Cooperative Relay Selection Based UEP Scheme for 3D Video Transmission over Rayleigh Fading Channel

Ibrahim Khalil Sileh, Khalid Mohamed Alajel, and Wei Xiang
Faculty of Engineering and Survying
University of Southern Queensland
Toowoomba, QLD 4350
Email: *ibrahimkhalil.sileh, khalid.alajel, wei.xiang@usq.edu.au*

***Abstract*—In this paper, we propose an unequal error protection (UEP) scheme for 3 dimensional (3D) video transmission based on dual AF-DF relay selection protocol. In the proposed scheme, we consider an Amplify-and-Forward (AF) and Decode-and-Forward (DF) cooperative diversity together with the unique properties of video plus depth format to improve 3D transmission over wireless networks. We assume that the relays have the ability to perfect error-checking and the source encoded each frame of 3D video data and classify it into two sequences. The former one is the color sequence which is relayed in high reliable scheme by using perfect DF relay and the latter is depth sequence which is transmitted through AF relay. Results show that the proposed scheme improved the quality of color and depth data by exploiting the relay selection diversity, where the color data has better performance than depth data due to channel reliability.**

***Index Terms*—3D video transmission; relay selection; UEP**

I. Introduction

3D video has received increased attention during the last years due to the recent advances in capturing, coding, and display technologies and it is anticipated that the 3D video applications will increase rapidly in the near future. One of the most popular and widely used formats for representing 3DV is video plus depth (V+D) [1]. In Depth Image Based Rendering [DIBR] technique [2], depth map are required to generated good quality of 3D video but does not need to be significantly high to render 3D scene unlike color sequence. Color and depth images need to be transmitted over communication channels to the end user for display. However, the color sequence is directly viewed by the user. Therefore, in transmission, if the color sequence is lost, it will be degraded 3D video quality than the loss of depth sequence. Transmitting 3D video over networks such as the Internet and wireless networks presents new challenges and consumer applications will not gain much popularity unless the transmission problem of 3D video is addressed. However, transmission of 3D video contents is expected to be the next big revolution in multimedia applications.

MIMO system [3], [4] has been proposed to achieve higher data rates and mitigate the effect of fading by realized multiple antennas at transmitter, receiver or both sides to achieve diversity. In practical applications, multiple antennas implementation is unfeasible due to restrictions on hardware, software and limitation of the size. Subsequently, several protocols for cooperative communication have been proposed to improve system performance [5], [6], [7] where the nodes located between the source and destination attempt to help forward information, this will lead to extend the coverage area and further improved system performance [7], [8]. However, this may decrease the system capacity when there is a large number of intermediate nodes and when it is distributed in an arbitrary form. Relay selection (RS) protocol [8], [9] is an efficient technique to solve this problem by choosing a best relay between source and destination to achieve high end-to-end throughput and improving the diversity in a distributed mode. There are two main types of relay which are: amplify and forward (AF) [10] and decode and forward (DF) [11]. In AF protocol, the relay simply amplifies the received signal as well as its own received noise, which is the major drawback of AF protocol and then forwards it to the destination. In DF protocol, the relay decode received signal, which experience error propagation, then re-encoded and forward to the destination. It has been proven that combined AF and DF protocols can be further improve the performance of wireless relay networks by choosing the best relay for transmission [9], [8], [12].

The rest of the paper is organized as follows. Some related work is briefly discussed in Section II. Section III describes the system model and the analysis of relay selection algorithm is given in Section IV. In Section V we show the results obtained with the proposed technique and Section VI concludes the paper.

