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SERIES H: AUDIOVISUAL AND MULTIMEDIA SYSTEMS

IPTV multimedia services and applications for IPTV – General aspects

Content delivery error recovery for IPTV services

Recommendation ITU-T H.701

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Recommendation ITU-T H.701

Content delivery error recovery for IPTV services

Summary

Recommendation ITU-T H.701 provides content delivery error recovery (CDER) mechanisms for IPTV services. It details the error recovery functions in the IPTV architecture and specifies detailed CDER mechanisms. It also provides guidelines on the applicability of the CDER mechanisms to different IPTV services and network conditions.

Source

Recommendation ITU-T H.701 was approved on 16 March 2009 by ITU-T Study Group 16 (2009-2012) under Recommendation ITU-T A.8 procedures.

Keywords

Content delivery error recovery, forward error correction, retransmission.

FOREWORD

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Recommendation ITU-T H.701

Content delivery error recovery for IPTV services

1 Scope

The ability to deliver high level of service quality to users is an essential aspect of IPTV services, and thus captured in many IPTV-related requirements. As IPTV services can easily be degraded if the media decoders are exposed to impairments such as packet losses, mechanisms are needed to reliably deliver good IPTV service quality in the presence of such defects.

This Recommendation integrates error recovery in the IPTV architecture, describes specific mechanisms and discusses the applicability of the mechanism to IPTV services and network conditions, and provides recommendations and guidance on their use.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.1541] Recommendation ITU-T Y.1541 (2006), *Network performance objectives for IP-based services*.

[ITU-T Y.1910] Recommendation ITU-T Y.1910 (2008), *IPTV functional architecture*.

[ITU-T Y.Sup5] ITU-T Y-series Recommendations – Supplement 5 (2008), *ITU-T Y.1900-series – Supplement on IPTV service use cases*.

[ARIB STD-B24] ARIB Standard, ARIB STD-B24, *Data Coding and Transmission Specification for Digital Broadcasting*.

[ATIS-0800005] ATIS-0800005 (2006), *IPTV Packet Loss Issue Report*.

[ETSI TS 102 034] ETSI TS 102 034 v1.3.1 (2007), *Digital Video Broadcasting (DVB); Transport of MPEG-2 TS Based DVB Services over IP Based Networks*.

[SMPTE 2022-1] SMPTE specification 2022-1 (2007), *Forward Error Correction for Real-time Video/Audio Transport Over IP Networks*.

[IETF RFC 793] IETF RFC 793 (1981), *Transmission Control Protocol*.

[IETF RFC 3550] IETF RFC 3550 (2003), *RTP: A Transport Protocol for Real-Time Applications*.

[IETF RFC 5052] IETF RFC 5052 (2007), *Forward Error Correction (FEC) Building Block*.

[IETF RFC 5053] IETF RFC 5053 (2007), *Raptor Forward Error Correction Scheme for Object Delivery*.

3 Definitions

This Recommendation defines the following terms:

3.1 FEC base layer: Most important FEC layer. In the context of this Recommendation, this refers to the base layer in the FEC as specified in [ETSI TS 102 034].

3.2 FEC enhancement layers: Subsequent FEC layers. In the context of this Recommendation, this refers to the enhancement layers in the FEC as specified in [ETSI TS 102 034].

3.3 FEC layer: One FEC stream of multiple ordered FEC streams where support of this layer means that all FEC streams with more important order are also supported.

3.4 FEC stream: IP packet stream associated with a media stream that contains redundant data to reconstruct a media stream locally at the IPTV terminal.

3.5 forward error correction (FEC): FEC-based CDER mechanisms generate redundant data to allow the IPTV terminal to correct packet losses. With this redundant information, the receivers can recover from packet losses locally at the IPTV terminal.

3.6 retransmission: Retransmission-based CDER mechanisms use feedback messages to recover from packet losses.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ALC Asynchronous Layered Coding

AFEC Adaptive FEC

ARQ Automatic Repeat Request

ATIS-IIF Alliance for Telecommunication Industry Solutions – IPTV Interoperability Forum

AVP Audio-Visual Profile

CBR Constant Bit Rate

CDER Content Delivery Error Recovery

DSL Digital Subscriber Line

DVB Digital Video Broadcasting

ECG Electronic Content Guide

EPG Electronic Program Guide

FEC Forward Error Correction

FLUTE File delivery over unidirectional transport

FTP File Transfer Protocol

ID Identifier

IDR Instantaneous Decoder Refresh

IP Internet Protocol

IPDV IP Packet Delay Variation

IPER IP Packet Error Ratio

IPLR IP Packet Loss Ratio

IPTD IP Packet Transfer Delay

IPTV IP Television

MTBA Mean Time Between Artefacts

NACK Negative ACKnowledgement

QoE Quality of Experience

QoS	Quality of Service
RMT	Reliable Multicast Transmission
RTCP	Real-Time Control Protocol
RTP	Real-Time Transport Protocol
RTT	Round-Trip Time
SCP	Service and Content Protection
TCP	Transmission Control Protocol
TF	Terminal Function
TS	Transport Stream
TTS	Timestamped Transport Stream
UDP	User Datagram Protocol
VoD	Video on Demand
XML	eXtensible Markup Language

5 Conventions

None.

6 Introduction

Content delivery error recovery (CDER) is an important aspect for IPTV services. Data being delivered over IP networks may suffer from packet losses. In case of the delivery of video and audio, data errors, such as packet losses or bit errors being delivered to the media decoder, generally degrade the IPTV service quality. Moreover, losses in metadata such as electronic program guides (EPG), electronic content guides (ECG), and interactive user data may cause more severe problems in IPTV services. Therefore, data reliability support is essential to IPTV services.

This Recommendation addresses the requirement that the IPTV architecture provide a mechanism for resiliency of the service provider infrastructure in order to maintain a high QoE for video services [ITU-T Y.Sup5]. It addresses specific realizations of the content delivery error recovery function and the content delivery error recovery client function in the IPTV architecture [ITU-T Y.1910]. Reference point E4 is used to exchange messages for delivering and requesting error recovery information [ITU-T Y.1910].

The support of content delivery error recovery mechanisms is not required for all networks, in particular for networks that can fulfil the desired IPTV service requirements.

In case that a network cannot fulfil the packet loss requirements necessary to achieve the IPTV service requirements, the use of a content delivery error recovery solution is recommended.

Retransmission, forward error correction (FEC), and hybrid combinations of both are known mechanisms for error recovery. When an error recovery scheme and the associated protocol is selected, at least the following aspects should be taken into account:

1) type of IPTV service, e.g., linear TV, content-on-demand, content download, EPG distribution, application data;
2) type of data delivery mechanisms, e.g., broadcast, multicast, unicast, overlay multicast, or peer-to-peer;
3) protocol or processing overhead at senders and receivers;
4) network bandwidth overhead aspects.

This Recommendation is structured as follows:

Clause 7 introduces the content delivery error recovery architecture and provides some high-level descriptions of the involved functional blocks and interfaces.

Clause 8 provides an overview on different CDER mechanisms for streaming, i.e., for solutions in which the media stream is distributed in real-time and consumed at the same time.

Clause 9 provides an overview on different CDER mechanisms for content download services, i.e., for solutions in which a media file is distributed to terminals for later consumption.

This Recommendation also contains several annexes that contain specific recommendations for CDER mechanisms. The first release of this Recommendation is restricted to one annex specifying recommended FEC-based error recovery mechanisms for streaming distribution.

It is expected that in future releases, additional annexes will be added to specify recommendations at least on:

– Retransmission-based error recovery mechanisms for streaming delivery.

– Content delivery error recovery mechanisms for content download services.

This Recommendation also includes appendices for background information on the evaluation of CDER mechanisms as well as on configuration of specific CDER mechanisms in IPTV networks.

