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An Emergency Alert Message Broadcasting System using Null-Packet on Digital TV Broadcasting

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ABSTRACT

In digital TV broadcasting, such as terrestrial, cable, satellite, and IPTV, the head-end of digital TV broadcasting has a more complicated transmission structure than that of analog TV broadcasting. Furthermore, digital TV broadcasting has a feature that supports multiplex models, such as Multiple Program Transport Stream (MPTS). Therefore, the purpose of our work was to design and examine a more efficient new system of emergency alert message transmission to support the digital TV broadcasting environments. Digital TV broadcasting is the IP generation or RF transmission of 8-VSB, QAM, and QPSK modulated through a multiplexer or re-multiplexer multiplexed stream as a MPEG-2 Transport Stream after content encoding. The new system proposed in this paper transmits an emergency alert message without scrambling after replacing the PID and payload of the null-packet with the message prototype in the TS stream from the multiplexer. If we need to transmit an emergency alert message under digital TV broadcasting services, then the receiver first checks the PID of each packet in the TS stream for the emergency alert message. Next, if a packet is determined to be an emergency alert message, then the set-top box displays the message on the TV screen using its function of On Screen Display, or the PC based software displays the message on the monitor screen using its function of overlay with user interface if the packet is found to be an emergency alert message. We have designed an emergency alert message protocol and a system model. By experiments and analysis of the system, we concluded that the system achieved efficiency and the ability to send and receive emergency alert messages using the system under different digital TV broadcasting service environments.

Key words: Digital TV Broadcasting, Null-Packet, Emergency Alert Broadcasting System, MPEG System, MPEG-2 Transport Stream

1. INTRODUCTION

In this paper, we propose an efficient novel method, our protocol, and the system of emergency alert message transmission for digital TV broadcasting, such as Internet Protocol Television (IPTV), IP (Internet Protocol) based digital broadcasting, digital cable TV, terrestrial, or satellite digital broadcasting. We also perform experiments and analyze the system. This system transmits an emergency alert message to TV viewers or subscribers of IPTV using a null-packet of the MPEG-2 transport stream [1] via digital TV broadcasting when it needs to transmit an alert message of a national emergency, disaster, severe weather, fire, flood warning, and so on.

All existing digital TV broadcasting services, such as terrestrial digital broadcasting, cable TV digital broadcasting, satellite digital broadcasting, IPTV with IP network, and IP based digital TV broadcasting services, use the MPEG-2 transport

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stream for the digital TV broadcasting transmission stream standard [2]. These transmission streams were synchronized with different bitrates from each other for each media type of digital TV broadcasting. This process uses a method to add additional null-packets into the TS stream to fix the transmission bit rate. These null-packets are only for the size of the transmission rate. Therefore, these null-packets carry the payload without any information. A receiver discards all these null-packets after identifying the unnecessary packets, so these null-packets are called non-necessity packets, which are not related to digital TV broadcasting decoding.

These null-packets will be sent to the receiver included in all MPEG-2 transport streams of digital TV broadcasting with PSI (Program Specific Information) packets, elementary packets, and other packets. We will transmit an emergency alert message to warn of disasters, severe weather, fire, terror attacks, and other emergencies using these null-packets. These alert messages will be transmitted in various ways such as audio, video, text message, and through radio, TV, internet, and phone.

This system is called the emergency alert system, and the research relating to the system is quite advanced. There are many message types and contents for each receiver or receiving range of alert message, but it is efficient to send alert messages through TV if there is an urgent situation such as a national disaster, severe weather, and fire. Because the broadcasting environment is now changing from analog to digital, the emergency alert messages must show a TV screen independent of the TV program being viewed. The existing system often uses a hardware caption method as an open caption that has a method to encode a new video frame after merging the message into the original video frame before encoding the TV program content.

