FirstNet
CASE STUDY

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Police Executive Research Forum

Beyond Signal Strength: Measuring Performance of Public Safety Mobile Broadband Networks

A Protocol for Testing FirstNet and Commercial Carriers

Executive Summary

For decades, and continuing today, public safety agencies have relied on Land Mobile Radio (LMR) networks for their mission-critical voice communications. In evaluating LMR systems, the primary factor has always been the strength of the radio signal and the quality of the audio. Can a police officer or firefighter clearly communicate via radio to dispatchers and other first responders? The answer to that question depends almost entirely on whether the radio signal at the first responder's location is strong enough.

Today, more public safety agencies are adopting mobile technologies that transmit and receive both voice *and data* across wireless broadband networks. The criteria for evaluating these LTE (or Long Term Evolution) networks are more complex than measuring signal strength. In the LTE environment, signal strength—the number of "bars" on a smartphone or tablet—is still important for establishing connectivity to the network.

However, signal strength is not the only measure—or even the most important measure—for evaluating LTE networks for public safety. Other factors include:

- How quickly can first responders upload and download data from their mobile devices?
- Can they reliably send and receive data-heavy content, such as photos and especially video, over the network?
- How reliable is the network during major events when large numbers of people are using their mobile devices, stretching the capacity of the cellular networks?

Key Takeaways

- The criteria for evaluating wireless broadband networks are more complex than simply measuring signal strength; the ability to move data—text, photos and video—quickly and reliably is critical.
- During everyday "drive tests" in one mid-sized city, FirstNet phones generally had faster data download and upload speeds and greater reliability than the average of devices operating on major commercial networks, even though the FirstNet devices often had weaker signal strength.
- During two large-scale demonstrations that put strain on cellular networks, devices operating on FirstNet were, on average, more reliable and had better performance than devices operating on major commercial networks.
- These results only represent testing done in two locations in two time periods. Agencies should conduct performance tests that measure the user experience of first responders in their jurisdictions.

In other words, when firefighters are responding to a structure fire or police officers are racing to a school where there is an active shooter, can they quickly and reliably download building plans and other useful data to their mobile devices? Or when officers at a music festival or other large event want to upload photos or video of a critical missing person or a suspicious vehicle to the command post, will that content get through? Those are the types of performance questions that public safety leaders need to consider as they make decisions about their mobile data networks.

To help public safety officials answer these questions, the Police Executive Research Forum (PERF) and a team of subject matter experts developed a protocol for testing the performance of both commercial networks and FirstNet, the Nationwide Public Safety Broadband Network. Using this protocol, the team then ran a series of tests in two different settings:

- While driving the streets of Camden, NJ, a mid-sized city, on an average day. This test was designed to measure what police officers might experience while on regular patrol.
- During a pair of large-scale demonstrations in Washington, DC that were attended by tens of thousands of individuals. This test was designed to measure how the networks perform when large crowds of people are using their mobile devices at the same time and, as a result, are putting stress on cellular networks.

During these tests, tens of thousands of data points were collected measuring signal strength, data upload and download speeds, image transfer rates, and service reliability. Data were collected on several devices operating on three major commercial networks and FirstNet. Importantly, all of these tests were performed from the perspective of the user—what police officers, sheriffs' deputies, firefighters, emergency medical technicians, and other first responders would likely experience in the field.

These tests produced a significant (and seemingly counterintuitive) finding: stronger signal strength does not automatically translate into better performance when it comes to moving data over mobile broadband networks. In fact, devices with weaker signal strength operating on FirstNet generally provided faster upload and download speeds and greater reliability than devices with stronger signal strength on the commercial networks.

For example, during the drive tests in Camden, devices operating on FirstNet typically had weaker signal strength than devices operating on commercial networks. However, the FirstNet devices had generally faster data upload and download speeds (known as "throughput") and thus were able to transfer images faster and more reliably.

Similarly, during the two major demonstrations the testing team found that even though the signal strength on all devices (operating on commercial networks and FirstNet) was mostly strong throughout these events, the FirstNet devices in general had faster throughput and greater service reliability. These performance advantages were especially pronounced when the FirstNet devices were operating on the Band 14 spectrum that has been dedicated to public safety users on FirstNet. (See p. 3 for more on Band 14.)

This report describes how the performance tests were conducted and the key findings. ***It should be noted that these results reflect the experiences in those specific locations at those specific times.*** Running similar tests at different locations—or even the same locations at different times—would not necessarily produce the same results. Network performance is influenced by a number of factors such as the infrastructure that individual carriers have built in a specific region, the status of the FirstNet build-out in an area, geography, and user density and demands.

