

High Reliability 4G and 5G Cellular Wireless Services for Smart Cities

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Abstract— Smart cities are supported by many vital utility and service industries that can take advantage of data collection and remote control applications. The rich data repositories provided in smart cities can be used to tailor services to user needs and to more safely, reliably, and responsively provide key services. Even though not widely used today, many vital utilities and service industries are considering the use of Long Term Evolution (LTE) 4th generation (4G) cellular communications, due its low cost and availability. These industries include electric utilities (especially for smart grid applications), air traffic control, railways, and FirstNet emergency public safety communication networks. Serious limitations exist, however, with LTE. These include availability, traffic prioritization, coverage, and security. This paper gives key research agendas for improvement.

Keywords—public safety, smart grid, LTE, 5G

I. INTRODUCTION

Smart cities depend on their infrastructure to provide a foundation for innovation. In addition, smart cities leverage their knowledge base to enhance those industries.

A wide variety of vital utilities and service industries depend on high reliability communications to remote sites and users. These include electric utilities (especially for smart grid applications), air traffic control, railways, security systems, gas utilities, water utilities, emergency communication networks, and FirstNet public safety networks. Some of these organizations are considering the use of Long Term Evolution (LTE) cellular systems to provide critical connections to users, sensors, and equipment on their networks. LTE is attractive due to its widespread deployment, low cost, and ease of use compared to fixed wireless, leased line, and fiber optic communication that has been used for decades.

Later versions of 4G networks and newly emerging 5G networks are being designed with additional focused interest in machine-to-machine (M2M) communications as a development of the Internet of Things (IoT). In IoT, potentially billions of devices will connect with each other and with humans to provide health, safety, energy conservation, medical, weather, and enhanced transportation services. IoT provides the input for smart city applications. It also can implement education and remote control.

IoT devices can be connected through short range communications like WiFi, Bluetooth, etc. IoT can certainly also include public safety applications, smart cities, and utility operations, but IoT must be supported over long distances, most likely using cellular communications.

However, there are serious limitations to 4G LTE and 5G architectures that need to be addressed before they should widely be used by these industries. Many applications have stringent latency targets that are not easily achieved by LTE, especially if five-nines (99.999%) or six-nines (99.9999%),

31.5 sec. downtime per year) availability is required. Some of the following limitations may exist for using cellular systems.

- **Coverage** can be inconsistent. LTE providers deploy networks to cover customers, not necessarily geographic areas or hard-to-reach areas. But many of the most important devices for these utilities are in such locations.
- Even if coverage exists for difficult locations, **geographic redundancy** to those locations may not be present. If the eNodeB base station for that location fails, the location and its devices may have no service.
- Since the infrastructures are of such vital importance, high **security** should be provided, not just over the air interface but in all of the components through which data will travel.
- To deliver traffic from the remote location to the utility or emergency provider, there are **several points of potential failure** within the LTE system that must be traversed. These are illustrated in Figure 1 where the end device, known as the User Equipment, sends and receives traffic. To reach the destination, traffic must traverse the following.
 - Wireless link from UE to eNodeB
 - Through the eNodeB
 - Backhaul from the eNodeB to the Serving Gateway (SGW) in the Evolved Packet Core
 - Through the SGW
 - Link between the SGW and the Packet Data Network Gateway (PGW)
 - Through the PGW
 - Through the Internet

If the UE itself is included, there are eight potential points of failure.

The research need is an *availability analysis of the LTE architecture*. It must develop solutions for *improving* such availability if LTE were to be used to support critical traffic. The solution will include the following.

- It should include requirements and architectures for equipment, link, and connection **redundancy**. Especially for wireless networks that combine macro cells and small cells, multiple connections should exist simultaneously to provide redundancy, since small cells and their backhaul are likely unreliable.
- LTE providers have not widely deployed the **latency-aware scheduling** that would be needed. Utility communications may not always need high throughput, but low latency is critical.
- Mechanisms to **prioritize** traffic are needed, but LTE providers generally schedule users according to fairness and system efficiency criteria, not based on priorities for critical traffic.

