



5G Operator Survey

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TIA's 5G Operator Survey 2016

EXECUTIVE SUMMARY

5G heralds a unified network architecture optimized to support agile business models, diverse applications, and wireless connectivity demands needed for emerging mobile solutions. To achieve this, 5G needs to be a “chameleon” technology that can adapt to differing demands of wireless services -- whether to support high bandwidth, low latency, bursty traffic, ultra-reliable services, or a combination of these capabilities.

As the mobile industry faces tremendous market disruption, there is a great deal at stake for 5G. This report presents the findings from an online survey of communication network operators that investigates their current and future 5G strategies. The survey was conducted in the winter of 2016 by the Telecommunications Industry Association (TIA) with support from InterDigital and Tolga Research.

Notable findings from the survey include the following:

Thirty-two percent of respondents have already commenced technology trials, and a further 26 percent plan to trial 5G over the next 24 months, despite the standardization process still continuing.

5G is unusual in that extensive trials are being conducted even though the standardization process will not be complete for several more years. Operators that are testing or planning to test 5G within the next 24 months are eager to understand its complexities and to determine its performance in practical operating environments. The findings from these tests will play a critical role in determining the initial 5G services that operators are likely to deploy.

More than two-thirds of survey respondents envision conducting trials of radio technologies rather than core network technologies first.

In nearly half these cases, the operators are conducting trials of radio technology that operates both above and below 6GHz. The operators' core network efforts today tend to be focused toward testing and deploying NFV and SDN functionality, which are precursors to 5G.

Almost a third of respondents plan to launch pre-standard 5G products.

Pre-standard 5G launches are occurring in specific markets, such as Australia, China, Japan, Korea, and the United States. Several key drivers of pre-standard deployments that were observed in the survey, and that are consistent with public announcements, include the opportunity for competitive advantage, the ability to showcase 5G at major events, and in response to politically motivated efforts by nation-states.

Nearly half of respondents expect to have made 5G investments as part of their CAPEX budgets by the end of 2020.

While the respondents were bullish in terms of the timing of 5G CAPEX, they also stressed that they did not expect 5G CAPEX to ramp at nearly the same rate as 4G. Instead of large scale network rollouts, many of the respondents anticipated making targeted 5G deployments for several years until 5G use cases can be commercialized with mass-market scale.

By the end of 2020, 33 percent of respondents expect their companies will be offering commercial 5G services.

This reflects the aggressive approach operators in some markets are taking toward 5G. These operators tend to have networks in mature markets where they believe they can capture competitive advantage with their technologically savvy customers.

A lack of partner diversity is likely to challenge 5G network densification efforts.

Most survey respondents indicated that they planned to partner with building owners (75 percent), electrical utilities (64 percent) and public lighting companies (61 percent) for their network densification efforts. Fewer than 40 percent of respondents identified alternative partners. Without broader partnership strategies, operators in many markets may struggle with their 5G network densification objectives.

Operators have diverse data offload strategies in unlicensed spectrum.

The sentiment toward LTE in unlicensed spectrum (LTE-U) and Wi-Fi® varied among respondents and appeared to be influenced heavily by the legacy systems they operate, market conditions, and competitive landscapes. More than half (55 percent) of respondents plan to deploy Licensed Assisted Access (LAA) and prefer the notion of operating LTE in unlicensed spectrum. Wi-Fi offload solutions, such as LTE + Wi-Fi Link Aggregation (LWA) and LTE Wi-Fi Integration, (a forerunner to the LWA), were both favored by 41 percent of respondents.

Fiber back-haul is preferred, but watch out for millimeter wave.

Not surprisingly, fiber was ranked as the most important backhaul and transport technology for 5G. Interestingly, however, survey respondents ranked millimeter wave technology in second place, ahead of more traditional technologies such as microwave. Although millimeter wave as a backhaul technology has languished due to line-of-sight alignment challenges, it is expected to benefit greatly from the technology advancements associated with 5G millimeter wave access technologies.

Operators are uncertain about how 5G will prove to be transformative.

There was a lack of consensus among respondents regarding how and to what extent 5G will transform its primary use cases. For enhanced broadband services, 56 percent of respondents believed use cases will be significantly transformed. However the remaining 43 percent of respondents were less optimistic or uncertain. Only 30 percent of respondents believed that machine-type communications will be significantly transformed by 5G, and 50 percent expected that ultra-reliable and ultra-low latency services will be not be significantly transformed by 5G.

Since 5G is still nascent, it is difficult to anticipate exactly how it might prove to be transformative. However, history suggests that while it may underachieve relative to expectations in the short term, it will overachieve in the long term.

Security concerns for 5G vary dramatically among use cases.

Security threats are on the increase as wireless and mobile services become more pervasive. Among wireless use cases, 90 percent of respondents believed security will be more challenging for autonomous vehicles. In addition, 67 percent of respondents expected security to be more challenging for ultra-reliable and low-latency services, and 63 percent expected security to be more challenging for massive machine-type communications. Heightened security demands were expected for these applications, primarily because of the nature of the services 5G enabled. These concerns were offset by the improved security capabilities being implemented in 5G solutions.

Optimism for network slicing prevails.

Network slicing is a technology that will be introduced natively in 5G, and it inspired optimism among the survey respondents. Eighty-three percent of respondents believed network slicing will be either very important or extremely important for creating revenue-generating opportunities, 73 percent for enabling enhanced service quality, and 70 percent for introducing network efficiencies. However, although respondents were generally optimistic about network slicing,

some indicated that business and operational support system upgrades are needed for network slicing to be effective.

Operators have high expectations for 5G-enabled autonomous vehicles.

In the survey, 70 percent of respondents identified the role of 5G in automotive applications as being either very or extremely important. Many Tier 1 network operators have targeted the automotive vertical because of its potential value and its relatively favorable market characteristics. Operators are targeting 5G toward autonomous vehicle applications such as platooning. However, 5G deployments in this space may be shaped by potential developments in Dedicated Short-Range Communications (DSRC), a technology promoted by the automotive industry.

There is optimism for telemedicine in remote regions and emerging markets.

A majority of respondents were not convinced by 5G telemedicine applications such as remote surgery, with some skeptics citing regulations and possible safety concerns. Yet 43 percent of respondents believed that 5G is either extremely or very important for health care applications, and identified factors such as the need for both high-capacity and low-latency connectivity as important. Several respondents also identified opportunities to deliver telemedicine services in remote regions and in emerging markets where basic healthcare services are lacking.

Industrial IoT is expected to fuel unprecedented connection densities and connection latency demands

Industrial IoT has benefited from growing market opportunities and increased attention from network operators. 73 percent of the survey respondents believed that 5G was either extremely or very important for industrial IoT services and applications. These respondents identified several factors including 5G's potential to enable massive connection densities and low latency connectivity capabilities that can be used for closed loop automation.

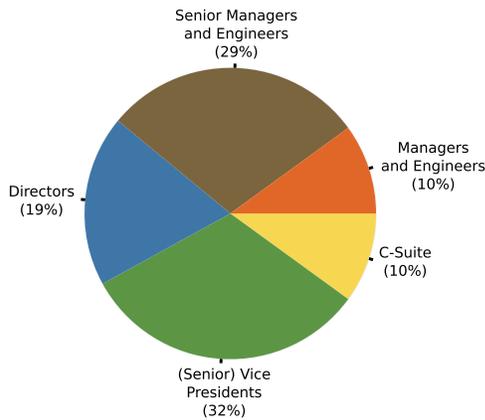
SURVEY METHODOLOGY AND RESPONDENT DEMOGRAPHICS

An online survey was commissioned by the Telecommunications Industry Association in the winter of 2016. The survey consisted of 28 questions developed with the collaboration of subject matter experts from TIA, InterDigital, and Tolaga Research. The objective of the survey was to gain insights into 5G trial and deployment activities, design priorities, and target markets for communication network operators across different global regions.

