A Survey on Smart Grids Communication Technologies, Standards and Challenges

***Abstract* — the smart grid is the next generation of traditional power distribution networks. The communication infrastructure is essential for modern smart grids to function properly. The utilization of communication technology ensures energy consumption reduction, optimal smart grid operation, and coordination across all smart grid components, from generating to end users. This paper provides an overview of existing communication technologies such as ZigBee, WLAN, cellular communication, WiMAX, and Power Line Communication (PLC), as well as their applications in smart grids, as well as their benefits and drawbacks. Furthermore, the article compares the communication infrastructure of the legacy grid with that of the smart grid, as well as smart grid communication standards. In addition, the study discusses research problems and potential communication system trends for smart grid applications. While current power systems rely on a reliable information and communication infrastructure, the future smart grid will require a separate, far more complicated infrastructure due to its much larger size.**

***Index Terms*—Smart grids, Zig-bee, OFDM, wireless LAN, standards, WiMAX, Wireless sensor networks**

I. INTRODUCTION

The legacy grid was constructed on the premise of unidirectional power flow from large power plants (which use fossil fuels like coal, gas, and nuclear materials) to customers via transmission and distribution networks. Due to rising worldwide electricity demand and the effects of global warming, green renewable energy sources such as solar and wind energy are increasingly being used to replace fossil fuels [1]–[2][3]. In addition, the legacy grid lacks automated analysis, is sluggish to respond to rapidly changing loading, has limited control, and has poor coordination between generated and consumed energy. Several big blackouts have occurred as a result of this in recent decades. The smart grid is the next generation of the power distribution infrastructure, designed to address the issues that have plagued it in the past. [4], [5] are examples of legacy grids. Many countries' governments and businesses are conducting research into smart grid applications. Many smart grid technologies, including as sensors and wireless networks, have previously been applied in other industries. To increase monitoring, protection, and optimization of all grid components, including generation, transmission, distribution, and consumers, the smart grid employs two-way communications, digital technologies, advanced sensor and processing infrastructure, and software capabilities. By utilizing improved and controlled large-scale integration of renewable energy sources, the smart grid minimizes greenhouse gas emissions. To minimize unanticipated frequency and voltage variations, this large-scale integration necessitates the use of advanced distributed control algorithms. The smart grid ensures full coordination between generated and consumed energy by utilizing energy storage devices, grid-to-customer communication, and improved algorithms for forecasting generation and grid loading. This lowers grid energy losses, peak demand, and energy prices.

Energy consumers can obtain accurate real-time prices and bills because to two-way communication. The grid operator can receive real-time information from consumers regarding the amount of electricity consumed. The successful operation of a smart grid requires a dependable real-time information flow between all grid components. A dependable and effective communication infrastructure, whether wired or wireless, can be used to accomplish this. Wireless infrastructure has a number of advantages over conventional infrastructure, including lower costs. Interference with other communications and electromagnetic fields, as well as battery dependency, are downsides. This paper is organized as follows: section II we briefly compare the current standard infrastructure with the smart grid. Section III shows overview of communication technologies that can be used in smart grid and section IV describes various standards and their application while section VI describes the workload distribution among the group members. Section VII concludes the survey with few insights. Section VIII gives the documents and articles referred while contributing to this report.

II. COMPARISON OF INFRASTRUCTURE BETWEEN STANDARD GRID AND SMART GRID

The legacy power grid's existing communication infrastructure is designed to allow only one-way power flow from central power plants to users, with minimal efficiency and information sharing. The traditional grid communication systems are primarily utilized for data collecting from a small number of sensors positioned in the main transmission and distribution points, as well as the transmission of a small number of control signals and the identification of problems. Supervisory Control and Data Acquisition Systems (SCADA) are used to collect data. In comparison to the traditional grid, the smart grid features a substantially higher number of sensors and actuators. They're used at all levels of the grid, including power plants and substations, generators, transformers, and end-users. The sensors are used to collect data and exchange information between data centers and equipment. The actuators are utilized to control all grid components optimally. The smart grid needs have modern, dependable, and strong communication infrastructure capable of providing real-time secure communications in order to handle such massive data flows. To ensure a high rate of information transmission, the communication infrastructure must have a large bandwidth. Furthermore, the communication infrastructure must be self-healing and adaptable to changes automatically.

