The Ethernet Evolution
From 10 Meg to 10 Gig
How it all Works!

Hadriel Kaplan & Robert Noseworthy

Atlanta 2001

NETWORLD+INTEROP

Who Are we?

- Robert Noseworthy
  - Manager 10 Gigabit Ethernet Consortium & Interim Technical Director, University of New Hampshire InterOperability Lab (UNH IOL)
  - Co-Editor of IEEE 802.3ae and voting member, 802.3 Working Group
  - Developed early Fast, Gigabit, and 10Gigabit Ethernet test devices
  - Part of team that built the first multi-vendor Fast Ethernet and Gigabit Ethernet networks (Hadriel's group beat me by a day!)
- Hadriel Kaplan
  - Product Line Manager, Avici Systems; in charge of Gigabit and 10-Gigabit Ethernet products
  - Former member, 802.3 Working Group
  - Led the team that built the first multi-vendor Gigabit Ethernet and 802.1Q networks (long before Bob's group…)
  - Went to the dark side (marketing) in March

What Will You Learn?

- Teach you about what you need to know to understand, troubleshoot, and design Ethernet networks.
- Discuss the common problems, work-arounds, and issues in Ethernet hardware.
- Introduce new and upcoming technologies related to the Ethernets (And help you avoid the “hype”)

What Won’t You Learn?

- Pricing - We don’t know, We don’t care.
- Specific product features – We’re not here to sell.
- The following technologies:
  - ATM
  - QoS
  - IPv6
  - VoIP
  - DWDM
  - OSPF
  - MPLS (well, a little on that)
  - How to make money in the stock market

  Those are all other workshops…
- How to design a real, complete network. (we’ll cover Ethernet and switching, but not routing)

Outline

- Ethernet Essentials
- Media
- Core PHYs
- Auto-Negotiation
- Future Ethernet
  - DTE Power via MDI
  - 10 Gigabit Ethernet
  - Ethernet in the FIRST Mile (EFM)
- Switched Network Design
  - Spanning Tree
  - Link Aggregation
  - VLANs
- Future non-Ethernet (but want to be)
  - RPR
  - PONs

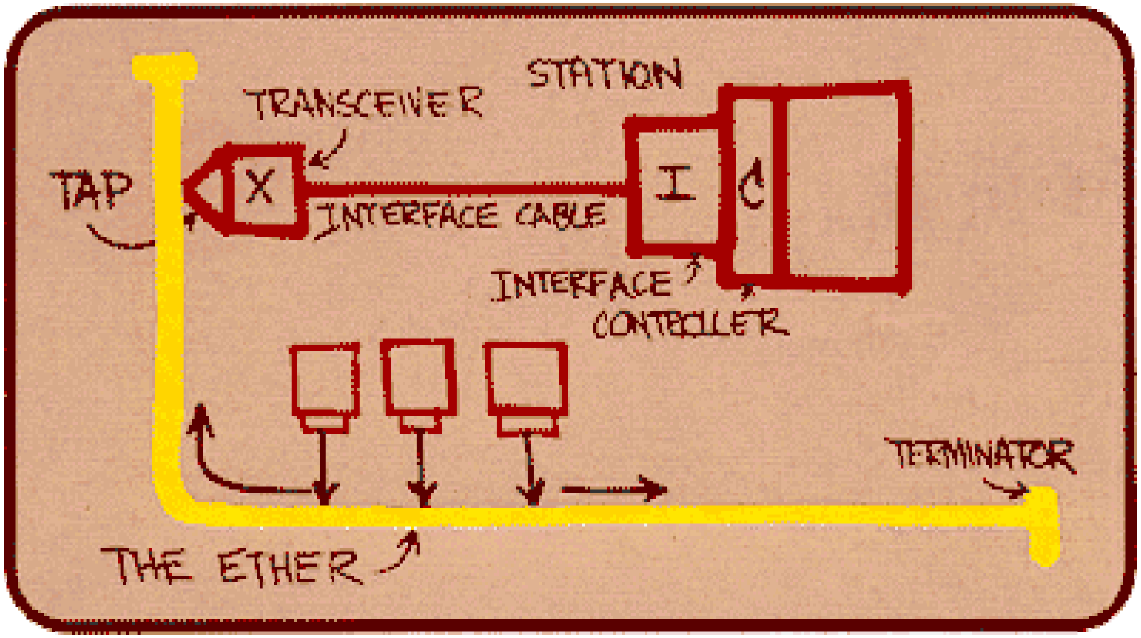
Ethernet Essentials - Outline

- Ethernet History
- Ethernet Standards
- Ethernet Frame
- Half Duplex MAC
- Repeaters
- Full Duplex MAC
- Switches
- Flow Control

Ethernet History

- Why is it called Ethernet?
  - “In late 1972, Metcalfe and his Xerox PARC colleagues developed the first experimental Ethernet system to interconnect the Xerox Alto, a personal workstation with a graphical user interface. The experimental Ethernet was used to link Altos to one another, and to servers and laser printers. The signal clock for the experimental Ethernet interface was derived from the Alto's system clock, which resulted in a data transmission rate on the experimental Ethernet of 2.94 Mbps.
  - Metcalfe's first experimental network was called the Alto Aloha Network. In 1973 Metcalfe changed the name to "Ethernet," to make it clear that the system could support any computer-not just Altos-and to point out that his new network mechanisms had evolved well beyond the Aloha system. He chose to base the name on the word "ether" as a way of describing an essential feature of the system: the physical medium (i.e., a cable) carries bits to all stations, much the same way that the old "luminiferous ether" was once thought to propagate electromagnetic waves through space. Thus, Ethernet was born.”

Ethernet History

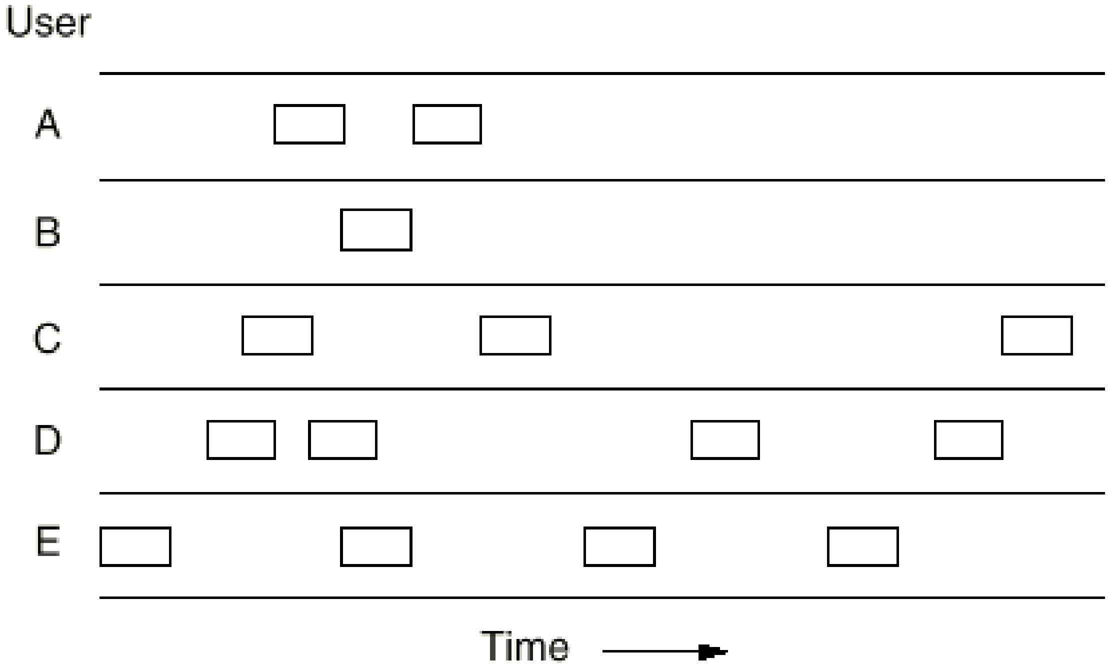


This is Bob Metcalfe’s original drawing for Ethernet

- Invented by Metcalf at Xerox in 1973 and patented in 1976
- Xerox convinced Digital and Intel to join in making products (hence the group called DIX)
- IEEE standard in 1989

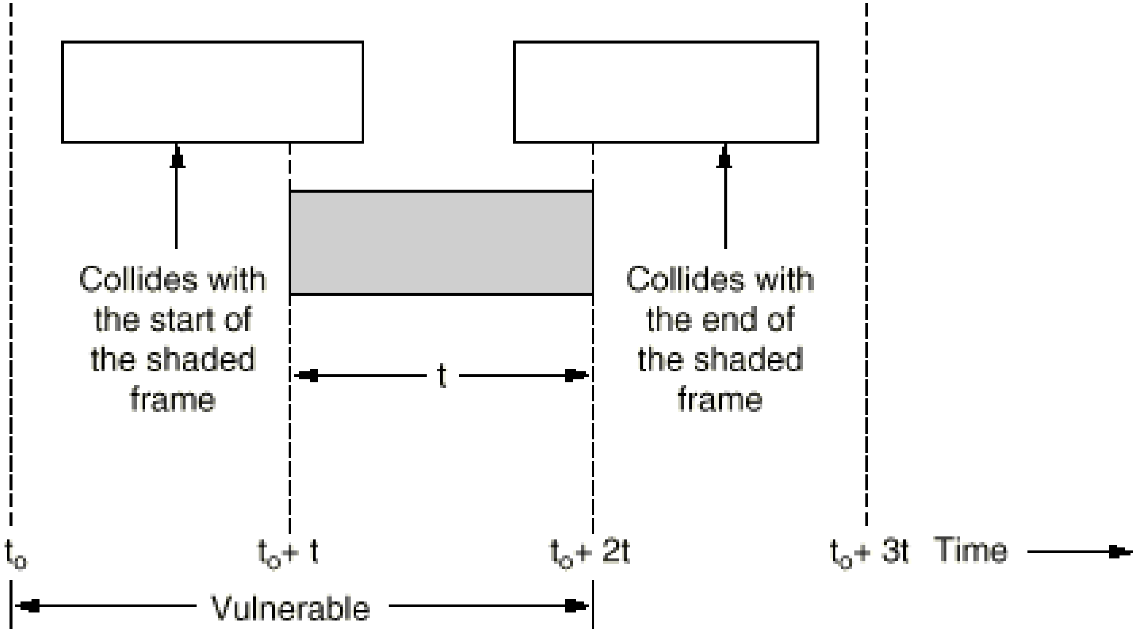
Ethernet History: Pure ALOHA

- **Transmit when you want to, regardless of others.**



Ethernet History: Pure ALOHA Collisions

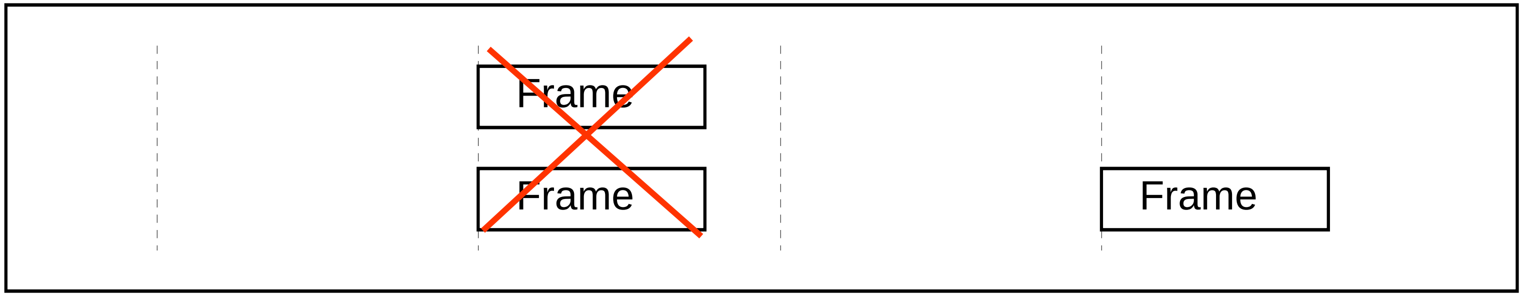
- **Extremely inefficient, since the worst-case period of vulnerability is the time to transmit two frames.**



Collides with the start of the shaded frame
Collides with the end of the shaded frame
t
t_o
t_o+ t
t_o+ 2t
t_o+ 3t
Time
Vulnerable

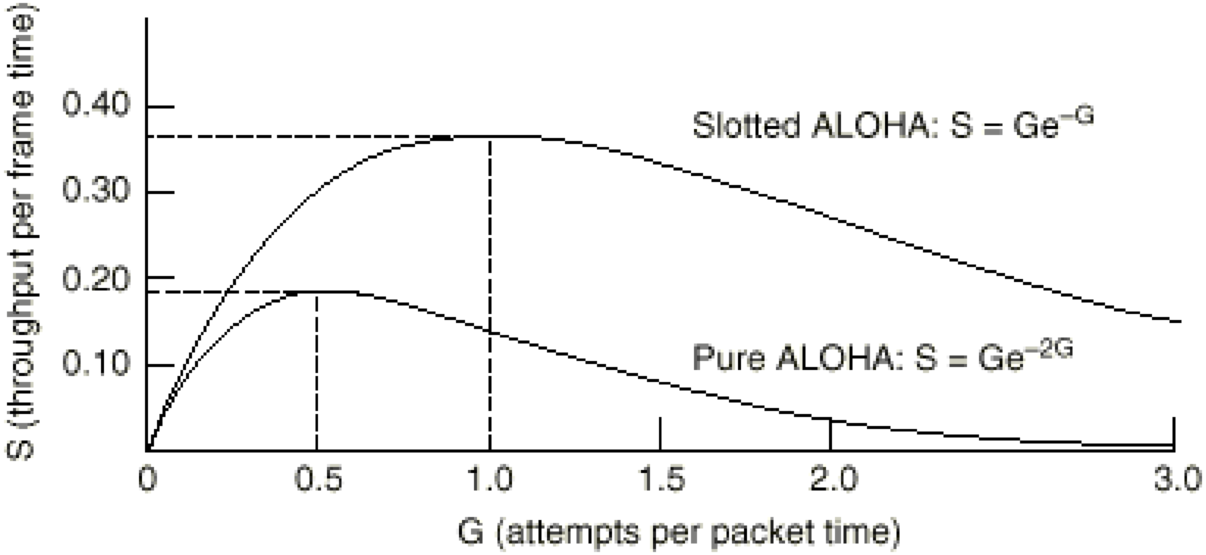
Ethernet History: Slotted ALOHA

- Transmit only at the beginning of synchronized “slot times”
- Collision inefficiency limited to one frame transmission time



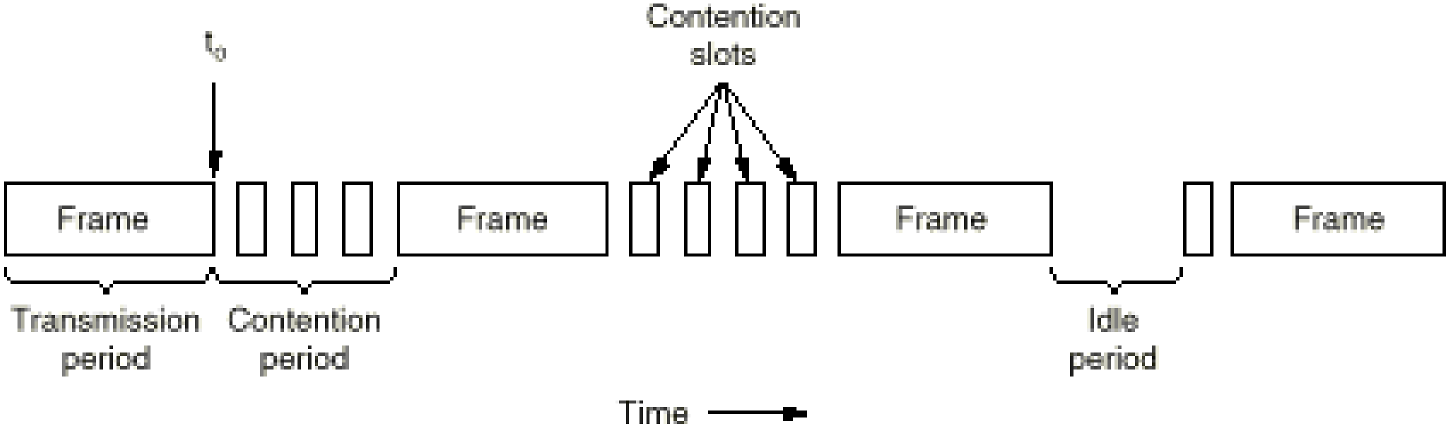
Ethernet History: ALOHA v Slotted ALOHA

- **Throughput efficiency increases dramatically for Slotted Aloha.**



Ethernet History: CSMA/CD

- Take Slotted ALOHA to the next level, use the slots as “contention periods”.
  - If no collision occurs before the end of the period, then complete transmission of the frame.
- CSMA/CD can be in one of three states: contention, transmission, or idle. More on CSMA/CD later…



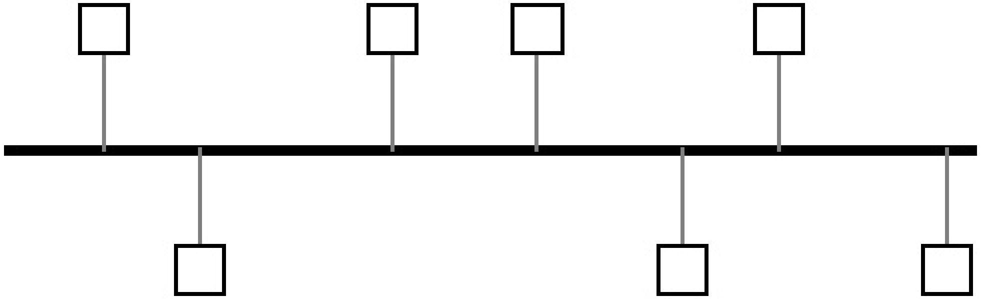
Ethernet History: Collisions

- Collisions
  - Two or more transmissions literally collided with one another on the same medium.
  - Result corrupts the data contents of the transmissions.
- Possible due to the medium used by the original Ethernet

Ethernet History: The Shared Bus Topology

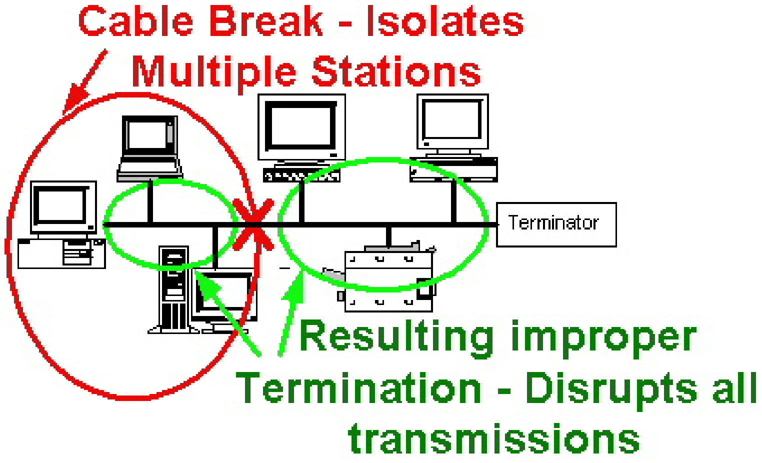
- Coaxial Cabling, 10 Mbps
  - – 10BASE-5 “ThickNet”
  - – 10BASE-2 “ThinNet”

- Bus Topology = Truly shared media

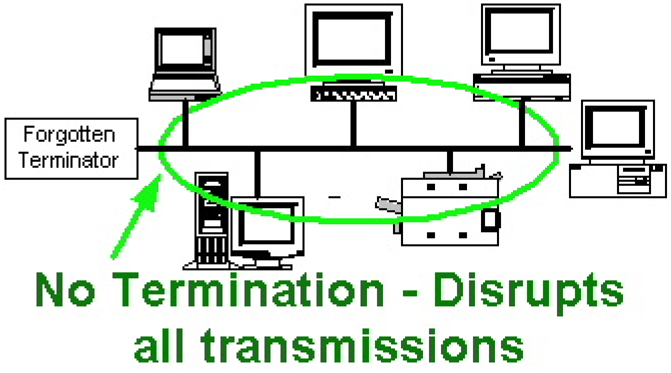


Ethernet History: Bus Topology Extinction

- Problems with Bus Topology
  - Break in Coax cable can sever service to multiple nodes
  - Fault in Coax cable can disrupt service to all nodes
    - » ground fault
    - » Incorrect termination
  - Adding/Removing nodes disrupts network

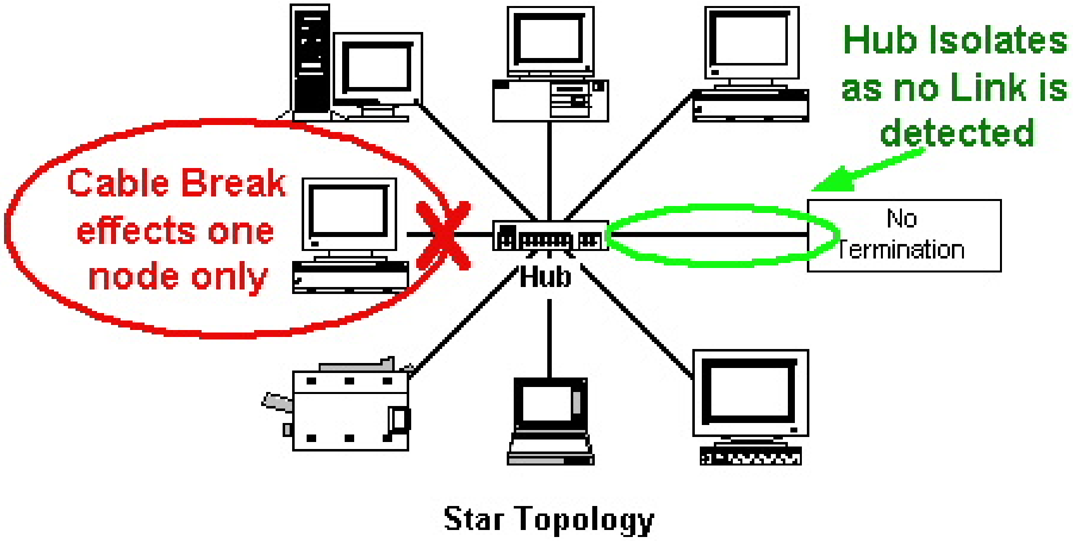

Cable Break - Isolates Multiple Stations

Resulting improper Termination - Disrupts all transmissions


No Termination - Disrupts all transmissions

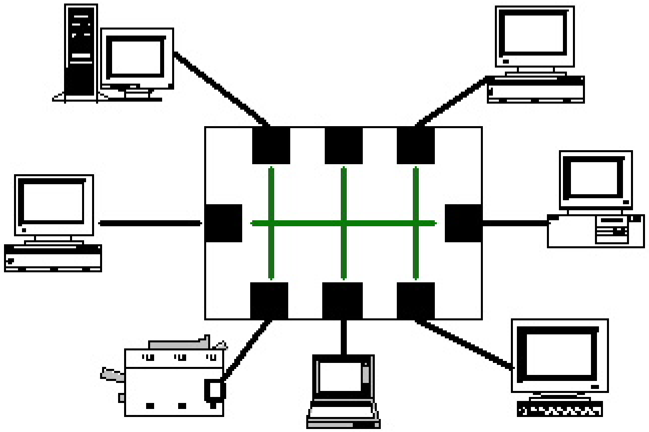
Ethernet History: Star Topology

- **Bus Topology Evolved into a Star Topology**
  - Driven by cabling issues
    - » Single cable breaks/faults effect only one node
    - » Emergence of cheap unshielded twisted pair (UTP) cable
  - Introduces “Hub” or “Concentrator” that isolates faulty nodes/cables


Hub Isolates as no Link is detected
Cable Break effects one node only
No Termination
Hub
Star Topology

Ethernet History: Hub

- Hub can refer to either:
  - – Repeater ("Bus in a Box")
    - » Star Topology with Logical Bus
  - – Switch / Bridge
    - » Still Star Topology: Allows simultaneous transmissions between different stations

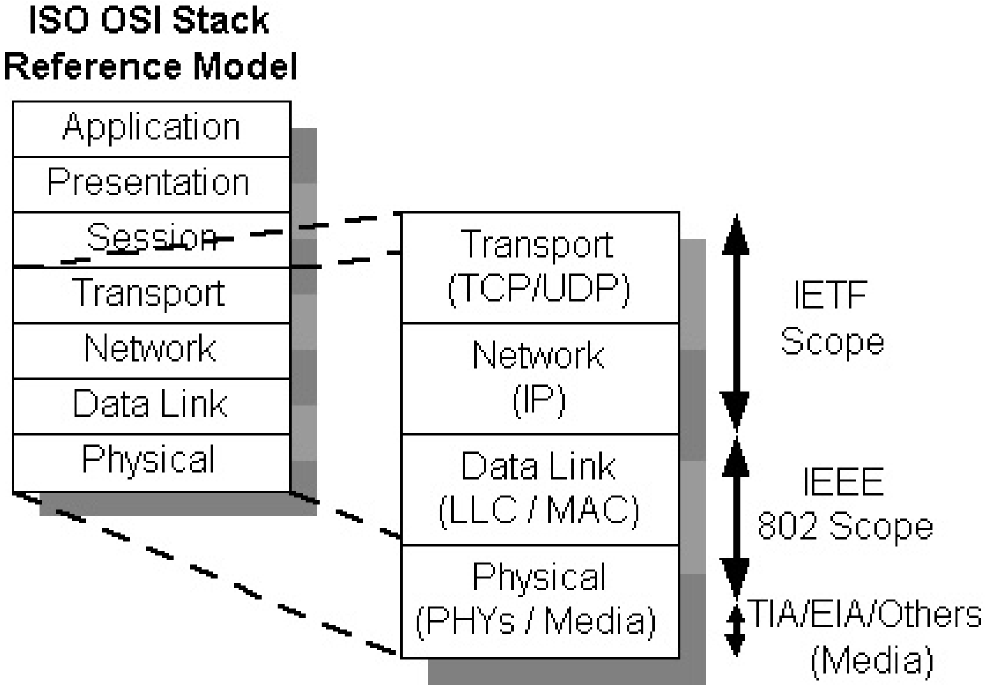


Ethernet History: Standardization

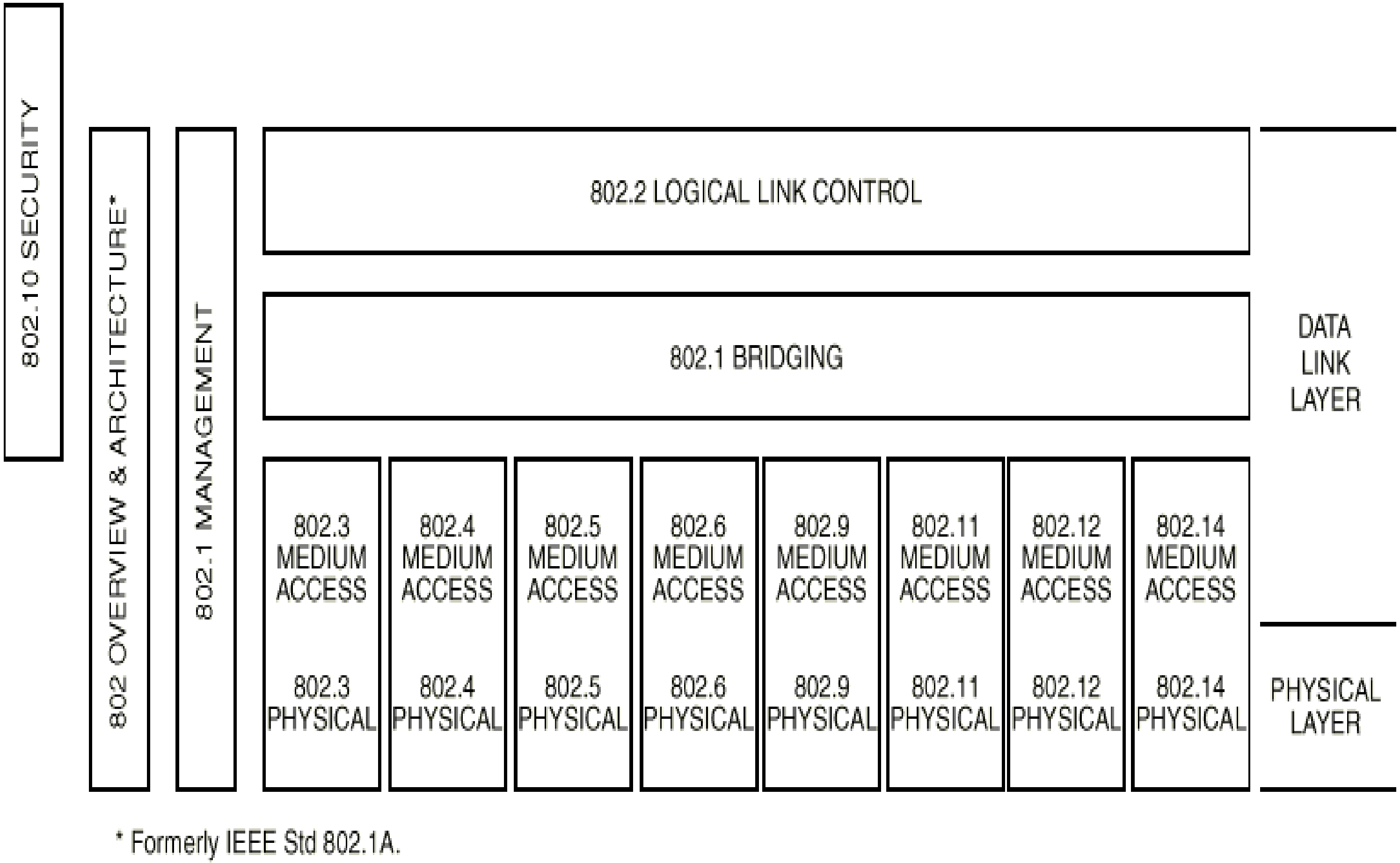
- First IEEE Ethernet Standard in 1985
- Standardization
  - Preferred over competing proprietary solutions
  - Creates a shared, open market for component and systems vendors
  - Defines interfaces and mechanisms to permit interoperable solutions
    - Permits creation of heterogeneous (multi-vendor) networks

Ethernet Standards

- **Ethernet fits in the Open Standards Interface (OSI) model of the International Standards Organization as shown.**



Ethernet Standards: IEEE 802 Architecture



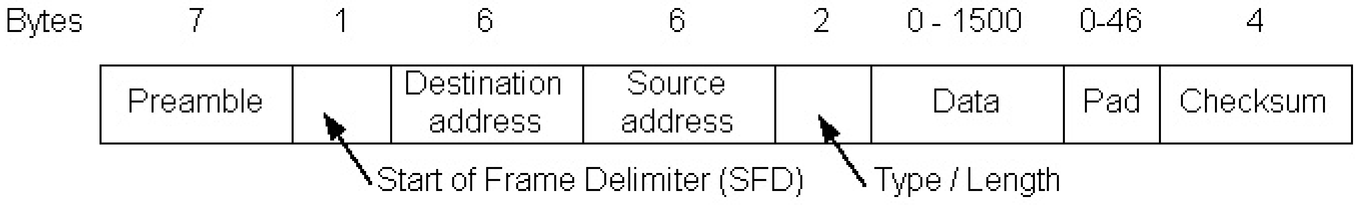
* Formerly IEEE Std 802.1A.

Ethernet Standards: IEEE 802.3

- 802.3 Now encompasses
  - Original 802.3: 10BASE-T 10BASE-5 10BASE-2 10BROAD-36
  - 802.3u Fast Ethernet: 100BASE-TX 100BASE-FX 100BASE-T4
  - 802.3x: Flow Control
  - 802.3z Gigabit Ethernet: 1000BASE-SX / -LX / -CX
- 802.3ab Copper Gigabit Ethernet: 1000BASE-T
- 802.3ac Frame Tagging for VLAN support
- 802.3ad Link Aggregation
- 802.3ae 10 Gigabit Ethernet: Completion by March 2002
- 802.3af DTE Power via MDI: Completion by Sept 2001

Ethernet Frame

- Transmitted Data is embedded in a container, called a frame
- This Frame Format DEFINES Ethernet
  - – Historically, two types of frames existed:
    - » 802.3 Framing used a Length field after the Source Address
    - » Ethernet II (DIX) Framing used a type field after the Source Address
  - – Now both frame types are defined and supported within IEEE 802.3



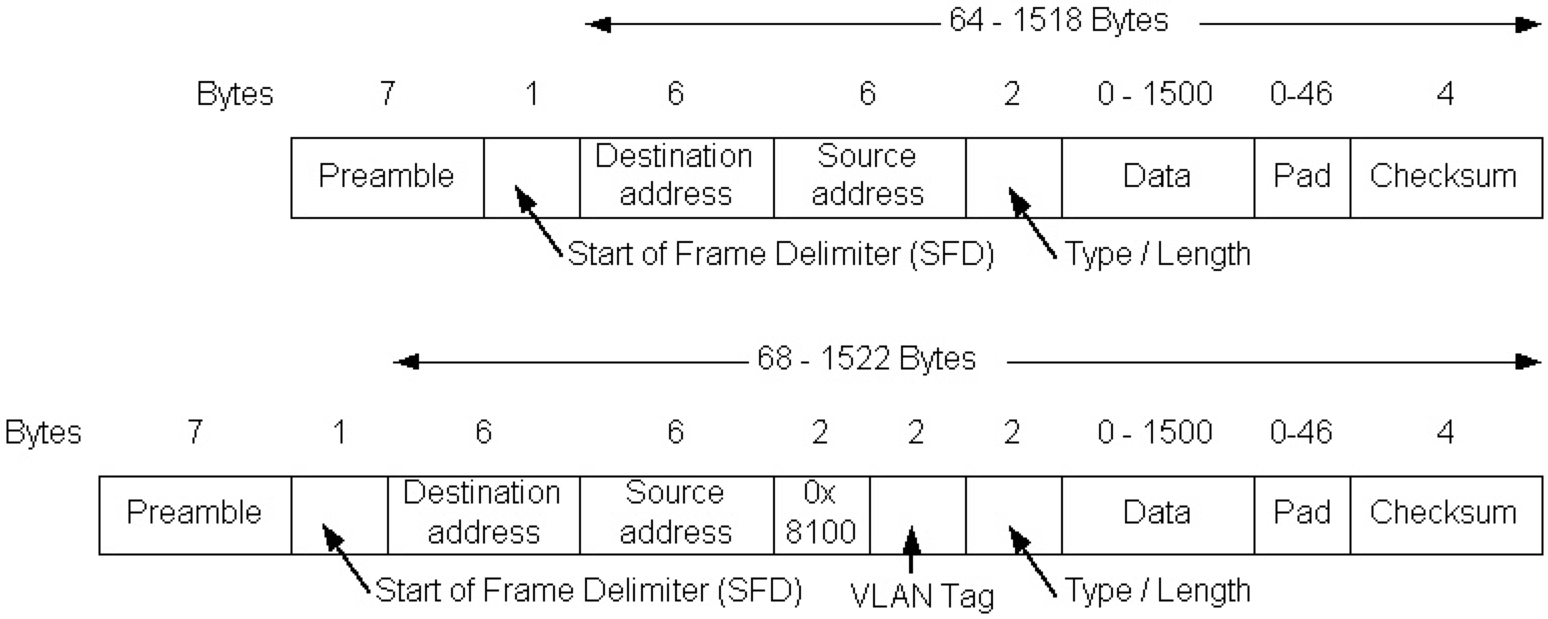
Bytes	7	1	6	6	2	0 - 1500	0-46	4
	Preamble		Destination address	Source address		Data	Pad	Checksum

Start of Frame Delimiter (SFD)

Type / Length

Ethernet Frame

- **Frame size varies from 64 to 1518 Bytes except when VLAN tagged (more on that later…)**



64 - 1518 Bytes

Bytes	7	1	6	6	2	0 - 1500	0-46	4
	Preamble		Destination address	Source address		Data	Pad	Checksum

Start of Frame Delimiter (SFD)

Type / Length

68 - 1522 Bytes

Bytes	7	1	6	6	2	2	2	0 - 1500	0-46	4
	Preamble		Destination address	Source address	0x 8100			Data	Pad	Checksum

Start of Frame Delimiter (SFD)

VLAN Tag

Type / Length

Ethernet Frame: Addresses

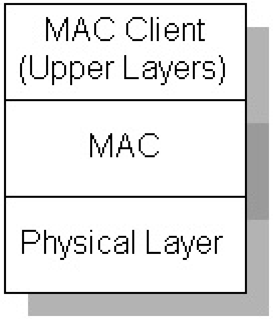
- Station Addresses
  - Must be unique on every LAN
  - Unless locally administered (uncommon), each node has a unique address assigned by the manufacturer. First 3bytes of address are assigned by IEEE (Organization Unique Identifier - OUI)
- Source Address: Must always be Station Address
- Destination Address: May be –
  - Unicast Address (Addressed to Station Address of one other station)
  - Multicast Address (Addressed to multiple stations simultaneously)
    - Broadcast Address (FF FF FF FF FF FF) To All Stations

Ethernet Frame: Other Fields

- Preamble: repeating 1010 pattern needed for some PHYs
- Start of Frame Delimiter: mark byte boundary for MAC
- Type / Length: length, or type of frame if >1536 (0x0600)
- Data: protocol data unit from higher layers (ie: IP datagram)
- Pad: Only used when necessary to extend frame to 64 bytes
- Checksum: CRC-32 Detect if frame is received in error
- Idle: Occurs between frames, must be at least 96 bit times.

MAC

- **Ethernet Frame transmission and reception must be controlled – via the Media Access Control (MAC) layer.**
- Ethernet MAC
  - Operates in either Half or Full Duplex dependent on support from the Physical Layer
    - Original Ethernet was Half Duplex Only
  - Handles
    - Data encapsulation from upper layers
    - Frame Transmission
    - Frame Reception
    - Data decapsulation and pass to upper layers
  - Does NOT care about the type of Physical layer in use
    - Does need to know speed of physical layer



MAC: Half Duplex

- **Half Duplex: Only one station may transmit at a time**
- **Requirement on shared mediums (Bus Topologies)**
  - **10Base-2, 10Base-5**
- **Half Duplex Mechanism employed by Ethernet is:**
  - **Carrier Sense, Multiple Access with Collision Detect (CSMA/CD)**

MAC: CSMA/CD

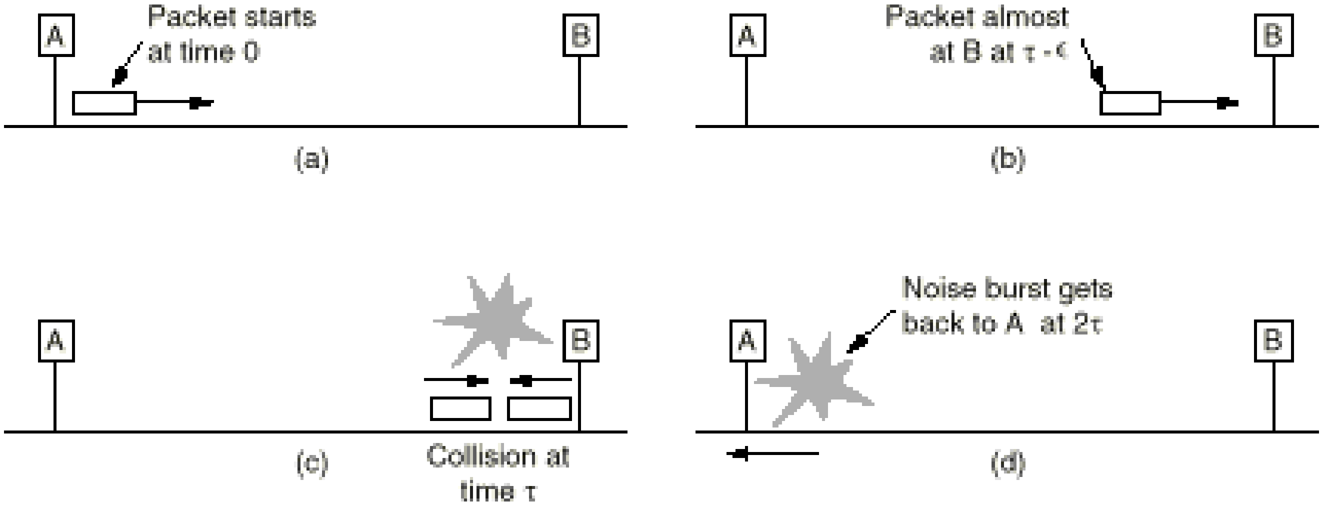
- CS - Carrier Sense (Is someone already talking?)
- MA - Multiple Access (I hear what you hear!)
- CD - Collision Detection (Hey, we’re both talking!)

1. If the medium is idle, transmit anytime.
2. If the medium is busy, wait and transmit right after.
3. If a collision occurs, send 4 bytes Jam, backoff for a random period, then go back to 1.

- We use CSMA/CD in normal group conversation.

MAC: Collision Domain

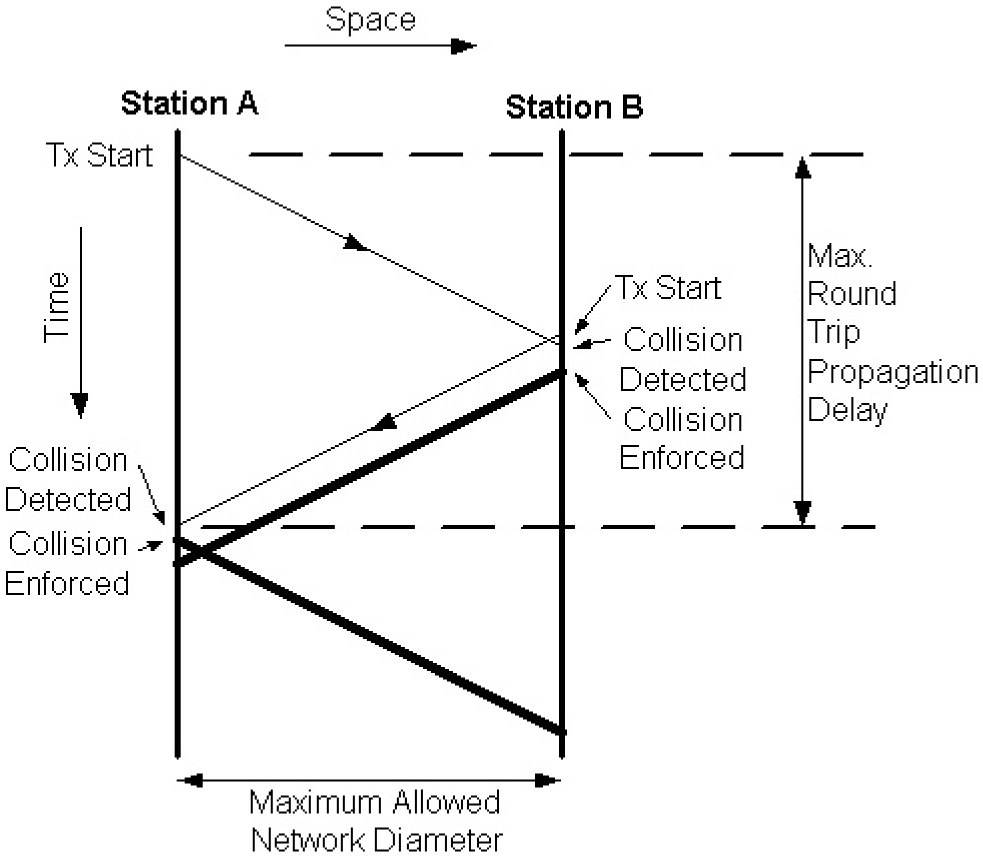
- Collision detection can take as long as twice the maximum network end to end propagation delay, worst case.
- This “round-trip” delay defines the max Ethernet network diameter, or collision domain.
- Round-trip delay = 512 bit times for all Ethernets up to this point.



A
B
Packet starts at time 0
(a)
Packet almost at B at $\tau - \epsilon$
(b)
(c)
Collision at time τ
Noise burst gets back to A at 2τ
(d)

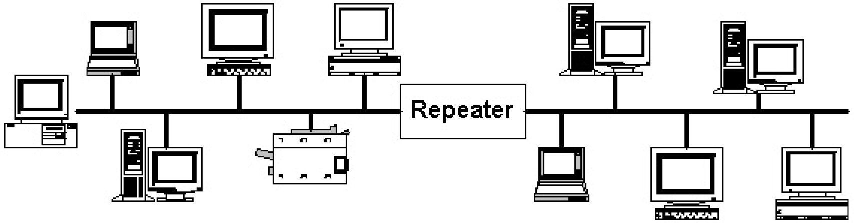
MAC: Collision Domain

- **Space-Time depiction of Collision Domain**

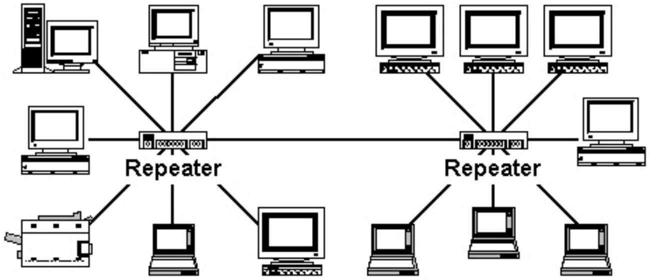


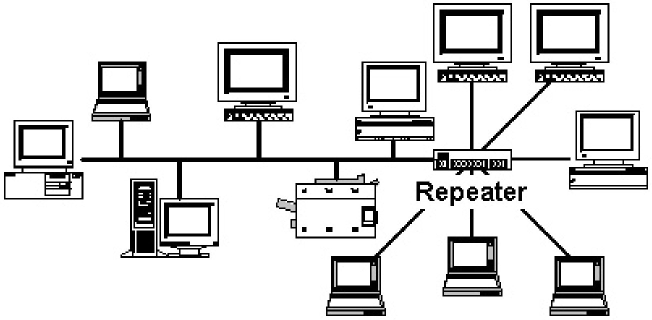
Repeaters

- Works at layer 1 (PHY layer) ONLY
  - thus it doesn’t understand frame formats
- Repeat incoming signal from a port to all other ports with:
  - restored timing
  - restored waveform shape
  - very little delay



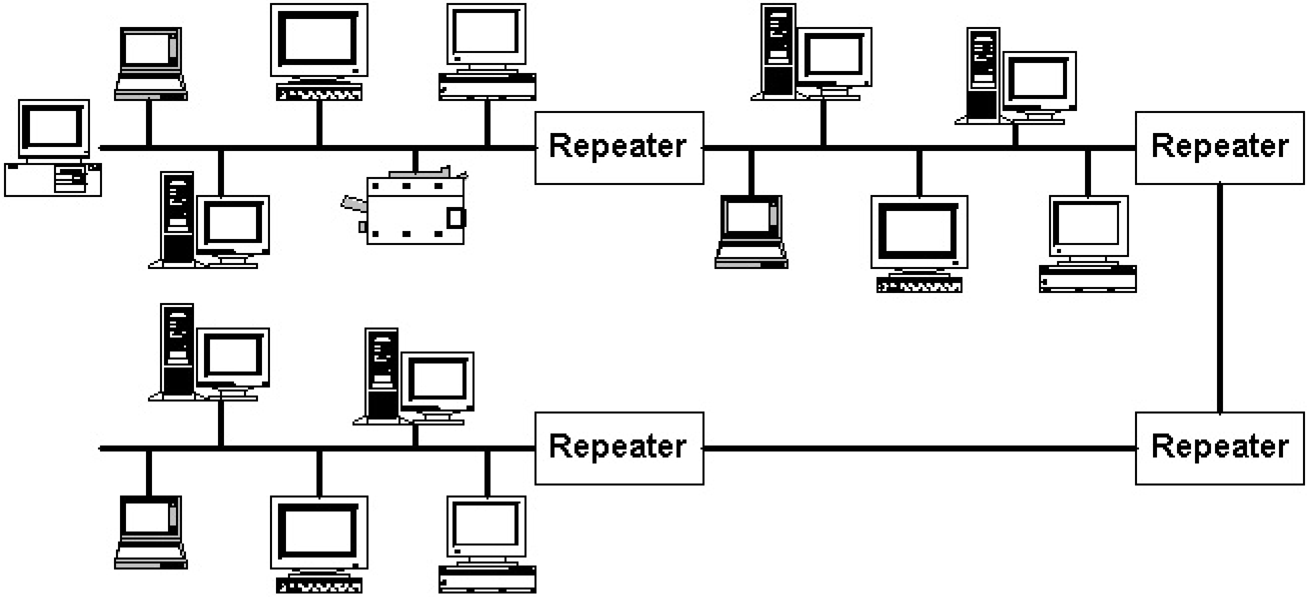
- Half Duplex ONLY: If 2 or more receptions, transmit jam
- Can connect dissimilar media/PHY types (e.g., 10base-T and 10base-2)





Repeaters: 10Mbps

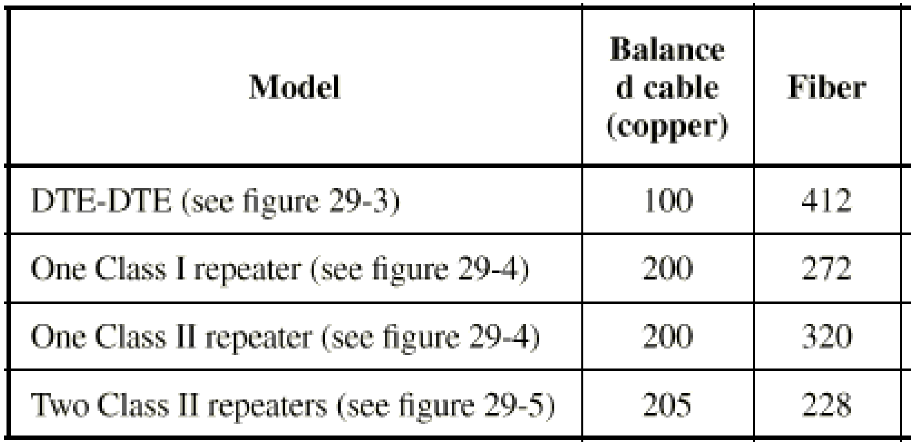
- **5-4-3 Rule**
  - 5 Segments
  - 4 Repeaters
  - 3 Populated segments (in the case of 10Base-5 or 10Base-2)



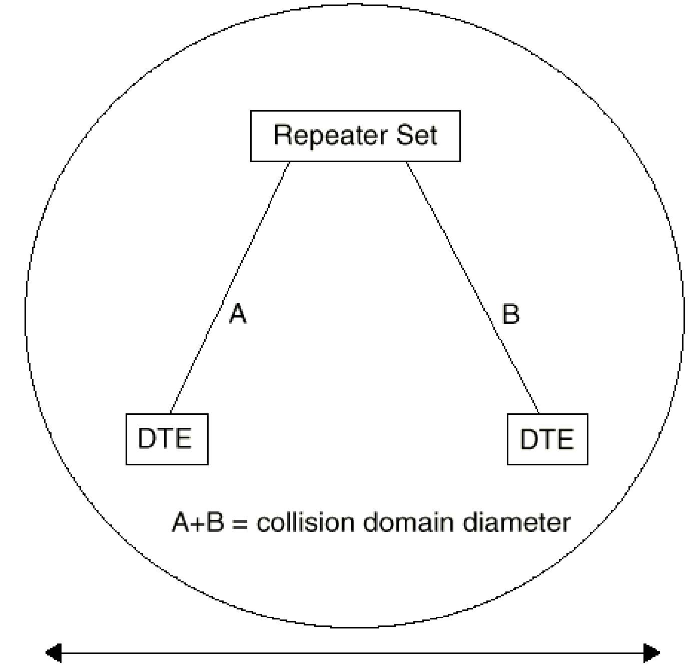
Repeaters: 100Mbps

- **512 bit times isn't much for F.E., because the bit time is 1/10 what it was for 10mbps**
  - **Even on fiber, the max diameter is 412 meters, and that's purely because of the round-trip time.**

Maximum Model 1 collision domain diameter



Model	Balanced cable (copper)	Fiber
DTE-DTE (see figure 29-3)	100	412
One Class I repeater (see figure 29-4)	200	272
One Class II repeater (see figure 29-4)	200	320
Two Class II repeaters (see figure 29-5)	205	228

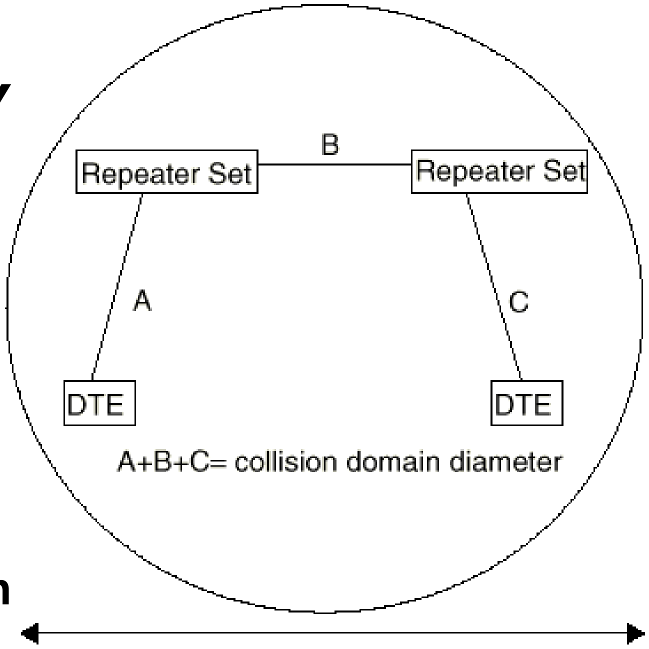


See table 29-2 for maximum collision domain diameter.

Figure 29-4—Model 1: Single repeater

Repeaters: 100Mbps

- **Repeater delay is VERY significant. So much so, they defined two types or speeds of repeaters:**
  - **Type I are slower**
  - **Type II are faster**
  - **Even using a Type II, you can only have 2 of them in a shared segment!**

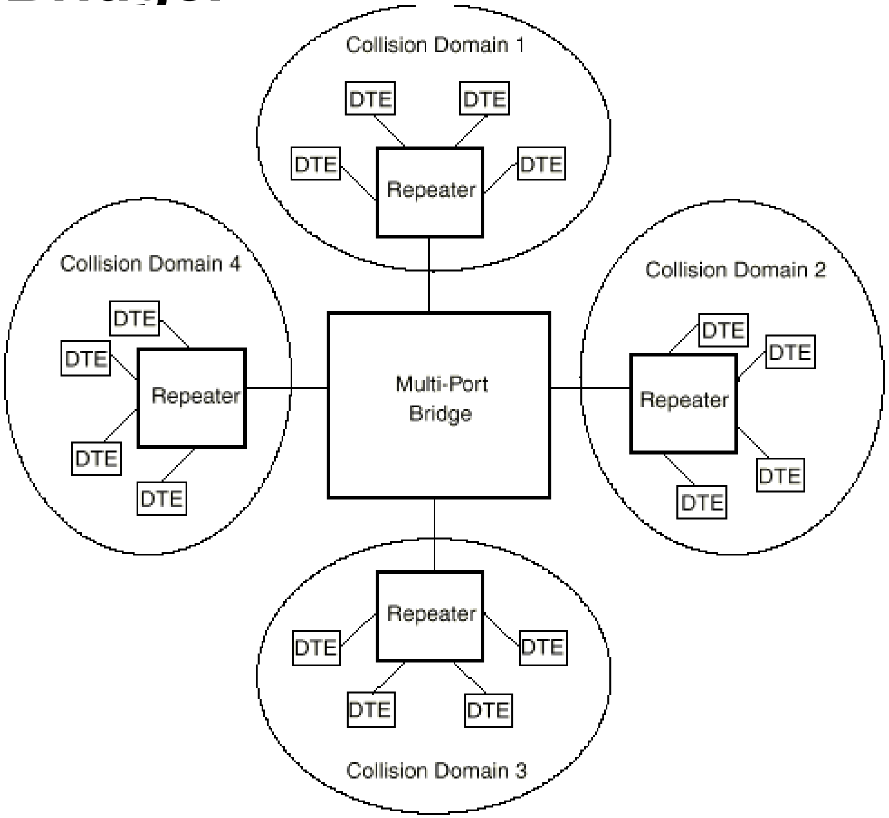


See table 29-2 for maximum collision domain diameter.

Figure 29-5—System Model 1: Two Class II repeaters

The Ethernet Bridge

- **How do you make a half duplex Ethernet network bigger than the Collision Domain allows?? Use a Bridge.**



- Repeaters are inside the collision domain, since they propagate collisions
- Bridges/Switches break up the domains, since they operate at layer 2 and buffer packets before sending them

Evolution…

- **10Base-T became dominant in early 90s**
  - Half Duplex / CSMA/CD is simple
  - Repeaters are cheap (not complex / low-speed)
  - Growth of Star Topology in building infrastructure
  - Unshielded Twisted Pair (UTP) cheaper than coax

- **Predominant use of UTP allows for the creation of Full Duplex MAC.**
  - Media is no longer SHARED
    - » 10BASE-T devices transmit on one pair of UTP, and receive on an entirely separate pair.
    - » Unlike coax – simultaneous reception and transmission on the media does NOT corrupt the data transmission.

MAC: Full Duplex

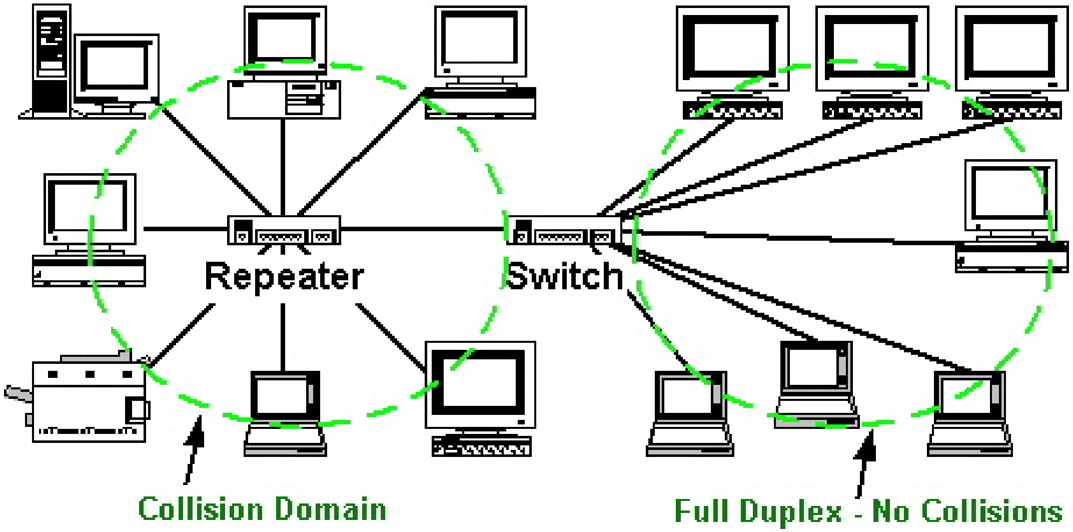
- Remember CSMA/CD? Now forget it.
- As long as we don’t need to share a network (like with a repeater or coax), why bother “colliding”?
- New MAC: transmitting while receiving is OK
- Still maintain IPG, frame sizes, and physical layer

MAC: Full Duplex Pros and Cons

- **Pros:**
  - aggregate throughput = 200mbps
  - no collision efficiency penalty
  - no need to defer to incoming transmission
  - no collision domain - Distance is media dependent and not affected by the protocol.
- **Cons:**
  - Must be point-to-point link (i.e., no repeaters)
  - Higher throughput means higher speed equipment which means higher cost.
  - no built in back pressure mechanism (see MAC Control / Flow Control)
  - Need for point to point links requires new hub device to interconnect multiple station – a full duplex capable switch.

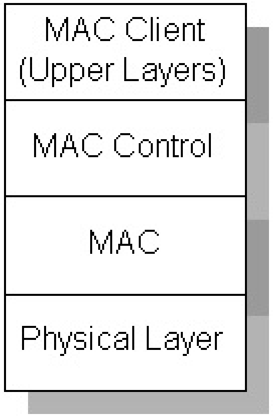
The Ethernet Switch

- Each port of Switch has its own MAC
- Typically can support either Half or Full Duplex
- Can switch between different network speeds (i.e., 10Mbps and 100Mbps)
- More on this to come…



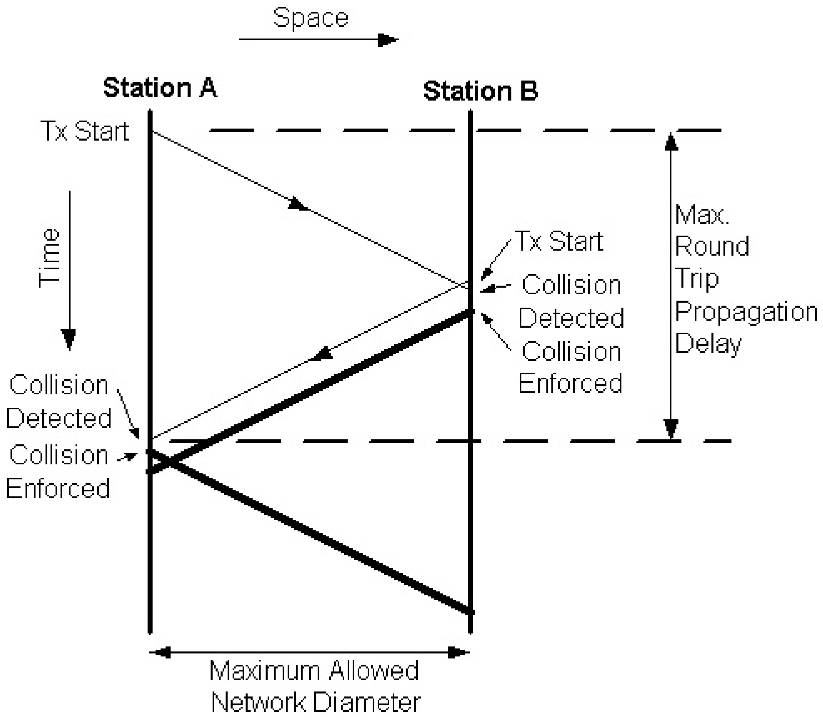
Flow Control

- Supported on Full Duplex links only.
- Sends MAC Control Frames called Pause Frames
- Pause Frames
  - Destination address is a special multicast address that is never forwarded by bridges/switches.
    - Thus, Link Level Flow Control ONLY
  - Tells MAC Control to pause frame transmission to the MAC for a period of time
- Useful for input constrained devices such as network interface cards (NICs) and buffered distributors (more on those in a bit).



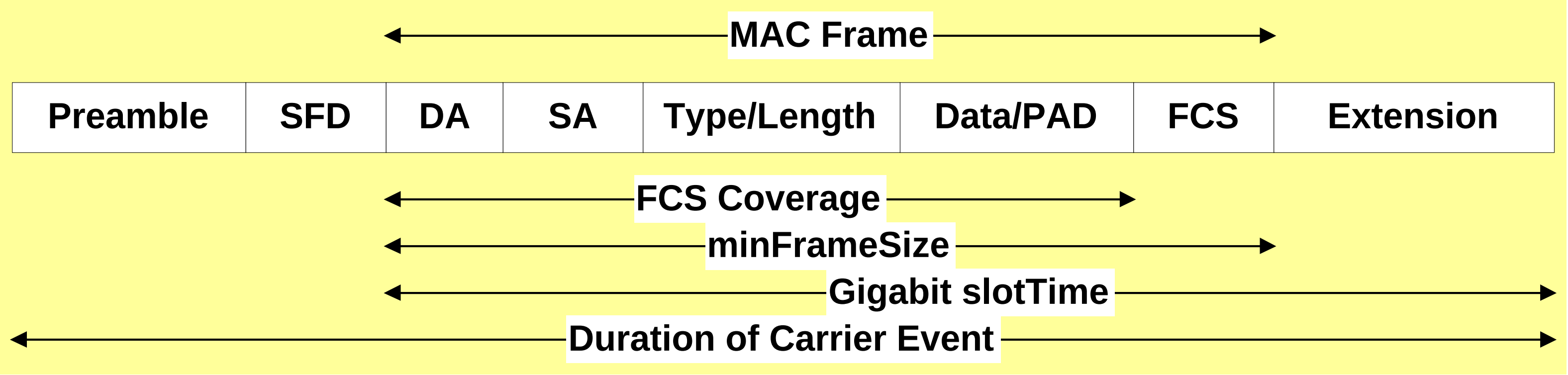
MAC: Half Duplex at 1 Gbps

- **Recall the maximum network diameter from 100Mbps is only ~200m.**
  - **Without modification to the Ethernet MAC, the allowed diameter at 1Gbps (10x faster) would be ~20m (10x smaller)**
  - **To fix this, the minimum transmission size must be increased such that an acceptable distance (~200m) is covered. Recall the diagram at right:**



MAC: Half Duplex at 1Gbps

- **Solution: MAC adds Extension (non-data) bits after the end of the frame until transmission is at least 4096bits**
- **Benefits of the extension system**
  - **Extends collision diameter**
  - **Maintains compatibility**
  - **Bigger frame size would add complexity (more on that soon…)**



MAC Frame

Preamble	SFD	DA	SA	Type/Length	Data/PAD	FCS	Extension

FCS Coverage

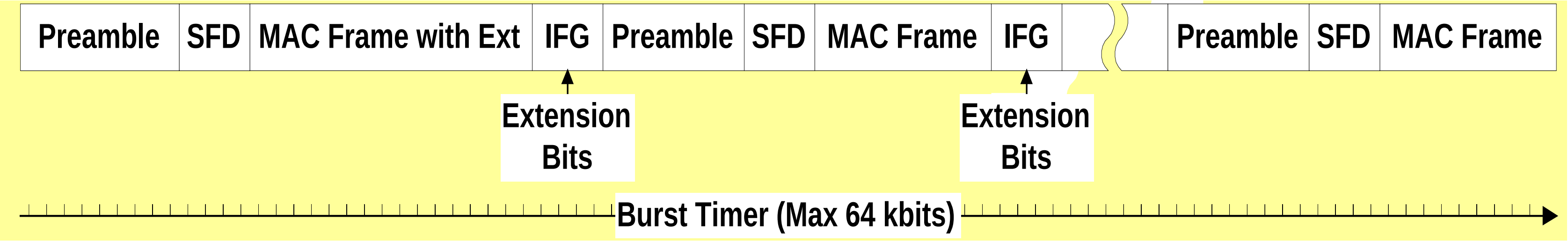
minFrameSize

Gigabit slotTime

Duration of Carrier Event

MAC: Half Duplex at 1Gbps

- **Extension fields create waste in small packets**
  - This waste cannot be eliminated but can be reduced by frame bursting
- **Frame Bursting**
  - First frame, if less than 512 Bytes must be extended to 512 Bytes, but may be followed minimum size inter frame gaps (IFGs) filled with extension bits and frames of any size
  - Maximum size transmitted burst ~64Kbits
  - MAC must end burst if no frame is ready to be sent
  - Useful for Servers/Switches transmitting high loads on a half duplex network



Buffered Distributors

- Very rare devices - That said, they are far more common than half-duplex 1 Gbps devices (which are essentially non-existent) Why?
- Where a repeater is a “bus in a box”, a buffered distributor (BD) is “CSMA/CD in a box”.
  - Each attached device is connected to an input buffer via a full duplex link. If the input buffer is full, the BD uses PAUSE frames to stop traffic from the attached device. When a frame is removed from the input buffer, it is transmitted out all other ports – hence BDs are sometimes called “Full duplex repeaters”
  - Thus the collision domain is the maximum delay within the box, infact, the medium access method used in the box need not be CSMA/CD, so long as it is fair.
- Benefit: Silicon cheaper than a switch (max speed 1Gbps) and less complex than frame extension and bursting
- These are not specified in the standard explicitly, but all the “enabling mechanisms” are - device internals (ie: “bus in a box”) rarely need to be standardized

Ethernet JUMBO Frames

- **BAD IDEA**
- **Recall that HALF DUPLEX 1 Gig Ethernet chose to use extension bits to pad a frame out to 512Bytes to enable a larger collision domain**
- **Why didn’t they just change the frame size? (change the min to 512Bytes, and max to, oh say, 4K or 9K)**
- **Because such equipment would NOT work with any previously deployed equipment – NOT a smart move for the WORLDS most popular networking technology.**

Jumbo Frames cont. 1

- The Problem:
- “Software”/Users think that this is a simple problem – simply change the MTU (max transmission unit) to 4K (or more) then let the switches adapt the frame size (fragment and reassemble – this is HARD HARD HARD to do in hardware – read as, costly) -- OR – don’t care about backward compatibility (interesting world you live in then… can I join you?)

Jumbo frame cont. 2

- **The Reality:**
- **Hardware is built with certain expectations about frame sizes, interframe-gaps, and transmission rates – simply “changing” the MTU of your system and using hardware not built for Jumbo frames WILL RESULT in frame/data loss (things called “elasticity buffers”, which bridge digital clock domains in systems, must be built with these “certain expectations”) --- not to mention buffer allocation problems, etc…**

Jumbo frames cont. 3

- That said, Jumbo frames _are_ out there but they are NON-STANDARD
- But be careful (SANs like iSCSI intend to use them, but there are real risks there)
- And don't PLAN on them working beyond the SINGLE vendor's equipment that you are using them with (yes, there's a good chance that multi-vendor jumbo frames would work – but that's what a standard would protect – and I assure you – IEEE 802.3 will NEVER adopt a larger frame size, as they are COMMITTED to supporting the installed base.

This page left intentionally blank.

This page left intentionally blank.

This page left intentionally blank.

Physical Media Overview

Media Outline

- Copper and Copper and Copper
- Fiber and Fiber

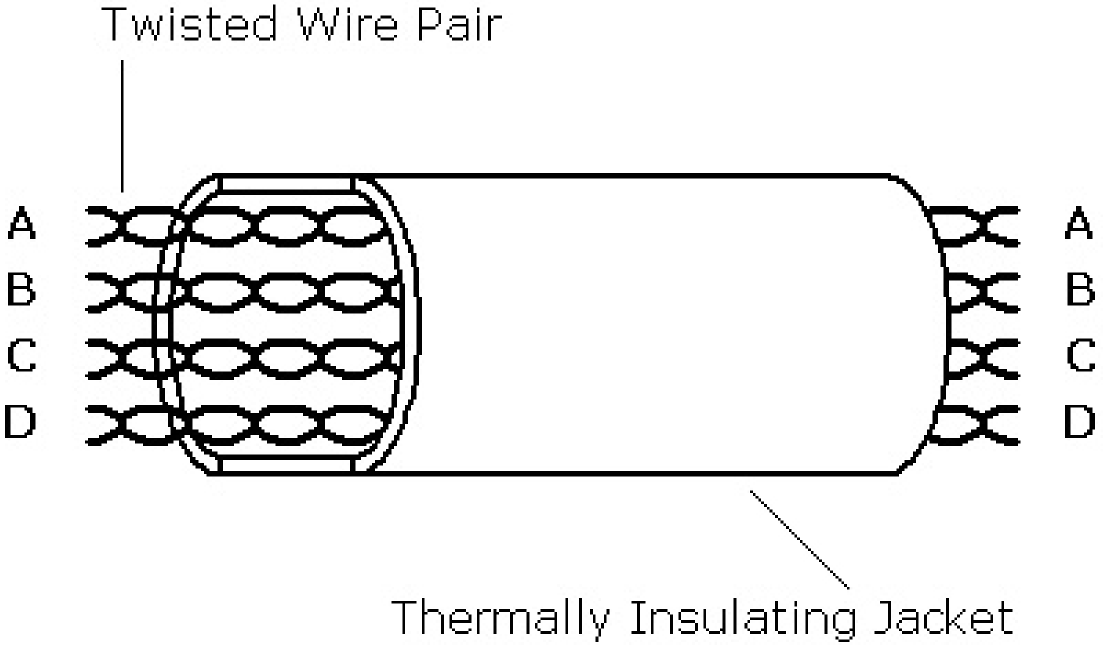
Structured Cabling

- Defines a generic telecommunications cabling system for commercial buildings.
- Specifies the performance of the cable and connecting hardware used in the cabling system.
- Why?
  - The installation of a cabling system is simpler and cheaper during building construction than after the building is occupied.
  - Such a cabling system must have the flexibility to allow the deployment of current and future network technologies.
  - A structured cabling standard provides a design target for the developers of new network technologies (like 1000BASE-T).

