IHS TECHNOLOGY

5G Strategies

Global Service Provider Survey

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Contents

List of Exhibits

Top Takeaways

This year's survey clearly indicates that 5G developments are booming and well underway with pre-commercial trials set for 2017-2018 and commercial deployments starting in 2020 or later. Because the 5G standard won't be available until 2020, this ongoing 5G race is quickly leading us to a marketing battle around what 5G truly is, similar to what happened with 4G versus LTE in 2010. Other major findings are as follows:

- 54% of our respondents see 5G as evolutionary, an extension of current LTE, LTE-Advanced, and LTE-Advanced Pro; the rest think 5G is revolutionary, moving away from cellular and requiring a brand new architecture
- Meanwhile, three-quarters of respondents think 5G should be codependent with LTE and LTE-Advanced, which suggests the evolutionary camp should have garnered a larger lead
- Millimeter wave, new air interface, and user-data/system-control plane separation are chief 5G components
- Nokia is perceived as the top 5G vendor, closely followed by Ericsson and Huawei
- Ultra-low latency is the top 5G upgrade driver, trailed by ultra-high bandwidth throughput and increasing network capacity
- IoT is the top 5G use case
- Sub 1ms latency remains the toughest technology challenge to overcome

Introduction

The 5G race is on and raging! The very first discussions started in 2013, and in October 2013, NTT DoCoMo garnered attention by seriously discussing the possibility of rolling out 5G in time for the Tokyo Olympics in 2020. Right after, South Korea woke up and set the target for pre-commercial 5G showcasing commercial pre-standard evolutionary 5G—in reality, something like a 4.5G—for the PyeongChang Winter Olympics in 2018. Since then, major 5G R&D developments have happened in China, Europe, Japan, and South Korea, fueling the hype to a level never seen for 3G and 4G! And finally, Verizon caught everyone off guard last year at CTIA by announcing its aggressive 5G plan with first commercial deployments in 2017.

There are 2 schools of thought that currently define 5G

As every stakeholder—vendors, mobile operators, 5GPPP, the ITU, and others—has its own ideas and thoughts about what 5G should be, there is currently a split between 2 schools of thought:

- **Evolutionary**: Extension of current LTE and LTE-Advanced networks, which is defined as evolutionary and is backward compatible with all 3GPP technologies
- **Revolutionary**: Brand new network architecture requiring new air interface and RAT moving away from current cellular design

To assess the situation, we interviewed our 4G respondents

In June through August 2016, using online, telephone, and in-person survey methods, we interviewed 24 service providers from around the world who have deployed or trialed LTE or will do so by the end of 2017. Running in parallel with our 4G survey, this one specifically focuses on 5G, the next generation of mobile technology that is currently being developed and defined.

To participate in this survey, respondents are required to have detailed knowledge of, and purchase influence for, their companies' mobile network infrastructure and technologies, including LTE. Unlike last year, the sample is no longer skewed toward EMEA with 38% of respondents (vs. 55%), followed by Asia Pacific with 33%, North America with 21%, and CALA with 8%. Key network characteristics are as follows:

- 71% have deployed FD-LTE networks
- 21% have deployed a mix of FD-LTE and TD-LTE networks
- 8% are running TD-LTE networks

Please see "Methodology and Demographics" for details on the sample.

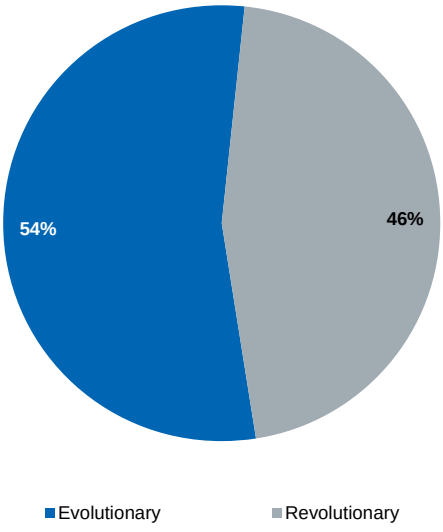
The Definition of 5G Is Leaning toward an Extension of Current LTE, LTE-Advanced, and LTE-Advanced Pro

This finding is almost a carbon copy of last year's survey, which was the first we did on 5G. The only difference is that this year our respondents have a better idea of what they think 5G should or could be, and consequently, everyone selected an option. Here is a look at the difference:

- Evolutionary 5G (extension of current LTE, LTE-Advanced, and LTE-Advanced Pro): 54% versus 32% last year
- Revolutionary 5G (brand new architecture requiring new air interface moving away from cellular): 46% versus 27% last year
- Don't know: 0 this year compared with 32% last year

This data suggests a gradually clarifying picture: 4G will not evolve to meet 5G requirements, so 5G requires a new RAT, architecture, etc. All of this means, as we have always stated, that 4G will continue to evolve in parallel to 5G and won't be superseded by it.

Exhibit 1 Defining 5G
n=24



Source: IHS

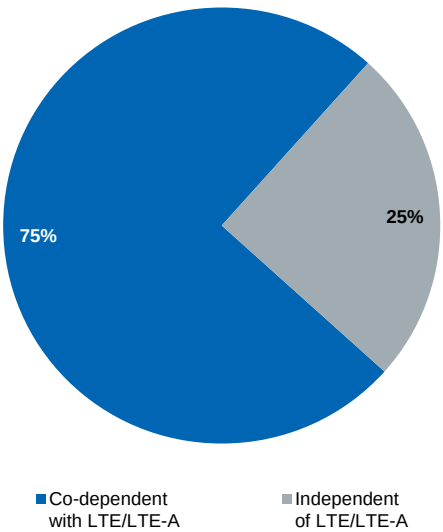
Last year’s findings really showed that we were still in the early stages with substantial work ahead aimed at defining 5G. In fact, on June 22, 2015, the ITU chose IMT-2020 as its official designation of what will one day be standardized as 5G. ITU-R Working Party 5D of the UN's telco arm finalized its 5G vision and rubber-stamped it as IMT-2020. The next step is to establish detailed technical performance requirements for the radio systems to support 5G, taking into account a wide portfolio of future scenarios and use cases. It will then set out its evaluation criteria for how it will assess candidate radio interface technologies.