This hardware caption method can enable a TV viewer to comprehend an emergency alert message from the TV screen without interfering with the viewing of a TV program. However, this method requires some additional systems for the head-end. One problem is that merged alert messages have to merge with all TV programs before encoding the broadcasting content if an alarm is required. Further, we can find a problem that is the re-decoding and re-encoding of the TV program for the message added at each of the digital TV broadcasting re-transmission sides. This problem requires some additional devices, such as decoders, encoders, and caption inserting systems that do not need re-transmission. The original broadcasting quality may be reduced due to the frequent decoding and encoding steps. Also, we can send an alert message using the closed caption of digital TV broadcasting, but the original purpose of this feature is intended for an auxiliary service of the TV program context and its contents. Closed caption synchronizes with the audio of a TV program, and it is not suitable for use in alert message transmission because it enables the On or Off caption display to the user. Therefore, we should send the text message separately from the TV program data if it is necessary to broadcast some emergency alert messages.

If a TV viewer and an internet user receive a digital TV broadcasting signal using a set-top box or internet application, then the signal overlay with an alert message in the form of a text string uses OSD (On-Screen Display) and an overlay function of the set-top box when receiving the packet, irrespective of the user's selection of which PID (Packet Identifier) is for an alert message while watching TV. There is a need to compose a system in order to help the TV viewer understand when they see a message on the TV screen. Furthermore, we need to apply an efficient method of emergency alert messaging using the null-packet of the TS stream without inserting additional packets, which causes the bit rate to change.

To describe this, the remainder of the paper is organized as follows. We explain related works and the background concerning emergency alerts along with the digital TV broadcasting multiplex model in Section 2. Section 3 describes the design of the emergency alert message transmission system using the null-packet of digital TV broadcasting. Section 4 evaluates the proposed system via experiments. Section 5 summarizes our approach and discusses future work.

2. RELATED WORKS

In this section, we discuss some research and background on emergency alert broadcasting and how such systems are used worldwide. We reviewed Common Alerting Protocol (CAP) [3] for alert message exchanging standards and three types of text information transmission with TV broadcasting, which are Open Caption, Rendered Caption, and Closed Caption. We also reviewed caption services using TV, the MPEG system of digital TV broadcasting multiplex standard, and the digital TV broadcasting multiplex model.

2.1 Overview of Emergency Alert Broadcasting System

Many countries are currently working on an emergency alert broadcasting system for various types of disasters. There are the Emergency Alert System (EAS) in the United States [4], the Emergency Warning System (EWS) in Japan, and analog television [5] and radio auto alarm broadcasting systems in the Republic of Korea. Also, research of the emergency alert broadcasting system of Terrestrial DMB (T-DMB) for mobile digital TV broadcasting was advanced in the Republic of Korea [6,7]. In the Republic of Korea, standardization of emergency alert broadcasting is currently taking place. Moreover, there are some patents belonging to industries for a system or a method of emergency alert messaging over digital TV broadcasting [8].

2.2 Common Alerting Protocol (CAP)

Common Alerting Protocol (CAP) is an emergency alert protocol developed by the Emergency Management Technical Committee (EMTC) of the Organization for the Advancement of Structured Information Standards (OASIS) [3,9]. Many organizations such as the National Weather Service (NWS), use the CAP protocol, which is a common message protocol based on XML for exchanging alert messages.

We need a protocol for message exchange to relay information in the case of disasters. There are various types of national disasters, so it is necessary to design a system capable of exchanging information pertaining to each situation. Therefore, this protocol is designed for common use. CAP is composed of four sections, including <alert>, <info>, <resource>, and <area>, and this protocol was specially designed to exchange information for organizing efficient usage of emergency alert messages [3].

2.3 Caption

Caption is a basic method to display text information on a TV screen. Analog TV broadcasting and digital TV broadcasting have different means of transmitting media for TV programs, but they use the same caption service for TV viewers. There are three types of captions, which are Open caption, Rendered caption, and Closed caption.

