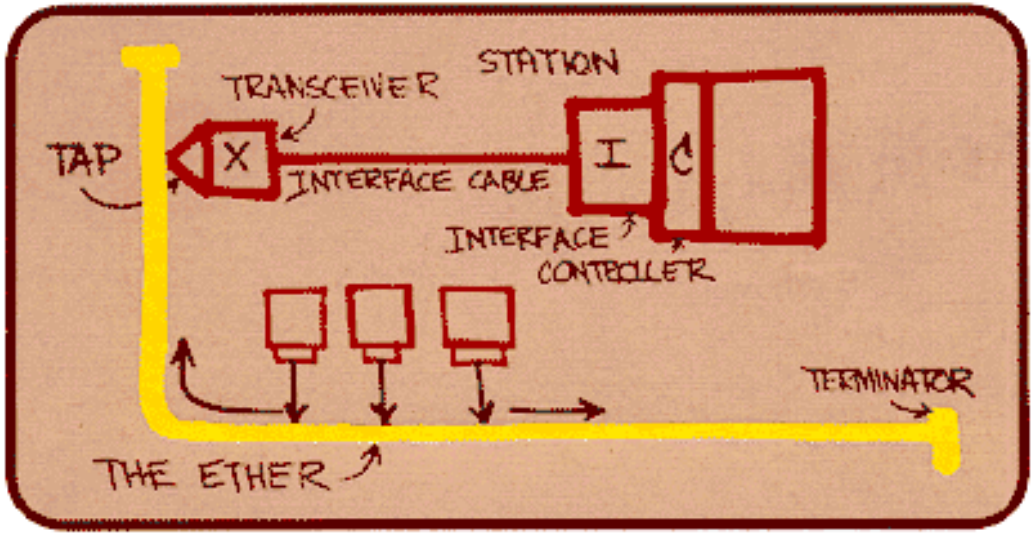
Carrier Ethernet Roll-out (i)

ALBEDO Telecom

the Path to Excellence

Ethernet: A Success Story

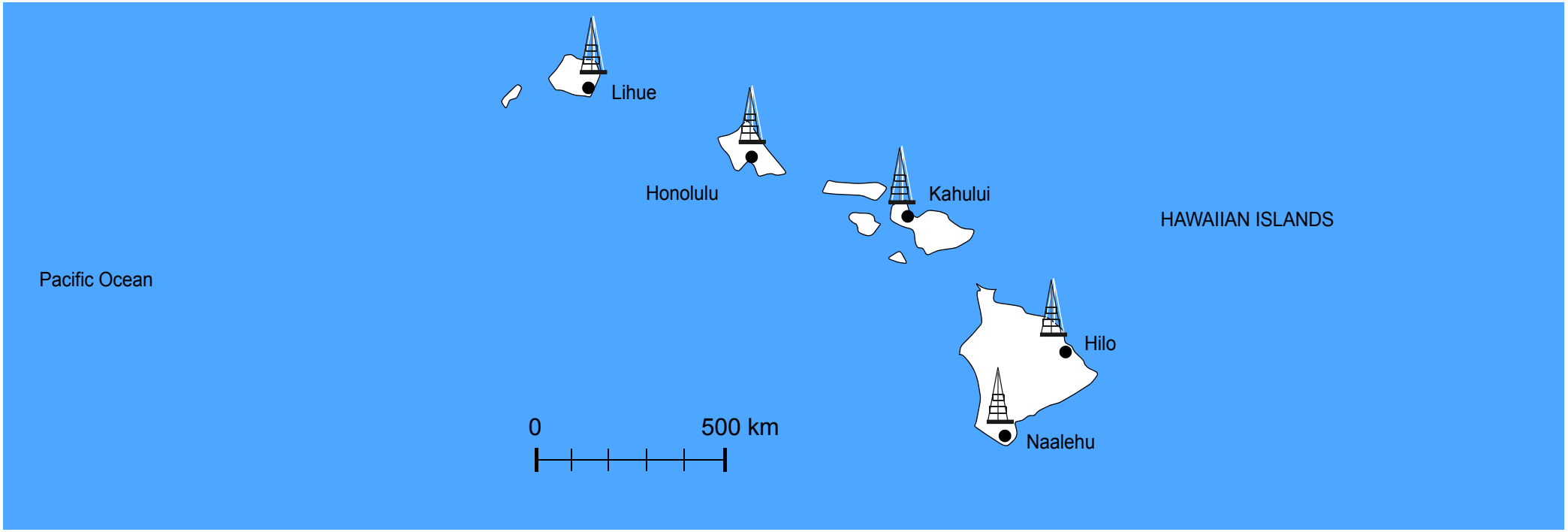


Ethernet is the *de facto* standard in Local and Campus Networks.

Ethernet refers to a family of technologies for LAN that have some things in common:

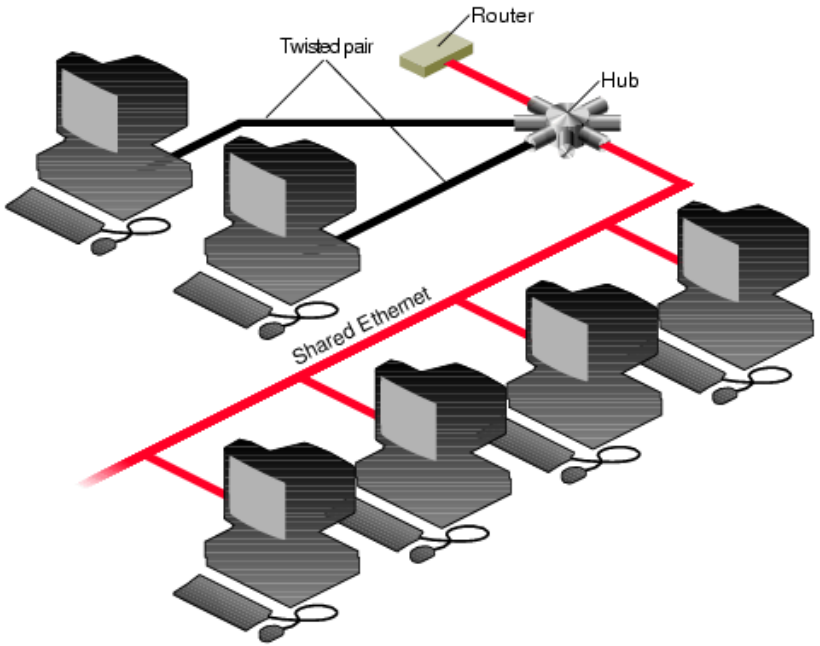
- Packet-oriented and statistical multiplexing technology
- Very efficient for data transport
- MAC layer and frame formats (common to all Ethernet)
- Connectionless; requires a bridging procedure of constant address learning
- Low cost, scalable, multiple transmission media
- Distributed control plane
- L2 VPNs: Point and multipoint configurations

A Brief History of Ethernet



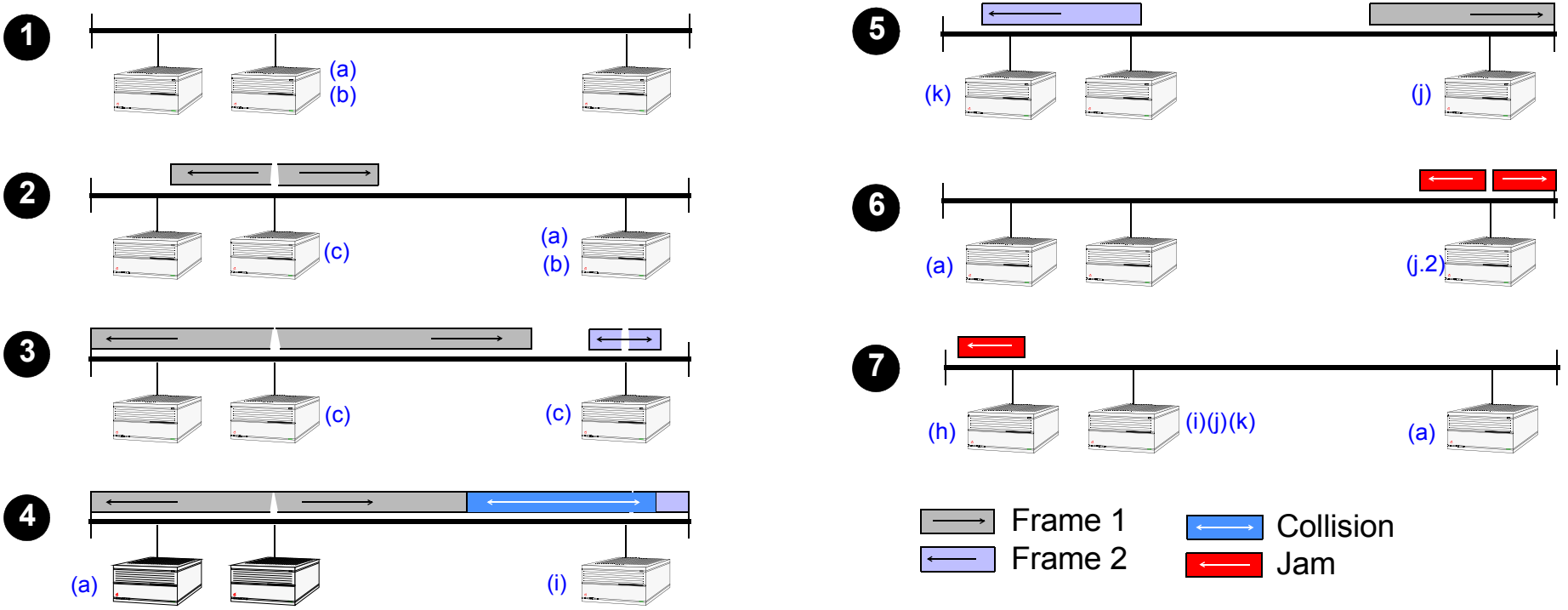
- 1968: ALOHA
- 1973: Bob Metcalfe CSMA/CD
- 1983 IEEE 802, 1986 Fibre Optic link, Repeater, etc.
- 1990 10BASE-T, 1994: 100BASE-T, 1997: Gigabit Ethernet, 1999:1000BASE-T, etc.
- 2002: 10 Gigabit Ethernet, 2004: Local Loop Ethernet

Ethernet Architecture



Section

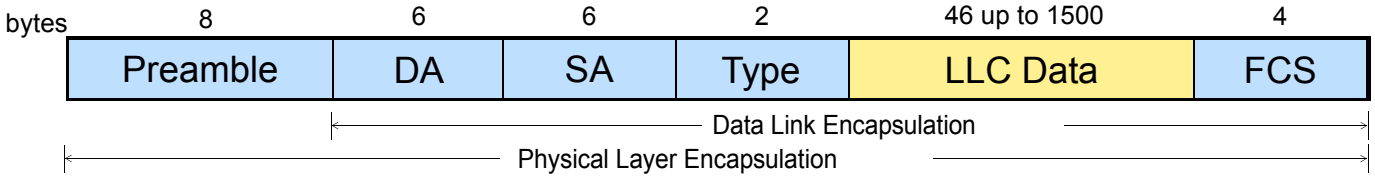
Half-Duplex CSMA/CD



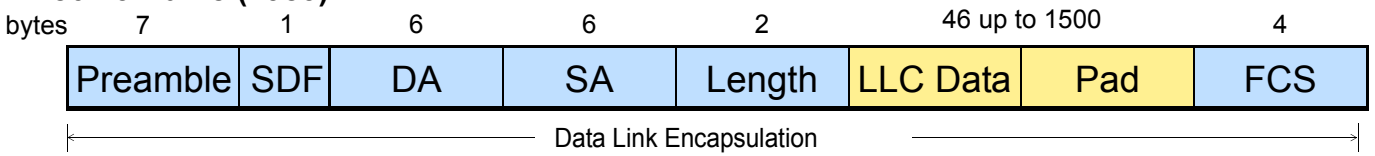
- In half-duplex mode, two or more stations may attempt to transmit at about the same time, and a collision may occur.
- If there is a high number of collisions, network efficiency is severely affected.

