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# P25 LMR Systems:
# Improving Resiliency and Redundancy with Modern IP Distributed Architecture

## Executive Summary

Public safety communications have evolved slowly since the 1930s. At first, police officers walking a beat had to locate the special phones assigned to them to call in and see if they were needed at an incident. Then one-way radio was deployed in patrol cars and officers could hear calls but not respond. Finally, two-way radio and push-to-talk voice communications came to public safety communications and it revolutionized how law enforcement, fire departments and much later, EMTs communicated with the dispatch center and with each other.

Not many advances were made in public safety communications technology until 1989 when Digital Land Mobile Radio (LMR) was established and then became "Project 25," which is what The Associated Public Communications Officials (APCO) named the standards group working on the digital technology to ensure it would remain a compatible and open standard. It then took 25 years to provide a standard for P25 that enabled multiple vendors to sell into the public safety P25 market. From that point on, very little has changed with P25.

Now Public Safety has FirstNet, a dedicated nationwide broadband network based on Long Term Evolution (LTE), the same technology available to us on our smartphones but on a dedicated Internet Protocol (IP)-based network. Still, Land Mobile Radio and P25 have not changed much in many years.

Then the installation of Next Generation 9-1-1 (NG911) began. This technology is designed to overhaul the Public Safety Answering Points (PSAPs) used to receive calls from citizens that require a response from the public safety community. This technology is also based on broadband access and is IP-based. Meanwhile, LMR remains as it has been for years.

Finally, one vendor looked at public safety voice communications, especially P25 systems, and decided there had to be a way to bring LMR into the 21st century along with FirstNet and NG911. After much effort and consideration of the possibilities, this vendor decided that using IP for a back-end and to connect radio sites to each other at the edge of the network made the most sense. It also concluded that this new P25 standards-based system should not be based on a central core technology as are other P25 systems available in the public safety market. By using IP distributed network architecture with servers/controllers located at each site, this modern P25 LMR system is built using the same site controller to control peer-to-peer communications and multiple functions in the system.

This white paper is based on the results of this work and new ways of looking at LMR communications. The products featured below are in service in multiple installations and are all IP-based. For the first time, LMR systems are up to the same level of interconnection being deployed by FirstNet and NG911. As a result, today all of the public safety communications systems can be IP-based, which means sharing back-end resources and simplifying the architecture for a more resilient and more redundant LMR system that is much closer to meeting the public safety grade standard.

Many public safety communications systems are now being managed within an IT department. IT professionals are not radio experts but they do fully understand the value of IP for back-ends in radio systems and for interconnecting disparate systems to provide a common set of capabilities for the public safety community.

## Introduction

One issue that has long plagued public safety communications is network failures at any time, but especially during major incidents. Public safety networks need to be resilient and when possible, they should be built with several levels of redundancy. One of the ways to provide more resiliency and redundancy is to add redundant components to the network in various places. The most efficient way is to build redundancy into certain portions of the network. This paper will explore how to implement the second option at prices that are affordable. Recently, some vendors have come to recognize the vulnerability of networks that have a central core (brain) where each site is connected directly to the core. At least one vendor has developed solutions that help mitigate core failures and connection to the core failures in a new and unique way.

The proper term for public safety network survivability was coined during the writing of a report by the National Public Safety Council in 2014.[1] The term "public safety grade" was used to differentiate these networks from the more common and more confusing term "Mission Critical" that has been misused in many instances.

This report was the work of a large number of public safety professionals, public safety communications personnel, consultants, vendors, and federal agencies. It was released and provided to the Public Safety Advisory Council for FirstNet the Authority, which reviewed it and sent it on to FirstNet (Built with AT&T). It was also widely distributed to many public safety entities.

In reality, neither FirstNet nor Land Mobile Radio (LMR) systems meet all of the requirements set forth in the report though it has become the bible for agencies and vendors upgrading LMR networks and it is also the model for FirstNet as it expands its coverage and network capabilities.

## Points of Failure

One of the primary matters called out in this report are the potential points of failure for these networks and suggestions concerning how to increase their reliability. The points of failure discussion begins with the tower sites and then moves to the way in which communications traffic is moved from a site back to the dispatch center and the rest of the network. This report also identifies the difference for potential network failures depending on the region. It covers earthquakes, major storms including hurricanes and tornadoes, and much more.

