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MALAYSIA EQUITY

NEW S-CURVE FOR THE INDUSTRY?

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NEW S-CURVE FOR THE INDUSTRY?

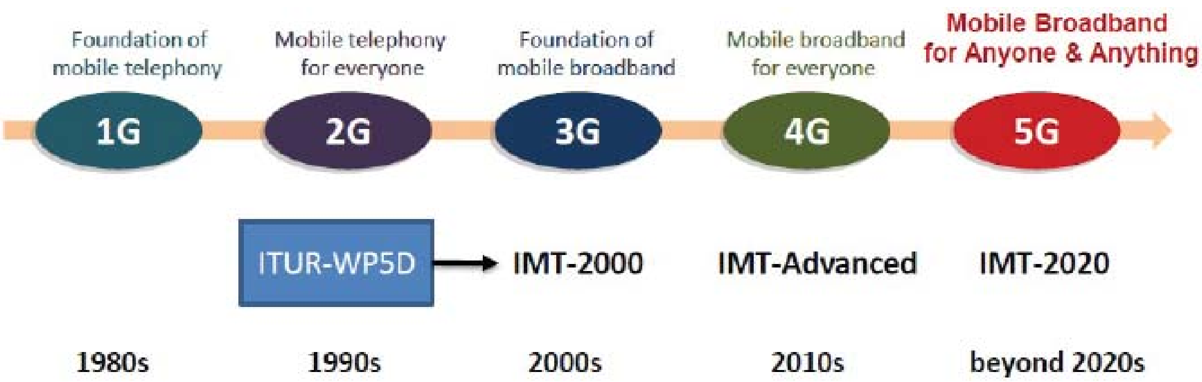
- Wireless access technology was introduced in the early 1980s through the launch of 1G. This formed the foundation of mobile telephony. Since then, a new cellular advancement is made every 10 years. We are currently embracing 4G whereby faster and better mobile broadband are available to the masses. Globally, over 170 countries have deployed LTE network.
- As early as 2009, a number of operators and equipment vendors have started exploring the possibilities of 5G. National governments and various industry associations are also attempting to drive the 5G agenda. Europe, which previously fell behind in the rollout of 4G, are determined to rollout 5G in-tandem with the rest of the world. The fifth generation mobile technology is positioned to address the demands and business contexts of 2020 and beyond.
- Based on the historical 10-year cycle, the 5G system is scheduled to be deployed sometime around the year 2020. 5G is the natural progression to faster and higher-capacity broadband internet. In addition, 5G is said to cater for services that are not achievable with the existing 4G networks. According to GSMA, there are two views on 5G. The first view is that 5G is all about hyper-connected vision. Meanwhile, another view pointed out 5G as the next-generation radio access technology. More often than not, both views are taken as a single set with their requirements being grouped together.
- Despite early venture into 5G, the development on 5G is still at its infancy as there are no define standards or specifications yet. However, in December 2014, GSMA has outlined eight main criteria for 5G. A network connection should meet the majority of the eight criteria to be qualified as 5G. These criteria principally revolve around improving speed, latency, user experience, bandwidth capacity and energy consumption. Meeting the criteria would also indicate that 5G would need to be more than just a mobile network in order to enable the volume and diversity of devise and applications envisaged.
- As with the previous generation of mobile technology, the implementation of the next generation of mobile network will also represent a new set of challenges. Apart from technical challenges, there are two main stumbling blocks which the industry has to resolve. The radio frequencies used by the existing three generations of mobile technology (i.e. 2G, 3G and 4G) are rather congested. As such, new spectrum will be required to be assigned for 5G. Governments and regulators also play a vital role in ensuring that there is proper allocation and management of spectrum. In addition, certain quarters also commented that there may also be a need to develop ways of using the spectrum more intelligently. This means assigning the exact amount of spectrum that is needed for each specific task.
- On another note, cost is another big consideration. There is a need to ensure that end users are not burden with excessively high costs. Given that the data requirement may increase exponentially, we cannot expect that the costs will escalate in the same manner. Exorbitant cost may limit the accessibility of the new technology. However, it is hard to estimate the cost of developing a 5G system until its standards have been finalized and the technology is developed.

A. INTRODUCTION TO WIRELESS ACCESS TECHNOLOGIES

I. WIRELESS ACCESS TECHNOLOGIES

- Wireless access technologies allow connectivity and communication over wireless links. They are based on the principles of radio engineering. A generic wireless transmission system performs the function of transmission, propagation and reception.
- New wireless access technologies surface every 10 years since the introduction of 1G in the 1980s. The word "G" mainly refers to the generation of the underlying wireless network technology. Each successive generation carries increasing sophistication in speed, performance and efficiency to enable user access, networking and applications.

Figure 1: Evolution of mobile communication



Source: various

II. 1G NETWORK - ESTABLISHING THE FOUNDATION OF MOBILE

- 1G is the first generation of wireless telephone technology which was introduced in the 1980s and completed in the early 1990s. It was the first form of wireless communication which was available on analog form. It used various analog modulations for data transfer. 1G network were conceived and designed purely for voice calls with little consideration for data services. The location of the first commercialisation was in the United States of America utilising the 800 MHz frequency band. 1G has less complex network elements with mobility element.
- Some drawbacks for 1G include: (i) Poor voice quality and/or background interference (deployment of 1G requires large gap of spectrum between users to avoid interference); (ii) Poor battery life; (iii) Large phone size; (iv) No security; and (v) Limited capacity (analog transmissions are inefficient at using limited spectrum).

