Orchestrating a brighter world with 5G Communication

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Abstract - *This research article revolves around 5G (fifth generation) technology and the various ways in which it is transforming our lives. It collates the varied and multifarious applications that will be fuelling to make processes digitally empowered. Flow of the research article starts with an introduction to fifth generation technology and evolution of preceding technologies. Next section moves on to specify its need and primary defining features. Section four highlights the architecture and how SDN and NFV together with massive MIMO form an integral part of this technology. Section five takes a dive into how we can integrate a smart society by spinning various industry threads together to better allow the technology evolution. Since the beginning, inherent interest in evolution of technology has been at the forefront. Subsequent section investigates the use cases on major fronts: eMBB: enhanced mobile broadband; who's data rates are in Gbps and covers large areas via broadband. mMTC: massive machine type communication which revolves around wireless connectivity and sensors and URLLC; ultra-reliable low latency communication, latency requirements for it is less than 5 ms. Final comments are incorporated in the conclusion section.*

Key Words: **5G Communications, Latency, LTE eMBB, 5G NR, URLLC**

1. INTRODUCTION

The speed at which wireless data traffic has grown over the past two decades has been relentless. The next generation of wireless communication network, 5G, is expected to deal with 1000 times more traffic alongside maintaining a high reliability. A critical requirement of 5G can be described as ultra-low latency; the time required for transmitting a message through the network. The present fourth-generation (4G) wireless networks possess a nominal latency ranging from 40-50ms; however, this remains unpredictable, often reaching up to several seconds.

The explosive demand for broadband services coupled with a high capacity network to give out content rich services and secondly Internet of things (IoT), which supports mass connectivity of devices can be suggested as the enablers.

5G is followed by some performance indices to support its functioning on a ground level. Some of these can be attributed as: end to end latency, capacity density of a network, spectral efficiency and throughput per connection. Meeting all these criterion involves, developing technology to enhance the present LTE network and finally, coming up with a new radio interface.

1.2. Evolution towards 5G

Every new generation of wireless technology delivers faster speeds and more functionality to the end user's smart phones. The table below, shows the comparison wrt the cellular technology.

Generation	Services Offered	Features	Challenges
1G	Analog phone calls	Mobility	Major security issues
2G	Messaging	Large scale adoption	Dates rates insufficient to provide internet
3G	Phone calls/ SMS/Data	Good Online and Data experience	Real performance failed in front of the hype generated
3.5G	Calls/SMS/ Broadband Data	Internet Applications	Was associated with mobile specific protocols
4G	All IP services (voice, data)	Lower delay rates, Fast internet availability	Weakened data speed,

Table 1: Comparison of Technologies in terms of features & challenges

Cellular technology has travelled an evolutionary path staring from 1979. Initially, communication meant speaking at two fixed locations. All of a sudden, interacting with people irrespective, started becoming a possibility. 1G provided voice calls using Frequency Division Multiple Access. Onset of 2G came in 1992 which used digital signals, requiring lesser power which resulted in cell phones. Digital signals not only improved voice quality but also brought about digital encryption and better security.

Transmission of text messages was also offered by 2G. Owing to its limited data capacity, we saw, development of GSM (Global System for Mobile Communication) and CDMA (Code Division multiple Access, which was enhanced by moving to GPRS (General Packet Radio Service). Data rates now touched up to 100 kbps.

Next in line was 3G which came with HSPA (High Speed Packet Access) and EVDO (evolution data optimized).

Data speeds now started measuring in mbps instead of kbps. Improving the end user equipment greatly advanced the internet service delivery. Multimedia experience was introduced by integrating digital cameras, new SIM (Subscriber Identity Module) card and better display. Evolving to semi-conductors gave us pocket fitting cell phones. 4G bought the customer closest to connecting them 24*7 with the technology driven world by utilizing LTE(Long Term Evolution). Data speeds ranged up to 100mbps. The evolution from packet switching network to IP packet switched 4G system was noticeable.

It is now expected that, 5G will bring about massive accomplishments while integrating our vehicles, appliances, buildings, infrastructure etc. Today, we are about to usher in 5th Generation which is touted to have capacities to handle 1000X traffic and 10X faster than 4G LTE.

