GL Communications

Validation and Regression Testing for Emergency Services Mobile Networks

(Whitepaper)

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Introduction

Emergency services mobile networks include Land Mobile Radio Systems and often interface with the Public Switched Telephone Network (PSTN). These networks are used by police officers, firefighters, and other first responders and must reliably transmit audio between endpoint devices.

In responding to emergency situations, clear communication between personnel is mandatory. Poor voice quality and long latency can lead to miscommunication resulting in catastrophic consequences such as loss of life and damage to critical infrastructure. Clear voice quality is needed not just outdoors but in vehicles, aircraft, buildings, and underground as well.

Objectively measuring end-to-end voice quality in a wide range of scenarios spanning different locations can be challenging but is essential. In this whitepaper, GL Communications propose a systematic way to test voice quality over emergency services mobile networks. The resulting testing will identify gaps in coverage, potential sources of interference and other obstructions. This will allow the users to identify and eliminate vulnerabilities in their emergency services mobile networks and better protect their citizens.

Test Tools

Testing the emergency services network will require sophisticated hardware and software for controlling endpoint devices such as radios and telephones. GL Communications possesses dedicated hardware and software solutions which can be controlled via Graphical User Interfaces (GUI) and scripting interfaces. Each component of the solution is described below.

VQuad™ Probe

The VQuad™ Probe contains many physical interfaces for connecting to telecommunications endpoints such as radios, landline telephones and cellular phones. For radios, the VQuad™ Probe can trigger Push-To-Talk (PTT) for call control and send audio during PTT enable while receiving audio during PTT disable. In addition, the VQuad™ Probe can act as an analog telephone for connecting to the PSTN as an endpoint. For mobile phone networks, the VQuad™ Probe can connect to and control any mobile phone, including any network and any carrier, supporting Call Control (Place Call and Answer Incoming Call) and sending/recording audio during the established call. Each individual VQuad™ Probe can connect to minimal two endpoint devices simultaneously, and up to 12 endpoints simultaneously with additional hardware.

The VQuad™ Probe includes the Dual Universal Telephony Adapter High Density (Dual UTA HD) which contains interfaces such as Bluetooth®, 2-wire Analog, 4-wire Analog, RJ-11 and PTT. In addition, the VQuad™ Probe includes an embedded single board computer running Windows® 10 64-bit operating system. The GL VQuad™ software, installed in the VQuad™ Probe, controls the Dual UTA HD hardware with both manual and fully automated operation using the VQuad™ scripting. In addition, remote operation is available using the VQuad™ API and CLI controls.

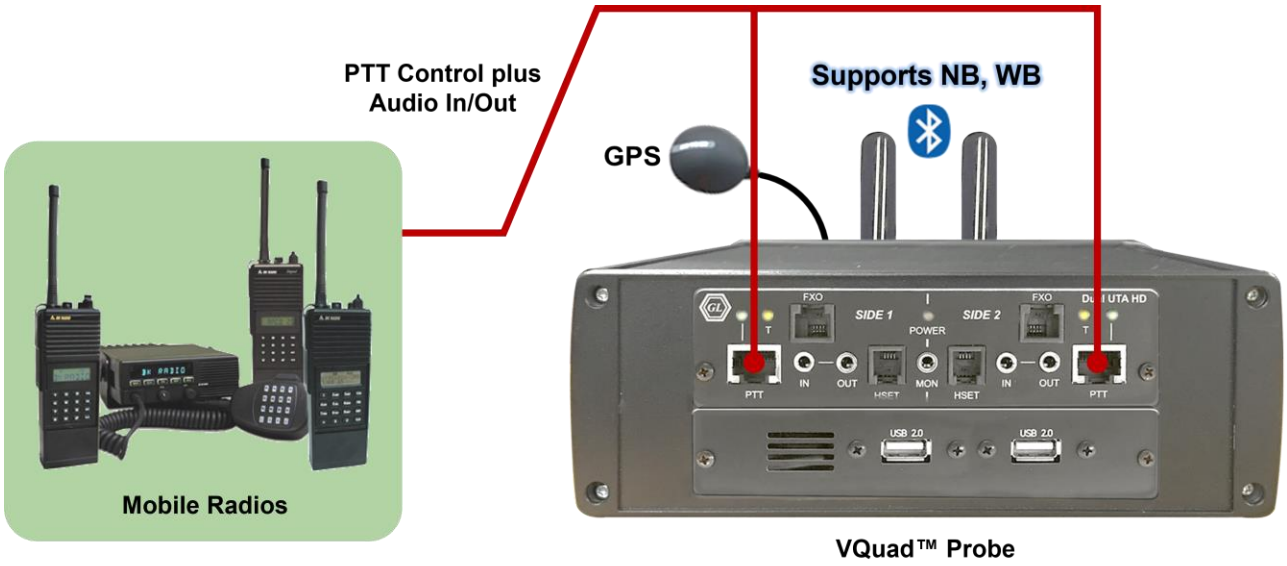

Figure 1: The VQuad™ Probe contains interfaces for connecting to and controlling radios, telephones or cellular phones. It also includes a computer for hosting the VQuad™ software.

The VQuad™ Probe also comes with a Global Positioning System (GPS) receiver for determining precise location during the mobile testing and including the location as part of all results and events.

For walking tests the VQuad™ Probe is lightweight and can be placed in a backpack while carried through a building. For Drive testing the VQuad™ Probe can be placed in vehicles, connected to the vehicle power, for fully autonomous operation using the VQuad™ scripting.

In addition, the VQuad™ Probe can be enhanced to communicate directly with the individual Radios via a USB connection. Using an API provided by the radio manufacturer, the VQuad™ Probe can be modified to gather additional information from the radio including RSSI. This information can be included as part of the overall test results.

vMobile™

The vMobile™ hand portable device can connect to a single mobile radio and perform same operations as the VQuad™ Probe. This solution is ultra-portable with a self-contained battery for ease of operation during Walking tests. Using the onboard WiFi, the vMobile™ can tether to a mobile phone while connecting to the Central Console for remote operation, can also be controlled directly from any mobile phone using the installed Console app, and runs fully autonomous using the vMobile™ scripts. In addition, the vMobile™ and VQuad™ Probe can work independently or together as part of a single end to end call.

