

## **IOT AND 5G: THE INTERCONNECTION**

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### **ABSTRACT**

*Across the world, the invent of Internet of things is rapidly growing, increasing the interconnectedness between devices and people through the means of the internet. As the Internet of things ecosystem evolves through an increasing number of users, there is a wide range of requirements that needs to be met. The 5G network is expected to massively improve or expand IoT security, greatly increase speed, boost cellular operation with increased bandwidth while also resolving several network challenges faced in the previous generations of mobile networks.*

*Along this article, the advent of 5G which is proposed to be fully operational by 2020 would be discussed extensively and its interconnection with Internet of things would be explained as it would be the technology on which IoT would run.*

### **1. INTRODUCTION**

Research on the fifth generation (5G) network is becoming more and more intense and it said to improve the range of IoT applications. From a recent statistics released by International Data Corporation (IDC), 5G will drive 70% of companies across the world to spend \$1.2billion on connectivity solutions. New business would require IoT with better and much improved performance criteria such as security, trustworthiness, wireless coverage, ultra-low latency, mass connectivity but to mention a few for IoT devices. To match up with these requirements, the Long Term Evolution (LTE) and 5G technologies would provide/ introduce new connectivity interfaces for future IoT applications. The next generation of networks, 5G which is still at its early stage, would introduce new Radio Access technologies(RAT), well improved antenna (Smart antennas) and also make use of higher frequencies while also altering or re-architecting networks.

According to Gartner, by 2017, a total of 8.4 billion devices would be connected through machine to machine(M2M) connection and this number would increase to about 20.4billion in 2020. The 5G enabled IoT would help the connection of an enormous number of these IoT devices and would help meet market demands for wireless services which would in turn lead to rapid economic and social development [1-2]

## **1.1 INTERNET OF THINGS (IOT)**

The internet of things, otherwise known as IOT can best be described as a network of gadgets, appliances and other things made up of electronics or installed software interconnecting to exchange data. Each device or appliance is identifiable by its installed computer system but has the ability of functioning within the provided internet premises. IOT enables interaction between humans and appliances /devices by sensing or remotely controlling these devices resulting in improved efficiency, accuracy, reduced human efforts and maximum comfort. However, security concerns of IOT has been an area of research in recent times, aiming at making IOT even more accurate and efficient than it currently is.[1]

## **1.2 AREAS OF APPLICATION OF INTERNET OF THINGS**

The interaction of systems or devices with provided internet infrastructure and less regard for the location broadens its area of application even more and more to an infinite extent ranging from agriculture, health care etc. to manufacturing, and even smart home. A brief description of some of the areas of application are given below;

### **1.2.1 Agriculture**

Environmental conditions such as humidity, temperature, wind speed, soil nutrients, etc. are very vital in agriculture and most importantly in cropping than livestock. IOT innovates farming methods by integrating wireless sensors with mobile apps and cloud platforms to provide this environmental information to farmers with the sole purpose of collation, accurate decision making and implementation based on the provided information. The use of IOT in agriculture aids accurate utilization of agricultural recourses and also aids reduce risks [3].

### **1.2.2 Health care**

Large number of wearable devices, interconnected machines and cloud computing technologies are these days adopted to retrieve patient's data without any sort of interruption, constantly monitoring patients and instigating dispatching of medications when necessary. Of recent, some hospitals have put in place smart beds which recognize and indicate If or not it is occupied by a patient and also provides the appropriate pressure and support needed by the patient with aid from the patient's weight [3].

### **1.2.3 Transportation**

Electronic toll collection system is the most popular application of IOT in the area of transportation, where sensors are put in strategic locations to detect vehicle approach towards toll gates [3]. If

vehicles have been registered, which involves provision of the account details of the driver to be debited at every entrance into the toll gate, it permits entrance, but if not registered, it provides an avenue for cash payment from driver before granting entrance to the vehicle. Other aspects of transportation influenced by IOT are; smart traffic control, smart traffic, fleet management etc.

#### **1.2.4 Home Automation**

The influence of internet of things in our homes, most importantly our appliances with accurate interaction and maximum response is not news anymore as energy can now be conserved adequately due to the non-operation of appliances or devices in the absence of the inhabitants of that home by putting in place sensors and remote controlling these devices in whichever way is convenient for the inhabitants. In recent times, from any location, one could switch on and off any device or appliance in their homes without being present, providing convenience, comfort and flexibility of operation [3].

