, intercoms, and other dispatch related equipment. The dispatch console acts as a switch that routes audio and control signals between various equipments involved in the radio system. When the console connects different audio sources together for radio interoperability, it is called “patching” the audio.

The user interface for a dispatch console can be buttons, video displays (CRTs or LCDs), or a combination of the two. A classic button-based console has dedicated buttons assigned to commonly used functions for each channel. Channel buttons are augmented with system buttons that operate only on selected channels. Different colored LEDs adjacent to each button show system and function status. This approach provides a fast, flexible, and intuitive means of controlling the console. Installations with more than about 15 - 20 channels will have large “button fields” that must be carefully organized to avoid overwhelming the operator. Button-based consoles feature programmable buttons to allow optimization of the interface for the user’s particular application.

As channel requirements have increased, many dispatch centers have transitioned to video display based consoles. This trend has been accelerated by increased public safety use of trunked radio systems and by the functional integration of the radio console with other communications center equipment. The CRT displays icons representing conventional buttons such as status, control settings, and ANI information. These icons show available actions using color, video intensity, and text. To "activate a button," the operator uses a mouse, trackball, or touch screen display. The CRT may be configured to provide controls on multiple pages arranged in a hierarchy. This allows frequently used functions and channels to be placed at the top of the hierarchy. A CRT can display a practically unlimited number of functions and channel controls. The CRT is the preferred approach for installations that employ trunked radio systems or that require a high-degree of functional integration. CRT displays not only present information in a more readily understood manner, they can also be dynamically reconfigured for specific tactical situations.

As discussed thus far the typical dispatch console has many features and options, which are utilized to control a public safety communications system. One of these features is named "console patch". Patch is a standard feature with most console vendor's equipment. Since Motorola CENTRACOM console equipment is utilized by public safety agencies throughout the State, this discussion is oriented toward that product offering.

The term "patch" originated many years ago when dispatchers were required to use "patch panels" with cables and jacks in order to connect audio circuits together. Patch is a dispatch operation, which allows audio communications between radio groups, which are normally unable to communicate with each other because they operate on different channels or Talkgroups. It is a major interoperability feature of the console. This operation brings the audio together, but digital signaling messages are not distributed to the members of a patch. Radio groups can include trunking talkgroups and Private Calls (from same or different trunking systems) and base stations (which include conventional and MDC signaling base stations), and phone lines. A "Patch Group" can contain a trunking talkgroup, Private Call, Conventional, MDC Advanced Conventional, ASTRO 25 Conventional, or Phone lines. Patch operation is simplex if any channels/Talkgroups in the patch are not duplex. This means the audio of the first user to key up is sent out to all other channels/talkgroups. Audio from all other subscribers is ignored until the first subscriber dekeys. If all channels/talkgroups in the active patch support duplex, a conference call is established. All receive audio is then transmitted to all channels/talkgroups.

It is important to note that each user member is restricted to one active Patch Group. It is not possible to have a member belong to two different active Patch Groups on the same console or on different consoles. However, it is possible for the same member to be in several inactive patch groups on one or more consoles. A member may be in an active patch when another operator position activates a patch that contains that same member. In this case, the member is excluded from the 2nd patch and the operator is notified that the member is excluded. When the 1st patch is made inactive, the excluded member will not be automatically enabled. The operator has to deactivate then activate the 2nd patch to add the excluded member back in.

As can be seen console patching of many channels into many patch groups in a large dispatch center can become quite complicated. Many vendor consoles allow up to 16 patch groups to exist at any time. However, if the dispatcher is using a CRT/LCD type display position, then the organization of patch groups, using the "drag-and-drop method", is fairly straightforward and can be accommodated with minimal training. A significantly larger dispatcher training effort would be required if the console positions were of the button and LED type.

8.2 RF Gateways with Analog Baseband Audio

Over the past few years several companies have addressed the issue of utilizing RF gateway technology to interconnect radio channels. Public safety operates in ten separate radio frequency bands. Even though public safety has gained spectrum through licensing on much or their entire allocated spectrum, which has added capacity, it has also caused the fragmentation that characterizes the public safety spectrum today. In addition to the wide span of frequencies in use, systems utilize simplex operation, repeater operation, Conventional and Trunked 800 MHz operation, and NEXTEL wireless. As more wireless technologies become available to the public safety community, more integrated and multiple solutions will also become available. They must coexist with each other now as well as being backwards compatible with various previous versions of those technologies.