And RAT should be co-dependent with LTE and LTE-Advanced

This is just another way of rephrasing “what will 5G be?” or “what should 5G be?” by focusing on radio access technologies (RAT). The findings are dramatically different: three-quarters of our respondents think 5G RAT should be codependent with LTE and LTE-Advanced.

The quarter left thinking 5G RAT should be independent of LTE and LTE-Advanced is very intriguing because this option is directly correlated with the revolutionary view of moving away from the cellular networks that were invented by Bell Labs engineers Douglas H. Ring and William Rae Young, Jr. in 1947.

Exhibit 2 5G RAT Development
n=24

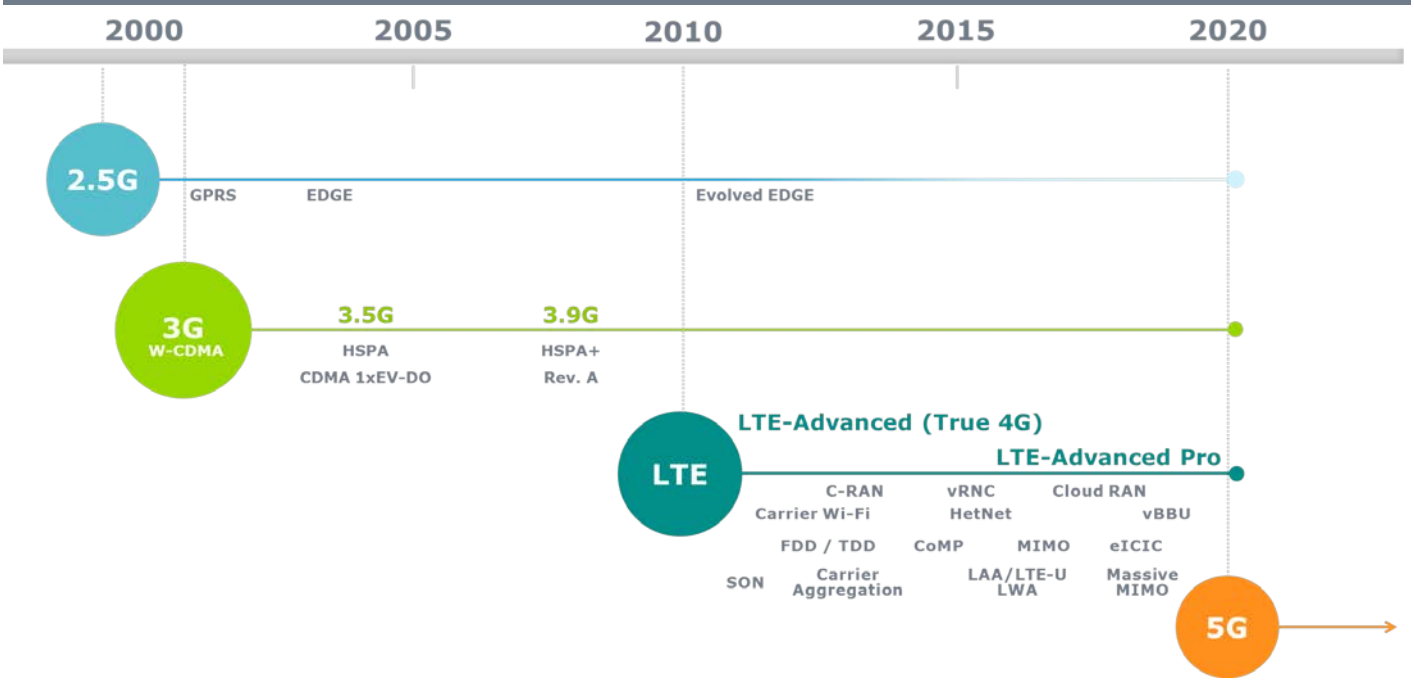


Source: IHS

Though we think it's time to move away from cellular, creating something that works with existing networks makes sense but adds another layer of complexity

On the one hand, no service provider on this planet wants to deploy a next-generation network that does not work with the existing infrastructure because it would be cost prohibitive. However, what about shutting down old technologies? Japan and South Korea have successfully done so. On the other hand, adding new 5G technology on top of existing networks will add another layer of complexity, as illustrated in the following simplified diagram.

Exhibit 3 The Battle of the Gs Leading to Complexity



Source: IHS

Making 5G co-dependent with LTE and LTE-Advanced only prolongs the existence of the other Gs, with all the associated burden

The Japanese and Korean operators have been operating in saturated markets characterized by revenue flatness at best, declining ARPU, and unabated traffic growth. Yet they successfully managed the generational transitions and have always embraced the deployment of brand new, cutting edge technologies in their networks. They claim the move kept them afloat, and they are still in business.

The question service providers should really ask themselves is, "How long can I ride those old horses and at what cost?" We could also argue the REAL question is, "What are we trying to achieve with the networks, and what do customers want?" There is an argument that 5G will be the first network driven by the needs of use cases, services, apps, and traffic rather than just physics, and underneath all the technology debate is the fundamental question "Why do we even need 5G?"

Given the reality of physics dictated by Shannon's Law, the above questions deserve some attention. Basically, while working at Bell Labs in 1948, Shannon theorized that the amount of error-free data that could be transmitted over a channel of any given bandwidth was limited by noise. Though more and more efficient technologies—HSPA+ in 3G and LTE-Advanced in 4G being the best shots so far in mobile—can be developed to push more data into a channel, there is a ceiling at which any gains of capacity would essentially be canceled out by noise. That fundamental limit became known as Shannon's Law, or mathematically speaking:

capacity (bit/s) = bandwidth * log2 (1 + signal-to-noise ratio).

In LTE-Advanced, the combination of at least 2 channels (e.g., 5MHz, 10MHz, 20MHz) or carriers increases the bandwidth and provides higher capacity. The signal-to-noise ratio can be improved by developing higher order of modulation, such as QAM256. But again, how far can we go in the current spectrum scheme? Some of our respondents have already launched 4-channel carrier aggregation that provides a bandwidth of 80MHz. In the context of evolutionary 5G, a new RAT using millimeter waves is coming next to again increase bandwidth because large channels of 100MHz or more can easily be found.

