A Survey on 5G Mobile Connectivity Systems and its Prospects on Communication

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***Abstract*— The fifth generation of wireless communication or popularly know as 5G is being in hype these days and due to which a part of many discussions. Once 5G can be launched commercially for majority of the people it will bring revolution in the digital communication field. The 5G networks are considering mmWave bands to provide the promised high throughput by using the extreme data rate coverage provided by mmWave technology. Several 5G service scenarios are presented and different approaches are needed for them with related essential technical requirements which are proposed by different people for it.For Example, the mmWave can only be used for small distances else the it starts having a considerable amount of loss due to the diffraction of the waves. In this survey paper, I have gone through such many proposed approaches and discussed the best fittings as per my understanding along with a competitiveness analysis on 5G services,networks for industries and home networks, devices and few financial factors with the current condition of 5G technologies. Besides identifying challenges, my work also states the new advancements which 5G application in various field would create, which will also shed some light on future development for the technology.**

Index terms - 5G, Wireless Communication, Mobile communication, Data rates, Low latency, Mobile Tower, IoT and IIoT using 5G service

I. INTRODUCTION

The fifth generation technology of telecommunication popularly known as 5G is one of the most emerging research domain these days. It is intended to have a major shift in cellular technology, similar to the preceding fourth- generation technology (4G) which is been used today and had a large impactful change which has broken backward compatibility. 5G technology intend much more connections and data rates nearly 20 times faster than current network (eventually up to 10 Gbit/s) by trying to integrate 5G air spectrum together with LTE and WiFi to provide universal high- bandwidth coverage with great user experience [1]. It also makes it possible for many new application which require very less latency rate to having seem less user experience like Mixed reality, Internet of Things (IoT). 5G can ultimately lead to a society truly connected with IoT devices.

In the recent years, the 5G has became primary interest of discussion on board, as the long-term evolution (LTE) has embodying 4G has been deployed and reaching its maturity it will be very soon a companion of 5G as it would only provide service as a backup option when a high speed, reliable network of 5G is not available. With this every increasing data speed and low latency with the 5G networks, as per the GSMA (Global System for Mobile Communication Association) Intelligence report it is expected that 5G would have more than 1.72 billion subscriptions worldwide by the end of 2025. They also say that every four in five connections globally will be a smartphone by 2025 [2]. As per Qualcomm Economic impact report, the 5G is driving global economic growth which will be \$ 13.1 Trillion global economic output, \$ 22.8 Million new job created and \$ 265 Billion global 5G CAPEX and R&D annually over the next 15 years [3].

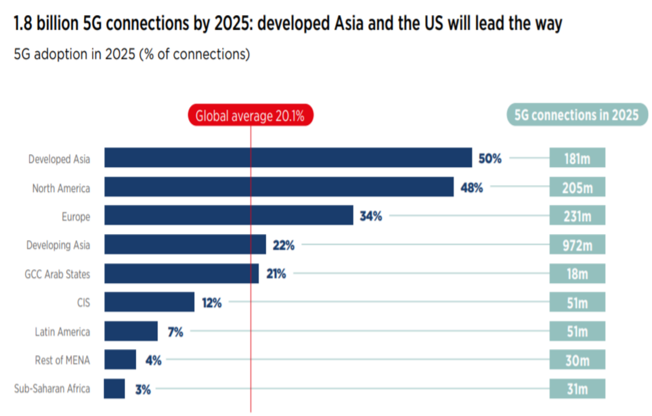

Fig. 1. 5G adoptation by the end of 2025 [2]

Mobile phones has passed through the previous generations of technologies before getting to this stage, which where used extensively in there times. A brief description of the previous technologies are as follows [4].

1) 1G - It is the first generation of mobile telecommunications. In which the analog telecommunication standard were used.
2) 2G - The second generation overpowered the predecessors by digitally encrypting the conversations, more efficiency and starting data service like SMS (Short Message Service). It was commercially launched on the GSM standards.
3) 3G - Third generation provided a huge improvement by allowing an information transfer rate of 144 kbit/s. Which later also improved to Mbit/s and that mobile broadbands usually know as 3.5G and 3.75G
4) 4G - Mobile broadband Internet access was introduced in fourth generation in addition to the services provided by the predecessors. Also, 4.5G is introduced which

provided better service than the 4G and also acts as a process step towards the full 5G technology deployment.