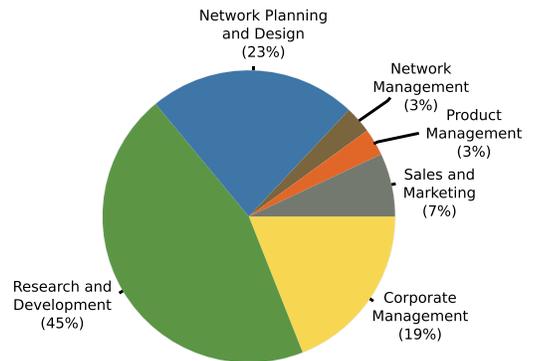
The survey targeted executives employed by network operators that are either directly involved in 5G technology development and trials or have a clear understanding of the 5G activities being pursued by their company. Overall, 31 qualified network operator executives responded to the online survey. Of these respondents, 90 percent were director level or above, with 45 percent being involved in research and development, 23 percent in network planning and design, and 19 percent in corporate management. To complement the survey, consultants from Tolaga Research conducted in-depth interviews with 19 of the survey respondents.

The network operators surveyed had annual service revenues ranging from US \$1 billion to \$146 billion and spanned Europe (32 percent), Asia and Oceania (24 percent), North America (22 percent), Latin America (15 percent) and Africa (7 percent). The spectrum assets used by the operators incorporated all the major mobile bands, with more than 90 percent of the respondents holding 100 MHz or more of radio spectrum licenses.

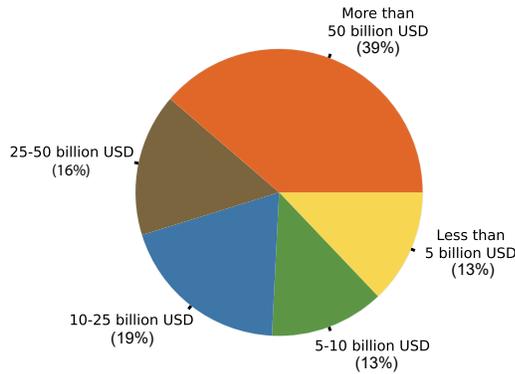
What is your level of responsibility at your company?



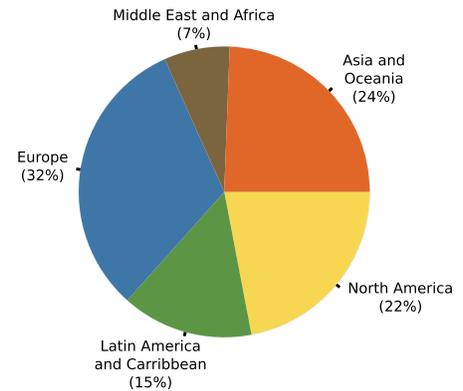
What is your main job function?



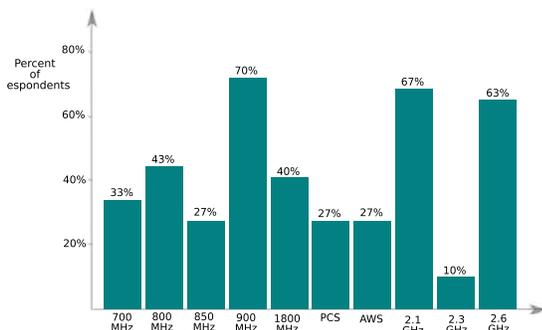
What were your company's annual revenues?



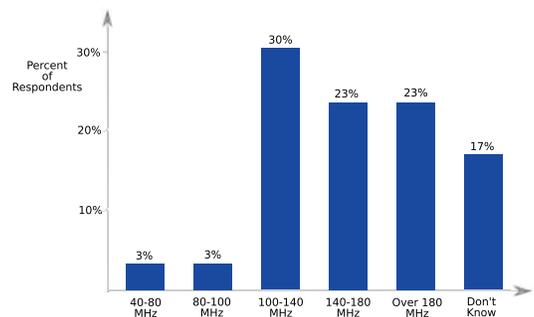
In which world region(s) does your company offer mobile service?



At which licensed spectrum bands does your company currently operate?

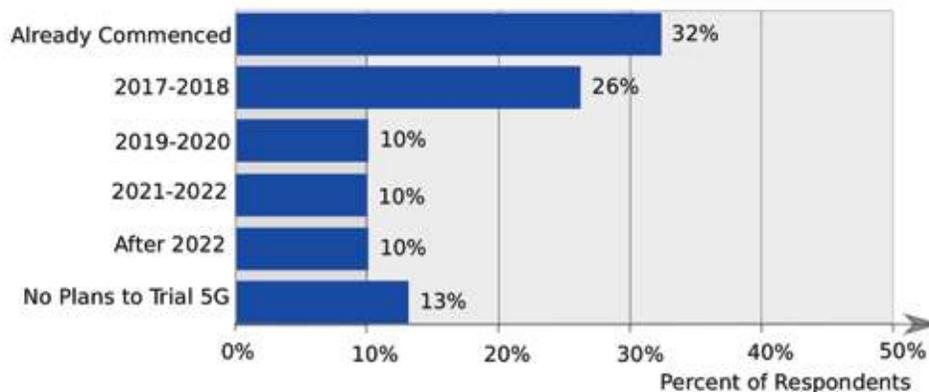


How much licensed radio spectrum does your company currently own and operate?



SURVEY RESULTS

When does your company plan to start trialing 5G?



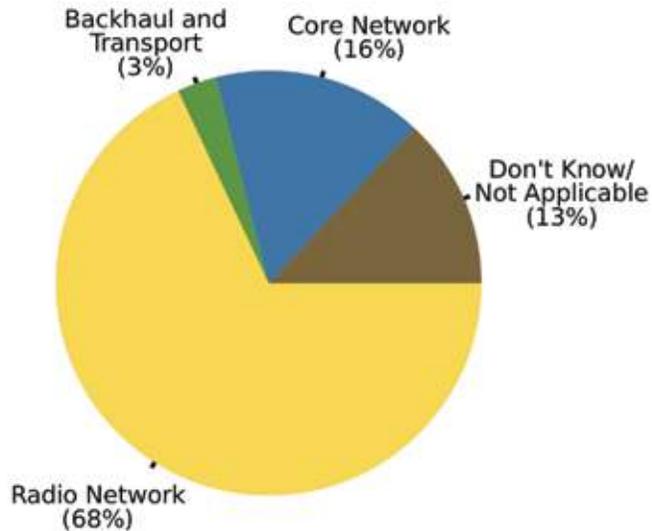
It is common for network operators to test new technologies to determine their performance characteristics in practical operating environments. However, 5G is unusual, in that it is fueling heightened trial activity even though 5G standards are not expected to be completed before 2020.