Logically, Millimeter Wave, New Air Interface, and Separation of System Control Plane and Data Transmission Are Chief 5G Components

In this question, we asked respondents which technologies they think will be key 5G components. Not finding sub 6GHz among the top 3 is somewhat surprising because that's likely where the very first commercial 5G deployments will occur as the spectrum is easily available and propagation schemes are known and well managed. However, there is so much buzz about millimeter wave (mmWave)—30GHz to 300GHz, sometimes starting at 18GHz—that 83% of our respondents selected this option as a top component. This brings the analysis to beamforming, which only comes 4th with 79% and should have come up along mmWave as it needs beamforming to work properly as a new RAT for cellular networks.

User-data/system-control plane separation is a key component for 5G deployments that rely heavily on beamforming for user-data delivery

Operating at frequencies above 6GHz requires serious propagation analysis and channel modeling to understand how those frequencies work and provide valuable information about how to build a mmWave network. And as result, a new air interface will be needed, as well as an "only transmit when needed" functionality that minimizes any transmission not directly related to the delivery of the user data. This latter concept was introduced as "ultra-lean design" in 2015 by Ericsson. On the other hand, the system-control plane includes the provisioning of system information, including procedures needed for devices to access the system.

Combining ultra-lean design with a logical separation of user-plane data delivery and basic system-connectivity functionality will enable a much higher degree of user-centric network optimization of the active radio links in the network.

Overall, our findings show that respondents are closely following 5G developments

As previously discussed, the first 2 groups are logically linked together. For the rest, starting at massive MIMO selected by 75%, followed by active antenna with 71%, the scores remain high and show the high expectations for these 2 technologies that are being designed within 4G. In fact, active antennas are used along with some variants of MIMO in commercial LTE-Advanced networks.

What's surprising is that only half of our respondents selected centimeter waves—3GHz to 30GHz, which partially overlap the sub 6GHz band and will likely be the spectrum used for early commercial 5G deployments. However, this does seem to show that the 3-6GHz range is of primary interest and the spectrum above 6GHz is less clear-cut for 5G.

Exhibit 4 Key 5G Components
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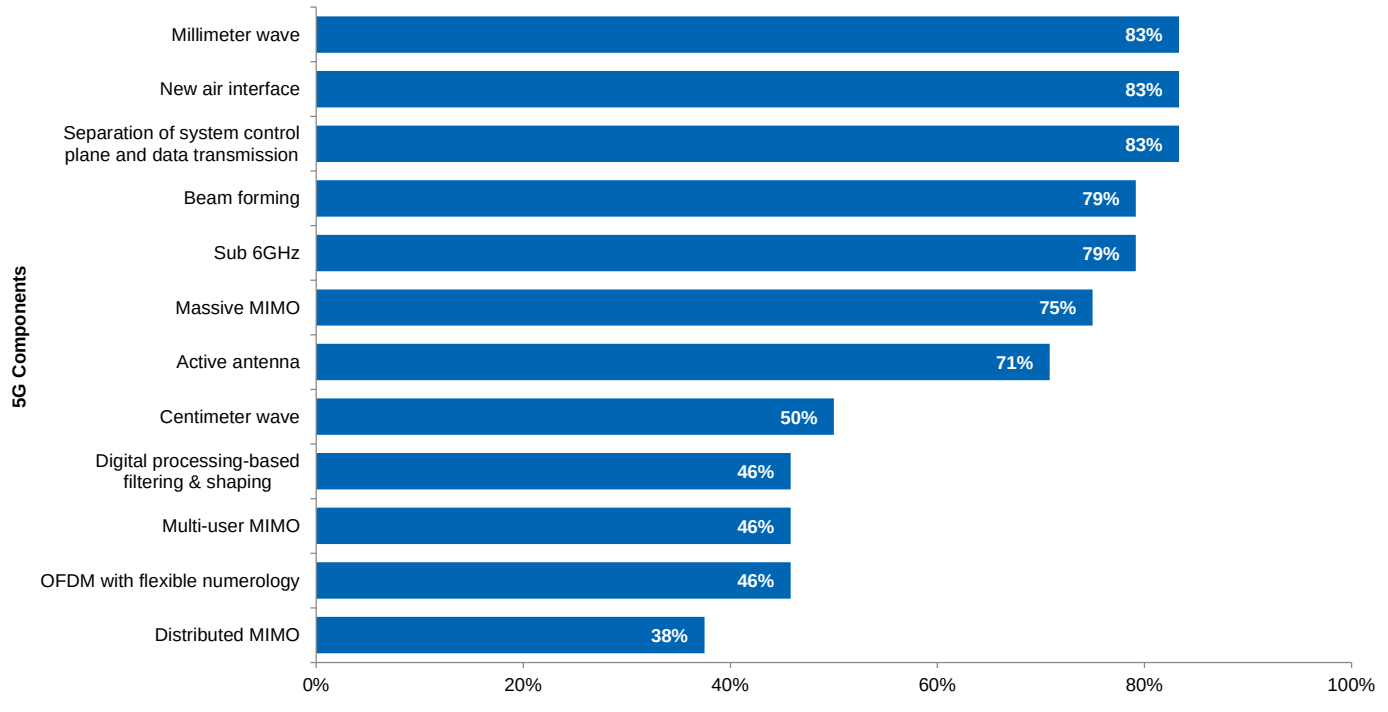


