Effective Relay Communication for Scalable Video Transmission

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***Abstract*—**In this paper, we propose an effective relay communication for layered video transmission as an alternative to make the most of limited resources in a wireless communication network where loss often occurs. Relaying brings stable multimedia services to end clients, compared to multiple description coding (MDC). Also, retransmission of only parity data about one or more video layer using channel coder to the end client of the relay device is paramount to the robustness of the loss situation. Using these methods in resource-constrained environments, such as real-time user created content (UCC) with layered video transmission, can provide high-quality services even in a poor communication environment. Minimal services are also possible. The mathematical analysis shows that the proposed method reduced the probability of GOP loss rate compared to MDC and raptor code without relay. The GOP loss rate is about zero, while MDC and raptor code without relay have a GOP loss rate of 36% and 70% in case of 10% frame loss rate.

***Keywords*—**Relay communication, Multiple Description Coding, Scalable Video Coding

I. Introduction

These days, the same video content could be requested by several clients with different capabilities, e.g., variable available bandwidth and different display size. Scalable video coding is an attractive solution to these heterogeneous problems. The scalable video coding extension of H.264/AVC (SVC) [1] codes a video signal with different spatial, temporal and quality resolutions within the same bit stream, which can be used to adjust the amount of data to be transmitted according to the changes in bandwidth or in terminal capabilities.

Multiple Description Coding (MDC) [2] is an error-resilient video coding technique which has been proposed for use in video streaming systems to deal with packet loss in error-prone environments. MDC codes a video sequence into two or more bit streams, namely descriptions. Each description can be decoded independently to provide a basic level of reproduction quality of the original source, and high quality can be achieved when all descriptions are reconstructed in combination. The different advantages of SVC and MDC have motivated many researchers to look for an approach to integrate them together.

In [3], the authors present a scalable multiple description video coding (SMDC) scheme based on SVC which produces two spatial and otherwise scalable descriptions. Two balanced and standard-compatible multiple scalable descriptions are generated by mixing the pre-encoded scalable bit streams.

However, by using MDC, heavy bandwidth consumption is required to distribute the data from the service provider. In order to reduce the burden on the service provider, cooperative communication is an effective method. Relay Networking is a new method to achieve a space diversity gain in wireless communications, and is based on the concept of the cooperative diversity or collaborative diversity in [4]-[6]. In order to analyze low-complexity cooperative diversity protocols, Laneman et al. [7] introduced incremental relaying schemes using channel state information (CSI) based upon limited feedback from the destination terminal. On the other hand, the proposed method in [8] could choose one of the multiple relays using ready-to-send (RTS) and clear-to-send (CTS) instead of CSI. This reduces additional overhead for CSI and increases the diversity gain using only the best relay.

In this paper, additional data is employed for users who don't receive satisfactory services, by using CSI. Here, the additional data consists of two descriptions using MDC or additional parity through channel coding and relaying. MDC introduces about 39% overhead compared with a single SVC; the overhead is used for channel coding in case of a single SVC and relaying. MDC transfers multiple descriptions through a similar loss channel condition, but our proposed scheme, including the relaying, is a more effective way to respond to the loss. This is because relays are located more efficiently than the end clients.

This paper is organized in the following sections: Section II introduces the proposed method of relay communication. Section III presents a brief summary of SVC and MDC. We analyze our proposed method in Section IV. In Section V, the performance of the proposal is shown as results of experiments. Finally, conclusions are given in Section VI.

II. Relay Communication for Scalable Video

In the relay network, there are several approaches to relay information. Among these, we introduce two kinds: amplify-and-forward (AaF) and decode-and-forward (DaF), as shown in Fig. 1. In Fig. 1, the left uses the AaF method and the right uses DaF. 'S', 'R' and 'D' represent the source, relay and

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destination or end client, respectively. In the case of using the AaF method, R simply amplifies the received data from S and relays it to D, while in DaF, R decodes the received data from S, re-encodes them and relays to D.

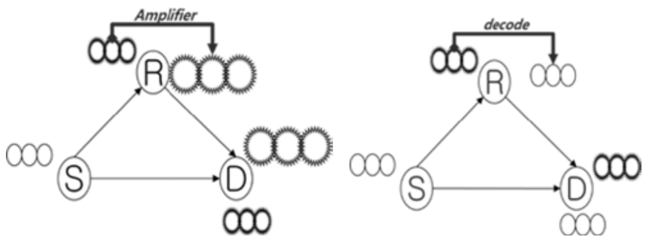

Fig. 1. Two relaying methods.

Each packet of data having different priority is transmitted to the relay. In the relay, high priority data received from the source is decoded using a channel code such as Raptor code, re-encoded, and forwarded to the destination. Then the diversity effect can be further increased: the performance by the use of AaF and DaF approaches is different depending on channel conditions. Using DaF minimize the chance that two identical packets are lost at the both channels. A relay can provide stable and minimum multimedia services to the destination in the network in case of a lot of losses. Using the channel information between the source and the destination, the sender may re-transmit data packets depending on the priorities.