II. Related work

Many techniques to achieve UEP for multimedia data over MIMO systems have been proposed [13], [14], [15], [16]. All described techniques were obtained through multiple antenna. In [13], joint design between application and physical layers to transmit multimedia data over a closed-loop MIMO system has been proposed, where UEP can be achieved automatically for scalable video. Experimental results show that the proposed system achieved better performance compared with open-loop system. Channel coding and spatial diversity can be combined together to achieve UEP as reported in [14]. In this scheme, more channel coding rate and spatial diversity have been allocated to more important bits, whereas the more spatial diversity and less coding rate to less important bits. To further improve the performance of 3D video transmission, joint source channel coding (JSCC) is an effective method. JSCC scheme for V+D 3D video format was proposed in [17]. In this method, different channel coding rate have been implemented to protect color and depth sequences. The obtained results show that the quality of depth image does not significantly affect the reconstructed quality. Therefore, low protection can be used for depth sequence compare to the color one. In [18], 3D video transmission scheme based on UEP was proposed, where the UEP method assign more protection levels to the color sequence than the depth map sequence. Different levels of protection have been achieved by allocating unequal transmission power to 3D video components.

There are several relay protocols that have been proposed in the past [19], [9], [8], [12]. In [9], a relay selection algorithm alternative to distributed space-time coding was proposed. This algorithm, assumes that all relays can correctly decode the received signal and then the signal was forwarded to destination by a single relay with the maximum destination SNR. One major drawback of this scheme is that the perfect decoding is not always established, especially when errors occur at relays. In [19], [8], a relay selection algorithm (AF) where only one relay node is chosen to relay the source signal has been introduced. The proposed scheme has significantly improve the system performance. However, in the AF selection cooperative system, the one "best" chosen relay not only amplify the signals, but also the noise. Therefore, if the SNR at the relays is low, then the relay mostly forward their own noise. An alternative relay selection scheme based on a hybrid relay protocol has been proposed in [12]. The proposed algorithm divided the relays into two groups, which are AF and DF relay groups and then exploits the advantages of both relay groups. In this case, noise amplification in AF relay and error propagation in DF relay will be avoided. However, non of these algorithms were directly aimed at 3D video transmission. Thus, by exploiting unique properties of 3D video and diversity of relay selection, an improved 3D video transmission system could be archived.

In this paper we propose an improved relay selection scheme based dual relay selection protocol to assign more protection to the color sequence than depth sequence through DF and AF relays respectively. We assume that the relays have the ability to perfect error checking. Since the DF relay has better performance than AF relay [20]. Therefore, we propose to apply the perfect DF relay selection for transmitting color data that has high priority, while the AF relay selection is used for depth data.

III. System Model

The proposed relay selection system is illustrated in Fig. 1, which consists of one source denoted as S, one destination denoted as D, and n relays allocated between S and D. We assume that each node in the system is equipped with a single antenna, and the half-duplex transmission mode is considered. The channels will be experience quasi-static Rayleigh fading, where the channel coefficients will remain unchanged throughout one block but change independently from block to another where each block consists of N frames as shown if Fig. 2.

The complete CSI is known at the destination only and the relay selection is conducted at the beginning of each transmitted block, in which the source broadcasts a training symbols to the relays and destination as proposed in [21]. In this scheme, We assume that the relays have the ability to perfect error-checking and the source encoded each frame of multimedia data and classified it into two sequences. The former one is the color sequence which is relayed in high reliable scheme by using perfect DF relay and the latter is depth sequence which is transmitted through AF relay. In the first time slot, the source broadcast the color sequence to relays appended with CRC.

