Internet Engineering Task Force **RMT WG**
INTERNET-DRAFT
draft-ietf-rmt-bb-fec-05.ps

M.Luby/Digital Fountain
L.Vicisano/Cisco
J.Gemmell/Microsoft
L.Rizzo/ACIRI and Univ. Pisa
M.Handley/ACIRI
J. Crowcroft/UCL

21 November 2001
Expires: May 2002

RMT BB Forward Error Correction Codes

This document is an Internet-Draft and is in full conformance with all provisions of Section 10 of RFC2026.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF), its areas, and its working groups. Note that other groups may also distribute working documents as Internet-Drafts.

Internet-Drafts are valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as a "work in progress".

The list of current Internet-Drafts can be accessed at http://www.ietf.org/ietf/1id-abstracts.txt

To view the list Internet-Draft Shadow Directories, see http://www.ietf.org/shadow.html.

This document is a product of the IETF RMT WG. Comments should be addressed to the authors, or the WG's mailing list at rmt@isi.edu.

Abstract

This memo describes the abstract packet formats and IANA registration procedures for use of Forward Error Correction (FEC) codes within the context of reliable IP multicast transport. This memo should be read in conjunction with and uses the terminology of the companion memo [1], which describes the use of Forward Error Correction (FEC) codes within the context of reliable IP multicast transport and provides an introduction to some commonly used FEC codes.

1. FEC Abstract Packet Fields and Out-of-Band Information

This section describes FEC information that is either to be sent out-of-band or in packets. The FEC information is associated with transmission of data about a particular object. There are three classes of packets that may contain FEC information: data packets, session-control packets and feedback packets. They generally contain different kinds of FEC information. Note that some protocols may not use session-control or feedback packets.

Data packets may sometimes serve as session-control packets as well; both data and session-control packets generally travel downstream from the sender towards receivers and are sent to a multicast channel or to a specific receiver using unicast.

As a general rule, feedback packets travel upstream from receivers to the sender. Sometimes, however, they might be sent to a multicast channel or to another receiver or to some intermediate node or neighboring router that provides recovery services.

This document specifies the FEC information that must be carried in data packets and the other FEC information that must be communicated either out-of-band or in data packets. This document does not specify out-of-band methods nor does it specify the way out-of-band FEC information is associated with FEC information carried in data packets. These methods must be specified in a complete protocol instantiation that uses the FEC building block. FEC information is classified as follows:

1) FEC Encoding ID

   Identifies the FEC encoder being used and allows receivers to select the appropriate FEC decoder. The value of the FEC Encoding ID MUST be the same for all transmission of data related to a particular object, but MAY vary across different transmissions of data about different objects, even if transmitted to the same set of multicast channels and/or using a single upper-layer session. The FEC encoding ID is subject to IANA registration.

2) FEC Encoding Name

   Provides a more specific identification of the FEC encoder being used for an Under-Specified FEC scheme. This value is not used for Fully-Specified FEC schemes. (See Section 1.1 for the definition of Under-Specified and Fully-Specified FEC schemes.) The FEC encoding name is scoped by the FEC encoding ID, and is subject to IANA registration.

3) FEC payload ID

   Identifies the encoding symbol(s) in the payload of the packet. The fields in the FEC Payload ID depend on the encoder being used (e.g. in Block and Expandable FEC codes this may be the combination of block number and encoding symbol ID).

4) FEC Object Transmission Information

   This is information regarding the encoding of a specific object needed by the FEC decoder (e.g. for Block and Expandable FEC codes this may be the combination of the source block lengths and the object length). This might also include specific parameters of the FEC encoder.

The FEC Encoding ID, FEC Encoding Name (for Under-Specified FEC schemes) and the FEC Object Transmission Information can be sent to a receiver within the data packet headers, within session control packets, or by some other means. In any case, the means for communicating this to a receiver is out of the scope of this document. The FEC Payload ID MUST be included in the data packet header fields, as it provides a description of the data contained in the packet.

Within the context of FEC repair schemes, feedback packets are (optionally) used to request FEC retransmission. The FEC-related information present in feedback packets usually contains an FEC Block ID that defines the block that is being repaired, and the number of Repair Symbols requested. Although this is the most common case, variants are possible in which the receivers provide more specific information about the Repair Symbols requested (e.g. an index range or a list of symbols accepted). It is also possible to include multiple of these requests in a single feedback packet.