Despite all the advancements in 4G wireless network technology, providing mobile services that demand high speed, fast response, high dependability, and energy efficiency is difficult. Guarantee quality experience for mobile users for seem less instantaneous cloud services, Internet of Things(IoT) or communication for robotics, etc. cannot be provided by any of the network currently.As a result, 5G era expects these features to be a necessary upgrade for its services [5]. As stated by many reports the number of 5G connections will increase tremendously by the year 2025 so will the data traffic will do because of the new connections and the more bandwidth consumption of the older connections.So, because of these massive amount of traffic which will be created by humans and machines, 5G network operators must shift their attention only from throughput-optimized to energy-efficiency-optimized resource allocation solutions also. Massive machine-type communication (mMTC) helps connecting higher number of low-rate low-power devices with the network and hence it is expected to revolutionize the 5G systems and beyond as per the needs[6].

Given that 5G is still in its early stage, with all such exciting advantages also comes challenges to be solved in order to enjoy the technological enhancements as described above. It take tremendous efforts and time in order to design and deploy such technologies architecture and protocols. The best approach for better connectivity with low latency and high data speeds, low energy consumption, network efficiency, data traffic handling, etc. need to be found and applied. Research on 5G services and its requirements is been done by the International Telecommunication Union-Radiocommunication (ITU-R) Sector, the 3rd Generation Partnership Project (3GPP) and the Next Generation Mobile Networks (NGMN) Alliance [7].

The scope of 5G services are not just limited to personal or commercial use it extends to areas of societies including mobile phones, wearable devices, sensors, actuators, vehicles, robots, and so on [5]. Key performance indicators (KPIs) that are considered by researching bodies as the technical requirements include high data rate, area traffic capacity, network energy efficiency, connection density, latency, mobility, spectrum efficiency, and user-experienced data rate for the 5G mobile services.And therefore, 5G networks can be regarded as the key infrastructure that innovates societies, as well as ICT industries.

II. IMPACT OF 5G MOBILE SERVICES

By the introduction of 5G services, it will give stage to technological advancements and will be set for emerging Tactile Internet which would be able to give real-time control and physical tactile experiences remotely, thanks to ultra-reliable and ultra-responsive network connectivity it will have. By delivering low latency enough to develop real-time interactive systems, the Tactile Internet will bring a new dimension to human-computer interaction(HCI). [8]. Once this scenario is made possible it would lead to few more drastic changes which will happen with the fifth generation of mobile communication technology which are listed as under [5].

- Mobile data traffic will skyrocket which needs to be handled
- Everything would be on cloud servers
- Knowledge as a service enabled by Big data
- Very rapid increase in the connected devices and new connections

With the increasing popularity of the 2D multimedia, even the new technologies like Virtual Reality, Mixed Reality etc., are emerging which would have seem less performance with the low latency network and it would also increase the need of cloud storage and cloud processing as it needed over the network. Worldwide, it is predicted that the market for mobile handsets and other IoT devices will grow from USD 7.9 billion in 2015 to USD 11.6 billion in 2020 [5]. Costs and energy usage should ideally reduce as we progress to 5G, but they should not increase on the cloud server side else it would not make any sense.

When it comes to discussion on 5G, it is always centered towards the consumer's benefits. However, this focus seems to be slightly incorrect when 5G comes into picture because just the consumers demand alone wont satisfy the massive construction cost of 5G networks. The speed of 5G would be so great that it would exceed the capacity of consumer devices(at least at current time).On other hand,the high data speeds, reduced latency, energy savings, cost reductions, and increased system capacity are projected to have a positive influence on the industrial internet of things (IIoT) and Commercial internet of things(IoT). Wind turbines, jet turbines, locomotives and railways, heavy machinery and quarrying tools, all reside in the IIoT space while the other application which are related to making life easy or home automation lies in commercial IoT.Faster and more appropriate informed business decisions will be made with the help of these 5G sensors connected to these systems. 5G will revolutionise how we think about connectivity in the home, in the workplace, and in almost every industry [9] .

