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TECHNOLOGY

5G is here: Early insights from our experts

Contents

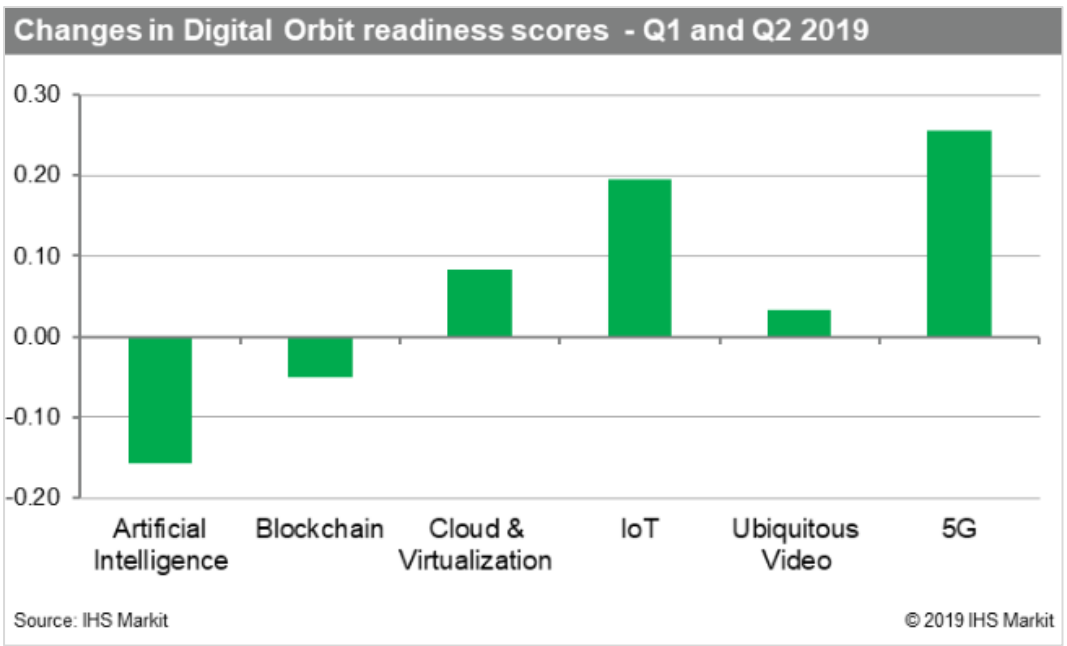
Readiness for 5G continues to grow

Josh Builta, senior principal analyst for transformative technologies

Digital Orbit is an executive briefing that tracks the development, impact, and disruption caused by six transformative technologies—Artificial Intelligence (AI), Internet of Things (IoT), 5G, Cloud & Virtualization, Blockchain, and Ubiquitous Video—across key industries.

The readiness scores in the latest edition of Digital Orbit (Q2 2019) show many similarities to those in the Q1 edition. The average readiness score for the six transformative technologies covered in Digital Orbit changed only slightly, increasing from 4.4. to 4.5. Also, as seen in the Q1 results, AI, IoT, and Cloud & Virtualization were at the top of the readiness score rankings. These three technologies netted an average readiness score of 5.2, compared to an average of 3.6 for the remaining three technologies (5G, Blockchain, and Ubiquitous Video).

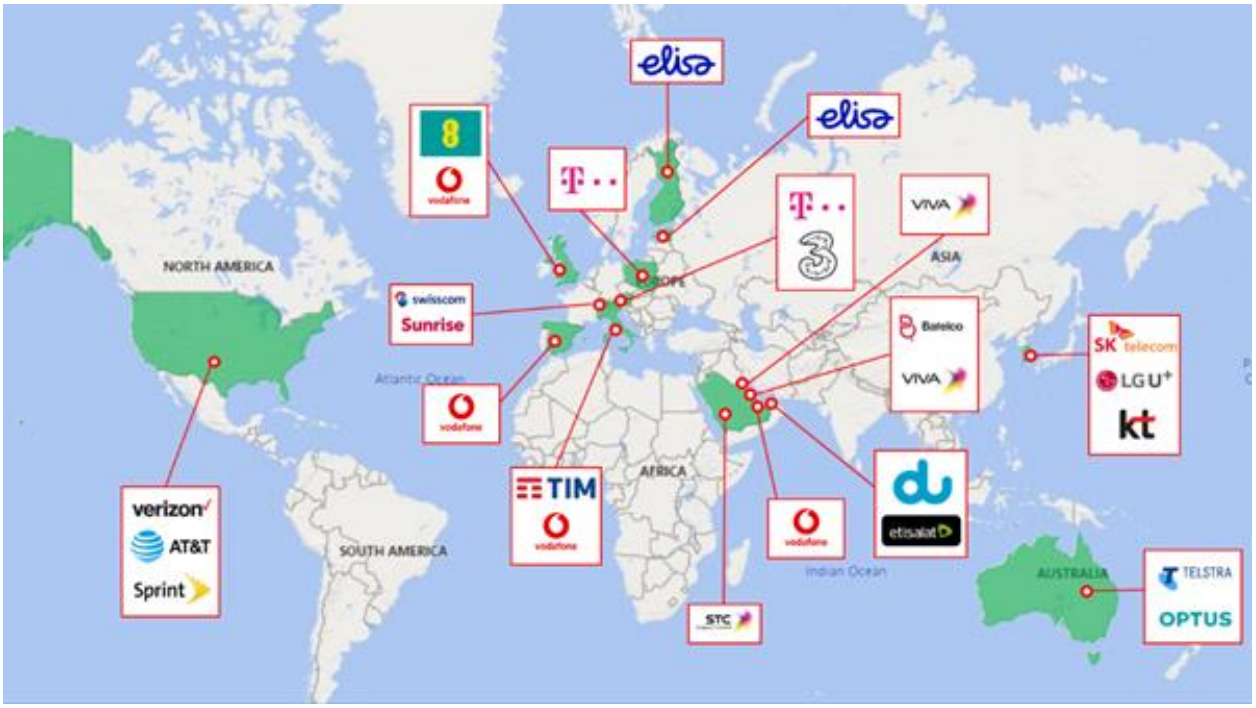
While most of the Digital Orbit readiness scores were flat quarter over quarter, the scores for two technologies—5G and IoT—experienced a moderate increase, while the score for AI dropped slightly. Next, we'll look at the factors and rationale behind the scoring variances.



