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STREAM CONDITIONING FOR SWITCHING OF ADDRESSABLE CONTENT IN DIGITAL TELEVISION RECEIVERS

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TABLE OF CONTENTS

1.0 SCOPE **1**

2.0 NORMATIVE REFERENCES **1**

2.1 SCTE REFERENCES 1
2.2 STANDARDS FROM OTHER ORGANIZATIONS 1
2.2.1 Normative Reference Acquisition 2

3.0 INFORMATIVE REFERENCES **2**

3.1 SCTE REFERENCES 2
3.2 STANDARDS FROM OTHER ORGANIZATIONS 2
3.2.1 Informative Reference Acquisition 3

4.0 COMPLIANCE NOTATION **3**

5.0 DEFINITIONS AND ACRONYMS **3**

6.0 STANDARDS COMPLIANCE **6**

7.0 THE PMT **6**

8.0 LEVEL 0 REQUIREMENTS **6**

8.1 USE OF TRANSPORT STREAMS AND SERVICES 7
8.2 CONDITIONING OF PRIMARY CHANNEL STREAMS 7
8.3 FILLER 7
8.3.1 MPEG-2 Video Filler 7
8.3.2 AVC Video Filler 8
8.3.3 AC-3 Audio Filler 8
8.4 FILLER ALIGNMENT 8
8.5 FILLER PRESENTATION DURATION 9
8.6 ADDRESSABLE CONTENT SET DURATION 9
8.7 MPEG-2 VIDEO CODING REQUIREMENTS 10
8.8 AVC VIDEO CODING REQUIREMENTS 10

9.0 LEVEL 1 REQUIREMENTS **10**

9.1 USE OF TRANSPORT STREAMS 10
9.2 USE OF SERVICES 11
9.3 THE GAP 11
9.4 MPEG CODING REQUIREMENTS 11
9.4.1 The System Clock and Program Clock Reference 11
9.4.2 MPEG Syntax 11
9.4.3 Constraints on MPEG-2 Video Streams Adjacent to a Gap 11
9.4.4 Constraints on AVC Video Streams Adjacent to a Gap 12
9.4.5 Constraints on AC-3 Audio Streams Adjacent to a Gap 13
9.5 BUFFER MANAGEMENT 14

10.0 APPENDIX 1 SYSTEM OVERVIEW (INFORMATIVE) **15**

10.1 CLIENT-DPI RECEIVER FUNCTIONALITY 15
10.2 THE MPEG-2 TRANSPORT STREAM 15
10.3 LEVEL 0 SYSTEMS 16
10.3.1 Level 0 Stream Conditioning 16
10.3.2 Level 0 Head-End 18
10.3.3 Level 0 Client-DPI Receiver 19
10.4 LEVEL 1 SYSTEMS 21
10.4.1 Level 1 Stream Conditioning 21

10.4.2 Level 1 Head-End *22*
10.4.3 Level 1 Client-DPI Receiver *24*
10.5 SIGNALING 25
10.5.1 Selection Criteria Data *26*
10.5.2 Trigger Signals *26*
10.5.3 Command and Control *26*

TABLE OF FIGURES

FIGURE 1 EXAMPLE LEVEL 0 TRANSPORT MULTIPLEX 17
FIGURE 2 BACK TO BACK LEVEL 0 ADDRESSABLE INSERTIONS 18
FIGURE 3 – EXAMPLE LEVEL 0 HEAD-END CONFIGURATION #1 19
FIGURE 4 – EXAMPLE LEVEL 0 HEAD-END CONFIGURATION #2 19
FIGURE 5 – EXAMPLE LEVEL 0 SET-TOP DECODER ARCHITECTURE 20
FIGURE 6 – EXAMPLE LEVEL 1 TRANSPORT MULTIPLEX 21
FIGURE 7 – EXAMPLE LEVEL 1 HEAD-END CONFIGURATION 23
FIGURE 8 – EXAMPLE LEVEL 1 SET-TOP DECODER ARCHITECTURE 25

1.0 SCOPE

This document describes the stream Conditioning required to enable Client-DPI Receivers to implement switching of MPEG-2 and AVC video streams with associated AC-3 audio.

For “Level 0”, or “L0” systems, it defines switching among MPEG-2 streams, among AVC streams and between AVC and MPEG-2 video streams in a non-seamless fashion (similar to a channel change).

For “Level 1”, or “L1” systems, it defines switching among MPEG-2 video streams and among AVC streams in a seamless fashion. Switching between MPEG-2 and AVC video streams is forbidden in L1 systems.

Triggers and signaling are out of scope for this standard.

Note: Client-DPI devices include Receivers conforming to OCAP as well as other cable-compatible Receivers.

2.0 NORMATIVE REFERENCES

The following documents contain provisions, which, through reference in this text, constitute provisions of the standard. At the time of Subcommittee approval, the editions indicated were valid. All standards are subject to revision; and while parties to any agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of the documents listed below, they are reminded that newer editions of those documents may not be compatible with the referenced version.

2.1 SCTE References

1. ANSI/SCTE 30 2009: Digital Program Insertion Splicing API.
2. ANSI/SCTE 43 2005: Digital Video Systems Characteristics Standard for Cable Television.
3. ANSI/SCTE 54 2009: Digital Video Service Multiplex and Transport System for Cable Television
4. ANSI/SCTE 128-2010: AVC Video Systems and Transport Constraints for Cable Television
5. SCTE 172 2011: Constraints On AVC Video Coding For Digital Program Insertion

2.2 Standards from other Organizations

6. ISO/IEC 13818-1 (2007): International Standard, Information Technology – Generic coding of moving pictures and associated audio information: Systems.

7. ISO/IEC 13818-2 (2000): International Standard, Information Technology – Generic coding of moving pictures and associated audio information: Video
8. ISO/IEC 14496-10 (ITU-T H.264): International Standard (2010), Advanced video coding for generic audiovisual services.
9. ATSC A/52 (2012): Digital Audio Compression Standard (AC-3, E-AC-3)
10. ATSC A/53 Part 5 (2010): AC-3 Audio System Characteristics

2.2.1 Normative Reference Acquisition

2.2.1.1 ANSI/CEA Standards:

American National Standards Institute, Customer Service, 11 West 42nd Street, New York. NY 10036; Phone 212-642 4900; Fax 212-302-1286; email: sales@ansi.org; Internet: http://www.ansi.org.

2.2.1.2 SCTE Standards: United States of America:

Society of Cable Telecommunications Engineers Inc., 140 Philips Road, Exton, PA 19341; Telephone 800-542-5040; Facsimile: 610-363-5898; E-mail: standards@scte.org; URL: http://www.scte.org.

2.2.1.3 ISO/IEC Standards:

Global Engineering Documents, World Headquarters, 15 Inverness Way East, Englewood, CO. USA 80112-5776; Phone 800-854-7179; Fax 303-397-2740; Internethttp://global.ihs.com; email global@ihs.com.

2.2.1.4 ATSC Standards:

Advanced Television Systems Committee (ATSC), 1776 K Street NW STE 200 - Washington, DC 20006-2304; Ph.-202.872.9160 Fax-202.872.9161; http://www.atsc.org/standards.html.

3.0 INFORMATIVE REFERENCES

The following documents may provide valuable information to the reader but are not required when complying with this standard.

3.1 SCTE References

11. ANSI/SCTE 35 2013: Digital Program Insertion Cueing Message for Cable.

3.2 Standards from other Organizations

12. SMPTE 312M-2001: Television – Splice Points for MPEG-2 Transport Streams
13. OC-SP-OCAP1.1-I01-061229: OpenCable Application Platform Specification OCAP1.1 profile

14. OC-SP-HOST2.1-CFR-I09-090904: OpenCable Host Device 2.1 Core Functional Requirements

3.2.1 Informative Reference Acquisition

3.2.1.1 ANSI/CEA Standards:

See Section 2.2.1.1.

3.2.1.2 SCTE Standards: United States of America:

See Section 2.2.1.2

3.2.1.3 SMPTE:

https://store.smpte.org/.

3.2.1.4 OC - OpenCable Specifications:

Cable Television Laboratories, Inc., 400 Centennial Parkway, Louisville, CO 80027; Phone 303-661-9100; Fax 303-661-9199; Internet: http://www.opencable.com/ email: opencable@cablelabs.com.

