EAST WEST UNIVERSITY

Title of Thesis

Study on 5G

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5 September 2016

Letter of Transmittal

5 September 2016

To
Dr. Mohammad Arifuzzaman
Assistant Professor
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Subject: Submission of Thesis Report on 5G (ETE-498)

Dear Sir,

I am pleased to let you know that I have completed my Thesis program on 5G. The attaché contain of the Thesis report that has prepared for your evaluation and consideration. The Thesis has given me a great opportunity to work with the networking system closely and also gave me the opportunity to apply the theoretical knowledge in real life situation which I have acquired since last four years from you and the other faculty of EWU, which would be a great help for me in future.

I am very grateful to you for your guidance throughout the Thesis period, which helped me a lot to acquire knowledge.

Thanking You.

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Declaration

We hereby declare that, this Thesis was done under ETE 498 and has not been submitted elsewhere for requirement of any degree or diploma or for any purpose except for publication.

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Acceptance

We hereby declare that this thesis is from the student's own work and best effort of us, and all other source of information used have been acknowledge. This thesis has been submitted with our approval.

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Acknowledgement

Firstly our most heartfelt gratitude goes to our beloved parents for their endless support, continuous inspiration, great contribution and perfect guidance from the beginning to end. We owe our thankfulness to our supervisor **Dr. Mohammad Arifuzzaman** and also thank **Sarwar Jahan** for their skilled, almost direction, encouragement and care to prepare our self. Our sincere gratefulness for the faculty of Electronics and Communications Engineering whose friendly attitude and enthusiastic support that has given us for four years. We are very grateful for the motivation and stimulation from our good friends and seniors. We also thank the researchers for their works that help us to learn and implement the Determination of average acoustic speed in underwater Environment.

Abstract

The purpose of this report is to take a step toward clarifying what ‘5G’ really means in the technological sense, by: reducing 5G to its fundamental core (including acknowledging what it is arguably not); expanding on some of the use case scenarios that 5G might enable; and discussing conceivable implications for operators in terms of network infrastructure and commercial opportunities. This can only be achieved by framing the discussion around 5G in a broader context alongside existing network technologies and those currently in development.

Table of Content

Chapter: 1

Introduction

Objectives of this report

In summary, there are three key questions that this report will address:

1. What is (and what isn't) 5G?
2. What are the real 5G use cases?
3. What are the implications of 5G for mobile operators?

Notes on terminology

GSMA Intelligence's definition of 4G includes the following network technologies: LTE, TD-LTE, AXGP, WiMAX, LTE-A, TD-LTE-A, LTE with VoLTE and WiMAX 2.

Due to the commonality of operator definitions classifying LTE and TD-LTE as 4G technologies, we follow this convention. This differs from the ITU's strict definition of transitional versus true 4G. Also, where we use the term 'LTE' in this document it incorporates all LTE variants (LTE, TD-LTE, AXGP, LTE-A and TD-LTE-A). Finally, for simplicity we do not consider WiMAX in this analysis, so where the term '4G' is used it incorporates all LTE variants but not WiMAX (a transitional 4G technology) or WiMAX 2 (a true 4G technology). Therefore for the purpose of this report the terms '4G' and 'LTE' are interchangeable.

Executive summary

5G offers enormous potential for both consumers and industry

As well as the prospect of being considerably faster than existing technologies, 5G holds the promise of applications with high social and economic value, leading to a 'hyper-connected society' in which mobile will play an ever more important role in people's lives.

The GSMA will work for its members and with its partners to shape 5G

As the association representing the mobile industry, the GSMA will play a significant role in shaping the strategic, commercial and regulatory development of the 5G ecosystem. This will include areas such as the definition of roaming and interconnect in 5G, and the identification and alignment of suitable spectrum bands. Once a stable definition of 5G is reached, the GSMA will work with its members to identify and develop commercially viable 5G applications. This paper focuses on 5G as it has developed so far, and the areas of technological innovation needed to deliver the 5G vision.

There are currently two definitions of 5G

Discussion around 5G falls broadly into two schools of thought: a service-led view which sees 5G as a consolidation of 2G, 3G, 4G, Wi-fi and other innovations providing far greater coverage and always-on reliability; and a second view driven by a step change in data speed and order of magnitude reduction in end-to-end latency. However, these definitions are often discussed together, resulting in sometimes contradictory requirements.

Sub-1ms latency and >1 Gbps bandwidth require a true generational shift

Some of the requirements identified for 5G can be enabled by 4G or other networks. The technical requirements that necessitate a true generational shift are sub-1ms latency and >1 Gbps downlink speed, and only services that demand at least one of these would be considered 5G use cases under both definitions.

Achieving sub-1ms latency is a hugely exciting challenge that will define 5G

Delivering 1ms latency over a large scale network will be challenging, and we may see this condition relaxed. If this were to happen, some of the potential 5G services identified may no longer be possible and the second view of 5G would become less clear. This paper looks at some of the challenges that must be overcome to deliver 1ms latency.

At the same time 4G will continue to grow and evolve

Technologies such as NFV/SDN and HetNets are already being deployed by operators and will continue to enable the move towards the hyper-connected society alongside developments in 5G. Considerable potential also remains for increasing 4G adoption in many countries, and we expect 4G network infrastructure to account for much of the $1.7 trillion the world's mobile operators will invest between now and 2020. Operators will continue to focus on generating a return on investment from their 4G (and 3G) networks by developing new services and tariffing models that make most efficient use of them.

Chapter: 2

Why 5G

One of the main benefits of 5G technology over 4G will not be its speed of delivery – which admittedly could be between 10Gbps and 100Gbps – but the latency. At present, 4G is capable of between 40ms and 60ms, which is low-latency but not enough to provide real-time response. Multiplayer gaming, for example, requires a lower latency than that to ensure that when you hit a button, the remote server responds instantly.

Another example was given to us by EE's Sutton, who said that 5G's prospective ultra-low-latency could range between 1ms and 10ms. This would allow, he said, a spectator in a football stadium to watch a live stream of an alternative camera angle of the action that matches what is going on the pitch ahead with no perceivable delay.

The capacity is an important factor too. With the Internet of Things becoming more and more important over time, where gadgets and objects employ smart, connected features that they have never had before, the strain on bandwidth will continue to grow.

Initial ideas behind 5G is that an infrastructure will be in place to avoid that. It will be more adaptive to user's needs and demands and therefore able to allocate more or less bandwidth based on the application.

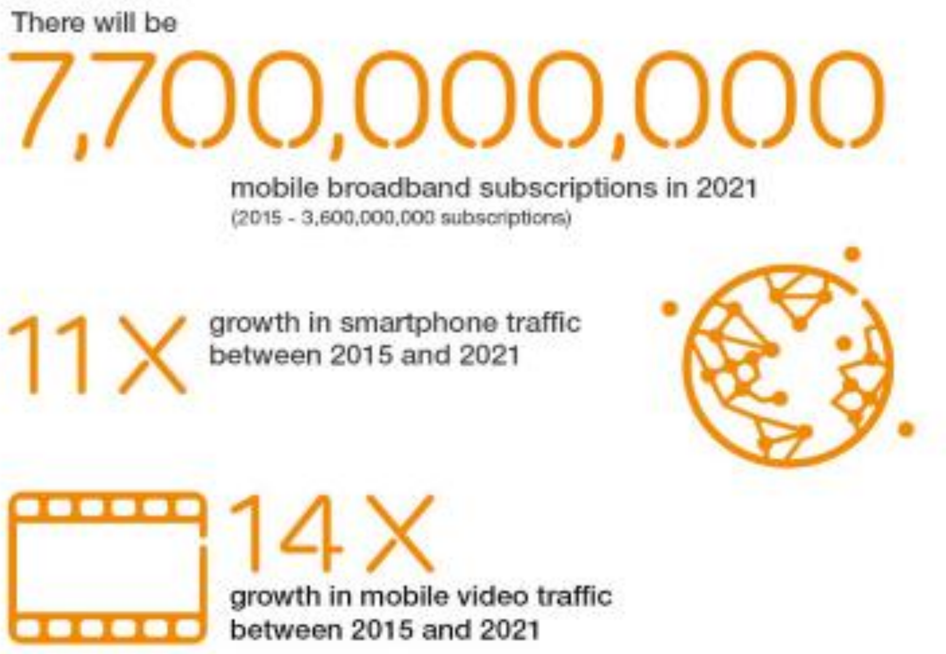

Figure 1: The future of 5g

The Internet of Things

By the year 2020, it is predicted by analysts that each person in the UK will own and use 27 internet connected devices. There will be 50 billion connected devices worldwide. These can range from existing technology, such as smartphones, tablets and smart watches, to fridges, cars, augmented reality specs and even smart clothes. Some of these will require significant data to be shifted back and forth, while others might just need tiny packets of information sent and received. The 5G system itself will understand and recognize this and allocate bandwidth respectively, thereby not putting unnecessary strain on individual connection points.

The work has already begun for 4G implementation, but will become even more vital to a 5G future. As part of a “heterogeneous network", the points, or cells, will be used for LTE-A and the technology will be increased and refined to adapt to 5G too. Cells will automatically talk to each device to provide the best and most efficient service no matter where the user is.

Larger cells will be used in the same way as they are now, with broad coverage, but urban areas, for example, will also be covered by multiple smaller cells, fitted in lampposts, on the roofs of shops and homes, and even inside bricks in new buildings. Each of these will ensure that the connection will be regulated and seemingly standard across the board.

Algorithms will even know how fast a device is travelling, so can adapt to which cell it is connected to. For example, a connected car might require connection to a macro-cell, such as a large network mast, in order to maintain its connection without having to re-establish continuously over distance, while a person’s smartphone can connect to smaller cells with less area coverage as the next cell can be picked up easily and automatically in enough time to prevent the user noticing.