Figure 2: 1G handsets

Source: CNTR, Salford University

III. 2G NETWORK – MOBILE FOR THE MASSES

- 2G represents the second-generation of wireless telephone technology. It is the first digital cellular system which was launched in 1991 in Finland based on the GSM standard. It can carry voice and data to more people and in more places. Digital transmission enables compressed voice and multiplexing multiple users per channel. Based on the 2G systems, phone conversations were digitally encrypted. This means that data is transferred in such a way that only the intended recipient can receive and read it.

- In addition, the 2G systems were significantly more efficient on the spectrum usage, allowing for far greater mobile phone penetration levels as compared to its predecessor. Despite this, the network range remains low. The weaker digital signal transmitted by a cellular phone may not be sufficient to reach a cell tower, especially if the 2G network runs on higher frequencies. At present, 2G network is still being used in most parts of the world. Digital calls tend to be free of static and background noise in comparison to analog calls.

Figure 3: 2G handsets

Source: Techguide

- Soon after, the industry adopted the 2.5G. 2.5G is a technology between the second and third generation of mobile telephony. It is sometimes described as 2G cellular technology combined with GPRS. GPRS is a packet oriented mobile data service on 2G and 3G cellular communication system's GSM.

IV. 3G NETWORK – MOBILE BROADBAND

- 3G technology is the results of research and development work carried out by the ITU. The first commercial launch took place in Japan by NTT DoCoMo in October 2001. The mobile devices used on the 3G platform are typically called smartphones. The bandwidth and location information available to smartphone give rise to new applications for the mobile users. This includes GPS, location-based services, mobile TV, telemedicine, video conferencing and video-on-demand. The 3G networks also provide a greater level of security as compared to 2G.

- However, the deployment of 3G technology led to higher power consumption for the devices leading to shorter battery life. For the mobile service providers, there is also the need to bear the high cost of spectrum license as well as a sizeable capital spending to build the infrastructure for 3G.

Figure 4: 3G handsets

Source: CNET

V. 4G NETWORK – FASTER AND BETTER MOBILE BROADBAND

- 4G refers to the fourth generation of mobile phone communication standards. LTE and WiMAX are the technology standards use in 4G. The mobile WiMAX standard is initially deployed in South Korea in 2007. Meanwhile, LTE is first released in Norway and Sweden in 2009. Potential and current applications include amended mobile web access, IP telephony, gaming services, high-definition mobile TV, video conferencing, 3D television and wearable devices.

- Some improved features include more security, higher speed, higher capacity and lower cost per bit. However, there are certain drawbacks from the implementation of 4G network. These are: (i) higher battery usage; (ii) higher implementation cost and; (iii) more complicated and expensive hardware to carry out the network upgrade.

- There are still considerable potential for future LTE growth, especially for the developing world. This represents some opportunity for operators to generate returns on their investment in LTE network. Operators are already making a considerable amount of progress in increasing the data speeds of their existing networks by adopting multiple-carrier LTE-A technologies. These advancements will enable operators to offer many of the services that have been put forward in the context of 5G long before 5G becomes a commercial reality.

Figure 5: 4G handsets

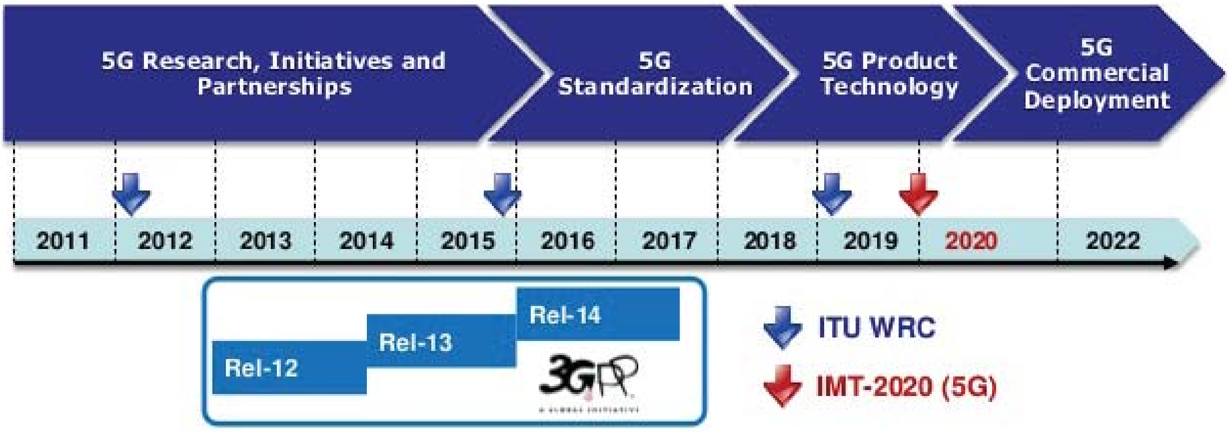
Source: Import.io

B. WHAT IS 5G?

I. 5G NETWORK

- 5G is the next major phase of mobile telecommunications standards beyond the current 4G standards. It is the natural progression to faster and higher-capacity broadband internet. In addition, 5G is said to capture value from the massive IoT opportunities, address the limited flexibility to support bespoke services across industry verticals and develop the next generation services that are not achievable with 4G network. Despite huge interest, 5G development is still at the very early stages with no approved standards or specifications.

