SPECIFICATION OF A MEGA-FRAME FOR SFN SYNCHRONISATION

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Scope

This document specifies a mega-frame, including a Mega-frame Initialisation Packet, MIP, which may be used for synchronisation of the Single Frequency Networks as well as for the optional control of other important parameters in an SFN.

Normative References

[1] ISO/IEC 13818-1 (1994): "Information Technology - Generic Coding of Moving Pictures and Associated Audio: Systems"

[2] prETS 300 744: "Digital broadcasting systems for television, sound and data services; Framing structure, channel coding and modulation for digital terrestrial television"

Definition and Abbreviations

Definitions

Frame: For the definition of a DVB-T frame, see [2], section 4.4.

Super-frame: For the definition of a DVB-T super-frame, see [2], section 4.4.

Abbreviations

CRC	Cyclic Redundancy Check
DVB	Digital Video Broadcasting
ERP	Effective Radiated Power
GPS	Global Positioning System
MFN	Multi Frequency Network
MFP	Mega-frame Packet
MIP	Mega-frame Initialisation Packet
MPEG	Moving Pictures Expert Group
PID	Packet Identifier
PPS	Pulse Per Second
SFN	Single Frequency Network
SI	Service Information
STS	Synchronisation Time Stamp
TPH	Transport Packet Header
TPS	Transport Parameter Signalling
TS	Transport Stream

General Description

Figure 1 shows a block diagram of a complete SFN system.

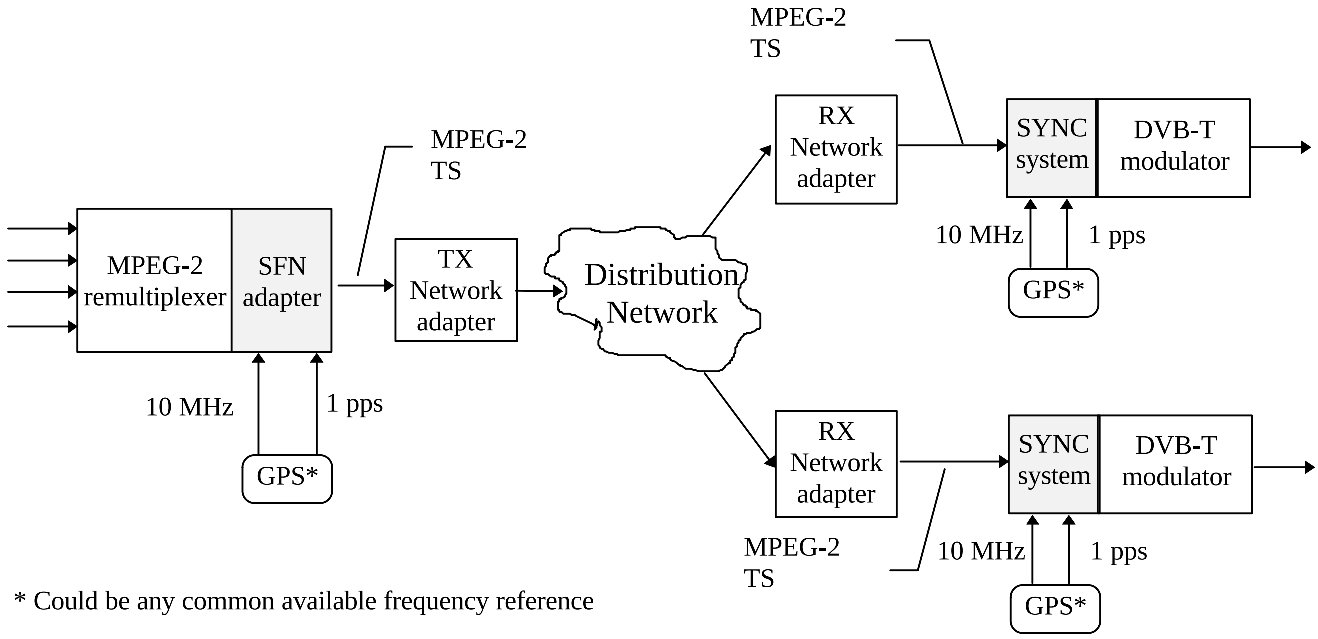

Figure 1. DVB-T primary distribution with SFN adaptation

The SFN functionality is an extension to the DVB system. The blocks associated with SFN functionality are the grey boxes in the figure above. These blocks could be implemented either as separate equipment or integrated in the multiplexer and/or the DVB-T modulator.

