Design and Implementation of 5G for IoT and E-village applications

Kshitij Jha, Vikram Verma, Shambhavi Jha, Vijay Nath
Department of ECE, BIT Mesra, Ranchi-835215(JH), India
kshitij.jha.kj@gmail.com, vikverma01@gmail.com, jhashambhavi007@gmail.com, vijaynath@bitmesra.ac.in

***Abstract*—This paper encapsulates briefly the evolution of mobile wireless communication over the last few decades and also describes the scope of improvement in the existing technologies as well as illuminates the way ahead. The paper then explores the possibilities of using 5G and 5G+ technologies in IoT and implementation of e-villages.**

***Keywords*—1G, 2G, 3G, 4G, 5G, 5G+, 6G, CDMA, Wireless Communication, Mobile Broadband, Generation, IoT, Internet of Things, Smart Village, E-Village**

I. INTRODUCTION

The field of Mobile Wireless Communication gained momentum after the invention of the first wireless mobile phone "The Motorola DynaTAC 8000X" in 1973. The first phone call was placed on this very phone by Dr Martin Cooper who was a pioneer in the field of wireless communication. This was based on the AMPS standard defined by Bell Labs and Motorola. This was the 1st generation of mobile wireless communication. In the early to mid-1990s 1G was superseded by newer 2G (second generation) cellular technologies such as GSM and cdmaOne. 3G started replacing 2G in the early 2000s. 2G and 3G networks provided data services which was not provided by its predecessor. High Speed data services was introduced by 4G and 4G is now being phased out by its successor 5G. Throughout this evolution of variation generations of wireless communication technologies, there has always been a trade off in terms of data speed, bandwidth, and coverage, cost and power consumption of these generation of communication systems. In the new world 5G brings to us the possibility of wireless world Wireless Wide Web (WWWW) with across the globe coverage and path breaking data transfer speed accompanied by very high quality voice and video calling. The birth of IoT has started a new race between corporations to develop smarter devices and sensors. Fast evolving mobile communication systems and IoT enabled smart devices are being used in creating E-Villages and Smart Villages which is accelerating the development of rural areas **[1-4].**

II. 1ST GENERATION

1st Generation mobile wireless communication supported only voice calls. It was based on AMPS (Advanced Mobile Phone System) standard defined by Bell Laboratories and Motorola. AMPS divides the entire geographical region into smaller sub-regions which are referred to as "cells". There is a particular frequency associated with each cell and neighboring cells never share the same set of frequencies. AMPS has small cell sizes which reduces power consumption and leads to the possibility of use of smaller and cheaper transmitters and handsets. Frequency Divided Multiple Access (FDMA) is used for the multiplexing of traffic in this system **[1-4].**

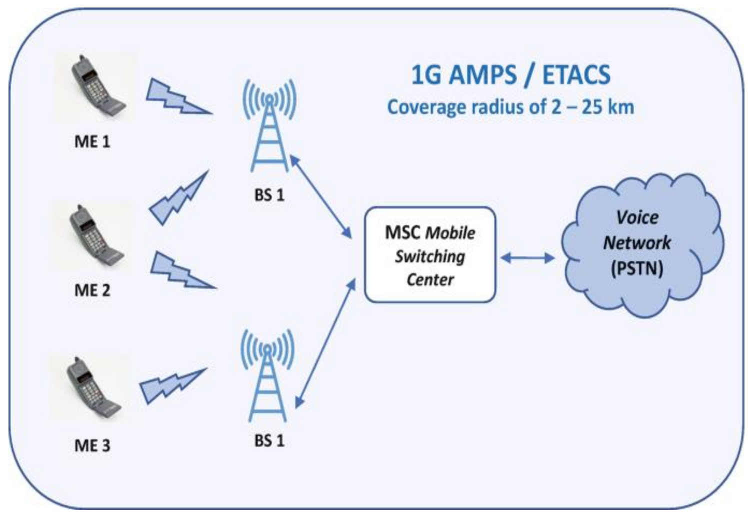

Figure 1: Overview of AMPS network Architecture [3]

