A SPIRENT REPORT

Cutting Through the Edge Computing Hype

5G MEC Latency Expectations vs. Reality

spirent™

What's Inside

Executive Summary

5G multi-access edge computing (MEC) services are moving quickly to the forefront as operators position themselves to support latency-sensitive enterprise use cases.

But today, a disconnect exists between what performance end user customers believe applications will require, and the performance levels network operators are actually preparing to deliver.

Spirent and STL Partners have teamed up to bridge this information divide with real-world edge network testing and more than 150 interviews with prospective edge customers. Our benchmarking analysis provides critical insights into MEC performance measurements that matter most, what can already be achieved via today's networks, and use cases with the greatest potential for near-term monetization.

KEY TAKEAWAYS:

- Edge application demand and supply sides are disconnected in terms of what latency will be required, when it will be required, and for which use cases.
- Enterprise users overwhelmingly prioritize latency consistency to support the edge applications they plan to deploy.
- The latency of the real-world MEC services we measured fluctuated significantly by time and across regions, and lacked symmetry between the uplink and downlink.
- The mean MEC latency we observed would support several of the edge use cases outlined in 3GPP R16; however, performance optimization will be required to support use cases that rely on consistent latency.
- Achieving support for a broader set of 3GPP R16 edge use cases will require additional MEC performance optimization to further lower uplink and downlink latency levels and improve consistency.
- Numerous factors beyond the choice of network architecture can impact latency, highlighting the need for rigorous acceptance testing and benchmarking during and after deployment.
- Continuous latency benchmarking can help prioritize and optimize network efficiency by identifying and isolating what is impacting latency inside and outside the network.

A SPIRENT REPORT

Cutting Through the Edge Computing Hype

One of the major goals of 5G has been to provide the network performance required to support next-gen capabilities across industries. This desire for near-real-time responsiveness has generated sustained interest and investment in MEC network architectures that push cloud computing capabilities to the edge of the network.

Visions of remote surgery, autonomous cars, and immersive gaming are driving market enthusiasm and innovation. By running applications and performing related processing tasks closer to the customer, network congestion is reduced, delivery paths are optimized for low latency, and applications perform better.

While a relatively basic concept, execution and exploration has been marred with complexity and confusion as network operators, application developers, and end users wade through a bevy of marketing buzz, endless trials, and big promises in search of answers to key questions:

- What latency rates are actually required to support near-term and long-term use cases?
- How consistent and deterministic does latency need to be?
- What is the actual demand from end users? How will the demand be monetized and assured?
- How will operators go to market based on the number of edge locations needed to serve demand?
- What latencies can be delivered by various MEC network architectures versus what is actually required?
- What latency-driven services can currently be delivered with existing infrastructure?

In Spirent's experience testing and assuring next-gen networks for operators around the world, we've repeatedly run into these questions from stakeholders.

3GPP latency requirements

Industry forces are also coalescing in search of answers. To guide industry network and service planning, the 3GPP standards group asked leaders across market sectors what latency levels they expect will be needed to support various service use cases, based on Release 16 standards.

Category	Use Case	Latency
AR/VR/Gaming	AR/VR motion-to-photon	7-15ms
	Collaborative gaming	<20ms
Industrial	Motion control	0.5-2ms
	Control-to-control communication	≤10ms
	Mobile robots:	
	• Precise cooperative robotic motion control	1ms
	• Machine control	≤10ms
	• Cooperative driving	10-50ms
	• Real-time video streaming	10ms
	• Video-operated remote control	10-100ms
	Discrete automation	10ms
	Process automation	50ms
	Mobile control panels (assembly robots; milling machines)	4-8ms
	Mobile control panels (mobile cranes, pumps)	<12ms
	AR monitoring	<10ms
Automotive	Wireless roadside backhaul (RSU <-> TCC)	10ms
	Sensor sharing	<20ms
	Platooning (highest degree of automation)	≤10ms
	Cooperative collision avoidance	≤10ms
	Cooperative lane change (highest degree of automation)	≤10ms
	Emergency trajectory alignment	≤3ms
	Remote driving information sharing	≤5ms
	Video sharing (highest degree of automation)	≤10ms
	Information sharing for automated driving	≤100ms
	HD digital map update	100ms
Transport & Logistics	Time-critical sensing	<30ms
	Remote drone operation	10-30ms
	Real-time control for discrete automation	≤1ms
Smart Cities	Smart grid (transmission)	<5ms
	Smart grid (distribution)	<50ms
	Time-critical sensing	<30ms

Table 1: 3GPP latency requirements by 5G use case (source: 3GPP 22.261, 22.104, 22.186).

As shown in Table 1, anticipated requirements range from boundary-pushing levels of performance to latencies that can already be achieved by some existing networks.

For instance, the **gaming industry**, which is likely to lead initial adoption of low-latency mobile use cases, plans to soon provide immersive, multi-player user experiences via an array of AR/VR headsets, haptic and voice controls, and HDR-supported scene renderings. They expect these experiences to require 7-15ms continuous latency for the motion-to-photon latency between the physical movement of a user's head and the updated picture in the VR headset.

Industrial use case latency requirements will range from 1ms for precise cooperative robotic motion control to 50ms for process automation. In **transport and logistics**, remote drone operations are expected to require 10-30ms, with real-time control for discrete automation needing <1ms.

What will be challenging with the 3GPP survey is the latency **consistency** required by these use cases. This is important to understand, as fluctuations in latency will be a nonstarter for many of 5G's most promising use cases.

This report combines our real-world uplink and downlink latency benchmarking test data with insights from a collaboration with STL Partners on actual enterprise user requirements and operator strategies for meeting these needs. Our goal is to begin arriving at answers that can help illuminate the path ahead.

Read on to understand how well the demand and supply sides of the edge equation are synchronized on latency requirements, and our findings on what will be required in the near term to deliver revenue-generating edge services to initial market customers.

Market Expectations for Low-Latency Services

In our experience testing edge networks, it was not uncommon to find that just a few edge clouds across a vast region were sufficient to drive down latencies.

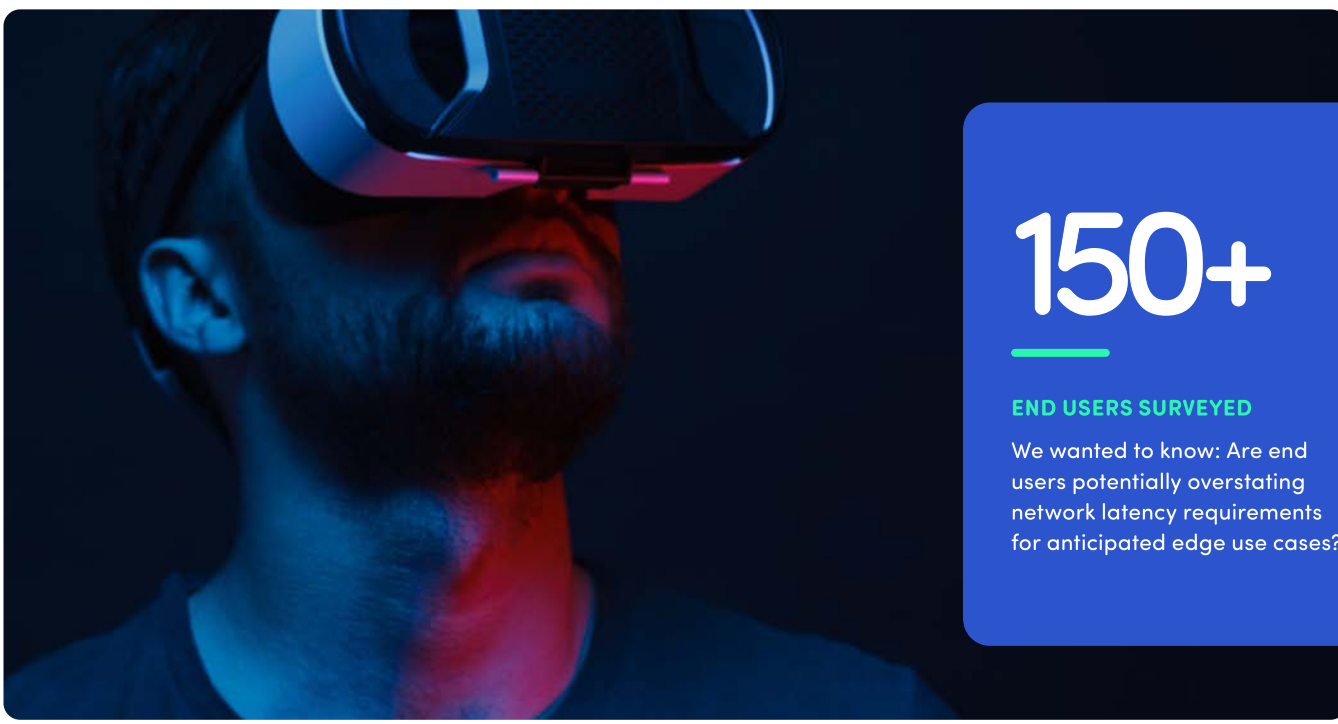
While operators are anticipating more dense edge coverage, these investments are potentially unnecessary in the short to medium term given the limited early revenue-generating use cases they'll actually be serving.

This raises the question: Are end users potentially overstating network latency requirements for anticipated edge use cases?

To help bridge this disconnect, we collaborated with STL Partners to survey more than 150 end users with the goal of better understanding planned use cases and expectations around required latencies. STL Partners also conducted interviews with operators prepping edge strategies.

Outside of some trials and proofs of concept, it is evident operators and prospective end users tend to not be in lock step around edge computing needs. Not surprisingly, the research confirms a disparity between what end users believe they need and what operators are preparing to deliver.

The results provide insights into priority adjustments operators can make to better meet and monetize the needs of the marketplace in the near and longer term.



150+

END USERS SURVEYED

We wanted to know: Are end users potentially overstating network latency requirements for anticipated edge use cases?

Demand-side latency needs

STL interviewed 150 enterprises in North America, primarily in the manufacturing and construction sectors, given these businesses are among those with the most advanced thinking on 5G requirements. Low latency targets only one part of the equation.

