40GE 10km SMF PMD Alternatives Historical Cost Comparison

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Introduction

- 40GE-CWDM (4x10G) and 40GE-Serial (1x40G) are two proposed alternatives to meet the 40GE 10km SMF PMD objective
- The alternatives are technically feasible
- Cost is the key deciding factor in selecting between the alternatives
- 40GE-Serial cost is much higher today then 40GE-CWDM cost
- 40GE-Serial cost is expected to cross-over 40GE-CWDM cost in the future
- Predicting the cross-over point is central to making a decision
- Presentation conclusions:
  - Based on technology and volume, the fair historical analogy for 40GE-CWDM is 10GE-LX4, and for 40GE-Serial is 10GE-ER (not 10GE-LR.)
  - Today, 6 years after 802.3ae standard adoption, 10GE-ER has 60% higher cost than 10GE-LX4.
  - Based on historical cost data and reasonable component cost assumptions, aggressive cross-over of 40GE-CWDM cost by 40GE-Serial cost is in 2013, with more likely cross-over after 2016.

All market cost data in this presentation is from Lightcounting, based on actual transceiver sales confidentially shared by 21 optics vendors with Lightcounting.

10GE PMD Technology

ALL VALUES ARE APPROXIMATE	10GE-LR	10GE-ER	40GE-Serial	10GE-LX4	40GE-CWDM
IC Technology (typical)	4:1 XAUI	4:1 XAUI	4:1 Mux / DeMux	4:4 XAUI	4:4 CDR
TX Technology (typical)	Un-cooled DFB	Cooled EML	Cooled EML	Un-cooled DFB/MUX (7dB loss)	Un-cooled DFB/MUX (2dB loss)
RX Technology (typical)	PIN	PIN	PIN	DeMux/PIN (2dB loss)	DeMux/PIN (2dB loss)
Typical feasible TP2 OMA power (not spec)	3dBm	2dBm	3dBm	-4dBm	1dBm
Link Budget	9dB	15dB	9dB	8dB	9dB
Typical feasible TP3 OMA sens. (not spec)	-17dBm	-18dBm	-7dBm	-20dBm	-15dBm
Technology Margin: TP2 – Budget – TP3	11dB	5dB	1dB	8dB	7dB

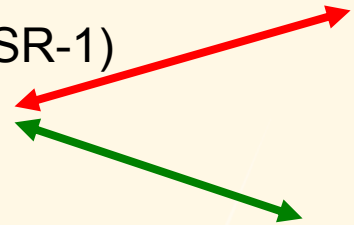
Optics technology type and margin determines PMD manufacturing difficulty, which drives PMD cost.

10GE Technology and Margin Comparison

- 10GE-LX4 and 40GE-CWDM have same transmitter technology (un-cooled DFB/Mux) and similar technology margin, so are fair historical analogies.
- 10GE-ER and 40GE-Serial have same transmitter technology (cooled EML) and similar technology margin, so are fair historical analogies.
- 10GE-LR and 40GE-Serial have different transmitter technology (un-cooled DFB vs. cooled EML) and large difference in technology margin (~10dB), so are unfair historical analogies.
- Based on technology type and technology margin (i.e. manufacturing cost) comparison, the fair historical analogy for 40GE-CWDM is 10GE-LX4, and for 40GE-Serial is 10GE-ER (not 10GE-LR).
- 40GE-CWDM has more technology margin (~6dB) then 40GE-Serial, which offsets manufacturing costs due to multiple optical channels.

