TUTELA

Southeast Asia

State of Mobile Experience

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MARCH 2021

Annual Report

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Introduction

The last decade has seen internet connectivity become almost ubiquitous across Southeast Asia, and the vast majority of users are primarily online via a mobile device. Previous studies have suggested[1] that users in the region are some of the most likely to be performing critical tasks, like mobile banking or online shopping, on a mobile device.

Of course, the combination of rapid mobile device penetration and their utilization for critical tasks presents operators with a unique set of challenges. The mobile network experience for the majority of current users, which is primarily provided over 3G and 4G networks, needs to be maintained in the face of ever-increasing demand for mobile data. At the same time, operators need to ensure that

their infrastructure is correctly aimed towards next-generation 5G networks. In the long run, 5G infrastructure (and more 5G-suitable spectrum) will be needed to provide the capacity and capability required for serving hundreds of millions of subscribers.

To measure how operators are performing in this challenging environment, Tutela collects and analyzes millions of measurements from real-world users to provide the most accurate picture of subscriber mobile experience possible. For this report, Tutela has analyzed over 55 million speed and latency measurements, conducted on the smartphones of real-world users of national mobile operators within Common Coverage Areas, between August 1st 2020 and January 31st, 2021.

[1] Nikkei Asia, Southeast Asia eclipses China as world's mobile economy hot spot
https://asia.nikkei.com/Business/Business-trends/Southeast-Asia-eclipses-China-as-world-s-mobile-economy-hot-spot
Retrieved 03/03/21

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Key findings

- In some countries, a clearly dominant operator emerged: Telkomsel won six out of seven categories in Indonesia, and a similar story emerged for Smart in the Philippines, and Viettel Mobile in Vietnam. In other countries, however, the top spot was shared between multiple operators across the different metrics tested, such as StarHub and Singtel in Singapore.

- As could be expected from a small country with an extremely high population density, Singapore swept the board for country-level awards, providing a mobile experience (as well as underlying metrics) well in excess of any other country. However, Vietnam was able to comfortably take second place for most metrics — surprising, given that the country is still relatively dependent on older 3G networks.

- Many of the countries in the region have up-and-coming operators, which have notably different spectrum holdings and deployment strategies to other operators — Smartfren in Indonesia and DTAC in Thailand are notable examples. They are currently behind the competition when it comes to mobile experience and performance, but the changes on the horizon with 5G deployment could provide an opportunity for these challenger networks to outmaneuver the incumbents.

Results overview

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Mobile experience results

Singapore, March 2021

	StarHub	Singtel	M
Excellent Consistent Quality	⭐ Winner		
Core Consistent Quality	⭐ Winner		
Download throughput	⭐ Winner		
Upload throughput		⭐ Winner	
Latency	⭐ Winner		
5G/4G coverage		⭐ Winner	
Total coverage		⭐ Winner	

Results from over 25 million measurements taken from real-world smartphone users, collected between August 1, 2020 and January 31, 2021.

"StarHub delivered the highest percentage of Excellent Consistent Quality in Tutela's tests"

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Best Mobile Network Experience

MARCH 2021

Based on the highest Excellent Consistent Quality in Common Coverage Areas.

Results overview

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Mobile experience results

Indonesia, March 2021

	TELKOMSEL	indosat ooredoo	XL	3	smartfren.
Excellent Consistent Quality	★ Winner				
Core Consistent Quality	★ Winner				
Download throughput	★ Winner				
Upload throughput		★ Winner			
Latency	★ Winner				
5G/4G coverage	★ Winner				
Total coverage	★ Winner				

Results from over 661 million measurements taken from real-world smartphone users, collected between August 1, 2020 and January 31, 2021.

"Telkomsel delivered the highest percentage of Excellent Consistent Quality in Tutela's tests"

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Results overview

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Mobile experience results

Malaysia, March 2021

	U mobile	digi	celcom	maxis	unifi
Excellent Consistent Quality	⭐ Winner				
Core Consistent Quality	⭐ Winner				
Download throughput		⭐ Winner			
Upload throughput	⭐ Winner				
Latency				⭐ Winner	
5G/4G coverage			⭐ Winner		
Total coverage			⭐ Winner		

Results from over 340 million measurements taken from real-world smartphone users, collected between August 1, 2020 and January 31, 2021.

"U Mobile delivered the highest percentage of Excellent Consistent Quality in Tutela's tests"

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Based on the highest Excellent Consistent Quality in Common Coverage Areas.

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Results overview

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Mobile experience results

Thailand, March 2021

	AIS	truemove H	dtac
Excellent Consistent Quality	⭐ Winner		
Core Consistent Quality		⭐ Winner	
Download throughput		⭐ Winner	
Upload throughput		⭐ Winner	
Latency	⭐ Winner		
5G/4G coverage	⭐ Winner		
Total coverage	⭐ Winner		

Results from over 118 million measurements taken from real-world smartphone users, collected between August 1, 2020 and January 31, 2021.

"AIS delivered the highest percentage of Excellent Consistent Quality in Tutela's tests"

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Based on the highest Excellent Consistent Quality in Common Coverage Areas.

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Results overview

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Mobile experience results

Philippines, March 2021

	Smart	Globe
Excellent Consistent Quality	⭐ Winner	
Core Consistent Quality	⭐ Winner	
Download throughput	⭐ Winner	
Upload throughput	⭐ Winner	
Latency	⭐ Winner	
5G/4G coverage	⭐ Winner	
Total coverage		⭐ Winner

Results from over 39 million measurements taken from real-world smartphone users, collected between August 1, 2020 and January 31, 2021.

"Smart delivered the highest percentage of Excellent Consistent Quality in Tutela's tests"

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Best Mobile Network Experience

MARCH 2021

Based on the highest Excellent Consistent Quality in Common Coverage Areas.

Results overview

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Mobile experience results

Vietnam, March 2021

	viettel	vinaphone	mobifone	vietnamobile
Excellent Consistent Quality	⭐ Winner			
Core Consistent Quality			⭐ Winner	
Download throughput	⭐ Draw	⭐ Draw		
Upload throughput	⭐ Winner			
Latency	⭐ Winner			
5G/4G coverage	⭐ Winner			
Total coverage	⭐ Winner			

Results from over 7 million measurements taken from real-world smartphone users, collected between August 1, 2020 and January 31, 2021.

"Viettel delivered the highest percentage of Excellent Consistent Quality in Tutela's tests"

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Best Mobile Network Experience

MARCH 2021

Based on the highest Excellent Consistent Quality in Common Coverage Areas.
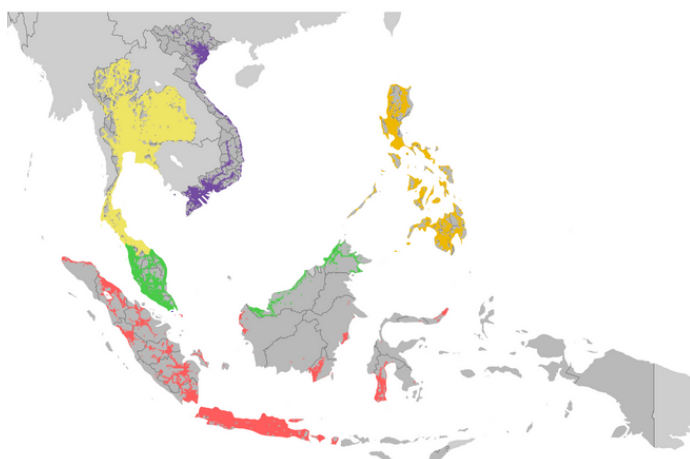
Understanding this report

Tutela uses two key methodological components to best compare user experience across operators: Consistent Quality and Common Coverage Areas. Consistent Quality is a set of metrics that Tutela has developed to objectively evaluate when connections networks are (and are not) enabling users to do almost everything that they want to do on their smartphones.

To best serve Tutela's goal to accurately measure and represent the real-world, end-to-end experience of actual users, our methodology is subject to ongoing improvements, which allow us to update the methodology in line with changes in network technology, measurement capabilities, and the realities of how people use their smartphones. As of this report, the methodology includes an updated version of Consistent Quality that better accounts for reliability, an area-based Coverage Score, a more granular Common Coverage Areas definition, and the separation out of users on MVNO or flanker brands. As a result, changes in the numeric values in this report compared to 2019 are not necessarily representative of year-on-year changes in the end-to-end user experience.

The methodology is covered in detail at the end of this report and on our website, but simply put, there are two sets of thresholds, Excellent and Core. A connection that hits the Excellent threshold is sufficient for use-cases like 1080p video streaming or multiplayer gaming, while a Core connection will stream standard-definition video or handle things like web browsing or uploading photos to social media. The percentages you see in this report represent the percentage of tests on a given operator that were above the Excellent or Core thresholds.
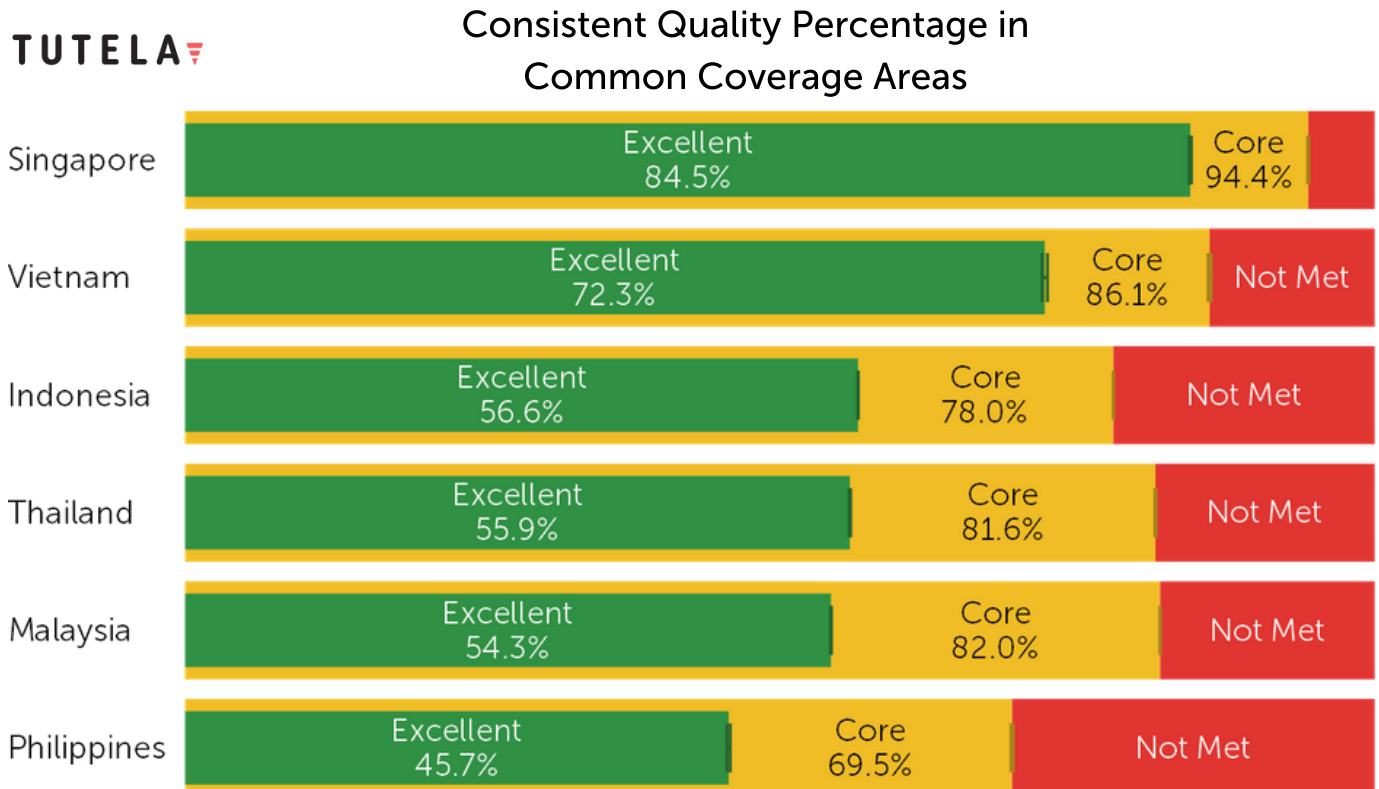
Common Coverage Areas are parts of the country where all national operators offer service, either on their own network or through a domestic roaming agreement. Comparing performance within common coverage areas ensures that user experience is being compared in places where networks are competing head-to-head, and ensures that operators with more diverse coverage are not being penalized. In this report, all performance metrics are taken from tests conducted in Common Coverage Areas only.

Measurement locations

Common Coverage Areas

Consistent Quality

Given the extreme demographic differences between Singapore — one of the most densely-populated countries in the world — and other countries in the region, it's no surprise to see the smallest country come out on top in terms of mobile experience. 84.5% of tests from subscribers on the main networks in Singapore passed the Excellent Consistent Quality thresholds, meaning that nearly 17 times out of 20, when a user in Singapore has a connection, it's good enough to sustain demanding use-cases like HD video streaming, group video calls, or

mobile gaming. For Core Consistent Quality — Tutela's measure of whether a connection is good enough for everyday uses, like email, social media, and SD video streaming — Singapore was also on top by a healthy margin, with nearly 95% of tests from real-world users on the main networks good enough for those everyday use-cases. Vietnam, the second-place country for both Excellent and Core Consistent Quality, saw 86.1% of its tests pass the less stringent thresholds.

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Consistent Quality Percentage in Common Coverage Areas

Country	Excellent	Core	Not Met
Singapore	84.5%	94.4%	
Vietnam	72.3%	86.1%	Not Met
Indonesia	56.6%	78.0%	Not Met
Thailand	55.9%	81.6%	Not Met
Malaysia	54.3%	82.0%	Not Met
Philippines	45.7%	69.5%	Not Met

Behind Singapore and Vietnam, Indonesia, Thailand, and Malaysia were all extremely close for Excellent Consistent Quality, with results all close to 55%. Just 0.4% separated Malaysia and Thailand for Core Consistent Quality, while Indonesia was a few percentage points behind, at 78%.

Mobile users in the Philippines, meanwhile, did not fare so well. It was the only country in the region where more than 50% of tests did not meet the Excellent Consistent Quality threshold, and with only 69.5% of tests meeting the less demanding Core Consistent Quality standards, performance for everyday use-cases suffered as well. Singapore

"The Philippines was the only country in the region where more than 50% of tests did not meet the ECQ threshold"

Consistent Quality

SINGAPORE

Within Singapore, StarHub was the clear leader for both Excellent and Core Consistent Quality. The operator's users saw 87.3% of their tests pass the threshold for demanding use-cases, putting StarHub distinctly in front of Singtel and M1: more than 3.5% separated StarHub from second-place Singtel, while just 1% separated Singtel and M1. For Core Consistent Quality, there was less differentiation between operators. The ranking order was the same — StarHub first place, Singtel second, and M1 third — but with Singtel on 95.3%, and M1 on 94.0%, less than 1.5% separated first and last place.