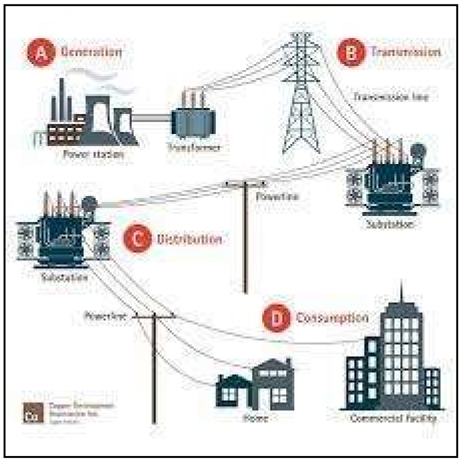

Figure 1 Power grid

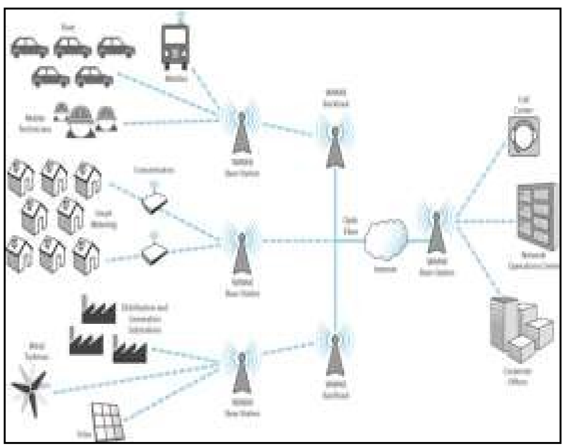

Figure 2 Smart Grid

There are many differences between the standard grid and smart grid. In standard grid we majorly have the towers, power lines, substations, transformers, and meters. But when this grid is integrated with sensors which can detect the voltage surge and also can pinpoint the exact location of issue in a power line and can be moderated to the regulated supply with the help of feedback loops and other IOT devices can also be integrated to pass on the information to the control centers and necessary actions be taken. Smart grid consists of NAN (Neighborhood Area network), Wide area network (WAN), HAN (Home Area Network). These are just new terminologies but exactly these are just segregated area networks which are load consumers from the grid.

III. Overview of Technologies Used in Smart Grid

The smart grid infrastructure relies heavily on communications systems [1]. A large quantity of data from various applications will be generated as a result of the integration of modern technologies and applications for attaining a smarter power grid infrastructure, which will be used for further analysis, control, and real-time pricing methods. As a result, it's vital for electric utilities to define communications requirements and select the optimum communications infrastructure to handle output data and deliver a reliable, secure, and cost-effective service across the entire system. Electric utilities are attempting to attract customers' attention in order to encourage them to join in the smart grid system, which will increase service and efficiency. Demand side management and consumer participation are well understood for effective electricity usage, as are outages following disasters. The relevance of the interaction between electric grids and communications networks is clearly highlighted in the existing power structure [1]. For data transfer between smart meters and electric utilities, a variety of communications technologies supported by two main communications media, wired and wireless, can be employed. Wireless communications have some advantages over wired communications in specific situations, such as low-cost infrastructure and ease of connection to difficult or inaccessible places. The signal may, however, be attenuated according to the transmission path's characteristics. Wired solutions, on the other hand, do not suffer from interference and are not reliant on batteries, as do many wireless systems.

In a smart grid system, two types of information infrastructure are required for information flow. The first flow is from sensors and electrical appliances to smart meters, and the second is between smart meters and data centers at the utility. The first data flow can be achieved using powerline communication or wireless communications such as ZigBee, 6LowPAN, Z-wave, and others. Cellular technology or the Internet can be employed for the second information flow. Nonetheless, there are important limiting elements to consider in the smart metering adoption process, including as deployment time, operational expenses, technology availability, and rural/urban or indoor/outdoor environment, among others. A technology decision that is appropriate for one context may not be appropriate for another.

Let’s discuss some of the famous technologies which are in implementation for the current grids.

A. **ZigBee*:*** ZigBee is a wireless communications system with low power consumption, data rate, complexity, and deployment costs. It's a great solution for smart lighting, energy monitoring, home automation, and automatic meter reading, among other things. The US National Institute of Technologies and Technology (NIST) has identified ZigBee and ZigBee Smart Energy Profile (SEP) as the best acceptable communication standards for smart grid home network domain. It's critical that smart meters, as well as intelligent home appliances and in-home displays, communicate with one another. Many AMI vendors, including Itron, Elster, and Landis Gyr, favor smart meter’s that can be integrated with the ZigBee protocol. Smart meters with ZigBee integration can connect with and control ZigBee-enabled devices.