5G networks are considered to have heterogeneous offering, which are often optimized for various services as per the end user. Services which require high reliability and are considered mission critical such as e-health can be offered basis 5G architecture.

Characteristics of a 5G Network:

- These networks possess data rates that theoretically go up to 20GB/sec thus making it 10-100X capable of the current 4G networks
- Latency in 5G is extremely low, 1millisecond, as compared to current 4G, where it is 40 ms
- Bandwidth: 5G networks are estimated to have enormous bandwidth of 1000 per unit area
- Connected Devices: 5G offers as high as 100 connected devices within an area which when compared to 4G stands at just a single device.

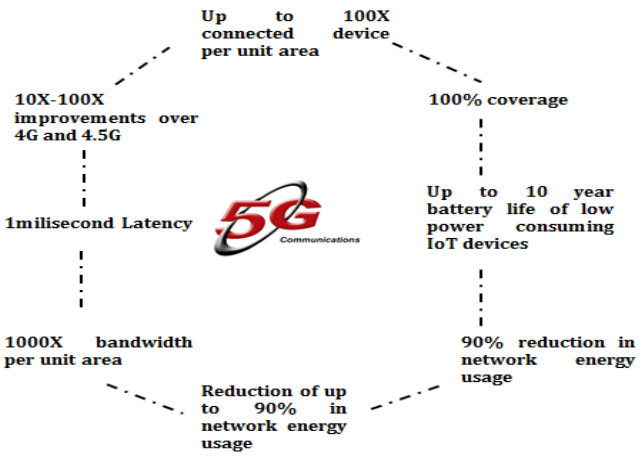


Figure: Specifications of 5G

5G technology is expected to unleash enormous growth in connectivity, support increasing mobile traffic capacity, providing greater throughput, ultra-low latency combined with super-high reliability, high connection density and an expanded range of mobility. 5G services will offer advantages along three parameters simultaneously; *data rates, connectivity and reliability.*

Services are set to roll out in majority of countries by 2020 with Japan, already testing the implementation with the upcoming Tokyo Olympics 2020. With the completion of 5G new radio standards in 2017, we will be witnessing an early rollout of 5G in commercial services. Players such as Qualcomm, Huawei, China Telecom, Ericsson, NEC Corporation etc are conducting trials with a focus to develop viable solutions to enable 5G technology benefits by 2019-2020.

2. 5G New Radio:

5G New Radio or 5GNR is the new air interface which is under development to enable advanced 5G offerings.

End objective is to achieve a scalable air interface capable of handling extreme variations of 5G applications.

Spectrum for NR: Radio technologies comprise of varying spectrums. 5G constitutes of spectrum with varying range such as:

- 1-3Ghz which is for mobile bands
- 3-6Ghz for emerging bands
- Above 6 Ghz-centi meter wave and millimeter wave (mm wave) bands

Millimeter waves have spectrum range between 30 Ghz to 300 Ghz, it is presently under development and is referred to as VHF i.e very high frequency waves by ITU. They have a shorter range of about a kilometer and are often absorbed by gases in the atmosphere.

In the sub 6 Ghz band, 5G aims to target, 700 Mhz in Europe region, 3.5Ghz for China and 4Ghz for Japan and typically utilize 2G, 3G and 4G spectrum over a period of time. Spectrum of the lower bands however being constrained, is substantial for coverage. Efforts are under way to reuse the already existing cell sites such as towers etc to enable 5G deployment at much lower cost. 5G interest area lies in the higher frequency waves of mm wave and cm wave since they offer greater spectrum at disposal.

Some of the first 5G deployments are expected to be in higher bands, as high as 28 Ghz, which is attracting attention particularly in the US

Sharing in terms of licensed and unlicensed spectrums between operators will be the next milestone to be achieved for 5G deployments.

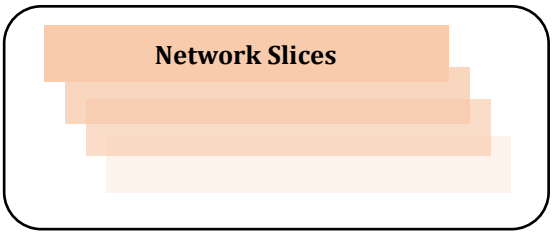
2. 5G Key Features:

5G's penetration in our daily life will be enormous. The speed at which the expectation of the customer is changing is difficult to predict.

