

# Cloud gaming and 5G

## Realizing the opportunity

### White paper

As many as 2.5 billion people play video games today, according to games market analysts Newzoo<sup>1</sup>, equivalent to roughly every third person alive. From the classic arcade game Pac-Man in 1980 to the modern run-and-gun game Call of Duty, video games have always been defined by the technology available. Now a new trend is set to make gaming even more widely accessible than ever before: cloud gaming. Research and Markets estimates the global cloud gaming market will grow from US\$306 million in 2019 to US\$3,107 million by 2024, a compound annual growth rate of 59%<sup>2</sup>. This will be driven in part by the roll-out of 5G.

This paper outlines the opportunities for Communication Service Providers (CSPs) in cloud gaming, including the demand it will place on the network, and how the quality of experience (QoE) can be measured.

<sup>1</sup> The Global Games Market Will Generate \$152.1 Billion in 2019 as the U.S. Overtakes China as the Biggest Market, 18 June 2019

<sup>2</sup> Cloud Gaming Market by Offering, Device Type, Solution, Gamer Type, Region - Global Forecast to 2024, January 2020

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## Executive Summary

Cloud gaming represents a huge re-think in how video games are delivered to players. The games software runs in the cloud, and the user devices simply view the game and interact with it. This means cheaper and less powerful devices can be used to play the kind of games that are only available on dedicated gaming consoles today. A huge amount of data must be sent over the network, though, and this presents both an opportunity and a challenge.

CSPs can grow their businesses by creating and marketing 5G services that offer a great gaming experience. By working with gaming providers, CSPs can enter into agreements to bundle games and connectivity together, and provide private network connectivity for gaming tournaments and other events.

In order to deliver a good gaming experience, it is important to be able to determine the user experience. Key quality indicators (KQIs) such as content resolution, video quality, frames per second, and application lag can be mapped to network key performance indicators (KPIs) so that the user experience can be inferred from the known network parameters.

This paper introduces cloud gaming, some of the leading providers, and the architecture options for hosting games in the cloud. It outlines how users will access cloud gaming, the demands that cloud gaming will place on the network, and how CSPs can rise to the challenge to provide new gaming services.

## What is cloud gaming?

Traditionally, games software has run on the device that the gamer is using to play the game. For example, the software might be downloaded to a console, installed on a PC, or bought as an app for a mobile phone. The game relies on graphics processing units (GPUs) in the device to generate the high-quality images that make for an atmospheric or attractive game. Many games require powerful and expensive hardware to play. A games console costs between US\$350 and US\$500, and a gaming PC capable of playing the most demanding games could cost as much as US\$4500.

Cloud gaming works differently. It moves the compute and graphical processing into the cloud so that less powerful devices can be used to play the games. That includes smart TVs, cheaper PCs and older laptops. Phones and tablets can play games with a graphical sophistication far beyond the casual games popular on mobile devices today. Games can be played anywhere there is a connection, from a wide range of devices, while achieving an experience similar to a dedicated device.

Most importantly, because there is no need to install software, gameplay is frictionless. Players can pick a game and start playing straight away. This is a far cry from the experience using a console where a game session might begin with a hefty download, resulting in a delay. Mobile subscribers may be more likely to try new games, and more willing to add a little to their subscription fee for the ability to dip into games on demand, similar to the way that many people subscribe to all-you-can-eat music services today. For mobile CSPs, cloud gaming represents an opportunity to grow their business in partnership with gaming providers.

**Several cloud gaming services are launching or have launched already.**

- **Google Stadia** launched publicly in November 2019 and is advertised as offering 4K video at up to 60 frames per second on TVs with mobile device compatibility over Wi-Fi<sup>3</sup>.
- **Microsoft Project xCloud** is in preview now, offering 50 Xbox games to stream on Android phones or tablets<sup>4</sup>.
- **NVIDIA GeForce NOW** brings cloud gaming to laptop, desktop, Mac, SHIELD TV and Android devices<sup>5</sup>. It formally launched in February 2020 and aims to enable players to bring the games they previously bought into the cloud.
- **PlayStation Now** brings Sony's catalogue of PlayStation PS4, PS3 and PS2 games to PS4 or Windows PCs using the cloud<sup>6</sup>.
- **Apple Arcade** enables 100+ games to be played across Apple phone, tablet, computer and TV devices<sup>7</sup> with a single subscription.
- **Shadow** provides a cloud PC with dedicated storage that you can access from any device<sup>8</sup>.
- **Hatch** offers mobile gaming without downloads, with Android compatibility available now and other platforms to follow<sup>9</sup>.

**There are two different ways that cloud gaming can work (see Figure 1).**

- **Video streaming** is the dominant approach, whereby all the game logic and graphics are processed in the cloud and video is sent back to the device. This does not require a powerful GPU on the gaming device so it can work with a wider range of devices. It does, however, require the bandwidth to stream the high-quality video back to the device.
- **Command streaming** is the approach used by Hatch. As with video streaming, game logic and graphics commands are processed in the cloud, but the graphics are rendered on the gaming device using the GPU. The cloud sends the device the instructions to render the scene. These instructions are lightweight compared to a video stream, so the bandwidth requirements are lower than they are for video streaming, but the quality of graphics is limited to the capabilities of the device's GPU.

