Fusion of Communications and Broadcasting through the Internet Satellite

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Abstract: This paper describes a proposal and a preliminary experimental result on re-transmission of terrestrial digital broadcasting on a multi-beam satellite for eliminating uncovered terrestrial broadcasting areas. As the satellite is for the internet purpuse, this approach will be a good example of fusion of communications and broadcasting. The re-transmission bit-rate are designed to be less than 15% of one beam capacity, in order to keep the satellite for internet use. Subscribers in the uncovered areas can at least watch terrestrial digital broadcasting program all day long even at heavy traffic conditions. The experimental system by using JGN (Japan Gigabit Network) demonstrates the possibility of the fusion.

1. Introduction

Simultaneous broadcasting of digital terrestrial TV and analog TV has started since 2006 in Japan. At the year of 2011, analog broadcasting will be terminated. The UHF transmission of digital TV broadcasting will generate new uncovered areas by high mountains, deep valleys or isolated islands, due to more straight propagation nature than that of VHF.

Recently, JAXA launched a multi-beam satellite for internet purposes. They believe that broadband zero areas will melt down by using this satellite. This is because Japan islands are covered with 9 different regional beams, each having 4 channels of 135Mbps. This capacity seemed enough for internet purposes at the design phase of the satellite. However, judging from the recent trends, this capacity is not enough for heavy internet users who wish to subscribe acTVila or YouTube videos, thorough the internet. In addition, uncovered areas and broadband zero areas are generally overlapped each other. Therefore, people in such areas cannot easily watches video or TV through the satellite.

Safety net services to be employed are based on the application of a single beam BS satellite. However this approach cannot deliver local news and local programs, due to the global broadcasting nature and the limited capacity of the satellite. Therefore, people in uncovered areas are isolated from information of nearby typhoon as well as local news or local advertisement.

Our approach[1] enables 118 local TV companies (hereunder, the word of "station" is used for representing the corresponding company) over Japan broadcasting their own programs by using only a small part of the beam capacity, although one beam area contains 13 local broadcasting stations in average. Unlike the safety net services, where only SD (Standard Definition) video and audio parts of network TV programs are broadcasting, our approach realizes data broadcasting in addition to the distribution of HDTV and high quality audio from these 13 stations at the same time.

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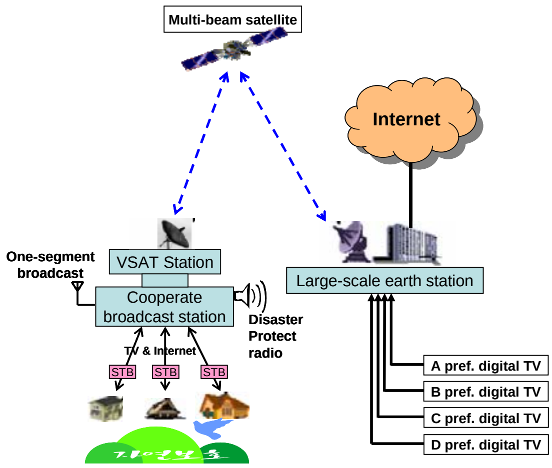

Fig.1. Fusion of communications and broadcasting through the internet Satellite.

The approach employed here utilizes the combination of H.264[2] encoding scheme on HDTV and a network program sharing among local stations, which send the same network programs around 70% of a day. By this approach, only 12.5% of beam capacity can provide all of local digital terrestrial TV broadcasting services.

The paper describes basic system design in section 2, video switching using signal processing in section 3 and preliminary experimental trials in section 4.

2. System Design

In our target system, the allowable bit-rate per broadcasting is around 5Mbps, although digital terrestrial broadcasting uses 23.3Mbps. This is because only 50% of one channel in a beam is designed to be occupied by the TV re-broadcasting. Then, our designed system can be depicted in Fig.1, where the large-scale earth station combines Internet services and broadcasting services. TV signals are also

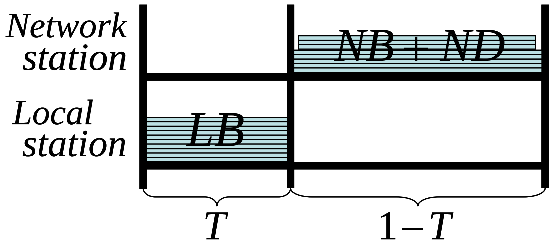

Fig.2. Bit-rate on the satellite. Data Broadcasting is only allowed for network presentation time period.

planned to be sent by IP packets in the form of Transport Stream (TS) over IP. These packets are received by an cooperate broadcast station, which acts as a gateway between subscribers and the satellite. Local TV programs occupy only 12.5% of the total 600Mbps beam capacity. The remaining bit-rate is used for internet purposes.