The G stands for Generation which differs vastly from its previous counterparts in terms of features and capabilities. 5G is the fifth generation in the wireless technology after the current 4G LTE.

5G network will be supporting the increasing number of connected devices around the world, starting from fitness-tracking watches to internet-linked television and computer systems that are responsible to operate city traffic lights.
Two key features which define 5G can be categorized as:

3. Network Slicing:



In network slicing, multiple networks can be deployed as separate operations using a common infrastructure. It can also be stated as a concept where we create multiple architectures on a physical infrastructure. Slicing allows the operator to portion the network to provide services for various market scenarios.

From a business view point, a slice includes all the relevant network resources, functions and services to fulfill a targeted business case or a service. Using this feature, multiple virtual networks can be created within same physical network. Slice, can be considered as, Iaas; infrastructure as a service which can be customized as per requirements

It makes use of the available spectrum effectively and meets the capacity requirements of applications by aligning the resources to the applications. Network slicing will augment the implementation of 5G with the help of infrastructure sharing.

3.1 Ultra low latency:

Interactive experiences where subject is at a remote location requires a very low end to end latency in the range of 40ms to 300ms.

When latency reduces, in general it leads to an increased interaction often leading to vast areas of use cases ranging from online gaming to remote medical procedures.

When engaging with remote machinery control via a user guiding the entire tele-procedure demands a roundtrip latency of 100ms.

With 5G, we are expecting latency to go as low as 10ms, with such less delays in delivering the service, an entirely new spectrum of services will be unveiled, such as augmented reality and virtual reality.

4. 5G Architecture:

5G system focuses on the development of

- SDN (Software defined networking)
- NFV (Network Function Virtualization)

4.1 Software defined networking:

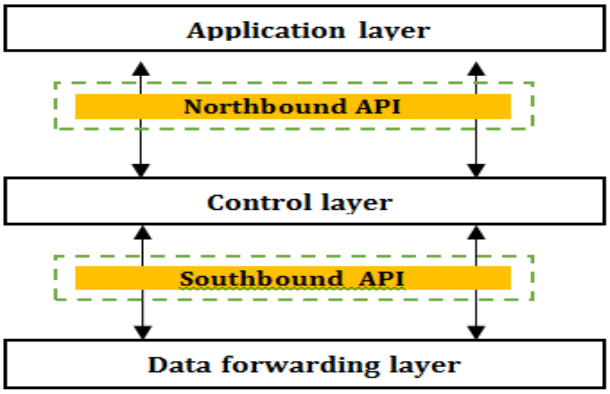


Figure: Elements of SDN

SDN helps immensely in provisioning infrastructure on demand apart from streamlining the physical infrastructure and offering the ability to scale the resources as per the application and data requirements. SDN initially began in early 2000's with International Telecommunication Society (ITS) from where Stanford University and Open Network Foundation started promoting SDN.

It achieves the decoupling of hardware from the software. The current architecture of the internet operates in a manner that every device is independent and autonomous. Network just connects these diverse devices eg: IP routers and computer terminals. Now comes the question of interaction among the devices to achieve desired result. Managing these interactions for the network becomes tedious to handle.

SDN comes into picture by separating the control of the devices and their data forwarding functions. End result being, these devices will send data packets whereas the actual decision and routing are now performed by a control plane which is separate and independent, for which it can now be easily centralized and the desired changes can be made to the whole configuration without disturbing hardware and the original network deployment.

It also allows a huge level of programmability to be incorporated by separating network into different slices. These slices are now used to offer a different type of service.

The application layer provides various ways to program the controller. The bottom most layer forwards both hardware and software data packets. Two interfaces communicate within these three layers with Northbound API connecting the application layer with the control one. On the other hand southbound API lies below the controller, connecting the data forwarding devices with control layer. Open flow protocol can be categorized as a south bond interface. Deployment of SDN is on the rise given its dynamic nature to manage and also reduce the CAPEX and OPEX of the operator.

4.2 Network Function Virtualization

Open platforms offer us better flexibility and scalability in comparison to hardware of existing network.5G is shifting from specialized hardware which was being used in previous generations to open platforms.

