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ATSC Standard:
Synchronized/Asynchronous Trigger

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The Advanced Television Systems Committee, Inc., (ATSC) is an international, non-profit membership organization developing voluntary standards for the entire spectrum of advanced television systems.

Specifically, ATSC is working to coordinate television standards among different communications media focusing on digital television, interactive systems, and broadband multimedia communications. ATSC is also developing digital television implementation strategies and presenting educational seminars on the ATSC standards.

ATSC was formed in 1982 by the member organizations of the Joint Committee on InterSociety Coordination (JCIC): the Electronic Industries Association (EIA), the Institute of Electrical and Electronic Engineers (IEEE), the National Association of Broadcasters (NAB), the National Cable Television Association (NCTA), and the Society of Motion Picture and Television Engineers (SMPTE). Currently, there are approximately 180 members representing the broadcast, broadcast equipment, motion picture, consumer electronics, computer, cable, satellite, and semiconductor industries.

ATSC Digital TV Standards include digital high definition television (HDTV), standard definition television (SDTV), data broadcasting, multichannel surround-sound audio, and satellite direct-to-home broadcasting.

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1. SCOPE

This document defines a Standard for the transmission of synchronized data elements, and synchronized and asynchronous events, building on the synchronized delivery mechanisms of ATSC Standard A/90. This Standard specifically enables the synchronized delivery of data modules through the decoupling of the timing from the delivery of the data element. It also enables the delivery of events to receivers, including application-defined events. This standard was prepared by the Advanced Television Systems Committee (ATSC) Technology Group on Distribution (T3). The document was approved by the members of the ATSC on April 1, 2002.

1.1 Organization

This document is organized as follows:

Section 1 — This general introduction.

Section 2 — References and relevant documents.

Section 3 —Definition of terms, acronyms and abbreviations used in this document.

Section 4 — An informative introduction to triggers and background information.

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Section 9 — Normative descriptor signaling.

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2. REFERENCES

2.1 Normative References

The following documents are normative for this Standard. These references form a part of this standard as explicitly constrained and supplemented herein. In the event of conflict among the below references, this ATSC Standard takes precedence and Ref [1] takes precedence over the other normative references below.

1) ATSC Standard A/90 (2000): *ATSC Data Broadcast Standard*, Advanced Television Systems Committee, Washington, D.C. 2000.

2) ATSC Standard A/65A (2000): *Program and System Information Protocol for Terrestrial Broadcast and Cable*, Advanced Television Systems Committee, Washington, D.C., 2000.

3) ATSC Standard A/53 (1995): *ATSC Digital Television Standard*, Advanced Television Systems Committee, Washington, D.C. 1995.

4) ITU-T Rec. H.222.0 | ISO/IEC 13818-1:1996, Information Technology — Generic coding of moving pictures and associated audio — Part 1: Systems.

5) ISO/IEC 13818-6:1998, Information Technology — Generic coding of moving pictures and associated audio — Part 6: Extensions for Digital Storage Media command & Control, Chapter 2, 4, 5, 6, 7, 9 and 11.
6) ISO/IEC 13818-6, 2000, Amendment 2: Additions to support synchronized download services, opportunistic data services, and resource announcement in broadcast and interactive services.
7) SMPTE 343M, Declarative Data Essence - Local Identifier (lid:) URI Scheme, Society of Motion Picture and Television Engineers, White Plains, N.Y.
8) IETF RFC 2045, Multipurpose Internet Mail Extensions (MIME) Part One: Format of Internet Message Bodies, Section 5.
9) IETF RFC 2616, Hypertext Transfer Protocol — HTTP/1.1.
10) IETF RFC 2396, Uniform Resource Identifiers: Generic Syntax

2.2 Informative References

The following documents are informative for this Standard:

11) ATSC Recommended Practice A/91 (2001): *ATSC Data Broadcast Standard Implementation Guidelines*, Advanced Television Systems Committee, Washington, D.C., 2001.
12) ATSC Informative Document IS-151 (1999): *Implementation of Data Broadcasting in a DTV Station*, Implementation Subcommittee, Advanced Television Systems Committee, Washington, D.C., 1999.
13) ATSC Technology Group Report T3-548r1 (2001): *ATSC Usage of the MPEG-2 Registration Descriptor*, Technology Group on Distribution, Advanced Television Systems Committee, Washington, D.C., 2001.
14) ATSC Technology Group Report T3-549 (2001): *Collision Avoidance for Private Fields and Ranges*, Technology Group on Distribution, Advanced Television Systems Committee, Washington, D.C., 2001.

3. DEFINITIONS AND STRUCTURES

3.1 Compliance Notation

As used in this document, *shall* denotes a mandatory provision of the standard. *Should* denotes a provision that is recommended but not mandatory. *May* denotes a feature whose presence does not preclude compliance, that may or may not be present at the option of the implementer.

3.2 Acronyms and Abbreviations

The following acronyms and abbreviations are used within this specification:

bslbf bit serial, leftmost bit first
CRC cyclic redundancy check
DAU data access unit
DEB data elementary stream buffer
DES data elementary stream

DET	data event table
DSM-CC	digital storage media command and control
DST	data service table
EIT	event information table
ES	elementary stream
MPEG	Moving Picture Experts Group
MRD	MPEG-2 registration descriptor
PES	packetized elementary stream
PID	packet identifier
PMT	program map table
PSIP	Program and System Information Protocol
TS	transport stream
uimsbf	unsigned integer, most significant bit first
VCT	virtual channel table

3.3 Global Terms

The following terms are used throughout this document.

action A trigger semantic that implies some behavior on the receiver without any associated data item.

activation The process of enabling the target referenced by a trigger which may cause rendering. For a trigger referring to graphic data, activation might cause the rendering of a graphical object on the screen. For a trigger referring to audio data, activation might cause the emission of the appropriate sounds.

activation time The System Time Clock instant at which the target of a trigger is activated.

application identifier A globally unique identifier of an application that is used for binding triggers to applications.

asynchronous trigger A structure transmitted within an MPEG-2 transport stream containing a reference to a target and some opaque user data bytes which may also include a reference to an application that is intended to process it.

