Video Transmission Over an In-Air Acoustic Link

Rameez Ahmed
Northeastern University
Boston MA 02115
rarameez@gmail.com

Laura Dubreuil Vall
Massachusetts Institute of Technology
Cambridge MA 02139
lauradv@mit.edu

Milica Stojanovic
Northeastern University
Boston MA 02115
millitsa@mit.edu

Ranga Narayanaswami
Scientific Systems Company, Inc.,
Woburn, MA 01801-6562
rangan@ssci.com

ABSTRACT

In this paper, we present the development of an in-air acoustic test-bed for rapid proof-of-concept testing of (underwater) communication technologies. In addition to more accurately representing the actual channel when compared to simulation, the test-bed also provides an easy method to introduce channel impairments, such as Doppler distortion, in a controlled manner. This can be advantageous when the experiments need to be reproduced at a later time. We present the testing of video transmission over an acoustic channel using this test-bed. We utilize MPEG-4 video compression as it has efficient low bit rate compression capabilities. OFDM is chosen as the modulation technique as it provides robust high speed acoustic communication over underwater channels which are characterized by frequency selectivity and Doppler distortion.

1. INTRODUCTION

Wireless underwater video transmission has a wide range of applications such as port and harbor surveillance, inspection of submerged experiments, deep sea oil exploration, etc. Most of these applications require video transmission over a short range. Underwater wireless video transmission for supervisory control was considered in [4].

On the one hand, for efficient video transmission over an underwater acoustic communication link, video signals (which typically have high bit rates) have to be compressed in order to meet the low bit rates of the communication link. Because of the recent advancement in compression techniques, readily available compression methods, such as MPEG-4, compress video signals down to 64kbps. On the other hand, modulation techniques used in underwater communications, such as OFDM, allow an efficient use of the limited bandwidth and increase the bit rate supported by the system. New technologies such as wireless LAN (IEEE 802.11) and DSL use OFDM because of its ease of implementation using the FFT/IFFT pair and robustness against frequency selectivity. Differentially coherent detection in frequency [5, 2], which relies on the assumption that a channel is slowly varying between sub-carriers, is employed as the detection technique as it eliminates the overhead of pilot assisted channel estimation while improving the bandwidth efficiency of the system.

The lack of widely accepted statistical channel models for underwater channels requires actual experimentation for the analysis of various communication technologies. Simulations do not provide complete justice, while actual underwater experiments (generally conducted in lakes and rivers) are not only time consuming but also expensive. A mid-way solution is proposed by building an in-air test-bed [1]. Such an approach will provide a more comprehensive analysis of the channel than a computer simulation and, at a lower cost when compared to actual underwater experiments.

2. TEST-BED DESCRIPTION

The in-air test-bed was developed using the EDIROL FA-101 board. EDIROL FA-101, a feature-packed 10×10 audio interface which can handle 10 inputs/outputs at 24-bit/96kHz, is used as the data acquisition interface. The Edirol-FA101 sound card connects to the computer using a high speed IEEE 1394 port. Once correctly set-up, this device can be made to act as the primary sound card for a computer which makes it easier to use MATLAB for signal generation and processing. The transmitter is a multimedia speaker connected to the EDIROL FA-101 board using a stereo to mono $1/8^{th}$ to $1/4^{th}$ inch connector. The receiver is a capacitive microphone connected to the XLR port of the EDIROL FA-101 sound card. EDIROL FA-101 powers the microphone with a 48V phantom power supply through the XLR port.

The transmitter hardware setup is shown in Figure 1 and the receiver hardware setup is shown in Figure 2.

Figure 1: Transmitter hardware

3. SYSTEM DESCRIPTION

Figure 2: Receiver hardware

In this demonstration, we use a 2 seconds video captured using the laptop's webcam, which is then compressed using MPEG-4 compression. This standard combines spatial and temporal compression techniques to provide high compression ratios while maintaining a good visual quality. After compression, the bit rate of the original video (3.4Mbps) is reduced to 64kbps, which has proven sufficient to fit the video into the available bandwidth while providing sufficient visual quality for human perception.

The block diagram of the signal processing at the transmitter is shown in Figure 3.

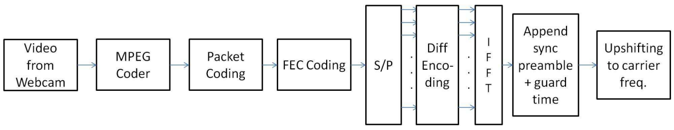

Figure 3: Transmitter block diagram

At the transmitter, after video compression, the bit stream is split into packets and a network coding procedure according to [3] is applied to the packets. Rateless packet coding technique with a redundancy of 10% has been found to be sufficient for robust communication over the in-air acoustic channel. In addition, after network coding, each coded packet is encoded with a BCH(63,18) forward error correction code. These coded packets are mapped to symbols and differentially encoded, followed by the OFDM signal generation. The OFDM parameters used in the experiment are shown in Table 1.

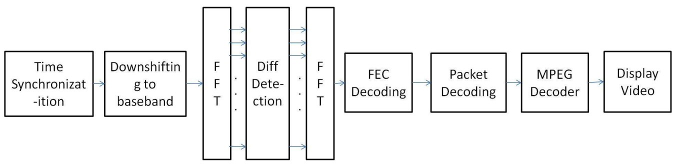

Figure 4: Receiver block diagram

At the receiver (Figure 4), after synchronizing using the synchronization preamble appended to signal and downshifting to baseband, each block is passed through an FFT operation, followed by differential detection. The received packets are fed to the BCH decoder followed by a Gaussian Elimination step in the packet decoder. MPEG-4 decoder decodes the received packets to regenerate the original video and displays it on the screen.

4. RESULTS AND CONCLUSION

The demo consists of real time transmission of a 2 seconds video. The video is captured on one computer and transmitted to another over the in-air acoustic communication link. The video is captured with a resolution of 128 × 96 pixels at 30fps. Two cases are considered for this experiment: with and without motion between transmitter and receiver. The results are summarized in Table 2. The packet coding scheme with a redundancy of 10% and BCH(63,18) code were found to be sufficient to produce a video with enough visual quality for human perception. This test-bed is presented as a supporting experimental demonstration for the short paper "Towards Underwater Video Transmission" submitted to WUWNET'11.

Table 1: OFDM Parameters

Bandwidth B	12kHz
Sampling frequency f_s	48kHz
First carrier frequency f_0	4kHz
No. of subcarriers K	$1024, 16384$
Modulation method	QPSK

Table 2: Results

Frame rate	30fps
Video bit rate	64kbps
Bit rate after coding	164kbps
BER(before BCH decoding, no motion)	10^{-3}
BER(before BCH decoding, with motion)	10^{-2}

5. REFERENCES

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