

# 3DTV System for HFC Network

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**Abstract**— In this paper, we propose 3DTV systems and introduce demonstrations for providing 3DTV service over HFC network. We introduce two types of 3DTV system using single broadcasting channel or multiple communication channels to broadcast or transmit 3DTV contents over HFC network, respectively.

The 3DTV system using single broadcasting channel has an advantage being compatible with the current digital cable broadcasting system except 3DTV camera, video multiplexer and demultiplexer added to capture and process the stereoscopic 3DTV video contents. By using downstream channel bonding scheme, another 3DTV system also has an advantage enabling to transmit massive broadcasting contents for 3DTV and UHDTV services. Those massive broadcasting contents usually requires much larger bandwidth than that of single broadcasting channel.

In order to verify the proposed 3DTV systems, we have conducted demonstrations and provided the real 3DTV services over HFC network during the KCTA 2009 Digital Cable Show held in June, 2009. The 3DTV systems are expected to be used and referred for developing 3DTV standards and conducting the real 3DTV broadcasting trial services in Korea.

**Keywords**— 3DTV, 3DTV System, 3DTV Service over HFC Network, Channel Bonding, DOCSIS 3.0

## I. INTRODUCTION

As digital broadcasting services have been rapidly deployed in recent years, more sensational and realistic broadcasting services such as 3DTV and UHDTV are attracting viewer's interests. Some domestic demonstration trials for 3DTV service were introduced during 2002 Korea-Japan World Cup event as described in [1], [2]. Recently, among TV broadcasters and cable operators, the interests for providing 3DTV services have been increased to add new revenue to their businesses. But, there are some obstacles preventing wide deployment of the new services.

First, there is no technical standard providing interoperability between the 3DTV systems. For example, regarding 3DTV display, there are a couple of types of 3DTV display, and each type of display supports different display modes. For example, because some of 3DTV displays support only polarized filtering mode to display 3DTV contents and others support shuttering glass method, consequently they are not interoperable with each other.

Another obstacle is the transmission bandwidth. The current data bandwidth of single cable broadcasting channel is enough to transmit single HD broadcasting content. But, some of 3DTV contents require much more bandwidth than that of single broadcasting channel, because 3DTV contents are acquired by multiple cameras. As a result, the total data rate of the 3DTV contents is much higher than that of HD contents. Moreover, regarding the data rate of UHDTV contents and current compression technologies for video data, several broadcasting channels are needed to transmit single UHDTV content over HFC network.

In this paper, in order to transmit massive broadcasting contents for 3DTV or UHDTV service, we propose a 3DTV system supporting downstream channel bonding defined in DOCSIS 3.0 specifications [3]. We also propose a 3DTV system which is compatible with the current digital cable broadcasting system. The configurations of each 3DTV system and key technologies used in demonstrations are introduced as well.

This paper is organized as follows. In section II, the architectures of the conventional digital cable broadcasting system and 3DTV systems are described and compared. In section III, key technologies and equipments for providing 3DTV service over HFC network are described, and then demonstrations conducted during an exhibition event are briefly introduced in section VI. Finally the conclusion remarks are given in section V.

## II. 3DTV SYSTEM CONFIGURATION

Figure 1, 2, and 3 show the configurations of the conventional HD broadcasting system, 3DTV system using single broadcasting channel, and 3DTV system using multiple communication channels, respectively. In this section, the overall architectures of the 3DTV systems used for demonstrations are described and compared with each other. The figures in this section may show the minimum of equipments needed to transmit HD or 3DTV contents over HFC network.

First, the conventional HD broadcasting system shown in Figure 1 consists of HD camera, encoder, modulator, up-converter, combiner, HD STB and HD display. HD camera captures digital video, encoder compresses the video contents for delivery. The modulator, upconverter and frequency

combiner generate RF signal. HD STB receives and decodes HD video contents, and HD display presents the HD contents.

Second, the 3DTV system shown in Figure 2 uses a single broadcasting channel. Compared to the conventional broadcasting system, this system has more equipments added to process the stereoscopic HD contents. The added equipments are 3DTV camera, 3DTV video multiplexer, 3DTV demultiplexing module in the 3DTV receiver, and the 3DTV display. The configuration of this system is very similar to that of the current digital cable broadcasting system except those added equipments. The 3DTV camera captures stereoscopic contents, and then 3DTV video multiplexer converts the stereoscopic contents into the side-by-side format being compatible with full HD format. The 3DTV demultiplexing module in the 3DTV receiver restores stereoscopic 3DTV contents from the side-by-side HD contents. Other than those added equipments for providing 3DTV service, the equipments for HD digital cable broadcasting service can be commonly used.