Figure 2: vMobile™ connected to a Push-To-Talk radio.

Central System

The Central System includes a Server grade PC running Windows® along with a local database (either Oracle or MySQL). The Central System is connected to the internet and communicates with and controls the individual VQuad™ Probes and vMobile™ devices via TCP/IP. All VQuad™ Probes and vMobile™ devices, along with the VQT POLQA/PESQ and Audio Analyzer analysis software, send results and events to the Central Database with access supported using the GL WebViewer™ (web browser).

WebViewer™

This WebViewer™ is a browser-based application which connects to the Central System and provides full access to the entire solution. Using the WebViewer™ one can query and filter results, generate custom reports, schedule reports to be generated and emailed, plot results within Google Maps, and obtain network status of all deployed devices (including VQuad™ Probes and vMobile™ devices). In addition, the WebViewer™ allows full remote control of the VQuad™ Probe and vMobile™ devices including loading and running automated scripts. The custom reports provided by the WebViewer™ are user-specified and can include the voice quality results along with additional audio metrics, Call Control events, and the Radio specific events including RSSI.

Indoor Tracking System (ITS)

As part of the VQuad™/vMobile™ and Voice Quality Testing (VQT) software applications, the Indoor Tracking System (ITS) is used to track Voice Quality testing while walking within a building or underground location where GPS is not available. ITS allows the user to upload floor plans as a JPG prior to conducting the test, configure test points on the JPG, and traverses the space while indicating on the GUI as they pass each pre-defined point. As a result, the ITS can plot the Voice Quality test results directly on the floor plan and show the path the user took during the test. This allows the user to accurately identify locations within a building or underground where voice quality is degraded.

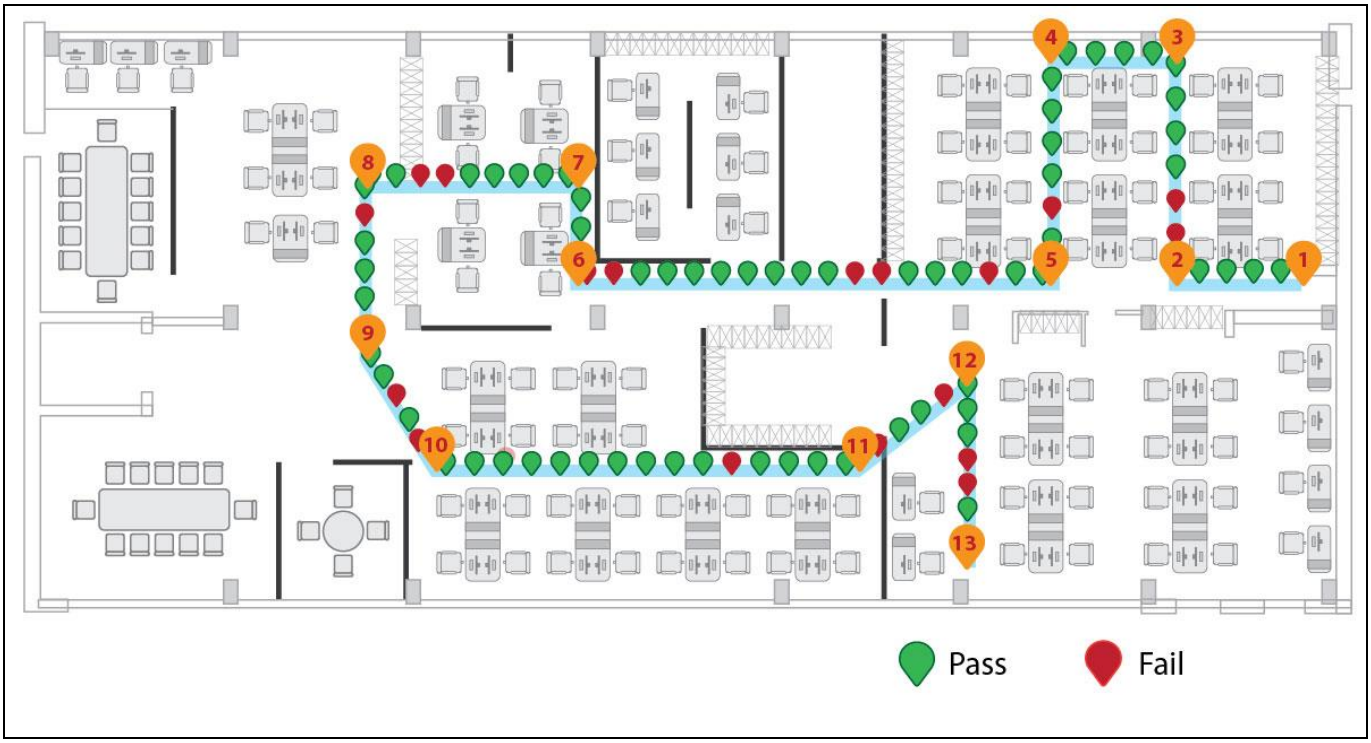

Figure 3: Hypothetical voice quality measurements using ITS.

Test Methodology

Many commercial off-the-shelf solutions seek to measure signal strength for radio communications. However, signal strength alone does not determine the actual voice quality that an operator will experience. It is possible to receive a strong signal and yet still suffer from unintelligible voice reception. Conversely, it is possible to have clear voice communication in a low signal strength environment. Therefore, to determine the true user experience, it is essential to measure voice quality along with the Radio RSSI.

Validation Testing

As part of the Validation Testing, comprehensive audio tests encompassing the wide area mobile network can be performed in an automated fashion. These comprehensive tests will generate reports and coverage maps showing both Audio Quality and RSSI signal throughout the entire testing area, including inside buildings and underground facilities where GPS is not available. Automated scripts will conduct these tests while sending and recording the male and female audio files (three files each per call per direction). Additional metrics include Audio Dropout Analysis, Signal and Noise Level, and RSSI. All results are accessed using the WebViewer™ and displayed within Google Maps and the ITS.

