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A REVIEW OF EXISTING TELECOMMUNICATION NETWORK TECHNOLOGIES: CHALLENGES AND PROSPECTS FOR IMPROVED PERFORMANCE

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Abstract

Mobile Network Technologies have made the world a global digital village. Today we live in a fast-changing work environment that has its standards of communicating and connecting with people as fast as possible without the constraints of the demography of users. The continuous demand and requirements for wireless communication systems have led to the need for a better understanding of fundamental issues in communication theory and electromagnetic applications. This paper reviewed existing mobile network technologies ranging from 1G to 4G, examined the advantages, limitations, and effects of the various generations of technologies in communication using descriptive qualitative designobtained from secondary sources respectively. The paper suggested the introduction of the 5G New Radio(5G NR) Network Technology as the most efficient mobile network, with theoretical and diagrammatic solution scenarios. The paper also describes the 5G technology emphasizing its important features, technological design (architecture), advantages, challenges, and future scope.

Keywords

Network, Technologies, Telecommunication, 1G,4G, Data, Internet, Mobile

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Introduction

Research on Mobile communication technologies has a quantum jump since inception and there are growing competition and high needs[1]. Devices continue to shrink in size while increasing in processing power[2]. Consumers are demanding more advanced and functional applications. Therefore, there is an urgent need for sustainability in wireless communications. Major cellular wireless communication techniques have been proposed to meet these user expectations from analog to digital and then to hybrid IP based latest generation. The advent of 1G (AMPS based), 2G (CDMA based), 3G (GPRS based), 4G (based on 2G, 3G, Wi-Fi, WI-PAN or Bluetooth, and Wi-Max technologies) technologies has been phenomenal.

Radio technologies have evolved a leap and multi-directional evolution with the launch of the analog cellular systems in the 1980s. Thereafter, digital wireless communication systems are innovating consistently with the main objective which is to fulfill the growing need of individuals (1G, 4G, or now 5G)[3].

Figure 1: Generational Advancement of Mobile Technology[4]

Overview of Existing Mobile Network Technologies

According to Khana*et al*. 2014, the "G" in wireless networks refers to the "generation" of the basic wireless network technology. The first network in this G category was the First Generation Mobile Network (popularly known as 1G).

1G was introduced in the early 1980s,basically used for voice calling or voice communication and very little thought was given about exploring the other users of this network such as internet browsing but as the technology evolved 2G, 3G and finally 4G was introduced covering various other areas such as packet data transfer, video calling, ultra-fast broadband connections, etc.

Table 1: Evolution of Generations of Mobile Technologies

Generation	Year Launched	Mobile Technology/Switching Method	Data Bandwidth Offered(Upper Bound)	Services Offered
1G	The early 1980s	Analog Cellular/Circuit Switched	9.6 kps	Voice
2G	The early 1990s	Digital Cellular/Circuit Switched	14.4Kps	Voice (main), SMS
2.5g	1996	Digital Cellular/Circuit Switched-Packet Enabled	144Kbps	Voice and Packet Data Introduced
3G	2000	Digital Cellular/Circuit Switched Voice, (Later VOIP) and Packet-Switched Data	Up to 14Mbps	Packet Data on high –speed, voice, IMS-Enabled multimedia applications
4G	2012	Digital Cellular/Packet Data enable Packet-based Voice	20 to 1000 Mbps	Mobile Broadband, Mobile TV, VoD, Location-Based services, High-Speed Data and Security

5G	2019	Enhanced Mobile Broadband(eMBB) Ultra-reliable Latency Communication(URLCC) Massive Machine Type Communication(mMTC)	10Gbps	Mobile Broadband and Connected things

First Generation Mobile Networks (1G)

