# DVB-T2 modulator design supporting multiple PLP and auxiliary streams

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*Abstract*—**This paper presents the design of a DVB-T2 modulator algorithm supporting multiple PLP and auxiliary streams. The algorithm works over an asynchronous modulator design, presenting per stream scheduling policies, T2 Frames capacity management, and DFL computation.**

**A software tool was developed in order to create system configurations, validate input parameters, and manage per stream capacity distribution, according to proposed scheduling policies.**

*Index Terms*—**Content management; DTV and broadband multimedia systems; Signal processing for transmission; DVB-T2; Multiple PLP.**

## I. Introduction

DVB-T2 standard [1] was presented as a proposal to occupy the free left spectrum after analogue switch-off and digital television introduction. New coding, modulation, FFT sizes, guard intervals, between other parameters were included comparing to DVB-T standard [2], as stated in [3] and according to implementation guidelines [4]. One of its main contributions is the possibility to transmit video, voice and data as different streams, each with their own parameters, allowing better system capacity allocation as well as individual stream robustness management thanks to PLP concept.

This work presents specific design for per stream scheduling policies, T2 Frames capacity management, Base Band Frames DFL computation, and auxiliary streams (AUX) transmission scheme. All are based on design decisions over DVB-T2 standard free options. It presents also a design proposal of Scheduler and Frame Builder modules in a DVB-T2 transmission chain, including multiple PLP and AUX (Fig. 1). Mode Adaptation (MA) and Stream Adaptation (SA) blocks were designed to simulate service real encapsulation bandwidth load, according to formats presented in [1] and [5].

A software tool has been developed in order to configure the general parameters needed in a DVB-T2 transmitter, as well as per stream parameters including TS, GCS, GFPS and GSE encapsulations, and AUX. Encapsulation references were taken from [1], and in the case of GSE, models from [6] and [7]. Capacity is distributed by the Scheduler, first between PLP and then between AUX according to user input capacity requirements measured in bits per second or FEC blocks per T2 Frame, and also following scheduling policies developed.

In next section DVB-T2 transmitter architecture, L1 signalling, Input Processing modules relevant for this design, as well as Scheduler and Frame Builder functionalities are presented. Section III describes the algorithm development and adaptation to support many PLP and AUX. The configuration tool created is presented in Section IV. Finally, conclusions are given in Section V.

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## II. Design Principles

### A. DVB-T2 Transmitter architecture

PLP streams get an independent processing in DVB-T2 transmitter modules until reaching the Frame Builder, whose output is passed to the Frequency Interleaver and then to the OFDM signal generation block according to block diagram in [1].

In MA block, PLP are synchronized and delays are compensated. In case of TS, CRC is calculated and NPD process is executed optionally. Synchronism and NPD information is included in Base Band Frame (BB Frames) headers in SA block, where Inband information or padding is also added before passing the data to the scrambling process as described in [5].

In BICM (Bit Interleaved Coding and Modulation) block, demultiplexing, constellation mapping, cell and time interleaving are executed for each PLP in an independent manner. Pre and Post signalling get a similar treatment.

Once in Frame Builder module, all the streams are multiplexed in a T2 Frame, with the correspondent signalling information in P2 symbols as illustrated in [8].

Symbols in the generated T2 Frame are processed by the OFDM block, in which pilot carriers are added, IFFT and optional PAPR is done, P1 symbol is added and modulation process occur.

### B. L1 signalling

The first symbol in a T2 Frame (P1) allows receiver to distinguish between a SISO and a MISO system, and to store the FFT size value for current configuration.

As stated in [4], apart from P1 symbol, DVB-T2 uses 3 additional signalling types: Pre, Post and Inband. Pre has a

