## INTRODUCTION

*The Silvus Technologies Tactical MIMO radios provide long-range, mobile and non-line of sight HD video, voice and telemetry data using Wireless Mesh Networks (also referred to as Mobile Ad hoc Networking (MANET)). The radios employ a number of technologies in order to achieve this performance, including (1) self-forming/self-healing, (2) link adaptation, (3) adaptive routing, (4) transparent IP networking, (5) optimized multicast transmissions, and (6) multi-channel transmissions (https://silvustechnologies.com/why-silvus/technology/introduction-to-manet/ accessed 27 August 2018).*

During a Government sponsored test event, Silvus Technologies demonstrated their StreamCaster 4200 handheld radio (Figure 1) and StreamCaster 4400 fixed installation radio (Figure 2), along with their StreamScape Network Management GUI (Figure 3). The radios form a digital "mesh network" of nodes which are addressed by IP address via the software. One of the radios was connected to a laptop which was running the StreamScape software. Although the software allows the operator to communicate with, and modify the operation of all radios, the software does not control routing or communications between the other nodes – they operate autonomously. A dynamic routing protocol running on each node is constantly evaluating the best route for passing messages to other nodes, taking into account the number of hops (each hop requires transmission which uses battery power and network bandwidth) and the signal strength of the node-to-node links. In addition to the radios, each operator wore a small body cam which transmitted images back to the StreamScape laptop for display.

## STREAMCASTER 4200

### (SC4200) 2X2 MIMO RADIO

*Portability without compromising performance.*

SC4200 is a 2×2 MIMO radio, delivering best-in-class performance and efficiency in a miniature package. It is ideal for use in portable and embedded applications where size, weight, power or cost are key.

### SC4200 FEATURES

- Up to 4 Watts of output power (up to 8W effective performance thanks to TX Beamforming)
- Available in 3 form factors to suit a variety of applications:
  - » Rugged "brick" (externally powered)
  - » Rugged handheld (w/ twist-lock battery connector)
  - » Non-rugged OEM (for embedding in custom products and sub-systems)

*Figure 1: Silvus Technologies StreamCaster 4200 Mobile Tactical MIMO radio (from company website).*

## STREAMCASTER 4400

### (SC4400) 4X4 MIMO RADIO

*The world's most powerful tactical MIMO radio.*

SC4400 delivers the power of 4×4 MIMO in a ruggedized package. SC4400 is ideal for use in fixed infrastructure, vehicular, long range, and airborne applications where maximum performance is desired.

### SC4400 FEATURES

- Up to 8 Watts of output power (up to 32W effective performance thanks to TX beamforming)
- Rugged outdoor rated housing with optional pole mount and surface mount hardware available
- Available in 2 form factors to suit a variety of applications:
  - » Rugged (can be deployed with a variety of antennas)
  - » Non-rugged OEM (for embedding in custom products and sub-systems)

*Figure 2: Silvus Technologies StreamCaster 4400 Tactical MIMO radio designed for fixed sites (from company website).*