For example, in order to transfer a scalable video such as SVC, the layer information could be considered with the features of AaF and DaF relaying methods. The AaF method has features such as low complexity, slight waiting time until packet forwarding, low latency, but weakness for packet loss. On the other hand, the DaF method has features such as high complexity, long waiting time until packet forwarding, high latency, but strength for packet loss. So AaF and transmission of enhanced layers in SVC is a proper match, and so is DaF and transmission of the base layer. This paper doesn't consider AaF relaying, but DaF relaying only. Because of limited resources, the relay should select lower layers from the multiple layers to forward.

III. Scalable Multiple Description Coding

SVC completely supports spatial, temporal and quality scalability. Temporal scalability can be provided using hierarchical prediction structures, such as hierarchical B-pictures or non-dynamic hierarchical prediction structures. Quality scalability is supported by coarse grain quality scalable coding (CGS) and medium grain quality scalable coding (MGS). Spatial scalability is supported by using multilayer coding. Each layer corresponds to a supported spatial resolution. In [3], two standard compatible scalable descriptions are produced by combining pre-encoded streams coded at different bit rates. In order to produce standard compatible scalable descriptions, we change only the quantization step size to generate low and high bit rate steams. Moreover, in order to combine NAL units of different descriptions at the decoder, both descriptions use the same picture parameter sets (PPSs) and sequence parameter sets (SPSs). Different quantization step sizes are indicated using the slice_qp_delta parameter in the slice header (SH).

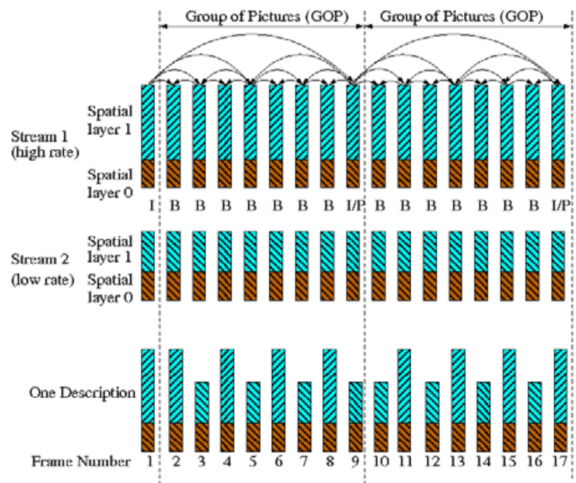

Fig. 2. Illustration of generating two descriptions.

To generate balanced multiple descriptions, the combination of different bit rate streams is performed to assign high and low rate NAL units from alternating frames to a description over a period of two GOPs. In Fig. 2, an example of the proposed combination scheme is shown. As seen, the even numbered frames of the first GOP are from a high bit rate stream and the odd numbered frames of the first GOP are from a low bit rate stream, which is the opposite for the second GOP. This produces two balanced descriptions in terms of bit rate and quality.

At the decoder, a preprocessor before a standard SVC decoder is employed to parse arrived packets and extract the packets from the highest quality bit stream. However, without the preprocessor, each description is still decodable by an SVC decoder. Moreover, any side decoder for an MDC description is not necessary in this scheme. The received packets from both descriptions are parsed and arranged to a new stream which is passed to an SVC decoder.

In this paper, in order to meet the needs of the service on the destination, we compare the performances of MDC and relaying with channel coding in multipath environments.

IV. Proposed Method

As mentioned earlier, users who don't receive a satisfactory service should receive additional data or redundancy. At this point, there are two methods for transmitting several descriptions using an MDC from the source or redundancy using channel coding such as Raptor code from the source and relay. We compared the effects of these two approaches using mathematical definition and analysis. We propose using a relay scheme as shown in Fig. 3.

At first, the source exploits limited feedback from the destination, e.g., a single bit indicating the success or failure of the direct transmission. If the S-D channel is very good, the source transmits original data and parity after Raptor encoding without using relay. But if the source doesn't receive an acknowledgment (ACK), the relay is needed to help the source. The relay receives original data with parity information from the source. Relay selects the low layer or the high layer, decodes, re-encodes, and if relays the parity bits. Finally, destination can combine symbols from the source and the relay without requiring phase synchronization using simple combining such as selective combining in [9].