This document does not provide any detail about feedback schemes used in combination with FEC nor the format of FEC information in feedback packets. If feedback packets are used in a complete protocol instantiation, these details must be provided in the protocol instantiation specification.

1.1. FEC Encoding ID and FEC Encoding Name

The FEC Encoding ID is a numeric index that identifies a specific FEC scheme OR a class of encoding schemes that share the same FEC Payload ID format.

An FEC scheme is a Fully-Specified FEC scheme if the encoding scheme is formally and fully specified, in a way that independent implementors can implement both encoder and decoder from a specification that is an IETF RFC. The FEC Encoding ID uniquely identifies a Fully-Specified FEC scheme. Companion documents of this specification may specify Fully-Specified FEC schemes and associate them with FEC Encoding ID values. These documents MUST also specify a format for the FEC Payload ID and specify the information in the FEC Object Transmission Information.

It is possible that a FEC scheme cannot be a Fully-Specified FEC scheme, because a specification is simply not available or that a party exists that owns the encoding scheme and is not willing to disclose the algorithm or specification. We refer to such an FEC encoding schemes as an Under-Specified FEC scheme. The following holds for an Under-Specified FEC scheme:

- The format of the FEC Payload ID and the specific information in the FEC Object Transmission Information MUST be defined for the Under-Specified FEC scheme.
- A value for the FEC Encoding ID MUST be reserved and associated with the format of the FEC Payload ID and the specific information in the FEC Object Transmission Information. An already reserved FEC Encoding ID value MUST be reused if it is associated with the same format of FEC Payload ID and the same information in the FEC Object Transmission Information as the ones needed for the new Under-Specified FEC scheme.
- A value for the FEC Encoding Name MUST be reserved.

An Under-specified FEC scheme is fully identified by the tuple (FEC Encoding ID, FEC Encoding Name). The tuple MUST identify a single scheme that has at least one implementation. The party that owns this tuple MUST be able to provide information on how to obtain the Under-Specified FEC scheme identified by the tuple, e.g. a pointer to a publicly available reference-implementation or the name and contacts of a company that sells it, either separately or embedded in another product.

Different Under-Specified FEC schemes that share the same FEC Encoding ID -- but have different FEC Encoding Names -- also share the same format of FEC Payload ID and specify the same information in the FEC Object Transmission Information.

This specification reserves the range 0-127 for the values of FEC Encoding IDs for Fully-Specified FEC schemes and the range 128-255 for the values of Under-Specified FEC schemes.

1.2. FEC Payload ID and FEC Object Transmission Information

A document that specifies an FEC scheme and reserves a value of FEC Encoding ID MUST define a packet format for the FEC Payload ID and specify the information in the FEC Object Transmission Information according to the needs of the encoding scheme. This applies to documents that reserve values of FEC Encoding IDs for both Fully-Specified and Under-Specified FEC schemes.

The packet format definition for the FEC Payload ID MUST specify the meaning and layout of the fields down to the level of specific bits. The FEC Payload ID MUST have a length that is a multiple of a 4-byte word. This requirement facilitates the alignment of packet fields in protocol instantiations.

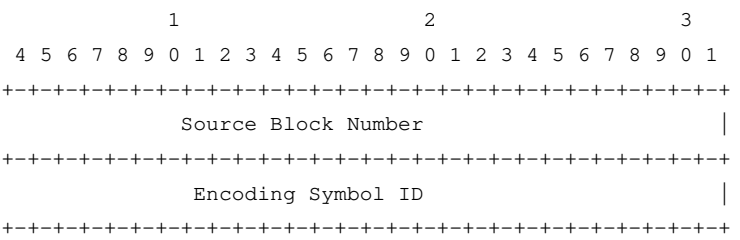
2. Preassigned FEC Encoding IDs

This section specifies the FEC Encoding ID and the associated FEC Payload ID format and the specific information in the FEC Object Transmission Information for a number of known Under-Specified FEC schemes. Under-specified FEC schemes that use the same FEC Payload ID format and specific information in the FEC Object Transmission Information as for one of the FEC Encoding IDs specified in this section MUST use the corresponding FEC Encoding ID. Other FEC Encoding IDs may be specified for other Under-Specified FEC schemes in companion documents.

2.1. Small Block, Large Block and Expandable FEC Codes

This subsection reserves the FEC Encoding ID value 128 for the Under-Specified FEC schemes described in [1] that are called Small Block FEC codes, Large Block FEC codes and Expandable FEC codes.

