VIDEO TRANSMISSION FOR MULTI-HOP NETWORKS USING IEEE 802.11 FHSS

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ABSTRACT

In many applications such as construction, manufacturing, ground robotic vehicles, and rescue operations, there are many issues that necessitate the capability of transmitting digital video and that such transmissions should be performed wirelessly and in an ad-hoc manner. Recently, we proposed an ad-hoc, cluster-based, multihop network architecture for video communications. For implementation, the IEEE 802.11 FHSS wireless LAN system using 2GFSK modulation has been deployed.

To enhance the overall throughput rate for higher quality video communications, we present a performance evaluation of the IEEE 802.11 FHSS when 4GFSK modulation option is selected. Unfortunately, the 2 Mb/s system utilizing 4GFSK modulation is not very efficient in terms of RF range. Therefore, to improve its performance for multihop applications, a combination of diversity and non-coherent Viterbi based receiver is considered. For the video transmission part, we have considered a bitstream splitting technique together with a packet-based error protection strategy to combat packet drops under multipath fading conditions. Finally, the paper presents the simulation results, including the effects of the receiver design and diversity on the quality of the received video signals.

1. INTRODUCTION

Current and emerging wireless LAN (WLAN) networking technologies, when coupled with video and other sensor data, promise to enable a wide range of applications such as emergency response to natural disasters, search and rescue operations, hazardous material cleanup, and heavy construction. To support operations where existing communication infrastructures are not available, rapid deployment of an unstructured mobile network, where each unit is capable of transmitting video information and sensor data, would be essential. The requirements may include some or all of the following: a higher bandwidth (for transmitting video data), mobility, sufficient area coverage, and communications beyond the line of sight.

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Recently, we have designed a multihop network architecture, which is based on a cluster-to-cluster operation, using IEEE 802.11b FHSS (Frequency Hopping Spread Spectrum) [5]. FHSS is considered to provide better network scalability in terms of area coverage[2]. Please note that in order to support a large coverage area, multihop communication is vastly favored over long range, single-hop links. The use of multihop is to combat a rapid decay of the electromagnetic received signal strength as communication distance increases. In addition, multihop communication between distributed mobile nodes offers pathways around electromagnetic transmission obstacles that would otherwise prevent formation of a long-range network. In this architecture, as shown in Figure 1, the participating nodes in one cluster communicate with nodes in other clusters via their respective mobile Access-Points (APs)[5]. As indicated in this figure, there are two types of nodes in the network, Master Nodes (MNs) and Slave Nodes (SNs). The difference between an MN and an SN is that an MN is equipped with an access point (AP) and a wireless LAN interface, while an SN has only one wireless LAN interface. A wireless LAN card in an SN operates in a managed network mode and can only communicate through APs. The link between the mobile APs is accomplished using the Adhoc On-demand Distance Vector (AODV) routing protocol [2]. This network has been implemented using a set of APs and PDAs devices for demonstration and field-testing. Video streaming was based on H.263+/RTP/UDP/IP/802.11. For our experimental set up, we have deployed commercially available IEEE 802.11b FHSS Wireless LAN (WLAN) cards and associated Access Points (AP). In these experiments, the modulation for WLAN devices was 2GFSK, as specified by the standard[1].

In assessing the network performance, which consisted of 4-clusters, we observed that the number of hops in which the video packets travel has a considerable effect on the packet loss rate. Furthermore, the packet loss situation becomes worse when more nodes are involved in simultaneous transmission of video signals.

Therefore, to improve the throughput rate, the 4GFSK modulation option of the IEEE 802.11 FHSS has been considered. This option has been adopted mainly to enhance the transmission rate from 1 Mb/s (using 2GFSK) to 2 Mb/s. However, the main drawback with the 4GFSK option is its significant impact on the RF range, which could consequently result in more hops for the same coverage area. Another important factor which could also affect the performance of the 4GFSK, is its sensitivities to Inter symbol interference (ISI) as well as multipath fading.