While exploring a potential match between system solutions and short-term goals, many manufacturers were found, which produce products that address the RF gateway solution. Several companies produce products that find their home in an incident command vehicle. This is a mobile-only application that "cross-patches" a rack of mobile radios contained inside an emergency communications van. When talking of RF gateways, some think only of the mobile RF cross patch devices used in a mobile command van application. This type of system design results in a limited radio coverage RF gateway.

This subsection of the study addresses the use of a RF interconnect system that is part of the fixed infrastructure and links radio systems with <u>known</u> radio coverage areas.

RF gateway technology must be, (1) easy to implement, (2) easy to maintain, and (3) easy for the PSAP or EOC dispatcher to operate in time of an emergency, (4) cost effective, and (5) take into account the ability to gateway multiple frequency bands.

The most popular product in this category comes from JPS Communications of Raleigh, North Carolina and is named the ACU-1000 Intelligent Interconnect System. The ACU-1000 modular interface / interconnect system is a computer controlled radio router that can be configured to meet almost any interface application involving telephones and radios.

The ACU-1000 is a modularized approach to controlling and interconnecting various types of communications systems. Its basic components are interface modules, each designed to connect a specific communications medium (VHF/UHF radio, telephone, HF radio, or local operator), a control module, a chassis to accommodate the modules, and a backplane to route the digitized audio and control signals between modules. Adding a new communications format to the system can be as simple as plugging in the appropriate interface module and connecting the new equipment to the ACU-1000 backplane.

The interface modules convert communications traffic into its essential elements: receive and transmit audio, and accompanying control signals required to fully control the device that the module is interfacing.

The ACU-1000 is designed for standard 19-inch rack mounting. The Euro card chassis accommodates a Power Supply Module, Control Processor Module and Handset/Speaker/Prompt Module which occupy dedicated slots, and up to twelve interface modules. An expansion chassis option is also available. The interface modules are selected based on the type of interface required.

A similar product is available from Telex/Vega named the IP-223. This unit combined with other interface modules will enable interconnection and control of two or more radios in different frequency bands. The IP-223 will also connect directly to an IP network.

Additional vendors are appearing regularly in the public safety marketplace as the need for interoperability solutions gains momentum.

8.2.1 Current Deployments

Currently there are over 2,100 ACU-1000 units in use around the world providing interoperability solutions. There are many success stories utilizing this device in public safety communications applications.

Approximately two years ago the State of Maryland started with one ACU-1000 to do RF gateway interconnects. Today they have eight units cross-linking agencies throughout the state. Since the ACU-1000 is an Ethernet based product it allows any console within their system (through memos of understanding) to access any dispatch center ACU-1000 via the Ethernet. The State of Maryland in conjunction with JPS engineers has used a WAIS (Wide Area Interoperability Software) approach to achieve this goal.

Boulder County, Colorado is using the ACU-1000 to connect disparate radio systems. The Boulder County Drug Task Force is a partnership of Denver area agencies, an area of seven counties and many municipalities, which are all working to reduce the drug problem. The agency radio systems are attached to the switching system of the ACU-1000. The dispatch center has a computer program that allows "point and click patching" or connection of various agencies. Up to seven operations can be connected simultaneously. This system was also successfully employed during the Colorado wild fire season, where it was used to patch together two fire departments using different radio systems.

Under a grant from the National institute of Justice (NIJ) a cross band audio switching system was installed at the Alexandria, VA Police Department (APD) to improve communications systems interoperability in the Washington DC area. The Gateway Sub-system is installed at APD's headquarters and includes antennas, radios, and an ACU-1000 interconnect unit. The antennas are mounted on the roof of APD, while the radios and ACU-1000 are mounted in an equipment rack (see photo at right) in the Equipment Room of the APD Dispatch Center within APD headquarters. The radios in the Gateway Subsystem are programmed for frequencies licensed to the participating agencies and typically are set to a channel programmed for a default frequency corresponding to the channel that a participating agency designates for inter-agency communications. Mutual Aid channels can also be utilized. Radio channels may be changed manually as required to transmit and receive on different frequencies.

