A Modulator Interface Protocol for GSE over DVB-SH

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Abstract. The evolution of DVB networks towards IP systems has led to the introduction of a Generic Stream format in second-generation systems. A Generic Stream Encapsulation (GSE) protocol was designed as an efficient and extensible IP encapsulation protocol for the DVB-S2 system, and there is growing interest to adopt GSE for other second-generation DVB carriers. The DVB-SH mobile standard includes provisions for GSE, but a number of adaptations are required for full support. This paper focuses on the seamless transport of GSE packets over the DVB-SH distribution network towards modulators. To this end architectural aspects are discussed and a specific protocol is proposed.

Keywords: Modulator Interface Protocol, IP, GSE, DVB-SH.

1 Introduction

DVB-SH (Digital Video Broadcasting - Satellite to Handheld) [2] is a second-generation mobile broadcast standard designed for universal coverage of multimedia services through a hybrid satellite-terrestrial infrastructure. It inherits the MPEG-2 Transport Stream (TS) as a means for data transport from first-generation systems, though it includes provisions for the newer Generic Stream Encapsulation (GSE) protocol. GSE [1] was originally designed as an efficient and extensible encapsulation protocol for IP and other network layer protocol data over the DVB-S2 forward link, but is now increasingly being considered for other second-generation DVB networks. This reflects an ongoing process of accepting IP as a common transmission technology, thereby extending connectivity beyond the DVB network and enabling the use of existing IP-based technology. In DVB-SH the full support for GSE requires a number of adaptations. [5] describes physical and link layer modifications. This paper focuses on the seamless transport of GSE packets over the DVB-SH distribution network towards modulators. GSE is dependent on the underlying base-band frame format, which is not uniquely defined among DVB standards and may vary depending on the coding used. This means that a DVB-based distribution network may not be used "as is" for the delivery of a transmission multiplex towards broadcast modulators, and a transparent means of forwarding GSE packets formatted for the DVB-SH carrier is needed.

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2 Outline of the DVB-SH System Architecture

The DVB-SH system aims to provide universal coverage by combining a Satellite Component (SC), which provides global outdoor coverage, with a Complementary Ground Component (CGC) for cellular-type service in environments where reception via satellite may be impaired. The CGC consists of terrestrial broadcast head-ends, which may be classified as "terrestrial transmitters" for the reception in mainly urban environments, "personal gap fillers" for local/in-door enhancement of satellite signals, and "mobile transmitters" as a complementary moving infrastructure such as on trains or ships.

Both the SC and the CGC are fed by a central Service and Network Head-End (SNHE), which bundles different types of content (TV, IP services, etc.) into a multiplex for transmission over some Distribution Network (DN). The distribution network delivers the multiplex to the satellite broadcast head-end and the CGC, using broadcast infrastructure such as DVB-S2, fibre, or xDSL. All transmitters (modulators) may be operated in Single Frequency Network (SFN) configuration, which improves reception performance, supports seamless handover between transmitters, and avoids the bandwidth overhead inherent to traditional multi-frequency network (MFN) planning.

3 Transmission over the DVB-SH Distribution Network

The DVB-SH [2] specification states that the SNHE is responsible for encapsulation of the video streams and other input data into a constant bit-rate transmission multiplex consisting of MPEG-2 TS or GSE streams. This works well for traditional MPEG-2 TS but raises a number of issues for the GSE protocol, as discussed below.

3.1 GSE-Based Delivery

Direct transmission of a GSE multiplex is (only) possible when a second-generation DVB link (e.g., DVB-S2) is utilized as a DN. However, this has several implications. Retransmission of the multiplex at the broadcast head-ends (SC and CGC) requires GSE packet refragmentation because the GSE protocol is dependent on the underlying base-band frame format, which is different in the DVB-SH standard than in other second-generation DVB specifications. This means that a constant bit rate from the SNHE to the receivers cannot be guaranteed. In MPEG-2 TS systems, this is required to achieve a constant end-to-end delay, allowing receivers to synchronize with the source based on Program Clock Reference (PCR) values in the multiplex. This synchronization model is not required for GSE-based video transmission because synchronization can be effected by a receiver buffering model and the use of timestamps in the RTP protocol, used for video delivery over IP streams. However, some additional overhead at the DVB-SH link may need to be accounted for due to the different GSE encapsulation. Delivery of a transmission multiplex implies a static mapping from DN Input Streams or radio channels to DVB-SH Input Streams or channels. In this case, signalling information carried within the multiplex is destined for the DVB-SH link and must not be interpreted by the DN receiver equipment.