10GE Volume Comparison

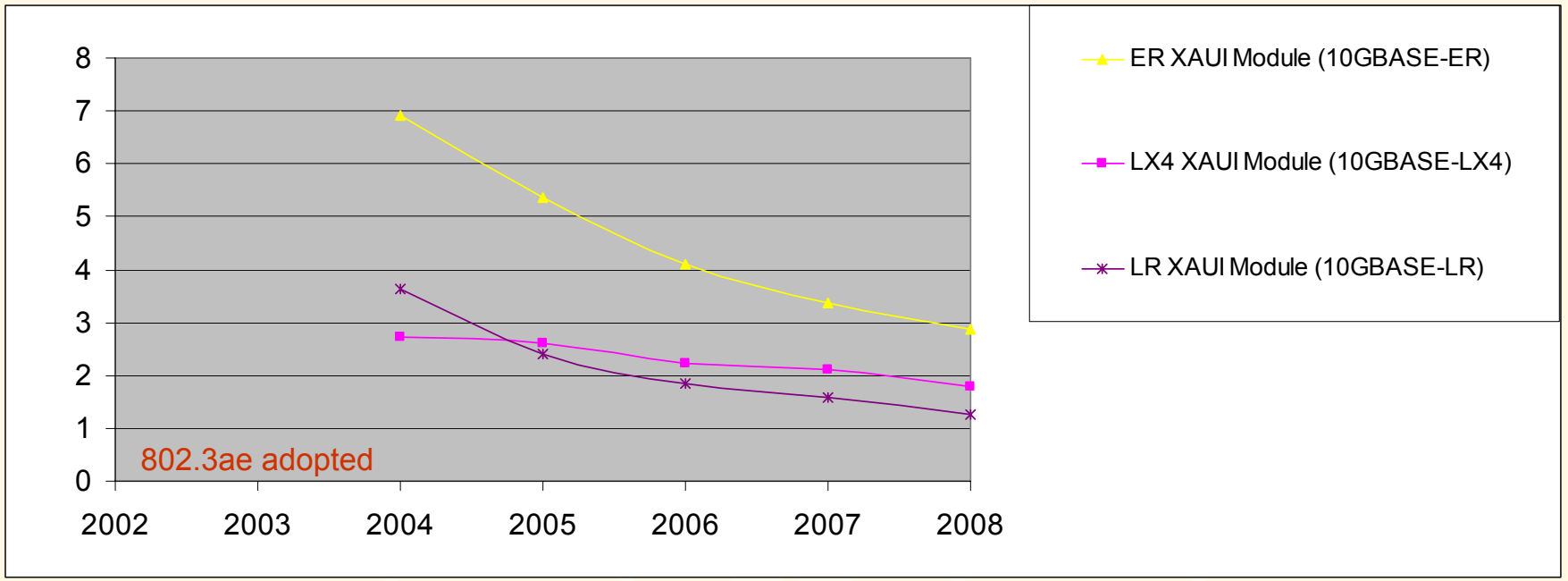
- 2008 unit count of all 10G 10km un-cooled DFB Modules: 380,537
  (all XAUI, XFP, SFP+, for LR and OC-192 SR-1)
- 2008 unit count of all LX4 Modules: 58,902
  (all XAUI for LX4)
- 2008 unit count of all 10G 40km cooled EML Modules: 95,222
  (all XAUI, XFP, SFP+, for ER and OC-192 IR-2)



- ER optics have similar volume to LX4 optics so are fair historical comparisons.
- LR optics are 6x volume of LX4 optics so are unfair historical comparisons.
- Based on volume comparison, the fair historical analogy for 40GE-CWDM is 10GE-LX4, and for 40GE-Serial is 10GE-ER (not 10GE-LR).