Thus, the overall goal of this paper is to evaluate the performance of 2 Mb/s IEEE 802.11 for video-based sensor operation that involves some degree of mobility. We will show that a well-designed receiver with antenna diversity can improve the quality of the received video signal under multipath fading environments. Another important part of this investigation is the deployment of an error resilient video decoding technique based a dual priority transmission system in order to mitigate the effect of packet drops.

2. SYSTEM MODEL

2.1. Packet-Based Error Correction

Although forward error correction codes would be essential to protect the error-sensitive compressed video bitstream for wireless transmission, the IEEE 802.11 physical layer does not provide any forward error correction capabilities. In addition, the IEEE 802.11 MAC protocol discards a packet that is corrupted by a single error. For error corrections, 802.11 relies only on the packet retransmission, which is known as ARQ (Automatic Repeat reQuest). Unfortunately, packet retransmission for multihop communications is not a good solution for real-time video for multihop transmission. For this reason, packet-based forward error correction at the application layer can be considered to compensate for packet loss in an IP-based network system[3].

Thus, in this paper, a simple packet-based forward error correction technique for the CBR (constant bit rate) transmission of video signals has been considered. Figure 2 shows the packet-based rate 2/3 parity check code. In the encoding process, additional parity packets are generated from two data packets by exclusive-or operation. As a result, the number of packets to be transmitted increases by a factor of 1.5.

At the receiver, if data packets are received without error, the parity check packets are ignored. In the event of a single data packet loss, the lost packet can be combined with the other data packet and the parity packet, resulting in recovery of the missing data packet. If more than one packet is discarded, the discovery of the missing packets would be impossible. In this case, the receiver has to rely on the robustness of the error resilient capabilities of its decoder in order to decompress the corrupted video bitstream with minimal subjective deterioration.

2.2. Dual Priority Video Transmission

Although packet-based error correction techniques can reduce the packet loss rate, they cannot guarantee an error free packet transmission. Indeed, under more severe channel fading conditions, a larger number of parity check packets, may not be able to provide an error free transmission. Thus, apart from developing an efficient error protection strategy, designing a robust error resilient decoding scheme, for resynchronization of the uncorrectable video bitstream, would be essential.

One efficient method is to apply an error correction code to the most error-sensitive part of the compressed video bitstream. This would require developing a scheme to split the compressed video data into a number of separate bitstreams where each can be transmitted with a different error protection. For instance, all video compression standards are based on the hierarchical layering structure where each layer has a different sensitivity to transmission errors [5]. Figure 3 shows a general block diagram of the splitting process for the encoded video.

In this paper, we have considered a dual-priority video transmission with packet-based error correcting coding. In this approach the coded video bitstream is split into two separate streams in accordance with the sensitivity of each hierarchical layer to packet loss or transmission errors. At the transmitter the video stream is first partitioned into two streams, according to the video partitioning method given in [5]. We assume that the first stream contains more error-sensitive information than the second stream, without loss of generality. After partitioning, each stream is packetized and then encoded with a different error correcting code, e.g. packet-based rate 2/3 parity check code for the first stream and no error correcting code for the second stream. At the receiver's application layer, missing packets are replaced by all-zero packets before undergoing a packet-based error correction decoding process. Please note that a packet-based error correction process causes an additional delay as well as an increase in the packet transmission rate.

Anticipating that there would be some packet-drops despite extra error protection, the video decoder should be able to detect which regions within a frame or which frame(s) within a video sequence have been corrupted. Subsequently, this would require reassembling and resynchronization of the bitstreams that can also conceal the corrupted areas in the video sequence. This process is performed by a predecoder that is placed prior to the video decoder. Figure 4 shows a general block diagram of the predecoder and further details of its design, using the ITU-T H.263 video coding standard [4], can be found in [5].

2.3. Receiver Design

To carry out the performance evaluations of the receiver design, we have developed a simulation model of the IEEE 802.11 FHSS physical layer using the SPW (Signal Processing Workstation)[1] simulation tools.

For this model we implemented differing types of noncoherent receivers based on a limiter-discriminator integrator detector and a differential detector. Please note that noncoherent receivers have practical advantages over coherent because of low implementation costs and inherent robustness against frequency and carrier phase offsets.

