

# Mobile cloud gaming: the real-world cloud gaming experience in Los Angeles







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# The 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 carriers in Los Angeles can deliver a smooth mobile cloud gaming experience for both casual games in standard definition and multiplayer online games in high definition on 4G LTE compared to 5G. Note that the results in this report are specific to gaming in LA, and the gaming experience could be different in other cities.

Why did we choose Los Angeles? LA is a city of innovation, a driver of entertainment trends, and one of the first markets where all four carriers offered 5G services. 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 Los Angeles.

**IHS Markit** expects the cloud gaming content and services markets to grow from **\$387 million in 2018 to \$2.5 billion in 2023**, with 5G driving much of that growth.

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 video 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 Call of Duty could eventually be as smooth on a smartphone as it is using 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 the bare minimum download speeds and latency established by three major gaming platforms:

Google  
Stadia

Microsoft  
xCloud

Steam  
Remote  
Play

Using the bare minimum speed and latency requirements set by those platforms, we took results from our most recent mobile performance testing in Los Angeles in the first half of 2020 to show which carriers are capable of delivering smooth mobile cloud gaming experiences on both 4G LTE and 5G.

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 Madden NFL 2020.



# 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.

Streaming games on the cloud is similar to streaming a movie on Netflix, but with cloud gaming, the user is in control. For example, when streaming a movie on Netflix, the user has zero influence on what happens in a scene, but with cloud gaming, the user's inputs guide every stage of the game.

In effect, gamers send commands from a mobile device to platforms like Stadia or xCloud or Steam's Remote Play by, say, 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 speeds and latency 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 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 has multiple benefits for gamers. It's much cheaper since there's no need to buy consoles or gaming PC's, and if the user's smartphone or other connected device breaks or freezes temporarily while cloud 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). Plus, gaming companies need only pay for bandwidth that gamers use while playing, which is far less expensive than manufacturing physical copies of games. Further, cloud gaming is a perfect medium for cross-promotional opportunities. Consider Fortnite, for example: it's free to play, but in-game upgrades have led to millions of dollars in sales.

While the benefits are almost countless, 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 PC's 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 and low enough latency, an Esports competitor could play a high-stakes Fortnite 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 recently conducted a **comprehensive study of always-on mobile users**, and while faster data speeds topped the list of what users want and expect, **our study also 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.



# 5G, edge computing, and lower latency

While latency is an inherent challenge for cloud gaming, good news is on the horizon in the form of 5G and edge computing, both of which will allow game providers to mitigate the effects of latency on gameplay.

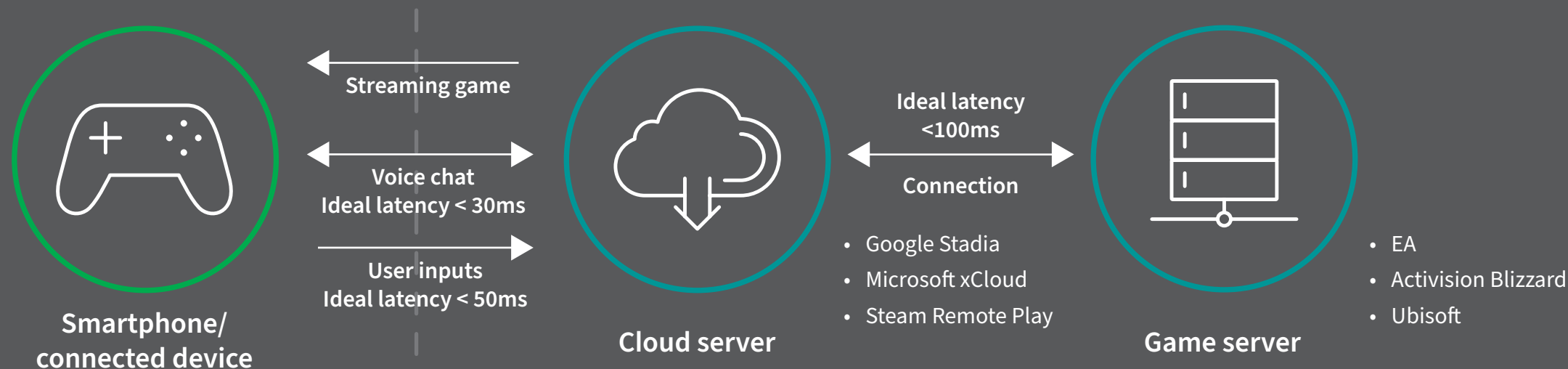
5G will provide greater capacity that will allow cloud gaming providers to support countless games at the same time (and more and more users), and it will also improve the gaming experience in areas of heavy congestion. Perhaps more importantly, 5G will also (eventually) provide much lower latency and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

Edge computing, meanwhile, is perhaps the best tool game providers and mobile carriers 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 the user is from that server, the more lag they're likely to experience. That's a particularly big issue for multiplayer online games or Esports competitions where every frame is critical and even the smallest delay could mean the end of the game.

