Video Transmission over Wireless Networks
-A Survey

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Abstract
Last decade have shown the rapid increase in video based applications over wireless standards such as, WiMAX, LTE and LTE-Advance. Transmission of real-time video for various applications such as video-conferencing, telemedicine and video streaming over wireless channels is a challenging task because of high bit error rate in these channels. Furthermore, for the limited bandwidth in the wireless standards and memory devices, state-of-the-art compression techniques are required. However, the coded video becomes very sensitive to channel errors. Thus, error resilient techniques are required to protect the coded video bitstreams. In this paper, various methods and techniques are reviewed that minimized the effect of channel errors in the transmission of video over noisy channels.

I. INTRODUCTION
In recent years, wireless communication and networking have experienced unprecedented growth. Various state-of-the-art standards and technologies such as IEEE 802.15 based Wireless Personal Area Network (WPAN), IEEE 802.11 based wireless local area networks (WLAN), IEEE 802.16 based Wireless Metropolitan Area Networks (WMAN) and Fourth generation (4G) mobile telecommunication networks, have been developed in the past years to facilitate the high speed communication between the multimedia devices. The availability of high speed networks and the decreased cost of video capturing and displaying technology have opened the door of video communication which was earlier believed to be almost impossible. It is expected
that video communication will be the dominating traffic over wireless and IP networks in future and is envisioned for a vast range of applications such as video-telephony, video-conferencing, tele-medicine, surveillance, security monitoring, disaster rescue, environment monitoring, gaming and entertainment and wildlife activity monitoring [1].

II. CHALLENGES IN WIRELESS VIDEO COMMUNICATIONS

Wireless networks usually provide the last mile of connectivity to users in a communication network. Though these networks have advantages of deployment and user mobility, video communication over these networks faces severe challenges [2], [3]. The wireless networks suffer with interference, noise, bandwidth variation. Video transmission in itself possess certain difficulties. These two aspects, one associated solemnly with wireless networks and the other with video communication will be discussed one by one.

A. Wireless Networks

The major issue with wireless network is the fading [4]. It occurs due to multipath propagation, in which the received signal consists of a series of attenuated, time delayed and phase shifted replicas of the transmitted signal. The resultant received signal is the vector sum of these individual signal components arriving from different paths. These components add either constructively or destructively depending upon their relative phase difference, thus giving random amplitude variation in the received signal. In such a time varying channel sometimes the signal may go into the deep fade (results in burst errors) or it may cause an outage where detection and demodulation of the signal is almost impossible, resulting in the dis-connectivity and drop of communication.

Another issue with wireless network is the limited and dynamically varying bandwidth. Although wireless network support high data rate, they usually provide limited capacity. For example, IEEE 802.11 standard supports up to 54 Mbps, but due to protection mechanism such as binary exponential back off, rate adaptation, and protocol overheads reduces the throughput by approximately 50% [5]. The actual throughput of IEEE 802.11a and 802.11g is up to only 27 Mbps and 24 Mbps as reported in [6]. Moreover, as the wireless medium is shared by multiple users, the actual bandwidth available to the individual users is usually much lower.

Interference is another issue with the wireless channels. Interference occurs because of the signal arriving at the same frequency from other sources either due to the use of unlicensed frequency spectrum (which other standards may be using) or arriving from the neighboring cells (in case of cellular systems). Interference usually degrades the quality and capacity of wireless links.
B. Video Communication

As mentioned earlier that wireless channels have limited bandwidth, whereas uncompressed video possess very high bandwidth and therefore such networks are not suitable to transmit the video directly over them. For example, a raw video of standard Television (TV) with resolution of 720 × 480 pixels per frame, 24 bits per pixel and 30 frames/second generates data at the rate of approximately 237.3 Megabits per second (Mbps). This data rate is very large to be transmitted at even 4G networks (which promises to provide approx. 100 Mbps) and with the demand shifting towards high definition TV of resolution 1920 × 1080 pixel/frame, it is impossible to transmit video even on the latest wireless technologies. Therefore, compression of video sequence is a viable part of video communication which reduces the redundancies lying within and among the sequences. Over a period of time, several international compression standards have been developed including MPEG-1, MPEG-4 by International Standards Organization (ISO) [7], [8], H.261, H.263 by International Telecommunication Union (ITU) [9], [10] and MPEG-2, H.264/AVC (also known as MPEG-4 Part 10), H.265/HEVC by Joint Video Team, a collaborative effort from ISO and ITU [11], [12], [13].

