

M2CATALYST GLOBAL MOBILE INSIGHTS REPORT

Coverage-QoE / Mobile Traffic / Digital Divide

January - June 2023

This global study examines both the mobile quality of experience, as measured by M2Catalyst's proprietary coverage accessibility algorithm, and the percentage of mobile traffic carried by each network technology on an MNO-by-MNO basis for 70+ countries. Analysis of these metrics enables an enhanced understanding of the digital divide of the subject country.

The M2 Coverage-QoE algorithm was developed by M2Catalyst in conjunction with industry-leading RF engineering consultants. It takes into consideration numerous elements including: signal strength, signal quality, and throughput from the 4G/5G service footprint for each country's national MNOs; the 2G/3G-only service footprint for each MNO; and the areas where mobile devices are used but have detected no service. Each 800m x 800m bin with mobile activity is then classified as to the highest mobile use case (see below) it can support, leading to its further categorization as Connected, Under-Connected, or Unconnected.

| Category | Category Definition | Use Cases | Description | Avg.Speed (Mbps) |
|-----------------|--|---|---|------------------|
| Connected | Locations where consumers have full mobile broadband 4G/5G connectivity. |  | High-resolution video capabilities, facilitating remote work, education, and telemedicine | >9 |
| Under-Connected | Locations where consumers use mobile devices but only have access to 2G/3G or poor RF conditions on 4G/5G. |  | 2G/3G Only | 3 |
| | |  | Low-resolution video chat and streaming, marginal reliability | >4 to 9 |
| | |  | Audio and basic browsing, excluding video | >1 to 4 |
| | |  | Text only communication | >0 to 1 |
| Unconnected | Locations where consumers use mobile devices, but only no-signal readings were detected. |  | No signal / inability to send a text | 0 |

“The M2 crowdsourced data is so robust that we’ve been able to create the M2 Coverage-QoE algorithm which simplifies the process of identifying and predicting network performance characteristics. This means all the heavy lifting is taken care of so that mobile operators, tower companies, government authorities, and others can immediately gain insights and move faster into triage and prioritization.”

- **Martin Donnelly**

With 20+ years of experience, Martin has specialized in establishing and overseeing wireless networks in Europe and the USA. Rooted in data analysis and automation, he's been pivotal in launching one of the telecom industry's premier big data platforms.

“The M2 Coverage-QoE offers a straightforward gauge of wireless broadband quality, designed for clarity even to non-tech users. We have worked extensively with M2 to build this advanced algorithm using RF traits like signal strength, quality, and throughput. The result is an algorithm that predicts the true user experience, factoring in more than just speed.”

- **Eric Law**

Eric has specialized for 30 years in RF Engineering, Planning, Design, and Operations. His expertise includes big data and crowdsourced analysis, bolstered by spatial analysis skills.

Data Collection

The hundreds of billions of network performance measurement that constitute the data for this study were collected from M2Catalyst mobile applications installed on mobile devices during the period of January 1 through June 30, 2023. All such data collection was performed with the express permission of the mobile device owners.

Global Reach:

- 🌐 70+ countries covered
- 💾 Hundreds of billions of crowdsourced & anonymized data points

Where We Checked:

- 🏠 Residential Areas
- 🛣️ Roads & Train Lines
- 🏢 Office Buildings
- 🛍️ Retail Properties
- ☕ Stadiums and Venues

M2-QoE Categories & Use Cases:

- 🟢 Connected Consumers
- 🟡 Under-Connected Consumers
- 🔴 Unconnected Consumers
- 📱 5 distinct mobile phone use cases



Mobile Traffic by MNO:

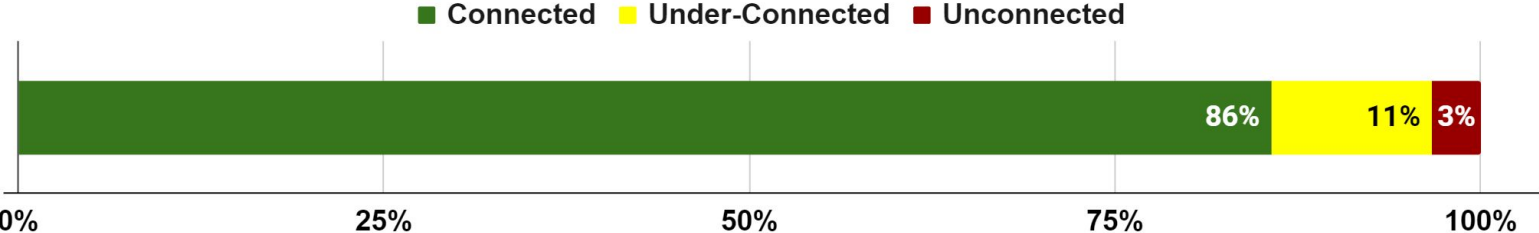
- 📱 2G
- 📱 3G
- 📱 4G
- 📱 5GSA/5GNSA
- 📱 No Signal

