Public Safety LTE Demonstration Network Final Report May 2015

Town of Vail & Beaver Creek, Eagle County | Colorado

FNC CO

FirstNet Colorado

Section 1: Introduction

From February 2-15, 2015 the world of alpine ski racing came to the Town of Vail and Eagle County, Colorado for the International Ski Federation (FIS) 2015 Alpine World Ski Championships (AWSC). During the two week event, 220,000 athletes, coaches, staff, media and spectators called the mountain communities throughout Eagle County home. With multiple daily activities, world-class competitions and nightly celebrations, the 1,100 local first responders and volunteers had their hands full ensuring the event was safe and enjoyable for everyone.

In preparing for the event, local first responders had an idea; lets quit talking about Public Safety LTE and see what it can actually do. During the ensuing process an incredibly powerful partnership formed between the public sector - [the Town of Vail, Eagle County, the State of Colorado (FirstNet Colorado), and the Federal Bureau of Investigations (FBI)] and the private sector [General Dynamics-Mission Systems (GD-MS), Crown Castle, Sonim Technologies, SLA Corp, Drakontas, CalAmp and inMotion] – that was able to develop and create a first-of-its-kind, Band Class 14 (BC 14) Public Safety Long Term Evolution (LTE) Demonstration Network (PSLDN) utilizing an existing multi-carrier, Distributed Antenna System (DAS), along with deployable solutions that provided communications throughout the Town of Vail and in some of the most difficult to reach areas of the Beaver Creek Ski Resort. Through the process of building, deploying and using the network we gained tremendous insights not only about the technology but how it will be used and integrated from a holistic perspective as well.

This report will provide a quick review of the construction and implementation of the network and then focus on the practical use of the network, detail the technical performance and finally discuss lessons learned. A second companion report prepared by the Department of Homeland Security, Office of Emergency Communications, Interoperable Communications Technical Assistance Program (DHS-OEC/ICTAP), 2015 FIS Alpine World Ski Championships Band-Class 14 LTE Demonstration Network Assessment Report is available that focuses on the technical aspects of the demonstration. Our hope is that the lessons learned from this experience will assist in the development of a Nationwide Public Safety Broadband Network that will meet the needs of all local responders.

Section 2: Background

The Environment

Eagle County sits in the Central Rocky Mountains in Colorado, home to two of the world's top ski resorts, Vail and Beaver Creek. Each resort had its own unique challenges with regards to deploying an LTE network. For Vail, the challenge was developing a solution to enhance public safety communications during events in which 10,000 people, concentrated in a few square blocks would overwhelm the commercial networks. Vail has strict building codes and is located in a long narrow valley surrounded by national forest so the use of existing assets was a necessity. For Beaver Creek, the challenge was providing even basic service at an elevation of almost 9,000 feet above sea level in a secluded mountainous area that was deemed by one public safety official as "one of the most hostile" areas for radio frequency (RF) coverage they had ever encountered. With upwards of 7,000 spectators and athletes pushing their physical abilities in such a remote area, communications is critical.

Figure 1: Map of Beaver Creek and Vail with Terrain

Frequencies?

Obviously to build a wireless network you need frequencies. The current Spectrum Manager Lease Agreement (SMLA) between FirstNet and the Adams County Communications Center (ADCOM) pilot project limits the coverage to Adams County. After initial discussions to expand the scope of this agreement provided no solution, the State of Colorado applied for and received a 30-day Special Temporary Authority (STA) from the Federal Communications Commission (FCC) with the approval of FirstNet. The STA was structured to begin two weeks prior to the races to allow for proper optimization and testing before the event.

How the Network Came to Be

While preparing for the event, the Town of Vail initiated conversations with the FirstNet Colorado team, hoping to address a major dilemma based on some simple truths:

1. They traditionally had problems with cellular (voice and data) communications during large events.
2. Mobile broadband communications had become more integrated and integral to their daily operations. The commercial networks, even with increased investment, would become overwhelmed at points.
3. They had recently worked an arrangement with Crown Castle to develop a brand new fiber fed Distributed Antenna System (DAS) that had the capacity to carry Band Class 14.

Early on, it became evident that private sector partners would be critical for the success of the project. Additionally, in order to provide a comprehensive demonstration, the Eagle County Sheriff's Office (whose jurisdiction included the Beaver Creek venue) and federal partners needed to be integrated into the discussions to create a comprehensive solution. As each entity was folded into the conversation the perspective was the same, we needed reliable, robust broadband communications and had to work together to develop a solution.

