MASS CONNECTIVITY IN THE 5G ERA

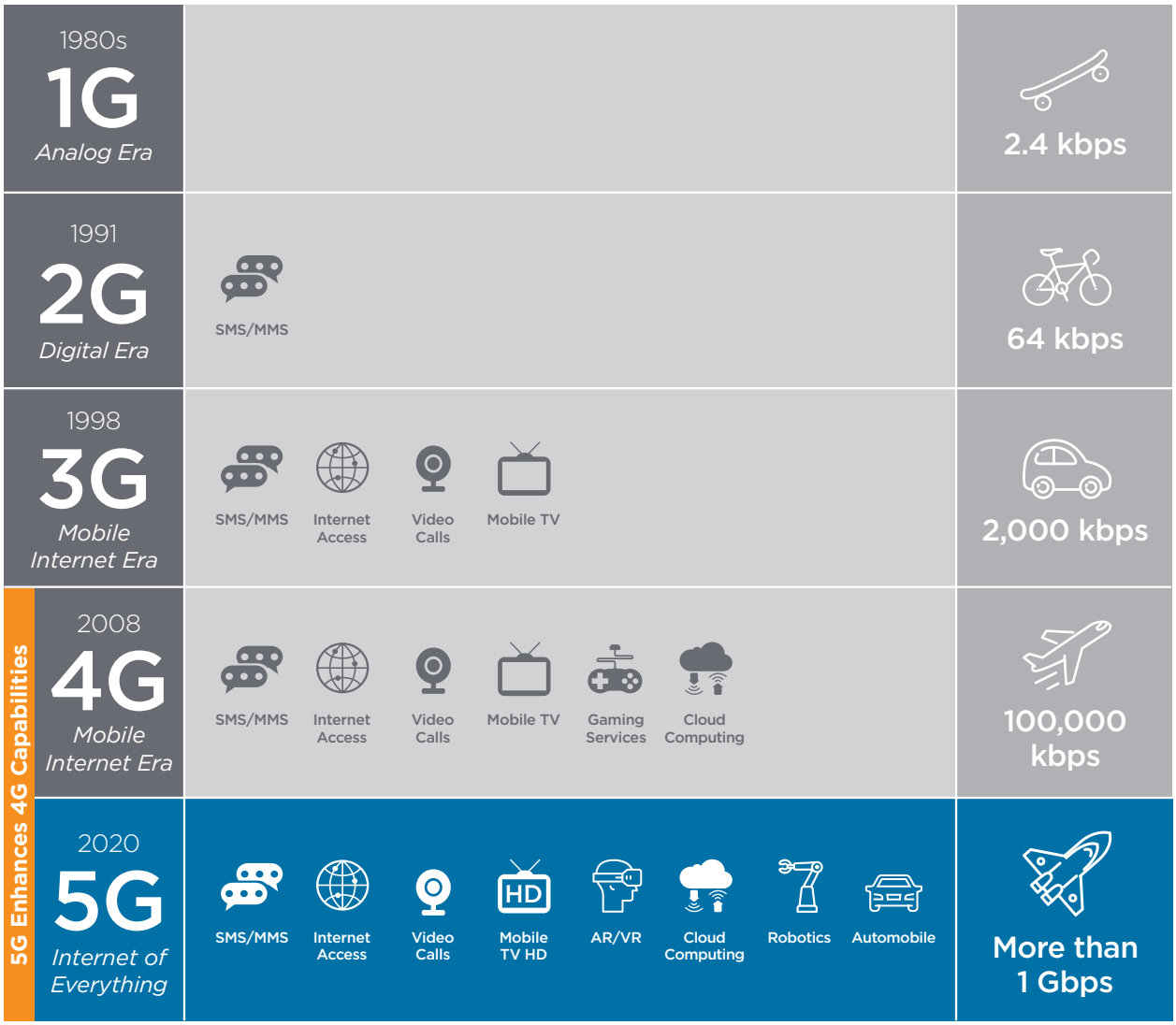
Preparing Now for the Future

5G Enabling a Fully Connected World

The fifth generation of mobile networks (5G) is about to enable a fully connected world.