The Outcome:

- 📊 A distinctive perspective on mobile broadband coverage accessibility and mobile traffic worldwide
- 📈 Analysis for each MNO
- 🏆 Awards for mobile experience category leaders

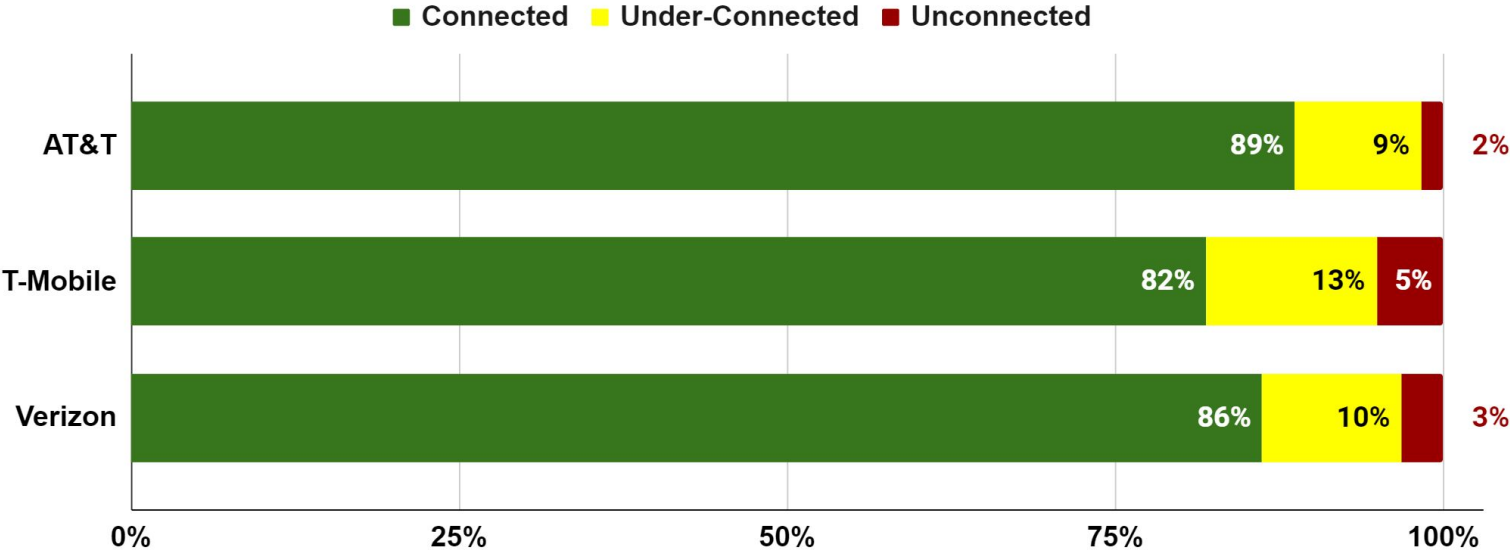
Coverage-QoE: Where are people trying to use their smartphones, but do not have access to a strong enough 4G/5G mobile broadband signal to support remote work, education, and telemedicine? This location-based analysis using M2's proprietary Coverage-QoE algorithm shows exactly where mobile phone users are connected, under-connected, and unconnected.

Chart 1 - USA: Coverage-QoE (Countrywide)



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Chart 2 - USA: Coverage-QoE by MNO



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Best Coverage-QoE

AT&T



Lowest Percentage of Unconnected Locations

AT&T

Chart 3 - USA: Coverage-QoE Location Percentages by MNO

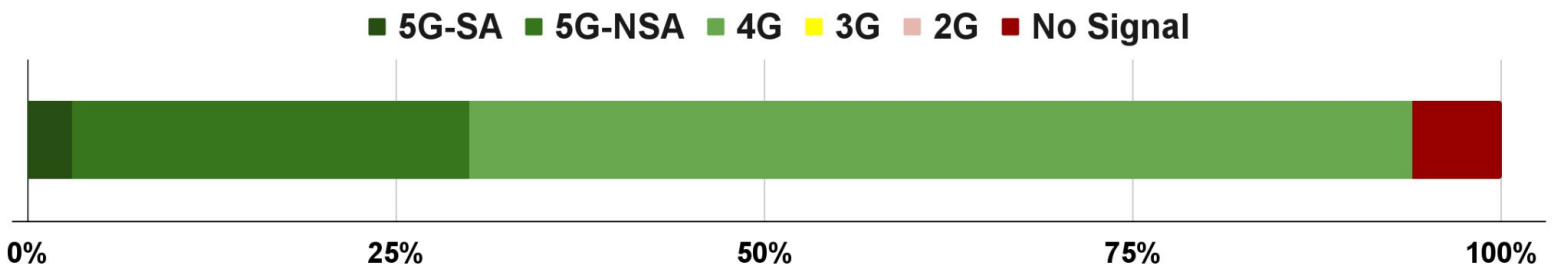
■ Connected ■ Under-Connected ■ Unconnected