4K video streaming

Capacity will also be important for the future of video streaming. By 2030, EE predicts that 76 per cent of its data traffic will be used streaming video. And a large amount of that will be at 4K or even 8K resolutions.

The data rates of 4G can cope with that – it is expected that a 14Mbps connection should cope with streaming 4K video, 18Mbps for 8K – but if everybody was to do that at the same time, like statistics suggest, the network would have difficulty keeping up with demand.

Other, non-consumer sectors will also be served better with 5G, but as EE itself admits, some of the applications of a low-latency, high capacity network are yet to even be thought of. You kind-of need the technology in place to figure out much of what to do with it.

And finally, another major benefit to 5G technology is that standards and which spectrum bands will be reserved for its deployment will have been agreed globally, by members during the World Radio communications Conferences. Your 5G phone in the UK, for example, will work on the exact same system and spectrum band as in the US, South Korea and wherever else.

Well, that’s the idea anyway.

When is it coming?

It is expected that standards for 5G will be agreed upon and set by 2020 and that business applications for the technology will start to appear in 2022/23. It could take another two to three years for consumer access to the tech.

It is expected to utilize higher radio frequencies than currently, as well as existing spectrum held by mobile networks. But it is in just the fundamental research stage at present.

Development will continue on 4G technologies before then, with much ground yet to be covered. “This is the decade for 4G,” said Professor Sutton. “The next for 5G.

“4G can take us to 1Gbps,” he added. “5G is everything beyond that.”

What is 5G

The 5G technology is expected to provide a new (much wider than the previous one) frequency bands along with the wider spectral bandwidth per frequency channel. As of now, the predecessors (generations) mobile technologies have evidenced substantial increase in peak bitrate. Then — how is 5G different from the previous one (especially 4G)? The answer is — it is not only the increase in bitrate made 5G distinct from the 4G, but rather 5G is also advanced in terms of

- High increased peak bit rate
- Larger data volume per unit area (i.e. high system spectral efficiency)
- High capacity to allow more devices connectivity concurrently and instantaneously
- Lower battery consumption
- Better connectivity irrespective of the geographic region, in which you are
- Larger number of supporting devices
- Lower cost of infrastructural development
- Higher reliability of the communications

As researchers say, with the wide range of bandwidth radio channels, it is able to support the speed up to 10 Gbps, the 5G *WiFi* technology will offer contiguous and consistent coverage − “wider area mobility in true sense.”

Evolution beyond mobile internet

From analogue through to LTE, each generation of mobile technology has been motivated by the need to meet a requirement identified between that technology and its predecessor (see Table 1). For example, the transition from 2G to 3G was expected to enable mobile internet on consumer devices, but whilst it did add data connectivity, it was not until 3.5G that a giant leap in terms of consumer experience occurred, as the combination of mobile broadband networks and smartphones brought about a significantly enhanced mobile internet experience which has eventually led to the app-centric interface we see today. From email and social media through music and video streaming to controlling your home appliances from anywhere in the world, mobile broadband has brought enormous benefits and has fundamentally changed the lives of many people through services provided both by operators and third party players.

Generation	Primary services	Key differentiator	Weakness (addressed by subsequent generation)
1G	Analogue phone calls	Mobility	Poor spectral efficiency, major security issues
2G	Digital phone calls and messaging	Secure, mass adoption	Limited data rates – difficult to support demand for internet/e-mail
3G	Phone calls, messaging, data	Better internet experience	Real performance failed to match hype, failure of WAP for internet access
3.5G	Phone calls, messaging, broadband data	Broadband internet, applications	Tied to legacy, mobile specific architecture and protocols
4G	All-IP services (including voice, messaging)	Faster broadband internet, lower latency	?

More recently, the transition from 3.5G to 4G services has offered users access to considerably faster data speeds and lower latency rates, and therefore the way that people access and use the internet on mobile devices continues to change dramatically. Across the world operators are typically reporting that 4G customers consume around double the monthly amount of data of non-4G users, and in some cases three times as much. An increased level of video streaming by customers on 4G networks is often cited by operators as a major contributing factor to this.

The Internet of Things (IoT) has also been discussed as a key differentiator for 4G, but in reality the challenge of providing low power, low frequency networks to meet the demand for widespread M2M deployment is not specific to 4G or indeed 5G. As Table 1 suggests, it is currently unclear what the opportunity or 'weakness' that 5G should address is.

Two views of 5G exist today:

View1 –Thehyper-connectedvision:

In this view of 5G, mobile operators would create a blend of pre-existing technologies covering 2G, 3G, 4G, Wi-fi and others to allow higher coverage and availability, and higher network density in terms of cells and devices, with the key differentiator being greater connectivity as an enabler for Machine-to-Machine (M2M) services and the Internet of Things (IoT). This vision may include a new radio technology to enable low power, low throughput field devices with long duty cycles of ten years or more.

View 2 – Next-generation radio access technology:

This is more of the traditional 'generation-defining' view, with specific targets for data rates and latency being identified, such that new radio interfaces can be assessed against such criteria. This in turn makes for a clear demarcation between a technology that meets the criteria for 5G, and another which does not.

Both of these approaches are important for the progression of the industry, but they are distinct sets of requirements associated with specific new services. However, the two views described are regularly taken as a single set and hence requirements from both the hyper-connected view and the next-generation radio access technology view are grouped together. This problem is compounded when additional requirements are also included that are broader and independent of technology generation.

5G technology requirements

As a result of this blending of requirements, many of the industry initiatives that have progressed with work on 5G (see Appendix A) identify a set of eight requirements:

- 1-10Gbps connections to end points in the field (i.e. not theoretical maximum)
- 1 millisecond end-to-end round trip delay (latency)
- 1000x bandwidth per unit area
- 10-100x number of connected devices
- (Perception of) 99.999% availability
- (Perception of) 100% coverage
- 90% reduction in network energy usage
- Up to ten year battery life for low power, machine-type devices

Because these requirements are specified from different perspectives, they do not make an entirely coherent list – it is difficult to conceive of a new technology that could meet all of these conditions simultaneously.

Equally, whilst these eight requirements are often presented as a single list, no use case, service or application has been identifed that requires all eight performance attributes across an entire network simultaneously. Indeed some of the requirements are not linked to use cases or services, but are instead aspirational statements of how networks should be built, independent of service or technology – no use case needs a network to be significantly cheaper, but every operator would like to pay less to build and run their network. It is more likely that various combinations of a subset of the overall list of requirements.

Finally, while important in their own right, six of these requirements are not generation-defining attributes. These are considered below:

Perceived 99.999% availability and 100% geographical coverage:

These are not use case drivers, nor technical issues, but economic and business case decisions. 99.999% availability and 100% coverage are achievable using any existing technology, and could be achieved by any network operator. Operators decide where to place cells based on the cost to prepare the site to establish a cell to cover a specific area balanced against the benefit of the cell providing coverage for a specific geographic area. This in turn makes certain cell sites and coverage areas - such as rural areas and indoor coverage - the subject of difficult business decisions.

Whilst a new generation of mobile network technology may shift the values that go in to the business model that determines cell viability, achieving 100% coverage and 99.999% availability will remain a business decision rather than a technical objective. Conversely, if 100% coverage and 99.999% availability were to be a 5G 'qualifying criteria', no network would achieve 5G status until such time as 100% coverage and 99.999% availability were achieved.

Connection density (1000x bandwidth per unit area, 10-100x number of connections):

These essentially amount to 'cumulative' requirements i.e. requirements to be met by networks that include 5G as an incremental technology, but also require continued support of pre-existing generations of network technology. The support of 10-100 times the number of connections is dependent upon a range of technologies working together, including 2G, 3G, 4G, Wi-fi, Bluetooth and other complementary technologies. The addition of 5G on top of this ecosystem should not be seen as an end solution, but just one additional piece of a wider evolution to enable connectivity of machines. The Internet of Things (IoT) has already begun to gain significant momentum, independent of the arrival of 5G.

Similarly, the requirement for 1,000 times bandwidth per unit area is not dependent upon 5G, but is the cumulative effect of more devices connecting with higher bandwidths for longer durations. Whilst a 5G network may well add a new impetus to progression in this area, the rollout of LTE is already having a transformational effect on the amount of bandwidth being consumed within any specific area, and this will increase over the period until the advent of 5G. The expansion of Wi-fi and integration of Wi-fi networks with cellular will also be key in supporting greater data density rates.

Meeting both of these requirements will have significant implications for OPEX on backhaul and power, since each cell or hotspot must be powered and all of the additional traffic being generated must be backhauled.

Reduction in network energy usage and improving battery life:

The reduction of power consumption by networks and devices is fundamentally important to the economic and ecological sustainability of the industry. A general industry principle for minimising power usage in network and terminal equipment should pervade all generations of technology, and is recognised as an ecological goal as well as having significant positive impact on the OPEX associated with running a network. At present it is not clear how a new generation of technology with higher bandwidths being deployed as an overlay (rather than a replacement) on top of all pre-existing network equipment could result in a net reduction in power consumption.

Some use cases for M2M require the connected device in the field to lie dormant for extended periods of time. It is important that innovation in how these devices are powered and the leanness of the signaling they use when becoming active and connected is pursued. However, this requirement is juxtaposed with 5G headline requirements on data rate – what is required for mass sensor networks is very occasional connectivity with minimal throughput and signaling load. Work to develop such technology predates the current 5G requirements and is already being pursued in Standards bodies.

