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The Technologies of 5G: Opportunities, Applications and Challenges

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Abstract: 5G which stands for 5th Generation Mobile technology, is a groundbreaking technology that the world now witnesses in mobile telecommunications and which has proven to be twenty or more times faster than the existing 4G technology. New standard releases beyond 4G are already in progress by standardization bodies, but at this time implementation and rollout of systems compliant with 5G is still under way in some parts of the world. The goals of a 5G-based telecommunications network would ideally answer the challenges that a 4G model would present once it has entered widespread use. The innovative features of 5G in many ways can be employed to support governments, established companies, new ideas, business models and services that require continuous connections between multiple parties that may include enterprises, telecom providers, mobile operators, government regulators, infrastructure providers and much more. This research highlighted the idea behind 5G technologies, its interconnections with smart objects of Internet of things (IoT) as well as offerings it has gained from others like Blockchain technology. The design for system model of network architecture for 5G mobile systems is described including creating IP tunnels over IP interfaces obtained by connection to the terminal via the access technologies available to the terminal (i.e., mobile user). The economic impact and the contributions of 5G technology is vigorously highlighted while some of the challenges that is faced in designing, deploying and managing the technology is also probed.

Keywords: 5G Technology, Blockchain, Internet of things (IoT), Wireless Communication, Virtual Network, Mobile Broadband, Smart Grid

1. Introduction

Since the first breakthrough, the world has witness incredible changes and evolution in the communication realm. From using landlines between few users, the better part of world's population now enjoys mobile phones that are smart, in varieties and with multiple functionalities. These mobile handsets now keeps us connected across the world in so many ways and serve purpose in diverse human routines. The telecommunication sector has seen numbers of incredible improvements over the years from 1G to 2.5G to 3G, 4G and now 5G, each with substantial improved performance. With 2G and later generations of mobile communication, users access their electronic handheld devices with a level of call volumes and data transmission, but with 5G the level of control is even far more promising. 5G technology now offers data transmission in large volumes that is pushed over VOIP enables gadgets [1]. The leading and one of the most important motive that drives phone manufacturers into competition with other innovative rivals is the creation of best and latest technology. With the advent of 5G these possibilities are close to limitless.

Not only will it change the manner in which cellular services are offered worldwide, but with the down of 5G technology, a revolution in data transmission has just begun. The possibility of global cell phone is no longer a dream but a reality that is just around the corner. With this new technology communication between people will greatly enhance and altogether upgrade as localities from Japan can call and access UK's local phone. The world is going to witness an improved and accessible connectivity across the globe with the utilization of the technology and the gadgets it supports. With just an electronic gadget that resembles a 21st century Personal

Digital Assistant (PDA) [2] your office will now almost shrink into your smart phone.

With the advent of technology of wireless communication [3], the 5th generation mobile communication system otherwise 5G emerged at a timely moment and focused in making a historic mark at the face of information age. Swiftly, innovative market giants have recently developed several advanced 5G technologies to meet up with the requirements of numerous different applications. Nevertheless, before these technologies can be applied to practical systems, there is need for effective testing methodologies to evaluate them in comprehensive, real, flexible and rapid manner. As more developments of new 5G technologies continues to unveil so are the new challenges faced in their testing methods.

The fifth-generation of mobile communication system offers remarkable improvements in performance and progression as well as the new value chain it brought along. This research paper will highlight key aspects of 5G blockchain, its potency, the challenges associated with the technology and the applications offered in especially the IoT. As explain in Srinivasan's study [4], The Internet of Things (IoT) is another new paradigm which emerged almost in parallel to 5G and interconnects massive communication-capable heterogeneous smart objects. With the deployment of 5G technology, the dream behind IoT can now be fully realized, while its scope and applicability can even be broadened. Even though the application of 5G is still at its infant stage, there are still challenges in meeting with the requirements 5G-enabled-IoT use cases and this can be attributed to the fact that the current mobile networks as well as the IoT systems are based on centralized models. Among the innovative technologies that will emerge to help solve some of these inevitable challenges is the technology of Blockchain [5]. Concrete domains for applications, privacy issues, scalability, performance, financial benefits, are all some of the essential insight that requires attention when looking at the marriage between Blockchain with 5G and IoT.

This section will conclude by summarizing some important needs for the application of 5G technology so as to become an accepted revolution that is globally accessible. Not only does 5G technology increased maximum throughput but offers much more than the other generations of mobile communications techniques. Here are some few worth mentioning:

1) Offers multiple concurrent data transfer paths.
2) Consumes less power from batteries of connected electronic devices.
3) Provides higher data rates available at cell edge, better coverage and lower out age probability.
4) Provides a more secure; better cognitive radio/SDR Security [6].
5) It pushed the possibilities of World Wide wireless web (WWWW) [7].
6) Because of low infrastructure deployment cost, it offers a cheaper traffic fees.
7) It has around 1Gbps data rate in mobility.
8) Since human lives are largely surrounded by artificial sensors that are able to communicate with our smart phones, 5G offers even more applications that are coupled with Artificial Intelligence (AI).