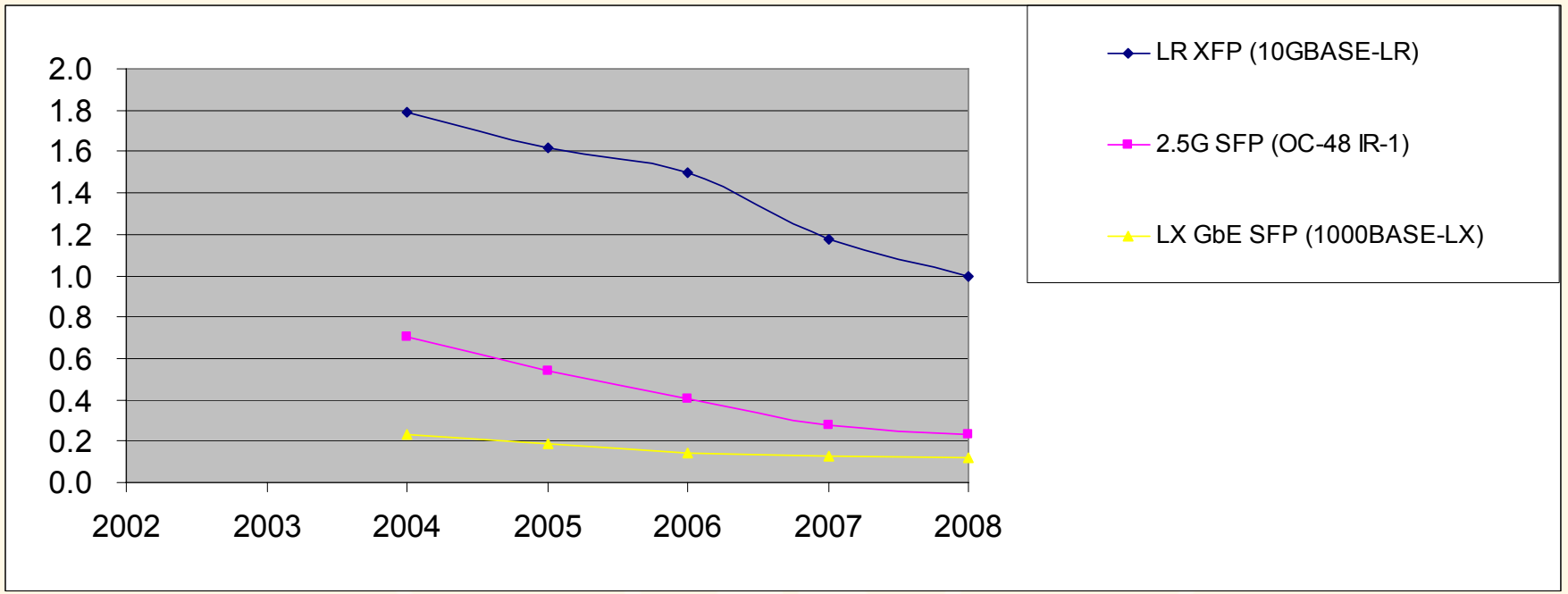
- 2008 unit count of all XAUI modules: 378,352
  (all XAUI, for ER, LR and SR)
- LR and ER use high volume XAUI IC which favors their cost versus LX4

10GE XAUI PMD Historical Relative Market Cost



- 10GE-LX4 is being supplanted by 10GE-LRM and therefore has limited cost reduction investment; cost curve is atypically flat for Ethernet optics.
- 6 years after 802.3ae standard adoption in 2002, 10GE-ER still has 60% higher cost than 10GE-LX4.
- 3 years after standard adoption 10GE-LR cost crossed over 10GE-LX4 cost.
- 6 years after standard adoption and despite 6x higher volume, 10GE-LR has only 30% lower cost than 10GE-LX4.

1GE, 2.5G, 10GE PMD Historical Relative Market Cost



- All curves on this graph and all other graphs normalized to 2008 LR XFP cost.
- The cost of Gigabit Ethernet has declined significantly during 10GE adoption (about 50% in 4 years.)
- A similar decline can be assumed for the cost of 10GE during 40GE adoption, which will benefit 40GE-CWDM cost decrease.
- Ratio of 10G PMD cost to 2.5G PMD (OC-48 IR-1 SFP) cost gives a historical basis for estimating ratio of 40G PMD cost to 10G PMD (LR XFP) cost.