4.0 COMPLIANCE NOTATION

"SHALL"	This word or the adjective "REQUIRED" means that the item is an absolute requirement of this specification.
"SHALL NOT"	This phrase means that the item is an absolute prohibition of this specification.
"SHOULD"	This word or the adjective "RECOMMENDED" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighted before choosing a different course.
"SHOULD NOT"	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
"MAY"	This word or the adjective "OPTIONAL" means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.

5.0 DEFINITIONS AND ACRONYMS

Throughout this standard the terms below have specific meanings. Because some of the terms are defined in other documents having very specific technical meanings, the reader is referred to the original source for their definition. For terms used within this standard, brief definitions are given below.

Addressable Content Set: A collection of simultaneously transmitted elementary streams of equal presentation duration typically containing appropriate combinations of media streams (video, audio and data) that may be selected as the result of a Switch.

AVC: Advanced Video Coding refers specifically to video compression standardized in ISO/IEC 14496-10 [8].

CAT: Conditional Access Table. [6]

CPB: Coded Picture Buffer [8].

Client-DPI Receiver: A Receiver that is able to select among elementary streams from within an Addressable Content Set.

Conditioning: This term refers to the set of rules that specify constraints on transport, video and audio that enable both a seamless and a non-seamless Switch within Client-DPI Receivers.

Decision Engine: The algorithm in a Client-DPI Receiver that selects which particular content should be selected from an Addressable Content Set and presented to the viewer.

DPB: Decoded Picture Buffer [8].

DPI: Digital Program Insertion. [1] [11]

DTS: Decode Time Stamp. [6]

Filler: Used in Level 0 Streams, this is the region within which the Client-DPI Receiver begins and completes a Switch. The Filler is inserted into all video and audio elementary streams that comprise an Addressable Content Set.

FPP: Forward Predicted Picture [4]

Gap: Used in Level 1 Streams, this is the region within which the Client-DPI Receiver begins and completes a Switch. The Gap is inserted into all video and audio elementary streams that comprise an Addressable Content Set.

GOP: Group of Pictures. [7]

IDR: Instantaneous Decoding Refresh. A picture type defined in ISO/IEC 14496-10 [8].

IDR NAL unit: An IDR slice [8]. (A NAL unit with nal_unit_type = 5.)

Insertion Channel: The MPEG Programs comprising the Addressable Content Set that replaces the Primary Channel in whole or in part for the duration of a Switch Event.

Insertion Sequence: A set of back-to-back Switch Events.

Level 0 / L0: Streams or Switches resulting in non-seamless transitions. Transitions between MPEG-2 video and AVC video are permitted.

Level 1 / L1: Streams or Switches resulting in seamless transitions. Transitions between MPEG-2 video and AVC video are not permitted.

Level 0 Stream: A Primary Channel or Insertion Channel that has been conditioned in order to enable a Level 0 Switch. [1]

Level 1 Stream: A Primary Channel or Insertion Channel that has been conditioned in order to enable a Level 1 Switch. [1]

Level 0 Switch: This term refers to a Switch from one video elementary stream to another video elementary stream (MPEG-2 video or AVC video) and one AC-3 audio elementary stream to another AC-3 audio elementary stream without any perceptible audio or video artifacts, but which may include the use of black pictures and audio silence to mask any artifacts during the latency of the Switch.

Level 1 Switch: This term refers to a Switch from one video elementary stream to another video elementary stream (MPEG-2 video or AVC video) of the same stream_type and/or one AC-3 audio elementary stream to another AC-3 audio elementary stream without any perceptible delay, or audio or video artifacts.

MPTS: Multiprogram Transport Stream. [6]

NAL: Network Abstraction Layer defined in ISO/IEC 14496-10 [8].

PAT: Program Association Table. [6]

PCR: Program Clock Reference. [6]

PES: Packetized Elementary Stream. [6]

PID: Packet Identifier. [6]

PMT: Program Map Table. [6]

Primary Channel: The MPEG Program that is replaced in whole or in part by members of the Addressable Content Set during a Switch Event.

PSI: Program Specific Information. [6]

PTS: Presentation Time Stamp. [6]

Receiver: A cable television receiving device which is typically a set-top box or a DTV receiver.

Seamless: A transition from one content set to another (either video or audio, or both) without any artifacts or discontinuities. This transition is usually invisible and inaudible to the viewer.

Signaled Switch Point: The point within the MPEG-2 transport stream where the Switching Engine may initiate a Switch.

SRAP: SCTE Random Access Point. Defined in ANSI/SCTE 128 [4].

Switch: The action performed by a Client-DPI Receiver, which chooses certain elementary streams out of an Addressable Content Set. Note: switch and splice are typically used interchangeably.

Switch Event: The time between two adjacent switches during which Client-DPI Receivers present an Insertion Channel.

Switching Engine: The functionality that executes a Switch in a Client-DPI Receiver.

Trigger Signal: An element within the MPEG-2 transport stream multiplex which indicates the location of a Signaled Switch Point.

6.0 STANDARDS COMPLIANCE

All transport streams (with video and audio components) delivered to Client-DPI Receivers shall be compliant with SCTE 54 [3] and SCTE 128 [4] as appropriate. In addition, MPEG-2 video coding shall be compliant with SCTE 43 [2], AVC video coding shall be compliant with SCTE 128 [4], and audio coding shall be compliant with ATSC A/52 [9] as constrained by A/53 Part 5. [10]

7.0 THE PMT

SCTE 54 constrains each PMT PID to contain a single TS_program_map_section. Any PMT structures used by Addressable Content should conform to this constraint. [3]

In systems where addressable content is present in the same transport stream as the Primary Channel, all of the PMTs shall be present in the transport stream at all times. Changes to any PMT in the vicinity of a Filler or Gap should be avoided.

Note: The preceding requirement will result in one or more PMTs being present in the transport stream that describe PIDs for which data will be present only when addressable content is present.

Note: It may be necessary to transmit PAT, CAT and PMT more frequently than required by SCTE 54 during the Filler in Level 0 Streams. The aggregate of PAT, PMT and CAT transmitted in this interval should not exceed 80,000 bits/second.

8.0 LEVEL 0 REQUIREMENTS

Level 0 Conditioning consists of a Filler, as defined in section 8.3, and MPEG coding requirements defined in sections 8.7 and 8.8. The Conditioning described in this section shall be present in the transport stream at the input to a Client-DPI Receiver when a Level

0 Switch is enabled. In this context, “enabled” means that a Client-DPI Receiver may, as determined by its Decision Engine, perform a Level 0 Switch. The following requirements for Level 0 apply to both standard definition and high definition formats in both MPEG-2 and AVC video streams.

8.1 Use of Transport Streams and Services

In Level 0 systems, one or more transport streams may be used to convey the elementary streams comprising an Addressable Content Set. All elementary streams selected as the result of a Level 0 Switch shall reside in the same transport stream and in the same service.

8.2 Conditioning of Primary Channel Streams

All of the video and audio elementary streams comprising the Primary Channel shall be Level 0 conditioned, as defined in section 8.0 of this standard, when a Level 0 Switch is enabled.

8.3 Filler

Filler shall be present in all of the audio and video elementary streams which comprise an Addressable Content Set when a Level 0 Switch is enabled. Filler in video elementary streams shall consist of picture data that will be decoded as black pictures. Filler in audio elementary streams shall consist of audio data that will be decoded as silence.

The content on the Primary Channel including all Fillers and non Filler content shall use the same audio and video codecs.

All Filler and non Filler content shall use the same audio and video codecs and the same PMTs during an Insertion Sequence in an Insertion Channel.

Picture format changes during an Insertion Sequence shall be restricted to changes in horizontal resolution and shall be compliant with either ANSI/SCTE 43 [2], or ANSI/SCTE 128 [4].

The transition from Filler to subsequent non-Filler content and non-Filler content to subsequent Filler in both video and audio streams should not introduce any visible or audible artifacts.

Note: There is no requirement that the codec used on any Insertion Channel be the same as any other Insertion Channel or Primary Channel.

Note: Filler may be produced at any point in the signal processing chain. For example, it could be included in stored advertising content, or inserted by a splicing device.

