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Smart City's Energy Management- IoT Integrated Smart Grids and Communication Technologies

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Abstract - *The concept of a smart city is based on consistent power supply. Traditional power grids are being transformed into Smart Grids (SGs) to solve the problems of Uni-directional information flow, energy wastage, growing energy demand, reliability and security. IoT integrated Smart Grids can result in efficient power transmission and energy management. SGs require connectivity, automation and the tracking of such devices. This is achieved with the help of Internet of Things (IoT). IoT help SG systems to support various network functions throughout the generation, transmission, distribution and consumption of energy. In the paper we have discussed about the Smart City, Smart Energy, Traditional Power Grids, Smart Grids, Iot Integrated Smart Grids and Iot and Non-Iot Communication Technologies for SGs. We have also discussed the India's Smart Grid Scenario. The main objectives of this paper are to study the Smart Grids along different communication technologies and put it in simplest way for the new learners.*

***Key Words*: Internet of Things (IoT), Smart Grids (SGs)**

1. INTRODUCTION

1.1 Smart City

Smart Cities Mission is an urban renewal and retrofitting program by the Government of India with the mission to develop 100 cities across the country making them citizen friendly and sustainable. A smart city is a sustainable and efficient urban centre that provides a high quality of life to its inhabitants through optimal management of its resources.

Energy management is one of the most demanding issues within such urban centers. Therefore, significant attention and effort need to be dedicated to this problem.

1.2 Smart Energy

Smart Energy [1] is one of the most important research areas of IoT because it is essential to reduce overall power consumption [4]. Smart Energy includes a variety of operational and energy measures, including Smart Energy applications, smart leak 260 monitoring, renewable energy resources, etc. Using Smart Energy (i.e., deployment of a smart grid) implies a fundamental re-engineering of the electricity services [5] Smart Grid is one of the most important solutions for Smart Energy.

1.3 Traditional Power Grids

A traditional power grid consists of a large number of loosely interconnected synchronous Alternate Current (AC) grids. As shown in Figure 1, it performs three main functions: generation, transmission and distribution of electrical energy [6], in which electric power flows only in one direction, i.e., from a service provider to the consumers. In power generation, a number of large power plants generate electrical energy, mostly from burning carbon and uranium based fuels. Secondly in power transmission, the electricity is transmitted from power plants to remote load centers through high voltage transmission lines. Thirdly in power distribution, the electrical distribution systems distribute electrical energy to the end consumers at reduced voltage.

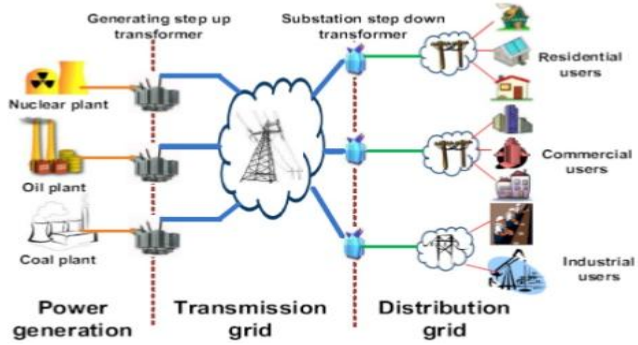

Figure 1: Traditional Power Grid Architecture [6]

2. SMART GRIDS

Traditional power grids are being transformed into Smart Grids to solve the problems of uni-directional information flow, energy wastage, growing energy demand, reliability and security. As shown in [2] Figure 2, SG offers bi-directional energy flow between service providers and consumers. The SG is comprised of four main subsystems such as power generation, transmission, distribution and utilization. Three types of networks, a wide area network (WAN), a neighborhood area network (NAN) and the home area network (HAN) are used in SGs. The power flows through the subsystems while information flows through networks. SGs employ various devices for the monitoring, analysis and control of the grid, deployed at power plants, distribution centers and in consumers' premises in a very large number. Hence, SGs require connectivity, automation and the tracking of such devices. This is achieved with the help of Internet of Things (IoT). IoT helps SG systems to support various network functions throughout the generation, transmission, distribution and consumption of energy by incorporating IoT devices (such as sensors, actuators and smart meters), as well as by providing the connectivity, automation and tracking for such devices.