### **1.3. 5G; THE TECHNOLOGY ON WHICH IOT WOULD OPERATE ON.**

As indicated by Godfrey A. Akpakwu , The Internet of Things (IoT) is a promising innovation which has a tendency to alter and associate the global world by means of heterogeneous keen gadgets through consistent availability. The idea of the IoT has drawn the consideration of the research community with the ultimate objective of guaranteeing that wearables, sensors, smart apparatuses, clothes washers, tablets, advanced mobile phones, keen transportation framework, and so on., and different substances are associated with a typical interface with the capacity to speak with each other.

The test nonetheless, is the means by which the fifth generation (5G) mobile network will meet the differing prerequisites of the IoT. 5G mobile networks are imagined to guarantee that massive devices and new services, for example, enhanced Mobile Broadband (eMBB), massive Machine-Type Communications (mMTC), Critical Communications and Network Operations are effectively upheld. It is trusted that essential prerequisites, for example, high throughput, low latency as far as information conveyance, high versatility to empower huge number of gadgets, productive energy utilization system and the provision of ubiquitous connectivity for end-clients will be effectively bolstered utilizing the 5G mobile system for the IOT [7].

5G supported services matrix

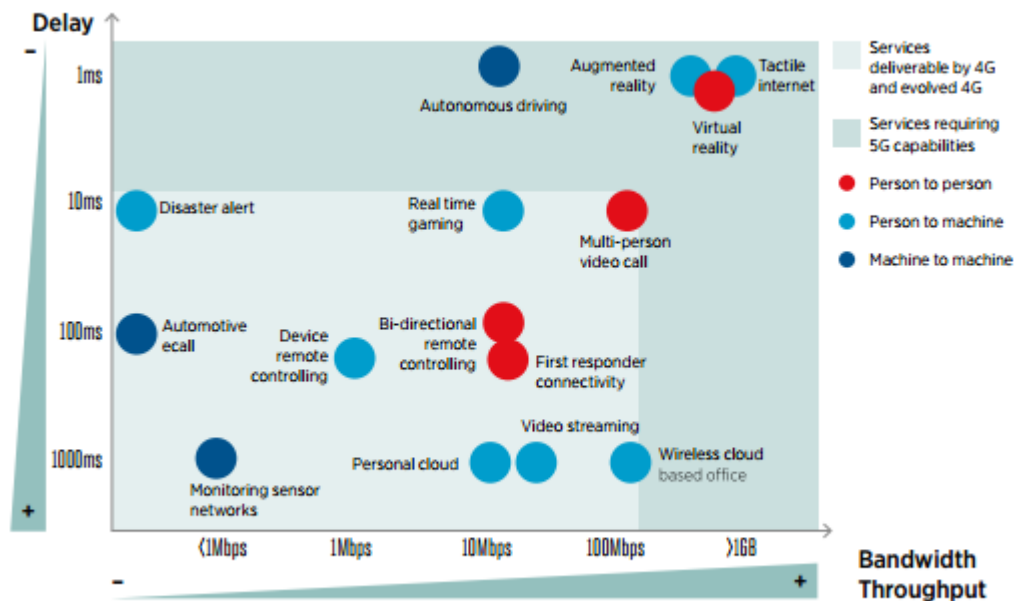


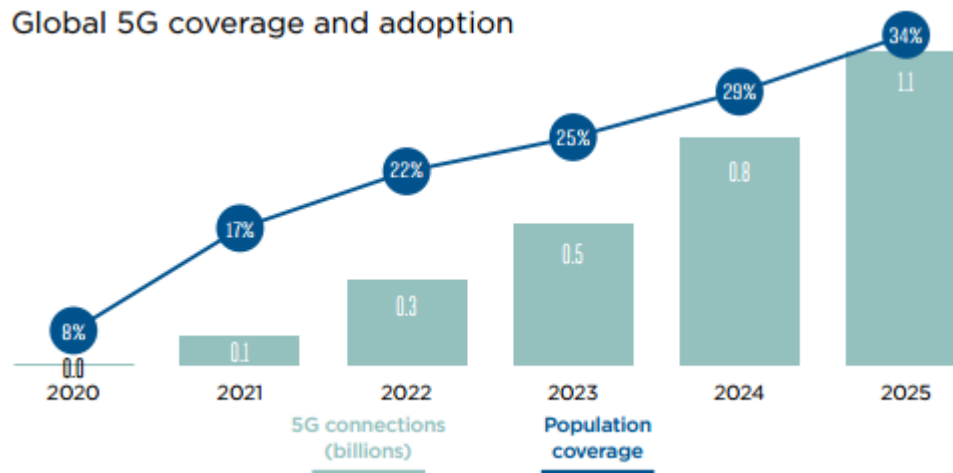
Fig 1- 5G supported services matrix