1G was the first commercially automated cellular network launched by Nippon Telegraph and Telephone(NTT) in Japan,1978[5].1G networks comprises of NMT and TACs in 1980 across Europe. This started basically in the 1980s.Advanced Mobile Telephony System(AMPS) was launched into operation on October 13,1983, by Illinois Bell after series of Researches in Bell Labs in New Jersey[6] with 40MHz bandwidth. First Generation mobile phone networks were the earliest cellular systems to develop, and they relied on a network of distributed transceivers to communicate with mobile phones. Devices were strictly analog, used for voice calls only, no data consideration, no built-in modems, and their signals were transmitted by the method of frequency modulation. These systems typically allocated one 25 MHz frequency band for the signals to be sent from the cell base station to the handset, and a second different 25 MHz band for signals being returned from the handset to the base station. This Advanced Mobile Phone System (AMPS) was a frequency-modulated analog mobile radio system using Frequency Division Multiple Access (FDMA) with a narrow band of 30KHz channels occupying the 824MHz – 894MHz frequency band, frequency deviation of ±12KHz, and 100% modulation[7]. There are such limitations in 1G mobile communications. First of all, it has no data service that can convert the voice into digital numbers consequently leads to no data security. Secondly, the global roaming service was not available. Thirdly, it contains an analog system in such a way that only voice is carried by these systems. The inevitable problem was its inability to interoperate between countries[5, 7]. In the matter of fact, the main problem that was held in the 1G is that there was only one channel that carries the data from one caller (source) to another (destination). More clearly, the available radio spectrum was not efficient for the space of channels. In other words, the first caller (source) will have to wait for a response from the other caller once the voice is received. This means poor call service quality- that the two callers are not able to hear each other simultaneously since the number of calls was limited by this effect. (Basudeo; Jasmine, 2012).

Second Generation Networks 2G

Second Generation mobile telephone networks were the logical next stage in the development of wireless systems after 1G which introduced a mobile phone system towards the end of 1980. 2G comprised of GSM,CDMA,D-AMPS. Follow the need to improve call service quality,T there are needs for multiple access technology,traditional speech service,lower bit rate of data services which led to the introduction of Time Division Multiple Access(TDMA),Code Division Multiple Access(CDMA) technology which improved the quality of dataservices and give space for data roaming services. The demands placed on the networks, particularly in the densely populated areas within cities, meant that increasingly sophisticated methods had to be employed to handle a large number of calls, and so avoid the risks of interference and dropped calls at handoffs. Although many of the principle involved in a 1G system also apply to 2G - they both use the same cell structure - there are also differences in the way that the signals are handled, and the 1G network isnot capable of providing the more advanced features of the 2G systems, such as caller identity and text messaging. 2.5G: In term "2.5G" usually describes a 2G cellular system combined with General Packet Radio Services (GPRS), or other services not generally found in 2G or 1G networks. A 2.5G system may make use of 2G system infrastructure, but it implements a packet-switched network domain in addition to a circuit-switched domain. It can support data rates up to 144kbps.GPRS, EDGE, & CDMA 2000 were the focal 2.5G technologies. This does not necessarily give 2.5G an advantage over 2G in terms of network speed, because bundling of timeslots is also used for circuit-switched data services (HSCSD). (Basudeo, Jasmine, 2012)

Third Generation Networks 3G

Third Generation mobile telephone networks are the latest stage in the development of wireless communications technology. Significant features of 3G systems are that they support much higher data transmission rates and offer increased capacity, which makes them suitable for high-speed data applications as well as for the traditional voice calls. In essence, 3G systems are designed to process data, and since voice signals are converted to digital data, these results in speech being dealt with in much the same way as any other form of data. Third Generation systems use packet-switching technology, which is more efficient and faster than the traditional circuit-switched systems, they do require a different infrastructure[8]. The benefits of higher data rates and greater bandwidth mean that 3G mobile phones can offer subscribers a wide range of data services, such as mobile Internet access and multimedia applications. Compared to earlier mobile phones a 3G handset provides many new features, and the possibilities for new services are almost limitless, including many popular applications such as TV streaming, multimedia, videoconferencing, Web browsing, e-mail, paging, fax, and navigational maps. 3G technologies make use of TDMA and CDMA[9].3G (Third Generation Technology) technologies make use of value-added services like mobile television, GPS (Global Positioning System) and video conferencing. The basic feature of 3G Technology is fast data transfer rates. 3G technology is much flexible because it can support five(5) major radio technologies. These radio technologies operate under CDMA, TDMA, and FDMA.CDMA holds for IMT-DS (direct spread),

IMT-MC (multi-carrier). TDMA accounts for IMTTC (time code), IMT-SC (single carrier). FDMA has only one radio interface known as IMT-FC or frequency code[10]. Third-generation technology is affordable due to the agreement of the industry. This agreement took place to increase its adoption by the users. 3G system is compatible to work with the 2G technologies. The 3G aim is to allow for more coverage and growth with minimum investment. There are many 3G technologies as W-CDMA, GSM EDGE, UMTS, DECT, WiMax and CDMA 2000[11].

