



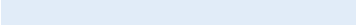
5G IMPACT ON THE GLOBAL MOBILE NETWORK EXPERIENCE

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Opensignal is the independent global standard for analyzing consumer mobile experience. Our industry reports are the definitive guide to understanding the true experience consumers receive on wireless networks.



Approximately once a decade the mobile industry unveils a new network technology standard with the goal of revolutionizing users' mobile network experience. The first commercial 5G networks launched in April 2019 in the U.S. and in South Korea. Many other countries have since followed.

Now, almost three years on, Opensignal examines the real-world impact that 5G has had on the mobile experience. We have analyzed 100 global markets including those with and without 5G services to understand the difference that 5G has made to date.

- How have mobile speeds changed in the first three years of the 5G era?
- Has 5G relieved congestion at peak hours of the day?
- Have markets with 5G deployed early on outperformed those still to launch 5G? Or markets that launched 5G much later?
- To what extent has multiplayer mobile gaming benefited from 5G?

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Key Findings

In the 5G era, overall average download speeds have increased almost everywhere

Across both 4G-only markets and in 5G markets, Download Speed Experience has risen in the last three years. In 95 of 100 global markets, smartphone users have seen their average download speed increase between the first quarter of 2019 – before 5G – and the last quarter of 2021.

Global rankings have changed because of 5G

South Korea now tops global Games Experience, up from 10th place at the start of 2020. Markets where 5G arrived later (e.g. Malaysia, New Zealand, Czech Republic) or where new wireless spectrum capacity for exclusive 5G usage is in short supply (e.g. Singapore) have fallen down the download speed rankings. While those with ample new 5G spectrum have risen, notably Finland, Saudi Arabia, Switzerland, the UK, and the UAE.

National average speeds have broken the 100 Mbps barrier for the first time

In South Korea average download speeds were 129.7 Mbps at the end of 2021, up from 52.4 Mbps at the start of 2019, before 5G. Similarly, our users' speeds more than doubled in Germany rising from 22.6 to 48.7 Mbps, in the Philippines (from 7 to 15.1 Mbps), Saudi Arabia (13.6 to 31.1 Mbps), and in Thailand (5.7 to 17.4 Mbps) – all of which are 5G markets.

All top 20 global markets for Games Experience in 2021 have launched 5G

In first place is South Korea with a score of 88.5 on a 100-point scale, followed by the Netherlands (85.5). Both markets rate as Excellent (85 or above). But there is less evidence that 5G explains these high rankings because comparing the percentage change we see for scores in 4G markets have jumped similarly to the Games Experience in 5G markets.

In 98% of 5G markets speeds have risen at the slowest hour of the day

New 5G wireless spectrum and improved backhaul from cell sites has helped operators relieve congestion. At the slowest hour of the day, typically 8pm or 9pm at night, average download speeds have increased despite growth in mobile data usage.

The best 5G experiences are yet to come

Current 5G networks mostly use Release 15, but there are new standards coming. More wireless spectrum will arrive which should boost speeds considerably, even in markets that already offer 5G. Responsiveness will improve with updated 5G technology, e.g. Release 17. Networks will support many more devices simultaneously. Reliability should be boosted. Analyzing the real-world mobile experience, using a single methodology globally, enables everyone to see if the promises of 5G's designers are being fulfilled for users.