The initial operational use of this Gateway Sub-system was in support of security for the Inauguration of President Bush. Since this initial application the sub-system has been expanded to connect with another remote ACU-1000 and now includes interoperability connections with 18 different radios to every major law enforcement agency in the metropolitan region. APD is also participating with local Fire Departments in the development of a mobile response unit, which will include an ACU-1000.

8.2.2 Subscriber Control

In addition to the console dispatcher controlling the RF gateway, subscribers (mobiles or portables) having DTMF encoders can also control ACU-1000. As an example let's say an RF gateway is set up as patch number "02" between the County Sheriff and the Forest Preserve Police. Any subscriber having DTMF control would send *02 to set up the link. The link prompts the user for their password, i.e., 1755, and the link is established. The link is then knocked down with a #02. As can be seen this would give personnel in the field the ability, in addition to the dispatcher, to establish interoperability connections.

The JPS ACU-1000 has been used to even link volunteer search teams using FRS radios and given them the ability to talk direct with public safety search and rescue. The combinations are nearly endless. The only real downside to this type of radio frequency patch is that they are spectrum inefficient since each participant essentially gives up one channel to each patch talk path.

8.3 Gateways with Digital Baseband Audio & Packet Switching

Interoperability solutions in this category utilize an Internet Protocol (IP) based network to link disparate radio systems together. IP is probably the most ubiquitous standard in the world of communications and computers. It's what allows dissimilar desktop computers and software applications to communicate with each other. IP can enable the same communications capability between dissimilar radio systems.

The best-known supplier of this network interoperability technology approach is M/A-COM Wireless Systems, and they call this solution *NetworkFirst*. It links disparate systems together through a packet-switched IP network using "SkyGates" where necessary and includes network control using M/A-COM's Regional Operations Center (ROC) to provide interoperability capability. The system uses commercial off-the-shelf (COTS) networking equipment such as Sun Workstations, Cisco routers, and Ethernet interface cards to provide high reliability with reasonable economy and virtually unlimited scalability in the number of users or systems that can be accommodated.

NetworkFirst is an interoperability solution built on IP switching instead of audio patching. IP switching enables the ROC to make switching decisions based on talk-groups, call priority, preemption, and blocking. These are features normally associated only with Trunked radio systems and differentiates *NetworkFirst* from either console patch or baseband analog audio switching approaches. These features provide interoperability with greater user flexibility than either of the previous two alternatives.

A key innovation of *NetworkFirst* is that it enables public safety agencies to proactively create interoperability talk-groups for preplanned incidents while providing the flexibility to quickly create new interoperability groups as needed. As was outlined in the beginning of this section, dispatchers play a critical role in nearly all public safety communications. NetworkFirst enables dispatchers and appropriate field personnel to maintain their usual communications within their agency while allowing selective communications with additional agencies during interoperability situations.

There are also some emerging systems being developed by non-PSMR companies that offer IP-based switching and connectivity using the municipal/State network and the Internet. One product, WAVE (Wide Area Voice Environment), developed by Twisted Pair Solutions, Inc. offers the ability to connect virtually any communications device to any other communications device by using software and a set of COTS hardware products. This could theoretically allow a radio in the field to connect to any other radio in the country, or more likely it can provide intercommunications between field radio units, dispatch centers, supervisory personnel, and other agencies using radios, telephones, and mobile data computers or personal computers and PDA's. These solutions are relatively new but could fit well with certain operational scenarios where a broad reach of communications is necessary.

9 Emerging Wireless Services and Technologies

The digital revolution has prompted a flood of cell phones, pagers, personal digital assistants (PDAs) and laptop computers into consumer markets. Advances in wireless technology are enabling users of these devices to communicate without the need for cables and/or phone jacks. Wireless usage increased by 145 percent during 2003 in 13 industrialized countries according to a study conducted by the market research firm Ipsos-Insight. Principle among these new innovations is the wireless LAN type technology for home and business applications. Because of the high visibility and strong interest in these technologies a number of vendors are proposing applications for the public safety market.