ATSC Advanced Television Systems Committee, the committee responsible for the coordination and development of voluntary technical standards for advanced television systems.

CRC The cyclic redundancy check used to verify the correctness of the data.

data access unit (DAU) The contiguous portion of a synchronized or synchronous data MPEG-2 Program Element associated with a particular MPEG-2 Presentation Time Stamp.

data module The fundamental data entity resulting from the in-order re-assembly of the payload of the DSM-CC downloadDataBlock messages pertaining to the same downloadId, moduleId, and moduleVersion field values.

decoder An embodiment of a decoding process.

decoding (process) The process defined in the ATSC Digital Television Standard [3] that reads an input coded bit stream and outputs decoded pictures, audio samples, or data objects.

earliest target acquisition time The target acquisition time of the first instance of a target transmitted by means of one of the asynchronous delivery protocols specified in [1].

earliest activation time The earliest activation time is the earliest System Time Clock instant at which a specific target is activated using all emitted triggers (both asynchronous and synchronized).

elementary stream (ES) A generic term for one of the coded video, coded audio, or other coded bit streams. One elementary stream is carried in a sequence of PES packets with one and only one stream_id.

event A trigger that contains user-defined payload which has meaning to the receiver.

latest target acquisition time The target acquisition time of the last instance of a target transmitted by means of one of the asynchronous delivery protocols specified in [1].

latest activation time The latest activation time is the latest System Time Clock instant at which a specific target is activated using all emitted triggers (both asynchronous and synchronized).

maximum target acquisition period The period between the earliest target acquisition time and the latest activation time for a specific target using all emitted triggers.

minimum target acquisition period The time period between the latest possible target acquisition time and the earliest possible activation time for a specific target.

MPEG Refers to standards developed by the ISO/IEC JTC1/SC29 WG11, *Moving Picture Experts Group*. MPEG may also refer to the Group.

MPEG-2 Refers to the collection of ISO/IEC standards 13818-1 through 13818-6.

object Any arbitrary data item available to a receiver.

packet A packet is a set of contiguous bytes consisting of a header followed by its payload.

packet identifier (PID) A unique integer value used to associate MPEG-2 Transport Stream packets of an MPEG-2 Program Element in a single or multi-program transport stream.

payload Payload refers to the bytes following the header byte in a packet.

pre-load data DAU's or objects accessible to the receiver delivered in advance of their activation by subsequent triggers.

program clock reference (PCR) A time stamp in the transport stream from which decoder timing is derived.

PCR discontinuity a time point at which the PCR changes by more than one unit.

program A collection of program elements. Program elements may be elementary streams. Program elements need not have any defined time base; those that do have a common time base and are intended for synchronized presentation. The term *program* is also used in the context of a "television program" such as a daily-scheduled news broadcast. In this specification the term "EIT event" is used for the latter to avoid ambiguity.

program element A generic term for one of the elementary streams or other data streams that may be included in an ISO/IEC 13818-1 (MPEG-2) Program. The MPEG-2 Transport Stream packets conveying a Program Element are referenced by a unique PID value in the MPEG-2 Program.

PTS Presentation time stamp used to indicate when a referenced target is activated.

reserved This term, when used in clauses defining the coded bit stream, indicates that the field may be used in the future for Digital Television Standard extensions. All reserved bits shall be set to "1".

service location descriptor (SLD) A descriptor specifying the stream type, PID, and language code for some of the MPEG-2 Program Elements comprising a virtual channel [2].

synchronized trigger A structure transmitted within an MPEG-2 transport stream containing a the same information as an asynchronous trigger but with the addition of a PTS.

system time clock (STC) The clock in the receiver derived from the arriving PCR values that matches the clock in the emission system.

target Pre-load data that refers to a DAU or a data object available to a receiver.

target acquisition time The time instant at which the last byte of a target leaves the Transport System Target Decoder for the asynchronous MPEG-2 Program Element conveying the target.

transport stream Refers to the MPEG-2 transport stream syntax for the packetization and multiplexing of video, audio, and data signals for digital broadcast systems [4].

transport system target decoder (T-STD) A hypothetical reference model defined in [1] of a decoding process used to describe the semantics of the Digital Television Standard multiplexed bit stream.

transport stream packet header The leading fields in a transport stream packet up to and including the continuity_counter field.

trigger A collective name referring to either asynchronous or synchronized trigger.

virtual channel A virtual channel is the designation, usually a number, that is recognized by the user as the single entity that will provide access to an analog TV program or a set of one or more digital MPEG-2 Program Elements. It is called "virtual" because its identification (name and number) may be defined independently from its physical location.

3.4 Section and Data Structure Syntax Notation

Tables defined in this standard conform to the generic private section syntax defined in [4] and the DSM-CC section format defined in [5]. This document contains symbolic references to syntactic elements. The notation used is distinctive to aid the reader in recognizing elements that are the same as they are in referenced standards. These references are typographically distinguished by the use of a different font (e.g., restricted), may contain the underscore character (e.g., sequence_end_code), and may consist of character strings that are not English words (e.g., dynrng). When syntactic elements from [5] are used the form used therein is retained (e.g. thisIsString). When elements from [1], [2], or other existing ATSC Standards are used the notation form "sequence_end_code" is used. Where an element has a difference from a similar term in a reference, a variation in the form—which may be a combination of the two styles—is used. New elements have an entirely new name.

