PRIVATE FAN (FIELD AREA NETWORK) FOR NEXT GENERATION SMART GRIDS

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ABSTRACT

An Integrated Communications Infrastructure is a foundational component of any Smart Grid strategy and requires solutions that not only support legacy services, but evolve to enable a wide variety of useful applications.

A Field Area Network (FAN) is a 21st-century solution that takes visibility and control deep into the distribution grid's middle and last miles. It extends the smart grid in an economical fashion, using a variety of technologies working together seamlessly to create a cost-effective connection to growing numbers of data collection points.

4G LTE is a cutting-edge wireless technology that can be well-adapted to a FAN. It provides highly scalable broadband connectivity for both fixed and mobile applications and allows you to converge your data needs on to a single network technology.

Elektro Gorenjska d.d. (EG) started a pilot project of 4G LTE private FAN (pLTE). With vast experience in its existing private WiMAX broadband wireless access network analyses of almost all possible telecommunication requirements of Smart Grid was foreseen. Including the cyber security as inseparable part of modern Smart Grids.

INTRODUCTION

The pLTE will provide communication services for:

- AMI
- Real time operational data for SCADA/DMS
- SCADA control functions on grid elements (switches, tap changers..)
- Wide area awareness data for grid protection functions (IEC 61850, GOOSE, ...)
- Quality control according to IEC 50160
- Time synchronization
- European funded projects (STORY, TDX-ASSIST)

EG pilot will give a thorough insight in suitability of modern 4G LTE and NB IoT technology as a part of it. Pilot project will cover different aspects from technology, cost and benefit perspective. Another important aspect is reliability and coherence of wireless technologies to the main distribution grid control and acquisition technologies. Regulatory issues will also be covered in pilot project.

Benefit of pilot project for DSO is excellent example of practical implementation of high tech telecommunications. Results of the project will give thorough insight how the future Smart Grid ICT network might look like.

Gained knowledge and experience will help EG to focus their activities on future telecommunication networks research. Using standardized and well-known technologies can provide a range of new system services, reduce the costs and provide required quality of service through reliable and affordable wireless network.

Future smart grid development will be based on experiences from 4G LTE private FAN pilot and EU project Story.

pLTE NETWORK

EG already owns a system of 12 base stations connected in a ring through microwave packet radio. Two of them were selected for a pLTE pilot.

The pilot is composed of two LTE base stations. One positioned in mountains, 1478m ASL, providing radio coverage for rural areas and second one mounted on the top of EG headquarters to provide radio coverage for populated area.

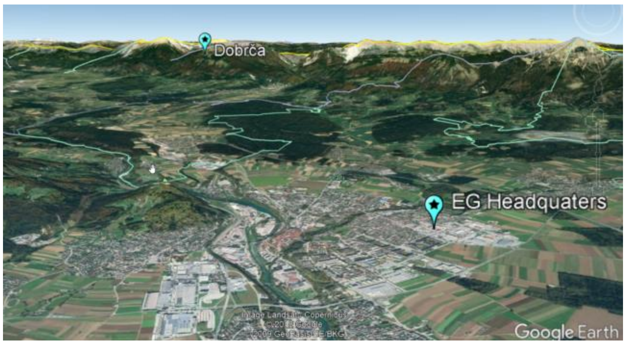


Figure 1: pLTE base stations

Solution is combining standard base station and virtualized Evolved Packet Core (EPC) functionality integrated on BTS HW extension. Only packet data services are enabled. Since this is a private network there are no public internet connections neither. The EPC functionalities are provided as a software solution only. The product is complying with

3GPP recommendations and supports all required EPC functionalities.

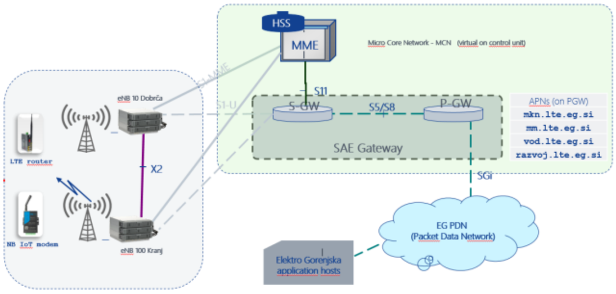


Figure 2: 4G LTE private FAN

The main idea of ICT network supporting MV/LN power distribution network is to provide a common all IP communication platform for almost every application in that part of distribution network.