The goal of this report is to identify weak links in a communications system and to propose ways to mitigate them. This includes tower inspections for wind-loading, the amount and type of back-up power at each site, and the type of backhaul (telephone lines, fiber, and/or microwave) and then moves to the back-ends of the networks that, in many cases, are the brains of a public safety network. If there is a failure in in this area, it will bring down the entire network.

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[1] Pdf
http://www.npstc.org/download.jsp?tableId=37&column=217&id=3066&file=Public_Safety_Grade_Report_14052

## Existing Graceful Degradation of Networks

I use the term "graceful degradation" to explain that over the years, Land Mobile Radio systems, especially, have been designed to operate under a variety of circumstances. For example, a Project-25 digital LMR network[2] normally works across multiple sites and multiple channels. However, today if the network loses connection to the brains or core of the network, it will fail-over to standalone radio sites. If a site fails, the final fallback is simplex or off-network communications, which has been part of LMR systems since they came into existence in the 1930s.

When this type of fail-over occurs, it disrupts communications. While most systems may continue to operate on a site-by-site basis, they are no longer part of the network. Once the disruption is repaired, the network must be returned to normal operation. Still, this was the best effort we had prior to recent advancements in network architecture. The end result is that with this new architecture for systems it is much less likely that the entire network will fail due to an issue with connectivity or with the core. Since all the sites have redundant cores that can also handle simulcast, each site will continue to operate even if it is disconnected from the others. When the system is repaired, because it is also self-healing, the full network is quickly back in service.

In the meantime, we are experiencing more major incidents each year than the previous year. In 2018, the number of wildland fires, hurricanes, and tornadoes increased over the previous year. FirstNet has done an excellent job of providing emergency services for its network during these times but many agencies have lost their LMR systems due to one or more of the above failures. There is now a need to review the way in which P25 networks are designed and find ways to improve their resilience and reliability. This paper will delve into what is being done by some LMR vendors to provide new levels of redundancy and resilience. These efforts are being pioneered by one LMR vendor though others, if they are pushed into it, can step up and provide some of the same redundancy. However, they appear to be reluctant to do so because the network design no longer fits what they are accustomed to providing.

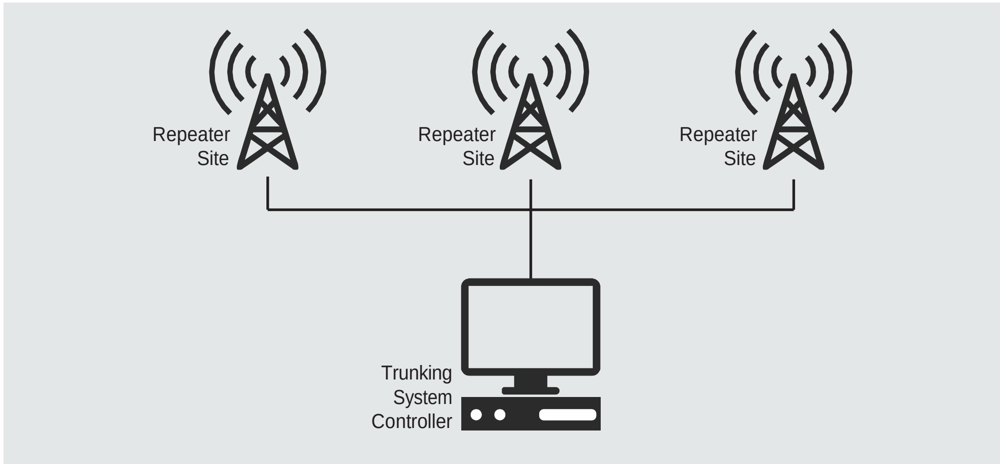
## P25 Network Architecture

To fully understand the impact of this new way to design a P25 network, let's start with a typical P25 trunked and/or simulcast system.[3] These systems have been developed over the past twenty-five years, but while network capabilities have changed and been refined, one important part of the network has remained basically the same.

P25 trunked and simulcast networks all use a central brain or core for controlling the various sites, the number of radio channels at each site, and most of the operational functions of the system. It is clear that any failure that prevents the various sites to be interconnected to the core will result in the network failing to perform up to the level needed by public safety until the failure is discovered and repaired, and the network is returned to full service.

