# Demonstration of Bidirectional Services Using MPEG-4 BIFS in Terrestrial DMB Systems

Jitae Shin, Doug Young Suh, Yongchan Jeong, Seung Ho Park, Byungjun Bae, and Chunghyun Ahn

**Digital broadcasting technology has developed focusing on multi-channel/multi-media, high-definition quality, and mobility-support. Recently, there has been a clear trend toward bidirectional service with the convergence between broadcasting and communication. The broadcasting viewer is no longer simply a passive receptor but has also become an information generator. Currently, the digital multimedia broadcasting (DMB) specifications are the major standard for portable digital broadcasting and have been establishing the overall guidelines for bidirectional service using the MPEG-4 system. While detailed specifications for DMB systems are not well-established for bidirectional service yet, they share the basic concepts underlying the European Eureka-147 Digital Audio Broadcasting (DAB) system. This paper develops key scenarios for bidirectional service in DMB, describes the signal transaction of broadcasting and return channels, and demonstrates typical scenarios using binary format for scenes (BIFS) in the MPEG-4 system.**

**Keywords: DAB, DMB, bidirectional service, MPEG-4 BIFS.**

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## I. Introduction

Terrestrial digital multimedia broadcasting (T-DMB) [1] systems provide various multimedia data services including moving pictures as well as CD-quality digital audio services in moving situations.

The T-DMB system proposed by Korean researchers, which is also based on the Eureka-147 digital audio broadcasting (DAB) system [2], adopts H.264/advanced video coding (AVC) [3] for video compression, bit-sliced arithmetic coding (BSAC) [4] for audio coding, and binary format for scenes (BIFS) in the MPEG-4 system [5] for other in-band data accompanied by audio/video streams. As a system specification of multimedia broadcasting service, coded streams are wrapped into the MPEG-2 transport stream (TS) as a system standard for synchronization and multiplexing [6].

Originally, digital broadcasting technology was developed to implement multi-channel/multi-media, high quality video/audio, and mobility-support. The convergence of broadcasting and communication has led to bidirectional services and has extended the customer's role into that of a participator who creates information. Bidirectional service in T-DMB systems will be expected as a value-added service. The concept of a return channel adopted for digital video broadcasting handheld (DVB-H) devices will be used for bidirectional service. Currently, DVB-H is moving toward standardization for value-added services using general packet radio service (GPRS) or universal mobile telecommunications system (UMTS) communication links as a return channel, while T-DMB is still at an initial stage in standardization for bidirectional services.

To our knowledge, there have only been a few references in research literature referring to bidirectional service in DMB systems including B. Bae and others [7]. In [1], B. Bae proposes a T-DMB extended wireless Internet platform for interoperability (WIPI) over a code division multiple access (CDMA) system for the return channel. That study mentions an added simple WIPI API for T-DMB application but the proposed platform does not use BIFS data. Another reference mentions an architecture for interactive service in a DAB system, which provides conceptual structure using agent-based software components unlike our detailed and possibly scenario-based services [8].

In this paper, we present an interactive DMB system based on the MPEG-4 BIFS for bidirectional services which we have developed and extended. We provide a detailed design for synchronization and multiplexing of multimedia data using MPEG-4 system BIFS. The transaction structures for key scenarios between communication networks and broadcasting networks are proposed. We describe typical scenarios and corresponding data in detail for bidirectional services. Also, we provide infrastructure using the in-band data with audio/video streams and its capacity analysis. We demonstrate the use of MPEG-4 BIFS for the various scenarios. The functions of BIFS, as a binary version of extensible markup language (XML) in DMB would be a fraction of its full scope because the interactivity of bidirectional service in broadcasting is quite limited with respect to one-to-many interactive service. The bidirectional services introduced in this paper are between full BIFS capability and the interactive services of current TV systems. We could say that current TV broadcasting, also, provides interactive services indirectly, such as quiz program and voting based on viewers' feedback over telephone lines. This paper proposes extending these services from the indirect mode of current TV broadcasting to a direct mode by using a BIFS mechanism installed in the DMB terminal.

