Efficient MIMO Video Transmission Scheme for the Scalable Video Coding Extension of HEVC

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Abstract—**High efficiency video coding (HEVC) is the newest video coding standard of the ITU-T Video Coding Experts Group and the ISO/IEC Moving Picture Experts Group. The introduction of multiple-input multiple-output (MIMO) eigenbeam-space division multiplexing (E-SDM) systems makes it possible to increase data rate by multiplexing different data streams on multiple parallel eigen-channels. In this paper, we propose a MIMO video transmission scheme for scalable high efficiency video coding (SHVC), which is the scalable extension of H.265/HEVC. Simulation results show that our video transmission scheme has more potential to broadcast video streams efficiently than conventional MIMO systems.**

Keywords—MIMO E-SDM; H.265; HEVC; video coding standard; SHVC

I. INTRODUCTION

Nowadays, there are many professional HD video camcorders. The large size of the video file is created. There must be a convenient way to transport home videos with the same bandwidth with internet connections. This can be done in several ways. The easiest way is compressing video streams a lot, which results in the quality degradation of the videos. Therefore, the compression technology to reduce the video size without affecting image quality is very importance.

The scalable extension of the HEVC standard is the scalable high efficiency video coding (SHVC), which is the newest video coding standard of the ITU-T Video Coding Experts Group and the ISO/IEC Moving Picture Experts Group [1-3] , finalized in July, 2014. This extension includes temporal, spatial and quality scalability. SHVC can compress videos twice as efficiently as the H.264 video coding standard with equal quality. It supports many types of image quality at the same bit rate.

Multiple-input-multiple-output (MIMO) is a wireless system that can transmit and receive signals at greater distances and more economically, and it is popularly used for communication links with multiple antennas [4-5]. This technology has been recognized as one of the most promising technologies for high-performance delivering for today's rapidly growing wireless communications.

Various methods have been proposed for the communication focusing on MIMO systems. Especially, researches have been active on space-time coding (STC), which improves transmission quality while spatial multiplexing techniques can improve transmission rate. MIMO spatial multiplexing is a method of spatially multiplexing data streams by transmitting a plurality of information signals (streams) simultaneously through multiple transmit and receive antennas. This MIMO spatial multiplexing method can be roughly divided into a method of transmitting a stream for each transmit antenna and a method of transmitting a stream for each transmit beam. The former is called a space division multiplexing (SDM) method, and the latter is an eigenbeam-space division multiplexing (E-SDM) method [6]. A brief diagram on the both formulas is shown below. The SDM method is based on almost the same concept as SDMA, where transmit signals are independently sent from each transmit antenna, and at the receiving side, it separates and detects the signals multiplexed by a MIMO channel. On the other hand, when information on the propagation path (channel) situation is obtained at the transmitter side, the signal is transmitted with the weight added in advance to the transmission so that it is easy to separate at the receiver side and to improve the stream quality. That is, smart antenna processing is also performed at the transmitter side. Especially, E-SDM forms a spatially orthogonal optimum stream, and the streams can transmit signals to the receiver side without interfering with each other.

Our system transmits the SHVC videos in MIMO broadcast networks. According to simulation results, the bit error rate (BER) obtained by conventional MIMO systems is higher than that of the proposed video transmission system so much. Especially the base layer has fewer errors than the enhancement layers.

II. MIMO E-SDM

In general, MIMO systems are constructed by N transmit (N-Tx) and L receive (L-Rx) antennas. The $L \times 1$ received signal vector through the MIMO channel is expressed by

$$\boldsymbol{r}(t) = \boldsymbol{A}\boldsymbol{x}(t) + \boldsymbol{n}(t), \qquad (1)$$

where $\boldsymbol{x}(t)$ is the $N \times 1$ transmitted signal vector, $\boldsymbol{A}$ is the $L \times N$ channel matrix expressed by

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$$\boldsymbol{A} = \begin{bmatrix} a_{11} & \cdots & a_{1N} \\ \cdots & a_{ij} & \cdots \\ a_{L1} & \cdots & a_{LN} \end{bmatrix}, \tag{2}$$

and $\boldsymbol{n}(t)$ is the $L \times 1$ noise vector. Each element of $\boldsymbol{n}(t)$ is an i.i.d. complex Gaussian component which satisfies

$$E[\boldsymbol{n}(t)\boldsymbol{n}^H(t)] = \gamma \boldsymbol{I}_L, \tag{3}$$

where $\boldsymbol{I}_L$ is the L-dimensional identity matrix. This is MIMO channel model [6].

