SMART METERING COMMUNICATION PERFORMANCE ANALYSIS IN EDP DISTRIBUIÇÃO

Mário Tomé Correia CHAVES
EDP Distribuição – Portugal
mario.chaves@edp.pt

Rui Santos BARBOSA
EDP Distribuição – Portugal
rui.santosbarbosa@edp.pt

Luís Miguel Costa AMORIM
EDP Distribuição – Portugal
luismiguel.costaamorim@edp.pt

ABSTRACT

Nowadays, electrical meters have been increasing its importance in the power distribution system and the research efforts are mainly focused on the development of Smart Metering. This application requires the use of communication technologies to access to a large number of point of supplies, covering the low voltage segment assuring the best cost–benefit ratio. In Portugal, the smart grid is expanding to several cities and EDP Distribuição is committed about to improve its communication performance with smart meters.
This paper aims to analyze the behavior of different communication technologies based on the knowledge gathered on real field.

INTRODUCTION

The communication ratio assumes a critical importance for the success of the implementation of smart grid and all of its possibilities.
This paper aims to analyze the behavior of different communications technologies based on the knowledge gathered on real field.
Thus, the main goals are:

- Comparative analysis of communication technologies as well pros and cons of each communication technology analyzed;
- Best suitable communication technology for different environments through inner characteristics such as electric grid characteristics, populational density, etc.
- Analyze if the actual communication technologies used in EDP Distribuição Smart Grid implementation will answer positively to the requirements of future scenarios.

The communication technology that will be approach in this paper will be based on cable and wireless communications. Nowadays, EDP Distribuição is using PLC as cable communication technology and GSM/GPRS as wireless communication technology. It will be analyzed the behavior of these two technologies considering the knowledge obtained from the site exposed before and considering the grid characteristics (rural or urban).
In the future, the distribution system will face significant changes such as decarbonization, digitalization and decentralization. All of these 3 "D's", including the decentralization of power generation, storage and commercialization will lead to a change of paradigm in operation of the network. There'll start to appear more microgrids with capacity to operate in island mode.

Will the communication technologies used by EDP Distribuição be flexible enough to answer to all of these requirements?

RURAL AND URBAN COMMUNICATION ENVIRONMENT

An interesting fact about rural areas is that they are covering the major part of mainland in most countries and as reported in [1], more than half of the world's population lived in rural areas by the year 2000.
Planning communication networks inside of rural areas are always full of considerations because of: i) its difficult topologies (florest, mountains, lakes, long distances between settlement areas); ii) lack of public facilities such as access roads, regular transport and sometimes reliable electricity power; iii) Severe climatic conditions impose heavy demands on the outdoor equipment.
On the other hand, there's urban areas where most of the constrains identified above are not present such as: i) high population density and proximity; ii) presence of public facilities such as access roads, regular transport and reliable power supply. [2]
In this paper, was studied the communication environment in rural and urban areas of Guimarães. This city was European Capital of Culture in 2012, together with Maribor in Slovenia and its historic town center is listed as UNESCO World Heritage Site since 2001.
The municipality of Guimarães is composed by several parishes with different electrical characteristics.
In its city center, electric grid has urban characteristics such as:

- Mainly electric underground grid;
- High population density and proximity;
- Industrial and residential consumers (different voltage levels);

On the other hand, there are parishes with rural characteristics:

- Mainly electric aerial grid;
- Low population density and proximity;
- Low industrial consumption.

COMMUNICATION TECHNOLOGIES

Before carrying out the study of different technologies to apply, it is necessary to study which zone to apply.
From the Home Area Network, to Local Area Network and the Wide Area Network, thus eliminating from the study possible technologies to apply due to the range they have.

An example of this is ZigBee and Bluetooth. Although they present low implementation costs in the grid, they have limitations at the level of their range, increasing the final cost of implementation. So, it is concluded that these technologies are suitable to the Home Area Network, revealing the Zigbee better features than the Bluetooth.
In this paper, it will be analyzed the communication technologies which suits better in Local Area Network.

CABLE TECHNOLOGY

Cable technologies are more expensive to implement in wide areas but it allows higher communication capacity, reliability and security. This technologies are generically characterized by it's low latency (Optical Fiber) and it's higher cost of construction/utilization when compared to wireless. There is many cable technologies in the market, like optical fiber, PLC, DSL, etc…
The selected technology to study in this paper it's PLC. This is the main technology chosen by EDP Distribuição to develop it's rollout of smart meters.