Figure 6: 5G expected timeline



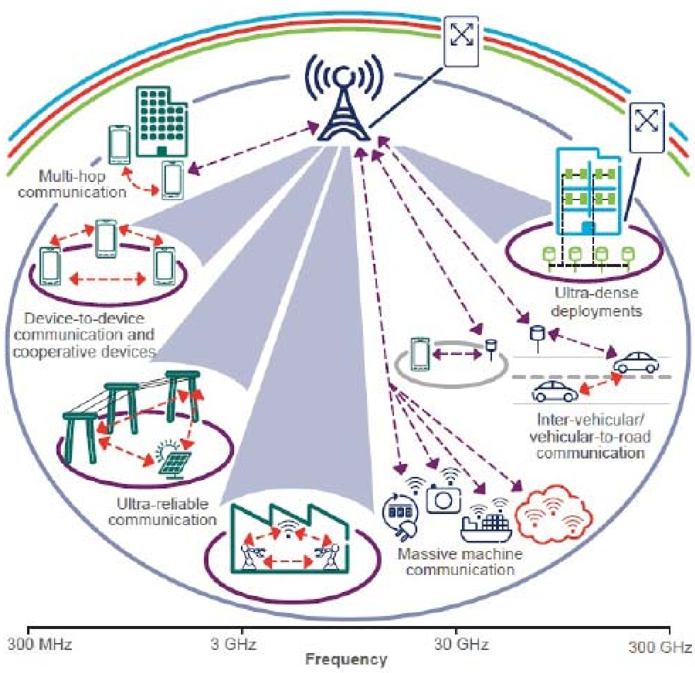
Source: CPQD

- Making reference to GSMA, there are two schools of thoughts on 5G. First thought is the hyper-connected vision. In this view, 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. The key differentiator is greater connectivity as an enabler for M2M services and the IoT. This vision may include a new radio technology to enable low power and low throughput field devices with long duly cycles of ten years or more.

- 5G is also viewed as the next-generation radio access technology. This is more of the traditional "generation-defining" view, with specific targets for data rates and latency being identified. This in turn makes for a clear distinction between a technology that meets the criteria for 5G, and another which does not.

- Nonetheless, the two views described above are regularly taken as a single set and hence requirements from both

Figure 7: 5G Technology Key Visions



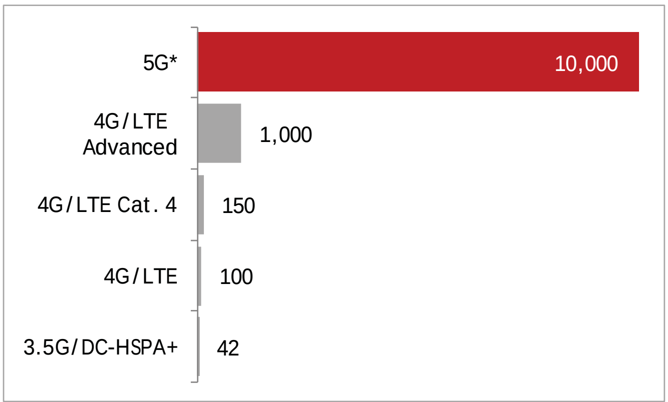
Source: Ericsson

the hyper-connected view and the next-generation radio access technology view are grouped together. Requirements for the 5G network are as follows.

II. SPEED

- No exact speeds have been ascribed to 5G yet. However, early tests indicated that 5G will come with remarkable speed. It is expected to make 4G and broadband look sluggish in comparison. According to NGMN, for something to be considered 5G it must offer data rates of several tens of megabits per seconds to tens of thousands of users simultaneously. Meanwhile, a minimum of 1 gigabit per second should be offered to tens of workers on the same office floor. Based on initial calculations, download speeds could be up to 1000 times faster than 4G, potentially exceeding 10Gbps. Some researcher also claimed that 5G can reach a record breaking speed of 1Tbps. This will place the wireless speed similar to that of fibreoptics. It is supposed to be fast enough for everyone, everything and the IoT.
- Similarly for uploads, the speed will be tied to the download speed. In general, uploads speed will be slower than download speed, likely coming in at no more than half the download speed.

Figure 8: Speed comparison (in Mbps)

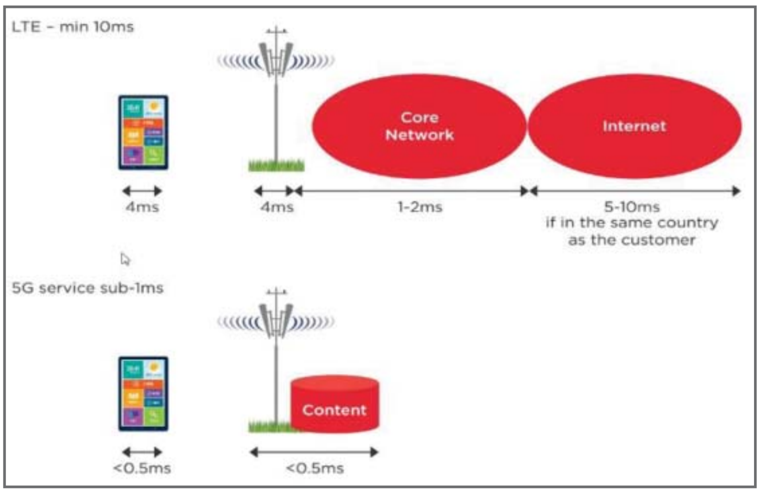


*10Gbps is the minimum theoretical upper limit speed specified for 5G
Source: GSMA, MIDFR