2. 5G Network Architecture

Data-demanding devices like our smart mobile phones and fast processing computers drove mobile data traffic to grow substantially. System designers and researchers, more than ever, are challenged with developing even more sufficient and efficient network designs. This section will attempt to breakdown a simpler model architecture that supports 5G networks.

IP based model used for wireless as well as mobile network interoperability is the backbone for the system model when designing network architecture that supports the 5G mobile systems. Aside few autonomous, independent radio access technologies, user terminal is part of the new architecture that plays key important role. The network is seen with IP links to the internet world outside which are aided by radio access technologies that is within each of the user terminals. However, each of the Radio Access Technology (RAT) embedded in the mobile terminals has to maintain different radio interface in order to have the architecture functional [8]. Let's say we intend to access eight different RATs then within the mobile terminal we will need to have eight different access-specific interfaces, while, at the same time, all of them are active simultaneously. The radio access technologies are defined by the data-link and physical levels of the OSI and which provides internet access with further support from technologies like WLAN, 3G and WiMAX that have explicit support from quality of service (QoS) mechanisms [9, 10]. But then in the OSI model of today's communication world, the network layer or the IP (Internet Protocol) is just above these first two OSI-1 and OSI-2 layers and regardless of the radio access technologies it will be either IPv4 otherwise IPv6. For a fast application connection – sessions on the internet between servers and client applications will require proper routing of IP packets, thus the purpose of IP to ensure enough data control. For 5G networks, the routing of these packets should be done in line and in harmony with the policies of user.

Internet sockets serves as endpoints of channels for data communication flows within 5G network and it is through these sockets that application connections are actualized between clients and servers in the internet. For each one of these sockets across the internet is a unique combination of appropriate local transport communications port and local IP address, target appropriate communication port and target IP address, as well as type of transport protocol [11]. To flag the proper internet socket distinctively chosen by the client-server application, the use of internet protocol is necessary in order to establish target communication between client and server. The local IP address as well as the destination IP address should be fixed and unchanged in a situation where interoperability exists between heterogeneous networks or when there is vertical handover between respective radio infrastructure. Therefore, fixing these two parameters is essential because if

there is at least one mobile user at one end of such connection, the setup will ensure end-to-end handover transparency to the internet connection.

Routing to target destination and back ought to be unique and should use same path so as to sustain appropriate layout of the packets and also prevent or, at least reduce packets losses. In the other hand, when achieving connectivity with relevant radio access, each of the radio access technology available to the user is presented with appropriate IP interface. For each of the terminals' IP interface is categorized by its net mask, its IP address, and the parameters associated with routing IP packets across the network. The vertical handover otherwise change of access technology in regular inter-system handover would mean to change the local IP address [8]. Therefore, changing one or any of the parameters of a socket will mean to close that socket and open a new one or simply ending the connection and starting a new one. As 5G network infrastructure is evolving, experts pointed out that this approach is based on today's Internet communication and is not flexible. Later these experts would come up with a new level in order to solve this deficiency which will take care of the abstraction levels of network access technologies to higher layers of the protocol stack [12]. A layer that is of high importance in the new architecture of 5G network.

It was Kachhavay, Meenal G., and Ajay P. Thakare in [24] that first proposed additional architecture which introduces a control system in the functional architecture of the networks so as to enable the functions of the applied transparency and control or direct routing of packets through the most appropriate radio access technology. This new architecture provides not only packets routing based on defined policies but also a network abstraction functions which works in complete coordination with the user terminal. For determining service quality of each transmission technology, this control system has become an essential element of the network. According to Kachhavay, Meenal G., and Ajay P. Thakare, user on the Internet side of their proposed architecture, and as such represents an ideal system to test the qualitative characteristics of the access technologies, as well as to obtain a realistic picture regarding the quality that can be expected from applications of the user towards a given server in Internet (or peer).

Through the creation of IP tunnels over IP interfaces, network abstraction level is provided where the tunnels and interfaces are obtained when connecting to the terminal via the mobile user or rather the access technologies available to the terminal [13]. Policy Router which is a term that refer when, between user terminal and control system, tunnels are established to perform routing based on designed policies. This policy enables the client side to generate suitable number of tunnels that connects to the same number of radio access technologies, setting only a local IP address that formed with sockets for Internet communication between clients and servers. Policies where rules exchanges through virtual network layer protocol presides over the manner in which IP packets choose right tunnel and how they are routed via these tunnels. At the mobile terminal, it is possible to realize the targeted abstraction of the network to the client applications. Originating from the mobile terminal Virtual Network-level Protocol, the Policy Router are immediately initiated soon after establishing IP connectivity across the radio access technology. The lunching of tunnel connections while maintaining them denotes essential functionality of the virtual network level otherwise network level of abstraction [14].