SFN system blocks

<u>MPEG-2 remultiplexer</u>
The MPEG-2 remultiplexer remultiplexes the programmes from various input channels, updates the SI and provides an MPEG-2 TS which, after SFN adaptation, should be transmitted via the DVB-T modulators in the SFN.

<u>SFN adapter</u>
The SFN adapter forms a mega-frame, consisting of n TS-packets corresponding to 8 DVB-T frames in the 8k mode or 32 frames in the 2k mode, and inserts a Mega-frame Initialisation Packet (MIP) with a dedicated PID value. Inserted anywhere within a mega-frame of index M, the MIP of that mega-frame, MIP_M ,allows to uniquely identify the starting point (i.e.the first packet) of the mega-frame M+1. This is accomplished by using a pointer carried by the MIP_M itself to indicate its position with regards to the start of the mega-frame M+1.
The time difference between the latest pulse of the ‘one-pulse-per-second’ reference, derived e.g. from GPS, that preceeds the start of the mega-frame M+1 and the actual start (i.e. first bit of first packet) of this mega-frame M+1 is copied into the MIP_M. This parameter is called Synchronisation Time Stamp, STS.
The time duration of a mega-frame is independent of the duration T_u, constellation and code rate of the DVB-T signal. Four different time durations exist depending on the chosen guard interval proportion:
0.502656 s (Δ/T_u =1/32), 0.517888 s (Δ/T_u =1/16),
0.548352 s (Δ/T_u =1/8), 0.609280 s (Δ/T_u =1/4).

The output of the SFN adapter should be fully DVB/MPEG-2 TS compliant.

TX/RX Network adapter
The network adapters should provide a transparent link for the MPEG-2 TS from the central to the local units. The maximum network delay - caused by the different paths of the transmission network - the SYNC system can handle is 1 second.

SYNC system
The SYNC system will provide a propagation time compensation by comparing the inserted STS with the local time reference and calculate the extra delay needed for SFN synchronisation. See annex B for an example of the synchronisation process.

DVB-T modulator
The modulator should provide a fixed delay from the input to the air interface. The information inserted in the MIP could be used for the direct control of the modulator modes or control of other transmitter parameters. The modulator clocks at the different sites have to be synchronised. Since it is a requirement of an SFN that all transmitted signals are identical, the MPEG-2 TS inputs to the various DVB-T modulators have to be bit identical.

GPS

GPS is one among many possible time references but is the only one available globally. GPS receivers are available which provide both a 10 MHz frequency reference and a 1 pulse per second (1 pps) time reference. The 1 pps time reference, used in SFN synchronisation, is divided into 100 ns steps of the 10 MHz clock. The 10 MHz system clock is assumed to be available at all nodes in the network.

The functional blocks *SFN adapter* and *SYNC system* are additional elements for SFN use, and not necessary in MFN applications.

Mega-frame definition

The output of the SFN adapter shall be a valid MPEG-2 Transport Stream, where the individual packets are organised in groups, which constitute a mega-frame. Each mega-frame consists of n packets, where n is an integer number which depends on the number of RS-packets per super-frame in the DVB-T mode that will be used for DVB-T emission of the MPEG-2 TS (see [2], section 4.7: ”Number of RS-packets per OFDM super-frame”). In the 8k mode n is (the number of RS-packets per super-frame) x 2. In the 2k mode n is (the number of RS-packets per super-frame) x 8.

Each mega-frame contains exactly one Mega-frame Initialisation Packet. The actual position may vary in an arbitrary way from mega-frame to mega-frame. The pointer value in the MIP is used to indicate the start of the following mega-frame. In figure 2 the overall structure of the mega-frame, including the positioning of the MIP, is given. The exact definition of the MIP format is found in chapter 0.