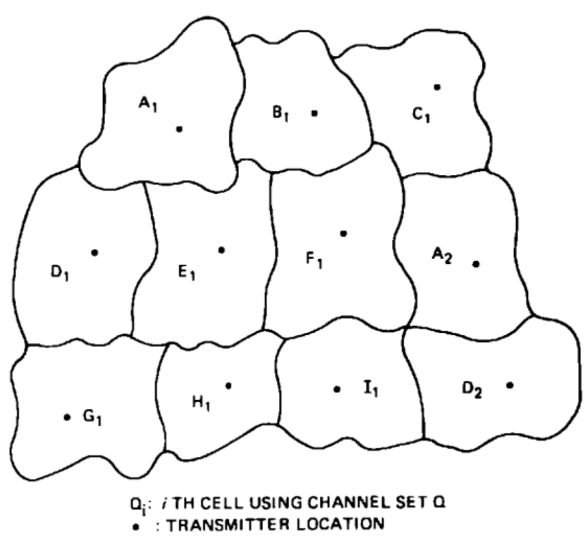

Figure 2: Cellular Nature of Mobile networks [8]

AMPS has following components:

1. Mobile Station : These are the handheld devices in a region which exchange information with the Base Stations in a region
2. Base Station (BS): These consist of a computer and a transmitter and receiver which are connected to an antenna for exchange of information with the mobile stations.
3. Mobile Switching Centre (MSC): This acts as a node in the network to which many base stations are connected. This is used for the purpose of Authentication, Registration and routing of calls to a mobile subscriber. MSC is connected to PSTN.
4. Public Switched Telephone Network: A public switched telephone network is a combination of telephone networks which interconnects various smaller networks **[4-6].**

This was purely Analog Cellular network.

III. 2ND GENERATION :

The advent of digital cellular networks was heralded by the Second Generation. It offered SMS and MMS capabilities and had a 64kbps data transfer rate. Digital modulation techniques like TDMA and CDMA were employed. The most extensively used 2G communication standard is GSM. Additionally, GSM was the first technology to offer global roaming. This made it possible for mobile users to utilize better-quality and more-capable mobile phone connections across a variety of nations **[1-2]**. A GSM Network has the following components:

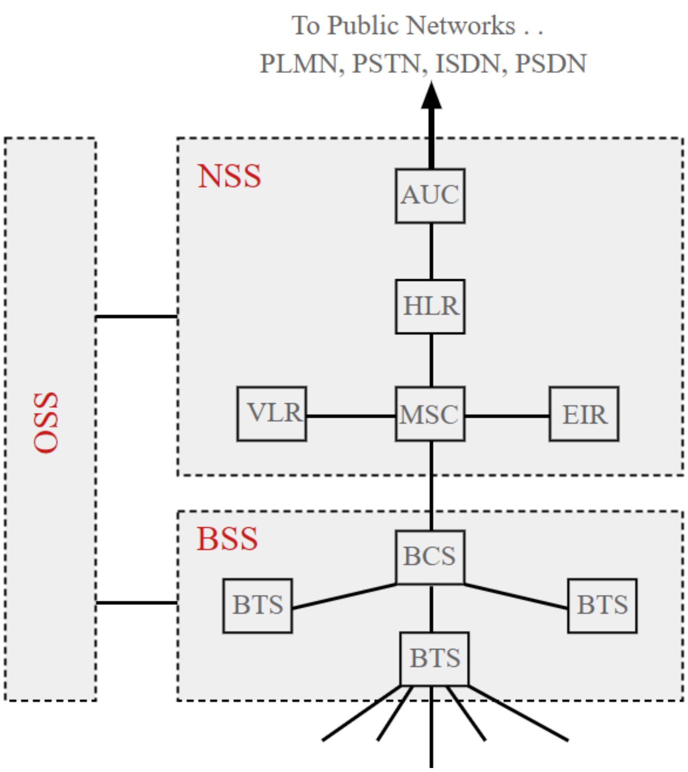

Figure 3: Flowchart of GSM Network [9]

1) BSS: The basic function of the base station subsystem is to facilitate communication with mobile devices connected to the network. Multiple users can access the system at once thanks to the BSS. The following are its sub parts:
   a) Base Transceiver Station is the sub part of a GSM network which consists of both radio transmitters and receivers. It also consists of antenna through which it communicates with the mobile stations in an area. Um interface is the name given to the interface between the Mobile Station and Base Transceiver Station.
   b) Base Station Controller controls a group of Base Transceiver Stations and forms the next stage back into the GSM network. It manages the radio resources and controls the handover within a group of BTSs and also allocates channels.
2) The handsets used by the users are called the Mobile stations. These are called mobile because they are not stationery and are always moving.
3) Network Switching Subsystem: A mobile network's core control and interface are provided by the Network Switching Subsystem, which is effectively a data network with numerous entities. The major elements within this include:
   a) MSC: The Mobile Switching centre in this generation is very similar to the ones used in previous generations. It is the link between the BSS and NSS. It provides features which include registration of users, authentication of users, tracking call location and handovers between different Mobile Switching Centres. It also facilitates the routing of calls to the correct Base Station for the Mobile Station (User).
   b) HLR: The home location register stores the last known location of each user on the network. This knowledge helps in accurate routing of calls.
   c) EIR: This stores the IMEI number of each user connected to the network. If an equipment is allowed on the network, then it has its IMEI number stored in the EIR of the GSM network.
   d) AuC: The Authentication Centre is used for security reasons. It stores a unique key which is also simultaneously stored on the subscriber's SIM card **[9].**