As shown in Figure 1, enterprises are emphasizing **consistency** of latency as the most important SLA. This is because many of the types of services and applications set for launch are extremely sensitive to latency fluctuations and have specific tolerances that must be maintained.

As the chart shows, 56% of respondents would prefer and be willing to pay for an SLA with guaranteed latency that is never outside a predefined window, compared to an average or percentage of time within the window. In other words, their systems are critical and performance within the specification window must have deterministic, consistent latency.

Depending on the application, enterprises specify a variety of latency windows. As noted in Figure 2, the vast majority (66%) needed latency of 50ms or less. The window needed most, at 37%, was 20-50ms of latency. Just over 25% require between 10 and 20ms and just 3% less than 10ms. Those requirements are pushing the current limitations of the network and putting stress on the network's ability to consistently meet them.

A cloud gaming platform provider said, "While a service like cloud gaming needs to have great bandwidth, more important is to have low latency and this latency is stable and consistent — the brain can adapt to some latency but can't adapt to jitter."

While latency consistency was a clear demand-side requirement, our upcoming benchmarking results in the Latency consistency by region section below reveal that initial MEC offerings will require additional optimization to meet consistency expectations.

What type of SLA would you prefer around your network's latency and reliability?

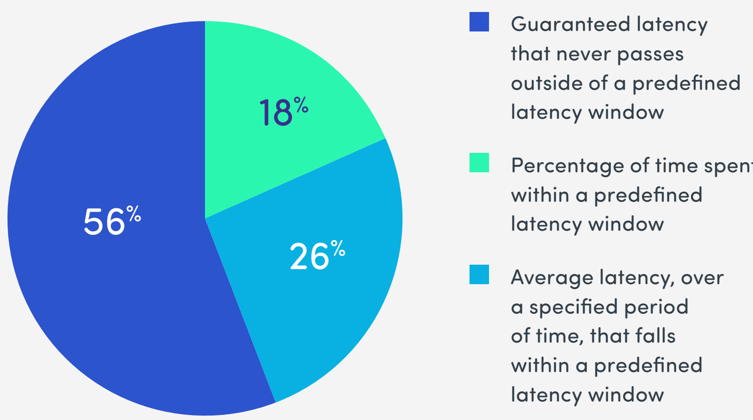


Figure 1: Most customers want a high-performing solution, and some want to guarantee this performance through SLAs (source: STL Partners survey 2021).

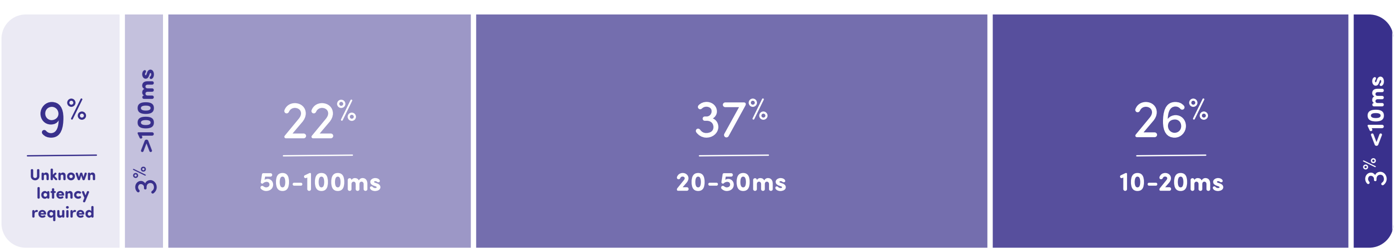


Figure 2: The specific latency corridors required are likely industry, use case, and customer specific (source: STL Partners survey 2021).

n = 151

Anticipated benefits of edge computing

The surveyed enterprises were asked what the primary benefit of edge computing could be for their organization should they adopt it (see Figure 3). The top anticipated benefit for using edge computing among 24% of respondents was improved service reliability via reliable latency and less variance (jitter). 14% viewed reduced costs as a benefit (via reduction in backhaul requirements).

Supply side feedback from operators and suppliers

STL also performed one-on-one interviews with about a dozen supply-side stakeholders, primarily Tier 1 mobile operators, to understand what enterprises are requiring of their networks.

Several participants echoed the need for guaranteed latency. From a global Tier 1 operator's perspective, "Customers are looking more to guaranteed latency — if the network is full, they still want the network they need."

Another Tier 1 operator highlighted the fact that their end-to-end network provides 15ms latency, but that the applications themselves cause 2 seconds latency. This spotlights the importance of measuring latency from end-to-end.

Two operators have seen a willingness among end users to pay a premium for low-latency SLAs.

Others expect a boom in ultra-low-latency use cases in the near term, driven by healthcare and industry 4.0, while recognizing they can't currently meet those needs.

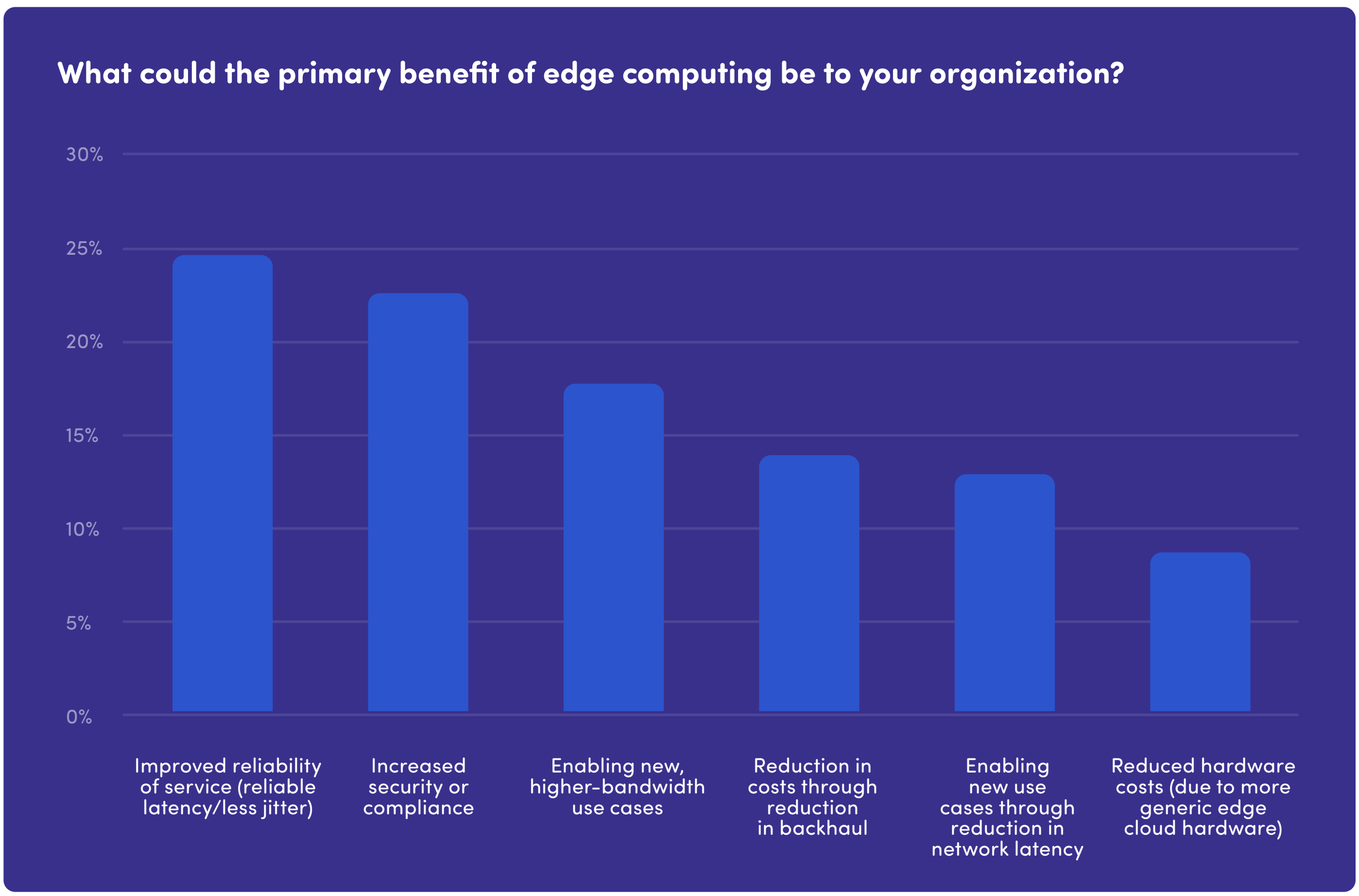


Figure 3: The main requirement customers have is around more reliable latency and less jitter (source: STL Partners survey 2021).

