Coupling of 5G Networks with Smart Grids (December 2019)

Etsegenet Zewdie, ITEC 452 Final Project

Abstract - The role of wireless cellular networks is taking a prominent position in large scale communication, obtainment, and processing with the evolution of the 5G (fifth generation) network. In the upcoming time and in the present time, the new 5G technologies are considered to be beneficial for the smart grids. The services provided by the fifth-generation networks are the critical and timely if implemented in the smart grids. The present-day electricity markets see 5G technology as the new business model that can be implemented for improving the working of traditional grid systems.

In this survey paper, present-day wireless technology the changes before this are explained. For the development of an understanding of the smart grid and the implementation of 5G networks, the 5G architecture are considered with the smart grid perspective. The recent analysis of 5G is given in the paper that reflect the system efficiency. Current research issues are discussed along with the future research issues related to the topic. The major focus of this paper is to provide the basis of research for the development of reliable smart grid 5G communicational networks with the future challenges and roadmaps that have to face by the researchers. The work gives a deep analysis of the fifth-generation networks and gives a comprehensive analysis of future networks.

I. INTRODUCTION

The increased power demand is considered a critical issue during the era of smart grids. An electric grid that has various operations including the energy measures including smart appliances, smart meters, renewable energy resources, and resources that are energy efficient is known as the smart grid.

The distributed generation and the power storage can be achieved using the new technologies model that are wireless and they can be installed in the grid. It is a fact that the smart grid relies on a large centralized generation. The reason for converting the conventional grid to the smart grid is to produce the same power as demanded by the customer [4]. However, there are various security concerns associated with the transmission and distribution are needed that make sense from both sides to be efficient.

There are data management systems, smart meters, sensors and the monitoring in the smart grid. The smart grid would be considered more sustainable if there is the implementation of smart metering technologies and the smart grid [9].

The major issue in the development of such system is the remote communication management between the different ends of the systems where the meters are connected. Different communicational standards are suggested by the communication technologies that can be wired or wireless technologies. The wireless communications are preferred more these days because they can efficiently handle distant applications and reliable cost. While choosing a proper system there is a need to consider stable, reliable and proper communication systems. A lot of development in the infrastructure of new technologies is observed in previous decades. The rapid transfer of technologies from 2G to 4G from 1990 to 2010 [8]. However, it is estimated that above 2020 the 5G technology would be fully functional that have a better data rate, better service quality, and low latency [8].

The fifth-generation or 5G technology is found to be flexible and multi-functional. This can help address critical issues and solve problems concerning power applications and cost analysis. It is expected that 5G technologies would establish in the upcoming time and it provides the sensing, persuasive broadband and intelligence that causes the changes to the industrial markets and society [8]. When moving to the wireless communications networks, the IoT or internet of things can be helpful in future power markets and this provides a great benefit to the consumers to utilities. Along with the wire modes and benefits form this, the 5G can be developed across the energy paradigm [1]. The 5G networks can be implemented to the smart grid systems as the new business models at the utility side with fog and edge computing with intelligent control and automation.

The smaller cell functions the slicing network that provides assets that are located at both the transmission and distribution side ubiquitously. This survey paper explains the need for 5G technologies for the smart grid and the areas where the linking of 5G with a power grid can give the benefit. Moreover, it also explains the current approaches for addressing the topic. The paper also elaborates on the future challenges faced by the researchers and helps them in developing better concepts whether they are junior or senior researchers because of the simple approach to address the topic [7].

II. APPROACH TO EXPLAIN THE 5G NETWORK

Several applications are associated with the 5G network and it can provide an advantage in them. These applications can be healthcare systems, IoT, financial technology and energy sectors, etc. IoT is getting vast attention because of the capability of connecting several devices at a time with the network. This enables the connectivity between several devices having different functionalities and increases the mutual interaction between the devices. 5G network can provide high throughput and lower latency for the between these heterogeneous and wide-area distributed devices. Similarly, another area of the same research is the IoV or the internet of vehicles where the congestion and reduction in the traffic issue can be done. The large bandwidth and the low latency of the fifth-generation networks can be used for compiling the technology with other routine matters. Similarly, in the medical field, the continuous monitoring of the data from the patient can provide real-time health monitoring because of the extraordinary features of the 5G networks [1].