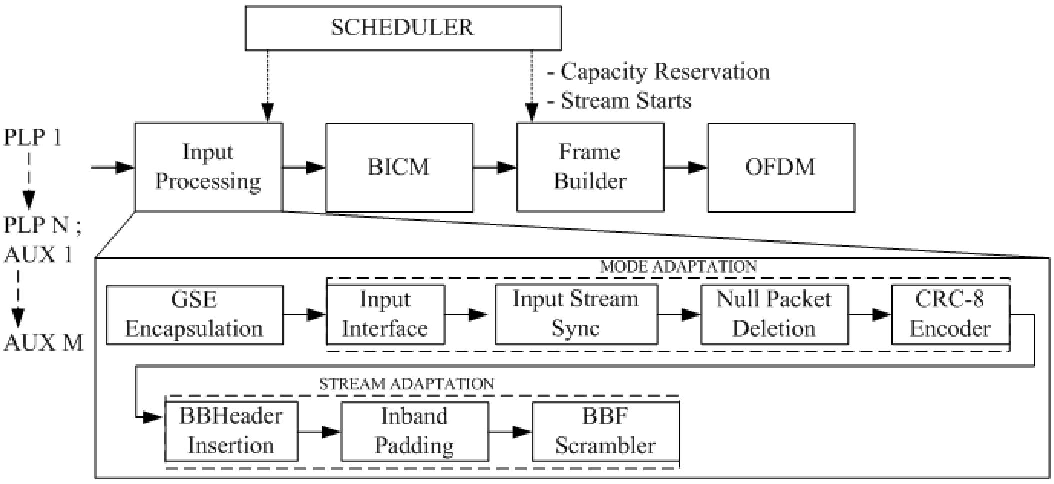


Fig. 1. General system diagram

fixed length in bits and handles system general information; Post is divided into Configurable and Dynamic fields, an optional extension field, CRC and padding as stated in [9].

Post Configurable parameters correspond to general stream configuration values that remain constant until PLP are added or deleted.

Post Dynamic signalling correspond to data transmitted in current T2 Frame, and if repetition option is in use, the second group of Dynamic fields correspond to the following T2 Frame. Post Dynamic information varies with more regularity that Post Configurable, for example, the start position for a certain PLP and its cell budget.

In this design, AUX_RFU field that appears for each AUX in Post Configurable signalling is used to indicate the receiver of the modulation type, coding, and LDPC length used in each AUX mapped in current T2 Frame. AUX_RFU in Post Dynamic is used to signal the number of FEC blocks for each AUX in current T2 Frame. This constitutes a proposal since those two fields are reserved for future use [1].

Inband signalling appears once per interleaving frame and is used to speed up the Post Dynamic signalling information processing and to be used as a backup in cases where Dynamic signalling could not be decoded, for that reason most of the fields are repeated and correspond to the next interleaving frame to be transmitted.

Additionally it is possible to send Inband signalling information from other PLP in only one PLP Inband signalling, as explained in [1]. This option can impact in a positive manner over receiver processing load, since Inband information of all streams should only be decoded once. Support for other PLP Inband signalling could be performed in further updates of current design.

### *C. Mode and Stream Adaptation (MA and SA)*

In general, MA process consists in adapting data streams from different services to become BB Frame's payload, and to get all the information needed to compute the correspondent header fields as illustrated in [5].

The most important SA element is the Scheduler, which is in charge of making T2 Frame construction decisions, generating all the information that Frame Builder and BICM modules need, as well as the Inband signalling information that will be inserted once per interleaving frame.

MA block uses 2 possible modes: Normal Mode (NM) and High Efficiency Mode (HEM), whose difference lies in the treatment data streams get before passing to the SA block. There are 4 types defined: TS, GSE, GCS and GFPS.

Initially GFPS was included as a stream type in DVB-T2 to be compatible with DVB-S2, but it is expected to be replaced by GSE, since it can also handle fixed-length packets [1].

In NM for TS, original SYNC field is replaced by CRC value. ISSY (Input Stream Synchronization) field is added for synchronism purposes (2 or 3 bytes corresponding to short or long selection). DNP (Deleted Null Packets) field is 1 byte long and indicates the number of continuous deleted null packets, increasing capacity from the DVB-T2 interface point of view. In HEM for TS, CRC and ISSY fields are not used and DNP field is optional, making it possibly to increase system capacity even more when DNP field is not in use, as computed in [4].

In this design ISSY field, according to selected configuration, is included in Input Processing block as a null fixed value, in order to simulate real capacity load.

DNP field is used as defined in [1], taking into account that the maximum number of deleted null packets in a single group cannot be greater than 255.

Finally, in SA block Inband signalling is added to the first BB Frame of each interleaving frame, if it applies, and its reserved field acts as padding until getting the needed $K_{BCH}$ coding length. If Inband signalling must be added to a certain BB Frame, reserved field length is computed so DFL field remains as a byte multiple. In this way, DFL is computed as shown in (1).

$$DFL = KBCH - BBHeader - Reserved - Inband \quad (1)$$

For GSE data stream type, restriction of 4096 bytes from GSE length field is validated [6]; Frag ID and Ext fields are not used in GSE headers; Label Type field is used with a static broadcast value, allowing multicast support for next updates with minor modifications.