5G technology, its architecture and infrastructure are evolving daily through improved support to meet up with the ever-demanding human thirst for technological advancement. Today, 5G technology is pushed to support advance human operations of modern era while allowing users of mobile phones to perform multiple incredible operations. According to [15], such technology has infrastructure that supports large volume data distribution in Gigabit and also provides 5G carrier distribution gateways with unparalleled maximum stability without delay. This amount of data transfer over the infrastructure is farfetched and more organize, more accurate and reliable. Aside the speed and reliability of 5G technology, the infrastructure also supports other technologies like available global connectivity, virtual private network, download and upload speed touching peak and much more.

3. Potential 5G Technologies

Wireless systems are already receiving substantial technologies as a result of various wireless research activities over the years and the theme for 5G environment is that of low-latency and high-speed data. According to Dubey, et al, the major impacts on 5G processing can be rounded to five key areas which are: Millimeter-wave communications, D2D, M2M, M-MIMO and Dense small deployment. Other areas with significant impact on the technology of 5G are: Network virtualization, the emergence of cloud radio access networks (C-RAN), new waveforms, carrier aggregation, efficient coding techniques, advanced coordinated multipoint (CoMP), and Multiple radio access technology (M-RAT). This section will summarize these technologies into five groups, judging from the impacts they have on the performance of 5G networks.

Dense Small Cell Deployment – In order to improve signal power as well as offload macrocells in 5G infrastructure, it is essential that dense small cell is deployed. As mobile traffic massively grow, small cells can offer cost-effective yet simple solution to such issues that may arise from the network capacity. These cells can be deployed either outdoors or indoors with limited cell radius that helps reuse the spectrum (i.e. spectral efficiency increase) as well as increase in network capacity (i.e. during increase in network resources). In traditional generations of communication, users continuously move from one small cell area coverage to the other, triggering a problem of significant increase in handoff rate thus creating unnecessary handovers. This problem can lead to increased handover failures and call drops since the mobile stations will have to move to and from many hotspots. In the 5G heterogenous networks, control/user plane (C/U plane) splitting is used to minimize handoff rate. This feature

enables mobile terminals to receive system information, issue access requests to base stations, and get assigned radio resources for high-rate data transmission at a different base station. Also macro base stations that provides signaling services for the whole area in a licensed, low frequency band is used in the heterogenous networks while the millimeter-wave small cells (phantom cells) is applied as it specializes in data resources for high-rate transmission along with a light control overhead and appropriate air interface.

Millimeter-wave Frequency Band – The favorable characteristics of propagation led most communication systems to operate below 3GHz in microwave band (MW) and for this reason MW band is a scarce resource. To address such bandwidth scarcity, the fifth-generation communication networks offers solution using simple logic; additional spectrum will be needed anytime there is more additional need for higher network capacity and connectivity. Through utilizing additional spectrum otherwise wider bandwidth and higher frequencies, nonetheless, mobile networks have significantly improved the quality of service (QoS). Therefore, in addressing bandwidth scarcity, 5G utilizes higher spectrum through millimeter-wave band because of its huge available bandwidth. Using Local Multipoint Distribution Service (LMDS), millimeter-wave band provides considerable amount of bandwidth at various frequencies. Millimeter-waves have atmospheric absorption, hardware limitations compared to MW and very different propagation conditions thus using larger antenna array and beamforming is employed to address these challenges. Actions that befits the trend of dense small cell deployment.

Massive MIMO (Massive Multiple Input Multiple Output) and Beamforming – M-MIMO technology which is an extension of MIMO is considered as one of the major keys to unlocking 5G user experiences. The system requires combinations of antenna expansion and complex algorithms. It is multifaceted yet MIMO has been used in wireless communications for a long time. It's common for both mobile devices and networks to have multiple antennas to enhance connectivity and offer better speeds and user experiences through M-MIMO. Massive MIMO expands beyond the legacy systems by adding a much higher number of antennas on the base station which helps to focus energy that brings drastic improvements in throughput and efficiency. Along with the increased number of antennas, both the network and mobile devices implement more complex designs to coordinate MIMO operations. Beamforming on the other hand can best be described as power concentration in a particular direction with large gain yet limited beam-width and both are key technologies for 5G systems. Massive MIMO is significantly capable of improving signal strength, which in turn yield better cell-edge performance and much higher cell throughput than the traditional 4G systems. Pilot orthogonality is optimized in M-MIMO without consuming network resources so as to address the issues caused by increase in number of antennas while sophisticated algorithm is used to enable accurate channel estimation in frequency division duplexing (FDD) as well as reduce signaling overhead. Also, successful marriage to pair millimeter-wave band with M-MIMO is employed to address the challenge of large-scale architecture that can house the physical size of M-MIMO.