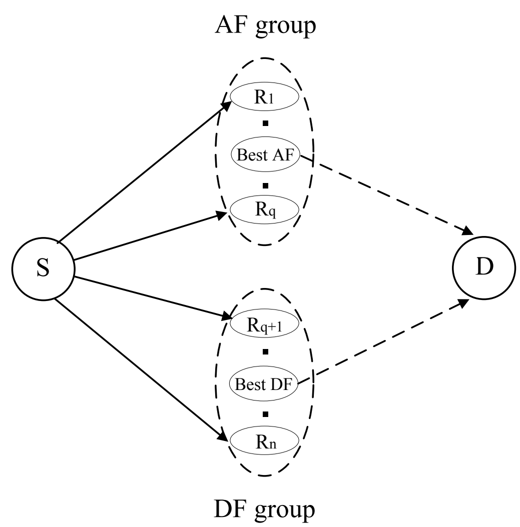

Fig. 1. Relay selection system model

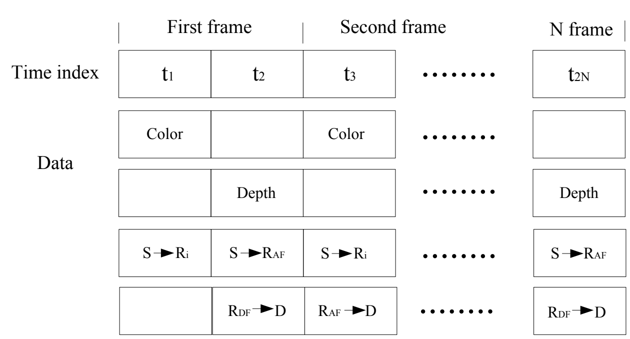

Fig. 2. Time slot organization

The relay which can perform CRC checksum successfully will be included in DF group. In the second time slot, the source will broadcast the depth data to AF relays group, at the same time, the DF group will decode the received signal in first time slot and re-encode and transmit the signal to the distinction. Finally, in the third time slot, the AF best relay will simply amplify the received signal in the previous time slot and broadcast it to the destination, meanwhile the source will broadcast the color sequence of second frame to the relays as shown in Fig. 2.

The channel fading gains between the source-relays and relays-destination are denoted as $h_{sr,i}$ and $h_{rd,i}, (i = 1, ...n)$, respectively. Due to the Rayleigh fading channel,however, the channel power between $S - R_i$, and $R_i - D$ are denoted by $|h_{sr,i}|^2$ and $|h_{rd,i}|^2$ $(i = 1, ...n)$, respectively are independent, exponentially distributed random variables with zero mean and unit variance. In addition, perfect time and frequency synchronization is assumed. The noise at all nodes is additive white Gaussian noise $(AWGN)$ with zero mean and power spectral density N_0.
The received signals at the relay i at time t, in the first slot can be represented as [5],

$$y_{sr,i}(t) = \sqrt{P_{sr,i}} h_{sr,i} x(t) + w_{sr,i}(t), (i = 1, 2, ..., n) \quad (1)$$

where $P_{sr,i}$ is the amount of power received at the relay i. Denotes by $x(t)$ is a unit energy symbol to be transmitted from the source at time t. In addition, $w_{sd}(t)$ and $w_{rd,i}(t)$ are AWGN at the destination and relay i at time t, respectively. The transmitted signal from the relay i at time t denoted by $x_{r,i}(t)$ either from DF or AF group with power constraint,

$$E(|x_{r,i(t)}|^2) \leq P_{r,i} \quad (2)$$

where $P_{r,i}$ is limitation transmitting signal from the relay i in both groups. At time t, the received signal at the destination represented by $y_{rd,i}$, can be described as

$$y_{rd,i}(t) = h_{rd,i} x_{r,i(t)} + w_{rd,i}(t) \quad (3)$$

where $h_{rd,i}$ is the channel fading between the relay i and destination and $w_{rd,i}(t)$ is the AWGN at the destination.

IV. Relay Selection

In this section, we introduce the proposed dual relay selection system. The relays which located between the source and destination have been classified into two groups AF group and DF group. However, before describing the proposed protocol, we will briefly introduce the AF and DF groups.