The rest of this paper is organized as follows. The overall structure of the proposed DMB system for bidirectional services and the key scenarios described section II. The formats of the required data and BIFS capacity analysis for the services are explained and the BIFS components are described in relation to scenarios are in section III. Demonstrations for key scenarios based on MPEG-4 system BIFS are described and explained in section IV. Concluding remarks and a note on our future work are given in section V.

## II. Proposed Bidirectional-Broadcast Architecture

### 1. Overall Structure

The channel of a T-DMB system for bidirectional service is composed of a broadcasting channel and a return channel. A broadcasting channel exists basically as a common channel between a DMB server and all other DMB terminals; but multiple return channels exist and each one serves the feedback of each DMB terminal individually. The broadcasting channel is used to transport commonly received information and each DMB terminal sends back its requests through an individual connection with the return server via a return channel.

The broadcasting channel uses a common DMB channel while the return channel could be any accessible wireless network a DMB terminal can use. For example this wireless network could be a CDMA cellular network, a wireless local area network (WLAN) in a hot-spot service area, or another kind of communication network. In order to operate commonly under several network environments, it is necessary to set the protocol of data transfer in the return channel. Our transfer protocol is operated over the IP network of whatever network is used for the wireless return connection.

Both CDMA networks and WLANs enable the sending and receiving of data in the IP network. Then data communication between the return server and the DMB terminal can be performed over a common IP network platform. The overall structure of the connection and the data transfer protocol for effective bidirectional service is shown in Fig. 1.

In a basic DMB system, MPEG-2 TS provides hard synchronization capability in millisecond order, which is critical for lip synchronization between audio and video, but is not really necessary for BIFS related services, especially the proposed services in this paper. Other multimedia contents

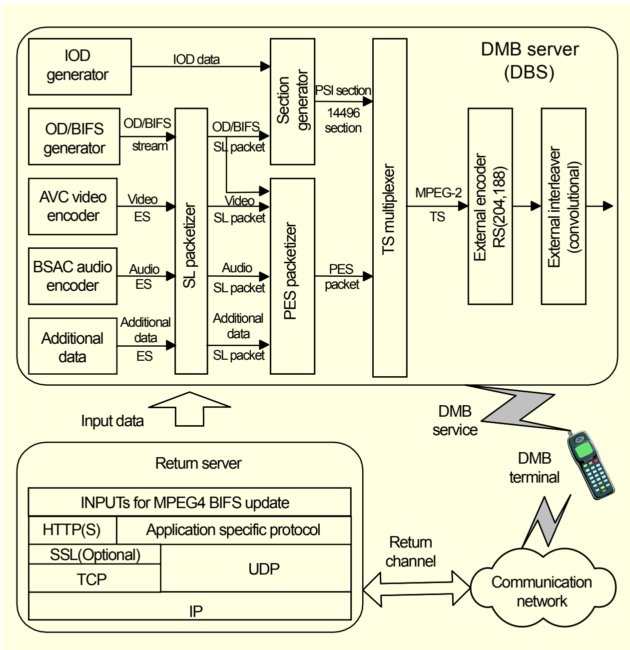


Fig. 1. The DMB system with the proposed mechanism of bidirectional service.

written in MPEG-4 (or MP4) file format are transported through the MPEG-2 TS tunnel. The MPEG-2 TS synchronization mechanism can be used for clock recovery while the provided time stamps of the MP4 file format are used for synchronization between media such as audio, video, and BIFS data.

## 2. Basic Key Scenarios

The scenarios for bidirectional DMB service are classified in Table 1 and representative scenarios are selected for deployment. The key scenarios are investigated and the required data for each one is summarized. It is assumed that the format of data transfer from the return server to the DMB server can be any proprietary message form after the data processing of the return server.