Of the six transformative technologies covered in Digital Orbit, 5G saw the largest growth in its readiness score from Q1 to Q2, going from 3.5 to 3.8. Increased momentum in several facets of the technology—discussed below—were the primary catalysts for an increase in the 5G readiness score.

Real-world 5G networks are now a reality. In the first half of 2019, multiple operators in North America and Asia launched wireless 5G networks. As of early 2019, IHS Markit noted launches of 5G networks in 11 countries by 20 different operators. Although the availability of many of these networks is limited to a handful of markets as carriers stress-test the systems and slowly roll them out to different users, the launches do represent an important stepping stone for 5G technology. These initial networks will expand in coverage and capability in the coming months, and more operators will launch their first 5G networks by the end of the year.

5G network deployments as of Q2 2019



Growing 5G infrastructure revenue indicates increased investment and preparation for the technology. While much of the growth in 2019 stems from activity in South Korea and the US, mobile operators in other countries are expected to ramp up their investment in 5G equipment over the next 12 months. In China alone, its three service providers have budgeted at least $1.34 billion for 5G in 2019. IHS Markit estimates that total 5G hardware infrastructure revenue will increase from just $759 million in 2018 to over $20 billion in 2022.

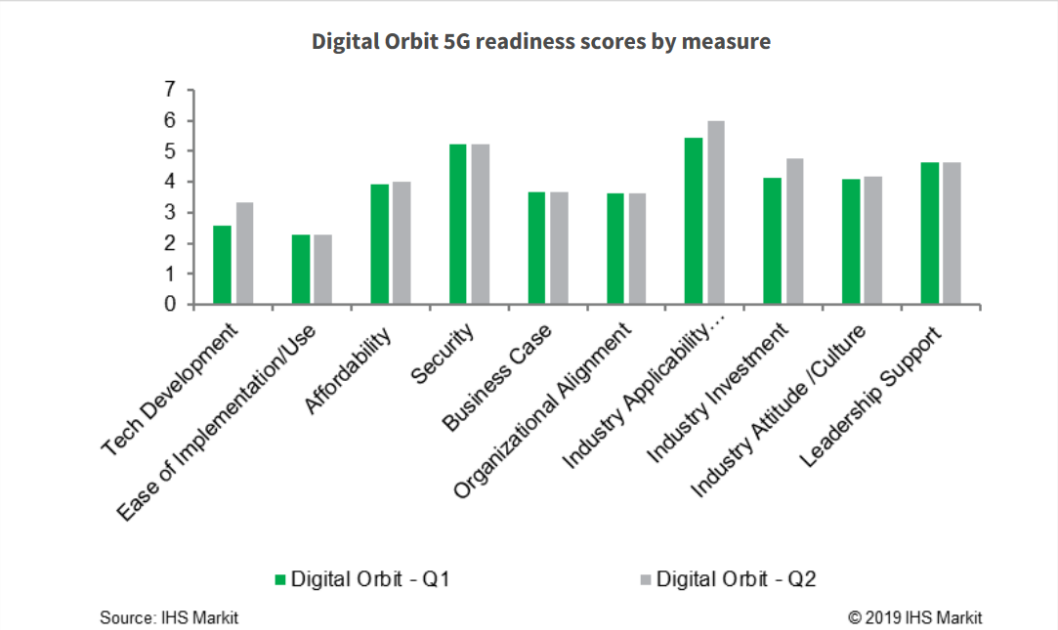
The first 5G-capable devices have been released in recent months. Given the initial focus on the enhanced mobile broadband (eMBB) and fixed-wireless access features of 5G technology, it is not surprising that the first wave of devices have been smartphones and routers. While the initial selection of devices is limited and the devices come with very high average sales prices, this represents an important milestone for the technology. Less expensive devices are expected to be released in the next six months, supported by a growing list of competitive 5G modems from Qualcomm, Samsung, Intel, Mediatek, HiSilicon, and UNISoC. An IHS Markit survey of consumers found that demand for 5G devices is strong: 66% of respondents said they would wait for a 5G device before making their next smartphone purchase. As a result, IHS Markit estimates shipments of 5G handsets to reach nearly 9.5 million in 2019 and 609 million by 2025.

Another driver for the growth in the 5G readiness score is growing interest and investment from the potential enterprise end-users of 5G technology. An IHS Markit survey of decision-makers from six industries—automotive, consumer, healthcare, manufacturing, power and energy, and telecoms—found that 78% believe there is strong-to-significant interest in 5G adoption within their industry. Perhaps more important, the survey also found that 48% of respondents believe their organizations will invest high or significant resources in the technology over the next 12 months, which will be critical to hastening adoption.

The confluence of these factors led to the increase in the overall 5G readiness score in Digital Orbit Q2 2019. Looking at the scores in more detail, we can see which specific measures contributed to this increase:

- Technology development, which grew due to the growing number of networks and devices
- Industry investment, an indication of the financial outlay from operators and potential enterprise adopters
- Industry demand, an increase based on survey results

Note: The overall readiness score for each technology is made up of ten different measures: Technology development, ease of implementation/use, affordability, security, business case, organizational alignment, industry applicability, industry investment, industry attitude/culture, and leadership support.



5G – The best is yet to come

In this video, Jenalea Howell, director of transformative technologies, explains that while 5G lags behind other transformative technologies in terms of readiness, many key technology decision makers believe 5G will have a high-to-significant impact within their industry in the next three years.

5G for the home: Huge opportunities for fixed-wireless access

Faster speeds promised by 5G will be key to convincing consumers to switch services with the new standard

Josh Builta, senior principal analyst for transformative technologies

While most of the attention around the introduction of 5G networks surrounds smartphones, the technology also presents huge opportunities for the home through fixed-wireless access (FWA). However, 5G will have to deliver upon the promises of faster speeds to convince subscribers to move away from fixed-line broadband solutions such as fiber, cable, or DSL.

These are among the findings of a new IHS Markit report, which summarizes the results of a survey on how consumers perceive 5G and how they intend to use the new technology. The survey was conducted in May 2019 among 2,031 respondents, 95% of whom were US-based. The median age of the survey respondents was 43, and 63% lived in urban areas.

