COLORADO

Center of Excellence for Advanced Technology Aerial Firefighting

Department of Public Safety

Rapidly Deployable Data Network Report

CoE-19-003.1

Purpose

Many of the research and development projects at the Center of Excellence for Advanced Technology Aerial Firefighting (CoE), from situational awareness and mobile mapping apps to unmanned aerial system operations, require Internet or local data connectivity to function. While this connectivity is easily available from cellular and commercial Internet providers in urban and suburban areas, in rural and wilderness areas where many public safety incidents in Colorado occur, there is frequently no connectivity from commercial providers.

Many small businesses work to solve these problems for homes and businesses in rural areas by establishing wireless Internet service providers (WISPs). WISPs use radio links to connect rural homes and businesses to the Internet by way of fixed radio towers. The CoE purchased WISP radio equipment and tested it to determine if this technology could be deployed on public safety incidents where data connectivity is lacking. This testing sought to determine if the equipment could be deployed quickly on a temporary basis, while still providing reliable connectivity.

Development Summary

The CoE selected radio and video equipment from Ubiquiti Networks to develop a rapidly deployable data network. Ubiquiti Networks has been producing wireless networking equipment since 2005 (Ubiquiti) and has since branched into video surveillance and Wi-Fi access points, which are also areas of interest for this project. All radios purchased for this evaluation operate in the 5 GHz unlicensed band, negating the need to secure any permissions or licenses prior to deployment.

With the exception of the NVR (network video recorder) video server, all equipment in Table 1 is capable of being powered either by AC or by the SolarPoint system for off-grid use. The CoE built two solar power setups for this project, each consisting of a solar panel, battery, and SolarPoint controller.

Three use cases were identified for this technology. The first use case was to extend Internet connectivity into a fixed area, such as an Incident Command post, spike camp, helibase, or other incident location where an Internet connection might be absent but desired. The second use case was to provide video surveillance of an area of interest over a long duration, such as a wildland fire as viewed from a nearby mountaintop. The third use case was to adapt the radio technology, which is intended by the manufacturer to be used at fixed locations, for mobile use; specifically, to use the radios to communicate with vehicles and aircraft in motion, primarily to extend Internet connectivity to the vehicles.

Table 1—Equipment Evaluated as Part of Pilot Project

Product	Intended Purpose
Rocket Prism AC	Long-distance radio for creating point-to-point links, serving multiple field sites, and testing mobile networks
Power Beam AC	Medium-distance radio for deployment at field sites or in point-to-point links
Bullet AC	Short-distance, lightweight radio for testing of aerial and mobile networks
SunMAX SolarPoint	All-in-one solar solution that handles solar panels, battery charging, and power over Ethernet for radios and cameras
UniFi NVR	Network video recorder that manages video cameras, records video, and serves video streams over the Internet
UniFi G3 Pro	Video camera with 4x optical zoom and infrared capability
UniFi Mesh	Wi-Fi access point with outdoor ruggedization, power over Ethernet, and mesh networking with other Wi-Fi access points
Sierra Wireless RV50	LTE modem capable of being powered off the SolarPoint

The CoE's test system was designed to either extend Internet connectivity from a fixed site, such as a public building or fire station that already has Internet access, or to extend Internet connectivity from an area that has cellular Internet service. CoE staff believed that extending connectivity from an area with cellular service, rather than from a fixed site, would allow for the system to make shorter wireless hops, which would in turn improve data speeds and the reliability of the system. Accordingly, the CoE purchased a Sierra Wireless RV50 modem, which uses dual SIM cards to access cellular data service from both Verizon and AT&T FirstNet. The Sierra Wireless modem is advertised as consuming 1 watt of power, making it suitable for integration into the solar power system.

After the equipment was purchased, the CoE first conducted a test deployment in the vicinity of Rifle, Colorado. This deployment sought to (1) make two wireless hops to establish video surveillance of a mountainous area south of the CoE office, and (2) extend Internet connectivity to a rural area that had marginal commercial cellular service. Two of the three nodes in the test network were to be powered by the SolarPoint system; the ability of this system to provide reliable power to the nodes was of interest to the CoE.

