

# Mobile cloud gaming in Seoul:

the real-world mobile gaming experience on 5G vs. 4G LTE  
in South Korea's capital





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# The mobile cloud gaming landscape is booming

With the arrival of 5G, more and more gamers are putting away their consoles and replacing them with cloud-based games that can be enjoyed anywhere and everywhere they go—and on any connected device they choose.

This report shows which operators in Seoul, South Korea, can deliver a smooth mobile cloud gaming experience on 5G compared to 4G LTE for both casual games in standard definition and multiplayer online games in high definition. **It's important to note that the results in this report are specific to gaming in Seoul, and the gaming experience in other cities could be different.**

#### Why did we choose Seoul?

Seoul is an area where seamless and fast connectivity is critical for consumers, businesses, and government agencies alike, and it's also known for its world-class 5G. More importantly, the 5G results we've seen in Seoul (and other cities in South Korea) have been outstanding and much better than those in other countries we've tested. In short, the South Korean operators are providing their subscribers with widespread access to 5G and incredibly fast speeds, with results that significantly top what we've seen in other countries to date. What better place to look closely at how 5G might help transform the gaming experience? Read on to see what to expect in terms of the real-world mobile cloud gaming experience in Seoul.

Gaming analytics firm **Newzoo** forecasts the cloud gaming market to grow from **\$584.7M in 2020 to \$4.8B in 2023**, with cloud gaming serving as an excellent use case for the potential of 5G.





# 5G in Seoul could offer a blueprint for stronger 5G and improved mobile gaming in other countries

South Korean mobile operators were the first in the world to deploy 5G on a wide scale, and the operators in Seoul are providing the level of seamless connectivity that consumers have long been looking forward to enjoying. Indeed, the 5G results we've seen in Seoul have been stronger than those in other major cities we've tested across the globe, including markets in Switzerland, the UK, and the US.





In fact, the remarkable 5G availability and speed performances we saw in Seoul could be a harbinger of stronger 5G and more responsive gaming experiences to come in other countries going forward, particularly for multiplayer games that require precision and accuracy.

The tables on the right show the highest 5G availability and fastest 5G median download speed in Seoul compared to the top 5G availability and speed results recorded during second-half 2020 testing in the most populated cities in Switzerland, the UK, and the US. The bottom line is that the 5G results we recorded in Seoul clearly surpassed those in other major cities.

## Highest 5G availability in major cities around the world

Country	City	Operator	5G availability
 South Korea	Seoul	LG U+	90.9%
 Switzerland	Zurich	Swisscom	45.6%
 United Kingdom	London	EE	39.9%
 United States	New York City	AT&T	54.6%

## Faster 5G median download speeds in major cities around the world

Country	City	Operator	5G speeds
 South Korea	Seoul	LG U+	476.5 Mbps
 Switzerland	Zurich	Sunrise	324.6 Mbps
 United Kingdom	London	Vodafone	216.6 Mbps
 United States	New York City	AT&T	53.1 Mbps

# 5G and mobile cloud gaming

While cloud gaming has long been a part of the digital services landscape, its full potential on smartphones and other connected devices hasn't been fully realized because cloud gaming requires consistent connectivity, fast speeds, and low latency that 4G LTE networks often can't support.

5G, however, could quite literally change the game when it comes to streaming games from the cloud: latency-based delays could become a thing of the past, and the experience of streaming precision-based, graphics-heavy multiplayer online games like League of Legends or Call of Duty could eventually be as smooth on a smartphone as it is on a console at home.

To show you what to expect in terms of the quality of the mobile cloud gaming experience, we looked at multiple elements of gaming, including Google Stadia's **recommended speeds** for good cloud gaming, as well as Microsoft's **latency recommendation** for optimal gaming on Xbox Game Pass. We used those speed and latency recommendations as proxies for smooth cloud gaming on any gaming platform, and we've also looked at other key gaming metrics such as packet loss and jitter.

In this report, we discuss the gaming experience in the context of three major cloud gaming platforms, but our findings and results should be considered proxies that apply to other platforms as well. However, it's important to note that the gaming experience could differ across platforms, and the results in this report aren't intended to reflect gaming on a particular platform.

Google  
Stadia

Microsoft  
xCloud

Steam  
Remote  
Play

Using Google's speed recommendations and Microsoft's latency recommendation as benchmarks for smooth cloud gaming on any platform, we took results from our most recent mobile performance testing in Seoul in the second half of 2020 to show which networks are capable of delivering a good mobile cloud gaming experience on both 5G and 4G LTE. It's important to note that we did not test gameplay in Seoul; the findings in this study are based on mobile operator speeds, latency, and other gaming-related results we recorded during testing.

We looked at gaming across two broad categories at two different resolutions:



## Casual games in standard definition (720p)

These include single player casual games such as Candy Crush or Tetris in SD.



## Multiplayer online games in high definition (1080p)

These include games that must be played online, are designed to be multiplayer experiences, and require quick reactions and perfect accuracy—games such as Call of Duty or Final Kick 2020 in HD.