Note: Client-DPI Receivers may utilize any appropriate methods to minimize the time required to perform a Level 0 Switch, including communicating PID values in a manner that eliminates the need to parse the PSI (See section 7.0).

8.3.1 MPEG-2 Video Filler

The following requirements apply when performing an L0 switch when MPEG-2 video content is present. These requirements are defined in order to ensure that the Client-DPI device has adequate time to change codecs, if needed, during the retune and reacquisition process.

In MPEG-2 video streams, the Filler shall begin with an I picture, and shall consist of alternating I and P pictures in transmission order throughout the duration of the Filler. The Filler may end on an I or P picture. All I pictures shall be preceded by a sequence header and appropriate sequence extension. The transition between Filler and non-Filler content shall be compliant with MPEG-2. Field parity shall be maintained during these transitions.

In each service carrying Filler there shall be a PCR transmitted on the designated PCR_PID within 5 milliseconds prior to the transmission of the PES header that begins each I picture.

8.3.2 AVC Video Filler

The following requirements apply when performing an L0 switch when AVC video content is present. These requirements are defined in order to ensure that the Client-DPI device has adequate time to change codecs, if needed, during the retune and reacquisition process.

In AVC video streams, the Filler shall begin with an IDR picture, and shall consist of alternating IDR and FPP pictures in transmission order throughout the duration of the Filler. The Filler may end on an IDR or FPP picture. All IDR pictures shall be preceded by an SPS and appropriate VUI. The coded video sequence comprised of Filler and the adjacent content shall be compliant with SCTE 128 [4]. Field parity shall be maintained during these transitions.

In each service carrying Filler there shall be a PCR transmitted on the designated PCR_PID within 5 milliseconds prior to the transmission of the PES header that begins each IDR picture.

8.3.3 AC-3 Audio Filler

The following requirements apply when performing an L0 switch when AC-3 audio content is present. These requirements are defined in order to ensure that the Client-DPI device has adequate time to change codecs, if needed, during the retune and reacquisition process.

The Filler in AC-3 audio elementary streams shall be comprised of complete AC-3 access units. Each AC-3 access unit shall be in its own PES packet. The transition between Filler and non-Filler content shall be compliant with AC-3 standards ATSC A/52 [9] and ATSC A/53 Part 5 [10].

8.4 Filler Alignment

For a given Switch, all Fillers shall be aligned. This requirement shall apply to all streams involved in a Switch regardless of whether they are contained within the same transport stream or in different transport streams.

For alignment purposes, within a service an alignment point is defined as the later of the start of Filler in either the video or audio elementary stream. Across all services involved in a given Switch, all alignment points shall occur within 35 milliseconds.

Following the alignment point, all video Fillers shall have the same transmission duration. Following the alignment point, all audio Fillers shall have the same transmission duration.

Note: The alignment point establishes the earliest point at which a Client-DPI Receiver can initiate a Switch. The start of Filler is aligned to guarantee that a Client-DPI Receiver which completes a Switch very quickly does not join the destination service before the transmission of the Filler on that service has started. The transmission duration of the Filler is chosen to guarantee that a Client-DPI Receiver which completes a Switch slowly does not join the destination service after the transmission of the Filler on that service has ended. The minimum Filler transmission duration would be chosen to accommodate the tuning time of the Client-DPI Receiver. For example if the Client-DPI Receiver can complete a tune in 500 milliseconds or less the minimum Filler duration would be 533 milliseconds. In certain implementations, the Filler transmission duration may be greater than 533 milliseconds based upon other system requirements, for example to accommodate time base discontinuities or to allow for changes in an encryption key.

8.5 Filler Presentation Duration

The presentation duration of Filler in video elementary streams is defined as the time from the PTS of the first presented video access unit in the Filler to the PTS of the last presented video access unit in the Filler plus the presentation duration of the last presented video access unit in the Filler. The presentation duration of all Fillers in video elementary streams shall be the same across all video elementary streams involved in a given Switch.

The presentation duration of Filler in audio elementary streams is defined as the time from the PTS of the first presented audio access unit in the Filler to the PTS of the last presented audio access unit in the Filler plus the presentation duration of the last presented audio access unit in the Filler. The presentation duration of all Fillers in audio elementary streams shall be the same across all audio elementary streams involved in a given Switch.

The presentation duration of Filler in video and audio elementary streams cannot be constrained to be identical due to the fact that the access unit duration of video is not the same as the access unit duration of audio. The presentation duration of Filler in audio elementary streams shall not differ from the presentation duration of Filler in video elementary streams by more than 35 milliseconds.

8.6 Addressable Content Set Duration

The presentation duration of the video within an Addressable Content Set is defined as the time from the PTS of the first presented video access unit in the Addressable Content Set to the PTS of the last presented video access unit in the Addressable Content Set plus the presentation duration of the last presented video access unit in the Addressable Content Set. The presentation duration of all video streams shall be the same across all video streams in an Addressable Content Set.

The presentation duration of the audio within an Addressable Content Set is defined as the time from the PTS of the first presented audio access unit in the Addressable Content Set to the PTS of the last presented audio access unit in the Addressable Content Set plus the presentation duration of the last presented audio access unit in the Addressable Content Set. The presentation duration of all audio streams shall be the same across all audio streams in an Addressable Content Set.

Within an Addressable Content Set, the presentation duration of audio shall not differ from the presentation duration of video by more than 18 milliseconds.

In the case where Filler is included in the encoded Addressable Content Set, these constraints apply only to the non-Filler portion, while the Filler portion is constrained as required in section 8.5.

Note: The presentation duration of video and audio in an Addressable Content Set cannot be constrained to be identical due to the fact that the access unit duration of video is not the same as the access unit duration of audio.

8.7 MPEG-2 Video Coding Requirements

Following the Filler, the first transport packet carrying video elementary stream payload shall start with a PES header, and the payload of that PES packet shall start with a sequence header, and a GOP header followed by an I picture. In the first GOP header, the closed_gop bit shall be set to ‘1’, indicating that this first GOP is closed. In order to accommodate changes to horizontal_size_value in the video stream between Filler and Addressable Content, a sequence end code shall be used at the end of the last access unit, in decode order, in the Filler.

8.8 AVC Video Coding Requirements

Following the Filler, content shall begin with an IDR access unit. The initial IDR access unit should have no_output_of_prior_pics_flag set to ‘1’ in all slice headers within that access unit, unless there is another way to guarantee conformance with both ANSI/SCTE 128-2008 [4] and SCTE 172 [5].

9.0 LEVEL 1 REQUIREMENTS

Level 1 Conditioning consists of a Gap, as defined in section 9.3, and specific MPEG coding requirements defined in sections 9.4 and 9.5. This Conditioning shall be present in the transport stream at the input to a Client-DPI Receiver when a Level 1 Switch is enabled. In this context, “enabled” means that a Client-DPI Receiver may, as determined by its Decision Engine, perform a Level 1 Switch. The following requirements for Level 1 apply to both standard definition and high definition MPEG-2 and AVC video streams.

9.1 Use of Transport Streams

In Level 1 systems, a Switch shall be limited to elementary streams within the same MPTS.

9.2 Use of Services

PMTs within the MPTS shall be constructed such that all elementary streams that are selected as the result of a Level 1 Switch, including a video-only or audio-only Switch, shall reside in the same service.

9.3 The Gap

When a Level 1 Switch is to be enabled, a Gap shall be inserted into all coded video elementary streams that may be switched away from or switched to. There shall exist a minimum 10 millisecond period (as measured in transmission time) that is wholly contained within all of the video Gaps. A separate Gap shall be inserted into all coded audio elementary streams that may be switched away from or switched to. There shall exist a minimum 10 millisecond period (as measured in transmission time) that is wholly contained within all of the audio Gaps.

During the Gap, there shall be no transmission of transport packets containing PES headers or PES data in the video or audio elementary streams that may be switched away from or switched to.

Note: For a given switch opportunity, the Gap in video streams will not necessarily be aligned with the Gap in audio streams. The offset between them will be equal to the difference in decoder buffer delay between video and audio, which is a function of a number of encoding parameters affecting both the video and audio streams.