Structured Cabling Standards

- TIA/EIA-568-A, North America
- ISO 11801, International
- Scope:
  - define performance of unshielded twisted pair (UTP), shielded twisted pair (STP), and fiber optic cables and connecting hardware.
  - define how these cables will be used in a generic cabling system.
- Both standards define similar distribution systems and performance requirements.
  - developers do not have to hit two separate targets

Unshielded twisted pair (UTP) cable



The Category System

- **TIA/EIA-568-A defines a performance rating system for UTP cable and connecting hardware:**
  - **Category 3 performance is defined up to 16MHz.**
  - **Category 4 performance is defined up to 20MHz.**
  - **Category 5 performance is defined up to 100MHz.**
    - **Original Cat 5 - Not suitable for 1000Base-T**
    - **Category 5n - Suitable for 1000Base-T**
    - **Category 5e - Exceeds requirements for 1000Base-T**
  - **Category 6 performance is defined up to 200MHz**

Performance Parameters for UTP Cable

- DC resistance
- characteristic impedance and structural return loss
- attenuation
- near-end crosstalk (NEXT) loss
- propagation delay

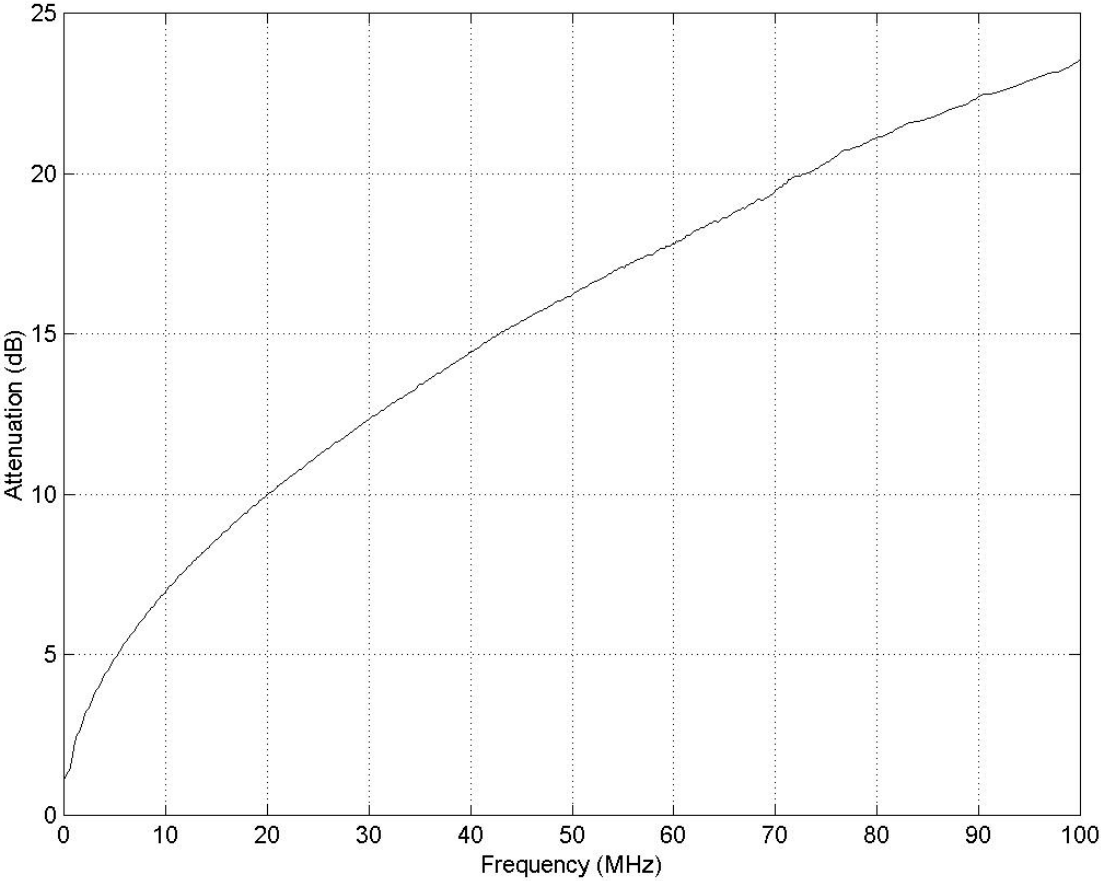
Parameters for UTP Connecting Hardware

- DC resistance
- attenuation
- NEXT loss
- return loss

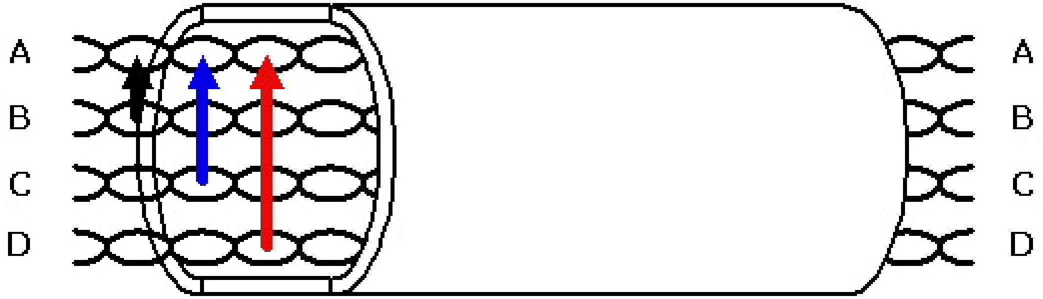
Attenuation

- **Electrical signals lose power while traveling along imperfect conductors.**
- **This loss, or attenuation, is a function of conductor length and frequency.**
- **The frequency dependence is attributed to the skin effect.**
- **Skin Effect:**
  - **AC currents tends to ride along the skin of a conductor.**
  - **This skin becomes thinner with increasing frequency.**
  - **A thinner skin results in a higher loss.**
- **Attenuation increases up to 0.4% per degree Celsius above room temperature (20^{o}C).**

Attenuation vs. frequency

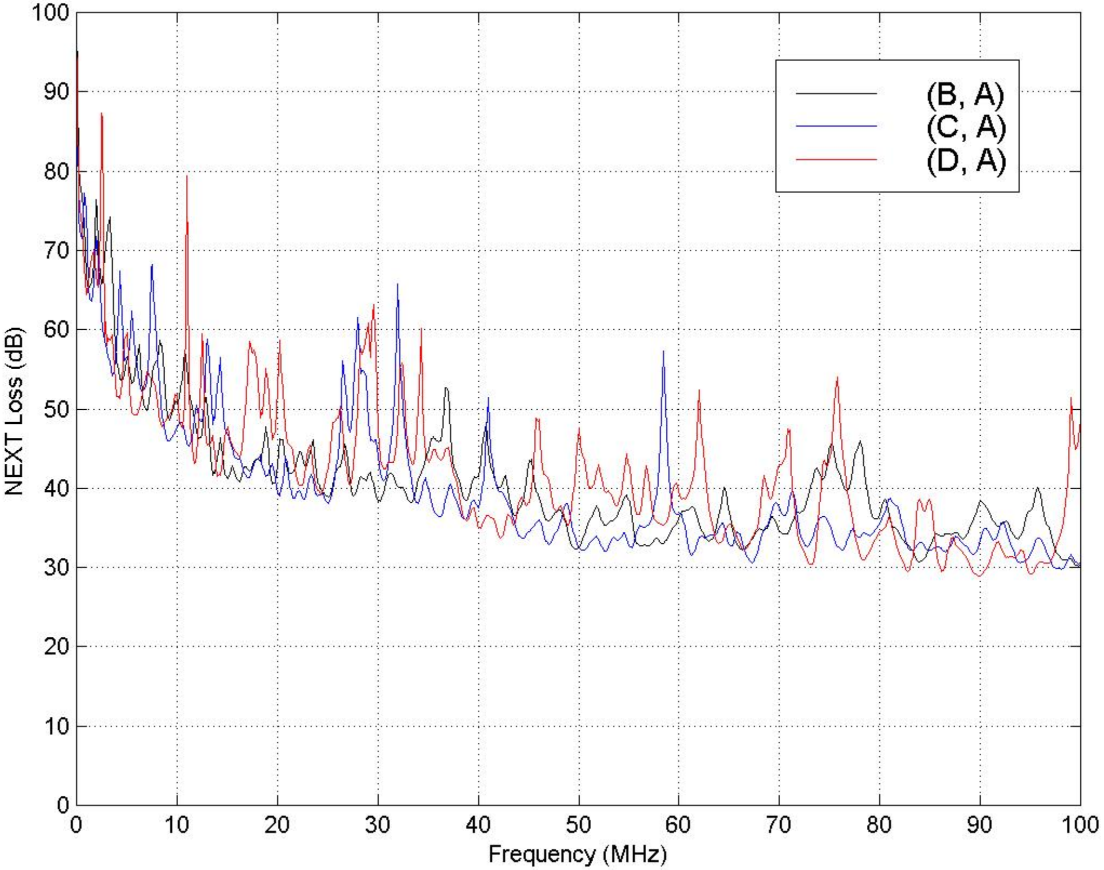


Near-end crosstalk (NEXT) loss



- Crosstalk:
  - Time-varying currents in one wire tend to induce time-varying currents in nearby wires.
- When the coupling is between a local transmitter and a local receiver, it is referred to as NEXT.
- NEXT increases the additive noise at the receiver and degrades the signal-to-noise ratio (SNR).

NEXT loss vs. frequency (pair A)



Return loss

- The reflection coefficient is the ratio of the reflected voltage to the incident voltage.
- The return loss is the magnitude of the reflection coefficient expressed in decibels.

Structured cabling overview I

- Work area
  - for example, an office
- Telecommunications closet
  - focal point of horizontal cabling
  - access to backbone cabling and network equipment
- Equipment Room
  - can perform any of the functions of a telecommunications closet
  - generally understood to contain network resources (for example, a file server)
- Entrance Facility
  - the point at which the network enters the building, usually in the basement

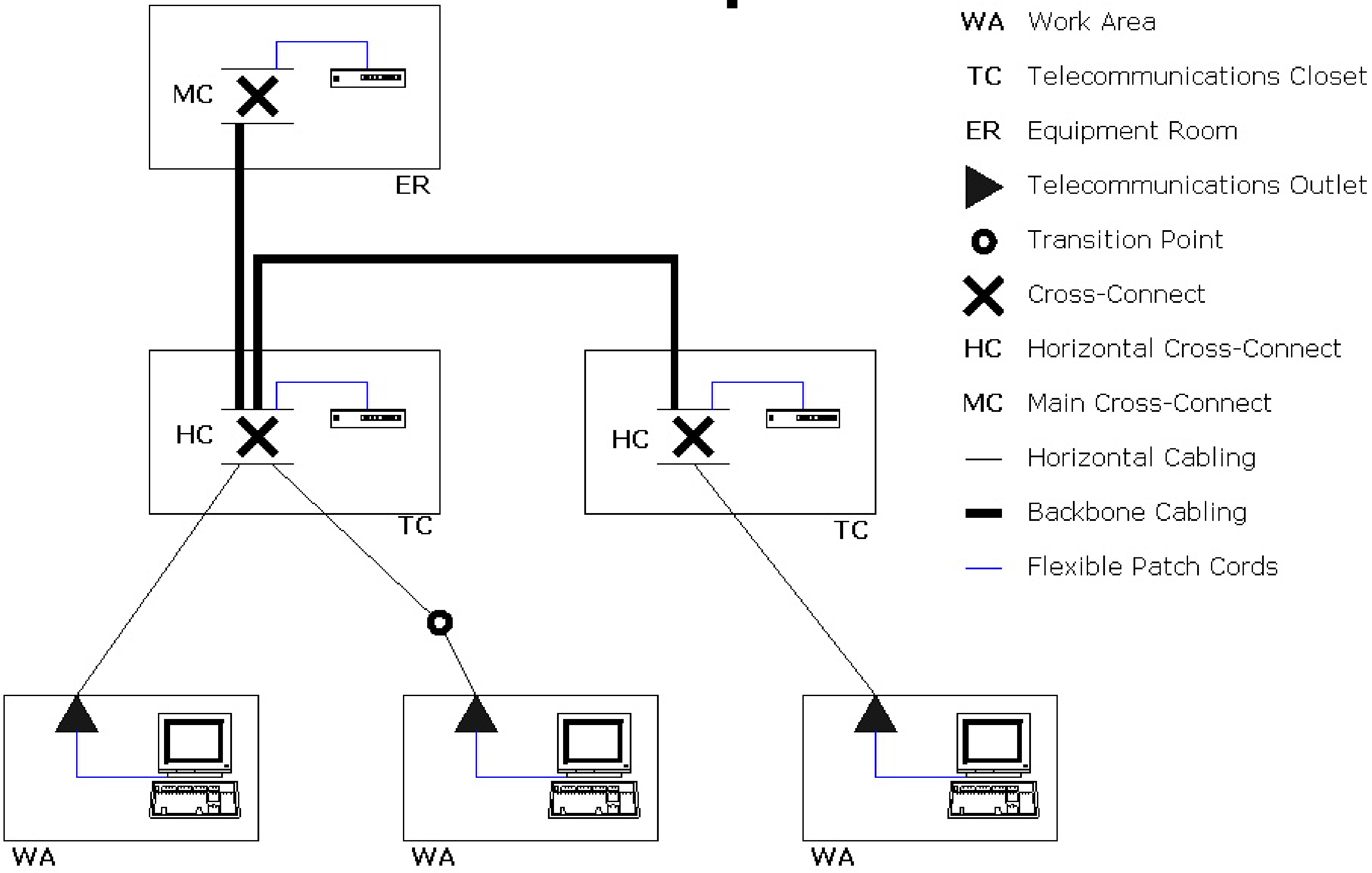
Structured cabling overview II

- Horizontal Cabling
  - from the work area to the telecommunications closet.
  - up to 90m of 4-pair unshielded twisted pair (UTP) cable.
- Backbone Cabling
  - between telecommunications closets, equipment rooms, and entrance facilities.
  - up to 90m of 4- or 25-pair UTP cable.
- Flexible Patch Cords
  - cables use solid conductors making them inflexible and difficult to work with
  - cords use stranded conductors for greater flexibility at the expense of up to 20% more loss than the same length of cable.
  - cords are used at points where the network configuration will change frequently

Structured cabling overview III

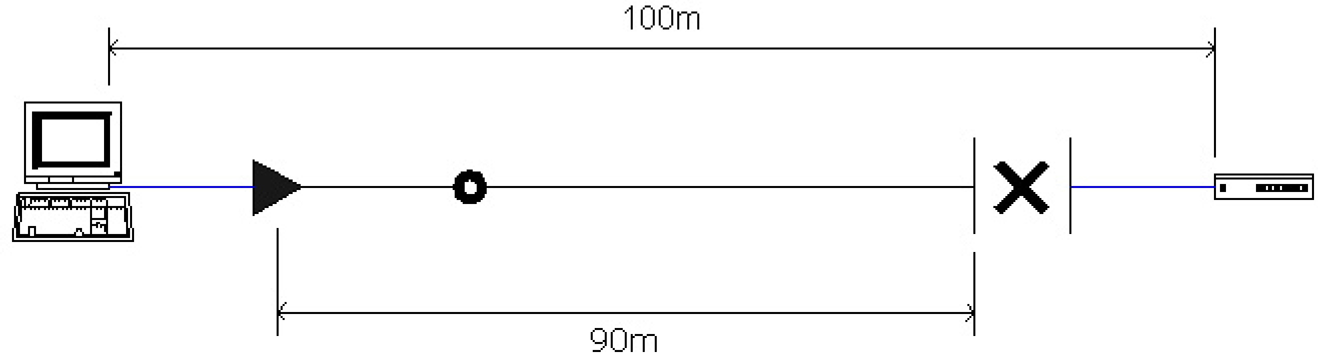
- **Transition point**
  - connects standard horizontal cable to special flat cable designed to run under carpets.
- **Cross-connect**
  - a patch between two interconnects
  - horizontal and backbone cabling runs end at interconnects
  - network equipment may use an interconnect
- **For UTP cabling systems, horizontal and backbone runs are always terminated in the telecommunications closet and equipment room**
  - for example, you cannot cross-connect a horizontal run to a backbone run.

Structured cabling system example



WA	Work Area
TC	Telecommunications Closet
ER	Equipment Room
▶	Telecommunications Outlet
○	Transition Point
✕	Cross-Connect
HC	Horizontal Cross-Connect
MC	Main Cross-Connect
—	Horizontal Cabling
▬	Backbone Cabling
—	Flexible Patch Cords

TIA/EIA-568-A channel definition



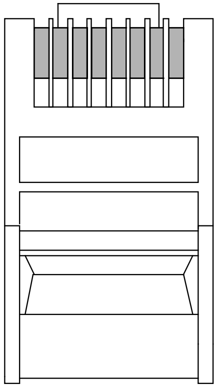
- 90m of horizontal cable
- 10m of flexible cords
- 4 connectors
- ISO 11801 channel definition does not include a transition point (3 connectors).
- The channel definition is the developer’s design target.

UTP Copper Info

- Two types of UTP – Solid Core (for Horizontal runs) and Stranded Core (for patching)
- RJ-45 connectors – when making cable:
  - solid: use 8-pin modular (RJ-45) plug with three prongs on the metal contacts
  - stranded: two prongs on metal contacts
- Wiremap – there are four pairs in a normal UTP cable: orange, green, blue, and brown. In each pair there is a white wire with a colored stripe and a colored wire with a white stripe. By convention, the white wire carries the signal and the colored wire carries the inverted signal.

More UTP Copper Info

- **looking down at the top of the RJ-45 (locking tab facing down)**



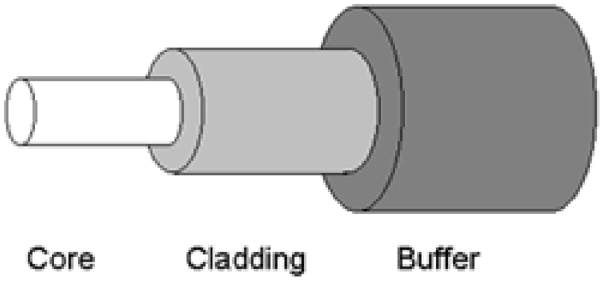
1	2	3	4	5	6	7	8
Solid White, Orange Stripe	Solid Orange, White Stripe	Solid White, Green Stripe	Solid Blue, White Stripe	Solid White, Blue Stripe	Solid Green, White Stripe	Solid White, Brown Stripe	Solid Brown, White Stripe

- **A good UTP cable will have:**
  - **All 8 wires visible at the very end of the RJ45 cable**
  - **The Jacket of the cable fully inserted into the RJ45 (so when you pull on the cable, you pull the jacket and the RJ45, and not the wires and contacts)**

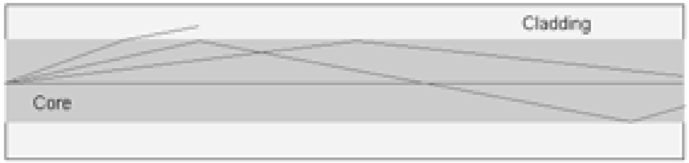
Fiber Types

- **Fiber's form and 3 basic types**

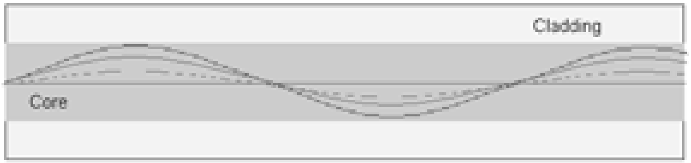
Fiber Structure



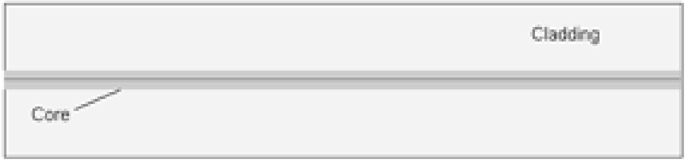
Multimode Step Index



Multimode Graded Index



Singlemode



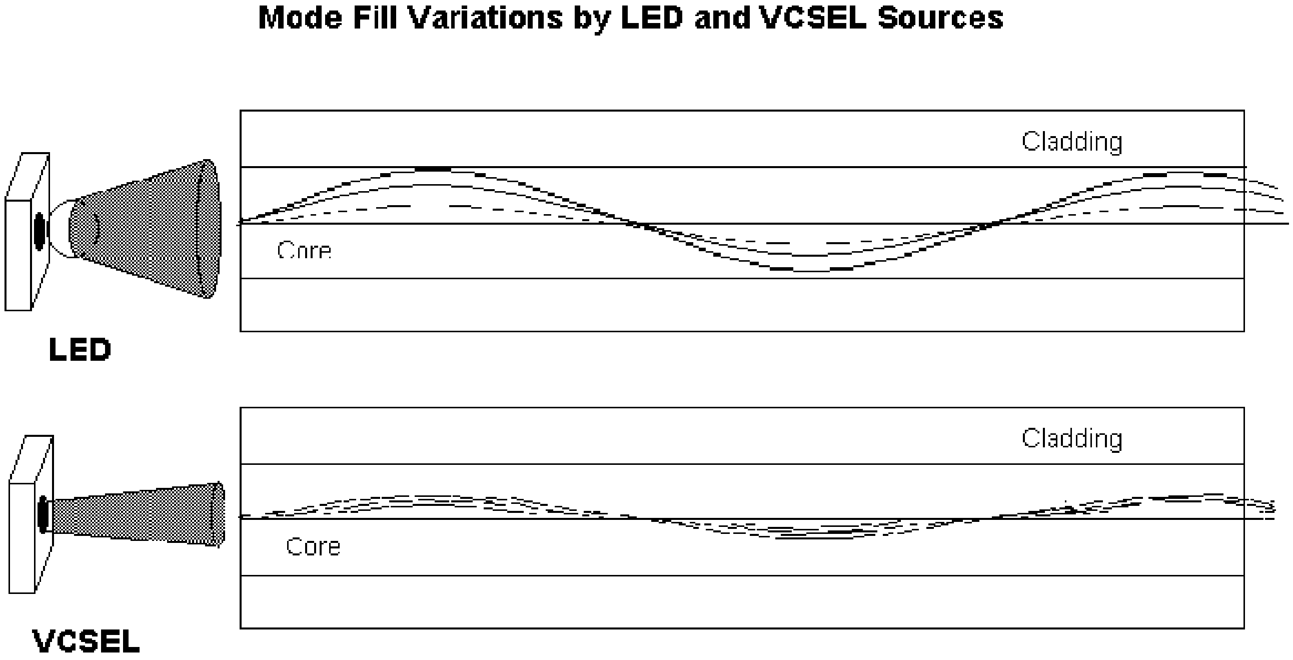
Fiber Core Sizes

- Multimode: Two most common are 62.5 and 50 micron
- Singlemode – To be singlemode, diameter must be no more than ~6 times the wavelength, thus for 1330 – 1510 nm light, the diameter must be 7 to 9 micron
- Mismatching core sizes can be done, but in general is bad!

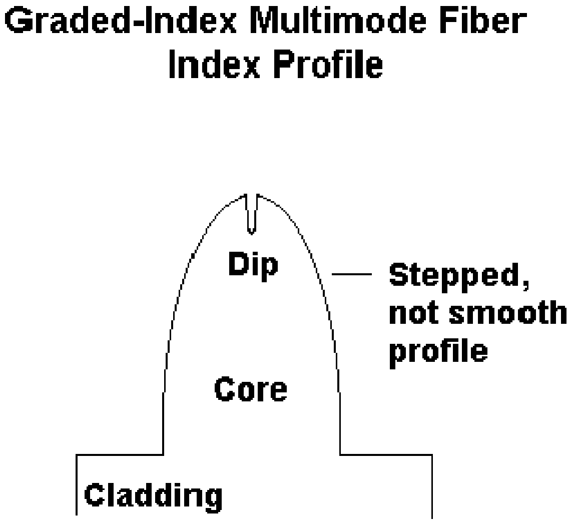
Modal Dispersion

- A flashy name to describe how in a multi-mode fiber, the multiple paths arrive at the end of the fiber at different times.
- This multi-path delay causes a “small” input pulse to smear into a “wide” output pulse, degrading the rate at which those data pulses can be sent down the fiber (degrading the bandwidth)
- Note that a multimode step index fiber has high modal dispersion, as a result, such fiber is not typically used today.
- Graded index fiber varies the refraction index of the fiber material from the center of the fiber out to its edge. The result is that the modes traveling the longer sinusoidal paths actually propagate faster than the modes traveling the shorter, straighter paths – thus, in a perfect graded index fiber, all modes would arrive at the same time at the output of the fiber, and no smearing would occur. (of course perfection is impossible to achieve)

Fiber Launches



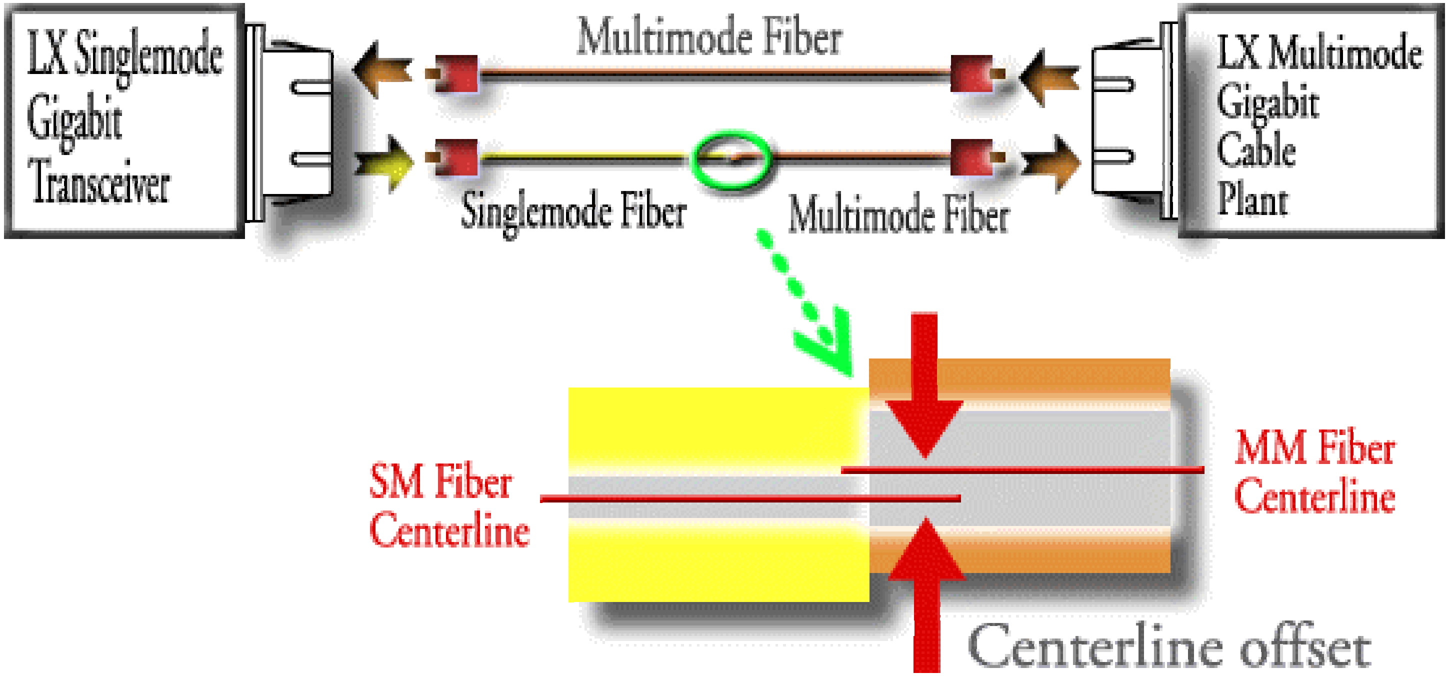
Recent Modal Dispersion Issues



- As a side-note: During the development of Gigabit Ethernet, it was discovered that a sizeable percentage of installed (old) multimode graded index fiber had a deviation in the center of the core, as depicted at left. This was determined to cause increased modal dispersion (DMD, differential modal delay as the gig folk called it)
- The result of this discovery of a flaw in the installed media was the subsequent reduction in supported link lengths for GbE on installed multimode fiber.
- Which leads to the following new term…

Launch Conditioning

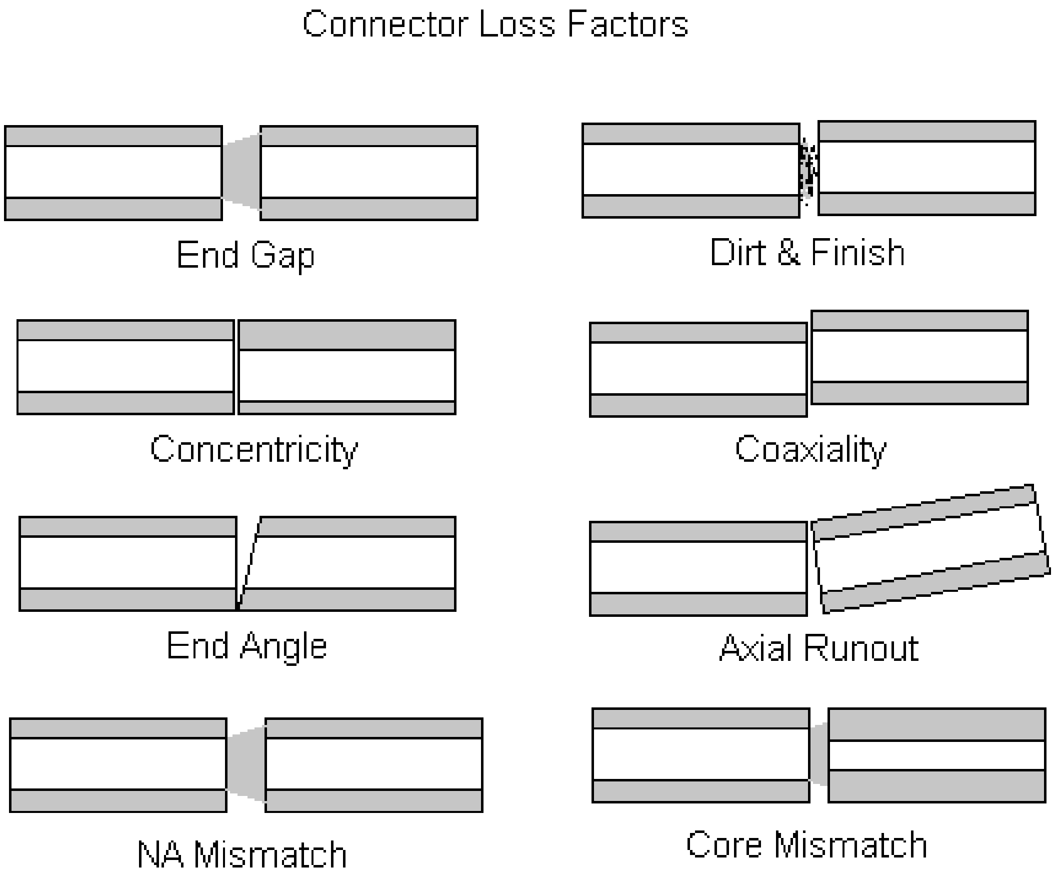
- Many options exist to minimize the DMD effect, one of which is to use a single-mode “pig-tail” to condition/reduce the modes launched into the multi-mode segment, by launching them off-center (and thus avoiding the index “notch” in the center of the installed fibers)



Chromatic Dispersion

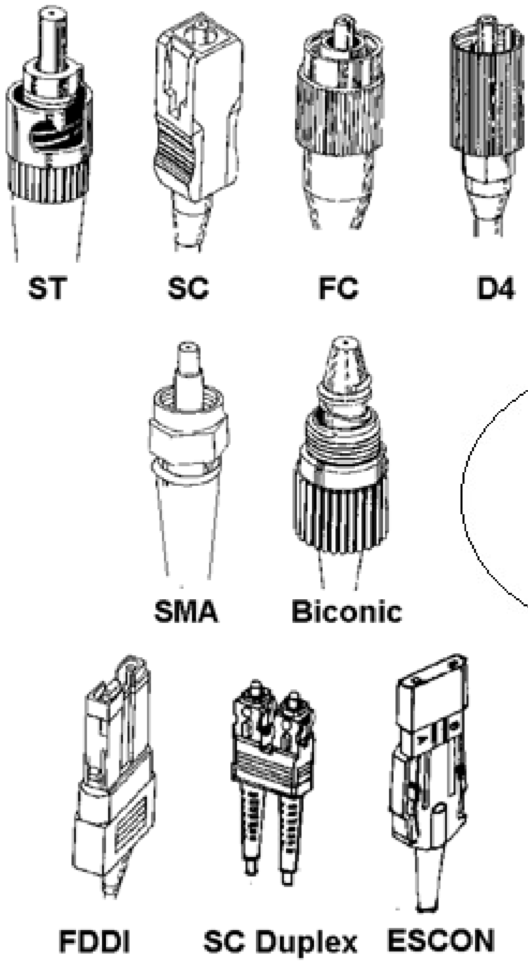
- Effects all fiber types, but is one of the primary limiting factors of long-haul single-mode connections.
- As mentioned earlier, EM waves propagate at different speeds in different media. Well, simply put, EM waves at different frequencies propagate at different speeds, even in the same media! In general, this is referred to as group delay, but in Fiber Optics, its more commonly called chromatic dispersion.
- This spreading of different colors smears the transmitted pulses just as with modal dispersion

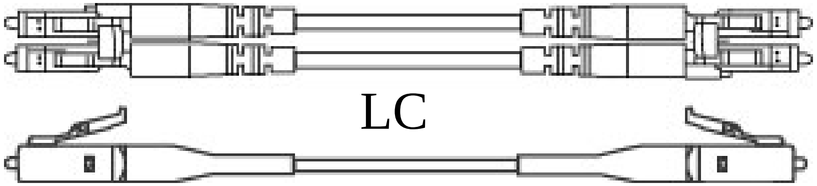
Bad Fiber Connections

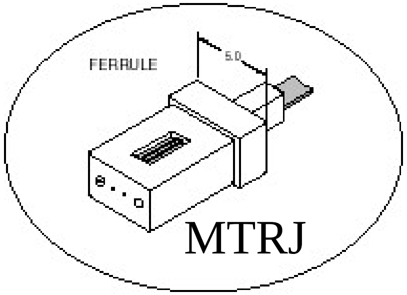


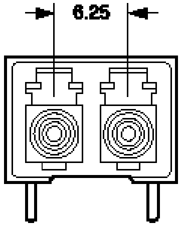
- **Always keep your Fiber CLEAN! And Capped when not in use (both patch and ports)**

Some Types of Connectors



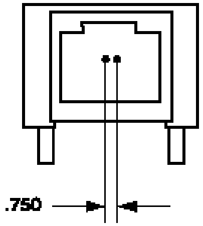






LC Transceiver

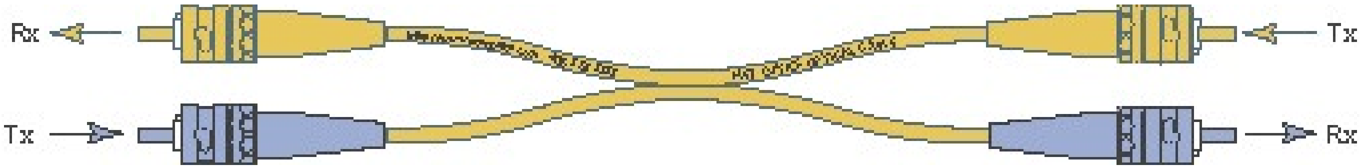
Especially note SC, ST, LC, and MTRJ



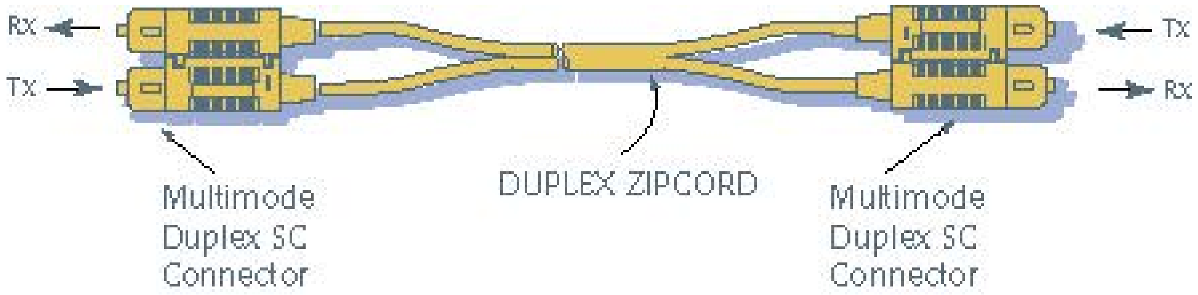
MT-RJ Transceiver

Most Common Connectors

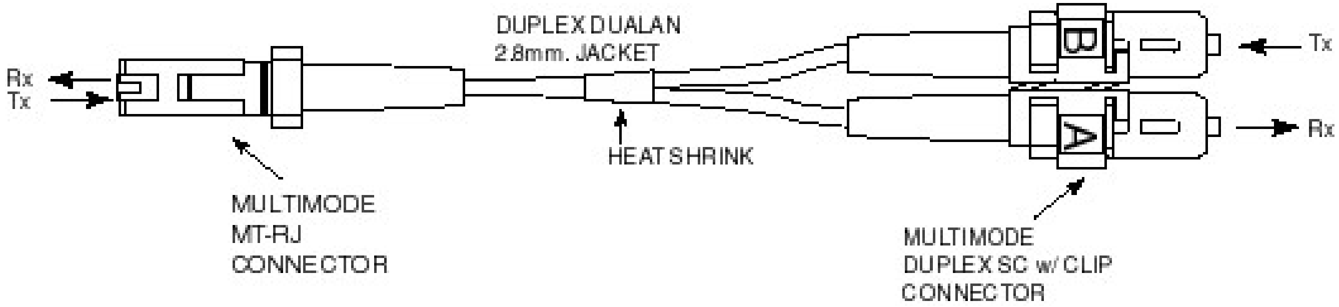
- ST



- SC

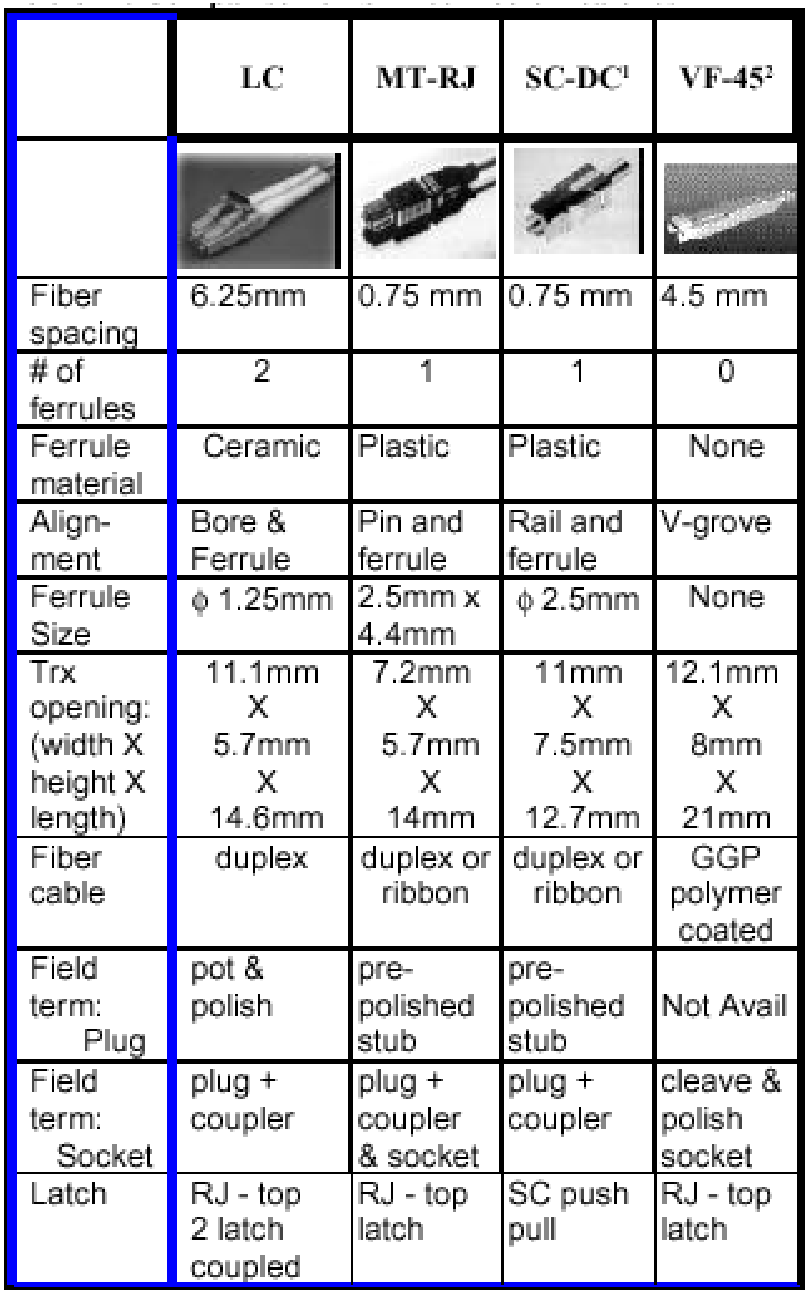


- MTRJ and LC to SC


Rx
Tx
DUPLEX DUALAN 2.8mm. JACKET
HEAT SHRINK
B
A
Tx
Rx
MULTIMODE MT-RJ CONNECTOR
MULTIMODE DUPLEX SC w/ CLIP CONNECTOR

SFF Connectors

- Small Form Factor (SFF) allows more interfaces in same footprint
- 4 Competing types, but LC and MT-RJ are the 2 big ones
- SFF has a hot-pluggable version (like GBICs)



	LC	MT-RJ	SC-DC[1]	VF-45[2]
Fiber spacing	6.25mm	0.75 mm	0.75 mm	4.5 mm
# of ferrules	2	1	1	0
Ferrule material	Ceramic	Plastic	Plastic	None
Align-ment	Bore & Ferrule	Pin and ferrule	Rail and ferrule	V-grove
Ferrule Size	ϕ 1.25mm	2.5mm x 4.4mm	ϕ 2.5mm	None
Trx opening: (width X height X length)	11.1mm X 5.7mm X 14.6mm	7.2mm X 5.7mm X 14mm	11mm X 7.5mm X 12.7mm	12.1mm X 8mm X 21mm
Fiber cable	duplex	duplex or ribbon	duplex or ribbon	GGP polymer coated
Field term: Plug	pot & polish	pre-polished stub	pre-polished stub	Not Avail
Field term: Socket	plug + coupler	plug + coupler & socket	plug + coupler	cleave & polish socket
Latch	RJ - top 2 latch coupled	RJ - top latch	SC push pull	RJ - top latch

Fiber Info

- Not only must the fiber be kept clean, but its end should be polished (to eliminate scratches) and rounded.
- The rounding of the ends allows the two fiber ends to touch without an airgap forming between them.
- DO Keep your fiber clean. If in doubt, use an airgun or alcohol swab to clean the ends.
- DO Keep your fiber capped when not in use (to prevent dust and scratches)
- DO Keep fiber ports on devices capped when not in use – dust collected on a transmitter or receiver can only – at best, be blown at with an airgun.

More Fiber Info

- **DON’T EVER allow the fiber to bend more than the diameter of your closed fist. Fiber is glass, bent glass breaks and/or creates microfractures.**
- **DON’T touch the tip of the fiber with your finger/body – The core may be protruding and slice you open (it is glass!)**
- **DON’T look down a fiber! Its YOUR EYESIGHT at stake!! Use a power meter to check your cable!**
- **Quick way to test fiber / find the right fiber –Hold one fiber at the far end up to a light, look in the other end to find the white dot! – If you don’t see it, it’s the wrong fiber, or its EXTREMELY broken.**

This page left intentionally blank.

This page left intentionally blank.

This page left intentionally blank.

Core PHYs

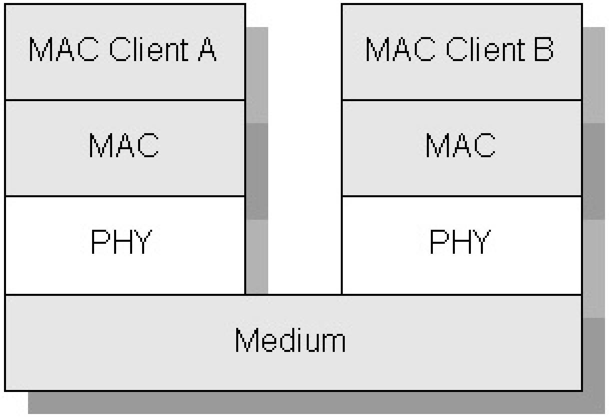
Core PHYs Outline

- Review of the Physical layers role
- UTP Copper Phys
- Fiber Phys

- Primary focus on 10Base-T, 100Base-TX, and 1000Base-T

Review

- **MAC**
  - Sends/Receives data to/from higher layer client
  - Handles addressing of data frames for the LAN
  - Appends a checksum to ensure frame validity on reception
- **Medium**
  - Available channel in infrastructure for data transmission
  - May be copper or fiber
  - Medium selected is typically a matter of cost and installed base
- **PHY – Physical Layer**
  - Prepares MAC frame for Medium
  - Drive signal across Medium (Tx to Rx)

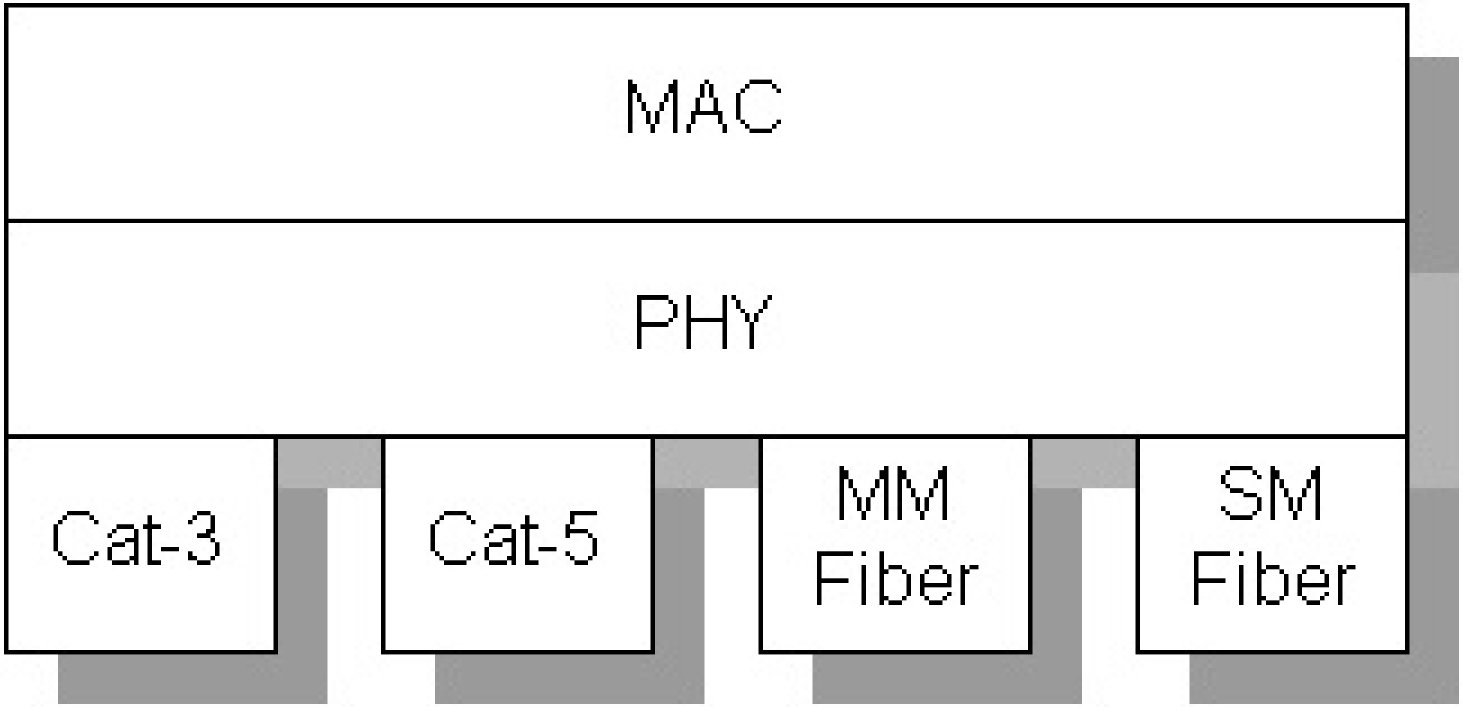


PHY Objectives

- Balance of the following desirables:
  - Low Cost
  - Long Distance
  - High Data Rate capability
  - Low Bit Error Rate
  - Support the current installed media when possible

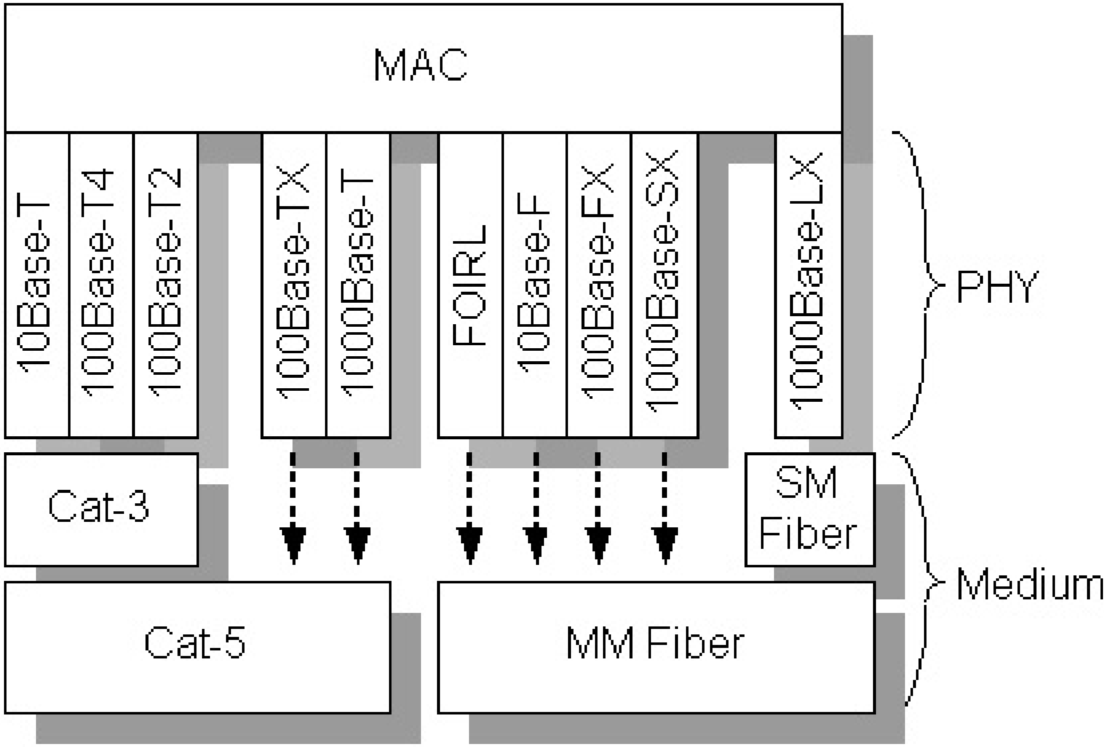
PHY Stack Model - Slide 1

- Notice the PHY connects the SAME MAC layer to different types of Media, the four most common are shown:



PHY Stack Model – Slide 2

- To support different media, different PHYs are required.
- Each PHY balances the objectives (cost, speed, etc) differently



PHY Evolution

- 1985 – IEEE 802.3 – 10Base-5 & 10Base-2
- 1987 – IEEE 802.3d – FOIRL
- 1990 – IEEE 802.3i – 10Base-T
- 1993 – IEEE 802.3j – 10Base-F
- 1995 – IEEE 802.3u – 100Base-T4 / TX / FX
- 1997 – IEEE 802.3y – 100Base-T2
- 1998 – IEEE 802.3z – 1000Base-SX / LX / CX
- 1999 – IEEE 802.3ab – 1000Base-T

UTP Copper Evolution Summary

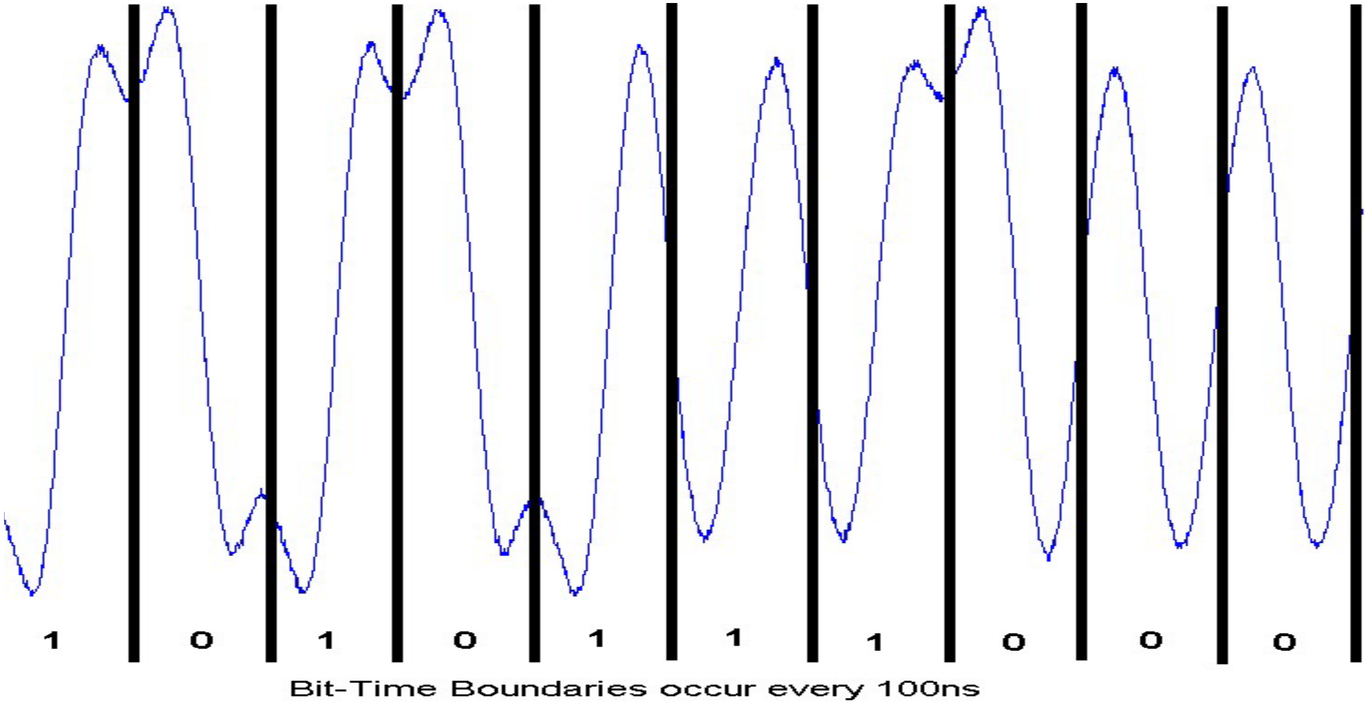
- **1989 – 10Base-T:**
  - Cat-3 Cabling dominant (pre Cat-5)
- **1995 – 100Base-T4:**
  - Support Cat-3, using all 4 pairs, only half duplex capable
- **1995 – 100Base-TX:**
  - Capitalizing on CDDI (FDDI) work
  - Requires Cat-5 (low installed base at time), full duplex capable
- **1997 – 100Base-T2:**
  - Cat-3 or better, requires only 2 pair, full duplex capable
- **1999 – 1000Base-T:**
  - Cat-5, requires all 4 pair, full duplex capable

10BASE-T Overview

- 10 Mbps (Million Bits per second)
- Category 3 cable (voice-grade) or better
- 2 pairs DATA (1,2 & 3,6) leaves center pair (4,5) for PHONE
- 100 meter runs (limited by cable attenuation)
  - All that's necessary to support building structured cabling
- Star/Hub Topology
- Inherently Full Duplex (Upper layer MAC/Repeater may be half duplex though)

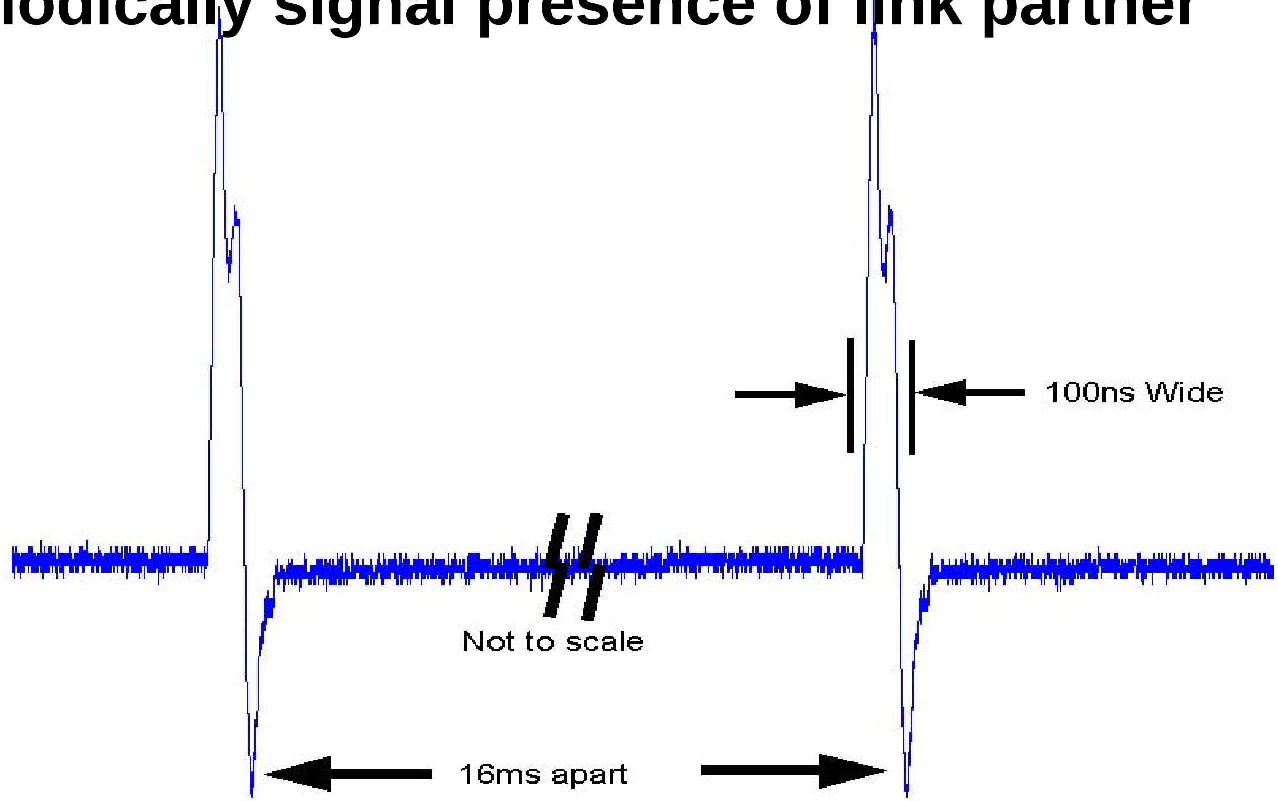
10BASE-T: Data Encoding

- 10base-T uses Manchester Encoding
- + to - transition = “0”   - to + = “1”
- Always DC balanced & Always has a transition each bit-time for clock recovery.



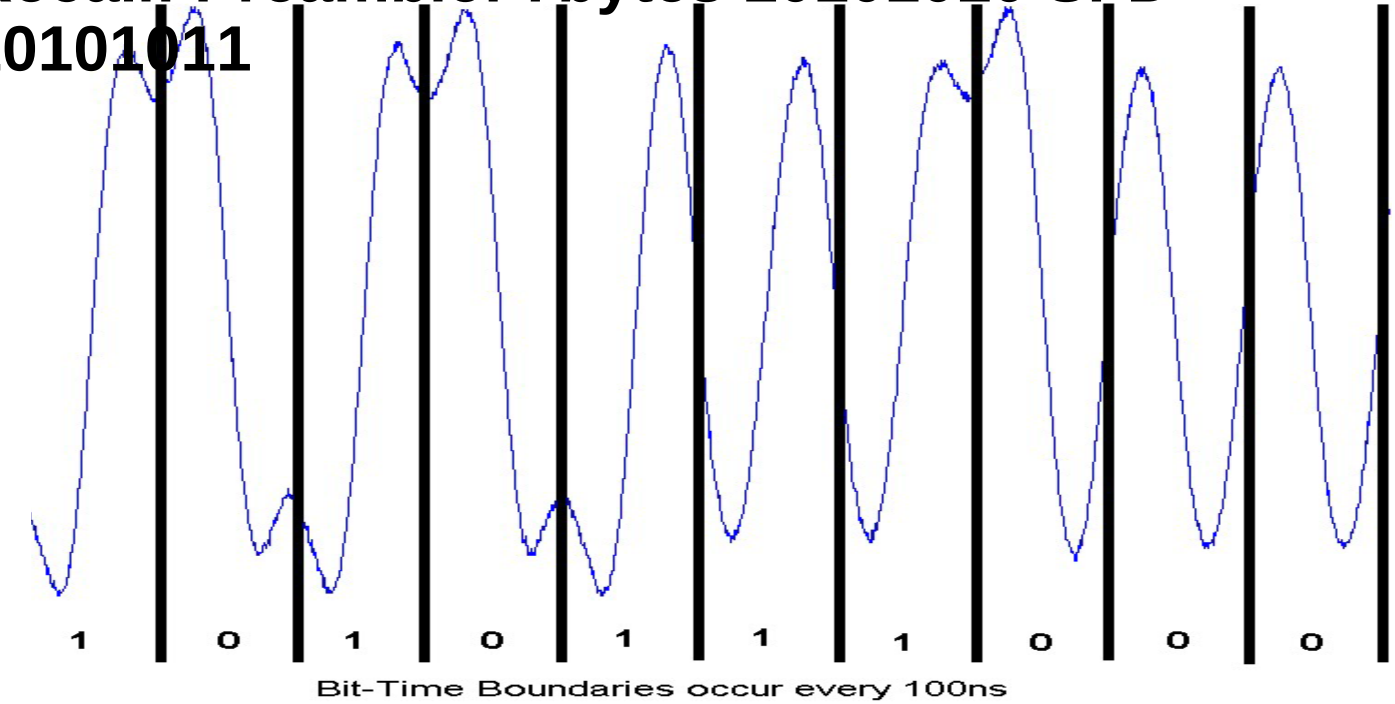
10BASE-T: Between the frames

- Idle between frames is filled with Link Test Pulses (LTPs)
- Periodically signal presence of link partner



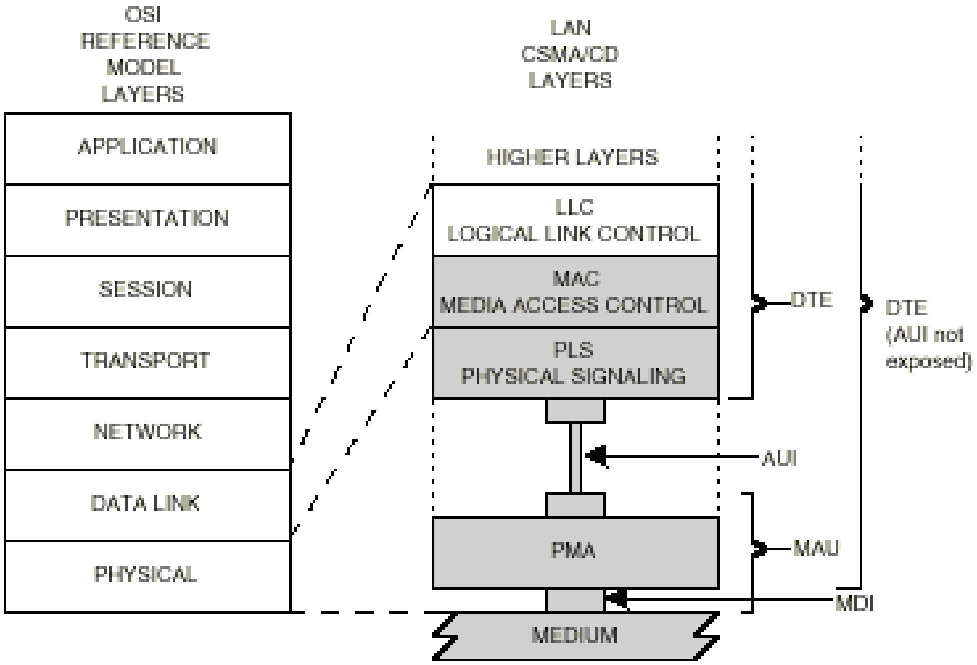
10BASE-T: Preamble and SFD

- Preamble allows device to recover clock of link partner
- Since “x” bits will be lost until clock is recovered, start frame delimiter (SFD) marks byte boundary
- Recall: Preamble: 7bytes 10101010 SFD= 10101011



10BASE-T: AUI

- Model at right for all 10Mbps Ethernet PHYs including:
  - 10BASE-2, 10BASE-5, 10BASE-T, 10BASE-FP / -FB / -FL
- Attachment Unit Interface (AUI) allows different PHYs to be attached to the MAC. Also used in repeaters.
- Medium Attachment Unit (MAU) = PHY



AUI = ATTACHMENT UNIT INTERFACE
MAU = MEDIUM ATTACHMENT UNIT
MDI = MEDIUM DEPENDENT INTERFACE
PMA = PHYSICAL MEDIUM ATTACHMENT

100BASE-T4 Overview

- 100Mbs
- Cat-3 or Better, 100 meter max
- Uses all 4 pair
  - Transmits on 3 pair, listens for collision on 4th.
  - Creates half-duplex only limitation in PHY
- Extinct – Why?
  - Introduced at same time as 100Base-TX(Cat-5 or better) when 10Base-T(Cat-3 or better) was prevalent.
  - 100Base-TX based on pre-existing CDDI, thus low cost TX chips emerged rapidly
  - Provided customers with option –
    - Buy T4 equipment supporting installed base of Cat-3
    - OR… Install new Cat-5 cable and buy TX equipment
    - Most choose to install new cable to “future proof” network

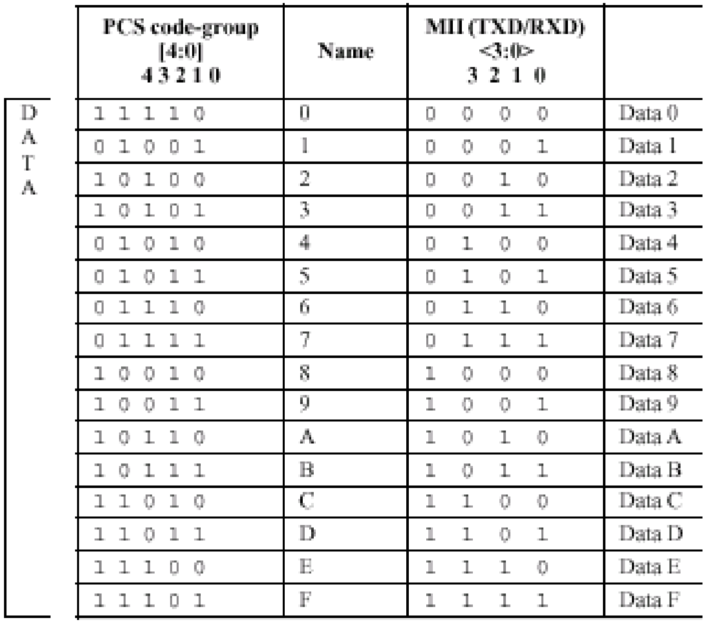
100BASE-TX Overview

- The critter commonly called Fast Ethernet
- 100 Mbps
- Category 5 cable (data-grade) or better
- Same 2 pairs for DATA as 10BASE-T (1,2 & 3,6)
- 100 meter runs (limited by cable attenuation)
  - All that’s necessary to support building structured cabling
- Inherently Full Duplex (Upper layer MAC/Repeater may be half duplex though)

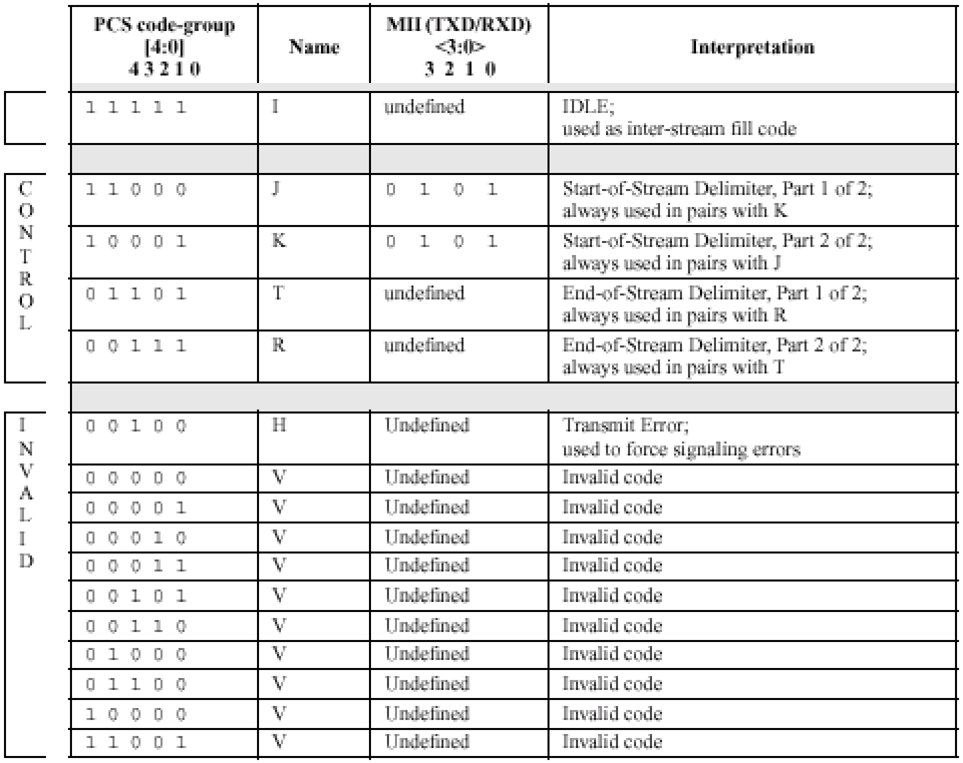
100BASE-TX: Data Encoding

- 4B/5B Block Code
- 4B/5B means 100Mbps data requires 125Mbps on the media (a 25% speedup – resulting in 20% overhead(non-databits transmitted)
- Why is this useful? Creates control codes.
- “I” (Idle) = 11111 Which is sent continuously to provide a good clock to the link partner’s receiver
- “J” and “K” = 11000 & 10001 – Start of Frame, unique bit pattern, cannot be made from any combination of other VALID symbols
- 2^5=32 symbols, only need 16 (2^4) symbols for data, 1 for idle, 2 for start of frame, 2 for end of frame, rest are invalid

100Base-TX: 4B/5B Tables



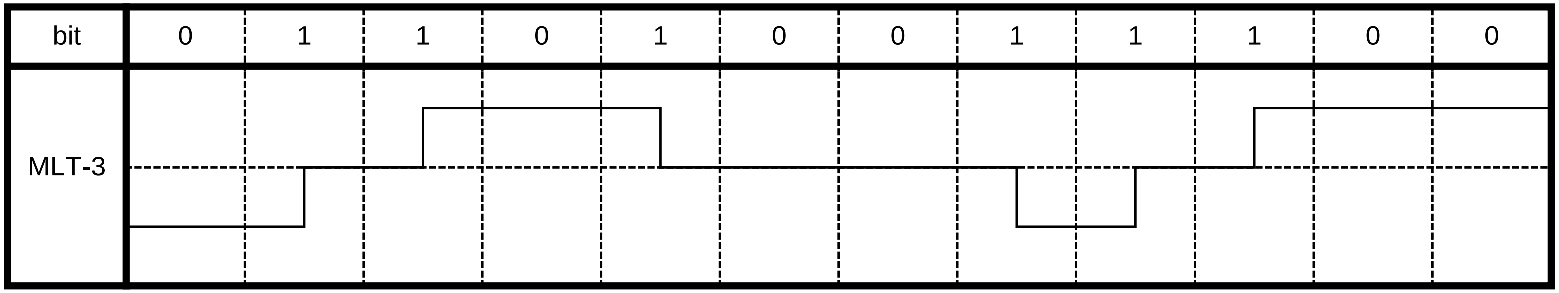
	PCS code-group [4:0] 4 3 2 1 0	Name	MII (TXD/RXD) <3:0> 3 2 1 0	
DATA	1 1 1 1 0	0	0 0 0 0	Data 0
	0 1 0 0 1	1	0 0 0 1	Data 1
	1 0 1 0 0	2	0 0 1 0	Data 2
	1 0 1 0 1	3	0 0 1 1	Data 3
	0 1 0 1 0	4	0 1 0 0	Data 4
	0 1 0 1 1	5	0 1 0 1	Data 5
	0 1 1 1 0	6	0 1 1 0	Data 6
	0 1 1 1 1	7	0 1 1 1	Data 7
	1 0 0 1 0	8	1 0 0 0	Data 8
	1 0 0 1 1	9	1 0 0 1	Data 9
	1 0 1 1 0	A	1 0 1 0	Data A
	1 0 1 1 1	B	1 0 1 1	Data B
	1 1 0 1 0	C	1 1 0 0	Data C
	1 1 0 1 1	D	1 1 0 1	Data D
	1 1 1 0 0	E	1 1 1 0	Data E
	1 1 1 0 1	F	1 1 1 1	Data F



	PCS code-group [4:0] 4 3 2 1 0	Name	MII (TXD/RXD) <3:0> 3 2 1 0	Interpretation
	1 1 1 1 1	I	undefined	IDLE; used as inter-stream fill code
CONTROL	1 1 0 0 0	J	0 1 0 1	Start-of-Stream Delimiter, Part 1 of 2; always used in pairs with K
	1 0 0 0 1	K	0 1 0 1	Start-of-Stream Delimiter, Part 2 of 2; always used in pairs with J
	0 1 1 0 1	T	undefined	End-of-Stream Delimiter, Part 1 of 2; always used in pairs with R
	0 0 1 1 1	R	undefined	End-of-Stream Delimiter, Part 2 of 2; always used in pairs with T
INVALID	0 0 1 0 0	H	Undefined	Transmit Error; used to force signaling errors
	0 0 0 0 0	V	Undefined	Invalid code
	0 0 0 0 1	V	Undefined	Invalid code
	0 0 0 1 0	V	Undefined	Invalid code
	0 0 0 1 1	V	Undefined	Invalid code
	0 0 1 0 1	V	Undefined	Invalid code
	0 0 1 1 0	V	Undefined	Invalid code
	0 1 0 0 0	V	Undefined	Invalid code
	0 1 1 0 0	V	Undefined	Invalid code
	1 0 0 0 0	V	Undefined	Invalid code
	1 1 0 0 1	V	Undefined	Invalid code

