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Digital transmission of television signals - Part 4

Architecture and functional specifications of a radio frequency (RF)/Internet protocol (IP) video switching system

Recommendation ITU-T J.483

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Architecture and functional specifications of a radio frequency (RF)/ Internet protocol (IP) video switching system

Summary

Recommendation ITU-T J.483 defines the architecture and functional specifications of a radio frequency (RF) / Internet protocol (IP) video switching system.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Keywords

Audience rating, headend (HE), internet protocol (IP), network bandwidth, radio frequency (RF), set-top box (STB), switching.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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Introduction

This Recommendation is Part 2 of a multi-part deliverable covering both the requirements [ITU-T J.482] and the architecture and functional specifications for the RF/IP switching system, as identified below:

Part 1: Requirements [ITU-T J.482]

Part 2: Architecture and functional specifications

Cable television operators provide subscribers with a variety of video services composed of RF-signal-based video (RF-video) and IP-signal-based video (IP-video) over cable networks. While the bandwidth is limited, cable operators are facing subscriber needs to watch a higher quality video such as 4K in either RF or IP format.

Under these circumstances, the purpose of the RF/IP switching system is to create an environment where almost all the subscribers can watch 4K videos if they so wish.

Recommendation ITU-T J.483

Architecture and functional specifications of a radio frequency (RF)/Internet protocol (IP) video switching system

1 Scope

This Recommendation defines the architecture and functional specifications of the RF/IP switching system over the cable network. It is Part 2 of a multi-part deliverable covering the architecture and functional specifications for a radio frequency (RF)/Internet protocol (IP) switching system. Part 1 provides the requirements as defined in [ITU-T J.482].

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T H.222.0] Recommendation ITU-T H.222.0 (V8) (2021) | ISO/IEC 13818-1:2015, *Information technology – Generic coding of moving pictures and associated audio information – Part 1: Systems.*

[ITU-T J.297] Recommendation ITU-T J.297 (2018), *Requirements and functional specification of cable set-top box for 4K ultra high definition television.*

[ITU-T J.482] Recommendation ITU-T J.482 (2021), *Requirements of a radio frequency (RF)/Internet protocol (IP) video switching system*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.2.1 4K video: [ITU-T J.482].

3.2.2 audience rating: [ITU-T J.482].

3.2.4 HD video: [ITU-T J.482].

3.2.5 SD video: [ITU-T J.482].

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 audience satisfaction degree: The index that is used to determine the necessity of switching the quality and the distribution scheme for each video content.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ASD Audience Satisfaction Degree

CAS	Conditional Access System
DB	Database
DEMUX	De-multiplexer
DRM	Digital Rights Management
EPG	Electronic Programming Guide
ES	Elementary Stream
FEC	Forward Error Correction
GOP	Group of Picture
HE	cable television Headend
INT	IP/MAC Notification Table
IP	Internet Protocol
MUX	Multiplexer
PAT	Program Association Table
PMT	Program Map Table
QAM	Quadrature Amplitude Modulation
RF	Radio Frequency
RTP	Real-Time Transport Protocol
SI	Service Information
STB	Set-Top Box
TS	Transport Stream
UDP	User Datagram Protocol

5 Conventions

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6 Architecture

6.1 Fundamental system architecture

The purpose of RF/IP switching is to create an environment where almost all the subscribers can watch 4K videos. To realize this concept, the system shares both the RF and IP network resources, and controls and switches video qualities (formats) and distribution scheme for each video content adaptively, according to the following three parameters: attribute of the video content (e.g., emergency degree), available network bandwidth, and an audience rating of the content.

Figure 6-1 shows a fundamental system architecture including the key components of the system.