These six requirements should be and are being pursued by the industry today using a range of techniques (some of which are covered later in the paper) but these amount to evolutions of existing network technology and topology or opportunities enabled by changing hardware characteristics and capabilities. These will in turn open business opportunities for operators and third parties. However, none of these business opportunities exist today – they are constrained by limitations greatly governed by economics, and much of these six requirements are motivated by improving the economic viability of those opportunities, rather than filling technological gaps that explicitly prohibit these opportunities, regardless of the amount they might cost to enable.

Thus in the strictest terms of measurable network deliverables which could enable revolutionary new use case scenarios, the potential attributes that would be unique to 5G are limited to sub-1ms latency and >1 Gbps downlink speed

Chapter: 3

Evolution of Mobile Wireless Communication

1. First generation (Analog):

First-generation mobile systems used analog transmission for speech services. In 1979, the first cellular system in the world became operational by Nippon Telephone and Telegraph (NTT) in Tokyo, Japan. Two years later, the cellular epoch reached Europe. In the United States, the Advanced Mobile Phone System (AMPS) was launched in 1982. The two most popular analogue systems were Nordic Mobile Telephones (NMT) and Total Access Communication Systems (TACS). The system was allocated a 40-MHz bandwidth within the 800 to 900MHz frequency range by the Federal Communications Commission (FCC) for AMPS. In fact, the smallest reuse factor that would fulfill the 18db signal-to-interference ratio (SIR) using 120-degree directional antennas was found to be 7. Hence, a 7-cell reuse pattern was adopted for AMPS. Transmissions from the base stations to mobiles occur over the forward channel using frequencies between 869-894MHz.The reverse channel is used for transmissions from mobiles to base station, using frequencies between 824-849 MHz AMPS and TACS use the frequency modulation (FM) technique for radio transmission. Traffic is multiplexed onto an FDMA (frequency division multiple access) system.

2. Second Generation (Digital):

Second-generation (2G) mobile systems were introduced in the end of 1980s. Compared to first-generation systems, second-generation (2G) systems use digital multiple access technology, such as TDMA (time division multiple access) and CDMA (code division multiple access). Consequently, compared with first-generation systems, higher spectrum efficiency, better data services, and more advanced roaming were offered by 2Gsystems. In the United States, there were three lines of development in second-generation digital cellular systems. The first digital system, introduced in 1991, was the IS-54 (North America TDMA Digital Cellular), of which a new version supporting additional services (IS-136) was introduced in 1996.Meanwhile, IS-95 (CDMAOne) was deployed in 1993. 2G communication is generally associated with global system for mobile (GSM) services; 2.5G is usually identified as being fueled by general packet radio service (GPRS) along with GSM.

3. Third Generation (WCDMA in UMTS, CDMA2000 & TD-SCDMA):

3G uses Wide Brand Wireless Network with which clarity is increased. 3G telecommunication networks support services that provide an information transfer rate of at least 2Mbps.In EDGE, high-volume movement of data was possible, but still the packet transfer on the air-interface behaves like a circuit switches call. Thus part of this packet connection efficiency is lost in the circuit switch environment. Moreover, the standards for developing the networks were different for different parts of the world. Hence, it was decided to have a network which provides services independent of the technology platform and whose network design standards are same globally. Thus, 3G was born. 3G is not one standard; it is a family of standards which can all work together. An organization called 3rd Generation Partnership Project (3GPP) has continued the work by defining a mobile system that fulfills the IMT-2000 standard. In Europe, it was called UMTS (Universal Terrestrial Mobile System), which is ETSI-driven. IMT2000 is the ITU-T name for the third generation system, while cdma2000 is the name of the American 3G variant. WCDMA is the air-interface technology for the UMTS. The main components includes BS (Base Station) or nod B, RNC (Radio Network Controller), apart from WMSC (Wideband CDMA Mobile Switching Centre) and SGSN/GGSN. 3G networks enable network operators to offer users a wider range of more advanced services while achieving greater network capacity through improve

Spectral efficiency. The first commercial 3G network was launched by NTT Do Co Mo in Japan branded FOMA,based on W-CDMA technology on October 1, 2001.

4. Fourth Generation (All-IP)

The first successful field trial for 4G was conducted in Tokyo, Japan on June 23rd, 2005. NTT Do Co Mowas successful in achieving 1Gbps real time packet transmission in the downlink at a moving speed of about20km/h. To use 4G services, multimode user terminals should be able to select the target wireless systems. Incurrent GSM systems, base stations periodically broadcast signaling messages for service subscription to mobile stations. However, this process becomes complicated in 4G heterogeneous systems because of the differences in wireless technologies and access protocols. To provide wireless services at anytime and anywhere, terminal mobility is a must in 4G infrastructure. Terminal mobility allows mobile clients to roam across geographic boundaries of wireless networks. There are two main issues in terminal mobility: location management and handoff management. With location management, the system tracks and locates a mobile terminal for possible connection. Location management involves handling all the information about the roaming terminals, such as original and current located cells, authentication information etc. On the other hand, handoff management maintains ongoing communications when the terminal roams. Mobile IPv6 (MIPv6) is a standardized IP-based mobility protocol for IPv6 wireless systems. In this design, each terminal has an IPv6 home address. Whenever the terminal moves outside the local network, the home address becomes invalid, and the terminal obtains a newIPv6 address (called a care-of address) in the visited network. The design and optimization of upcoming radio access techniques and a further evolution of the existing system, the Third Generation Partnership Project (3GPP) had laid down the foundations of the future Long Term Evolution (LTE) advanced standards-the

3GPPcandidate for 4G. The target values of peak spectrum efficiency for LTE Advanced systems were set to30bps/Hz and 15 Bps/Hz in downlink and uplink transmission respectively. Apart from the multiple access schemes, enhanced multiple-input multiple-output (MIMO) channel transmission techniques and extensive coordination among multiple cell sites called coordinated multipoint (CoMP) transmission/reception were accepted as the key techniques for LTE.

5. Fifth Generation (WiMAX, WWWW, RAT)

The 5G (Fifth Generation Mobile and Wireless Networks) can be a complete wireless communication without limitation, which bring us perfect real world wireless – World Wide Wireless Web (WWWW). 5G denotes the next major phase of mobile telecommunications standards beyond the 4G/IMT-Advanced standards. At present, 5G is not a term officially used for any particular specification or in any official document yet made public by telecommunication companies or standardization bodies such as 3GPP, WiMaxForum, or ITU-R. Each new release will further enhance system performance and add new capabilities with new application areas. Some of the additional applications, benefiting from mobile connectivity are home automation, smart transportation, security, and e-books. IEEE 802.16 is a series of Wireless Broadband standards authorized by the Institute of Electrical and Electronics Engineers (IEEE). It has been commercialized under the name “WiMAX” (from “Worldwide Interoperability for Microwave Access") by the WiMAX Forum industry alliance. IEEE 802.16standardizes the air interface and related functions associated with wireless local loop. 5G mobile technology has changed the means to use cell phones within very high bandwidth. User never experienced ever before such a high value technology. The 5G technologies include all type of advanced features which make 5Gmobile technology most powerful and in huge demand in near future. For children rocking fun Bluetooth technology and Pico nets has become available in market. Users can also hook their 5G technology cell phones with their Laptop to get broadband internet access. 5G technology includes camera, MP3 recording, video player, large phone memory, dialing speed, audio player and much more one can never imagine. In fifth generation, Network Architecture consists of a user terminal (which has a crucial role in the new architecture) and a number of independent, autonomous radio access technologies (RAT). 5G mobile system is all-IPbased model for wireless and mobile networks interoperability. Within each of the terminals, each of the radio access technologies is seen as the I Plink to the outside Internet world. Comparative account of all generations (1G-5G) has been depicted in Table 2.

Table 2: COMPARISON OF ALL GENERATIONS OF MOBILE TECHNOLOGIES

Technology ⇨ Feature ⇩	1G	2G	3G	4G	5G
Start/ Deployment	1970 – 1980	1990 – 2004	2004-2010	Now	Soon (probably 2020)
Data Bandwidth	2kbps	64kbps	2Mbps	1 Gbps	Higher than 1Gbps
Technology	Analog Cellular Technology	Digital Cellular Technology	CDMA 2000 (1xRTT, EVDO) UMTS, EDGE	Wi-Max LTE Wi-Fi	WWWW(coming soon)
Service	Mobile Telephony (Voice)	Digital voice, SMS, Higher capacity packetized data	Integrated high quality audio, video and data	Dynamic Information access, Wearable devices	Dynamic Information access, Wearable devices with AI Capabilities
Multiplexing	FDMA	TDMA, CDMA	CDMA	CDMA	CDMA
Switching	Circuit	Circuit, Packet	Packet	All Packet	All Packet
Core Network	PSTN	PSTN	Packet N/W	Internet	Internet

Table 2: COMPARISON OF ALL GENERATIONS OF MOBILE TECHNOLOGIES

Chapter: 4

Potential 5G use cases

Imagining the mobile services of the next decade

As with each preceding generation, the rate of adoption of 5G and the ability of operators to monetise it will be a direct function of the new and unique use cases it unlocks. Thus the key questions around 5G for operators are essentially:

What could users do on a network which meets the 5G requirements listed above that is not currently possible on an already existing network?

How could these potential services be profitable?

Figure 1 illustrates the latency and bandwidth/data rate requirements of the various use cases which have been discussed in the context of 5G to date. These potential 5G use cases and their associated network requirements are described below.