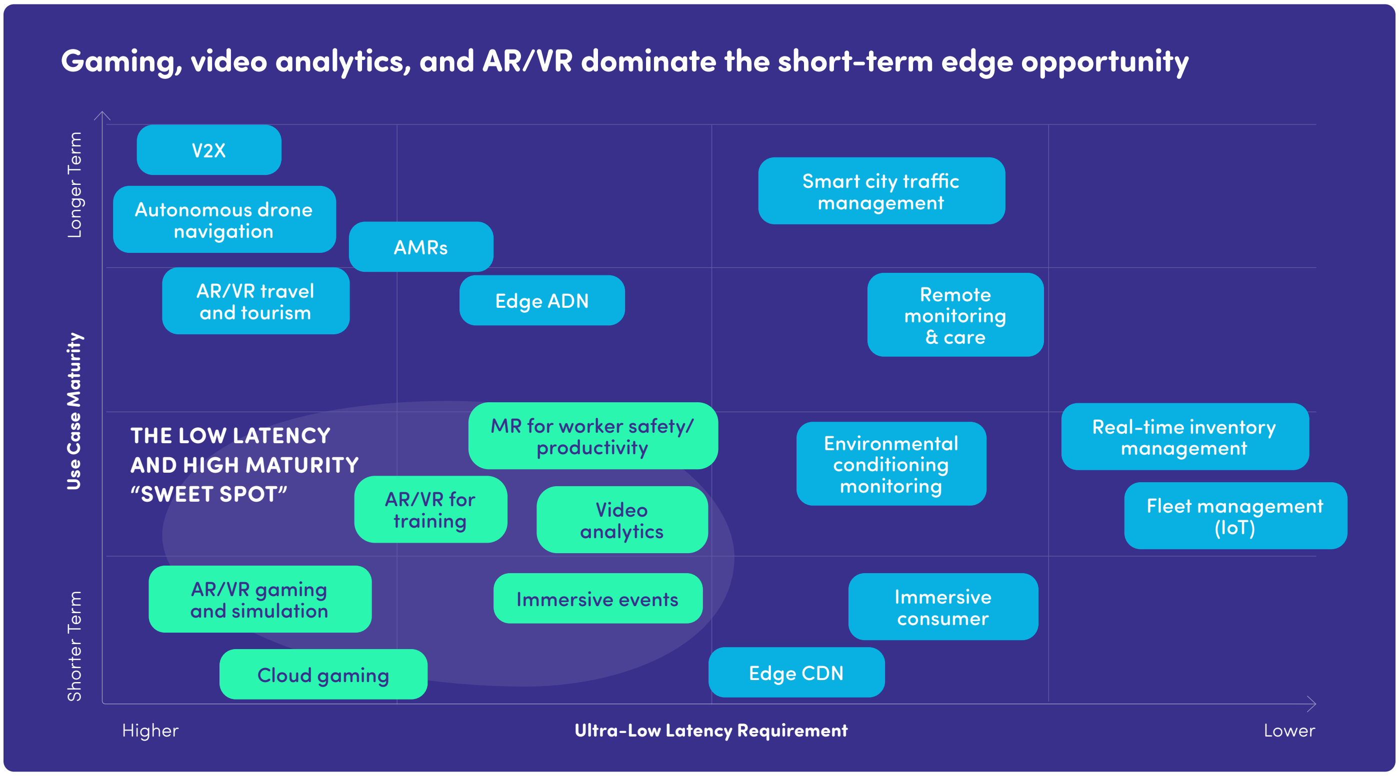


Figure 4: Low-latency use cases by maturity and relative latency levels (source: STL Partners survey 2021).

Mapping supply and demand by use case

STL's research identified a wide variety of low-latency services that supply and demand sides are exploring and evaluating. The maturity of those use cases was mapped against the level of latency needed to implement them, as shown in Figure 4 above. The maturity level indicates whether application categories are expected to be up for adoption or market-ready in the short term or longer term.

Some use cases are viewed as long term because they are dependent on 3GPP standards Releases 17 or 18. Others will require a broader ecosystem and development lifecycles to be in place before they can be enabled, such as chipset and device manufacturer alignment.

Gaming, video analytics, and AR/VR dominate the short-term edge opportunity. They are near-term opportunities that have a strong requirement for low latency, and will continue to evolve rapidly with unique requirements, so are out of sync with current reality — at least until consistently low latency can be provided through 5G edge solutions.

The cloud gaming use case is directly impacted by latency, latency fluctuations, and symmetrical bandwidth. Once the edge can provide those capabilities, video gaming will use them.

Assessing supply- and demand-side alignment

The STL research confirms that many use cases do not require ultra-low latency and can be delivered now. Others can be delivered with proposed MEC architectures that deliver ultra-low latency.

With these insights, operators can more accurately place anticipated use cases onto a value matrix of revenue possibilities to determine viable opportunities.

However, in some cases there must be a reality check on what applications need and what is possible in the network and application. A technical trial or PoC would inform a conversation on what latency and jitter are actually needed and what is feasible.

Benchmarking Real-World MEC Performance

There are several 5G network architectures under consideration for achieving low latency.

- **Co-locating MEC clouds at network edge peering points located in major cities**. This is expected to drive latencies down to around 20-35ms.
- **Bringing MEC edge clouds into a RAN/transport aggregation point such as a central office**. This can potentially bring latencies down to less than 10-15ms.
- **Establishing a private MEC on the customer's premises that includes radio and core network functionality**. The resulting latency could be as low as 5-10ms.

As shown in Figure 5, the most common mobile network architectures deployed today provide connectivity from a mobile device through the 5G network to the public cloud via the Internet. Some incorporate MEC architectures, often in collaboration with a public cloud provider, to bring workload processing for certain use cases closer to end users.

TODAY

- Public cloud / Internet outside network
- Latency typically: 20-75ms

OPTION 1

- Edge cloud at peering points (major cities)
- Latency potential: 20-35ms

OPTION 2

- Edge cloud at RAN/Transport aggregation points (central offices)
- Latency potential: <10-15ms

OPTION 3 (NOT SHOWN)

- Edge cloud on customer prem (private MEC)
- Latency potential: <5-10ms

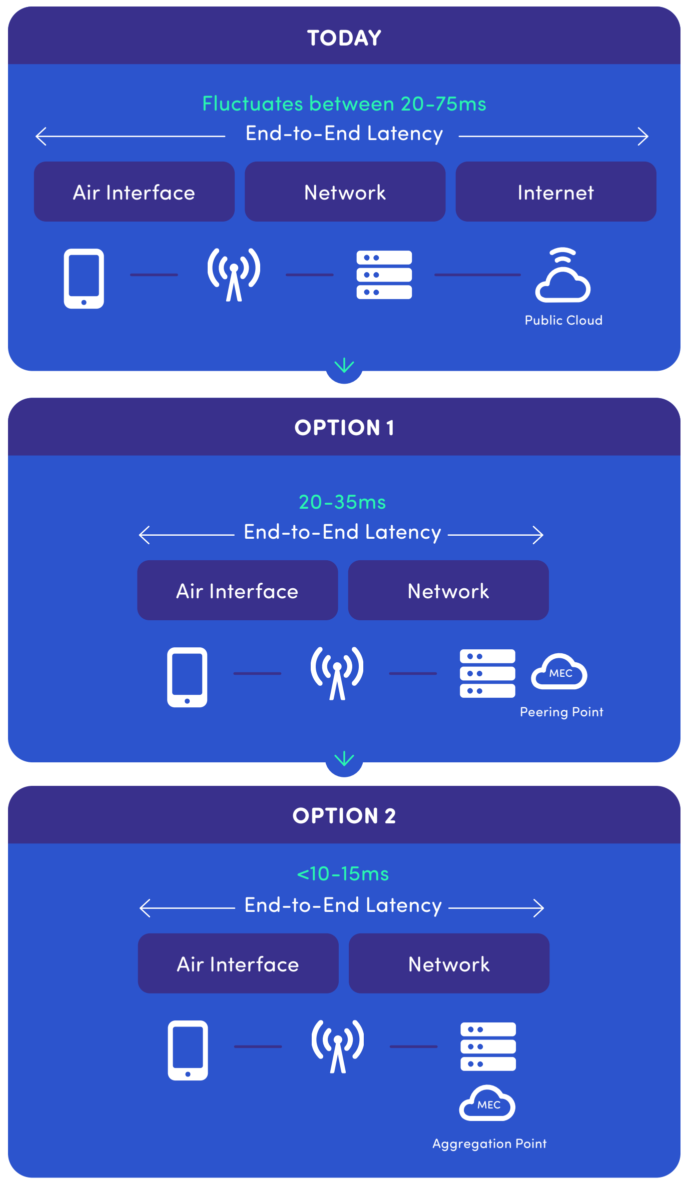


Figure 5: Mobile network architectures and target latency levels (source: Spirent analysis of public sources).

Location	Latency	AWS	Microsoft Azure	Google Cloud
Country/ Regions (Public Cloud)		Regions	Regions	Regions
City (Public MEC)		Local Zones	Availability Zones	Zones
CSP Network/ City (Hybrid MEC)		Wavelength	Edge Zones	Anthos for Telecom
On-Premises (Private MEC)		Outposts	Private MEC	Anthos for Telecom

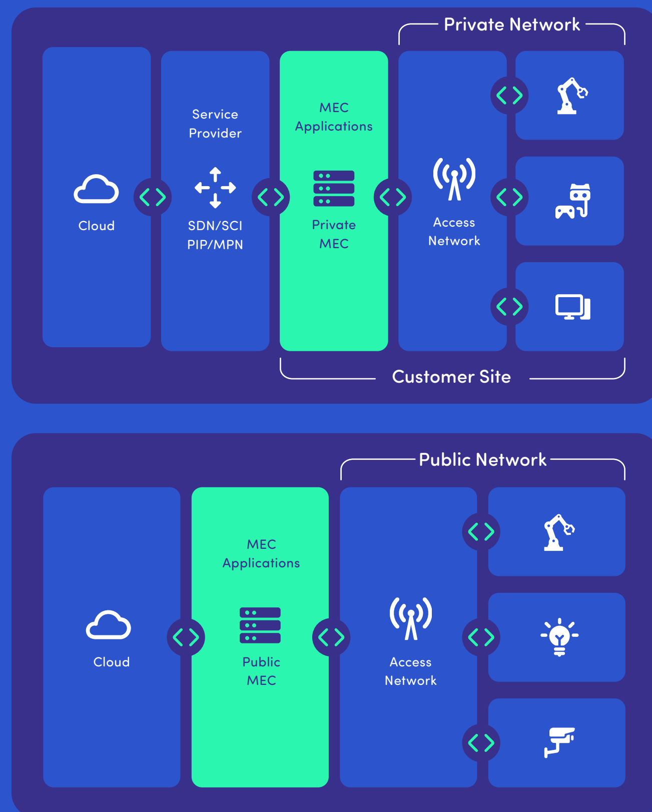


Figure 6: How cloud SPs fit within the network architecture (source: Spirent).

Many operators are partnering with public cloud providers like Amazon AWS, Microsoft Azure, or Google Cloud to implement edge clouds. Public cloud can provide a single location for nationwide public cloud access; public or hybrid MECs in cities; or private MECs on premises (see Figure 6). The potential for lower latency depends on how close the access point is to the end user.

But how does the performance of these architectures measure up in live networks?

To answer that question and measure the baseline latencies found in networks today, Spirent conducted a global benchmarking study in Seattle, Chicago, New York City and Tokyo. We performed mobility tests to publicly available MEC zones offered by a single hyperscaler and to a public cloud endpoint location.

Spirent's test methodology begins with testing real-world devices. UDP, HTTP/TCP, and ping tests are run at varying data rates to match an edge application's data footprint to media servers installed at edge zones. Mobility and stationary scenarios and testing in a mix of 5G and 4G RAN environments provide indications of performance in a range of real-world situations. We tested downlink UDP data rates of 2, 10, and 25 Mbps and uplink UDP data rates of 1, 2, and 5 Mbps.

