An Efficient 4K and 8K UHD Transmission Scheme on Convergence Networks with Broadcasting and LTE by using Coordinated Multi-Point Transmission System

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Abstract

In this paper, an efficient 4K and 8K UHD(Ultra High Definition) transmission scheme is proposed on the convergence networks with broadcasting and LTE(Long Term Evolution) by using CoMP(Coordinated Multi-Point). A video data is compressed and divided into BL(Base Layer), E(Enhanced layer)1, E2 and E3 by scalable HEVC(High Efficiency Video Coding). The divided layers can be combined by the scalable HEVC such as mobile HD, full HD, 4K and 8K UHD(Ultra High Definition). The divided layers are transmitted through the convergence networks with DVB-T2(Digital Video Broadcasting-2nd Generation Terrestrial) broadcasting system and LTE CoMP. This scheme transmits mobile HD and full HD layers through DVB-T2 broadcasting system by using M-PLP(Multiple-physical Layer Pipes), and adaptively transmits 4K or 8K UHD layer through LTE CoMP with MMT(MPEG Media Transport) server. An adaptive transmitting and receiving scheme in the LTE CoMP system provides 4K or 8K UHD layer to a user according to the user status. The proposed scheme is verified by showing the system-level simulation results which is better BER(bit-error-rate) performance than the conventional scheme. The results show that the proposed scheme provides the stable video contents to the user especially at the cell edge.

Keywords: M-PLP, scalable HEVC, UHD, convergence networks, LTE CoMP

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1. Introduction

In the next generation, the convergence broadcasting service which is combined with a conventional broadcasting and network services is necessary since the broadcasting resource is limited and the capacity of contents is on the increase. The standards such as DVB 2.0 in Eruope, ATSC(Advanced Television Systems Committee) 3.0 in the USA, and ISDB(Integrated Services Digital Broadcasting)-Tmm(Terrestrial mobile multi-media) in Japan have been developed or are being developed[1]. Especially, the transmission scheme of 4K UHD through DVB-T2(2nd Generation Terrestrial) using a M-PLP and scalable HEVC is proposed to overcome the limit of broadcasting resource[2].

However, for 8K UHD, it has the limit to transmit the content through DVB-T2 system since the minimum transmission data rate of 8K UHD is 88 Mbps. 60fps 4K UHD compressed by HEVC needs 22~28Mbps and 60fps 8K UHD compressed by HEVC needs 88~112Mbps for the transmission[3]. **Table 1** shows the transmission data rate according to the video compression schemes. For this reason, the concept of convergence broadcasting service is proposed and currently on study[2].

Table 1. Transmission data rate according to the video compression schemes

Codec \ Quality	HD (1920×1080)	4K UHD (3840×2160)		8K UHD (7680×4320)
		30fps	**60fps**	**60fps**
MPEG-2	16~20 Mbps	64~80 Mbps	90~112 Mbps	360~448 Mbps
H.264	8~10 Mbps	32~ 40 Mbps	45~56 Mbps	180~224 Mbps
HEVC	4~5 Mbps	16~20 Mbps	22~28 Mbps	88~112 Mbps

The concept of convergence broadcasting service is to transmit the low data rate video by a terrestrial transmitting station and transmit the high data rate video by wired and wireless networks. It is efficient for wired and wireless networks to transmit the additional data based on the data from terrestrial transmitting station by using scalable HEVC. Especially, it is necessary to use LTE on the wireless network to provide the high data rate and also mobility stably. However, LTE with MIMO(Multiple Input Multiple Output) technique has interference problem such as inter-cell interference which degrades the reliability[4]. Inter-cell interference degrades the reliability extremely at the cell-edge. To solve that, CoMP is proposed in LTE advanced, 3GPP Release 11, to remove the inter-cell interference factors.

In this paper, an efficient 4K and 8K UHD transmission scheme on convergence networks with broadcasting and LTE by using CoMP transmission system is proposed. The proposed scheme transmits the mobile HD(1280×720) and full HD(1920×1080) layers through the conventional broadcasting system using DVB-T2 and adaptively transmits the 4K or 8K UHD layer through LTE CoMP system connected with MMT server. Video data is compressed and divided into BL, E1, E2 and E3 by using scalable HEVC. The divided layers can be combined as mobile HD, full HD, 4K and 8K UHD by using scalable HEVC. In addition, the proposed adaptive transmitting and receiving scheme provides the reliable BER and the throughput to the moving or fixed user by using LTE CoMP JT(Joint Transmission) system.

2. System and Channel Model

This section shows system model and channel model. The system model consists of scalable HEVC, DVB-T2 broadcasting system with M-PLP, and LTE CoMP with 2 TPs(Transmission Point) connected with MMT server. The channel model is considered for LTE CoMP which consists of 2 TPs of 2×2 MIMO and a precoding scheme. In addition, inter-cell interference and path-loss between UE(User Equipment) and multiple TPs are considered in the channel model.

