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# Wireless Handover with Application to Quadcopter Video Streaming over an IP Network

S. Al-Majeed

School of Engineering  
Nazarbayev University  
Astana, Kazakhstan  
salah.almajeed@nu.edu.kz

M. Fleury

School of Comp. Sci. and Electron. Eng.  
University of Essex  
Colchester, U.K.  
fleum@essex.ac.uk

**Abstract**—Monitoring of oilfield well-head installations can be enhanced by Quadcopters equipped with video cameras flying at low altitude. Backhaul of a video stream from a Quadcopter's camera takes place via WiMAX base-stations within the installation. This paper considers a problem that arises: Video stream interruption as a handover occurs between WiMAX base-stations. The paper presents a scheme for hard handover recovery during video streaming to a remote monitoring station. The selective Negative ACKnowledgment (NACK) scheme trades a reduced but acceptable video quality during handover for improved end-to-end latencies compared to unselective NACKs. Both forms of NACK (selective and unselective) promise better video quality (by several dB) than with UDP transport or traditional congestion-controlled streaming, which results in long delays during handovers.

**Keywords**—NACKs; Quadcopter; video streaming; WiMAX; wireless handover

## I. INTRODUCTION

The Quadcopter [1] is a micro airborne vehicle (MAV) with has four rotors, each of which can be independently controlled to guide its flight path. The interest in this paper is in streaming video from a camera that is mounted between two of the rotor-bearing arms of Quadcopters. We intend to take advantage of such a camera to stream video to a remote monitoring station, sending video over an Internet Protocol (IP) network.

In some installations, if there is a well-head leak of high- pressure oil and associated natural gas containing poisonous hydrogen sulphide [2] then a hazardous environment is created requiring remotely controlled robots to be deployed. These robots move on wheels and are equipped with a single robotic arm. Due to their sturdy construction their speed and maneuverability is restricted. Because the robots are manually guided, each component of the robot has its own camera which presents part of a composite view transmitted in real-time to the operator to which the Quadcopter view can be added. However, due to the urgent need to affect a repair and the real-time nature of robot operation, any interruption to the video stream, however brief could be important.

In this application, a number of IEEE 802.16e (mobile WiMAX) [3] base stations (BSs) are placed within the installation in order to backhaul the video stream to a remote monitoring station. If a Quadcopter flies within the installation, it could pass out of range of one BS and into wireless range of another, whereupon a horizontal handover takes place. We assume that the Quadcopter is equipped with H.264/AVC codec for video compression and a WiMAX transceiver for communication to BSs.

This paper proposes a Hard-Handover (HHO) scheme with selective Negative ACKnowledgements (NACKs) to recover lost video during the handover process, as this is preferable to WiMAX video transport directly through UDP transport with no built in response to packet loss, or through an industry-standard congestion controller, TCP-Friendly Rate Control (TFRC) [4], or indeed with un-selective NACKs (which respond to the loss of all video packets). In the selective variety examined, only intra-coded I-frame packets when lost are retransmitted, which has the effect of speeding up video stream recovery after an HHO. I-frames, only employing spatial coding, act as anchor frames, allowing a compressed video frame sequence to be reset, whereas other standard frame types, P- and B-, reference other frames in order to be decoded.

## II. METHODOLOGY

In Fig. 1's simulation scenario, a remote monitoring station (RM) for the Quadcopter, RM, receives a video stream over an IP network. The Quadcopter (QC in Fig. 1) flies between the mobile WiMAX BSs. The QC moves in parallel to the BSs, which are separated by 1.9 km. During this motion a handover occurs at the overlap between the signaling ranges of the BSs. Various sources of congestion exist on the IP network that connects the BS to the RM. These are included in an ns2 simulation to show the effect of other traffic, as the video stream passes over the IP network, with two routers (R) shown. Node A sources to node B constant bit-rate (CBR) data at 1.5 Mbps with packet size 1 kB and sinks a continuous TCP FTP flow sourced at node B. Node B also sources an FTP flow to the BS and CBR data at 1.5 Mbps with packet size 1 kB.

In simulations of the video stream, 35.5 s of the reference Paris video clip were H.264/AVC variable bitrate encoded with Common Intermediate Format @ 30 Hz. Group of Pictures structure was IBBP... with an intra-refresh rate of 15. H.264/AVC slicing was used to restrict the Maximum Transport Unit size to 1 kB.