2. https://www.chicomm.com/blog/whats-the-difference-between-a-conventional-and-trunked-radio-system

3. https://www.efjohnson.com/resources/dyn/files/972772z218319c9/_fn/Simulcasting+Project+25.pdf




*Traditional Trunked Radio System with Central Core*

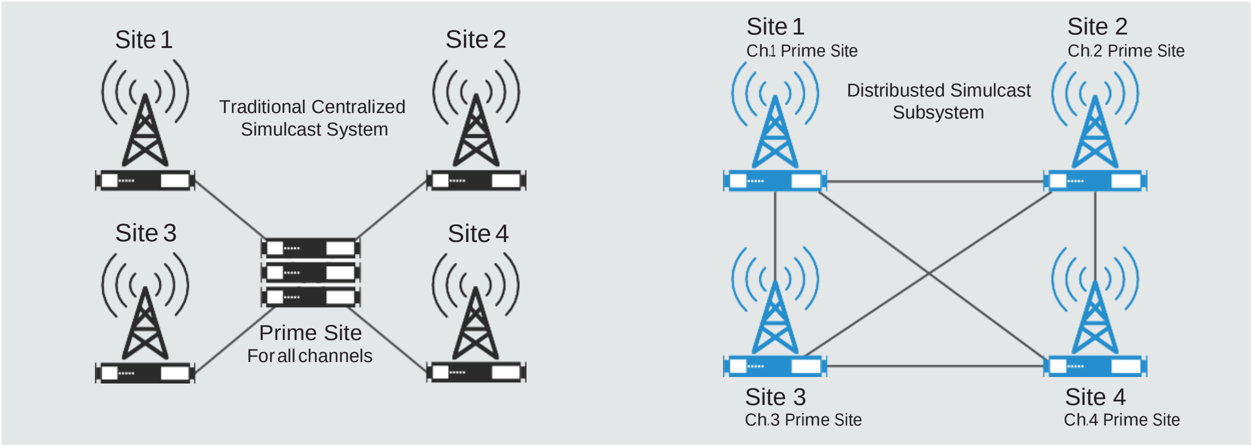
As can be seen in the diagram above, the heart of the typical P25 trunked system is the trunking controller. Without access to the master controller, the network will not continue to operate as a trunked radio system.

**New P25 Network Architecture**

Most P25 vendors have continued to offer this type of trunking system even as the technologies have advanced and the need for increased redundancy has become more apparent. Several years ago, EFJohnson, now a JVCKENWOOD Company, realized there might be a better way of deploying a P25 trunked and/or simulcast system. The company's ATLAS system solution was first introduced to the public safety community in 2011 but it has remained one of the best-kept secrets in the world of P25.

The ideas explored by this company included the point that in today's information and communications market, many of the network's control tasks could be accomplished with software rather than relying on hardware. Further, if the major features of the master controller were put into software and required much less expensive hardware for the network core, then how about moving the controller from a central location so it resides at each radio site? A further level of redundancy can be obtained by installing a second software-operated controller at each site and connect them so they are in tandem with each other.

Now you have a P25 system with a great deal of operational flexibility. Instead of having to connect each radio site back to a central controller, this new design enables each site to be connected directly to each other. Once this is accomplished, the network operates exactly to the P25 system standard, where hardware is decoupled from the software, creating a P25 system as a software-defined network, and there are a significantly greater number of fall backs available on the ALTAS system vis a vis traditional systems.




*Two Types of P25 Trunking/Simulcast Systems*

As you can see from the diagram above, the system on the right has its controllers disbursed and located at each site, and the links are over private IP systems for peer-to-peer communications. If one of the links between two sites is broken, the system continues to function because the site is still connected to the network.

Once the connection has been restored, the system, which is self-healing, automatically returns to full operation. If a system loses multiple connections and the sites are now standalone, because each site has one or two controllers built-in, each site will fall back to a single-site trunked system using a portion of the assigned radio channels.

