OPENSIGNAL

THE STATE OF MOBILE VIDEO EXPERIENCE

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Opensignal active userbase:

Total Devices	Total Measurements	Data Collection Period
37,671,772	94,086,045,513	Aug 1 – Oct 30, 2019

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.

Key Findings

In one year mobile Video Experience has significantly improved in 59% of 100 countries analyzed

Users now experienced Very Good mobile Video Experience in 22 countries, including major markets like Canada, Germany, Italy, Japan and the U.K. Similarly, 21 countries moved into the Good category this year, including Brazil, Chile, Mexico, Russia and Vietnam. France was the only country to jump two categories, rising from Fair to Very Good in just one year. In total, 59 countries changed Video Experience category.

Top-ranked countries for mobile Download Speed were far from top in Video Experience

South Korean users' experience ranked first for download speed yet 21st for video, while Canadians' were third fastest for download speed in Opensignal's State of Mobile report, but just 22nd for video. This contrast between results in part reflects the way wireless operators routinely manage mobile video traffic differently to file downloads in order to prevent the vast quantities of video data hurting the experience of other mobile apps and services.

Real-world growth in mobile video consumption requires true real-world video analytics

Opensignal's unique mobile Video Experience measure is derived from an ITU-based approach for determining perceived video quality. Among other inputs, our methodology takes picture quality, video loading time and stall rate into account to create a score on a scale of 0-100, reflecting users' perceived mobile video quality. Uniquely, Opensignal tests mobile video streaming at scale and does not estimate video experience based on speed tests or other indirect measurements.

The U.S. is lagging behind on mobile video as carriers face a spectrum crunch

While there was an improvement in Americans' Video Experience — with the score increasing from 46.7 to 53.8 points — it was not enough to shift U.S. consumers up a gear into the Good category. Instead, Video Experience remained stuck in the Fair category. Americans had the lowest Video Experience score of any of the G7 economically leading countries as U.S. carriers struggle with the combination of enormous mobile video consumption and insufficient new spectrum. Opensignal's results highlight the need for the release of more mid-band spectrum to help U.S. carriers meet the mobile video needs of Americans.

For the first time, we see six countries rate as Excellent for mobile video quality

In Opensignal's analysis of 100 countries, only mobile users in Norway, the Czech Republic, Austria, Denmark, Hungary and the Netherlands enjoyed the top category of mobile Video Experience, although overall, users in 37% of countries enjoyed either a Very Good or Excellent experience. Notably, in 2018 no country rated as Excellent.

28% of countries ranked just Fair for mobile Video Experience

Those countries in the Fair category include large markets like Indonesia, the Philippines, Russia, and even the U.S. By contrast, in 9% of countries users suffered a Poor mobile Video Experience, meaning mobile video is practically unwatchable.

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Mobile TV, movie and short video viewing is mainstream

Viewing smartphone video is extremely important to consumers in 2019. New video apps continue to launch on mobile first — most recently TikTok — while video has become a part of the fabric of social networks that started out distributing just text and photos: on Facebook and Instagram, 51% and 35% of U.S. consumers respectively now watch video on their smartphone, Opensignal has found in a recent survey.

Smartphone TV viewing is common, but video app offline modes are a hassle

Mobile is now a central part of multiscreen TV streaming services because smartphone screens are larger than ever, and everyone has a phone with them at all times. For both Apple TV+ and Disney+, the smartphone is a significant part of the offer: Every iPhone bought includes one year of free access to Apple TV+. The mobile app for Disney+ was downloaded 3.2m times in the first 24 hours after the service launched, even though the service launched in just three countries: the U.S., Canada and the Netherlands. Older services are no different in the importance they place on the mobile screen: Netflix has reported that 25% of total streaming is happening on mobile networks.

However, consumers often have to use these apps' offline functions to download programs or movies ahead of time to sidestep potential issues with the cellular connection. Opensignal has found 43.4% of U.S. consumers report they have experienced stuttering or freezing when watching video on their smartphone. But having to remember to download a video onto a smartphone is inconvenient for consumers because it's easy to forget to download a video ahead of time.

Mobile video traffic causes wireless operator engineering teams pain

Wireless operators understand that video is of critical importance to their business. Carrier technical teams know that video makes up the vast majority of the data traffic on their networks and telecom vendors forecast video data traffic will continue to rise. Ericsson forecasts video will rise from 60% of mobile data traffic in 2018 to nearly three quarters by 2024. The technical challenges of this enormous amount of data traffic mean many operators treat video differently than other kinds of data

traffic to ensure video does not overwhelm everything and cause the experience of other activities like voice calling, mobile gaming, or even web browsing to suffer.

Carriers use TV streaming bundles to acquire mobile customers

Similarly, the marketing teams at wireless operators use the attraction of TV, movies and other video services to spur consumers to join their network, or to trigger customers to upgrade to a more expensive tariff plan. Operators often bundle a Netflix or an iFlix package alongside a contract commitment.

For example, in the U.S. at the end of 2019: T-Mobile U.S. includes Netflix on its Magenta plans; Sprint includes Hulu and/or Amazon Prime on a number of its plans; Verizon advertises 5G as suitable for 4K video quality on mobile and bundles Disney+ with its 5G wireless home broadband plans; and AT&T offers one of HBO, Starz, Cinemax, or Showtime as part of its Unlimited and More Premium plan.