Of the respondents surveyed, 32 percent had already commenced 5G trials, and a further 26 percent expressed plans to begin trials of 5G within the next 24 months – still preceding standardization. Several factors contributing to heightened trial activity were identified in the survey interviews, which included the following:

- ▶ 5G is transformational at a time when the communications network operators are responding to market disruptions. The stakes are high for industry players. Technology vendors are eager to promote 5G with technology trials, and network operators are eager for insights into the performance of 5G in practical operating environments and the business models and commercial services 5G might enable.
- ▶ 5G encompasses a complicated array of technologies and innovations, many of which will require new network modeling and optimization capabilities for operators. These capabilities are still being researched in coordination with vendors and will require shorter development cycles to align with the availability of 5G products.
- ▶ In some cases, large Tier 1 operators are using technology trials as an opportunity to develop 5G intellectual property. One notable example is AT&T's "Project AirGig."

Thirteen percent of survey respondents did not have 5G trial plans. They generally operate in markets that are still in the early stages of 4G deployments or are relying on operator partners or parents in other markets to conduct trials on their behalf.

Which 5G network domain did you or do you plan to test first?

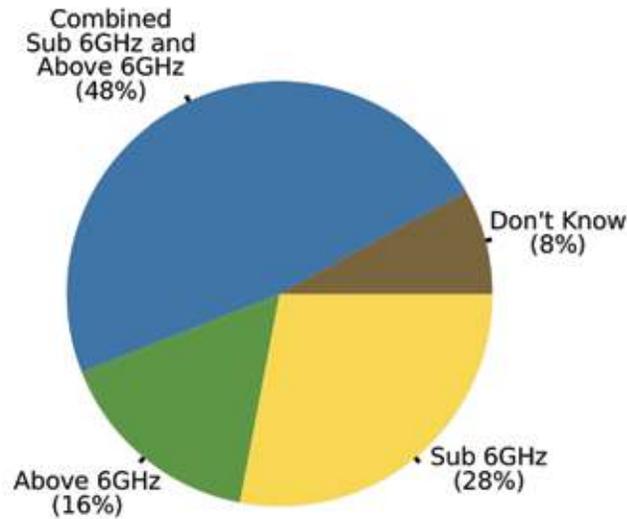


Although 5G enables an evolved end-to-end ecosystem spanning radio, backhaul and core, 68 percent of respondents indicated an initial focus toward testing radio network technology. Only 16 percent planned to begin testing with the core network, and just 3 percent with backhaul and transport.

For many operators, the radio network is regarded as an appropriate domain for initial trials, with an emphasis on lower-layer functionality. These trials tend to be less costly and easier to conduct in isolation from other systems. Furthermore, in parallel to 5G trial activities, many operators are testing and deploying core network technologies like network function virtualization (NFV) and software defined networking (SDN).

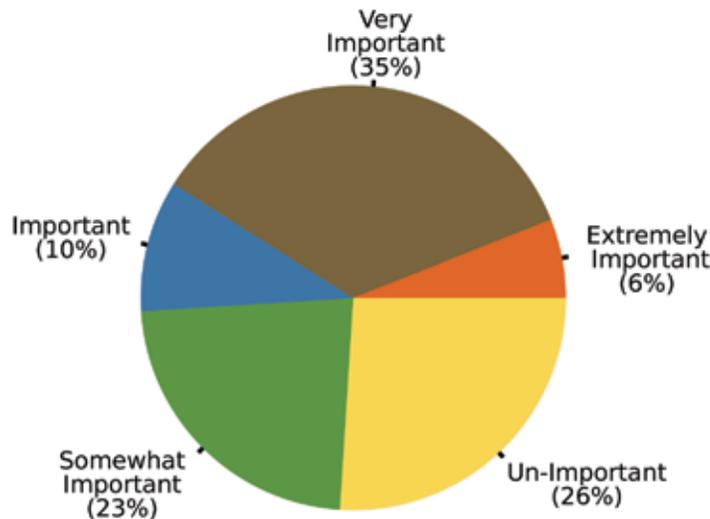
To deliver on its performance promises, 5G will break new ground with radio technology enhancements in both the sub-6 GHz and above-6 GHz radio spectrums. In principle, sub-6 GHz-based solutions align relatively well with conventional mobile radio network architectures, but introduce unique design challenges in the radio protocols that are used. Meanwhile, solutions that operate above 6 GHz have relatively short range, potentially limited mobility, and require new radio modeling and optimization techniques. These solutions also depend greatly on advanced signal processing and antenna systems for signal reception. Since centimeter and millimeter wave solutions use ultra-wide-bands, they would enable lofty peak data rates.

On which bands will your company most likely test 5G radio technology first?



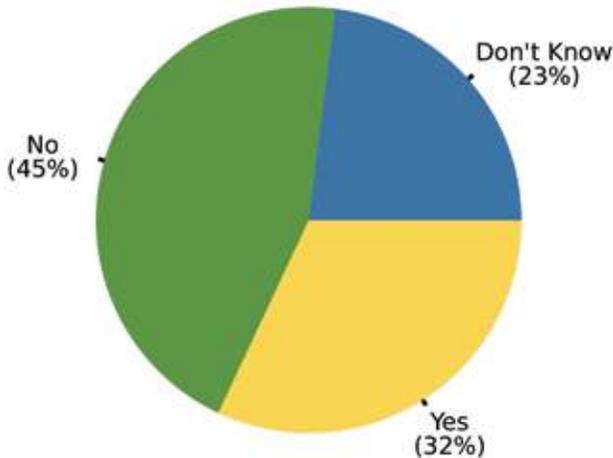
In the survey, 48 percent of respondents indicated they were initially testing 5G solutions operating both below and above 6 GHz. Twenty-eight percent indicated they would initially focus on trials with sub-6 GHz, and 16 percent on above-6GHz spectrum.

Rank how important it is for you company to be first to launch 5G as a competitive advantage



There was general consensus among most of the operators surveyed that 5G is of strategic importance. However, there is a lack of consensus regarding the competitive advantage that might be gleaned from being first to market. Almost half the respondents (48 percent) ranked being first to market as being either unimportant or only somewhat important for their company's competitive position. In contrast, 35.5 percent of respondents believed it was very important, and 6.4 percent extremely important. In general, operators in technologically advanced and mature markets place greater emphasis on being the first to launch 5G, while those that operate in less technologically advanced or less mature markets do not.

Does your company plan to launch pre-standard 5G products?



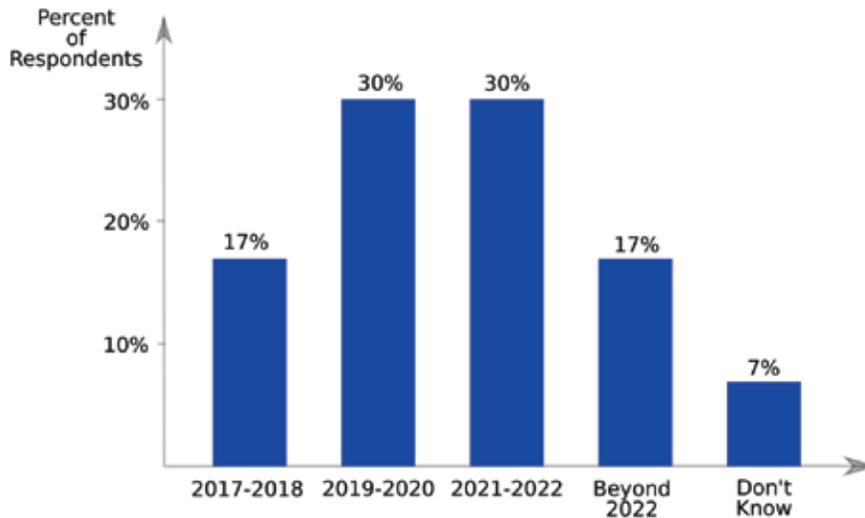
Since technology standardization is crucial for the communications industry, it is unusual for network operators to commercialize technologies before they are standardized. However, 32 percent of respondents plan to deploy pre-standard 5G solutions, and an additional 23 percent of respondents are undecided.

