# MOBILE VIDEO COMMUNICATIONS IN WIRELESS ENVIRONMENTS

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**Abstract - A novel system providing effective and efficient access to video archives for mobile users communicating over low bandwidth error-prone wireless links is proposed. The developed system has three components: First, the middleware, implemented as mobile proxy server located at the mobile support station, is chosen for the seamless integration of both mobile users and video servers by hiding the specific details of the underlying system. Second, for efficient video transmission, our three-dimensional significant-linked connected component analysis video codec well suited for wireless environments, is used. Finally, multilayer transmission error control mechanism is applied to cope with channel errors. As a result, no additional requirements are imposed on the mobile client and video server so that mobile users interact with the server in exactly the same way as stationary users, and all they experience are better picture quality, less jerky video, and shorter delays.**

## INTRODUCTION

Recent technological developments have led to several mobile systems providing personal communication services, which support not only speech but also data transmission. One of the most promising applications is video communications, whose importance is also evidenced by extensive research in both academia and industry resulted in large number of standards being adopted. But, most of the these standards are mainly designed for wired visual communications and would not be effective if straightforwardly applied to the wireless case [1].

In the paper, a middleware-based system is developed that allows the user of a mobile computer to control the way the data from the video server is retrieved and dynamically transformed, being totally transparent to both the mobile user and video server. The proposed system has three main components. First, the mobile proxy server (MPS) located at the boundary of the wired and wireless network is used to transform the video into the format most suitable to the mobile client. All details of the underlying source and channel coding algorithms are hidden to both the mobile client and video server.

Second, our high performance low computational complexity video coding algorithm termed three-dimensional significance-linked connected component analysis (3D-SLCCA) [2, 3] is chosen for video compression due to its high robustness against channel error propagation. Third, our multilayer error control coding mechanism, which includes synchronization, forward error correction (FEC), and retransmission, is used to achieve robustness against channel errors [4].

## SYSTEM DESCRIPTION

We use the popular mobile networking model [5], which consists of fixed hosts and mobile hosts (MHs). Fixed hosts communicate with each other on a high bandwidth reliable wired network. MHs are supported by some designated fixed hosts termed as mobile support stations (MSSs), which act as gateways between the wired and wireless networks. Mobile hosts have very limited resources, they usually communicate over wireless links characterized by lower bandwidths, higher bit error rates (BER), and more frequent disconnections in comparison to wired networks. Moreover, in a mobile environment, changes in network bandwidth occur quite common [6].

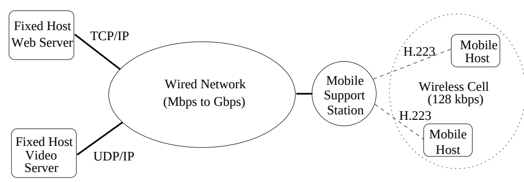


Figure 1: System architecture.

### Mobile Proxy Server

The developed system extends the basic MSS-MH model by adding a proxy server as a middleware to each MSS as shown in Fig. 1. The *mobile proxy server* (MPS) is responsible for providing effective and efficient video communications between the video server and the MH. The functionalities of the MPS include:

- Protocol translation;
- video transcoding;
- video streaming whenever necessary;
- error control coding;
- caching and retransmission; and
- maintaining the capabilities of the MHs.

In the proposed system, no assumption is made as to how the video is provided by the server. However, between the MSS and MH, at the data link layer, we exclusively use the H.223 Recommendation [7] for transferring video as shown in Fig. 1. We decided on H.223 since it provides quality-of-service (QoS) parameters and minimal overhead for short packets, which is inevitable for efficient low bit rate video communications. Furthermore, for Internet access, IP can be readily implemented over H.223. Although H.223 provides checksum mechanism, corrupted packets are still delivered to the application with error indication. Channel error prevention and control in the data field for video communications will be accomplished by designing error resilient video codec and by using a number of effective channel error control strategies.