That is why it is important for public safety agencies, as they are making choices about their mobile broadband networks, to conduct extensive testing in their own jurisdictions to document the performance of different networks. This report provides an outline for how agencies can go about conducting their own performance tests and how to interpret the results.

In doing this testing, agencies need to understand that, unlike in the LMR environment, signal strength is just one factor to consider when evaluating LTE networks—and not necessarily the most important factor. Rather, agencies should focus on how quickly and reliably the network can move text, photos, video, and other data that are increasingly critical to their public safety mission.

Mobile Data Networks: Considerations for Public Safety Agencies

The terrorist attacks of September 11, 2001, exposed the obstacles that public safety agencies face when communications networks become inoperable or overloaded by large numbers of people attempting to connect. To address this shortcoming, the 9/11 Commission recommended that Congress support legislation which provided for the increased and expedited assignment of radio spectrum for public safety purposes.[1]

A decade later, in February 2012, President Obama signed the law that created the First Responder Network Authority for the purpose of overseeing creation of the Nationwide Public Safety Broadband Network (NPSBN).[2] In 2017, following a competitive bidding process, the FirstNet Authority selected AT&T as the private-sector partner to build the network. Under contract, AT&T is required to build out the entire FirstNet network within five years, with completion milestones established along the way.[3]

By the end of 2017, all 50 states, five territories, and the District of Columbia had chosen to "opt-in" to FirstNet, which means that they accepted the network build-out plans developed by AT&T-FirstNet for their states or jurisdictions. The FirstNet network core went live in March 2018, essentially creating another carrier that public safety agencies could select for their mobile broadband needs. As of August 2019, approximately 9,000 public safety agencies had subscribed to FirstNet, and 750,000 devices were connected to the network.

However, just because every state opted-in to FirstNet does not mean that individual public safety agencies within those jurisdictions are required to join FirstNet. They can continue with the service providers they have been using or choose another commercial carrier.

Since August 2018, PERF has been interviewing dozens of agencies regarding their views and experiences on FirstNet adoption. While many agencies reported economical and procedural advantages to FirstNet adoption, other agencies have expressed reservations about making the change. A primary reason for the hesitation is that agencies want to determine if FirstNet would provide at least as good, or better, coverage, performance, and reliability as their current service provider, which is an important question.

For police, fire, and EMS chiefs, transitioning to a new carrier can be risky. Public safety leaders cannot afford to adopt a new system that fails to provide adequate coverage and service for their personnel. In addition, transitioning to a new network can require significant investments in new hardware, such as smartphones and tablets for employees, in-vehicle modems, and other expenses specific to the carrier. Understanding exactly what they are getting is critical for public safety executives considering any new wireless carrier.

To help public safety officials collect the information they need to support informed

What Is Band 14?

Band 14 is spectrum the Federal Communications Commission licensed to the First Responder Network Authority specifically for use by public safety personnel on FirstNet. Band 14 resides in the 700 MHz band which, according to the FCC, is an important swathe of spectrum that allows signals to cover larger geographic areas and to penetrate buildings more easily. Under its contract with the First Responder Network Authority, AT&T is in the process of deploying Band 14 capacity and coverage throughout the U.S.

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1. *The 9/11 Commission Report*. Available at https://www.9-11commission.gov/report/911Report.pdf.

2. For a brief history of FirstNet and the First Responder Network Authority, see https://firstnet.gov/about/history.

3. AT&T recently announced that the scheduled build-out of the NPSBN was 60% complete at the end of June 2019; officials expect is to be 70% complete by the end of 2019, which would be ahead of schedule. Donny Jackson, "AT&T CEO says FirstNet buildout 60% done, with 70% mark targeted by end of year," *Urgent Communications* (July 26, 2019). Available at https://urgentcomm.com/2019/07/26/att-ceo-says-firstnet-buildout-60-done-with-70-mark-targeted-by-end-of-year/

decision-making, PERF and its subject matter experts began researching how agencies can measure the coverage and performance they would receive in their jurisdictions from different carriers—both commercial networks and FirstNet.

Understanding coverage and performance in the LMR and LTE environments

To better understand the testing process and interpret the results, it is important to understand basic concepts about coverage and performance in a wireless broadband (LTE, or Long Term Evolution) environment, and how they differ from the Land Mobile Radio (LMR) world that most public safety officials are familiar with.

Radio systems consume a relatively small and constant amount of bandwidth: Since the early 1900s, the primary method of mission-critical voice communications for both military and public safety users has been the two-way radio. Land Mobile Radios (LMR) continue to be a reliable, hardened method of voice communications.

> The true power of LTE is its ability to move large amounts of data—text, images, and video—over the network.