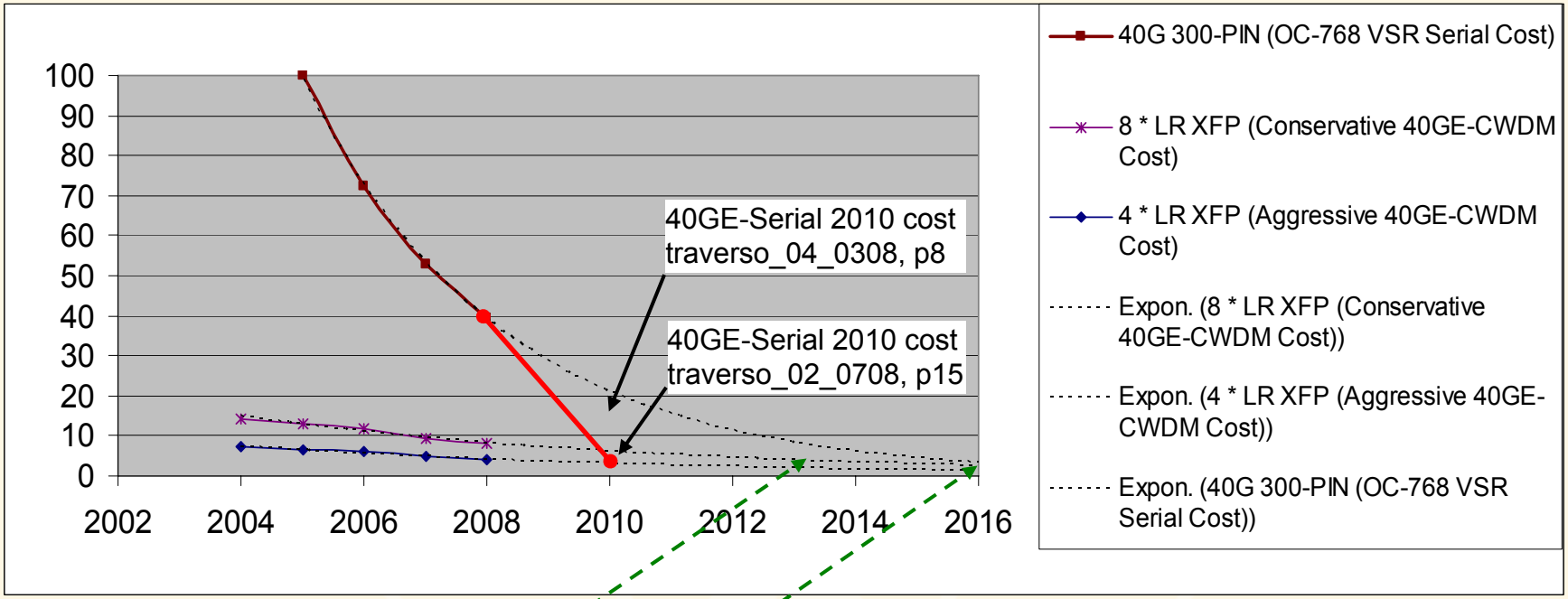
40GE PMD cost multipliers from 2008 10GE costs

- Conservative cost multipliers based on comparison to 2.5G SFP (OC-48 IR-1)
  - 40GE-CWDM cost / 10GE-LR XFP [1]
    ≈ 10GE-LX4 XAUI cost / 2.5G SFP cost (from p.6 and p.7)
    ≈ 8 x
  - 40GE-Serial cost / 10GE-LR XFP cost [2]
    ≈ 10GE-ER XAUI cost / 2.5G SFP cost (from p.6 and p.7)
    ≈ 12 x
- Aggressive cost multipliers based on aggressive component costs
  - 40GE-CWDM cost / 10GE-LR XFP cost [1]
    ≈ 4 x
  - 40GE-Serial cost / 10GE-LR XFP cost [2]
    ≈ 6 x

[1] 40GE-CWDM PMD will use existing 10GE-LR technology so cost multipliers are immediately usable for predicting cost.

[2] 40GE-Serial PMD will use new 3rd Gen 40G ICs and Optics (based on PCB 40G I/O,) which is a major departure from existing 1st and 2nd Gen 40G ICs and Optics (based on GPPO 40G I/O.) A lengthy development period is required before cost multipliers are usable for predicting cost.