The smart grids can communicate, assimilate information and automated with the legitimate powerful arrangements and this can change the way to store and utilize the energy based on customer demand.

The smart grids are considered the important source of energy-saving approach that is considered important in act growing countries. All functions of the smart grid can be well controlled and monitored with a different management system. A transfer of large amounts of data would be required for linking the consumers with the wireless communication network and this would require the proper channeling.[7]

Various issues related to the security can be fixed because of the wireless communication and smart meters and it make it efficient, reliable, and intelligent way to transform the conventional grips to the smart grids. The data distribution can be divided into sections one is known as Home Area Network or HAN and there is the user and generation side interaction.

The power line communication was thought to be the best way in the past and it can also increase the authenticity of the communications in the future and helps in the integration of information and communication. This can be done with the development of digital communications in the power lines along with the electric transmission [4]. The 5G architecture and the smart grids pave the way for various assets for the transmission and distribution side. The 5G network layers can provide the multiple domains at the user and utility side.

The diverse services can increase the challenges associated with load balancing. Another important feature can be the on-demand deployment where the functioning of the network is analyzed based on service's needs. Moreover, the network slicing of 5G provides demand deployment at the side of the user.

The end to end legal agreement can provide the key elements for reducing the costs of the networks and the on-demand deployment. The 5G provided networks can be considered logically isolated and they are shared with the telecom networks at a larger scale. From the perspective of service, this control is carried out at a very precise level i.e. millisecond level [7]. The 5G slicing can provide the customizable agility and the services that are isolated uniquely at the grid side.

A flexible network can provide a secure network. The design helps in the reduction of capital expenses and the network speed could also be controlled. With the 5G technology the slicing layers can be achieved, and this means that there would the distributed automation of the feeder with the higher latency and the bandwidth that is low. The information delivered by the low voltage distributed systems exhibits the formation of the new architecture that meets the low latency and bandwidth requirements. This also reflects the low isolation requirements for the service and the medium service priority [6].

In the scenario that has the distributed supply of the power, the high or medium-level latency is archived with the high-reliability requirements. The multi-slice architecture that can be developed in the grids considers different scenarios with intelligent automated feeders and low distribution systems. The development of the smart grid system requires the virtual 5G slice infrastructure layers [9].

The current connection between the simultaneous power and wireless allows the advancements in wireless communications. The manual change of battery is associated with wireless devices connected to the systems. But, the low communication availability and the high initial costs during the bad weather conditions and natural disasters make it such an approach which is not preferred. The use of digital mobile radio can be used for exchanging data traffic between utility providers and consumers. The use of microwave is also observed to be installed for the consumers in different sectors. The working of cognitive radio networks can be used by utilizing the available resources of the spectrum [1].

In the new internet technologies, the smart grids with 5G can be considered as rising the new field of Internet of Energy that demands the rise in production and provide the stable communications for meeting the needs of the energy. The interconnection of these devices with the 5G network can help in the management of the energy balance and reduces the energy costs. Efficient data analysis is also the property of the 5G network that helps the cities for developing their energy plans. This would provide cost-effective solutions based on demographic analysis. The elements in the smart grids can include secondary substations and smart meters. The backhaul network connects the elements in the secondary substations, and these are the medium voltage areas. However, the backbone domain of the network is used in high voltage power grids such as the primary substation [9].

A transformation from 4G to 5G would alter its several properties. For instance, the frequency of the 4G network is 2600 MHz while for the 5G its 3 to 90 GHz, the maximum speed for 4G is 100 Mbps while for 5G it would be around 10 Gpbs [7]. It's true that the core network in both 4G and 5G could be internet but the technology and the data type is not well defined yet. However, it is confirmed that in new network, there would be SDN's and IoT as the core technologies.