III. LATENCY

- One of the technical requirements for 5G is achieving the sub-1 ms latency rate. Latency refers to the time delay between data being generated and transmitted from one device (e.g. a sensor) and the

Figure 9: Latency performance for LTE compared to latency requirement for 5G

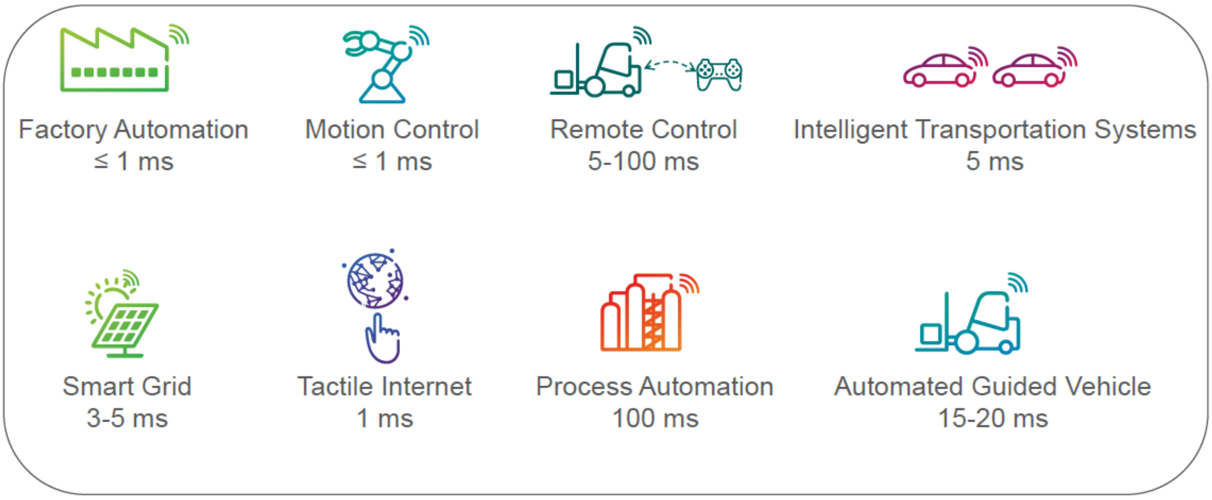


Source: GSMA

same data being correctly received by another device (e.g. an actuator). This will require a significant undertaking in terms technological development and investment in infrastructure.

- Currently, all existing services that require a delay time of less than 1ms must have all of their content served from a physical position which is very close to the user's device. The distance could be less than 1 kilometer, which means that any services requiring such a low latency will have to be served using content located possibly at the base of every cell, including the many small cells that are predicted to be fundamental to meeting densification requirements. To carry out such services, a significant amount of capital spending needs to spend on infrastructure for content distribution and servers.

Figure 10: Diversity of requirement



Numbers are examples, requirements vary within one application area

Source: Ericsson

- It would be more cost effective to implement a single network infrastructure which would be utilised by all operators. Base on this infrastructure, all users 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.

- However, the implementation of such practice would require unprecedented levels of co-operation between operators and regulators. It would also impact the nature of inter-operator competition, shifting focus to services rather than data rate and coverage differentiation. Spectrum auctions would no longer be necessary since only one radio network being built would mean that there would only be one bidder and one license per market.

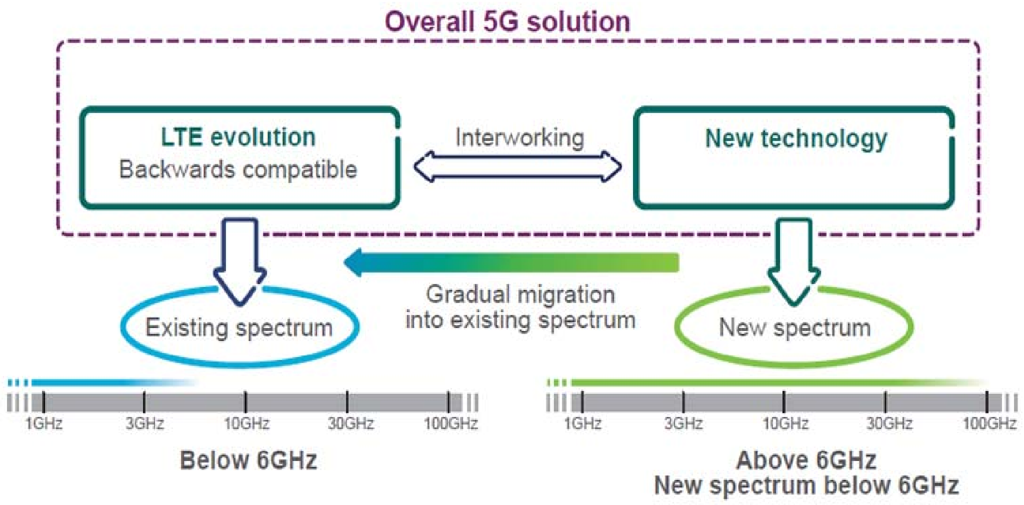
IV. RELIABILITY AND AVAILABILITY

- Reliability refers to the capability of guaranteeing a successful message transmission within a defined latency budget. This means that the network will have a high level of certainty that a message is correctly delivered to the receiver within a latency bound. It will not be reliable if the message is lost, received late or has residual errors. Meanwhile, availability refers to the system endurance against possible outage scenarios. 5G network is perceived to have ultra high-reliability and availability. The industry is expecting that the 5G network to have ultra high-reliablity with less than one out of 100m packets lost and 99.99% availability. However, availability of 5G network will pretty much be a business decision. Operators will need to decide where to place the cells. Costs to prepare the site to establish a cell will be determined. This will then be compared to the benefit of the cell obtained by providing coverage for a specific geographical area.

