**5G Technology as the Panacea for Wireless Home Automation Using Internet of Things (IoT)**

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**ABSTRACT**

Advancement in home automation involves wireless control of home electrical and electronic gadgets/devices using Internet of Things (IoT). With the advent of Fifth Generation (5G) technology, home automation is gaining ground in most countries as the internet services is becoming more reliable; and more smart and efficient communication devices are available in the market at an affordable price(s). In this paper, a comparative analysis (in terms of performance & electrical energy management) between 3G, 4G LTE and 5G networks-based home automation were carried out. Secondary data was obtained from related articles and analyzed. It was observed that the performance of home automation system increases with a corresponding increase in the speed of the network. Conversely, the energy consumption of the system decreases in proportion to the increase in speed of the network. The millimeter wave (mmWave)-based 5G network has data rate of up to 6.5Gbps for downlink and 3.5Gbps for uplink as compared to 4G LTE which has 2.0Gbps and 1Gbps for downlink and uplink respectively. This incredibly high speed gives 5G network an advantage over others as a viable telecommunication technology for IoT application in modern home automation.

**KEYWORDS:** *5G Technology, Energy Management, Home Automation, Internet of Things (IoT), Performance Analysis*

# INTRODUCTION

The Internet of Things (IoT) is a general term describing any device used to collect data from the world around us and then share that data across the Internet where the data can be intelligently processed to provide information and services. This definition can be extended to an industrial closed loop control system where data is acquired, coalesced with related data, transmitted to an intelligent station, analyzed, and then acted upon to influence the environment.

Network and connectivity are nevertheless of paramount importance. IoT systems must enable connections over short-, medium-, and long-range distances. The IoT solutions often must satisfy a wide range of transmission quality requirements that may also need optimizations for low latency, isochronous, asynchronous, store-and-forward, mobility, or streaming. IoT systems must consider environmental disturbances such as radio interference or emissions from other electronic equipment, low-power conditions, congestion, and resource starvation scenarios. Guaranteed service levels also add to the mix of requirements

Simply, the "G" stands for "GENERATION". While connected to the internet, the speed of the connection depends upon the signal strength that is shown in abbreviations like 3G, 4G, 5G, etc. on any mobile device. Each generation of wireless broadband is defined as a set of telephone network standards that describe the technological implementation of the system.

**Millimeter Wave (mmWave)**

 The mmWave spectrum operates in high frequencies found between 30 GHz and 300 GHz, and is attractive for a number of reasons. First, the shorter wavelengths of mmWave create narrower beams, which in turn provide better resolution and security for the data transmission and can carry large amounts of data at increased speeds with minimal latency. Secondly, there is more mmWave bandwidth available, which improves data transfer speed and avoids the congestion that exists in lower spectrum bands (prior to researching potential 5G uses of mmWave frequencies, the only major operators in that area of the spectrum were radar and satellite traffic). A 5G mmWave ecosystem would require a significant infrastructure been built, hence an improved data transfer at up to twenty times (20x) the speed of current 4G LTE networks is achieved when deployed. Finally, mmWave components are smaller than components for lower bands of the spectrum, allowing for more compact deployment on wireless devices. Aside, its physical properties, mmWave is also attractive to U.S. 5G developers because the U.S. government owns large swaths of the sub-6 spectrum, particularly in the 3 and 4 GHz range, making it difficult for carriers to purchase dedicated spectrum licenses at FCC auctions or even to share that part of the spectrum (Milo Medin and Gilman Louie, 2019). The aim of wireless communication is to provide high quality, reliable communication just like wired communication and each new generation represents a big leap in that direction. This is depicted in fig.1.0 which shown the evolution in wireless communication.

