Control Center Viewing of UAS-based Real-Time Sensor and Video Measurements at an Electric Utility Facility

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Abstract – *Drones equipped with video cameras, LIDAR and thermal imagers have been demonstrated in industrial and utility settings. In such instances, the images are typically locally stored onboard the drone then retrieved from the image storage media and analyzed. We report on a project involving the transport and display of measurements and thermal and visual video streams into a utility control center. Relying on an integrated multimedia communications network, realtime control center viewing of sensor readings and image streams is achieved. Details of this activity are reported.*

Key Words: *wireless sensors, drones, communications*

1. Introduction

Industrial sites are complex systems and structures with inspection and maintenance procedures required for optimal operation and regulatory compliance. Typically, such activities involve sensors and systems being installed at key locations (assets) within the site augmented by humans performing varying levels of measurements and inspections. As a specific example, consider just the bulk electric power system which in the USA is comprised of more than 200,000 miles of high-voltage transmission lines, thousands of generation plants and millions of digital controls. More than 1,800 entities own and operate portions of the grid system, with thousands more involved in the operation of distribution networks across North America. The interconnected and interdependent nature of the bulk power system requires a consistent and systematic application of measuring, monitoring and risk mitigation across the entire grid system to be truly effective. In many instances a question arises regarding the potential use of unmanned aerial systems (UAS) for conducting some of the required measurements particularly in locations where it may be more difficult for a human to perform the measurement.

The use of drones for sensing applications is certainly not new for remotely piloted aerial vehicles have been used, primarily by military forces, since the Second World War. Recent technological advancements in microprocessor computing power, miniaturization of sensors, and purpose-built software have enabled UAS technology to establish a significant new niche in the evolution of aviation.

Alternatively labelled unmanned aircraft systems, unmanned aerial vehicles, or simply drones, small UASs (sUASs) are becoming readily accessible for commercial, governmental, and private use across a myriad of far-ranging applications [1,2].

While using drones for vegetation management has been demonstrated and is now commercially available for utilities to use as a service [3], our efforts involved conducting drone-based sensing with a real-time data and video transport from the drone to the demonstration utility's control center.

2. Installation, Location and Components Details

The location of the sensor-laden drone and the utility control center – separated by 7.44km- is illustrated in Figure 1.

Fig. 1. Training site (where drones are flown) to Control Center (viewing) is approximately 7.44km (urban setting).

As with any sensor and/or control system, a communications fabric is necessary for the transport of the signals and measurements. In the case of this specific technology demonstration, we relied on an optical fiber backbone core network that the utility has in place. This 1-10 Gbps fiber network provided an exceptionally high speed transport with endpoints at the control center and training site. A layered communication system, illustrated in Figure 2, incorporating wireless, wired, and fiber optic

communications was designed and implemented. The network is Internet Protocol (IP)-based with all of the drone's sensors and video cameras and the communications signalling equipment IP addressable. A Virtual Local Area Network (VLAN) was established specifically for this demonstration allowing for segmented security and delineation of the drone information "traffic" from other communications traffic on the network. The various communications layers and their specific uses are identified in Figure 2. Of particular note is that a cellular connection was used for Virtual Private Network (VPN) remote access into the VLAN then ported to the utility's SCADA and video applications thereby allowing us to see the video links and sensor measurement readings at the field site while being simultaneously displayed on the control center's display wall.

Fig. 2. Layered communications architecture for transport of signals and measurements from drone-mounted sensors to utility control center.

A commercially available drone, DJI Phantom II, was selected as the sensor transport platform. Control of the Phantom used its standard controller and 2.4 GHz wireless communication signalling. The Phantom's stock video camera was removed allowing a custom sensor pod to be attached to the drone using the camera's mounting points. Parameters to be measured included: 3-axis accelerometers, gyroscopes, temperature, humidity, magnetic field, and barometric pressure. The sensors, GPS receiver and thermal and visual video cameras were attached to a Raspberry Pi 2. An IP-addressable 900 MHz wireless (WiFi) transceiver, Microtek Metal 9, with accompanying omnidirectional 0dBi gain antenna were used to transport the signals to/from the drone's sensor pod to a companion ground-based WiFi transceiver. An ethernet switch and a 2600mAh battery were also placed into the sensor pod. All devices operated at 5 Volts; the battery capacity was chosen based on the Phantom's 22 minute flight time (using its standard battery and a 1.1 kilogram sensor pod weight).

The sensor pod design – which was 3d printed – is shown in the exploded views of Figure 3.

Fig. 3. Sensor pod design (3d-printed).

A 900 MHz WiFi transceiver was configured as an Access Point, mounted inside an enclosure which was rack mounted inside a communications cabinet with its radio output connected to a 3dBi gain omnidirectional antenna. A fiber optic to wired Ethernet media convertor along with an Ethernet switch was mounted inside the enclosure. A dynamic host controlled protocol (DHCP) server located at the utility control center provided the IP addresses for all devices (in the enclosure and in the drone's sensor pod).

The information flow – or path – therefore consisted of command and control of the drone via its handheld controller (with radio signals in the 2400 MHz frequency band). Sensor readings (signals) and thermal and visual video feeds were broadcast from the drone to the communications enclosure on the 900 MHz WiFi radio channel. These signals and video feeds then went from the enclosure-mounted 900 MHz radio to the Ethernet switch to the media converter then into the utility's fiber optic core network for transport to the control center. Aspects of the in-field deployment and testing of the communications system are shown in Figure 4.

