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High Utility Video Surveillance System on Public Transport using WiMAX Technology

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Abstract — **Video surveillance on public transport is a useful tool to fight against anti-social behaviour like vandalism, harassment, graffiti and terrorism. Real-time video surveillance on moving public transport faces serious technological challenges mainly due to limited throughput offered by existing communication technologies at high vehicular speeds. Success of real-time video surveillance on public transport heavily depends on future communication technologies like WiMAX. WiMAX has emerged as an exciting technology with promises to offer high throughput and improved quality of services (QoS), key requirements for video surveillance on public transport. WiMAX however, offers limited throughput at high vehicular speeds mainly because of multipath fading that causes high bit error rate at the receiver at vehicular speeds. In our previous works, we showed that it is possible to estimate the bit error rate at the receiver end at various vehicular speeds in WiMAX and accordingly, some proactive measures can be adopted to improve the throughput to some extents. Overall throughput however, may still be insufficient to support the streaming video data from all the cameras mounted on a public transport at high vehicular speeds. In this paper, we propose a new scheme that estimates utility for different cameras and puts some low utility cameras offline and thereby maintains high utility of the video surveillance system when the throughput at high vehicular speeds become insufficient. Simulation results confirm the effectiveness of the proposed scheme.**

Keywords: Video surveillance, vehicular speeds, wireless communication, fading.

I. INTRODUCTION

The upward trend of fuel cost and an increase in environment awareness motivate more and more people to leave their private transports at home and use public transport instead. It is highly likely that there will be a significant rise in public transport users in near future. Passengers' safety and security is an issue of supreme interest to all transport authorities and live video surveillance on public transport can be a powerful tool to the transport authorities to ensure passengers' safety and security. Real-time video surveillance has long been used in stationary environments like airports, bus and train stations with great success to fight against odd events. Video surveillance systems on moving public transports however, are still non real-time. A real-time video surveillance system on moving vehicles encounters serious technological challenges mainly due to the limited throughput offered by the existing communication technologies at high vehicular speeds. In a centrally monitored video surveillance system, real-time video data from multiple video cameras mounted on a mobile transport needs to be uploaded to the base stations (BS) that are connected to a high speed wide area network (WAN). BSs then forward the video data to a central control room where the security experts monitor and interpret the video contents. For a real-time video surveillance system on a moving public transport, wireless communication is the most suitable technology that has so far been dictated by the IEEE 802.11 standards. Almost all mobile video cameras (e.g., videocomm RT mobile systems [1]) available in the market place adhere to the IEEE 802.11 [2-4] standards with a promise to deliver a data rate up to 64 Mbps for a near ideal communication environment where the nodes are fixed. Throughput starts to decrease exponentially with the increase in speed and mobility of nodes [5]. Other video surveillance technologies reported in the literature, are either for static environment [6-8] (e.g., intelligent analysis of CCTV coverage at train stations/airports) or for very low mobility environment [9] (e.g., robot vision in underground mining). To the best our knowledge, there is no suitable technology that can be readily adopted to facilitate video transmissions from a vehicle moving at high vehicular speeds. Success of real-time video surveillance system therefore largely depends on future wireless technologies like WiMAX.

The IEEE 802.16, also known as WiMAX [10-13], has emerged as an exciting wireless technology with a promise to deliver long range coverage, high mobility support, and higher throughput. This holds true mainly for static environments and performance of WiMAX technology is not yet proven in scenarios where the nodes are not fixed and free move at vehicular speeds. Recent studies suggest that while WiMAX has the potential to deliver a data rate up to 75 Mbps for fixed wireless communications, throughput fails drastically for mobile wireless communication, often reaching a data rate less than 1 Mbps when the mobile nodes travel at about 100 km/hr. Many objects surrounding the transmitter and the receiver, act as reflectors of the original radio signal, which create multiple paths that the original signal can traverse, causing the receiver to experience the overlapping of multiple copies of the transmitted signal, each traversing a different path and having differences in attenuation, delay and phase shift. Such overlapping of signals causes interference, either amplifying or attenuating the signal power received at the receiver, known as the *fading problem*. Multipath fading is the main reason for low throughput at high vehicular speeds, even in WiMAX, especially when the carrier frequency is in the lower range [3].