7 Content delivery error recovery architecture

7.1 Content delivery error recovery in IPTV architecture

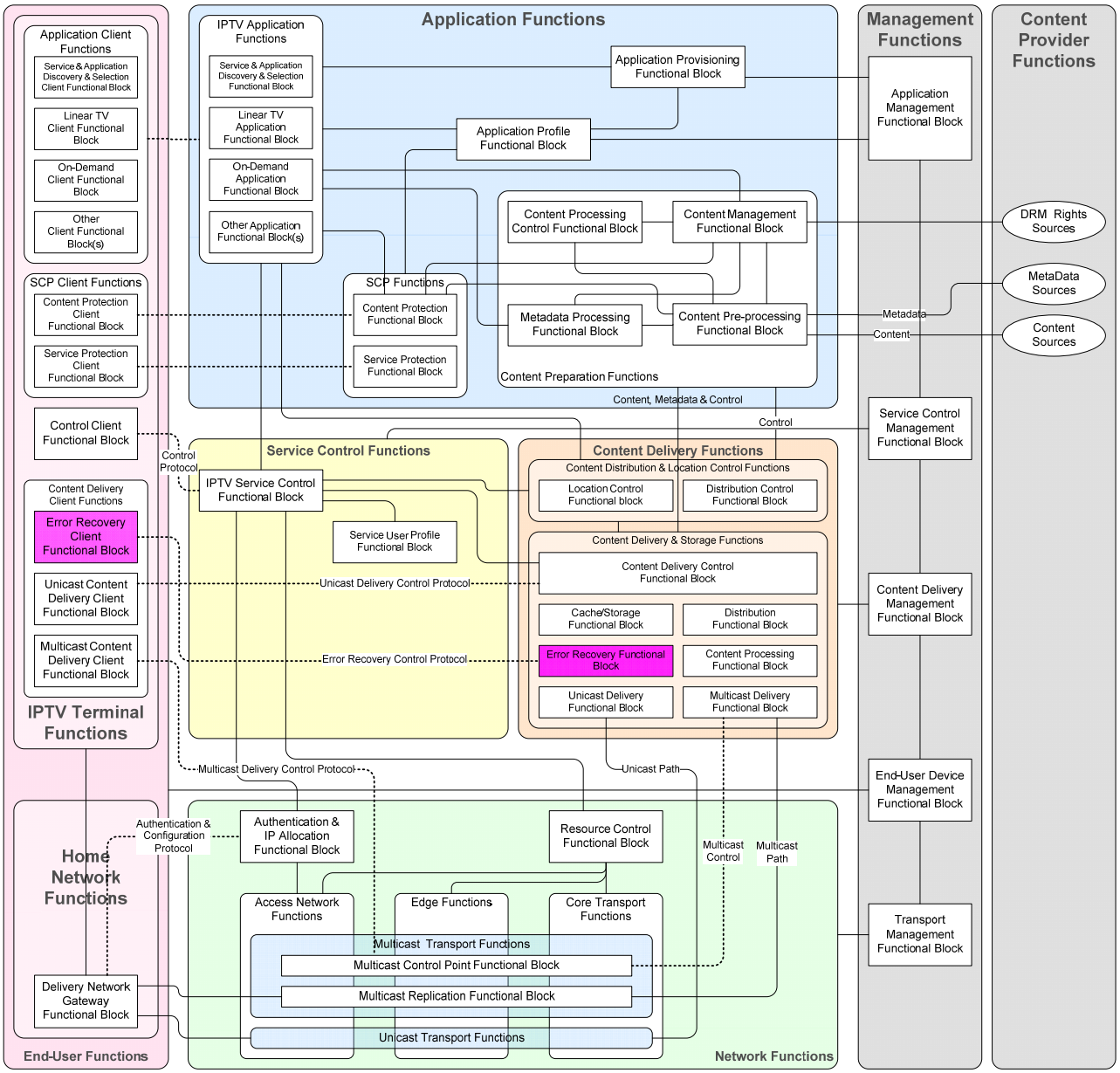

Figure 7-1 – Error recovery functions in IPTV architecture [ITU-T Y.1910]

[ITU-T Y.1910] adopts error recovery as an optional function in the content delivery functions in the IPTV architecture in case that the network functions cannot provide sufficient QoS for IPTV services, as shown in Figure 7-1. The error recovery function consists of the content delivery error recovery functional block and the error recovery client functional block. The configure/control interactions between these two functional blocks is established by an error recovery control protocol.

7.2 Content delivery error recovery functions

Figure 7-2 shows the content delivery error recovery function and error recovery client function decomposed into constituent functional blocks.

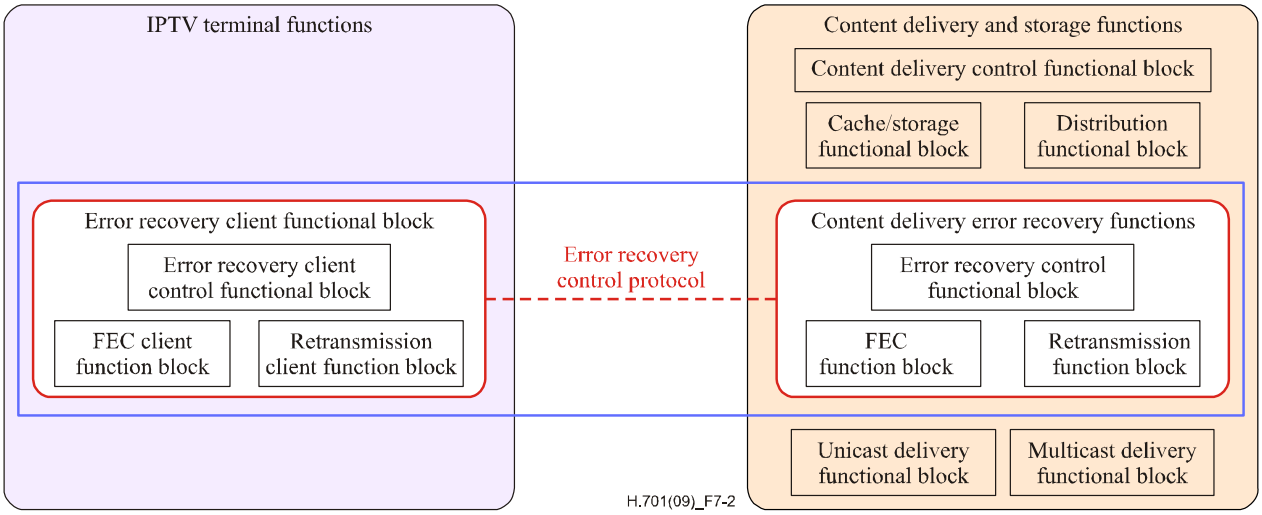

Figure 7-2 – CDER Functions

The constituent functional blocks are described in the following:

– FEC functional block: The FEC functional block generates FEC packets from the media data that are sent along with the media data to allow the receiver to correct packet losses in the media data. With this FEC information, the receivers can recover from packet losses locally at the receiver. The FEC may generate packets in layers that can be distinguished by the FEC Client function and can be individually selected using the error recovery control protocol. FEC may be used in unicast and multicast delivery.

– Retransmission functional block: The retransmission functional block retransmits lost packets to recover from packet losses on request of the retransmission client functional block through the error recovery control protocol. Retransmission may be unicast or multicast, depending on the distribution of clients reporting the errors.

– Error recovery control functional block: The error recovery control functional block controls the behaviour of the FEC functional block and the retransmission functional block. For example, it generates information such that the FEC client or the retransmission client functional block is informed on where to access redundant information, on the syntax and semantics of this information, etc. It also permits to send feedback information, if required.

– FEC client functional block: The FEC client functional block receives redundant information generated by the FEC functional block to correct packet losses in the original media data locally.

– Retransmission client functional block: The retransmission client functional block receives information generated by the retransmission functional block to correct packet losses in the original media data.

– Error recovery client control functional block: The error recovery client control functional block manages the behaviour of the FEC client functional block and retransmission client functional block. It receives configuration/control information generated by the error recovery control functional block, negotiates with the content delivery error recovery function on which CDER mechanism (FEC, retransmission or combination of the two) is available, and among those available, which is suitable for this terminal/service combination. It may also select the appropriate FEC layers.

The support of the CDER functions is not required for all networks, in particular for networks that can fulfil the desired IPTV service requirements. In case that a network cannot fulfil the packet loss requirements necessary to achieve the IPTV service requirements, the use of a content delivery error recovery solution is recommended.

If a content delivery and storage function implements CDER functions, it is required to implement at least the error recovery control function as well as one of the two functions: the FEC functional block or the retransmission functional block. The content delivery and storage function is permitted to implement both, the FEC and the retransmission functional blocks.

If an IPTV terminal error recovery client function implements an error recovery client functional block, it is required to implement at least the error recovery control client function as well as one of the two functions: the FEC client functional block or the retransmission client functional block. The IPTV terminal is permitted to implement both, the FEC and the retransmission client functional blocks.

7.3 CDER interfaces and protocols

Information generated in CDER functions relates to one or multiple media streams encapsulated in a certain protocol and packetized into IP packets.

CDER functions are permitted to be used with different services and different types of media protocols. For the transport of the repair packets, it is recommended to use the same protocol as for the media stream. Even though the error recovery packet streams are recommended to have a similar format as the original media stream, it must be ensured that the FEC packets can be differentiated from original media packets. This may be accomplished by sending the error recovery packets using different payload IDs, ports or IP addresses.

For example, in linear TV services, a service encapsulated in a MPEG-2 transport stream is distributed over RTP/UDP/IP. The media stream and the error recovery packet streams typically use similar protocols, i.e., also RTP/UDP. The error recovery packets generated in CDER functions are sent to the receiver. These packets permit to recover lost RTP media packets and the contained MPEG-2 TS packets. The receiver may differentiate original packets and FEC packets by using different payload IDs, different port numbers, or different IP addresses.

Specific realizations of CDER protocols for media streams encapsulated in a certain protocol are specified along with specific CDER functions in the annexes of this Recommendation.

7.4 CDER control functional block

The CDER control functional block is recommended to ensure that all non-preconfigured necessary information on the CDER functions and interfaces is sent to the CDER client control functional blocks and vice versa. This information includes the connection between the media stream and the error recovery packet streams. It also contains the access information of the CDER streams and provides additional information on the details of the CDER streams. The description of this set up information as well as the transport of this set up information is out of the scope of this Recommendation, but is part of [b-ITU-T H.770], clauses 10 and 11, respectively. The CDER control functions may also exchange real-time control information such as feedback information from the error recovery control client function to the error recovery control function.

8 Content delivery error recovery mechanisms for streaming

8.1 General

This clause introduces retransmission-based error recovery functions, FEC-based error recovery functions, and combinations of the two for streaming distribution of media. Streaming distribution is applied in linear TV and content-on-demand services. In most cases, the media streams are transported over the real time protocol (RTP) [IETF RFC 3550].

Retransmission and FEC are two different techniques to recover from RTP packet losses during the delivery of streaming IPTV services. The retransmission approach recovers from packet losses by

requesting retransmission from the sender or intermediate retransmission server. The FEC approach operates by adding redundant information to the data at the sender.

8.2 Retransmission

Retransmission-based CDER mechanisms use feedback messages to recover from packet losses. They require a return feedback path and one or more retransmission servers that host the retransmission functional block. On detecting a packet loss, e.g., by noting a gap in the packet sequence, a receiver requests a sender or designated repair servers to retransmit the lost packets. Retransmission may be either unicast or multicast, depending on the distribution of clients reporting the errors.

