Mobile and Satellite Communication Assignment

Internet of Things and Fifth Generation of Cellular Network Technology(5G)

Submitted by

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Internet of Things

Introduction : The global technological advancement is all about dumb physical things interacting and solving problems for ‘us,’ an intelligent species. Kevin Ashton coined the phrase 'Internet of Things' in 1999,the exciting world of ‘network of things’ or Internet of Things (IoT) is definitely good at sensing our needs and satisfying them.

Communication through radio frequency (RF), light and sound, and Bluetooth allows physical things to communicate with each other without wires, making the IoT a reality.

What is IoT : In a nutshell, the Internet of Things is the concept of connecting any device (so long as it has an on/off switch) to the Internet and to other connected devices. The IoT is a giant network of connected things and people – all of which collect and share data about the way they are used and about the environment around them.

That includes an extraordinary number of objects of all shapes and sizes – from smart microwaves, which automatically cook your food for the right length of time, to self-driving cars, whose complex sensors detect objects in their path, to wearable fitness devices that measure your heart rate and the number of steps you’ve taken that day, then use that information to suggest exercise plans tailored to you. There are even connected footballs that can track how far and fast they are thrown and record those statistics via an app for future training purposes.

How does it work?

Devices and objects with built in sensors are connected to an Internet of Things platform, which integrates data from the different devices and applies analytics to share the most valuable information with applications built to address specific needs.

These powerful IoT platforms can pinpoint exactly what information is useful and what can safely be ignored. This information can be used to

detect patterns, make recommendations, and detect possible problems before they occur.

For example, if I own a car manufacturing business, I might want to know which optional components (leather seats or alloy wheels, for example) are the most popular. Using Internet of Things technology, I can:

Use sensors to detect which areas in a showroom are the most popular, and where customers linger longest;
Drill down into the available sales data to identify which components are selling fastest;
Automatically align sales data with supply, so that popular items don't go out of stock.
The information picked up by connected devices enables me to make smart decisions about which components to stock up on, based on real-time information, which helps me save time and money.

With the insight provided by advanced analytics comes the power to make processes more efficient. Smart objects and systems mean you can automate certain tasks, particularly when these are repetitive, mundane, time-consuming or even dangerous. Let's look at some examples to see what this looks like in real life.

Mobile IoT : To support the further expansion and evolution of the Internet of Things (IoT), the mobile industry has developed and standardised a class of dedicated cellular technologies. These Mobile IoT networks support devices requiring broad coverage, a long battery life and low cost, yet secure, connectivity across both rural and urban locations.

Drawing on interviews with 24 mobile operators, this report outlines how LTE-M and NB-IoT networks are being rolled out around the world, what operators and their partners have learnt so far and what they plan to do next. It explains how the Mobile IoT is creating value in

commercial settings, while outlining initial tariff plans and the availability of modules, chipsets and other equipment.

The report also provides an overview of the features of LTE-M and NB-IoT, which have been standardised by the 3rd Generation Partnership Project's (3GPP) for use in licensed spectrum. Together, these technologies are enabling mobile operators to address a very wide range of potential use cases, ensuring customer choice and helping the IoT to flourish globally.

Now launched commercially by 36 mobile operators in 33 countries, the Mobile Internet of Things (Mobile IoT) is expanding rapidly with over 60 Commercial networks available globally, a combination of LTE-M and NB-IoT. Operating in licensed spectrum, low power wide area networks can provide low cost, yet secure, connectivity to battery-powered devices in both rural and urban locations. Following successful pilots involving a wide variety of use cases, Mobile IoT connectivity has now been deployed across North America, Latin America, China, South-East Asia, South Africa and in many European countries.

- ***Widespread Commercial Services***

In the U.S., Verizon and AT&T have both upgraded their entire nationwide LTE networks to support commercial LTE-M services, while T-Mobile has deployed NB-IoT nationwide. In the Asia-Pacific region, Vodafone has deployed NB-IoT in Australia, where Telstra has launched nationwide LTE-M and NB-IoT networks. China Telecom has configured 310,000 base stations now to support NB-IoT, China Mobile has launched NB-IoT networks in several cities (including Hong Kong) and China Unicom has rolled-out NB-IoT in over 300 cities. There are also now three technologies in Thailand with AJS supporting both LTE-M and NB-IoT, and True deploying NB-IoT.