Table 1. Key scenarios.

| Interactivity types for bidirectional broadcast | | Related scenarios |
|---|---|---|
| Local interactivity | | Commercial advertisement |
| Remote interactivity | One to one | Shopping |
| | | Viewer's audio/video phone |
| | One to many | On-line voting,<br>On-line quiz program |

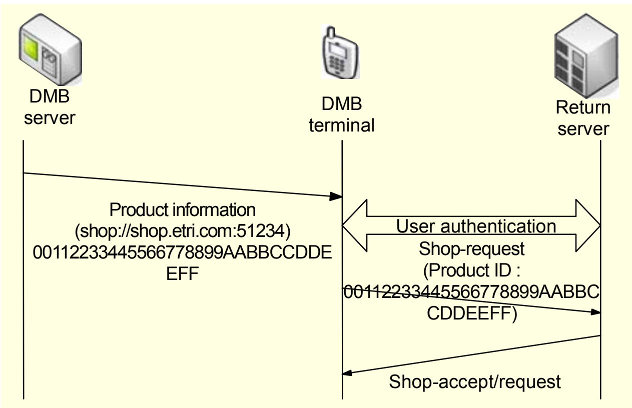


Fig. 2. Shopping transaction.

### A. Commercial Advertisement

In this scenario, the service does not interact with the return server. When a client wants to get detailed information about a commercial product to appear on the DMB terminal screen, it can be made to appear by touching or clicking a certain part of the screen. Then the information is displayed on that part of the screen. For this service, the DMB server has to tacitly transport the related information as a form of in-band data using MPEG-4 BIFS.

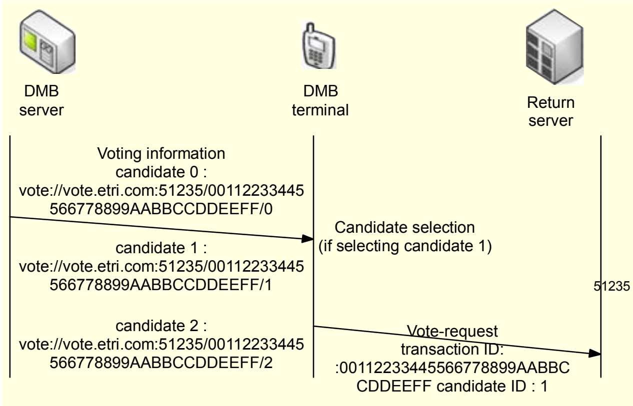


Fig. 3. On-line voting transaction.

### B. Shopping

This scenario provides a service to purchase selected commercial products from among broadcast contents or advertisements and also covers all kinds of remote shopping. This case requires unique identification to indicate selected products and a proper connection procedure and encryption for the safe authentication of purchaser identity. The procedure for this scenario is described in Fig. 2.

The DMB server sends out product information when broadcasting as a form of in-band data using MPEG-4 BIFS. As an option, the DMB terminal can be directed to the seller's WWW server.

### C. Electronic On-Line Voting

The DMB server broadcasts a survey of public opinion or on-line voting offering several alternative choices. Viewers select one of those choices and send their replies to the return server. The collected polling results are updated and broadcast via the DMB server. This on-line voting service is intrinsically secret, and does not require user authentication; however, it identifies and rejects double-voting from the same DMB terminal ID. Also the return server has the capability and simple communication protocol to treat many instant transactions at the same time. The basic procedure is shown in Fig. 3.

### D. On-line Quiz Program

This scenario is quite similar to the case of on-line voting except it requires user authentication. The broadcasting DMB server broadcasts a unique ID per inquiry and subsequent IDs for corresponding choices. The statistics or results are broadcast via the DMB server.

A disadvantage of on-line voting is that it requires the viewer's authentication with his response. Then there is the authentication procedure between the return server and the

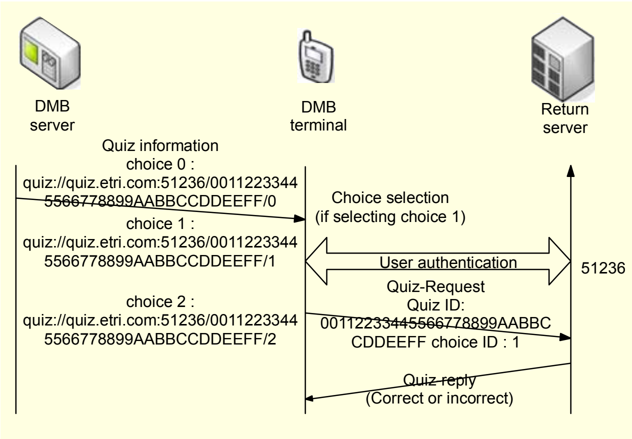


Fig. 4. Quiz program transaction.