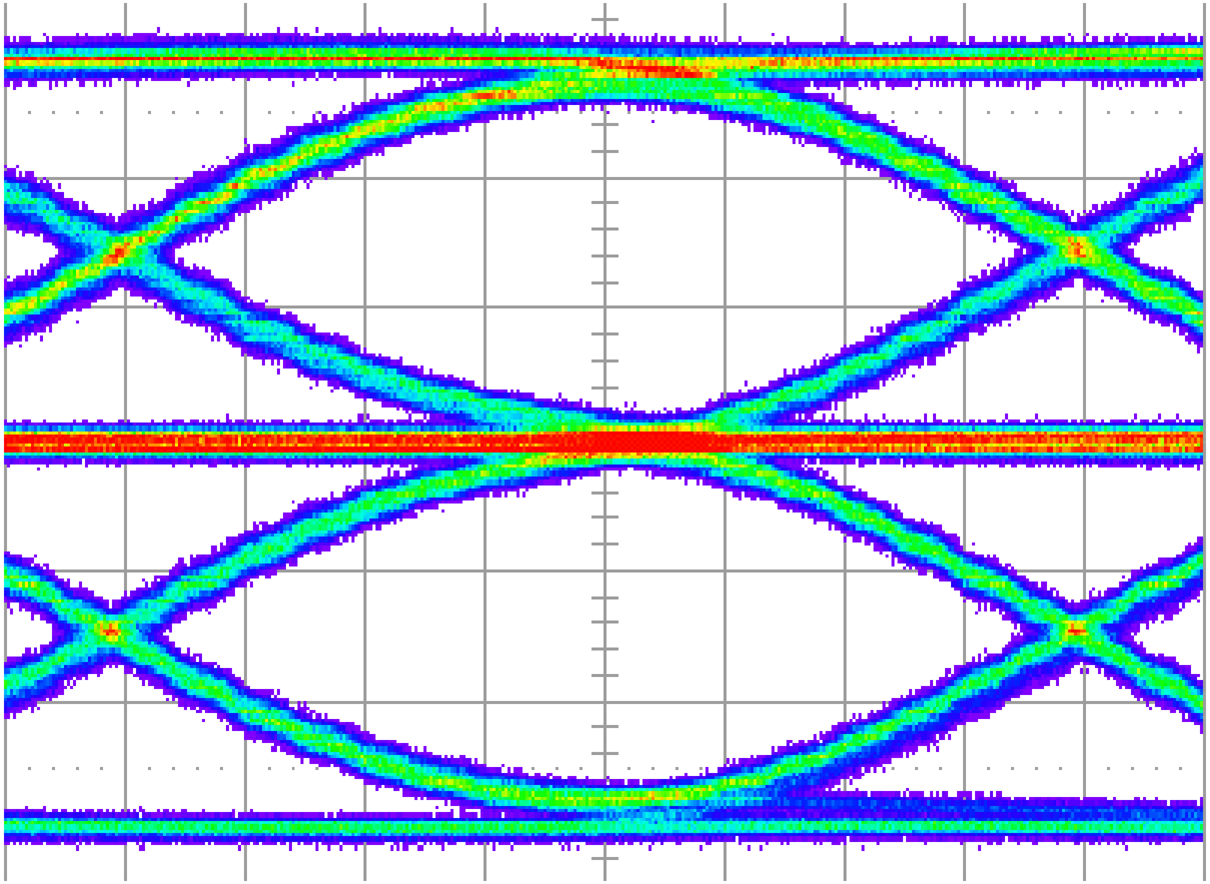
100BASE-TX: MLT-3 Coding

- 5B Idle code is 11111, at 125Mbs (NRZI) that’s a 125MHz tone, recall cat-5 performance specification ends at 100MHz!
- Multi-Level Transition with 3 levels a.k.a. MLT-3 Reduces frequency of 5B encoded data.
- If data is “1”, then transition from current level to next level. ie 1111=+1,0,-1,0 reducing freq by 1/4
- If bit data is “0”, then don’t transition



100Base-TX: MLT-3 Eye Diagram

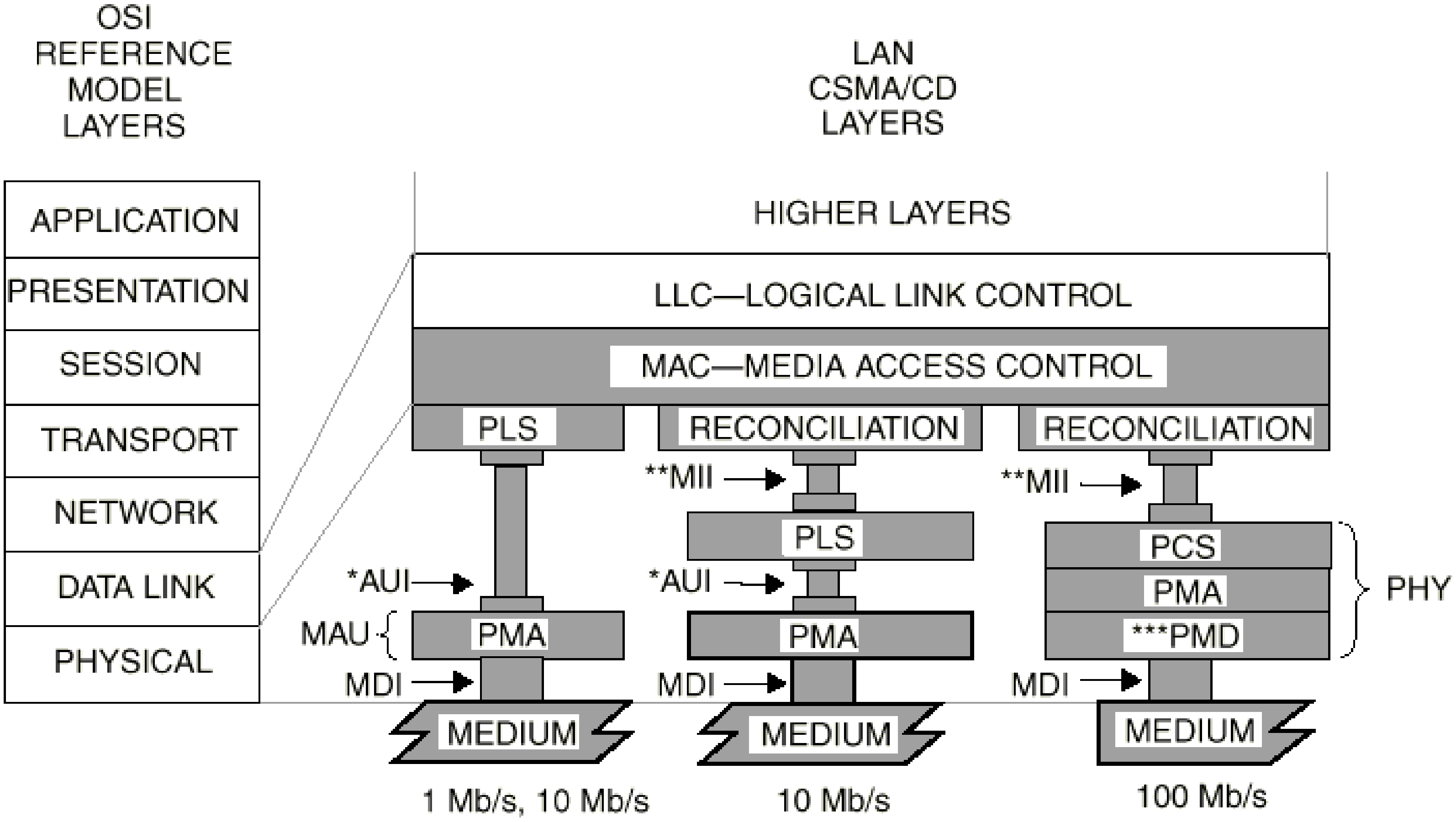
- **1-Bit Time shown, with all possible transitions**



100BASE-TX: Scrambling

- **MLT-3 successfully reduces frequency of 5B encoded data, but recall the 5B idle stream is sent continuously between frames.**
- **After MLT-3 encoding, Idle went from a 125MHz tone to a 31.25MHz tone (125/4). Since most of the transmitted energy is at this frequency, it radiates strongly, which the FCC does not like, hence…**
- **Scrambling of the 5B encoded stream is required.**
- **Prior to MLT-3 encoding, the 5B stream is pseudo-randomly scrambled, this breaks up the repeating 1s and spreads the transmitted energy across many frequencies, thus no single frequency has much energy.**

100BASE-TX: Media Independent Interface



100BASE-T2

- 100Mbs
- Cat-3 or Better
- Uses only 2 pair
  - Uses 5 level signaling
  - Transmits and receives on both pairs simultaneously
  - Allows use of other pairs.
  - Full-duplex capable
- Extinct – Why?
  - Limited market potential due to 100Base-TX

1000BASE-T Overview

- 1000Mbs
- Cat-5 or Better
- Uses all 4 pair
  - Uses 5 level signaling
  - Transmits and receives on both pairs simultaneously
  - Full-duplex capable
- Emerging –
  - Growing number of PHY chip vendors
  - 10/100/1000 single chip solutions and multiport chips

The 1000BASE-T Solution

- **Start with 125 MHz signaling rate**
  125Mbps
  - Exactly like 100BASE-TX
- **Transmit/Receive on all 4 pairs of cable** x 4
  - Similar to 100BASE-T4 500Mbps
- **Use multilevel signaling – PAM5**
  - Similar to 100BASE-TX (3-level MLT-3 signaling) 500Mbps
  - Exactly like 100BASE-T2 (5-level PAM5 signaling) x 2
  - Allows 2 bits per symbol 1000Mbps
- **Allow simultaneous bi-directional signaling on all 4 pair**
  - Exactly like 100Base-T2
  - Allows full-duplex communication at 1000Mbps

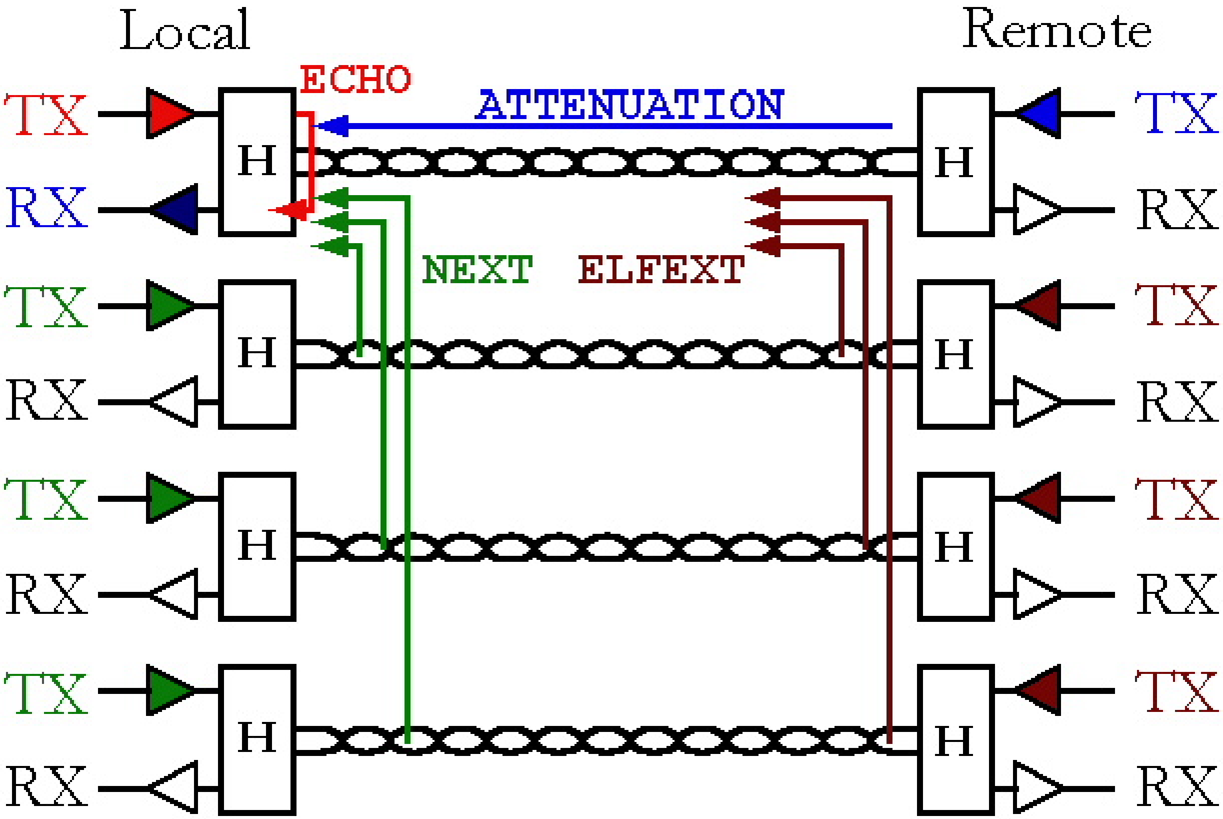
1000Base-T: 4D-PAM5

- 4 Dimensional Pulse Amplitude Modulation with 5 levels
- 5 levels on 4 pairs yields 625 possible symbols (5^4)
- To encode 8bits every 8ns (125MHz), only 256 symbols are needed (2^8).
- Remaining symbols can be used for control characters (idle, start of packet, end of packet, etc).
- Data frames are transmitted using a convolutional (Trellis) code
  - Adds structure to the transmitted symbols needed for Viterbi Decoding

1000Base-T: Error Correction

- Viterbi Decoder
  - Takes the last few received symbols
  - Calculates the most likely sequence of symbols
  - A symbol error results in an impossible or unlikely sequence
  - The most likely sequence probably contains the correct symbols
  - “Most likely sequences” are known in advance due to the trellis code structure

1000Base-T: Noise Environment



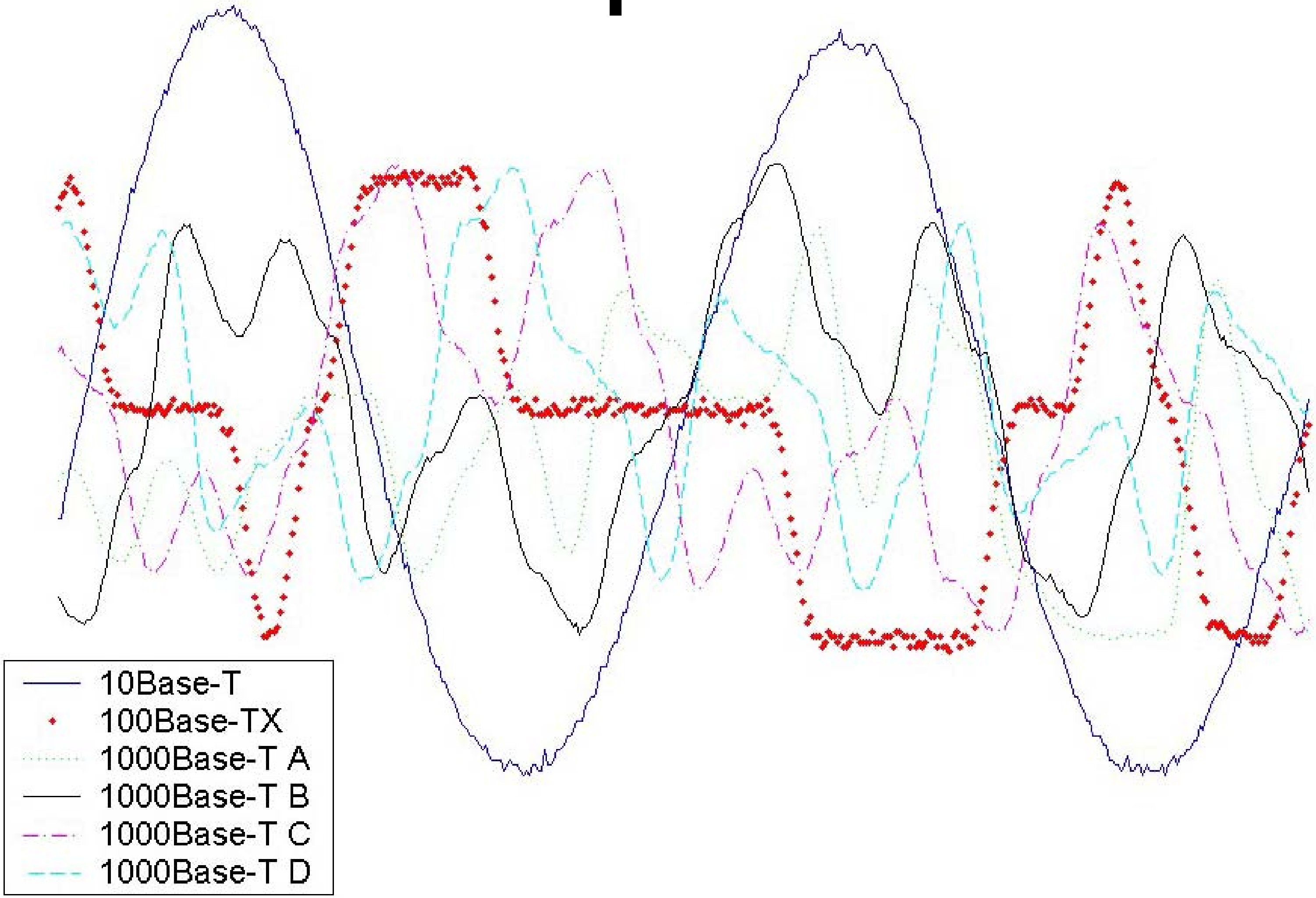
1000Base-T: DSP

- Digital signal processing (DSP) techniques can reduce effects of echo and NEXT
  - These are caused by local transmissions
  - Tap the signal on all 4 transmitters
  - Cancel out these signals from the received waveform
- ELFEXT is not easily cancelled with DSP
  - Originates from remote transmitters
  - Relies on cable and connectors to meet new Cat5 specification, so that ELFEXT is minimal
- Alien Crosstalk also unpredictable
  - Unknown source
  - Thus, cannot be cancelled
- 25-pair bundles not allowed!
  - Crosstalk between bundled pairs too high

1000Base-T: Master/Slave Timing

- Synchronization to implement adaptive filters for canceling echo and NEXT
  - Need a common master clock to reference
  - Symbols transmitted & received at the same rate
- Link pair must have a Master and a Slave
  - Master uses internal clock to transmit
  - Slave recovers the master clock from the data received
  - Slave uses recovered clock to transmit its data
- Need a means of deciding who is who –
  - uses Auto-Negotiation (more on that later)

10, 100, 1000 Signal Comparison



UTP Copper Phys Wrap-up

- Combo PHYs
  - 10/100 PHYs – 10Base-T & 100Base-TX
  - 100/1000 PHYs – 100Base-TX & 1000Base-T
  - 10/100/1000 PHYs – emerging
- Quad / Hex / Octal PHYs
  - Reduces chip and other component count required to manufacture multiport devices, thus lower cost.
  - Most multi-phy devices are also Combo PHYs

Fiber Evolution Summary

- **1987 – Fiber Optic Inter-Repeater Link (FOIRL):**
  - Link 10Mbps repeaters via multimode fiber (2km max)
- **1993 – 10Base-F:**
  - 10Mbps to end stations via multimode fiber (2km max)
- **1995 – 100Base-FX:**
  - Capitalizing on FDDI work
  - 100Mbps via multimode fiber (2km max) to repeaters or end stations
- **1998 – 1000Base-SX / LX:**
  - Capitalizing on FibreChannel work, but spedup
  - 1000Mbps

10Mbps Fiber Overview

- All use multimode fiber, driven by LEDs
- FOIRL: Fairly common
  - FOIRL = Fiber Optic Inter-Repeater Link
  - Typical use: FOIRL Medium Attachment Unit (MAU) attached to Attachment Unit Interface (AUI) of repeaters w/o built in fiber support
- 10BASE-F
  - Catch all for 10Base-FP, 10Base-FB, 10Base-FL
- Distances:
  - 10Base-FP: 500m max
  - All others: 2000m max – limited by cable attenuation
- Same speed, but different techniques – identical type of MAU required on both sides of fiber

100BASE-FX Overview

- 100 Mbps
- Multimode Fiber
- Inherently Full Duplex (Upper layer MAC/Repeater may be half duplex though)
- Full Duplex Distance: 2000 meter runs
  - Limited by cable attenuation
- Half Duplex Distance: 412 meters
  - Point-to-point link, no repeaters
  - Limited by collision domain

100BASE-FX: Similar to -TX

- Like all 100Mbps Fast Ethernet, supports Media Independent Interface (MII)
- Like 100BASE-TX, uses 4B/5B Coding to encode data and idle
- Similarity ends here though – No need for:
  - Scrambling
  - MLT3 Encoding
- Why?
  - MLT3 is unnecessary due to high bandwidth of fiber
  - Scrambling is unnecessary as fiber does not radiate, thus no possibility of interference.

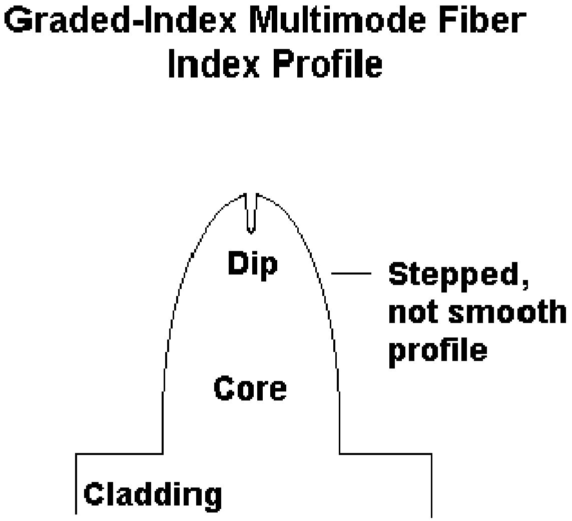
1000BASE-SX/LX Overview

- 1000 Mbps
- Multimode Fiber for SX or LX
- Singlemode Fiber for LX only
- Inherently Full Duplex (One fiber for Tx, one for Rx)
  - Upper layer MAC may be half duplex, but this is highly unlikely
- Distance:
  - Tricky issue

1000Base-SX/LX: Distance and Launch Cable

- Remember from the physical media section the following two slides…

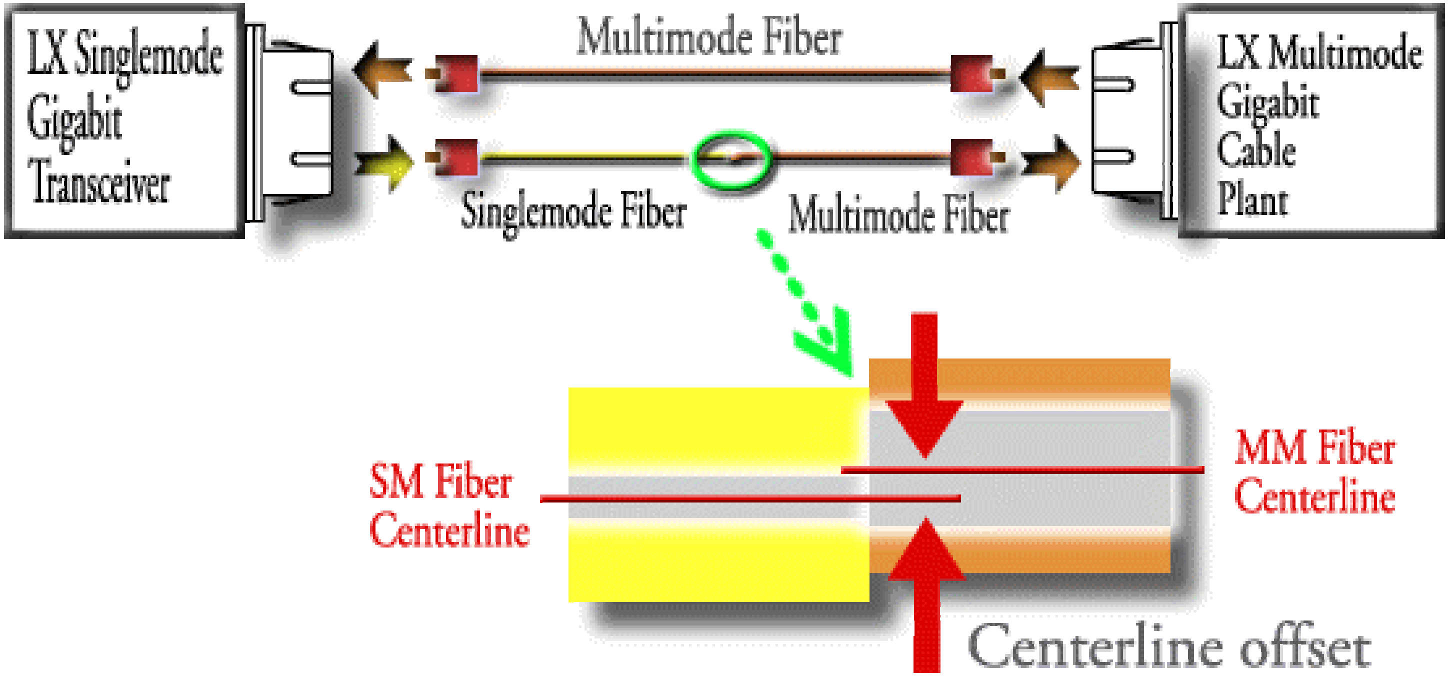
Recent Modal Dispersion Issues



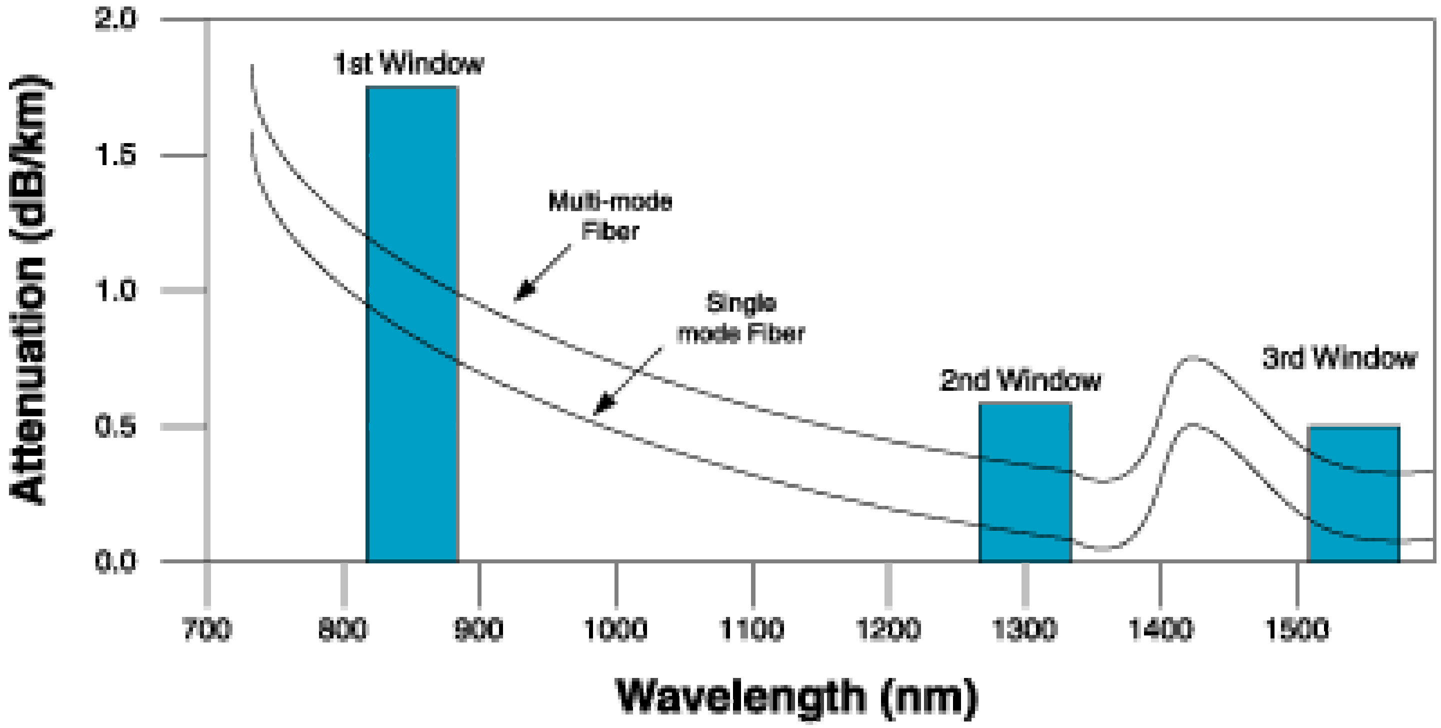
- As a side-note: During the development of Gigabit Ethernet, it was discovered that a sizeable percentage of installed (old) multimode graded index fiber had a deviation in the center of the core, as depicted at left. This was determined to cause increased modal dispersion (DMD, differential modal delay as the gig folk called it)
- The result of this discovery of a flaw in the installed media was the subsequent reduction in supported link lengths for GbE on installed multimode fiber.
- Which leads to the following new term…

Launch Conditioning

- Many options exist to minimize the DMD effect, one of which is to use a single-mode “pig-tail” to condition/reduce the modes launched into the multi-mode segment, by launching them off-center (and thus avoiding the index “notch” in the center of the installed fibers)



Wavelength vs. Attenuation



1000Base-SX Distances

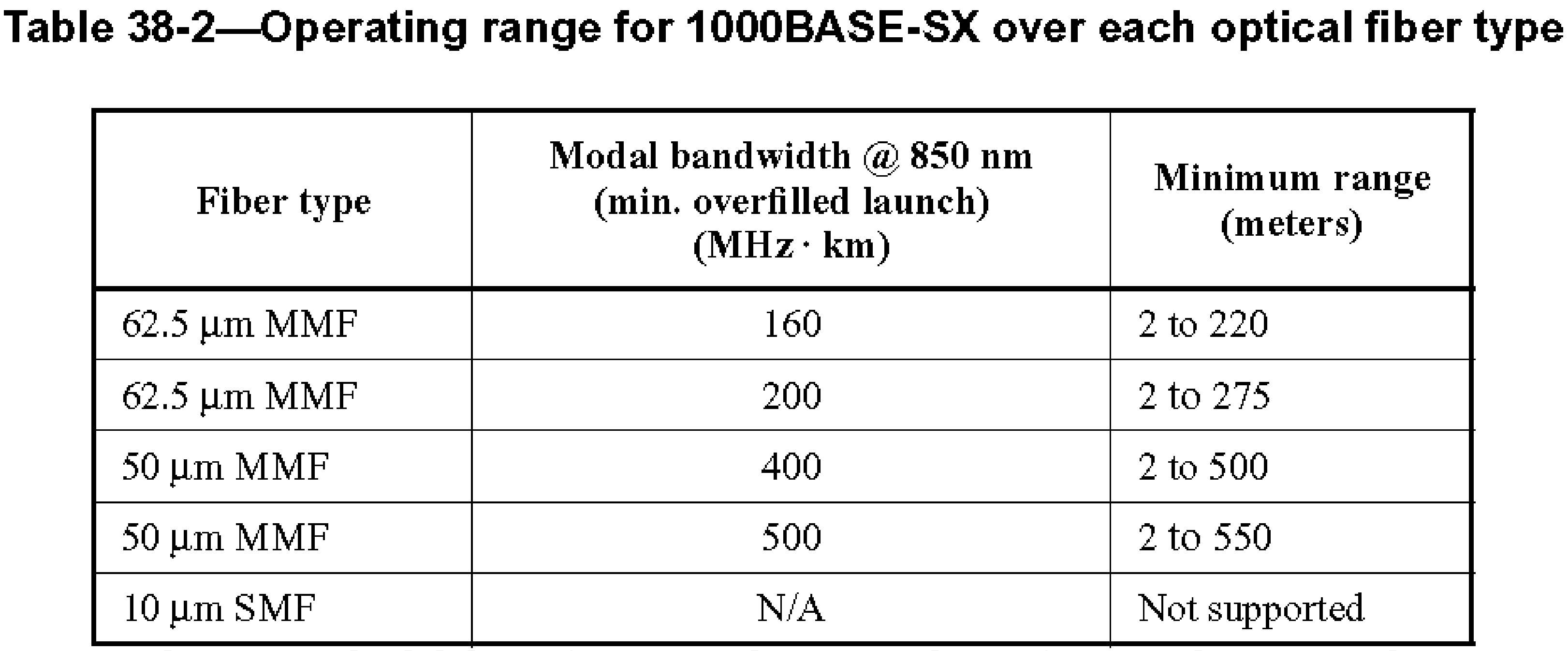


Table 38-2—Operating range for 1000BASE-SX over each optical fiber type

Fiber type	Modal bandwidth @ 850 nm (min. overfilled launch) (MHz · km)	Minimum range (meters)
62.5 µm MMF	160	2 to 220
62.5 µm MMF	200	2 to 275
50 µm MMF	400	2 to 500
50 µm MMF	500	2 to 550
10 µm SMF	N/A	Not supported

- **Modal Bandwidth refers to the quality of your installed MM fiber.**
- **Recall, SingleMode Fiber (SMF) is not supported for SX**
- **Greater distances are likely, but not recommended by the standard**

1000Base-LX Distances

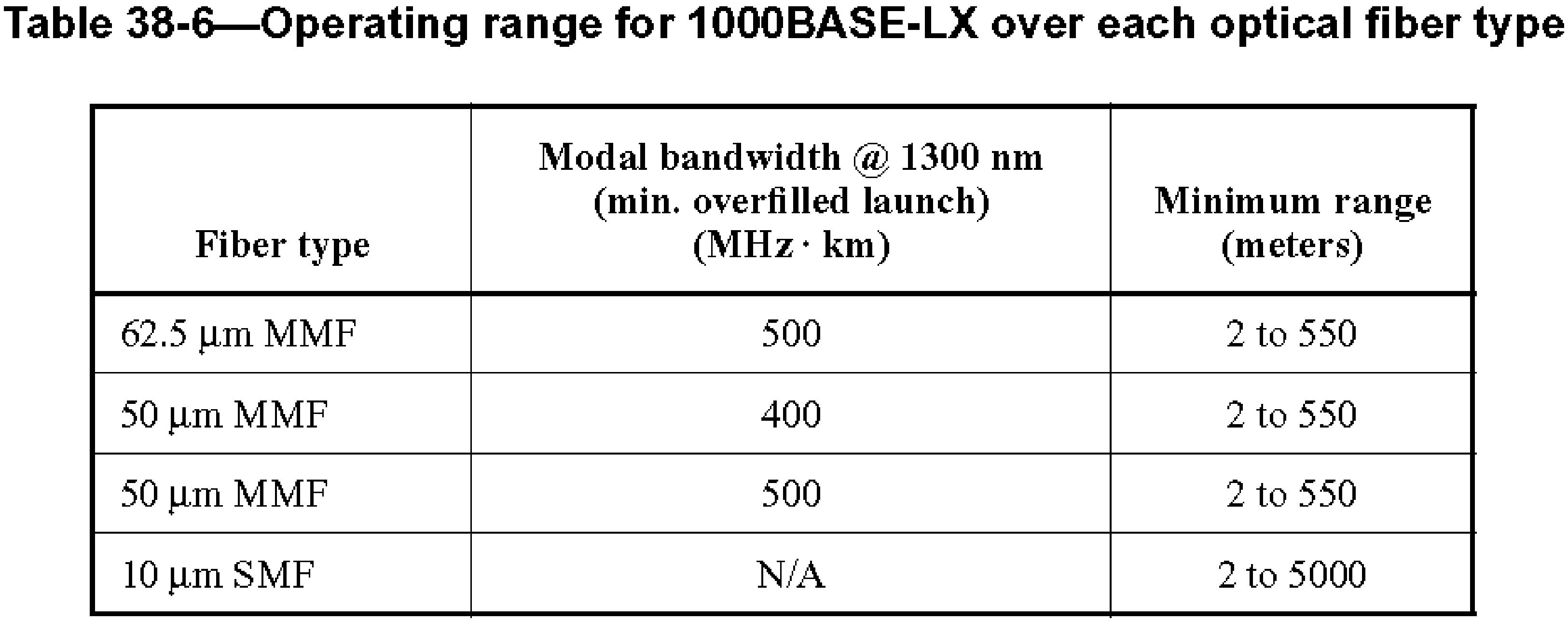


Table 38-6—Operating range for 1000BASE-LX over each optical fiber type

Fiber type	Modal bandwidth @ 1300 nm (min. overfilled launch) (MHz · km)	Minimum range (meters)
62.5 µm MMF	500	2 to 550
50 µm MMF	400	2 to 550
50 µm MMF	500	2 to 550
10 µm SMF	N/A	2 to 5000

1000Base-SX/LX: Data Encoding

- 8B/10B Block Code
- Code developed by IBM in the 80s, used by FibreChannel.
- Like 4B/5B, has 20% overhead, used not only for control characters (idle, start of packet, end of packet) but also for data code redundancy.
- Running Disparity:
  - Every data code has a + and a – running disparity version
  - The form of each data code determines whether the NEXT data code should be + or –
  - If data is received that does not follow the running disparity rules, then an error has occurred.

Non-Standard Interfaces

- 1000Base-LH
  - Provides up to 10km distances over single mode
  - Interoperates with LX for 5km (same wavelength, just higher transmit power and lower receive sensitivity)
- 1000base-XD
  - Provides up to 50km distances over single mode
  - Does not interoperate with any other interface type
- 1000Base-ZX
  - Provides up to 70km distances over single mode (100km on dispersion shifted fiber)
  - Does not interoperate with any other interface type

GBIC

- GigaBit Interface Converter – industry agreement (SFF Committee)
- Allows for hot-pluggable transceiver
- Support both 1000Base-SX and LX, so user can choose after purchasing the box

This page left intentionally blank.

This page left intentionally blank.

This page left intentionally blank.

Autonegotiation

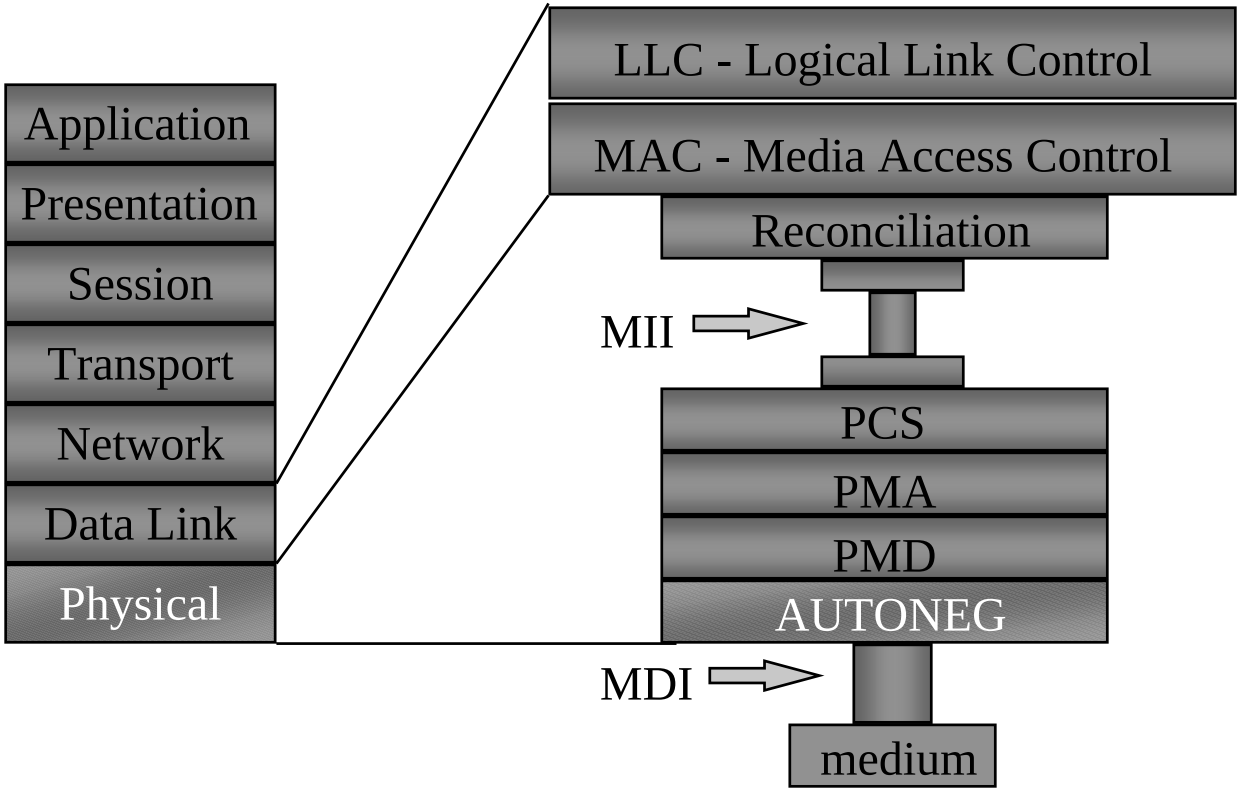
Clauses 28 and 37 of 802.3

Autonegotiation vs. Autosensing

- **Autonegotiation**
  - standardized speed handshake
  - auto-configures to best possible link (e.g., 100 full duplex)
  - still links with older or non-autoneg devices
  - sometimes causes autosensing (NOT autonegotiating) devices to link at 10 and not 100
  - user error/misunderstanding cause problems

- **Autosensing/Speed Detection**
  - several different proprietary methods
  - only auto-configures to 10 or 100, not duplex settings
  - creates many interoperability headaches

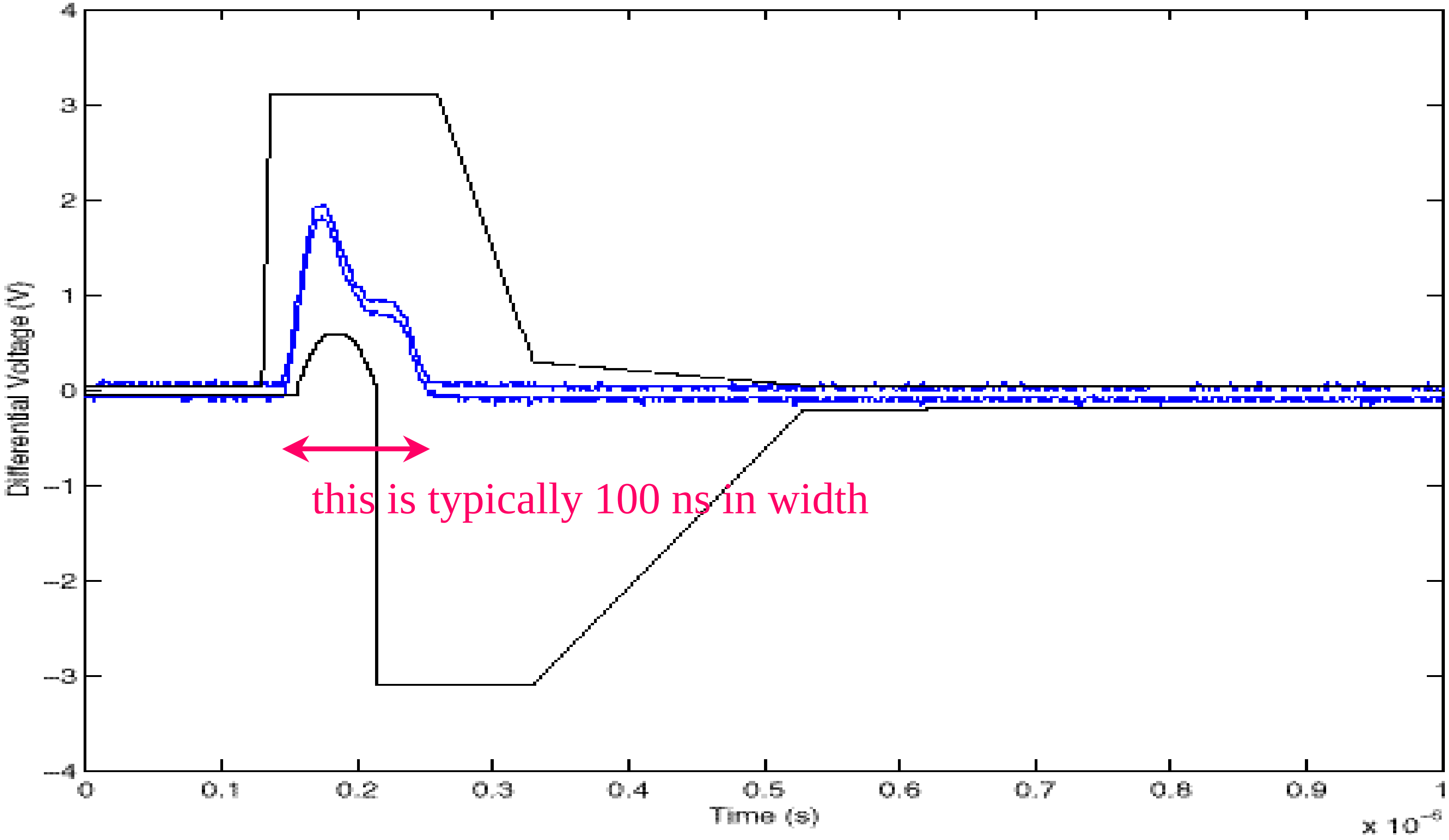
ISO-OSI model



Autonegotiation - How?

- Constantly sends out 10base-T Link Test Pulses before linking
- The pulses are grouped together in defined “words” that convey meanings, such as “I can do 100 half and full duplex”
- Older 10base-T devices just think they’re LTPs
- Autoneg devices understand them as words and exchange handshake info to link at best possible link
- If the autoneg device sees regular LTPs coming in (not autoneg words), it just links at 10 half duplex
- If the autoneg device sees Fast Ethernet IDLE stream coming in, it just links at 100 half duplex.
- Unfortunately, this only works on copper for 10/100 - it’s supported on fiber and copper for gig (i.e., there is no autonegotiation for 100base-FX)

NLP (Normal Link Pulse)

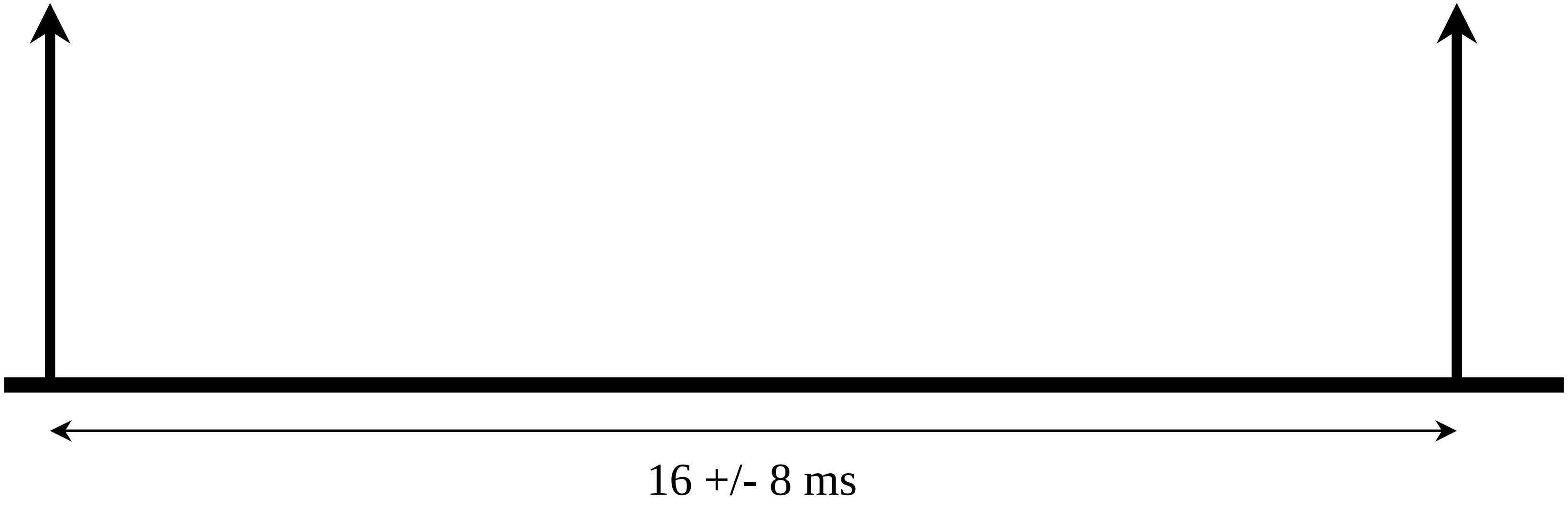


this is typically 100 ns in width

- Looks just like a 10base-T Link Test Pulse (LTP)

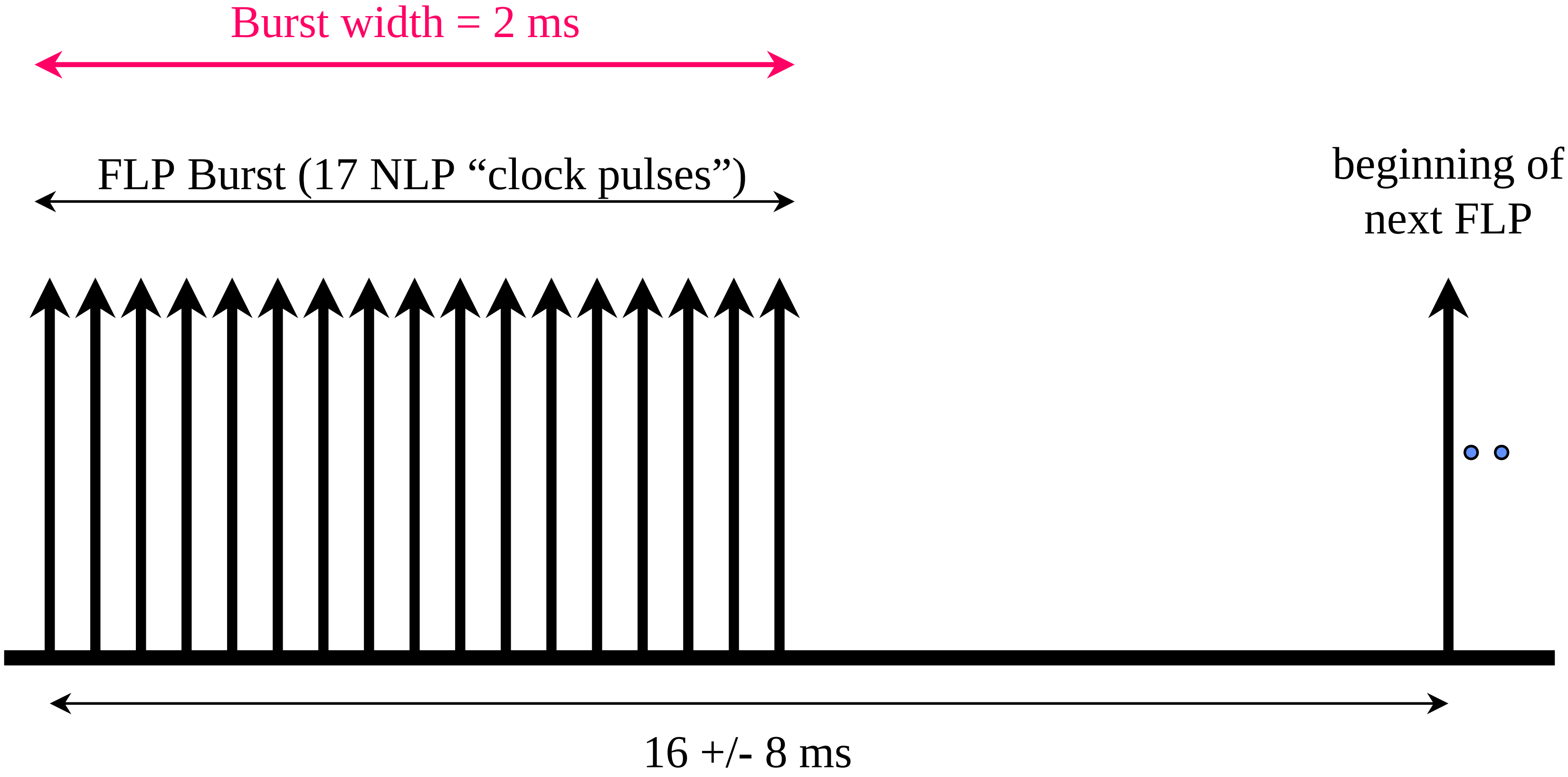
When do we care about NLPs?

- When the NLPs are spaced apart they look just like normal 10base-T Link Test Pulses (LTPs)
- So an old 10base-T legacy device will see them as normal link
- But a legacy device won’t care if we send the NLPs more often than normal, so...



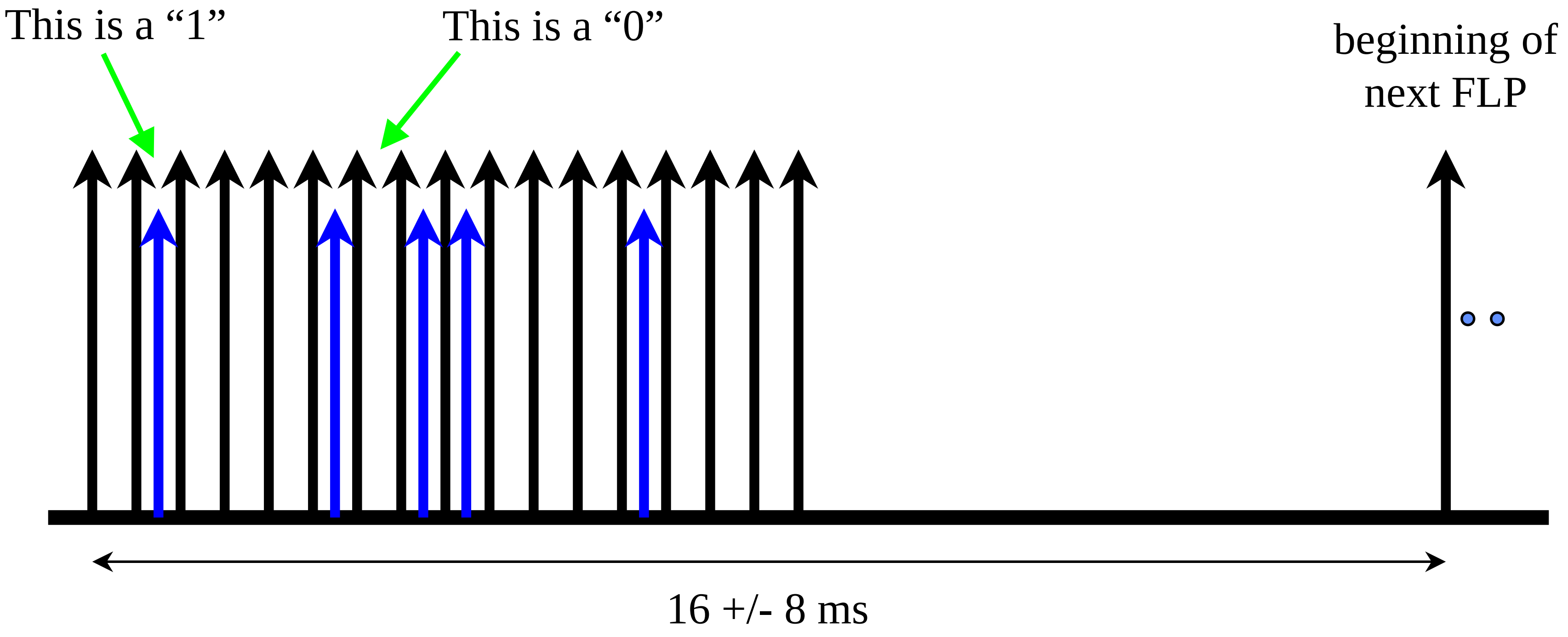
When they are FLP Bursts!

•Stick a bunch of NLPs together and use it to signal info (like Morse code)



Data Pulses

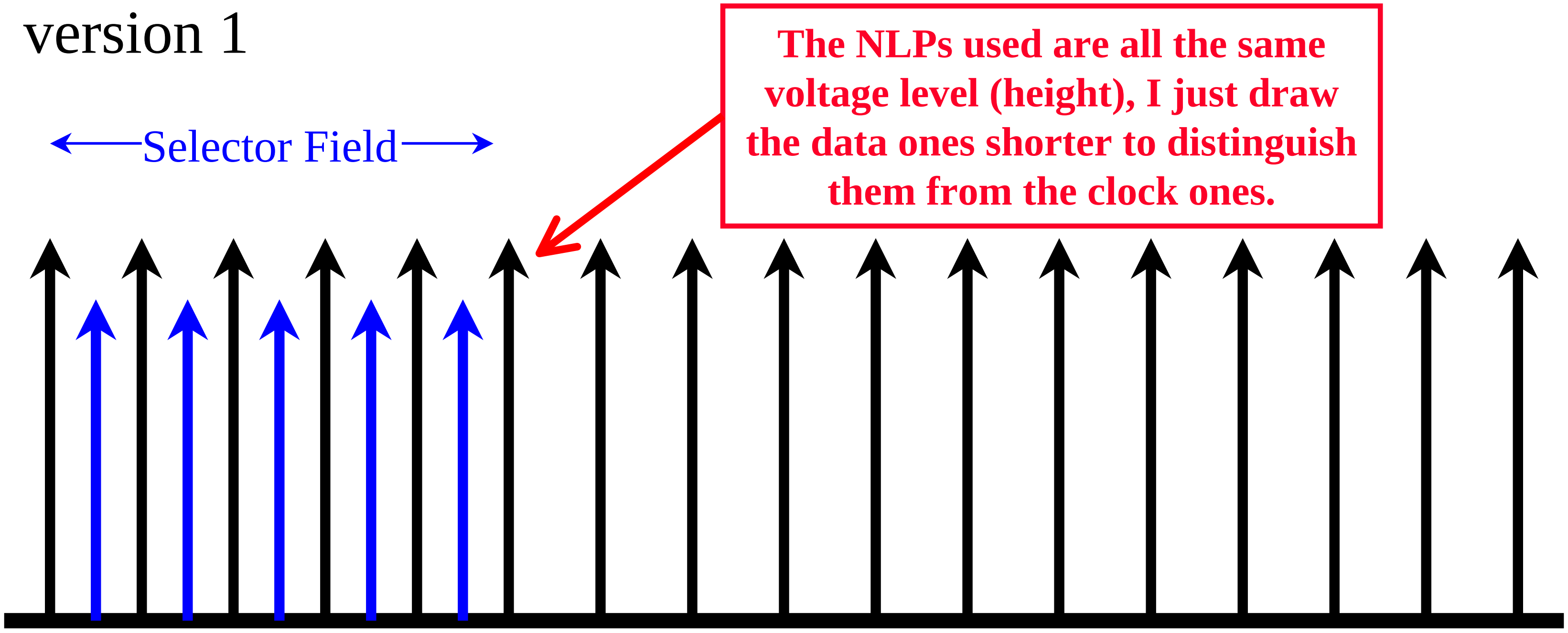
- In between the “clock pulses” we can put a data pulse to signify a value of 1, or not put one to signify value of 0



right….What's an FLP for again?

The data fields are pre-defined for specific meanings

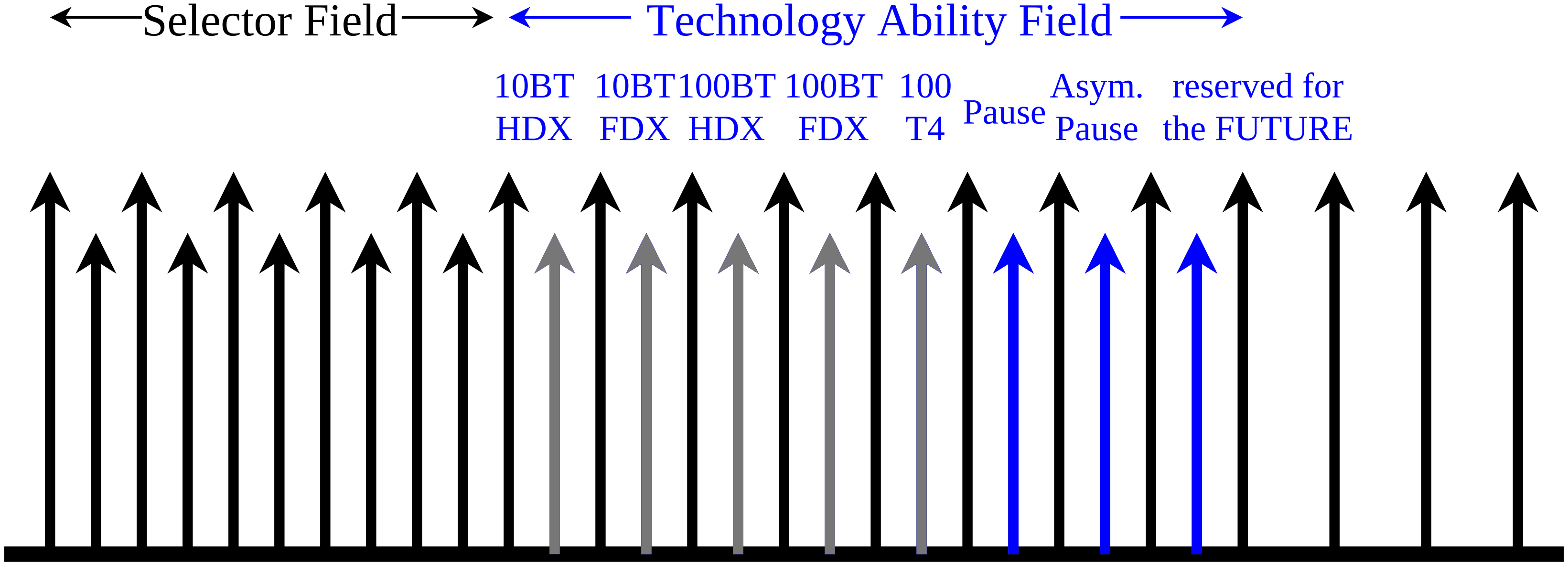
The selector field is used for version info, such as "802.3 version 1



The NLPs used are all the same voltage level (height), I just draw the data ones shorter to distinguish them from the clock ones.

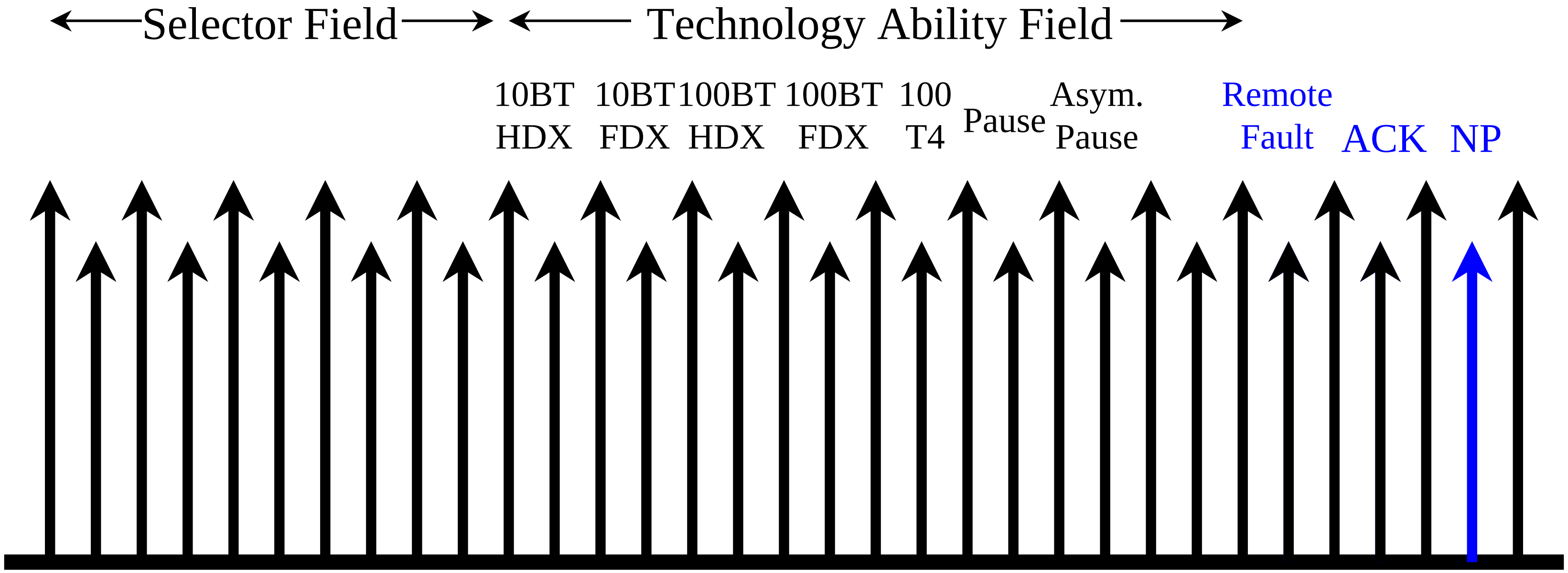
right….What’s an FLP for?

The Technology Ability Field is used to signal which modes the device can handle, for example 100base-T Full Duplex

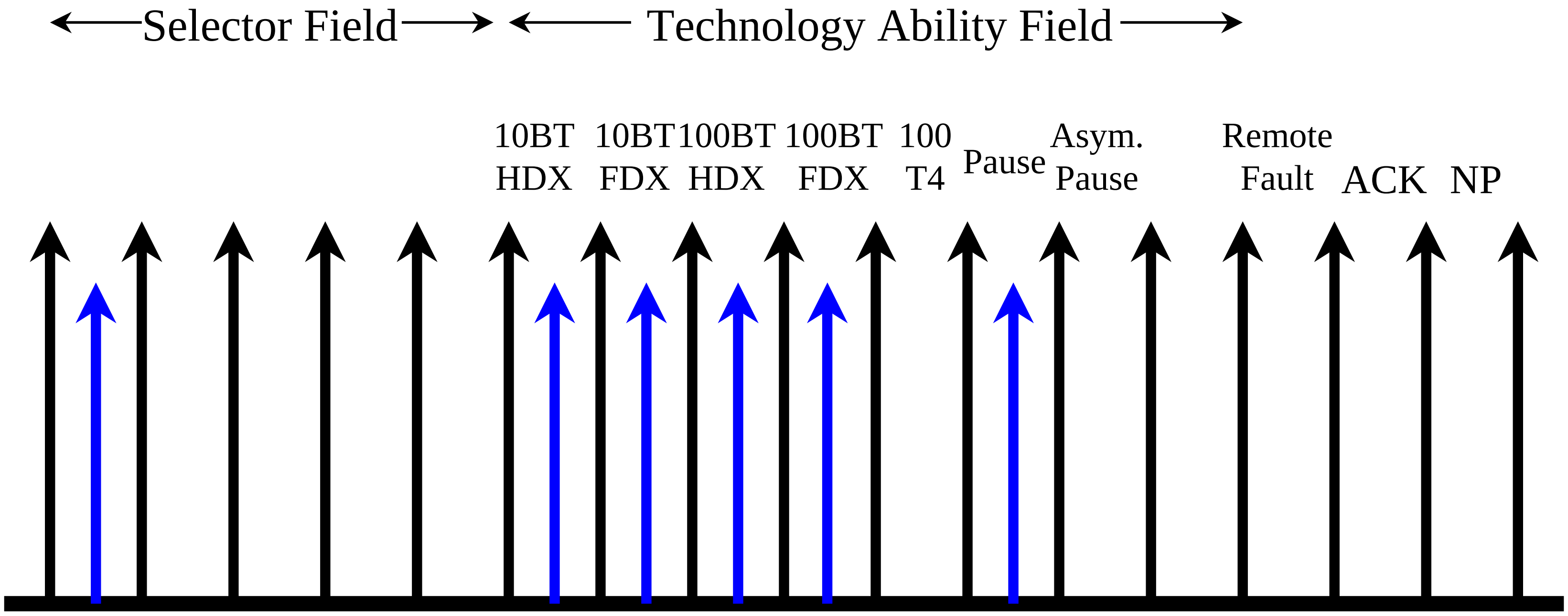


right….What's an FLP for again?

The last fields are used to tell the link partner of a remote fault, acknowledge the receipt of its partner's FLPs, or that there are more "pages" of FLP fields to send

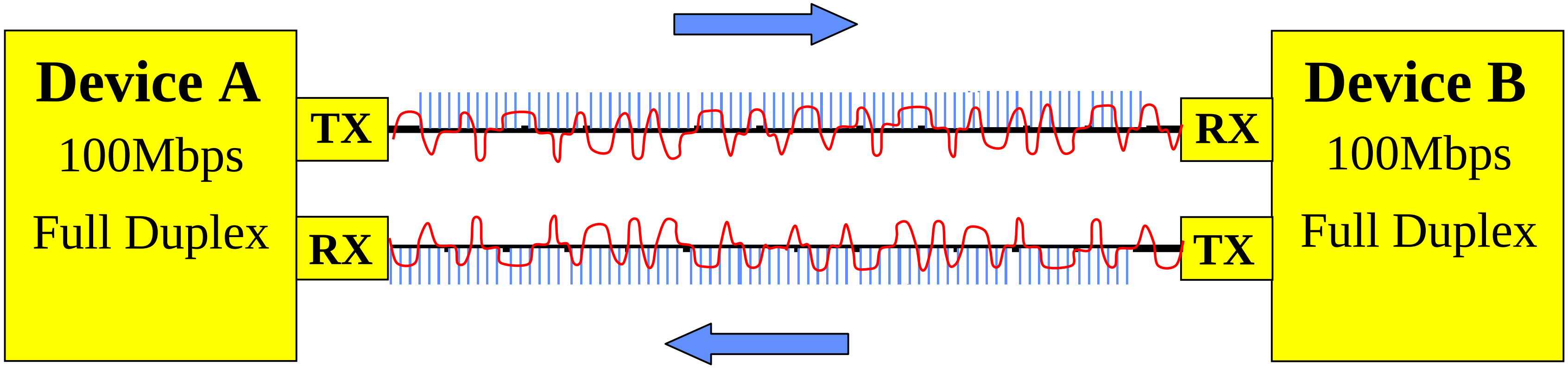


A Sample FLP


Selector Field
Technology Ability Field
10BT HDX
10BT FDX
100BT HDX
100BT FDX
100 T4
Pause
Asym. Pause
Remote Fault
ACK
NP

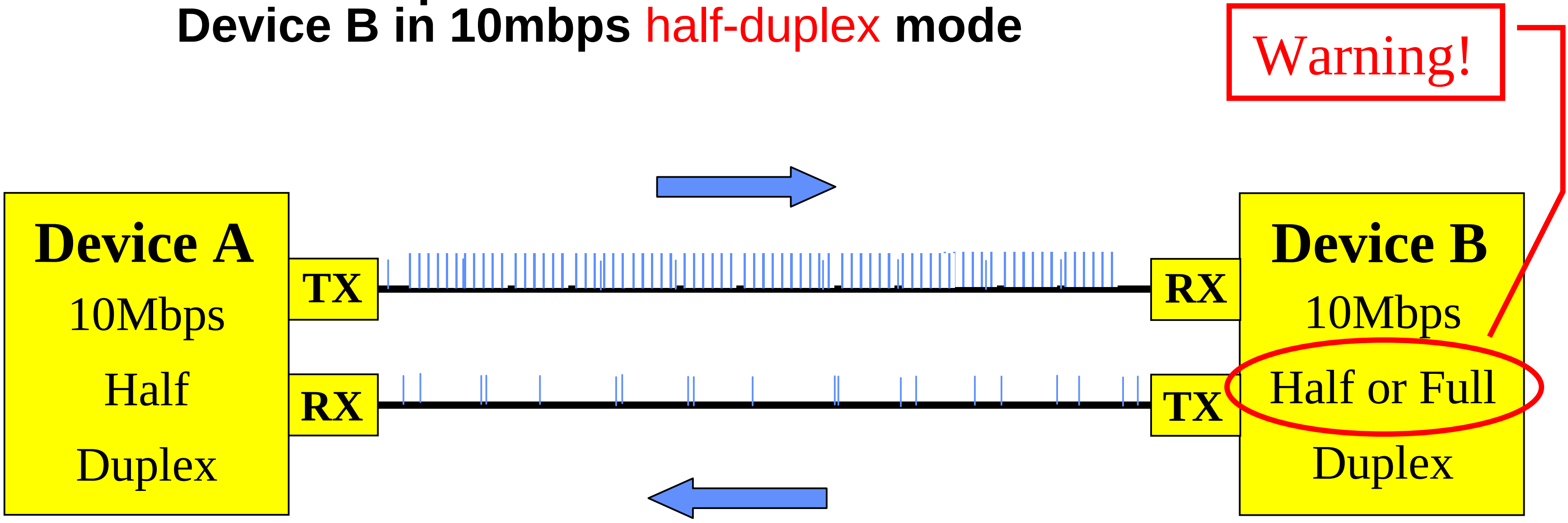
How It Works: 2 Aneg Devices

- Device A sends FLPs out, while Device B does the same
- Each device receives the other's FLPs and sets their ACK bit to true (a value of "1")
- They then choose the best possible mode that both support and start transmitting IDLE, and it's linked!