For retransmission-based CDER, it is required that feedback from receivers to senders or designated repair servers be available. A retransmission server is required to store the original data, such that retransmission requests can be served. The physical location of the retransmission servers is out of the scope of this Recommendation. For fast retransmissions, it is recommended that the retransmission server be in the proximity of the IPTV terminals. The retransmission server functionality may for example be hosted in an edge server, or it may even be hosted in IPTV terminals.

For streaming services, RTP retransmission is one recommended packet loss recovery technique for real-time applications. Retransmitted RTP packets are recommended to be sent in a separate stream from the original RTP stream. To support retransmission with RTP, the RTP protocol [IETF RFC 3550] is not sufficient. This is so because the companion protocol to the real time protocol (RTP), the real time control protocol (RTCP) as specified in [IETF RFC 3550] does not acknowledge single RTP packets but only reports statistics on packet loss and jitter. Extensions to RTCP for the audio-visual profile (AVP) that enable receivers to provide, statistically, more immediate feedback to senders, allowing for efficient feedback-based repair mechanisms (e.g., retransmission) are recommended to be used. Such extensions are recommended to provide a retransmission request of specific, lost packets, for example by sending negative acknowledgements (RTCP NACK) to a retransmission server. Furthermore, it is recommended that a single feedback packet could be used to request transmission of one or multiple lost packets. The retransmission server is recommended to provide a retransmission of the missing packets over IP unicast or alternatively via IP multicast (for multicast sessions).

Specific realizations of retransmission-based CDER protocols for media streams encapsulated in a certain protocol will be specified along with specific CDER functions in the annexes of this Recommendation.

8.3 Forward error correction

An FEC-based error recovery function generates redundant data to allow the receiver to correct packet losses. The redundant data is sent in one or multiple FEC streams. With this redundant information, the receiver can recover from packet losses locally. FEC may be used in unicast and multicast delivery.

FEC to be applied in CDER functions refers to packet erasure correction techniques. In these techniques, an amount of data is sent which is in total greater than the original media stream to be communicated, with the property that the original media stream can be reconstructed from any sufficiently large subset of the transmitted data. The original stream is thus resilient to a certain amount of loss (at most the difference between the transmitted and the original data size).

For streaming services with delay constraints, it is recommended to use systematic FEC codes. Systematic FEC codes have the property that the original data to be protected is not modified by the FEC encoding operation. If used in streaming services, it is recommended that the original media packets of the stream be sent unmodified. In addition to the unmodified original data packets, a

certain amount of additional FEC packets is sent. The FEC packets can be used to recover original media packets that have been lost between sender and receiver, without requiring any feedback from the IPTV terminal to the FEC functional block in the network.

To apply FEC to media streams, a certain configuration information is required to be available to the FEC functional block and the FEC client functional block. This information includes the information of the original media data streams to be protected, the definition of the FEC stream and the relationship between the original media stream and the FEC stream. Furthermore, each packet of the FEC stream is required to contain implicit or explicit information on which original media stream packets it protects and how it has been protected. For example, if RTP is used as the media stream protocol, then the RTP sequence number range that the FEC packet protects may be specified.

An FEC client function is recommended to use all received original media packets and FEC packets to recover lost media packets, but minimizing the buffer delay in the FEC client function.

An FEC stream is required to protect at least one media stream. However, a FEC stream may protect multiple media streams at the same time.

Furthermore, one media stream or multiple media streams may be protected by multiple FEC streams at the same time. Multiple FEC streams may be provided such that the CDER client function can distinguish and individually select FEC streams. The selection may be based on the IPTV terminal capabilities, or on some observed error conditions, or any other criteria.

If multiple FEC streams are provided, it is required that the FEC client functional block can select each of the multiple streams individually. Furthermore, if multiple FEC streams are provided, it is recommended that the FEC functional block provide an order of the FEC streams and that the FEC client functions select the streams in the order they are provided. In case of multiple ordered FEC streams, a FEC stream is referred to as a *layer*, and support of this layer means that all FEC streams with more important order are also supported.

An FEC client function is recommended to select FEC streams in an ordered way up to the layer it wants to have access to.

In multicast distribution, the FEC function block may offer multiple layers on different IP multicast addresses. The FEC client functional block may subscribe up to the layer it wants to have access to.

In unicast distribution, the FEC client functional is recommended to indicate to the FEC functional block which FEC layers are requested. The FEC functional block is recommended to only send up to the requested layer.

Specific realizations of FEC-based CDER protocols are specified along with the respective CDER functions in the annexes of this Recommendation.

8.4 Hybrid combinations of FEC with retransmissions and feedback

FEC and retransmission technologies for error recovery are not necessarily mutually exclusive technologies, but they may be used combined and complementarily. By applying such combinations, some interesting benefits may be obtained. The significance of the benefits depends, among others, on the considered service, the considered distribution mean, i.e., multicast or unicast, and/or the number of available retransmission servers. This clause provides a high-level overview of possible combinations.

For retransmission-based mechanisms when combined with an FEC repair mechanism, negative acknowledgements (NACKs) of packets may result in the transmission of FEC packets instead of original data packets. This may be beneficial especially for the case of multicast transmission as the FEC packets may serve the retransmission request of several receivers, which may have observed the loss of different data packets. Such a scheme may allow to reduce the average transmit bandwidth.

For FEC-based mechanisms, the introduction of feedback messages may be used to influence the sender strategy. For example, if receivers are aware that the sender will transmit some small amount of initial FEC data for the current source block, retransmission requests need only to be sent in case this initial FEC information is not sufficient. If the loss exceeds what can be repaired by the initial FEC data, retransmission requests can be made and in response the sender can send additional FEC data for the source block that is independent of the initial FEC data. Such a scheme may reduce the amount of necessary feedback messages and therefore may allow reducing the amount of necessary retransmission servers, when compared to conventional retransmission mechanisms. In an alternative setup, a default level of FEC protection is provided which is capable of correcting all anticipated errors (i.e., the same level of FEC protection as for an FEC-only mechanism). For each FEC source block, the receiver may send an acknowledgement packet requesting that sending of FEC data for that source block should be terminated early, because the receiver has received enough data to recover the block. Such scheme may allow reducing the average bandwidth, if compared to an FEC-only mechanism.

8.5 Usage guidelines for retransmission and FEC

The main advantage of FEC is that there is no need for a back channel to request retransmission from the sender. It is therefore very suitable for unidirectional communications, but can obviously also be used on any (bidirectional) network. FEC introduces a fixed delay due to the generation and processing of the redundant information and to the fact that data must be buffered before error recovery can take place. The delay depends, among others, on service bit rates, FEC block size, and sending arrangements.

In case of retransmission-based error recovery, since the error recovery is handled by requesting and receiving a retransmitted packet from a server with a copy of the original stream, the time needed to receive a repair packet is composed of the round trip time (RTT) between the receiver and the recovery retransmission server plus any jitter imposed in the packet repair process.

Jitter could be caused by variations in time for detecting the lost packet and for generating the repair packet due to server loads. Buffering at the receiver is needed to provide time to receive repair packets before the data stream is sent to the decoder. There are trade-offs among buffer size, latency through the buffers, server load based on the number of users on the server, and quality of the video delivery.

In terms of bandwidth consumption in case of FEC, since the redundant information should always be sent along with the original packets, it generally consumes more average bandwidth than retransmission. Since a retransmission is done on demand, the additionally required average bandwidth for error recovery can be lowered. However, note that to serve the retransmission request fast enough, a certain peak bandwidth higher than the average bandwidth needs to be reserved for retransmission. Therefore, for the case of retransmission, the bandwidth being saved compared relative to FEC may generally only be used for lower priority traffic on the shared access.

The complexity in encoding and decoding FEC data may provide some computational overhead at both the sender and receiver. Retransmission approaches do not require extra decoder computing resources because the entire lost packet is retransmitted to the receiver.

In the retransmission-based approach, an intermediate retransmission server may receive many feedback messages from multiple receivers who experience packet losses. This may lead to the phenomenon of feedback implosion: the concept of receiving many feedback messages for common errors.

To reduce the problem of feedback implosion for retransmission-based mechanisms, a careful architectural design is necessary. When retransmission is used in multicast delivery, proper attention must be paid to the ratio of clients to retransmission servers to avoid any scalability issues. A distributed retransmission approach can be introduced to resolve the issues of timeliness,

scalability, and feedback implosion. A local retransmission server placed in the vicinity of the receiver can be used to recover the losses across the access and consumer environment and a core retransmission server located near the head end can be used to recover losses in the core and common losses requested via the local retransmission server. However, such architecture may require additional network equipment to serve retransmission requests, or the function may reside in servers already present for other purposes. Due to the different architectural design, feedback implosion is not existent for FEC-based approaches.

Any content delivery error recovery scheme has a non-zero probability that a complete recovery from packet loss cannot be done. Lowering the probability for missing packets is a balance between complexity of design and quality of the received video. In case of FEC, if the packet loss exceeds the repair capabilities of the FEC scheme, recovery will not be possible. In case of retransmission, recovery may be deficient due to non-persistent automatic repeat request (ARQ) protocols or late arrival of packets.

In these unlikely cases of failure, media post-decoder remediation schemes may need to be used.

9 Content delivery error recovery for content download services

9.1 General

In content download services, large media files are distributed. File distribution can only be considered successful if the entire file is received correctly. In the case of lossy networks, this is obviously a challenging task. However, in contrast to streaming services, for download services the delay and latency requirements are significantly lower. Therefore, for media delivery generally mechanisms other than RTP-based real-time distribution are used. These alternative distribution means also enable and require alternative CDER mechanisms.