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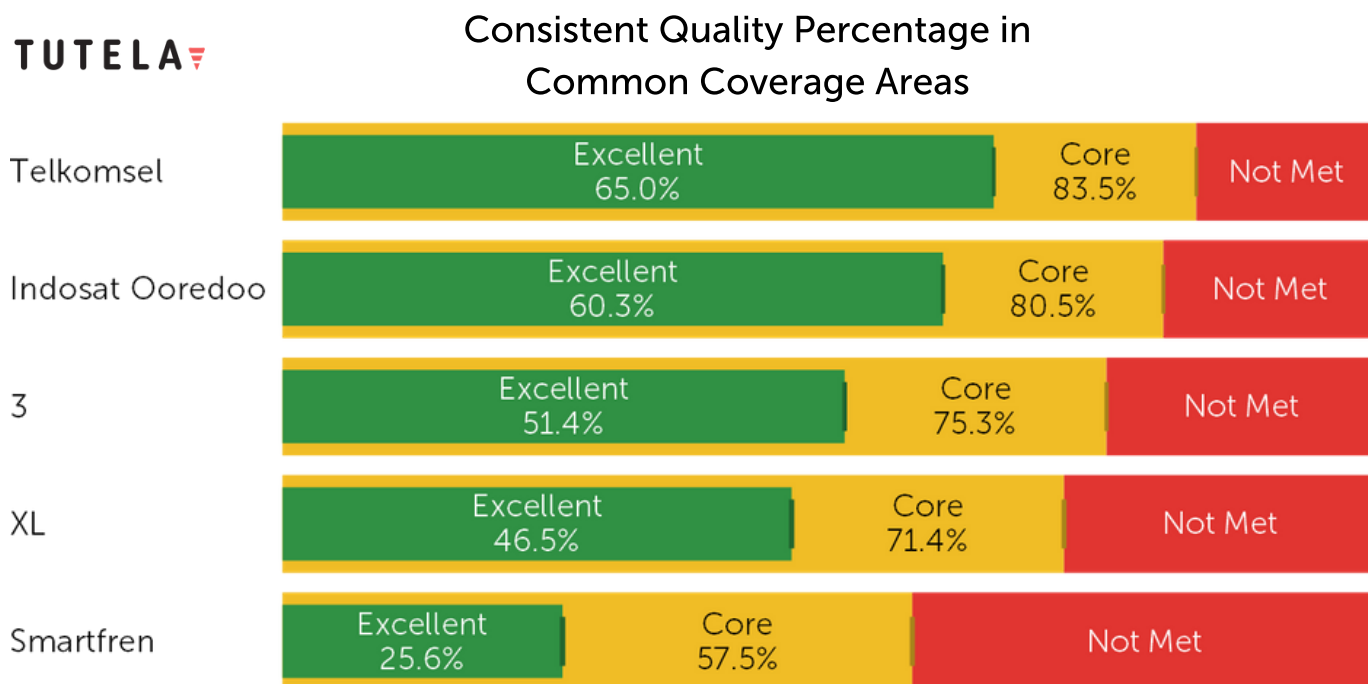
Consistent Quality Percentage in Common Coverage Areas

StarHub	Excellent 87.3%	
Singtel	Excellent 83.8%	Core 94.2%
M1	Excellent 82.8%	Core 94.0%

Consistent Quality

INDONESIA

Telkomsel was the undisputed leader for Consistent Quality in Indonesia. The operator's subscribers had by far the most tests exceed the Excellent Consistent Quality thresholds, with Indosat Ooredoo in second place, and a significant gap back to last-place Smartfren, whose users only saw 25.6% of tests sufficient for demanding use-

cases, like group HD video calls, HD video streaming, and multiplayer gaming. For Core Consistent Quality, Telkomsel once again came out on top, but with less of a commanding lead. Indosat Ooredoo was once again in second place, but just 3% separated first and second place.
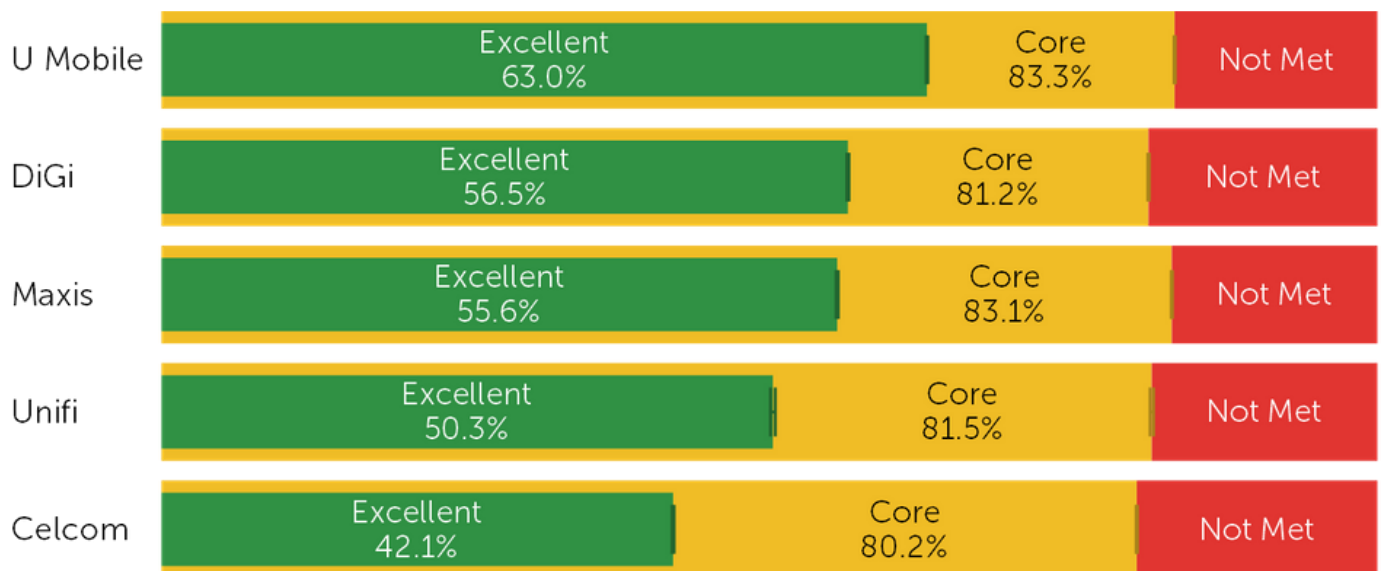
Consistent Quality Percentage in Common Coverage Areas

	Excellent	Core	Not Met
Telkomsel	65.0%	83.5%	Not Met
Indosat Ooredoo	60.3%	80.5%	Not Met
3	51.4%	75.3%	Not Met
XL	46.5%	71.4%	Not Met
Smartfren	25.6%	57.5%	Not Met

Consistent Quality

MALAYSIA

U Mobile came out on top for Excellent Consistent Quality in Malaysia, with 63% of tests from users passing the thresholds, implying that the connection would be sufficient for demanding use-cases like group HD video calling, multiplayer gaming, and HD video streaming. DiGi, Maxis, and Unifi finished behind U Mobile, with DiGi and Maxis providing a particularly similar experience to their users. Celcom was the only operator to see fewer than 50% of tests pass the more demanding thresholds. However, Celcom's performance was notably better for Core Consistent Quality, the thresholds that represent everyday use-cases like SD video streaming and web browsing. Although Celcom was once again in last place, all five operators provided a similar experience to users: just 3.1% separated first-place U Mobile from Celcom, and all operators exceeded 80% for the less demanding set of thresholds.

Consistent Quality Percentage in Common Coverage Areas

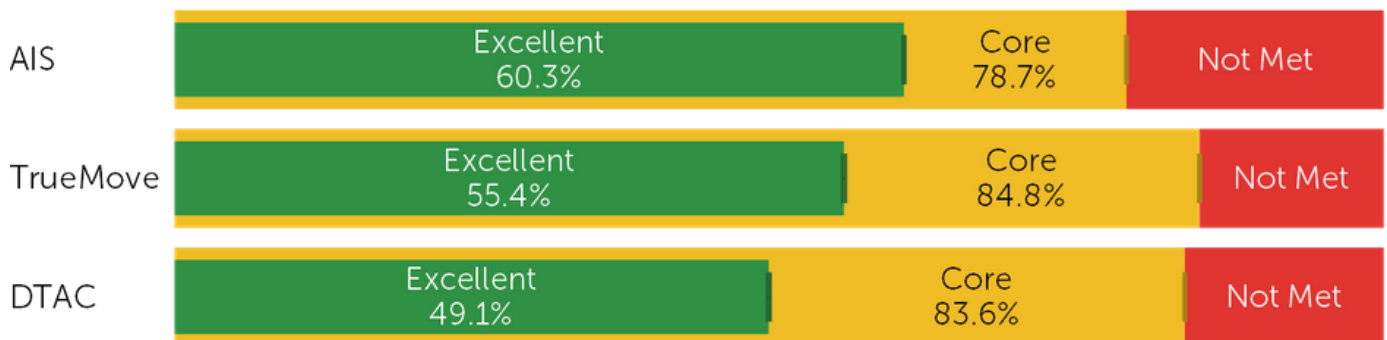| Operator	Excellent	Core	
U Mobile	Excellent 63.0%	Core 83.3%	Not Met
DiGi	Excellent 56.5%	Core 81.2%	Not Met
Maxis	Excellent 55.6%	Core 83.1%	Not Met
Unifi	Excellent 50.3%	Core 81.5%	Not Met
Celcom	Excellent 42.1%	Core 80.2%	Not Met

Consistent Quality

THAILAND

Operators in Thailand provided an interesting split for Consistent Quality: AIS, which finished in first place for Excellent Consistent Quality, was in last place for Core Consistent Quality. As the Excellent Consistent Quality thresholds are significantly higher than those for Core Consistent Quality (as a much faster, more responsive, and stable connection is required for applications like HD video calling and online gaming, compared to web browsing), this implies that AIS provides a network connection that is higher-performance, but less consistent for day to day uses, than its competitors. TrueMove, meanwhile, finished in second place for Excellent Consistent Quality, but first place for Core Consistent Quality. DTAC was third for Excellent Consistent Quality, but snagged a close second-place finish for Core Consistent Quality.

Consistent Quality Percentage in Common Coverage Areas

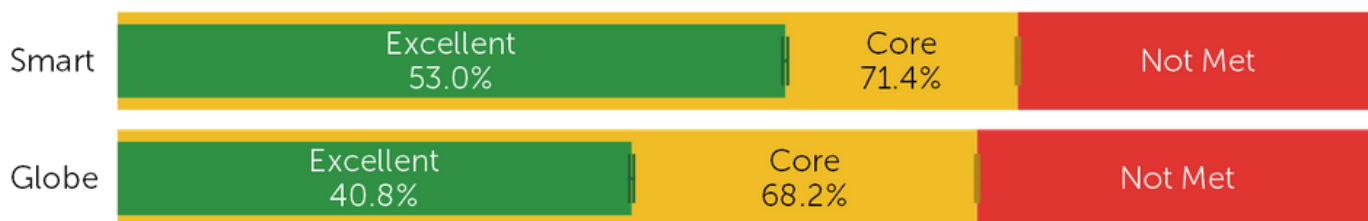|	Excellent	Core	Not Met
AIS	60.3%	78.7%	Not Met
TrueMove	55.4%	84.8%	Not Met
DTAC	49.1%	83.6%	Not Met

Consistent Quality

PHILIPPINES

Smart took first place for both Excellent and Core Consistent Quality in the Philippines, with a notably significant lead over Globe when it comes to the more demanding network quality required for Excellent Consistent Quality. Over 12% separated Smart and Globe for the Excellent thresholds, while Globe was much closer behind for Core Consistent Quality.

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Consistent Quality Percentage in Common Coverage Areas

Smart — Excellent 53.0% | Core 71.4% | Not Met

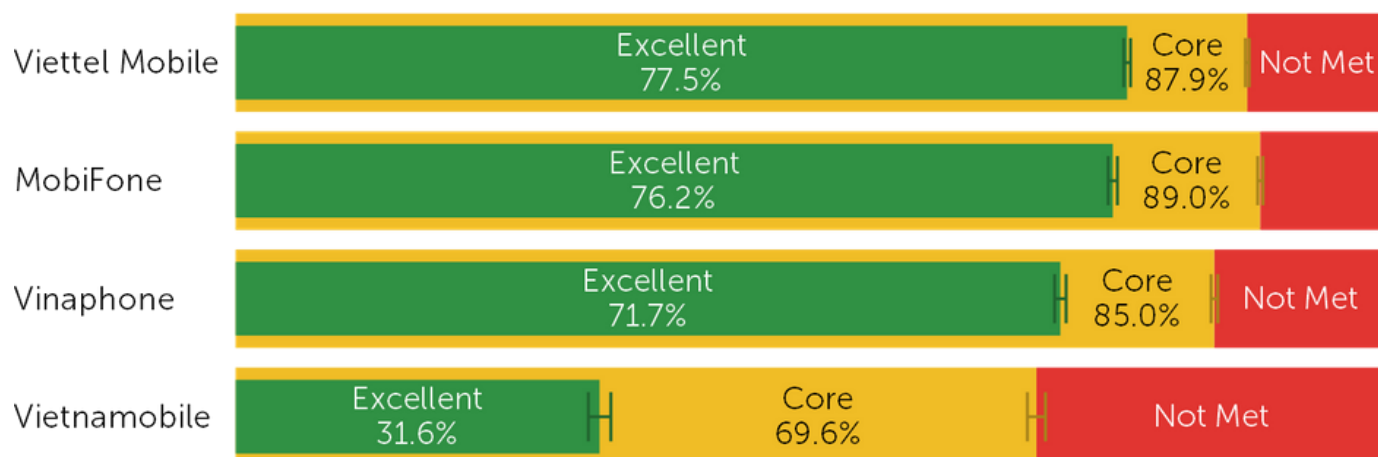Globe — Excellent 40.8% | Core 68.2% | Not Met

Consistent Quality

VIETNAM

Viettel Mobile took a narrow first-place victory over MobiFone for the best Excellent Consistent Quality in Vietnam. Just 1.3% separated the two operators, but the rankings were reversed for Core Consistent Quality, where MobiFone took first place. Vinaphone, meanwhile, handily beat out Vietnamobile for third place in both Excellent and Core Consistent Quality.

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Consistent Quality Percentage in Common Coverage Areas

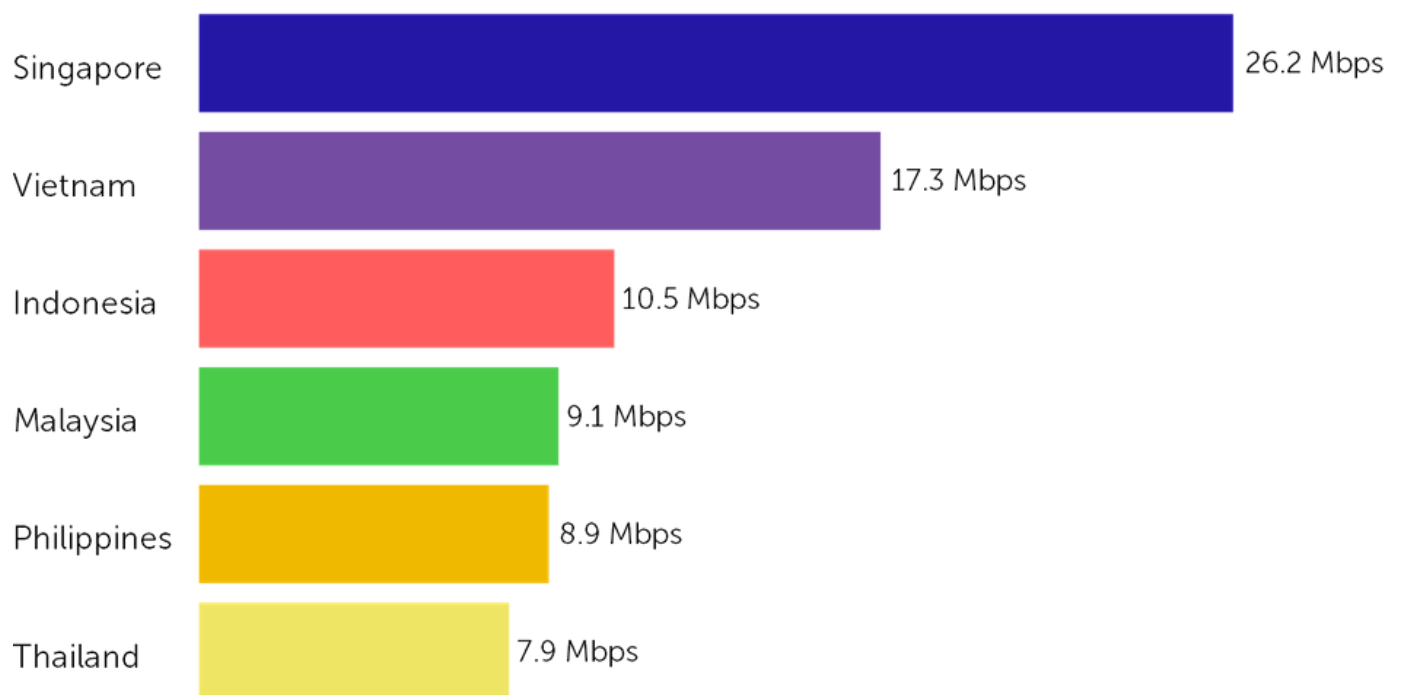|		
Viettel Mobile	Excellent 77.5%	Core 87.9%	Not Met
MobiFone	Excellent 76.2%	Core 89.0%	
Vinaphone	Excellent 71.7%	Core 85.0%	Not Met
Vietnamobile	Excellent 31.6%	Core 69.6%	Not Met

Download throughput

For download throughput, the top half of the ranking table looks identical to that for Consistent Quality: Singapore in a commanding first place, Vietnam in second, and Indonesia third. The second half of the ranking table, however, looks quite different:

Malaysia is in fourth, with the Philippines fifth, and Thailand in last place, with a median download throughput of just 7.9 Mbps, when comparing tests taken from subscribers on the major mobile network operators in those countries.

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Median Download Speed in Common Coverage Areas

Country	Speed
Singapore	26.2 Mbps
Vietnam	17.3 Mbps
Indonesia	10.5 Mbps
Malaysia	9.1 Mbps
Philippines	8.9 Mbps
Thailand	7.9 Mbps

Download throughput

SINGAPORE

Within Singapore, the results between operators were the same for download throughput as they were for Consistent Quality: StarHub in first, with a commanding lead over second-placed Singtel, and third-placed M1. It should be noted, however, that all three operators recorded a median download throughput well in excess of the 5 Mbps required for many demanding use-cases, like streaming HD video or participating in a group video call. However, StarHub's significant lead in download throughput implies a well-developed wireless network, and for the occasional use that does stress download throughput — like downloading a large app on the fly — StarHub subscribers are likely to be left waiting for less time.

