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Channel Coding for 10GBASE-T

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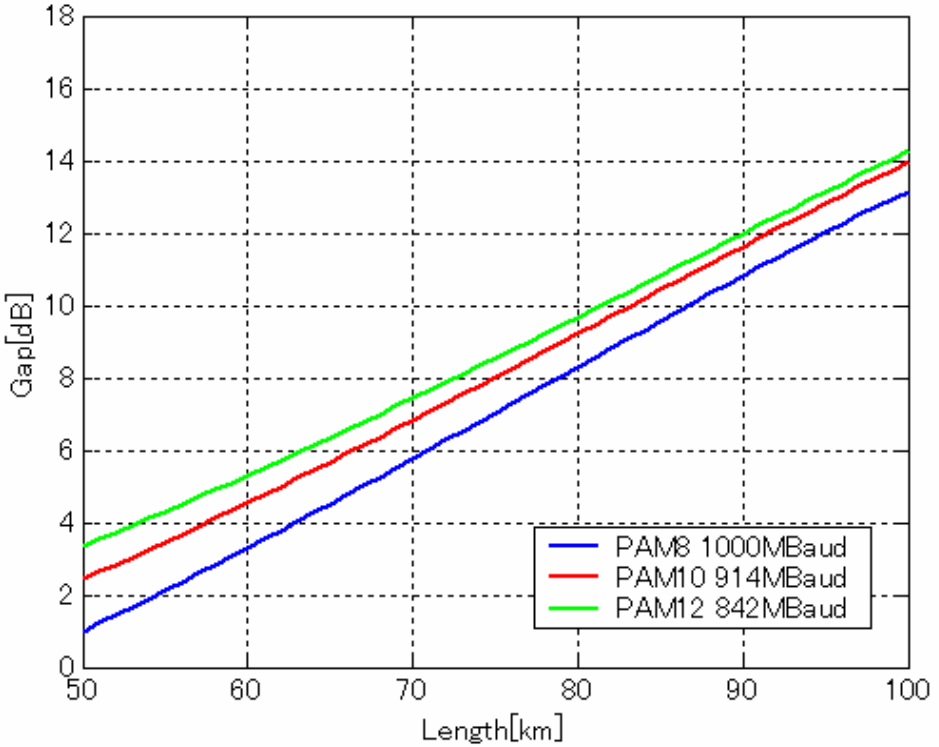
Purpose

-Consideration on number of levels for PAM

-Compare different channel coding schemes in terms of performance, complexity and latency

LDPC (Proposed by rao_1_1103.pdf)
Concatenated TCM-RS (Based on powell_1_0104.pdf)
TCM Turbo Equalizer (Based on kavehrad_1_1103.pdf)

Consideration on Number of Levels for PAM



Packet overhead + FEC redundancy: 20%
Baud rate : 842MBaud(PAM12)
914MBaud(PAM10)
1GBaud(PAM8)
Channel : Cat6
Noise: -150dBm AWGN
ANEXT measured data
(SG Material)(5dB Mitigation)
AFE noise:-36dB to Signal
Ideal echo/NEXT/FEXT cancellation
Target BER : 1E-12

Gap= (Required SNR for uncoded PAM) - (Slicer SNR)
= (Required gross coding gain)
= 12.26+6.02xlog2(M) - (Slicer SNR) M: The num. of PAM

PAM8 has better performance than PAM10/12 for cat6 channel

LDPC

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8PAM LDPC proposed by rao_1_1103.pdf
LDPC(2040,1723)
FEC redundancy: 11.83%
2.68 effective bits/symbol

We verified the result of rao_1_1103.pdf

- Excellent coding gain : 8.7dB @BER=1E-12
  5.8dB @BER=1E-6
- NEC Estimated latency : <1μsec
- NEC Estimated Complexity: 2-3Mgates + 100Kbits