These open platforms contain, commercial off the shelf (COTS) hardware where applications are installed. This is termed as virtual network function. They are capable of implementation in any type of physical hardware. The physical location is subject to change basis the demand and latency needs.

5G networks provide us with different virtualized Core Network or, slices, as they are referred to, for various subscribers which includes different device types, such as m-MTC or x-MBB and additionally customer specific slices such as e-Health.

Network slices have the ability to give out different services, along with sharing a common radio network. Isolating these network slices is very essential. Virtualization is transparent to many 5G nodes and also to devices and subscribers. However some 5G node components are also able to actively modify the structure and behavior of the core network

4.3 Massive MIMO:

Mimo stands for multiple input multiple output and involves the usage of multiple antennas in cellular system which are deployed at both the transmitter and receiving locations to improve the spectral efficiency. It helps in combating noise and mitigating intercell interferences. Massive mimo is when we increase the antennas at base station, to scales up this effect up to 1000x. It helps in increasing the network capacity by serving more users. When combined with millimetre waves, they help in reducing the latency to enhance data rate provided and also increasing area traffic capacity.

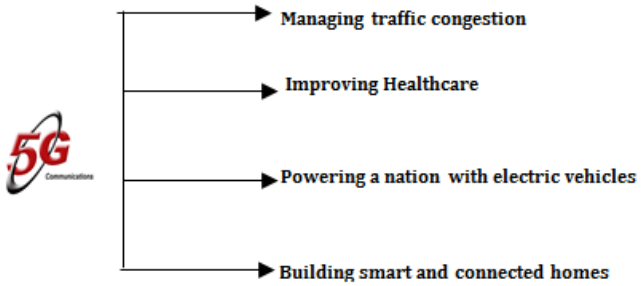
5. APPLICATION IN SMART CITIES:

Smart city, to start off, is a set up with basic infrastructure in place, which makes use of technology to augment the user experience to another level. It can be termed as an ecosystem having a dense network of wireless sensors interacting with each other, establishing device to device communication, sharing the data over cloud to draw meaningful insights and provide, on time services.

Fifth generation, is about to re-invent the way we live our daily lives. It will have profound effect on the way we communicate with each other. Smart cities will bring about smart homes with them to form an ecosystem of a smart society which will be driven by wireless sensor technology.

5G as a technology will have the potential to transform a normal city to an interactive one by bringing along higher speeds, greater network availability and billions of connected devices to start with.

When we talk about 5G and various sectors which are associated with it, everything goes far beyond network speeds. It is because of the increased network efficiency. The foundation of the building is on 4G LTE but this Smart City benefits will be accelerated with the help of 5G.



Smart cities will be connecting multiple low powered digital devices via IoT(Internet of Things) Implementing it will not only make the functioning more efficient but also smarter.
To implement smart cities we ideally require that the autonomous vehicle, water systems, smart city energy grids and transportation system, all to be controlled by the cloud. However this is not possible unless the path to cloud is low latency, ultra-fast and secure.

This is where 5G comes into picture as it is estimated to be 10-100 times faster and agile as compared to 4G-LTE

5.1 Smart Transportation:

Fig: Vehicle to vehicle communication

Connected and autonomous vehicles are an opportunity area of 5G, since they have sensors, will allow, the self-driving cars to share information with each other regarding an accident, collision, red light, pedestrians, and other stoppages etc. It is transmitted wirelessly to all the vehicles behind. Hence alternative route can be opted to avoid traffic congestion.

Autonomous driving lets the vehicle to sense its surroundings and finally navigate without any human intervention. Technologies which these cars use are wireless communication, GPS tracking, radar sensing, computer vision and odometers etc. Vehicles will communicate with traffic lights to send the traffic intensity information to the cloud from where it will be sent to the drivers to notify them of alternate routes,

This virtually allows vehicles to talk to each other. If implemented in public transportation, it will result in smart 5G bus stops, having sensors to give out information pertaining stoppage time at bus stops. It efficiently allows, the empty bus stops to be skipped and additionally sends out information about the ones which are overcrowded or if any accident has happened, resulting in increased frequency of buses to that particular location. It will further help in easing out crowding during peak time.