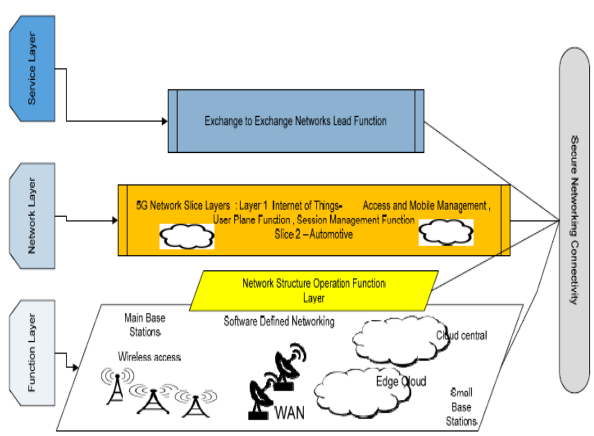

Figure 1: 5G Network architecture slice layers [7]

The Figure 1 above represents the overall 5G architecture and explains the advantages of the network. The three layers defined below are Fusion Layer, Network Layer and the Service

Layer. At different layers different operations can be performed. At the service layer, the exchange to exchange network lead functions. At the Network layer, the 5G network can be divided into Slice layers into slice layer 1 and slice layer 2. The slice layer 1 include the Internet of Things, Access and Mobile management and the session management functions. However, in the slice 2, automotive functions could be performed. Now comes the third layer which is the Function layer, and this can be used between the 5G network and the smart grids [6]. This operation function layer can include the software defined networking such as WAN that acts as the connection between the Main Base stations of smart grids having the wireless access and with the cloud central or edge cloud network.

III. EXISTING RESEARCH ISSUES ON 5G NETWORK

The 5G can outperform wireless communications. The new technologies are capable of providing diverse abilities and encourage networking among different countries. However, different approaches are given for the 5G networks and their communication with the smart grids.

There are both unlicensed and licensed frequency bands for the 5G architecture. In the recent study, the licensed range is about 60 GHz and the unlicensed range is 57 GHz to 71 GHz. These wireless networks implement a high quality of service. For entertaining these 5G services, different technologies are under consideration including the Hetnets, Millimeter-wave communication, visual light communication and the Massive multiple-input-multiple-output (MIMO). [3]

The 5G networks can be implemented in the future domain and it provides the fully connected society prospects. This proliferation provides a broad rate of business structures that pave the path for various industry profiles, such as manufacturing and energy sectors. The 5G shall provide the subsequent connections that provide the possibility for the machine-to-machine and human-to-human interactions. This simultaneous existence gives indications for considering the 5G networks to provide magnificent support [7].

However, to satisfy the current energy demands there must be a specific architecture with the slicing networks. Different architectures for the implementation of the 5G networks are given by the researchers. The comparison between different architectures is given below that includes the general overview of the architecture, advantages, and disadvantages of each of four architectures.

A. Multi-tier Architecture

The multi-tier architecture is the mm-Wave Base station (WBS) is considered as the higher-tier and there is a smaller base station that is controlled under the MBS. The equipment of the users is connected to the networks. The major advantage of this is the higher data rates which have higher rates of data with reduced consumption of energy [6]. Through this architecture, less congestion can be made, and the easy hand-off is attained. The major disadvantage of this architecture is that is less reliable, have high operational costs between the MBS [6].

B. Cognitive Radio Network Architecture

This architecture is the analogous to the multitier and the base cell stations are cognitive and have the cognitive radio nodes for the users that are secondary. The primary license users are present in the primary nodes. The working of secondary users is at different frequencies even if there is no primary user [7]. The major architecture advantage is the improved interference and improved network bandwidth that enables the transfer of data. However, the limitations of this architecture are less energy efficient, outage range and the spatial frequency [3].

C. Device to Device Architecture

Device to Device communication architecture has less involvement in MBS and this allows the equipment of users to give effective communication. This architecture is reliable, and it provides a high data rate [5]. The communication, in this case, is considered quick and the file-sharing is rapid. However, the weakness of this architecture is that it relies on the relay nodes in the networks and the secure communication must have the proper links [5].

D. Cloud-Based Architecture

The final architecture is cloud-based. The pools of the resources that can be easily accessed are present in this architecture [5]. The base stations can be executed in the cloud. The strength of this architecture is the resource sharing that is done with the management of easy traffic. The reduced costs can be considered with the spectrum utilization in this structure. The limitations of this system are the MBS critical function at the cloud, and this can arise to the privacy and security concerns [5].