The advertising industry now sees a majority of video ads playing on mobile

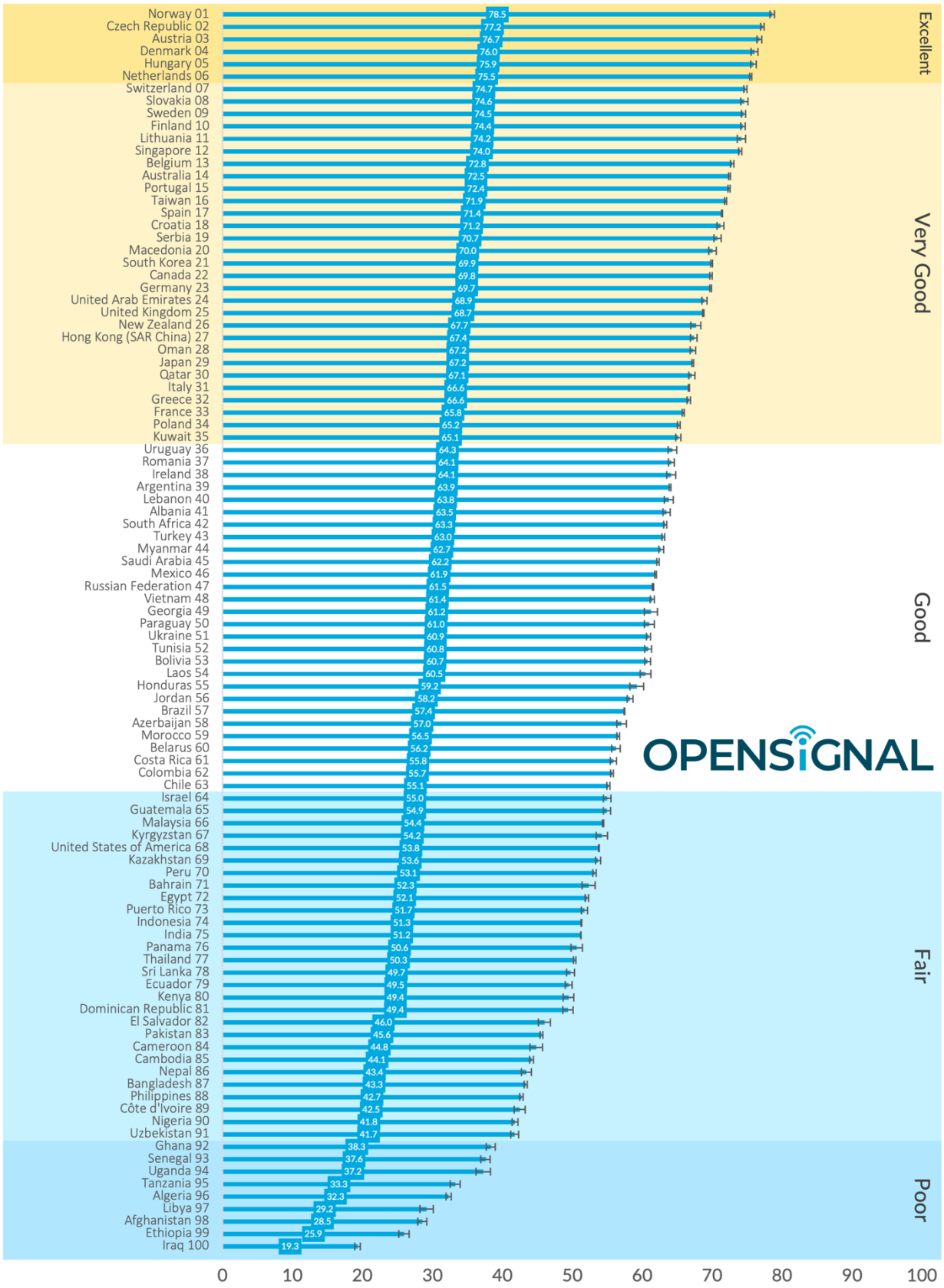
Full-screen mobile video ads now create vital revenues that support many otherwise free apps. The Internet Advertising Bureau (IAB) has quantified the scale of mobile video advertising: 62% of total video ad starts are happening on mobile; similarly, 63% of total video ad revenue is from mobile as part of an online video ad market that grew 37% between 2017 and 2018 to reach $16.3bn. Upshot, it's not only consumers, media companies and wireless carriers that care about mobile video experience but mobile video is also increasingly important for advertisers.

Video Experience

Measures the average video experience of Opensignal users on 3G and 4G 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, with scores falling into the following categories:

75-100 Excellent
65-75 Very Good
55-65 Good
40-55 Fair
0-40 Poor

The quality of the Mobile Video Experience varies dramatically globally



Data collection period August 1 – October 30, 2019.

In 37% of the 100 countries that Opensignal analyzed, users enjoy a Very Good or Excellent mobile Video Experience. The top 11 countries are all in Europe, with Norway, the Czech Republic and Austria taking the top three positions. Those three are joined by Denmark, Hungary and the Netherlands as the only countries which feature in the Excellent category for mobile Video Experience in 2019.

The highest-ranked non-European country is Singapore, which falls into the Very Good category. Singapore is routinely top-ranked for other measures of mobile network experience, but our Singaporean users rank lower on their mobile video experience than in other areas, perhaps as a knock-on effect of rising operator competition in the last year and resulting price pressures for Singapore's established operators.

Strikingly, like Singapore, there are other countries where users enjoy extremely fast mobile speeds yet are also much lower down Opensignal's ranking of countries on mobile Video Experience than they are for speed. For example:

- **South Korean users' experience ranked first for download speed yet 21st for video**. This contrast indicates the difference between measures of raw speed and video streaming and that the arrival of 5G is not a panacea that will solve mobile video challenges overnight despite 5G's adoption by millions of Koreans, although over time new 5G spectrum capacity should help. Read the list of countries ranked by Download Speed Experience in Opensignal's recent The State of Mobile Network Experience report.