5G beyond the phone

Phones are the first primary use case every time a new "G" is introduced, and it's no different with 5G, the fifth generation of wireless communication standards. The first smartphones supporting the technology are already on the market, and additional releases are coming through the end of 2019. The attention on phones is understandable given their impact on our daily lives. However, the use cases for 5G do not stop there.

5G's lower latency, for instance, could take augmented reality (AR) and virtual reality (VR) to new levels of functionality, and 5G-enabled AR glasses and VR headsets could eventually be vying with smartphones as the main devices through which consumers relate to the world. Pairing low-latency functionality with the new standard's much-vaunted fast speed will also enable mission-critical use cases not possible with previous cellular technology. These include autonomous cars, remote surgery, robots and drones, and industrial automation.

With 5G FWA, the technology can also impact how broadband access is delivered to the home.

Massive opportunities for 5G in the home

Fixed wireless access has traditionally been the established means of providing internet service to homes that lack internet access to fixed-line solutions such as fiber, DSL, or cable. Even so, overall use of FWA is relatively limited. Of the approximately 765 million households worldwide projected to have broadband access by the end of 2019, less than 2% use FWA or other non-fixed-line technologies.

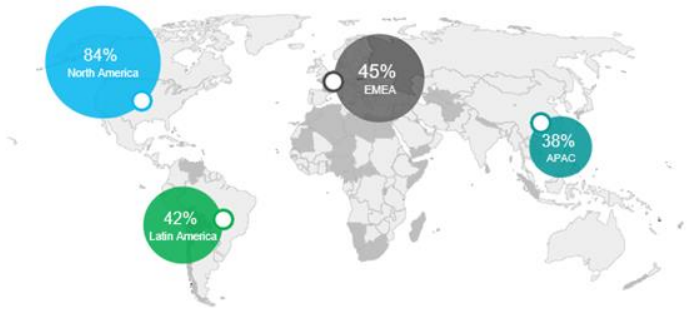
Most current FWA solutions utilize 4G LTE technology, which can deliver broadband speeds up to 12 megabits per second (Mbps). This is relatively slow, compared to what is available via fixed-line technologies. With 5G FWA, however, much higher bandwidth is theoretically possible—up to 1 gigabit per second (Gbps) in some cases; 1 gigabit is equivalent to 1,000 megabits.

Yet there are challenges. An outside receiver will be required to achieve these speeds, as 5G frequencies face propagation concerns. But if that issue can be resolved, 5G's increased speeds could allow FWA to emerge as a viable replacement for fixed-line solutions.

FWA can also make huge inroads into the overall broadband space given that nearly 60% of all households worldwide—a global total of about 1 billion homes—have no broadband access at all.

The graphic below shows the rate of broadband penetration throughout the world by region. Except for North America, which enjoys the highest penetration rate at more than 80%, every region reveals a broadband penetration rate of less than 50%. In the Asia Pacific region, the 38% broadband penetration rate means 62% of households in that region—or roughly 670 million households in all—are without broadband access.

Household broadband penetration by region



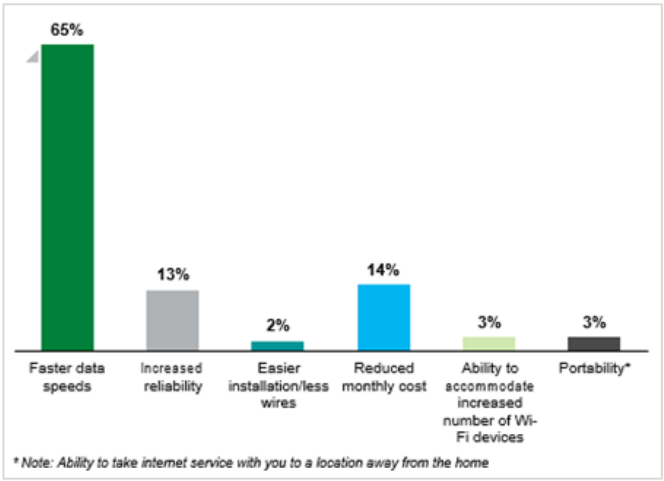
For those without access to fixed-line solutions, 5G FWA can be a viable solution to deliver “last-mile connectivity” to the home. It achieves this without physical cabling of any sort, requires no digging up of roads, and keeps disruption of existing infrastructure to a minimum. In many locations, carriers will have an easier time rolling out 5G than in implementing fiber. For customers, FWA can often be self-installed, resulting in quicker, less expensive installation.
All told, the flexibility of 5G FWA makes it suitable for urban and rural areas alike. The technology can address the challenge of upgrading wireline infrastructure in urban areas, while also eliminating the need to build out a fixed-line broadband infrastructure in the rural countryside or in poorer areas of the world.

5G benefits to convince consumers to switch

To entice consumers to move to 5G FWA and draw them away from traditional fixed-line broadband solutions, 5G must offer tangible benefits. In addition to easing installation and setup, a key attribute of FWA often cited is portability, which will allow a customer to take one’s equipment from one location to another.

However, as indicated in the survey, the most compelling benefit to make consumers currently subscribed to fixed-line home internet to switch services is fast data speeds, as shown by the following graph.

Benefits that will compel consumers to replace current home internet service with one that relies on 5G technology - % of respondents



The survey also showed that consumers are willing to pay for 5G home internet service if it’s shown that 5G delivers on its promises. Nearly 70% of the respondents said they would be willing to switch right away to a provider with 5G service regardless of the status of their contracts. And at least 30% of consumers are willing to pay a 10% premium for 5G home service compared to their current plan. The percentage of consumers prepared to pay more for 5G home declines to 19% if the services are priced 20% higher than their current plan.

Looking ahead

FWA solutions have traditionally played a minor role in the overall residential broadband market. Because technical hurdles related to 5G FWA implementation must still be resolved, fixed-line solutions will continue to enable broadband in most households for the foreseeable future.

However, data from the survey indicate there is enthusiasm and willingness to pay for alternatives to fixed-line broadband access. With the release of 5G, FWA will finally be able to provide performance that matches—and perhaps, eventually surpasses—that offered by fixed-line solutions. For this reason, we believe FWA solutions will play a growing role in connecting homes in upcoming years.

US consumers may suffer sticker shock from the first wave of 5G-enabled phones

Josh Builta, senior principal analyst for transformative technologies

Nearly everyone expects to pay more money for 5G smartphones—but the cost of the initial wave of phones is dramatically exceeding expectations, with the price premium as much as 29 times higher than many consumers anticipate, according to a new IHS Markit survey examining consumer perceptions regarding the technology.