Source: IHS

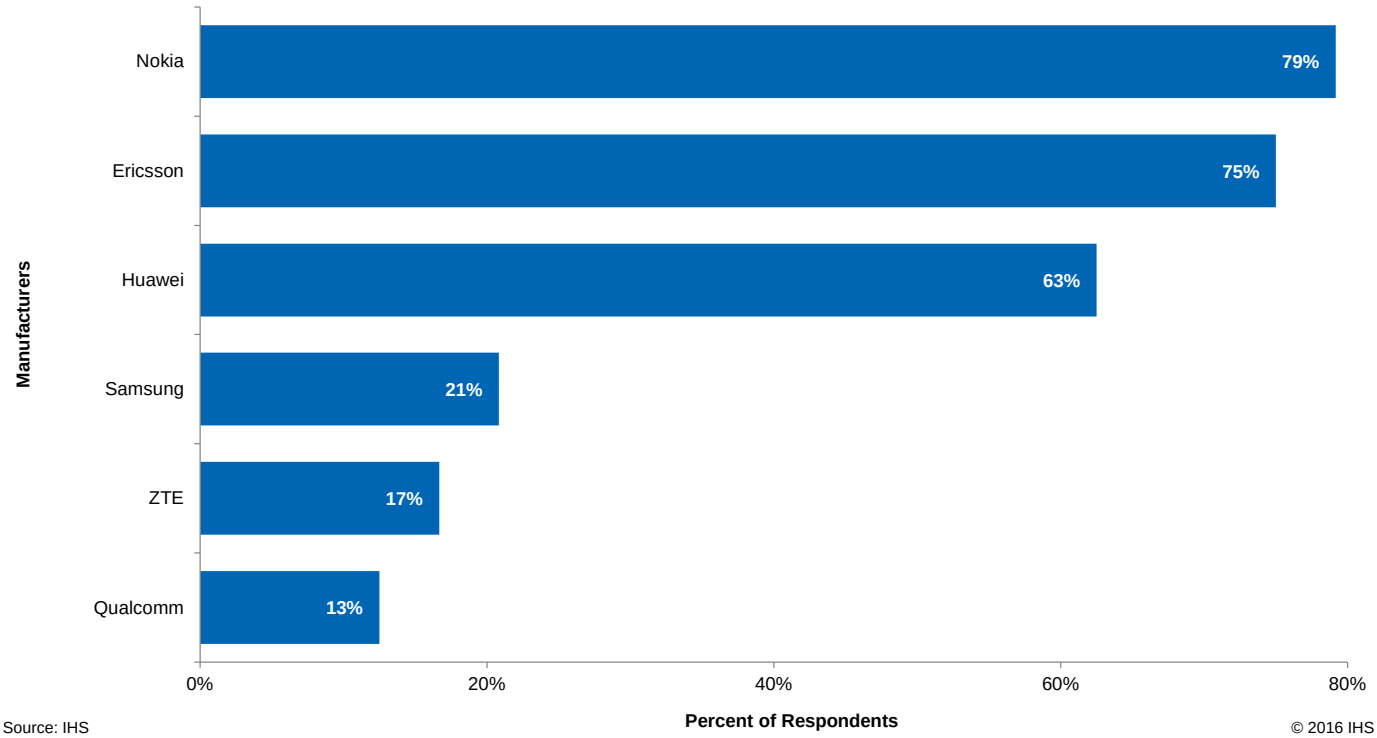
Nokia Is Perceived as Top 5G Vendor, Closely Followed by Ericsson

In an open-ended question, respondents named the manufacturers they consider to be the top 3 in 5G research and development. This measure is called *unaided brand awareness*, and it provides a good view of overall brand strength. Typically, the larger a manufacturer (e.g., broad product portfolio) and the more visible their brand, the better they fare in this question.

Here is why this ranking does not come as a surprise:

- Nokia and Ericsson have been at the forefront of 5G developments and are both engaged together in every single account that matters in Japan, South Korea, and the US, where the 5G frontrunners are.
- The narrow gap between Ericsson and Nokia may come from the composition of our sample but also from the fact that Nokia has shown bigger marketing muscle so far with the organization of flagship events, such as The Brooklyn 5G Summit last April in coordination with New York University.
- Huawei is also involved in many 5G projects but misses some markets such as the US, where the company is banned, and is not a leader like Nokia and Ericsson in Japan and South Korea. In addition, the 4.5G marketing campaign may have hurt Huawei, which as a result is not seen as a 5G front runner but instead as focused on sweating 4G assets.
- Samsung only has South Korea as its home turf and strongest market and is leading 5G developments there, but in Japan and the US, 2 overseas markets where Samsung has a strong foothold, the vendor is overshadowed by Nokia and Ericsson.
- ZTE is also active in 5G developments but simply lacks the clout of Nokia, Ericsson, and Huawei.
- Qualcomm has a nice surprising showing here! Although we asked about vendors, some of our respondents could not resist the opportunity to throw Qualcomm in the mix, which makes some sense due to its leading edge involvement on the chipset design front.

Exhibit 5 Top 5G R&D Manufacturers
n=24



Source: IHS

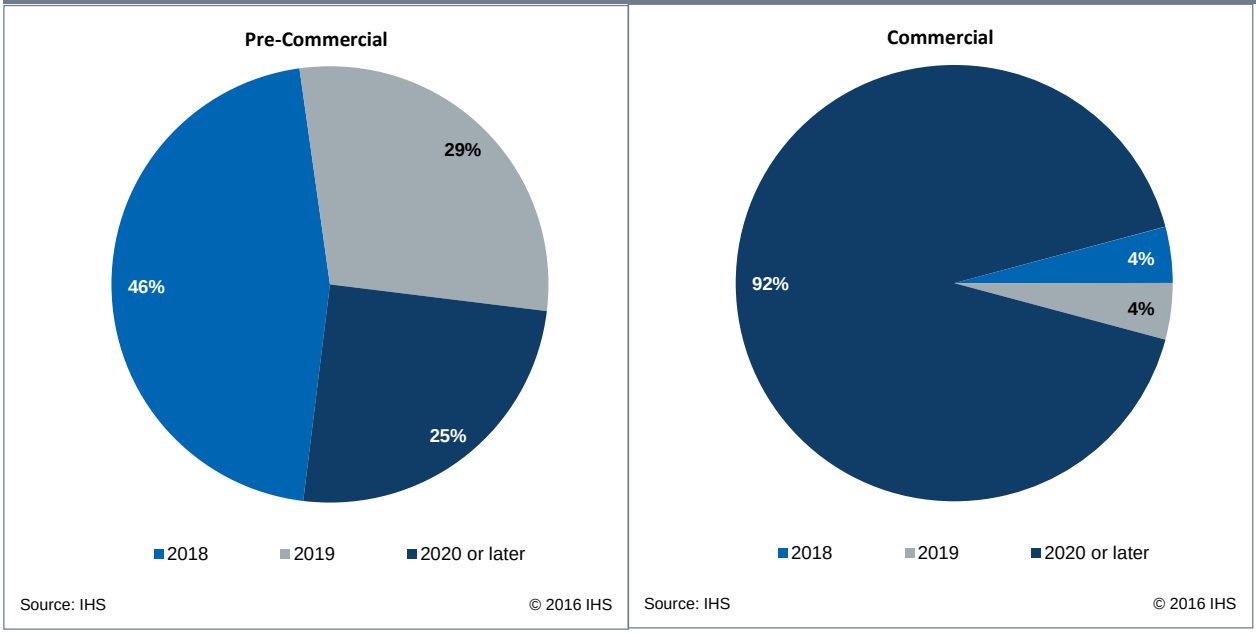
Near Half of Our Respondent Foresee Pre-Commercial 5G Trials by 2018 but Unanimously See Commercial Deployments in 2020 or Later