Regression Testing

Once Validation Testing is complete, the wide area mobile network should routinely run Regression tests (i.e., weekly, or monthly). The Regression testing will use same VQuad™ scripts used in Validation Testing, however the Regression Tests are not required to test the entire wide area mobile network. Rather, Regression testing is required routinely or whenever updates to the network infrastructure occur, including operation software, network hardware, console equipment and mobile radio devices. Regression testing can also be performed periodically within specific regions of the wide area mobile network to confirm proper operation and audio quality.

How to Measure Voice Quality

Voice quality can be objectively measured by sending a pre-defined audio file from one location within the network while recording the audio at the far-end. The recorded file is analyzed against the Reference file (file which was sent through the network) in order to generate a MOS (Mean Opinion Score). A low MOS value can be the result of degradation introduced by the network due to congestion (other users transmitting simultaneously), electromagnetic interference, faulty infrastructure, lack of infrastructure, bad weather, or other determining factors. By using the latest industry standard algorithms to compare the reference and degraded files, the Voice Quality measurements can provide insight into issues within the network.

The GL solution supports both the POLQA algorithm (per ITU-P.863) as well as the predecessor PESQ algorithm (per ITU-P.862). If required, the PESQ algorithm can also be converted to Delivered Audio Quality (DAQ) using the supplied DAQ conversion table.

In addition to the MOS, the GL VQT software generates the Signal and Noise levels as well as Jitter measurements in order to provide understanding of why the MOS might have been low. Additional audio metrics are available from the VQuad™ software and the GL Audio Analyzer software including Speech Activity, RMS power, Audio Dropout Analysis, and Delay Measurements (both One Way and Round Trip). All VQT and VQuad™ results, along with the Radio specific metrics, are automatically sent to the Central System and accessed using the GL WebViewer™.

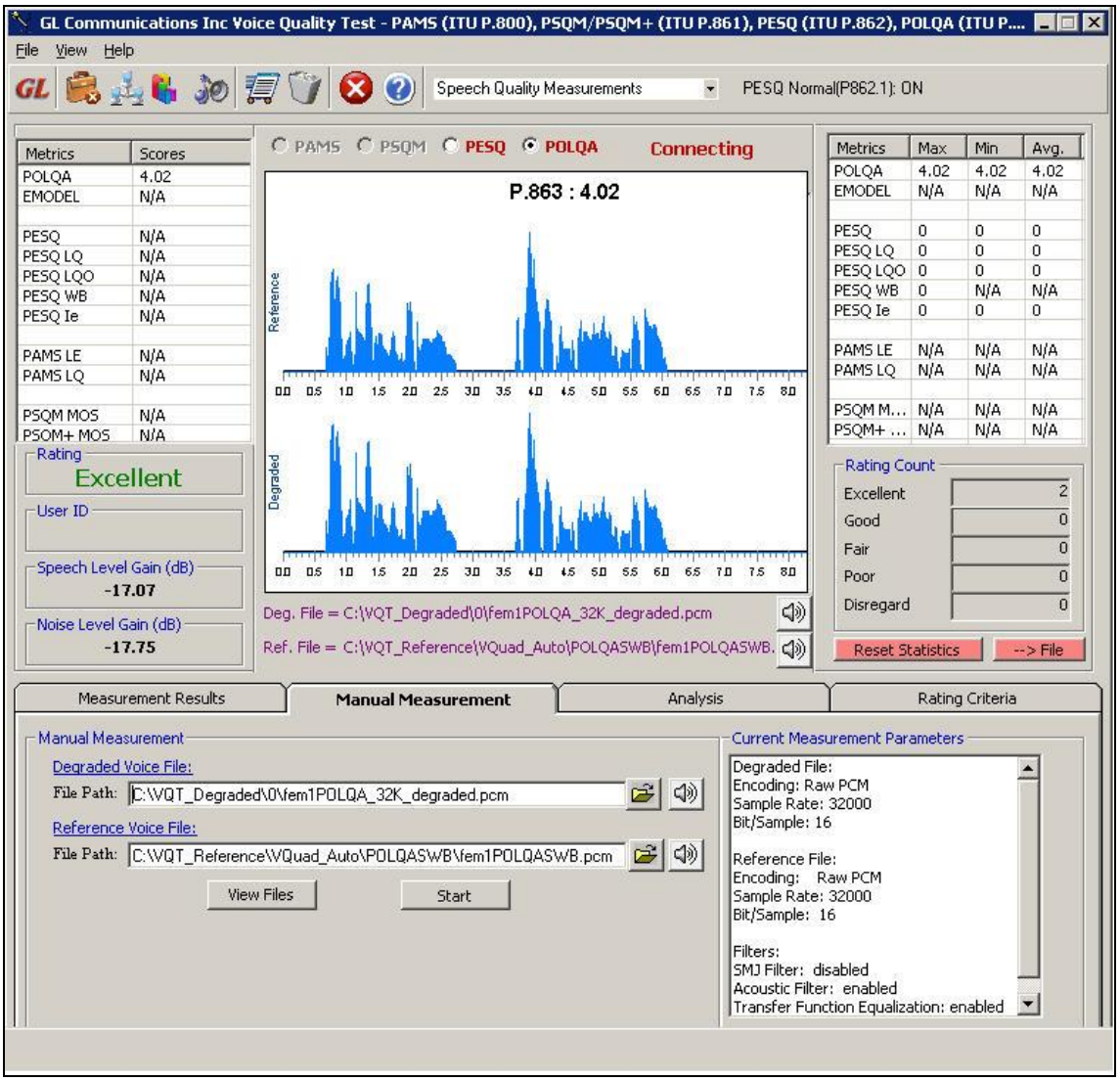

Figure 4: Measuring Voice Quality by comparing the Degraded audio file to the Reference audio file.

