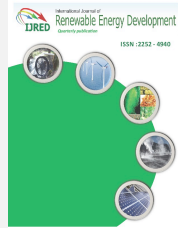




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Research Article

# Integration of 5G Technologies in Smart Grid Communication: A Short Survey

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**ABSTRACT.** Smart grid is an intelligent power distribution system that employs dual communication between the energy devices and the substation. Dual communication helps to oversee the internet access points, energy meters, and power demand of the entire grid. Deployment of advanced communication and control technologies makes smart grid system efficient for energy availability and low-cost maintenance. Appropriate algorithms are analyzed first for the convenient grid to have proper routing and security with a high-level of power transmission and distribution. Information and Communication Technology plays a significant role in monitoring, demand response, and control of the energy distribution. This paper presents a broad review of communication and network technologies with regard to Internet of Things, Machine to Machine Communication, and Cognitive radio terminologies which comprises 5G technology. Networks suitable for future smart-grid are compared with respect to standard protocols, data rate, throughput, delay, security, and routing. Approaches adopted for the smart-grid system has been commended based on the performance and the parameters observed. ©2019. CBIOR-IJRED. All rights reserved

**Keywords:** Smart Grid, Information and Communication Technology, Home Area Network, Software Defined Network, Cognitive Radio, Internet of Things, Machine to Machine Communication

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## 1. Introduction

Industry 4.0- the fourth industrial revolution's key vision is the industries has to identify and react to the fault within short duration and the industries have to increase economic benefits with higher production (Faheem et al., 2018). This has paved a way to modernize the existing electric grid. Generation, transmission and distribution are the main subsystems in electric grid (Hamidi, Smith, & Wilson, 2010). Intelligence added to the existing electric grid is called Smart Grid (Marah & El Hibaoui, 2018). Smart Grid (SG) includes the unification of wind and solar energy which requires quality-of-supply (QoS), storage facility, power management and monitoring to empower bidirectional communication between the grid system and the customer devices (Colak, 2016) (H. Alsafasfeh, 2015). The power obtained from solar energy is used for PV cooling, solar desalination, water heating and thermoelectric applications (Ramezanizadeh, Nazari, et al., 2018). Nano fluid improves the overall performance in geothermal and solar-based energy systems (Ramezanizadeh, Alhuyi Nazari, Ahmadi, & Açikkalp, 2018) (Ahmadi et al., 2018). Synchronization of renewable energy has advantage over fossil fuels to

reduce the power demand (Alizadeh et al., 2018). Figure 1 shows the simple architecture of smart grid (Rehmani, Davy, Jennings, & Assi, 2018a). The upcoming 5G technology wants to bind different network technologies like Cloud Computing, Smart Grid, Big Data, Internet-of-Things (IOT) and Device-to-device communication (Singh, Saxena, Roy, & Kim, 2017)(Panwar, Sharma, & Singh, 2016). The motivation behind the integration of different devices is due to the development of smart devices and communication technologies. The deployment of smart grid increases power generation. The main challenge in smart grid is to handle large amount of precise data for correct prediction of renewable energy (Shine Let G, Josemin Bala G, 2018).

Information received from the customer cannot be retrieved properly for energy supply due to the lack of monitoring and QoS. Good QoS is determined by latency, throughput, data rates, reliability and bandwidth. With low latency and high throughput, data can be transmitted at maximum speed. To meet the power demand, it is necessary to monitor the entire energy system but power consumption found to be high on the usage of battery for monitoring (Erdem & Gungor, 2018). An efficient storage system is required for big data as the

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SG cover many applications such as Internet of Things (IoT), Demand response (DR), Home energy management, plug-in hybrid electric vehicles etc. Having good storage capacity, buildings can support the smart grid providing demand response services (Carr, Brissette, Ragaini, & Omati, 2017).

Bidirectional communication can be achieved, only if there are proper routing and protocols. Cyberattack happens on the different layers of Open System Interconnection (OSI) and also on data exchange (Luo, Yao, Wang, & Guan, 2018). The need for secure authentication and transmission of data between the devices and the substations paved the way to use Information and Communication Technology (ICT).

Integration between ICT and energy infrastructures hence proposed to achieve a future sign of SG.

