5G WIRELESS COMMUNICATIONS-THE IDEAL CANDIDATE FOR FUTURE INTERNET OF THINGS

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ABSTRACT

Internet of Things (IoT) is a Ubiquitous network in which all things in a network are connected together remotely using sensors in order to share data. Techniques like Device to Device (D2D), Machine to Machine (M2M) communication give us a clear view on how IoT works. The fifth generation of wireless communications (5G) is the next generation that is expected to offer high data rates and improved Quality of Service (QoS). Millimeter wave (mm wave), massive MIMO, Cognitive networks, Visible Light Communication (VLC), and NOMA are key technologies that will facilitate us to reach 5G's expectations. Research is undergoing on how 5G architecture would be, how devices handling 5G would be designed and how IoT would be implemented in 5G. In this paper, IoT, its requirements, and key technologies of 5G are studied at first and then, how 5G would be the ideal candidate for IoT is discussed towards the later part of the paper.

Keywords: *5G, D2D, IoT, M2M, IoT*

I. INTRODUCTION

Smart objects are released on the market day by day. What makes them smart is not that they have brain but the fact that they can be connected to internet to share data, make big new services and accept applications. From the very first evolution of wireless networks, speed and latency were and are still the main goals that move us from one generation to another. IoT offers 100% pure automation but it is completely different from home automation.

For devices to connect, a very high Bandwidth is required. The 5th Generation (5G) technology is expected to offer a speed up to 1Gbps which makes it an ideal candidate for IoT.

When 5G features are implemented in IoT, the performance and coverage area of IoT will be improved.

Currently, 4G Long Term Evolution-Advanced (LTE-A) system is being implemented but the main challenge is how to transit from it to 5G. 5G has not yet been implemented but by the year 2020 it is expected to be on the market and be in use up to 2040.

II. INTERNET OF THINGS REQUIREMENTS AND CHALLENGES

There are three important requirements of IoT; Sensing data, Processing, and connectivity. All these requirements provide obstacles to implement IoT in future by challenging us by several issues related to the huge number of devices and huge data transferred in the world.

The challenges of IoT-devices can simply be clarified as follows [1]:

2.1. Signaling

A reliable bidirectional signaling is very important with IoT connected devices to make the routing data easy. Data needs to be shared between point A and point B in a fast, secure and reliable way.

2.2. Security

Security is a very important factor in IoT's connectivity. When sending or receiving a stream of data, it is essential to make sure that the IoT device or server has a correct authorization to send or receive the data. Open ports: An IoT device is dangerously defenseless when it's about an open port out to the Internet. Therefore, end to end encryption between IoT devices is needed.

2.3. Omnipresent Detection

It is the ability to know immediately when an IoT device drops off, or connects to the network. Omnipresent detection gives an exact state of all devices connected to a network. This gives the ability to monitor IoT devices and fix any problems that may arise within the network.

2.4. Power consumption

Sending data among IoT Devices takes a toll on power and CPU consumption. With all this, communication needs an efficient cellular system using HetNet 4G or 5G as a long battery life, and also a smart sensor built in IoT device.

2.5. Bandwidth

As expected in future, billions of IoT devices are connected to the network, so the bandwidth consumption is another challenge for IoT connectivity. Bandwidth on a cellular network is expensive.

III. DEVICE TO DEVICE (D2D) COMMUNICATION

LTE based D2D technology is a technology extending LTE. Its transmission is above 1km (much longer than other technologies). It uses LTE frequency (Bluetooth=2.4GHz, Near-field Communication-NFC operates at 13.56MHz). It is also known as High frequency RFID (HFRFID). NFC reaches up to 10cm, bluetooth reaches up to 100m, and LTE D2D reaches up to 10km.

LTE D2D can work when there is an obstacle like a wall, doesn't affect batteries, and reduces the phenomenon of slowing communication speed caused by heavy traffic load of base stations. Base station authenticates and traces the distance between the devices and ensures that D2D can take place. Each device plays the role of base station itself.

D2D can be applied to the mobile advertisement service sector where users can receive discount coupons from stores in proximity and use this info to purchase that item. It can also be applied in the public safety sector (police and firefighters) where there is no network or base stations are damaged in time of disaster.

