Test Considerations for 5G

With the implementation of 5G over the next decade, both network equipment manufacturers (NEMs) and operators will face new challenges in testing their hardware, software, and end-to-end deployments. 5G technology, as currently envisioned, is quite different from 4G/Long Term Evolution (LTE) and will bring together some of the most challenging aspects of existing approaches. It will also introduce new challenges, described further here. As these challenges are overcome, the technology will usher in a host of potentially game-changing applications, depicted in blue in the figure below.

![Diagram showing potential game-changing applications enabled by coming 5G standards](image)

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**Figure 1** Potential game-changing applications enabled by coming 5G standards
Ixia is leading the way in delivering a first-to-market post 4G/LTE test architecture, called Advanced-Pro (Pre-5G). The hardware and software available today paves the path for the introduction of a true next-generation 5G test architecture that will help both operators and their equipment suppliers validate their configurations and underlying hardware and software, ensuring that they perform as expected.

**USE CASES FOR THE EVOLUTION OF TEST ARCHITECTURE**

Test architecture must evolve and adapt for 5G, effectively handling the three major use cases identified by the Third-Generation Partnership Project (3GPP). As background, the 3GPP is responsible for the technology evolution and works with the better-known GSM Association (GSMA), which represents the operators.

The three use cases are:

1. **Enhanced Mobile Broadband (eMBB).** This is an evolution of today’s 4G use case—streaming video, conferencing, and basic broadband connectivity—but with greater emphasis on uplink capacity. The downlink speeds will increase by an order of magnitude—10-20 Gbps per cell. 5G is also expected to replace fixed broadband connections in some cases. In fact, this use case will be the very first 5G deployment.

2. **Massive Machine Type Communications (mMTC).** This is an evolution of today’s IoT, but with orders of magnitude more additional endpoints. Solutions here focus on power efficiency and the ability to support extreme node density.

3. **Ultra-Reliable and Low Latency Communications (URLLC).** This is an entirely new set of applications made possible by low latency, high reliability, and in many cases, high bandwidth. They include virtual and augmented reality, remote real-time surgery (tactile internet), and autonomous vehicles. Connections must be secure and maintained at high speed.

Figure 2
International Mobile Telecommunications system requirements for the year 2020 (IMT-2020) mapped to 5G use cases

Luckily, not all of these use cases will appear at once, enabling the test architectures supplied to both NEMs and the operators to evolve over the 5G adoption timeframe.
3GPP ROADMAP

Looking at requirements, as described by the GSMA and adopted by the carriers, a basic tenet is that the technology will support 10-20 Gbps per cell with potentially 1 Gbps real (or perceived) downstream bandwidth to a user at less than 1 ms latency. This is an important distinction, since LTE was advertised as having high peak data rates, but the end user rarely, if ever, experienced them. Even fixed broadband networks must rise to the challenge of providing these rates and, thus, the required new architectures. This implies a network that is:

- Capable of supporting much greater data volumes
- Secure
- Fluid and flexible to support potentially trillions of devices (i.e., IoT)
- Adaptable to the application versus the other way around

An effective way to understand these requirements and the required network evolution is to map them to the phases of the 3GPP’s International Mobile Telecommunication system requirements for the year 2020 (IMT-2020). There are two phases to this. Phase I is focused on early availability and an evolution of existing LTE deployments and is aligned to 3GPP Release 15. It is defined as a non-stand-alone version (NSA), where 5G is anchored by a 4G LTE core network. This is expected to be standardized by 3GPP by end of 2017. The stand-alone version, also referred to as Phase 2, will be defined by 2019 if not sooner, with commercial deployments in the 2020 timeframe and beyond. It aligns to 3GPP Release 16.