#### 1.4. 5G NEW RADIO ENHANCEMENTS FOR THE INTERNET OF THINGS

Research has demonstrated that the future 5G mobile systems need to provide for the massive organization of IoT with billions of connected smart articles and sensors that will be a worldwide representation of this present reality and to help the arrangement of mission basic IoT utilize cases, which will require constant responses and automation of dynamic procedures across over various field of tasks including vehicle-to-infrastructure (V2I), high speed motion, vehicle-to-vehicle (V2V), and process control system. In light of this, further upgrades are presently being presented in M2M and NB-IoT system as indicated in the current 3GPP Release-14 for cellular IoT, being the primary regulating stage for 5G standards. Right now, 3GPP standardization is working towards guaranteeing that further upgrades of KPIs are introduced into existing 4G systems with guarantee that the 5G mobile system is designed from scratch keeping in mind to oblige the developing span of the IoT utilize cases into the market, and limiting the cost of growing new networks [8].

The requirement of 5G mobile network will be massive to empower mission– basic services, and will be programming driven including SDWSN, NFV, and CR to help dynamic information control, give a centralized system and to empower the adaptation of new services necessities for enabling

Massive to Critical IoT use cases with productive scope and high limit focuses for lifetime MTC devices [9]. For future advancement of IoT, it is in this manner recommended to build up a context-aware congestion control (CACC) scheme for lightweight CoAP/UDP-based IoT network as a multi-target function that would bolster the exponential activity development pattern of the conceived 5G mobile networks for MTC application [10].