Latency Reduction: Network latency can be explained as the time it takes a signal to complete a single, full transaction. 5G technology offers an extremely low latency rate, the delay between sending and receiving information. Latency dropped incredibly from 200 milliseconds (200ms) for 4G to 1 milliseconds (1ms) for 5G. latency reduction is crucially important not just for achieving high data rates but also serves in saving energy and long battery lifetimes. The latency for the traditional 4G technology is acceptable and perfect for most current applications but then 5G is unveiling new technologies cloud-based applications, augmented reality which the 4G latency cannot support, two-way real-time gaming, and tactile internet among others. To meetup with the design choices at all layers, 5G infrastructure should support 1ms latencies and lower.

Through device-to-device (D2D) communications and dense small cells, latency can also be reduced. D2D communications can handle the communication of two devices in close proximity without consuming network resources thus, it has capacity to handle local traffic efficiently. For applications that require low latency, this technology has offered appropriate option. Even though latency reduction is a success in 5G technology, there is still challenges like network integration, efficient proximity, and native support in network upgrades.

Spectral Efficiency improvement – More than ever before, smartphones, tablets and other gadgets are in demand for ultra-fast data speeds which is why spectral efficiency improvement is vital to 5G network. The spectral efficiency is increased when the modulation order is increased and this can be achieved through D2D communications, adopting later and efficient transmission waveforms, as well as M-MIMO. In such communication network, Inter Symbol Interference (ISI) is delinquently a problem that for recommended solution is through Orthogonal Frequency Division Multiplexing (OFDM). OFDM has potential way to combat multipath and ISI since it carries multiple carriers. Unlike the traditional way of sending the information on a single carrier, it divides the main stream, modulate each subframe on a different subcarrier frequency and transmit simultaneous subframes. 5G network requires the 5G waveforms to establish low latency, high spectral efficiency as well as complexity and limited cost. To achieve these, the technology employs the use of millimeter-wave band, dense small cell deployments and substantial influence as the physical layer uses the modulation format. Despite the advantages, the OFDM has its own drawbacks like its high peak-to-average-power ratio (PAPR) which decreases power amplifier efficiency.

The Internet of Things (IoT) and Mass Connectivity: With the advancement of technology, the number of human devices is falling behind the number of connected devices until most likely all devices with capacity of network connectivity will eventually get connected. Today machine-to-machine (M2M)

communication can get connection due to rise in mobile broadband availability. The 5G technology has proven its capacity to provide network access from anywhere as well as moving data access to the cloud. Unlike the traditional network, the technology offers reuse of network infrastructure through Network Function Virtualization (NFV) which enables some hardware components to run on cloud computing infrastructure. Also, the CoMP can be used to turn interference into useful signals. With the rise of broadband availability comes huge traffic advance from communications through billions of connected devices, the network can get congested. 5G technology uses dense small cell deployment, network densification and M-MIMO to enhance connectivity and increase capacity.

4. Potential Applications of 5G

This section will attempt to categorize the impacts of 5G technological contributions to all facets of global economy with sustainable economic benefits.

Massive Internet of Things (MIoT): With increased IoT applications 5G is already pushing traditional investments to boost their economies to larger scale which drives adoption and utilization in the vast sector. Beside the ability to operate within both licensed and unlicensed spectrum as well as its low power requirements, 5G do also provide more flexible and deeper coverage and in so doing, lowering cost within settings of MIoT [17]. Here are some the contributions 5G and general mobile technologies has provided to significantly addressed applications for MIoT.

Remote Monitoring – Predictive maintenance as well as improvements in incremental performance are largely the motivation behind industrial automation application in many different industries today. 5G technology was able to provide robust alternative to the traditional solutions that readily rely on wired technologies which are for both new and existing equipment. Inhospitable environments, physical monitoring, leaks explosions and other safety risks can be prevented through pervasive sensing. This feature helps reduce downtime as well as increase efficiency and output.

Smart agriculture – Monitoring soil chemical composition and moisture level through specialized sensors is now possible as 5G provides more connected sensor technologies in general agriculture. This market in itself is gaining more acceptance recently and its largely due to availability and drop in price for low-power wide-area networks (LPWAN). The overall effect will be replacing manual labor with improved farm operational efficiency through various processes like growing and harvesting scheduling, optimized watering and feeding scheduling, and generally improved reporting and accountability on movements of farm produce. Clearly the technology has wide range of applications within agriculture but it is not strictly MIoT. The market is going to be used in various capacities like monitoring crops through sophisticated cameras and sensor packages in real time. Leveraging its EMBB capabilities, 5G is expected to provide so much more meaningful benefits in productivity and efficiency for agricultural activities.

Asset Tracking – 5G technology offers urban areas with large population the ability to monitor the distribution of assets and/or people. Just as practiced in machine-to-machine communication (M2M) markets today, 5G technology offers applications capable of tracking high value goods as well as people in real-time. Evidently, the growth of this market has been limited due to the high cost of connectivity. But with increased deployment of 5G the market is going to see further low cost and low power, deep coverage, and 3GPP standard technology. With these improvements the world is going to witness improved employee safety, minimized losses due to improved efficiency in asset tracking, and generally optimized logistics within various range of industries. Assets tracking is already much needed as modern-day shopping is increasingly turning to online retailers, 5G offers ability to, dynamically, track extensive range of goods in transit.