In terms of bit-rate reduction, all HDTV videoes should be compressed to 7Mbps by H.264. Normally in digital TV terrestrial broadcasting, HDTV encoding is carried out by MPEG-2, and its bit-rate recently drops to 14Mbps from the allotted 17Mbps bandwidth. Observation of a 7Mbps HDTV video by H.264 shows reasonable quality, as the H.264 compression ratio is designed to be about a half of MPEG-2. In addition to HDTV video, Hi-Fi audio and other important service or control information such as PSI (Program Specific Information), SI (Service Information), EPG (Electronic Program Guide) and language subtitles for a program as well as one-segment video service, should be sent to the satellite from every broadcasting station. Around 1.5Mbps is required for these purposes. As a result, HDTV program re-transmission from a station requires 8.5Mbps. This means that more than 110Mbps capacity is still required for 13 different TV programs.

Further bit-rate reduction is possible by utilizing the correlation between broadcast signals. As a covered area by a beam is quite wide, a plural number of local TV stations exists which distributes the same network program except local programs. In order to reduce the bit-rate, all local TV signals in a beam are segregated into classes having the same network broadcasting signals, except local programs. Local TV stations send only their own local program portions to the satellite. Only a single network program is transmitted for every class. In a small cooperate broadcast station, shown in Fig.1, a selected compressed video from local programs and a network program are decoded and combined to form a proper broadcasting signal for this local area. The combined video is sent to subscribers by wireless transmission.

Let us evaluate the total bit-rare on a satellite, by defining the parameters in the following way.

N: number of network station.
L: number of local station.
B: broadcasting program bit-rate.
D: data broadcasting bit-rate.
T: local program time-rate.
A: Average bit-rate on satellite.
I: Internet service bit-rate.

The bit-rate on the satellite can be shown in Fig.2. N (normally 5) network stations broadcast their own programs as well as data broadcasting programs during network distribution time period of (1-T). L (Normally 13 in average) local stations broadcast their local programs during local broadcasting time period of T (normally 30%). As a result, bit-rate used on the satellite becomes

$$A = (1-T)N(B+D) + LBT. \qquad (1)$$

Therefore, the allotted bit-rate to the Internet in Mbps becomes

$$I = 135 - A. \qquad (2).$$

As the bit-rate of HDTV broadcasting is set to 8.5Mbps and that of the data broadcasting is 4Mbps, Eqs (1) and (2) become to have A=67.7Mbps and I=62.8Mbps. Therefore, the total bit-rate required for TV broadcasting is around 50% of the 135Mbps cannel capacity, which is our system target.

3. Video Switching using Signal Processing

As TV broadcasting is carried out all day long, clock maintenance is quite severe in terms of editing or merging videos. Note that the bit-rate of video compression encoder such as MPEG-2 or H.264 cannot be immediately changed, due to the existence of a buffer in the encoder. Also, please note that a priori local program distribution becomes very expensive cooperate broadcast stations, because continuous editing of a received TS stream on a network program and a stored TS stream on a local program is not so easy, due to non-synchronized GOP (Group of Pictures) forms. Therefore, decoded local HDTV news for 10 minutes, for example, have to be stored in HDTV tape recorder or huge silicon files for merging the two video signals.

In order to make the cooperate broadcast equipment low cost, non-stop broadcasting has been employed in both local videos and a network video, because the clock synchronization mechanism is contained within the video content streams. In order to reduce bit-rate of local programs during no show time periods, blue pictures are introduced into the (1-T) time periods. Thanks to the high performance H.264 prediction of intra/inter modes, this part requires only 1/50 bit-rate, compared to active pictures. This approach enables simple video editing. A routing switch, which selects either a network program video or a local program video, can produce a local broadcasting video.

The employment of blue pictures in a network program during the no-show time may be a possible approach. However, the network video should keep the last frame picture during the time. The reason is that even if video synchronization between the local video and the network video has a frame difference, the combined video mask out

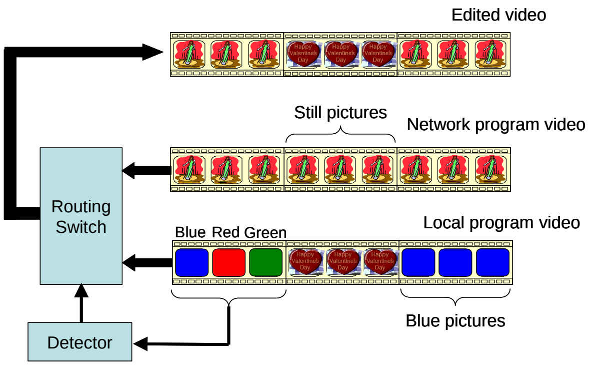

Fig. 3. Robust video combination on a local program video an a network video.

the gap of these videos. This approach can be easily shown in Fig. 3. Therefore, the still pictures in the network video make a robust nature to delayed switching, due to transmission delay from a broadcast station. In addition, the VBR mode, instead of the CBR, is employed which reduces buffer occupancy in a coder to reduce switching delay.