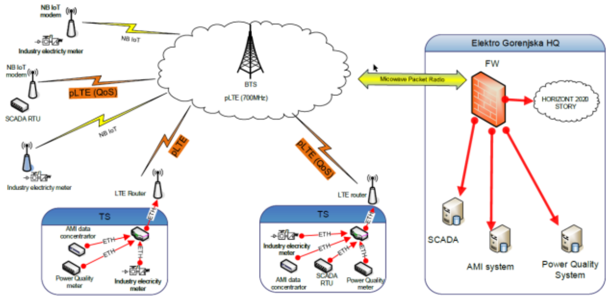
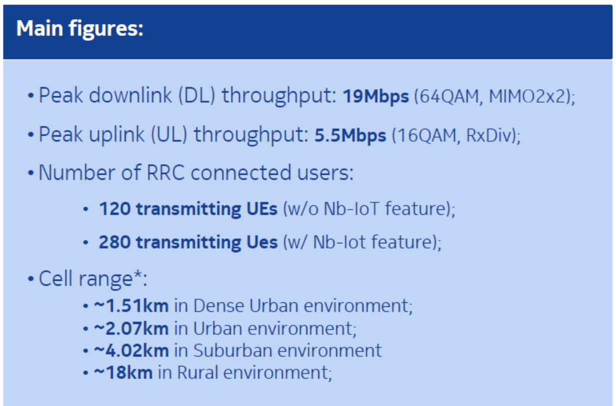


Figure 3: EG common communication platform

Available 3 MHz frequency band is currently sufficient for all communication services requested from the side of EG power distribution network provisioned through pLTE.



* Approximate values. Simulation assumes static UE, 128kbps throughput targeted at cell edge, 3MHz carrier in 700 MHz band, tower mounted RF, light indoor losses and others.

Figure 4: What can be achieved with 3 MHz carrier in 700 MHz band

The pLTE pilot is divided in two phases. LTE is planned to provide communication with MV/LV secondary stations through a common communication platform. While NB IoT is planned for communication with power metes and other remote terminal units that don't require high data rates and low latency and jitter. In Phase 1 LTE communication is tested. In Phase 2 NB IoT technology is foreseen for testing.

The LTE coverage map is calculated using a computer simulation. Various factors impact the propagation of radio waves in the environment, so there may be deviations between the calculated (optimum) and actual (expected) coverage and speed.

Signal quality and strength depend on many factors:

- the terminal device model and its capacity to achieve maximum speeds
- artificial and natural obstacles
- the undulation of the terrain, the geographic conditions, artificial obstacles (metal and reinforced concrete constructions, metalized glass, metal shutters on windows, attics made from metallic materials, insulation with metallic elements, etc.)
- outdoor or indoor use
- inclement weather conditions, especially precipitation
- the occupation of the base station, i.e. the density of concurrent users in an individual cell and its capabilities
- the used frequency spectrum
- limitations to the data allowance
- network coverage

Figure 5: EG optimum LTE coverage map

APPLICATIONS

AMI

Advanced meter infrastructure is one of the key components of Smart Grids. To utilize its full potential, it is essential to have a reliable means of communication. Electronic meters and PLC data concentrators use different communication interfaces (ethernet, GSM/GPRS module, RS485) to connect and send data to out head end system through our private or public mobile network.

Testing the pLTE in Phase 1 we achieved more than sufficient communication speeds, low latency and security. Low latency network enabled us to use PLC gateways instead of PLC data concentrators which means that we get the data directly from the PLC meters to head-end system without the need to store it on a third device in a way that is comparable to P2P meters.

In Phase 2 of pLTE field trials the communication using NB IoT will used for industrial electricity meters and potentially for residential electricity meter readings.

Real time operational data

To provide reliable grid operation and delivery of electric power to our customers, utilities install remote controlled reclosers switches all over distribution power grid. This switch could be located on overhead line poles or inside low voltage substations. Modern recloser switch remote control unit can provide a large amount of different data (switch position, measurements, fault detection,) in real time. To achieve reliable service from remote controlled units modern communication platform is needed.

In the area of control and acquisition functions new communication technologies provide improvements in time synchronization, real time measurements and management functions for remote terminal units. Well known reliable process automation protocols like IEC 60870-5-104 and DNP3 TCP/IP are already used in the field. Protocol IEC61850 which is well used in middle voltage substation area starts his way also in the area or remote-control units distributed over power grid. At the moment no operating device is installed in EG power grid, but some laboratory and field tests of Phase 1 are already done with IEC61850 equipment and pLTE.