Smart Cities – This sector is broad and even offers more opportunities for wide range of applications and new potential businesses with the increasing interest for cellular operators. Security, lightening, physical infrastructure, energy/utilities, transport mobility, and environmental monitoring are some of the key technology applications provided in smart cities. Smart cities applications are expected to extensively leverage the existing carrier infrastructure by replacing traditional mode deploying dedicated propriety network thus improving service quality and lowering costs. It is worthy to note that in reality, applications that rely on MCS capabilities of 5G and EMBB are likely to be categorized under smart cities. This can be seen in instances like management and control of dynamic traffic, application that can greatly influence many of the MCS features of 5G. similarly, the EMBB features of 5G offers the ability to utilize both fixed cameras and security drones for safe city solution. According to economic impact assessments by IHS Markit, smart cities will be at relatively early stage of development even with the wide but not pervasive applications deployments for quite some years to come.

Physical Infrastructure – from smaller structures like elevators to bigger ones like bridges and overpasses, connected sensors is combined with MIoT feature of the technology to improve monitoring of physical structures generally. Such application is that of improving tourism experience where in large cities where AR is used on visitors through geotagging. In many countries today, wireless sensors are deployed through 5G to monitor physical structures like train tracks, roads, overpasses, bridges, etc. in real-time so as to prioritize maintenance and repairs.

Energy / Utility Monitoring – 5G technology is out to improve economies of scale by connecting devices through unified platform that has the potential to address wide range of gaps in the historical utility market which has been heavily regulated and fragmented. In the traditional (2G/3G) cellular, Zigbee, LPWAN and general proprietary radio technologies, 5G is updating wide range of technologies to utilize smart meter deployments thereby saving cost through the single technology platform. The technology has the ability to incorporate almost all of its rival competitions since it allows

both licensed and unlicensed spectrum, private networks as well as radio hopping/mesh thereby producing smart materials that are more accessible to far more utilities worldwide.

Smart Homes – Unreliability in home devices, high latency, difficulties in device set-up and many other consumer complaints can now be addressed through 5G technology's revolutionizing of smart home devices. Consumers can now have incredible experience in especially configuration and set-ups as the smart home markets is turning completely autonomous. Consumers can now enjoy streamlined user experience as well as secure devices since it is now possible to leverage on cellular connectivity via 5G without having to rely on consumer's knowledge on to correctly configure firewalls, home WLAN or other smart household devices.

Beacons and connected shoppers – Today brick-and-mortar shopping experience is enhanced through the use of beacons and smartphones to the current retail technology. The technology offered by 5G is capable of supporting interaction between consumers in a more dynamic way to not only retailers but for products/brands as well. There is need for more robust wireless connectivity for this market to grow in parallel as it is gaining more adhesion in industrial applications. Traditionally, beacons use Bluetooth for service deployment but with low power variant in 5G, there is potential to fortunately leverage.

Enhanced Mobile Broadband (EMBB): Value creation and adoption in 5G economy is been driven by two important key sections of EMBB. The ability of the network to extend cellular coverage to far broader range across structures like shopping malls, office buildings, large venues, industrial parks etc. is one key facet. The other is the capacity improvement that enables the network to handle large volumes of data from significantly large number of devices in especially localized areas. The use of broadband applications on mobile network is driven by lower cost-per-bit for data transmission and this is possible through these enhancements to the network which aids more efficient data transmission [16]. Here are summaries of some important potency of the broadband network.

Extending Mobile Computing – it is now possible for 5G smartphones to carryout productive task traditionally undertaken by computers when provided with easily accessible cloud computing combined with larger wireless data pipes. Even though is an inclination that has been in existence since the advent of digital mobile technology, 5G technology has unlocked far much opportunities for smartphones. When using the technology today, without regard to what form of device is used, it is capable of providing robust mobile computing experience.

Enhanced Outdoor Wireless Broadband – One of the remarkable features of the 5G technology is its ability to provide mass connectivity and large control capacity. In especially densely populated urban areas, the technology provides improved coverage and the capacity to handle numerous connected devices. By providing internet access to mass transportation systems, users can now work online while on transit time or on their way to work. Service provision is so powerful that application like infotainment to cars or streaming high-definition (HD) are amongst the few outdoor events that will be common in highly populated urban areas.

In summary, one of the benefits here will be to encourage people in the urban areas to use mass transit because of the services they provide thus reducing traffic congestion to possibly a bearable minimum. As promised, the technology is already improving coverage as well as the capacity for live events in amazing ways. Like the Indoor wireless broadband coverage, the beneficial services provided by 5G infrastructure are neither industrial nor application specific and therefore expected to have wide range of positive impact in the industrial sector as well.

