Considerations on FEC and Line code

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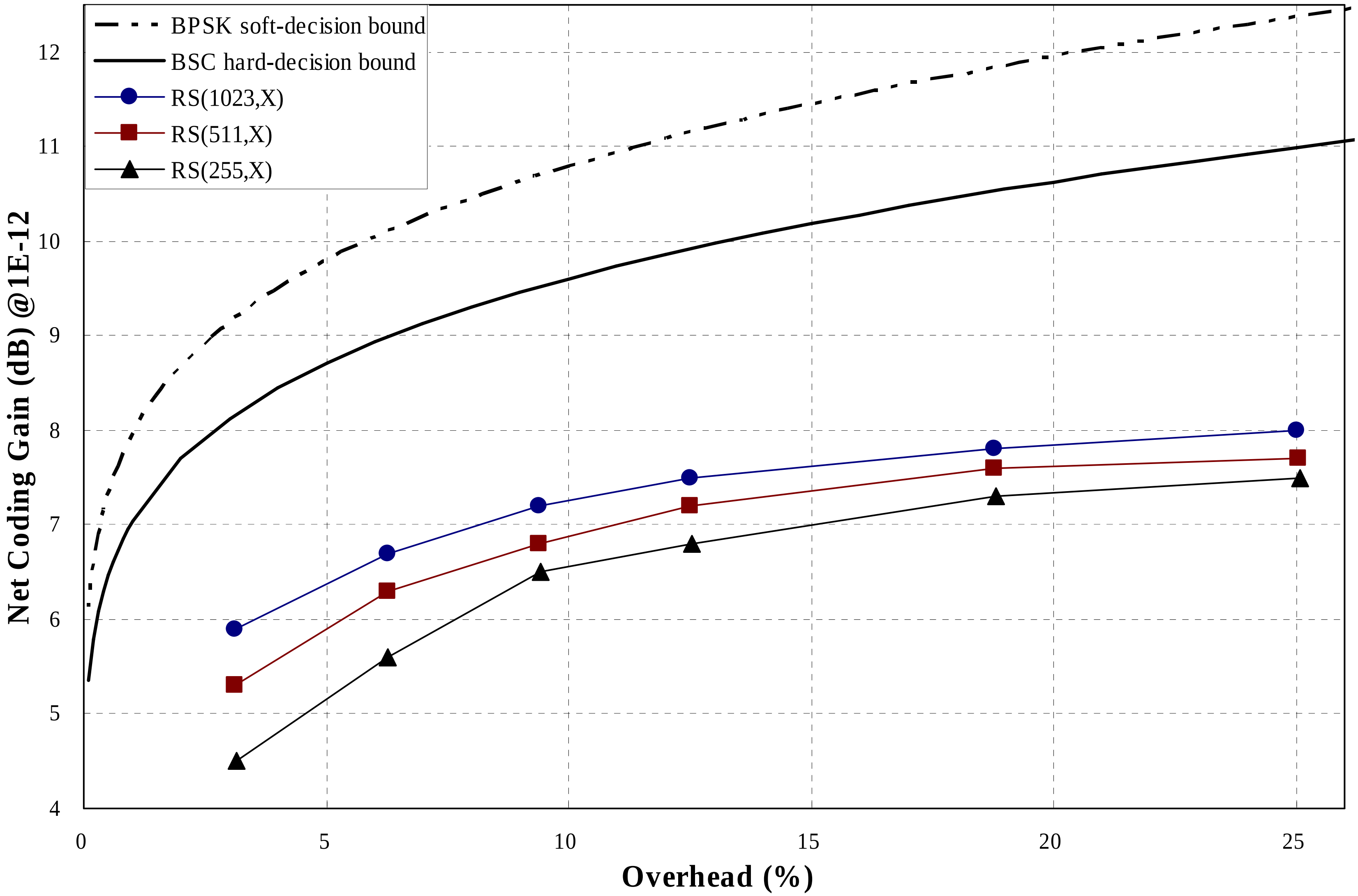
FEC Coding Gain

- The expected FEC coding gain
  - Theoretical bound shown in next chart
    - Binary Symmetric Channel model
    - The FEC codeword length is assumed to be infinity
  - For a FEC code length of about 2000 bits
    - ➢ The expected practical FEC coding gain is around 2 dB_e less than the theoretical bound

FEC Coding Gain vs Overhead



FEC Coding Gain

- Relationship between Optical and Electrical gain
  – PIN : Gain $dB_o \approx$ ½ Gain dB_e
  – APD: Gain $dB_o \approx$ ¾ Gain dB_e (Practically)
- If 4 dB_o is required for FEC
  – PIN: Gain $dB_e = 8$
  – APD: Gain $dB_e = 5.4$
- For FEC Coding Gain to be 8 dB_e
  – Overhead should be around 13%
  – For a 30 66-bit block codeword, 4 parity blocks are required