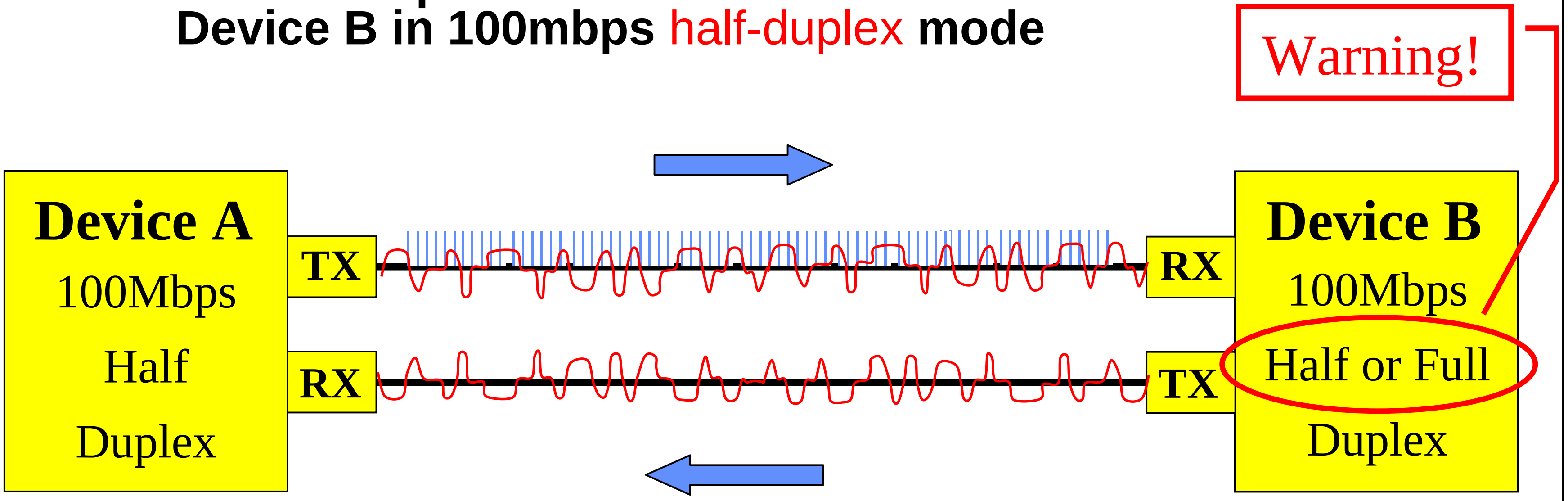
How It Works: an Aneg Device with a 10Mbps Legacy Device

- Device A sends FLPs out, while Device B sends out LTPs
- Device A “parallel detects” the LTPs and links with Device B in 10mbps half-duplex mode



How It Works: an Aneg Device with a 100Mbps Legacy Device

- Device A sends FLPs out, while Device B sends out Fast Ethernet IDLE
- Device A “parallel detects” the IDLE and links with Device B in 100mbps half-duplex mode



Autoneg Problems

- Three types of problems are sometimes encountered:
  1) A Duplex mismatch occurs whereby one side is Half-Duplex, one side is Full-Duplex

  2) The wrong speed link is used (10 instead of 100)

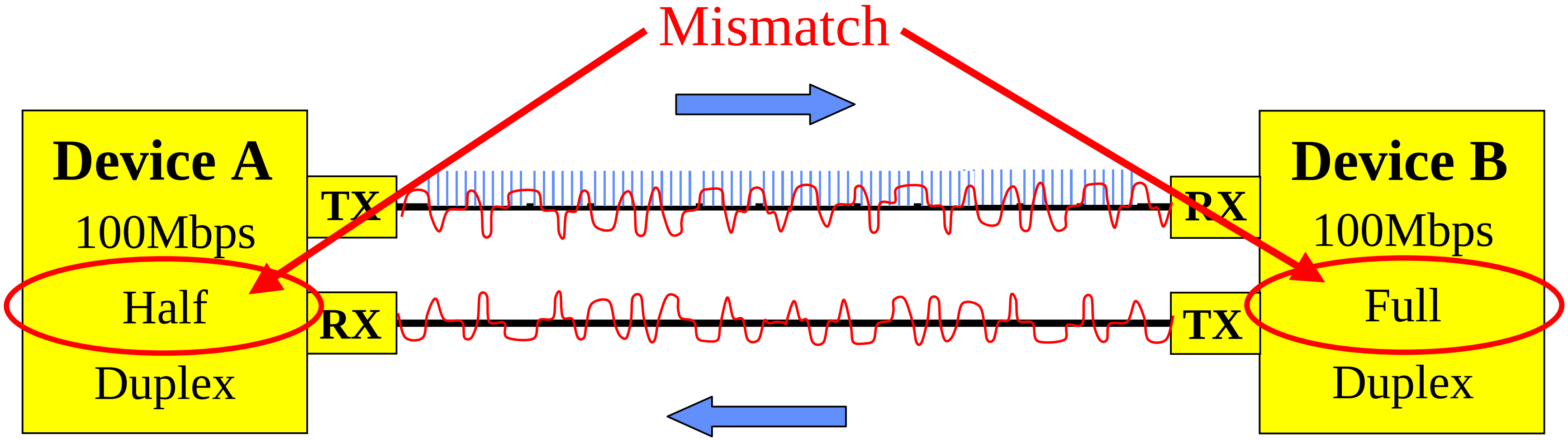
  3) The devices never link
- Let’s look at how these happen...

Aneg Error #1: User Misconfiguration

User configures Device B to be 100Mbps Full Duplex, not knowing this disables Autoneg (sending FLPs)

Device A sends FLPs out, while Device B sends out IDLE

Device A sees IDLE and assumes Device B is 100Mbps Half-Duplex, thus it links in Half-Duplex mode

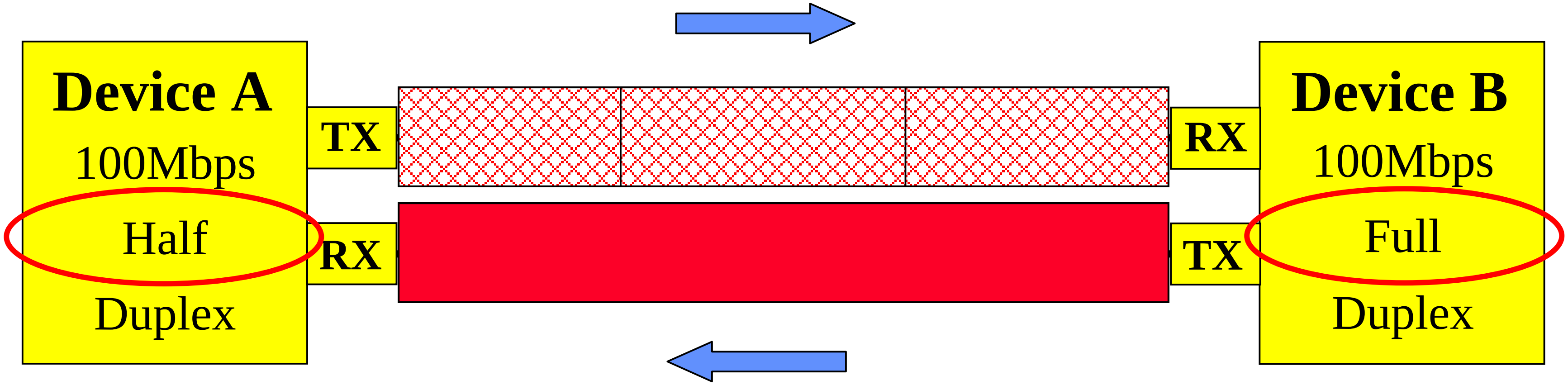


Duplex Mismatch Problem

If Device A and B send out a frame at the same time, then:

1) Device A will believe a collision occurred and corrupt its outgoing frame while discarding Device B's frame, and then attempt to resend its own frame

2) Device B will not resend its frame, and see Device A's frame as corrupted

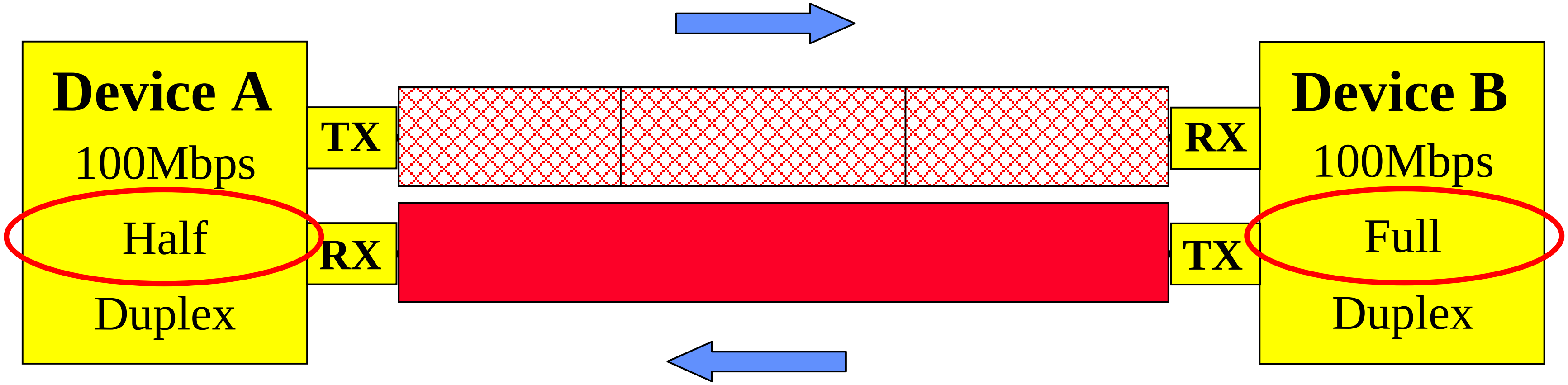


Duplex Mismatch Symptoms

Device A will record many “Late Collisions” in its counters

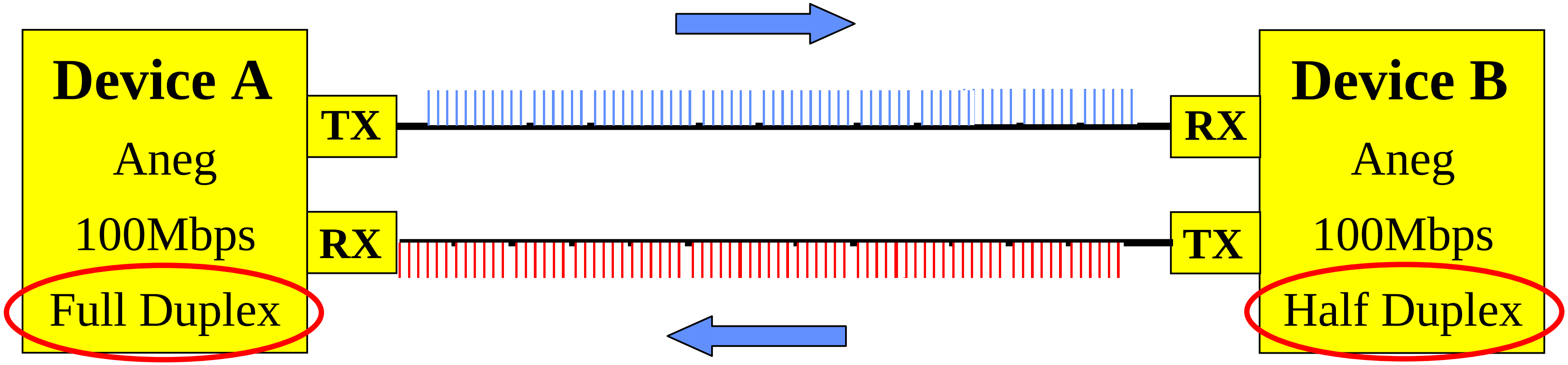
Device B will record many “CRC Errors” in its counters

The connection will appear slow, as the dropped frames aren’t resent until a higher layer times out (usually 1 second later)



Aneg Error #2: User Misconfiguration

- User configures Device A for 100Mbps Full-Duplex and Device B for Half-Duplex (or Device B is only Half-Duplex) while leaving Aneg (sending FLPs) turned on for both
- Each device receives the other’s FLPs, but the mismatch never resolves to a link because there is no common option



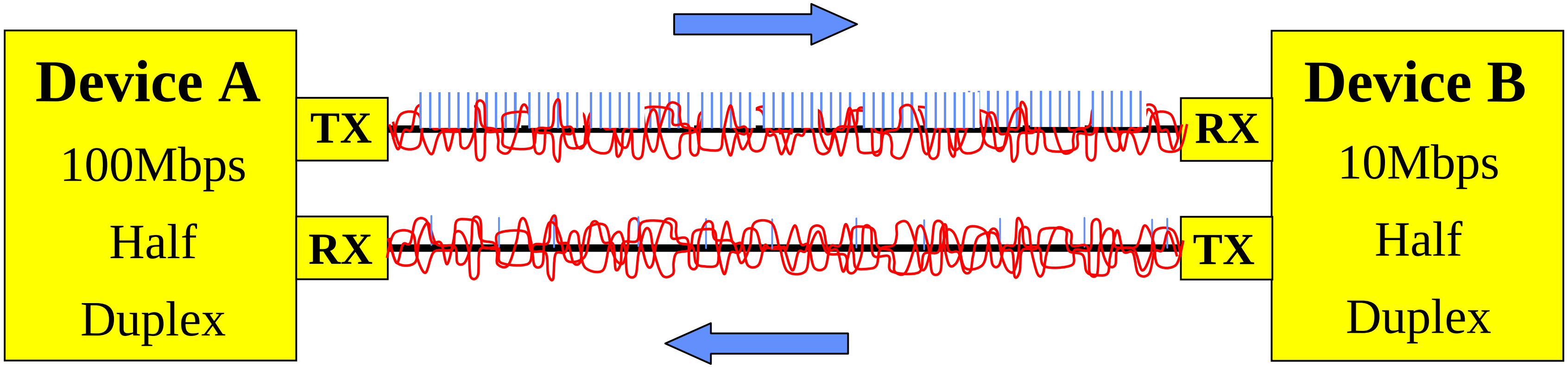
Aneg Error #3: Autosensing Devices

Autosensing devices do not use FLPs

Instead, they send IDLE while watching the RX line for LTPs or IDLE and decide based on that

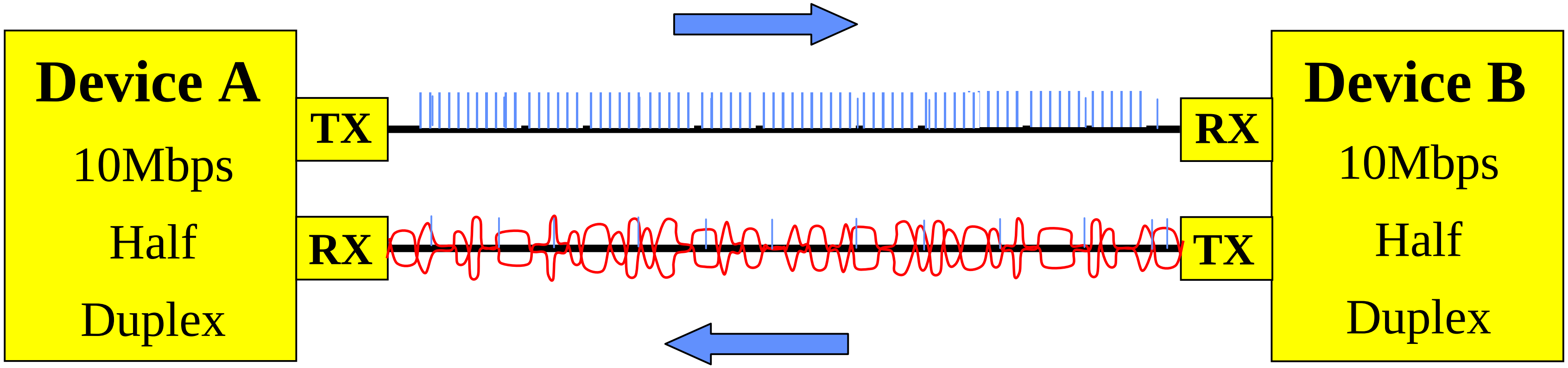
So Device A will send FLPs, which Device B will interpret as LTPs and switch to transmitting LTPs itself

Meanwhile, Device A may have seen the IDLE from B and “parallel detected” over to sending 100Mbps IDLE, which Device B will now see as 10Mbps junk data (yes, this is legal) - this should fix itself in a few seconds, or never



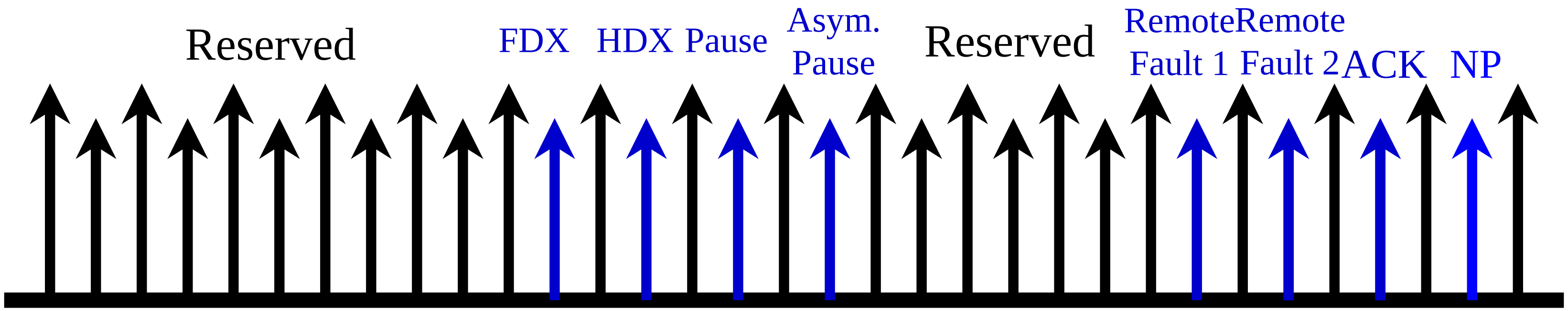
Aneg Error #3: Autosensing Devices

OR, Device A will see the LTPs from Device B and parallel detect to 10mbps, thereby successfully forming a 10mbps link, which is not optimal



Gigabit Ethernet Autonegotiation

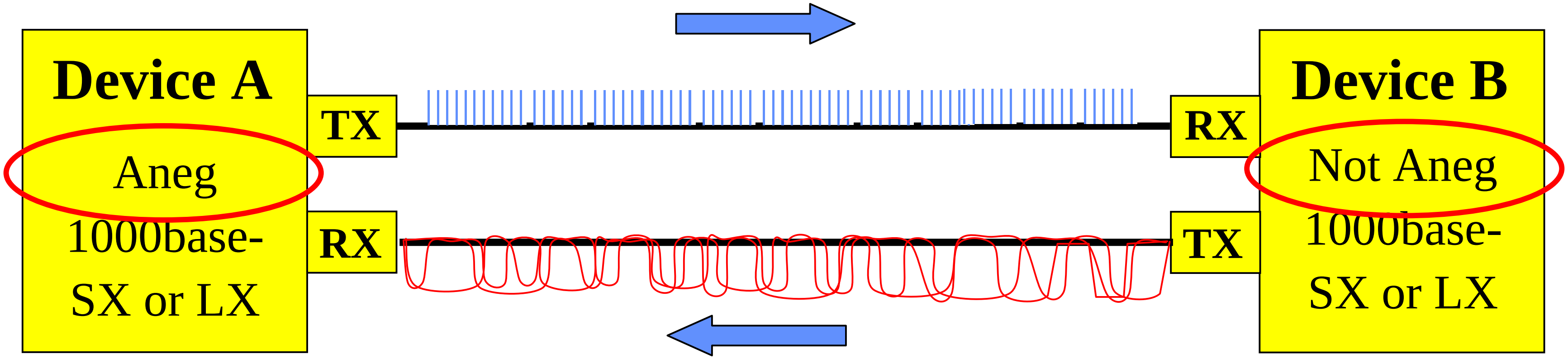
- Gigabit Ethernet uses the same Aneg mechanism as 10/100 copper Ethernet (remember there is no Aneg for 10 or 100 fiber)
- For 1000base-SX and 1000base-LX, it's used to determine duplex and flow-control parameters using the pre-defined fields shown below
- For 1000base-T, the Next Page field is used to indicate there is additional info that must be exchanged using more "pages"



Base Page for Gig fiber technologies

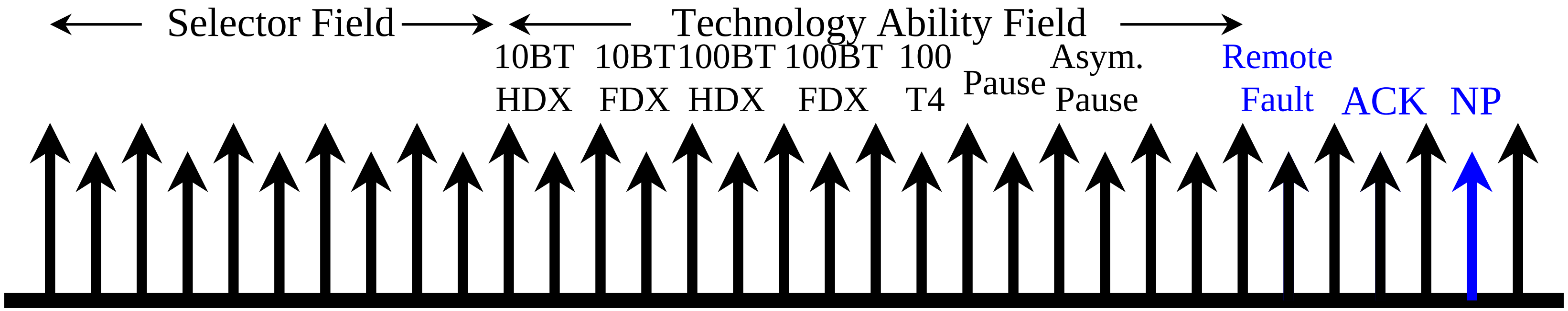
Gig Aneg Error #1: User Misconfiguration

- There are almost no Half-Duplex Gig devices, so we never have the mismatch problem of 10/100 Aneg
- The biggest problem is when users configure one device to “Autoneg Enabled” and the other device to “Autoneg Disabled”
- Such misconfigured devices will not link, or only one side will think it’s linked



Gigabit Copper Autonegotiation

- For 1000base-T, the Next Page field is used to indicate there is additional info that must be exchanged using more “pages”
- These pages contain the same type of info regarding duplex and speeds, but they also contain a couple new things:
  - a field to indicate whether the device is a single-port or multi-port device
  - a field for whether the master/slave determination is manually configured
  - a field for whether this device is the master or slave
  - a seed value



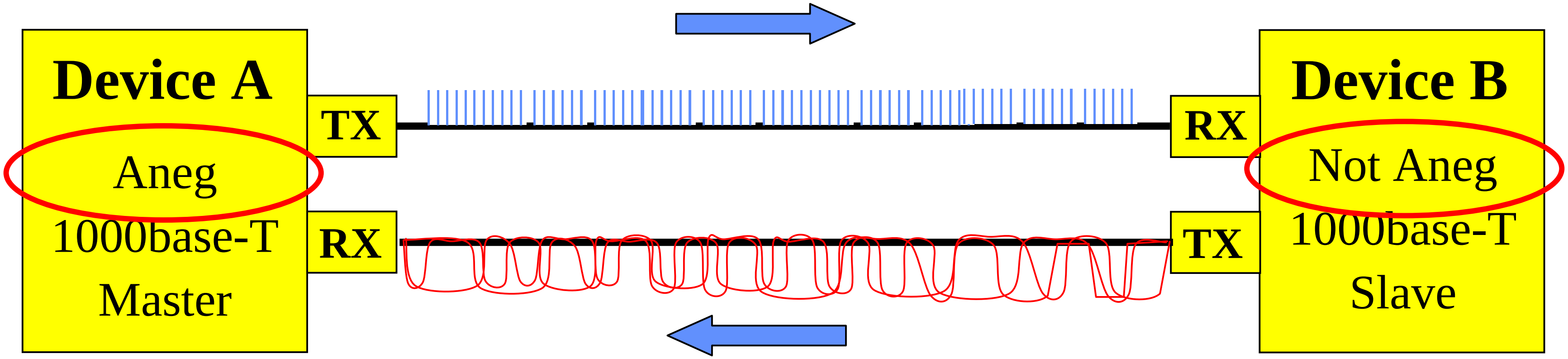
Base Page for Gig copper technologies

Gigabit Copper Autoneg (cont.)

- The purpose for the new fields is to resolve which side is the master and which the slave for a training sequence to adjust to the cable characteristics (like a DSL modem does)
- If the user does nothing, then it will automatically select a master based on:
  - if one side is multi-port, it is the master
  - if both sides are or both sides are not multi-port, then the seed is used to randomly choose
- Or the user can manually configure one to be the master and the other a slave

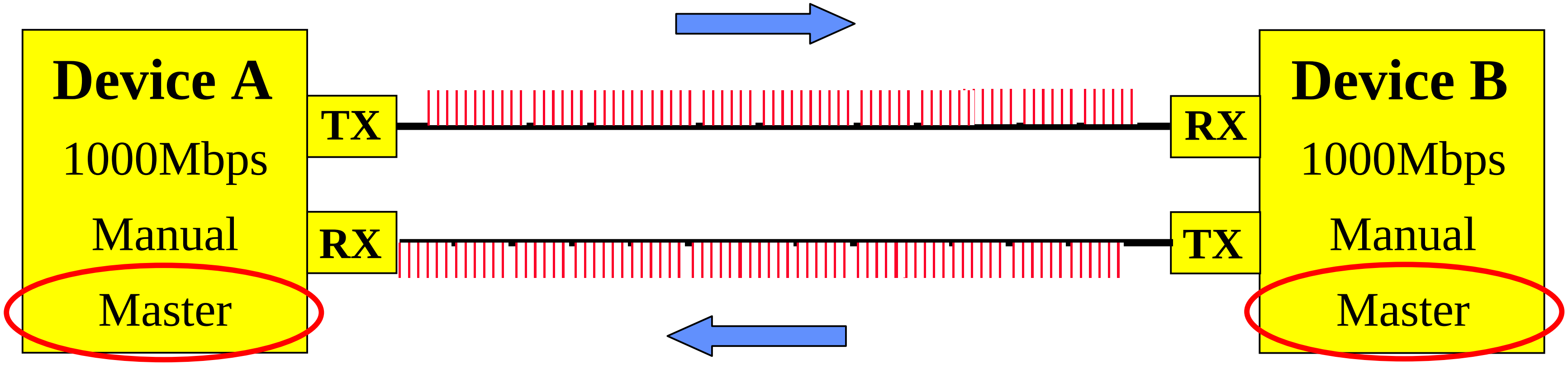
Gig Copper Aneg Error #1: User Misconfiguration

- There are almost no Half-Duplex Gig devices, so we never have the mismatch problem of 10/100 Aneg
- The biggest problem is when users configure one device to “Autoneg Enabled” and the other device to “Autoneg Disabled”
- Such misconfigured devices will not link, or only one side will think it’s linked



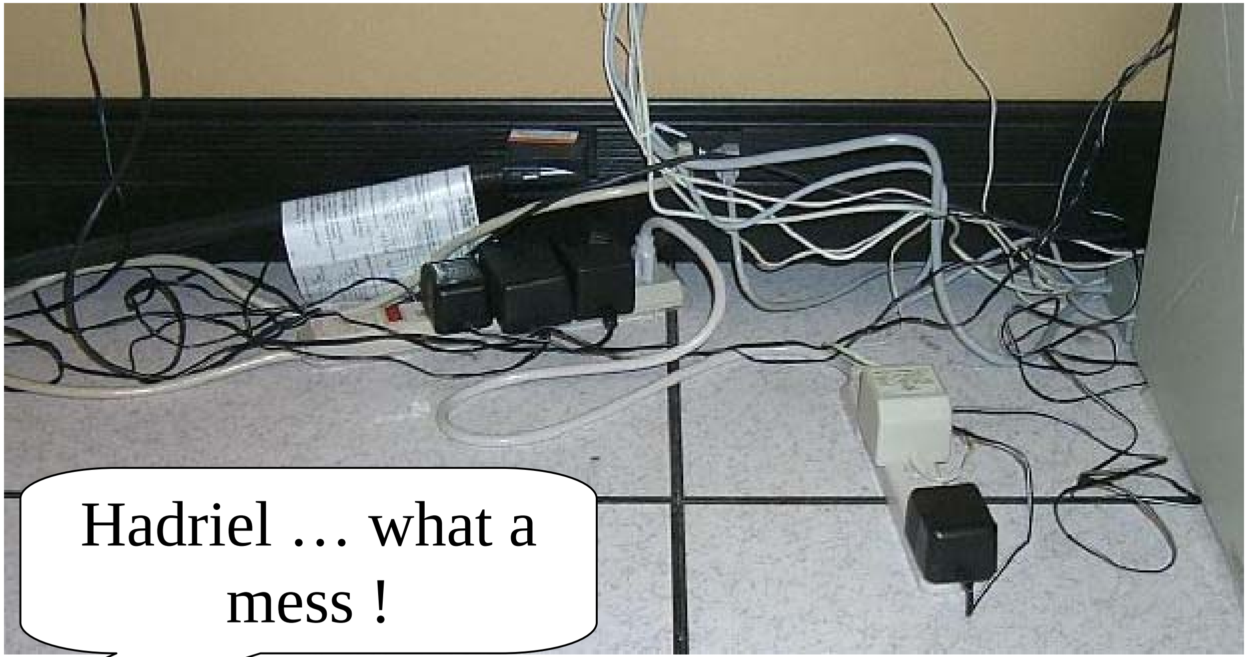
Gig Copper Aneg Error #2: User Misconfiguration

- A user configures both devices to be master or both to be slave
- Such misconfigured devices will never link - even if they’re also both autonegotiating, or both manual
- The problem is manually configuring master/slave overrides automatically selecting which side is which



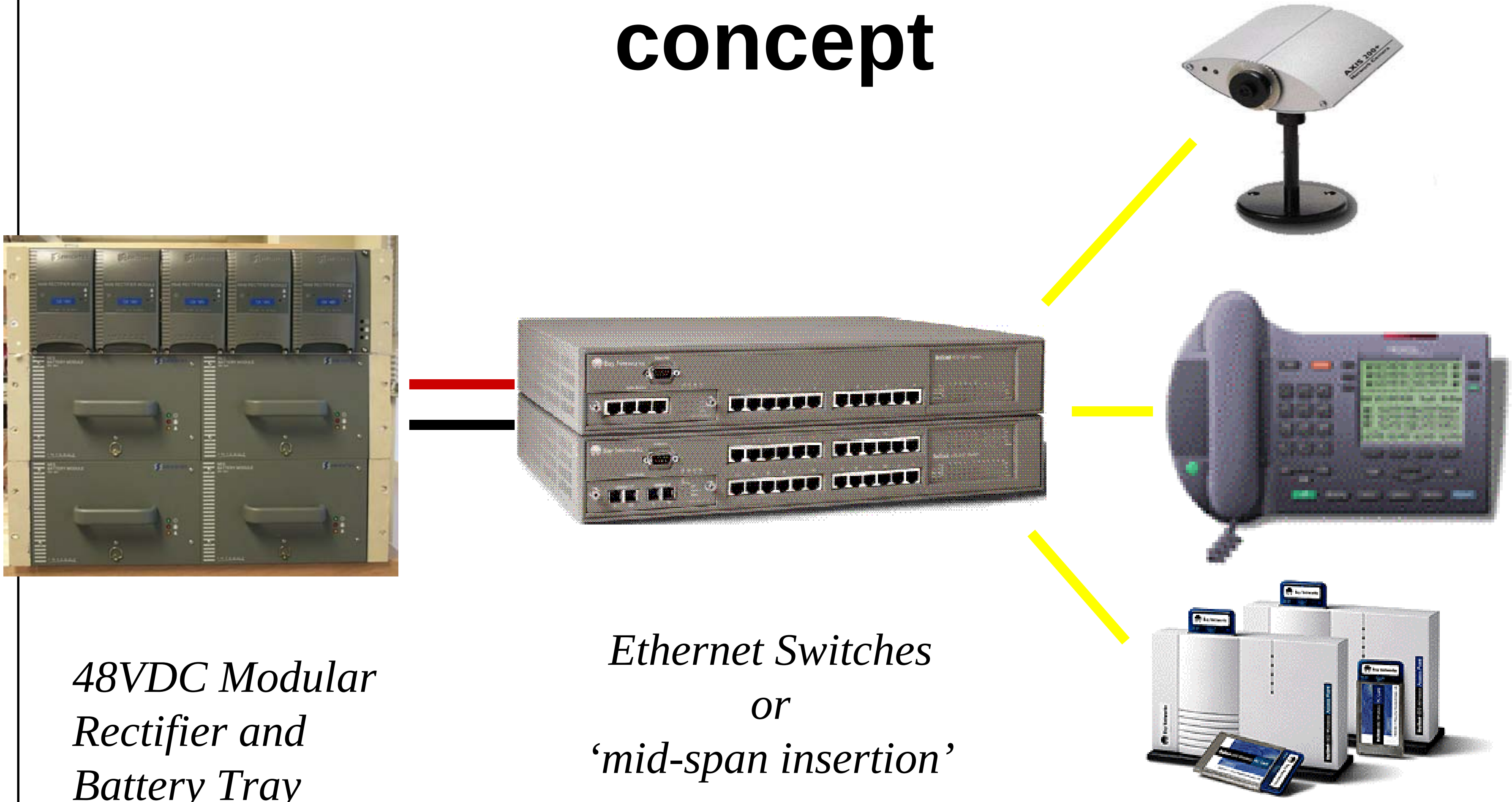
Power over Ethernet - 802.3af

Etherpower = No More Wall Warts !!



Hadriel … what a mess !

Power over Ethernet: the concept

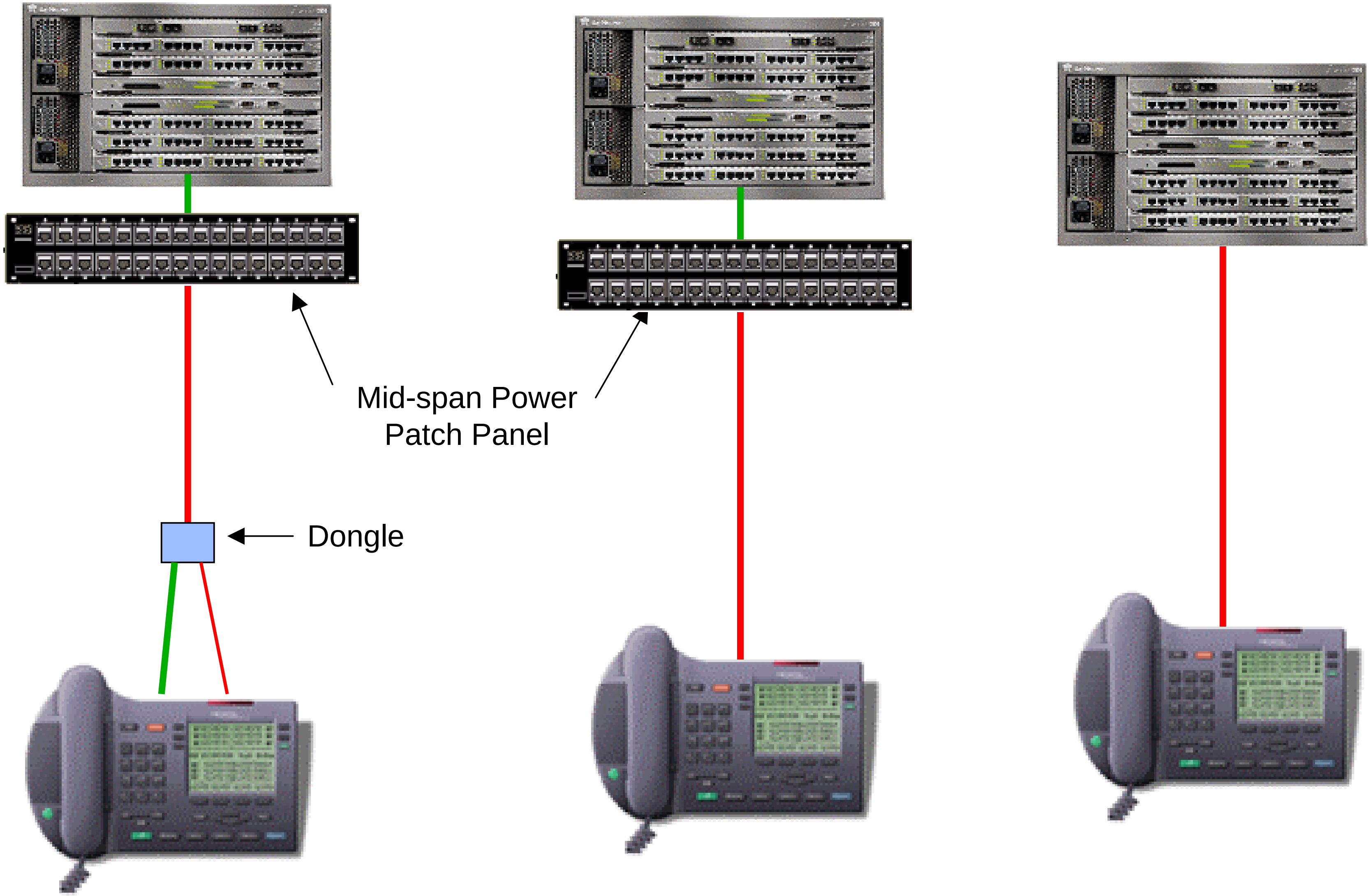


48VDC Modular Rectifier and Battery Tray

Ethernet Switches
or
‘mid-span insertion’

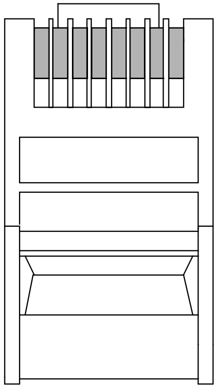
Data Appliances

Power over Ethernet: the details



UTP Copper

- looking down at the top of the RJ-45 (locking tab facing down)



1	2	3	4	5	6	7	8
Solid White, Orange Stripe	Solid Orange, White Stripe	Solid White, Green Stripe	Solid Blue, White Stripe	Solid White, Blue Stripe	Solid Green, White Stripe	Solid White, Brown Stripe	Solid Brown, White Stripe

- 10base-T and 100base-TX/T2 only use wires 1, 2, 3, and 6 - wires 4, 5, 7, and 8 are unused
- 100base-T4, and 1000base-T use all 8 wires

Power Over What?

Unused pairs (4/5,7/8)

- Safer
- Cheaper for phone side
- Allows for mid-span insertion (but this breaks 1000Base-T
- Allows for cheap “dongles” and non-data equipment

Signal pairs (1/2, 3/6)

- Doesn’t need all 4 pairs
- Works with 1000Base-T
- Cheaper for switch side

Power Method Options

- Voltage: 44-57v nominal DC
- Amperage: 350mA Max
- Power: 12.95 Watts max during use
- Use either pair sets: the source can feed power on one or the other, but the sink (device to be powered) will draw it from either
  - this makes the receiver (the phone side) more expensive
  - this allows for both a cheap powered patch panel and cheap powered switch method
  - this does not allow both data and unused pairs to send power simultaneously (not safe)

Power Discovery

- Method for power source to determine if connected device needs power
- Needs to be fool-proof (doesn’t fry old stuff)
- Needs to be cheap
- Needs to work before the other side is powered up (obviously)
- Needs to be safe regardless of cable-type connected: could be regular, crossover, flipped, wrong, broken
- Uses 19k-26.5kOhm Resistor

Houston, we have a problem…

- One company has filed a suit against another for patent infringement
- Their patent covers a security method whereby they monitor a small current (<1ma). If the current drops off then they produce an alarm.
- Power over Ethernet's minimum current is 10ma and if the PD's current draw falls below 10ma then the PSE removes power.
- By sending current over active Ethernet links, their patent may cover power over Ethernet
- If they don’t sign a Fair Use Agreement, the standard will be stopped/blocked

…and hopefully a solution

- **Power/current detection has been used in this manner “for all time”, including for Token Ring (phantom signaling)**
- **IEEE will likely persevere, or find a way around this legal snafu**
- **To continue towards this solution, IEEE P802.3af DTE Power via MDI Interim Meeting will be held Sept 24-26 in Portsmouth, NH, hosted by UNH IOL**
  http://grouper.ieee.org/groups/802/3/interims/portsmouth.html

This page left intentionally blank.

This page left intentionally blank.

10 Gigabit Ethernet - 802.3ae

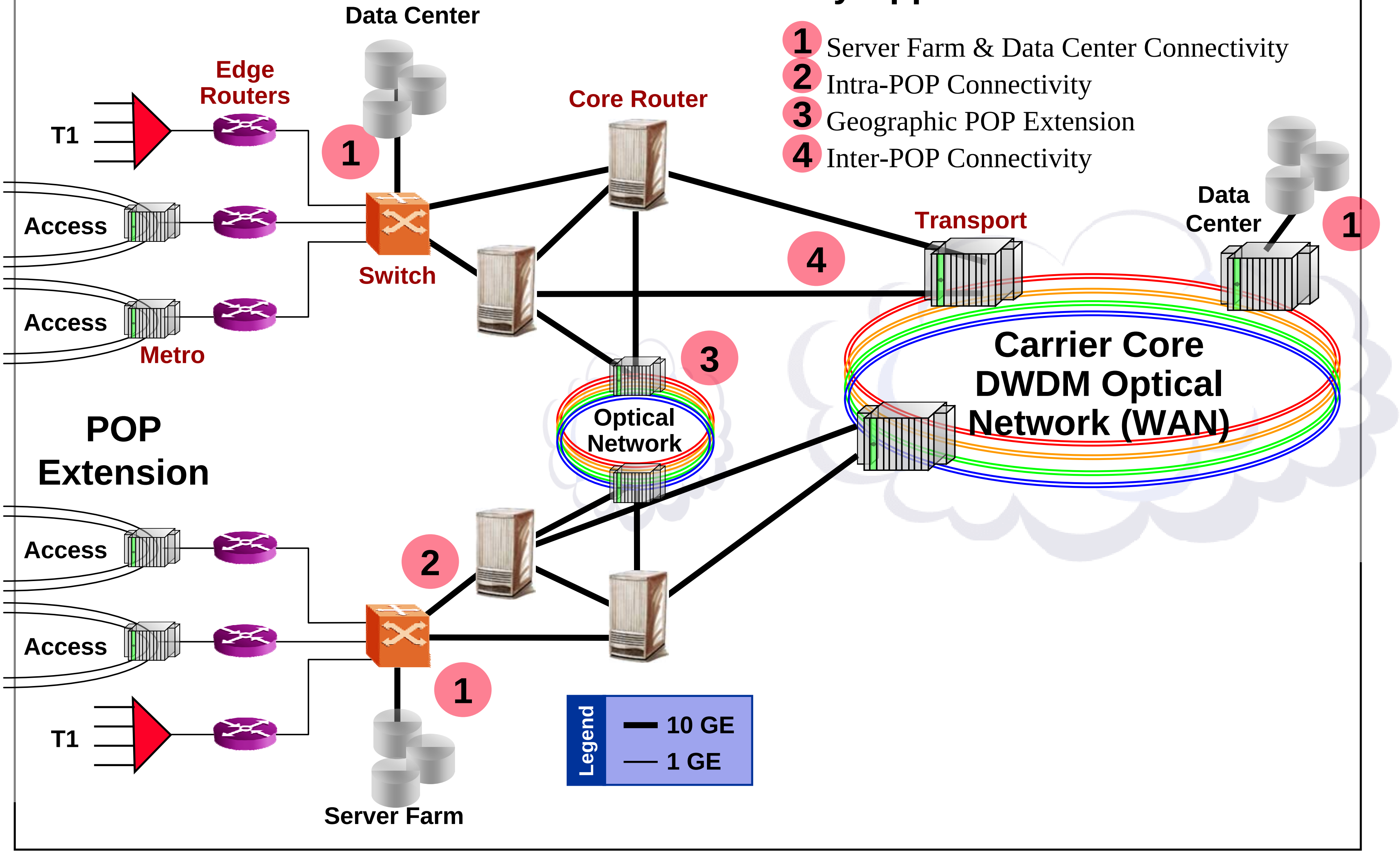
IEEE 802.3ae Objectives

- Support full-duplex operation only.
- Provide Physical Layer specifications which support link distances of:
  - At least 300 m over installed MMF
  - At least 65 m over MMF
  - At least 2 km over SMF
  - At least 10 km over SMF
  - At least 40 km over SMF
- Define two families of PHYs
  - A LAN PHY, operating at a data rate of 10.000 Gb/s
  - A WAN PHY, operating at a data rate compatible with the payload rate of OC-192c/SDH VC-4-64c

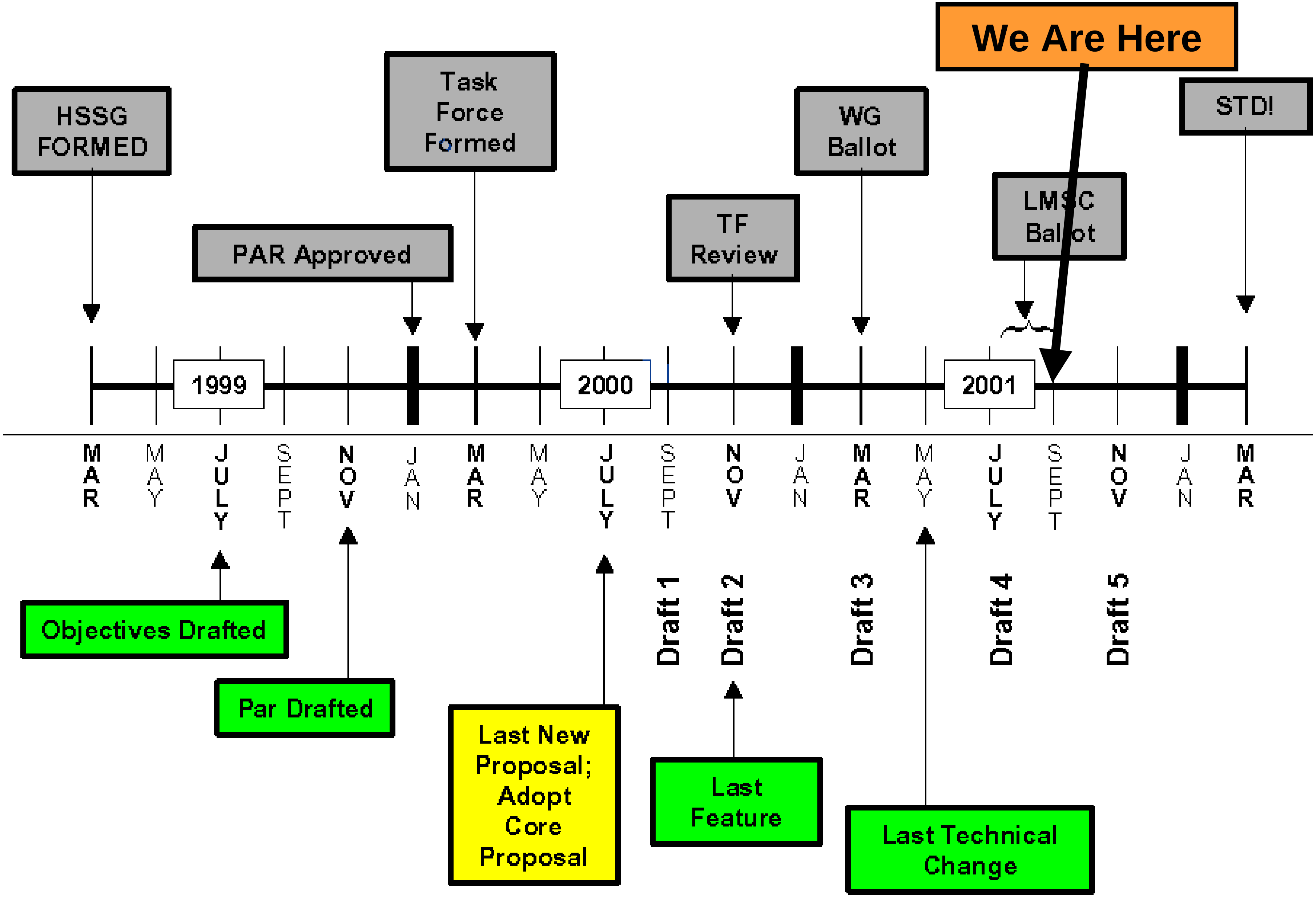
Where does 10GE fit ?

Key Applications

1. Server Farm & Data Center Connectivity
2. Intra-POP Connectivity
3. Geographic POP Extension
4. Inter-POP Connectivity



Long Term Schedule



We Are Here

HSSG FORMED

PAR Approved

Task Force Formed

TF Review

WG Ballot

LMSC Ballot

STD!

1999

2000

2001

MAR MAY JULY SEPT NOV JAN MAR MAY JULY SEPT NOV JAN MAR MAY JULY SEPT NOV JAN MAR

Draft 1

Draft 2

Draft 3

Draft 4

Draft 5

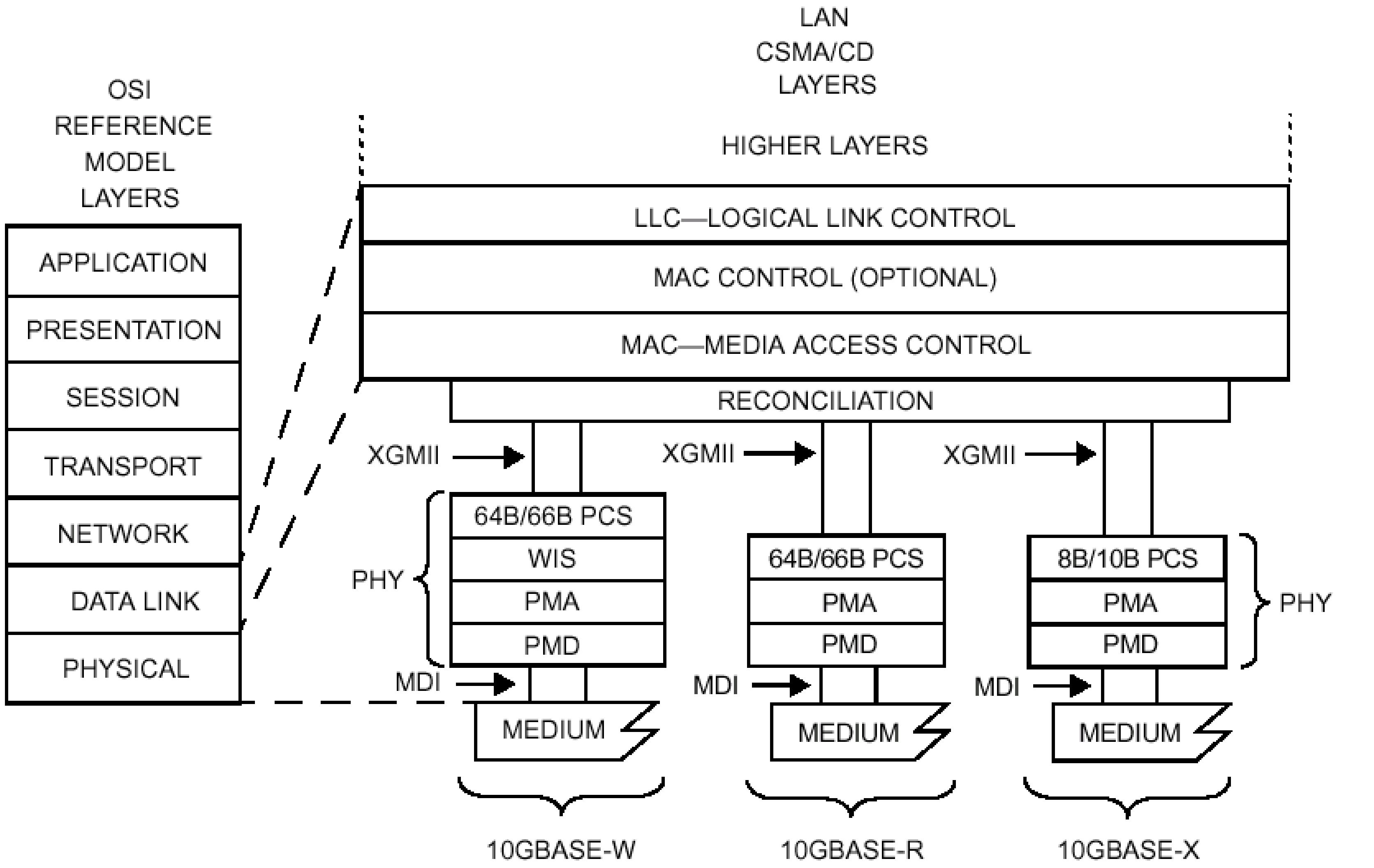
Objectives Drafted

Par Drafted

Last New Proposal; Adopt Core Proposal

Last Feature

Last Technical Change

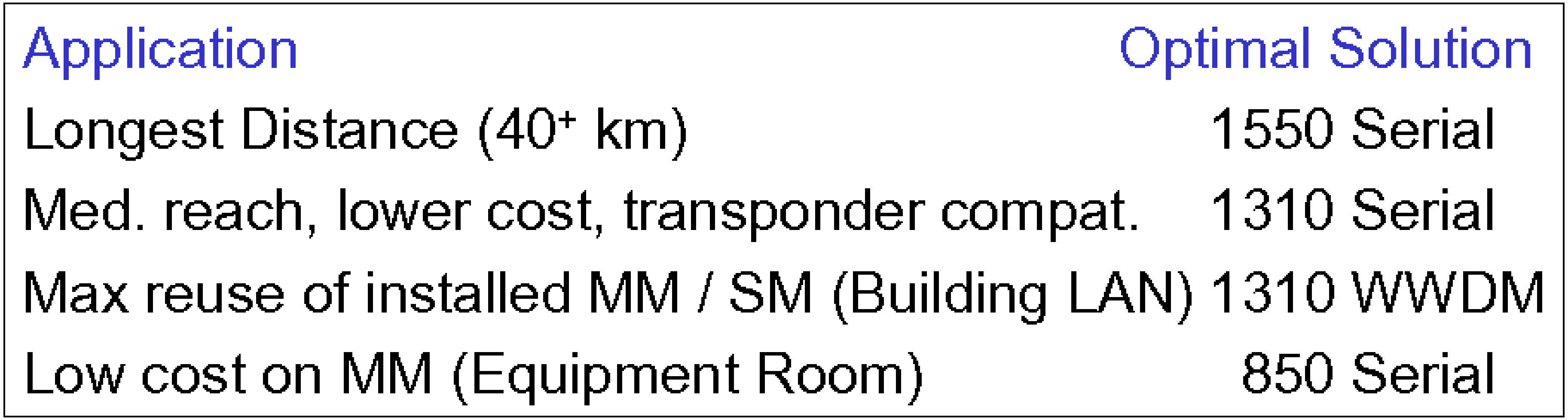


MDI = MEDIUM DEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT

PMD = PHYSICAL MEDIUM DEPENDENT
WIS = WAN INTERFACE SUBLAYER
XGMII = 10 GIGABIT MEDIA INDEPENDENT INTERFACE

The PMDs

- **Set of 4 PMDs (Physical Media Dependent) to optimize balance between distance objectives, cost and application.**



Application	Optimal Solution
Longest Distance (40^+ km)	1550 Serial
Med. reach, lower cost, transponder compat.	1310 Serial
Max reuse of installed MM / SM (Building LAN)	1310 WWDM
Low cost on MM (Equipment Room)	850 Serial

PMD Distance

Fiber Type per 11801 (Bandwidth @ 850nm//1310nm)	850 Serial	1310 WWDM	1310 Serial	1550 Serial
Legacy 62.5 MMF (160-200//500)	1-25 m	*1-300 m	NA	NA
Legacy 50 MMF (400-500//500)	1-75 m	*1-300 m	NA	NA
SMF	NA	1-10 km	1-10km	1-40km+

* Offset Launch Patch Cord required for distances > 100m

PMD Names

- Wavelength: S=850nm L=1310nm E=1550nm
- PMD Type:
  - X=WDM LAN(Wave Division Multiplexing – 4 wavelengths on 1 fiber)
  - R=Serial LAN using 64B/66B coding (LAN Application)
  - W=Serial WAN – SONET OC-192c compatible speed/framing

- 10GBASE-LX4
- 10GBASE-SR / -LR / -ER
- 10GBASE-SW/ -LW / -EW

So that's 7 interface types!

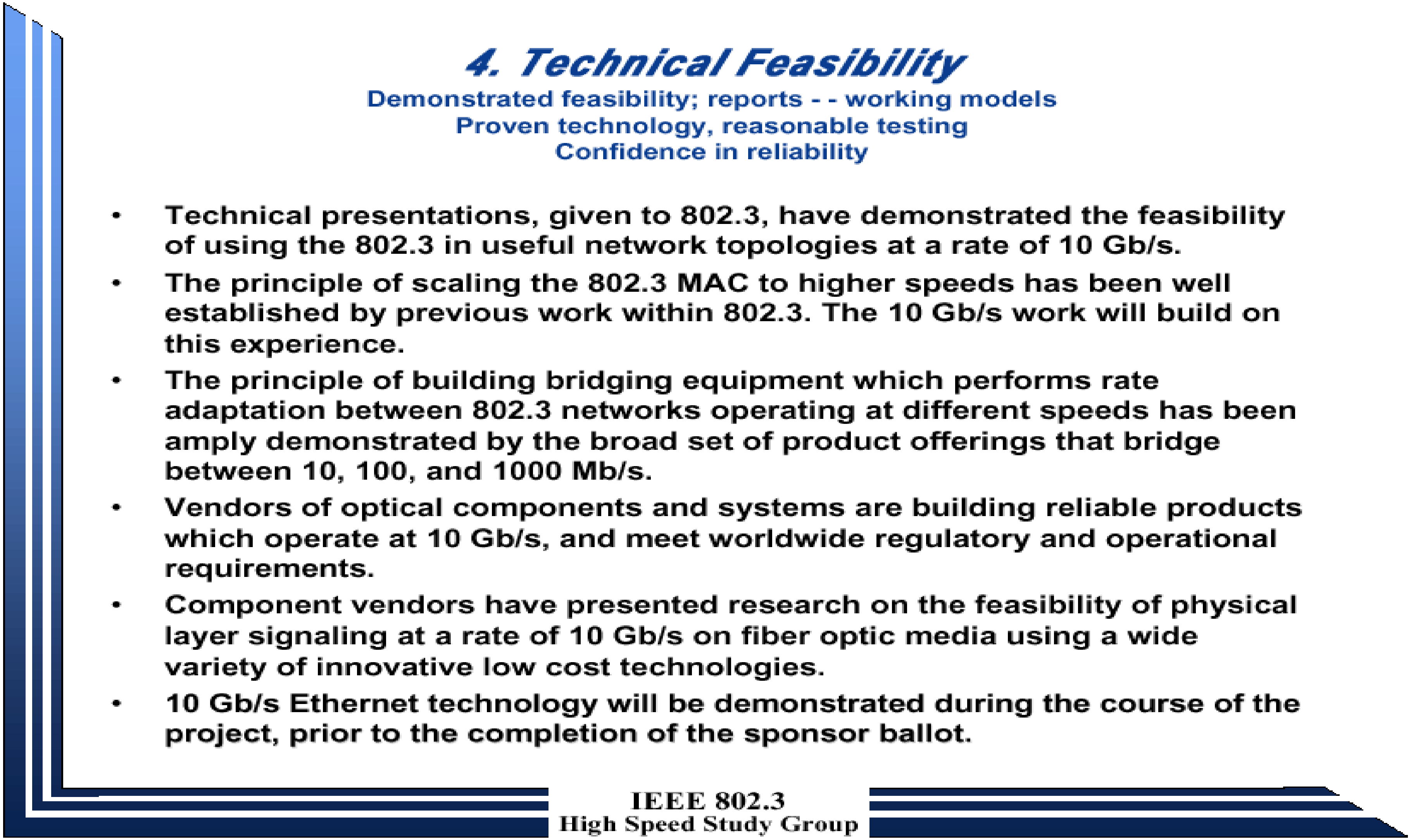
Types of 10Gig

	Interfaces	Type	Encoding	Wave-length	Fiber Type	Distance
LAN	10GBASE-LX4	WWDM	8B/10B	1310nm	MMF or SMF	300m or 10km
	10GBASE-SR	Serial	64B/66B	850nm	MMF	65m
	10GBASE-LR	Serial	64B/66B	1310nm	SMF	10km
	10GBASE-ER	Serial	64B/66B	1550nm	SMF	40km
WAN	10GBASE-SW	Serial	64B/66B, SONET	850nm	MMF	65m
	10GBASE-LW	Serial	64B/66B, SONET	1310nm	SMF	10km
	10GBASE-EW	Serial	64B/66B, SONET	1550nm	SMF	40km

Types of NON-STANDARD 10GigE

- 850nm CWDM – very similar to the 1310nm WWDM – everything is “identical” except the laser/optics are 850nm vcsels – LAN and WAN options are likely to exist – but this is NOT likely to be adopted by the standard (already has too many options, and this phy can only go 100m on installed MMF, and 300m on NEW fiber)
- Parallel Optics – 4 lasers, 4 receivers, 4 fibers, but otherwise like the WWDM solution – useful for short interconnects at either LAN or WAN (cable is too expensive for long reach)

A bit on Technical Feasibility,



4. Technical Feasibility

Demonstrated feasibility; reports - - working models
Proven technology, reasonable testing
Confidence in reliability

- Technical presentations, given to 802.3, have demonstrated the feasibility of using the 802.3 in useful network topologies at a rate of 10 Gb/s.
- The principle of scaling the 802.3 MAC to higher speeds has been well established by previous work within 802.3. The 10 Gb/s work will build on this experience.
- The principle of building bridging equipment which performs rate adaptation between 802.3 networks operating at different speeds has been amply demonstrated by the broad set of product offerings that bridge between 10, 100, and 1000 Mb/s.
- Vendors of optical components and systems are building reliable products which operate at 10 Gb/s, and meet worldwide regulatory and operational requirements.
- Component vendors have presented research on the feasibility of physical layer signaling at a rate of 10 Gb/s on fiber optic media using a wide variety of innovative low cost technologies.
- 10 Gb/s Ethernet technology will be demonstrated during the course of the project, prior to the completion of the sponsor ballot.

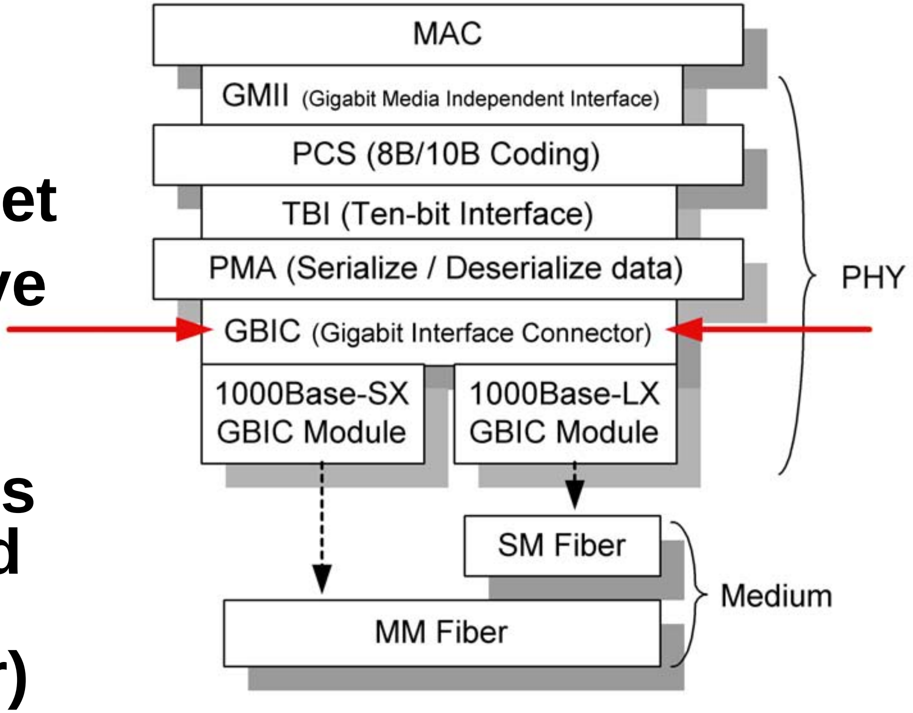
IEEE 802.3
High Speed Study Group

Technical Feasibility

- These new PHYs must be shown to be technically feasible by this November.
- Bob will be presenting additional data/info on this as these demos/studies will have been conducted in the past two weeks with UNH IOL support. Also check out the trade show floor for real demos of 10GigE and stay tuned to the outcome of next weeks IEEE P802.3ae Interim Meeting in Copenhagen, Denmark, where some presentations on this topic will be made.

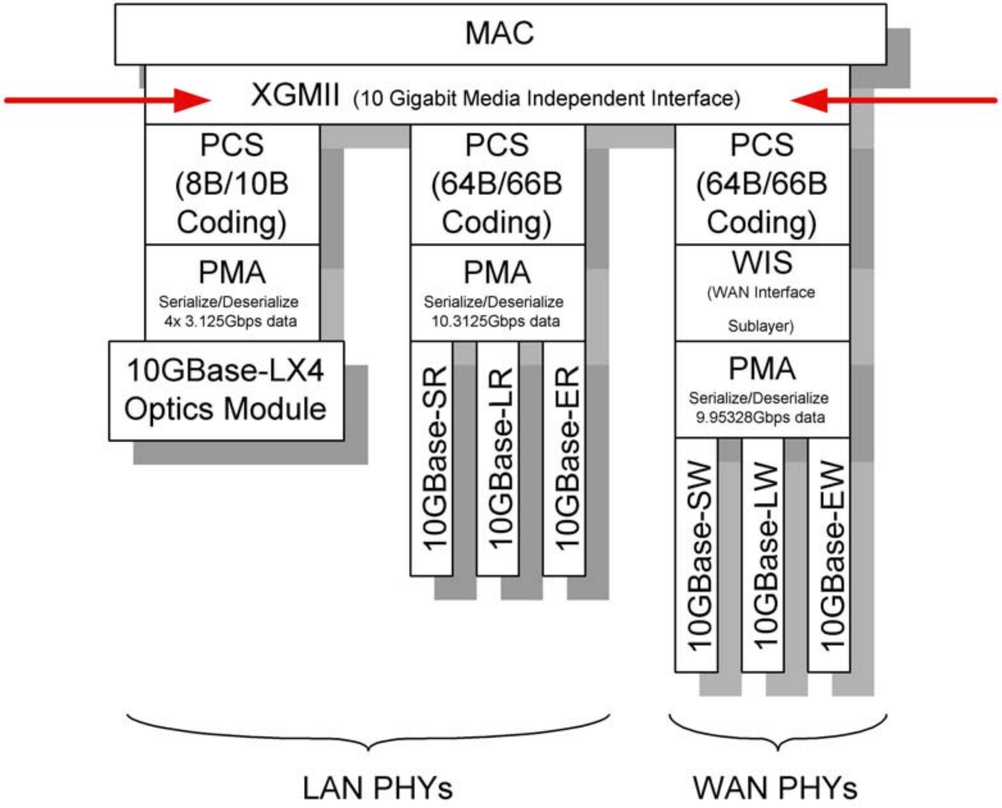
History: Gig Ethernet GBIC

- GBIC is a hot-swappable connector for Gigabit Ethernet
- All layers above GBIC are identical
- GBIC module is simply O/E and E/O (laser and photo detector)



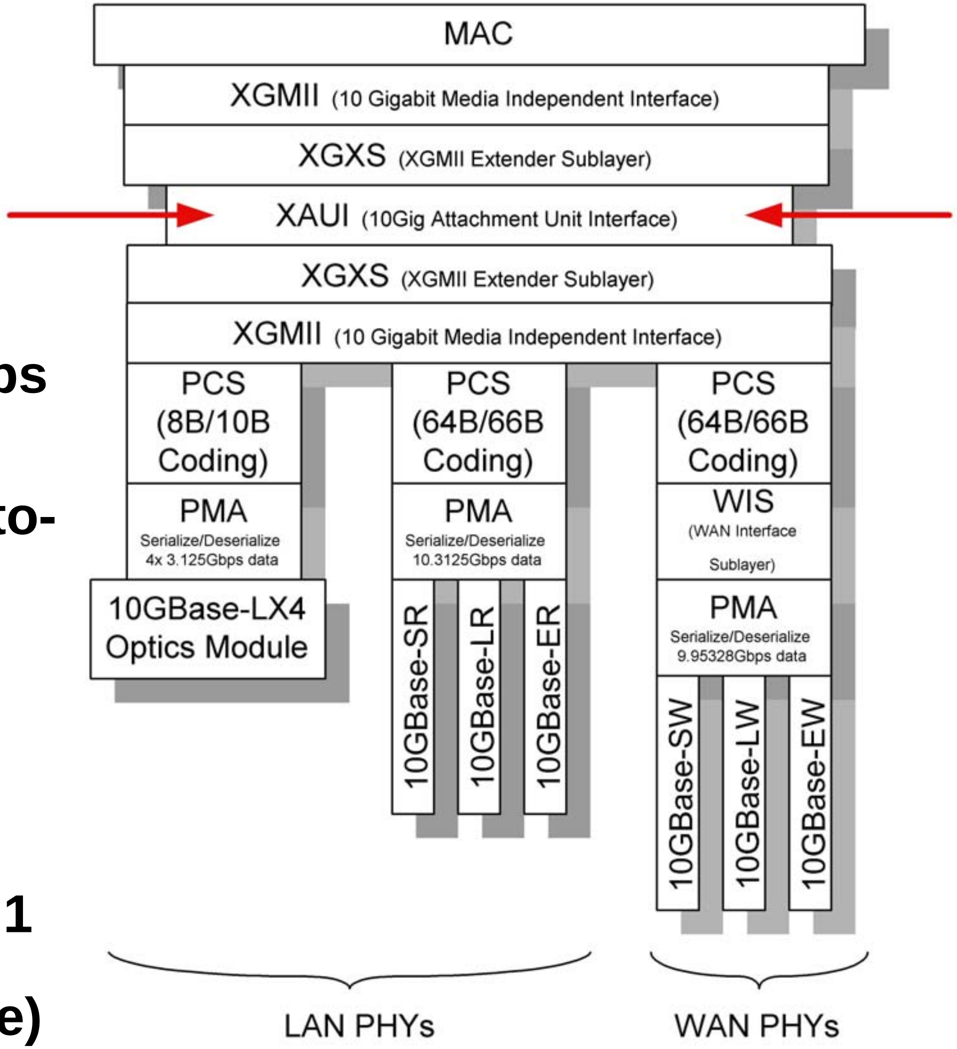
XGMII

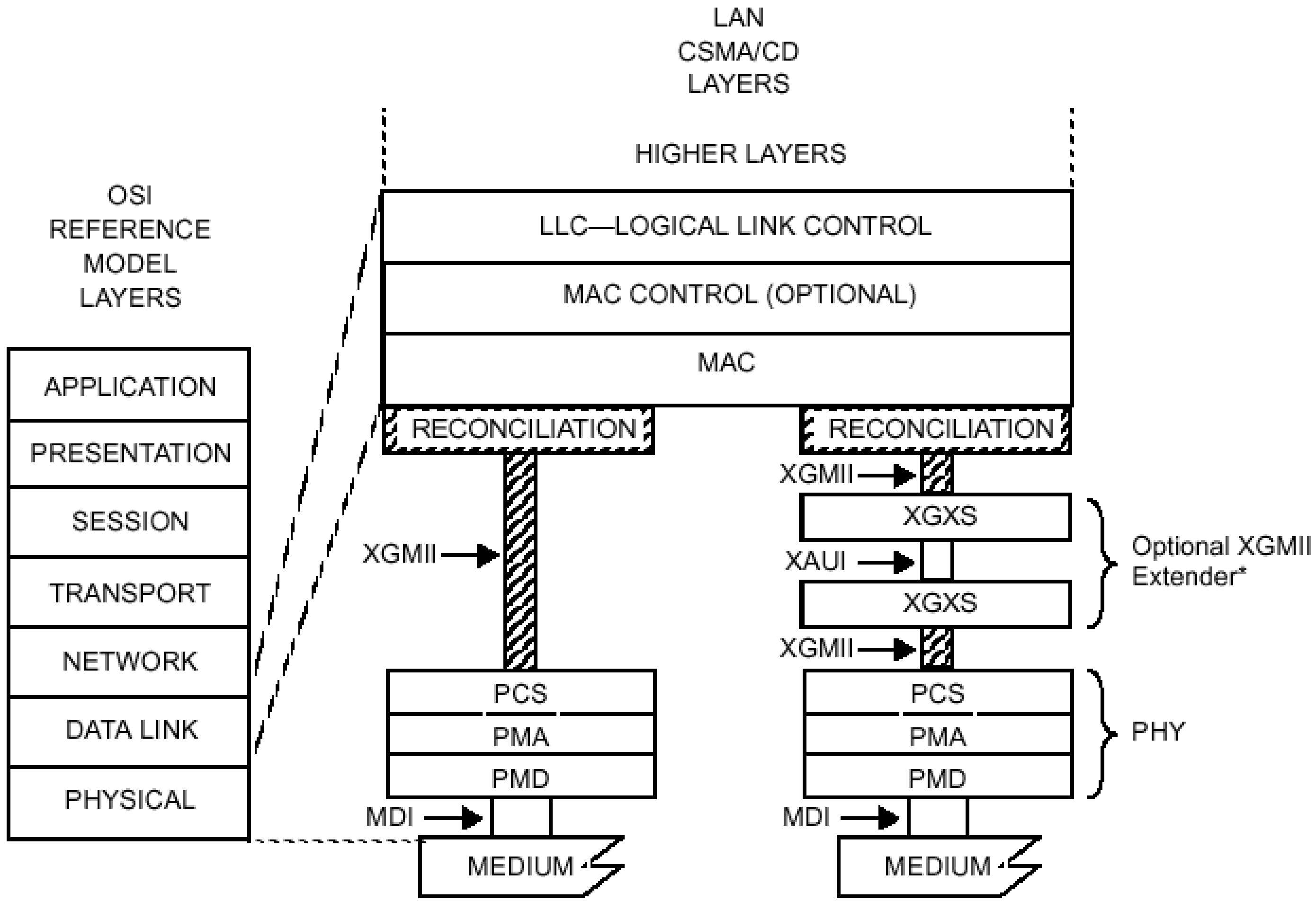
- PHY independent interface
- XGMII is a 32bit wide data bus, split into 4 8bit lanes, and a 4bit control bus
- Requires 74 pins!


