An OFDM-based Underwater Acoustic Multimedia System

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Abstract: - In this paper, we propose an orthogonal frequency division multiplexing (OFDM) based underwater acoustic multimedia system. An essential feature of this system is that it offers larger power and schemes providing significant error protection for the transmission sensor data information that requires higher quality of service (QoS). To realize maximum resource utilization, or minimum total transmission power, we also include an adaptive modulation strategy into the system. Thus, in the proposed underwater acoustic multimedia system, high power, low speed modulation, and scheme providing significant error protection schemes are employed for the transmission of sensor data messages that require a stringent bit-error rate (BER). In contrast, low power, high speed modulation, and less capable error protection schemes are provided for messages that can tolerate a high BER. A simulation is carried out to verify the proper functioning of the proposed system in a practical underwater acoustic multimedia scenario.

Key-Words: - underwater, acoustic, OFDM, QoS, multimedia, power assignment.

1 Introduction

Underwater acoustic communication scheme is an interesting research topic. [1-11] There are various multiple access schemes such as frequency division multiple access (FDMA), time division multiple access (TDMA), code division multiple access (CDMA), and orthogonal frequency division multiplexing (OFDM). These schemes are similarly to cellular system or wireless local area network (WLAN) in land. The performance of a mobile telemedicine transmission scheme that adopts multi-code code division multiple access (CDMA), or wideband CDMA, or orthogonal frequency division multiplexing (OFDM), or direct-sequence ultra-wideband (DS UWB) techniques has been scrupulously studied in our earlier work [10-15].In addition, an OFDM-based as well as OVSF(orthogonal variable spreading factor)-based transmission architectures of underwater acoustic communication are proposed toward underwater acoustic multimedia communication [10,11]. Research on underwater communication commonly includes investigation of design challenges such as low communication bandwidth, large propagation delay, and high error probability. In [10], we discuss an OFDM-based underwater acoustic transmission scheme for image and audio signals transmission. In this paper, we study the transmission performance of sensor data, audio, and image signals in the proposed multimedia communication system. An essential feature of this scheme is that higher power is allocated to the information that requires higher quality of service. To achieve the purpose of maximum resource utilization, or minimum total transmission power, we also incorporate unequal error protection and adaptive modulation techniques into the proposed power assignment scheme. Specifically, we employ high power, low level modulation, and high level error protection scheme for sensor messages that dictate stringent bit error rate (BER). For a practical underwater acoustic communication scenario, a simulation has been