Third, the 3DTV system using multiple communication channels is more complex than the other two systems. This system is using channel bonding scheme which combines multiple downstream channels to transmit 3DTV contents. As a result, this system can provide much more transmission bandwidth than that of single broadcasting channel. To support downstream channel bonding, this 3DTV system consists of two sub-systems. Each sub-system has several components to transmit or receive the 3DTV contents over multiple downstream channels. The first sub-system is used to transmit the 3DTV contents, and includes a headend CM(Cable Modem) and a frequency combiner. The headend CM may include DEPI(Downstream External PHY Interface), modulator, and RF modules in it. Another sub-system is used to receive and display the 3DTV contents. This sub-system consists of terminal CM module to receive data packets containing 3DTV contents, a STB or decoder module, 3D processing module to demultiplex the stereoscopic contents, and 3DTV display.

Equipments added for providing 3DTV services over HFC network are described in more detail in section III.

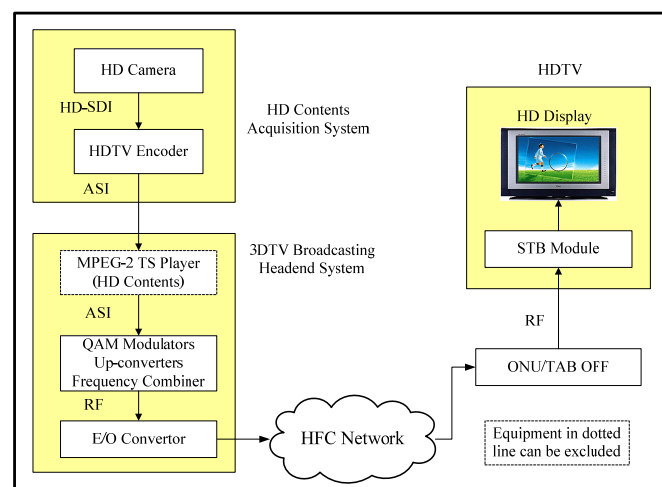


Figure 1. HDTV Broadcasting System Configuration

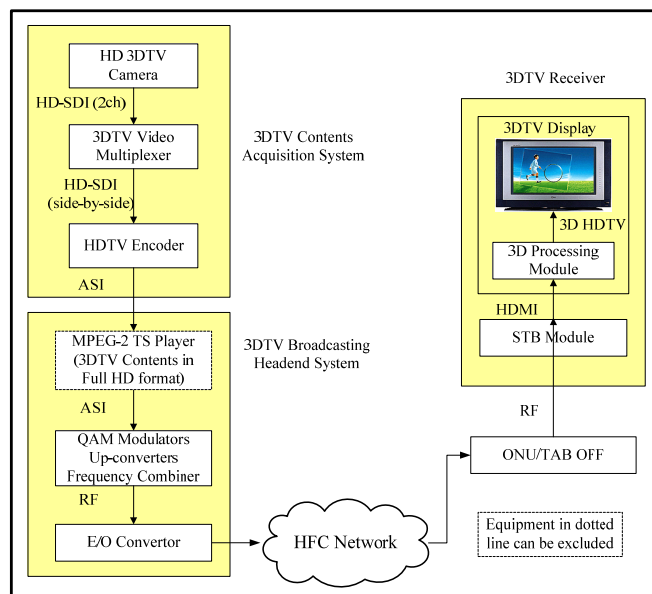


Figure 2. 3DTV System Configuration (using Broadcasting Channel)

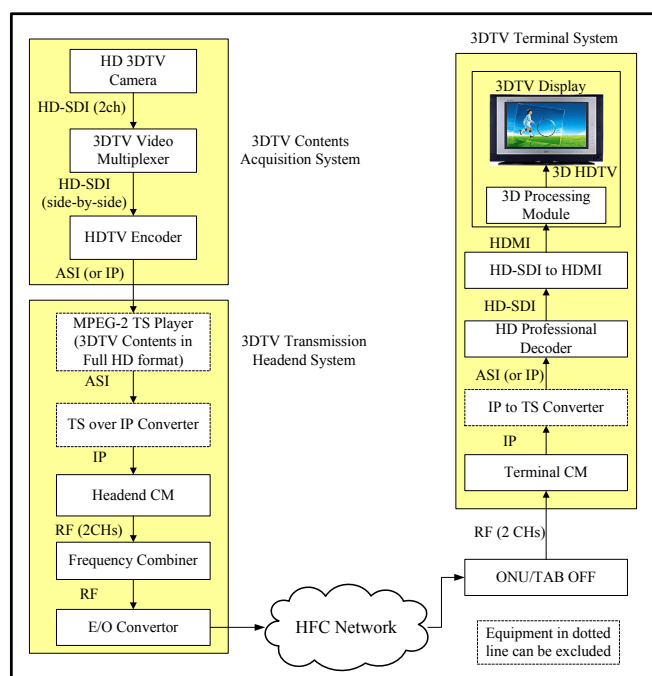


Figure 3. 3DTV System Configuration (using Communication Channels)