- **Canadians enjoyed the third fastest download speeds but for video were 22nd**. Canada routinely tops Opensignal's international comparisons, but as in other countries, mobile video presents a special challenge for carriers.

Differences in the results for Download Speed Experience and Video Experience are often because of the technologies that wireless operators routinely deploy to manage the vast quantity of data traffic which mobile video viewing creates. In short, mobile video streaming is not treated the same by wireless operator networks as a file download test and this shows through in Opensignal's analytics results.

Still many mobile video issues in numerous countries

It's not all good news for mobile users around the world. A sizable 28% of countries ranked just Fair for mobile Video Experience — including large markets like Indonesia, the Philippines, Russia, and even the U.S. — while in 9% of countries our users suffered a Poor mobile Video Experience.

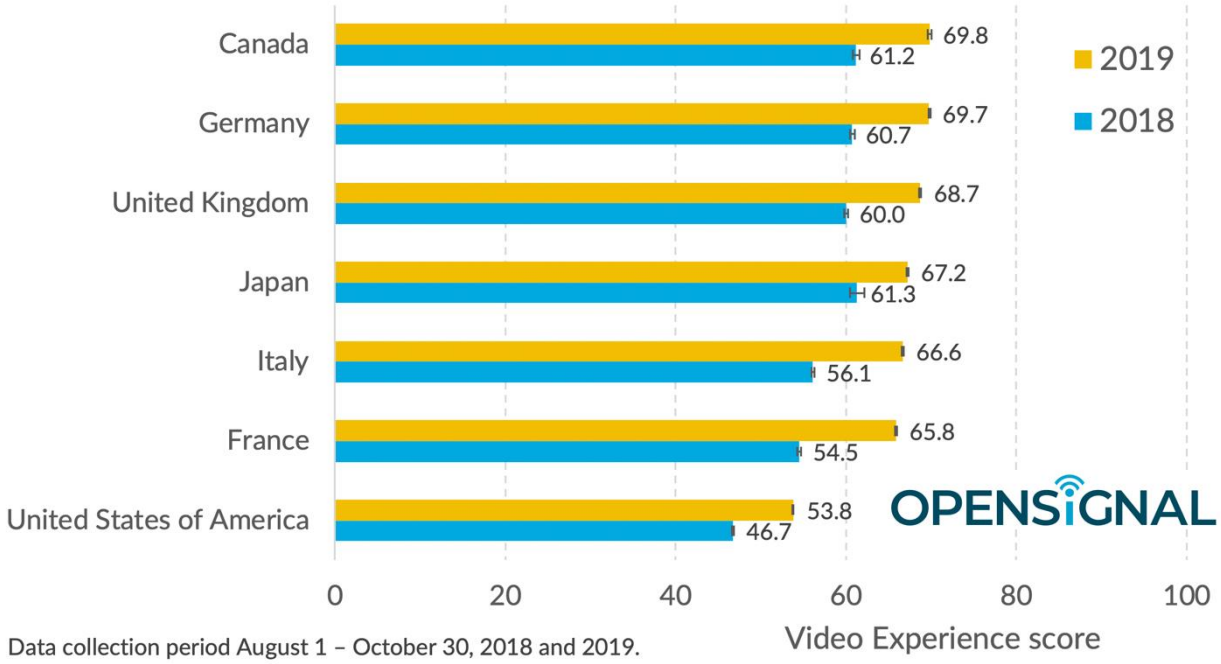
In large emerging economies like Indonesia and the Philippines, the challenge for carriers is every bit as acute as it is in developed markets, because consumers routinely rely on their phone as their main, sometimes their only, digital device. This means mobile video viewing may not only be a personal preference because a football game happens to be on at a slightly inconvenient time when someone happens to be away from home, but in these mobile-first countries the smartphone is often simply the only screen available at home to watch the game.

On mobile video, the US is lagging behind

Comparing the group of seven leading industrial economies — the G7 — highlights that in none of these countries do our mobile users enjoy an Excellent Video Experience, at least not yet. In all of these countries, the mobile Video Experience improved in the last year with users in six countries now enjoying a Very Good Video Experience having scores ranging from 65.8 to 69.8.

Notably, in France mobile users enjoyed an increase in Video Experience by two categories in just one year, from Fair to Very Good.

Among G7 countries the US ranks last for Video Experience



Data collection period August 1 – October 30, 2018 and 2019.

However, the mobile Video Experience continues to lag in the U.S. Although here too our users' experience did improve — the U.S. Video Experience score rose over seven points from 46.7 to 53.8 — but the U.S. remained in the Fair category. The rapid improvement in France demonstrates that it's possible to improve users' mobile Video Experience markedly, at least if there is spectrum capacity available to support a higher mobile video quality experience for millions of users.

Wireless carriers in the U.S. face two key challenges not seen in many other countries, which make it harder to greatly improve the Video Experience:

- **U.S. consumers watch a lot of TV, and lots of mobile video too.** Opensignal has found that 39% of U.S. consumers watch TV programs on their smartphones, and similarly, 38% watch movies. Also, we uncovered that 28% of consumers sometimes switch to cellular connections in order to watch video, and 38% of consumers watch video on their smartphone at home on a cellular connection (compared with 71% that watch at home on Wifi). This tremendous quantity of mobile video viewing highlights the importance of mobile video to Americans, despite users having just a Fair mobile Video Experience when using a cellular connection.

