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PHY proposal for 10GBASE-T

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Outline

- Main features of the PHY proposal
- Modification to Dariush's LDPC code
- Frame structure
- Tomlinson-Harashima Precoder
- Startup sequence proposal
- Performance results
- Conclusion

Main features of PHY proposal

Modulation	PAM12
MAC Frame Encapsulation	10GBASE-R 64B/66B
FEC code	LDPC(845,1024)
Symbol rate	821MHz
Transmitter Equalization	THP - 32 Taps - Coefficients determined at start up then fixed

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Features of Dariush's LDPC Proposal

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LDPC(781,1024) code with PAM12 mapping

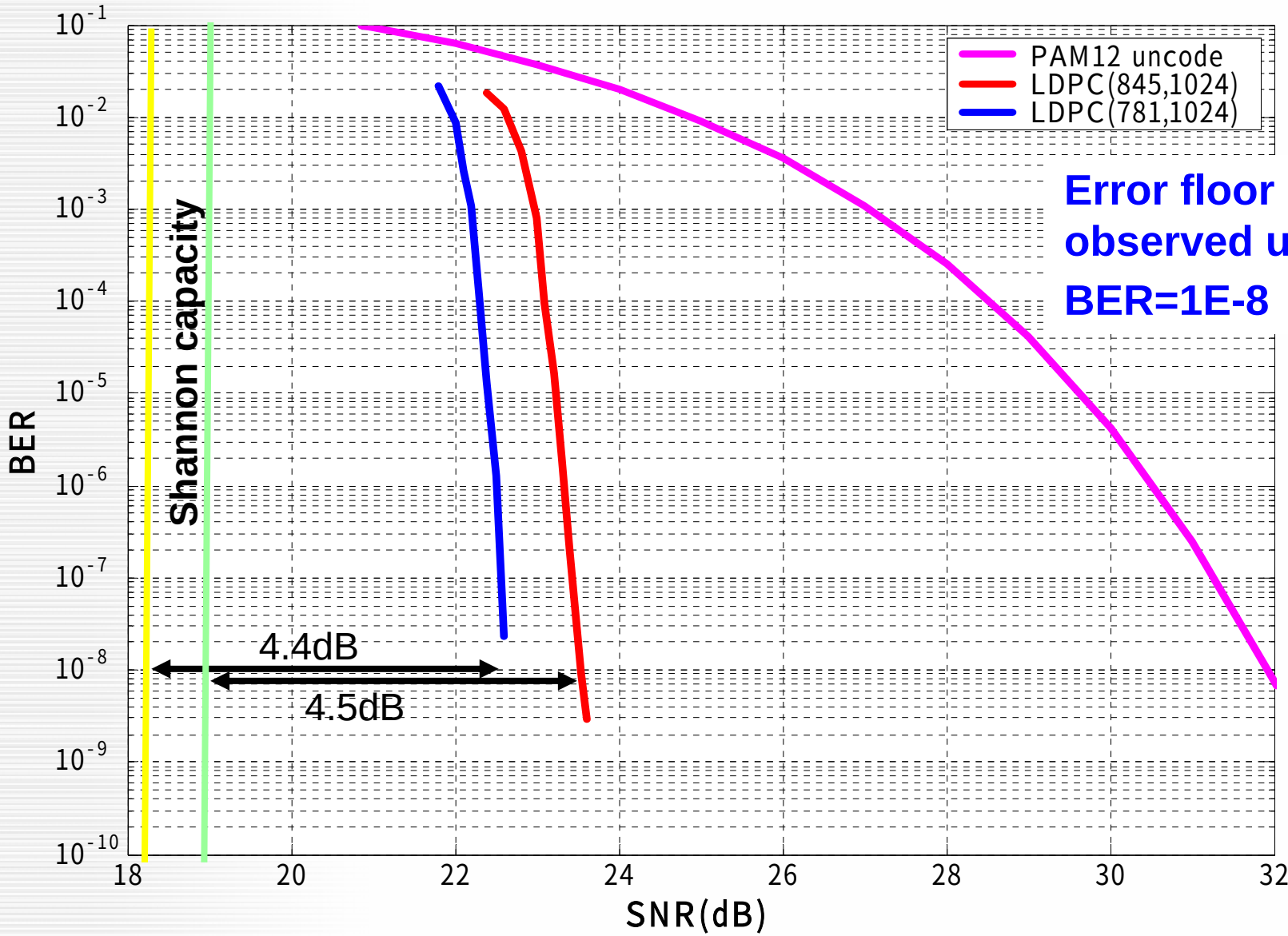
- **Low latency due to small block code length of 1024bits**
- **Low symbol rate of 850MHz for 3% packet overhead due to PAM12 mapping**
  - 12dB set partitioning
  - Gray mapping
  - Each 4D co-set carries 8 coded bits and 6 uncoded bits