802.3 MAC Frame Formats

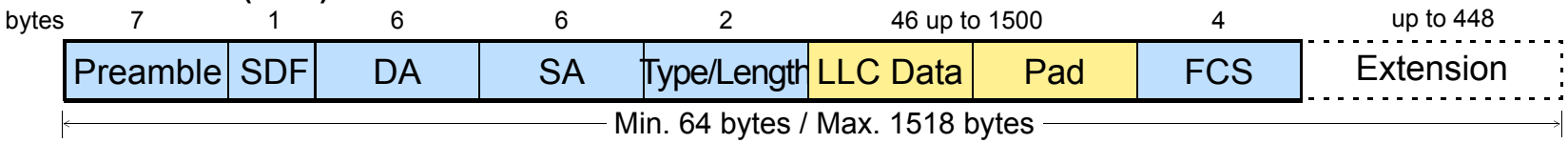
DIX frame (1970):



IEEE 802.3 frame (1983):

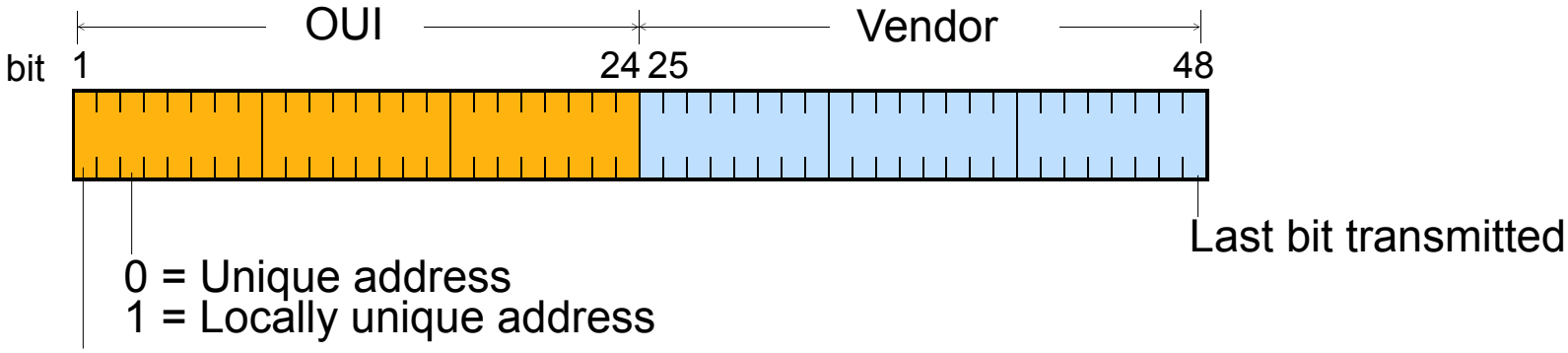


IEEE 802.3x frame (1997):



Preamble: Synchronization pattern
SDF: Start Frame Delimiter (10101011)
DA: Destination Address
SA: Source Address
Type: Indicates the nature of the client protocol (IP, IPX, AppleTalk, etc.)
Length: Number of bytes of the LLC data
LLC data: Information supplied by the LLC layer
Pad: Bytes added to ensure a minimum frame size of 46 bytes
Extension: Only for Gigabit, ensures a minimum frame size (depending on the version)
FCS: Frame Check Sequence CRC code based on all the fields except Preamble and SDF

Address Coding

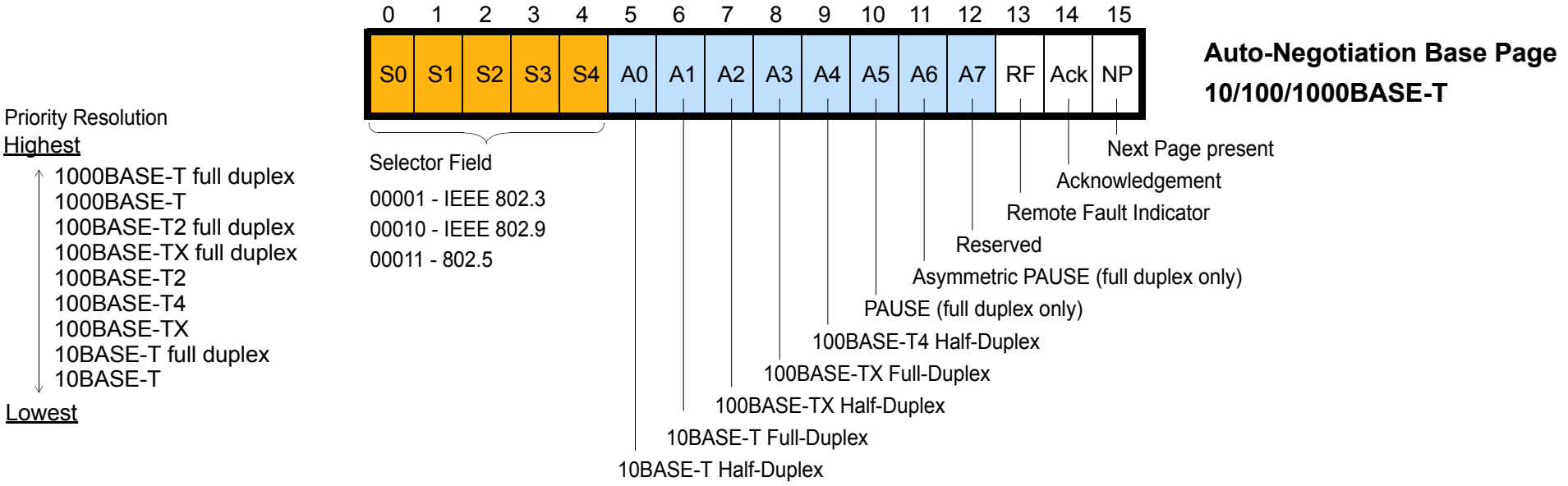


OUI (Organizationally Unique Identifier), IEEE administrated code

Vendor Code administrated by the manufacturer

- The layer-2 MAC addresses are not hierarchical
- To get a full addressing capability, a layer-3 address is required

Auto-Negotiation

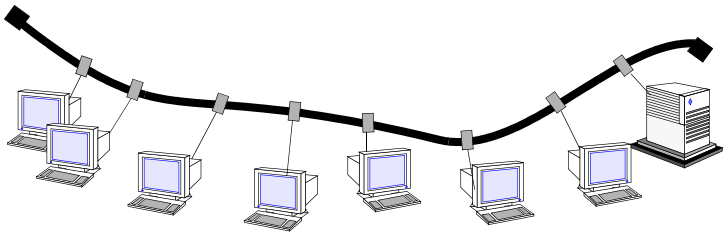


Some of the many Ethernet versions can talk to each other by means of *Autonegotiation*:

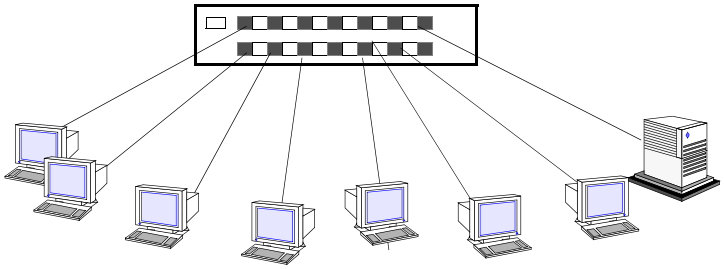
1. Inform the far end on which Ethernet version and options have been implemented
2. Acknowledge features that both stations share, and reject those that are not shared
3. Configure each station for highest-level mode of operation that both can support