Deployment plans for pre-standard 5G solutions are most prevalent in a few countries, including Australia, China, Japan, Korea and the United States, and are driven by several key factors, which include:

- ▶ Opportunities to showcase targeted 5G implementations at high-profile events, such as the 2018 Winter Olympics in South Korea, 2018 Commonwealth Games in Australia, and the 2020 Summer Olympics in Tokyo.
- ▶ Potential opportunities to gain a competitive edge, particularly in markets with tech-savvy subscribers who might be swayed by 5G performance claims.
- ▶ Politically motivated efforts, particularly in markets where 5G leadership is treated as having strategic importance by nation-states.

The mobile industry must eventually recoup the tremendous investments that have and continue to be made in 5G technologies. For equipment vendors, this will occur when network operators commit to meaningful 5G capital expenditures (CAPEX).

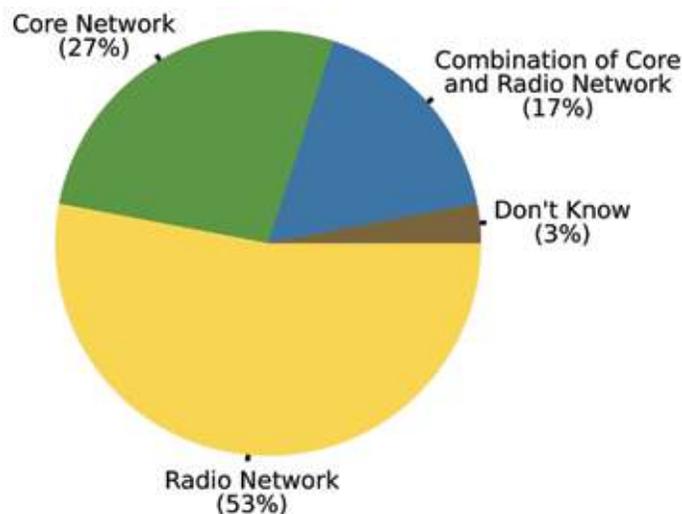
When do you expect to make 5G investments as part of your CAPEX budget?



In the survey, 17 percent of operators indicated that 5G CAPEX will be reflected in their 2017–2018 budgets. By the end of 2020, 47 percent of respondents anticipated that 5G investments will be reflected in their capital budgets. While this seems astonishingly early, given the expected timing of 5G standardization, it further demonstrates interest in pre-standard deployments among early adopters.

Interviews with survey respondents provided additional clarity into the timing of initial 5G CAPEX relative to the rate of CAPEX expansion. Many respondents stressed they did not expect 5G CAPEX to ramp at the same rate as 4G. Instead of large scale rollouts, they anticipated making targeted 5G deployments for several years until 5G use cases can be commercialized with mass market scale.

In terms of priorities, what might be the first 5G network domain you are likely to acquire and install?

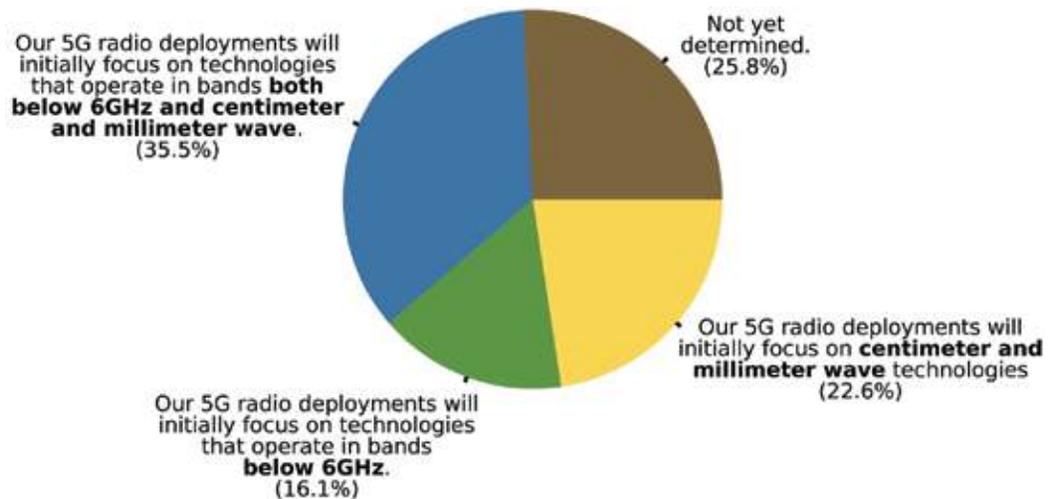


Since 63 percent of the survey respondents identified radio as the first domain for technology trials, it is no surprise that 53 percent of respondents anticipate that their 5G acquisitions and installations will focus initially on radio technology. Twenty-seven percent of respondents indicated their 5G investments would focus initially on core network functionality,

and 17 percent indicated their initial 5G investments will focus on a combination of core and radio network functionality.

Although the survey demonstrated that most respondents are targeting their initial 5G investments toward radio technology, subsequent interviews highlighted the tremendous investments operators are also making in NFV and SDN capabilities. In addition, some interviewees identified the critical importance of telecom software investments and business process transformations to support the diverse business models and system architectures being proposed for 5G. Underinvestment in these areas could stifle the rate at which meaningful 5G commercialization can be achieved.

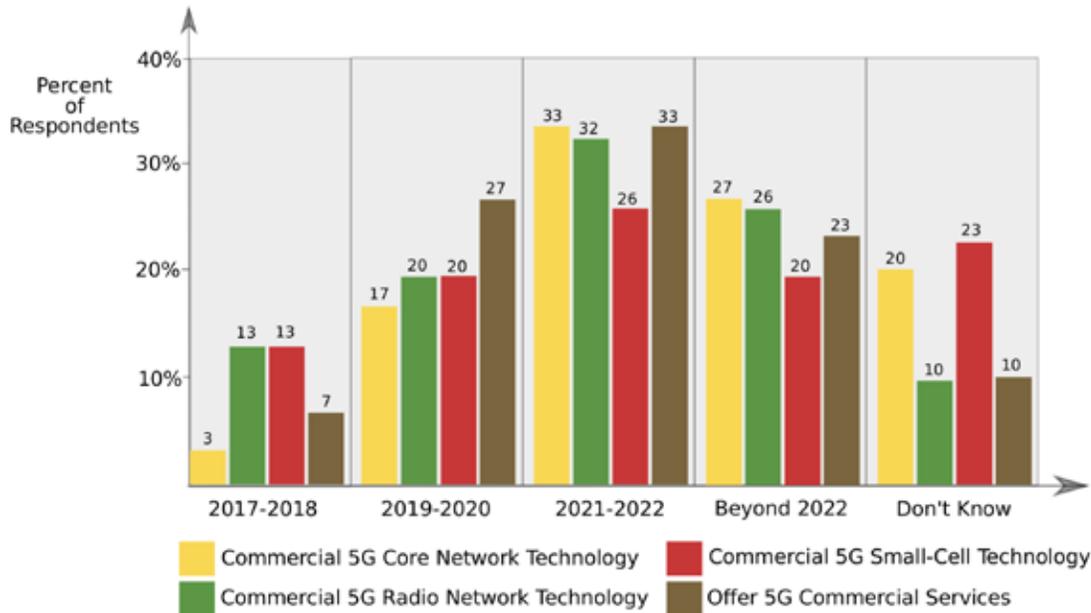
For 5G radio technology deployments, please select the statement that applies to your company



The radio spectrum bands targeted by operators can have an impact on their deployment strategies and the nature of services they offer. This is particularly the case when comparing services in the sub-6 GHz spectrum bands relative to those that operate above 6 GHz. In particular, 5G solutions that operate in sub-6 GHz bands are likely to be deployed in a similar manner to existing mobile services, with a focus on protocol changes that enable low-latency operations and concatenation of spectrum across bands to achieve high peak data rates. In contrast, solutions operating above 6 GHz will likely be targeted toward short range and/or limited mobility services, with ultra-high peak data rates and coverage areas resembling those of small-cells.