9.4 MPEG Coding Requirements

9.4.1 The System Clock and Program Clock Reference

A switch from one stream to another (of the same type) during the Gap is expected to maintain the continuity of the system clock in a Client-DPI Receiver. All of the services comprising an Addressable Content Set shall either reference a common PCR_PID, or individual services may each contain a different PCR_PID all of which shall carry the same program clock.

9.4.2 MPEG Syntax

A switch from one stream to another (having the same stream_type) during the Gap in a Client-DPI Receiver shall not cause a discontinuity in or non-compliance of MPEG syntax at any layer, except for the continuity_counter in the transport packet header.

9.4.3 Constraints on MPEG-2 Video Streams Adjacent to a Gap

In video streams, the last byte of the payload of the transport packet transmitted prior to the Gap shall be the last byte of a video access unit and the last byte of a PES packet.

The last picture in presentation order prior to a Gap shall be either a P or an I picture.

Prior to a Gap, the value of DTS for the last decoded picture shall be the same in all video streams that may be switched from. The value of PTS for the last presented picture shall be the same in all video streams that may be switched from.

To accommodate horizontal resolution changes after the Gap, the last access unit prior to the Gap shall end with a sequence end code.

Following a video Gap, the first transport packet carrying a payload shall start with a PES header. The payload of that PES packet shall start with a sequence header, sequence extension and GOP header.

The sequence header fields vertical_size_value, aspect_ratio_information, frame_rate, progressive_sequence and constrained_parameters_flag shall contain values identical to those fields within the last sequence header transmitted prior to the Gap. The field horizontal_size_value is permitted to change within the constraints specified by SCTE 43 [2]. The sequence extension shall be identical to the last sequence extension transmitted prior to the Gap. Field parity shall be maintained across the Gap.

In the first GOP header, the closed_gop bit shall be set to '1', indicating that this first GOP is closed. The first coded picture in the first GOP shall be an I picture.

Following a Gap, the first video transport packet carrying payload shall start with a PES header and the start of a video access unit. The values of PTS of the first video access unit in all of the MPEG-2 video streams, that may be selected as the result of a Switch, shall be the same. The value of that PTS shall be equal to the PTS of the last video access unit prior to the Gap plus the presentation duration of that video access unit.

The first picture in decode order following a Gap shall have a DTS such that the decoding of this picture follows the decoding of the last picture decoded prior to the Gap at the proper time as determined by the access unit duration.

Following a Gap, the values of DTS of the first coded picture in all video streams that may be selected as the result of a Switch shall be the same. The value of PTS for the first presented picture in all video streams that may be selected as the result of a Switch shall be the same.

Note: Changes in bar data and/or active format description (AFD) data across the Gap may affect the presentation of selected content at the receiver.

9.4.4 Constraints on AVC Video Streams Adjacent to a Gap

In video streams, the last byte of the payload of the transport packet transmitted prior to the Gap shall be the last byte of a video access unit and the last byte of a PES packet.

Prior to a Gap, the value of DTS for the last decoded picture shall be the same in all video streams that may be switched from.

When the last access unit prior to the Gap is decoded, all of the pictures in the DPB which are not yet output (displayed/presented) shall be, starting immediately, contiguously displayable (no discontinuity in their PTS values).

The value of PTS for the last presented picture in all video streams that may be switched from shall be the same.

Following a video Gap, the first transport packet carrying a payload shall start with a PES header. The payload of that PES packet shall start with an SRAP containing an IDR access unit constrained by SCTE 172 [5] and SCTE 128 [4]. The SPS and VUI parameters of this IDR access unit shall be the same as the SPS and VUI parameters of coded video sequence transmitted prior to the Gap except for the field ‘PicWidthInMBs’ as constrained by SCTE 128 [4]. The no_output_of_prior_pics_flag in this IDR access unit shall be set to ‘0’.

Following a Gap, the first video transport packet carrying payload shall start with a PES header and the start of a video access unit. The values of PTS of the first video access unit, in all of the AVC video streams that may be selected as the result of a Switch, shall be the same. The value of that PTS shall be equal to the PTS of the last video access unit prior to the Gap plus the presentation duration of that video access unit.

The first picture in decode order following a Gap shall have a DTS such that the decoding of this picture follows the decoding of the last picture decoded prior to the Gap at a proper time as determined by the access unit duration.

Following a Gap, the values of DTS of the first coded picture in all video streams that may be selected as the result of a Switch shall be the same. The value of PTS for the first presented picture in all video streams that may be selected as the result of a Switch shall be the same.

Note: Changes in bar data and/or active format description (AFD) data across the Gap may affect the presentation of selected content at the receiver.

9.4.5 Constraints on AC-3 Audio Streams Adjacent to a Gap

In audio streams, the last byte of the payload of the transport packet transmitted prior to the Gap shall be the last byte of an audio access unit and the last byte of a PES packet.

Preceding a Gap, the values of PTS of the last presented audio access unit in all of the audio streams that may be switched from shall be the same.

Following a Gap, the first audio transport packet carrying payload shall start with a PES header and the start of an audio access unit. The values of PTS of the first audio access unit in all of the audio streams that may be selected as the result of a Switch shall be the same. The value of that PTS shall be equal to the PTS of the last audio access unit prior to the Gap plus the presentation duration of that access unit.

9.5 Buffer Management

At each Gap, all possible Switches shall not result in any buffer or time base discontinuities, and shall maintain full compliance with the T-STD model.

10.0 APPENDIX 1 SYSTEM OVERVIEW (INFORMATIVE)

This standard enables a form of addressable content delivery in digital television systems by conditioning video and audio elementary streams in an MPEG-2 transport stream. The following is an example application of telecast addressable advertising that employs this Conditioning.

In this telecast addressable advertising implementation, multiple advertisement streams are simultaneously delivered to a Client-DPI Receiver. The Client-DPI Receiver selects one of the advertisements based upon received addressing information and locally stored selection criteria, and switches at the appropriate time. The switch may be accomplished in a non-seamless manner, herein referred to as Level 0 (L0) switching, or in a seamless manner, herein referred to as Level 1 (L1) switching, as described below.

An addressable advertising system may employ either or both Level 0 and/or Level 1 switching.

10.1 Client-DPI Receiver Functionality

In order for a Receiver to be Client-DPI capable, specific functionalities herein referred to as the Decision Engine and Switching Engine are present on that Receiver.

The Decision Engine implements a methodology for determining which stream(s) should be selected for presentation at the time of each Switch.

The Switching Engine implements Level 0 and/or Level 1 switching, and provides an interface that enables a Decision Engine to cause the required switching to take place.

10.2 The MPEG-2 Transport Stream

The transmission of addressable advertising within a digital cable television system is in compliance with MPEG-2 and SCTE standards. This section reviews some of the basic concepts, the knowledge of which is fundamental to understanding how addressable advertising systems might operate.

Typically, a number of separate television channels are combined in a single transport stream, as described in ISO/IEC 13818-1 [6]. The MPEG-2 transport stream is a packetized multiplex. Packets are fixed in length, and are comprised of a header portion and a payload portion. Video and audio coded data from each elementary stream within the multiplex is carried in the payload portion. The header portion carries, among other items a unique PID value that indicates to which elementary stream the contents of the payload portion belongs.

In addition to the data comprising encoded video and audio information for each television channel, the transport stream carries System Information streams which describe the video and audio data and enable a Client-DPI Receiver to select the proper streams to be decoded based on channel selection. There may also be data associated with applications, sometimes specific to the television channels contained within the multiplex, and there may be data transmitted to support decryption of encrypted video and audio elementary streams.

In accordance with the MPEG-2 Systems standard [6], the transmission of video, audio, and data is timed to insure that data from each stream is available at the Receiver in time for it to be decoded without overflowing that stream's buffer in the Receiver. Null packets may be used in the stream as necessary to satisfy QAM modulator requirements. The result, as seen at the input to the Receiver, is a continuous stream of packets.

10.3 Level 0 Systems

10.3.1 Level 0 Stream Conditioning

Level 0 systems permit addressable advertisement streams designated for insertion into a particular Primary Channel to be transmitted in an MPEG-2 transport multiplex different from the one that is carrying the Primary Channel. The Client-DPI Receiver, then, acquires the alternate multiplex before it can select and decode the required addressable advertisement. Typically, this will involve tuning to the RF channel carrying the multiplex that carries the addressable advertisements.