- ***Very Versatile & Highly Capable***

Following standardisation by 3GPP in June 2016, the versatile and flexible Mobile IoT technologies are now being used to enable everything from smart metering and smart parking to asset tracking and consumer

wearable devices. In agriculture and forestry, Mobile IoT connectivity can enable farmers to monitor the location and condition of their livestock, while tracking the health of crops and plantations. NB-IoT and LTE-M can also be used to cost-effectively connect sensors monitoring the performance of an array of industrial machinery.
Upgrading an existing cellular network to support the Mobile IoT technologies can deliver as much as a sevenfold increase in coverage area, while penetrating deep inside buildings and below ground. That makes them particularly well suited to connect water, gas and electricity meters, as well as applications in manufacturing and logistics. Mobile operators have also found that these new technologies can support very dense networks and can scale easily.

- ***An Expanding Ecosystem***

As demand grows, the Mobile IoT ecosystem is expanding fast with dozens of operators and equipment vendors supporting the new technologies. A multitude of Mobile IoT modules, chipsets and software have now been certified as compliant with Release 13 of the 3GPP standards.
Operators can typically adapt their networks to support LTE-M and NB-IoT, which generate less signalling traffic than existing technologies, via a simple software upgrade. In many cases, tariff plans and modules are priced well below those associated with traditional cellular machine-to-machine propositions.
In 2018, many more mobile network operators are likely to roll out commercial Mobile IoT services. By March 2019, the GSMA expects the Mobile IoT will be available in more than 40 countries.

Technology - LTE-M (Long Term Evolution for Machines)

LTE-M is the simplified industry term for the eMTC LPWA technology, which was standardised by 3GPP in Release 13 specification. It specifically refers to LTE CatM1, which is designed to support the IoT. LTE-M is a low power wide area (LPWA) technology, providing low

device complexity and extended coverage, while allowing the reuse of existing LTE base stations.
The technology can allow connected devices to have a battery lifetime of at least 10 years for a wide range of use cases, with the modem costs reduced to 20-25% of the current EGPRS modems. LTE-M also supports relatively fast data throughput, mobility, roaming and potentially voice services.
Supported by all major mobile equipment, chipset and module manufacturers, LTE-M networks will co-exist with 2G, 3G, and 4G mobile networks and benefit from all the security and privacy features of mobile networks, such as support for user identity confidentiality, entity authentication, data integrity, and mobile equipment identification.
Commercial launches of LTE-M networks are now underway.
AT&T, KPN, Orange, Telefónica, Telstra and Verizon are among the operators rolling out LTE-M, following pilots of the technology across a wide variety of use cases, including monitoring individuals' location and vital signs using wearable devices. AT&T and its enterprise customers have also piloted LTE-M for smart shelving, asset management, logistics, fleet management and other use cases that require low cost mobile connectivity.

Technology - NB-IoT (NarrowBand IoT)

Standardised by 3GPP, Narrowband IoT (NB-IoT) is a low power wide area (LPWA) technology that can enable a wide range of new IoT devices and services. NB-IoT minimises the power consumption of connected devices, while increasing system capacity and spectral efficiency, especially in locations that can't easily be covered by conventional cellular technologies. In a wide range of use cases, NB-IoT connected devices can have a battery life of more than 10 years.
NB-IoT employs a new physical layer with signals and channels to meet the demanding requirements of extended coverage in rural areas and deep indoors, while enabling very low device complexity. The underlying technology is much simpler than that of GSM/GPRS modules, and the

cost of NB-IoT modules is likely to decrease rapidly as demand increases.

Supported by all major mobile equipment, chipset and module manufacturers, NB-IoT can co-exist with 2G, 3G, and 4G mobile networks. It also benefits from all the security and privacy features of mobile networks, such as support for user identity confidentiality, entity authentication, data integrity, and mobile equipment identification. Many different operators are rolling out NB-IoT services in Asia, the Middle East, Latin America and Europe, with commercial launches now underway. China Mobile, China Telecom, China Unicom, Deutsche Telekom, Etisalat, KT, NOS, TDC, Telefónica, Telia and Vodafone are among the operators to be deploying NB-IoT, having piloted the technology across a wide range of use cases, such as smart metering, smart parking and smart agriculture, which all require large numbers of low cost and low maintenance connected devices.