The FEC Payload ID is composed of a Source Block Number and an Encoding Symbol ID structured as follows:



The Source Block Number idenfities from which source block of the object the encoding symbol(s) in the payload are generated. These blocks are numbered consecutively from 0 to N-1, where N is the number of source blocks in the object.

The Encoding Symbol ID identifies which specific encoding symbol(s) generated from the source block are carried in the packet payload. The exact details of the correspondence between Encoding Symbol IDs and the encoding symbol(s) in the packet payload are dependent on the particular encoding algorithm used as identified by the Fec Encoding ID and by the FEC

Encoding Name, and these details may be proprietary.

The FEC Object Transmission Information has the following specific information:

- o The total length of the object in bytes.
- o The number of source blocks that the object is partitioned into, and the length of each source block in bytes.

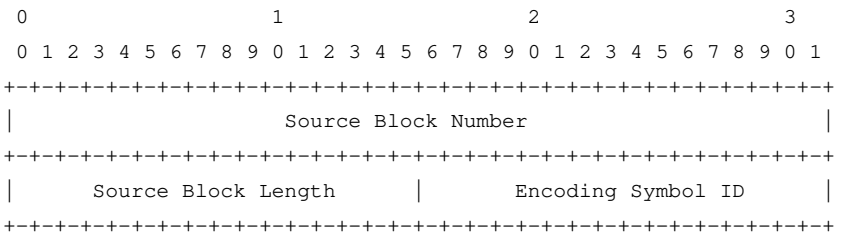
How this out of band information is communicated is outside the scope of this document. As an example the source block lengths may be derived by a fixed algorithm from the object length. As another example, it may be that all source blocks are the same length and this is what is passed out of band to the receiver. As a third example, it could be that the full sized source block length is provided and this is the length used for all but the last source block, which is calculated based on the full source block length and the object length.

2.2. Small Block Systematic FEC Codes

This subsection reserves the FEC Encoding ID value 129 for the Under-Specified FEC schemes described in [1] that are called Small Block Systematic FEC codes. For Small Block Systematic FEC codes, each source block is of length at most 65536 source symbols.

Although these codes can generally be accommodated by the FEC Encoding ID described in Section 2.1, a specific FEC Encoding ID is defined for Small Block Systematic FEC codes to allow more flexibility and to retain header compactness. The small source block length and small expansion factor that often characterize systematic codes may require that the data source changes frequently the source block length. To allow the dynamic variation of the source block length and to communicate it to the receivers with low overhead, the block length is included in the FEC Payload ID.

The FEC Payload ID is composed of the Source Block Number, Source Block Length and the Encoding Symbol ID:



The Source Block Number idenfities from which source block of the object the encoding symbol(s) in the payload are generated. These blocks are numbered consecutively from 0 to N-1, where N is the number of source blocks in the object.

The Source Block Length is the length in units of source symbols of the source block identified by the Source Block Number.

The Encoding Symbol ID identifies which specific encoding symbol(s) generated from the source block are carried in the packet payload. Each encoding symbol is either an original source symbol or a redundant symbol generated by the encoder. The exact details of the correspondence between Encoding Symbol IDs and the encoding symbol(s) in the packet payload are dependent on the particular encoding algorithm used as identified by the Fec Encoding ID and by the FEC Encoding Name, and these details may be proprietary.

The FEC Object Transmission Information has the following specific information:

- The total length of the object in bytes.
- The maximum number of encoding symbols that can be generated for any source block. This field is provided for example to allow receivers to preallocate buffer space that is suitable for decoding to recover any source block.
- For each source block, the length in bytes of encoding symbols for the source block.

How this out of band information is communicated is outside the scope of this document. As an example the length in bytes of encoding symbols for each source block may be the same for all source blocks. As another example, the encoding symbol length may be the same for all source blocks of a given object and this length is communicated for each object. As a third example, it may be that there is a threshold value I, and for all source blocks consisting of less than I source symbols, the encoding symbol length is one fixed number of bytes, but for all source blocks consisting of I or more source symbols, the encoding symbol length is a different fixed number of bytes.

Note that each encoding symbol, i.e., each source symbol and redundant symbol, must be the same length for a given source block, and this implies that each source block length is a multiple of its encoding symbol length. If the original source block length is not a multiple of the encodin symbol length, it is up to the sending application to appropriately pad the original source block to form the source block to be encoded, and to communicate this padding to the receiving application. The form of this padding, if used, and how it is communicated to the receiving application, is out of the scope of this document, and must be handled at the application level.

