PRIVATE LTE FIELD TESTS AND RESULTS FOR SMART GRID SERVICES

Marta SOLAZ HERNÁNDEZ
Iberdrola Distribución –Spain
msolaz@iberdrola.es

J. S. GOMEZ GUAJARDO
Iberdrola España –Spain
jgua@iberdrola.es

Alberto SENDÍN ESCALONA
Iberdrola España - Spain
asendin@iberdrola.es

Javier NOGUEROL OLIVÁN
Ericsson - Spain
javier.noguerol@ericsson.com

ABSTRACT

Iberdrola is committed to the digitalization of the network business, with the evolution of the electrical grid towards the Smart Grid as the most relevant example. Smart Grid services need to rely on an evolved telecommunications infrastructure, blending both public and private, wireless and wireline access telecommunication technologies. Specifically, Private Wireless access technologies are needed in ambitious and pervasive deployment schedules.

Iberdrola owns a private wireless network based on licensed narrowband UHF/VHF Point to multipoint Digital Radio which is reliable and convenient for some data connectivity scenarios. Commercial wireless access services show weaknesses that render them inappropriate for some use case. Both solutions present constraints; the former in terms of performance derived from its narrowband nature and the lack of suitable standards; the latter, due to its inability to cope with the requirements of Smart Grid services.

The use of private 4G Long Term Evolution (hereinafter LTE) can probably solve the performance needs of higher demand service aggregation points in Smart Grid deployments.

INTRODUCTION

There are new obligations for utilities derived from European environmental regulations that require new Smart Grid-related services. Smart Grids are the evolution of traditional grids, where the ICTs (Information and Communication Technologies) are integrated in electricity assets and processes to improve electricity services. Additionally, ICTs are integrated into Smart Grids to support the new enabling technologies that arise connected to the new uses and applications in the grid including Electric Vehicles, the different Distributed Energy Resources and grid edge technologies in general [1]. .

Utilities have always used available technologies. These technologies have evolved from pure electromechanical domain into the ICT world. . In the telecommunications arena, some utilities have developed their own private network in the areas where commercial networks were not available, convenient or fit for purpose. As an example of this, private narrowband wireless (VHF/UHF) networks have traditionally been used by utilities for mission critical applications such as Supervisory Control and Data Acquisition (SCADA), Distribution Automation (DA) and operational voice.

Telecommunication networks with enhanced features such as high performance, resiliency, security and scalability are strategic to the evolution of utilities towards Smart Grids. In the wireless domain, for example, ETSI Technical Report TR 103 401 [2] details the Smart Grids requirements for utilities and the suitability of private wireless networks to achieve the goals. Wireless broadband private network deployments over licensed spectrum are the solution to solve these needs in a quick and effective manner if and when broadband spectrum is allocated to utilities.

Today, however, hybrid telecommunication networks based on a combination of private and commercial networks enable Smart Grid field implementations. This combination of resources is a consequence of a compelling need to offer smart metering services and other evolutionary smart grid services that cannot wait to be taken to the field due to market or regulatory needs. The fact that utilities use private and commercial telecommunication networks and services should not hide the reality that the vast majority of telecommunication commercial services used in the smart grid domain do not offer the required performance, coverage, control, security and reliability targets of the critical electricity distribution service [3]. Furthermore, this situation is worst with the new and challenging requirements of the modern smart grid enabling technologies such as Electric Vehicles and the different Distributed Energy Resources.

Most of the wireless spectrum useful for broadband point to area networks is primarily held by commercial networks, and Defence purposes [4]. Commercial networks exhibit various limitations if they need to be used for mission critical or professional uses [5]. This is a consequence of regulatory, implementation, deployment, operation & maintenance, decisions and processes, rather than a limitation of the telecommunication standards themselves. Most public networks are not suitable for certain types of traffic profiles [3] [5]. In the case of commercial cellular networks, poor or inexistent coverage in rural areas or deep underground urban assets is the rule. Service performance is highly dependent on Mobile Network Operator's (MNO's) network design. Dimensioning and redundancy of the different network elements are key to avoid service unavailability in congestion scenarios or network incidents. Furthermore, utilities require enhanced resiliency so that networks can operate in the absence of electrical power for an extended period. This requirement cannot be fulfilled by MNOs as of today. Additional to this, important limitations such as the impossibility to prioritize critical traffic flows make it necessary to promote private network deployments.