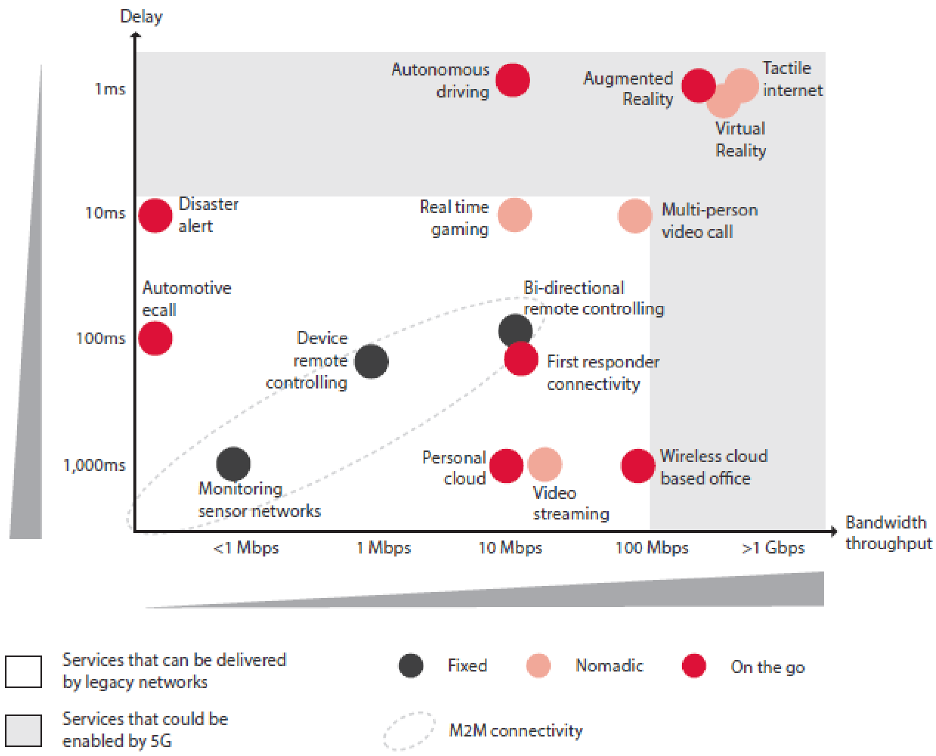

Figure 1: Bandwidth and latency requirements of potential 5G use cases

Virtual Reality/Augmented Reality/Immersive or Tactile Internet

These technologies have a number of potential use cases in both entertainment (e.g. gaming) and also more practical scenarios such as manufacturing or medicine, and could extend to many wearable technologies. For example, an operation could be performed by a robot that is remotely controlled by a surgeon on the other side of the world. This type of application would require both high bandwidth and low latency beyond the capabilities of LTE, and therefore has the potential to be a key business model for 5G networks.

However, it should be pointed out that VR/AR systems are very much in their infancy and their development will be largely dependent on advances in a host of other technologies such as motion sensors and heads up display (HUD). It remains to be seen whether these applications could become profitable businesses for operators in the future.

Autonomous driving/Connectedcars

Enabling vehicles to communicate with the outside world could result in considerably more efficient and safer use of existing road infrastructure. If all of the vehicles on a road were connected to a network incorporating a traffic management system, they could potentially travel at much higher speeds and within greater proximity of each other without risk of accident - with fully-autonomous cars further reducing the potential for human error.

While such systems would not require high bandwidth, providing data with a command-response time close to zero would be crucial for their safe operation, and thus such applications clearly require the 1 millisecond delay time provided in the 5G specification. In addition a fully ‘driverless’ car would need to be driverless in all geographies, and hence would require full road network coverage with 100% reliability to be a viable proposition.

Wireless cloud-based office/Multi-person videoconferencing

High bandwidth data networks have the potential to make the concept of a wireless cloud office a reality, with vast amounts of data storage capacity sufficient to make such systems ubiquitous. However, these applications are already in existence and their requirements are being met by existing 4G networks. While demand for cloud services will only increase, as now they will not require particularly low latencies and therefore can continue to be provided by current technologies or those already in development. While multi-person video calling - another potential business application - has a requirement for lower latency, this can likely be met by existing 4G technology.

Machine-to-machine connectivity (M2M)

M2M is already used in a vast range of applications but the possibilities for its usage are almost endless, and our forecasts predict that the number of cellular M2M connections worldwide will grow from 250 million this year to between 1 billion and 2 billion by 2020, dependent on the extent to which the industry and its regulators are able to establish the necessary frameworks to fully take advantage of the cellular M2M opportunity.

Typical M2M applications can be found in ‘connected home’ systems (e.g. smart meters, smart thermostats, smoke detectors), vehicle telemetric systems (a field which overlaps with Connected cars above), consumer electronics and healthcare monitoring. Yet the vast majority of M2M systems transmit very low levels of data and the data transmitted is seldom time-critical. Many currently operate on 2G networks or can be integrated with the IP Multimedia Subsystem (IMS) – so at present the business case for M2M that can be attached to 5G is not immediately obvious.

A true requirement for a generational shift?

Thus many of the services that have been put forward as potential ‘killer apps’ for 5G do not require a generational shift in technology, and could be provided via existing network technologies. Only applications that require at least one of the key 5G technical requirements – sub-1ms latency and >1 Gbps downlink speed – can be considered true next generational business cases.

Of these two requirements, reducing latency to sub-1ms levels may provide the greatest technical challenge (see page 12). Meanwhile, as discussed in more detail in Appendix B, operators are already making a considerable amount of progress in increasing the data speeds of their existing networks by adopting LTE-A technologies (see Figure 2). While it is important to note that although many of the use cases and services discussed in this section do not strictly require 5G, they could offer an enhanced user experience on a 5G network. However this amounts to an incremental benefit that is more difficult to market than a genuine new service, and not a core component of any 5G business case.

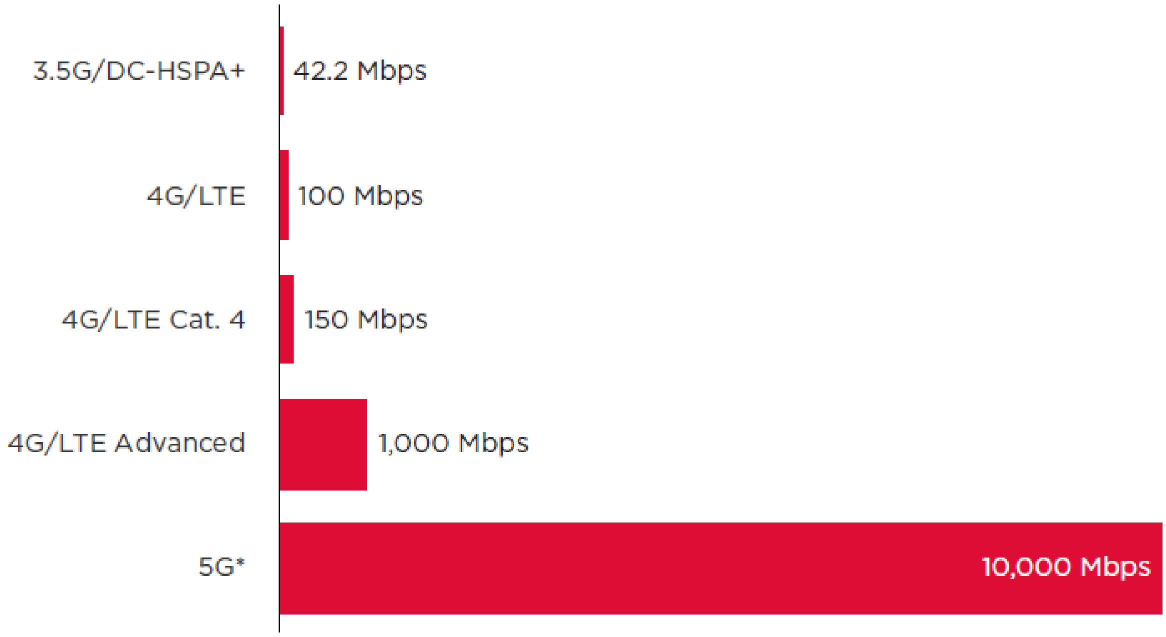

Figure 3: Maximum theoretical downlink speed by technology generation, Mbp
(*10 Gbps is the minimum theoretical upper limit speed specified for 5G)

Chapter: 5

5G – Architecture

Architecture of 5G is highly advanced, its network elements and various terminals are characteristically upgraded to afford a new situation. Likewise, service providers can implement the advance technology to adopt the value-added services easily.

However, upgradeability is based upon cognitive radio technology that includes various significant features such as ability of devices to identify their geographical location as well as weather, temperature, etc. Cognitive radio technology acts as a transceiver (beam) that perceptively can catch and respond radio signals in its operating environment. Further, it promptly distinguishes the changes in its environment and hence respond accordingly to provide uninterrupted quality service.

