Architecture for Real-Time Stream Error Handling in Converged DVB-SH/Cellular Network

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Abstract—The DVB-SH system relies on a hybrid satellite/terrestrial infrastructure. A complementary solution using the interworking with a bi-directional path offered by cellular network is under investigation in DVB-Convergence of Broadcast and Mobile Services Group. This aims to provide good QoS of DVB-SH service anywhere anytime. Due to the strict reception conditions and the severe satellite channel propagation, many time-sliced bursts are lost impacting negatively the subjective video quality because the new link layer: inter-burst FEC, fails to recover the burst losses even with an adequate coding rate. In this paper, we propose a repair mechanism and a suitable architecture for real-time streaming service error handling. By recovering only some specific lost information of the broadcasted stream, the quality of TV service is improved.

I. INTRODUCTION

Video on demand or live TV services on mobile devices such as handled phones or notebooks are expected to be a key services in future wireless network. One of the challenges that the wireless technologies face today is to provide a good-quality and location-independent access to multimedia contents. Multimedia Broadcast/Multicast Services (MBMS) are proposed as extension to the existing GPRS/EDGE and 3G cellular networks [1]. Nevertheless, MBMS seems only suitable for light traffic services such as short video clips and thus should not be suited for the broadcasting of many TV channels over a wide area [2]. Digital Video Broadcasting for Satellite services to handled devices (DVB-SH) represents a promising solution to respond to such capacity challenge.

DVB-SH system is a new standard for hybrid satellite and terrestrial broadcasting of multimedia services to mobile handheld receivers [3], [4]. It proposes an efficient transmission for frequencies below 3 GHz suitable for satellite link. Typically the allocated band is in S-band offering a 30 MHz slot adjacent to the terrestrial UMTS band enabling easily the integration of terrestrial repeaters in existing 2G or 3G cellular sites including antennas, and providing a reduction of the infrastructure costs.

DVB-SH reuses the IP datacast, time slicing (data bursts) and Orthogonal Frequency Division Multiplexing (OFDM) technologies of DVB-H standard in order to keep the compatibility. It complements and improves the existing DVB-H physical layer specifications (Time Division Multiplex mode, 1k FFT,...etc) [5]. It implements a turbocode and long interleaving. Indeed in order to guarantee a high quality of service of the user in severe mobile conditions such as deep fading events or non line of sight (NLOS) condition, DVB-SH makes use of long time diversity that can be provided by interleaver located either at physical layer (for class 1 terminals) or at link layer (for class 2 terminals) through a burst interleaver, called Multi-Protocol Encapsulation Inter-bursts FEC (MPE-IFEC) [5]. Nevertheless, improving link budget performance relies on an adequate design and dimensioning of the different layers of DVB-SH protocol stack and some labs simulations summarized in the implementation guidelines [5] reveal that such optimization is strongly determined by the satellite transmission channel model. In many scenarios over the satellite transmission link, the burst interleaver in link layer is not suitable to fill the service coverage gap causing many service interruption.

A repair mechanism for non real time service based on the application layer FEC is proposed in [6]. Unlike a real-time stream, all the file date are to be first received and stored into the terminal before being used by appropriate applications. To ensure the completeness and integrity of received files, a unidirectional file delivery protocol is used. In addition to that, post delivery repair mechanisms may be defined by the operator, which may not necessary use the cellular channel. The following procedure is a part of the Content Delivery Protocol of the DVB-H standard. For DVB-SH standard, the CDP is under amendment. In this context, it is interesting to have a concept of real time stream repair. This paper presents a framework to do that.

First, a description of the system DVB-SH, under standardization in DVB project, is given in order to highlight the major new features and concepts. A special interest will be given to the link layer which is compliant with the well known Multi-Protocol Encapsulation layer. The new link layer called MPE-Interbursts FEC is the mixture of two concept: MPE-FEC and service/burst interleaving. With MPE-IFEC, the terminal is able to recover a several complete burst lost avoiding a full service interruption as is the case in DVB-H system. By exploiting the fact that the link layer MPE-IFEC could be fed by two independent channels. The first one is the DVB-SH channel and the second one is the cellular one. Of course, in our framework, the terminals are supposed to be dual-mode. Our proposed mechanism needs to recover only some specific lost information of the broadcasted stream by retransmitting them via the cellular network upon a terminal request to a
retransmission server. The key idea is that the retransmitted information burst must respect the time deadline of the burst expiration in the MPE-IFEC. The value of the deadline depends on the link service interleaving depth. Depending on the position of the retransmission server, we distinguish two main architectures.