Certain Algorithms are identified for better routing, lossless compression, and isolation of cyber-attacks to prevent the loss of information between the channels which has not been considered much in the previous works of SG. Characteristics of power availability, Bandwidth, Fault recovery, and Congestion control unveil adequate terminology for the fifth generation. Also, self-diagnosis of the grid is an important mechanism. Existing grid electromechanical switchgear component is replaced with digital component for the intelligent grid.

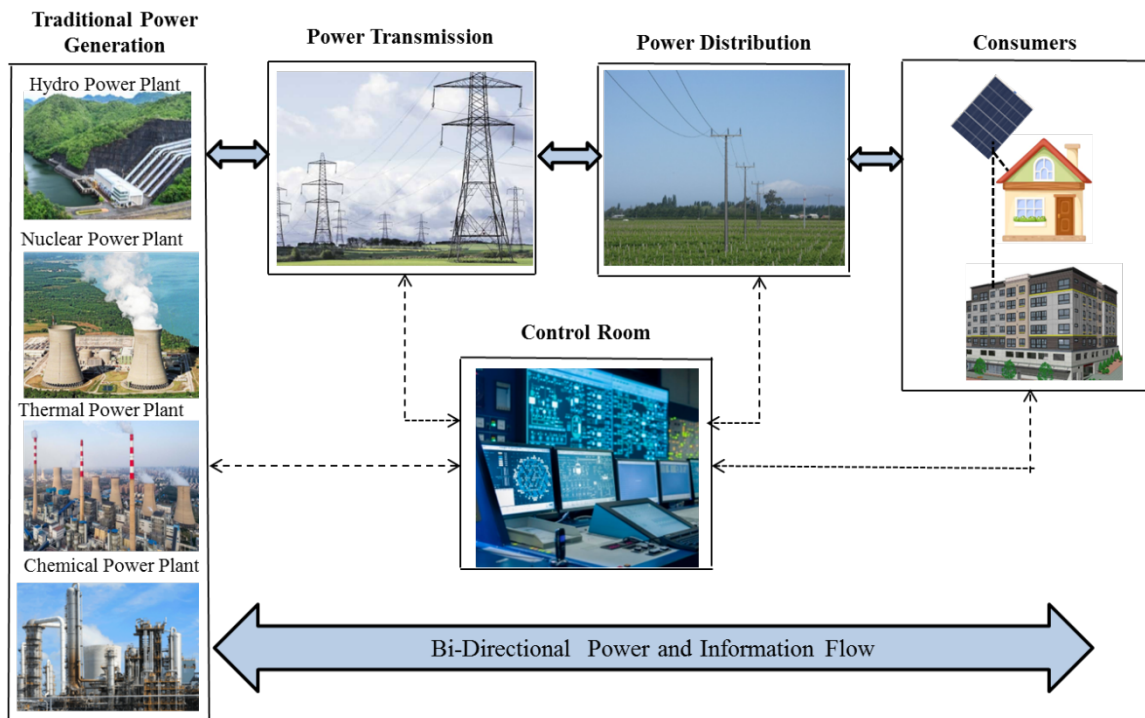


Fig. 1 Illustration of Smart Grid

## 2. Proposed Methodologies for the Development of SG

As the Smart Grid system approaches carbon free environment, it hybrids the wind energy and photo voltaic energy, also it uses the thermal energy for sustaining the energy demand. Communication between the smart devices and the substations are bidirectional and found to be critical in security realm. Bidirectional communication results in achieving the required power according to the demand of the devices where the meter reads the usage and provides economic efficiency. The requirements and benefits of smart grid was suggested by National Institute of Standards and Technology (NIST) in 2010 (Nist, Publication, & National Institute of Standards and Technology, 2010). Similar to existing telecommunication network for voice and data transmission, the smart grid communication has to cover large geographical area. So the existing smart grid architecture shown in figure.1 is added with

communication architectures like home area network (HAN), neighbourhood area network (NAN) and wide area network (WAN) (Le, Chin, & Chen, 2017) . Figure 2. shows the illustration of smart grid communication architecture. Bidirectional information exchange is automated between different modules in smart grid for efficient energy generation, distribution and usage (Niyato, Xiao, & Wang, 2011). Data communication is done in different phases such as substation control, transmission line monitoring, automatic meter reading, demand response decisioning and energy usage scheduling (Güngör et al., 2011). Certain limitations that are to be considered on the implementation of the SG plan which could be resolved by the suggested techniques of researchers.