Applications and Services with various requirements (M2M/IoT, Content Delivery, Tactile)

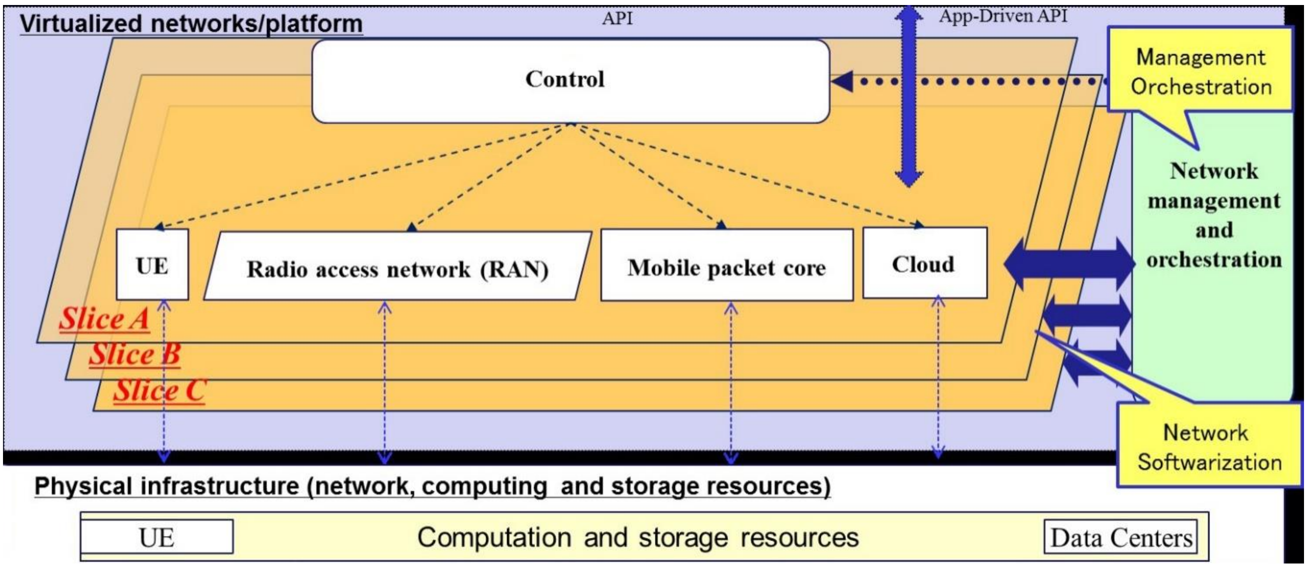

Figure 4:Architecture of 5G

Architecture of 5G

As shown in the following image, the system model of 5G is entirely **IP** based model designed for the wireless and mobile networks.

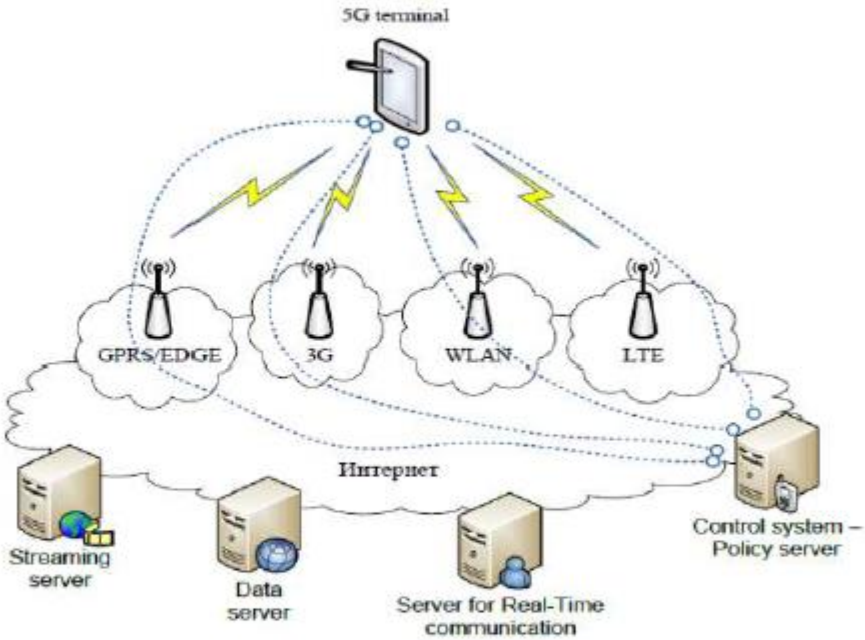

Figure 5: The system model of 5G

The system comprising of a main user terminal and then a number of independent and autonomous radio access technologies. Each of the radio technologies is considered as the IP link for the outside internet world. The IP technology is designed exclusively to ensure sufficient control data for appropriate routing of IP packets related to a certain application connections i.e. sessions between client applications and servers somewhere on the Internet. Moreover, to make accessible routing of packets should be fixed in accordance with the given policies of the user (as shown in the image given next page).

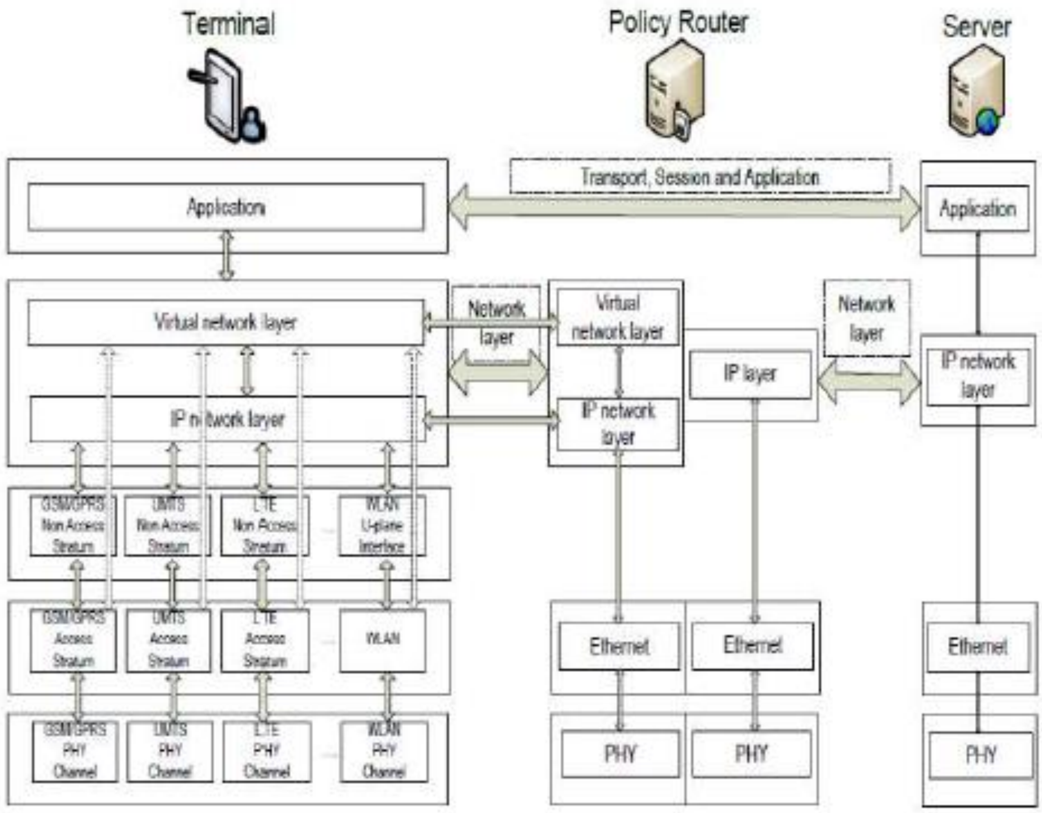

Figure 7: accessible routing of packets policies of the user

The Master Core Technology

As shown in the Figure 5, the 5G MasterCore is convergence point for the other technologies, which have their own impact on existing wireless network. Interestingly, its design facilitates MasterCore to get operated into parallel multimode including all IP network mode and 5G network mode. In this mode (as shown in the image given below), it controls all network technologies of RAN and Different Access Networks (DAT). Since, the technology is compatible and manages all the new deployments (based on 5G), it is more efficient, less complicated, and more powerful.

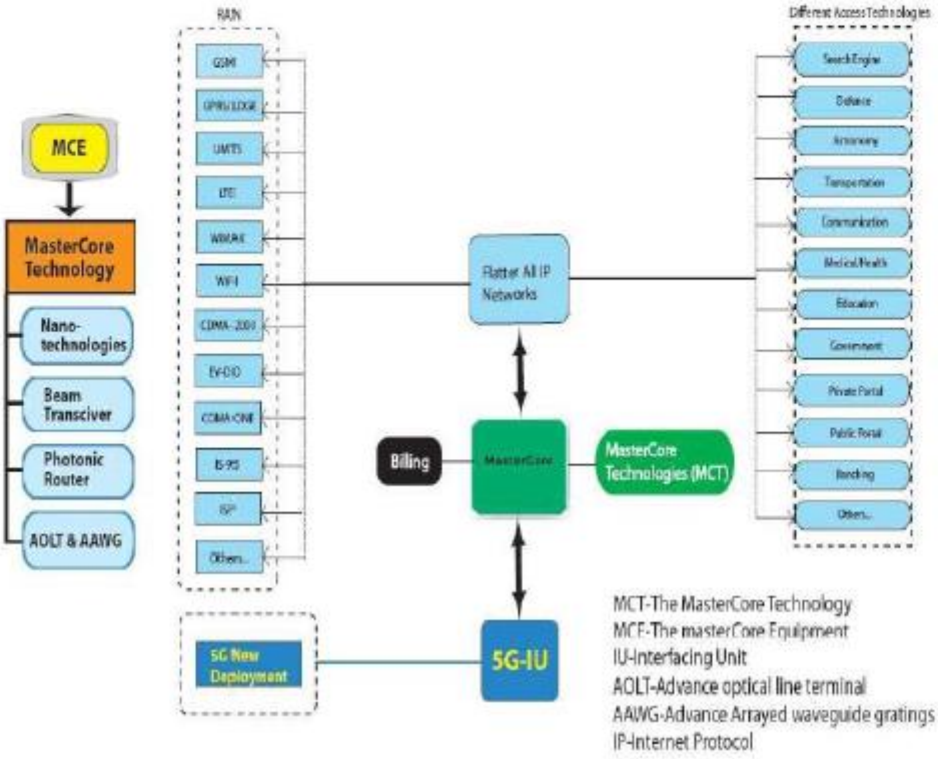

Figure 8: The Master Core Technology

Surprisingly, any service mode can be opened under 5G New Deployment Mode as World Combination Service Mode (WCSM). WCSM is a wonderful feature of this technology; for example, if a professor writes on the white board in a country – it can be displayed on another white board in any other part of the world besides conversation and video. Further, a new services can be easily added through parallel multimode service.