With a dramatic increase in data rates and the number of connected devices, we will soon be able to enjoy expanded communication between devices (Figure 1) and no longer be limited to user-to-user and user-to-device communication. By 2025 an enormous 25 billion devices are expected to be connected under 5G.[1]

Figure 1. Evolution from 1G to 5G



5G, which can be considered an overlay to the existing 4G network, represents not only a change to cellular networks but also an integration with communications networks such as Wi-Fi and telemetry (Table 1).

[1] © GSMA Intelligence (2018) - The Mobile Economy 2017

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Table 1. What 5G can do that 4G cannot

Networks	Data Rate	Latency	Mobility	Spectrum Efficiency	Connection Density
5G Target	>100Mb/s (avg) >10,000Mb/s (peak)	~ 1ms	>500km/h	Target is more than 2x 4G	>100,000
4G	>25Mb/s (avg) >150Mb/s (peak)	Typically ~50ms 10ms for 2-way Radio Access Network	Functional up to 350km/h	Download: 0.1-6.1 b/s/Hz Upload: 0.1-4.3 b/s/Hz	Typical ~2000 active users/km²

According to the Next Generation Mobile Networks (NGMN) Alliance, "5G is an end-to-end ecosystem to enable a fully mobile and connected society. It empowers value creation for customers and partners, through existing and emerging use cases, delivered with consistent experience, and enables sustainable business models."[2]

Imagine a future where 5G connectivity is embedded into nearly everything you can virtually try on clothing and shop at home using a virtual reality (VR) headsets your autonomous vehicle can self-navigate and drive you to your favorite restaurant for dinner: your thermostat can preheat/precool at a desired temperature by retrieving the arrival time of your car as well as current and forecasted weather conditions.

Possible 5G Enhancements

- ☑ Realistic and seamless video streaming
- ☑ High definition video downloads in a matter of seconds
- ☑ Connected and autonomous driving vehicles
- ☑ Connect all your devices and smart home equipment through the IoT ecosystem enabled by 5G
- ☑ Increase in internet-enabled tech: smart traffic lights, wireless sensors, mobile wearables, and car-to-car communication

> ***5G technologies could integrate and enable the full potential of mobile technology, big data, IoT, and cloud computing while supporting digital transformation across various sectors, including healthcare, smart vehicles, smart home, industrial automation, and more.***

[2] © GSMA Intelligence (2014) - Understanding 5G: Perspectives on future technological advancements in mobile, December 2014.

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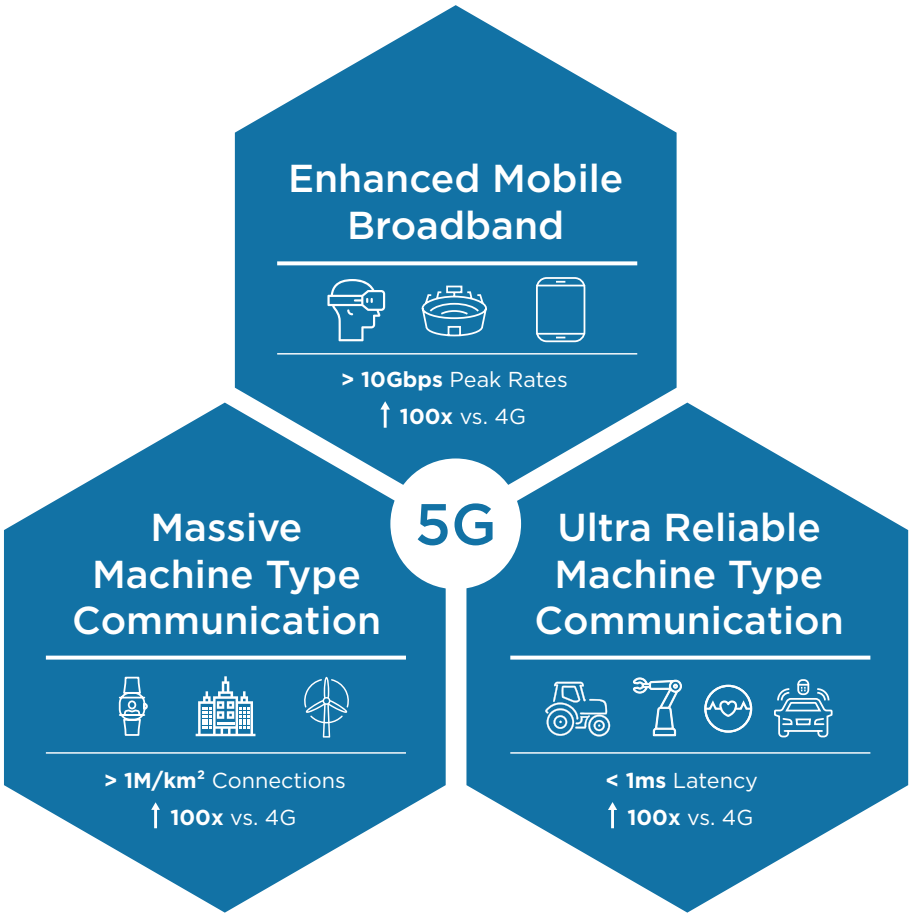
Advanced and reliable connectivity is one of the most critical drivers to enable 5G-powered use cases, which can be summarized into three family categories (Figure 2).