Simultaneous OTA logging of RAN data is used to characterize the MEC latency performance and provide actionable information for improvement. We also account for the reality of certain applications benefiting from the placement of video and/or simulated cloud gaming servers at the edge to provide quantified QoE metrics.

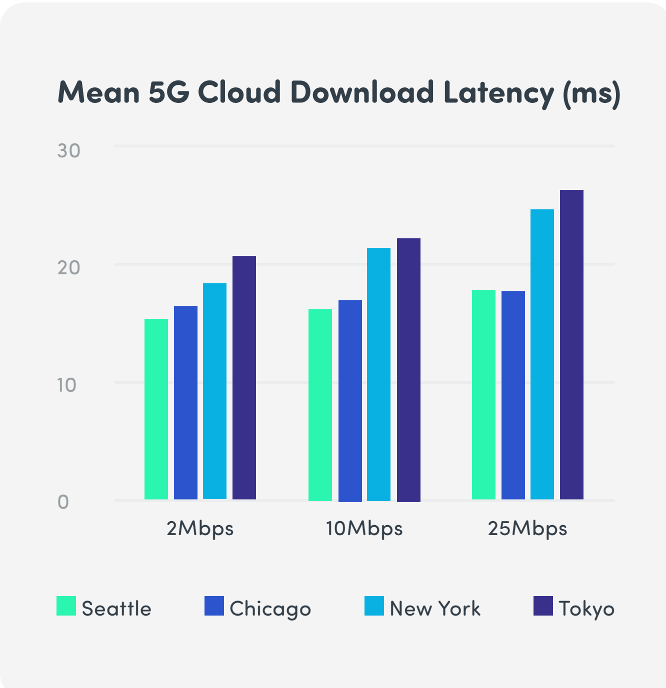


Figure 7

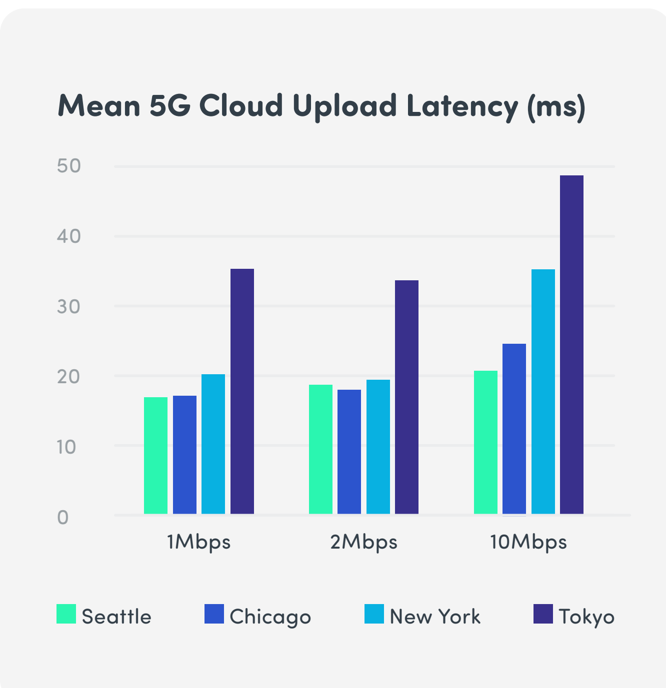


Figure 8

Public cloud latency

Based on our benchmarking tests of public cloud access, the mean end-to-end latencies range from 16 to 27ms for downloads and a much wider range of 17 to 49ms for uploads. These latencies exceed many of the use case requirements in the 3GPP study.

The lack of download/upload symmetry identified in the study is also an issue for some use cases, such as gaming.

As can be seen in Figures 7 and 8, mean latencies vary considerably by city, in some cases by a factor of two.

Figures 9 and 10 show that latency also varied significantly within each city. Approximately two thirds of latency values fell within one standard deviation of the mean as indicated by the lines on top of the bars for each chart.

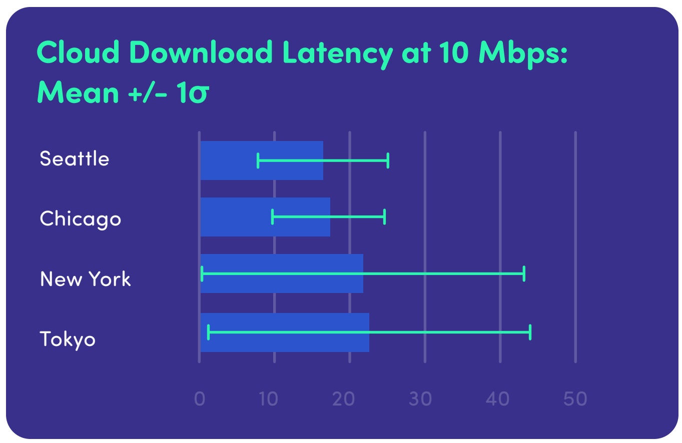


Figure 9

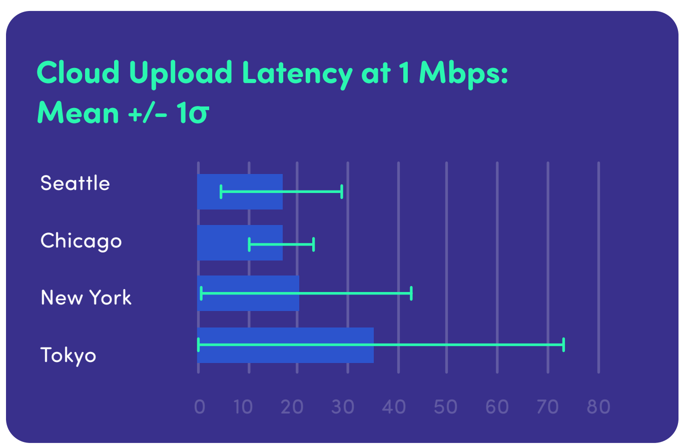


Figure 10

MEC latency and MEC vs. public cloud latency

Spirent's real-world testing results reveal lower average MEC latencies (vs. public cloud) for both uplinks and downlinks in all markets tested (see Figures 11-14). However, maintaining consistent low-latency performance proved challenging.