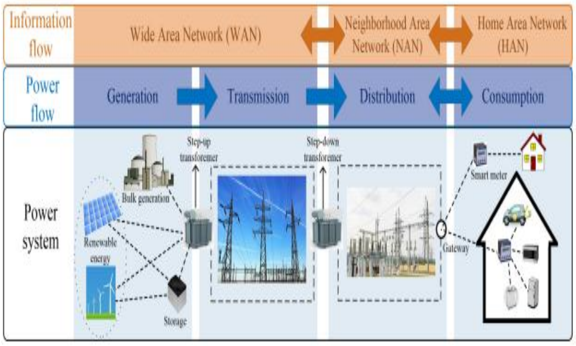

Figure 2: Smart Grid Architecture presenting power systems, power flow and information flow [2]

2.1 Iot Integrated Smart Grids

IoT technology plays a significant role in SG construction. IoT technology provides interactive real-time network connection to the users and devices through various communication technologies. IoT realizes real-time, two-way and high-speed data sharing across various applications, enhancing the overall efficiency of a SG [7].The application of the IoT in SGs can be classified into three types. Firstly, IoT is applied for deploying various IoT smart devices for the monitoring of equipment states. Secondly, IoT is applied for information collection from equipment with the help of its connected IoT smart devices through various communication technologies. Thirdly, IoT is applied for controlling the SG through application interfaces. IoT sensing devices are generally comprised of wireless sensors, RFIDs, M2M (machine-to-machine) devices, cameras, infrared sensors, laser scanners, GPSs and various data collection devices. The information sensing in an SG can be highly supported and improved by IoT technology. The IoT technology also plays an essential role in the infrastructure deployment of data sensing and transmission for the SG, assisting in network construction, operation, safety management, maintenance, security monitoring, information collection, measurement, user interaction etc. Prototype plays an important role in the deployment of system in order to test various functions and verify the operation before the actual commercial implementation. Figure 3, describes the one of the three layered architecture [2] of an IoT aided SG system. It comprised of a perception layer, a network layer and an application layer. The perception layer consists of two sub-layers, a communication extension sub-layer and perception Control sub-layer. Some other prototypes such as energy efficient proto type, web enabled architecture etc. also have been developed for IoT integrated SG systems.

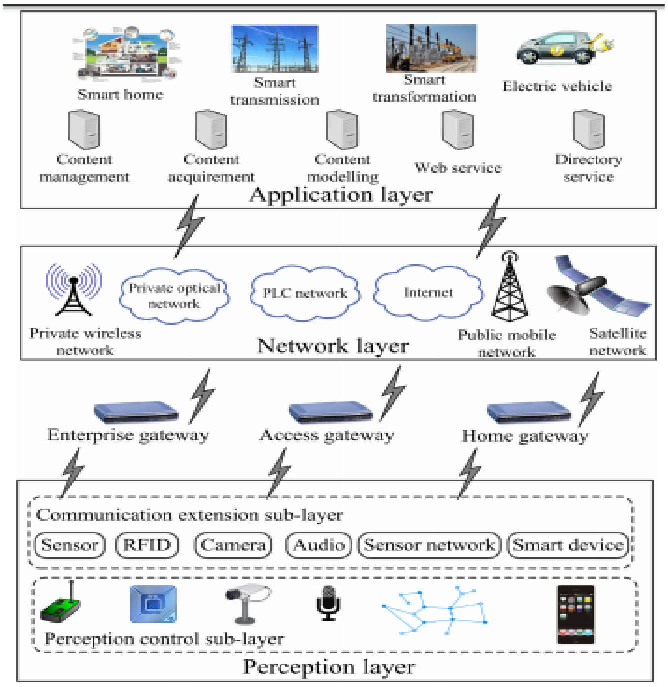

Figure 3: Three Layered Architecture of IoT integrated SG [2]

3. INDIA'S SMART GRID SCENARIO

[3] "Energy conservation is critical to resolving India's power crisis. Millions of people have no access to power, with 40% households (about 400 million) going without power. Initiatives like Smart City and Digital India depend on power supply. The concept of a smart city is based on consistent power supply.