In order to test system capacity, the possibility to manipulate packet and header lengths is one of the user inputs for GFPS and GSE streams, always taking into account the maximum length restriction mentioned above.

### D. Scheduler and Frame Builder

Scheduler is the core decision module in a DVB-T2 modulator, since it decides how capacity will be distributed. In this design as long as there is enough capacity, measured in T2 Frame cells, to be given to a certain stream (PLP or AUX), it is allocated. Scheduling is done following configuration order, from the first to the last PLP and idem for AUX.

Frame Builder gets T2 Frames filled with L1 signalling information (in P2 symbols), Common PLP are mapped if any, then Type 1 PLP followed by Type 2 PLP taking into account the number of subslices for current configuration, according to [10]. Finally AUX are mapped, and if there are still free cells available, dummy cells mapping is performed. Mapping is done in a per symbol manner in Frame Builder module, so it is aware of stream starts and subslice interval for current configuration, both values are present in L1 signalling and consequently can be dynamically decoded.

## III. The Algorithm

### A. Content Management: PLP and AUX

The designed algorithm consists in adding multiple PLP and AUX functionality, as well as Scheduler, Frame Builder and static Mode and Stream Adaptation blocks to a DVB-T2 software modulator, including the validation of configuration parameters associated to the corresponding modules.

Scheduling algorithm has been created in a modular basis, independent for each type of stream and encapsulation: TS, GCS, GFCS and GCS, and AUX. This makes easier to include additional allocation policies in the future, according to the type of stream selected.

Fig. 1 shows the general system diagram, including PLP and AUX processing in modules developed in the software DVB-T2 modulator.

AUX have a reduced group of parameters comparing to PLP. There are no restrictions or formats to be followed by AUX according to [1], other than maintaining a similar power-level average that carriers modulated by PLP data. In this implementation AUX are treated as PLP that are only processed by certain system modules and have no format but a fixed length for data packets.

The Input Processing functionality covers all MA modules from Input Interface to Inband Padding and BBF Scrambler.

GSE Encapsulation module showed in Fig. 1, adds a static GSE header to simulate additional encapsulation load for this type of PLP.

Input Interface module is used only for packetized streams, i.e., TS and GFPS. In TS case, this module syncs with 0x47 byte, and for GFPS sync value must be passed as configuration parameter.

Input Stream Sync adds a static null ISSY value in streams configured as NM, in order to simulate bandwidth load in this asynchronous design.

Null Packet Deletion modules removes consecutive null packets, until reaching maximum allowed value of 255 according to what can be signalled in the correspondent 8-bit field [1]. After each group of removed null packets, the next non-null packet is sent with DNP field indicating the number of null packets that must be reproduced in reception.

Once Null Packets are removed, for TS in NM a CRC-8 value is computed over OUP (188 bytes), and it replaces the sync value (0x47) before transmission.

BBHeader Insertion module adds BB Frame headers using the static field values shown in Table I.

TABLE I
BB Frame Header fields

| Field | Description |
|---|---|
| *MATYPE (2 bytes)* | The first byte indicates the stream type (GFPS, TS, GCS or GSE), if signal has multiple PLP, if streams use different coding and/or modulation, and if DNP field is in use. If there are multiple PLP, second byte signals PLP Id, otherwise is set to zero. |
| *UPL (2 bytes)* | Packet length taking into account added fields in MA. |
| *DFL (2 bytes)* | Data Field Length |
| *SYNCD (2 bytes)* | Distance measured in bits until first User Packet transmitted. It is not used for GCS. |

Inband Padding adds Inband signalling information, if this option is activated in configuration, or if $I_{JUMP}$ and $P_I$ are both equal to 1, as stated in [1]. Reserved field is filled with zero values until both Padding (Inband signalling plus Reserved) and DFL reach a byte multiple value.

Finally BBF Scrambler module randomizes bits of each BB Frame, using PRBS sequence presented in [1].

AUX are not processed neither by MA nor by SA modules.

### B. Modular Scheduling and Frame Builder

Scheduling applied for each PLP depends on stream type. For AUX, no BB Frames are constructed; instead the whole $K_{BCH}$ length packet is filled with data.

