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A Review Article on Wireless Sensor Network in Smart Grid

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Abstract: The problems associated with convention power grids are overcome by smart grid. The major advantage of the smart grid is to use conventional as well as non- conventional energy resources. While traditional grids are based on coal and fossil-fuels, but these energy resources are diminished now a days. So we move toward the renewable energy resources. Smart grids are allowing two-way communication system between utilities and customers, and it is based on digital technology. Smart grid includes more efficient transmission of electricity, reduced operation and maintenance cost, improve security, based on renewable energy system. The communication technology used is 'Wireless Sensor Network' which makes the system cost effective for monitoring, controlling, measurement and fault diagnosis in various domain of smart grid. Zigbee can be use as a communication medium which is based on IEEE 802.15.4 standard.

Keywords: Smart Grid; Wireless Sensor Network; Zigbee; Renewable Energy Sources; IEEE 802.15.4 Standard.

I. INTRODUCTION

An electric power grid is a network in which electricity has been delivered from sending end to receiving end. It consists of generating station, transmission lines and distributed line. If some intelligence are build into electric grid than it become the Smart Grid. The smart grid is the modern electric power-grid infrastructure for improved efficiency, reliability, and safety, with smooth integration of renewable and alternative energy sources, through automated control and modern communication technologies [1, 2, 3]. To make the Smart Grid cost effective a new communication technology called Wireless Sensor Network is used. WSNs have number of sensors, each such sensor nodes have several parts such as: a radio transmitter, internal antenna, a micro-controller, battery sources. The applications of WSN are the sensing [4], data processing [5], gathering [6], and data forwarding [7]. WSNs are suitable for monitoring applications for their ability to operate in harsh environments [8][9]. In military defence, disaster relief, environment monitoring, biological and commercial applications, and other fields have broad application prospects [10]. Wireless sensor networks are sensing and monitoring the specific object, transmission lines, substation and home automation. On the other hand, the wired monitoring systems require installing expensive communication cables and need to maintain regularly, thus, they are not widely implemented nowadays because of their high cost [3]. Hence, there is an urgent need for cost-effective wireless monitoring and diagnostic systems which can improve system reliability and efficiency [11]. A promising WSN technology will facilitate efficient communication for monitoring electric power infrastructure [12].WSN is self-organized and cost- effective network which formed through wireless communication mode. In this network, the supervisors can get the information everywhere in the network and the data is transferred in the route build up by the nodes [13]. WSNs have various applications like sensing, processing, data collecting, data forwarding etc. WSNs are well suitable for monitoring applications for their ability to operate in harsh environments [14] [15].

Figure.1 shows the architecture of home automation network which is connecting to smart grid through AMI. This HAN network is based on the wireless sensor network in which Zigbee provides the communication medium. This Zigbee allow the hub to communicate with (HVAC, PV etc.), or wired and wireless networks. HAN implements the two-way communication channel, on the other side hub communicate to the outer world through gateway like Wi-Fi and Ethernet.

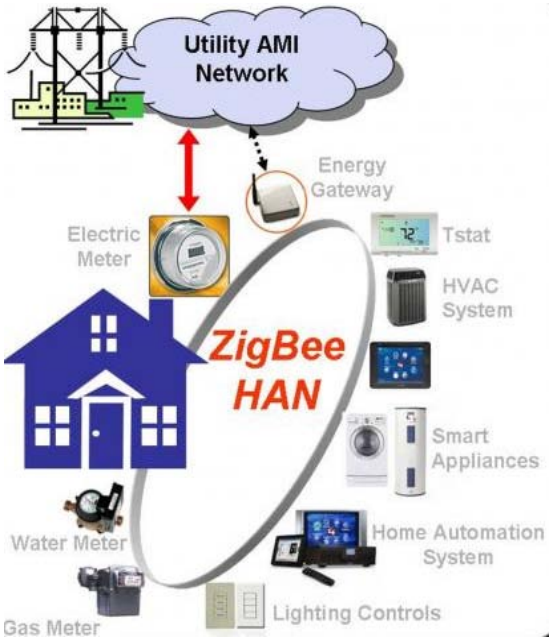

Fig.1. WSN in Home Automation Network (HAN)