For unicast download modes, it is recommended to use TCP [IETF RFC 793] for reliable data delivery. In case of multicast delivery, the following is recommended. For multicast download using file delivery over unidirectional transport (FLUTE) [b-IETF RFC 3926], FEC [b-IETF RFC 3695], [IETF RFC 5052] and [IETF RFC 5053] is recommended as CDER mechanisms. Furthermore, multicast delivery may be supported by associated file repair procedures that are invoked if the multicast delivery of a media file is not successful.

9.2 Retransmission-based mechanism: reliable unicast download with TCP

TCP provides a reliable communication service for file delivery applications over the Internet Protocol (IP). Due to network congestion, traffic load balancing, or other unpredictable network behaviour, IP packets can be lost or delivered out of order. TCP detects these problems, requests retransmission of lost packets, rearranges out-of-order packets, and even helps minimize network congestion to reduce the occurrence of the other problems. Once the TCP receiver has finally reassembled a perfect copy of the data originally transmitted, it passes that datagram to the application.

TCP is used extensively by the most popular file delivery protocols such as HTTP or FTP. As TCP is optimized for accurate delivery rather than timely delivery, TCP sometimes incurs in relatively long delays (in the order of seconds) while waiting for out-of-order messages or retransmissions of lost messages. However, for download services these delays are irrelevant.

To guarantee reliability over unreliable networks, positive acknowledgment with retransmission is used to guarantee reliability of packet transfers. This fundamental technique requires the receiver to respond with an acknowledgment message as it receives the data. The sender keeps a record of each packet it sends, and waits for acknowledgment before sending the next packet. The sender also keeps a timer from when the packet was sent, and retransmits a packet if the timer expires.

9.3 FEC-based mechanism: reliable multicast file distribution with FLUTE and FEC

To deliver large multimedia files to many hosts, the file delivery over unidirectional transport (FLUTE) protocol is commonly used. Despite the fact that IP multicast is inherently massively scalable, this best effort service does not provide a session management functionality, congestion control or reliability. FLUTE provides these functionalities and therefore permits to distribute large objects over the asynchronous layered coding (ALC) [b-IETF RFC 3450] protocol and IP multicast without sacrificing the inherent scalability of IP multicast.

In particular, for the delivery over unreliable networks, it is recommended to use the FEC building block inherited from ALC. ALC uses the FEC building block to provide reliability. In this case, the sender generates encoding symbols based on the file to be delivered using FEC codes and sends them in packets to channels associated with the session. Receivers simply wait for enough packets to arrive in order to reliably reconstruct the object. Thus, there is no request for retransmission of individual packets from receivers that miss packets in order to assure reliable reception of a file, and the packets and their rate of transmission out of the sender can be independent of the number and the individual reception experiences of the receivers.

9.4 Retransmission-based file repair procedures

The distribution of large multimedia files using TCP or FLUTE sessions may still result in situations where the download is interrupted due to network congestion, powering off the IPTV terminal device or other reasons that lead to the interruption of the service reception. In this case, it is recommended that the IPTV terminal be able to invoke file repair procedures to restart and complete the delivery of the file. Because of the feedback request, file repair procedures can also be viewed as a retransmission-based mechanism. File repair procedures are recommended to minimize the additional load by using as much data as possible from what has already been received. This can for example be accomplished by requesting only the missing byte ranges of the file, or by requesting only the necessary FLUTE symbols to recover a file using FEC.

Annex A

FEC-based error recovery mechanisms for streaming distribution

(This annex forms an integral part of this Recommendation)

This annex provides recommendations for CDER mechanisms based on FEC for streaming distribution of FEC.

A.1 Assumptions

For the remainder of this annex, it is assumed that the original media streams to be FEC-protected are transported over a single RTP flow. Examples for media streams that fall into this category are:

– RTP-encapsulated MPEG-2 transport stream transported according to [ETSI TS 102 034], clause 7.1.1,

– RTP-encapsulated timestamped transport Streams (TTS) transported according to [ARIB STD-B24], or

– any other RTP encapsulated stream that contains media data.

A.2 Forward error correction according to [ETSI TS 102 034]

A.2.1 Overview

Annex E of [ETSI TS 102 034] specifies a FEC-based CDER mechanism, in which the IPTV data stream is MPEG-2 TS encapsulated in RTP. The specification provides the option to add FEC streams on top of any legacy RTP stream.

This FEC mechanism provides the option to generate multiple FEC streams for a single media stream. In particular, it also consists of two forward error correction codes, a simple packet-based interleaved parity code equivalent to a subset of the code defined in [SMPTE 2022-1] and Raptor codes defined in [IETF RFC 5053].

Based on this construction, FEC packets may be sent in one (or more) layers: the first layer contains packets generated by the interleaved parity code and the optional second and subsequent layers contain packets generated by the Raptor code. In particular, clause E.3 of [ETSI TS 102 034] defines the first layer based on [SMPTE 2022-1], referred to as base layer in this Recommendation. Clause E.4 of [ETSI TS 102 034] defines the subsequent layers, based on [IETF RFC 5053] referred to as enhancement layers in this Recommendation.

Receivers process only packets from the layer or layers they support. Clause E.5 of [ETSI TS 102 034] describes the decoding procedures. A receiver only supporting [SMPTE 2022-1] decodes lost media packets using packets from the base layer only. One key property of the code defined in Annex E of [ETSI TS 102 034] is that simultaneous support of multiple layers is possible and FEC packets from these multiple layers can be combined at the receiver in the decoding process. The so-called hybrid decoding procedures can make use of packets from all layers of the code. The sender is recommended to align the source blocks of the base layer and the enhancement layers.

Finally, clause E.6 of [ETSI TS 102 034] defines complete FEC protocols for multicast and unicast video.

A.2.2 Configuration information

The details of the configuration of the FEC in the IPTV architecture are outside the scope of this Recommendation. All or some of the parameters may be pre-configured, or configuration methods

as specified in [b-ITU-T H.770] may be used. It is required that the FEC client functional block has access to the following service discovery information.

Table A.1 is related to the setup of each FEC stream.

Table A.1 – Setup parameters for FEC streams

Attribute	Explanation	Comments
`FECStreamMulticastAddress`	IP multicast address for this FEC stream.	*Optional.* If the IP multicast address is omitted, then the FEC stream is assumed to be on the same multicast address as the original data.
`FECStreamMulticastPort`	IP multicast port to access the FEC stream.	*Mandatory*, if FECStreamMulticastAddress is given. Otherwise, then the FEC stream is assumed to be on the same multicast port as the original data.
`FECStreamMulticastSource`	IP multicast source address for FEC stream.	*Optional*. If the IP multicast source address is omitted, then the FEC stream is assumed to be on the same multicast address as the original data.
`FECStreamMaximumBitrate`	Specifies the maximum bit rate (in kbit/s) of this FEC stream.	*Optional*. If not provided, then the receiver cannot make any assumptions on the maximum bit rate.
`FECStreamPayloadTypeNumber`	RTP payload type number for this FEC stream.	*Optional.* It shall be 96 (the 1st dynamic payload number) for the base layer FEC stream if SMPTE-2022 compatibility is required.

The order of the FEC stream elements determines the order of the layers. However, to be more specific, the attribute may for example explicitly contain the layer it refers to, e.g., BaseLayer or EnhancementLayer (see for example [b-ITU-T H.770]).

Furthermore, if FEC streams are defined, the information in Table A.2 may be available.

Table A.2 – Additional information for FEC streams

Attribute	Explanation	Comments
`MaximumPacketNumber InBlock`	Maximum number of stream source packets that will occur between the first packet of a source block (which is included) and the last packet for that source block (source or repair).	*Optional*.
`MaximumFECBlockDuration`	Maximum transmission duration of any FEC block (source and FEC packets).	*Optional*.

Table A.2 – Additional information for FEC streams

Attribute	Explanation	Comments
`FECObjectTransmission Information`	FEC object transmission information for the FEC enhancement layer. This information contains the maximum source block length and the encoding symbol size (see [ETSI TS 102 034], clause E.4.3.1.1.1).	*Mandatory*, if at least one FEC enhancement layer element is included.

The FEC functional block is required to generate the FEC streams such that they conform to the configuration, i.e., the FEC streams are sent on adequate IP addresses, ports and use the adequate signalling.

An IPTV terminal and in particular the FEC client functional block that supports receiving FEC streams is required to acquire the adequate configuration information.

A.2.3 Syntax and configuration protocols

To configure FEC streams with some of the parameters as specified in clause A.2.2, a minimum set of attributes are required to be available at the FEC client functional block, either by pre-configuration or by the use of methods defined in [b-ITU-T H.770].

A.3 Recommended FEC for linear TV services

For a CDER mechanism based on FEC for linear TV services, the provisions in Annex E of [ETSI TS 102 034] are recommended.

The FEC protocol comprises two layers of FEC protection:

– 1-D interleaved parity FEC (referred to as base layer); and

– Raptor FEC (referred to as enhancement layer).

For some background information, refer to clause A.2.

If the error recovery functional block supports FEC for linear TV services, then the generation of FEC protection of the MPEG-2 transport stream shall be required to be provided according to clause E.3 of [ETSI TS 102 034]. This corresponds to the support of the base layer.

If the error recovery functional block supports enhanced FEC for linear TV services, then the base layer FEC and the generation of FEC streams according to clause E.4 of [ETSI TS 102 034] shall be supported. This corresponds to the support of the enhancement layer. If the enhancement layer is applied, the FEC scheme defined in clause E.4.3.2 of [ETSI TS 102 034] shall be used.