2.1 Scalable HEVC for 8K UHD

Scalable HEVC encoder compresses 8K UHD data as scalable video layers which are hierarchical. The encoder generates four layers such as BL, E1, E2, and E3. **Fig. 1** shows the scalable HEVC encoder for 8K UHD.

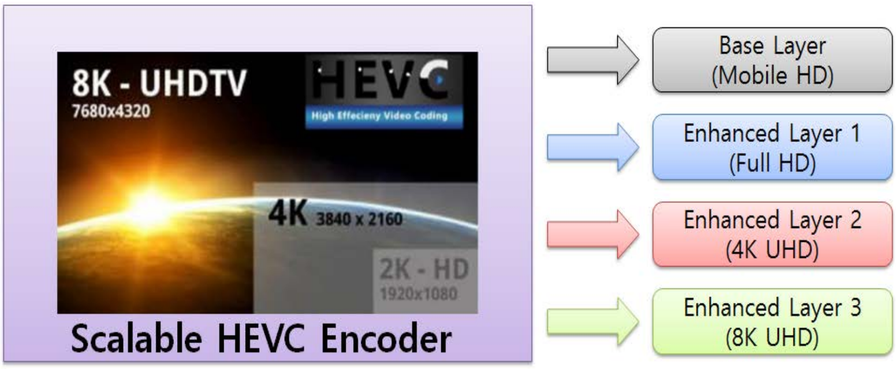

Fig. 1. Scalable HEVC encoder for 8K UHD

Base layer contains the mobile HD data and E1 has the additional full HD data except the part of mobile HD. E2 has the additional 4K UHD data except the lower parts of E2 and E3 also has the additional 8K data except the lower parts of E3. Every layer is dependent on the its lower layers except the base layer. Mobile HD can be played by scalable HEVC with the only base layer, however, full HD or other UHD needs all lower layers of its layer to play it. **Fig. 2** shows the hierarchical structure of scalable HEVC layers.

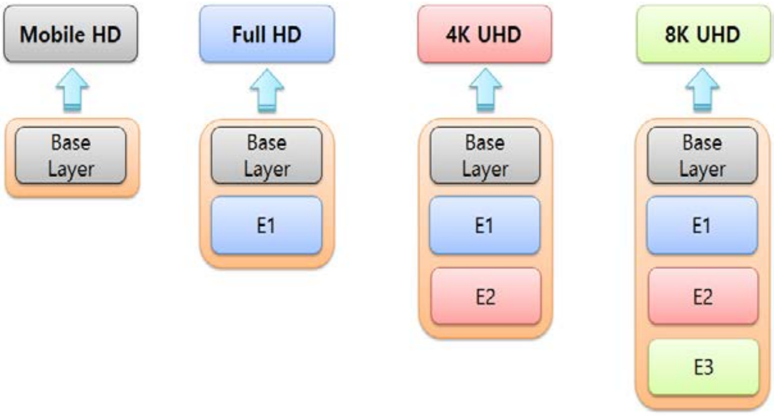

Fig. 2. Hierarchical structure of scalable HEVC layers

2.2 DVB-T2 Broadcasting System with M-PLP

DVB-T2 broadcasting system is to transmit mobile HD and full HD layers. BL and E1 layers are encapsulated with the time-stamp that provides for the receiver to synchronize the layers. Encapsulated layers are transmitted to DVB-T2 multiplexer. The DVB-T2 multiplexer uses M-PLP, and then transmits the multiplexed data to DVB-T2 broadcasting system. The DVB-T2 broadcasting system generates RF signal with received M-PLP data from the multiplexer. **Fig. 3** shows the DVB-T2 broadcasting system model with M-PLP for mobile HD and full HD