Enhanced Indoor Wireless Broadband coverage – Provides consistent coverage even with complex and expensive commercial WLAN and small cell deployments, thus suppressing the challenges faced by many buildings and other complex structures. Wireless broadband coverage is employed to improve cellular coverage in structures of varying nature so that a range of applications and devices within can be supported. The benefits are not just industrial nor application specific, yet the impact is expected to be derived heavily by industrial sector.

Fixed Wireless Broadband deployments – 5G has already proven to offer far superior consumer experience than what is provided by varying LTE networks today. Some of the benefits are; making it possible for carriers to offer improved services without rise in investment cost, providing little/no-fixed infrastructure but high wireless penetration for underserved rural areas and emerging markets. For dense urban areas or developed markets this was used to address less mile deployments as lower cost alternative to fiber or where it is impractical to use wired solution.

Education / Training – In both academia and training enterprise users, the technology is providing unparalleled solutions that include underserved or remote areas. Through these benefits, societies can now possess the capability to training as well as general and specialized education for an expanded number of students significantly.

Enterprise teamwork/ collaboration – the need to collaborate using wider range of enterprise communication gears has deepened as global firms and cooperates heavily rely on virtual as well as remote teams to achieve many of their routine objectives. With 5G, tactile internet, video telepresence, AR/VR as well as streaming ultra-high definition (UHD) is coming to fruition therefore enhancing the existing communication among enterprises, encouraging dynamic interactions between team members in the process and/or client/end-users in other use cases. This has massively impacted the ICT industry and with the spread of the technology, affecting wide range of professional service industries.

Augmented and Virtual Reality (AR/VR) – To enable heavy computational AR/VR user interactions, there is need for multiple Gb per second speeds as well as latency reduction and also the need for 5G interface in order to support dynamic AR content at reasonable scale. These means that field support can be provided while telehealth services can be rendered to

remote places via technology. To achieve this, smart glasses are used to mobilize AR/VR to provide, without additional hardware, the virtual display of such remote surface or environment. In the other hand, highly trained and experienced workers can support much larger field support teams while centrally located and thereby reducing the cost of field support workers itself. Social service organizations, construction or manufacturing companies, or much larger industries could highly benefit from this feature of 5G support.

Enhanced Digital Signage – With digital signage becoming more popular and 5G significantly increasing and improving UHD and AR support, the combination provides support for variety of applications from retail experience to smart cities. Just as in online shopping, the retail market can now struggle to compete in the same environment thanks to these technological enhancements. Other services that have come to rely on digital signage includes hospitality and services industries, transportation, real estate and home improvement, as well as smart cities.

Mission Critical Services (MCS): In mobile technology, MCS now represents new market opportunity where 5G supports applications that require ultra-low latency connectivity with strong security and availability as well as high reliability. Critical applications where failure is not an option like remote operation of complex automation and autonomous vehicles can now enjoy ultra-reliable connection through the wireless technology [18]. This section will highlight some of the opportunities that high bandwidth, secure wireless solution 5G technology has provided to many critical applications requiring.

Remote Patient Monitoring / telehealth – Traditionally, healthcare delivery relies on disparate connection strategies between monitoring equipment, healthcare providers and the patient. 5G implementation is already working towards eliminating such reliance and with other technologies like HD image quality they are already increasing the use of applications like wound care, dermatology, advanced telemedicine (like AR/VR and remote surgery and treatment using robotics), prevalent access to imaging and medical records as well as remote clinical care. Using tools to minimize risk of abuse and potential improvement of pain management can be achievable by health workers through the use of wearables to perform controlled substance management that leads to higher implementation, standard connectivity platforms and lower costs. Healthcare services and medical professionals will now have faster, easier file sharing/management, more secure access to patients' records on remote devices at any location, thereby reducing in-hospital stays and increasing the use of outpatient monitoring. generally, this will go a long way to reducing both healthcare cost and improving patient comfort medically.

Drones – Today, many industries like the security, agriculture, commercial transport, manufacturing, construction among others widely use commercial drones for various potential benefits. With improved drone technology, their many benefits for industrial and commercial applications has made corporations and governments to increase demand for unmanned Arial vehicles (UAVs). As the 5G technology keeps improving, drones will now have wide range of application benefits spanning from enhanced functionality and effectiveness, cost reduction, minimize risk and time in industries, while used for patrolling, police reconnaissance, riot control, ant-terrorism, tracking, search and rescue, weather monitoring, traffic regulation, exploration surveys as well as general safety by the government. For safe and reliable operation of commercial fleets of drones, it is essential that HIS Markit included it in the MCS segment due to high reliability, availability and low latency. In practice, 5G has moved to critically address the handle of generated large volume of data through enhanced mobile broadband capabilities as the need for sensors and HD cameras packages on drones increases.

