Demo: An Efficient and Reliable Wireless Link for Mobile Video Surveillance Systems

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ABSTRACT

In this demo, an efficient and reliable wireless link is designed for mobile video surveillance systems. In the link, the idea of cognitive radio is utilized and an adaptive channel switching mechanism is employed to avoid unpredictable interferences. Packets pipelining and accumulative acknowledgement (ACK) is proposed based on the stop-and-wait ARQ protocol to improve the communication efficiency of the link. Moreover, an integration design of the ACK packet is used to piggyback different kinds of control messages. With the efficient and reliable wireless link, a cognitive radio prototype is developed for video transmission between the telerobot and teleoperator. The video information from the telerobot can be transmitted back to the teleoperator quickly and reliably even under channel interferences. The telerobot can also be controlled timely and accurately. A video demo shows the whole story and performance.

Keywords

ARQ; cognitive radio; throughput; SDR

1. INTRODUCTION

Co-channel or adjacent-channel interference becomes more and more serious in the ISM band because of the proliferation of wireless devices and standardized protocols in this licensed free band. The conventional static wireless protocols may not guarantee the quality of service (QoS) requirements for some specific applications under the complex and dynamic spectrum environment. With the recent advances in software-defined radio (SDR) technology and hardware, the design and implementation of wireless protocols with adaptive and dynamic adjustment ability is a trend. In this demo, we design an efficient and reliable wireless link for mobile video surveillance systems to embrace this trend. These systems can be used for industrial surveillance, customs and border protection and disaster environment exploration. As shown in Fig. 1, a telerobot can be sent into some surveillance environments to obtain the video information, which needs to be transmitted back to a teleoperator timely and reliably. Then the teleoperator can have a understanding of the detected environment and operate the telerobot precisely and efficiently. However, the crowded spectrum environment with unknown interferences set up a barrier for the real-time requirement. Facing the dynamic interferences, the standardized protocols such as 802.15.4, 802.11 may not perform well without adaptive capacity. Hence, an efficient and reliable wireless link is designed and implemented on the SDR platforms as shown in Fig. 1. The USRP node on the telerobot and the PXI platform as the teleoperator are SDR transceivers with frequency-agile ability. The newly designed wireless link is based on the popular stop-and-wait automatic repeat-request (ARQ) protocol.

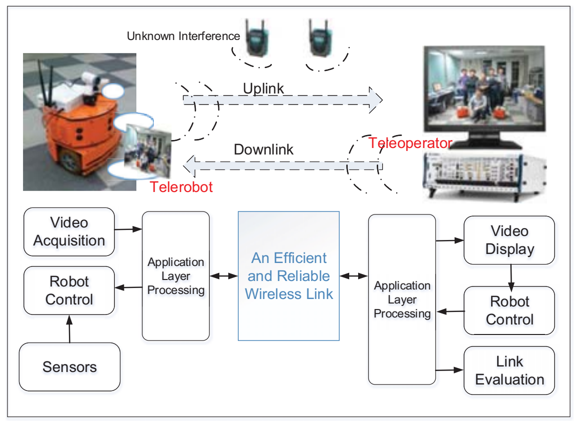

Figure 1: Setup of demonstration and system architecture.

2. WIRELESS LINK DESIGN

In the wireless link, two different strategies are proposed to improve the communication efficiency and reliability. Moreover, integrated design of the ACK packet reduces the ACK overhead and improves the throughput further.

2.1 Packets Pipelining and Accumulative ACK

Since the wireless link is unreliable, ACK and retransmission are necessary to guarantee the quality of video trans-

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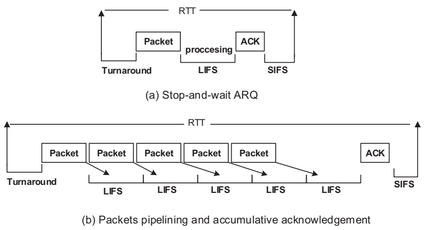

Figure 2: Time cost of a round-trip communication.

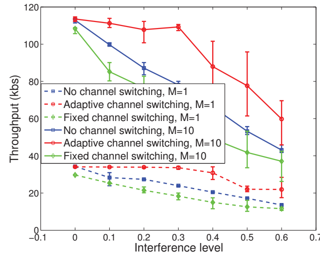

Figure 3: Throughput vs. interference level.