- **High complexity due to high variable node degree of 32.**
  - Complexity is proportional to variable node degree

An Alternate code with lower complexity

LDPC(845,1024) whose variable node degree = 8

Simulation results



Error floor cannot be observed up to BER=1E-8

Comparison of LDPC codes

Code	LDPC(781,1024)	LDPC(845,1024)
Information bits/ Symbol	3.025bits	3.150bits
Shannon bound (=6.02* num. of bits)	18.21dB	18.97dB
Gap to capacity @BER =1E-8	4.4dB (SNR=22.6dB)	4.5dB (SNR=23.5dB)
Symbol rate (3% packet overhead)	851MHz	817MHz
Variable node degree	32	8
Check node degree	32	32

LDPC(845,1024) has comparable performance to LDPC(781,1024) with lower complexity and lower symbol rate .

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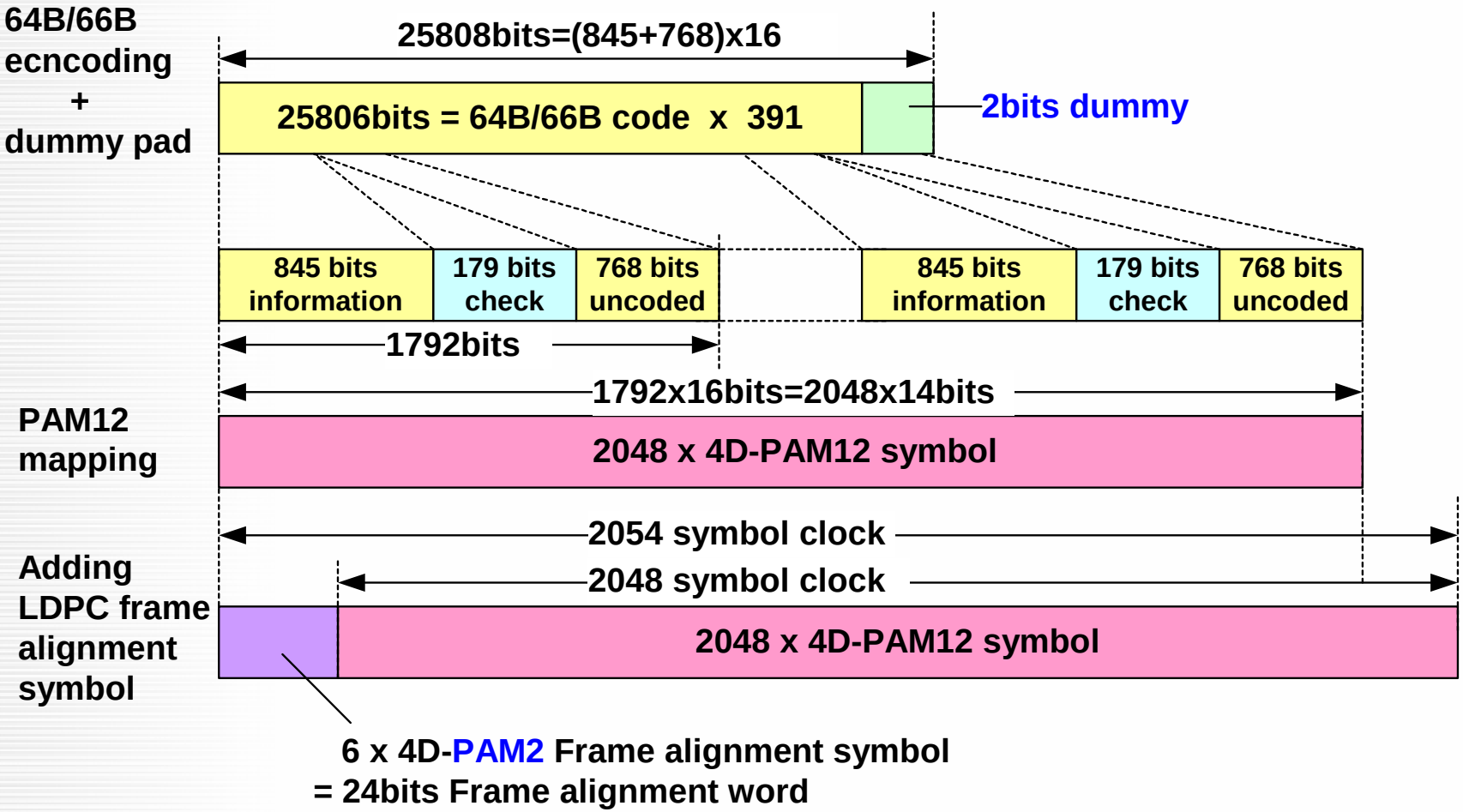
Frame structure



