10 Gb/s Ethernet Fiber Optic Link Alternatives

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10 Gb/s Ethernet (10GbE) Fiber Optic Link Perspective

- Gigabit Ethernet (GbE) Fiber Optic Link Models Provide A Framework For Evaluating 10GbE Link Alternatives
- Jitter Budget Projections For Fiber Optic Link & SerDes Are Key In Evaluating Alternatives
- There Will Be Considerable Synergy & Leverage Between Premises 10GbE & OC-192 Fiber Optic Link Alternatives
- Technology Will Be Available At Appropriate Cost Points To Support Development Of A 10GbE Standard

Objectives

- Summarize Analysis Of 2.5 Gb/s & 10 Gb/s Links
  - Multimode & Single Mode Fiber Distance Limits
  - Compare 850 nm & 1300 nm Sources
  - Compare Serial & Multi-Channel Parallel Cases
- Summarize Lower-Overhead Line Code Issues
- Illustrate Scaled Jitter Budget Parameters For 3.125 GBd & 12.5 GBd Line Rates

Some 10GbE Full Duplex Link Alternatives

- Multi-Channel Parallel Transmission
  - 10 @ 1 Gb/s (10 Fiber Pairs; New Ribbon)
    - Utilize GbE Specifications, Not Installed Fiber
  - 4 @ 2.5 Gb/s (1 Fiber Pair; Use Existing MMF & SMF)
- Serial 10 Gb/s (1 Fiber Pair; Use Existing SMF)
- Issues
  - Are MMF Link Lengths Viable?
  - Are Link Jitter Budgets Viable @ 2.5 &/Or 10 Gb/s?
  - Relative Cost Of Transceiver Alternatives?

4 @ 2.5 Gb/s WWDM Links

- Space Channels @ 1280 nm, 1300 nm, 1320 nm & 1340 nm To Utilize Low Cost Optical Mux-Demux Technology
- Uncooled Distributed Feedback (DFB) Lasers Will Operate Over 0-70 Deg C Ambient Temperature Range
- Supports Installed MMF Or SMF Full Duplex Links
- Does Not Require Optical Isolator For RIN Control
- Does Not Require External Laser Modulator For Jitter Control
- Quad Ser-Des Circuits Will Match Transceiver Interface
- Bundled SerDes-Transceiver Interfaces Will Ease Jitter Budget

WWDM: Wide Wavelength Division Multiplexing

10 Gb/s Serial Link Issues

- Can SONET OC-192 Long Reach Link Performance Be Cost Reduced For 5 km 10 Gb/s Serial Ethernet Links?
- Can A Directly Modulated (DM) Uncooled DFB Laser Meet Jitter Specifications?
- Is An External Optical Modulator Required?
- Is An Optical Isolator Required To Control RIN?
- Can An 8 dB Optical Power Budget Be Achieved With A PIN Detector & Suitable Preamplifier Circuits?

WWDM: Wide Wavelength Division Multiplexing

8B10B Line Code vs. Scrambling

- 8B10B Line Code (Fibre Channel & Gigabit Ethernet)
  - 25% Transmission Overhead
  - DC Balanced: Max Run Length =5; Max RDS =3
  - Supports Fast Processing Of Data & Control Characters
  - Matches GbE PCS Interfave
- Scrambling: SONET/SDH (1 + X^6 + X^7)
  - Avoids Transmission Overhead Line Rate Penalty
  - No Guarantee Of DC Balance; Can Have Long Run Length
  - Will Be Utilized In OC-192 SONET/SDH Links

RDS: Running Digital Sum

Lower Overhead Block Codes

- Objectives
  - Reduce Line Rate Overhead Compared To 8B10B
  - Allow Some Relaxation Of Run Length & RDS
- Example: 16B18B Block Code (12.5% Overhead)
  - Max. Run Length =42 Bits, Max. RDS = +/- 26
  - Does Not Cause Error Multiplication
- Issues
  - Impact On Jitter Relative To The 8B10B Block Code?
  - Compatibility With Existing GbE 8B10B-Based PCS?

RDS: Running Digital Sum PCS: Physical Coding Sublayer

MMF Link Lengths vs. Line Rates

Data Rate (Gb/s)	**1.0**	**2.5**	**2.5**
Line Rate (GBd)	**1.250 (8B10B)**	**2.500 (Scramble)**	**3.125 (8B10B)**
Power Budget (dB)	7.5*	6.5	6.5
Source Tr 20-80%, (ps)	260*	130	104
Link DCD, (ps)	80*	40	32
Modal Bandwidth (MHz*km)	**Link Length @ 850 nm, (m)**	**Link Length @ 850 nm, (m)**	**Link Length @ 850 nm, (m)**
200* @ 62MMF	275*	135	110
500* @ 50MMF	550*	280	225
Modal Bandwidth (MHz*km)	**Link Length @ 1300 nm, (m)**	**Link Length @ 1300 nm, (m)**	**Link Length @ 1300 nm, (m)**
Spectral Width, nm rms	4.0*	2.5	2.5
500* @ Both MMFs	680 (550*)	320	265