### 2.1 Information and Communication Technology

As the ICT utilization is mainly focused on data exchange and control ability between the customer

devices and the substations, the grid requires flexible, decentralized and dynamic topologies where the current power grid topologies are inadequate.

Integration between ICT and energy infrastructures mainly depends on:

- Interoperability – the conjunction of ICT and SG protocols
- Reliability and security –for preventing cyber attacks
- Decentralized and self-organizing architecture– for flexible grid control and for self-diagnosis
- Innovative business models-collaboration between the network operators

Common protocols are used for the Smart Grid communication where certain standards are significant for interoperability. Communication protocols according to International Electrotechnical Commission (IEC) standard are IEC 60870-6, 61970/61968, 61850, 62357, 60870, 62325, 61850, 61400, and 62351(Zheng, Gao, & Lin, 2013). For reliability and security the NIST has listed IEC 62351, IEC 62443, IEC TC57 and WG13 standards. IEC 62443 has the control ability for Automated Energy Management (AEM). Unique frequencies for the smart devices have to be considered for power supply according to their requirement which can be performed by RFID technology by identifying the individuals and the transport unit.

ISO/IEC 18000, ISO/IEC 15963–2009 series helps in finding the RFID tags. IEC and ISO developed a standard for automatic identification techniques. IOT is provided with unique protocols such as 6LowPAN, RPL, CoAP for integrating with the devices (Bekara, 2014). Research, development and demonstration (RD&D) policies increases the efficiency for system operation, increases the storage capacity, enhances the load, responds quickly to the demand and reduces the cost expenditure. Full potential access of the frequencies from different stakeholders evolves in energy value chain to avoid the blackouts. Lossless compression of electricity waveform with the sampling rates of kilohertz in range is done with the TTA 2.3.and MP4 ALS techniques (Jumar, Maaß, & Hagenmeyer, 2018).

## 2.2 Recommended Algorithms

Knapsack problem with Branch and Bound algorithm are approached to maximize the customer with the limited power supply (Marah & El Hibaoui, 2018). To solve the routing problem and to manage the power flow Max-Flow algorithm is introduced. In extensive smart grid systems, detection and isolation of the unknown attack (DoS, Price manipulation) are found by the observer-based algorithm (Luo et al., 2018). To counter these unknown attacks, Cumulative Sum (CUSUM) algorithm along with the abnormal behavior detection is proposed analyzing the behavior of the network to prevent the stealing of data and financial losses (Attia, Senouci, Sedjelmaci, Aglizim, & Chrenko, 2018).

Advanced Encryption Standard (AES) and Triple Data Encryption Algorithm (3DES) provides strong security and high performance with least cost option (Mourshed et al., 2015). The multi-channel utilization and dynamic frequency switching algorithms provide solutions for TV white space (TVWS) reliability problems

as TVWS enhances the footprint of the system which we discuss in the latter content (Le et al., 2017).

According to Seokcheol Lee proposed model, HAN centric smart grid architecture follows the hybrid of NIST and ITU-T reference models which contains customer domain, distribution domain, service provider domain, operation domain, and market domain to communicate with the devices in the HAN (Lee, Lim, Go, Park, & Shon, 2015). Customer affinity is found high.

- a) Customer Domain: a system which operated by the Customer such as Electric vehicle, ESS (Energy Storage System) and the smart devices.
- b) Distribution Domain: performs transmission and distribution of electricity from power plants for customers. Distribution Data Collector, Substation Controller, and ESS are typical facilities of distribution domain.
- c) Service Provider Domain: It includes electricity billing, usage of electricity information, managing distributed resources, etc.
- d) Operation Domain: Controls the system over power system management, transmission, distribution, and Advanced metering infrastructure)
- e) Market Domain: Handles management of electricity market and inspects request of electricity demand and the service of the response.

HAN is security constrained as it is closer to the customer environment and has self-diagnosing capabilities. Customer usage of electricity is checked via In-Home Display (Lee et al., 2015)(Yu et al., 2016). Energy Service Interface is used to communicate with the outside of HAN (Emmanuel & Rayudu, 2016)(Nist et al., 2010). Advanced Metering Infrastructure (AMI), measures the consumption of energy. Home Energy Management System is for electricity management and control. As the smart devices work with customer's private information on communicating data within the HAN and HAN to another network, information should be kept secure.