The term "two-way" indicates a device that not only can receive a radio signal, but also can transmit a return signal to a base station or to another portable or mobile device. In most modern LMR systems, handheld or mobile devices are broadly interconnected to a wide area network, such as a regional or even statewide digital radio network. A radio device sends a voice signal to a fixed transceiver, which in turn forwards the signal to higher-power transmitters to cover greater distances.

In this environment, coverage and signal strength are paramount. Voice messages consume a specific, and relatively small and constant, amount of radio bandwidth. For users, the main issues are how far the signal reaches, and whether the signal is strong enough at each location to support simple voice transmissions.[4]

Jurisdictions generally control their own LMR infrastructure: Another important distinction is that individual public safety agencies or jurisdictions generally specify and control their own LMR infrastructure. In building out their networks, government agencies can invest in as many radio towers and other hardware they consider necessary and affordable to meet their voice communications needs.

Coverage and performance for LMR networks are largely matters of ownership, investment, budgets, and costs. If a jurisdiction is willing and able to spend more money, it can install more radio sites, achieve greater coverage, and provide better radio service for its public safety agencies.

The LTE environment is dramatically different in several important ways:

- Public safety agencies rely on LTE networks for much more than voice. **The true power of LTE is its ability to move large amounts of data—text, images, and video—over the network.**
- **With LTE, jurisdictions do not build and control their own communications infrastructure, as they generally do with LMR systems.** Commercial wireless broadband networks are shared among both public-sector and private users. The FirstNet network is being built out according to individual plans prepared for and approved by each of the 50 states, five territories, and the District of Columbia, as part of the FirstNet opt-in process.

4. For radio systems, performance traditionally has been measured on a scale known as DAQ, or Delivered Audio Quality. Although it is largely a subjective measure, DAQ is a commonly used method to measure and rank various levels of audio quality. It ranges from DAQ 1 (unusable audio or OOC – Out of Coverage) to DAQ 5 (audio is subjectively superior, with no distortion). As viewed by APCO Project 25 (an LMR industry standard), the most common standard for LMR audio quality is DAQ 3.4, which is defined as a voice transmission that is "understandable without repetition." See, *Specifying Your P25 System* (2014). P25bestpractice.com. http://www.npstc.org/download.jsp?tableId=37&column=217&id=3204&file=P25_Best_Practice_Specifying.pdf

The key point is that in the LTE environment (both commercial and FirstNet), individual police or fire agencies do not have the type of control over the network infrastructure that they do with most LMR systems.

- **In LTE networks, coverage and performance dynamically adjust to user demands and capacity at any given time.** Cellular carriers can reroute calls and data requests and otherwise react to continuously changing user demands in an effort to maintain a high level of service overall. As a result, agencies at times may experience changes in coverage and performance based not only on how the network is configured, but also on how the network is being used at any given time.

Understanding the factors that influence performance in LTE networks, and being able to accurately measure those factors, are important for public safety agencies evaluating their mobile broadband options.

The Testing Process

To measure the performance of various wireless broadband networks—both commercial carriers and FirstNet—PERF and its subject matter experts developed a testing protocol and implemented it in two different settings:

- **Everyday operations:** "Drive tests" were conducted in Camden, NJ on March 11–12, 2019. Approximately 80,000 test samples were collected during the two days of drive testing. These tests were intended to measure the performance of LTE carriers that a police department might experience during normal operations patrolling streets and highways.
- **Large-scale events:** To measure the performance of LTE networks during large-scale events, tests were run at the March for Life, held in Washington, DC on January 18, 2019, and the Women's March, also held in Washington, DC on January 19, 2019. Approximately 38,000 test samples were collected during these two events. These tests were designed to measure network performance during major events in relatively compact areas. In these types of "high-capacity events," large numbers of people are using mobile devices to go online, make phone calls, post photographs and other content on social media, stream video, and share photos and other images. This barrage of activity can severely strain and test the limits of cellular networks.

We looked at performance from the perspective of how well a network would work for the police officer or firefighter in the field.

This testing was done at the street level only. It did not measure coverage and performance inside buildings, including at different elevations. **In jurisdictions where this is an important issue, agencies should consider in-building testing as part of their overall testing protocol.**

Testing from the perspective of the user

A key feature of the testing protocol is that **it measures the "user experience."** We looked at performance from the perspective of how well a network would work for the police officer or firefighter in the field, as opposed to relying on the technical performance indicators of the overall network or generalized crowd-sourced data based largely on signal strength.