Regarding system configurations, Table 1 shows the difference between the current digital cable broadcasting system and the 3DTV systems introduced in this paper. The advantages and drawbacks of each system are summarized as well in Table 1. Unless we use the 3DTV broadcasting system using single broadcasting channel, most of broadcasting equipments need to be doubled to deliver the stereoscopic 3DTV contents. By the 3DTV system using single broadcasting channel, we can keep compatibility and use the current digital cable broadcasting system.

**Table 1. Comparison between 3DTV Systems and Conventional Digital Cable Broadcasting System**

|           | Conventional digital cable broadcasting system                                                                                                                                                                                                                          | 3DTV system (using broadcasting channel)                                                                                                                                                                                                                                                                                                     | 3DTV system (using communication channel)                                                                                                                                                                                                                                                                                                                                                  |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Equipment | <ul style="list-style-type: none"> <li>- HD camera</li> <li>- Encoder, or TS Generator with encoded contents</li> <li>- QAM Modulator</li> <li>- Upconverter</li> <li>- Frequency Combiner</li> <li>- HD STB</li> <li>- other editing equipments and servers</li> </ul> | <ul style="list-style-type: none"> <li>- 3DTV camera</li> <li>- Video multiplexer</li> <li>- Video demultiplexer</li> <li>- Encoder, or TS Generator with encoded contents</li> <li>- QAM Modulator</li> <li>- Upconverter</li> <li>- Frequency Combiner</li> <li>- 3DTV Receiver</li> <li>- other editing equipments and servers</li> </ul> | <ul style="list-style-type: none"> <li>- 3DTV camera</li> <li>- Video multiplexer</li> <li>- Video demultiplexer</li> <li>- Encoder, or TS Generator with encoded contents</li> <li>- Transmission headend system</li> <li>- QAM Modulator</li> <li>- Upconverter</li> <li>- Frequency Combiner</li> <li>- 3DTV terminal system</li> <li>- other editing equipments and servers</li> </ul> |
| Advantage | -                                                                                                                                                                                                                                                                       | - compatible with the conventional digital broadcasting system                                                                                                                                                                                                                                                                               | - transmitting massive broadcasting contents                                                                                                                                                                                                                                                                                                                                               |
| Drawback  | -                                                                                                                                                                                                                                                                       | - limited bandwidth for massive broadcasting contents                                                                                                                                                                                                                                                                                        | - relatively high system costs                                                                                                                                                                                                                                                                                                                                                             |

### III. KEY TECHNOLOGIES AND EQUIPMENTS FOR 3DTV SYSTEM

In this section, some of key technologies and equipments used for 3DTV service demonstrations over HFC network are described. They are 3DTV contents multiplexing and demultiplexing technologies, headend CM, and terminal CM equipments. 3DTV contents multiplexing and demultiplexing technologies used for the proposed system are very important to deliver the stereoscopic contents with synchronization between the right and left images, and to provide interoperability with the current HD digital cable broadcasting equipments. We have used side-by-side format to multiplex and demultiplex the stereoscopic 3DTV contents as explained in [4].

And, headend CM and terminal CM are also very important to support downstream channel bonding functionalities defined in DOCSIS 3.0 specifications. Each key technology and equipment is described in the following paragraphs.

#### A. 3DTV Contents Multiplexing and DeMultiplexing

There are a couple of techniques by which stereoscopic images can be encoded onto a standard video signal. These methods are field-sequential, side-by-side, and separate channels. Each technique has trade-off between video quality and efficiency. Field-sequential is a simple method to encode the stereoscopic video into a standard video format, but it has a problem with flicker when used with a standard television because each eye only receives half the overall field rate. Separate channel method maintains two separate video signals containing the left and right images, respectively. Although this method can have the advantage of maintaining full video resolution, it has a drawback which has to maintain synchronization between dual channels while transmitting and decoding the contents. It is obvious that synchronization between stereoscopic images is one of critical problems for recording, transmitting, receiving and playing the left and right videos separately. Figure 4 shows side-by-side format (a) and field-sequential format (b) for multiplexing the stereoscopic video.