Fifth Generation of Cellular Network Technology(5G)

Introduction: The first generation of mobile communication system based on analog signal was born in the 1980s, and it helped people get rid of the shackles of telephone line. In the 1990s more efficient second-generation (2G) mobile communication systems based on digital communication occurred, and after that personal mobile communications have had a rapid development on a global scale. After 2000, with the deployment of 3G systems, people can enjoy faster mobile Internet experience, such as video telephony. When it comes to 2010, deployment of Long Term Evolution (LTE) based 4G commercial network further enhanced the system capacity and user experience. According to the statistics of Global TD-LTE Initiative (GTI), 364 LTE commercial networks have been launched by the third quarter of 2015.

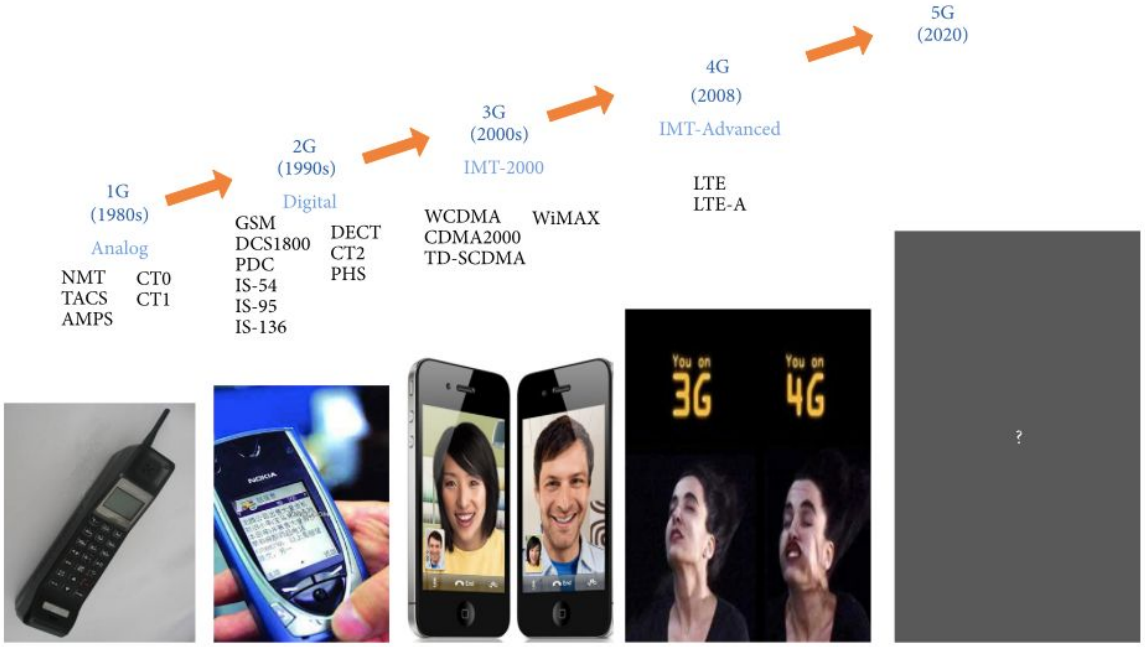

Figure 1: Evolution map of mobile communications.

In order to drive future development of mobile communication techniques, the METIS (Mobile and Wireless Communications Enablers for the Twenty-Twenty Information Society) project of European Union started research work of 5G at the end of 2012.

Vision for Mobile Communication towards 2020: The global deployment of LTE cultivates the mobile users to be use to the mobile data in their daily life tremendously. The video service and social applications, for example, WeChat, Facebook, and Twitter, have changed our life very much with the capabilities of LTE, especially high data rate and low latency. It is believed that the mobile communication will penetrate into every element of future society and create an all-dimensional, user-centered information ecosystem.
Accordingly, **the Mobile Broadband (MBB) service and the Internet of Things (IoT) will be the two main drivers in the future development of mobile communications, and they will provide a broad prospect for the next generation mobile communication system (5G).**

Figure 2: Overall visions of 5G [10].

Mobile Broadband service disrupted the traditional business model of mobile communications, enabling unprecedented user experiences and making a profound impact on every aspect of people's work and life. Looking ahead year 2020 and beyond, MBB service will promote the continued evolution of the way humans interact and provide users with ultimate experience through more immersive services such as augmented reality, virtual reality, ultra-high-definition (UHD) 3D video, and mobile cloud.
Looking ahead to the year 2020 and beyond, there will be explosive growth in mobile data traffic.