V. SPECTRUM

- There are a number of spectrum bands which the industry is currently considering in order to meet some of the 5G requirements. The focus is primarily on the higher frequency radio spectrum. Operators, vendors and academia are currently exploring the technical solution for 5G that could use frequencies above 6GHz. Nonetheless, 5G need both higher and lower frequencies to support a variety of applications. Spectrum above 6GHz is needed for applications requiring extremely high data rates. It may accommodate wider channel bandwidths within a coverage area that may reach 100 meters. Propagation characteristics may also lead to higher spectrum reuse and may facilitate sharing with existing services.

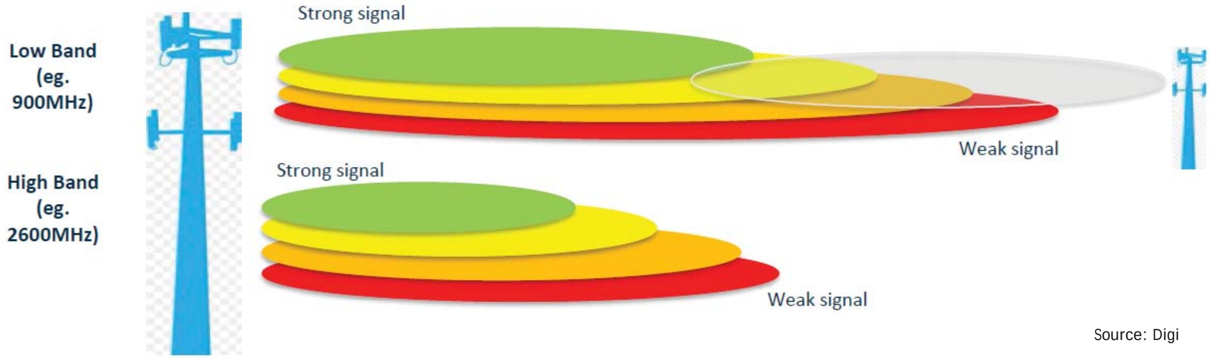
Figure 11: Spectrum comparison



Source: Ericsson

- However, higher frequency bands offer smaller cell radiuses. Spectrum below 6GHz is also necessary for wider network coverage. This will allow cost effective delivery of mobile services. In addition, bandwidths will be considerably wider than those of today, providing a combination of capacity and coverage.

Figure 12: Coverage comparison



Source: Digi

- Spectrum harmonisation remains an important development of international mobile telecommunication. It plays an even more crucial role for higher frequencies bands in order to support the development of the new ecosystem for them. It will allows for: (i) adequate economies of scale for cost effective solutions for end users; (ii) global roaming for end user devices; (iii) reduced efforts in cross border coordination and; (iv) reduced equipment design complexity, preserving batter life and improving efficiency in spectrum use. In the initial stage, there could be challenges in implementing different sets of radio components to support non-contiguous bands. Without spectrum harmonisation, it is unlikely that mobile would have become the success it is today.

- 5G communications standard promises to enable a thousand-fold increase in wireless data capacity. As such, multi-antenna technologies such as beam-forming and MIMO are expected to play a significant role in the 5G systems.

- Beam-forming is the focusing of the radio interface into a beam which will usable over greater distances. The limitation of beam-forming is that the beam must be directed at the end user device that is being connected in order to track the device. In addition, beam-forming 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 user that are connected.

- High-order MIMO is another method for increasing bandwidth. 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.

Figure 13 Beam-forming vs traditional technology

Source: PCworld

C. APPLICATIONS OF 5G

I. AR/VR, IMMERSIVE OR TACTILE INTERNET

- These technologies can be applied to enhance and further revolutionise the entertainment industry. In addition, they can also be used in more practical scenarios such as manufacturing or medicine, and could extend to many wearable technologies. For instance, an operation could be performed by a robot that is remotely controlled by a surgeon on the other side of the world. The development of AR/VR will primarily be dependent on the availability of other complementary technologies such as motion sensors and HUD.

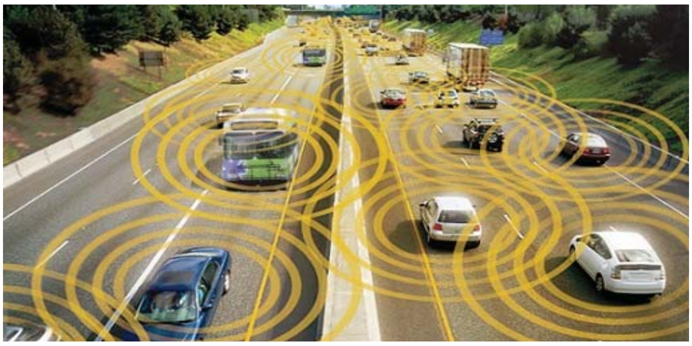
Figure 14: VR application

Source: GPU Technology Conference

II. AUTONOMOUS DRIVING / CONNECTED CARS

- 5G can enable a safer and more autonomous transportation system. Vehicles on the road will be able to communicate with each other, resulting in a more efficient and safer use of existing road infrastructure. For example, if all the vehicles are linked to a traffic management system, it would lead to a safer and more efficient road condition as potential human error will be minimised.