Choice of Audio File

Degradation in the network can affect various audio sources differently. The GL solution uses both male (low frequency) and female (high frequency) voice files during the testing. Results should be viewed with male and female independently and together for a more thorough understanding of the network quality. During the tests it is recommended that for each individual call a total of three male and three female files be sent and recorded.

Bidirectional Testing

During the testing it is important to measure voice quality in both directions of the call. Audio should be sent from the mobile radio (PTT enabled) and captured at the far end (PTT disabled) which can be a mobile radio, static radio, base console, or PSTN. In addition, the audio should then be sent from the opposite end to the near-side mobile radio. With this testing configuration a total of twelve voice files are transferred in a given call (three male audio files from the local end to the remote end, three female audio files from the local end to the remote end, three male audio files from the remote end to the local end and three female audio files from the remote end to the local end).

All automated operations can be included in the VQuad™ or vMobile™ scripting. In other words, during each bi-directional call a total of six audio files will be sent and recorded in each direction, and during each call additional metrics will be generated including Audio Dropout Analysis, P56 measurements, and optionally Delay measurements. The number of calls can be looped for duration of test or simply configured to run continuously until the test is stopped.

Determining Location using GPS

For each measurement of the voice quality, the GPS receiver will record the time, longitude and latitude of the measurement. These results will be stored and sent to the WebViewer™ for plotting within Google Maps. In addition, the Google Maps pins are user-defined and fully configurable for custom Google Maps reporting.

Testing Along a Street or Highway

Drive testing is essential for ambulances, fire trucks, police cars and other vehicles used in emergency situations. The operators in the vehicles use radios to communicate with first responders in the near vicinity. To ensure that they have good voice quality, a test can be performed as follows: Connect the VQuad™ Probe to one or two radios and place the equipment in the vehicle. If using two radios, the radios can make calls directly to each other or can be used for two separate and simultaneous tests. The opposite side of the call can be a VQuad™ Probe system placed in a stationary location or in another mobile vehicle.

The VQuad™ Probe, using the VQuad™ scripting, will be configured to enable PTT and send audio through the radio where it's captured (recorded) at the far-end. During the same test the radio is placed in PTT disable mode while the audio is sent from the far-end location and captured (recorded) on the mobile radio. The operator drives along the pre-defined route while the VQuad™ Probe automatically runs the test and sends the results and recorded files to the Central Location for analysis.

The VQuad™ Probe can also be controlled remotely by the Central System for starting and stopping the test. As a result of this test all voice quality measurements, along with other audio and radio specific metrics, can be seen in the WebViewer™ and plotted in Google Maps. Areas where the radio experiences poor voice quality (or no coverage) can be seen in the resultant Google Maps graphic. Figure 7 shows hypothetical results superimposed on a map of Washington, USA. To acquire data across the entire network in a reasonable amount of time, GL Communications recommends several vehicles would be needed, each equipped with a VQuad™ Probe running automated tests.

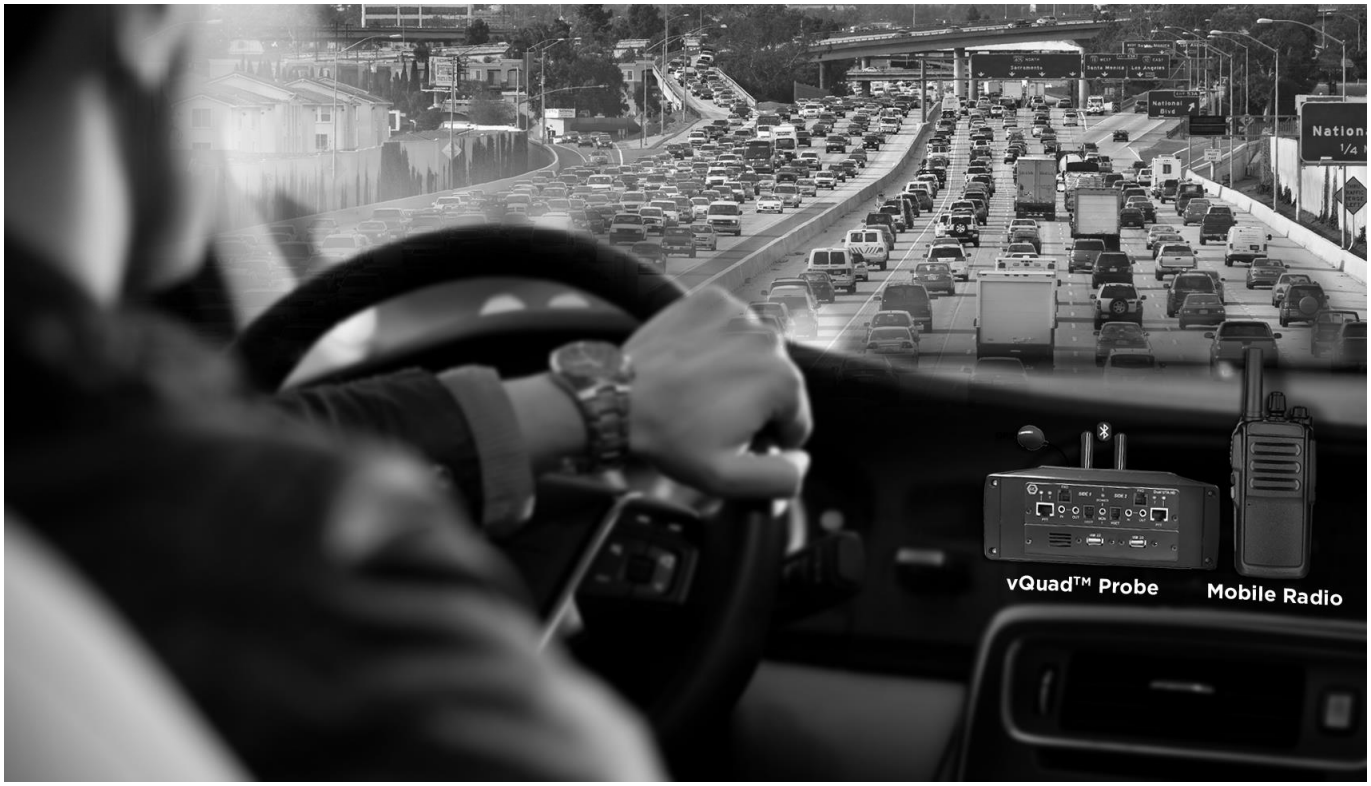

Figure 5: VQuad™ Probe and Mobile Radio in a Vehicle.