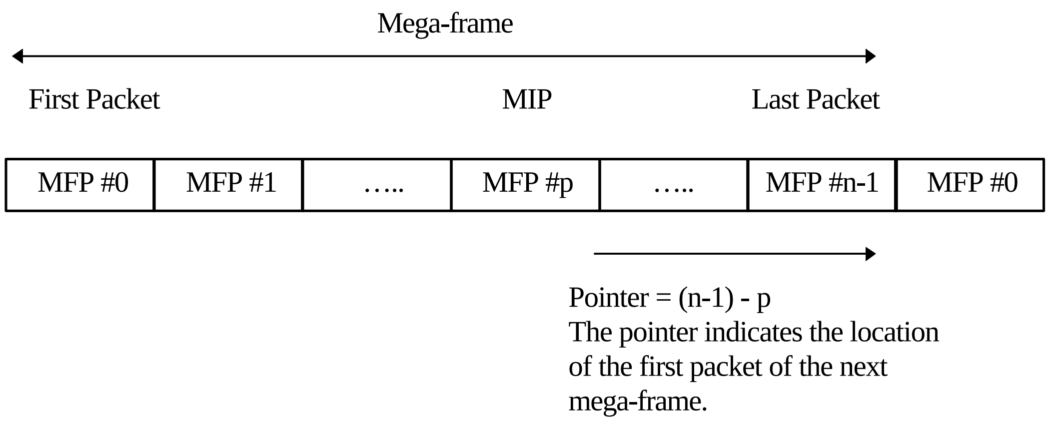

Figure 2 Overall mega-frame structure

The start of a mega-frame in the DVB-T signal is in this specification defined to coincide with the beginning of a DVB-T super-frame and the start of an inverted sync byte, being part of transport multiplex adaptation.

The use of a mega-frame and the insertion of a MIP are additional elements for SFN use, and not necessary in MFN applications.

Mega-frame Initialisation Packet (MIP)

The MIP is an MPEG-2 compliant Transport Stream packet, made up of a 4 byte header and a 184 byte data field. The organisation of the MIP is shown in table 1.

Table .1: Mega-frame Initialisation Packet

Syntax	No.of Bits	Identifier
mega-frame_initialisation_packet(){		
transport_packet_header	32	bslbf
synchronisation_id	8	uimsbf
section_length	8	uimsbf
pointer	16	uimsbf
periodic_flag	1	bslbf
future_use	15	bslbf
synchronisation_time_stamp	24	uimsbf
maximum_delay	24	uimsbf
tps_mip	32	bsblf
individual_addressing_length	8	uimsbf
for (i=0;i<N;i++){		
tx_identifier	*16*	*uimsbf*
function_loop_length	*8*	*uimsbf*
for(i=0;i<N;i++){		
function()		
}		
}		
crc_32	32	rpchof
for (i=0, i<N,i++){		
stuffing_byte	8	uimsbf
}		
}		

Note 1: *Optional parameters are shown in italic*.
Note 2: All parameter values in the MIP$_M$ apply to mega-frame M+1, i.e. to the mega-frame pointed out by the pointer, except for the tps_mip which describes the parameters of mega-frame M+2. See annex C for details.
Note 3: For the definition of the CRC decoder model, see annex A.
Note 4: The length of a MIP is always 188 bytes.

transport_packet_header: The transport_packet_header shall comply with ISO/IEC 13818-1 paragraph 2.4.3.2., table 2-3.

The PID value for the Mega-frame Initialisation Packet is 0x15.

The payload_unit_start_indicator is not used by the SFN synchronisation function and is set to 1.

The transport_priority value is not used by the SFN synchronisation function and is set to 1.

The transport_scrambling_control value is set to 00 (not scrambled).

The adaptation_field_control value is set to 01 (payload only).

All other parameters are according to ISO/IEC 13818-1 paragraph 2.4.3.2.

The Transport Packet Header is mandatory.

Mandatory SFN parameters

synchronisation_id: The synchronisation_id is used to identify the synchronisation scheme used. See table below.