Fourth Generation Network 4G

A fourth-generation (4G) network is the alternate name foran IP-based mobile system that provides access through a collection of radio interfaces. A 4G network promises seamless roaming/handover and best-connected service, combining multiple radio access interfaces into a single network that subscribers may use. With this feature, users will have access to different services, increased coverage, the convenience of a single device, one bill with reduced total access cost, and more reliable wireless access even with the failure or loss of one or more networks. At the moment, 4G is simply an initiative by R&D labs to move beyond the limitations and deal with the problems of 3G (which is having trouble meeting its promised performance and throughput). At the most general level, the 4G architecture will include three basic areas of connectivity: Personal Area Networking (such as Bluetooth), local high-speed access points on the network including wireless LAN technologies and cellular connectivity. 4G calls for a wide range of mobile devices that support global roaming. Each device will be able to interact with Internet-based information that will be modified on the fly for the network being used by the device at that moment. In short, the roots of 4G networks lie in the idea of pervasive computing. 4G is being developed to accommodate the QoS and rate requirements set by forthcoming applications like wireless broadband access, Multimedia Messaging Service (MMS), video chat, mobile TV, HDTV content, Digital Video Broadcasting (DVB), minimal services like voice and data, and other services that utilize bandwidth. The definition of 4G is to provide adequate RF coverage, more bits/Hz and to interconnect all wireless heterogeneous networks to provide seamless, consistent telecom experience to the user. Mobile networks have been designed up to this point for circuit-switched voice. Wireless networks were designed in a hierarchal fashion to aggregate, authenticate, manage and direct calls. (Basudeo, Jasmine, 2012).

Fifth Generation Network (5G)

5G wireless access technology is known as New Radio(NR). 5G is an initiative of the 3rd Generation Partnership Project(3GPP)[12, 13]. 5G network is the next generation of mobile internet connectivity, with faster speeds, more reliable connections on smartphones and mainly for the internet of things devices otherwise called 'connected things'. It was first launched by Verison in Chicago in April 2019 followed by Vodafone in the United Kingdom in July 2019. It uses enhanced Mobile Broadband(eMBB), Ultra-reliable low latency communication(URLCC), massive machine type communication(MMTC), thereby conforming to the International Mobile Telecommunication for 2020(IMT-2020)[14].Its key features are Ultra-lean transmission, support for low latency,

advanced antenna technologies, spectrum flexibility using operation in high frequency, working between high and low-frequency bands, dynamic time division duplex(TDD)[15].It uses the synchronization signals(SS),the physical Broadcast channel(PBCN), physical random access channel(PRACH), Physical uplink shared channel(PUSCH), physical downlink control channel(PDCCH), Physical uplink control channel(PUCCH) [16].

Limitations of Various Network Technologies: 1G, 2G, 3G & 4G

Singh and Jasmine 2012 carried out a well-researched study on Wireless Communications and state that Wireless mobile communication networks have experienced four generations of change. First Generation (1G) mobile phone networks were the earliest cellular systems to develop, and they relied on a network of distributed transceivers to communicate with mobile phones. Second Generation (2G) mobile telephone networks were the logical next stage in the development of wireless systems after 1G, and they introduced the mobile phone system that used purely digital technology. Third Generation (3G) mobile telephone networks are the latest stage in the development of wireless communications technology. Significant features of 3G systems are that they support much higher data transmission rates and offer increased capacity, which makes them suitable for high-speed data applications as well as for the traditional voice calls. Fourth Generation (4G) is known as beyond 3G, stands as an acronym for Fourth-Generation Communications System. It is used to describe the next step in wireless communications. A 4G system will be able to provide a comprehensive IP solution where voice, data and streamed multimedia can be given to users on an anytime, anywhere" basis, and at higher data rates than previous generations (Singh, Jasmine 2012).

Evaluations of 5G Mobile Network Technologies

Several studies on salient features of the 5G have proven that 5th Generation Mobile Network or simply 5G is the revolution of mobile technology. The features and its usability are much beyond the expectation of a normal human being. With its ultra-high-speed and low latency communication, it is potential enough to change the meaning of cell phone usability.

Figure 2 below indicates a huge array of innovative features of 5G technology; it is possible to use broadband internet connection. Other significant features that fascinate people are more gaming options, wider multimedia options, connectivity everywhere, zero latency, faster response time, and high-quality sound and HD video can also be transferred to other cell phones without compromising with the quality of audio and video. (Tutorialspoint, 2016).