Once again, the finding shows a departure from last year's confusion and lack of credible information; our respondents are well informed and have a clear idea of the 5G deployment timeframe. Those findings are aligned with the official ITU-R timeframe that has set the deadline for a definition by 2019. By then, a fair amount of pre-standard 5G trials will have been completed, and the first commercial 5G rollouts will follow immediately in 2020. One caveat though—let's watch what happens next year in the US, where FCC Chief Tom Wheeler said there is no need to wait for the standard! And in the meantime, 5G will be showcased in 2018 in South Korea during the PyeongChang Olympics.

We're heading back to the marketing argument of calling it a G when it is not a real one!

Without a standard, will any of these be "true 5G?" Or will they just a proprietary implementation that has 5G characteristics? Without a standard, they might just be deployments of certain feature-sets, but many of those features would apply to LTE-A/Pro as well! And we're back to the same argument we had about 4G definitions—arguably LTE is "not true 4G," so what actually "counts" as 5G? And the argument is looming, for instance, at upcoming Olympics events; one can argue that these networks will only be 5G if they are deployed for industrial/IoT functions and not solely for the spectators in the Olympics arena. In other words, operators need to showcase as many potential use cases as possible.

Exhibit 6 5G Readiness: Pre-Commercial Trials, Commercial Deployment
n=24, 24



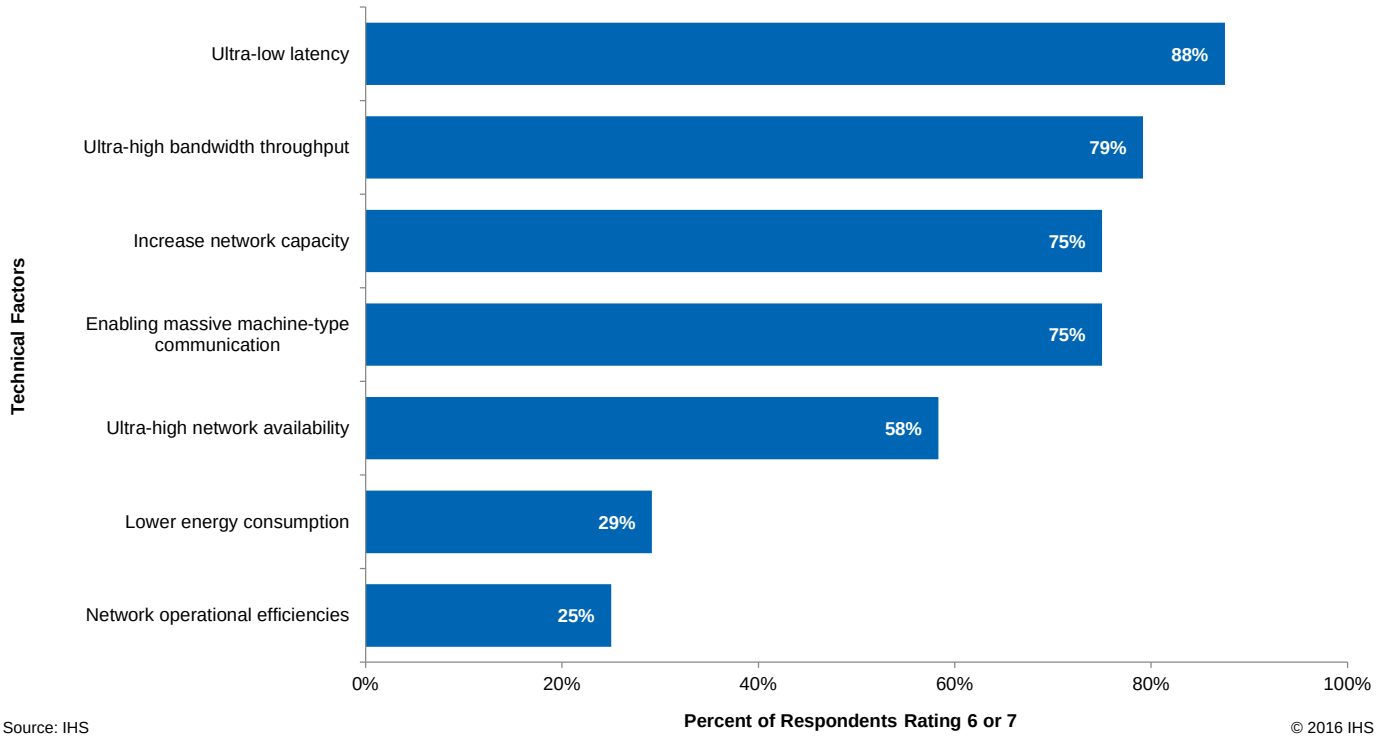
Ultra-Low Latency Is the Chief 5G Upgrade Driver. . .

Respondents rated technical factors in the upgrade to 5G on a scale of 1 to 7, where 1 is *not a driver*, 4 is *somewhat of a driver*, and 7 is *a strong driver*. The chart below shows the percentage of respondents rating each factor 6 or 7, or *very important.*

As service providers get more and more accustomed to the potential 5G technologies and components under development, they have been able to refine their expectations, and this is reflected in this year's findings. Last year, ultra-low latency, ultra-high bandwidth throughput, and increase network capacity were all grouped together as top drivers with 73%. This time around, all 3 drivers have increased their ratings starting with ultra-low latency with 88%, followed by ultra-high bandwidth throughput (79%) and increase network capacity (75%), itself tied with enabling massive machine-type communication, only rated 50% last year.