In our previous work [15], we showed that it is possible to estimate the bit error rate at the receiver end in WiMAX for various vehicular speeds of the transmitter node. Based on the estimated bit error probability, we proposed a proactive error correction scheme that improves the throughput at various vehicular speeds. The improved throughput however, may not be sufficient to accommodate the streaming video data from all the cameras mounted on a public transport moving at high vehicular speeds. A crucial requirement for a video surveillance system is that video quality (hence data rate) must not fall below a certain limit as the contents must be perceivable to the security experts. In the standard system, when the effective throughput drops sharply, data rate for all the cameras drops equally and the utility of the whole video surveillance system drops significantly. In this paper, we propose a scheme that estimates the utility of different cameras mounted on a public transport and, based on the estimated utility, decides which camera(s) to put offline so that overall utility of the whole video surveillance system improves.

II. THROUGHPUT IN THE IEEE 802.16E AT HIGH VEHICULAR SPEEDS

The 802.16e standard includes the air interfaces for fixed and mobile broadband wireless access. The standard contains the specifications in relation to the convergence sublayer (CS), medium access control (MAC) layer, and physical layer (PHY) [10]. Since the 802.16e is for mobile wireless networks, it inherits some of the historical problems evident in mobile wireless communications. Radio signal propagation can experience fast and slow fading. Slow fading is normally caused by shadowing, and is considered as a slow variation in the mean envelop over a distance and can be assumed to be relatively unchanged over time and absorbed into the average symbol energy at the receiver [11]. Fast fading is normally caused by multipath signal propagations, and varies drastically in response to the mobility and speed of the mobile stations. For fast fading, Rayleigh fading [11][12] has proven to be an excellent model that can emulate the error in radio signal when there are many objects in the environment scattering the radio signal before the receiver receives the signal.

In [15], we showed a scheme to estimate the bit error probability at various vehicular speeds in WiMAX technology. Based on the estimated bit error rate, we presented a proactive forward error correction (FEC) mechanism that improves throughput at various vehicular speeds. The error correction scheme takes the estimated bit error rate into consideration and computes a code size *C*, strong enough to recover the lost information at the received end and thereby, saving the packet from being declared as corrupted. This improves the throughput at the cost of some extra parity bits added to each packet. At high vehicular speeds, the code size becomes significantly large causing effective throughput to drop sharply. When the overall effective throughput becomes small, the video quality of the transmitted video becomes unacceptably poor and some measures need to be taken to maintain the utility of the video surveillance system. In the following, we propose a scheme that estimates the utility of various video cameras and decides when and which camera(s) to put

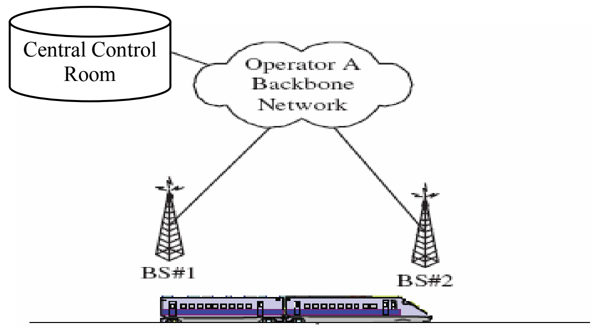

Figure 1: Simulation scenario of a real-time video surveillance system on a public train.

offline, when the estimated effective throughput becomes insufficient to support the streaming video data transmission from all cameras.

III. PROPOSED SCHEME TO MAINTAIN HIGH UTILITY OF LIVE VIDEO SURVEILLANCE APPLICATION ON PUBLIC TRANSPORT

As shown in Figure 1, live video data needs to be uploaded at vehicular speeds for a real-time video surveillance application on public transport. The main challenge here is to achieve sufficient throughput to support multiple video streaming from different cameras installed in the train. WiMAX medium access control (MAC) has the scheduler to maintain QoS of video streams as long as the throughput remains satisfactory. One of the key requirements for surveillance video is that the received video data rate must not fall below a certain limit where the security experts/ automated software can not interpret the information contents of the surveillance environment because of the poor video quality. As such, the utility for a streaming video decreases dramatically if the transmission rate is not maintained above a certain limit. In consultation with the commonwealth security experts, we propose a utility function for CCTV camera in public transport as:

$$U_i(d_i) = \begin{cases} e^{\beta_i(\frac{d_i}{D_i}-1)} & \text{if } d_i \geq b_i \\ \mu & \text{if } d_i < b_i \end{cases} \quad (1)$$

Here, U_i stands for the utility of streaming video from i-th camera, d_i is the current rate of received video sent from i-th camera source, b_i is the minimum acceptable video data rate, D_i is the desired transmission rate (bandwidth demand), μ is the insignificant utility for poor quality video (μ = 0 in Fig. 2), and β_i is used to select the priority of the i-th camera based on its location. The utility model is depicted in Figure 2 and it is evident that utility of streaming video decreases with decreasing received data rate and the utility becomes insignificant beyond a certain transmission rate (50% of the bandwidth demand in this case). In cases where the average received video data rate falls below the acceptable level, we propose to stop live feeding from one or more cameras and store the data into the storage device installed at the train that can be uploaded once the situation improves and the available throughput permits.