5.2 Smart Parking

Finding a parking spot in any major metropolitan worldwide is becoming a hassle, following which, people end up parking in the “no parking” zone.

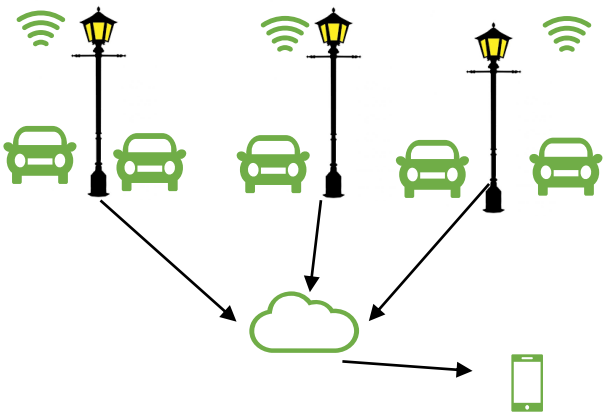


Fig: Functioning of a Smart Parking System

A smart parking system has direct effect on congestion reduction and eliminates pollution by removing the circling of vehicles who are on the lookout for a parking space. City authorities can ease the parking problems by installation of smart parkin technology which allows the driver to gain insights about available parking spaces via mobile, website or calling the hotline for real time availability and billing information.

5G is required to implement the low cost wireless sensors which are installed at street lamps, in multiple places, to let them function efficiently

5.3 Smart Waste Collection System

Waste generation is a huge problem in developing nations primarily, India, for instance. Leading cities generate waste to the tune of 5000-7000 million tonnes annually. Bangalore, Mumbai, Delhi etc all are looking forward for innovative waste management solutions. People tend to generate waste, but none come forward to dump it wisely. At one of the music festivals in Bangalore, a start-up pioneered the concept of Smart bins, where dumping the trash in the bin, gave people access to free Wi-Fi for 15 minutes. It was tested at 6 music festivals and lead to an efficient way to collect waste post a public gathering.

In Mumbai, it was observed recently that, civic authorities have encouraged waste dumping in bins, by rewarding people with small token of gift every time they dump the garbage in the bins.

All this leads to a conclusion that bins which can function in an efficient manner is the need of the hour.

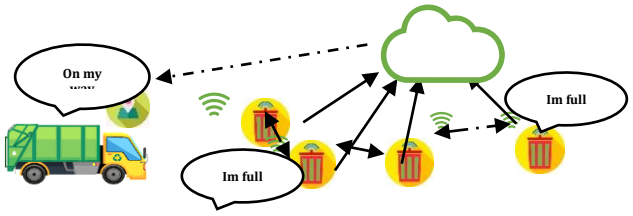


Figure X: Functioning of Smart Bins in a Smart City

Smart bins come to the rescue wrt the technology which they bring in to ease the situation.

They have sensors installed in them which give out real time information to the civic authorities, about the exact location of the bin and the garbage level. With the help of 5G, information can be relayed on the cloud thereby giving out the most optimum route for garbage collection using GPS and eliminating the round trips of empty trash bins. This not only helps in fuel saving, by sending optimized routes to the drivers directly but also lets the staff function in the most time efficient manner. Information pertaining to bins across city can be accessed from anywhere and anytime with a customizable dashboard.

Such a solution was offered by leading corporation, NEC, in the city of Santander, Spain, where Machine to Machine sensors recording the real volume of trash in the bins, were sending out information to the control centre via a mobile network.

Pune Municipal Corporation is also implementing such a solution using GPS tracking and Frequency Radio Frequency Identification. These solutions end up providing a clear strategy on waste management across the city.

5.4 Smart Grids :

5G lets us unify the unconnected and energy consuming devices into the grid by making use of low cost sensors. These sensors can be monitored more precisely in order to forecast the energy needs.

When large cities capture such data, it results in planning the energy infrastructure spending to reduce the present downtime. In the circumstances of power failure, these grids help us reach the affected area of concern, zeroing down to the exact pole which requires immediate action to mend the situation at hand, thus helping in real time diagnosis, by shifting the load to a transformer or device at different location.