Recent public consultations by different Regulators [6] with regards to spectrum allocation that are taking place both at national and European level, show that Spectrum regulatory authorities are becoming aware of the need of private radio networks to fulfil the requirements of Smart Grids. Broadband wireless LTE technology is referred to in literature [7] as a suitable state-of-the-art technology for Smart Grids. In the context of prospective LTE-based deployments, harmonized access to broadband spectrum across Europe would significantly facilitate synergies and boost the industry.

This document describes the field tests to be performed by Iberdrola to validate private LTE technology. It first summarizes the need and expectations, and then describes the architecture to solve the different Smart Grid use cases. Some early results are included and a first set of conclusions is derived.

REQUIREMENTS AND EXPECTED RESULTS

Iberdrola's expectations on LTE technology are that it should be able to address the following business needs:

- Future proof and scalable technology solution in terms of:
    - Performance: high throughput and low latency.
    - Coverage that can be tailored depending on the needs.
- Multi- service support.
- Critical service support: QoS capabilities (including Radio Access Network- RAN- level).
- Resilient and self-managed network independent of third parties.
- Deployment based on Licensed Spectrum in order to avoid interferences (licensed 3GPP LTE Bands).
- 3GPP standard based LTE with guarantee of full interoperability between the different parts of the network and with a broad vendor ecosystem.
- Cost-effectiveness.
- Cyber security addressed from an integral perspective.

The field test consists in testing private LTE as an evolution of narrowband radio technologies and to check its ability to cover expectations as described above. Once the services that can be offered have been validated, the technical implications of performing a private LTE deployment are to be understood (spectrum needs -frequency band and bandwidth channel- and infrastructure needs -number of repeater sites-). Thus the economic implications and spectrum needs will be derived to fix the conditions of a prospective deployment of private LTE for Smart Grid services.

LTE TECHNOLOGY AND ARCHITECTURE

In this section LTE technology overview will be presented with a focus on how it can be integrated into Iberdrola's Smart Grid services architecture.

LTE technology

LTE topology, in the access segment, shows a point to area configuration, consisting of base station locations (eNodeB), connecting to multiple end devices (CPE). A dedicated core (EPC) is required to orchestrate the network. eNodeBs should be connected to the EPC by means of a reliable backhaul infrastructure (point to point microwave links over licensed bands or fiber optics).

A brief description of the main components of LTE architecture (Figure 1) is included:

- Enhanced Packet Core (EPC). It handles IP transport and control including functions such as authentication, policy control and QoS bearer management. EPC will be dimensioned in terms of the number of eNodeBs and end devices. It is a critical element of the network and, as such, it should be fully redundant.
- Evolved Node B (eNodeB). This element is responsible for radio resources allocation, admission control and scheduling of the uplink and downlink traffic. The major component of LTE deployment "Total Cost Ownership" (TCO) is the number of eNodeB sites needed to deliver the desired level of coverage. This number will depend on several factors such as frequency band and vertical infrastructure height. The sites that could be eventually used as eNodeB locations are Primary Substations and existing Narrow band radio repeater sites.
- Customer Premises Equipment (CPE). This element will connect to the eNodeB by means of radio interface. It will concentrate all the services required at the end target (Primary/Secondary Substation, Distribution Automation site, AMI concentration site) to be transmitted over LTE network.
- Backhaul network. It is the data packet transport and switching network connecting all the system elements.
- Network Management Platform (NMP). These are the elements in charge of controlling the proper performance of the system, network and elements.

Network architecture for Smart Grid services in Iberdrola

Iberdrola is using over 200 repeater sites covering approximately 600 thousand km2 equipped with narrowband point to multipoint base stations with backbone access to the core network by means of private telecommunications (point to point microwave links or fiber optics together with SDH and IP/MPLS technologies). This existing infrastructure is to be reused for any prospective deployment of LTE eNodeB's.