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Median Download Speed in Common Coverage Areas

Operator	Median Download Speed
StarHub	33.7 Mbps
Singtel	25.0 Mbps
M1	21.4 Mbps

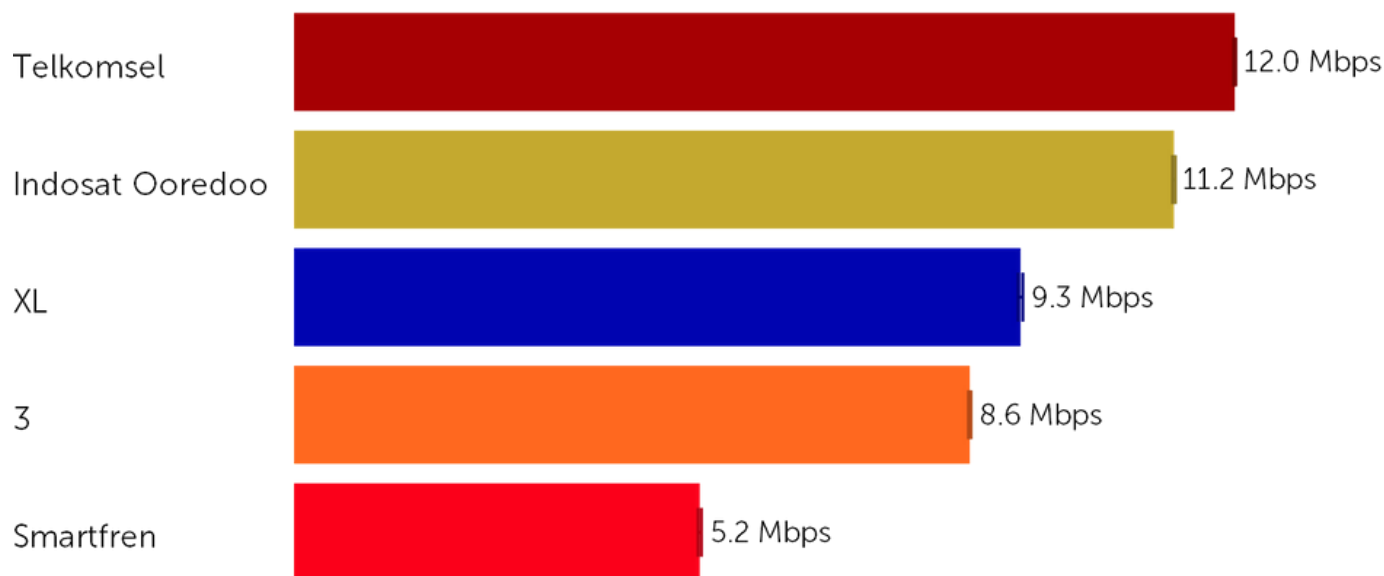# Download throughput

INDONESIA

For download throughput, as for Consistent Quality, Telkomsel came out on top within Indonesia, with Indosat Ooredoo just behind. There was more of a gap back to third and fourth place, occupied by XL and 3 respectively, who were around the 9 Mbps mark.

Smartfren, however, was an outlier amongst Indonesian operators. With a median download speed of just 5.2 Mbps, it's no surprise that Smartfren's Excellent Consistent Quality was the lowest of an individual operator in the region. Nearly half of Smartfren's tests would fail Excellent Consistent Quality due to download throughput alone; when taking other factors, like reliability and latency into account, the fact that just 25% of Smartfren's tests pass the Excellent Consistent Quality thresholds is to be expected.

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Median Download Speed in Common Coverage Areas

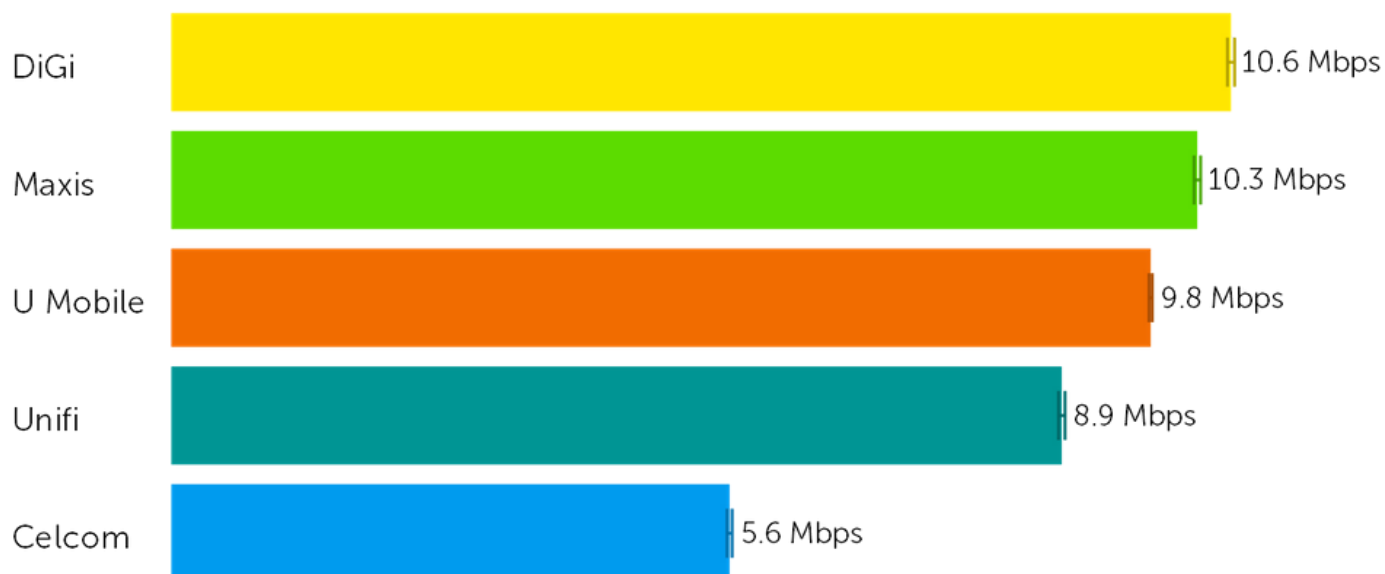| Operator	Median Download Speed
Telkomsel	12.0 Mbps
Indosat Ooredoo	11.2 Mbps
XL	9.3 Mbps
3	8.6 Mbps
Smartfren	5.2 Mbps

Download throughput

MALAYSIA

Competition for first place in download throughput was fierce: just 0.8 Mbps separated first and last place, with DiGi taking top spot, ahead of Maxis. U Mobile, which had the best Excellent Consistent Quality, was in third — showing that an operator does not have to have the fastest download speed in order to provide the best network quality. Apart from U Mobile being bumped down, the ranking order for download throughput was the same as it was for Excellent Consistent Quality. Unifi and Celcom filled out the last two places, with Celcom falling significantly behind other operators, at just 5.6 Mbps median download throughput.

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Median Download Speed in Common Coverage Areas

Operator	Median Download Speed
DiGi	10.6 Mbps
Maxis	10.3 Mbps
U Mobile	9.8 Mbps
Unifi	8.9 Mbps
Celcom	5.6 Mbps

Download throughput

THAILAND

All three operators in Thailand provided a similar median download throughput, with just 1.2 Mbps separating first and last place. TrueMove takes first place by a clear margin, however, with a median of 8.8 Mbps. AIS and DTAC are much closer, at 7.7 and 7.6 Mbps respectively.

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Median Download Speed in Common Coverage Areas

TrueMove	8.8 Mbps
AIS	7.7 Mbps
DTAC	7.6 Mbps

Download throughput

PHILIPPINES

A sizeable difference exists in the typical download experience of mobile customers in the Philippines: while Smart recorded a median download throughput of 11.5 Mbps in Tutela's testing — faster than the best operator in Malaysia and Thailand — Globe customers recorded a median download throughput of 7.6 Mbps.

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Median Download Speed in Common Coverage Areas

Smart — 11.5 Mbps

Globe — 7.6 Mbps
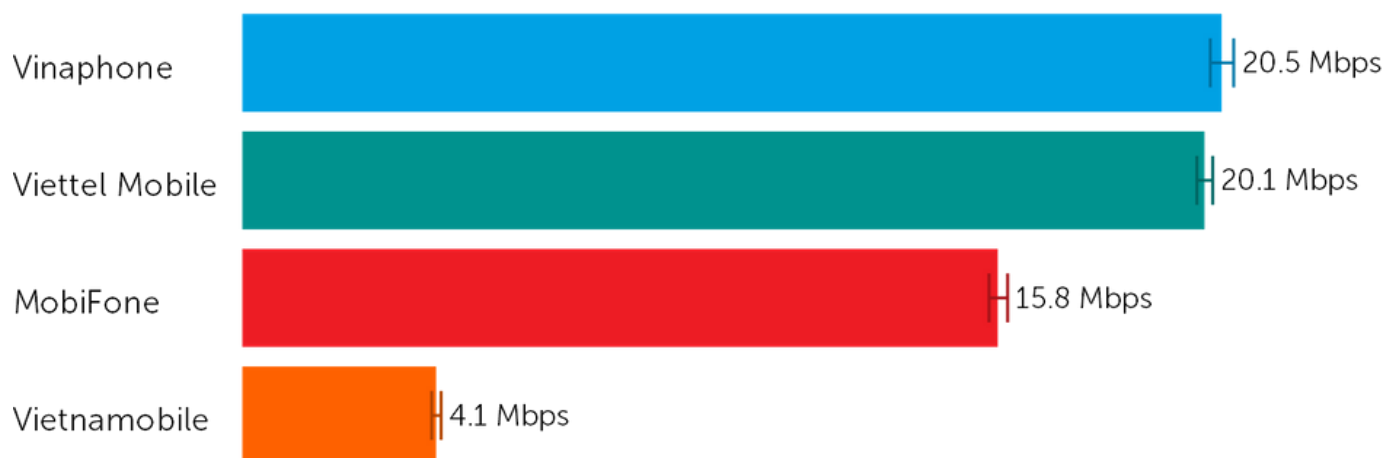
Download throughput

VIETNAM

Vietnam had the greatest difference between operators at the top and bottom of the download throughput ladder. While competition was so close between Vinaphone and Viettel Mobile that the two operators tied for first place, right around 20 Mbps, the same cannot be said for the other operators. MobiFone was in third place, with a median download speed of 15.8 Mbps — noticeably behind the two operators tied for first, but still amongst the upper echelon of mobile operators in the region. Vietnamobile, on the other hand, registered a median download throughput of just 4.1 Mbps, making it the slowest operator in the region.

Median Download Speed in Common Coverage Areas

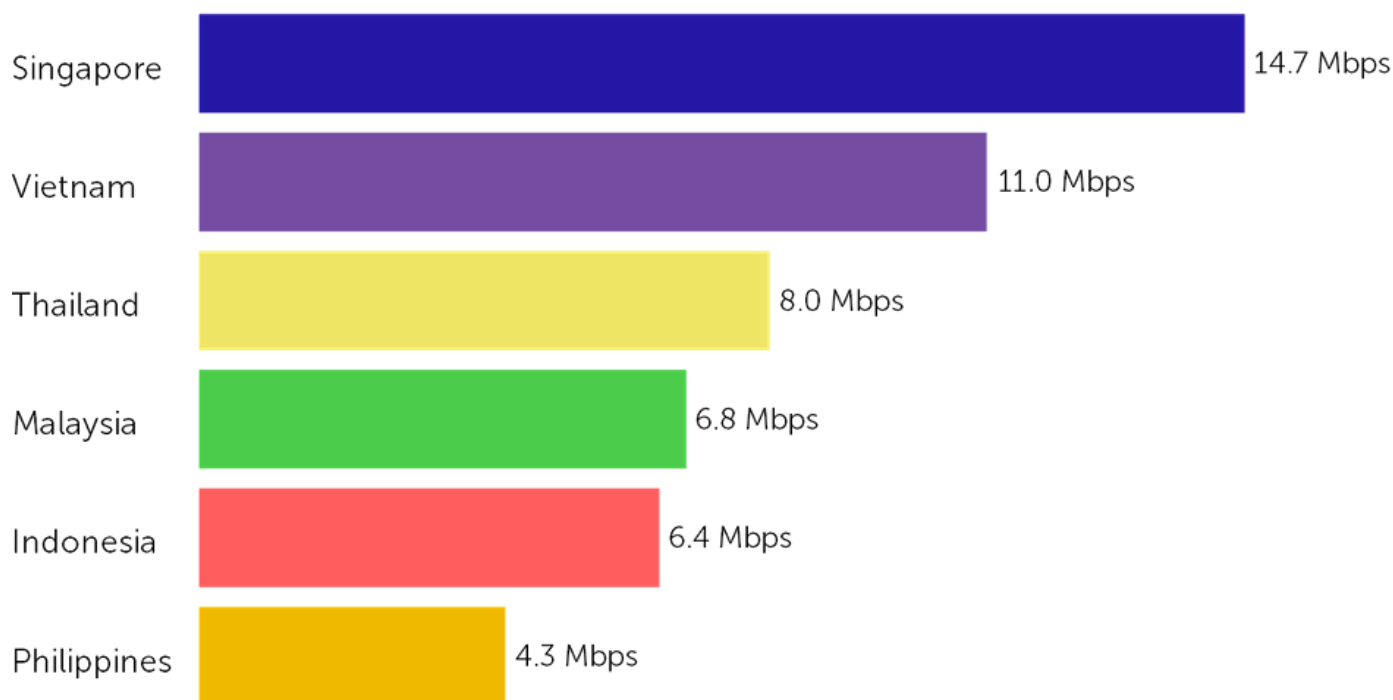| Operator	Speed
Vinaphone	20.5 Mbps
Viettel Mobile	20.1 Mbps
MobiFone	15.8 Mbps
Vietnamobile	4.1 Mbps

Upload throughput

Singapore retained its first-place honors for upload throughput, with a median upload speed recorded from subscribers on its main networks that was faster than the median download speed of many countries — again, to be expected, given the demographic differences between countries in the region. Vietnam once again came in second place, but from there, the rest of the rankings changed somewhat compared to other metrics: Thailand rose to take third place, while Indonesia sank to fifth. Upload throughput is particularly important for applications such as social media content sharing and video calling.

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Median Upload Speed in Common Coverage Areas

Country	Speed
Singapore	14.7 Mbps
Vietnam	11.0 Mbps
Thailand	8.0 Mbps
Malaysia	6.8 Mbps
Indonesia	6.4 Mbps
Philippines	4.3 Mbps

Upload throughput

SINGAPORE

While the ranking order of operators was the same for upload throughput as for many other metrics — Singtel first, StarHub second, and M1 third — the gaps between operators were less pronounced. 4.1 Mbps separated first and last place, with the most pronounced difference being the 2.7 Mbps gap between Singtel and StarHub.

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Median Upload Speed in Common Coverage Areas

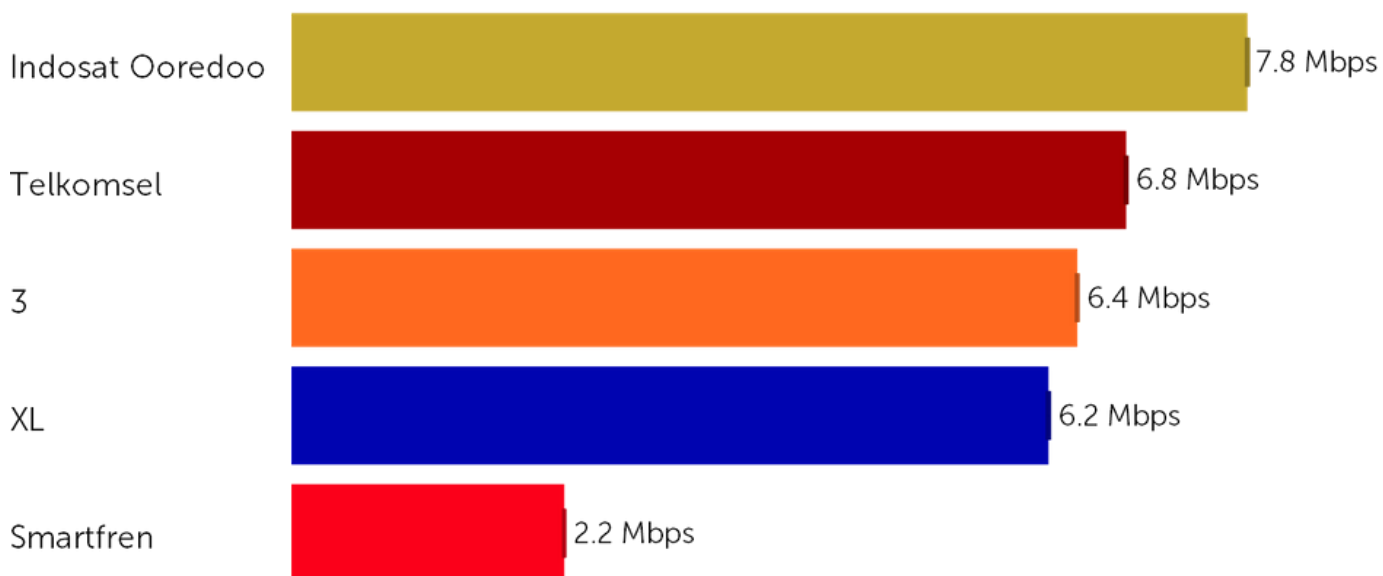| Operator	Median Upload Speed
Singtel	16.7 Mbps
StarHub	14.0 Mbps
M1	12.6 Mbps

Upload throughput

INDONESIA

Indosat Ooredoo took first place for upload throughput — the only category in which Telkomsel did not take first place. Ooredoo's advantage over Telkomsel was a full megabit, but behind Ooredoo, there was little difference between second and fourth place. Smartfren once again found itself at the bottom of the ranking list, with a median upload throughput of just 2.2 Mbps.