IV. 3RD GENERATION:

With the arrival of 3rd generation mobile wireless communication technology, we entered into the era of Megabit/s speeds. The maximum speed of 3G systems was 2Mbps. This allowed for use of internet on mobile phones. With change from 2G to 3G, the focus of development shifted from voice call quality to data transfer speeds. Rather it is made of many standards which all work together. The standards for 3G although compatible with each other are known by different names in different regions. WCDMA is the air-interface technology for UMTS. The first commercial

3G network was launched by NTT Docomo in Japan, in 2001 **[1-2].**

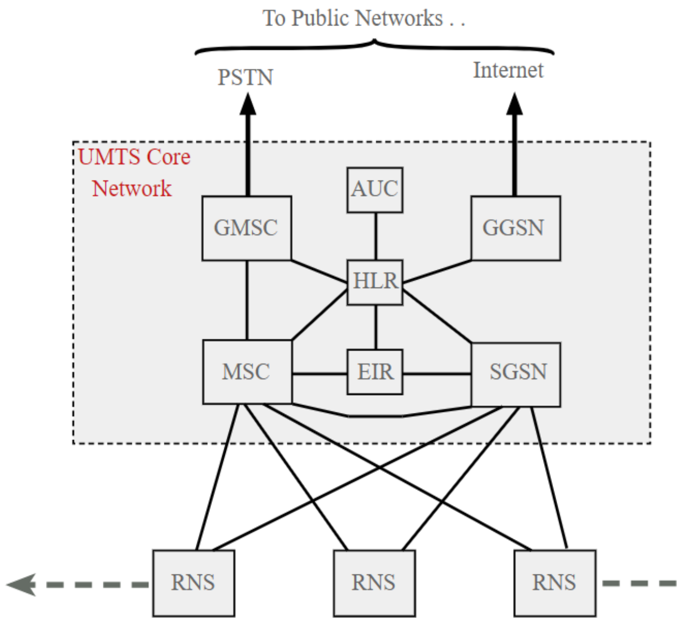

Figure 4: UMTS Architecture Block diagram [12]

UMTS Architecture has the following components:

1. UMTS Core Network: This consists of two types of elements:
   a. **Circuit Switched elements**: The circuit switched elements assist in providing calling and SMS features. The various circuit switched elements are :
      i. **MSC:** The Mobile Switching Centre has a similar function to the MSCs of the previous generations. It carries data in a circuit switched manner.
      ii. **GMSC:** This connects the UMTS core network to the Public Switched Telephone network.
   b. **Packet Switched Elements**: These elements enable the connection of the User Equipment to the Internet. It transfers data in the form of packets and not in the form of switching. The various elements present in this part are :
      i. ***SGSN (Serving GPRS Support Node):*** The SGSN is used for managing the mobility of users between different cells. It also handles the sessions of the subscribers on the network. It also helps to measure the amount of data each user has used and thus helps in billing.
      ii. **Gateway GPRS Support Node (GGSN):** This is the part of the UMTS architecture which connects the UMTS core network to the Internet.
   c. **Home Location Register (HLR):** This has the same function as that of the HLRs used in previous generations.
   d. **Equipment Identity Register (EIR):** It is a database which stores information about each User Equipment in a region. It stores this information in the form of IMEI number.
   e. **Authentication Centre (AuC):** It contains secret keys associated with each user which is also stored in the SIM card of each User Equipment.
2. **User Equipment:** User equipment is the handset or mobile phone the user uses to interact with the network. It consists of Radio Frequency Circuitry to send and receive signals in the form of electromagnetic radiation. USIM known as Universal Subscriber Identity Module contains the International Mobile Subscriber Identity number (IMSI) as well as the Mobile Station International ISDN Number (MSISDN). It also has internal circuitry for processing of baseband signals. All of this electronic circuitry is powered by a battery.
3. **Radio Network Subsystem (RNS):** Also known as the UMTS Radio Access network and the UTRAN this is the section of the UMTS architecture which is the interface between the User Equipment and the Core Network. It manages the wireless communication **[10-11].**

V. 4TH GENERATION

The world's initial fully IP (Internet Protocol) network system was 4G. Its primary objective was to deliver fast data speeds and top-notch voice call quality using Voice over LTE (VoLTE) technology. It can achieve speeds ranging from 100 Mbps to 1 Gbps. By combining various present and upcoming network technologies, 4G offers mobility and uninterrupted roaming across different technologies. The 3GPP has published the LTE standard as an expansion of the UMTS technology (which is based on the 3GPP standard) and the 1xEV-DO technology (which is based on the 3GPP2 standard). LTE network is custom made for high speed internet access and can provide speed of 300 Mbps in uplink **[1-2]**.