Ethernet evolution

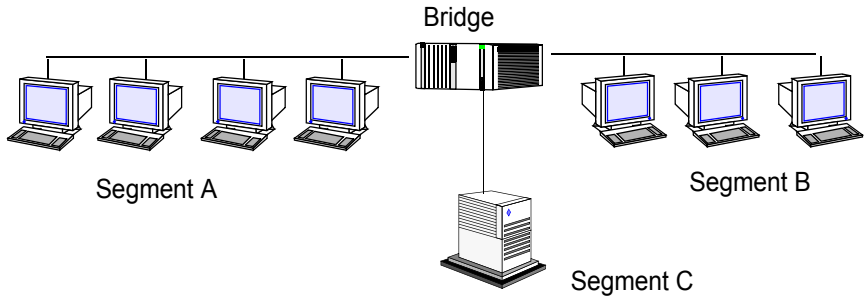
From Shared to Dedicated Media

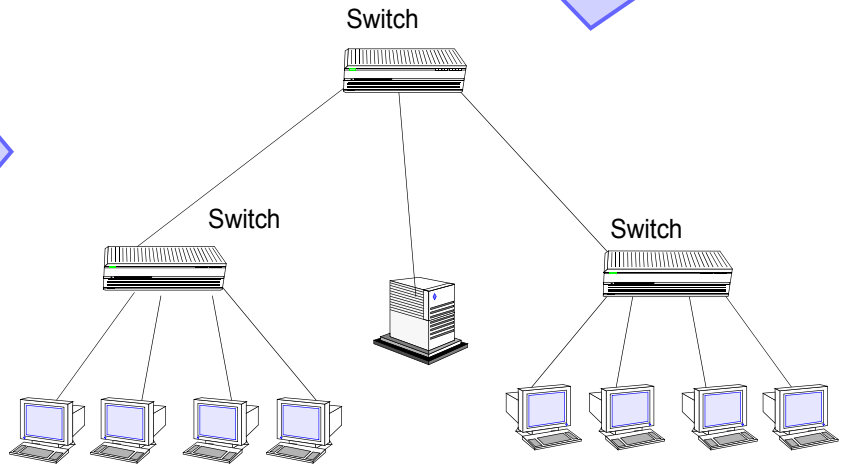


Shared media

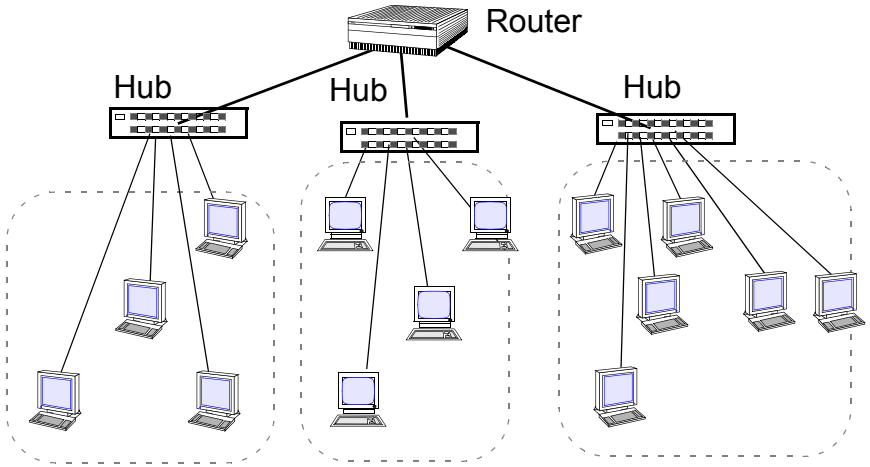


Dedicated media

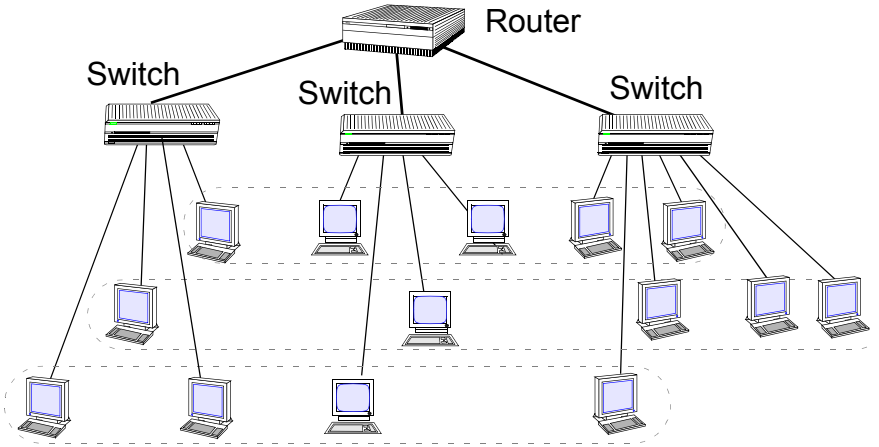




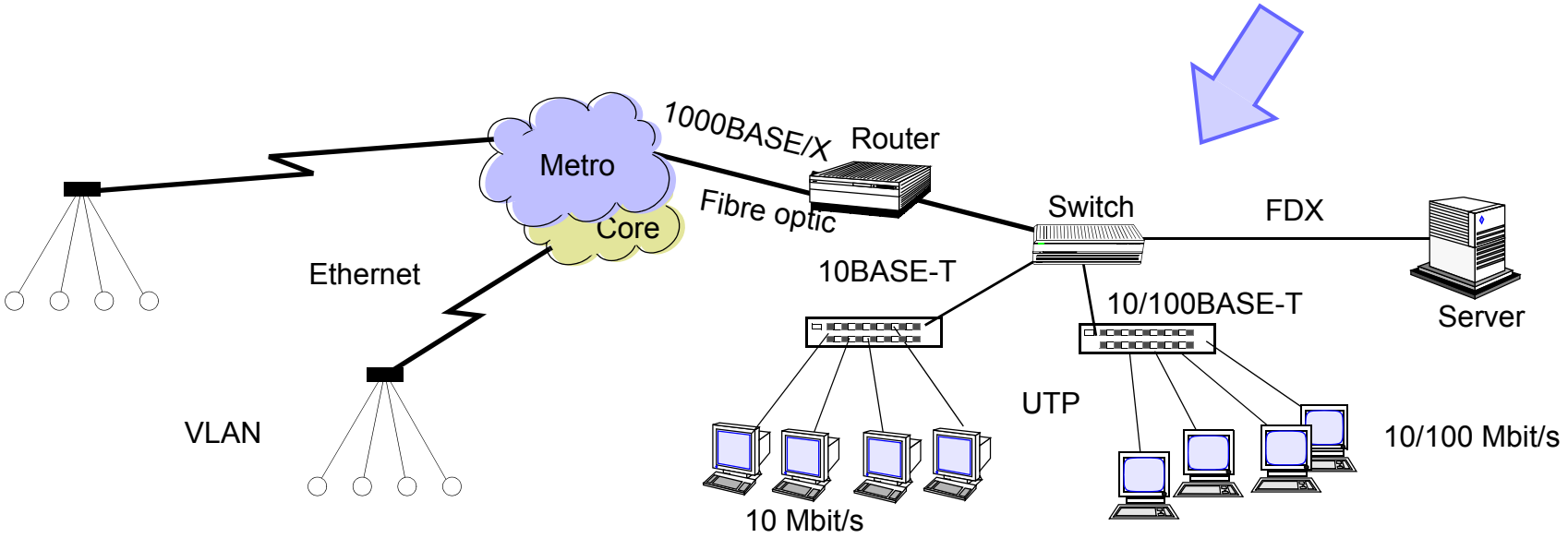
From Physical to Logical partitioning



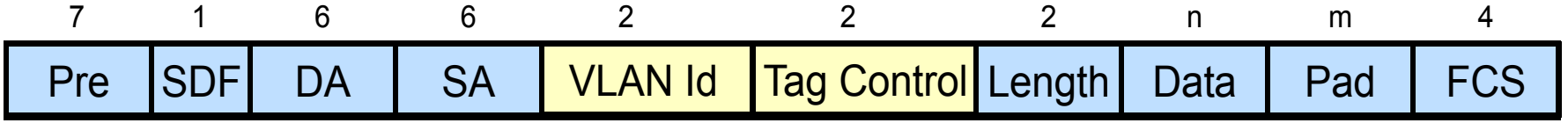
Physical segmentation



Logical segmentation with VLAN



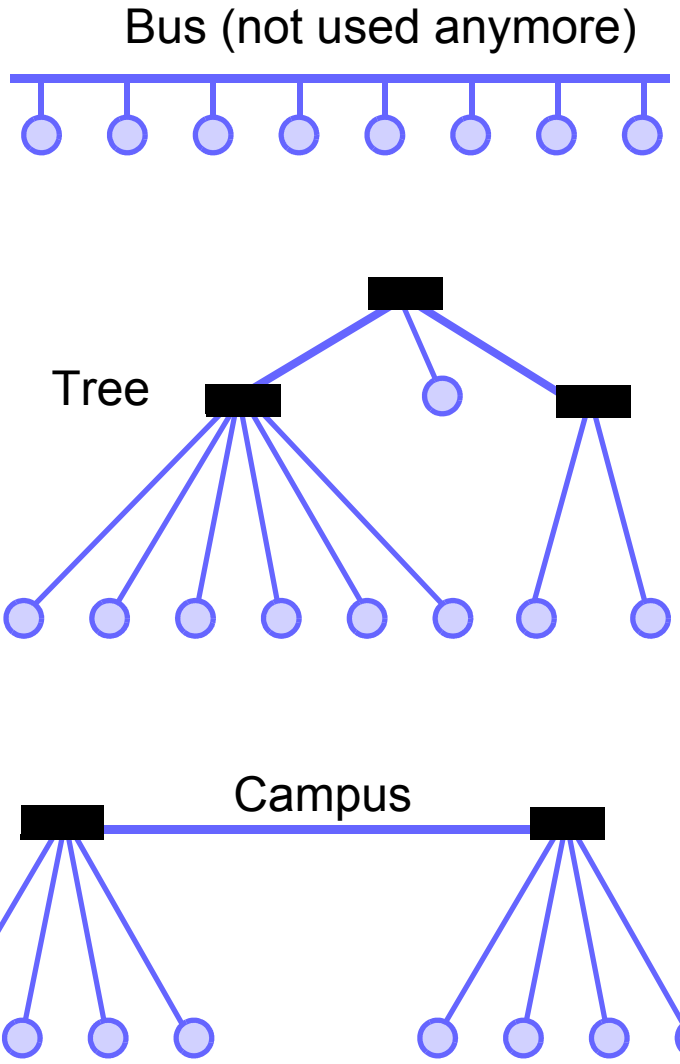
Virtual LAN

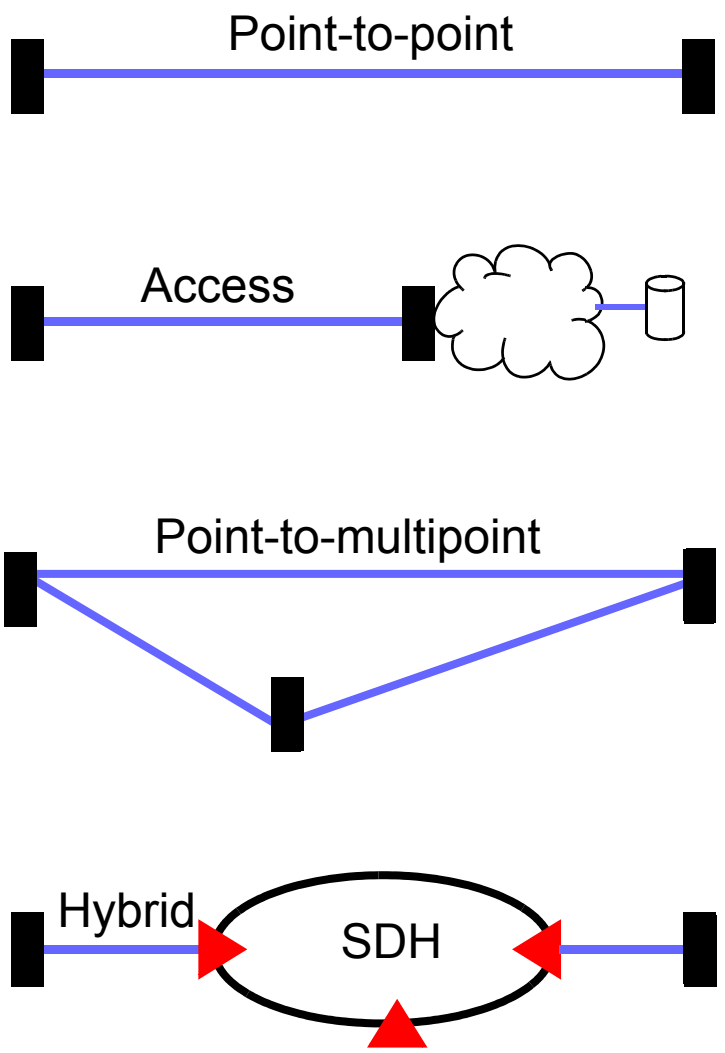


VLAN Id: frame indicator for VLAN
Tag Control: contains transmission priority and VLAN Id

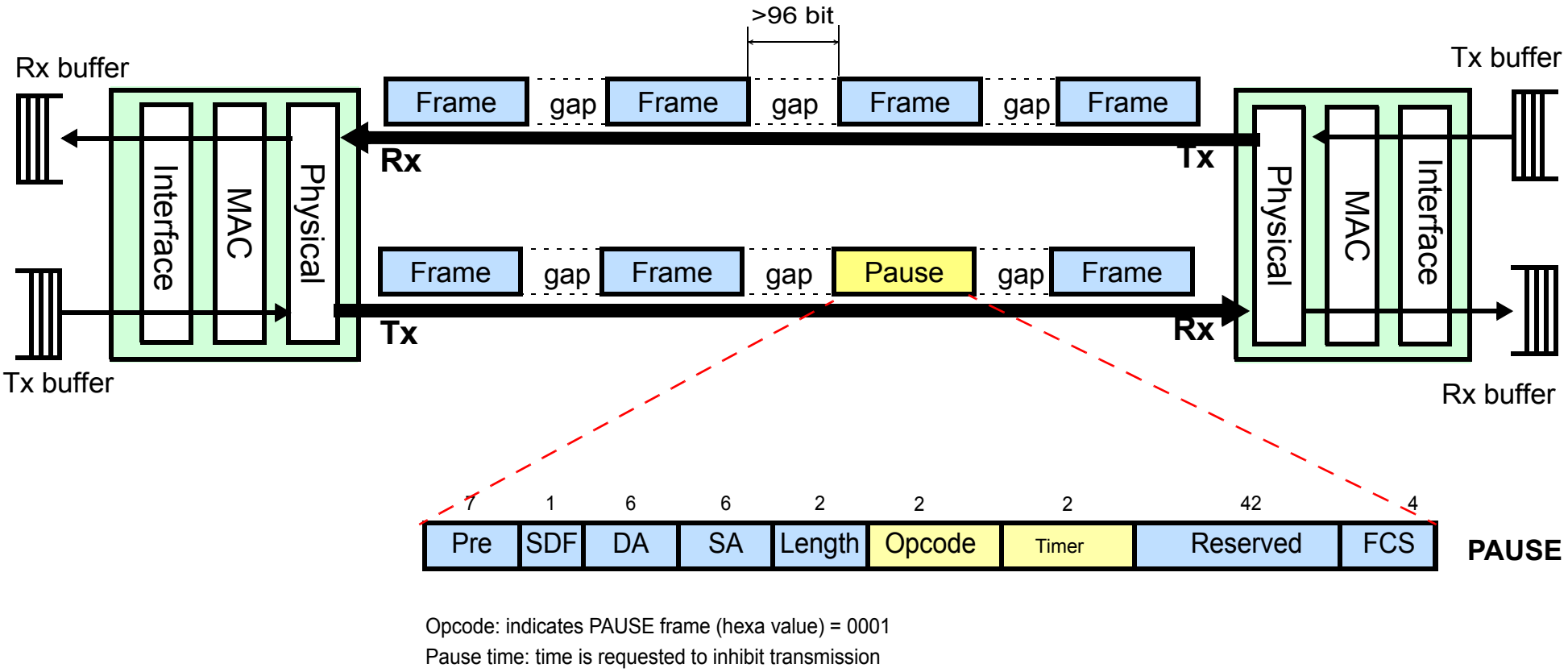
- VLANs provide the segmentation independently of the physical configuration
- Two distant stations could be part of the same virtual segment
- VLANs address scalability, security, and network management
- VLAN routers provide broadcast filtering, addressing, and traffic flow management

Topology diversity and evolution





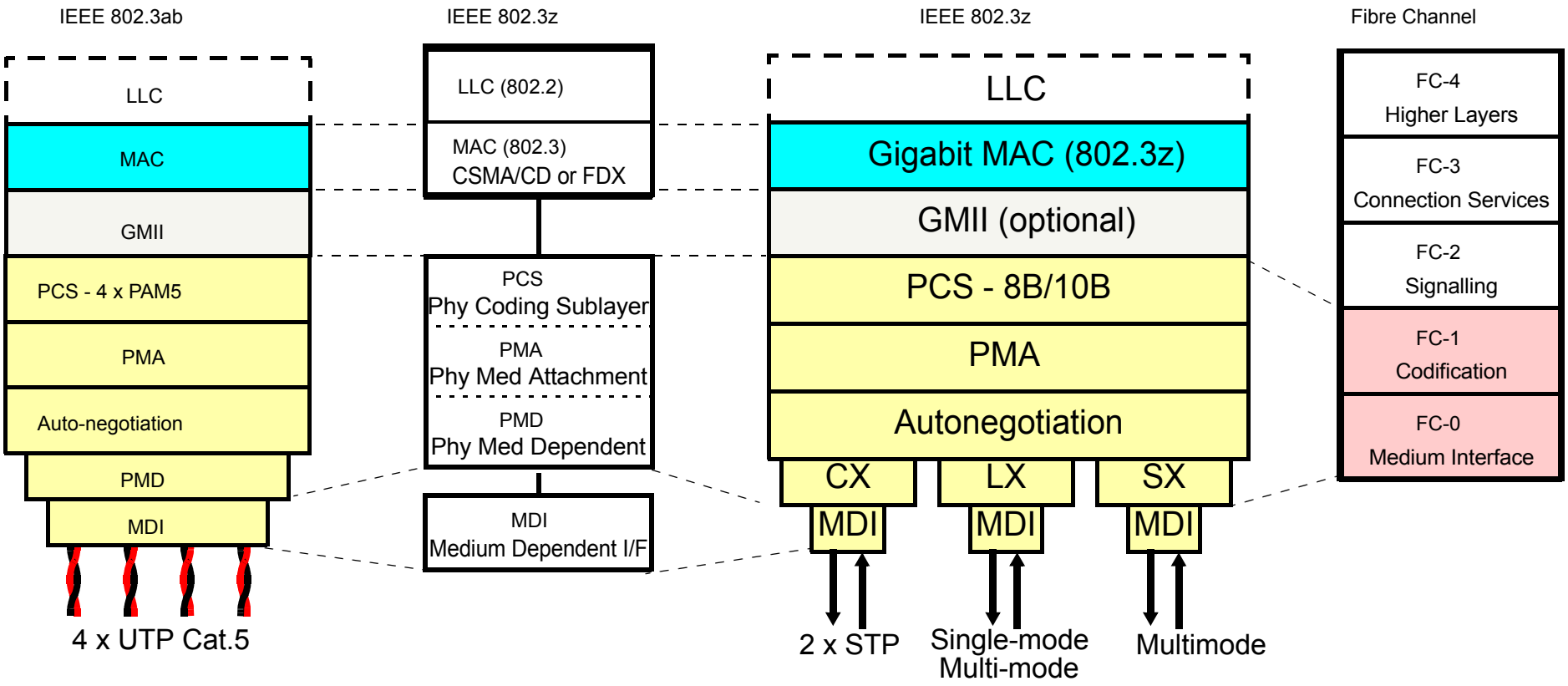
Full-Duplex Operation



Opcode: indicates PAUSE frame (hexa value) = 0001
Pause time: time is requested to inhibit transmission

