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Comprehensive study on Future communications: 5G Networks

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Abstract: Wireless cellular networks are emerging to take a strong stand in attempts to achieve pervasive large scale obtainment, communication, and processing with the evolution of the fifth generation (5G) network. Both the present day cellular technologies and the evolving new age 5G are considered to be advantageous for the smart grid. The 5G networks exhibit relevant services for critical and timely applications for greater aspects in the smart grid. In the present day electricity markets, 5G provides new business models to the energy providers and improves the way the utility communicates with the grid systems. In this work, a complete analysis and a review of the 5G network and its vision regarding the smart grid is exhibited. The work discusses the present day wireless technologies, and the architectural changes for the past years are shown. Furthermore, to understand the user-based analyses in a smart grid, a detailed analysis of 5G architecture with the grid perspectives is exhibited. The current status of 5G networks in a smart grid with a di_erent analysis for energy e_ciency is vividly explained in this work. Furthermore, focus is emphasized on future reliable smart grid communication with future roadmaps and challenges to be faced. The complete work gives an in-depth understanding of 5G networks as they pertain to future smart grids as a comprehensive analysis.

Keywords: 5G; smart grid; smart meters; wireless communication; energy e_ciency

1. Introduction

The continuous demand for power has been a critical issue that needs significant attention in the present day of the smart grid era. In order to achieve more distributed generation and power storage, new modes of wireless communication technologies should be incorporated with the grid. Smart grids deal with small distributed generation sources, in contrast to a conventional grid, which relies on large centralized generation. The main objective of the conventional power grid is to change the generation of power to match the necessary power demand. This requires smart grids move on to adjusting the demand in accordance with the available generation [1–4]. Therefore, highly secure communications for both sensing and control in all means of interactions between the transmission and the distribution side are needed.

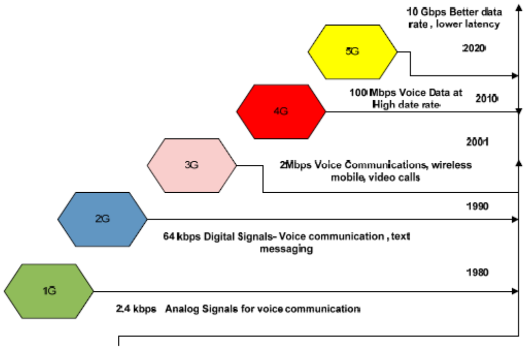


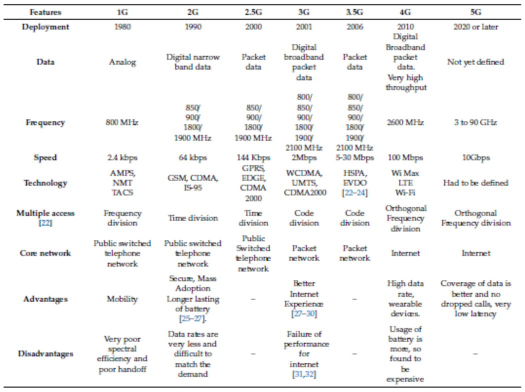
Figure 1. Wireless communications technology and its evolution over the years.

In accordance with the report by Navigant research [20], fifth generation (5G) communication networks are found to be more multi-functional and also very flexible. This provides a greater platform to support many critical issues and also solves many problems with respect to cost analysis and power applications. The 5G networks are expected to establish a greater scale upon which to pivot to the fourth industrial revolution. It provides a convergence of pervasive broadband, sensing, and intelligence, which causes greater change in society and industrial markets. Moving into new wireless communication networks can bring the Internet of Things (IoT) into future power markets, providing greater benefits to the utilities and the consumers

2. Overview of Wireless Communications Technologies

Over the past few decades, the world has seen a gradual and steady growth of communication networks, starting from the first generation and moving towards the fourth generation. Currently, there are many advancements occurring in wireless technologies, such as orthogonal frequency division multiplexing [23,24] with access to many brand new frontrunners with effective frequency. By this growth, there has been a parallel increase of smart devices growing rapidly in day to day life. At this onset, new applications and new business market providers with wireless technology are also increasing at a larger scale. Table 1 depicts the wireless communication technology era for the past few decades and its benefits.

Table 1. Wireless communication technologies era.