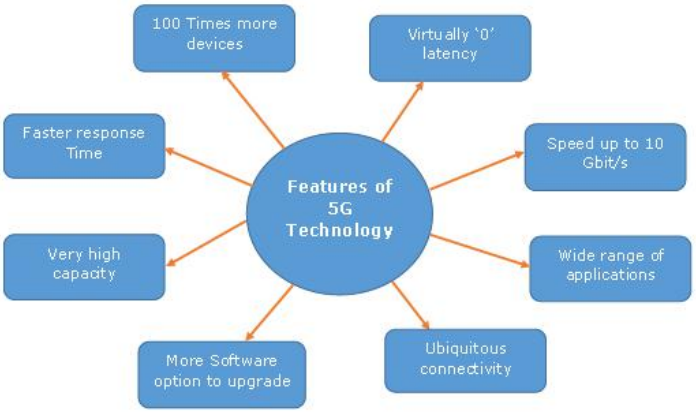


Figure 2: Innovative Features of 5G Technology (Tutorials Point, 2016).

The 5G technology is expected to provide a new (much wider than the previous one) frequency bands along with the wider spectral bandwidth per frequency channel. It is advanced in terms of high increased peak bit rate, larger data volume per unit area (i.e. high system spectral efficiency); high capacity to allow more devices connectivity concurrently and instantaneously; lower battery consumption; better connectivity irrespective of the geographic region in which you are; a larger number of supporting devices; lower cost of infrastructural development; higher reliability of the communications. With the wide range of bandwidth radio channels, it can support the speed of up to 10 Gbps. The 5G *WiFi* technology will also offer contiguous and consistent coverage

5th generation technology also offers a wide range of features, which are beneficial for all groups of people including, students, professionals (doctors, engineers, teachers, governing bodies, administrative bodies, etc.) and even for a common man.

The 5G Architecture

The architecture of 5G is highly advanced; its network elements and various terminals are characteristically upgraded to afford a new situation. Likewise, service providers can implement technology to adopt value-added services easily[11].

However, upgradeability is based upon cognitive radio technology that includes various significant features such as the ability of devices to identify their geographical location as well as weather, temperature, etc. Cognitive radio technology acts as a transceiver (beam) that perceptively can catch and respond to radio signals in its operating environment. Further, it promptly distinguishes the changes in its environment and hence responds accordingly to provide uninterrupted quality service. (Tutorialspoint, 2016)

Features of 5G

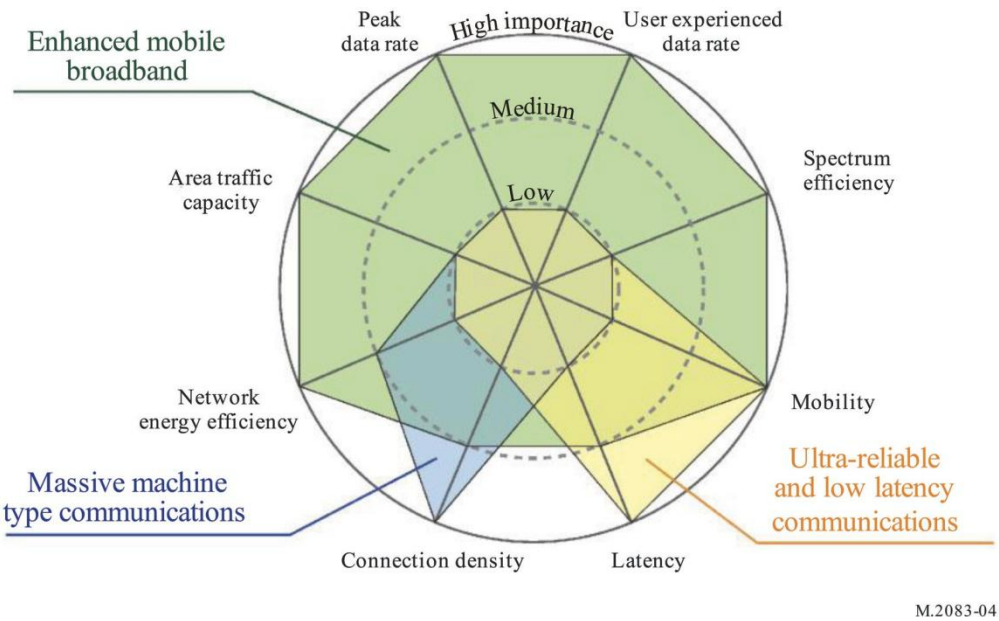
Following the standards set by International Mobile Technology 2020(IMT-2020) and International telecommunication union (ITU), the three features of 5G are:

- Enhanced Mobile Broadband (eMBB),
- Massive Machine-type Communication (mMTC),
- Ultra-reliable and Low Latency Communication (uRLLC).