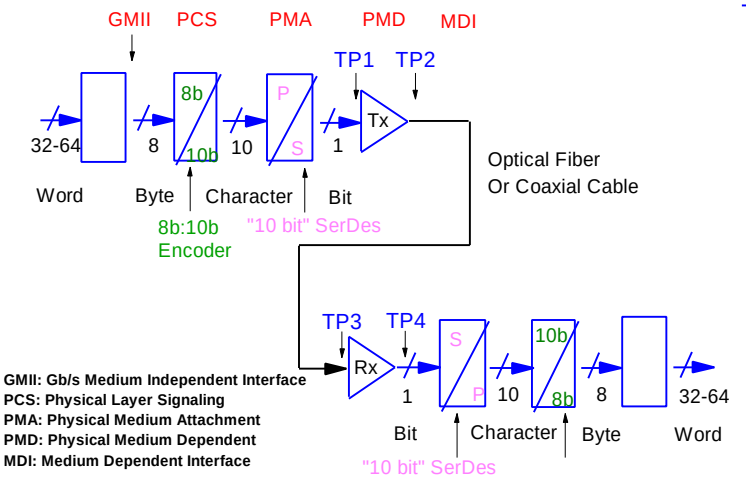
*: Gigabit Ethernet Specification

SMF Link Lengths vs. Data Rate

Data Rate, (Gb/s)	**1.0**	**2.5**	**10.0**
Line Rate, (GBd)	**1.250 (8B10B)**	**3.125 (8B10B)**	**12.500 (8B10B)**
Source Tr, 20-80%, ps	260*	104	26
Link DCD, ps	65*	26	6.5
Link Length, (km)	**5.0***		
Link Budget, (dB)	**8.0***		
Spectral width, nm rms	4.0*	1.6	0.35
Link Length, (km)	**10.0**		
Link Budget, (dB)	**10.5**		
Spectral width, nm rms	2.0	0.75	0.16

*: Gigabit Ethernet Specification

GbE Link Partitioning & Test Points



GMII: Gb/s Medium Independent Interface
PCS: Physical Layer Signaling
PMA: Physical Medium Attachment
PMD: Physical Medium Dependent
MDI: Medium Dependent Interface

GbE Jitter Budget At Test Points

1 Gb/s Ethernet			Optical PMD Draft D5.0						
		Input	**BOLD**	UI Parameters					
Line Rate (MBd)=	**1250**								
Baud Period (ps)=	800								
		Table 38-10							
	Total		**DJ**		**DCD**			**RJ**	
	TJ(UI)	TJ(ps)	DJ(UI)	DJ(ps)	rms, (ps)	% of DJ		RJ(UI)	RJ(ps)
SerDes Tx, TP1	0.240	192	**0.100**	80				**0.140**	112
FO Tx Added	0.284	227	**0.100**	80				**0.184**	147
FO Tx Out, TP2	0.431	345	0.200	160	46	29		0.231	185
Fiber Added	0.170	136	**0.050**	40				**0.120**	96
Fiber Out, TP3	0.510	408	0.250	200	65	33		0.260	208
FO Rx Added	0.332	266	**0.212**	170				**0.120**	96
FO Rx Out, TP4 **	0.749	599	0.462	370	80	22		0.287	229
SerDes Rx Window	0.251	201							

Scaled 3.125 GBd Jitter Budget

Line Rate (MBd)=	3125		With 8B10B Line Code						
Baud Period (ps)=	320								
		Input	**BOLD**	UI Parameters					
	Total		**DJ**			**DCD**		**RJ**	
	TJ(UI)	TJ(ps)	DJ(UI)	DJ(ps)		rms, (ps)	% of DJ	RJ(UI)	RJ(ps)
SerDes Tx, TP1	0.240	76.8	**0.100**	32.0				**0.140**	44.8
FO Tx Added	0.284	90.9	**0.100**	32.0				**0.184**	58.9
FO Tx Out, TP2	0.431	138.0	0.200	64.0		18.4	29	0.231	74.0
Fiber Added	0.120	38.4	**0.000**	0.0				**0.120**	38.4
Fiber Out, TP3	0.460	147.4	0.200	64.0		0.0	0	0.260	83.4
FO Rx Added	0.332	106.2	**0.212**	67.8				**0.120**	38.4
FO Rx Out, TP4	0.699	223.6	0.412	131.8		26.0	20	0.287	91.8
SerDes Rx Window	0.301	96.4							

Scaled 12.5 GBd Jitter Budget

Line Rate (MBd)=	12500		With 8B10B Line Code						
Baud Period (ps)=	80								
		Input	**BOLD**	UI Parameters					
	Total		**DJ**			**DCD**		**RJ**	
	TJ(UI)	TJ(ps)	DJ(UI)	DJ(ps)		rms, (ps)	% of DJ	RJ(UI)	RJ(ps)
SerDes Tx, TP1	0.240	19.2	**0.100**	8.0				**0.140**	11.2
FO Tx Added	0.284	22.7	**0.100**	8.0				**0.184**	14.7
FO Tx Out, TP2	0.431	34.5	0.200	16.0		4.6	29	0.231	18.5
Fiber Added	0.120	9.6	**0.000**	0.0				**0.120**	9.6
Fiber Out, TP3	0.460	36.8	0.200	16.0		0.0	0	0.260	20.8
FO Rx Added	0.332	26.6	**0.212**	17.0				**0.120**	9.6
FO Rx Out, TP4	0.699	55.9	0.412	33.0		6.5	20	0.287	22.9
SerDes Rx Window	0.301	24.1							

Conclusions

- A 4 @ 2.5 Gb/s WWDM Transceiver Will Cost-Effectively Support Installed 5 km SMF Links & MMF Links In Time For Development Of The 10GbE Standard
- Quad-SerDes Circuits @ 2.5 Gb/s Per Channel Will Be Available To Support Interface Specifications
- Serial 10 Gb/s Needs To Be (& Can Be) Specified For Long Reach Single Channel & Dense WDM SMF Links But Will It Be Cost Effective For 5 km Campus Links?