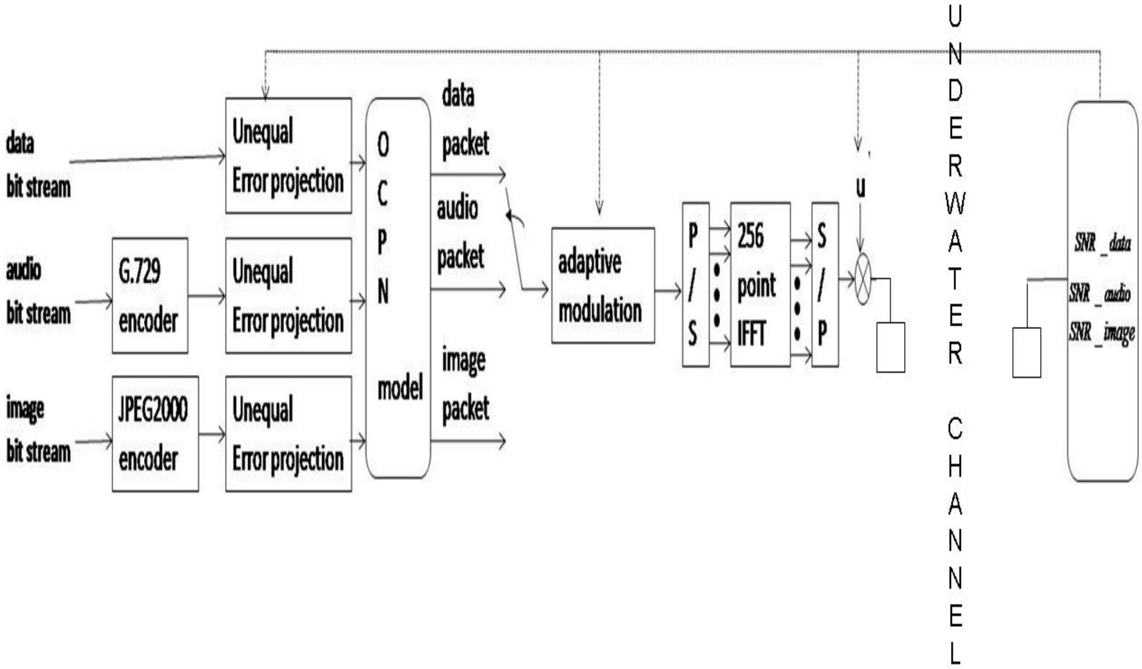

Figure 1 The proposed OFDM-based underwater acoustic communication system

carried out to verify proper functioning of the proposed scheme.

2 OFDM-based Underwater Acoustic Multimedia Communication System

A sketch of the proposed OFDM-based underwater acoustic communication system is depicted in Fig. 1. From this figure we can see that the system under consideration can deal with various types of signals, such as (i) G.729 audio signals, (ii) JPEG2000 image signal, and (iii) data sgnals. Note that processing of pre-orchestrated medical information requires synchronous playback of time-dependent medical data based on some pre-specified temporal relations. For this purpose, a patient needs a model by which temporal constraints among various data objects that must be observed at the time of playback can be specified. In this regard, a well-known model, which is called Object-Composition Petri-Net (OCPN) model [13]. Usually, the QoS requirements for various messages in a wireless medical system are different. Here, we assume that the acceptable bit error rates (BERs) for data, audio, and image packets are 10^{-5}, 10^{-3}, and 10^{-4}, respectively [10-11]. For this purpose, it is assumed that the system can perform unequal power level, as illustrated in Fig. 1. To satisfy the differentiated QoS, we adopt power control strategies and different transmission techniques for different types of packets. Specifically, we impart high transmission power, and low level modulation to data packets that dictate low BER. In contrast, low transmission power, and high level modulation are used for the transmission of audio and image packets that can tolerate less stringent BER. Assume that there are M OFDM symbols in an OFDM transmission packet and there are N sub-carriers in an OFDM symbol. Furthermore, it is assumed that each packet can be modulated independently. Let $S_{n,k}$ denote the complex modulated symbol transmitted in the n-th OFDM symbol over the k-th sub-carrier before the IFFT for the considered OFDM block. Then the transmitted signal after the IFFT can be represented as

$$s_{n,k} = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} S_{n,k} \mu e^{j2\pi k/N} \quad (1)$$

where, μ, $1/30 \le \mu \le 1$, is the transmission power weighting factor. If the underwater channel impulse response is denoted by h_l, the received signal can be expressed as

$$y_{n,k} = h_l * s_{n,k} + n_{n,k} \quad (2)$$

where $*$ denotes convolution and $n_{n,k}$ is the additive white noise of the channel. Thus, the received signal after the FFT, $R_{n,k}$, can be written as

$$R_{n,k} = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} y_{n,k} e^{-j2\pi k/N} \qquad (3)$$

If the sub-carrier spacing Δf is chosen much smaller than the coherence bandwidth and the symbol duration T is much smaller than the coherence time of the channel, then the radio channel transfer function, $H(f,t)$, can be considered constant within the bandwidth Δf of each sub-carrier and the duration T of each symbol $S_{n,k}$. As a result, $R_{n,k}$ can be obtained as

$$R_{n,k} = H_{n,k} S_{n,k} + N_{n,k} \qquad (4)$$

To calculate $R_{n,k}$ from (4), we need to perform channel estimation to obtain estimated channel transfer function $\hat{H}_{n,k}$. The decision on the output is

$$D^{c}_{n,k} = \frac{R_{n,k}}{\hat{H}_{n,k}} = S_{n,k} + \frac{N_{n,k}}{H_{n,k}} \qquad (5)$$

$$\hat{S}_{n,k} = dec\{D^{C}_{n,k}\}$$

For $D^{c}_{n,k,l}$, the receiver makes a decision according to the specified thresholds. We summarize our power assignment algorithm below:

Step 1: Based on the output information of the OCPN, obtain throughputs of data, audio, and image messages for transmissions.