3. <https://store.google.com/gb/product/stadia>

4. <https://www.xbox.com/en-GB/xbox-game-streaming/project-xcloud>

5. <https://www.nvidia.com/en-gb/geforce-now/>

6. <https://www.playstation.com/en-gb/explore/playstation-now/>

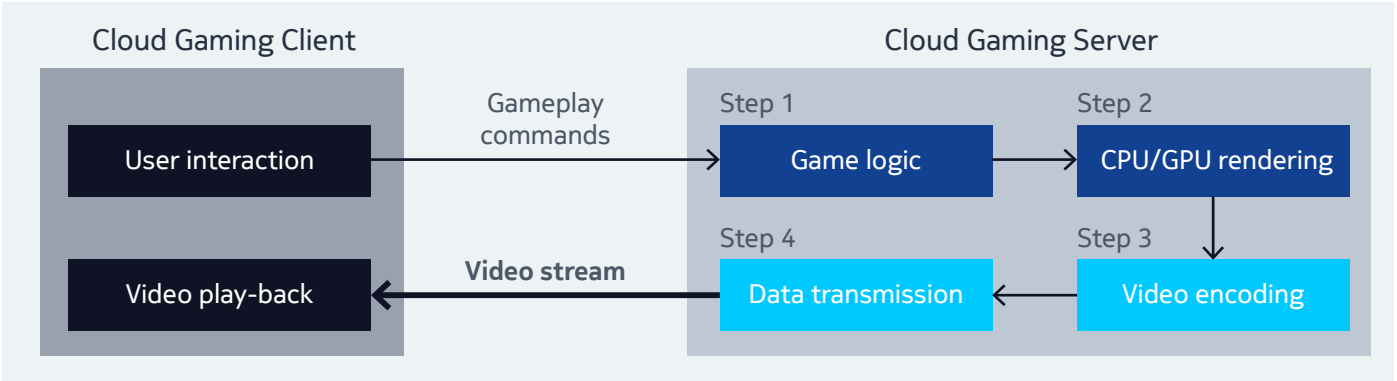
7. <https://www.apple.com/apple-arcade/>

8. <https://shadow.tech/gben>

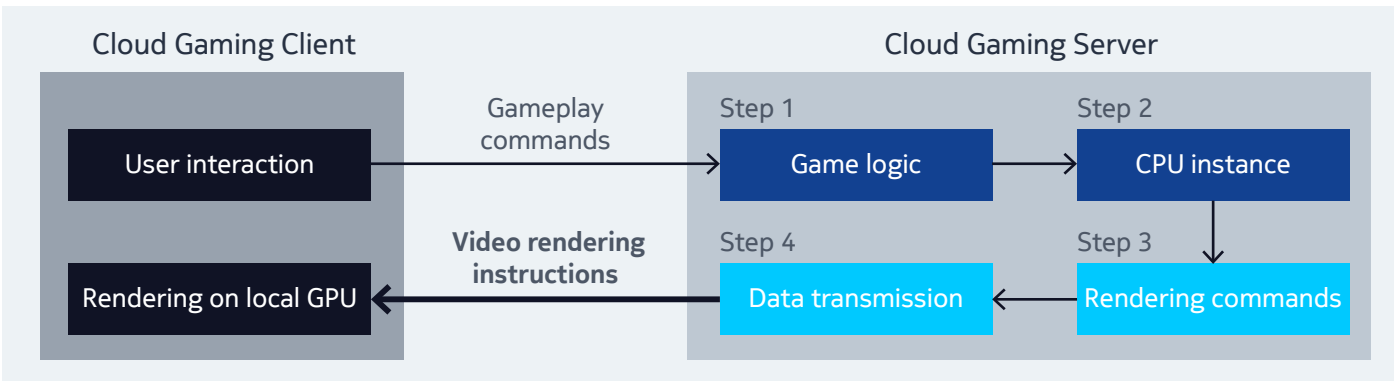
9. <https://playhatch.com/>

Figure 1. Video streaming versus command streaming. In both cases, gameplay commands are sent to the cloud. Video streaming returns a video stream of the game and command streaming returns instructions to render the scene

**Video Streaming**



**Command Streaming**



**Why has cloud gaming (re)emerged?**

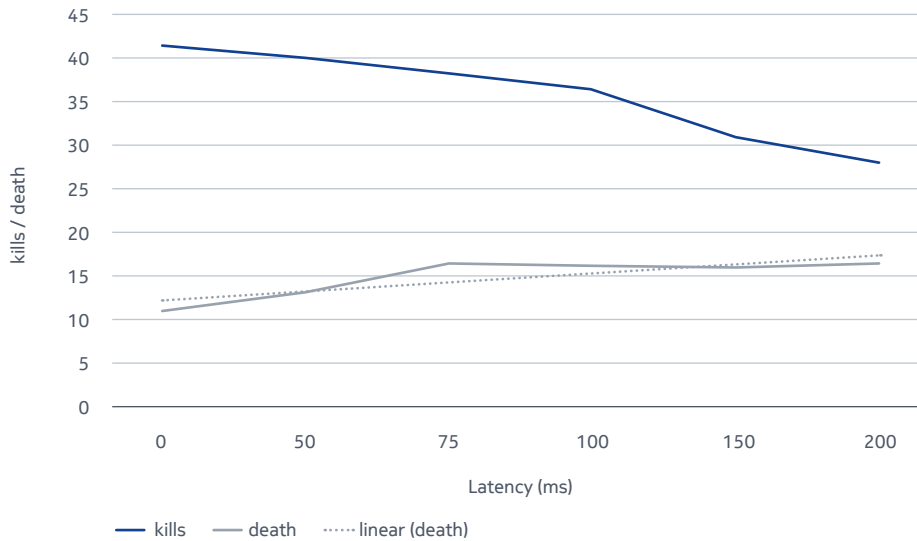
The casual gamer might not be aware that cloud gaming has been pioneered for more than 10 years with companies like Gaikai, StreamMyGame and OnLive. These companies attempted to achieve a console-like experience but by most accounts were unsuccessful, although PlayStation Now is based on Sony’s acquisition of Gaikai. How will the recent cloud gaming entrants achieve success where others have failed?