Seeing the Future of Distributed Small Cells

More than two years ago, the Town of Vail leaders realized they had a problem. The demands of running a world-class year-round resort were quickly outpacing the capabilities of available wireless infrastructure. Further, they knew the problem would only get exponentially worse. Realizing the need to be creative, the town turned to Crown Castle for a solution. Working together, the town provided certain real estate and rights-of-way to Crown Castle in order to build a fiber network that would support a DAS network and other high bandwidth product offerings throughout the town that Crown Castle would own and manage. A solution was needed that could provide reliable wireless service in difficult to cover areas in and around the Village pedestrian areas, where small streets, tall buildings, and dense crowds congregated at the base of the ski slopes. The existing wireless infrastructure, which included a limited number of rooftop antennas, did not have sufficient capacity to handle the increasing data demands of visitors throughout the area. The Town of Vail wanted a solution that would limit the proliferation of infrastructure in the town and could also be used by all major wireless service providers. The town also required deployment of a municipal WiFi network that could be used by the public.

Working together, the Town and Crown Castle were able to deploy a multi-carrier DAS, a network of antennas locations, or nodes, connected by approximately six miles of fiber optic cable, providing enhanced coverage and much needed additional capacity. Crown Castle constructed the system, laying the fiber optic cable and installing new poles in the public right-of-way. The original system consisted of 22 nodes mounted on newly deployed poles, and one rooftop node at the fire station, in addition to a complimentary Crown Castle neutral host indoor DAS in the multi-story Vail Transportation center parking structure. This system was later was expanded to a total of 29 nodes to meet the demands of a second wireless service provider which joined the network. Figures 2 show examples of the independent nodes within the DAS.

This forethought and partnership between the Town of Vail and Crown Castle would prove to be the foundation for the Public Safety LTE Demonstration Network.

Figure 2: Actual Distributed Antenna System nodes within the Town of Vail

Communicating on the Racecourse

With the racecourse and finish line (where the grandstands would be) nestled in the mountains at almost 9,000 feet above sea level the next challenge would be to provide similar communications to the responders in Beaver Creek. With each race having up to 7,000 spectators watching athletes hurl themselves down a mountain at 70 MPH; you have a potential public safety communications nightmare. As the situation was analyzed, it became clear, we needed a deployable solution.

Implementing Deployable Solutions

After deciding on a deployable Cell on Wheels (COW) solution provided by GD-MS, the question was how to place the COW to provide the best coverage. While this deployable technology had been used in multiple situations, the needs of this event were unique. Even placed at a high point in the Beaver Creek Resort, the terrain would be too difficult to get widespread propagation. Working with the local first responders, GD-MS determined that the most beneficial use would be to place the COW to provide coverage at the race finish area where the largest crowds would be located and there was significant potential for critical incidents. Working with local providers, the COW was deployed and connected via a landline circuit (20MB provisioned over a 1GB DIA circuit) to provide a direct IP link back to the main network in Vail. Figure 3 provides a view of the terrain covered by the COW.

Figure 3: Looking up toward the race venue from the location of the COW

Section 3: Building The Network

While the DAS provided the foundation for a potential network, the next step was determining how to best use it for Public Safety LTE. With three of the four major carriers already on the DAS, the type of eNodeB's to be utilized as well as how to integrate them into the existing infrastructure and utilize the BC-14 radios without affecting the commercial carriers was the critical next step.

Network Infrastructure

As the vendor to the current ADCOM pilot project, GD-MS agreed to participate in the demonstration by providing the eNodeB's, the Virtual Core Network (VCN), mobile hotspots, engineering and services to deploy the PSLDN.