A. AF group

An AF group consist of the relays that cannot decode the received signal from the source successfully, which mean that the channel between the source and relay is weak. In this case, the relay just simply amplify the received signal by an amplification factor β_i and forward it to the destination. The amplification factor which satisfies the power constrain in (2) and it can be expressed as

$$\beta_i = \sqrt{\frac{P_{r,i}}{|h_{sr,i}|^2 P_{sr,i} + N_0}}, \quad (4)$$

The transmitting signal from the i^{th} relay of AF group, can be written as

$$x_{r,i}(t) = \beta_{i,n} y_{sr,i}, i \in 1, ...q \quad (5)$$

where q is the number of relays in AF group.
The received signal at the destination from the i^{th} relay in the AF group can be denoted as

$$\begin{aligned} y_{rd,i}(t) &= \beta_i h_{rd,i} y_{sr,i} + w_{rd,i}(t) \\ &= \beta_i h_{rd,i} (\sqrt{P_{sr,i}} h_{sr,i} s(t) + w_{sr,i}(t)) + w_{rd,i}(t) \end{aligned} \quad (6)$$

The instantaneous SNR at the destination from the i^{th} relay can be evaluated as

$$\begin{aligned} \gamma_S^{AF} &= \max_i \frac{\frac{P_s |h_{sr,i}|^2}{N_{sr,i}} \frac{P_{ri} |h_{rd,i}|^2}{N_{rd,i}}}{\frac{P_s |h_{sr,i}|^2}{N_{sr,i}} + \frac{P_{ri} |h_{rd,i}|^2}{N_{rd,i}} + 1} \\ &= \max_i \frac{\gamma_{sr,i} \gamma_{rd,i}}{\gamma_{sr,i} + \gamma_{rd,i} + 1} \end{aligned} \quad (7)$$

where $\gamma_{sr,i} = \frac{P_{sr,i} |h_{sr,i}|^2}{N_0}$ and $\gamma_{rd,i} = \frac{P_{rd,i} |h_{rd,i}|^2}{N_0}$.

B. DF group

Each relay in the DF group can recover the received signal from the source s(t) correctly, because the channel between the source and relay substantially good. Therefore, it can make an error free decoding [12]. Finally, the relays re-encoded the received signal and conveys to the destination. The transmitted signal from the j^{th} relay in the DF group to the destination can be given by

$$x_{rd,j}(t) = \sqrt{P_{r,j}} h_{rd,j} s(t) (j = 1, 2, ..., n - q) \quad (8)$$

The received signal at the destination corresponding to the j^{th} relay for DF group can be modeled as

$$y_{rd,j}(t) = \sqrt{P_{rd,j}} h_{rd,j} s(t) + w_{rd,j}(t), (j = 1, 2, ..., n - q) \quad (9)$$

The corresponding SNR at the destination is equal to

$$\begin{aligned} \gamma_S^{DF} &= \max_i \frac{P_{sr,j} |h_{rd,j}|^2}{N_0} \\ &= \max_i \gamma_{rd,j} \end{aligned} \quad (10)$$

where $\gamma_{rd,j} = \frac{P_{sr,j} |h_{rd,j}|^2}{N_0}$ is the instantaneous SNR of the $R_j - D$ link.

$$y_d = \begin{cases} \sqrt{P_{rd,j}} h_{rd,j} s(t) + w_{rd,j}, & \text{for even slots} \\ \beta_i h_{rd,i} (\sqrt{P_{sr,i}} h_{sr,i}) s(t) + \beta_i h_{rd,i} w_{sr,i} + w_{rd,i}, & \text{for odd slots} \end{cases} \tag{11}$$

C. Dual AF-DF RS

In this subsection, we proposed a dual AF-DF relay selection by selecting two relays among n relays by achieving maximum SNR at the destination. The first one, is the best relay from the AF relay group and the latter is the best relay from the DF group. Since the destination has full knowledge of complete CSI of all links, It can calculate the instantaneous SNR for each relay in both groups independently. Then, it will chose the best relay in each group and inform the selective relays by feedback signal and other relays are in idle state. According to the AF group, the destination obtained the weaker link for first and second hop of each relay. Substitute Eq.(6) and Eq(9) in Eq(11) then we have Eq(12)

$$y_d = \begin{cases} y_d^{DF}, & \text{for even slots} \\ y_d^{AF}, & \text{for odd slots} \end{cases} \tag{12}$$

Then selective relay which has the maximum lowest SNR will be chosen as candidate relay. Similarly, the destination chooses the best relay from DF group according to the relays-destination channels regardless to the source-relays channels because it is sufficiently good as we mentioned before. The destination chooses the relay which has the best SNR. Then, the destination decode the received signals from the best relay in AF and DF groups independently.