In IoT, nearby (proximity) objects will use D2D while objects that are far from one another will use internet.

Figure 1: Example of application scenarios for Device to Device (D2D)

D2D is recognized by METIS (Mobile and wireless communications Enablers for the Twenty-twenty Information Society) as one of the technology components of the evolving 5G architecture. D2D technology can play a major role in various scenarios such as vehicle-to-vehicle communication, national security and public safety, cellular network offloading or service advertisement.

IV. MACHINE TO MACHINE (M2M) COMMUNICATION

Machine to Machine (M2M) communication is the communication between two or more physical objects to internet without the need of any direct human intervention. M2M services intend to automate decision and communication processes.

M2M is managed by ***oneM2M*** as a global standard [3].

Figure 2: oneM2M logo

M2M Device: A device that runs M2M application(s) using M2M service capabilities. M2M devices connect to network domain in the following two ways :

a) Direct Connectivity*:* M2M devices connect to the network domain via the access network. The M2M device performs the procedures such as registration, authentication, authorization, management and provisioning with the network domain. The M2M device may provide service to other devices connected to it that are hidden from the network domain.

b) Gateway as a Network Proxy*:* The M2M device connects to the network domain via an M2M gateway.M2M devices connect to the M2M gateway using M2M area network. The M2M gateway acts as a proxy for the network domain towards the M2M devices that are connected to it.

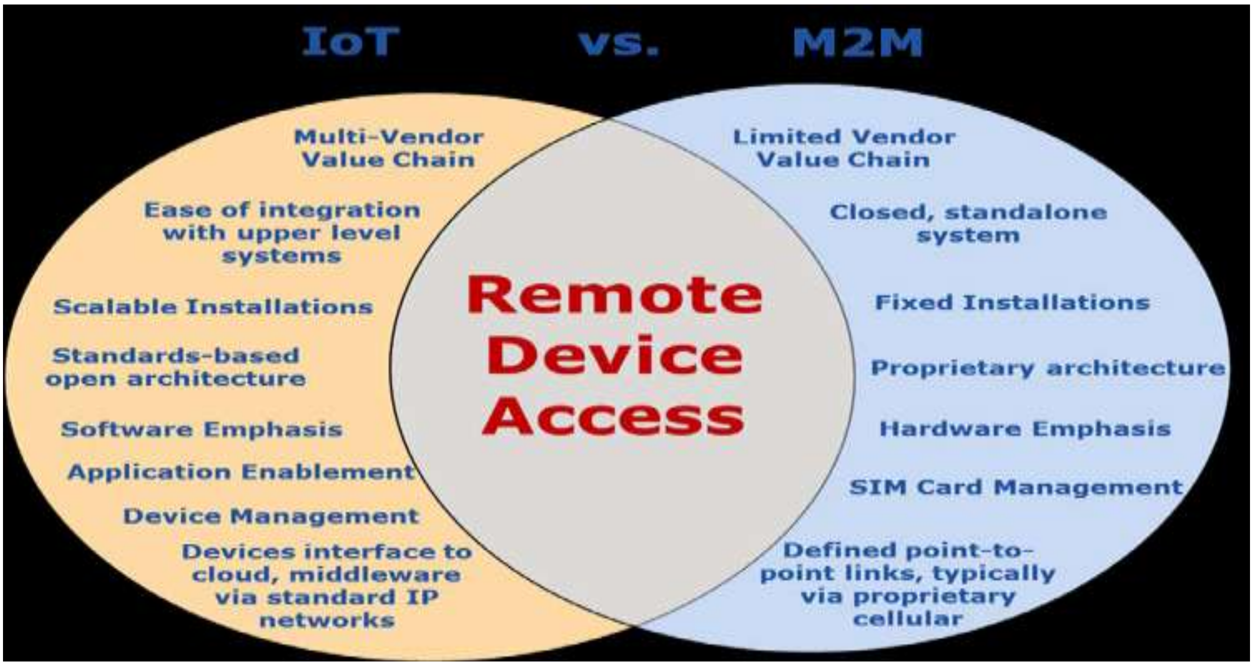

Figure 3: IoT vs M2M

V. 5G WIRELESS COMMUNICATIONS

5G is the next generation for mobile system proposed to be commercially available by the year 2020. This technology has amazing data capabilities and universal coverage by using high data broadcast within the latest mobile operating system. A proposed 5G heterogeneous wireless cellular architecture is shown in fig. 4 [10]. 5G provides high connectivity and the same multitier network in 4G. Some of its features are following:

- 5G Cellular system provides a high resolution for bi-directional large bandwidth with effective billing system.