| Category | AT&T | T-Mobile | Verizon | Speed (Avg. Mbps) |
|--|-------------|-------------|-------------|----------------------|
| Connected (High-Resolution Video Capabilities with 4G/5G mobile broadband) | 89% | 82% | 86% | >9 |
| 2G/3G Only | <1% | <1% | <1% | Avg. 3 |
| Low-Resolution Video Chat and Streaming | 8% | 10% | 8% | >4 to 9 |
| Audio and Basic Browsing | 1% | 2% | 2% | >1 to 4 |
| Text Only Communication | <1% | <1% | <1% | >0 to 1 |
| Under-Connected Total | 9% | 13% | 10% | |
| Unconnected (No Signal) | 2% | 5% | 3% | 0 |
| Total | 100% | 100% | 100% | |

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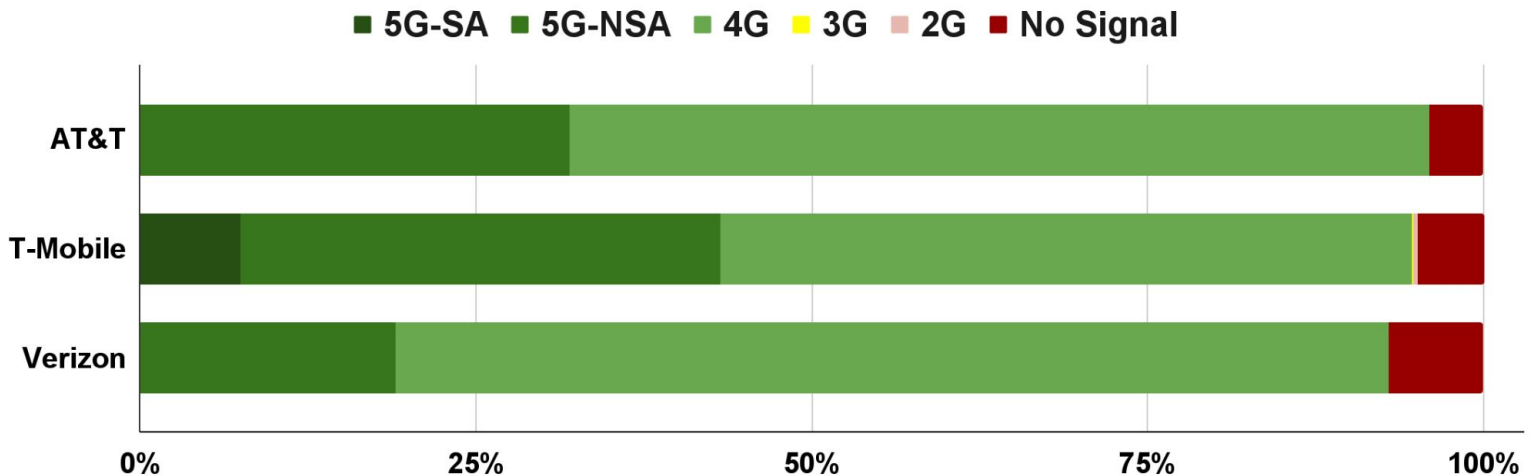
Mobile Traffic: How often are mobile phone users connecting on 4G, 5G-SA, and 5G-NSA, as opposed to connecting on 2G and 3G, or receiving No Signal whatsoever? Unlike other mobile traffic metrics, M2's Mobile Traffic analysis does not take payload into consideration because of its potential to bias the analysis (faster networks allow greater data flow). We focus solely on the percentage of measurements acquired by M2 categorized by network connection type.

Chart 4 - USA: Mobile Traffic Percentage by Network Type



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Chart 5 - USA: Mobile Traffic Percentage by MNO and Network Type



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Lowest Percentage of No Signal Occurrence

