Advances in Science, Technology and Engineering Systems Journal Vol.2, No. 3, 569-577 (2017)

www.astesj.com

Special Issue on Recent Advances in Engineering Systems

ASTESJ

ISSN: 2415-6698

The Search for a Convergent Option to Deploy Smart Grids on IoT Scenario

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A R T I C L E I N F O

Article history:
Received:29 March, 2017
Accepted:16 May, 2017
Online: 01 June, 2017

Keywords:
Distribution automation
Electric power distribution
LoRaWAN; RF Mesh
Smart city
Smart grid
Smart metering

A B S T R A C T

Smart city projects are quickly evolving in several countries as a feasible solution to the urban organization to provide sustainable socioeconomic growth and solve problems that arise as the populations of these cities grow. In this sense, technology application plays an important role in enabling automation of processes, improving the citizen's quality of life and reducing the costs of public services for municipalities and enterprises. However, automation initiatives of services such as electricity, water, and gas which materialize by the so-called smart grids, have emerged earlier than smart city projects, and are consolidating in several countries. Although smart grid initiatives have arisen earlier to projects of smart cities it represents a subset of the great scenario of IoT that is the vision in which the smart city projects are based. The time difference from developments between these two initiatives made the alternatives of communication technologies for infrastructures construction of communication followed different paths. However, in view of the great scenery of IoT is desirable to determine technologies that provide convergence of a single urban communication infrastructure capable of supporting all applications, whether they are typically IoT or traditional smart grid applications. This work is a review which presents and discusses the two main technologies which are currently best positioned to play this role of convergence that is RF Mesh and LoRaWAN. The strengths and weaknesses of each one of them are also presented and propose that in actuality LoRaWAN is a promising option to offer the required conditions to take on this convergent position.

1. Introduction

The first initiatives of smart grids have begun about ten years ago, in the year 2007. At that time the discussions about the intensive use of technology to automate public services in urban centers were very preliminary. In this context, technology options for building communications infrastructure was only scoped to support smart grid projects to the specific demands of utilities in segments such as electricity, water, and gas. In the specific case of the electric sector applications that motivated these initiatives were remote metering of consumption, automation of distribution networks, demand control, and to become viable an automated environment capable of enabling distributed generation development based on renewable sources [2, 3].

More recently, after the first smart grid projects implementation on a large-scale basis, initiatives of intensive use of technology for automation of public services in urban environments has emerged. These initiatives have defined smart city projects that use the concept of Internet of Things (IoT) as a technology to support the communication infrastructure. This new vision has stimulated technologies development aimed to meet applications with a particular profile, such as low data rate and tolerance of high latency. Smart grids typical applications were not primarily in focus [4, 5]. In this way, these two initiatives have created the conditions for industry to develop two different and parallel approaches regarding communication infrastructure. But it didn't take long for the vision about the need for convergence arises.

Considering this new scenario smart grid applications represents a subset in the bigger context of smart cities. As the industry developed initially without this convergent and integrated vision between smart grid applications and smart city the next step was the industry of smart grid communication systems expands the scope to cover other smart city applications. In the other hand, the IoT communication systems industry began to focus their products

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on meeting the demands typically smart grid with all its peculiarities.

In terms of well-established platform, RF Mesh assumed an outstanding position for smart grid projects. Regarding IoT applications, although there are currently various proposals under development, the technology that has to emerge as the most suitable for IoT and smart grid at the same time is LoRaWAN [6, 7].

This paper presents a review of the main technical requirements for smart grids, the main features of these two prominent technologies (RF Mesh and LoRaWAN) and makes a comparison between them. The goal is to discuss the possibilities of LoRaWAN to take on the role of convergence and interoperable option between different manufacturers required to support demands of smart cities and smart grids.

2. Smart Grid Requirements

The challenges faced by the electricity sector in all world markets have brought about deep changes in all three segments of the industry: generation, transmission, and distribution. From the point of view of the growing demand for electrical energy and urgency in environmental issues comes leveraging the renewable generation technologies development and transforming the traditional centralized array into distributed.

Transmission systems also go through a process of change. Search for technical solutions that reduce system losses is one of the actions. Another change is transmission lines construction to connect efficiently the new array of generation and ensure a suitable protection system [8].

Distribution segment might be the one that has been more challenged to promote changes in their way of operating. The distribution plant that was static becomes endowed with computational intelligence to promote operational gains and improvement of service quality indices, as well as add new services and features to consumers. The concept of smart grids represents this new way to operate and maintain the electrical system. It requires a telecommunications network overlaps grid interconnecting the systems to a centralized computer system. Smart grids add value to the entire industry, but the segments in which its application is most intensive is in distributed generation and mainly in the distribution system [8, 9].