Open Caption is a method to display frames that merge two forms of content, text and video frames, into one. Open caption provides a caption service using only a TV signal receiving devices such as TV, set-top box, or computer software without the need for extra hardware or software for caption decoding. Rendered Caption is a type of caption frame that inserts caption information into an extra video frame that can be inserted into the original video.

Finally, Closed Caption is a method to overlay a text string on a TV screen after separately synchronizing video caption information from the video and caption[10]. Rendered Caption and Closed Caption have the function of caption on/off on TV screen according to the user's operation via the remote controller. The techniques of these caption methods can send information in text format, but, as explained in Section 2.3, captions are generally used for caption broadcasting as an auxiliary service of TV broadcasting.

2.4 Caption Service with TV

Caption service with TV is in use for several purposes. We use the caption service as an auxiliary service for the detailed information transmission of TV programs. For example, caption services represent the audio or context information of a TV program, actor or actress information partaking in a TV show or movie, TV program information, and/or other broadcasting information in text format using a caption service method such as Open Caption or Closed Caption. We use a caption service with TV for an auxiliary service without causing any effect to the viewing of TV programming by viewers.

2.5 MPEG System and Multiplex Model of Digital TV Broadcasting

Digital TV broadcasting has a feature that can send a binary stream of MPTS (Multiple Program Transport Stream) after multiplexing for multiple broadcasting programs. Further, the stream has a special feature of program replacement using PID filtering and packet replacing or re-multiplexing. Fig. 1 shows a digital TV broadcasting multiplex model concerning the feature [1,11]. As shown in this model, a program is composed of video, audio, and other data. These programs are made of TS streams including multiple programs with a multiplex.

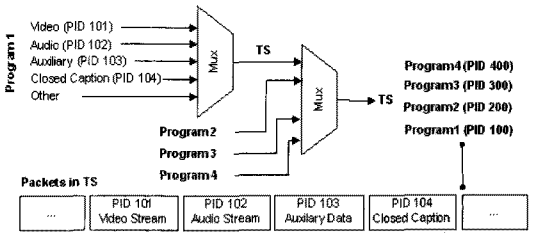


Fig. 1. Multiplex model of digital TV broadcasting and MPEG-2 transport stream.

3. NULL-PACKET OF TRANSPORT STREAM

3.1 Null-Packet

In the case of digital TV broadcasting, a difference occurs between the bandwidth of the physical channel and bit rate of the TS stream that synchronizes the program decoder. To compensate for this problem, we filled non-necessity packets into the transport stream to fix the transmission bit rate. We use null-packets for non-necessity packets that do not have any broadcasting information. That means that the receiver is expected to ignore its contents [1,9]. We use different bitrates for each digital TV broadcasting transmission media, so each TS stream has a different null-packet ratio.

As explained in Chapter 1, it is efficient to insert alert messages into the TS stream just before modulating the TS stream without requiring some additional system for head-end, re-decoding, re-encoding, and scrambling. Thus, we have to use null-packet enabling to replace the necessity payload, and we can expect the merits of alert message broadcasting without effecting the TS stream bit-rate. Also, if the existing or assigned PID's packet is used as an alert message packet, then we will face a problem where the packets will scrambling with elementary packets, bit-rate will change, and etc.; thus, we have to use a null-packet for in this situation.

