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Taiwan 5G White Paper

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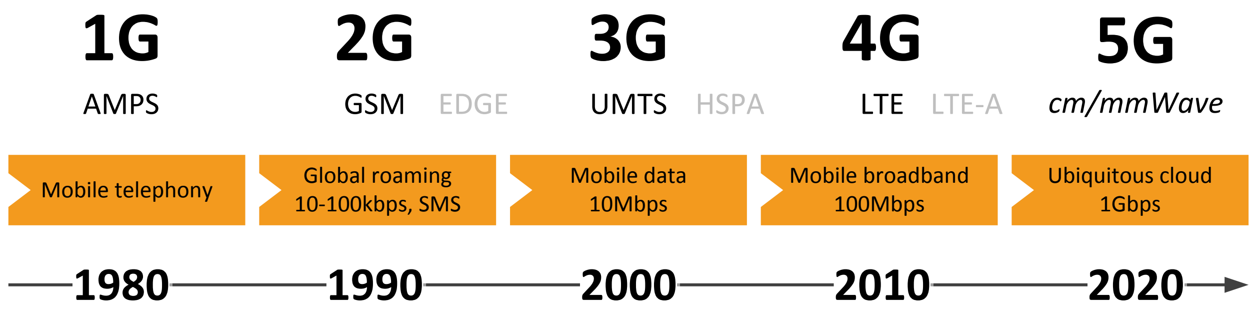
INTRODUCTION

Poised for availability starting in 2020, 5G follows the 10-year pattern also seen with earlier cellular generations. But with 5G expected to address a range of use cases and requirements that are broader than ever before, its definition will demand a strong industry commitment in order to secure timely completion of the necessary standards. This is a critical step to ensure that new spectrum above 6GHz, essential for the success of 5G and expected to be unlocked by ITU in 2020, may be made available for 5G as an IMT-2020 system.



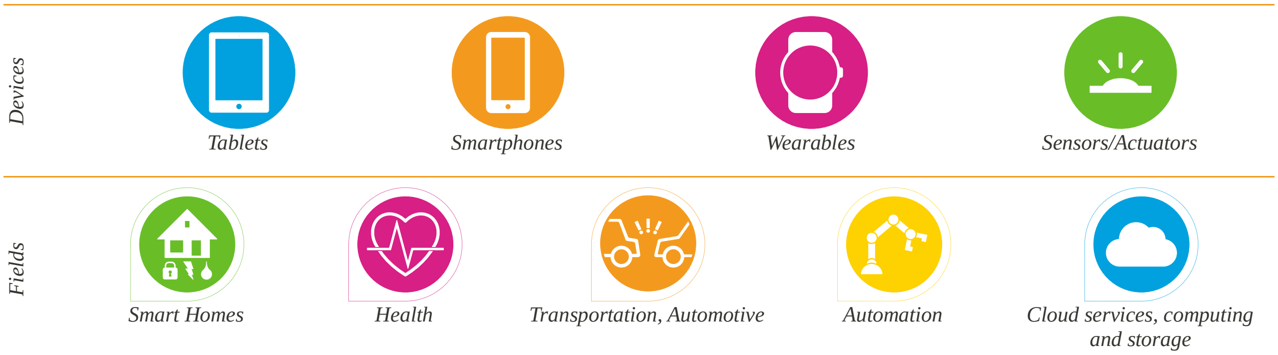
In order to ease standardization, a number of early consensus building activities, grouping industry and academia, have been taking place (e.g. EU METIS (FP7), EU 5GPPP (H2020), NGMN 5G Initiative, China IMT-2020 5G Promotion Association, Japan ARIB 2020 and Beyond to name but a few) that ought to bring a major leverage for the future success of 5G.

A global standardization effort is also underway in 3GPP as part of Release 14, and the first activity kicked off in Q1 2015 aimed at identifying use cases and associated requirements that will pave the way for the future standardization efforts in that forum. We expect 3GPP Release 14 to deliver, primarily through the evolution of LTE, the first technology enablers towards 5G in 2020; and to study the definition of a new radio access operating in spectrum above 6GHz. Release 15 will see the dawn of this new radio access commonly referred to as centimeter wave access (above 6GHz) and millimeter wave access (above 30GHz). 3GPP Releases 14 and 15 will contain the core technology components towards 2020 commercialization. It will also be necessary to ensure all IMT-2020 requirements are met; to this end, new enhancements will be defined in Release 16. It should be noted that the Releases timeline is open at the time of writing.

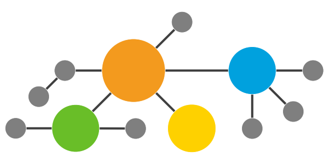
5G – ENABLING A BRAND NEW WORLD

Unlike all previous cellular generations, 5G will address an extremely diverse set of use cases and requirements in different markets. Not only does it need to take into account the reality of today's connected world, it must be ready for addressing the challenges of tomorrow's Brand New World with all things cloud-connected.

5G shall provide ubiquitous unlimited access to information over a growing range of devices and fields, in particular those listed below.



Massive unified IoT



The Internet of Things (IoT) revolution is under way, transforming all industry sectors whilst creating a huge growth opportunity for the ICT sector. 2G, 3G and 4G technologies that were not originally designed with IoT in mind, have all since been adapted to better meet the needs of IoT. 5G has to be tailored for IoT. This is about single purpose IoT such as low energy smart utility meters in remote locations that report small amounts of data infrequently for smart city applications, about cars that communicate with imperative reliability and with zero latency to prevent accidents regardless of cellular coverage, about manufacturing robots with control actuators linked to critical functions, about video surveillance systems in possibly adverse environments[1]. It is also about **cooperative, unified IoT** where systems of machines serving different purposes cooperate with each other for a common purpose. Imagine for instance a system of seismic sensors, a system of weather sensors, and a system of transportation and automotive sensors and actuators that operate together for the very purpose of saving lives should a natural disaster strike. And finally, it is about **massive IoT connectivity** with huge numbers of machines (sensors, actuators, etc.) served alongside more traditional devices like smartphones or tablets.

[1] Adverse conditions from a technology standpoint e.g. deep in-building, remote outdoors, etc.