Transmission losses in India stand at 40–48% compared to world standard of 8%. If losses can be controlled, power shortage could be managed. According to the World Resources Institute, power transmission losses in India are highest in the world. For a cleaner and safer environment, measures would have to be in place to drastically reduce electricity losses and conserve energy.

Smart grid is very essential to meet the constantly increasing energy needs and the target of supplying 24/7 power for all by 2022. The country is making several efforts and is active in bringing the best of its solutions out of which smart grid is one solution that is expected to meet the energy demand. It is indeed the need of the hour as it transforms the electricity grid into more reliable grid which also helps in controlling and monitoring the electricity flow. Smart tripping of feeders and voltage fluctuations, finally sees some progress, in the Smart Grid project that was approved in October 2015. The

city will soon see an end to diesel generators and chronic power woes.
The numbers of Smart Grid projects have been introduced and are currently underway such as KEPCO in Kerala, BESCOM in Bangalore, etc. Such project plays vital role to meet growing electricity demands of the country, curb power losses and enhance accessibility to quality power."

4. IOT AND NON-IOT COMMUNICATION TECHNOLOGIES FOR SG

Figure 4 shows the Classification of Communication Technologies for the Smart Grid. There are many [2] IoT and non-IoT communication technologies available for SGs and the users have to select among them, suitable to their needs. There is a lack of proper guidelines for the selection of communication technologies for SG. In this section, we have listed various IoT communication technologies together with non-IoT communication technologies, including their characteristics, advantages and disadvantages and application areas. Table 1, provides a summary of communication technologies. This table will be helpful to take better decision for the selection of most suitable communication technology.

The IoT and non-IoT communication technologies used in the SG for data transmission between smart meters and electric utilities. These are categorized into two types, wireless and wired technologies. Wireless technologies have some advantages over wired technologies in some cases, such as their ease of connection to otherwise unreachable or difficult areas, as well as their low cost infrastructure. An SG requires information flows. The first data flow can be achieved through power line communications or wireless communications, such as by using 6LowPAN, ZigBee and Z-wave [8]. The second data flow can be achieved by using cellular communications or via the Internet. However, there are various key limiting factors that should be considered in the deployment process of smart metering, such as operational costs, deployment time, availability of technology, and the operating environment (such as rural, urban, indoor, outdoor). Hence, the choice of technology that suits one environment may not be applicable for another.

The main motivation of the [2] Table 1 is to provide some guidelines for the selection of communication technologies of SG based on the requirements. We came to know that most of the communication technologies are designed by focusing HAN.

Furthermore, it is important to note that there is no overall the best technology, but certain ones are more suitable to particular SG applications than others. In general, wired technologies such as DSL, PLC and optical fiber are expensive for wide area deployments, especially in rural areas. However, they can maximize both communication capacity and security. Wireless technologies, on the other hand, can reduce installation costs but they have bandwidth and security limitations.

