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A Comparative Study among Possible Wireless Technologies for Smart Grid Communication Networks

Kashif Laeeq

Dept. of Computer Science
National University of Computer & Emerging Sciences, Karachi, Pakistan

kashiflaeeq@fuuast.edu.pk, kashiflaeeq@yahoo.com

Wasif Laeeq

Building Technologies/Smart Grid Division
Siemens Pakistan Engineering Co. Pvt. Ltd., Karachi, Pakistan

wasif.laeeq@siemens.com, wasiflaeeq@yahoo.com

Abstract. the worlds of power grids technologies are converging towards a new concept that is smart grid (SG) technology. The basic objective of smart grid technology is to design an autonomous network in which all type of energy resources, consumers and any other entity related to electricity or energy are linked up together to enhance the energy conservation. In-contrast to traditional grid technologies, the smart grid has numerous benefits like bidirectional flow of information, safety and reliability, efficiency, resilience and sustainability of energy network. By utilizing modern technologies, SG is turning into the next generation grid. With all these blessings, SG is still in its nascent stage and gathering the goodness of related technologies to be more reliable and dependable. It is a large modular system consisting of different sub systems. The SG can be examine by exploring three layers, that are power and energy layer, communication layer and information technology layer. The scope of this paper is communication layer in which we emphasize the use of wireless communication rather than wired links in most of SG communications and study the possible wireless technologies and their utilization in SG. This paper also provides a comparative study of different wireless technologies for SG, on the basis of their standards, possible utilization and limitations in SG that may provide a direction and new thoughts for researchers in this domain.

Keywords: Smart Grid; Wireless Communication; Wireless Standard; Wireless Protocol; Power grids.

1 Introduction

Today's world believes on automation, sustainability, continuity of services and globalization. No one can even think any interruption of services specially that they pay. The past experiences of the world about electric system is pathetic, they have observed numerous blackout that plunk whole city into dark. The smart grid (SG) is the conceptual framework that provides the solution of all aforesaid issues. The next generation power grid is smart grid that differs with traditional electric power grid in many ways like traditional power grids follow uni-directional flow of electricity but SG allows bidirectional flows of electric current and other information to produce extensively distributed autonomous electricity delivery network[20]. The main objective of Smart grid is to optimize energy with economic, environmental and other benefits that must directly transfer to humanity by means of non-stop, cost effective, improve transmission quality, efficient power distribution, control greenhouse gas etc.

Initially wireless technologies were not so mature to deploy with other high-tech technology like SG but now in-hand advanced wireless technologies fully developed to organize with any technology particularly for SG. [1]. Owing to advance wireless system, smart grid being paid benefits of inexpensive commodities, ease of installation, rapid deployment, widespread access, mobile communications that wired technologies of smart grid and other older wireless technologies cannot provide [2].

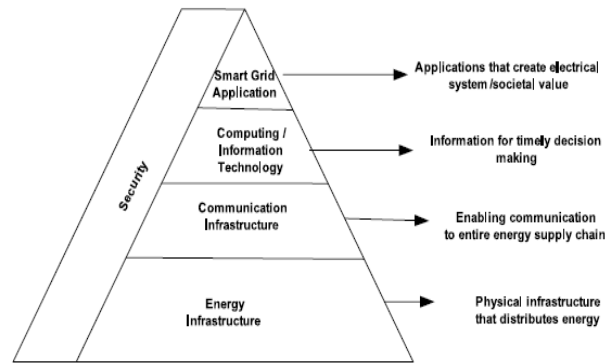


Fig. 1. Smart Grid Explanation [22]

The main objective of this paper is to elucidate the foremost wireless technologies for future smart grid communication networks and enlightens a comparative study among possible wireless technologies for future smart grid communication networks.

The rest of paper is organized as follows. Section 2 provides an overview of smart grid communication networks, section 3 describes requirements of smart grid, section 4 provides a study for wireless technologies for smart grids, section 5 describe the challenges for deploying wireless technology to smart grid section 6 present a comparative study among various wireless technologies for smart grid and finally conclude paper in section 7.

2 Smart Grid Architecture

National Institute of Standards and Technology (NIST) in [3] proposed that SG architecture be supposed to include the following entities: customers, service providers, markets, operations, Transmission, bulk generation and distribution. This NIST architecture is fully illustrated and organized architecture among in-hand or in literature. This architecture further classified customer area into following three categories

2.1 Neighborhood Area Network(NAN)

Different Building Area Networks (BANs) combined together to form Neighborhood Area Networks (NANs). A NAN includes one or more 3G support stations and number of BANs. The NAN Gateway (GW) can observe how much energy is being distributed to any particular neighborhood.