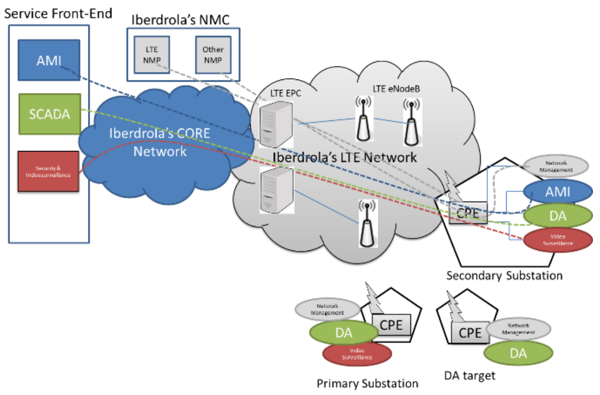

Figure 1. Network architecture for Smart Grid services

As shown in Figure 1, different Smart Grid services are to be transported over LTE network up to the core network. Their characteristics can be found in [3]:

- Advanced Metering Services (AMI-related).
- Automation (SCADA-related).
- Security and video surveillance data.
- Network Management.

Different services have different performance requirements in terms of latency, application layer throughput and availability. Three traffic profiles should be considered for the Smart Grid applications in Iberdrola:

- Basic traffic profile, for which the desirable network performance parameters should be the following:
  - Uplink Throughput >= 10 kbps and <200 kbps.
  - Latency<= 1,500 ms.
  - Availability >=98.5%.
- Medium level traffic profile:
  - Uplink Throughput >= 200 kbps and <1 Mbps.
  - Latency<= 200 ms.
  - Availability >=99%.
- High level traffic profile:
  - Uplink Throughput >=1 Mbps.
  - Latency <=50 ms.
  - Availability >=99.8%.

DESCRIPTION OF THE FIELD TEST

Iberdrola has launched a field test based on a small scale private LTE deployment

Spectrum management

The frequency band used for the pilot is 3GPP Band 38 TDD (2.6GHz), specifically using 5 MHz (2,600 to 2,605 MHz) within the wider Band 38 (2,570-2,620 MHz). This band has just been selected for the purpose of the test. Other bands below 1 GHz (such as Band 31 -450 MHz-) could be more suitable for utility usage due to the wider coverage that can be produced.

Network planning and design

Network planning tasks include the Radiofrequency (RF) design taking as an input the following parameters:

- Sites location:
  - eNodeB location: Existing Iberdrola's repeater site.
  - Target end sites for CPE location in order to cover different use cases (DA reclosers, AMI concentration sites, Primary automation sites).
- Target performance levels to serve the different traffic profiles (Basic, Medium, High). Performance estimations based on uplink throughput for different signal reception levels (RSRP and RSRQ/SINR) at the selected sites yields important information to take as a reference for the tests phase.

The result of this RF analysis is the characterization of the coverage area with coverage plots around the eNodeB and the confirmation of the viability of the connection at target end sites.

Network design includes the definition of the architecture with regards to: LTE network elements integration with Iberdrola's network, NMP integration, KPIs definition and QoS and prioritization policies definition among others.

End-to-end QoS and traffic flows prioritization are implemented by means of the following mechanisms:

- EPC's PCRF entity configuration: PCRF QoS control function identifies the input traffic, maps it into default or dedicated bearer and assigns a QoS Class Identifier (QCI) according to the defined QoS mapping. By this means, each bearer is allocated an index which enables the PCRF to prioritize or shape traffic flows according to the Quality of Service assigned.
- Traffic flows have been aggregated into 2 different Access Point Names (APNs) with 4 different bearers per APN. Bearers defined are Non-Guaranteed Bit Rate to provide highest flexibility in the radio resource management. PCRF is configured to implement a different QoS priority control policy on an APN and bearer basis, i.e., prioritizing "APN1" over "APN2" and some bearers over others within "APN2".
- CPEs configuration: As mentioned before, 2 APNs will be configured in the CPEs:
  - "APN 1" will have the highest priority and will allocate production traffic flows (AMI and Automation), DMVPN architecture will be implemented on top of this APN to reach service Front-ends in a secure and transparent way.
  - "APN 2" will have a lower priority and will be enabled to carry out intensive performance tests together with QoS tests to prioritize traffic flows.

Network architecture for the pilot

Figure 2 shows, in a high level, the network architecture for the pilot.

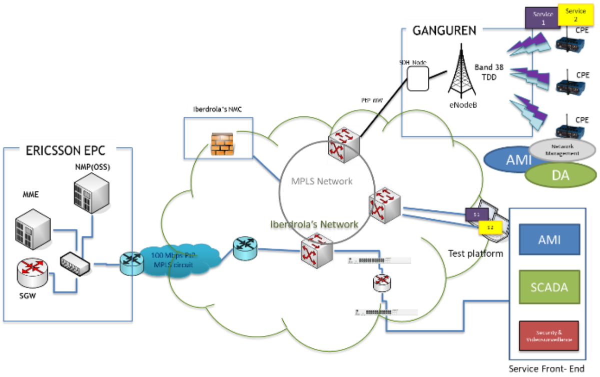

Figure 2. LTE Network architecture for the pilot.