- **Carriers face a spectrum availability crunch in the U.S.** Wireless capacity is essential to offering large numbers of users both fast speeds and plans with the large volumes of data needed for large scale high-quality mobile video delivery. If spectrum supply is tight, and consumers' appetite for mobile video is high, then carriers face difficult choices around increasing the price of data, or of managing video streaming traffic tightly, for example to lower picture quality. If they do neither, the download experience of their users will likely suffer as video traffic overwhelms everything else on the network.

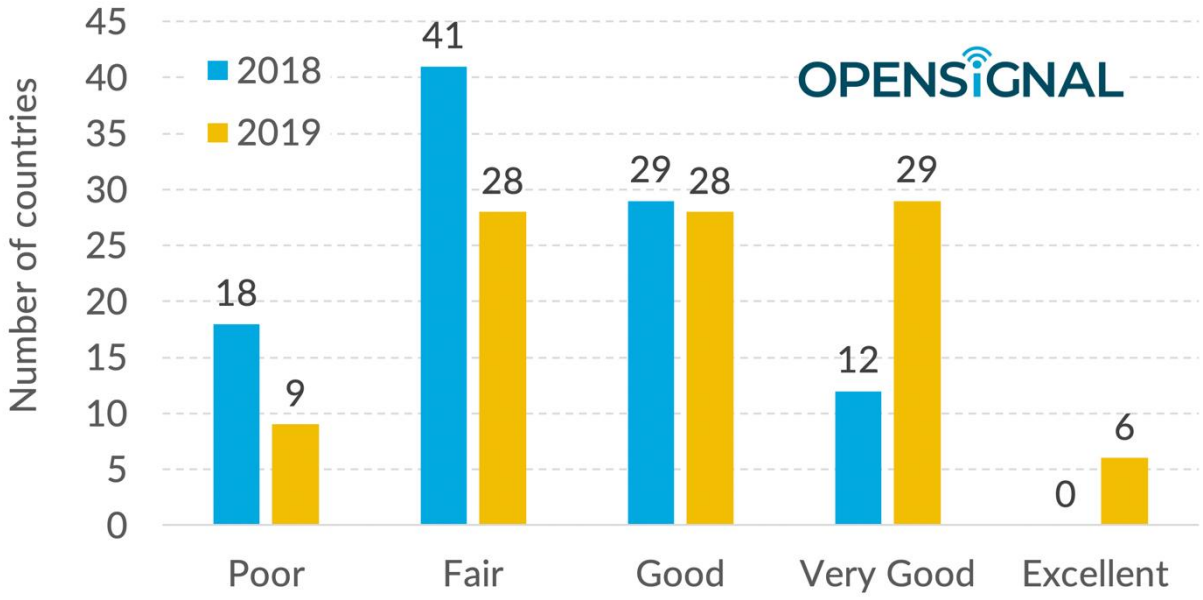
To improve mobile video quality in the U.S., what carriers need above all else is affordable new mid-band spectrum in order to support more users and more simultaneous high-definition video consumption. The very high mmWave 5G spectrum U.S. carriers have deployed is insufficient to improve the user experience because of the very limited reach of networks using those frequencies. But the U.S. has existing users in many of the key spectrum bands, which is proving challenging and delaying the release of the desperately needed capacity that is available in countries in Europe and across much of Asia.

Opensignal's analysis of the state of U.S. mobile Video Experience provides evidence of the pressing U.S. consumer need for new capacity to support a great mobile Video Experience. These measures can help regulators, and carriers, to make a stronger case for the rapid transition of existing spectrum users and, as a result, to accelerate the needed upcoming U.S. spectrum auctions, especially in the mid-band.

Mobile Video Experience has significantly improved in 59% of countries

We have seen an improvement in users' mobile Video Experience across many countries in the last year. While 18 countries rated as Poor in 2018, this has fallen to just nine this year. Similarly, we see a fall from 41 to 28 countries that rate as Fair for Video Experience.

Number of countries by Video Experience category



Data collection period August 1 – October 30, 2018 and 2019.

For the first time, we see six countries rate as Excellent for mobile video quality, and we see the number in the Very Good category rise from 12 to 28 countries. Large markets that moved into this Very Good tier for the first time include Canada, Germany, Italy, Japan, South Korea, Spain and the U.K.

Across the globe, we see ongoing network deployments using newer 4G technologies, which means users' smartphones connect to multiple frequency bands at once, with higher-grade encoding. Perhaps more significantly, as carriers in major developed countries look to wider 5G roll outs, they often prepare first by upgrading 4G sites with improved backhaul links to existing cell towers, which has the effect of boosting the 4G experience for current users.

Twenty-one countries moved into the Good category this year, including Brazil, Chile, Mexico, Russia and Vietnam. France was the only country to jump two categories, rising from Fair to Very Good in just one year.

Users across India now enjoy a Fair experience, up from Poor a year ago. Similar gains were made in Cambodia, Nigeria and the Philippines, where the experience also jumped up one category.