3.5 Reserved Fields

reserved — Fields in this Standard marked "reserved" shall not be assigned by the user, but shall be available for future use. Decoders are expected to disregard reserved fields for which no

definition exists that is known to the decoder. Each bit in the fields marked "reserved" shall be set to one until such time as they are defined and supported.

user_private — Indicates that the field is not defined within the scope of this Standard. The owner of the field, and hence the entity defining its meaning, is derived via its context within a message.

zero — Indicates that the bit or bit field shall have the value zero.

4. BACKGROUND

This standard addresses the need to synchronize data with video and to deliver events to receivers. This standard could serve as the transport-layer infrastructure for applications such as the display of a data advertisement (e.g., a web-page that allows purchasing) at specific time points within the video.

The key technical issue addressed by the ATSC trigger design is to remedy the lack of a guarantee for a continuous system time clock for the accurate frame/field synchronization of data requiring long decoding times. This standard allows an arbitrary complex data access unit (DAU) to be activated by an arbitrary simplified receiver to achieve tight synchronization in the context of a discontinuous time line.

The ATSC Data Broadcast Standard [1] specifies that non-streaming, synchronized data access units are encapsulated with the synchronized download protocol. This encapsulation carries a Presentation Time Stamp (PTS) with each DAU, which indicates the time of DAU activation.

The model standardized in [1] is not guaranteed to achieve the desired synchronization. For example, a problem occurs when DAUs carrying complex data objects having long decoding times are combined with timeline (PCR) discontinuities. In this circumstance, there can be ambiguity in the meaning of the PTS value in the encapsulation. The synchronized trigger is designed to address this situation, as well as other complications.

Additional informative statements relative to the generation, the transmission, and the acquisition of triggers are provided in Annex A of this document.

4.1 Requirements

The intention of this standard was to enable frame-level ("tight") synchronization of arbitrary Data Access Units (DAUs) as defined in [1] on the ATSC transport. To achieve this goal, the design of the synchronized trigger standard was guided by the following requirements:

1) The overall trigger design should not preclude long term delays (days or months) between transport of the target and the trigger.
2) Triggers should be compatible with, and not adversely impact, synchronization of DAUs conveyed in synchronized MPEG-2 Program Elements.
3) Triggers shall be implemented in such a way as to not be subjected to any problems with MPEG-2 PCR discontinuities.
4) Triggers may reference objects and actions in addition to related DAUs (all targets).
5) Triggers shall have a mechanism to allow them to be hidden from unauthorized applications (for example, commercial detection).

6) The design should be transport independent provided it does not negatively impact ATSC transport functionality.
7) Targets shall be signaled with a unique invariant identifier.
8) The objects and related DAUs shall be stored according to some application buffer model(s) until the trigger is received and processed.
9) A trigger shall reference one and only one target.
10) A goal is for decoding time associated with trigger to be minimal.
11) Triggers have no time sequence restrictions with respect to objects and actions.
12) The trigger structure shall permit maintenance of the proper time relationships between the trigger and the target by re-multiplexors.
13) Related DAU's shall precede triggers in time.
14) Triggers shall fit in a single MPEG-2 Transport Stream packet.
15) The delivery and processing of triggers shall be such that there is the capability of it being within *N* (where *N* is small) frames of any PCR timeline discontinuity.

4.2 Temporal concepts used in this standard

Figure 4.1 illustrates the various temporal concepts introduced by this standard. The pre-load data, referred to as *target*, is considered to be acquired, and the trigger is regarded as received, only after it leaves the smoothing buffer of the Transport System Target Decoder (T-STD) associated with the MPEG-2 Program Element that carries it. A synchronized trigger and its target are considered activated when the PTS value matches for the first time, the 90 kHz portion of the receiver System Time Clock. The acquisition period, during which the receiver is expected to acquire and decode the target, is the period between the time the target leaves its associated T-STD and the time of activation. Unpredictable behavior may occur in case the target is not fully decoded and ready at the time of activation.

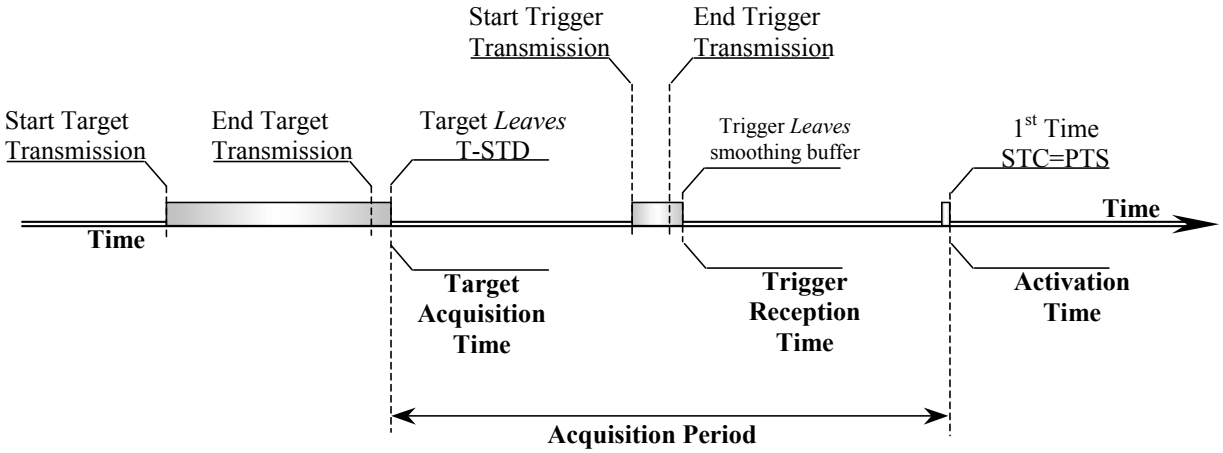

Figure 4.1 Trigger time line.