Different approaches for under the LTE or Long-Term Evaluation domain and the different architecture designs are important for the development of the 5G cellular architecture for the smart grids. The 5G proposed architecture depends on different techniques [7]. NOMA or the non-orthogonal multiple access techniques are capable of optimizing and improving the 5G networks. This ensures the usage of the simultaneous spectra by various users and gives the channel for the transfer of radio resources. There is also the use of continuous cancelation of the interference signal at the side of the receiver. An important component in this regard is building the 5G architecture for archiving the high output for the overloaded cells present in the network [7]. This gives the requirement for the resources to the active mobile network areas that provide high benefits to the network. Concerning the time, the resource allocation is done properly based on channels and the ratio between them. This gives rise to the shortest path routing issue and this can be solved with the use of hierarchical processes with structured learning.

IV. POSSIBLE FUTURE RESEARCH ISSUES

Although the potential of the 5G networks is much more to be used as the communicational networks in the smart grids these systems are still not fully adopted in practice because of various challenges. In the conventional grip systems, there is the predictability at both sides i.e. the generation system (hydro-electric or thermal system) and the appropriate generation can be estimated easily based on demand. In the smart grid networks, as there is the unpredictability associated with the various small generation stations and the fluctuating use in energy at the level of the end-user. The demand and supply side of the conventional grid are considered to be exclusive. However, with the smart grid system, there is the possibility that the end user becomes the producer as well. There is the need to address the communicational technology at the level of the end-user [9]. The major challenge here would be the standardization of the new technology. The complete standardization of the 5G networks is expected in the year 2020 but there must be the backward compatibility and interoperability of the new technology with the previous technology. There is a need to utilize the current infrastructure for making it compatible with the new 5G technology [4].

Moreover, it must be kept in mind that with any fundamental network, there is the requirement of not only spectral efficiency but there is also a need that the technology is energy efficient. The introduction of the 5G network would result in the connection of multiple devices with the network and raise the power consumption of the network [8]. It is, therefore, crucial to implement the sustainable network that has renewable power sources, minimum power leakage and the optimum utilization of the power. The authentication of the network device is also an important task and it requires the delay of hundreds of milliseconds in the present system, but this might become the problem in the 5G network that assures the zero latency.

Like all other automation control context, the major concerns for wireless communication can be security, safety, latency, availability, coexistence, and system integration. The security mechanism that can be used for providing authenticity and integrity is considered highly important because of the encryption that is applicable in different cases like the metering. However, the basic strategy for coping with these issues is to first avoid, second is detection and the third is the security threat for providing the reliable grid system that provides the power.

The set of end-to-end security is defined by the IEC 61850 that helps in protecting the data integrity and the communication infrastructure is also needed to address the issues such as unauthorized access to the network and the jamming of radio signals and this can result in the denial of service. The communication infrastructure can be perceived as a secure network as compared to the VPN or point-to-point fiber. There would be also the need for the support for the service like VPN and the ability to detect the radio jamming attack in the 5G network [4].

The low communication latency with higher reliability is considered as the major challenge for the development of 5G because the latency in the average form is the state of practice in the cellular domain. The change from the average latency to the worse case latency is ongoing and addressed by the network slicing concepts. The challenges with the time diversity and the frequency can be addressed by implementing dual base stations, dual operators, and the dual end to end services [5]. However, this again depends on the costs that are associated with the dual support development for the base stations, modems and other techniques that helps to achieve the redundancy, in the cellular systems, the issue of coexistence cannot be considered as the challenge because of the use of licensed frequency bands. However, as stated above, the unlicensed bands can be possible in the case of 5G and this can be useful for off-loading during peak times [2].

The deployable and cost-effective communication system is needed for providing the data links between the power generators that are remote and the centralized control in the microgrids. In such systems, there are the power source and currents that are shown with the signals generations. This compensates the unbalanced loads by the compensator and this power is shared among the sources. The cloud-based computing functionality at the network edge can suitable in the implementation of centralized control and scalable computing power is achieved with low latency that is incurred by the short distance [5]

There might be issues in power management in large microgrids. In these microgrids, the distributed sources are far from each other and there are medium and low voltage lines present in them. This results in high resistance and becomes a challenge for the droop-based power-sharing. This power-sharing can be improved in the decentralized control scenario which is conventional, and it can be improved by correcting the reference signals of the distributed generators [2]. In this case, the reference signals comprise the first component that is based on the local measurements from the decentralized control. The second component of the reference signals can be obtained by the power network adapters and it is communicated by different power sources and power measurement units related to the lines. This function enables the low latency but, the 5G can be considered a suitable choice for covering large distances and providing a reliable and secure communication link [2].