The survey looks at how consumers perceive 5G and how they intend to use the new technology. It was conducted in May 2019 among 2,031 respondents, 95% of whom were US-based. The median age of the survey respondents was 43, and 63% lived in urban areas.

A total of 91% of survey respondents said they expect to pay more for 5G devices compared to existing 4G LTE smartphones. Three quarters of respondents stated they foresee paying an additional 10-25% for a 5G-capable phone. With the average sales price (ASP) of a smartphone amounting to $319 in 2019, a 10% hike in pricing would add $32 to the cost, while a 25% increase would boost it by $80.

However, the actual pricing of the first wave of 5G phones is far higher. For instance, Samsung's S10 5G phone is retail priced at $1,300, a 335% premium compared to the $388 average for the company's existing 4G smartphone models. In dollar terms, this would represent a $912 increase in price, an order of magnitude higher than consumers' expectations.

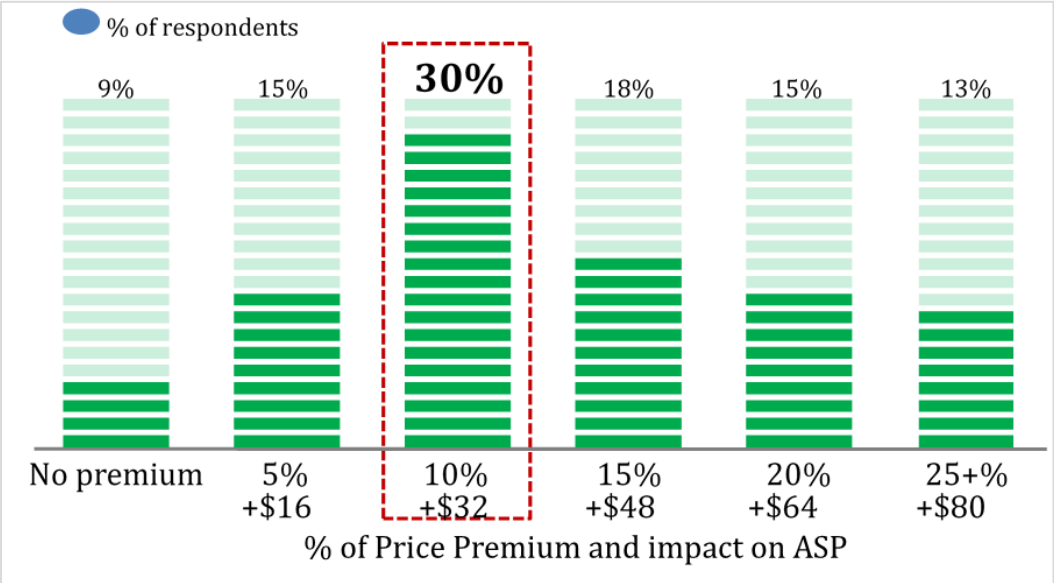
It should be noted that this comparison is of a flagship smartphone price against an industry ASP. Naturally, newer technologies almost always come first to premium smartphones, which typically are two to three times as much as industry ASP. Also, given the nature of 5G radio design, these early 5G smartphones are configured with larger-than-typical displays and packed with extra features such as time-of-flight (ToF) cameras to enable AR applications. All of these extras do contribute to a higher-than-expected retail price from a consumer perspective.

In another example, the Huawei Mate 20 X 5G smartphone carries a retail price of $1,200, a more than 400% premium compared to $295 for the company's 4G models.

This pricing discrepancy could instill sticker shock among many consumers. While such pricing premium is not likely to impact early adopters, it could slow sales of 5G devices to the wider, more mainstream consumer market.

The 5G market is primed for massive growth, with the transition to the new technology expected to occur at a much faster pace than any previous wireless generation during the first five years of deployment. However, as with each new wireless generation, the first wave of phones carries sky-high costs because of the additional electronics required to support the enhanced features. With smartphone brands passing these additional costs down to consumers, many buyers will be turned off by the high prices and will wait until they come down before purchasing a 5G phone.

Expectation of price premium for 5G smartphones



Fast wireless technology makes slow initial progress

Global 5G handset shipments are expected to soar to 424.5 million units in 2023. However, shipments will start rather modestly, amounting to just 9.5 million in 2019—the first year of deployment—and only 73.7 million in 2020. This represents a slower initial rate than for 4G LTE when it first deployed a decade ago, although the longer-term outlook for subscriber growth for 5G is more optimistic than for 4G.

The early 5G smartphones analyzed by IHS Markit demonstrate why their cost and pricing is so elevated. For example, some 5G phones include a highly complex radio-frequency (RF) subsystem designed to support millimeter wave capability for high-speed data transfer. Specifically, in the US, the Moto Z3 with 5G Mod and a version of the Samsung Galaxy S10 5G both integrate multiple separate millimeter wave antenna modules that are strategically placed throughout the device to allow clear signal reception. When considering that most smartphone designs employ just one antenna module, it's easy to see how this redundant design drives up costs significantly.

Lower prices for a bigger market

However, just as occurred in the 4G LTE era, 5G phone pricing is expected to decline quickly. Prices will begin to decrease next year as phone OEMs use more efficient designs employing multimode modems. Within the next few years, prices will fall to between the $700 to $800 range, making them more affordable for price-conscious consumers. Elsewhere, markets such as China will deploy a standalone 5G network which will further simplify RF front-end design requirements to further push down the industry ASP.

Consumer expectations

Many consumers equate 5G with faster data speeds and aren't aware of the technology's other benefits. As a result, their low expectations for pricing premiums may not take into account all of the advantages and allures of 5G technology. For example, improved immersive entertainment experiences like virtual reality (VR) have been cited as a key benefit of 5G. The 5G standard eventually can provide the kind of ultra-low latency that VR requires. However, fewer than 30% of survey respondents said they would increase their use of VR with the arrival of 5G.

As the market waits for prices to decline, brands may be able to overcome consumer reticence regarding pricing by promoting the other attributes of 5G beyond speed.

Video streaming emerges as the killer app for 5G in the US, IHS Markit survey reveals

Josh Builta, senior principal analyst for transformative technologies

The 5G era is set to drive the next wave of growth in video streaming, with 78% of U.S. consumers indicating they will expand this activity as they adopt the next-generation wireless standard in smartphones and home-networking solutions, according to a survey conducted by IHS Markit Digital Orbit.