The application computes the number of FEC blocks to be allocated according to L1 parameters and bandwidth selection. Additionally, it is possible to configure this number manually, facilitating some field measurements reception processing.

The compatible number of data symbols range depends on general parameters selection. A short variation in frame length and time interleaving parameters can impact severely on system capacity. For this reason it is important to have a total control over T2 Frames length. The software tool developed computes the range mentioned above and lets user select a specific value.

The available number of subslices is computed once parameters of all Type 2 PLP that will be allocated have been configured. These values must satisfy (2). The tool only shows the options for number of subslices parameter compatible with all Type 2 PLP ($M_2$) configured.

$$N_{CELLS}(i) \bmod \{5 \times N_{SUBSLICES\_TOTAL} \times P_I(i) = 0\} \quad (2)$$
$$i \in \{1..M_2\}$$

PLP encapsulation consists of a BB Frame header, a data field (filled with data from MA block), optional Inband signalling and Padding (with Reserved field). In the case of AUX for this design, data from previous modules is fragmented into packets of $K_{BCH}$ length, without header or Inband signalling information. Padding is not used since data is processed in an asynchronous manner, and $K_{BCH}$ is a byte multiple.

The bandwidth for a certain stream can be computed as shown in (3). The number of Fec Blocks scheduled in an interleaving frame can be computed working out the NB term in the same expression.

Frame Time is computed according to (4), X value is computed according to (5), and packet header average (PHA) for packetized streams is computed as shown in (6).

$$AB = \left[ \frac{NB \times K_{BCH} - BBH - PHA - IB - RES}{FT \times \left( \frac{OUPL + X}{OUPL} \right) \times P_I \times I_{JUMP}} \right] \quad (3)$$

$$FT = FL \times T_U \times (1 + GI) + 0{,}224e^{-3} \quad (4)$$

$$X = \begin{cases} \text{HEM} \begin{cases} \text{!NPD} \rightarrow \text{X} = \text{-1} \\ \text{Rest} \rightarrow \text{X} = 0 \end{cases} \\ \text{NM} \begin{cases} \text{Issy Short} \rightarrow \text{X} += 2 \\ \text{Issy Long} \rightarrow \text{X} += 3 \\ \text{NPD} \rightarrow \text{X} += 1 \end{cases} \end{cases} \quad (5)$$

$$PHA = \begin{cases} \left( \frac{DFL}{PL} \right) \times PHL & \text{for GSE, GFPS} \\ 0 & \text{for the rest} \end{cases} \quad (6)$$

NB = Number of Fec Blocks, $K_{BCH}$ = BCH coding length, BBH = BB Frame header length, PHA = Packet Header Average, IB = Inband signaling length, RES = Reserved field length, FT = Frame Time, OUPL = Original User Packet Length, $P_I$ = number of T2 Frames to which interleaving frame is mapped, $I_{JUMP}$ = Frame interval.
X = for a TS -1 if HEM is in use and NPD is not in use, +2 or +3 if short or long ISSY is in used in NM, and additional +1 if NPD is in used in NM; zero otherwise.

## IV. The Configuration Tool

The tool allows general transmission parameters configuration and also individual L1 parameters and bit rate for each stream: PLP and AUX. Fig. 2 shows an example of the simulation tool screen.

The most relevant configuration parameters included in this tool are listed in Table II.