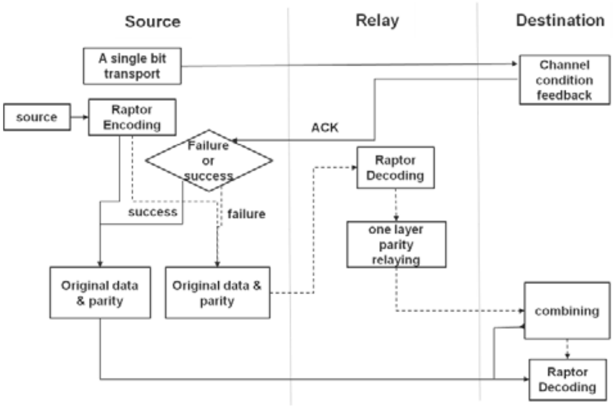

Fig. 3. The relay structure of the proposed scheme.

In this paper, the following parameters are used for mathematical analysis, as summarized in Table I.

In MDC, if any data for an I-picture is not received, a GOP cannot be decoded. Then the probability of a GOP loss is as follows:

$$P_{GOP}(P_F) = \prod_{j=1}^{N_D} P_{GOP}(N_{I_j}, P_F). \qquad (1)$$

Where,

$$P_{GOP}\left(N_{I_j}, P_F\right) = 1 - (1 - P_F)^{N_{I_j}}. \qquad (2)$$

is the probability of a description loss, and $j=1,2,\ \dots,\ N_I$.

Instead of using an MDC, the parity of the Raptor code as

TABLE I
UNITS FOR THE PROBABILITY DEFINED

Symbol	Quantity
N_I	the number of frames per I-picture
N_D	the number of descriptions per GOP
N_F	the number of frames per GOP
N_S	the number of symbols per GOP
N_{x-S}	the number of symbols per GOP from x
n_r	the number of received symbols
n_r'	the number of lost symbols
ℓ_I	the size of I-frame per GOP
ℓ_F	the size of frames per GOP
ℓ_S	the size of symbols per GOP
P_F	the probability of PHY frame loss
P_S	the probability of symbol loss
$P_{R_{x-y}}$	the residual frame loss rate from x to y
P_{x-y}	the frame loss rate from x to y
k	the number of source symbols
ε	received overhead which is showing in n_r-k [9]
d	the duplication of parity from source and relay

I = I-frame, D=description, F=PHY frame, p=parity, S=symbol, x,y=source or relay

redundancy is considered further. In order to determine whether channel conditions are really good or not, the relay has to decide on a threshold and the threshold depends on the user's service requirements. If the number of lost frames is between *0* and $N_{total} - (k+\varepsilon)$, one GOP is not lost. Therefore, using the above parameters, the probability of one GOP loss is

$$P_{GOP}(\varepsilon) = 1 - \sum_{n_r'=0}^{N_{total}-(k+\varepsilon)} \binom{N_{total}}{n_r'} (P_S)^{n_r'} (1-P_S)^{N_{total}-n_r'} \qquad (3)$$

with $P_S = P_F$. Approximating $P_{GOP}(\varepsilon)$ using Poisson distribution gives

$$P_{GOP}(\varepsilon) = 1 - \sum_{n_r'=0}^{N_{total}-(k+\varepsilon)} f(n_r';\ \lambda) \qquad (4)$$

with

$$f(n_r';\ \lambda) = \frac{\lambda^{n_r'} \cdot e^{-\lambda}}{n_r'!}. \qquad (5)$$

When applied to the relay,

$$P_{S-R-D} = P_{R_{S-R}} + (1 - P_{R_{S-R}})P_{R-D} \qquad (6)$$

is the probability of frame loss from S to D via R. Here, $P_{R_{S-R}}$ is the residual frame loss after Raptor decoding at relay. Because $P_{R_{S-R}}$ can be close to *0* using Raptor code, equation (6) becomes P_{R-D}. So N_{total} of equation (4) is changed to $N_{total} = N_{source\ S} + N_{relay\ S}(1-d)$ and $\lambda = N_{source\ \_S} \cdot P_S + N_{relay\ S}(1-d) \cdot P_{S-R-D}$.

V. EXPERIMENTAL RESULTS

In order to determine the efficient relay communication using adaptation of SVC video data transmission, the following configurations are used in Table Ⅱ.

TABLE Ⅱ
THE CONFIGURATIONS USED IN THE EXPERIMENT

software : H.264/SVC reference software JSVM 9.18 [10]
Sequence : Foreman
SVC layer : 2 spatial layers (QCIF, CIF), 4 temporal layers, 1 quality layer
frame loss rate (P_F) : 0 ~ 0.1
PHY frame size (ℓ_F) : 512 bytes
Intra frame size(ℓ_I) : 4435 bytes ~ 8370 bytes
GOP size : 8 frames, 1 I-frame per 1 GOP
Bit rate : 812 kbit/s (first description), 823 kbit/s(second description)

Raptor code is used as the channel code, while the relay used the time-division (TD) of the time sharing cooperative protocol in [4].

