Qualified Partner Programme QPP

Fiber Optic Gigabit Ethernet Theory

Felice Guarna

R&M
Convincing cabling solutions

Applications

- The protocols used in LAN mostly base on Ethernet technology.
- In 1998 the IEEE 802.3z was passed (Gigabit Ethernet on glass FO) and for the first time brought about significant restrictions in FO cabling. Such as:
  - Variance of the max. link length (220 m - 550 m); dependent on:
    - fiber type (50/125 or 62.5/125)
    - fiber quality (bandwidth)
  - Channel insertion loss of up to 3.56 dB
  - Necessity - under certain conditions - to use a mode conditioning patchcord (MCP).

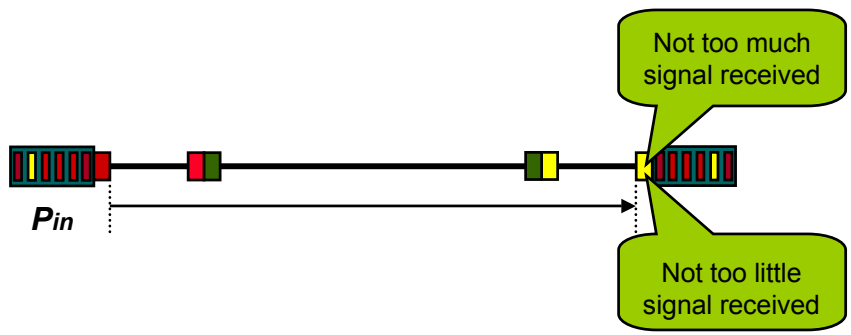
Attenuation limited applications

The good old days….

Optical power budget (OPB)

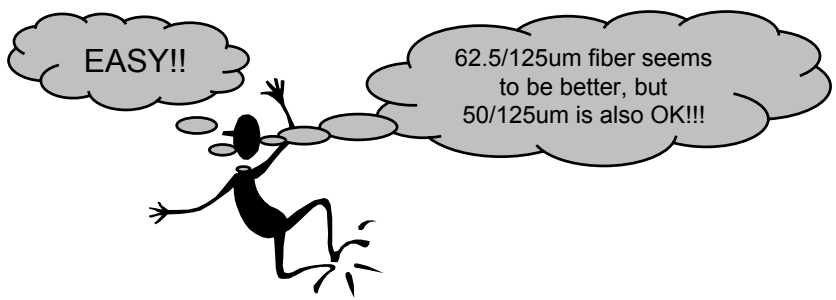
- Make sure that not too much signal is received (it could damage the receiver)
- Make sure that enough of the signal is received

We test and measure the attenuation the check that there is enough of the message which is received



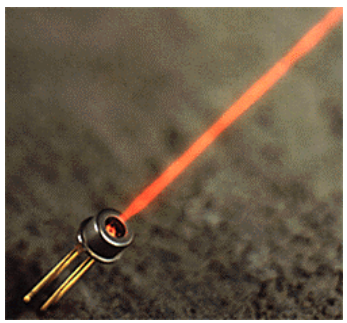
Attenuation limited applications

		50/125um		62.5/125um		
		Max Length metres	OPB max dB	Max Length metres	OPB max dB	OPB Diff.(dB)
850 nm	ISO/IEC 8802-3:FOIRL	514	3.3	1000	9.0	5.7
	ISO/IEC 8802-3:10Base FL/FB	1514	6.8	2000	12.5	5.7
	ISO/IEC TR 11802-4:4&16Mb/s Token Ring	1857	8.0	2000	13.0	5.0
	IEEE 802.12: Demand priority	371	2.8	500	7.5	4.7
1300nm	ISO/IEC 9314-3: FDDI PMD	2000	6.0	2000	11.0	5.0
	ISO/IEC 8802-3: 100 Base FX	2000	6.0	2000	11.0	5.0
	IEEE 802.12: Demand priority	533	2.3	2000	7.0	4.7
	ATM@52Mb/s	2000	5.3	2000	10.0	4.7
	ATM@155Mb/s	2000	5.3	2000	10.0	4.7



Bandwidth limited applications

- New applications use high data rates
- New Laser technologies using VCSEL CD Lasers (manly for 850 nm) and standard Lasers instead of LED
- Bandwidth requirements define channel lengths