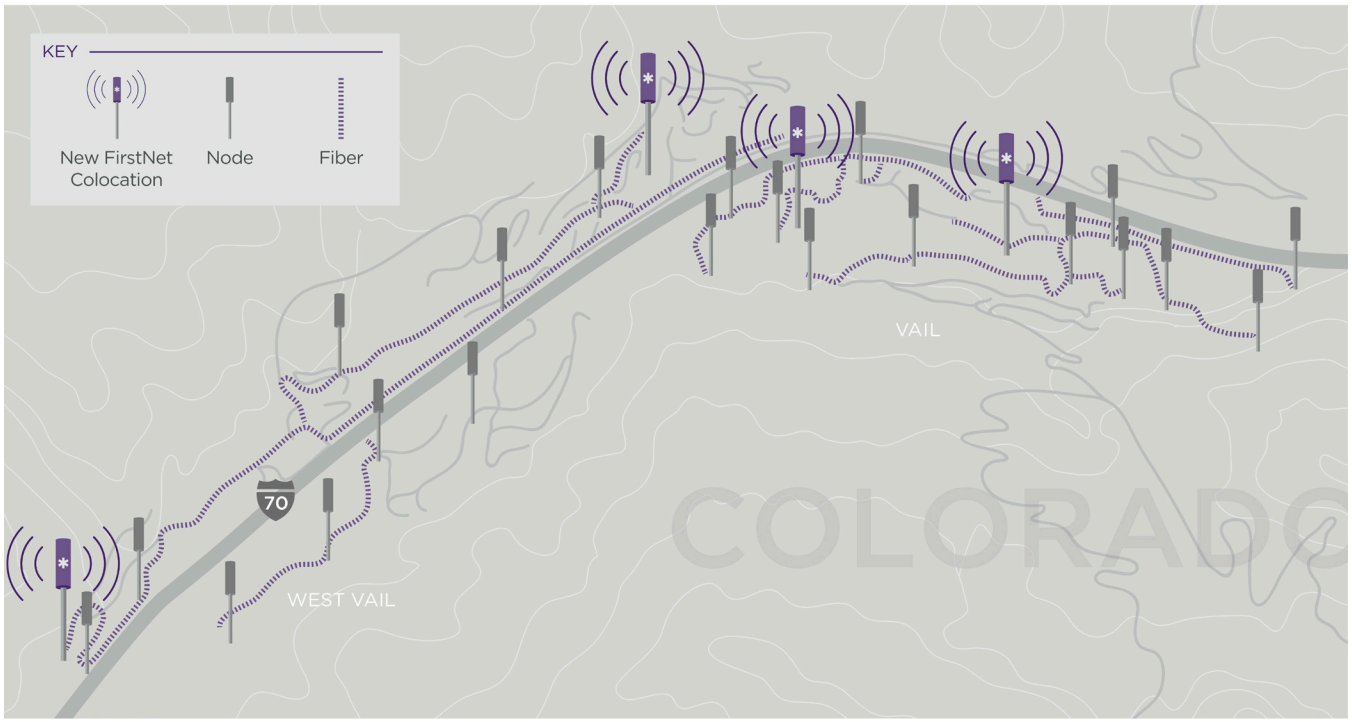

Figure 4: Location of Public Safety eNodeB's in Crown Castle's Vail DAS: Image courtesy of Crown Castle.

With the core infrastructure components decided upon, there were still a number of questions to answer before deploying the PSLDN. How would the eNodeB's interact with the DAS? Would there be interference with the commercial carriers? Could we tie the Beaver Creek and Vail networks together? Answering these questions resulted in the basic design of the overall network being completed. The PSLDN would utilize four available sites within the DAS, and be interconnected via the VCN located at the existing DAS operations center. The existing Internet access used by the Town of Vail would be tied into the network and all traffic would be routed back to the Event Command Post (ECP). The COW deployed at the Beaver Creek venue would have its own VCN to manage the specific venue traffic; the two VCN's in Vail and Beaver Creek would be tied together to form a seamless system. Figure 4 shows the PSLDN eNodeB deployment within the Town of Vail.

The final step was network implementation. With strict Town of Vail building codes that limited construction activity between the hours of midnight and 6:00 a.m. and a limitation on the available installation resources due to deadlines associated with completing the commercial portion of the DAS there was significant doubt the network could be implemented in time. The existing infrastructure proved to be the game changer; working together, GD-MS, Crown Castle, the Town of Vail and Eagle County were able to design and install the BC-14 network elements in less than three weeks.

New software available through this technology will have a dramatically positive effect on public safety, but it will take a tremendous amount of up-front planning.

Section 4: Using the Network

With the BC-14 Public Safety LTE signal now propagating throughout the Vail Village and the race venue at Beaver Creek, the team needed to identify the best way to provide a valuable end user experience. Working with the local first responders it was determined that the network would focus on the operational needs related to crowd control and traffic management. Based on these needs an initial list of potential uses was developed:

- Ruggedized smartphones to provide Push-To-Talk (PTT) voice communications and situational awareness
- Fixed video surveillance throughout both venues
- Mobile vehicular modems to provide WiFi hotspots, which were also accessible on commercial devices

Smartphones

The primary end-user experience would be via 35 ruggedized smartphones provided by Sonim Technologies. The smartphones came pre-loaded with a PTT application, ESChat by SLA Corp, and the situational awareness application DragonForce by Drakontas.