The MPS downloads the MPEG encoded video stream from the video server, reconstructs the video sequence, and reformats it appropriately according to the allowable spatial resolution, frame rate, and quality based on both the bandwidth and display hardware of the MH. The reformatted video sequence will be encoded exclusively by using our 3D-SLCCA video coding technique. The reconstructing, reformatting, and encoding by 3D-SLCCA compose the so-called *transcoding*. 3D-SLCCA is advantageous over MPEG due to its high error resilience, which is absolutely necessary for transmission over error-prone wireless channels. Transcoding is also required due to the different hardware capabilities of MHs. The MPS usually receives the video sequence at the highest resolution from the video server, which, based on preferences of the MH and the allowable bandwidth, is reformatted into the most suitable form.

By using video streaming, downloading, decoding, and displaying occur simultaneously at the MH, which considerably reduces both the storage requirement for the MH and the waiting time. In the developed system, when the video server cannot support streaming, the MPS downloads the entire video from the server and streams it to the MH. As usual, work-ahead at the MH is used to hide the delay effect caused either by retransmission due to burst errors, lost packets, or by connection reestablishment.

In video servers, which are designed for wired communications, channel coding is rarely used. In the proposed wireless video communication system, H.223 is used at the data link layer, which may deliver erroneous packets to the application. Both bit errors and burst errors are handled by using our multilayer error control coding mechanism. This means that the MPS embeds parity bits into the bitstream during transcoding.

The MPS is also responsible for caching and retransmission. Since most of the packet losses occur at the "edges" of the network [8], locating caches at MPS not only protects other parts of the network from frequent retransmission, but also considerably reduces latency. The latter is due to the fact that the lost data is to be retransmitted only from the MPS, which is located in the vicinity of the MH, and not from the video server.

Finally, the MPS maintains information about each client. The preferences can be updated by the user of the MH whenever there is a change in the network connection or available resources. Preferences include resolution, frame rate, color depth, etc.

## Source Coding

In the developed system, our 3D-SLCCA [2, 3] video coding technique, which is based on our high performance image coding algorithm termed significance-linked connected component analysis (SLCCA) [9], is applied for video transport. In 3D-SLCCA, the Haar wavelet is used for temporal filtering, i.e., in the time domain, the temporal lowpass and temporal highpass subbands are obtained as the sum and difference of two consecutive frames, respectively. After dyadic spatial decomposition of each temporal subbands, the SLCCA data organization and representation strategy is applied, followed by bit-plane-based high order Markov source modeling and encoding of significant wavelet coefficients. In addition to high coding efficiency, 3D-SLCCA provides scalable transmission, low computational complexity, and transmission error resilience.

## Channel Coding

Error control coding adds redundancy in forms of parity bits to the source bitstream so that transmission errors can be detected and recovered. Since our goal is to transmit video over low bandwidth erroneous channels, the tradeoff between the bandwidth increase and error correction capability must be made. That is achieved by using our three-layer error control coding mechanism, which includes:

- Algorithmic protection with synchronization;
- unequal forward error correction; and
- retransmission.

Frequent synchronization is necessary due to variable length coding (implemented as adaptive arithmetic coding) applied in 3D-SLCCA. Synchronization is implemented by both transmitting the *length* of each coded bit-plane in the beginning of the bitstream with the highest degree of error protection and inserting synchronization characters into the bitstream. Since the model of adaptive arithmetic coder is reinitialized for every bit-plane, decoding can continue from the next bit-plane in the case of *uncorrectable* errors in the current bit-plane.

Reed-Solomon (RS) codes over GF(256) are used for unequal forward error correction. More significant bit-planes are allocated more check bits than less significant bit-planes. In the proposed system, the total number of parity bits is allocated among bit-planes based on the contained energy.