Figure 2. Three 5G use categories



Mobile Subscribers

The number of unique mobile subscribers is estimated to reach 5.9 billion by 2025, equivalent to 71 percent of the world's population. (© GSMA Intelligence (2018) The Mobile Economy 2018)

Mobile Data Traffic

Globally, mobile data traffic is expected to increase sevenfold between 2016 and 2021. Mobile data traffic will grow at a CAGR (Compound Annual Growth Rate) of 46 percent between 2016 and 2021, reaching 48.3 EB (exabyte) per month by 2021. (Cisco Visual Networking Index: Forecast and Methodology, 2016–2021)

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eMBB (Enhanced Mobile Broadband) focuses on providing services that pose high bandwidth requirements, based on user demand for an increasingly digital lifestyle. Typical applications include Virtual Reality (VR) and Augmented Reality (AR), 8K video, and 3D video. eMBB use cases are expected to grow rapidly, led by Asia-Pacific countries, particularly Olympic hosts South Korea and Japan. The recent 2018 Pyeongchang Winter Olympics stands as one of the industry's first non-test environments of a 5G network. The pilot project contained live or on-demand VR coverage for 30 events, powered by 5G's ubiquitous coverage across venues, as well as low latency to enable real-time control.

uRLLC (Ultra-Reliable and Low-Latency Communications) aims to cater to the demanding digital industry and focuses on latency-sensitive services. Typical applications include autonomous vehicles, public and mass transit systems, drones, remote healthcare, and smart grid monitoring and control. Latency can also be critical for cloud VR use cases where sub-millisecond latencies will be important to ensure a compelling user experience.

mMTC (massive Machine Type Communications) aims to address demands for a further developed digital society and focuses on services that pose high requirements on connection density as the expansion of the service scope for mobile networks also enriches the telecommunications network. Typical applications include smart cities, industrial automation, and farming.

4K TV sets: By 2021, more than half (56 percent) of connected flat panel TV sets are expected to be 4K, up from 15 percent in 2016. Installed/in-service 4K TV sets will increase from 85M in 2016 to 663M by 2021.[3]

Virtual Reality and Augmented Reality: traffic is expected to increase 20-fold between 2016 and 2021, at a CAGR of 82 percent.[4]

Connected Vehicle: By 2020, it is anticipated there will be a quarter billion connected vehicles on the road, enabling new in-vehicle services and automated driving capabilities.[5]

IoT Connections: The number of Internet of Things (IoT) connections (cellular and non-cellular) is expected to increase more than threefold worldwide between 2017–2025, reaching 25 billion.[6]

Mobile Technologies and Services : In 2017, mobile technologies and services generated 4.5 percent of GDP (Gross Domestic Product) globally, a contribution that amounted to $3.6 trillion of economic value added. By 2022, this contribution is expected to reach $4.6 trillion, or 5 percent of GDP.[7]

[3]Cisco Visual Networking Index Predicts Global Annual IP Traffic to Exceed Three Zettabytes by 2021

[4]Cisco Visual Networking Index Predicts Global Annual IP Traffic to Exceed Three Zettabytes by 2021