In this paper, we used a limiter-discriminator integrator detector (LDD) with Viterbi algorithm as a GFSK receiver as show in Fig. 5. Since GFSK signals induce the intersymbol interference even without channel distortions, it is important to use a well-designed receiver especially for demodulating the 4GFSK signals. In addition, we also considered the diversity reception[6] to further enhance the receiver performance.

3. SIMULATIONS

In our experiments, a packet-based error correction code with a rate of 2/3 has been used for the first stream. No error protection was considered for the second bitstream. The packetized bitstreams were then multiplexed together (packet-by-packet) before being fed to the input of the 802.11 FHSS model. In these experiments the ITU-T H.263+[4] has been used to encode the input video signal (QCIF format) at 64 kb/s (constant bitrate, CBR). Please note that the packet size was set to 100 byte (for convenience of simulation) excluding preamble with addition headers. In the 802.11 FHSS transmitter, each packet, including headers and preamble, is modulated by 4GFSK and then transmitted over AWGN (additive white Gaussian noise) or Rayleigh fading channel. We used the limiter-discriminator integrator detector with Viterbi algorithm to demodulate the 4GFSK signals, as shown in Figure 5. Figure 6 shows the packet loss rate in AWGN (additive white Gaussian noise) channel for dual priority transmission. Bit error rate (BER) performance is also shown in this figure.

The results in this figure verify that packet-based forward correction coding can significantly decrease the packet loss rate, even with such a simple code. The difference in video quality with and without dual priority transmission is also shown in Fig. 8. This figure presents the last coded frame of the 'Clair' and 'Container' sequences transmitted over this channel. Thanks to the lower packet loss of the first stream, the quality of the reconstructed video is clearly superior to the one with only one priority transmission.

Figures 7 shows the packet loss rate and bit error rate with diversity reception in a flat Rayleigh fading channel. For simplicity, we assume the quasi-static fading channel, in which the channel is time-invariant during the transmission of a packet, and that the channel realization for each packet is independent. As can be observed from this figure, the diversity technique has greatly improved the receiver performance. With the diversity technique, we can expect to achieve the same quality of the reconstructed video with about 3 dB less received power than that without diversity, which results in a larger coverage in the multi-hop network system.

4. CONCLUSION

The main objective of this paper was to evaluate various receiver design techniques that can improve the performance of the IEEE 802.11b FHSS. This investigation was motivated by our earlier experiments in developing an experimental set up for a multihop ad-hoc network. For instance, in these experiments we observed that selecting a higher throughput rate option of the 802.11 FHSS would be advantageous for video communications. Unfortunately, selecting this option would require deployment of 4GFSK modulation, which is inefficient in terms of RF range for multihop communications. Therefore we have considered designing efficient receivers in order to enhance the RF range. In addition, we have also developed a combination of bitstream partitioning and packet based forward error correction techniques to evaluate the receiver performance. We hope the result of this evaluation may help future implementations of 802.11 FHSS WLAN receivers.

5. REFERENCES

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[1] SPW is a registered trademark of Cadence Design Systems, Inc. The SPW is identified in this paper to foster understanding. Such identification does not imply recommendation nor endorsement by the National Institute of Standards and Technology, nor does it imply that this product is necessarily the best available for the purpose.

[6] F.Adachi and K.Ohno, "Experimental evaluation of postdetection diversity reception of narrow-band digital FM signals in Rayleigh fading," *IEEE Trans. Veh. Technol.*, vol.38, No.4, pp.216-221, Nov. 1989.