Signalling format for the synchronisation_id

synchronisation_id	Function
0x00	SFN synchronisation
0x01-0xFF	Future use

section_length: The section_length specifies the number of bytes following immediately after the section_length field until, and including, the last byte of the crc_32 but not including any stuffing_byte. The section_length shall not exceed 182 bytes.

pointer: The pointer is a 2 byte binary integer indicating the number of transport packets between the MIP and the first packet of the succeeding mega-frame.
The range of the pointer depends on the DVB-T mode used for emission.

periodic_flag: Indicates if a periodic or an aperiodic insertion of the MIP is performed. Periodic insertion means that the value of the pointer is not time varying. A '0' indicates aperiodic mode and a '1' indicates periodic mode. All SFN SYNC Systems must be able to handle both aperiodic and periodic mode.

future_use: Reserved for future use.

synchronisation_time_stamp: The synchronisation_time_stamp of MIP_M contains the time difference, expressed as a number of 100 ns steps, between the latest pulse of the 'one-pulse-per-second' reference (derived e.g. from GPS) that preceeds the start of the mega-frame M+1 and the actual start (i.e. beginning of first bit of first packet) of this mega-frame M+1.

maximum_delay: The maximum_delay contains the time difference between the time of emission of the start of mega-frame M+1 of the DVB-T signal from the transmitting antenna and the start of mega-frame M+1 at the SFN adapter, as expressed by the value of its synchronisation_time_stamp in the MIP_M. The value of maximum_delay must be larger than the sum of the longest delay in the primary distribution network and the delays in modulators, power transmitters and antenna feeders. The unit is 100 ns and the range of maximum_delay is 0x000000-0x98967F, this equals a maximum delay of 1 second.

tps_mip: The tps_mip consists of 32 bits, P_0-P_{31}. The relationship between the TPS as defined in prETS 300 744 and tps_mip as defined in this specification is described below.

Relationship between TPS (as defined in prETS 300 744) and tps_mip (as defined in this specification)

Bit number (TPS)	Format	Purpose/Content	Bit number (tps_mip)
s_0	see subclause 4.6.2.1, prETS 300 744	Initialisation	Not used
s_1- s_{16}	0011010111101110 or 1100101000010001	Synchronization word	Not used
s_{17} - s_{22}	010111	Length indicator	Not used
s_{23}, s_{24}	see table 12, prETS 300 744	Frame number	Not used
s_{25}, s_{26}	see table 13, prETS 300 744	Constellation	P_0,P_1
s_{27}, s_{28}, s_{29}	see table 14, prETS 300 744	Hierarchy information	P_2,P_3,P_4
s_{30}, s_{31}, s_{32}	see table 15, prETS 300 744	Code rate, HP stream	P_5,P_6,P_7
s_{33}, s_{34}, s_{35}	see table 15, prETS 300 744	Code rate, LP stream	P_5,P_6,P_7
s_{36}, s_{37}	see table 16, prETS 300 744	Guard interval	P_8,P_9
s_{38}, s_{39}	see table 17, prETS 300 744	Transmission mode	P_{10},P_{11}
s_{40} - s_{53}	all set to "0"	Reserved for future use	P_{15} - P_{31}
s_{54} - s_{67}	BCH code	Error protection	Not used
-	see table "Signalling format for the bandwidth"	Bandwidth of the RF channel	P_{12},P_{13}
-	see table "Signalling format for the bit stream priority"	The priority of the transport stream	P_{14}

Note: There are 17 bits allocated for future use in tps_mip, whereas there are 14 bits allocated in the TPS of prETS 300 744.

Signalling format for the bandwidth

Bits P_{12}, P_{13}	Bandwidth
00	7 MHz
01	8 MHz
10	reserved for future use
11	reserved for future use

Signalling format for the bit stream priority

Bit P_{14}	Transmission mode
0	Low Priority TS
1	High Priority TS

In case of inconsistent values of $\mathbf{P_0}$**-**$\mathbf{P_{13}}$ for the High Priority and Low Priority Transport Streams, the HP value is valid. In case of change of DVB-T mode, see annex C for the time relationship between $\mathbf{P_0}$**-**$\mathbf{P_{13}}$ and the TPS data of the DVB-T signal.

individual_addressing_length: The individual_addressing_length field gives the total length of the individual addressing field in bytes. If individual addressing of transmitters is not performed the field value is 0x00, indicating that the crc_32 immediately follows the individual_addressing_length.

crc_32: This 32 bit crc_32 field contains the CRC value that gives a zero output of the registers in the decoder defined in ISO/IEC 13818-1, Annex B after processing the entire MIP. The decoder model is included in Annex A of this specification..

stuffing_byte: Every stuffing_byte has the value 0xFF.