9.1 Hot-spot 802.11 Wi-Fi Networks

The components for wireless LAN networks have been shipping in the consumer market place for nearly ten years. However, as with most new technologies, significant adoption didn't begin until a standard existed. In 1997, the Institute of Electrical and Electronics Engineers (IEEE) created the first WLAN standard. It was called 802.11 after the name of the working group that developed it. This initial standard only supported a maximum bandwidth of 2 Mbps, which the early users determined was too slow for most applications.

The IEEE expanded the original 802.11 standard in 1999 into two extensions, the 802.11a for business applications and the 802.11b for home use. Sales of the 802.11b standard devices took off first because they used the same radio frequency band – 2.4 GHz – as the original standard. The maximum bandwidth was increased to 11 Mbps, which is comparable to traditional Ethernet. These frequencies, however, are in the Industrial, Scientific, and Medical (ISM) band, which is unregulated and congested with transmissions from many different devices including cordless phones, microwave ovens, and other appliances. This congestion makes 802.11b type WLANs more susceptible to potential interference, which must be understood during system installation.

By comparison the 802.11a standard allows for a much higher bandwidth of up to 54 Mbps along with forward error correction, greater scalability, and better interference immunity. 802.11a uses 300 MHz of spectrum in the 5 GHz Unlicensed National Information Infrastructure (U-NII) bands. While devices in the U-NII band encounter less congestion and interference than the ISM band, they also have less range because signals have more difficulty penetrating walls, trees, and other obstructions.

In mid 2003 the IEEE ratified the 802.11g standard. This standard combines the best of both the 802.11a and the 802.11b by supporting bandwidths up to 54 Mbps in the 2.4 GHz band. 802.11g is also backwards compatible with 802.11b, which means that 802.11g wireless access points (WAPs) will work with 802.11b wireless network adapters and vice versa. The maximum power output of a WAP for either standard is one watt. A comparison of the features of the 802.11 series is contained in Table 9.1 below.

Wi-Fi, short for wireless fidelity, is the industry standard for wireless technology. It is, in fact, a brand name developed by the Wi-Fi Alliance to ensure compatibility among products. Before the alliance was founded in August of 1999, WLAN system integrators encountered problems assembling products from various vendors. The Wi-Fi alliance currently has more than 200 member companies and has certified more than 1,250 products for interoperability. These products carry the Wi-Fi seal on their packaging. The Alliance keeps a listing of certified products on it's own Web site at www.wi-fi.org/certified_products.

Characteristics	802.11	802.11a	802.11b	802.11g
Application	Wireless data networking	Broadband LAN Access	Wireless data networking	Broadband LAN Access
Spectrum Band	2.4 GHz ISM	5 GHz U-NII	Unlicensed 2.4 GHz ISM	Unlicensed 2.4 GHz ISM
Modulation Scheme	FHSS or DSSS	OFDM	DSSS	OFDM or DSSS
Number of Channels	79 channels with FHSS; 3 or 6 channels with DSSS	12	3	3
Optimum Data Rates (Mbps)	2	54	11	54
Range (meters)	100	50	100+	100
Date established	July 1997	September 1999	September 1999	July 2003
Compatibility	802.11 only	802.11a only	802.11g	802.11b
Global Operability	North America, Europe, Asia	North America, Europe, Asia	North America, Europe, Asia	North America, Europe, Asia

Table 9.1 - Comparison of Characteristics Specified within the IEEE 802.11 Suite

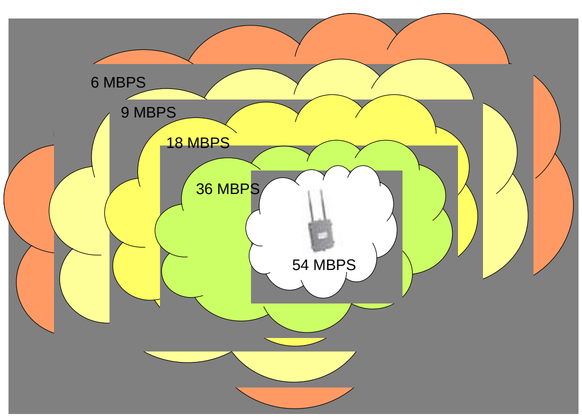
New IEEE 802.11 Standards in Process

The IEEE standards bodies are currently working on a number of new WLAN standards of interest to public safety, which are summarized in Table 9.2 below. Standard 802.11p is of particular interest to public safety in that it will define the air interface requirements for operation of vehicles in motion in the 5.9 GHz Digital Short Range Communications (DSRC) band. This new standard was requested by the Intelligent Transportation System (ITS) organization, however the IEEE working group is also receiving public safety inputs on requirements from NPSTC. The standard will be released in 2005 and will be applicable to the 2.4, 4.9, and 5 GHz bands also. The desire of the IEEE working group is that current equipment will only require a software upgrade to interoperable with this new standard.