That said, edge computing could help level the latency playing field and remove any 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 LA below and those recommended by the game providers, 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 carriers and cloud providers, it's always there. That being said, if latency is reduced on the carrier side by 5G or edge computing, then overall lag will be reduced, even though that 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 that don't rely on edge computing or the promises of 5G to mitigate the impact of latency.

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, the user recognizes that he or 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 happens over time, and it can reduce lag.

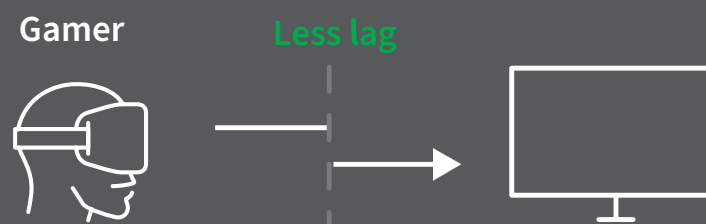
Game-adjusted latency is also common, though it's unpredictable in that gamers don't know which games have been adjusted to compensate for lag. In effect, game-adjusted latency happens when game developers learn that higher-than-normal latency occurs at certain points in a game and then create ways to 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 that target by a pixel or two so that gamers are more likely to hit the mark and move to the next phase of the game.

## Compensated latency

### Ideal latency

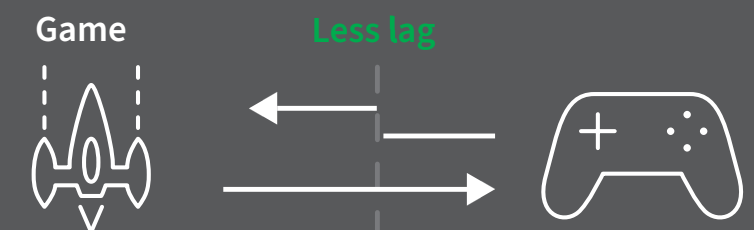


### User-adjusted latency



Gamer adjusts behavior.

### Game-adjusted latency



Game developers modify certain points in a game.



# Benchmarking what matters most to gamers

To provide a holistic view of each network's ability to reach or surpass the bare minimum speed and latency requirements for streaming games as determined by Stadia, xCloud, and Remote Play, we've included visuals below showing each carrier's 5G availability, 4G LTE and 5G speeds, and 4G LTE and 5G latency results along with other key metrics and insights for the end-user gaming experience.

We tested each carrier's latency during our secure web and app testing, which measures latency during activities that require continuous data usage, such as gaming and AR/VR. We also looked at whether each carrier met the bare minimum speed and latency requirements on 4G LTE compared to results recorded entirely on 5G. Taken together, this complementary information provides a full picture of the current end-user gaming experience in Los Angeles on both 4G LTE and 5G.



## 5G median download speeds

End-users won't always access a 5G network as they move through a city, so we've removed all non-5G (4G LTE) test results to show what to expect when 5G is available. Our 5G median download speeds offer a look at "everyday" 5G speeds and show how those speeds can impact cloud gaming when gamers connect to 5G.



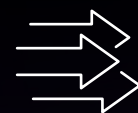
## 4G LTE median download speeds

Since an end-user won't access 5G all the time (or hasn't upgraded to 5G yet), 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 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 on 4G LTE.



## 4G LTE and 5G latency

Latency is critical for gamers—even more so than speed—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 4G LTE and 5G to offer a look at the end-user latency experience on 4G LTE compared to that on purely 5G.