While operators are taking varied approaches toward their radio network deployment strategies, 36 percent of respondents indicated their deployments will include radio solutions in both sub-6 GHz and above-6 GHz spectrum bands. Initial deployments focused only above 6 GHz are being pursued by 23 percent of respondents; 16 percent of respondents indicated they plan to focus initially only on sub-6 GHz bands. These survey results illustrate a diversity of radio technology deployment strategies being pursued for 5G, which contrasts the more uniform strategies operators have adopted in the past for 3G and 4G services.

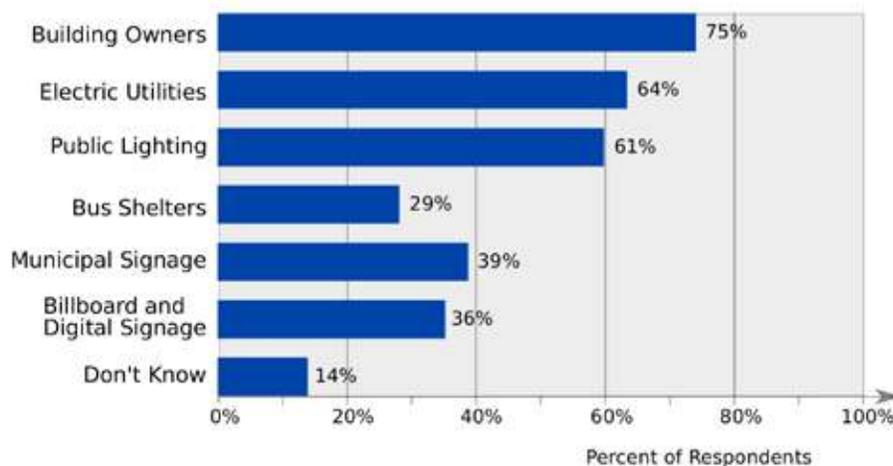
When do you expect your company will deploy?



More than 33 percent of the online survey respondents expect that by the end of 2020 their companies will be offering 5G commercial services, with 32 percent of the respondents having launched commercial 5G radio and small-cell technology, and 20 percent having launched commercial 5G core network technology. Given that 5G standardization is not expected before 2020, this further illustrates the bullish expectations many of the respondents have toward 5G.

Interestingly, 23 percent of respondents did not know when they were likely to deploy 5G small cells. Upon further investigation, it was apparent that much of the uncertainty regarding small cells was in outdoor environments and among operators that were not focused on the commercialization of centimeter and millimeter wave radio technologies. Practical challenges such as site acquisition are hindering some expectations for wide-scale small-cell deployments. It is crucial for the mobile industry to resolve these challenges as it looks to leverage the ultra-high bandwidth and low latency capabilities that underpin much of the 5G value proposition.

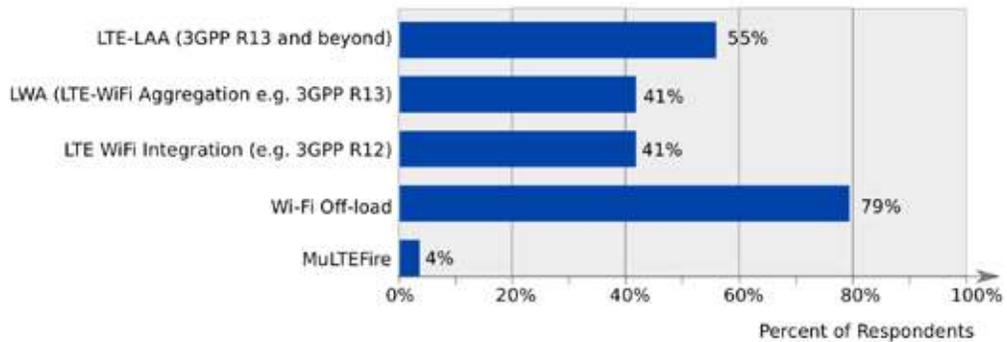
What types of partners do you plan to leverage for network densification for small cells?



Operators need partnerships to address the site acquisition challenges for small cells. It is common for operators to partner with building owners, particularly for indoor small cell implementations, and it is becoming increasingly common for operators to partner with municipalities and other entities such as electrical utility companies to gain sites for outdoor small cells.

The survey demonstrated that operators are continuing to focus on traditional partnerships for their small-cell densification strategies. In particular, 75 percent of respondents plan to partner with building owners, 64 percent of respondents plan to partner with electric utilities, and 61 percent with municipalities that provide public lighting. Less than 50 percent of respondents indicated they had partnership plans with other entities. It is crucial for operators to broaden their range of partnerships to enable the small-cell densification demanded by 5G.

Which of the following data off-load technologies might you deploy?

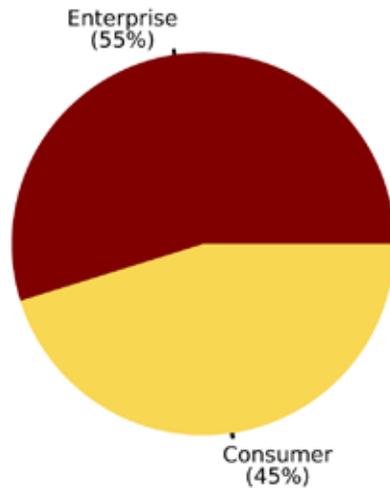


While 5G will be of strategic importance to operators, it will commonly be deployed in complement with other licensed and unlicensed wireless technologies – particularly in the case of mobile broadband services. Today, most data is delivered to mobile devices using Wi-Fi. This has culminated in the development and standardization of a variety of operator-led initiatives to leverage unlicensed spectrum, including LTE-LAA, LWA, LTE WiFi Integration, Wi-Fi offload and MuLTEFire. LTE-LAA and MuLTEFire have LTE radio technology operating in unlicensed spectrum. LTE-LAA essentially straddles both licensed and unlicensed spectrum bands, and MuLTEFire enables LTE radio technology to operate entirely in unlicensed spectrum.

Operators have different data offload strategies depending primarily on market conditions, competitive landscapes and the legacy systems that they operate. Some operators favor using Wi-Fi, while others are more interested in LTE-LAA technology. In some cases, operators plan to leverage MuLTEFire in markets where they do not have access to licensed spectrum or as an alternative technology for small-cell partnerships.

In the survey, 79 percent of respondents were interested in deploying Wi-Fi offload, 41 percent favored LTE Wi-Fi integration, and 41 percent favored the more advanced LWA technology. 55 percent of respondents are interested in deploying LTE-LAA, and 4 percent were interested in deploying MuLTEFire.