When asked to name which types of activities they are likely to increase due to the arrival of 5G, consumers ranked video streaming first, ahead of video calling, social media, mobile gaming, virtual reality, and augmented reality. As a result, the deployment of 5G will help cause video usage to grow to account for 70% of mobile network traffic in 2022, up from 47% in 2015.

The promise of faster video streaming through 5G is generating enthusiasm among consumers. Interest is particularly high for those younger than 50, with 81% of survey respondents in that age range citing video streaming as the top activity for 5G. Consumers are expressing strong interest in video streaming both on smartphones and for home internet services, which are equally supported by 5G.

Smartphone streaming moves to 4K

Current 4G wireless services already provide sufficient performance to support most types of video content commonly streamed today. As a result, 5G's largest impact will be felt in emerging areas of the market.

One of these areas is 4K ultra-high definition (UHD) video. The 5G standard enables 4K on mobile platforms because of its increased capacity and speed. When coupled with the growing demand and supply of 4K UHD content, the proliferation of 5G will help drive mobile consumption of UHD content.

The 5G standard will also be critical to promoting the consumption of general live video. This is particularly true for sports and live events, where lower latency and higher speed and bandwidth are critical.

Home 5G promotes video streaming

In parallel with the trends in the smartphone market, US consumers are expressing intense interest in engaging in 5G video streaming via home internet access.

While often regarded purely as a mobile technology, the 5G standard also supports fixed wireless access (FWA) in the home. However, unlike fixed solutions such as DSL, cable, or fiber, 5G FWA uses wireless mobile network technology to extend internet access into homes.

Most consumers say they are attracted to 5G FWA by its faster speeds. The average speed of broadband connections in the US in 2018 was about 35 megabits per second. In contrast, 5G can theoretically operate at up to 1 gigabit per second, although initial deployments will be much slower.

Survey respondents cited streaming of video, both prerecorded and live, as the most compelling reason to upgrade home internet service. A total of 74% of those surveyed named video streaming as the chief motivation for upgrading to 5G in the home.

This phenomenon is not surprising as IHS Markit forecasts that global over-the-top (OTT) video subscriptions will pass the 1 billion mark in 2021, up from 620 million at the end of last year. In 2022, OTT video subscriptions will surpass pay-TV subscriptions.

About the survey

IHS Markit's Digital Orbit report summarizes the results of a survey on how consumers perceive 5G and how they intend to use the new technology. The survey was conducted in May 2019 among 2,031 respondents, 95% of whom were US-based. The median age of the survey respondents was 43, and 63% lived in urban areas.

5G set to transform manufacturing, will help to realize flexible factories

But ultra-low latency, a critical factor in industrial operations, isn't available yet

Alex West, senior principal analyst, industrial technology, and Josh Builta, senior principal analyst for transformative technologies

As the next generation of mobile technology, 5G promises to transform the manufacturing industry with a digital infrastructure that enables intelligent factory automation and production, making smart factories a reality.

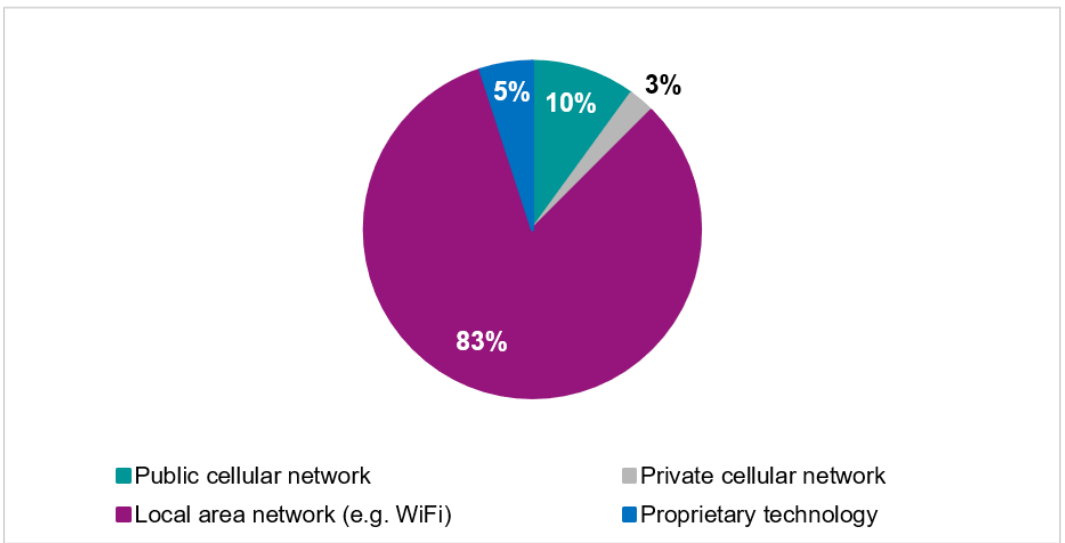
However, a key 5G specification of critical importance to the factory floor won't be ready until later this year. That is when the 5G feature known as ultra-reliable low-latency communications (URLLC) is scheduled for rollout by the 3GPP standards organization.

Of vital significance in manufacturing and production, URLLC is necessary in precision robotics and other similar factory applications where no lag time or delay in response can be tolerated. The technical specs governing URLLC can be found in Release 16, and 5G radio modules as well as network infrastructure supporting Release 16 are expected to follow in early 2020. 5G deployment in factories will begin following 2020, starting with automated guided vehicles (AGVs) and mobile workers.

The timing of these developments suggests that 5G adoption on the factory floor will be delayed. IHS Markit does not expect 5G to filter down to ubiquitous field use in manufacturing within the next 4-5 years, and a widespread 5G rollout in industrial settings is not likely within the next 10 years.

Even so, recognition of the growing importance of wireless technology in general—but also of 5G specifically—is taking hold. In a survey of how industries perceive and plan to use 5G, 80% of the respondents said their organization used wireless networks on the factory floor, with 46%—nearly half of the total—stating that wireless was deployed in mission-critical applications within a production environment. Only 4% in the survey said their organization had no plans within five years to implement wireless on the manufacturing floor.