Step 2: Select appropriate unequal error protection and suitable modulation modes to fulfill the requirements of transmissions for an underwater acoustic communication network.

Step 3: Assign original transmission power weighting, μ, $0 < \mu \le 1$, for data, audio, or image packets.

Step 4: Measure the received SNIR's for data, audio, or image packets.

Step 5: If the measured SNIR of the received signal is larger than the threshold SNIR that can result in the required BER, update the transmission power weighting to $\mu = \mu - \Delta$ and go to Step 4. Otherwise, go to Step 6.

Step 6: Increase the transmission power weighting to $\mu = \mu + \Delta$. If $\mu > 1$, re-select the unequal error protection as well as the mode of modulation, and go to Step 3. If $\mu \le 1$, go to Step 4 and repeat the remaining steps.

The parameter Δ depends on the variation in channel fading. The greater the variation in channel fading, the larger is the value of Δ. In addition, the smaller the Δ variation, the larger is the power saving. The rates of channel coding are obtained using 1/2 (561, 753) and 1/3 (557, 663, 771) convolution codes. The possible modulation type, and channel coding for audio, image, and data packets are (1/2, BPSK), (1/2, QPSK), (1/3, BPSK), and (1/3, QPSK). The initial power for audio, image, and data packets is 1/30, and the maximum power is 1.

3 Simulation Results

We performed a simulation to demonstrate the functionality of the proposed OFDM-based underwater transmission system. In the simulation, we used adaptive modulation, power assignment algorithm, and the unequal error protection scheme. Yang's underwater channel model [13] was adopted in this simulation. In the channel model, the transmission range is 10 km with a depth of 100 m, which includes a sediment rock bed at a depth of 40m; the sonic speed is 1572 m/s, with the source end situated in water at a depth of 35 m; further, there are 15 vertical line array receiving terminals, each deployed at a depth of 5 m; the frequency of a carrier wave is 750 Hz, and the bandwidth is 250 Hz. The BER performance of the proposed underwater transmission system is shown in figure 2. We use BPSK modulation, K=9 1/2 (561, 753) and 1/3 (557, 663, 771) convolution codes with soft decoding [19]. In figure 2, we can also observe the performances of 1/2 (561, 753) convolution channel coding with soft decoding, and 1/3 (557, 663, 771) convolution channel coding with soft decoding in the case of BPSK and QPSK modulation. Channel coding can mitigate the noise fading of the proposed OFDM-based underwater acoustic transmission system. The greater the length of spreading codes, the lower is the transmission BER. The transmission power weighting under different noise conditions for the proposed system for BERs of 10^{-3}, 10^{-4}, and 10^{-5} for audio, image, and data packets, respectively, is shown in figure 3 as a function of

N_o, which is adaptive white Gaussian noise. From figure 3, we can observe that higher the noise, the higher is the transmission power. Further, less restrictions on transmission BER result in low transmission power. Figure 4 show the transmission image performance of the proposed OFDM-based system. The BER is 10^{-4} and PSNR is 31.1 dB .We observe that the proposed power assignment algorithm is feasible in the underwater acoustic communication system. Therefore, we can conclude that the proposed system can efficiently transmit audio and image signals. In addition, it can achieve maximum transmission data rates or minimum transmission power.

4 Conclusion

In this paper, we study an OFDM-based underwater acoustic multimedia system. Power assignment mechanism, adaptive modulation, OFDM scheme, and unequal error protection are adopted in the system. he simulation results show that the proposed scheme is a feasible underwater audio and image transmission system. In addition, it can achieve maximum transmission data rates or minimum transmission power.

