The Future Impacts of 5G Technology On Consumers and Businesses (November 2019)

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***Abstract*— The rise of wireless communication among many different types of devices gave way to the development of fourth generation wireless communication which has since been deployed in many environments. Although with the growing numbers of wireless devices needing to be connected in various systems and even personal use, the fourth generation wireless itself is not able to cover all of the needs and wants of new applications and hardware. Expected to be deployed post-2020, the fifth-generation wireless systems are being thoroughly researched and tested to advance from the previous generations' limits. Thus, this paper will go over the advantages, disadvantages, and possible deployments of 5G.**

I. Introduction

Cellular connection technologies such as 5G (Fifth Generation) are extremely important in the modern world. With smart phones being essentially portable computers and being used by almost everyone and the advancements of IoT devices, consumers and businesses rely on cellular communication through such devices to be able to stay up to date and communicate reliably. This requires cellular communication to be available all the time and be available from almost anywhere. Considering the number of devices requiring cellular connections in the modern day the need for new technology in the cellular connection realm is extremely high. This shows the importance of new technologies such as 5G which are needed to fulfill the number of devices, amount of data, and the 24/7 availability that is expected and needed in the modern and future days to come.

5G itself is a digital cellular network technology, it works by dividing up an area into cells. Each cell has a local antenna which the devices in the area communicate with. The antenna itself is connected to the internet and telephone network, where it can pass off the devices' communications to their respective destinations. Cells and their antennas are also able to smoothly handle a device passing from one cell to another without interrupting communication. The cellular network infrastructure can be seen as a system of long-range wireless routers that work as a sort of net that can cover a wide area and act similar to a WAN (Wide Area Network) where devices can connect to internet and similar services along with telephone networking. 5G technology expands on this cellular network infrastructure by providing new ways to send communications and build cellular networks.

II. Approach to Explain the Topic

5G technology has been in the works since early 2012 when ordered by the United Nations, the International Telecommunication Union (ITU) started a program to research and develop an International Mobile Telecommunication (IMT) structure for the year 2020 and after as well. This request from the United nations started a worldwide research race to create 5G, which had not yet been termed at the time. Since 2015 this idea of 5G has taken more shape and has evolved a few requirements to be considered 5G. These requirements come from an ITU-Radiocommunication Standardization Sector Draft Recommendation for IMT-2020, the requirements or recommendations themselves are low latency and ultra-reliable performance, immense machine-type communications, and improved mobile broadband [4].

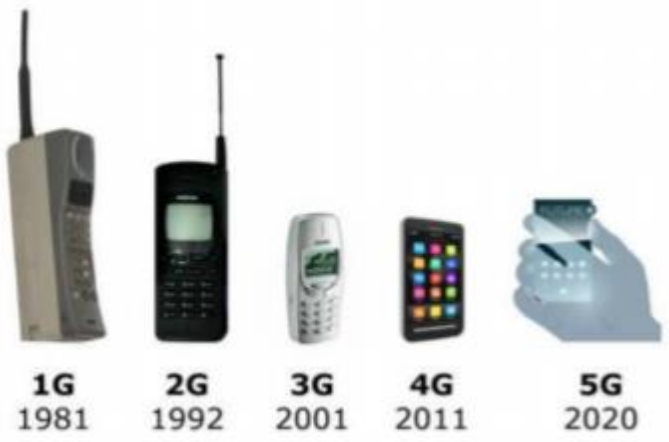


Figure 1 1-5G Technologies [4]

Previous to the upcoming 5G technology, most modern mobile communication networks have been built to support 4G and also some the past versions 1G-3G. To show how 5G will be different and improving off of it's previous 4G version, how 4G works and how the future 5G could work will be explained.

To be considered a fourth generation of broadband cellular network technology, a 4G system must be able to meet certain defined capabilities which come from the ITU in IMT Advanced. These capabilities include things such as 3D television, video conferencing, high definition mobile television, quality gaming services, telephone through IP, and

mobile web access. Compared to its successor 3G, 4G provides the same services as some listed previously and more. 4G also includes less costly and faster data transfer rates up to one gigabit per second. Although, when considering all the features of 4G, the eradication of parallel circuit switching and packet switching using Internet Protocol 6 (IPv6) instead of the previous Internet Protocol 4 (IPv4), is probably one of the most important features due to its eliminating the issues of limited IP's through IPv6 and an overall smoothing and streamlining of the user experience [4].