Figure 15: Self-driving vehicles



Source: AutomotiveIT

- For this to take place, the communication must be seamless and in real time. Allowable time delay could only be up to one millisecond delay which is in accordance to 5G specification. On a longer time frame, we could be also looking at driverless cars which are functioning in all geographies. This would require full road network coverage with 100% reliability.

III. WIRELESS CLOUD-BASED OFFICE / MULTI-PERSON VIDEO CONFERENCING

- With the availability of high bandwidth and low-latency of 5G data networks, the need for physical office could be minimise further. This could lead to the creation of a wireless cloud office, with vast amounts of data storage capacity sufficient to make such systems ubiquitous.

- At present, there are businesses that offer basic virtual office service. However, the type of services is limited. The arrival of 5G could further unlock the variety of services offered.

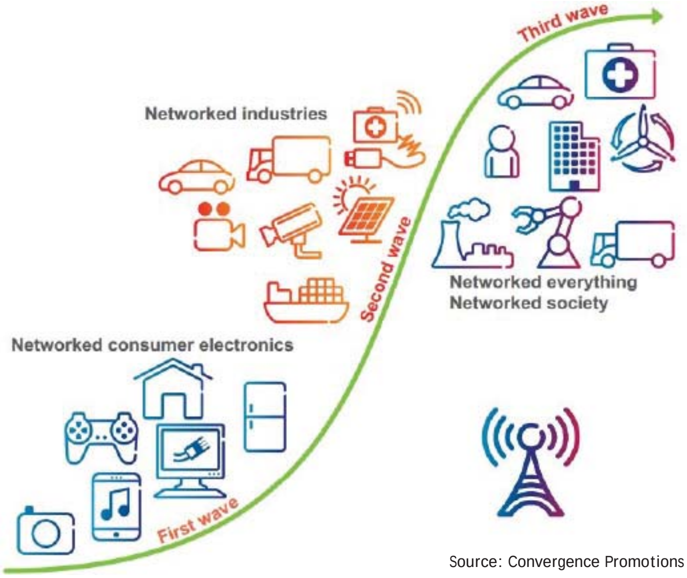
Figure 16: Multi video conferencing and telepresence

Source: Huawei

IV. M2M CONNECTIVITY

- At present, M2M connectivity has been used in a vast range of applications. However, the current systems transmit very low levels of data. Most of the data transmitted is also less time-critical. The usage of 5G technologies will further drive the application of M2M. According to the GSMA, the number of cellular M2M connections worldwide will grow from 250m this year to between one to two billion connections by 2020. This will depend 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.

Figure 17: M2M connectivity



Source: Convergence Promotions

- Typical M2M applications can be found in 'connected home' systems (e.g. smart meters, smart thermostats, and smoke detectors), vehicle telemetric systems (a field which overlaps with connected cars), consumer electronics and healthcare monitoring.

V. TELEHEALTH

- The 5G platform will enable effective and efficient practice of telehealth. This includes making remote access to healthcare affordable and scalable. Communication between doctor and patient can be done through tablets and smartphones and this can help to reduce healthcare costs. For instance, a telehealth solution, with the use of a private network, can transmit patient images to physicians. This can help to reduce the number of times a patient has to visit a doctor or hospital to receive care and treatment. Surgery or operation can also be done by doctors who are at a different geographical location with the use of robots.

Figure 18: Telehealth application

Source: University of Pittsburgh

D. CHALLENGES

I. SYSTEM-LEVEL CHALLENGES

- Apart from the need to meet the criteria for 5G, there are also system-level challenges that arise from changing the ecosystem in which 5G is expected operate. Below is the list of system-level challenges taken from NetWorld 2020.

  » **Privacy by design challenge**
  Provide accountability within the communication substrate and enable truly private communication when needed, aligned with policy constraints in terms of data management and ownership, ensured by the infrastructure operators that realize the overall service.

  » **Quality of Service challenge**
  In order to allow for optimizing the Quality of Experience (QoE) for the end user, 5G should provide differentiated services across various dimensions such as throughput, latency, resilience and costs per bit as much as possible independent of users' location with respect to the antennas deployment geography. This includes increased security, availability, resilience and delivery assurance for mission critical applications such as health-related or emergency applications, but also ultra-low cost solutions for emerging countries with less stringent QoE requirements.

  » **Simplicity challenge**
  Provide 5G users the best network services seamlessly without complex customer journeys.

  » **Density challenge**
  Increased number of diverse devices connected in proximity, e.g., challenging the current architecture for mobility management.

  » **Multi-tenancy challenge**
  Provide service solutions across different infrastructure ownerships, with the different networks (not necessarily IP-based) co-existing and providing and providing an integrated as well as efficient interaction between the wireless domain and the backhaul.

  » **Diversity challenge**
  Beyond the aforementioned diversity of stakeholders, 5G must support the increasing diversity of optimized wireless solutions (to different application domains, e.g., M2M) and the increasing diversity and number of connected devices, and associated diversity of traffic types.

  » **Harnessing challenge**
  Exploit any communication capability, including device-to-device (D2D), for providing the most appropriate communication means at the appropriate time.

  » **Harvesting challenge**
  Devise radically new approaches to provide devices with power, which not only has to come from batteries, but also harvests existing environmental energy.