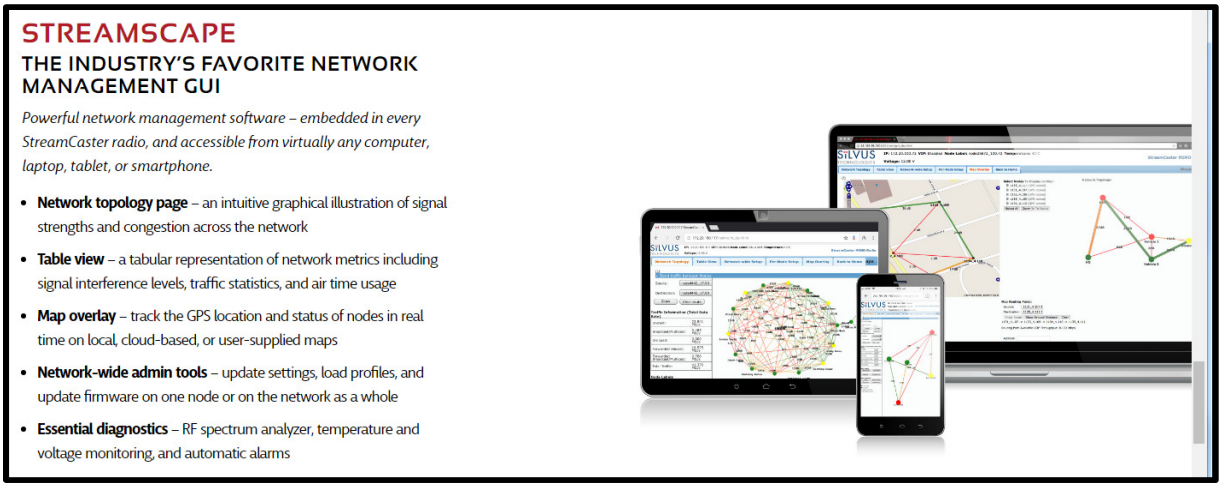



*Figure 3: Silvus Technologies StreamScape network management software (from company website).*

# Demonstration Plan And Results

## East Side Access (ESA) Tunnel

Silvus demonstrated their mesh radio network in the ESA tunnel. The ESA tunnel provided an opportunity for Silvus to display the capability of their radios to establish an ad-hoc mesh network. Figure 4 shows laptops connected to one of the radios and running the StreamScape network management software.

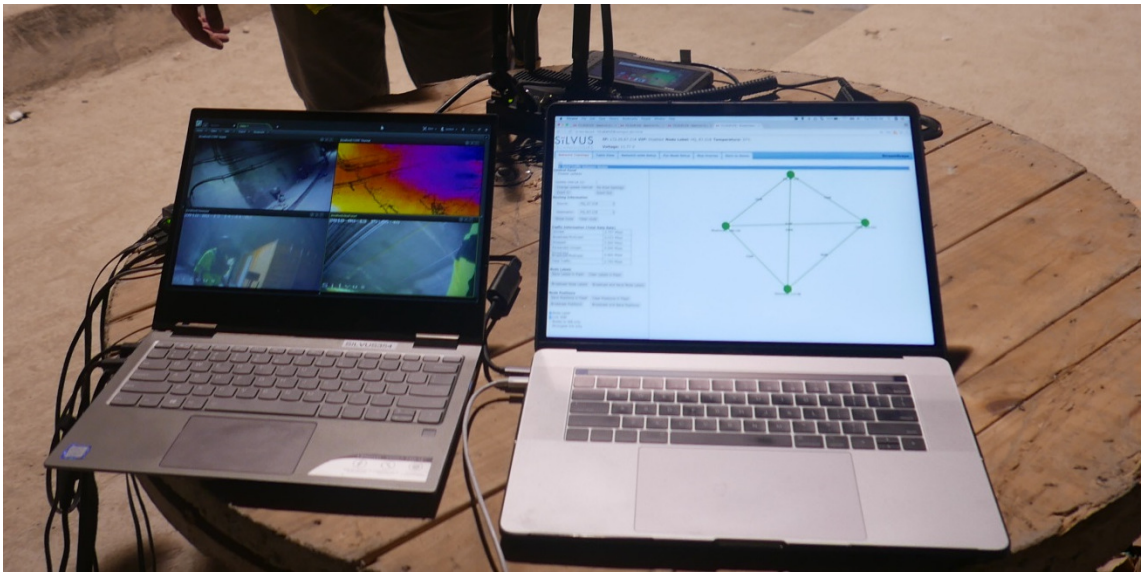


*Figure 4: Silvus laptops running StreamScape in the ESA tunnel. The laptop on the right shows the nodes (radios) comprising the network, including the SNR of all inter-node links. The left laptop displays video feeds from cameras connected to radios.*

A one-hour tour was conducted along an adjacent tunnel, during which time the Silvus radios were deployed to form a mesh network which allowed video, data and voice messages to be transmitted back to the Silvus laptop which had remained back in the main tunnel. The original plan was for the tour to climb the stairs back up to the ESA entry and connect the network with a Command Post at street level, but time limits required the tour to be cut short and the ascent to the surface was scrubbed. The Silvus experiment consisted of 4 operators sending 5 video feeds:

- 3 Dismounts with Silvus Obscura bodyworn HD cameras
- 1 Dismount with Tactical Electronics CORE EOD camera with two sensors
    - Standard + Thermal

The mesh network established during the ESA tunnel tour at the farthest point from the Base Station is shown in Figure 5. At this time, messages between the 'dismount' radios and the laptop radio (HQ) are being routed via four other radios in the network, labeled Relay 1 through Relay 4 in Figure 5.