To answer this, we must first understand what makes online gaming an enjoyable experience. Bell Labs research has shown that application lag is one of the most important user experience factors in gaming<sup>10</sup>. Application lag is simply the time between a user-initiated action and the game response which is shown as an updated rendered image. Application lag includes the time taken for remote server processing, rendering, encoding, and streaming the update to the user’s screen. Who wins and who loses in a competitive game is often decided by the application lag of one user relative to another. Figure 2 illustrates this by showing the impact of latency in an online first-person shooter (FPS) game<sup>11</sup>.

10. 3 M Jarschel\*, D. Sven Scheuring, T. Hoßfeld, Gaming in the clouds: QoE and the users’ perspective, Math. Comput. Model., vol. 57, no. 11, pp. 2883–2894, 2013.  
 11. T. Beigbeder, R. Coughlan, C. Lusher, John Plunkett, Emmanuel Agu, Mark Claypool, The Effects of Loss and Latency on User Performance in Unreal Tournament 2003, SIGCOMM’04 Workshops Aug. 30+Sept. 3, 2004

Figure 2. Online gaming study on the impact of latency on competitive play

Online first-person shooter (FPS) competition



“Application latency directly impacts the results of competitive gaming – destroying user experience and QoE”

The graph shows that a player’s ability to defeat (or kill) their opponent drops, and their character is more likely to die, as latency increases. This is why gamers demand low latency and would quickly abandon online gaming if latency was high. While this study was based on first-person shooters, other games were tested including racing games and team soccer matches, with similar results.

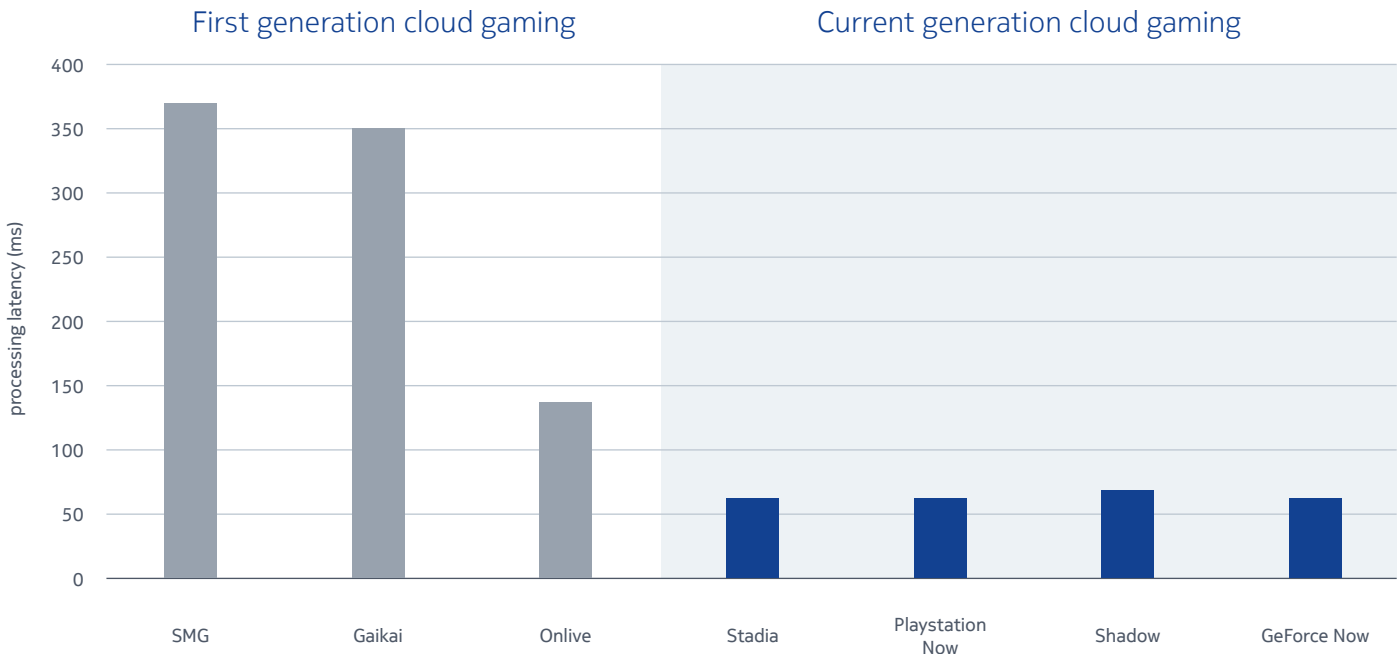
It’s important to distinguish between network latency and processing latency. Processing latency is associated with computation and rendering. There is a non-trivial amount of delay in rendering complex gaming images, and the processing latency can be larger than the network latency (see Figure 3).