3.2 Packet Rates Analysis

We performed experiments to analyze the packet

Table 1. Packet rates for transport streams to various digital TV broadcastings

TS Stream File Name	Program	Bit rate (Mbps)	File Size (KBytes)	Packet Rate (%)					Media Standards
				PAT	PMT	AV Elem. Packets	Null Packet	Other and Unknown	
TBS_IP	SD 1	1.999902	146,508	0.30	0.30	97.35	2.05	0.00	IP
YBN_LS	HD 4	38.84506	1,001.088	0.08	0.04	68.04	30.38	1.45	IP and QAM
SAMS	SD 6	38.09634	615,218	0.04	0.26	43.28	56.41	0.00	QAM
645_C	SD 6	38.84912	144,038	0.04	0.06	65.24	34.13	0.54	QAM
669_C	SD 7	38.84763	144,853	0.04	0.07	91.17	8.11	0.62	QAM
HD_09	HD 1	19.39294	665,601	0.12	0.02	93.28	3.34	3.23	ATSC
567_C	HD 1	19.39255	72,012	0.12	0.05	82.70	12.52	4.60	ATSC
BBCNS	SD 6	24.12832	625,000	0.07	0.41	86.47	7.21	5.83	DVB
Average		27.44398	301,778	0.10	0.15	78.44	19.27	2.03	

rates for the transport streams of eight captured stream files for transmission media such as IP, cable, terrestrial, and satellite. As shown in Table 1, we can confirm the component ratio of non-necessity packets and data packets such as PAT (Program Association Table) packets, PMT (Program Map Table) packets, PSI packets, audio elementary packets, video elementary packet, or other packets throughout the TS stream.

The terrestrial digital TV broadcasting of 8-VSB modulation and ATSC can transmit one HD program or about four SD programs for 19.38 Mbps with 6 MHz bandwidth per one channel. Satellite, cable TV broadcasting, and IPTV have different bitrates for each media. Digital TV broadcasting uses the MPEG-2 Transport Stream for a transmission stream, as explained in Section 2.5. We know that the null-packet of a TS stream rate is about 3% - 20% and the null-packet rate is relative to the bit rate of the digital TV broadcasting transport stream, as is shown in Fig. 2.; therefore, we can confirm that this enable us to use null-packet for transmitting information transmission over digital TV broadcasting.

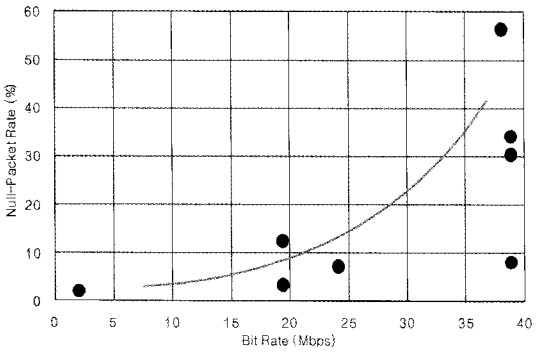


Fig. 2. Null-packet rates of transport stream in different bit-rates of digital TV broadcasting.

4. Alerting Messaging System using Null-Packet

4.1 System Architecture

We propose an efficiently system in this paper that can transmit emergency alert messages via digital TV broadcasting using the null-packets of a TS stream. As shown in Fig. 3, the system is composed of an ASI In Adaptor, Stream Buffer, Re-Generation Processor, and IP Adaptor [12], ASI Out Adaptor [13], and Message Manager.

The ASI In Adaptor and Stream Buffering have the function of TS stream capturing. The Re-Generation Processor has the function of inserting an emergency alert message into the null-packets of a TS stream. The IP Adaptor supports the feature of transmitting the MPEG-2 transport stream over an IP network for outgoing IP streams. ASI Out Adaptor supports ASI out in-

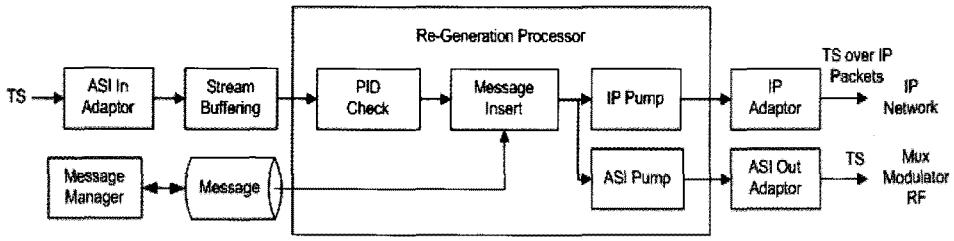


Fig. 3. Architecture of the emergency alert message broadcasting system.

