Considerations on FEC Code

Fumio Dadio - Sumitomo Electric

Contributors and Supporters

Toshihiko Okamura - NEC

Yoshikuni Miyata - Mitsubishi Electric

Introduction

- FEC framing has been approved as baseline on last meeting, but a FEC code is not defined yet
- To add about 1dB optical gain to gain of standard FEC RS(255,239), enhanced FEC is expected
- The purpose of this presentation is to list and compare candidate FEC codes

Parameters to Compare FEC Codes

- the FEC codes have been analyzed based on the following parameters
  - **FEC overhead**
  - **Input BER of FEC Decoder**
  - **Latency**
  - **Size of FEC circuit**
  - **Bit error characteristics**
    - **Random error tolerance, Burst error tolerance**
  - **Lost synchronization of upstream burst**

Definition of Overhead

- Overhead (FEC Code)
  - **Overhead of FEC code before FEC frame mapping**

    e.g. RS(255,223)： 32 bytes /255 bytes = 0.125
- Overhead (FEC Frame)
  - **Overhead after FEC frame mapping**

    e.g RS(255,223)： 4 blocks / 31 blocks = 0.129
- Overhead (uniform load)、Overhead(1 busy ONU)
  - **FEC overhead on upstream burst using the FEC frame**
  - **“FEC_overhead_Ver4.xls” distributed in 802.3av e-mail reflector is used to calculate the overhead. the number of ONU and the grant cycle time are changed to 32 and 0.5ms.**

Comparison of FEC Codes (Codeword length is less than 1K bytes)

FEC Code	Codeword length (bytes)	Overhead (FEC Code) (%)	Overhead (FEC Frame) (%)	U/S Overhead (Uniform Load) (%)	U/S Overhead (1 busy ONU) (%)	Electrical Coding Gain (dB) @10^{-12}	Input BER of Decoder	Estimated Latency (us)	Estimated Circuit Size of Encoder	Estimated Circuit Size of Decoder	Burst Error Tolerance (bit)
RS(255,239)	255	6.3	6.5	7.34	7.56	5.9	1.8E-4	2	1 (*1)	10	57
RS(255,223)	255	12.5	12,9	13.53	13.69	7.2	1.1E-3	2	1.5 – 2	20	121
RS(511,463)	575	9.4	9.86	11.33	12.35	7.2	1.1E-3	4	2.5	40	208
RS(255,235)x3 +Hamming(128,120) (2 iteration)	816	13.6	14.0	16.01	17.55	7.2	1.1E-3	8	2?	25	73?
BCH(4083,3705)	511	9.3	9.5	10.83	11.69	7.79	2.1E-3	3.5	3	35	32
RS(511,447)	575	12.5	12.86	14.27	15.23	7.8	2.1E-3	4	3.5 – 4	40 – 55	280
BCH(1944,1690)	243	13.1	13.33	13.93	14.06	7.84	2.1E-3	2.4	2	30	23
RS(816,712)	1020	12.7	13.49	15.98	18.06	7.9	2.3E-3	6.5	7	70	511

(*1) It is assumed that the encoder size of RS(255,239) for 10Gbps is about 20Kgates

Comparison of FEC Codes (codeword length is more than 1K bytes)

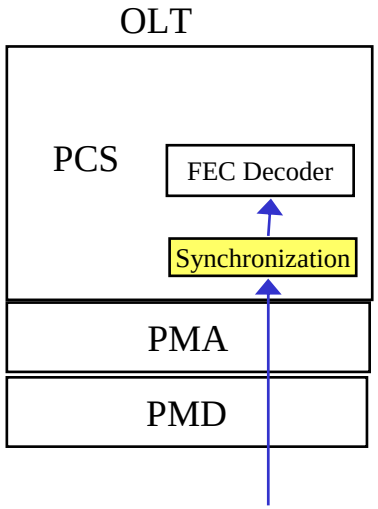
FEC Code	Codeword length (Kbytes)	Overhead (FEC Code) (%)	Overhead (FEC Frame) (%)	Overhead (Uniform Load) (%)	Overhead (1 Busy ONU) (%)	Electrical Coding Gain (dBm) @10^{-12}	Input BER of Decoder	Estimated Latency (us)	Estimated Circuit Size of Encoder	Estimated Circuit size of Decoder	Burst Error Tolerance (bit)
G.975.1 RS(2720, 2550)	3	6.25	6.37	14.6	22.8	7.3	1.2E-3	20	11	110	1009
G.975.1 RS(1023, 1007) + BCH(2047, 1952) concatenated	16	5.9	6.0	NA	NA	7.9	2.3E-3	30	?	?	
RS(255, 239)x15 + Hamming(128,120) concatenated (3 iteration)	4	12.1	12.3	22.4	32.3	8.2	3.1E-3	30	1.5	40	953
RS(252,236) + BCH(2700,2520) Concatenated	4.388	12.6	12.9	24.3	34.9	8.38	3.7E-3	30.7	3.5	85	1031

∗ **Encoder of RS(255,239) is 1**

FEC Codes other than RS Code

- BCH Code
  - **Slightly better FEC gain than RS for random bit error**
  - **low burst error tolerance compared to RS**
- Concatenated Code
  - **When the codeword length is less than 1K bytes, the FEC gain of the concatenated codes are generally less than that of RS**
  - **When the codeword length is more than 1K bytes, the better FEC gain can be achieved, but the overhead of U/S is high due to long codeword length**

Lost Synchronization of Upstream Burst



Input BER of Sync block	Probability of lost burst	Mean time of lost burst (years)
4E-3	6.65E-17	4767
2.37E-3	1.34E-19 (GPON)	2.3E+6
1.14E-3	3.04E-23	1.37E+10 (universe time)
1E-3	4.67E-24	7E+10

(*) Probability of lost burst and mean time is calculated based on page 25 of ” 3av_0701_effenberger_1.pdf “ baseline document

Two criteria for allowed input BER of synchronization block

(1) If the mean time of loss of sync should be less than universe time(1.37E+10 years)

input BER < 1.14E−3

(2) If the probability of loss of sync is less than GPON(G.984.2) (delimiter 24bits, allowed bit error 5 bits) input BER < 2.37E−3

Summary

- We have listed and compared the FEC codes which have FEC gains more than gain of RS(255,239)
- Allowed FEC overhead should be discussed in Task Force
- Toward draft 1.0, the FEC code candidates should be narrowed down