This graph highlights the challenge faced by the first-generation game providers: the processing latency reached a third of a second or more before the network latency was added. Today, the processing latency is much lower as a result of advances in server technology and the use of GPUs. GPUs are by their nature good at image processing and so have been widely used in gaming consoles and have more recently been introduced in cloud infrastructure. Recent testing indicates cloud game processing latencies as low as 60ms.

Game processing latency of course depends on the game, with the more graphically rich games requiring more time. Now that virtual GPUs (vGPUs) have cut the game processing latency in the cloud, the network’s role is even more critical in enabling cloud gaming. With lower network latencies and GPU-based cloud servers, the possibility of a seamless transition from console gaming to the cloud can transform the industry.

Figure 3. Processing latency of past and present cloud gaming platforms, including StreamMyGame (SMG), Gaikai, OnLive, and current generation services Stadia, PlayStation Now, Shadow, and GeForce NOW

Cloud gaming processing latency



## What makes a good gaming user experience?

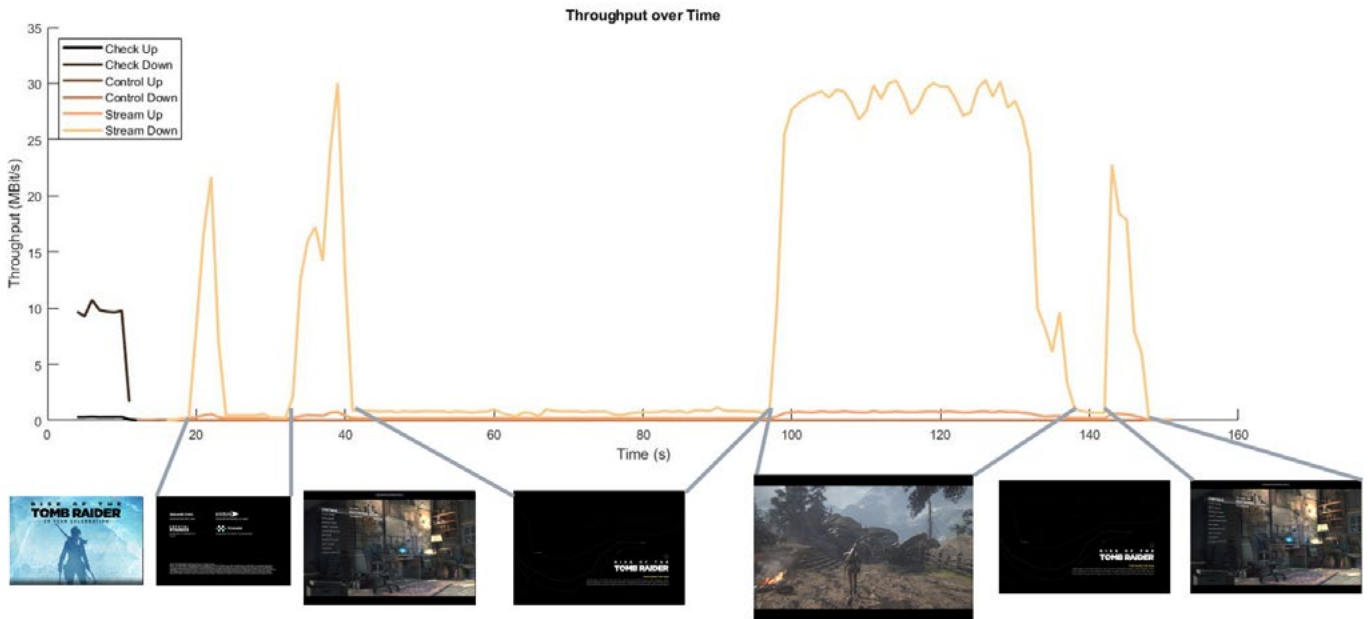
We have made the case that overall latency is a significant factor in QoE for cloud gaming, but it’s certainly not the only metric. Related to lag is something called video frame rate (measured as frames per second), which is dependent on the application lag and available bandwidth. Traditional video has frame rates of 24 or 30 frames per second, but the gaming market is moving to higher frame rates (60/120) particularly with higher resolution video. A higher video frame rate not only increases the smoothness of the playout, but also improves users’ ability to compete<sup>12</sup>, similar to the effect of reducing application lag.

Often game rendering servers adjust video frame rate dynamically based on the bandwidth and network round trip time. Higher frame rates can increase the bandwidth requirement by 20% or more.

Bell Labs evaluated the bandwidth requirements for Google Stadia for the first few minutes of launching the game ‘Rise of the Tomb Raider’ streamed at 1080p/60 FPS (see Figure 4). From Figure 4 we see that during the active part of the game ~30Mbps is required for 1080p. The evaluation also found that Stadia supports resolutions of 4K at 45Mbps, 1080p at ~30Mbps, and 720p at 10Mbps. Stadia continually tests that the maximum round trip time (RTT) is 75ms before the user session is dropped.

