Airborne Traffic Surveillance Systems – Video Surveillance of Highway Traffic

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ABSTRACT

Timely information about highway traffic conditions is very important for the Department of Transportation (DOT) and other relevant agencies. Such live information would be very important when traffic incidents or accidents occur. An aerial view is the best for traffic situations, particularly over highways. Unmanned aircraft equipped with monitoring video cameras and/or other sensors may be able to deliver the necessary information through video images with relatively low operational costs and risks to human life. ATSS (Airborne Traffic Surveillance System), a project funded by the Florida Department of Transportation, attempts to make this vision a reality. This paper describes how the University of Florida research team implemented a system for ATSS from ground up, using unmanned aerial vehicles, digital video encoding, and transmission of data and multimedia video streams over FDOT's microwave IP networks.

Categories and Subject Descriptors

J.1 [**Computer Applications**]: Administrative Data Processing – *government, law, military.*

General Terms

Algorithms, Management, Measurement, Design, Reliability, Security, Legal Aspect.

Keywords

Traffic, video surveillance, transportation, roadways, highways, video switching, unmanned aerial vehicle, multimedia streaming.

1. TRAFFIC MONITORING AND UAVS

The Department of Transportation (DOT) and many other agencies have been interested in real-time surveillance of highway traffic. Other than statistics that will enable the DOT to improve the highways, the more critical objective for the use of traffic surveillance would be to monitor traffic crisis, especially to provide emergency services.

Current traffic surveillance depends on magnetic loop detectors underneath highways [1]. These loop detectors only serve the purpose of counting traffic. Advanced video monitoring systems and research techniques, such as IBM's Real-time Video Traffic Surveillance [2] and UC Berkeley's Machine Vision Based Traffic Surveillance [3] are being developed address real-time surveillance of traffic and analysis of traffic over highways.

However, actually getting the video transmitted to the office that handles the surveillance is the problem. This issue can be addressed by using cameras mounted on towers along the highways, or through manned or unmanned aircraft. The problem with having cameras mounted on highways is the cost and time involved in setting up such equipment. The cost would be particularly high for rural deployments. The problem with manned aircraft is that they would be too expensive. In this case, Unmanned Aerial Vehicles (UAVs) are a better choice.

The use of UAVs began to a certain extent in the early part of the 20th century. In World War I and II, they were used in prototype form. In the 1960s to 1980s, more research was done on UAV development by United States and Israeli forces. DARPA (Defense Advanced Research Projects Agency) has in recent times initiated projects to increase use of UAVs in military applications, including developing unified, networked teams of aircraft systems [4].

Since the 1990s, UAVs, once used almost exclusively in military applications, have been finding commonplace usage in civilian applications, such as traffic monitoring. In March 2004, New Mexico State University demonstrated the uses of UAVs in civilian applications. One of their projects with the US Coast Guard involved seeing whether fishermen were fishing in legal areas [5]. In April 2004, television station KVOA, Tucson reported that the US Border Patrol was starting to use two UAVs to patrol the Arizona/Mexico border [6]. A report in May 2004 by USA Today focused on use of UAVs in traffic management in Ohio [7]. In the same month, BBC reported on a very interesting use of UAVs in the United Kingdom – to create a detailed record of stained glass windows at a historic Gothic cathedral [8].

In Spain, a project called COMETS is being conducted by the University of Seville and IST (Spain's traffic authority) to improve the capabilities of UAVs in aerial missions like natural disaster remediation, traffic surveillance and law enforcement [9].

More information about the increasing use of UAVs in military and civilian applications can be found at [10].

2. INTEREST IN TRAFFIC SURVEILLANCE

Traffic surveillance has been important to the Department of Transportation. Several options were considered for the necessity of developing a system that would enable the next generation of traffic surveillance, but unfortunately, most of them were not practical.

For example, as discussed earlier, the methods of using cameras and manual aircraft would be too expensive and time-consuming. In this situation, the Florida Department of Transportation (FDOT) decided to explore the possibility of using unmanned aerial vehicles in traffic surveillance. A proof-of-concept test was organized by the FDOT, and the University of Florida (UFL) was chosen as the primary contractor for conducting this project.