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Median Upload Speed in Common Coverage Areas

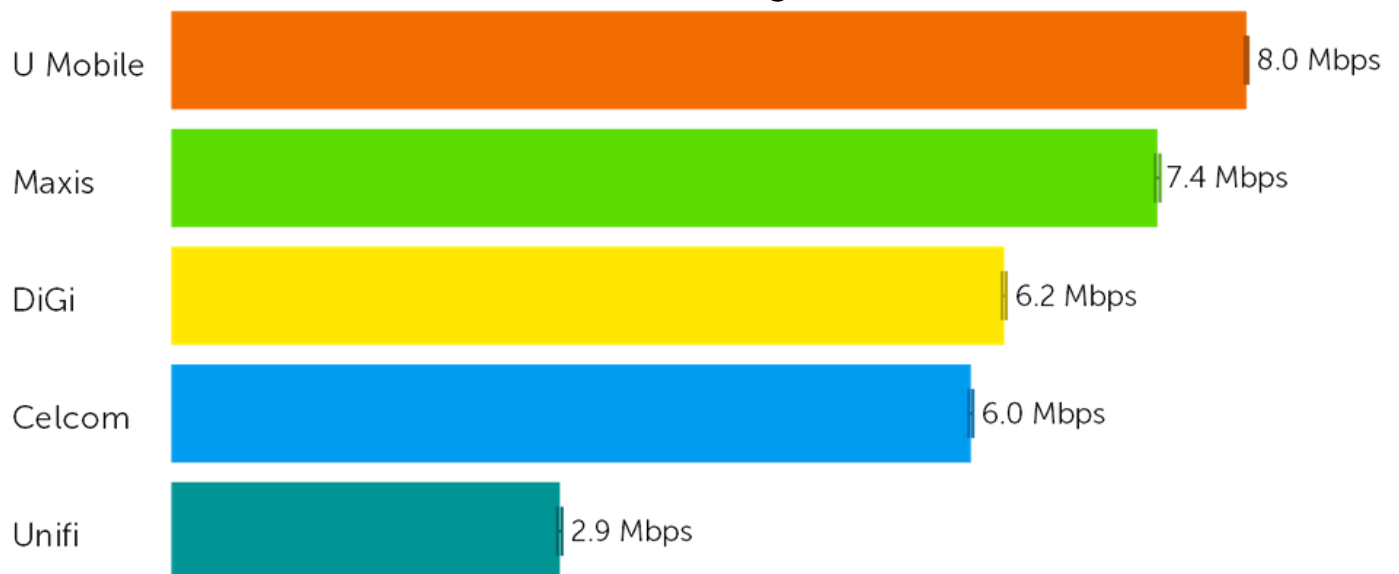|	
Indosat Ooredoo	7.8 Mbps
Telkomsel	6.8 Mbps
3	6.4 Mbps
XL	6.2 Mbps
Smartfren	2.2 Mbps

Upload throughput

MALAYSIA

In Malaysia, U Mobile took first place for upload throughput, with a median speed of 8.0 Mbps. Maxis, DiGi, and Celcom were positioned close behind, with DiGi and Celcom particularly close for third place, at 6.2 and 6.0 Mbps respectively. Unifi, which managed to avoid last-place finishes for both Consistent Quality and download throughput, was in a firm last place, significantly behind the other four operators at just 2.9 Mbps.

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Median Upload Speed in Common Coverage Areas

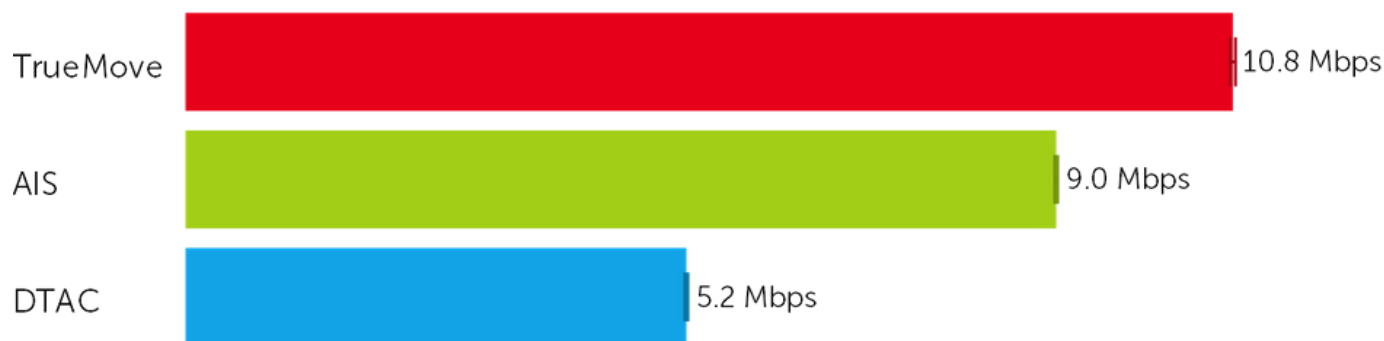| Operator	Speed
U Mobile	8.0 Mbps
Maxis	7.4 Mbps
DiGi	6.2 Mbps
Celcom	6.0 Mbps
Unifi	2.9 Mbps

Upload throughput

THAILAND

In Thailand, TrueMove was in first place for upload throughput, as it was for download throughput. It was also the only operator in Thailand to record a median upload speed faster than 10 Mbps. AIS was relatively close behind, with a median upload of 9 Mbps, while DTAC was in a more distant third place, recording a 5.2 Mbps median upload speed.

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Median Upload Speed in Common Coverage Areas

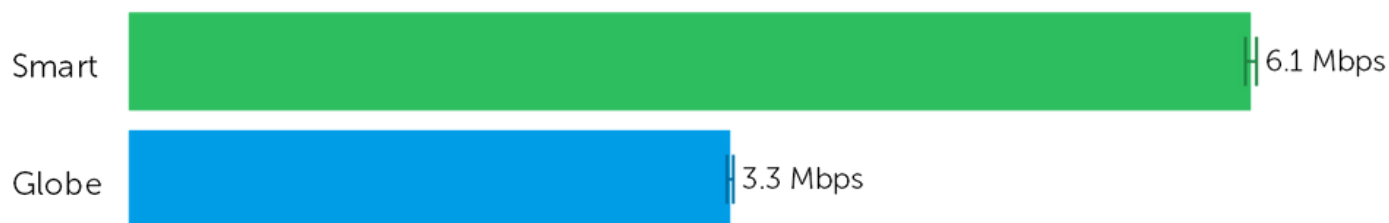| Operator	Speed
TrueMove	10.8 Mbps
AIS	9.0 Mbps
DTAC	5.2 Mbps

Upload throughput

PHILIPPINES

While neither Smart nor Globe would rank amongst the upper echelons of operators in the region, Smart's 6.1 Mbps median upload speed gave it a commanding first place in the Philippines. Globe's upload speed was barely half that of Smart, at just 3.3 Mbps.

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Median Upload Speed in Common Coverage Areas

Smart   6.1 Mbps

Globe   3.3 Mbps

Upload throughput
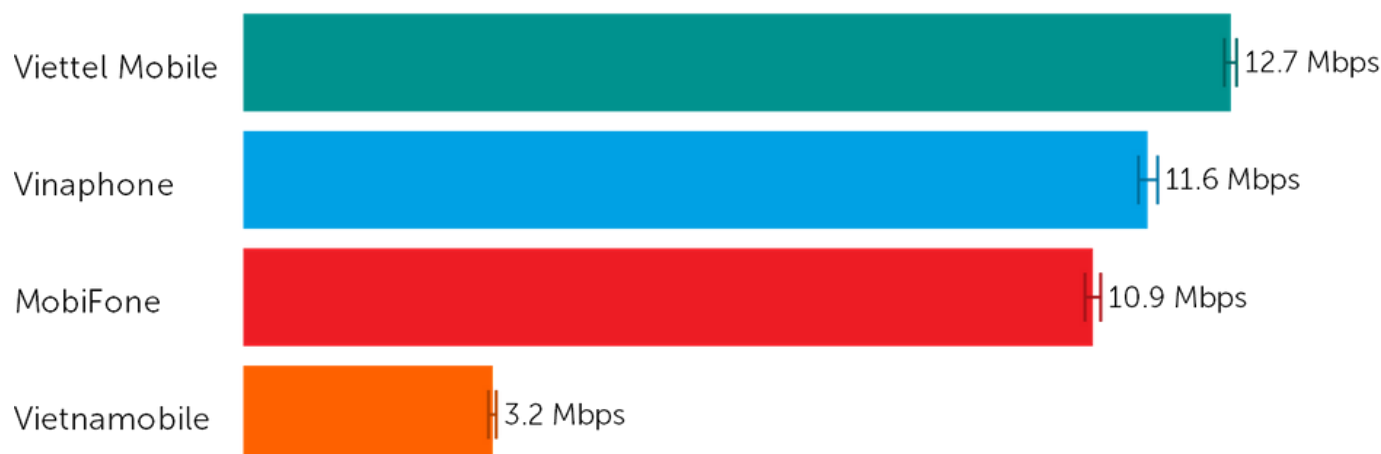
VIETNAM

As seen with other metrics, the results of Vietnamese mobile operators were split into two distinct categories. Viettel Mobile, Vinaphone, and MobiFone occupied the first three spots, with relatively close results — Viettel Mobile was in first, with a median upload speed of 12.7 Mbps, while Vinafone and MobiFone were close behind at 11.6 and 10.9 Mbps respectively. Vietnamobile, however, trailed the rest of the pack, recording a median upload speed of just 3.2 Mbps.

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Median Upload Speed in Common Coverage Areas

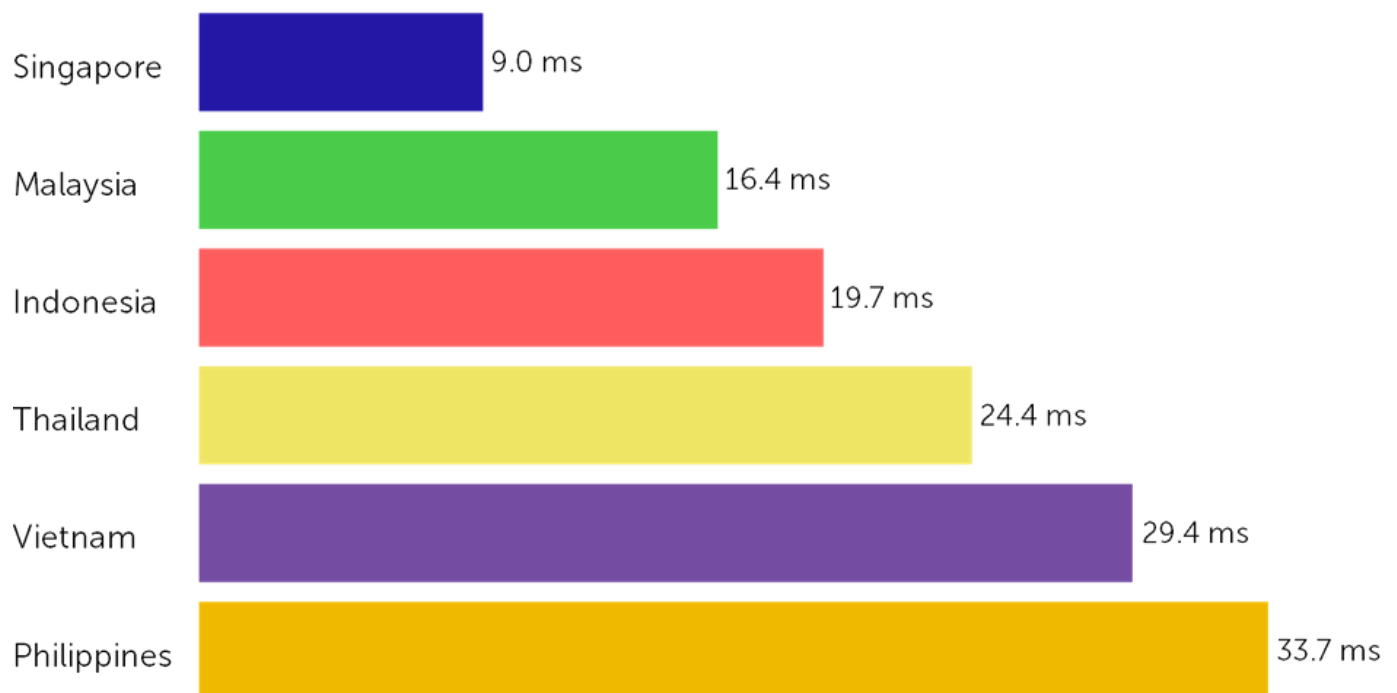| Operator	Speed
Viettel Mobile	12.7 Mbps
Vinaphone	11.6 Mbps
MobiFone	10.9 Mbps
Vietnamobile	3.2 Mbps

Latency

The country-level results for latency were something of a change from what we saw with other metrics: while Singapore, unsurprisingly, still occupied first place, Vietnam — which was in second place for Consistent Quality, download speed, and upload speed — sank to fifth place for latency. The rest of the ranking table was more aligned with other results, as Malaysia and Indonesia occupied the second and third spots.

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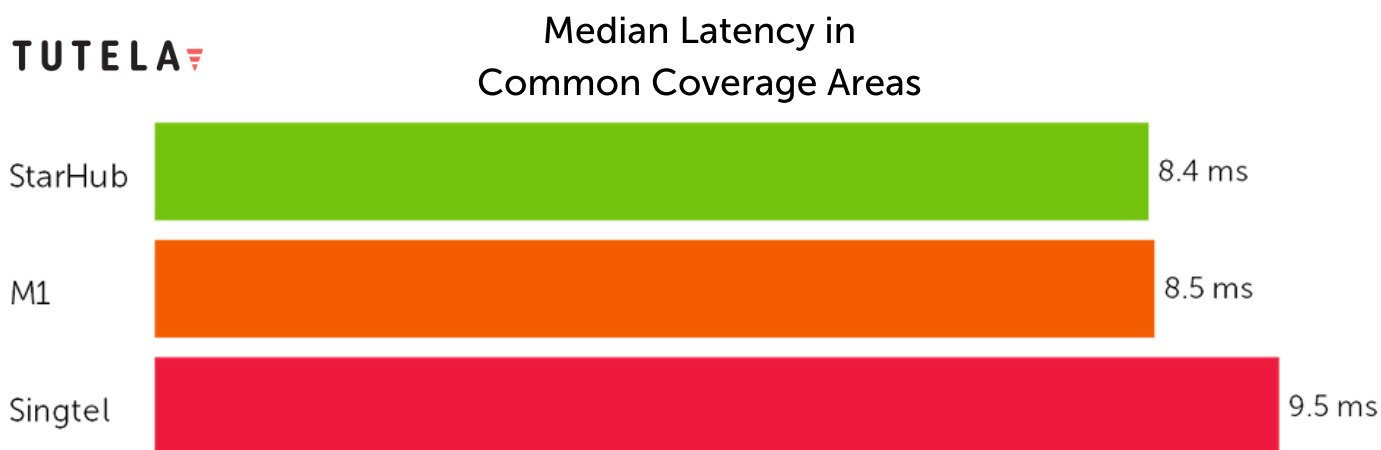
Median Latency in Common Coverage Areas

Country	Median Latency
Singapore	9.0 ms
Malaysia	16.4 ms
Indonesia	19.7 ms
Thailand	24.4 ms
Vietnam	29.4 ms
Philippines	33.7 ms