12. M. Claypool, K. Claypool and F. Damaa, The Effects of Frame Rate and Resolution on Users Playing First Person Shooter Games, 5th ISCA/DEGA Workshop on Perceptual Quality of Systems (PQS 2016)

Figure 4. Bandwidth requirements for Google Stadia at 1080p/60 FPS.



To determine overall user experience, we need to identify the factors that impact user experience – the KQIs. KQIs for gaming include content resolution, video quality, frames per second, and application lag. Video quality in our context will refer to the artifacts that occur in live video delivery – for example, freezing, pixelization, and tiling, which are often the result of packet loss.

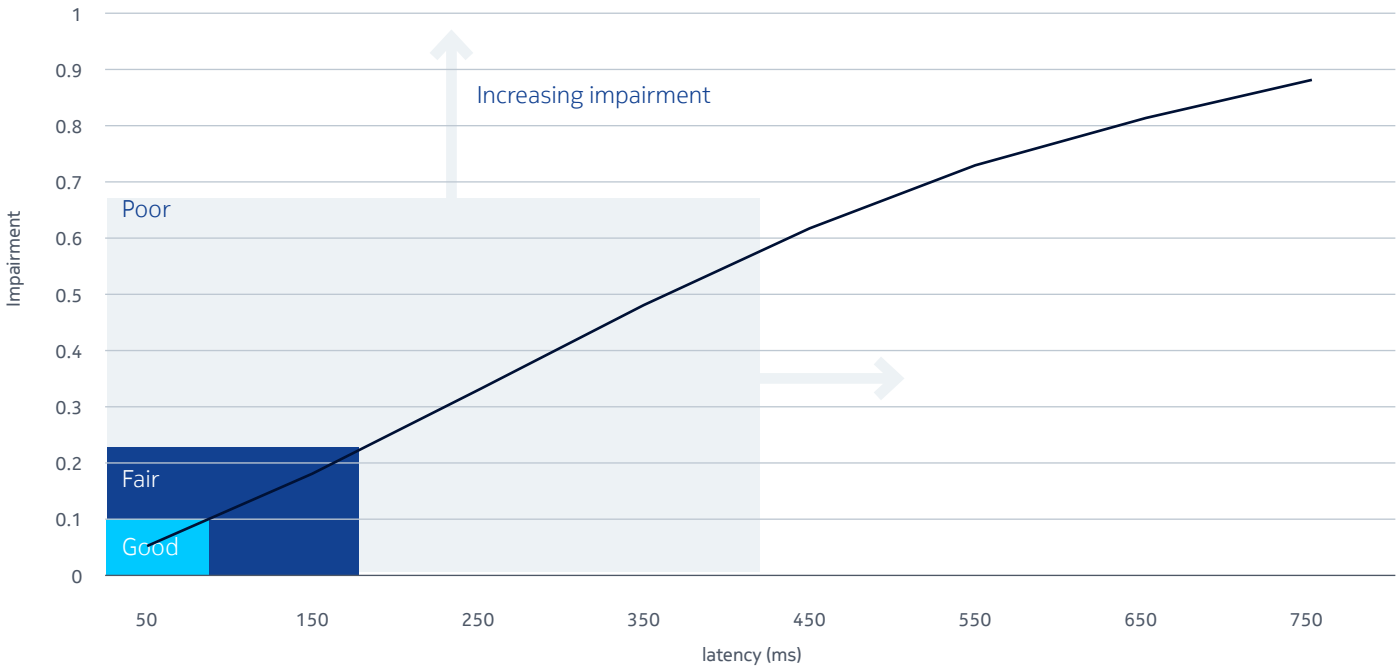
A KQI is often measured as the amount by which it misses its target value. This is called the impairment in the KQI and is characterized as a percentage. By way of example, let’s look at application lag. Figure 5 is an application lag impairment model for augmented reality(AR)/virtual reality(VR) gaming that was developed by Bell Labs Consulting<sup>13</sup>. We see from this graph that at below 75ms latency the impairment is less than 10% for gaming. The light blue area on the graph represents a good degree of impairment, dark blue represents a fair amount of impairment, and grey indicates a poor amount of impairment.

In a similar manner an impairment model is used for content resolution and frames per second to determine the overall user experience for cloud gaming. These are not described here but some examples are given in the previous Bell Labs & BLC studies<sup>10 13</sup>.

10. 3 M Jarschel\*, D. Sven Scheuring, T. Hoßfeld, Gaming in the clouds: QoE and the users’ perspective, Math. Comput. Model., vol. 57, no. 11, pp. 2883–2894, 2013.  
 13. B. Krogfoss, P. Perez, J. Bouwen, J. Duran, Quantifying the value of 5G and edge cloud on QoE for AR/VR, 2020 Twelfth International Conference on Quality of Multimedia Experience (QoMEX)