terface for TS stream. The Re-Generation Processor is composed of PID Check for PID checking, Message Insert for emergency alert message inserting into null-packets, IP Pump for TS stream insertion into IP packets, and ASI Pump for TS stream output interfacing. The TS stream from the IP Adaptor is transmitted over the IP network encapsulated into IP packets with UDP (User Datagram Protocol) or RTP (Real-time Transport Protocol). Also, the TS stream from the ASI Out Adaptor is applicable to a multiplexer of stream multiplexing or re-multiplexing, a modulator for RF (Radio Frequency) [9] signal, and other applications.

Fig. 4 shows the structure of the packet of the emergency alert message. The size of the packet is 188 bytes for the MPEG-2 transport stream. The packet is composed of a 4-byte header of Sync_byte, PID, and other fields and a 184-byte payload. The payload of the packet contains the emergency alert message for AlertMessage_Section.

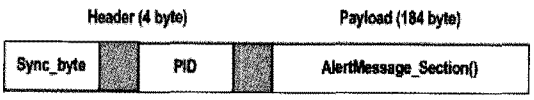


Fig. 4. Structure of the emergency alert message packet.

4.1.1 TS Stream Receiving and Transmitting Interface

Digital TV broadcasting enables the exchange of TS streams using IP, ASI, or other interfaces before the final TS transmission to the subscriber. These transmission interface standards can enable the exchange of broadcasting data stream real-time between many systems or organizations and to efficiently process TS streams.

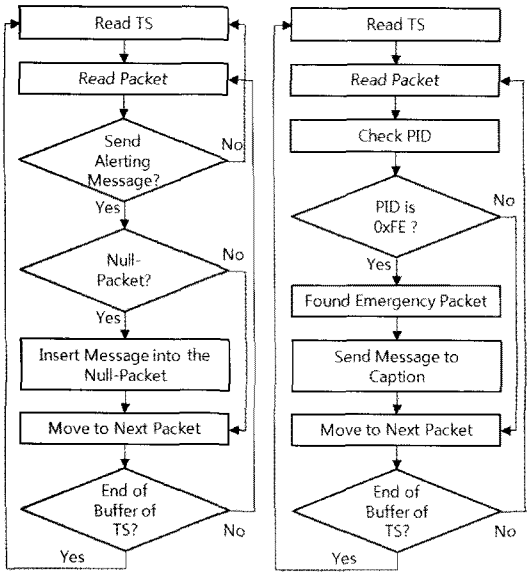
For example, the digital TV broadcasting input/output interface is an interface type that enables the reception of TS streams using PCI type ASI Input (or Capture) Adaptor for TS stream reception. There are two output interfaces in the TS stream output interface, as is shown on the right side of Fig. 3. One is for the IP packet stream generated with the IP adaptor.

The other interface is for the TS stream generated with the ASI Out Adaptor for other application connections, like a modulator. This will send the TS stream to the IP network after achieving encapsulation into the IP packet through the IP adaptor and interface of the ASI Out Adaptor with an ASI In Application.

4.1.2 Alert message Re-Generation Processor

As shown in Fig. 3, the Re-Generation Processor is a block to process the message re-transmission after the content changing of a null-packet from the TS stream when there is a need to send an alert message during the digital TV broadcasting TS stream scanning.

As shown in Fig. 5 (a), an alert message insertion process requires three steps: fixed size TS stream buffering, buffered TS stream insertion into memory, and packet reading. The flow should replace the content of the alert message if the read packet PID's value is '0x1FFF' if there is an alert message for broadcasting.



(a) Adding at sender (b) Receiving at receiver

Fig. 5. Flow of the emergency alert message.

The null-packet's PID changes a fixed value for '0x1FFE', alert message's content replacement into the payload, and the transmission flag of the alert message is turned on. Next, repeat the steps as explained above after the next TS stream buffering for fixed size memory if the TS stream processing is finished.