The primary interest of this project to the FDOT is monitoring remote and rural areas of the state. Also, while the viability of using UAVs is also important, the Airborne Traffic Surveillance System (ATSS) proof-of-concept project aims to evaluate the feasibility of the wireless communications systems, as well as switching of the video [11]. This project, among others, will also serve as case-study for the use of UAVs in remote sensing and multimodal transportation, which is of interest to the DOT and NASA [12].

3. CONSIDERATIONS AND POTENTIAL PROBLEMS

The primary aim of this study was to investigate the integration of ATSS into FDOT's existing microwave network, Traffic Management Centers (TMCs) and the State Emergency Operations Center (SEOC). A key element of this study is telecommunications, since the system must be capable of exchanging information in the form of audio, video, data and control signals. A UAV uses sensors for digital video, infrared cameras and Road Weather Information Systems (RWIS), all of which may need to be transmitted across the network as required.

Several issues had to be addressed in this study, and some of them are listed in brief below. The full list and details are available in [13]. Among the issues that have to be addressed are physical layer issues (dealing with the wireless and microwave links and bandwidth), communications issues (security of data, reliability, integration with other aspects of the system), network layer issues (configuration, signaling, mobility) and most importantly, institutional issues (approval from FAA and other organizations). The last one is of primary importance, as it is critical to get approval from various regulatory government agencies, convincing them of the safety of the flight.

Some of the key issues that were addressed in this study are summarized below.

Physical Layer Issues

- Bandwidth requirement
- Current network ground base stations and existing FDOT microwave towers
- Communications security

Communications Properties Issues

- Ability to transmit video, data, and control signals in a reliable/failsafe manner
- Asymmetric data communications (aircraft-to-tower requires much higher bandwidths)
- Integration with ground sensors
- Interaction with models for forecasting

Communications Network Layer Issues

- Mobility management (location update and handoff)
- Network configuration and reconfiguration