What all this means is 5G is seen as a next generation of mobile network that will deliver huge amounts of bandwidth and capacity faster, and industry, not humans, will drive use cases—see our 4/28/16 Analyst Insight: *The Brooklyn 5G Summit: Industry, Not Humans, Will Be Chief 5G Driver*.

Exhibit 7 5G Upgrade Drivers: Technical Factors
n=24



Source: IHS

. . . but also remains the toughest 5G technology challenge and won't disappear anytime soon

Respondents rated technical factors in the upgrade to 5G on a scale of 1 to 7, where 1 is *not a challenge*, 4 is *somewhat of a challenge*, and 7 is *a strong challenge*. The chart below shows the percentage of respondents rating each factor 6 or 7, or *a challenge*.

It's worth mentioning that the options offered in our questionnaire come from the 8 key 5G requirements that have been suggested so far, and the ITU's role is going to be to sort them out:

- 1-10G connections to end points in the field (i.e., not theoretical maximum)
- 1 millisecond end-to-end round trip delay (latency)
- 1000x bandwidth per unit area
- 10-100x number of connected devices
- Perception of 99.999% availability
- Perception of 100% coverage
- 90% reduction in network energy usage
- Up to 10-year battery life for low power, machine-type devices

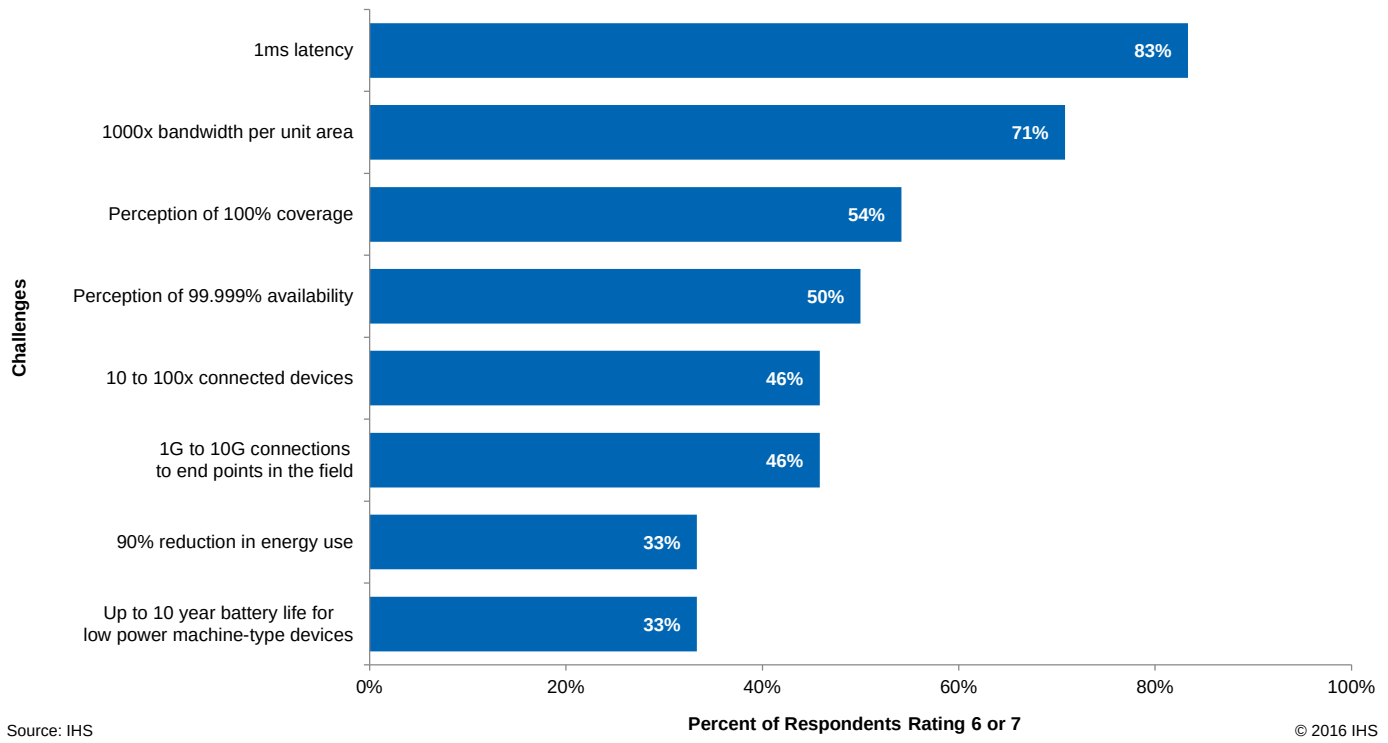
As it was last year, achieving 1ms latency is rated highly by 83% of respondents; it emerges as the chief challenge. Given that in a fully optimized LTE network the lowest achievable latency is 10ms—we rarely encounter such low latency in current LTE networks; 20ms is at best the norm—it does not come as a surprise that going down to a tenth of what 4G can potentially deliver is a tremendous challenge. This 1ms target requires significant network architecture changes such as moving much of the content to the closest radio, which is contradictory to moving everything to the cloud unless all links are fiber based. In addition, there is a lot of debate about moving from centralized RAN to cloud RAN architectures as part of a 5G architecture, but the reality indicates that round time processing in layer 1 and 2 of the baseband unit (BBU) is in the hundreds of microseconds, which added up seriously alters the delivery of overall sub 1ms latency.

At this point, the general idea is that using mmWave technology will allow a huge bandwidth while significantly decreasing the latency. This is something that was demonstrated by all vendors: they all have a mmWave demo showing multi Gbps throughput and slightly below 1ms latency. However, as said at the beginning of this report, mmWaves are very difficult animals to tame.

1000x bandwidth per unit area moves to second from third last year (at 71% this year vs. last year's 64%) and is related to the use of mmWave. In other words, let's use a spectrum band where wide channels of 100MHz bandwidth or more are available.