SCADA control functions on grid elements

To achieve mature level of automation on Smart Grid some SCADA functions are needed. For correct decision, how to control grid elements SCADA needs fast, reliable data channels from the field and back to grid elements. One of the real application is control of transformer tap changer in one of the low voltage substation. Normally tap changers operates according to local data. The problem is that in some cases only locally collected data do not lead to the most effective voltage regulation. To achieve optimal efficiency of the voltage control over larger area, data from whole area should be collected. Decision making software (SCADA) is in server room in Elektro Gorenjska HQ. The input data are collected via AMI, Quality control meters and remote terminal units. All this system use modern Ethernet communications. The result from SCADA is then send to transformer tap changer, to set output voltage. With the system increased percentage of our customers has optimal voltage conditions.

Field tests with pilot pLTE demonstrated that chosen technology can provide appropriate services for SCADA control functions.

Quality control according to IEC 50160

EG regularly installs power quality meters on the secondary side of MV/LV substations. Meters can also be installed at PV generation points to provide supervisory and control measurements.

Meters are used for measuring basic electric quantities, like voltage, current, active and reactive current and harmonics. Newer meters are also able to measure power quality parameters like harmonics and flicker. The device is used for permanent analysis of electricity supply quality in compliance with the EN 50160 standard. Measured data are transmitted to centralized head-end system via pLTE.

Time synchronization

Legacy power utility systems until now operated independently: the protection and control of power system, electric meter measurements, power quality. With the advent of new technologies such as smart meters, power quality measurement, new methods of protection and control, IEC 61850, the new systems in the field of information and communication technology (ICT), the items are becoming increasingly intertwined with each other. Applications like DMS features, Volt-var control, state estimator and others need accurate time-consistent data. Normally legacy systems have proprietary methods of time synchronisation. Nowadays more and more devices use Ethernet based time synchronisation protocols (SNTP, NTP). Some investigation and tests according to selected communication paths are performed successfully.

European funded projects

STORY

STORY wants to demonstrate and evaluate innovative approaches for energy storage systems. The challenge is to find solutions, which are affordable, secure and ensure an increased percentage of self-supply. The project consists of eight different demonstration cases each with different local/small-scale storage concepts and technologies, covering industrial and residential environments.

EG part of STORY project is besides the main activities to take an active part in work packages, contributing mostly in improvement of flexibility and robustness of large scale battery, ICT definitions and others.

Some field test of communication between power meters, quality meters and SCADA RTUs were already carried out with success. In Phase 2 of pLTE field trials the communication using NB IoT will be performed.

TDX-ASSIST

The TDX-ASSIST project aims to design and develop novel Information and Communication Technology (ICT) tools and techniques that facilitate scalable and secure information systems and data exchange between Transmission System Operator (TSO) and Distribution System Operator (DSO). The three novel aspects of ICT tools and techniques to be developed in the project are: scalability – ability to deal with new users and increasingly larger volumes of information and data; security – protection against external threats and attacks; and interoperability information exchange and communications based on existing and emerging international smart grid ICT standards.

Unfortunately, at the time of writing this document, the field trials haven't started yet. It is foreseen to collect quality control data, needed for DSO-TSO coordination, via pilot pLTE system as well.

CYBER SECURITY

As cyber-attacks have the potential to severely impact power grids, multi-layered protection is vital for securing the smart grid end-to-end. Compliance to regulations – i.e. NERC CIP, as well as standards that include NIST, IEC, and ISO, and preparing for security audits are forcing extensive changes in the overall utility security framework.

EG Smart Grid Communications solution is designed and tested with end-to-end security in mind.

Base to the our pilot pLTE network we are focused on:
- Network security-segmentation of network (different APNs), encryption data traffic between BTS location (encryption over the air)
- System security-isolating the pLTE system from the other EG communication systems
- LTE air encryption (EAS 256bit)
- User Authentication–registration of user in HSS, avtentication of user at RADIUS
- Device (router/modem) security-accessibility of device over different protocols: HTTP, HTTPS, SSH, Telnet, SNMP ..
- Firewall-specially in a connection with IoT devices

Multi-layered, defence-in-depth cyber security solutions for operational communications let our company combine the capabilities of several solution and services portfolios to address our specific needs.