A network program video and a local program video are switched to generate a local broadcasting video by a routing switch, shown in Fig. 3. This timing control is carried out by the local program video. The switch timing from local video is implemented by replacing a couple of blue pictures, located just before a series of local program frames. A red picture frame followed by a green picture frame is put onto the local program video.

The local video signal is first fed into a detector which detects starting timing by checking the couple of successive frames. It also detects the termination timing by checking a blue frame. An output signal from the detector becomes precise time duration of T, and is fed into the control terminal of a routing switch.

Let us evaluate video bit-rate on the satellite, when a network program and a local program are continuously sent to the satellite. An encoded video is first packed into TS stream[3] with Program Clock Reference (PCR) for establishing clock synchronization between an encoder and a decoder. Then, instantaneous bit-rate on the satellite is calculated by the following equation.

$$27 \times \frac{1504 \times P}{PCR(n) - PCR(n-1)} \quad , \qquad (3)$$

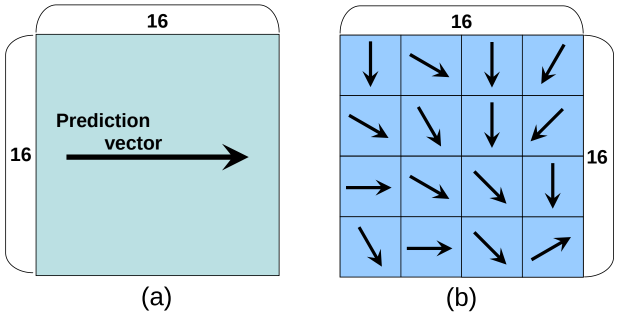

Fig. 5. H.264 intra-prediction. (a) 16x16 prediction creates a single prediction vector. (b) 4x4 prediction create 16 prediction vectors in the same area.

where PCR(n) shows the n-th PCR, having a content of a counter operated at 27 MHz. Parameter P shows number of TS packets between PCR(n) and PCR(n-1). The number of 1504 is a total number of bits in a TS packet, having the length of 188 Byte.

Figure 4 shows the result of evaluation by using Eq. (3) on the combination of a local program video with blue pictures during no-show time and a network program video with still pictures during the active local program time. Three conditions are evaluated. The first one, shown in Fig. 4(a), is the direct application of a local program video and a network program video. The measurement in Fig. 4(b) employs special still pictures in the network program video, where every still picture is first divided by 16x16 pixel blocks and every block has its average values. Therefore, the still picture becomes to have low resolution, although the picture size remains the same. The third one, in Fig. 4(c), is the employment of still pictures with the resolution by 32x32 blocks.

As blue pictures in a local program video generate only 1/50 information rate, every result shown in Figs. 4(a), (b), (c) shows 7.1 Mbps during the active network video period. However, when the local program video becomes active, Fig. 4(a) shows double bit-rate, telling that still pictures generates almost the same bit-rate to that of active video. This comes from the poor intra-frame prediction of H.264. In the intra-frame prediction of H.264, only two block sizes are allowed. They are 4x4 and 16x16. When textures of a still picture becomes fine, intra-frame prediction will always use 4x4 fine blocks and generates a lot of prediction vector information, as is show in Fig. 5. In addition, I-

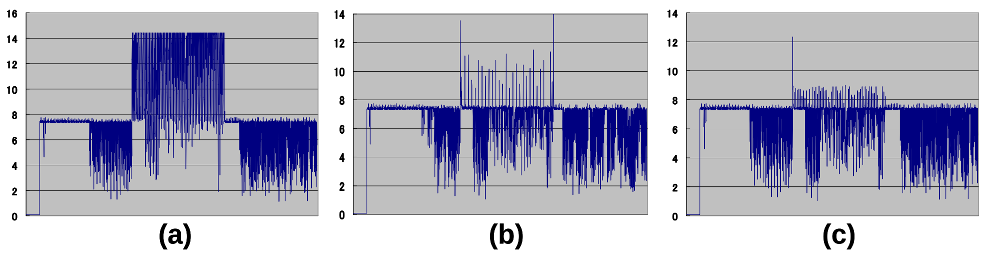

Fig. 4. Bit rate variation on a satellite channel successive, when a single local video and a network video are employed. (a) The last frame pictures are employed at the still picture period. (b) The 16x16 averaging is carried out for the still picture. (c) The averaging range is increased to 32x32. (Every video is encoded by 7 Mbps VBR mode.)

