Implementation Options for 150m 100GBASE-SR4 Links

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Introduction

- 150m links:
  - Eases upgrade path from 40GBASE-SR4 to 100GBASE-SR4
    - Utilize existing infrastructure
  - Minimize datacenter physical layout redesign
    - Small percentage of population, yet
    - Big impact to physical layout in large data centers
  - Maintain end user confidence in MMF technology
  - Further data center and overall SMF/MMF Ethernet growth through effective technology implementation

Introduction

- Demonstrate implementation options for 150m links on OM4 with FEC
  - Impact of:
    - Spectral width
    - Rise/fall time
    - Equalization
    - Fiber bandwidth

- The benefits 150m links offer seem achievable with small changes based on the June 2012 Fiber Channel spreadsheet.

References

- David Cunningham, *Thoughts on Initial Parameters for the 32GFC MMF Link Model*

  http://www.t11.org/ftp/t11/pub/fc/pi-6/12-211v0.pdf

- David Cunningham, *Modifications To The Mode Partition Noise Penalty Calculation For Equalised 32GFC Links*

  http://www.t11.org/ftp/t11/pub/fc/pi-6/12-042v0.pdf

- Jonathan King, *MMF links, EQ and FEC*
  http://www.ieee802.org/3/100GNGOPTX/public/nov11/king_01_1111_NG100GOPTX.pdf

- Stephen Bates et al., *Backplane NRZ FEC Baseline Proposal*

  http://www.ieee802.org/3/bj/public/mar12/gustlin_01_0312.pdf

Spreadsheet Model Parameters

- Based on Fiber Channel 12-211v0 with following exceptions in red.
- FEC: Q=4.3, targeting BER < E-12 after FEC.
- Data rate = 25781 MBd, Power budget = 8.0 dB
- Transmitter
  - Center wavelength Uc = 840nm
  - RMS spectral width and rise/fall time: variables.
  - Power OMA = -2dBm
  - RIN (OMA) = -128dB/Hz
  - DJ = 8.56ps; DCD_DJ = 2.14ps.
  - MPN k(OMA) = 0.3; Modal Noise Penalty = 0.3dB

Spreadsheet Model Parameters

- OM4 MMF
  - BWm = 4500 MHz.km
  - Attn. = 3.5dB/km, connector loss = 1.5dB
  - Disp. min. Uo = 1316nm; Disp. So = 0.10275 ps/(nm^2.km)
- Receiver
  - Nominal Sensitivity OMA = -11.00dBm
  - Rec_BW = 19039MHz
  - RMS Baseline Wander SD = 0.013 fraction of 1/2 eye

Tx Characteristics (150m and FEC)

RMS spectral width (nm)	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
Ts (20-80) (ps)	22.7	22.2	21.5	20.8	19.9	18.9	17.7	16.3	14.6
Pisi (dB) <3.6	3.59	3.60	3.59	3.60	3.60	3.60	3.60	3.60	3.59
System margin (dB) >0	1.2	1.1	1.1	1.0	0.9	0.8	0.6	0.4	0.2
V.E.C.P. (dBo) <4.0	3.76	3.77	3.76	3.77	3.77	3.78	3.77	3.77	3.76

- VCSELs with narrow spectral width or fast rise/fall time may not be effective to implement
- Pisi limited to 3.6 dB