An IPTV terminal and in particular the FEC client functional block that supports receiving the FEC base layer packets only is required to perform any FEC decoding to meet the minimum decoder requirements according to clause E.5.1.1 of [ETSI TS 102 034].

An IPTV terminal, and in particular the FEC client functional block that supports receiving and decoding both the base and enhancement-layer FEC, is required to perform decoding to meet the enhanced decoder requirements according to clause E.5.1.2 of [ETSI TS 102 034].

– The relation of this FEC mechanism to the QoS classes in [ITU-T Y.1541], especially recommended parameters settings for different QoS classes and different services is discussed in clause III.1.2, specifically in Table III.1. Consumer television quality can be achieved using the standard Y.1541 QoS Classes 0 and 1 together with this FEC mechanism, low to modest overhead, and the enhanced decoder according to clause E.5.1.2 of [ETSI TS 102 034].

For configuration information and protocols to setup FEC streams for linear TV services in different IPTV architectures, refer to clause A.2.

For more detailed performance results and recommended parameter settings, please refer to clause III.1.

A.4 Recommended FEC for content-on-demand services

For a CDER mechanism based on FEC, Annex E of [ETSI TS 102 034] is recommended. The same principles as for linear TV services apply also for content-on-demand services. For details, refer to clause A.3.

For configuration information and protocols to setup of FEC streams for content-on-demand services in different IPTV architectures, refer to clause A.2.

Annex B

Retransmission-based error recovery mechanisms for streaming delivery

(This annex forms an integral part of this Recommendation)

For further study.

Annex C

Content delivery error recovery for content download services

(This annex forms an integral part of this Recommendation)

For further study.

Appendix I

Evaluation of CDER mechanisms for IPTV services

(This appendix does not form an integral part of this Recommendation)

I.1 Introduction

When proposing a technical mechanism, the relevant performance evaluation results produced under different impairment conditions should be provided. The evaluation results should be able to evaluate the following characteristics of a CDER mechanism:

– A CDER mechanism's actual recovery ability, given certain impairment conditions. The definition of ability could be how well a CDER mechanism can actually improve an IPTV service quality, compared to that before recovery, under a certain impairment condition.

– The cost of CDER mechanisms, provided the actual recovery ability of the mechanism is reached under certain impairment conditions. The cost may include the bandwidth overhead caused by a CDER mechanism, the memory required by implementing a CDER mechanism in IPTV equipment(s), the processing requirement by implementing a CDER mechanism in IPTV equipment(s), etc.

– Comparison to existing CDER mechanisms already specified in this Recommendation.

– Other characteristics.

These characteristics should be taken into account when approving additional mechanisms in CDER work. And for those mechanisms that have been recommended as optional CDER functions for IPTV services, these characteristics may help estimate which one is appropriate to work under a certain set of circumstances.

To be comparable and fair for evaluation of CDER mechanisms characteristics, the agreement may be generally reached as guidelines at least in terms of:

1) The objective impairment conditions. For "Content Delivery Error" notion, the objective impairments usually refer to those errors occurring during content transport, which can be reflected by various QoS parameters including packet loss pattern, packet loss rate, end-to-end packet transfer delay, delay variation, etc.

2) The content to be handled by the CDER mechanism. For multimedia services, the content may refer to a specific video/audio sequence to be tested. The content of other services, if necessary, need to be discussed as well.

3) The quality estimation method/model for IPTV services. The CDER's ultimate objective is to improve the quality of IPTV services. Therefore, the estimation of service quality may be a measure for performance of CDER mechanisms. For example, by comparing the actual service quality after using a CDER mechanism to that before recovering, the mechanism's actual gain on service quality under a certain impairment condition can be rated and thus, is comparable to other CDER mechanisms. A trusted quality estimation method/model is the basis of such measurement. For multimedia services, QoE estimation and corresponding method/model may be a reasonable choice. ITU-T SG 12 is also working on this subject and its results may be considered for CDER mechanism evaluation. For other services, if necessary, the quality estimation method/model needs to be discussed as well.

4) The target quality requirements for IPTV services. With these requirement sets, we can assess how well the actual service quality, after being recovered by a CDER mechanism, meets the target requirements. For multimedia services, QoE is a subjective notion perceived by end users. It is usually collectively determined by subjective factors (human component) and objective factors (QoS). However, conducting the unanimous comprehensive target QoE requirements, with the contributions due to subjective factors

being taken into account, is very difficult for the moment. [b-ITU-T G.1080] recommends some objective transport layer parameters for satisfactory QoE for various encoded standard definition video materials, which for the time being avoid the issue of subjective factors. The CDER mechanisms for video and audio content delivery may take these objective parameters as the provisional target quality requirement. And for CDER mechanisms for services other than multimedia, the objective target requirements also may be a reasonable choice.

5) The cost metrics and corresponding estimation method/tools.

I.2 Evaluation criteria for multicast linear TV

[ITU-T Y.1541] describes a number of QoS classes for IP networks. Specifically, Table 1 of [ITU-T Y.1541] defines six IP network QoS classes and the respective network performance objectives. In addition, Table 3 of [ITU-T Y.1541] proposes two additional provisional QoS classes mainly for the purpose of supporting sufficient QoS for digital television transmission. The difference to those in Table 1 of [ITU-T Y.1541] is that these values need not to be met by networks until they are revised (up or down) based on operational experience.

Appendix VIII of [ITU-T Y.1541] considers digital television transmission on IP networks and concludes that, by the use of specific application layer error recovery mechanisms, digital television quality requirements can be met using the new provisional QoS classes.

However, as stated in this Recommendation, additional experience on content delivery error recovery may allow revising the considerations on QoS classes 6 and 7. Error recovery mechanisms being considered in the ITU-T IPTV architecture are related to the QoS classes in [ITU-T Y.1541] and appropriate parameter settings should be applied.

For this relation, suitable performance metrics shall be applied. Table VIII.1 of [ITU-T Y.1541] proposes some loss/error considerations. DVB and the ATIS IIF [ATIS-0800005] propose to measure the performance of mechanisms in terms of the *mean time between artefacts* (MTBA) in the video playout. Both have used a quality target of four hours MTBA, which also fits into the loss ratio recommendations of Table VIII.1 of [ITU-T Y.1541].

Y.1541 QoS classes specify an upper bound on the packet loss ratio (Class 0-4: 10^{-3}, provisional classes 6 and 7: 10^{-5}), but do not specify packet loss patterns. However, suitable parameter settings to meet the requirements may be affected not only by the loss rate, but also by loss patterns. In order to present application layer reliability performance with different loss patterns, different packet loss models may be considered, e.g., independent random loss model or burst loss models.

[ITU-T Y.1541] also specifies limits on the IP packet transfer delay (IPTD), IP packet delay variation (IPDV), and IP packet error rate (IPER). The effect of these parameters in relation to the error recovery mechanism is also of interest.

The performance and parameter settings for a certain mechanism may also depend on the service bit rate. This effect should also be considered when relating mechanisms to QoS classes.

I.3 Evaluation criteria for content-on-demand services

For further study.

I.4 Evaluation criteria for content download services

For further study.

Appendix II

Use cases for content delivery error recovery

(This appendix does not form an integral part of this Recommendation)

II.1 Linear TV service

Figure II.1 illustrates general high-level error recovery flow applied in linear TV loose model [ITU-T Y.1910].