Apps with legs

5G shall enable cloud-connected unified devices that work together as one e.g. around a user-defined cloud-connected hub cluster spanning health, car, entertainment and so on. Apps will no longer be constrained to the device on which they run, they will interact with other devices in the same cluster. **Imperceptible latency will be essential.** Imagine a driver with a safety feature app on her smartphone that connects to a wearable monitoring her health, to actuators on the car linked to a safe braking system and through a cloud-connection to emergency responders as well as to home contacts. Should the driver suddenly have a seizure, the safety app with legs would automatically activate its safety feature, safely pulling the car over, contacting emergencies informing about the health condition, about the health details of the patient, her location data as well as family contacts. Also, safely pulling the car over would automatically involve communication with neighboring vehicles to ensure safety at all times.

Tactile Internet

Technology aimed at humans need to be designed with human senses in mind. For instance, the technical solutions enabling speech calls in mobile communication systems were defined to make the end-to-end (mouth-to-ear) delay imperceptible to the human ear. Advances in human-machine interaction, processing power and artificial intelligence are transforming the way we interact with and use technology; by adapting technology to our senses and to their expectations, technology barriers are removed, making the use of technology natural, human. Touch and voice interactions are compelling popular examples of this trend e.g. we flip through photos by moving a finger on a screen as we would in a photo album, we ask a device as we would ask someone, to call a friend or find restaurants nearby. These work well when the reaction time matches or exceeds what our senses expect. Latency plays a crucial role. With content and services more and more cloud-based, such latency requirements have direct implications on the design of the systems through which these content and services are delivered. The ability to interact directly and in real-time with cloud content and services gave birth to the notion of **tactile internet**[2]. The tactile internet

[2] ITU-T Technology Watch Report, "The Tactile Internet", August 2014

should accommodate the most challenging latency requirements, involving sensory coordination between touch and vision or hearing; in this case **1ms** is required which should be feasible for proximal internet. The tactile internet is characterized by extremely low latency coupled with high reliability, availability and security. It will provide a considerable leverage for a diverse range of applications like e.g. *remote healthcare, automation, games, virtual immersive reality, augmented reality*. **5G shall be designed for the real-time, tactile internet.**

Mobile life-like Video

Video traffic represents a large portion of the entire traffic in mobile networks today, thanks to mobile broadband, the increasing quality of mobile devices' display with growing pixel density and the expanding availability of popular video streaming services. With more and more users expected to own a smartphone in the future, video will not only continue being a dominant traffic contributor, its volume will also increase. In just a few years, Full HD video (1080p) has become mainstream, and today 4K video (typ. 2160p) is starting to spread across theaters and living rooms alike while 8K video (4320p) is already on its way. Coupled with a high frame rate, 4K video looks life-like. One could of course wonder whether a 4K or higher resolution makes a difference on a relatively small screen like that of a smartphone or a tablet when the related pixel density reaches beyond what the human eye can distinguish. But the growing trend of virtual reality headsets could further accelerate the adoption of 4K and 8K beyond theaters and TV sets, into mobile devices by providing an immersive life-like experience in a confined space. Imagine watching the Olympic Games live with an unprecedented level of details – surely, the best seat to the event will be yours, wherever you may be! 5G systems shall enable the efficient transport of life-like video over the air to a wider range of devices be it that of a smartphone, a tablet, a TV set, a virtual-reality headset, a video projector, a billboard etc.

Ambient Broadband

In order to fulfill the growing demand and need for mobile broadband, 5G will not only increase by an order of magnitude the peak data rates vs. 4G, reaching well over 1Gbps. It will also considerably improve the average data rates over any given geographical area to guarantee the

availability of mobile broadband anytime and everywhere, indoors and outdoors, whether moving or not, whether crowded or not. **5G shall deliver Ambient Broadband.** Ambient broadband will be the enabler of advanced bandwidth-hungry services such as life-like video streaming, or cloud-based cooperative tools in office or education environment. Importantly, Ambient Broadband will also be essential to secure internet connectivity for everyone.

These use cases are but a few examples of the Brand New World enabled by 5G. No matter the use case, 5G must be designed to be scalable and flexible enough to be ready for the unexpected.

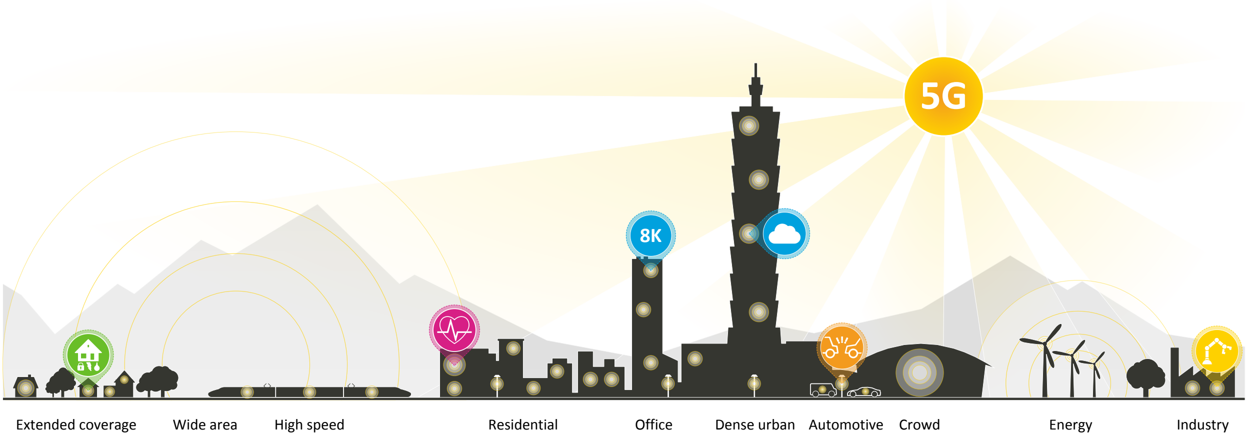
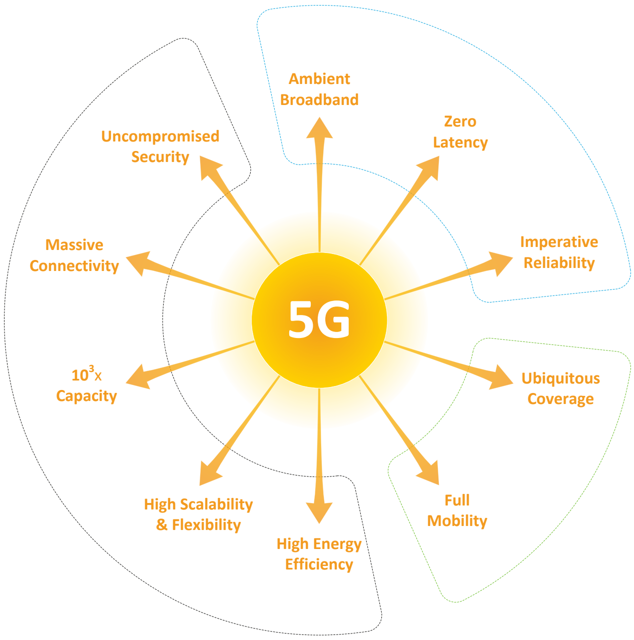


Figure 1. Towards a Brand New World

Each of the above use cases poses given requirements on the 5G System be it about latency, reliability, data rates etc. Taking a holistic approach to the 5G System towards enabling a Brand New World allows identifying and classifying a set of requirements from a system-design perspective as shown below.