PLC

PLC (Power Line Carrier) uses the electric power distribution grid to transmit data. It allows to use the main power grid as a communication infrastructure reducing the implementation costs of communications mainly when exists about several (millions) of equipments with communication necessities.
As an advantage, among of being a low-cost technology, PLC communication provides important information about low voltage endpoints mapping.
Powerline communications methods are divided into broadband and narrowband. Broadband is used to send high-speed data, like Ethernet, around the home, while narrowband works at a bit more leisurely pace for utility meter reading, industrial command and control, home automation, and many lighting control applications. There are two main standards for narrowband nowadays: G3 and PRIME. [3] For this kind of applications, it must be certain the data will arrive, maybe not at top speed, but it does arrive.
PoweRline Intelligent Metering Evolution (PRIME) is the proposed protocol for physical layers and medium access control layers of power line communications stack from PRIME Alliance regarding the development of the IEEE P1901.2 standard. PRIME propose the use of a part of CENELEC, a frequency band with a bandwidth of 47,36 kHz located above 40 kHz. The frequencies under 40 kHz are being affected by major perturbations. [4]

ANALYSIS OF PLC PRIME IN GUIMARÃES URBAN AREA

Advantages:

- Economical solution – utilization of the electrical network infrastructure;
- Provides visibility of the underground electrical network, indirectly allowing mapping part of the city's electricity network (with aid to sensorization, currents variation, etc.);
- Greater concentration of customers in an urban area, which allows for a smaller cable length, more communication points (Advantage from the point of view of loss reduction and transmission of the signal to the EBs, but disadvantage in the opposite direction, since the communication of the EB to the DTC may be lost).

Disadvantages:

- Existence of industry, equipment that emits noise, among other aspects that can distort the signal.
- Multipath can cause distortion and attenuation of PLC signals.

ANALYSIS OF PLC PRIME IN GUIMARÃES RURAL AREA

Advantages:

- Electric grid in rural areas is simpler than urban areas;
- Exists some cases where information is sent from isolated clients via wireless to Virtual DTC;

Disadvantages:

- As the electrical network is typically aerial, it will suffer more with severe weather conditions, thus damaging the communication via PLC;
- Power energy losses can affect communication, especially if lines are long. The lower the line impedance, the better for communications; This situation it's dependent of the cable used; (better cables (underground armored)) worse: aerial cables.

PRACTICAL ANALYSIS

Nowadays, EDP Distribuição smart grid is mainly based in PLC PRIME. Most of the smart meters are communicating through PLC to the concentrator. There is an important indicator about smart meters which is measured by smart meters in telemetering vs smart meters registered in concentrators. To be in telemetering, the smart meter shall collect data and successfully send it to concentrator.
In Guimarães this indicator is slightly higher than 80% which indicates a moderate performance of PLC.
But, the PLC communication rate is influenced by several external variables such as synchronous noise caused by regulator switches, high frequency noise created by devices that use engines in some applications,

harmonics caused by switching on/off electronic devices, attenuation and interference.
These external variables makes the study about PLC communication rate inconclusive for now. Although, its possible to conclude that there are still some challenges to overcome in this technology.

WIRELESS TECHNOLOGY

The communication by wireless works through electromagnetic signals that are broadcast by an enabled device within the air, physical environment or atmosphere. This technology has low cost of installation, low security and bandwidth restrictions.
The main advantage of wireless technologies, is it's facility of connection to remote/difficult access locations, however, it's possible to occur a lost of signal for higher distances. On the other hand, wireless technologies can be affected by signal fading – difficult proliferation in high popular density areas.
There are many wireless communication technologies like RF Mesh, communication by satellite, cellular networks (2G, 2,5G, 3G, WiMAX, LTE), etc…
As an alternative to PLC Prime, EDP Distribuição uses GPRS as mode of communication in some cases, like public illumination. Due to this, it will be analyzed some advantages and disadvantages of cellular networks.

Cellular Networks (2G, 2,5G, 3G, WiMAX, LTE)

This technology is suitable to do the communication between Smart Meters and far places, although cellular networks brings up a high risk of obsolescence.
For example, WiMAX technology is now a dead technology and the market is more interested in LTE technology.

Advantages:

- The maintenance costs of a cellular network are responsibility of the mobile operator;
- Utilities when in use of public networks can have contracts with more than one mobile operator which gives more flexibility.
- Portugal has approximately 100% coverage of Cellular Networks;

Disadvantages

- Operational costs are higher when in comparison with PLC and private wireless networks (MESH).
- In abnormal situations like storms, the cellular networks may not provide the correct quality of service.
- Cellular networks as technology has not sufficient reliability.
  The infrastructures belongs to mobile operators which are subject to network congestion, resulting in a reduction of network performance in emergency situations.
- Low bandwidth;
- High risk of obsolescence;

ANALYSIS OF CELLULAR NETWORKS IN GUIMARÃES URBAN AREA

Advantages:

- Network coverage - 2G, 3G, 4G;

Disadvantages:

- Possible network congestion - non-critical services may limit use of service (lack of differentiation of service);
- Weak network coverage of underground transforming stations MV/LV.

ANALYSIS OF CELLULAR NETWORKS IN GUIMARÃES RURAL AREA

Advantages:

- Coverage of air transforming stations MV/LV.