Codec I and Codec II are designed for average BER = 0.001 and BER = 0.01, respectively. While the applied channel codes are shown in Table 1, the resulting bit rates are tabulated in Table 2 for the "Foreman" sequence sampled at 7.5 frames-per-second (fps) and coded at 48k bits-per-second (bps).

The last layer of the developed error control coding mechanism is retransmission. Generally, the main problem with retransmission is the introduced

| Bit-Plane | Codec 0 | Codec I | Codec II |
|---|---|---|---|
| 6 | (120,120) | (104,120) | (80,129) |
| 5 | (120,120) | (104,120) | (80,120) |
| 4 | (120,120) | (110,120) | (84,120) |
| 3 | (120,120) | (110,120) | (84,120) |
| 2 | (120,120) | (110,120) | (84,120) |
| 1 | (120,120) | (114,120) | (88,120) |
| 0 | (120,120) | (114,120) | (88,120) |

Table 1: Applied shortened RS codes.

| Codec | Rate [kbps] | | |
|---|---|---|---|
| | Source | Parity | Total |
| Codec 0 | 48.05 | | 48.05 |
| Codec I | 41.89 | 6.21 | 48.10 |
| Codec II | 33.13 | 15.02 | 48.15 |

Table 2: Bit allocation for the "Foreman" sequence.

time delay. However, in the proposed system, the time delay is substantially reduced by locating the MPS (which caches the video) in the vicinity of the MH. Due to small time delay and decoder work-ahead, retransmission can be successfully applied in the developed system in the case of severe transmission errors occurring at important part of the bitstream. Since least significant bit-planes only marginally contribute to the visual quality, retransmission is only applied when uncorrectable packet errors occur at the three most significant bit-planes.

## PERFORMANCE EVALUATION

The H.223 simulator [10] was extended to incorporate sequence numbering and back channel for retransmission request as specified in the H.223 Recommendation. The wireless link is modeled by Rayleigh fading errors at Doppler speed of 1.4 km/h and 14 km/h. For each speed, the signal-power-to-noise-power ratio $E_s/N_0 = 14$ dB and $E_s/N_0 = 24$ dB are used resulting in average BER = 0.01 and BER = 0.001, respectively (Table 3).

| Symbol | Channel Characteristics |
|---|---|
| C0 | Noiseless Channel |
| C1 | Rayleigh, 1.4 km/h, $E_s/N_0 = 24$ dB, Average BER = $8.99 \times 10^{-4}$ |
| C2 | Rayleigh, 1.4 km/h, $E_s/N_0 = 14$ dB, Average BER = $9.33 \times 10^{-3}$ |
| C3 | Rayleigh, 14 km/h, $E_s/N_0 = 24$ dB, Average BER = $1.09 \times 10^{-3}$ |
| C4 | Rayleigh, 14 km/h, $E_s/N_0 = 14$ dB, Average BER = $9.79 \times 10^{-3}$ |

Table 3: Five different channel error profiles used in the experiments.

The performance of the proposed system for the "Foreman" test sequence sampled at 7.5 fps and coded at 48 kbps among the five channel models is summarized in Table 4. As seen, the importance of error protection increases with decreasing $E_s/N_0$ and increasing Doppler speed. The relatively good performance of Codec 0 demonstrates the excellent error resilience of the proposed 3D-SLCCA source coding technique.

| Channel | Codec 0 | Codec I | Codec II |
|---|---|---|---|
| C0 | 28.77 | 28.06 | 27.40 |
| C1 | 27.32 | 27.43 | 26.85 |
| C2 | 22.78 | 25.24 | 24.94 |
| C3 | 26.15 | 26.84 | 26.75 |
| C4 | 18.33 | 22.15 | 23.18 |

Table 4: Performance evaluation of the three codecs on the "Foreman" test sequence among five different channel conditions.

## CONCLUSIONS

In the paper, an effective and efficient system is developed for supporting mobile access to video information in wireless environments. Further research directions include more realistic wireless channel modeling and more efficient joint source and channel coding.

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