Reducing the redundancies within the video enables to achieve the compression such that it can be transmitted over limited bandwidth. However, it also makes the coded bitstream vulnerable to channel errors and distortions. More specifically, all the compression standards use variable length coding (VLC) which makes the bitstream highly dependent. This makes the bitstream very prone to channel errors. Moreover, different bits generated by the video coder have different degrees of vulnerability to the channel errors [14]. Some bits have a local effect, whereas, error in other bits may disturb the synchronization between encoder and decoder which leads to catastrophic failure in reconstruction of the video. Furthermore, as all the latest codecs use motion compensated prediction, the errors in one frame propagate to the subsequent frames which were otherwise received error free. Fig. 1 shows the effects of different types of errors in a compressed video. The original frame is shown in Fig. 1(a). Fig. 1(b) shows the error affecting the video locally, whereas the effects of some errors distorting the frame globally is shown in Fig. 1(c), which is due to the error in important or critical bits such as header and motion vector bits. Finally, the effect of error propagation from one frame to subsequent frames is shown in Figs. 1(d)-1(f). It may be noted in Figs. 1(d)-(f) that, though 2nd and 3rd frames are received correctly, due to the use of motion compensated prediction in the video coding, the errors from 1st frame propagated to the subsequent frames. Therefore, some error resilient technique is needed to transmit the compressed video bitstream over error prone channels such as wireless and IP networks.
For real time video communication, video encoding and decoding processes are also constrained to the time delay. For example, in playback of video sequences at 30 frames/sec, the maximum allowable delay (coding and transmission delays) between two successive frames should not be more than $1/30 = 33.33$ millisecond. For real time video communication application such as video conferencing, transmission delay is an important issue. Usually the human visual system (HVS) can tolerate an end-to-end delay of not more 6-7 frames (about 200 ms) [15]. If delay increases beyond this limit, real time video communication will appear to be annoying.

Moreover, there is a growing trend to access video services using hand-held portable multimedia devices such as smart-phone, PDA and laptop. These devices have limited processing power and battery life. Contemporary video coders such as H.264/AVC [16] or MC-EZBC [17] give state-of-the-art compression performance; however, use of large number of optimized coding tools makes them highly complex and time consuming. When used in hand-held multimedia devices, they drain up the battery power at a very fast rate. Thus, computational complexity of a video coder is also an important issue from power consumption point of view. Low complexity algorithms are essential for wireless video communication using hand-held portable devices, having limited processing power and battery life.
In summary, wireless video communication has to cope with time-varying channel conditions such as high error rates, burst error, link outage in case of severe fading, and capacity variations as well as limited power and low complexity issues.

III. REVIEW OF ERROR RESILIENT TECHNIQUES

A variety of solutions for reliable video communication over noisy channels have been proposed to cope with the challenges. These include forward error correction (FEC), joint source-channel coding (JSCC), adaptive modulation, retransmission using automatic repeat request (ARQ), adaptive source channel coding, robust source coding, multiple-description coding, data partitioning, error concealment by post processing, scalable coding with transport prioritization and hierarchical modulation [2], [3].

One of the most popular error resilient techniques is the forward error correction (FEC). FEC can be applied using either block or convolutional coding. Reed-Solomon (RS) and Low Density Parity Check (LDPC) codes are the most widely used block codes, whereas, Rate-Compatible Punctured Convolutional (RCPC) and turbo codes are the popular convolutional codes. These codes are capable of correcting random errors and erasures in a block of symbols. A number of FEC codes has been studied and applied successfully for reliable video communication [18], [19], [20], [21], [22]. However, the use of FEC codes for error protection increases the bandwidth requirement for the transmission of video signals. To overcome this problem, joint source-channel coding (JSCC) was proposed [23], [24]. The JSCC scheme adapts the source coding and channel coding parameters according to channel conditions such that the overall distortion of received video is minimized.