Ambient Broadband

Multi Gbps peak, 1Gbps typical, x10Mbps cell edge

Zero Latency

Imperceptible end-to-end latency

Imperative Reliability[3]

Failure is not an option. Guaranteed delivery

Ubiquitous Coverage

From deep indoor to far outdoor. Seamless

Full Mobility

Static 0km/h to high-speed 500km/h train

Seamless service continuity

High Energy Efficiency

Years of battery life

Flat electricity consumption

High Scalability & Flexibility

Dynamic system-wide adaptation to needs and to the unexpected. Includes flexible spectrum.

10^3x capacity

Millions of devices per square kilometer

Massive Connectivity

Billions of connected things

Uncompromised Security

System, Data, User

Figure 2. 5G Requirements: Ready for the unexpected

The proposed system-design classification aims at maximizing synergies for the design of the 5G system in order to avoid technology fragmentation from market verticals as far as possible. A

[3] This can often be required in conjunction with imperative availability

number of requirements have a direct link to the quality of service offered by 5G i.e. Ambient Broadband, Imperative Reliability and Zero Latency. The next relate to the deployment conditions in which the service is offered and experienced i.e. Ubiquitous Coverage, Full Mobility. The others pertain to the system's overall ability to deliver these services to the largest device population with the highest efficiency and security. Like previous generations, security is indeed essential to the 5G System. The security requirements on the 5G System are to protect the system itself, the data it transports and its users (operators and subscribers) i.e. confidentiality, integrity and privacy must be ensured whenever required. In addition, means to strongly assure the security of the 5G system components themselves against unauthorized access are required; this was first introduced in 3GPP Release 12 in the EPC (MME). One important aspect to highlight as well will be the need to ensure the security of lifeline communications and of critical systems such as used in road safety or industrial applications, independently of whether or not security is provided to consumer types of services.

SPECTRUM

Radio spectrum is the key to mobile and wireless communications. Its use is regulated and varies geographically; it can be licensed to one or multiple users or unlicensed such that anyone can use it following given rules. A common harmonized spectrum is usually the best approach for a fast technology adoption and for improving cost efficiency but it cannot always be guaranteed; in this case specific solutions are needed in order to limit the negative impact it could have on the technology take-up. For instance, the spectrum used for 4G LTE being fragmented worldwide, between operators and also sometimes within an operator allocation has led to the definition of three major items; flexible system bandwidth, operation in paired and unpaired spectrum and carrier aggregation, all of which have allowed 4G LTE to fully adapt to the local spectrum situations with maximum synergies to ensure economies of scale. The support of multiple 4G LTE bands has been an absolute necessity for 4G LTE devices to achieve global roaming.

Unified spectrum

The rapid surge of mobile internet puts an unexpected pressure on mobile operators especially when facing capacity shortage and/or coverage gaps with existing spectrum. In order to meet the continued growing demand for mobile broadband, the capacity of mobile networks must be improved. Additional spectrum is an obvious answer; licensed of course, but also unlicensed. Unlicensed spectrum in particular has been a godsend to address these issues, relying on WIFI and more recently 4G LTE for the delivery of operator services in complement to licensed spectrum. More than that, unlicensed spectrum also unlocks new opportunities for expansion. But, in all, the end target is clear: **an operator should be able to treat radio spectrum it owns or shares as a complete unified pool of resources**, no matter whether licensed or unlicensed, such that it can *fully* exploit it to best deliver its services to end users. 5G will incorporate means to allow the flexible use of heterogeneous spectrum resources into a **unified spectrum** building upon the evolution that has taken place with 4G LTE.

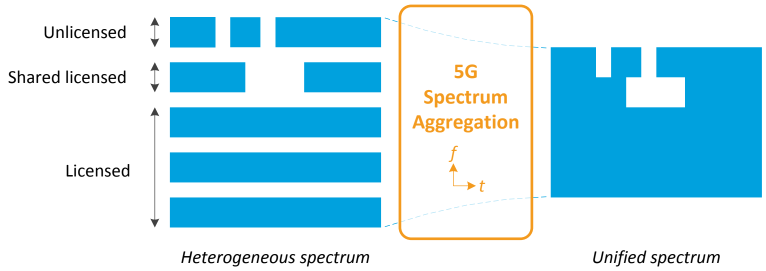


Figure 3. Unified Spectrum

New spectrum

Other untapped spectrum is also under consideration to meet the future capacity demand of 5G and enable the Gbps Ambient Broadband. Radio spectrum above 6GHz is not only highly promising to meet the future demand in capacity, it is essential to unleash the full potential of 5G. It is also highly coveted, whether for commercial, ISM or military uses. The telecom industry and regulators must therefore speak in unison to secure IMT spectrum above 6GHz with ITU-R: the first step is to guarantee the addition of this spectrum on the ITU-R WRC-19 agenda at ITU-R WRC-15 (ongoing activity by ITU-R WP5D to identify spectrum requirements for IMT-2020 – *ITU-R m.IMT above 6GHz*) and the second step is to unlock this spectrum at ITU-R WRC-19 while a new ITU-R recommendation for IMT-2020 systems is expected in 2020. Given the magnitude of the task to determine suitable spectrum, priorities must be set as follows: to identify the existing allocations of spectrum to the mobile service in regulations, the level of regional and global harmonization, the 5G bandwidths requirements (500MHz to 1GHz is the current industry direction), the co-existence requirements (be it within 5G or with incumbent users), the availability of contiguous spectrum and to characterize the propagation properties of the potential spectrum. The EU FP7 METIS project and the UK regulator Ofcom have taken actions to identify promising candidate bands for 5G use above 6GHz, taking all ITU regions into account.

In addition, new spectrum below 6GHz for IMT-Advanced is expected to be made available by ITU-R at WRC-15 that will contribute to expanding the footprint of 4G LTE and its evolution towards 5G.