A. WSN Communicating Medium

Wireless technologies like ZigBee, WI-FI, Z-Wave and Power Line Carrier (PLC) are preferred in HAN applications which can suffice low data and short range communication requirements [16, 17].Out of these Zigbee is best suited technology because Zigbee has short-range, low-data rate, energy-efficient that is based on IEEE 802.15.4 standard. ZigBee communication was subjected to interference from the thick walls of the building but it helped in energy efficient communication since it suffered least interference compared with Wi-Fi [18].WSN based on IEEE 802.15.4 standard and operate on 2.4GHz provides maximum energy efficient data transmission. The RF spectrum of Zigbee has implemented around 2.4 GHz ISM band, the 915MHz band in North America and one channel in the 868 MHz band in Europe. Zigbee has two types of devices such as Full Function Device (FFD) and Reduced Function Device (RFD). In Zigbee sensor nodes are either organized in star, mesh, and cluster topology. But mesh topology is the top most among all the topologies.

- *IEEE 802.15.4 based Zigbee Protocol*

The high power consumption, high rate of interference and data congestion associated with the other wireless sensor networks can be overcome using ZigBee networks [19]. Zigbee is the low power wireless network suitable for Home Area Network Monitoring. ZigBee Alliance, an industrial consortium, designed the ZigBee Standard and applications have shown a growth rate of 35% in usage of ZigBee in Smart Grid from 2009 to 2015 [18, 20]. It is based on IEEE 802.15.4 standard having 2.4GHz frequency band. The data transfer rate stipulated for ZigBee standard is 250kbps and the communication range depends on the module being used [21]. The wireless sensor nodes based on Zigbee have used in three different types of functions. Zigbee coordinator acts as the bridge between the control station and the entire network. The Zigbee router helps in transmitting the message from one node to another. The Zigbee end device is connected to the sensors and actuators to collect the information from them and send the acknowledgement to the coordinator.

B. Communication Network Topology

For achieving the energy efficient performance in the smart grid, we arrange the devices in the best suited topology. The different topologies use in WSN is star, mesh, ring, cluster as shown in figure 2.

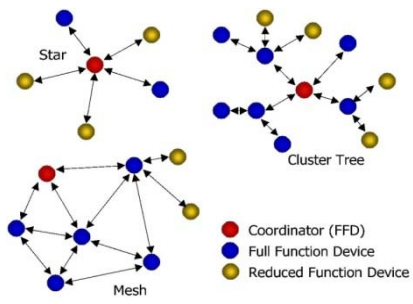

Fig.2. Network Topology

- *Start topology* is the one in which all the sensor nodes connected only with the base station.
- *Ring Topology* is the one in which the data is transferred from one part of the network to the other only through a specified path. . If a link in the ring topology collapses, the ring topology fails and the communication may collapse.
- *Mesh topology* is a more efficient topology when compared to the rest of them. In mesh topology, each network nodes or devices are interconnected with one another. Every node not only sends its own data but also relays data from other nodes. This is very expensive as there are many reducdant connections. So it is use only in wireless network.
  - *i.* In mesh topology data can be transmitted from different nodes simultaneously.
  - ii. Even if one of the component will fail, than there is always an alternative present. So data transfer doesn't affect.
  - iii. In mesh topology expansion and modification can be don
  - iv. Overall cost is high in mesh topology.
  - v. Set-up and maintenance is very difficult.
  - *vi.* There are high chances of redundancy.

II. COMMUNICATION SYSTEM IN SMART GRID

For exchanging the data and information between various entities a communication system is required. These entities may be AMI, substation, central data ware house. This section discuss about the various part of the smart grid.