The Data Aggregator Unit collects information from various AMI for data billing via a customer premises network (CPN) (Emmanuel & Rayudu, 2016). It is also utilized for Demand response as it acts as a gateway to the CPN also performs routing, managing and prioritizing for traffic concern. Mobile workforce unit is a manual work which accesses the Energy meter via CPN helps to retrieve the data to solve the flaws. Phasor measurement units (PMUs) monitor and control the voltage flow to suppress the blackouts over the large area distribution (Luo et al., 2018). The NAN collects all the energy usage data from various HANs to the Utility backbone via its gateways (AMI).

The WAN provides the backbone/core communication for all types of distributed area networks that exist at different segments of the grid. Wired communication is preferred to avoid the interferences between the frequencies. High data rates can be transferred through a wired network but its implementation cost is high and can be used only for limited coverage area. NIST working with the FCC and DOE to prevent the wireless interference issue operating in unauthorized frequencies. Long distance communication between NAN and HAN is accomplished by TVWS where its reliability problem can be solved by multi-channel utilization and dynamic

frequency switching algorithms. TVWS is applied for cognitive radio technology which resolves the Bandwidth scarcity and restrains unauthorized interferences.

For a good line of sight and power management H.E. Erdem (Erdem & Gungor, 2018) have proposed two methods called Schedule driven and Event-driven which helps in energy harvesting following the WSN network where the sensor nodes support in linking the devices. A lifetime of the sensor node is increased and the usage of battery is reduced by the tasks performed by Schedule driven method such as sleeping, sensing, computation, and communication where the Event-driven wakens the sensor node. WSN network has good Line-of-Sight and hence this network can be considered on HAN and NAN where the full potential of the spectrum is utilized. In smart grid system, the waveform we prefer is Electromagnetic which is a promise for energy harvesting. It is found that Non-Line of sight

environment and Conductor Winding Harvester increases the lifetime of the sensor by the proper duty cycle process. Considering the performance metrics of Software Defined Network (SDN) it is more advantageous than other network in providing congestion control, low latency, security, load balancing, shortest path forwarding, traffic shaping, multiple grid applications and QoS regardless to the conventional grid (Ibdah, Kanani, Lachtar, Allan, & Al-Duwairi, 2018). SDN works against Address Resolution Protocol poisoning, congestion attack and power delivery delay in the HAN with PMU and Supervisory Control and Data Acquisition (SCADA) protocols. MAC address is not disturbed at any cause during transmission. The different networks recommended for the smart grid is shown in figure.3. Table 1. shows the data rate and communication range requirements of different networks (Palak P. Parikh, Mitalkumar. G. Kanabar, 2010).