Disadvantages:

- Lack of 4G coverage. (Limited to the use of 2G Technology and others with low bandwidth).
- Cell coverage dependent of the telecommunications operator and ineffective in up-country area;
- Need additional investment by the telecommunication operator to meet expectations;

PRACTICAL ANALYSIS

It was deployed a pilot project where were installed around of 50 smart meters that communicate through GPRS. Most of Guimarães' parishes have rural characteristics and for that reason there were deployed more than 2/3 of these meter in rural areas.
Analyzing the communication rates, it is possible to conclude the following:

Table 1: Values to urban and rural area.

Rural area	Urban area
86,8%	90,3%

As explained before there are restrictions in rural areas that do not exist in urban areas.
However, the sample is too small to conclude and to claim that GPRS suits better in this urban area than in rural areas. To prevent communication anomalies, can be concluded that the combined use of GPRS with PLC are better to increase the success of this ratio of communication.

FUTURE SCENARIO

Considering the actual status of the electric distribution network and a likely future, it is observed that the actual

technologies of communication used in Local Area Network, may be reconsidered to suit into new paradigm shifts.
The use of microproduction and self-consumption unities, associated with the introduction of storage unities, provides the costumer the possibility to sell its own energy between other costumers, as exposed bellow.

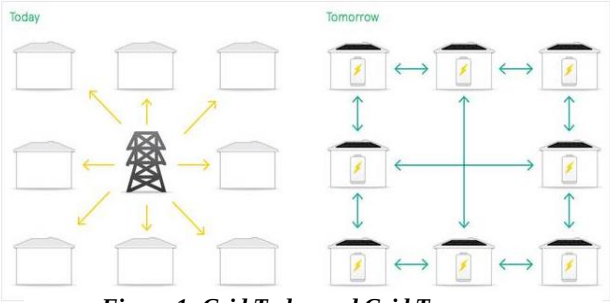

Figure 1: Grid Today and Grid Tomorrow.

This energy management system will allow the consumer to sell energy in peak hours (if he is not using that energy). It's sure to say that this scenario will change the loads diagram.
To ensure the success of this scenario (island mode), the applications will require low latency, so that, protections and other devices will need to work quickly and autonomously after the signal order.
It's certain that the single use of cable communications such as PLC will not be as effective as wireless communications in this scenario.

CONCLUSION

Different solutions can be suitable to different situations, through the needed necessities and what's better in order to have a successful data communication.
To Advanced Metering Infrastructure, latency is not a priority, however, latency is a "must" in Distribution Automation.
Different solutions are adjusted to several situations, for example, for a "Mission Critical" necessity, criterion like reliability and low latency has priority in detriment of the technology cost.
The same logic is applied to the choice of the best technology for each environment.
Different environments have different necessities which requires the use of different technologies.
Below there are some technologies that suits better to different requirements.

Table 2: Best Suitable Technologies to different requirements.

Standard	Suitable Technologies
High Bandwidth	Optical Fiber, BPL, WiMAX, 3G, LTE;
Low Latency	DSL, Optical Fiber;
High Reliability	Optical Fiber, LTE, Satellite, DSL, RF Mesh;
High Security	Optical Fiber, BPL, WiMAX, Satellite;
Low Price	PLC, Zig-Bee, RF Mesh, Bluetooth, GPRS (Public Network);

With the characteristics exposed above, and analyzing the different necessities of each environment, as well as the typification of electrical grid and populational density, it is possible to conclude the following:

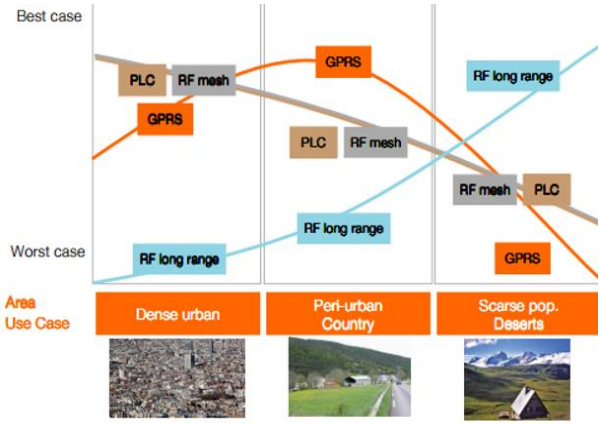

Figure 2: Best Suitable Technologies to different environments.

The main lesson learned is that "one size does not always fits all".
There are several technologies to be use in several purposes, and it's better combine some technologies to ensure the success of data communication.

REFERENCES

[1] Y. Li, H. A. Chan and J. I. Agbinya, "Networking in Rural Environments: Benefits, Feasibilities, and Requirements", June 2006. Available: http://epress.lib.uts.edu.au/journals/index.php/ajict/article/view/325

[2] M. Silva, R. Barbosa, R. Matos, "Reliability prediction methods – the procedure used by edp", Proceedings CIRED Workshop Lyon 2015, paper 1165.

[3] J. Harrison, Lincoln Technology Communications - Available: http://epress.lib.uts.edu.au/journals/index.php/ajict/article/view/325

[4] C.Males, V.Popa A.Lavric, I.Finis, "PLC Performance evaluation through a power transformer using PRIME" - Available: http://www.agir.ro/buletine/1392.pdf