A data packet of size K has overhead in the form of a header h and RS code C at a speed v, and the overhead q per data bit can be expressed as:

$$q = (h + C) / K \quad (2)$$

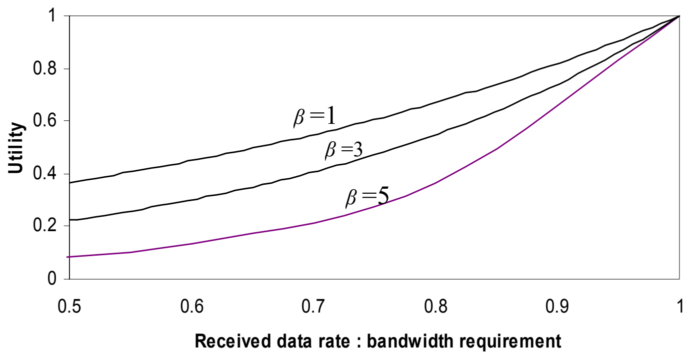

Figure 2: Utility of streaming video at various received data rate.

If q per bit can be estimated at various vehicular speeds at the mobile node, this can assist to estimate the effective data transmission rate W^* (W^*= W - qW where W is the maximum data rate in bps supported by the system) at different speeds. Based on the estimated effective data transmission rate, a decision can be made at the transmitter end whether the available bandwidth will be able to support all the streaming videos at acceptable video quality. If b_i stands for the minimum bandwidth demand for streaming video from i-th camera, then the overall minimum bandwidth demand B_{min} is given by

$$B_{\min} = \sum_{i=1}^{j} b_i \quad (3)$$

and if $W^* < B_{\min}$ then the mobile node needs to stop live feeding from one or more cameras until $W^* \geq B_{\min}$ condition is satisfied. The overall algorithm of the proposed solution can be summarized as:

Procedure *live_feeding_status_check* (v, K)

begin

C_r = *compute_FEC_code_size* (v, K) [15]

q = (h+C_r) / K

W^*= W – qW

$$B_{\min} = \sum_{i=1}^{j} b_i$$

While ($W^* < B_{\min}$)

{

Stop live feeding from camera i where camera i

has the lowest utility return U_i and store the data offline.

$B_{\min} = B_{\min} - b_i$

}

end *live_feeding_status_check* (v, K).

IV. SIMULATION RESULTS

The simulation is conducted for a centralized real-time video surveillance system in a train (Figure 2) using the WiMAX technology. The train is equipped with 3 video cameras (one at front, one at rear and one at the middle); each of them sending video data at a rate of 512 Kbps to the base stations. The maximum data rate capacity of the wireless channel is 2 Mbps and carrier frequency is 2.6 GHz, number of sub-carriers is 2048 and the modulation style is QPSK. For the simulation scenario, the train moves from a stop and gradually increases its speed, reaching a speed of 40 km/hr at 20 sec and a top speed of 70km/hr at around 60 sec time. The train continues to cruise at that speed for sometime before the train starts to slow down at 110 sec. The train continues to slow down and finally stops at the next station at 180sec. The whole scenario was simulated in Network Simulator 2 (NS-2) [14], a widely used simulator for networking research. We monitored the overall throughput and actual video data received by the base station while the train was moving. The overall throughput contains bits representing headers and protocols related packets while the video data is the actual information contents transferred across the wireless channel.

Figure 3 shows the received throughput at various vehicular speeds. While packets with larger data size (256 bytes) offer lower overheads and hence carries extra data bits at low vehicular speeds, packet corruption rate increases sharply at high vehicular speeds for larger packets because the probability of containing corrupted bit(s) is higher in a large packet compared to a small packet. Smaller data packets perform efficiently compared to larger packets at high vehicular speeds. However, extra overheads limit the performance of smaller packets at low vehicular speeds. Figure 4 shows the comparison of received video data rate at the receiver end in standard (i.e., without bit error estimation and FEC) and our previously proposed proactive FEC (PFEC) scheme. It is evident that PFEC scheme achieves improved effective throughput compared to the standard scheme at various vehicular speeds. At high vehicular speeds however, the effective throughput becomes insufficient to support the

