IMPACT OF WIRELESS COMMUNICATION NETWORKs ON SMART GRID & ELECTRICAL POWER DISTRIBUTION SYSTEMS OF ELECTRICITY INFRASTRUCTURE

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ABSTRACT: *Smart energy grid and smart electricity distribution is envision to meet the requirements of the 21st century in a sophisticated distributing ways with real time transmission approaches. For real time transmission the various wired and wireless communication and technological approaches have been integrated with smart grid and smart electrical power distribution system. These wireless communication and advance control system connect consumers to their smart grid station and smart electrical power distribution system by remotely. This research systematically review the roll of wireless technologies and network attributes in advancement of smart electrical power systems. In addition, various wireless technologies involved in smart electrical power distribution such as internet (wide area network), ZigBee, Bluetooth, WI-FI (Home area network) and GSM, WIMAX (Neighboring area networks) has been discussed in this paper. This research particularly focused on the comparison of the attributes, issues and robustness of wireless home area network technologies. The key aim of this research paper is to propose a conceptual communication architecture known as energy management middleware for smart energy grid and distribution on the basis of wireless technologies analysis. The proposed architecture can be adopted as base for communication middleware between smart home appliances, smart meter and smart energy grid and distribution.*

KEYWORDS: Smart energy grid and smart distribution, wireless technologies, comparison table, proposed architecture.

1. INTRODUCTION

Wireless communication play a key role in the revolution of the electrical power system. For examples upgrading efforts associated to increased communications in the electrical power system to expand reliability and productivity [1]. It is not only limited to increase the electrical power system productivity but also perform the processes control and monitoring networks throughout the electric power structure. Sensors are mounted to monitor the generation , distribution systems and power used in the system. Furthermore, theseoperational sensing and control networks can be further classified according to their location. Electricity thieving is common Patrice rest of the counrties and Pakistan is one of them. The government of Pakistan losses Rs 86 billion per year due to electricity thieving, unpaid electricity bills, poor infrastructure, line losses, mess management, overstaffing ,inappropriate and costly investments, poor quality of services, undue political interference, mis-handling routine matters and law and order situation. To minimize the electricity losses recently the government of Pakistan decided to install the smart meter based on wireless technology. The aim of installation of wireless smart meter will be cut down of theft of electricity at various level [2]. A more interesting byproduct is going to be the ability to top-up your electricity bill. Many researchers and leading companies provide ICT (information and communication technology) solutions in electric power industry into the advance metering infrastructure. The AMI helps electrical power companies to reduce line losses, improve the electricity monitoring, power quality and operating efficiency while reducing consumption, carbon emission and operating cost. The Huawei Company provide smart meter infrastructure for the improvement of billing systems, line losses analysis and device based consumer interaction. Generally, the more advancement in electrical power supply and demand system needed to make the grid stations more reliable, secure and efficient[3]. This can be possible to make by future electrical power network smarter by embedding the real time communication modules with power grid and distribution sites[2].To address the encounters of the present electrical power grid system an advance concept of smart electrical grid has emerged[4]. The smart electrical power grid system and smart distribution system can be considered an advance electrical power grid structure for improving effectiveness and reliability over automatic control system, advance transmission and distribution network, electricity sensing devices, new energy management methods, smart meter technologies, and high electrical power converters make faster the transmission and distribution of powers[5]. Thegovernment of Pakistan started to install the electrical energy mobile meter reading processes through the mobile phone based on android application. The main purpose of these android based mobile meter reading is to improve the efficiency, accuracy and transparency with in system performance and system response. According to the direction of National Assembly of Pakistan these procedure have been originated by electricity distribution companies in Pakistan. After the deployments of these system a significant decrease has been noted in the number of grievances. MMR (Mobile meter reading) schemes has been in progress in several areas of rural areas of Pakistan. Figure 1 described the meter reader getting the meter reading through MMR (mobile meterreading) by android based mobile phones. The rest of paper isdivided into six sections, first section is consist with introduction while second section represent the demonstration of smart grid and smart distribution system and wireless technologies used in SEGDS has been discuss in section three. Section four is comprised with proposed architecture for SEGDS and section five drawn the conclusion and section six represent the references. The reader visit the remote place once during a month and collect the reading information. The table 1 shows the brief summary of android based metering system installed over the various cities of Pakistan. Although, small number of meters have been installed and had positive outcome to electrical power companies.