MAC
XGMII (10 Gigabit Media Independent Interface)
PCS (8B/10B Coding)
PMA Serialize/Deserialize 4x 3.125Gbps data
10GBase-LX4 Optics Module
PCS (64B/66B Coding)
PMA Serialize/Deserialize 10.3125Gbps data
10GBase-SR
10GBase-LR
10GBase-ER
PCS (64B/66B Coding)
WIS (WAN Interface Sublayer)
PMA Serialize/Deserialize 9.95328Gbps data
10GBase-SW
10GBase-LW
10GBase-EW
LAN PHYs
WAN PHYs

XAUI (Sounds like Zowie)

- Phy Independent Interface
- XAUI works just like 10GBase-LX4, 8B/10B encoding 4 XGMII 8bit lanes to 4 10bit lanes, serialized to 4 3.125Gbps
- Requires only 16pins!
- Allows for longer chip-to-chip distance
- Same interface as Infiniband and Fibre Channel use
- Hot-swappable PHYs likely to emerge at this interface (like GBIC for 1 Gig Ethernet) – called XGP (Ten Gig Pluggable)


MAC
XGMII (10 Gigabit Media Independent Interface)
XGXS (XGMII Extender Sublayer)
XAUI (10Gig Attachment Unit Interface)
XGXS (XGMII Extender Sublayer)
XGMII (10 Gigabit Media Independent Interface)
PCS (8B/10B Coding)
PCS (64B/66B Coding)
PCS (64B/66B Coding)
PMA Serialize/Deserialize 4x 3.125Gbps data
PMA Serialize/Deserialize 10.3125Gbps data
WIS (WAN Interface Sublayer)
10GBase-LX4 Optics Module
10GBase-SR
10GBase-LR
10GBase-ER
PMA Serialize/Deserialize 9.95328Gbps data
10GBase-SW
10GBase-LW
10GBase-EW
LAN PHYs
WAN PHYs



LAN
CSMA/CD
LAYERS

OSI
REFERENCE
MODEL
LAYERS

APPLICATION
PRESENTATION
SESSION
TRANSPORT
NETWORK
DATA LINK
PHYSICAL

HIGHER LAYERS
LLC—LOGICAL LINK CONTROL
MAC CONTROL (OPTIONAL)
MAC

RECONCILIATION
XGMII
PCS
PMA
PMD
MDI
MEDIUM

RECONCILIATION
XGMII
XGXS
XAUI
XGXS
XGMII
Optional XGMII Extender*
PCS
PMA
PMD
PHY
MDI
MEDIUM

MAC = MEDIA ACCESS CONTROL
MDI = MEDIUM DEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE

PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT
XAUI = 10 GIGABIT ATTACHMENT UNIT INTERFACE
XGMII = 10 GIGABIT MEDIA INDEPENDENT INTERFACE

Why do YOU care about XAUI?

- XAUI will form the basis for your hot plugable
- Now a word from….

Agilent Technologies

agere systems

MITSUBISHI ELECTRIC

tyco / Electronics

optillion

XENPAK
10 Gigabit Ethernet MSA

PINE PHOTONICS
communications

NORTEL
NETWORKS™

Infineon
technologies

BLAZE™
NETWORK PRODUCTS

PICOLIGHT

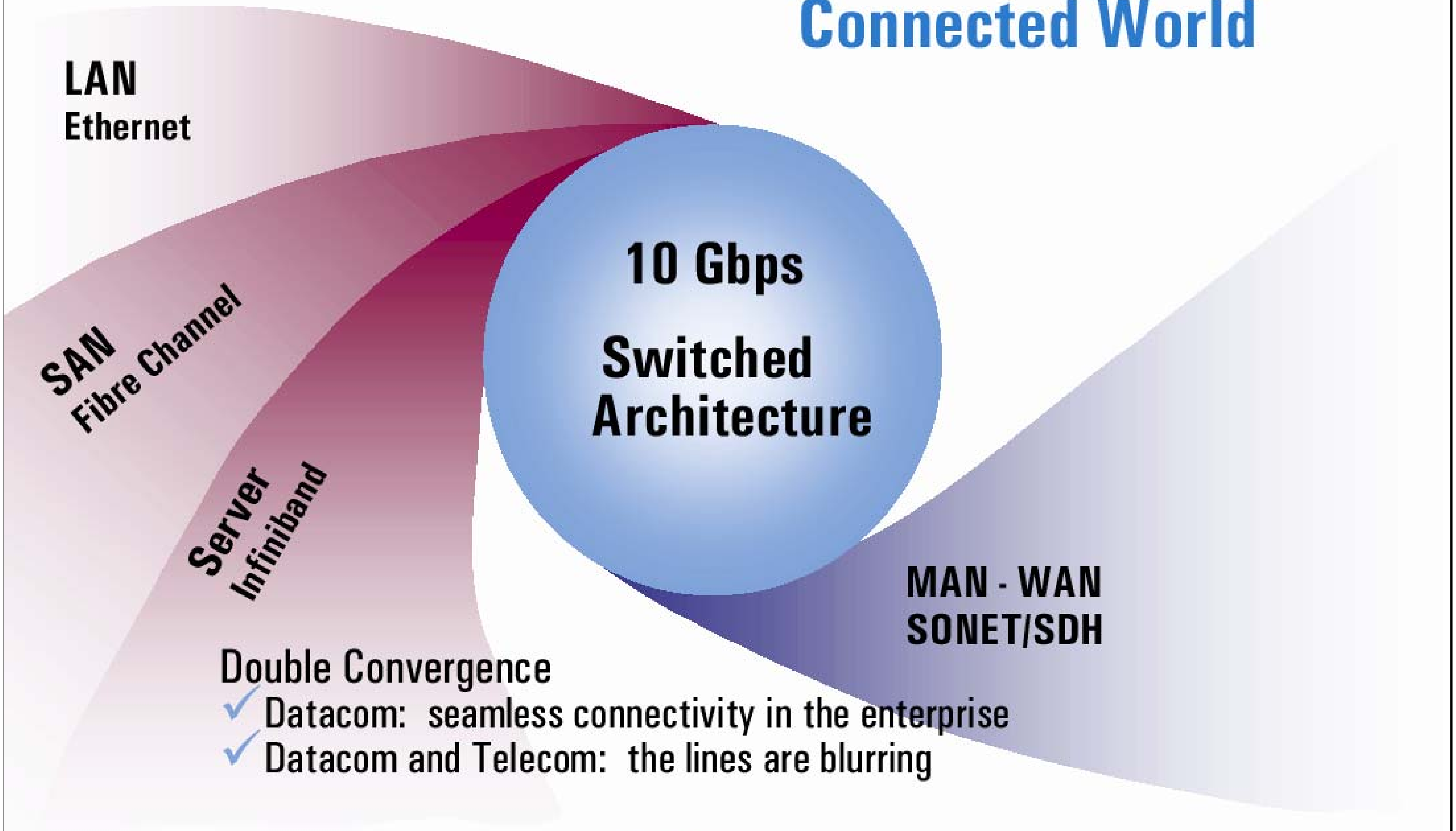
op|next
Powered by HITACHI

molex®

LightLogic

Luminent
Bringing Communications to Light™

The Network Convergence of the Connected World



LAN
Ethernet

SAN
Fibre Channel

Server
Infiniband

10 Gbps

Switched Architecture

MAN - WAN
SONET/SDH

Double Convergence

- ✓ Datacom: seamless connectivity in the enterprise
- ✓ Datacom and Telecom: the lines are blurring

XENPAK
10Gigabit Ethernet MSA

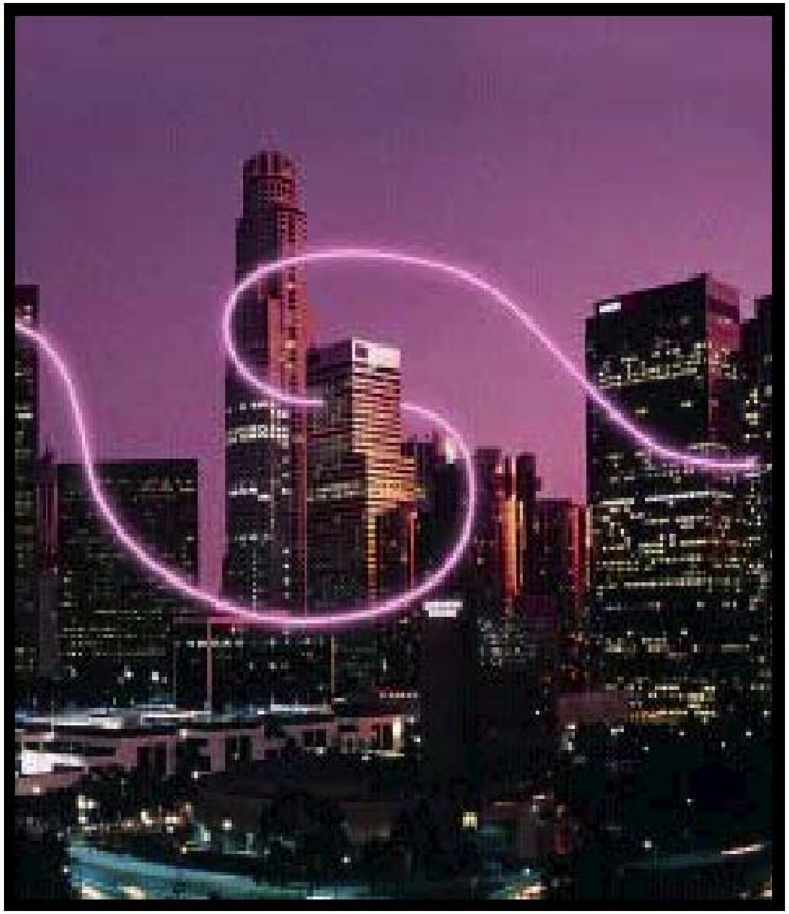
Challenges of Installing an Evolving Network

- Interoperability
- Equipment cost
- Scalability
- Flexibility
- Reliability
- Quick and easy field repair
- Size

XENPAK
10 Gigabit Ethernet MSA

Page 3

Challenges Faced by Networking Equipment Suppliers



- Big market disruption in progress
  - Standards emerging
  - Need for architecture flexibility
- Optimizing thermal performance at high port densities
- Satisfying QoS expectations and SLAs
- Aligning aggressive cost points

XENPAK
10 Gigabit Ethernet MSA

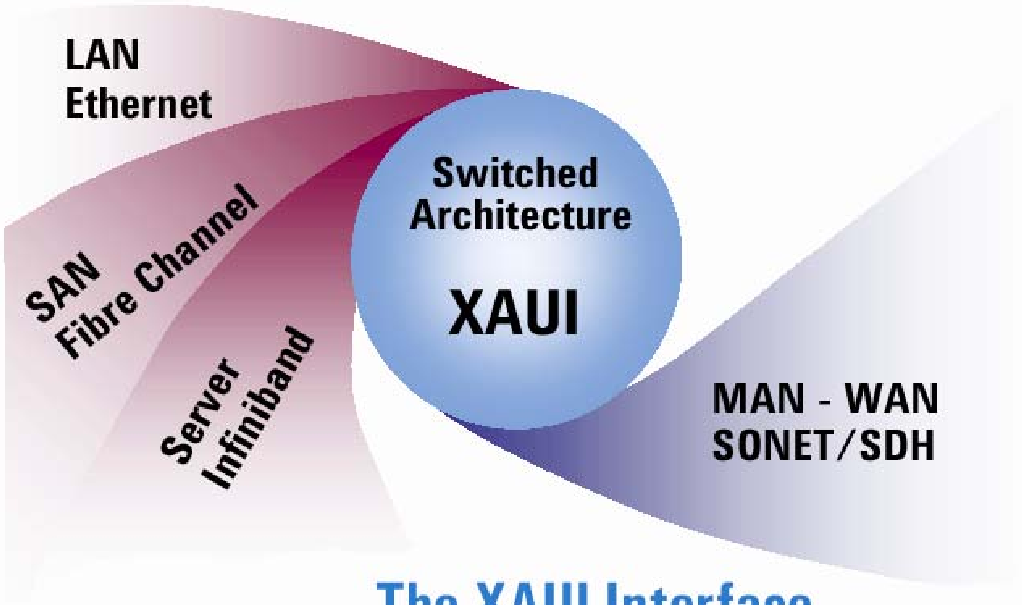
Expanding Ethernet beyond the Enterprise

Proposed 10 GbE Platform Standard

- IEEE 802.3ae 10 GbE MSA
  - Four wide XAUI interface
  - Compliant for all IEEE 802.3ae mediums
    - 850 nm Serial
    - 1310 nm WWDM, 1310 nm Serial
    - 1550 nm Serial
  - Front Panel Hot Pluggable
  - Allows very high port densities
  - SC duplex fiber optic connector
  - Industry standard 70 pin electrical connector

XENPAK
10 Gigabit Ethernet MSA

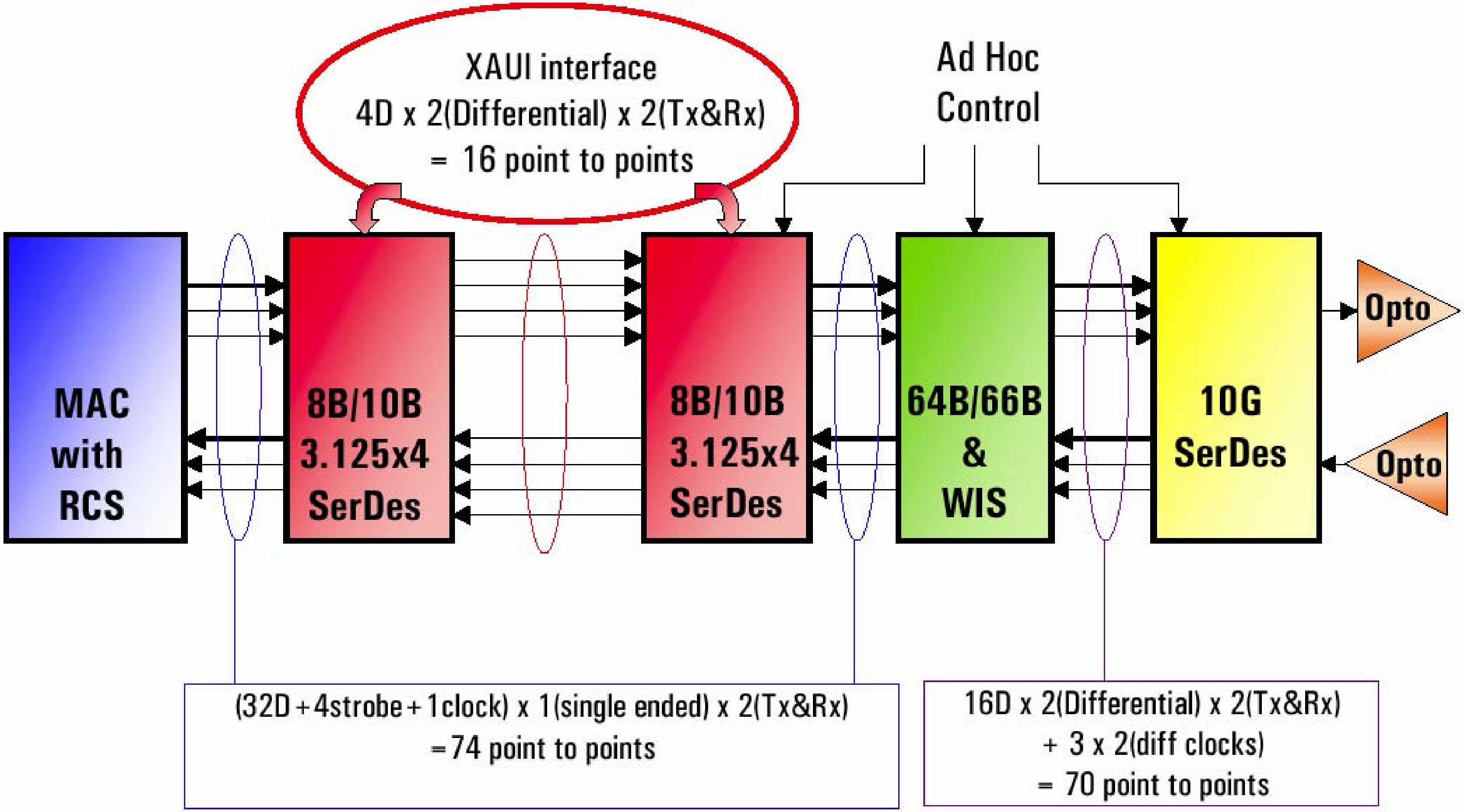
Enabling Architectural Flexibility



The XAUI Interface

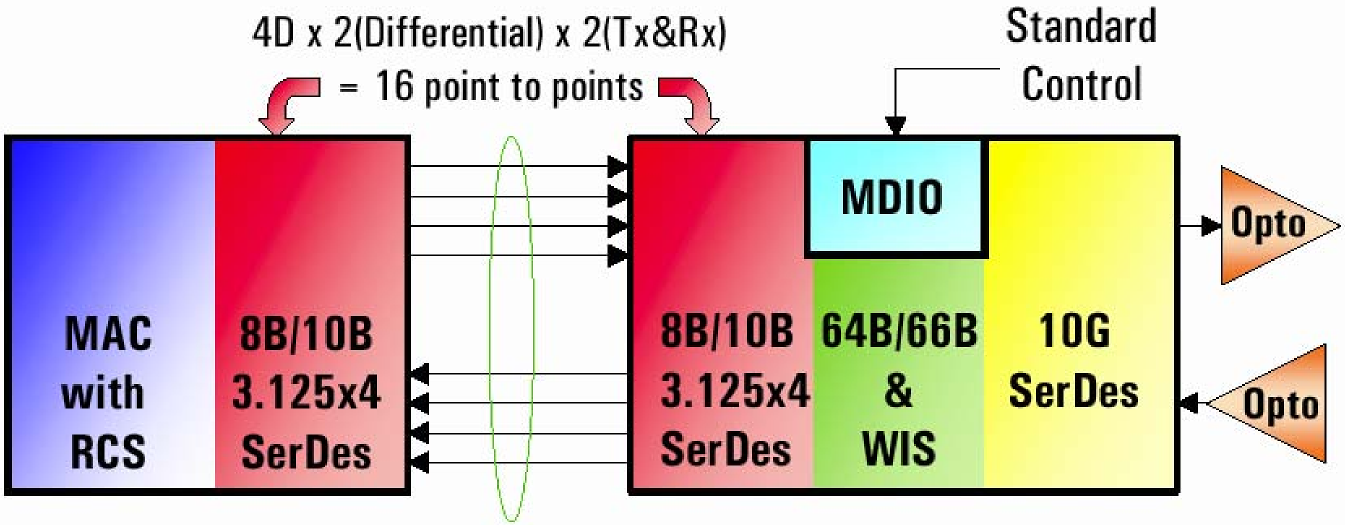
- 10 Gigabit Attachment Unit Interface
- Commonality with emerging Fibre Channel, Infiniband and SONET standards
- Industry-wide adoption
- Economies of scale support the evolution of the Network

10 Gig Building Blocks



XENPAK 10 Gigabit Ethernet MSA

Benefits of selecting XAUI as interface between System Electronics and Optical Transceiver



- Self-clocked XAUI lanes eliminates clock to data and data skew issues
- Robust CML differential, un-clocked interface allows trace-lengths of 18" on FR4
- Commonality with emerging Fibre Channel, Infiniband and SONET standards
- Bi-directional interface requires only 16 point-to-point connections

XENPAK
10 Gigabit Ethernet MSA

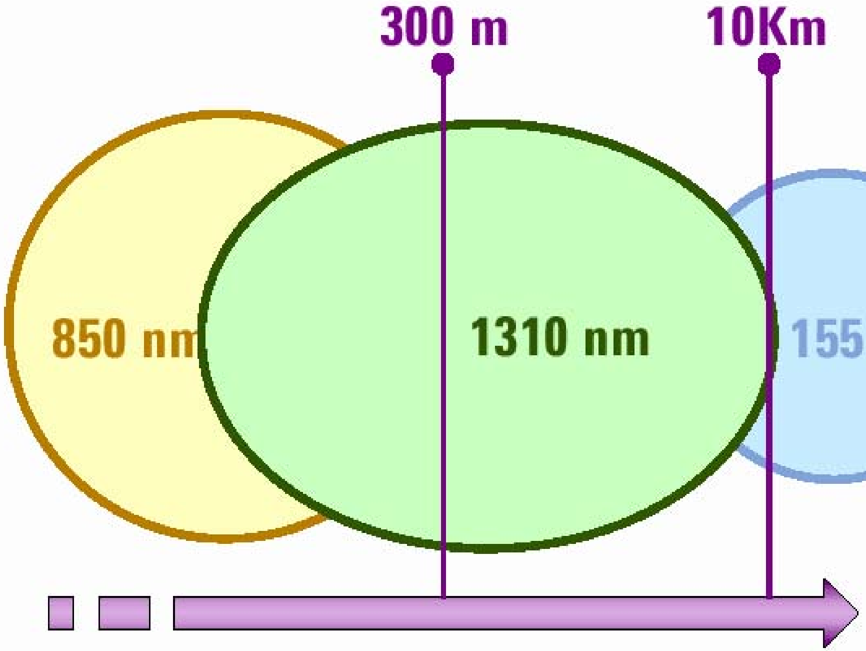
Page 8

Enabling Architectural Flexibility

Plug and Play Distance

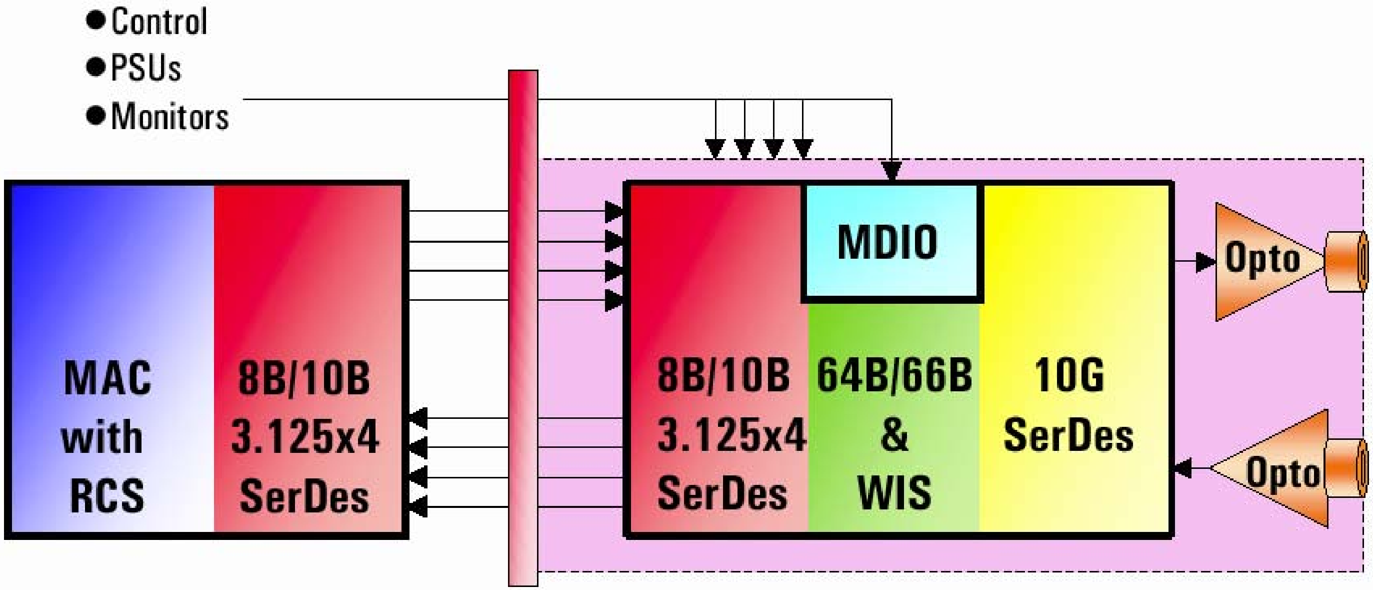
- Increases network flexibility, enables organic network growth
- Compliant to all 802.3ae PMDs*

  850 nm Serial
  1310 nm WWDM
  1310 nm Serial
  1550 nm Serial



** Physical Medium Dependent*

Benefits of Front Panel Hot Pluggable Transceiver

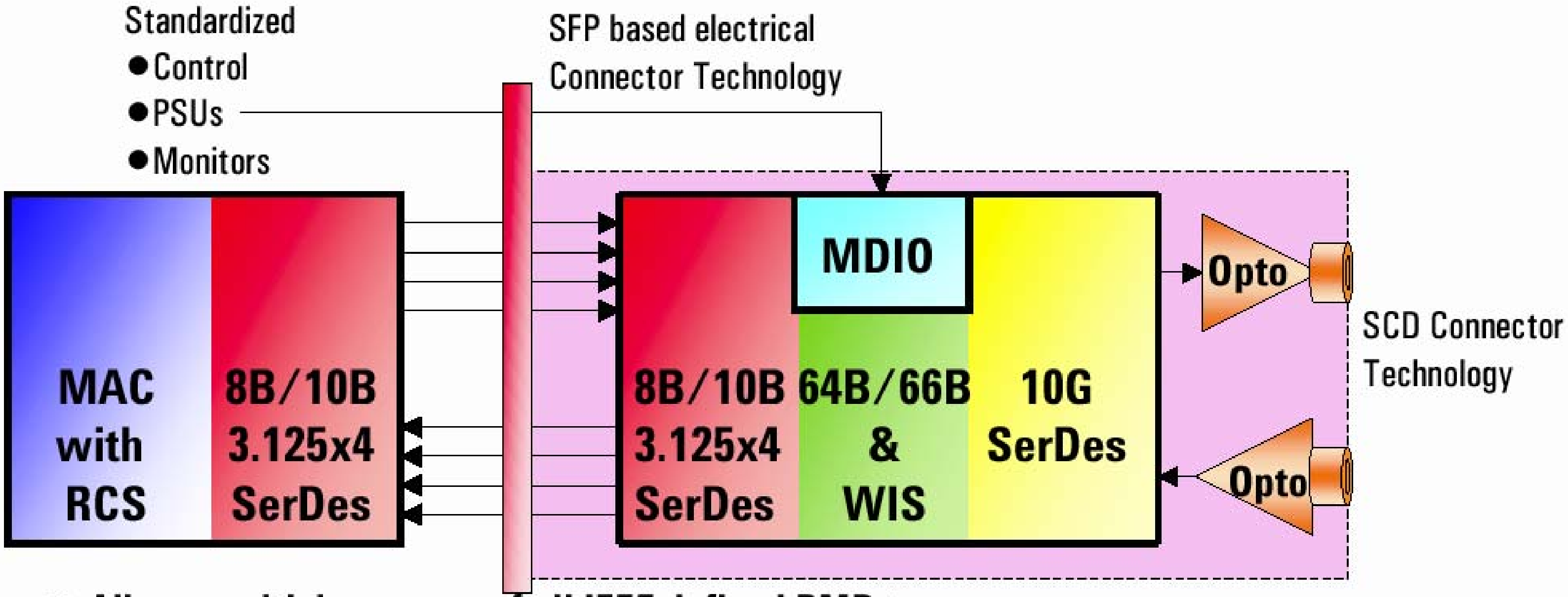


- Multiple sources of all IEEE defined PMD types
- Quick and easy field repair, Minimal MTTR
- Permits easy reconfiguration of PMDs in manufacturing and service
- Supports the "Pay as you Populate" model

XENPAK 10 Gigabit Ethernet MSA

Page 10

Benefits of Xenpak MSA

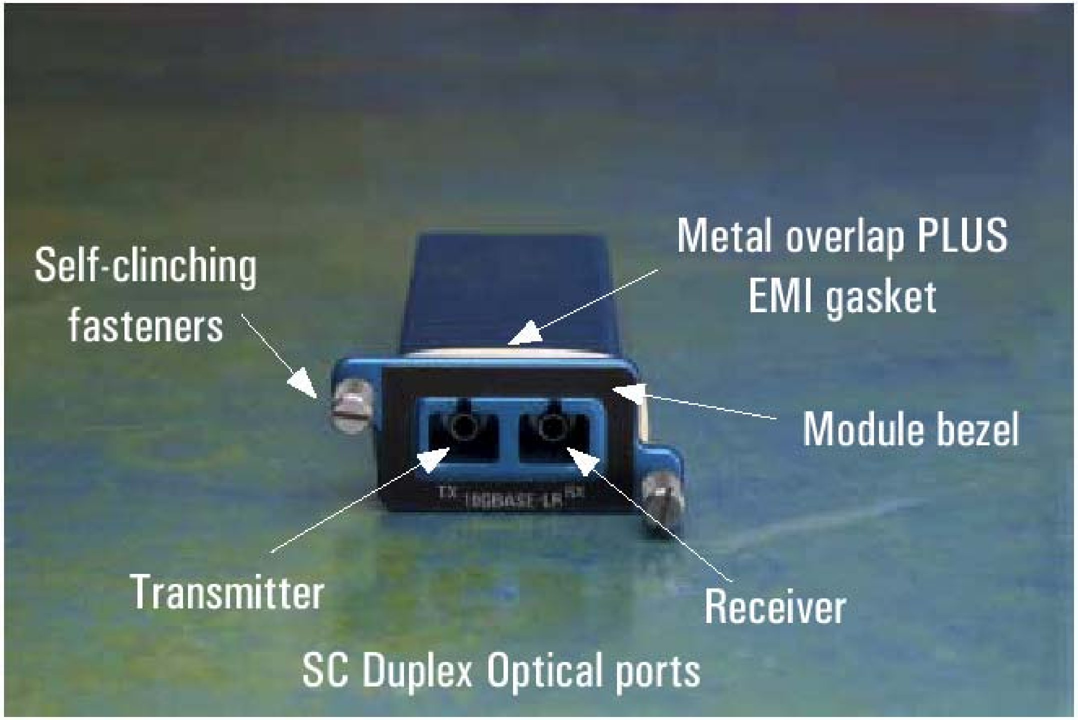


- Allows multiple sources of all IEEE defined PMD types
- All port types interchangeable via front panel pluggability
- Proven connectorized optical interface
- Proven electrical interface
- Standardized, Control, PSUs, Monitors
- Supports very high physical port densities (8 per 19inch Card)
- Extensive design focus on EMI and Thermal management

XENPAK
10Gigabit Ethernet MSA

Page 11

Specific Features of the 10 Gig Pluggable Module

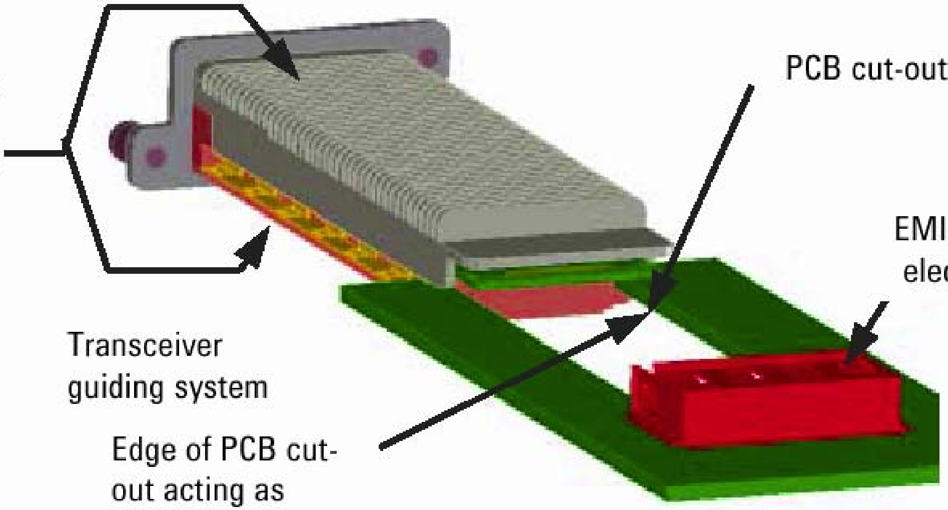


Robust Module, Straight Forward Pluggability, Proven Connectorized optics.

Excellent Thermal Management

XENPAK
10 Gigabit Ethernet MSA

Balancing Flexibility with Cost



Thermal Fins on the TOP and BOTTOM. Air flow on 2 faces!

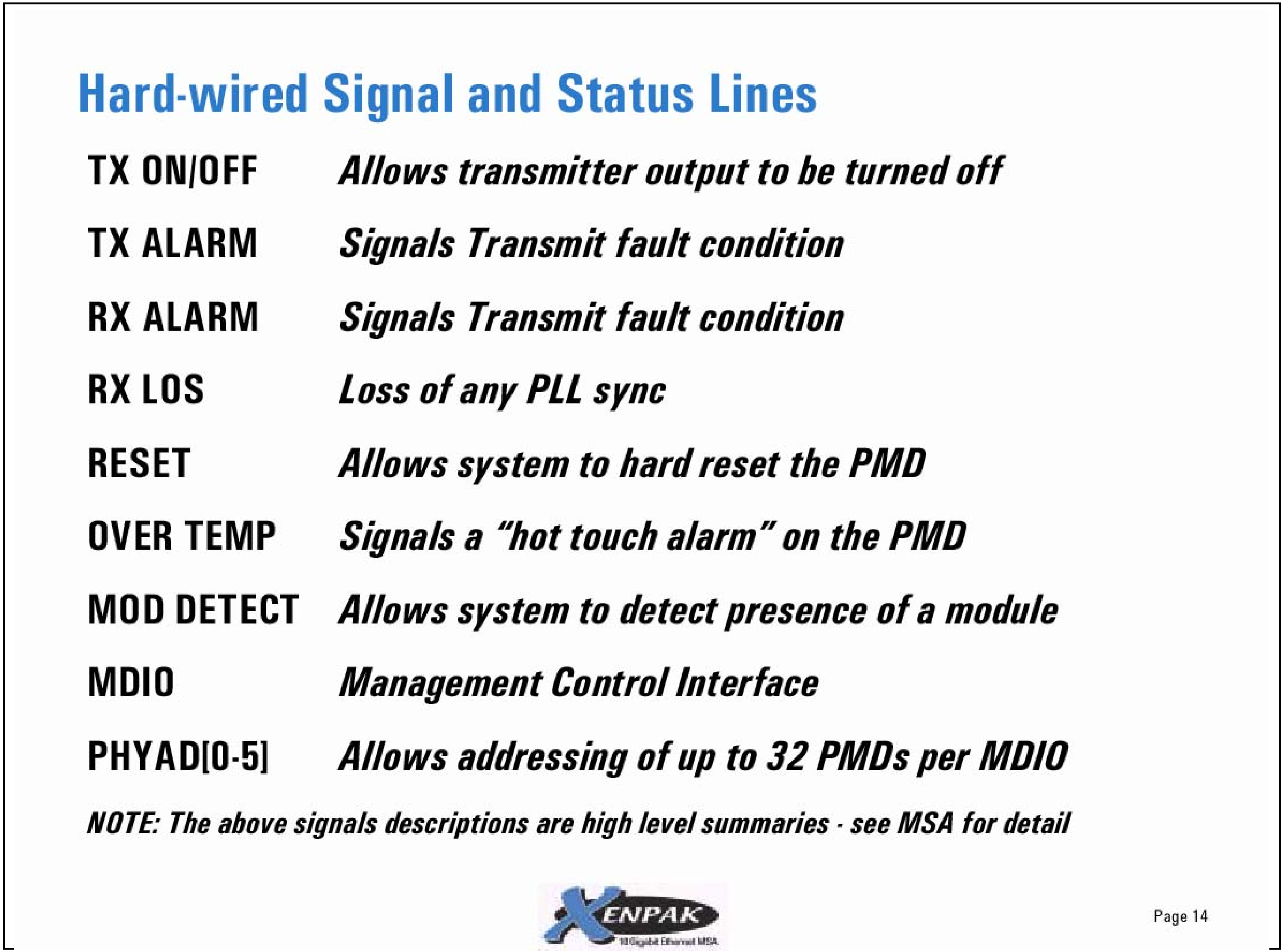
PCB cut-out

EMI shroud, covering electrical connector

Transceiver guiding system

Edge of PCB cut-out acting as guide rails

- All port types interchangeable via front panel pluggability
- Eliminates system downtime during upgrades and repairs
- Transparent to system reconfigurations
- Supports EMI and Thermal management for high port densities
- Designed to be manufactured in high volumes
- Enables "Pay-as-You-Populate" cost structure during the Installation process



Hard-wired Signal and Status Lines

TX ON/OFF	*Allows transmitter output to be turned off*
TX ALARM	*Signals Transmit fault condition*
RX ALARM	*Signals Transmit fault condition*
RX LOS	*Loss of any PLL sync*
RESET	*Allows system to hard reset the PMD*
OVER TEMP	*Signals a "hot touch alarm" on the PMD*
MOD DETECT	*Allows system to detect presence of a module*
MDIO	*Management Control Interface*
PHYAD[0-5]	*Allows addressing of up to 32 PMDs per MDIO*

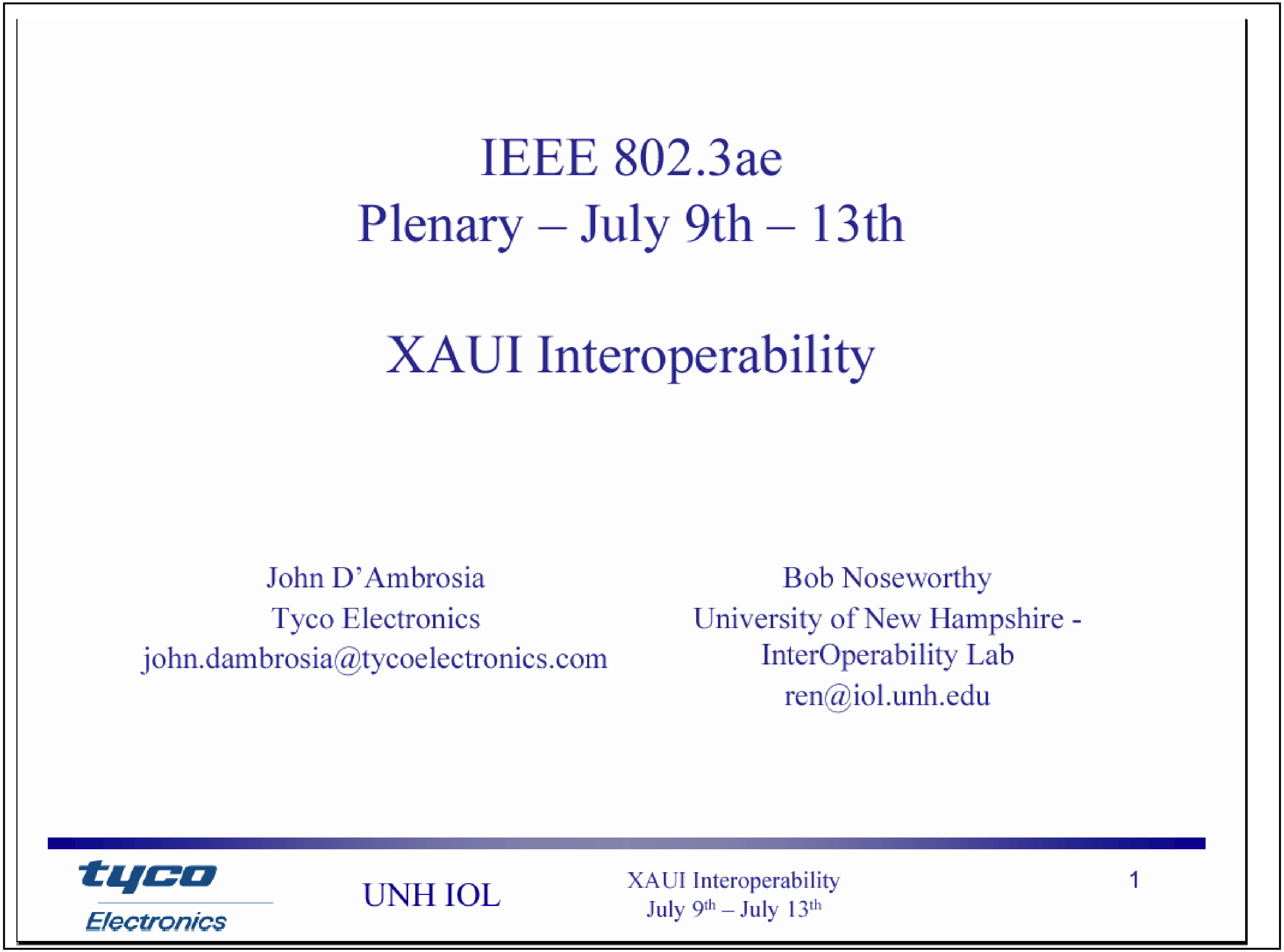
NOTE: The above signals descriptions are high level summaries - see MSA for detail

XGP

- A competing hot-plugable connector to XENPAK
- Also uses XAUI as the common communication scheme between transceiver and system
- Should be smaller, cooler, lower pin count, lighter

Ok, but does XAUI WORK!?

- Funny you would ask…

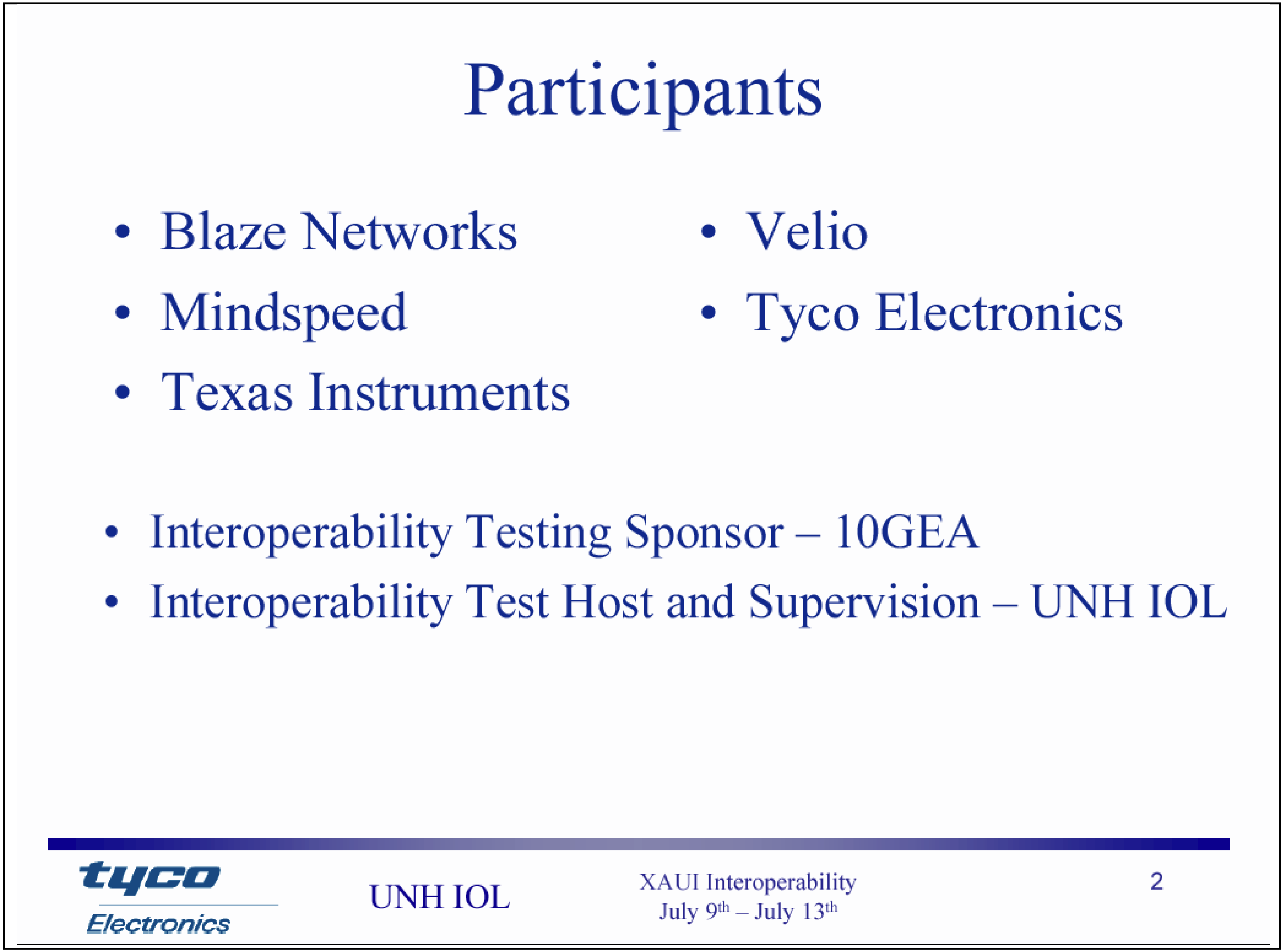


IEEE 802.3ae
Plenary – July 9th – 13th

XAUI Interoperability

John D'Ambrosia
Tyco Electronics
john.dambrosia@tycoelectronics.com

Bob Noseworthy
University of New Hampshire -
InterOperability Lab
ren@iol.unh.edu

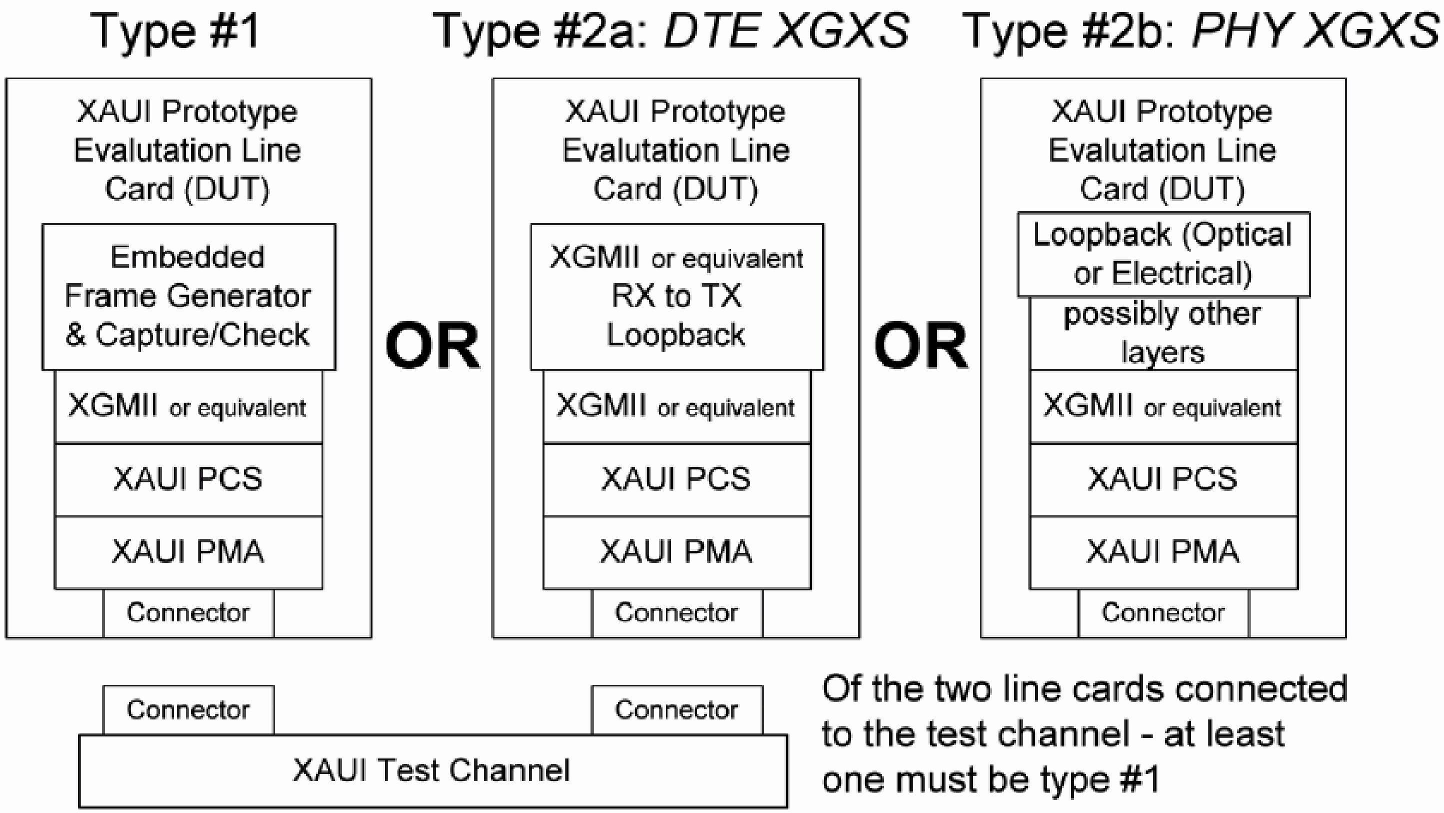


Participants

- Blaze Networks
- Mindspeed
- Texas Instruments
- Velio
- Tyco Electronics

- Interoperability Testing Sponsor – 10GEA
- Interoperability Test Host and Supervision – UNH IOL

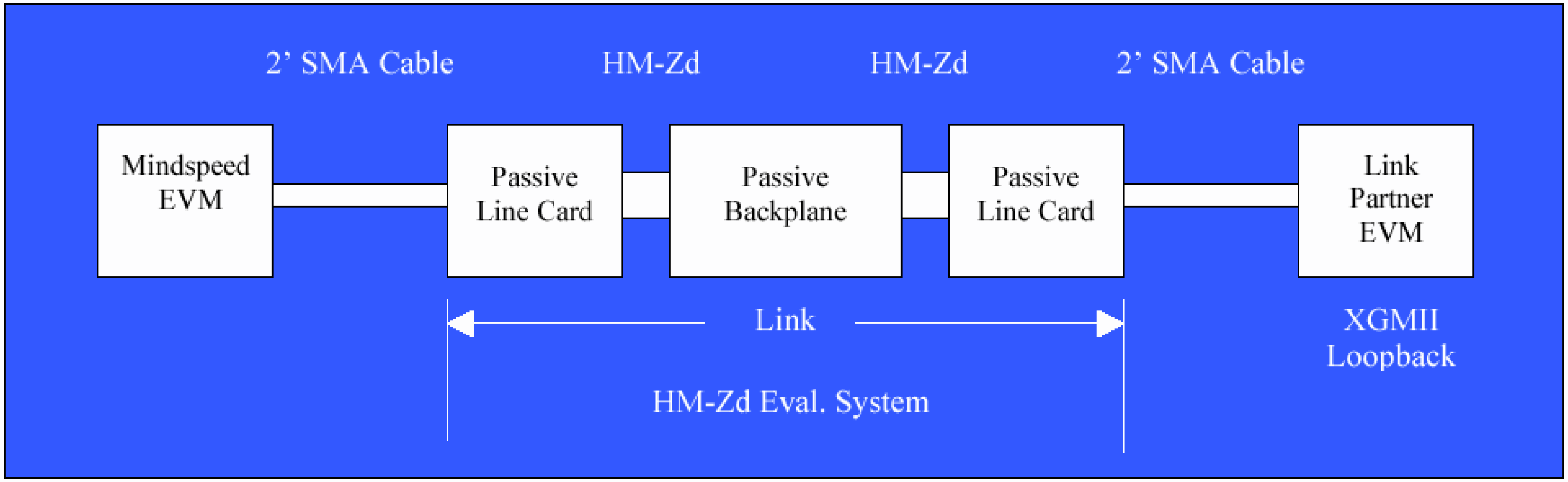
10GEA XAUI Interoperability Test Proposal



Of the two line cards connected to the test channel - at least one must be type #1

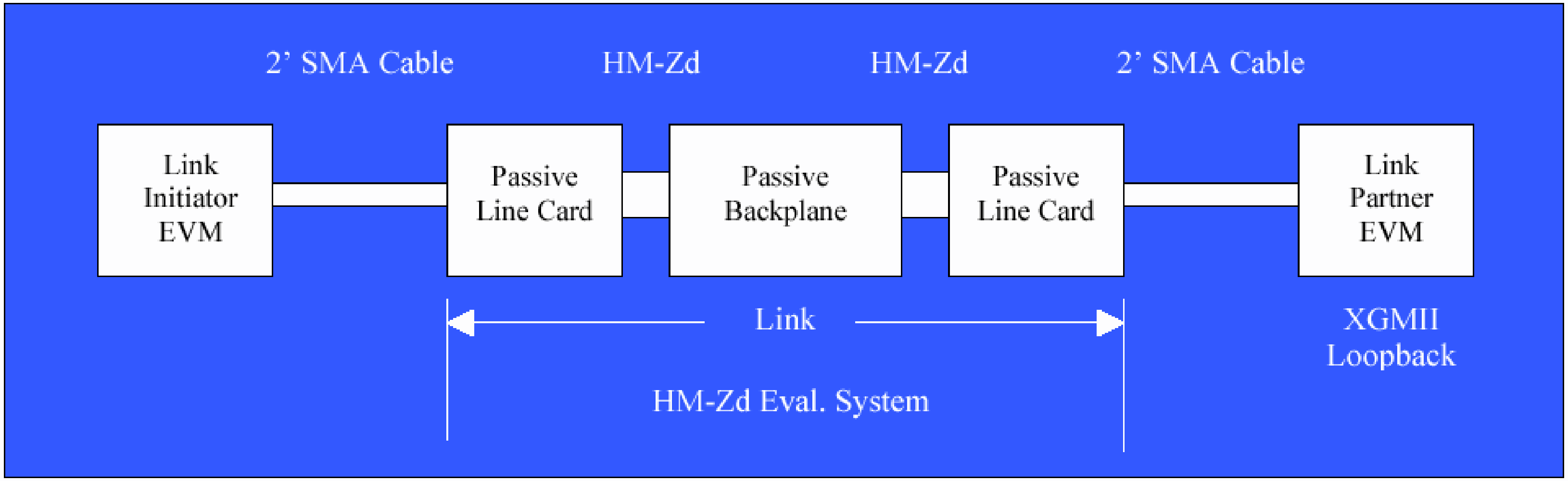
Test 1 – Mindspeed Driving 8B / 10B Data

Link Partner	EVM Length	Link Length	Line Card Length	Backplane Length	Total Trace Length	Total Cable Length	# of Errors
TI	2.5" (min)	10"	3"	4"	15"	4'	0
		22"	3"	16"	27"	4'	0
Velio	2.5" (min)	10"	3"	4"	15"	4'	0
		22"	3"	16"	27"	4'	0



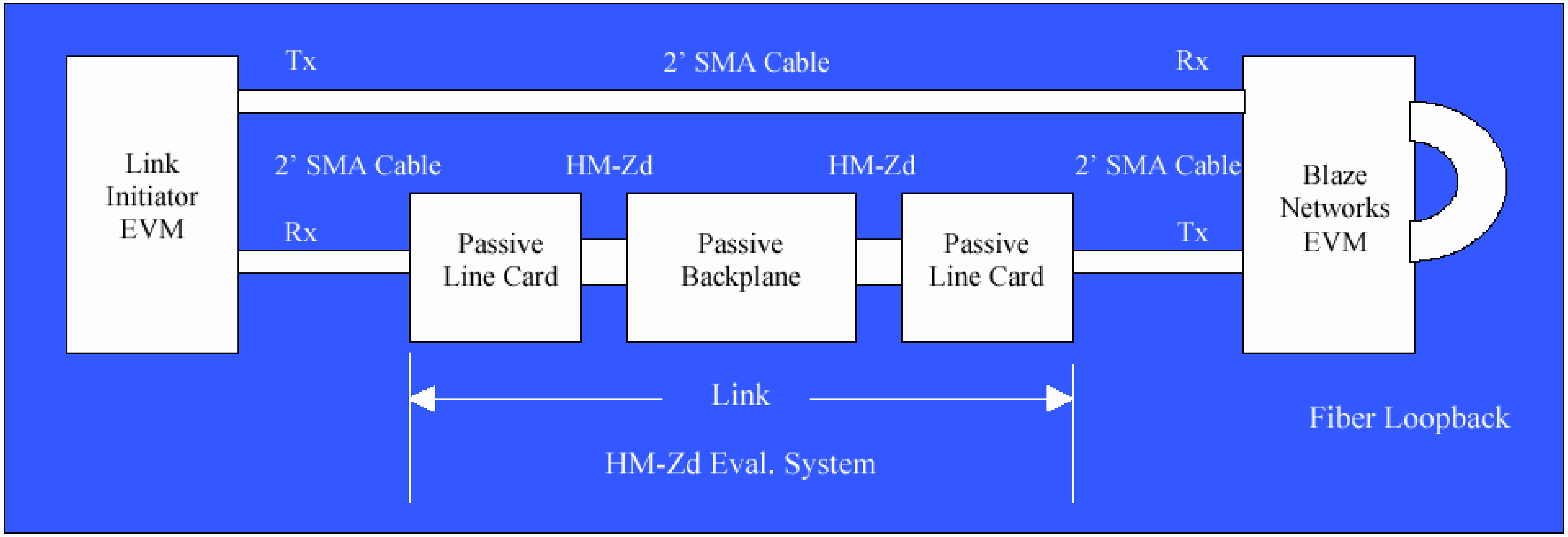
Test 2 – PRBS Data

Link Initiator	Link Partner	Data Pattern	EVM Length	Link Length	Line Card Length	Backplane Length	Total Trace Length	Total Cable Length	# of Errors
TI	Velio	2^7	2.5" (min)	10"	3"	4"	15"	4'	0
				22"	3"	16"	27"	4'	0
Velio	TI	2^10	2.5" (min)	10"	3"	4"	15"	4'	0
				22"	3"	16"	27"	4'	0



Test 3 – Blaze Networks

Link Initiator	Data Pattern	EVM Length	Link Length	Line Card Length	Backplane Length	Total Trace Length	Total Cable Length	# of Errors
TI	2^7	2.5" (min)	10"	3"	4"	20"	6'	0
Velio	2^10	2.5" (min)	10"	3"	4"	20"	6'	0
Mindspeed	8B/10B	2.5" (min)	10"	3"	4"	20"	6'	0



XAUI Conclusions

- Will form the basis for the 10GigE version of a “GBIC”
- Transceiver interface, with Hot pluggable connectors like Xenpak and XGP
- Works TODAY and components are shipping!
- Technical feasibility already accepted by IEEE 802.3ae working group

64B/66B Coding

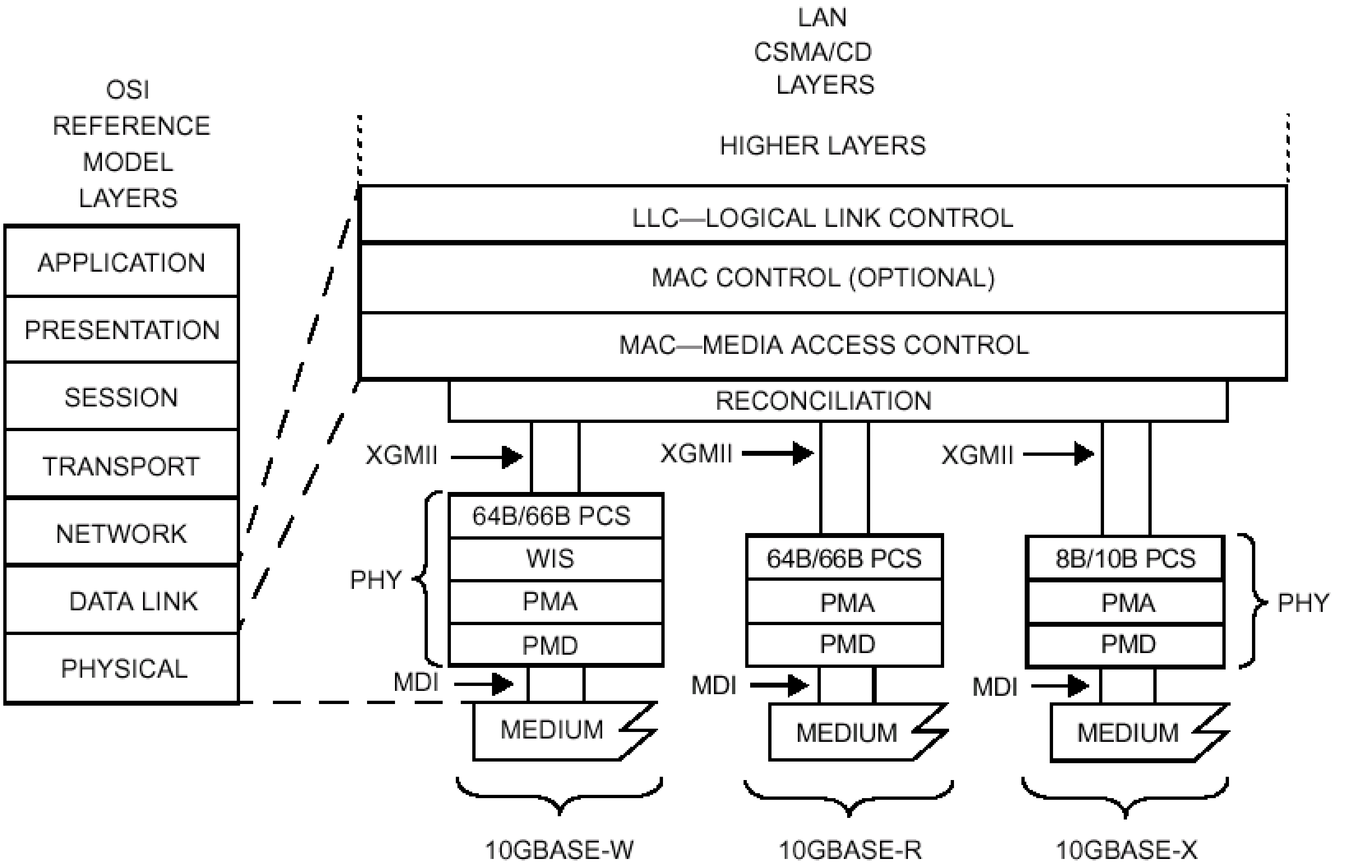
- Used in serial LAN and WAN PHY
- 8B/10B code has 25% overhead. 10Gbps data requires 12.5Gbps signaling on fiber (deemed too expensive to attempt)
- 64B/66B code has 3.125% overhead. 10Gbps data requires only 10.3125Gbps signaling on fiber.
- NEW code developed by Agilent for 10GigE

LAN PHY

- Simple Ol' Ethernet
- Transmits/Receives MAC frames at 10.000Gbps
- Allows easy/simple speed scaling/aggregating of 10 1-Gbps links
- Supports Link Aggregation
- Can drive 2m to 40km depending on PMD
- Useful for:
  - Campus backbones (connect Gig E switches together)
  - Dark Fiber runs
  - Computer Rooms
  - SANs, etc…

WAN PHY

- Transmit/Receive MAC Frames at 9.29419 Gig Why?
- SONET/SDH OC-192c Data rate compatible
- Take coded (via 64b/66b) MAC frames and place in the payload section of SONET frame and transmit onto SONET at OC-192c speeds (9.95328)
- For what purpose?
  - Make use of the existing SONET Photonic Network
  - Predominate optical infrastructure in North America, Europe, and China
  - Avoid use of costly features of SONET – Optics, Stratum Clock, and many management features
- Likely that most 10GigE WAN phys will be nearly indistinguishable from an OC-192c interface using 10GigE compatible payload encoding



OSI REFERENCE MODEL LAYERS

APPLICATION

PRESENTATION

SESSION

TRANSPORT

NETWORK

DATA LINK

PHYSICAL

LAN CSMA/CD LAYERS

HIGHER LAYERS

LLC—LOGICAL LINK CONTROL

MAC CONTROL (OPTIONAL)

MAC—MEDIA ACCESS CONTROL

RECONCILIATION

XGMII

64B/66B PCS

WIS

PMA

PMD

PHY

MDI

MEDIUM

10GBASE-W

XGMII

64B/66B PCS

PMA

PMD

MDI

MEDIUM

10GBASE-R

XGMII

8B/10B PCS

PMA

PMD

PHY

MDI

MEDIUM

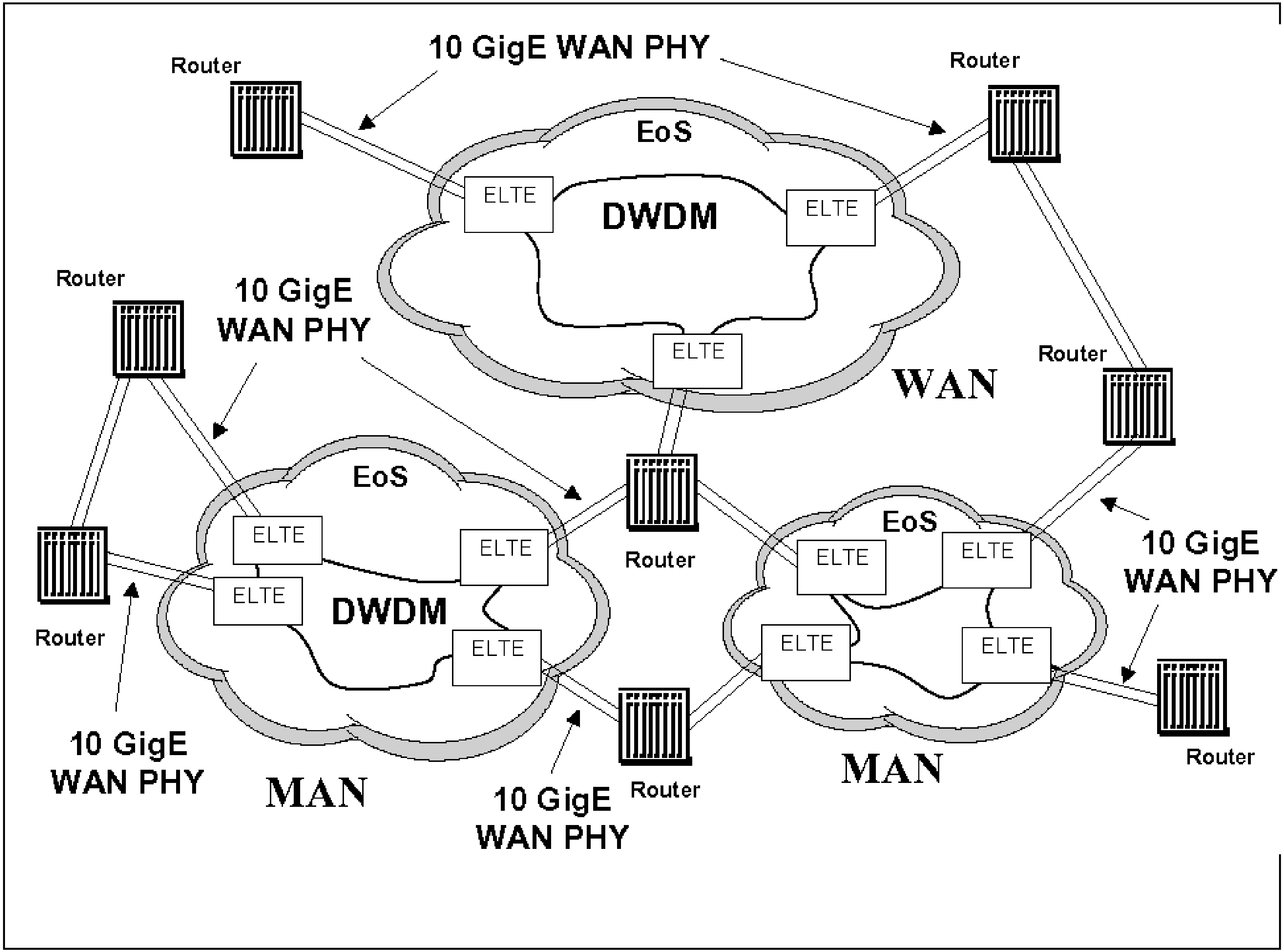
10GBASE-X

MDI = MEDIUM DEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT

PMD = PHYSICAL MEDIUM DEPENDENT
WIS = WAN INTERFACE SUBLAYER
XGMII = 10 GIGABIT MEDIA INDEPENDENT INTERFACE

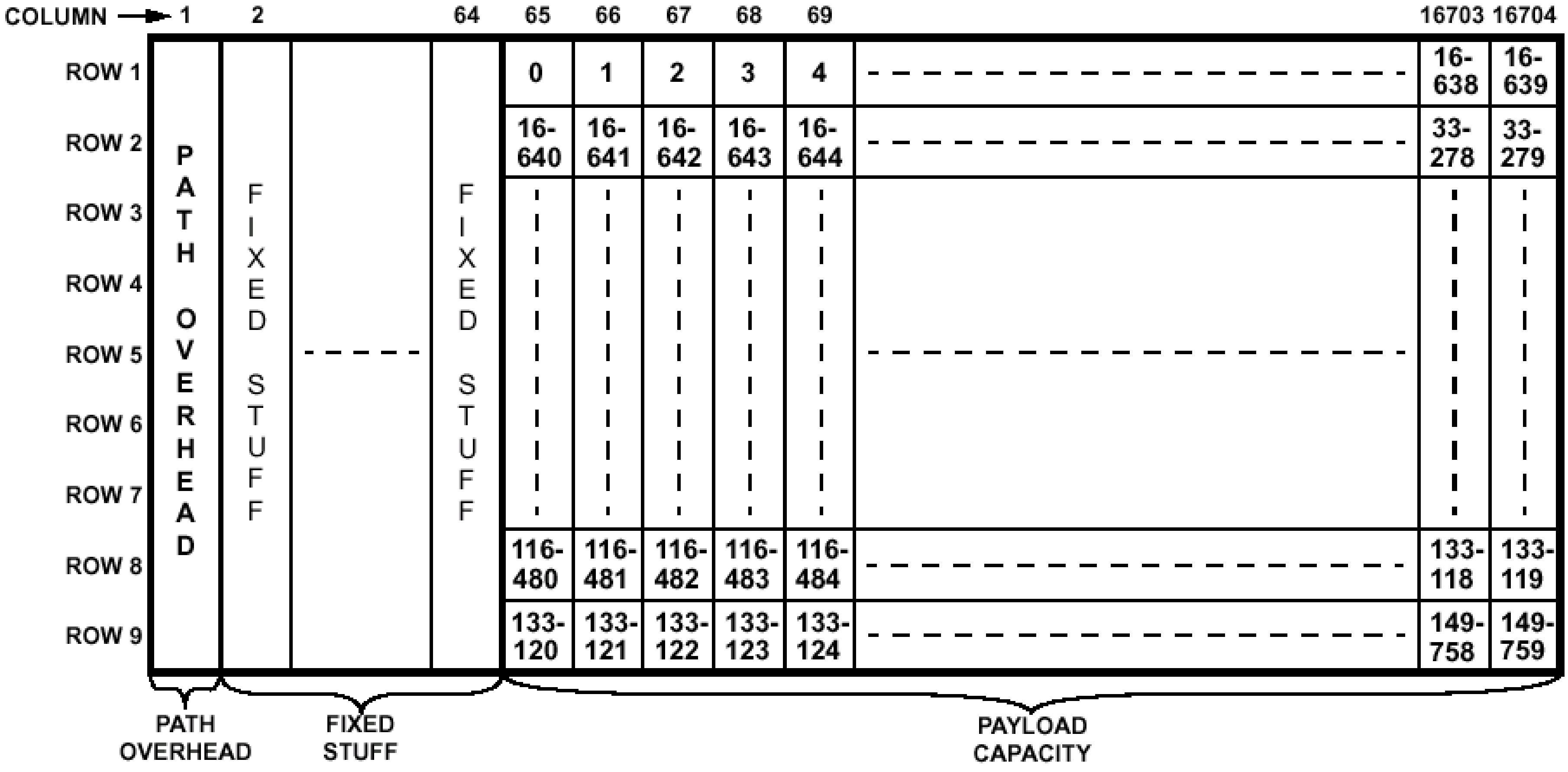
WAN Interface Sublayer (WIS)

- MAC (and higher layers) OPERATES AT 10Gbps!!!
- Takes coded (via 64b/66b) MAC frames and places in the payload section of SONET frame (and builds the Path Section and Line Overhead) and transmits onto SONET at OC-192c speeds (9.95328)
- MAC must be configured to WAN mode, which thus increases the inter-frame gap (using “ifsStretchRatio”) to slow the frame rate to 9.29419 BUT the MAC (XGMII/XAUI/ etc) signaling rate is still 10Gigabit
- WIS must delete IDLES (on the transmit path) and insert IDLES (on the receive path) to rate match between 10Gig MAC and 9.29419 Data rate
- By being able to “Turn on/off” the WIS, a PHY could be a “UNIPHY” (both WAN AND LAN!!!) in one ‘box’


10 GigE WAN PHY
Router
Router
EoS
ELTE
DWDM
ELTE
Router
10 GigE WAN PHY
ELTE
Router
WAN
EoS
ELTE
ELTE
Router
EoS
ELTE
ELTE
10 GigE WAN PHY
ELTE
DWDM
ELTE
ELTE
ELTE
Router
Router
10 GigE WAN PHY
MAN
Router
MAN
Router
10 GigE WAN PHY

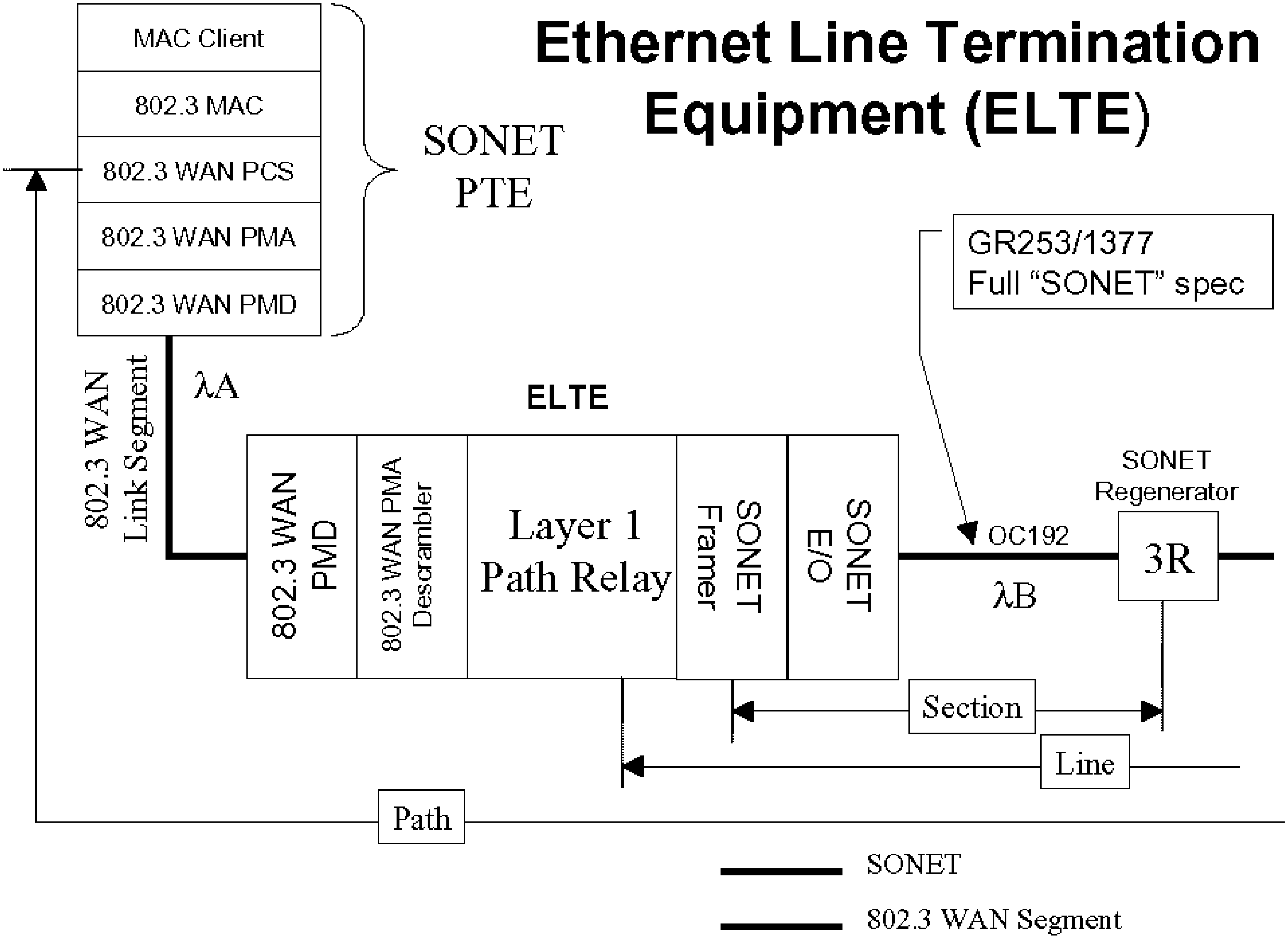
WAN PHY

- Does use/fill-in some of the Path, Section, and Line overhead – but need not use all of it



COLUMN →	1	2		64	65	66	67	68	69		16703	16704
ROW 1	PATH OVERHEAD	FIXED STUFF		FIXED STUFF	0	1	2	3	4	- -	16-638	16-639
ROW 2					16-640	16-641	16-642	16-643	16-644	- -	33-278	33-279
ROW 3												
ROW 4												
ROW 5			- - - - - -							- -		
ROW 6												
ROW 7												
ROW 8					116-480	116-481	116-482	116-483	116-484	- -	133-118	133-119
ROW 9					133-120	133-121	133-122	133-123	133-124	- -	149-758	149-759

Ethernet Line Termination Equipment (ELTE)

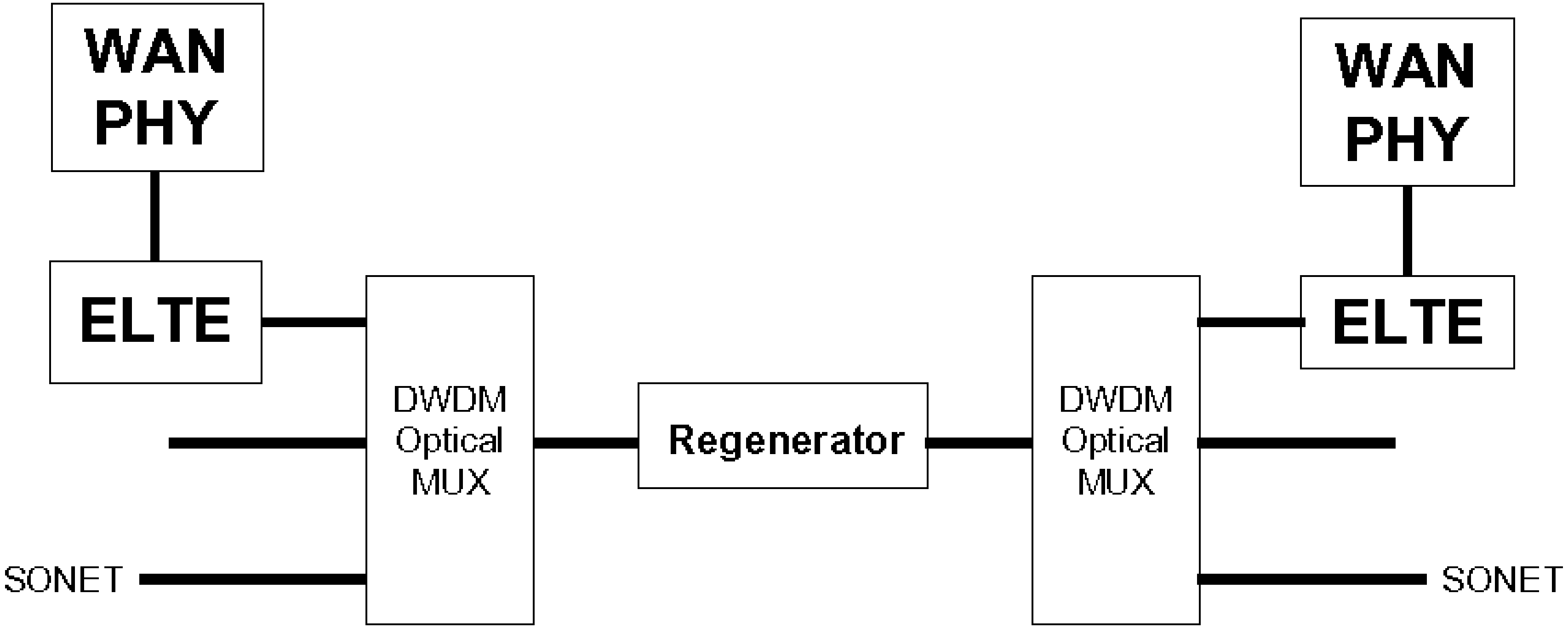


A 10GigE Phy Type Joke

- LAN PHYs - LOCAL Area Network Phys will be able to reach 40km!!!