Figure 1 below depicts portions of two different MPEG-2 transport stream multiplexes showing the presence of a single Level 0 Addressable Content Set, comprised of four addressable advertisements. Also shown are the time boundaries within which the transport packets containing video, audio and data associated with the Addressable Content Set may be transmitted. Packets carrying streams not related to the Addressable Content Set, including null packets, would also be present in a real system. For clarity, this unrelated data is not shown in the Figure.

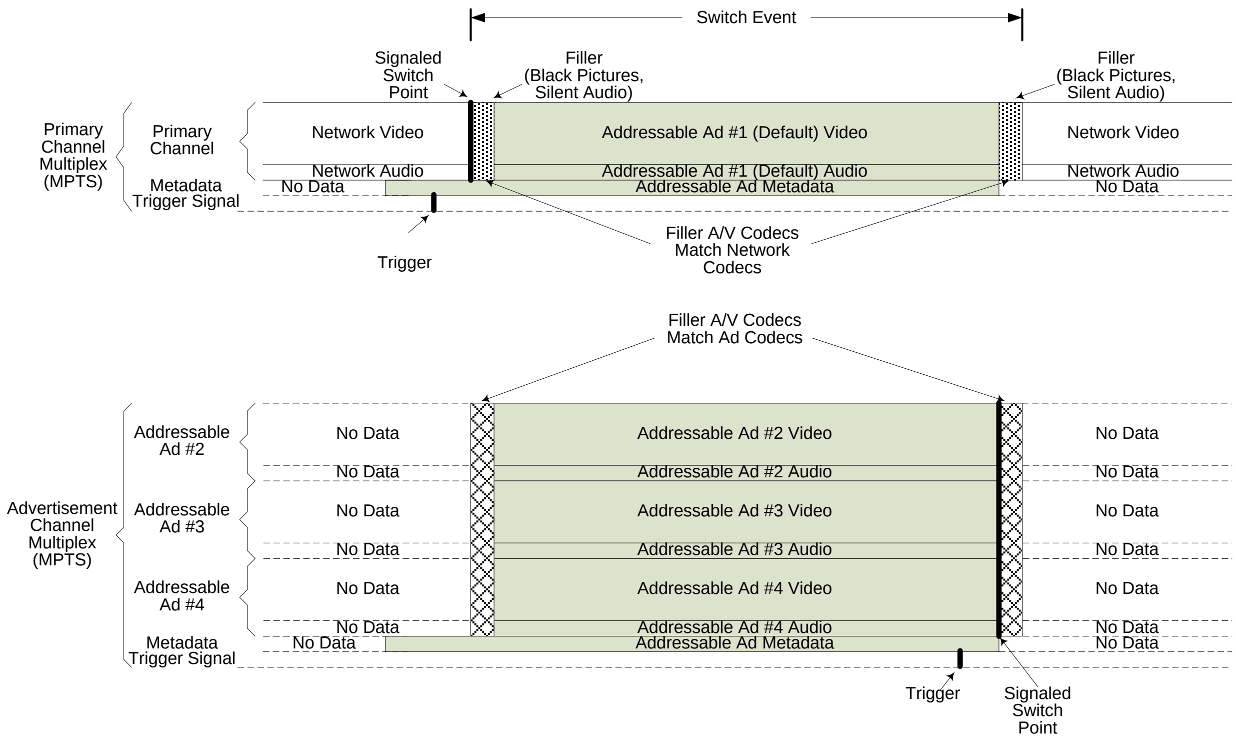

Figure 1 Example Level 0 Transport Multiplex

In this example, one of the addressable advertisements, designated as the default advertisement, is present in the Primary Channel and exists on the same PIDs as the Network's video and audio PIDs. The default addressable advertisement will be displayed by Receivers that do not implement Level 0 switching. Also, the default addressable advertisement will be selected by Level 0 capable Client-DPI Receivers that, as determined by the Decision Engine, do not respond to selection criteria for this Addressable Content Set. The remaining addressable advertisements are present in the advertisement channel multiplex.

An opportunity to switch from the Primary Channel video and audio streams is shown as a Signaled Switch Point at the start of the Addressable Content Set. Another Signaled Switch Point marks the opportunity to switch back to the Primary Channel video and audio streams at the end of the Addressable Content Set. A transmission Filler follows each of these Signaled Switch Points. During these Fillers, the Client-DPI Receiver will tune to and begin decoding the new multiplex. Properly formatted picture data for black pictures, and audio data that represents silent audio, are transmitted during this time. This insures that the Client-DPI Receiver will be able to acquire and begin decoding the new content without displaying any artifacts or losing any significant video or audio data as defined in OC-SP-HOST2.1 [14]. The duration of the Filler is selected to allow for the time required for the slowest Client-DPI Receiver to tune to and begin decoding the new multiplex.

The Signaled Switch Points and Fillers occurring in both the Primary Channel and advertisement channel multiplexes are aligned in time. Similarly, the transmission of addressable advertisement #1 in the Primary Channel multiplex is aligned in time with the transmission of addressable advertisements #2, #3, and #4 in the advertisement channel multiplex. This standard specifies the stream properties at the receiving Client device. The preparation of the Filler for the Primary Channel may be performed either in the head-end or at the network feed origination site. When Filler is present in the Primary Channel it will always be entirely within Switch Event boundaries.

A single Trigger Signal is associated with each Signaled Switch Point. The Trigger Signal indicates the location of the Signaled Switch Point in time. Even though Figure 1 shows the Trigger Signal as data that is not contained within the video or audio streams, other methods of providing the Trigger Signal not shown here may be used.

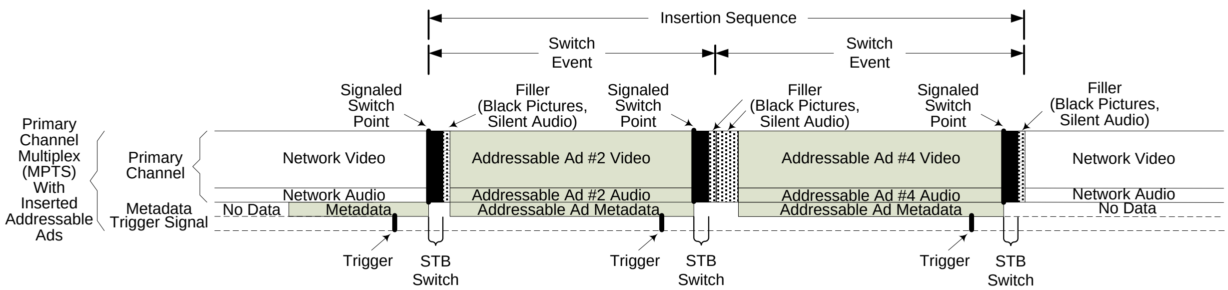

Figure 2 Back to Back Level 0 Addressable Insertions

Figure 2 illustrates a back-to-back Level 0 addressable insertion. This diagram shows the result of 2 addressable ads that have been selected by a Client-DPI Receiver.

In this example, Insertion Channels 1, 2 and 3 contained the following addressable advertisements:

Insertion Channel 1	Addressable Ad #1	Addressable Ad #4
Insertion Channel 2	Addressable Ad #2	Addressable Ad #5
Insertion Channel 3	Addressable Ad #3	Addressable Ad #6

This figure shows the bit stream being presented to the Client-DPI Receiver's decoder after switching. As a result of Switches, Addressable Ads 2 and 4 were selected from two separate Insertion Channels: 2 and then 1. There is no data during the STB Switch before the Client-DPI Receiver acquires valid data in the next Insertion Channel or Primary Channel.

10.3.2 Level 0 Head-End

Figure 3 and Figure 4 below show hypothetical head-end architectures suitable for inserting Level 0 Addressable Content Sets.

In Figure 3, the splicer inserts addressable advertisements using both the Primary Channel multiplex and the advertisement channel multiplex, as well as advertisement selection criteria and Trigger Signals.