The main elements integrating the architecture are the following:

- EPC: Provided by Ericsson as a service, it includes basic entities together with PCRF and User Data management functions. It is integrated with the NMP (OSS) [8]. EPC is connected to Iberdrola's network by means of a point to point 100 Mbps MPLS circuit.
- eNodeB: Located in the repeater site (Figure 3). eNodeB configuration is based on a modular solution composed of [9]:
    - 1 Base band unit wall mounted indoor installed. LTE FDD & TDD capable and, frequency band-agnostic.
    - 3 sectors (radio units + antennas) installed at existing vertical infrastructure. Radio units are configured as MIMO 2x2 and are specific to B38.
- CPEs: Located at 20 end targets to serve different Iberdrola's Smart Grid use cases. CPE device used for the pilot [10] offers dual SIM connection so that it can be configured to have Private LTE connection and Public cellular connection as fall back mechanism.

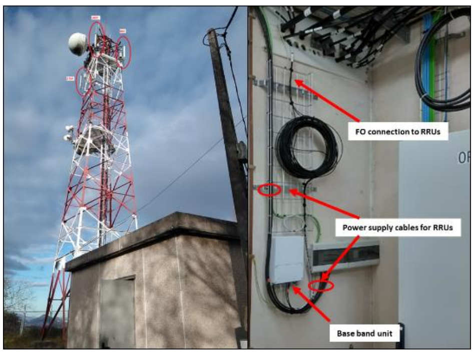

Figure 3. Outdoor/Indoor installations at eNodeB site.

Tests

The objective of the tests is to validate the adequacy of LTE to meet Iberdrola's expectations for present and future Smart Grid deployments.

Performance tests

Throughput and latency are the performance indicators that will be measured at every CPE location. As a result, the following performance ranges will be obtained:

- Throughput (kbps): Uplink/Downlink at Application layer
- Latency range (ms): Minimum/Maximum/Average

Both ranges will be obtained in different RAN scenarios:

- Different antenna configurations (MIMO vs SIMO).
- Different TDD configurations.
- Different coverage levels based on the location of the CPE.

Coverage

These tests are strictly related to the ones mentioned above. They seek to take the technology to its limits from the coverage point of view carrying out performance tests (latency, throughput) to identify the coverage levels required to achieve the performance levels required for the different traffic profiles.

Each CPE will have specific coverage levels depending on its location within the area of coverage of the eNodeB.

CPE locations have been chosen in order to cover different coverage situations: Low, acceptable and optimal levels

The main outcome of these tests will be the following:

- Coverage parameters thresholds (RSRP -dBm-,) needed to meet Iberdrola's traffic profiles described in previous sections).
- Coverage range (km) for the frequency band of the pilot (B38 2.6 GHz).

Real field results will be compared with the theoretical results obtained during the Network planning and design phase with the aim to take out conclusions that will be used in a full deployment scenario.

QoS tests

The objective of these tests is to confirm the effectiveness of QoS configuration in LTE technology. Performance parameters of prioritized traffic flows will be measured whilst subjecting end to end connection to an additional load of traffic.

Stability tests

The main aim of these tests is to monitor the stability of the network above certain quality thresholds.

The tests will mainly consist of one ICMP packet sent to the CPEs every one minute for the duration of the pilot and the outcome will be:

- Average Packet Loss rate (%).
- Average Latency (ms).

The KPI values obtained will be compared to the existing over alternative access network technologies (Public cellular networks and Private Narrow band UHF radio), with the data already recorded by Iberdrola in its Smart Grid 100,000+ network devices deployment.

FIELD TESTS RESULTS

The results of the first phase of tests performed in the field are presented in this section.

Coverage and Performance

Performance tests (UL/DL Throughput and latency) were executed in different RAN scenarios: Throughput measurements were performed by means of iperf tool [11] which allows end to end performance testing at application layer The tests consisted in setting up an IP path between the CPE's end site in the field and the Service Front-end at Iberdrola's core network which allowed the transmission of bidirectional TCP traffic flows. Full path latency was also tested sending a battery of ICMP 256 bytes sized packets during a certain period of time.