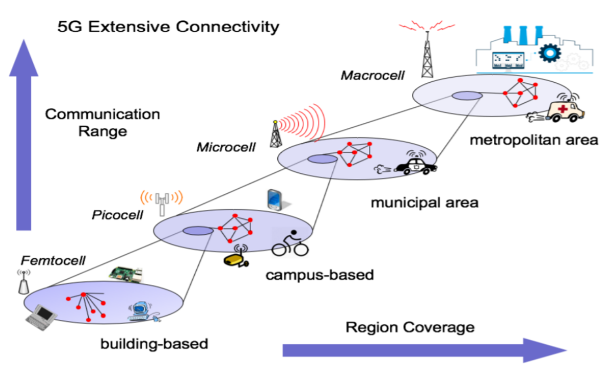

Fig. 2. 5G Network Connectivity Service Overview [10]

The figure (Fig.2) above accurately describe 5G's extensive connectivity with the different types of ranges it would cover ranging from a building's range to a metropolitan city area range. Now, as per one of the top researchers in the 5G technology (Qualcomm), the 5G is used across three main types of connected services [3]. First, Enhanced Mobile broadband which being one of the major update for the common users in which apart from the normal faster data speed they will be also experiencing immersive experience of VR and AR technologies.Second, Mission-critical communications which enables industries with ultra-reliable, available remote control and lastly, Massive IoT which will seamlessly connect a massive number of embedded sensors in virtual world with very low cost connectivity solutions.While, as per [5] the 5G services are classified into five categories considering the end-users in mind, they are immersive 5G services, intelligent 5G services, omnipresent 5G services, autonomous 5G services and public 5G services.

III. WORKING OF 5G MOBILE SERVICES AND FEW PROBLEMS

Any wireless systems use radio frequencies to carry information through the air which is also know as spectrum in technical terms. In 5G, its operation is same as the previous generation but it uses higher bands called as 'millimeter wave' (mmwaves) which indeed have less cluttering and can therefore carry more information at much higher speeds [11]. 5G network design depicting 5G and 4G networks functioning together, with central and local servers offering consumers with quicker content and low-latency apps. The 'Radio Access Network' and the 'Core Network' are the two fundamental components of a mobile network [12].

Radio Access Network - The radio access network consist of all the access point for the network like towers, masts and dedicated in-building modules, small cells, etc. But, for 5G technology small cells are the major feature because of the new mmwaves which are having very short range but very high speed.

Core Network - For mobile networks the core networks consist of the basic function modules of the network like voice services, data and internet services. But, for 5G the core network is redesigned to have more focus on better integration with the internet, cloud services and the service responce time (latency).

For providing local service with high data speed and low latency, 5G uses techniques like Network slicing and Network Function Virtualization (NVF). Whenever, in real life scenario a 5G connection is established, the device will automatically join to both 4G and 5G networks to provide control signalling. Hence, when 5G coverage is restricted, data is transported through the 4G network and prevents from a connection loss [12].Also, the 5G technology from physical layer to the application layer is designed as an open platform. Currently, work is being done on modules that will

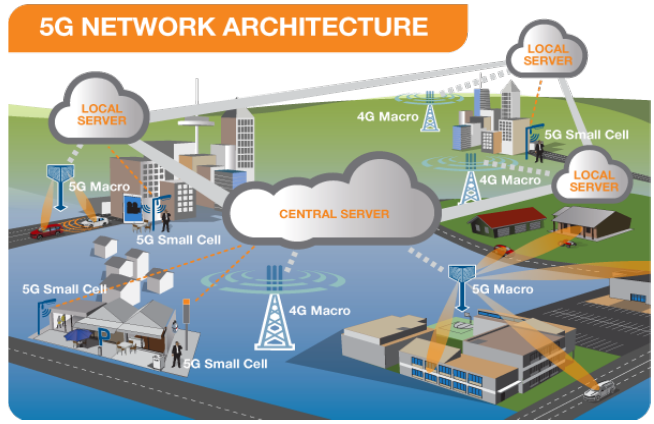

Fig. 3. 5G Network Architecture [11]

provide the best Operating System and lowest cost for a certain service employing one or more wireless technologies at the same time from a 5G mobile.