Optional MIP section Parameters

tx_identifier: The tx_identifier is a 16 bit word used to address an individual transmitter. The tx_identifier value 0x0000 is used as a broadcast address to address all transmitters in the network.

function_loop_length: The function_loop_length field gives the total length of the function loop field in bytes.

function: The functions are described in chapter 6.1.

Functions

Parameters common to all functions:

function_tag: The function_tag specifies the function identification.

function_length: The function_length field gives the total length of the function field in bytes.

The table below gives the function_tag value for the functions defined in this document.
Note that all functions are optional and that similar commands could be sent via a separate management network.

Tag value of functions

Function	function_tag value
tx_time_offset_function	0x00
tx_frequency_offset_function	0x01
tx_power_function	0x02
private_data_function	0x03
Future_use	0x04-0xFF

TX Time Offset function

The tx_time_offset_function is used to apply a deliberate offset in time of the transmitted DVB-T signal, relative to the reference transmission time (STS+maximum_delay) modulo (10^7).

Function Transmitter Time offset

Syntax	No.of Bits	Identifier
tx_time_offset_function(){		
function_tag	8	uimsbf
function_length	8	uimsbf
time_offset	16	tcimsbf
}		

time_offset: The deliberate time offset of the mega-frames. The unit is 100 ns. The range is [-32768, 32767] x 100 ns. Note: The use of the complete range is not foreseen.

Tx Frequency Offset function

The tx_frequency_offset_function is used to apply a deliberate frequency offset of the centre frequency of the emitted DVB-T signal relative to the centre frequency of the RF channel.

Function TransmitterFrequency offset

Syntax	No.of Bits	Identifier
tx_frequency_offset_function(){		
function_tag	8	uimsbf
function_length	8	uimsbf
frequency_offset	24	tcimsbf
}		

frequency_offset: The deliberate frequency offset relative to the centre frequency of the RF channel in use. The unit is 1 Hz. The range is [-8388608, 8388607] x 1 Hz . Note: The use of the complete range is not foreseen.

Tx Power function

The tx_power_function can be used to configure the transmitter ERP.

Function Transmitter Power

Syntax	No.of Bits	Identifier
tx_power_function (){		
function_tag	8	uimsbf
function_length	8	uimsbf
power	16	uimsbf
}		

power: The power of the transmitter, defined as the ERP. The unit is 0.1 dBm. The range is [0, 65535] x 0.1 dBm. Note: The use of the complete range is not foreseen.

Private Data function

The private_data_function is used to send private data to the transmitters via the MIP.

Function Private Data

Syntax	No.of Bits	Identifier
private_data_function(){		
function_tag	8	uimsbf
function_length	8	uimsbf
for(i=0;i<N;i++){		
private_data	8	bsblf
}		
}		

private_data: The private data can be used for proprietary functions.

