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Smart Grid Communication Protocols

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ABSTRACT
Present power grids are getting replaced by smart grids, mainly for improving performance of existing power grid. Integration of electrical, electronics and computer science have led this technology more popular. Smart grid technology is characterized by full duplex communication, automatic metering infrastructure, renewable energy integration, distribution automation and complete monitoring and control of entire power grid. Wireless sensor networks (WSNs) are small micro electrical mechanical systems that are deployed to collect and communicate the data from surroundings. Security of wireless sensor based communication network is a major concern for researchers and developers. The address oriented design and development approach for usual communication network requires a paradigm shift to design data oriented WSN architecture. This paper is presents different communication protocols used in smart grid technology.

***KEYWORDS**: Smart Grid, WSN, Zigbee, WiFi, GSM*

I. INTRODUCTION
The electrical grid is being revolutionarily transformed as Smart grid. Smart Grid is an automated and broadly distributed energy generation, transmission and distribution network. It is characterized by full duplex network with bidirectional flow of electricity and information. It is a close loop system for monitoring and response [1]. Smart Grid is being conceptualized and developed by various organizations around the world such as National Institute of Standards and Technology (NIST), Institute of Electrical and Electronics Engineers (IEEE), European Technology Platform (ETP), International Electrotechnical Commission (IEC), Electric Power Research Institute (EPRI), etc. Diverse set of standards and harmonization between various standards are also being rigorously researched by these organizations [2]. It is an intelligent power grid with assimilation of various alternative and renewable energy resources. Automated monitoring, data acquisition, control and emerging communication technologies are the most prominent features of smart grid deployment. Use of diverse set of communication standards requires analysis and optimization depending upon constraints and requirements. These requirements can be decided on the basis of area of coverage, type of application, bandwidth requirement, etc [3-4]. Smart grid hierarchical communication network can be categorized as Home Area Network (HAN), Neighbourhood Area Network (NAN) and Wide Area Network (WAN) as per the applications of communication technologies at various levels of deployment of smart grid [5].

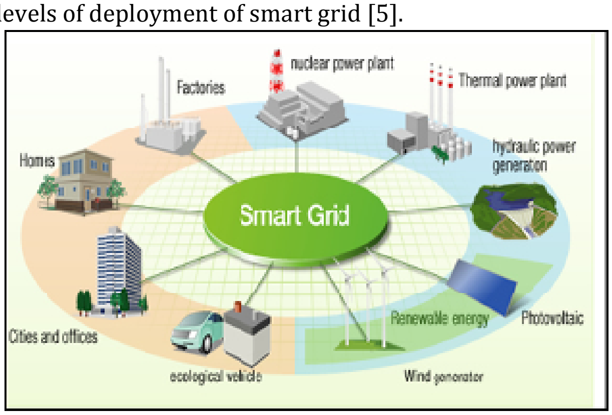

Fig. 1 Smart Grid

The unidirectional nature of communication and centralized generation makes the traditional grids less efficient, thus reengineering of current grid is required in such a way that they are able to meet increasing demand, are less prone to faults and power loss, reduce electricity thefts and air pollution, extends life of equipment etc. This bidirectional grid with integrated communication system, highly efficient sensors and measuring units, advanced components and control methods, decentralized generation and smart distribution is called smart grid. They are self-healing, have efficient OMS, reduce greenhouse gas emission and focus on improving the PQ. Their main objective is smart and optimal utilization of all available resources.

The major characteristics of smart grid are –
- It allows informed participation of consumers to modify their use and purchase of electricity and monitor their consumption pattern.
- It allows use of all generation and storage options i.e. centralized as well as distributed (incorporates renewable energy resources also).
- It enables new services, markets and products.
- Provides real time pricing.
- It improves power quality by self-healing, load forecasting, fault prediction and control and monitoring of frequency.
- Asset utilization and operating efficiency is optimized by the use of latest technologies.

II. Architecture of Smart Grid
The bidirectional smart grid is composed of a smart generating system, smart transmission and smart distribution system and an advanced metering infrastructure with highly efficient meter data management system. Below figure shows the basic architecture of smart grid.