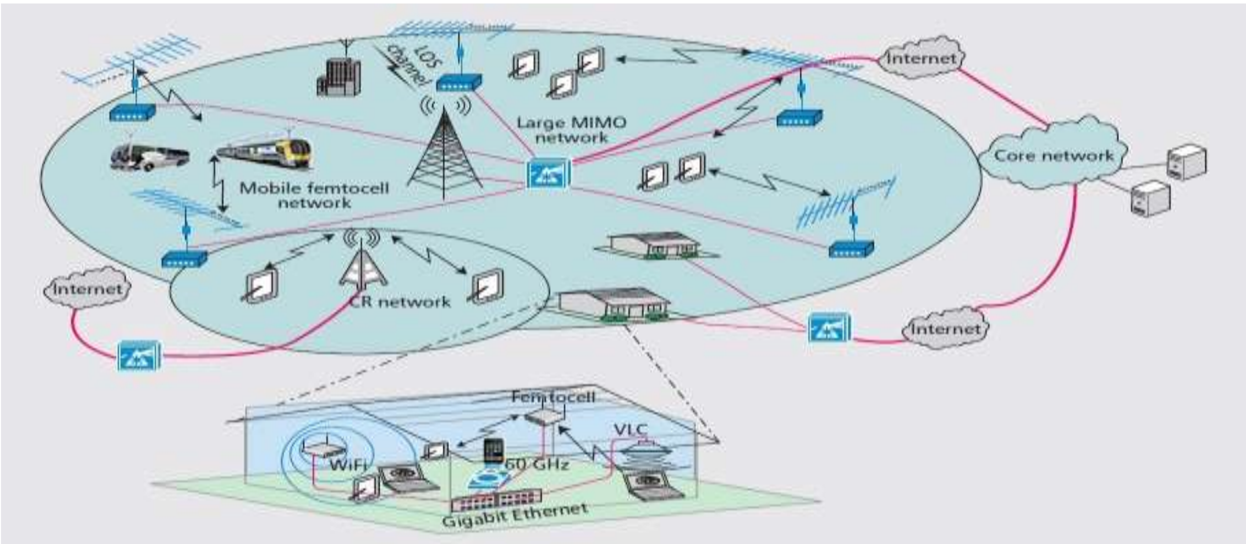

Figure 4: A proposed 5G heterogeneous wireless cellular architecture

- 5G Cellular system offers subscriber supervision tool.

- High quality service by using special policy to avoid error.
- 5G Cellular system provides large data in terms of gigabit and will become more accurate.
- 5G provides up to 25Mbps connectivity speed. Uploading and downloading speed is touching peak. This will come by using the splitting techniques from 4G with new access scenarios by Macro, Micro, Pico, relay and Femto to get more users in small coverage areas.

5.1. MIMO

Multiple-Input Multiple-Output (MIMO) makes a clean break with current practice through the use of a large excess of service-antennas over active terminals and time division duplex operation.

MIMO systems consist of multiple antennas at both the transmitter and receiver. By adding multiple antennas, a greater degree of freedom in wireless channels can be offered to accommodate more information data. Hence, a significant performance improvement can be obtained in terms of reliability, spectral efficiency, and energy efficiency. In massive MIMO systems, the transmitter and/or receiver are equipped with a large number of antenna elements.

Furthermore, in massive MIMO systems, the effects of noise and fast fading vanish, and intracellular interference can be mitigated using simple linear pre coding and detection methods. By properly using multiuser MIMO (MU-MIMO) in massive MIMO systems, the medium access control (MAC) layer design can be simplified by avoiding complicated scheduling algorithms. With MUMIMO, the BS can send separate signals to individual users using the same time-frequency resource, as first pro. Consequently, these main advantages enable the massive MIMO system to be a promising candidate for 5G wireless communication networks.