## 4G LTE and 5G jitter

While latency is arguably the single most important factor for mobile cloud gaming, jitter can also cause problems for gamers if it's too high. Jitter, which we measure during our UDP tests, effectively 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). We looked at jitter on both 4G LTE and 5G to provide a closer look at how 5G can impact jitter and the real-world gaming experience. In order for smooth gaming, we recommend jitter below 30ms for casual games in SD and below 10ms for online games in HD. We've included these recommendations in the carrier sections below.



## 4G LTE and 5G packet loss

Like jitter, we measure packet loss during our UDP tests. 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 4G LTE and 5G to show how packet loss affects the gaming experience across different technologies. We consider packet loss below 3% low enough for smooth casual gaming in SD, while packet loss for multiplayer online games in HD should be around 1% or lower. In the carrier sections below, we've defined our recommended packet 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, generally speaking, casual games are usually not as fast paced or precise as multiplayer online games like Call of Duty or Tomb Raider. 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 measured the quality of each carrier's mobile cloud gaming experience

Google Stadia, Microsoft xCloud, and Steam Remote Play each use the same “bare minimum” speed and latency requirements for casual and online cloud games in both standard definition (720p) and high definition (1080p).

Those minimums are, according to the providers, the absolute slowest speeds and highest latency that gamers need to play different types of cloud games in either standard- or high-definition. That said, while the bare minimum latencies range from 10-30ms, some gaming developers have publicly stated that latency below 50ms should provide a generally good mobile gaming experience (especially for relatively simple single-player casual games), so we've kept that in mind in our carrier-by-carrier section below.

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

| Bare minimum speed and latency | Casual games in standard definition (720p) | Online games in high definition (1080p) |
|--------------------------------|--------------------------------------------|-----------------------------------------|
| Minimum download speed         | 7-10 Mbps                                  | 20-35 Mbps                              |
| Minimum latency                | 10-30ms                                    | 10-30ms                                 |

With those bare minimum requirements established, we looked at results from the four major mobile carriers in Los Angeles during our testing in 1H 2020 to determine which networks could provide a good mobile gaming experience for casual games in standard definition and multiplayer online games in high definition. In short, we compared each carrier's speed and latency results on 4G LTE and 5G to the bare minimum speed and latency requirements of those three cloud game providers. In addition, even though the providers didn't set bare minimum requirements 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.



# The results: what we found for the mobile cloud gaming experience in LA

Which carriers met the bare minimum  
speed and latency requirements in LA?

## Met median download speed requirements:

### 4G LTE

Casual games (SD)



Online games (HD)



### 5G

Casual games (SD)



Online games (HD)



## Met minimum latency requirements: None

● AT&T ● Sprint ● T-Mobile ● Verizon

## High-level key findings:

Our carrier-by-carrier section below includes insights on the gaming experience for each network in LA on both 4G LTE and 5G, but in a nutshell, some of the high-level findings from our study on mobile cloud gaming include:

- Casual cloud gaming on mobile devices should be a relatively smooth experience, but playing multiplayer online games could be challenging on most networks, even on 5G.
- Speeds were generally fast enough for both casual and multiplayer online gaming for all four carriers in LA.
- Latency was a different story, with none of the carriers meeting the 10-30ms minimum latency requirement set by the game providers.



A person is shown from the chest down, sitting and holding a black video game controller with both hands. They are wearing a brown long-sleeved shirt and blue jeans. A gold watch is visible on their left wrist. The background is dark and out of focus, suggesting an indoor setting. The text "A carrier-by-carrier look at the real-world gaming experience on 4G LTE and 5G" is overlaid in a light blue, sans-serif font on the upper left portion of the image.

# A carrier-by-carrier look at the real-world gaming experience on 4G LTE and 5G





AT&T’s speeds were fast enough for both casual and multiplayer online gaming, with only minor lag likely during precision-based games like Call of Duty.

AT&T’s median download speeds on both 4G LTE and 5G easily surpassed the bare minimum speed requirements set by the cloud gaming platforms. AT&T’s latency, meanwhile, was by far the lowest among all four carriers in LA on both 4G LTE and 5G and was very close to the minimums of the providers.

While AT&T’s latency was the lowest among the carriers, it was still slightly higher than the game providers’ 30ms minimum standard on both 4G LTE and 5G. That said, the good news is that in the context of mobile cloud gaming, latency below 50ms is generally low enough to allow for relatively smooth gameplay for both casual games in SD and most multiplayer online games in HD.