A. Smart Grid Infrastructure

The conceptual framework developed by National Institute of Standard and Technology (NIST [22, 23] illustrate the domains involved. The information among the various domains is exchange so that a specific task has been accomplished which is shown in figure 3. The lower layer consists of four parts generation station, transmission substation, distribution substation, and customer. The generation and transmission domain controlled by control center (CC), distribution domain controlled by distribution control center (DCC), and customer domain is connected to utility through AMI (Advanced Metering Infrastructure) which can control it through Home Area Network (HAN). The new concept of Distributed Energy Resource (DER) is introduced in smart grid, it involve plant automation, residential or industrial customer automation system. The higher layer domains of power market, regional system operator, energy service provider needs information which is required to make decisions. This figure shows the two-way communication which is accomplished by

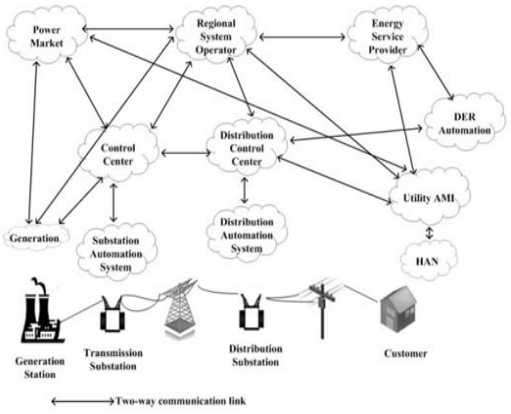

Fig.3. Smart Grid Infrastructure

The various technologies like Zigbee, WI-FI, cellular networks, optical networks, power line communication.

B. Challenges for Smart Grid Communication Medium

Going from physical layer to application layers, communication systems will include the transmission media, the protocols to enable robust communication among entities and through heterogeneous environments [22]. The various challenges present in such systems are:

i. One of the challenges is to hide the heterogeneity of the communication system while fulfilling the various other requirements in terms of delay and throughput. It is done by developing the interoperable protocol.
ii. Identification of different communication technologies for different part of the system.
iii. Cyber security for different part of the network [16].

III. OPPORTUNITIES FOR WSNs IN SMART GRID

WSN is widely use in scientific, medical, military, and recently in smart grid application due to its decentralized and lightweight architecture. WSN is used in different applications of smart grid such as generation, transmission, distribution and customer area. WSN becomes the vital part in the next Generation smart grid as it deliver the information needed by the intelligent algorithms which are running in the applications. An overview of few opportunities by using the WSN in smart grid is discussed below:

A. Renewable Energy For Residential Micro-Grids

Micro- Grid is the basic building block of smart grid, and it is use in energy management. If the locally generated energy from renewable energy resources are enough to maintain the operation of micro-grid than micro-grid should be disconnected from the smart grid. But if the energy is degrading than micro-grids are reconnected to the smart grid. This mechanism is helpful in tracking the generation level, consumption level of the energy. Wireless Sensors are the efficient technology for tracking the consumption and generation levels. WSNs and wireless mesh network both form an ideal architecture for the deployment of AMI (Advanced Metering Infrastructure) at the residential micro-grid side. In a recent work [17], a Wireless Mesh Architecture for the Advanced Metering Infrastructure in Residential Smart Grids has been proposed, see Fig. 4.

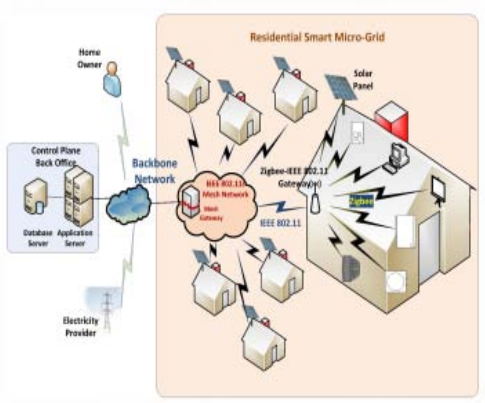

Fig.4. Smart Micro-Grid AMI Architecture

This architecture shows how the Zigbee, WSNs are connected to the different residential appliances such as (TV, PC, washers etc.) and solar renewable sources. The Zigbee based on IEEE 802.11 forms a gateway for the interconnection of various residential WSNs. This IEEE 802.11 becomes the bridge between the smart grid and the control plane. For wireless connection WSNs are highly depends on Zigbee technology as compare to Wi-Fi.