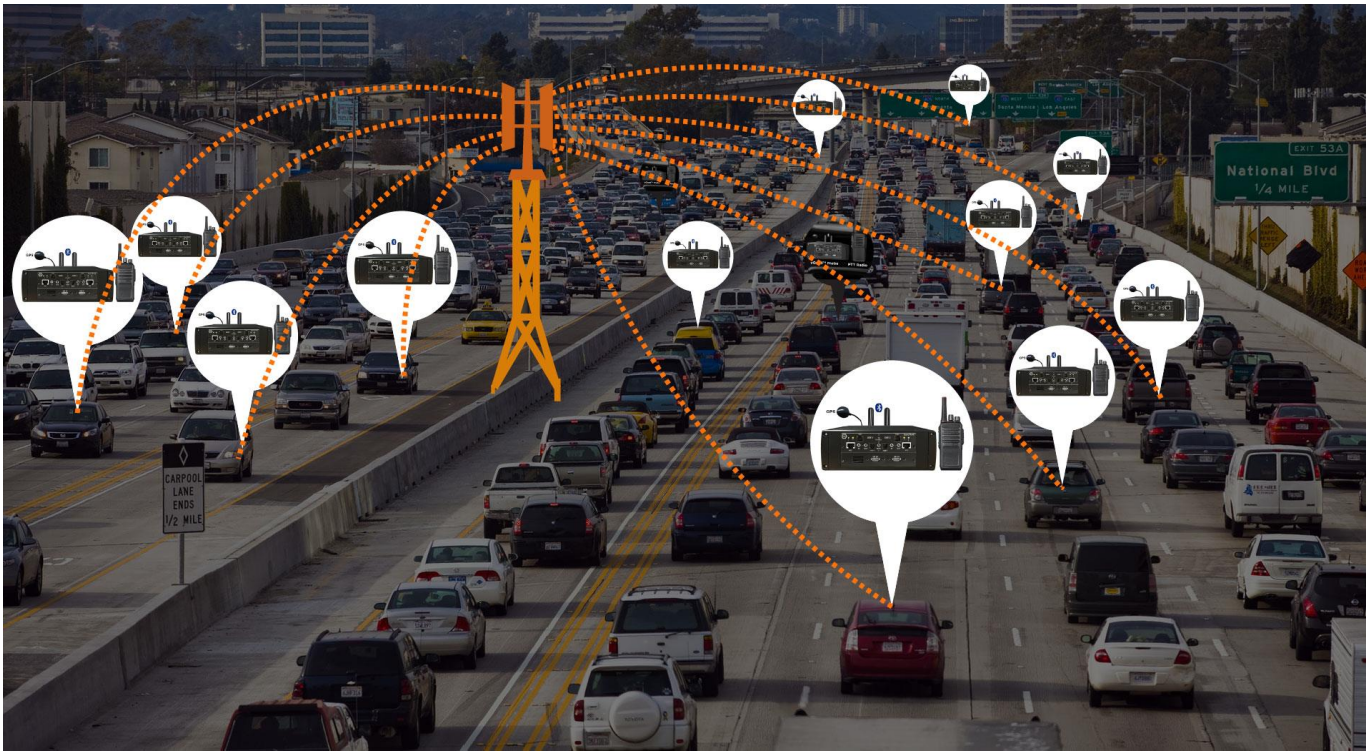

Figure 6: Multiple VQuad™ Probes and Mobile Radios connecting to a single base station.