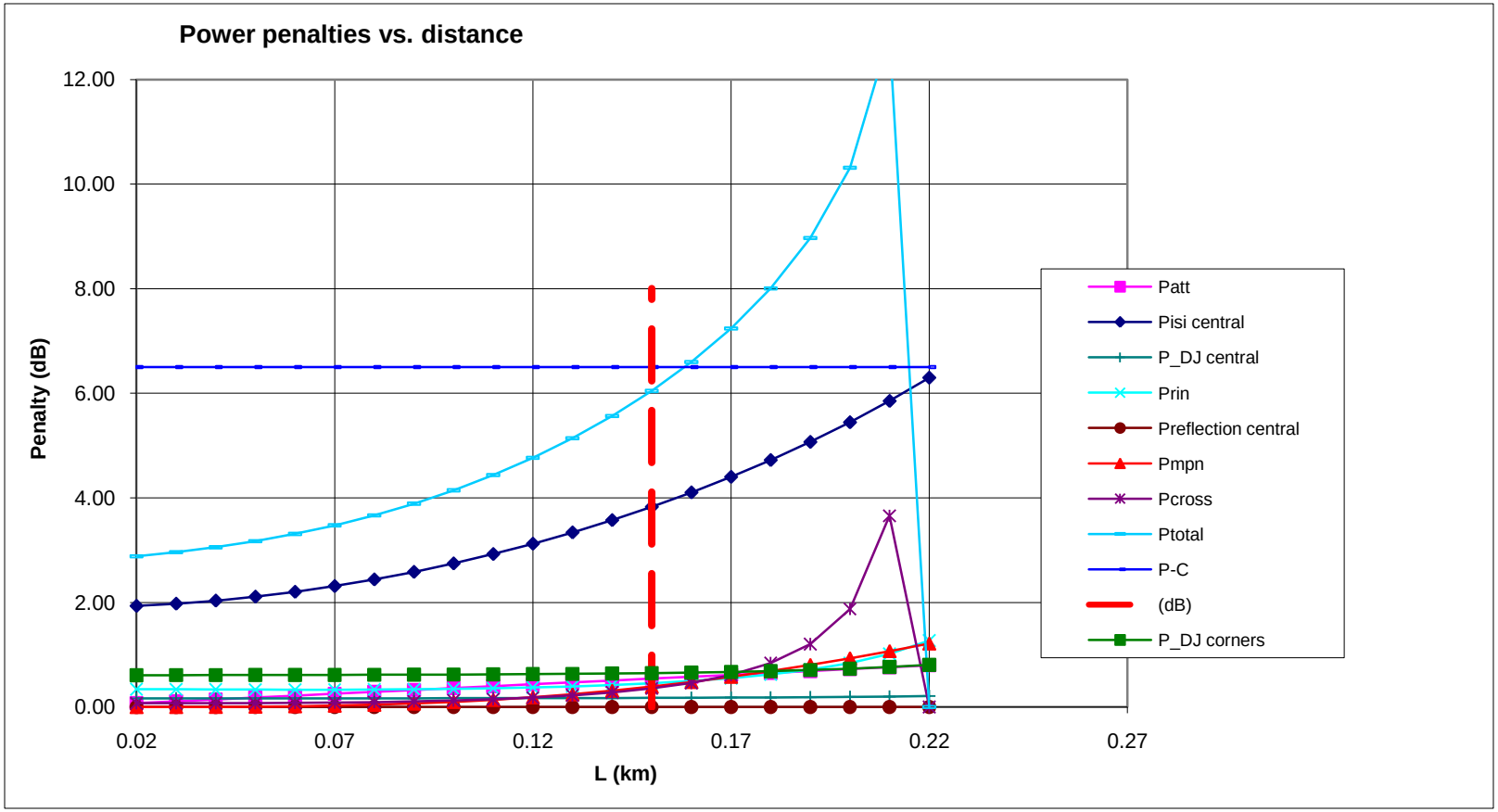
Tx Characteristics (150m with FEC)

- What if allowing Pisi<3.9dB, as in 12-211v0?

RMS spectral width (nm)	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
Ts (20-80) (ps)	23.6	23.0	22.4	21.7	20.8	19.9	18.7	17.4	15.3
Pisi (dB) <3.9	3.83	3.81	3.82	3.82	3.81	3.83	3.81	3.81	3.71
System margin (dB) >0	0.8	0.8	0.8	0.7	0.6	0.5	0.3	0.1	0.0
V.E.C.P. (dBo) <4.0	4.00	3.98	3.99	4.00	3.99	4.00	3.99	3.99	3.88

Power Penalties vs. Distance
150m on OM4 is Well Behaved at 180m

- RMS spectral width = 0.55nm and Ts (20-80) = 19.9ps.



Tx Characteristics (150m FEC + equalization)

RMS spectral width (nm)	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
Ts (20-80) (ps)	23.6	23.0	22.4	21.7	20.8	19.3	17.3	14.8	11.5
System margin (dB) >0	0.6	0.5	0.4	0.2	0.1	0.0	0.0	0.0	0.0
V.E.C.P. (dBo) <4.0	4.00	3.98	3.99	4.00	3.99	3.86	3.69	3.50	3.29

- 3-tap FFE equalization (T11/12-042V0), γ = 1.0, fixed EQ tap value = 0.14.

RMS spectral width (nm)	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
Ts (20-80) (ps)	23.6	23.0	22.4	21.7	20.8	19.9	18.7	17.4	15.3

- Equalization provides no improvement compared to FEC only (Pisi < 3.9).