Local first responders worked with Sonim, ESChat and Drakontas to develop a plan that would allow them to utilize the devices and applications to their fullest extent in support of achieving the goals for the demonstration. Focusing on the goals of crowd and traffic control the smartphones would be distributed to both venues (Vail and Beaver Creek), to responders that would best be able to test the network given the overall goals. This included the Quick Response Team (QRT) assembled to deal with any critical incident that may occur. The PSLDN also provided complimentary communications to the mission critical Land Mobile Radio (LMR) voice system. The group communications and situational awareness would be used by the command center to communicate with and to provide a seamless mechanism to distribute information to first responders.

Video

As with any large-scale event, video surveillance is critical in dealing with active situations and preventing potential situations from escalating. During the event, local and federal law enforcement officials utilized multiple video cameras, including state of the art Megapixel cameras throughout the venues to monitor activity. These Megapixel cameras provide super high-resolution images of areas that can be a game-changer for video monitoring. Unfortunately, the cameras are bandwidth hogs. As part of the overall PSLDN design, GD-MS worked with first responders to ensure there would be adequate capacity for all operational needs.

Mobile Hot Spots – BYOD for Public Safety

Unfortunately, the difficulties in reconfiguring existing Computer Aided Dispatch (CAD) and Records Management Systems (RMS) networks to utilize the vehicular modems proved too much to overcome for a worthwhile test of the network. However, the availability of the vehicular modems proved to be incredibly powerful tool after all. What if the vehicular modems were deployed as mobile WiFi hot spots utilizing BC-14 spectrum to allow for additional access through personal or agency-issued commercial devices? Through some ”creative engineering” and multiple trips to the local hardware store, four mobile hot spots were deployed which allowed for targeted venue placement to support additional first responders, event security, and volunteers. This included placement for better in-building coverage and the primary venue locations.

This last minute change of plans turned out to be critical. In any large-scale event, ad-hoc first responders, volunteers and private firms can play a critical role in the overall public safety effort.

Given the high cost, logistical and security issues related to providing public safety devices to these groups, the concept of Bring Your Own Device (BYOD) proved tremendously valuable. The event applications could be deployed on almost any smartphone; access to the dedicated BC-14 network eliminated the problem of congestion caused by the general public. Mobile WiFi hot spots were utilized to provide the necessary access and were met with tremendous success.

LMR Integration

During the initial preparations, the team opted not to integrate the existing LMR system with the BC-14 PSLDN to minimize the complexity of the demonstration. During the second week, there was an opportunity to demonstrate a proof of concept LMR/LTE integration via a gateway. While the integration was only for a single talk group, it provided an excellent way to expand the reach of primary talk group in to the field. Additionally, this integration demonstrated how first responders could utilize the BC-14 smartphones to support LMR capabilities.

Section 5: Network Performance

Overview

In general, the network solidified many of the initial expectations and functioned exceptionally well. This section will discuss the performance of the network at a high level and highlight the critical takeaways from the demonstration. For a thorough technical analysis, please see the companion assessment report created by the Department of Homeland Security, Office of Emergency Communications, Interoperable Communications Technical Assistance Program (DHS-OEC/ICTAP), at State of Colorado 2015 FIS Alpine World Ski Championships Band-Class 14 LTE Demonstration Network Assessment Report. You may also find this report on the FirstNet Colorado website at firstnetcolorado.org/psldn2015.

Speeds

During the event, the BC 14 network showed consistent download (DL) speeds of 20-22 Megabits Per Second (Mbps) with upload (UL) speeds of 10-12 Mbps. While these speeds were analyzed and found to be lower than one commercial carrier, they were significantly higher than two other commercial carriers and the speeds were maintained throughout the event.

Comparison with Commercial Networks

As expected, the BC-14 PSLDN maintained consistent performance when commercial networks became overloaded. While commercial networks generally had equal or better performance during non-peak times, the decrease in commercial network capacity during peak times was substantial.

As discussed in the corresponding DHS/OEC report, commercial carriers saw up to a 70% decline in upload (UL) speeds during peak events while the BC-14 PSLDN maintained a consistent DL speed of 20-25 Mbps. Figure 6 shows the performance during a peak period.