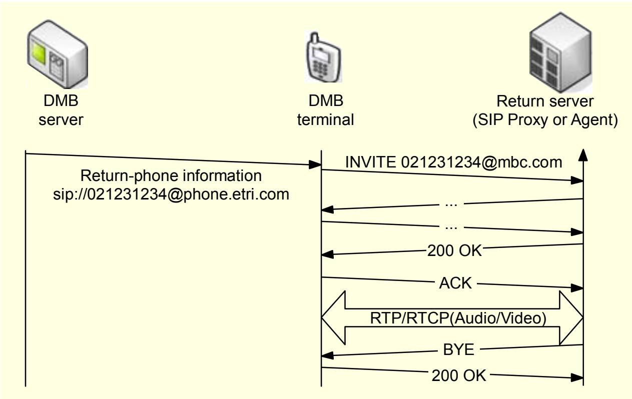


Fig. 5. The transaction for viewer's phone participation.

viewer. The viewer's information such as ID, password, address, and so on is registered with the return server in advance of the quiz program. The transaction of the quiz program proceeds as illustrated in Fig. 4. The quiz program case is quite similar to the on-line voting procedure except the viewer's authentication is added. Also, in the case of the quiz program, the response order is important and the timing synchronization should be considered in order to keep the received order among participants.

### *E. Viewer's Audio/Video Phone*

This scenario is a service to get the response of an audience via on-line audio/video phone calls during a talk show or a discussion program. Viewers use DMB terminals for their participation via an IP based connection over a CDMA cellular network or a WLAN. In this scenario, each DMB terminal is equipped with a prevailed session-initiation-protocol (SIP) [9] stack for IP-based multimedia communication and the relevant audio and video codec. A gateway is required to convert the viewer's audio/video data into broadcasting data when the viewer's data is broadcast through the DMB broadcasting server. The procedure for this scenario is shown in Fig. 5 in which an SIP transaction is assumed. The typical signaling in an SIP is described in detail at RFC 3261 [9].

## III. Analysis of MPEG-4 BIFS for Correspondent Scenarios

Assuming a given allocated bit rate for a video service including BIFS per channel in T-DMB (the effective bit rate is about 1.15 Mbps per a channel typically), mainly 400 to 800 kbps, it is necessary to analyze how much bit budget can be used for BIFS data covering several other data for bidirectional services except main video and audio broadcasting data while maintaining reasonable quality.

### 1. Required Data Type and Capacity Analysis

In order to provide T-DMB service in a broadcasting station, one channel in the underlying DAB system, of which the bandwidth is already determined, needs to be divided into several sub-channels to incorporate audio, video, and other additional in-band data using BIFS. Basically, the required bandwidth of BSAC audio and H.264 video streams should be selected and allocated first on the basis of possible and allowable bit rate. Then we can figure out the remaining available transmission rate of the in-band data for bidirectional broadcasting service using MPEG-4 BIFS.

First, the appropriate bit rate of BSAC audio and H.264 video are assessed for reasonable audio and video quality. Then the available bandwidth of the additional in-band data for value-added DMB service can be estimated. [3], [4] For DMB video streaming, we consider the relationship between bit rate and peak signal-to-noise ratio (PSNR) as major factors in video quality, for different video types using the H.264 video codec. According to the related specification [5], the maximal video resolution is 352×288 pixels (common intermediate format, or CIF) at 30 frame per second (fps), the DMB terminal display window size should be seven inches, and the period of broadcasting DMB service data should be 500 ms.

First, it is necessary to deduce the minimum bit rate for video using H.264 and for audio using BSAC in T-DMB systems to maintain reasonable end-user quality. To deduce the minimum bit rate for H.264 encoded video data, we must consider the following. The bit rate of this kind of video has quite a big gap compared to other video sequence types. We need a classification of video sequences with their screen activities, that is, spatial or temporal activity. Video sequences can be classified according to their screen activity representing high motion information because this activity information increases the coded bit rate from the higher number of intra macroblocks which result from the higher motion. Then we propose a method to reflect the activity degree in temporal and spatial aspects quantitatively. The activity metrics are defined as follows and are used to classify video sequence types according to this metrics.