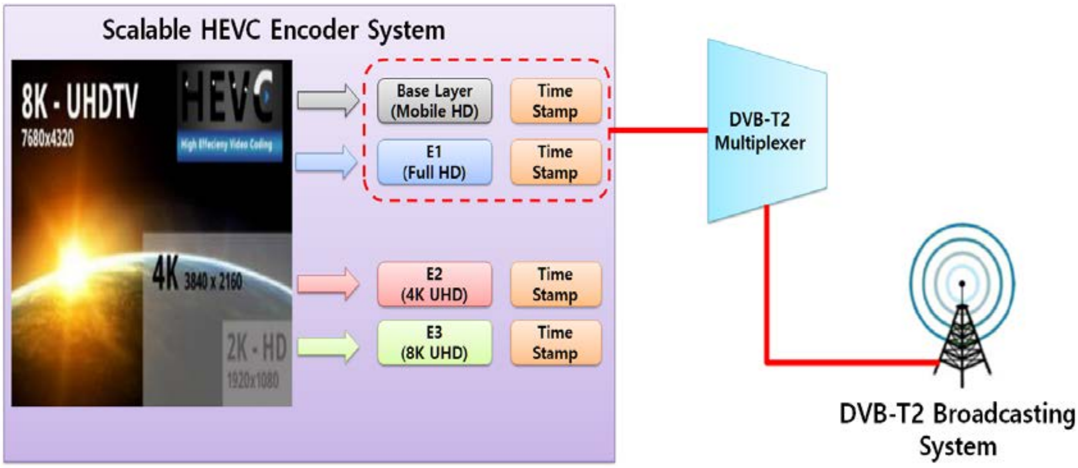

Fig. 3. DVB-T2 broadcasting system model with M-PLP for mobile HD and full HD

M-PLP is designed as 5-PLPs on the multiplexer of DVB-T2. 5-PLP consists of 2 video pipes and 3 data pipes. 2 video pipes are composed with BL and E1. 3 data pipes are composed with XML(Extensible Markup Language) based program information, JPG program image, and XML based MMT server URL. The structure of 5-PLP for DVB-T2 broadcasting system is illustrated in **Fig. 4**. **Table 2** shows the parameters of 5-PLP for DVB-T2 broadcasting system.

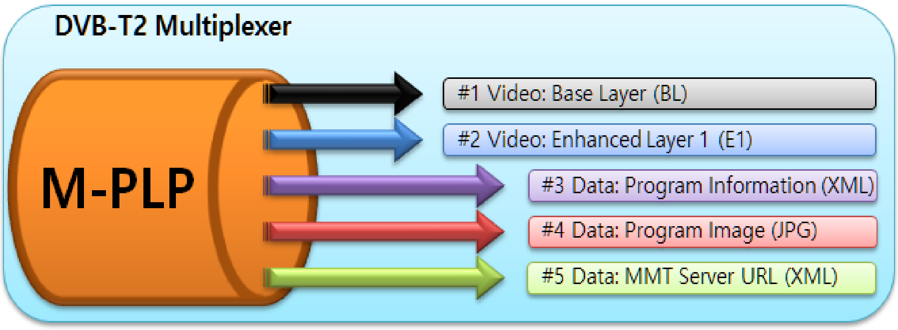

Fig. 4. Structure of 5-PLP for DVB-T2 broadcasting system

Table 2. Parameters of 5PLP for DVB-T2 broadcasting system

Number of PLP	Modulation	Code Rate	FEC	Blocks
0	64 QAM	2/3	64K	20
1	256 QAM	5/6	64K	50
2	16 QAM	1/2	64K	10
3	16 QAM	2/3	64K	10
4	16 QAM	3/5	64K	10

2.3 LTE CoMP System with MMT Server

LTE CoMP system with MMT server provides 4K or 8K UHD data to a user according to CSI(Channel State Information) of the user. E2 and E3 layers are encapsulated with the time-stamp that is the same with BL and E1 layers. The encapsulated E2 and E3 layers are transmitted to MMT server using FTP(File Transfer Protocol). The MMT server would broadcast the 4K or 8K UHD data to LTE CoMP system by UDP if LTE CoMP System requests the data.

The LTE CoMP system consists of 2 TPs which are connected each other by a backhaul and uses the CSI to transmit the data to the user adaptively[4]. One TP is a serving-TP and the other is inter-TP. The multiple TPs transmit the 4K or 8K UHD layer to the user simultaneously. The multiple TPs will transmit the 4K UHD data that consists of encapsulated E2 layer if the CSI of a user is bad. If the CSI of a user is good, the multiple TPs will transmit the 8K UHD data that consists of encapsulated E2 and E3 layers. **Fig. 5** shows the LTE CoMP system model with MMT server for 4K and 8K UHD.