Another application can be *Smart Lighting*, where the lights automatically dim out on the roads when no human interaction is observed around. This leads to reduced power and energy costs

The Chattanooga district in Tamil Nadu has established itself as the test bed for a smart grid research. A partnership between Electric Power Board and Oak Ridge National Laboratory collects real time senor data which tracks the fluctuations in power and balances the load.

Sensors helps in collating measurements from electric system. Data pertaining to grid is fed into the supervisory control and data acquisition system (SCADA) and city's fiber network transmits the data back to the control room, which, helps us determine the sensor giving out maximum output for a greater scale implementation.

In addition to stationary sensors, research is underway by Electric board to understand how drone mounted sensors will help in improving the system reliability.

5.5 Smart Healthcare:

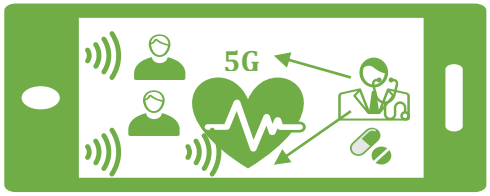


Figure: Smart Healthcare in today's world

One of the most important application of 5G for a smart city will be the implementation of mission critical healthcare services. Using 5G, medical services can be delivered via video conferencing to the patients situated at remote locations.

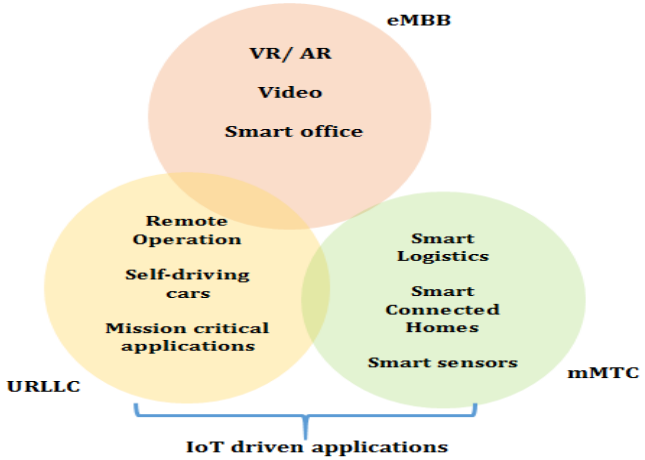
They can also result in delivery of surgery via robotic arm, utilizing low latency of 5G networks. Here, the speed and reliability of the internet will play a huge role in determining the effectiveness of the services rendered. 5G's need increases by the existence of wearable along with the need to have a long lasting battery life and security of those devices.

Ultimate goal can be defined as extending remote diagnosis of medical services combined with assisted robotic surgery. People in the low income groups will also have access to equitable health at much reduced costs.

5G is expected to come with a wave of technologies such as Ultra-Reliable Low latency Communications (URLLC) to make health communications more resilient and henceforth opening many new healthcare opportunities like remote surgery and diagnosis which makes use of haptic feedback. Telemedicine and e-Health will be addressing the need of scaling up the health services in rural areas by making use of wireless connectivity and delivering services such as remote consultation and surgery. In cities as well, 5G will enable the adoption of high-quality tele health via video conferencing, which will enable people to consult the medical practitioner on their smartphones or devices.5G will lead to an increased acceptance of digital health monitoring devices which will result in sharing of the vital signs of health with the doctor hence detecting chronic illness in time.

5G will enable new technology such as (OFDMA) orthogonal frequency division multiple access and MIMO (multiple inputs multiple outputs) will enhance the usage of the available spectrum ultimately leading to an increase in user throughput rates and coverage.

6. USE CASES of 5G TECHNOLOGY



For 5G, the biggest challenge can be said, to design a platform which can manifest such diverse requirement of these applications efficiently. If we take into account the physical layer of 5G, we will observe the presence of MIMO techniques which enhances the system capacity to great levels thereby resulting in dense deployment of a wide bandwidth.5G's vision is to put applications at the centre of its system design for which virtualization of the network and MEC (mobile edge computing) are key tools. mmW (millimetre) waves will also play a significant role in delivering IT services of very low latency and high reliability, as and when required. These waves have a spectrum ranging between 30-300Ghz and are used for wireless communication.
The use cases for 5G fall into three broad categories namely:

6.1 Enhanced Mobile Broadband:

It is referred to as eMBB. The target of this category remains the higher area capacity and higher peak data rates going up to 20 Gbps. It has 1ms latency in air interface. In order to achieve these specifications, enablers such as aggregating more chunks of spectrum, increasing the bandwidths at higher frequencies above 6Ghz, deploying denser cell topologies using MIMO, all are implemented.