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Fig. 1.0: Evolutional trend of 1G, 2G, 3G 4G and 5G technology in wireless communication

Table 1.0: Comparison between the existing telecommunication technology in terms of bandwidth, standard, multiplexing, network and service type

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Technology** | **1G** | **2G** | **2.5G** | **3G** | **4G** |
| **Year**  | 1970 | 1980 | 1985 | 1990 | 2000 |
| **Standards** | AMPS,NMT, ETACS,TACS | GSM,D-AMPS | EDGE, GPRS  | CDMA2000, WCDMA | Single standard LTE-Advanced |
| **Data bandwidth** | 1.9Kbps |  14.4Kbps | 384 Kbps  | 2 Mbps  | 200Mbps |
| **Core network** |  PSTN  | PSTN  | PSTN, Packet network |  Packet network  | Internet |
| **Multiplexing** | FDMA |  CDMA, TDMA | CDMA, TDMA  | CDMA 2000, WCDMA | OFDMA |
| **Service** | Analog | Digital | Voice packet data and high capacity |  High capacity and broad-band data | Broad-bandwith high speed |

**2.0 LITERATURE REVIEW**

Mobile network technology is moving at a relentless pace, and its being built around not one, but two industry juggernauts: Fourth-generation wireless and fifth-generation wireless. The assimilation of the Internet of Things (IoT) world into both 4G and 5G technologies makes this wireless labyrinth even harder to get around. According to Hodgkinson (2007), the emergence of wireless communication never came on board recently but for many decades the improvements were done to make it more developed to meet the end users’ needs, more importantly in the area of mobile communications. The development in mobile broadband use is vivid recently, such that Internet generation grows to having broadband access everywhere. This affirms the mobile broadband market share and forecast report given by The NPD Group that active mobile broadband devices will reach 34million, a nearly 50 percent increase from 2013. In recent times, browsing of the Internet, sending and receiving of emails, sending and receiving of music and videos are done through the use of the 3G network.

With 4GLTE, the user experience is better enhanced as the lower latency brings better experience in gaming and other graphics related software. LTE was initially planned by NTT DoCoMo of Japan in November, 2004 as the international standard (Sengar et al.,2011). Today different cellular and wireless firms want a major increase in capacity which has to be carried in coming years beyond fourth generation of wireless standards in Long Term Evolution (4GLTE) (Choudary,2014)or 3GPP Long Term Evolution(Tsai et al.,2007).According to Kumaravel (2011), 4GLTE network brings better benefits in its performance and capacity to both the end users and service providers. Even the migration from 4GLTE to LTE-Advanced and device to device communication was done to a certain extent in non-African countries (Dropper et al., 2009). But African countries are still experiencing challenges even to use and implement the 4GLTE network. Some of the promised benefits of 4GLTE are: downlink peak rate of 100mbps and an uplink peak rate of 1Gbps, a low latency of less than 20ms, and a speed of 200mbps. With these improvements over 3G network, 4GLTE is superior and can be regarded as the needed technology for present developing world. The three primary benefits of 2G network over its predecessor is that - phone conversations were digitally encrypted; 2G systems were significantly more efficient on the spectrum allowing for far greater mobile phone penetration levels; and 2G introduced data services for mobile, starting with SMS text messages. This network is primarily designed to offer voice services to the subscriber hence it has a low transfer rates. It is primarily based on CDMA and TDMA, depending on the multiplexing technique used. The 2G is widely referred to as the GSM

5G is the coming fifth-generation wireless broadband technology based on the IEEE 802.11ac standard. 5G will provide better speeds and coverage than the current 4G. 5G operates with a 5 GHz signal and is set to offer speeds of up to 1 Gb/s for tens of connections or tens of Mb/s for tens of thousands of connections.

4G is synonymous with Long Term Evolution (LTE) technology, which is an evolution of the existing 3G wireless standard. In fact, LTE is an advanced form of 3G that marks an audacious shift from hybrid data and voice networks to a data-only IP network.There are two key technologies that enable LTE to achieve higher data throughput than predecessor 3G networks: MIMO and OFDM. Orthogonal frequency division multiplex (OFDM) is a transmission technique that uses a large number of closely-spaced carriers that are modulated with low data rates. It is a spectral efficiency scheme that enables high data rates and permits multiple users to share a common channel.Multiple-input multiple-output (MIMO) technique further improves data throughput and spectral efficiency by using multiple antennas at the transmitter and receiver. It uses complex digital signal processing to set up multiple data streams on the same channel..

The LTE standard uses both forms of duplex operations: Frequency division duplex (FDD) and time division duplex (TDD).

Finally, a quick note about the LTE categories. There are different categories of LTE networks, and from a consumer perspective, they mainly differ in terms of theoretical speed under ideal conditions.