MIMO eigenbeam-space division multiplexing (E-SDM) systems can increase channel capacity very much compared with the conventional MIMO-SDM systems. In order to perform a controlled resource allocation and make a transmit weight matrix at the transmitter (TX) side, the channel state information (CSI) is required. The advantage of this system is the priority antenna based sorting based on SNR levels. Figure 1 shows that the unequal quality of subcarriers and spatial streams, where orthogonal transmit beams are formed by the singular value decomposition (SVD) of the channel matrix, which is factorized as

$$\boldsymbol{A} = \boldsymbol{U}\boldsymbol{\Sigma}\boldsymbol{V}^T, \tag{3}$$

where $\boldsymbol{\Sigma}$ is a diagonal matrix whose ith diagonal element can be denoted by σ_i. σ_i is the singular value of the channel matrix. Finally, the beamforming matrix for E-SDM transmission is the right singular matrix $\mathbf{V}$.

The most important thing in the proposed system is that the quality (SNR) of each spatial stream (called eigen-channel) is proportional to the singular value of the channel matrix, $\sigma_1 > \sigma_2 > \cdots > \sigma_N$. The first spatial stream has the highest SNR and the last one is the lowest SNR in that system. The order of SNR values of the orthogonal channels is determined by the singular value of the channel matrix.

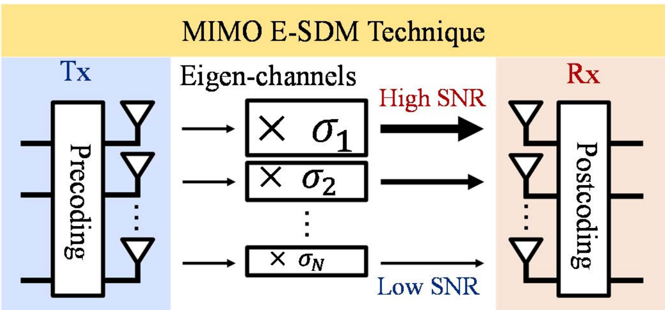

Figure 1. MIMO E-SDM system.

III. Proposed Video Transmission System

Scalable High efficiency Video Coding (SHVC) is the scalable extension of H.265/HEVC that supports SNR, spatial, and color gamut scalability, and bit depth choices [7]. SHVC has a scalable format that can be adapted to network conditions or terminal capabilities. Both scalability and bandwidth savings are a desirable part of an adaptive video streaming application in limited bandwidth wireless networks. In the SHVC scheme, a video sequence is encoded into one base layer (BL) and one or more enhancement layers (EL). An encoded bitstream of a video sequence is made up of multiple NAL units, as shown in Figure 2. The lowest quality video is obtained from the base layer, and the enhancement layer can improve the video quality by using the information of the base layer. For improving the coding efficiency by enhancement layers, interlayer prediction (ILP) is a very important tool. The interlayer prediction is concerned with predicting an enhancement layer from a base layer or the other lower enhancement layers by using the reference index. In the reference index, the picture reconstructed by the base layer is an interlayer reference picture (ILRP) that can know the enhancement layer frame which comes from the base layer or the current enhancement layer. In addition, SHVC as well as HEVC uses the common high-level syntax (HLS) framework, including bitstream structure, coded data unit structures, parameter sets, etc.

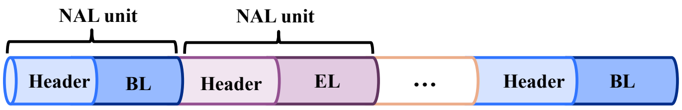

Figure 2. Bitstream of SHVC.