Symbol rate = 10Gx(66/64)x(25808/25806)x(1792/1613)/14 x(2054/2048) = 820.8MHz

Why PAM2 Frame alignment

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Frame alignment parameter

	PAM2 Frame alignments	PAM12 Frame Alignments
The num. of Frame alignment word(FAW) bit	24bits	28bits
The num. of candidate positions	2048+6	2048+2
Assuming BER before decoding	<1E-12	2E-2
Average reframe time (Trf)	2.00	4.86
Variation reframe time (Vrf)	0	12.56
False In-frame time (Tff)	1.37E11	3.51E13
Out-of-frame detection time (Tof)	4.00	4.00
Misframe time (Tmf)	3.01E42	48.77

Note 1 : Trf, Vrf, Tff, Tof and Tmf have frames as units
Note 2 : Two successive good FAW confirmation for frame alignment
Note 3 : Four successive bad FAW confirmation for frame misalignment
Ref. : D.Choi, “Frame alignment in digital carrier system – A tutorial”, IEEE Communications magazine, Feb. 1990, p47-54

PAM12 Frame alignment can NOT achieve fast reframe and negligible misframe due to its high BER.

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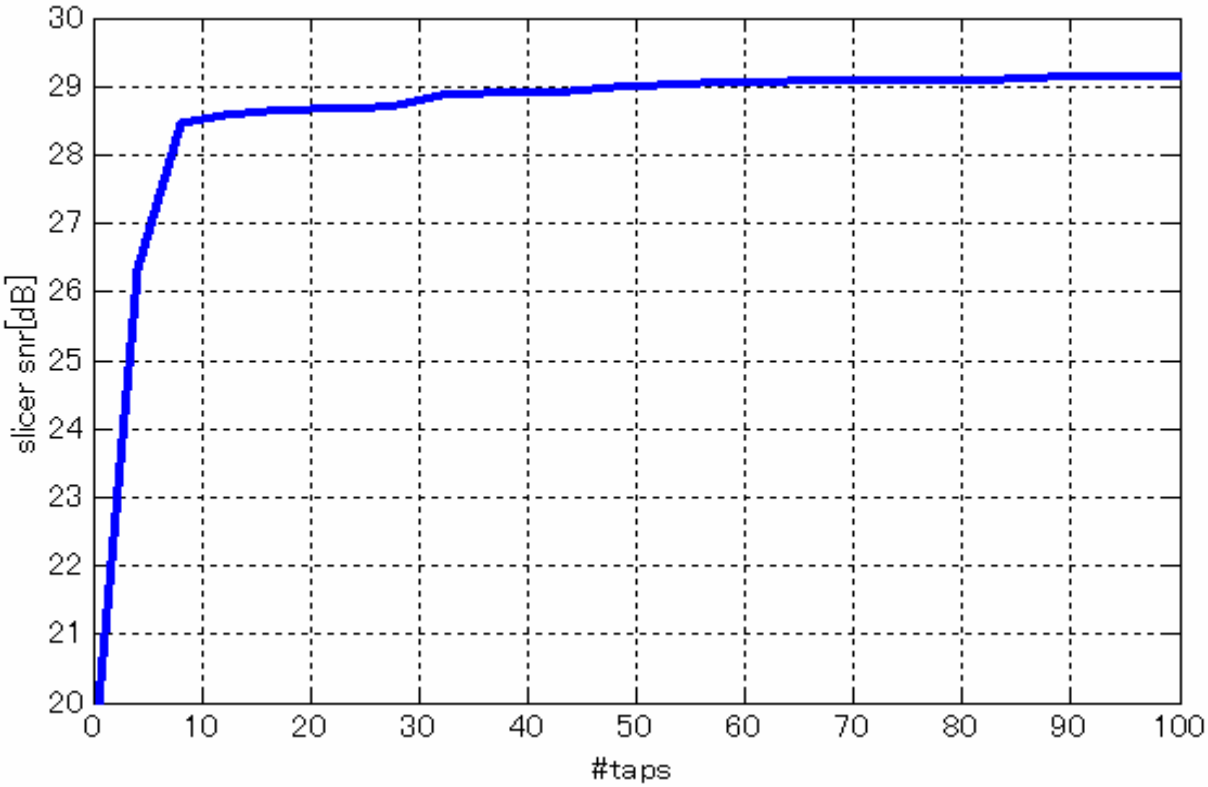
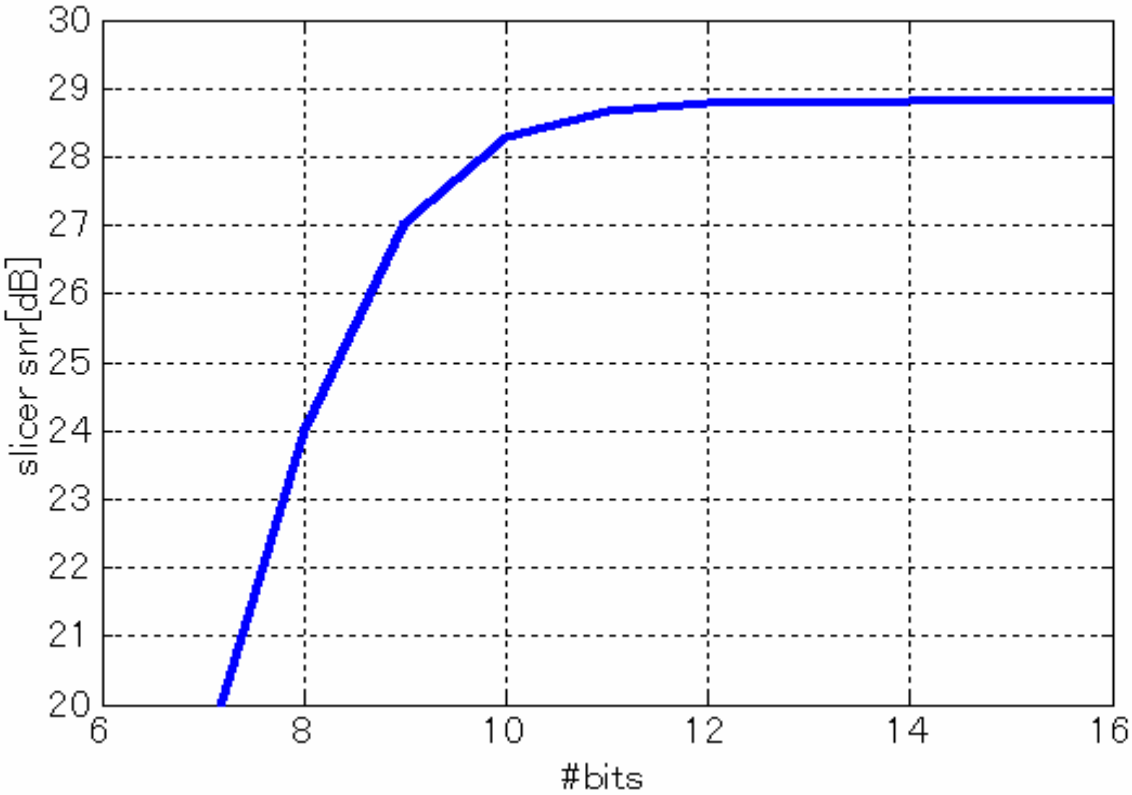
Required THP Tap Number



IL Model :
P802.3 Task Force Material
Measured Class E model
ANEXT :
64.5 - 10.0*log10(F/100)
(F < 100MHz)
64.5 - 15.0*log10(F/100)
(F >= 100MHz)
BGN : -150dBm/HZ
Without other impediments
FFE : 64 taps

Meaningful SNR gain cannot be observed beyond 32 taps

Required bit accuracy of THP coef.