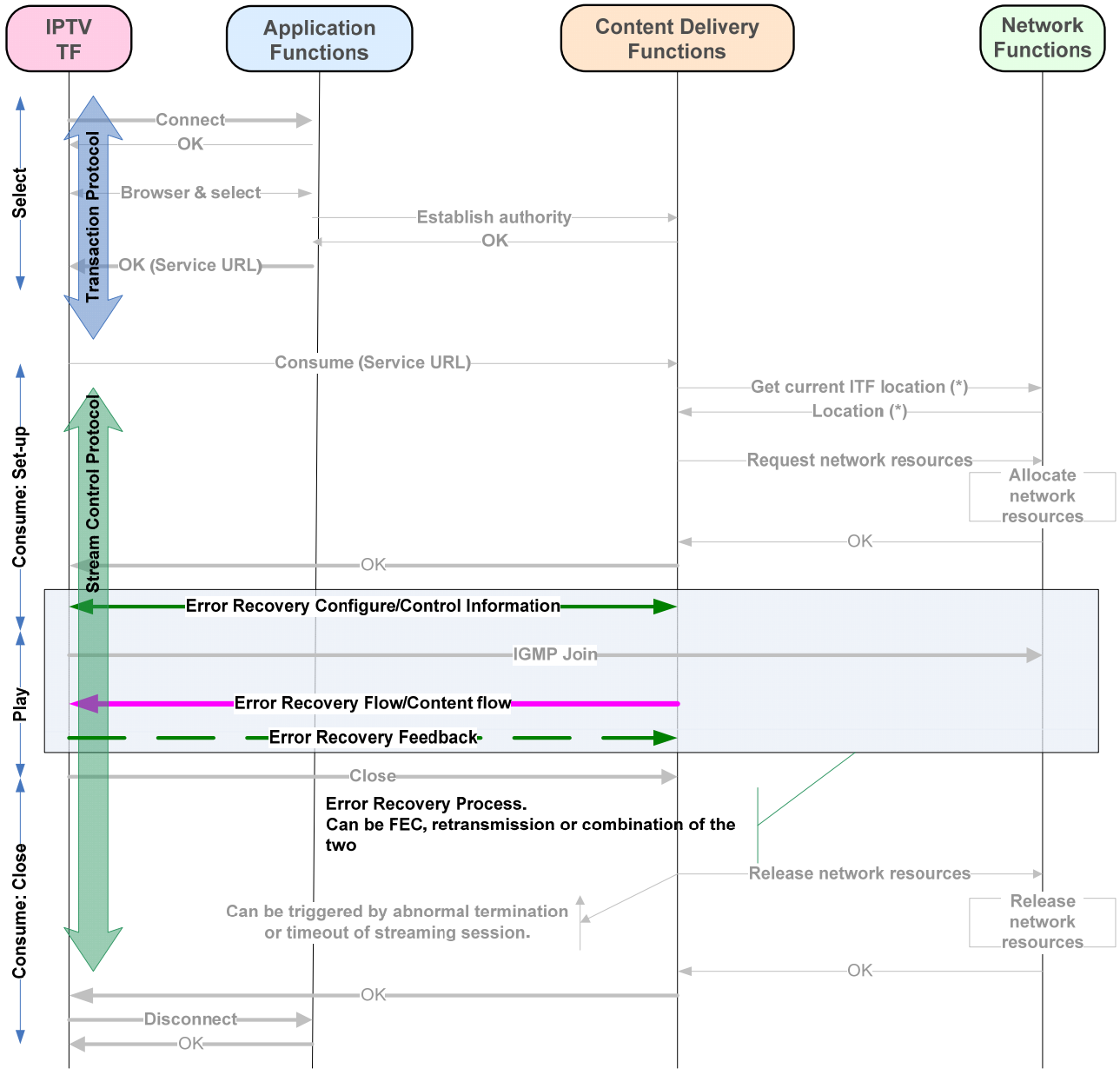

Figure II.1 – Error recovery flow for linear TV service

The description of the flow is as follows:

1) During setup, the error recovery configure/control information is exchanged between IPTV terminal functions (IPTV TF) and content delivery error recovery functions to prepare for the subsequent error recovery actions.

2) Content delivery functions send error recovery flow along with content flow to IPTV TF right after joining the channel (as step "IGMP Join" indicates) to carry out error recovery in case that content flow is damaged.

3) IPTV TF may send error recovery feedback to error recovery functions depending on the CDER mechanisms it prefers to use.

In the above steps, the error recovery configure/control information, the error recovery feedback and the information exchange and error recovery flow need to be standardized.

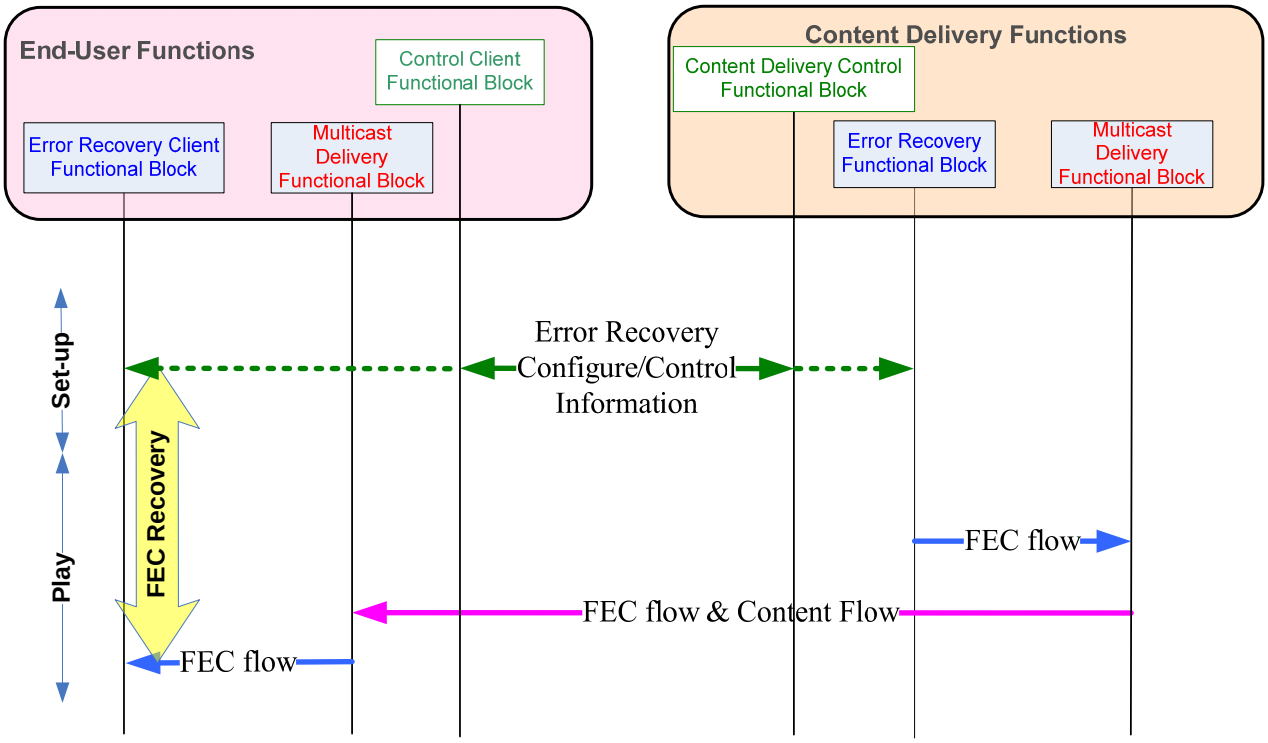

Figure II.2 – FEC recovery flow for linear TV service

FEC is suitable for linear TV service, where a feedback channel may not exist or may exist but has the risk of feedback implosion if feedbacks are frequently used. An example of FEC error recovery flow is depicted in Figure II.2. The feedback channel may be used during the Setup phase only, to exchange FEC codec information (which should be standardized) and after that, the feedback channel is no longer needed.

A retransmission error recovery function may also be used for linear TV service for the purpose of reducing channel change delay, as shown in Figure II.3:

1) When a user changes from the current channel to a new channel, it may trigger the procedure of leaving the current channel and simultaneously send a retransmission request with the necessary information.

2) Upon receiving a retransmission request, the error recovery functional block responds immediately with the proper flow of the new channel cached for recovery purposes.

3) The error recovery client functional block receives the recovery flow; delivers the flow to, for example, the application client function and immediately plays it out without waiting for the end user to join the new channel and for the arrival of the new content flow.

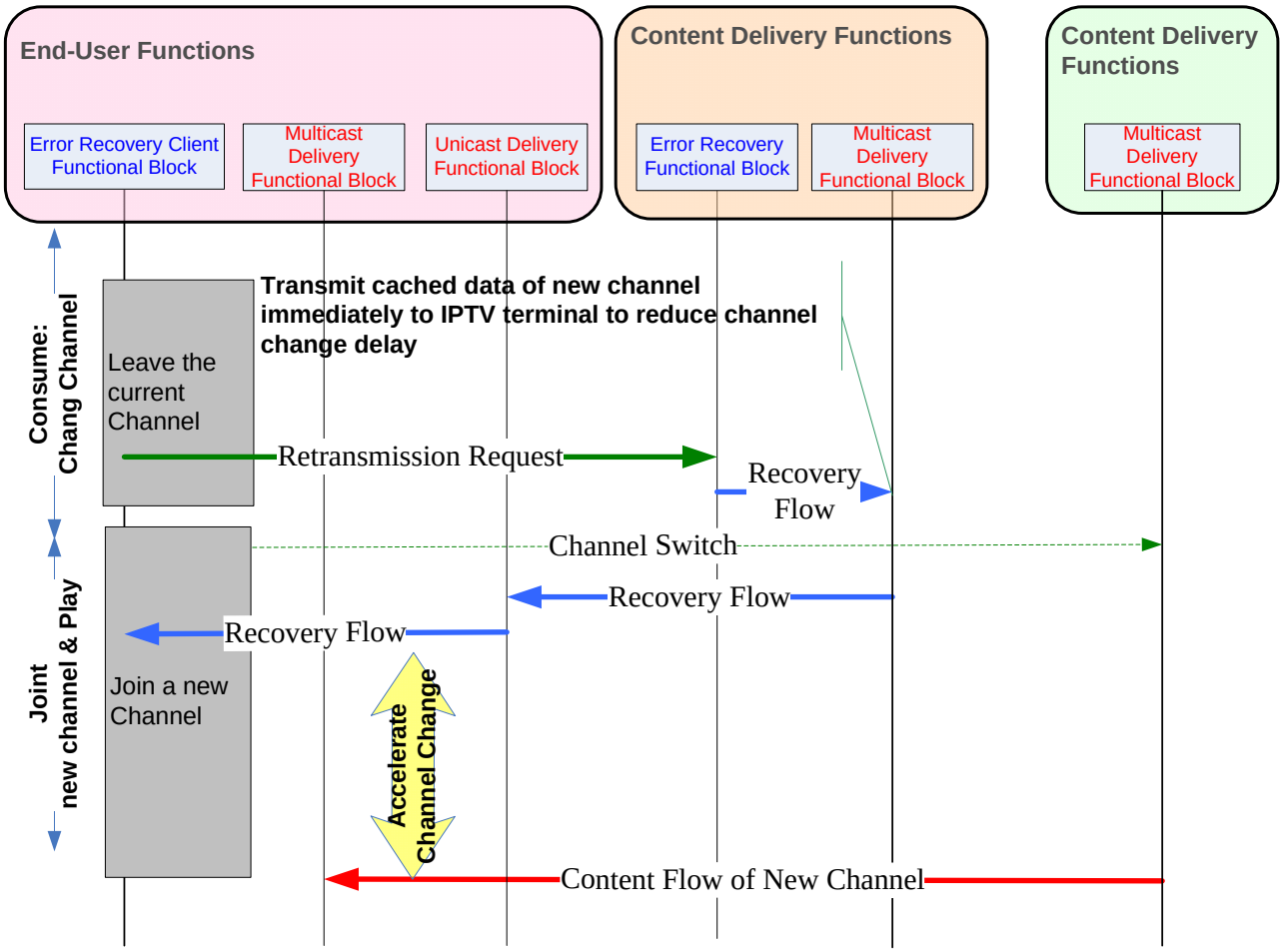

Figure II.3 – Retransmission for fast channel switch flow for linear TV service

II.2 Tightly coupled content-on-demand service

Figure II.4 illustrates general high-level error recovery flow applied in tightly coupled content-on-demand service [ITU-T Y.1910]. The flow is similar to steps shown in Figure II.1.

