Ethernet Overview

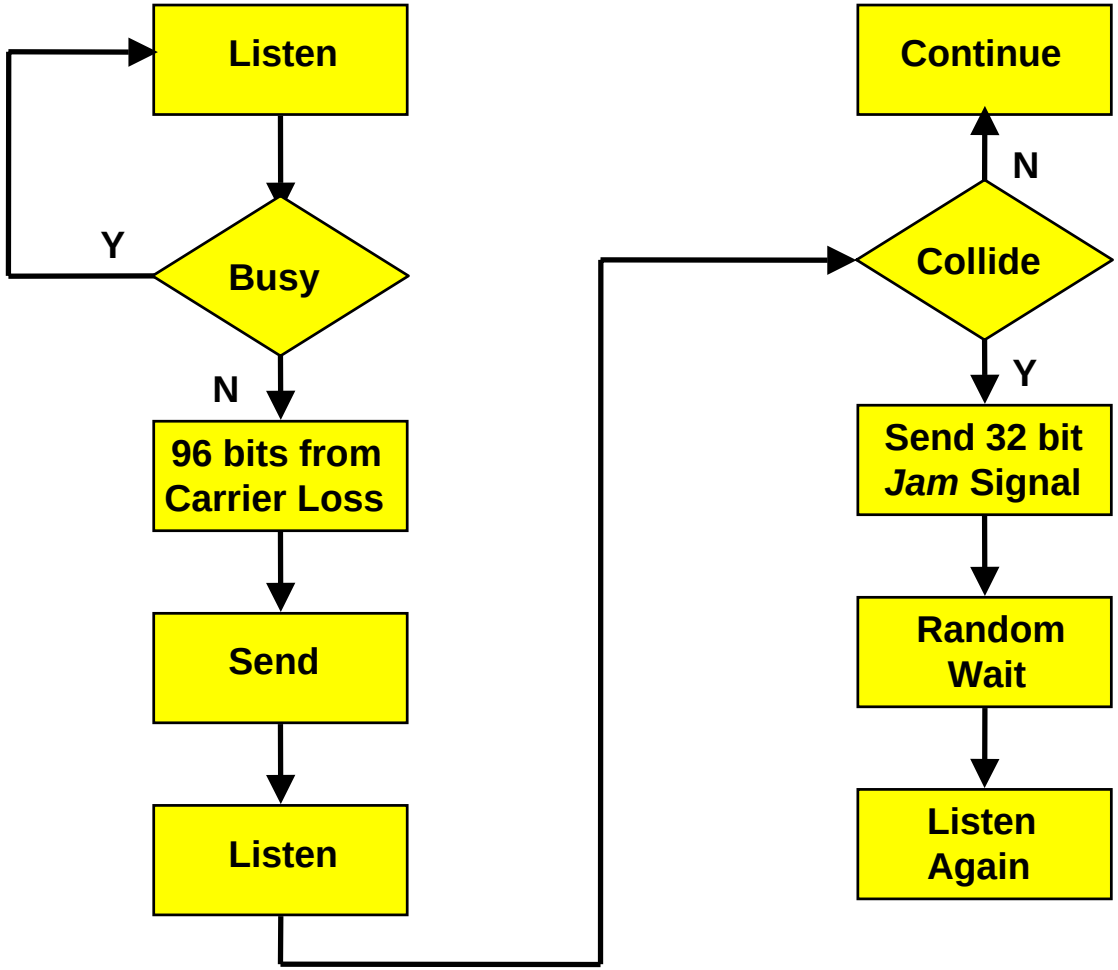
(tutorial with text in slides)

Ethernet Roadmap

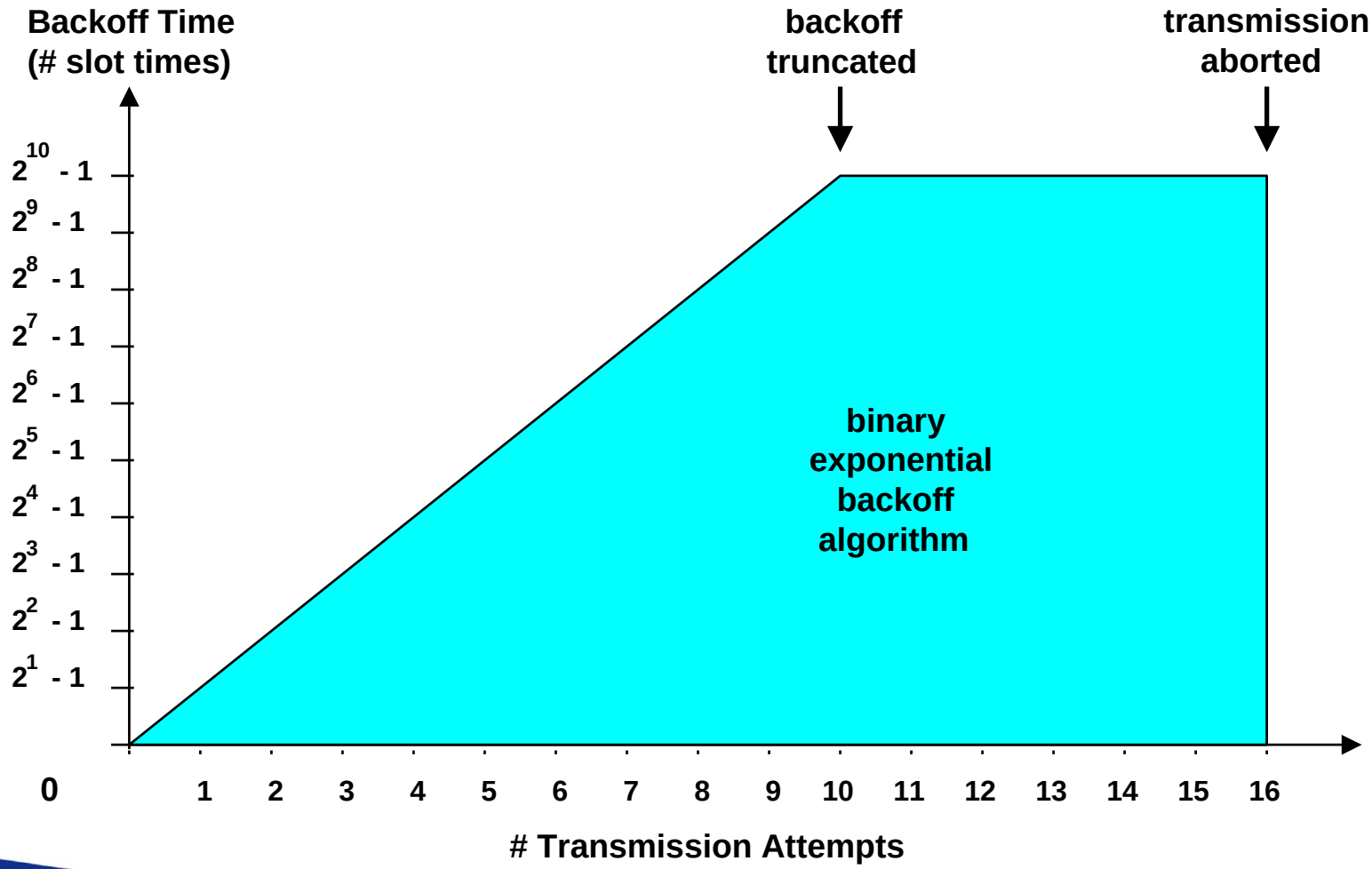
Brand-Rex

1976	originated as *Alohanet*
1980	industry standards initiatives
1982	Thick Coax deployment started
1984	Thin Coax products emerge
1988	1 Mbit/s *Starlan* became popular
1990	10BASE-T Twisted-Pair took over
1991	*Switched* Ethernet products
1992	100 Mbit/s Ethernet initiatives
1995	Gigabit Ethernet work started
1999	10 Gbit/s Ethernet proposed