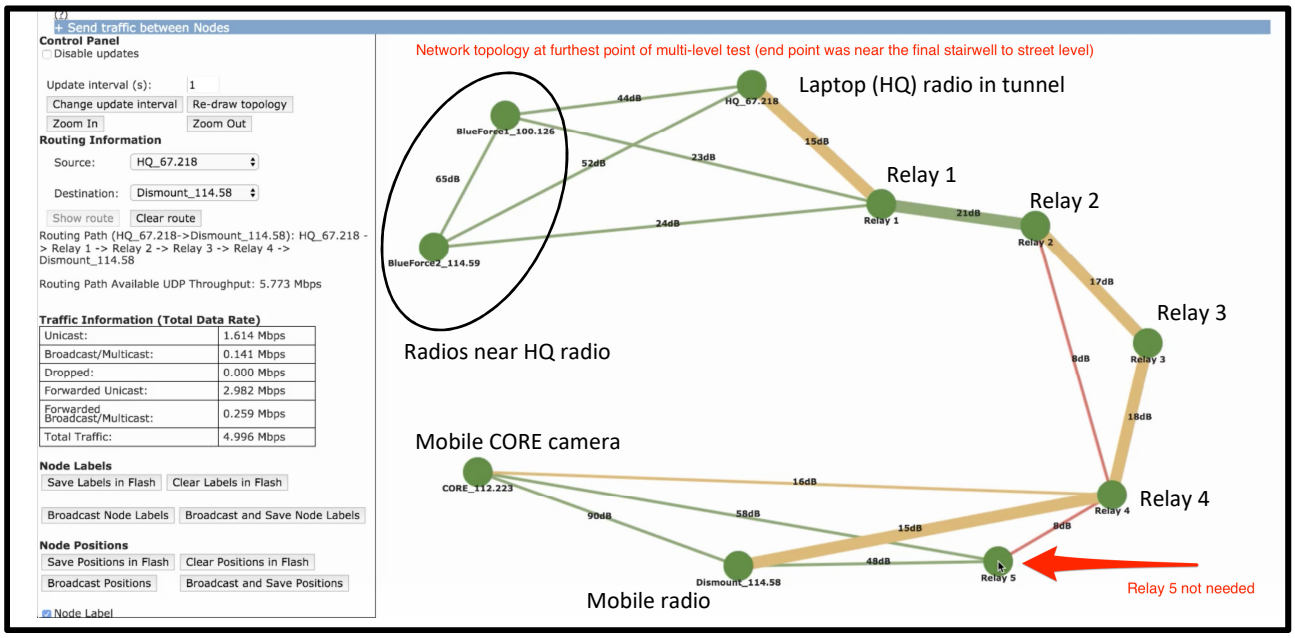


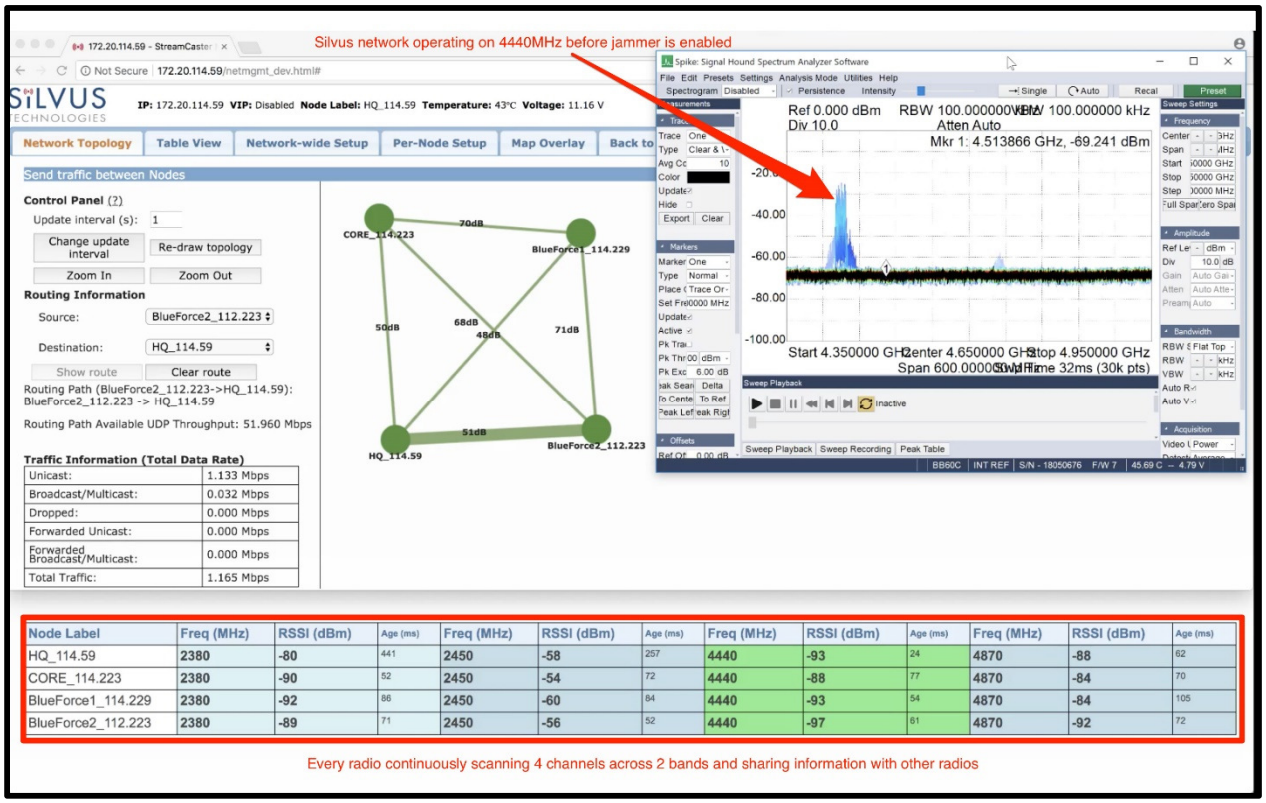

*Figure 5: Mesh radio network operating in the East Side Access (ESA) tunnel during the tour. The mobile radio and CORE camera are furthest from the HQ radio, which remained back in the main tunnel during the tour. The mobile radio and CORE camera had moved away from the HQ radio, deploying five radios, denoted Relay 1 through Relay 5 in the figure, in order to maintain communications. Relay 5 radio was not needed. Links shown in green have 20 dB or more SNR. Orange links have 10-20 dB SNR. Fat lines indicate links which are being used.*

## World Trade Center (WTC) – Back-of-the-House

The WTC Back-of-the-House venue presented another good opportunity for Silvus Technologies to display their mesh network radio capabilities. Silvus participated in two tours which led upstairs and along a series of hallways, down another set of steps and arrived back at the starting point. During the first tour, Silvus demonstrated their MANET Interference Avoidance (MAN-IA) feature, in which each radio continuously monitors four bands in the RF spectrum for interference or jamming, and when

interference is detected, moves the entire network to the next best channel and continues operation. Isolated radios will automatically rejoin the network, even if the network has changed channels while the radio was out of the network.