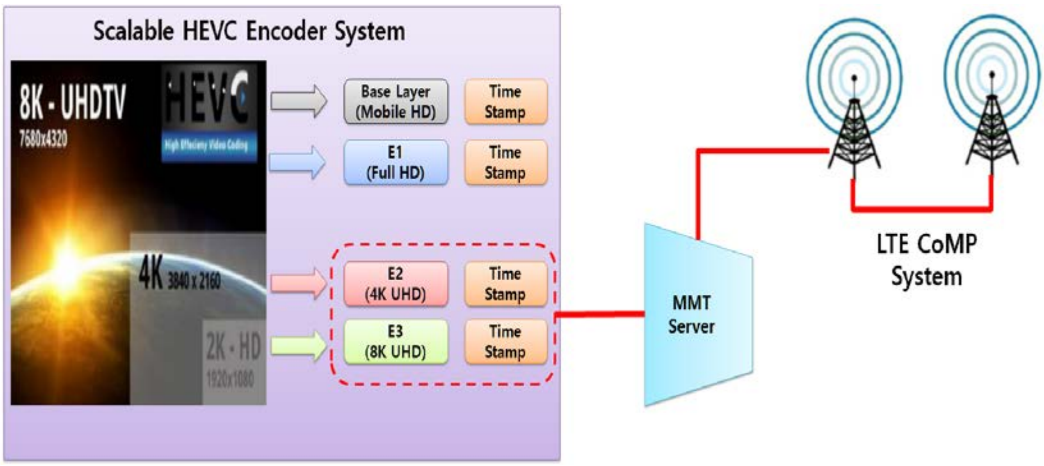

Fig. 5. LTE CoMP system model with MMT server for 4K and 8K UHD

2.4 Convergence Networks Model with Broadcasting and LTE CoMP System

Convergence networks model with broadcasting and LTE CoMP system is designed to broadcast BL and E1 by DVB-T2 with M-PLP, and to transmit 4K or 8K UHD data by LTE CoMP system according to the CSI of a user. UE is designed to receive two different wireless communication signals. Basically, UE receives DVB-T2 broadcasting signal consistently. UE can request 4K or 8K UHD data through LTE communication system by using time stamp data and 5th pipe data in the received M-PLP based DVB-T2 broadcasting signal. LTE CoMP system decides the transmission modulation order by the CSI of UE and receives 4K or 8K UHD data from MMT server using UDP. The received data can be shared among the multiple TPs connected by a backhaul and can be transmitted to UE by using LTE CoMP technology. **Fig. 6** shows the convergence networks model with broadcasting and LTE CoMP system for 4K and 8K UHD.

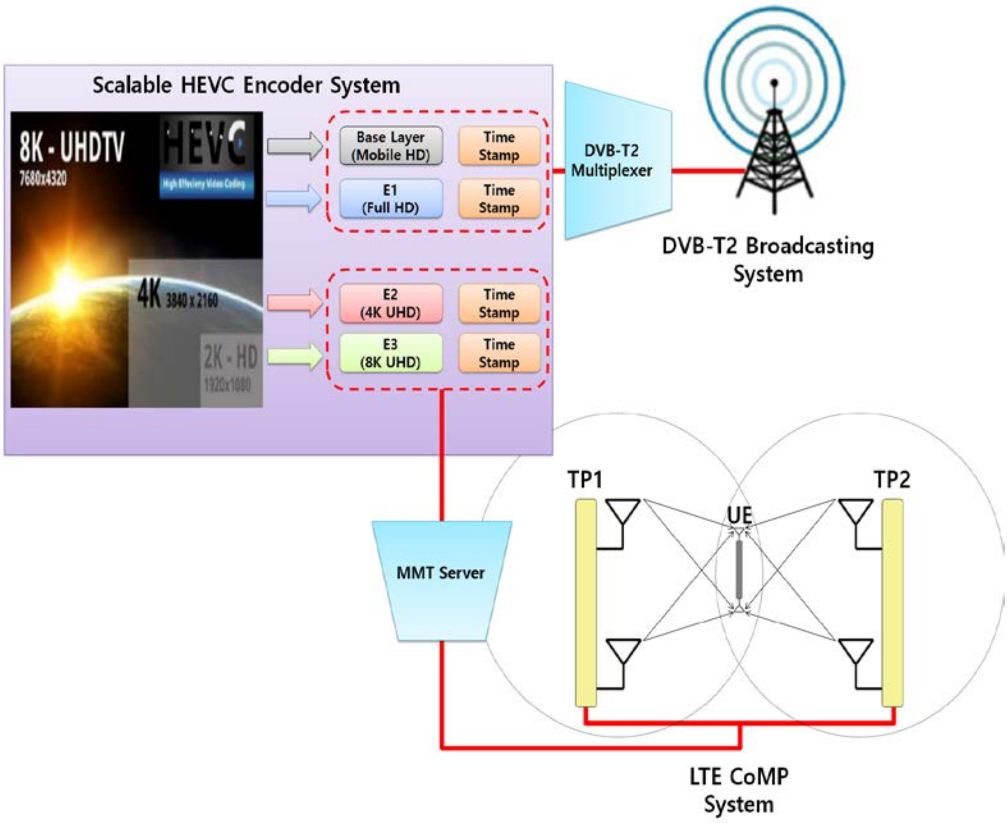

Fig. 6. Convergence networks model with broadcasting and LTE CoMP system for 4K and 8K UHD