Autonomous Vehicles – Even before the advent of 5G, automobile industries are well on track to provide more sophisticated advanced driver assistance systems (ADAS) and enable all forms of extra-vehicle communication (V2X). The MCS features of 5G that provides high reliability, ultra-low latency and high availability has pushed the automation further into reality while other EMBB features supports many data intensive to complement the market. Today fully autonomous vehicles are no longer a dream since the network also has the ability to receive and offload large amounts of mapping, sensor, and delay tolerant or less time critical data, all so they no longer rely on human operator. Traditionally, the train systems had to transmit signals through scientific, industrial, and medical (ISM) frequency bands or narrow frequency bands, which was unable to meet the requirements of the train autonomous circumambulate system (TACS) [19]. With availability of 5G network, the (TACS) will be capable of operating urban rail transit system in a safer, more efficient, and more economical mode. Thus, with the fifth-generation communication technology, alternative technologies no longer have to dedicate entire infrastructure to just automotive applications thereby reducing cost of investment in the market. In general, the ability to safely operate equipment for extended periods at a lower operational cost is greatly significant, and will have a transformative impact on relatively many industries.

Industrial Automation – Today 5G network is gradually moving to address the traditional reliance on wired connectivity on most infrastructure on the factory floor by providing secure wireless solution, high bandwidth, and in the process creating augmenting workers, smarter factories and mobility of assets on factory floors. Hands-free machine monitoring and control as well as real-time close loop communication which supports manufacturing process and remote control of equipment are two areas of benefits mission-critical 5G has to offer. Therefore, the overall equipment effectiveness (OEE) is maximized with such connectivity between robots, mobile equipment and machines generally. With sufficient improvements and connectivity in 5G network, factory employees can be able to use wearables and gesture control for remote operations, allowing them to safely monitor production line performance through

hands-free machine monitoring and control.

Smart Grid – In some developed nations downtime is penalized while uptime is heavily regulated in many, the low latency feature of 5G networks is essential to set standards in this regard as well. 5G technology is already working towards providing cheaper, more abundant low-latency electrical and electronics appliances and thus unlocking the huge scenario for automated real-time grid switching. This will provide a critical leap towards creating a more essential and super-reliable grid that will significantly impact economy of nations.

5. Current Challenges in 5G Deployment

The aim behind 5G design and deployment is to enable digital transformation that will build a better-connected world. While on the road to transition to a new generation of wireless network, telecom operators have to face challenges exposed to many factors causing a delay in the 5G rollout. Aiming at 5G network deployment with identification of 5G network deployment challenges to strike out these barriers can help operators be prepared beforehand, deal with difficult situations and accelerate large-scale deployment of 5G networks that will potentially impact consumers' daily lives and businesses' productivity and service revenues. This section will highlight some of the challenges and possible solutions that is been faced when it comes to the deployment of 5G network globally.

Need for skilled professionals – In order to execute deployment tasks, firms are required to make sure that their power distribution networks and fiber solutions with cell towers are in place that can easily accommodate 100-400 Gbps devices made feasible by the new telecoms policy. As telecom companies are planning to rollout 5G as quickly as possible, they are in need for skilled engineers to implement the new-age technology. However, current workforce at most enterprises is not enough capable to perform and adding to it is the scarcity of such skilled talent in the market which is like searching a pearl in the ocean of talent pool. All this makes it a critical 5G network deployment challenge for operators in their execution of 5G deployment but can overcome this by preparing their 5G workforce with reskilling programs like online/offline courses, certifications involving around 5G technologies courses to upgrade their skills with the required skillset and become efficient in handling network deployment workloads.

Approach for 5G network deployment – First of all, operators need to have a strategy for 5G network deployment. Secondly, after deciding on the strategy, their approach towards implementing this strategy decides the future of deployment process. Based on the spectrum networks they have, and the densification and coverage they need, operators develop their deployment model and approach that is ultimately required for targeting specific 5G use cases. Further, 5G network deployment challenges include use of mmWave frequencies and 5G small cells in a huge amount and will require a new approach to 5G network deployment and its regulatory standards.

5G networks testing is forever in demand – Network demand for better connections and high data throughput, low latency and better video streaming requires of 5G has increased the demand for testing 5G networks with several 5G technical KPIs. Thus, it becomes really important to test 5G network parameters to meet 5G technical requirements. This is a 5G challenge and possible solutions include deploying RantCell app on mass scale to field engineers to perform 5G drive test based on various testing cases. It is compatible with most of the Android smartphones (supported on latest 5G devices only) available in the market and reduces your manual efforts and testing time by 30%. Additionally, data is uploaded on RantCell in real-time thus saving time in post-processing.

Managing expenses involved in 5G network deployment – 5G deployment is not so easy as it seems. From spectrum bands to cell sites, equipment's like cell tower, fiber cables to skilled labor, moreover, commercializing charges demanded by the regulators before making it available to users. Costs are involved in each and every process of 5G installation and is a challenge for most of the operators. It needs to be strategized and planned before investing. Step-by-step cost investment can save them from spilling out unwanted money reserving it for satisfying critical needs.