Standard	Key Improvement	Comments
802.11n	Higher throughput (>100 Mbps)	Physical & MAC layer standards revisions.
802.11p	Moving vehicle wireless access	Based on 5.9 GHz DSRC Band. Up to 200 kph speeds.
802.11r	Fast BSS transition	Reduces handoff delays.
802.11s	Mesh Networking	Developing support for multi-hop wireless networking to improve coverage & reduce installation costs.

Table 9.2 - Emerging WLAN Standards.

All of these wireless LAN standards typically operate over a range of approximately 100 meters in a business environment to a typical omni-directional access point. Although each of these standards is often referred to by their peak data rates, that data rate is typically only achieved when in a good signal area fairly close to the access point. The true data rate can be as low as 1/5 to 1/10 that speed at the edges of the coverage area or in a high interference environment. However, the data rate for a 802.11a or g WLAN is always higher than for a 802.11b WLAN at the same distance from the WAP.



It is also important to note that the throughput is always less than the data rate due to signaling overhead and contention for the bandwidth. This contention can be significant if several users are on the same wireless access point, or if the wireless LAN system is also used for back-haul (as in a mesh type network). Most wireline LAN systems have evolved from a shared medium with daisy chained cables and hubs, to an architecture with dedicated links for each terminal, terminated in a switch or router. The wireless LAN architecture maintains that older “Shared Medium” design due to its inherent nature.

9.2 Public Safety 4.9 GHz Band.

A key disadvantage of the 802.11 a, b, or g type WLAN implementations is the frequencies are in unlicensed spectrum. Thus, the potential for interference and range reduction can be fairly high. The FCC directly addressed this issue with the release of service rules for the new 4.9 GHz band in the Third Report and Order on Docket No. 00-32 in May 2003. This new band (4940 – 4990 MHz) will support a variety of broadband applications both temporary and permanent.

The FCC purposely didn't specify an air interface standard for use in this band. However, it is expected that the 802.11g standard will be "tweaked" to utilize the 18 channels created. These channels are either 1 MHz (Qty 10) or 5 MHz (Qty 8) wide and can be aggregated up to 20 MHz of bandwidth. The rules allow a maximum total power output of 33 dBm (2 watts) per 20 MHz channel with a maximum antenna gain of 9 dBi.

Public safety agencies can apply for licenses to use the spectrum within their areas of jurisdiction. The jurisdictional areas will include all states, counties, cities, towns, municipalities, etc., and will encompass every geographical area that has an established public safety entity. All frequencies will be shared among licensees, and adjacent and co-located licensees are required to cooperate and coordinate in use of the spectrum. Public safety entities are also allowed to enter into sharing agreements or other arrangements with entities (such as power, petroleum, and railroad industries) performing operations in support of public safety.

Coordination for this new band is to be done by the 700 MHz Regional Planning Committees (RPCs). The RPCs are to call an initial meeting to begin planning within six months of the effective date of the rules publication. They must then provide the FCC with a copy of their plan within twelve months of the effective date of the rules. In the event a 700 MHz RPC does not establish a plan governing coordination procedures, 4.9 GHz band licensees would not be precluded from voluntarily establishing a local 4.9 GHz planning committee, appointing one or more band managers or other coordinator(s), or implementing other procedures to facilitate effective coordination of operations in the band.

Progress on the 4.9 GHz plans in the Regional Planning Committees has been slow nationwide as the RPCs currently struggle with their 700 MHz band plans. Region 54, which includes southeastern Wisconsin will work on the 4.9 GHz band issues subsequent to completion of the 700 MHz plan in August or September of this year.