5. THE FRAMEWORK

This standard supports both synchronized and asynchronous trigger types. The particulars of synchronized trigger types are normatively defined in Section 7, and the particulars of asynchronous trigger types are defined in Section 8.

This section contains normative definitions and constraints common to both types of triggers. Constraints applicable to a single trigger type can be found in Sections 7 and 8.

5.1 Triggers

5.1.1 Identification

Triggers shall have a unique triplet of downloadId, moduleId, moduleVersion within the program element.

5.1.2 Encapsulation

Triggers are conveyed as data modules in the download protocol as defined in [1]. This means that triggers shall be carried in the blockDataByte field(s) of the downloadDataBlock (DDB) message as further defined in Sections 7 and 8 of this standard. A data module shall contain exactly one trigger. Trigger payloads shall be structured as specified in Section 6 of this standard. Triggers shall only be conveyed by means of a one-layer control Download protocol.

5.1.3 Equivalence

Triggers carrying a given moduleId value, downloadId value, and moduleVersion value shall be considered equivalent for purposes of activation.[1] This constraint may be useful when multiple instances of the same triggers are emitted in response to the need by receivers to acquire one of these triggers upon random access tuning.

5.2 Targets

A target is the pre-load data that refers to a DAU available to a receiver.

5.2.1 Target Encapsulation

Targets may be carried as data modules in the non-flow-controlled download protocol or in the data carousel protocol [1]. For this situation, this means that the target bytes are encapsulated in the blockDataByte fields of *asynchronous* downloadDataBlock (DDB) messages as defined in Chapter 7 of [1].

5.2.2 Target Acquisition Time

The target acquisition time shall be earlier than the earliest trigger reception time. The target shall be signaled for purposes of acquisition as specified in Section 9 of this standard.

5.2.3 Target Acquisition

Receivers should not purge the target at anytime during the maximum target acquisition period, where the maximum target acquisition period is the period between the earliest target acquisition

[1] As stated in Section 7.2 for synchronized triggers, all triggers transmitted on the same PID shall have distinct PTS values. This means that the concept of equivalence of triggers is primarily useful for asynchronous triggers.

time and the latest activation time among all emitted triggers for that target. The maximum target acquisition period shall be signaled using the acquisition directive specified in Section 9 of this standard.

5.2.4 Target Reference

A trigger shall reference *at most* one target. The reference to a target shall not be modified during the maximum target acquisition period. The content of the target, however, may be updated subject to target acquisition time constraints specified in this standard and as specified in [1].

5.2.5 Target Availability

The target should be decoded and available by the activation time. Unpredictable behavior may occur in the event that the target is not available by the activation time.

5.3 Events

When there is no explicit target, a trigger may be used to deliver an event to a receiver. An event is a trigger that contains user-defined payload which has meaning to the receiver. An event implements an action.

6. PAYLOAD SYNTAX AND SEMANTICS

The event_info structure of a trigger shall represent the payload of a data module as defined in chapter 7 of [1].

6.1 Event Information Structure

Table 6.1 Event Information Structure Syntax

Syntax	No. of Bits	Format
event_info() {		
event_type	8	uimsbf
app_id_byte_length	16	uimsbf
if(app_id_byte_length > 1) {		
app_id_description	16	uimsbf
for(i=0;i< app_id_byte_length-2;i++) {		
app_id_byte	8	bslbf
}		
}		
target_type	8	uimsbf
target_length	16	uimsbf
if (target_type == 0x01) {		
downloadId	16	uimsbf
groupId	16	uimsbf
moduleId	16	uimsbf
} else if (target_type == 0x02) {		
tap_id	16	uimsbf
} else if (target_type == 0x03) {		
for(i=0; i<target_length; i++) {		
absolute_URI_byte	8	uimsbf
}		
} else if (target_type == 0x04) {		
for(i=0; i<target_length; i++) {		
URI_with_lid_scheme_byte	8	uimsbf
}		
} else if (target_type == 0x05) {		
for(i=0; i<target_length; i++) {		
URI_with_http_scheme_byte	8	uimsbf
}		
} else {		
for(I=0; i<target_length; i++) {		
ATSC Reserved	8	bslbf
}		
}		
user_data_length	16	uimsbf
for(i=0; i<user_data_length; i++) {		

user_data_byte	8	uimsbf
}		
}		

6.2 Semantic Definition of Fields in Event Information Structure

event_type This field shall define the type of trigger. The contents of this field shall be an enumeration of a set of values defined in table 6.2.

Table 6.2 Definition of Event Type

event_type	Value
Trigger Event	0x00
ATSC Reserved	0x01-0xFF

app_id_byte_length This 16-bit field shall be as defined in Table 12.3 of [1]. As stated in [1], the value 0x0001 is forbidden.

app_id_description This 16-bit field shall be as defined in Table 12.3 of [1].

app_id_byte This 8-bit field shall be as defined in Table 12.3 of [1].

target_type This 8-bit field shall define the type of the target namespace as enumerated in the Table 6.3

Table 6.3 Definition of the Target Type Field

target_type	Value
none	0x00
downloadId-groupId-moduleId	0x01
tap_id	0x02
Absolute URI which adheres to [10]	0x03
URI with lid scheme (scheme not included in the URI) [7]	0x04
URI with http scheme (scheme not included in the URI) [9]	0x05
ATSC Reserved	0x06-0xFF

target_length This 16-bit field shall convey the length of the target_byte sequence in bytes. When set to zero (no explicit target defined), then this event does not apply to any specific data. This field shall be set to zero when the value of the target_byte field is set to "none" (0x00).

downloadId This 16-bit field shall represent the downloadId of the instance of the download scenario conveying the target.

groupId This 16-bit field shall represent the groupId of the download group conveying the target.

moduleId This 16-bit field shall represent the moduleId of the download module conveying the target.

tap_id This 16-bit field shall represent the identifier of the Tap which specifies the target.

absolute_URI_byte This 8-bit field shall represent a character of an absolute URI (adhering to [10]) which specifies the target. The string includes the characters representing the scheme. ASCII encoding shall be used for the contents of this field.