Video Experience category change from 2018 to 2019

From 2018 to 2019	Countries		
Very Good to Excellent (6 countries)	Austria Czech Republic	Denmark Hungary	Netherlands Norway
Good to Very Good (22)	Canada Croatia Finland Germany Greece Hong Kong Italy Japan	New Zealand Kuwait Macedonia Oman Poland Portugal Qatar	Serbia Slovakia South Korea Spain Sweden United Arab Emirates United Kingdom
Fair to Very Good (1)	France		
Fair to Good (21)	Albania Argentina Azerbaijan Belarus Brazil Chile Colombia	Costa Rica Honduras Jordan Laos Lebanon Mexico Morocco	Paraguay Russian Federation Saudi Arabia Tunisia Ukraine Uruguay Vietnam
Poor to Fair (9)	Bangladesh Cambodia Côte d'Ivoire	El Salvador India Nigeria	Pakistan Philippines Uzbekistan
No Change (41)	Afghanistan Algeria Australia Bahrain Belgium Bolivia Cameroon Dominican Republic Ecuador Egypt Ethiopia Georgia Ghana Guatemala	Indonesia Iraq Ireland Israel Kazakhstan Kenya Kyrgyzstan Libya Lithuania Malaysia Myanmar Nepal Panama Peru	Puerto Rico Romania Senegal Singapore South Africa Sri Lanka Switzerland Taiwan Tanzania Thailand Turkey Uganda United States of America

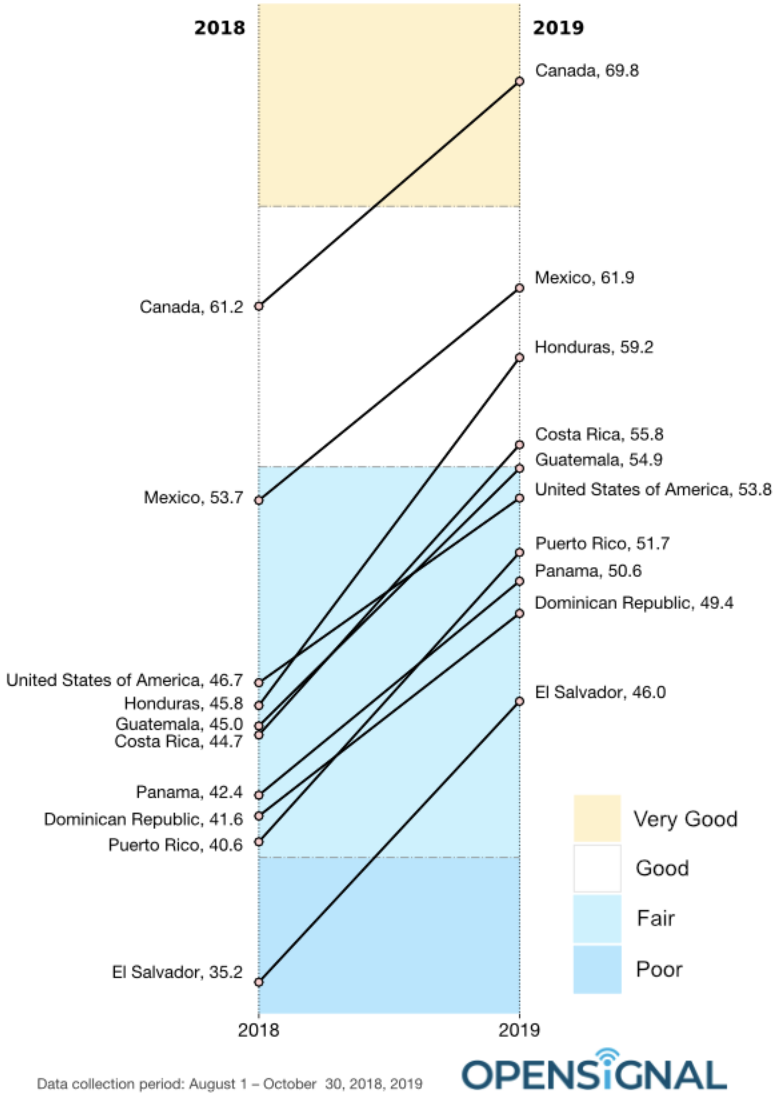
Mobile Video Experience regional trends 2018-2019

Canada scores highest Video Experience ranking in North & Central America

Canada, with its powerful 4G networks, was the only country in North and Central America to score a Very Good ranking, meaning our users experienced generally fast loading times with only occasional stalling. As Opensignal noted in our August 2019 report, Canada's 4G networks offer download speeds as high as 200 Mbps to our users, which is a very high bar to attain. Although download speeds don't necessarily correlate to good Video Experience, in Canada's case they do. This was the first time any country in North and Central America has scored in the Very Good category. Canada, with a score of 70 (on a 0-100 scale), jumped nine points from its score of 61 in 2018.