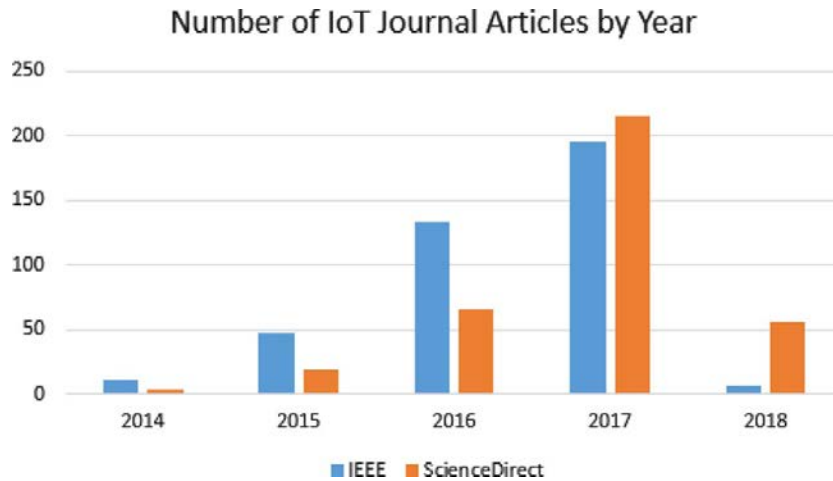


**Fig 2- Global 5G coverage and adoption [1]**

## **1.7 REVIEW OF RELATED WORKS**

### **1.4.1 CASE STUDY 1: IOT'S TINY STEPS TOWARDS 5G: TELCO'S PERSPECTIVE**

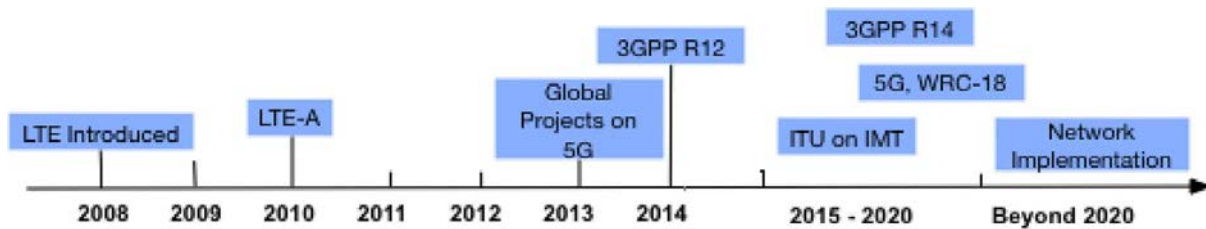
The several and well diversified applications of modern day Internet of Things (IoT) cannot be overemphasized as it has the ability to change a large percentage in the lives of several individuals, organisations and societies. A wide and well comprehensive knowledge of the performance and applications of IoT is essential for defining the technologies that can be used towards the implementation of the fifth generation (5G) networks, while avoiding high costs [11]. The 2G networks (old) covers 90% of the earth's population, 3G covers 65% of the earth's population, 4G and 4G Long term evolution (LTE) came into existence in 2012 being the fastest and most consistent network yet. The next generation 5G networks is supposed to solve the areas where the 4G network is lagging. In the past years, 5G-IoT has drawn a lot of attention in industries. Early 5G networks (more advanced than LTE) have been said to be available by 2020, while the full 5G would be available by 2025.



**Fig 3- A graph of the number of articles written on 5G from 2014-2018.**

Quite a number of researches carried out on IoT and 5G systems ranging from academics to the industry sector with an aim to suggest an avenue for the applications, theory and also, the implementation of 5G technologies in IoT setup. Over the years, works on 5G in relation to IoT have been done. CISCO, Verizon and Intel have together developed a wireless research project based on 5G to make known, a fresh set of ‘Neuroscience-based algorithms’ that does the function of adapting video quality to the way the human eye wants it, giving hints that structures wireless networks would possess built-in human intelligence. 5G can contribute to the future of IoT through the connection of billions of smart devices to interact and share data independently. Presently, a mixed domain of applications is making it tough for IoT to identify if the smart devices will be able to meet the application needs. IoT systems only make use of definite application domain e.g. BLF, Zigbee, Wi-Fi, cellular communication (3GPP, 4G&4G LTE).

The already existing 3GPP and LTE networks remain the most engaging technique for communication in the IOT connectivity, offering IoT systems with a wide area coverage, high security, simplicity in management, access to trusted spectrum. However, the already existing networks cannot support mobile telecommunications company (MTC) which is essential in IoT. This is where 5G comes into play, providing a solution to the issue. The 5G network can provide the fastest network data rate with relatively low expectancy and better coverage for MTC communication in relation to present 4G(LTE). The Machine-to-Machine (M2M) communication enables a large number of smart devices and sees a world that is well connected [11].