Concatenated TCM+RS with Iterative decoding

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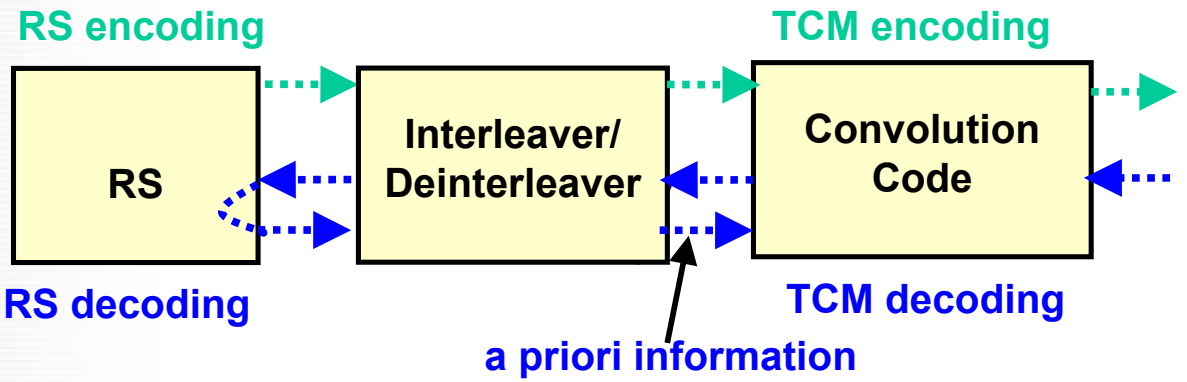
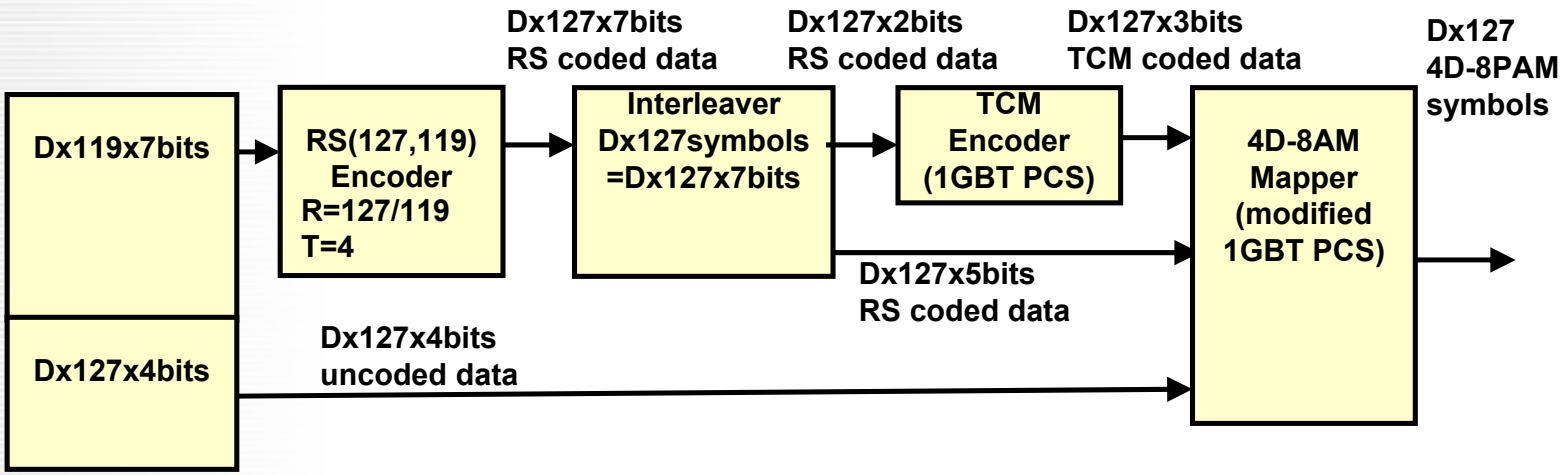
Based on powell_1_0104.pdf

- Iterative decoding using a priori information
- Excellent coding gain : around 9dB @1E-12 with ideal interleaver
- The coding gain depends on interleaver size



PAM-8 8state 4D-TCM + RS(127,119)



FEC redundancy:

R_{rs}= 127/119, R_{tcm}= 3/2

$R = 7/11 * R_{rs} * (5/7+2/7*R_{tcm})+4/11=1.1365$

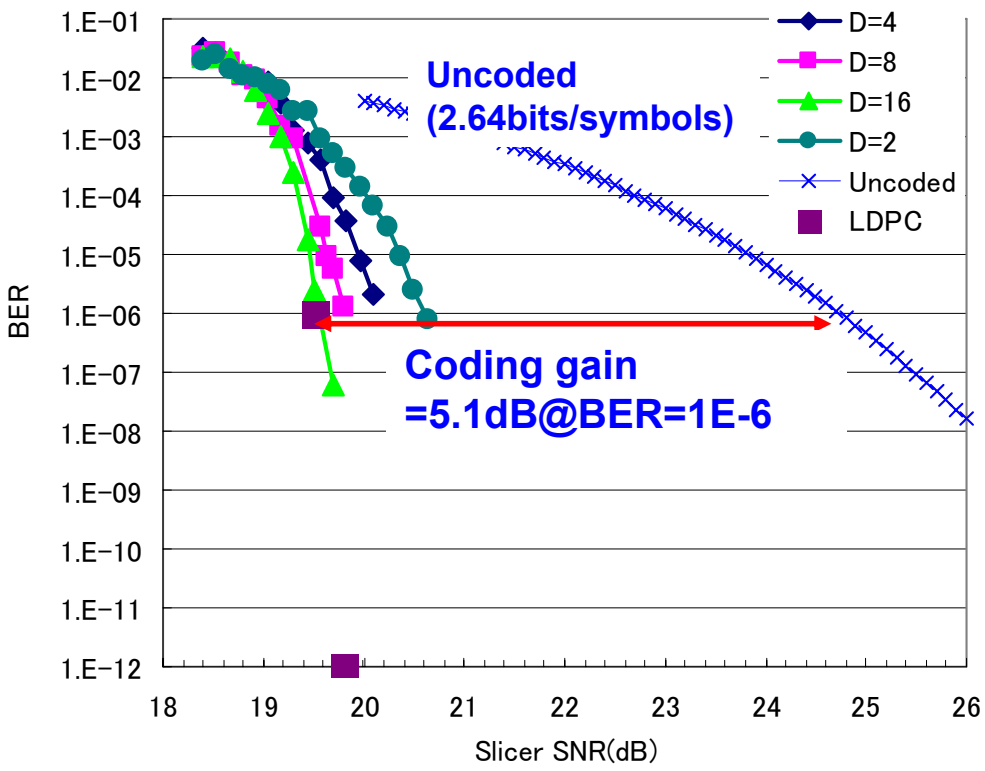
2.64 effective bits/symbol (approx. LDPC proposal)

Latency : 127xDx4(baud/iteration)

6dB coset partitioning TCM (same as 1GBT PCS)

3 times iterative decoding

Performance of TCM+RS



Packet overhaed:3%
Baud rate : 975MHz
Channel : Cat6
Noise: -150dBm AWGN
ANEXT(5dB Mitigation)
AFE noise: -36dB to signal
The num. of Iteration : 3
Complexity :1-2Mgates+100kbit (D=16)
Latency : D=2 : 1μsec
D=4 : 2μsec
D=8 :4μsec
D=16 :8μsec
Coding gain :5.1dB@BER=1E-6
7-8dB@BER=1E-12
w/ D=16 interleaver

Cf. LDPC 5.8dB gain@1E-6
8.7dB gain@1E-12
< 1msec latency

TCM+RS decoding requires around 8μsec latency for the performance comparable to LDPC