In other words, the testing tried to answer questions such as these: Will a firefighter or police officer responding to a scene be able to download maps or video captured by a drone on their tablet or smartphone? Or, can a sheriff's deputy or emergency medical technician reliably upload photos and video from the site of a traffic crash to the 911 center and other agencies? And will public safety personnel be able to quickly and reliably access federal, state, and local databases on their mobile devices?

One key consideration to understand is that commercial carriers generally focus on optimizing the network to benefit as many **people** as possible, rather than the **geographic**

The 2019 March for Life in Washington, DC attracted tens of thousands of participants, putting strain on existing cellular networks.

For that event, and the Women's March the following day, a variety of public safety agencies in the DC region came together to provide security and protection.

area covered. Hence, claims such as "our network covers 98% of the population," even though the network may cover a much smaller percentage of the geographical area.

For public safety personnel, however, geography matters. Police officers, firefighters, and other first responders must serve the entire layout of their communities, regardless of how densely populated any one area is. Natural disasters, for example, can happen across broad, often sparsely populated geographic areas.

Performance testing from the user's perspective more closely mirrors the actual experiences of public safety personnel working in the field. It measures how responsive the network is to user demands in different locations, at different times, and under different conditions. This type of testing also measures performance at both the geographic heart of the network as well as at the edge, where conditions may not be optimal.

Devices and types of performance tests

For the performance testing, the testing team used a combination of Samsung S9 phones and Apple Xr iPhones. Two of the devices—one Samsung, one Apple—ran on FirstNet. The other six devices operated on three major commercial networks.

The purpose of these tests was not to evaluate individual carriers, but rather to validate the testing protocol and to see how FirstNet performed in relation to commercial networks generally. Therefore, in the analysis, results for the three major commercial carriers that were tested have been aggregated into overall averages.

A series of tests were run on each device at specified intervals:[5]

Signal Strength: Signal strength was measured through a series of automated five-second interval samples which captured and stored Received Signal Strength Indicator (RSSI) data.[6] The five-second samples also produced a specific longitude/latitude location (accurate to approximately +/- 15 feet) and a unique time stamp of each sample. This information provided a means to determine the location and time of any weak or "out of coverage" test samples, so they could be

5. To conduct the tests, PERF and its subject matter experts researched applications that can run signal strength analysis, take samples of band detection, and assign the data collected to a specific location and time. The team selected a collection of apps that provide reliable results, were considered by industry standards to be accurate, and could be used for coverage and performance analysis.

6. RSSI was measured in terms of dBm, or decibel-milliwatts, collected at the base port of the smartphone antenna and prior to signal amplification across the band of LTE affiliated with the device. This allowed for the consistent measurement across different devices. For these tests, -85 dBm or higher was considered "good to excellent;" -86 to -105 dBm was considered "average to marginal;" and 106 to -115 dBm was considered "marginal to poor." Anything over -115 dBm was considered "out of coverage." Also, signal strength was collected on the Samsung S9 devices only; automated signal strength tests were not available for the Apple iPhones.

compared to other samples taken in proximity of that test.

Band Detection: For each signal strength sample collected, the testing team also sought to identify the specific radio band that was used during that test. The intent was to assess both how often FirstNet devices were accessing Band 14 and how those devices performed when compared to devices on other bands.[7] Band 14 is the 20 MHz of spectrum that FirstNet dedicates to public safety on a priority basis.

Speed Testing: At five-minute intervals, automated upload and download speed samples, as measured by megabits per second (Mbps), were run on each of the devices. These tests were correlated with the signal strength samples to provide data on the location, time, and band accessed for each speed test. In addition to capturing the Mbps data for each five-minute test, PERF established a reliability threshold. Any tests that did not achieve 5 Mbps download or 2 Mbps upload were considered to be unreliable, as they failed to meet a basic level of everyday data transfer needs of public safety personnel.[8]

Image Transfer: At 15-minute intervals, image transfer tests were run that involved manually downloading a fixed 20 megabyte (MB) file from a website and tracking how long it took to fully render the image on the mobile device. These tests were designed to simulate real-world use cases in which a firefighter or police officer might be downloading building floor plans or photos of a missing person. File transfers that took longer than two minutes to complete were considered failures.[9]

For the "everyday drive tests" in Camden, the testing team rode in a police vehicle that systematically travelled the vast majority of the city's streets (and some alleys, as well). The routes were aligned with each of Camden's police districts, so that data reflecting how and where officers patrol could be analyzed. In addition, separate tests were run on highways and interstates within the city where patrol vehicles would travel at higher rates of speed.