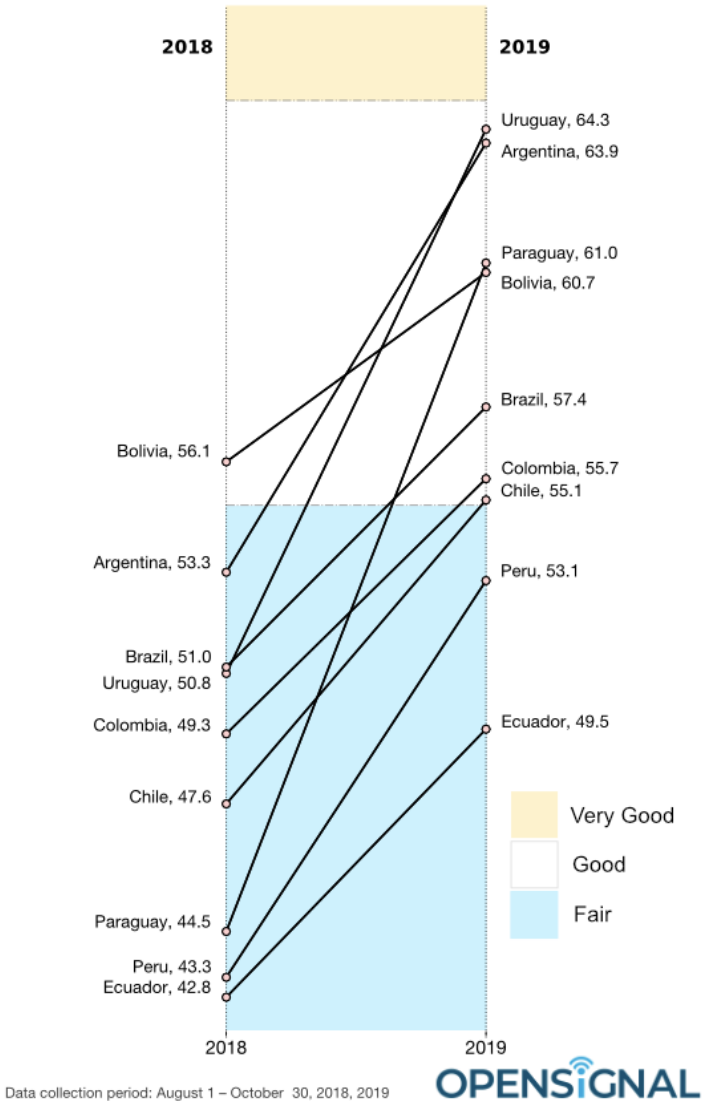
In the U.S. we saw Video Experience improve seven points, from 47 in 2018 to 54 in 2019. The U.S. and its territory of Puerto Rico had the lowest improvement of any country in North and Central America. However, the U.S. now is just one point shy of moving into the Good category. Currently, it still falls into the Fair category, meaning video streamed to smartphones often exhibits longer loading times and frequent interruptions, especially at higher resolutions.

The country in this region that saw the most improvement from our 2018 Video report was Honduras, which jumped 13 points from a score of 35 in 2018 to a score of 46 in 2019. The country now falls into the Fair category in Video Experience.



South Americans enjoyed big gains in mobile Video Experience

A year ago, Bolivia was the only country in South America where users enjoyed a Good mobile Video Experience. Now, six countries have moved into the Good category, with Uruguay, Argentina and Paraguay taking the top three positions in the region ahead of Bolivia. These four countries are joined by Brazil, Colombia and Chile in the Good category. Paraguay's users saw the highest rate of improvement in the last year, with their Video Experience score improving from 45.5 to 61.0, or a 16.5 point change, which was the greatest in any of the one hundred countries Opensignal analyzed.



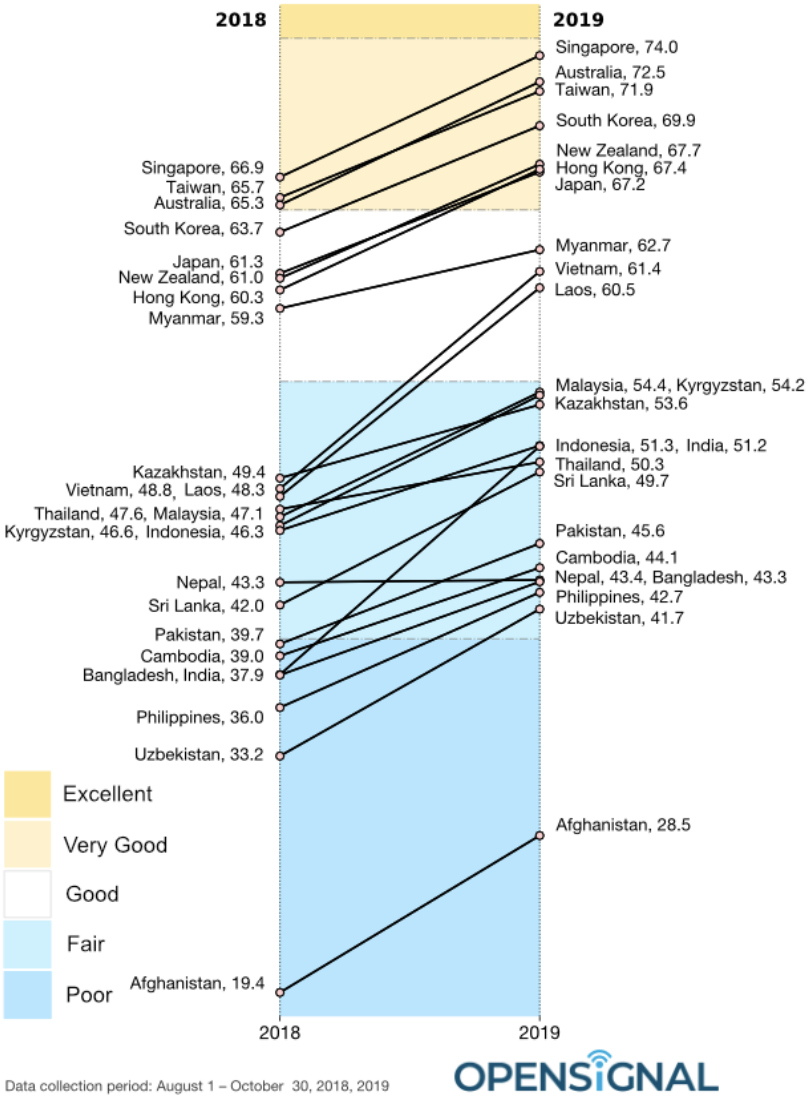
Enormous range in Video Experience across Asia Pacific

Singapore was the top-ranked country in Asia for mobile Video Experience, with a score of 74 up from 67 a year ago. Australia ranked second, followed by Taiwan, South Korea and New Zealand. In total, seven countries across Asia rated Very Good for Video Experience, but no country in the region yet enjoys an Excellent mobile Video Experience, despite it being home to some of the world's most advanced mobile markets.