URI_with_lid_scheme_byte This 8-bit field shall represent a character of a URI with lid scheme (adhering to [7]) which specifies the target. The string does not include the characters representing the scheme designation (i.e., excluding "lid://"). ASCII encoding shall be used for the contents of this field.

URI_with_http_scheme_byte This 8-bit field shall represent a character of a URI with http scheme (adhering to [9]) which specifies the target. The string does not include the characters representing the scheme designation (i.e., excluding "http://"). ASCII encoding shall be used for the contents of this field.

user_data_length This 16-bit field shall represent the length of the user_data_byte sequence in bytes.

user_data_byte This 8-bit field shall represent a byte of the fields specifying the user data. The contents of these fields shall be user private.

6.3 Collision Avoidance

The inclusion of information in the user_data_byte field of the Event Information Structure (i.e. when the value of the user_data_length field is non-zero) shall require the placement of an MPEG-2 defined Registration Descriptor (MRD) [13] [14] in the instance of the Tap descriptor loop that references the program element carrying the trigger. The MPEG-2 Registration Descriptor contains a 32 bit format identifier field administered by SMPTE. The proper registration of a format identifier value allows unique identification of the syntax and semantics of the contents of the user_data_byte field to allow collision avoidance. At most one MRD shall be allowed in a given Tap descriptor loop referencing the program element carrying the trigger. A DST conveying an MRD in the Tap descriptor loop referencing the program element carrying the trigger must be received before parsing of the user_data_byte field can begin.

7. SYNCHRONIZED TRIGGERS

This section contains the constraints and specific requirements for synchronized triggers.

7.1 Buffer Model

The delivery of synchronized triggers shall adhere to the Target System Target Decoder (T-STD) buffer model established in [1] for synchronized Program Elements of stream_type 0x14.

7.2 PTS Uniqueness

Since the T-STD for synchronized triggers includes only one transport packet-level de-multiplexor at its input, it follows that two synchronized triggers referencing the same instant of the same System Time Clock (as specified by the value of the PTS field) cannot be conveyed in the same synchronized Program Element, even if these two triggers are conveyed in distinct synchronized data modules (as specified by the value of their moduleId field). Consequently, all triggers transmitted on the same PID shall have distinct value of PTS; the PTS value shall be modified for each new trigger conveyed. Two synchronized triggers referencing the same PTS of the same System Time Clock, within a PTS wrap-around period, shall be conveyed in distinct program elements.

7.3 Program Map Table (PMT) and Service Location Descriptor (SLD)

The TS_program_map_section of any MPEG-2 Program that includes at least one synchronized trigger program element shall satisfy the following constraints:

1) The value of the stream_type field associated with the MPEG-2 Program Element conveying the synchronized triggers shall be set to 0x14.
2) An association_tag_descriptor shall be present in the descriptor loop of the PMT for the MPEG-2 Program Element conveying the synchronized triggers to enable signaling as described in Section 9.
3) A valid PCR_PID value shall be specified.
4) The value of the PCR_PID field in the PMT shall be equal to the PCR_PID value in the Virtual Channel Table Service Location Descriptor (SLD) of the virtual channel that includes the synchronized trigger program element.

7.4 System Time Clock and Activation

As required in Section 2.7.2 of [4], the time interval between successive occurrences of the PCR base field in Transport Stream packets of the Program element referenced by the same PCR_PID value shall be less than or equal to 100 milliseconds.

A synchronized trigger shall be activated at the first time point after the trigger reception time that the value of the 90 kHz portion of the receiver STC strikes the PTS value. The latest activation time is the latest time at which the value of the 90 kHz portion of the receiver STC strikes the PTS value for any triggers referencing the same target.

7.5 Protocol Encapsulation

The synchronized encapsulation of the event payload described in Section 6 above is the Synchronized Data Download protocol (carried in an MPEG-2 Program Element of stream_type 0x14), as defined in [1] and [6]. The payload shall be carried in a Synchronized Download Data Block (DDB), including a valid Presentation Time Stamp (PTS) in the adaptation field of the message header. The value of the PTS shall specify the activation time of the synchronous trigger.

As required by [1], a DownloadInfoIndication message (DII) shall be formatted to reference the DDB messages conveying the synchronized triggers. With the constraint (below) that each trigger is carried within a single packet, the DII message is not absolutely needed to reconstruct the trigger message and a receiver may choose to not wait for receipt of DII before processing triggers.

The synchronized download protocol allows for a one-time delivery of the synchronized event trigger. The transactionId field of the DownloadInfoIndication message of the Synchronized Download protocol shall be used as a versioning and filtering mechanism. The value of the downloadId field in the DownloadInfoIndication message shall match the value of the downloadId field of the Synchronized Download Data Block messages conveying the synchronized events.

7.6 Message Encapsulation Constraints

7.6.1 MPEG-2 Transport Stream Packet Constraints

The synchronized trigger message, whose syntax is specified in Section 6, shall be constructed to be no larger than 145 Bytes to allow it to fit within a single MPEG-2 Transport Stream packet. Furthermore, a single Transport Stream packet shall contain at most one synchronized trigger message. Note that this is an explicit clarification of the implications in [1] and [6].

The packet header of the MPEG-2 Transport Stream packet that carries a synchronized trigger message shall be constrained as follows:

1) The value of the payload_unit_start_indicator field shall be set to '1'.
2) The value of the pointer_field field shall be set to '0' (indicating that the message starts immediately after the pointer_field).
3) The value of the adaptation_field_control field shall be set to '01' (indicating payload only—no adaptation field).