The receiver processes the received alert message as shown in Fig. 5 (b). First, the receiver confirms a packet's PID from the received TS stream in the fixed size of memory. If the read packet's PID is 0x1FFE, then packet is an emergency alert message, so the packet is sent to the caption API to display it on the screen. Next, the offset moves the next packet and reads the packet. If all packets in the buffer are completed to finish processing, then we read next TS stream for fixed size and repeat the steps as explained above.

The receiver, such as set-top box, must have the function of remote update for software through internet or forward path for receiving and processing alert messages from the system proposed in this paper.

4.2 Alert Message Insert System Model

Fig. 6 shows the proposed physical configuration of the Emergency Alerting Insert System Model. In the case of emergency alert message display with TV, the Open Caption method is widely used to broadcast an alert message. This method sends an alert message after digital encoding by an encoder merges an alert message into the original video frame before the program contents enter the encoder.

We need a system model to insert an alert message into a final TS stream from a multiplexer, re-multiplexer, or etc. without an encoder when it is necessary to broadcast an alert message because of some demerit, as explained in Section 2.3. As shown in Fig. 6, this model can transmit digital TV broadcasting and alert messages all together through IP or RF without effecting the TS stream bit rate and other bitrates, so we can expect to achieve efficiency and convenience.

As shown in Fig. 7, red arrows indicate the system points in the general digital TV broadcasting system of terrestrial, satellite, cable TV, and IPTV. We are able to place the emergency alert message broadcasting system proposed in this paper at each the system point following the red arrows in Fig. 7. Therefore, we can add the message into the TS stream using the system at any step in digital TV

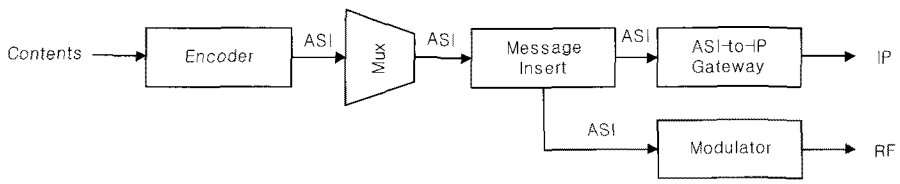


Fig. 6. System model of the emergency alert message adding.

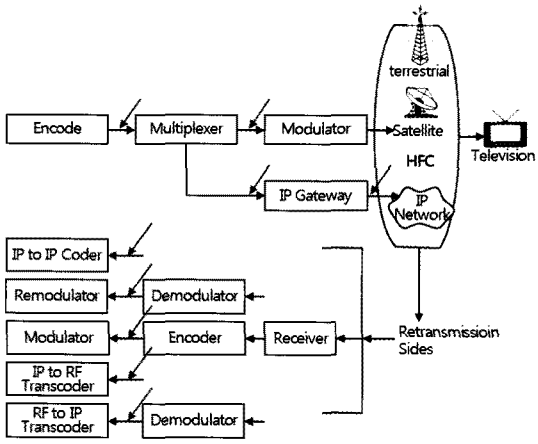


Fig. 7. System overview of the digital TV broadcasting system and topology

broadcasting system and topology in Fig. 7.

5. EXPERIMENTAL RESULTS AND ANALYSIS

We conducted experiments on our system that are comprised of a Generation block for digital TV broadcasting TS stream generation, Transmission block for TS stream IF or RF generation, and Receive block for digital TV broadcasting, as is shown in Fig. 8. First, the generation block, shown on the left side of Fig. 8 is a personal computer based system that is comprised of a generation processor, message inserting manager, IP output adaptor [12], ASI output adaptor [13], and hard disk. The transmission block is comprised of an IP network and 8-VSB modulator with an Up-convertor. The receiving block is comprised a DirectShow-based filter solution for the IP receiving test and uses an 8-VSB capturing adaptor [14] for the RF receiving test. Moreover, the block uses an ASI Input (or Capture) Adaptor [13] for an ASI stream receiving test and evaluates all digital TV broadcasting environments of IP, RF, and ASI.