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(F < 100MHz)
64.5 - 15.0*log10(F/100)
(F >= 100MHz)
BGN : -150dBm/HZ
Tx Power : 10dBm(Flat PSD)
FFE : 64taps
DFE : 32taps

Bit lengths after the decimal point
= #bits – 3bit

THP coefficients requires 12 bits accuracy for negligible loss

THP Summary

Proposal for THP coefficients

TAP Number : 32 taps

Bit accuracy : 12 bits

THP coefficients setting method

If THP coefficients update is not necessary,

HDSL2 approach can be adopted, whose coefficients determined at start up then fixed.

TF needs further investigation about necessity of periodic coefficients update.

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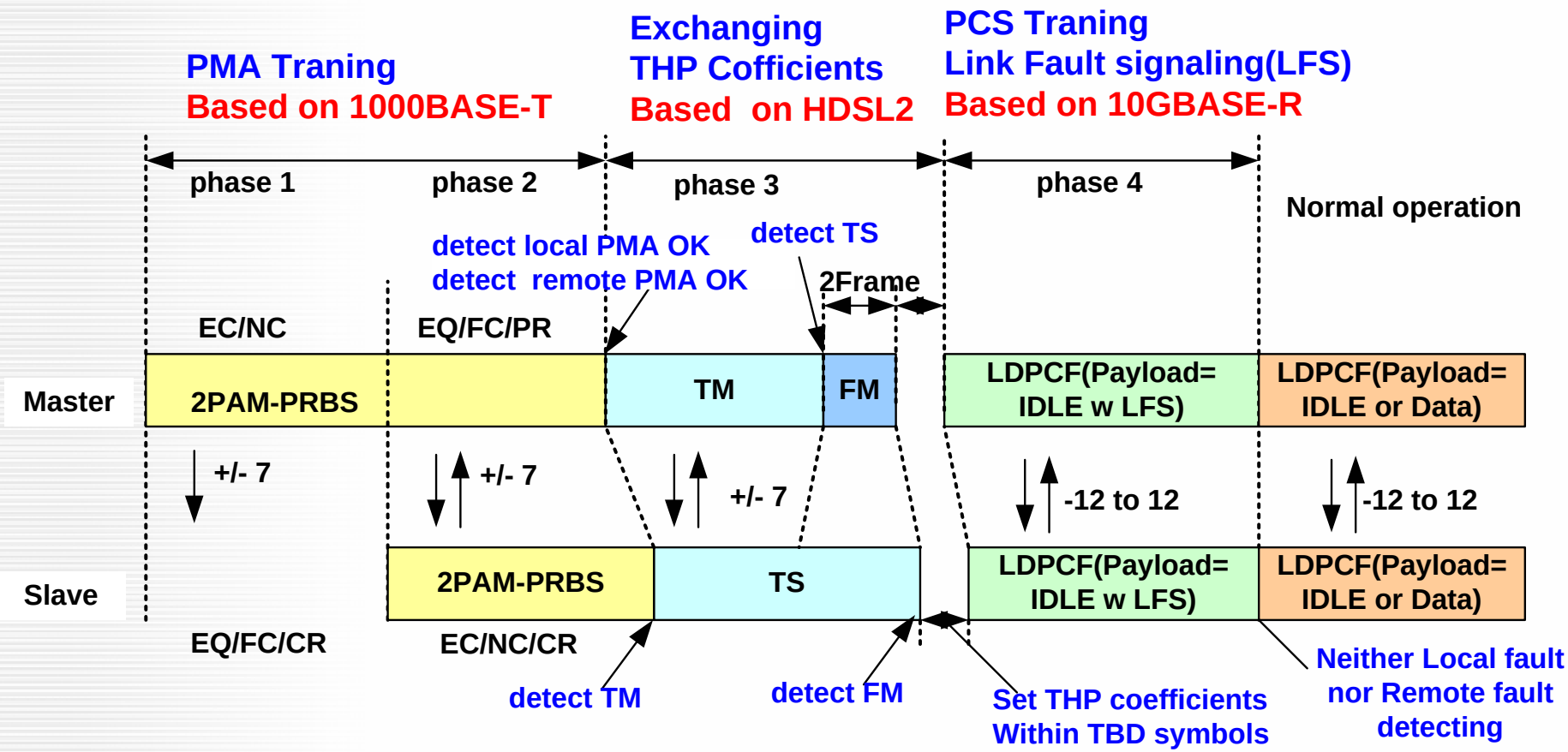
Start up sequence