# What is cloud gaming?

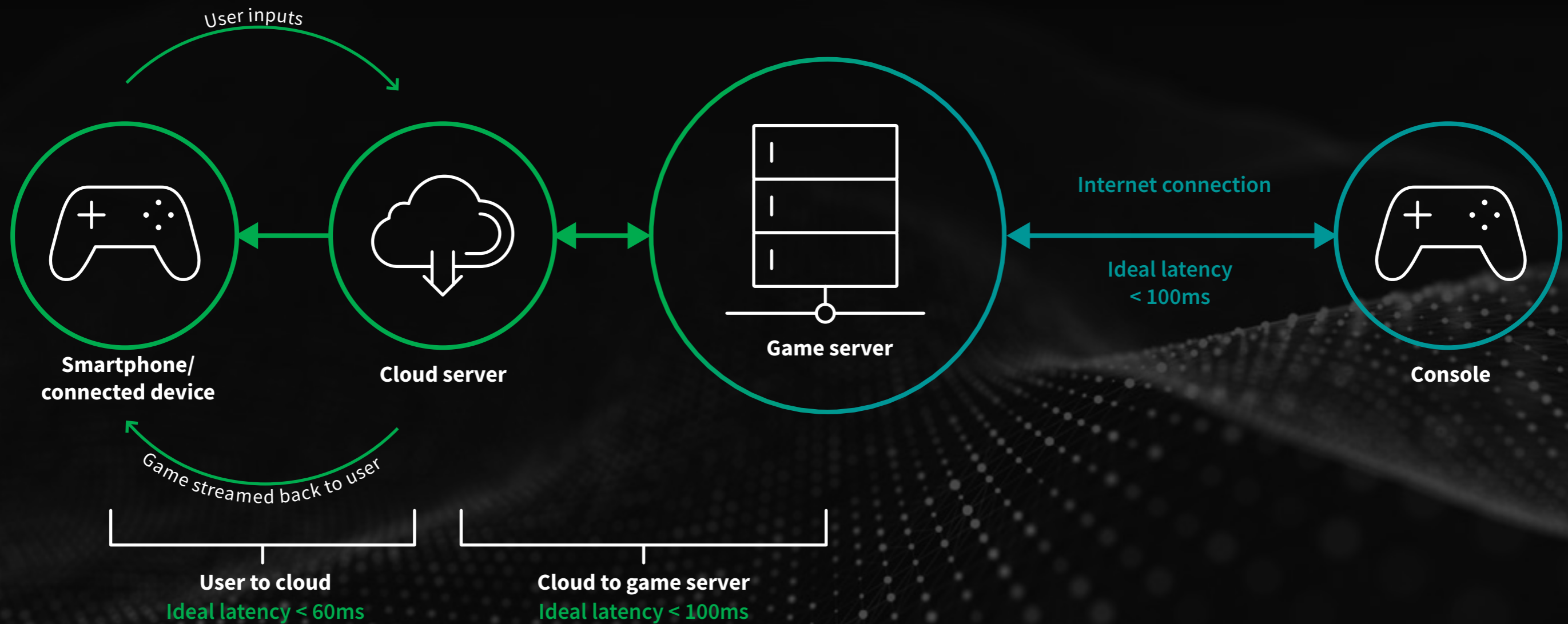
Cloud gaming allows users to play games hosted on the cloud, rather than on a console or gaming PC, and all the processing, graphics, and video rendering that historically took place on consoles now takes place on the cloud.

Gamers send commands from a mobile device to platforms like Stadia or Xbox Game Pass by pressing a button or entering a series of keyboard commands. The cloud server receives and executes those commands and then streams the results back to the gamer. If your speed, latency, and other gaming-relevant results are strong enough, gameplay happens in effectively real time and without any delays or problems.

Gaming consoles like PlayStation, Xbox, and others were designed to process massive amounts of data on the console itself, but mobile devices simply don't have that kind of processing power. Processing on the cloud, however, can solve that problem, allowing for smooth and responsive gaming on mobile devices without the glitches and delays that can occur when processing takes place at the device level.

According to gaming analytics firm **Newzoo**, the worldwide cloud gaming market will grow to **124.7 million users by 2022**, and research firm **Niko Partners** expects the number of cloud gamers in **Asia alone to grow from 3 million in 2019 to 60 million by 2023.**

# Snapshot of cloud gaming vs. console gaming



● Cloud gaming ● Console gaming



Cloud gaming has multiple benefits for gamers. It's much cheaper since there's no need to buy consoles or gaming PCs, and if a user's smartphone or other connected device breaks or freezes temporarily while gaming, the game can be picked up at the same exact spot later. The biggest benefit for cloud gamers, though, is that they can play any game they want, anywhere they go, and on any device they choose.

Gaming companies can also benefit from cloud gaming. Without physical copies of games, piracy becomes much more difficult (if not impossible), and gaming companies need only pay for bandwidth that gamers use while playing, which is far less expensive than manufacturing physical copies of games. Cloud gaming is also a perfect medium for cross-promotional opportunities. Consider Fortnite, for example. It's free to play, but in-game upgrades have led to millions in sales.

While the benefits are plentiful, cloud gaming isn't quite perfect yet. In order for cloud gaming to reach a point where it's capable of truly replacing the gaming experience found on PCs or consoles, connectivity must be consistent and nearly flawless, with fast speeds and ultra-low latency, particularly for fast-paced, multiplayer online games that require precision and quick reactions.