The use of time-slicing such as defined in the DVB Data Broadcasting specification within GSE streams requires knowledge about the bit-exact transmission over the DVB-SH link. This is a caveat for SNHEs delivering a GSE multiplex because the DVB-SH link encapsulation (GSE framing, base-band framing, and physical-layer signalling) needs to be carried out twice, once logically at the SNHE, and once at the set of transmitters. The requirement for knowledge about SH link encapsulation also applies to MPEG-2 TS transmission - in the DVB-SH Implementation Guidelines, a (suboptimal) solution is described based on calculating the approximate starts of time-slices assuming an average constant bit-rate. In place of the SNHE, the broadcast head-ends could be responsible for inserting or updating time-slicing information in the GSE streams. This would add unwanted complexity to transmitters acting as pure modulators.

In SFN operation, the SNHE must deliver synchronization information along with the multiplex to the set of transmitters within the DVB-SH network. For MPEG-2 TS transmission, an SH Frame Initialization Packet (SHIP) carried within a single TS cell has been specified in the SH standard. As the SHIP specifies all the physical-layer settings and the beginning of SH Frames, the start of each EFrame can be computed. Thus, an adaptation of the SHIP to the GSE protocol could support SFN operation provided that refragmentation is carried out in the same way at all transmitters and the possible additional refragmentation overhead is accounted for at the SNHE. Note that in difference to time-slicing an approximate calculation of synchronization time-stamps based on an assumed average bit-rate cannot be used. Furthermore, even when bit-exact broadcast transmission is replicated at the SNHE, loss of a single GSE packet at a modulator affects an entire SH Frame because the exact number of bytes to be left out due to GSE refragmentation cannot be derived. This means that the transmitter cannot stay in synchronization with the other broadcast head-ends for the rest of the SH Frame.

3.2 IP-Based Delivery

The DN may be IP-based. In this case, the SNHE and the transmitters are end nodes in an IP infrastructure, and the connection may consist of several intermediate links, possibly over different physical media. This requires the carriage of GSE streams over some IP-based tunnelling mechanism. While this is possible and can avoid the need for GSE refragmentation at the broadcast head-ends as long as packets are reliably transmitted or their offset within base-band frames is known, base-band framing and physical-layer signalling still needs to be considered at SNHEs while being carried out at transmitters.

3.3 Transmission of Base-Band Frames

The DVB-T2 [3] standard defines a specific Modulator Interface Protocol (MIP) [4] for the carriage of base-band frames and physical-layer signalling over MPEG-2 TS or IP links. Delivering base-band frames (containing GSE data) instead of raw GSE packets has a number of advantages: It allows control over each frame, such as over the Input Stream Identifier (ISI) and the use of a base-band frame CRC [5], physical-layer settings and other transmitter instructions can be directly signalled instead of indicated indirectly via some GSE extension header (e.g., a GSE adaptation of the SHIP [5]), and loss of a base-band frame does not affect the entire SH Frame in an SFN setting. Moreover, it does not require broadcast head-ends to carry out any further encapsulation.

4 Modulator Interface Protocol

Because of the advantages of an MIP compared to the delivery of raw GSE streams such a protocol, applicable to DVB-SH systems, is introduced in this section. The MIP is also suggested when the DN consists of a DVB second-generation broadcast link because of the little overhead it introduces. In the case that the broadcast transmission of another DVB system is to be forwarded over DVB-SH (terrestrial) components/repeaters it is recommended that a gateway be defined that is acting as an SNHE and carries out the re-encapsulation of the GSE streams present in the multiplex.

A number of requirements can be identified for the MIP:

- Support for the carriage of EFrames and physical-layer signalling information
- Support for the delivery of multiple transmission multiplexes over a single link
- In-order delivery of data and fragments thereof
- Reliable detection of packet errors and of missing packets
- Identification of the SH Frame associated with an EFrame or physical-layer signalling packet
- Identification of the relative position of an EFrame within a particular SH Frame
- Transparent carriage over different transport protocols, including UDP, TCP, and RTP

The protocol design, depicted in Figure 1, has been chosen to fulfil these requirements. Each MI packet is made up of a 3-byte header, a variable-length payload field, and a CRC-32. The header includes a 4-bit *version* identifier to consider future changes to the protocol, a 12-bit *stream identifier*, which allows for the parallel transport of independent multiplexes, and an 8-bit *payload type* field that indicates the format of the payload field. The *version* field is set to zero for this specification of the protocol. The *stream identifier* may be chosen by the MI encapsulator or negotiated out-band between encapsulator and the modulator side. Physical-layer settings pertaining to a stream may be signalled