AT&T

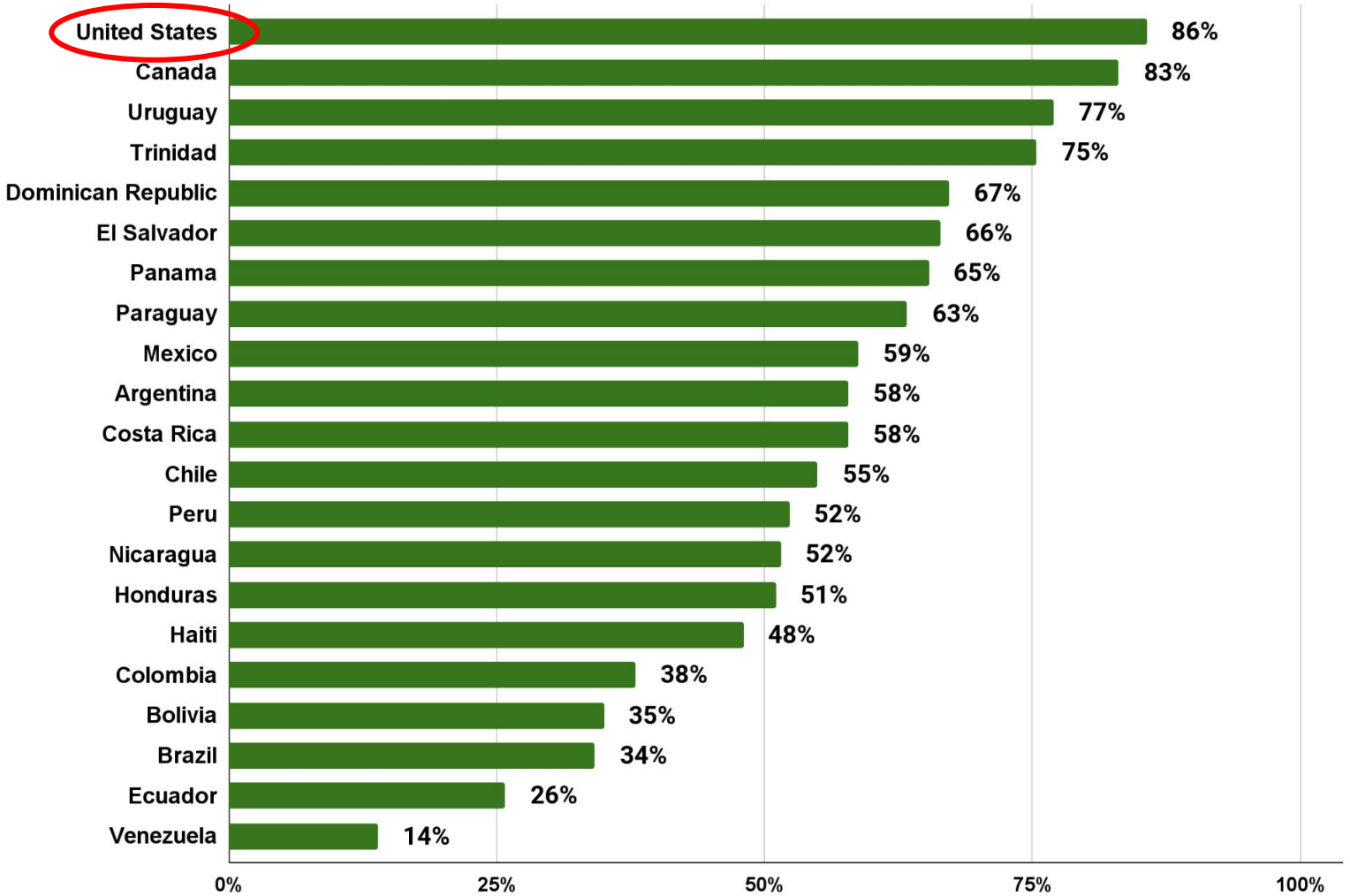


Most 4G/5G Mobile Traffic

AT&T

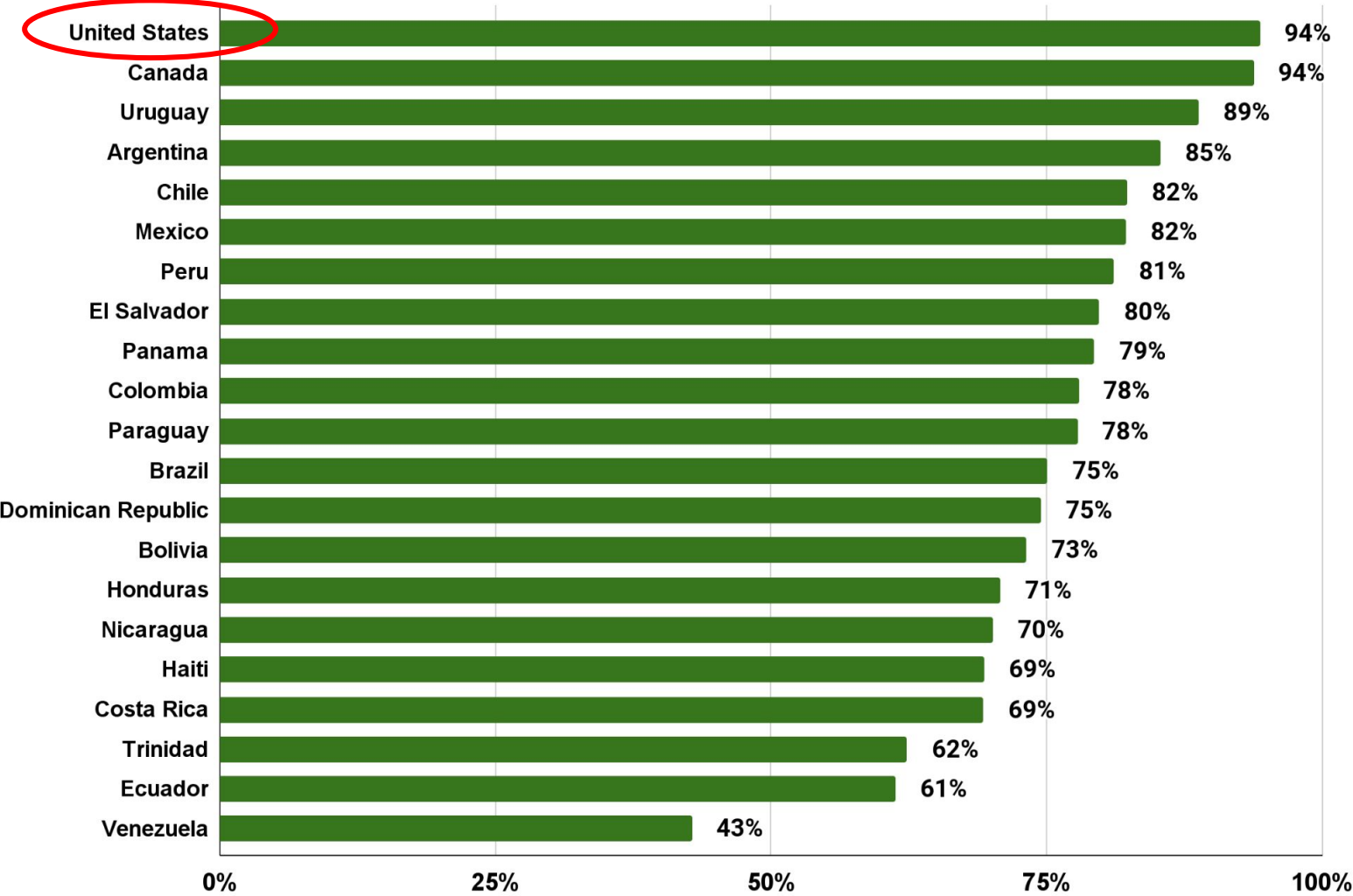
Learn more about the [methodology](#) and [rights to republish](#).

**Chart 6 - Americas Region Countries
Ranked by Connected Coverage-QoE**



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**Chart 7 - Americas Region Countries
Ranked by 4G/5G Mobile Traffic Percentage**



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In Summary

What will it take to bridge the Digital Divide in USA?

The challenging aspect to bridging the Digital Divide is clear. While building mobile infrastructure in wealthy and/or dense urban areas can be very profitable for MNOs, building in rural, remote, or disadvantaged regions will often require governmental assistance to be financially feasible.

M2's Coverage-QoE report provides a new take on the state of the Digital Divide. We calculate the number of locations (800m x 800m bins) countrywide, on an MNO-by-MNO basis, where people have no connectivity or they're under-connected, and therefore unable to perform remote work, access educational opportunities, or avail themselves of the convenience of telemedicine. This Coverage-QoE analysis shows a far larger Digital Divide than does our Mobile Traffic analysis, which is the more common view in mobile broadband deployment reports.

While USA has 89% of its connections on 4G/5G, only 77% of its locations are "Connected".

Regionally (Americas), USA ranks #1 (tied with Canada) out of 21 countries in 4G/5G Mobile Traffic, and #1 in Coverage-QoE.

M2Catalyst can provide the specific location data that can help the MNOs address the United States Digital Divide. This chart shows the extent of the Divide.

**Chart 8 - USA: Coverage-QoE Location Counts by MNO
(800m x 800m Bins)**

| | AT&T | T-Mobile | Verizon |
|--|---------|----------|---------|
| Unconnected (No Signal) Locations | 20,899 | 61,619 | 53,281 |
| Under-Connected Locations | 115,186 | 157,048 | 174,934 |

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Coverage-QoE CSV Exports Available for 200+ Countries

Coverage-QoE csv exports can provide detailed insights for any specific MNO or group of MNOs, or for all MNOs across more than 200 countries. These layers are optimized for integration into network planning and GIS tools, including Esri ArcGIS and similar platforms.