2.5 Channel Model

The 2 TPs of LTE CoMP system consider the downlink of 2×2 MIMO with a single UE and ZF(Zero-forcing) precoding. The inter-cell interference and the path-loss are considered to the UE. An AWGN(Additive White Gaussian Noise) is also added to the UE. The received signal of the UE can be expressed as follows:

$$\boldsymbol{Y}_d = \sqrt{\boldsymbol{P}_d}\boldsymbol{H}_d\boldsymbol{X}_d + \boldsymbol{I}_d + \boldsymbol{N}\ , \tag{1}$$

where d refers the distance between the multiple TPs and the UE as the positive number, $\boldsymbol{Y}$ is the received complex signal of the UE, $\boldsymbol{P}$ is the root-mean-square power depending on d, $\boldsymbol{H}$ is the complex channel factor, $\boldsymbol{X}$ is the transmitted MIMO-OFDM signal, $\boldsymbol{I}$ is the inter-cell interference complex factor introduced by inter-TP, and $\boldsymbol{N}$ is a complex AWGN with zero mean. Since the system uses LTE CoMP JT system, $\boldsymbol{I}$ is the transmitted signal by the inter-TP which means that $\boldsymbol{I}$ is the same signal with the serving-TP. In addition, as the system uses ZF precoding, the resulted received signal of the UE can be expressed as follows:

$$\boldsymbol{Y}_d = \sqrt{\boldsymbol{P}_{1,d}}\boldsymbol{H}_{1,d}\boldsymbol{W}_{1,d}\boldsymbol{S}_d + \sqrt{\boldsymbol{P}_{2,d}}\boldsymbol{H}_{2,d}\boldsymbol{W}_{2,d}\boldsymbol{S}_d + \boldsymbol{N}, \quad (2)$$

where the subscripts of 1 and 2 indicate the cooperative multiple TPs, $\boldsymbol{W}$ is the precoding vector, and $\boldsymbol{S}$ is the MIMO-OFDM symbols.

Precoding is a signal processing technique by using the CSI to achieve high spectral efficiency before transmission[5]. Since ZF precoding is based on the inverse matrix of the channel[6], it is the most common linear precoding technique. The ZF precoding vector, W_{ZF}, is expressed as follows:

$$\boldsymbol{W}_{ZF} = \beta\boldsymbol{H}^H(\boldsymbol{H}\boldsymbol{H}^H)^{-1}, \quad (3)$$

where β is the constant factor of a total power constraint. $(\cdot)^H$ is the conjugate transpose operation and $(\cdot)^{-1}$ is to transform into inverse matrix.

Scalable HEVC encoder compresses the video data dependently as scalable video contents. The encoder

3. Conventional CoMP Joint Transmission Scheme

In wiress communication system, the interference from other signals makes the throughput inferior. Especially, the throughput is decreased very sharply at the cell edge by the interference caused by inter-cell. For dealing it, some schemes called CoMP are proposed in LTE-A. CoMP is a promising concept to reduce inter-cell interference in 3GPP Release 11[7]. **Fig. 7** shows JP(Joint Processing) techniques of CoMP.

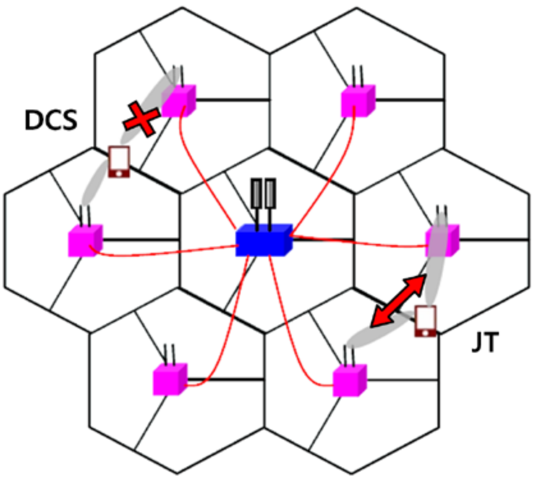

Fig. 7. Joing processing techniques of CoMP

CoMP DCS(Dynamic Cell Selection) is one of CoMP JP(Joint Processing) techniques, only one TP transmits the data to UE and it makes the other TPs silent. The other technique of CoMP JP is CoMP JT, the multiple TPs transmit the same data to the UE simultaeously. The transmission data and CSI between the multiple TPs and the UE are shared by the backhaul among the multiple TPs. The UE can get more reliable data, however, the usage of transmission resource is increased.

4. Proposed Efficient 4K and 8K UHD Transmission Scheme

Fig. 8 shows the moving UE model of the downlink 2×2 single user-MIMO with two TPs.