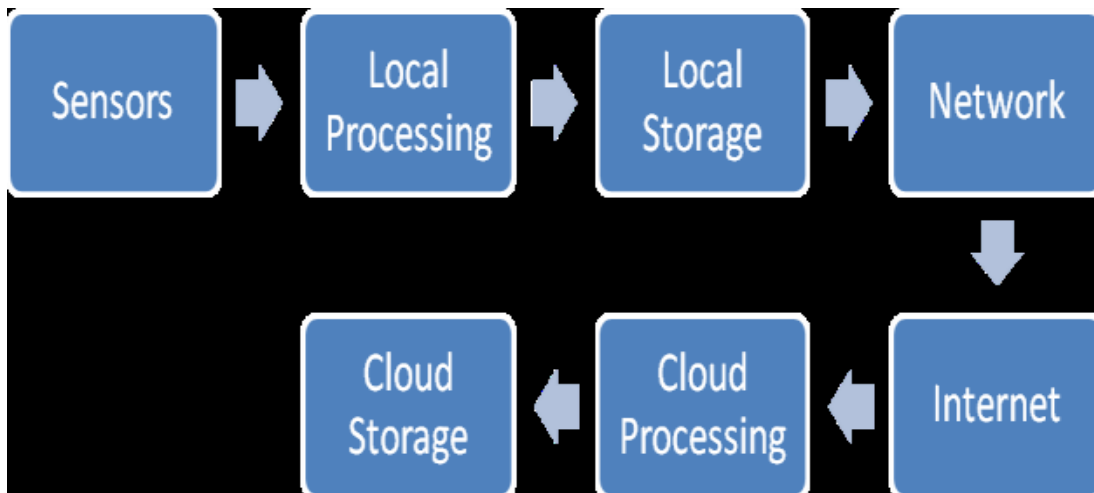


**Fig 4- The evolution of cellular networks from 3G to 5G enabled IoT.**

Wireless network function virtualisation (WNFV) does the enabling of virtualization of the whole network functions to make simpler, the deployment of 5G IoT in which NFV will perform certain functions to allow 5G-IoT concentrate on generic cloud servers providing all these in the most scalable and flexible form. The NFV has the ability to split physical network into multiple virtual networks where the devices can be reconfigured to create multiple networks. It would provide 5G-IoT applications with immediate processing ability to improve the speed, coverage, and capacity to meet the demands of applications. Network function virtualization will also enhance the feasibility Radio access network (RAN) [12].

### **1.4.2 CASE STUDY 2: FUTURE OF INTERNET OF THINGS (IOT) IN 5G WIRELESS NETWORKS**

The internet of things is a network of connected devices; electronics, mechanical, sensors etc. both hardware and software that are interconnected that allow them to speak to each other and exchange data without requiring human-to human or human-to-computer interaction.

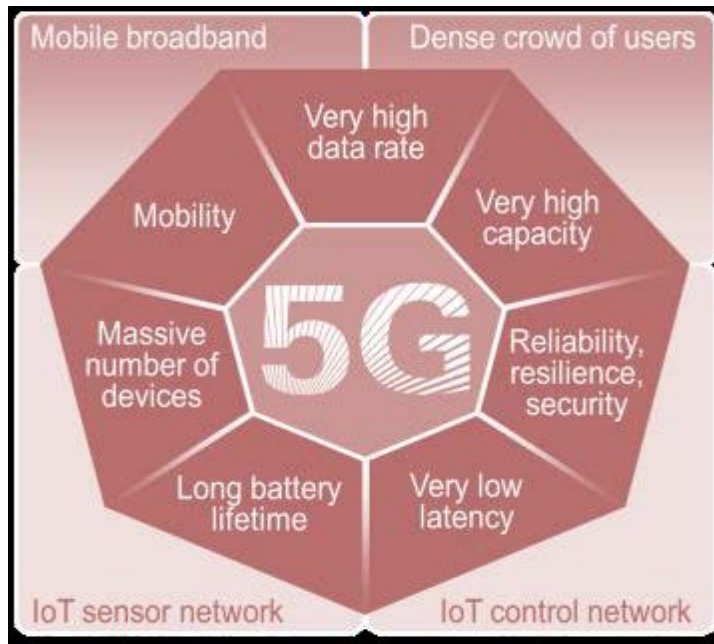


**Fig 5: Schematics of IoT [3]**

IoT cuts across different fields in life, like; Medical, Transportation, education, environmental monitoring, energy management etc.

Over time, a new generation of wireless communication has been introduced around every decade. From the time of introduction of 1G in 1982, this was succeeded by 2G, which commenced text messaging features in 1992. Thereafter, 3G networks appeared in 2001, which allowed phones to access the Internet. Thereafter, in 2012, 4G emerged, which added video streaming features. Now, 5G is being developed with gigabit speeds. The first 5G networks are likely to be unveiled in 2020 [13]

5th Generation wireless Network is the impending revolution of mobile technology.



**Fig 6- Features of 5G [1]**

5G's model is IP based architecture and is being designed for mobile as well as wireless networks. The advantages of 5G over the former wireless technologies are humungous; ultra-high speed ranging from 1 to 10 Gbps; Per unit area bandwidth will be 1000 times, more devices can connect, Global coverage, Usage of network energy will be reduced by 90%, Longer battery life and a whole lot more.

The emerging technology, 5G, would facilitate the expansion of the internet of things in lots of ways;

- Higher bandwidth: 5G would support 1000 times the traffic that is being handled by the existing networks. This also gives speed of the range of 10 Gbps [14].
- Smaller device packaging: 5G shall be operated at frequencies up to 80 GHz shrinking the size required for antennas up to 1-10mm [15].