[5]https://www.gartner.com/newsroom/id/2970017

[6]© GSMA Intelligence (2018) - The Mobile Economy 2018

[7]© GSMA Intelligence (2018) - The Mobile Economy 2018

Wave to Greater Capacity

5G is expected to provide an order of magnitude improvement in performance in the areas of greater capacity, lower latency, more mobility, more accuracy of terminal location, increased reliability, and availability.[8]

> ***To address the expected high capacity of 5G, there are three methods to be considered from the radio perspective: 1) densifying networks with small cell deployments, 2) delivering high spectral efficiency, 3) gaining access to more spectrum. There are all closely linked to strategic spectrum deployment.***

As a critical but scarce resource in the 5G era, spectrum in three key frequency ranges, each with unique features, is expected to deliver widespread coverage and support all 5G use cases: sub-1 GHz, 1-6 GHz, and above 6 GHz. The first two are often referenced as sub-6GHz.

This is important as cellular data traffic continues to rise, and eMBB is set to become the core consumer value proposition. We expect both the USA and China to lead the first wave of 5G deployments, with different approaches. China, in our opinion, will focus initial deployments in the C-band (3-5 GHz) targeting IoT use cases. The USA, on the other hand, will focus initial deployments on fixed wireless access through mmWave (above 24 GHz) frequency spectrum, as well as deployments in low bands (600 MHz).

In the long run, we believe C-band spectrum may be challenged to deliver enhanced mobile broadband due to limited spectral efficiency and system capacity improvements, as well as less than 10 ms latency. To support the requirements for wide contiguous bandwidths, mmWave bands may need to be considered.

> ***Due to the fast-growing 4K/8K ultra-HD video applications and the ever-increasing use of AR and VR applications, 5G is needed to supplement the capacity of 4G networks.***

> ***Considering the current technical maturity and economic feasibility, a hybrid network is very likely - in major urban areas, mmWave will be deployed, while sub-6GHz is expected to deploy in suburban areas or small cities. Of course, 5G will also co-exist with 4G.***

[8] The 5G Infrastructure Public Private Partnership (5G PPP): 5G Vision

These bands can support large capacity increases for high bandwidth applications. In addition, with techniques like beam forming, wireless signals could be made highly directional without causing much interference, allowing for improved spectral efficiency. However, with increasing carrier frequency, both path loss and diffraction loss become more severe, and the atmospheric effects must be considered.

Currently, there are a large number of preliminary 5G tests worldwide that are using various spectrum bands, particularly 3.5 GHz and 26/28 GHz. In more than 30 regions, there are plans to assign spectrum in two bands over the next two years. (Figure 3)

Designed for Diverse Spectrum Bands/Types

Figure 3. Global snapshot of 5G spectrum bands allocated or targeted[9]

	<1GHz		3GHz	4GHz	5GHz	24-28GHz	37-40GHz	64-71GHz
USA	600MHz (2x35MHz)	2.5GHz (LTE B41)		3.45-3.55GHz 3.55-3.7GHz 3.7-4.2GHz	5.9-7.1GHz	24.25-24.45GHz 24.75-25.25GHz 27.5-28.35GHz	37-37.6GHz 37.6-40GHz 47.2-48.2GHz	64-71GHz
Canada	600MHz (2x35MHz)			3.55-3.7GHz		27.5-28.35GHz	37-37.6GHz 37.6-40GHz	64-71GHz
EU	700MHz (2x30MHz)			3.4-3.8GHz	5.9-6.4GHz	24.5-27.5GHz		
UK	700MHz (2x30MHz)			3.4-3.8GHz		26GHz		
Germany	700MHz (2x30MHz)			3.4-3.8GHz		26GHz		
France	700MHz (2x30MHz)			3.46-3.8GHz		26GHz		
Italy	700MHz (2x30MHz)			3.6-3.8GHz		26.5-27.5GHz		
China				3.3-3.6GHz	4.8-5GHz	24.5-27.5GHz	37.5-42.5GHz	
Korea				3.4-3.7GHz		26.5-29.5GHz		
Japan				3.6-4.2GHz	4.4-4.9GHz	26.5-28.5GHz		
Australia				3.4-3.7GHz		24.25-27.5GHz	39GHz	