Figure 1: Android based mobile meter reading

Table indicate the deployments of total number of AMM (Android based mobile meters) in various cities by different electricity distribution companies.

Electricity Distribution Companies	Number of cities with AMM	Number of cities without AMM	Trained staff to use AMM
SEPCO	23	40	0%
HESCO	22	67	0%
LESCO	05	10	300

Table 1. Number of android based mobile monitoring systems

SEPCO (Sukkhar electrical power company) has been started to installed mobile android based system in 23 cities rest of 40 and HESCO has been initiated in 22 cities out of 67 and IESCO recently initiated the installation of mobile metering in 5 cities rest of 10 cities. By installation of these mobile based metering system the meter reader are bound to visit the remote site and took pictures of every actual reading on meter. New android based mobile with high pixel camera have been provided to meter reader to take good quality of pictures without any problem. The various electrical power distribution companies arrange the computer operation trainings and mobile software application skills to the related staff for providing better services.

2. SMART ENERGY GRID AND DISTRIBUTION SYSTEM (SEGDS)

For the decades, no change has been occurred in the basic infrastructure of the electrical power grid and distributed system. The traditional transmission and distribution electrical power system was a sources of electricity supply but now the traditional component of electrical power infrastructure are near to end of their time.The existing electricity distribution structure is very complex and DO not appropriate to the meet the requirements of the 21st Century. The present electrical power infrastructure is consist with deficiency of automatic inquiries, poor prominence, and mechanical controls, triggering slow time of reaction and absence of smart aware system. While the new smart electrical power grid station has been emerging with in power sector [6]. Figure 2 demonstrated the basic infrastructure of smart grid and smart distribution power system.

(SEGDS)

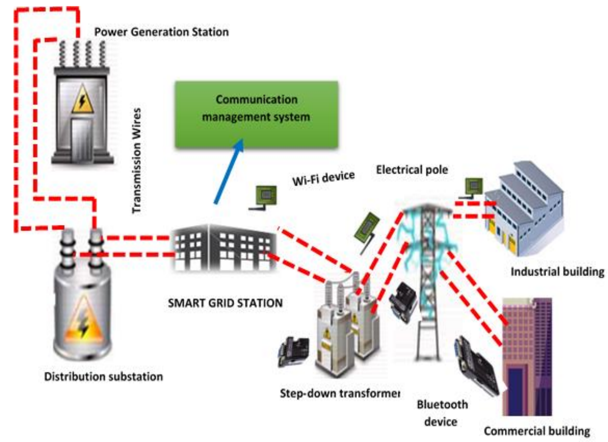

Figure 2. Smart grid and power distribution system

These deficiencies and inappropriate structural components have added the severe power failure over the past decades. Furthermore, the other preventing aspects are, the intensive growth of population and accumulative demand of electricity, global environmental changes, failure of equipment, limited energy production and distributions, poor communication methods, small generation of electricity from winds, solar and hydro. Meanwhile a smart power grid structure is instantly required to address these issues [7]. To recognize these deficiencies and address the existing challenges, the concept of smart electrical grid has emerged [8]. This SEGDS (SmartEnergy Grid and Distribution System) is structure for next generation of electrical power system. The SEGDS is advance smart infrastructure for enhancing power productivity, consistence power distribution, security and smooth incorporation of new renewable energy resources through smart control and by advance information and communication mediums [9]. To make the SEGDS system better and smarter, some efforts has been approved in the basic infrastructure of electrical power system. The various smart application services using wireless communication mediums have been emerging within these system like Bluetooth, ZigBee, Wi-Fi, Wimax, sensors, 2G/ 3G/4G cellular networks and ad hock networks based on different area coverage ,bandwidth , data rates and quality of services. [10]. the proposed frame work of SEGDS contain different component for smart communication between transmission and distribution sites. The SEGDS architecture has various domains from electrical power generation station to distribution end. It works with multiple layer for supplying the electricity from its source to destination. the layer one consist with initial power generation station ,layer two support the transmission of energy power from the generation to distributed substation, layer three and layer four consist with step-up and step-down transformer who performed the accelerating and step-down the electricity for the traveling on the electrical wires for domestic and commercial purposes respectively. The last one layer five where home level consumers are involved in electricity consumption. This layer deals with different wired and wireless technologies in smart and optimal management of electrical power in domestic level.