Annex A (informative): CRC decoder model

The 32-bit CRC decoder is specified in figure A.1

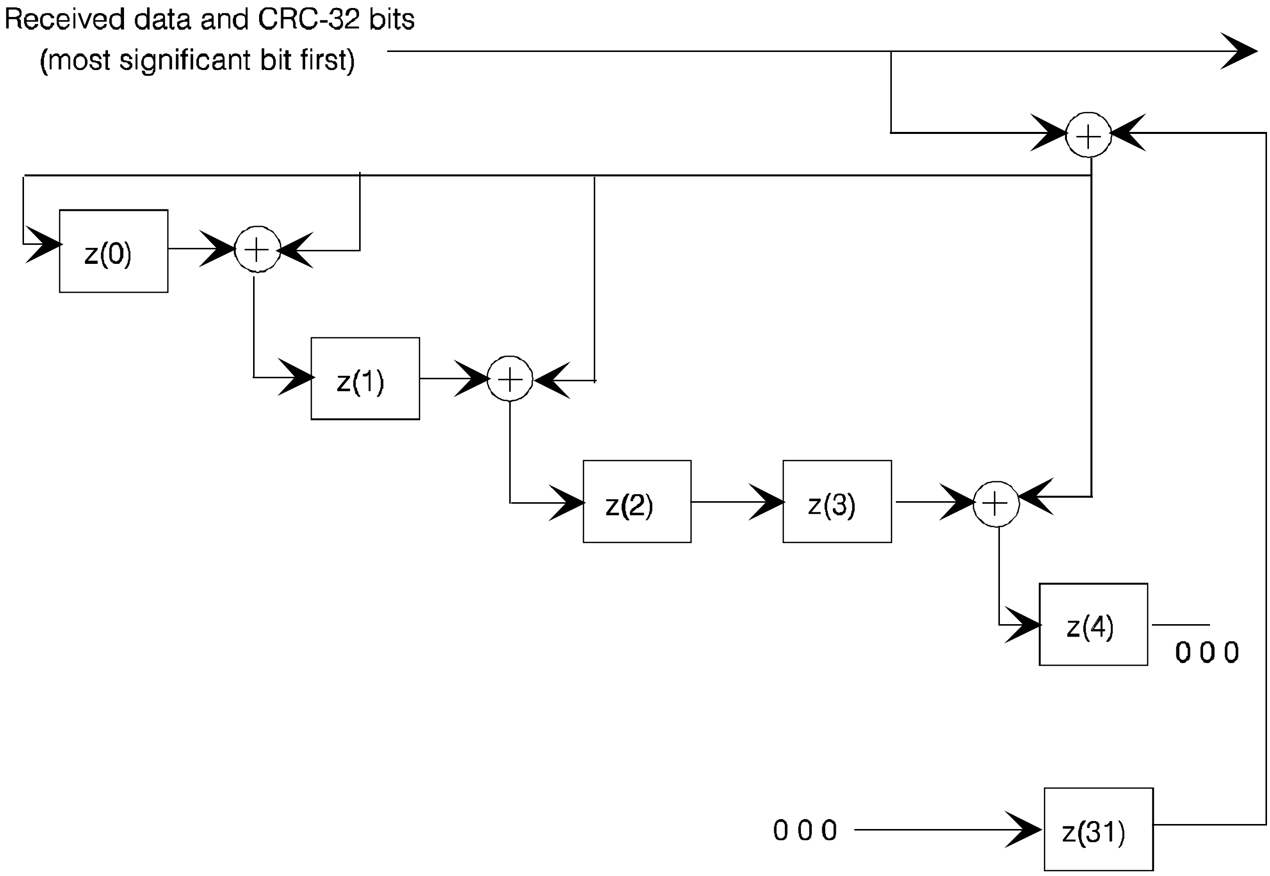

Figure A.1: 32-bit CRC decoder model

The 32 bit CRC decoder operates at bit level and consists of 14 adders + and 32 delay elements z(i). The input of the CRC decoder is added to the output of z(31), and the result is provided to the input z(0) and to one of the inputs of each remaining adder. The other input of each remaining adder is the output of z(i), while the output of each remaining adder is connected to the input of z(i+1), with i = 0, 1, 3, 4, 6, 7, 9, 10, 11, 15, 21, 22, and 25. See figure above.

This is the CRC calculated with the polynomial:

$$x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^{8} + x^{7} + x^{5} + x^{4} + x^{2} + x + 1.$$

At the input of the CRC decoder bytes are received. Each byte is shifted into the CRC decoder one bit at a time, with the most significant bit (msb) first, i.e. from byte 0x01 (the last byte of the startcode prefix), first the seven "0"s enter the CRC decoder, followed by the one "1". Before the CRC processing of the data of a section the output of each delay element z(i) is set to its initial value "1". After this initialization, each byte of the section is provided to the input of the CRC decoder, including the four CRC_32 bytes. After shifting the last bit of the last CRC_32 byte into the decoder, i.e. into z(0) after the addition with the output of z(31), the output of all delay elements z(i) is read. In case of no errors, each of the outputs of z(i) has to be zero. At the CRC encoder the CRC_32 field is encoded with such value that this is ensured.