To reiterate and continue in more depth, 5G's requirements come from ITU-R, which includes Enhanced Mobile Broadband (eMBB), Ultra-Reliable Low Latency Communications (URLLC), and Massive Machine Type Communication (mMTC). eMBB means increased user mobility, improved connectivity, enhanced data capacity to transport more data, quicker connection, and lastly elevated throughput. URLLC relates to the connection of devices between each other that require extremely low latency to the point of being real time in order to carryout critical jobs that are very time sensitive. Lastly mMTC is in relation to enormous amounts of devices being able to connect to a system at the same time and able to do so with low energy cost, although this may also incur the probability of slower data rates [3]. Figure 2 depicts these requirements uses.

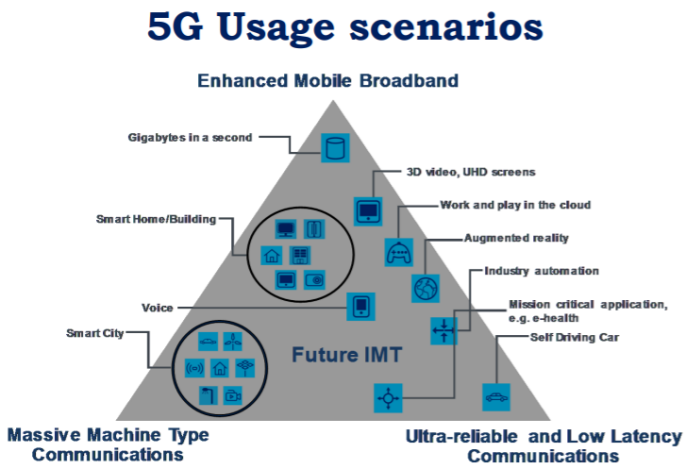
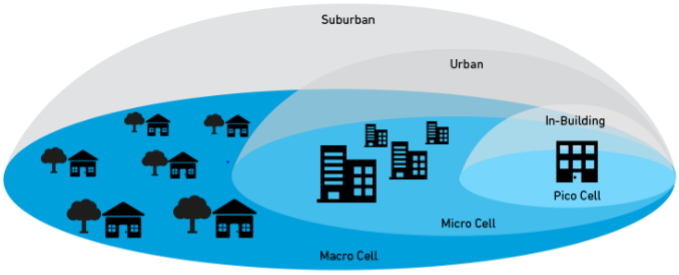


Figure 2 5G Usage Scenarios [2]

For 5G to meet these requirements set before it several techniques and technologies have been researched and developed to be integrated together into what will possibly become 5G. Some of these technologies include small cell designs, millimeter waves, cross network cooperation, edge communications, parallel links, hopping, MIMO and beamforming, and lastly network slicing. To explain how 5G will incorporate these we will go into further detail.

A. Small Cells

Unlike its predecessors 2G through 4G, 5G will not use the same giant wide range limited placement cell towers. Instead 5G will use a small cell technique. This technique will help 5G to get closer to the increased capacity needed by its requirements. The small cells are made to cover more of a smaller local population and use local means to offload higher bandwidth traffic. These smaller cells require a lower power and use a higher frequency which will allow them to communicate a higher throughput but also need a different type of design then the cell tower norm. Instead of having these few and far between cell tower distributions, 5G's small cells would have companies and consumers have 5G cells at their locations. This is where the cells could connect to the wired and wireless networks of their consumer or company host and be able to connect to the core backhaul and redistribution through software and virtualized tunnels and networks. Small cell technology and techniques are extremely important to 5G as it provides increased data capacity, lower overall cost from rooftop systems, and it will also allow mobile devices to be more energy efficient when connecting to networks. 5G provider businesses will also be able to take advantage of the use of different levels of small cell design to enhance connection quality. The different levels of small cell designs are microcell, metrocell, picocell, and femtocell. Figure 3 shows an example of the different levels of small cells.



Cell Type	Output Power (W)	Cell Radius (km)	Users	Locations
Femtocell	0.001 to 0.25	0.010 to 0.1	1 to 30	Indoor
Pico Cell	0.25 to 1	0.1 to 0.2	30 to 100	Indoor/Outdoor
Micro Cell	1 to 10	0.2 to 2.0	100 to 2000	Indoor/Outdoor
Macro Cell	10 to >50	8 to 30	>2000	Outdoor

Figure 3 Base Station Types [5]

Small cells also help with the millimeter wave type of connections that 5G will use.