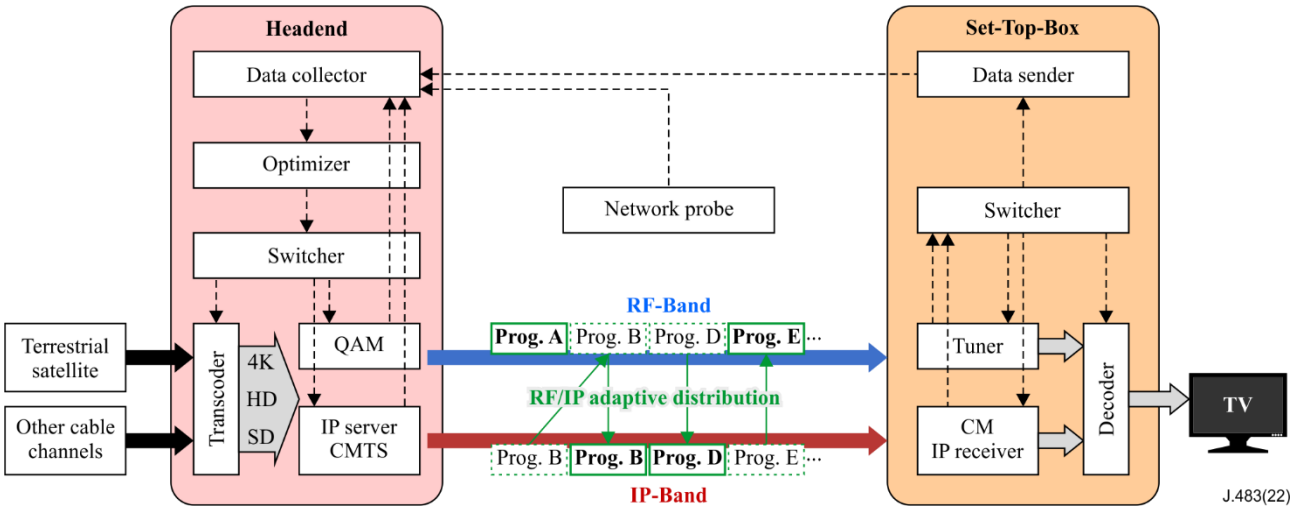

Figure 6-1 – A fundamental RF/IP switching system architecture

6.2 Cable television headend (HE) system architecture

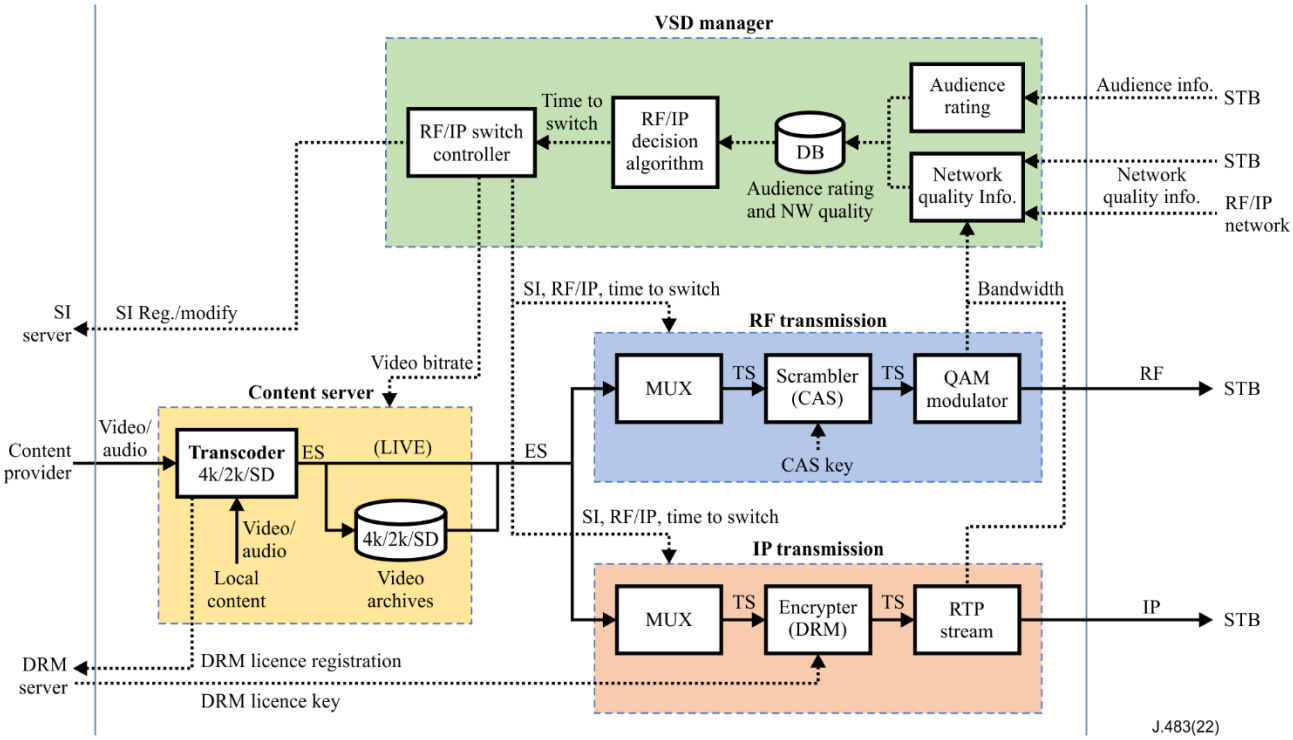

Figure 6-2 – RF/IP switching cable HE system architecture

As indicated in Figure 6-2, RF/IP switching cable headend comprises of four parts: content server, audience satisfaction degree (ASD) manager, RF transmission and IP transmission.