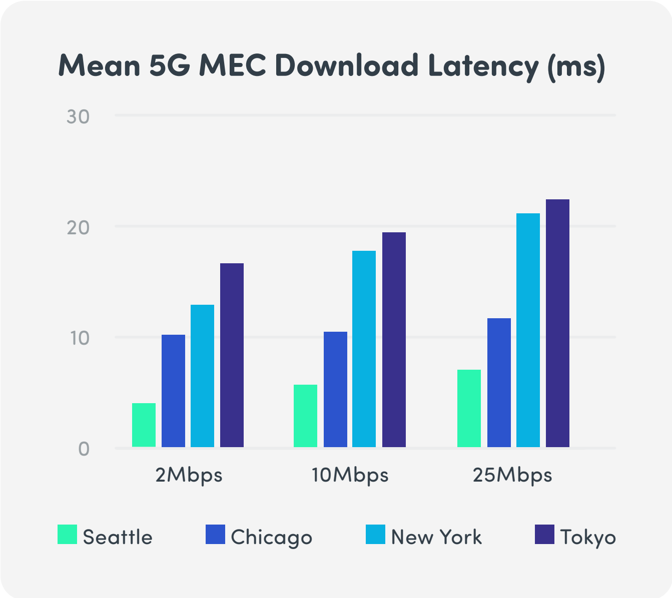


Figure 11

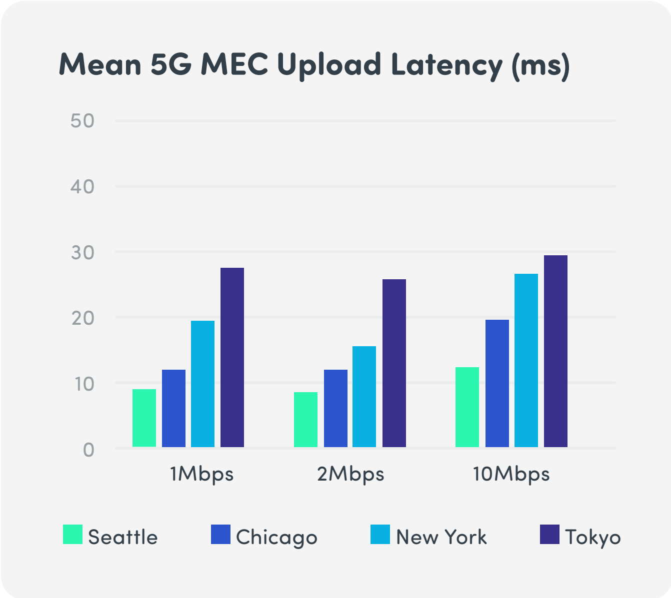


Figure 12

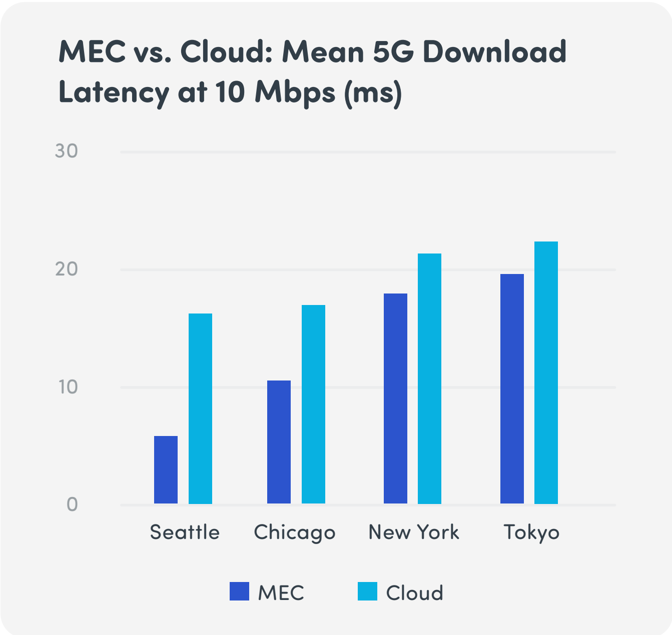


Figure 13

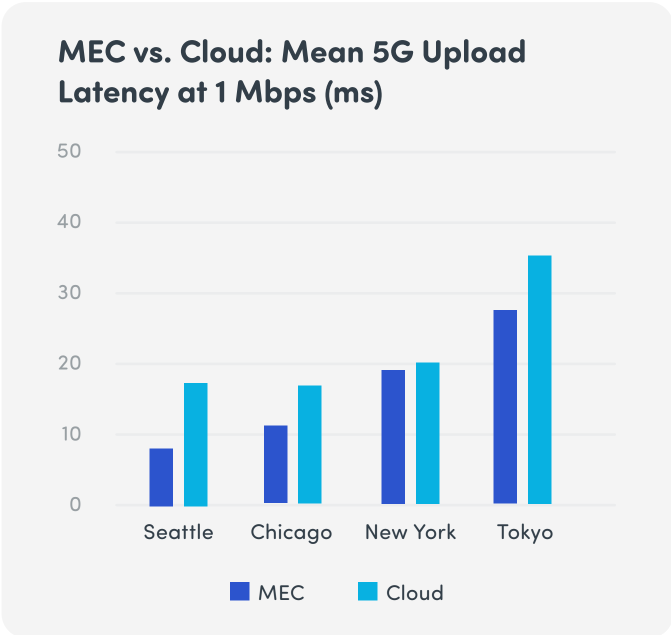


Figure 14

MEC latency consistency by region

The benchmarking results reveal a wide variation in latency, not only between cloud and MEC implementations, but also between different markets within the same region. Note the considerable variations measured for Seattle, Chicago, New York, and Tokyo, as shown in Figures 15 and 16.

These performance variations have particular implications for operators, enterprises, and application developers aiming to provide a consistent experience across regions.

We also analyzed how variability is impacted as data rates increase by calculating the coefficient of variation (CV) which is the ratio of the latency standard deviation to the mean expressed as a percentage. The downlink MEC latency CV remained relatively consistent in New York and Chicago but increased significantly in Tokyo and Seattle. The uplink MEC latency CV typically fell between 50% and 170% with the exception of New York, which showed a CV of over 300% at 10 Mbps.

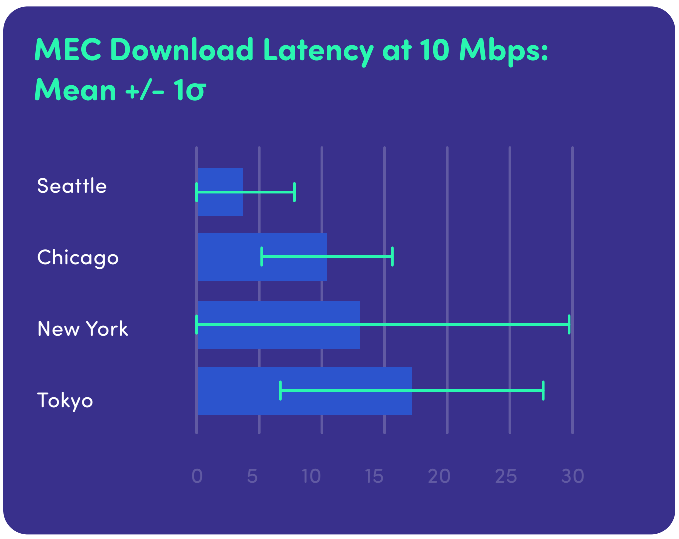


Figure 15

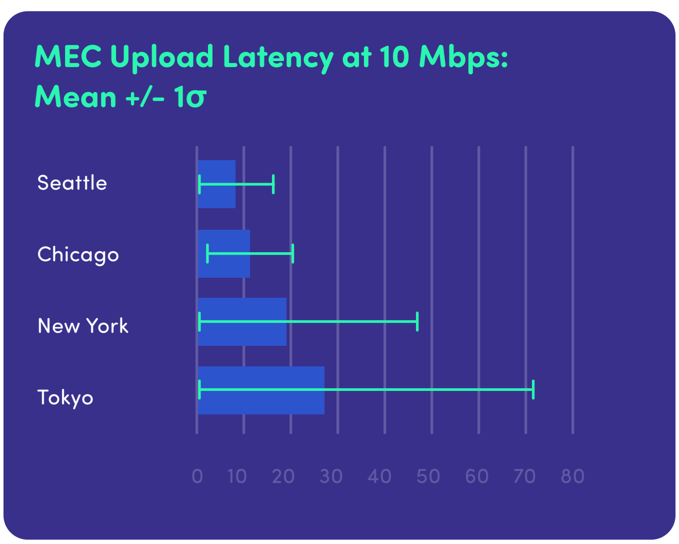


Figure 16

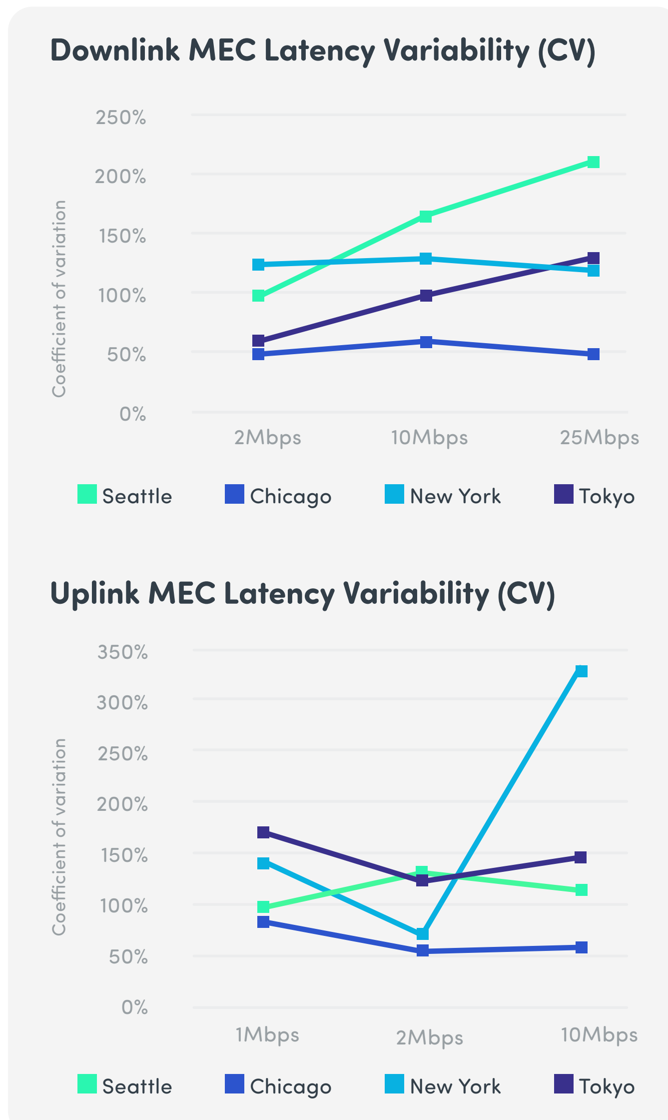


Figure 17 and 18

Drilling into the PDF distributions (as shown in Figures 19-26) sheds additional light on the variability of latency in each region. Downlink latencies were most consistent in Seattle, Chicago, and New York. Uplink latencies show the most consistency in Tokyo. In cases where both MEC and cloud latency reveal similar inconsistency (New York uplink and Tokyo downlink), one might conclude this is due to the impact of RAN or core performance outweighing endpoint placement.