TCM Turbo Equalizer

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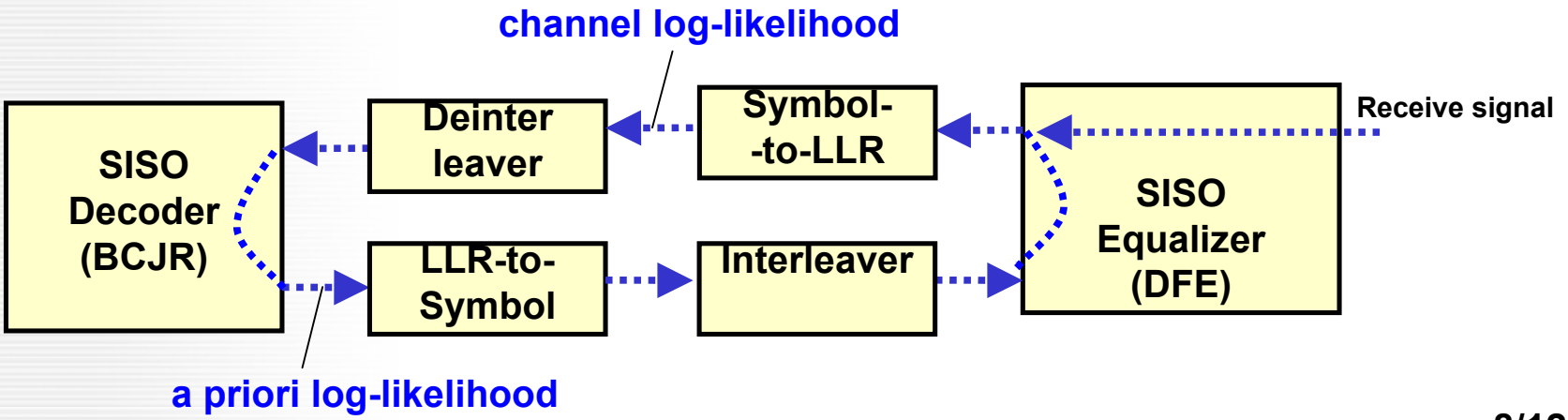
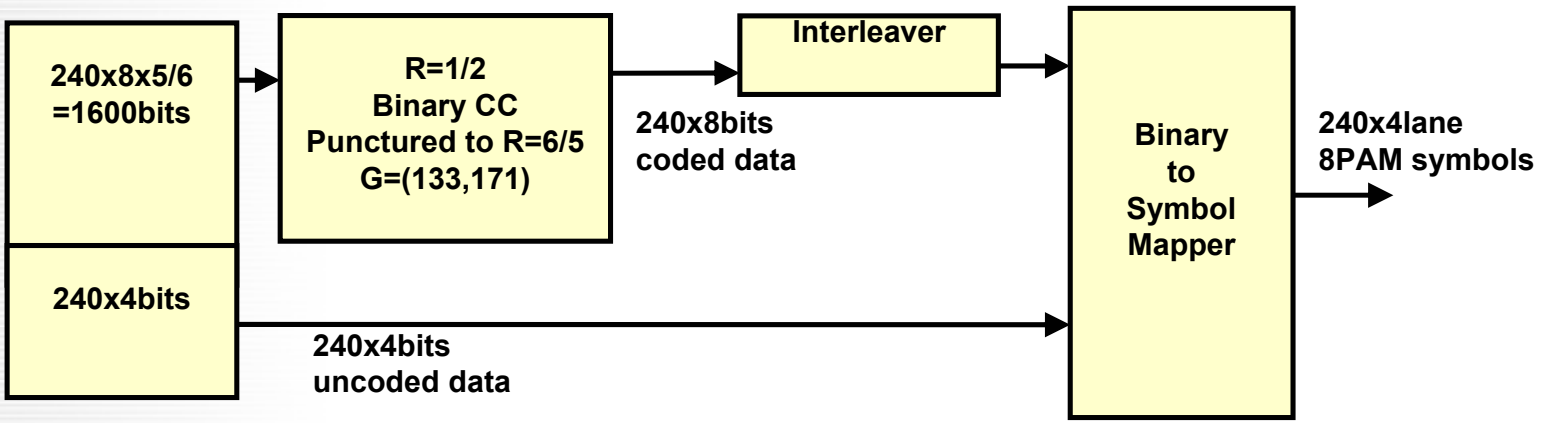
Based on kavehrad_1_1103.pdf

- **Turbo equalization using a priori information**
  - ISI is completely removed by equalizer without noise enhancement, when transmitted data is a priori known.
  - It is possible to obtain a reliable estimate of transmitted data by using a priori information provided by previous iteration.
- **Suitable for channel with high IL at higher frequency range thanks to the low noise enhancement of equalizer.**