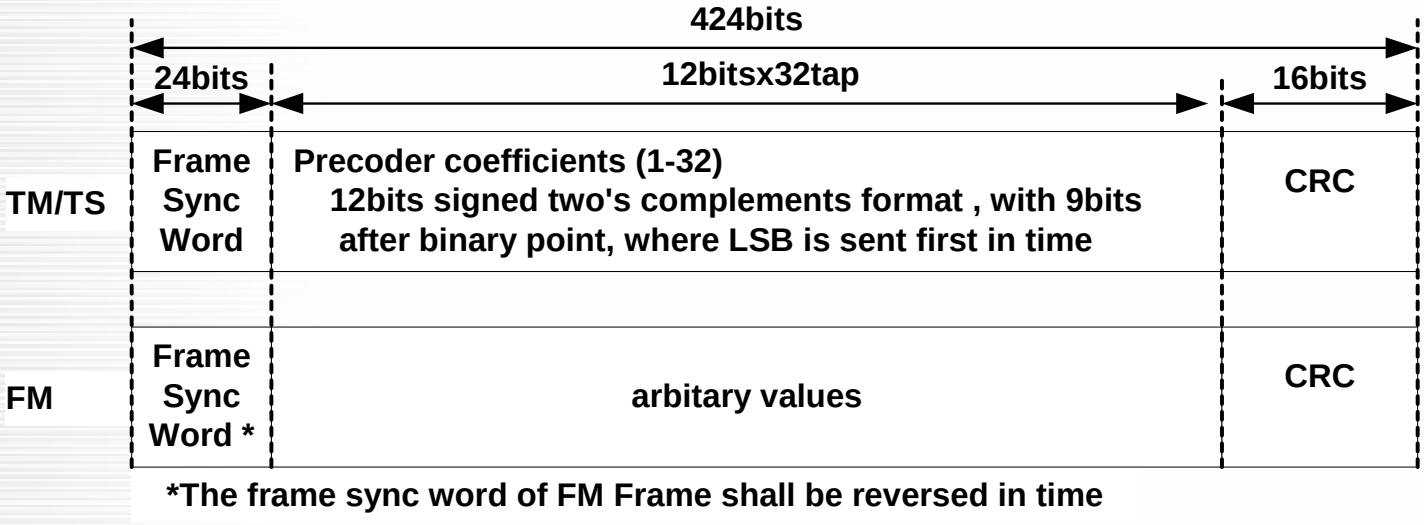


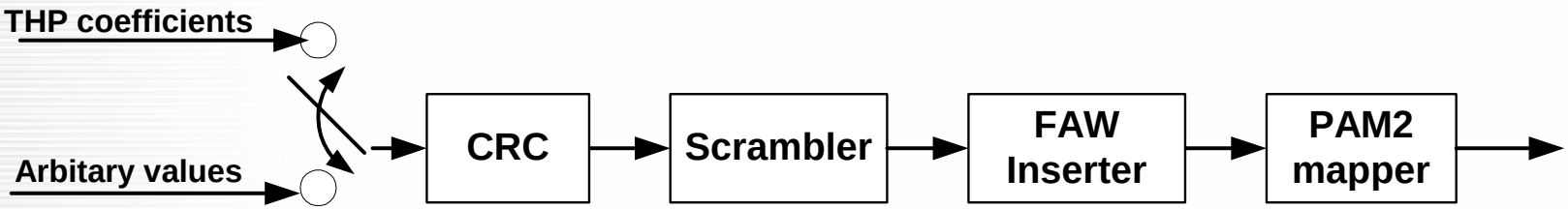
EC: Echo Cancellation
NC:NEXT Cancellation
EQ: Equalization
PR: Phase recovery
CR: Clock recovery

TM/TS : Frame for exchanging THP coefficients
FM : Frame for phase3 termination
LDPCF : LDPC Frame