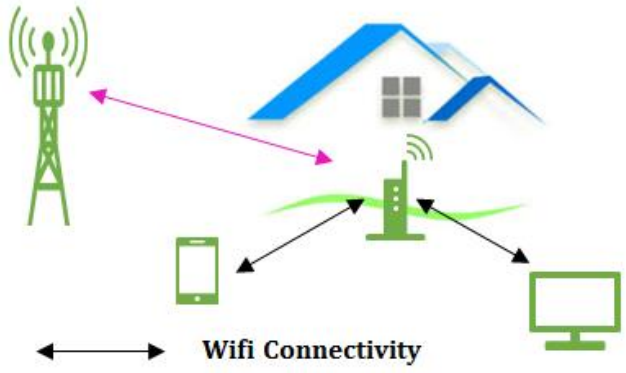


Fig: To the home 5G connectivity

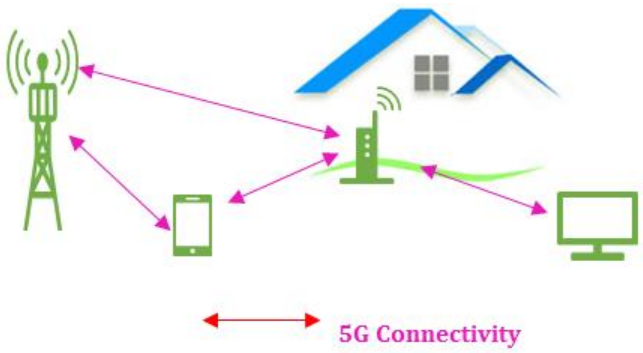


Fig: Inside home 5G connectivity

6.2 Ultra Reliable Low Latency Communications

It deals with the transmission of short data packets. The latency requirements for these applications are 5ms for an end to end process and a super high reliability of 99.999%. Many future applications will depend on services providing guaranteed latencies of 1ms or lesser. *Tele surgery and remote surgical consultation* will be one of them, where the entire procedure will be performed by surgeon, where hands will be replaced by robotic arms.

Another use case is Smart transportation and Industry automation; where industry control is automated by deployment of networks in factories with latency of 0.5 ms.

Additional possible applications of uRLLC can be Tactile Internet, augmented and virtual reality, fault detection and frequency and voltage control in smart grids V2X will be based on ultra-reliable services. URLLC use cases are covered by the Tactile Internet applications such as industrial automation or remotely controlling the vehicles over the networks. They require stringent fulfilment with regards to packet deliveries combined with end-2-end trip delay of 1ms, or lesser. Applications, which target industrial automation or autonomous driving, and running them as close as possible to the radio access points is strategy to meet the severe requirements of uRLLC applications in terms of latency and reliability.

6.3 Massie machine type communications

Aims to have a high device density of up to 200,000/km2 and low power requirement of up to 15 years battery life.

The applications under its purview range from smart city infrastructure which requires massive connected objects with sensors and actuators. Autonomous vehicle control and factory cell automation also features under its umbrella.

CONCLUSION

As the time approaches for 5G's commercial introduction in the year 2020, the idea of ubiquitous connectivity will drive towards the development of new use cases and applications. All the possible products surrounding us, from smartphones, to wearable, to machines, everything will be driven by 5G's prime requirement such as high reliability, low latency and connectivity services. Industries right from energy, health, media, transport, manufacturing, energy and other mission critical services will move on to incorporate 5G, as solution instead of looking at it as an option, to achieve improved efficiency. This paper touches upon the applications, which 5G will usher for achieving a connected life, in an ever connected city. The use cases also elaborate how 5G

will re-design the way, we function. To conclude, it will be expected of 5G to not only add colours to our needs but also develop flavours as the trio of time, technology and customer evolves.

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