Fig. 4 shows the probability of GOP loss according to equation (4) as a function of the frame loss rate (FLR). Equation (4) shows results of the probability of lost GOP using the ε without relaying

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In order to evaluate the performance of our proposed approach with relaying, the frame loss rate (FLR) between S and D was fixed at 10%, the FLR between S and R was fixed at 5%, the FLR between R and D was fixed at 5%, and the failure probability of the Raptor code is 10^{-4} when received overhead ε is about 16 symbols [9].

And *d* duplication of parity frames from S and R was 75%. In MDC, each FLR of two descriptions is 5% and 10%.

As shown in Fig. 5, the 'Foreman' sequence is used as the test sequence. Experimental results were obtained by applying the same criteria in the case of using a relay. Experimental methods are applied to transmission of MDC, single SVC video data without relaying, and single SVC video data with relaying. When using the relay, only the parity of one layer of SVC layers after re-encoding using Raptor decoder was sent to the destination.

In the network in which D can receive data from S through two-channel, the effect of using a relay with FEC (forward error correction) such as Raptor code is compared with MDC. Transmitting the single SVC video data without using the relay gives the highest probability of one GOP loss being the highest. In terms of the probability of GOP loss, using the relay method is better than using MDC.

The overhead for error resilience is used for a second description in case of MDC or parity information in case of relay with Raptor codes. Experiments show that FEC with Raptor codes outperform MDC.

Fig. 6 shows the probability of GOP loss by changing the FLR from 0% to 10%. Using the relay with Raptor code has more benefits than using 2 descriptions across all ranges. But, in case of using only FEC without relay for FLR > 8.4%, FEC breaks down.

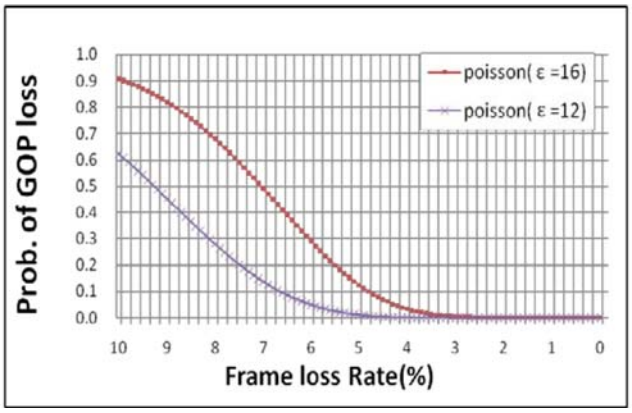

Fig. 4. The frame loss rate and the probability of one GOP loss from source to destination without relaying (k=152)

VI. CONCLUSION

This paper proposed a method for reducing the probability of GOP loss rate of SVC by using relay without increasing the transmission rate. That is, the probability of GOP loss using

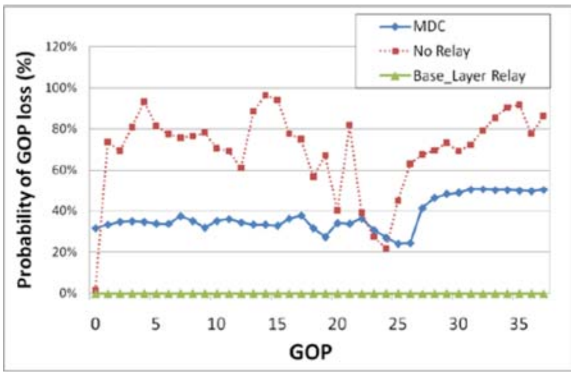

Fig. 5. Comparison of the probability of GOP loss (%) using three different methods. (FLR = 10%)

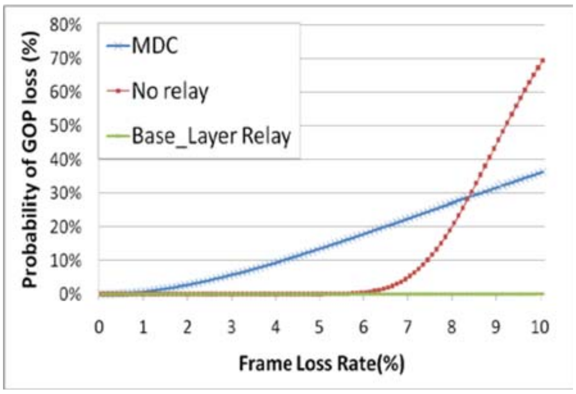

Fig. 6. The frame loss rate (%) and the probability of GOP loss.

base layer relay is 0, while the probability of GOP loss using MDC increases up to 36% for 10% FLR. If the relay knows the channel condition between a base station and end client, relay station can ensure optimal service for the end client. Also, this advanced method can be applied in the field of relay communication or data packet transmission for transmitting data between several clients. Furthermore, this can be used in a mobile ad-hoc network (MANET) consisting of nodes with mobility without the help of the existing infrastructure environment.

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