Speeds have risen in the 5G era

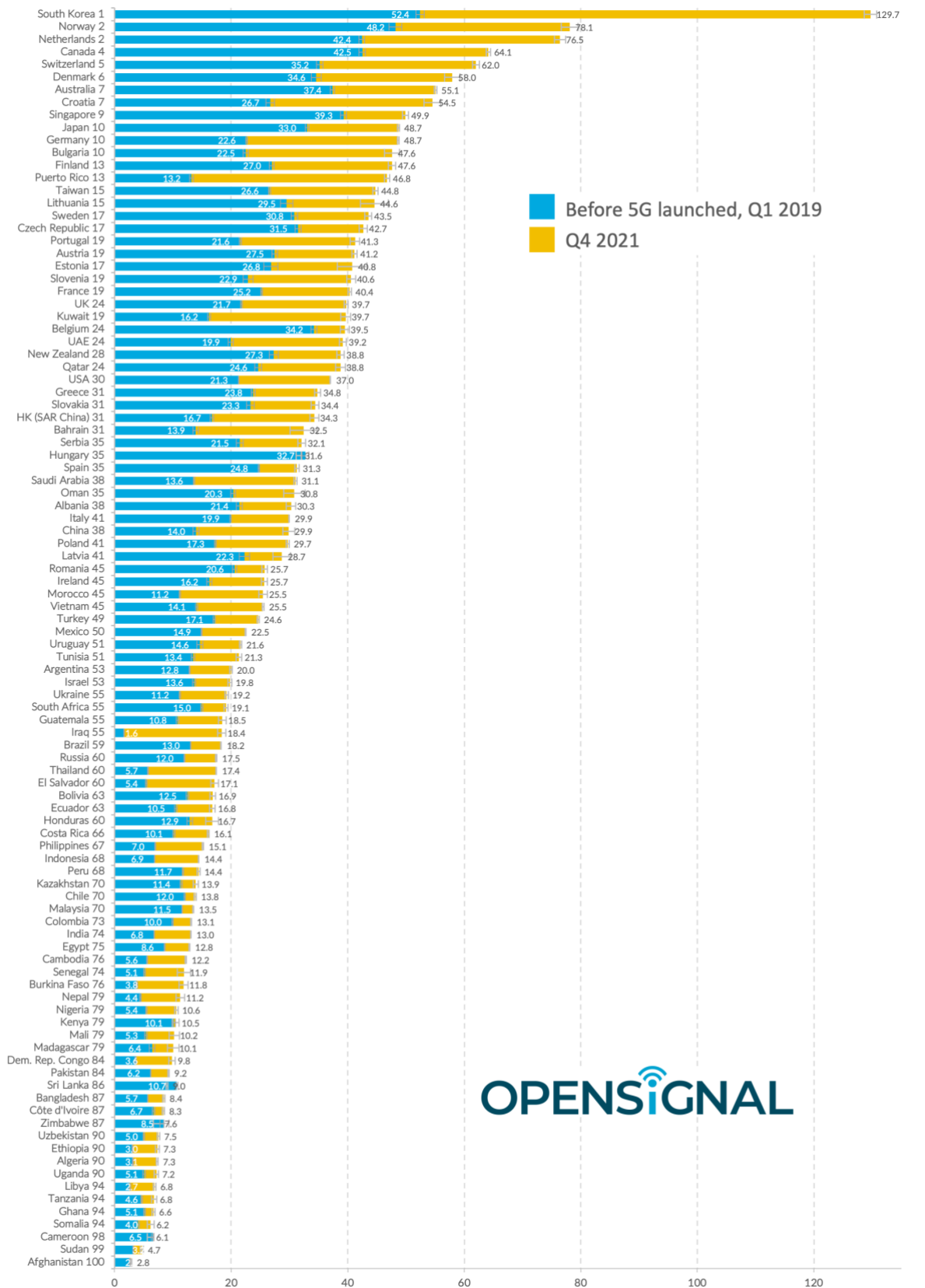
The first markets began launching 5G in the second and third quarters of 2019. Initially, 5G arrived in South Korea and the U.S. but rapidly other markets followed including the UK, Germany, Switzerland and Australia. However, it takes time to see the impact of 5G on the overall mobile experience as 5G not only needs to be significantly different to older technologies but also it has to be adopted by enough mobile users to shift the overall bar.

Over the course of the last three years since 5G's initial small steps we have seen major impacts on the overall mobile network experience of users. The average download speed in numerous markets has increased.

For example, comparing the first quarter of 2019 and the last quarter of 2021, overall Download Speed Experience across global markets has:

- **Broken the 100 Mbps barrier for the first time.** In South Korea average download speeds were 129.7 Mbps at the end of 2021, up from 52.4 Mbps at the start of 2019, before the 5G era.
- **More than doubled speeds in Germany, the Philippines, Saudi Arabia and Thailand.** In Germany, average download speeds increased from 22.6 to 48.7 Mbps, our users saw similar increases in the Philippines (from 7 to 15.1 Mbps), Saudi Arabia (13.6 to 31.1 Mbps), and in Thailand (5.7 to 17.4 Mbps).
- **Caused Singapore and Malaysia to drop down the global ranks.** Strong and early 5G markets have leapfrogged markets where 5G launched late such as Malaysia or where new spectrum for 5G is limited such as Singapore and also Malaysia. In early 2019, Singapore ranked fifth for average download speed out of 100 markets but had fallen to ninth by late 2021. Malaysia fell from 61st to joint 70th in the same period, with 5G services only arriving at [the end of 2021](#) as part of the single 5G wholesale network (Digital Nasional Berhad or DNB).
- **Boosted Switzerland and the UK up the rankings.** Swiss and UK operators were among the first to launch 5G in 2019. Both markets have seen increases in their international position, Switzerland from joint 7th to 5th and the UK from joint 30th to joint 24th across 100 markets.