There were different trends across countries too in how the Video Experience changed in the last year. India had the greatest jump in Video Experience, rising 13.3 points in just twelve months to reach 51.2. If the country continues this rate of change, users across India will move into a Good category in 2020.

However, users in Nepal saw no significant improvement year-on-year, with just 0.1 separating each year's score. In Myanmar, growth was also well below the region's average improvement, with users' Video Experience score rising just 3.4 points to reach 62.3 in 2019 and staying in the Good category.

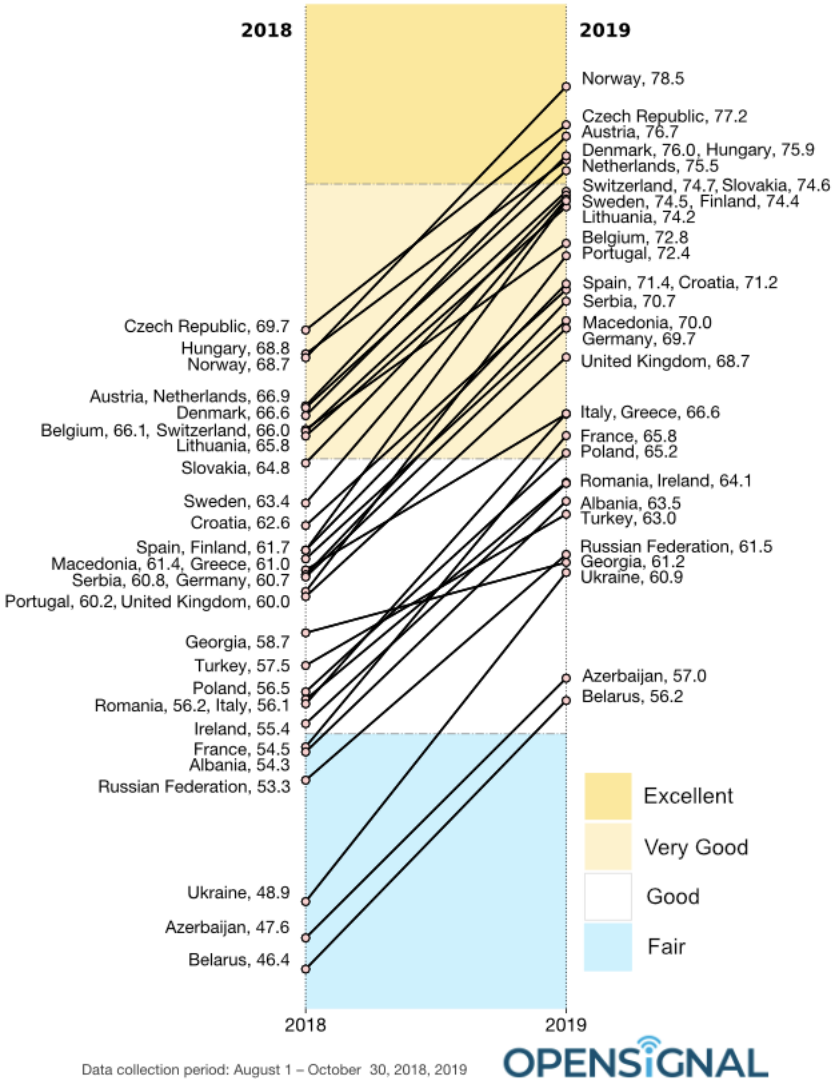
On a more positive note, looking at some of the region's more populous countries, Video Experience in Malaysia, Indonesia and Japan improved. Although both Malaysia and Indonesia remained in the Fair category, our users in Malaysia only missed out on moving into the Good Video Experience category by under one point.



Europe is the only region with countries rated Excellent for mobile Video Experience

Six European countries moved into the Excellent Video Experience category this year: Norway, the Czech Republic, Austria, Denmark, Hungary and the Netherlands. No country in any other part of the world, including markets in Asia with an even faster Download Speed Experience, rated as Excellent for Video Experience in Opensignal's analytics. Moreover, five European countries are less than 1 point away from reaching Excellent Video Experience, including Slovakia, Sweden, and Finland, which were ranked just Good in 2018.