$$EC = \frac{\sum_{u=0}^{3}\sum_{v=0}^{3} T_{uv}^2}{\sum_{u=0}^{7}\sum_{v=0}^{7} T_{uv}^2} \times 100\%,$$

$$MV = \sqrt{(MV_x^2 + MV_y^2)},$$

where EC denotes the degree of spatial activity and $T_{UV}$ represents related DCT coefficients and MV denotes the motion vector indicating temporal activity to cover the x- and y- axis. Then the mean values of two activity metrics are used to group the typical test video sequences in Fig. 6. From the overall bit rate assessment of these classified groups in Fig. 6 and 7, the average bit rate should be greater than 250 kbps in order to maintain reasonable video quality, that is, around 30 dB PSNR with respect to the typical video sequence in class B having middle-degree screen activity.

Next, we need to derive the minimum bit rate for BSAC-coded audio data with reasonable quality in T-DMB system.

Figure 8 shows the evaluation results of BSAC audio quality using different bit rates for coding compared with other AAC audio coding. The numeric numbers in the x-axis are the used bit rates for coding in kbps. For example, "BSAC64" denotes the target bit rate of 64 kbps used in BSAC audio coding. The mean-opinion-score (MOS) value in the y-axis indicates an audio quality derived from the mean-blind-evaluation score of a group of people participating in this study. An MOS value of at least 3 is adequate to provide service. Moreover, a bit rate higher than

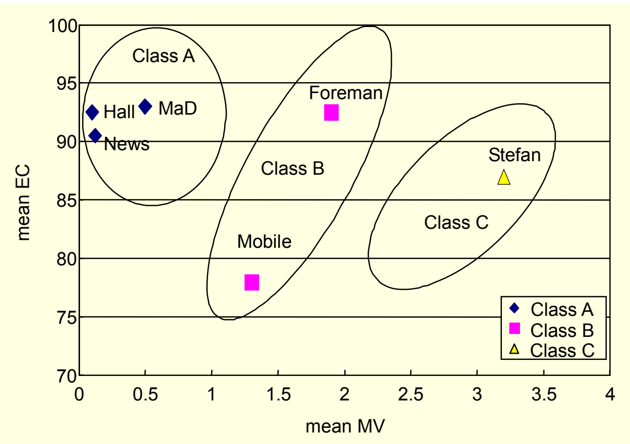


Fig. 6. Grouping of typical test video sequences based on the degrees of motion vectors (MV) and spatial complexity (EC).

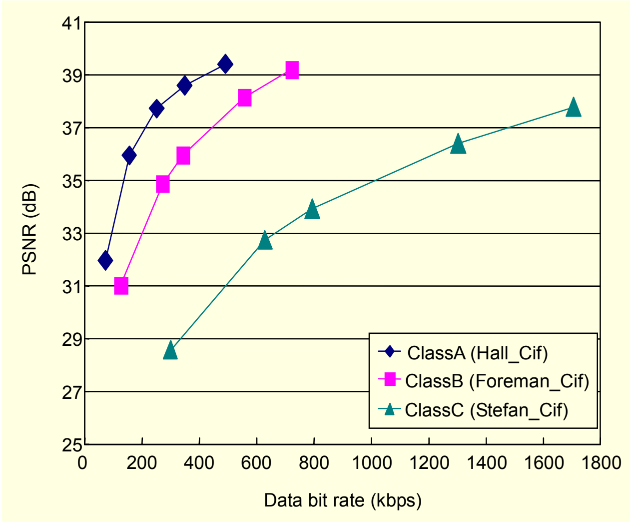


Fig. 7. Typical video examples with different spatial and temporal activities that are represented as video quality in PSNR with corresponding bit rate.