For the two large-scale events in Washington, DC, two teams of testers were deployed; each team was equipped with a selection of the devices being tested. One team was embedded in the middle of the crowds, both during the rallies that preceded or followed the actual marches and during the marches themselves. This team was intended to replicate the experience of a police officer, firefighter, or EMS worker responding to an incident in the heart of the crowds. The second team stayed on the immediate periphery of the events, outside the densest parts of the crowds, but close enough to the primary activity. This was designed to mirror the experience of first responders who might be monitoring the rallies and marches, but are not fully embedded in them.

Presence of Band 14

For each set of tests, an important consideration was the detection of Band 14 on the FirstNet devices. Band 14 resides on a portion of the 700 MHz spectrum that is reserved exclusively for public safety users on demand. When Band 14 is not available in an area, FirstNet devices operate with priority on other bands on AT&T's commercial network.

For the March for Life in Washington, DC, AT&T-FirstNet deployed a mobile device, called a Cell

7. The PERF team discovered that some testing software identified only the general band in use, such as 700 MHz or 1900 MHz. Because the team wanted to pinpoint the exact band that was being used (e.g., Band 2, Band 12, or Band 14), a selection of software that provided exact Band ID was used. In this way, PERF was able to determine, for each device in the test, what band was active during any particular sample that was taken.

8. The download speed of 5 Mbps represented a threshold for successfully streaming relatively high-resolution video (such as from a fixed security camera); the upload speed of 2 Mbps represented a threshold for successfully streaming lower-resolution video (such as from a dash-camera).

9. On the first day of testing, at the March for Life in Washington, DC, a 40 MB file was used for the image transfer tests. However, this size file produced a larger-than-expected number of failures (downloads that exceeded two minutes), so a 20 MB file was used for subsequent tests, which is more in line with typical files sizes that first responders may be dealing with.

FirstNet has 75 dedicated deployables to enhance coverage during planned events (like the marches in Washington, DC) and unplanned disasters such as hurricanes or forest fires.

on Wheels (or COW), on the National Mall adjacent to the stage where the pre-march rally took place. This boosted the Band 14 capacity in that immediate area. There were indications that some commercial carriers also deployed additional mobile assets for this event to increase their capacity.

For the drive tests in Camden, no FirstNet mobile deployables were in place. The tests relied on the existing fixed wireless broadband infrastructure in the area, including the Band 14 build-out that had been completed at the time of the tests. Interestingly, officials in Camden were under the impression that Band 14 had not yet been deployed in their area; however, the tests revealed that Band 14 was detected in approximately one-third of the samples that were taken over the course of the two days of testing.

Summary of Test Results

This section summarizes the major findings that were documented in the two sets of tests that were conducted. As noted earlier, these results represent what was documented at these particular locations during these specific points in time. Running the same tests at different locations and times will not necessarily produce the exact same results.

Nevertheless, the findings point to some interesting and significant considerations for agencies weighing their options for wireless broadband carriers and wanting to test the performance of different networks.

Key findings: Camden, NJ drive tests

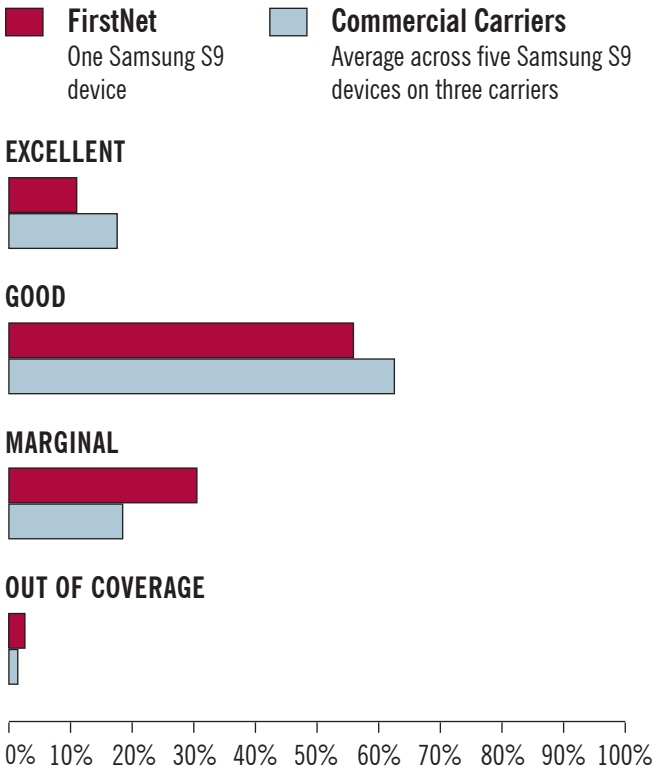
"Drive tests" were conducted on March 11–12, 2019 in Camden, NJ. These tests were intended to simulate the real-world experiences of patrol officers in that mid-sized city.