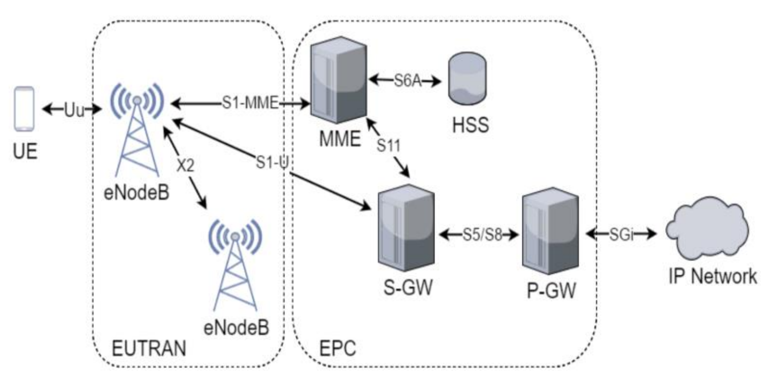

Figure 5: Overview of LTE Architecture [14]

The LTE architecture comprises several key components, including:

1. **User Equipment (UE):** The UE refers to the mobile device used to access the LTE network. The UE consists of a mobile terminal, a subscriber identity module (SIM), and a Universal Integrated Circuit Card (UICC).

2. **Evolved Node B (eNodeB)**: The eNodeB is a base station that connects to the UE and provides radio access to the LTE network. It is responsible for handling radio resource management, radio bearer control, and encryption/decryption of user data.

3. **Mobility Management Entity (MME)**: The MME is responsible for the management of mobility-related functions, such as authentication, security, and tracking of UEs. It also manages the distribution of paging messages to the eNodeBs.

4. **Serving Gateway (SGW)**: The SGW provides mobility anchoring for UEs, which enables seamless handovers between eNodeBs. It also manages the user data flow between the eNodeBs and the PDN Gateway (PGW).

5. **Packet Data Network (PDN) Gateway (PGW)**: The PGW is responsible for connecting the LTE network to external networks, such as the internet or corporate networks. It also manages the IP address allocation and the QoS (Quality of Service) of user data.

6. **HSS (Home Subscriber Sever)**: The HSS (Home Subscriber Server) is a crucial database that stores comprehensive information related to a particular subscriber, serving as a centralized location for network nodes. This data includes user credentials, security, location, and subscription details. As an essential component of both LTE and IMS (IP Multimedia Subsystem), the HSS is responsible for managing and storing all user-related information in a central location.

The LTE architecture is designed to provide high-speed data services to mobile users while maintaining compatibility with existing networks. The use of IP-based protocols enables seamless integration with other networks, and the separation of control and user planes enables efficient network management. Overall, the LTE architecture provides a scalable, flexible, and efficient platform for wireless communication **[13-14].**

VI. 5TH GENERATION

5G is the currently most advanced mobile wireless communication system which has already started to overtake 4G in terms of user base. Just like 4G, 5G is also based entirely on IP for both calling and data services. 5G is based on IPv6.5. The 5G Core Network utilizes a standardized API to enable the invocation of services. Service Based Architecture is the name given to the interconnected network of services within the 5G Core. Network Functions (NFs) make up this architecture and provide authorized NFs with services. These NFs are software implementations that run on commercial off-the-shelf hardware, often in the cloud. Each NF can provide multiple services. This makes 5G network service oriented, Modular, Reusable and self-contained.