Key Features:

- **Connected:** Visualize areas where MNOs achieve an average throughput speed of 9 Mbps or higher, suitable for high-resolution video streaming.
- **Under-Connected:** Filter and pinpoint locations optimized for specific connectivity needs, such as low-resolution video, audio-only, or text-based communication.
- **Unconnected:** Identify regions where specific MNOs register no signal, highlighting areas of connectivity gaps.



Learn More About Our Solutions

M2Catalyst is the creator of Crowd SiteIntel (CSI), a leading data analytics platform trusted by MNO and tower companies worldwide. CSI enables the analysis of 1000 sites per hour, benchmarking mobile network performance of all MNOs.



- No RF engineering experience required
- Instantly available in over 200 Countries
- Trillions of MNO performance measurements
- Over 40 million cell IDs mapped globally
- Benchmarking more than 800 MNOs
- Map each Cell ID by RSRP, RSRQ, SINR, range, date first detected, frequency/band channel, eNodeB and PCI
- Variety of configurations available to user
- Geographical Selection:
 - Country
 - Region
 - City
- Customizable Features:
 - Diverse zoom levels
 - Various size categories
- Raw data feeds are available and aggregated data layers are available for use in other platforms such as Esri ArcGIS (see the next 2 pages for more info).
 - Data Delivery Options:
 - One-time provision
 - Recurring updates: 3, 6, or 12 months



For a demo and a detailed discussion on your data configuration requirements, please contact us at:

info@m2catalyst.com

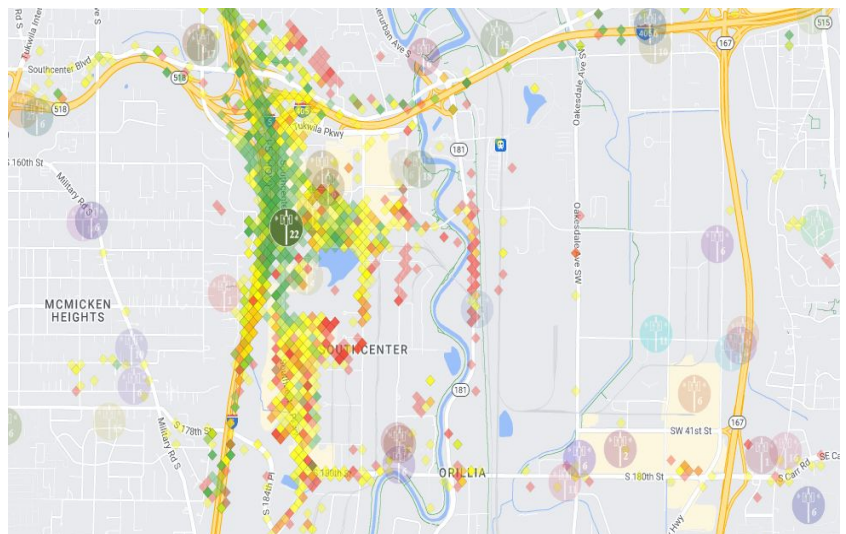
Our Data Is Also Available on the Esri ArcGIS Marketplace!

With a commitment to improve the mobile experience for all, M2Catalyst stands at the forefront of innovation for mobile network performance geospatial data, consistently providing advanced solutions and datasets tailored to the ever-evolving needs of the industry. M2Catalyst has also released 4 new data layers on the Esri ArcGIS Marketplace

Featured Data Layers include:

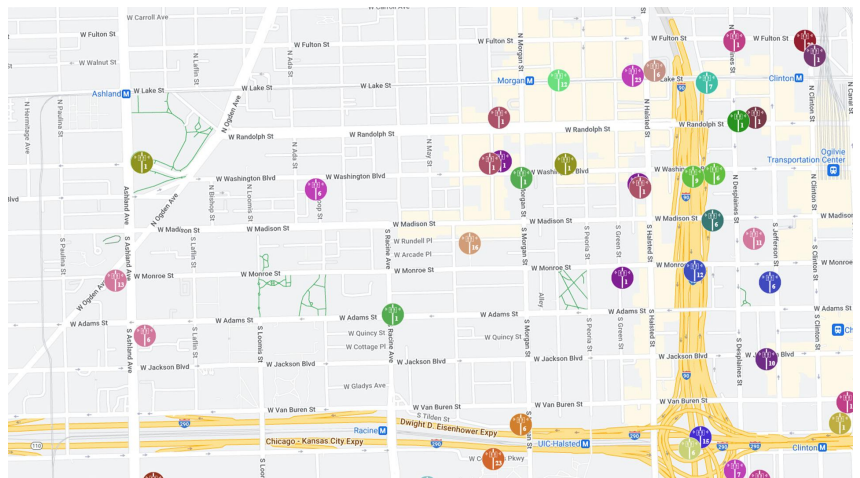
Global Cell ID Maps

Discover intricate coverage footprints by Cell ID and eNodeB (cell sites) for each Mobile Network Operator across 200+ countries. Available in CSV format, these data layers offer seven bin sizes, ranging from 20 m x 20m to 11km x 11km, allowing you to examine coverage areas of Cell IDs by MNOs. Additionally, insights on band frequencies deployment are available.