Public safety agencies have high hopes for data communications systems in the 4.9 GHz band. The broadband wireless data communications capabilities of Wi-Fi have a huge potential for new applications at acceptable costs. The ability to “downband” the 802.11 standard into controlled spectrum is a significant plus. Public safety agencies continue to look for cost-effective, robust, secure solutions that will provide higher data transmission rates that can handle larger user data loads over wider coverage areas. Although they are functional, present private RF and commercial solutions provide a maximum throughput of about 19 kilobits per second and do not provide the bandwidth necessary for many of the emerging graphical, photographic, and biometric applications that public safety agencies desire to deploy. These applications normally require and will result in the need to transfer large amounts of data over a wireless network. Shown in Figure 9.1 is a common public safety WLAN application that could be implemented today.

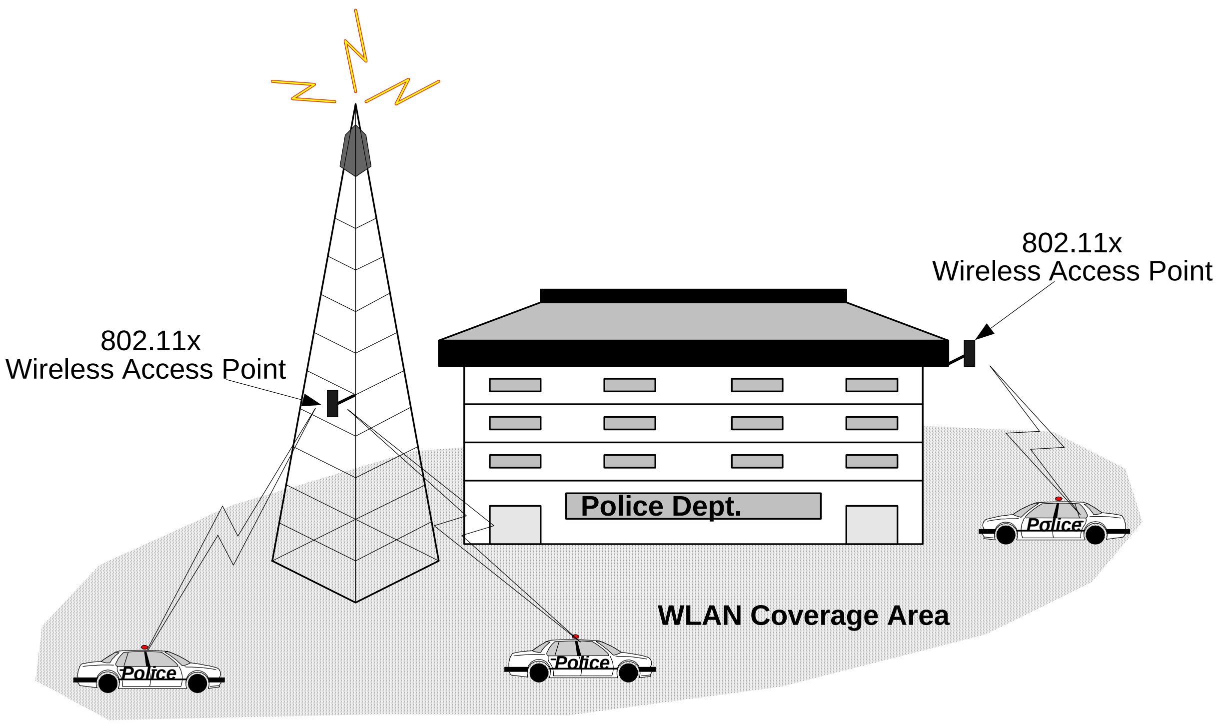


Figure 9.1 - Public Safety Scenario (Source PSWN)

These two WAPs, mounted outside the police facility, are connected to the police department’s wired network via a network switch or hub. As a result the officers outside can access the department’s network through the laptop computers in their vehicles with a broadband connection. This allows the police officers to upload and download necessary information to and from available applications and systems in much the same manner as if they were working at a workstation in the facility.