Spectrum access and use

According to ITU-R WP5D, more than 500MHz spectrum resource shortage has been identified in order to fulfill the explosive mobile traffic growth. It is important to further explore more candidate spectrum for the use by mobile communication services. Besides the question itself of the exact spectrum above 6GHz for IMT, a main question is that of the use of (access to) this spectrum – these questions go hand in hand. Three main spectrum uses exist today, subject to local regulations:

- *LEA* Licensed, exclusive access
- *LSA* Licensed, shared access
- *UA* Unlicensed access

Cellular systems are typically tailored for LEA. Within the boundaries of a well-defined regulatory framework (e.g. wide population coverage, technology, support for emergency calls), a mobile cellular operator licensee has entire control over the spectrum it "owns" and exploits. In particular this means mobile communications in this spectrum are only possible if allowed by the operator itself. LEA fuels technology innovation, investments and competition amongst operators while ensuring economies of scale. LEA also provides a service level, a quality of service guaranteed by the operator to its users for different types of services. LEA has been decisive in the evolution of cellular systems; licensed spectrum will be decisive for the 5G System.

UA is the opposite of LEA. Subject to regulations and "good citizen" rules, mobile communications are possible without any other authorization. This has two obvious consequences; one on the design of the technology to minimize its impact on itself and on possible other technologies co-existing in the same spectrum (thus it is best suited to low power, short-range radio transmissions), one on the deterioration of performance as the load increases (uplink being a primary limiting factor). In turn, this means only best effort communications are guaranteed, which is not to say stringent QoS requirements cannot be met. UA opens the door to a very different, possibly more agile, technological ecosystem than LEA; miscellaneous. technologies can flourish and co-exist.

LSA is very similar to LEA in the sense that it provides exclusive access to some spectrum by means of a shared access between an incumbent, say priority, operator and other licensee(s). The sharing rules accounting for time and location enable LSA to unlock spectrum an incumbent operator has access to in e.g. given strategic locations and/or at given times for use by other operators in a different location and/or at a different time. The exclusive use of the spectrum at any given time and location provides the same benefits as LEA during that time and in that location.

Recent developments allowing operation of LTE in unlicensed spectrum may affect the way *new* spectrum is treated and made available in the future, and especially for 5G. The current inability of UA to provide a *guaranteed* QoS means it is, in its current form, likely impractical for 5G – the 5G System must be designed to guarantee QoS and QoE irrespective of the spectrum used. Also, recent developments allowing mobile operators to share network infrastructure and radio resources, coupled with the growing need for a flexible, cost-effective network infrastructure could pave the way to approaching new spectrum itself for 5G in a more flexible manner. A licensed and fully shared spectrum among mobile operators with no priority incumbent operator could bring a strong leverage to 5G, its deployment and adoption.

Ubiquitous coverage

The last question is that of ubiquitous coverage which of course is primarily intertwined with aspects of capacity; the challenge is typically to provide at minimal costs for a given deployment, as wide coverage as possible with as good capacity as possible. Spectrum holds a large part of the answer. Simply put, lower spectrum is more capacity-limited and less coverage-limited than higher spectrum; in other words, lower spectrum is more adequate to build coverage while higher spectrum is more fitted to build capacity. Bearing this in mind, it is also relatively clear that a regulatory mandate on 5G mobile operators to cover a large portion of the *human* population is expected; this implies rural, sub-urban, urban and dense-urban coverage with corresponding capacity demands (lower to higher). But it is also clear that IoT requires coverage in areas that are very sparsely populated or unpopulated by humans; this implies deep rural, and deep in-building coverage.

The 5G System will provide ubiquitous coverage by making use of heterogeneous spectrum resources from ultra-high-frequency (sub-GHz), adequate for meeting wide coverage demand with lower capacity needs for e.g. deep rural and rural areas to super and extremely high frequency (multi-GHz) adequate for meeting high capacity demand under small coverage areas, as needed in densely populated urban environment. On other hand, extremely high frequency will result in denser deployment, where the inter-cell coordination and backhauling become more challenging.

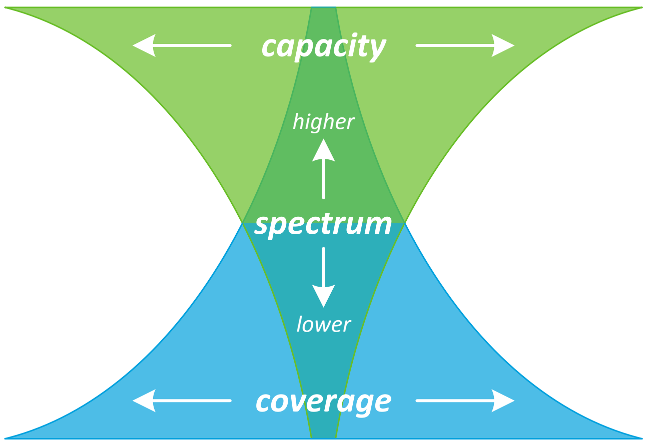


Figure 4. Spectrum, coverage and capacity in the 5G System

TECHNICAL ENABLERS

Earlier cellular generations have made mobile communications a reality and a commodity. Mobile communication systems have become so capable that it is expected their capabilities can and will be further improved to reach beyond what is possible today. 5G will tap into a great variety of use cases with diverse, stretched requirements and should be scalable to adapt to those that are unforeseen yet, whilst facing a continued growing demand for mobile data and mobile broadband.

5G Access: Operational symbiosis

5G will make use of a unified radio spectrum (licensed, licensed (fully) shared, unlicensed) spanning from lower frequency bands for wide area coverage to beyond 6GHz delivering Gbps Ambient Broadband, reduced latency and a significant capacity increase. Given the magnitude of the spectrum at play ranging from ultra high frequency (sub-GHz) to super and extremely high frequency (multi-GHz) different radio propagation properties (such as multipath, scattering, diffraction and absorption) need to be taken into account that may be highly dependent on the environmental including meteorological/atmospheric conditions[4]. Besides the spectrum use itself, diverse radio propagation properties and spectrum bandwidths will necessitate the definition of suitable radio access schemes. The 5G System will offer means to dynamically identify and select the best unified combination of spectrum and of corresponding radio access technologies to deliver a given service as a function of a number of conditions including e.g. QoS requirements, system load, environment. *The 5G System will be a cohesive, unified set of technologies operating in symbiosis over a unified spectrum.* This marks an important departure from earlier generations in that 5G will emerge from this combination of technologies while hiding technology from the end user. In particular, the 5G System will fully integrate, around a single core, LTE and its evolution towards 5G requirements i.e. 5G LTE, WiFi and new radio access technologies. Not only will this bring a considerable leverage of/to LTE deployments worldwide and to WiFi integration into operators' networks, but it will also prevent further technology fragmentation.