TABLE II
SOFTWARE TOOL INPUT PARAMETERS

| Class | Parameter | Options |
|---|---|---|
| GENERAL | FFT size | 1K, 2K, 4K, 8K, 16K, 32K |
| | Extended mode | True, False |
| | Preamble Format | Siso, Miso |
| | Bandwidth | User input |
| | Guard Interval | 1/4, 1/8, 1/16, 1/32, 1/128, 19/128, 19/256 |
| | Pilot Pattern | PP1, PP2, PP3, PP4, PP5, PP6, PP7, PP8 |
| | PAPR | ACE, TR, Both |
| | Number of PLP | User input |
| | Number of RF | User input (valid in future updates) |
| | Number of AUX | User input |
| | Mixed Preamble option | In future updates |
| | Regenerations | In future updates |
| | Number of Frames in a Superframe | User input |
| | Number of Data Symbols | User input |
| | Subslices per frame | User selection |
| *L1 Sig.* [a] | Repetition | Post Dynamic repetition: True, False |
| | Modulation | BPSK, QPSK, 16QAM, 64QAM |
| | Post Extension | In future updates |
| *PLP* | Type | Type 1, Type2 |
| | Payload Type | TS, GFPS, GCS, GSE |
| | Rotation | True, False |
| | $I_{JUMP}$ | User input |
| | IL Type | One T2 Frame, Several T2 Frame |
| | $N_{TI}$ | User input |
| | $P_I$ | User input |
| | Inband | True, False |
| | Other PLP Inband | In future updates |
| | Number of Other PLP Inband | In future updates |
| | Mode Adaptation | NM, HEM |
| | Issy | No ISSY, Short, Long |
| | Npd | True, False |
| | Number of GSE packets | User input |
| *PLP & AUX* | Id | User input |
| | Modulation | QPSK, 16QAM, 64QAM, 256QAM |
| | Coding | 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 |
| | FEC Type | 16K, 64K |
| | CIR | User input (Mbps) |
| | MIR | User input (Mbps) |
| | Number of FEC Blocks min. | User input |
| | Number of FEC Blocks max. | User input |

[a]L1 Sig. = L1 Signalling parameters.

The tool performs configuration validations, and is open to updates in order to include all the standard restrictions, making user parameter selections easier. Taking into account the amount of configurable parameters and combinations of them that DVB-T2 offers, automatic validations are appreciated.

Additionally, some functions were included to validate if there is enough capacity, from T2 Frames point of view, in order to add a new stream (PLP or AUX). The tool gives also the possibility to delete a certain stream and add it again with other L1 parameters that correspond to a new cell budget requirement.

A result tracking example of implemented algorithms is shown in Fig. 3, in which configuration and running outputs