And finally, perception of 100% coverage and perception of 99.999% have significantly improved their ratings from 36% for both last year to 54% and 50%, respectively.

Exhibit 8 5G Technology Challenges
n=24



Source: IHS

Finally, IoT is the top 5G use case

Respondents rated use cases in the upgrade to 5G on a scale of 1 to 7, where 1 is *not a driver,* 4 is *somewhat of a driver,* and 7 is *a strong driver*. The chart below shows the percentage of respondents rating each factor 6 or 7, or *very important.*

The findings suggest a clear positive correlation with the previous section: industry will drive 5G, and consequently 5G networks should be designed to enable a vast IoT connectivity. This explains why IoT was rated 79% by our respondents as the top use case for 5G. Last year IoT was third with 55%, but the sample was slightly smaller, and as we have been saying since the beginning of this report, respondents are now well versed in 5G.

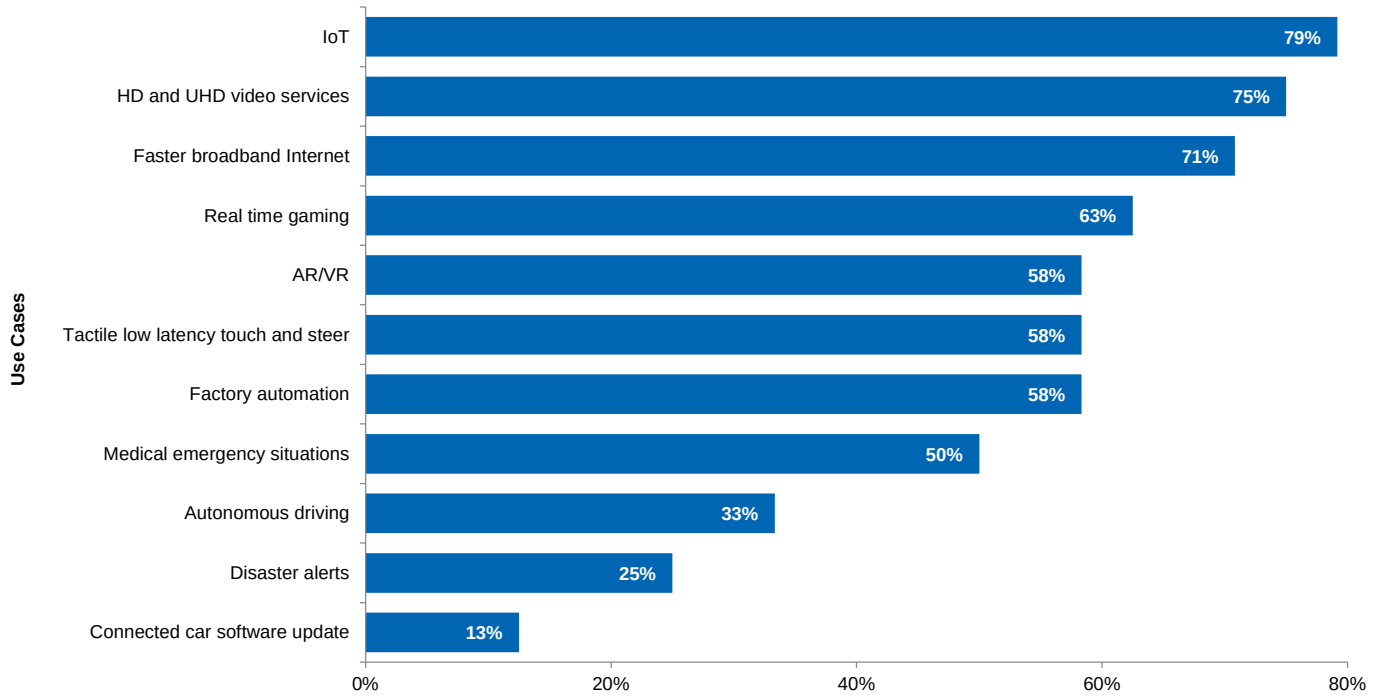
The position remained unchanged for HD and UHD video services since last year, but they had a better rating this year with 75%, up from 55%. We have seen a lot of HD and UHD video over 5G demos over the past 6 months, particularly at the Mobile World Congress in Barcelona, which may explain the increased rating.

Though faster broadband Internet was the number-1 use case with 82% last year, its rating improved to 71% but its rank fell to 3rd. In 5G jargon, this is called enhanced broadband (eBB) and is seen as a top use case that provides a better user experience over faster networks.

Real-time gaming has also improved its rating to 63% from 55% last year and stays in 4th place, followed by augmented and virtual reality (AR/VR), which makes a spectacular jump from last to 5th position. Like for HD and UHD videos, there has been a lot of buzz around AR/VR over the past 6 months accompanied by impressive demos, but apparently content is lacking and commercial gear is too expensive for the market to really take off. Consequently, this is not a network problem so far, and all demos showed a proper functioning over our existing 4G network.

Finally, the rest of the use cases have the same ranking as last year with better ratings.

Exhibit 9 5G Upgrade Drivers: Use Cases
n=24



Source: IHS

Methodology and Demographics

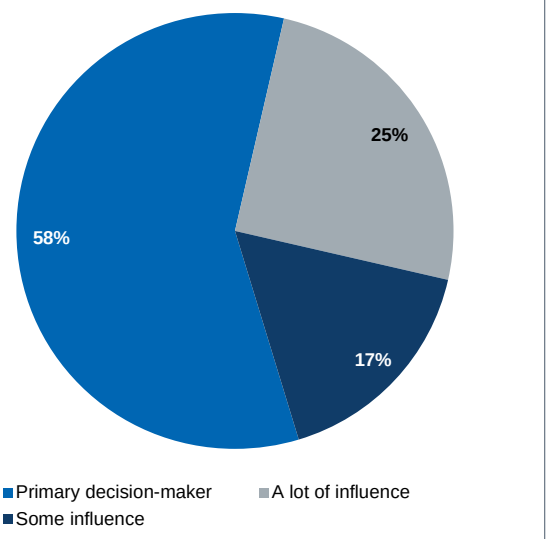
In June through August 2016, using online, telephone, and in-person survey methods, we interviewed 24 service providers from around the world who have deployed or trialed LTE or will do so by the end of 2017.