Current usage of wireless technology



On the factory floor, 5G's fast speed and low latency will enable rapid tracking and responsiveness to data, enabling manufacturers to be more flexible and to adjust networks as needed to deliver goods in time. With consumers demanding fast production turnaround or quick order-customization capabilities, the constant communication among devices in a 5G system will help factories attain new levels of agility and productivity.

Key manufacturing issues for 5G

Given 5G's superior speed, lower latency, and greater connectivity capabilities, factories are looking to the technology to address a variety of manufacturing concerns.

Latency is a significant consideration for many manufacturing operations. Nearly 3 out of 4 companies indicate that real-time or near-real-time latency is required for their most demanding factory floor applications. The finding underscores the importance of ultra-low-latency when it becomes available from 5G, which will allow the technology to serve the most time-sensitive industrial automation applications.

Integration of 5G with TSN, the Ethernet standard of Time-Sensitive Networking, will help speed up the development of industrial-grade networks. An important connectivity technology, TSN offers a convergence of proprietary industrial protocols to potentially replace legacy industrial Ethernet systems like PROFINET and SERCOS.

On the factory floor, 5G will enable flexibility by coupling powerful cloud- and edge-computing capabilities with agile networking virtualization technologies. Manufacturing systems can be easily reconfigured or adjusted to allow quick changes to product lines. Overall,5G will be the catalyst that unleashes the full potential of transformative and emerging technologies like artificial intelligence and the Internet of Things, supercharging the manufacturing process in ways never possible before.

5G can also scale easily in diverse production environments across the manufacturing spectrum, thanks to powerful yet adaptable features. Among the various possible use cases of 5G, respondents said they utilized 5G primarily for asset monitoring and quality control, with both applications tied in first place.

The road ahead

The arrival of 5G is fortuitous, coming at the same time as transformative and emerging technologies such as artificial intelligence, machine vision, and cloud computing are advancing and scaling for broader deployment.

And while adoption of 5G by factories will take time, the potential for the new technology to completely transform manufacturing is too great for the industry and its players to ignore. Ultimately, 5G's powerful features can lay the foundation for maximizing productivity and fueling innovation to supercharge the Factory of the Future.

First-generation 5G designs highlight critical importance of modem and RF integration in future smartphones

Wayne Lam, principal analyst, mobile devices and networks

- Physical disassembly performed on a batch of first-generation 5G smartphones from six different OEMs to uncover core 5G electronic and RF designs
- Commonalities were identified from these initial 5G designs and characterized with simplified functional block diagrams
- Information gleaned from existing 5G designs will help inform the direction of future 5G smartphone designs
- In 5G, unlike in earlier wireless generations, modem and RF front-end integrations are significantly more critical to the success of 5G devices

The market availability of 5G smartphones at this early stage of a new wireless technology transition has been unprecedented for the industry. Unlike the previous 4G LTE evolution, more handset vendors are making new devices available to consumers on day one of 5G. Not only were the critical modem chipsets and RF front-end (RFFE) components made available earlier in the design cycle to smartphone OEMs, many of those solutions also included complete "modem-to-antenna" designs that further helped to accelerate time-to-market of these first-generation 5G smartphones.

In this insight, we examine more closely the RF technologies and components that enable 5G devices to be made available so early in the 5G network life cycle. As part of IHS Markit Technology's "early look" into both the network and device performance of 5G, we evaluated at least six early 5G smartphones and identified, through teardown analysis, core 5G wireless components and system design. This early batch of 5G smartphones includes smartphones from Samsung, LG, Xiaomi, Oppo, OnePlus, and Huawei.

Figure 1: Early 5G smartphone samples used in teardown analysis

Diving deep into the fundamental 5G design of these early smartphones, we were able to identify the key components of 5G modems and RFFEs, along with the vendors involved in supplying the components. Of the six OEM brands under evaluation, five out of six of the 5G designs sampled were supplied by Qualcomm. Meanwhile, one variant of the Samsung Galaxy S10+ 5G contained an Exynos Samsung LSI solution, while another model from Huawei used its internally developed modem solution, the HiSilicon Balong 5000. These two "captive" modem suppliers are usually the exception to the rule or norms of the industry. Creating modems and RFFE requires a significant investment of resources, but with the impressive scale and scope of both Samsung and Huawei, these rarified OEMs can afford to invest in the vertical integration of their 5G designs.

On the merchant side of the 5G ecosystem, Qualcomm stands alone with its Snapdragon X50 modem, first announced in 2016. To date, there are no other merchant modem suppliers with 5G modems built into smartphones. Both MediaTek and UNISoC (Spreadtrum) have announced their first 5G chipsets, but those chipsets have not been designed into any known OEM smartphones. Also, worth noting is that Intel recently sold its smartphone modem division to Apple, which was the sole customer of Intel's 4G LTE modems, reducing the field of merchant modem suppliers down to just three players.

As the smartphone industry matures and consolidates, only OEMs matching the scale possessed by Apple, Samsung, and Huawei—the Big Three—can afford to invest substantial R&D dollars to create their own chipsets. The remainder of the market, including significant players like Xiaomi, Oppo, and Vivo, all draw from merchant modem vendor chipset offerings as well as proven RF designs. However, these smartphone OEMs can now better compete with the Big Three, banking on a proven commercial 5G solution from Qualcomm and its early leadership in 5G. Such a sourcing strategy allows the OEMs to focus on product innovation and market differentiation, rather than expend resources investing in core 5G modem and RFFE technology.

Path to 5G paved with discrete parts and increasingly tight RFFE coupling

Just as with 4G nearly a decade ago, where LTE connectivity was built atop existing 3G technology, early 5G capabilities were added to existing LTE designs through a discrete chipset fashion. This meant that 5G components were essentially bolted onto the smartphone design, as opposed to being baked into the core chipset. This not only facilitated in the time-to-market for smartphones but also reduced potential risks during the development stage by reusing existing proven designs.

The block diagrams below illustrate the observed core electronic designs from modem to antenna, drawing commonalities among the six 5G smartphones IHS Markit has evaluated.