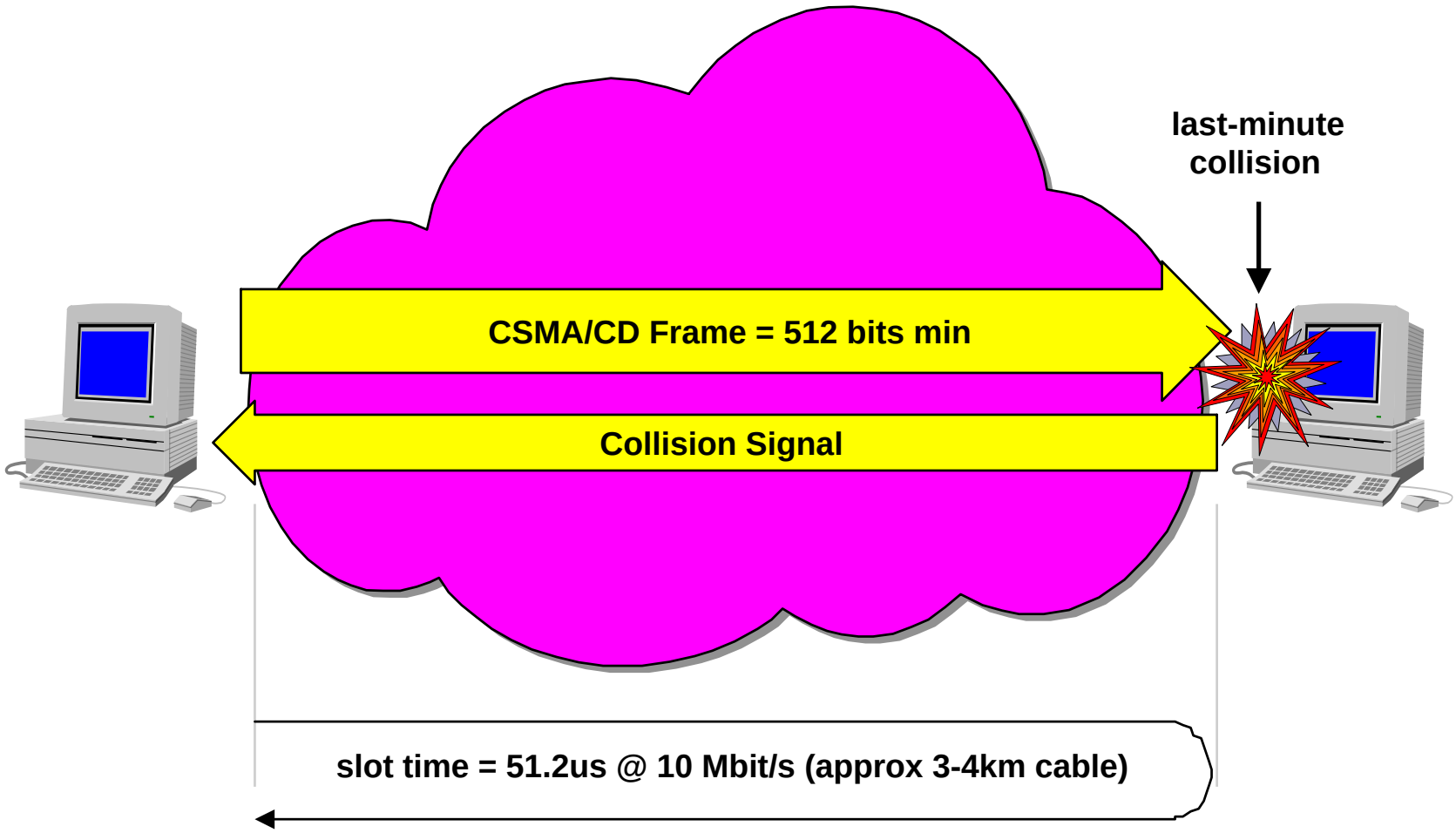
CSMA/CD Protocol



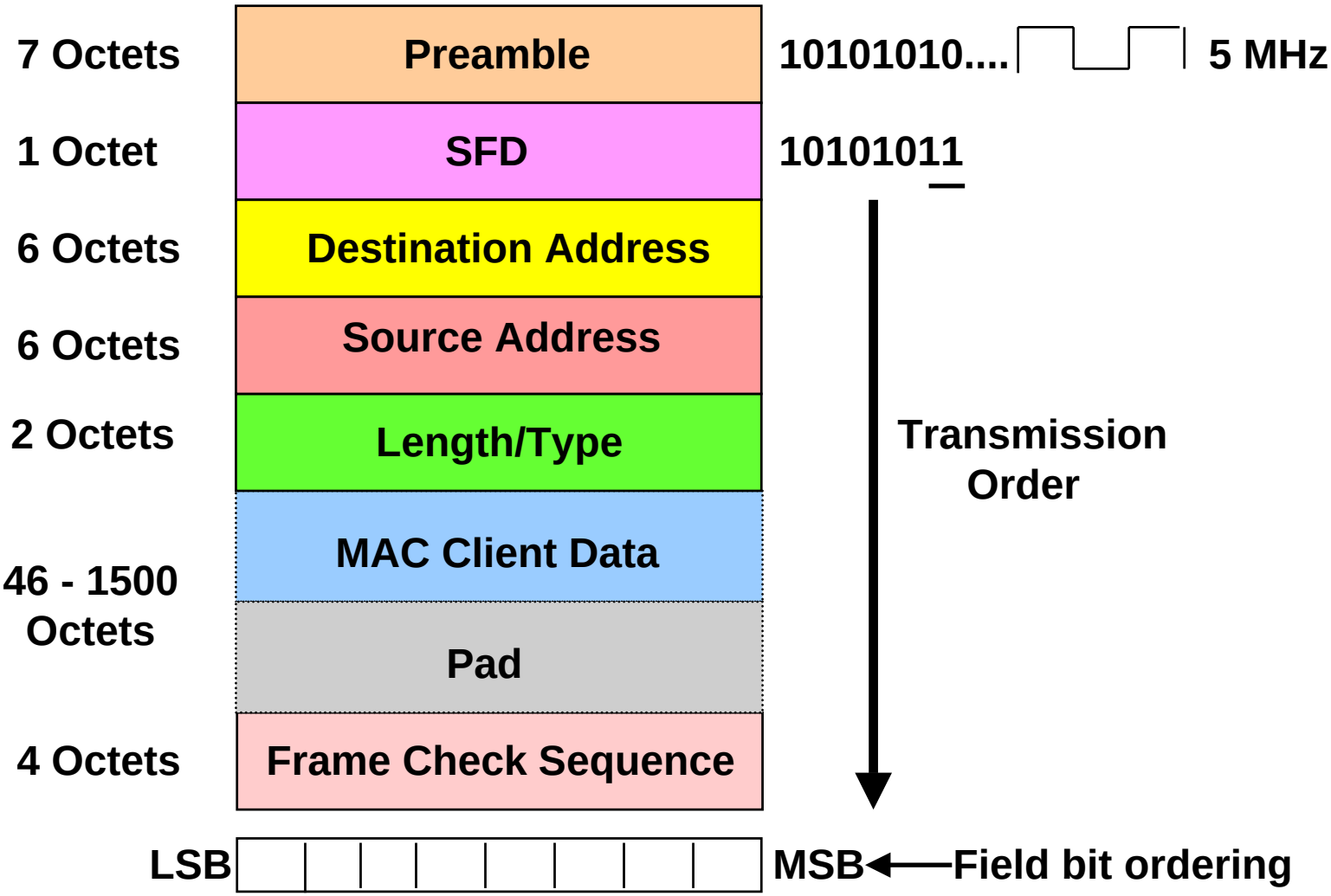
CSMA/CD Backoff Algorithm



CSMA/CD Collision Domain



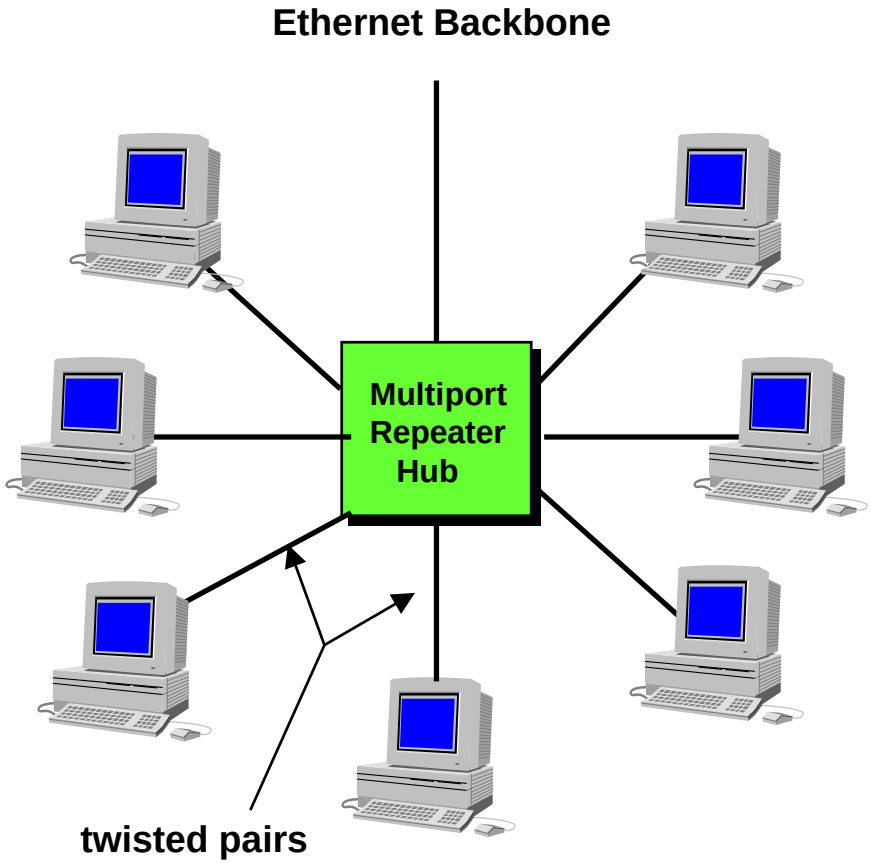
CSMA/CD Frame Format



Ethernet Standards

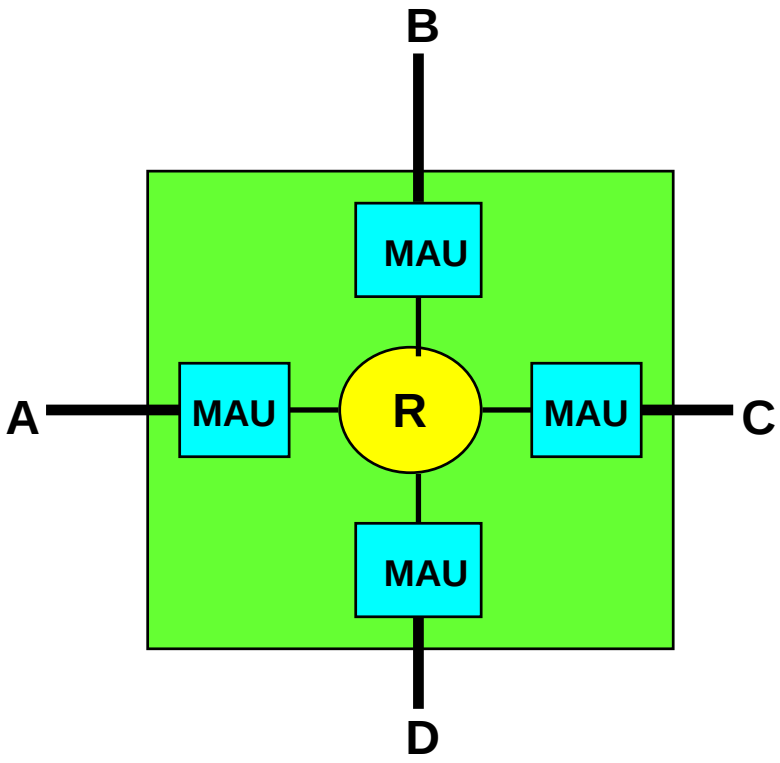
Name	Medium	Standard
1BASE 5	Twisted Pair	ISO/IEC 8802-3 (1996)
10BASE 5	Thick Coax	ISO/IEC 8802-3 (1996)
10BASE 2	Thin Coax	ISO/IEC 8802-3 (1996)
10BASE-F	Optical Fibre	ISO/IEC 8802-3 (1996)
10BASE-T	Twisted Pair	ISO/IEC 8802-3 (1996)
100BASE-F	Optical Fibre	IEEE 802-3u (1995)
100BASE-T	Twisted Pair	IEEE 802-3u (1995)
Full Duplex	-	IEEE 802-3x (1997)
1000BASE-F	Optical Fibre	IEEE 802-3z (1998)
1000BASE-T	Twisted Pair	IEEE 802-3ab (1999)
VLAN Tagging	-	IEEE 802.3ac (1998)
Link Aggregation	Optical Fibre	IEEE 802.3ad (2000)
10GBASE-F	Optical Fibre	IEEE 802.3ae (2002)
Remote Powering	Twisted Pair	IEEE 802.3af (2002)
10GBASE-T	Twisted Pair	IEEE 802.3an (2006)

10BASE-T



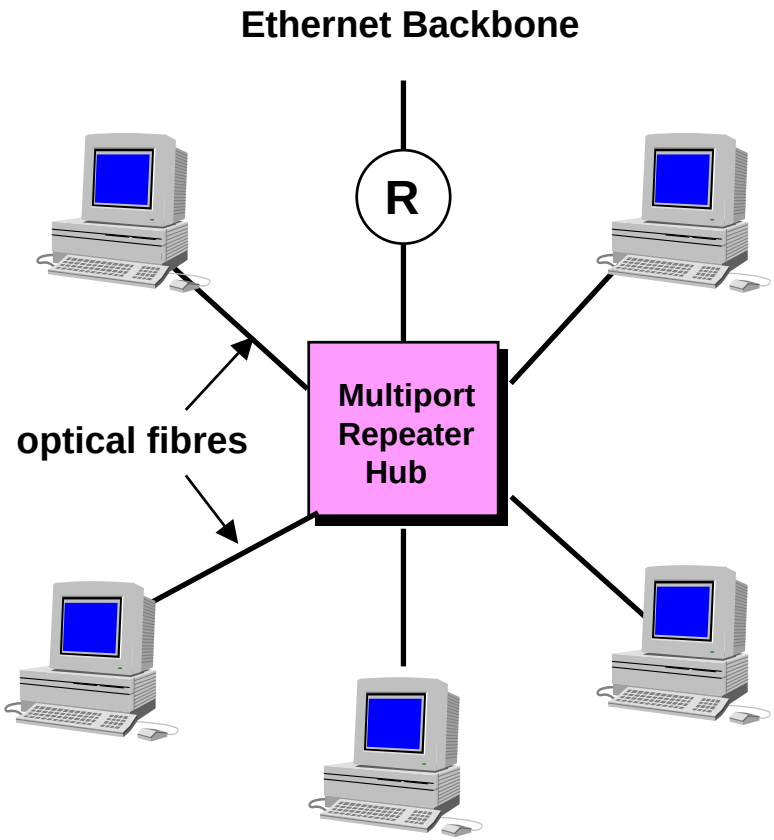
- based on existing phone wiring
- operates over 100m Cat 3 UTP
- uses 8-pin modular connectors
- requires multiport repeater hub
- hubs may be star - cascaded
- uses 1 bit/Hz Manchester code
- has powerful Rx signal squelch
- has a link integrity test facility

Multiport Repeater



- amplitude & timing recovered
- preamble regenerated on-the-fly
- fragments extended to 96-bits
- collisions enforced by jam signal
- collision/SQE test not implemented
- auto-partitioning of faulty segments
- min port MTBF reliability specified

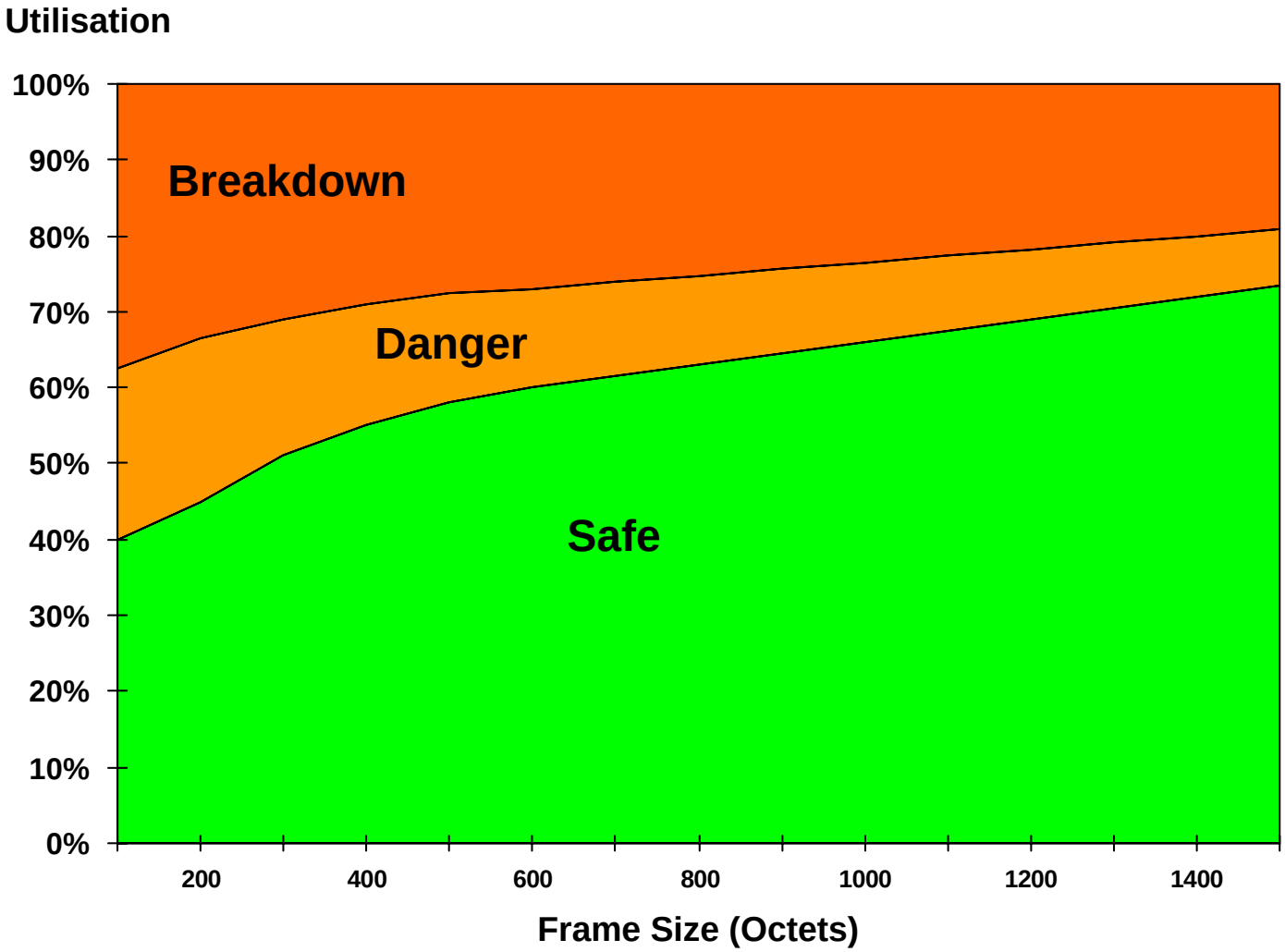
10BASE-F



- uses 2 multimode optical fibres
- ST optical connector specified
- up to 2km radius star topology
- active hub uses multiport repeater
- passive hub is optical star-coupler
- stations limited by passive hub only