These features above make the technology support low latency,ultra-lean transmissions, advanced antenna technologies, dynamic Time-division duplex(TDD) and spectrum flexibility and massive machine-to-machine communications[14].

The physical-layer design of the uRLLC servicesare:

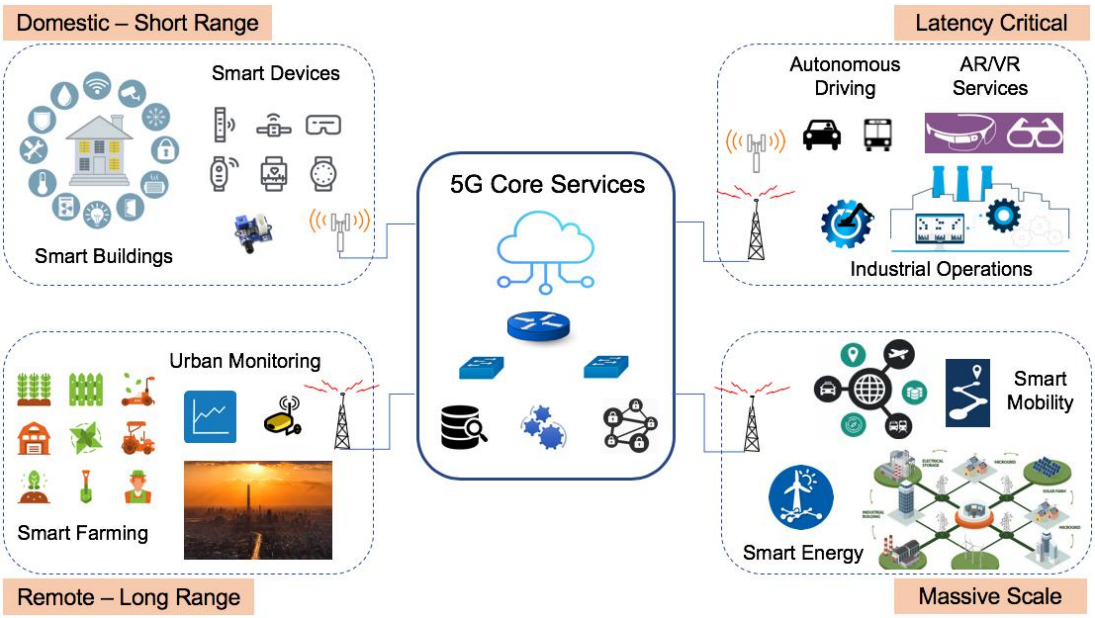
- Synchronization Signals (SS)
- Physical broadcast channel (PBCH)
- Physical Random Access Channel (PRACH)
- Physical Uplink Shared Channel (PUSCH)
- Physical Downlink Control Channel (PDCCN)
- Physical Uplink Control Channel (PUCCH)



Key Features of 5G[17]

Advantages of 5G

5G is the new wave of technology revolution in that it is going to change our lives,work and communication mode. Its services and applications will require lower latency in contrast to LTE, enhanced network coverage, multiple connected wireless sensors, data rates approx. 100mbps,increased efficiency of signals, enhanced data coding techniques, eliminate black-out problem common to 4G network, reduce traffic cost[18]. It will further reduce battery utilization, increase security via SDR and the peak of it is connected world via Wireless World Wide Web(WWWW)[19].