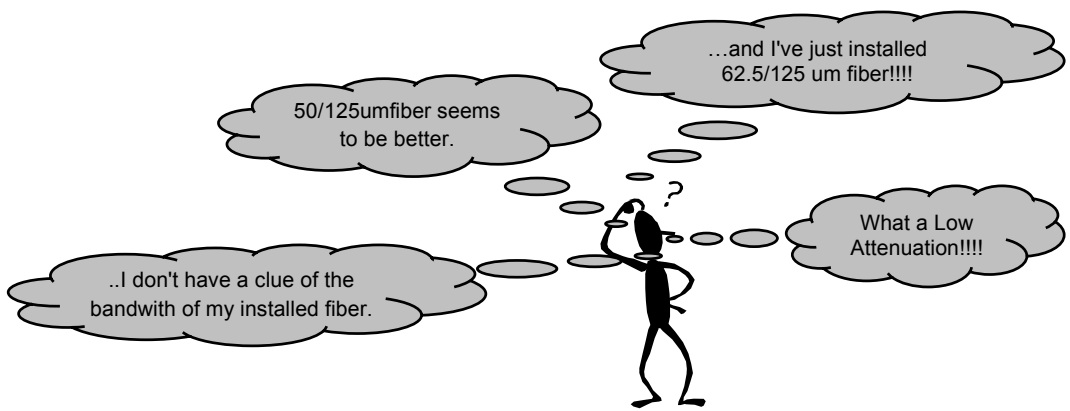


Problems

- Modal bandwidth was very rarely specified by installers
- Difficult to measure modal bandwidth on site
- Change of mentalities: Low attenuation channel do not guaranty longer length

Bandwidth limited applications

		50/125um 500/500 Mhz.km		62.5/125um 200/500 Mhz.km		
		Max Length metres	OPB max dB	Max Length metres	OPB max dB	OPB Diff.(dB)
850 nm	ATM@155Mb/s	1000	7.20	1000	7.20	0.00
	CD 14165:Fibre Channel @266Mb/s	2000	12.00	700	12.00	0.00
	CD 14165:Fibre Channel @531Mb/s	1000	8.00	350	8.00	0.00
	ATM@622Mb/s	300	4.00	300	4.00	0.00
	IEEE 802.3:1000BASE-SX Gigabit Ethernet	550	3.56	275	2.60	-0.96
	CD 14165:Fibre Channel @1062Mb/s	500	4.00	300	4.00	0.00
1300nm	CD 14165:Fibre Channel @133Mb/s	371	1.30	1500	6.00	4.70
	CD 14165:Fibre Channel @266Mb/s	2000	5.50	1500	6.00	0.50
	ATM@622Mb/s	330	2.00	500	6.00	4.00
	IEEE 802.3:1000BASE-LX Gigabit Ethernet	550	2.35	550	2.35	0.00



Bandwidth limited applications

Gigabit Ethernet

- Subject to many discussions
- What are the real issues?
  - Depends of the building
  - Maximum distances in the building
  - Expansion
  - Future application
  - Low attenuation
- Need to keep standard values for mated connectors IL < 0.5 dB

Bandwidth limited applications - Gigabit Ethernet

Fiber size(um)	Bandwidth (MHz.Km) 850nm	Bandwidth (MHz.Km) 1300nm	1000 BASE- SX 1st window 850nm CD Laser/VCSEL	1000 BASE- LX 2nd window 1300nm SM Laser
62.5/125	160	200		
62.5/125 (ANSI/EIA/TIA/568A)	160	500	220 meters @ 160MHz.Km	550 meters @ 500MHz.Km
62.5/125	200	400		
62.5/125	200	600		
62.5/125	250	1000		
50/125 & 62.5/125 ISO 11801 & EN 50173	200	500	275 meters @ 200MHz.Km	550 meters @ 500MHz.Km
50/125	200	400		
50/125	400	600		
50/125	400	800		
50/125	400	1000		
50/125	400	1200		
50/125	400	1500		
50/125 Proposal for 11801/EN50173	500	500	550 meters @ 500MHz.Km	> 550 meters @ 500MHz.Km
50/125	600	1000		

Classes and cables

Gigabit Ethernet (according to draft EN50173 (August 2001))

- **Given:**
  - Class **OF-300** channels support defined applications over a minimum length of **300 m.**
  - Class **OF-500** channels support defined applications over a minimum length of **500 m.**
  - Class **OF-2000** channels support defined applications over a minimum length of **2000 m.**
  - The channel attenuation limits are:

Class	Maximum channel attenuation (dB/km)			
	Multimode		Singlemode	
	850 nm	1300 nm	1310 nm	1550 nm
OF-300	2.55	1.95	1.80	1.80
OF-500	3.25	2.25	2.00	2.00
OF-2000	8.50	4.50	3.50	3.50

Category

Gigabit Ethernet (according to draft EN50173 (August 2001)

- **Given:**
- Multimode cable requirements:

Category	Maximum attenuation (dB/km)		Minimum Modal Bandwith (MHz*km)			
			Overfilled launch		Laser bandwith 1)	
	850 nm	1300 nm	850 nm	1300 nm	850 nm	1300 nm
OM1	3.5	1.5	200	500	ffs	ffs
OM2	3.5	1.5	500	500	ffs	ffs
OM3	3.5	1.5	500	500	2'000 ffs	ffs

1) Laser lauch conditions are currently under developement by IEC SC 86A. Optical fibers that only meet the overfilled launch conditions may not support the channel length of clause 5 and 6.