The rest of the paper is organized as follows: Section II describes the main technical features of DVB-SH. Section III presents the new link layer MPE-IFEC; its principle and characteristics. The proposed repair mechanism and the associated architecture is described in section V. The system model and simulation results are presented in Section VI. Finally, section VII draws some conclusions.

II. DVB-SH: SYSTEM OVERVIEW

DVB-SH standard is a DVB broadcast standard under study in DVB-project. In Dec 2007, the physical layer is adopted by ETSI [3]. It aims to provide IP-based multimedia services (TV content, data delivery, Video-on-Demand, interactive services) at frequency below 3 GHz to mobile handset as well as portable and vehicular devices. It provides a universal coverage by combining a Satellite Component (SC) and a Complementary Ground Component (CGC) in a cooperative mode. The SC ensures a global coverage while CGC provides cell-type coverage. All types of environment (indoor/outdoor, urban/suburban/rural, static/mobile) are addressed. The figure 1 presents the hybrid architecture combining SC and CGC this latter being composed of a battery of repeaters co-localized within 3G sites.

Fig. 1. Overview of DVB-SH architecture

DVB-SH introduces the Time Division Multiplex (TDM), [4], as a second scheme in addition to the classical OFDM modulation used in DVB-H [7]. As a consequence, two reference architectures are proposed in DVB-SH:

- **SH-A**: it uses OFDM waveform both on the satellite and the terrestrial links. In this mode, three modulation modes are selected QPSK, 8-PSK and 16-APSK,

- **SH-B**: it uses TDM on the satellite link and OFDM over terrestrial links. In this mode, applied modulation scheme are QPSK, 16-QAM and non-uniform 16-QAM modulation.

Furthermore, DVB-SH incorporates a number of enhancements compared to DVB-H such as more alternative coding rates, the support of 1K FFT for L band where the target bandwidth is 1.75MHz (in addition to 2K, 4K and 8K modes), physical layer forward error correcting coding using 3GPP2 turbo coding scheme [8].

In order to guarantee a high quality of service at the end user receiver in severe mobile conditions such as deep fading events or NLOS, DVB-SH makes use of long time diversity provided by a link layer burst interleaver. This burst interleaver is build in the link layer of DVB-SH resulting in the new link layer: Multi-Protocol Encapsulation Inter-bursts FEC (MPE-IFEC) [5]. This is classified as class 1 receiver. Another class is proposed: class 2 receiver. It is based on a long physical layer protection (in the order of several bursts) that may be complemented by a link layer protection, as in class 1 receivers, for even longer protection.

DVB-SH reuses the time slicing (data bursts) and Multi-Protocol Encapsulation (MPE) of DVB-H standard in order to keep the compatibility. It benefits, also, from the set of IP Datacast specifications, which were originally defined to specify an end-to-end DVB-H solution. IP Datacast is now under amendment by DVB-Convergence Broadcast Multicast System group.

III. MPE-IFEC: PRINCIPLE AND CHARACTERISTICS

DVB-SH standard specifies a FEC scheme at the link layer called MPE-IFEC. MPE-IFEC is introduced to support reception in situations of long duration erasure on the MPE sections level spanning over several consecutive time slice bursts. Such erasure situation may for instance occur on satellite mobile channels (LMS: land mobile satellite) where for example obstacles may hide direct satellite reception and induce losses of several successive bursts. The principle of MPE-IFEC is summarized in figure 2.

Fig. 2. MPE-IFEC process encoding

**MPE-IFEC** is based on a parallelization of the encoding/decoding matrices (structured as the following: the application data table (ADT) filled with IP data, and FEC data table
(FDT) containing the parity symbols). The redundancy bytes or FEC are calculated by combining columns of \( B \) different ADST (Application Data Sub Table) and they are further spread over \( S \) time-slice bursts. The data and parity referring to a single datagram burst are transmitted over the air in time sliced bursts, where \( D \) is the delay, expressed in terms of number of burst, between the reception of the datagram burst and its transmission over the air, and \( S \) is the number of bursts over which the generated parity are spread. So, on the receiver side, every time a time sliced burst arrives at the link layer, only a portion of data columns can be corrected, corresponding to the FEC that has been calculated and data already received. Parity symbols are generated by a Reed Solomon code or a Raptor code.

\( B, S \) and \( D \) are related through the function giving by:

\[
M = B + \max(0, S - D) + \max(0, D - B) \quad (1)
\]

where \( \max(.) \) denotes the maximum function. These parameters are provided to the receiver in the time_slice_fec_identifier inside the INT table [5].