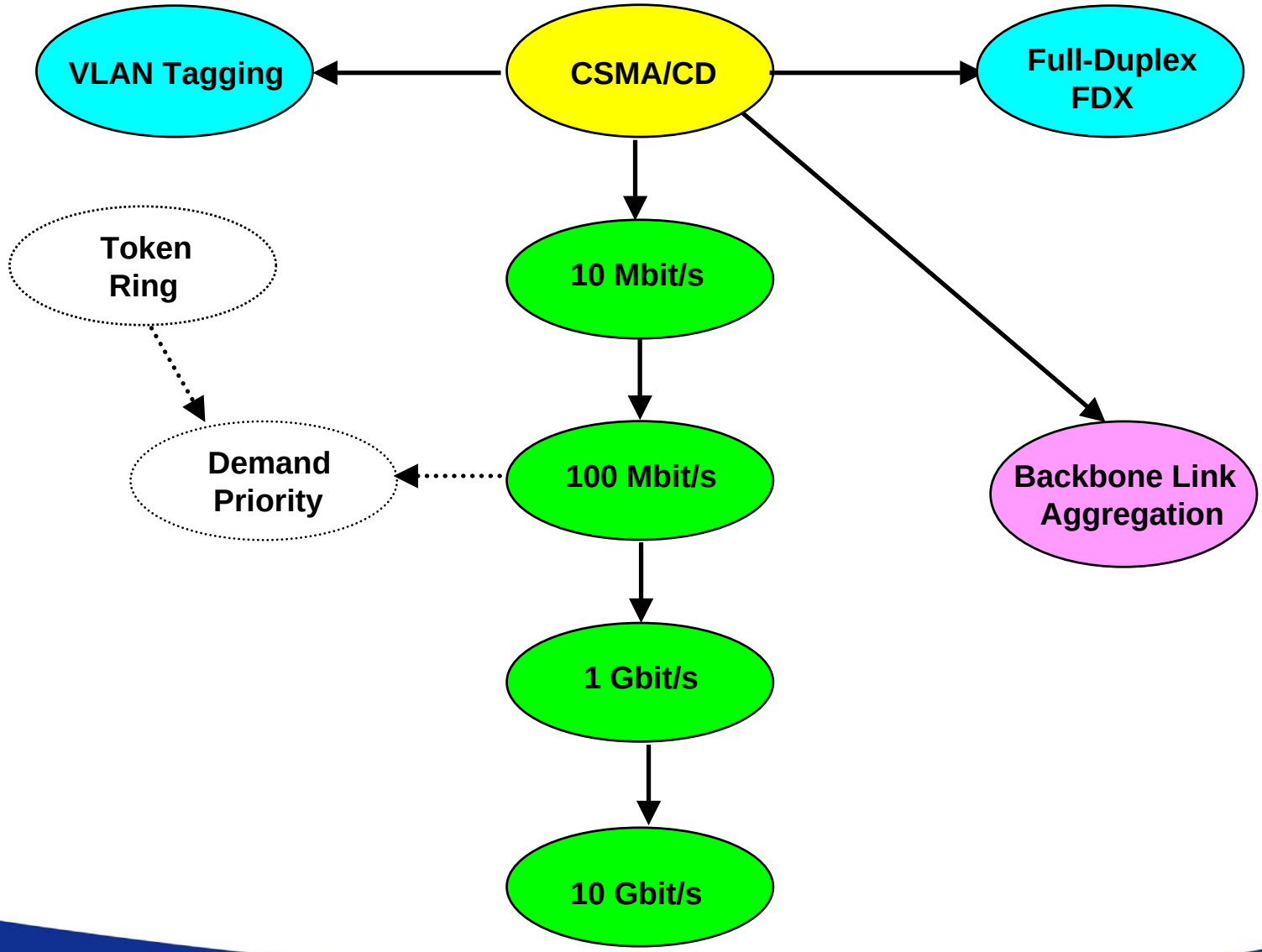
10 Mbit/s Half-Duplex Ethernet Performance

Brand-Rex



Source: ICL Tech.J Nov 1986

Ethernet Evolution



Full-Duplex (FDX) Ethernet

Brand-Rex

- provides double bandwidth capability
- best suited to real-time, interactive traffic
- IEEE 802.3x defines FDX, published 1997
- flow control based on *pause* command
- *pause* programmable 0 to 64k slot times
- *pause* via globally-assigned multicast ID
- switches *throttle back* when buffers full

“Fast” Ethernet Objectives

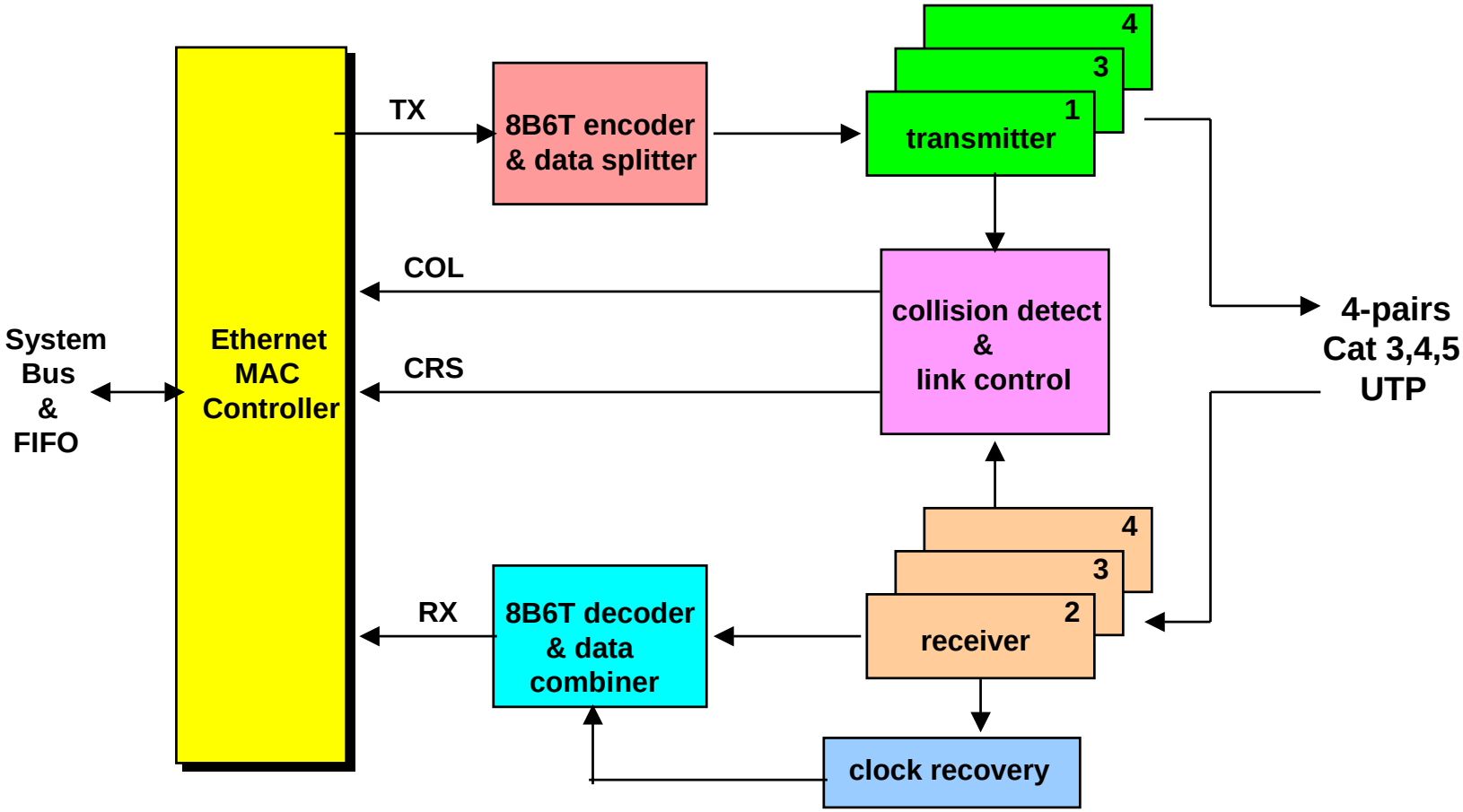
1. low-cost migration to 100 Mbit/s
2. provide simple 10/100 Mbit/s connection
3. leverage existing Ethernet investment
4. facilitate rapid standards development
5. support desktop multimedia applications
6. 100 metres over Category 3 UTP cable
7. compliant with structured cabling

100BASE-T Overview

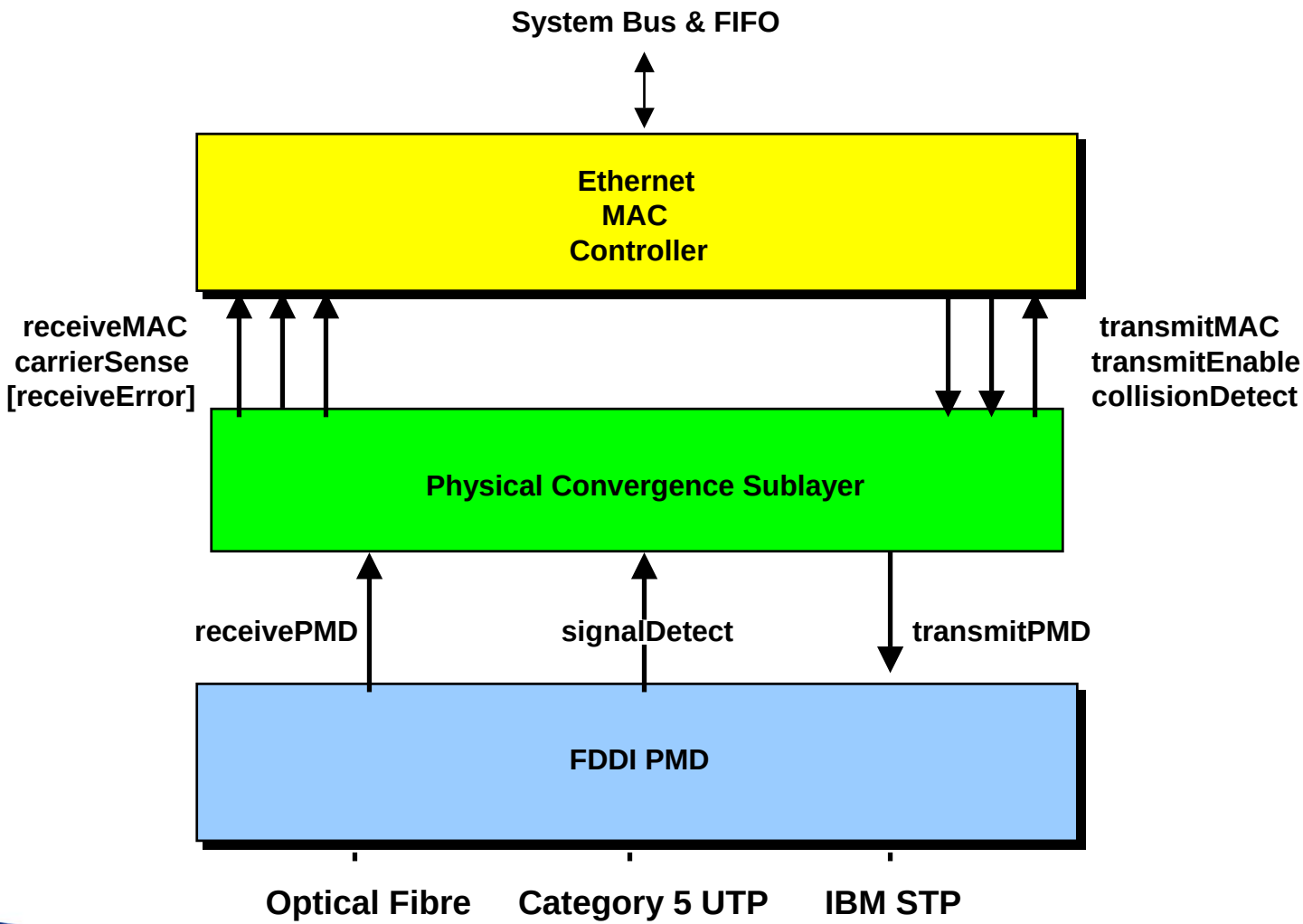
Brand-Rex

- scaled version of CSMA/CD protocol
- simple bit-regenerating repeaters
- 10/100 Mbit/s in single silicon chip
- 10/100 Mbit/s devices auto-configured
- 4-pair Category 3 cable = 100BASE-T4
- 2-pair Category 3 cable = 100BASE-T2
- 2-pair Category 5 cable = 100BASE-TX
- dual optical fibre cable = 100BASE-FX