The ASD manager part receives information on the audience rating information and available network bandwidth quality from the set-top boxes (STB) and proves in the RF/IP network, decides on a distribution scheme to maximize the ASD as a whole, and sends out a trigger to execute the switch between RF and IP.

The content server part transcodes the video and audio elementary streams (ESs) into bitrates indicated by the ASD.

RF transmission part receives video and audio ES's from the content server, multiplexes them together with the service information (SI) from the RF/IP switch controller to form a transport stream (TS), encrypts the TS for conditional access system (CAS) protection and the quadrature amplitude modulation (QAM) modulates the TS for transmission to the cable RF network.

Likewise, IP transmission part receives the video and audio ES's from the content server, multiplexes them together with SI from the RF/IP switch controller to form a TS, encrypts the TS for the digital rights management (DRM) protection, and generates real-time transport protocol (RTP) packets for transmission to the cable IP network.

Table 6-1 shows the functions of each block that comprise the respective parts.

Table 6-1 – Functions comprising RF/IP switching cable headend

Part	Block	Function
Content server	Transcoder	Transcodes video and audio ES's from content providers and locally produced content to bit rate indicated by the RF/IP switch controller. Output the transcoded content to video archives, RF transmission part and IP transmission part.
	Video archives	To switch video streams without interruption at the end and beginning of a group of pictures (GOP), for each video and audio ES of different bitrates, the time stamp is inserted in the transcoded ES in sync with the GOP boundary.
		Stores ES of different bitrates from transcoders and based on an indication from the RF/IP switch controller, output the ES of the requested bitrates to RF or IP multiplexer (MUX).
ASD manager	Audience rating receiver	Receives audience information from STB and forwards it to the audience rating and network quality information database.
	Network quality info. receiver	Receives network quality information from STB, and bandwidth utilization information from QAM modulator and RTP streamer and forwards them to the audience rating and network quality information database (DB).
	Audience rating and network quality information DB	Receives audience information and network quality information and stores them as a database. Sends information on the audience rating and the available network bandwidth into the RF/IP decision algorithm.
	RF/IP decision algorithm	Determines distribution scheme (RF or IP) based on information received from the audience rating and the available network bandwidth information DB, and sends out control messages including time to switch, to the RF/IP switch controller.
	RF/IP switch controller	Based on the distribution scheme determined by the RF/IP decision algorithm, performs the following: • Determines the order and schedule of RF/IP switching • Generates SI which includes a distribution scheme

Table 6-1 – Functions comprising RF/IP switching cable headend

Part	Block	Function
		• Sends out control messages to the content server based on the determined schedule • Registers SI to SI server and modifies it as necessary • Outputs messages to MUX to tell the order and time to switch
RF transmission	MUX	Multiplexes video and audio ES from the content server and SI from the RF/IP switch controller, and generates a transport stream (TS), for output to the CAS scrambler. Implements switch of video and audio ES at the end of GOP following the switch time received from the RF/IP switch controller.
	Scrambler (CAS)	Encrypts TS from MUX using CAS scramble key and outputs the stream to the QAM modulator.
	QAM modulator	QAM modulates TS from the CAS scrambler for transmission to cable RF network using the frequency as instructed by the RF/IP switch controller.
IP transmission	MUX	Multiplexes video and audio ES from the content server and generates a transport stream (TS), for output to the DRM encryptor. Implements switch of video and audio ES at the end of GOP following the switch time received from the RF/IP switch controller.
	Encrypter (DRM)	Encrypts TS from MUX using the DRM license key, for output to RTP streamer.
	RTP streamer	Adds IP header to TS for transmission to the cable IP network using RTP and user datagram protocol (UDP), using the multicast address as instructed by the RF/IP switch controller.