REGULATORY ISSUES

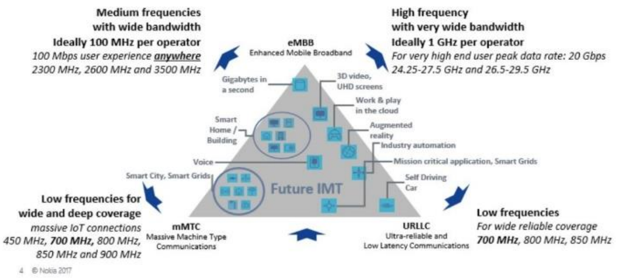


Figure 6: Frequency bands for LTE

For 4G LTE and NB IoT technology 2 x 3 MHz spectrum will be used in accordance with COMMISSION IMPLEMENTING DECISION (EU) 2016/687 of 28 April 2016 on the harmonization of the 694-790 MHz frequency band for terrestrial systems capable of providing wireless broadband electronic communications services and for flexible national use in the Union in accordance Articles 2 and 3, where subject to national decisions and choice, Slovenia designated and made available the portions of the 700 MHz frequency band for M2M. In accordance with Annex within the frequency bands 733-736 MHz and 788-791 MHz the use for M2M radio communications shall be as follows: the mode of operation shall be Frequency Division Duplex; the duplex spacing shall be 55 MHz with terminal station transmission (M2M uplink) located in the 733-736 MHz frequency band and base station transmission (M2M downlink) located in the 788-791 MHz frequency band.

ECC Report 242 Compatibility and sharing studies for M2M applications in the 733-736 MHz / 788-791 MHz band provides the coexistence analysis between machine-to-machine communication (M2M) applications in 733-736 / 788-791 MHz and services in adjacent bands for LTE-based M2M and narrowband M2M technologies (GSM-based M2M and NB-IoT), where narrow band M2M can be implemented with 200 kHz system bandwidth.

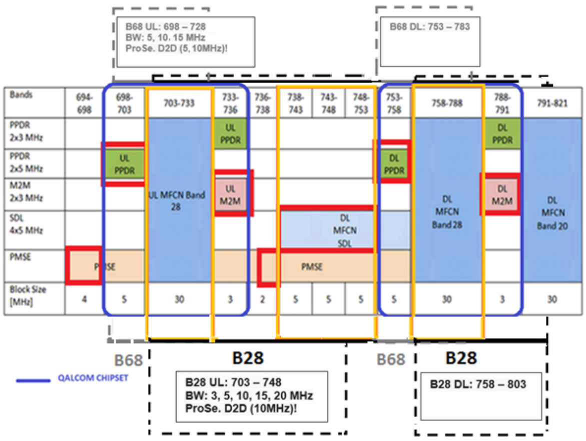


Figure 7: situation in 700 MHz band, Reference: 3GPP TS36.101

As 700 MHz frequency band is in accordance with the EC Decision (EU) 2017/899 used by Digital Terrestrial Television (DTT) till 30. 6. 2018, current testing is within DTT assignment that belongs to Slovenia.

Public tender with public Auction is planned after adoption of draft Spectrum strategy for smart dedicated networks for machine to machine (M2M) in 700 MHz frequency band (733 – 736 MHz/788 – 791 MHz).

It is also expected that the deadlines for the implementation of the obligations from the public tender will be adapted, and the Agency for Communication Networks and Services of the Republic of Slovenia will propose lower frequency fee because of spectrum unavailability and in case of achieving the agreement, propose to modify the valid General Act on the method of calculating payments for the use of radio frequencies (Official Gazette of the Republic of Slovenia, No. 30/13, 33/13 - Popr., 40/13 - Popr., 81/14, 21/16 and 63 / 16) accordingly.

CONCLUSIONS

There are not many private LTE networks serving the Smart Grid applications at the moment. Slovene power distribution companies, EG between them, are still striving to get needed frequencies for their private networks. The public tender is planned in 2019.

Nevertheless, EG succeeded to finish Phase 1 of pLTE trial. Most of communication test were done successfully. What we still should preform is testing of NB IoT (Phase 2) for metring purposes and testing of QoS (Quality of Services) for some of mission critical applications (e.g. GOOSE messages and time synchronisation in heavy network traffic).

In Phase 1 some problems with interoperability of user equipment occurred. With the help of manufacturers major problems were solved.

All in all the tested system, so far, proved as appropriate solution for next generation Smart Grids.

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