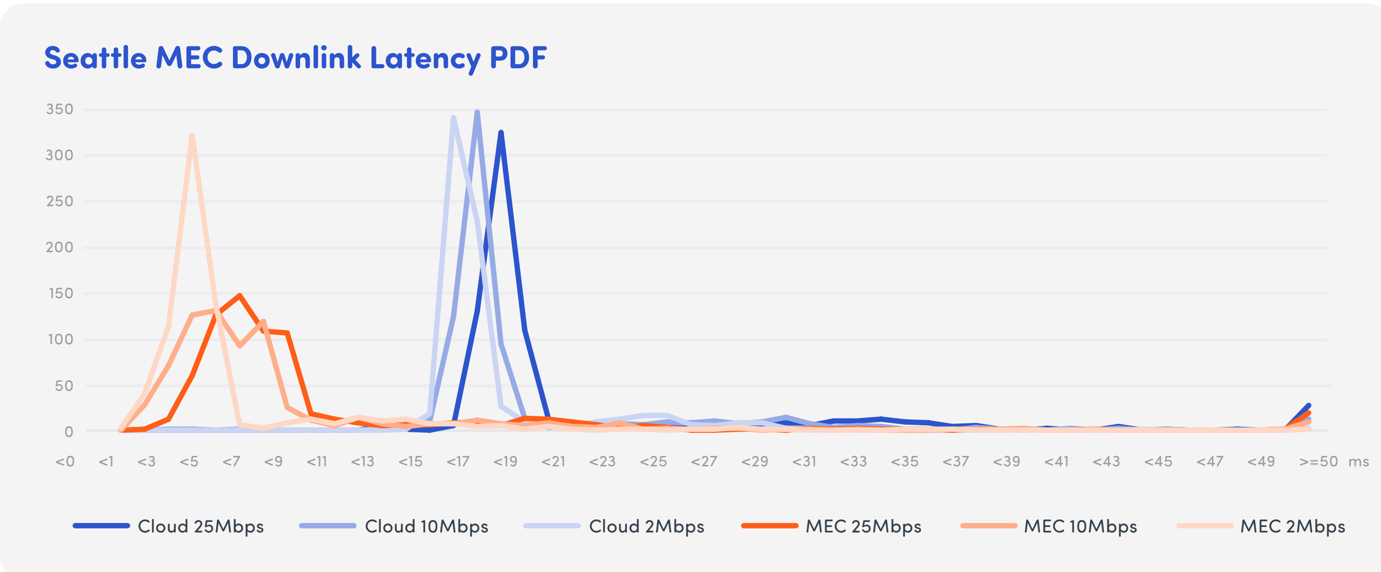


Figure 19

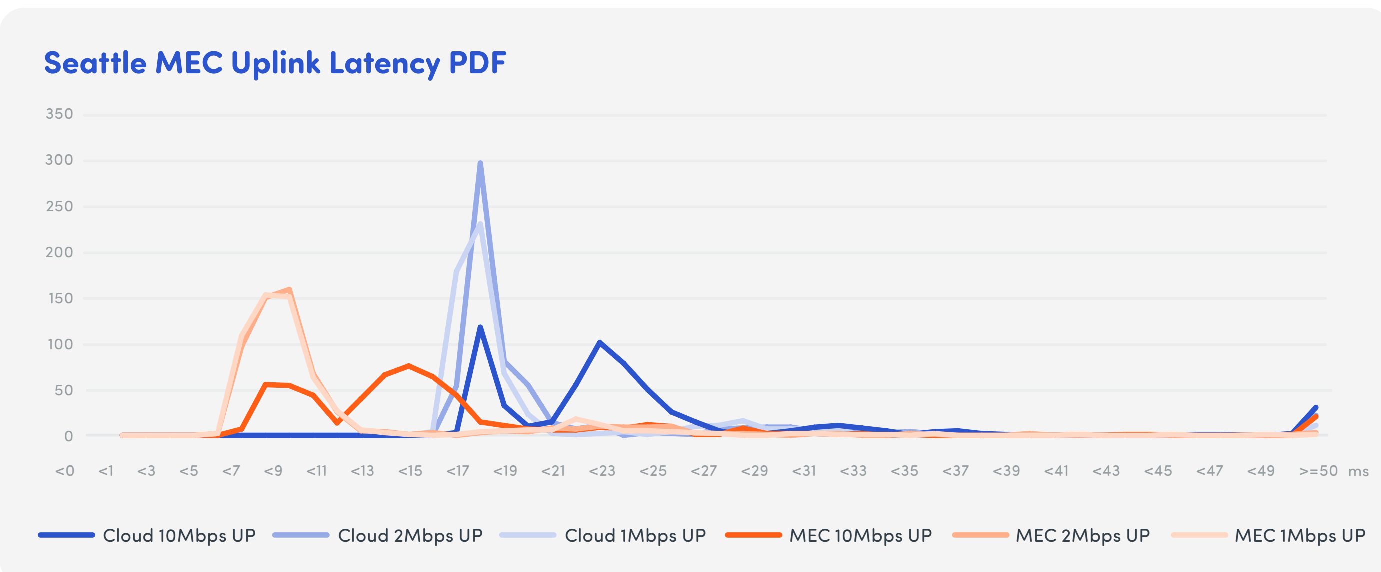


Figure 20

Chicago MEC Downlink Latency PDF

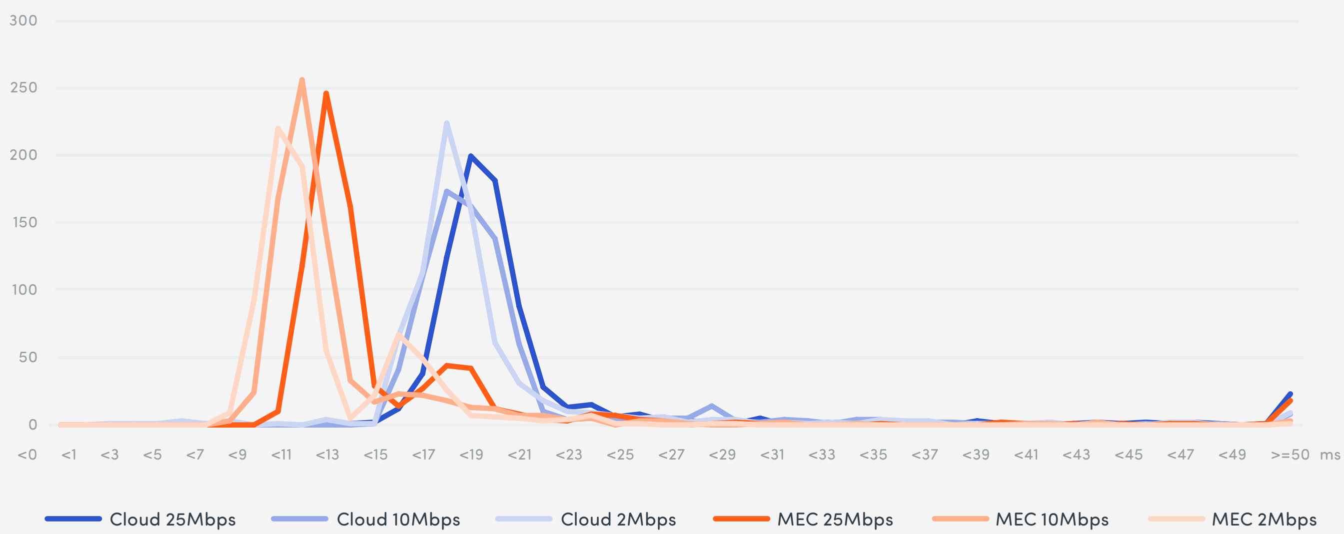


Figure 21

Chicago MEC Uplink Latency PDF

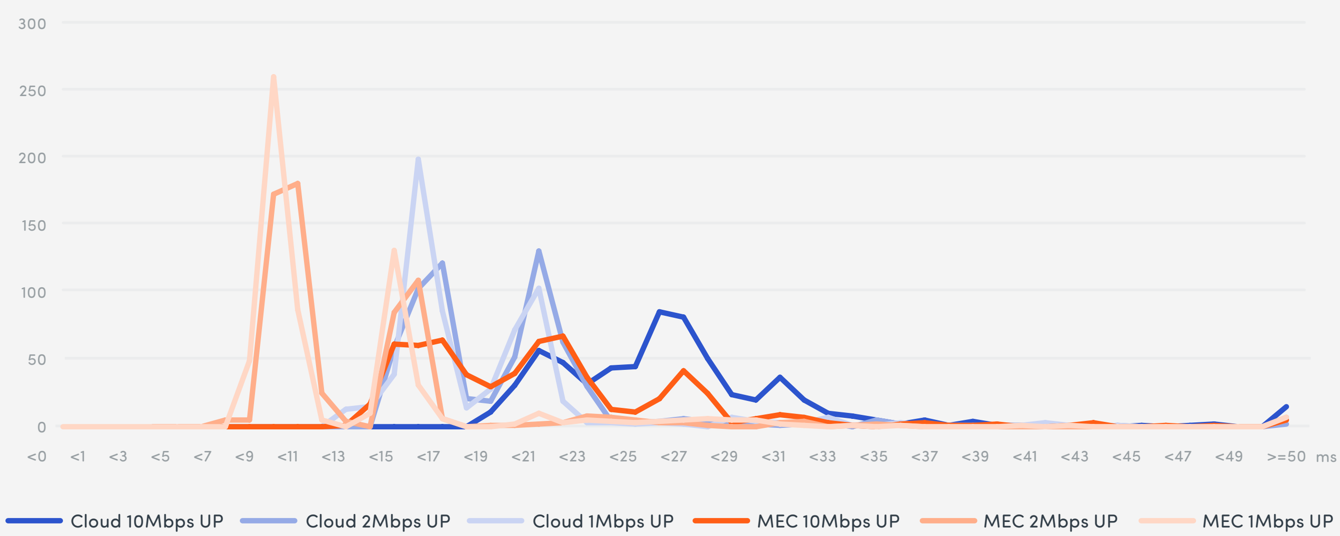


Figure 22

New York MEC Downlink Latency PDF

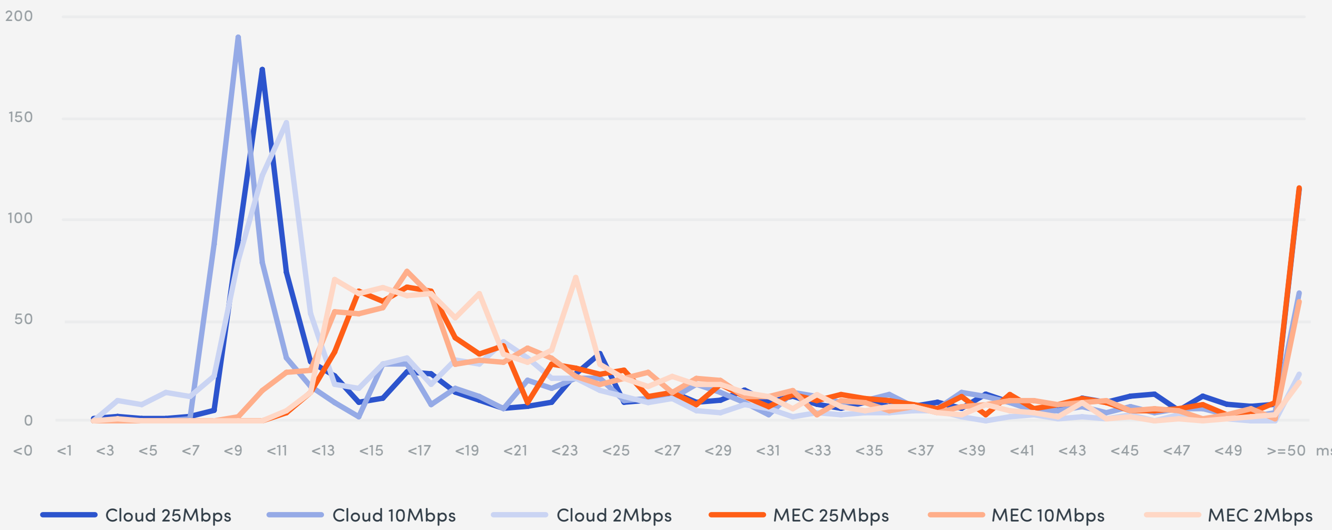


Figure 23

New York MEC Uplink Latency PDF

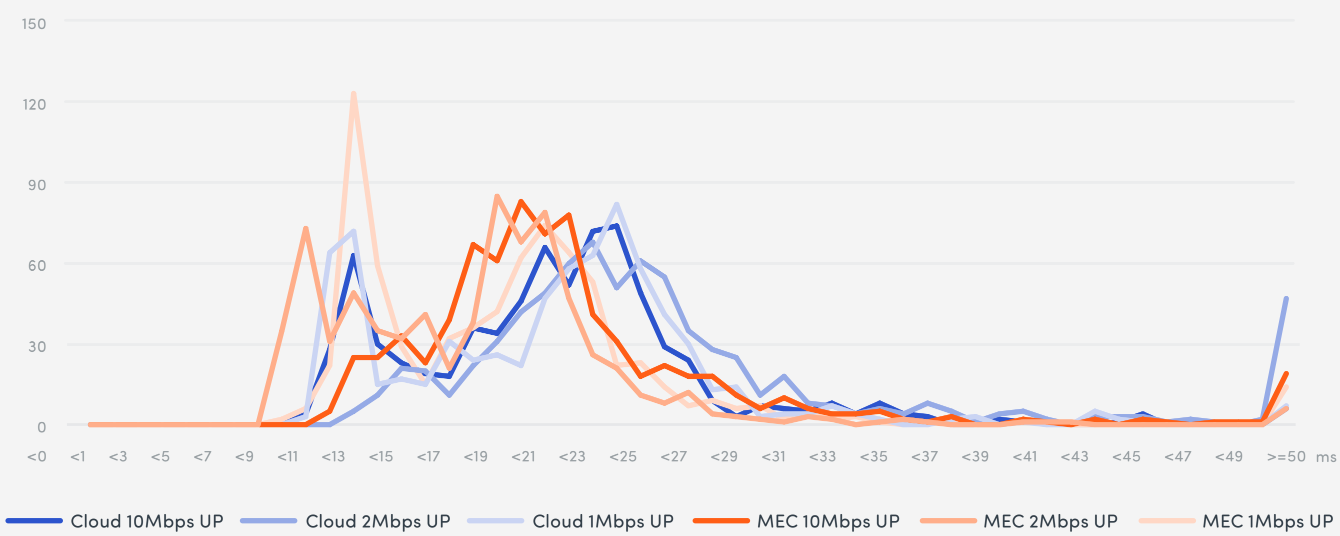


Figure 24

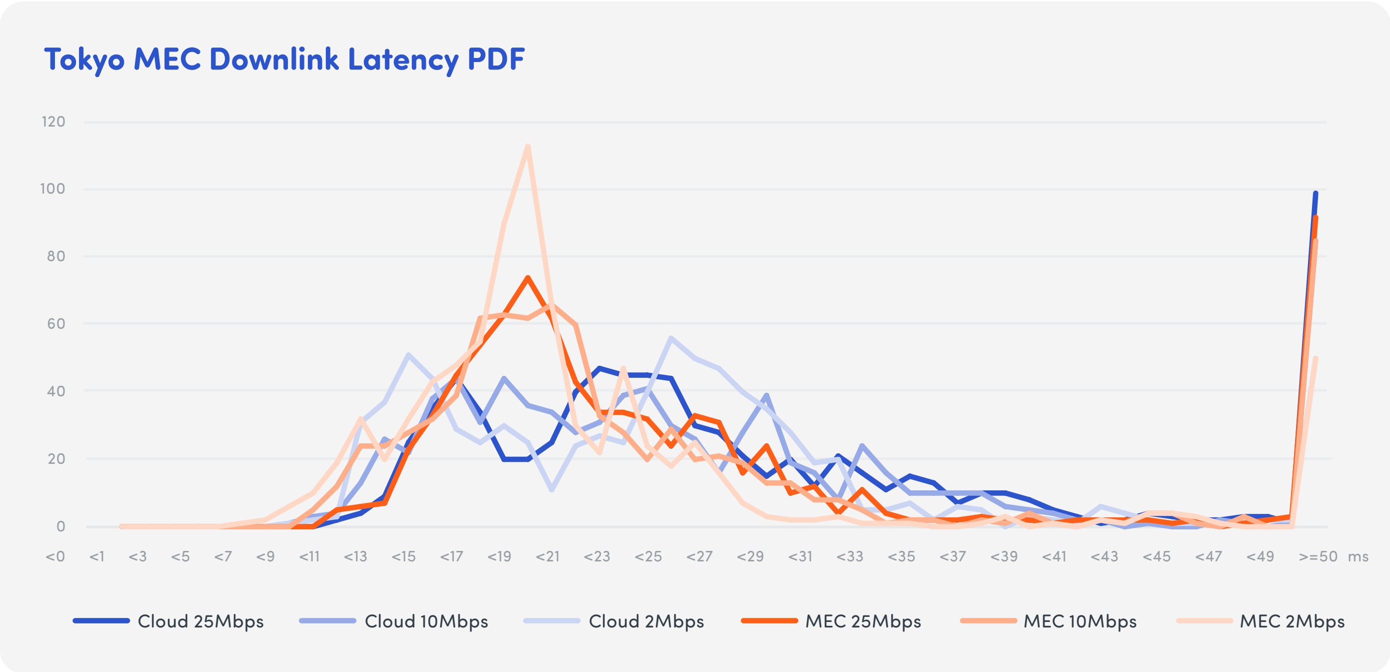