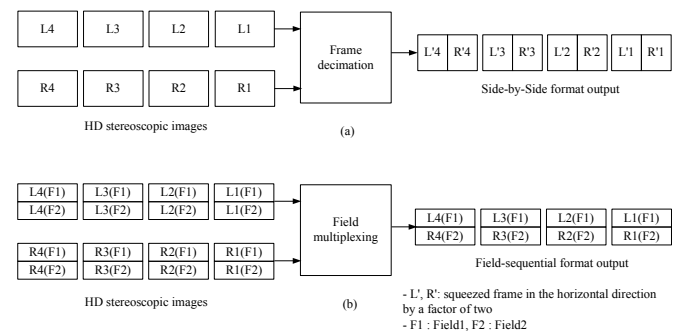


**Figure 4. Side-by-side Format (a) and Field-sequential Format (b)**

The side-by-side method is used to store the stereoscopic video into a standard video format. This method stores the left and right HD images side-by-side by using decimation. The left and right images are squeezed in the horizontal direction by a factor of two.

In order to multiplex the stereoscopic video having 1920\*1080 full HD format, the 3DTV Video Multiplexer provides side-by-side multiplexing method. Side-by-side multiplexing technique is an efficient method of solving the problems related to encoding and decoding equipments, synchronization between left and right videos, and so on. By using the side-by-side multiplexing method, we are able to save resources for recording, transmitting, and receiving stereoscopic video. Furthermore, it is compatible with the existing HDTV transmission system as well. Figure 5 shows the structure of a multiplexed frame in side-by-side format. The shaded region denotes the area of active video.

For restoring the stereoscopic images, each multiplexed image is separated into the left and right HD images, and restored by using an interpolation filter. Figure 6 shows the demultiplexing process for the stereoscopic images.

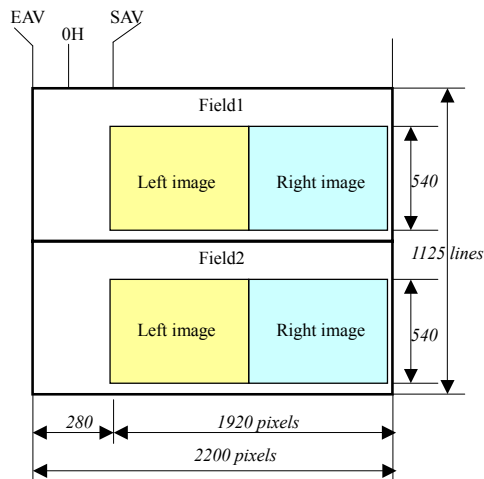


Figure 5. Structure of a multiplexed frame in Side-by-side Format

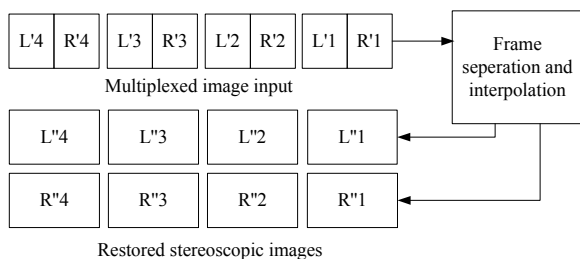


Figure 6. Demultiplexing Process for Stereoscopic Images

### B. Headend Cable Modem

Figure 7 shows the architecture of the headend cable modem supporting downstream channel bonding. The headend cable modem consists of a network interface module, a MAC processing module, a MAC scheduler module, downstream modulator modules, and RF modules as explained in [5].

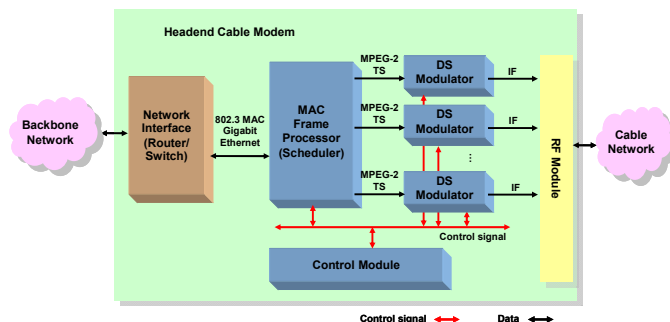


Figure 7. Architecture of Headend CM

The Network Interface module in the headend CM provides an interface with backbone network through Gigabit Ethernet interface. The MAC Processing module generates and distributes the MAC Frames to each downstream channel in a channel bonding group. It also supports packet

classification and transmission based on the packet priority. The MAC scheduler module generates MAC Management Messages (MMM) including MAP, UCD, and SYNC messages. The Modulator and RF modules generate RF signals based on [6] to transmit data over HFC network.