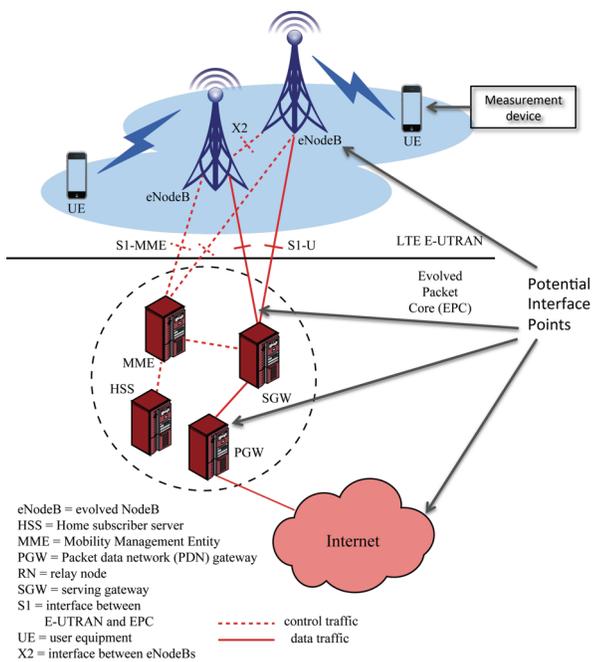


Figure 1 – The Evolved Packet System of LTE with Interface Points

- Analysis of **potential points of interface** with the LTE network. Some of these potential interconnection points are also illustrated in Figure 1. Some utilities may wish to connect close to the eNodeB and then use their own networks thereafter.
- LTE networks can experience **congestion** during peak loads or when network resources are limited. If critical traffic is not protected, it will suffer.

II. BACKGROUND

Two industries that have placed considerable attention toward the potential use of LTE for critical communications in smart cities are electric utilities and the public safety sector.

A. Smart Grid

Electric utilities have a wide variety of wireless communication opportunities, both for traditional uses such as meter reading and for advanced controls through the development of the smart grid for smart cities. Smart grid applications include control of distribution devices, coordination of distributed generation (wind or solar), and demand-side management for interactions with customers regarding energy savings and electric vehicle charging.

To meet smart grid requirements, LTE must meet stringent IEC 61850 communications requirements, of which latency is the key parameter. The need is for virtually zero latency (< 1ms) and ultra-reliability (99.999%) in machine type communications for the P1-P3 performance classes (out of classes up to P6) [1]. Several investigators, however, have shown that typical LTE deployment configurations are unable to meet these requirements [2-5]. They have proposed various resource allocation and prioritization schemes, and these should be improved to also meet high availability requirements.

B. FirstNet Public Safety

Along with release of some of the 700 MHz spectrum to the public safety sector, the Middle Class Tax Relief and Job Creation Act of 2012 created the First Responder Network Authority (FirstNet) to provide emergency responders with the first nationwide, high-speed, broadband network dedicated to public safety. These public safety communications are based on commercial standards to bring the benefits of lower costs, consumer-driven economies of scale and rapid evolution of advanced communication capabilities. Public safety workers need the latest smartphones and apps to engage smart cities.

FirstNet is based on the LTE standard and enhancements of LTE for public safety requirements. The first focus is to provide mission-critical voice. To reduce susceptibility to outages, FirstNet sites will have redundant power backup that relies on a variety of sources. Power, backhaul, sites and coverage will be designed to avoid single points of failure. FirstNet also prioritizes the importance of local control, so that incidents can be managed at the local level.

“FirstNet will be operated as a nationwide public safety broadband network with the ability for national and regional operations centers (NOC/ROC) to exercise control. FirstNet intends to make it possible to shift capacity to different parts of the network. Local control means that agencies will determine who has local priority to use the network to ensure public safety priorities are met.” [6]. “Public safety services can set tighter coverage, security and resilience requirements than is commonly planned in commercial networks. Furthermore, prioritization of public safety subscribers and services is critical in emergency situations.” [7]

III. CONCLUSION

Long Term Evolution and future 5G networks provide great opportunities to smart cities and their critical utility and infrastructure organizations, but severe limitations must be overcome. Research agendas need to make important strides to improve LTE service availability and latency performance.

REFERENCES

- [1] Horsmanheimo, S.; Maskey, N.; Tuomimaki, L., "Feasibility study of utilizing mobile communications for Smart Grid applications in urban area," *Smart Grid Communications (SmartGridComm), 2014 IEEE International Conference on*, vol., no., pp.440,445, 3-6 Nov. 2014
- [2] Xu and Fischione, "Real-Time Scheduling in LTE for Smart Grids," *Proceedings of the 5th International Symposium on Communications, Control and Signal Processing, ISCCSP 2012*, Rome, Italy, 2-4 May 2012
- [3] Brown, J.; Khan, J.Y., "Performance analysis of an LTE TDD based smart grid communications network for uplink biased traffic," *Globecom Workshops (GC Wkshps), 2012 IEEE*, pp.1502,1507, 3-7 Dec. 2012
- [4] Brown, J.; Khan, J.Y., "Performance comparison of LTE FDD and TDD based Smart Grid communications networks for uplink biased traffic," *Smart Grid Communications (SmartGridComm), 2012 IEEE Third International Conference on*, vol., no., pp.276,281, 5-8 Nov. 2012
- [5] Jie Du; Manli Qian, "Research and application on LTE technology in smart grids," *Communications and Networking in China (CHINACOM), 2012 7th International ICST Conference on*, vol., no., pp.76,80, 8-10 Aug. 2012
- [6] <http://www.firstnet.gov/about/guiding-principles#Reliability>
- [7] Nokia Networks, "LTE Networks for Public Safety Services," Nokia White Paper.