B. Millimeter Waves

Millimeter wave technology will be the main way that a 5G network will connect. Millimeter waves are 10 millimeters to 1 millimeter wavelengths on the radio frequency spectrum. The waves are also used at a frequency of 30 GHz to around 300GHz. These high frequency smaller waves have a slight downside which is the range. Since the waves are small and high frequency, they are able to fall prone to more atmospheric interference by being absorbed by atmospheric gases. Rain and humidity also have a negative impact on the signal strength and performance by causing rain fade. In addition, objects such as buildings and large vegetation such as trees also prove to block millimeter waves. Although this short-range problem may cause concern, the range is around, line in sight, a kilometer which is still considerably good especially for small cell type systems as mentioned previously. This is why the small cell design with the millimeter wave technology complement each other. Despite the range problem, millimeter waves are able to produce 10 Gbps to provide fast connections for a variety of

services. At this current time millimeter waves that are targeted are still on the undeveloped side. Although, they are used currently in a broad range of products such as broadband access, high quality Peer-to-Peer connectivity, and wireless local area networks.

C. Cross Network Cooperation

In order for 5G to have a successful release, cross network cooperation techniques and technology will play a big part in 5G's architecture. It is extremely important for 5G to be able to support multiple standards of other and previous networks like Bluetooth, Wi-Fi, and LTE. Also as mentioned and shown previously 5G will need to be able to work on different scales of cell design. The goal with cross network cooperation techniques being employed in 5G is so that 5G will create a reliable and secure network that can support multiple cellular standards while also functioning with vehicle-to-everything and machine-to-machine standards.

D. Edge Communications

Another possible feature of 5G is edge communications. Edge communication is the ability for devices to communicate to one another when one or more of the devices is outside the range of the closest cell tower or provider. This works by using one of the devices as a sort of makeshift small cell controller. This device can then establish links to the other devices within its range and establish and authorize connections. This sort of technology would be extremely useful in situations of emergencies when signal service is down or even having signal to other devices in unpopulated areas that have poor service or no service.

E. Parallel Links

Parallel links is another technology that can make 5G an improvement. Currently mobile radio communications systems are being designed with around a max of thirty-two antennas on the system. Those thirty-two antennas represent the total throughput a system can handle if all of the antennas work collectively. A mobile device usually has multiple interfaces such as cellular waveforms, Bluetooth, Wi-Fi, and millimeter waves. These forms of communication have the potential to be all be used to improve the bandwidth of communications through heterogeneous connectivity and potentially prevent jamming.

F. Hopping

Similar to edge communications, hopping is a technique that uses the mobile devices themselves to extend the range of cell service. Essentially, each mobile device is used as a mini-base station, this way each device accepts and passes messages from the other devices near it and eventually to a cell tower. This will make it so that if a device is just outside the range of service, another device that is in range, can act as a bridge or repeater to allow the other device to acquire signal. In addition to being able to extend signal to one device out of range of service, this technique can be used to make several hops in a sort of chain to extend signal to devices, figure 4 illustrates this.

Figure 4 Signal Hopping Diagram [3]

G. MIMO and Beamforming

Multiple Input Multiple Output (MIMO) and beamforming are two interesting technologies that give 5G the possibility to connect to devices in a different manner than usual. MIMO is a currently used technology that allows wireless system base stations to connect to end devices using multiple antenna interfaces to maximize performance. The newer developments of this technology allow better efficiency by using the multiple antenna on the base station smartly to connect to many end devices at the same time. This efficiency comes from the multiple antenna working smartly to send more efficient streams to multiple single antenna end devices. This technique is Beamforming, in other words, forming a concentrated beam of data to each end device. Beamforming is a child of MIMO technology in this way used to command the direction of data streams by accurately determining the phase and magnitude of each antenna signal in the array of multiple antenna systems. In an area covered by 5G beamforming techniques, the area is not cell based but beam based. Using one or more Synchronization Signal Block (SSB) beams for each cell, the beams are made semi or purely static and aiming at the same direction. To distinguish between the beams and cells, a Physical Cell ID and beam ID is used to identify. These SSB beams create a layer of hybrid mini cells which with the use of time spacing, have little interference and quick beam strength measuring. Beamforming's traffic-signaling gives the most efficient data delivery while at the same time have the lowest interference with close by end devices. The beamforming base stations are also able to calculate the best route through the air to get to the devices, even bouncing the stream of data off objects and buildings. This becomes extremely advantageous with the millimeter wave technology mentioned earlier. Since a concern with millimeter waves was natural interference like humidity, using beamforming with millimeter waves can focus the waves at an end device increasing the chances of that device receiving data without any interference corrupting the data. Figure 5 demonstrates an example of beam forming.