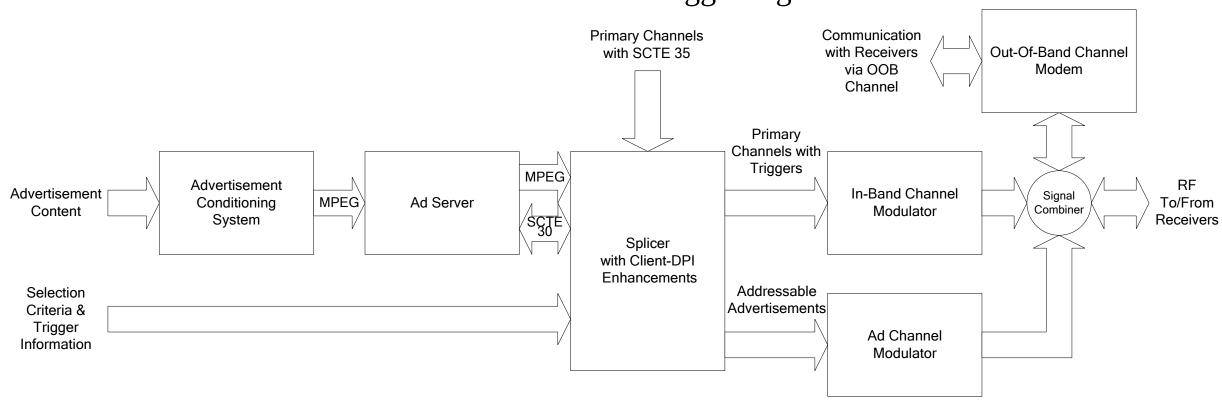

Figure 3 – Example Level 0 Head-End Configuration #1

In the example shown in Figure 4, the Client Edge Device is a specialized device for implementing certain types of client-based systems. It can handle all signaling, can stream out addressable advertisements on a dedicated advertisement channel, interface with cable plant to negotiate and acquire bandwidth, and perform basic conditioning on addressable advertisements and network feeds to enable Level 0 switching.

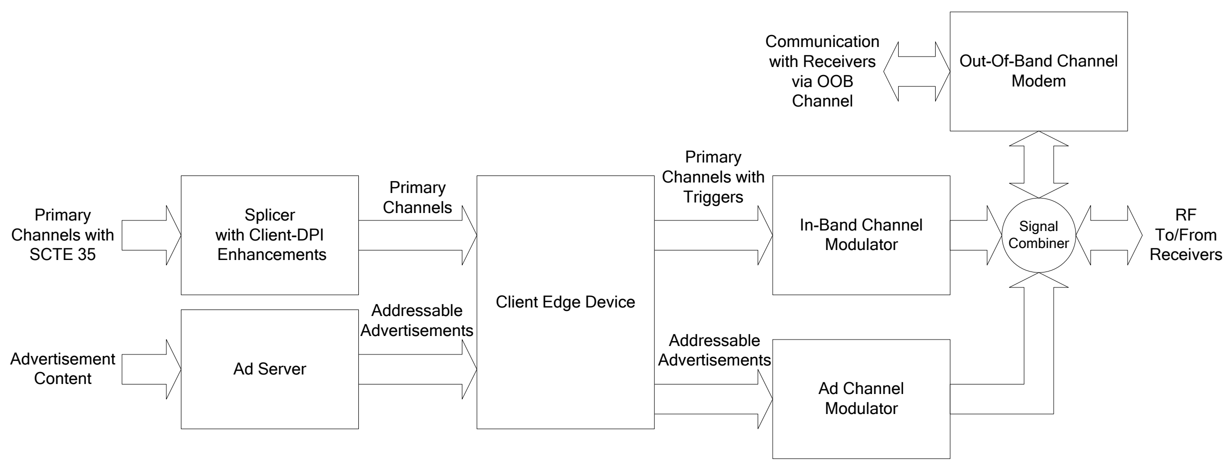

Figure 4 – Example Level 0 Head-End Configuration #2

10.3.3 Level 0 Client-DPI Receiver

Figure 5 below depicts a hypothetical Client-DPI Receiver architecture suitable for use in a Level 0 system. The Decision Engine and Switching Engine are shown, along with relevant signal flows. The Trigger Signal is assumed to be in the form of a data message carried on a separate stream from the streams carrying the video and audio data.

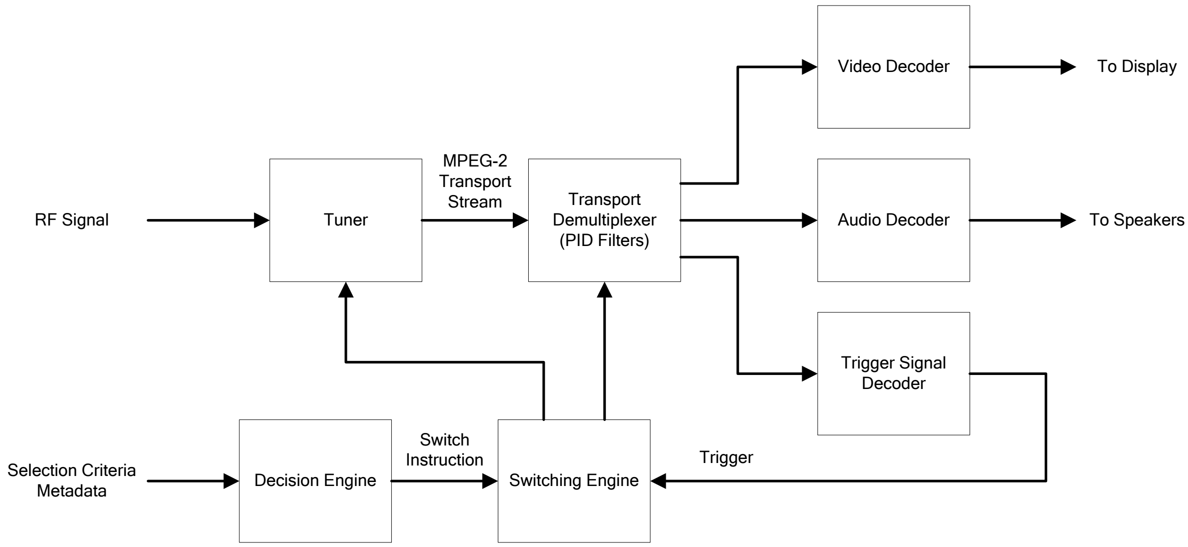

Figure 5 – Example Level 0 Set-Top Decoder Architecture

In this Figure, the selection of the required transport multiplex is performed by the tuner, and selection of the required addressable advertisement within the multiplex is performed by the demultiplexer. There are three registers within the demultiplexer; one that holds the PID value for transport stream packets containing coded picture data that is to be forwarded to the video decoder, another that holds the PID value for transport stream packets containing coded audio data that is to be forwarded to the audio decoder, and a third that holds the PID value for transport stream packets containing Trigger Signal data that is to be forwarded to the Trigger Signal decoder. The Switching Engine directs the tuner to the proper RF channel, and then selects the streams comprising the addressable advertisement by loading the proper PID values into these registers. The Trigger Signal arrives sufficiently early to permit the Client-DPI Receiver to process it, and the presence of the Filler following the Switch Point ensures that there is time for the Client-DPI Receiver to perform this operation without losing important video and audio data. Implementations may utilize any appropriate methods to ensure that these timing requirements are met, including communicating PID values and stream_types in a manner that eliminates the need to parse the PSI. (See section 7.0)

To provide a transparent viewing experience, there may be other software in the Client-DPI Receiver that maintains a state associated with the currently tuned Primary Channel (for example, to display the channel number on the front panel). In such a case, to avoid confusing the viewer, it is necessary that the Switching Engine be able to control the tuner and the demultiplexer without altering this state. Worst case Level 0 switching occurs when switching across 2 separate frequencies although Level 0 switches can occur within a single multiplex.

10.4 Level 1 Systems

10.4.1 Level 1 Stream Conditioning

In this example of a Level 1 addressable advertising system, all of the addressable advertisement streams comprising an Addressable Content Set for a particular Primary Channel are present in the same MPEG-2 transport stream multiplex as the Primary Channel. The Primary Channel stream and addressable advertisement streams are conditioned to enable the Client-DPI Receiver to switch to the selected advertisement seamlessly.

