MAYAH Communications Application Note 31

Using Forward Error Correction

General description

Not all IP based connections are within trusted and well-managed networks. Many times – especially when using public networks - like the Internet - IP packets may be lost due to different causes, such as:

- routers discarding damaged packages (e.g. invalid checksum)
- an overload situation that causes a router to discard packages
- different packages of the same stream are routed differently – which may cause high latency and subsequently package loss.

Forward Error Correction (FEC) provides the possibility of error detection and/or correction by adding redundant data streams. Thereby retransmission or corruption of data can often be avoided at the cost of higher bandwidth needs and increased delay.

The FEC algorithm used by MAYAH is described in the “Pro-MPEG Code of Practice #3 release (www.pro-mpeg.org) based on RFC 2733 (www.ietf.org/rfc/rfc2733.txt).

Opposed to other FEC schemes used for e.g. satellite transmissions this algorithm does not correct single bits inside an IP packet, but attempts to recreate the entire lost IP packet. This is essential for the use in IP based networks, since due to the nature of these networks a transport problem always leads to a complete loss of one or several successive packets (burst loss).

Technical description

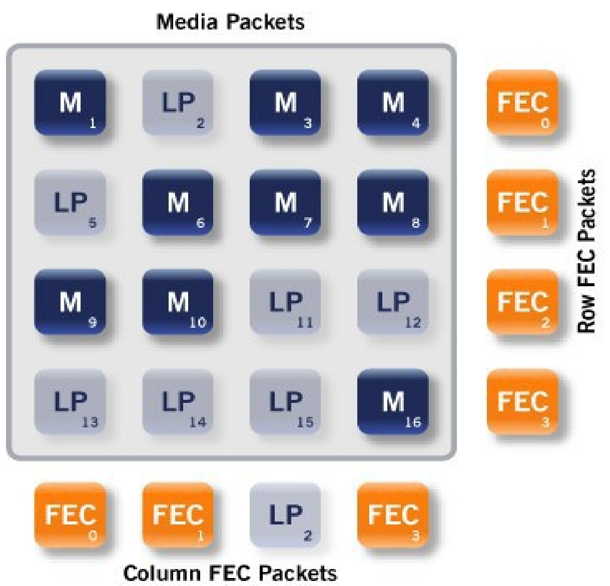
FEC generates additional packets using matrixes. Every FEC matrix has got **C**olumns and **R**ows to create additional packets, but with the following restrictions:

C x R <= 100

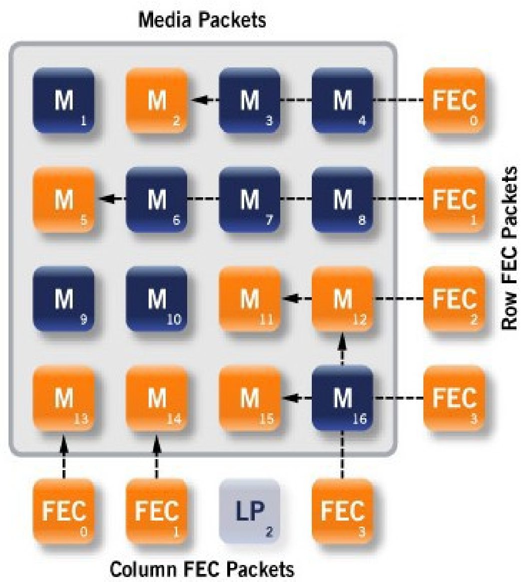
1 <= C <= 20

1 <= R <= 20

FEC packets are generated from RTP packets by a XOR (exclusive or) operation. Each FEC packet corresponds to one row or column.
The FEC packets are transmitted on dedicated ports in separate streams. There is always a stream for column FEC packets (2 ports above media port; usually port 5006), optional also row FEC packets can be sent (4 ports above media port; usually port 5008).



[Lost Packets at a RTP transmission using a FEC (4,4) matrix]



[Recreation of lost packets in a FEC (4,4) Matrix]

As you can see in the example above all lost RTP media packets could be rebuilt.

Generally all matrix sizes are possible. However, MAYAH has chosen to offer presets for FEC parameters for all typical scenarios. These are described in the diagram below.

						Latency[ms]			
Preset name	**C**	**R**	**Mode**	**Overhead**	**Buffer size [bytes]**	**3Mbps**	**10Mbps**	**100Mbps**	**Recovery**
lowestdelay	4	2	C	50%	10656	28,42	8,52	0,85	4
lowdelay	5	5	C	20%	33300	88,8	26,64	2,66	5
middledelay	10	4	C	25%	53280	142,08	42,62	4,26	10
lowbitrate	5	20	C	5%	133200	355,2	106,56	10,66	5
highsecurity	20	5	CR	25%	133200	355,2[1]	106,56[1]	10,66[1]	20+[2]

[FEC Parameters presets]

[1] Due to the nature of the decoding scheme for CR mode the actual latency will be significantly higher than the theoretical.