Latency

SINGAPORE

The latency results were extremely close in Singapore, with just 1.1 milliseconds being the difference between first and last place. StarHub claimed the top spot, and M1 was second — Singtel finished in third place for latency, the only metric where it was outside of the top two. In practical terms, however, the latency experienced by users of all three networks would be virtually indistinguishable: single-digit latency is more than sufficient for even the most real-time applications, and the responsiveness of Singapore's mobile networks is not in question.
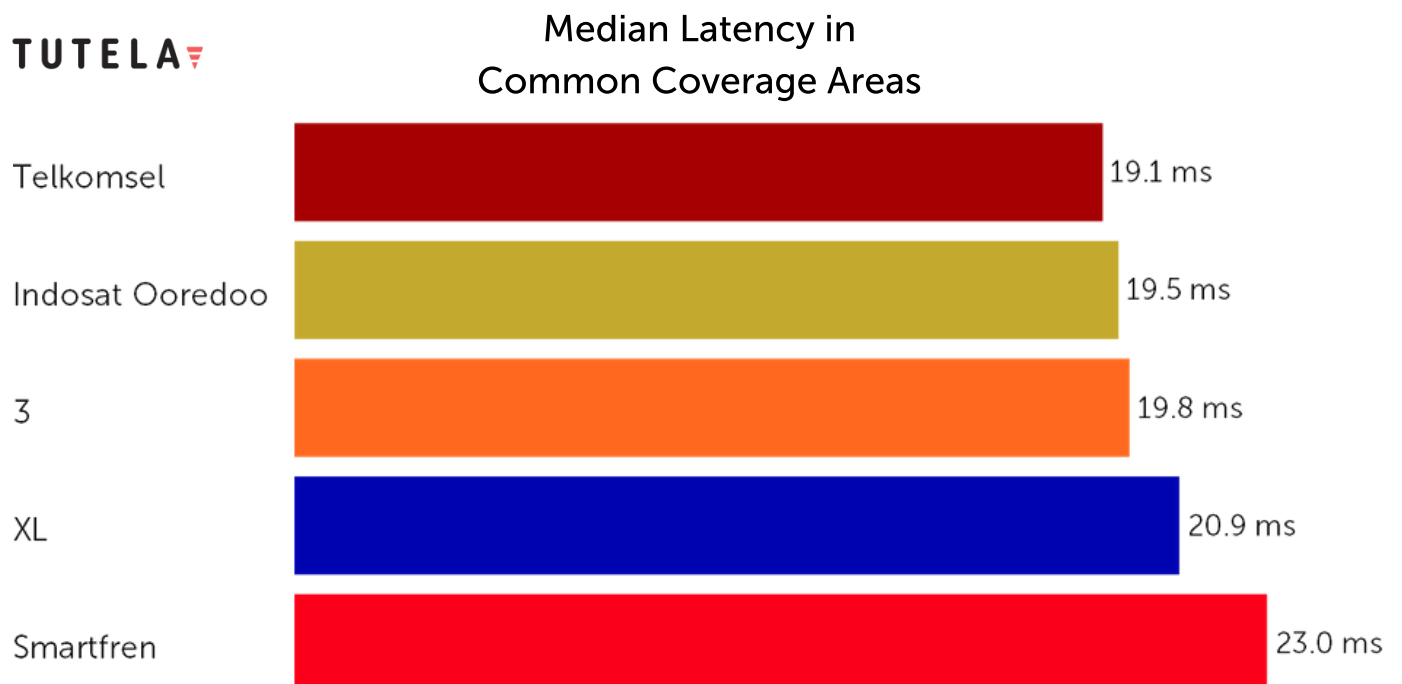
Median Latency in Common Coverage Areas

Network	Median Latency
StarHub	8.4 ms
M1	8.5 ms
Singtel	9.5 ms

Latency

INDONESIA

Just 0.7 milliseconds separated the top three operators in Indonesia, with Telkomsel taking the top spot with a median one-way latency of 19.1 ms. Indosat Ooredoo and 3 took second and third place, while XL was slightly further behind with a median one-way latency of 20.9 ms. Smartfren was in last place, with a median one-way latency of 23.0 ms. While it's par for the course for Smartfren to finish in fifth place for other metrics, its last-place finish for latency is somewhat surprising. Smartfren users spend by far the greatest proportion of time connected to 4G compared to other operators' users, and one of the greatest advantages of 4G over 3G is typically the much lower latency.

TUTELA

Median Latency in Common Coverage Areas

Operator	Median Latency
Telkomsel	19.1 ms
Indosat Ooredoo	19.5 ms
3	19.8 ms
XL	20.9 ms
Smartfren	23.0 ms

Latency

MALAYSIA

Maxis, Celcom, and U Mobile took the top three spots for latency in Malaysia, with just 1.2 milliseconds separating Maxis and U Mobile. Celcom's second-place finish for latency is interesting, given that it finished in last place for Consistent Quality and download speed. The competitive latency result is promising for Celcom, and implies that if it can improve its download throughput, major improvements in Consistent Quality could be expected to follow.

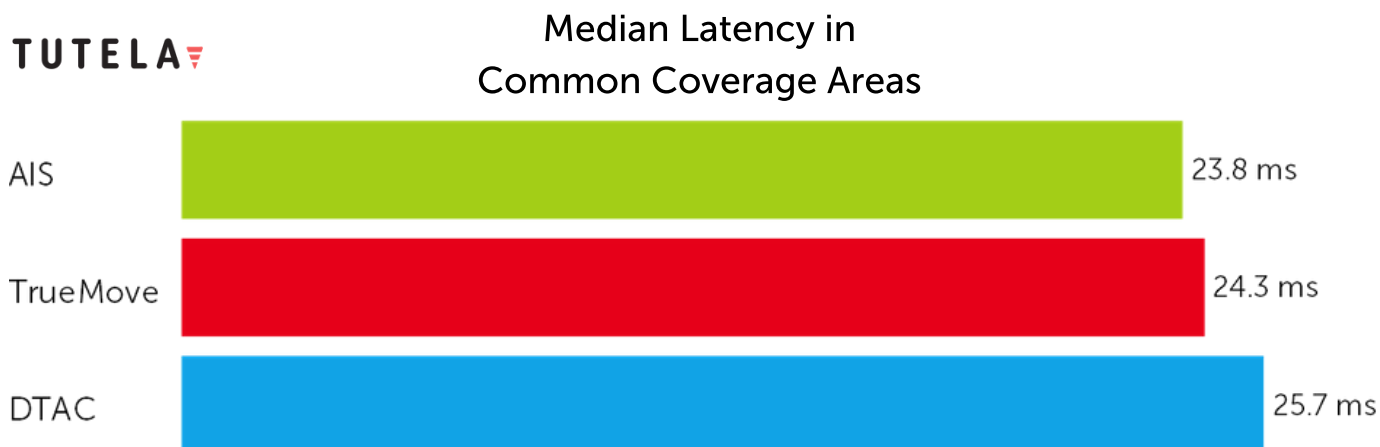**TUTELA**

Median Latency in Common Coverage Areas

Operator	Median Latency
Maxis	15.1 ms
Celcom	15.6 ms
U Mobile	16.3 ms
DiGi	18.1 ms
Unifi	19.6 ms

Latency

THAILAND

All three operators in Thailand provide a similar latency experience to their users. AIS was in first place, with a median one-way latency of 23.8 ms, but TrueMove and DTAC were relatively close behind, with DTAC's median less than two milliseconds behind AIS. Although that represents a statistically significant difference in the responsiveness of the connections, users are unlikely to notice a two-millisecond difference in their experience, even when on a VOIP call or multiplayer gaming.

TUTELA

Median Latency in
Common Coverage Areas

Operator	Latency
AIS	23.8 ms
TrueMove	24.3 ms
DTAC	25.7 ms

Latency

PHILIPPINES

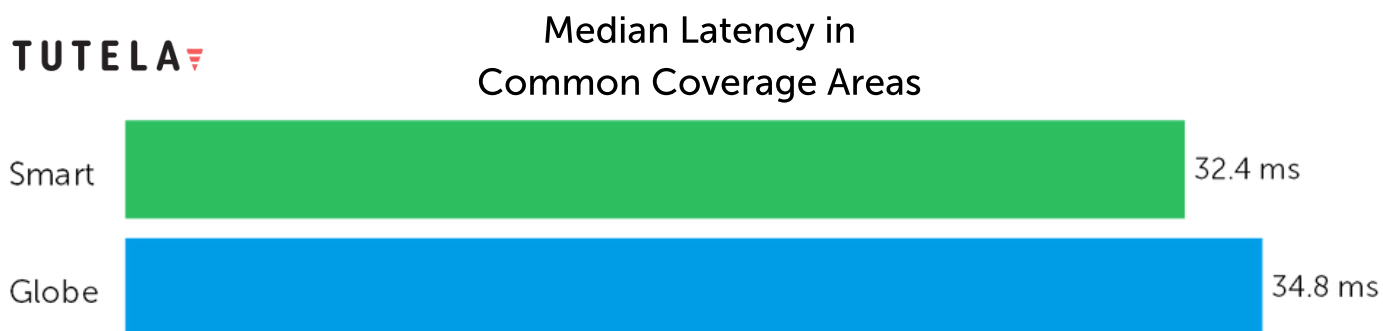Although we saw some significant differences between Smart and Globe on other metrics, such as upload throughput, no such significant differences were present in the latency results. Smart's median one-way latency was 32.4 ms, putting it in first place, but Globe was just 2.4 ms behind.

TUTELA

Median Latency in Common Coverage Areas

Smart	32.4 ms
Globe	34.8 ms

Latency

VIETNAM

As with many other metrics, Viettel Mobile once again finished in first place for latency. Compared to the other countries in the region, Vietnam also saw more differentiation between operators: MobiFone, in second place was nearly five milliseconds behind, while last-place Vinaphone had nearly double the latency of Viettel.

Median Latency in Common Coverage Areas

Operator	Median Latency
Viettel Mobile	25.8 ms
MobiFone	30.1 ms
Vietnamobile	35.7 ms
Vinaphone	49.0 ms

Coverage

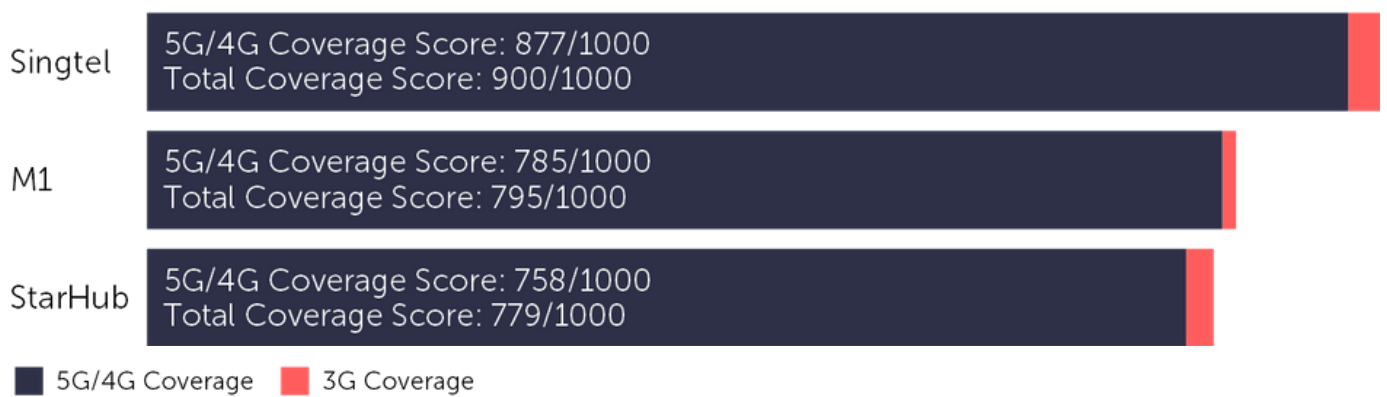SINGAPORE

Within Singapore, Singtel has a distinct advantage on coverage over the other two operators, providing a 10% boost in the observed area covered. For all three operators, the overwhelming majority of the coverage footprint was 4G or better, with only a tiny proportion of the observed coverage area being provided solely by 3G.

TUTELA   **Relative Area Coverage Score**

Singtel
5G/4G Coverage Score: 877/1000
Total Coverage Score: 900/1000

M1
5G/4G Coverage Score: 785/1000
Total Coverage Score: 795/1000

StarHub
5G/4G Coverage Score: 758/1000
Total Coverage Score: 779/1000
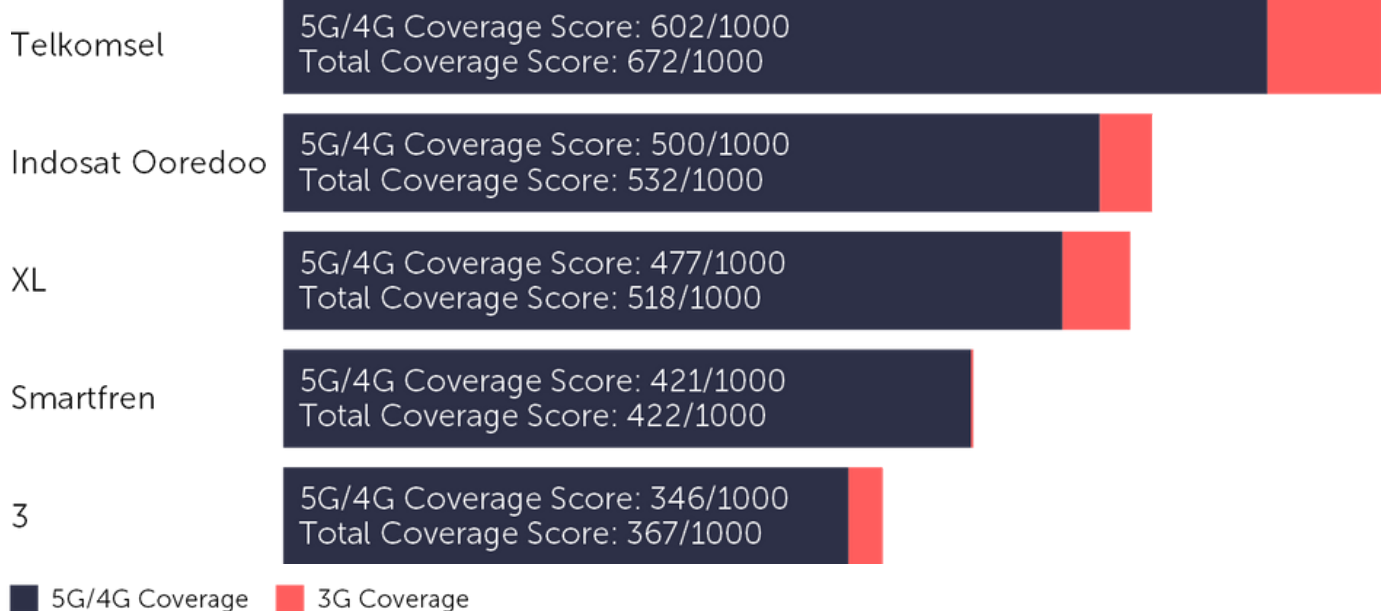
■ 5G/4G Coverage   ■ 3G Coverage

Coverage

INDONESIA

Telkomsel had an undisputed advantage over other operators in Indonesia when it comes to the covered areas, with its relative observed 4G footprint significantly larger than any other operator's total observed coverage footprint (even including older technologies like 3G). Smartfren, which finished in last place for many of the performance metrics, avoided the fifth-place finish here, and has a coverage footprint that is almost entirely 4G.

TUTELA

Relative Area Coverage Score

Telkomsel
5G/4G Coverage Score: 602/1000
Total Coverage Score: 672/1000

Indosat Ooredoo
5G/4G Coverage Score: 500/1000
Total Coverage Score: 532/1000

XL
5G/4G Coverage Score: 477/1000
Total Coverage Score: 518/1000

Smartfren
5G/4G Coverage Score: 421/1000
Total Coverage Score: 422/1000

3
5G/4G Coverage Score: 346/1000
Total Coverage Score: 367/1000
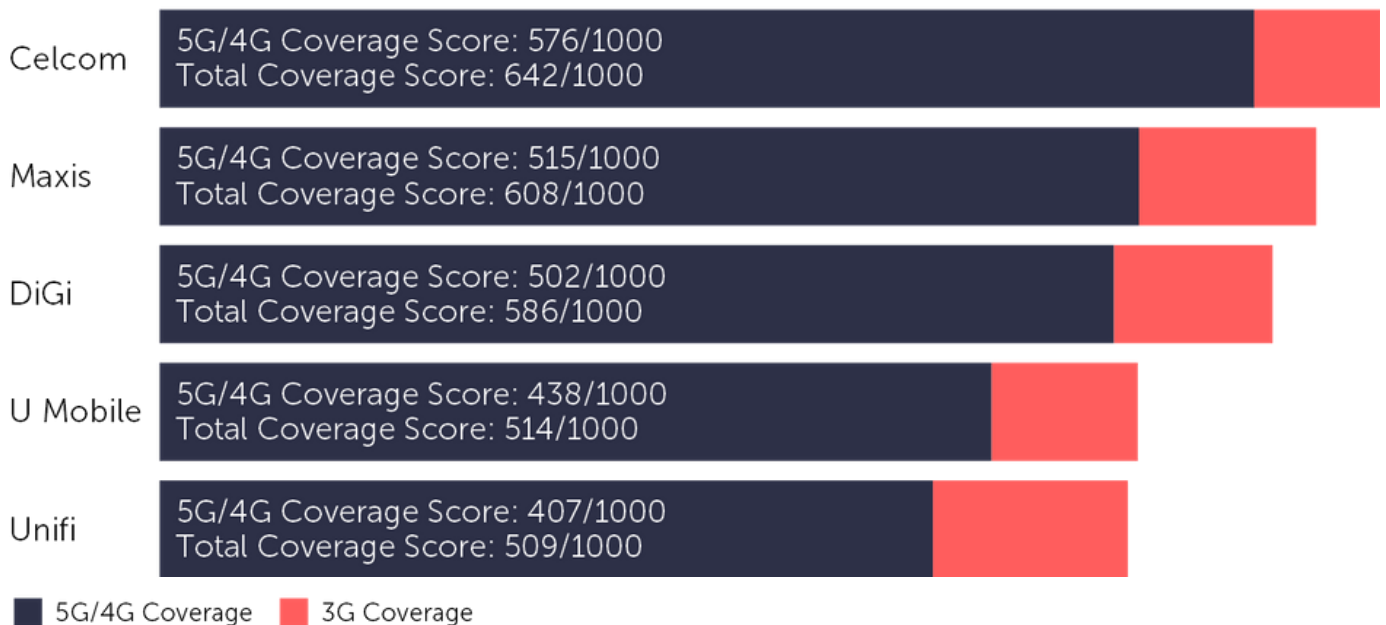
■ 5G/4G Coverage   ■ 3G Coverage

Coverage

MALAYSIA

Celcom led all Malaysian operators for the relative area coverage score, more than 34 points better than next-closest Maxis. All five operators still have a sizeable proportion of their coverage footprint served by older 3G technology — all five operators saw 3G account for 15-20% of their observed geographic coverage.