Applications affected by this technological innovation are the consumption measurement and distribution operation. This new concept involves smart metering and Distribution Automation (DA), which evolves into the Advanced Distribution Automation (ADA), which allows the system to reconfigure them in the case of network failure. There are also other applications such as automation of street lights and asset management of the electrical system. Both smart metering and DA have specific technical requirements with regard to telecommunications support systems. As presented in the following items, it demands more stringent parameters from the point of view of data rate available and network latency tolerance.

2.1. Smart Metering

Smart metering means consumption measurements automation eliminating any human intervention in the process. Measuring routines are possible in real-time, every 15 minutes, every hour or in larger intervals. Smart metering processes uses an Advanced Metering Infrastructure (AMI).

Besides the main function, remote metering can provide electricity network, quality parameters and service availability together with the data collected from the SCADA systems of distribution substations.

The parameters contribution of quality and availability extracted from smart meters working as remote sensors enhances the diagnostic map of operation centers due to its capillarity and represent the points of service delivery [9].

2.2. Demand Response (DR)

The main motivation for the control of electrical energy demand is to adjust it to the generation capacity, transmission, and distribution, especially during peak times. In the case of mismatching down between available energy in the system and the total demand, actions are necessary to adjust it and try to balance the electricity system. In the context of smart grids, this interaction between consumers and the distributor of electric energy is possible in real-time.

The main source of consumer information is the smart meter that communicates with the utility systems via a communication network. In this same communication network, the load control takes actions on actuators installed in the facilities of consumers with the goal of providing the necessary adjustments in the consumption level. As the information system for the actions of demand response is the smart metering system, the technical requirement of AMI systems will meet DR's systems as well.

2.3. Distribution Automation (DA)

The basic idea of distribution system automation is to allow management (supervision and control) of network elements remotely from an operations center [9]. This concept is applicable to sub-transmission and distribution substations and distribution network using Automatic Reclosers (ARs).

In the case of DA, actions must be taken by an operator who performs a fault diagnosis and tries to restore as much as possible of network segments [4, 5].

Advanced Distribution Automation (ADA) gives more automatic actions by sending supervisory information to a centralized computer system. This system shall take decisions autonomously to open and close ARs in order to restrict the scope of a failure and restore a maximum number of possible network segments [9].

With regard to the requirements of communications network, three aspects are crucial: maximum data rate available, network availability, and low latency especially in the case of the ADA.

2.4. Other Applications

In addition to typical smart grid applications such as smart metering and distribution automation, there are new demands directly related to electric power sector. Among them are: assets management automation and street light automation. Supervision and control of the street lighting are already a reality in various cities around the world and has been usually supported by RF Mesh networks designed for smart grids. Regarding asset management (transformers, current transformers/potential transformers, capacitors, etc.), increasingly arise projects aimed at accelerating the information flow to empower management processes. Asset management processes more efficient represent gains in logistics, inventory optimization, and improvement of operational and financial results of companies.

With regard to requirements of telecommunications systems, both streetlight and assets management automation do not require any specific characteristics different of those observed in smart grid applications. Thus, a network Field Area Network (FAN) or Neighborhood Area Network (NAN) designed for smart metering and DA applications will be also capable of supporting them. In this sense, these new applications in the context of a smart grid network reinforce the convergence around a single IoT platform. The question is which technology is best suited to take on this role. Although RF Mesh is in theory capable of supporting all these applications they have a typical IoT profile and suggest the use of a communications infrastructure more adherent to this scenario.

2.5. Telecom infrastructure

Telecommunication infrastructure to support smart grid applications is divided into Outdoor RF Concentrator Devices, and Network Interface Cards (NICs). Concentrators are RF equipment installed on Telecom towers, top of buildings or even poles and are responsible for communicating with endpoints and concentrated those located within its covered area. The NICs are interfaces embedded on endpoints and are responsible for communicating with nearest RF Concentrator and make the interface with endpoint device’s application.

Outdoor RF infrastructure is usually divided into private and public networks. Public networks are those provided by third parties, generally, Telcos that share infrastructure with several other users. These are services like mobile network (GPRS, 3G, 4G) and Internet. Private are those in which a network or a network segment dedicated to the exclusive use of a single user. It can be considered private assets those acquired and operated by the company itself or contracted third-party companies, such as telecommunications operators. These are examples of services contracted to third parties: MPLS, dedicated circuits, satellite services, among others [10].