As we know there are limitations to any technology, similarly to overcome the limitations of 4G technology, 5G was suggested. With the increasing hype around 5G network services, also the expectation of people is increasing and the need of eliminating the limitations of the previous generations also stays in place. Based on the analysis done in [5], it can be clearly seen in its table 2 that if we want to reduce the latency it is not possible to have a huge mobility at the same time, it is only possible when the movement is of the speed of a pedestrian and also the traffic density would be potentially high. While, when we want mobility and speed, always the latency is affected.

	User Experienced Data Rate	End-to-end Latency	Mobility	Device Autonomy	Connection Density	Traffic Density
Broadband access in dense area	DL: 300 Mbps UL: 50 Mbps	10 ms	On demand, 100 km/h	>3 days	2500/km^2 (Activity factor: 10%)	DL: 750 Gbps/km^2 UL: 125 Gbps/km ^{2}
Indoor ultra-high broadband access	DL: 1 Gbps UL: 500 Mbps	10 ms	Pedestrian	>3 days	75,000/km^2 (Activity factor: 30%)	DL: 15 Tbps/km^2 UL: 2 Tbps/km ^{2}
Broadband access in a crowd	DL: 25 Mbps UL: 50 Mbps	10 ms	Pedestrian	>3 days	150,000/km^2 (Activity factor: 30%)	DL: 3.75 Tbps/km^2 UL: 7.5 Tbps/km ^{2}
50+ Mbps everywhere	DL: 50 Mbps UL: 25 Mbps	10 ms	120 km/h	>3 days	400/km^2 in suburban 100/km ^{2} in rural	DL: 20/5 Gbps/km^2 (suburban/rural) UL: 10/2.5 Gbps/km ^{2} (suburban/rural)
Ultra low-cost broadband access for low ARPU areas	DL: 10 Mbps UL: 10 Mbps	50 ms	On demand, 50 km/h	>3 days	16/km^2 (Activity factor: 10%)	DL: 16 Mbps/km^2 UL: 16 Mbps/km ^{2}
Mobile broadband in vehicles	DL: 50 Mbps UL: 25 Mbps	10 ms	On demand, up to 500 km/h	>3 days	2000/km^2 (Activity factor: 10%)	DL: 100 Gbps/km^2 UL: 50 Gbps/km ^{2}
Airplanes connectivity	DL: 15 Mbps UL: 7.5 Mbps	10 ms	Up to 1000 km	N/A	80 per plane 60 planes/18,000 km^2	DL: 1.2 Gbps/plane UL: 600 Mbps/plane
Massive low-cost long-range/low-power MTC	Low (typically 100 kbps)	Seconds to hours	On demand, 500 km/h	Up to 15 years	Up to 200,000/km^2	Not critical
Broadband MTC	DL: 300 Mbps UL: 50 Mbps	10 ms	On demand, 100 km/h	>3 days	2500/km^2 (Activity factor: 10%)	DL: 750 Gbps/km^2 UL: 125 Gbps/km ^{2}
Ultra low latency	DL: 50 Mbps UL: 25 Mbps	<1 ms	Pedestrian	>3 days	Not critical	Potentially high
Resilience and traffic surge	DL: 1 Mbps UL: 1 Mbps	Not critical	120 km/h	>2 weeks	10,000/km^2	Potentially high
Ultra-high reliability & Ultra low latency	DL: 10 Mbps UL: 10 Mbps	1 ms	On demand, 500km/h	Not critical	Not critical	Potentially high
Ultra-high availability and reliability	DL: 10 Mbps UL: 10 Mbps	10 ms	On demand, 500km/h	>3 days	Not critical	Potentially high
Broadcast like services	DL: Up to 200 Mbps UL: Modest	<100 ms	On demand, 500 km/h	From days to years	Not relevant	Not relevant

Fig. 4. Technical requirement for 5g services [13]

In order to solve the engineering challenges faced by the 5G communication systems, first we need to identify the requirements of the 5G systems.Varying applications will have different performance needs, and the peak requirements that must be met in specific conditions are as shown below. For example, very-low latency and reliable connection is needed for any gaming application, for any high-definition streaming service the latency is not a issue but high-speed is needed, while some application which can have low data rates but needed very high reliability and low latency like self-driving or driver less vehicles.