How does one build a test architecture for this technology shift? One way is to look at the use case instead of the technology itself. For example, model the top 10 user scenarios, and determine the architecture required. This is important, since developing these capabilities to validate an Internet of Things (IoT) sensor, an autonomous vehicle, streaming of a high-definition (HD) movie, or a remote surgery are all very different. Endpoints appear and disappear at high rates, cell-site complexity grows with network sharing, and even the radios deployed and the bandwidth required for the visibility traffic itself will require new ways of thinking.
IMPLICATIONS OF 5G

The GSMA has listed a set of goals for 5G, all of which will not be attainable at once due to technology or, more realistically, commercial limitations. As mentioned above, the “line in the sand” is 1G sustained bandwidth and 1 ms latency. But this is only the beginning.

Aspirational goals include a perception of 99.999% availability and 100% coverage, as well as a 10x reduction in network energy usage and a 10-year battery life for low-power devices. All this at 1000x the effective bandwidth per unit area or, in other words, base stations that can support 1000x the capacity of current base stations. This comes at a cost of requiring much higher frequencies. These higher frequencies imply much higher density cell deployment (i.e., microcells), which then require a much higher density backhaul infrastructure. The user perception of availability is also impacted by roaming, made more difficult by the above network requirements. However, looking at the three use cases, roaming may really only be applicable to enhanced mobile broadband where users may also fall back to 4G/LTE.

One of the most difficult challenges of 5G deployments will be latency. Both bandwidth and availability have known engineering solutions, including the deployment of additional hardware or the allocation of additional frequencies. But we cannot change the speed of light, and some of the use cases for 5G, such as virtual reality (VR) and distributed control, require real-time response. Currently, LTE latency may be in the range of 40 ms or more, impacting application performance and user perception.

For 5G, reducing latency by an order of magnitude implies that some of the servers and intelligence will need to be within proximity of the cell site, and the driving factor will be the cost of delivering the service versus the net gain. Some of the work involving edge data centers and fiber buildouts in support of the distributed cloud by the cellular providers align to these requirements. There may be different approaches to the edge and “near edge,” depending on who is building the network and providing the content.
A number of other considerations come into play with 5G deployments, issues that were either not applicable to 4G/LTE or that were on the periphery. For radios, 5G will operate at much higher frequencies than earlier technologies, with current investigations up to 70 GHz (figure below). Technologies, including beamforming and higher-order multiple input, multiple output (MIMO), come into play, and any deployment will need to avoid interference with existing technologies, such as Wi-Fi and small cells. It is also possible that different services, based on different over-the-air requirements, may use different frequencies. The basis of this is defined as the 5G New Radio (5G NR), with first availability part of Release 15. Adding to test requirements is a newly defined “Non-Standalone” 5G NR planned for 2019. Any test hardware will need to support these new frequencies and test for interference.

The massive increase in the number of devices will only be served by a combination of greater over-the-air bandwidth, antenna designs that efficiently handle this bandwidth and subscriber density, and the addressing space available with Internet Protocol version 6 (IPv6).

More interesting and challenging is the concept of network slicing, described as “dynamically and automatically expanding and contracting network capacity to support a given use case, the adaptation and coordination of network segments to deliver a certain flow to a specific is endpoint at a given specific time.”
In either a single operator or a shared deployment, any test architecture will need to properly characterize how the network is partitioned, the logical slices, and the services offered over each with regards to latency, throughput, and availability. Given the role software and services play in this architecture, we can use the term “Software-Defined Test” (SD-Test) to reflect this software-centric test architecture. Here, it must match the 5G architecture itself, an evolved software-defined networking (SDN)/network function virtualization (NFV) infrastructure enabling “stateless” network functions that offer total flexibility based on a micro-services architecture.

**ENHANCED MOBILE BROADBAND**

In eMBB, the user experience is based on the perceived data rate, both upstream and downstream. This implies sufficient capacity, which is also a function of spectrum and network energy efficiency. Testing must scale to expected 100x network capacities and 100x effective data rates; model radio performance in some of the new frequency bands, such as 6 Ghz; model small cell access/macro cells; and simulate the different applications that will include HD video and video conferencing.