The main options currently available for utility companies to construct private telecommunication networks for smart grid applications are:

- i Backbone layer: Optical Systems, and SHF Point-to-Point Radios.
- ii Backhaul layer: WiMAX, LTE, and Point-to-Multipoint Radios.
- iii Access layer (FAN/NAN): RF Mesh and LoRaWAN, which are the focus of this work.

Considering the criticality of smart grid applications an aspect that needs increasingly be observed in the infrastructure construction of telecommunications and information technology (IT) is the information security.

With regard to communication technology selection to meet the requirements of high availability (on the order of 99.9% or higher), performance, and security are more under control of distribution company if the infrastructure is its own [8]. Table 1 presents the typical requirements of a smart grid network. [8, 9, 11].

Table 1: Typical Smart Grid Requirements – Access Layer

Smart Grid Requirements				
	Smart Metering/DR	DA	ADA	Asset Management/ Street Light
Frequency Range (FAN/NAN)	≤ 2.4 GHz	≤ 2.4 GHz	≤ 2.4 GHz	≤ 2.4 GHz
Transmission Mode	Bidirectional	Bidirectional	Bidirectional	Bidirectional
Maximum Data Rate per Terminal	10 kbps	10 kbps	100 kbps	Best effort
Average Latency End to End	≤ 2 s	< 1 s	< 160 ms	Best effort
Mobility of Endpoints	Not Required	Not Required	Not Required	Required (AM)
Geolocation	Important	Important	Important	Required (AM) Important (SL)

With respect to the defined values for the parameters, it is interesting to define the concept of "best effort". This term refers to the traffic on IP network information according to the features that are available at a given moment, without any compromise with the service quality standards.

Therefore, the information flow on the network will occur in a way that is possible. This operation mode is used to meet applications not sensitive to certain parameters.

In this work, the requirements selection studied and compared to the technologies considers the most critical factors to ensure the minimum acceptable performance by type of application. Each technical aspect listed in Table 1 is presented below with their respective most relevant comments and their impact on smart grid applications.

- i Frequency Range (FAN/NAN): The frequency band of operation of wireless systems that support the applications of smart grids is preferably not licensed and must be in such a way that meets the commitment between the longer range with the lowest possible transmission power and less sensitivity to obstructions between transmitter and receiver. Although the unlicensed frequency bands are much more susceptible to disturbance from other systems, they offer the great advantage of not requiring licensing processes before the telecommunications sector regulators, which also impacts in reducing the cost of the project, does not require payment of licenses for the use of the frequency spectrum. The range of the frequency spectrum in most markets that meet these requirements is in the range of 450 MHz to 2.4 GHz. Regarding disturbances caused by other systems operation in unlicensed frequency bands, the technologies used in smart grids applies countermeasures such as signal encoding, frequency-hopping, among others.
- ii Transmission Mode: Applications of smart grids imply an interaction between the endpoint and the operation center of electric power distributors for sending a data requested

in the same way as AMI and asset management automation and lighting, or for confirmation of reception and confirmation of a remote command execution just like in the case of the DA/ADA and DR. This makes two-way communication is a mandatory requirement in smart grid support technologies.

iii Maximum Data Rate per Terminal: This parameter indicates the maximum throughput of each endpoint. The data transmission rate in a communication network based on wireless technologies can vary according several factors, of which the main ones are the frequency range, the transmission power, the level of obstruction to the radio frequency signal propagation, the load of traffic to be transmitted over the network in a given time interval, and network latency. Although a typical smart grid application requires a throughput ranging from 1 Kbps to 100 Kbps by endpoints depending on the application, higher values of data transmission rate enable implementation of more elaborate projects and the traffic of more detailed information between the endpoint and the operation center.

iv Average Latency End to End: The delay in data transmission in a communication infrastructure has a critical rate depending on the type of application to be supported. Real-time applications or those which require a quick response time of endpoints, latency must assume values as low as possible. In the case of smart grids, most critical applications are DA and ADA in particular. Another scenario in which communication network latency is a critical factor is when a polling based system requests information from a large number of endpoints. The total time of a polling cycle and information collection from all endpoints need to occur within a certain period of time acceptable and pre-defined in order to make the process feasible. This is the case of the smart metering of consumers and demand control (DR). In some cases, the number of endpoints to be measured and controlled can reach tens of million.