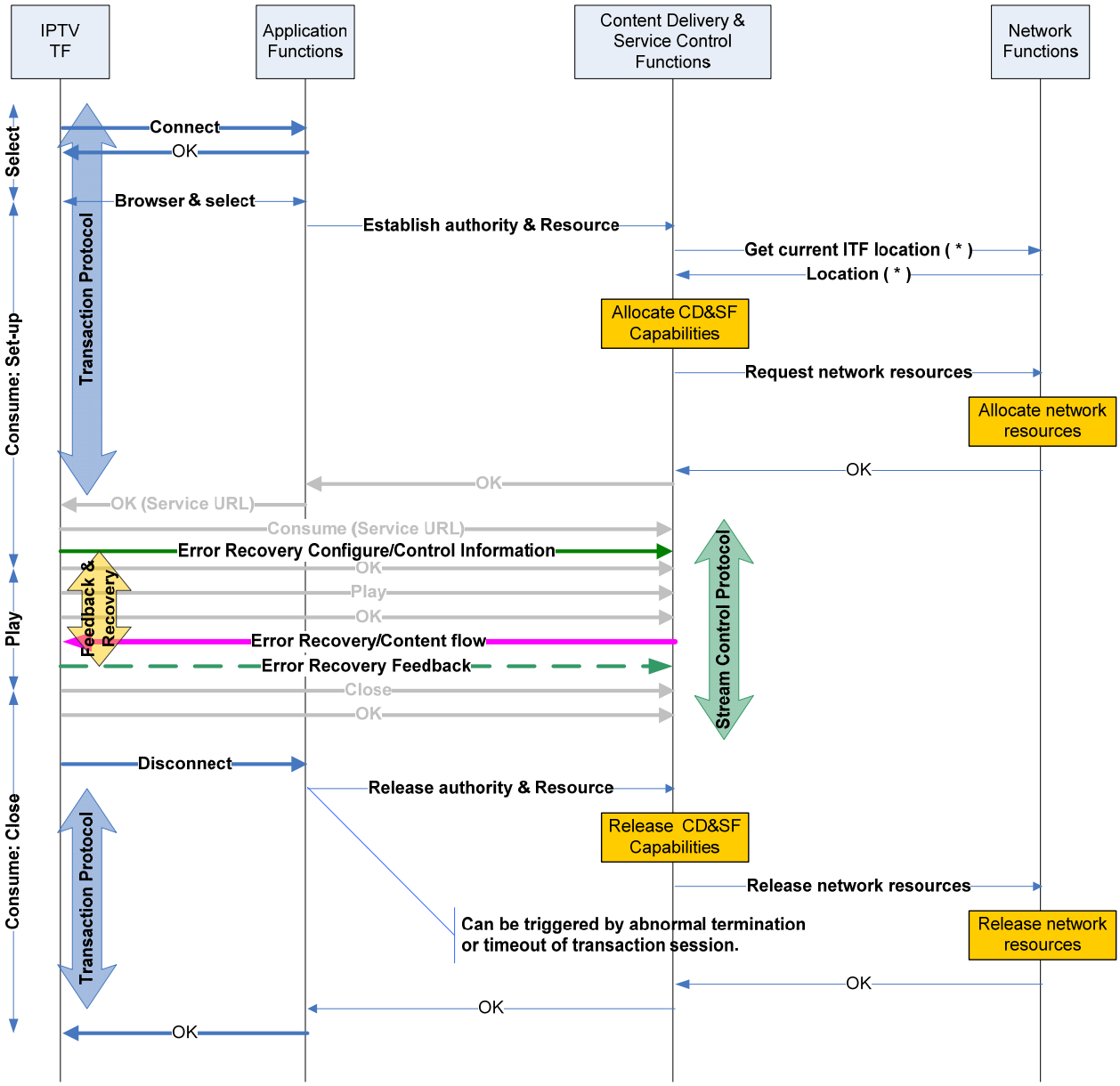

Figure II.4 – Error recovery flow for tightly coupled content-on-demand service

Applying retransmission for tightly coupled content-on-demand service may result in a lower risk of feedback implosion than for IPTV linear TV because tightly coupled content-on-demand service flow is based on unicast delivery and a packet loss would only affect one on-demand flow, probably resulting in one retransmission feedback. Retransmission may, however, not be the exclusive CDER mechanism. FEC may also be a viable choice. Sometimes, the combination of the two in a complementary manner may be better than having only one. Figure II.5 shows an example of such a combination:

1) The error recovery functional block sends FEC control information to the error recovery client functional block.

2) The error recovery functional block generates FEC flows to the error recovery client functional block for recovering the content flow.

3) If the damaged content flow (for example, a long burst loss) cannot be recovered by the received FEC flow, the error recovery client functional block may send a retransmission feedback, requesting additional FEC recovery information rather than all the lost content.

This may reduce the amount of feedback messages, the traffic overhead due to retransmission along the content forwarding path and the amount of retransmission servers, as compared with conventional retransmission mechanisms [ITU-T Y.1910].

4) The error recovery functional block sends additional FEC flows to recover from the pending errors.

In this case, the retransmission feedback information plays a key role and may be standardized.

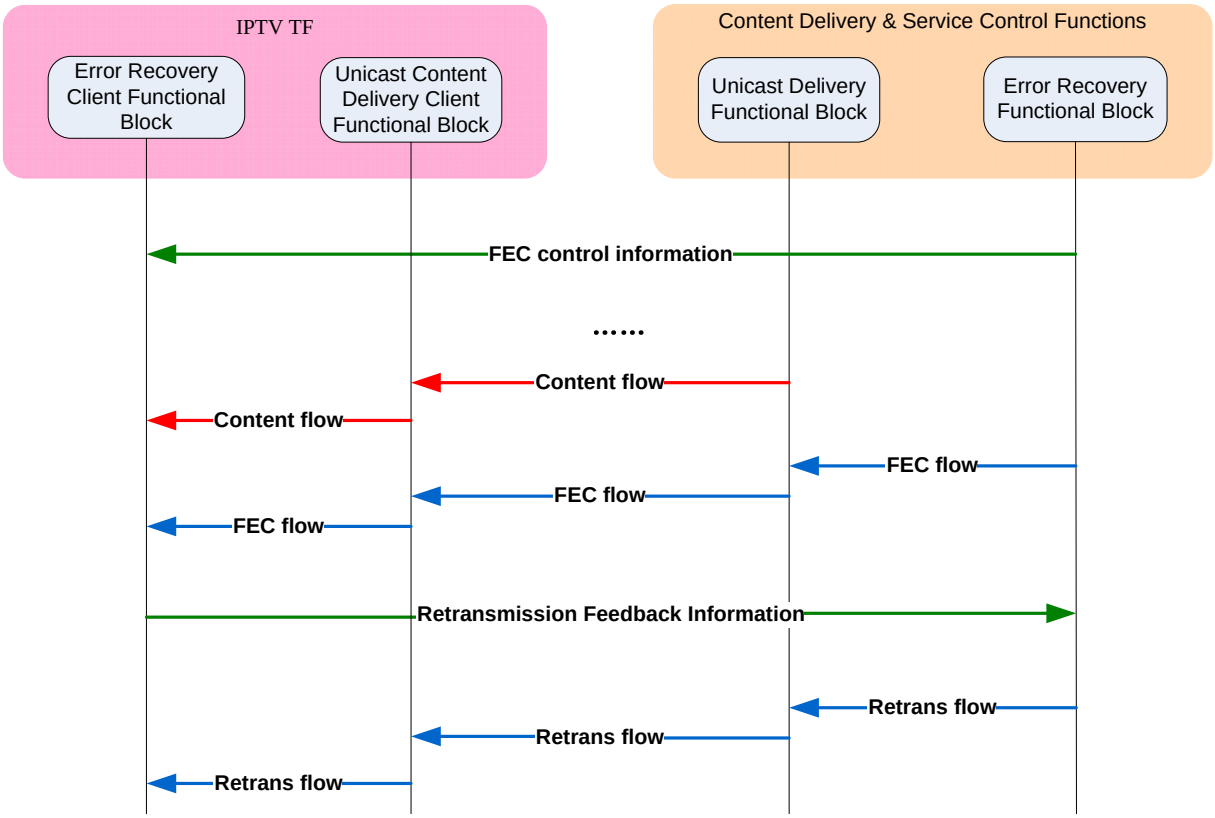

Figure II.5 – Error recovery flow for tightly coupled content-on-demand

II.3 Place-shifting service

An IPTV service in which subscribers can access (pause, rewind, fast forward, etc.) IPTV contents without placing limitations. That is, the end-user sees his or her subscribed IPTV contents anywhere. The place-shifting basically addresses requirements of end-users who move from one place to another. This service assumes that the end-user's terminal device can be a mobile phone [ITU-T Y.Sup5].