[2] Due to the nature of the decoding scheme for CR mode the potential number of packets that can be recovered is much higher and depending on the pattern of which packets are lost.

C, R
Number of columns and rows

Mode
C: column FEC only
CR: column and row FEC

Overhead
Overhead introduced by FEC
Example: C=4, R=2 -> matrix size = 8 packets -> 4 column FEC packets generated and transmitted per matrix equals 50%.

Buffer size
In order to perform the FEC operation C x R packets have to be retained in a buffer. The above table presumes that one media packet has a size of 1316 bytes. A FEC packet has the size of a media packet plus a special FEC header of 16 bytes: 1316bytes + 16 bytes = 1332 bytes. A matrix size of 4 x 2 = 8 corresponds thus to a buffer of 8 x 1332 = 10656 bytes.

Latency
This shows what a given buffer size corresponds to at a certain line speed (3Mbps, 10Mbps, 100Mbps). (10656bytes x 8 = 85248 bits / 3 Mbps = 0,02842s = 28,42ms)

N.B.: This is just the theoretical minimum latency. Encoding time, decoding time and decoding buffer are not evaluated. Especially in CR mode with certain patterns of packet loss the latency will be significantly higher.

Recovery
The maximum number of IP-Packets that can be recovered. In CR mode this value is determined by the pattern of which packets are lost.

Audio delay

RTP packet time

A RTP stream contains a time stamp. This time stamp could be used to calculate the audio time for a RTP packet.

Example: 24ms for a **MPEG audio** frame with 48kHz in one RTP packet.
36ms for a **MPEG audio** frame with 32kHz in one RTP packet.
10ms for a **OPUS** audio packet.
4ms for a **PCM**, **aptX** or **EaptX** audio packet.

FEC time

FEC time is calculated through the matrix size multiplied with the RTP packet time.

Audio delay of MAYAH devices will be automatically set to the FEC time if FEC is enabled and detected.

FEC time will be used to hold a constant audio delay and give FEC the possibility to correct failed packets during this time.

Examples for 48kHz:

Algorithm	**Frame [s]**	**RTP [s]**	**Sample rate [Hz]**	**FEC:**	**special**	**Lowest**	**Low**	**Middle**	**Low bit rate**	**High Security**
			48000	Rows:	5	1	1	1	1	5
				Columns:	5	4	5	10	5	20
AAC(HE)	0,043	0,043			1,067	0,171	0,213	0,427	0,213	4,267
AAC(MPEG2, MPEG4)	0,021	0,021			0,533	0,085	0,107	0,213	0,107	2,133
G.711, G.722, G.729	0,020	0,020			0,500	0,080	0,100	0,200	0,100	2,000
AAC(DRM)	0,020	0,020			0,500	0,080	0,100	0,200	0,100	2,000
MPEG Layer 2	0,024	0,024			0,600	0,096	0,120	0,240	0,120	2,400
MPEG Layer 3	0,024	0,024			0,600	0,096	0,120	0,240	0,120	2,400
AAC(LD)	0,010	0,010			0,250	0,040	0,050	0,100	0,050	1,000
OPUS	0,010	0,010			0,250	0,040	0,050	0,100	0,050	1,000
aptX, EaptX	0,001	0,004			0,100	0,016	0,020	0,040	0,020	0,400
Linear	0,001	0,004			0,100	0,016	0,020	0,040	0,020	0,400
									FEC Delay [s]	

NTP decoder synchronization

Activated NTP decoder synchronization will use the audio delay for time synchronization.

How to use FEC on MAYAH devices

FEC can currently be used with any RTP connection and is enabled via direct command or via web remote.

with Direct Commands

The standard way of using FEC is via the com_fecmode command.

com_fecmode <parameter>
Parameter: [no, lowestdelay, lowdelay, middledelay, lowbitrate, highsecurity, ?]

This sets the default FEC mode for following connect commands. If used with the question mark parameter it queries the current status of FEC operation.

Also, the com_connect command can be extended by " FECcolumnsXrows CR", where columns and rows correspond to the desired numbers of columns and rows. Please note, that the restrictions described in Chapter 2 apply.
The parameter CR indicates a FEC with two FEC streams (one for column and one for row FEC packets). Alternatively C can be used to operate in column only FEC mode with one FEC stream.

Please note that sending FEC has to be enabled separately on each subcodec of a device - while receiving and decoding is done automatically. So if you want to use FEC on a bidirectional link for both directions each connection has to be enabled individually.

Using FEC on a SIP connection requires the configuration of “Receiver FEC modes” to introduce the SIP server/proxy to allocate the corresponding routes.

with Web remote