5G Application group[20]

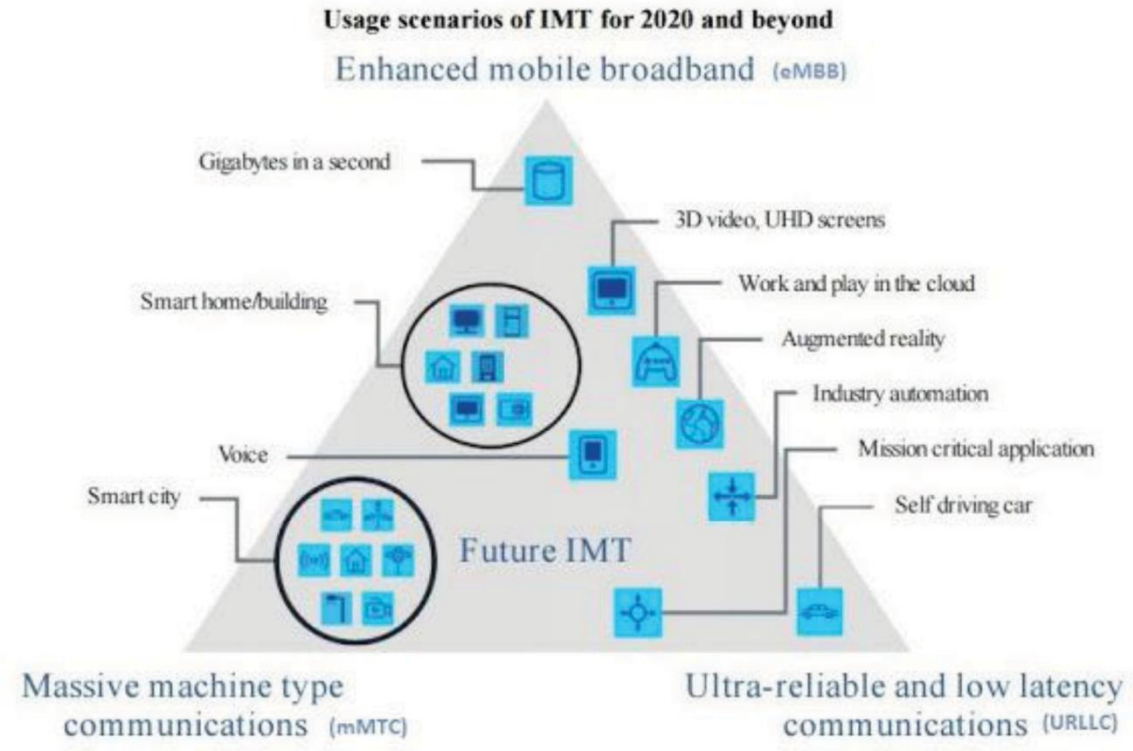
Applications of 5G

Smart home to Smart buildings to Smart City– This involves the use of smart devices connected to the internet via Radio Frequency Identification (RFID) sensors embedded in them. This is the most important feature of IoT which is the future of IT[21].

Smart Energy- This uses Machine to Machine applications, power plant monitoring, smart charging stations and management, This leads to Smart Industry, it makes use of Industry IoT(IIoT) technology[22].

Smart Mobility – It uses autonomous driving services that use Vehicle to Vehicle communication thereby birthing a smart transport system. This will reduce traffic congestion efficient routing, accident prevention, energy saving, reducing smoke emission thereby boosting the quality of the environment[23].

Smart Health care – This uses sensor technology embedded in wearables that conducting an automated diagnosis, mobile-based condition monitoring, environment quality inspection and most importantly Augmented Reality/Virtual Reality (AR/VR) surgery [22, 23].



Summary of 5G Applications[17]

Shortcomings of 5G

Considering the heterogeneous Network (HetNet) nature of IoT, the stakes are high with using 5G for its devices – 5G IoT. Standards required for 5G IoT by 3rd Generation Partnership Project (3GPP) and International Mobile Technologies (IMT – 2020) are high, IoT requires massive connection network, enhanced Machine Tape communication(eMTC), extended coverage Global System for Mobile Communication for IoT(EC GSM-IoT), Narrow bases IoT(NB-IoT) technology for it to function effectively. A systematic security procedure is needed to encrypt the sensor data generated while using 'connected things'.

Conclusion and Recommendation

Mobile Network Technologies from 1G to 4Ghas eased the living and communication standards but have their own sets of problems. More research has been carried out and it has been discovered that 5G mobile network technology is better for faster and safer communication.5G mobile network will fulfill many requirements, and a critical one is to deliver high network energy performance. This is crucial to reduce operational costs and to facilitate network connectivity in remote areas, and to provide network access in a sustainable and resource-efficient way. 5G networks promise radically expanded capabilities and a confluence of technologies that enables an adaptable network that effectively provides numerous new functions. Sequel to the above benefits 5G mobile network has to offer, 5G mobile network is hereby recommended as the best and fastest mobile network. Further work

still needs to be done on data security, privacy and trust model issues with 5G IoT.

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