v Mobility of Endpoints: Mobile communications are important to utilities mainly for voice and data communication between the field teams and operation centers. These applications are supported by communication technologies specifically developed for this purpose and are different from those designed to meet the applications that are part of the scope of this work. Although typical applications of intelligent network (AMI, DR, and ADA) do not require communication platform mobility, automating asset management, which is a very important application for the utilities, as commented previously requires this feature to allow the ability to monitor the assets displacement until the positioning at the place of installation and commissioning.

vi Geolocation: Electricity energy distribution networks need georeferenced systems due to its extension and capillarity. This feature is essential for the operation and maintenance of the electricity grids and provides necessary visibility for operation centers to the actions of operation and dispatch processes of service orders to the field teams. The Geographic Information System (GIS) is computational systems responsible for positioning the assets and grid lines itself on the map. In the context of smart grids, a communication platform on which it is possible georeferencing of communications network elements and endpoints represent an important functionality. This feature enables a smart metering platform to work as a sensor network, allowing the mapping of massive or punctual failures. For distribution automation application a georeferenced communications network is an important tool for the network operation according to the DA or ADA vision. For the projects of automation of the asset management geolocation is essential. Associated to the mobile possibility of terminals it is possible to follow and locate a particular asset since the warehouse to its positioning and start-up in the distribution network. Another interesting application of this feature in the plant communication to the public lighting service that allows lamps location on their respective poles.

Based on these main technical features evaluation of communication technology in comparison with the requirements of the smart grid applications, it is possible to determine the adequacy of this particular technology in order to meet the demands. The goal should be map options that provide the wide scope and service convergence in order to optimize the investments required for infrastructure construction, and operation and maintenance costs.

In the following items will be discussed the main features of the two options of communication network technology in the access layer that stand out today: the already established RF Mesh and the emerging LoRaWAN. In the case of LoRaWAN is evaluating its suitability for smart grid applications. Then a comparison is made between these two technologies showing the advantages and disadvantages between them.

3. RF Mesh

This technology for construction of private wireless networks is based on mesh topology in which each network element is a repeater. In this way, each element can be accessed directly from an access point or via another network terminal element through one or several hops. The basic topology of an RF Mesh Network is presented in Fig. 1. It is based on the IEEE 802.15.4g standard in the physical layer, IEEE 802.15.4e standard in the link layer, MAC sublayer, and the IETF 6LoWPAN Protocol on sublayer LLC [10, 11].

For the purposes of the network address, the IPv6 protocol is used which is able to address 3, 4x1038 different IPs. An IP address is associated with a terminal device so that should not exist on the same network one IP address associated with two different terminal devices.

RF Mesh aims to be a technology based on open standards to ensure interoperability between networks and devices from different manufacturers. To operate in this way should be adopted the protocol stack as shown in Fig. 2 [11, 12, 13].

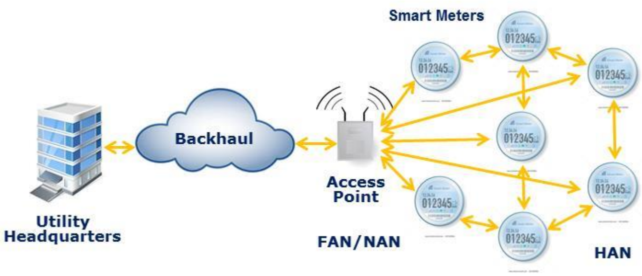

Fig. 1: Basic RF Mesh network topology

The RF Mesh standard was adopted by Wireless Smart Utility Networks Alliance (WI-SUN Alliance). WI-SUN Alliance is a global non-profit organization to promote industry solutions based on open standards and interoperable wireless networks. Officially formed in April 2012 has a mission to test and certify interoperability among different vendors. The focus is smart utility networks and smart cities. It has approximately 95 companies including utilities, government institutions, products manufacturers, and software companies [11]. The current movement of Wi-SUN seeks to expand the scope of its activities to meet IoT services.

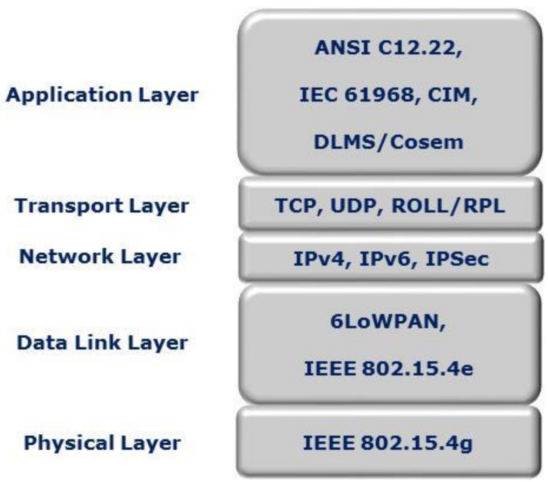

Fig. 2: Wi-SUN Alliance RF Mesh protocol stack

For utility applications, RF Mesh is a fully established technology and of proven effectiveness. The sum of the number of points serviced by the network deployed in several countries reaches over a hundred million. From the point of view of the technical and functional feature, RF Mesh was set to meet the requirements of utility companies' essential applications, such as smart metering and distribution automation, in the case of the electric sector companies [14].