Imagine this, for example: with consistently fast speeds, low enough latency, and outstanding packet loss and jitter results, an Esports competitor could play a high-stakes League of Legends tournament from a park bench with zero-lag gameplay, real-time responses, and perfect chat features, all while switching from a smartphone to a tablet and back without missing a beat. We're not at that point quite yet, but that's where the future of 5G and cloud gaming is headed.

### **Mobile gaming: the most popular lifestyle activity for always-on mobile users**

We conducted a comprehensive study of always-on mobile users early in 2020, and results showed that mobile gaming is the single most popular mobile lifestyle activity, with 64% of respondents stating they use their smartphone for mobile gaming on a daily basis. During the COVID-19 pandemic, the popularity of mobile gaming has only continued to increase.



# 5G, edge computing, and lower latency

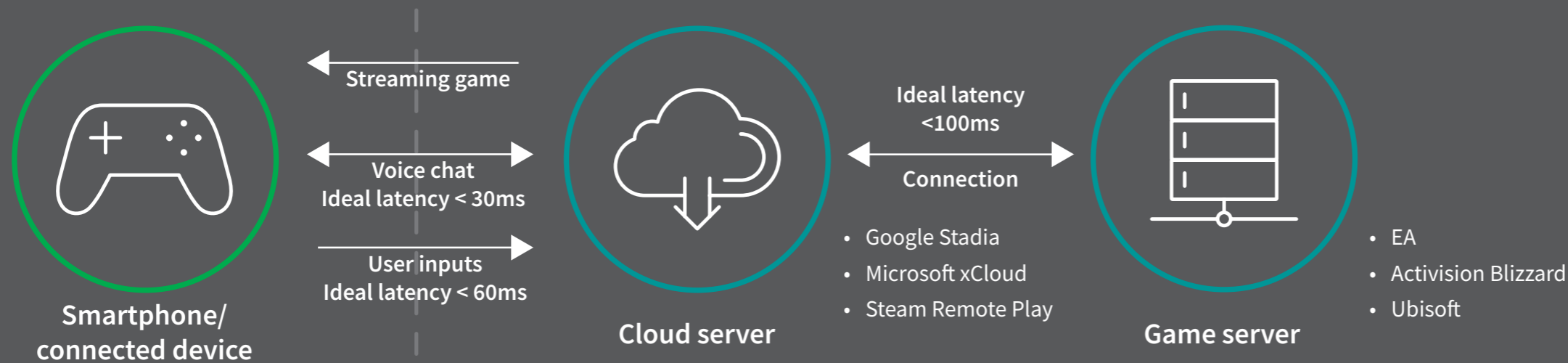
While latency is an inherent challenge for cloud gaming, 5G and edge computing will ultimately allow game providers to mitigate the effects of latency-based delays on gameplay.

5G will provide greater capacity that will allow cloud gaming providers to support countless games at the same time (and more and more users), and it will also improve the gaming experience in areas of heavy congestion. Perhaps more importantly, 5G holds the potential to provide much lower latency and faster speeds than 4G LTE networks can offer—particularly in Seoul, where 5G is already providing remarkable speeds.

Edge computing, meanwhile, is perhaps the best tool game providers and mobile operators have for improving latency. It essentially moves processing, video rendering, and video encoding physically closer to the user, which in turn reduces lag. Game streaming services typically have centralized cloud servers in different locations, and the farther away a user is from that server, the more lag they're likely to experience. That's a particularly big issue for multiplayer games or Esports competitions where every frame is critical and even the smallest delay could mean game over. However, edge computing could help level the latency playing field and remove advantages gamers currently have if they are closer to the cloud server than their geographically disadvantaged counterparts.

It's also important to understand that most latency metrics, including ours for Seoul below and those recommended by game providers like Microsoft, only factor in the round-trip time it takes for user inputs to reach the cloud server and return to the user. But there's also lag that happens between the cloud server and the actual game server (for example, EA's servers). While that "second layer" of latency is out of the control of both mobile operators and cloud providers, it's always there. That said, if latency is reduced on the operator side by 5G or edge computing, then overall lag will be reduced, even though cloud-to-game server latency exists. Ideal lag between the cloud server and game server is less than 100ms.

## Cloud gaming network architecture



### 5G Benefits

- Lower latency for inputs
- Higher speeds for better graphics

# Compensating for latency: user-adjusted latency and game-adjusted latency

Gamers and game developers alike employ innovative ways to mitigate the impact of latency that don't rely on edge computing or the benefits of 5G.

Compensated latency is effectively a shortcut used by both gamers and game providers to reduce lag, and oftentimes, compensated latency is a subconscious act on the part of a gamer.

While compensated latency isn't measurable, it can make games move a bit quicker and play a little smoother. For example, say a character in Super Mario Brothers has to run around a wall to reach the next level, but because of minor lag that always happens in the same place, a user recognizes that she must hit a button to make Mario jump a split-second earlier than what the screen would indicate. That almost imperceptible shortcut is a learned behavior that can reduce lag.