6.3 Cable STB architecture

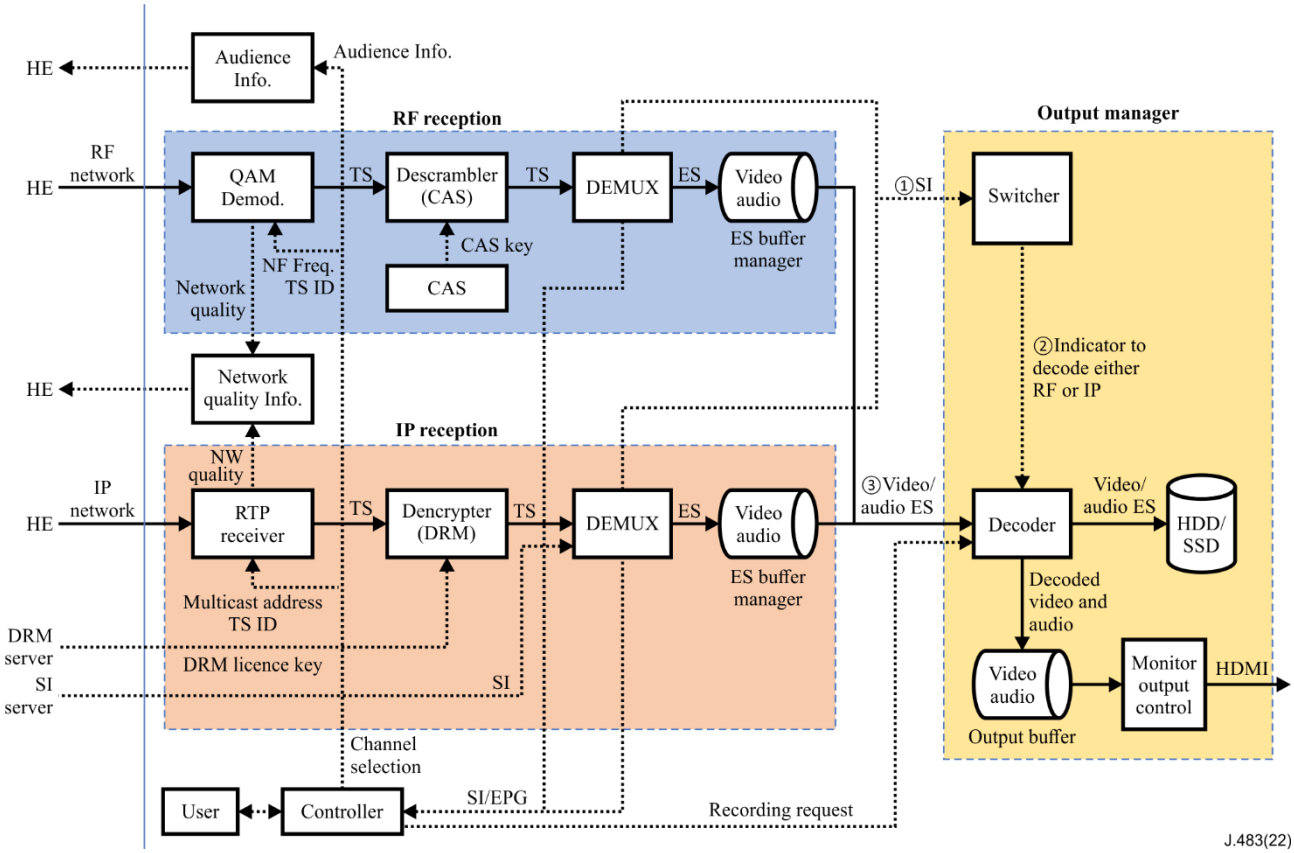

Figure 6-3 – RF/IP switching STB architecture

As indicated in Figure 6-3, the STB function comprises of three parts: RF reception, IP reception and output manager.

RF reception part receives QAM modulated signals from the cable RF network, tunes into RF frequency indicated by the controller, demodulates the QAM signal to retrieve TS, and demultiplexes the TS to retrieve the video/audio ES's and SI.

IP reception part receives IP signals from the cable IP network, filters out IP packets destined to the multicast IP address assigned by the controller, recovers TS, and demultiplexes the TS to retrieve the video/audio ES's and SI.

Received signal output part selects the ES received from either the RF or IP reception part and decodes the video and audio ES's from the selected ES for output to the player.

STB also has functions to select channels based on user interaction and collects information regarding the audience and network quality for transmission to the RF/IP switching cable headend.

Table 6-2 shows the functions of each block that comprise the RF/IP switching cable STB.