2.1 Power Generation Station

It is responsible for electricity production and sent it through wires to distribution substation via step-up-transformer. The transformer increases the pressure of electrical power accordingly. Thus, the electricity flow the lengthy distances, it's upraised the 756,000 voltage.

2.2 Power Distribution Substation

The electrical current then travel through the electrical transmission lines to the distribution transformer where power force is let down to between 2000 and 13000 voltage. Electrical energy is then reserved through the transmission power lines to a mounted pole transformer or underground transformer box and density is dropped by step down transformer among 120 and 240 voltage.

2.3 Step-Up-Transformer

It is responsible for increases the pressure of power and transmit the electrical power current to distribution station via power lines.

2.4 Step-Down Transformer

It is responsible to step down the voltage traveled from distribution station from the high voltage to lower voltage

2.5 Electrical Power at Homes

Then the electrical power reached at homes from the services box via smart meters which measure how much electricity is used by the consumers. The electricity travel with closed circuits via transmission wires to substation if the circuit is open electricity cannot flow. In homes smart wireless technologies are used to perform the energy management.

3. WIRELESS TECHNOLOGIES USED IN SEGDS

Additional efforts have been initiated to make more efficient the smart electrical power grid and distribution system. This is known as SEGDS or smart grid, intelligent grid and advance grid system. The SEGDS is responsible for fast delivery of electricity, provide security, and protect consumer privacy, monitoring real time energy consumption, transmission and smart distribution by using the various wireless technologies according to the preferences of electricity consumers [11]. The wireless technologies make smarter and intelligent the grid and distribution system of electricity. Figure 3 represent the various wireless technologies used by smart energy grid and distribution system in electrical power structure. Various wireless communication mediums have been identify to considering in smart grid communication architecture, how much capabilities offered by these proposed technologies in terms of bandwidth, data rates, traffic congestion and coverage area. Although, every wireless technology has its own issues, limitation and technological benefits. The potential concerns encounter by various wireless technologies have been highlighted in this research. The frame work in figure 3 shows that several domestic consumers have different preference of electricity utilization in their homes for optimal and smart energy management.Some consumers used Bluetooth technology to transmit the real time energy consumption and a number of other consumers has wireless local area network connectivity for wireless data transmission. Furthermore, some consumers prefer the ZigBee and 2G/3G/4G cellular communication. Besides the advantages and features of wireless technologies it is difficult to categorize appropriate network technologies for smart grid and distributed wireless communication framework. The research paper highlight some technological issues of Bluetooth, WI-FI and ZigBee technology during the incorporation in smart energy grid and distribution infrastructure.

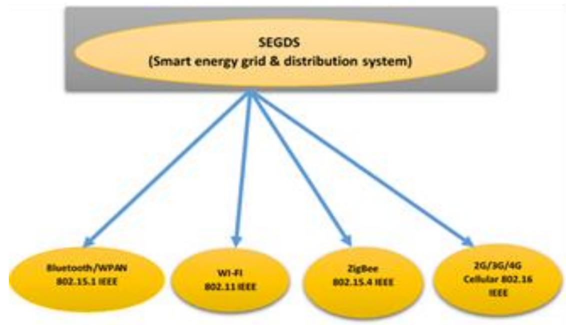

Figure 3. SEGDS with wireless technologies

3.1 Wi-Fi (Wireless Local Area Network IEEE 802.11)

IEEE define a stander 802.11 for Wi-Fi wireless technology with its maximum 11Mbps data rate. It provides single point to multipoint and point to point robust high speed communication. The IEEE 802.11 allows several users to occupy the same frequency channel at a time with minimal interferences to adjutant subscribers. The wireless LAN covering three non-interoperable technologies like direct sequence spread spectrum, infrared technology and frequency hopping at 1 and 2 megabit per seconds (1 and 2Mbps) on 2.4 GHz frequency channel [11]. The other generation of Wi-Fi technology are as IEEE 802.11b, 802.11a, 802.11g, 802.11n and 802.11i. These are the enhanced version of Wi-Fi technology operate on 2.4GHZ and 5.8 GHz frequency channel. The maximum offered data rates 54Mbps to 600Mbps by enhanced versions like IEEE802.11b, 802.11a and 802.11n respectively. IEEE802.11a and 802.11g support up to 54Mbps but both have different operating frequencies. IEEE802.11a operated on 5.8 GHz frequency channel with orthogonal frequency division multiplexing modulation technique where 802.11g used 2.4 GHz frequency band [11]. The IEEE 802.11n is introduced to support multiple inputs and multiple outputs technology and increased data rate up to 600Mbps [12]. The enhanced versions of Wi-Fi (802.11i) support the WPA-2 protocol for cyber security. It has many advantages such as easy to installed, support mobility and less expansive devices [13].