IV. EXPERIMENTAL RESULTS

In the simulations, SHVC-coded videos are transmitted by two MIMO systems; one is the proposed scheme using E-SDM shown in Figure 3, and the other is the conventional SDM. We evaluate the performance of the two systems in terms of bit error rate (BER) of the base and enhancement layers

Our scheme begins from encoding the original video to SHVC by using SHM Reference software [8]. We use a 352×288 color video for encoding and decoding. After encoding, 150 frames are transmitted by the two systems with SNR 10 to 40 dB. Each packet includes 500 bytes from the base layer and 500 bytes from the enhancement layer. This simulation sends packets through 4 antennas at the transmitter to 4 antennas at the receiver. In the conventional SDM MIMO, each packet is sent by random SNR that makes it have more error at the base layer. Base layers are very important for SHVC because they keep all of importance base data. The interlayer prediction in the enhancement layer needs to the base layer data for prediction. The video cannot be decoded if the base layer has many errors. In the proposed scheme, each packet is sent by sorting importance and SNR level. The base layer will be sent via the best SNR spatial streams and the enhancement layer will be sent via lower SNR spatial streams.

The simulation results in Figure 4 show that the proposed scheme has less BER than the conventional SDM MIMO in both of the base and enhancement layers. The base layer has errors only when SNR is 10 dB while the conventional system has errors at every SNR value in both the base and enhancement layers.

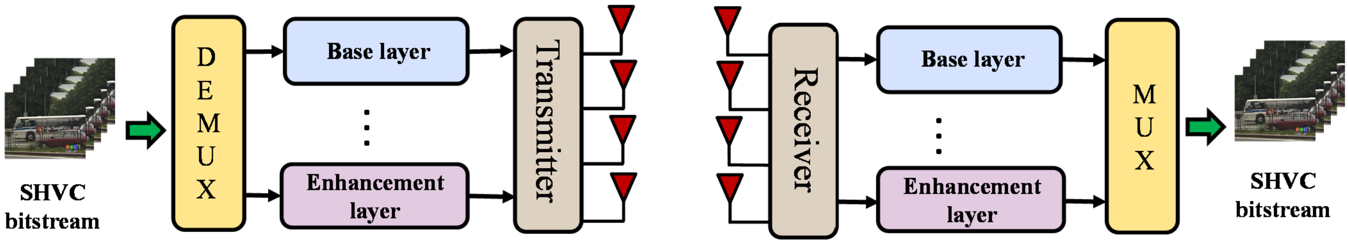

Figure 3. Proposed video transmission scheme for SHVC bitstreams with the MIMO E-SDM system.

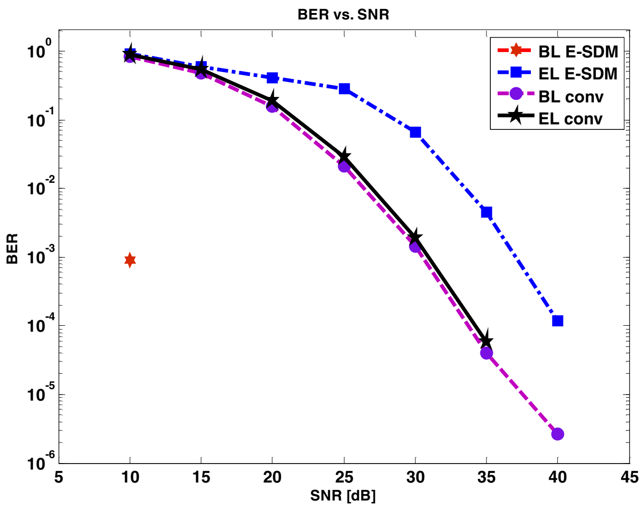

Figure 4. BER of the base and enhancement layers vs. SNR.

V. CONCLUSIONS

In this paper, we have shown that the E-SDM MIMO system has higher performance than the conventional SDM MIMO system when it is used for video transmission. In the scalable video coding extension of HEVC, a base layer is the most important and enhancement layers are used only for improving video quality. Our next task will measure and improve the quality of SHVC video streams.

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