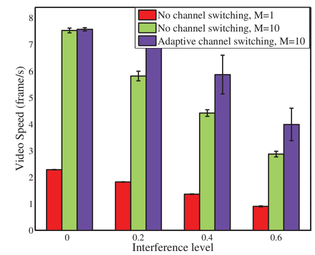

Figure 4: Video speed vs. interference level.

mission. For the stop-and-wait ARQ protocol, the time costs for each round communication are shown as Fig. 2 (a). The turnaround time (T_{td}) is the switching delay from receiving to transmitting state. The packet and the ACK time (T_{packet}, T_{ack}) are the transmission time of a packet and an ACK given a specified data rate respectively. The LIFS time (T_{LIFS}) is the processing delay of each packet and the SIFS time (T_{SIFS}) is the processing delay of the ACK. Because of the signal processing delay [2], T_{LIFS} and T_{SIFS} are larger than the packet and ACK transmission time. Hence, the traditional stop-and-wait ARQ is inefficient because of waiting cost and frequently ACK overhead.

To improve the communication efficiency of the wireless link, we modify the traditional stop-and-wait ARQ protocol and propose packets pipelining and accumulative ACK strategy as shown in Fig. 2 (b). The transmitter continues to send a number of packets specified by a window size M in a pipelined way. The receiver captures and processes the packets in a concurrent way to improve efficiency. After processing all packets in the round, then the receiver acknowledges the transmitter with an accumulative ACK to reduce overhead. The round-trip time (RTT) for the both strategies is given by $RTT = T_{td} + T_{packet} + M * T_{LIFS} + T_{ack} + T_{SIFS}$. The communication efficiency [1] is defined as $\eta = M * T_{packet}/RTT$. Obviously, the communication efficiency increase with M. When $M = 1$, it is the traditional stop-and-wait ARQ protocol. However, M cannot be set too large because large M leads to a longer retransmission delay of the false packet.

2.2 Adaptive channel switching

To combat the dynamic and unpredictable channel interferences at the crowded ISM band. An adaptive channel switching mechanism is employed for the wireless link. After decoding all packets in each round communication, the receiver analysis the link quality based on packets lost probability P_e in each round. The receiver senses another available channel if P_e is larger than a threshold δ. The channel switching information is integrated into the ACK packet and is shared with the transmitter by downlink transmission from the receiver. Both devices adjust the communication channel according to channel switching information. The link failure is inevitable because of ACK lost or deliberately jamming. Hence, we introduce a SYN (Synchronization) state that devices enter into when they detect a link failure. The transmitter will enter into the SYN state if it does not receive any ACK after retransmitting the packets R rounds. If the receiver does not receive any data for a time period T_s, it will also transfer to the SYN state. In the SYN state, devices communicate on a dedicated narrow-band channel to exchange the channel switching information.

3. IMPLEMENTATION AND EVALUATION

We fully implement the efficient and reliable link on National Instruments (NI) SDR platforms including NI-USRP nodes and NI-PXI platform as shown in Fig. 1. The performance is evaluated between the traditional stop-and-wait ARQ protocol and the proposed packets pipelining and accumulative ACK strategy with window size $M = 10$. Moreover, the throughput is also compared between adaptive channel switching mechanism, fixed channel switching mechanism and no channel switching mechanism. There are three channels for the transmitter and receiver. Three interference nodes are set to interfere a dedicated channel respectively. The interference level is a ratio between the time duration that interference nodes transmit on the channel and the total time consumption of each experiment.

In Fig. 3, the throughput increases almost 4 times for our proposed strategy ($M = 10$) compared with the traditional ARQ protocol ($M = 1$). Moreover, adaptive channel switching strategy always perform the best when dealing with channel interference. Especially when the interference level at each channel is relatively low (less than 0.3), the effective throughput nearly keeps the same level as no channel interference existing. The adaptive channel switching mechanism not only avoids channel interference smartly, but also saves unnecessary channel switching cost when no interference appears. Hence, the wireless link throughput can be improved greatly when we combined the two strategies together in the communications.

A mobile video surveillance system based on the wireless link is implemented, the performance is as Fig. 4, and the demonstration can be seen from a video [1] [2].

4. ACKNOWLEDGMENTS

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[1] `https://youtu.be/-YhhA3qslNU`

[2] `http://v.youku.com/v_show/id_XOTMOMDkyNzk2.html`