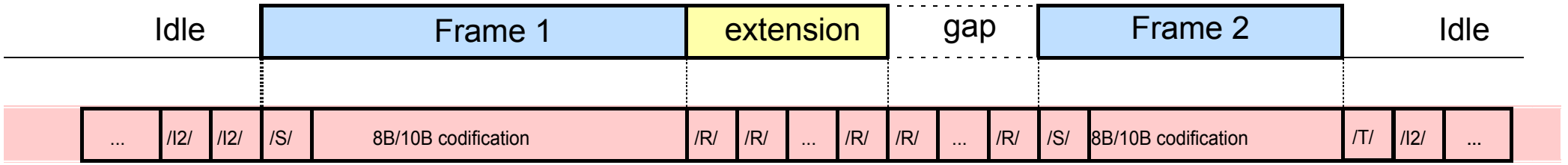
- Full-duplex (FDX) operation enables two-way transmission without contention
- A gap must be allowed between two consecutive frames
- FDX may need flow control, PAUSE, to request the transmitter to stop transmitting

Gigabit Ethernet Architecture



- The IEEE 802.3z-specified 1000BASE-X is based on the same physical layers as the existing fiber channel technology
- The IEEE 802.3ab-specified 1000BASE-T uses UTP cable for compatibility and easy migration from 10/100BASE-T installations

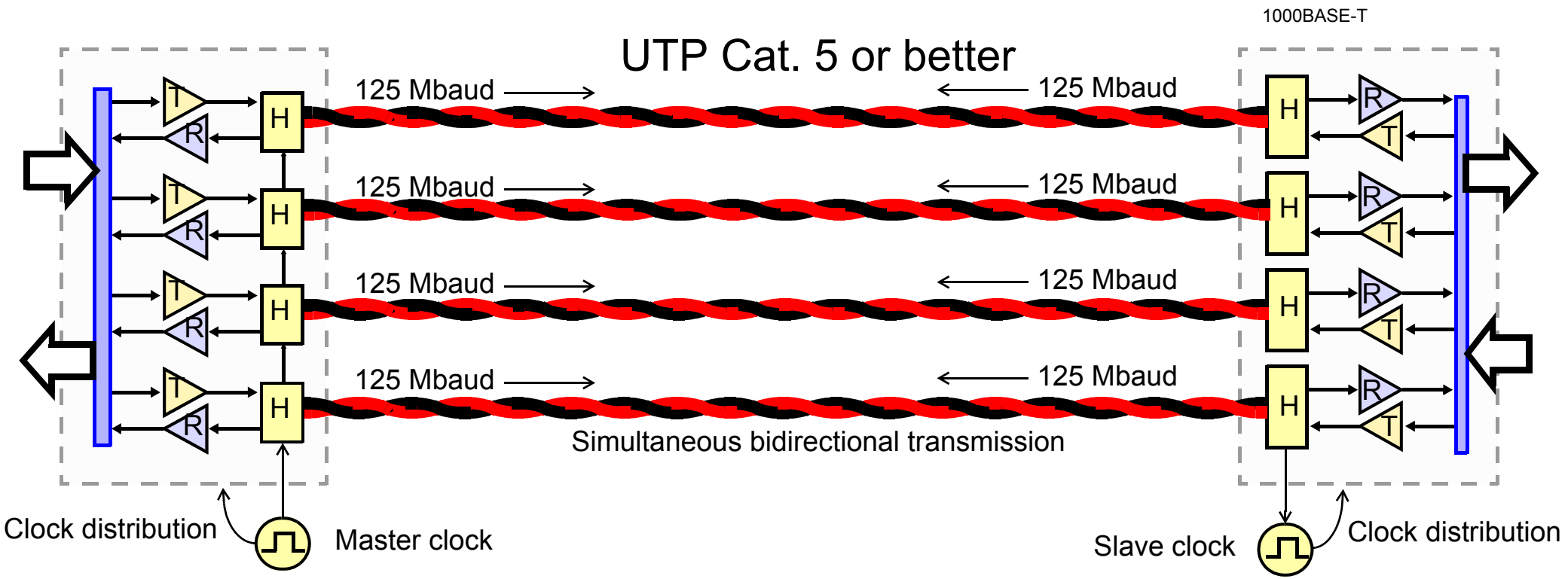
8B/10B is the 1000BASE-X Line Coding



- Distinguish data from control information unambiguously
- 8B/10B has excellent error detection capabilities
- Provides reliable synchronization and clock recovery
- GFP-T can map 8B/10B directly onto NG SDH envelopes

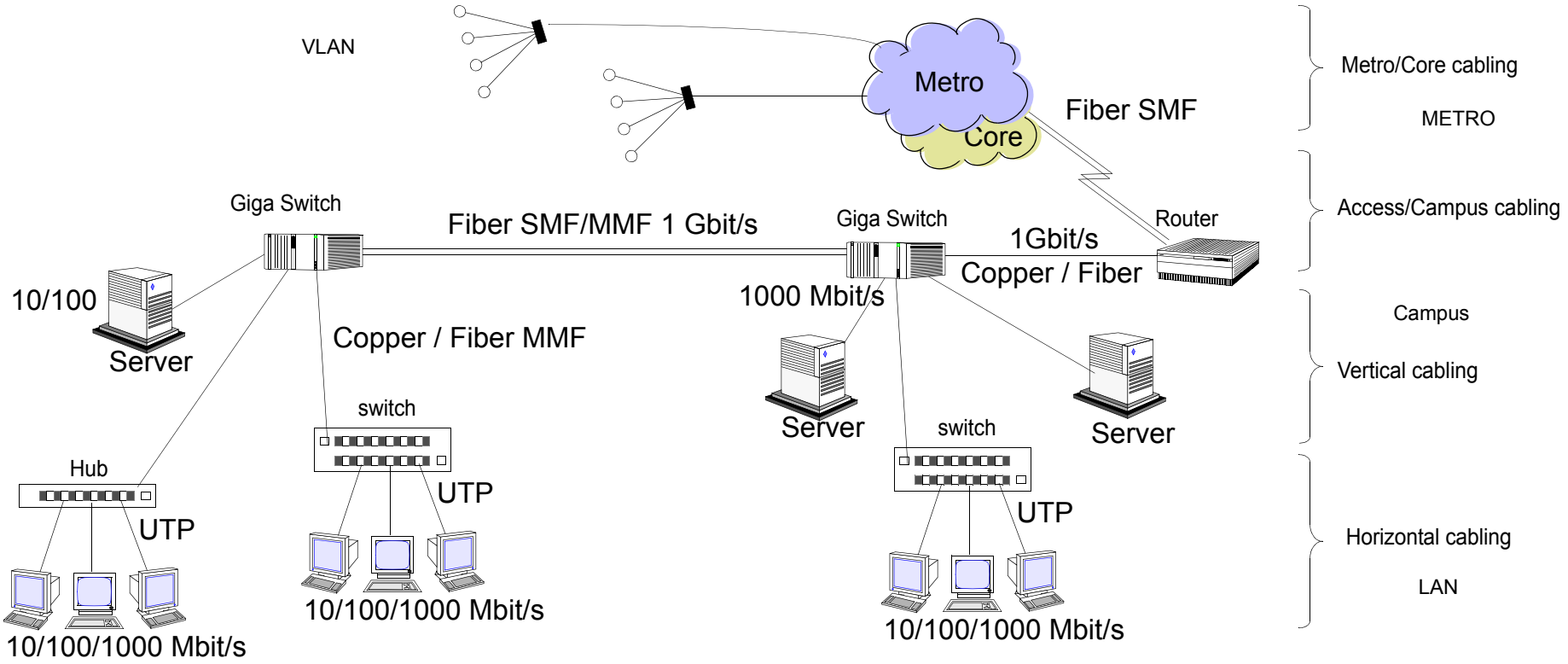
$$5Chex = \overbrace{y}^{010}\ \overbrace{x}^{11100} = \text{/Dx.y/} = \text{/D28.2/} \Leftrightarrow \overbrace{\text{abcdei}}^{001110}\ \overbrace{\text{fghj}}^{0101}$$

4D-PAM5 is the 1000BASE-T Line Coding



- The four data lines (4 UTP wires) are used simultaneously to transmit/receive
- A sophisticated DSP is used to filter and equalize the received signal
- Each pair achieves 250 Mbit/s using baseband at 125 Mbaud: total 1 Gbit/s
- Coding leaves 113 codes for control, such as idle, start of packet, end of packet

GigE Migration



- Horizontal cabling Cat.5e or better: cable can power IP phones, cameras, etc. - fibre can't
- Vertical cabling, mixture of multimode and single-mode devices and cabling
- Campus & Access cabling, multimode or single mode fibre using existing base
- Metro & Core single-mode fibre is the best option: hi-speed and future-proof

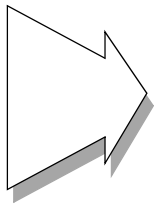
Metro Ethernet
-
Carrier-Class Ethernet

Section

Ethernet migration to Carrier Ethernet

Ethernet

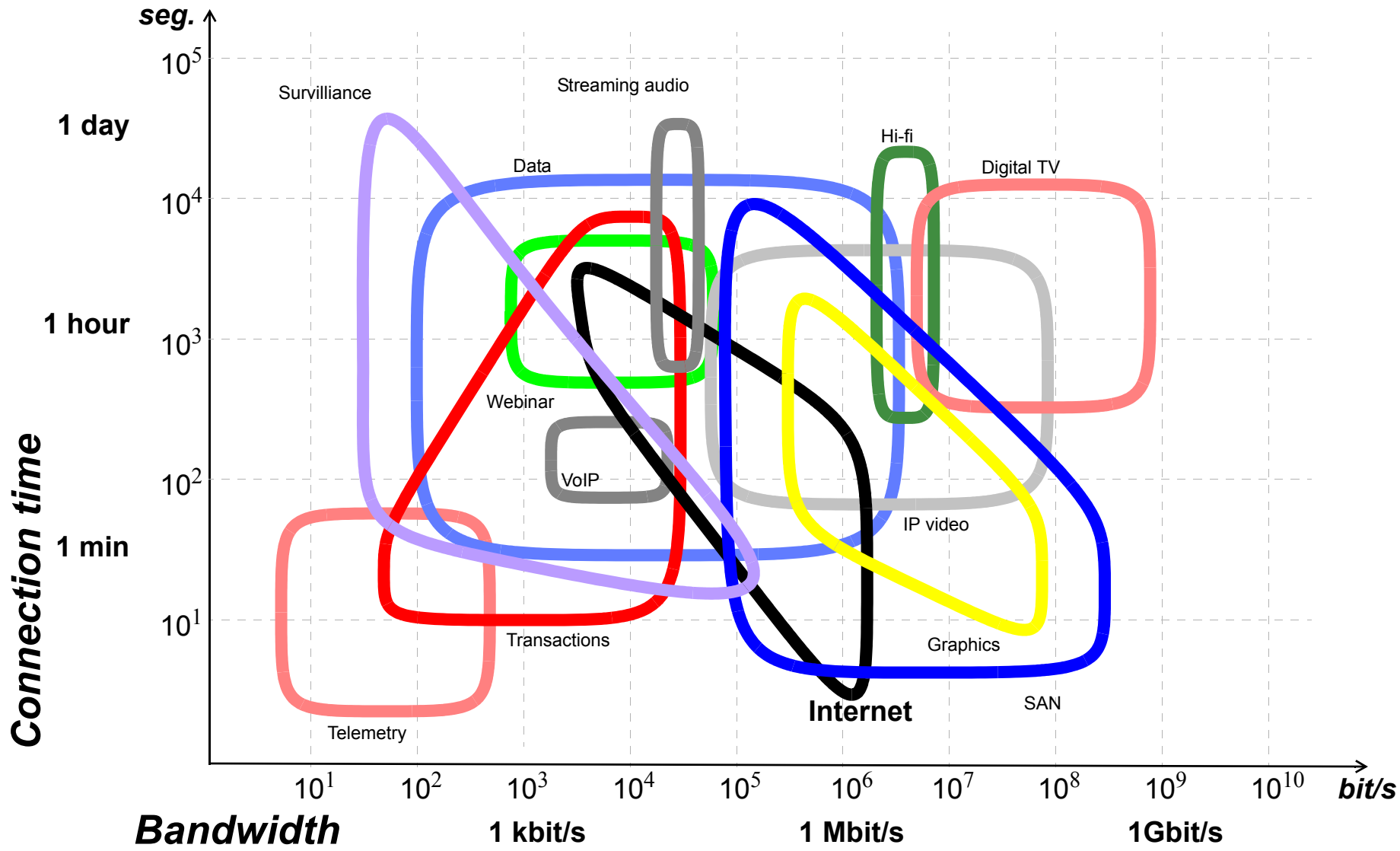
- Connectionless
- Data efficient
- UTP, Fiber
- Multipoint
- Bridging
- STP, RSTP
- Tree topology
- Best effort
- VLAN
- Free



Carrier Ethernet

- Applications*
  - Data
  - Internet
  - VoD
  - VoIP
  - Triple Play
- Roll-out
  - Low Cost
  - Single-ended test
  - Optical Integration
- Architecture
  - MAN / WAN
  - Connection
  - Connectionless
  - Multitechnology
- Service
  - QoS
  - SLA
  - E-Line
  - E-LAN
- Topologies
  - Start
  - Ring
  - Meshed
- Maintenance
  - Event Detection
  - Fault Propagation
  - Monitoring
  - Service verification
- Reliability*
  - = 50 ms restoration
  - 99,999% availability
  - Carrier protection
- Billing
  - Fixed
  - Variable
- Management (OAM)*
  - Centralized / Distributed
  - Separated Data/Control
  - Integrated