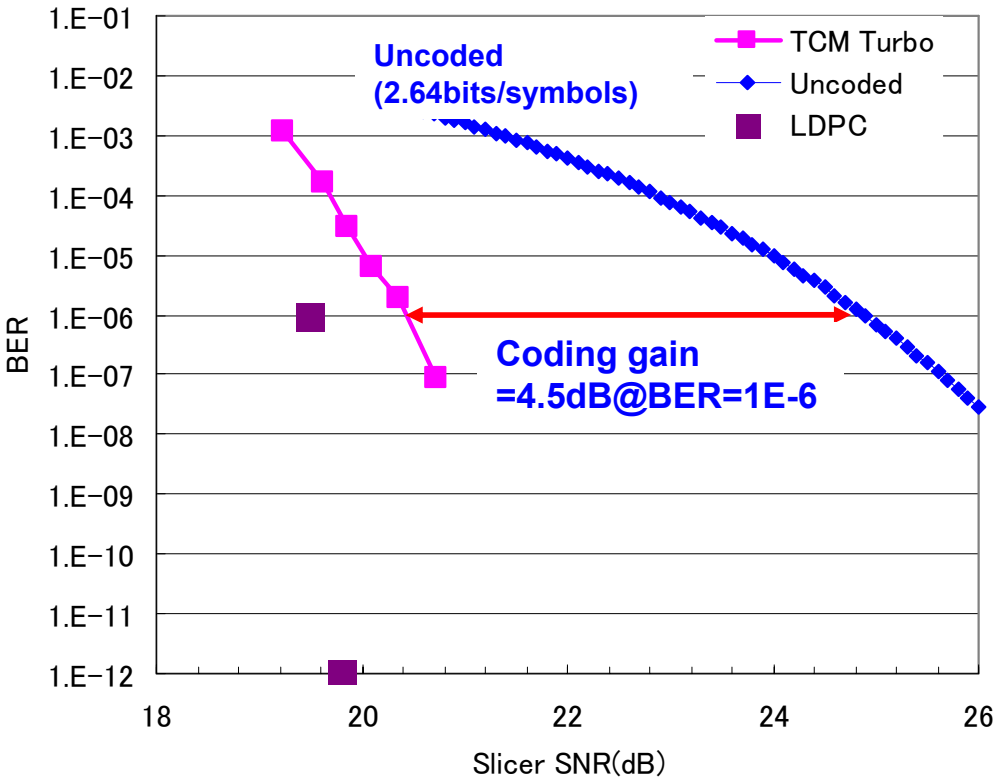


Punctured BCC(G=(133,171),R=6/5) with Turbo Equalizer



FEC redundancy:12.25%
2.67 effective bits/symbol (approx. LDPC proposal)
12dB coset partitioning (same as LDPC proposal)
8PAM mapping (same as LDPC proposal)
BCJR algorithm for decoding
2 times iterative decoding

Performance of TCM Turbo Equalizer



Packet overhaed:3%
Baud rate : 965MHz
The num. of THP tap : 2
Channel : Cat6
Noise: -150dBm AWGN
ANEXT(5dB Mitigation)
AFE noise: -36dB to signal
The num. of Iteration : 2

Complexity:2-3Mgates+3Mbits
Latency : 1-1.5(μsec)
Coding gain :4.5dB@BER=1E-6
6-7dB@BER=1E-12

Cf. LDPC 5.8dB gain@1E-6
8.7dB gain@1E-12
< 1μsec latency

TCM Turbo Equalizer has lower performance than LDPC

Comparison of Channel Codes

	PAM	line baud rate *1 (Msps)	Coding Gain BER =1E-6	Estimated Coding Gain BER =1E-12	Complexity	Latency
8state 4D TCM	10	857	3.8dB	4dB	100s Kgate	0.1μsec
LDPC(1723,2048)	8	960	5.8dB	8.7dB	2-3Mgate +100kbits	<1μsec
8state 4D TCM +RS(127,119) Interleave depth(D)=16	8	975	5.1dB	7-8dB	1-2Mgate +100kbits	8μsec
Punctured BCC (G=(133,171),R=6/5) with Turbo Equalizer	8	965	4.5dB	6-7dB	2-3Mgate +3Mbits	1-1.5μsec

*1 Assuming 3% packet overhead

LDPC shows reasonable complexity, performance and latency.

Summary

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-PAM8 has better performance than PAM10/12 for cat6 channel

- **Optimal number of levels for PAM depends on channel conditions.**
- **Complexity must be considered.**

- LDPC shows reasonable complexity, performance and latency compared with TCM +RS and TCM Turbo Equalizer.