- Millisecond latency: Latency is the amount of time needed to transmit one packet of data. 5G networks will provide latency less than 1 millisecond which is required for critical applications such as self-driving vehicles as well as surgeries aided by robot [13].
- High capacity networks: Networks with high effectiveness well as efficacy, connecting billions of physical objects at lightning speed will be the key feature of 5G technology.
- Forward compatibility: 5G technology would work with all the various types of devices to be connected in the future. Since newer devices would be added in the IoT network, this is one of the key requirements to support the growth of IoT.

### **1.4.3 CASE STUDY 3: THE ROLES OF 5G MOBILE BROADBAND IN THE DEVELOPMENT OF IOT, BIG DATA, CLOUD AND SDN**

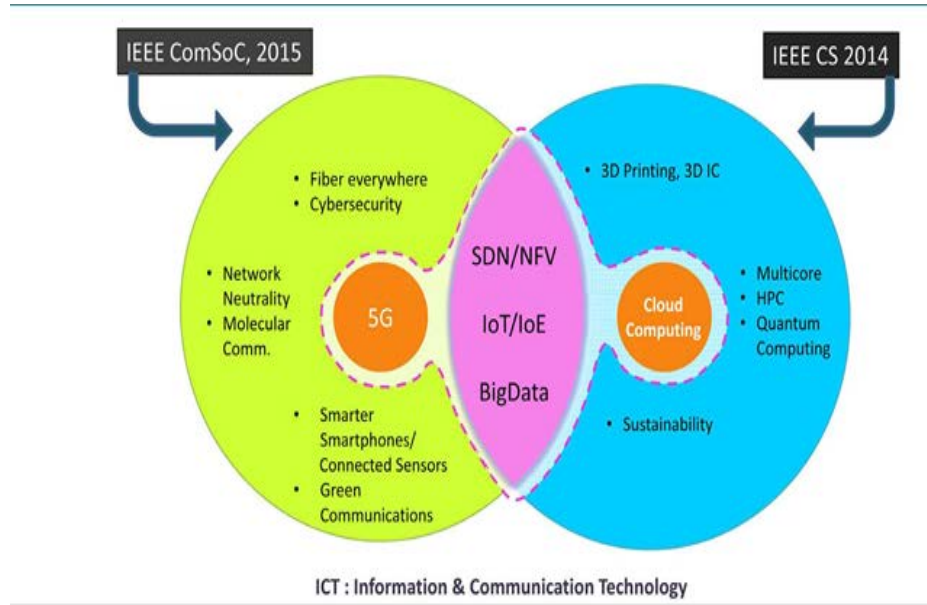
Bao-Shuh Paul Lin, Fuchun Joseph Lin and Li-Ping Tung in their paper “The Roles of 5G Mobile Broadband in the Development of IoT, Big Data, Cloud and SDN” wrote about the quick innovation advancement of 5G versatile broadband (5G), Internet of Things (IoT), Big Data Analytics (Big Data), Cloud Computing (Cloud) and Software Defined Networks (SDN) has made those advances in a steady progression and made solid relationship among each other.

The Roles of 5G, IoT, Big Data, Cloud, and SDN till 2020

Albeit so far, the 5G portable broadband prerequisites and standard details are not prepared yet, 5G innovation investigation and advancements are as of now began and somewhere in the range of 5G highlights are promptly accessible. By the Year 2020, the business 5G will be accessible and IoT applications will be conveyed wherever with portable broadband innovation. Additionally, the Big Data produced by IoT applications will turn into a standard and Cloud will be to a great extent used to figure, store and virtualize arrange capacities (NFV). Likewise, the basic system foundation will embrace SDN to diminish both capital cost (CAPEX) and operational cost (OPEX) [16].

#### **TECHNICAL RELATIONSHIPS AMONG IOT, BIG DATA, CLOUD, & SDN IN 5G ERA**

IoT is fit for producing Big Data with four Vs: volume, speed, assortment, and veracity. At that point, Cloud is acquired for Big Data stockpiling and preparing. At long last, SDN is utilized to give more proficient and adaptable systems for Cloud information transport [5].



**Fig 7- ICT major trends for 2015-2020**

#### **1.4.4 CASE STUDY 4: HOW 5G TECHNOLOGY ENABLES THE HEALTH INTERNET OF THINGS. DARRELL M. WEST**

According to Darrell West, the fifth generation (5G) technology promises a data transmission of 100 mega-bites per second, this means that there will be more data bandwidth and fewer delays due to build in computing intelligence that will handle data very efficiently. This new era of 5G is said to improve connectivity, cloud based storage as well as an array of connected devices and services. Virtual system architecture alongside an extensive computing capability will be able to open up a mobile Internet of Things (IoT). Darrell said that an advanced digital network(s) will be capable of bringing together a system that will connect billions of devices and sensors enabling advances in areas like education, agriculture, health care, transportation, education and many others [16].