TUTELA — Relative Area Coverage Score

Operator		
Celcom	5G/4G Coverage Score: 576/1000 Total Coverage Score: 642/1000	
Maxis	5G/4G Coverage Score: 515/1000 Total Coverage Score: 608/1000	
DiGi	5G/4G Coverage Score: 502/1000 Total Coverage Score: 586/1000	
U Mobile	5G/4G Coverage Score: 438/1000 Total Coverage Score: 514/1000	
Unifi	5G/4G Coverage Score: 407/1000 Total Coverage Score: 509/1000	

■ 5G/4G Coverage ■ 3G Coverage

Coverage

THAILAND

AIS scored best for relative area coverage amongst all operators in Thailand, with both the best total coverage score, as well as the largest observed LTE footprint.

Relative Area Coverage Score

AIS
5G/4G Coverage Score: 617/1000
Total Coverage Score: 674/1000

TrueMove
5G/4G Coverage Score: 557/1000
Total Coverage Score: 626/1000

DTAC
5G/4G Coverage Score: 512/1000
Total Coverage Score: 572/1000
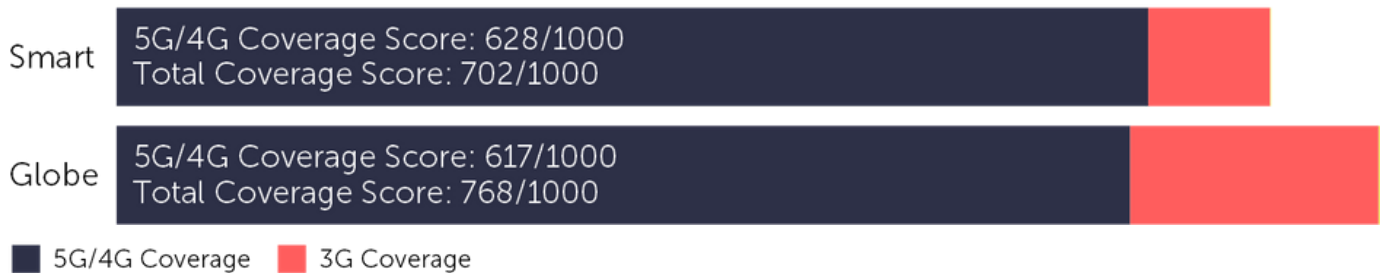
■ 5G/4G Coverage   ■ 3G Coverage

Coverage

PHILIPPINES

In the Philippines, we saw a rare split in the coverage scoring: although Smart's LTE coverage score was slightly above that of Globe (although by only 11 points), Globe has a more expansive network when considering 3G coverage as well. For users that prioritize having any kind of connection, Globe may provide a better option, but Smart takes the crown for coverage with the newer 4G technology.

Relative Area Coverage Score

Smart
5G/4G Coverage Score: 628/1000
Total Coverage Score: 702/1000

Globe
5G/4G Coverage Score: 617/1000
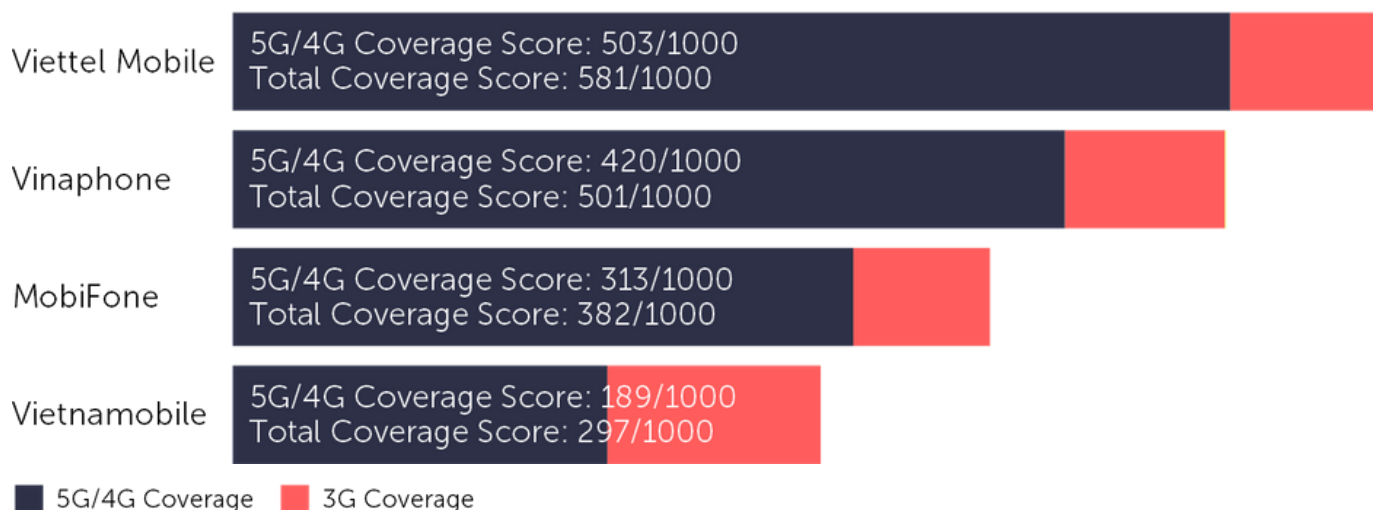Total Coverage Score: 768/1000

5G/4G Coverage   3G Coverage

Coverage

VIETNAM

Viettel Mobile, which was in first place for all the performance metrics, also took home the award for the best relative area coverage score. For both the total network and the 4G/5G footprint only, Viettel Mobile was the best. Vinaphone and MobiFone were in second and third place, while Vietnamobile was in a distinct fourth place. In fact, Vietnamobile's total coverage score — which includes a substantial amount of 3G-only coverage — is lower than any other operator's LTE-only coverage score.

TUTELA

Relative Area Coverage Score

Viettel Mobile
5G/4G Coverage Score: 503/1000
Total Coverage Score: 581/1000

Vinaphone
5G/4G Coverage Score: 420/1000
Total Coverage Score: 501/1000

MobiFone
5G/4G Coverage Score: 313/1000
Total Coverage Score: 382/1000

Vietnamobile
5G/4G Coverage Score: 189/1000
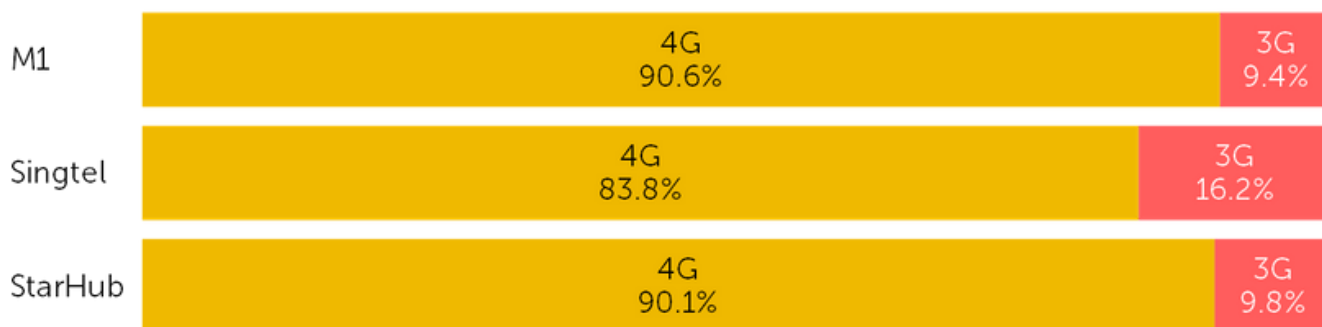Total Coverage Score: 297/1000

■ 5G/4G Coverage   ■ 3G Coverage
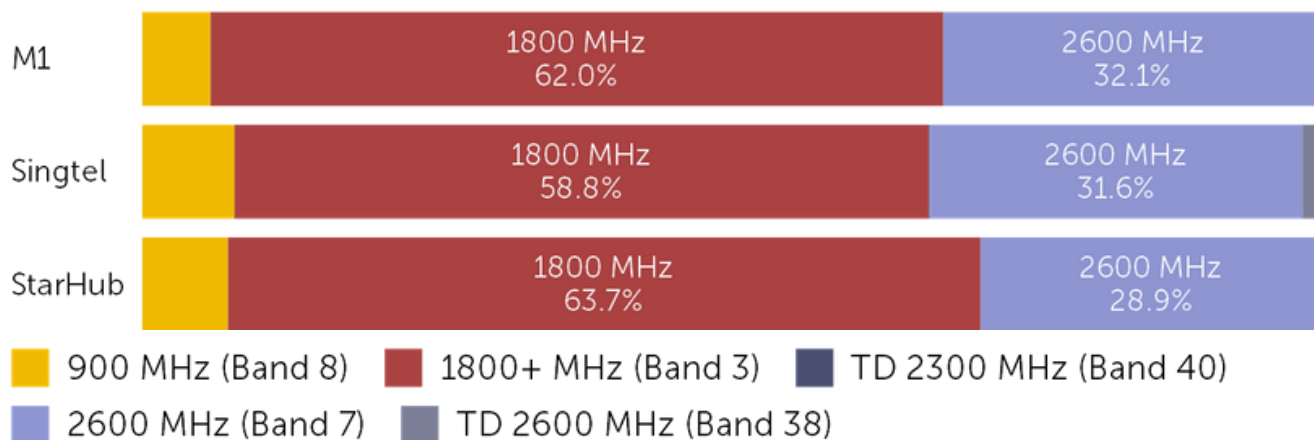
Technology usage

SINGAPORE

M1 subscribers spent the greatest proportion of time connected to 4G, with 90.6% of observed connection time on the newer connection technology. StarHub was just 0.5% behind, while Singtel's users spent a much greater 16.2% of time connected to the older 3G technology. When it comes to spectrum usage, all three operators have a nearly identical distribution: 1800 MHz and 2600 MHz account for the majority of data traffic, with low-band spectrum accounting for just a fraction of observed data traffic.

TUTELA

Percent of Time by Mobile Connection Type
Nationwide

Operator	4G	3G
M1	4G 90.6%	3G 9.4%
Singtel	4G 83.8%	3G 16.2%
StarHub	4G 90.1%	3G 9.8%

TUTELA

Mobile Data Volume by LTE Band
Nationwide

Operator	900 MHz	1800 MHz	2600 MHz
M1		1800 MHz 62.0%	2600 MHz 32.1%
Singtel		1800 MHz 58.8%	2600 MHz 31.6%
StarHub		1800 MHz 63.7%	2600 MHz 28.9%

- 900 MHz (Band 8)
- 1800+ MHz (Band 3)
- TD 2300 MHz (Band 40)
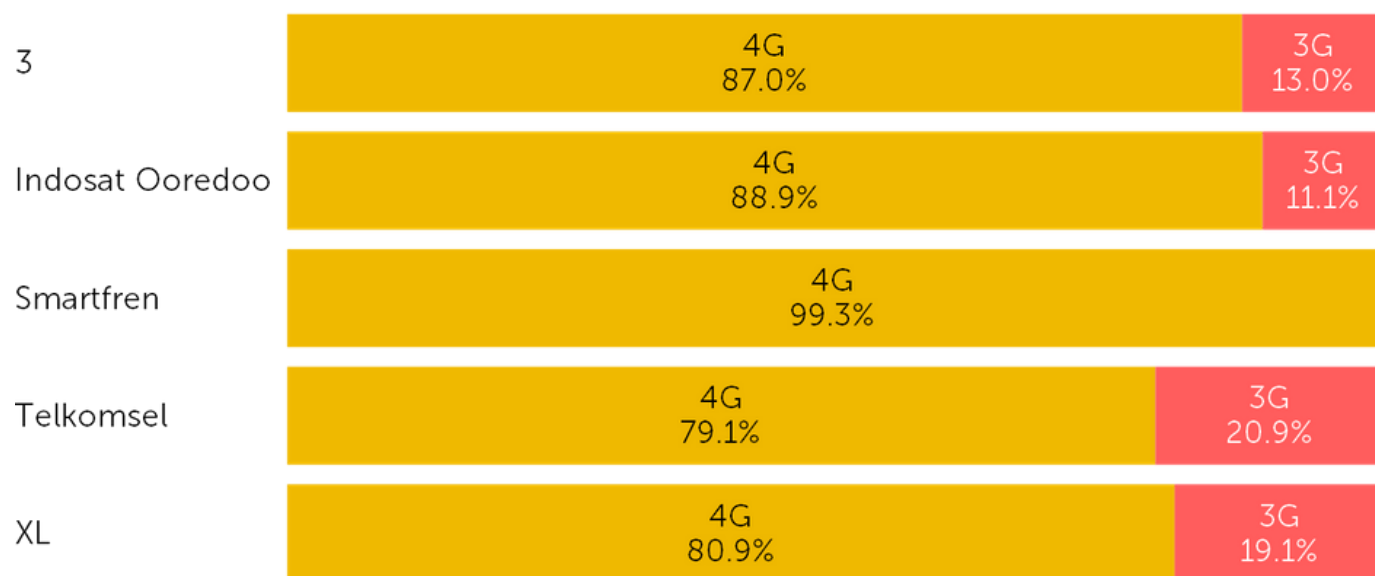- 2600 MHz (Band 7)
- TD 2600 MHz (Band 38)

Technology usage

INDONESIA

Smartfren stands out as having by far the highest time-on-4G percentage, as well as a very different spectrum utilization to other operators. 99.3% of the time, when a Smartfren user has a connection, it's on 4G — well in excess of the next-closest operator, Indosat Ooredoo. With regards to spectrum, Smartfren is also an outlier, as the only holder of 850 MHz spectrum. It uses its low-band 850 MHz spectrum for nearly 30% of total LTE data traffic. XL and 3, however, rely more heavily on mid-band 1800 MHz and 2100 MHz for data traffic, which can potentially cause issues with rural coverage and coverage deep inside buildings.