LTE-Advanced: The bridge between 4G and 5G. LTE Advanced or LTE-A is the evolution of the original LTE technology toward even higher bandwidths. LTE-A promises nearly three times greater speed than the basic LTE network and comprises of the following five building blocks:i. Carrier Aggregation: Carrier aggregation or channel aggregation is a transmission scheme that allows up to 20 channels from different spectrums to be combined into a single data stream

ii. Increased MIMO: LTE-A raises the MIMO bar to 8×8 antenna configurations to increase the number of radio streams using the beam-steering technique

.iii. Coordinated Multipoint (CoMP): or cooperative MIMO, allows mobile devices to send and receive radio signals from multiple cells to reduce interference from other cells and ensure optimum performance at the cell edges

iv. Relay Station: A relay in an LTE-A setting is a base station that uses multi-hop communications at the cell edges; it receives a weak signal and retransmits it with an enhanced quality.

v. Heterogeneous Network or HetNet: is a multilayered system of overlapping big and small cells to pump out cheap bandwidth. HetNet, gradually evolved the cellular architecture, as vastly more complex network of small cells add hundreds or even thousands of entry points into the cellular system. The self-organizing network (SON) concept is one of the key enabling technologies being considered for LTE-A applications. However, it is worth noting that while LTE-A standard creates a bridge between 4G and 5G in variegated ways, the notion can equally imply that HetNet is serves as glue between LTE-A and 5G. That is why many wireless industry observers call 5G wireless an enhanced form of LTE-A.That makes sense because the main concept behind 5G systems is to expand the idea of small cell network to a whole new level and create a super dense network that will put tiny cells in every room.The Next Generation Mobile Networks (NGMN) Alliance defines 5G as below:“5G is an end-to-end ecosystem to enable a fully mobile and connected society. It empowers value creation toward customers and partners, through existing and emerging use cases delivered with consistent experience and enabled by sustainable business models.”

In this section we discuss the merits of 4GLTE over 3G networks. Based on literature review, the following features show the advantage of 4GLTE network over 3G network. They are stated as follows:

* **Interoperability:** This feature shows LTE as a network that has the ability to roam with other existing networks. It helps LTE to be a mobile and portable network such that the service providers are not limited to a single network system. Conversely, in 3G different standards makes it hard to interoperate and roam with other existing networks.
* **Latency:** It simply means the delay of packet sent from a server to get the client and then back. In the LTE network, there’s a very low latency which enhances speed of the network because they are interconnected with other. The lower the rate of latency or delay in response time, the faster the interaction between the device and the network to which it is connected. Low latency in LTE is as a result of its support for games, application sharing, video and voice conferencing over IP.
* **Scalability:** The ability to handle increasing numbers of users and diversity of services is referred to as scalability. It is a challenging process in 3G but done with ease in 4GLTE because it is an IP based network.
* **Design Specification:** The 3G technology provides both circuit design and packet design such that the combination of these patterns makes 3G faster and better than the preceding network. 4GLTE which is regarded as a seamless network uses only packet switching which makes data transfer done in nanoseconds compared to 3G network.
* **Convergence:** In contrast to 3G, the fourth generation network based on research is said to be a conglomerate of all the existing network technologies rather than been a new standard alone. By analysis, 4G network is defined as combination of a local area network with the existing second generation network.
* **Networking:** Unlike the third generation (3G) network which is specifically based on a wide-area concept whereby networking is limited, the 4GLTE network involves the hybrid networks which include both the wireless LAN and the base station WAN design. For this reason, the end users have access to internet connectivity due to the presence of base stations everywhere.
* **Cost Effectiveness:** 4GLTE is a cost effective network which doesn’t require the purchase of an extra spectrum as it builds up on the existing networks. This is due to its capacity to interoperate with the existing networks. Therefore interoperability in LTE makes it a cost effective network compared to the 3G network.
* **Data Transmission Rate:** the 3G network which is based on wideband CDMA operates in 5 MHz of bandwidth and produces minimum download data rates of 384 kb/s under normal conditions and close to 2 Mb/s as maximum rate. 3G phone standards was expanded and enhanced to further expand data speed and capacity. The WCDMA phones adds high speed packet access (HSPA) of higher level QAM modulation to get speeds up to 21 or 42 Mbps downlink (cell site to phone) and up to 7 and/or 14 Mbps uplink (phone to cell site). While in the fourth generation network, a completely contrasting radio technology is used. LTE support both FDD (Frequency Division Duplexing) and TDD (Time Division Duplexing) and works with two multiplexing techniques namely OFDMA and SC-FDMA for uplink and downlink respectively.Unlike CDMA in 3G, Orthogonal Frequency Division Multiplexing (OFDM) and OFDM access are used. Here, the modulation technique divides a channel usually 5, 10 or 20 MHz wide into smaller sub-channels or subcarriers each 15 kHz wide. Each is modulated with part of the data. The fast data is divided into slower streams that modulate the subcarriers with one of several modulation schemes like QPSK or 16QAM.