B. Wireless Advanced Metering Infrastructure

Wireless sensor networks are providing a low-cost solution that enables Wireless Advanced Metering Infrastructure (WAMI) systems for electric utilities. WAMI systems offer several advantages that include reduced meter reading operational costs, by eliminating human readers, real time pricing based on the energy consumption of the customers [24]. WAMI provides a reliable two-way communication between electric utilities and customer's premises. For addressing this requirement efficiently WSN provides a low cost and low-power wireless communications.

C. Remote System Technology for Monitoring and Fault Diagnostics

Safety and reliability are essential characteristics of smart grid. Due to some operational faults or natural disasters failure of smart grid will occur, which cause huge economical losses. For instance, the August 2003 blackout that happened in U.S. and Canada caused between 7 and 10 billion U.S. dollars of economical losses and left over 50 million people out of electricity [25]. To monitor and diagnose these fault WSN technology is used which is feasible and cost- effective. In real time system monitoring, system contingency would be detected and isolated before it causes cascading effects and results to more catastrophic system breakdown.

D. Solar Energy In Smart Grid

In the smart grid, customers are supplying their energy from solar panels by implementing solar energy generator systems. This generator is use to deliver electricity to its

need. Due to this system customers can draw more energy from the grid, store, and send back to the grid. In other words, customers will buy, store, or sell energy. For this scenario to happen, the customer's system must be communicated with the grid in order to get all necessary control information. WSN provides the interfacing between smart grid and solar energy generator.

IV. CHALLENGES FOR WSNs IN SMART GRID

The challenges face by WSN in smart grid environments are:

A. Harsh environmental

Due to RF interference, harsh outside conditions that causes corrosion, introduce vibrations, dust, high humidity of wireless connectivity of the network may vary due to link failures [26][27]. These are affecting the topology as well as protocols running on the WSN. These conditions and dynamic network topologies may cause a portion of sensor nodes to malfunction, impact reliability and performance of the network, or make the information gathered obsolete [28].

B. Reliability and Quality of Service (QoS)

Different applications of WSNs have different quality of service requirement in terms of reliability, latency, network throughput. In addition, in certain application where sensor data are time sensitive, e.g., accidents in the electric power systems or control systems, it is important to receive the data at the controller node in a timely manner [22].

C. Packet errors and variation in link capacity

In WSNs, the link capacity depends upon the signal level, interference, and bit error rate. The characteristics of wireless links varying over the time and space due to obstructions in electric power systems. Hence, at each wireless link its bandwidth and communication latency are location dependent and can vary intermittently. This makes it challenging to meet QoS requirements [28].

D. Resource constraints

Energy, memory, and processing are constrain of WSNs. These constrains must be taken in consideration while implementing the algorithms and protocols in WSNs. In smart grid some algorithms has implemented at mote level of WSN and therefore processing and memory requirement in WSNs has taken into the consideration. A balance between the operating systems, communication protocols, and algorithms must be determined. RF communication required more energy at the mote level, and in harsh electric-power system environments, variations in the wireless channel will cause packet loss and retransmissions which takes more energy.

V. CONCLUSION

Our traditional grid is moving towards the smart grid which consists of intelligent devices and digital technology. It allows the two-way communication system between the utilities and customers. By using the WSN as a communication technology, it will make the system cost and power effective. So WSN is a cost effective solution for monitoring, controlling, measurement and fault diagnosis in various domain of smart grid. The WSNs are build up of nodes from several hundreds to thousands, where each node is connected to one sensor, which monitors the physical or environmental conditions such as temperature, pressure, humidity etc.. Zigbee is used as a communication medium in Wireless Sensor Network. Zigbee has short range, low data rate, energy efficient wireless technology, and based on IEEE 802.15.4 standard. Smart grid uses the renewable energy resources for power generation which are require for the operation of the sensors. These renewable resources are solar and wind that are available in abundant, so our new technology becomes the cost effective. On the another hand, WSNs work in harsh environmental condition, so our main concern is toward its reliability, quality of service, packet loss, energy consumption, and delay. We should design a system that must be cost effective and provide better reliability, and quality of service.

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