Figure 4 shows maximum DL throughput levels, close to 4 Mbps. Asymmetrical throughput with uplink levels constrained to roughly one third of the full capacity, has been confirmed after the tests.

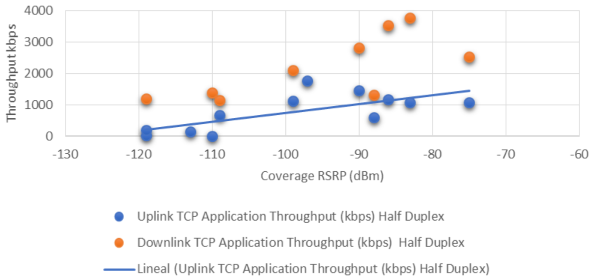

Figure 4. Throughput vs Coverage results

Results validate that performance is strictly related to coverage level. This fact will allow the definition of a set of design rules for the different traffic profiles targeted in the different locations, so that deployment can be planned in a deterministic way for different traffic profiles based on the coverage levels.

The maximum achieved distance for Iberdrola's Smart Grid basic level profile (200 kbps UL throughput) is 22.0 km, close to the predicted LOS simulation cell range for rural areas (20.3 km). Considering the design considerations of current UHF/VHF narrowband radio repeater sites (each covering typically a range of 30 km), a factor of 1.86 needs to be applied to the needed 2.6 GHz eNodeBs. Thus, a total of 350 repeater sites could be needed to cover the full territory with LTE over band 38.

Loose measurements performed in different RAN scenarios based on different antenna conditions in transmitter and receivers (MIMO and SIMO) have also confirmed the positive effect of MIMO configuration in throughput levels achieved.

Latency test results have shown a consistent average level below 100 ms for optimal and acceptable coverage scenarios. However, RAN conditions dramatically affect latency in harsh coverage conditions (RSRP below -110 dBm), with levels increasing up to 500 ms.

CONCLUSIONS AND NEXT STEPS

The main conclusion obtained out of the first conclusions of the field test is that Private LTE is able to meet Iberdrola's requirements for Smart Grid deployments. The coverage ranges achievable for Smart Grid targets in rural areas on a frequency band above 1 GHz, such as the one used in the deployment, exceed initial expectations. The clear consequence is that this kind of networks can be realistically approached with a variety of frequency band options, each with certain investment constraints (the higher the band, the higher the cost).

The next testing phases will include QoS and network stability tests, to check that Smart Grid full requirements can be fulfilled with Private LTE.

REFERENCES

[1] *The Future of Electricity: New Technologies transforming the Grid Edge*, http://www3.weforum.org/docs/WEF_Future_of_Electricity_2017.pdf, Consulted on February 27th 2019.

[2] ETSI Technical Report TR 103 401 v1.1.1 (2016-11), *Smart Grid Systems and other radio systems suitable for utility operations and their long-term spectrum requirements.*

[3] A. Sendin, M. Sanchez-Fornie, I. Berganza, J. Simon, I. Urrutia, 2016, *Telecommunication Networks for the Smart Grid*, Artech House.

[4] ECC Report 25, The European table of frequency allocations and utilisations in the frequency range 9 kHz to 3000 GHz, Electronic Communications Committee.

[5] S. Forge, Horvitz and C. Blackman, 2014, *Study on use of commercial mobile networks and equipment for "mission-critical" high-speed broadband communications in specific sectors"*, European Commission.

[6] ECC Consultations, https://cept.org/ecc/tools-and-services/ecc-consultation, Consulted on January 7th 2019.

[7] Draft ECC Report 292, *Current Use, Future Opportunities and Guidance to Administrations for the 400 MHz PMR/PAMR frequencies*, Electronic Communications Committee.

[8] Ericsson Enterprise Core, https://www.ericsson.com/en/portfolio/digital-services/cloud-core/cloud-packet-core/enterprise-core, Consulted on January 7th 2019.

[9] Ericsson Radio System, https://www.ericsson.com/en/portfolio/networks/ericsson-radio-system, Consulted on January 7th 2019.

[10] GE Orbit LTE Router , http://www.gegridsolutions.com/Communications/catalog/MDSOrbit.htm, Consulted on January 7th 2019.

[11] iperf tool, https://iperf.fr/, Consulted on March 7th 2019.