Signal Strength. All of the test devices experienced good to excellent signal strength throughout most of the two days of testing. However, among the Samsung S9 devices, the FirstNet phone showed the weakest signal strength overall.[10] It was good to excellent about 67% of the time, and was marginal (30.5%) or out of coverage (2.6%) for the remainder. By contrast, the Samsung S9 devices operating on commercial networks experienced good to excellent signal strength more than 80% of the time on average. (See Figure 1.)

Band Detection. On the FirstNet phones, Band 14 was detected in approximately 32% of the samples taken over the course of the two days.

Even when Band 14 was detected, only about half of the signal strength (RSSI) samples were in

Figure 1. Average Signal Strength
Drive Testing, March 11-12 – Camden, NJ



10. As noted earlier, automated signal strength tests were run on the Samsung S9 devices only. Apple devices did not support this type of automated testing.

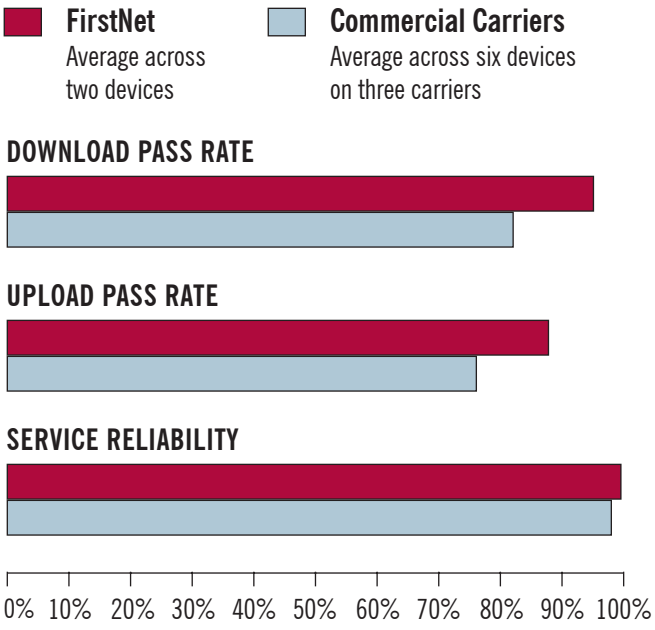
the good to excellent range. However, as detailed below, even with these lower signal strength readings, FirstNet generally provided higher performance levels.

Service Reliability and Performance. "Service reliability" was established as a simple assessment of data connectivity during each sample test. If a device was unable to receive or send data during a test, it was considered non-operational for that sample and the result was recorded as a service reliability failure.

During the drive tests, all of the devices had service reliability measures of 95% or greater. One of the FirstNet phones and one of the commercial carrier phones had 100% service reliability, and all but two of the commercial devices delivered at least 99% service reliability during the tests. There were relatively few service outages on any of the devices during the city drive tests. (This was in contrast to the two major events in DC, where numerous service reliability failures on commercial devices were recorded.)

Figure 2. Performance and Service Reliability

Drive Testing, March 11-12 – Camden, NJ



Notes: The pass rate thresholds were a minimum of 5 Mbps for data downloads and 2 Mbps for uploads. Service reliability measures the percentage of sample tests in which a device was able to receive or send data.

> The FirstNet devices had faster and more reliable data uploads and downloads, even though they generally had weaker signal strength.

In terms of performance, the FirstNet devices in general had faster and more reliable data uploads and downloads. For purposes of the tests, the testing team assigned a minimum of 5 Mbps for the download threshold and 2 Mbps for the upload threshold. These were considered conservative thresholds that would realistically support public safety operations in the field. (See footnote 8.)

The FirstNet devices met the download threshold approximately 95% of the time and the upload threshold in more than 87% of the tests. Combined, the commercial devices passed the download and upload threshold tests at lower rates: 82% for the download tests, and 76% for the uploads. (See Figure 2.)

On average, download and upload speeds were faster on the FirstNet devices than on the devices operating on the commercial carriers. (See Figure 3.) And in the image transfer tests, the devices operating on FirstNet fully downloaded the 20 MB file in an average of just over 11 seconds. Devices on the commercial networks overall averaged 20 seconds for these image transfers.

Key findings: Washington, DC major events

Tests were run during the March for Life on January 18, 2019 and the Women's March on January 19, 2019. During these two "high-capacity events," cellular networks were strained by large numbers of users in a small geographic area.