Increasing Fiber Bandwidth (150m with FEC)

Fiber Bwm (MHz.km)	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000
RMS spectral width (nm)	0.54	0.57	0.59	0.60	0.61	0.62	0.62	0.63	0.63	0.64
Pisi (dB) <3.9	3.80	3.83	3.84	3.82	3.82	3.83	3.80	3.83	3.80	3.84
System margin (dB) >0	0.5	0.4	0.3	0.2	0.2	0.1	0.2	0.1	0.1	0.0
V.E.C.P. (dBo) <4.0	3.98	4.00	4.01	4.00	4.00	4.01	3.97	4.00	3.98	4.01

- Model parameters from slides 5-6 (except fiber BWm)
- Ts (20-80) = 20ps
- Increased Fiber BWm to maximize RMS spectral width
- For this scenario, increasing Fiber BW yields limited gains

Summary

- Retaining 150m reach will:
  - best service existing infrastructure
  - maintain positive technology perception
  - increase industry adoption
- 150m drops may be a smaller percentage of deployment, but tend to have a bigger impact upon overall layout
- 150m appears reasonable from most recent FC spreadsheet
  - Increasing Pisi to 3.9dB relaxes rise/fall time (as in FC 12-211v0)
  - Equalization does not appear to be required

Suggest further group investigation of the effects of spectral width, rise/fall time, Pisi, and equalization to enable 150m reach

Backup, Snapshot of 25.8Gb/s, FEC

Nexans

Spreadsheet by David Cunningham, Avago Technologies								Rev.	#REF!	This file	#REF!	of	#REF!					
Basics	Input=	**Bold**	Ts(20-80)	*19.9*	ps	Case: 850nm serial	**newMMF**	Attenuation=	**3.5**	dB/km	Model/format rev	####	of	#REF!				
	Q=	**4.30**	Ts(10-90)	30	ps	*Target* Target reach	**0.15**	km	*Fiber*	at	850	nm	NomSens OMA	**-11.00**	dBm	Margin	0.45	dB at
Base Rate=	**25781**	MBd	RIN(OMA)	**-128**	dB/Hz	*and* L_start=	**0.02**	km	C_att=	1.00		*Receive* Refl Rx	**-12**	dB	*Answer!*	0.15	km	
Transmitter			RIN at MinER	-136.0	dB/Hz	*graph* L_inc=	**0.01**	km	Attenuation=	3.62	dB/km	Rec_BW=	**19,039**	MHz	est Rx BW	**19,039**	MHz	
Wavelength Uc	**840**	nm	RIN_Coef=	**0.70**		Power Budget P=	8.00	dB	at	840	nm	c_rx	**329**	ns.MHz				
Uw (see notes)	**0.55**	nm	Det.Jitter	**8.56**	ps inc. DCD	Connections C	**1.50**	dB	Disp. min. Uo=	**1316**	nm	T_rx(10-90)	17.3	ps	Test Source ER=			
Tx pwr OMA=	**-2.00**	dBm	DCD_DJ=	**2.14**	ps TP3	Pwr.Bud.-Conn.Loss	6.50	dB	Disp. So=	**0.10275**	ps/nm^2*km	TP4 Eye	8	ps	*Test Tx*	**6.5**	dB	
Min. Ext Ratio=	3.65	dB	Effect. DJ=	0.18	(UI) ex DCD	C1=	**480**	ns.MHz	Disp. D1=	-108.41	ps/(nm.km)	Opening	(=Tx ey	TestERpen	1.98	dBo		
"Worst"ave.TxPwr	**-1.0**	dBm	MPN k(OMA)	**0.3**		Reflection Noise factor	**0**	no units	γ =	**1.0**		RMS Baseline wander SD	**0.013**	fraction of 1/2 eye				
Ext. ratio penalty	4.01	dBo	Tx eye height	39.1%		Effective Rate	27286	MBd	(not in use)	**10**					V.E.C.P.	4.00	dBo	
Tx mask X1=	**0.3**	UI	Refl Tx	**-12**	dB	Tb_eff=	37	ps	BWm=	**4500**	MHz*km	P_BLW(no ISI)	0.01	dB				Stressed
X2=	**0.4**	UI	ModalNoisePen	**0.3**	dB	Effective Rec Eye	0.21	UI	Eff. BWm=	4.5E+03	MHz*km	P_BLW	0.01	dB				Rx sens
Y1=	**0.25**		Tx mask top	0.2	UI													