Fig. 4. Installation of the communications infrastructure at the training site.

3. Operation

The drone with sensor pod was flown at the utility's training site (of Figure 1). As shown in Figure 5, there were numerous power lines present at this site with a number of pole-mounted electrical transformers. Measurements from the drone's sensor pod were transmitted through the communications network and injected into the utility's SCADA system database.

Additional commercially available drones – equipped with their associated video cameras were flown above the training site (typically at 100m elevation). This situation is shown in Figure 6 – a photo taken from ground level looking up at the drone with sensor pod. Another drone – at a higher elevation (~65m) – is seen in the photo.

Fig. 5. Drones navigating electric grid components.

Fig. 6. Drones at different elevations over the site.

A diagram depicting the communications network and information-flow path is presented as Figure 7.
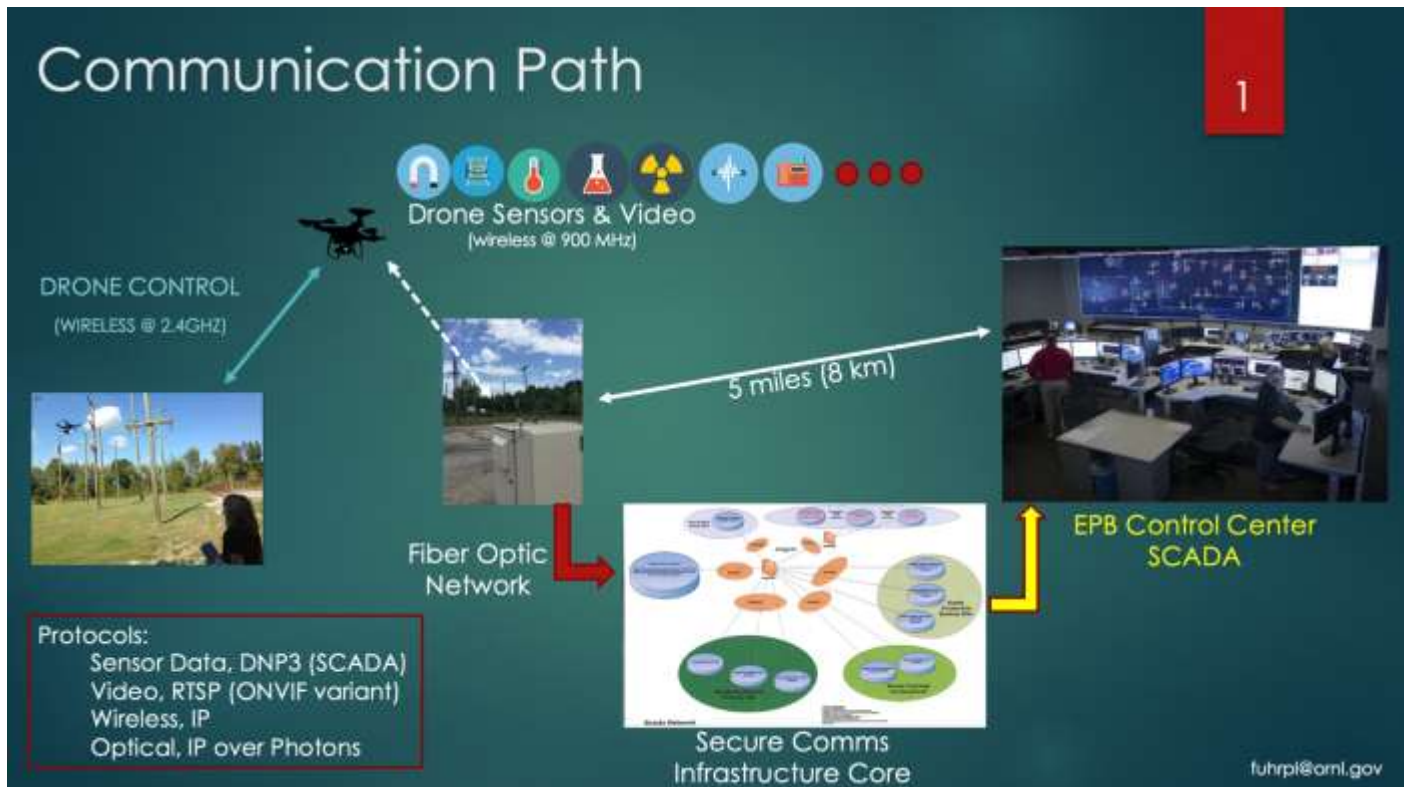
Fig. 7. Communication networks used for transport of control and measurement signals.

A photograph of the drone video feeds (thermal and visual) as they were being viewed in the utility control center is presented as Figure 8..

Fig. 8. Photograph of control center screens with thermal and visual drone-based video feeds being displayed.

4. Summary

As demonstrated, drones may serve as a transport means to take sensors to a location of importance. While local on-drone storage of sensor and camera readings and recordings is highly useful, the notion of real time viewing of a drone's sensors and camera readings and imagery occurring at a control center (kilometres away) may prove highly beneficial. A system incorporating levels of communications technologies coupled with a commercially available drone and customized sensors and an associated sensor pod (3d printed package) has been designed and implemented. Of particular note is that within minutes of the utility control center engineers seeing the drone's realtime video feeds, they began requesting control center-based remote control of the drones – an activity that is currently not permitted in the USA.

5. References

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