Download Speed Experience — In the 5G era



Data collection period 1 Jan - 30 Mar 2019 and 1 Oct - 29 Dec 2021 | © Opensignal Limited

Overall Download Speed Experience (Mbps)

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Why 5G impacts the mobile experience

When earlier network technology transitions occurred – from 2G to 3G, or 3G to 4G – the newer network generation was significantly more efficient in its use of spectrum than the older generation¹. This meant all an operator needed to do to improve the experience was deploy the new generation on existing wireless spectrum and their users would see an uplift in the amount and speed of data they could send or receive.

However, with 5G it is not as simple. There are only very modest efficiency gains from deploying 5G instead of 4G on the same amount of spectrum (measured in MHz). Instead, the uplift from 5G stems from the new technology's ability to operate on new spectrum bands not previously available for mobile usage – most commonly in the 3-6 GHz range, and occasionally very high frequency mmWave spectrum (mainly in the U.S. to date).

There are many reasons why 5G helps users to enjoy a better mobile network experience, notably:

- **Large boost in additional wireless spectrum capacity with 5G.** The large quantities of new spectrum, where available, reduce congestion and enable more data consumption. Use of 50-100 MHz of new spectrum capacity between 3 GHz and 5 GHz is common across Europe, Australia, Japan and South Korea. In a few markets where there are only two operators, like the UAE, each operator can have even more new mid-band 5G spectrum allocated.
- **Investments in stronger network foundations benefit 4G users too.** Because 5G boosts radio capacity through the use of new spectrum, operators improve the links connecting cell sites to their core network, as well as often improving other aspects of their network. These help 5G users enjoy a real 5G experience, but they also mean that 4G users often see a significant improvement too because these links are shared across both 4G and 5G users. Operators will even sometimes start these foundational network upgrades ahead of a 5G launch.
- **In time, improved signal reach and a more responsive service.** Newer versions of the 5G standards that leverage a 5G core network and standalone access (SA) aim to reduce network latencies which will help with latency-sensitive applications like real-time communications,

¹ Examples of 2G technologies include GSM, GPRS or Edge; 3G standards are called WCDMA, UMTS or CDMA2000; while the main 4G technology is LTE (Long Term Evolution).

multiplayer gaming and Internet of Things (IoT) uses. This will improve users' experience. But the initial 5G roll outs rely on non-standalone access (NSA). Similarly the reason 5G is suited to new 3-6 GHz spectrum over older 4G is due to its [improved signal reach](#). Users will likely see benefits as operators deploy SA and also put 5G on lower frequency bands, in other words, not quite yet for most 5G users in most markets.

As we have seen, 5G-related investments can boost the experience of users in 4G-only markets through investments in shared infrastructure foundations that boost the 4G experience (and in time the 5G experience) ahead of 5G's arrival. Similarly, they can also boost the experience of 4G users in markets that have already launched 5G. Also, if 5G users connect less to existing 4G frequencies, 5G users' absence can make more room for 4G users to transmit mobile data on 4G bands even in markets where 5G is available.