[4] Some frequencies have been shown to be considerably more sensitive to rainfall and/or atmosphere than others.

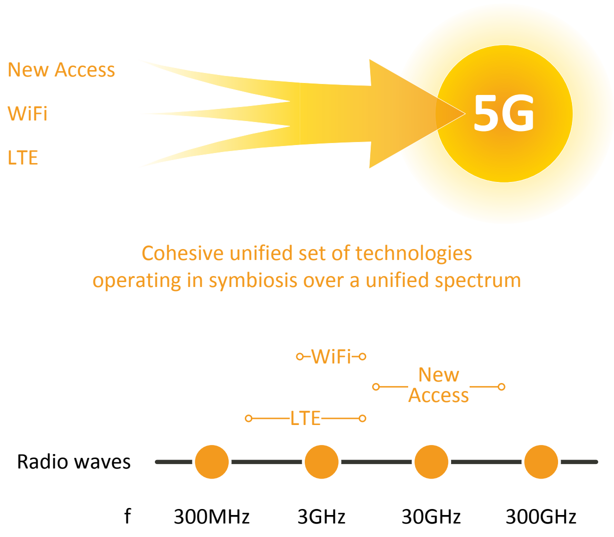


Figure 5. 5G Access: Operational symbiosis

Small cells densification

The evolution of 4G LTE for better coverage and capacity has followed three complementary primary directions:

1. Improvements to wide area deployments with e.g. new spectrum, carrier aggregation, smart antennas, remote radio heads (fixed fronthaul), mobile relays (wireless fronthaul);
2. Wide area deployments densification through adding more sectors per cells or more cells;
3. Local area deployments and improvements thereof with low-power small LTE cells and/or Carrier WiFi.

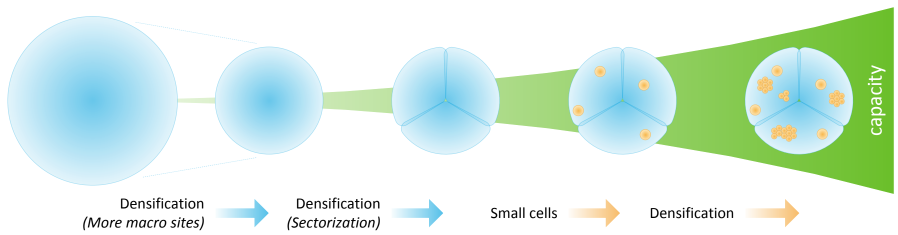


Figure 6. Cellular topology evolution towards more capacity (and better coverage)

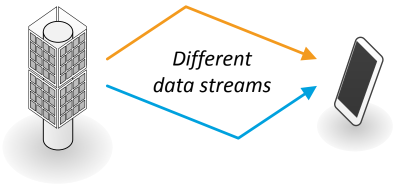
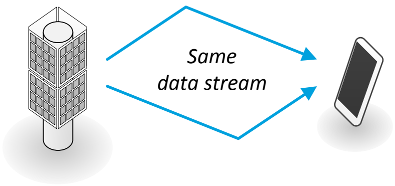
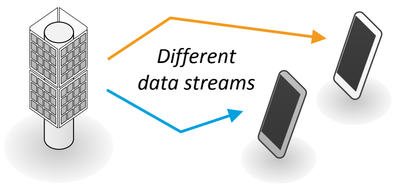
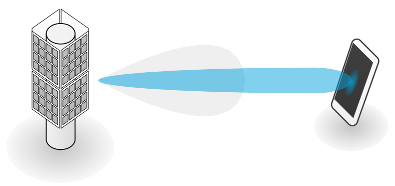
While the first approach is a relatively traditional evolution path with techniques not all necessarily tied to macro deployments, adding more macro cells with the second approach has obvious limitations in particular in urban areas where new macro cell sites may simply not be possible (which does not imply small cell sites would necessarily be easier to access). The third approach has received considerable attention for it promises the timely addition of the needed data capacity and coverage especially in areas where the first and second approaches are not suitable be it for spectrum, cost and/or performance reasons, while also contributing to reducing the power consumption of the device (due to better signal level/quality). The resulting heterogeneous networks require a high orchestration and integration in order to provide a seamless user experience, particularly given little or no operator coordination exists with small cell deployments. Therefore, automated means to avoid, mitigate or cancel small cell interference between themselves and in devices, as well as the self-configurability and optimization of small cells are crucial to their successful deployment. Furthermore, the quality of the backhaul connectivity between small cells in the same cluster as well as between a small cell and the rest of the network (core network or macro cell anchor) dictate the capabilities of the small cells as well as the role they play in the network. A very good backhaul (fiber or wireless) enables a tight low-level integration that can dynamically adapt to changing conditions.

A central element towards boosting capacity in 5G systems will be local area **small cells** deployments. These will be essential in particular to bring 5G to densely populated urban environment. The considerations above will hold true for 5G small cells as well which will not only exploit and improve techniques introduced for LTE but also introduce means specific to the higher spectrum. Also, in order to ease the deployment of 5G small cells, reduce its costs and ultimately accelerate the adoption of 5G, self-backhauling where 5G radio access will be used to provide a wireless backhaul will be of considerable interest.

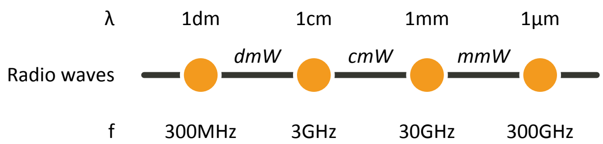
Spectral efficiency

Despite the expected high availability of new spectrum above 6GHz, spectral efficiency will remain paramount to the 5G system across the addressable spectrum range in order to improve the overall capacity per node and the overall cost efficiency of the network. **MIMO and Advanced receiver techniques** will be two major contributors to improving spectral efficiency hence system capacity in 5G systems. At these frequencies, the size of the MIMO's multi-antenna system is no longer a major impediment to the size of the device, hence allowing exploiting further multi-antenna gains with the device, while making large-scale antenna arrays possible in the base station which will contribute to multiplying the gains from traditional MIMO schemes. The spatial diversity hence multipath propagation obtained with a MIMO antenna system translates directly into capacity gains by using the very same radio resources in time and frequency domains but separated in space. Different techniques are available, depending on the intended target, the available spectrum and the device's complexity and cost: single-user MIMO, multi-user MIMO, beam-forming. 5G systems will make full use of advanced MIMO and advanced receiver techniques to increase throughput, reliability, connectivity and coverage with maximum spectral efficiency.