40G PMD Cost Projections

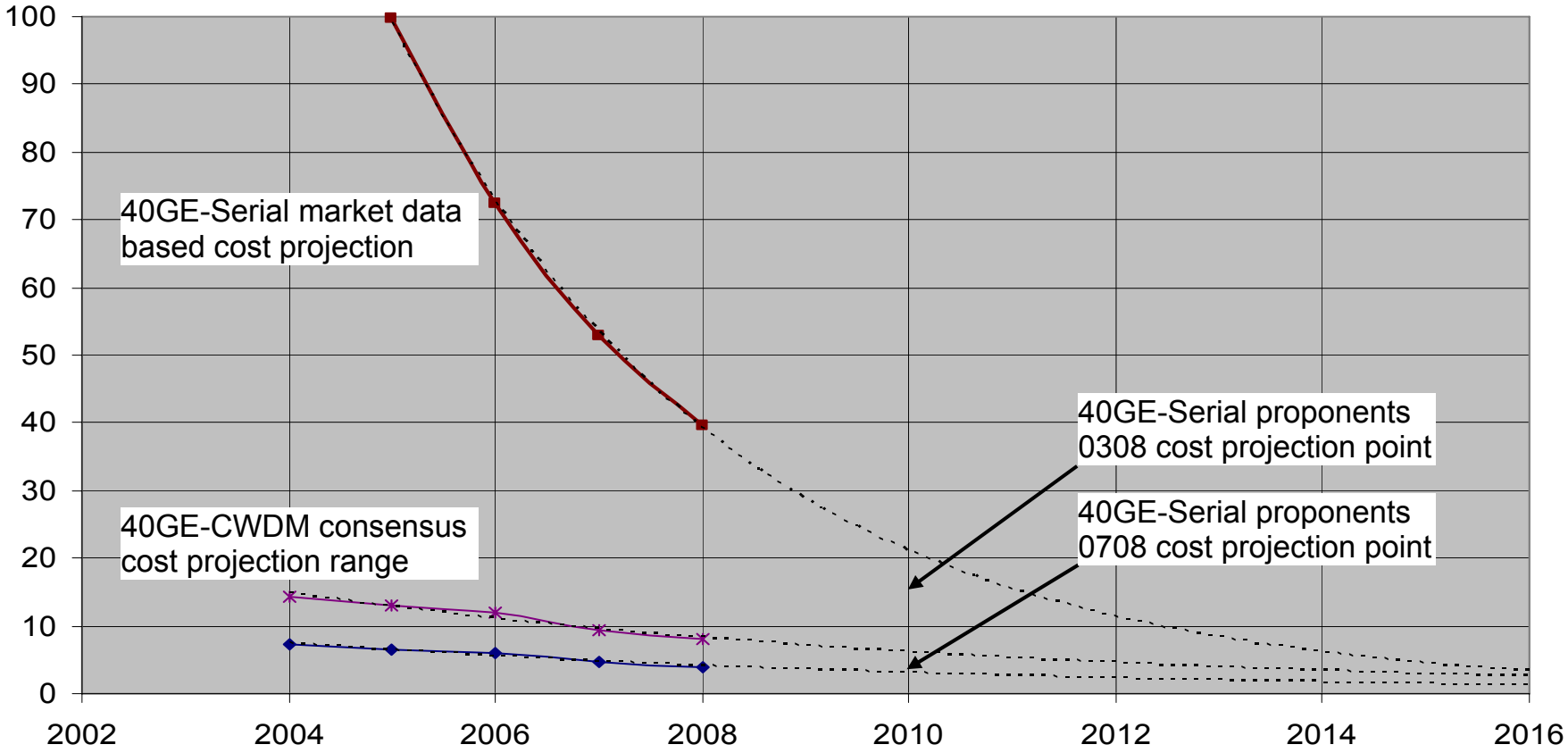


- Solid curves are actual 40G VSR cost, and LR XFP multiplier 40GE-CWDM cost.
- Dashed curves are solid curves exponentially trend lined to predict future cost.
- Red line shows 40G Serial technology going from 2008 40x cost to claimed 2010 4.6x 10GE LR cost. This is a 9x cost reduction in two years, which is an unprecedented departure from all historical cost decrease trends.
- Aggressive cross-over of 40GE-CWDM cost by 40GE-Serial cost is in 2013, with more likely cross-over after 2016.

Conclusions

- The fair historical analogy, based on technology and volume, for 40GE-CWDM is 10GE-LX4, and for 40GE-Serial is 10GE-ER (not 10GE-LR.)
- Despite 10GE-LX4 cost curve being atypically flat compared to other Ethernet optics cost curves, today 10GE-ER has 60% higher cost than 10GE-LX4 (6 years after 802.3ae standard adoption.)
- Despite being an unfair historical analogy (different technology and 6x higher volume,) today 10GE-LR has only 30% lower cost than 10GE-LX4.
- The cost of 10GE during 40GE adoption is expected to decrease, continuing 40GE-CWDM cost reduction and lowering cross-over target for 40GE-Serial.
- Claimed 40GE-Serial cost cross-over in 2010 is unsupported by any historical cost data:
  - Requires aggressive 40G-Serial cost multiplier and conservative 40GE-CWDM cost multiplier,
  - Requires an unprecedented 9x optical PMD cost reduction in two years.
- Based on historical cost data and reasonable component cost assumptions, aggressive cross-over of 40GE-CWDM cost by 40GE-Serial cost is in 2013 (3 years after 40GE standard adoption,) with more likely cross-over after 2016 (6 years after 40GE standard adoption.)

Appendix 1: 40G PMD Cost Projection Worksheet



Same data as on page 9. Refer to legend on page 9 for exact definition of cost curves.