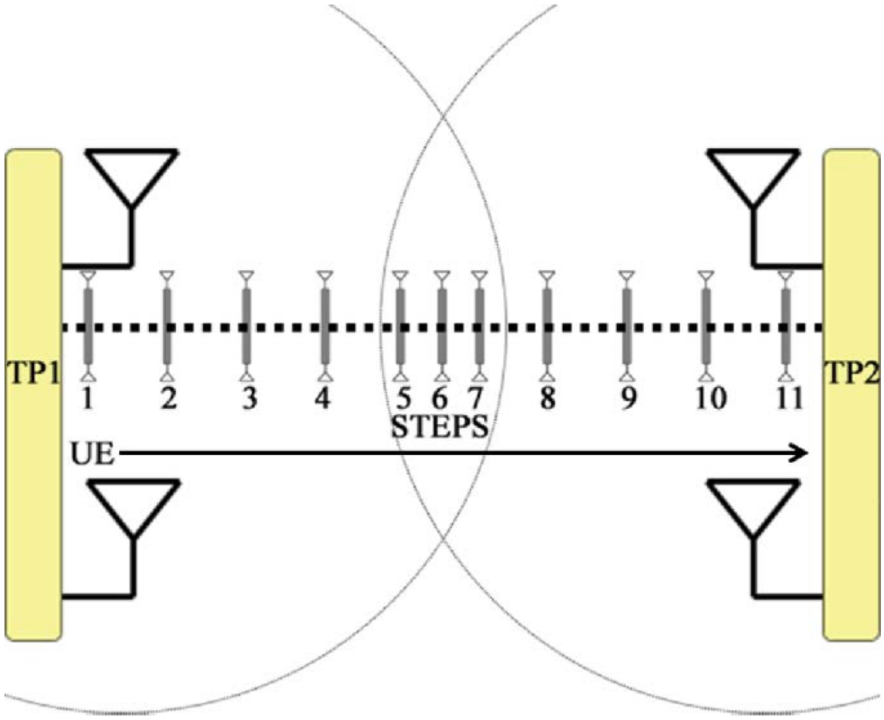

Fig. 8. Moving UE model of the downlink 2×2 single user-MIMO with two TPs

The conventional CoMP JT scheme transmit the same data to the UE simultaneously[7]. It provides more reliable data rate. However, even using CoMP JT, when the UE moves or fixed at the cell-edge, it cannot provide reliable data rate. The main reason is that the 8K UHD needs more 4 times data rate than the 4K UHD. The proposed scheme is that the multiple TPs transmit the 8K UHD when the UE is close at the TPs and transmit the 4K UHD when the UE is at the cell-edge or moving quickly. The UE can receive the precoded signals from multiple TPs and decode the signals adaptively by using scalable HEVC. **Table 3** shows the adaptive transmission scheme with CoMP JT for 4K and 8K UHD.

Table 3. Adaptive transmission scheme with CoMP JT for 4K and 8K UHD

State	Transmission Contents
Step 1, 2, 3, 4	E2 + E3
Step 5, 6, 7	E2
Step 8, 9, 10, 11	E2 + E3

The UE receives a base layer and E1 layers through M-PLP based DVB-T2, and E2 and E3 layers through LTE CoMP. It is necessary to synchronize the transmitted data from convergence broadcasting systems with different networks. In real, network delay is inevitable. Therefore, the Scalable HEVC encoder adds the time stamp data to the base layer and enhanced layers before sending the layers to DVB-T2 broadcasting system and LTE CoMP system.