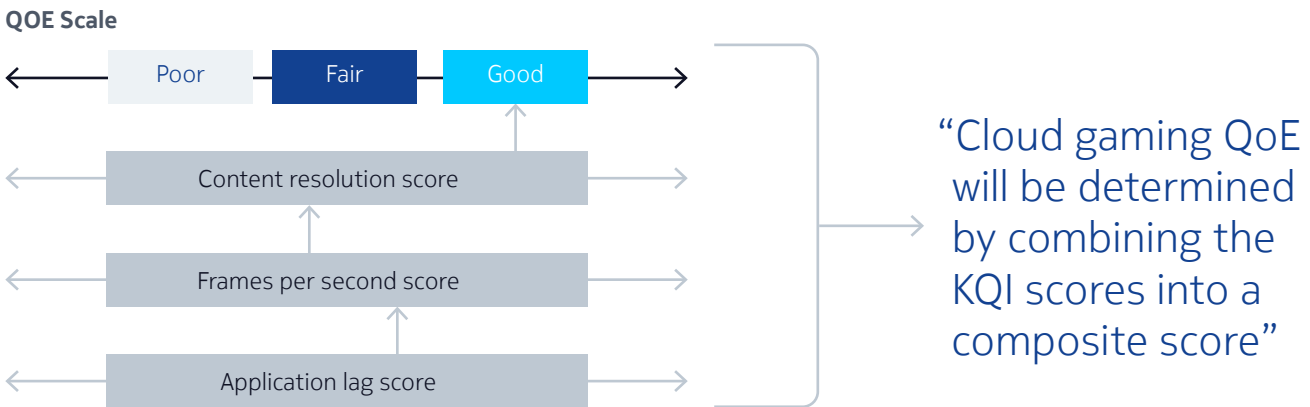


Figure 5. Cloud Gaming impairment model for application lag.



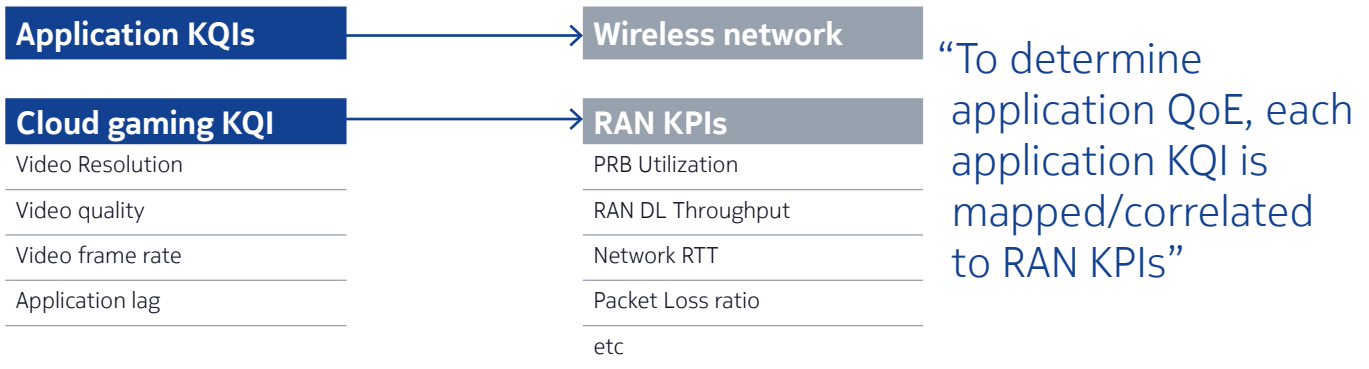
To create a composite QoE score that reflects overall user experience we combine (additively or multiplicatively) each KQI score (see Figure 6).

Figure 6. Creating a composite QoE score based on individual KQI scores.



To understand how gaming QoE is evaluated in CSP networks we need to connect the KQIs to measurable parameters in the CSP’s network. Normally we correlate each application KQI to one or more network KPIs (see Figure 7). This means we can infer KQI performance based on the network KPIs. For example, content resolution is primarily influenced by throughput, so tracking the radio access network (RAN) throughput will give us an indication of the content resolution delivered to the user. Video quality can be impacted by the packet loss ratio (PLR) as packet loss results in picture artifacts that impair the overall experience. By tracking PLR, we can infer the video quality impairment.