The purpose of the above constraints is to fix the offset (from the packet header) of the PTS field carried in the adaptation_header of the synchronized DownloadDataBlock.

7.7 Insertion and Delivery

7.7.1 Timeline Discontinuities

There shall not be a PCR discontinuity between the trigger reception time and the activation time of a synchronized trigger. The purpose of this constraint is to ensure that the activation time, as defined above, is not ambiguous.

7.7.2 Value of the Presentation Time Stamp Field

The value of the PTS field in a synchronized trigger shall reference a future instant in time relative to the value of the receiver STC instant that corresponds to the trigger reception time. The time interval between trigger reception time and activation time (namely, the instant of the System Time Clock corresponding to the PTS value of the synchronized trigger) shall be greater than 512 cycles of a 90 kHz clock to allow for trigger decoding time. Trigger reception time is defined here as the time when the last byte of the synchronized trigger leaves the smoothing buffer SBn [1].

The difference in the PTS value of two consecutive synchronized triggers in the same MPEG-2 Program Element shall represent a minimum time interval of 512 cycles of a 90 kHz clock.

8. ASYNCHRONOUS TRIGGERS

This section contains the constraints and specific requirements for asynchronous triggers.

8.1 Program Map Table (PMT)

The TS_program_map_section of any MPEG-2 Program that includes at least one asynchronous trigger program element shall satisfy the following constraints:

The value of the stream_type field associated with the MPEG-2 Program Element conveying the asynchronous triggers shall be set to 0x0B.

An association_tag_descriptor shall be present in the descriptor loop of the PMT for the MPEG-2 Program Element conveying the asynchronous triggers to enable signaling as described in Section 9.

8.2 Protocol Encapsulation

The asynchronous encapsulation of the event payload described in Section 6 above shall be the non-flow-controlled Data Download protocol (conveyed in a Program Element of stream_type 0x0B), as defined in [1].

As required by [1], a DownloadInfoIndication message (DII) shall be formatted to reference the DDB messages conveying the asynchronous triggers. With the size constraint listed below (Section 8.6), the DII message is not absolutely needed to reconstruct the trigger message and a receiver may choose to not wait for receipt before processing triggers.

The non-flow controlled Download protocol allows for a one-time delivery of the event trigger. The transactionId field of the DownloadInfoIndication message of the non-flow-controlled download protocol shall be used as a versioning and filtering mechanism. The value of the downloadId field in the DownloadInfoIndication message shall match the value of the downloadId field of the DDB messages conveying the asynchronous events.

8.3 Buffer Model

Asynchronous triggers shall employ the Transport System Target Decoder buffer model for asynchronous Program Element defined in [1].

8.4 Activation

Asynchronous triggers should be activated as soon as they are taken out of the smoothing buffer and decoded, according to the buffer model for asynchronous Program Elements defined in [1].

8.5 Message Encapsulation Constraints

The size of the asynchronous trigger message shall not exceed 255 sections (about 1 MBytes).

9. SIGNALING

This section describes normative signaling of triggers and targets.

9.1 Trigger Taps

Applications that contain triggers shall include one or more taps in the DST application loop of the application to which the triggers belong. These taps, called the trigger taps, refer to the (asynchronous or synchronized) trigger streams, as follows. Each association_tag shall match the value of the association_tag field in the TS_program_map_section for the program element carrying the trigger stream. Triggers in the referred module shall either contain an app_id_length field value equal to 0 or app_id_byte fields that are identical to the app_id_byte of this application as specified in the DST.

9.1.1 Content Type Descriptor

The presence of a program element carrying triggers shall be signaled by means of a content type descriptor. Table 9.1 defines the content type descriptor.

Table 9.1 Content Type Descriptor

Syntax	No. of Bits	Format
contentTypeDescriptor () {		
descriptorTag	8	0x72
descriptorLength	8	uimsbf
for(i=0; i<descriptorLength; i++) {		
contentTypeByte	8	bslbf
}		
}		

descriptorTag This 8-bit field value shall have the value 0x72 to identify this descriptor as a contentTypeDescriptor.

descriptorLength This 8-bit field shall represent the remaining size of the descriptor in bytes.

contentTypeByte This field shall be set to the value of MIME media type (as defined in RFC 2045, Section 5 of [8]) of the data referenced by the Tap with which this descriptor is associated. ASCII encoding shall be used for the contents of this field.

9.1.2 Signaling of triggers in the DST

The content type descriptor, specified in Table 9.1, shall be present in the Tap descriptor loop of any trigger Tap. In this case, the value of the descriptorLength field in the Content Type Descriptor shall be equal to 0x18 and the contentTypeByte fields shall be set to the MIME type "application/atsc-trigger"[2].

9.2 Acquisition Descriptor

Any trigger target shall be signaled by means of an acquisition descriptor, as defined in Table 9.2. Receivers should acquire signaled targets as soon as they are received.

In the case where the trigger refers to a target which is not a data module, then the acquisition descriptor shall be in the descriptor loop of the Tap referencing the target; the Tap signaling the target shall be distinct from the trigger Tap. In the case that the trigger target is a module, an acquisition descriptor shall be either in the descriptor loop of the Tap referencing the target, or in the groupInfoByte descriptor loop of the DownloadServerInitiate message, or in the moduleInfoByte descriptor loop of a DownloadInfoIndication message, as desired, to convey acquisition metadata about application modules, groups of modules, or individual modules, respectively.

The location of the acquisition descriptor impacts its scope as follows:

Placing the acquisition descriptor in the DSI groupInfoByte descriptor loop renders the descriptor applicable to an entire group within the data carousel (not the entire data carousel).

Placing the acquisition descriptor in the DII moduleInfoByte descriptor loop renders it applicable to that module regardless of what applications reference it.