2.2 Building Area Network (BAN)

Different Home Area Network's (HAN) apartments combine to form Building Area Networks (BANs). Every building linked to the power grid maintains its own BAN. The BAN gate way (GW) can be used to supervise the power usage and requirement of the building of residents.

2.3 Home Area Network (HAN)

Each apartment or home has their own Local Area Network (LAN) that is referred to Home Area Networks (HANs). Within a home, different appliances, devices or meters can communicate in Home Area Network. The HAN gateways are can be used to facilitate Machine to Machine (M2M) communications in the smart grid framework.

These networks either wireless or wired networks, depends on scenarios. These networks support smart metering, messaging among devices, energy controlling devices, applications and consumers. These network also driven communication and applications from Building Automation and control network (BACnet), Home Energy Management System (HEMS) or some other energy management systems [4]

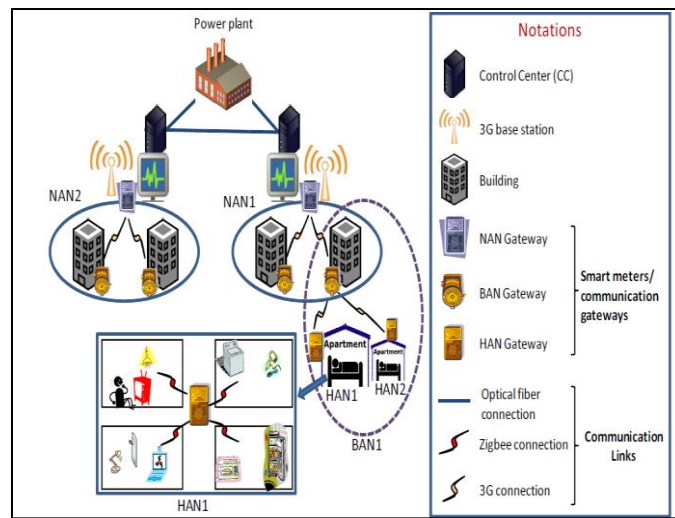


Fig. 2. Smart Grid Architecture [21]

3 Smart Grid Requirements

The author in [5] observed that the smart grid entire infrastructure needs interoperability among different applications with sufficient bandwidth, low latencies, reliable and secure communications. In addition the overall system security is vital in smart grid. In the following lines this paper provides some critical smart grid necessities.

3.1 Security Needs in Smart Grid

The smart grid technology is the combination of many different technologies. Different technology entails different scheme or solution for security, like wireless network security needs are totally alter with wired networks security. Therefore, smart grid security issues are in fact the biggest challenge for researchers of this domain. To avoid security attacks, robust security schemes should be implemented particularly for smart billing and controlling phase [6]

3.2 Reliability and Trust

Trust and reliability are two main needs of smart grid network. As a part SG infrastructure is reliable but as a whole, the SG system is still vulnerable and raising many queries on its trustworthiness. Aging power communications, increasing energy utilization and peak demands are some of basic reasons that emphasize unreliability issues for smart grid [7]. For improving the trust and reliability SG needs more robust protocols, modern IT solutions, faster and vigorous control devices, use of intelligent devices etc.

3.3 Scalability

Scalability is a major concern of today's smart grid. According to [8] a smart grid supposed to be scalable enough to help out the process and operation of the smart grid. Number of meters, sensors, renewable energy resources and data collectors are joining with smart grid technology.

3.4 Supervisory Control

The organized information of regular generation manages and regular voltage control requests to switch with the power share network control center. The supervisory control operations are vital to achieve smart grid characteristics like have room for a wide

variety of generation sites, dynamic power markets, participated customers and optimized assets. For better control and management smart grid have to use intelligent functions for interactions of telecommunication, optimization and control[24].

3.5 Quality of Services(QoS)

According to [23] interoperability is a foremost necessity for data communications in the smart grid networks. The smart grid data communications have to maintain the interoperability of Quality of Services (QoS) across the whole power grid. There are several nonfunctional QoS properties, like delay, rate, criticality, confidentiality and availability. In order to achieve QoS, inter related elements of smart grid technology requires more tightly bound together with more concrete algorithms.