The main characteristics are presented in Table 2 [11, 13, 14]. Data were based on theoretical information that was confirmed through field measurements on an RF Mesh network deployed in seven electric power distribution companies of CPFL Energia Group in State of São Paulo, Brazil deployed for smart metering of all its C&I customers and distribution automation.

Table 2: Main RF Mesh features

RF Mesh Features	
Application	Smart Grid (Smart Metering, DA) and Public Lighting. IoT in development.
Topology	Mesh
Frequency Range	863-876 MHz/915-921 MHz (Europe) 865-867 MHz (India) 902-928 MHz (North America and Brazil) 470-510 MHz (China) 920-928 MHz (Japan) 917-923.5 MHz (Korea)
Maximum Data Rate per Terminal	10-100 kbps
Average Latency	700 ms per hop (recommended up to 3 hops)
Maximum Aggregation per Concentrator	10,000 terminals
Urban Range (without repetition)	3-5 km
Rural Range (without repetition)	10-15 km
Technology Maturity Level	Smart Grid: Established IoT: In development
Mobility of Endpoints	Possible with restrictions
Geolocation	Not possible

Some highlights should be made regarding the technical RF Mesh specifications. First is related to the frequency band. The 900 MHz band is non-licensed in most markets. It dispenses with the obtaining of an operation license from the regulator agency of the telecommunications industry. The counterpart is the interference possibility, but that is outlined using advanced modulation techniques. Another aspect is the coverage area. It is a very interesting frequency range to bypass obstacles and provides a very convenient compromise between transmission power and available bandwidth.

The second point is about the network latency that is related to the topology. Mesh topology offers the advantage of range extension and creation of alternative routes automatically, on the other hand, can cause increased latency in the network. For smart metering applications, this feature does not represent a problem but produce an undesirable impact for DA applications. In order to overcome this restriction for DA applications, RF Mesh designs usually build specific paths in the network or use additional specific network elements, which lead to the rise of network costs. Endpoints can connect to the central Server via any network concentrator. This provides mobility in all coverage areas, but with restrictions in the sense that there is a trend of increase routing information traffic due to neighbor endpoints interaction.

4. LoRaWAN

This newly created technology won momentum with the LoRa Alliance foundation in March 2015. This non-profit organization gathers currently about 330 companies from various countries of the world between telecom operators, equipment manufacturers, semiconductor manufacturers, software companies, computer companies and consulting firms [15].

LoRaWAN is a fully convergent technology based on open standards, low-cost, and was designed from the start to build urban platforms for it. Thus the scope of application is very comprehensive. Among the possible applications are smart grids for utilities, including companies of the electric power sector. The offer of embedded devices grows constantly and includes portable device monitoring, public and patrimonial security solutions, management of urban infrastructure, healthcare, and smart meters [16].

Unlike RF Mesh topology LoRaWAN has a star topology which simplifies the operation, and significantly reduces traffic on network destined to routing information. On the other hand, it does not count with the coverage possibility of extension through the relay on the neighboring terminal device. This loss of functionality as well as being convenient for the context of it does not represent a problem due to the fact a LoRaWAN concentrator device has an average cost of approximately 5 times less than a Mesh RF concentrator.

As the frequency range of operation is also located on non-licensed 900 MHz spectrum, covered area tends to be very similar to RF Mesh. Advanced modulation techniques and access (CDMA) are also used to make the network virtually immune to interference and increased sensitivity of LoRAWAN embedded interfaces on endpoint devices [6, 17].

If a coverage expansion is needed, it can be done by using additional concentrators in RF shadow regions without causing a significant rise in project costs, considering the margin of investments reduction if compared to RF Mesh. Fig. 3 shows the reference topology of LoRaWAN and Fig. 4 the protocol stack [18].