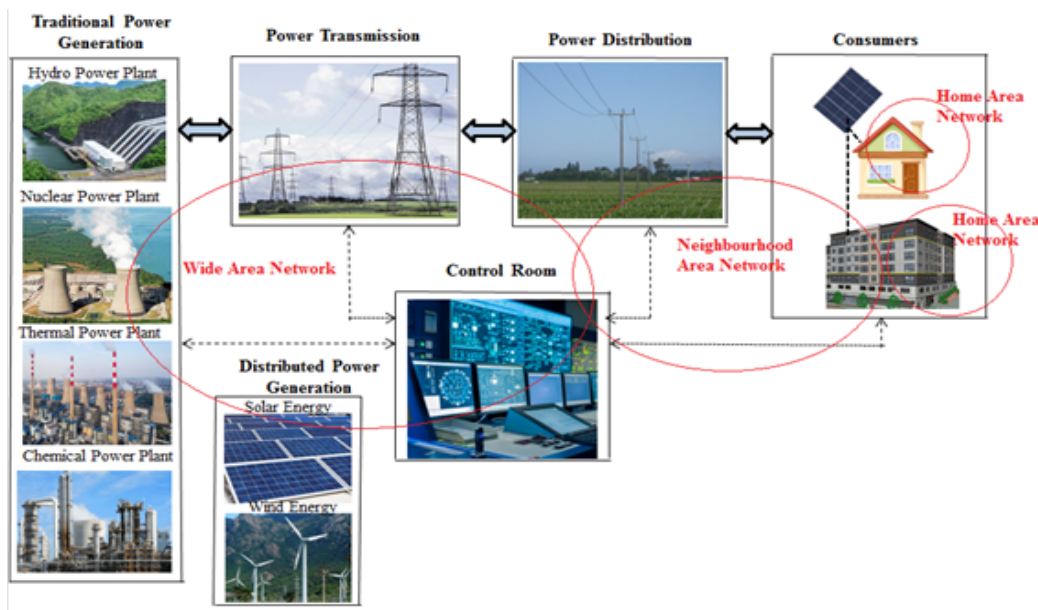


Fig. 2 Illustration of Smart Grid Communication Architecture

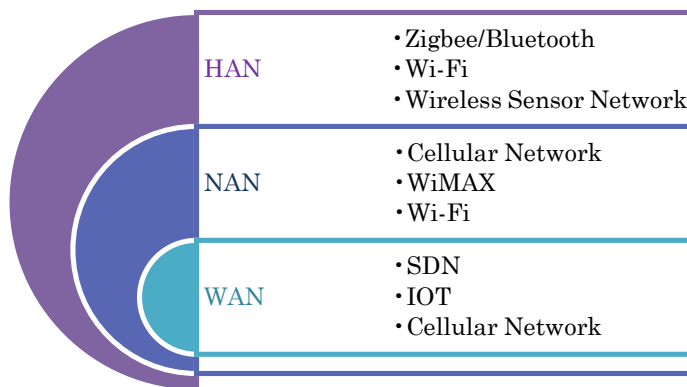


Fig. 3 Networks recommended for SG

Comparison of different communication technologies referring results Zigbee for HAN and WiMAX for NAN based on their performance needed for SG (Mahmood, Javaid, & Razzaq, 2015). IEEE 802.15.4 standard that defines physical and MAC layers support the Zigbee. As

SDN is suitable also for the HAN network expected outcome of the SG can be achieved by transmitting at high data rates. However, HAN is required only for the smaller coverage area Zigbee is suggested for HAN (Mahmood et al., 2015). WiMAX optimizes the Voltage



with low communication cost which is supported by standards of IEEE 802.16 series (Emmanuel & Rayudu, 2016) (Al-Ali & Aburukba, 2015). SDN is implemented for the wide area Network for better routing, control, and monitoring with respect to the SG demand (Rehmani, Davy, Jennings, & Assi, 2018b).

**Table 1**  
Requirements of Data rate and communication range

Network	Data Rate	Range
WAN	10Mbps to 1Gbps	Some hundreds of square kilometers
NAN	100kbps to 10Mbps	Some square kilometers
HAN	1bps to 100 kbps	100m to 30m
SDN WSN	Some packets/sec Based on the duty cycle	100 km distance Limited distance-7m to 25m (depending on schedule and Event scheme) Retransmission is possible

### 3. Networking Technologies

#### 3.1 Software Defined Networking based Smart Grid Communication

SDN based SG performs well in routing, traffic flows, security, fast failure detection, identifying errors in data paths and unidentified packets, self-diagnosis (Rehmani, Davy, et al., 2018b). SDN controller access maximizes the advantage over SG with the open flow protocol. SDN controller is Global and Local where the congestion can be controlled by the substation. RYU, Floodlight, and POX are some SDN controller which overthrows the cyber-attacks and observed that RYU and Floodlight performance is higher than POX. Power line communication technique is introduced for handling the Cyberattacks in microgrid environment (Ibdah et al., 2018). Researchers have proposed the WSN implementation in SDN without proof. The disadvantage is that a single failure in an SDN controller leads to critical control and response. Control plane is attacked on isolation of data and control plane (Dong, Lin, Tan, Iyer,

& Kalbarczyk, 2015). LFLMAB algorithm has been proposed to detect the link failure. SDN based Machine to Machine (M2M) communication is considered for future sign SG in view of Industry 4.0. Table.2 gives the comparison of various protocols in software-defined radio used in the smart grid.