Push-to-talk (PPT) is a requirement, not an option.

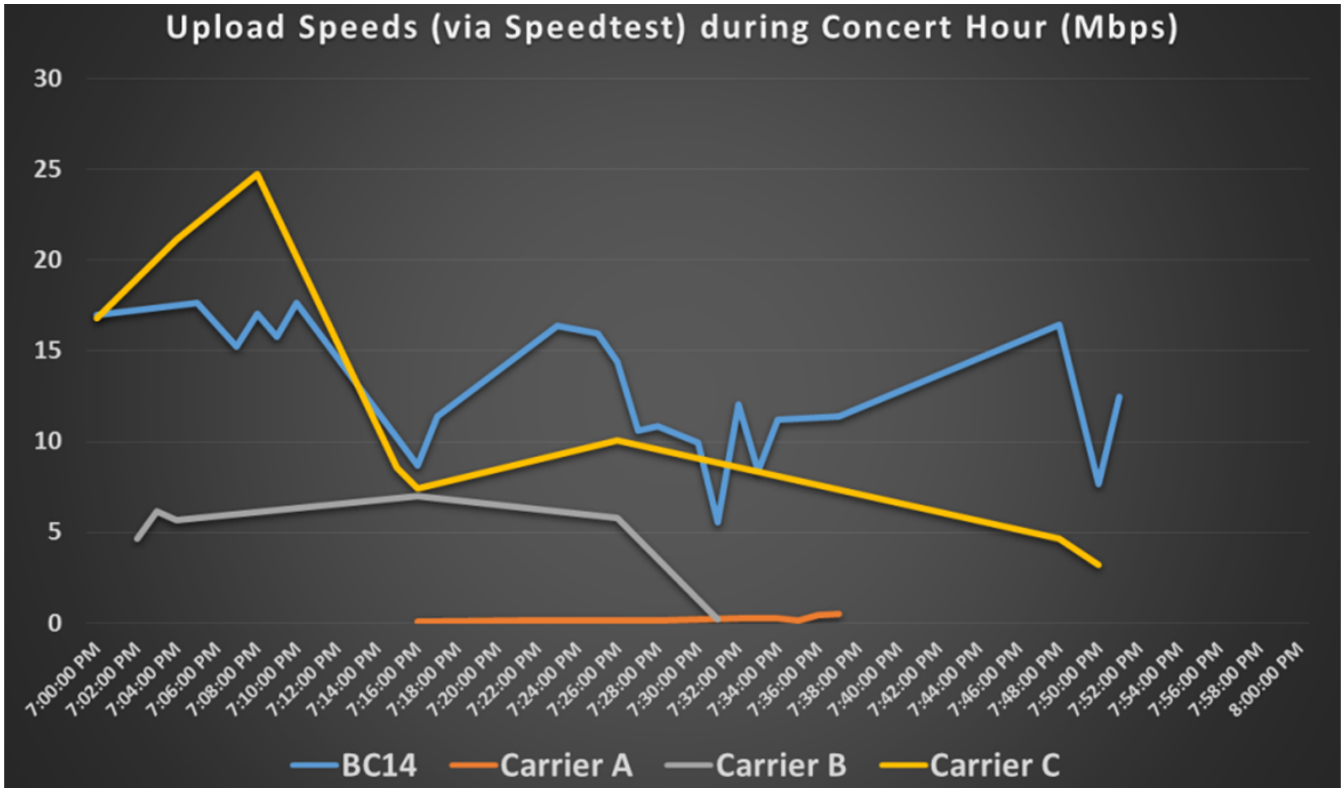

Figure 6: Performance of networks during Phillip Phillips concert, courtesy of DHS/OEC

Coverage

Network coverage exceeded expectations. As Figure 5 shows, the PSLDN covered a vast majority of the Town of Vail with only four eNodeB's with 2 sector antenna installations. Extensive drive testing in the Town of Vail validated the coverage.

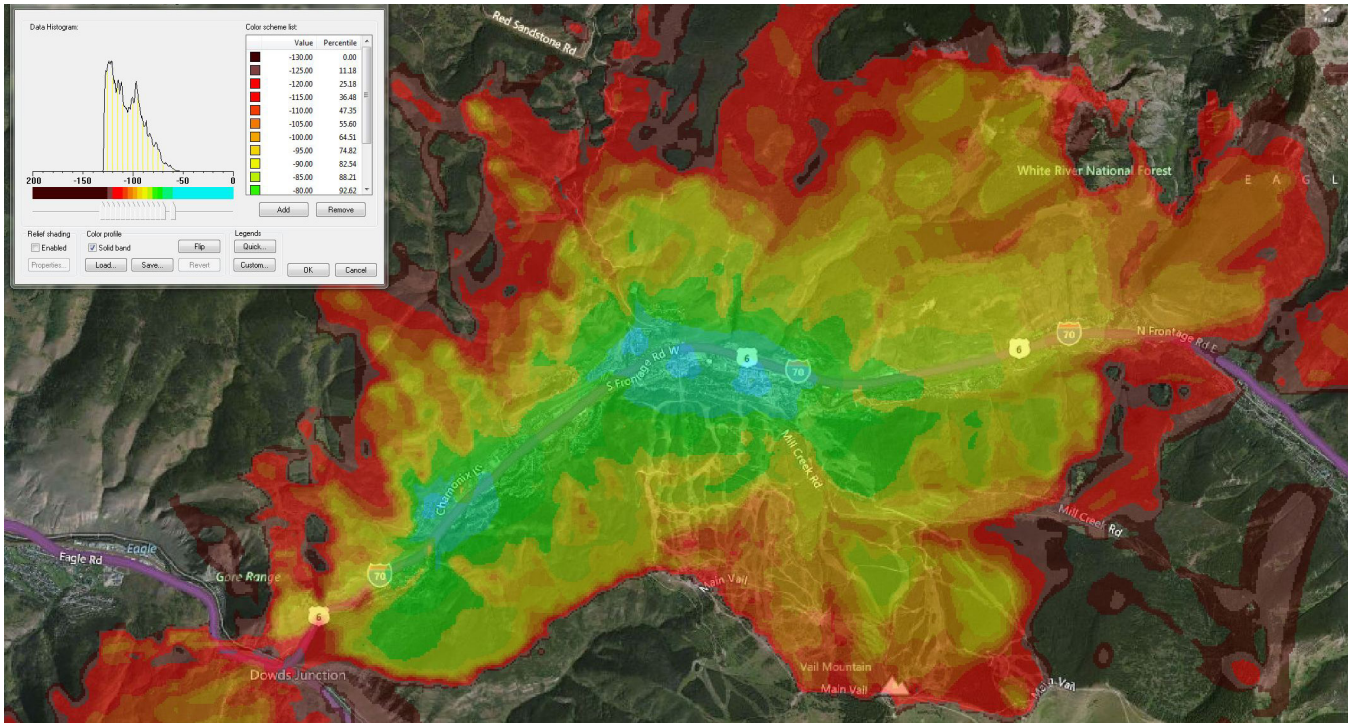

Figure 5: Coverage provided by demonstration network in Town of Vail

In Beaver Creek, the COW provided reliable BC-14 LTE coverage in remote areas and as an augmentation to LMR capabilities. The single sector eNodeB COW afforded solid coverage throughout the race finish venue, especially when combined with the WiFi hot spots to improve indoor and/or specific location coverage.

Unanticipated Findings

The Capacity of a Single eNodeB

Based on the available resources, a single eNodeB within the Town of Vail handled a vast majority of the LTE traffic during events. As a result, it was an excellent way to test the operational capacity of an eNodeB. This eNodeB handled a tremendous amount of traffic: 4 high-definition cameras, 20 devices and multiple personal devices through mobile hotspots. While the number of devices was nothing extraordinary, the constant throughput to the devices was remarkable. By dedicating a specific bearer to the cameras (which was identified as a top priority), the network maintained a high-level of reliability for video while allowing additional use as well. Each camera was able to maintain an (8 – 10 Mbps functional data stream), and had adequate bandwidth for use by other devices.

Proving the Distributed Core Architecture

One of GD-MS's key learning goals was validated - a distributed core architecture, in which multiple VCN's (equivalent of an Evolved Packet Core) were networked to form the larger system. This test will have significant implications on the nationwide effort. GD-MS set up the COW (configured with a VCN) at the race finish area in Beaver Creek with a second VCN at the DAS control room in Vail. These VCN's were connected via a combination of fiber within the DAS and a leased-circuit from a private provider. The results were clear. First responders, functioning on two unique networks seamlessly communicated across the VCN's providing ubiquitous interoperability. Additionally, this interoperability was extended to personal or agency issued commercial devices (with the various applications loaded) which accessed the network via the BC-14 WiFi hotspots – responders and event staff could communicate securely with other first responders.

Initially, core-to-core communications that would let first responders between Vail and Beaver Creek communicate seamlessly was not a confirmed element of the network design. Fortunately this capability was achieved, and proved to be a powerful element of the network. While the scope of the test was limited, the concept that multiple cores could work together, linking smaller disparate networks will be critical to solving many of the public safety communications LTE needs.

Section 6: Lessons Learned

Overall, the PSLDN provided numerous operational, technical and central lessons that can be applied to the development of the National Public Safety Broadband Network (NPSBN).

Operational Lessons

The App revolution must be planned: New software available through this technology will have a dramatically positive effect on public safety, but it will take a tremendous amount of up-front planning. As the stakeholders began working with the application providers to set-up the applications for use, it quickly became apparent that this technology is different than what public safety has historically used. With the emphasis on dynamic, ad-hoc communications and group communications the process of setting up the applications was critical. The lack of time to draft a comprehensive operational approach with input from the first responders and the application developers caused the limited scope of use; it would have been used significantly with more time. The ability to understand

and bridge the technology capabilities with the operational requirements of a specific jurisdiction will be critical. Agencies will need to ensure this expertise is either on staff or readily available.

Must balance technology and old school: The technology will have impacts on how first-responders interact with the public. Within a few days of using the technology one first responder noted that while the devices were fantastic and powerful, if he was constantly staring down at his screen, he could not observe the large crowds for suspicious behavior, which was his primary duty. Just as we have all accidentally walked into someone because we were focused on our phones, first responders must learn how to balance the influx of data, with the critical human interactions and physical observations. Similar to Next Generation 9-1-1 (NG911), these technologies will have significant 'human' impact factors that must be addressed.

BYOD will become a major issue: As any emergency management professional can attest, managing planned or unplanned events relies on a wide range of individuals working together successfully. Once the NPSBN is deployed, not everyone involved in an incident will have a BC-14 device. The utilization of the mobile hot sports during the event proved that WiFi is a complimentary technology within the NPSBN and that agencies must consider that some responders will be utilizing personal or agency issued commercial devices in day-to-day operations as well as critical events.

Technical Lessons

Push-to-talk (PTT) is a requirement, not an option: Far and away, the most positive feedback was the ability to have PTT communications on the LTE device. Additionally, there was a strong sentiment that the responders desired to use a single device for all operations. For example, one first responder said (while holding up his LMR radio) 'When can I get rid of this?'

- The ability to efficiently define and utilize group communications was commended
- The PTT voice quality was excellent
- It's a viable alternative to existing LMR system capabilities

The NPSBN must have effective PTT capabilities from day one to increase the adoption of the network.

We need a 'single' device: Once this technology is placed into the hand of first-responders, they will quickly demand it become their only device. While full-fledged mission critical voice over LTE will take time to implement, first responders will require that a single device provide both LMR and LTE communications.

We need more types of devices: There were not enough BC-14 devices available to deploy to all event responders; largely due to the grass roots planning efforts with private partners. The ability to distribute devices to all responders from initial NPSBN deployment will be critical.

Integrating LMR and LTE is easier than expected: As with most things unfamiliar, the fear of the unknown is worse than the reality. So it is with LMR and LTE integration. The quick integration of these disparate technologies was easier than anticipated and extremely powerful. In order for public safety to quickly embrace LTE technology operational integration of these technologies must occur with the initial deployment of the NPSBN.

Video is an Elephant and 800-pound Gorilla combined: While the success of the enhanced video capabilities was a welcomed outcome, it unfortunately complicates the future of the NPSBN. Extrapolating the bandwidth consumption of video on the future NPSBN, engineers should recognize the network must be built to withstand and accommodate the load it creates. While this technology should be paired with fiber optics backhaul whenever possible, the desire to utilize the wireless network for enhanced video is inevitable. The implications of extensive video use range from realistically eliminating revenue generating excess capacity in high-density urban areas to increasing

the cost in rural and/or recreational areas. Video streaming must be accounted for in the initial build-out; failure to do so could have significant impacts on the long-term stability of the network.

Rural coverage and capacity is more achievable than people think: Perhaps the most welcomed revelation was that this technology can be implemented in rural areas providing a tremendous beneficial impact to the first responders in those areas. While many believe it could take years, extraordinary effort, and significant cost to deploy into rural areas, the PSLDN demonstrated that with local collaboration, the use of existing infrastructure and a little creativity, the technology can be of great benefit to rural areas.

Central Lessons

The Technology Works and We Need It Sooner Rather Than Later

The acceptance of and response to the PSLDN was eye opening. Local first responders, with no or limited professional exposure to or training in the technology quickly 'personalized' it and craved more. Working together, they determined out how to best integrate it into their operational needs and when the demonstration was to (originally) terminate a few days prior to the end of the event the response was "I don't think that will go over very well" with repeated requests that the network not only continue through the end of the event but become permanent. Just as most of us have become reliant on smartphones in our personal and professional lives, first responders are no different. The additional capabilities provided by Public Safety LTE have become a requirement for first responders to efficiently and effectively do their jobs.

The Rural Impact

Rural jurisdictions will use and rely on this technology as much as their urban counterparts. It's a common argument that responders in the urban areas have a greater need for this than their rural counterparts; this could not be further from the truth. Based on the observations from this event, the antithesis could be argued. A long-standing complaint from first responders in rural areas (especially mountainous areas) is that LMR is spotty due to its reliance on high sites designed to cover large areas of land. The concentrated, and smaller footprint of the LTE architecture may actually help rural areas more as LTE will augment those areas where LMR is inadequate. With the ease of integration between LMR and LTE, rural areas still requiring even basic communication can quickly benefit from the implementation of the NPSBN.

Local Needs Still Rule

The implementation of the network must be flexible and will be influenced greatly by local needs. From the make-up of local first responders to different local-state structures to the various geographic challenges, this demonstration was an example of a localized need and localized solution. While Eagle County and Vail Valley responders have significant incident experience, none would claim to know how to replicate this network in the Gulf Coast for a major tourist event during hurricane season. Just as the tranquil waters of the Gulf and the majestic mountains of Eagle County represent the opposite extremes of this country, the first responders that call these areas home must take a unique approach to protecting their citizens and their solving their communications challenges. Understanding these needs and implementing the critical communications infrastructure properly will be a crucial element of the success or failure of the NPSBN. National interoperability means little without local operability.

Multi-faceted Public-Private Partnerships Work and Utilization of Existing Assets is Critical

The success of this demonstration was centered on two things, 1) the power and determination of the partnership, and 2) the ability to tap into existing assets. As previously stated, this network would not have been possible without utilizing the existing DAS, local government assets and the

private partnerships and relationships created to build those resources. Furthermore, the integration of local first responders into the requirements analysis and network implementation was critical. We must leverage the existing infrastructure and first-hand operational knowledge to create effective local operability.

Let's Get Agile

In the 1990's, software developers tried to figure out why large scale projects kept failing despite the best efforts of everyone involved. What they found was the 'Waterfall' approach, grounded in idea that you must follow a highly structured, rigid and linear process focused on 'requirements' and 'metrics' was itself flawed. By the time the requirements were gathered, deciphered, coded and tested, they had changed and so had the environment in which the system existed. From this revelation, Agile Development found its genesis. Rather than spending precious time, energy and money trying to identify the 'perfect' application, developers should create and deploy something 'functional' into the hands of users and go from there. One of the key tenets of this movement became 'Responding to change rather than following a plan.' This approach has revolutionized the software industry and has led to the 'App' platform that is reshaping the world. Based on the lessons learned from this demonstration applying Agile methodologies to the development of the NPSBN may be the difference between finally providing long-promised communications solutions to our first responders and wandering through a multi-year process that will leave everyone wondering what could have been.

Section 7: Conclusion

For almost 10 years, public safety has seen countless videos and heard numerous stories about the benefits of dedicated public safety broadband network. While these stories and videos have heightened expectations and created wonder, there has been minimal evidence or proof of concept to support the futuristic tales. By its nature, the public safety community is skeptical of the unproven; this skepticism has left many wondering if we are chasing something unattainable. The most valuable aspect of this demonstration was that it took the fantasy out of Public Safety LTE and made it reality. Putting this technology directly into the hand of first responders, rather than those of actors on screens, helped to prove the technology is critical to the success of the first responders. While this demonstration exceeded expectations in understanding the adoption and impact of the technology, it also emphasized that we must do this right the first time. A successful public safety broadband network requires not just input, but actual buy-in and partnership from all levels of government, all disciplines and the private sector.