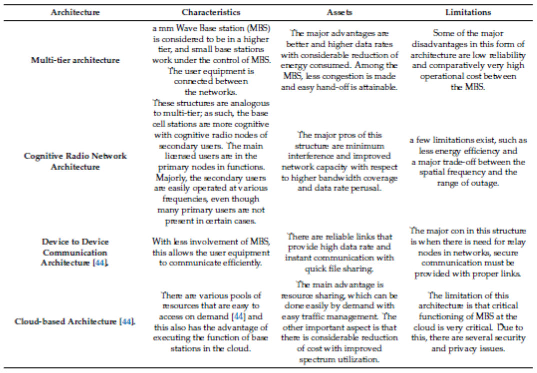


Features	1G	2G	2.5G	3G	3.5G	4G	5G
Deployment	1980	1990	2000	2001	2006	2010	2020 or later
Data	Analog	Digital narrow band data	Packet data	Digital broadband packet data	Packet data	Digital Broadband packet data. Very high throughput	Not yet defined
Frequency	800 MHz	850/ 900/ 1800/ 1900 MHz	850/ 900/ 1800/ 1900 MHz	800/ 850/ 900/ 1800/ 1900/ 2100 MHz	800/ 850/ 900/ 1800/ 1900/ 2100 MHz	2600 MHz	3 to 90 GHz
Speed	2.4 kbps	64 kbps	144 Kbps	2Mbps	5-30 Mbps	100 Mbps	10Gbps
Technology	AMPS, NMT TACS	GSM, CDMA, IS-95	GPRS, EDGE, CDMA 2000	WCDMA, UMTS, CDMA2000	HSPA, EVDO [22–24]	Wi Max LTE Wi-Fi	Had to be defined
Multiple access [22]	Frequency division	Time division	Time division	Code division	Code division	Orthogonal Frequency division	Orthogonal Frequency division
Core network	Public switched telephone network	Public switched telephone network	Public Switched telephone network	Packet network	Packet network	Internet	Internet
Advantages	Mobility	Secure, Mass Adoption Longer lasting of battery [25–27].	–	Better Internet Experience [27–30]	–	High data rate, wearable devices.	Coverage of data is better and no dropped calls, very low latency
Disadvantages	Very poor spectral efficiency and poor handoff	Data rates are very less and difficult to match the demand	–	Failure of performance for internet [31,32]	–	Usage of battery is more, so found to be expensive	–

3. 5G Networks—Outlook

The 5G networks stand for fifth generation mobile technology and can outperform earlier versions of wireless communication technology. The new technology provides diverse abilities and encourages full networking among countries globally [32–35]. Accordingly, 5G architecture constitutes both licensed and unlicensed frequency bands. In a recent study from 2016, the Federal Communications Commissions (FEC) announced the use-case [34] of 60 GHz spectrum with the range of 57 GHz–71 GHz for the unlicensed wireless category. These networks are expected to implement very high service quality. In order to entertain these 5G services [36,37] for the new generation communication system, different new technologies have been proposed, namely Millimeter wave communication, Hetnets, Massive multiple-input multiple-output (MIMO), and visual light communication [38]. The Millimeter wave communication [36,37] represents a low latency network that is achieved by utilizing underutilized mm wave spectra ranging from 3 GHz to 300 GHz as the carrier frequency. This technology provides very large bandwidth allocation, which can support thousands of folds of area throughput in comparison with the existing 4G systems. With respect to Hetnets technology [38,39], these are the path changers for 5G networks. This network addresses the need for data requirements as large numbers of small cells that are placed outdoors and indoors. By deploying small base stations, extensive coverage and sufficient improvements in network capacity can be made on a large scale. The needed optimization and maintenance of Hetnets can be easily attained by creating cloud assisted platforms with the stations. Massive MIMO (also known as hyper MIMO) utilizes extensive service antennas by spatial multiplexing [39].

Table 2. Comparison between the existing fifth generation (5G) architectures.