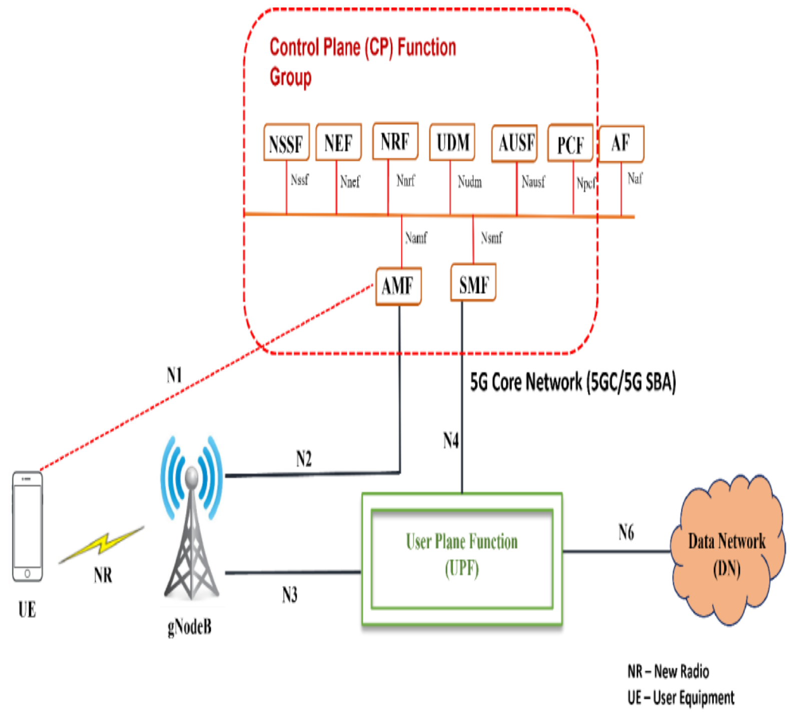

Figure 6:5G Service Based Architecture [15]

The functions of the major elements of the 5G Service Based Architecture (SBA) are:

1. **AMF (Accessibility and Mobility Function):** As the name suggests this control plane function present in the SBA handles access and mobility. It also manages User Equipment registration.
2. **SMF (Session Management Function)**: This control plane function manages the user sessions. It handles establishment, modification and release of sessions. SMF communicated indirectly with the User Equipment via the AMF which relays session relevant messages between the UE and SMF.
3. **UPF (User Plane Function):** UPF handles the process of packet forwarding and routing. It also ensures Quality of Service implementation by inspecting the data packets.
4. **NSSF (Network Slice Selection function):** Used to select the optimal network slice relevant to the service that has been requested by the User Equipment.
5. **NRF (Network Repository Function)**: As the name says it is a repository or in index to which other Network functions consult so they can gain

information about the other elements present in the core network.

6. **NEF (Network Exposure Function):** This responsibility of this function is to securely expose the capabilities of the network and events to the Application Function (AF). This is natively built into the 5G network. This provides a means for the AF to securely provide information
7. **UDM (Unified Data Management):** This function stores the information about subscriber which helps in identification, access authorization and billing.
8. **AUSF (Authentication Server Function):** This is similar to the AuC present in the previous generations. It contains authentication keys to authenticate the User Equipments.
9. **PCF (Policy Control Function):** This ensures maintenance of network policies which are necessary for required network behavior.
10. **AF (Application Function):** The Application Function (AF) is an influential but frequently underestimated Network Function (NF) in 4G and 5G networks. Its significance lies in managing traffic and ensuring Quality of Service (QoS) by communicating with policy elements. Its primary function is to make the Application Layer available for communication with 5G NFs and network resources.
11. **gNodeB:** This has a similar function to that of the base station present in the earlier versions of cellular network. gNodeB handles the wireless communication with the User Equipments in its coverage area known as cell. It does it either using a Radio Communication Tower or using a virtual entity like a Software Defined Radio (SDR).
12. **DN (Data Network):** This is the external network namely the Internet **[15-18].**

The rise of 5G network shall also greatly develop our advancements in the field of IoT (Internet of Things). IoT requires instantaneous transfer of data from one device to another to achieve the highest degree of sensor fusion possible. This is helped by the extremely low latency and high speed of 5G networks. Also 5G has a higher device density when compared to 4G and thus it can support more number of IoT devices in an area when compared to 4G. 5G also has the potential of improving the battery life of IOT devices and will thus save energy and will also increase the up time of a device by conserving battery life **[20].**

Although 5G is the most advanced wireless networking system which is available in the public domain it still has some shortcomings. The high frequency radio waves used in 5G communication may interfere with other communication systems and there have been cases reported where 5G communication has cause interference to the instruments present on aircrafts. The frequencies used by 5G communication are very close to the frequencies at which the radio altimeters present on Aircrafts operate and here is a slight chance that 5G may disrupt the normal functioning of Air travel. Another disadvantage is that old devices often may not support and a change of the mobile phone may be required to access the 5G network. 5G right now has spotty coverage across the world. Another cons of this advanced communication system is the high developing cost of the infrastructure needed to provide 5G access. Due to the cost of infrastructure the cost of using 5G may be higher than 4G and may prevent the users from switching to the 5G network **[19].**

VII. 6TH (5G+) GENERATION

6G aims to integrate the 5G networking with satellite communication to provide worldwide coverage of high speed internet and high quality voice calling facility. The focus of 5G has been ultra fast data speed but the focus of 6G will be both coverage and speed. 6G will enable seamless connection between devices and will enable new use cases which were previously not possible.