The data issued from datagram bursts are used as input of the MPE-IFEC. The datagram burst is mapped by an ADST function (see equation (2)) onto a number of ADTs rising up to \( B \) parallel encoding matrices. The ADT index, for a given modulo, datagram burst number \( k \), and a given ADST column number \( j \) is given as:

\[
\text{adt}_\text{index}(k, j) = (k + j[B])[M] \quad (2)
\]

where \( n[m] \) denotes \( n \) modulo \( m \) operation.

The IFEC burst collects all MPE-IFEC sections from FDTs of several encoding matrices using the function presented in equation (3) where the resulting parity is also be spread over several bursts instead of one single burst as in the MPE-FEC case: each burst contains parity coming from \( S \) FDT matrices.

\[
\text{ifdt}_\text{index}(k, j) = (k - j[S] - 1 + M)[M] \quad (3)
\]

What it is sent over the air is called the time-slice burst. For example, the time-slice burst corresponding to datagram burst \( k \) consists of a collection of:

- MPE sections (data) generated from datagram burst \( k-D \),
- MPE-IFEC sections (parity bits) generated from datagram burst \( k-D \) (if MPE-IFEC is also used),
- IFEC burst \( k \) containing MPE-IFEC sections (parity bits) generated when datagram burst \( k \) was received.

The data and FEC referring to a single datagram burst are transmitted in \( B+S-D \) time sliced bursts, where \( D \) being the delay between the generation of an ADT and its transmission. Erroineous bursts are gradually corrected because the corresponding FEC redundancy is spread over several bursts \( S \) in order to obtain time diversity.

The \( M \) value, in addition to give the number of encoding matrices, gives the dimension of receiver latency and the memory requirements. The equation (1) highlights the importance of the \( D \) parameter and its impact on end user perception (via the latency) and terminal sizing (via memory). For instance for a \( B \) equal to 6 and a \( S \) equal to 4, we obtain the curve presented in the figure 3.

![Fig. 3. Trade-off between memory requirement \( M \) and delay \( D \) for \( B=6 \) and \( S=4 \)](image)

We note that:

- The minimum value of \( M \) is obtained for \( D \) taken in the range \([4; 6]\). This reduces memory requirements in receiver and also the latency. Increasing \( D \) increases the end-to-end latency.
- When \( D \) is equal to 0, \( M \) is rather large and equal to \( B+S=10 \); this configuration corresponds to the situation when the MPE-IFEC sections are always sent after the data they protect. But such high \( M \) value implies long jitter-free receiver interface delay and large memory requirements.

The burst index, for example \( k \), is an important information in the MPE-IFEC decoding process. All the operations of de-interleaving of data (columns of ADST) and iFEC columns are based on it. This information is transmitted only in the header of the IFEC section (section containing the parity symbols of MPE-IFEC). Then, the first step that a MPE-IFEC capable receiver must do is to determine to which time-slice burst the sections belongs to.

### IV. CODE RATE CHARACTERIZATION OF MPE-IFEC

The code rate, denoted here by \( R \), implemented by the MPE-IFEC is defined on a per encoding matrix (EM) basis by the formula combining, for a given EM denoted by \( m \), \( 1 < m < M \), the number of ADT data columns, denoted by\( (C(m)) \), and the number of FDT parity columns \( (F(m)) \):

\[
R(m) = \frac{C(m)}{F(m) + C(m)} \quad (4)
\]

As a result this value tends to vary from one EM to another, since each EM is not filled with the same amount of data due to the variation of the video traffic in case of Variable Bit rate video coding. In case of Constant Bit Rate (CBR) video coding, the number of columns in the ADST is constant thus inducing a constant coding rate per EM.

In the case of CBR video traffic, the code rate of MPE-IFEC could be approximated by the following expression:

\[
R \simeq R(m) \simeq \frac{B}{B+S} \quad \forall m \in \{1, ..., M\} \quad (5)
\]
It is clear from equation (5) that the code rate $R$ could be obtained by a freely choice of many combination of the couple $(B, S)$. For cases where $D = 0$, the optimal parameters $B_{opt}$ and $S_{opt}$ can be derived from targeted code rate denoted by $R_{target}$ and a certain interleaving depth $B + S$ by using the following formulas:

$$S_{opt} = \left\lfloor (1 - R_{target}) \times (B + S) \right\rfloor \quad (6)$$

$$B_{opt} = (B + S) - \left\lfloor (1 - R_{target}) \times (B + S) \right\rfloor \quad (7)$$

where $\left\lfloor . \right\rfloor$ denotes rounding to the next larger integer.