- WAN PHYs – WIDE Area Network Phys, while ABLE to reach 40km, are likely to only be used for short connections between 10GigE LAN (or other) equipment and SONET LTEs - OR – they the WAN PHYs _will_ be SONET OC-192c PHYs (performing the WIS payload encoding).

Use in today’s DWDM



Stay Tuned…

- 10 Gigabit Ethernet promises 10 times your current maximum Ethernet speed at only 3 times the cost?
- Will they succeed?
- Will you see shipping systems soon?
- Will Scooby Doo solve the mystery in time?

This page left intentionally blank.

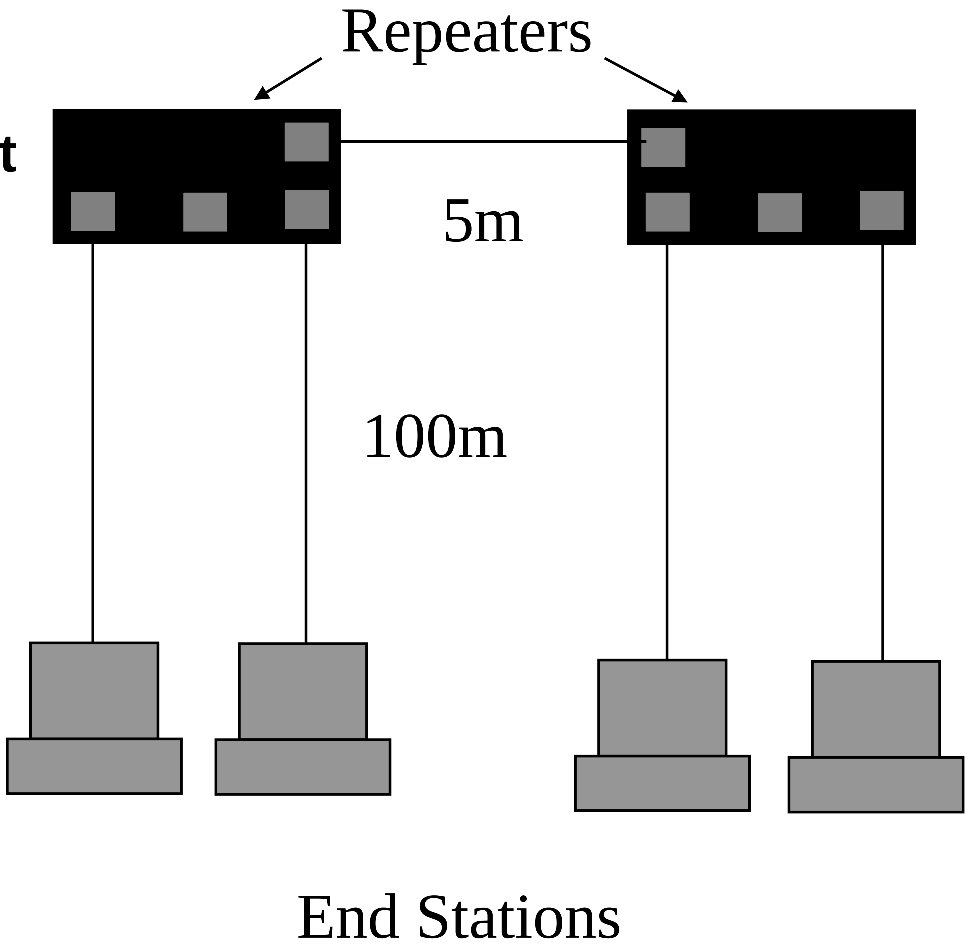
Switched Networks

Topics

- Quick Background
- Spanning Tree
- VLANs
- 802.1p/QoS
- L3 Switching
- Link Aggregation
- Multiple Spanning Trees
- Rapid Reconfiguration

Shared Medium (Repeated Network)

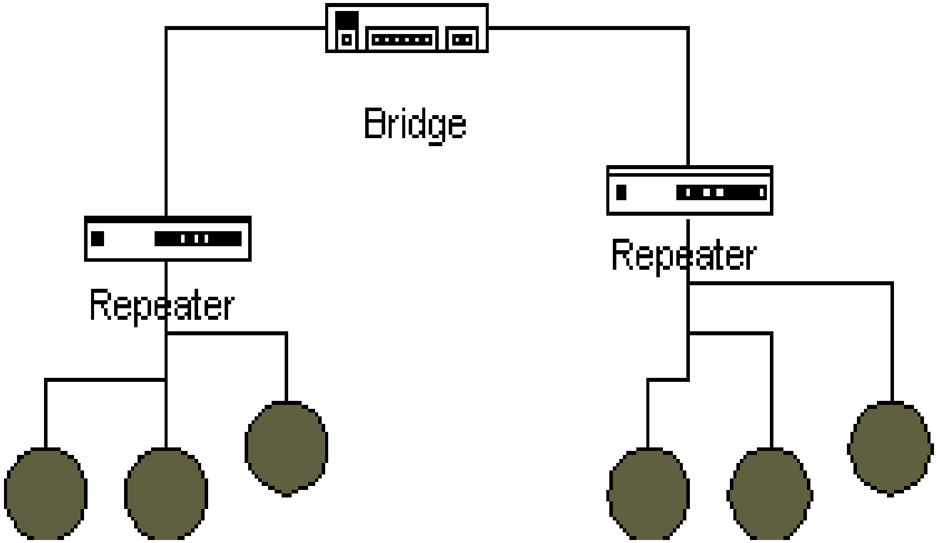
- **All machines “share” the network**
- **Only one machine can talk at any one time**
- **Distance limitations**
  - **At most 205m for Fast Ethernet**
- **Total throughput limited**
- **Single collision domain**



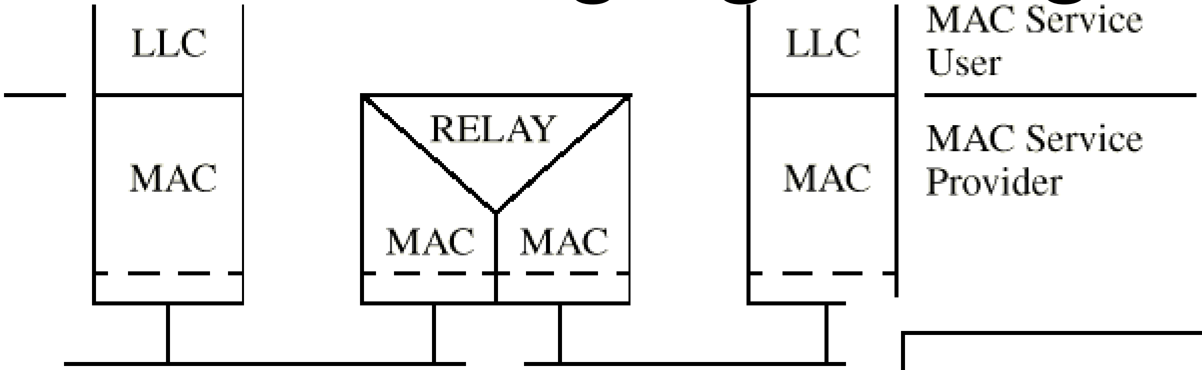
Bridging Review

- Connects Separate shared Networks
- Frame Translation/ Encapsulation (Token Ring to Ethernet)
- Reduces Unicast Traffic
- Switches: Allow for multiple conversations

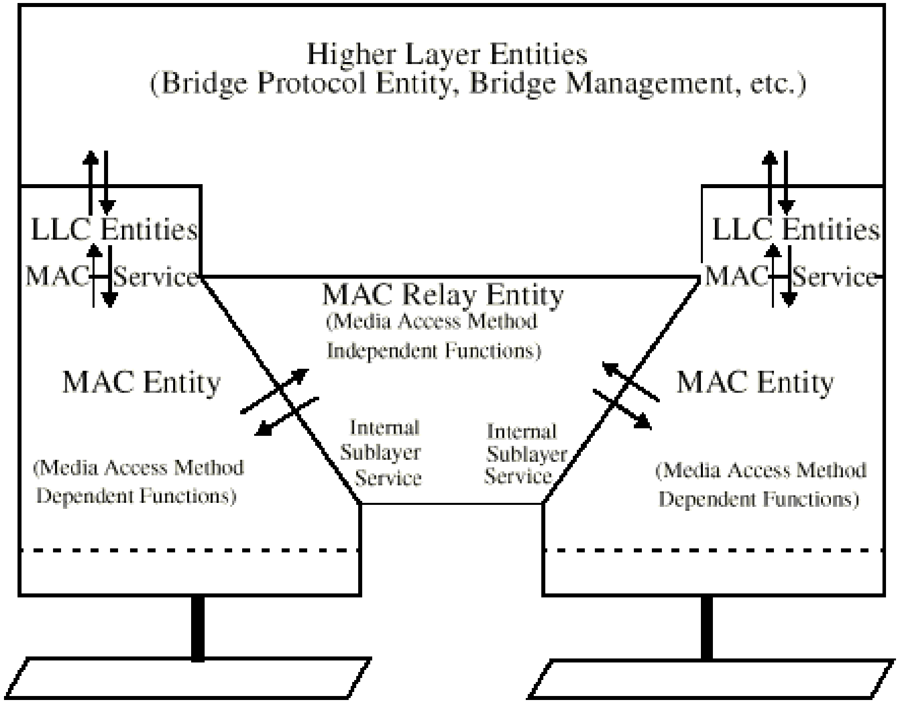
One Broadcast Domain
Two Shared Mediums



Bridging Background



- **Bridges work at layer 2 of the OSI Model**
- **Their primary function is to relay frames**


Higher Layer Entities
(Bridge Protocol Entity, Bridge Management, etc.)
LLC Entities
MAC Service
MAC Relay Entity
(Media Access Method Independent Functions)
LLC Entities
MAC Service
MAC Entity
Internal Sublayer Service
Internal Sublayer Service
MAC Entity
(Media Access Method Dependent Functions)
(Media Access Method Dependent Functions)

Bridge Tables

- **One table lists MAC addresses, which port they’re on, and if they’re active or disabled**

Entry	MAC Addr	Port	active
1	0800900A2580	1	yes
2	002034987AB1	1	yes
3	0500A1987C00	2	yes
4	00503222A001	2	yes
5			
6			
7			
8			
9			
10			
11			
12			

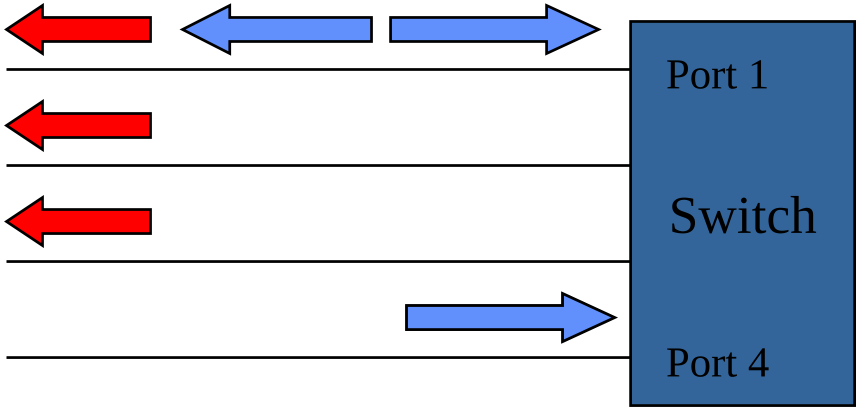
Learning of addresses

The Filtering Database learns a station’s location from the source address on an incoming frame.

This source address is “learned” by the filtering database. All future frames destined for this MAC address will be forwarded ONLY out of this Port.

Frame with source address 002222333344 is received on Port 1.

Frames with the destination address 002222333344 are only forwarded on port 1



Frame with destination address 002222333344 is received on Port 4.

Since this is not learned, it is FLOODED out all of the other ports.

The Learning Bridge

That was a bit fast and complex. Let’s review.

Every bridge has a table called a Filtering Database.
Entries in this table are updated upon receipt of frames,
the source addresses and the ports they arrive on are learned.

Once a MAC address is associated with a port, frames
containing that destination address are only forwarded
out of that port.

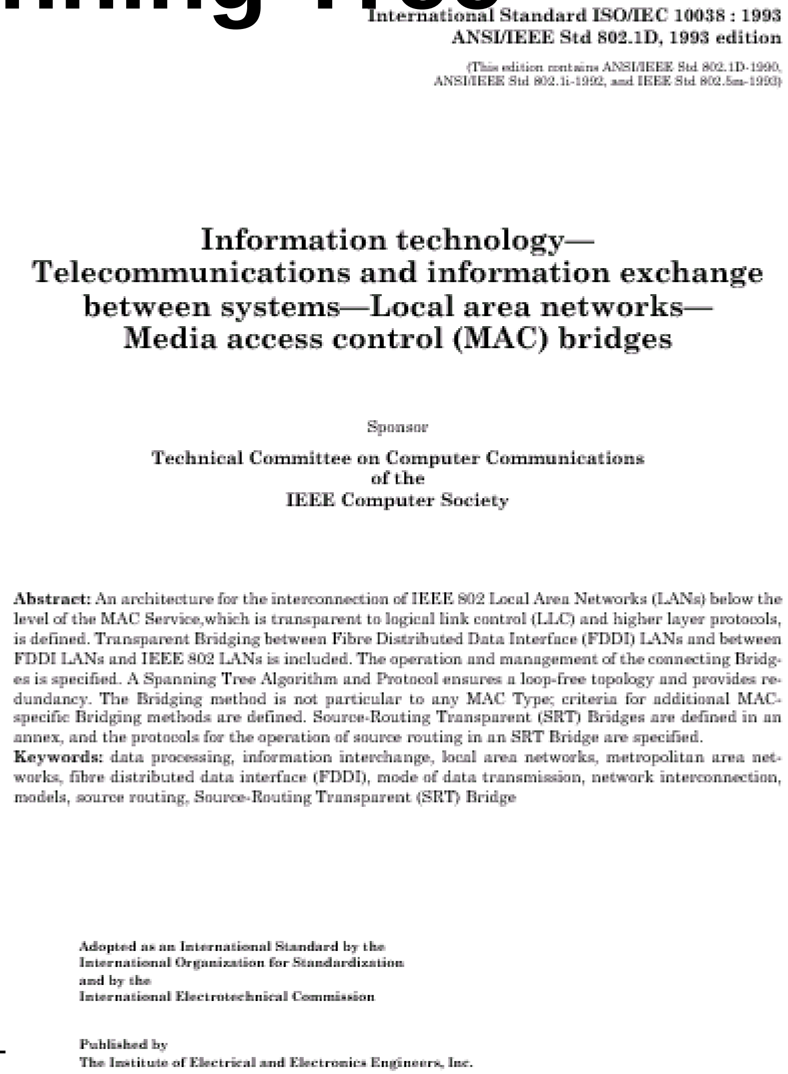
In the real switches these tables vary in size, most have the
capability of holding several thousand MAC addresses.
I’ve seen one that has the capacity for more than 150,000
addresses.

Spanning Tree

Part of 802.1D

802.1D - Spanning Tree

- Configures arbitrary physical topology into one loop-free spanning tree
- provides fault-tolerance by using redundant links as backups
- configures deterministically/ reproducibly
- low overhead/bandwidth
- auto-configures



International Standard ISO/IEC 10038 : 1993
ANSI/IEEE Std 802.1D, 1993 edition

(This edition contains ANSI/IEEE Std 802.1D-1990,
ANSI/IEEE Std 802.1i-1992, and IEEE Std 802.5m-1993)

**Information technology—
Telecommunications and information exchange
between systems—Local area networks—
Media access control (MAC) bridges**

Sponsor

**Technical Committee on Computer Communications
of the
IEEE Computer Society**

Abstract: An architecture for the interconnection of IEEE 802 Local Area Networks (LANs) below the level of the MAC Service,which is transparent to logical link control (LLC) and higher layer protocols, is defined. Transparent Bridging between Fibre Distributed Data Interface (FDDI) LANs and between FDDI LANs and IEEE 802 LANs is included. The operation and management of the connecting Bridges is specified. A Spanning Tree Algorithm and Protocol ensures a loop-free topology and provides redundancy. The Bridging method is not particular to any MAC Type; criteria for additional MAC-specific Bridging methods are defined. Source-Routing Transparent (SRT) Bridges are defined in an annex, and the protocols for the operation of source routing in an SRT Bridge are specified.

Keywords: data processing, information interchange, local area networks, metropolitan area networks, fibre distributed data interface (FDDI), mode of data transmission, network interconnection, models, source routing, Source-Routing Transparent (SRT) Bridge

**Adopted as an International Standard by the
International Organization for Standardization
and by the
International Electrotechnical Commission**

**Published by
The Institute of Electrical and Electronics Engineers, Inc.**

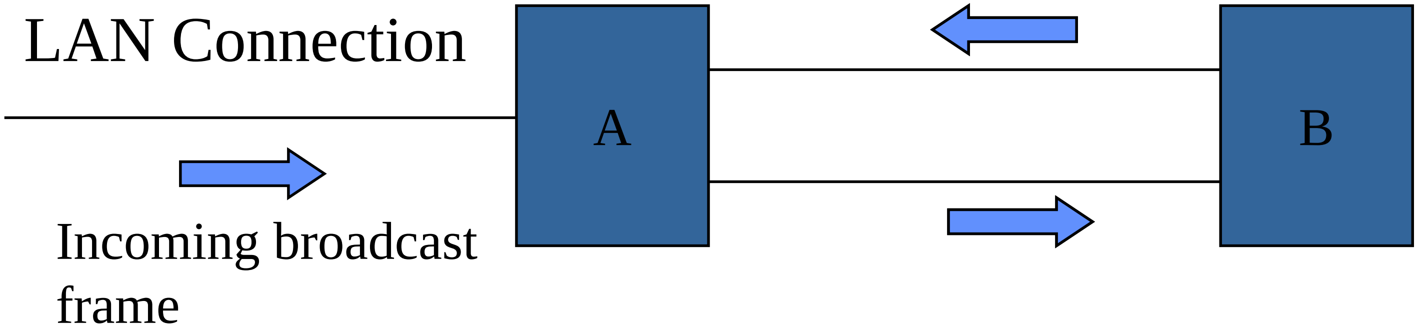
Auto-Configuration

- Default values allow out-of-box configuration without user interaction
- If the user wants, though, they can control the relative priority of bridges and ports to be used
- The user can also control the “path cost” of each port, so a least-cost tree can be built according to the user’s specifications

Spanning Tree

Why a tree?

If you have 2 switches that are connected in parallel, it could create a loop.



More Reasons

Spanning Tree Disables one of these connections.

It also keeps track of each of these connections. If the active connection becomes disconnected, it will activate a disabled one to take over and make a new tree.

How does it do this?

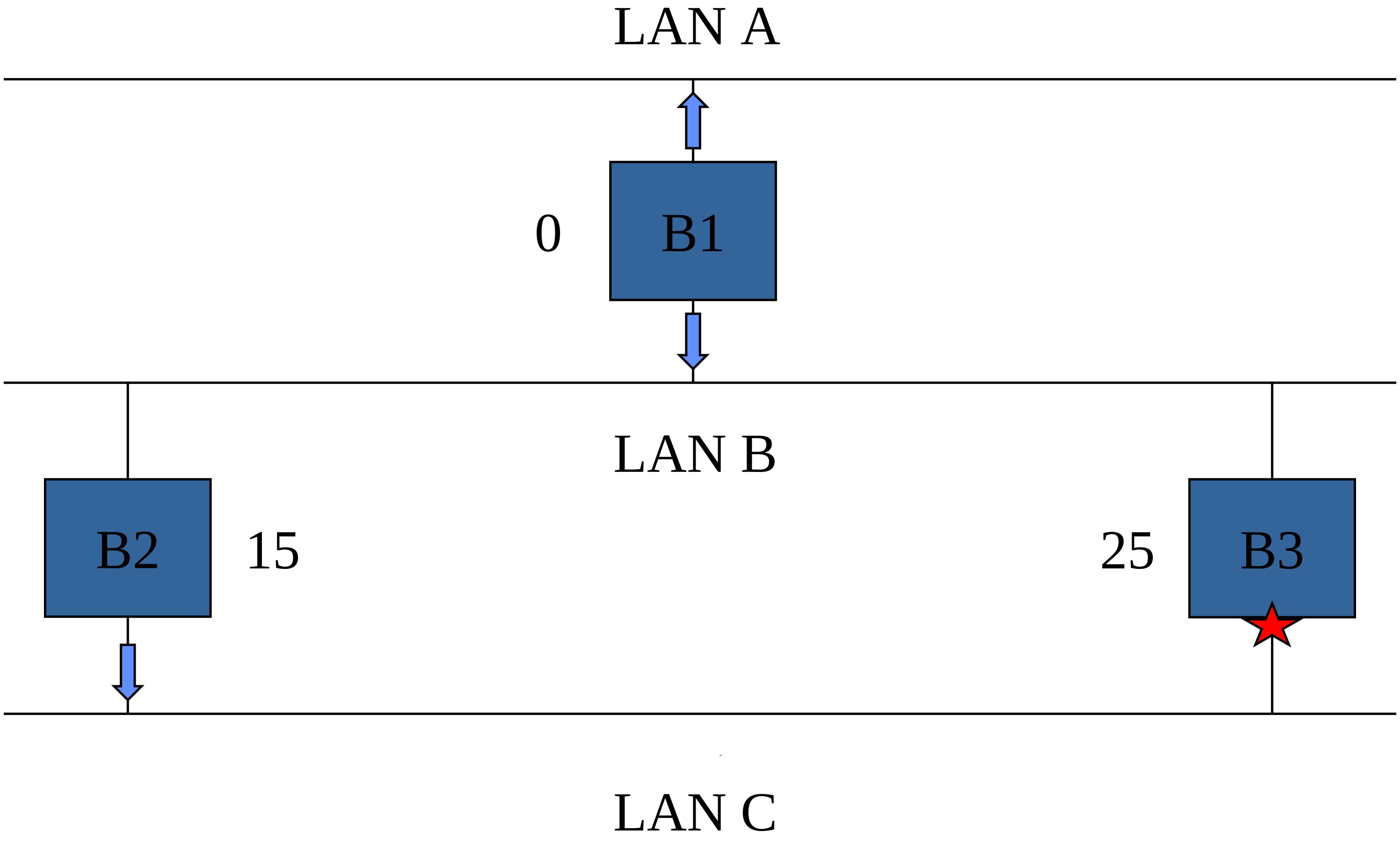
Initial Bridge Parameters:

Bridge	Priority	Path Cost
B1	1	20
B2	2	15
B3	2	25

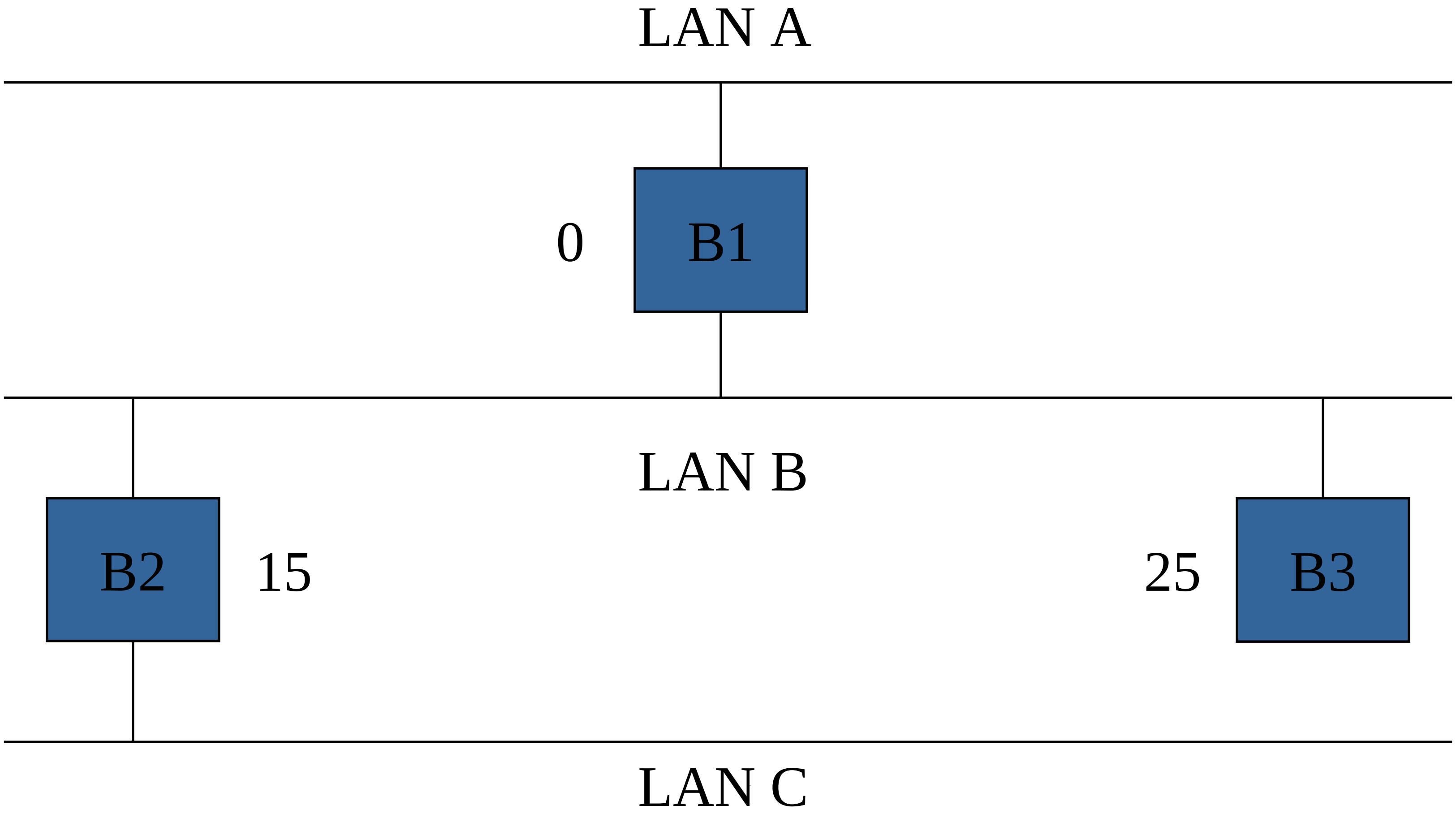
- All Ports on each bridge have the same Path Cost in this example.

- The Max Age, Hello Time, and Forward Delay parameters are left at their default values of 20.0, 2.0, and 15.0 respectively.

Initial Bridged LAN Topology



Active Bridged LAN Topology after Bootup

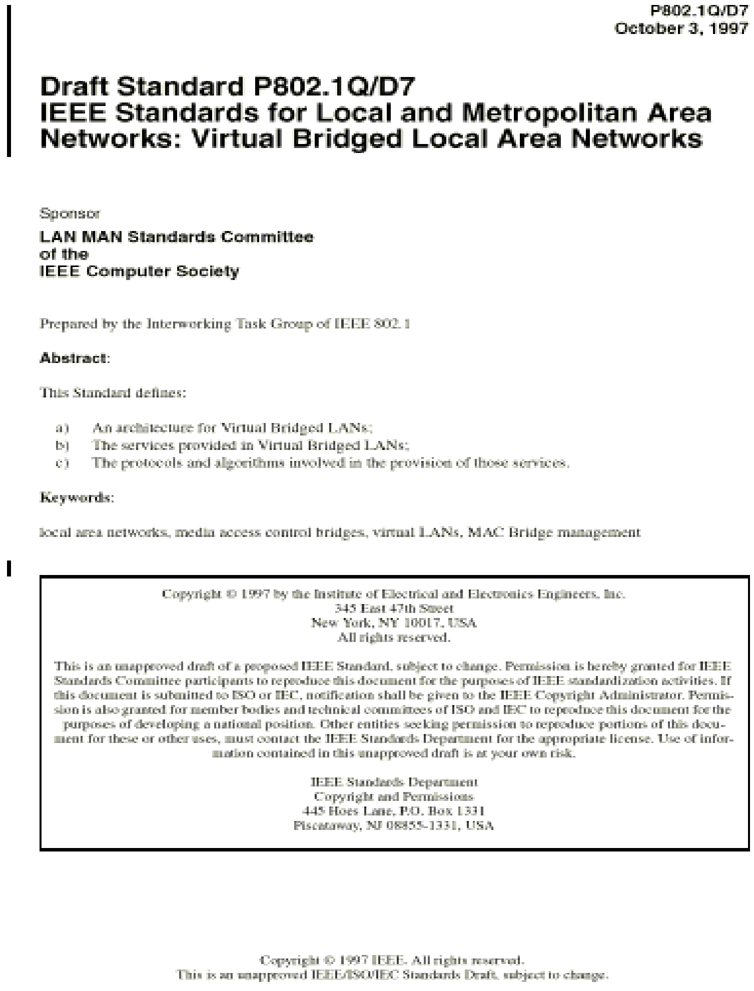


VLANs

802.1Q

802.1Q - Standard for VLANs

- Defines a method of establishing VLANs
- Establishes the Tagged Frame
- Provides a way to maintain priority information across LANs



P802.1Q/D7
October 3, 1997

Draft Standard P802.1Q/D7
IEEE Standards for Local and Metropolitan Area Networks: Virtual Bridged Local Area Networks

Sponsor

LAN MAN Standards Committee
of the
IEEE Computer Society

Prepared by the Interworking Task Group of IEEE 802.1

Abstract:

This Standard defines:

a) An architecture for Virtual Bridged LANs;
b) The services provided in Virtual Bridged LANs;
c) The protocols and algorithms involved in the provision of those services.

Keywords:

local area networks, media access control bridges, virtual LANs, MAC Bridge management

Copyright © 1997 by the Institute of Electrical and Electronics Engineers, Inc.
345 East 47th Street
New York, NY 10017, USA
All rights reserved.

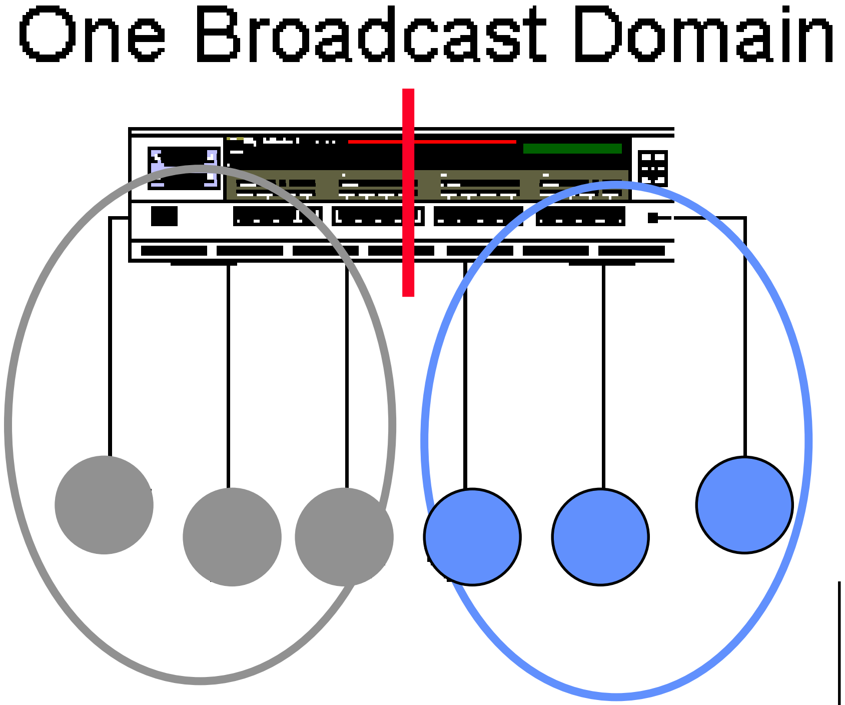
This is an unapproved draft of a proposed IEEE Standard, subject to change. Permission is hereby granted for IEEE Standards Committee participants to reproduce this document for the purposes of IEEE standardization activities. If this document is submitted to ISO or IEC, notification shall be given to the IEEE Copyright Administrator. Permission is also granted for member bodies and technical committees of ISO and IEC to reproduce this document for the purposes of developing a national position. Other entities seeking permission to reproduce portions of this document for these or other uses, must contact the IEEE Standards Department for the appropriate license. Use of information contained in this unapproved draft is at your own risk.

IEEE Standards Department
Copyright and Permissions
445 Hoes Lane, P.O. Box 1331
Piscataway, NJ 08855-1331, USA

Copyright © 1997 IEEE. All rights reserved.
This is an unapproved IEEE/ISO/IEC Standards Draft, subject to change.

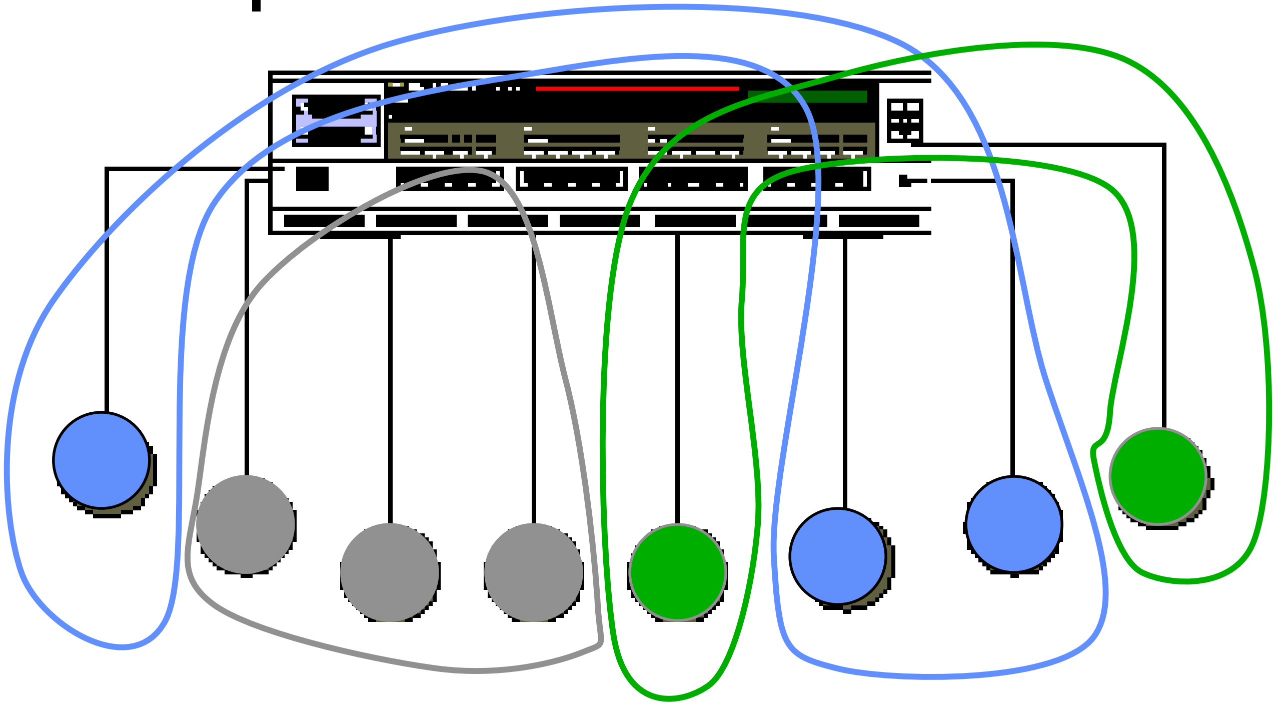
What are VLANs - Virtual Local Area Networks?

- **Divides switch into two or more "virtual" switches with separate broadcast domains**
- **Achieved by manual configuration through the switches' management interface**
- **Only that switch will be segmented**



Multiple VLANs in One Switch

Multiple Broadcast Domains

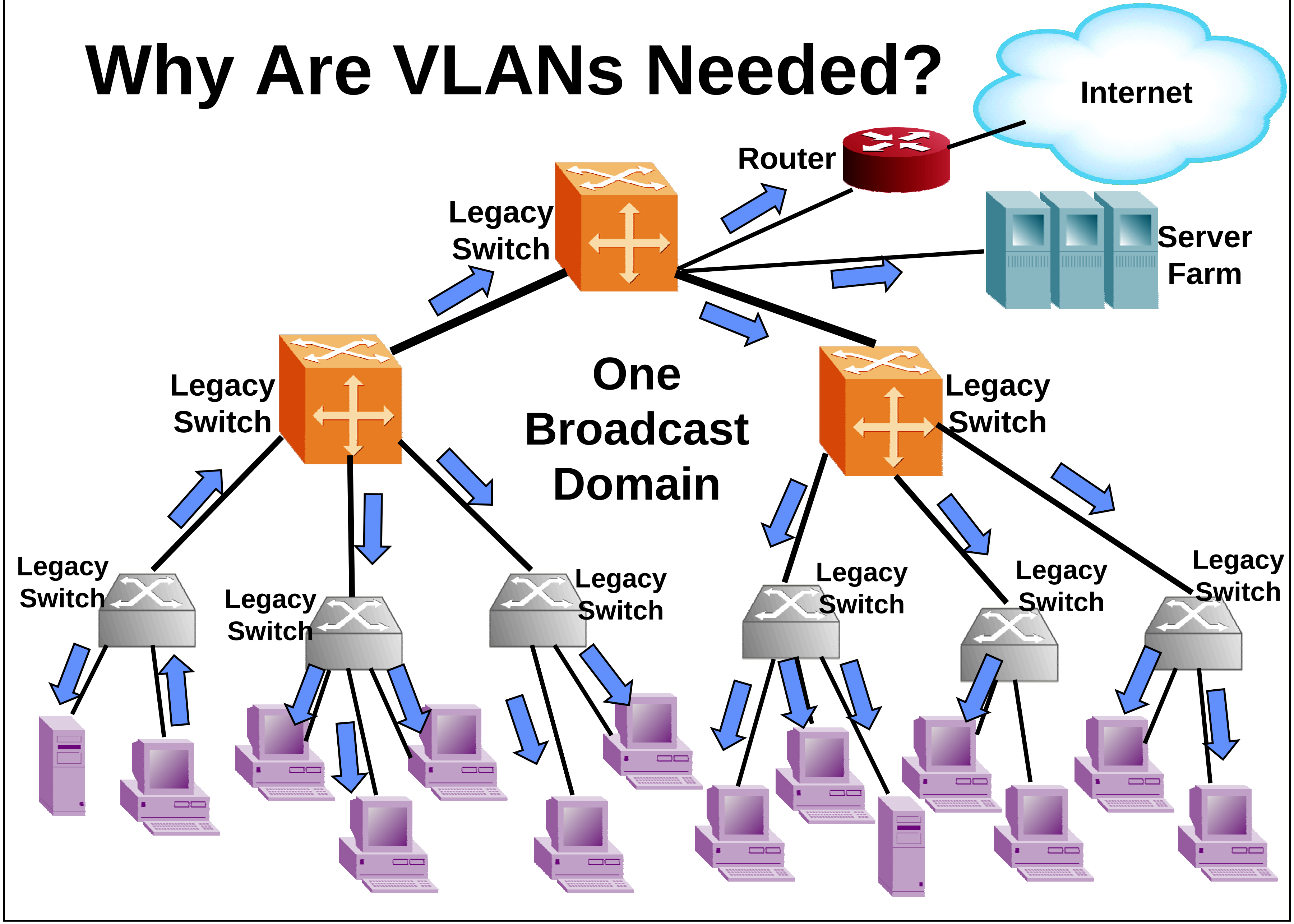


- **Multiple VLANs can be defined on the same switch**

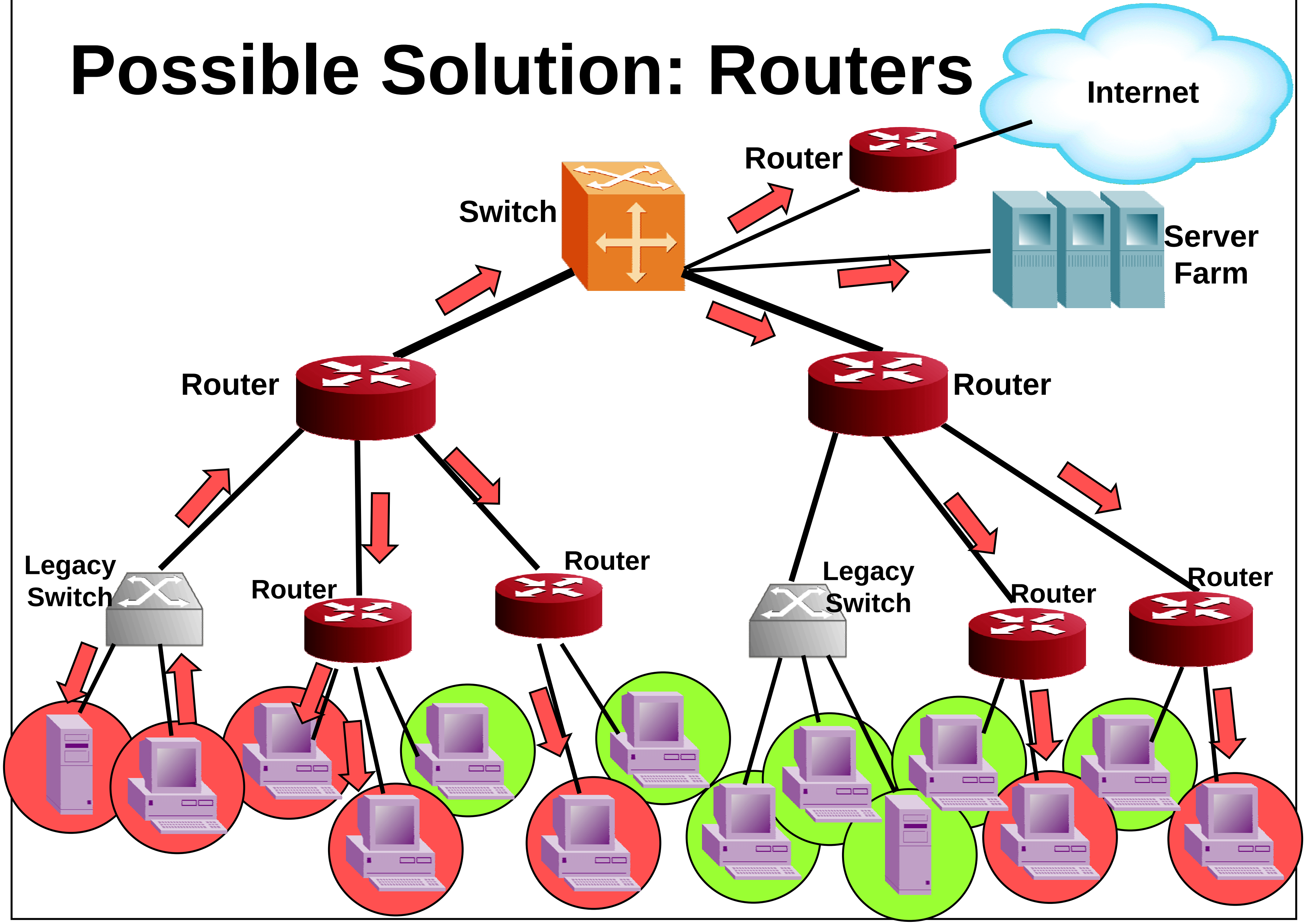
Why VLANs?

- Lots of broadcast traffic wastes bandwidth
  - VLANs create separate broadcast domains
    - Microsoft Networking
    - Novell Networking
    - NetBEUI
    - IP RIP
    - Multicast (sometimes acts like broadcast)
- VLANs can span multiple switches and therefore create separate broadcast domains that span multiple switches

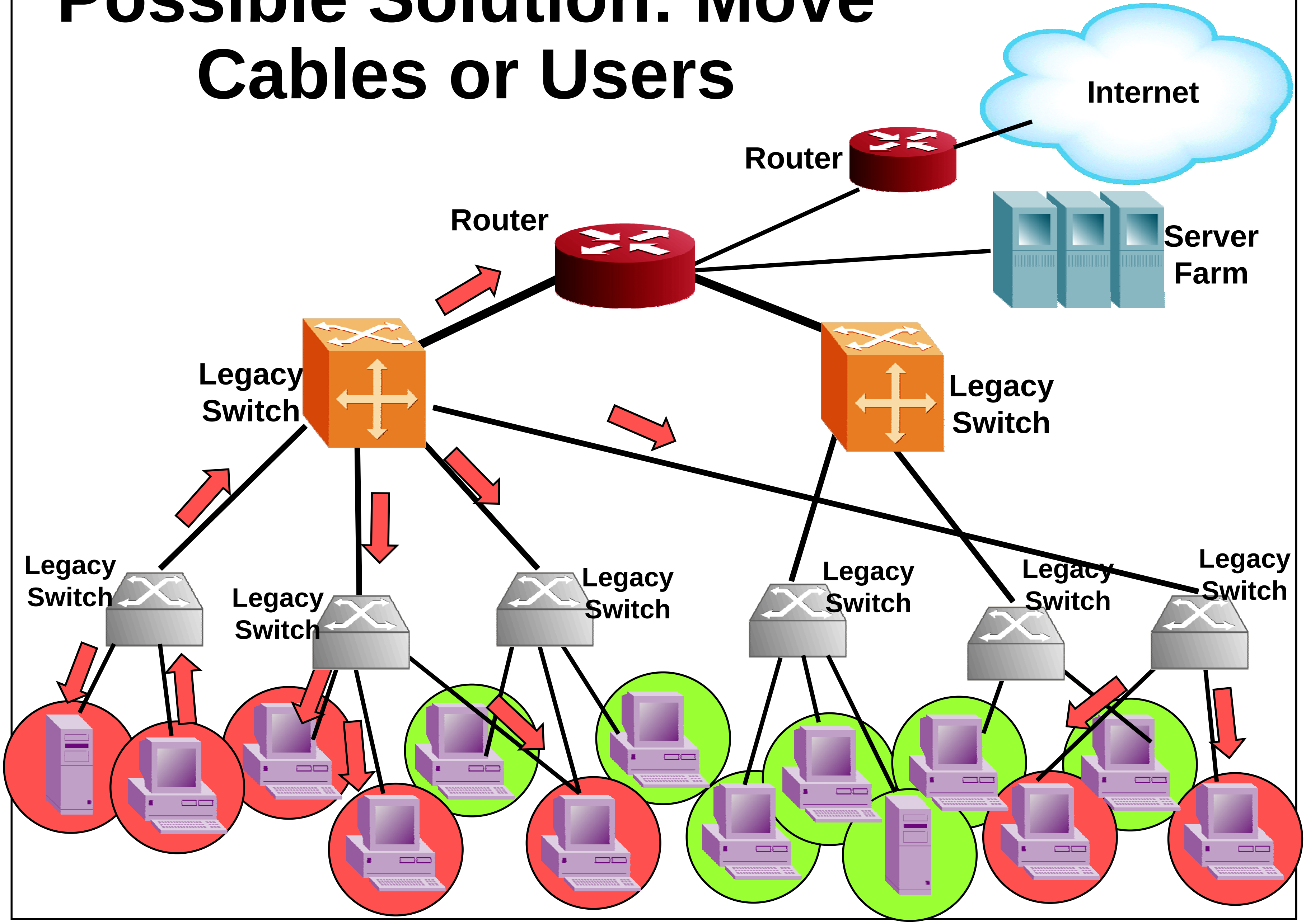
Why Are VLANs Needed?



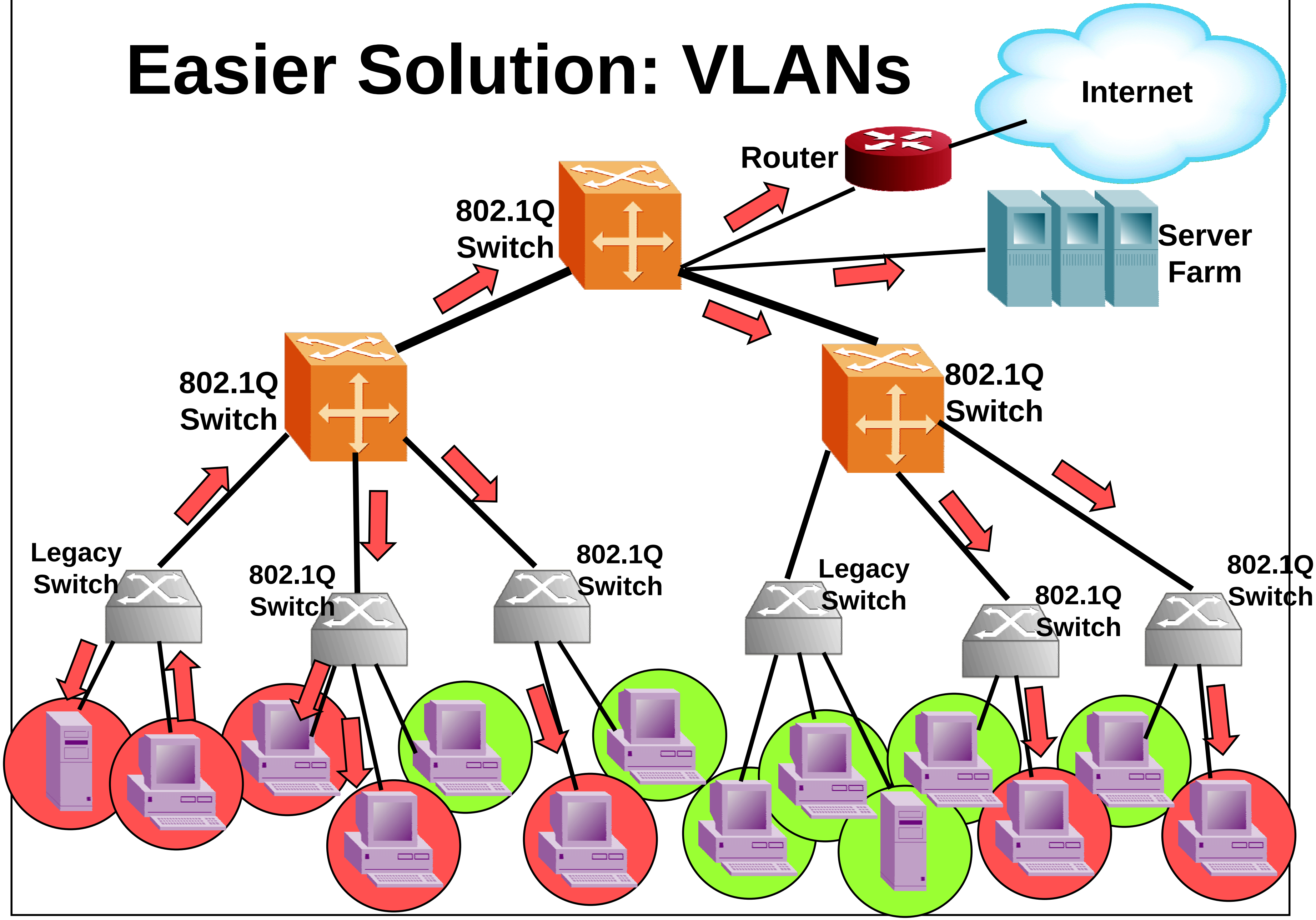
Possible Solution: Routers



Possible Solution: Move Cables or Users



Easier Solution: VLANs



More Reasons...

- Link Multiplexing
  - slower speed technologies share the high-bandwidth uplink
  - multiple IP subnets on one physical link with layer 3 switching
- Security
  - Without it, broadcasts are seen by everyone
  - Virtual private tunnel – “VPN Like” service
- Moving end-stations to different ports
- Switching is faster and cheaper than routing, but you still need full routing for some applications and to connect VLANs (IP Subnets) together

Standards Based VLANs

- Includes definition for a new GARP application called GVRP (GARP VLAN Registration Protocol)
  - Propagate VLAN registration across the net
- Associate incoming frames with a VLAN ID
- De-associate outgoing frames if necessary
- Transmit associated frames between VLAN 802.1Q compliant switches

Basic VLAN Concepts

- **Port-based VLANs**
  - Each port on a switch is in one and only one VLAN (except trunk links)
- **Tagged Frames**
  - VLAN ID and Priority info is inserted (4 bytes)
- **Trunk Links**
  - Allow for multiple VLANs to cross one link
- **Access Links**
  - The edge of the network, where legacy devices attach
- **Hybrid Links**
  - Combo of Trunk and Access Links
- **VID**
  - VLAN Indentifier

Tagged Frames

- **4 Bytes inserted after Destination and Source Address**
- **Tagged Protocol Identifier (TPID) = 2 Bytes (x8100)**
  - **length/type field**
- **Tagged Control Information (TCI) = 2 Bytes**
  - **contains VID**

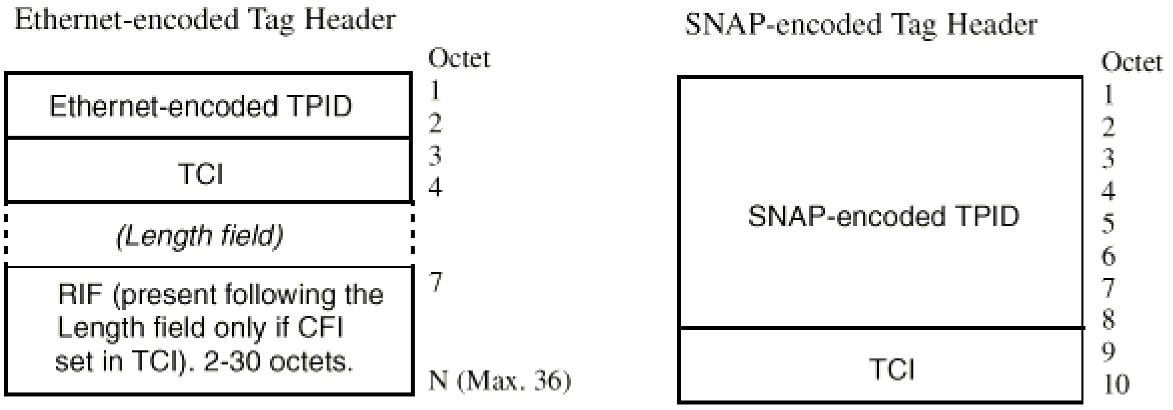


Figure 9-1—Tag Header format

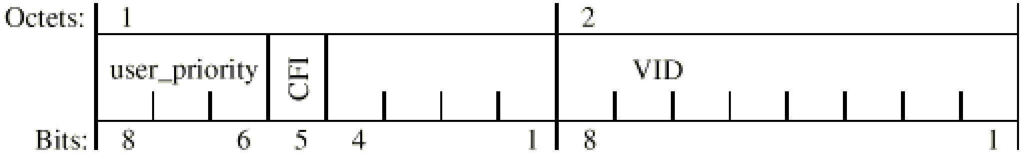


Figure 9-4—Tag Control Information (TCI) format

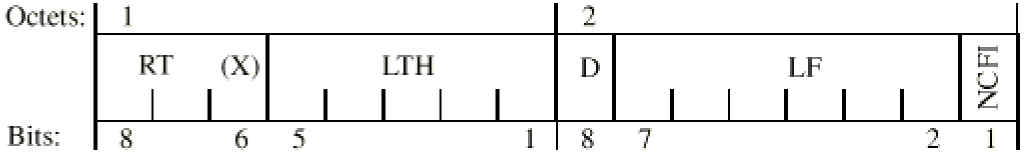


Figure 9-5—Route Control (RC) field

Trunk Link

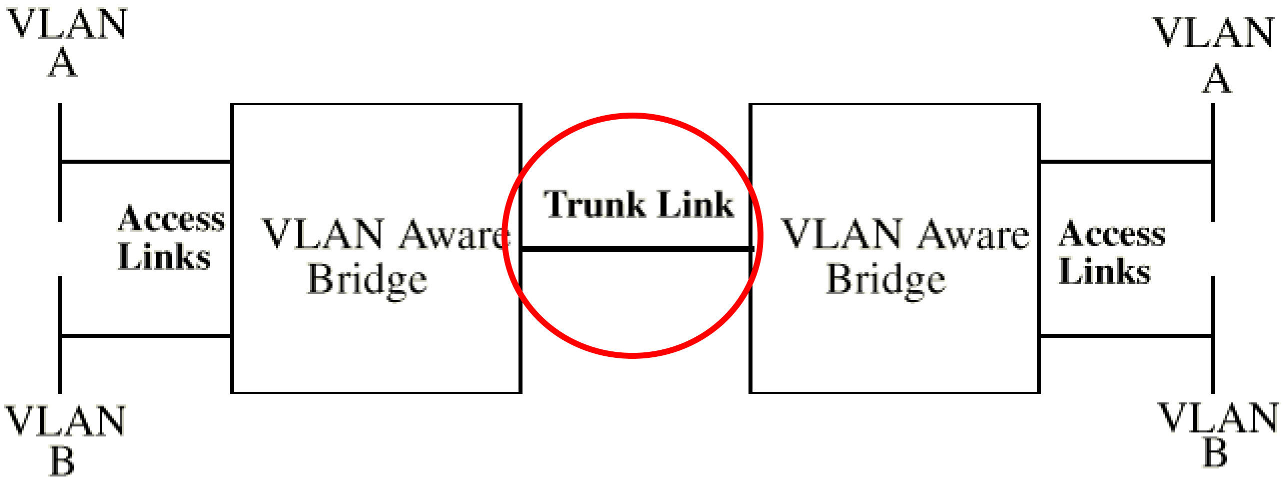
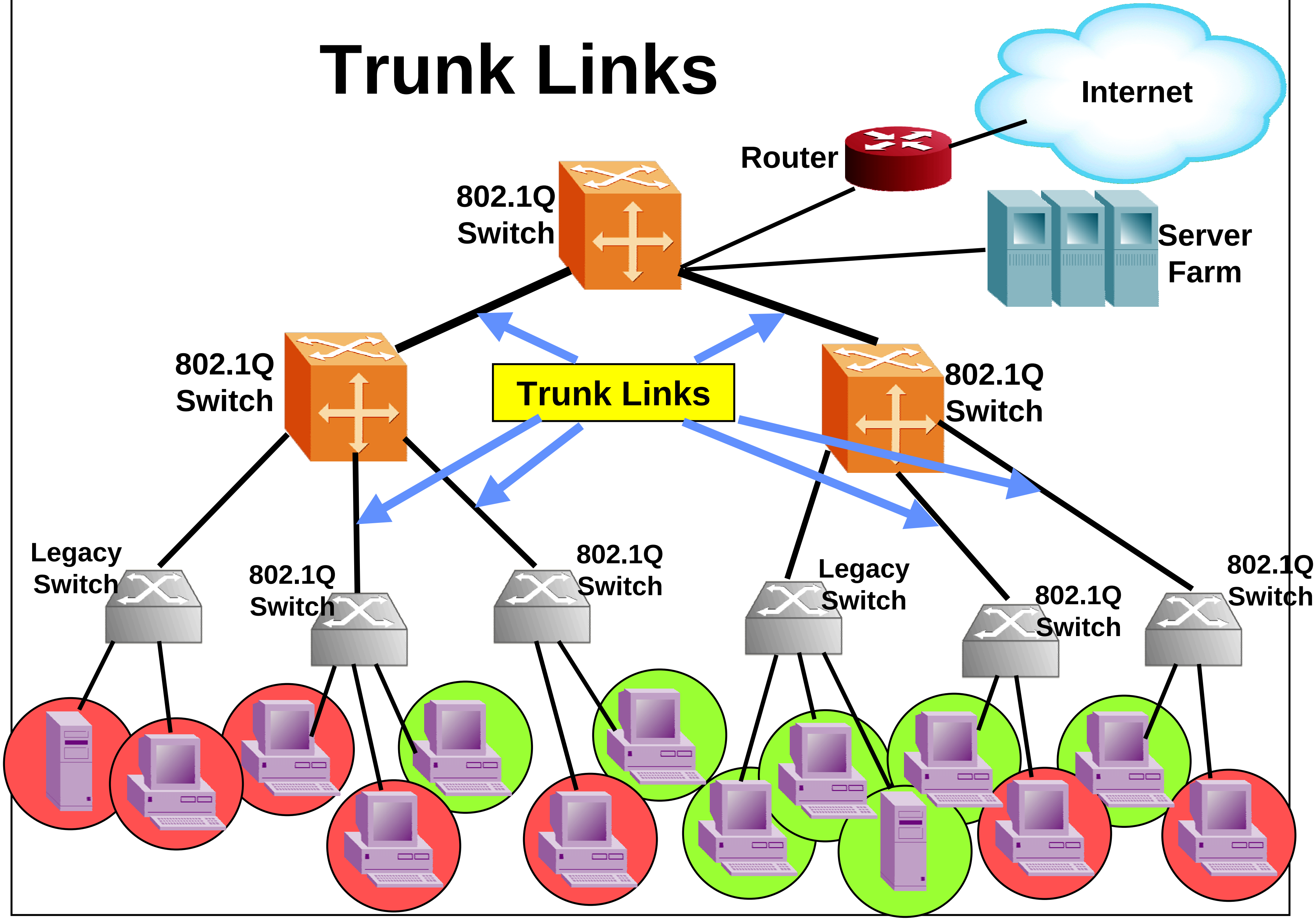


Figure C-1—Port-based VLANs

- **Attaches two VLAN switches - carries Tagged frames ONLY.**

Trunk Links


Internet
Router
802.1Q Switch
Server Farm
802.1Q Switch
Trunk Links
802.1Q Switch
Legacy Switch
802.1Q Switch
802.1Q Switch
Legacy Switch
802.1Q Switch
802.1Q Switch

Access Links

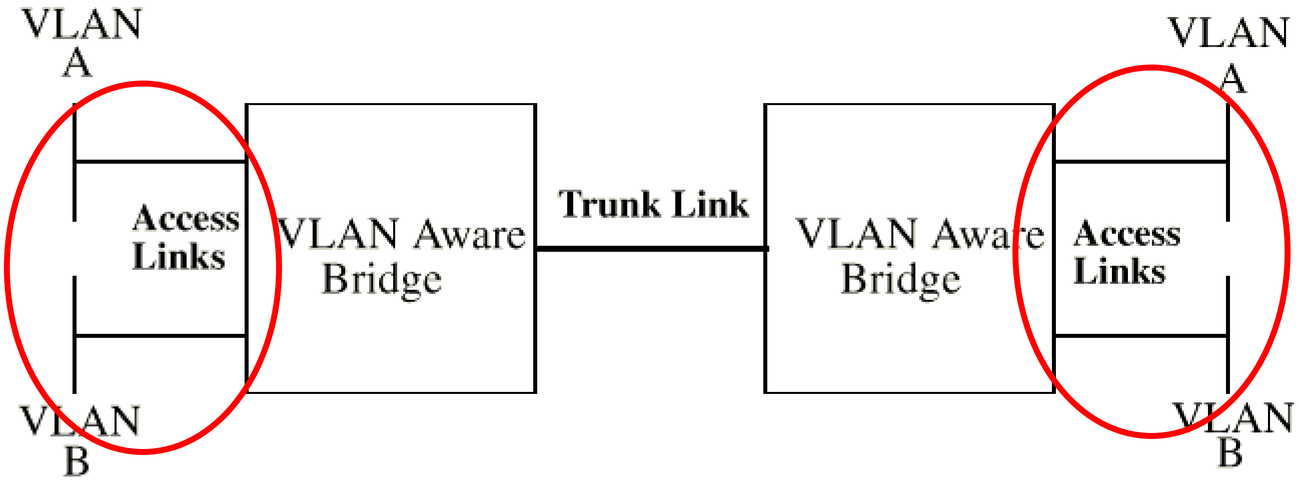
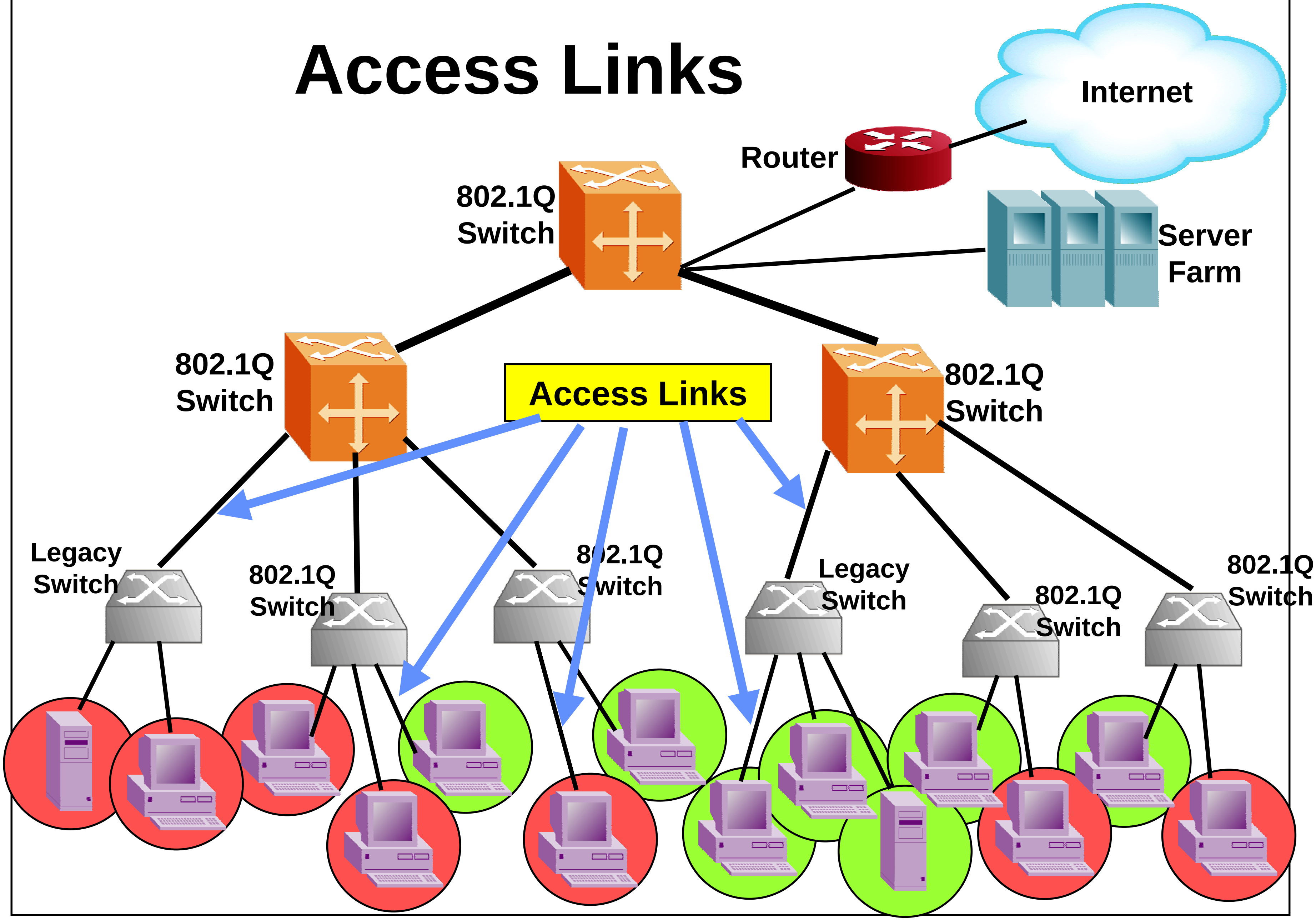


Figure C-1—Port-based VLANs

- Access Links are Untagged for VLAN unaware devices - the VLAN switch adds Tags to received frames, and removes Tags when transmitting frames.