V. Results and discussion

A. Experimental setup

Two color and depth map sequences, namely Interview and Ballet [22], which represent different motion profile where, Interview is a very slow motion sequence and Ballet has a high motion are encoded at spatial resolution of 720 X 576. The test sequences are encoded using H.264/AVC reference software JM version 16.1 [23]. The encoded parameters are 10 frames, IPPP....sequences with Content Adaptive Binary Arithmetic coding (CABAC). For relay selection, all simulations are performed for BPSK modulation over quasi-static fading channel. The 1/2 code rate for conventional code with generator matrix of (3,7/5).

B. Performance Analysis of Dual AF-DF RS

Fig. 3 shows the simulated BER of coded BPSK modulation at the distention terminal for color and depth sequences for different number of relays in each group versus average SNR. For simplicity, we assume each group has the same number of relays. As we can see from Fig.3, the BER performance for color sequence outperform the depth sequence irrespective to the number of relays in each group due to noise amplification of the AF relay. In case of single relay in each group, the color achieves 2dB gain compare to depth data due to use of DF relays where the channel between the source and relay substantially good. When the number of relays are set to 2, 4, 6 relays in each group, the performance gain was about 3 dB, 3.5 dB, 4.5 dB respectively.

In order to visually illustrate the resulting, we transmitted Interview sequence over Rayleigh fading channel. Fig.4 illustrate the original color image with its associated depth map for Interview sequence. Fig.5 shows (a):the transmitted color and depth sequences over Rayleigh fading channel at SNR=12 dB and number of relays equal to 1 relay and (b):the same sequences at SNR=12 dB and number of relays equal to 3 relays. It can be seen from the Figure that UEP combined with unequal dual AF-DF cooperative diversity performs better in terms of subjective quality.

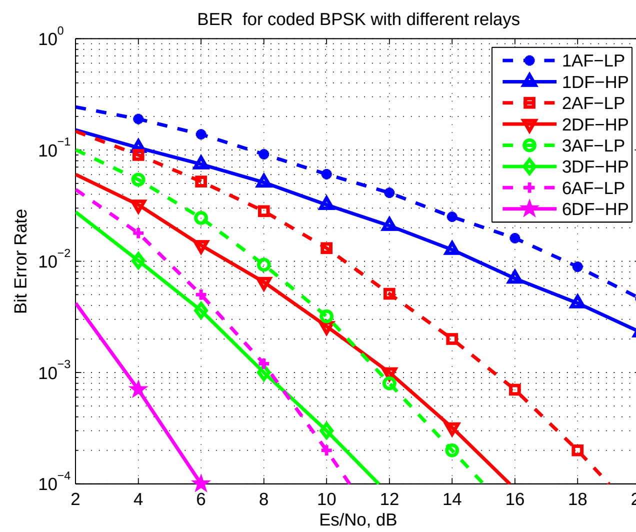

Fig. 3. BER performance with different relays

Color image

Associated depth map

Fig. 4. Color plus depth representation

Color image (a) Associated depth map

Color image (b) Associated depth map

Fig. 5. Transmission over a Rayleigh fading channel at SNR=12 dB with number of relay equal to (a) 1 relay and (b) 3 relays

VI. Conclusion

In this paper we presented an UEP scheme for dual AF-DF relay selection which archives very high performance in fading channels. The proposed scheme can provide different levels of protection in both AF and DF relays for color and depth video sequences. Simulation results show that DF relays can provide a significant performance gain for color sequence compare to AF relays and this gain increases as the number of relays increases. The obtained results show that the color sequence outperform the depth sequence by 3dB, 3.5dB, and 4.5dB when each group consist of 2, 4, and 6 relays, respectively.

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