- Singlemode cable requirements:

Category	Maximum attenuation (dB/km)	
	1310 nm	1550 nm
OS1	1.0	1.0

1) The cut-off wavelength of singlemode optical fibre cables shall be less than 1280nm when measured in

How to calculate the lengths?

Gigabit Ethernet (according to draft EN50173 (August 2001))

- Formula:

Optical Fibre Type	Class	Implementation equations		Maximum length (m)
Multimode		**850 nm**	**1300 nm**	
Cable Category OM1/OM2/OM3	OF-300	L = 735-145x-90y	L = 1300-330x-200y	300
	OF-500	L = 935-145x-90y	L = 1500-330x-200y	500
	OF-2000	L = 2435-145x-90y	L = 3000-330x-200y	2000
Singlemode		**1310 nm**	**1550 nm**	
OS1	OF-300	L = 1800-500x-300y	L = 1800-500x-300y	300
	OF-500	L = 2000-500x-300y	L = 2000-500x-300y	500
	OF-2000	L = 3500-500x-300y	L = 3500-500x-300y	2000
C = the length of the channel [m]				
x = total number of mated connections in the channel				
y = total number of splices in the channel				

- **Note:** These equations assume 0.5dB attenuation per mated connection (as for two connection systems only 0.25% would exceed that value)

How to calculate the lengths?

Calculation for e.g. 2 splices and 2 connections:

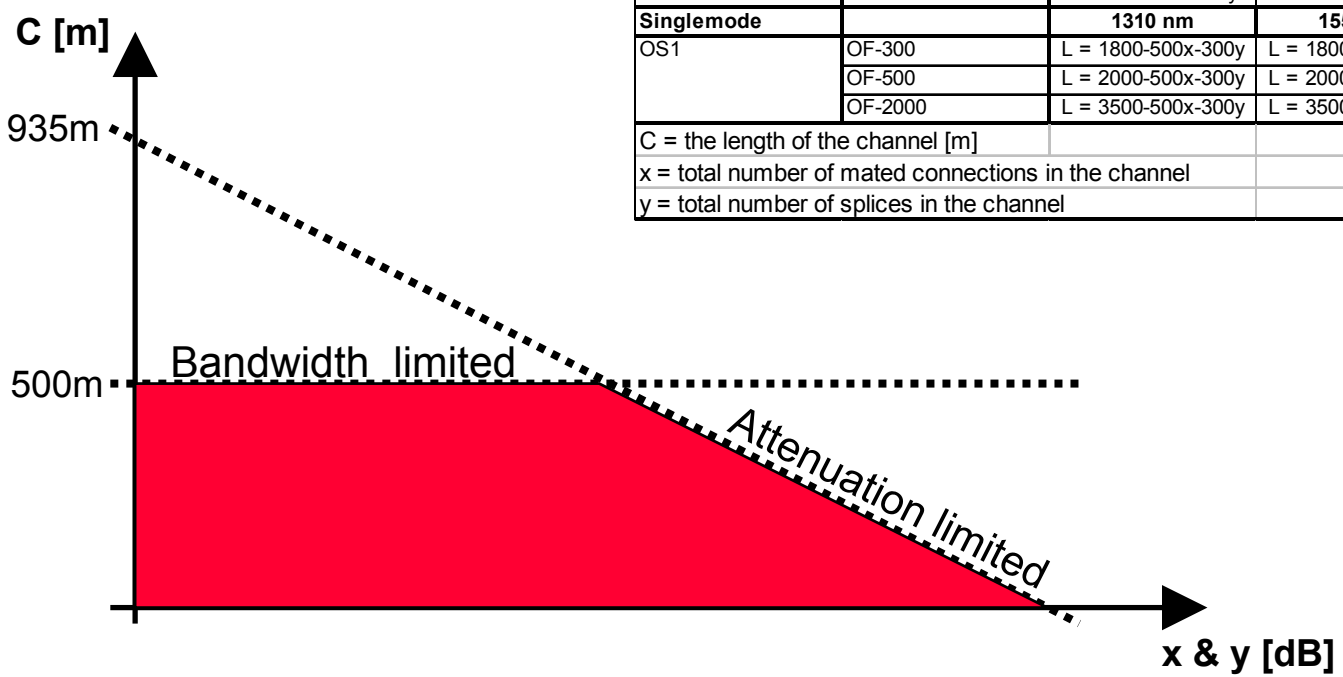
- x = 2 → 2 * 145 = 290
- y = 2 → 2 * 90 = 180
- → 935 - 290 - 180 = **465 m for OF-500 @ 850 nm (50/125)**
- → 735 - 290 - 180 = **265 m for OF-300 @ 850 nm (62.5/125*)**
- → 1500 - 660 - 400 = **440 m for OF-500 @ 1300 nm (50/125 & 62.5/125)**