[2] The quote characters are not part of the string carried in this field.

Placing the acquisition descriptor in the DST in an application Tap descriptor loop renders the descriptor applicable to an entire download, a group of modules, a single module, or another non-module target, depending on the type of the Tap.

In the case of modules, where there may be an occurrence of the acquisition descriptor in multiple locations that could apply, the value of the max_age field with the most narrow scope shall be used; other values shall be ignored. When the acquisition descriptor appears both in a DII moduleInfoByte descriptor loop and the DSI groupInfoByte descriptor loop, the value of the max_age field in the DII descriptor loop shall be used (as it is the most specific), and the other max_age field values shall be ignored. When the acquisition descriptor appears both in a Tap descriptor loop and the DSI groupInfoByte descriptor loop, the value of the max_age field in the Tap descriptor loop shall be used and the other max_age value in the DSI message shall be ignored. When the acquisition descriptor appears both in a Tap descriptor loop and the DII moduleInfoByte descriptor loop, the value of the max_age field in the Tap descriptor loop shall be used and the other max_age value in the DII message shall be ignored.

Table 9.2 Acquisition Descriptor

Syntax	No. of bits	Format
acquisition_descriptor () {		
descriptor_tag	8	0x89
descriptor_length	8	0x04
max_age	32	uimsbf
}		

descriptor_tag This 8-bit unsigned integer shall have the value 0x89, identifying this descriptor as an acquisition_descriptor.

descriptor_length This 8-bit unsigned integer shall be assigned to the value 0x04 to indicate that four bytes follow this field up to the end of this descriptor.

max_age This 32-bit field shall represent the maximum target acquisition period in units of 90 kHz clock cycles.

Annex A: Triggers (Informative)

1. OVERVIEW

A key property of the trigger design is its ability to decouple the asynchronous delivery (and decoding) from the activation of objects or events (synchronized or asynchronous activation). ATSC Triggers are light-weight constructs that carry pointers to the objects to be activated, to the application that needs to process the pre-load data for purposes of presentation, and some additional self-contained user-data (see Figure A.1). Synchronized triggers also carry a Presentation Time Stamp (PTS) that indicates the point along the content timeline for synchronized presentation. While the DAU referenced by a trigger should be emitted *before* the trigger, the PTS of the trigger synchronizes with an instant of the System Time Clock as reconstructed by the receiver.

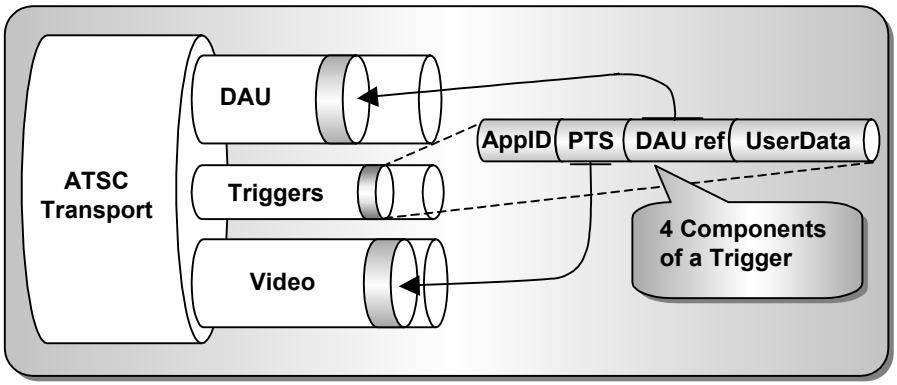

Figure A.1 Overall trigger structure.

Figure A.2 presents a simplified trigger timing diagram. In this example, the System Time Clock (STC) is discontinuous at time t_0 due to, for example, commercial insertion. In addition, a data carousel may be used to deliver the pre-load data (Note: depending upon the application, non-carouseled or other non-download protocol-based delivery methods may be used as well). The Presentation Time stamp (PTS) of the trigger indicates when the pre-load data, referenced by the trigger, needs to be activated; however, this standard does not specify what to do with the data activated, nor whether or how to display it.

Synchronized triggers are activated when the 90 kHz part of the STC in the receiver matches the value of the PTS specified by the trigger. To remove ambiguity regarding activation time, one of the requirements of this standard is that the packet carrying a synchronized trigger must be transmitted after the packet carrying the first PCR value of a new timeline, t_0. The PTS must be sufficiently delayed after t_0 (at least 33 milliseconds) in order to enable the receiver to place the trigger in the buffer, decode it, and activate the pre-load data at the time that the value of the 90 kHz portion of the receiver STC strikes the PTS, denoted t_{pts}.

The pre-load data is transmitted asynchronously, possibly using a data carousel. To ensure that the pre-load data arrives and is decoded sufficiently early, consideration must be given to the bandwidth allocated to the carrying carousel as well as its repeat rate. As recommended in [11] and [12], when the receiver fully receives a Data Access Unit (DAU) representing pre-load

data, decoding should begin immediately, so the object will be in the appropriate state for presentation as directed by the synchronized trigger message.

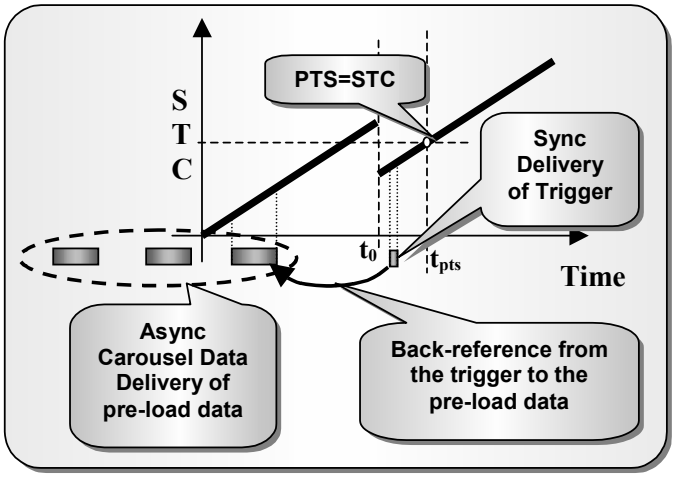

Figure A.2 Simplified ATSC trigger timing diagram.