LTE, in its basic form, does not support uplink Multiple Input Multiple Output (MIMO) [12]. LTE MIMO technique that refers to utilize of multiple antennas at transmitter and receiver area may be applied for both DL as well as for UL channel. LTE’s ability to improve spectral efficiency much beyond the current LTE performances is very much unlikely, and so the only way to achieve that higher data rates is to increase the channel bandwidth.

**4G And 5G Difference**

a) First and foremost, while the LTE-based 4G networks are going through a rapid deployment, 5G networks mostly comprise of research papers and pilot projects.

b) Wireless networks till 4G mostly focused on the availability of raw bandwidth, while 5G is aiming on providing pervasive connectivity to lay grounds for fast and resilient access to the Internet users, whether they are on a top of a skyscraper or down under a subway station.c) The 5G networks are not going to be a monolithic network entity and will be built around a combination of technologies namely 2G, 3G, LTE, LTE-A, Wi-Fi, M2M, so on. In other words, 5G will be designed to support a variety of applications such as the IoT, connected wearables, augmented reality and immersive gaming. Unlike its 4G counterpart, 5G network will offer the ability to handle a plethora of connected devices and a myriad of traffic types. For example, 5G will provide ultra-high-speed links for HD video streaming as well as low-data-rate speeds for sensor networks.d) The 5G networks will pioneer new architectures like cloud RAN and virtual RAN to facilitate a more centralized network establishment and make the best use of server farms through localized data centers at the network edges.e) Finally, 5G will spearhead the use of cognitive radio techniques to allow the infrastructure to automatically decide about the type of channel to be offered, differentiate between mobile and fixed objects, and adapt two conditions at a given time. In other words, 5G networks will be able to serve the industrial Internet and social network apps at the same time.

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Fig. 2.1: Eight notable characteristics of 5G technology that will transform the telecommunication sector

Table 2.1: Comparison between 4G and 5G telecommunication technologies.

|  |  |  |
| --- | --- | --- |
| **Specifications** | **4G** | **5G** |
| **Full form** | Fourth generation | Fifth generation |
| **Data bandwidth** | 2Mbps to 1Gbps | 1Gbps and higher as per need |
| **Frequency band** | 2 to 8GHz | 3 to 300GHz |
| **Standards**  | Al access convergence including OFDMA,MC-CDMA,network-LMPS  | CDMA and BDMA |
| **Technologies** |  Unified IP, seamless integration of broadband LAN/WAN/PAN and WLAN | Unified IP, seamless integration of broadband LAN/WAN/PAN/WLAN and advanced technologies based on OFDM modulation used in 5G |
| **Service**  | Dynamic information access, wearable devices, HD streaming, global roaming | Dynamic information access, werable devices, HD streaming, any demand of users |
| **Multiple access** |  CDMA  | CDMA,BDMA |
| **Core network** | All IP network | Flatter IP network, 5G network interfacing(5G-NI) |
| **Handoff**  | Horizontal and vertical  | Horizontal and vertical  |

**CONCLUSION**

It is observed that the performance of home automation system increases with a corresponding increase in the speed of the network. Conversely, the energy consumption of the system decreases in proportion to the increase in speed of the network. The millimeter wave (mmWave)-based 5G network has data rate of up to 6.5Gbps for downlink and 3.5Gbps for uplink as compared to 4G LTE which has 2.0Gbps and 1Gbps for downlink and uplink respectively. This incredibly high speed gives 5G network an advantage over others as a viable telecommunication technology for IoT application in modern home automation. Furthermore, the futurist potential of 5G cannot be over emphasized with the possibilities of unlocking various innovations that are eco-friendly and has the propensity to changing or unconsciously awaking a new technological civilizations.

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