Table 6-2 – Functions comprising RF/IP switching cable STB

Part	Block	Function
RF reception	QAM demodulator	Receives QAM modulated signal from the cable RF network, and demodulates it to retrieve TS, for output to the CAS descrambler.
	Descrambler (CAS)	Descrambles TS from the QAM demodulator using CAS descramble key, for output to de-multiplexer

Table 6-2 – Functions comprising RF/IP switching cable STB

Part	Block	Function
		(DEMUX).
	DEMUX	Demultiplexes TS from the CAS descrambler to retrieve video/audio ES and SI. Send retrieved SI to switcher and controller, and video/audio ES's to ES buffer manager.
	ES buffer manager	Buffers or temporarily stores video and audio ES from DEMUX. Outputs video and audio ES to the decoder when switcher instructs to decode the RF received signal.
IP reception	RTP stream receiver	Receives RTP stream from the cable IP network for output to the DRM decrypter. Recovers packet errors with received forward error correction (FEC) packets.
	Decrypter (DRM)	Decrypts TS from RTP stream receiver using the DRM decryption key, for output to DEMUX.
	DEMUX	Demultiplexes TS from DRM decrypter to retrieve video/audio ES. Send retrieved SI to Switcher and Controller, and video/audio ES to ES buffer manager. Receives SI from SI server and forwards it to the switcher. Output SI (electronic programming guide; EPG) to the controller.
	ES buffer manager	Buffers or temporarily stores video and audio ES's from DEMUX. Outputs video and audio ES to the decoder when the switcher instructs to decode the IP received signal.
Output manager	Switcher	Based on SI received from DEMUX, determines either to decode the RF or IP received video/audio ES's and instructs the decoder to decode thus selected ES.
	Decoder	Based on instruction from switcher, decodes either the RF or IP received video/audio ES, generates uncompressed video and audio signals, and stores them in the output buffer.
	Output buffer	Stores uncompressed video and audio signals from the decoder. Outputs the stored uncompressed video and audio signals in sync with the timing generated by the monitor output controller.
	Monitor output controller	Output uncompressed video and audio signals from the output buffer.
Others	Audience information transmission	Send audience information from the controller to the RF/IP switching cable HE.
	Network quality info. transmission	Sends network quality information from QAM demodulator and RTP stream receiver to the RF/IP switching cable HE.
	User	User of an STB. Instructs the controller to display a list of channels, to select a channel, record a program, and so on.
	Controller	Creates a list of channels from SI (EPG) received from RF or IP DEMUX or SI (EPG) and displays it for the user's view.

Table 6-2 – Functions comprising RF/IP switching cable STB

Part	Block	Function
		Retrieves multicast addresses of programmes and outputs them for use by the RTP stream receiver.

7 Functional specifications

7.1 RF/IP common general specifications

RF/IP switching system is required to transmit and receive RF and IP video streams of 4K, HD, and SD, along with the associated audio streams.

7.1.1 STB specification

RF/IP switching system is required to use 4K STB as defined in [ITU-T J.297], Requirements and functional specification of cable set-top box for 4K ultra-high definition television. Note that the STB supports HD and SD video as well.

7.1.2 RF system specification

RF part of RF/IP switching system is required to use MPEG-2 transport stream (MPEG-2 TS), as defined by [ITU-T H.222.0].

7.1.3 IP system specification

IP part of RF/IP switching system is required to use MPEG-2 transport stream (MPEG-2 TS) over IP, using RTP/user datagram protocol (UDP).

7.2 System specifications

7.2.1 Collection of audience information

To collect real-time audience information from a bunch of STB, it is required to use a protocol that supports the following three capabilities:

– Real-time response,

– Lightweight (short header length), and

– Publish / subscribe messaging model.

Message queuing telemetry transport (MQTT) is the one that meets these requirements and is recommended, but other protocols may also be used.

7.2.2 Switching indicator to trigger RF/IP switching

The switching indicator is used to determine the necessity of switching the quality (bitrate) and the distribution scheme (RF or IP) for each video content at each switching cycle. As the indicator, audience satisfaction degree (ASD) is defined as the following formula.

A: a measured score which is the sum of products of the measured audience rating $R_i(t)$ and the score S_i corresponding to the bitrate in use for each video content.

B: an ideal score which is the sum of products of the measured audience rating $R_i(t)$ of each video content and the maximum score S_{max} corresponding to the highest bitrate, which is RF4K in this system.

$$ASD(t) = \frac{A}{B} = \frac{\sum_{i=1}^{n} R_i(t) \times S_i}{\sum_{i=1}^{n} R_i(t) \times S_{max}} \times 100$$

Where,

R: audience rating

S: score based on video bitrates as indicated in Table 7-1

i: index of video content (programme)

n: total number of content (programme), and

t: time.