The pre-load data may be referenced by various means, including specific download parameters, Tap reference or URIs with lid scheme [7]; object types other than a DAU can be supported as well. Furthermore, the pre-load data could be activated asynchronously.

1.1 Activation

Trigger activation is the process of enabling the target referenced by a trigger, which may cause rendering. For asynchronous triggers, activation occurs as soon as the trigger decoding is complete; the trigger decoding may start as early as when it has been fully received. For synchronized triggers, activation occurs at the time that the value of the 90 kHz portion of the receiver STC strikes the PTS carried in the trigger; as before, the trigger decoding starts as soon as it is fully received. This process is achieved as normatively described in this standard and subject to the buffer models in [1].

This standard does not present any normative receiver behavior requirements with regard to the presentation of the data. In particular, there are no normative display (or un-display) specifications.

Triggers may be transmitted repeatedly to ensure capture through random tuning. Upon repeated transmission, however, it is critical to ensure that the identities of the triggers are generated so as to ensure their uniqueness. In particular, as stated in Section 7.2, duplication of the same PTS value over several triggers on the same MPEG-2 Program Element is not allowed.

1.2 Content Creation Ramifications

At authoring time, the time instant for which synchronization occurs for data relative to a video, audio, or data elementary stream is captured relative to a story timeline; for example such as defined by SMPTE 12M time code. These synchronization time instants are regarded as the originators of the trigger instances defined in this standard, with their activation times in story timeline units.

The trigger instances need to be generated before emission. Upon generating a trigger and an associated set of pre-load data, the authoring system may need to compute an arrival time relative to the trigger activation time point. Furthermore, trigger generation requires conversion of trigger activation times and target acquisition times from the story timeline units to STC units. The duration between the arrival time of the target and the first trigger activation time point should be greater than or equal to the decoding time needed by any receivers to decode the pre-load data. This duration may be derived by the authoring system based on a set of metadata associated with the pre-load data to be synchronized. See Sections 5, 7, and 8 for normative insertion constraints.

Since the pre-load data could be delivered asynchronously, e.g., via a data carousel, the authoring system needs to compute a maximum target acquisition time period during which the receiver should not purge the pre-load data from the cache. This maximum target acquisition period is to be metadata-associated to the pre-load data via an acquisition descriptor. The maximum target acquisition period is the period between the earliest target acquisition time and the latest activation time for a specific target using all emitted triggers.

Note that the calculation of time delays needs to be robust so as to avoid synchronization errors to be introduced by re-multiplexers that will not likely parse the trigger content to analyze activation times. Unpredictable behavior may occur in the event that the pre-load data is not available (or accessible or decoded) at the activation time.

1.3 Timing examples

The insertion time of the target (pre-load) data into an ATSC Transport Stream should be selected such that there is enough time for receivers to decode the target data once they have acquired it (sufficiently in advance of the anticipated activation time). Computation of the insertion time should also take into account the status of the Transport System Target Decoder for the asynchronous data elementary stream conveying the asynchronous pre-load data. Insertion should also take into account the time needed to deliver the pre-load data to receivers. This time may be estimated as the ratio of the size of the pre-load data by the average bit rate available to transit this data. Upon receipt, the pre-load data is decoded by the receiver and kept valid for a period of time equal to max_age in the acquisition descriptor.

In the case of a single pre-load data module and a single synchronized trigger, the data server computes the value of the max_age field as follows

$$\text{max-age} = \text{activation\_time} - \text{target acquisition\_time}$$

The data server determines the time to emit the target based on the Data Decode Delay (DDD), the size of the target, the bandwidth allocated, and any emission station latency. These factors will ultimately be the basis for calculating the target acquisition time.

At the time of authoring, all values above may be in different time units. These values are metadata that *must* be provided to the data server to generate any of this in the first place. Upon preparation of the transport stream, these values are translated into PTS timestamps in units of a 90 kHz clock, where each tick represents 11.111 microseconds.

The receiver may compute the target expiration time, when the target may be safely purged (in the absence of other information), as follows

$$\text{target\_expiration\_time} = \text{target acquisition\_time} + \text{max\_age}$$

Note, however, that the receiver may choose to retain the target for display refresh or purposes related to target lifecycle, which are out of the scope of this standard. Receivers can assume that no triggers are scheduled to arrive after target_expiration_time. Thus, at this time, receivers may choose to purge the target from its cache.

Considering that pre-load data may be delivered on a carousel, and multiple triggers may be transmitted, to calculate the proper max_age, the following information is needed:

The time window over which the triggers are sent (to determine the trigger with the maximum PTS value).

The size of the pre-load data (i.e., target) and the rate at which the pre-load data is transmitted (to determine time of receipt of the first instance of the pre-load data).

Consequently, the above computation of max_age and target_expiration_time is modified as follows:

target_acquisition_time is replaced by the earliest_target acquisition_time, and

activation_time is replaced by the latest_activation_time.

Therefore, in the general case, the value of max_age is defined as

$$\text{max\_age} = \text{maximum target acquisition period}$$

$$\text{max\_age} = \text{latest activation time} - \text{earliest target acquisition time}$$

If the first emission of the target is missed, then the target_expiration_time will extend beyond the minimum required time. This calculation error is not harmful since all triggers (referring to this target) should cease to arrive before the erroneous extended target_expiration_time.