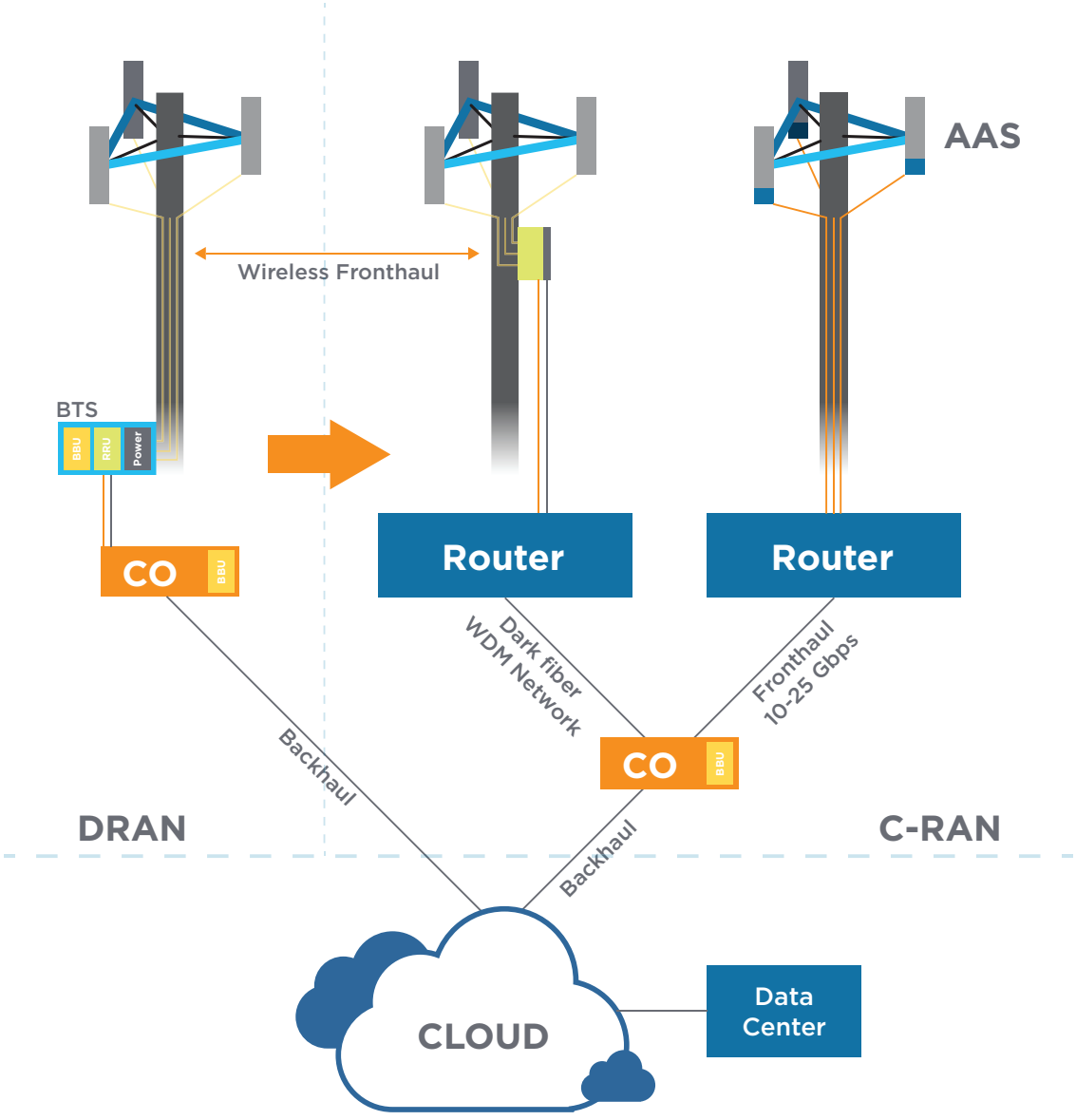
New 5G Band — Licensed | Unlicensed/shared | Existing band

[9] Qualcomm Technologies, Inc.