Application requirements



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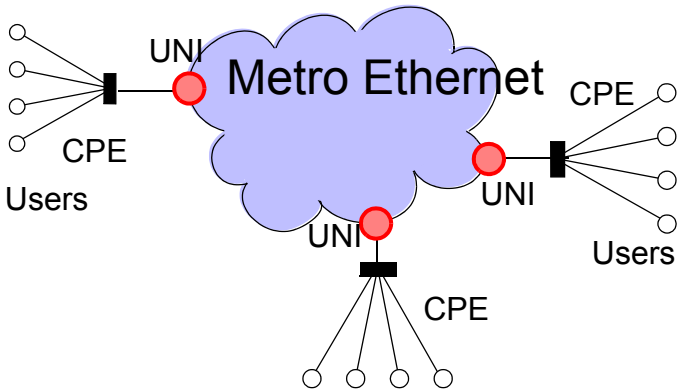
QoS Requirtements

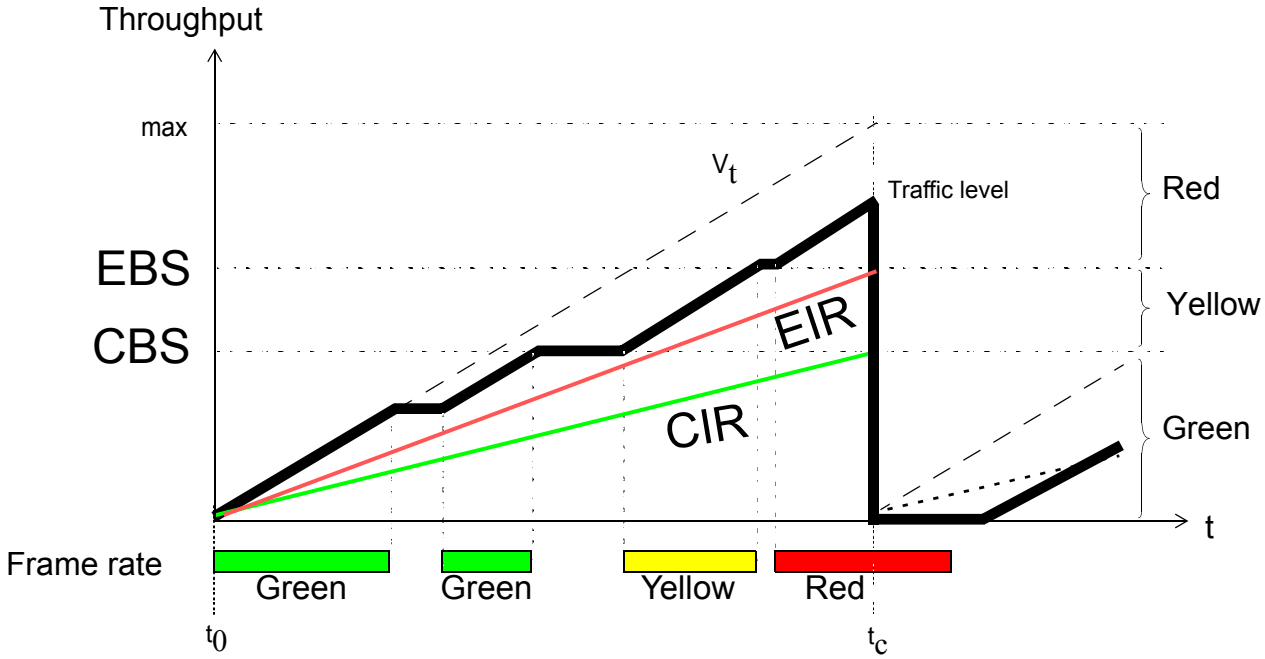
Application	*Bandwidth*	*Packet Loss*	*Delay*	*Jitter*
Data	variable	sensitive	insensitive	insensitive
VoIP	12 ~ 106 kbit/s	< 1 %	< 150 ms	< 30 ms
Streaming audio (MP3)	32 ~ 320 kbit/s	< 2 %	< 5000 ms	insensitive
Video-conference (H.261)	100 kbit/s	< 1 %	< 150 ms	< 30 ms
Streaming video (MPEG-4)	0.005 ~ 10 Mbit/s	< 2 %	< 5000 ms	insensitive

Ethernet is a best effort and connectionless technology.

Consequently it has difficulties to supply customised QoS per each application type

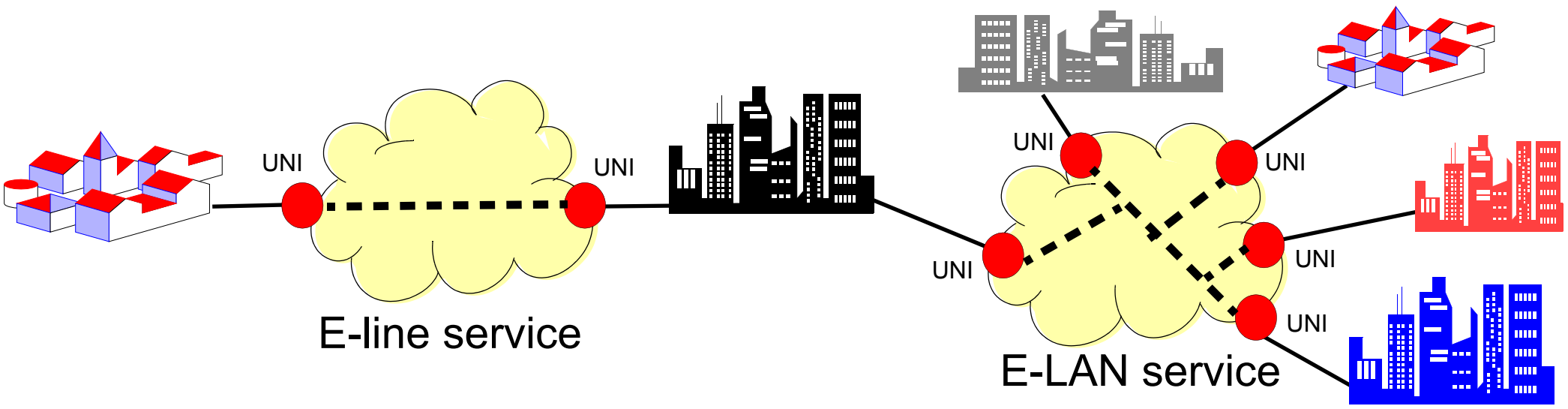
Carrier-Class Ethernet





- Metro Ethernet Forum (MEF) has defined a *bandwidth profile* based on four parameters: *Committed Information Rate* (CIR), *Committed Burst Size* (CBS), *Excess Information Rate* (EIR), *Excess Burst Size* (EBS)
- The aim is to accelerate the adoption of optical Ethernet in metro networks, offering specific profiles of services equivalent to Carrier services rather than “best effort”

Generic Services by Metro Ethernet Forum (MEF)



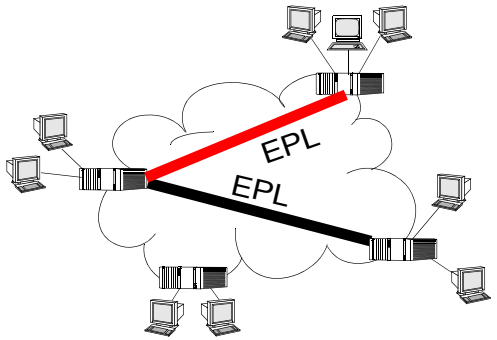
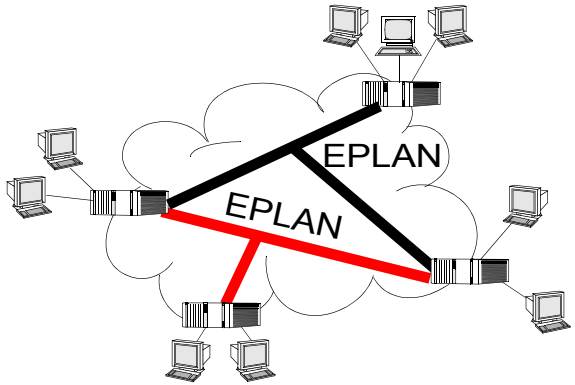
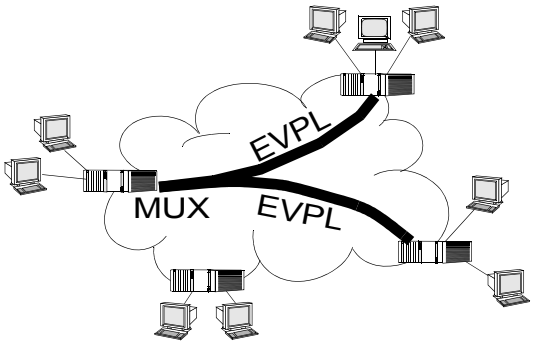
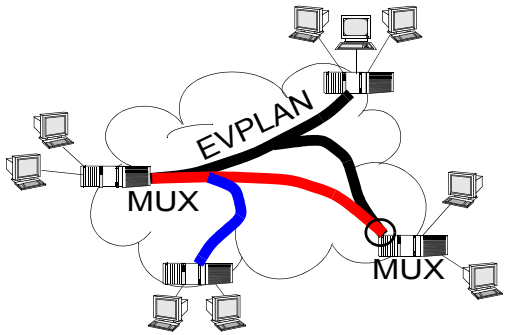
E-line service is used to create:

- Private-line Services (equivalent to Frame Relay)
- Internet access
- Point-to-point VPN

E-LAN service is used to create:

- Multipoint VPN
- Transparent LAN service

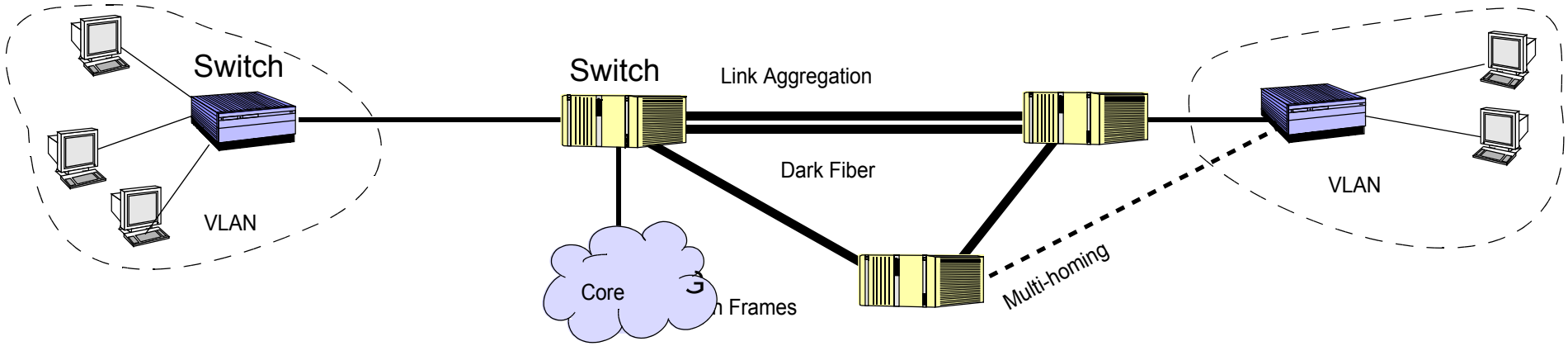
Generic Ethernet Service Type (MEF)

EVC to UNI	E-Line Point to point, best effort / guaranteed QoS, Optional multiplexing and bundling	E-LAN Multipoint to multipoint, Best effort or guaranteed QoS, multiplexing and bundling
Port-based - No Service Multiplexing - Dedicated Bandwidth	**Ethernet Private Line (EPL)** 	**Ethernet Private LAN (EPLAN)** 
VLAN-based - Service Multiplexing - Shared Bandwidth	**Ethernet Virtual Private Line (EVPL)** 	**Ethernet Virtual Private LAN (EVPLAN)** 

Services Types and Features

Type	*Topology*	*SLA*	*Bandwidth*	*How*	*Resilience*
E-line	Point-to-point	Jitter, Availability, Loss, Protection, Latency	Dedicated	TDM, WDM, NG SDH	1+1 APS
E-Virtual Line	Point-to-point	Availability, Loss, Protection, Latency, CEIR, EIR	Shared	Encapsulation, Labeling	Spanning Tree, RPR
E-LAN	Multipoint	Availability, Loss, Protection, Latency, CEIR, EIR	Dedicated, multi/broadcast	TDM, WDM, NG SDH	Spanning Tree, RPR
E-Virtual-LAN	Multipoint	Availability, Loss, Protection, Latency, CEIR, EIR	Shared, multi/broadcast	Encapsulation, labeling	Spanning Tree, RPR

Metro Ethernet a large LAN?