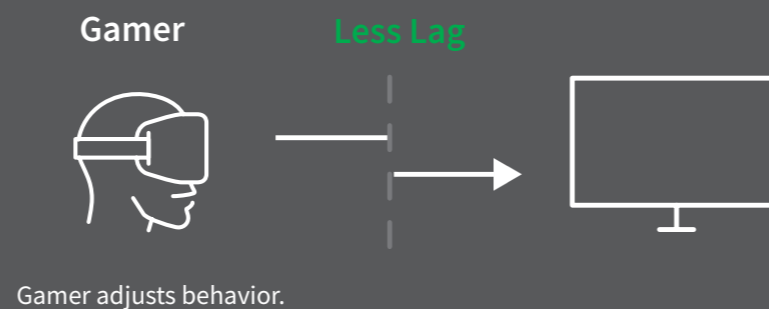
Game-adjusted latency is also common, though it's unpredictable in that gamers don't know which games (or which points in a game) have been adjusted to compensate for lag. Game-adjusted latency happens when game developers learn that higher-than-normal latency occurs at certain points in a game and then create ways to lessen that lag. For example, if gaming developers notice high latency at a stage in a first-person-shooter (FPS) game in which the player must hit a target in order to advance, the developers might increase the size of the target by a pixel or two so that gamers are more likely to hit the mark and advance to the next phase of the game.

## Compensated latency

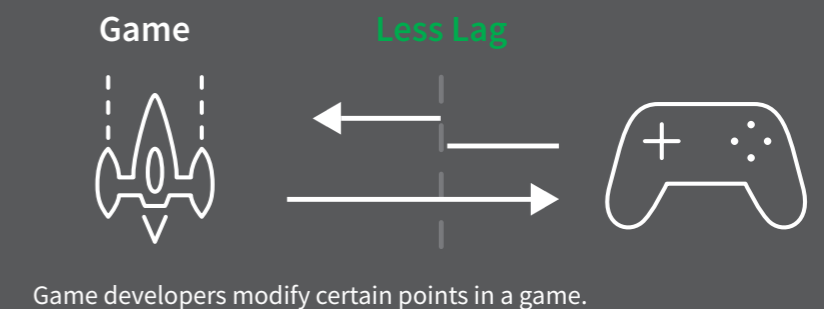
### Ideal latency



### User-adjusted latency



### Game-adjusted latency



# Benchmarking what matters most to gamers

To provide a holistic view of each network's ability to reach or surpass the speed recommendations of Google Stadia and the latency recommendation of Microsoft Xbox Game Pass, we've included visuals below showing each operator's 5G availability, 5G and 4G LTE speeds, and 5G and 4G latency results along with other key metrics and insights for the end-user gaming experience. Taken together, this information provides a full picture of the current end-user gaming experience for major mobile operators in Seoul on both 5G and 4G LTE.



## 5G median download speeds

Our 5G median download speeds offer a look at "everyday" 5G speeds and show how those speeds can impact mobile cloud gaming when purely on 5G and offer a direct comparison to speeds entirely on 4G LTE. Note that 5G users will sometimes switch back and forth between 5G and 4G LTE during the same data activity, which is known as "mixed mode" technologies. Performance on mixed mode typically isn't as strong as that 5G-only. Therefore, to provide the most accurate view of a true 5G gaming experience and to assure the most direct comparisons between 5G and 4G LTE, we did not include mixed mode results in our reporting.



## 4G LTE median download speeds

5G users in Seoul will likely access 5G the vast majority of the time while using their smartphones, but to show what performance looks like on the rare occasions when 5G isn't available, we also looked at speed results on 4G LTE. Comparing 4G LTE to 5G speeds helps give a more nuanced view of what gamers can expect on different network technologies. Median download speeds on 4G LTE offer a look at typical 4G LTE speed performance and show how speeds affect the everyday gaming experience for users not connected to 5G. They also provide a look at how the gaming experience can differ for users on 5G compared to those on 4G LTE.



## Latency (5G and 4G LTE)

Latency is critical for gamers, and the lower the latency, the better. After all, when you press the "fire" button, you need to know you'll hit your mark immediately or it's game over. High latency can disrupt (or even stop) a game in mid-stream, while low latency can provide smooth, buffer-free gaming. We measured latency on both 5G and 4G LTE to offer a look at the end-user latency experience on different network technologies. The latency results in this report are based on our web and app testing, which characterizes use cases that require continuous data usage such as gaming and AR/VR applications.



## Jitter (5G and 4G LTE)

While latency is critical, jitter can also cause problems for gamers if it's too high. Jitter, which we measure during our UDP tests, is effectively a measure of the consistency of each network's latency. Higher jitter means that latency is inconsistent rather than stable. The effects of jitter are similar to those of latency: high jitter can lead to choppy or laggy gameplay and/or distorted audio and chat functionality, while low jitter can keep games running smoothly (as long as latency is also low). In short, the lower the jitter, the better. We looked at jitter on both 5G and 4G LTE to provide a closer look at how 5G can impact jitter and the real-world gaming experience. For smooth mobile cloud gaming, we recommend jitter below approximately 30ms for casual games in SD and below roughly 10ms for multiplayer online games in HD. We've included those recommendations in the operator sections below.



## Packet loss (5G and 4G LTE)

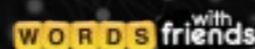
Like jitter, we measure packet loss during our UDP tests. High packet loss can lead to an extremely frustrating gaming experience since, in effect, packet loss means that pieces, or packets, of game data are lost in transit to and from the user and cloud server. Packets can also arrive out of order, which could theoretically lead to a game that's unintelligible. We measured packet loss on both 5G and 4G LTE to show how packet loss affects the gaming experience across different network technologies. We recommend packet loss below 3% for smooth casual gaming in SD, while packet loss for multiplayer online games in HD should be 1% or lower. In the operator sections below, we've included our recommended packet loss metrics for seamless gaming.