The Evolving Architecture

Large amounts of spectrum are required to deliver massive increases in capacity to achieve higher speeds and lower latency. Thus, upgraded architectures and further advances in connection technologies are expected to assist the realization of 5G's full potential (Figure 4). There are three key architectural shifts that impact 5G connectivity.

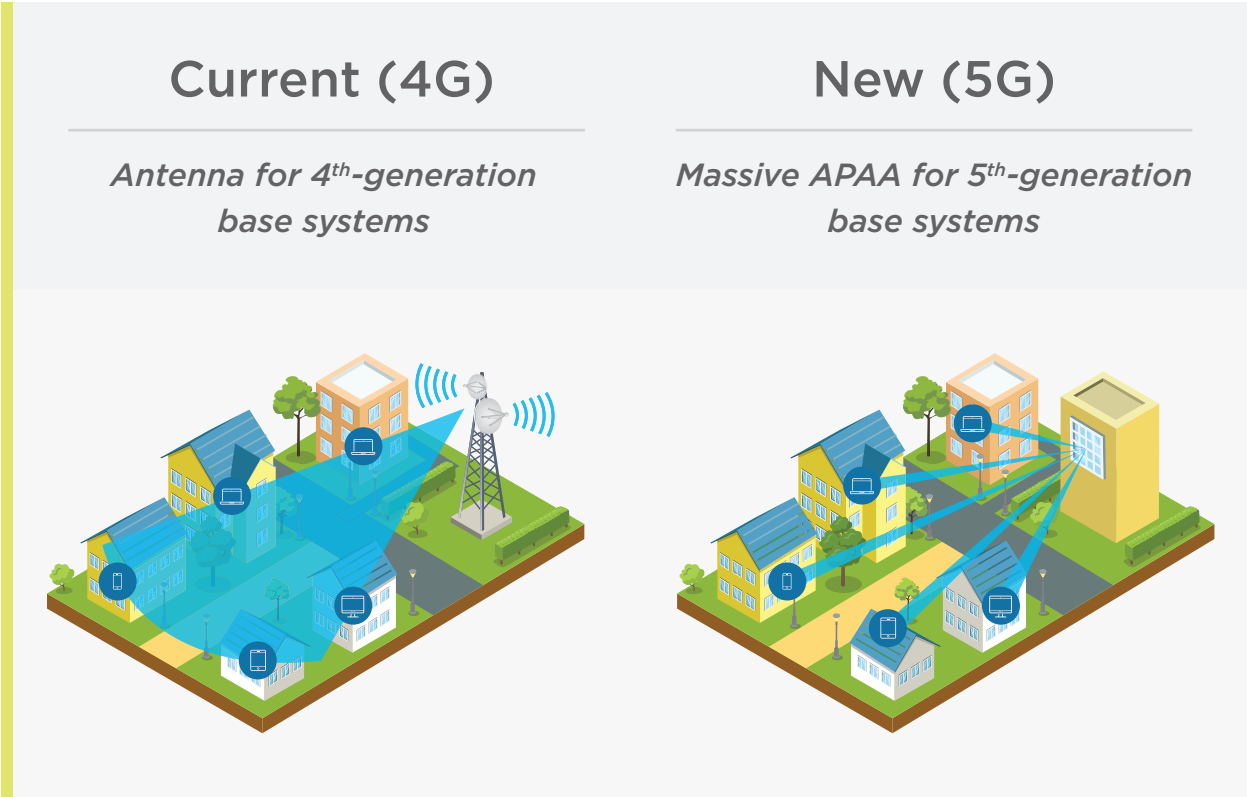
Figure 4. The evolving architecture



1. Adoption of Massive Multi-input Multi-output (MIMO) active antenna systems (AAS)

The 5G ecosystem is expected to support high-density networks by adding new features to the radios and overall system layout. The traditional combination in 3G/4G networks of a remote radio head connected to an external antenna will be extended by active antenna systems (AAS) or active phased-array antennas with massive antenna elements (massive APAA's) (Figure 5), in which the electronics will be embedded in the antenna system and operating over a wide frequency range (600 MHz to 28 GHz and above). This primary system will be supported by complementary systems in dense areas (Figure 6). These complementary systems will have a high number of antennas to support multi-user MIMO (MU-MIMO). These antenna elements will feature their own control electronics, requiring new connectivity solutions. Frequencies above 6 GHz will be predominantely supported by highly integrated systems. These radio frequency integrated circuits (RFIC) often feature integrated antennas on the top surface of the chipset.