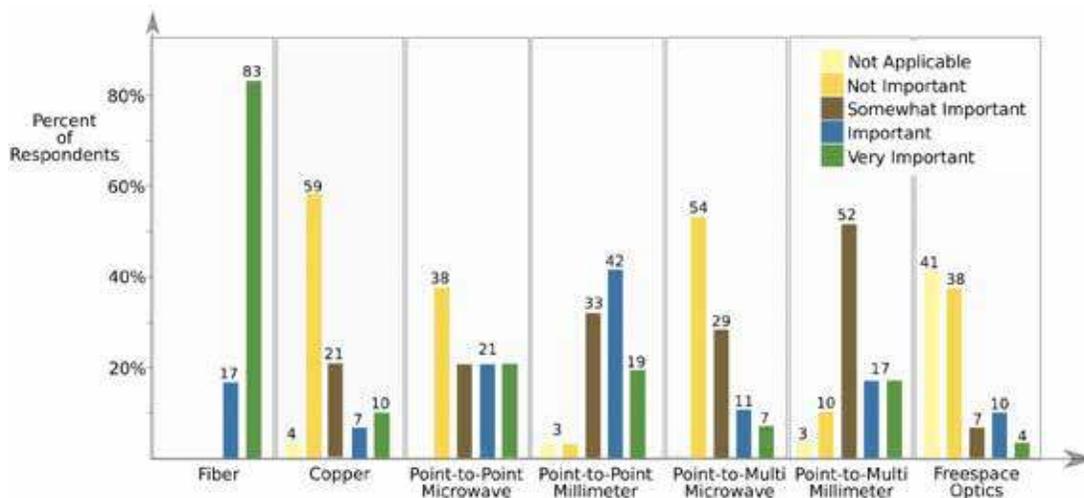
Which market segments do you think will generate the most incremental value to you from new 5G services?



The services and applications being targeted for 5G are vast and span both enterprise and consumer markets. Many of the services being proposed for 5G are nascent, and while some have large market potential, they do not necessarily offer equally large value for operators. In the survey, there was a relatively even split among survey respondents as to whether greater value would come from enterprise (55 percent) or consumer (45 percent) markets.

Upon further investigation, these responses were impacted by a variety of factors, including the operators’ target markets for 4G, the maturity of emerging services, such as those associated with the Internet of Things (IoT), and the relative revenues the respondents’ companies are capturing today from enterprise and consumer markets. While these factors will influence the early market priorities for 5G, their role will likely diminish as 5G matures with mass market services.

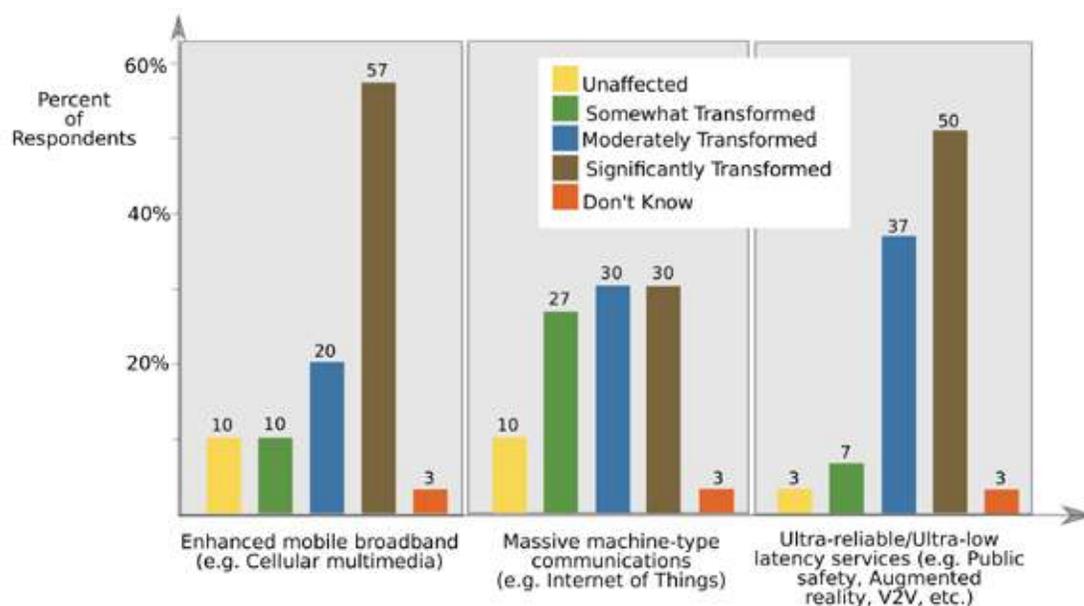
Rank the importance of the following backhaul technologies for 5G on a scale between “Not Applicable” to “Very Important”



5G requires high capacity backhaul and transport to deliver its intended peak data rates. For this reason, it is not surprising that every survey respondent identified fiber as either an important or very important backhaul and transport technology for 5G. Interestingly, point-to-point millimeter wave technology was also identified as either important or very important by 61 percent of respondents – higher than all other technologies identified except fiber.

Ideally, fiber is the best-suited backhaul and transport technology for 5G. However, it is costly to implement and is not necessarily economical for many deployment scenarios. Meanwhile, other conventional technologies like point-to-point microwave are widely deployed, but lack the capacity needed for 5G. Millimeter wave backhaul technologies have traditionally been challenged by operational complexities, such as sustained antenna bore-sight alignment. However, advancements in antenna technologies and signal processing being spearheaded for 5G access technologies may also address the operational challenges of millimeter wave back-haul.

On the following scale, rank which use cases will be most transformed with 5G.

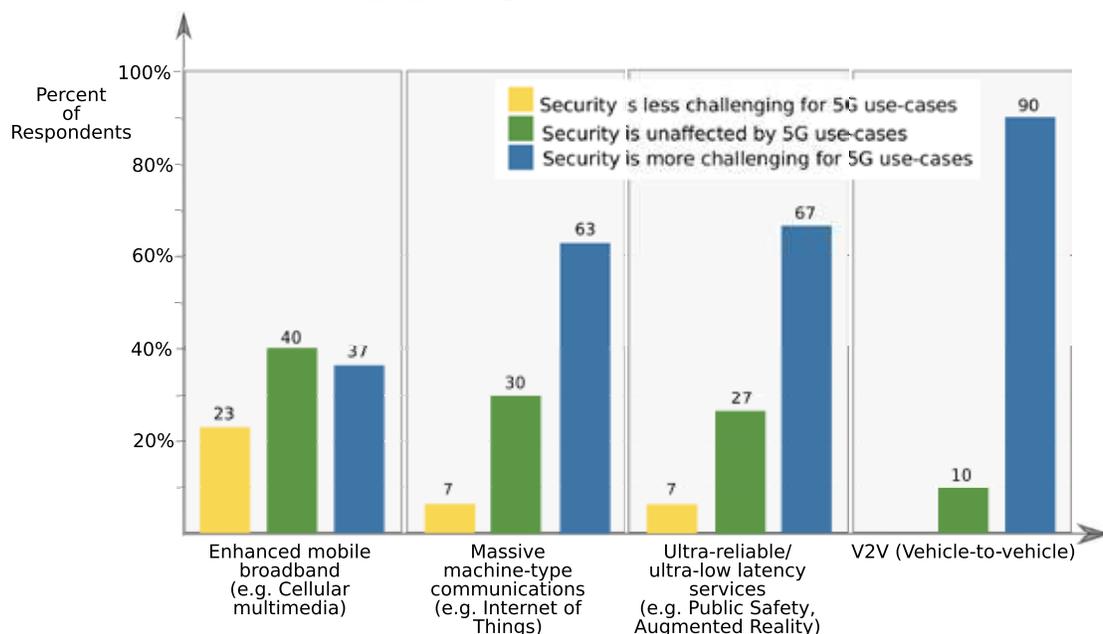


The targeted services and applications for 5G are vast, but can be divided into essentially three service categories, each having unique design criteria. These are:

- ▶ **Enhanced mobile broadband services** that capitalize on the tremendous peak data rates offered by 5G. In the survey, 57 percent of respondents believed that enhanced mobile broadband services will be significantly transformed by 5G. This is a testament to the expected impact of 5G peak data rates on the type of mobile broadband services that might be offered in the future.
- ▶ **Massive machine-type communications** aim to leverage 5G design features for massive connection densities. There was a varied response among survey respondents regarding the transformative impact of 5G for machine-type communications. In particular, 30 percent of respondents believed 5G would be significantly transformative, 30 percent believed it would be moderately transformative, and 27 percent believed 5G would be somewhat transformative to machine-type communications. Upon further investigation, these survey results reflected a belief among some respondents that the 5G connection densities were unnecessary, and that current and emerging 4G technologies and other unlicensed solutions are adequate for the foreseeable future.

- ▶ **Ultra-reliable and ultra-low latency services** will become possible due to the unique design characteristics of the anticipated 5G protocols. In the survey, 50 percent of respondents believed 5G would significantly transform, and 37 percent believed it would moderately transform, ultra-reliable and ultra-low latency services. While there was recognition of the unique features 5G aims to enable for ultra-reliable and ultra-low latency services, some respondents did not believe it was necessarily transformative. These respondents identified other technologies and architectures they believe can achieve comparable capabilities. They also identified other capabilities, such as edge computing and peer-to-peer networking, they believe are needed and potentially more important than 5G.

For the following use cases, do you think that security will be less challenging, unaffected or more challenging with 5G?



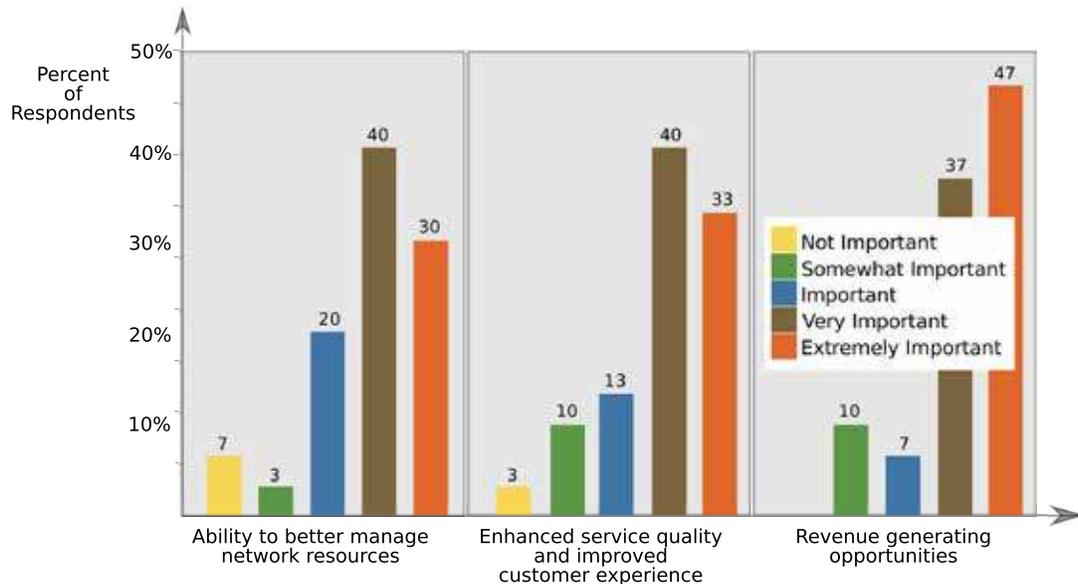
Security threats are on the increase as wireless and mobile services become increasingly pervasive. This being the case, there were somewhat diverse opinions amongst respondents regarding the impact of 5G use cases on the security of the various applications to which it is being targeted. In particular:

- ▶ There was no clear consensus among respondents regarding the impact of 5G use cases on the security of enhanced mobile broadband services. This can likely be attributed to a lack of specific use case definition in this particular service category.
- ▶ Of the survey respondents, 63 percent believed security would be more challenging for 5G use cases associated with machine type communications, and 30 percent of respondents believed security will be unaffected. In drawing these conclusions, the respondents focused on several key use case attributes, most notably the impact of a massive increase in the number of connected devices on the potential attack surface relative to the impact of the improved security features associated with 5G.
- ▶ Sixty-seven percent of respondents in the online survey believed that security is more challenging for the 5G use cases associated with ultra-reliable and ultra-low-latency services. However, 5G use cases for ultra-reliable and ultra-low-latency services are targeted toward new service categories such as augmented reality (AR) and the enhancement of public safety services. Therefore, this is not a surprising survey result. The associated services essentially bring closer alignment between the

connected, virtual and physical domains in the case of AR and increase the stakes for connectivity in the case of public safety.

- ▶ The 5G use cases associated with V2V connectivity are generally associated with autonomous vehicle control, such as vehicle platooning. As a consequence, the stakes are high for V2V connectivity, and security is paramount. As such use cases are still nascent, the survey results likely recognize the inherent security challenges of these use cases, with 90 percent of respondents indicating that they believed security is more challenging for the use cases associated with V2V connectivity.

Please rank the importance of the following capabilities that are enabled with network slicing (from “Not Important” to “Extremely Important”)



Network slicing is a capability that will be introduced natively in 5G architectures. In essence, network slicing is a service architecture that enables operators to deploy many end-to-end “virtual networks” to support specific service and application demands. For example, real-time applications require low-latency network resources, while batched services do not. The resources for these services can be optimally provisioned using network slicing.

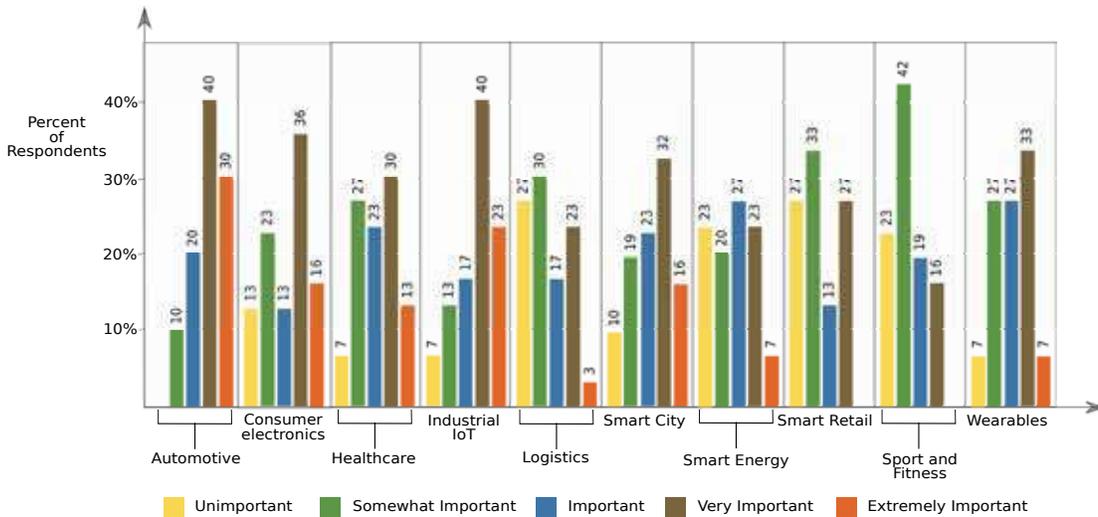
Key value propositions for network slicing include:

- ▶ **The ability to manage network resources better**, since network slicing eliminates resource silos and enables resources to be provisioned as they are needed. In the survey, 30 percent of respondents believed this was an extremely important capability enabled by network slicing, while 40 percent of respondents believed it was very important. The remaining 30 percent of respondents were less optimistic. Upon further investigation, the less optimistic respondents indicated they believed the emerging 5G standards will not provide the agility needed for network slicing, particularly relative to the integration with business and operating support systems.
- ▶ **Enhanced service quality and improved customer experience**, a consequence of enabling better alignment between the allocated resources and services demanded. In the survey, 73 percent of respondents identified enhanced service quality and improved customer experiences as either very important or extremely important in the context of network slicing. Several respondents noted that the fundamental principles of agility which underpin network slicing pioneered by Web scale

players like Facebook and Google, have enabled tremendous improvements in service quality and customer experience. However, skeptics believed the end-to-end architectures implemented by operators will likely fall short of the agility capabilities needed for network slicing, to the detriment of service quality.

- ▶ **Revenue generating opportunities** are often identified as a key value proposition for network slicing. In the survey, 83 percent of respondents believed network slicing was either very important or extremely important to their revenue generating capabilities.

What IoT use cases do you see as benefiting the most from 5G? Rank the following on a scale of 1 to 5 (1 = Unimportant to 5 = Extremely Important)



Most of the services and applications being touted for 5G are targeted toward non-telecom verticals, reflecting the broadening scope of addressable markets for communication services. In particular:

- ▶ As the **Automotive** industry advances autonomous vehicle programs, it requires ultra-reliable and low latency connectivity between vehicles (V2V) and from vehicles to roadside infrastructure (Vehicle-to-Infrastructure – V2I). For reliable V2V connectivity, latencies on the order of 1ms are required. Since these latencies are achievable with 5G, mobile industry players are promoting its use for autonomous vehicle solutions. In the online survey, 70 percent of respondents believed 5G was either extremely important or very important for automotive services and applications. Based on further investigation, the respondents were generally referring to the role of 5G in delivering autonomous vehicle capabilities. In contrast, 30 percent of respondents identified automotive use cases only as important or somewhat important for 5G. In these cases, respondents may have anticipated that 5G might be eclipsed by potential alternatives, such as DSRC (Dedicated Short-Range Communications). DSRC has been developed by the automotive industry for low latency V2X connectivity.
- ▶ IoT based **Consumer Electronics** support an enormous variety of services and applications such as video, gaming, infotainment, education, etc. It is anticipated that 5G will enable tremendous enhancements to existing services and applications and enable new capabilities such as augmented reality and the tactile Internet. Amongst the survey respondents, 52 percent believed 5G was either extremely important or very important for IoT-based Consumer Electronics. The remaining 48 percent of respondents were less optimistic, with some suggesting that continued advancements in 4G technologies are adequate and questioning whether 5G was needed for this use case.

- ▶ The **Health Care** vertical offers tremendous potential for IoT, but has regulatory and safety hurdles that hinder market adoption. 5G is commonly touted for its ability to support telemedicine applications, such as remote surgery. While we believe that many of the proposed telemedicine applications are impractical, we also anticipate that as 5G becomes available innovative telemedicine solutions will be developed, with much of the innovation being driven by the needs of emerging markets. In the online survey, 43.3 percent of respondents believed that 5G was either very or extremely important for IoT based Healthcare applications. Some of these respondents identified the benefits the combination of high bandwidth and low latency connectivity would bring to telemedicine applications and highlighted the need for wireless telemedicine in remote geographies. The less optimistic respondents identified the lack of compelling use cases and the regulatory challenges with healthcare innovation.
- ▶ **Industrial IoT** (IIoT) is focused primarily on the application of IoT to industrial manufacturing. IIoT is supported by a wide variety of industry-led initiatives, such as Industry 4.0, with an emphasis toward delivering improved automation, data analytics and cognitive intelligence to manufacturing processes. Interestingly, 73 percent of survey respondents believed 5G is either extremely or very important for IIoT services and applications. Several contributing factors identified by the respondents included the ability of 5G to support massive connected device densities and low latency connectivity to support closed loop automation.
- ▶ A variety of IoT services and applications that use cellular network connectivity have already been adopted for **Logistics**, particularly in the transportation sector. However, only 27 percent of survey respondents identified 5G as being extremely important or very important for IoT-based Logistics services and applications. While these respondents were in the minority, some identified compelling applications such as autonomous transportation.
- ▶ Cities are coming under increased pressure to improve energy efficiencies, modernize infrastructure and create high-quality living environments. As cities transform, a seemingly unlimited array of **Smart City** applications are emerging. These include sophisticated city monitoring and operation systems, **Smart Energy** solutions, Intelligent Transportation systems, sophisticated infotainment technologies, and Intelligent Buildings and Urban Spaces. In the future, Smart City and Smart Energy solutions are likely to incorporate autonomous and closed-loop management systems that will benefit from the ultra-low-latency capabilities of 5G, and augmented reality solutions that might also capitalize on the peak data rates offered by 5G. Coverage requirements for Smart City and Smart Energy applications will likely align well with probable 5G deployment strategies.

Forty-eight percent and 30 percent of respondents identified 5G as being very important or better for Smart City and Smart Energy applications, respectively. Most respondents were less optimistic, and questioned the need for 5G for these use cases and the extent of Smart City and Smart Energy innovations that will actually be deployed.

- ▶ **Smart Retail** applications aim to leverage IoT technology to improve in-store customer experiences and enable efficiencies in areas such as inventory management, logistics, and transaction management. Sixty percent of survey respondents identified 5G as being unimportant or only somewhat important for Smart Retail. Some questioned whether 5G was necessary, given that there are adequate local area wireless solutions to support in-store demands, and that adequate fixed communications capability was generally available for wide area coverage.
- ▶ **Sports and Fitness** is being revolutionized by IoT devices to sense, monitor and predict an endless array of performance indicators for the well-being of athletes, consumers and fitness enthusiasts. Sports and Fitness is a massive industry that is becoming increasingly connected. Some operators

are targeting Sports and Fitness solutions to their existing mobile subscribers, with the aim of driving increased revenue opportunities. However, many of these efforts have been challenged by freemium Sports and Fitness applications that are readily available. In the online survey, 65 percent of respondents viewed 5G as either unimportant or only somewhat important for Sports and Fitness applications. While 5G could deliver tremendous benefits in end-user experience, such as in the area of augmented reality, some respondents questioned whether consumers would be willing to pay a premium for the 5G-enabled services.

- ▶ **Wearables** is a rapidly expanding category of IoT devices spanning both consumer and enterprise markets and many application verticals including healthcare and sports and fitness. Thirty-three percent and 7 percent of respondents, respectively, believed that 5G is very important or extremely important for IoT Wearables. Upon further investigation, many of these respondents were focused primarily on the role of 5G in enabling augmented reality capabilities. Some of the respondents who were less optimistic toward the role of 5G in wearables acknowledged the potential for augmented reality, but believed it would represent only a small percentage of the overall market for wearables.

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