The equations (6) and 7 indicate the amount $(1 - R_{target})$ of redundancy that is needed for fixed value of $B + S$ and under a given environment (link budget, propagation channel,...). We are able to determine the optimal value of data interleaving depth given by $B$.

V. STREAM REPAIR PROCEDURE

For power saving reason, DVB-SH employs discontinuous transmission technique based on time slicing, where data is periodically sent in bursts as shown in Figure 4.(a).

![Fig. 4. Burst loss prediction in case of CBR video traffic](image)

Terminal receivers synchronize onto the burst of the desired service and switch off after burst reception. Once the data burst is decoded by the MPE-IFEC link layer, it is delivered to the service and switch off after burst reception. Once the data burst is decoded, it is delivered to the service and switch off after burst reception. Once the data burst is decoded, it is delivered to the service and switch off after burst reception.

When the burst loss counter exceeds a specified threshold denoted by $T_h$, the terminal sends a request to a retransmission server demanding the first occurrence of the lost bursts in its observation window. From time constraint point of view, the receiver must get the requested lost burst before its consumption by the media player. The maximum allowed end-to-end delay is then equal to $B + S - D - 1 - T_h$ seconds if we assume $T_c = 1$ second. The value of max-end-to-end delay impacts the throughput consumed over the cellular network which is equal to $\frac{B 	imes S}{T_c}$ Kbit/s where $B_e$ is the burst size of the burst. The value of the threshold is upper-bounded by the value of $C_{corr}$.

On figure 5, we plot the variation of the cellular throughput versus number of transmitted burst per window of $B + S$ bursts. All the simulated configurations $(B,S)$ have the same coding rate which is equal to 1/2. We focus our interest on the streaming service encoded by H264 AVC encoder with an encoding rate at 200 kbps.

![Fig. 5. Burst loss monitoring and access to the cellular network](image)
ASSOCIATED PROCEDURE DESCRIPTION OF A REAL TIME STREAM REPAIR

VI. ARCHITECTURE AND ASSOCIATED SIGNALLING

To implement the described stream repair procedure, a retransmission server is introduced in system architecture as is presented in figure 7. The server will have a network interface to the head-end of DVB-SH system in order to have a copy of the last broadcasted burst of the multiplex over $2 \times (B + S)$ bursts. The server will be identified by an URI.

The media stream repair capability related to the streaming delivery session has to be previously signaled to terminals to enable these receivers to initiate such a stream repair activity following the procedure described in last section. The identities of the retransmission servers may be announced in-band within the delivery session, or out-of-band (within the Electronic Service Guide (ESG), before start of delivery session). All configuration parameters of one associated delivery procedure are contained as attributes of an associated Procedure Description element announced within ESG as an XML file:

```xml
<PostStream OffsetTime=50 RandomTimePeriod=1000/>

TABLE I
AN XML FRAGMENT CONTAINING THE ASSOCIATEDPROCEDUREDESCRIPTION OF A REAL TIME STREAM REPAIR

When the terminal detects the need to repair the stream, it identifies the index of the burst to be demanded and send an HTTP request to one server URI element selected randomly from the element listing the repair service (see Table 1).

The location of the retransmission server inside the 2.5G or 3G networks is related to the business model approach:

- Mobile network operator (MNO) centric:
  - Retransmission server above GGSN
  - Retransmission server located in base station

- Broadcast operator centric:
  - Retransmission server above GGSN but not controlled by the MNO.

These different possibilities have an impact on the set of functions that must be supported by the retransmission server such as: Authentication & Authorization of users, implemented protocol stack...etc

In the figure 7, we show the example of a retransmission server located above GGSN in the MNO centric model.

VII. CONCLUSION

In this paper, we propose an efficient mechanism able to repair a real-time streaming service broadcasted over DVB-SH interface without need to freeze the pictures nor to add some additional parity data. By recovering only some specific lost information of the broadcasted stream, the quality of service is improved. The converged DVB-SH/cellular network architecture is presented with the corresponding signalling. A testbed is under construction in Alcatel-Lucent with other partners involved in TV Mobile Sans Limite (TVMSL) french project. The proposed mechanism is a good candidate in DVB-CDMS to be a procedure ensuring an inter-system mobility (DVB-SH / cellular network).

REFERENCES