Optical Fibre Type	Class	Implementation equations		Maximum length (m)
Multimode		**850 nm**	**1300 nm**	
Cable Category OM1/OM2/OM3	OF-300	L = 735-145x-90y	L = 1300-330x-200y	300
	OF-500	L = 935-145x-90y	L = 1500-330x-200y	500
	OF-2000	L = 2435-145x-90y	L = 3000-330x-200y	2000
Singlemode		**1310 nm**	**1550 nm**	
OS1	OF-300	L = 1800-500x-300y	L = 1800-500x-300y	300
	OF-500	L = 2000-500x-300y	L = 2000-500x-300y	500
	OF-2000	L = 3500-500x-300y	L = 3500-500x-300y	2000
C = the length of the channel [m]				
x = total number of mated connections in the channel				
y = total number of splices in the channel				

What does this mean?

Gigabit Ethernet (according to draft EN50173 (August 2001))

Optical Fibre Type	Class	Implementation equations		Maximum length (m)
Multimode		**850 nm**	**1300 nm**	
Cable Category OM1/OM2/OM3	OF-300	L = 735-145x-90y	L = 1300-330x-200y	300
	OF-500	L = 935-145x-90y	L = 1500-330x-200y	500
	OF-2000	L = 2435-145x-90y	L = 3000-330x-200y	2000
Singlemode		**1310 nm**	**1550 nm**	
OS1	OF-300	L = 1800-500x-300y	L = 1800-500x-300y	300
	OF-500	L = 2000-500x-300y	L = 2000-500x-300y	500
	OF-2000	L = 3500-500x-300y	L = 3500-500x-300y	2000
C = the length of the channel [m]				
x = total number of mated connections in the channel				
y = total number of splices in the channel				



How to calculate the lengths?

Gigabit Ethernet (according to IEEE 802.3, 1998 edition)

- **Given:**

Operating Range for 1000Base-SX:

Fiber Type	Modal Bandwith @ 850nm [MHz*km]	minimum range [m]
62.5/125	160	2 to 220
62.5/125	200	2 to 275
50/125	400	2 to 500
50/125	500	2 to 550

Operating Range for 1000Base-LX:

Fiber Type	Modal Bandwith @ 1300nm [MHz*km]	minimum range [m]
62.5/125	500	2 to 550
50/125	400	2 to 550
50/125	500	2 to 550
10/125	N/A	2 to 5000

How to calculate the lengths?

Gigabit Ethernet (according to IEEE 802.3, 1998 edition)

- **Given:**

Optical fiber and cable characteristics

Description:	62.5/125	62.5/125	50/125	50/125	10/125	Unit
Wavelngth	850	1300	850	1300	1310	nm
Cable attenuation (max)	3.75 or 3.5	1.5	3.5	1.5	0.5	dB/km
Bandwith	160	500	400	400	N/A	MHz*km
Bandwith	200	500	500	500	N/A	MHz*km

Channel Insertion loss

Description:	62.5/125	62.5/125	62.5/125	50/125	50/125	50/125	10/125	Unit
Wavelngth	850	850	1300	850	850	1300	1310	nm
Bandwith	160	200	500	400	500	400 or 500	N/A	MHz*km
Operating Distance	220	275	550	500	550	550	5000	m
Channel insertion Loss #1,2	2.33	2.53	2.32	3.25	3.43	2.32	4.5	dB

#1 These channel insertion loss numbers are based on the nominal operating wavelength.
#2 Operating distances used to calculate channel insertion loss those are listed in this table.