The MAN-IA capability was demonstrated by turning on a continuous wave, 5MHz wide jammer in the channel currently being used by the radios and observing that they automatically change the entire network to another band. Figure 6 shows the spectrum with the radios operating on the 4400 MHz channel, unjammed. The panel at the bottom shows that all radios are monitoring SNR in 2380, 2450, 4440 and 4970 MHz channels.




| Node Label | Freq (MHz) | RSSI (dBm) | Age (ms) | Freq (MHz) | RSSI (dBm) | Age (ms) | Freq (MHz) | RSSI (dBm) | Age (ms) | Freq (MHz) | RSSI (dBm) | Age (ms) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HQ_114.59 | 2380 | -80 | 441 | 2450 | -58 | 257 | 4440 | -93 | 24 | 4870 | -88 | 62 |
| CORE_114.223 | 2380 | -90 | 52 | 2450 | -54 | 72 | 4440 | -88 | 77 | 4870 | -84 | 70 |
| BlueForce1_114.229 | 2380 | -92 | 86 | 2450 | -60 | 84 | 4440 | -93 | 54 | 4870 | -84 | 105 |
| BlueForce2_112.223 | 2380 | -89 | 71 | 2450 | -56 | 52 | 4440 | -97 | 61 | 4870 | -92 | 72 |

*Figure 6: Silvus network operating on a 4400 MHz channel prior to interference being present.*

Figure 7 shows the Silvus network operating after jamming was introduced in the 4400 MHz channel. The entire network has moved to the 4870 MHz channel.

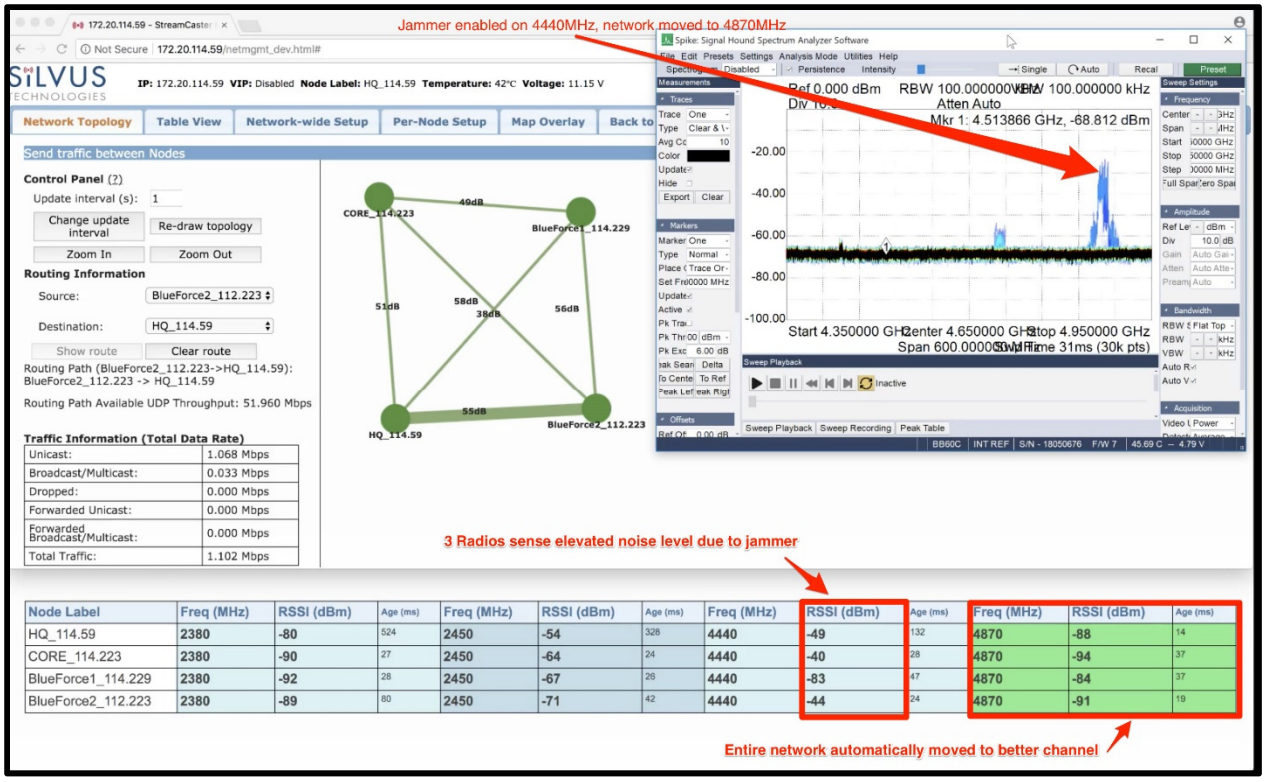



*Figure 7: Silvus network has switched over to 4870 MHz channel after interference was introduced in the 4400 MHz channel.*

During the second tour, Silvus radios were deployed along the route in order to extend the network, including the CORE camera and IR feeds, back to HQ. The evolution of the mesh network as the tour progressed is shown in the figures which follow.