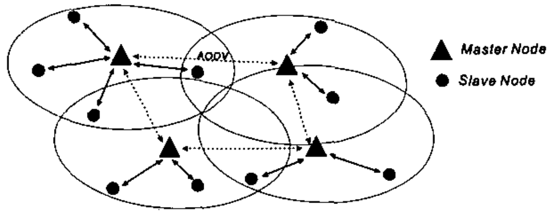

Fig. 1. Multi-hop cluster-based ad-hoc network

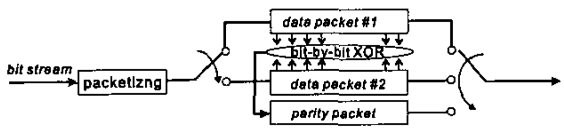

Fig. 2. Packet-based rate 2/3 parity check encoder

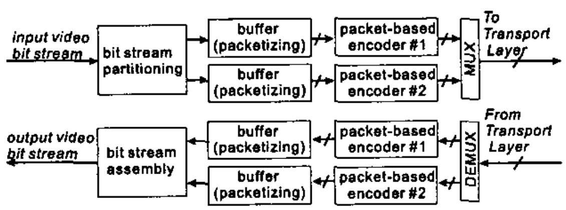

Fig. 3. Dual priority video transmission system model

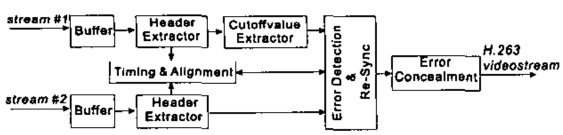

Fig. 4. General block diagram of the predecoder

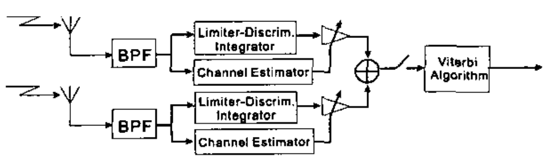

Fig. 5. GFSK receiver with post-detection diversity

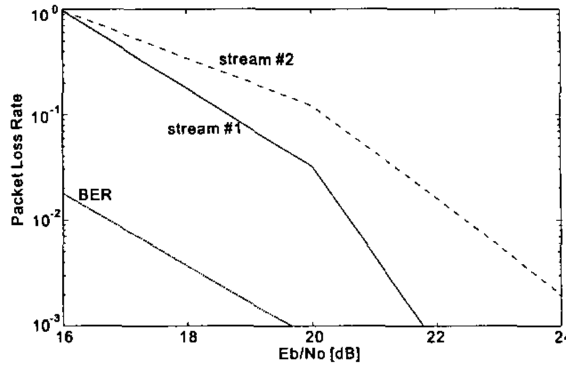

Fig. 6. Packet loss rate for dual priority transmission in AWGN channel

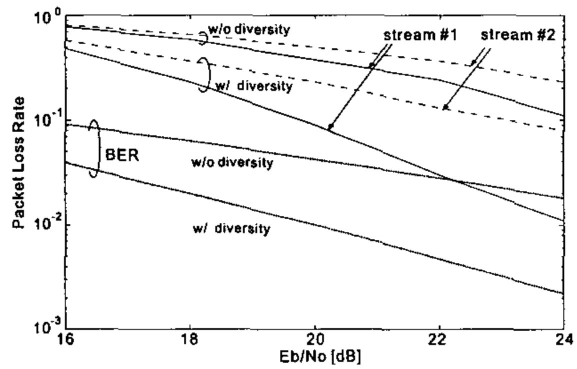

Fig. 7. Packet loss rate for dual priority transmission with diversity in Rayleigh fading channel

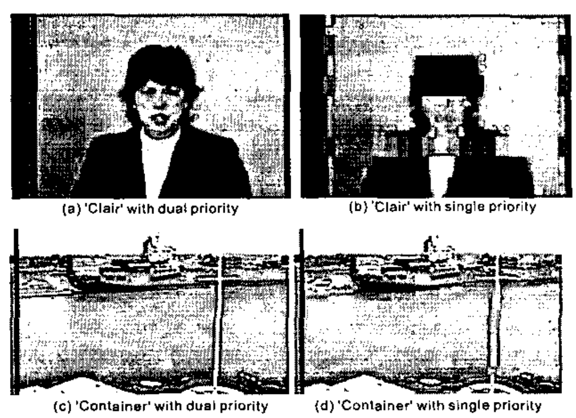

Fig. 8. Last reconstructed frame of the ' Clair ' and 'Container' sequences