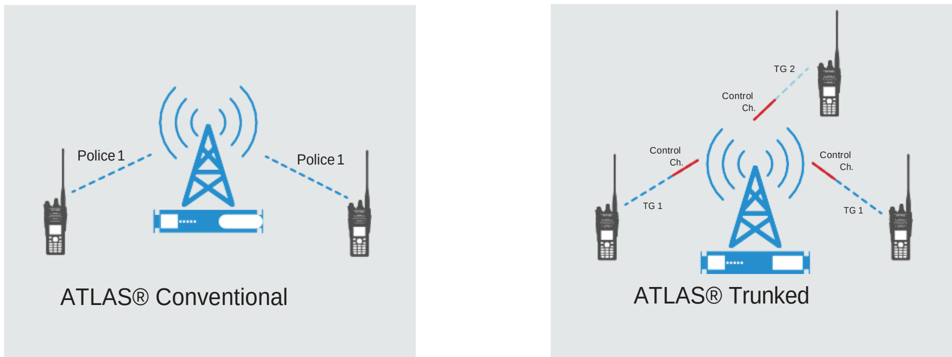
**IP Connectivity**

As depicted above, the connections between sites are all IP-based. This does not mean over the Internet, it means over private IP networks for security purposes. The fact that this network is an IP-based solution means as we move forward in the overall public safety communications systems, all three types of network can and will be IP-based. This includes incoming voice, data, pictures, and videos from the public to the Public Safety Answering Points (PSAPs), LMR, and FirstNet to units and personnel in the field. The end goal here is to be able to create and sustain a total communications solution for public safety as well as other types of entities that need the best possible levels of redundancy available.

Moving to an all-IP back-end also allows for use of wireline, fiber, and microwave on an almost interchangeable basis. A major advantage to an all-IP network is that generic hardware can be used, thus lowering the cost. This means IP-based technology cost and capability curves can be followed on the hardware side, hosting of public safety-specific functions and applications can be enabled, and the necessity for proprietary or costly custom hardware can be eliminated. Today's private IP systems are developed and implemented to be more robust than existing backhaul systems. Further, IP systems are much more familiar to IT departments that are playing a more significant role in public safety communications as many public safety communications personnel retire and their departments are combined with IT departments, which already handle IP circuits for data services, email, and in many cases, replacement for landline phone systems.

**System Capabilities**

In addition to P25 trunked and simulcast systems, this system is also capable of controlling P25 conventional and hybrid systems.




*ATLAS Conventional System and Trunked System*

Systems based on distributed software cores or brains have already been installed in a number of networks from smaller local networks to networks that cover much broader areas. One system that has been installed and is up and operating in a U.S. territory encountered a huge amount of damage after a hurricane. Both LMR and cell phone service was non-existent and as these systems were being rebuilt, this architecture was chosen to increase the robustness of the system.

One of the best examples of the ATLAS system is found on the island of Puerto Rico. The ATLAS system replaced the typical LMR architecture previously in place and is functioning as advertised, providing a higher level of service to the public safety community on the island. Hawaii has installed an ATLAS system as has the Dallas-Fort Worth International Airport (DFW). These systems are operational and have proven to be more reliable due to this new architecture.

There are systems installed and up and running, and those that have moved to this new architecture are pleased with their decision. The system includes all the components and software needed. The ATLAS system offers P25 base stations with power levels adjustable from 30 to 100 watts, gateway/interfaces (that replace the standard core or central-system brain), network management, and dispatch consoles if desired.

The system I visited at DFW has been up and running for several months after final acceptance and the organization is in the process of expanding its reach to interoperate with cities in the area. This system is an 11-channel trunked system at multiple locations. The site equipment takes up only three racks, with the radio transmitters/receivers stacked in one rack and the gateways/interfaces and power supplies in the others. In this case, the owner had decided to have two gateway/controllers at each site for another level of redundancy. This particular installation was one of the nicest I have seen and included back-up batteries and a generator, fire suppression equipment, entry and exit alarms, and video surveillanc**e.**

The site is connected to the other sites in the system and the gateways/interfaces are sharing data about network status, users on a given site, and much more. As mentioned earlier, these controllers are small and sleek but the software inside them supports many different functions including communication with other controllers, managing the trunking and simulcast at a given site, and much more.