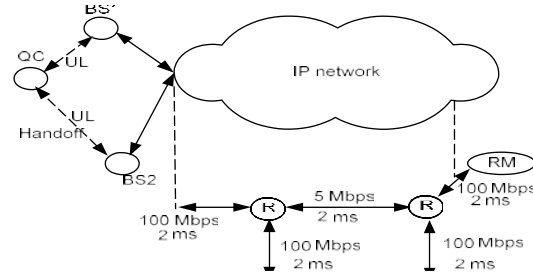


Fig. 1. Video streaming during handover scenario

A Gilbert-Elliott wireless channel model with ‘bursty’ packet losses modeled ‘bursty’ errors resulting from fast fading on the WiMAX wireless channel from the QC to a BS. The probability of remaining in the good state was set to 0.95 and of remaining in the bad state was 0.94, with both states modeled by a Uniform distribution. The packet loss probability in the good state was 0.01 and the bad state probability (PB) was 0.15.

The WiMAX PHYsical-layer settings were: a 5 ms Time Division Duplex frame, 16-QAM  $\frac{1}{2}$  coding rate, guard time 1/16, resulting in a raw downlink data-rate 10.67 Mbps, with an approximate range of 1.0 km. The Quadcopter acts as a mobile subscriber station (MS) flying at a height of approximately 1.2 m. Buffer sizes were set to 50 packets.

### III. EVALUATION

The effects on video quality and latency were assessed by simulation of the horizontal handover period, while streaming the *Paris* sequence as a test. Excessive packet jitter can result in display delays, while excessive packet end-to-end delay, becomes important if the video display is used to control the motion of the Quadcopter.

For naming convenience, the NACK scheme is called broadband video streaming (BVS) in Fig. 2, and when used with selection of I-picture packets, as proposed, BVS-I. Fig. 2 represents a 10 s extract, illustrating the general drop in received throughput during the handover period. TFRC’s throughput is much reduced, because it increases the inter-packet gap when packet loss occurs, even though some packet loss may be due to channel error rather than congestion at the buffers. Immediately after the handover, BVS transport results in a large increase in throughput through re-transmissions. BVS-I has less re-transmissions, whereas UDP simply increases packet transmissions as much as possible as soon as bandwidth becomes available.

From the summary in Table I, without retransmissions by UDP, packet loss approaches 10%. TFRC reduces its sending rate by increasing the inter-packet gap but only by effectively doubling the sending period of the *Paris* sequence. BVS without selective retransmission has better throughput but its latencies are larger, especially the maximum packet delay that can result. However, by reduced retransmission in BVS-I, end-to-end latencies are reduced, thus identifying the selective NACK scheme as a suitable compromise between the greater packet losses of UDP and the delay from unselective NACKs.

BVS-I’s objective video quality at the remote monitoring station were compared for increasing QC speeds. At around 20 mps (45 mph) and above, BVS-I’s video quality becomes ‘poor’ as it drops below 25 dB. At low QC speeds, with shorter error bursts, BVS-I delivers ‘good’ quality video (above 31 dB). Simulation has also shown that at speeds above 45 mps (100 mph), HHO latency grows rapidly.

Received Throughput (xMbps)

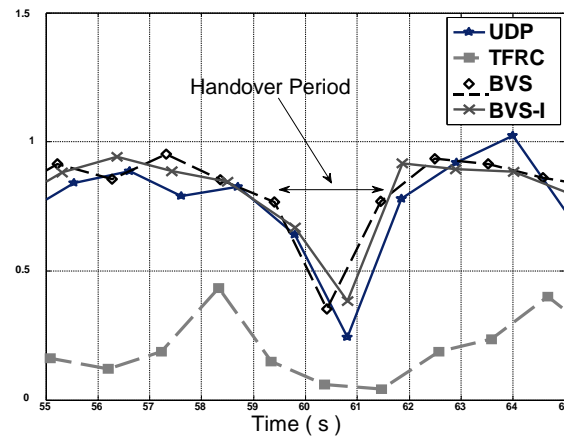


Fig. 2. Received data throughput during a handover for a QC speed of 10 mps with PB = 0.15.

TABLE I. STREAMING PERFORMANCE DURING HANDOVER AT 10 MPS WITH PB = 0.15.

	<i>UDP</i>	<i>TFRC</i>	<i>BVS</i>	<i>BVS-I</i>
Throughput ( kbps)	762.9	371.1	819.2	766.4
Sending period ( s )	35.43	72.97	35.70	37.49
Packet loss ( % )	9.75	7.29	1.69	3.81
Packet jitter ( s )	0.008	0.066	0.007	0.008
Mean packet end-to-end delay ( s )	0.008	0.007	0.015	0.011
Max. packet end-to-end delay ( s )	0.256	0.247	0.631	0.329
Mean PSNR ( dB )	25.29	27.26	34.82	29.05
Standard Deviation of PSNR (dB)	3.28	3.31	3.42	4.91

#### IV. CONCLUSION

Video surveillance of oilfield installations by an MAV Quadcopter is a cost-effective method of improving remote monitoring. Monopole antennas now represent a viable implementation technology for dedicated WiMAX communication. Future work will involve field tests of a Quadcopter surveillance system.

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