As shown in Fig. 8, we performed experiments to analyze the performance of the system under the environment of digital TV broadcasting with an ASI output interface through the ASI Output adaptor [13] and TS stream generation through an IP Output Adaptor from the streams stored on a hard disk. At the receiving block, it is possible to overlay the message on the TV screen using the alert message from buffered TS stream by 'Caption Filter' and null-type 'Message Retrieval Filter'. 'IP Source Filter' can capture the TS stream from the IP network. We also experimented on how to display decoded audio and video data on the screen via decoder filters and renderer filters. The filters in the experiments were DirectShow's filters, and we performed experiments the digital TV broadcasting stream decoding and caption overlay of the received emergency alert message using GraphEdit of Microsoft DirectX utilities.

5.1 Analysis of Alert Message Transmission Efficiency with Noise

As shown in Fig. 9 and Fig. 10, we have conducted experiments and analyzed how to obtain successful result rates of emergency alert message transmission under noisy environments of digital TV broadcasting signals. We used RF signals modulated 8-VSB by a modulator for digital TV

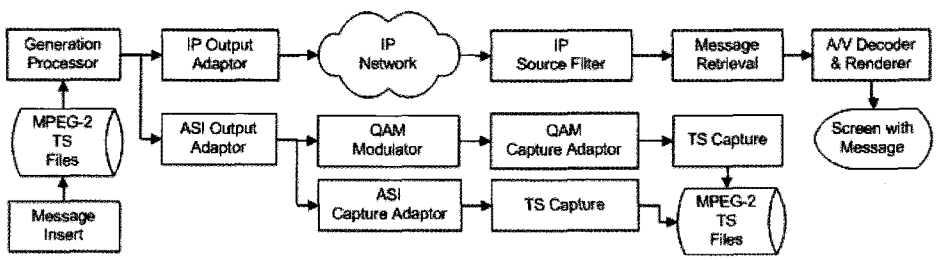


Fig. 8. The testing environment for collecting the analysis results and performance of the system.

Table 2. Success rates for emergency alert message reception when the messages are carried in different SNRs

Step	SNR (dB)	EVM (%)	BER	Decode Status	Number of Send Message	Received Message	Broken Message	Loss Message	Success Rate (%)
1	> 27.8	3.98	0.000000	OK	20	20	-	-	100
2	23.9	5.91	0.000000	OK	20	20	-	-	100
3	20.8	8.41	0.000000	OK	20	20	-	-	100
4	18.1	11.76	0.000000	OK	20	20	-	-	100
5	17.0	13.05	0.000000	OK	20	20	-	-	100
6	16.0	13.93	0.000078	OK	20	20	-	-	100
7	15.3	15.83	0.262167	NG	20	16	2	2	80
8	14.4	15.62	0.777503	NG	20	5	12	3	25
9	13.8	18.92	1.003292	NG	20	-	5	15	0
10	12.6	21.53	1.003292	NG	20	-	4	16	0

broadcasting TS stream transmission with noise simulation for the experiment.

We have experimented and analyzed the system using decoder software and MPEG-2 TS analyzer software with a file type captured TS stream by a PC based system including 8-VSB or QAM capturing PCI adaptor. We have measured the SNR (Signal-to-Noise Ratio) [9] and EVM (Error Vector Magnitude) [9] of the RF signal from the digital signal processer for each increasing 5 dB step attenuation using a variable attenuator connected to a modulator for noise simulation. We have confirmed the result of analysis for the digital TV broadcasting decoding status of digital TV for each attenuation step.