100BASE-T4 Operation



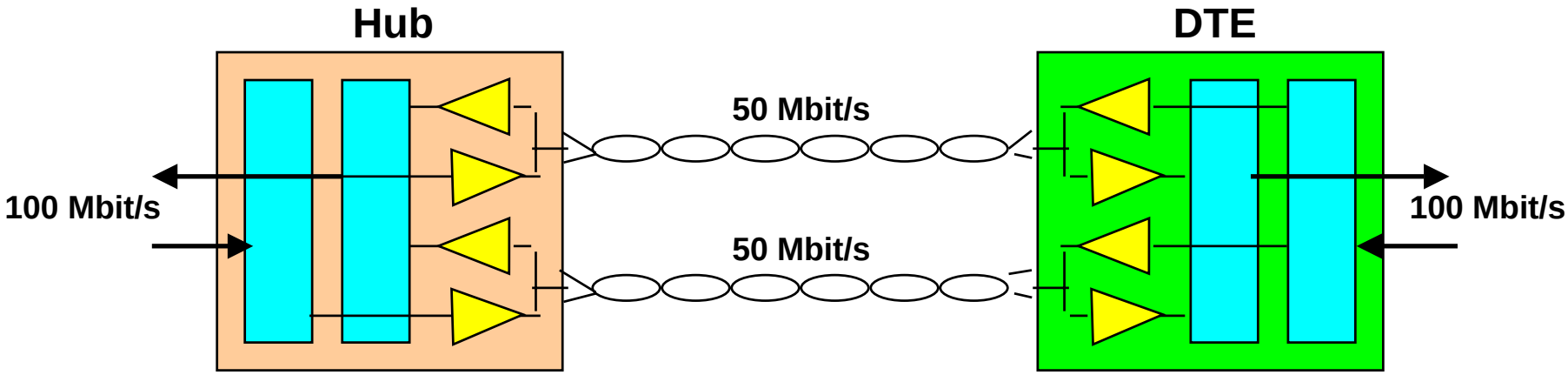
100BASE-X Operation



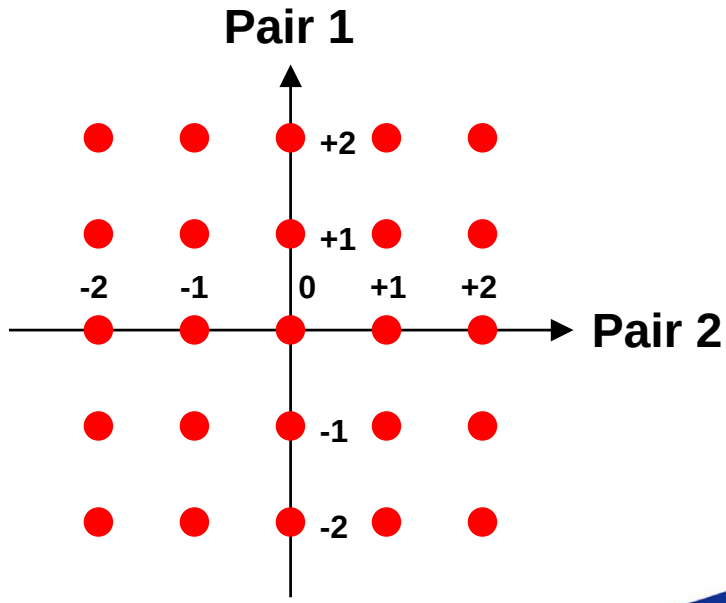
100BASE-TX Revision

- **IEEE 802.3u specification updated 2001**
- **outwards reference to TP- PMD media replaced by ISO/IEC 11801, TIA/EIA 568A:**
  - **» insertion loss = Class D, Cat 5**
  - **» NEXT loss = Class D, Cat 5**
  - **» return loss = Class D (2000), TSB- 95**
  - **» noise environment to support BER $\leq 10^{-9}$**
- **Cat 5/Class D cabling has RL shortfall**

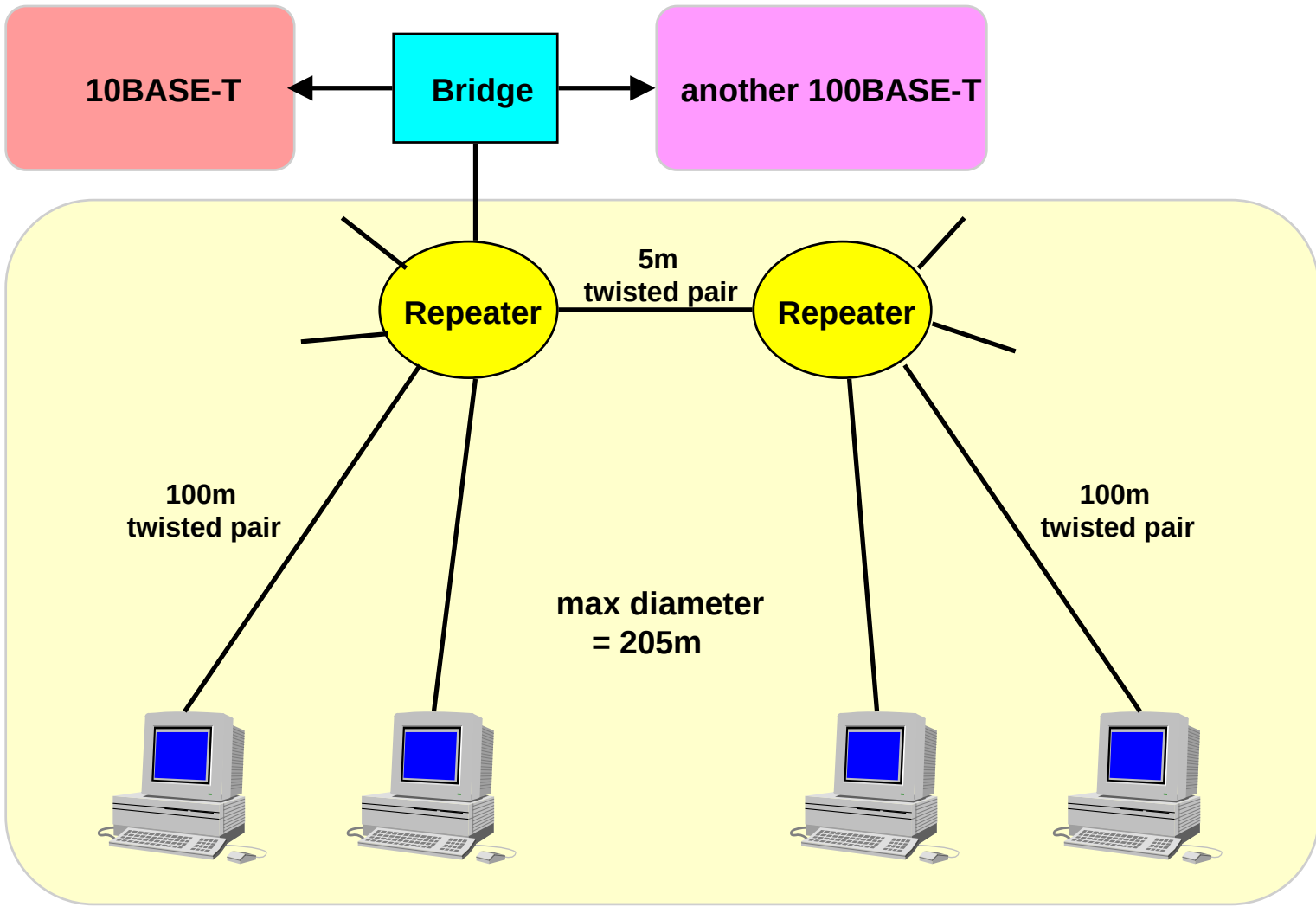
100BASE-T2 Operation



- two bi-directional 50 Mbit/s links
- uses efficient PAM 5x5 encoding
- echo/NEXT cancellation techniques
- adaptive equalisation deployed
- auto polarity/pair swap feature
- smart pair skew compensation
- ends up as a commercial failure



100BASE-T Configuration



Link Auto-Negotiation

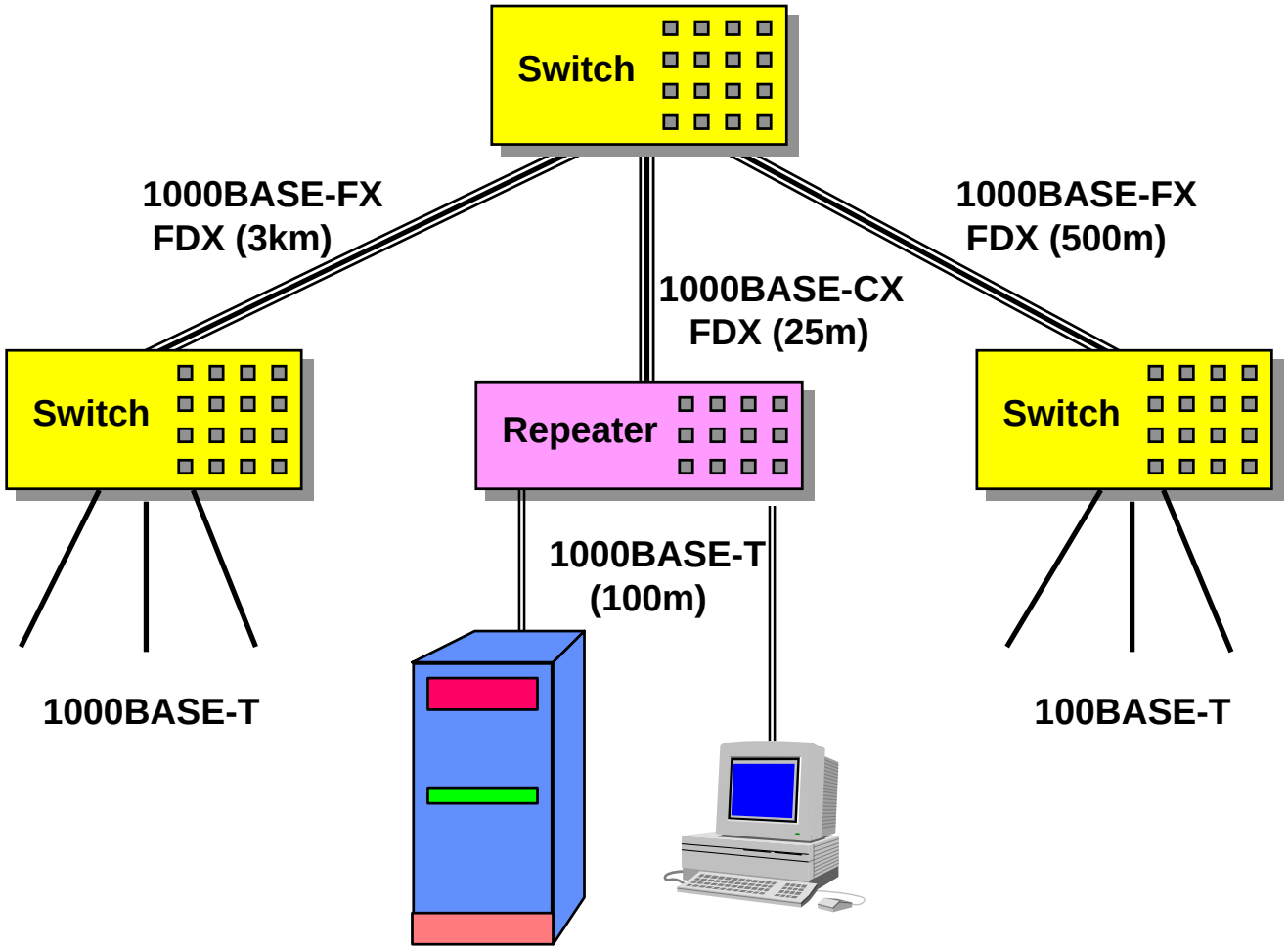
Transceiver Type	Minimum Cable Requirements	Full/Half Duplex	Priority
100BASE-TX	2-pair Cat 5 UTP	Full	High
100BASE-TX	2-pair Cat 5 UTP	Half	
100BASE-T4	4-pair Cat 3 UTP	Half	
10BASE-T	2-pair Cat 3 UTP	Full	
10BASE-T	2-pair Cat 3 UTP	Half	Low