Disadvantages: For practical implementations, ZigBee has some limitations, including low processing capabilities, small memory sizes, low delay requirements, and interference with other appliances that share the same transmission medium, the license-free industrial, scientific, and medical (ISM) frequency band, which includes IEEE 802.11 wireless local area networks (WLANs), Wi-Fi, Bluetooth, and Microwave. As a result, these worries about ZigBee's robustness in noisy environments raise the risk of the entire communications channel being corrupted due to 802.11/b/g interference in ZigBee's vicinity. To extend network life and provide a dependable and energy-efficient network performance, interference detection techniques, interference avoidance schemes, and energy-efficient routing protocols should be employed.

B. **Wireless Mesh*:*** A mesh network is a flexible network madeup of a set of nodes in which new nodes can be added at any time and each node can operate as its own router. If a node drops out of the network, the network's self-healing feature allows communication signals to find a new path through the active nodes. RF mesh-based systems are particularly prevalent in North America. Every smart gadget in PG&E's Smart Meter system has a radio module, and each of them routes metering data through surrounding meters. Until the collected data reaches the electric network access point, each meter works as a signal repeater. The data is then transmitted to the utility across a communication network. Sky Pilot Networks, a private corporation, uses mesh networking for smart grid applications because of mesh technology's redundancy and high availability.

Disadvantages*:* Wireless mesh networking solutions have numerous issues, including network capacity, fading, and interference. Because the meter density cannot offer comprehensive coverage of the communications network in urban areas, mesh networks have encountered a coverage difficulty. A sufficient number of smart nodes, taking into consideration node cost, are required for mesh networks to achieve a balance between dependable and flexible routing. Furthermore, the network must be managed by a third-party organization, and because metering data flows via each access point, some encryption techniques are used to protect the data. Furthermore, while data packets travel around several neighbors, loop problems might occur, resulting in additional overheads in the communications channel, resulting in a drop in performance of the available bandwidth.

C. **Bluetooth over IEEE 802.15.1*:*** Bluetooth is a short-range wireless radio technology standard that can be configured as a Wireless Personal Area Network (WPAN). It can be used to replace computer peripheral cables such mice, keyboards, joysticks, and printers. Piconet and scatternet are the two connectivity topologies that have been defined. Piconet is a Bluetooth-enabled device that connects two or more other Bluetooth-enabled devices, such as current cell phones or PDAs. Scatternet, on the other hand, is the number of interconnected piconets that can communicate with more than eight devices. All of these qualities enable Bluetooth to be used in smart grid applications such as home automation and home area networks.

Disadvantages: Bluetooth's network range is limited to 100 meters. Although scatternet setup can expand coverage, there is a limit to the number of nodes that can be supplied by the scatternet. As a result, boosting the coverage area in Bluetooth is a difficult operation.

D. **WiMAX Over IEEE 802.16*:*** One of the most important wireless broadband technologies is worldwide interoperability for microwave access (WiMAX). It's primarily designed for use in a Wireless Metropolitan Area Network (WMAN). It is part of the IEEE 802.16 series, which was created with the goal of achieving worldwide microwave access interoperability. WiMAX's key goals are long-distance coverage and extremely high data speeds. It has a data rate of 70Mbps and a coverage of 50 kilometers. The range varies depending on whether the application is Line Of Sight (LOS) or Non-LOS. To improve performance in a Non-Line of Sight environment, Mobile WiMAX uses the Orthogonal Frequency Division Multiple Access (OFDMA) air interface. Fixed and mobile communication bands are 3.5 and 5.8GHz for fixed and 2.3, 2.5, and 3.5GHz for mobile and, 3.5GHz is used. It has a bandwidth of 1.25-20MHz and a channel count of 128,256. WiMAX systems, sometimes known as 'Last Mile' technology, provide internet access services over extended distances. As a result, WiMAX technology provides a viable alternative to wired technologies such as cable modems, DSL, and T1/E1 lines.

Disadvantages: The biggest downside of WiMAX is the high cost of dedicated WiMAX hardware, which makes it prohibitively expensive to deploy on a local scale. WiMAX frequencies beyond 10 GHz are unable to pass past obstructions, and hence cannot be used in metropolitan areas for AMI applications. Because the lower frequencies and unlicensed ISM band are already crowded, the only option is to lease it from a third party. However, it will eventually contribute to the deployment cost.

E. **WLAN***:* The IEEE 802.11 Wireless Local Area Network (WLAN) enables users with constant communication at increased data speeds. It allows multiple users to access the service [6] without interfering too much with coexisting technologies, thanks to the use of spread spectrum technologies like Direct Sequence Spread Spectrum (DSSS) and Frequency Hopping Spread Spectrum (FHSS), as well as an access technique called Carrier Sense Multiple Access-Collision Avoidance (CSMA-CA). The original WLAN standard was IEEE 802.11 a. The Wireless Ethernet Compatibility Alliance (WECA) made more changes in 1999 to bring interoperability across IEEE 802.11 equipment from different suppliers. The efforts resulted in the creation of the ubiquitous Wireless-Fidelity standard based on 802.11 b, which became known as Wi-Fi. Various standards have been produced as part of the WLAN initiative. Despite the fact that IEEE 802.11a supports data speeds of up to 54Mbps, it operates on the 5.8GHz licensed frequency band. Wi-Fi uses the 2.4GHz ISM frequency range and uses DSSS modulation to achieve a maximum data rate of 11 Mbps. Additionally, the use of Orthogonal Frequency Division Multiplexing (OFDM) in packet-based communication has increased data speeds on the ISM band to 54 Mbps. This served as the foundation for upgraded 802.11g Wi-Fi. In addition, the Multiple Input Multiple Output (MIMO) technology is used to create the IEEE 802.11n standard, which allows for data rates of up to 600 Mbps. The IEEE 802.11i standard was created to be more secure. Despite the fact that WLAN's coverage area is only 100m It is, nevertheless, appropriate for medium-range smart grid applications like as remote monitoring, Home Area Network (HAN), distribution protection systems, and Advanced Metering Infrastructure (AMI).

Disadvantages: Although mesh topology can extend the range of a WLAN network, it increases routing complexity. Because packets must flow through each node, an additional overhead is necessary, resulting in lower bandwidth usage. Furthermore, critical metering information must be sent through each access point in smart grid applications such as Home Area Network (HAN) or Advanced Metering Infrastructure (AMI). For data security, this necessitates the use of robust encryption techniques. As a result, providing a vast coverage area, similar to cellular technology, is a difficult issue with WLAN, especially in metropolitan areas. Also, if a mesh network is adopted, network capacity, fading, and the tradeoff between dependable and flexible routing, as well as interference and network cohabitation, will be key problems.

F. **Powerline Communication*:*** PLC (powerline communication) is a method of transmitting high-speed (2–3 Mb/s) data signals from one device to another using existing powerlines. Due to the direct connection with the meter and successful installations of AMI in metropolitan locations where other solutions struggle to meet the needs of utilities, PLC has been the main choice for communication with the electricity meter. One of the research subjects for smart grid applications in China has been PLC systems based on the LV distribution network. Smart meters are connected to the data concentrator by powerlines in a conventional PLC network, and data is sent to the data center via cellular network technology. Any electrical device, such as a powerline smart transceiver-based meter, can, for example, be linked to the powerline and used to send metering data to a central location. The "Linky meter project" in France aims to convert 35 million traditional meters' to Linky smart meters. PLC is used for data connection between smart meters and the data concentrator, whereas GPRS is utilized to send data from the data concentrator to the utility's data center. PLC technology was chosen by ENEL, an Italian electric utility, to carry smart meter data to the nearest data concentrator, and GSM technology was chosen to convey the data-to-data centers.

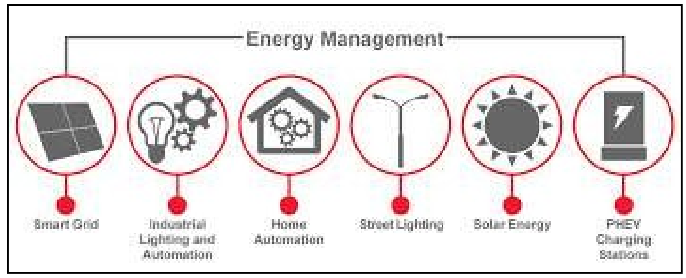

Fig. 3PLC Communication

Disadvantages: Because of the nature of powerline networks, there are inherent technological obstacles. Because the powerline transmission medium is a hostile and loud environment, modelling the channel is difficult. PLC technology is limited for applications that require higher bandwidth due to its low bandwidth (20 kbps for neighborhoods area networks). Furthermore, network structure, the quantity and type of devices connected to powerlines, and the wire distance between transmitter and receiver all have an undesirable effect on the signal quality that is conveyed via powerlines. The sensitivity of PLCs to disturbances and their reliance on signal quality are two drawbacks that make them unsuitable for data transfer. However, certain hybrid systems have been developed, in which PLC technology is integrated with other technologies like as GPRS or GSM, to enable full connection that PLC technology cannot provide.

Improved Wi-Fi, which is based on IEEE 802.1lg, direct sequence spread spectrum (DSSS) modulation is utilised. It has a large deployment all over the world. It has widespread support and is incredibly popular; practically every electronic device, including computers, laptops, mobile phones, gaming devices, music devices, and peripheral devices, is equipped with it. Wi-Fi is a type of network that connects users to the internet via an access point, allowing them to wander around within the local service area while remaining connected to the network. It is quite simple to add or delete devices from this system, and it can be accessed from anywhere within the range. Wi-Fi is quite popular for the reasons and for HAN applications that demand a high data rate, such as video monitoring.

However, security and interference with other devices communicating on the HAN network are significant issues. Wi-Fi power consumption may be excessive in many smart grid device applications.

Advantages and metrics by which we can compare the different technologies are in the image below.

Technology	Spectrum	Data Rate	Coverage Range	Applications	Limitations
GSM	900 - 1800 MHz	Up to 14.4 Kpbs	1-10 km	AMI, Demand Response, HAN	Low date rates
GPRS	900 - 1800 MHz	Up to 170 kbps	1-10 km	AMI, Demand Response, HAN	Low date rates
3G	1.92-1.98 GHz 2.11-2.17 GHz (licensed)	384 Kbps-2 Mbps	1-10 km	AMI, Demand Response, HAN	Costly spectrum fees
WiMAX	2.5 GHz, 3.5 GHz, 5.8 GHz	Up to 75 Mbps	10-50 km (LOS) 1-5 km (NLOS)	AMI, Demand Response	Not widespread
PLC	1-30 MHz	2-3 Mbps	1-3 km	AMI, Fraud Detection	Harsh, noisy channel environment
ZigBee	2.4 GHz- 868 - 915 MHz	250 Kbps	30-50 m	AMI, HAN	Low data rate, short range

Fig 4 - Smart Grid Technologies

IV. SMART GRID SECURITY CHALLENGES

In a traditional grid, power flows in only one direction: from centralized production facilities to transmission lines, then to consumers via distribution utilities. The grid's clustered architecture has historically resulted in facility and maintenance efficiencies, but it has also made it vulnerable to hostile activities and natural calamities. The smart grid is exposed to a number of threats and challenges. This section covers a variety of data security topics.

Security: The number of items that must be managed, such as those seen from a utility, would increase dramatically - maybe by orders of magnitude. This creates challenges in terms of upkeep, trust protection, and cyber-surveillance for any cyber-attacks. One area where problems are predicted to arise is key management. Many monitoring initiatives, such as defining smart meters and establishing cryptographic sessions, would rely on keys. Managing such solutions needs the utilization of staff services, as well as time and processing capacity, which may not be readily available.

User Privacy: The smart grid should be well-secured and well-maintained while respecting user privacy. Users' privacy was jeopardized by the integration of smart meters into the smart grid. Smart meters may risk privacy and security, in addition to providing some crucial facts about the user's power usage. Because it will infer the user's behavior based on the information collected from the service provider. Customers' information contains details like whether they are available at home or on the road. Criminals planning a heist, businesses, advertisers wanting to advertise, and even competitors are concerned about the information gathered. As a result, data should be safe during transmission and storage to prevent unauthorized access to data and protect the privacy of users.

Connectivity: The smart grid's networking network is advanced since it includes a large number of compatible components. The smart grid world's decentralized design necessitates a high level of security against threats and attacks. An attack can result in physical harm, blackouts, and a loss of productivity. Because the attackers get control of the machine, this is the case.

Software Issues: Software is vulnerable to a variety of flaws, including ransomware. General-purpose hardware is used to build supervisory control and data acquisition (SCADA) applications, making them vulnerable to ransomware and malicious updates. A general-purpose computer contains a number of well-known bugs that can be patched to maintain the system current. Patching, on the other hand, is a challenging task, especially in sensitive networks like the smart grid, because it is costly and might cause downtime.

V. SMART GRID STANDARDS

Many applications, methodologies, and technological solutions for smart grid systems have been established or are currently being developed. The main issue is that the whole smart grid system lacks widely acknowledged standards, which restricts the integration of advanced apps, smart meter's, smart devices, and renewable energy sources while also limiting interoperability. Adoption of interoperability standards for the entire system is a must if the smart grid system is to become a reality. Some of the goals that can be realized with smart grid standardization initiatives are seamless interoperability, robust information security, increased safety of new goods and systems, compact set of protocols, and communication exchange. Many regional and national efforts are underway to achieve this goal; for example, the European Union Technology Platform's strategic energy technology plan focuses on the development of a smart electricity system over the next 30 years, and the Ontario Energy Board in Canada has committed to completing a smart meter installation. On the other hand, NIST, the American National Standards Institute (ANSI), the International Electro technical Commission (IEC), the Institute of Electrical and Electronics Engineers (IEEE), the International Organization for Standardization (ISO), the International Telecommunication Union (ITU), the Third Generation Partnership Project (3 GPP), and the Korean Agency for Technology and Standards (KATS), as well as the Joint Information Systems Committee (JISC) at the regional level, are all involved in the Third Generation Partnership Project (3 GPP). In addition, the CEN, CENELEC, and ETSI have formed a Joint Working Group on Smart Grid Standardization, with the goal of achieving the European Commission's smart grid policy objectives. Their activities in Europe are focused on smart metering features and communication interfaces for the electric, water, and heat sectors. Figure 4 provides an overview of smart grid standards. The details of these standards are discussed in the following sections.

Type/Name of Standards	Details	Application
IEC 61970 and IEC 61969	Providing Common Information Model (CIM): IEC 61970 works in the transmission domain and IEC 61969 works in the distribution domain	Energy management systems
IEC61850	Flexible, future proofing, open standard, communication between devices in transmission, distribution and substation automation systems	Substation Automation
IEC 60870-6 /TASE.2	Data exchange between utility control centers, utilities, power pools, regional control centers	Inter-control center communications
IEC 62351 Parts 1-8	Defining cyber security for the communication protocols	Information Security Systems
IEEE P2030	A Guide for smart grid inter-operability of energy technology and IT operation with the electric power system (EPS)	Customer-side applications
IEEE P1901	High speed power line communications	In-home multimedia, utility and smart grid applications
ITU-T G.9955 and G.9956	ITU-T G.9955 and G.9956 contain the physical layer specification and the data link layer specification	Distribution Automation, AMI
OpenADR	Dynamic pricing, Demand Response	Price Responsive and Load Control
BACnet	Scalable system communications at customer side	Building automation
HomePlug	Powerline technology to connect the smart appliances to HAN	HAN
HomePlug Green PHY	Specification developed as a low power, cost-optimized power line networking specification standard for smart grid applications	HAN
U-SNAP	Providing many communication protocols to connect HAN devices to smart meters	HAN
ISA100.11a	Open standard for wireless systems	Industrial Automation
SAE J2293	Standard for the electrical energy transfer from electric utility to EVs	Electric Vehicle Supply Equipment
ANSI C12.22	Data network communications are supported and C12.19 tables are transported	AMI
ANSI C12.18	Data structures transportation via the infrared optical port bus	AMI
ANSI C12.19	Flexible metering model for common data structures and industry "vocabulary" for meter data communications	AMI
Z-Wave	Alternative solution to ZigBee that handles the interference with 802.11b/g	HAN
M-Bus	European standard and providing the requirements for remotely reading all kinds of utility meters	AMI
PRIME	Open, global standard for multi-vendor interoperability	AMI
G3-PLC	Providing interoperability, cyber security, and robustness	AMI
SAE J2836	Supporting use cases for plug-in electric vehicles communication	Electric Vehicle
SAE J2847	Supports communication messages between PEVs and grid components	Electric Vehicle

Figure. 5 Standards and Applications

Name/Type of Standards	Application
ANSI C12.19	Utility applications
M-Bus	Utility meters
ANSI C12.18	Meter communications
BACnet	Building automation
IEC 61850	Substation automation
HomePlug Green PHY	Powerline networking
PRIME	Powerline networking
G3-PLC	Powerline networking
U-SNAP	HAN utility
IEEE P1901	HAN utility
Z-Wave	HAN utility
IEC 61970	Transmission between devices and networks
IEC 61968	Transmission between devices and networks
OpenADR	Software systems
IEEE P2030	Data transmission
ANSI C12.22	Transport ANSI C12.19
ISA100.11a	Multivendor device interoperability
ITU-T G.9955	Narrowband OFDM powerline communications
G.9956	Narrowband OFDM powerline communications
IEC 62351	Cyber Security
SAE J2293	Electric Vehicles
SAE J2836	Electric Vehicles
SAE J2847	Electric Vehicles

Figure. 6 Standards and Applications

VI. Future trends and challenges

Smart meters that also act as transmitters/receivers, wired or wireless communication channels, and software-based control systems make up the smart grid communication system, which is a complex system made up of numerous primary subsystems. This complicated system has a number of issues that must be addressed in order to develop a dependable and stable communication system.

a. ***Interference***:
The Home Area Network is the most fundamental layer of smart grid connectivity. HAN networks are typically densely installed in metropolitan areas. This intensive deployment may generate HAN network interference, resulting in the transmission of unreliable smart meter signals. Interference within the HAN network is another issue. Hundreds of electrical devices will connect with the main smart meter in the future home. This communication has a lot of potential for interfering with home life. These issues could be overcome by creating algorithms that eliminate or limit interference. In addition, harmonics generate interference in power lines. Active filters could be used to lessen the interference.

b. ***Data Transmission Rate:***
Data collecting, data processing, and control of smart grid components and devices are all dependent on the communication infrastructure. Throughout the smart grid, there are hundreds of smart meters and controlled devices. As a result, the communication system must convey a large volume of data in a continuous and bi-directional manner. As a result, research efforts should be focused on developing adequate high-data-rate communication technology or upgrading current technologies like WLANs and cellular networks. WLAN and cellular network data rates are now rather high in comparison to other technologies, but they can be raised further by employing new modulation techniques and better transmitters/receivers.

c. ***Standardization:***
standards are indispensable for the smooth roll-out of smart electricity grids and optimizing costs for consumers. Distribution grid operators have been persistent about the standardization priorities. Standards that allow DSOs to manage peak demand and flexible loads, optimize the grid and power quality, and connect renewables and other forms of energy resources to the distribution system should be the focus of standardization efforts. To that purpose, a recently published report offers advice on the workload ahead in three key areas:

1) Network management that is smart
2) Distributed generation and e-mobility are cleverly combined.
3) Market intelligence and engaged customers.

DSOs are already confronted with difficulties that necessitate smart grid functions and services, such as the expansion of intermittent decentralized renewables in the distribution grid.

d. ***Cyber Security:***
Ensure the quality of the data within the various systems is a major problem in reaching the operational model. The grid is evolving from a relatively static architecture in which physical infrastructure changes were relatively infrequent to a more dynamic model in which power sources, power consumers, information sources, and information consumers will all change much more frequently. In terms of trustworthiness and complexity, both suppliers and consumers will differ significantly more than in the past. Power sources will, for example, range from very big commercial power plants to modest domestic renewable energy systems. Information sources will range from the utility's extensive sensor capabilities installed across the distribution network to highly changeable data sources in connected cars and other connected devices. When anomalies are detected that could indicate equipment failure, cyber-attacks, or other issues, the utility must be able to maintain an up-to-date operational model that reflects this dynamism in both the communication and electricity networks so that accurate analysis can be performed, and appropriate decisions can be made.

VII. WORKLOAD DISTRIBUTION

A. **Workload Distribution**:
All group members were active in data gathering, assessing papers, and compiling material according to the parts split as background, infrastructure, standards, and technologies applied in present grids, as stated in the proposal.

Team Members	Project Duties	Presentation Duties
Nithish Reddy Yalaka	• Literature review • Analyzing the data • Implementation • Summarizing the views/opinions	• Background
Siva Teja Narayanabhatla	• Literature review • Implementation • Research • Reviewing the papers	• Methodology

Figure 7 – Workload Distribution

B. **My Contribution**:

a) ***Introduction***:
In this section, introduction to the smart grids was surveyed using different articles. The articles surveyed are given below [1],[2],[3].

b) ***Comparison between standard and Smart Grid***:
In this portion, I studied a few publications to better grasp the differences between smart grid and regular grid architectures. In the smart grid, the levels in charge of connectivity are depicted. To complete the network, the multilayered solution was implemented over the entire smart grid. Lot of web content was studied to get the better understanding.

c) ***Smart Grid Security Challenges***:
The initial paper failed to address the issues. We talked about the major issues with smart grid connectivity networks in this session. Smart grids pose a number of data security concerns. This portion will also contain suggestions for smart grid improvements. The following papers were examined: [11] [7] [1]

d) ***Technologies used in Smart Grids***: In this section, I conducted research on wired communication technologies, including Power Line communication and its benefits and drawbacks. The papers examined are as follows:[1] [7]

e) ***Future Trends and Challenges***: We evenly divided the standards to be researched in this section. Data Transmission Rate and Cybersecurity were among the sections I surveyed.