Adaptive modulation is another way of increasing the error resiliency of the video transmission and has been used in many wireless communication systems. Switching to lower values of the modulation level, M, decreases the bit error rate of the signal for a given channel condition. For example, Digital Video Broadcasting – Terrestrial (DVB-T) uses three modulation schemes namely QPSK, 16-QAM and 64-QAM for different channel conditions [25]. If 64-QAM based video transmission system is unable to deliver target video quality, the transmitter switches to 16-QAM system. However, if the target video quality is still not achieved, it further switches to QPSK (also called 4-QAM). Similarly, LTE uses QPSK, 16-QAM, 64-QAM in downlink transmission and QPSK, 16-QAM, 64-QAM (optional) in uplink transmission, to adapt according to the channel conditions [26], [27]. Likewise, WiMax uses BPSK, QPSK, 16-QAM, 64-QAM in downlink and BPSK, QPSK, 16-QAM, 64-QAM (optional) in uplink transmission to switch according to channel conditions [28]. Thus by adapting the modulation levels according to the channel conditions, video can be sent over wireless channels reliably. However, a system based on adaptive modulation is
generally a complex system as well as all modulation schemes need to be incorporated at both the transmitter and receiver.

Another very popular scheme for providing error resiliency to a video transmission system is layered coding combined with the prioritized error protection [29]. In layered coding, video is partitioned into a base layer and one or more enhancement layers on the basis of non-uniform importance of the coded video in reconstruction [29]. The base layer contains the basic and significant information of the video, and alone, it can yield acceptable quality on decoding. Whereas, the enhancement layers contain details of the video, which on decoding, further improve the quality of the reconstructed video. As more enhancement layers are received, higher quality can be obtained. To achieve robust video transmission, the layered coding is combined with prioritized error protection in such a manner that the base layer gets high protection against channel errors while enhancement layers get relatively lower error protection [30], [31]. This is known as unequal error protection (UEP). The graceful degradation of video is achieved with increased channel error probability, as enhancement layer can be dropped in decoding while base layer can withstand this increased channel distortion and thus may be decoded to achieve the acceptable quality. UEP to layered coded video can either be applied at application layer (using FEC) [29] or at physical layer (using Hierarchical QAM) [32]. In FEC-based UEP at application layer, the different priority layers are protected using FEC of different channel coding rate. In Hierarchical QAM (HQAM) based UEP, the signal constellation is partitioned so that the specific blocks of the partition contain message points with maximum possible Euclidean distance between them at the expense of message points in the other blocks that are separated by a much smaller distance. The parameter which controls the relative maximum Euclidean distances of different blocks is usually termed as modulation parameter, $\alpha$. The message points are mapped over the constellation diagram such that the specific bits assigned to the widely separated points have lower error probabilities than the others. This feature of HQAM is exploited to provide more protection to important base layer at the expense of less important enhancement layers. That is, the error protection of different priority layers can be controlled by varying the modulation parameter, $\alpha$.

In addition to applying error control strategies at individual layers of layered-network architecture, the error control strategies have also been implemented using cross-layer approach. It exploits the joint error control strategies of different layers of the communication network [2], [33]. The idea behind the cross-layer design is to maintain the functionality associated with the original layers, while allowing coordination, interaction and joint optimization of protocols over multiple layers. The cross-layer approach efficiently utilizes the available resources such as bandwidth, time-varying nature of the channel and delay.
Though error protection of video against channel noise may increase the error resiliency of the coded bitstream, the error resiliency is achieved at the expense of transmission resources. For example, if FEC is employed to provide the error protection of bitstream, the bandwidth requirement of the transmitted video signal would increase. That is, there is a trade-off between error resiliency and bandwidth requirement. Therefore, optimization of parameters that control the error resiliency of the transmitted video is needed so that the available resources can be utilized efficiently. A substantial research work has been carried out to develop optimized error control strategies for video communication [34], [35]. The studies were focused for discrete cosine transform (DCT) based standard video coders such as MPEG-2, MPEG4, H.263, H.264/AVC. The optimized error control scheme for discrete wavelet transform (DWT) based video coders have been studied in [36], [37].

IV. CONCLUSION

In this paper, various challenges of the video-based applications over wireless channels have been explored. Firstly, the wireless networks have very high bit error rate with limited and dynamically varying bandwidth. Secondly, to achieve compression redundancies in the video are reduced so that it can be transmitted over limited bandwidth and in addition, motion estimation, compensation and variable length coding (VLC) are used in almost all video coding standards that all makes bitstream highly dependent and very sensitive to channel errors. The paper explored various error resilient methods that proposes the robust transmission of wireless video.

REFERENCES


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