# The types of games we looked at

We focused on mobile cloud games of two broad types and at two specific resolutions in this report: **casual games in standard definition (720p)** and **online games in high definition (1080p)**.

## Casual games in SD (720p)

We consider SD an optimal resolution for casual, single-player games like Words with Friends or Tetris. While some casual games are certainly best played in HD and do require low latency for an optimal experience, casual games are, generally speaking, usually not as fast paced or precise as multiplayer online games like Call of Duty or League of Legends. In short, latency is less important for casual games where instant reactions and absolute precision aren't necessary for a good gaming experience. On the other hand, latency is critical for multiplayer online games. Examples of casual games in SD for this report include:



## Online games in HD (1080p)

The online games discussed in this report are assumed to be played in HD, are usually intended to be multiplayer games, and must be played online (that is, you can't just download Call of Duty to your smartphone and play by yourself). In these multiplayer online games, fast reactions and pinpoint accuracy are required, and every frame can make the difference in the outcome. These multiplayer online games typically require perfect chat functionality, exceptional audio and video quality, real-time inputs, and minimal (or zero) delays or lag during gameplay. The online games discussed in this report include games like:



# How we evaluated the quality of each operator's mobile cloud gaming experience

Google Stadia recommends **median download speeds of at least 10.0 Mbps for casual games in SD and speeds of 35.0 Mbps or better for online games in HD.** In terms of latency, Microsoft Xbox Game Pass recommends **latency below 60ms for an optimal gaming experience.** We used those speed and latency benchmarks as proxies for good cloud gaming on any platform.

To determine which networks could provide a good mobile cloud gaming experience for casual games in SD and online games in HD, we compared each operator's speed results on 5G and 4G LTE to the speed recommendations of Google Stadia, and we compared each network's latency results to the latency recommendation of Microsoft Xbox Game Pass.

## Recommended speed and latency for casual games in SD and multiplayer online games in HD

Recommended speed and latency	Casual games in standard definition (720p)	Online games in high definition (1080p)
Recommended median download speed	10+ Mbps	35+ Mbps
Recommended latency	<60ms	<60ms

In addition, even though the providers didn't make recommendations for jitter or packet loss, we factored both metrics into our results because jitter and packet loss are key elements of the real-world gaming experience.

### A note on data speeds and their broader effect on gaming

It's important to note that faster speeds can sometimes offset issues caused by other poor gaming results and/or network issues which might otherwise disrupt gameplay, like high latency, jitter, or packet loss. To use an analogy, think of bandwidth or speed as a highway, and then consider high latency, jitter, or packet loss as congestion on that highway. The larger the highway, the more data it can handle, and the transfer of more data at faster rates can help overcome potential shortcomings that result from high latency, jitter, or packet loss. In effect, access to faster speeds can provide additional advantages beyond just a quick and responsive gaming experience; it can also help smooth out other potential issues and lead to a stronger overall gaming experience.

# The results: a high-level look at the cloud gaming experience in Seoul

## High-level key findings:

Our operator-by-operator section beginning on page 15 includes insights on the gaming experience for each network in Seoul, but in a nutshell, some of the high-level findings from our study include:

- **All three operators deliver stellar gaming results, especially on 5G:** Great news for gamers in Seoul: all three operators surpassed all recommended metrics for speed, latency, jitter, and packet loss on both 5G and 4G LTE. Gamers on any network in Seoul should see quick video rendering and smooth gaming in general, and 5G should lead to particularly seamless gaming.
- **FAST 5G speeds in Seoul:** The 5G median download speeds we recorded in Seoul were remarkable and much faster than those on 4G LTE. All three carriers delivered 5G speeds above 425 Mbps.
- **Impressive latency results across the board:** Latency was generally low in Seoul, with each operator's latency on 5G lower than its latency on 4G LTE and well below Microsoft's recommended 60ms. Gamers should find a generally lag-free experience, especially on 5G.
- **Outstanding jitter and packet loss:** Each operator's jitter and packet loss results were excellent on both 5G and 4G LTE, with all three operators registering jitter of 0.0ms on 5G.
- **Widespread 5G availability in Seoul, with LG U+ leading the competition:** LG U+ offered the most 5G in Seoul at 90.9%, allowing its 5G gamers to access the operator's incredibly fast speeds and strong gaming results nearly all the time. KT and SK Telecom weren't far behind, with generally widespread 5G availability of at least 71.3%.

Which operators met the game providers' recommended speed and latency results in Seoul?

## Met median download speed recommendations in Seoul

### 4G LTE

Casual games in SD (10+ Mbps)



Online games in HD (35+ Mbps)



### 5G

Casual games in SD (10+ Mbps)



Online games in HD (35+ Mbps)



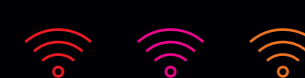
## Met latency recommendation in Seoul

### 4G LTE

Casual games in SD (<60ms)



Online games in HD (<60ms)

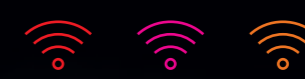


### 5G

Casual games in SD (<60ms)



Online games in HD (<60ms)



● KT ● LG U+ ● SK Telecom 📶 Met speed or latency recommendations

An operator-by-operator look  
at the real-world gaming  
experience in Seoul





KT's network should provide an excellent gaming experience for any type of game on either 4G LTE or 5G, but users on 5G should enjoy even faster and more responsive gaming.