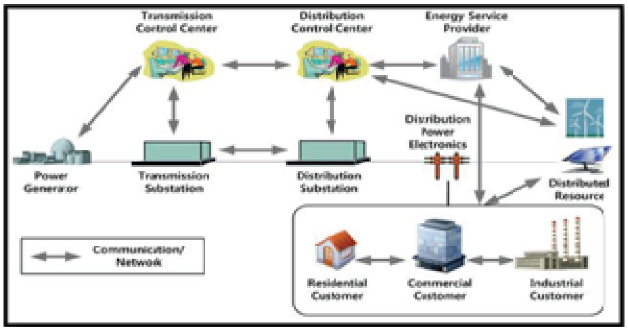

Fig. 2 Architecture of Smart Grid

Table 1 Brief Comparison of Between Existing and Smart Grid

Parameter	Existing Grid	Smart Grid
Generation	Centralized	Centralized and distributed
Metering	Electromechanical (only for billing not much control)	Digital (Enabling real-time pricing and net metering)
Operation	Manual equipment checks, maintenance	Remote monitoring, predictive, time-based maintenance
Reliability	Prone to failures and cascading outages	Automated, prevents outages before they start
System topology	Radial, generally one way power flow	Network, Multiple power flow paths

III. Overview of Various Network

A. Home Area Network

HAN is applicable for home automation. It is used for the consumer domain and consists of electronics appliances and wireless sensor networks. These consumer electronics appliances communicate their energy consumption statistics to central home monitor and regulator or smart meter. Central regulator or smart meter sends it to the central electricity grid for monitoring, control, fault detection and billing purposes. Smart meters and intelligent electronic devices receive the commands from central power grid and they control the home appliance based on the received commands. Home Area Networks (HANs) have the coverage area of few meters. IEEE 802.15.1 (Bluetooth), IEEE 802.15.4 (Zigbee), IEEE 802.11 (WLAN/Wi-Fi), IEEE 802.3 (Ethernet), Narrowband PLC (Power line communication), etc. standards can be used for Home area networks .

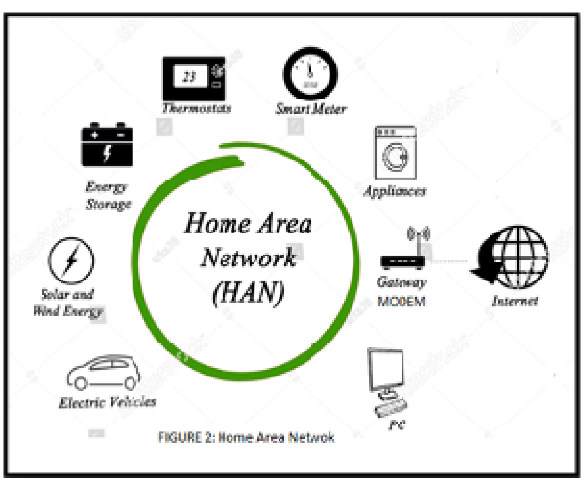

Fig. 3 Home area network

B. Neighborhood Area Network

The function of Neighborhood Area Network (NAN) is to communicate the information collected by smart meters to central controller. The NANs may contain few hundreds of smart meters deployed in HANs. Smart meters are linked with different gateways through NANs. The coverage region of NANs is around 1–10 square miles.

IV. Communication Standards for Wireless Sensor Networks

The address oriented traditional communication network is based on dedicated physical and network identification of transmitter and receiver. As WSNs include redundant nodes to compensate for degraded signal strengths of the nodes or node failure, in a WSN, the specific address of a node is of least concern. Measured values must be communicated between nodes irrespective of an address of the node. Thus, WSN communication is data oriented. WSN communication architecture design entails a conceptual paradigm shift based on applications. The communication standards applicable for WSN are described as below

A. Zigbee

Zigbee is based on IEEE 802.15.4 standard. It is an energy proficient short range wireless communication technology. It functions in the ISM (Industrial, scientific and medical) band which is allocated for industrial, scientific and medical applications. Zigbee operates in the band of 2.4 GHz, 868 and 928 MHz with full duplex wireless data transmission. IEEE 802.15.4 standard describes physical layer and media access layer and Zigbee Alliance has expanded the configuration of an application layer and network layer. The maximum throughput achievable by Zigbee is 250 Kbps. Zigbee can play an imperative role in operation and maintenance of power grid, data accumulation, parameter measurement, security, monitoring and consumer interface.