### C. Terminal Cable Modem

Figure 8 shows the architecture of terminal CM supporting downstream channel bonding. The terminal CM consists of RF blocks, demodulator blocks, a MAC processing block, a MAC scheduler block, and a CPE interface block. The RF and Demodulator blocks receive RF signals and recover errors occurred during transmission through HFC network. The MAC processing block restores and resequences the received MAC frames, and the MAC scheduler block processes the MMMs to get information about the CM's transmission opportunities, synchronization, and status controls from the headend CM. The CPE interface block provides Gigabit Ethernet interface to communicate with CPE devices.

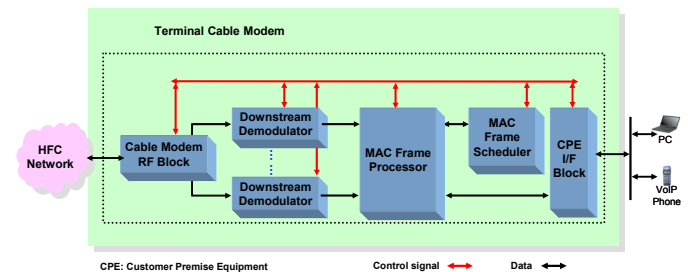


Figure 8. Architecture of Terminal CM

## IV. EXPERIMENTS AND DEMONSTRATIONS

The 3DTV systems described in section II and III have been demonstrated at the 2009 KCTA Digital Cable TV Show held in June 4th through 7th, 2009. For the demonstrations, we have used 3 types of stereoscopic contents listed in Table 2. All of the stereoscopic contents are multiplexed in side-by-side format to broadcast or transmit over HFC network. The contents are encoded in MPEG-2 MP@HL format in order to keep compatibility with the current digital cable broadcasting system. The detailed information of the contents used for the demonstrations is shown in the Table 2.

Figure 9 shows some pictures of the stereoscopic contents in side-by-side format (b, d, f) and the restored images displayed on a 3DTV (a, c, e) after decoding and demultiplexing processes. Figure 9 also shows the polarized glasses (g) used for demonstrations.

In the demonstrations, we have used 45Mbps and 25Mbps encoding rates for each 3DTV system, respectively. In order to guarantee the best video quality of the stereoscopic 3DTV contents and to perform experiments of channel bonding scheme using multiple communication channels, we have used 45Mbps encoding rate. We have also used 25Mbps encoding rate to verify the 3DTV broadcasting system using single broadcasting channel.

For displaying the 3DTV contents, we have used a commercial 46 inch 3D LCD TV. The LCD TV has circular polarizing filter on the display panel to separate the right and left images. Viewers are able to enjoy the 3DTV contents by using polarized glasses matching the filter on the display panel.

**Table 2. 3DTV Contents used for Demonstrations**

| Name         | Length | Content Format         |
|--------------|--------|------------------------|
| Sun and Moon | 15'7"  | Side-by-side (Full HD) |
| B-Boy        | 8'18"  | Side-by-side (Full HD) |
| No-Ryang     | 4'20"  | Side-by-side (Full HD) |



**a) B-Boy (stereoscopic image)**



**b) B-Boy (side-by-side format image)**



**c) No-Ryang (stereoscopic image)**



**d) No-Ryang (side-by-side format image)**



**e) Sun and Moon (stereoscopic image)**



**f) Sun and Moon (side-by-side format image)**



**g) Polarized Glasses**

**Figure 9. 3DTV Contents and Polarized Glasses**

## V. CONCLUSIONS

In this paper, we have introduced 3DTV systems and key technologies required for providing 3DTV service over HFC network. We have also described the system configuration, advantages, and drawbacks of each 3DTV system, and introduced demonstrations conducted during a domestic exhibition event.

The 3DTV systems are used to broadcast and transmit the stereoscopic 3DTV contents through HFC network. In order to provide 3DTV services over HFC network, we have proposed two types of systems using a single broadcasting channel and multiple communication channels, respectively. The 3DTV system using a single broadcasting channel has an advantage being compatible with the current digital cable broadcasting system. Another 3DTV system using multiple communication channels is very useful to transmit massive contents for 3DTV and UHDTV services requiring much more bandwidth than that of single broadcasting channel.

The 3DTV systems introduced in this paper are expected to be used and referred for developing 3DTV standards and conducting the real 3DTV broadcasting trial services in the near future in Korea.

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