Figure 7: 6G holds great potential for the future generations of Wireless communication. [20]

6G will use Terahertz wave for communication which allows for a much higher bandwidth. It will also provide an extremely small latency and lightning fast data transfer rate. The larger bandwidth will also allow more devices to interact with the network at one time increasing the large scale concurrent access of the network resources. The ultra-low latency will allow for unmatched real time communication of the highest quality. The outcomes of such a network will be:

1. 6G network will provide blazing-fast internet access with a maximum speed of upto 10-11 Gbps
2. This will help us build Smart Homes, Cities and Villages and will bring people living in distant areas closer to the mainland civilization.
3. 6G will bring a revolution in space technology, home automation and defense industry as it brings into the picture the possibility of real time sensor data fusion.
4. This may make it possible to create Mind to machine interface and Mind to Mind interface. This will allow us to revolutionize prosthetics and will help the disabled people to return back to their normal lives. Mind to mind interface may facilitate communication without use of speech using only thoughts.

Although 6G is still under early development phases, it holds great potential **[1-3].**

VIII. IMPLEMENTATION OF 5G AND 5G+ TECHNOLOGIES IN INTERNET OF THINGS (IOT)

Internet of Things is an emerging technology which involves communication between different machines, devices and sensors through the internet wherein, each component of the IoT network shares some information to some common cloud service where information from various components can be accessed by every other device. The devices then use this information to take some action. For e.g. a temperature sensor may upload the temperature constantly to a cloud based server. An AC reads the temperature form the temperature sensor and turns itself ON when the temperature increases some threshold. This way a room may be cooled without the hassle of manually turning on the AC and this also saves power as the AC doesn’t turn on when it is not needed. One can easily thus observe the machine to machine communication which takes place in this process. This machine to machine communication is the unique feature of IoT. In the above example the AC can be called a smart device as it turns ON and OFF automatically on the basis of the room’s temperature. Such IoT enabled smart devices can be used to automate many processes which require some sort of manual effort. This automation can be of great assistance in industries as well as in our homes.

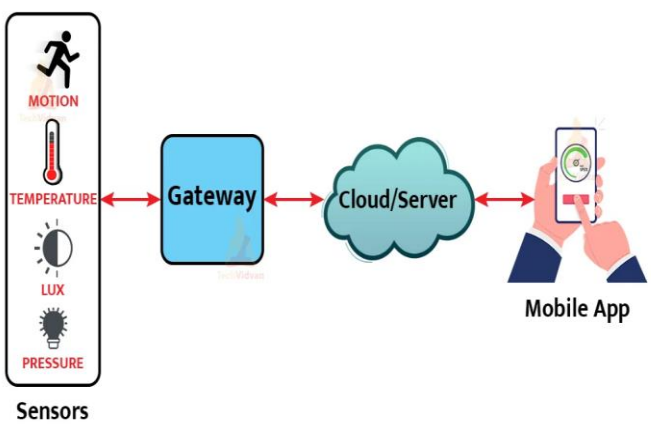

Figure 8: Flowchart describing the working of IoT. [22]

IoT doesn’t require the exchange of a humungous amount of data. What it requires is very low latency and a wide area of coverage. Narrow Band 5G (NB-5G) is the type of 5G network used for IoT applications which don’t require high data transfer rates. Narrow band 5G provides a comparatively low data rate but allows more number of devices to connect at a time. This also consumes less battery and thus provides longer battery life. The main advantage of using 5G in IoT applications over the previous 4G technology is that the latency of 5G is of the order of 10 milliseconds. On the other hand the latency of 4G network is generally between 50 milliseconds to 150 milliseconds. This tenfold reduction in the latency from 4G to 5G opens up a whole lot of opportunities in the field of IoT and Automation. This way 5G and IoT can together accelerate a new wave of IoT applications. The low latency means that Real-Time tasks can be executed in a better manner when compared to previous generations of mobile communication **[20].** Some examples of real time tasks which can be made easier through use of 5G and IoT are:

1. **Remote Inspection and Maintenance**: At times in the industry, technicians need to perform the maintenance of machinery which is difficult to access. Machinery may be distributed over very huge areas. For instance, transformers are distributed over a large area in a power distribution grid. It is logistically impractical to visit every transformer and perform inspection. IoT and 5G together open up the possibility of transmitting camera footage or real-time sensor data from such distributed machinery to the cloud for inspection using AI based algorithms. This eliminates the requirement of visual inspection to be performed by technicians. Thus less time of technicians is wasted and technicians need only to be present on the site when some sort of malfunction occurs and the Inspection process is automated. Similar strategy can be used for inspection of cracks, rust and corrosion in aging bridges, buildings and other civil infrastructure. This technology can also be extended for use in inspection of wiring and pipelines. Data collection can be through automated drone footage, sensor data and though video feed from a camera. Data fusion techniques can then be used for inspection and can be used to predict any sort of malfunction in any distributed system of machines.