Figure 1—Mountaintop Radio Site During Test Deployment

The test deployment was successful and provided valuable lessons learned. Initially, two of the three hops in the network were deployed with omnidirectional antennas, with the third hop deployed using a highly directional dish antenna. The CoE found that the hop with a directional antenna on one end of the link performed much better than the hop with two omnidirectional antennas, even though the link distance was less than one-third the length of the link that included the directional antenna. Once the short hop was modified to include a directional antenna on one-half of the link, the system's performance improved and the system was then able to provide Internet connectivity to the remote area and to stream a video feed from the remote mountaintop.

During the test deployment, the system was able to sustain a 5 Mbps Internet connection. Initially, this appeared to be a disappointing result, as the Internet connection at the CoE office is capable of 200 Mbps links. However, the mountaintop site was not visible from the office, so the CoE used Ubiquiti mesh Wi-Fi radios to extend a connection to the office parking lot, from which the mountaintop was visible. This mesh Wi-Fi link was found to be responsible for slowing the connection to the 5 Mbps figure, whereas the actual long-distance radios were capable of significantly higher speeds.

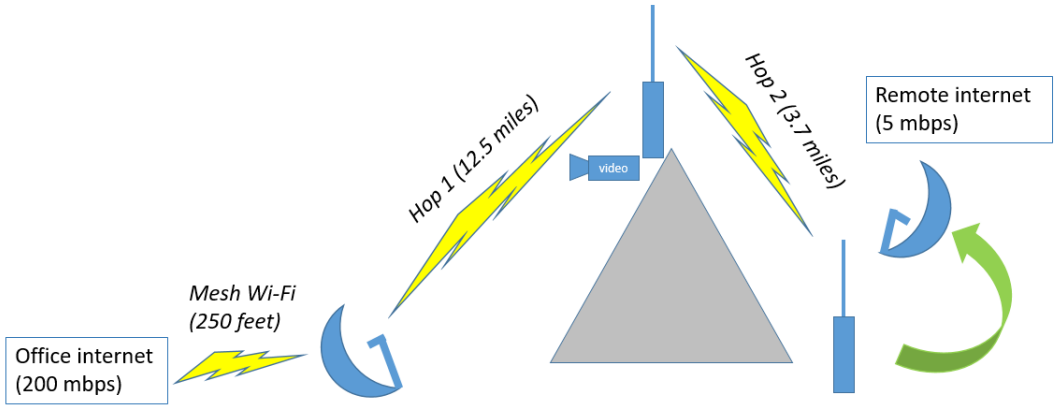

Figure 2—System Schematic During Test Deployment

The CoE was also interested in simultaneously testing the performance of the SolarPoint system. The sites in the office parking lot and on the mountaintop were each powered by 180-watt solar panels, 75 amp hour (AH) batteries, and the SolarPoint charge controller. Both solar systems performed well during the 48-hour test, in spite of a storm during the first day that caused overcast conditions and rain for half the day.

Based on the results of the test deployment, the CoE purchased additional dish-type radios to improve the performance of links to fixed sites, as well as 120-degree sector antennas that can serve or bridge multiple locations but with less loss than omnidirectional antennas. The CoE will continue to experiment with omnidirectional antennas to provide connectivity to mobile vehicles.

Operational Summary

The first opportunity to test this equipment on a public safety incident took the form of a video surveillance mission in response to potential flooding in Lake City, Colorado, and surrounding Hinsdale County. During March 2019, significantly above-normal snowfall occurred throughout Colorado, triggering widespread avalanches. In particular, the northern San Juan Mountains in Southwest Colorado experienced significantly extreme snowfall and, according to the Colorado Avalanche Information Center, the area around Lake City was subjected to the largest avalanches in the state during the winter of 2018–2019. Many of these avalanches occurred in areas that had not slid in living memory and took out entire stands of 200–300-year-old trees (Jennifer).

Approximately 40 avalanches slid in the two river drainages upstream of Lake City: the Lake Fork of the Gunnison River and Henson Creek. Most of these avalanches reached the river bottom, creating dams composed of hardened snow, mature trees, and boulders. By late April 2019, the two rivers had seeped through the avalanches and resumed flowing, but concern was high that runoff from snowmelt could

overwhelm the natural dams and trigger a flood of water and debris that could impact Lake City. On May 6, 2019, the governor declared a State of Emergency in Lake City, thus activating a State response (DHSEM).

By mid-June 2019, mitigation activities and sandbagging had been completed around Lake City and the rivers crested with minimal flooding noted. However, several avalanches were still damming the rivers and water was flowing through the slides, which resulted in uncertainty regarding how the slides would change over time and if they could obstruct the flow of water later in the year.