Respondents have purchase influence

To qualify, respondents must have detailed knowledge of the mobile network infrastructure and technologies, including LTE, operated by their companies and must influence planning and purchase decisions for mobile network equipment, including LTE.

As shown in the next chart, 83% of respondents are either the primary decision-maker or have a lot of influence. This is a key part of the screening process to ensure that we receive responses from people who are knowledgeable decision-makers that influence the buying process.

Exhibit 10 Respondents Have Purchase Influence
n=24

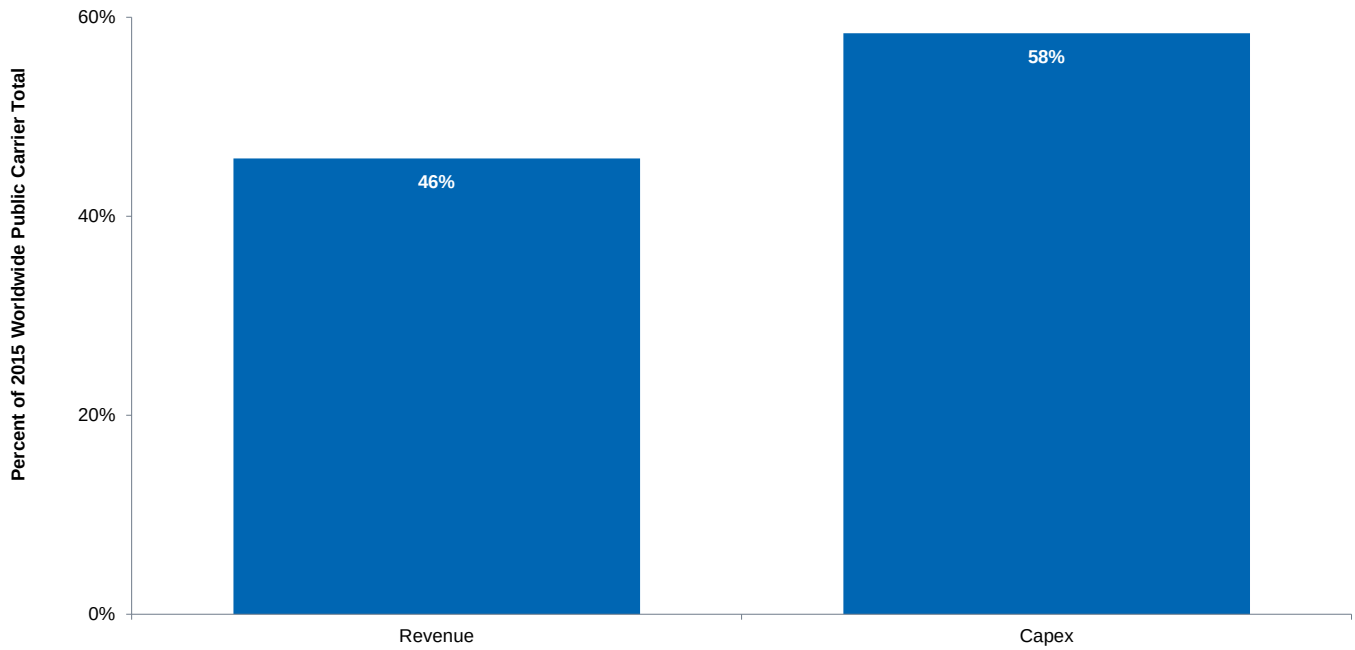


Source: IHS

Our sample accounts for almost half of worldwide telecom revenue and more than half of worldwide telecom capex

This is significant and reflects the fact that we have captured a significant number of the world's largest service providers as ranked by revenue; many of them are in the top 10 service providers ranked by revenue. All together, they have almost 2.3B mobile subscribers, or 39% of the 6B mobile subscribers worldwide. Some of the companies represented in our sample are major groups with a presence in several countries.

Exhibit 11 Respondents Represent a Significant Portion of 2015 Worldwide Capex and Revenue
n=24, 24

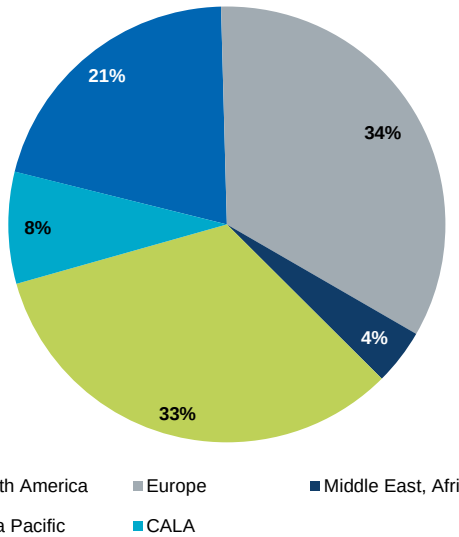


Source: IHS

Unlike last year, our sample is not skewed toward EMEA

This year, we worked on better balancing the number of respondents by region while adding 2 more service providers to the roster. Overall, the Americas remains challenging for 2 reasons: there are not many mobile operators left in North America and even less so in Latin America, which is dominated by 2 large groups controlling more than 75% of the total mobile subscriber base.

Exhibit 12 Respondent Geographic Distribution
n=24



Source: IHS

YoY Survey Sample Comparison

50% of last year's respondents participated again this year, which is useful to consider when comparing data year over year. This year, we managed to slightly increase the number of respondents in North America, Asia Pacific, and CALA.

In addition, we mainly focused on large mobile operators strongly active in LTE-Advanced and VoLTE so that we could find better insights on those cutting-edge technologies.

Exhibit 13 Survey Sample, 2015 vs 2016

	2015 Survey	2016 Survey
Number of respondents	22	24
EMEA operators (% of respondents)	55%	38%
North America operators (% of respondents)	14%	21%
Asia Pacific operators (% of respondents)	27%	33%
CALA operators (% of respondents)	5%	8%

Source: IHS

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