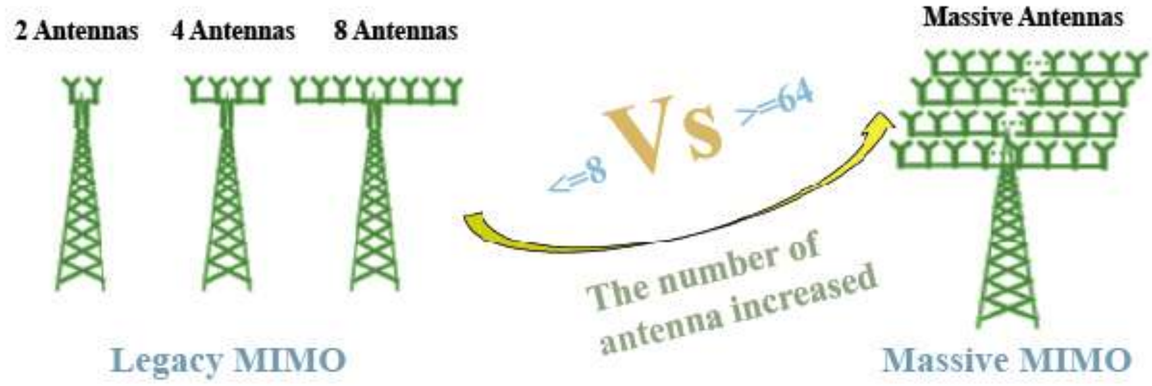

Figure 5: Legacy MIMO Vs Massive MIMO

5.2. Millimeter Wave

Millimeter wave generally corresponds to the radio spectrum between 30 GHz to 300 GHz, with wavelength between one and ten millimeters. However, in the context of wireless communication, the term generally corresponds to a few bands of spectrum near 38, 60 and

94 GHz, and more recently to a band between 70 GHz and 90 GHz (also referred to as E-Band), that have been allocated for the purpose of wireless communication in the public domain.

Millimeter wave is an undeveloped band of spectrum that can be used in a broad range of products and services like high speed, point-to-point wireless local area networks (WLANs) and broadband access. In telecommunications, millimeter wave is used for a variety of services on mobile and wireless networks, as it allows for higher data rates up to 10 Gbps.

Radio signals of all types, as they propagate through the atmosphere, are reduced in intensity by constituents of the atmosphere. This attenuating effect, usually in the form of absorption or scattering of the radio signals, dictates how much of the transmitted signal actually makes it to a cooperative receiver and how much of it gets lost in the atmosphere. The atmospheric loss is generally defined in terms of decibels (dB) loss per kilometer of propagation. Since the fraction of the signal lost is a strong function of the distance traveled, the reader should note that the actual signal loss experienced by a specific millimeter wave link due to atmospheric effects depends directly on the length of the link.

The propagation characteristics of millimeter waves through the atmosphere depend primarily on atmospheric oxygen, humidity, fog and rain. The signal loss due to atmospheric oxygen, although a source of significant limitation in the 60 GHz band, is almost negligible – less than 0.2dB per km in the 70 and 80 GHz bands. The beam of mmWave is very narrow as shown in fig. 6 [6].

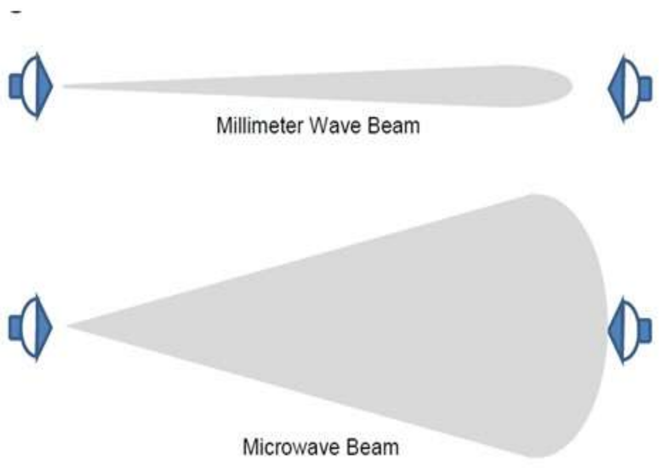

Figure 6: Millimeter wave beam is narrow

High-bandwidth point-to-point communication links are used on millimeter wave ranging from 71 GHz to 76 GHz, 81 GHz to 86 GHz and 92 GHz to 95 GHz, and require a license from the Federal Communications Commission (FCC). Unlicensed short-range data links can be used on 60 GHz millimeter wave. The IEEE Wi-Fi standard 802.11 will run on 60 GHz millimeter wave.