Table 1. MIMO Techniques

Technique	What	Target
SU-MIMO		Better throughput per device *(n data streams, 1 user)*
		Better reliability per device *(n x same data stream, 1 user)*
MU-MIMO		Better connectivity per network node *(n streams, n users)*
Beam-forming		Better coverage per device. Tackle propagation losses.

New radio access schemes are also being explored for use above 6GHz and 30GHz respectively named centimeter-wave (cmW) and millimeter-wave (mmW), owing to their associated wavelengths. These will play a major role in 5G reaching its latency and data rate targets in particular.



As indicated above, the propagation properties at these frequencies will have to be carefully characterized in order to select appropriate spectrum and system design. For instance, the penetration loss of a mmW signal as well as the higher free-space path loss (i.e. line of sight atmospheric path) at these frequencies due to smaller antennas, both require the use of antenna(s) with a large gain. This in turn implies narrowly focused radiations that are difficult to align and track in a mobile environment. As a result, beam-forming becomes a critical element for mmW access in both downlink *and* uplink directions, and more aggressive duplexing may be considered to remove the traditional boundary between downlink and uplink (e.g. having simultaneous transmit/receive over same radio resource with proper isolation/cancelation).

Furthermore, as a function of beam-forming the channel's characteristics may vary greatly; for instance a narrowly-beam-formed channel is typically less dispersive than a wider one. The modulation waveform may need to be flexible enough to adapt to such variation. Therefore, accurate channel model to adequately capture the impact by user mobility will be critical to ensure the system design and standardization can well resolve the problem in the field.

Latency and Reliability

Regarding latency, considerable reductions over the radio interface can be achieved with appropriate measures in time, frequency and space domains. The most important contributor however will be in time domain including:

- Reduction of the frame duration and transmission time interval
- Reduction of switching times between downlink and uplink transmissions
- Reduction of access times (e.g. acquisition of broadcast information, contention-based access) and round trip times

Special attention will also be required to ensure whenever necessary that both zero latency and imperative reliability can be delivered simultaneously; as identified earlier, this will be essential for a number of use cases such as autonomous driving and tactile internet that demand very fast real-time interaction and very reliable communications. In these cases, first-attempt transmissions should be successful with very high probability. Second-attempt transmissions and further re-transmissions of an erroneous message could be obsolete due to the time-critical property of the message. While orthogonal waveform design in LTE has proven to be very suited for scheduling access, it requires significant overhead to synchronize devices and keep them synchronized. Scheduling delay adds to signaling overhead and latency as devices need to get scheduling resource before they can transmit message in scheduled resources. New waveform design may allow relaxed synchronicity and orthogonality requirements for a more efficient access.

Additional measures that can increase the throughput will also contribute to reducing the overall latency. Thus, using space and/or frequency separation will be beneficial.

But in addition to defining a low-latency radio interface, it is also important to keep in mind the physical limits inherent to latency as illustrated below. The end-to-end latency will be heavily influenced by the transmission mediums separating endpoints, hence the importance of a non-limiting fronthaul and backhaul (e.g. fiber, wireless vs. wired), of optimizing the data path between endpoints as a function of the overall delay budget, and of bringing (time-critical) content closer to its point of consumption if and whenever possible.

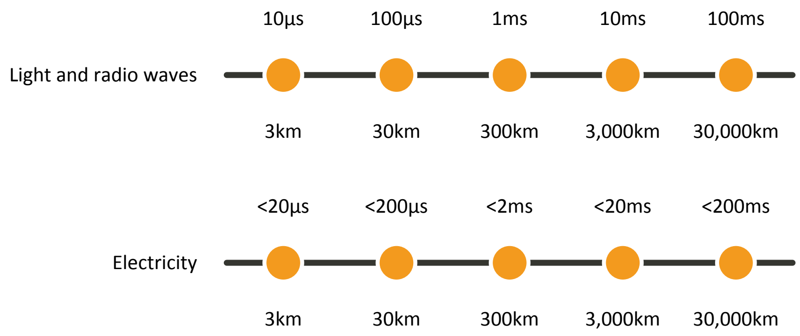


Figure 7. Physical limitations to latency

IoT

The Internet of Things has received a lot of attention in recent years, especially for the growth opportunities it promises beyond the more traditional "handset" market. Nearly every industry is concerned. IoT is probably the toughest challenge yet for the cellular industry for, as described previously, its use cases and requirements are highly disparate. The recent evolution of 2G, 3G and 4G systems has focused essentially on the low-end IoT market with most notably smart-metering in mind. Changes made have been two-fold; a) to protect the system against a signaling surge from a large number of smart-meters that transmit delay-tolerant data infrequently has ensured the protection and availability of traditional services; b) to serve the IoT market by defining specific technology components to better meet its needs i.e. deep coverage, low power consumption and low complexity, most importantly through LTE and GSM evolutions.