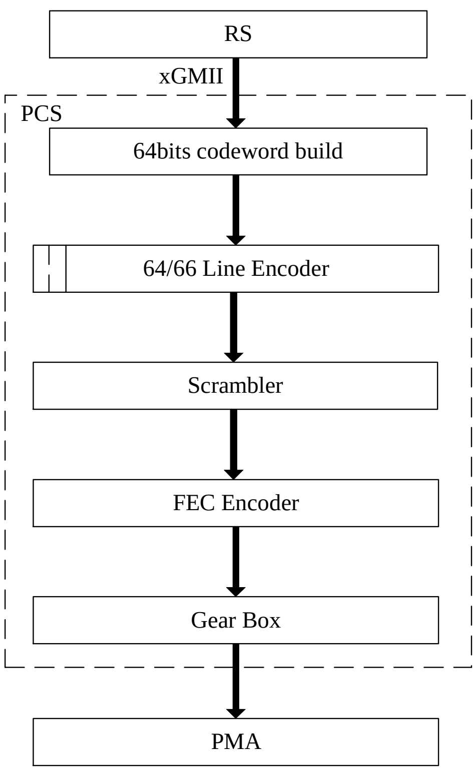
Observations on 66b code

- The two sync-header bits of 64-bits payload block is either ‘01’ or ‘10’, only two alternatives.
  - The first sync-header bit is always a complement (reversed version) of the second sync-header bit.
- In the information theory point of view, the first bit and the second bit carry the same information.
  - Hence, it is only necessary for the FEC to protect the second sync-header bit.
- Therefore, the FEC payload should be a multiple number of 65-bits blocks instead of 66-bits blocks.
  - This increases the FEC performance

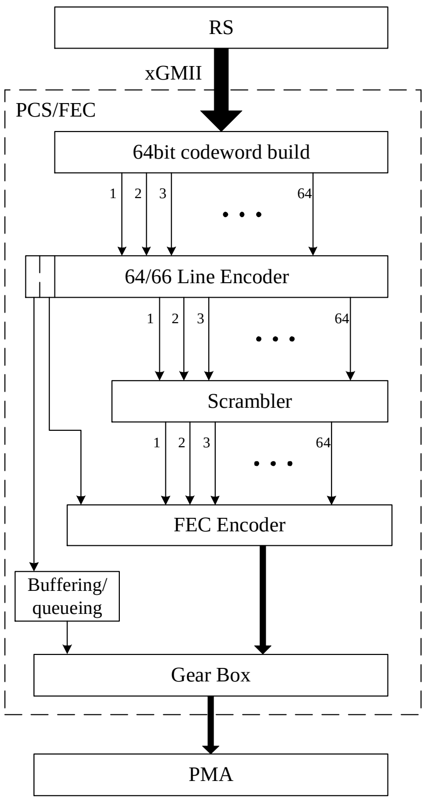
Proposed ‘65 bit’ method

1. The second sync-header bit carries the information of the transmitted sequence, which will be protected by FEC coding
    - 1 – Data only
    - 0 – Control or Control+Data
2. The transmitter still sends both bits
    - Line code is unchanged
3. The receiver FEC only considers the second sync-header bit in its calculation
    - The first bit is generated locally

Original vs Proposed TX



Original block diagram



Proposed block diagram

Error Probabilities (1/2)

- Assuming random errors and a FEC code that accepts N blocks of 66 bit code and can correct M-1 errors, the probability of an uncorrectable codeword is:

$$p_{Uncorrectable} \approx \binom{66N}{M} (1 - p_e)^{66N-M} \, p_e{}^{M}$$

- For the improved mapping of 65 bit codewords, the probability of an uncorrectable codeword is:

$$p_{Uncorrectable} \approx \binom{65N}{M} (1 - p_e)^{65N-M} \, p_e{}^{M}$$

Error Probabilities (2/2)

- The ratio of uncorrectable error probability is

$$\frac{p_{Uncorr,66b}}{p_{Uncorr,65b}} \approx \left(\frac{66}{65}\right)^{M} (1 - p_e)^N$$

  – This is because the same FEC parity protects less data

- For the case where N=28 and M=9, we get

$$\frac{p_{Uncorr,66b}}{p_{Uncorr,65b}} \approx \left(\frac{66}{65}\right)^{M} (1 - p_e)^N = 1.14$$

Thank You!