Table 7-1 – The priority rule of distribution schemes and qualities and an example of the score based on video bitrate for ASD

	High ← Priority determined by audience rating and attribute → Low					
Scheme-quality	RF-4K	IP-4K	RF-HD	IP-HD	RF-SD	IP-SD
Bitrate (bps)	20M	15M	10M	7M	5M	3M
Score	20	15	10	7	5	3

7.2.3 Switching algorithm for automatically RF/IP switching

The switching algorithm is used to keep the highest score of ASD all the time. It is realized by the recursive check and optimization of the distribution scheme and quality (bitrate) for each video content with audience rating, available network bandwidth and attribute of the video content. Note that the implementation of the algorithm may be left to the cable operators and manufacturers' decisions. An example is indicated as follows.

1. Collect the latest ratings, bandwidth, and attributes of the video content.
2. Sort programmes / channels by ratings.
3. Assign programmes with high ratings to the RF at a high bitrate (such as 4K).
4. Change scheme (RF to IP) and quality (bitrate) if the bandwidth becomes insufficient.
5. Recourse No. 3 and No. 4 processes until all the programmes are completely assigned.
6. Calculate the difference between new and old ASDs based on the new/old assignments.
7. Switch scheme and quality if the difference is greater than the predetermined threshold.

7.2.4 Switching interval and threshold for RF/IP switching

The switching interval and threshold are the factors that determine the video quality perceived by the audience, as well as the workload of the switching system. Normally, a short switching interval and low threshold will result in a better ASD but increase the number of processes that the system has to complete in a time interval. It is therefore necessary to find a set of parameters that achieves the best balance of quality (ASD) and workload.

7.2.5 Seamless switching of video streams

For seamless switching of video streams, it is recommended to use video elementary streams (ESs) encoded with closed GOP and execute switching at the GOP boundary. This will minimize the effect of switching on inter prediction.

The details of seamless switching using GOP are as follows.

1. HE transcoders synchronize the GOP boundary of video ESs of different bitrates using time stamps.

2. HE optimizer sends a switching trigger to HE switcher at the end of the GOP near the switching time calculated from the switching algorithm described in clause 7.2.3.
3. HE switcher finishes the distribution of the old video ES by adding an end of sequence (EOS) flag at the end of GOP. At the same time, HE switcher starts the distribution of the new video ES from the closed GOP with a sequence header.
4. For an uninterrupted switching to take place at STB in a stable manner, it is recommended that the old and the new video ES have a minimum of one GOP overlapped by each other.

Moreover, it is recommended to align the GOP size of old and new video ES even if their frame rates are not the same.

Figure 7-1 illustrates this concept of overlapped GOP and aligned intra-period. In this figure, the old stream continues for another GOP after the EOS flag.

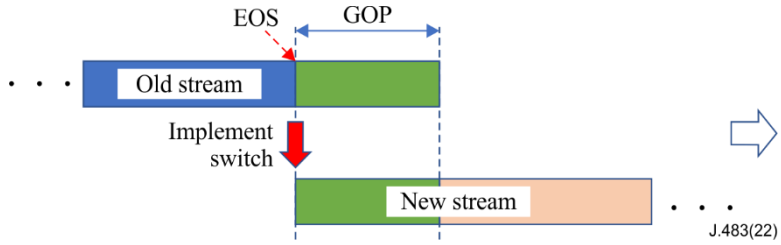

Figure 7-1 – Overlapped GOP for uninterrupted switching

7.2.6 Notification of switching timing for seamless RF/IP switching

SI (service information) of MPEG2 transport system is used to notify the switching time from HE to STB. The following four parameters included in SI are utilized for the notification.

1. service_id
2. IP/MAC notification table (INT) TSID
3. Program map table (PMT)_PID
4. ES_PID and video_encode_format of video_dedcode_control descriptor

Service_id of the video stream is required to be the same before and after switching.

Video ES and audio ES of the video stream whose service_id is the same but the resolution or bitrate is different, are required to use different ES_PID.

7.2.7 Buffer design for seamless RF/IP switching

For stable reception of IP video streams, it is recommended that STB should have a UDP buffer that can store a maximum bitrate video and audio streams for a minimum duration of one second. A frame buffer should have a size larger than the size of GOP.

The buffer size should also take into account jitter that may incur due to congested network conditions or others.

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