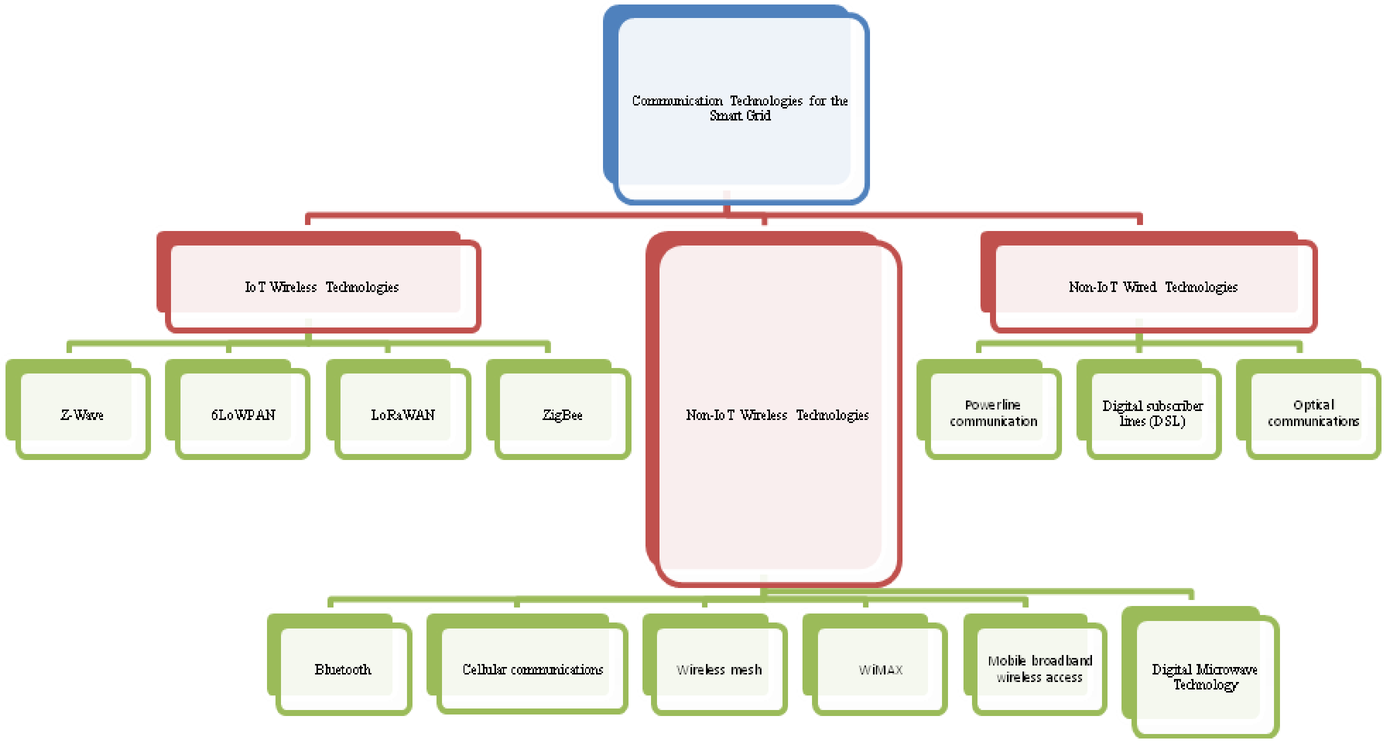

Figure 4: Classification of Communication Technologies for the Smart Grid

Table 1: IoT and Non IoT communication technologies for the Smart Grid [2]