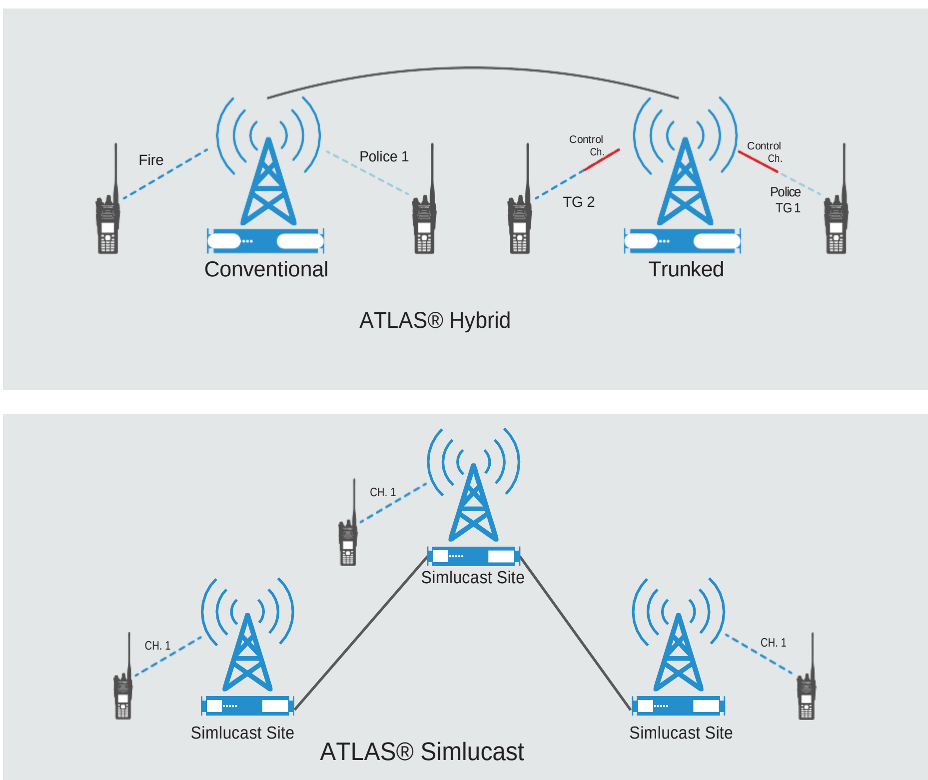
**P25 Licenses**

One of the other features I found to be unique is the new software and hardware licensing system JVCKENWOOD has pioneered. Normally, any time a new site is added, or more radios are deployed, the vendor charges additional license fees. The difference here is that the ATLAS solution does not require a software license fee regardless of how much new equipment is added or new sites are built. This makes it easier to manage capital and operational expenditures without licenses required and, hopefully, the move to this new license model will be duplicated by other vendors.

The ATLAS solution by JVCKENWOOD also ensures that other vendors could build equipment for their networks. Today there are two other vendors that offer base station radios compatible with the system. Thus, when an agency wants to issue a Request for Proposal or a bid request, multiple vendors can respond. Further, as mentioned, there are other vendors that could also offer the same type of architecture to customers. However, they seem reluctant to do so, perhaps because they would be less cost-effective with their systems than JVCKENWOOD.

**Types of Systems**

This does not have to be the only architecture used for a complete system overhaul. It can be added to many existing P25 systems and over time it can be used to replace those systems or remain as a working sub-section of the system. This P25 platform has been developed with the ability to connect to other P25 systems in mind.



**Conclusions**

The work JVCKENWOOD has done to create a more modern, more robust P25 platform has not been touted widely, but agencies that have installed it have only praise for the way it works, the flexibility it provides, the automatic discovery of a new site or sites coming back online, and the robustness of the network even when one or more links between the sites fail. While it is an IP-based network, it should be reiterated that it is designed for private IP networks with no Internet connection, which means it remains totally secure from a network perspective.

It appears from my research into this product that a typical ATLAS P25 system is less expensive, from both a capex and opex perspective, than systems from other vendors offering the central core approach to P25. The ATLAS no license fee model for the system regardless of how many sites or devices are added over time makes it easy to budget.

One of the exercises being required today by many agencies is not to go to bid simply for the equipment and installation but to require a bidder to provide a total cost of ownership for ten or fifteen years. The numbers I have been shown and the math behind them shows me that this system is less expensive to purchase and the opex over a fifteen-year period is considerably less than many systems offered by JVCKENWOOD’s competitors.

I am impressed with JVCKENWOOD’s development of this type of P25 system and I think it is a logical advancement in LMR communications. It has enabled others to bid on the base stations in the system to ensure lower pricing and other vendors could but don’t seem to want to submit bids for this type of system architecture.

Not only as an author but as a consultant to the public safety communications industry, I am recommending that you purchase JVCKENWOOD’s ATLAS architecture and system. Still, I am suggesting that you consider this in your next LMR purchase and give JVCKENWOOD an opportunity to demonstrate what it can provide. This new P25 architecture delivers new levels of resiliency and redundancy—two attributes that are becoming increasingly important in the world of public safety communications.

Andrew M. Seybold