Architecture	Characteristics	Assets	Limitations
Multi-tier architecture	a mm Wave Base station (MBS) is considered to be in a higher tier, and small base stations work under the control of MBS. The user equipment is connected between the networks.	The major advantages are better and higher data rates with considerable reduction of energy consumed. Among the MBS, less congestion is made and easy hand-off is attainable.	Some of the major disadvantages in this form of architecture are low reliability and comparatively very high operational cost between the MBS.
Cognitive Radio Network Architecture	These structures are analogous to multi-tier; as such, the base cell stations are more cognitive with cognitive radio nodes of secondary users. The main licensed users are in the primary nodes in functions. Majorly, the secondary users are easily operated at various frequencies, even though many primary users are not present in certain cases.	The major pros of this structure are minimum interference and improved network capacity with respect to higher bandwidth coverage and data rate perusal.	a few limitations exist, such as less energy efficiency and a major trade-off between the spatial frequency and the range of outage.
Device to Device Communication Architecture [44].	With less involvement of MBS, this allows the user equipment to communicate efficiently.	There are reliable links that provide high data rate and instant communication with quick file sharing.	The major con in this structure is when there is need for relay nodes in networks, secure communication must be provided with proper links.
Cloud-based Architecture [44].	There are various pools of resources that are easy to access on demand [44] and this also has the advantage of executing the function of base stations in the cloud.	The main advantage is resource sharing, which can be done easily by demand with easy traffic management. The other important aspect is that there is considerable reduction of cost with improved spectrum utilization.	The limitation of this architecture is that critical functioning of MBS at the cloud is very critical. Due to this, there are several security and privacy issues.

The understanding of various domains for Long-Term Evolution (LTE) advanced networks and the different architecture delivery for energy efficient requirements through device-to-device communications with its advantages are explained in [52–54], which provide desirable architecture for 5G cellular networks for smart cities. The need for the proposed 5G architecture depends on different techniques. The new emerging concept of the non-orthogonal multiple access (NOMA) technique [55] is very much capable of optimizing and improving the performance of 5G networks. This technique ensures the simultaneous usage of common spectra by different multiple users, but it also provides minimum interference among the users. Furthermore, this allows clusters of users with variable channel gains to transmit on the same radio resources. It also uses continuous interference cancellation during decoding of the signal at the receiver side. Figure 2 represents the overall 5G architecture, explaining the different advantages of each.

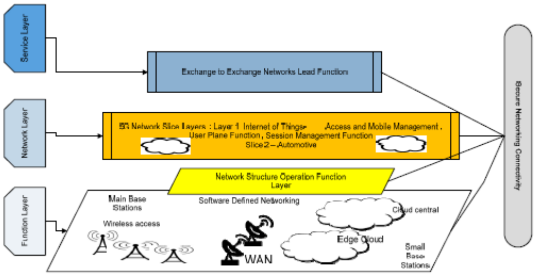


Figure 2. Overview of 5G architecture.

4. Smart Grid and 5G

Smart grids assimilate information, communication, and networking with automation into the legacy power arrangement, changing the way energy is stored and delivered between the utilities and the users. Nowadays, smart grids are regarded as the most imperative structure of many international energy strategies globally in various fast-growing countries. These smart grids operate on the convention of all components connected to the grid, which are well monitored and controlled in every function.

The role of data traffic distribution in a smart grid network [66–70] can be classified into two sections. The first among these is a home area network (HAN) [71], which involves interaction between the utility and the users through underlying connections such as smart meters and sensors. The next major segment is the direct connection between the utility providers and the generation side. In the past decade, power line communication has been considered as the best communication provider between these segments. The authenticity of the communication system [71] in the future shall be improved by allowing power line communication [72] for the integration of information and communication. This is achieved by enabling the digital communication in power lines in addition to electrical power transmission.

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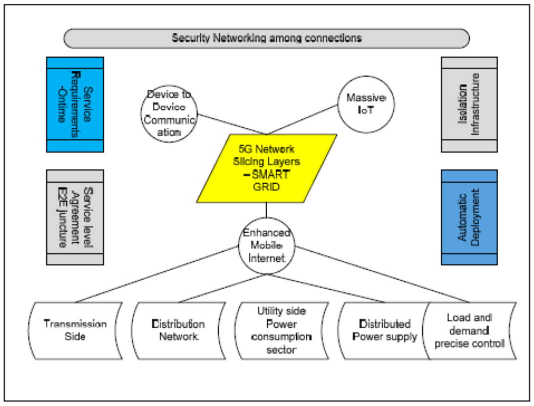


Figure 3. Roadmap architecture of 5G and smart grids.