Figure 2: First-generation 5G design using discrete 5G modem and RFFE

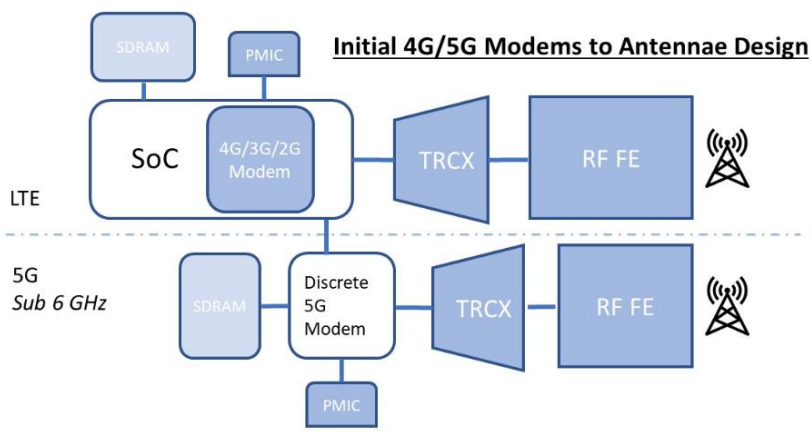
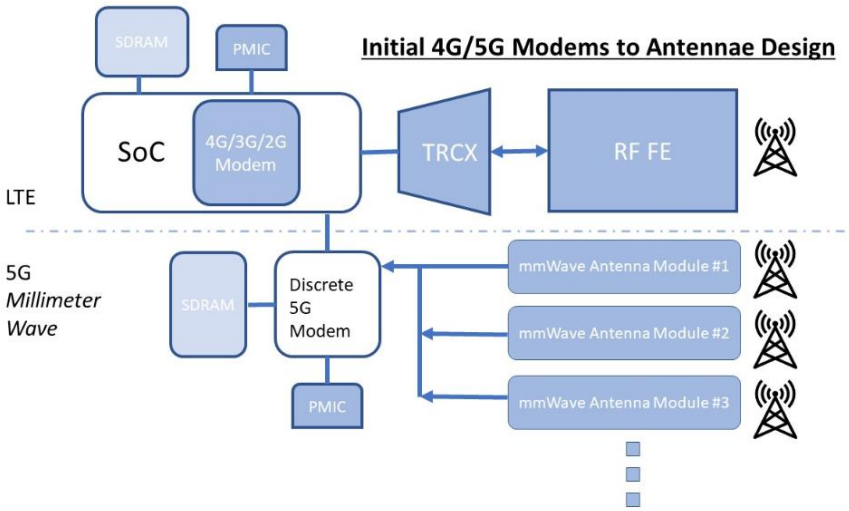


Figure 3: Millimeter-wave version of first-generation 5G smartphones using highly integrated RFFE antenna modules



From the two block diagrams illustrated above, we can deduce that first-generation designs are additive in nature. There are discrete 5G components, such as the single-mode 5G modem, 5G RF transceiver, and single-band 5G RFFE, which are separate from the existing LTE RF chain. The initial 5G modem designs also require supporting parts, such as SDRAM and PMICs, which are often duplicated in the LTE portions of the smartphone. By building upon mature existing 4G designs, OEMs augment 4G capability with the new 5G standard. Often, the acute time-to-market requirements of OEMs and operators—borne out of the fear of not being first on the market—are reflected in device design. In this case, early 5G smartphones contain additional components that otherwise would not exist in mature smartphone designs.

Of the six initial 5G smartphones we have analyzed, five have an architecture that resembles this first-generation 5G design. We discovered Qualcomm's Snapdragon X50 5G modem in all but the international version of the Samsung Galaxy S10+ model, which uses Samsung's Exynos 5100 5G chipset. Likewise, the 5G RFFE was primarily supplied by Qualcomm in all instances, indicating the close coupling of modem and RF front end in 5G communications design.

Further, a separate version of sub-6-gigahertz (GHz) 5G RFFE and millimeter-wave (mmWave) 5G variants had been created for first-generation 5G RFFE designs. Because of the size, power, and beamforming/tracking requirements of mmWave 5G, a highly integrated mmWave antenna (multiple) modules must be used. These modularized antennae contain RF components, starting with the transceiver all the way to the physical antenna. Currently, the only mmWave solution available on the market comes from Qualcomm. As a result, the mmWave 5G design is offered as a complete modem-to-antenna solution.

Meanwhile, all other competitive modem vendors are still in the early stages of mmWave development, with Intel no longer in the game after having dropped out of the market aimed at supplying the smartphone industry. Of the six OEMs evaluated here, both Samsung and LG have mmWave variants of their 5G smartphones to support the US carriers deploying mmWave 5G, such as AT&T, T-Mobile, and Verizon, all three of which use the Qualcomm solution.

Second-generation 5G modem design

One of the biggest observations of first-generation 5G modems is the lack of multimode capability; hence, a separate LTE modem is required, as described earlier. As the industry matures, the second generation of 5G modems will be defined by its multimode capability, integrating both LTE and 5G together onto a single chip. This evolution of core smartphone electronic design is necessary to reduce not just the physical footprint but also the power requirements and manufacturing costs of 5G smartphones. Of the six 5G smartphones reviewed, only the Huawei model employs a multimode modem design through its first 5G chipset, the Balong 5000. Even so, while this design helps to reduce the

need for a separate 4G/3G/2G modem, our teardown revealed that other design choices made on the Huawei Mate 20X were far from ideal, highlighting the challenges of early 5G technology.

Besides Huawei, those that have announced second-generation modems include Qualcomm with the Snapdragon X55, and Intel with the XMM8160. Given the recent market exit of Intel, however, adoption of the Qualcomm solution appears inevitable. In fact, at the time of publication, there are multiple designs with Snapdragon X55 which are already in the development pipeline being prepared for launch later this year.

The block diagram in Figure 4 illustrates the architecture of the Huawei Mate 20X 5G smartphone. While Huawei alone among the group employs the multimode 5G mode, it does so with many design compromises.