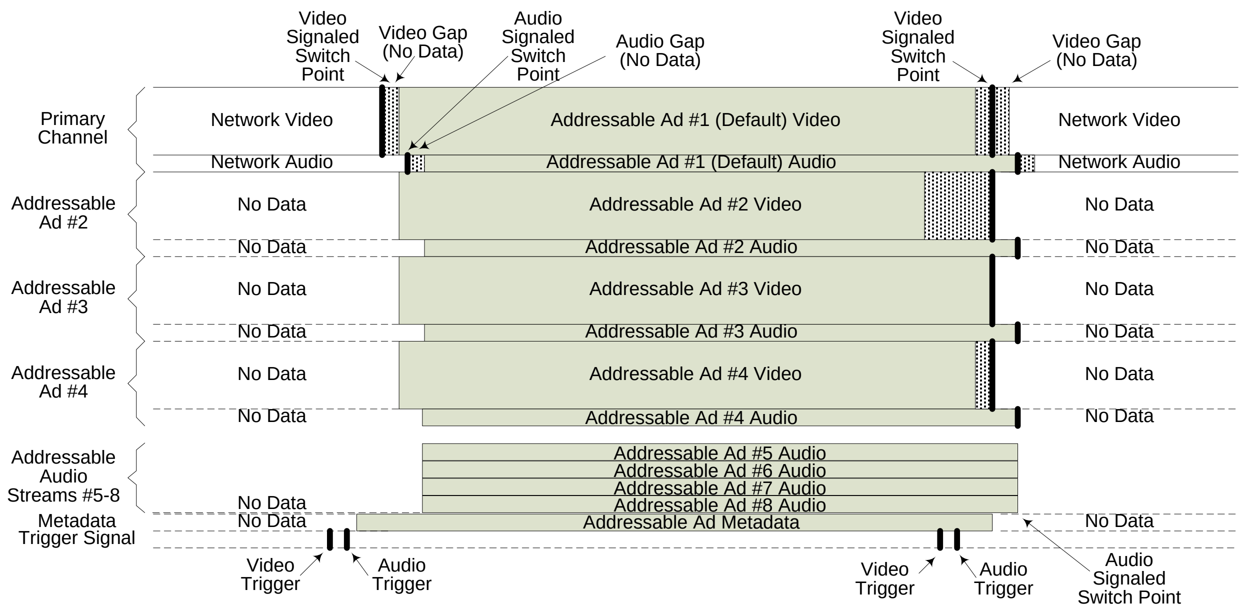

Figure 6 – Example Level 1 Transport Multiplex

Figure 6 depicts a portion of an MPEG-2 MPTS showing the insertion of a single Level 1 Addressable Content Set, comprised of four addressable advertisements. Also shown are the time boundaries within which transport packets containing video, audio and data associated with the Addressable Content Set may be transmitted. Packets carrying streams not related to the Addressable Content Set, including null packets, would also be present in a real system. For clarity, this unrelated data is not shown in the Figure.

One of the addressable advertisements is designated as the default and is present in the Primary Channel and exists on the same PIDs as the network’s video and audio PIDs. The default addressable advertisement will be displayed by Receivers that do not implement Level 1 switching. Also, the default addressable advertisement will be selected by Level 1 capable Client-DPI Receivers that, as determined by the Decision Engine, do not respond to the selection criteria for this Addressable Content Set.

The Signaled Switch Point represents an opportunity to switch streams. Because the transmission of video and audio intended to be presented simultaneously may occur at slightly different times, two Signaled Switch Points are indicated, one for video streams and one for audio streams. An opportunity to switch from the Primary Channel video and audio streams is shown as a pair of Signaled Switch Points at the start of the Addressable Content Set. Another pair of Signaled Switch Points marks the opportunity to switch back to the Primary Channel video and audio streams at the end of the Addressable Content Set. In Level 1 systems, the switching of audio streams without switching video streams is also possible as illustrated by addressable audio streams 5-8 in Figure 6. A transmission Gap follows each of these Signaled Switch Points. During these Gaps, no transport packets carrying PES headers or data for any of the component streams comprising the Addressable Content Set are transmitted. This Gap insures that the Client-DPI Receiver will not switch while it is receiving data associated with the Addressable Content Set. The duration of the Gap and its location following the Signaled Switch Point are selected to allow for a small amount of uncertainty in the timing of the stream selection process within the Client-DPI Receiver. The transport stream is a continuous data stream; therefore, packets carrying data from streams not related to the Addressable Content Set, or null transport packets, would be transmitted during the Gap to maintain the continuity of the stream.

A Trigger Signal is associated with each Signaled Switch Point. The Trigger Signal indicates the location of the Signaled Switch Point in time. Even though this Figure shows the Trigger Signal as data that is not contained within the video or audio streams, other methods of providing the Trigger Signal not shown here may be used.

At the start of the Addressable Content Set, the start of transmission of all of the addressable advertisement video streams is aligned in time. Likewise, the start of all of the advertisement audio streams is aligned in time, and that time may differ from the start of the video streams. This alignment is enforced to make it possible for the Client-DPI Receiver to switch from the Primary Channel video and audio streams to the selected addressable advertisement video and audio streams without loss of data.

It should be noted that each of the video streams within the Addressable Content Set might require a different amount of time to be transmitted. The transmission of the Primary Channel video and audio streams is able to resume only after the transmission of all of the addressable advertisement video and audio streams is complete. Addressable advertisement #3 contains the video stream having the longest transmission time, and therefore determines the location of the Signaled Switch Point, and when the Gap can begin. Packets carrying data from streams not related to the Addressable Content Set, or null transport packets, would be transmitted during this time.

10.4.2 Level 1 Head-End

Figure 7 shows an example of a head-end architecture suitable for inserting Level 1 Addressable Content Sets.

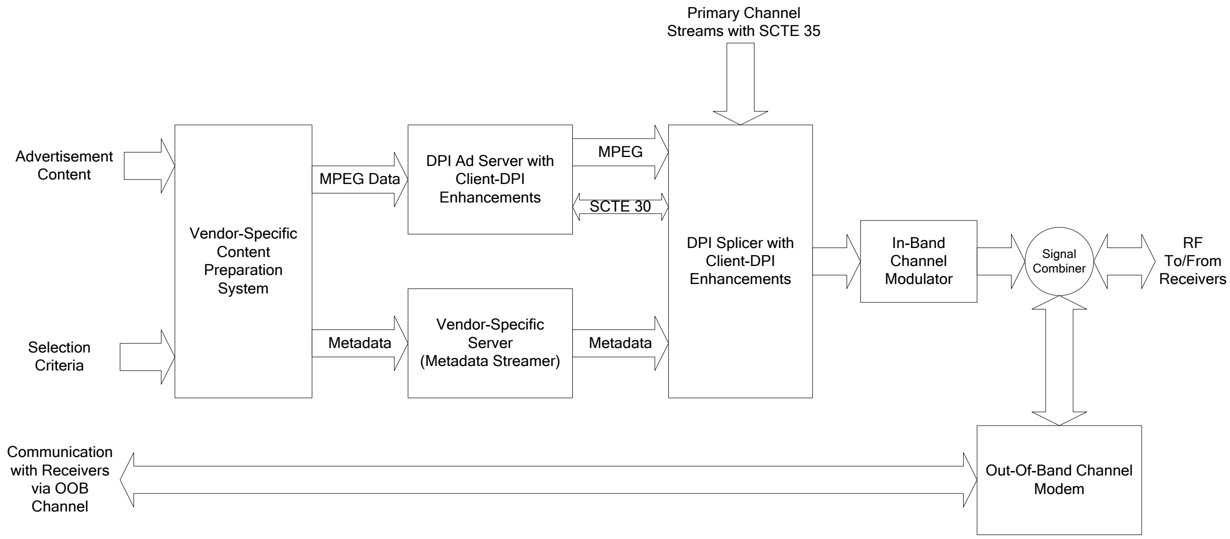

Figure 7 – Example Level 1 Head-End Configuration

In this Figure, the insertion of Addressable Content Sets and Trigger Signals is handled by the splicer. Some of the conditioning of the video and audio streams within the Addressable Content Set may be done by the content preparation system, and some may be done by the splicer.

Insertion of selection criteria is performed by the metadata streamer and the splicer. The metadata streamer transmits packetized selection criteria metadata to the splicer when that data is to be inserted into the multiplex. The splicer inserts that data into the multiplex on an opportunistic basis, using a PID set aside for that purpose. There is sufficient bandwidth reserved in the multiplex to allow the opportunistic insertion to take place in a timely manner.