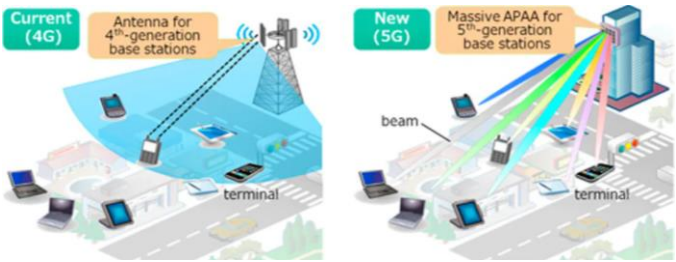


Figure 5 Beam Forming in 5G Compared to 4G [6]

H. Network Slicing

Lastly, network slicing is another technology that will be used to make 5G a possibility. Network slicing is a procedure of taking a single physical network and "slicing" it into multiple virtual networks. This gives the service provider a couple of abilities. It allows quality of service and experience techniques to be used for contracts specifying requirements and demands. What the best use of network slicing simply comes down to is, the ability to give the best network elasticity and efficiency while also maintaining the lowest cost available. So essentially, when new 5G network systems come out they will have the ability to create and maintain dynamic logical separation of network segments or "slices" and be able to dynamically change the service and bandwidth of each segment on demand. This technique is also valuable when is comes to network security and maintaining multiple levels of security [3].

III. Possible Future Research Issues on the Topic

Now that the technologies and techniques of 5G have been explained, the possible deployments of 5G will be discussed. There are three generic models that have been researched and developed for 5G, they are the vertical, horizontal, and oblique models. Figure 6 shows the basis of the models' construction.

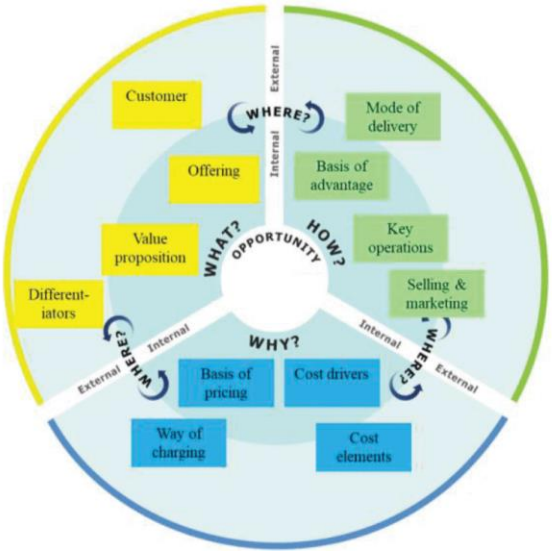


Figure 6 Business Model Wheel [1]

The vertical business model is made for providing custom services in an end-to-end fashion in restricted areas. Customers of this model would be industries such as production type industries, local utility companies looking into smart grid management, and operational areas like mining operations. The vertical method focuses on finding opportunities for constructing special requirements to act as a sort of solutions business. An example of a use case would be machine-to-machine communications wanted for Internet of Things enabled local industrial services. For these types of services in a vertical model, security, privacy, and reliability are important factors along with that ability to smartly make use of sent and received information data.

A Horizontal business model is quite different from its vertical brother. Horizontal business models focus mostly on the ability to give local hosted connectivity to service providers. This comes into play in a variety of restricted and public local places where it might not be a reasonable expense for service providers to build their own infrastructure. This could be places such as hospital and school campuses, and even local shopping malls. In these situations, a micro 5G operator could host the service providers service and deliver them to the customers for a charge to the service provider. Essentially this would be an infrastructure-as-a-service business pointed towards service providers who cannot construct their own infrastructure. This means the micro 5G operator would be in charge of maintaining, building, designing, and implementing the infrastructure.

Lastly, the oblique business model is based on mass-tailored and end-to-end services among various network segments. While the vertical model is based around scalability in relation to common ground between use cases, the oblique model focuses on a platform that maintains mass-tailoring. Although compared to the vertical model the oblique model can provide higher scalability due to not having to care about local specifications from stakeholders. Also, with this model the 5G operator will be able to offer connections with assured security, privacy, and augmented quality of service [1].

IV. Concluding Remarks

In this paper, we have looked in depth at what technologies 5G will incorporate from beamforming to network hopping. The advantages to each of these technologies and disadvantages has been mentioned so that a better picture of the future of 5G has been illustrated. The developing business models have also been discussed to show how the services 5G provides can be incorporated into the industry and consumer businesses. 5G technology is a big step in our future technologies and will hopefully be able to provide the quality and scalability we need in the modern and future days to come.

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