2. **Management of resources of a facility**: 5G and IoT can together work to create a system which can be used for efficient management of the resources of a building or facility like malls, airports, stadiums etc. Electric appliances like Lights and Air Conditioning Units can be switched ON and OFF depending upon the occupancy, temperature and time of the day. This can help in better power management of the facility. Private facilities can ensure only authorized personnel can enter an area by using a system of IoT enabled biometric authentication system. This can eliminate the number of security personnel required in a facility reducing the operating cost of the facility. Many modern smart factories use a Private-5G network. A Private 5G network is an enterprise specific and industry specific 5G network designed and used exclusively by an enterprise for their operation specific requirements. This allows a high level of customization in terms of hardware and spectrum used by the network. Industries customize this private 5G network for use in Industrial IoT applications to manage the manufacturing process using sensor fusion and machine to machine communication which paves the way to Smart Manufacturing.

3. **Autonomous Driving Systems**: Autonomous Driving systems and Driving Assist systems can benefit from the rise of 5G. Autonomous Driving vehicles today are collect a vast amount of data each day. We can use low latency 5G network to transfer data from sensors of each car to the neighboring cars allowing for a bi-directional channel of communication where data is shared between each neighboring car in an area and this thus effectively increases how far any car in an area can see. This can be used to predict amount of traffic on a route by counting the number of active cars on the network. The data gathered from this large number of sensors can thus be used to warn drivers about traffic congestions, potholes, accidents and construction activities on a particular route. This can also help calculate the optimum route for reaching a destination. The data gathered will also help in increasing the safety of autonomous vehicles by increasing the effective range upto which a car can detect obstacles.

4. **Shipping and Logistics**: In the field of logistics, there is the requirement for real-time tracking of a large number of shipments and containers which can be achieved through the low latency of 5G networks. This shall increase the predictability and controllability of supply chain logistics.

5. **Agriculture**: Drone footage and Satellite imagery can be both streamed and uploaded to cloud at a very high speed due to the high speed of 5G networks. Cloud based AI algorithms can then provide insight on the extent of pest infestation of crops, the growth rate of crops and other important metrics related to agriculture. These metrics can be displayed on the Mobile phone of the farmer. Thus drone surveying, satellite imaging and IoT together with the high speed and low latency of 5G networks can facilitate better planning of agriculture leading to an agricultural produce which is both higher in quantity and quality leading to better profit for farmers **[20].**

All these processes can be scaled up using 5G+ technologies which incorporate the high speed of 5G communication and the huge coverage satellite communications. Working hand in hand, 5G, 5G+ and IoT aids in speeding up of tasks, automation and reduces labor and production costs which are all favorable outcomes of any new technology.

IX. IMPLEMENTATION OF 5G AND 5G+ TECHNOLOGIES IN E-VILLAGES

A village in India is an area with low Human Development index where the major occupation of people is agriculture. Converting a backward village into an E-Village can accelerate the development of a village and can improve the living conditions of the people residing in the village. An E-Village is a village which boasts of services like e-commerce, e-health and e-learning. The village is digitally connected to the outside world. Being digitally connected not only provides these services but connects the residents of the village to the outside world causing exposure to modern technology and intellectual development in the residents. A digital village must not only be limited to availability of web services but must also use the power of Wireless Communication and the Internet to implement smart technologies which utilize IoT in the village. 5G network due to its low latency and high speed and reliability is an excellent choice for implementation of smart technologies. The various smart technologies which can be employed in an e-village are:

1. **Smart Grievance Forum:** People residing in rural areas face a lot of hardships like improper roads and power cuts. These grievance forums can be used to file complaints with the local governing body regarding any hardships faced by the residents of an e-village. 5G network ensures reliable and fast connection and is thus suitable for this process. The grievance forum should automatically forward the grievance to the relevant department.