Less market of 5G-enabled devices – There is still not much of 5G devices available in the market when benchmarked with non-5G phones. This may be because of the complex 5G architecture and shortage of engineers equipped in this cutting-edge technology to crack down the codes and set up 5G-enabled devices. This attributes to 5G challenges and opportunities for the chip makers to design chips that can support 5G devices with advanced technologies.

Regulations cause a hinderance in 5G network deployment – 5G will be developed at a different pace with few common and varied features across countries. This means that some technical parameters are common, but it cannot be said for rules and regulations as every country has their own set of norms and is one of the critical 5G network deployment challenges. Mobile network operators have to work in accordance with the standards developed for 5G network technology in the area where they are about to deliver 5G mobile network services to users. Hence, it is essential to recognize and understand 5G regulations in the country where they are planning to deploy the 5G wireless networks and develop their roadmap to 5G deployment accordingly. For instance, in 2018, the Canadian government had remarked on 'Revisions to the 3,500MHz spectrum band in order to accommodate flexible use and initial consultation on changes done on 3,800 MHz spectrum band' for making these available for 5G services in every regions of Canada.

Frequency band and availability of spectrum challenges – New use cases will emerge with the transition from 4G to 5G technology demanding for high frequency bands. However, spectrum is being considered as a critical resource due to its availability and cost depending on which operators will have to develop a robust business use case. The type and amount of spectrum network operators have or are able to purchase in

future spectrum auction will decide the feasibility of 5G network, and new 5G features and challenges that comes along with the selected spectrum bands [20].

Use of multiple small antennas and base stations – 5G involves higher frequency radio waves and they can be targeted. The biggest 5G implementation challenge with 5G antennas is its limited range irrespective of the fact that it can handle more users and data and can be beamed out over shorter distances [21]. Even though antennas and base stations used in such situations are smaller, it is likely that these would have to be installed on homes or buildings. Extra repeaters will be required to install in cities for proliferation of waves to a wider distance while also maintaining uniform speeds in densely populated areas. For now, providers will continue using spectrum bands with low frequency to cover wider areas until the 5G network matures.

It is expected that modems and Wi-Fi routers may be altered with 5G small cells and base stations or other hardware to facilitate 5G connections for personal and professional purpose. Moreover, expansion of 5G network access to rural areas will be as much of a challenge as it was with 4G LTE network.

Convoluted architecture makes it more critical – 5G promises to meet diversified service requirements with a single network infrastructure to support Radio Access Network (RAN) and core networks. Network Functions Virtualization (NFV) concept is being widely used in 5G networks for network slicing, creating intelligence networks at the edge, multiple radio networks / connections and many more [22]. Nevertheless, such new techniques require a new operating model which is different and complex from its previous versions and need proper knowledge to develop the architecture that can serve network requirements.

5G network deployment challenges with security and privacy concerns – Though 5G seems to be the frontrunner and bring new innovations in the ecosystem, there are some security and privacy issues that is attached with the new-age technology. In terms of customer point of view, privacy concern is encapsulated around identity, location tracking and personal data. Previous technology, 4G network is surmounted on a region with wide coverage and signals are broadcasted from a single cell tower. But this is not the case with 5G networks and has a smaller coverage area with signals unable to penetrate as good as 4G technology

As a result, 5G wireless networks works well in the presence of smaller antennas and base stations located indoors and outdoors. The information on this 5G cell tower / antenna can reveal a mobile user's location and even what building a user is present as the user communicates with the antenna each time. This data can lead to threats like semantic information attacks to cause harm. Access point algorithms in 5G mobile networks can also leak location data. Thus, more 5G antennas permit for precise location tracking of users inside and outside. Further, International Mobile Subscriber Identity (IMSI) is prone to reveal identity of mobile users [23]. In this regard, mobile network carriers and network consortium should take responsibility to provide users with digital safety and protect their confidential data with the implementation of cutting-edge security solutions.

6. Conclusion

The concept of hand held electronic devices is going to be revolutionized with the widespread of 5G. Now all the services and applications are going to be accessed by single IP as telephony, gaming and many other multimedia applications. The paper starts with introducing 5G technology along with the crucial benefits it accompanied for both individuals, cooperates, as well as governments. To further clarify this emerging technology, the paper went ahead to describe the implementation of 5G network using various infrastructure along with their needed purpose. It is resolved that 5G network is very fast and reliable where the 5^{th} wireless mobile internet networks are real wireless world that is supported by LAS-CDMA (Large Area Synchronized Code-Division Multiple Access), OFDM (Orthogonal frequency-division multiplexing), MCCDMA (Multi-Carrier Code Division Multiple Access), UWB (Ultra-wideband), Network-LMDS (Local Multipoint Distribution Service), and IPv6. The research also showed how fifth-generation technologies offer tremendous data capabilities, unrestricted call volumes and infinite data broadcast together within latest mobile operating system. The research discussed some of the challenges associated with 5G technology and as they are addressed consistently, the current fifth generation technology should make an important difference and add more services and benefits to the world over its predecessors. As explained, it is going to be a more intelligent technology that interconnects the entire world without much limits.

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