- Energy and Costing
- Latency
- Data rates
- Data Traffic management
- Multiple connections
- Reliability

The mmWave bands are considered for usage by 5G networks to provide the high data rate (gigabit-per-second) which are expected by the 5G networks as the mmWave technology has the ability to have so. But, the mmWave also has a very short rang as well as can easily get distracted with too many hurdles in place also for complying with its speed new type of connection integration between devices should be implemented aside from the traditional single-hop multi-cell networks used. Hence, it will requires some new approach instead of the traditional approach which wont work apparently[14]. When though of these from different perspective then it can be observed that these problem is focused to the regions which are equipped with good connectivity, what about the remote regions where even the basic connectivity is barely available. Some novice idea about the same has been presented by [15] but other factors of connectivity becomes the problem here.

As the technology moves toward smaller cells, Base Stations must get smaller, lower-power, and less costly, and there is no reason why a BS should be more expensive than a consumer device or a WiFi node [16]. After paying hefty monthly site rental fees also ensuring the fast and reliable connections for the end users for small-cell placements which are operator-controlled, however, has proven to be a major impediment to growth of picocells, distributed antenna and other enterprise-quality small-cell deployments.

The requirements from the emerging applications of 5G network would vary and needed to be considered from several new angles when architectural needed are considered. Smart vehicles, drones, and industrial IoT deployment will introduce data generation in very high volumes [10]. Also, energy consumption has been primary concern of the upcoming 5G network because of the economical operation,operational and environmental concerns which were not been considered a decade back and just optimization and performance were considered for the wireless communication services [17].

IV. PROPOSED METHODOLOGIES

Clearly, it can be seen that there is a lot of room for improvement before the 5G can be commercially be launched for the majority of the consumers and all the users taking advantage of it. The support of mobility to the users specifically considering the 5G networks is becoming more difficult with the networks continues to densify and heterogeneity increases. It is rightly said in [1] that it will be really difficult to restrict the users with high mobility to low rates and other with high rate because it will be very challenging at mmWave frequencies to do Handoffs since the transmitting and the receiving beams must be aligned to communicate. And as descried in [18] that mmWave is most promising to use for the 5G connectivity because of the high data rates but, it makes it more complex at the base station to process all the requests.

The millimeter wave which has small range and high data rates are used for the low latency and high speed purpose at places which has it own problems of diffraction and due to which signal fading happens mostly at crowded places which is discussed in detail in [19] where, the experiment were done on the streets of downtown Brooklyn, New York. In the experiment they used omnidirectional small-scale spatial auto correction which is a metric to characterize the auto-correlation of the voltage amplitudes of the received signals across uniformly separated track positions [19]. It was finally found that in the urban Micro-cell (uMi) setting for mmWaves when omnidirectional antenna is used the auto-correction required is in the form of sinusoidal-exponential distribution and exponential distribution for the directional antenna.

$$\rho = \frac{E[(A_k(X_k) - \overline{A_k(X_k)})(A_k(X_k+\Delta X) - \overline{A_k(X_k+\Delta X)})]}{\sqrt{E[(A_k(X_k) - A_k(X_k))^2]E[(A_k(X_k+\Delta X) - A_k(X_k+\Delta X))^2]}}$$

Where,
ρ = Spatial auto correlation coefficient
X_k = k^{th} linear track position
E= expectation operator
δX= spacing between different antenna positions on the track

Very similar to 5G wireless communication services the drones have recently attracted a lot of interest for their ability to perform a variety of tasks ranging from transportation of items to customers, scientific research,to observe or collect data about endangered species or in crucial military operations. When remote situation are considered these drones perfectly fits in due to there ability of remote control and range to reach these places. Hence, an approach has suggested by Authors of "Enhanced Deployment Strategy for the 5G Drone-BS Using Artificial Intelligence" in their paper [17] for the use of optimum number of drones which can cover such areas and do not compromise on the communication relevant parameters such as data rate, latency, and high throughput which are promised by the 5G services. A very similar and interesting study on the use of drone for this connection in the areas in been proposed in [20] which all mathematical calculation on optimal location and numbers of drones maybe used to observe the target but with an assumption that the terrain is a two dimensional one. But, as per my observation I don't find these solution to be very practical at the time being with the technology we have and the energy efficiency we expect.