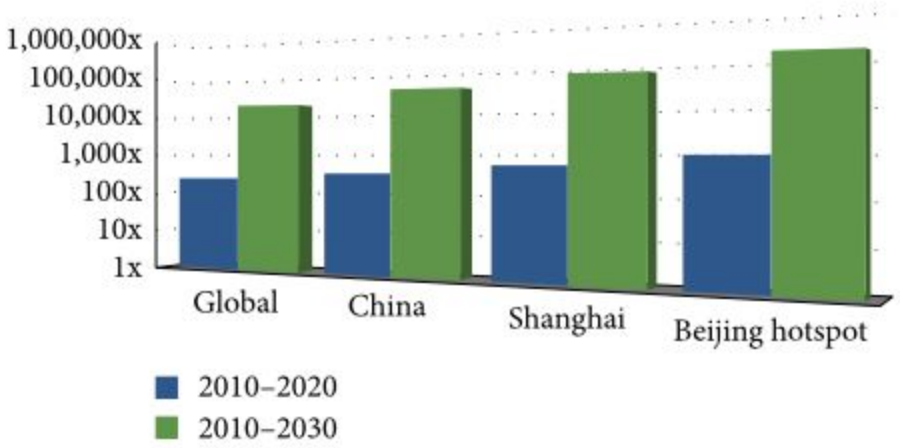

Figure 3: 2010–2030 growth of mobile data traffic [10].

The IoT has extended the scope of mobile communications services from interpersonal communications to smart interconnection between things and between people and things, allowing mobile communications technologies to penetrate into broader industries and fields. Looking ahead to the year 2020 and beyond, applications such as mobile health, Internet of Vehicles (IoV), smart home, industrial control, and environmental monitoring will drive the explosive growth of IoT applications, facilitating hundreds of billions of devices to connect to a network creating a true "Internet of Everything." This will give rise to emerging industries of unprecedented scale and instill infinite vitality to mobile communications which will pose new challenges to mobile communications.

The total number of devices connected by the global mobile communications network will reach 100 billion in the future.

Among all types of terminals, smartphones will contribute most of the traffic and IoT terminals will contribute less, even though the number of devices is much larger.

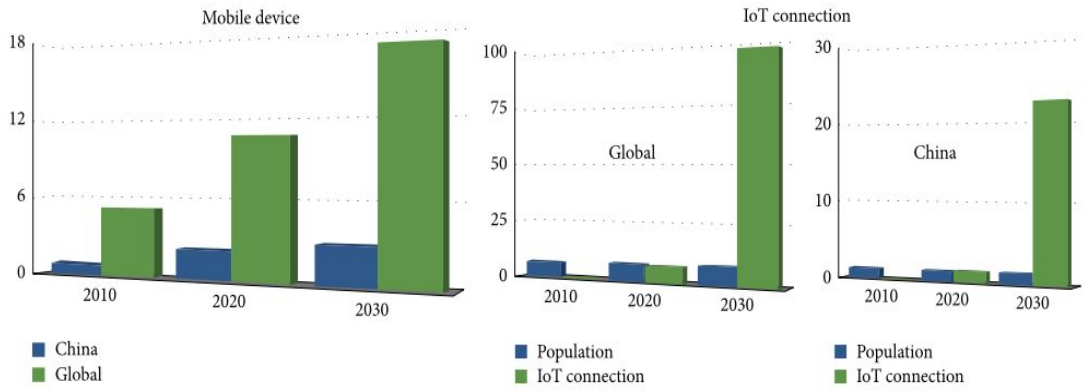

Figure 4: 2010–2030 growth of mobile device and IoT connection (unit: billion) [10].

Towards year 2020 and beyond, the typical trends could be summarized as follows.

(i) Explosive Growth of Data Traffic: There will be explosive growth in traffic; the global data traffic will increase by more than 200 times from 2010 to 2020 and about 20000 times from 2010 to 2030.

(ii) Great Increase of Devices in Connection: While smartphones are expected to remain as the main personal devices, the number of other kinds of devices, including wearable devices and MTC devices, will continuously increase.

(iii) Continuous Emergence of New Services: Different kinds of services, for example, services from enterprises, from vertical industries, and from Internet companies, will be exploited.

To meet the service and market demand towards year 2020 and beyond, the IMT-2020 is targeted to be deployed by 2020 (5G) and meet new and unprecedented demands beyond the capability of previous generation systems. 5G will break through the limitation of time and space to enable an immersive and interactive user experience. 5G will also shorten the distance between human and things and implement seamless integration to achieve an easy and smart interconnection between people and all things. 5G will provide users with fiber-like access data rate and "zero" latency user experience. 5G will be capable of connecting 100 billion devices. 5G will be able to deliver a consistent experience across a

variety of scenarios included the cases of ultra-high traffic volume density, ultra-high connection density, and ultra-high mobility. 5G will also be able to provide intelligent optimization based on services and users awareness and will improve energy and cost efficiency by over a hundred of times, enabling us all to realize the vision of 5G, "information a finger away, everything in touch."