In the place-shifting scenario, the channel condition may experience significant changes. The new condition after a change may last for a "long period" during which an adaptive FEC (AFEC) is possible to be applied to achieve more efficient bandwidth utilization as well as better service quality. That is, the end user may send feedback with the necessary information for the AFEC encoder to adjust, for example, its FEC redundancy based on the channel condition.

Depending on who is taking care of redistributing the IPTV traffic, two types of place-shifting services can be defined: subscriber-based place-shifting and network-based place-shifting service [ITU-T Y.Sup5]. An example of applying AFEC in network-based place-shifting is illustrated in Figure II.6.

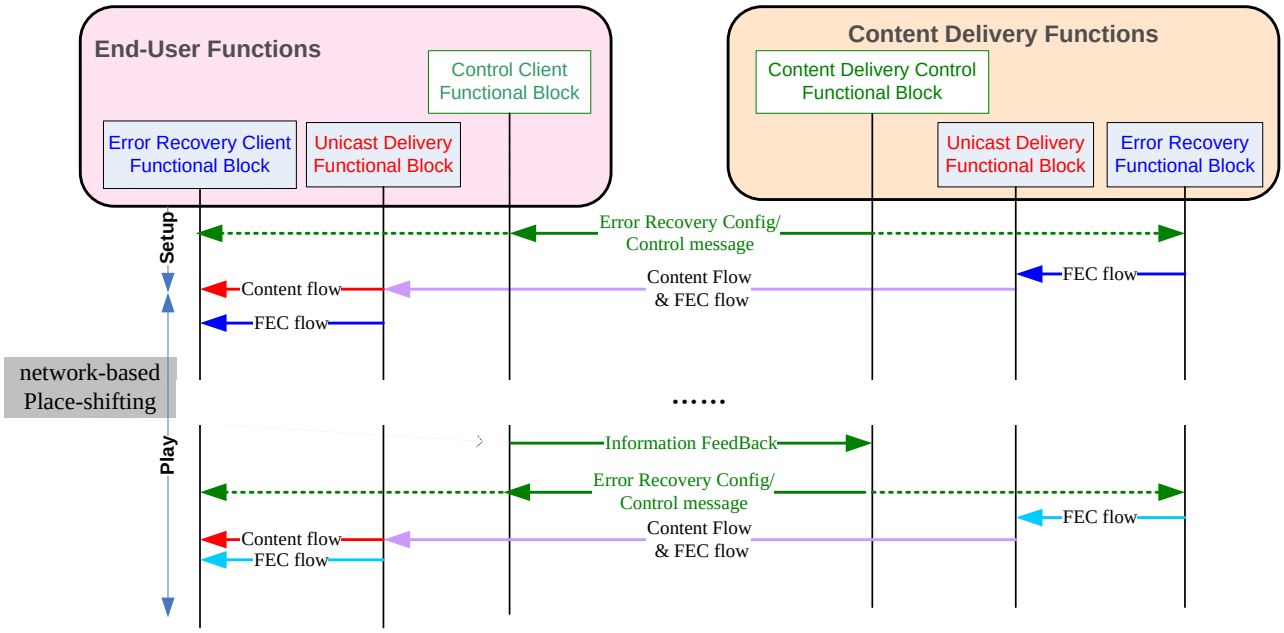

Figure II.6 – AFEC recovery flow for place-shifting service

In network-based place-shifting, the IPTV service provider sends the IPTV traffic to the moved-to place [ITU-T Y.Sup5].

The description of the flow is as follows:

1) During setup, the content delivery control functional block delivers FEC configure/control information to the error recovery functional block and the end user.

2) After setup, the error recovery functional block generates a FEC flow and sends the flow to the error recovery client functional block for error recovery.

3) During the play period, the control client functional block may periodically send feedback with the necessary information (including packet loss, delay, power, etc.) to reflect the current channel condition.

4) In case that a channel condition change is detected by using the information feedback, the content delivery control functional block may change the configure/control information in the error recovery functional block, resulting in a new FEC flow that adapts to the new channel condition.

In this example, the error recovery configure/control information and information feedback may be standardized.

Appendix III

Evaluation results and recommended parameter settings for error recovery mechanisms

(This appendix does not form an integral part of this Recommendation)

III.1 FEC according to [ETSI TS 102 034]

III.1.1 Parameters

The DVB-IPTV FEC code according to Annex E of [ETSI TS 102 034], and as recommended in Annex A of this Recommendation, is a block erasure code, meaning that it applies erasure protection to blocks of packets of the original stream. The code is basically fully determined by two parameters:

1) The size of each of these blocks is usually expressed in terms of the *protection period*, which is the interval of time taken to send the packets of a block.

2) For each block, the FEC code provides a number of additional "repair" packets that can then be sent immediately after the original packets of the block (the "source" packets). The number of FEC packets sent for each block is another parameter of the code, usually expressed as the *FEC overhead* – the ratio of FEC packets to source packets.

There is a trade-off between these two parameters of the code, protection period and FEC overhead: in general, if the protection period is increased, then the FEC overhead required will decrease and vice versa, all other factors remaining equal. The 'other factors' are the packet loss rate and pattern and the quality target. This feature allows service operators to trade efficiency vs. channel switching times.

Note that the channel switching times correlate to the latency added by the FEC. However, there are also many other things which contribute to channel change time, for example IGMP latency, the need to wait for an IDR frame, RTP buffering, video decoding buffer, etc. These factors have already led to the development of a number of channel change acceleration techniques. A good survey is available in [b-ISMA TD 00096] and some of the techniques described there are already deployed. These techniques can be used to mitigate the additional delay caused by the use of FEC, making it practical to consider relatively long protection periods without significantly impacting channel change time.

III.1.2 Relation to network performance parameters

By some representative investigations, the FEC mechanism is related to the different network parameters.

For the IP packet loss ratio (IPLR), two models are considered:

– An independent random loss model assumes that each packet is lost with independent probability. Although in practice IP packet losses are not independent, this channel provides some kind of baseline from which other cases can be assessed.

– A short burst loss model considers burst outages of fixed duration, occurring at independent random intervals (Poisson distribution). This is intended to simulate a DSL access line subject to electrical impulse noise. In this case, each impulse causes an outage equal in length to the DSL interleaving depth, which we take to be 8 ms.

For a streaming service such as IPTV, the absolute IPTD is only important insofar as it affects channel change time and so need not be considered further here for the simulations. The IPTD is additive to the latency introduced by the FEC mechanism.

The IP packet delay variation (IPDV) may affect the performance if it results in packets arriving too late to be rendered to the user. The use of FEC mitigates this problem, since as long as each packet arrives before the appointed time to decode its FEC block, there will be no problem. Packets at the beginning of a block could arrive extremely late and still arrive in time. On the other hand if packets at the end of the block arrive too late then they cannot be used, but these packets may be considered lost and recovered by the FEC.

In general, as long as the IPDV is in the range of the protection period, or the protection period is greater than the IPDV as defined in [ITU-T Y.1541], then for QoS classes 0-4, the IPDV does not have any influence on the performance. Therefore, for QoS classes 0 and 1 and protection periods of at least 50 ms, the IPDV does not influence the performance. Furthermore, it should be noted that with the addition of modest IPDV requirements, then Y.1541 classes 2-4 would also be suitable for IPTV applications, especially if the protection period is relaxed.

It is expected that erroneous packets are detected by the UDP checksum and therefore are converted to packet losses. As the IPER for QoS classes 0-4 is a magnitude less than the IPLR, this effect is negligible.

III.1.3 Recommended parameter settings

The recommended parameter settings for the DVB-IPTV FEC mechanism for QoS classes 0-4 are provided in the following. The influence of IPTD, IPDV, and IPER has been discussed previously. Therefore, the benchmarking and recommended parameter settings are provided for IPLR of 10^{-3} for two channel models, namely, independent random packet losses (random) and the short burst model (burst) with 8 ms independent burst losses.

Results are obtained for standard definition (2.1 Mbit/s) and high definition (9.4 Mbit/s) video streams. The streams are assumed to be CBR MPEG-2 transport streams (TS) encapsulated within RTP packets with 7 MPEG-2 TS packets per RTP packet, to achieve a MTBA of at least 4 hours. Table III.1 shows the required overhead for different bit rates, different channel models at IPLR 10^{-3}, and different protection periods.

Table III.1 – Required overhead for DVB-IPTV FEC for different bit rates, different channel models at IPLR of 10e-3, and different protection periods

Protection period	Random, 2.1 Mbit/s	Random, 9.4 Mbit/s	Burst, 2.1 Mbit/s	Burst, 9.4 Mbit/s
100 ms	16%	5%	20%	12%
200 ms	8%	3.5%	10%	6%
400 ms	5%	3%	7%	4%
600 ms	4%	2%	4%	2.5%
800 ms	3.5%	2%	4%	2.5%
1000 ms	3%	2%	4%	2%

The results show that with a modest additional delay and a low-to-modest FEC overhead, a consumer television quality target of a MTBA of 4 hours can be achieved using the standard Y.1541 QoS classes 0 and 1. The provisional QoS classes 6 and 7 are not required by the use of the DVB-IPTV FEC mechanism. Note that, in all cases, the enhanced decoder, according to clause E.5.1.2 of [ETSI TS 102 034], which was applied as the minimum decoder, could not fulfil the service requirements.

In addition, note that if the FEC source block structure is chosen with proper alignment, for example with the random access points of the video stream, then the FEC latency can be absorbed into the video decoding buffer latency. This would mean that the protection period is in general not additive to the end-to-end latency, but generally lower. With encoding parameters and alignment strategies, even no difference in the latency may be observed when FEC is used and when it is not.

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