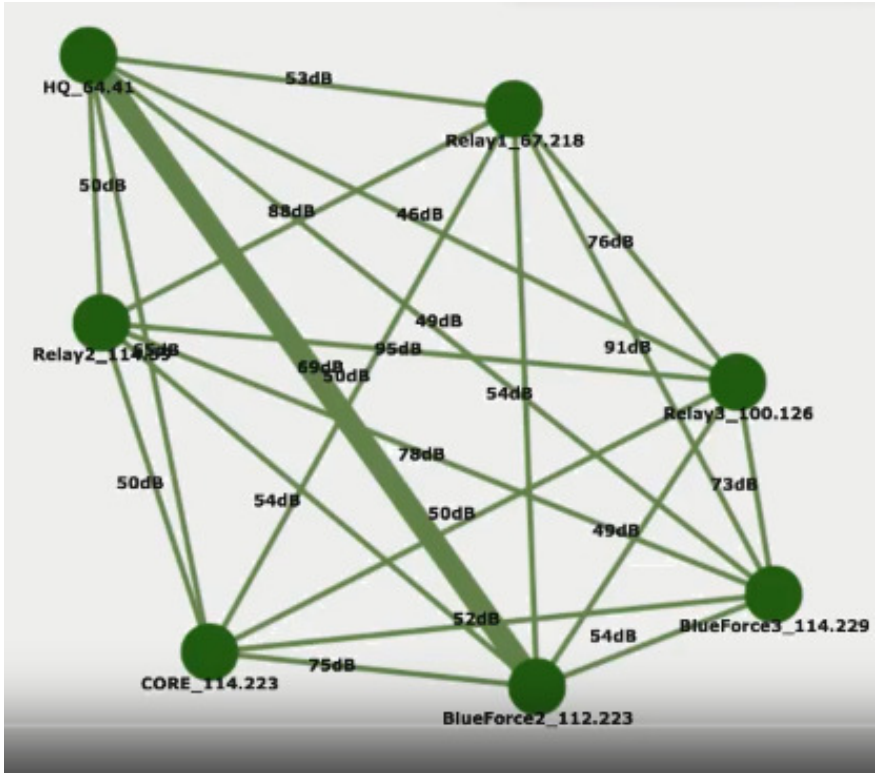



*Figure 8: Start of tour in WTC Back of the House. All radios in direct contact with the HQ laptop. Green links have > 20 dB SNR.*