3.2 Bluetooth

It is a universal short range wireless technology standard for point to point connectivity of a wide range of electronic equipment's [14]. The newly adopted Bluetooth small energy technology is design for low level power sensor equipment's and innovative web application facilities opens the new approaches for companies of domestic meters. This technology is used for monitoring the small devices that are operated on button cell batteries. Bluetooth technology is used in metering system to identify the maximum electricity consumption by the home based electronic devices and it also allow consumers to remotely track, adjustment and control and monitor the utility bill.

3.3 ZigBee

ZigBee is also included in wireless mesh network technologies, it is developed on IEEE 802.15.4 standard [15]. It is sufficient and cost-effective and commercially available wireless technology. However it support low data rate on personal area network. This technology is used for reliable message communication, home equipment automation, devices control, monitor health care activities remotely and automatic control of consumer devices [16]. ZigBee uses two band frequency channel for communication such as 2.4 GHz and 915 MHz used direct spread spectrum communication technology for data transmission and reception. The estimated data rate offer by ZigBee technology is 20Kbps to 250Kbps. ZigBee wireless technology is consist with different functional equipment used for wireless communication. Such as FFD (full functional device), Router and ZigBee end device RFD (reduction function devices) [17].

3.4 Comparison Table of Wi-Fi, Bluetooth and ZigBee

The table 2 shows the related issues in wireless technologies used by smart energy grid station and smart power distribution system. Different wireless technologies has different data rate, coverage area, frequency band, modulation techniques and issues regarding the usage.

Table 2. Issues, coverage, frequency and bandwidth comparison between various wireless technologies

Wireless Technology	Frequency Band	Data Rate	Coverage	Modulation Techniques	Issues
Wi-Fi	2.4GHZ, 5.8 GHz	1Mbps, 2Mbps, 11Mbps, 600Mbps	32meter or 105fts	DSSS,OFDM	• Interface Issues with Bluetooth, • interoperability problem with Bluetooth • Bluetooth and Wi-Fi cannot be operate at same environment • 802.11b has automatic data rate modification • security problems • bandwidth • coverage • traffic injection and modification [18] • 2.4Ghz frequency band • Quality of service
Bluetooth	2.4Ghz	2.1Mbps	10meter or 33fts	FHSS	• Data throughput degradation problem in existence of WI-FI • do not support same environment • lack of automatic repeat request when sensitive data is lost • lack of security • bandwidth • coverage • frequency agility • used same frequency band 2.4Ghz
ZigBee	2.4Ghz, 5.8Mhz	20Kbps, 250Kbps	10-20 meters	DSSS	• Heat up issue • data rate • coverage • channel overlapping with other wireless technology • use same frequency band 2.4Ghz[19] • latency • Quality of service[20]

4. PROPOSED ENERGY MANAGEMENT MIDDLEWARE ARCHITECTURE

For the electrical power load management and transmission of real time power in commercial, non-commercial and industrial level. Thesmart system will manage the electricity consumption within home at minimal level and transmit the consumption via wireless technologies to smart grid station. In this research paper two types of architecture has been proposed. The first one is hardware based architecture consist with smart metering devices to communicate with smart grid station and the second one is software service architecture which perform the dynamic adjustment of electricity in home at nominal level. The both architecture are incorporated to each other for the better management and dynamically adjustment of electricity with in homes by using various available wireless technologies.The SEGDS confronted with many challenges due to smartness, large amount of real time data transmission and wireless technological issues like security, heterogeneity, reliability, QOS, channel interferences, bandwidth and latency. Many researcher has been proposed the various solution to address these kind of challenges. This research work will proposed a SEGDS architecture which will provide the efficient energy management, better collection of information, better dissemination of data to end consumers and easy technological integration by using its energymanagement middleware at consumer sites. The proposed architecture for SEGDS will address the heterogeneity of network, provide better security, reliable communication, transparency and will also provide an openness interfaces for researcher. The architecture is consist with middleware system, smart home appliances, communication paths, smart meter and SEGDS.It will communicate with the smart home appliances and electrical devices for acquiring the real time energy consumption and disseminated to smart meter without any channel congestion then the smart meter transmit this real time information to DCU(data collection unit) and the DCU then again send it to smart grid station via preferred wireless technology. The EMM will also performed the energy management with homes by switching off the extra electrical and electronic devices. The DCU is responsible for communication between smart meter and smart grid station.