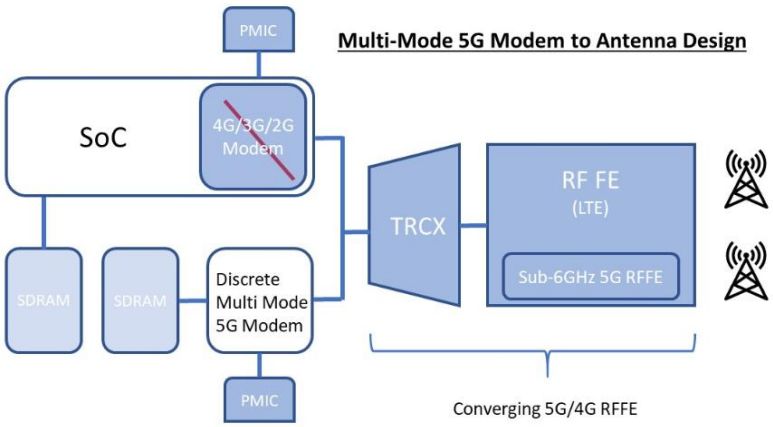
First, the Mate 20X is also designed with a HiSilicon Kirin 980 system-on-chip (SoC), which already contains an on-board LTE modem. However, only the multimode Balong 5000 modem is used for 5G/4G/3G/2G communications during operation, leaving the integrated modem in the Kirin SoC unused and—arguably—unnecessary. A better solution would have been to use an applications processor, without modem, in place of the Kirin 980 to reduce cost, power, and PCB footprint.

Furthermore, the Huawei Mate 20X 5G implemented a significantly denser supporting SDRAM for the Balong 5000. Whereas typical discrete modems are packaged with SDRAM chips that are measured in the hundreds of megabytes (MB) in density, the Huawei Mate 20X design packs a surprisingly large 3-gigabyte (GB) LPDDR4 in a package-on-package configuration—a full order of magnitude denser—which would rival the primary SoC SDRAM configuration of most smartphones. At the silicon level, the 7-nanometer (nm) Balong die size was found to be 50% larger than the Qualcomm X50 at 10nm, as indicated in findings collected through this batch of 5G smartphones. Although not an apples-to-apples comparison—one is multimode while the other single-mode, and both are manufactured on different fabrication nodes—Huawei's example reveals the design compromises taken by OEMs to enable 5G. Perhaps a better comparison to the Balong 5000 is the upcoming Qualcomm X55 5G modem. Both the X55 and Balong are multimode 5G modems and manufactured on 7nm, but even now we can deduce that the die size for Qualcomm will be smaller compared to the Balong 5000.

From a positive standpoint, the design efficiency afforded by the Huawei Mate 20X includes the simplified RFFE from transceiver to antenna. As opposed to the dual radio chain of first-generation designs, only one radio path is required for 5G/4G/3G/2G since all wireless communication standards go through a single multimode modem and RF transceiver path, instead of two.

Huawei's 5G design is currently limited to sub-6GHz RF capabilities, which is the most common spectrum used so far when 5G is deployed internationally. But for high-performance mmWave support, Huawei has yet to come to market with a viable RFFE solution. This means that for carriers and OEMs supporting mmWave 5G network deployment right now, the only choice available is Qualcomm's highly integrated mmWave modem-to-antenna design.

Figure 4: Schematic of 5G design in the Huawei Mate 20X



The Huawei Mate 20X design highlights some of the challenges in 5G modem design for OEMs, balancing feature requirements, electronic design, and costs. If the HiSilicon Balong 5000 modem were made available for other OEMs and came into direct competition with the offerings of merchant modem providers, the early-design benchmark of the Balong would indicate it is not as competitive in cost, utilization of board area, and power efficiency.

However, given the “captive” nature of the Huawei design, these concerns are secondary to the ostensibly more important goal to the company of bringing a functional 5G smartphone to the market on time. Also, since HiSilicon is a “captive” vendor of Huawei, there are fewer demands to tackle from what normally might be a call from OEM customers for greater design efficiency. Together, both factors may help account for the rationale behind Huawei’s first-generation design.

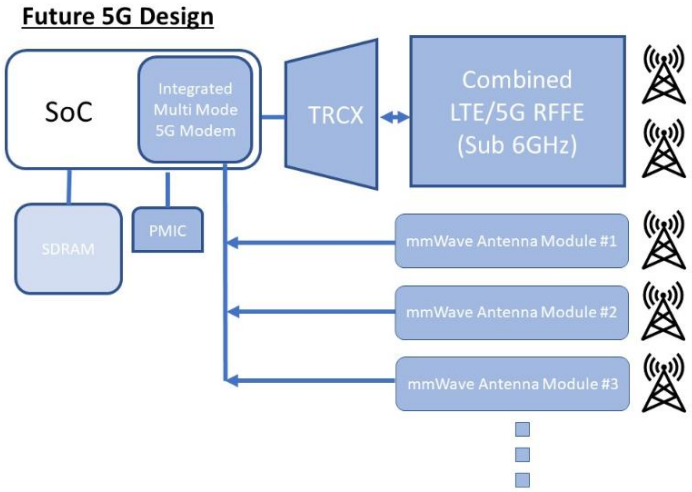
Optimizing future 5G designs

This early analysis of initial 5G smartphones ultimately points us to the direction of 5G design evolution in future products. Just as multimode modems will be introduced in second-generation designs, bringing a single modem and more tightly integrated RFFE design into play, the industry will look forward to further optimization of core electronic design as 5G technology matures.

What will we observe in future 5G designs? Following the evolutionary path of LTE modems nearly a decade ago (Figure 5), we will see the integration of multimode 5G modems into the smartphone SoC in the next iterations of 5G smartphone designs, expected sometime in 2020. This higher level of integration will leverage the existing SDRAM and PMIC components in supporting the SoC while eliminating another chipset on the motherboard and, more significantly, help reduce the total Bill of Materials (BOM) cost.

Further, we will see a highly integrated and cohesive RFFE architecture that supports both sub-6GHz and mmWave 5G in one device. Just as premium LTE smartphones on the market today include RF support for global roaming, future 5G smartphones will integrate additional support for 5G frequencies and modes in a cohesive modem-to-antenna design. The need for cohesiveness or optimization in modem-to-antenna design is crucial in 5G applications where any signal degradation would cause a noticeable lag or delay for the user. In summary, better, cheaper, and faster 5G smartphones are on the horizon.

Figure 5: Future 5G design



Component maturation is a cycle that every new wireless standard goes through. Early LTE designs were as complex as the first-generation 5G designs we identified in this insight. With advances coming in semiconductor manufacturing and the progression toward tighter silicon integration, especially the tight coupling of modem and the RFFE, the industry will begin to realize the benefits of maturing 5G chipset designs.

Also, as the transition previously forecast in smartphone design takes hold and shifts from LTE to 5G, an accompanying growth in manufacturing volume will inevitably drive down the overall cost of 5G devices. These benefits will ultimately flow down to the end-consumer in terms of greater affordability and expanded capabilities for future smartphones, set to arrive as early as next year.

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