#### 3.2 Internet-of-Things based Smart Grid Communication

IOT is the most recent technology that works with Smart appliances for transmitting and distributing the data into the SG system where certain protocols are dedicated to the process. Devices are ordained with IP address that can be accessed by the authorized user through the internet. Transmission status and the control operation is performed via the Internet. IPV4 protocol is extended to 128 bits from 32 bits for the addressing 232 devices requiring a large number of IP address whereas for IPV6 up to 2128 devices can be addressed. Smart appliances such as refrigerator, water heater, electric vehicle and substation devices such as voltage regulator, Sensor, meters, switches are considered as IOT devices. Utility data control and management system such as, Distribution management system, Geographic information systems, Outage management systems, Customer information systems, and SCADA are provided with unique IP address (Al-Ali & Aburukba, 2015). It is believed that IOT is the way for Industry 4.0 revolution (Li et al., 2016). Existing IOT technologies have to be replaced with new IOT model, taking into account reliability, demand response, security, decision making, and unknown attacks. Cyber-attacks can be prohibited with certain standards and protocols (Bekara, 2014). The 3GPP standard for IoT is introduced for using wide spectrum (Gozalvez, 2016). SDN-based SG can be used for integrating cloud and IoT. IoT has driven SDN is used for smart grid network fault management in (Al-rubaye, Kadhum, Ni, & Anpalagan, 2017). SDN controller can choose a short/long path for better services. In this, QoS is maintained, congestion of data flow is avoided, resiliency is achieved and latency is high.

**Table 2**  
SDR in Smart Grid

Reference	Protocol used	Parameters considered for analysis	Parameters analyzed	Remarks
(Dorsch, Kurtz, Girke, & Wietfeld, 2016)	Bidirectional Forwarding Detection(BFD)	Traffic recovery	QoS, Failover time	Recovery happens within 4.54 ms
(Fonseca & Mota, 2017)	Open flow protocol	Fault management	Resilience, performance, scalability and network redundancy	Open flow protocol helps for traffic monitoring
(Rehmani, Akhtar, Davy, & Jennings, 2018)	Spanning tree protocol	Optimal link selection	Link failure is 10% with less no of packet loss	The centralized approach is 100% reliable

### 3.3 Machine-to-machine based Smart Grid Communication

M2M communication technology plays a vital role in vehicular communication, home appliance, Health care management etc. M2M on integrating with the IOT technologies is widely approached by the researchers but independently its drawback is more. Due to spectrum scarcity issues, M2M communication is integrated with cognitive radio (Niyato et al., 2011). Cognitive radio based M2M communication improves spectral efficiency

and power efficiency in electrical distribution. Energy efficiency is low due to much communication between the devices. Reliability and latency is a negative response from M2M communication (Erol-Kantarci & Mouftah, 2015). Huge number of devices can be supported by M2M communication within small coverage area. IP protocol does not support M2M communication (Tuna et al., 2017). Table.3 gives the comparison of various protocols in machine-to-machine communication used in smart grid.

**Table 3**  
M2M for Smart Grid

Reference	Protocol used	Parameters considered for analysis	Parameters analyzed	Remarks
(Aijaz & Aghvami, 2015)	MAC protocol	Preamble and Frame duration, Maximum interference ratio and Delay tolerance	Synchronization overhead, Energy efficiency high, Scalability high, and throughput is above 60%	(PRMA) Packet Reservation Multiple Access based Communication Network, Interference is high
(Tuna et al., 2017)	Routing protocol	Interoperability, scalability, flexibility	Network Traffic & load is high, High throughput	Limitations in energy efficiency, storage, and computation
(Zhou, Gong, He, & Zhang, 2017)	Communication protocol	Spectral efficiency, the Transmission rate	QoS-has to be enhanced, High latency	Channel allocation should be improved

### 3.4 Cellular Network based Smart Grid Communication

Cellular provides an advantage over ubiquitous footprint, low latency, high data rate, QoS but the spectrum is centralized. The probability for the interference is high due to frequency reuse. General Packet Radio Service technology is used for monitoring the substation. LTE and GSM cover wide area network and provides high throughput and reliability. Based on the availability of cellular service the distance coverage and data transmission rate (60-240kbps) is high (Palak P. Parikh,

Mitalkumar. G. Kanabar, 2010). The main advantage of integrating smart grid with the cellular network is existing infrastructure can be utilized (Alam, Sohail, Ghauri, Qureshi, & Aqdas, 2017). Utilities are more in this network but the frequency band is centralized and licensed where only particular frequencies could be accessed which promotes traffic and demand in the network. Existing LTE system if replaced with respect to the SG technologies, performance would be highly countable. Table.4 gives the comparison of various protocols in the cellular network used in the smart grid.