3. IANA Considerations

Values of FEC Encoding IDs and FEC Encoding Names are subject to IANA registration. FEC Encoding IDs and FEC Encoding Names are hierarchical: FEC Encoding IDs scope ranges of FEC Encoding Names. Only FEC Encoding IDs that correspond to Under-Specified FEC schemes scope a corresponding set of FEC Encoding Names.

The FEC Encoding ID is a numeric non-negative index. In this document, the range of values for FEC Encoding IDs is 0 and 255. Values from 0 to 127 are reserved for Fully-Specified FEC schemes, as described in more detail in Section 1.1. The assignment of a FEC Encoding ID in this range can only be granted if the requestor can provide such a specification published as an IETF RFC, as described in more detail in Section 1.1. Values from 128 to 255 are reserved for Under-Specified FEC schemes, as described in more detail in Section 1.1. This specification already assigns the values 128 and 129, as described in Section 2.

Values of FEC Encoding IDs can only be assigned if the required format for the FEC Payload ID and the specific information in the FEC Object Transmission Information are specified in an IETF

RFC.

Each FEC Encoding ID assigned to an Under-Specified FEC scheme scopes an independent range of FEC Encoding Names (i.e. the same value of FEC Encoding Name can be reused for different FEC Encoding IDs). An FEC Encoding Name is a numeric non-negative index.

Under the scope of a FEC Encoding ID, FEC Encoding Names are assigned on a First Come First Served base to requestors that are able to provide point of contact information and a pointer to publicly accessible documentation describing the Under-Specified FEC scheme and ways to obtain it (e.g. a pointer to a publicly available reference-implementation or the name and contacts of a company that sells it, either separately or embedded in another product). The requestor is responsible for keeping this information up to date.

4. Acknowledgments

Brian Adamson contributed to this document by shaping Section 2.2 and providing general feedback. We also wish to thank Vincent Roca for his extensive comments and Justin Chapweske for his comments.

5. References

[1] Luby, M., Vicisano, Gemmell, J., L., Rizzo, L., Handley, M., Crowcroft, J., "The use of Forward Error Correction in Reliable Multicast", Internet draft draft-ietf-rmt-info-fec-01.txt, October 2001.

6. Authors' Addresses

Michael Luby
luby@digitalfountain.com
Digital Fountain, Inc.
39141 Civic Center Drive
Suite 300
Fremont, CA 94538

Lorenzo Vicisano
lorenzo@cisco.com
cisco Systems, Inc.
170 West Tasman Dr.,
San Jose, CA, USA, 95134

Jim Gemmell
jgemmell@microsoft.com
Microsoft Research
301 Howard St., #830
San Francisco, CA, USA, 94105

Luigi Rizzo
luigi@iet.unipi.it

ACIRI, 1947 Center St., Berkeley CA 94704
and
Dip. di Ing. dell'Informazione
Universita' di Pisa
via Diotisalvi 2, 56126 Pisa, Italy

Mark Handley
mjh@aciri.org
ACIRI
1947 Center St.
Berkeley CA, USA, 94704

Jon Crowcroft
J.Crowcroft@cs.ucl.ac.uk
Department of Computer Science
University College London
Gower Street,
London WC1E 6BT, UK

7. Full Copyright Statement

Copyright (C) The Internet Society (2001). All Rights Reserved.

This document and translations of it may be copied and furnished to others, and derivative works that comment on or otherwise explain it or assist in its implementation may be prepared, copied, published and distributed, in whole or in part, without restriction of any kind, provided that the above copyright notice and this paragraph are included on all such copies and derivative works. However, this document itself may not be modified in any way, such as by removing the copyright notice or references to the Internet Society or other Internet organizations, except as needed for the purpose of developing Internet standards in which case the procedures for copyrights defined in the Internet languages other than English.

The limited permissions granted above are perpetual and will not be revoked by the Internet Society or its successors or assigns.

This document and the information contained herein is provided on an "AS IS" basis and THE INTERNET SOCIETY AND THE INTERNET ENGINEERING TASK FORCE DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY WARRANTY THAT THE USE OF THE INFORMATION HEREIN WILL NOT INFRINGE ANY RIGHTS OR ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE."