LTE for Public Safety:

How FirstNet Can Deploy a National Public Safety Broadband Network Quickly and Cost Effectively

Contents

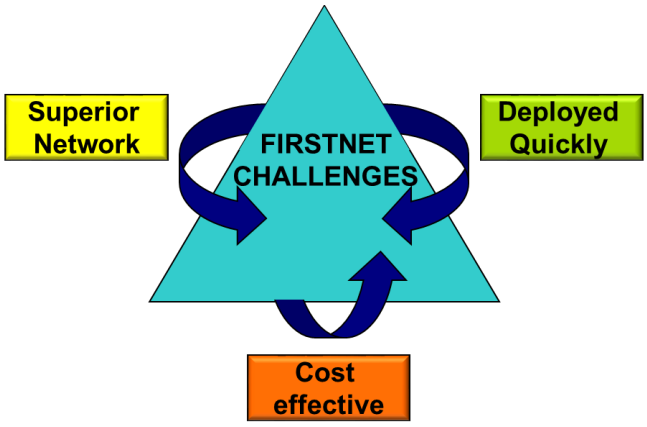
1 BACKGROUND

Over the last decade, events like the 9/11 attacks, Hurricane Katrina and the Boston bombings have highlighted the need for a nationwide interoperable public safety network. "*9/11 Commission Report*", Federal Communications Commission's (FCC) 2006 Independent Advisory Committee's Report on the "*Federal Response to Hurricane Katrina: Lessons Learned*", and the 2007 NSTAC Report to the President on "*Emergency Communications and Interoperability*" have all recommended the establishment of a national communications network to help increase national security.

On Feb 22, 2012, the Middle Class Tax Relief and Job Creation Act of 2012 reallocated 20 MHz of broadband public safety spectrum and established a Network Construction Trust fund of $7 billion to build a National Public Safety Broadband Network (NPSBN). This Act required the establishment of First Responder Network Authority (FirstNet), a 15 member independent board to oversee the design, deployment and operations of this network. To be built by leveraging commercial Long Term Evolution (LTE) technology, this network is intended to improve interoperability with a national network built from common standards, as well as enable higher bandwidth for next generation applications for public safety. These data intensive applications, such as high-definition streaming video, building plans, biometrics, advanced analytics and much more, will increase real-time situational awareness for first responders to better respond to emergencies.

2 THE CHALLENGE

More than a year has gone by since this legislation was enacted and the network is yet to get off the ground. The FirstNet board is faced with an unprecedented task of building a national network that meets three critical criteria:



1. **Provide superior service** – To get support from the public safety community, the NPSBN needs to be able to differentiate itself from commercial networks that some first responders use for their high speed data and voice needs. It must be secure, reliable and interoperable, while providing seamless coverage, priority and pre-emption for public safety users. It must provide superior coverage, while allowing for enhanced capacity and bandwidth to be able to handle heavy loading of the network during emergencies.
2. **Be cost effective** – Since mission critical voice capabilities using LTE are many years away, the network will primarily be used for data communications. Public safety users will have to

maintain their existing Land Mobile Radio (LMR) networks while finding a way to pay for using the NPSBN. The budgets of state and local communities are limited. If the NPSBN does not offer a superior network at enhanced value, the First Responders could opt out of using the network and instead use commercial networks.

3. **Deploy Quickly** - With the threats our nation faces, the public safety community needs a better network to respond effectively. To get support from the user groups, the Network needs to get off the ground quickly and show tangible progress. Every day that this network is delayed, is an avoidable day of delay during which the lives of first responder are put to undue risk.

The FirstNet board has a daunting task of choosing between the foregoing tradeoffs of functionality, cost and performance. They need to quickly develop a plan that ensures that the network is built to the standard of mission critical communications within their limited budget of $7 billion, which is a fraction of the resources the private sector has currently expended on an LTE network that currently covers less than half of the country. This Whitepaper seeks to outline the options for FirstNet to consider.

3 SUPERIOR NETWORK OPTIONS

The NPSBN must be a public safety grade network that meets the most important requirements, such as security, preemption, redundancy, reliability, and hardening. While LTE technology offers a low latency and high throughput network functionality, in order to provide a public safety grade user experience, this new network needs to be able to provide prioritization and session continuity for users. These requirements are not part of any commercial network or standard. It is critical for FirstNet to put a lot of thought into designing the NPSBN architecture to ensure the following elements are addressed:

1. **Design the initial network for vehicular coverage**: A major portion of data communications during emergencies occurs outside of buildings. Due to budget limitations, most large networks for public safety users (excluding fire departments) are designed for coverage on the street, rather than inside buildings. The assets of statewide LMR networks (towers, backhaul, shelters etc.) that States currently own/lease could be leveraged in the NPSBN to establish a large rural coverage footprint using tall towers and high powered Radio Access Network (RAN) equipment. User vehicles could then be equipped with mobile routers with high gain antennas to increase portable coverage while ensuring uplink quality. For users on the scene of an emergency with first responder vehicles, a mobile Wi-Fi hotspot could be enabled for command and control.

2. **Leverage Small Cell Technology for better capacity and in-building coverage**: One of the most efficient ways to improve capacity within a network in densely populated areas is to reduce the cell size radius, and place the cell sites closer to each other, resulting in a more densely packed network of smaller cells. There are various types of small cells like femtocells, picocells, and microcells. Due to the small form factor, the small cells are unobtrusive and can be installed anywhere. This offers the network designer the flexibility in providing targeted local capacity and coverage planning in specific areas. Since the area covered by small cells is limited due to lower transmit power, the users enjoy higher bandwidth since wireless resources are being shared by fewer devices. Small cell technology also helps with accurate location and

identification of first responders within buildings, which is a critical requirement for Fire personnel.

Most commercial wireless carriers have plans in 2014 and beyond to use small cell technology (low power RAN) to extend their service coverage into buildings / outdoor Metro areas and/or increase network capacity by offloading data usage in large venues from macro networks. By identifying critical buildings and partnering with commercial carriers, these investments can be leveraged by FirstNet. This will allow for network coverage in dense urban areas possessing a high concentration of users.

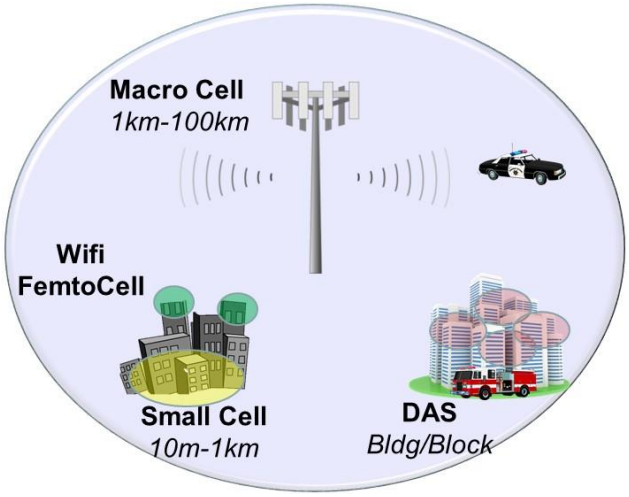


Figure 2: Proposed coverage model

3. **Encourage smaller network builds in dense cities**: Wireless networks of the future are going to be heterogeneous networks, built from small-cell networks based on multiple technologies: Distributed Antenna Systems (DAS), femtocells, picocells and Wi-Fi local area networks all woven together to form and operate as one wireless network. With the self-optimizing network (SON) capabilities of LTE technology, the typical network optimization activities such as setting downlink power levels, neighbor list updates, and database configuration can be done automatically and then transferred to other network elements. The advantage of including these networks into FirstNet is multi-fold:
    a. They spread the system load evenly across multiple sites, thereby reducing dependency on a single network.
    b. They provide higher data speeds and throughput necessary to support users' need for data.

    FirstNet should encourage the state and local jurisdictions to build local networks on their own, if they want to, and have the financial capability to do so, as long as they are interoperable with the national network and meets the minimum standards of security and reliability. This will allow jurisdictions to make investments for enhancements they need to make the FirstNet network work.

4. **Localize the service delivery platform**: FirstNet should try to localize the service delivery platform by locating some of Evolved Packet Core (EPC) components responsible for routing and terminating traffic (Serving Gateway SGW, Packet Data Network Gateway PGW) closer to the RAN sites. The policy, control and subscriber databases like Home Subscriber Server (HSS), Subscription Locator Function (SLF) and Policy and Charging Rules Function (PCRF) could be centralized in a geographically redundant configuration. This would have multiple benefits:
    a. It would allow high bandwidth local traffic to remain local by minimizing bandwidth necessary for backhaul transport. Only low bandwidth signaling traffic will need to be transported to the distant central core over a highly available connection.
    b. It would allow for a better user experience locally due to faster switching between RAN sites as the user moves around.
    c. It would allow better reliability as the local network can continue to operate in the event that a core site is down or the link to the distant EPC is broken.
    d. It would simplify the IP network interconnection and allow for better security of the network.

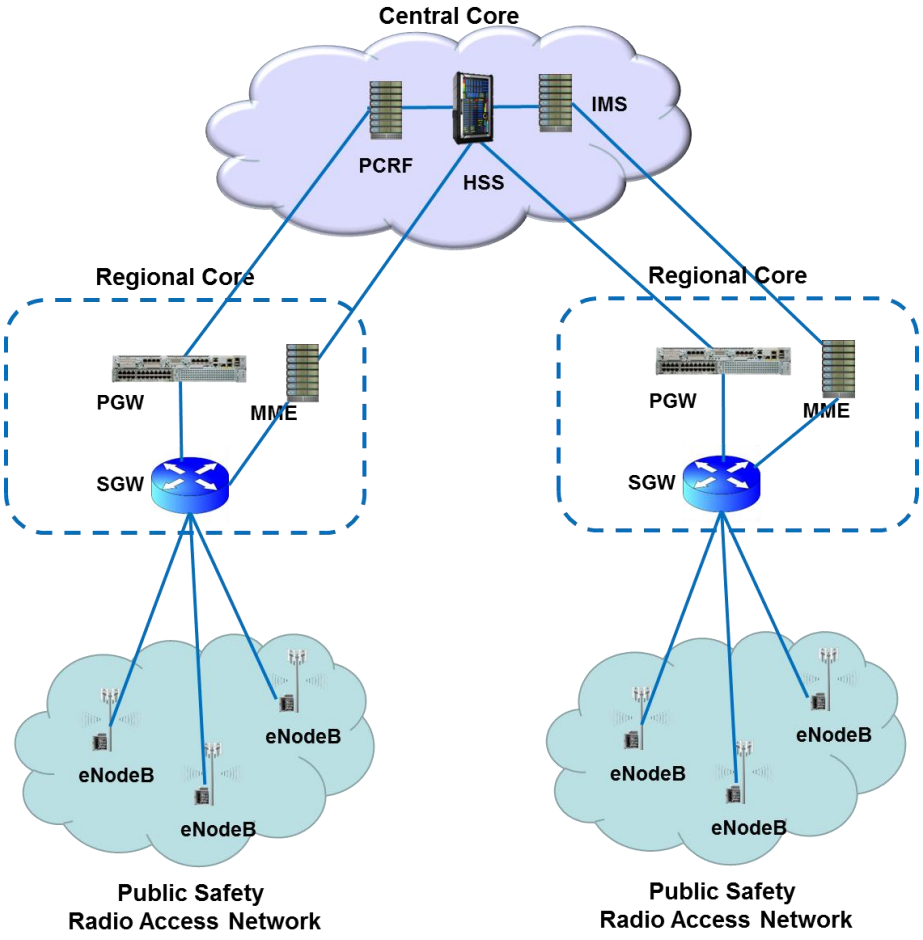


Figure 3: Distributed Architecture for PSBN

5. **Invest in emergency deployable systems**: It is impossible to predict where disaster will strike. During major disasters, there is a need for coverage and immediate additional capacity, in order to effectively carry out recovery operations. FirstNet should invest in transportable self-contained LTE sites (RAN and EPC) with power backup and satellite backhaul to ensure that communications in disaster affected areas can be quickly established and integrated into the national network. For rapid response, these deployable assets should be located regionally across the nation. FirstNet should also look into the possibility of using remote-manned drones that can be quickly deployed in an area to establish an ad hoc LTE network on the fly for mission critical needs on temporary basis.

6. **Partner with carriers to extend coverage in remote areas**: FirstNet should look into partnering with carriers and incent them to extend the network in areas where commercial wireless

coverage is not available today. By sharing the RAN and infrastructure build-out in these areas, both the general public and public safety community will benefit with the expansion of access to broadband infrastructure. When partnering with carriers, the prioritization, pre-emption and Quality of Service (QoS) for public safety users' needs should be built into the agreement so that the users can depend on the network during emergencies.

7. **Use satellite links for covering extremely remote areas**: In low population areas where existing infrastructure is inadequate, the deployment of the NPSBN may be cost prohibitive. In these areas, the coverage could be augmented with satellite networks that provide ubiquitous coverage.

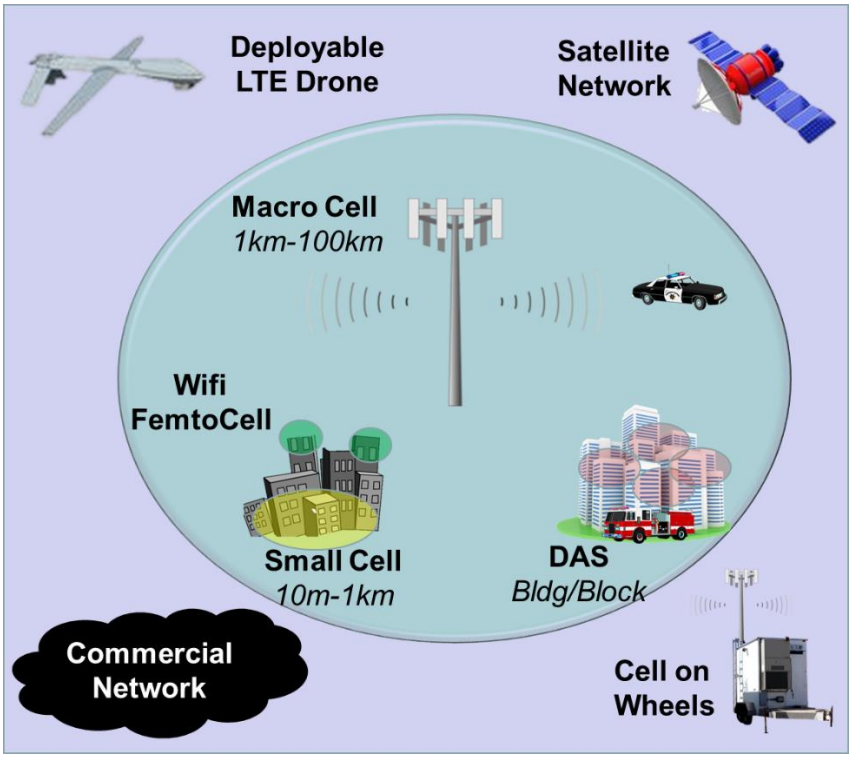


Figure 4: Options for Coverage Enhancement

8. **Enhance network security:** In designing the architecture, FirstNet should develop strong security specifications to protect the users and the network by enhancing security to reduce the threat to the network and its operations. At the same time, the architecture should be flexible to allow individual organizations to design their own security policy. This needs to be done at three levels:
    a. **Device Security**: Through a mobile device, it is possible to attack both the subscriber (and the government network, if any) and the mobile core network, as well as to launch attacks on the public Internet. Devices able to access the network should be required to have secure boot mode, authentication and verified software applications. Options like end to end encryption should be encouraged on an organization level.
    b. **Transport Security**: LTE mandated encryption supports symmetric-key cryptography. However, this encryption is not for the end-to-end network, and is only for traffic traveling on the air-link between a user device and the base station. The flatter LTE

architecture exposes backhaul traffic between eNodeBs to more entry points, because each eNodeB can connect through multiple links to other eNodeBs and network elements. To secure traffic, an IP secure tunnel should be mandated between the eNodeB, and the MME, SGW and O&M in the core network over the user, control and management plane via SSL/TLS, SSH, or a private VPN.

c. **External Networks**: Since the NPSBN will be connected to not only to the Internet but to other networks – roaming partners, commercial networks, enterprise networks, infrastructure partners – entry points for security threats multiply. Threats from external networks can be minimized by limiting the visibility of network elements and thus restricting access. In addition, Diameter Edge Agents should be employed, where NPSBN will interface with third-party networks, to protect the core network from both unauthorized access and traffic overload.

9. **Encourage local control:** State/local jurisdictions should be involved early on in the planning and design of the network. Providing them visibility in the planning phase will help build trust and gain their support, thereby increasing their desire to join the network that they helped architect. Since local jurisdictions are most knowledgeable about their staff, the functions of user setup, provisioning (device/application access) and priority assignment according to roles should be delegated to the local level. This will also allow each local jurisdiction to manage its users' privileges (like bandwidth during peak usage) as deemed necessary. Delegating the control and responsibility for operating, managing and maintaining some functions of their local network, will ensure support of public safety users. This will also allow nationwide interoperability while preserving a great deal of local flexibility.

4 COST EFFECTIVENESS OPTIONS

FirstNet is authorized to collect network user fees from public safety and secondary users and to receive payments under leasing agreements in public-private partnerships. The act requires that these fees be sufficient each year to cover annual expenses of FirstNet to carry out required activities, with any remaining revenue going to network construction, operation, maintenance, and improvement. However, the act does not mandate public safety entities to subscribe to the network. Some First responders currently use LTE broadband services offered by the commercial networks. User fees that NPSBN charges First Responders need to be comparable to what commercial carriers charge currently. To ensure long term financial viability of the network, FirstNet should consider the following:

1. **Develop a viable financial model to support the proposed architecture**: While the architecture is evolving, FirstNet should develop a financial model (subscriber based, pay per use etc.) for the system to ensure that planned investments will provide the desired revenue stream to be able to support the users in perpetuity. In developing the model, FirstNet should consider the following:
    a. What would the revenue streams look like, based on different scenarios of user participation, and scale of deployments?
    b. What are the various alternatives, cost associated with each alternative, and potential conservative revenue forecasts for each scenario?

c. How can the network "Self-fund" itself based on positive cash flow after 3-5 years of operation?

2. **Expand the user base:** With the "Opt Out" option provided to the states by the Act, some states, due to funding constraints, may prefer to concentrate their resources on improving mission-critical voice networks and acquire broadband access from a commercial provider. If many states choose to build their own networks and FirstNet cannot realize the economies of scale, then the cost of building the network may increase significantly. To defray the costs of building and maintaining a national network, NPSBN needs to expand the user base by adding secondary users who have critical communications needs such as federal agencies, utilities, transit/transportation agencies, hospitals etc. This expansion in user base will build support for the network and bring additional revenues. Besides, the users may be able to provide their existing assets for use in the system, which will lower the initial build out costs for the system.

3. **Consider a Build-Own-Operate Model**: If FirstNet can create the right environment and incentives; there may be interest from private groups to invest in the network. FirstNet should try to investigate interest in private investment to build and maintain the Network. If a Public-private partnership model can be built, it will have numerous advantages:
   - It will reduce the risk of implementation since the task is too large and complex for Government to execute within the constraints it operates under.
   - It will foster partnerships and bring project management and technical expertise that is necessary for implementing a network of such magnitude.
   - It will attract private resources in addition to $7 Billion that government has available.
   - It will allow FirstNet board to focus its attention on the critical few tasks of ensuring a public safety grade system.

   To make it attractive to private investors, FirstNet needs to be able to get support from the majority of States in order to attract sufficient interest based on a recurring revenue stream.

4. **Encourage Dynamic Spectrum Sharing**: Not all the spectrum available to FirstNet will be used all the time. With commercial industry's transition to small cells, carriers can use the available Band 14 spectrum for augmenting capacity in specific areas of congestion. FirstNet should explore the feasibility of spectrum sharing in real time to gain the best economic value from the spectrum allocated. By combining technological advances such as radio frequency (RF) sensing, geo-location database-coordinated access, radio resource management and wireless access extensions, dynamic spectrum sharing can increase capacity and improve coverage while mitigating interference. By sharing the spectrum with carriers in areas of low demand for public safety, FirstNet could realize additional revenues from commercial carriers. This will help allow FirstNet to leverage its most valuable asset (Band 14 spectrum) where it is being underutilized to offset some of the costs.

5. **Encourage smaller network builds in dense Cities**: FirstNet should allow the state and local jurisdictions to build local networks on their own, if they want to, and have the financial

capability to do so, as long as they are interoperable with the national network. Small cell technology is a quick and cost effective way to get additional coverage and capacity. Small cells essentially involve taking self-contained, hermetically sealed electronics, installing them on a steel pole or wall and transmitting wireless signals with small antennas. By leveraging existing public infrastructure (poles, buildings, traffic lights etc.) in dense areas of a metropolitan area small cell, FirstNet can build a "Network of Networks" all woven together to form and operate as one wireless network. The advantage of these networks is:

a. The equipment is cost effective and affordable.
b. The infrastructure required to support this equipment is minimal.
c. FirstNet allow Cities to make investments necessary to upgrade additional capacity they might need in dense areas, thereby lessening the financial requirements for FirstNet.

5 QUICK DEPLOYMENT OPTIONS

Building a broadband network from the ground up will take years, if not decades. Moreover with the funding limitations and regulatory constraints, building a brand new network would be next to impossible. In order to quickly deploy the network, FirstNet should evaluate these options:

1. **Leverage lessons from the Broadband Technology Opportunity Program (BTOP) build-outs**: FirstNet has taken the right steps by allowing the BTOP grantees to continue building their networks using Band 14 700 MHz spectrum. With these networks, FirstNet will have access to real world application of LTE technology for public safety needs. By working closely with grantees, FirstNet should try to ensure that the best practices that emerge from these systems and their applications are incorporated into the national network build-out. These first set of networks could be a good test bed for elements of network architecture that FirstNet plans to incorporate into the national network.

2. **Start deployment immediately of FirstNet Core**: While the architecture is being finalized and tested, FirstNet should procure the Evolved Packet Core (EPC), which controls the user mobility, data sessions and network policies. With BTOP grantees, FirstNet can use this EPC to test the architectural standards and policies in partnership with Public Safety Communications Research Program (PSCR). This would also allow FirstNet to define the interoperability and security environment in a pilot configuration prior to nationwide rollout.

3. **Encourage smaller network builds in dense cities**: Building wireless infrastructure (tall towers, generators etc.) in urban areas is becoming increasingly difficult, involving time-consuming permitting processes that can take months to years. Future wireless networks in dense cities are going to be mesh networks, built from small-cell networks based on multiple technologies: DAS, femtocells, picocells and Wi-Fi local area networks, all interconnected to form and operate as one wireless network. Since the equipment required for such installs is unobtrusive, these sites have minimal permitting requirements and can be installed quickly. This would allow FirstNet to make the best use of the spectrum quickly in dense areas where it is needed the most.

4. **Prioritize Build-out**: FirstNet should prioritize the areas where the network is most needed and focus on them first. The prioritization should take into account the following factors:
    a. **Low capital requirement**: In picking the sites for the network design, first priority should be given to the sites owned by users that will be part of this system. Lot of utilities and public safety entities interested in using the system currently have existing assets (towers, shelters, power, backhaul etc.) tied to the private wireless voice/data/LMR networks that they use currently. To get the network off the ground quickly, FirstNet should leverage the existing assets of users who intend to use the system. This will also get better user buy-in, as they will be able to off-set the cost of assets leased back to the NPSBN towards lowering the user fees. With less infrastructure requirement, the network will be able to be completed quickly for use by public safety.
    b. **High Impact**: First investments should be allocated to areas where small increments will bring large visible success with the network making a substantial difference in Public Safety. With the success in smaller network build, FirstNet will build the momentum for a successful nationwide rollout. Typically high population centers where the current commercial LTE networks are adequate would be the opportunity for making the most impact and gaining the user acceptance.
    c. **High Need**: There are numerous underserved areas across the nation where the carriers have no network due to economies of scale, but the need of broadband network for public safety is acute. The remote areas along the southern border are one such area of need where a superior network built in collaboration with carriers will satisfy a critical need of the public. At the same time, this network will enhance local safety and national security, by providing better tools to thwart and track illegal intrusions and drug trafficking.

6 CONCLUSION

Like any other complex project implementation, the success of NPSBN will depend on carefully balancing the triple constraints of scope, budget and schedule. This will require careful choice of available options presented herein, to ensure that the network meets the needs for which it is envisioned. To be able to sustain the network in the long term, FirstNet will need to develop a financial model that can fund the ongoing maintenance of the network in addition to initial network build-out. Emerging technologies of Self Optimizing Networks provides the potential for NPSBN to leverage various broadband technologies to deliver a hybrid network. At the same time, the small cells technology offers the promise to deliver higher capacity in high demand areas with minimal investment. The key to the success of the network in the end will depend on gaining support from a broad base of users in public safety, and supplementing it with users from federal government, utilities, transportation, hospitals, etc. who have similar needs. FirstNet should explore public-private partnerships to bring additional funding in order to build a truly world class network. With proper planning, the public safety community can finally enjoy a truly interoperable nationwide broadband network that leverages the global research and purchasing power of LTE to bring affordable equipment with cutting edge technology to the hands of public safety users.

Glossary of Terms

BTOP	Broadband Technology Opportunity Program
EPC	Evolved Packet Core
DAS	Distributed Antenna System
LMR	Land Mobile Radio
LTE	Long Term Evolution
NPSBN	National Public Safety Broadband Network
eNodeB	Evolved Node B
MME	Mobility Management Entity
PGW	Packet Gateway
SGW	Serving Gateway
O&M	Operations and Maintenance
RAN	Radio Access Network
PCRF	Policy and Charging Rules Function
HSS	Home Subscriber Server

ABOUT COMMDEX

Commdex Consulting, LLC, is a wireless systems integrator that specializes in design and implementation of wireless solutions for public safety. Commdex provides infrastructure engineering and management consulting services to the telecommunications industry across the country. Since inception in 2001, Commdex has designed and implemented numerous wireless systems nationwide, utilizing the most sophisticated features and functionality.

Commdex specializes in designing and implementing mission critical voice, video and data networks over Wi-Fi, Microwave, Land Mobile Radio, Fiber/SONET, WiMAX/LTE broadband wireless and other latest communications technologies. Commdex offers a broad, rich portfolio of proven telecom solutions. Its solutions, services and methodologies have been tested and proven in hundreds of customer environments. Its customer base ranges from state, local and federal customers, to large enterprises and equipment manufacturers. For more information, visit Commdex at http://www.commdex.com.