Access Links



Hybrid Links

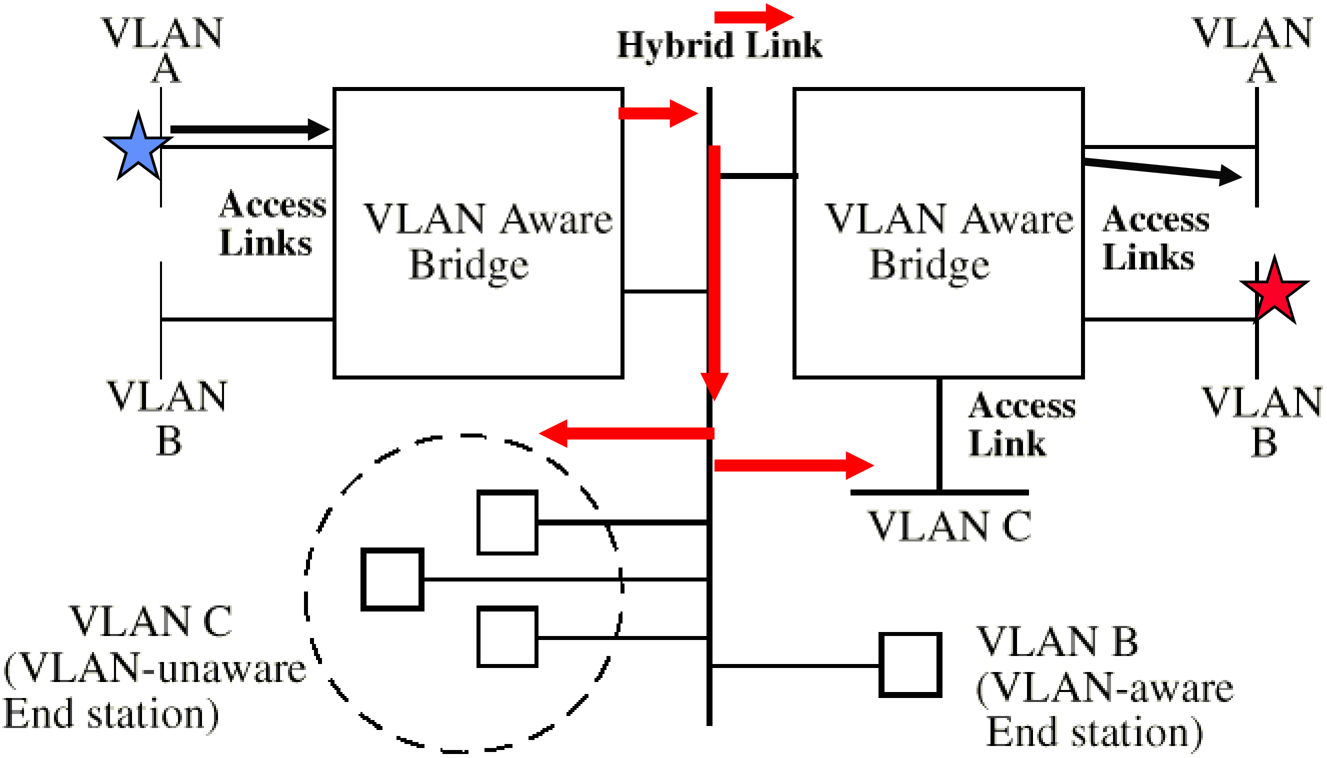
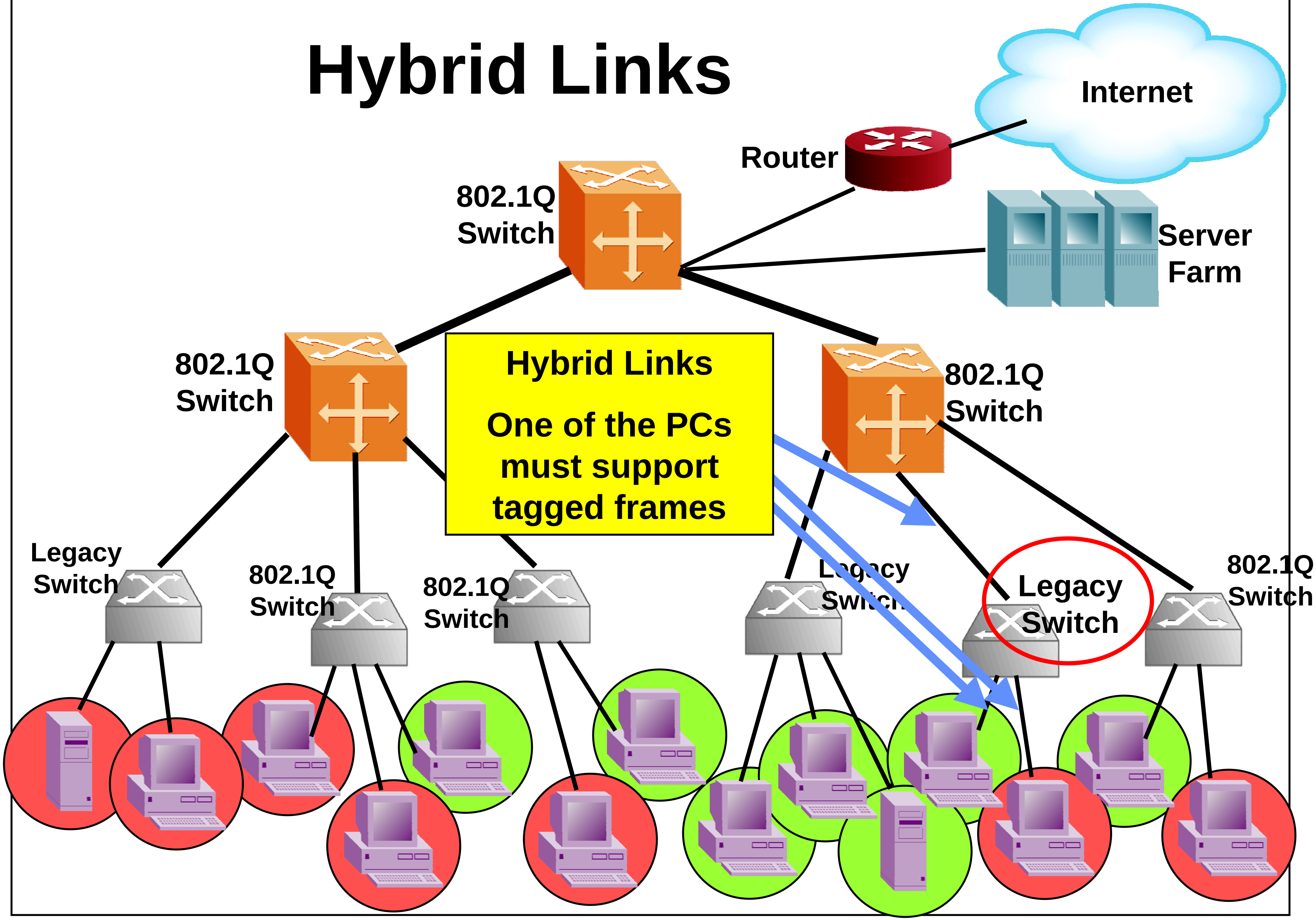


Figure C-2—Hybrid Links

- **Hybrid Links - ALL VLAN-unaware devices are in the same VLAN**

Hybrid Links



Hybrid Links

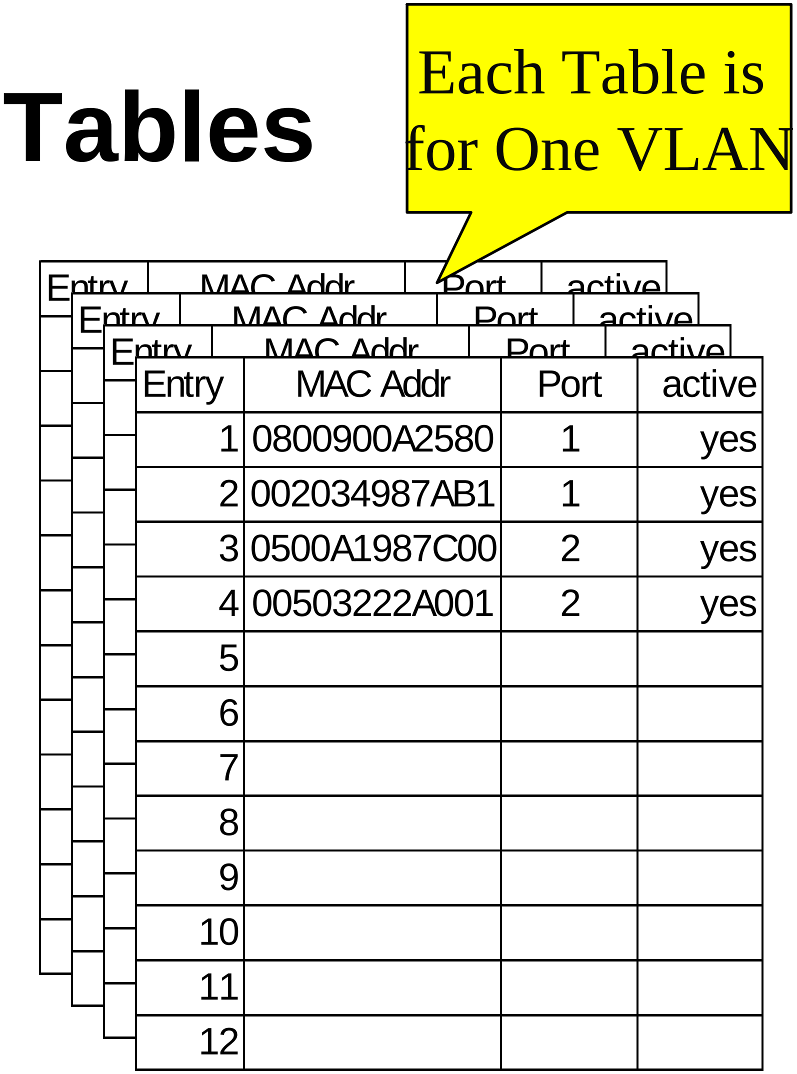
One of the PCs must support tagged frames

So Far So Good...

- So one might ask: “what does the Bridge table look like?”
- Two answers:
  - multiple (distinct) tables: one for each VLAN
  - one mother of all tables, with a VLAN column
- They sound similar, but it turns out they are VERY different

Multiple Tables

- Called MFD (multiple forwarding databases) or Independent Learning
- Each VLAN learns MAC addresses independently, so duplicate MAC addresses are OK.



Each Table is for One VLAN

Entry	MAC Addr	Port	active
1	0800900A2580	1	yes
2	002034987AB1	1	yes
3	0500A1987C00	2	yes
4	00503222A001	2	yes
5			
6			
7			
8			
9			
10			
11			
12			

One (Big) Table

- **Called SFD (Single Forwarding Database) or Shared Learning**
- **No duplicate MAC addresses**
- **Asymmetric VLAN possible**

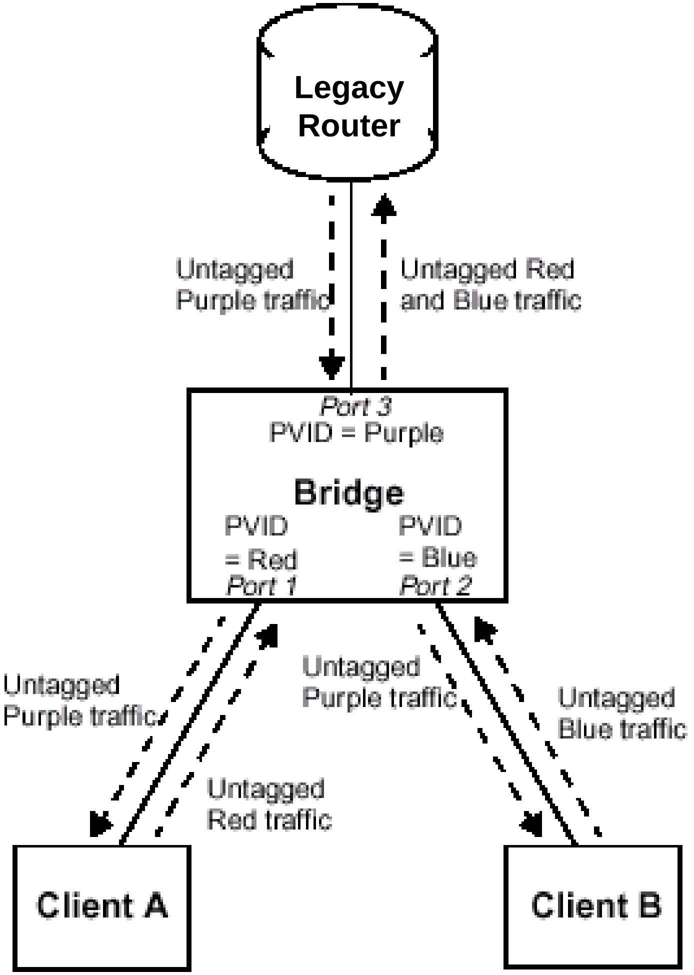
Entry	MAC Addr	Port	active	VLAN
1	0800900A2580	1	yes	2
2	002034987AB1	1	yes	2
3	0500A1987C00	2	yes	2
4	00503222A001	2	yes	2
5	080034090478	3	yes	1
6	049874987AB1	5	yes	1
7	0555A1945600	5	yes	3
8	00503222A023	5	yes	2
9				
10				
11				
12				

Asymmetric VLANs (also known as “interoperability killer”)

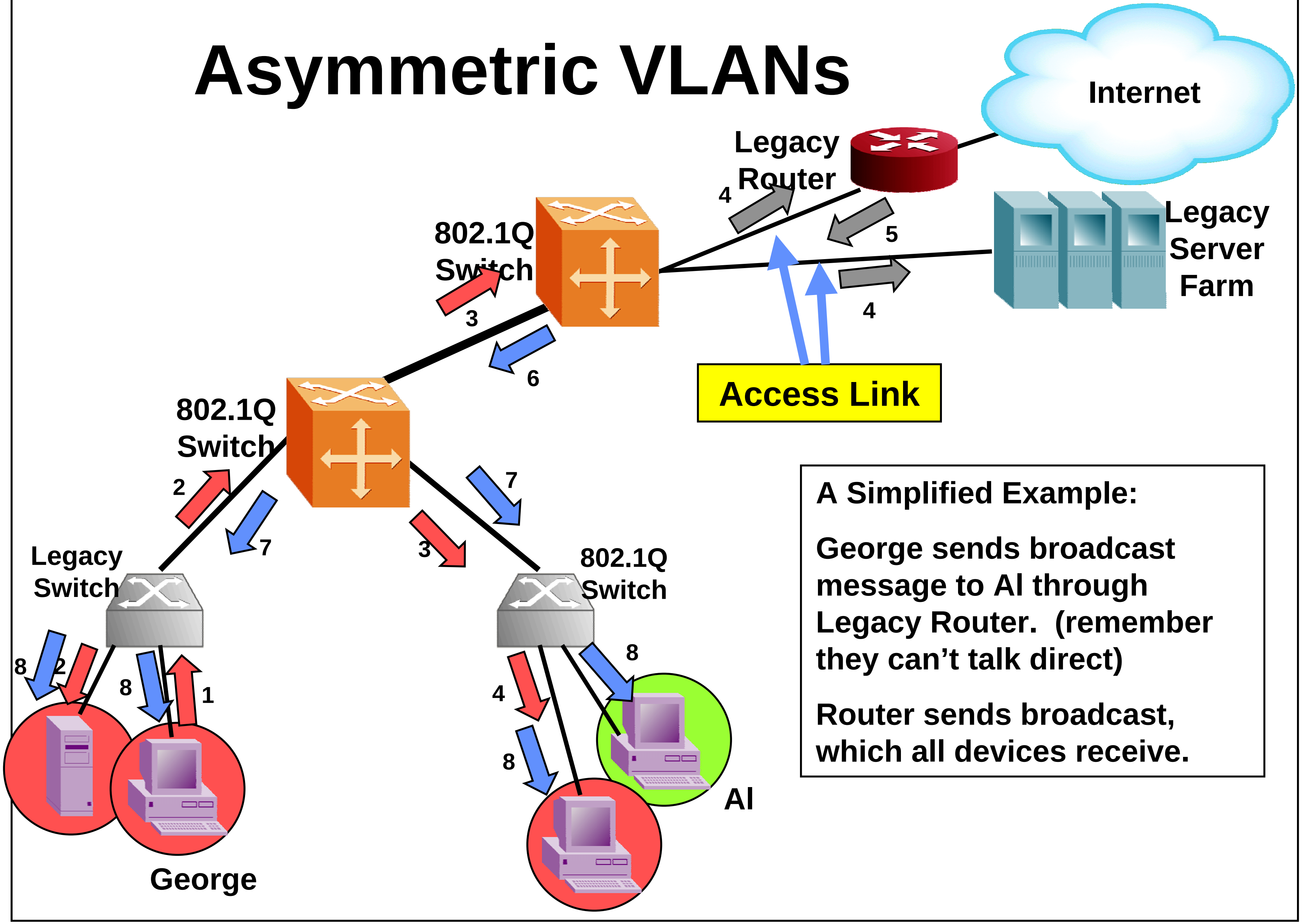
- **Legacy router can talk to legacy clients with one physical link**
- **Legacy clients cannot talk to each other**

Member Sets:
Purple - Ports 1 and 2
Red - Port 3
Blue - Port 3

Untagged Sets:
Purple - Ports 1 and 2
Red - Port 3
Blue - Port 3



Asymmetric VLANs



A Simplified Example:

George sends broadcast message to Al through Legacy Router. (remember they can’t talk direct)

Router sends broadcast, which all devices receive.

Independent Learning I

- **Legacy router learns MAC addresses from both VLANs**
- **Requires 2 physical links**

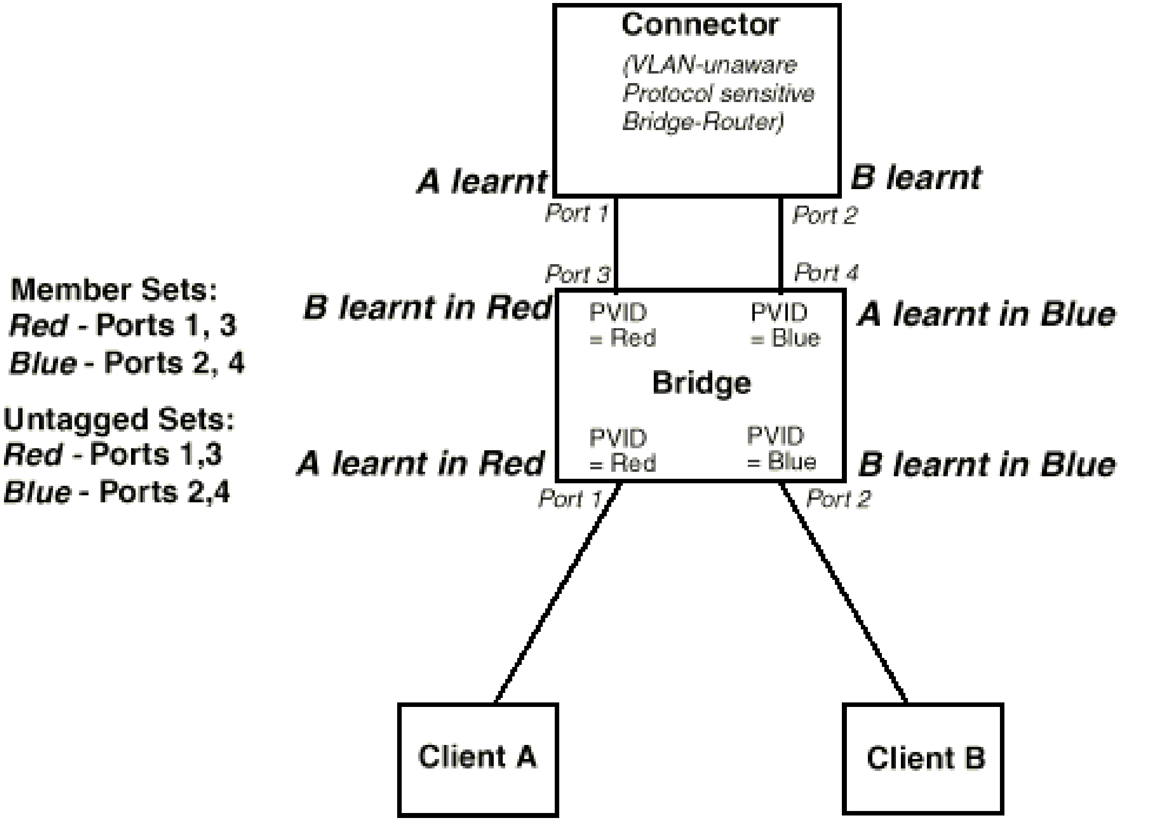
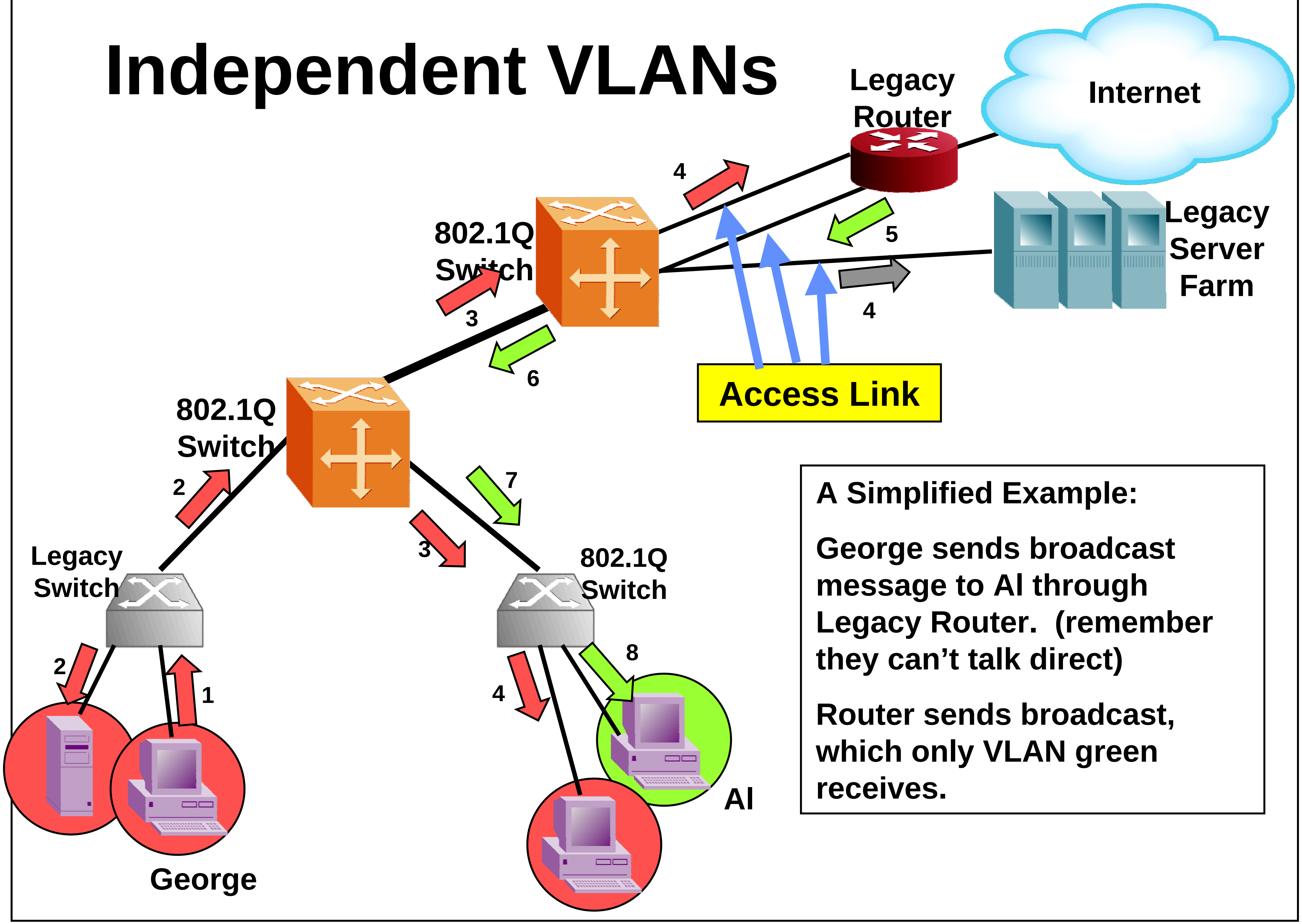


Figure B-2—Connecting independent VLANs - 1

Independent VLANs



A Simplified Example:

George sends broadcast message to Al through Legacy Router. (remember they can't talk direct)

Router sends broadcast, which only VLAN green receives.

Independent Learning II

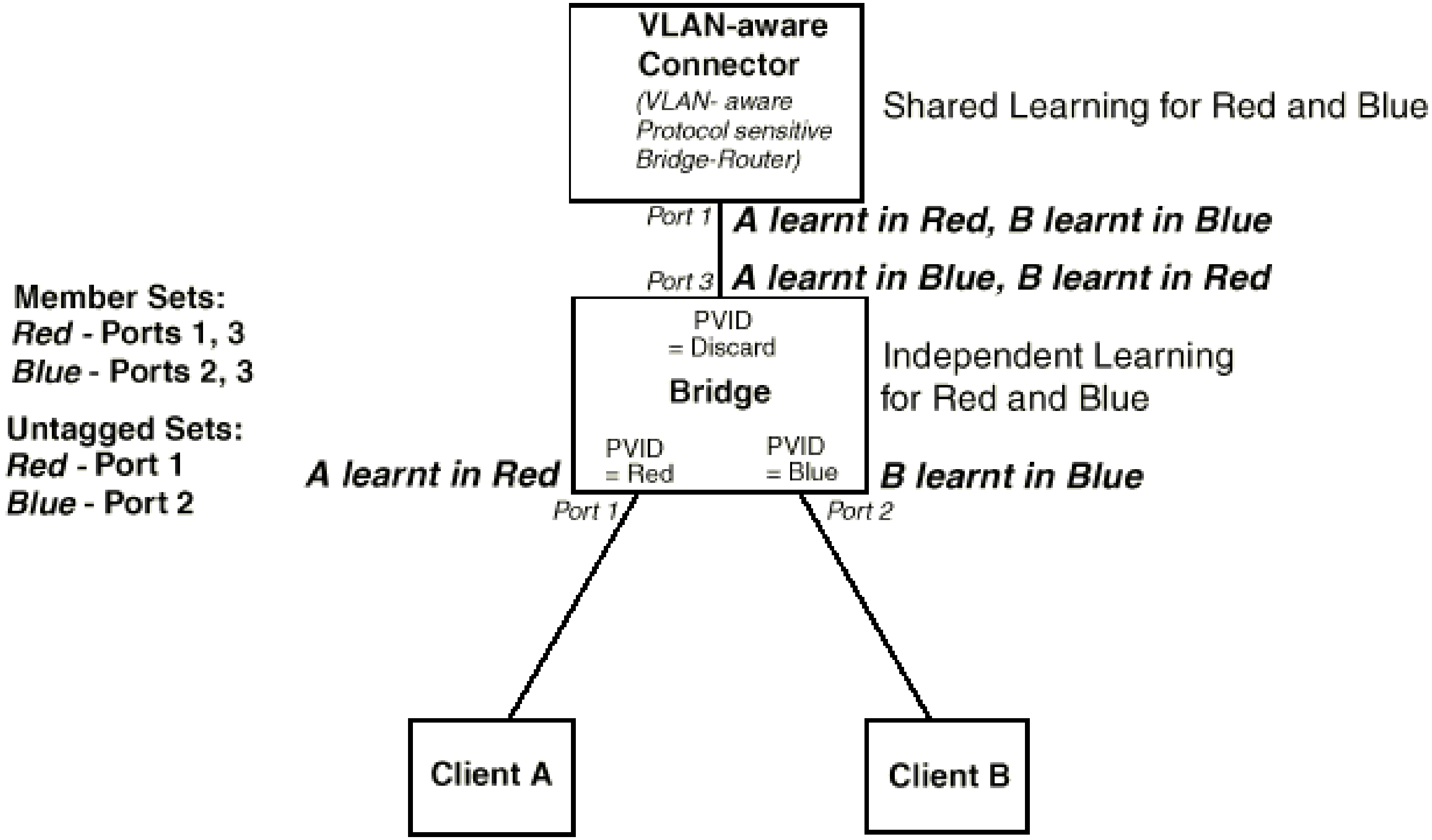
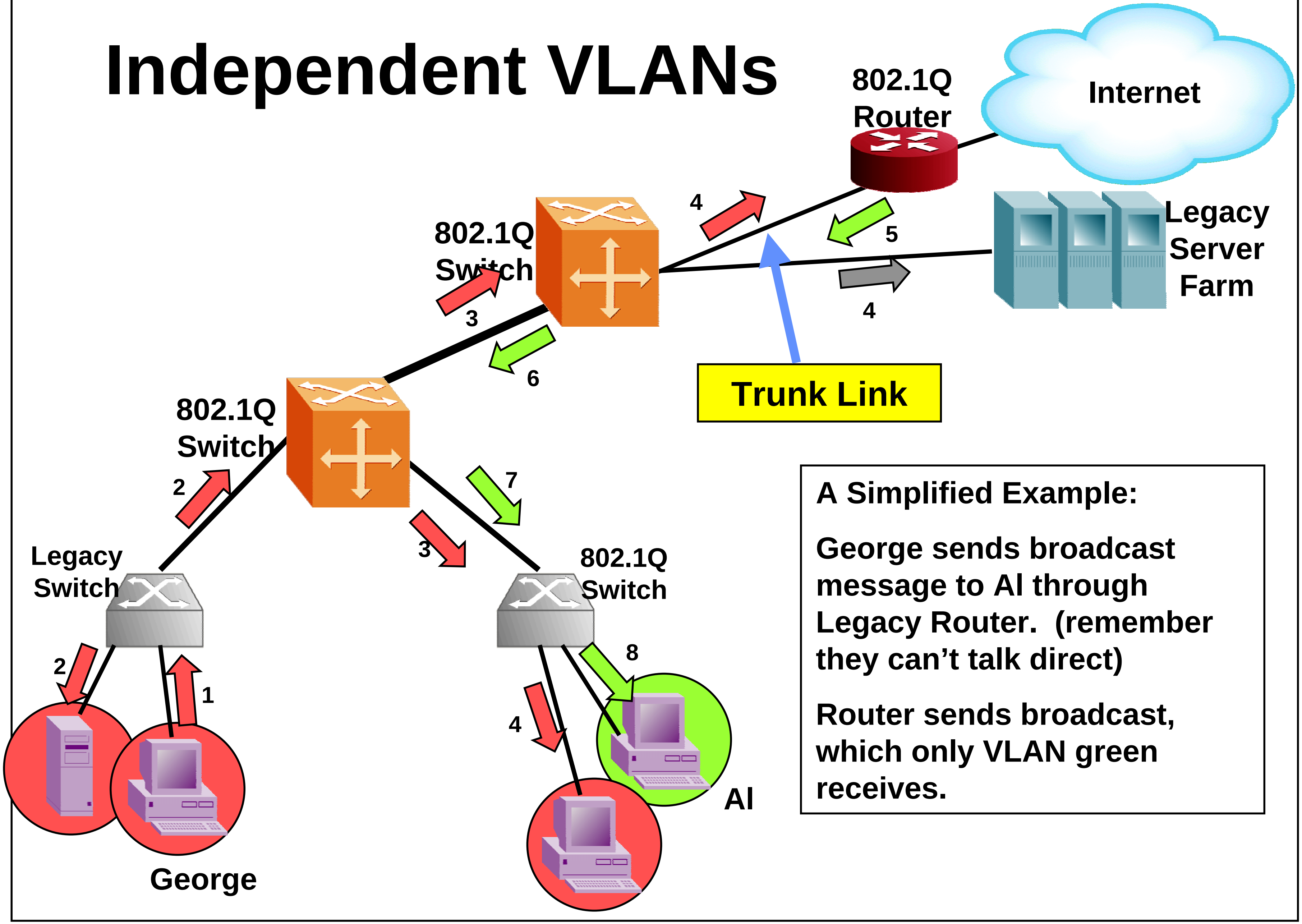


Figure B-3—Connecting independent VLANs - 2

- VLAN-aware router only needs one physical link

Independent VLANs



A Simplified Example:

George sends broadcast message to Al through Legacy Router. (remember they can't talk direct)

Router sends broadcast, which only VLAN green receives.

Problems

- Can’t combine SFD and MFD switches in one network
- Some switches only do one or the other, and can’t be changed
- Hybrids of SFD and MFD makes this tricky

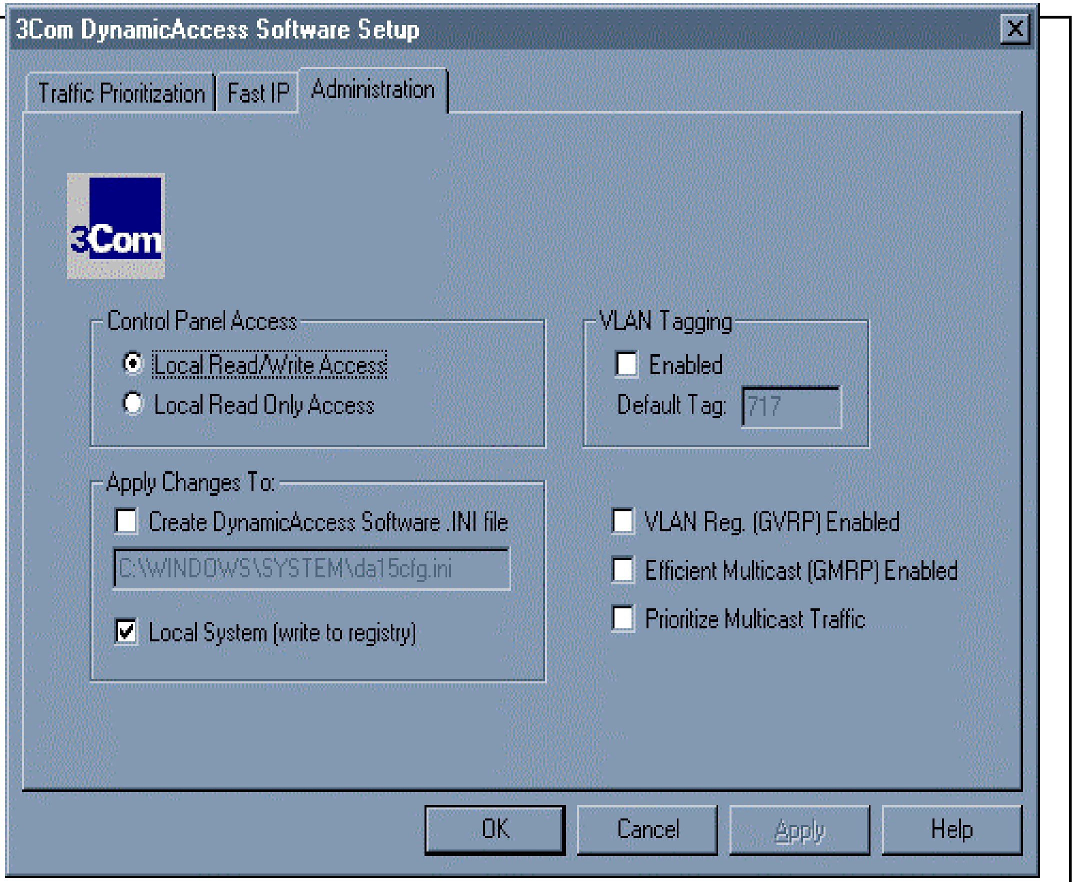
Other Additions

- **802.1v: Layer 3 based VLANs**
  - – IP traffic on a different VLAN than IPX
- **802.1s: Multiple Spanning Trees (one per VLAN)**
  - – allows for using the disabled links
- **ATM to IEEE VLAN mapping**
  - – VLAN to ELAN mapping (Emulated LANs)

GARP (yeah, I know, “the world according to”… that’s a new one!)

- Generic Attribute Registration Protocol
- Standard Defines:
  - method to declare attributes to other GARP participants
  - frame type to convey GARP messages: Protocol Data Unit (PDU)
  - rules and timers for registering/de-registering attributes
- GVRP: GARP VLAN Registration Protocol
  - GARP based method for VLAN info propagation
- GMRP: GARP Multicast Registration Protocol
  - GARP based method for multicast group propagation

Windows screenshot —>



Control Panel Access

● Local Read/Write Access

○ Local Read Only Access

VLAN Tagging

□ Enabled

Default Tag: 717

Apply Changes To:

□ Create DynamicAccess Software .INI file

C:\WINDOWS\SYSTEM\da15cfg.ini

☑ Local System (write to registry)

□ VLAN Reg. (GVRP) Enabled

□ Efficient Multicast (GMRP) Enabled

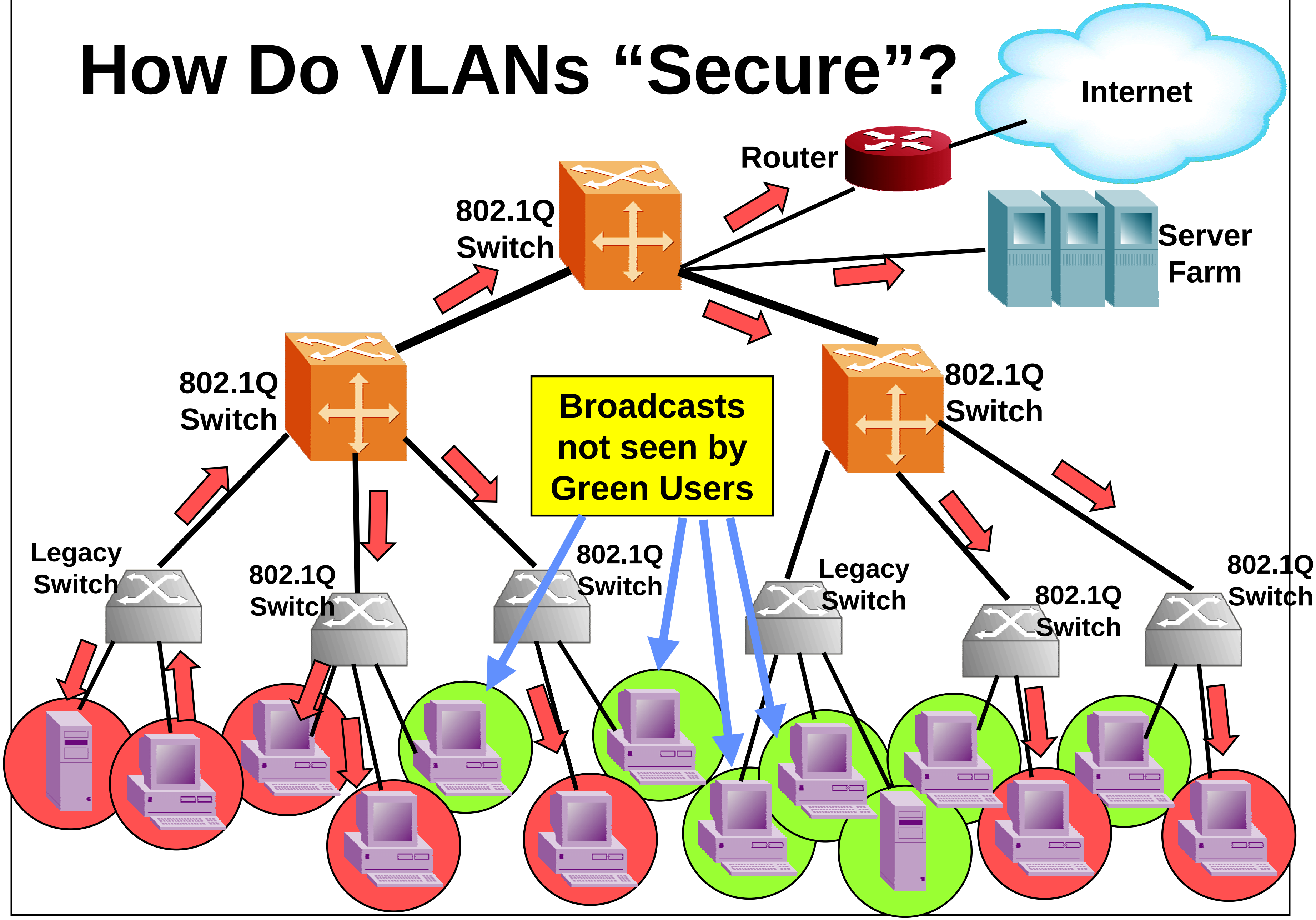
□ Prioritize Multicast Traffic

GVRP Vendors (current): Extreme, 3Com and HP

Several others are developing working implementations also.

- **Industry Implementation Example**
  - **3Com manufactures Network Interface Cards that take advantage of GVRP**
  - **Accessed via the Control Panel (DynamicAccess®)**
  - **Extremely easy to configure**

How Do VLANs “Secure”?



Broadcasts not seen by Green Users

VLAN Security

- VLAN is NOT a security mechanism, but its attributes provide some basic defenses against naïve users
- Ultimately, 802.3 and 802.1 do not provide real security – upper layers must be used to authenticate, encrypt, etc.
- Even 802.1x Network Access is not perfect either (more on that later…)

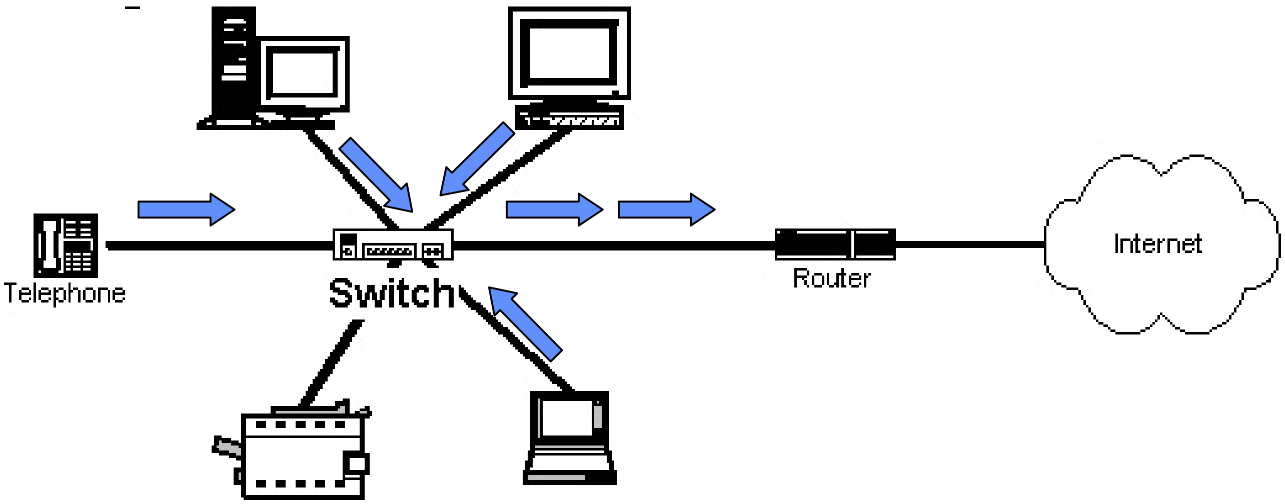
This page left intentionally blank.

This page left intentionally blank.

Priorities/QoS

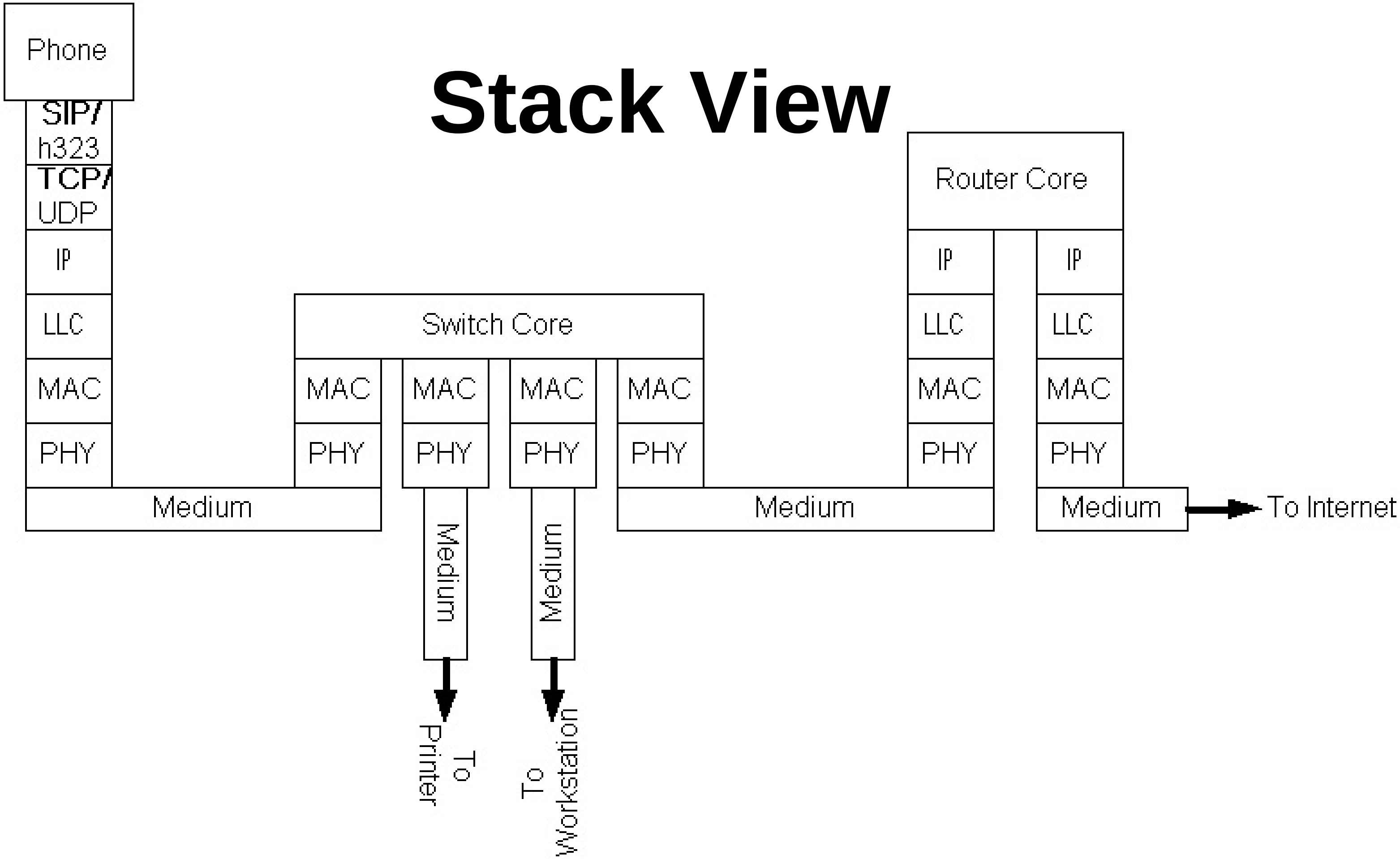
802.1p

The Problem



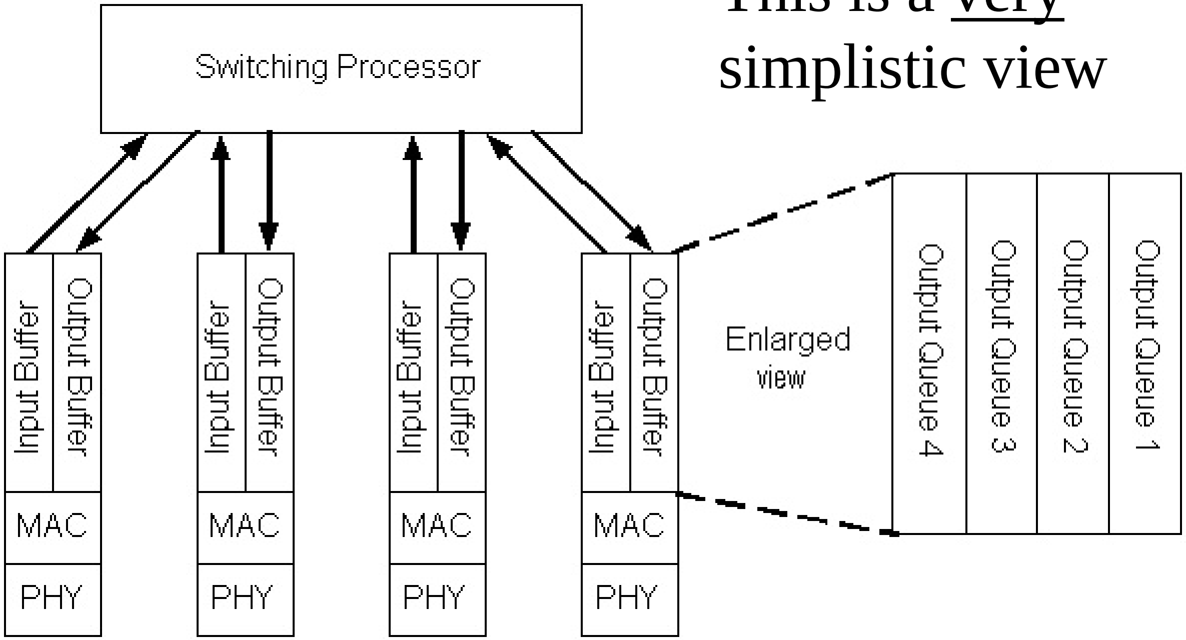
- In a switched network, if more than one device sends packets to the same destination at the same time, the switch will buffer them and send them out based on first-in first-out basis
- So time-sensitive traffic (like voice) has no priority over other types (mail, ftp, web)

Stack View



- **Same switched network drawn as stack models**

Inside the Switch



This is a <u>very</u> simplistic view

- **Buffers can have multiple queues for different priority traffic**
- **Higher-priority can be sent before lower-priority**

Possible Solution

- Q: How does switch know which traffic to prioritize?
- Possible answer: set priority for each port inside the switch configuration...
- But then how does it tell the next switch along the path what the priority was?
- And not all traffic from the same port should be treated equally - it may come from a router, or a shared link, or another switch

Better Solution

- Tag the priority of each packet with its relative priority value
- Then switch can put higher-priority tagged frames in a higher-priority queue based on the value

Remember VLAN Tagged Frames?

- **4 Bytes inserted after Destination and Source Address**
- **Tagged Protocol Identifier (TPID) = 2 Bytes (x8100)**
  - **length/type field**
- **Tagged Control Information (TCI) = 2 Bytes**
  - **contains VID**

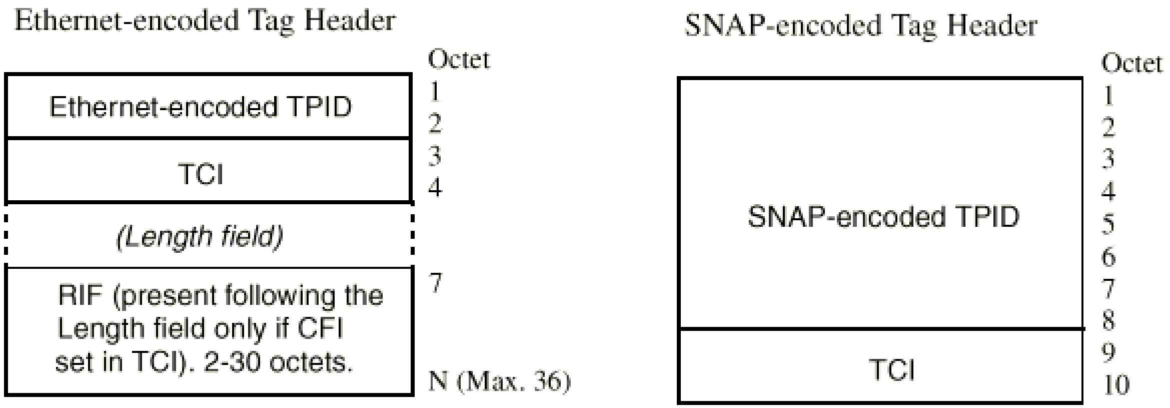


Figure 9-1—Tag Header format

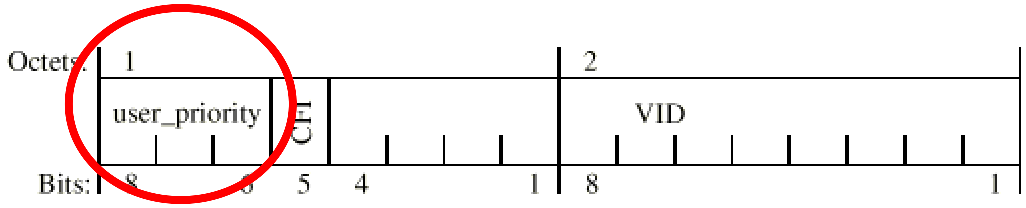


Figure 9-4—Tag Control Information (TCI) format

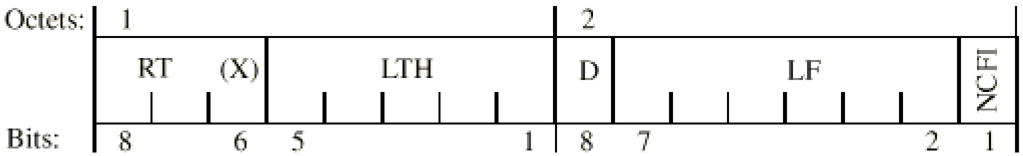


Figure 9-5—Route Control (RC) field

Priority Tagged Frames

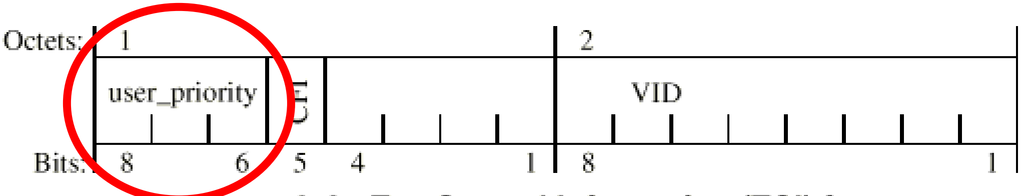


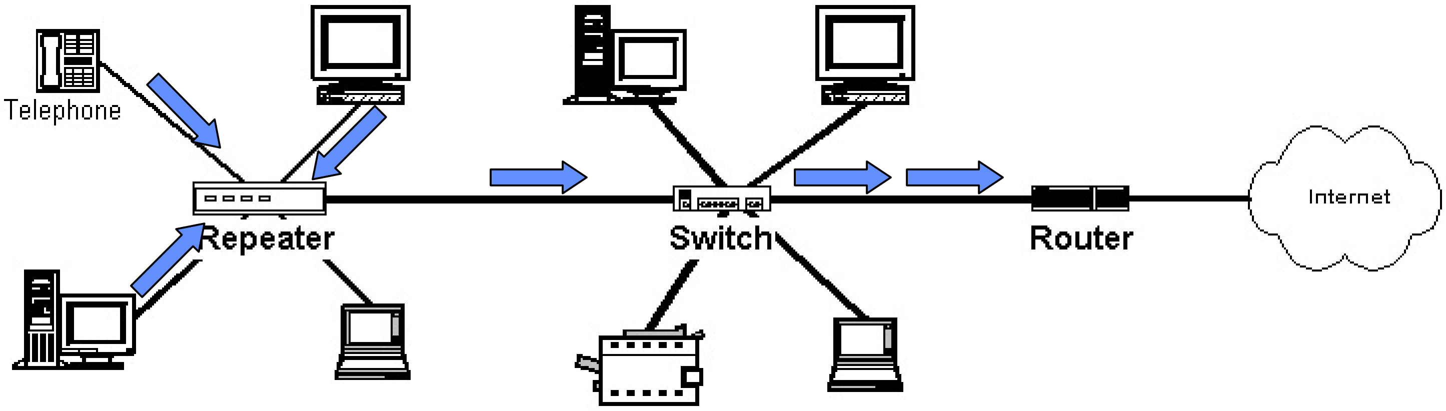
Figure 9-4—Tag Control Information (TCI) format

- **Uses user_priority field value of 0-7 for priority numbers**
- **VID may be a real VLAN ID number, or the value of x000 = “Priority Tagged”, meaning not a VLAN Tagged frame (x000 is illegal VLAN value)**
- **Same Ethertype of x8100**

Limitations of 802.1p

- It is NOT Quality of Service (QoS)
  - There is no guarantee of bandwidth, latency, nor jitter
  - If other devices use the same priority, no difference
  - If higher-priority fills the pipe constantly, lower-priority will never get through (depending on implementation)
- It IS Class of Service (CoS)
- Access to a shared ethernet medium/network isn’t helped - it’s still under the rules of CSMA/CD

Example



- **Even if the phone uses 802.1p tagged frames, it has to share the repeated network with the other devices with the same odds of success**
- **Once its frames get to the switch, then they will be sent through faster and with better odds than frames from other devices**

This page left intentionally blank.

This page left intentionally blank.

Layer-3 Switching

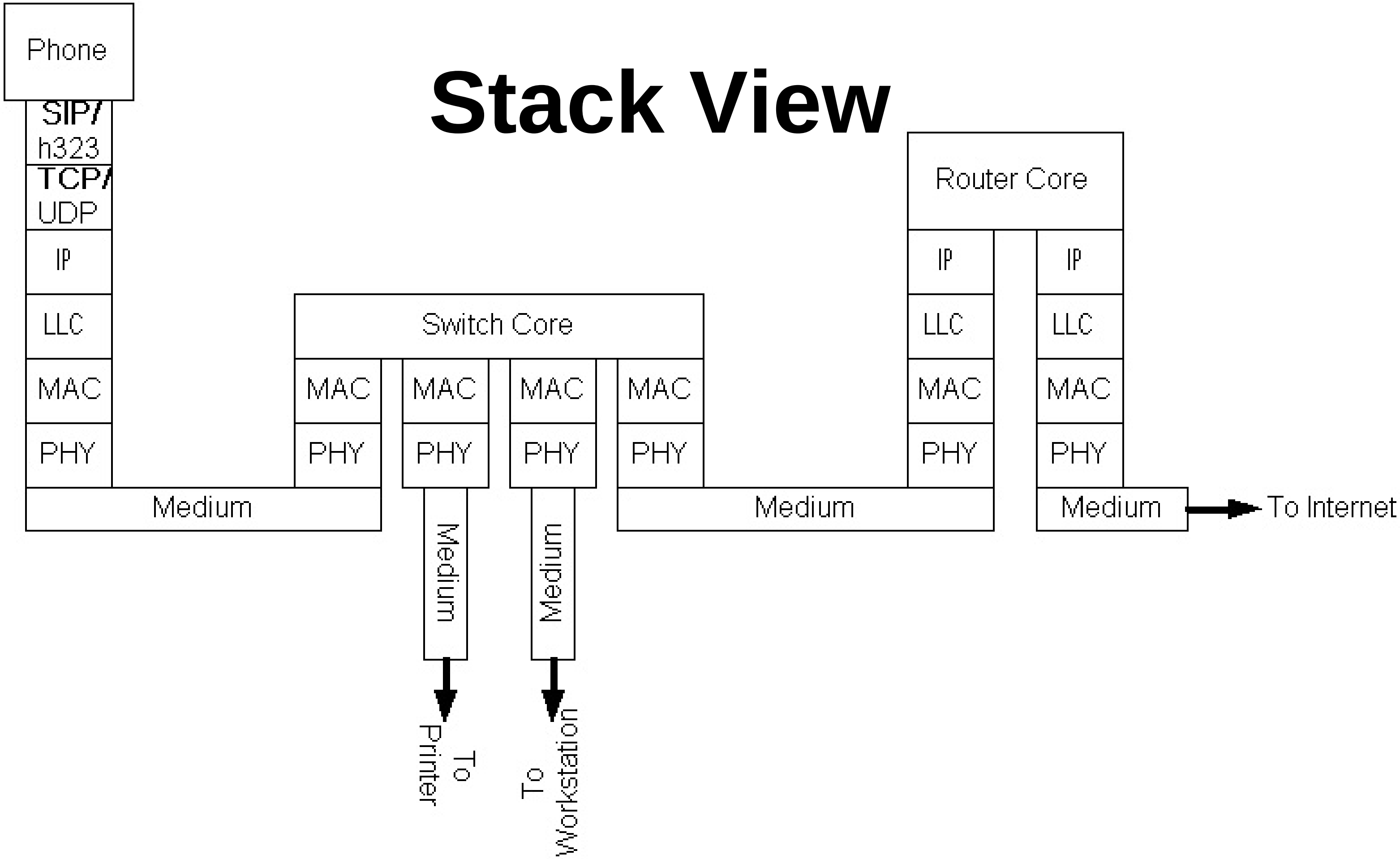
Routing vs. Switching

- Routing is done at layer 3 (IP layer), thereby connecting IP subnets
- Switching is done at layer 2 (MAC layer), thereby connecting Ethernet LAN segments
- Routing is slow because it’s done in software
- Switching is fast because it’s done in hardware
- So why not Route in hardware?

Routing in Hardware

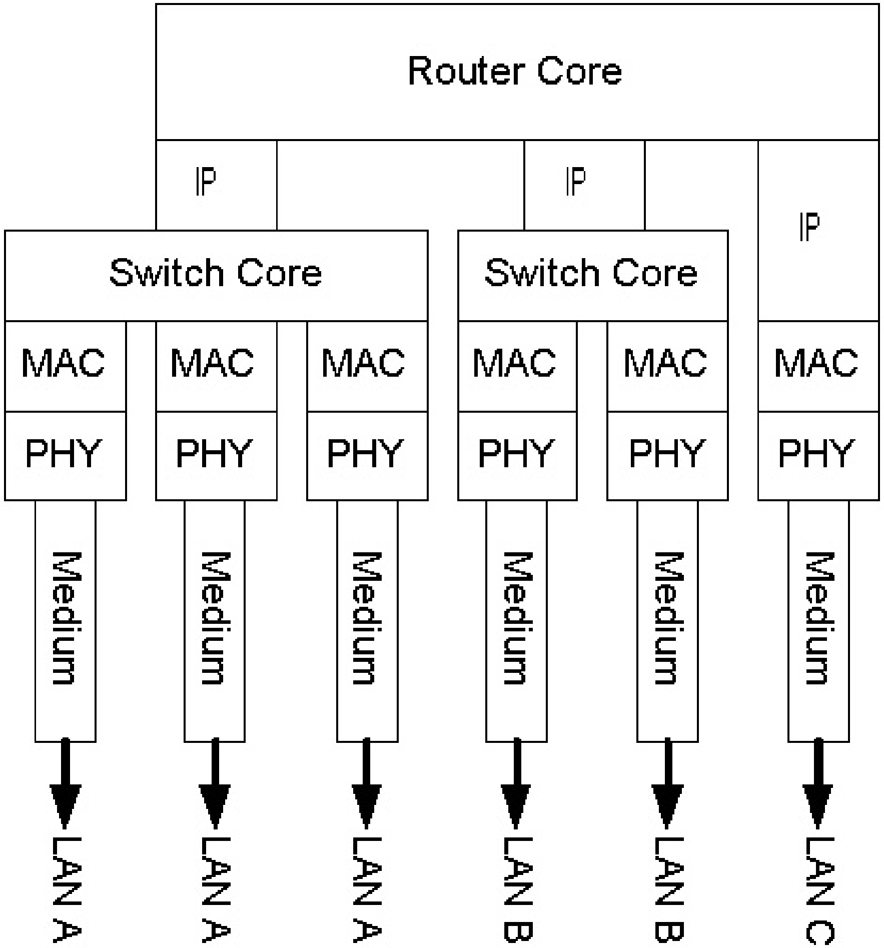
- Put forwarding engine into hardware, leave routing protocols/database in software
- Remove unnecessary or seldom-used protocols (IPX, Appletalk, etc.)
- Don’t route to non-Ethernet technologies (Token Ring, FDDI, Frame Relay, ATM, etc.)
- Lose advanced functions (statefull firewall, NAT, IP header compression, etc.)

Stack View



Remember this?

Layer-3 Switch Stack View



Layer-3 Switch Implementations

- Actual implementations vary depending on architecture
- Most have fast-forwarding engines per blade which can forward based on IP Address
- Usually, there is one or more central CPUs to handle exception cases, routing updates and management
- Some L3 Switches now offer advanced features:
  - filtering based on address, ports, etc.
  - IP multicast in the fast path
  - IPX, Appletalk, etc.
  - Advanced routing protocols such as BGP

This page left intentionally blank.

This page left intentionally blank.

MPLS over Ethernet

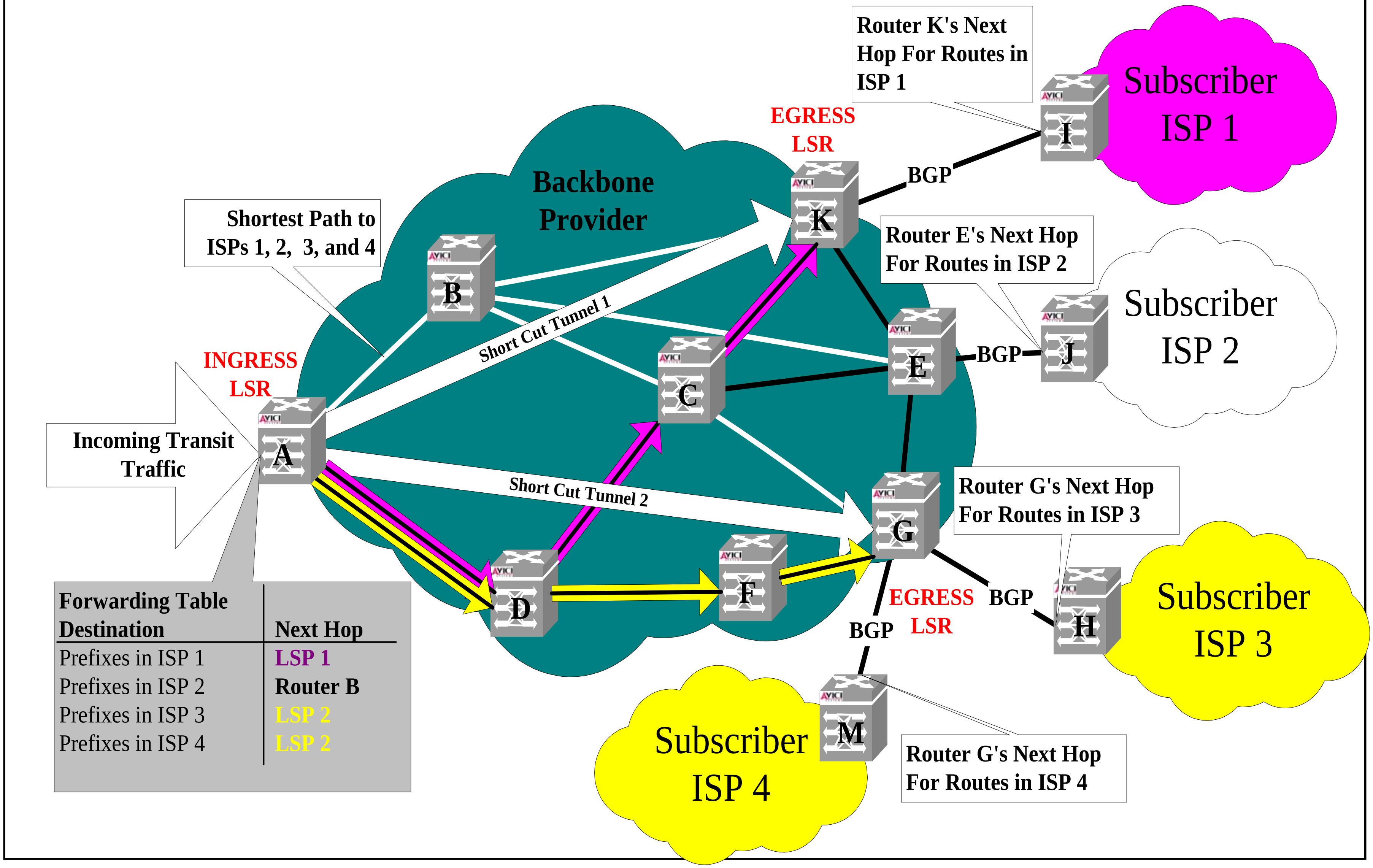
The Problem

- Today’s Internet Core isn’t scaling rapidly enough
- Traffic is doubling every 6 - 12 months
- Bandwidth consumption is not balanced across all possible paths (unless ECMP is used)
- All traffic traverses the shortest path without regard to QoS
- ATM switches in the core create a two-layer problem of ATM switching vs. IP routing

The Solution

- MPLS defines a method of switching packets by exchanging labels at each hop
- A router in the MPLS context is called a LSR (Label Switching Router)
- A Traffic engineered MPLS tunnel is a series of label switched hops (LSH) collectively called an LSP (Label Switched Path)
- The Tunnel is constructed by the Ingress LSR
- LSPs created with Label Distribution Protocol (LDP) are bounded by a pair of participating LSRs, the data plane topology is identical to IP hop by hop

Shortcut Routing



Incoming Transit Traffic

Shortest Path to ISPs 1, 2, 3, and 4

Router K's Next Hop For Routes in ISP 1

Router E's Next Hop For Routes in ISP 2

Router G's Next Hop For Routes in ISP 3

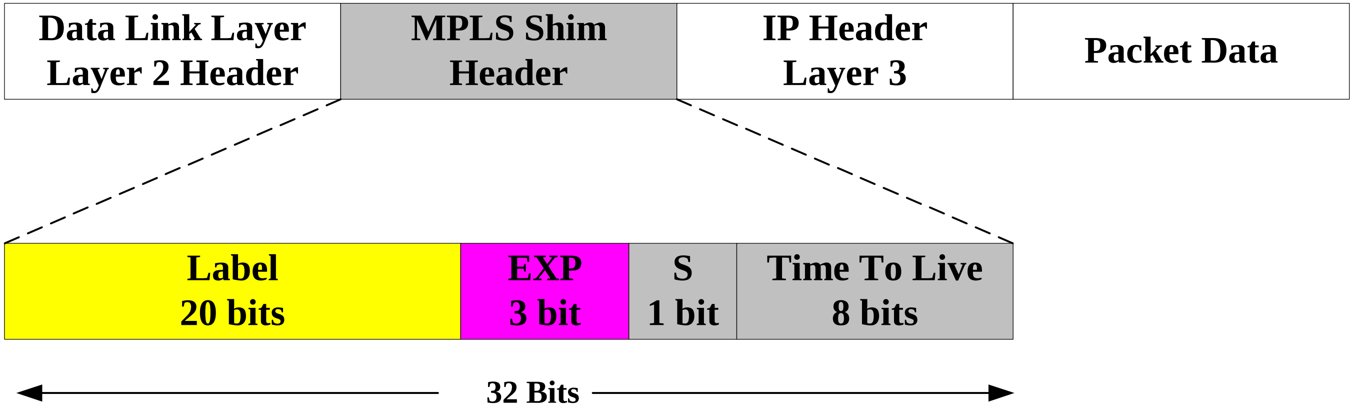
Router G's Next Hop For Routes in ISP 4

Forwarding Table

Destination	Next Hop
Prefixes in ISP 1	LSP 1
Prefixes in ISP 2	Router B
Prefixes in ISP 3	LSP 2
Prefixes in ISP 4	LSP 2

MPLS Encoding

- MPLS uses a 32 bit “Shim Header”
  - The Header is pushed onto the IP packet by the Ingress LSR
  - The Header is popped off by the Egress LSR or Penultimate LSR
  - Labels can be STACKED!