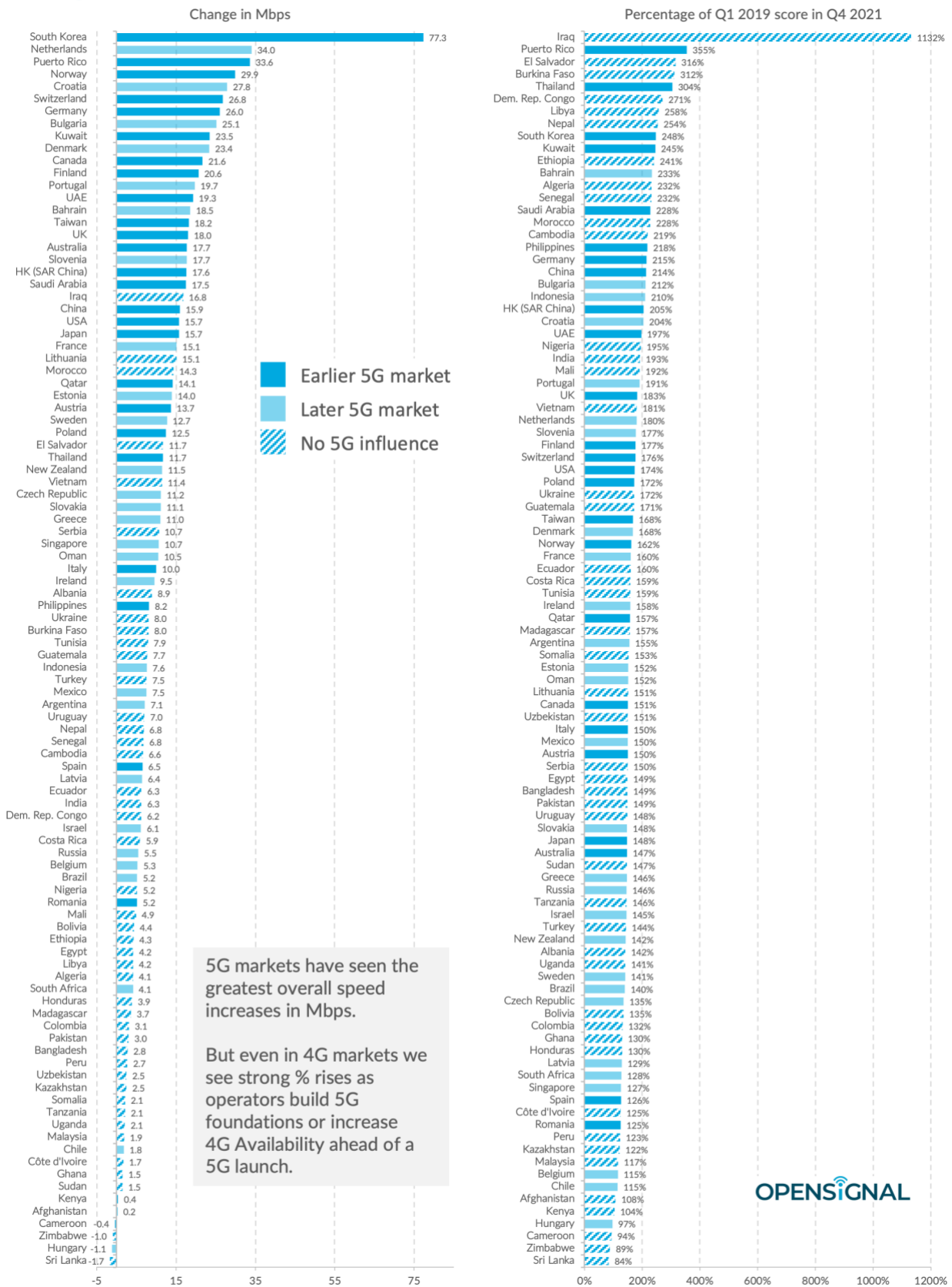
Hence, to understand 5G's complete impact we need to examine both 4G and 5G markets and we need to analyze the overall experience of all users.

We segmented 100 global markets into three groupings to understand how the experience has changed:

- **Earlier 5G market** — 5G services launched for smartphone users either in 2019 or the first half of 2020 from multiple operators.
- **Later 5G market** — Smartphone users saw 5G services in later 2020 or only at some point in 2021. For these markets, there is less time for the improved 5G services and 5G adoption levels to have had an impact on the overall experience in the market.
- **No 5G influence** — Markets where 5G had not fully commercially launched by the end of 2021. In these markets, older technologies such as 4G remain the best network technology.

When we compare markets using this segmentation we can see how and where download speeds have changed during the 5G era.

Change in Download Speed Experience: Q1 2019 - Q4 2021



How 5G markets compare with 4G-only markets

Most markets that saw the greatest increase in average download speeds in Mbps – or the absolute increase – had launched 5G in either the earlier or later 5G grouping. Only ten of the top 50 markets had no 5G impact. By contrast, when we look at the bottom 50 markets on the same basis, the vast majority (37 out of 50) had no 5G.

When we compare the uplift in percentage terms across markets we see a much more mixed picture. Some of the highest average download speed percentage increases are in 4G markets. Iraq tops the list because of the explosion in 4G usage during the period. Other markets without 5G with significant increases include: El Salvador (316% of 2019's average speed), Burkina Faso (312%), Democratic Republic of the Congo (271%), Libya (258%) and Nepal (254%).