  » **Mobility challenge**
  Support for unlimited seamless mobility across all networks/technologies

- **Location and context information challenge**
  Provide positioning and context capabilities in the sub-meter range in order to enable the Internet of everything, e.g., through the integration of cellular and satellite positioning systems.
- **Open environment challenge**
  Enable horizontal business models by opening the right business interfaces within the system in order to enable flexible operator models in a multi-tenancy fashion.
- **Manageability**
  Improve manageability of networks in order to reduce the need for manual management and reduce the human involvement.
- **Hardening challenge**
  Deploy a communication system through a combination of bearer techniques such as cellular and satellite that is intrinsically robust to attacks from malicious entities as well as to natural disasters; a resilience without which the smart-grid/smart-city paradigm will never be achieved.
- **Resource management challenge**
  Provide access agnostic control, policy and charging mechanisms and protocols for dynamic establishment, configuration, reconfiguration and release of any type of resource (Bandwidth, Computation, Memory, Storage), for any type of devices (e.g. terminal, car, robot, drone, etc.) and services (e.g. Network, Security, Data, Knowledge, Machine, and Thing as a Service), including in E2E fashion when necessary.
- **Flexibility challenge**
  Devise truly flexible control mechanisms and protocols for relocating functions, protocol entities and corresponding states in a truly end-to-end manner, leveraging programmable network technologies.
- **Identity challenge**
  Provide identity management solutions for any type of device (terminal, car, robot, drone, etc.) with access agnostic authentication mechanisms that are available on any type of device, device to device and network to device, independent from specific technologies of communication entities and of their current location.
- **Flexible pricing challenge**
  Provide methods for flexible pricing mechanisms across and between different parts of the future 5G value chain in order to enable pricing regimes that are common across the industries that will utilise the future 5G infrastructure. Furthermore, new business models could consider the underlying technology (e.g., wireless or mobile, legacy or later one) as well as other aspects like the contribution of a privately owned small cell to the operator's infrastructure through its open access.
- **Evolution challenge**
  Provide the ability for evolution and adaptation, allowing a transparent migration from current networks and permitting future development.

E. LOCAL 5G DEVELOPMENTS

I. WCC

- Malaysia's first foray into 5G
  - » On 3rd September 2014, the WCC under UTM initiated the first meeting with academics in the field of telecommunications to discuss the 5G initiative in Malaysia. This led to the establishment of the Malaysia 5G Committee. Members of the committee primarily consist of universities, research institutions, industries and MTSFB.
  - » The objectives of the 5G Committee are:
    - to foster collaboration and partnership between academia and industry in 5G R&D activities in Malaysia,
    - to contribute to the standardization of IMT-2020, and
    - to become evaluation group for IMT-2020 standardisation.

II. U-MOBILE AND ZTE

- ZTE and U Mobile announced partnership on 5G mobile network research in Malaysia
  - » On 4th August 2015, ZTE Corporation signed a MoU with U Mobile Sdn Bhd on the development of pre-5G mobile broadband technologies. The partnership will help U Mobile deliver substantial network performance upgrades using ZTE's proprietary pre-5G technologies including Massive MIMO. It also covers collaboration between the two companies on research and development of 5G technologies, in addition to Pre-5G. This is in tandem with the Malaysian Government's vision of being a 'Smart Digital Nation' by 2020.

III. ERICSSON AND UTM

- UTM AND Ericsson Malaysia collaborate in 5G
  - » On 22nd October 2015, UTM and Ericsson (Malaysia) Sdn Bhd has signed a MoU to seal the partnership in the research and development of the fifth generation mobile communication technology. The partnership will lay down the groundwork for the new mobile standard in Malaysia.
  - » Ericsson has been one of Malaysia's major sponsors and contributors in the country's endeavor towards becoming a smart nation. The main reason for this is because Ericsson believes that Malaysia as a country is set to benefit from all the fast emerging technologies such as 5G, IoT and even cloud services.
  - » The scope of the partnership will encompass:
    - Building a 5G roadmap (A joint effort to 5G research and development in Malaysia),
    - Connected mangroves (A joint effort to reforest mangroves in Malaysia), and
    - Hyperscale could event (Thought leadership towards optimising datacenters in Malaysia).