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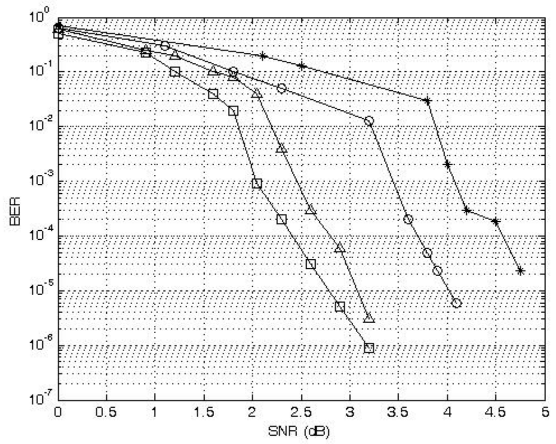

Figure 2 Bit error rate performance of proposed OFDM-based underwater acoustic transmission system. (*:QPSK with channel estimation and 1/2 (561,753) coding; o:QPSK with channel estimation and 1/3 (557, 663, 771) coding; Δ :BPSK with channel estimation and 1/2 (561,753) coding; □:BPSK with channel estimation and 1/3 (557, 663, 771) coding)

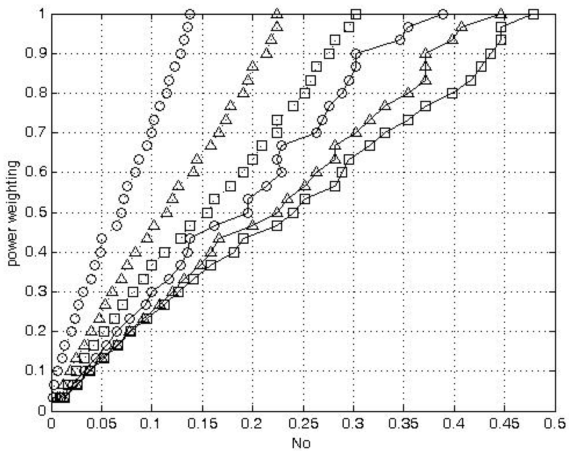

Figure 3 Transmission power weighting under different noise conditions. (□-line: BPSK with channel estimation, 1/2 (561,753) coding, and 10^{-3} ; Δ -line: BPSK with channel estimation, 1/2 (561,753) coding, and 10^{-4} ;o-line: BPSK with channel estimation, 1/2 (561,753) coding, and 10^{-5} ;□- dotted line: QPSK with channel estimation, 1/2 (561,753) coding, and 10^{-3} ; Δ - dotted line: QPSK with channel estimation, 1/2 (561,753) coding, and 10^{-4} ;o- dotted line: QPSK with channel estimation, 1/2 (561,753) coding, and 10^{-5})

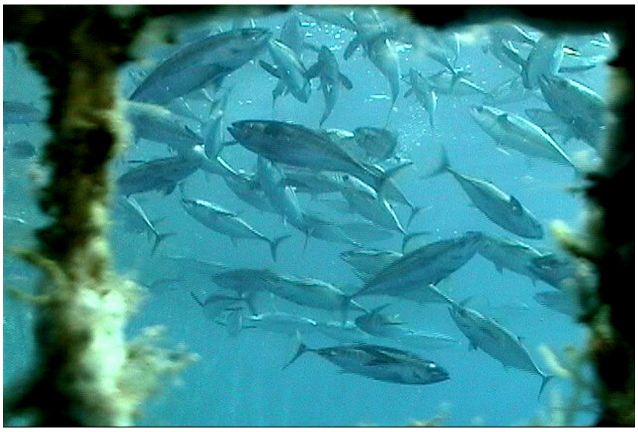

Figure 4 The transmission image performance of the proposed OFDM-based underwater acoustic multimedia system. (PSNR= 31.1 dB .)