AT&T’s 5G jitter and packet loss results were also quite strong and surpassed the recommended metrics we’ve identified, and both jitter and packet loss improved for the carrier on 5G compared to 4G LTE.

In short, gamers on AT&T’s network should be able to play casual games in SD without much (if any) trouble, and fans of multiplayer online games like Fortnite should also find a relatively smooth experience on mobile devices, though possibly with some minor lag.

| Latency and the effect on gaming |                                                                                    |
|----------------------------------|------------------------------------------------------------------------------------|
| Zero                             | Ideal                                                                              |
| 10-30ms                          | Minimum required by gaming platforms                                               |
| <50ms                            | A smooth experience for casual games in SD and most multiplayer online games in HD |
| >70ms                            | Could lead to lag or buffering for multiplayer online games in HD                  |

| AT&T 5G availability 18.3%                                                                  |                              |                        |                          |                        |
|---------------------------------------------------------------------------------------------|------------------------------|------------------------|--------------------------|------------------------|
| YES NO                                                                                      |                              |                        |                          |                        |
| AT&T speeds                                                                                 | 4G LTE median download speed |                        | 5G median download speed |                        |
| Median download speed                                                                       | 35.3 Mbps                    |                        | 37.5 Mbps                |                        |
| Met minimum for casual game in SD (7-10 Mbps)?                                              | <div><div></div></div>       |                        | <div><div></div></div>   |                        |
| Met minimum for online games in HD (20-35 Mbps)?                                            | <div><div></div></div>       |                        | <div><div></div></div>   |                        |
| AT&T latency                                                                                | 4G LTE latency               |                        | 5G latency               |                        |
| AT&T latency                                                                                | 44.0ms                       |                        | 45.5ms                   |                        |
| Met minimum for casual games in SD and online games in HD (10-30ms)?                        | <div><div></div></div>       |                        | <div><div></div></div>   |                        |
| AT&T packet loss and jitter                                                                 | 4G LTE packet loss           | 5G packet loss         | 4G LTE jitter            | 5G jitter              |
| AT&T packet loss and jitter                                                                 | 2.6%                         | 1.7%                   | 10.0ms                   | 5.0ms                  |
| Met recommended packet loss (3%) and jitter (<30ms) for casual games in SD?                 | <div><div></div></div>       | <div><div></div></div> | <div><div></div></div>   | <div><div></div></div> |
| Met recommended packet loss (<1%) and jitter (<10ms) for online games in HD?                | <div><div></div></div>       | <div><div></div></div> | <div><div></div></div>   | <div><div></div></div> |
| Note: Packet loss and jitter recommendations are from RootMetrics (not the game providers). |                              |                        |                          |                        |



# Sprint

Sprint’s network should provide a smooth experience for casual gamers, though fans of multiplayer online games could see some issues.

Sprint’s 4G LTE and 5G median download speeds were fast enough to provide both smooth casual gaming and multiplayer online gaming, and even though the carrier’s latency was above the bare minimum threshold for casual games in standard definition, we expect that gamers should still be able to play most casual games without much hassle—especially games that don’t rely on quick reactions and make minimal use of graphics.

That said, the carrier’s latency will likely cause issues for fans of multiplayer online games like Fortnite in HD. Sprint’s 4G LTE latency of 95.0ms was over three times as high as what the platforms consider the minimum needed for any type of cloud gaming, and Sprint’s latency on 5G was actually higher at 127.0ms. However, since latency is far more important for online games that require quick responses and precision timing, Sprint users interested in casual games should be able to play games like Candy Crush and plenty of others on a smartphone without much trouble.

Sprint’s packet loss could also cause issues for multiplayer online games. Sprint’s packet loss was higher than what we recorded for the other carriers, with a rate close to 5% on 4G LTE and a little over 4% on 5G. When packet loss is over roughly 3%, gamers can experience choppy audio, poor video, distorted chat functionality, and lag during play, especially for multiplayer online games in high definition. Poor chatting can be particularly frustrating because it can prevent you from planning strategies with your friends.