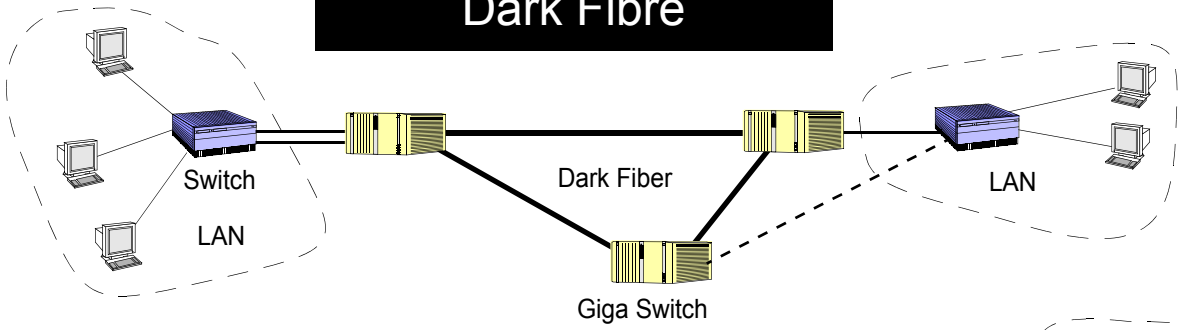


Native Ethernet drawbacks:

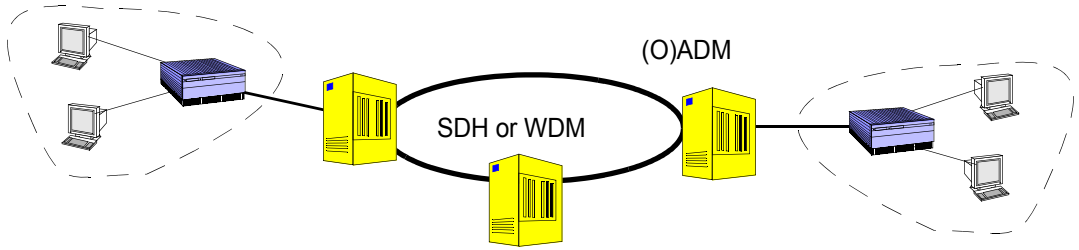
- Connectionless: this is often an advantage, but requires constant address learning
- **Privacy / efficiency**: switches and bridges use broadcasting for learning (IEEE 802.1d)
- **VLANs limitations** of 4 094 identifiers cannot be used in a WAN (IEEE 802.1q)
- **Non-hierarchical MAC** addresses are flat, so the switching table does not scale well
- **Spanning Tree Protocol (STP**) takes minutes! It cannot match 50 ms protection switch
- **No ring topologies**, because STP allows only tree or star topologies
- **Limited QoS**, because native Ethernet is basically a best-effort technology
- **Poor Management** of nodes, topologies, events, performance
- **Network demarcation,** Ethernet is everywhere without clear border between customer / provider

Ethernet Service in MAN / WAN

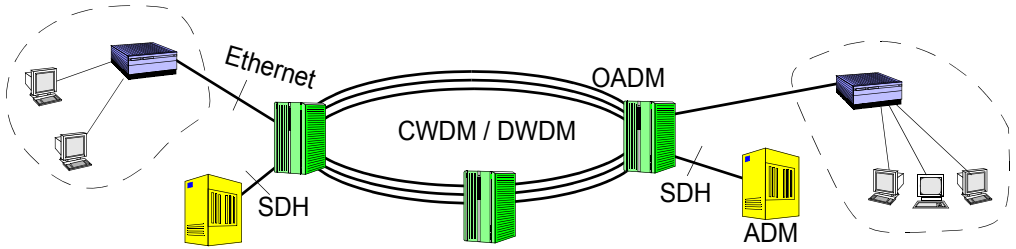
Dark Fibre



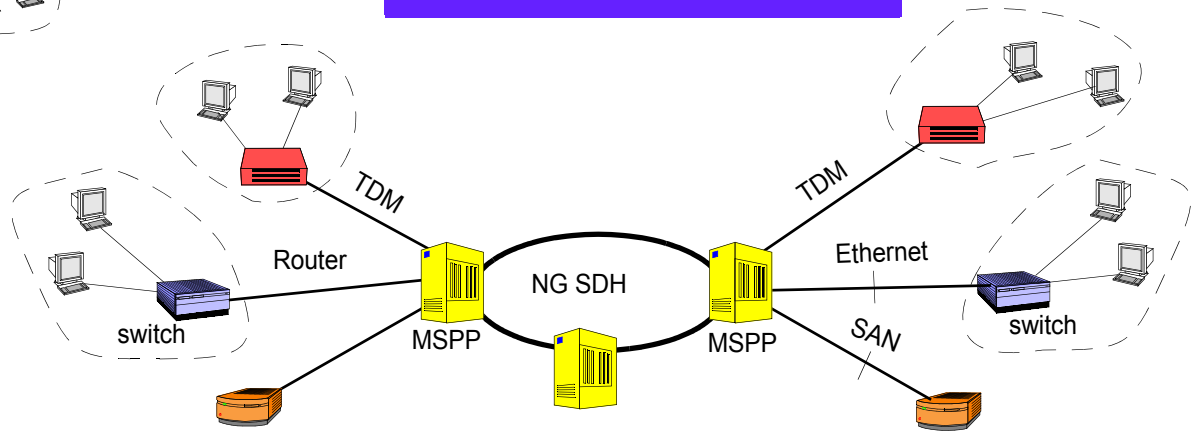
WIS (10 Gbit/s)



CWDM / DWDM



NG SDH



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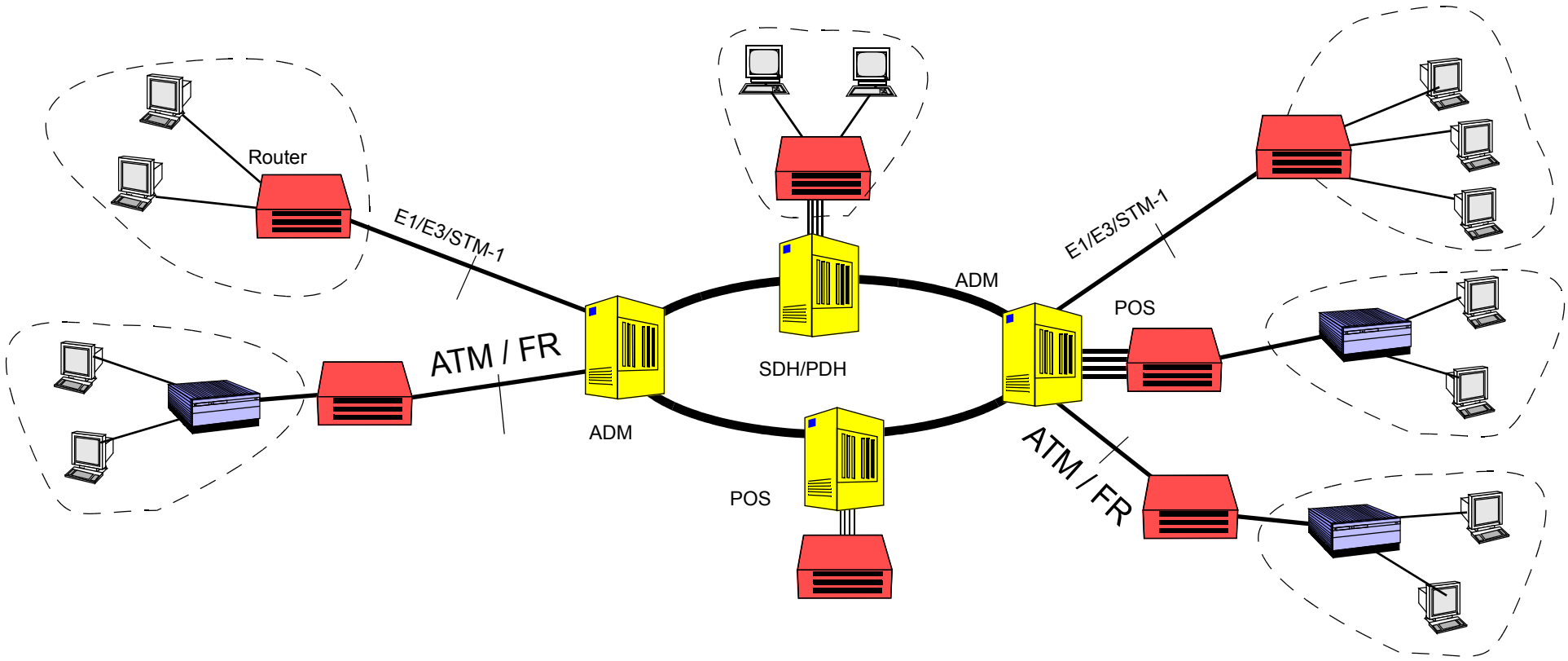
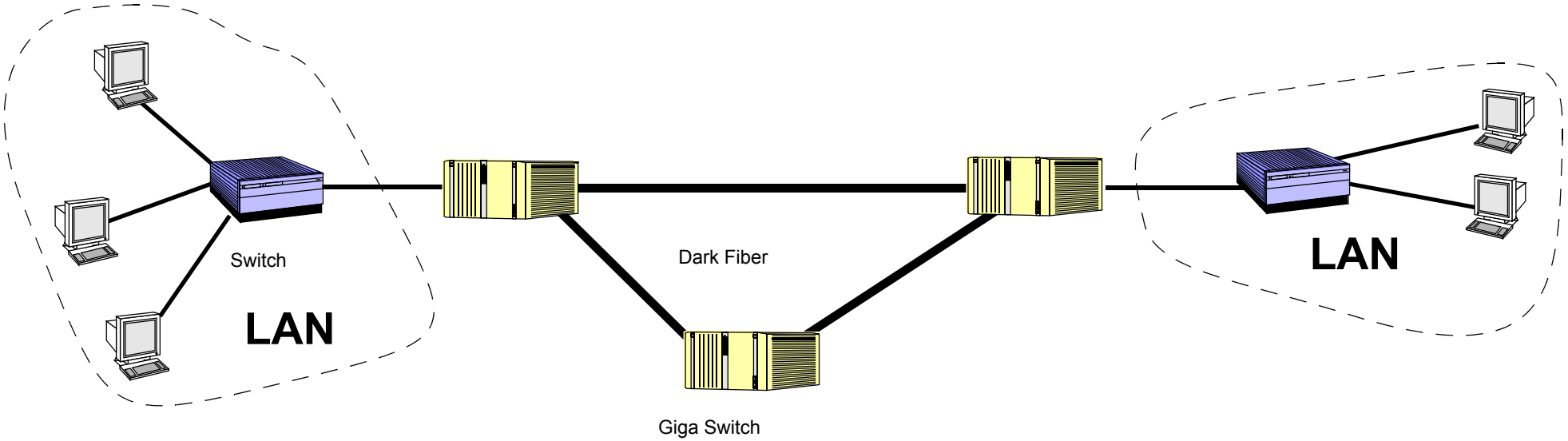
Ethernet and FR / ATM / Leased Line



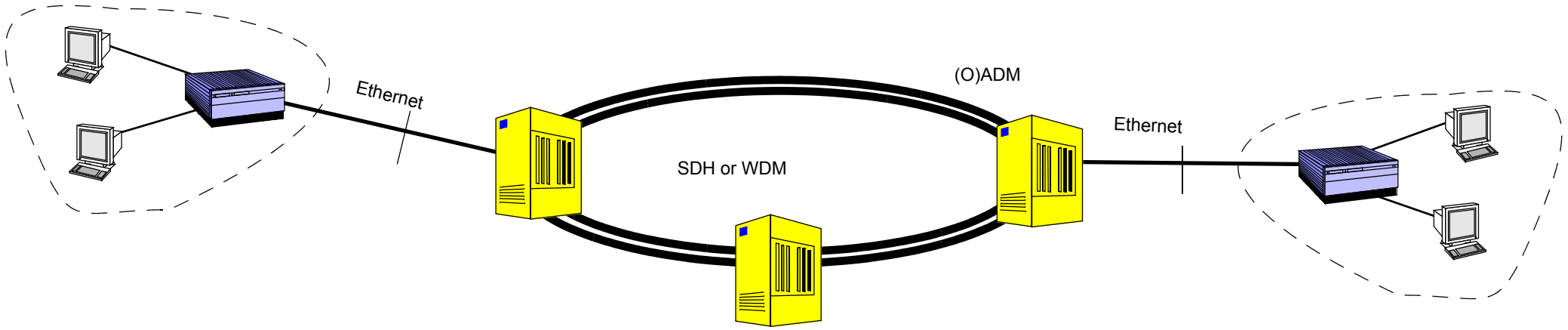
- :-) Popular routing architecture
- :-(is NOT a genuine Ethernet service, packet unfriendly, fixed bandwidth

Ethernet over Dark Fiber



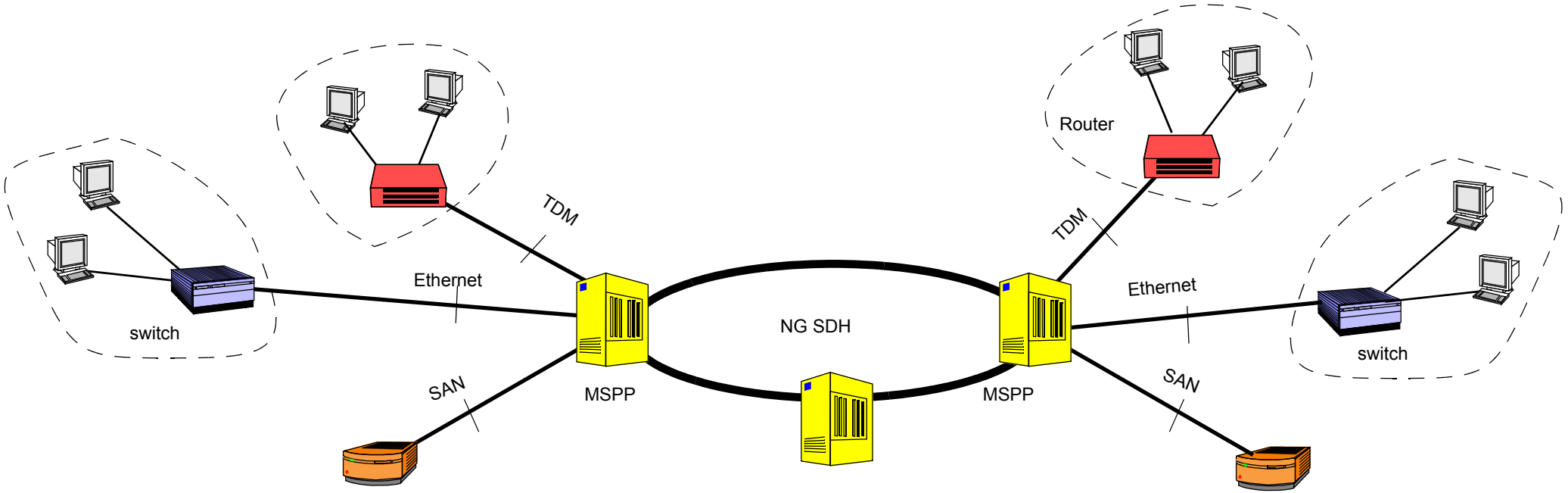
- :-) packet aggregation, simple, cheap
- :-(poor management, inefficient, no granularity