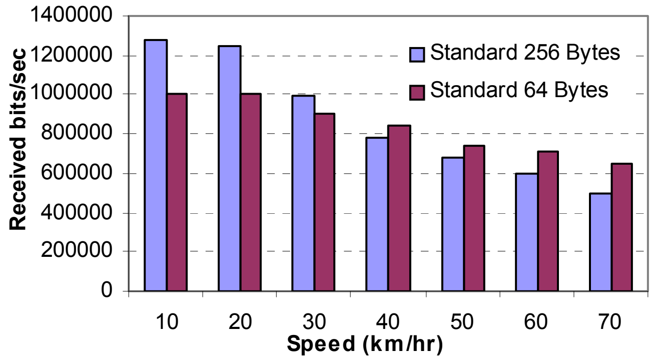

Figure 3: Throughput at various vehicular speeds.

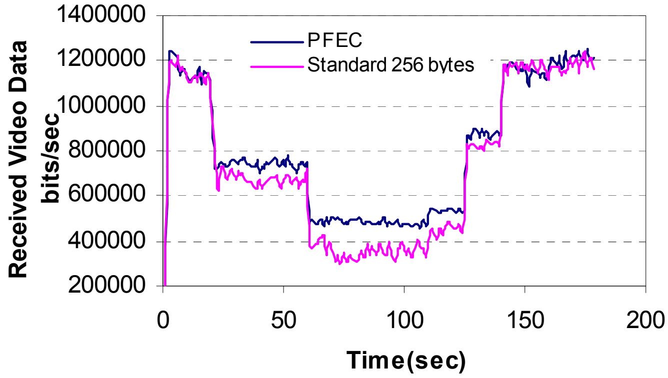

Figure 4: Received video data at different simulation time on a public train.

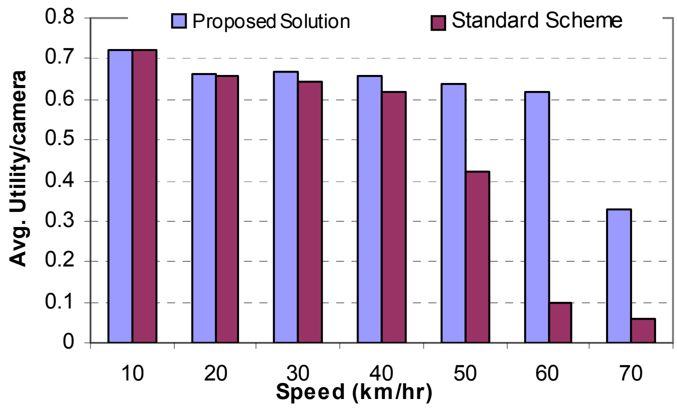

Figure 5: Average utility per camera in the proposed and standard schemes.

streaming video data from all cameras, and this is when our proposed scheme in this paper comes into rescue.

We monitored the average utility per camera of the video surveillance system in a public train. The utility for video transmission rate below half of the bandwidth demand is considered to be insignificant (0.05 in this case). The proposed *live_feeding_status_check* algorithm estimates the effective transmission rate at the transmitter end at various vehicular speeds and makes a decision whether to put one or multiple camera(s) offline. Utility for each offline camera is assumed to be 0.2 and all cameras are assumed to have the same priority (β=1). The result as reported in Figure 5, is the actual utility (i.e., measured against actual received data rate) measured at the receiver end. As evident in the Figure, while the proposed solution yields better utility compared to standard approach, the difference is not significant in terms of average utility per camera at low vehicular speeds (<30 km/hr). However, when the speed increases, the proposed solution achieves significantly higher utility gain compared to standard approach. This is because the *live_feeding_status_check* algorithm assists the WiMAX MAC to make a decision whether to put camera(s) offline based on the estimated video transmission rate and utility from various camera sourcers.

V. Conclusion

Although WiMAX is a promising technology for fixed wireless MAN, it's performance is still not good enough for high bandwidth demanding applications like video surveillance system when the node moves at vehicular speeds. Mutipath fading at high speed that causes high bit error rate at the receiver end is a major reason for low throughput at high speed, especially for low frequency carrier. In our previous work, we showed that proactive measures can be adopted once the bit error rate at various vehicular speeds can be estimated. Proactive measures may still prove insufficient at high vehicular speeds to accommodate the bandwidth demand for the streaming video data from all the cameras mounted on a public transport. In this paper, we propose a model that estimates the utility for various cameras and puts low utility camera(s) offline, if required, so that the overall utility of the video surveillance system remains satisfactory. Simulation results confirm that our proposed scheme comfortably achieves better utility compared to standard schemes.

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