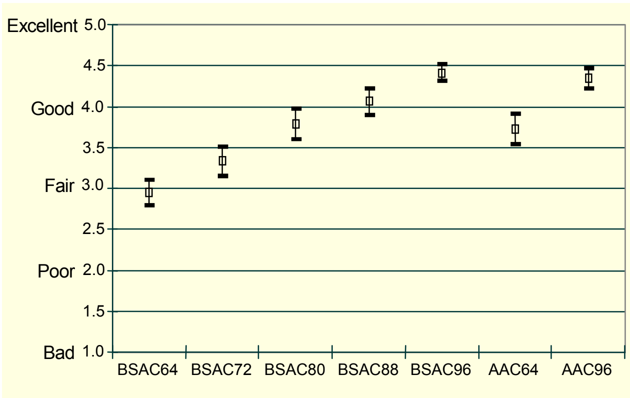


Fig. 8. Average scores for all items (in [10]).

64 kbps is required with the BSAC video codec.

As a result of the above analysis, we conclude that the approximate bit rates for H.264 video and BSAC audio should be greater than 250 kbps and 64 kbps.

Currently service providers of T-DMB consider and test the bit rate range from 400 to 800 kbps for video service including BIFS per DAB channels for available bandwidth. This work considers only the total available bit rates of 416, 640, and 800 kbps as the typical values for simplicity. The capacity analysis in this paper incorporates bit rates of 256, 384, and 512 kbps in H.264 video and bit rates of 64, 96, and 128 kbps in BSAC audio.

Next, we calculate the available bit rate of MPEG-4 BIFS for in-band data in order to provide DMB bidirectional service. In order to calculate the overhead of MPEG-4 data over MPEG-2 TS in DMB systems, we must consider the following facts. The total overhead is 38.5 bytes for 204-byte MPEG-2 TS including the packetization of the sync-layer and elementary stream in MPEG-4, and MPEG-2 TS multiplexing and channel coding. Then the resulting bit rate of the overhead is calculated from following equation:

$$\textit{overhead bitrate} = (X - 4 \text{ kbps}) \times (38.5 \text{ byte}/204 \text{ byte}) + 4 \text{ kbps},$$

where $X$ is total available bit rate (416, 640, and 800 kbps) and the 4 kbps corresponds to the bit rate for the initial object descriptor (IOD) and the object descriptor (OD) in the BIFS generator since that information is carried on separate MPEG-2 TSs and the rate is set at 4 kbps, coming from the updated-period value of approximately 204×8 bits per 500 ms.

The in-band BIFS data includes text data and graphic images. Figure 9 shows the possible BIFS data with the corresponding changes in the bit rate for H.264 and BSAC audio.

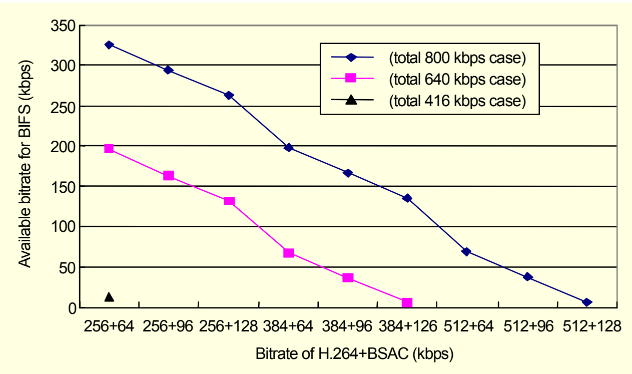


Fig. 9. The bit rate of BIFS with different combinations of H.264 and BSAC data.

### 2. BIFS Node Analysis for Corresponding Scenarios

In order to provide bidirectional service using DMB systems, BIFS in the MPEG-4 system is used to inform the user of necessary information. Data types needed for the previously defined scenarios and BIFS nodes therein are discussed in this section.

A "node" is an entity as defined in virtual reality modeling language (VRML) which is used for the implementation of BIFS. All nodes including child nodes composing a certain scene are represented according to their data types. These node data types (NDTs) make it possible to binarize and compress BIFS scenes. Usually there are more than 30 kinds of NDTs which can be used for BIFS scene description. Nodes are used to represent objects and diagrams, along with their attributes such as color, position, direction, Web URL links, and so on.