Figure 25

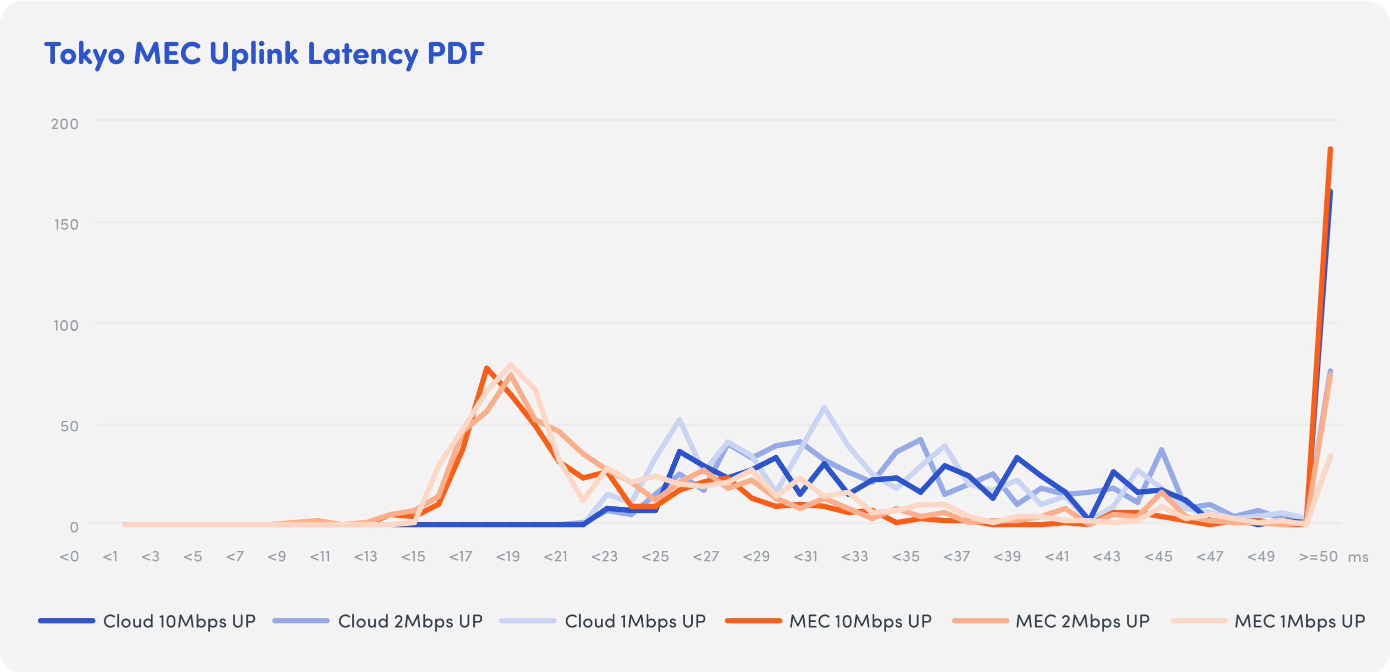
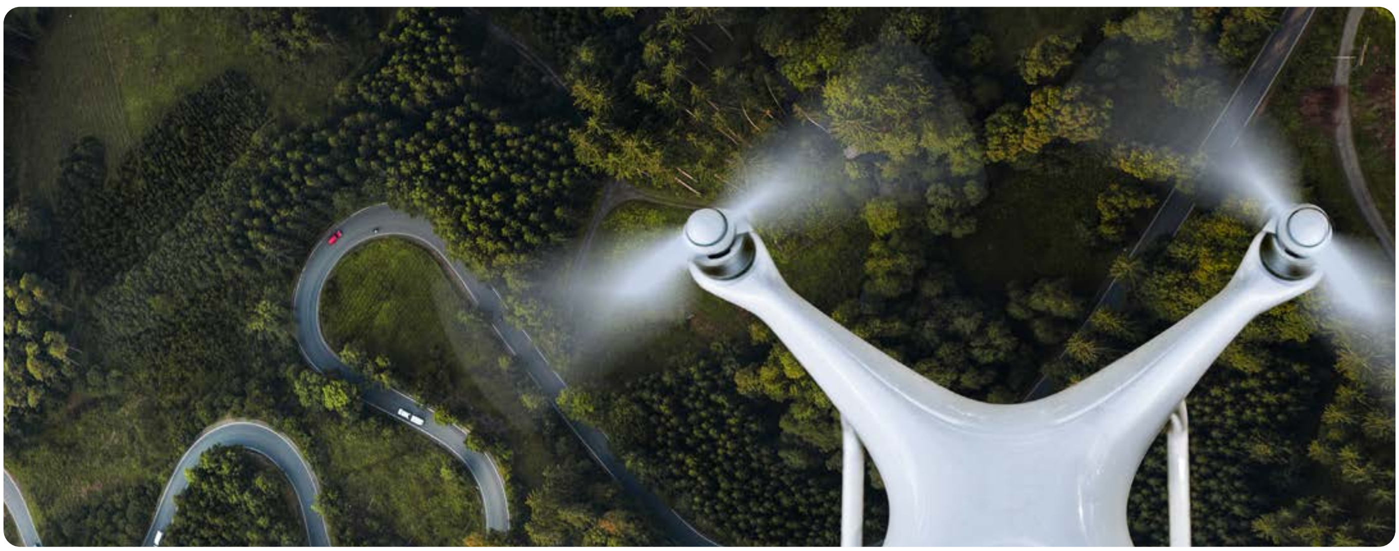


Figure 26

Market Expectations vs. Real-World MEC Latency: A Reality Check



The benchmarking latencies measured for cloud and MEC connectivity confirm that existing MEC implementations can reduce latency and are able to meet some of the 3GPP use case criteria. To meet near-term edge use case requirements, the edge may not need to be as geographically and widely distributed as initially anticipated.