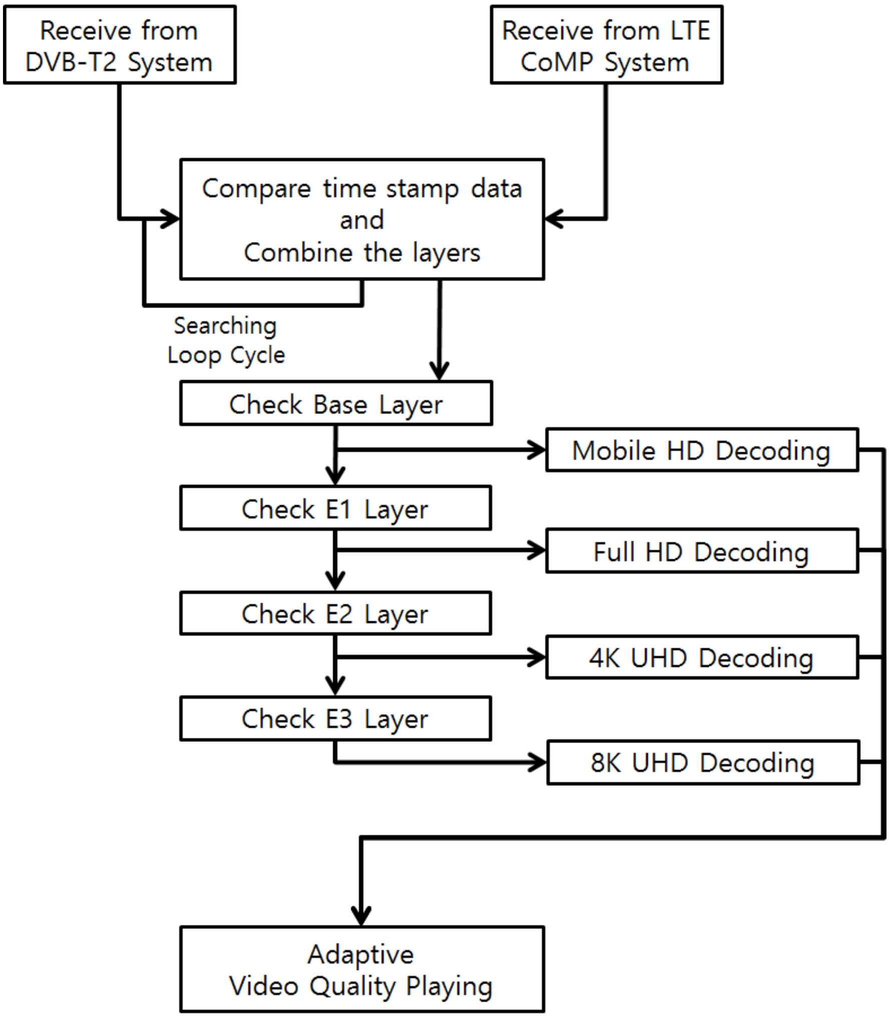

Fig. 9. Flow chart of adaptive receiving and decoding the scalable HEVC layers of 4K and 8K UHD

The UE uses the time stamp data to synchronize the layers transmitted from different networks and to decode the layers. When the UE receives the layers, it compares the time stamp data of layers in loop cycle. The UE combines the layers of same time stamp data, and decodes the combined layers by using scalable HEVC decoders. The scalable HEVC decoder checks the layers in consecutive order since the encoded layers are dependent on the upper layer successively. The decoder adaptively decodes the layers into mobile HD, full HD, 4K UHD, and 8K UHD according to the kind of the highest enhanced layer from the received layers. **Fig. 9** shows the flow chart of adaptive receiving and decoding the scalable HEVC layers of 4K and 8K UHD.

5. Simulation Results

In this section, the system-level simulation is conducted to show the BER and throughput according to the 11 steps of the moving UE model. OFDM with 1024 subcarriers, 64 QAM for 4K UHD and 256 QAM for 8K UHD, 1/4 CP(Cyclic Prefix) rate are considered. The transmission bandwidth is 20 MHz and the interval of subcarriers is 15 kHz. A convolutional code with 1/2 is used for FEC(Forward Error Correction). Rayleigh channel has 7 path lengths and the transmission power is assigned uniformly. The throughput can be expressed as follows:

$$Throughput = \frac{N_{bit} \times (1 - p(e))}{N_{sym} \times N_{FFT}} \ (bit / subcarrier), \tag{4}$$

where N_{bit} is the number of transmitted data bits, $p(e)$ is the BER, N_{sym} is the number of OFDM data symbols, and N_{FFT} is the number of subcarriers.

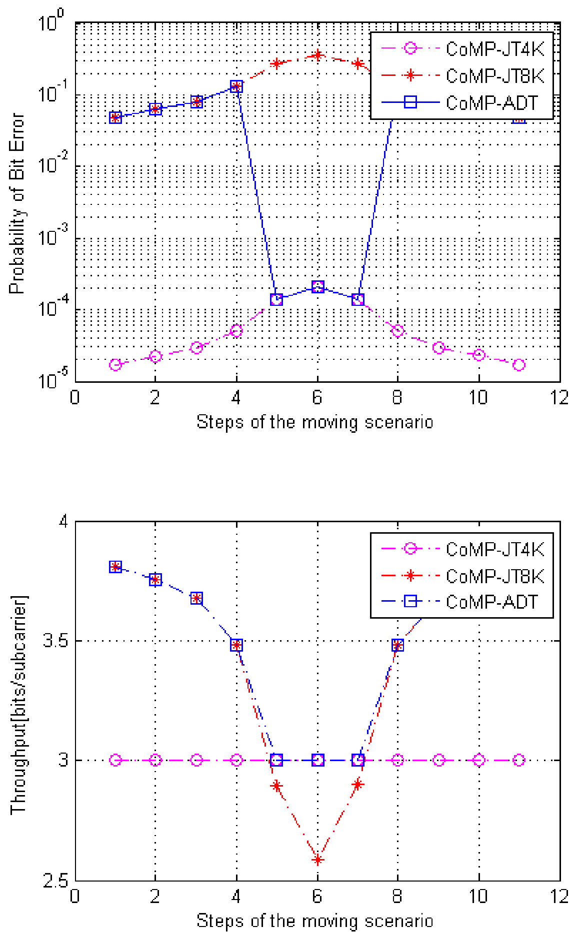

Fig. 10. BER and throughput performances of the conventional and the proposed shcemes accroding to the steps