PCS Traning includes LDPC sync, 64B/66B sync and XAUI Lane alignments

THP coefficients exchanging Frame





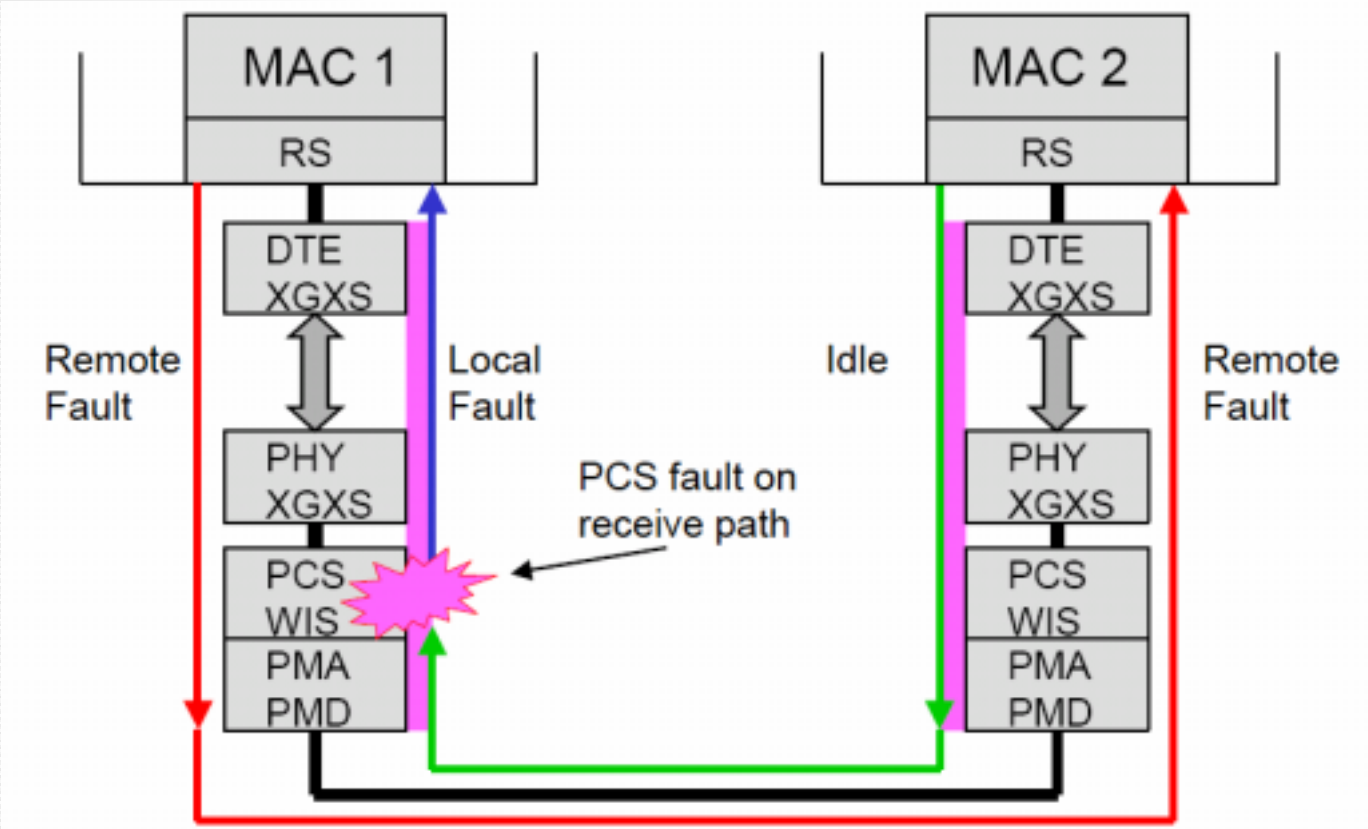
CRC generator polynomial : $g(x)=x^{16}+x^{12}+x^{5}+1$

Scrambler Polinomial : $g(x)=x^{23}+x^{5}+1$ **(Master)**

$g(x)=x^{23}+x^{18}+1$ **(Slave)**

Ref. ITU-T G.991.2 "Single-pair high-speed digital subscriber line(SHDL)" Sec .7.2

10GBASE-R Link fault signaling



From http://www.ieee802.org/3/efm/public/nov01/turner_1_1101.pdf

- Intermediate link elements initiate Local Fault(LF) and forward status message
- RS layer initiates Remote Fault(RF) status in response to reception of LF
- Link status should be "UP(OK to send packet)“ only when RS layer is detecting neither RF nor LF, that is, all sublayer's protocol is OK.