Gigabit Ethernet Objectives

Brand-Rex

1. provide 1000 Mbit/s effective data rate
2. simple forwarding between 10/100/1000
3. preserve min & max Ethernet frame sizes
4. support optical fibre & if possible copper
5. accommodate 500m MMF, 3km SMF links
6. support media selected from ISO 11801
7. support max collision domain dia of 200m
8. full-duplex (FDX) & half-duplex operation

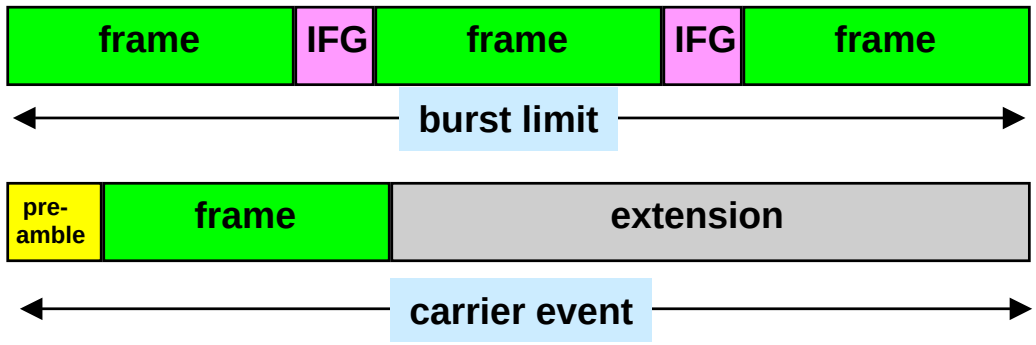
Gigabit Ethernet Architecture



Gigabit Ethernet Framing

Brand-Rex

- 512 bit minframe @ 1Gbit/s ~ 25m dia
- 200m via burst mode, carrier extension:



- performance 6.5x to 8.5x 100BASE-T
- price per port approx 3 x 100 Mbit/s

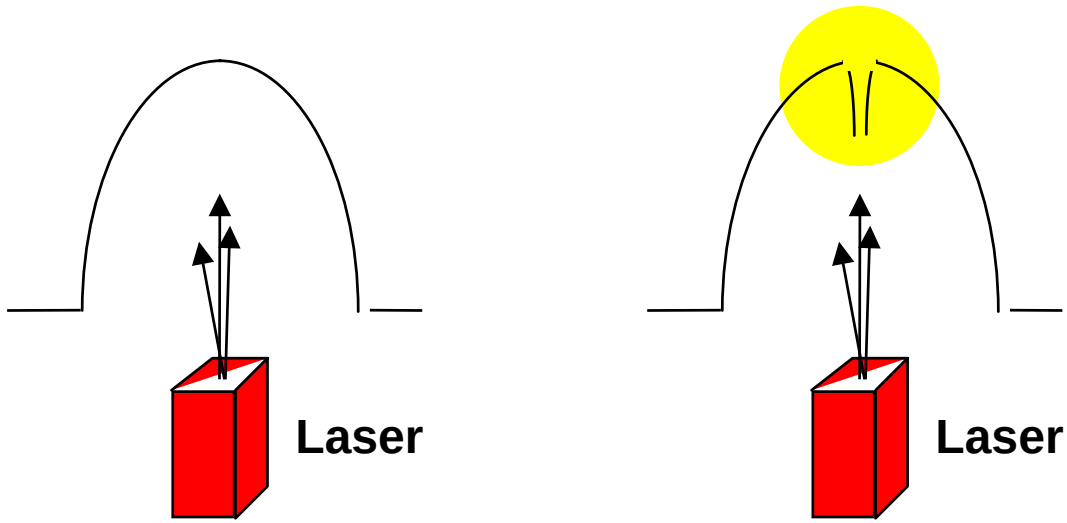
1000BASE-FX

Brand-Rex

- initial focus on optical fibre backbone
- based on Fibre Channel specification
- 8B10B coding with 1.25Gb transceivers
- low - cost 850nm VCSELs introduced
- conventional 1310nm lasers also used

Fibre Type	Modal Bandwidth Cell (MHz.km)	1000BASE-SX Link Length (m)	1000BASE-LX Link Length (m)
62 MMF	160/500	220	550
62 MMF	200/500	275	550
50 MMF	400/400	500	550
50 MMF	500/500	550	550
SMF		-	5,000

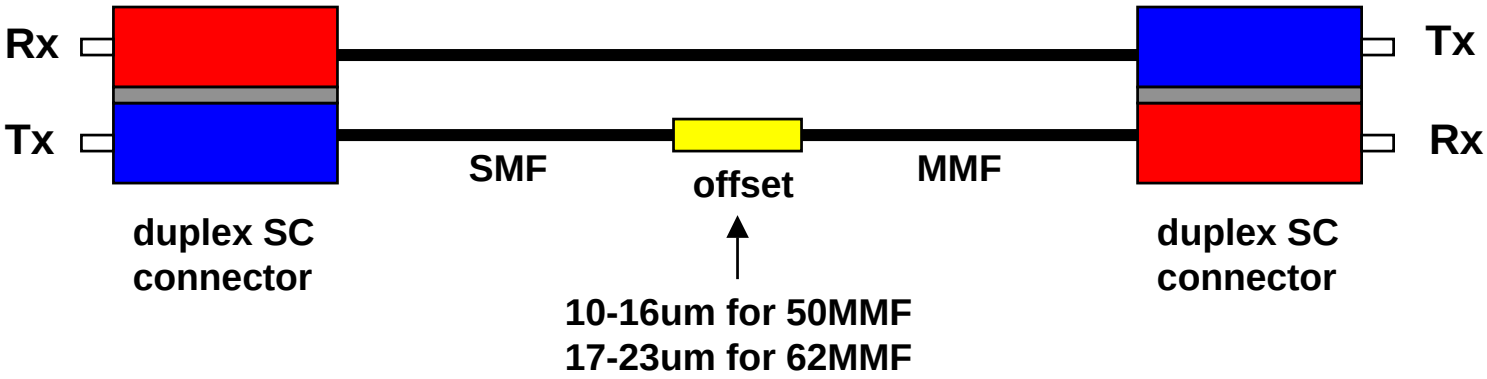
1000BASE-FX over MMF: Problem



- **laser-driven MMF bandwidth not as predicted**
- **non-compliance with 5 to 10% links tested**
- **problem identified as *Differential Mode Delay***
- **Corning, Lucent & Spectra see 1.5 to 2.0 ps/m**

1000BASE-FX over MMF: Solution

- **solution to limit link length is unacceptable**
- **solution to be based on *Conditioned Launch***
  - » **may be done internally for 1000BASE-SX**
  - » **SMF/MMF hybrid jumper for 1000BASE-LX**

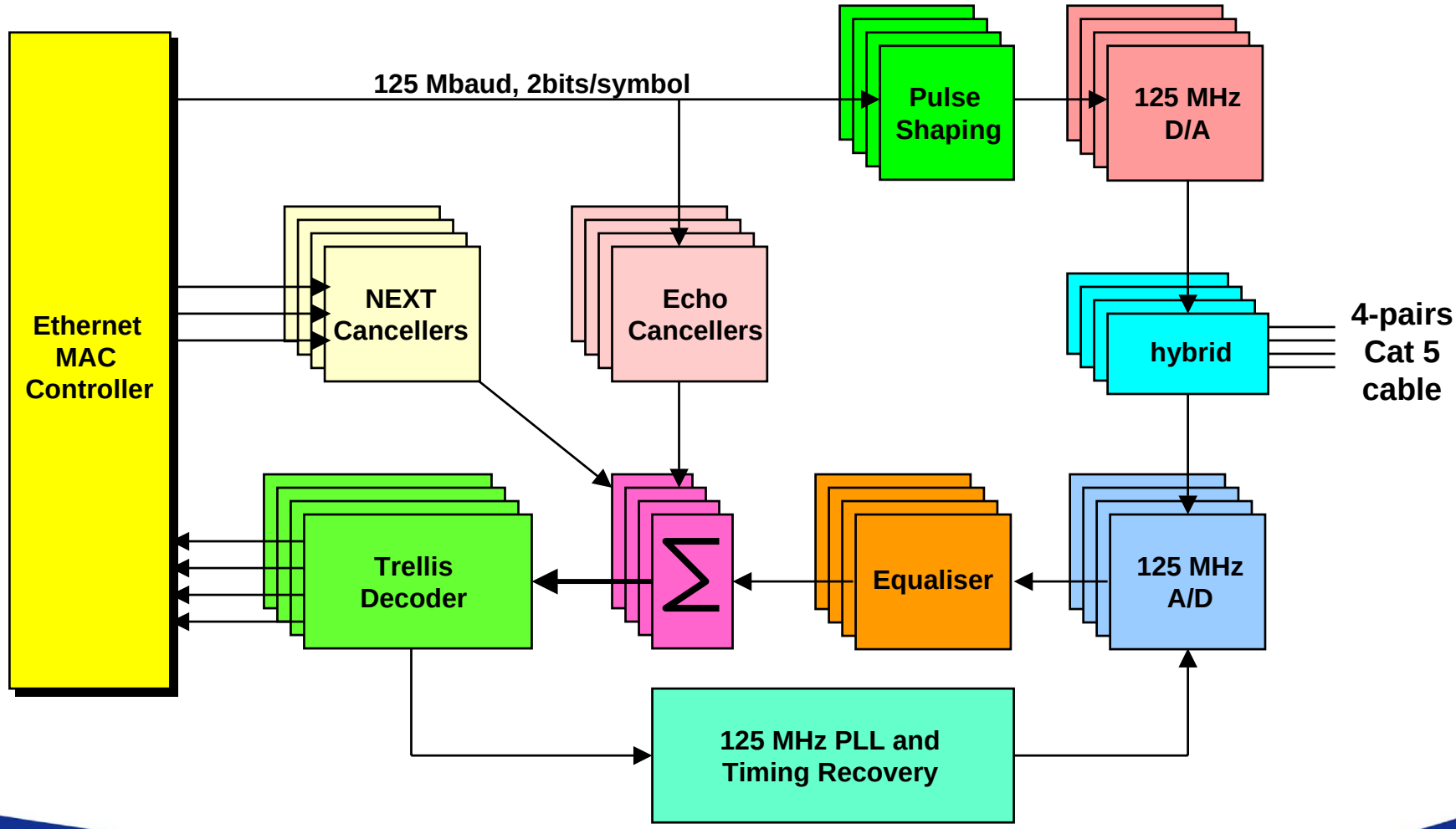


1000BASE-T

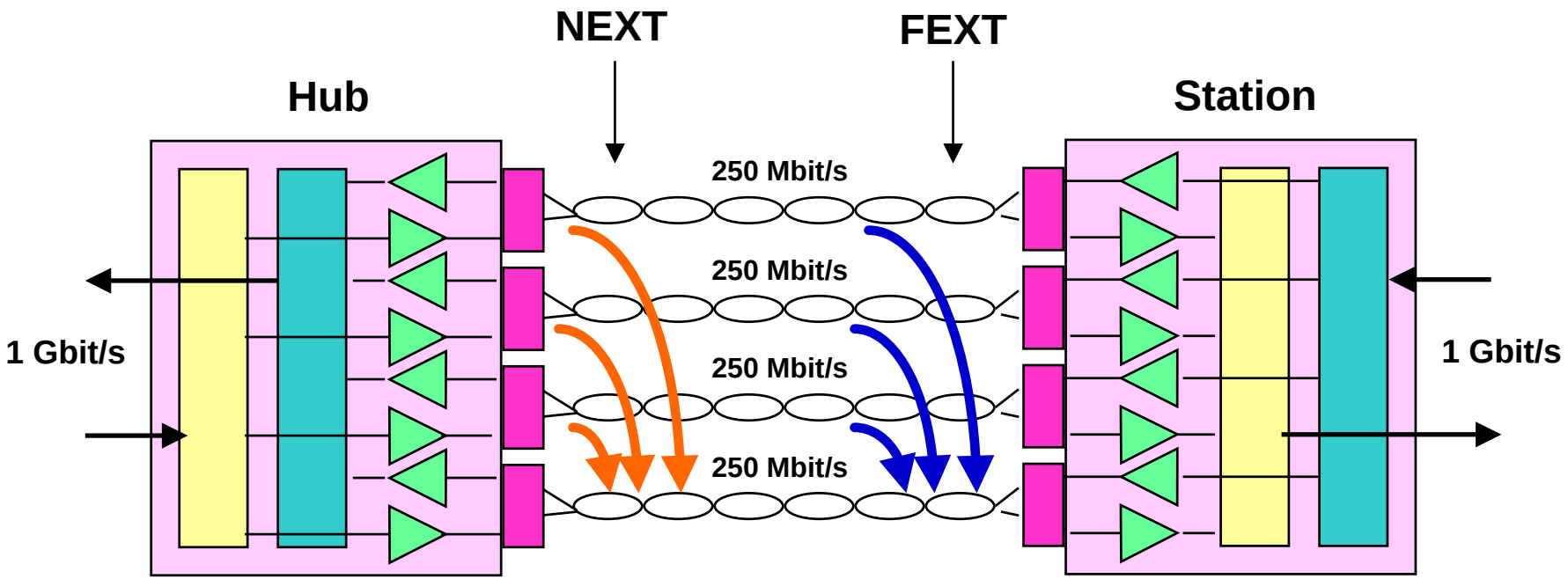
Brand-Rex

- 1 Gbit/s over installed Cat 5/Class D cabling
- full-duplex operation with bi-directional txn
- 5- level PAM code using 125 MHz clocking
- filtered to within 80 MHz for transmission
- adaptive digital filtering of NEXT and echo
- 0.35um CMOS with 200,000 gates, 4 watts