9.2.1 NPSTC Petitions to the FCC Regarding the 4.9 GHz Band

After reviewing the FCC's Third Report and Order of Docket 00-32, the National Public Safety Telecommunications Council (NPSTC) identified three areas of concern, which it feels will impact the rollout of equipment in this new band. These three issues are:

- The FCC's adoption of an unnecessarily restrictive emission mask will add significantly to the cost of equipment, forming another niche market for public safety, and potentially cause a significant delay in the introduction of equipment.

- Provision of a totally unregulated technology area within an open licensing system that will potentially lead to technology conflicts within common coverage areas of licensees to the point that interference renders the band useless, while at the same time severely hindering interoperability.

- Failure to adopt mandatory regional planning and a conflict resolution process for disputes arising between licensees, and within and between Regional Planning Committees.

NPSTC submitted their petition for reconsideration on July30, 2003 and the FCC hasn't as yet formally responded. The heart of the NPSTC argument is that it would like the FCC to require the 802.11 standards series be utilized in the new 4.9GHz band along with the 802.11 emissions mask. The perspective is that vendors will only need to make a software change on their current 5 GHz equipment in order to operate in the 4.9 GHz band. Thus, public safety will reap the cost benefits of high volume production.

Despite the controversy surrounding the FCC rules, some vendors are moving ahead with their plans for products in the 4.9 GHz band. Motorola, Inc. has formally met with the FCC on two occasions (Dec 2003 & April 2004) and suggested that the standard 802.11 chip set can be used with only a simple external passive filter to meet the FCC emissions specifications. Motorola is moving ahead with their plans and will ship product in the 4.9 GHz range during 2005.

MeshNetworks, Inc. demonstrated a prototype WLAN operating in the 4.9 GHz band at the ITS America Exposition on April 26. The system utilized 802.11 type equipments and showed high resolution, full motion video. This demo also included MeshNetworks proprietary MeshConnex ad-hoc network router/repeater software. MeshNetworks intends to ship equipment in the 4.9 GHz spectrum by yearend.

Tropos Networks, Inc. also intends to have their WLAN equipment shipping in the 4.9 GHz band by early 2005. Today, Tropos equipment is designed for applications in the 2.4 GHz spectrum and they also use proprietary network software called Metro-Scale Cellular Wi-Fi with their 802.11 products. However, Tropos raises the issue that real world RF losses for signals at 4.9 GHz are much worse than at 2.4 GHz. In particular, loss due to foliage absorption can be 20 dB greater along a typical residential street. Thus, Tropos believes that their WLAN products will have significantly less range at 4.9 GHz than at 2.4 GHz. Controlled beta testing will need to be done to determine if these potential higher losses are a serious issue.

9.3 Longer Term Technologies

Software defined radios (SDR) have been long-proposed as the solution to most if not all interoperability issues, except two – availability and affordability! These devices, which can essentially offer software-enabled capability to talk and receive on any frequency band to any other radio, are available to the military but little progress has been made towards having them available, and affordable, for the use of Public Safety entities. FE believes that this is an important area to watch, but that there are no solutions in any reasonable timeframe that could benefit the State of Wisconsin in developing a plan for interoperability.

10 Summary of Phase II

In this second phase of the PSMR Report we have completed a scan of the technical requirements that will impact our recommendations included in the Phase III plan. We began with an overview of the current radio systems being utilized by State and local public safety agencies in Wisconsin. The current licensed frequencies, system infrastructures, tower sites, and support personnel are the assets upon which our Phase II plan must be based.

A section is also devoted to the concepts of communications system interoperability to establish a frame of reference with which we can identify current best practices of agencies in Wisconsin.

We also reviewed the external environmental factors of regulatory and standards making bodies, which will affect the future planning of the State as well as the vendors supplying communications equipment. The significant pressure from the FCC and NTIA for public safety agencies to better utilize the current spectrum assigned will continue. Our recommendations must also take this into account.

And finally we concluded this phase with a number of sections that look at possible solutions, which support communications system interoperability. Included are proven technologies such as audio and RF gateway cross patching and emerging technologies such as Wi-Fi hot-spots. From these alternative solutions we will bring together a set of operational and technical specifications, which the State can utilize in the future to foster a greater level of interoperability across the state agencies and local municipalities. These specifications will be outlined in the Phase 3 section of this report and will form the basis of a set of standards to support improving the interoperability throughout the State.