5G - Time Period Required

Normally, it is expected that the time period required for the 5G technology development and its implementation is about five years more from now (by 2020). But to becoming usable for the common people in developing countries, it could be even more.

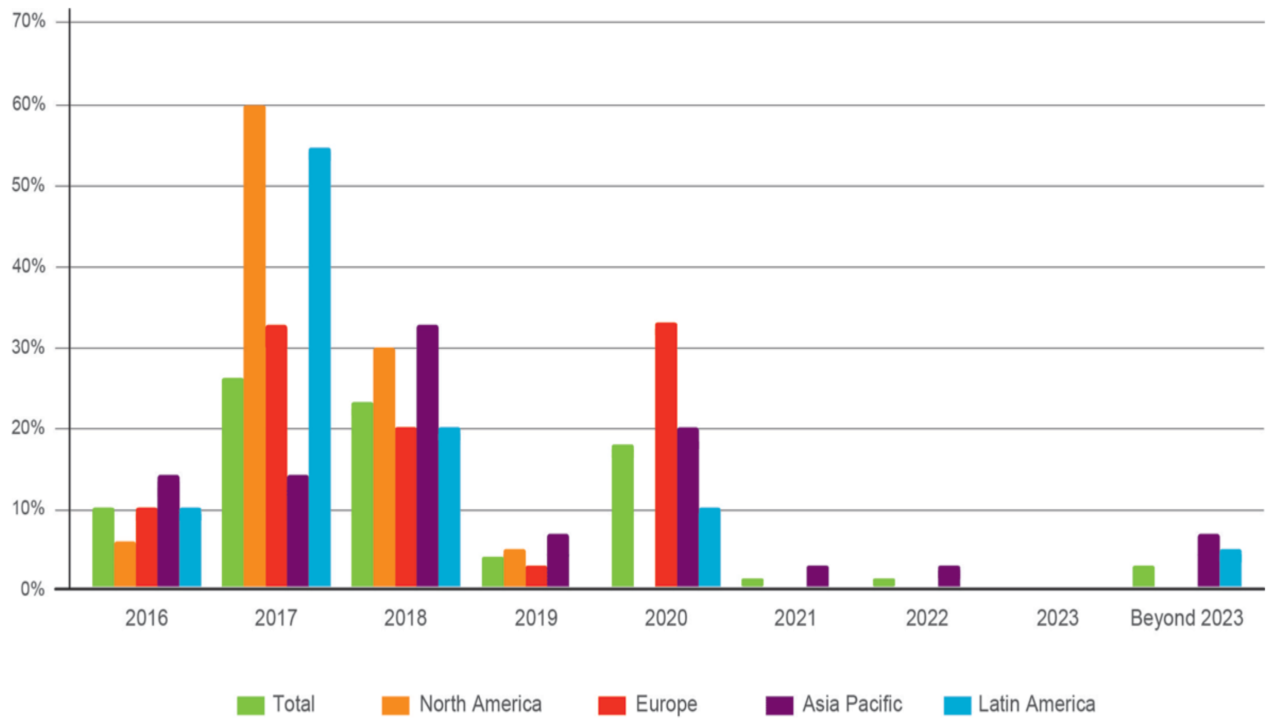

Figure 9: 5g trials

Expected Time Length

By considering the multiple utility and various fashionable salient features, researchers are anticipating that this technology will be in use until 2040s.

Chapter: 6

5G – Applications

5G technology is adorned with many as well as distinct features, which applicability is useful for a wide range people irrespective of their purposes (as shown in the *mweb* image).

Figure 10: A wide range people irrespective of their purposes

Applications of 5G

Some of the significant applications are −

- It will make unified global standard for all.
- Network availability will be everywhere and will facilitate people to use their computer and such kind of mobile devices anywhere anytime.
- Because of the IPv6 technology, visiting care of mobile IP address will be assigned as per the connected network and geographical position.
- Its application will make world real Wi Fi zone.
- Its cognitive radio technology will facilitate different version of radio technologies to share the same spectrum efficiently.

- Its application will facilitate people to avail radio signal at higher altitude as well.

5G – Advancement

Application of 5G is very much equivalent to accomplishment of dream. It is integrated with beyond the limit advance features in comparison to the previous technologies.

Figure 11: Equivalent application of dream

Advanced Features

In comparison to previous radio technologies, 5G has following advancement −

- Practically possible to avail the super speed i.e. 1 to 10 Gbps.
- Latency will be 1 millisecond (end-to-end round trip).
- 1,000x bandwidth per unit area.
- Feasibility to connect 10 to 100 number of devices.
- Worldwide coverage.
- About 90% reduction in network energy usage.
- Battery life will be much longer.
- Whole world will be in *wi fi* zone.

Hardware

- Uses UWB Networks with Higher BW at Low Energy
- BW is 4000 Mbps(400x Faster)
- Uses Smart Antenna
- Uses CDMA

Software

- Will be Single Unified Standard of Different Wireless Networks
- Unified IP & Seamless Combination of Broadband
- Software Defines Radio, Encryption, Flexibility, Anti-Virus

Chapter: 7

5G - Advantages & Disadvantages

5th generation technology offers a wide range of features, which are beneficial for all group of people including, students, professionals (doctors, engineers, teachers, governing bodies, administrative bodies, etc.) and even for a common man.

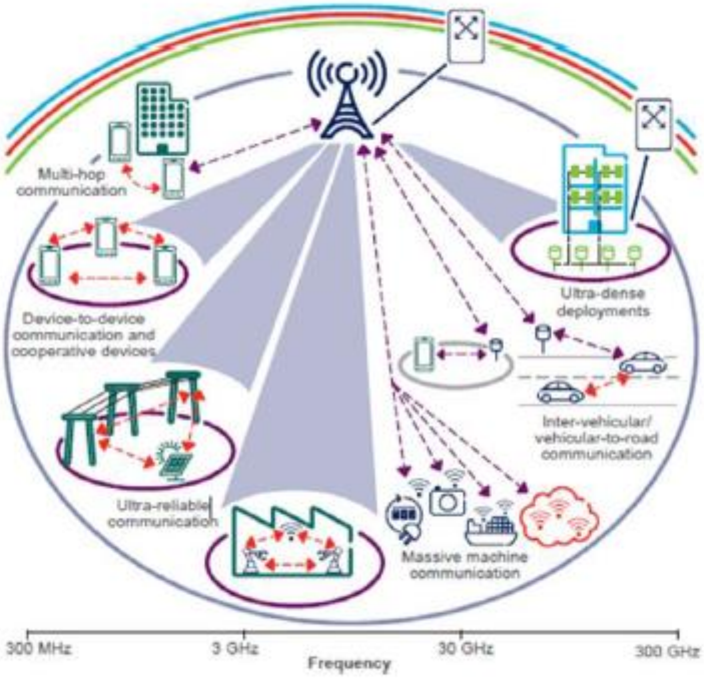

Figure 12: 5th generation technology

Important Advantages

There are several advantages of 5G technology, some of the advantages have been shown in the above *Ericsson* image, and many others are described below −

- High resolution and bi-directional large bandwidth shaping.
- Technology to gather all networks on one platform.
- More effective and efficient.

- Technology to facilitate subscriber supervision tools for the quick action.
- Most likely, will provide a huge broadcasting data (in Gigabit), which will support more than 60,000 connections.
- Easily manageable with the previous generations.
- Technological sound to support heterogeneous services (including private network).
- Possible to provide uniform, uninterrupted, and consistent connectivity across the world.

Some Other Advantages for the Common People
Parallel multiple services, such as you can know weather and location while talking with other person.
You can control your PCs by handsets.
Education will become easier − A student sitting in any part of world can attend the class.
Medical Treatment will become easier & frugal − A doctor can treat the patient located in remote part of the world.
Monitoring will be easier − A governmental organization and investigating offers can monitor any part of the world. Possible to reduce the crime rate.
Visualizing universe, galaxies, and planets will be possible.
Possible to locate and search the missing person.
Possible, natural disaster including tsunami, earthquake etc. can be detected faster.