1000BASE-T Operation



1000BASE-T Transmission



1000BASE-T Cabling

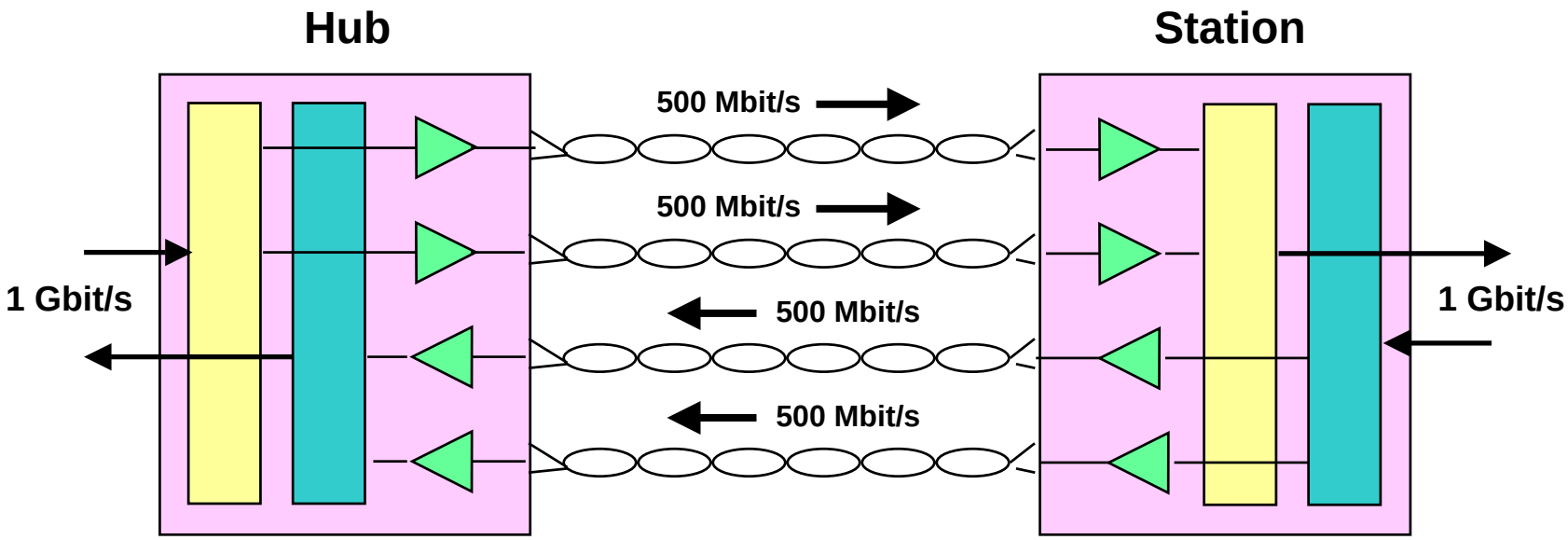
- designed to operate over installed Cat 5
- additional parameters are specified:
  - » Return Loss
  - » ELFEXT
  - » Power-sum ELFEXT
- limits derived from analysis of cable base
- extra requirements specified by TSB-95
- need to re-test for additional parameters
- ~ 10% links may not meet requirements

1000BASE-T Cabling Recommendations

Brand-Rex

- **Gigabit Ethernet Alliance recommends that if installed cabling is non-compliant:**
    1. **reduce cross-connect to an interconnect**
    2. **uprate transition point connector to Cat 5E**
    3. **uprate outlet connector to Cat 5E**
    4. **uprate interconnect to Cat 5E**
    5. **uprate patch cord to Cat 5E**
- **new cabling should be at least Cat 5E**

1000BASE-TX



- standard published as TIA/EIA-854
- full-duplex 1 Gbit/s over 4-pair Cat 6
- 75% less complex that 1000BASE-T
- lower electronics costs are possible

10 Gigabit Ethernet Objectives

Brand-Rex

1. preserve Ethernet frame size & format
2. support FDX (switched) operation only
3. support star-wired structured cabling
4. support 802.3ad Link Aggregation
5. support 10.000000 Gbit/s LAN operation
6. support 9.584640 Gbit/s WAN operation
7. define mechanism to adapt LAN/WAN rates
8. provide PHY spec family to support links of:
   - at least 2 km over SMF: at least 100m over installed MMF
   - at least 10 km over SMF: at least 300m over ……. MMF
   - at least 40 km over SMF:
9. support media from ISO 11801 2nd Edition

10 Gigabit Ethernet Nomenclature

Brand-Rex

10GBASE-xyz family of specs:

x = S (short, 850nm)
L (long, 1300nm)
E (extra long, 1550nm)

y = W (WAN using SONET STM-192 encoding)
R (LAN using serial txn & 64B/66B encoding)
X (LAN using CWDM & 8B/10B encoding)

z = # (number of CWDM channels)

10 Gigabit Ethernet Implementations

Brand-Rex

10GBASE- SR	850nm serial LAN
10GBASE- LR	1310nm serial LAN
10GBASE- ER	1550nm serial LAN
10GBASE-LX4	1310nm WDM LAN
10GBASE- SW	850nm serial WAN
10GBASE- LW	1310nm serial WAN
10GBASE- EW	1550nm serial WAN

10 Gigabit Ethernet Optical Technology

Brand-Rex

supported PMDs:

- **850nm VCSELs via 26m to 300m of MMF**
- **1300nm 4xWWDM via 300m legacy MMF**
- **1310nm lasers via 300m to 10km of SMF**
- **1550nm lasers for longer lengths of SMF**

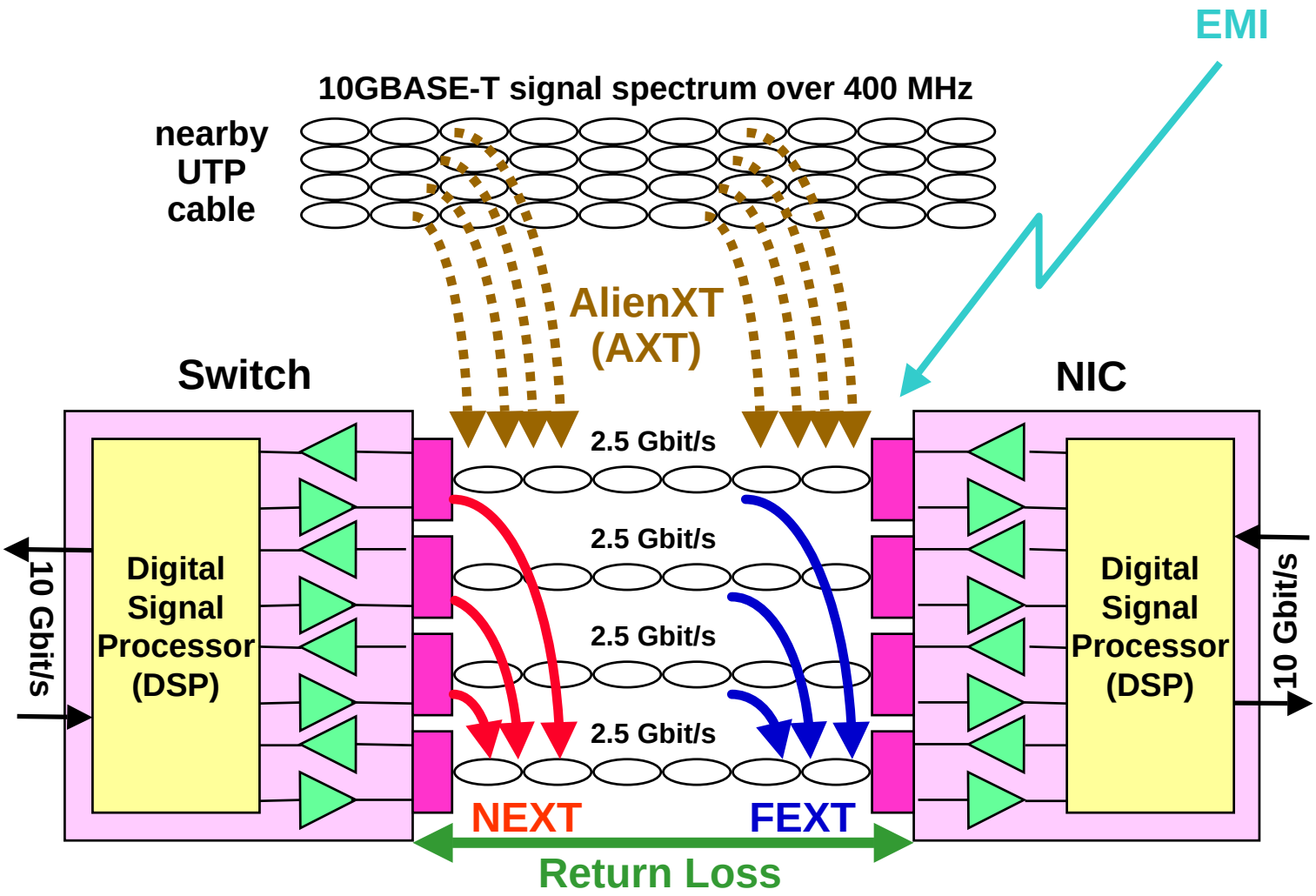
10 Gigabit Ethernet MMF Operating Lengths

Brand-Rex

fibre type	modal BW @ 850nm (MHz.km)	min operating range (m)
62MMF	160 200	2 to 26 2 to 33
50MMF	400 500 2000	2 to 66 2 to 82 2 to 300

fibre type	modal BW @ 1300nm (MHz.km)	min operating range (m)
62MMF	500	2 to 300
50MMF	400 500	2 to 240 2 to 300

10GBASE-T Transmission



10GBASE-T Implementation

Brand-Rex

- DSQ-128 modulation code
- 8-level power backoff scheme
- 55dB echo suppression
- 40dB NEXT suppression
- 25dB FEXT suppression
- automatic pair/polarity swap
- latency within 2.5us
- 12-15 watts with 90nm silicon
- POE support a non-objective

10GBASE-T Modulation Code Choice

Brand-Rex

options:

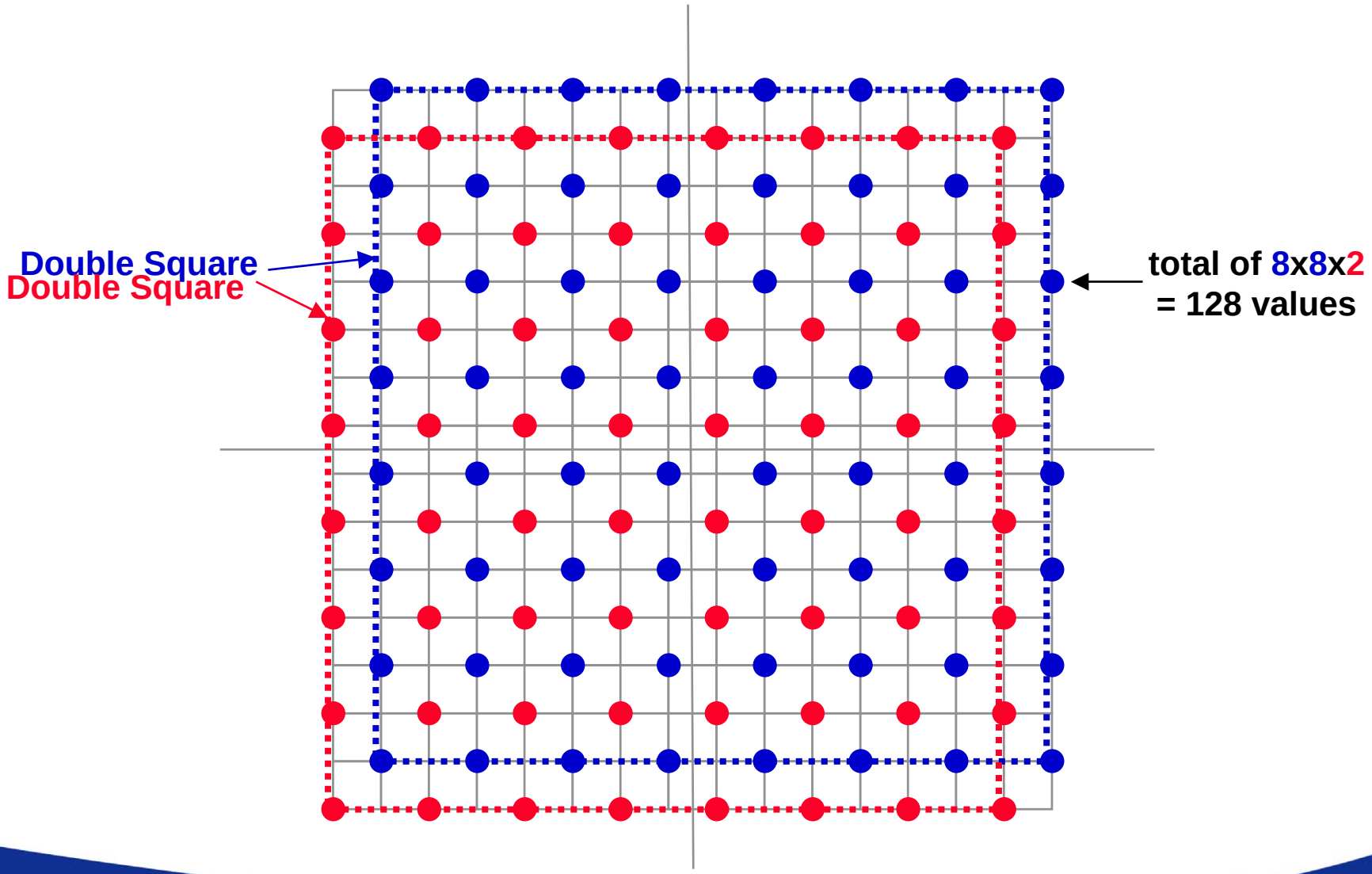
- PAM 5
- PAM 8
- PAM 10
- PAM 12
- DSQ 128
- OFDM

code selection criteria:

- bandwidth requirements
- RF emission compliance
- EM noise immunity
- BER/noise margin behaviour
- implementation complexity
- silicon power consumption

Selected for 10GBASE-T

DSQ128 Code



10GBASE-T Cabling

- must be specified to an upper frequency of 500MHz
- UTP is significantly challenged by alien crosstalk
- EMC compliance may also be a challenge with UTP
- alien crosstalk may be mitigated but it is complex
- field measurement of alien crosstalk not practical
- initial target of Cat 5e cabling virtually rejected
- Cat 6 UTP struggles to achieve respectable length

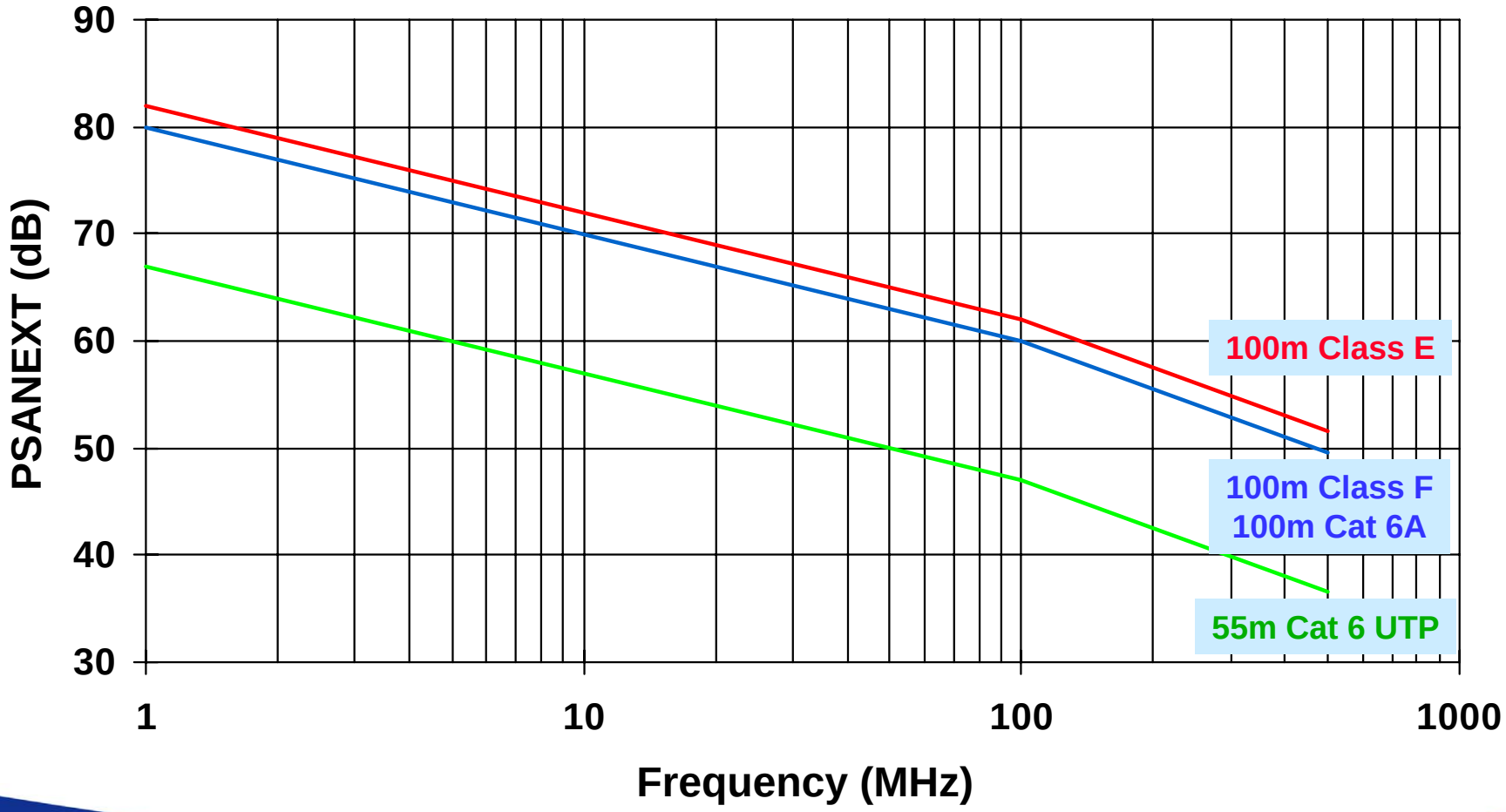
10GBASE-T Cabling Choices

Brand-Rex

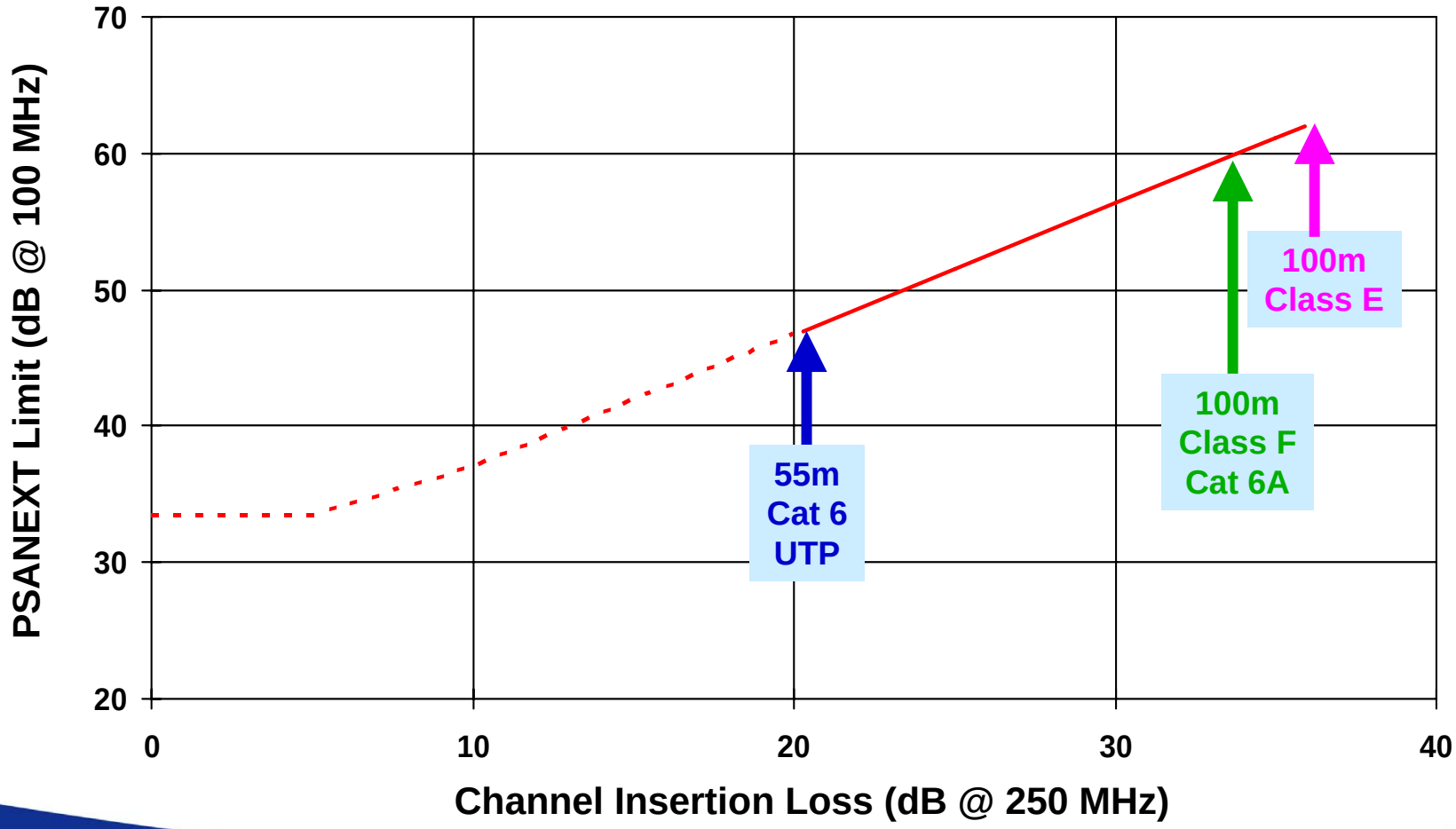
Cabling	Supported Link Distances
Class E / Cat 6 unscreened	up to 55m
Class E / Cat 6 screened	100m
Class F / Cat 7 (screened)	100m
new Class E / Cat 6A (unscreened)	100m