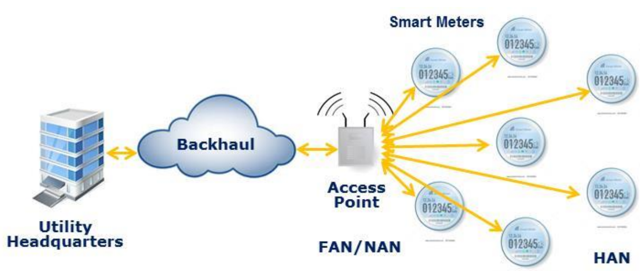

Fig. 3: Basic topology of LoRaWAN network

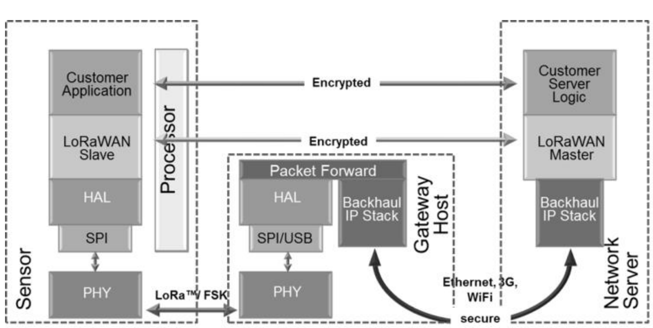

Fig. 4: LoRaWAN protocol stack

A prominent feature of this technology is the extremely low power consumption. The NICs in LoRaWAN endpoint devices are capable of detecting RF signals with power up to 20 dB below noise level consuming a minimum of electric energy. These LoRaWAN NICs can operate autonomously with the same internal battery for 10 to 20 years. This feature is extremely interesting to equip the utility's smart meters.

Regarding the performance characteristics given in Table 3 [6, 17, 19] it is observed significant advantages such as data rate available per terminal, uniform latency due to multiple hops absence to connect endpoints to a concentrator and aggregation capacity of terminals per concentrator. In the current version of LoRaWAN, this feature is 50% higher if compared to RF Mesh current version.

Table 3: Main LoRaWAN features

LoRaWAN Features	
Application	IoT, Smart Cities, Smart Grid (Smart Metering. DA needs to be studied)
Topology	Star
Frequency Range	867-869 MHz (Europe and India) 902-928 MHz (North America and Brazil) 470-510 MHz (China) 920-925 MHz (Japan and Korea)
Maximum Data Rate per Terminal	50 kbps
Average Latency	1 s
Maximum Aggregation per Concentrator	15,000 terminals
Urban Range (without repetition)	2-5 km
Rural Range (without repetition)	10-15 km
Technology Maturity Level	In positioning
Mobility of Endpoints	Possible
Geolocation	Possible

A highlight needs to be made regarding DA applications. Although the theoretical data suggest that this application can also be supported further studies must be done considering all requirements. It is necessary to consider the various situations of communication networks and the topology of distribution grid to determine a recommendation more assertive. The LoRAWAN suitability to any situation of DA projects still needs to be proven. A LoRAWAN differential is the three different classes of service available to allocate the applications according to its technical requirements [20]. Follows below a summary description of these three classes of services:

i. Bidirectional end-devices (Class A): The terminal’s uplink transmissions are based on an ALOHA-type protocol. The downlink from the server can only be made in two short receive windows that open after the uplink transmission. This class is that it provides the lowest consumption of energy in the terminal. It can be used for street light, smart meters of the residential segment and Asset Management.

ii. Bidirectional end-devices with scheduled receive slots (Class B): A pre-programmed transmission window is opened, which is managed from a timing signal (Beacon) that indicates when the receiver is ready to receive. It can be more convenient for smart metering of a C&I customer, smart metering substations located at the border of distribution and sub-transmission networks, or to load firmware updates of smart meters.

iii. Bidirectional end-devices with maximal receive slots (Class C): A transmission window continuously opens for transmission. This class is best suited for the possible allocation of the applications (Reclosers) and sub-transmission management systems based on SCADA.

Mobility is an inherent feature of technologies designed for IoT. In this sense, LoRaWAN is totally suitable for applications that require this functionality, such as asset management.

In the following item, a comparison is made between these two technologies for construction of smart grids FAN/NAN. The objective is to determine if LoRAWAN represents an appropriate option considering its technical characteristics of data rate available, low complexity, the guarantee of interoperability among different vendors, and mainly by its convergence around the IoT applications for smart cities.

5. Technologies Comparison

As demonstrated on items III and IV both technologies RF Mesh and LoRaWAN meet the requirements for the most part of smart grid applications. There is no restriction to use LoRaWAN for smart metering. An exception must be made for distribution automation (DA/ADA) in the case of LoRaWAN that still must be better studied. Table 4 presents a comparison between RF Mesh and LoRaWAN considering the parameters studied on this work.