Table 3: Other Advantages for the Common People

5G the Game Changer

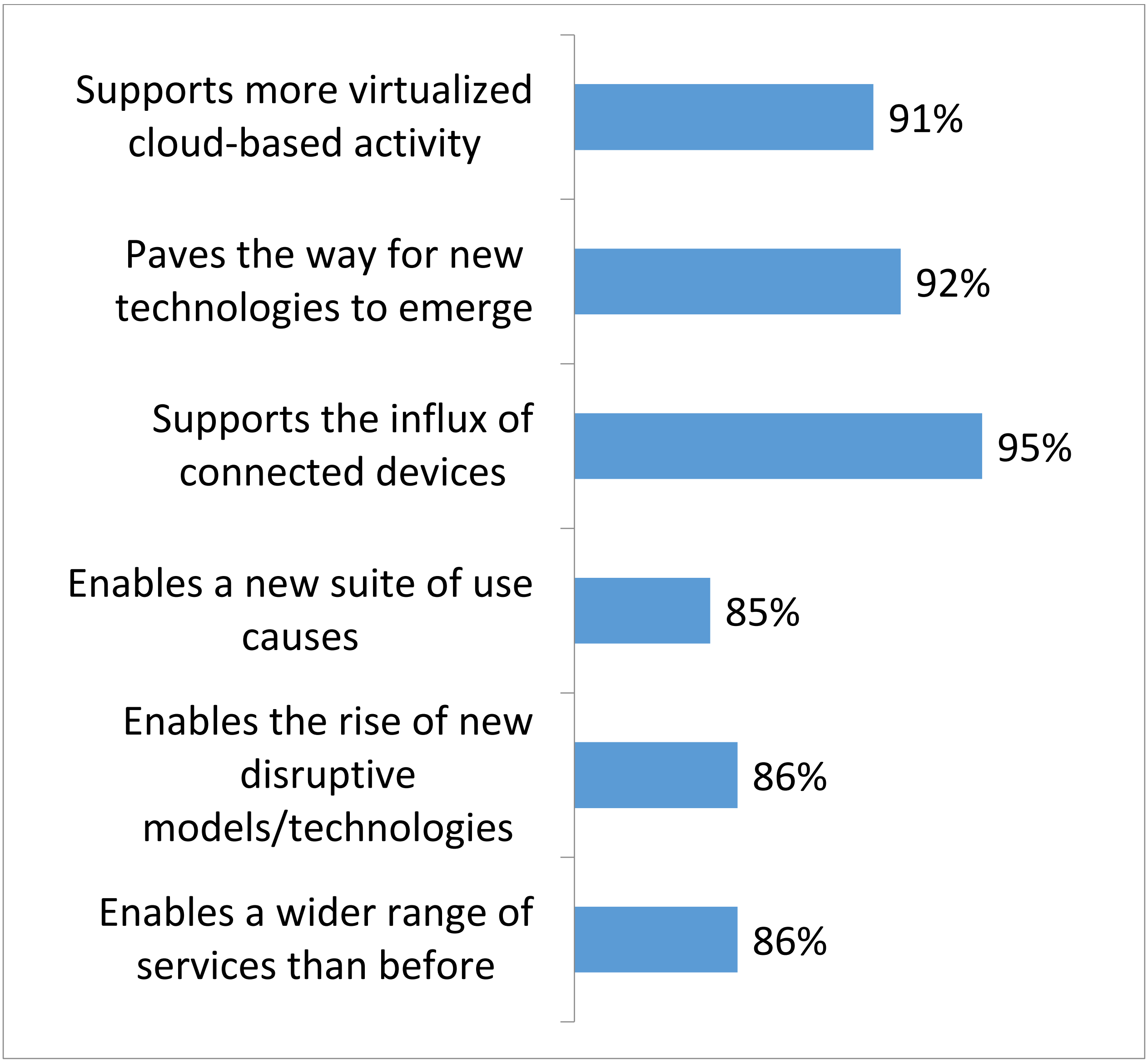

Table 4: 5G the Game Changer

Disadvantages of 5G Technology

Though, 5G technology is researched and conceptualized to solve all radio signal problems and hardship of mobile world, but because of some security reason and lack of technological advancement in most of the geographic regions, it has following shortcomings −

- Technology is still under process and research on its viability is going on.
- The speed, this technology is claiming seems difficult to achieve (in future, it might be) because of the incompetent technological support in most parts of the world.

Figure 13: Difficulties of 5th generation technology

- Many of the old devices would not be competent to 5G, hence, all of them need to be replaced with new one — expensive deal.
- Developing infrastructure needs high cost.
- Security and privacy issue yet to be solved.

Chapter: 8

5G – Challenges

Challenges are the inherent part of the new development; so, like all technologies, 5G has also big challenges to deal with. As we see past i.e. development of radio technology, we find very fast growth. Starting from 1G to 5G, the journey is merely of about 40 years old (Considering 1G in 1980s and 5G in 2020s). However, in this journey, the common challenges that we observed are lack of infrastructure, research methodology, and cost.

Figure 14: Challenges of 5th generation technology

Still, there are dozens of countries using 2G and 3G technologies and don't know even about 4G, in such a condition, the most significant questions in everyone's mind are −

- **How far will 5G be viable?**
- **Will it be the technology of some of the developed countries or developing countries will also get benefit of this?**

To understand these questions, the challenges of 5G are categorized into the following two headings –

- **Technological Challenges**
- **Common Challenges**

Technological Challenges

- **Inter-cell Interference** − This is one of the major technological issues that need to be solved. There is variations in size of traditional macro cells and concurrent small cells that will lead to interference.

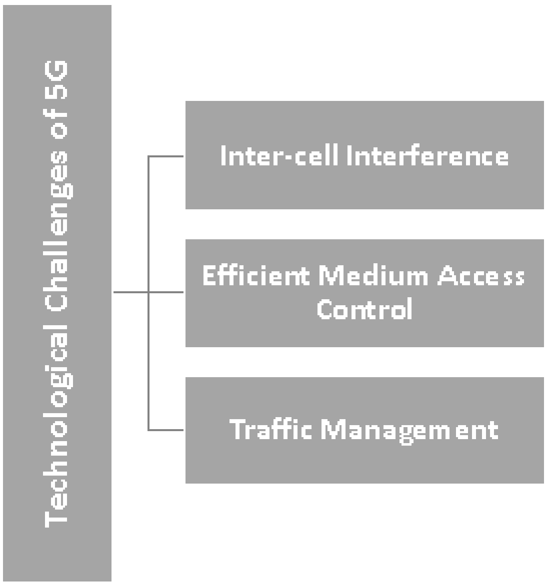

Figure 15: Inter-cell Interference

- **Efficient Medium Access Control** − In a situation, where dense deployment of access points and user terminals are required, the user throughput will be low, latency will be high, and hotspots will not be competent to cellular technology to provide high throughput. It needs to be researched properly to optimize the technology.

- **Traffic Management** − In comparison to the traditional human to human traffic in cellular networks, a great number of Machine to Machine (M2M) devices in a cell may cause serious system challenges i.e. radio access network (RAN) challenges, which will cause overload and congestion.

Common Challenges

- **Multiple Services** − Unlike other radio signal services, 5G would have a huge task to offer services to heterogeneous networks, technologies, and devices operating in different geographic regions. So, the challenge is of standardization to provide dynamic, universal, user-centric, and data-rich wireless services to fulfil the high expectation of people.

Figure 16: Challenges of 5G

- **Infrastructure** − Researchers are facing technological challenges of standardization and application of 5G services.

- **Communication, Navigation, & Sensing** − These services largely depend upon the availability of radio spectrum, through which signals are transmitted. Though 5G technology has strong computational power to process the huge volume of data coming from different and distinct sources, but it needs larger infrastructure support.

- **Security and Privacy** − This is one of the most important challenges that 5G needs to ensure the protection of personal data. 5G will have to define the uncertainties related to security threats including trust, privacy, cybersecurity, which are growing across the globe.

- **Legislation of Cyberlaw** − Cybercrime and other fraud may also increase with the high speed and ubiquitous 5G technology. Therefore, legislation of the Cyberlaw is also an imperative issue, which largely is governmental and political (national as well as international issue) in nature.

5G - Future Scope

Several researches and discussions are going on across the world among technologists, researchers, academicians, vendors, operators, and governments about the innovations, implementation, viability, and security concerns of 5G.

As proposed, loaded with multiple advance features starting from the super high speed internet service to smooth ubiquitous service, 5G will unlock many of the problems. However, the question is — in a situation, where the previous technologies (4G and 3G) are still under process and in many parts yet to be started; what will be the future of 5G?

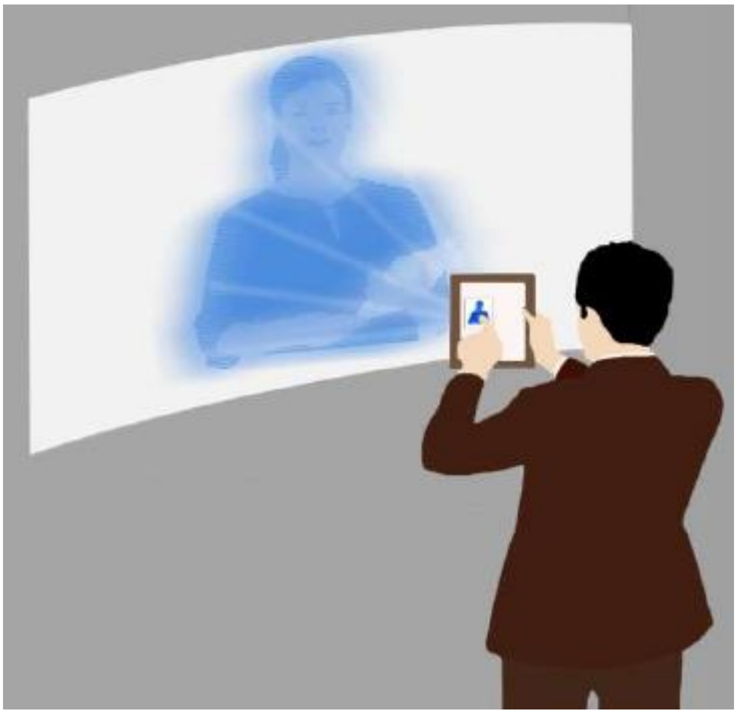

Figure 17: Future Scope of 5G

5th generation technology is designed to provide incredible and remarkable data capabilities, unhindered call volumes, and immeasurable data broadcast within the latest mobile operating system. Hence, it is more intelligent technology, which will interconnect the entire world without limits. Likewise, our world would have universal and uninterrupted access to information, communication, and entertainment that will open a new dimension to our lives and will change our life style meaningfully.

Moreover, governments and regulators can use this technology as an opportunity for the good governance and can create healthier environments, which will definitely encourage continuing investment in 5G, the next generation technology.