Figure 3—Treasure Mountain Slide

During the incident, the river of greatest concern was Henson Creek. Its channel is narrow and it empties directly into downtown Lake City before joining the Lake Fork. Two stream gauges were installed on Henson Creek during 2019, one in town and one 4 miles upstream of town. However, these gauges rely on satellite communications with several minutes of latency to provide information to weather forecast offices and to the U.S. Geological Survey WaterWatch website, limiting their utility to provide real-time warnings of sudden changes in Henson Creek. The U.S. Forest Service brought a camera system to Lake City during the response with the intent of providing a video feed of the river, but due to a lack of cellular reception in the canyons above Lake City they were unable to deploy this system.

The lack of real-time remote observation of Henson Creek was of concern to authorities and necessitated frequent in-person visits up the canyon to inspect avalanche slides for change. The Hinsdale County Sheriff's Office is the only paid-position public safety agency in Hinsdale County and employs the Sheriff and three deputies to cover an 1,123-square-mile county (Hinsdale). To relieve the need to physically check the canyon, the CoE offered to deploy the Ubiquiti system in a video monitoring configuration. Using the Ubiquiti AirLink planning tool, the CoE estimated that it would be possible to monitor the Treasure Mountain Slide where it intersects Henson Creek via live video feed. While this location had zero commercial cellular service, it did have a clear line of sight to the Station Eleven

Figure 4—Ubiquiti AirLink Estimate of Coverage from Station Eleven Mountain

mountain, which in turn also had line of sight to the Sheriff's Office in Lake City. The CoE planned to deploy a radio on the summit of Station Eleven, which would act as a repeater to send video footage from the creek to the Sheriff's Office.

CoE personnel, with the assistance of firefighters from the Division of Fire Prevention and Control's Montrose crew, carried out the installation of the Ubiquiti system in Lake City on June 26, 2019. Initially, they deployed a RocketPrism radio with an omnidirectional antenna at the Sheriff's Office and linked it to a router and the NVR video server. The NVR was configured to allow the Sheriff and staff to access the camera feeds and recordings over the local data network at the Sheriff's Office. The NVR was also configured to stream videos over the Internet to remote viewers using either a website or mobile apps.

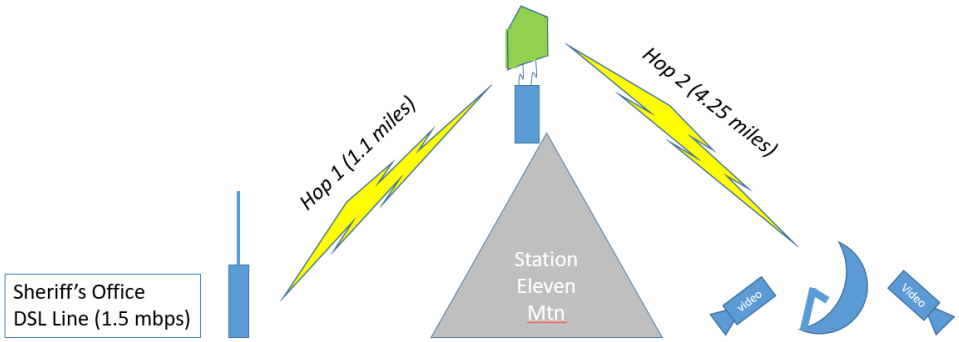

Figure 5—System Schematic During Lake City Deployment

The crew then installed the node at the Treasure Mountain Slide on Henson Creek. This site lacks facilities, so the crew deployed a solar power setup consisting of a 180-watt solar panel, a 75-AH deep cycle battery, and Ubiquiti SolarPoint to charge the batteries and distribute power to the radio and cameras. The crew initially attempted to set up three cameras: one looking downstream at the bulk of the avalanche slide, one looking upstream on Henson Creek, and one looking directly at the pool that had formed upstream of the avalanche. However, one of the cameras—a UniFi G3 Pro—experienced a hardware failure, so the crew ultimately set up two cameras: one looking downstream and one looking at the pool.

At the Henson Creek site, a PowerBeam was used to link to Station Eleven mountain. The crew stripped several limbs from a spruce tree at the site and attached the radio directly to the tree. The summit of Station Eleven mountain was clearly visible when looking down the canyon and the PowerBeam was manually aimed in that direction. Both cameras were attached to trees and were connected to the SolarPoint by Ethernet cables. The PowerBeam radio was also connected by Ethernet to the SolarPoint controller.