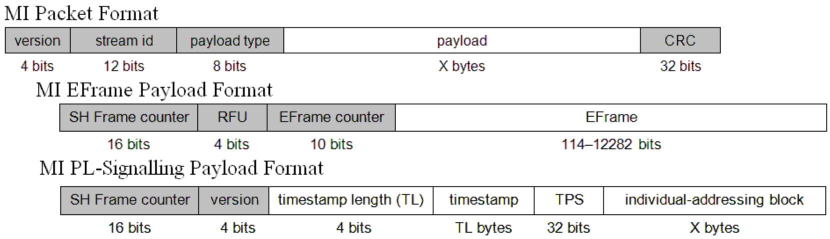

Fig. 1. MI Packet Format

in-band within the protocol or defined externally (e.g., via service-level agreements). The *CRC* that follows the payload is intended for the reliable detection of bit errors in transmission data or signalling information, and further considers the quasi error free (QEF) requirements of the GSE protocol.

Two *payload type* values are defined, one for the transmission of EFrames and one to configure the physical-layer settings of the DVB-SH carrier on a per-SH Frame basis. An MI packet carrying EFrame data is indicated by a type code of value 0x00. Its payload field (see Figure 1) contains a 16-bit *SH Frame counter*, 4 reserved (*RFU*) bits, a 10-bit EFrame counter, and the EFrame data, which includes the 114-bit header and the Data Field. EFrame padding may be omitted from the payload, though zero-bits must be used to align the Data Field to a multiple of 8 bits. The *EFrame counter* is reset to zero for the first EFrame within an SH Frame and incremented for each subsequent frame. The *SH Frame counter* is incremented for each SH Frame within a multiplex having the same *stream identifier*; its initial value in the distribution of the stream is unspecified. Both counters together allow the correct assignment of physical-layer settings per SH Frame and the reliable detection of lost packets in SFN scenarios. In MFN configuration, when constant bit-rate transmission and end-to-end delay is required (e.g., for rate control at the transmitters, or for backwards compatibility with MPEG-2 TS receivers when some EFrames contain MPEG-2 TS data) modulators can derive the constant number of EFrames per SH Frame via the physical-layer information signalled per SH Frame (described below).

MI packets for the signalling of physical-layer parameters are indicated by a *payload type* of value 0x01. The payload field of these packets includes a 16-bit *SH Frame counter*, which indicates the SH Frame to which the data applies, 4-bit *version* information, as well as signalling carried in the SH Frame Initialization (SHIP) packet defined for SFN configurations in the DVB-SH standard. This data is inserted once per SH Frame, and should precede any MI packets containing EFrame payload data for that frame. The exact format of the payload structure is shown in figure 1. The *timestamp length* field indicates the length (and format) of the *timestamp* field, and may be set to zero to omit the timestamp information in MFN signalling. A variable-length *timestamp* field has also been chosen to support transmission delays in the distribution network that are larger than 1 second, which is the currently permitted upper limit for

SFN signalling via the SHIP. The support for larger delays is crucial for distribution via non-dedicated IP network connections. The maximum delay field of the SHIP has been omitted as the encapsulator can adjust the *timestamp* values accordingly by referring to the frame emission times at the modulators. The *TPS* (Transmission Parameter Signalling) contains the physical-layer signalling for OFDM transmitters in the DVB-SH system. Signalling for a TDM satellite head-end can be delivered in a transmitter-specific function encoded in the *individual-addressing block*, which is composed of the individual-addressing fields described in the SHIP (i.e., all bytes following and including the *individual_addressing_length* field).

The MI protocol may be delivered over a variety of transport protocols (see Figure 2). Typical solutions include the transport over UDP and RTP, which can provide certain timeliness guarantees. If reliable transmission is desired TCP may be used as a transport protocol. In this case, an adaptation layer in the form of a 2-byte length field preceding each MI packet is needed. Such a solution is compatible to the approach specified for RTP delivery over TCP.

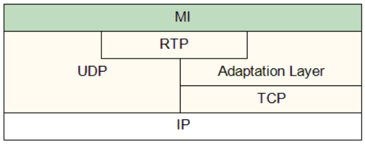

Fig. 2. MI Protocol Stack

5 Conclusion

Convergence to IP networks has become an essential functionality in the architecture of DVB networks. In this contribution we discussed the need for a Modulator Interface Protocol to enable the seamless transport of IP data over the DVB-SH distribution network and presented such a protocol. It supports the carriage of EFrames as well as physical-layer signalling for MFN and SFN transmission, and can be flexibly forwarded over DVB and IP links using various transport protocols including UDP, TCP, and RTP.

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