Signal Strength. On all devices, across all carriers, signal strength was consistently strong throughout both events. Tests run before,

Figure 3. Download and Upload Speeds

Drive Testing, March 11-12 – Camden, NJ

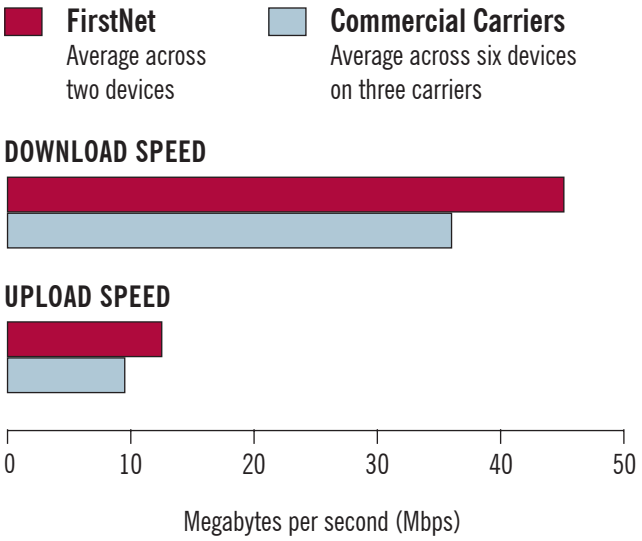
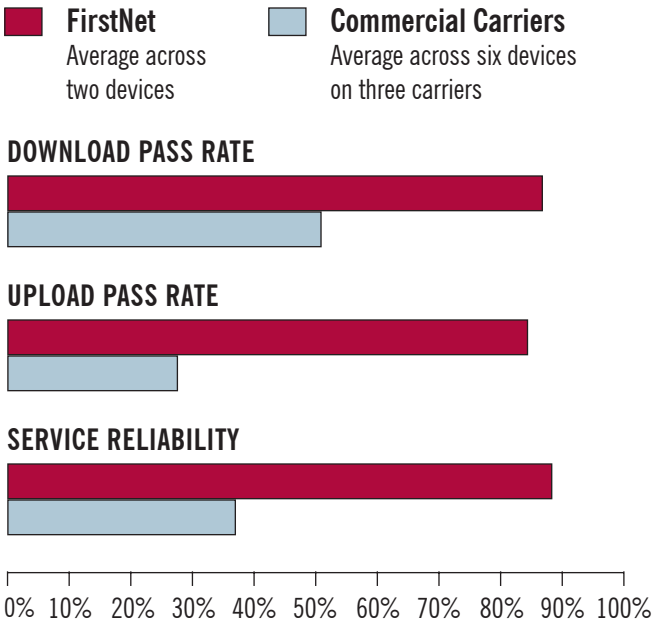


Figure 4. Performance and Service Reliability

March for Life, January 18, 2019 and Women's March, January 19, 2019 – Washington, DC



Notes: The pass rate thresholds were a minimum of 5 Mbps for data downloads and 2 Mbps for uploads. Service reliability measures the percentage of sample tests in which a device was able to receive or send data. For the Women's March, only five devices on the three major commercial carriers were tested.

during, and immediately after each of the two marches revealed that RSSI remained relatively constant and generally in the "good to excellent" range (with decibel-milliwatts, or dBm, of -85 or higher) on all carriers, including FirstNet.

Band Detection. Band 14 was detected in 46.3% of the samples during the March for Life and 84.4% of the samples during the Women's March. (In the March for Life, most of the Band 14 detections occurred at the beginning of the event, when people were gathered at the main stage on the National Mall near to where the FirstNet COW was deployed. As the march progressed to the U.S. Capitol, Band 14 was detected less frequently.) When Band 14 was not detected, the FirstNet devices were accessing various commercial bands on AT&T's commercial network. Similarly, the commercial devices accessed a variety of bands on their carriers' commercial networks.

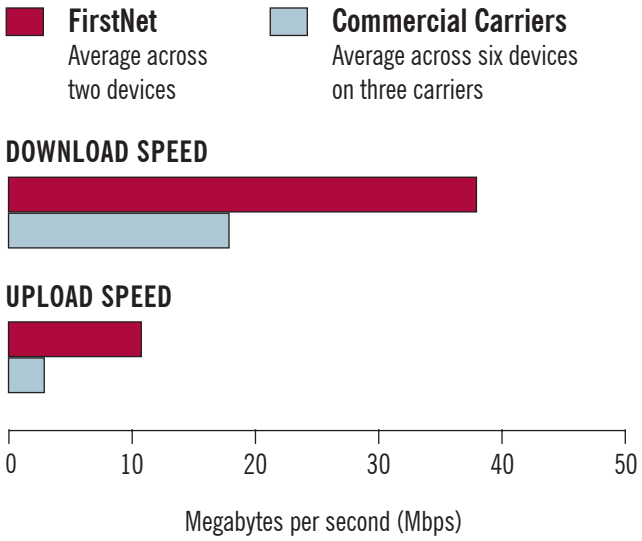
Service Reliability and Performance. Overall, the commercial networks experienced numerous "reliability failures" over the course of the two days.[11] These often occurred at times when the marches were ramping up or high-profile speakers were taking the stage at the rallies. On average, the commercial devices passed just 36.9% of the tests, an indication of the pressure these events put on cellular networks.