Data types necessary for the services of the proposed scenarios are listed in Table 2. Figure 10 shows a typical BIFS data representation. Data are exchanged between the broadcasting server and the DMB clients. Nodes which link to HTML include Anchor (general-use), NavigationInfo (general-use), Transform

Table 2. Data types used for the scenarios.

| | Required data |
|---|---|
| Commercial information (purchasing) | URL, product ID, image, icon etc. |
| Quiz program | URL, question/example ID, query text, icon etc. |
| Online voting | URL, candidate ID, voter ID, query text, icon etc. |
| Televiewer's call | URL, icon etc. |

```
Shape{
appearance Appearance {
Material DEF M Material { }
Texture DEF T ImageTexture {url "fish.jpg"}
}}
```

Fig. 10. Typical example for BIFS data representation.

(visual), Appearance (visual), Shape (visual) nodes. Text information can be represented by using text nodes included in geometry, and nodes for Shape (visual), Appearance (visual), Material (visual), Transform (visual), and so on. Image information can be represented by using nodes of ImageTexture (texture-related), Material (visual), Appearance (visual), Coordinate (visual), Shape (visual), and so on. Touchsensor (interactivity-related) nodes are used for information for icons and enable the server or client to recognize events.

## IV. BIFS Demonstrations for Correspondent Scenarios

### 1. Structure of Demonstration System

Figure 11 shows the structure of the demonstration system proposed for bi-directional services. The role of each component is as follows. First, the DMB server sends an MPEG-4 (or MP4) file to the client in real-time to receive the client's request and the event from the return server, and to send the client updated information including BIFS and additional elementary stream (ES). Second, the DMB client replays the MP4 file received from the streaming server, recognizes events invoked by the user while replaying the contents, and processes local events or sends event information to the return server. (Basic events include touch sensor, time sensor, and so on.) Third, the return server collects events invoked by users, and updates or creates content according to collected information.

The procedures of the demonstration system are as follows:

- Step 1 (from DMB server to client).

The server streams an MP4 file with an assigned ID to a node which notifies the client's events to the server. By using the ID, the server can predict which events will by caused by the client, such as when the touch sensor node of an ES is touched by a mouse click. Depending on the event, the server performs the appropriate reaction.

• Step 2 (from client to return server).

The client's reports invoke events to the return server. The node introduced in the previous step is used in this step and this node is defined in MPEG-4 Part 1 (14496-1).

• Step 3 (from return server to DMB server).

The return server receives event information from the client. Sometimes, the server responds to the events by modifying or updating content. In order to assist this action of the server, the return server summarizes the user's information and generates updated BIFS or new content.

• Step 4 (from DMB server to client).

In order to modify the scene sent to the client, the DMB server uses BIFS commands such as insertion, modification, and deletion of scene elements. These commands are included in the BIFS command frames.

Each BIFS command frame includes insertion, modification, and deletion of scene elements such as scene nodes, fields, routes, and so on. If a BIFS command is not appropriate, such a command is disregarded by the terminal. The referencing of wrong nodes is an example of an inappropriate command. If a command is disregarded, the remaining access unit is also disregarded.

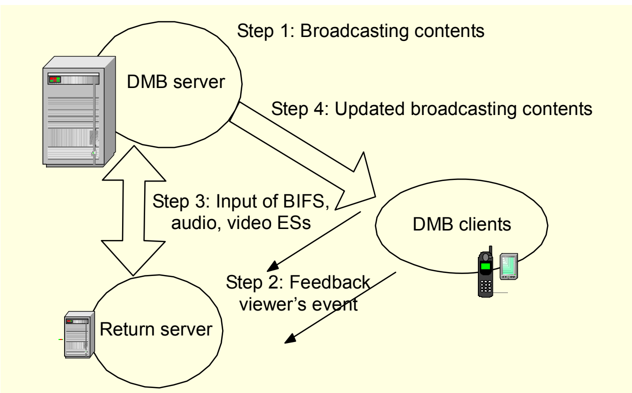


Fig. 11. Our demonstration system for DMB bidirectional service.

## 2. Discussion Issues for the Return Server and Clients

For clarification, it is necessary to discuss several issues before describing the implementation of our system.

Regarding the return channel, the return server is assumed to be a Web server, that is, an Internet application. The current Internet network has intrinsic drawbacks in synchronization because it is a packet switching network under a best effort policy. While our system has been tested in an intra network, the delay and packet loss which occurs in the public Internet network may impose severe problems on interactive services. Even security and the possibility of hacker attacks could be serious issues in relation to the return server.