WIS (10Gbit/s)



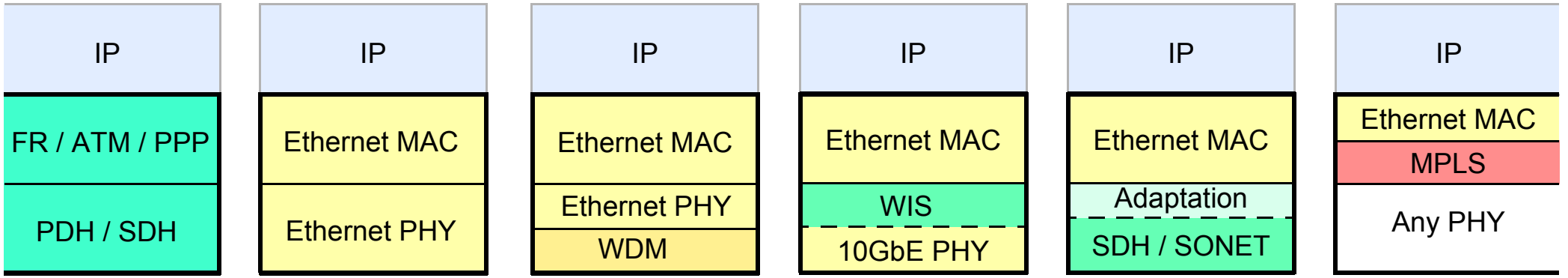
- :-) direct migration from SDH to 10GE
- :-(not Ethernet, not SDH, rare solution

NG SDH / LAPS



- :-) multi service, integrated management
- :-(complex, expensive

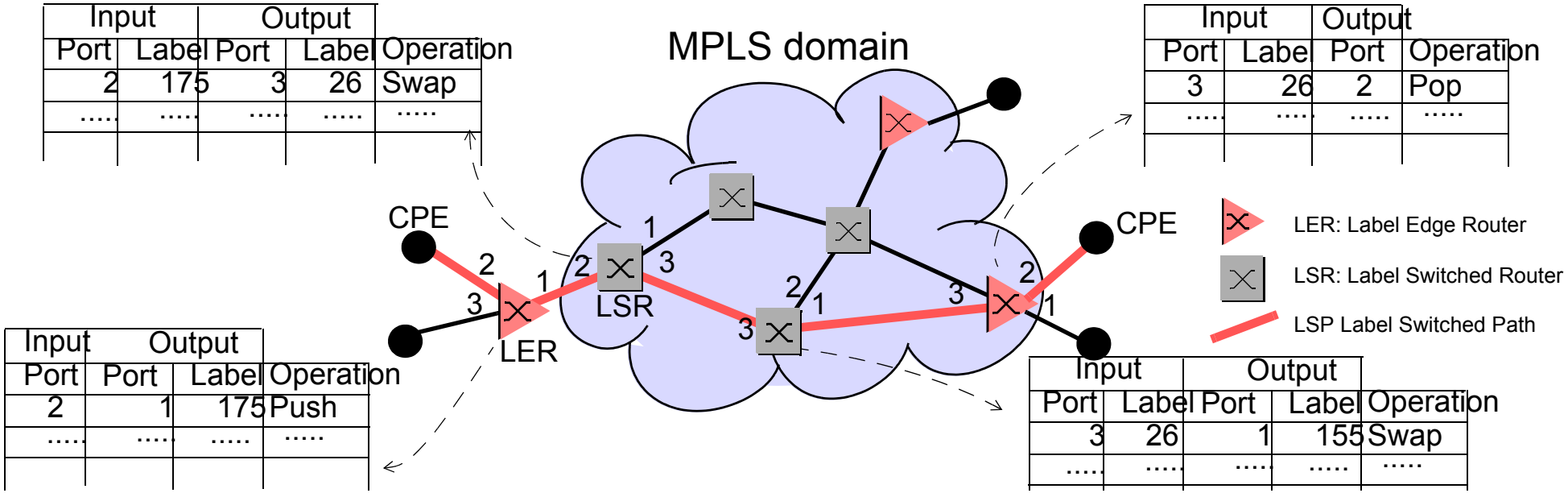
Protocol Towers per Carrier Ethernet



FR / ATM / Line (Not Ethernet!) | Dark Fiber | WDM | WIS (SDH framing) | LAPS / NG SDH | MPLS

- A proper Ethernet service keeps the MAC layer end to end
- MPLS works over any physical infrastructure
- VPLS uses MPLS to provide a Carrier Ethernet service

Multiprotocol Label Switching

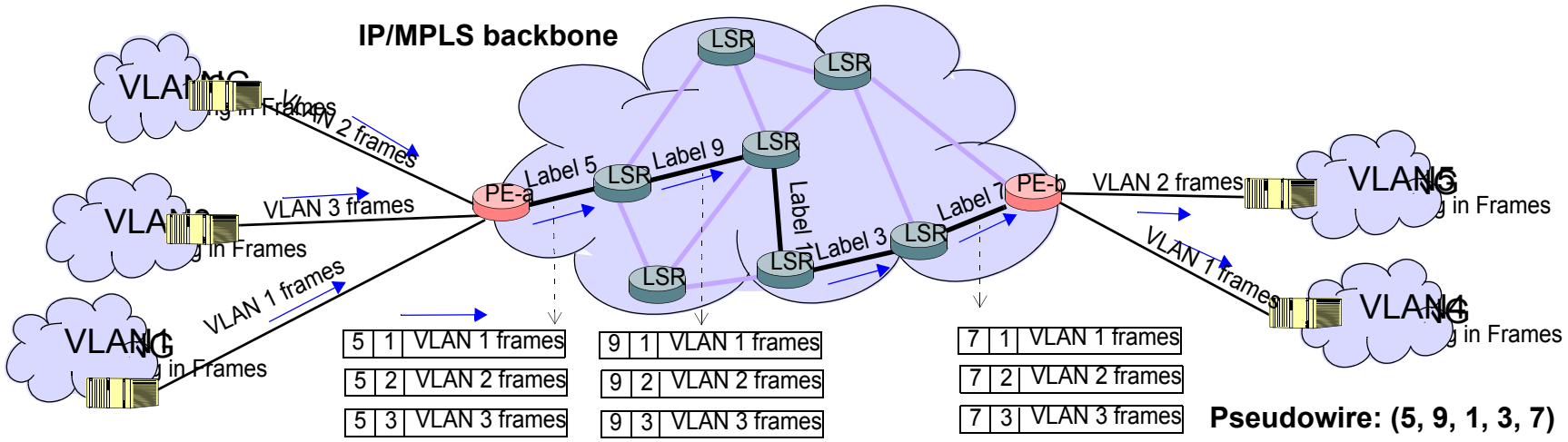


MPLS was designed to improve IP networks in aspects like QoS, speed, protection and engineering. MPLS manages traffic streams by separating route selection and packet-forwarding functions:

- **Route selection**: managed by the Control Plane that maintains the topology of the MPLS network protocols like OSPF, IS-IS, in a dynamic way similar to the IP internet.
- **Packet forwarding**: managed by the Forwarding Plane, uses a table to associate incoming labeled packets with an output port and a new label. Inside the MPLS domain, only Labels matter, while MAC and IP addresses are ignored.The predetermined route each labeled packet follows is called LSP.

Conclusion: MPLS is connection-orientated to be efficient forwarding packets, while the topology is managed automatically in a distributed way like IP networks.

PWE3: VPWS and VPLS

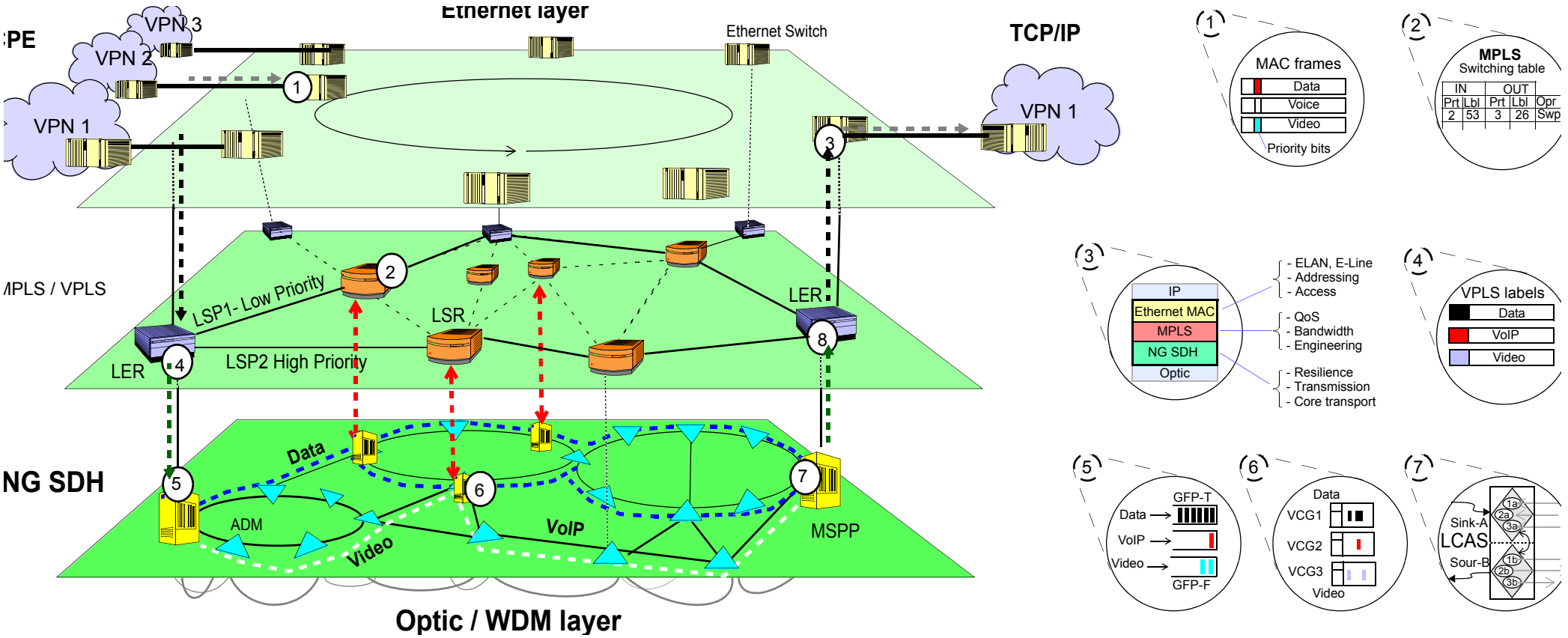


MPLS was designed to forward IP packets, but the demand to transport Ethernet, FRL and ATM moved the IETF to define **Pseudowire Edge-to-Edge Emulation** (PWE3, also known as the Martini draft), as a unifying layer that can transport layer-2 traffic through the IP/MPLS network.

PWE3 requires two labels: **Tunnel label**, used for guiding the frame through the MPLS domain, and **VC label**, used to identify each client traffic matching an MAC, Port, or VLAN tag to a constant label. There are two PWE3 implementations, and both emulate a learning bridge:

1. Virtual Private Wire Service (VPWS), a point-to-point transport interesting for the migration of legacy point-to-point services such as leased lines, FR and ATM.
2. Virtual Private LAN Service (VPLS), a multipoint transport very useful for Ethernet Services enabling customer sites to be connected to a VPN. It is being used for Triple Play.

NG SDH + MPLS Architecture



Ethernet frames are sent to the LER (1) of the MPLS domain. A label is attached to each packet (4) which is used to route the traffic through an MPLS path (LSP) that has an associated QoS.

Packets are then passed to one of the available VCGs (5) according to the priority of the label. NG-SDH immediately transmits the packet to the next LSR (2) that switches the packet to a new port according to the label and a table (6). When the packet finally reaches the destination MSSP (7) and the remote LER (8), the label is removed and the MAC frame is delivered to its destination (3).