While Sprint’s latency and packet loss could prove difficult for some multiplayer online games, the future of Sprint’s 5G appears bright. Sprint’s relatively widespread 5G availability in LA and its impressive 5G median download speed of 61.8 Mbps (compared to 33.0 Mbps on 4G LTE) suggest that Sprint’s mid-band spectrum 5G network is clearly showing improvement over 4G LTE, and we expect Sprint to deliver lower latency on 5G going forward.

| Latency and the effect on gaming |                                                                                    |
|----------------------------------|------------------------------------------------------------------------------------|
| Zero                             | Ideal                                                                              |
| 10-30ms                          | Minimum required by gaming platforms                                               |
| <50ms                            | A smooth experience for casual games in SD and most multiplayer online games in HD |
| >70ms                            | Could lead to lag or buffering for multiplayer online games in HD                  |

| Sprint 5G availability 25.1%                                                 |                              |                |                          |           |
|------------------------------------------------------------------------------|------------------------------|----------------|--------------------------|-----------|
| YES NO                                                                       |                              |                |                          |           |
| Sprint speeds                                                                | 4G LTE median download speed |                | 5G median download speed |           |
| Median download speed                                                        | 33.0 Mbps                    |                | 61.8 Mbps                |           |
| Met minimum for casual game in SD (7-10 Mbps)?                               | YES                          |                | YES                      |           |
| Met minimum for online games in HD (20-35 Mbps)?                             | YES                          |                | YES                      |           |
| Sprint latency                                                               | 4G LTE latency               |                | 5G latency               |           |
| Sprint latency                                                               | 95.0ms                       |                | 127.0ms                  |           |
| Met minimum for casual games in SD and online games in HD (10-30ms)?         | NO                           |                | NO                       |           |
| Sprint packet loss and jitter                                                | 4G LTE packet loss           | 5G packet loss | 4G LTE jitter            | 5G jitter |
| Sprint packet loss and jitter                                                | 4.8%                         | 4.2%           | 47.0ms                   | 35.0ms    |
| Met recommended packet loss (3%) and jitter (<30ms) for casual games in SD?  | NO                           | NO             | NO                       | NO        |
| Met recommended packet loss (<1%) and jitter (<10ms) for online games in HD? | NO                           | NO             | NO                       | NO        |

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



# T-Mobile

T-Mobile’s speeds and latency were strong enough for most mobile cloud games, and the carrier’s widespread 5G led to faster speeds, improved packet loss, and lower jitter.

T-Mobile’s 5G speeds were fast enough for casual and multiplayer online games in both SD and HD, and the carrier’s 5G availability was far more widespread than that of the other carriers, with 32.1% of our tests recorded on 5G. T-Mobile’s 5G helped the carrier improve its median download speed from 16.4 Mbps on 4G LTE to a much stronger 24.3 Mbps on 5G. In fact, T-Mobile’s 5G could make a big difference for gamers: the carrier’s 5G median download speed surpassed the minimum speed requirements for both SD and HD gaming, but T-Mobile’s 4G LTE speed fell short for multiplayer online games in HD.

T-Mobile also showed strong packet loss and jitter results on 5G. For instance, on 4G LTE, T-Mobile registered a relatively high packet loss rate of 3.2%, but on 5G, that number dropped to 0.5%, which was bested by only Verizon’s 5G (0.2%). Further, T-Mobile’s jitter improved on 5G, dropping from 24.0ms on 4G LTE to 15.0ms on 5G. In simpler terms, gamers on T-Mobile’s 5G shouldn’t see much impact from packet loss or jitter, especially for casual games in SD.

The carrier’s latency, meanwhile, was lower than that of either Sprint or Verizon but still higher than the minimums set by the game providers. That said, T-Mobile’s latency (roughly 77ms on both 4G LTE and 5G) likely won’t be an issue for fans of casual games in either SD or HD, though latency of around 70ms or higher can lead to some lag and/or jumpy gameplay for multiplayer online games that require precision and accuracy. It can also hurt chatting. In short, T-Mobile gamers playing Fortnite or Overwatch on a smartphone could see some issues, but the less a particular game relies on latency, the better the experience on T-Mobile’s network should be.