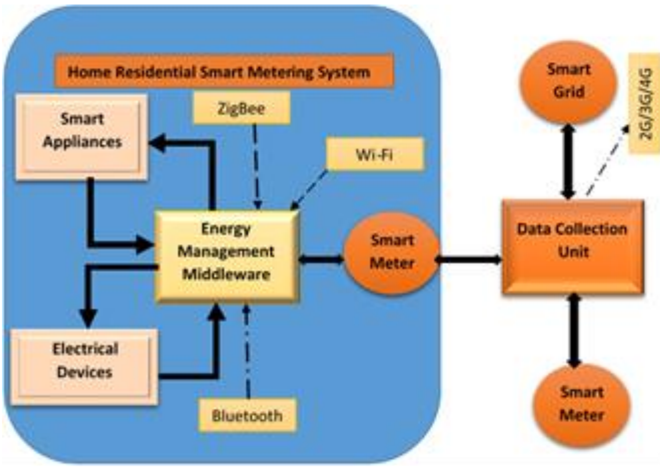

Figure 4. Energy Management Middleware

4.1 (EMM) Energy Management Middleware

Energy management middleware is service architecture provide a communication path among the home appliance to smart meter and smart meter to SEGDS. The EMM services architecture dynamically adjust the electricity consumption of homes appliances and electrical devices to save the cost for consumers and nominal electrical power load management at domestically. The consumption information will travel from electronic and electrical devices to EMM system via Bluetooth and ZigBee wireless technologies. The EMM will act as a monitor for consumer electrical load patterns as well as electrical power services providers. It will performed the dynamic energy management, power loadmonitoring, control the electricity consumption and smart power distribution. The wireless communication technologies are connecting with EMM from the certain locations. The EMM software is incorporated with arduino hardware system which provide an open interface for updating and modification of functions of hardware components. The consumers will also be benefited from this system because they monitor the real time energy consumption pattern of every individual appliance installed at homes.

4.2 Heterogeneity

The proposed architecture service is like a bridge for various wireless platforms to communicate each other. The heterogeneous network do not care about protocol, services, application and network architecture and other issues. These platforms just share their information to EMM services architecture which is responsible of hide the networks differences and compatible communication. The EMM platform manage the heterogeneity and interoperability between computing devices, networks, protocol and applications.

4.3 Transparency

Another network issues handle by this platform is communication transparency. It is very important challenge for developer to hide the communication differences of various communication mediums from the consumers and the related devices. Transparency hide the network complexity from its user. It will provide architectural module to consumers and devices to share their information and data from, anytime, anywhere, anyplace, any network and any user. This platform provide the communication transparency, location transparency, mobility transparency and application transparency to electricity consumers, smart meter and smart grid station.

4.4 Openness

The middleware will also provide any open interface for developer for modification and updating the software application for batter communication and managements of data from received and transmitted from various networks. The middleware support the different degree of openness to dynamically identify the new service station and access them.

4.5 Scalability

The proposed system also allow scalable communication between different communication technologies. It allows the system to acquire resources from other networks for resource allocation, maintain QOS on network and load balancing for a smooth data transmission.

5. CONCLUSION

Smart energy grid and distribution system performed key role in electricity transmission and distribution from its generation station to distributed points. The performance of smart grid and smart distribution is dependent of the rapid growth of communication application and network parameters. In this research, the issues come by wireless technologies has been discussed and a conceptual EMM architecture has been proposed for SEGDS. Proposed EMM is based on composition of software and hardware components which can implement for home automation, dynamic electrical power load management, monitoring the electricity consumption patterns and control the electrical power usage. The EMM architecture address the heterogeneity, transparency, scalability and openness of various communication networks connected on SEGDS. This architecture need some more devices, sensors for better data management, smart switching, data acquiring from various communication mediums and secure transmission of real time data for SEGDS.

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