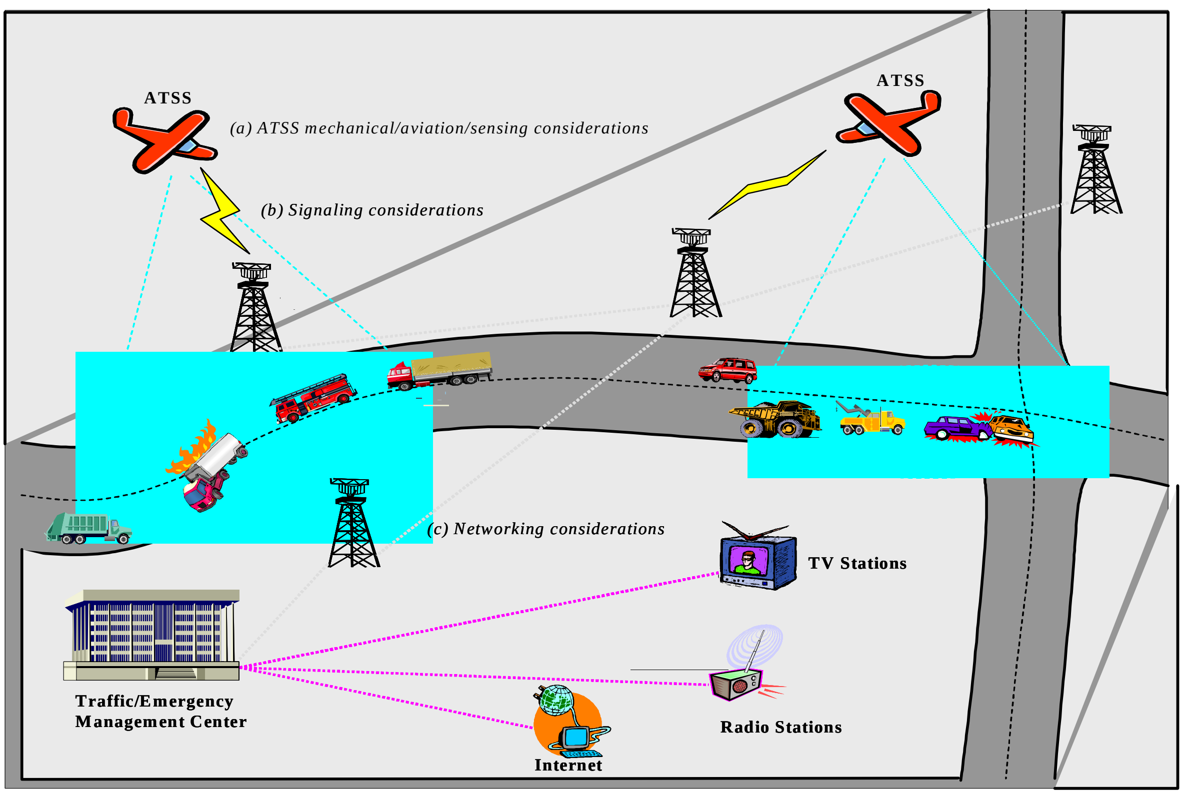

Figure 1: Overview of the ATSS project

- Data and control signaling between TMCs and network nodes (towers and ATSS)

Institutional Issues

- FAA and FCC regulations
- Spectrum allocation (unlicensed versus licensed)
- Data security
- Public and political acceptability.

4. IMPLEMENTING ATSS

The first part of our program was to select a vendor who would provide us with the Unmanned Aerial Vehicle, as well the services to allow us to control the UAV on its flight path.

Six UAV vendors were short listed in the first round. After reviewing the vendors by comparing the features and characteristics of the UAVs as well as flight experience, the UFL research team, in conjunction with FDOT project team, chose Adroit Systems, along with their partner, Aerosonde Communications, to be the UAV vendor. The choice was motivated mostly by flight experience.

Once the UAV vendor was selected, it was necessary to obtain the necessary telecommunications equipment that would be needed to facilitate proper communications and networking. For this, antennas capable of receiving the wireless video signal transmitted by the UAV were purchased. Also, other necessary communications equipment needed for the project included transmission lines capable of relaying the signal from the antenna on top of the tower to the ground station; transient voltage surge suppressors to prevent any spikes and other unwanted voltage signals; and a video receiver that was capable of converting the UAV video signals to standard PAL/NTSC format were also purchased.

Our proof-of-concept test would involve the UAV flying over a small segment of the highway between two of FDOT's microwave towers, at Lake City and White Springs, and capturing video as it flies along the highway [13]. This is shown in figure 2.

The UAV would transmit video of the highway throughout its journey and the video would be received and encoded at each of the two towers. Along with this, the signal strength of the video signal would also be digitally encoded, as it would be necessary