The protection of the system also increases with more connections to the grid. An additional challenge that is associated with the limited fault current detection. This can be addressed with the line differential protection that has high requirements for the infrastructure of communication. Other protection schemes such as taking account of nearby substations can be the possible solution. Here, the 5G flexibility provides the data access and this enables the new protection algorithms that don't need the new infrastructure for communication [2].

V. CONCLUSION

The survey paper elaborates the evolution of power grids is evolving to the smart grids and enabling the support of more renewable resources in the power grid. The evolving 5G technology can become the key to this transformation because it supports low latency, wide area communication, cybersecurity, scalable and highly reliable communications. This will introduce new businesses and services around the power grid domain. The success of 5G with the

Smart grid depends on the cost to support features such as redundancy, security, dedicated quality of service and the regulations.

A complete overview of the forthcoming fifth generation (5G) technology for the development of the smart grid for future energy demands is presented. Different architectures can be applied during the modification of the system from traditional power grids to smart grids. However, the advantages and disadvantages of each approach must be kept in mind. The use of 5G can enable the right acquisition of data sharing with the correct timescale along with the backup of the massive data and new computing techniques. This act to be the provider of great support for the upcoming smart grids for improvising the control and monitoring of access among the large networks. The survey paper gives an overview of the beginning of the 5G networks with the smart grids and sets the path for the researchers to work on this new technology and provide the future guidelines for new energy domains throughout the world.

References

[1] Agyapong, Patrick, et al. “Design Considerations for a 5G Network Architecture.” IEEE Communications Magazine, vol. 52, 2014, pp. 65–75. Semantic Scholar, doi:10.1109/MCOM.2014.6957145.J. Clerk Maxwell, *A Treatise on Electricity and Magnetism*, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp. 68-73.

[2] Bag, Gargi, et al. “Challenges and Opportunities of 5G in Power Grids.” CIRED - Open Access Proceedings Journal, vol. 2017, no. 1, 2017, pp. 2145–48. IEEE Xplore, doi:10.1049/oap-cired.2017.0374.B. Smith, “An approach to graphs of linear forms,” unpublished.

[3] Emmanuel, Michael, and Ramesh Rayudu. “Communication Technologies for Smart Grid Applications.” J. Netw. Comput. Appl., vol. 74, no. C, Oct. 2016, pp. 133–148. ACM Digital Library, doi:10.1016/j.jnca.2016.08.012..

[4] Farhangi, Hassan. “The Path of the Smart Grid.” Power and Energy Magazine, IEEE, vol. 8, Mar. 2010, pp. 18–28. ResearchGate, doi:10.1109/MPE.2009.934876.C. J. Kaufman, Rocky Mountain Research Laboratories, Boulder, CO, private communication, 2004.

[5] Le, Nam Tuan, et al. “Survey of Promising Technologies for 5G Networks.” Mobile Information Systems, 2016, doi:10.1155/2016/2676589.M. Young, *The Technical Writer’s Handbook.* Mill Valley, CA: University Science, 1989.

[6] Narayan Yadav, Ram, et al. “Spectrum Access in Cognitive Smart-Grid Communication System with Prioritized Traffic.” Ad Hoc Netw., vol. 65, no. C, Oct. 2017, pp. 38–54. ACM Digital Library, doi:10.1016/j.adhoc.2017.07.005.

[7] Raka et al. “Future Generation 5G Wireless Networks for Smart Grid: A Comprehensive Review.” Energies, vol. 12, June 2019, p. 2140. ResearchGate, doi:10.3390/en12112140.

[8] Osseiran, A., et al. “Scenarios for 5G Mobile and Wireless Communications: The Vision of the METIS Project.” IEEE COMMUNICATIONS MAGAZINE, vol. 52, no. 5, 2014, pp. 26–35.

[9] Tuballa, Maria Lorena, and Michael Lochinvar Abundo. “A Review of the Development of Smart Grid Technologies.” Renewable and Sustainable Energy Reviews, vol. 59, no. C, 2016, pp. 710–25.