Especially with regard to network latency, it is needed to evaluate boundary conditions about the possibility to use this technology, due to the fact that its performance on this item operates on the borderline of the requirements. For ADA the use of LoRaWAN in the current version of technology presents an even greater constraint also with regard to maximum permissible latency. For these two applications, a solution would be the use of technologies in Backhaul layer able to perform this function. In this scenario, the endpoint of distribution automation would be accessed and serviced directly by this layer of the network, without using the access layer LoRaWAN. Possible telecommunications technology for DA/ADA would be LTE, WiMAX, Point-to-Multipoint radio systems, or even an RF Mesh System specifically designed for this purpose or serving as a Backhaul solution for a LoRaWAN urban network. Table 4 presents a comparison of technical features of these two Network Access Layer technologies. It is proven the requirements compliance for smart metering and other applications such as street light and assets management automation.

Even if a restriction is observed for distribution automation applications, there is a boundary condition to be used which would be to build a network specifically designed to support this application while maintaining other smart grid services via LoRaWAN.

Table 4: RF Mesh X LoRaWAN Comparison

RF Mesh x LoRaWAN		
	RF Mesh	LoRaWAN
Topology	Mesh	Star
Maximum Data Rate per Terminal	10-100 kbps	50 kbps
Average Latency	700 ms per hop (recommended up to 3 hops)	1 s
Maximum Aggregation per Concentrator	10,000 terminals	15,000 terminals
Outdoor RF Concentrator Average Cost per Terminal	US$ 0,50	US$ 0,07
Technology Maturity Level	S.G: Established IoT: In development	In positioning
Mobility of Endpoints	Possible with restrictions	Possible
Geolocation	Not possible	Possible

One relevant advantage of LoRAWAN technology is the fact that is a fully convergent technology, open standards-based, low-cost, and ready to meet all IoT applications in the context of a smart city project. It is desirable that investments in a smart city platform meet all applications and services with an IoT vision, in order to optimize resources and simplification of telecommunications infrastructure. The LoRAWAN technology simplicity is another important aspect in comparison with RF Mesh. The fact that each terminal accesses directly a concentrator excludes the need for complex routing protocols present on RF Mesh. In the context of IoT, this functionality is not even desirable. There are various situations in which it is not even appropriate a terminal access a concentrator through another terminal.

Mesh topology provides the advantage compared to star topology extending the coverage area through NICs that act as a repeater. The endpoints of a neighborhood area network (NAN) can be aggregated in one NIC closer to the concentrator. If a failure event or unavailability of a NIC acting as an aggregator, another one can assume that role. Star topology does not have this functionality, but as discussed earlier, it does not represent a problem for the IoT scenario and offers the advantage of becoming latency uniform of the network. This occurs because star topology does not have hops among endpoints to access a concentrator as happens with RF Mesh.

The endpoints mobility is possible in both technologies. Endpoints of LoRaWAN and RF Mesh are not necessarily bound to a specific concentrator, but in RF Mesh there is a trend of increase traffic of routing information. In this sense, mobility is possible with restrictions. RF Mesh was initially designed to support applications such as smart metering, DA and street light, in which mobility is not an essential issue. Thus, this feature was not initially a priority. However, new smart grid applications with an IoT profile like asset management require a communication network capable of supporting mobility.

The geolocation possibility is an important aspect to be considered in the communication technology selection designed to support applications on smart grids. Utilities use georeferenced systems in their operational processes in order to plot on maps, geographical areas of distribution plant and locate through geographical coordinates their electrical grid assets. Geolocation becomes an important functionality for a communication network that aims to automate these assets, whether for operational processes or management. In this sense, LoRaWAN presents a significant advantage over the RF Mesh. Even though the studies point to restrictions on the use of LoRaWAN for DA, the ability to georeference smart meters in measuring plant extends its functionality to a sensor network which is able to geographically map failures occurrence in delivering of electric power. In addition to this application, the geolocation associated with communications mobility plays a key role in the projects of automation of management of electrical assets.

With regard to the frequency of operation and coverage, both urban and rural environments are well served by both technologies. They have similar characteristics and meet the requirements of the smart grids. However, considering a wider vision in the context of possible partnerships between utilities and municipalities to attend public services, a real scenario points out to the communication infrastructure construction in which coexist technologies such as LoRaWAN in the Access Layer, RF Mesh with mainly functions of Backhaul Layer besides LTE, WiMAX, PMP radios and Optical Fiber systems. Eventually, it will be necessary to complement the coverage with contract services from Telcos based on the public platform of NarrowBand IoT (NB-IoT) for RF shadow regions of the proprietary networks in which the investment on the part of the utilities and municipalities to cover those regions are not financially viable.