Fig. 10 shows the BER and throughput performances of the conventional and the proposed schemes according to the steps. It is shown that the proposed scheme adaptively traces the route of the conventional shcemes depending on the UE steps. At the cell-edge, the step of 5, 6, and 7, since the BER performance is rapidly improved, it could be guessed that the throughput of the proposed scheme would be more decreased than 8K. However, the througput of the proposed scheme is also improved rather than 8K. That means it is more efficient to tranmit the 4K data rather than 8K data at the cell-edge. This shows that the proposed scheme improves the performances remarkably.

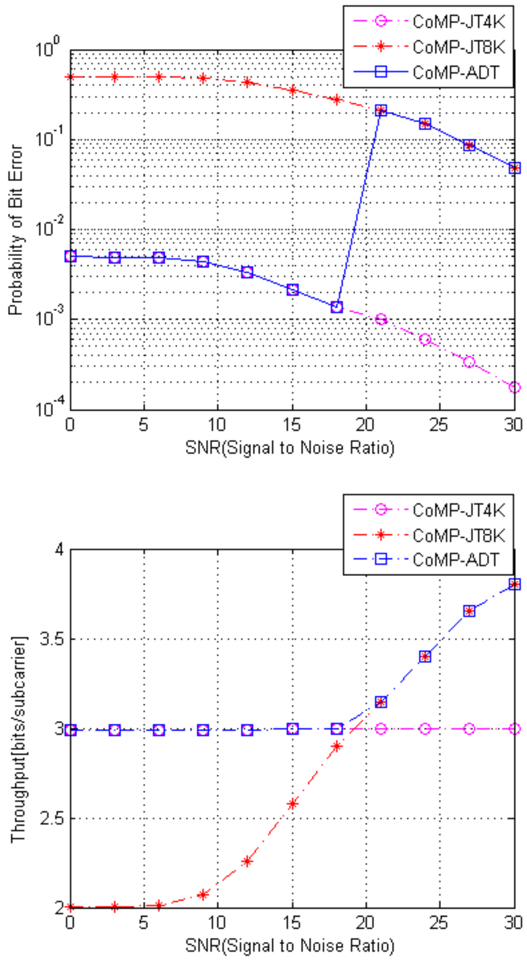

Fig. 11. BER and throughput performances of the conventional and the proposed schemes accroding to the SNR

Fig. 11 shows the BER and throughput performances of the conventional and the proposed schemes according to the SNR(Signal to Noise Ratio). It is also shown that the proposed scheme adaptively traces the route of the conventional shcemes depending on the SNR. When the SNR is under 18 dB, the multiple TPs transmit 4K UHD data to the UE. When the SNR is more than 18 dB, the multiple TPs transmit 8K UHD data to the UE. The SNR of 18 dB in

CoMP JT is same as the SINR(Signal to Interference plus Noise Ratio) of 5 dB in no CoMP. SINR can be expressed as follow:

$$SINR = \frac{P_S}{I + N}, \tag{5}$$

where P_S is the power of the incoming signal. When the SINR is under 5 dB, the power ratio of inter-cell interference and transmitted signal is over 0.4. As the result of **Fig. 11**, it is shown that when the transmission changed from 8K to 4K, the BER performance is rapidly improved. Since that, it could be assumed that the throughput of the proposed scheme would be more decreased than that of 8K, however, the simulation results shows that it is more efficient to tranmit the 4K data rather than 8K data. The system-level simulation results show that the proposed scheme improves the performances remarkably.

6. Conclusion

In this paper, an efficient 4K and 8K UHD transmission scheme on convergence networks with broadcasting and LTE by using coordinated multi-point transmission system is proposed. Especially at the cell-edge, transmitting 4K UHD looks like more inefficient than 8K UHD, however, the proposed scheme shows that transmitting 4K UHD at the cell-edge is more efficient than 8K UHD. It is expected that the next-generation convergence broadcasting system would provide more reliable 4K and 8K UHD contents for moving and fixed user. Also, it is expected that as the proposed scheme will be implemented to DVB-T2 system and CoMP system, the field test will be conducted.

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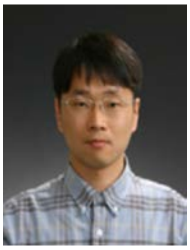

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