With T-Mobile offering the most 5G in LA (and in many other cities we’ve tested), and its 5G showing faster speeds and improved packet loss and jitter, we expect to see lower latency on 5G from the carrier going forward. We also expect that gamers will benefit in general as the carrier continues to invest and expand in its network, and that could happen sooner rather than later: thanks to the merger, once Sprint’s resources are integrated into T-Mobile’s network, T-Mobile and its 5G users could benefit from Sprint’s mid-band 5G spectrum holdings.

| Latency and the effect on gaming |                                                                                    |
|----------------------------------|------------------------------------------------------------------------------------|
| Zero                             | Ideal                                                                              |
| 10-30ms                          | Minimum required by gaming platforms                                               |
| <50ms                            | A smooth experience for casual games in SD and most multiplayer online games in HD |
| >70ms                            | Could lead to lag or buffering for multiplayer online games in HD                  |

| T-Mobile 5G availability 32.1%                                               |  |                                              |                                              |                                              |                                              |
|------------------------------------------------------------------------------|--|----------------------------------------------|----------------------------------------------|----------------------------------------------|----------------------------------------------|
| T-Mobile speeds                                                              |  | 4G LTE median download speed                 |                                              | 5G median download speed                     |                                              |
| Median download speed                                                        |  | 16.4 Mbps                                    |                                              | 24.3 Mbps                                    |                                              |
| Met minimum for casual game in SD (7-10 Mbps)?                               |  | <div><div></div><div></div><div></div></div> |                                              | <div><div></div><div></div><div></div></div> |                                              |
| Met minimum for online games in HD (20-35 Mbps)?                             |  | <div><div></div><div></div><div></div></div> |                                              | <div><div></div><div></div><div></div></div> |                                              |
| T-Mobile latency                                                             |  | 4G LTE latency (ms)                          |                                              | 5G latency (ms)                              |                                              |
| T-Mobile latency                                                             |  | 77.3ms                                       |                                              | 76.5ms                                       |                                              |
| Met minimum for casual games in SD and online games in HD (10-30ms)?         |  | <div><div></div><div></div><div></div></div> |                                              | <div><div></div><div></div><div></div></div> |                                              |
| T-Mobile packet loss and jitter                                              |  | 4G LTE packet loss                           | 5G packet loss                               | 4G LTE jitter                                | 5G jitter                                    |
| T-Mobile packet loss and jitter                                              |  | 3.2%                                         | 0.5%                                         | 24.0ms                                       | 15.0ms                                       |
| Met recommended packet loss (3%) and jitter (<30ms) for casual games in SD?  |  | <div><div></div><div></div><div></div></div> | <div><div></div><div></div><div></div></div> | <div><div></div><div></div><div></div></div> | <div><div></div><div></div><div></div></div> |
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Note: Packet loss and jitter recommendations are from RootMetrics (not the game providers).



# Verizon

Verizon’s 5G provided fast speeds and near-perfect jitter and packet loss, though latency could cause some issues for precision-based games on smartphones.

Verizon’s median download speeds far surpassed the minimum requirements for both casual and multiplayer online gaming, and the carrier’s mmWave 5G delivered a remarkable median download speed of 254.7 Mbps in LA. In fact, that speed ranks among the fastest 5G median download speeds we’ve recorded across our worldwide 5G testing to date. That said, finding consistent access to Verizon’s mmWave 5G could be an issue for gamers in LA. Due to propagation characteristics, Verizon’s mmWave spectrum doesn’t travel as far as low- or mid-band 5G used by the other carriers. Verizon’s lower 5G availability, therefore, isn’t a surprise, and the carrier is using its mmWave resources to provide targeted 5G service where it’s needed the most. To learn more 5G performance, [read our report discussing 5G expansion in the US](#).

In addition to its blazing-fast speeds on 5G, Verizon also had incredibly low 5G packet loss. Verizon has earned a reputation for offering reliable service, and its packet loss metrics certainly support as much. Verizon’s packet loss improved from a strong 1.7% on 4G LTE to a near-perfect 0.2% on 5G. Verizon’s jitter was also outstanding, dropping from an already low 12.0ms on 4G LTE to an outstanding 5.0ms on 5G, which tied with AT&T’s 5G for the lowest jitter in LA. This is all good news for gamers in LA, as packet loss or jitter shouldn’t cause any problems for any type of cloud gaming on Verizon’s 5G network.

While Verizon’s speeds, packet loss, and jitter were strong on both 4G LTE and 5G, the carrier’s latency was among the highest in LA. That said, playing casual cloud games in SD or HD on Verizon’s network should be a relatively smooth experience, but users could see some lag and/or buffering while streaming online games that require precision timing and/or real-time inputs and responses. It’s worth noting that Verizon’s 5G sample size of 14 during our testing in LA was low, and we’ll be looking forward to seeing how the carrier’s speed and latency perform as its availability grows.