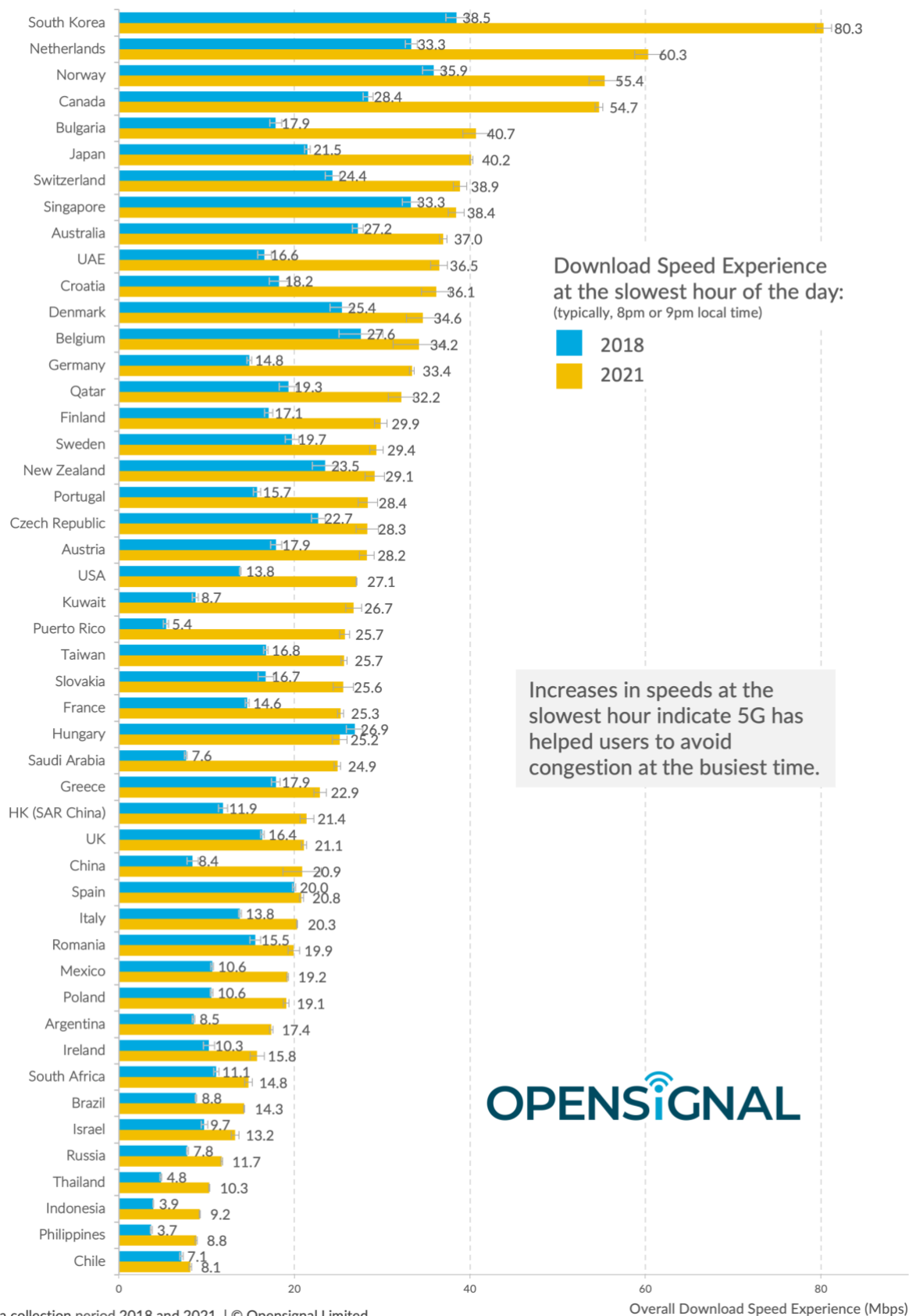
A number of 5G markets also see big percentage increases, notably South Korea – which has the greatest absolute increase of 77.3 Mbps between the first quarter of 2019 and the last quarter of 2021, this represents 248% of 2019's speed. Other markets with large jumps include: Thailand (304%), Kuwait (245%), Saudi Arabia (228%), Philippines (218%), and Germany (215%).

The 5G markets with limited amounts of new wireless spectrum capacity – often relying on dynamic spectrum sharing (DSS) – saw some of the smallest increases in speeds. For example, in Brazil average speeds at the end of 2021 were 140% of early 2019 speeds, Singapore's were 127%, and Belgium and Chile were both 115%. None of these were among the early 5G markets, instead 5G generally arrived in the second half of 2020 or in 2021.

During the busiest hour 5G boosts experience

Three years ago, before 5G smartphone services launched anywhere, Opensignal forecast that 5G would help to solve the congestion problems of 4G networks at peak hours. In the report, "[The 5G Opportunity](#)" we analyzed the difference in experience between nighttime, when networks have little load as users are asleep and speeds are very fast, and the slowest hour of the day. Typically, the hour when users' speeds drop as a result of high mobile data usage is in the evening, either 8-9pm or 9-10pm.

Even at the slowest hour of the day speeds have risen in almost all 5G markets



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Now, we've revisited this analysis to see the extent to which the experience has improved in 5G markets at this slowest hour of the day. Again we compared a time period from before 5G launched anywhere to a recent period. For both, we took a full year of data so that seasonal differences between markets in northern and southern hemispheres had no effect on the comparison.

Across 48 markets with 5G we found that when comparing average download speeds at the slowest hour of day between 2018 and 2021:

- **In 98% of 5G markets speeds have risen at the slowest hour of the day.** If mobile operators had been unable to boost capacity — for example with new wireless spectrum capacity or other 5G-related network investments — then [rising mobile data usage](#) would have depressed speeds. Instead, we have seen the mobile experience improve during the 5G era.
- **Despite the pandemic, the slowest hour of the day is unchanged.** While we have seen [past changes](#) in user behavior during the pandemic, we have seen mobile users behave [more normally](#) laterly. As a result, comparing pre-pandemic with the present, the evening remains the time when users see the slowest speeds indicating it remains the most congested. Now as then, users' mobile video traffic is a key driver of mobile data traffic.
- **Only in Hungary, have speeds not increased.** And, even in that market, the 2018 and 2021 results are statistically tied and users' speeds have not actually dropped.
- **The 5G future is already here — it's just not very evenly distributed.** The size of improvements in the experience varies significantly across 5G markets. In 12 markets (25%), the mobile experience was over twice as fast in 2021 at the slowest hour of the day compared with 2018: Puerto Rico, Saudi Arabia, Kuwait, China, the Philippines, Indonesia, Bulgaria, Germany, the UAE, Thailand, South Korea and Argentina. But in six markets (12.5%) — Czech Republic, Belgium, New Zealand, Singapore, Chile and Spain — the speed boost was one quarter or less.

The 5G future: more responsive and reliable

5G markets are top for global Games Experience

All of the top 20 global markets for real-time multiplayer mobile gaming in 2021 have launched 5G. In first place is South Korea with a score of 88.5 on a 100-point scale, followed by the Netherlands (85.5). Both markets rate as Excellent (85 or above) meaning the vast majority of users deemed this network experience acceptable and there was not a noticeable delay in almost all cases.

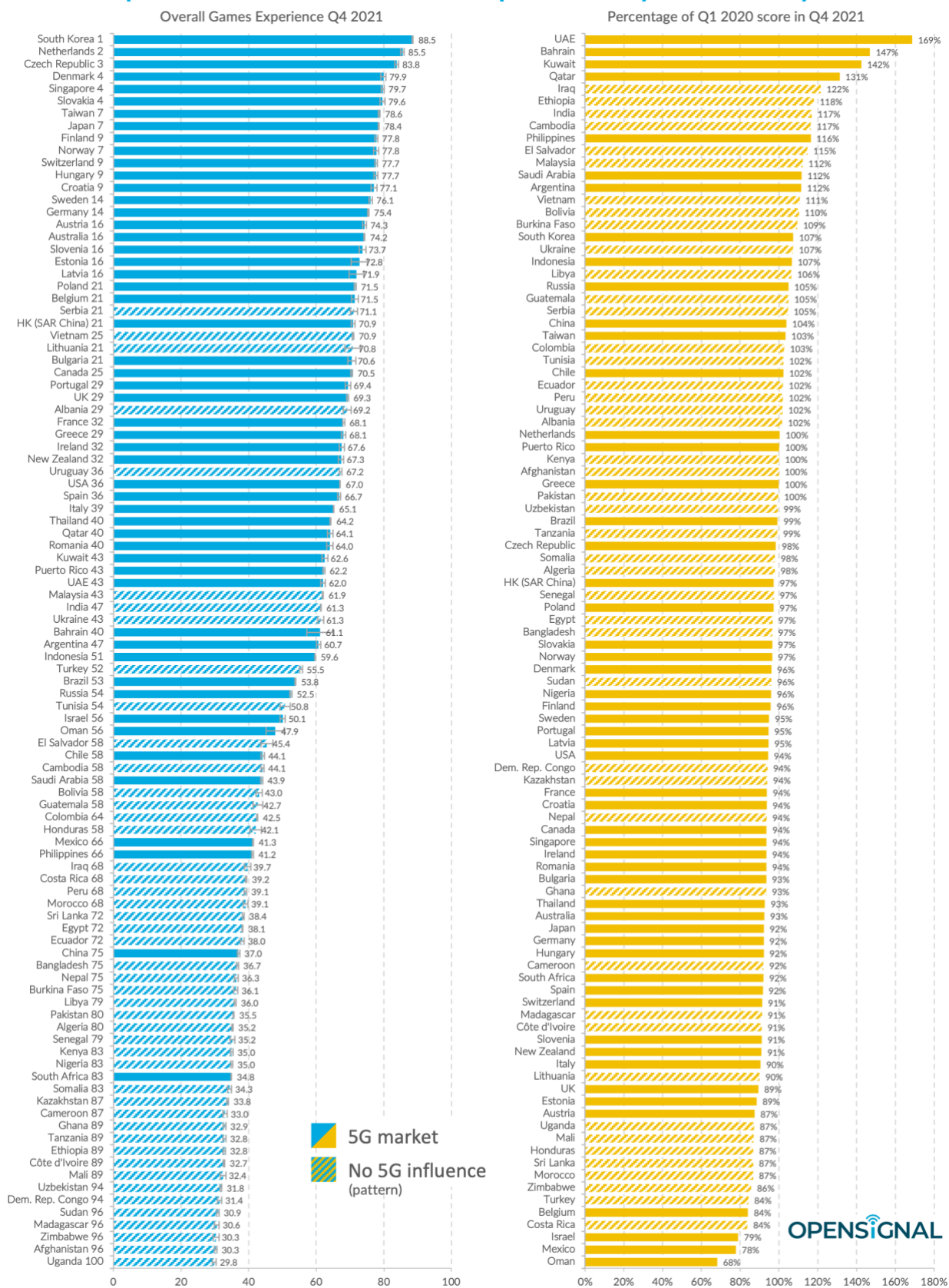
In a further 13 markets, the overall Games Experience was [Good](#) (75<85) including significant 5G markets such as Singapore (joint 4th, 79.7), Taiwan (joint 7th, 78.6), Japan (joint 7th, 78.4), Finland (9th, 77.8), and Germany (joint 14th, 75.4).

However, there is much less evidence that 5G explains these high rankings for 5G markets in Games Experience, at least so far. Yes, the [strongest 5G adoption market South Korea](#) jumped from 10th at the start of 2020 to be 1st at the end of 2021 in global Games Experience, but when we analyze which markets saw the greatest improvement in their multiplayer gaming scores we see a different picture.

Comparing percentage change, we see 5G markets spread right across the chart. The top four markets for improvement in Games Experience have all launched 5G. But, over half of the top 20 markets for change (55%) are markets without significant 5G influence. When we look at the absolute change in score, not percentage, we see a similar mixed picture with 5G markets spread widely and not clustered near the top of improvement in Games Experience.

The reason is simple — current 5G networks based on the initial 5G standards do not significantly improve the characteristics of mobile services that underpin a great real-time multiplayer gaming experience. Notably, a great Games Experience requires a combination of low latency, little packet loss and low jitter among other characteristics.

Games Experience: In most markets 5G's impact has not yet been felt by users



Why the best of 5G experiences is yet to come

We have not yet seen the full impact of 5G technology on users' mobile network experience.

For example, we expect speeds to rise considerably as more 5G spectrum becomes available for use, even in markets that already offer 5G. Responsiveness will improve with updated 5G technology. Networks will support many more devices simultaneously. Reliability should be boosted.

While the overall Games Experience now is little affected by 5G, monitoring mobile gaming now acts as a litmus test. Or, to mix a metaphor, it's a gaming canary which helps us to spot if the next stage of 5G experience is starting to happen.