2. **Smart Natural Disaster Warning System:** Rural areas are often affected by cyclones and floods. Using a distributed array of IoT enabled sensors and through satellite imagery it is possible to collect data and predict a natural disaster like flood, thunderstorm, cloud burst, cyclone, wild fire, and tornado hours before it strikes a village. Sensors like wind speed sensor, water level sensor, rain gauge sensor and temperature sensor may be used for this purpose. Such a system when connected to a reliable 5G network can aid in quick evacuation and rescue operation saving millions of lives every year. A mobile application can be installed on every phone in the village which receives warnings regarding any impending calamity. It can also display the steps which need to be taken to stay safe during such a calamity. Also the GPS location of the mobile phones can be tracked in event of a disaster for easy rescue operations.

3. **E-Learning:** Often rural areas have improper facilities for schooling. E-Learning ensures that the children of a village receive world class education. This is possible through the lightning fast and reliable nature of 5G networks which can be used for the purpose of hassle free E-Learning. The education imparted must not be limited to theoretical subjects but should also include practical subjects like Financial Awareness and ICT. Also the education must be either free of cost or practically affordable as residents of a village may not be able to afford a paid subscription.

4. **Smart Agriculture:** A distributed array of cheap IoT enabled sensors may be scattered across the village. These sensors should monitor the moisture, nutrients and humus content present in the soil. The sensors can be connected to the internet using a narrow band 5G (NB-5G) network which can help

accommodate a large number of these sensors. NB-5G also consumes less battery life. This can help in creating a map of fertility of soil of the entire village and this can help the farmers make informed decisions on when to water or fertilize their crops. Drone Surveying and Satellite imagery may be used to inspect the overall growth rate and pest infestation of the crops. This can help in overall better planning of agriculture and will lead to a better produce.

5. **Smart Farmer Markets:** Mobile applications can be used to send information to the farmers regarding the prevailing prices of pulses, grains, vegetables etc. in the local farmer market. This again can be facilitated through 5G networks. This adds an extra layer of convenience to the life of the farmer.

6. **Smart healthcare:** 5G network can be used to provide telemedicine and teleconsultation services to residents of the village. Often the healthcare facilities of villages are not upto the marks and this can help bridge the gap before further development of the village in terms of healthcare facilities takes place. Delivery of medicines and medical equipment like sphygmomanometer, glucometer and medical syringes can take place through e-commerce. Smart healthcare should also provide the facility of quickly calling an ambulance in case of emergencies. IoT based medical equipment can be used to monitor the health of patient from far away and prescribe medicines.

X. CONCLUSION

Albert Einstien said “The measure of intelligence is the ability to change”. The field of mobile wireless communication has gone through a huge change and a positive one. It has made a quantum leap which has led to the state of the art technologies we are using in our daily lives. We have moved from the era of voice calls with grainy quality to the era of High definition video calls, 4K video streaming and real time multiplayer online gaming. Mobile phone was luxury in its early days and is now a necessity important to cope up with the hectic lives we are living now. The technologies being used today, 4G and 5G are extremely reliable and fast. But we humans are a sapient species which are always developing and are coming up with better networking systems like 5.5G and 6G communication which will bring the world together. The world aims to become completely wireless without compromising on any of the have-goods of wired networking. The birth of IoT has brought before us a 4^{th} wave of Industrial revolution marked by the age of machine to machine communication, smart manufacturing and smart devices and sensors. The rise of ultra high speed internet and IoT enabled smart sensors has paved the way for converting technologically backward villages into modern e-villages which will accelerate the development of villages. The world as we know it today has become a smaller place and people, cultures, countries, communities are coming closer.

XI. ACKNOWLEDGEMENT

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We also like to thank the academics, research assistants, and staff from the department of Electronics and Communication Engineering for their efforts. The study has been substantially enhanced by their participation, insightful comments, and support at different phases of the research effort.

XI. COMPARISON WITH IEEE PAPERS:

Author	Title	Evolution of mobile communication	1G Architecture	2G Architecture	3G Architecture	4G architecture	5G Architecture	IoT using 5G network and possible applications	E-Village(or Smart City) using IoT and 5G networking
Akhil Gupta (2015)	**A Survey of 5G Network: Architecture and Emerging Technologies**	✓	✓	✓	✓	✓	✓	✘	✘
Amitabha Ghosh (2019)	**5G Evolution: A View on 5G Cellular Technology Beyond 3GPP Release 15**	✘	✘	✘	✘	✘	✓	✓	✓
Kinza Shafique (2020)	**Internet of Things (IoT) for Next-Generation Smart Systems: A Review of Current Challenges, Future Trends and Prospects for Emerging 5G-IoT Scenarios**	✓	✘	✘	✘	✘	✓	✓	✓

Table 1: Comparing content of our paper with other famous IEEE papers on same or similar topics.

REFERENCES

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