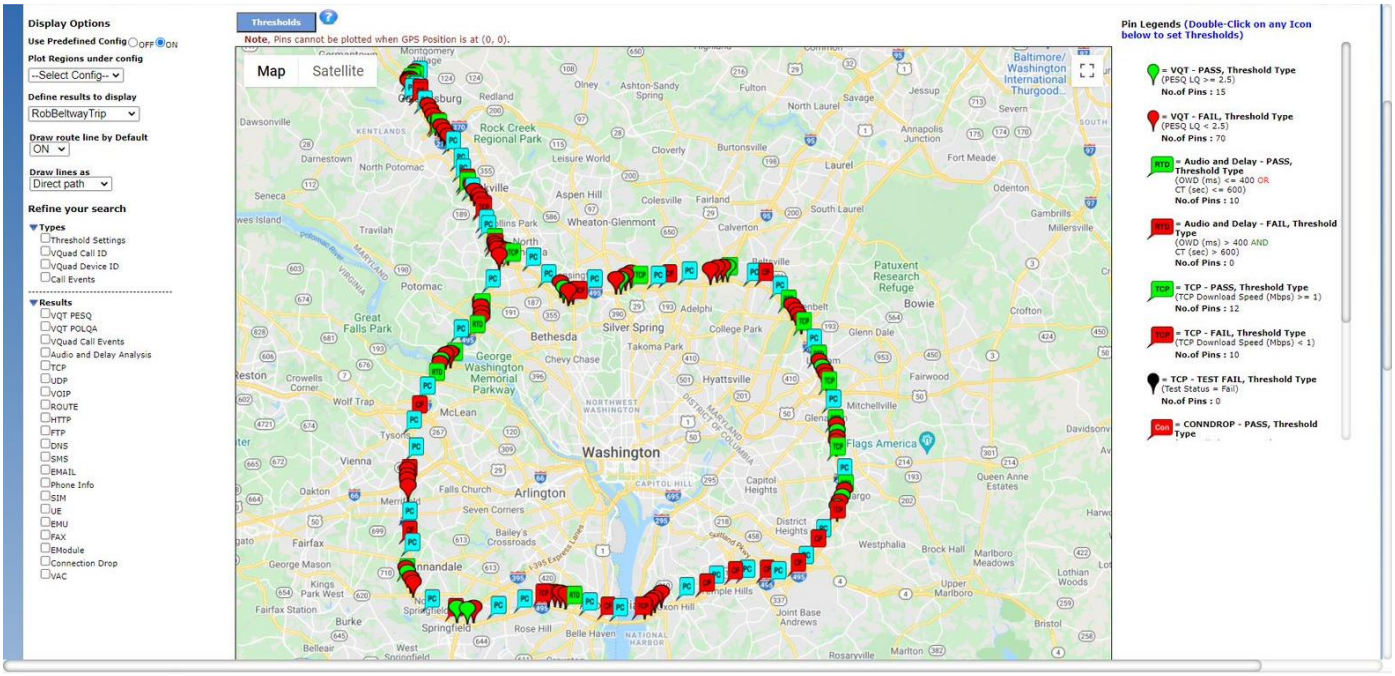

Figure 7:Voice quality scores on the Beltway around Washington D.C., USA.

Testing in a Building

This testing is essential for police officers, fire fighters and other first responders entering a building or walking in underground locations during an emergency situation such as a fire, building collapse, active shooter scenario, etc. It is essential that these personnel have adequate radio coverage and voice quality when receiving and transmitting on their radios no matter where their location. To test in a building or underground, or essentially anywhere GPS is not available, the operators should upload a blueprint or floorplan in JPG format to the GL ITS and configure a walking path within ITS prior to entering the building or location.

The operators then connect the radio to the VQuad™ Probe, or vMobile™, and carry both as they walk through the building on the pre-determined walk path. The far-end radio and VQuad™ Probe system should be placed in a stationary location outside of the building. The VQuad™ Probe, using the VQuad™ scripting, or vMobile™, using the vMobile™ scripting, will be configured to enable PTT and send audio through the radio where it's captured (recorded) at the far-end. During the same test the radio is placed in PTT disable mode while the audio is sent from the far-end location and captured (recorded) on the mobile radio.

The Voice Quality results, along with additional metrics including Radio RSSI, will be sent to the ITS solution which will plot the measurements directly on the floor plan. Areas of the building where the radio experiences poor coverage or poor Voice Quality should be remediated. This testing scenario is semi-autonomous since the user is required to interact with the VQuad™ Probe or vMobile™ during the walking test (specifying each next location using a simple NEXT button).

Figure 8: The user tests voice quality while walking in a building by simply using the VQuad™ Probe to connect to the radio and controlling the Indoor Tracking System from a tablet.

Figure 9: The user tests voice quality while walking in a building by simply using the vMobile™ to connect to the radio and controlling the Indoor Tracking System.

Testing Between Radios and the PSTN

The VQuad™ Probe can test the communication between a mobile radio and the PSTN, or a mobile radio and the Cellular Network. The VQuad™ Probe includes interfaces for 2-wire analog (FXO), which simulates an analog phone and can connect to a PSTN for receiving or placing calls as well as Bluetooth for connecting to any mobile phone via wireless Bluetooth headset. The testing methodology is similar to testing calls between radios. Audio files are sent from the radio to the emulated analog phone (three male audio files and three female audio files) and vice versa for full bi-directional testing. The same voice quality measurements along with additional audio metrics can be sent to the Central Database and accessed using the GL WebViewer™.

Figure 10: Testing the communication between a mobile radio and the PSTN.

Other Measurements of Network Performance

One-Way Delay

GL Communications' proposed solution can also measure one-way delay of the transmitted audio between the radios. To make this measurement, the VQuad™ Probe or vMobile™ at each endpoint is equipped with GPS receivers which are used to synchronize the send and receive audio pipes using GPS time and calculate the one-way delay with millisecond accuracy. These tests can be included within the VQuad™ or vMobile™ scripting so they are performed during voice quality testing.

Mobile Radio Metrics

As mentioned above, the VQuad™ Probe solution can communicate with the mobile radio through a USB connection and, using an API provided by the radio manufacturer, generate the additional radio specific metrics including RSSI. These tests can be included as part of the VQuad™ scripting for automated operation. All results are sent to the Central Database and can be included within custom reports as well as included in the Google Maps plot. Note, providing radio specific metrics requires interfacing with the radio manufacturer API and slight modifications to the VQuad software.

Sample Results

The screenshots below demonstrate several graphs and reports that are possible with the GL solution. The user can view all data through the WebViewer™ console including POLQA MOS, delay measurements, completed calls, failed calls, Signal and Noise levels, Radio specific metrics, along with several other audio metrics. The user can plot the MOS and one-way delay (or any other captured metric) throughout the call duration to see variations over time. The data can be viewed in the WebViewer™ or exported to a PDF or Excel file.