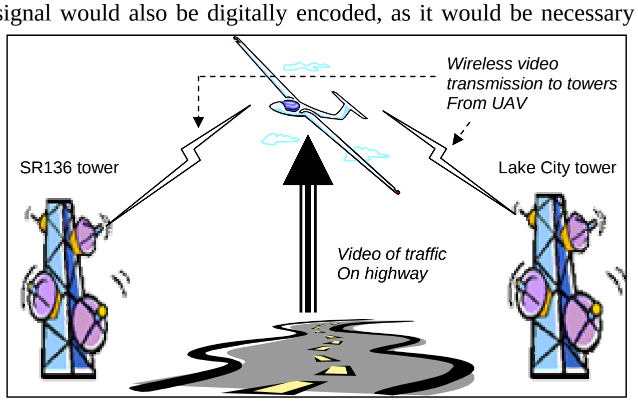

Figure 2: UAV Captures Video on Highway

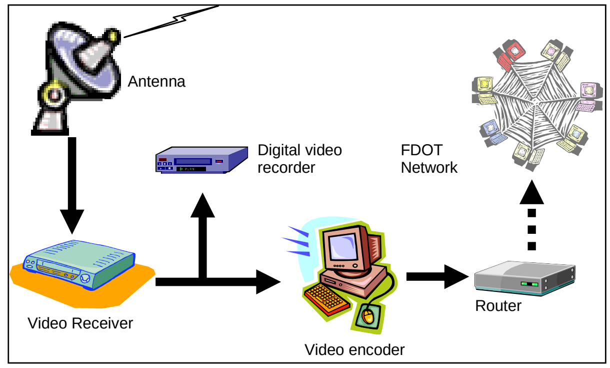

Figure 3: Video Encoding and Recording at the Microwave Tower

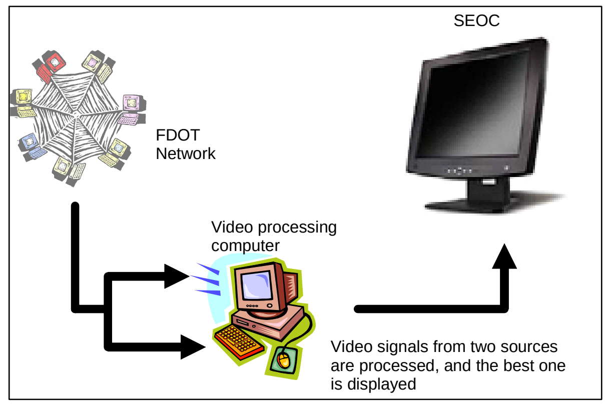

Figure 4: Video Decoding, Switching and Display at the SEOC

for determining the switching of the signals at the State Emergency Operations Center (SEOC), where the video of highway traffic would be shown. The digitally encoded video signals and signal strength data would also be transmitted over FDOT's microwave network. This is shown in figure 3.

Three computers, two of which would serve as video encoders, were set up at the microwave towers. The third computer, at the SEOC, would receive the two video signals and signal strength data over the network and switch the video signals based on the whichever signal strength is greater. This is shown in figure 4.

The UAV captures video of traffic on the highway using its video camera. It also captures any other required data, such as weather information, using its other sensors. Transmission of the video and other data is done wirelessly using a 2.4 GHz wireless link.

This information is received by the antenna that is installed at both the microwave towers. This signal is relayed to the ground station using a transmission line. At the ground station, the signal is first passed to a transient voltage surge suppressor, which guards against voltage fluctuations, and then to the video receiver unit. The video receiver converts the wireless analog video signal into PAL/NTSC format. This video signal in PAL/NTSC format is fed into the encoding computer, which digitally encodes the video and transmits it over FDOT's microwave IP network. The encoding computer also digitally encodes the strength of the video signal and sends it through the network.

At the SEOC, the decoding computer receives both the video signals from the two towers, as well as the signal strength data. Based on the signal strengths as well as a designated handoff algorithm, switching is performed to show the video that has more signal strength, and hence, will be clearer.

In order to make this project a success, software had to developed for specialized applications. While encoding of video can be done using Microsoft's free Windows Media Encoder [14], software was needed to (1) read in the signal strength data, and (2) switch video at the SEOC based on the signal strength.

For this purpose, the following software was developed by the University of Florida research team to fulfill the two roles:

SignalReader: This software reads the signal strength from the video receiver. The signal strength is provided by the video receiver as a voltage, and this voltage is read using RS-232 serial port communication from a digital multimeter that supports serial port connectivity. SignalReader polls the serial port to obtain the signal strength as a voltage, and uses an internal algorithm to parse the RS-232 signals in the correct format. Rigorous study and coding was performed by the UF project team to implement RS-232 interfacing correctly on the 'SignalReader' software, so that it could accurately decode the voltage signals from the digital voltmeter. SignalReader further transmits the signal strength value over the microwave IP network using TCP client sockets. It also displays the value of the signal and the fluctuation on a graph on the encoding computer.