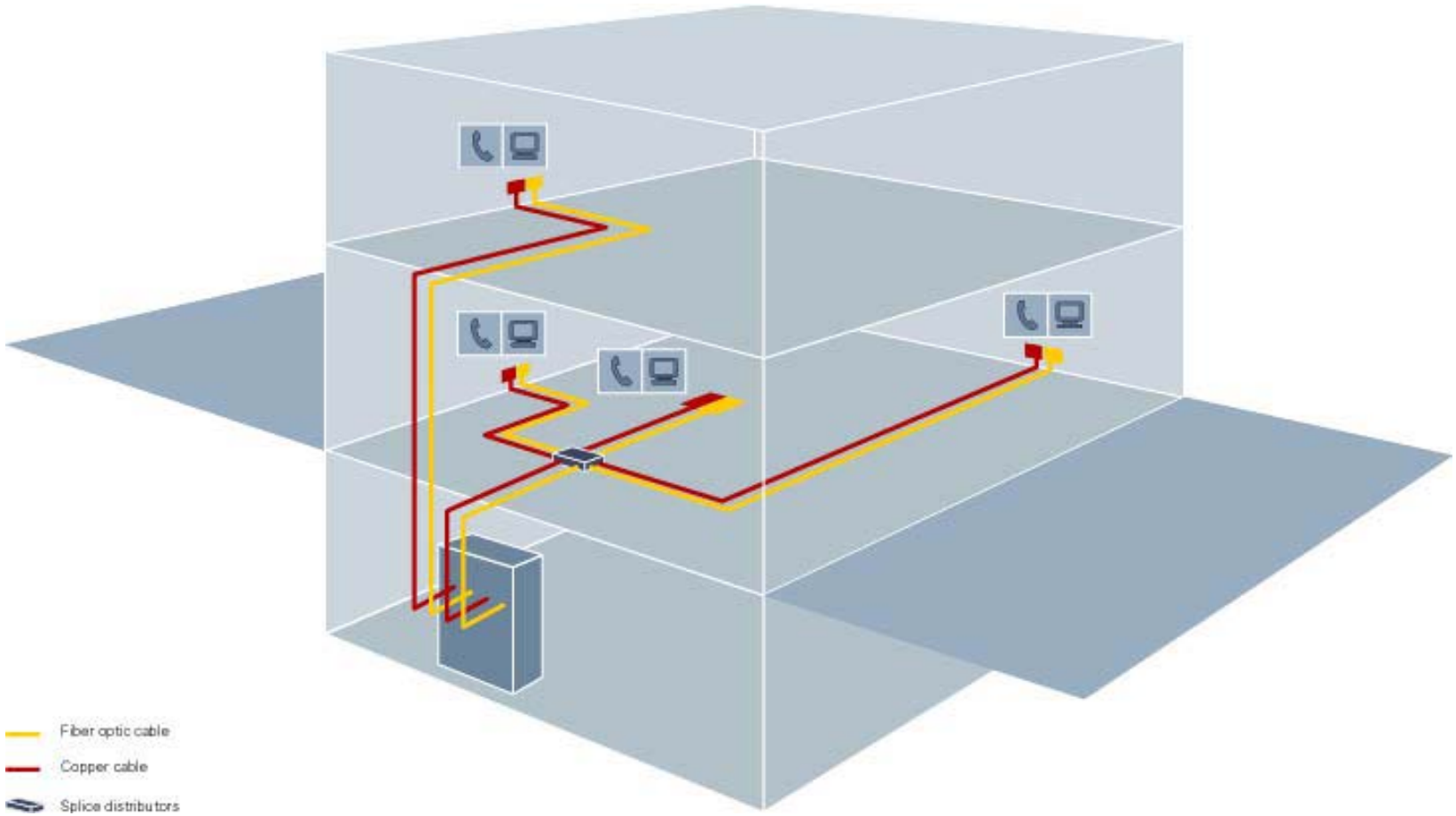
For MM fibers distance calculation done with 1.5 dB
For SM fibers distance calculation done with 2.0 dB

How to calculate the lengths?

Gigabit Ethernet (according to IEEE 802.3, 1998 edition)

- Calculation:
  - We know that 3.43dB is the limit for a 500 MHz*km fiber @ 850 nm
  - Where does this value come from?
    - 1.5dB calculated for connectors and splices
    - 550 m with attenuation of 3.5dB/km = 1.925dB
    - → 1.5dB + 1.925dB = 3.425dB ~ 3.43dB
  - For a system with 2 connectors and 2 splices this means:
    - 2 mated connectors = 2 * 0.5dB = 1.0dB
    - 2 splices = 2 * 0.3dB = 0.6dB
    - 1.6dB on “events” → 1.83dB left for the cable
    - 1.83dB / 3.5dB/km = **520 m**
  - Notice that 1 connector (0.5 dB) means in length:
    0.5dB / 3.5dB/km = 143m ~ 145m→ do you remember that value?

Collapsed backbone / Single point of administration



Any Questions?