5.3. Cognitive Radio Networks

The Cognitive Radio (CR) network is an innovative software defined radio (SDR) technique considered to be one of the promising technologies to improve the utilization of the congested RF spectrum [9].

The idea behind cognitive radio has come out of the need to utilize the radio spectrum more efficiently by developing a radio that is able to look at the spectrum, detect which frequencies are clear, and then implement the best form of communication for the required conditions. In this way, cognitive radio technology is able to select the frequency band, the type of modulation, and power levels most suited to the requirements, prevailing conditions and the geographic regulatory requirements.

One of the major factors that lead to the development of CR has been the steady increase in the requirement for the radio spectrum along with a drive for improved communications and speeds. In turn this has lead to initiatives to make more effective use of the spectrum, often with an associated cost dependent upon the amount of spectrum used. Research is still going on to determine the best methods of developing a radio communications system that would be able to fulfill the requirements for a CR system.

The required level of performance can only be achieved by converting to and from the signal as close to the antenna as possible. In this way no analogue signal processing will be needed, all the processing being handled by the digital signal processing.

Femtocell base stations have been developed to allow users to have achieved far better 3G coverage within their homes. To operate correctly, these femtocells must not cause interference to the main network, nor to any adjacent femtocells. To achieve this, cognitive radio technology has been used. By using CR, the femtocells are able to monitor their environment, select which geographic area they are in to ensure they comply with regulatory standards, and then choose a suitable channel frequency.

In many instances a single CR will communicate with several non-CR stations as in the case of a femtocell which requires cognitive functionality to set itself up, and then communicate with non-cognitive cell-phones. In other cases, several CRs will be able to form a network and act as an overall cognitive radio network.

The use of a CR network provides a number of advantages when compared to CRs operating purely autonomously:

- ***Improved spectrum sensing:*** By using cognitive radio networks, it is possible to gain significant advantages in terms of spectrum sensing.
- ***Improved coverage:*** By setting up cognitive radio network, it is possible to relay data from one node to the next. In this way power levels can be reduced and performance maintained.

5.4. Visible Light Communication (VLC)

Visible light communication (VLC) is a data communications medium between 400 and 800 THz (780–375 nm). VLC is a subset of optical wireless communications technologies.

Visible light communication uses off-the-shelf white light emitting diodes (LEDs) used for solid-state lighting (SSL) as signal transmitters and off-the-shelf p-intrinsic-n (PIN) photodiodes
(PDs) or avalanche photo-diodes (APDs) as signal receivers [9].

Imagine a flash light which you might use to send a Morse code signal. When operated manually this is sending data using the light signal, but because it is flashing off and on, it cannot be considered to be a useful illumination source, so it is not really VLC by definition. Now if the flash light is switched on and off extremely quickly via a computer, then we cannot see the data and the flash light appears to be emitting a constant light, so now we have illumination and communication and this does fits our VLC definition. Of course we would need a receiver capable of receiving the information but that is not too difficult to achieve.

Figure 7: Light transmitting data

The opportunity to send data usefully in this manner has largely arisen because of the widespread use of LED light bulbs. Consequently we can switch these bulbs at very high speeds that were not possible with older light bulb technologies such as fluorescent and incandescent lamps. The rapid adoption of LED light bulbs has created a massive opportunity for VLC. The problem of congestion of the radio spectrum utilized by Wi-Fi and cellular radio systems is also helping to create the market for VLC.