TUTELA

Percent of Time by Mobile Connection Type Nationwide

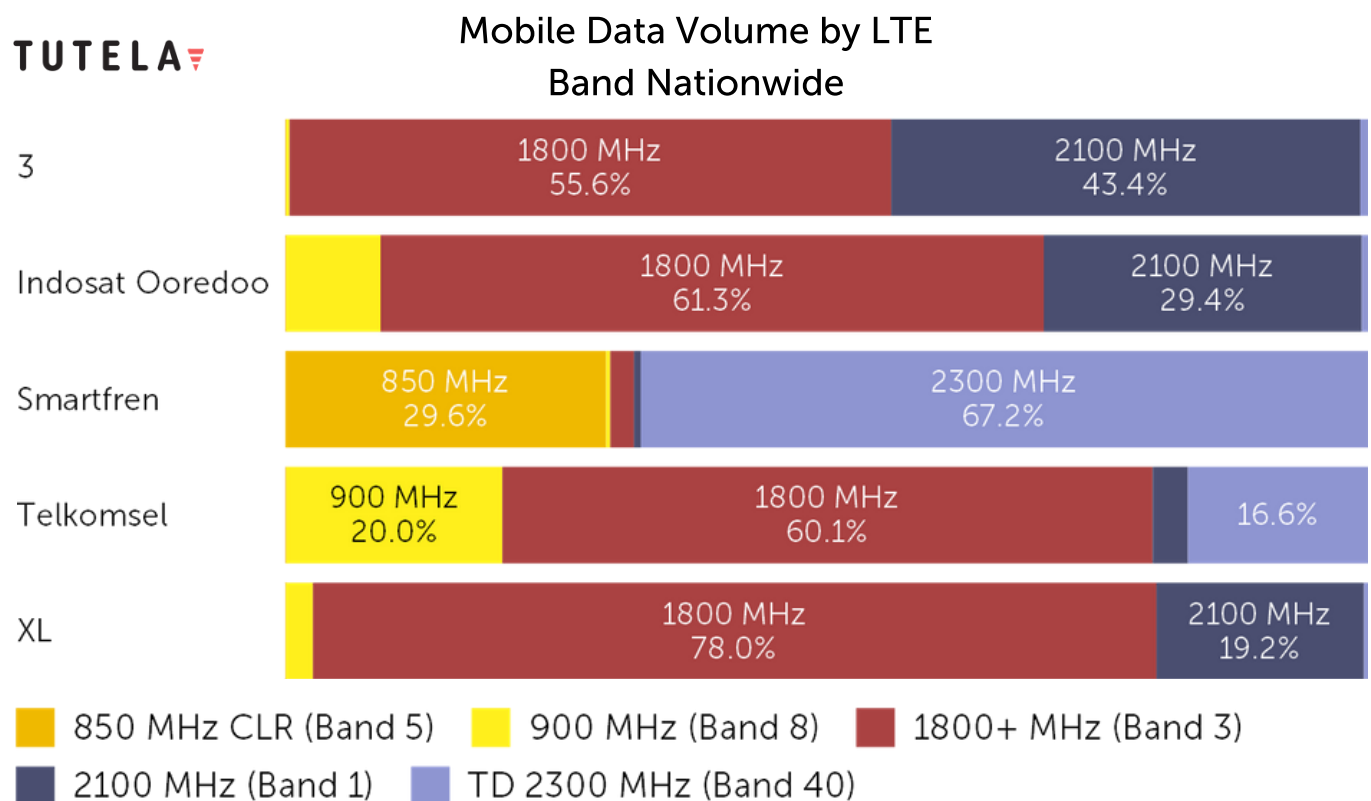| Operator		
3	4G 87.0%	3G 13.0%
Indosat Ooredoo	4G 88.9%	3G 11.1%
Smartfren	4G 99.3%	
Telkomsel	4G 79.1%	3G 20.9%
XL	4G 80.9%	3G 19.1%

Technology usage

INDONESIA

With regards to spectrum, Smartfren is also an outlier, as the only holder of 850 MHz spectrum. It uses its low-band 850 MHz spectrum for nearly 30% of total LTE data traffic. XL and 3, however, rely more heavily on mid-band 1800 MHz and 2100 MHz for data traffic, which can potentially cause issues with rural coverage and coverage deep inside buildings.
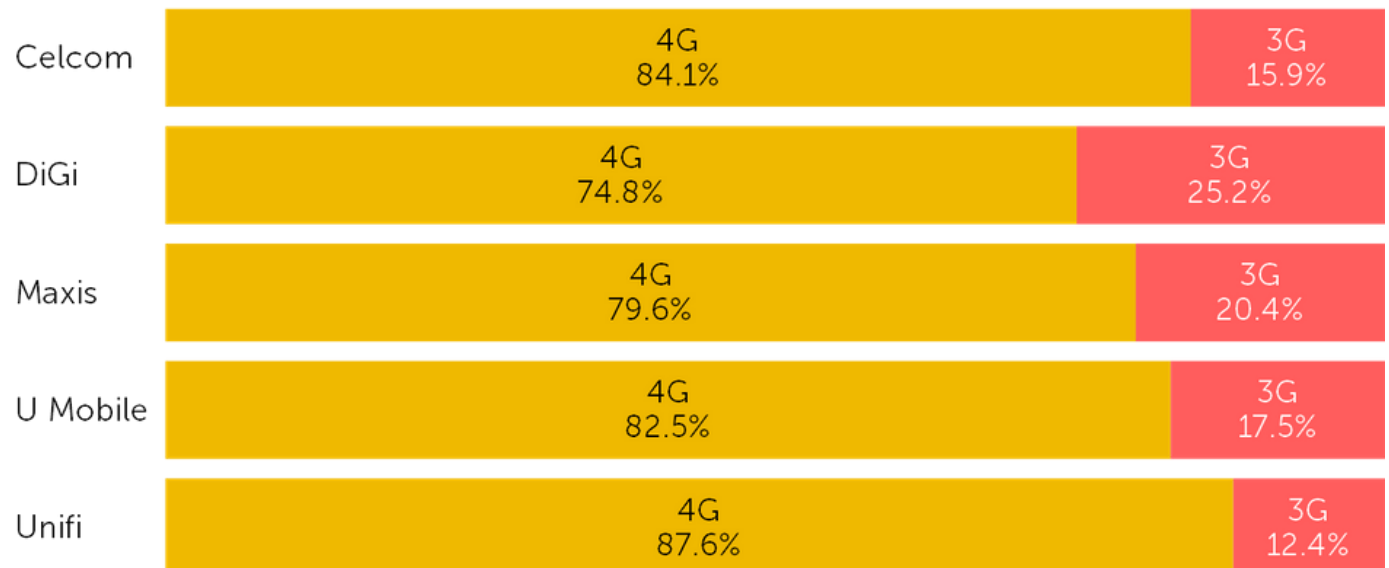
TUTELA

Mobile Data Volume by LTE Band Nationwide

Operator	Bands
3	1800 MHz 55.6% / 2100 MHz 43.4%
Indosat Ooredoo	1800 MHz 61.3% / 2100 MHz 29.4%
Smartfren	850 MHz 29.6% / 2300 MHz 67.2%
Telkomsel	900 MHz 20.0% / 1800 MHz 60.1% / 16.6%
XL	1800 MHz 78.0% / 2100 MHz 19.2%

Legend:
- 850 MHz CLR (Band 5)
- 900 MHz (Band 8)
- 1800+ MHz (Band 3)
- 2100 MHz (Band 1)
- TD 2300 MHz (Band 40)

Technology usage

MALAYSIA

There was less of a spread in the time spent connected to 3G or 4G amongst Malaysia operators, compared to the differences in some other metrics. Unifi users spent the greatest proportion of time on 4G, at 87.6%, but even users of DiGi, who used 3G the most, were connected to the older network technology just a quarter of the time.

TUTELA

Percent of Time by Mobile Connection Type Nationwide

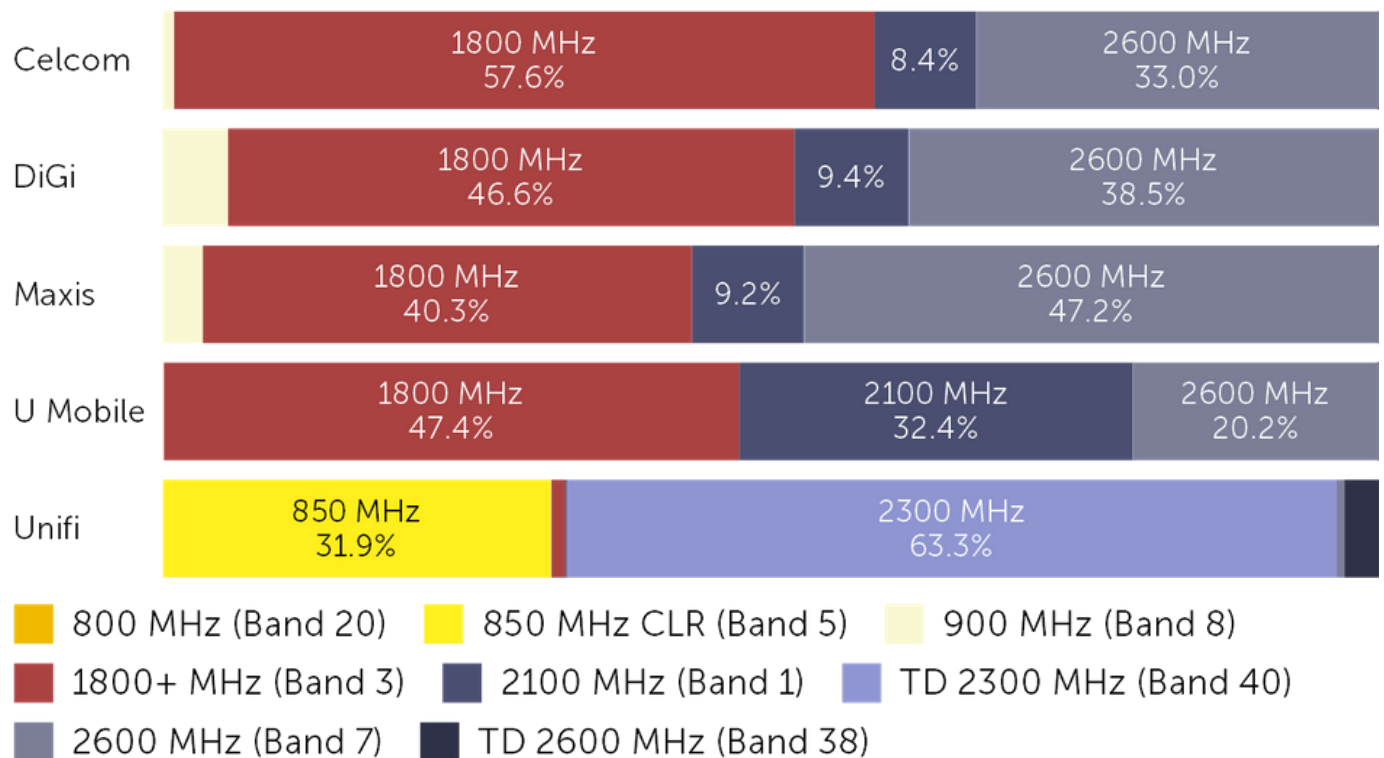| Operator	4G	3G
Celcom	4G 84.1%	3G 15.9%
DiGi	4G 74.8%	3G 25.2%
Maxis	4G 79.6%	3G 20.4%
U Mobile	4G 82.5%	3G 17.5%
Unifi	4G 87.6%	3G 12.4%

Technology usage

MALAYSIA

For spectrum usage, most operators were much more similar: mid-band and high-band (1800 MHz, 2100 MHz, and 2600 MHz) carried the bulk of 4G data traffic for Celcom, DiGi, Maxis, and U Mobile. Unifi, however, is the sole license-holder for 850 MHz spectrum, and therefore uses it for nearly a third of its LTE data volume. It is also the only operator to lean heavily on the 2300 MHz TDD spectrum. TDD spectrum can be biased to favour download over upload or vice versa, which may be the reason why Unifi's download throughput is competitive with other operators, but it's upload throughput falls behind.

TUTELA

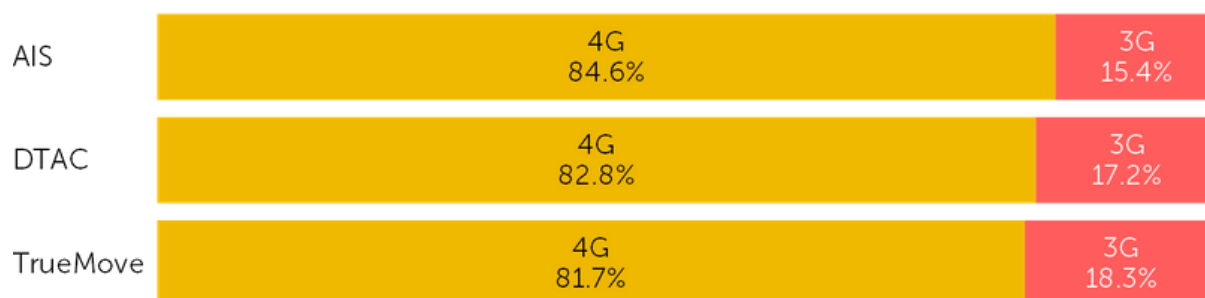## Mobile Data Volume by LTE Band Nationwide

Operator			
Celcom	1800 MHz 57.6%	8.4%	2600 MHz 33.0%
DiGi	1800 MHz 46.6%	9.4%	2600 MHz 38.5%
Maxis	1800 MHz 40.3%	9.2%	2600 MHz 47.2%
U Mobile	1800 MHz 47.4%	2100 MHz 32.4%	2600 MHz 20.2%
Unifi	850 MHz 31.9%	2300 MHz 63.3%	

Legend:
- 800 MHz (Band 20)
- 850 MHz CLR (Band 5)
- 900 MHz (Band 8)
- 1800+ MHz (Band 3)
- 2100 MHz (Band 1)
- TD 2300 MHz (Band 40)
- 2600 MHz (Band 7)
- TD 2600 MHz (Band 38)
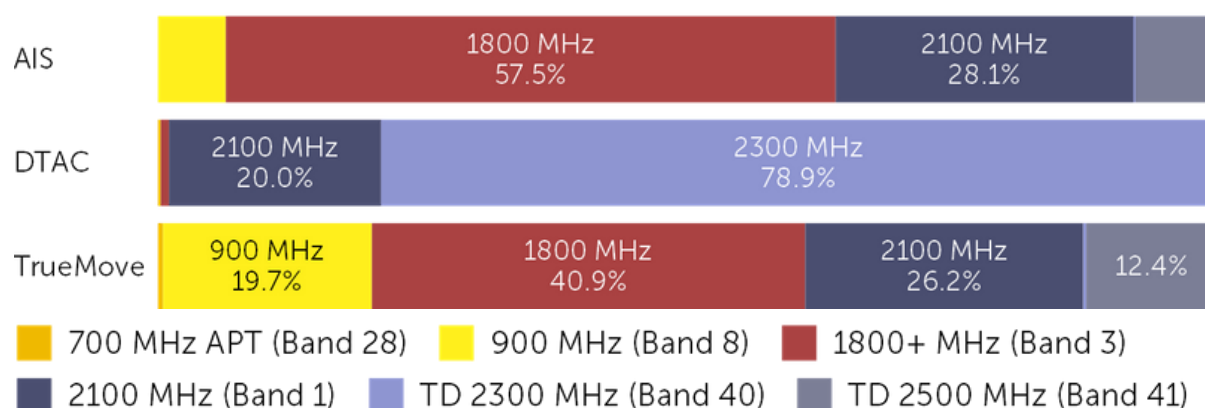
Technology usage

THAILAND

AIS, DTAC, and TrueMove customers all spend between 80% and 85% of their mobile connection time on 4G, with 3G only serving as a fallback for all three operators. The spectrum usage is much more different, however: while AIS and TrueMove both have a more conventional mix of low-band, mid-

band, and high-band spectrum, DTAC is almost entirely reliant on higher spectrum bands for its 4G data traffic. Of particular note is the 2300 MHz spectrum, which DTAC access through a roaming agreement with ToT[2].

TUTELA

Percent of Time by Mobile Connection Type Nationwide

	4G	3G
AIS	4G 84.6%	3G 15.4%
DTAC	4G 82.8%	3G 17.2%
TrueMove	4G 81.7%	3G 18.3%

TUTELA

Mobile Data Volume by LTE Band Nationwide

AIS		1800 MHz 57.5%	2100 MHz 28.1%	
DTAC	2100 MHz 20.0%	2300 MHz 78.9%		
TrueMove	900 MHz 19.7%	1800 MHz 40.9%	2100 MHz 26.2%	12.4%

- 700 MHz APT (Band 28)
- 900 MHz (Band 8)
- 1800+ MHz (Band 3)
- 2100 MHz (Band 1)
- TD 2300 MHz (Band 40)
- TD 2500 MHz (Band 41)

[2] dtac, Introducing New Spectrum from dtac
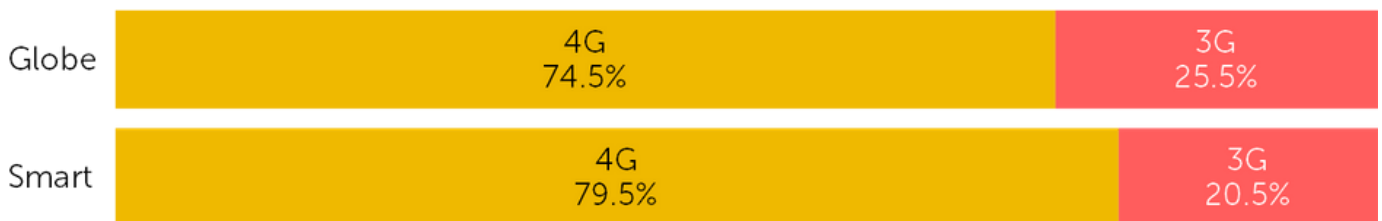https://www.dtac.co.th/en/network/dtac-2300mhz.html
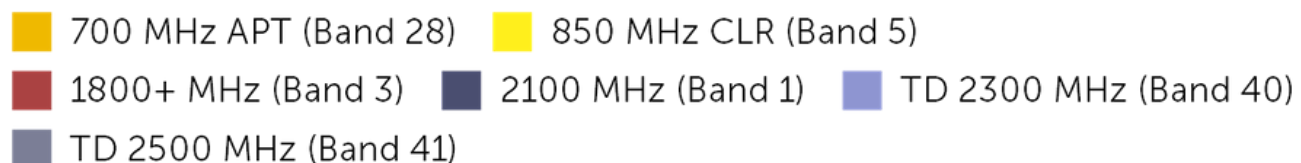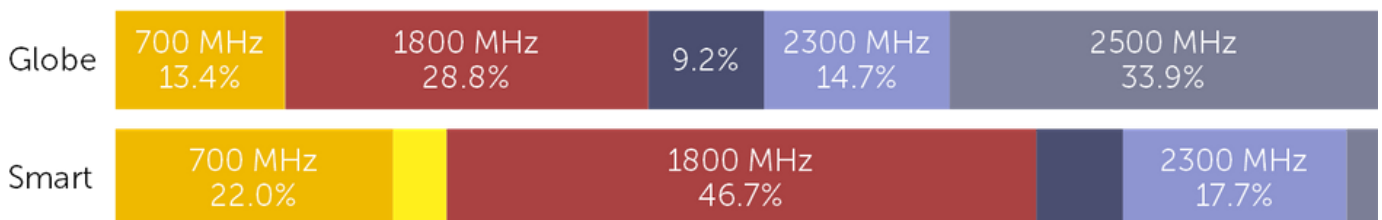Retrieved 03/03/21

Technology usage

PHILIPPINES

The Coverage Score suggests that Globe is more reliant on its 3G network than Smart, and that is reflected in the proportion of time that users spend connected to each technology: as a percentage of time that users spend connected to a mobile network, Globe subscribers are on the older 3G network 5% more often. For spectrum usage, it's interesting to see the sizeable mix of different LTE bands used by both operators. 1800 MHz does carry the most LTE data traffic for both, but the rest of the traffic is spread somewhat evenly over five bands in total. Operators in other countries often rely on three or four bands, so the reliance on a more diverse range of spectrum bands in the Philippines is a divergence from the norm.