KT's gaming metrics were outstanding across the board. Its speed, latency, packet loss, and jitter results on both 5G and 4G LTE exceeded all recommended benchmarks for smooth gaming of any type, from casual games in SD to multiplayer games in HD. That said, the gaming experience for users on KT's 5G network should be far quicker than that on 4G LTE.

KT's impressive 5G median download speed of 425.8 Mbps, while not as fast as those of the other operators, was over 7 times faster than its speed on 4G LTE (59.8 Mbps) and roughly 12 times faster than Google Stadia's recommended speed of at least 35 Mbps for multiplayer games in HD. Further, KT's 5G latency of 25.0ms was approximately twice as low as its latency on 4G LTE and much lower than Microsoft's recommended latency of 60ms or lower. It was also far lower than that of SK Telecom (45.0ms) but not quite as low as the 5G latency we recorded for LG U+ (20.5ms).

KT also excelled in our measures of packet loss and jitter. Low packet loss and jitter can lead to seamless gaming, and KT certainly delivered in that regard, recording packet loss of 0.0% and jitter of 0.0ms on both 5G and 4G LTE. Even better news is that KT's 5G availability was generally widespread at 78.8% (though not as high as LG U+'s 90.9%), providing KT's 5G gamers with access to its strong 5G results most of the time.

**The bottom line** is that while KT gamers on 4G LTE should enjoy smooth gameplay, the gaming experience on 5G should be far better. With incredibly fast 5G speeds, low latency, and strong results across the board, KT's 5G gamers should find quick video rendering and lag-free gameplay along with great audio and chat functionality.

YES NO

KT 5G availability 78.8%

KT speeds	4G LTE median download speed	5G median download speed		
Median download speed	59.8 Mbps	425.8 Mbps		
Met recommended speed for casual games in SD (10+ Mbps)?				
Met recommended speed for online games in HD (35+ Mbps)?				

KT latency	4G LTE latency	5G latency		
KT latency	51.0ms	25.0ms		
Met recommended latency for casual games in SD and online games in HD (<60ms)?				

KT packet loss and jitter	4G LTE packet loss	5G packet loss	4G LTE jitter	5G jitter
KT packet loss and jitter	0.0%	0.0%	0.0ms	0.0ms
Met recommended packet loss (3%) and jitter (<30ms) for casual games in SD?				
Met recommended packet loss (<1%) and jitter (<10ms) for online games in HD?				

Note: Packet loss and jitter recommendations are from RootMetrics (not the game providers).



# LG U+


LG U+ delivers outstanding gaming results on 5G in Seoul, including the fastest 5G speed, the lowest 5G latency, and the most 5G of any network.

Great news for gamers on LG U+'s 5G network in Seoul: the operator easily blew away all recommended benchmarks for any type of game.





Indeed, LG U+ clocked the fastest 5G median download speed in the city at an exceptional 476.5 Mbps, the lowest 5G latency at 20.5ms, near-perfect packet loss of just 0.2%, and jitter of 0.0ms. Perhaps more importantly, LG U+ recorded the highest 5G availability of any network in Seoul at 90.9%, allowing LG U+ 5G gamers to connect to 5G and enjoy the superb results that come with it nearly anytime they use their smartphone.



In addition to providing great gaming on 5G, LG U+ also surpassed all gaming benchmarks on 4G LTE. The main difference for LG U+ gamers on 5G compared to those on 4G LTE should come down to speed and latency: the operator's 5G speed was about seven times faster than that on 4G LTE, and its 5G latency was a little over twice as low as its latency on 4G LTE. LG U+'s packet loss of 0.2% on 5G, meanwhile, was five times lower than its still-low packet loss of 1.0% on 4G LTE, though the operator's jitter results were generally similar—and excellent—on 5G and 4G LTE.









**The bottom line** is that LG U+ delivered extraordinary gaming results across the board on 5G, providing gamers with a top-notch experience, whether for casual games like Tetris in SD or multiplayer games like League of Legends in HD.

 YES  NO

LG U+ 5G availability 90.9%

LG U+ speeds	4G LTE median download speed	5G median download speed
Median download speed	69.0 Mbps	476.5 Mbps
Met recommended speed for casual games in SD (10+ Mbps)?		
Met recommended speed for online games in HD (35+ Mbps)?		

LG U+ latency	4G LTE latency	5G latency
LG U+ latency	52.5ms	20.5ms
Met recommended latency for casual games in SD and online games in HD (<60ms)?		

LG U+ packet loss and jitter	4G LTE packet loss	5G packet loss	4G LTE jitter	5G jitter
LG U+ packet loss and jitter	1.0%	0.2%	-1.0ms	0.0ms
Met recommended packet loss (3%) and jitter (<30ms) for casual games in SD?				
Met recommended packet loss (<1%) and jitter (<10ms) for online games in HD?				

Note: Packet loss and jitter recommendations are from RootMetrics (not the game providers).

# SK Telecom

SK Telecom also exceeds all gaming benchmarks on both 5G and 4G LTE while providing 5G gamers with an especially smooth experience.