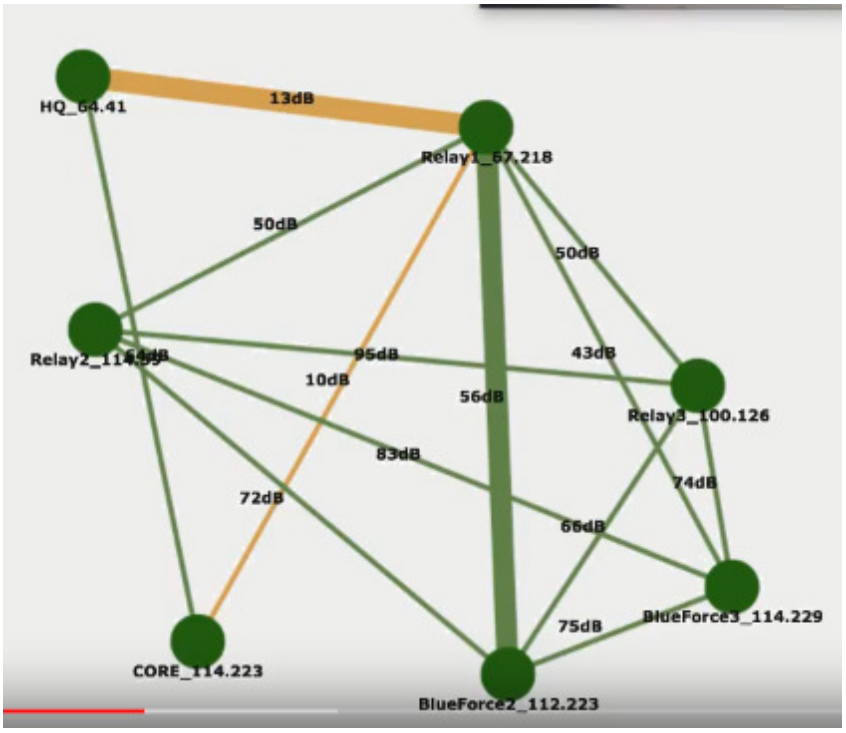



*Figure 9: Shortly into the tour at WTC Back of the House. Relay 1 has been deployed along the route and it providing communications with all other radios. Only Relay 1 has direct contact with the Base Station. The CORE radio was left at HQ.*

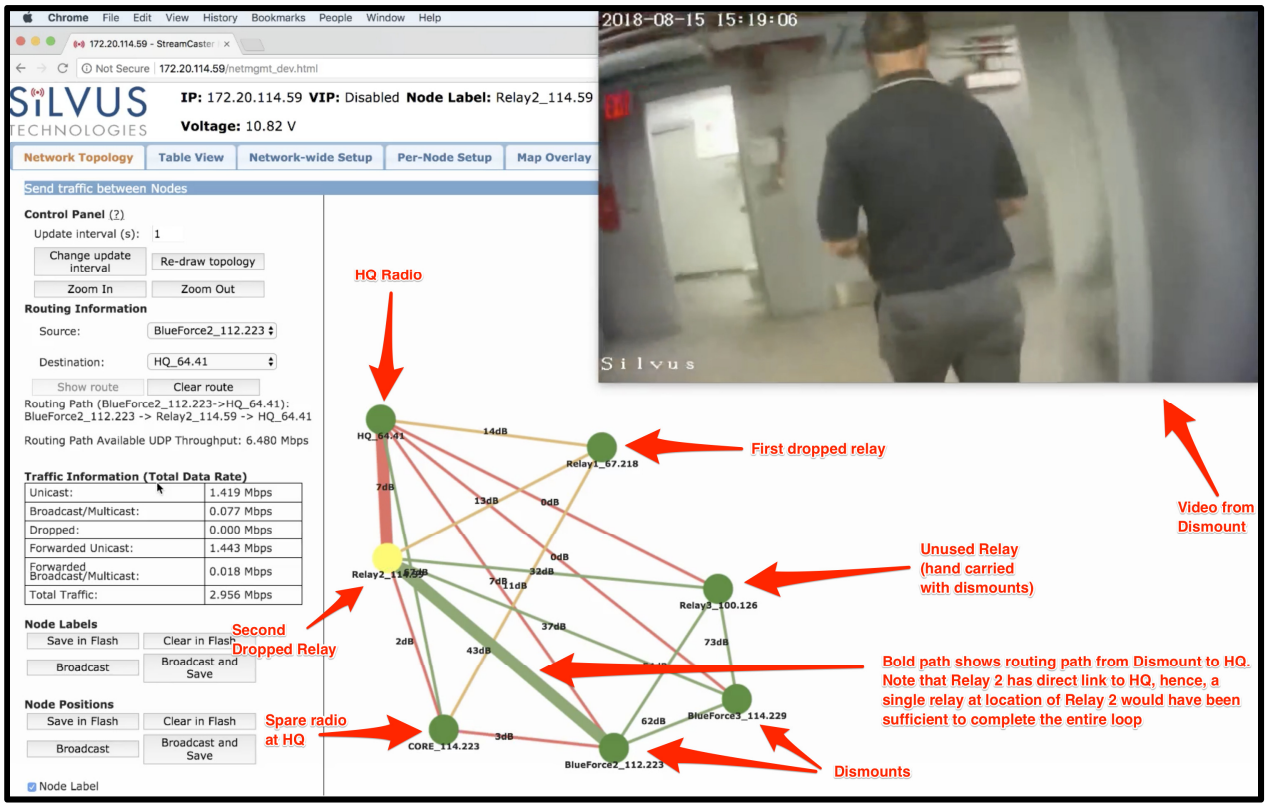



*Figure 10: Near the end of the second tour. Relay 2 is providing a strong, direct link between HQ and all of the dismounted radios. Relay 1 was not necessary and is not being used. Fat lines indicate links being used.*