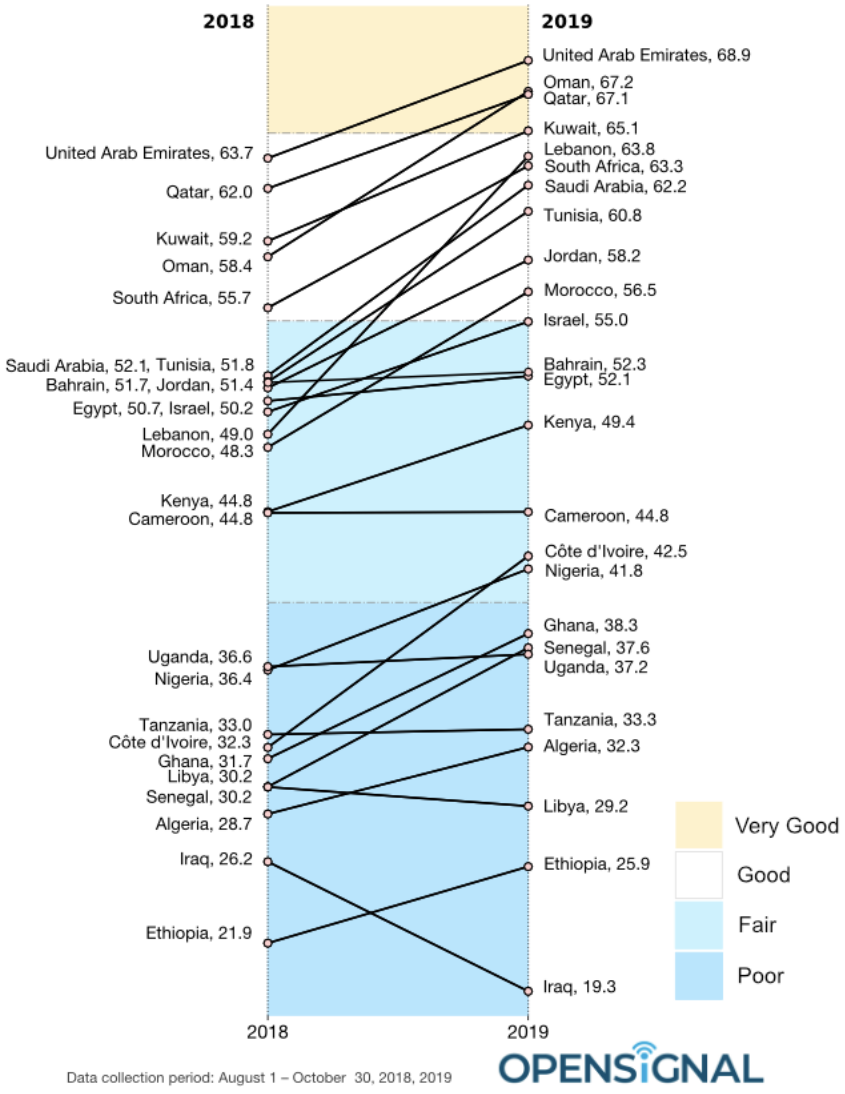
Across the board, Europeans in all parts of the continent experienced a much improved mobile Video Experience in 2019 compared with 2018. No country rated below Good in 2019, where six countries in 2018 rated as Fair.



Middle East and Africa see Video Experience setbacks as well as improvements

Four countries moved into the Very Good category for the first time across the Middle East and Africa in 2019: U.A.E., Oman, Qatar and Kuwait. Leading African countries narrowly missed out on joining these three in the top category for the regions, with users in South Africa enjoying a mobile Video Experience score of 63.3 — just behind Lebanon on 63.8 — followed by Tunisia with 60.8 and Morocco on 56.6.

These regions continued to see some of the lowest mobile Video Experience scores anywhere in the world. In 2018, ten countries across Africa and the Middle East rated as Poor and this has improved only slightly, with eight countries in 2019. In both Libya and Iraq the mobile Video Experience of users worsened by 1.0 and 6.9 points, highlighting the challenges of offering mobile services in countries which continue to suffer from geopolitical instability.



5G will transform the mobile video experience

On relatively small smartphone screens that typically have a display that is diagonal six inches (15.24 cm) or less, there is little reason to offer 4K video streaming. However, even offering HD video at 720p or 1080p uses enormous amounts of data per hour of viewing. To enjoy the best mobile picture quality, Netflix uses 3GB of data per hour of viewing. Netflix only recommends this option for those on unlimited data plans. Even on the default Automatic setting, a smartphone user will consume 250Mb of data per hour, which will rapidly eat through data capped plans.

Wireless operators understand the pressure that mobile video viewing places on their network capacity and the potential for widespread video consumption to damage the experience of using other services. Given limited wireless spectrum capacity, carriers routinely offer tight data caps on plans, or they manage video traffic to reduce the priority on their networks or to downgrade the quality of the video streams. For example, carriers often automatically convert the picture quality of video from 1080p full HD, down to 720p, or even to just standard definition quality.

5G enables wireless operators to use new very high-frequency and high-capacity wireless spectrum, enabling them to support many millions of more simultaneous smartphone users all watching HD video. The key bands are in the 3-6GHz range; although most of these frequencies are not yet available in the U.S., they are being deployed in Europe, Korea, Australia and in select other parts of Asia.

Today, there are not enough 5G smartphones in use for the impact of 5G on mobile video viewing to be visible. But in 2020, Opensignal expects that 5G users will be able to experience a consistent HD video stream more often and in more locations than in 2019. However, this is dependent on the availability of this critical mid-band spectrum. In parts of south-east Asia, the U.S. and South America availability of this spectrum is limited in the short term. While carriers will launch 5G, we do not expect to see the same immediate boost to wireless capacity.

In those markets where mid-band spectrum release for wireless operators is held up, regulators and carriers can use the international comparison in this Opensignal State of Mobile Video Experience report

to highlight the urgency with which the industry should move to transition users off these key bands.

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 and 4G 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.

75-100 Excellent
65-75 Very Good
55-65 Good
40-55 Fair
0-40 Poor

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.

95-100 Excellent - Most users very satisfied
87-95 Very Good - Most users satisfied
80-87 Good - Many users satisfied
74-80 Acceptable - Users satisfied
66-74 Poor - Many users dissatisfied
60-66 Very Poor - Most users dissatisfied
45-60 Unintelligible - Nearly all users dissatisfied
0-45 Impossible to communicate

Download Speed Experience

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

Upload Speed Experience

Measures the average upload speed experienced by Opensignal users across an operator's 3G and 4G networks. Upload Speed Experience doesn't just factor in 3G and 4G 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.

Latency Experience

Measures the average latency experienced by Opensignal users across an operator's 3G and 4G networks. Latency, measured in milliseconds, is the delay users experience as data makes a round trip through the network. A lower score in this metric is a sign of a more responsive network.

4G Availability

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