C. **Personal Motive on the Report**:
I learned how to work on a project from start to finish, starting with the project idea, through this procedure. It was absolutely uncertain how to begin the survey after picking the document, but the proposal really aided in keeping things structured. Equally sharing the tasks amongst themselves. This benefited in the study's technical preparation. Following our discussion about the idea, we focused on our individual assignments. We then worked on compiling the information into a single document. The goal of this survey was to see how communication technologies and standards play a role in the smart grid. Smart grid problems also help with further research into smart grid communication technology. I've worked on the methods for putting numerous wired and wireless technologies in the grid, as well as their drawbacks.

VIII. CONCLUSION

The conventional electric power and distribution networks are on the approach of being revolutionized by Smart Grid. For reliable and seamless connection, appropriate wireless technology must be employed in addition to well-developed and dedicated architecture. The application area in Smart Grid is influenced by numerous elements such as network span, data rates, security and dependability, number of channels, available bandwidth, and so on. This paper discusses the advantages and disadvantages of several wireless technologies such as WiMAX, ZigBee, Bluetooth, Wi-Fi, GSM, GPRS, and UMTS in relation to smart grid. It also demonstrates the layered architecture for smart grid connectivity, in which a variety of technologies can be used to improve performance. As a result, this paper provides a deeper grasp of how to implement any wireless technology as per the application spectrum in smart grid. In the smart grid, several communication technologies are thoroughly examined in terms of data rate, delay, coverage range, standard or protocol, applications, and limits. Future research could focus on developing improved security design algorithms that can be tuned for smart grid communication, as well as protocols and approaches for reducing interference and removing it.

IX. REFERENCES

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X. APPENDIX

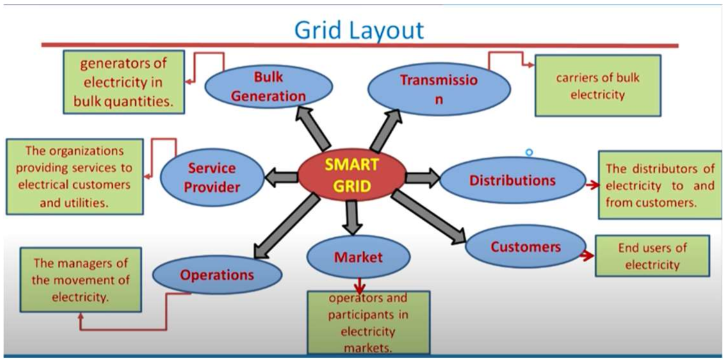

Fig.1 Smart Grid Architecture

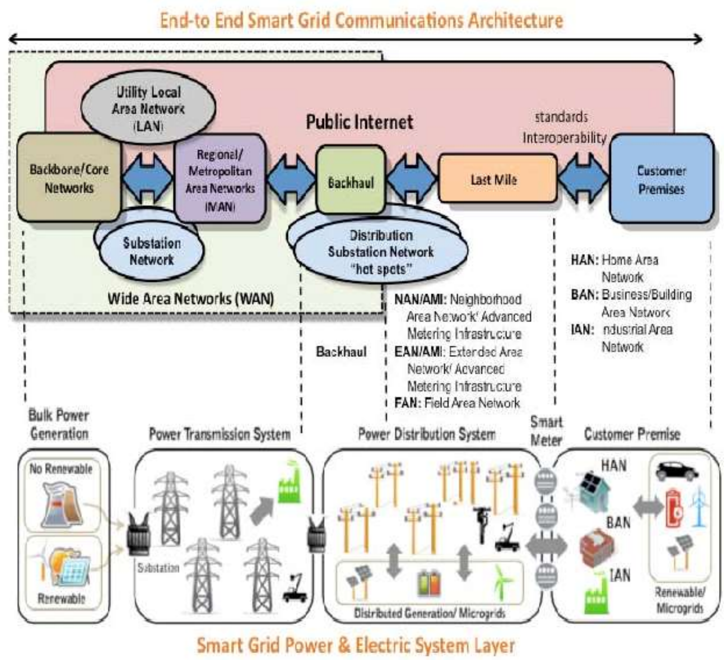

Fig. 2 End-to-end smart grid communications architecture [7]