Annex B (informative): Functional description of SFN synchronisation

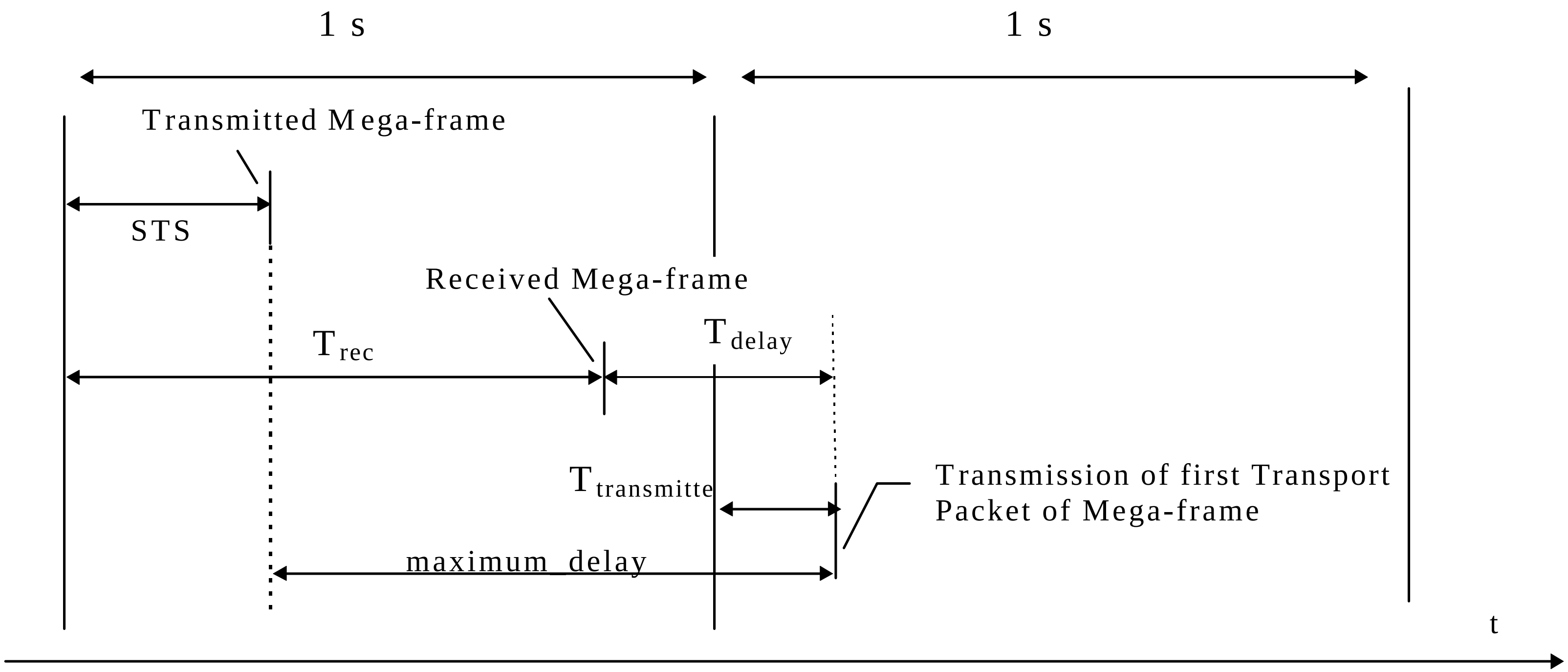

Figure B1

All values are in 100 ns (10 MHz clock)

$T_{transmitted}$ = (STS + maximum_delay) modulo (10^7) (From transmitter)

T_{delay} = STS + maximum_delay - T_{rec}

Annex C (informative): Reconfiguration of DVB-T modulator parameters by using the MIP

The tps_mip bits $\mathbf{P_0}$-$\mathbf{P_{14}}$, inserted in the MIP at the multiplexer, are used to reconfigure the parameters of the DVB-T modulator. The bits $\mathbf{P_0}$-$\mathbf{P_{11}}$ are also transmitted as the TPS bits s_{25} - s_{39} of the DVB-T signal, as information to the receiver. In the DVB-T specification, prETS 300 477, it is stated that "The TPS information transmitted in super-frame m' bits s_{25} - s_{39} always apply to super-frame m'+1, whereas all other bits refer to super-frame m'. In order to define a non-ambiguous switch time the following must apply: Inserted in the MIP being sent in mega-frame 1, the tps_mip describes the parameters of mega-frame 3. The DVB-T modulator will thus be able:

- first to update the data carried by its TPS carriers at the start of the last (i.e.the second in the 8k mode, and the 8th in the 2k mode) superframe of mega-frame 2
- then to update its new configuration at the start of mega-frame 3.