The bottom line for Verizon gamers is that the experience of playing casual games should be relatively smooth, especially on 5G, but more complex multiplayer online games could prove a bit challenging. That said, given Verizon’s lightning-fast 5G speeds (both in LA and elsewhere) as well as its low packet loss and jitter, it’s clear that the carrier’s 5G has great potential, and we expect to see lower latency from Verizon going forward.

## Latency and the effect on gaming

|         |                                                                                    |
|---------|------------------------------------------------------------------------------------|
| Zero    | Ideal                                                                              |
| 10-30ms | Minimum required by gaming platforms                                               |
| <50ms   | A smooth experience for casual games in SD and most multiplayer online games in HD |
| >70ms   | Could lead to lag or buffering for multiplayer online games in HD                  |

YES NO

Verizon 5G availability 0.3%

| Verizon speeds                                   | 4G LTE median download speed | 5G median download speed |
|--------------------------------------------------|------------------------------|--------------------------|
| Median download speed                            | 36.9 Mbps                    | 254.7 Mbps               |
| Met minimum for casual game in SD (7-10 Mbps)?   |                              |                          |
| Met minimum for online games in HD (20-35 Mbps)? |                              |                          |

| Verizon latency                                                      | 4G LTE latency | 5G latency |
|----------------------------------------------------------------------|----------------|------------|
| Verizon latency                                                      | 97.5ms         | 121.0ms    |
| Met minimum for casual games in SD and online games in HD (10-30ms)? |                |            |

| Verizon packet loss and jitter                                               | 4G LTE packet loss | 5G packet loss | 4G LTE jitter | 5G jitter |
|------------------------------------------------------------------------------|--------------------|----------------|---------------|-----------|
| Verizon packet loss and jitter                                               | 1.7%               | 0.2%           | 12.0ms        | 5.0ms     |
| 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 FPS game like Call of Duty, 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.

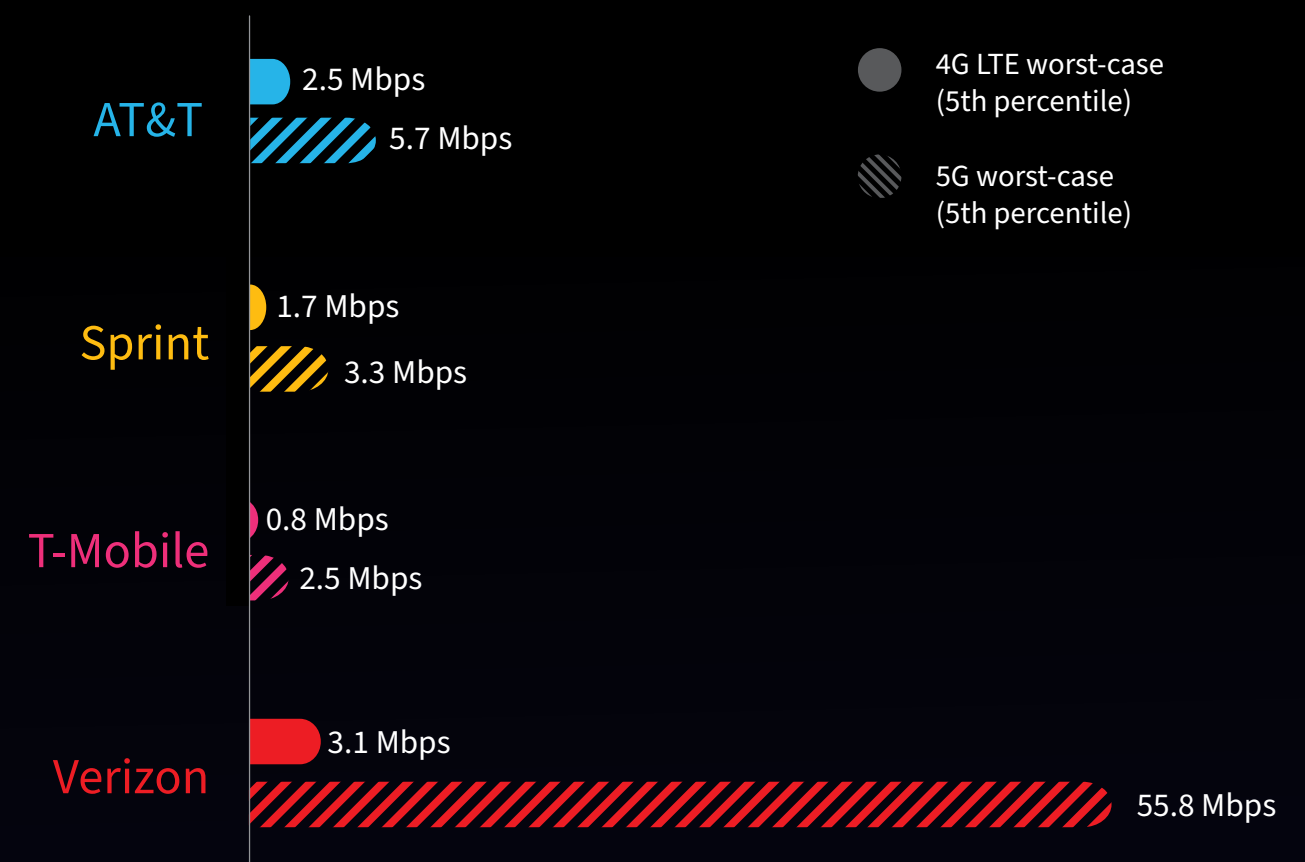
To that end, we're also showing the slowest or "worst case" speeds we recorded for each carrier on both 4G LTE and 5G. These were speeds found during only 5% of our tests and don't necessarily need to be factored into a typical gaming experience.