The FirstNet devices also experienced some reliability failures, but overall passed 88.2% of the reliability tests over the two days of testing. In addition, the FirstNet devices met the download (5 Mbps) and upload (2Mbps) thresholds in much

11. Again, service reliability was established as a simple test of data connectivity during each sample test. If a device was unable to receive or send data during a test, it was not considered operational for that sample and the result was recorded as a service reliability failure.

Figure 5. Download and Upload Speeds

March for Life, January 18, 2019 and Women's March, January 19, 2019 – Washington, DC



Note: For the Women's March, only five devices on the three commercial carriers were tested.

higher percentages of the tests overall. (See Figure 4.)

For both events, download and upload speeds were generally faster on the FirstNet devices than on the average of devices running on commercial networks. All of the networks, including FirstNet, experienced some variability in upload and download speeds throughout the course of the two events. Overall, FirstNet provided faster performance during both marches. (See Figure 5.)

Conclusion: Agencies Should Test Network Performance from the First Responder's Perspective

Since FirstNet was launched more than a year ago, leaders of public safety agencies have been asking a similar set of questions:

- Is FirstNet available in my jurisdiction?
- How does the coverage and performance of FirstNet compare to other service providers?
- How can I test the performance of FirstNet and other carriers in my jurisdiction, in a way that is accurate and not too costly?

To help agencies answer those questions, PERF and its subject matter experts researched and developed a rigorous but straightforward testing protocol. The team then tested that protocol in two different settings: 1) during drive tests meant to simulate "everyday" police operations in a mid-sized U.S. city; and 2) during major events that attracted tens of thousands of people to a relatively compact urban area, and thus put a strain on cellular networks.

One key feature of the testing protocol is that it focuses on the **perspective and experience of the user,** not the network. In other words, the testing protocol is designed to mirror, to the extent possible, the network performance that a police officer, sheriff's deputy, firefighter, emergency medical technician, or other first responder might experience in the field. This user perspective is something that agencies should adopt as they consider testing in their own jurisdictions.

Because the tests were conducted in two different settings, they provided useful experience in how to structure and carry out performance tests of LTE networks. The tests also produced some important takeaways:

- In the Land Mobile Radio (LMR) environment, signal strength and audio quality are paramount for supporting mission-critical voice communications. In the LTE environment, where moving large quantities of data across the network is critical, the performance indicators are more complex than simply measuring signal strength.
- Signal strength remains crucial for connecting to an LTE network, but signal strength alone does not necessarily translate into superior speed, reliability, or performance. During the drive tests, FirstNet devices generally delivered faster upload and download speeds than the average of devices operating on commercial networks, even though the FirstNet phones often had weaker signal strength.
- During the two major events, the signal strength on all devices (commercial networks and FirstNet) was generally strong. But the FirstNet

devices had faster upload and download speeds and did not experience the levels of service reliability failures that the devices on the commercial networks did. This suggests there is a Band 14 benefit during high-capacity events that put strain on cellular networks.

For public safety agencies evaluating their mobile broadband options, there is a new paradigm that goes beyond signal strength and focuses more broadly on performance—on the ability of first responders to transmit and receive text, images, and (increasingly) video for situational awareness and to help manage operations.

For a first responder trying to download an operational plan or upload video from the scene of a major traffic crash with injuries, the crucial factor is not just how many bars are on the smartphone or tablet. It's how quickly and reliably data can be transmitted over the network. This is especially important for first responders at the edge of the network, operating in less-than-optimal situations.

The selection of a wireless broadband network provider is a monumental decision for police and fire chiefs, sheriffs, and other public safety executives. Making the wrong decision can impede operations, increase costs, and threaten the efficiency and safety of first responders in the field. In making this decision, leaders need to look beyond broad "network coverage" claims or general crowd-sourced data, and instead conduct rigorous tests in their communities to measure network speed and reliability in moving data over the network.

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Using a testing protocol like the one described in this report should give public safety executives the type of information they need to make informed wireless broadband decisions for their agency and community.

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The points of view expressed herein are the authors' and do not necessarily represent the opinions of all PERF members.

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