Chapter: 9

The implications of 5G for mobile operators

The progress from initial 3G networks to mobile broadband technology has transformed industry and society by enabling an unprecedented level of innovation. If 5G becomes a true generational shift in network technology, we can expect an even greater level of transformation. There are varying implications of providing an increased level of connectivity or developing a new radio access network (RAN) to deliver a step change in per connection performance, or a combination of the two. This means that the final design of a 5G network could be any one of a range of options with differing radio interfaces, network topologies and business capabilities.

While a shift to 5G would be hugely impactful, the industry will need to overcome a series of challenges if these benefits are to be realised, particularly in terms of spectrum and network topology.

5G spectrum and coverage implications

While there are a number of spectrum bands which could potentially be used in meeting some of the 5G requirements identified to date, there is currently a substantial focus on higher frequency radio spectrum. As discussed in Appendix A, operators, vendors and academia are combining efforts to explore technical solutions for 5G that could use frequencies above 6GHz and reportedly as high as 300 GHz. However, higher frequency bands offer smaller cell radiuses and so achieving widespread coverage using a traditional network topology model would be challenging.

It is widely accepted that 'beam-forming' - the focussing of the radio interface into a beam which will be usable over greater distances – is an important part of any radio interface definition that would use 6GHz or higher spectrum bands. This however means that the beam must be directed at the end user device that is being connected. Since the service being offered is still differentiated from fixed line connections on the basis of 'mobility', the beam itself will have to track the device. This is innovation that could make 5G an expensive technology to deploy on large scale, since each cell may have to support several hundred individual beams at any one time and track the end users that are connected via these beams in three dimensional space.

High-order MIMO (Multi-Input, Multi-Output) is another method for increasing bandwidth that is often discussed. This is where an array of antennae is installed in a device and multiple radio connections are established between a device and a cell. However, high-order MIMO can have issues with radio interference, so technology is required to help mitigate this problem. This tends to focus on a need for the radio network to adjust its beam to take into account the specific orientation of the antenna at any given time.

All of this is incremental research and development over and above that currently being conducted for 4G. The use of bands higher than 6GHz will likely require operators to invest in an entirely new RAN since it will have fundamentally different masthead requirements. Given the level of infrastructure required to achieve the desired network topology, operators may be forced to rethink their existing business models. New technology is rarely a cheap option, and the nature of the new technology that is required in the radio network makes it very power-intensive, hence counter to the stated requirement for significant reduction in overall network power consumption.

That said, vendors are researching ways to include beam forming and MIMO technology in mobile devices. As a result, the process of identifying and aligning internationally around common bands for 5G will have a clear dependency on the technology that can be identified to overcome band usage in high frequencies for wide area coverage

Can 1 millisecond latency be achieved?

Achieving the sub-1ms latency rate identified as a technical requirement for 5G necessitates a new way of thinking about how networks are structured, and will likely prove to be a significant undertaking in terms of technological development and investment in infrastructure.

Despite the inevitable advances in processor speeds and network latency between now and 2020, the speeds at which signals can travel through the air and light can travel along a fibre are governed by fundamental laws of physics. Subsequently services requiring a delay time of less than 1 millisecond must have all of their content served from a physical position very close to the user’s device. Industry estimates suggest that this distance may be less than 1 kilometre, which means that any service requiring such a low latency will have to be served using content located very close to the customer, possibly at the base of every cell, including the many small cells that are predicted to be fundamental to meeting densification requirements. This will likely require a substantial uplift in CAPEX spent on infrastructure for content distribution and servers.

If any service requiring 1 millisecond delay also has a need for interconnection between one operator and another, this interconnectivity must also occur within 1 kilometre of the customers. This could well be the case in a service such as social networking content pushed into augmented reality. Today, inter-operator interconnect points are relatively sparse, but to support a 5G service with 1 millisecond delay, there would likely need to be interconnection at every base station, thus impacting the topological structure of the core network. Roaming customers would need to have visited network contextual roaming capabilities, and have content relevant to their applications available directly from the visited network, posing challenges for the existing roaming model.

In the most extreme case, it would make sense for a single network infrastructure to be implemented, which would be utilised by all operators. This would mean all customers could be served by a single content source, with all interaction and interconnect with localised context also being served from that point at the base station. This would also imply that only one radio network would be built, and then shared by all operators.

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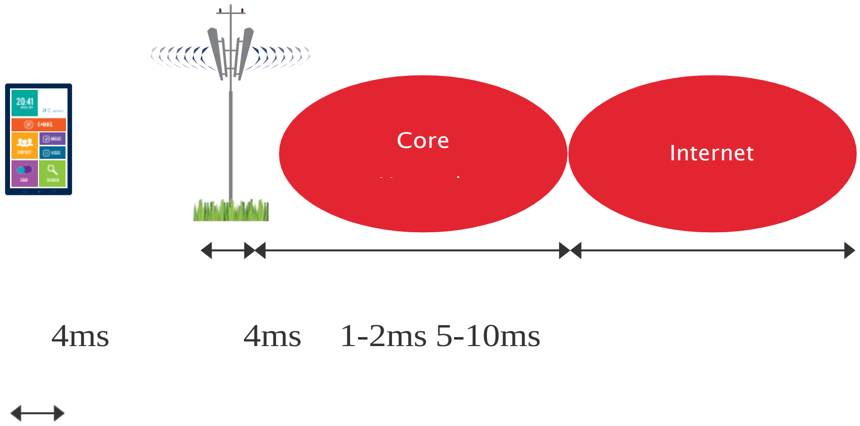
LTE – min 10ms



If in the same country

As the customer

5G service sub-1ms

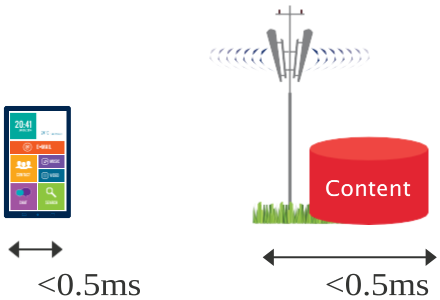


Figure 18: Latency performance for LTE compared to latency requirement for 5G

Such a model would considerably reduce CAPEX in the network build (since rather than say four operators building four parallel networks, only a single network would be built) but would require unprecedented levels of co-operation between operators. It would also impact the nature of inter-operator competition, shifting focus to services rather than data rate and coverage differentiation. It would also make spectrum auctions somewhat irrelevant, since only one radio network being built would mean there would only be one bidder and one license per market.

Once this is all realised, it is likely that requirements for sub-1ms delay will be relaxed or possibly removed entirely from 5G, rather than industry committing to the massive upheaval and resource acquisition that would be implied. If this were to happen, it may draw into question the viability of coupling services such as augmented and virtual reality, immersive internet and autonomous driving with mobility. However, if those services were removed from the expected service set, the justification for the technological view of 5G would also become questionable.

Chapter: 10

Continuing development of network technologies:

What 5G isn't

To further enhance the mobile broadband experience for customers, operators are continuing to develop their 4G networks through the deployment of LTE-Advanced technologies. Many are also deploying technologies such as network function virtualisation (NFV), software defined networks (SDN), heterogeneous networks (HetNets) and low power, low throughput (LPLT) networks. These allow different network upgrade paths and expansion of coverage through integration of broader wireless technologies, as well as potentially having a positive effect in the total cost of ownership of the network.

The term 5G is sometimes used to encapsulate these technologies. However, it is important to clarify that these technological advancements are continuing independently of 5G. While these are areas that will have significant impact on the mobile industry over the coming years, explicitly including them under the term 5G has the potential to adversely affect progress in the industry between now and the realisation of 5G as a commercial service.

A summary of these technologies follows:

Network Function Virtualization (NFV) and Software Defined Networks (SDN)

NFV is a network architecture concept that enables the separation of hardware from software or 'function', and has become a reality for the mobile industry due to the increased performance of 'common, off-the-shelf' (COTS) IT platforms. SDN is an extension of NFV wherein software can perform dynamic reconfiguration of an operator's network topology to adjust to load and demand, e.g. by directing additional network capacity to where it is needed to maintain the quality of customer experience at peak data consumption times. A number of operators have built or are building part or all of their LTE networks using NFV and SDN as the basis.

These technologies in combination can potentially reduce operator CAPEX as they offer a cheaper and simpler network architecture that is easier to upgrade, while OPEX is also reduced through power savings as network capacity is only provided when and where it is needed. However, shifting from existing structures to IT-based soft functions will bring new complexities for operators in terms of network provisioning and management, as well as requiring a new skill set within operator staff.

Heterogeneous Networks (HetNets)

HetNet refers to the provision of a cellular network through a combination of different cell types (e.g. macro, pico or femto cells) and different access technologies (i.e. 2G, 3G, 4G, Wi-fi). By integrating a number of diverse technologies depending on the topology of the coverage area, operators can potentially provide a more consistent customer experience compared to what could be achieved with a homogenous network.

Small cell deployments are a key feature of the HetNet approach as they allow considerable flexibility as to where they are positioned, however, the use of more cells brings implications in terms of power supply and backhaul, especially when they are located in remote areas. Wi-fi can also play a significant role in HetNets, both in terms of data offload and roaming.

HetNet technology has typically been developed in relation to data networking, but recently voice has been brought under the scope as well, not least because of support for Wi-fi calling being available in Apple’s iPhone 6 which was released in September 2014.

Chapter: 11

Conclusions

In this work, we studied extensively the 5G in different perspective. We want throw its technological view, serial impact, migration plan and overall architecture. We also summarize the different proposal by distinguished academic research and renowned companies about 5G.We also propose a comprehensive architecture for 5G.As a future work we have a plan to present more comprehensive survey about 5G

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