4 Wireless Technologies for Smart Grid

Due to infrastructure-less topology, low power consumption, low cost of deployment, flexible, auto-managed and easy availability, wireless technologies are becoming promising communication technology for smart grid. Wireless technologies have been a well-liked research area with smart grid technology; nowadays we can observe tremendous growth in this research area. Currently, we have numerous wireless technologies for long range smart grid applications like Satellite communications, Cellular mobile communications, Radio Frequency (RF) and with lots of short range communications like Infrared (IR), Bluetooth, ZigBee, Near Field Communication (NFC), Ultra Wide Band (UWB) etc. [9]

This section illustrates the opportunities and limitations for different wireless technologies for achieving a range of applications for smart grid technology.

4.1 ZigBee

According to NIST [10] the most suitable standard for smart grid Home Area Network (SG-HAN) is ZigBee and ZigBee SEP. This wireless technology is reliable, low cost, low power consumer and more suitable for home appliances communications, energy monitoring, home meter reading and home automation. Devices that use ZigBee protocol can easily communicate with ZigBee smart meters and ZigBee SEP specially design to send information of smart meters to the HAN owner to check timely their home energy level [11]

This technology developed by ZigBee Alliance working on an open standard but having compatibility with IEEE 802.15.4 standard. It has unlicensed frequency range that vary 864MHz, 915 MHz and 2.4 GHz and follow DSSS modulation scheme. The data rate of ZigBee ranged 20-250 Kbps and coverage area is approximate 10-100m [12]. ZigBee communication is considered secure because it has adopted 128-bit AES encryption scheme for security [13]. It can be support star, tree and mesh topologies.

ZigBee devices mostly have limited memory and processing capability that hinder its utilities other than HAN. In-fact the utilization of ZigBee in Industry Area Networks (IAN) is vital but due to aforementioned issues and not well document, this technology still has no room in IAN. Other main issue that ZigBee faces is interference problem with WiFi or WLAN communication signal that has also same non-licensed band of frequency; this research issue still needs some more attention.

4.2 Wireless Local Area Network (WLAN)

The Wireless Local Area Network (WLAN) is truly needed for major wireless communication technology for future smart grid that provides vigorous, high speed and fast, point to point (P2P) and point to multipoint (P2M) communications. The WLAN belongs to IEEE 802.11 standard family, mostly follow spread spectrum technology for providing high bandwidth to multiple users simultaneously engage the same band of frequency. Spread spectrum can also minimize the interference among users [25]. In smart grid the WLAN can be used for monitoring and distribution of sub-stations. WLAN should be the best choice for the region where wired links are very difficult.

4.3 Worldwide Inter-operability for Microwave Access (WiMAX)

WiMAX technology belongs to 802.16 series standards that is a family of Wireless Metropolitan Area Network (WMAN). WiMAX technology recognized as local loop that allows receiving of data by microwave signals and broadcast signal by radio waves. It has both types of spectrum, licensed and un-licensed, licensed spectrums are 2.3, 2.5 and 3.5 GHz and un-licensed spectrum operates at 5.8GHz frequency. It support data rate approximately 70 Mbps with coverage area up to 48Km [14]. Due to its coverage range and high data rate this technology is best fit in smart micro grid and AMI (Advanced Metering Infrastructure). For

any monitoring purpose, WiMAX technology should be first choice in smart grid communication networks. The deployment of WiMAX is bit costly due to its tower, intelligently places the tower may reduce its cost.

4.4 Cellular Communications

A cellular communication network, such as 3G (WCDMA, CDMA-2000), 4G, and GSM are based on radio network dispersed over land surface areas known as cells, served by base station. It is speedy and cost effective to establish data communications exposure over a big geographic area [15]

The licensed frequency bands of 3rd Generation (3G) or 4th Generation (4G) cellular technology perform its operation on 824-894MHz or 1900MHz [16]. The cellular communication has 60-240Kbps data transmission rate. Distance coverage is not fix, depends on the cellular service availability. For smart grid cellular communication has vital role, it has already strong structure that may be used in smart grid applications. In [17] author explained that for remote substation i.e. Remote Terminal Unit (RTU) and SCADA communication occurs by means of cellular communications.

4.5 Wireless Mesh Network

A network that is based on mesh topology, nodes are communicating through radio links are called a Wireless Mesh Network (WMN), emerging as an essential wireless technology [18]. IEEE 802.11 and 802.16 are actively working on developing new specifications for WMNs.

