1000BASE-T vs. GEPOF complexity comparison

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Agenda

- Objectives
- Complexity comparison
- Conclusions

Objectives

- The objective of this presentation is to compare the implementation complexity of a 1000BASE-T PHY against a GEPOF PHY
- The complexity comparison is going to be presented in the following aspects:
  - Digital computational complexity
  - AFE area
  - AFE power consumption
- It will be assumed same technology node is used for both PHY implementations

Complexity comparison

Communication system schemes - 1000BASE-T

- IEEE 802.3 Clause 40
- Full duplex 1000 Mbps over 4 UTP pairs, with echo and NEXT adaptive canceling
- 4D Trellis Code Modulation (TCM) 5-PAM
- 125 Mbaud symbol rate per pair
- 250 Mbps full-duplex per UTP
- Channel equalization based on Decision Feedback Equalizer (DFE) per pair
- ADC (Rx) ENOB ≥ 8 bits
- DAC (Tx) ENOB ≥ 8 bits

Communication system schemes - GEPOF

- Full duplex 1000 Mbps
- Coded modulation based on Multi-Level Coset Code of 3 levels (see [1])
- 16-PAM baseband modulation built on 7bits/2D RZ^2 QAM modulation (see [1])
- Symbol rate = 312.5 MSps,Spectral efficiency = 3.3145 bits/s/Hz/dim (see [1])
- Component codes of 1st and 2nd MLCC levels based on shortened BCH codes over Galois field of GF(2^{11}) (see [1])
- MLCC net coding gain = 6.7 dB at BER = 10^{-12} (see [1])
- Linearizer based on low cost adaptive Volterra filtering implemented in the receiver (see [2])
- Channel equalization based on adaptive Tomlinson-Harashima Precoding (THP) for ISI compensation plus noise whitening (see [3])
- PCS and PMA as presented at [4] and [5]
- ADC ENOB 8bits, DAC ENOB 8bits

Computational complexity comparison

	1000BASE-T 802.3ab, 4 pairs, 125MB			GEPOF, 1 channel, 312.5 MB (2.5 x 125)	
	Channels	Complexity / channel		Channels	Complexity / channel
Feed-Forward Filter (FFF)	4[6]	8 taps[6]	Feed-Forward Filter (FFF) at RX	1	16 taps · 2.5
Feedback Filter (FBF) at DFE	4[6]	16 taps[6]	Feedback Filter (FBF) at THP (TX)	1	9 taps · 2.5
NEXT canceling	4[6]	25 taps x 3[6]	Channel linearizer	1	84 taps · 2.5
Echo canceling	4[6]	125 taps[6]			
PCS/channel decoding/interface	1	D_1	PCS/channel decoding/interface	1	D_2
Digital complexity sub-total	**896 taps + D_1[6]**		**Digital complexity sub-total**	**273 taps + D_2**	
Digital complexity sub-total	**equiv. 1169 taps**		**Digital complexity sub-total**	**576 taps**	

- We can consider that the most relevant part of D_1 in terms of computational complexity is the squared distance based Viterbi's algorithm for 4D 8-States TCM decoding operating at 125 MHz
- For D_2 the most relevant part is a (2016, 1664) BCH Berlekamp decoder operating at 312.5 MHz
- $D_1 \approx D_2$, and D_2 in GEPOF can be considered equivalent to digital filtering complexity ($D_2 \approx 273$ taps)
- On the other hand, the computational complexity of DSP for adaptive filtering can be considered proportional to the number of taps to be calculated, assumed the same adaptation rate for both PHYs
- **Therefore, 1000BASE-T is estimated as > 2x GEPOF in terms of digital computational complexity**

AFE complexity comparison

AFE area comparison	1000BASE-T 802.3ab, 4 pairs, 125MB		Note: this size estimation is based on data interpolation of [6]	GEPOF, 1 channel, 312.5 MB (2.5 x 125)	
	Quantity	Complexity / unit		Quantity	Complexity / unit
ADC ENOB 8 bits	4	A	ADC ENOB 8 bits	1	1.8·A
DAC ENOB 8 bits	4	B	DAC ENOB 8 bits	1	1.6·B
PLL/PGA/LPF/Hybrid	4	C	PLL/PGA/LPF	1	C
AFE Area comparison	**4·A + 4·B + 4·C**		**AFE Area comparison**	**1.8·A + 1.6·B + C**	

AFE power consumption comparison	1000BASE-T 802.3ab, 4 pairs, 125MB		Note: this size estimation is based on data interpolation of [6]	GEPOF, 1 channel, 312.5 MB (2.5 x 125)	
	Quantity	Complexity / unit		Quantity	Complexity / unit
ADC ENOB 8 bits	4	E	ADC ENOB 8 bits	1	2.5·E
DAC ENOB 8 bits	4	F	DAC ENOB 8 bits	1	2.5·F
PLL/PGA/LPF/Hybrid	4	G	PLL/PGA/LPF	1	G
AFE power comparison	**4·E + 4·F + 4·G**		**AFE power comparison**	**2.5·E + 2.5·F + G**	

Conclusions

- Complexity comparison between 1000BASE-T and GEPOF has been presented attending to:
  - Digital computational complexity
  - AFE area
  - AFE power consumption
- The results of this comparison are:
  - 1000BASE-T is > 2x GEPOF in terms of computational complexity
  - 1000BASE-T is > 2x GEPOF in terms of AFE area
  - 1000BASE-T is ~1.6x GEPOF in terms of AFE power consumption
- The conclusion is: GEPOF is implementable

References

- [1] *Rubén Pérez-Aranda, "High spectrally efficient modulation schemes for GEPOF technical feasibility", GEPOF SG, Plenary Meeting, July 2014*
- [2] *Rubén Pérez-Aranda, "Optical transmitter characteristics for GEPOF technical feasibility", GEPOF SG, Interim Meeting, May 2014*
- [3] *Rubén Pérez-Aranda, "Shannon's capacity analysis of GEPOF for technical feasibility assessment", GEPOF SG, Interim Meeting, May 2014*
- [4] *Rubén Pérez-Aranda, "Proposal of a Physical Coding Sublayer for GEPOF technical feasibility", GEPOF SG, Plenary Meeting, July 2014*
- [5] *Rubén Pérez-Aranda, "Proposal of a Physical Medium Attachment for GEPOF technical feasibility", GEPOF SG, Plenary Meeting, July 2014*
- [6] *Benson Huang et al. (Realtek), "PHY Feasibility Study for One or Two pairs RTPGE", RTPGE SG, July 2012*

Questions?