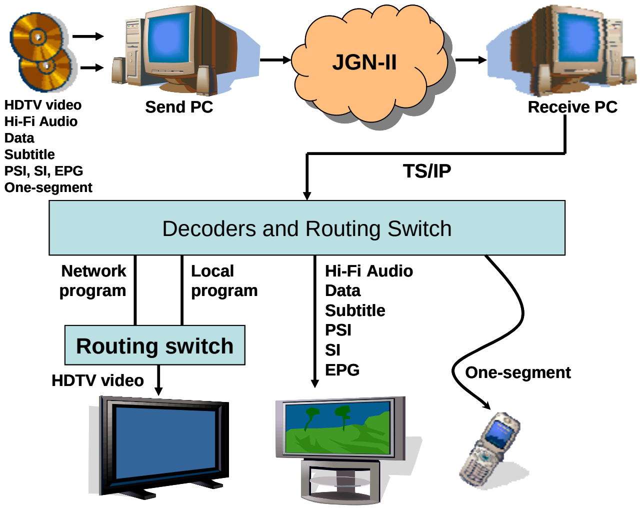

Fig. 6. Experimental System.

pictures generate a lot of information, because the internal buffer in the encoder is almost empty, due to the VBR control.

In order to reduce bit-rate during still pictures, the introduction of low resolution still pictures make sense, so as to be predicted by using only 16x16 blocks in intra-frame pictures. As the intra-frame picture becomes clear by assigning more bits for prediction residuals, the inter-frame prediction between still pictures work quite well. These facts can be observed in Fig. 4(b). Further bit-rate reduction is possible to use lower resolution still pictures. This is because the 16x16 block prediction comes from pixels on edges, located at neighboring blocks. When 32x32 blocks are used for lower resolution still pictures, clear bit-rate reduction is observed in Fig. 4(c). As a result, lower resolution still picture introduction produces small amount of information. Please note that peoples cannot easily recognize the low resolution pictures, even if they appear.

4. Experimental System

A real−time transmission and video observation system has been implemented, as shown in Fig. 6. As the satellite is now under adjustment phase for a year, the satellite is simulated by Japan Giga-bit Network. This is because both communications system are based on IP network. The off-line processing of MPEG-2/H.264 transcoding from 14Mbps CBR to 7Mbps VBR is first carried out. A multiplexed TS signal of audio, video and data is fed into JGN by using TS over IP equipment through a PC. At the receiving side, video combinations between a local video and a network video are carried out by a specially designed routing switch. The decoded results are arranged so as to be evaluated, in terms of actual human factors. The video information rate showed constantly 8.5Mbps during simultaneous broadcasting of a network and local broadcasting videos. One segment video and data broadcasting are not implemented for these measurements.

A demonstration system in Fig. 7 links Akihabara, Tokyo and Kochi University of Technology by using JGN-II. In the Fig. 7, five monitor screens had been arranged for the observation of every step in our approach. The screen

Fig. 7. Public demonstration in Akihabara.

(1) shows a local program video, but at the time period, it displays blue pictures for the non-active local program period. The screen (2) shows a network program video and the same video appeared in the screen (3) for the local broadcast video observation. The screen (4) shows the data broadcasting, where the local video in screen (3) should be placed on the blue box part. In addition, one-segment video can be seen in screen (5) through a local OFDM modulator.

Although subjective evaluation of the system had been scheduled, the presentation of a local broadcasting video and that of the corresponding data broadcasting appears in the different screens. Therefore, the comparison between the terrestrial digital TV and our system is not so easy at the moment. However, every people who visits our demo-site give us positive openion.

In addition, the jitter of the PCR was measured and resulted in +/-74nsec by a measurement.

5. Conclusion

Digital terrestrial TV broadcasting through a multi-beam satellite has been demonstrated by using JGN-II, which simulates the satellite. According to this experimental system, all terrestrial TV programs from local TV stations can be transmitted within12.5% of one beam capacity, due to the employment of H.264 and network program sharing. As the safety net is now planning by using the BS satellite, one way to encourage local broadcast companies is to employ the multi-beam satellite for local program distribution. The same procedure will work well to overlay the local program videos on the SD video from the safty net.

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