new type of UTP with improved alien crosstalk performance

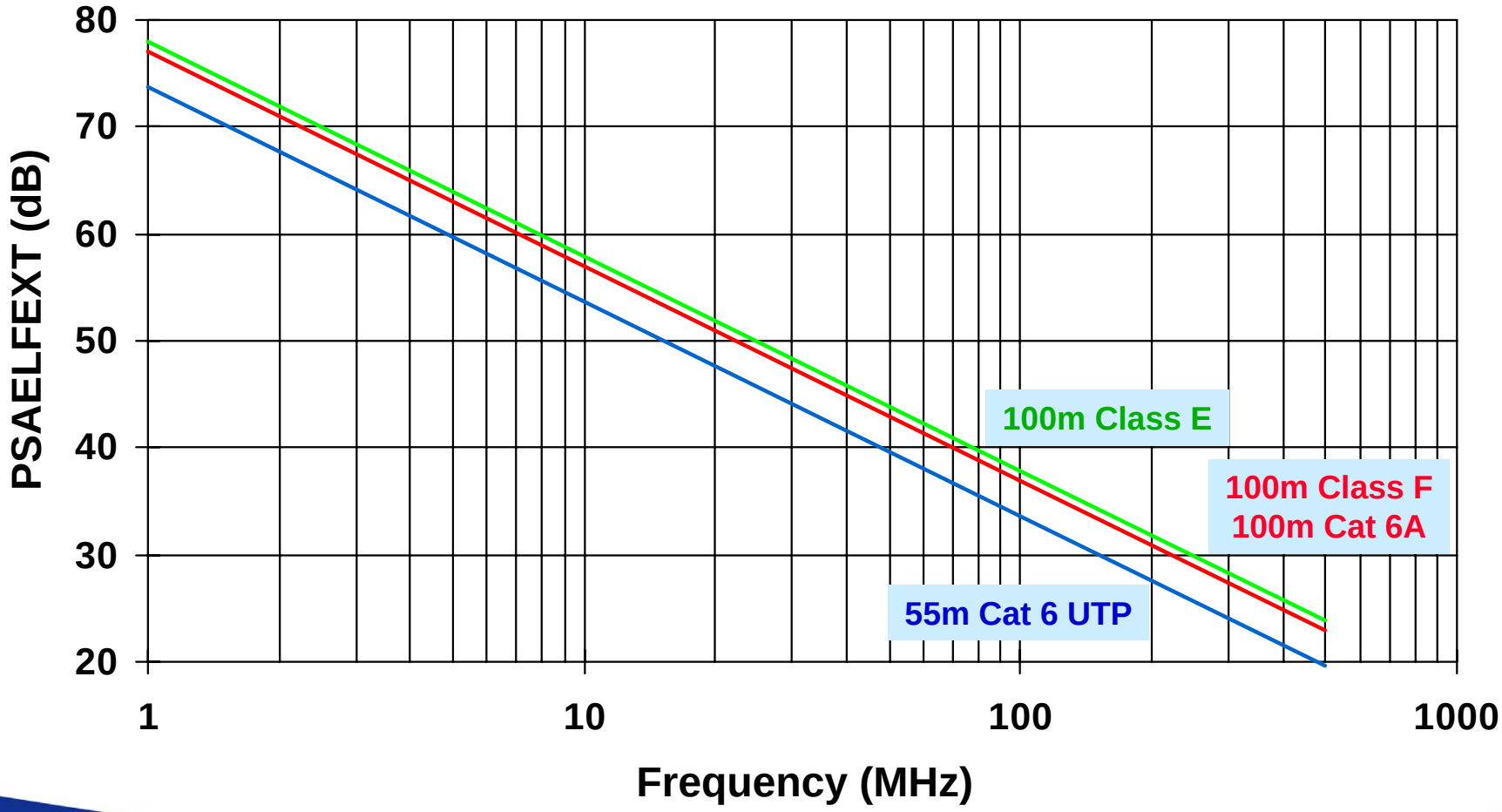
10GBASE-T Channel PSANEXT



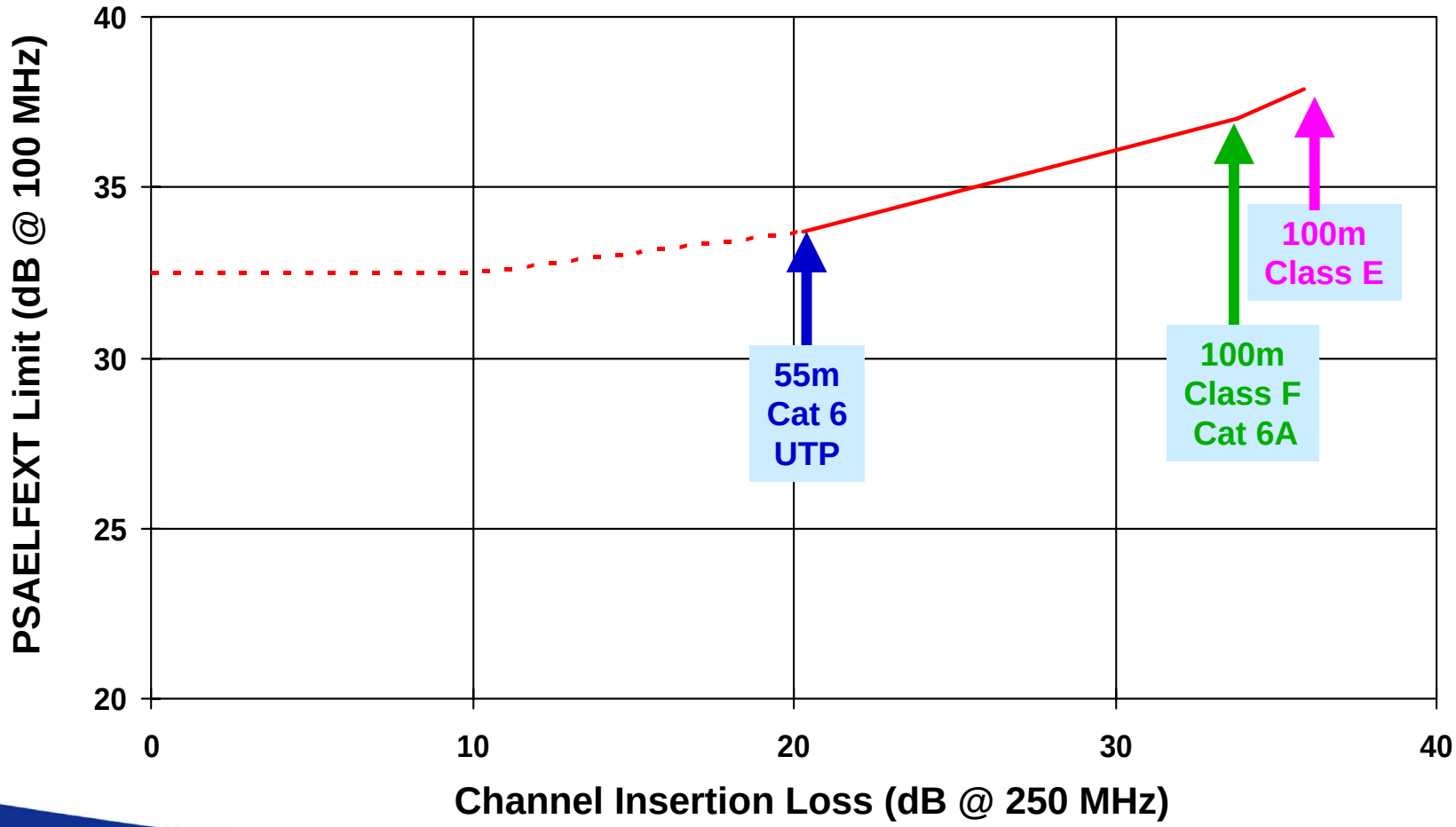
10GBASE-T PSANEXT vs Insertion Loss



10GBASE-T Channel PSAELFEXT



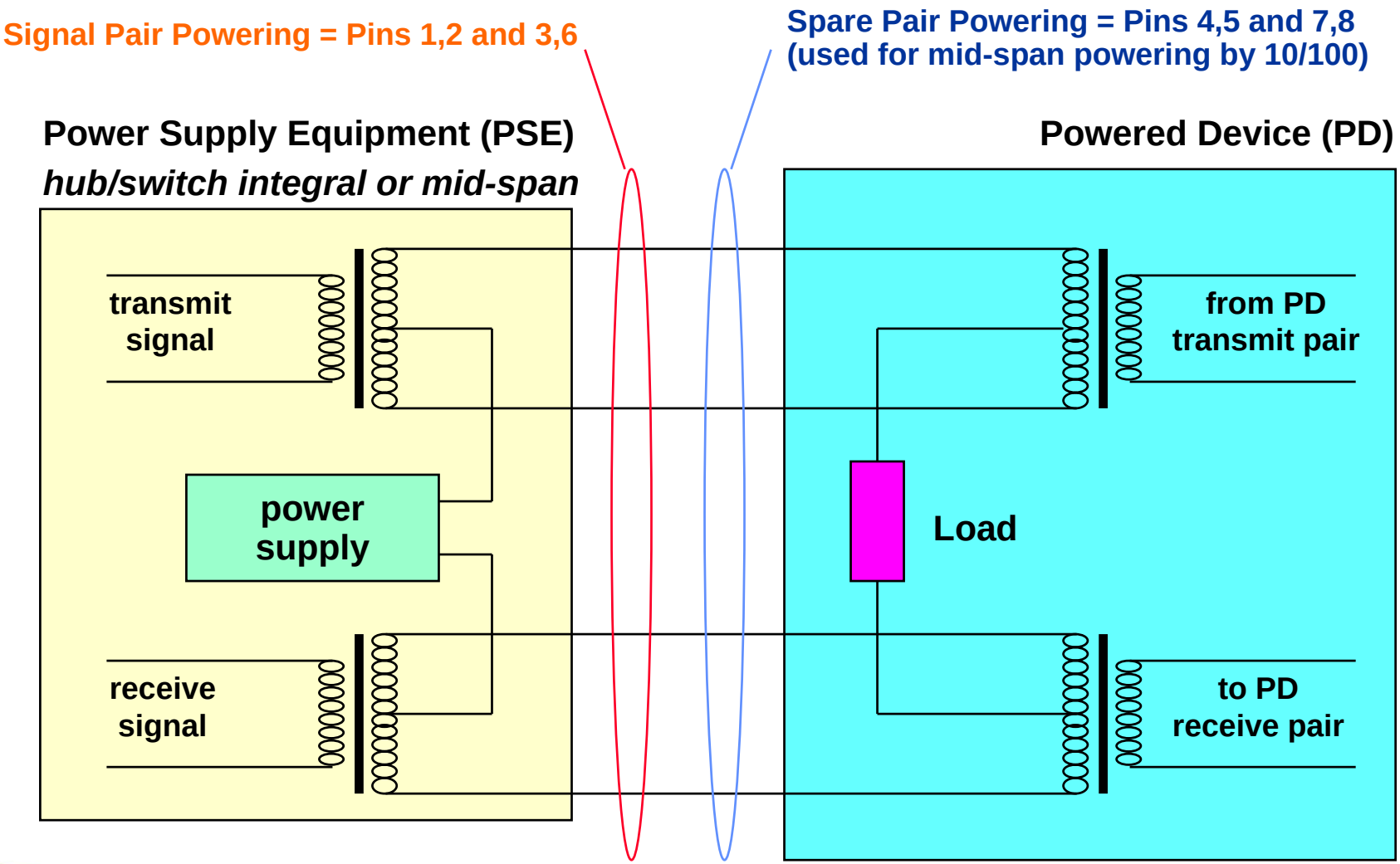
10GBASE-T PSAELFEXT vs Insertion Loss



10GBASE-T 30m Channel Option

- preferred switch module (X2) limits power to 4w
- latency of 2.5us too long for data centre apps!
- at least 2 generations of silicon predicted to achieve target power levels, could take 3- 4 yrs
- 30m Cat 6A or Cat 7 option loosely defined to enable low power/low latency implementations

Remote Power via Modular Connector



Remotely Powered Ethernet Supported

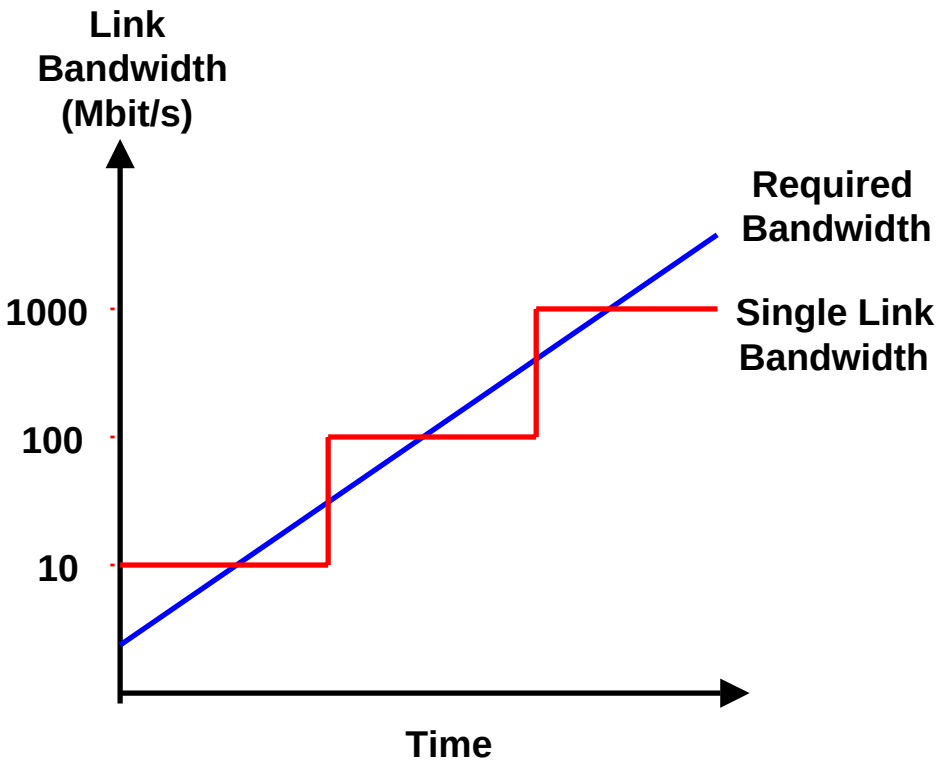
- 10BASE-T 10Mbs 2-pair Cat 3
- 100BASE-TX 100Mbs 2-pair Cat 5
- 1000BASE-T 1000Mbs 4-pair Cat 5

Remote Power Classifications

Brand-Rex

Class	Usage	Power levels at PSE output	Power levels at PD input
0	Default	0.50w - 15.00w	0.44w - 12.95w
1	Optional	0.50w - 4.00w	0.44w - 3.84w
2	Optional	4.00w - 7.00w	3.84w - 4.69w
3	Optional	7.00w - 15.00w	6.49w - 12.95w
4	Reserved	0.50w - 15.00w	Reserved
5	Reserved	0.50w - 15.00w	Reserved

Backbone Link Aggregation



- bandwidth growth continuous
- technology changes are *step*
- need to optimise the solution
- need for increased flexibility
- need to support multi Gbit/s
- need to provide resilience