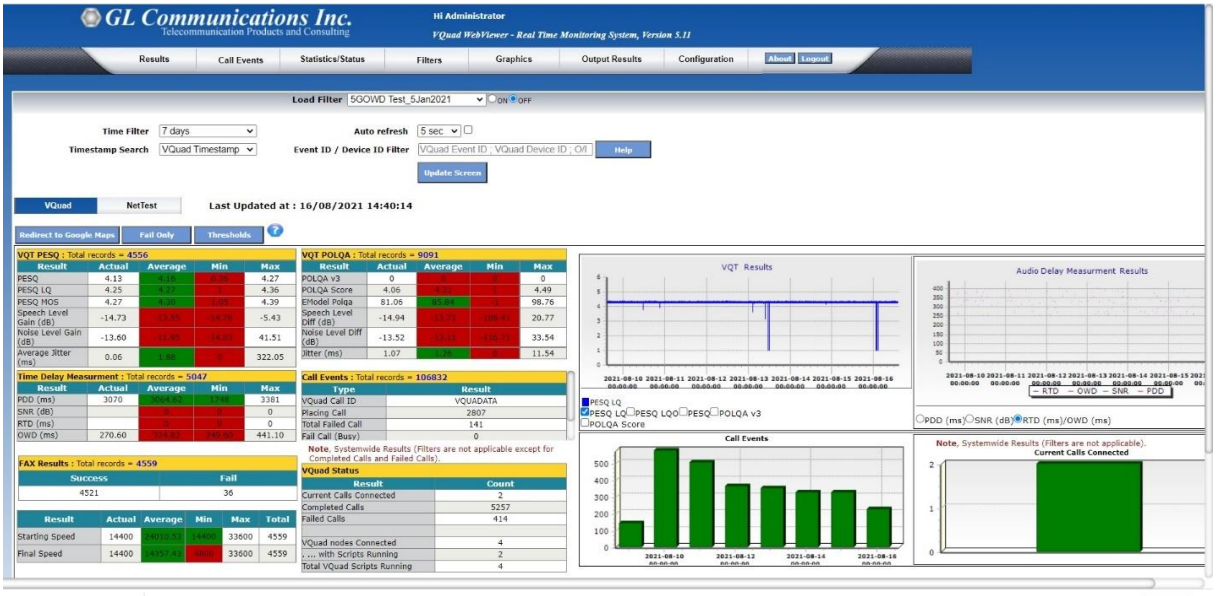

Figure 11: Console view through the WebViewer™ displaying essential test statistics.

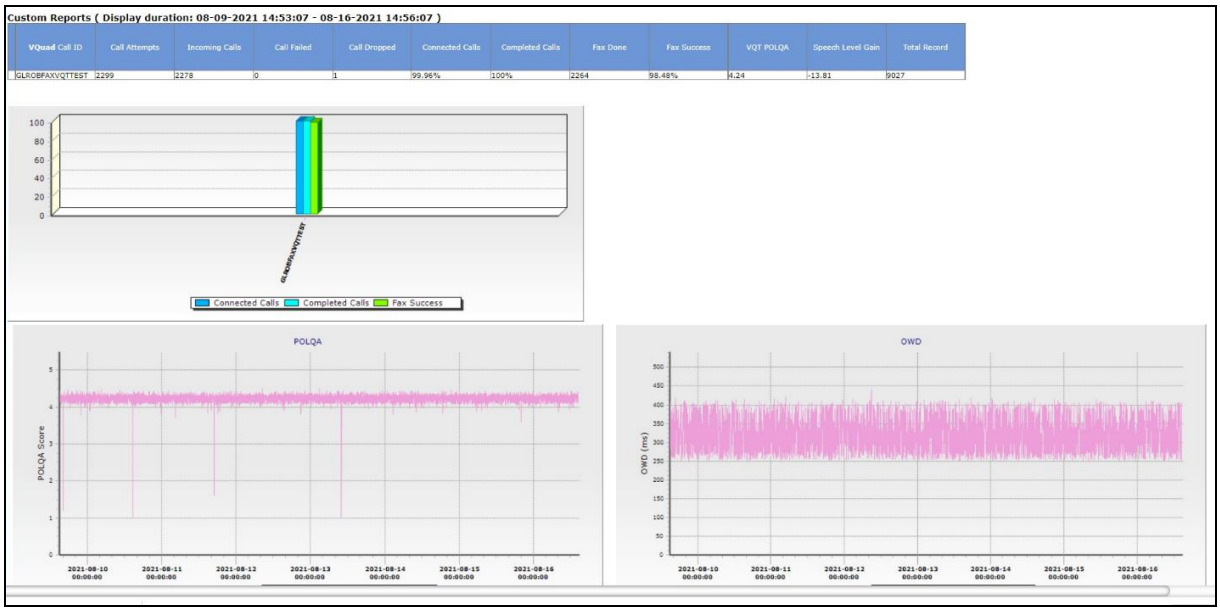

Figure 12: Voice quality statistics including connected calls, completed calls, MOS, and one-way delay.

The user can view all placed and answered calls (determined by PTT enable) as shown in the figure below.