L (km)	Patt (dB)	Ch IL (dB)	D1.L ps/nm	D2.L ps/nm	BWcd (MHz)	effBWm (MHz)	Te (ps)	Tc (ps)	Pisi central J=0, dB	P Eye corners (dB)	P_DJ central (dB)	P_DJ corners (dB)	Preflection central (dB)	Beta	SDmpn	Pmpn (dB)	Prin (dB)	Pcross central (dB)	Ptotal central (dB)	<Ptotal corners (dB)	LP Pen central (dB)	10GbE Method Margin (dB)	OMA central (dBm)
0.002	0.01	1.51	-0.22	0.00	2E+06	2.3E+06	30	35	1.90	0.24	0.17	0.61		-1E-02	0.00	0.00	0.34	-0.17	2.20	2.88	2.2	4.3	-4.5
0.02	**0.07**	**1.57**	**-2.2**	**0.00**	**156,810**	**225,000**	**30**	**35**	**1.93**	**0.24**	**0.17**	**0.61**	**0**	**-0.10**	**0.00**	**0.00**	**0.34**	**0.07**	**2.9**	**3.6**	**2.8**	**3.6**	**-4.7**
0.03	0.11	1.61	-3.3	0.00	104,540	150,000	31	35	1.98	0.24	0.17	0.61	0	-0.15	0.00	0.00	0.34	0.07	3.0	3.6	2.9	3.5	-4.7
0.04	0.14	1.64	-4.3	0.00	78,405	112,500	31	36	2.03	0.24	0.17	0.61	0	-0.20	0.01	0.00	0.34	0.07	3.1	3.7	2.9	3.4	-4.8
0.05	0.18	1.68	-5.4	0.00	62,724	90,000	32	36	2.11	0.24	0.17	0.61	0	-0.26	0.01	0.01	0.33	0.07	3.2	3.9	3.0	3.3	-4.8
0.06	0.22	1.72	-6.5	0.00	52,270	75,000	32	37	2.20	0.24	0.17	0.61	0	-0.31	0.02	0.01	0.33	0.08	3.3	4.0	3.1	3.2	-4.9
0.07	**0.25**	**1.75**	**-7.6**	**0.00**	**44,803**	**64,286**	**33**	**37**	**2.31**	**0.24**	**0.17**	**0.61**	**0**	**-0.36**	**0.03**	**0.03**	**0.33**	**0.08**	**3.5**	**4.2**	**3.22**	**3.0**	**-4.9**
0.08	0.29	1.79	-8.7	0.00	39,202	56,250	34	38	2.44	0.25	0.17	0.62	0	-0.41	0.03	0.04	0.33	0.09	3.7	4.4	3.4	2.8	-5.0
0.09	0.33	1.83	-9.8	0.00	34,847	50,000	35	39	2.58	0.25	0.17	0.62	0	-0.46	0.04	0.07	0.34	0.11	3.9	4.6	3.6	2.6	-5.0
0.10	0.36	1.86	-10.8	0.00	31,362	45,000	36	39	2.75	0.25	0.17	0.62	0	-0.51	0.05	0.10	0.35	0.12	4.1	4.8	3.8	2.4	-5.1
0.11	0.40	1.90	-11.9	0.00	28,511	40,909	37	40	2.93	0.25	0.17	0.62	0	-0.56	0.06	0.14	0.36	0.15	4.4	5.1	4.0	2.1	-5.2
0.12	**0.43**	**1.93**	**-13.0**	**0.00**	**26,135**	**37,500**	**38**	**41**	**3.12**	**0.25**	**0.17**	**0.63**	**0**	**-0.61**	**0.07**	**0.18**	**0.37**	**0.18**	**4.8**	**5.5**	**4.3**	**1.7**	**-5.3**
0.13	0.47	1.97	-14.1	0.01	24,125	34,615	39	42	3.34	0.25	0.17	0.63	0	-0.66	0.08	0.24	0.39	0.22	5.1	5.9	4.7	1.4	-5.5
0.14	0.51	2.01	-15.2	0.01	22,401	32,143	40	44	3.57	0.25	0.17	0.64	0	-0.72	0.08	0.31	0.42	0.28	5.6	6.3	5.1	0.9	-5.6
0.15	0.54	2.04	-16.3	0.01	20,908	30,000	41	45	3.83	0.26	0.17	0.65	0	-0.77	0.09	0.39	0.45	0.36	6.0	6.8	5.5	0.5	-5.8
0.16	0.58	2.08	-17.3	0.01	19,601	28,125	42	46	4.10	0.26	0.18	0.66	0	-0.82	0.10	0.48	0.50	0.46	6.6	7.3	6.0	-0.1	-6.0