Ixia’s IxLoad® LTE XAir2 permits service providers, equipment and chipset makers, and enterprises developing products and services to test LTE Advanced Pro (LTE-A Pro) circuits and network equipment and even emulate entire networks in support of these test scenarios. This testing will provide valuable experience in the development of 5G test gear. Some of the basic test capabilities include:

- **Carrier Aggregation.** LTE-A Pro supports aggregating up to 32 carriers to form larger bandwidth blocks. Getting more carriers will require tapping into the unlicensed bands.

- **Antennas.** LTE-A Pro supports single-input and single-output (SISO) and MIMO configurations that support greater LTE and Wi-Fi throughput. 5G will expand on this with “massive” MIMO density.

- **Symbol Density.** LTE-A Pro pushes this to 256 quadrature amplitude modulation (QAM), also a way to increase data throughput by encoding more bits per symbol. With 5G, we may go up to 1024 QAM and beyond.

- **Spectrum.** LTE-A Pro pushes deployments into the 5G unlicensed spectrum space, in addition to introducing frequencies down to 400 MHz. Experience across a wider spectrum will help with the testing of radios operating in the mmWave/small cell space.

Coupled with PerfectStorm™, XAir2 helps operators and NEMs prepare for 5G by supporting many facets of pre-5G support for LTE in unlicensed spectrum (LTE-U)/Licensed Assisted Access (LAA), Narrow Band IoT (NB-IoT), multiple carrier aggregation on downlink and uplink, 4x4 MIMO, 256 QAM, dual connectivity, and more.
MASSIVE MACHINE TYPE COMMUNICATIONS
With the advent of mMTC, there will be a greater emphasis on connection density (up to 1000x that of current deployments), low power utilization (potentially 1% of current hardware), and deep coverage. High bandwidth and low latency are less of a consideration, and IPv6 support is a given. To a large extent, this use case is an extension of today’s 2G/3G IoT networks, and much of the development will take place in designing optimized, low-cost, low-energy, and extended-life sensors.

Ixia’s XAir2 with high session counts, versus bandwidth per session, offers operators the first step in supporting different types of IoT tests.

ULTRA-RELIABLE AND LOW LATENCY COMMUNICATIONS
This challenging use case enables applications such as VR and autonomous control. It will depend on not only the “New Radio” described above, but also a new stateless software-defined architecture that includes distributed content and applications and reflects an SD-Test approach.

Peak bandwidth requirements may not be that of Enhanced Mobile Broadband, but this is balanced by high-speed mobility at up to 500 km/h (think of high-speed rail), low latency to 1 ms, and high reliability with potential packet loss of only 1 in 100 million. This is a segment that also mandates the strongest security guarantees. As noted earlier, URLLC will be defined after eMBB.

Ixia is working to develop the test hardware and software to effectively model this use case, taking into account velocity, reliability, and latency. Also, this architecture must correctly model the software-defined network architecture, and by extension, SD-Test. The final air interface, while it is still to be determined, will be orthogonal frequency-division multiplexing (OFDM)-based and will support very large carrier bandwidths to support the eMBB test cases. In addition, low latency will also require several baseband components to be optimized and a very close-to-the-air interface. Finally, while IoT will start with LTE-A Pro, it will eventually require 5G to support the massive scale and diverse nature of the devices.
CONCLUSION

It is obvious that 5G is not going to have a monolithic, one-size-fits-all deployment, and any test architecture must reflect this. Based on the use cases, there are very different requirements with regard to bandwidth, density, latency, radio characteristics, energy use, and mobility. Given the phased deployment and target markets, 5G may, in fact, end up as a set of parallel deployments and service offerings, sharing some technologies but differing widely in others.

Currently released Ixia products are well positioned with LTE-A Pro, which constitutes the building blocks for 5G: IoT, virtualizing the different packet core components, running LTE on the unlicensed spectrum, and last but not the least, increasing speeds through a combination of carrier aggregation, MIMO, and higher-order QAMs. Ixia’s products also have a clear evolutionary path that will crystallize when true 5G-NR eventually arrives.

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