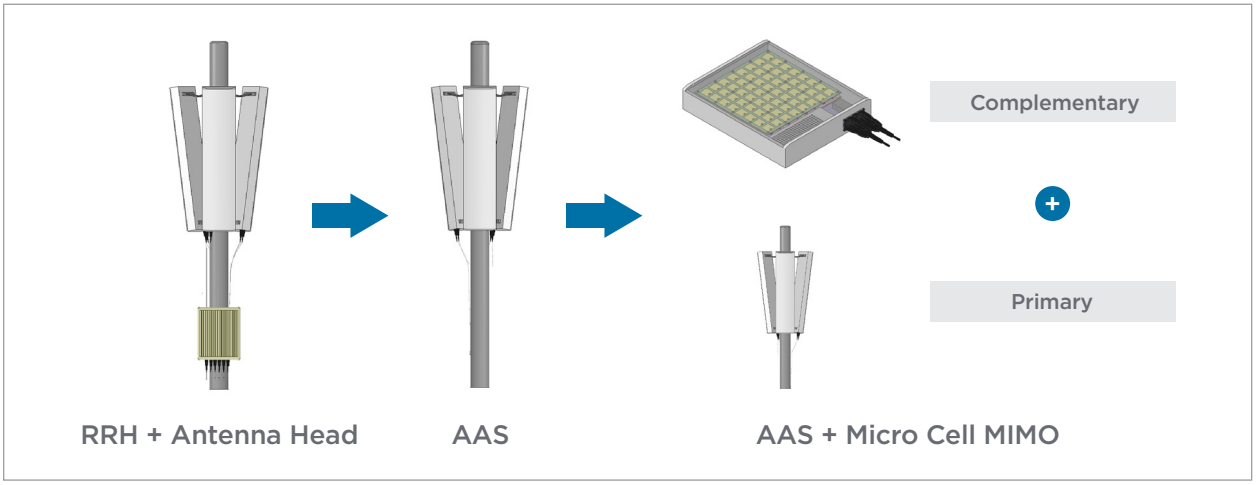
Figure 5. Current 4G compared to new 5G[10]



[10] Mitsubishi Electric Corporation, "Mitsubishi Electric's New Multibeam Multiplexing 5G Technology Achieves 20Gbps Throughput", No. 2984, Tokyo, January 21, 2016

5G massive active antenna systems are anticipated to increase system complexity, requiring greater miniaturization of antennas and greater integration of antennas with filters and power amplifiers. As a provider of customized embedded antenna solutions, TE offers a wide array of customized antenna solutions to accommodate the mechanical constraints of your application and design, in compliance with the most stringent of operating requirements, additionally, TE's high-speed input/output (I/O), internal connector and cabling solutions, cost-effective RF coax solutions, and antenna modules are all well suited for the next generation of antenna systems.

Figure 6. Evolution from remote radio head and antenna to primary and complementary systems.



2. Adoption of New Transmission Technology in Fronthaul

5G will bring very high capacity. For that reason, the fronthaul to the base band unit (BBU), backhaul and transport network will likely need to be upgraded to support increasing traffic requirements. We expect to see greater high-speed optical connectivity in the overall network, with TE's high-speed I/O portfolio, including SFP28, microQSFP, QSFP28, and FullAXS connectors as possible high-speed and dense connectivity solutions.

Small cells will be a key component in the 5G era. They will increase the density of the network and bring short-range solutions, potentially utilizing both sub-6 GHz and mmWave technology. For sub-6 GHz deployments, TE has an extensive portfolio of antennas and products that protect against electromagnetic interference (EMI). Deeper fiber penetration (closer to the small cell location) may also be required to backhaul traffic from small cells leveraging our high-speed product portfolio.