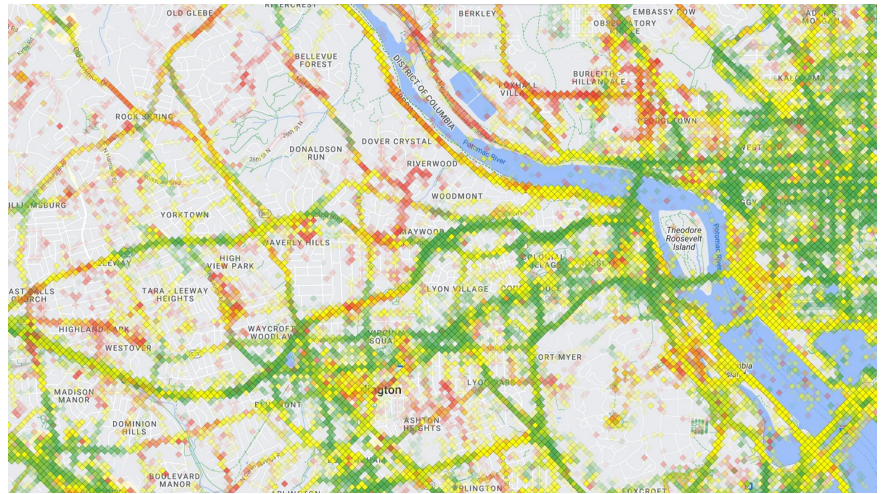
Global PoP Database

Harness the power of our cutting-edge AI algorithms that predict the location of cell sites, from macro towers and rooftops to monopoles, small cells, and DAS sites, across 200+ countries.



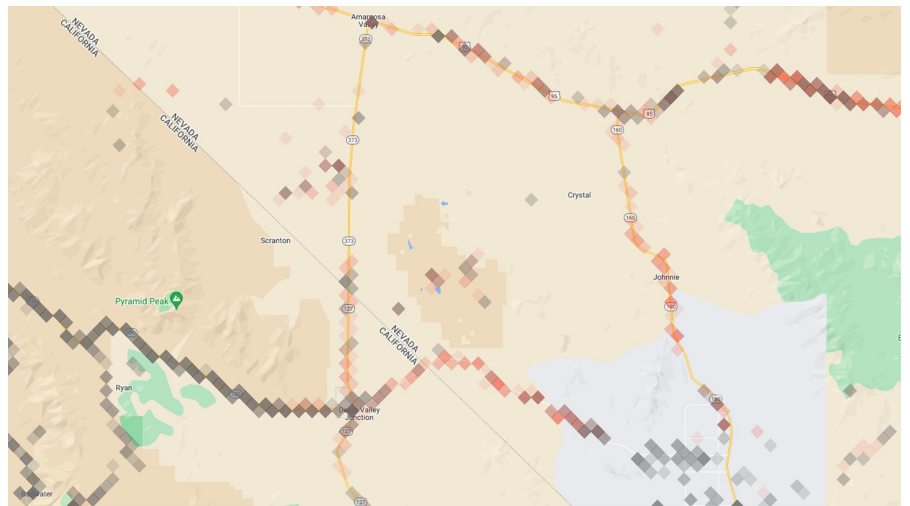
RF Conditions - From RSRP to No Signal and Beyond

Navigate the nuances of RF conditions, from RSRP and SINR to areas with no signal. These data layers are also available in CSV format for over 200 countries and offer a broad range of seven bin sizes from 4m x 4m to an expansive 11km x 11km.



Fringe Coverage and No Signal Locations

Unearth the true state of mobile network coverage across the globe with this in-depth data layer that illuminates areas with either fringe network coverage or a complete lack of signal.



For a demo of Crowd SiteIntel (CSI), our powerful mobile network performance data visualization platform, please contact us at:

info@m2catalyst.com

Methodology

Overview:

The Coverage-QoE / Mobile Traffic / Digital Divide Report has been designed as a tool for telecom professionals to gain insights into a smartphone user's quality of experience and mobile traffic availability. This is done by analyzing billions of crowdsourced RF and throughput data points by location using the M2Catalyst proprietary Coverage-QoE algorithm. Mobile Traffic was also analyzed to determine the percentage of mobile connections by network technology (2G/3G/4G/5G-NSA/5G-SA). The quality of coverage and available network traffic are two factors that can contribute to a user's digital divide.