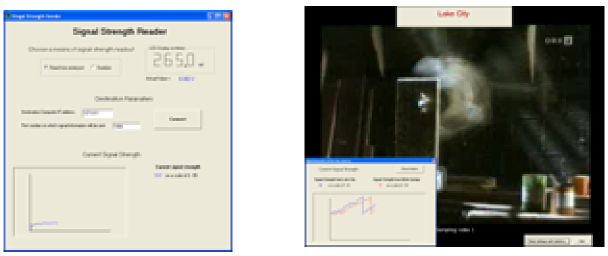

Figure 5: 'SignalReader' and 'VideoProcessor' software

VideoProcessor: This software receives the video signals from the two microwave towers. The two video signals are encoded in Windows Media format, and VideoProcessor uses an embedded multimedia player to play the streaming video. The signal strength is received from the two encoding computers using TCP server sockets (ports 1900 and 1950 are used by default, but these values can be changed). The video is switched seamlessly based on the signal strength. VideoProcessor switches the video signal based on a handoff algorithm built into the program.

Screenshots of the software are shown in figure 5. The software was developed using Microsoft Visual Studio 6. More information as well as details about how the applications work are provided in [15].

5. REAL WORLD TESTS

In December 2003 and January 2004, simulation tests were performed using the communications equipment, FDOT's microwave IP network and UFL-developed software to demonstrate the feasibility of the project. These initial tests aimed mostly at testing the connectivity, network issues, video streaming and signal strength issues.

The UF research team and FDOT project team decided that a demonstration of video encoding, streaming and switching capabilities of the installed ground network was needed. This was needed to be performed in order to verify that the system was ready and operational for the actual UAV vehicle. April 20th, 2004 was chosen as a suitable date for the test.

For this test, it was needed to ascertain whether, in addition to the networking and video streaming that were verified in the initial tests, the software could support switching video based on the signal strengths of the two video signals from the two microwave towers, and also switch video manually.

In order to verify that the software worked seamlessly, the software was tested at UFL research labs for functionality by connecting the three computers (that would be used in the ATSS project for video encoding and decoding) on an exclusive network. The switching and other aspects of the project were verified to work seamlessly.

UF researchers transported the required equipment to the sites and set up the equipment to simulate a full ground simulation. They were met by members of the FDOT project team at all the three sites, Lake City, White Springs and the SEOC. Two computers were set up at the two microwave towers, at Lake City and White Springs respectively, to encode the video from the analog source (a video tape player was used in the simulation) and transmit the video and signal strength data over the IP network. At the State Emergency Operations Center (SEOC), the switching computer was set up to read in the signal strength values and switch the signal based on a predetermined handoff.

In the simulation that followed, it was demonstrated how the video encoder, 'SignalReader' and 'VideoProcessor' could act in tandem and network with each other in order to both play video being transmitted from the two towers, as well as to seamlessly switch between the two signals based on the signal strength signals coming in over the network. It was shown that the software and hardware purchased and set up by the UFL research team demonstrated the feasibility of the ground communications of the system.

6. OBSERVATIONS

The ATSS project is still awaiting further approval from the FAA for flight tests. However, it has been demonstrated by the simulation tests, especially the test in April 2004 that the ATSS project is completely capable of supporting ground communication between the towers and the SEOC, thus bringing the vision of video surveillance of highways one step closer to reality. The tests also demonstrate how the project can be further extended to traffic surveillance over highways all over the United States.

Further research that is being done on UAVs should enable the widespread use and acceptance of UAVs in commercial and civilian applications like traffic surveillance. For instance, a system called Intelligent Aircraft System (IAS) [16] is being worked on at the Queensland University of Technology, Australia, which focuses on providing UAVs with artificial intelligence for mission planning. This would enable applications like ATSS to be brought to the real world much sooner.

7. CONCLUSIONS

This paper provided a brief overview of the ATSS project funded by the FDOT and implemented by the UFL research team. Other than providing details on how video surveillance of state highways can be implemented using unmanned aerial vehicles and the existing microwave network, the paper also describes how the UFL research team developed in-house software that enabled the transmission of signal strengths over the network, and implemented automatic switching of highway traffic video using the signal strengths obtained from the video signal.

We believe that the ATSS project is a ground-breaking project and could revolutionize highway traffic surveillance in the near future. This would enable the Department of Transportation and other emergency services to respond more quickly when accidents occur and for other operations that require urgent feedback.

Some of the documents referenced in this paper are available for download from [17].

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