3. The Adoption of C-RAN

In 5G networks, we expect to see greater utilization of cloud-like concepts applied to both the radio access network and core network. C-RAN (Cloud RAN) will focus on both centralizing BBUs and the adoption of cloud technologies like virtualization. The centralization phase is all about moving the BBU to a common location that serves multiple towers, which largely reduces the cost of land, power, cooling and operational expenses. The cloud phase virtualizes hardware-based BBUs, allowing them to run on commercial, off-the-shelf servers. BBU pooling, as well as the adoption of cloud technologies like SDN (Software-Defined Network), NFV (Network Functions Virtualization), network slicing, and virtualization, will all still require high-speed, high-data, high-density, reliable, and rugged connectivity solutions.

TE's connectivity solutions, which are useful for base station and optical transport, push the boundaries of speed and bandwidth within today's architectures and address challenging data rates, signal, and power requirements of emerging 5G mobile networks. In addition to our antenna expertise, our high-speed board-to-board and cabled solutions offer increased bandwidth for backplanes and mid-planes. We can leverage our expertise in data center and cloud technology to provide high-speed I/O solutions, high-speed cabled solutions, high-speed board-to-board solutions, and power solutions.

Against a backdrop of debate and unknown ramifications to the industry at large, the mobile industry is expected to reach numerous milestones leading up to the year 2025, including major progress in 5G with commercial launches anticipated to take place in the United States in 2018 and in major markets in Asia, North America, and Europe over the next three years[11] (Table 2). The official approval of non-standalone 5G new radio (NSA 5G NR) specifications in December 2017, as well as the commercial debut of 5G at the 2018 Pyeongchang Winter Olympics, display the desire for a 5G-powered future.

5G took center stage at Mobile World Congress (MWC) 2018 as an exciting and imminent new technology. The leading equipment manufacturers all announced dozens of innovative products: Huawei unveiled its first commercial 5G customer premises equipment (CPE), a terminal device supporting 3GPP 5G standards with a Huawei-developed Balong 5G01 chipset as part of its end-to-end 5G solution. Ericsson showcased super low latency of 5G (just 6 milliseconds), while Intel showcased the first 5G-enabled 2-in-1 concept PC;.Samsung announced that its complete commercial fixed-wireless access (FWA) 5G solution has become the first globally to receive approval by the United States Federal Communications Commission (FCC).

[11] The Mobile Economy 2018

5G is Just Around the Corner

Table 2. 5G operator rollout plans – timing, spectrum, scope

Country	Operator	5G Rollout Status
China	China Mobile	End of 2018: 5G field tests; pre-commercial 2019; commercial service in 2020
	China Unicorn	2020: 5G commercial launch but gradual uptake; to co-exist with 4G for a long time
	China Telecom	2017-2018: outdoor 5G trial; commercial trial in 2019, scale rollout in 2020 to co-exist with 4G for a while
Korea	KT	2018: pilot tests in 28 GHz during Winter Olympics; commercial service intended in 3.5 GHz and 28 GHz
Japan	NTT	2018: 5G rollout to commence. Has nationwide FTTH network; no spectrum auction in Japan – allocated by Govt. for free
	Softbank	2017: Trials ongoing in 4 / 4.5 GHz / 28 GHz in Tokyo; commercial launch planned for 2020
USA	Verizon	2018: FWA trials in 11 cities; commercial 5G FWA deployments in 2018 using mmWave in 28 GHz, 39 GHz
	AT&T	Late-2018: could launch standards-based 5G network
	T-Mobile	2019: 5G deployments to commence in 600 MHz aimed at IoT; full nationwide coverage in 202
	Sprint	Late 2019: 5G launch in late 2019 in 2.5 GHz
Europe	Multiple Carriers	By 2020: European Regulator pushing for one urban 5G market in each country with rollouts in 3.5 GHz initially. Carriers reserved about 5G plans.
Russia	MTS	2018: Gearing up for 2018 FIFA World Cup and expanding LTE network for increased capacity. 5G will be rolled out in targeted areas but will not have same coverage as LTE.

Get Ready Now

Partner with TE Connectivity

5G will achieve faster transmission rates, more powerful data exchange networks, and more seamless real-time communication, which will enable tremendous growth for advanced and innovative connectivity solutions.

TE is the go-to, one stop solutions provider for all of your connectivity needs.

As a committed innovator, TE enables our partners to capitalize on opportunities in the 5G era with our global footprint, broad product portfolio, and deep-rooted local engineering expertise.

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