Data Source and Description:

M2Catalyst crowdsources mobile network performance data from our app user base of millions of mobile consumers around the world. Utilizing a data set that is collected autonomously from a diverse range of users and locations is advantageous compared to other sources due to the following reasons:

- **Real-World Insights:** Unlike controlled, lab-based tests, crowdsourced data offers real-time feedback from actual users in genuine scenarios. This reflects the true performance users experience on a daily basis.
- **Geographical Breadth:** Crowdsourcing draws data from numerous locations, covering a broader geographic span than most dedicated test teams can. This means remote, rural, urban, and even transitional areas (like highways) can be monitored.
- **Device Diversity:** With users employing a vast array of devices with different capabilities, crowdsourcing gives insights into how a network performs across multiple device types and models.
- **Cost-Effective:** Gathering data from users who are already using the network eliminates the need for costly, specialized equipment and field testing teams.
- **Volume & Continuity:** Crowdsourced data collection can amass a vast volume of data points continually, allowing for real-time monitoring and trend identification.
- **Dynamic Conditions:** This data reflects network performance under various conditions, including peak usage times, different weather conditions, and during specific events.
- **Unbiased Data:** Since it's sourced from a diverse user base, it is less prone to biases that might arise from controlled, predetermined tests. Monitoring and testing is automated to eliminate bias that could be introduced by user interaction.

Data for this report is collected in each country over a six-month period. The data is verified for authentication (coming from a known host application) and properly formatted. Next, data containing non-typical values or anomalies are filtered prior to storing. During export and processing of the data, records with values outside valid ranges for RF parameters are removed.

Data Depth:

To ensure a detailed and exhaustive view, we rigorously analyze every 800m x 800m location (Bins) where M2Catalyst has pinpointed distinct network performance attributes. This includes locations that register no signal. This rigorous process encompasses the evaluation of billions of mobile network performance measurements produced across the entire service area for all mobile operators.

Both the Coverage-QoE and Mobile Traffic Analysis in this study are proprietary to M2Catalyst and designed to gain new insights into the global reach of mobile broadband, from a smartphone user's perspective.

Coverage-QoE Methodology:


Proprietary Algorithm to Interpolate Throughput Speeds based on RF Conditions

Our analysis encompasses three pivotal 4G/5G radio condition parameters: RSRP, RSRQ, and SNR. To bolster the accuracy of our algorithm, a curated set of global throughput tests served as foundational data, which ensured an elevated statistical significance in subsequent interpolations. Thus, our algorithm integrates these three parameters into a multifaceted array, leading to a comprehensive evaluation of radio conditions and the anticipated Quality of Experience (QoE).

Scoring

4G and 5G radio condition parameters within each 800m x 800m location bin, along with no signal data is processed using our proprietary algorithm, resulting in a comprehensive score for each 800m x 800m bin. This score mirrors the probable experience a user can anticipate within that specific vicinity, spanning a spectrum from a complete lack of signal to excellent mobile network performance (rated on a scale of 1-5). In essence, the Coverage-QoE report categorizes MNO network performance by five mobile use cases by location, determined by the calculated score.

The locations scored based on our proprietary algorithm for 4G and 5G connections were combined with locations reporting 2G and 3G connections and tabulated by five mobile use cases. The resulting data set provides a comprehensive geographic connectivity analysis for each operator per country. As a final step, the locations that comprise the data set are assigned to one of three categories: Connected, Under-Connected, and Unconnected.

| Category | Category Definition | Use Cases | Description | Avg.Speed (Mbps) |
|-----------------|--|---|---|------------------|
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| | |  | No signal / inability to send a text | 0 |
| Unconnected | Locations where consumers use mobile devices, but only no-signal readings were detected. |  | No signal / inability to send a text | 0 |

Mobile Traffic Methodology:

The Mobile Traffic analysis in this report focuses on the number of connections and readings mobile devices are making with different network types (2G/3G/4G/5G-NSA/5G-SA), and situations when mobile devices are active but unable to connect to the operator network. This data is used to assess the percentage of connections served by 4G and 5G, known broadband services, versus the percentage of connections on older 2G and 3G services. In contrast to the Coverage-QoE, this data set is not location based and instead shows which network types operators have made available to users.

Awards:

As described above, the data for this study was crowdsourced from smartphone users between January and June 2023. Data sets per MNO are comprised of these users. Due to the nature of crowdsourced data, not all MNOs are equally represented.

Coverage-QoE awards have been granted to the MNOs with the highest percentage of locations reporting connected experiences, and to the MNOs with the lowest percentage of locations reporting an unconnected or no signal experiences. Mobile Network Traffic awards have been granted to the MNOs with the highest percentages of devices connected to 4G or 5G combined, and to the MNOs with the lowest percentages of devices reporting no signal occurrences.