Technology	Protocol	Advantages	Disadvantage	Applicability SG	Application Areas	Data rate	Coverage
IoT Wireless Technologies	Z-Wave	No interference with other wireless technologies; reliable; low latency; scalable	Not suitable for NAN and WAN; only one propriety company for making chips; short range	HAN	Home automation	100 Kbps	30 m
	6LoWPAN	Robust; low-power; support large mesh network topology; can be applied across various communication platforms	Require extensive training and knowledge; short range; low data rate	HAN	Smart metering; home automation	250 Kbps	10-100 m
	LoRaWAN–	Low-power; long range; no interference with different data rates; enhance gateways capacity by creating virtual channels; low-cost secure bi-directional communication	-	NAN; WAN	Management of operation and equipment; online monitoring of power transmission lines and tower	0.3-50 Kbps	2-5km (urban environment); 15km (suburban environment)
	ZigBee	16 channels each with 5 MHz of bandwidth in 2.4 GHz spectrum; low power usage; low complexity; low deployment cost	Low data rates; limited energy of battery; low processing capabilities; short range	HAN	Energy monitoring; smart lightning; home automation; automatic meter reading	250 Kbps	10-100 m
Non-IoT Wireless Technologies	Bluetooth	Low power consumption	Low data rate; short range; weak security; prone to interference from IEEE 802.11 WLANs	HAN	Home automation	721 Kbps	1-100 m
	Cellular communications	Wide area coverage; improved QoS	Network congestion due to high density; critical for emergency applications; non-guaranteed service in unfavorable conditions (e.g., wind storms)	HAN; NAN; WAN	Monitoring and management of DERs; SCADA	60-240 Kbps	10-50 km
	Wireless mesh	Low cost; self healing; self organization;	Prone to interference and fading; network coverage problem in	HAN; NAN	Monitoring and controlling of DERs;	Depends upon	Depends upon

		high scalability; high data rate	rural areas due to low density of smart meters; prone to loop problem due to inclusion of multiple relay nodes		automation and protection of substation automation	protocol	deployment
	WiMAX	Long range; high data rate	Trade-off between performance and distance; costly RF hardware; low frequencies are already licensed and require leasing; high frequencies do not penetrate obstacles	HAN	Real time pricing; automatic meter reading; outage detection and restoration	75 Mbps)	10-50 km (LOS); 1-5 km (NLOS)
	Mobile broadband wireless access	Low latency; high mobility; high bandwidth	Communication infrastructure not readily available; high cost; moderate data rate	NAN; WAN	Broadband communication for electric vehicles; SCADA system; wireless backhaul for SG monitoring	20 Mbps	Vehicular standard (up to 240km/h
	Digital microwave technology	Long distance coverage; high data rate; high bandwidth	Prone to multipath interference and precipitation	HAN; NAN	Transfer trip between DER and distributed substation	155 Mbps	60 km
Non-IoT Wired Technologies	Powerline communication	Cost effective; low installation cost; wide availability; utility's own ownership and control; dedicated network	Noisy and harsh medium; sensitive to disturbances; signal quality gets affected by the type and number of devices, wiring distance between nodes and network topology; cost of ownership; complexity of management	HAN; NAN	Low voltage distribution; automatic meter reading	2-3 Mbps	1-3 km
	Digital subscriber lines (DSL)	High speed; low latency; low installation cost; high data rate, high capacity; long range; wide availability	Quality is distance dependent; high installation cost in low density (rural) areas; unreliable	HAN; NAN; WAN	Smart metering	1-100 Mbps	5-28 km
	Optical communications	Long distance communication; ultra-high bandwidth; robustness against radio and electromagnetic interference; high reliability	High deployment cost of fiber installation; high cost of terminal equipment; difficult to upgrade; not suitable for metering applications	WAN; NAN	Physical network infrastructure	Up to 100 Tbps	10-60 km

CONCLUSION

We discussed about the Smart City's Smart Energy requirements. Smart Grids along with IoT integration plays vital role. India is adopting the Smart Grid Technology. In IoT Integrated Smart Grids, IoT and Non-Iot Communication Technologies are used. With proper selection of communication technology, IoT integrated Smart grids increase quality of power supplies and increase energy efficiency with proper energy management. They have demand response capacity to strike a balance between power consumption and supply. Smart grids can integrate new energy sources like solar and wind with traditional sources. For the new learners comparison table of communication technologies is added for easy understanding and ready reference.

FUTURE SCOPE

IoT integrated Smart Grid can highly benefits from the IoT vision. There are lots of challenges in actual implementation of IoT integrated Smart Grid technology. To meet these challenges lots of research work is needed in the field of WSNs scalability, security issues and challenges.

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BIOGRAPHIE

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