Command and control signaling, typically delivered using an out-of-band channel, may be used to configure and deliver addressing criteria to Decision Engines.

Note that the conditioning functions to implement a Level 1 Switch are very similar to the functionality in existing DPI head-end splicing devices. The goal of this conditioning is to insure, as much as possible, that no video or audio artifacts are produced at the Receiver. Some of the features of this conditioning are:

- Conformance with appropriate standards (ATSC, MPEG, and SCTE) with respect to transport, video, AC-3 audio, buffer management and system clock is maintained across the splice.
- Vertical resolution and presentation duration of inserted content match those of the Primary Channel. Note: It is intended that the horizontal resolution of the Primary Channel will not be altered except for the Ads placed within the allowed Switch Event within the Primary Channel.
- Field parity is maintained across the splice.
- There are no timebase discontinuities.

- The number of pictures in the inserted content is adjusted, if necessary, to be consistent with the time slot into which it is being inserted. This might involve dropping pictures if the inserted content is too long, or adding black pictures if the inserted content is too short.
- The duration of audio in the inserted content is adjusted, if necessary, to be consistent with the time slot into which it is being inserted.
- The number of bits used to encode pictures and the timing of the transmission of video and audio data are adjusted so that the buffers in the Receiver do not underflow or overflow at any time.
- Video data transmitted following a splice can be decoded without referring to the video data transmitted prior to the splice.
- No portion of an audio access unit transmitted before a splice overlaps in presentation time with audio access units transmitted after that splice.

Additional conditioning for addressable advertisements within Level 1 Addressable Content Sets is required to insure that the Client-DPI Receiver is able to select one of the addressable advertisements from the Addressable Content Set without introducing visible or audible artifacts. This includes:

- Assuring that the conditioning described above is applied to all of the addressable advertisement streams.
- Assuring that the same PCR, PTS and DTS adjustments are applied to all of the addressable advertisement streams.
- Inserting Trigger Signals.
- Inserting the Gap.

10.4.3 Level 1 Client-DPI Receiver

Figure 8 depicts a hypothetical Client-DPI Receiver architecture suitable for use in a Level 1 system. The Decision Engine and Switching Engine are shown, along with relevant signal flows. The Trigger Signal is assumed to be in the form of a data message on a stream separate from those carrying the video and audio elementary streams.

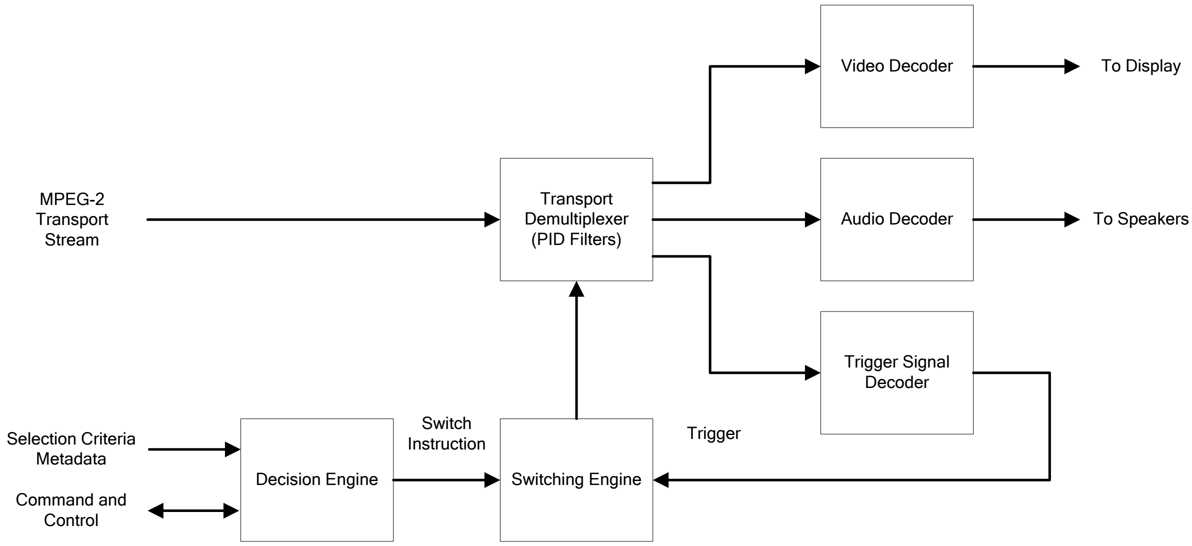

Figure 8 – Example Level 1 Set-Top Decoder Architecture

In this Figure, the selection of the required addressable advertisement is performed by the demultiplexer. There are three registers within the demultiplexer; one that holds the PID value for transport stream packets containing data to be forwarded to the video decoder, another that holds the PID value for transport stream packets containing data to be forwarded to the audio decoder, and a third that holds the PID value for transport stream packets containing data to be forwarded to the Trigger Signal decoder. The Switching Engine causes the required streams from the Addressable Content Set to be selected by loading the proper PID values into the first two of these registers. The Trigger Signal arrives sufficiently early to permit the Client-DPI Receiver to process it, and the presence of the Gap surrounding the Switch Point insures that there is time for the Client-DPI Receiver to perform this operation without disrupting the flow of data into the video and audio decoders.

It can be seen that, in this architecture, the video and audio decoders are not involved in the switching process. The objective of stream conditioning is to insure that, in ways relevant to decoding the affected streams, the signal supplied to these decoders appears to be continuous, as if no Switch had taken place.

Aspects of Decision Engine operation may be configured via command and control signaling.

To provide a transparent viewing experience, there may be other software in the Client-DPI Receiver that maintains a state associated with the currently tuned Primary Channel (for example, to display the channel number on the front panel). In such a case, to avoid confusing the viewer, it is necessary that the Switching Engine be able to control the demultiplexer without altering this state.

10.5 Signaling

Three distinct types of signaling may be employed in an addressable advertising system. One type of signaling provides the Client-DPI Receiver with selection criteria associated with each Addressable Content Set, so that the Client-DPI Receiver can select the proper content to present to the viewer. A separate signal, the Trigger Signal, indicates the location of each Signaled Switch Point. Finally, there may be command and control signaling used to control the behavior of the Decision Engine.

10.5.1 Selection Criteria Data

Selection criteria data is operated on and maintained by the Decision Engine. This data may be transmitted to the Decision Engine entirely in-band, as private data transmitted shortly before or concurrently with the Addressable Content Set, or entirely out-of-band, or a combination of both.

The Decision Engine could operate in a stand-alone fashion within a Client-DPI Receiver, or it could be implemented to utilize information from the head-end or programming source.

This standard does not specify the operation of the Decision Engine, or the format or syntax of selection criteria data.

10.5.2 Trigger Signals

A Trigger Signal is employed to indicate the location of a Signaled Switch Point. The Trigger Signal may also carry identifying information that the Client-DPI Receiver can use to match each occurrence of a Trigger Signal with a specific Addressable Content Set, which would, for example, allow the Client-DPI Receiver to determine if it has missed a Trigger Signal, or if it has received an unexpected one.

One possible Trigger Signal would be a single transport packet using a PID set aside for the purpose. This packet could contain private data which indicates the system clock value corresponding to the location of the next Signaled Switch Point. Additional elements of the private data could convey other vendor-specific information.

Another possible implementation of the Trigger Signal would be to use a sequence of packets which employs the MPEG-2 adaptation field constructs splicing_point_flag and splice_countdown, in each of the video and audio streams where a Signaled Switch Point is located. Using this method, the Signaled Switch Point is located at the end of the packet which causes splice_countdown to be decremented to zero.

Multiple implementations of the Trigger Signal may be present concurrently. In such a case, any particular Client-DPI Receiver implementation would not be expected to process more than one implementation of the Trigger Signal.

This standard does not specify the format or syntax of the Trigger Signal.

Note: OCAP devices will use a different trigger than legacy devices.

10.5.3 Command and Control

Aspects of Decision Engine operation may be configurable through a signaling means used for the purpose. Typically, this will be through a full-time connection to the Client-DPI Receiver, as is provided for by an out-of-band communications channel.

This standard does not specify the format or syntax of command and control signaling.