As shown in Table 2, there are no problems for digital TV broadcasting decoding from step 1 to 6 ranges under bad SNR and EVM on the receiver side, but we found some errors of digital TV broadcasting decoding causing increasingly bad SNR and EVM below SNR 15.3 dB. We conducted experiments and analyzed the success rates of emergency alert message reception on the receiver side, as is shown in Table 2. We have experimented with sending an alert message using the transmission of 20 messages for each of the 10 noise steps.

Fig. 9 and Fig. 10 show the curve of the experimental results of the success rate with white

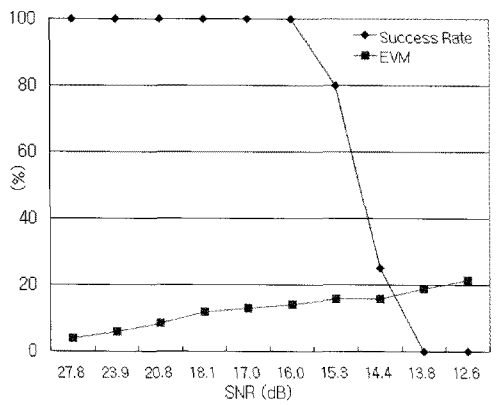


Fig. 9. Success rate of the emergency alert message reception.

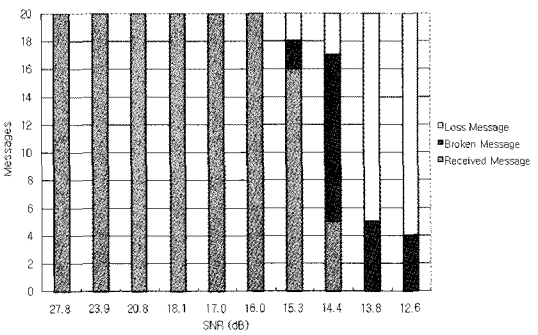


Fig. 10. The number of lost, broken and received packet when the message is carried in different SNR.

noise simulation, as is shown in Table 2. We have confirmed the normal decoding status of digital TV broadcasting programs without any effect on the success rate of alert message transmission up to 16.0 dB to 27.8 dB attenuation with noise simulation.

We have confirmed the decreasing success rate of message reception, increasing the TS stream error because of noise below 15.3 dB of SNR. Also, as shown in Table 2, we found it necessary to disable audio and video decoding of digital TV broadcasting including data errors, because of some noise when decreasing to 16.0 dB of SNR.

We have analyzed that the system can send or receive the alert message under some digital TV program decoding error from the low success rate of the message reception to 25% and below 16 dB of SNR. This shows that TV viewers can receive emergency alert messages irrespective of TV broadcasting status. Therefore, this fact should be emphasized to enable the increasing success rate of an alert message reception despite bad broadcasting environments, such as noise, if using error correction, consecutive message sending, or other advanced methods for alert message broadcasting.

6. CONCLUSIONS

In this paper, we have proposed an emergency alert message transmission method using the null-packet of an MPEG-2 transport stream for digital TV broadcasting. Furthermore, we have implemented and evaluated the system after designing an emergency alert message transmission protocol and a physical system model. We have shown the efficiency and ability of the emergency alert message broadcasting system using null-packet design and implementation.

The system proposed in this paper can send a message that does not affect the TS stream and transmission rate of the digital TV broadcasting at all. We showed that the system can send the emergency alert message using null-packets of the transport stream at any step of the digital TV broadcasting environment for multiplexing or re-multiplexing from contents or program providers and digital TV broadcasting service organization. We have confirmed the frequent reception of alert messages via poorly broadcasted digital programs due to communication jamming like noise. We are confident that our approach is practical and applicable to the digital TV broadcasting environments of an emergency alerting system.

Our future research will embark on enabling the sending of a message with a banner type small image data using only null-packets, enabling the viewing of the message with a GUI message ticker, and integrating our system with a home network such as a ubiquitous network.

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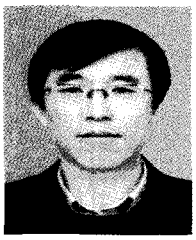

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