However, issues related to performance fluctuations may pose a challenge to implementations of some use cases. Large standard deviations in latency will impact use cases that require a controlled window of latency for proper operation. The lack of symmetry between upload and download latencies illustrates the importance of testing in both directions. Geographical differences in latency, globally and within nations, will impact the performance of applications intended for broad use.

The bottom line is that latency must be managed holistically, end-to-end, to achieve desired customer experiences and to meet SLAs. But there have been few definitive proof points to date that any one approach will be guaranteed to adequately deliver on anticipated latency or latency continuity from an end user perspective.

3GPP R16 defines target latencies for different edge applications. A simple mapping of those targets versus the real-world results from the Spirent study reveals a mixed picture. Table 2 compares the 3GPP targets to mean measured latencies in multiple markets. Several use cases are supported by today's MEC latencies; however, additional performance optimization will likely be required for use cases that require consistent latency levels.

Category	Use Case	Required Latency	Seattle	Chicago	New York	Tokyo
AR/VR/ Gaming	AR/VR motion-to-photon	7-15ms	●	●	X	X
	Collaborative gaming	<20ms	●	●	●	X
Automotive	Wireless roadside backhaul	10ms	●	X	X	X
	Sensor sharing	<20ms	●	●	●	X
	Platooning	≤10ms	●	X	X	X
	Cooperative collision avoidance	≤10ms	●	X	X	X
	Cooperative lane change	≤10ms	●	X	X	X
	Emergency trajectory alignment	≤3ms	X	X	X	X
	Remote driving information sharing	≤5ms	X	X	X	X
	Video sharing	≤10ms	●	X	X	X
	Info sharing for automated driving	≤100ms	●	●	●	●
	HD digital map update	100ms	●	●	●	●
Transport & Logistics	Time-critical sensing	<30ms	●	●	●	●
	Remote drone operation	10-30ms	●	●	●	●
	Real-time control for discrete automation	≤1ms	X	X	X	X
Smart Cities	Smart grid (transmission)	<5ms	X	X	X	X
	Smart grid (distribution)	<50ms	●	●	●	●
	Time-critical sensing	<30ms	●	●	●	●

Table 2: Comparison of 3GPP latency targets to mean 5G MEC latency from Spirent's real-world benchmarking.

Recommendations for Improving MEC Latency

While MEC is an important new capability to reduce latency, operators also need to make networks more efficient across the RAN, transport, and new 5G core architectures if they are to deliver consistent and deterministic latency.

There are additional factors beyond the choice of network architecture that can impact latency:

- 5G non-standalone (NSA) implementations with dependency on 4G networks have additional latency overhead.
- Air interfaces can pose challenges, especially during scheduling and handovers.
- The wired transport networks used for fronthaul and backhaul are not always optimized for routing efficiency.
- Applications themselves can insert latency due to processing overheads.

Continuous visibility and impact assessments can help prioritize and optimize network efficiency, helping to identify and isolate what is impacting latency inside and outside the network. Notably, these impact assessments can support understanding of acceptable end user and application performance tolerances.

Establishing the right test regimen

As with any new service, improvement starts with measurement. This means measuring from the end user or application perspective, taking note to model the testing after the data footprint of the MEC applications. The application testing profiles should take into account data volume to mimic required throughput, packet/frame size to mimic segmentation, and packet velocity to assure holistic results.

As mentioned previously, any testing program should prioritize consistency, not just latency means and medians. Testing should be performed in all target markets to measure consistency of performance in all customer locales.

Simultaneous RAN logging is critical to characterizing and improving latency performance and understanding impact of interRAT handovers and challenging RF environments, such as urban cores.

Depending on the edge application being tested, it is also important to address accessibility of edge-located endpoints ahead of time. DDOS detection or unexpectedly high data rates can trigger shutdown of hosted edge services and require reopening applications before continuing the test regimen. It is recommended to perform this testing as early as possible to account for unplanned delays.

Continuous visibility and impact assessments can help prioritize and optimize network efficiency.

Not only is it important to assess latency performance from the user/device perspective, simultaneous active-test-based service assurance can help segment and isolate the causes of high or inconsistent latency.

Realizing the benefits of 5G standalone upgrades

The move to 5G standalone (SA) introduces the 5G Core, reducing the overheads of NSA 4G interworking and benefiting from an optimized architecture designed for lower latency and enhanced QoS.

Early upgrades to 5G SA have demonstrated improvements in reducing network latency by over 20%, with more than 450 devices and form factors already supporting 5G SA. The time to upgrade is now.

Private MEC vs. Public MEC for industry

For enterprises and industries, the implementation of a private 5G MEC on the premises offers the potential for further latency reduction due to the proximity for localized processing. Local breakout can be provided to the public cloud and MEC, while the private MEC can be optimized for latency-sensitive applications where over-the-air and transport network impact performance.

Implementing 3GPP release upgrades

5G standards development has focused on a continued stream of enhancements for reliable low latency:

RELEASE 16*

- Enhancements in the 5G Core to support ultra-reliable low latency communications (URLLC)
- Physical layer enhancements for 5G new radio (NR) URLLC
- Improved DL transmission efficiency to help optimize power consumption, latency, and spectral efficiency
- V2X enhancements for low latency and high reliability

RELEASE 17**

- Enhanced multi-beam (M-MIMO) operations to reduce signaling latency
- Higher compression efficiency to reduce the uplink transmission latency
- Enhanced physical layer feedback
- Enhanced time synchronization
- Intra-device multiplexing and prioritization
- Network QoS enhancements

RELEASE 18 (STUDY ITEMS)

- Traffic management for resource-efficient and low-latency radio resource allocation
- Resource allocation and scheduling enhancements for bounded latency for XR and cloud gaming
- Co-existence of downlink and uplink at the same time within a TDD band
- Layer 1 and Layer 2 inter-cell mobility procedures to reduce latency, overhead, and interruption time

*Release 16 was frozen in mid-2020. The first commercial network upgrades are anticipated in 2022.

**Release 17 will be frozen in mid-2022 with upgrades targeted for late 2023 early 2024. Release 18 studies have just begun.

Conclusions

It is clear from the STL study that there is a lack of clarity on latency requirements. The demand and supply sides are disconnected in terms of what latency will be required, when it will be required, for which use cases, and the most efficient approaches to optimizing performance.

Following analysis of the Spirent benchmarking and STL studies, we share these key takeaways for enterprises and operators prepping deployments:

CONSISTENCY MATTERS.

Demand-side customers require reliability and consistency of uplink and downlink latency, not simply "low latency."

LOCATION MATTERS TOO.

For some near-term use cases, the edge doesn't need to be as geographically and widely distributed as initially anticipated.

SUPPLY AND DEMAND SIDES NEED ALIGNMENT.

Enterprises sometimes overestimate required latencies, underscoring the importance of close collaboration between operators and customers to determine precise needs.

THERE ARE LIMITS TO OPERATOR CONTROL OVER LATENCY.

An opportunity exists for operators to monetize latency via SLAs. To do so, operators will need to educate the demand side on boundaries of accountability (e.g., application latency challenges not resulting from the network), to be able to assure consistent latency ranges and provide holistic evidence of SLA adherence.

GREAT EDGE PERFORMANCE ISN'T JUST ABOUT EDGE LOCATION.

While MEC is an important new capability to reduce latency, operators should also make their networks more efficient across the RAN, transport, and new 5G Core architectures if they are to deliver consistent and deterministic latency.

The study and benchmarking data show that, in reality, 90% of the early use cases the market is demanding can be supported by today's network capabilities. This could open the door to early monetization opportunities, but only if latency SLAs can be met consistently. Longer-term use cases will require further optimization in the network and future upgrades to the 3GPP standards releases.

How Spirent Can Help

We're here to help you accelerate 5G and edge, from initial deployments to ongoing rollouts and operation of networks incorporating the latest open standards and innovations:

1. Our **continuous test and assurance solutions**, integrated into the DevOps pipeline processes, realize agility and deal with the continuous release nature of software from multiple vendors.

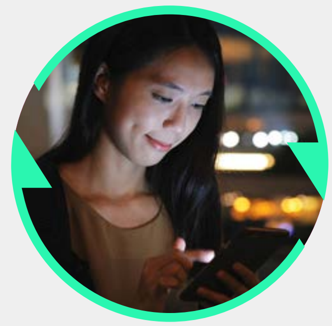
2. Our **automated framework** provides a holistic capability consumed across the 5G lifecycle to simplify labs, tests, and operational processes such as fulfillment.

3. Our **emulation and transport and security test solutions** have evolved to become Digital Twins, accelerating research and fostering innovation within adjacent industries.

4. Our **active testing and assurance** using synthetic traffic injected into an operational environment is crucial to proactively monitoring, isolating, and revalidating performance and security in elastic 5G networks.

5. Our **test as a service solutions** offer a new engagement model to address complex testing needs, such as **performance benchmarking of existing and new edge services**, with a managed service.

LEARN MORE ABOUT LATENCY EXPECTATIONS AT SPIRENT.COM



About Spirent

Spirent Communications plc. (LSE: SPT) is the leading global provider of automated test and assurance solutions for networks, cybersecurity, and positioning. The company provides innovative products, services, and managed solutions that address the test, assurance, and automation challenges of a new generation of technologies, including 5G, SD-WAN, cloud, autonomous vehicles, and beyond. From the lab to the real world, Spirent helps companies deliver on their promise to their customers of a new generation of connected devices and technologies.

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About Spirent Communications
Spirent Communications (LSE: SPT) is a global leader with deep expertise and decades of experience in testing, assurance, analytics, and security, serving developers, service providers, and enterprise networks.

We help bring clarity to increasingly complex technological and business challenges. Spirent's customers have made a promise to their customers to deliver superior performance. Spirent assures that those promises are fulfilled.

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