TUTELA

Percent of Time by Mobile Connection Type Nationwide

Globe	4G 74.5%	3G 25.5%
Smart	4G 79.5%	3G 20.5%

TUTELA

Mobile Data Volume by LTE Band Nationwide

Globe	700 MHz 13.4%	1800 MHz 28.8%	9.2%	2300 MHz 14.7%	2500 MHz 33.9%
Smart	700 MHz 22.0%		1800 MHz 46.7%		2300 MHz 17.7%

■ 700 MHz APT (Band 28)   ■ 850 MHz CLR (Band 5)

■ 1800+ MHz (Band 3)   ■ 2100 MHz (Band 1)   ■ TD 2300 MHz (Band 40)
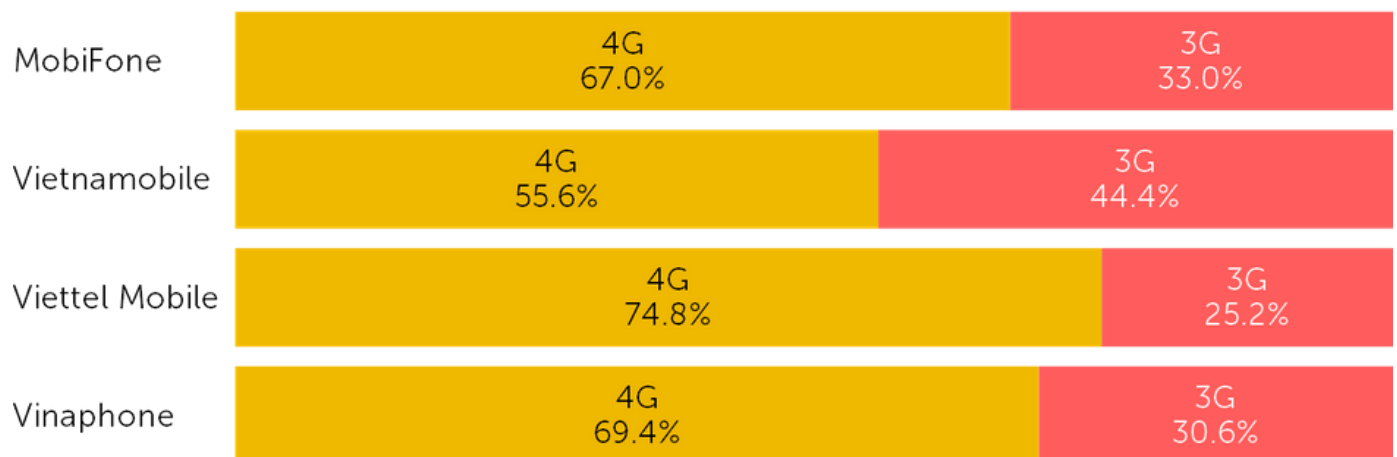
■ TD 2500 MHz (Band 41)

Technology usage

VIETNAM

Viettel Mobile, which came out on top in the majority of the performance metrics, also saw its subscribers spend the highest proportion of time connected to 4G. Given that the newer connection technology typically offers faster speeds and lower latency, that does make sense. The chart also shows how challenging it will be for Vietnamobile to improve its performance rankings to truly challenge its competitors, since subscribers spend barely half their time connected to 4G currently.

TUTELA

Percent of Time by Mobile Connection Type Nationwide

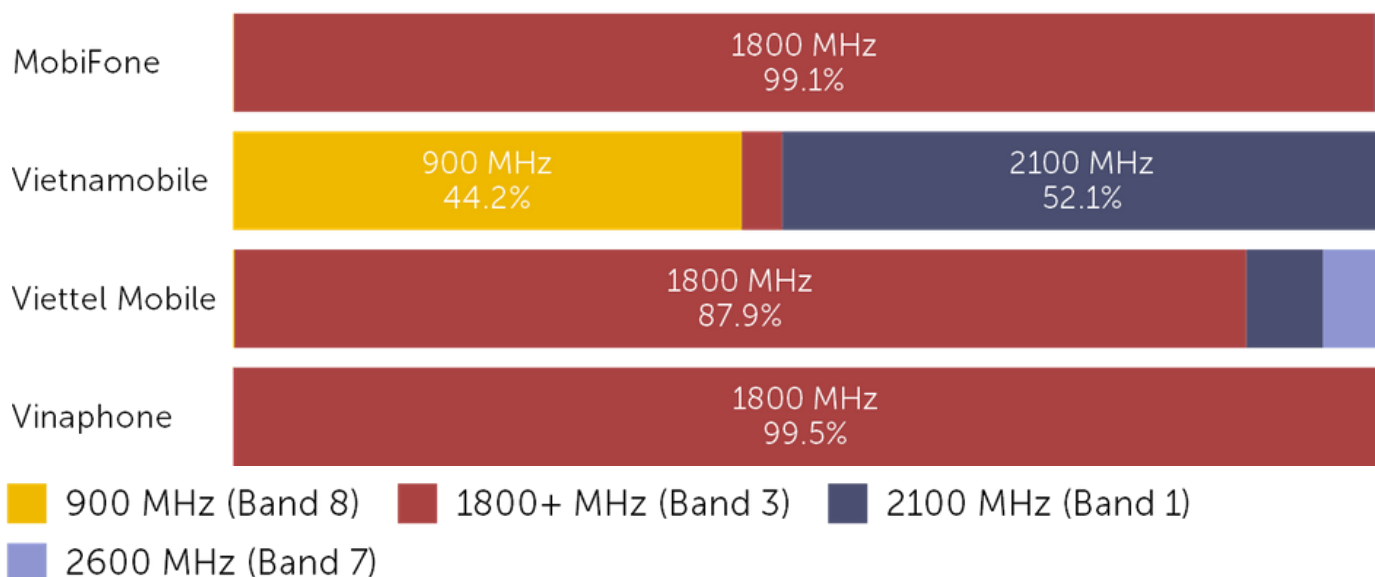|	4G	3G
MobiFone	4G 67.0%	3G 33.0%
Vietnamobile	4G 55.6%	3G 44.4%
Viettel Mobile	4G 74.8%	3G 25.2%
Vinaphone	4G 69.4%	3G 30.6%

Technology usage

VIETNAM

Mid-band 1800 MHz spectrum is absolutely dominant in Vietnam, accounting for the vast majority of 4G data traffic for three out of four operators. It is interesting to see that Viettel Mobile, which offered the best mobile experience to users, is the only operator to own and use 40 MHz of 2600 MHz spectrum, which provides extra capacity for its subscribers.

Mobile Data Volume by LTE Band Nationwide

Operator	Band
MobiFone	1800 MHz 99.1%
Vietnamobile	900 MHz 44.2% / 2100 MHz 52.1%
Viettel Mobile	1800 MHz 87.9%
Vinaphone	1800 MHz 99.5%

Legend:
- 900 MHz (Band 8)
- 1800+ MHz (Band 3)
- 2100 MHz (Band 1)
- 2600 MHz (Band 7)

Methodology

Tutela is an independent crowdsourced data company with a global panel of over 300 million smartphone users. We gather information on mobile infrastructure and test wireless experience, helping organizations in the mobile industry to understand and improve the world's networks. Tutela is a member of the Comlinkdata family.

Tutela collects data and runs network tests via software embedded in a diverse range of consumer applications, which enable the measurement of real-world quality of experience for mobile users, 24/7. For this report, Tutela has collected over 55 million speed and latency measurements, between August 1st 2020 and January 31st, 2021.

Tutela measures mobile experience based on the real-world performance of actual network subscribers for a given brand, inclusive of occasions when a network or tariff may be throttled or congested. Results in this report are based on a testing configuration designed to represent the typical (rather than maximum) performance that users experience. We use a 2 MB file to perform our download testing and a 1 MB file to perform our upload testing. Latency performance in this report reflects one-way UDP latency. Tests are conducted against the same content delivery networks that power many of the world's most popular consumer applications and websites, and as such reflect the end-to-end performance of the network.

Consistent Quality

Download speed is most often used as a proxy for network quality, but while download throughput is important, it's just one of several crucial requirements for a "good" connection.

As operators have upgraded 3G networks through to the latest 5G technology, theoretical (and even real-world) peak throughput speeds have increased to where they vastly outstrip the maximum needed for any current use-case. Real-world speeds above 100 Mbps are now common in parts of the world, and with a 4K video stream — which itself is rarely something smartphone users need — using a fifth of that, average download speed has lost some of its relevance as the dominant statistic used to measure the quality of wireless networks.

At its most basic, a good connection is one that doesn't get in the way of users doing what they want to do. In the real world, smartphone users aren't running speed tests all day — they're browsing the web, using apps, voice calling their friends, streaming Netflix and YouTube, or making video calls. To more objectively evaluate when connections are (and are not) enabling users to do those things, Tutela has developed a standard called Consistent Quality.

Simply put, it's two sets of thresholds, called Excellent and Core. If a connection hits the Excellent standard, it's sufficient for the most demanding mobile use-cases, like HD group video calling or 1080p video streaming. A Core connection is good enough for SD video streaming, web browsing, emails, and VOIP calling, but users are more likely to experience delays or buffering when trying to use more demanding apps. Tutela also considers times when a Consistent Quality style test was attempted, but subsequently failed for distinguishable connectivity issues on the download or server response component, towards the total percentage of "failed" tests against both sets of thresholds. Tutela bases the threshold values on the minimum performance requirements published by popular apps. We most recently updated our Consistent Quality thresholds on September 1st, 2020. Tutela's consistent quality metric, as used in our reports, simply measures the percentage of time that users can hit the thresholds. The higher the number, the more often users have a Core or Excellent quality connection.

Excellent Quality

KPI	Download throughput	Upload throughput	Latency	Jitter	Packet loss	Time to first byte
Minimum acceptable value	5 Mbps	1.5 Mbps	50 ms	30 ms	1%	3.2 s

Core Quality

KPI	Download throughput	Upload throughput	Latency	Jitter	Packet loss	Time to first byte
Minimum acceptable value	1.5 Mbps	500 Kbps	100 ms	50 ms	5%	10.67 s

Discover Tutela Explorer

Tutela Explorer is a powerful cloud-based solution for real-time analysis of crowdsourced data. Using the platform, mobile operators can:

- Create coverage and quality maps
- Benchmark network quality and coverage across all operators
- Drill down to any KPI at city, street or even building level
- Analyse spectrum utilisation, performance and more

Visit www.tutela.com/explorer to learn more

Learn more

Appendix

TUTELA

**Results Overview in
Common Coverage Areas**

		Download Throughput	Upload Throughput	Latency	Excellent CQ	Core CQ
Indonesia	3	8.6 Mbps ± 0.02 Mbps	6.4 Mbps ± 0.01 Mbps	19.8 ms ± 0.011 ms	51.35% ± 0.07%	75.27% ± 0.05%
	Smartfren	5.2 Mbps ± 0.02 Mbps	2.2 Mbps ± 0.01 Mbps	23.0 ms ± 0.021 ms	25.58% ± 0.11%	57.53% ± 0.10%
	Telkomsel	12.0 Mbps ± 0.01 Mbps	6.8 Mbps ± 0.01 Mbps	19.1 ms ± 0.007 ms	64.96% ± 0.04%	83.47% ± 0.02%
	XL	9.3 Mbps ± 0.03 Mbps	6.2 Mbps ± 0.01 Mbps	20.9 ms ± 0.019 ms	46.50% ± 0.11%	71.39% ± 0.08%
	Indosat Ooredoo	11.2 Mbps ± 0.02 Mbps	7.8 Mbps ± 0.01 Mbps	19.5 ms ± 0.010 ms	60.34% ± 0.06%	80.47% ± 0.04%
Malaysia	Celcom	5.6 Mbps ± 0.03 Mbps	6.0 Mbps ± 0.02 Mbps	15.6 ms ± 0.008 ms	42.08% ± 0.08%	80.22% ± 0.05%
	DiGi	10.6 Mbps ± 0.04 Mbps	6.2 Mbps ± 0.02 Mbps	18.1 ms ± 0.012 ms	56.45% ± 0.09%	81.18% ± 0.05%
	Maxis	10.3 Mbps ± 0.03 Mbps	7.4 Mbps ± 0.02 Mbps	15.1 ms ± 0.009 ms	55.57% ± 0.09%	83.10% ± 0.04%
	U Mobile	9.8 Mbps ± 0.02 Mbps	8.0 Mbps ± 0.01 Mbps	16.3 ms ± 0.008 ms	62.96% ± 0.07%	83.33% ± 0.05%
	Unifi	8.9 Mbps ± 0.03 Mbps	2.9 Mbps ± 0.02 Mbps	19.6 ms ± 0.024 ms	50.28% ± 0.20%	81.45% ± 0.14%
Philippines	Globe	7.6 Mbps ± 0.03 Mbps	3.3 Mbps ± 0.02 Mbps	34.8 ms ± 0.037 ms	40.79% ± 0.17%	68.22% ± 0.13%
	Smart	11.5 Mbps ± 0.08 Mbps	6.1 Mbps ± 0.03 Mbps	32.4 ms ± 0.032 ms	52.98% ± 0.20%	71.45% ± 0.14%
Singapore	M1	21.4 Mbps ± 0.18 Mbps	12.6 Mbps ± 0.07 Mbps	8.5 ms ± 0.009 ms	82.80% ± 0.23%	93.96% ± 0.11%
	Singtel	25.0 Mbps ± 0.08 Mbps	16.7 Mbps ± 0.07 Mbps	9.5 ms ± 0.010 ms	83.83% ± 0.13%	94.16% ± 0.06%
	StarHub	33.7 Mbps ± 0.17 Mbps	14.0 Mbps ± 0.05 Mbps	8.4 ms ± 0.010 ms	87.25% ± 0.17%	95.34% ± 0.08%
Thailand	AIS	7.7 Mbps ± 0.02 Mbps	9.0 Mbps ± 0.01 Mbps	23.8 ms ± 0.008 ms	60.33% ± 0.10%	78.73% ± 0.07%
	DTAC	7.6 Mbps ± 0.05 Mbps	5.2 Mbps ± 0.02 Mbps	25.7 ms ± 0.017 ms	49.14% ± 0.13%	83.56% ± 0.07%
	TrueMove	8.8 Mbps ± 0.06 Mbps	10.8 Mbps ± 0.03 Mbps	24.3 ms ± 0.013 ms	55.36% ± 0.14%	84.79% ± 0.08%
Vietnam	MobiFone	15.8 Mbps ± 0.21 Mbps	10.9 Mbps ± 0.10 Mbps	30.1 ms ± 0.092 ms	76.21% ± 0.40%	89.03% ± 0.23%
	Vietnamobile	4.1 Mbps ± 0.10 Mbps	3.2 Mbps ± 0.06 Mbps	35.7 ms ± 0.232 ms	31.62% ± 0.98%	69.58% ± 0.79%
	Viettel Mobile	20.1 Mbps ± 0.17 Mbps	12.7 Mbps ± 0.08 Mbps	25.8 ms ± 0.055 ms	77.46% ± 0.30%	87.90% ± 0.16%
	Vinaphone	20.5 Mbps ± 0.25 Mbps	11.6 Mbps ± 0.13 Mbps	49.0 ms ± 0.155 ms	71.66% ± 0.50%	85.04% ± 0.29%

About Tutela

Tutela Technologies, Ltd., is an independent crowdsourced data company with a global panel of over 300 million smartphone users. It gathers information on mobile infrastructure and tests wireless experience, helping organizations in the mobile industry to understand and improve the world's networks. Data and insights provided by Tutela are trusted by the engineering teams at mobile network operators and network equipment manufacturers around the world and used to compare operators as well as inform decisions in network and infrastructure planning and optimisation. The organization is headquartered in Victoria, British Columbia.

Tutela does not collect any sensitive personal data and is compliant with international privacy regulations including CCPA and GDPR.

For further information about the methodology, data and tools used to create this report, please contact analysis@tutela.com or visit www.tutela.com.

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