Why is 5G not completely here now? To date, almost all 5G services use [early versions](#) of the 5G standard — mostly Release 15. Every few years the main industry standards body — the [3GPP](#) — coordinates the creation of a new technology mark which vendors and mobile operators aim to use to improve users' experience. There are already [several versions of 5G](#) either at various stages of development or which have been finalized and will soon see widespread commercial deployments.

The same happened with 4G — that standard improved enormously over time. Initially, for example, 4G smartphones had to [fall back to 3G](#) to make or receive a phone call, and could only connect to a single 4G spectrum band. Now, 4G smartphones use 4G for phone calls (based upon voice over LTE, or VoLTE) and often connect to two, three or more spectrum bands at once combining their capabilities to offer a faster experience (variously called LTE Advanced Pro or carrier aggregation).

Vendors have promised for years that 5G would enable augmented reality (AR), edge computing, multiplayer gaming, industrial automation and a myriad of Internet of Things (IoT) use cases. But these gradually progressing 5G standards explain why the full 5G impact has not arrived and vendors' 5G claims are often still to be met.

Analyzing the real-world mobile experience, using a single methodology globally in all markets and on all networks, enables everyone to see if the promises of 5G's designers are being fulfilled for users. As 5G evolves, this continuous flow of analytics is critical because 5G technology and the mobile experience of users are forever changing (even when there is no pandemic).

Our Methodology

Opensignal measures the real-world experience of consumers on mobile networks as they go about their daily lives.

We collect billions of individual measurements every day from many millions of smartphones worldwide. Our measurements are collected at all hours of the day, every day of the year, under conditions of normal usage, including inside buildings and outdoors, in cities and the countryside, and everywhere in between. By analyzing on-device measurements recorded in the places where subscribers actually live, work and travel, we report on mobile network service the way users truly experience it. We continually adapt our methodology to best represent the changing experience of consumers on mobile networks and, therefore, comparisons of the results to past reports should be considered indicative only.

Confidence Intervals

For every metric we calculate statistical confidence intervals indicated on our graphs. When confidence intervals overlap, our measured results are too close to declare a winner. In those cases, we show a statistical draw. For this reason, some metrics have multiple operator winners.

In our bar graphs we represent confidence intervals as boundaries on either sides of graph bars. In our supporting-metric charts we show confidence intervals as +/- numerical values.

Our Metrics

Video Experience

Measures the average video experience of Opensignal users on 3G, 4G and 5G networks for each operator. Our methodology involves measuring real-world video streams and uses an ITU-based approach for determining video quality. The metric calculation takes picture quality, video loading time and stall rate into account. We report video experience on a scale of 0-100.

Voice App Experience

Measures the quality of experience for over-the-top (OTT) voice services — mobile voice apps such as WhatsApp, Skype, Facebook Messenger etc. — using a model derived from the International Telecommunication Union (ITU)-based approach for quantifying overall voice call quality and a series of calibrated technical parameters. This model characterizes the exact relationship between the technical measurements and perceived call quality. Voice App Experience for each operator is calculated on a scale from 0 to 100.

Games Experience

Measures how mobile users experience real-time multiplayer mobile gaming on an operator's network. Measured on a scale of 0-100, it analyzes how the multiplayer mobile Games Experience is affected by mobile network conditions including latency, packet loss and jitter to determine the impact on gameplay and the overall multiplayer Games Experience.

Download Speed Experience

Measures the average download speed experienced by Opensignal users across an operator's 3G, 4G and 5G networks. It doesn't just factor in 3G, 4G and 5G speeds, but also the availability of each network technology. Operators with lower 5G or 4G Availability tend to have a lower Download Speed Experience because their customers spend more time connected to slower generation networks.

Upload Speed Experience

Measures the average upload speed experienced by Opensignal users across an operator's 3G, 4G and 5G networks. Upload Speed Experience doesn't just factor in 3G, 4G and 5G speeds, but also the availability of each network technology. Operators with lower 4G Availability tend to have a lower Upload Speed Experience because their customers spend more time connected to slower 3G networks.

4G Availability

Measures the average proportion of time Opensignal users spend with a 4G or better connection on each operator's network.

4G Coverage Experience

Measures how mobile subscribers experience 4G coverage on an operator's network. Measured on a scale of 0-10, it analyzes the locations where customers of a network operator received a 4G signal relative to the locations visited by users of all network operators.