Another way for seem less connectivity can also be said to be converting the end-users connections to femtocells and Wifi access points as precisely described in [21] which will make the networks a very dense space. But, it leads to coordination and management of the network for providing seem less experience over connectivity and speed. This leads to proper handshaking and beam alignment problems [18] as properly explained and a simple solution to it is Markovian Beam Alignment protocol. As in this, once one side starts transmitting the data the other side will observe the data in at least one of its bins and the handshaking time is only defined once when any first side enters data transmission mode [18].

Even when Tactile Internet comes into picture, in which humans may wirelessly control actual and virtual objects, will not be achieved unless massive system design obstacles are overcome. For humans to interact with anything from nature to any system the interactive response time should be as low as 100ms, 10ms or 1ms for auditory, visual respectively. As a result, the requirements for technical systems that enable real-time interactions are dependent on the human senses that are involved. Hence, human beings should not only see and hear the thing far away but also touch and feel them [22]. Once the Tactile Internet is established we will be able to transmit touch and actuation's in real-time.

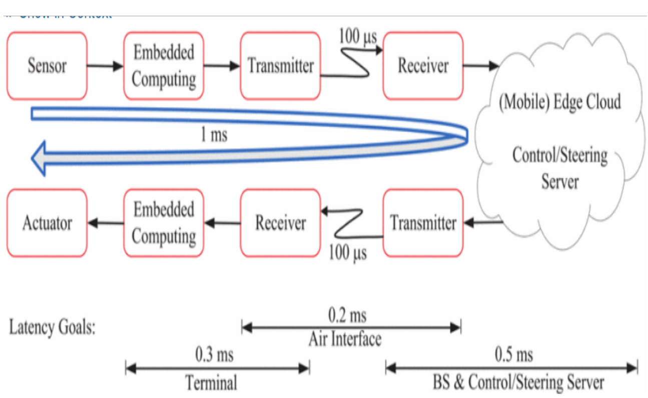

Fig. 5. Exemplary latency objective of Tactical Internet [21]

The 5G network for this kind of Tactile Internet service should be ultra reliable i.e. 99.9% reliable [23]. 5G is presently being standardised and will address new URLLC services, among other things. As well as, the latency which has been discussed above (1ms) is also the basic necessity for this internet.However, to make a network such reliable it comes with a cost of network performance on other services like reduced spectrum, etc. "5G Radio Network Design for Ultra-Reliable Low-Latency Communication" [24] has proposed a solution that this reduced latency and fast data rates can also be achieved from network side and not only from the software side. But, it has a minor impact on overall network performance which is quite moderate.

In terms of connectivity, most of the papers discussed above has their own way for the 5G mmWave band connectivity because of the complications faced in it due to the basic nature of mmWave as being highly susceptible to blockage, with too much interferences in between the quality degrades drastically. Out of all these method to manage the mmWave, I think the solution proposed in [25] is the most practicle and novel approch towards this connectivity problem. In this paper, they have developed over the results obtained in "Performance comparison of dual connectivity and hard handover for LTE-5G tight integration" [26]. Due to the propsed dual connectivity the result come up to be intresting as the latency has reduced by 50% of the original handshaking because it is already connected and switching between network has been easy.

V. CONCLUSION

The wireless business, as well as wireless research in general, is experiencing a period of growth and with everyday advancing technology and getting technical solutions to get connectivity even in the areas which are hard to connect. In this article primarily we have gone through what is the 5G communication technology and go through the limitations present in it and different approaches which are been proposed to eliminate that. The aim of this article was to investigate the interesting and lacking areas of 5G network with many interesting proposed solutions. I have gone through different research papers and described some of the paper which are proposing the best solution as per my understanding.

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