WMN is actually a self organized and easily self configured, this property of WMN is essential for smart grid communication system automation. This feature also enables electric or power utilities to deal with new connectivity requirements determined by customer demands[19]

5 Challenges to Apply Wireless Technologies in Smart Grid

Indeed wireless technologies have emerged as a key breakthrough in fixed wired technologies, in smart grid. it can be changed messy wired connections of power grids into clean, manageable and flexible atmosphere. Implementation of this wireless technologies take various performance, security and other technical challenges. The key technical challenges and issues of wireless technologies in smart grid applications should be summarized as follows.

5.1 Recourse Constrains

In general we can observe that mostly wireless technologies have inadequate battery power supply [26]. The most frequent constraints, that wireless technologies observed are energy, memory and processing capacity constraints. These are few very important considerations that limit the migration of smart grid wired technologies to wireless technologies.

5.2 Scathing environmental Conditions

Wireless communication has directly affected by their surroundings and harsh environment may disrupt the proper communications. In smart grid applications, wireless communications may agitate by highly caustic environments, vibrations, humidity levels, dust, radiations and various unseeing noises [27].

5.3 High Bit Error Rates

The bandwidth and latency at each link of wireless are location dependent and varying continuously that make wireless communication difficult to meet quality of service requirements. Due to noisy environment of electric power systems and obstructions, wireless communication observes high bit error rates.

5.4 Secure Communications

As wireless technology prone to security attacks specially denial of service (DoS) attack, ciphering, wormhole attacks, black-hole attacks etc. presence of these dangerous attacks, wireless technologies always at high security risk [28]. Wireless technologies are on air that's why security is a major concern for this technology and may be the biggest challenge for deploying in smart grid.

Secure data storage and information exchanges are enormously vital for energy utilities, particularly for smart billing and power grids control [29].

6 Compression of Various Wireless Technologies for Smart Grid

Varieties of wireless technologies for smart grid have been compared and provided a comparative study based on key parameters that illustrated in Table 1.

7 Conclusion

The smart grid technology has been envisaged as an evolution of traditional electric power systems. The integration of information technology with smart grid, make it to manage information over grids. The main objective of smart grid is to enhance efficiency, safety, reliability of the tradition power grid with two way communication of energy.

This paper highlighted wireless communication technologies and their requirements for future smart grid technology and also emphasized that in many situations wireless technologies are better idea in place of wired technologies in smart grid. This paper has provided a comparative study among various wireless technologies that may be the first choice for smart grid communications. This study may provide a way of thinking towards step up wireless technologies for smart grid. The role of this paper is to explicate the wireles technologies for future smart grid, lift some challenges and issues for deployment of wireless communication technologies for smart grid.

A Comparative Study Among Various Wireless Technologies for Smart Grid								
Wireless Technology	Coverage Area	Data Rate	Standard	Scalability	Latency	Security Level	Limitation	SG Application
WLAN	100m	1-54Mbps	IEEE 802.11	<250 nodes	<200	Moderate Level	Unavoidable bottlenecks in WLAN architecture	Automation and distribution protection
ZigBee	10-100m	20-250Kbps	IEEE 802.15.4	<100 nodes	< 250ms	Integrity checks may or not be used(Security Level is Low)	Short Range, Low Data Rate.	Home appliances communication
WiMAX	48Km	70Mbps	IEEE 802.16	<100 Nodes	< 250ms	Integrity checks may or not be used(Security Level is Low)	Not Wide-spread	Wireless automatic Meter Reading
Cellular	10-50Km	60-240Kbps	GSM, GPRS, CDMA	(3G)100-1000 nodes (4G) <100 modes	(3G) 250ms-1s (4G) <250ms	(3G) confidentiality may require but integrity checks must require. (4G) Security Level is Low	(3G) Costly Spectrum Fees (4G) Low data Rate	SCADA and monitoring remote locations
MobileFi	Vehicular Standard	20Mbps	IEEE 802.20	<100 nodes	< 250ms	Integrity checks may or not be used(Security Level is Low)	Delay in the communications	PEVs communication and remote monitoring
Bluetooth	1-100m	721Kbps	802.15.1	<8 nodes	<200ms	Very low level of security	Range and operational limitations	Short range monitoring
WiFi	35m indoor 100m outdoor	40-50 Mbps	802.11	<33 nodes	<200ms	Very low level of security	Operational limitations	Communication among different stations.

Table 1. Comparative study of major wireless technologies for smart grid applications

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