Figure 7. To determine QoE, each KQI must be correlated to RAN KPIs

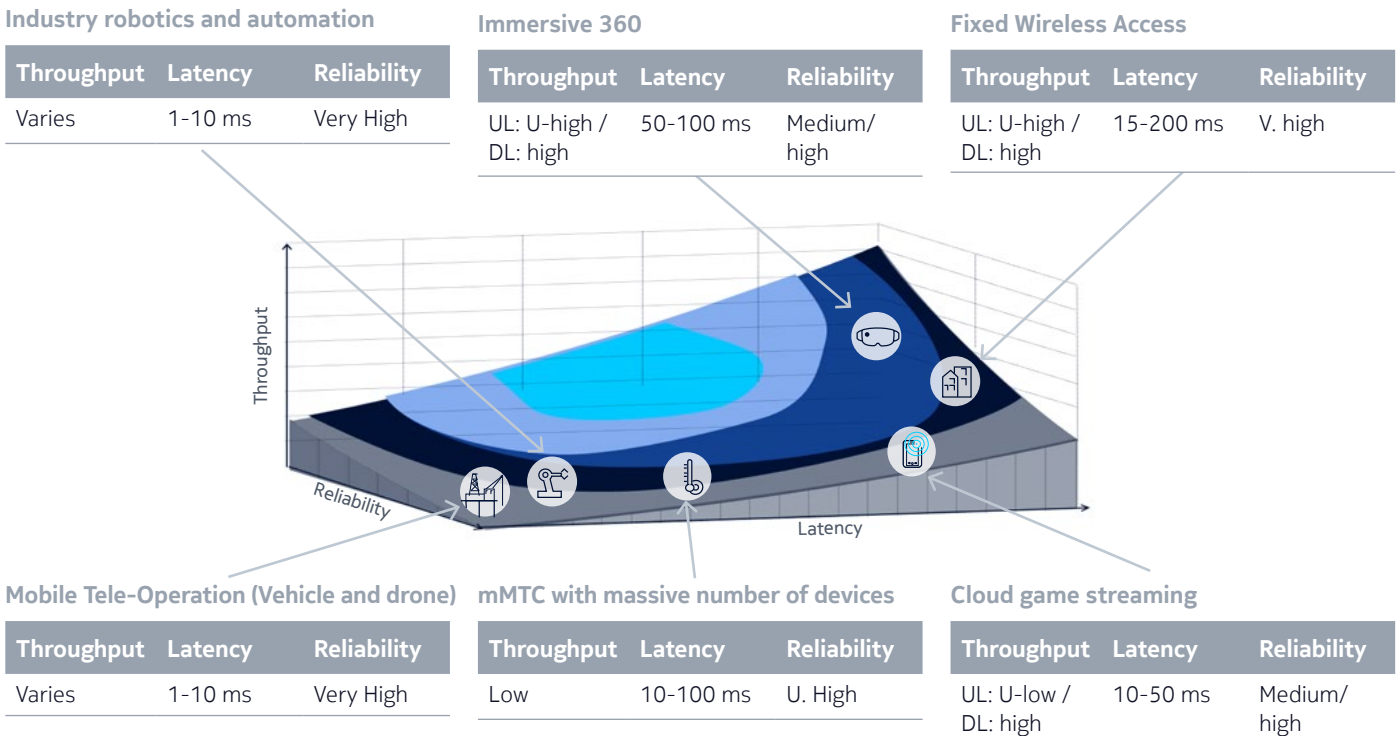


## Evaluating the network for QoE

Looking at the cloud gaming KQIs it should be clear that LTE would not effectively meet the thresholds needed for a good user experience. This is not a surprise because LTE was not designed with these high-performance applications in mind. It’s not an indictment of LTE, but more about the need for 5G to provide a good user experience for these emerging applications.

Figure 8 illustrates how 5G can address the needs of applications in terms of latency, throughput and reliability<sup>14</sup>.

Figure 8. Business drivers of the network requirements, showing LTE and 5G throughput and latency



14. ©2020 Nokia

In Bell Labs Consulting's analysis<sup>13</sup> of cloud VR gaming, we demonstrate how important the latency and throughput improvements of 5G are for the success of this market. The process of measuring and engineering a network for good quality is an area that CSPs are still struggling with. Normal dashboarding of standard network/RAN KPIs will not ensure a good user experience. We described a process for assessing user quality for cloud gaming, where each game type has a different set of KQIs and thus impairment models that need to be tracked. Additionally, beyond gaming, CSPs need to consider future applications like immersive collaboration and AR/VR which will drive network demand and add new constraints.

In recent studies, we find that CSPs over-engineer or under-engineer their network, and that through analysis we can help them optimize for cost and efficiency, extending the life of existing investments and improving the user experience. Using the proven QoE methodologies described here, Bell Labs Consulting works with CSPs to quantify and measure user experience using analytical correlations and industry best practices.

Going beyond a network-centric view provides visibility into how customers experience the service using metrics such as the customer experience index (CEI). It combines service data with information from marketing campaign systems, so that cloud gaming providers can see, for example, campaigns and the customer experience of those in the targeted area at the same time. This allows them to determine who their prime targets are that would want to subscribe to the service. Information can be imported from the operations support system (OSS), IT and transaction data, and notifications can be raised for proactive interventions where required to protect the customer experience.

## How will players access cloud gaming services?

There are two scenarios for cloud gaming:

- **Gaming in the home:** At first, the majority of gaming time will probably be spent at home. This is where fixed wired internet access will offer the best gaming experience, with most existing broadband customers having enough bandwidth and sufficiently low latency for cloud gaming. CSPs could tap into this home market, extending their existing subscriber base by using fixed wireless access on 5G. This brings broadband to underserved communities and extends the reach of cloud gaming to those communities too. The lower latency requirements and continuous high bandwidth consumption will prove challenging, but high-gain antennas can be used in outdoor receivers and indoor gateways to achieve the required quality of service.
- **Gaming out of the home:** Our mobile devices are always with us, keeping us constantly connected, and this means we use them during those transitional moments, such as when traveling. Part of the advantage of cloud gaming is that it will enable players to take games with them, and to play or continue a game wherever they are. The ability to play a game almost instantaneously, without having to wait for downloads, is therefore compelling.

The connectivity is crucial for ensuring cloud gaming is viable and offers a high-quality experience. Although mobility is an important part of the promise of cloud gaming, in the short term, it presents challenges. 4G can meet the bandwidth and latency requirements for command streaming but is unlikely to be able to meet the performance requirements of video based streaming platforms. When cloud game streaming takes off, 4G networks will be unable to scale to meet the demand, especially if adding additional services using AR and VR or other latency and bandwidth sensitive applications.