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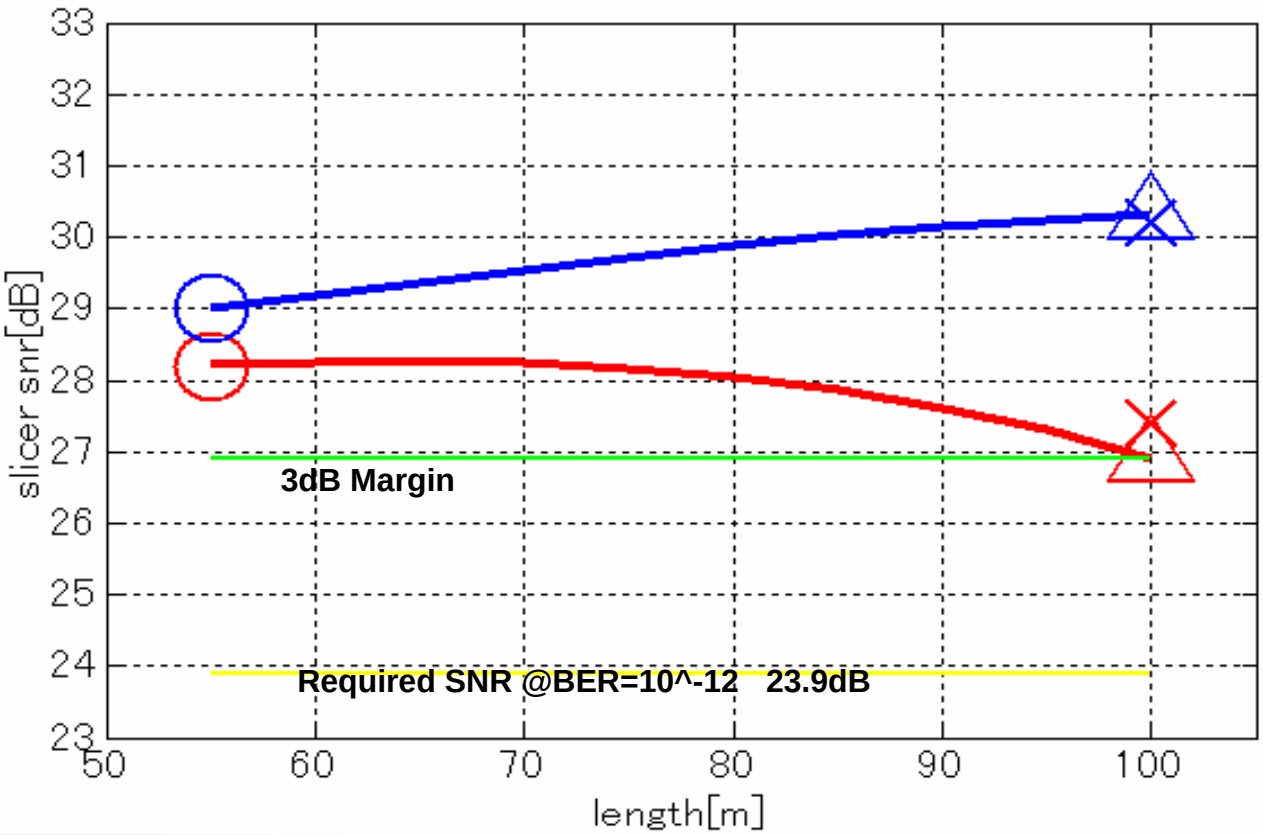
Performance Results



Model1(Ideal ADC)
Model2(Ideal ADC)
Model3(Ideal ADC)
Model4(Ideal ADC)
Model1(9.5bit ADC)
Model2(9.5bit ADC)
Model3(9.5bit ADC)
Model4(9.5bit ADC)

IL Model :
Specified channel models from March 04 plenary
ANEXT :
x1 - 10.0*log10(F/100)
(F < 100MHz)
x1 - 15.0*log10(F/100)
(F >= 100MHz)
x1=62.5(Model1)
x1=49.5(Model2)
x1=64.5(model3)
BGN : -150dBm/HZ
Tx Power : 10dBm(Flat PSD)
Ideal Echo/NEXT/FEXT Cancellation

Link Margins

model1 3.4dB
model2 4.2dB
model3 3.0dB

Conclusion

- LDPC(845,1024) has comparable performance to Dariush's LDPC proposal with lower complexity and lower symbol rate .
- 4D-PAM2 frame alignment symbol can achieve reliable framing parameter.
- THP requires 12 bits accuracy and 32 tap length for negligible loss.
- Our PHY proposal can meet reach distance objectives with 3dB margin.