**Table 4**  
Cellular Network in Smart Grid

Reference	Protocol used	Parameters considered for analysis	Parameters analyzed	Remarks
(Bag et al., 2018)	IEC 61850-90-5 protocol (IP)	Latency is 5ms to 25ms, throughput, availability 24 hours	Packet size and transmission frequency	Latency is improved with this protocol
(Hassebo, Obaidat, & Ali, 2018)	TCP/IP	QoS, packet delay 100ms-300ms, Traffic distribution, Modulation	Throughput 48Mbps, latency	Latency requirements are not met
(Feng, Peng, Yan, Lin, & Zhang, 2017)	MAC layer protocol	The frame structure, delay below 1ms	Packet loss is below 2% if users are 5-60, Throughput is 2.2 Mbps	Only a limited number of users are considered

### 3.5 Cognitive radio based Smart Grid Communication

Cognitive radio based technology has a dynamic spectrum that can be ultimately used for SG communication. TV white space, smart utility network,

and cognitive radio based communication are considered as the new technologies which can be integrated with the smart grid (Alam et al., 2017). Federal Communications Commission (FCC) assigned the spectrum in such a way that the licensed band can be utilized by the unlicensed user without the interference. Smart grid automatic

generation control communication infrastructure can be done using cognitive radio (Jiang, Wang, Daneshmand, & Wu, 2017). The cognitive radio network is modeled as the on-off switch with sojourn times. Sensing the vacant spectrum is a difficult task in a cognitive radio network. Compressed sensing algorithm for CR based SG is shown in (Ranganathan et al., 2011). To recover smart meter data transmission Bayesian compressed sensing and Kalman filter compressed sensing is proposed in (Ranganathan et al., 2011). CR technology is found to be

critical due to data packets loss, lack of system stability and traffic (Le et al., 2017). Data rate and spectrum level are found to be low when compared with the other technologies (LTE-4G) (Kalyani & Sharma, 2015). For long distance communication CR based SG is not applicable. Table 5. shows the comparison between different communication technologies and their performance.

**Table 5**

Comparison of different communication technologies for the revolution

Communication Technologies	Industry 4.0	Spectrum	Remarks
IOT	Hoped for	Decentralized	Reliable
SDN	Applicable	Centralized	Efficient with M2M
M2M	Not applicable	Centralized	Low energy efficiency
Cellular System (LTE-4G)	Applicable (with the changes in the topology)	Centralized	Limited number of users
Cognitive radio	Not Applicable	Decentralized	Licensed band, Costly

#### 4. Conclusion

This paper gives the review on the performance of different networking and communication technologies suggested for Smart Grid. As the smart grid is focused on Green Communication, a hybrid of renewable energy is possible only when the energy democracy movement and political power is enacted. Clean electricity can be transmitted with the elimination of fossil fuels. 5G technology is integrated with smart grid by using Software Defined Network or Cognitive Radio for WAN, Zigbee for HAN and WiMax for NAN. Standards and protocols have been observed in different networks for desired QoS. In 5G, failure in the SDN controller is not adaptable for control and response. Energy efficiency is poor in M2M communication. User Capacity for cellular communication is minimum hence it cannot meet the requirement of 5G. Cognitive radio is efficient but the implementation cost is very high. Smart grid towards IoT achieves strong reliability, interoperability, and Resilience. According to the development of 5G, IOT based Smart Grid performs well and its limitations are overpowered by the protocols and 3GPP standard. Fraudulent in automated meter reading and electromagnetic interference on the wireless network due to severe solar storms are the drawbacks and the future research sign in smart grid.

#### Abbreviations used

3GPP	Third Generation Partnership Project
5G	Fifth Generation
AEM	Automated Energy Management
AMI	Advanced Metering Infrastructure
CPN	Customer Premises Network
CR	Cognitive Radio
HAN	Home Area Network
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IoT	Internet-of-Things
LTE	Long-Term Evolution
M2M	Machine-to-Machine

NAN	Neighbourhood Area Network
NIST	National Institute of Standards and Technology
PMU	Phasor measurement unit
PV	Photovoltaics
QoS	Quality-of-Supply
SCADA	Supervisory Control and Data Acquisition
SDN	Software Defined Network
SG	Smart Grid
TVWS	Television white space
WAN	Wide Area Network
WSN	Wireless Sensor Network

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