SK Telecom users in Seoul should find a much better gaming experience on 5G compared to that on 4G LTE. SK Telecom's 5G results were generally outstanding, with a remarkable 5G median download speed of 436.2 Mbps (roughly 12 times faster than Google Stadia's recommendation of 35+ Mbps) along with perfect 5G packet loss of 0.0% and jitter of 0.0ms. The operator's 5G latency, meanwhile, while the highest in the city, still came in well below Microsoft's recommended latency of 60ms and should give users a lag-free experience.

While SK Telecom's 5G availability of 71.3% was the lowest in the city, it's still generally broad and will allow users to access 5G far more often than not, allowing gamers to take advantage of the operator's excellent 5G speed, packet loss, and jitter results in the process.

SK Telecom's results on 4G LTE also surpassed all recommended thresholds. Its strong median download speed of 98.3 Mbps was the fastest in the city and would easily support any type of game. Likewise, SK Telecom's packet loss and jitter results on 4G LTE were nearly perfect, and the operator's latency on 4G LTE of 48.5ms was low enough to provide smooth gaming of any type and similar to its latency of 45.0ms on 5G.

**The bottom line** is that with strong gaming results on both 5G and 4G LTE, SK Telecom gamers in Seoul should find a good gaming experience for any type of game, regardless of network technology.

YES NO

SK Telecom 5G availability 71.3%

SK Telecom speeds	4G LTE median download speed	5G median download speed
Median download speed	98.3 Mbps	436.2 Mbps
Met recommended speed for casual games in SD (10+ Mbps)?		
Met recommended speed for online games in HD (35+ Mbps)?		

SK Telecom latency	4G LTE latency	5G latency
SK Telecom latency	48.5ms	45.0ms
Met recommended latency for casual games in SD and online games in HD (<60ms)?		

SK Telecom packet loss and jitter	4G LTE packet loss	5G packet loss	4G LTE jitter	5G jitter
SK Telecom packet loss and jitter	0.5%	0.0%	0.0ms	0.0ms
Met recommended packet loss (3%) and jitter (<30ms) for casual games in SD?				
Met recommended packet loss (<1%) and jitter (<10ms) for online games in HD?				

Note: Packet loss and jitter recommendations are from RootMetrics (not the game providers).

# What happens to gameplay when speeds slow down?

Whether you're using your smartphone to play a relatively simple casual cloud game like Tetris or a more complicated game like League of Legends, any interruption can be frustrating and could mean the difference between winning and losing.

While this report has focused on median download speeds to show the most typical speed experience for mobile cloud gaming, avid gamers might also want to understand what can happen to the gaming experience if their speeds lag.

To that end, we're also showing the slowest or "worst case" download speeds we recorded for each operator on both 4G LTE and 5G. These were speeds found during only 5% of our tests and don't necessarily need to be factored into a typical gaming experience. Instead, consider this a worst-case scenario to keep in mind for your most important matches in Seoul, from Fortnite to Final Kick 2020 or any other game you might enjoy.

	Casual games in SD	Multiplayer online games in HD
Recommended median download speeds	10+ Mbps	35+Mbps
Recommended latency	<60ms	

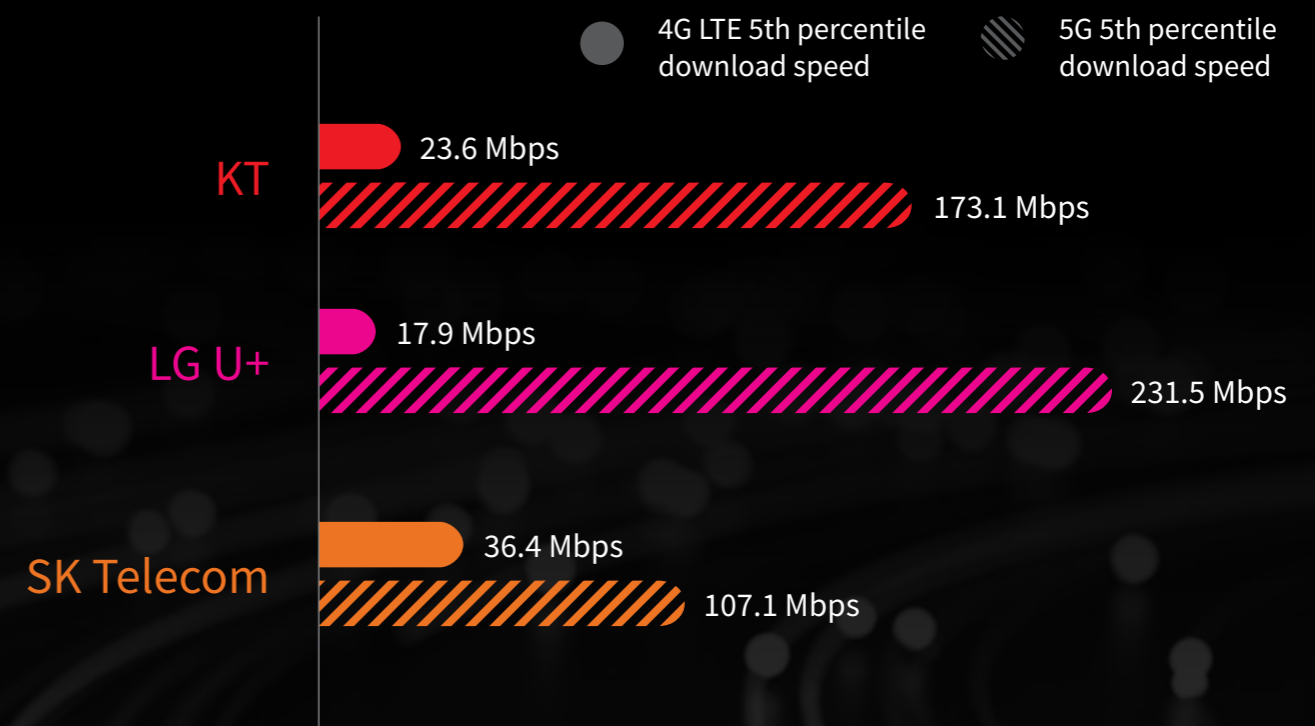
As you can see, LG U+'s 5G speed was the standout, with the operator's worst-case (5th percentile) download speed on 5G clocking in at a stunning 231.5 Mbps that would easily support any type of game.