13. B. Krogfoss, P. Perez, J. Bouwen, J. Duran, Quantifying the value of 5G and edge cloud on QoE for AR/VR, 2020 Twelfth International Conference on Quality of Multimedia Experience (QoMEX)

5G will offer far greater scalability, with the ability to address new spectrum bands to improve capacity of the radio network, novel transmission methods to reduce latency in the air interface, and new capabilities to manage the quality of the experience using edge computing and network slicing.

As the network's capability to support cloud gaming increases, cloud gaming platforms are expected to broaden their support for mobile devices.

## What's the business opportunity for CSPs?

As gamers adopt cloud gaming, the network will play a critical role in the quality of their experience. Even if CSPs do not create dedicated gaming services, customers are likely to try cloud gaming using their existing service. The CSP may find its brand tarnished if games are sluggish or unplayable. Today's unlimited mobile contracts that throttle the speed after a certain amount of bandwidth has been consumed are unlikely to be compatible with the huge data volumes cloud gaming requires.

CSPs can grow their businesses by working with gaming platforms to deliver new gaming services. For example, CSPs could host the games themselves and sell the subscription directly to the customer. This has a high perceived value among subscribers and puts the carrier in control of the entire user experience. It requires a significant investment, though, not just in technology but also in building the relationships to license and market the games.

An alternative model would be to partner with cloud gaming providers (CGPs). In this model, the CGP could host the graphics processing, compute and game content, while the CSP offers a connection with a guaranteed quality of Service. Customers would benefit from a reliable gaming experience, but the CSP would not have to invest in the technology or licenses to host the games. This would create opportunities to sell differentiated services to customers, with packages that offer a guaranteed level of stream resolution.

Alternatively, the CSP could provide edge computing resources using a Multi-access Edge Computing (MEC) platform for the CGP to host the game closer to the player, cutting latency. MEC is seen as essential to help realize the potential of 5G, by enabling applications to be hosted closer to the user, cutting latency and backhaul across the network. Furthermore, with advanced capabilities in the MEC platform, applications can be aware of the network performance in real time and respond accordingly to protect the end user experience.

For gaming tournaments and densely populated locations, the CSP could sell a private network that would offer the bandwidth and latency required for gaming on site. The customer would be the event host or venue.

Cloud gaming is seen as an iconic service for 5G and CSPs are already forming partnerships as shown in Figure 9 below.

8 IOPS: Isolated Operation for Public Safety networks. Allows network to operate whilst losing backhaul connection to central core.

Figure 9. Today’s cloud gaming partnerships.

Cloud gaming provider	Service provider
Activision	Three
Hatch	Elisa, NTT DOCOMO, Sprint, Verizon, Vodafone
Microsoft – Project xCloud	T-Mobile, SK Telecom, Vodafone
NVIDIA GeForce NOW	LG U+, SoftBank
Stadia	BT, Verizon
Ubisoft GameCloud	China Unicom, Korea Telecom, Vodafone

## Conclusion

Cloud gaming has the potential to make gaming more widely accessible with frictionless access across a variety of devices and independent of location. 5G will provide the bandwidth and latency required for a great gaming experience, so CSPs have an opportunity to grow their businesses by partnering with cloud gaming providers. CSPs must review their existing network capabilities and assess the requirements for cloud game streaming. Through consulting and digital design, detailed network planning must be used to ensure the service is dimensioned and optimized correctly. Newer technologies such as MEC are important to ensure a good QoE, and while initial deployments of 5G will use non standalone (NSA) architecture, standalone (SA) will support the ability to use end-to-end network slicing to define specific levels of service. To take advantage of the programmable nature of the 5G network, service orchestration and assurance play important roles. Given the large number of moving parts, each with their own set of policies and SLAs that must be met, manually provisioning and managing such a network would result in an exponential increase in operational costs. Automation in handling the end-to-end lifecycle of the service will be a critical factor for success. In parallel with building the connectivity, building the operational support systems to support new partnerships and business models will be key to creating new services. Identifying new customers and managing their experience using cognitive analytics will accelerate your path to new revenues.

This paper contains contributions from Bell Labs Consulting. As part of Nokia Bell Labs, Bell Labs Consulting leads the industry and advises customers in understanding and realizing the full economic, social and human potential of the next industrial revolution. Based on Bell Labs’ Future X network vision and considering emerging market dynamics, Bell Labs Consulting brings a cross-disciplinary team of technology experts, along with a proprietary toolset and rich industry experience in addressing each client’s specific situation.

## Learn more

**Nokia Monetization for Digital Service Providers**

**Nokia Edge cloud – Take computing capacity to where the traffic is**

**Bell Labs Consulting – Network evolution strategy**

## Abbreviations

AR	augmented reality
CEI	customer experience index
CGP	cloud gaming provider
CSP	communications service provider
GPU	graphics processing unit
KPI	key performance indicator
KQI	key quality indicator
MEC	multi-access edge computing
OSS	operations support system
PLR	packet loss ratio
PRB	physical resource block
QoE	quality of experience
RAN	radio access network
RTT	round trip time
VR	virtual reality

### About Nokia

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