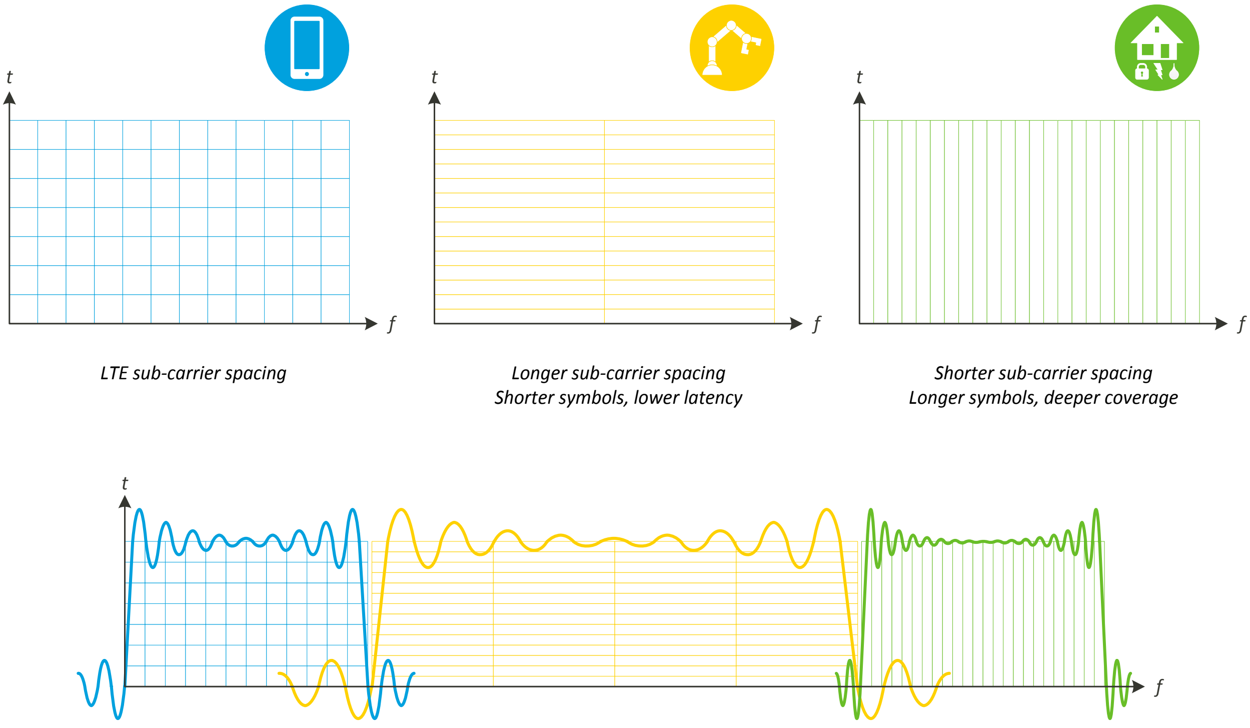


Figure 8. Optimized use of spectrum resources

The 5G system will be defined from day one for IoT to guarantee the best possible overall system efficiency whilst serving billions of "things" subject to wide-ranging requirements, in addition to other "non-IoT" scenarios both envisaged and unforeseen yet. By 2020, LTE will be broadly available especially thanks to deployments in sub-GHz spectrum that allows covering wide areas at minimal costs. Exploiting this spectrum for new services such as IoT while gracefully co-existing with mobile broadband service will be essential. Artful radio interface choices will be necessary to meet deep coverage and low latency requirements of various IoT applications.

Flexibility and Scalability

The 5G System will require an unprecedented system flexibility and scalability to provide cost- and energy-efficient context-aware[5] means for adapting to service demands. The separation between user and control planes will of course continue being essential for adequate system dimensioning, but more generally dedicated purpose-built physical nodes will give way to generic units that will be remotely, dynamically and programmatically (re-)configurable to meet given

[5] Contextual information pertains to the network, the user and the device. Such information should be available and manageable.

needs when and wherever, such that it will be possible to adapt the use of system resources to these needs as they evolve. This principle will span through the 5G system infrastructure unless otherwise dictated by performance (e.g. radio) or other requirements. In addition, the 5G system through increased flexibility and scalability will also provide improved agility to accelerate the deployment of new services.

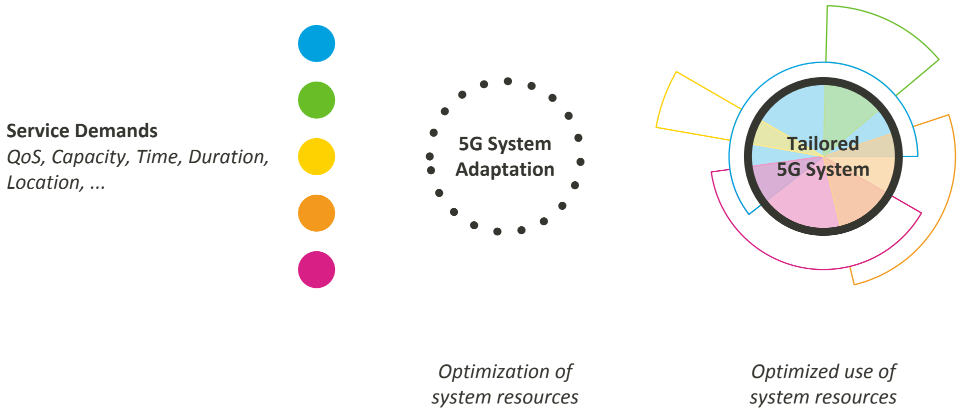


Figure 9. The 5G System dynamically adapts to service demands

GLOBAL STANDARDS

In order to prevent technology fragmentation, to guarantee competition and compatibility, to channel investments and enable economies of scale for operators and users alike, global standards are needed. 3GPP as a global partnership between major regional SDOs from Asia (ARIB, CCSA, TTC, TTA, TSDSI), Europe (ETSI) and the US (ATIS), will play the leading role in the standardization of the 5G System. It gathers the entire mobile industry and has a strong successful legacy with the open standards for GSM, UMTS and LTE. Besides, the evolution of LTE will play an important role in 5G. 3GPP is best positioned to successfully standardize the 5G System, a necessary condition for the future success of 5G.

TAICS members assume three releases for 3GPP to complete the 5G standardization works, i.e. Rel-14, Rel-15 and Rel-16, to meet ITU-R IMT2020 submission timeline. In addition, the standardization priority should be set based on market demand such that the technologies required for 2020 deployment will be prioritized in Rel-14 and Rel-15.

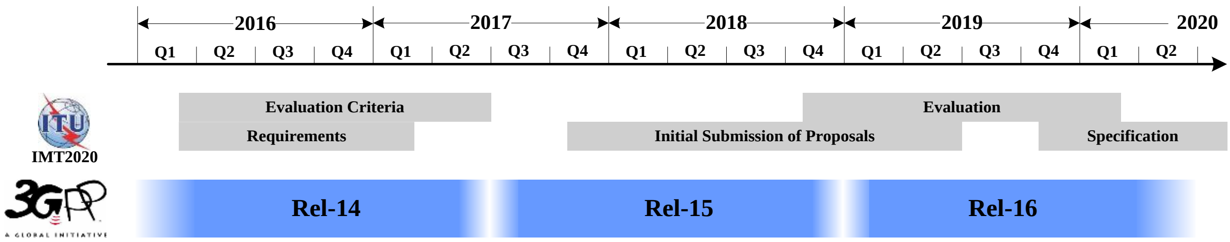


Figure 10. Envisioned 5G standardization timeline

APPENDIX – MOBILE BROADBAND IN TAIWAN

The first mobile communication network (AMPS) in Taiwan was commercialized in 1989. Then Taiwan became one of markets with fastest subscription rate in embracing each generation of mobile evolution. For example, the unique mobile subscription rate for Taiwan is 93% in 2015/Q2 (see Figure 11). This has laid a sound foundation for Taiwan to develop mobile broadband.