Sustainability: Several problems are anticipated if today's networks are used to handle the explosive development of mobile Internet and IoT as follows.

(i) The energy efficiency level, overall cost per bit, and complexity of network deployment and maintenance cannot effectively handle the 1000-time traffic growth and a massive amount of connected devices in the future next decade.
(ii) Coexistence of multiple radio access technologies (RAT) causes increased complexity and degraded user experience.
(iii) Existing networks cannot realize accurate monitoring of network resources and effective awareness of services, and therefore they cannot intelligently fulfill the diversified requirements of future users and services.
(iv) Widely distributed and fragmented spectrum will cause interference and coexistence complexity.

To solve these problems, 5G should have the following capabilities to achieve sustainability. In terms of network construction and deployment, 5G needs to

(i) provide higher network capacity and better coverage, while decreasing the complexity and cost of network deployment, especially the deployment of ultra-dense networks;
(ii) have a flexible and scalable architecture to adapt to the diverse needs of users and services;
(iii) make flexible and efficient use of various spectrum resources, including paired and unpaired spectrum, refarmed spectrum and new

spectrum, low-frequency and high-frequency bands, and licensed and unlicensed bands;
(iv) have stronger device-connection capabilities to deal with the access requirements of huge amounts of IoT devices.

In terms of operation and maintenance (O&M), 5G needs to

(i) improve network energy efficiency and the O&M cost per bit to cope with data traffic growth and the diverse needs of various services and applications;
(ii)
reduce the complexity caused by the coexistence of multiple radio access technologies, network upgrades, and the introduction of new features and functions, to improve users' experience;
(iii)
make intelligent optimization based on awareness of users behavior and services contents;
(iv)
provide a variety of network security solutions to meet the needs of all types of devices and services of mobile Internet and IoT.

Table 2: 5G key efficiency indicators.

Efficiency indicators	Definition
Spectrum efficiency (bps/Hz/cell or bps/Hz/km^2)	The data throughput per unit of spectrum resource per cell (or per unit area)
Energy efficiency (bit/J)	The number of bits that can be transmitted per joule of energy
Cost efficiency (bit/Y)	The number of bits that can be transmitted per unit cost

Key Capabilities of 5G: 5G systems must dramatically outperform previous generation systems. 5G should support the following:
(i) User experienced data rate: 0.1~1 Gbps.
(ii) Connection density: 1 million connections per square kilometer.
(iii) End-to-end latency: millisecond level.
(iv) Traffic volume density: tens of Gbps per square kilometer.
(v) Mobility: higher than 500 Km per hour.

(vi) Peak data rate: tens of Gbps.

Meanwhile, 5G needs to significantly improve the efficiency of network deployment and operations. Compared with 4G, 5G should have 3 to 5 times' improvement in spectrum efficiency and more than 100 times' improvement on energy and cost efficiency.

Candidate Technologies and Spectrum: To achieve the above 5G requirement objectives, there are some emerging technologies proposed by many organizations and companies including the following:
(i) Novel multiple access, such as SCMA (Sparse Code Multiple Access), MUSA (Mult-iuser Shared Access), PDMA (Pattern Division Multiple Access), and RSMA (Resource Spread Multiple Access) (this kind of technologies can increase the spectrum efficiency, user experienced data rate, system capacity, and connection density).
(ii) New waveforms, like filtered-OFDM, UFMC (Universal Filtered Multicarrier), window-OFDM, and so forth, to maximize the spectrum utilization.
(iii) Massive MIMO technologies to increase the spectrum efficiency, user experienced data rate, and system capacity.
(iv) New channel coding such as polar code and LDPC (Low Density Parity Check Code), to increase the spectrum efficiency.
(v) Software defined air interface and end-to-end network slicing to increase the system flexibility to support all kinds of services and to enhance the overall network cost efficiency.

There are three solutions to satisfy the increasing spectrum demands for 5G services. Identification of more spectra both below and above 6 GHz for IMT is the solution with the highest priority. Bands below 6 GHz are the core spectrum bands used for IMT, with C band being a key band in the near future. The second one is to refarm spectrum used by legacy systems. The third one is to promote new technologies to share spectrum of the other radio services.