In the paper, Darrell was able to show the difference and advantages of 5G from the previous generation of mobile connectivity (4G and 3G). He outlined four factors that distinguishes 5G connectivity from its predecessors. They include;

- Connected Devices
- Fast and intelligent Networks
- Back-end Services
- Extremely low latency

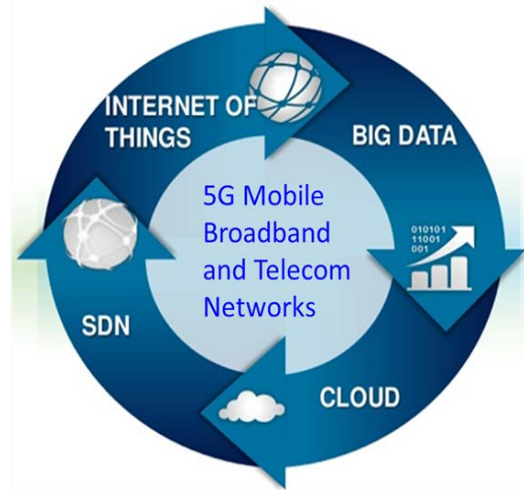
The qualities listed above will fully enable a connected and interactive world with varieties of applications. This will include the enhancement of mobile broadband, artificial intelligence advanced digital services and machine-to-machine communications.

His main focus was on Health Care facilities. He followed by discussing the applications of 5G in health sector and demonstrated how the development is said to enable new systems of care to deliver. He showed that connected medicine will help people to get quality care by the improvements in treatment and diagnostics and within a period of time businesses and consumers will develop an immense relationship with these digital devices. By doing so, they will in return obtain a high quality medical care in real time and at affordable prices. He suggested that rather than the use of separate and disparate computing equipment, the 5G world should be put in place, allowing us to enter an era where real-time health services becomes a norm instead of an exception; bringing patients closer to a science fiction (Sci-fi) concept of the digital integration than ever before.

Darrell went ahead to state the 5G impact on the medical access, quality and cost. Take for instance, there would be an ability to transmit medical information electronically to your doctor notwithstanding the distance and the doctor in return will be able to provide advice on diagnosis and treatment. Another instance, Health IoT has the advantage of reducing cost and saving money without compromising the health care facilities. Reason being that not all medical problem requires a visit to the doctor's office or hospital. Some routine visits can be attended to at a distance and this will offer patients a greater alternative to a conventional care. The last instance involves sensors and remote devices. Remote monitoring devices and sensors will help patients based in isolated areas to access top medical assistance. The use of a video conference facility (telemedicine) is encouraged to reduce the geographic divide and bringing a high quality health care to several under-served communities [16].

## **1.5. METHODOLOGY AND TECHNICAL REVIEW**

IoT (Internet of things) is used for producing Big Data with four V's i.e volume, velocity, variety and veracity. At that point, Cloud is acquired for Big Data storage and processing. At the final stage which is the SDN. SDN is utilized to give more proficient and adaptable systems between Cloud data transport. Out of Big Data, Cloud, and SDN, propelled advancements like machine learning investigation, Cloud RAN and software 5G are then developed.



**Fig 8- Relationship among 5G, IoT, Big Data, Cloud and SDN**

Based on Fig 1, 5G serves as a better gateway and transport network for IoT applications in a way data gotten from IoT is transmitted more efficiently and economically, IoT will then end up as one of the major source of Big Data by delivering expansive volume, quick speed, and numerous assortments of information.

Below are some technology's already put in place to effect this interconnection between 5G and IOT

- WIFI
- Bluetooth
- Zigbee
- LoraWAN
- Z-Wave.

## **1.6. CONCLUSION**

The Internet of Things is growing at a rapid rate and the applications are vast. There need to be a wireless network that can match the growth and application of IoT. The advantages and features of 5G are aptly suitable to support IoT in a big way. As IoT will help make our life easy by automating the physical objects, the emergence of 5G will help IoT take a big leap.

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