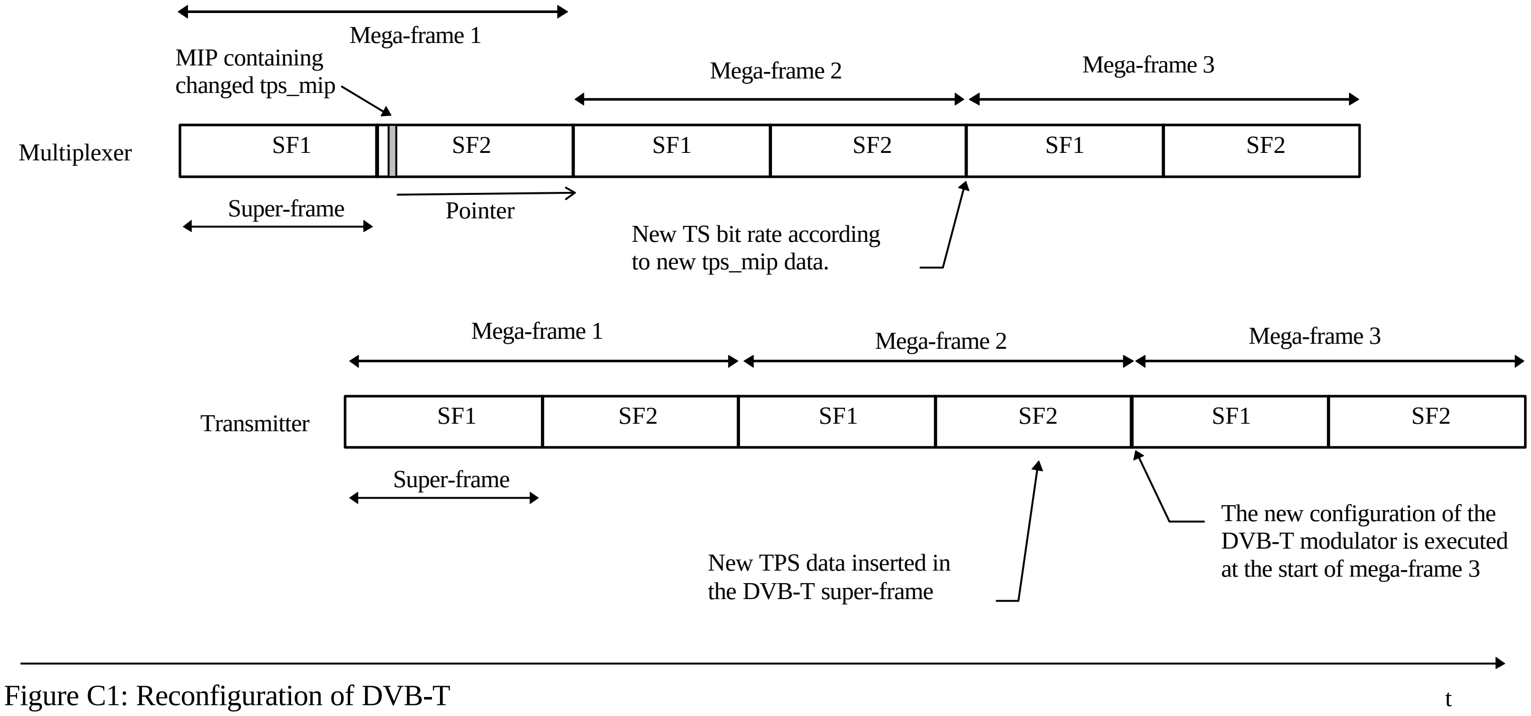

Figure C1: Reconfiguration of DVB-T modulator parameters by using the MIP.