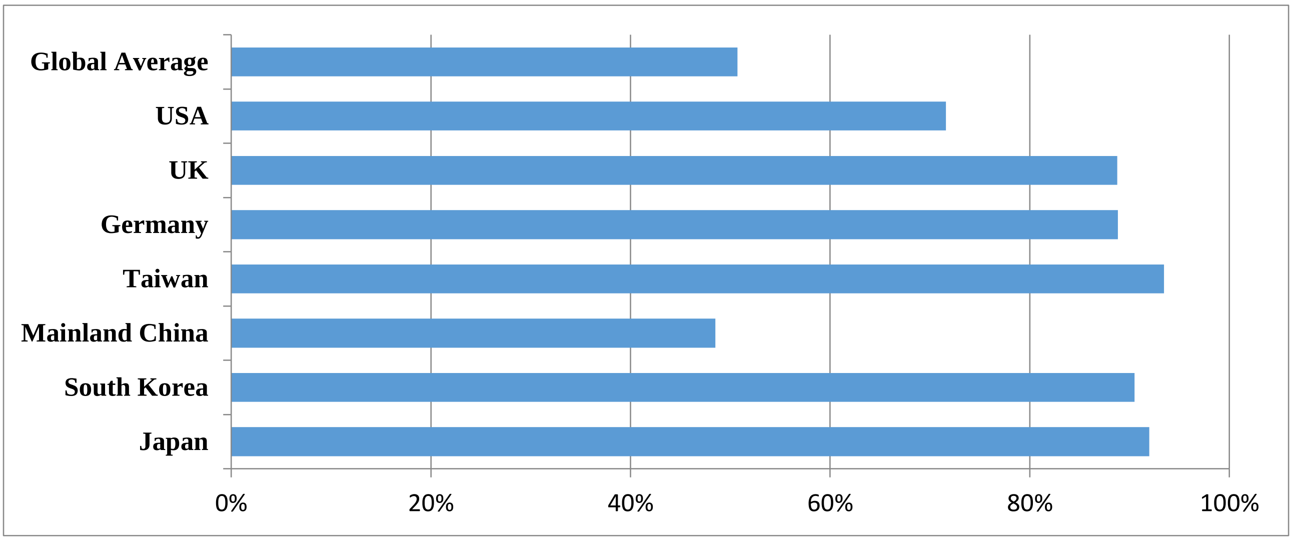


Figure 11. Unique Mobile Subscription Rate, 2015/Q2

The first LTE spectrum auction in Taiwan was taken in October 2013 and soon with commercial services launched in May 2014. Until 2015/Q3, it only took five quarters to reach a remarkable market penetration level (see Figure 12). The strong user demand on mobile broadband can be reflected through not only subscription growth rate but also data usage volume.

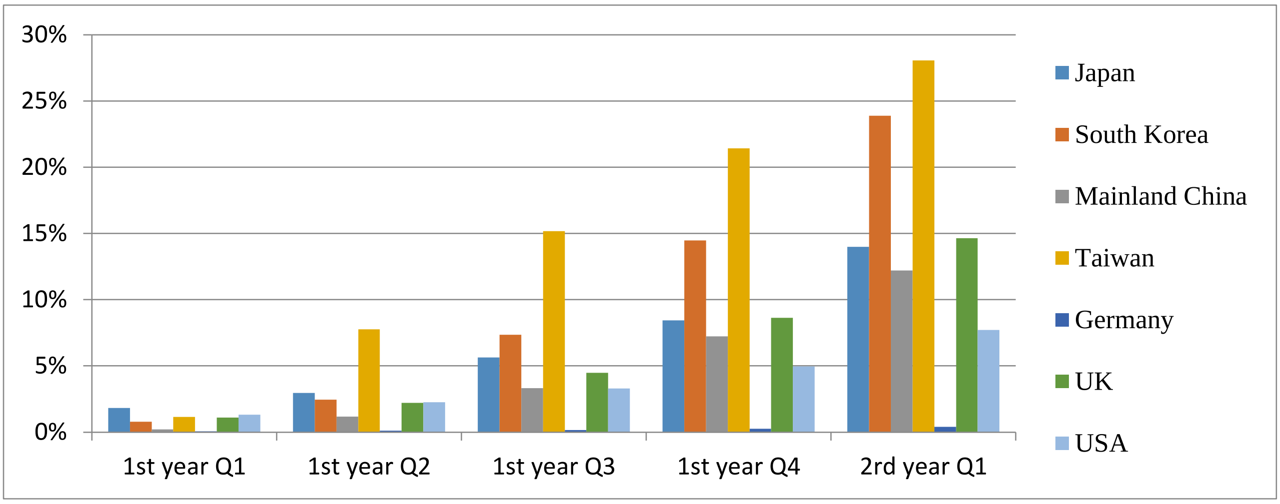


Figure 12. LTE market penetration in the first 5 quarters after commercial launch

In Taiwan, the average data consumption volume per user has reached approximately 7~10 GB/month, far surpassing the volume than most of the 4G LTE networks in the world (see Table 2). With the extremely strong market demands on mobile broadband applications and the people always eager in experiencing new technologies, Taiwan should be best place to test future 5G technologies and applications.

Table 2. Average data usage by LTE subscriber per month

	Data Traffic (GB/user/month)		Data Traffic (GB/user/month)
Japan	3~4	**Germany**	< 1
South Korea	3~4	**UK**	1~2
Mainland China	< 1	**USA**	2~3
Taiwan	7~10	**Global Average**	1~2

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[1] ITU-R WP5D 5D/TEMP/548-E, "IMT Vision – 'Framework and overall objectives of the future development of IMT for 2020 and beyond'," Feb. 2015.

[2] GSMA Intelligence, 2015/Q2.

[3] Ovum, "Smartphone & tablet usage trends & insights - 4G LTE and Wi-Fi powering data consumption," Feb. 2015.

ABBREVIATIONS

Abbreviation	*Explanation*
3GPP	***Third-Generation Partnership Project***
ATIS	***Alliance for Telecommunications Industry Solutions***
ARIB	***Association of Radio Industries and Businesses***
CCSA	***China Communication Standards Association***
ETSI	***European Telecommunications Standards Institute***
IMT	***International Mobile Telecommunications***
ITU	***International Telecommunication Union***
TTA	***Telecommunications Technology Association***
TTC	***Telecommunication Technology Committee***
TSDSI	***Telecommunications Standards Development Society, India***

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