For the collection of events invoked by users, some services such as voting are not particularly time–sensitive. In such cases, it is acceptable for the return server to periodically collect events stored in a queue of received packets though a certain TCP port. Time sensitive events, however, create synchronization issues. For example, a quiz game in which users compete is time-sensitive so that it is critical to know which user answers earlier. Currently, the public Internet does not provide an adequate solution to this problem which has been resolved in the case of telephone-based return channels by circuit switching. Nevertheless, considering the varying degrees of delay inherent in the Internet, if the DMB clients were synchronized by using the clock recovery function of MPEG-2 TS, the time stamp based on the clock might be used to tell when each user generates a packet. This function, however, was not implemented in our system because MPEG-2 TS was not used and the computers used in the experiments were not synchronized.

Regarding the updating of BIFS data, collected events are processed and converted into BIFS data in the return server. The return server merges the BIFS data with the permanent BIFS data of the MP4 contents. Control parameters such as duration and the repetition mode of the new BIFS data are also included in the updated BIFS data accordingly within the bandwidth allocated for the BIFS. Loss priority should be included if error resiliency is considered.

The communication between the return server and the DMB server is private and does not have to use Internet protocols while in our system, these two servers communicate through the Internet. The DMB server has a buffer for the BIFS data updated and sent by the return server. It periodically reads and inserts the data into the MPEG-2 TS stream without any modification.

## 3. Implementation of Demonstration System

OSMO4 [11] as an open source MPEG-4 player was used for replaying the MP4 file in real-time in the demonstration system. This sub-section describes the implementation of our system in the first four scenarios described in Section II.2.

### *A. Commercial Advertisement*

When the client wants to get more detailed information about the product advertised in Fig. 12, he or she can click the lower part of the screen and then can get the detailed information as shown in Fig. 13.


Fig. 12. Typical advertisement scene.


Fig. 13. Scene of selected commercial product.


Fig. 14. Advertisement connected to a website.

## B. Commercial Shopping

On clicking the button at the bottom, a web site of an insurance company pops up showing an on-line application for insurance.


Fig. 15. Information delivered to the return server.


Fig. 16. Examples of broadcasting channels.

## C. On-Line Voting

The candidate number is selected by clicking the mouse on the appropriate button, and this action is informed to the return server.

## D. Random Channel Selection

During the replay of certain contents, one may want to move to another channel. In this case, the client chooses to replay contents of the selected channel sent from the server. Instantly, the client is connected to the other service.

## E. Industrial Impact

MPEG-4 BIFS as a part of the MPEG-4 system standard is used for interaction with graphic data. It has been adopted by

T-DMB service, which will increasingly include bidirectional service. MPEG-4 BIFS provides functions which facilitate interactivity between various graphic objects. As presented in the demonstration of our system, on clicking a button in a broadcast program scene, the scene changes to another graphic object. As this bidirectional DMB service is becoming popular, the service will provide not merely high quality broadcasting, but will also contribute to changing future lifestyle and culture as a result of the convergence between telecommunications and broadcasting which includes bidirectional data broadcasting, real video-on-demand (VOD), and additional value-added services. Consequently, broadcasting service will not be passive as it is now, but will evolve to include mobile smart TV with portable Internet function, which will lead to convergence between DMB terminals and terminals for portable Internet communication.

## V. Conclusions and Future Works

Efficient interaction among broadcasting servers, return servers, and clients can be implemented by using MPEG-4 BIFS. This interaction enables bidirectional service in T-DMB systems. In this paper, we proposed a structure for an overall system for bidirectional service, and presented examples of its implementation in key scenarios of bidirectional services. We also introduced BIFS data types and capacity requirements for the services. This included analysis of available bandwidth for BIFS data. Our system was demonstrated to be practical and feasible in these scenarios using popular open sources for the MPEG-4 system standards such as Darwin Steaming Server and OSMO client.

For the future, we feel it would be valuable to research the periodic BIFS update mechanism which is more adaptive to practical bidirectional broadcasting services than the current simple system demonstrated in this paper. With respect to representing scenarios, the use of MPEG-4 BIFS should be more concretely based on the specific payload format efficient for delivery.


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