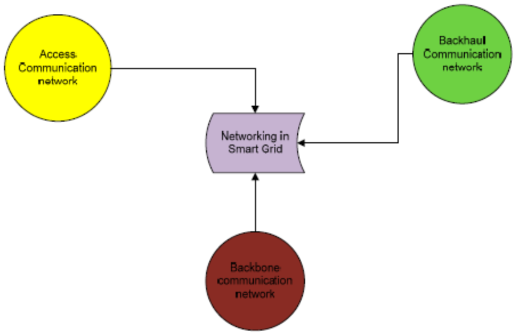
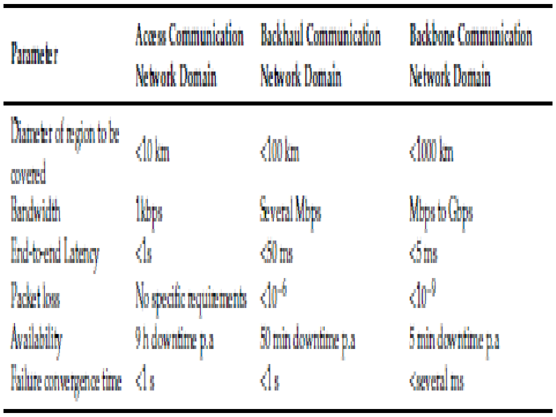


Figure 4. Network domains establishment for smart grid communication.

Different access networks connect the elements in a smart grid, such as smart meters and secondary substations, whereas the backhaul network connects the elements in medium voltage areas, such as secondary substations. The backbone network domain deals with connecting the elements in high voltage and extra high voltage power grids, such as primary substations, which have stringent requirements. Table 3 shows the specific requirements of each communication network domain in order to have a seamless operation of a smart grid

Table 3. Overview of the requirements for network domains in smart grid infrastructure.



Parameter	Access Communication Network Domain	Backhaul Communication Network Domain	Backbone Communication Network Domain
Diameter of region to be covered	<10 km	<100 km	<1000 km
Bandwidth	1kbps	Several Mbps	Mbps to Gbps
End-to-end Latency	<1s	<50 ms	<5 ms
Packet loss	No specific requirements	$<10^{-6}$	$<10^{-9}$
Availability	9 h downtime p.a	50 min downtime p.a	5 min downtime p.a
Failure convergence time	<1 s	<1 s	<several ms

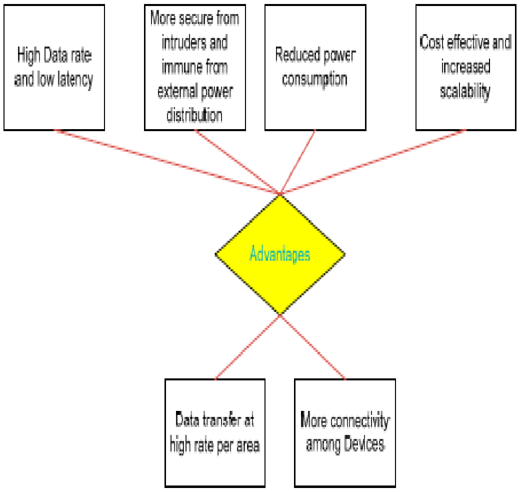


Figure 5. Benefits of 5G networks in smart grids.

Similarly, the circuit breakers used in the protective measures in the system find system faults that function with high time criticality. The speed of intervention of the circuit breakers in fault detection is proven to be better in the distributed network management in 5G [92] compared with the centralized network management in LTE. Demand response allows users to reduce or shift their electricity usage during peak periods based on a time dependent pricing [93]. The communication impairments can adversely affect the demand response control. This requires advanced communication technology for enabling a control feedback loop between the user and the energy providers. This can be achieved by efficient 5G small cell planning [94]. There is a need for interoperable structures with 5G and smart grids, which includes various features and is due to the resemblance of ubiquity of the 5G cellular network [95]. There are many advantages in these frameworks, including two way energy trading, dynamic energy pricing, and active wireless transmission spectra between the grid and the networks.

5. Conclusions

In this work, a complete overview of forthcoming 5G technology for the development of smart grids as a future energy arena is presented, and an analysis is made. The 5G services in a smart grid junction will build on the extensive and the decisive acquisition of information sharing at the correct timescale from the system in addition to massive storage backups and new computing techniques. This provides great support for future smart grids to improvise the control and the monitoring access among large networks in a successful brand. This review discusses the process of the needs of a smart grid with 5G and the areas where the network analysis can be made. This work establishes a beginning mark of bringing in new age 5G networks with smart grids and sets a path for budding researchers to work on new technology with smart grids and provide trendsetters for new energy domains worldwide.

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