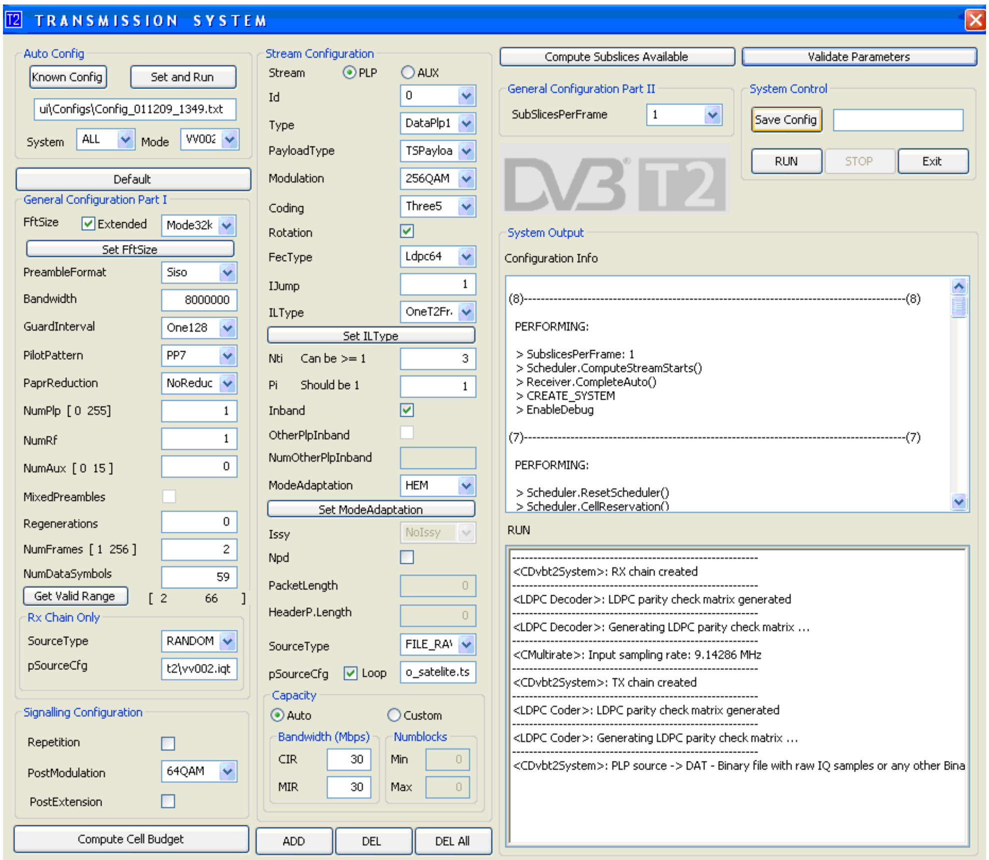


Fig. 2. Simulation Tool

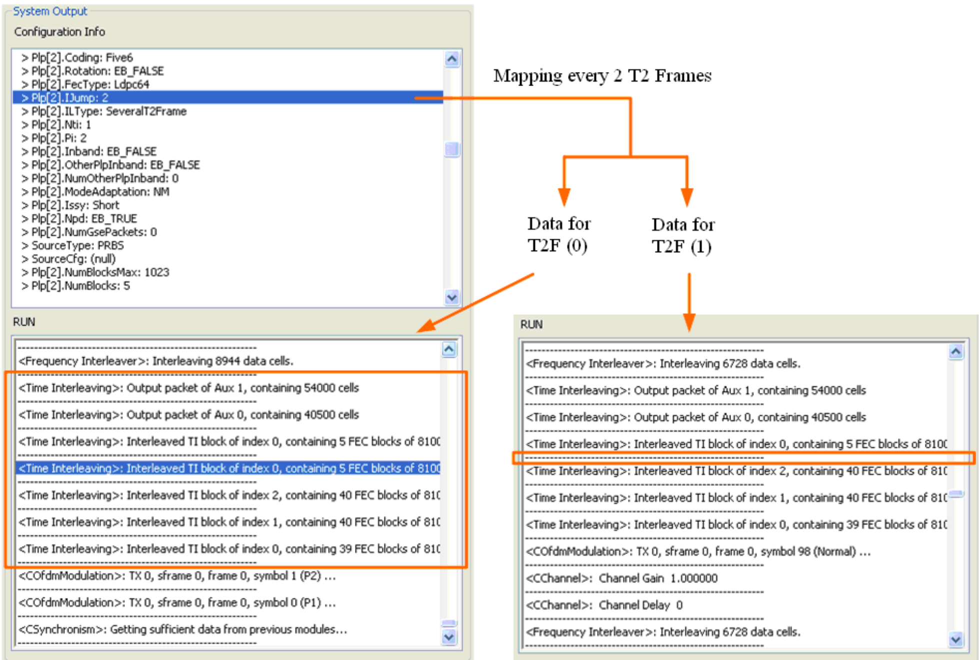


Fig. 3. Configuration and running example

allow user to verify $I_{JUMP}$ parameter for PLP number 2. With $I_{JUMP} = 2$, this PLP is only mapped every two T2 Frames, by this way time interleaving module processes only PLP 2 data in T2 Frame zero but not in T2 Frame one.

$I_{JUMP}$ y $P_I$ parameters are validated according to Superframe length selected. Superframes must contain an entire number of interleaving frames, so its length should be a $I_{JUMP}$ x $P_I$ multiple [1].

$N_{TI}$ parameter is validated also, according to time interleaving configuration, taking into account receiver TI Blocks memory limitations [1].

According to (7) and (8), the maximum number of cells per TI block shall not exceed $M_{TI} = 2^{19} + 2^{15}$, as described in [11].

$$N_{FEC\_TI\_MAX} = \left\lceil \frac{N_{BLOCKS\_IF\_MAX}}{N_{TI}} \right\rceil \quad (7)$$

$$N_{FEC\_TI\_MAX} \times N_{CELLS} \leq M_{TI} \quad (8)$$

The use of Inband Signalling is mandatory when a PLP is mapped on each T2 Frame ($I_{JUMP} = P_I = 1$), this is also validated.

## V. CONCLUSION

In this paper the design of a DVB-T2 algorithm supporting multiple PLP and AUX was presented.

For this purpose MA and SA blocks, as well as Scheduling, Inband signalling and Frame Builder modules design was proposed for an asynchronous implementation, giving support to TS, GCS, GFPS and GSE encapsulations with static Input Processing settings.

AUX_RFU fields utilization in Dynamic and Post Configurable signalling was proposed in order to decode AUX streams in reception.

A proposal for using L1 signalling reserved for AUX future use was given in order to decode this type of streams in the reception chain.

DFL computation proposal was presented for cases where Inband signalling is in use. A software tool was developed in order to create and validate system configurations, and also to manage per stream capacity distribution.

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