## NYC Skyscraper – 79th and 69th floors

The NYC Skyscraper 79th and 69th floor venue presented another opportunity for Silvus Technologies to display their mesh network radio capabilities. A tour was conducted from the 79th floor, down 10 flights of stairs, and out onto the 69th floor. The goal was to provide continuous voice, video and data services to dismounted units from HQ on 79th floor down to 'Area of Interest' on 69th floor. The HQ radio and laptops remained on the 79th floor, and three Silvus mesh radios were deployed in the stairway in order to extend the network onto the 69th floor. On the 69th floor, voice, data and video communications from 3 dismount radios, 2 video feeds, and TRX Systems NEON® boot tracking units were maintained with the HQ radio 10 floors above.

Figure 11 shows one of the relay radios being placed in the stairway.

*Figure 11: Silvus mesh radio placed in the stairway between the 79th and 69th floors of NYC Skyscraper.*

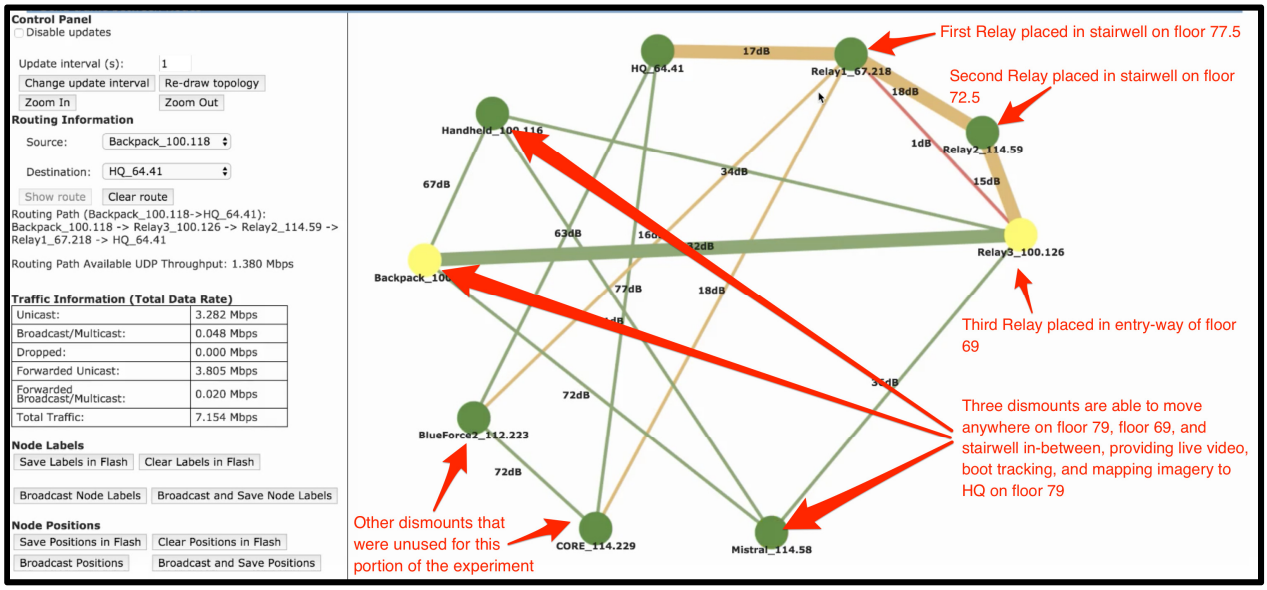



*Figure 12: Radios placed in the stairwell near the 77th, 72nd, and 69th floors provided the capability to transmit video, voice and data from anywhere on the 69th to the HQ laptop on the 79th floor.*