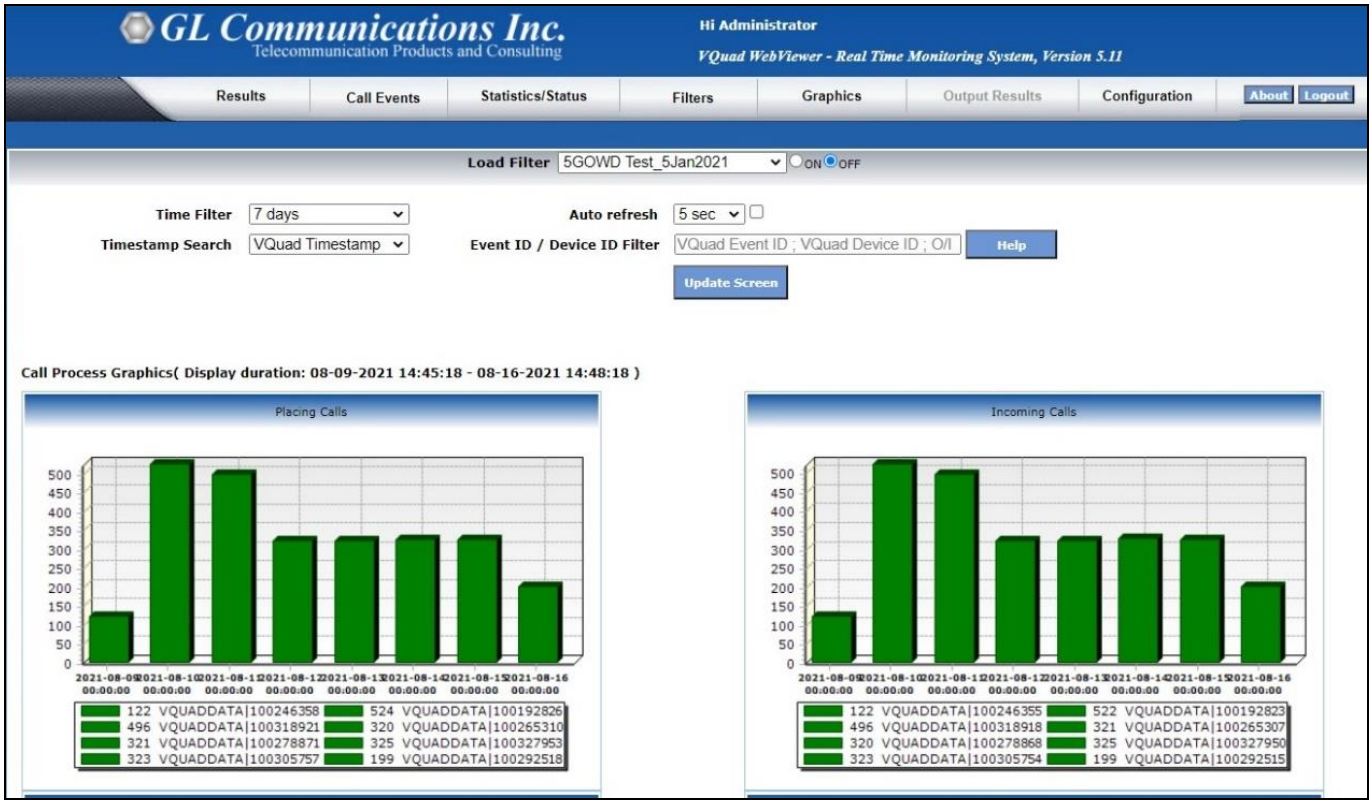

Figure 13: Bar graph showing placed and incoming calls.

Multiple VQuad™ Probes and vMobile™ devices can connect to the central system throughout the testing environment. Users can view a real-time status of all connected devices including location (latitude and longitude), IP address, device serial number, and current status of the device.

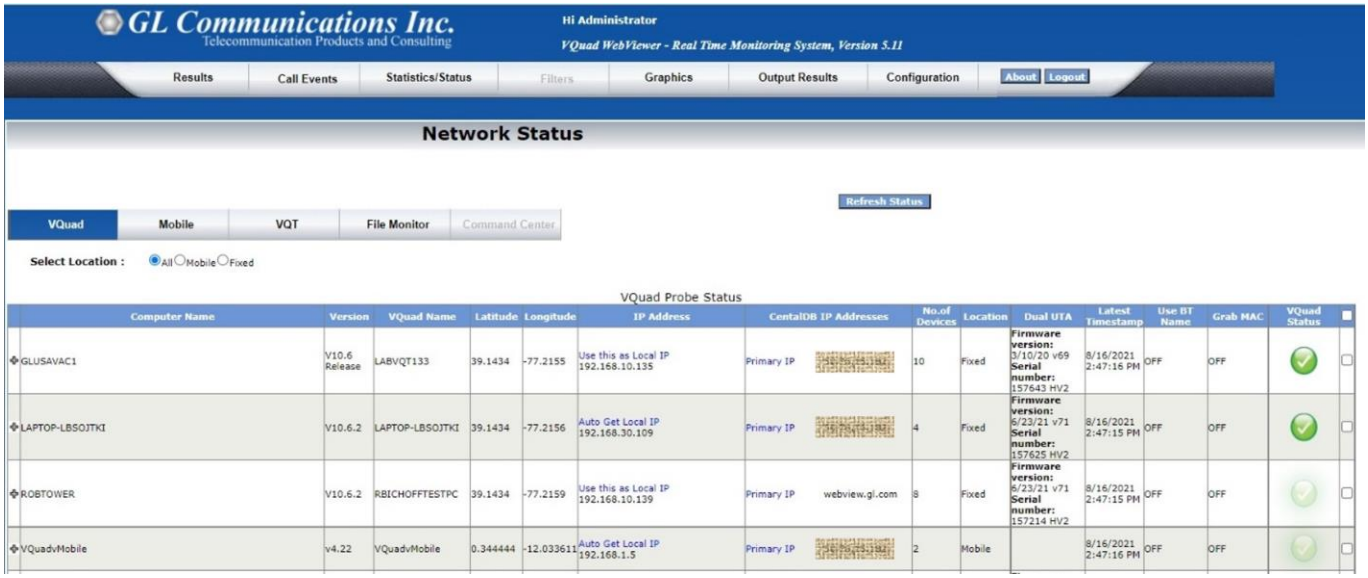

Figure 14: Network status of all connected VQuad™ Probes and vMobile™ devices including location, IP address and connectivity status.

Conclusion

The GL proposed solution provides a fully automated method for testing the Audio Quality and Coverage of the Emergency Services wide area mobile network. These tests can run continuously thus generating thousands of measurements per day in various spaces such as during Drive and Walking testing. The results can be mapped to identify areas of poor mobile radio coverage and poor voice quality. By improving these spaces, police officers, firefighters and first responders can have confidence that they can communicate clearly in any circumstance and thus save lives.

The GL solution relies on a combination of hardware and software. The hardware physically interfaces with the radios and telephones, while the software fully controls the test configuration and execution. The operator simply needs to carry the equipment while the software automatically makes the measurements. The results can be viewed on a central server, accessible to operators with an internet connection using the GL WebViewer™.

About GL Communications Inc.

GL Communications Inc. has over 30 years of experience in the telecommunications industry providing equipment and consulting services. GL has a comprehensive suite of testing solutions to verify network performance in various telecom networks including wireless, fiber optic and traditional land line networks. GL offers customers a team of seasoned experts with a strong understanding of the challenges they face and the technical creativity to meet complex requirements. GL works with major telecom equipment vendors, service providers and system integrators to meet testing requirements arising at various stages of the product development life cycle. Our test platforms provide unprecedented visualization, capture, storage, portability, convenience and cost-effectiveness.

References and Further Information

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- General information on the VQuad™ Probe: https://www.gl.com/vquad-probe.html
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- Indoor Tracking System: https://www.gl.com/indoortrackingsystem.html
- Voice Quality Measurements: https://www.gl.com/voice-quality-testing-pesq-polqa.html
- Drive Testing: https://www.gl.com/drive-testing.html