Data rate available per terminal in RF Mesh is typically 10 kbps, but some versions go up to 100 kbps. For IoT applications including smart grid, the data rate required by applications rarely exceeds this value. LoRaWAN technology that offers a maximum data rate per terminal of 50 kbps also meets this requirement. Certainly, the data rate effectively available at each point of the coverage area of a concentrator will depend on the level of obstruction to RF propagation, and the distance between the endpoint and the concentrator. In this sense optimization of effective data rate available on each endpoint will depend on the RF design.

Aggregation capacity is a parameter that defines how many endpoints can be connected using a single concentrator device. This implies directly in RF design which will affect the total cost of outdoor RF infrastructure and distribution of this cost per endpoint.

Outdoor RF Concentrator Average Cost per Terminal considers one RF concentrator distribution average cost among endpoints and the maximum aggregate capacity per concentrator. The cost of embedded NICs in the endpoint is not included. A comparison shows that LoRaWAN presents a lower cost in part due to the fact that the average price of the LoRaWAN concentrator device is about 5 times lower than in RF Mesh. Another fact is that aggregation capacity is higher reducing in about 7 times the cost of RF concentrator devices per endpoint.

The maturity level of technologies is different, mainly due to the time of startup of each one: Wi-SUN Alliance in April 2012 and LoRa Alliance in March 2015. This suggests that although the LoRaWAN is advancing fast in various markets, there is still much to be developed. The great interest of the industry demonstrated in just 1 year of organization, especially due to the adequacy of LoRaWAN on IoT projects makes the future of this very promising technology. On the other hand, RF Mesh is well established for the smart metering and automation. Although LoRaWAN is suitable for smart metering, there is an uncertainty regarding its support for distribution automation due to its high latency.

The next steps which certainly will follow from now on point out to an increasing engagement of industry; services companies, including utility sector; government entities; research agencies and academia. Studies of new applications that can be supported by LoRaWAN are advancing in various countries. In the context of smart grids, main applications that require focus to adjust this technology are related to electric grid automation.

6. Conclusion

Smart city projects in the urban environment introduce innovation in the infrastructure services provisioning, making applications accessible directly and fast anywhere. In this context, the concept of Internet of Things (IoT) plays a key role in the telecommunications platform construction that do these projects implementation possible on a large-scale basis. Smart grid initiatives for utilities represent part of this big scenario of smart cities.

Construction of a platform for IoT becomes reality by private and public networks combination, including the Internet as the main platform. Formation of private networks for IoT has two technologies that stand out currently: RF Mesh and LoRaWAN. In this sense, it is desirable to determine an option that provides smart grid and other smart city applications convergence around the same technology. In order to support smart grid applications, utility companies have widely adopted RF Mesh that aims to be an open and interoperable option to build private networks. Regarding interoperability that is essential for IoT projects, RF Mesh has yet work to be done.

For IoT services including smart grids the emerging technology LoRaWAN represents a really convergent alternative which also adopts open and interoperable standards, but at a lower cost if compared to RF Mesh. LoRaWAN technology provides the features necessary to take on the role of an adequate alternative infrastructure to support all smart cities applications, including smart grids. An exception must be made for DA and ADA, which needs to be better studied and tested under a LoRaWAN platform.

A boundary condition would be a separate network deployment specifically designed for this purpose. Another possibility is to build a LoRaWAN Backhaul network also capable of supporting DA and ADA. The currently available technology options that could play this role are WiMAX, LTE, Point-to-Multipoint Radio Systems, or even an RF Mesh System.

Finally, taking into account what was studied on this work it is recommended that utility companies that have not invested yet in a smart metering network based on RF Mesh should consider LoRaWAN inclusion as a possible option in their projects. This can help to find a viable way to build a smart grid infrastructure, taking into account the new context of smart cities, in order to provide a greater gain in scale, preparing the path for possible partnerships between companies providing public services and municipalities. The ultimate goal as well as to make feasible business plans that enable the projects, is to provide citizens quality public services based on technology-intensive application, at the lowest cost as possible.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgment

This work was supported by the Department of Electrical Systems (DSE), Institute of Electrical Engineering and Computing (FEEC), State University of Campinas – UNICAMP, SP, Brazil.

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