Data Link Layer Layer 2 Header

MPLS Shim Header

IP Header Layer 3

Packet Data

Label 20 bits

EXP 3 bit

S 1 bit

Time To Live 8 bits

32 Bits

- The **Label Field** is self explanatory
- The **EXP Field** is "Experimental" though it is proposed use is to inidicate Per Hop Behavior of labeled packets traversing Label Switching Routers
- The **Stack (S) Field** indicates the presence of a label stack
- The **Time to Live Field** is decremented at each LSR hop and is used to throw away looping packets

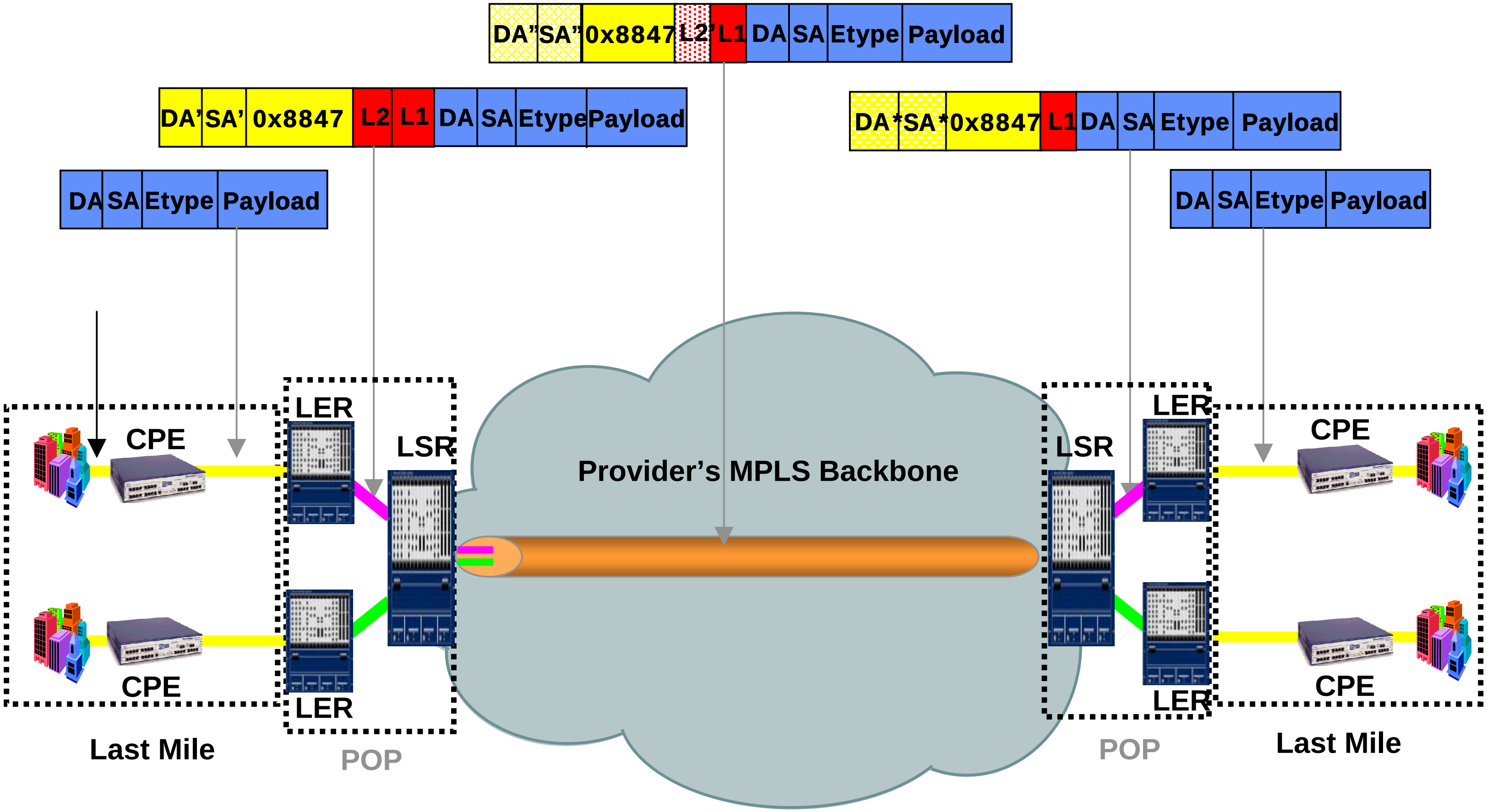
MPLS over Ethernet

- MPLS header adds 5 Bytes (as opposed to VLAN which adds 4)
  - There can be more than 1 MPLS header
  - Therefore, your GigE equipment must support more than 1518 bytes if you want MPLS to cross it (I.e., you use it in the core)
- MPLS is NOT VLANs
  - VLANs define a broadcast domain, MPLS defines an LSP tunnel
  - A broadcast packet with an MPLS label will still be broadcast to everyone (although MPLS packets never need broadcasting)

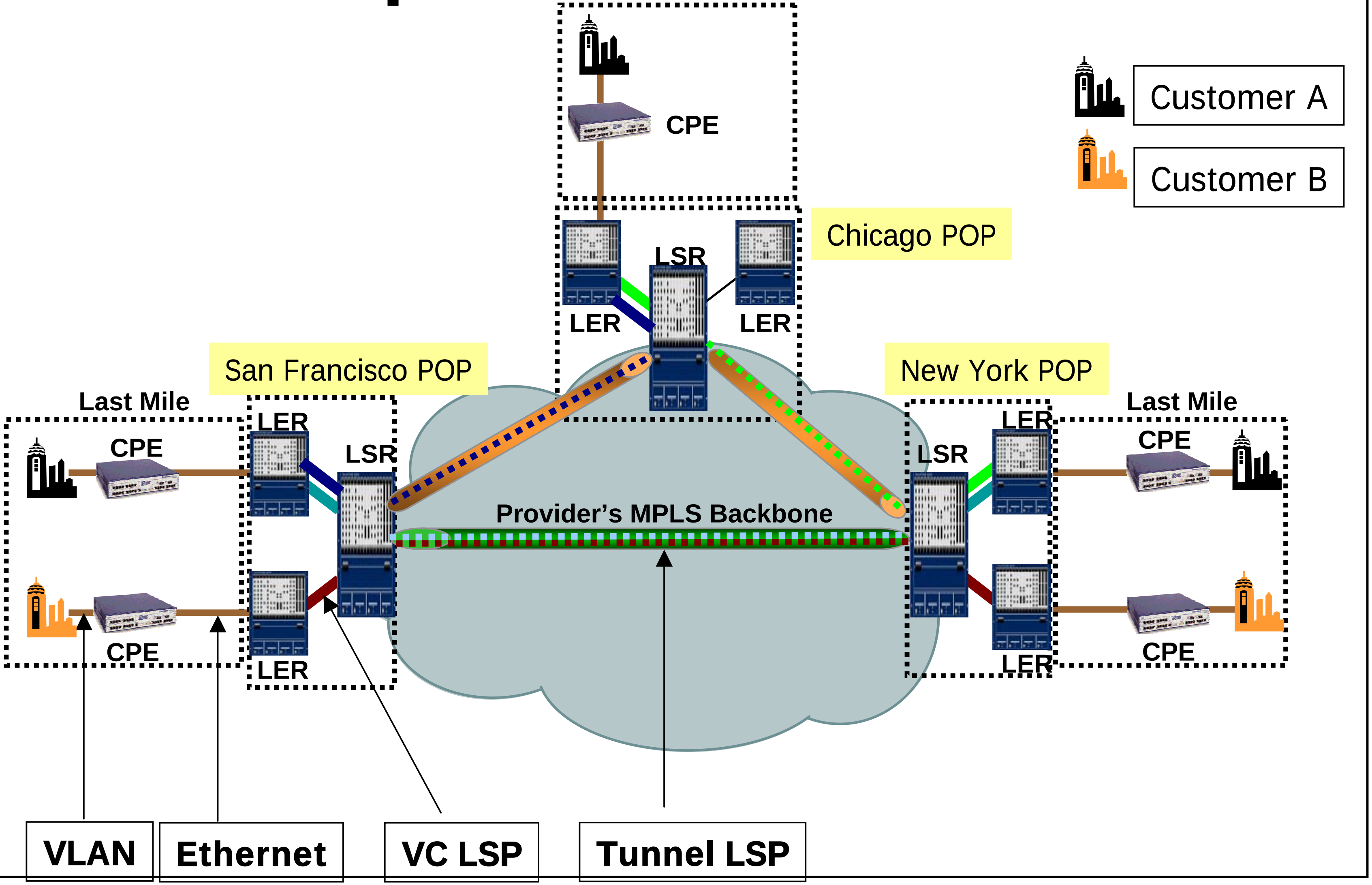
Ethernet over MPLS

- Because MPLS defines an end-to-end labeled tunnel, it’s very useful for creating VPNs
- The ISP can create VPNs between Enterprise/corporate regional offices
  - For internal VoIP calls
  - For internal data exchange
  - For intranet apps
- The Carrier can create VPNs between ISP POPs
  - To simulate a leased long-haul backbone
  - So the ISP can offer Enterprise VPNs
  - As a backup backbone or to offload bandwidth

Virtual Leased Line


DA” SA” 0x8847 L2’ L1 DA SA Etype Payload
DA’ SA’ 0x8847 L2 L1 DA SA Etype Payload
DA* SA* 0x8847 L1 DA SA Etype Payload
DA SA Etype Payload
DA SA Etype Payload
CPE
CPE
LER
LER
LSR
Provider’s MPLS Backbone
LSR
LER
LER
CPE
CPE
Last Mile
POP
POP
Last Mile

Transparent LAN Service



This page left intentionally blank.

This page left intentionally blank.

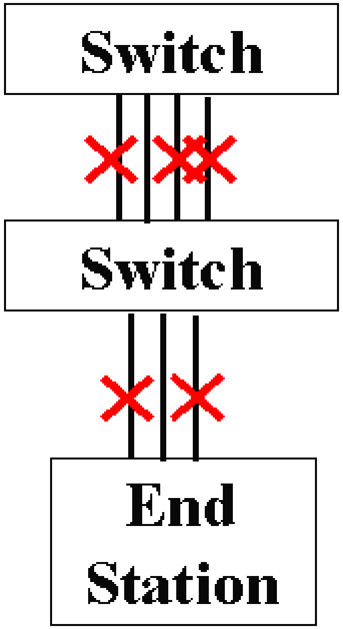
This page left intentionally blank.

Link Aggregation

802.3ad

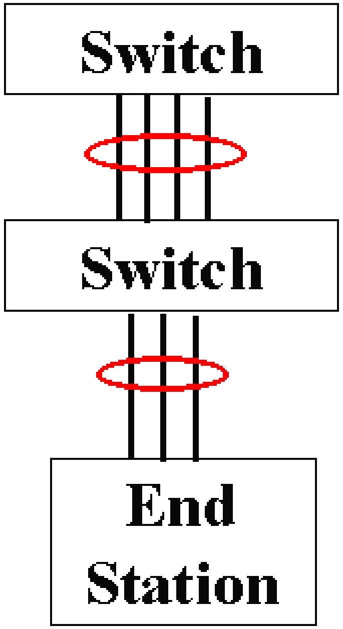
Basic Concept

- Originally only one of many separate physical links could be used (else loops)
- Spanning tree used to disable all but one
- Did provide redundancy, but not efficient use of links



Enter Trunking

- Multiple physical links joined into one logical link
- Only one MAC address used for trunk group
- All links in same group must be same speed and full-duplex

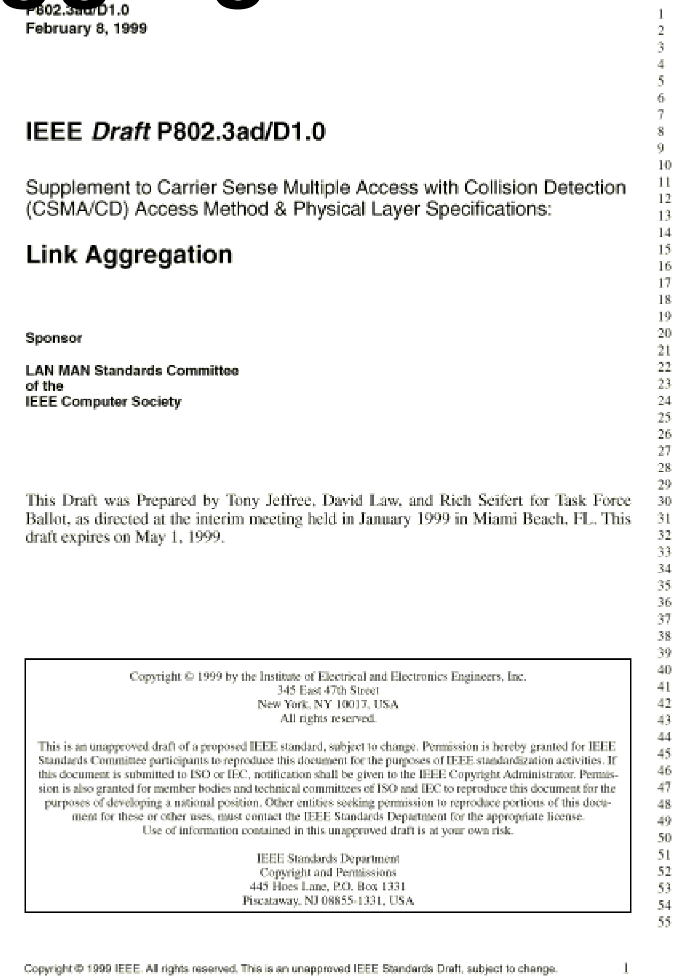


Proprietary Methods

- Very popular with users, but proprietary
- EtherChannel, Fast EtherChannel, Gig
  - Cisco’s protocol (routers, switches)
  - Also licensed by Adaptec, Intel, Compaq, Sun, HP, ZNYX, Phobos, Auspex (all NICs)
- MultiLink Trunking (MLT)
  - Nortel’s protocol (switches)
- Virtual Link Trunking (VLT)
  - 3Com’s protocol (switches)

802.3ad - Link Aggregation

- Study group started in November 1997 – Standard completed last year (2000)
- website: http://grouper.ieee.org/groups/802/3/ad/



P802.3ad/D1.0
February 8, 1999

IEEE *Draft* P802.3ad/D1.0

Supplement to Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method & Physical Layer Specifications:

Link Aggregation

Sponsor

LAN MAN Standards Committee
of the
IEEE Computer Society

This Draft was Prepared by Tony Jeffree, David Law, and Rich Seifert for Task Force Ballot, as directed at the interim meeting held in January 1999 in Miami Beach, FL. This draft expires on May 1, 1999.

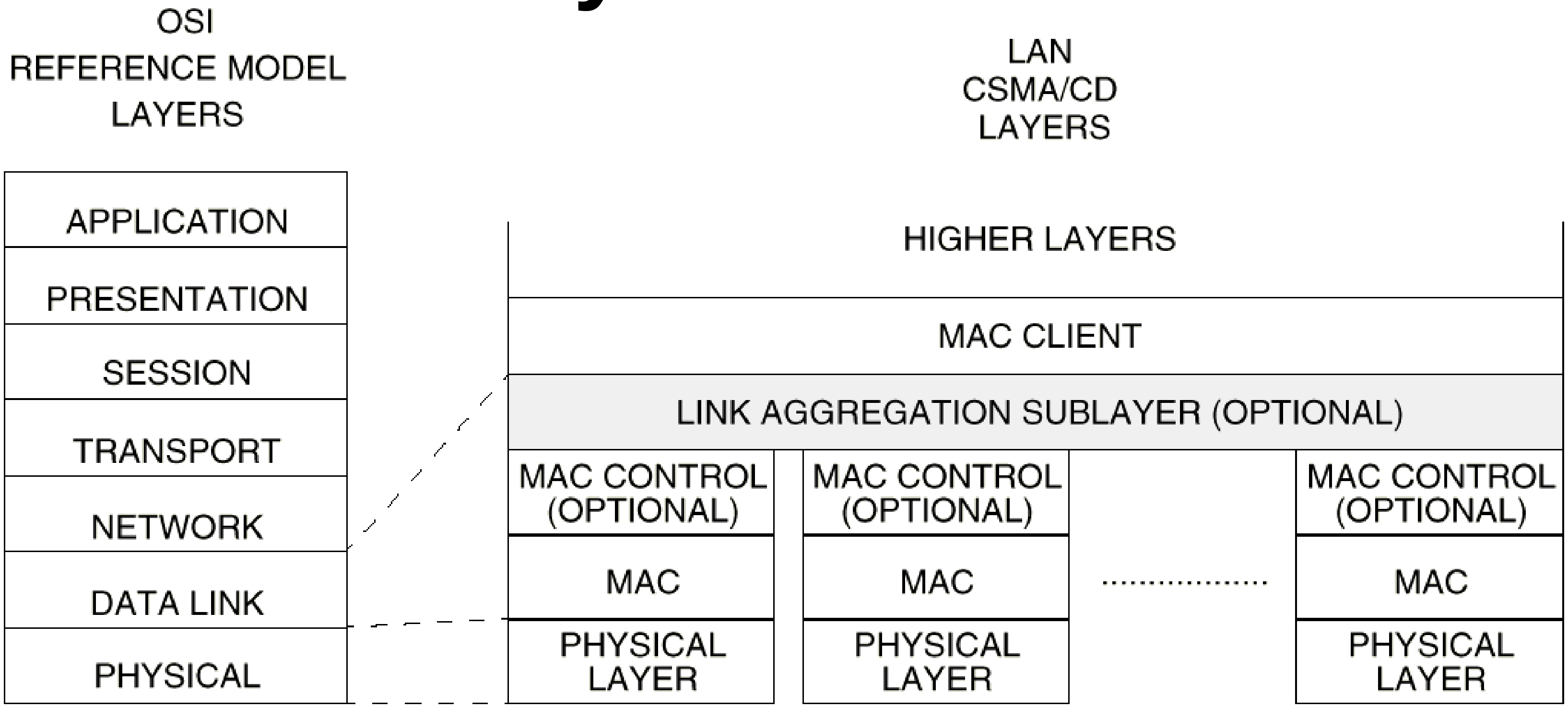
This is an unapproved draft of a proposed IEEE standard, subject to change. Permission is hereby granted for IEEE Standards Committee participants to reproduce this document for the purposes of IEEE standardization activities. If this document is submitted to ISO or IEC, notification shall be given to the IEEE Copyright Administrator. Permission is also granted for member bodies and technical committees of ISO and IEC to reproduce this document for the purposes of developing a national position. Other entities seeking permission to reproduce portions of this document for these or other uses, must contact the IEEE Standards Department for the appropriate license.
Use of information contained in this unapproved draft is at your own risk.

IEEE Standards Department
Copyright and Permissions
445 Hoes Lane, P.O. Box 1331
Piscataway, NJ 08855-1331, USA

Benefits and Goals

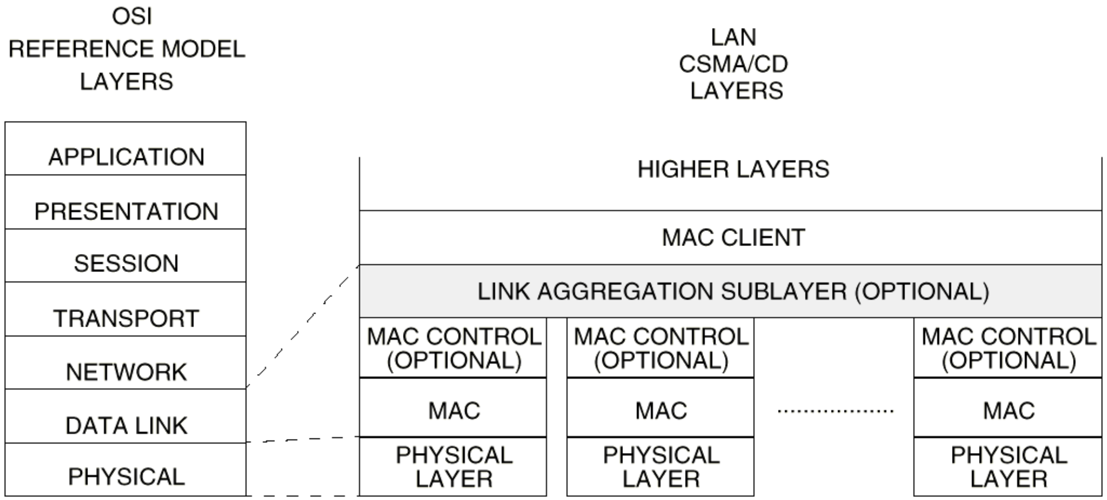
- Increased Bandwidth (duh)
- Incremental bandwidth increases - smaller jumps than 10 to 100 to 1000 - not perfect scaling, but better than one link’s worth
- Failure protection/redundancy (maybe)
- Automatic configuration - if it can aggregate, it will
- Rapid reconfiguration
- Deterministic behavior - configuration will not be dependent on the order in which events occurred
- NOTE: some of these goals are inconsistent (see later)

Layers Involved



- **IEEE Standard - adds to 802.3 CSMA/CD Standard**
- **Works with 10/100/1000 - portable to other MACs**

Layers Involved (cont.)



- **MAC Client is Bridge layer, LLC, etc.**
- **MAC Control (optional) is for Flow control (802.3x)**
- **MAC is CSMA/CD, CRC32, Frame Encapsulation**

This means Inter-Packet Gap and encapsulation is enforced by the individual link MACs (called physical MACs), but FCS and source MAC address can be sent from the single MAC above (e.g., if relayed)

No CSMA/CD since full-duplex required for link aggregation

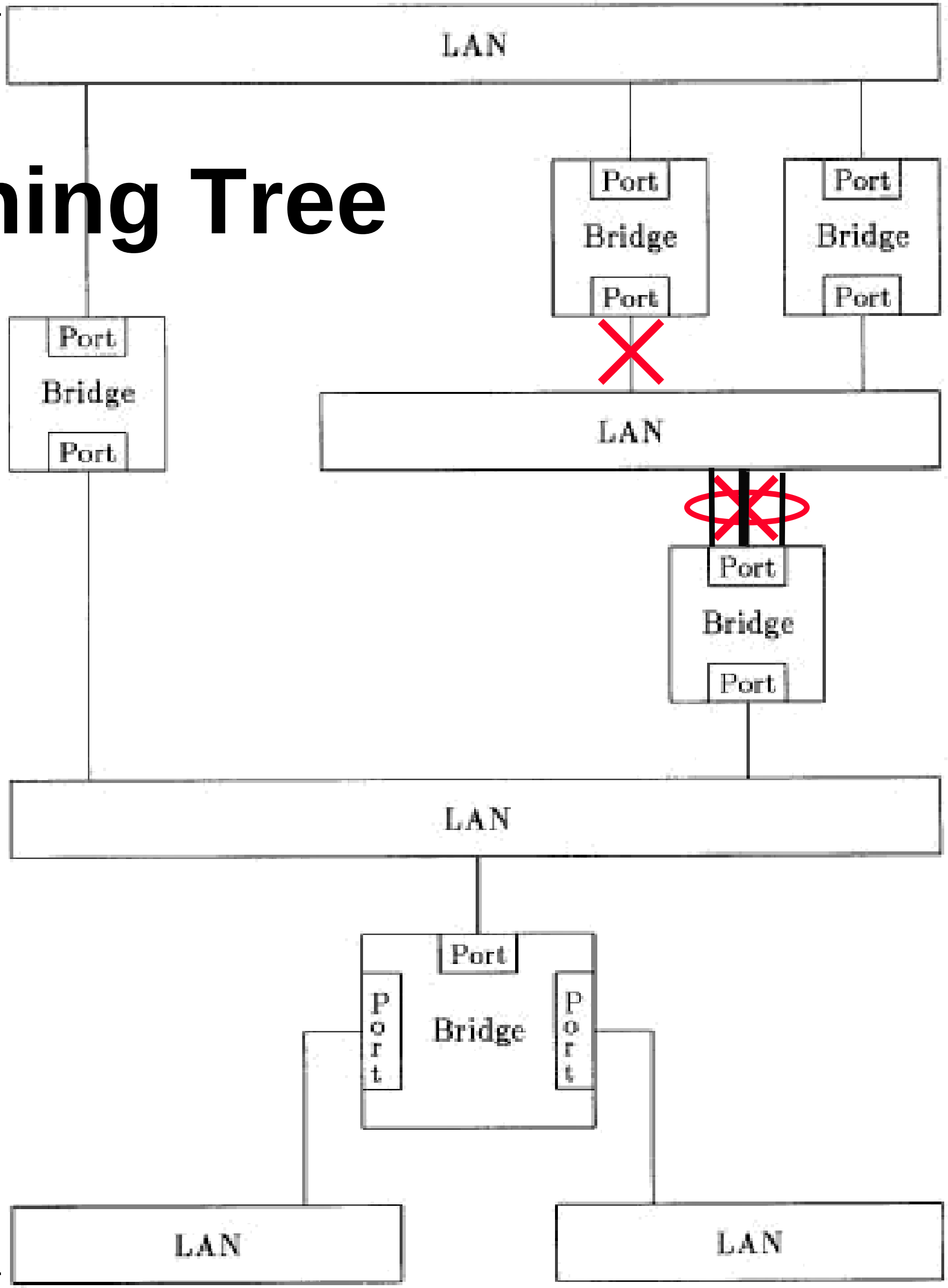
Notice the split happens at the traditional software layer, so changes need only be done in software (usually)

Flow control operates independent of the aggregation - it could pause link aggregation control frames (this is good, me thinks)

Spanning Tree

- **Assume redundant link on right is a trunk group**
- **Spanning Tree sees one logical link (because it operates above the LA sublayer)**

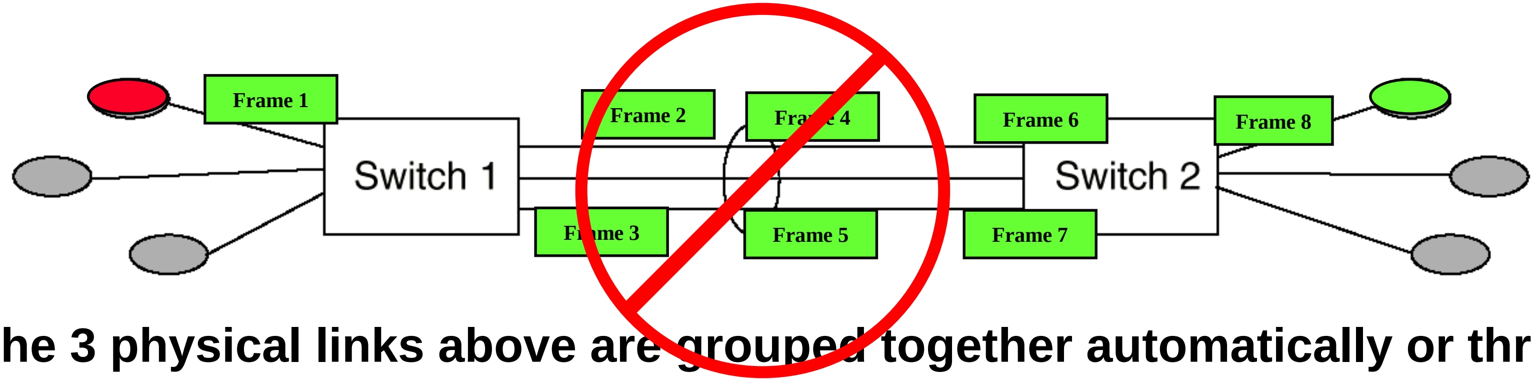
So Spanning Tree would disable the link - thus all physical links disabled
This is a bad example because it’s impossible for a bridge to be trunk linked to a shared medium (gotcha!)



Quick Overview

- Ports constantly send out packets
- When one or more cables are linked, they auto-configure an aggregate group link
- (yes, I do mean <u>one</u> or more)
- Once aggregated, they still send each other packets as a keep-alive

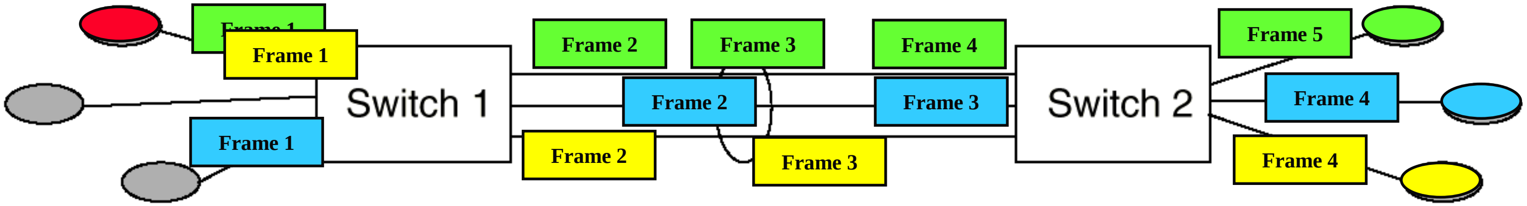
How it works (or doesn't)



- **The 3 physical links above are grouped together automatically or through configuration to be one logical link**
- **The green user on the right sends frames to the red user**

Each frame is NOT broken up/spread across the wires (we're still stuck with a normal MAC, after all)
Instead, they are each sent whole - on one wire.
Also, we CANNOT send one frame on one wire, another on a second wire, etc. (the way shown above) Why not?
Because they could arrive out of order - that would be BAD.

How it really works

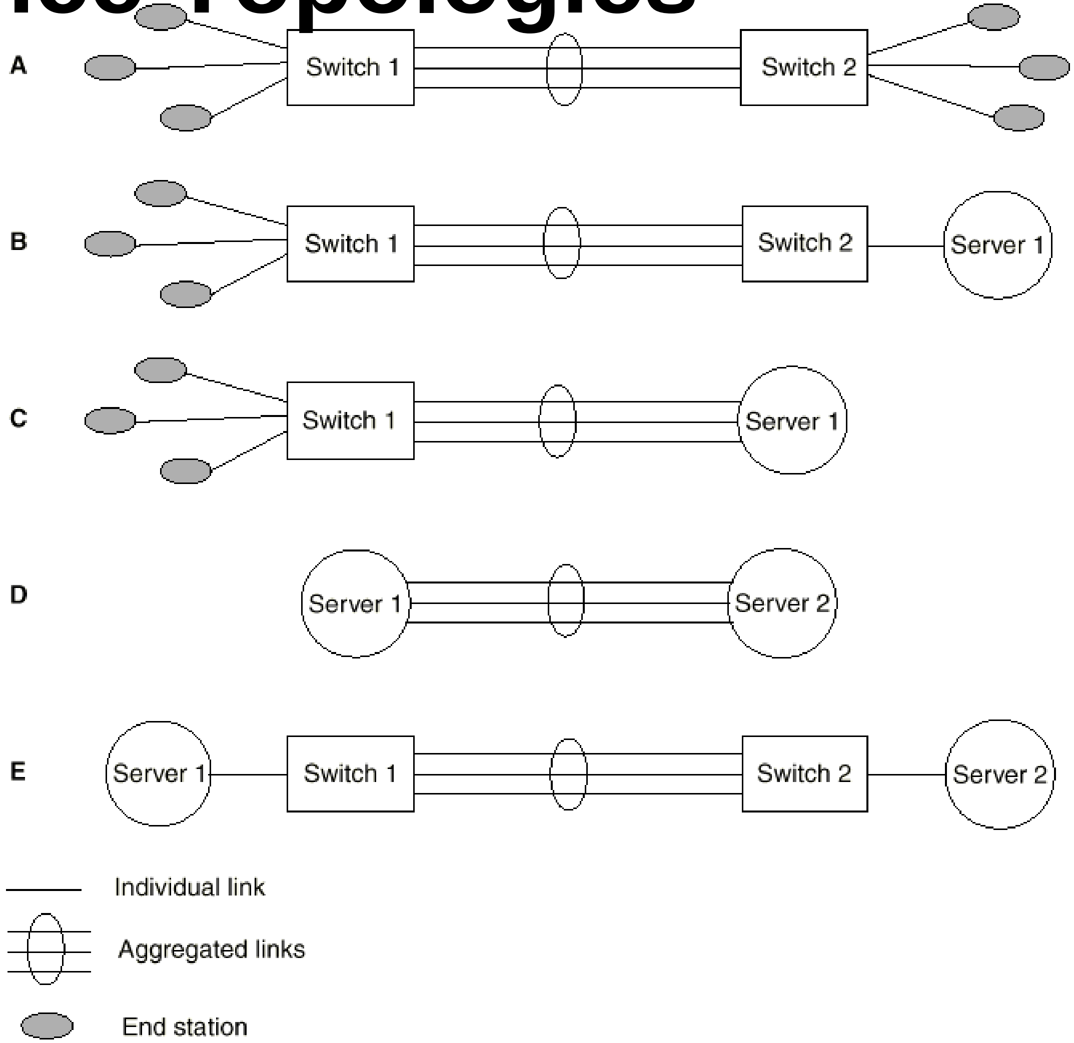


- So to protect against out of order delivery, the standard requires that the transmitting side (Switch 2) keep “conversations” together on one wire.
- A conversation is a one-way sequence of frames with same dest/src address for the same application. (i.e., anything that would be hurt by mis-ordering)
- In the case above, Switch 2 could keep all frames from station green to any other station on the same wire. (src. addr. based) So even if green sends frames to someone else on the left, it would still go through the same wire.

Likewise, any frames from other stations could be kept together on a separate wire. For example if blue and yellow sent frames, each of their streams could be on a separate wire. This is called a distribution algorithm, and is totally up to Switch 2. The standard only requires that a conversation not be misordered.

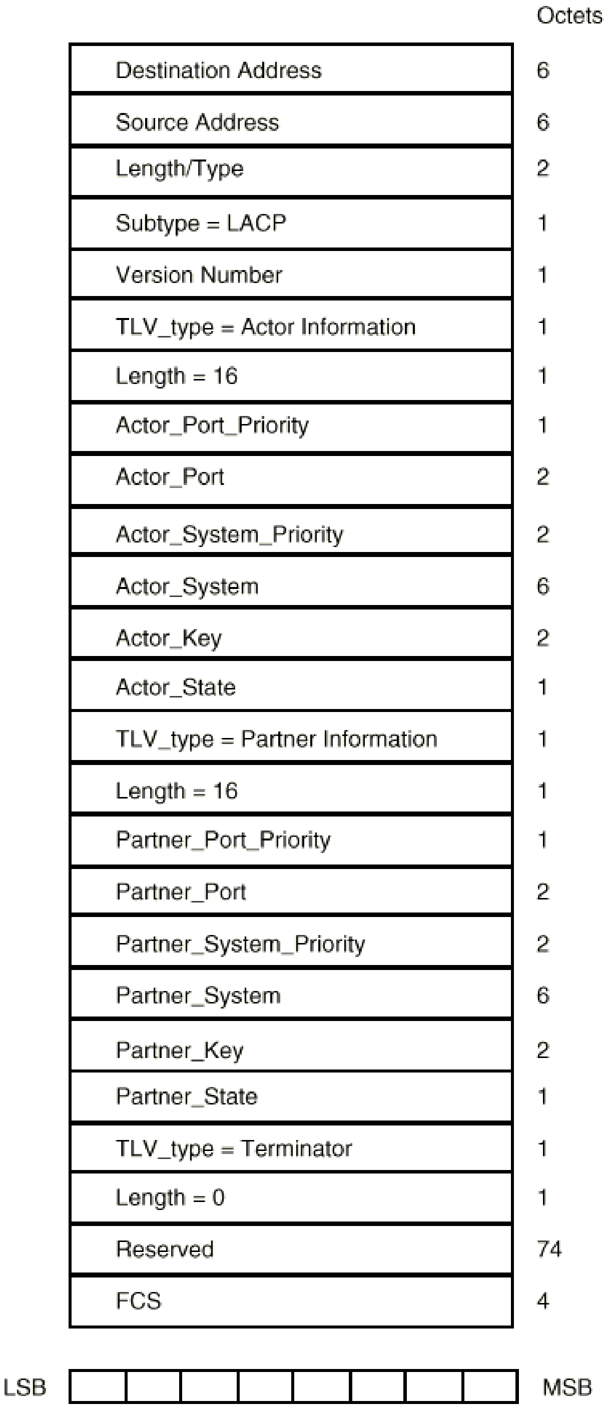
Reference Topologies

- Notice that repeaters cannot participate
- Each trunk link is one MAC layer to one MAC layer.
- All the trunks are MAC-to-MAC, but network A is many MAC addresses to many others, whereas B and C are many to one, and D and E are one to one. Thus the distribution algorithms will be different for them: based on src. addr., src & dest, src & dest & type, etc.



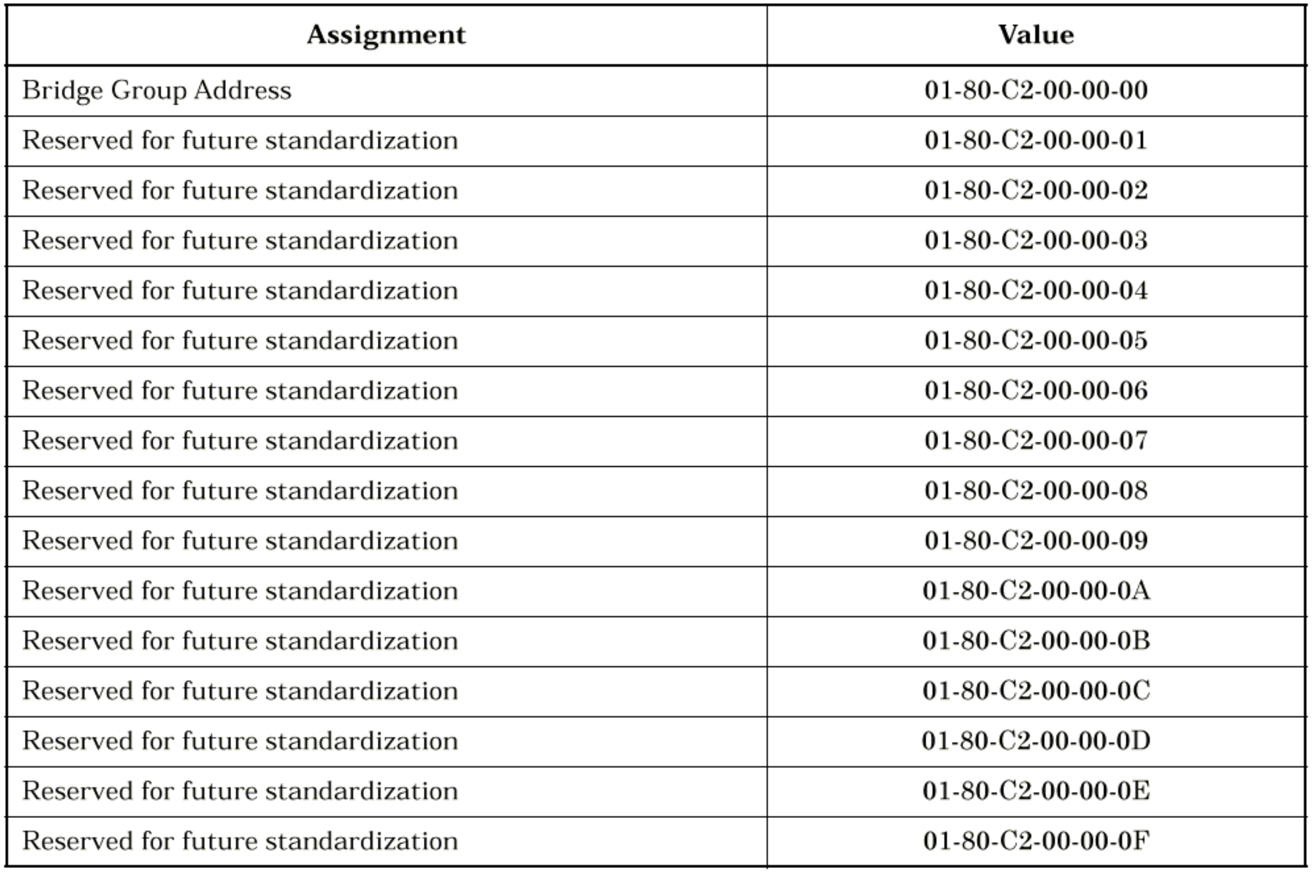
LACPDU

- **Link Aggregation Control (LAC) entities send each other configuration info using LACPDUs (LAC Protocol Data Units)**
- **The destination address of the LACPDU is a well-known multicast address**
- **If the link partner doesn't support LA, then it discards them (doesn't forward)**
- **Repeaters forward them like normal frames (remember, repeaters are layer 1 - they don't even know what a "frame" is!) - BUT if there's a repeater, then the link should be half-duplex and thus non-aggregatable (is that a word?)**



	Octets
Destination Address	6
Source Address	6
Length/Type	2
Subtype = LACP	1
Version Number	1
TLV_type = Actor Information	1
Length = 16	1
Actor_Port_Priority	1
Actor_Port	2
Actor_System_Priority	2
Actor_System	6
Actor_Key	2
Actor_State	1
TLV_type = Partner Information	1
Length = 16	1
Partner_Port_Priority	1
Partner_Port	2
Partner_System_Priority	2
Partner_System	6
Partner_Key	2
Partner_State	1
TLV_type = Terminator	1
Length = 0	1
Reserved	74
FCS	4

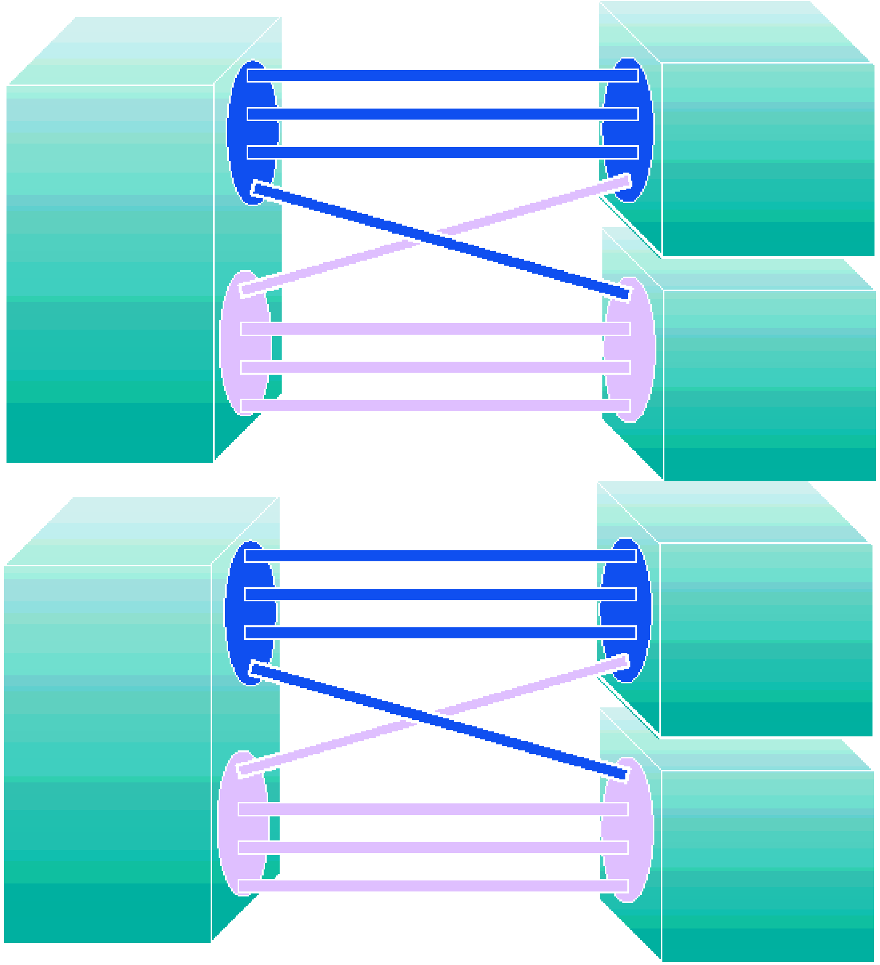
Destination Address



Assignment	Value
Bridge Group Address	01-80-C2-00-00-00
Reserved for future standardization	01-80-C2-00-00-01
Reserved for future standardization	01-80-C2-00-00-02
Reserved for future standardization	01-80-C2-00-00-03
Reserved for future standardization	01-80-C2-00-00-04
Reserved for future standardization	01-80-C2-00-00-05
Reserved for future standardization	01-80-C2-00-00-06
Reserved for future standardization	01-80-C2-00-00-07
Reserved for future standardization	01-80-C2-00-00-08
Reserved for future standardization	01-80-C2-00-00-09
Reserved for future standardization	01-80-C2-00-00-0A
Reserved for future standardization	01-80-C2-00-00-0B
Reserved for future standardization	01-80-C2-00-00-0C
Reserved for future standardization	01-80-C2-00-00-0D
Reserved for future standardization	01-80-C2-00-00-0E
Reserved for future standardization	01-80-C2-00-00-0F

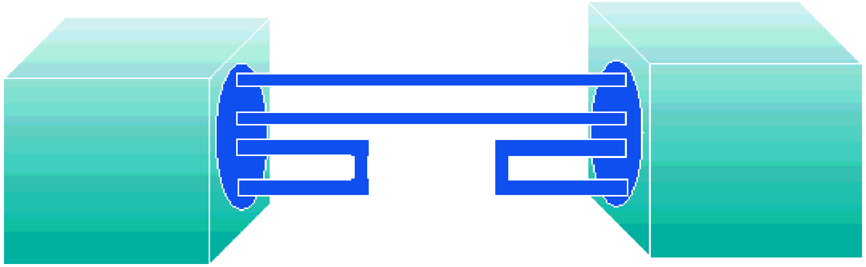
- **LACPDU Destination Address is a multicast of the type not forwarded by bridges (even if they don’t know what it’s for, they won’t forward it)**

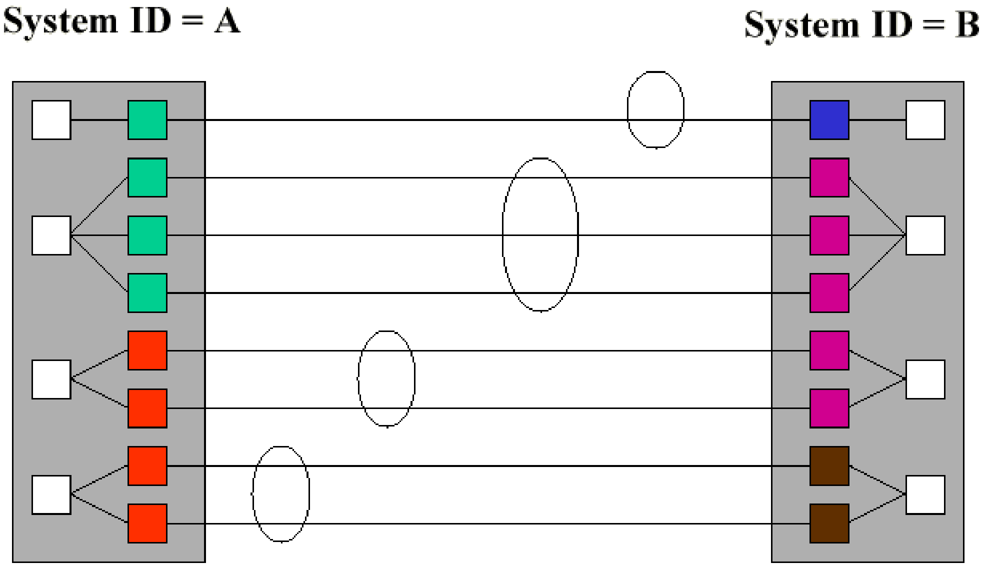
Some Background on Selection



- Wanted auto-config to avoid user mistakes, as well as be flexible
- For instance, when the user crosses wires from 2 systems (shown left)
- By using a System ID Key, this can be detected and fixed

More Goals



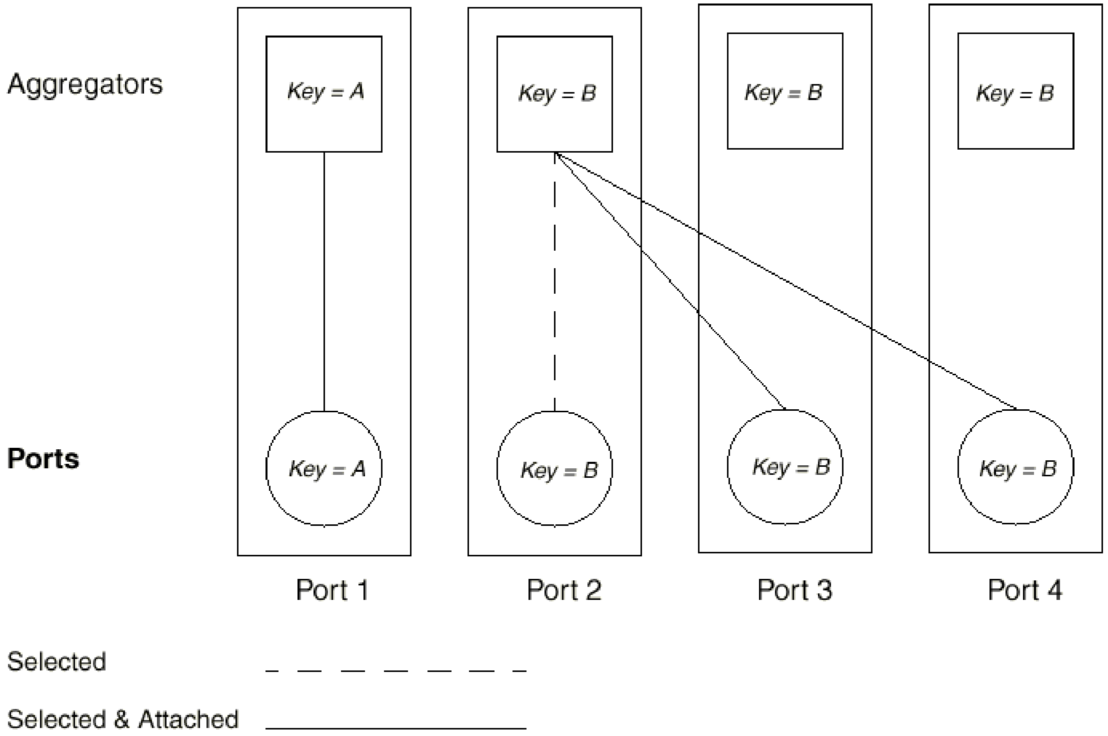


- Can also detect loopbacks and disable ports

Plus need Port ID Keys to detect which ports can be aggregated together

So for two systems A and B with ports 1 and 2, we call it {A1,B2}

One more set of Keys



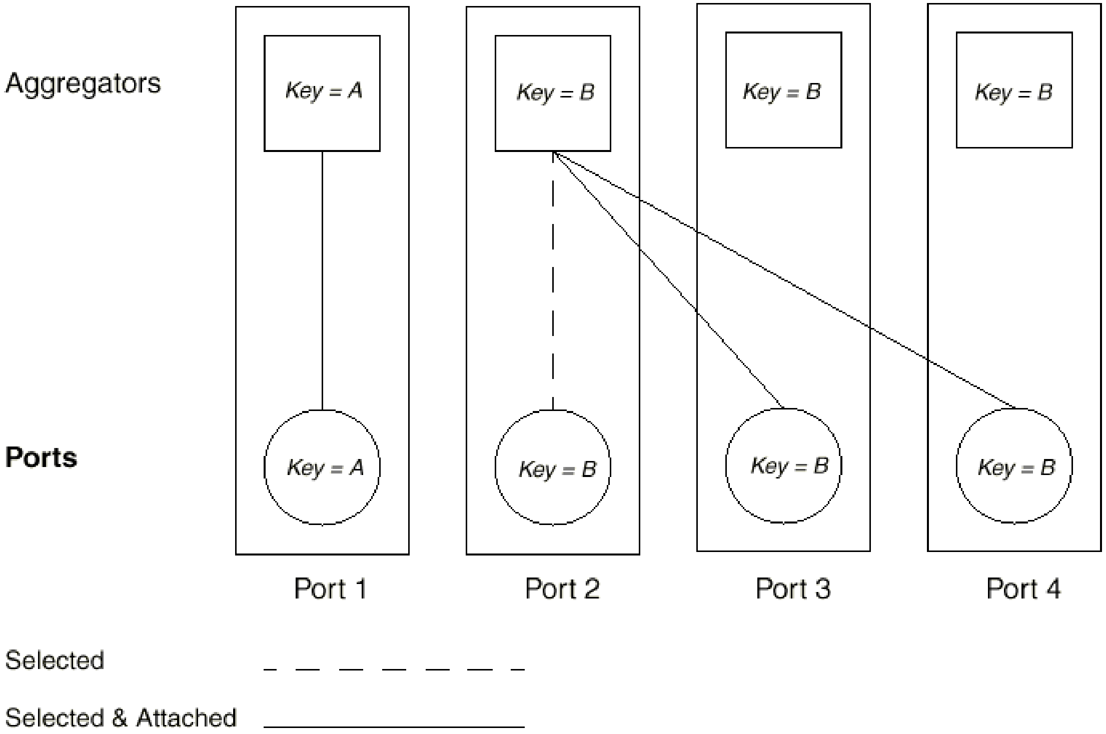
- **For manual config, and alernative selection algorithms, the Aggregators need a Key**
- **This way the Agg Group MAC address can be assigned to the ports**
- **Port selects Agg with same Key as itself**
- **This Key is internal - not transmitted - only port key and sys ID transmitted**

Selection Logic

- IEEE wanted differing implementations of selection, as long as the following are kept:
  - Each port assigned a Key - ports that can agg together have the same key - else unique Key
  - Each Aggregator assigned a Key and MAC address
  - Ports only select Aggs with same Key
  - Ports in the same LAG use the same Aggregator
  - Individual ports each have their own Agg
  - If a port can't select an Agg due to rules above, then it can't be attached to one
  - MAC Client won't see the port until it's selected and attached
- That's it. This leaves a lot open.

Default Selection Operation

- When multiple ports in an aggregation, select the lowest number Aggregator of the ports in the aggregation
- That port may be just selected but not attached



This algorithm has a flaw - can you see it?

Problems

- Not necessarily deterministic
- If deterministic, then a failover can take the net down for a LONG time (due to spanning tree)
- A few too many options for users
- Doesn’t support full-duplex repeaters (yes, there is a such a thing)

This page left intentionally blank.

This page left intentionally blank.

This page left intentionally blank.

Multiple Spanning Trees

802.1s

Multiple Spanning Trees

- If multiple VLANs are run on a network, they all run on the same spanning tree
- This means unused (blocked) links don’t carry any traffic
- But traffic from separate VLANs can be sent on different spanning trees, thereby utilizing the blocked ports
- So now one can assign VLANs to separate spanning trees
- (This is NOT trivial to actually deploy)

Rapid Reconfiguration

802.1w

Rapid Reconfiguration

- A broken spanning tree can take 50 seconds to re-converge
- A new algorithm, using new BPDU frames, can decrease the time down to 10 milliseconds (best case)
- It’s backwards compatible with legacy 802.1D bridges (they won’t converge faster, but they will work)

Port Based Network Access

802.1X

LAN Security

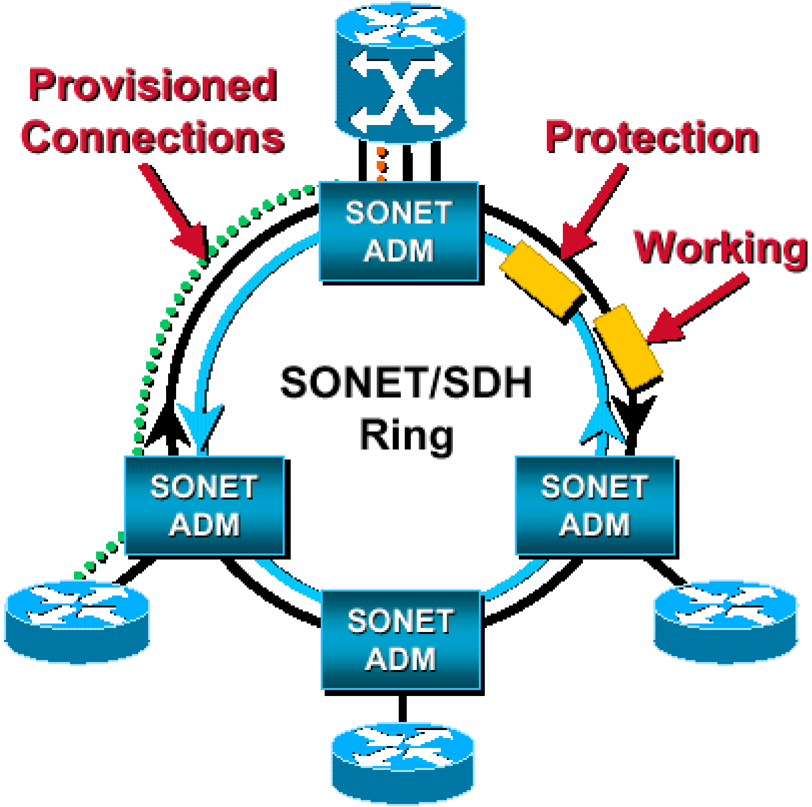
- Anyone can connect their notebook/PC to a switch and use/snoop the network
- 802.1x provides a method whereby the switch only allows the user to contact a RADIUS server with EAP packets to be authenticated
- Once authenticated the user will be able to access the net
- This is NOT fool-proof, but good enough for hotels, libraries, etc. (not good enough for the government)

Resilient Packet Rings

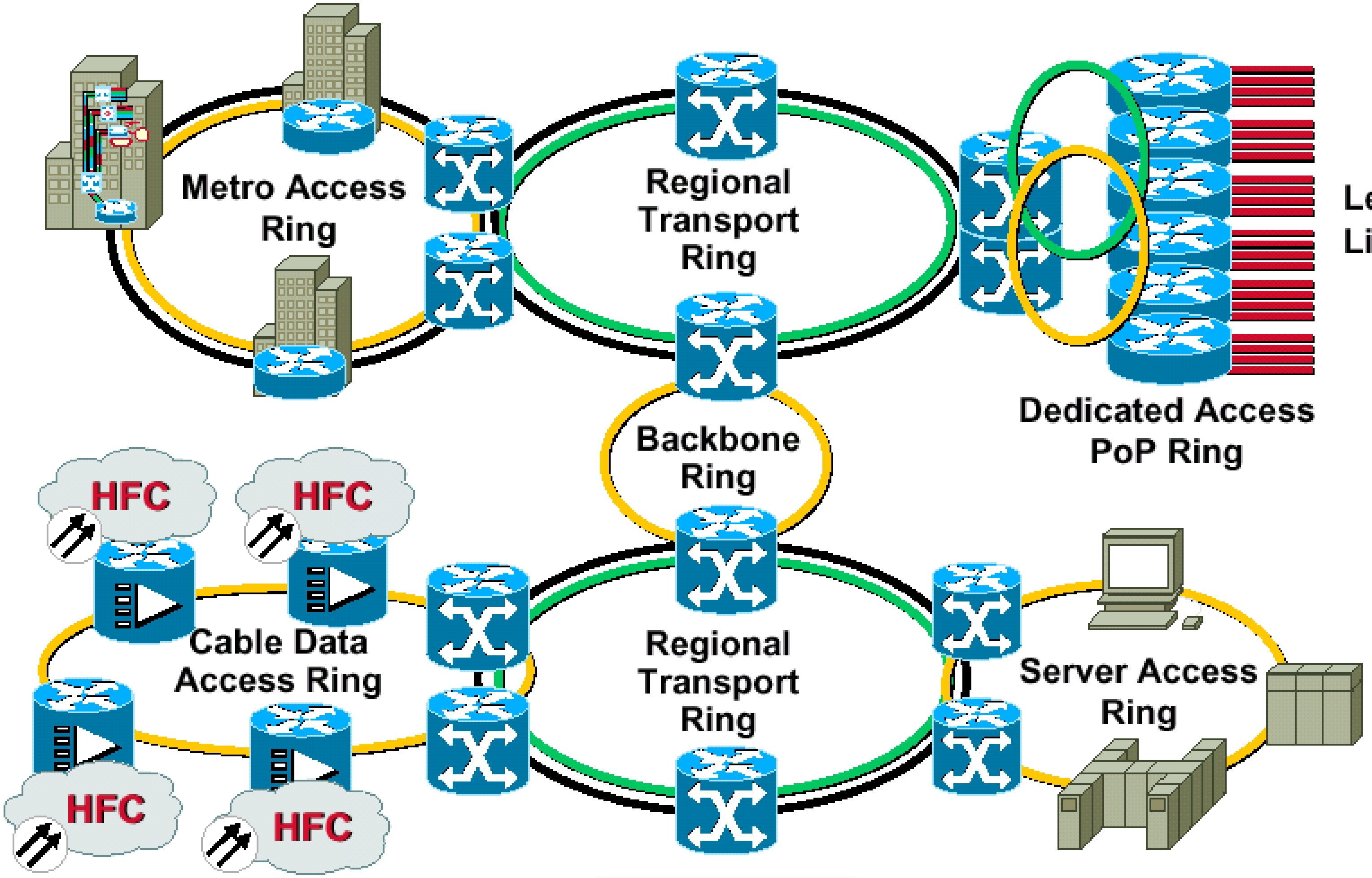
802.17

Resilient Packet Rings

- In a SONET ring, half of the fiber is never used for real traffic – this is a waste of possible bandwidth – better to use both rings
- Currently, several vendors (Cisco, Nortel, Lucent) have proprietary methods
- There’s still debate about the need for the standard, but they’re trying to move forward – working group 802.17



RPR Applications



RPR’s Goal

- Reuse as much of Ethernet as possible
  - Frame format (mostly)
  - Physical speeds (the higher ones)
  - Marketing name power (definitely)
- Connect in a ring topology like SONET & FDDI
- Have a fast SONET-like protection fail-over
- Apply QoS from upper layers to Layer 2
  - Similar to 802.1p but for media access as well
  - Possible changes/additions to IP to make use of it (yes, that sounds incredibly stupid, but there are people pushing for this)
- Create more work for people

This page left intentionally blank.

This page left intentionally blank.

Ethernet in the First Mile

802.3ah

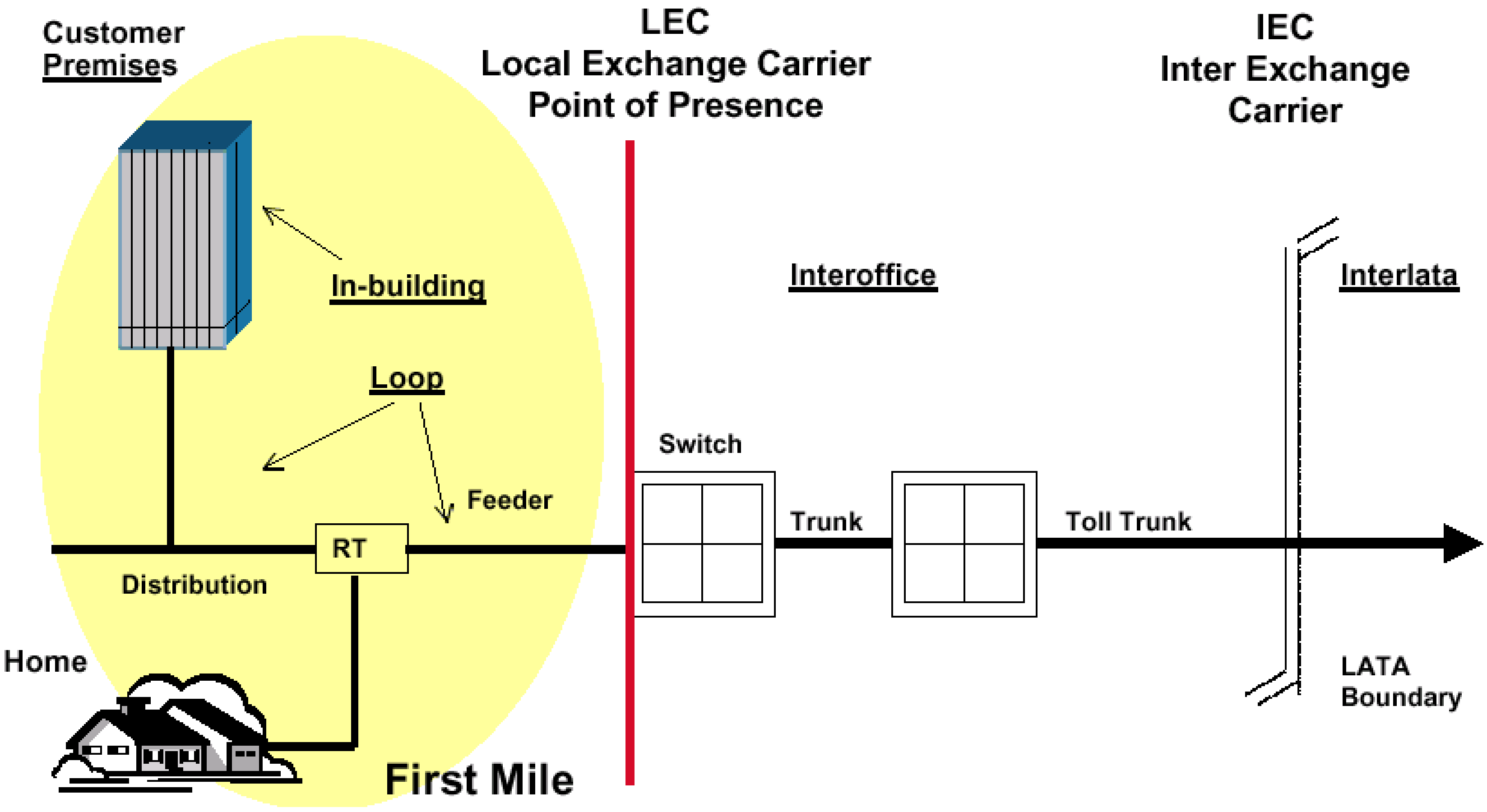
EFM

- VERY early stages – had 2 meetings so far
- Basic idea is delivering Ethernet to the local loop for FTTH, FTTC, FTTB markets
- Currently multiple vendor options for Multi-Tenant Units (MTU)
- Easy problem: getting industry interest (100-150 people at each meeting so far)
- Hard problems: determining the business models and market direction for the application

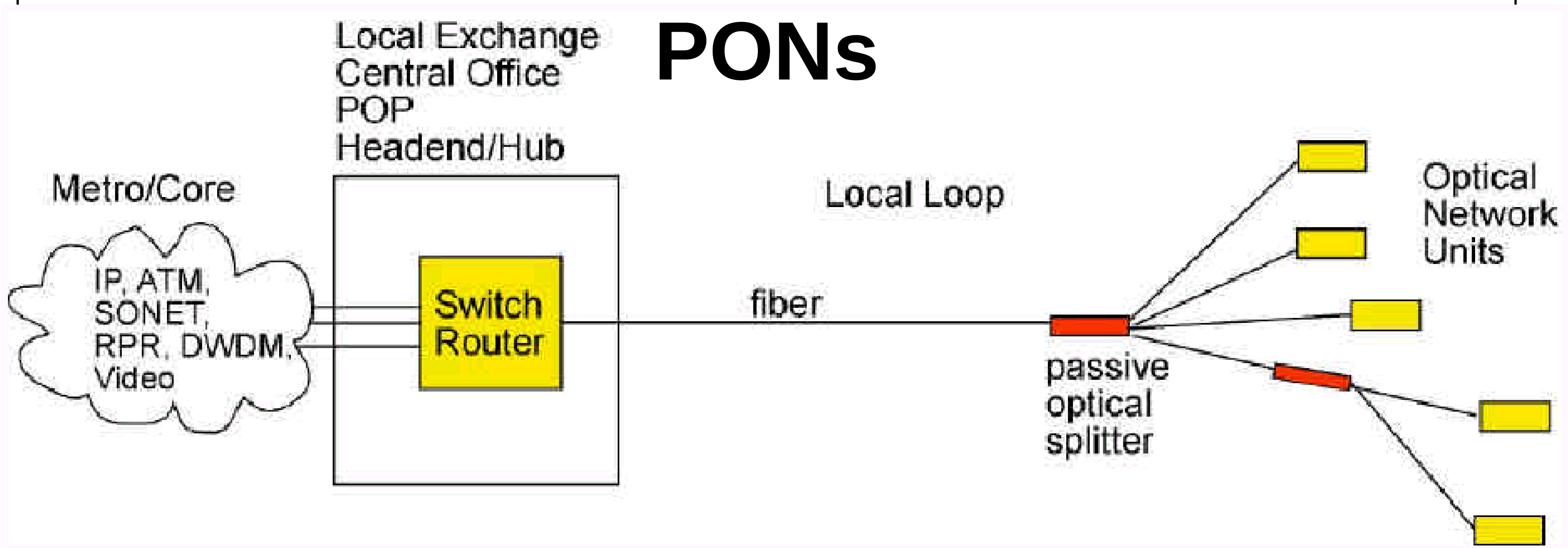
EFM Work

- Fiber Loop
  - Basic Gig Ethernet from CO to switch in the field out to CPE, like a bigger LAN – only needs some missing pieces
    - » Adds 1Gig over single-fiber (bi-directional) for 10km
  - PONs (Passive Optical Networks) using passive splitters
- Copper Loop
  - At 10mbps for <750m
  - Replace DSL MAC layer with Ethernet but use same PHY (thus, copper loop)
- Specify OAM
  - Remote failure, loopback, and link monitoring

First Mile Copper



PONs



- Passive Optical fiber plant, based on splitters
- Logically equivalent to Cable TV (HFC) plant
- MAC access protocol like DOCSIS over fiber – broadcast down from headend, upstream is TDM-like (requested slots of varying length)
- APON: ATM version, standardized by ITU and FSAN but no interop
- EPON: Ethernet frame version

This page left intentionally blank.

This page left intentionally blank.

This page left intentionally blank.

Wrap-Up

The Future

Acknowledgements

- **Some of the slides, drawings, and animations were ~~stolen~~ borrowed from:**
  - Gerry Nadeau
  - Benjamin Schultz
  - Adam Healey
  - Rupert Dance
  - Gary Pressler
  - Eric Lynskey
  - The IEEE standards and website

Websites

- **To get the most recent version of this presentation, wait 1 week, then go to:**

  http://www.iol.unh.edu/training/ethernet.html

- **IEEE website: http://grouper.ieee.org/groups/802**
- **IETF website: http://www.ietf.org**
- **10 Gigabit Ethernet Alliance: http://www.10gea.org**
- **My email address:**
  - **hadrielk@yahoo.com**

Acronym Expansion

- ARP – Address Resolution Protocol – the protocol used to discover a device's Ethernet address based on its IP address
- ATM - Asynchronous Transfer Mode – the Broadband-ISDN protocol based on circuits and cell switched communications.
- AUI – Attachment Unit Interface
- BPDU – Bridge Protocol Data Unit
- CIR – Committed Information Rate – the bandwidth level/rate for Frame Relay circuits which the user has agreement to transmit for
- CoS – Class of Service
- CRC – Cyclical Redundancy Check – a 4-byte value produced from a polynomial function, used to validate the integrity of the contents of the frame (like a parity check, or checksum)
- CSMA/CD – Carrier Sense, Multiple Access with Collision Detection – the name and description of the half-duplex protocol used to access the network in an Ethernet network
- CWDM – Coarse Wavelength Division Multiplexing – a method of sending multiple independent signals on the same fiber by sending them at different wavelengths (colors) – the Coarse version of WDM usually implies very few wavelengths are used (6 or less) and they may not be in the same band
- DIX – Digital, Intel, and Xerox – the three companies that produced interoperable Ethernet products before moving into an 802.3 working group to become a standard
- DMD – Differential Modal Delay
- DOCSIS – Data over Cable System Interface Specification – the industry standard for data communications over cable TV systems

Acronym Expansion

- DSCP – DiffServ Code Point – the binary value field in the IP packet to mark a packet with a particular per-hop behavior (PHB) for QoS parameters
- DTE – Data Terminal Equipment
- DWDM – Dense Wavelength Division Multiplexing – a method of sending multiple independent signals on the same fiber by sending them at different wavelengths (colors) – the Dense version of WDM usually implies all of the more than 8 wavelengths are within a fixed narrow band
- FEXT – Far End Crosstalk
- FR - Frame Relay - A packet-switched method of data communication (similar to, but more efficient than, the original X.25 WAN protocol) provided by telecommunications carriers and Internet service providers (ISPs). Frame Relay can provide guaranteed bandwidth at no additional charge if the lines are “open” during periods of low traffic. Frame Relay can run at speeds of 36 Kbps to 2 Mbps. It is now enjoying high popularity as a reasonably priced alternative to leased line service.
- FRF – Frame Relay Forum – the industry forum that coordinates and advances standards for Frame Relay.
- FCS – Frame Check Sequence
- GARP – Generic Attribute Registration Protocol
- GMRP – Generic Multicast Registration Protocol
- GMII – Gigabit Media Independent Interface
- GVRP – Generic VLAN Registration Protocol

Acronym Expansion

- IEEE – Institute for Electrical and Electronics Engineers – the standards body that defines electrical standards, including the 802 LAN/WAN committee which defines such protocols as Ethernet and Token Ring.
- IETF – Internet Engineering Task Force – the standards body that defines protocols for the Internet.
- IP - Internet Protocol - The communication protocol of the Internet. (version 4 is the current version)
- IPv6 – IP version 6 – the heir apparent for the current IP version 4 – version 6 adds a much larger address space, security, auto-configuration, and anycasting
- IPG – Inter-Packet Gap – the idle period between packets, defined as minimally 96 bit times
- ISDN - Integrated Services Digital Network - Allows for end-to-end digital transfer of voice and data. ISDN, used primarily by small offices, home offices, and individual households, combines digital switching and digital transmission and offers higher bandwidths than current analog modems.
- ISP - Internet Service Provider - A service company that provides customers access to the Internet.
- ITU – International Telecommunications Union – (formerly the CCITT) the standards body that defines many international standards, including the phone system.
- LLC – Logical Link Control
- LTP – Link Test Pulse
- MAC – Media Access Control – The layer of the 802.3 stack above the Physical below the Logical Link layer – the MAC is responsible for encapsulating/decapsulating the packet with Ethernet fields, accessing the medium (either in half-duplex or full-duplex mode), and padding or removing the pad on receipt.

Acronym Expansion

- MAU – Medium Attachment Unit
- MDI – Media Dependent Interface
- MFD – Multiple Forwarding Database – a bridge that supports independent learning, using a separate bridge table for each VLAN
- MII – Media Independent Interface – the interface between the Physical and MAC layers – it can be a physically exposed interface allowing the user to replace the transceiver (e.g., to use a fiber transceiver instead of copper)
- MMF – Multi-Mode Fiber
- MPLS - Multi-Protocol Label Switching – an IETF standard for assigning tags to multiprotocol frames for transport across packet or cell-based networks. It is based on the concept of label swapping, in which units of data (e.g., a packet or a cell) carry a short, fixed-length label that tells switching nodes how to process the data.
- NAT – Network Address Translation – the method whereby fake/illegal IP addresses are used inside a user's network and are translated to a real address on the public side of the NAT router/gateway. Also sometimes called NAPT for Network Address and Port Translators because they translate both addresses and TCP/UDP ports.
- NEXT – Near End Crosstalk
- NIC – Network Interface Card
- OC-3/12/48/192 - Optical Carrier Levels 3, 12, 48, and 192. SONET (Synchronous Optical Network) line interfaces/rates based on multiples of OC1 at 51.84mbps, so OC-3 would be 155.52mbps.

Acronym Expansion

- OSI - Open Systems Interconnection (Model) - An international set of rules for computer networking that creates open standards to allow a computer on any network to share iformation with any other computer on that network or a connected network. The OSI model is divided into seven layers based on the function and intelligence of the transmission equipment involved.
- PCS – Physical Coding Sublayer – a layer within the PHY that encodes/decodes the bitstream
- PHY – Physical Layer – the layer between the MAC layer and transmission medium (cable)
- PMA – Physical Medium Attachment
- PMD – Physical Medium Dependent – the lowest layer of the Physical layer that attaches to the transmission medium
- PON – Passive Optical Network
- QoS – Quality of Service
- RS – Reconciliation Sublayer
- RSVP – Resource reSerVation Protocol – the protocol used for reserving bandwidth for a particular flow.
- RTP – Real-time Transport Protocol – the IETF standard for a light-weight, sequenced, transport protocol to carry time-sensitive data.
- RTCP – Real-time Transport Control Protocol – a control protocol for RTP streams

Acronym Expansion

- SDH - Synchronous Digital Hierarchy - The European version of the SONET standard with two major differences: (1) the terminology and (2) the basic line rate in SDH is equivalent to that of the SONET OC-3/STS-3 rate (i.e., 155.52 Mbps). SDH is the ITU standard for high-capacity optical transmission.
- SFD (1) – Start Frame Delimiter – the byte after the 7 byte preamble used to indicate the beginning of the MAC frame
- SFD (2) – Single Forwarding Database – a bridge that supports shared learning, using the same bridge table for every VLAN
- SMF – Single-Mode Fiber
- SNMP - Simple Network Management Protocol - A protocol used in the development of network management S. It is used to report on the status of a network and the devices attached to it.
- SOHO - Small office/home office.
- SONET - Synchronous Optical Network - A transmission technology based on overlaying a synchronous multiplexed signal onto a light stream transmitted over fiber-optic cable. SONET is the ANSI standard for transmitting digital information over optical networks. Fiber-optic transmission rates range from 51.84 Mbps to 10 Gbps. SONET defines a physical interface, optical line rates, frame formats, and an OAM&P protocol. The base rate is known as OC-1 and runs at 51.84 Mbps. Higher rates are multiples of 51.84 Mbps.
- TDM - Time Division Multiplexing - An electrical multiplexing technique for transmitting a number of separate data, voice, and/or video signals simultaneously over one communications medium by quickly interleaving a piece of each signal one after the other

Acronym Expansion

- TCP - Transmission Control Protocol – the reliable, connection-oriented protocol for transporting data.
- UDP – User Datagram Protocol – the unreliable, connectionless protocol for carrying data.
- UTP – Unshielded Twisted Pair
- VID – VLAN ID – the VLAN number
- VLAN – Virtual Local Area Network – a method whereby the Layer-2 broadcast domain is broken up into multiple broadcast domains, by assigning some ports on switches to be in the same "VLAN" as other ports. This limits those ports to only be able to communicate (at layer 2) with others of the same VLAN (i.e., it requires a router to pass traffic between different VLANs).
- VoIP – Voice over IP – providing voice service over an IP data network instead of the traditional TDM-based method.
- VPN – Virtual Private Network
- X.25 - A standard (the standard's document number is X.25) for handling data in a packet-switched network (the predecessor to Frame Relay) that uses a virtual circuit to establish a connection between a sender and a receiver. Transmission in an X.25 network ranges from 9.6 Kbps to 64 Kbps and operates on levels 1, 2, and 3 of the OSI model.