PUTTING THE 5G PIECES TOGETHER

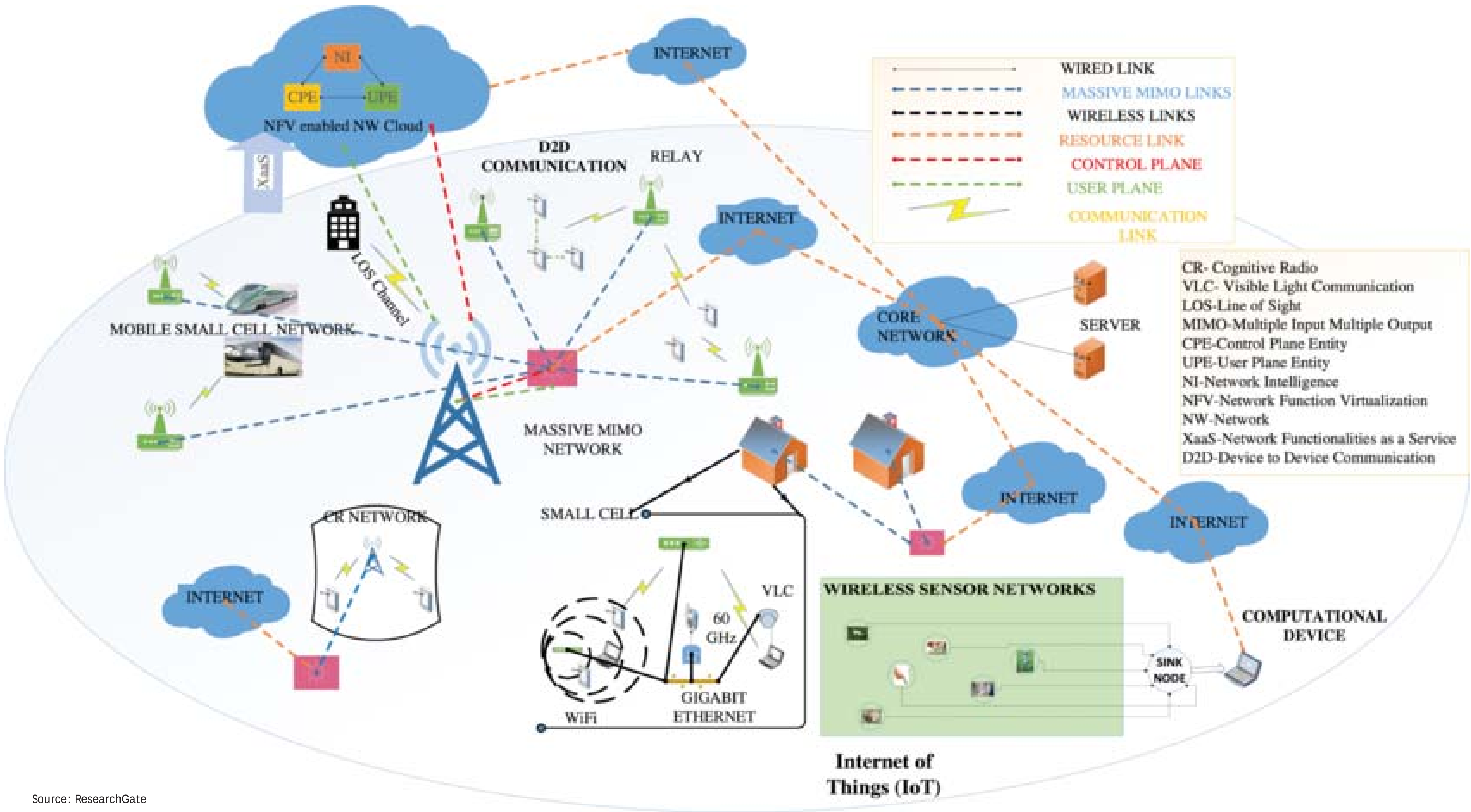
- **A special generation.** As advancements in 5G technologies are made, it becomes clearer that 5G would be more than just being the next generation of mobile technology after 4G. 5G is said to be a special generation of mobile technology. It will bring about a new ecosystem that will enable synergistic integration of diverse technique and solution. Remarkably higher bandwidth and low latency of the 5G system will open up a variety of life-changing experience which will give the users a truly immersive and rich experience. Various considerations such as users, enhanced service, management and operation, device and business model requirements are also being taking into account.
- **Countdown to commercialisation.** Various industry stakeholders are currently encouraging each other to work towards a plan that would deliver globally and commercially available solutions by 2020. However, the commercial introduction of 5G may vary from country to country and/or operator to operator. Regulators also play an important role to pave the way for the implementation of a lightning-fast next generation of wireless networks.
- **Pre-5G will still be relevant.** Despite a 10-year cycle between the launch of new technology, cellular technologies usually remain for approximately 20 years from launch to peak penetration. While 5G may arrive by 2020, 4G and earlier generations of mobile networks will still be pertinent. At present, the main focus of the industry stakeholders is still on improving further the existing LTE technology, especially in developing countries. Operators are still making notable progress in data speed through the adoption of LTE-A technologies. Such development will make the adoption of 5G more seamless.
- **Opportunities for industry stakeholders.** According to ABI Research, mobile broadband operators will reap 5G revenue of USD247b by 2025 with North America, Asia-Pacific and Western Europe being the top markets. This means that the possibilities to be unveiled by 5G will set to boost the financial standing of mobile operators, equipment vendors and infrastructure solution providers alike. Mobile operators' customer base may not be limited to people only but 'things' as well. More demand for infrastructure and telecommunication equipment will also supports the well-being of equipment vendors and infrastructure solutions providers. Thus, 5G is set reinvigorate the slowdown in growth experience in the telecommunication industry.

APPENDIX

GLOSSARY

Abbreviations	Remark
1G	1st Generation
2G	2nd Generation
3G	3rd Generation
4G	4th Generation
5G	5th Generation
AR	Augmented Reality
Gbps	Gigabits per second
GHz	Gigahertz
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	GroupeSpéciale Mobile
GSMA	GSM Association
HUD	Head-up Display
HSPA	High Speed Packet Access
IMT	International Mobile Telecommunications
IoT	Internet of Things
IP	Internet Protocols
ITU	International Telecommunication Union
LTE	Long Term Evolution
LTE-A	LTE Advanced
M2M	Machine to Machine
Mbps	Megabits per second
MHz	Megahertz
MIMO	Multiple Input Multiple Output
ms	Millisecond
MTSFB	Malaysia Technical Standards Forum Bhd
NGMN	Net Generation Mobile Networks
Spectrum	The entire range of wavelengths of electromagnetic radiation
TBps	Terabytes per second
UTM	Universiti Teknologi Malaysia
VR	Virtual Reality
WCC	Wireless Communication Centre
WiMAX	Worldwide interoperability for Microwave Access
Wi-Fi	Wireless Fidelity

General 5G cellular network architecture



Source: ResearchGate

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