KT and SK Telecom also delivered impressive worst-case download speeds that would support either casual games in SD or multiplayer online games in HD. The good news for gamers in Seoul is that with 5G availability generally high across the board in the city and all three operators clocking fast 5G speeds, gamers on 5G should still experience incredibly quick gaming even when things "slow down." Indeed, consumers likely won't even notice a change when speeds dip to this "worst case" scenario.

Moreover, these "worst-case" speeds are fast enough for consumers to access content and entertainment faster than users in other countries at many of the "typical" or median download speeds we've seen on 5G.

All three operators' worst-case speeds on 5G were also significantly faster than those on 4G LTE. In fact, LG U+'s worst-case speed on 5G was 13 times faster than its worst-case speed on 4G LTE, while KT's worst-case 5G speed was over 7 times faster than that on 4G LTE. SK Telecom's 5G speed, meanwhile, was almost three times faster than its speed on 4G LTE.

While gamers shouldn't find these worst-case speeds very often, they do offer an important barometer for how 5G is advancing the end-user gaming experience.






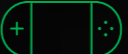




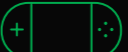



# Operators in Seoul offering the high-level of 5G performance that consumers have long been waiting for

The 5G performances we've seen in Seoul are far superior to those in other countries we've visited and are so impressive that they can help power connected communities fully and ultimately set the stage for new use cases and applications that wouldn't be possible in other countries.

Gaming, in fact, is an excellent example of a use case in which 5G can (pardon the pun) change the game. Just a few years ago, cloud gaming on a 4G LTE smartphone would have been a risky endeavor; depending on the network, gamers likely experienced extremely annoying delays, sluggish video rendering, and general frustration. However, that's no longer the case in Seoul, especially on 5G.

To put the strong 5G results we recorded in Seoul in broader context, the table on the right shows the 5G availability and speed results for all three networks in Seoul alongside the same metrics on Vodafone's network in London and Sunrise's network in Zurich. We chose to look at the results of Vodafone and Sunrise because both operators registered the fastest 5G median download speed of any operator in their respective city.

 YES  NO

City	Seoul			London	Zurich
	KT	LG U+	SK Telecom	Vodafone	Sunrise
5G availability	78.8%	90.9%	71.3%	9.7%	39.1%
5G median download speed (Mbps)	425.8	476.5	436.2	216.6	324.6
Met recommended speed for casual game in SD (10+ Mbps)?					
Met recommended speed for online games in HD (35+ Mbps)?					

While all five operators delivered great speeds that would support any type of gaming, the 5G availability and speeds in Seoul clearly surpassed those in both London and Zurich. The speeds in Seoul were lightning-fast across the board and much faster than those of Vodafone and Sunrise, but an even more important advantage for users in Seoul is their access to 5G: with 5G availability of at least 71.3% in Seoul, users there can access the fast speeds of 5G far more often than Vodafone users in London or Sunrise customers in Zurich. LG U+ in particular shined, providing users with access to 5G nearly every time they use their smartphone.

# Conclusion: looking ahead at 5G and the gaming experience in Seoul and beyond

The promises of 5G include greater capacity, much faster speeds, and lower latency, among other advantages. In combination, those benefits should eventually lead to dramatic improvements for cloud gaming on mobile devices, especially when we reach a point where latencies become consistently lower than what we're seeing today.

The good news is that we're already seeing incredibly fast speeds, generally low latencies, and excellent packet loss and jitter results on 5G in Seoul that should power extremely quick video rendering and delay-free gaming. Going forward, when the remarkably fast 5G speeds and near-perfect packet loss and jitter results we recorded in Seoul are coupled with ultra-low latencies that approach zero, the gaming experience on a smartphone or other connected device in Seoul should get even stronger and could be akin to playing a game on a heavy-duty gaming PC or a console.

It's also important to keep in mind that the 5G results we've seen in Seoul are outstanding and much better than what we've recorded in other cities around the globe to date. In fact, the 5G results we recorded in Seoul could offer an encouraging proxy for what's to come in other countries, with the broader 5G availability, super-fast 5G speeds, and strong 5G results in general potentially acting as a blueprint for 5G in cities around the world. For now, the good news is that both the present and future of mobile cloud gaming in Seoul is clearly bright.

We'll continue testing the networks to keep an eye on how 5G can impact the real-world mobile cloud gaming experience as we move further in 2021 and beyond.





For more information, visit

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