There are other terms used in the VLC space which are quite widely used but have slightly different meaning to VLC. Three terms closely associated with VLC are:

(i) **Free space optical (FSO) communication** is similar to VLC but is not constrained to visible light, so ultraviolet (UV) and infrared (IR) also fall into the FSO category

(ii) **Li-Fi** is a term often used to describe high speed VLC in application scenarios where Wi-Fi might also be used. The term Li-Fi is similar to Wi-Fi with the exception that light rather than radio is used for transmission

(iii) **Optical Wireless communication (OWC)** is a general term which refers to all types of optical communications where cables (optical fibers) are not used. VLC, FSO, Li-Fi and infra-red remote controls are all examples of OWC.

5.5. Non Orthogonal Multiple Access (NOMA)

NOMA is non-orthogonal multiple access which is a new proposed solution instead of Orthogonal Frequency Division Multiplexing (OFDM) using non orthogonal signal. The information at the transmitter side is superposed in the power domain or code domain and is demodulated at the receiver side. [1]

The key to NOMA is to have signals that possess significant differences in power levels. It is then possible to totally isolate the high level signal at the receiver and then cancel it out to leave only the low level signal. In this way, NOMA exploits the path loss differences amongst users, although it does need additional processing power in the receiver.

NOMA can be considered first as power-domain where NOMA power domain is an extension of the spatial, time or frequency domains and enables more users to access in the limited case; Secondly as one NOMA Code-domain which contains low-density CDMA and Interleave Division Multiple Access (IDMA).

Looking at NOMA in a little more detail, non-orthogonality is intentionally introduced either in time, frequency or code. Then as the signal is received, demultiplexing is obtained as a result of the large power difference between the two users. To extract the signal, successive interference cancellation is used within the receiver. The channel gain consisting of elements including the path-loss and received signal to noise ratio difference between users is translated into multiplexing gains. Although power sharing reduces the power allocated to each user, both users - those with high channel gains and those with low channel gains benefit by being scheduled more frequently and by being assigned more bandwidth. This means that NOMA enables system capacity and fairness of allocations to be improved for all users.

Table 4.1: Orthogonal Vs Non Orthogonal Multiple Access Techniques

Orthogonal Multiple Access Techniques	Frequency Division Multiple Access (FDMA) Time Division Multiple Access (TDMA) Orthogonal Frequency Division Multiple Access (OFDMA)
Non Orthogonal Multiple Access	Code Division Multiple Access (CDMA) Interleave Division Multiple Access (IDMA)

In addition to this, NOMA is able to support more connections than other systems and this will become particularly useful in view of the massive projected increase in connectivity for 5G.

VI. CONCLUSION

In 2015, there were 5 billion connected devices and the number is expected to escalate up to 25 billion in 2020. To satisfy this, we need a very wide Bandwidth to avoid delays. To implement this, new key technologies like Massive MIMO, NOMA, Cognitive Networks and mm-Wave, will play a major role to turn what was thought as impossible into reality. 5G is expected to offer a data rate of up to 1Gbps which will be 10 times the current 4G. D2D and M2M will enhance the connectivity of IoT. These are the factors that will be improved;

a) ***Data rate:*** 5G networks are intended to enable a practiced data rate of 300 Mbps and 60 Mbps in downlink and uplink respectively. This will facilitate things connected to share data instantly.

b) ***Latency:*** In any type of communication, delay has always been the main challenge and needs to be avoided. The average latency of 4G is 53.1 milliseconds but 5G is expected to offer up to 2 milliseconds. This will facilitate connected things to give their highest Quality of Service (QOS).

c) ***Multiple Radio Access Networks (RAN):*** 5G is not about changing current technologies but to enhance and support them with new technologies.

d) ***Energy efficient communications:*** 5G will improve the energy efficiency of the battery

e) ***Millimeter wave communication:*** Bandwidth is an important issue for high throughput. Millimeter wave provides data rates up to 10 Gbps. The major challenge for this is that the waves depend upon the atmospheric oxygen, humidity, fog and rain. This makes it useful in indoors communication systems. We know that the shorter the wavelength, the shorter the transmission range. This can be overcome by using high sensitivity receiver, high transmit power, and high antenna gains.

Research is still going on how to transit from 4G to 5G and how to overcome technical challenges in IoT.

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