Instead, consider this a worst-case scenario to keep in mind for your most important battles, from Madden NFL 2020 to Fortnite or any other game you might enjoy.

As you can see, Verizon's mmWave 5G is the standout. The carrier's worst-case (5th percentile) speed on 5G clocked in at a very impressive 55.8 Mbps and would easily support any type of gaming. In fact, that speed is a great example of the transformative potential of mmWave 5G. That said, keep in mind that mmWave 5G availability remains quite limited, with Verizon's 5G recorded during 0.3% of our tests in LA.

The 5G networks of AT&T, Sprint, and T-Mobile, meanwhile, delivered faster worst-case download speeds than those on 4G LTE, but AT&T's 5G worst-case speed was the only one that came close to meeting the cloud game providers' minimum speed requirement for casual games in standard definition. While gamers shouldn't find those worst-case speeds very often (about 5% of the time), they do offer an important barometer for how 5G is advancing the user experience. It's also important to note that we expect this type of worst-case speed scenario to continue to improve over time as 5G matures and expands.

|                                                   | Casual games in SD | Multiplayer online games in HD |
|---------------------------------------------------|--------------------|--------------------------------|
| Bare minimum speed requirements                   | 7-10 Mbps          | 20-35 Mbps                     |
| Bare minimum latency requirements (5G and 4G LTE) | 10-30ms            |                                |





# Conclusion: Looking ahead to 5G and the gaming experience in LA and elsewhere

The promises of 5G include greater capacity, much faster speeds, and lower latency, among others. Taken together, those benefits could eventually lead to dramatic improvements for cloud gaming on mobile devices, especially when we reach a point where latency below 20-30ms is the norm. The faster speeds of 5G should allow for more advanced and faster video rendering, which would allow gamers to stream more complicated online games on their smartphones with ease. And when those faster speeds are coupled with ultra-low latencies, the gaming experience on a smartphone or other connected device could be akin to playing a game on a heavy-duty gaming PC or a console.

While we haven't quite reached that point yet, it's important to keep in mind that we're already seeing encouraging 5G speeds and 5G availability. In short, the 5G landscape is changing fast and the carriers are making great progress, but it will take time before gamers can put away their consoles and start entering Esports competitions on smartphones. Indeed, new technologies always take time to expand and mature. Consider 4G LTE, for example: it took about three to four years for 4G LTE to become ubiquitous for all four carriers across the US, and when it did, the speed and reliability of 4G LTE dwarfed that on 2G or 3G. While 5G is being rolled out in a phased approach, that process has begun in earnest, and the future of 5G and mobile cloud gaming is clearly bright. We'll continue testing the networks to keep an eye on how 5G can impact your real-world mobile cloud gaming experience.

Updated on May 5, 2020: we updated this report to clarify that this study is specific to Los Angeles and gaming results could differ in other cities.





For more information, visit

[www.rootmetrics.com](http://www.rootmetrics.com)

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5G testing and insights? Contact us today:

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