Finally, the Station Eleven site was deployed to complete the link. A landowner granted the crew access across private property to reach the summit and the crew erected the radio using a tripod that was staked to T-posts that had been driven into the ground. A solar setup was deployed at this location as well, and when powered up was able to establish a link to both the Sheriff's Office and the Henson Creek Site.

Figure 6—Camera Secured to Treelimb

Figure 7—Equipment at Henson Creek

The Ubiquiti system operated for 71 days and transmitted approximately 2.5 terabytes of video data to the Sheriff's Office. The NVR video server was set up to constantly record the pool behind the Treasure Mountain Slide and to record the avalanche debris field when motion was detected. The CoE experimented with an alert function that notifies users through the mobile app when motion is detected by the cameras. This function can be tuned to monitor certain areas in the video frame and the amount of motion required to set off an alert can be adjusted as well. The CoE experimented with adjusting these parameters, but was unable to arrive at a setup that reliably alerted when genuine activity occurred. This was primarily due to the placement of the cameras on trees, which resulted in the field of view swaying when the trees encountered stiff winds. The alerting function was eventually turned off on the apps, but recordings still took place to document any motion detected by the cameras.

Figure 8—Motion Detection Area for Pool Camera

The NVR video server was able to reliably deliver video products to employees on the local data network at the Sheriff's Office. The Sheriff and staff were able to view live video, zoom the cameras in and out, and access recordings stored on the server. CoE personnel also had a limited ability to view video products over the Internet. Ubiquiti offers a free service that connects the NVR to mobile apps and a website, but in this case the connection required usage of the Sheriff's Office DSL line, which is the only option for broadband Internet in Lake City and has very limited capacity. The CoE was anecdotally informed that on busy summer weekends when tourism peaks, all Internet connections in town slow to the point of being unusable.

Figure 9—Equipment at Station Eleven Mtn

As a result, video was intermittently available to remote personnel and was most reliable during weekdays and early in the morning on weekends. Aside from the video, CoE personnel were also able to remotely view the status of the radio network and SolarPoint controllers using the Ubiquiti Network Management System (UNMS). UNMS securely connects the Ubiquiti radios and SolarPoints to a server operated in Google Cloud by the CoE, which can be accessed via a webpage or mobile app. CoE personnel were able to monitor the signal strength and amount of data moving through each radio. UNMS also allowed personnel to view the voltage of batteries, the watts of power

being collected by the solar panels, and the watts of power being used by radios and cameras. While the UNMS connections would occasionally time out (again, likely due to limited capacity on the DSL line), they were more reliable than the video streams and allowed CoE personnel to ensure that the network was working.

On September 4, 2019, CoE personnel decommissioned the network and retrieved the equipment from Lake City. By this point, Henson Creek was much lower than in June and the threat of rapid flooding had significantly diminished. Amazingly, the Treasure Mountain Slide debris pile was still intact in September, with hardened snow still covering the creek. Aside from the camera that initially experienced a hardware failure, all other equipment performed without issue and was quickly rehabbed and made available for other deployments.

Figure 10—Camera's View of Slide on July 8th

Figure 11—Camera's View of Slide on September 10th

Conclusion

During the summer of 2019, the CoE built and deployed a cache of Ubiquiti radios for incident support. These radios were found to be capable of extending an Internet connection and were successfully used on an incident to conduct video surveillance of an avalanche-created debris field. Two radio nodes powered by solar panels operated with zero interruptions for 71 days and streamed 2.5 terabytes of data across two radio hops. The CoE will continue to evaluate use cases for this technology and will conduct further deployments on public safety incidents to enhance the connectivity and situational awareness of first responders.

Works Cited

- **“**Company: Board of Directors.” *Ubiquiti*. http://ir.ui.com/company/board-of-directors
- Jennifer from Silverworld. “County, State Agencies Ponder Flood Potential.” *Lake City Silver World*. May 3, 2019. http://lakecitysilverworld.com/SWN16/2019/05/03/county-state-agencies-ponder-flood-potential/
- “Colorado State Emergency Operations Center Transitions to Level Two Operations in Support of Hinsdale County.” *Colorado Division of Homeland Security and Emergency Management*. May 6, 2019. http://www.coemergency.com/2019/05/colorado-state-emergency-operations.html
- “Hinsdale County, Colorado Est. 1874.” *Hinsdale County. https://www.colorado.gov/hinsdalecounty*