Fig. 4 Zigbee Wireless Sensor Network

B. Bluetooth

Bluetooth is a short distance wireless communication technology based on IEEE 802.15.1 standard. It uses short wavelength wireless transmission in the unlicensed ISM band from 2400 to 2480 MHz. It uses frequency hopping spread spectrum (FHSS) technology and around 1600 hops per second. Its key features are extensive availability, low power consumption and rapid data exchange. Bluetooth was initially developed in 1994 by Ericsson and then a group of firms formed a special interest group to retain and improve this technology. There are two network topologies used in Bluetooth which are termed as Piconet.

Fig. 5 Bluetooth Wireless Sensor Network

C. Wireless Fidelity or Wireless local area network

Wireless Fidelity (Wi-Fi) or wireless local area network technology is established on the basis of IEEE 802.11 standard. Wireless local area networks are prevalent for LAN applications with peak data rates of around 150 Mbps and extreme coverage range of 250 m. Wi-Fi (IEEE 802.11b) operating on 2.4 GHz band achieves maximum data rates of 11 Mbps. Other versions based on IEEE 802.11a standard operates in 5.8 GHz band using Orthogonal Frequency Division Multiplexing (OFDM) and IEEE 802.11g (improved version of Wi-Fi) operating on 2.4 GHz band provides data rate up to 54 Mbps. IEEE 802.11 provides data rates of up to 600 Mbps using Multiple Input-Multiple Output (MIMO) technology. Security concerns for Wireless local area networks are addressed and solved in IEEE 802.11i standard using Wi-Fi Protected Access (WPA-2) encryption. It uses an Advanced Encryption Standard (AES). The main feature of Wi-Fi is existing wide support in most of the electronic devices. It is an upper layer protocol which allows communication over an Internet without using a protocol translator. Restricted number of channels can be used without an overlap in Wi-Fi/WLAN. This means that a restricted number of wireless clients can be connected in a Network. However, advantages of Wi-Fi are high data throughput, wide spread availability, IP support and network scalability.

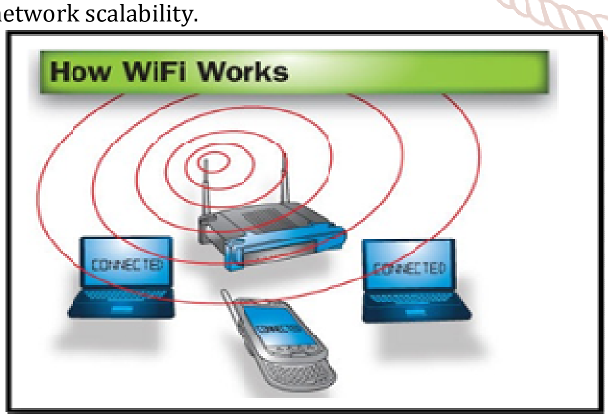

Fig. 6 WiFi Sensor Wireless Network

D. Z-Wave

Z-Wave protocol is specifically designed for smart home applications. It can be adopted in Home area networks of smart grid. Z-Wave is a low data rate, short range radio frequency mesh networking standard operating on 908 MHz band. The maximum coverage area is 30 m indoor. It does not require central coordinator but employs master and slave nodes. It can support 232 devices. The data rate is from 9.6 Kbps to 40 Kbps.

Fig. 7 Z Wave WSN

V. Sensors for the Smart Grid

Various sensors are used to measure and monitor smart grid parameters few have been listed below

- Basic measurements: voltage sensing, current sensing, temperature sensing, moisture sensing, continuity sensing and phase measurements.
- Wireless Sensor Networks for Automated Meter Infrastructure (AMI)
- Smart Voltage Sensors
- Smart Capacitor Control , that can monitor and control capacitor banks remotely
- Smart Sensors for Outage Detection.
- Smart Sensors for Transformer Monitoring.
- High Voltage Line Temperature and Weather Condition Sensors.
- Distributed Generation Sensors for load balancing
- Smart Grid Storage and in load monitoring and dispatch of energy.

Conclusion

In this paper we presented the different communication protocols that can be used for smart grids. The method to be used mainly depends on the various parameters such as distance, speed, cost etc. There still many protocols which are used for the smart grid application and are mainly depending on the fried such as automation, robotics medical etc.

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