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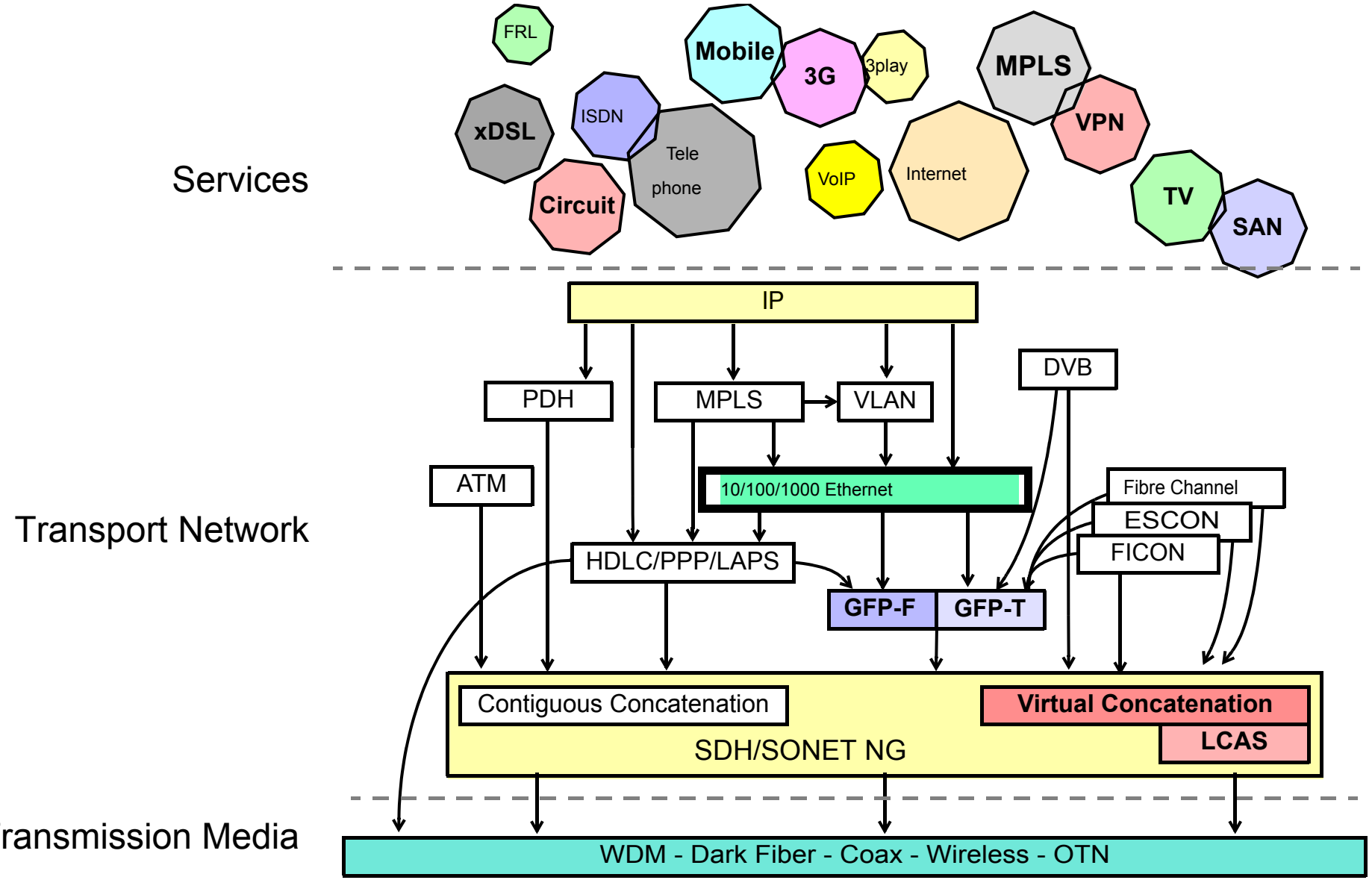
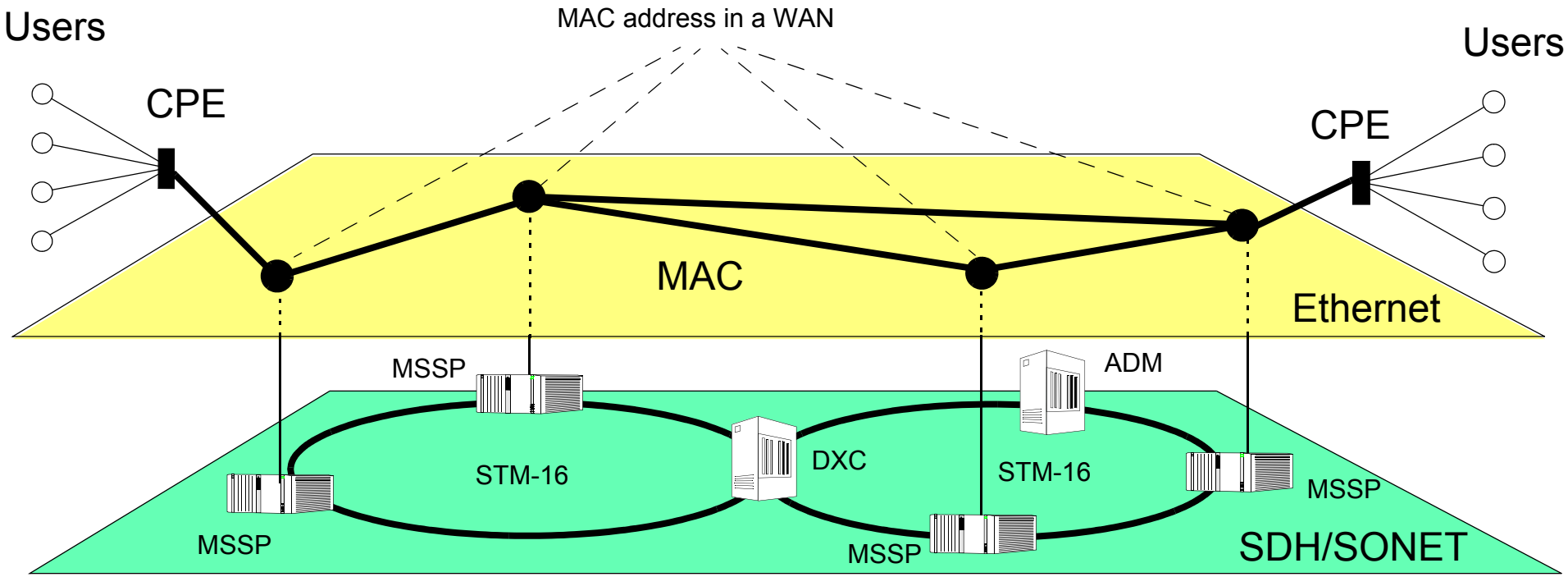
Next Gen. SDH Born for Ethernet

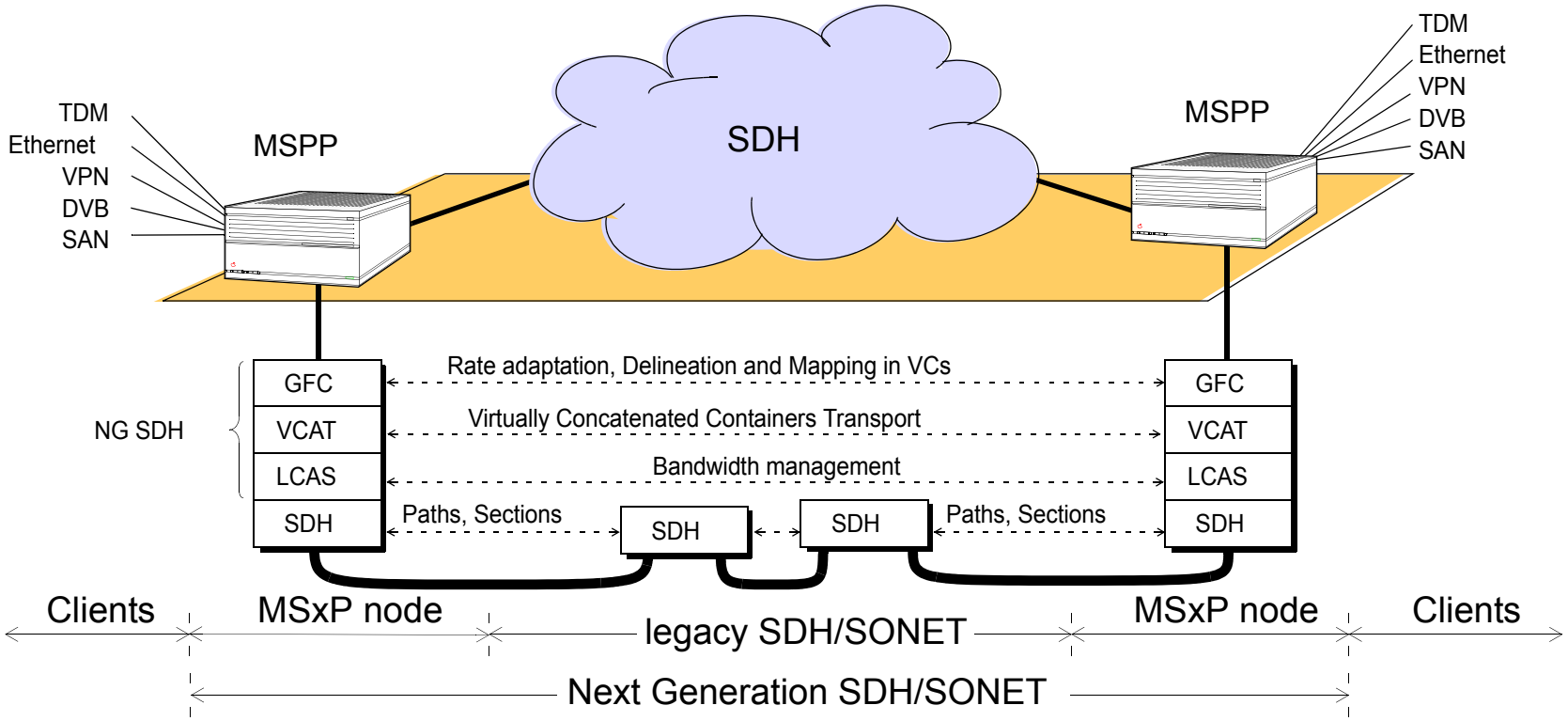


Bridged WANs and NG SDH



- Only the edge nodes have to be upgraded to NG to become MSSPP
- MSSP would be able to manage traffic by means of VLAN
- It is like a big LAN, equivalent benifits and issues, i.e. it is efficient butdoes not scalate well

Migration to NG SDH

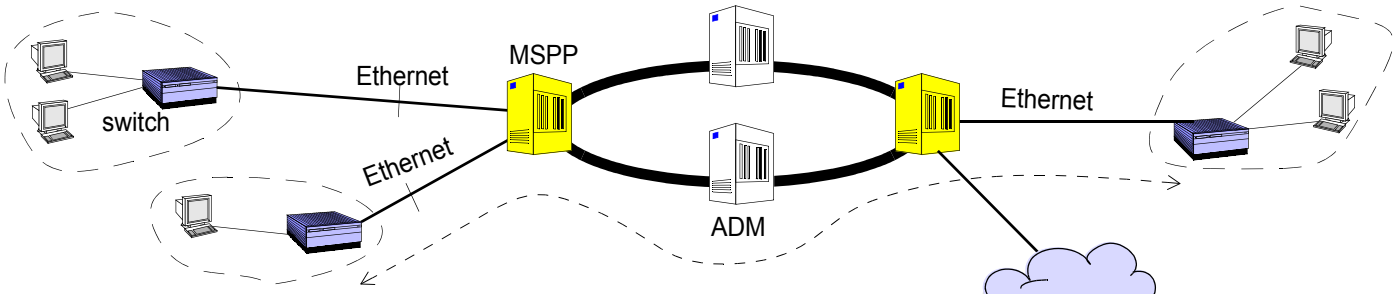


Next Generation SDH/SONET enables operators to provide more data transport services while increasing the efficiency of the installed SDH/SONET base, just by adding new MSPP edge nodes.

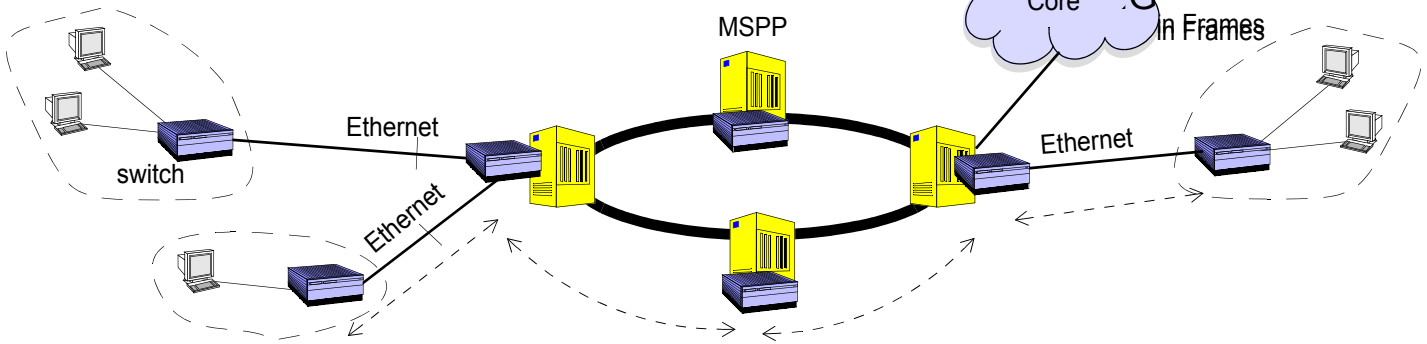
This means that it will not be necessary to install an overlap network or migrate all the nodes or fibre optics. This reduces the cost per bit delivered and will attract new customers while still keeping legacy services.

Ethernet over NG-SDH Alternatives

LAN switching



MAN switching

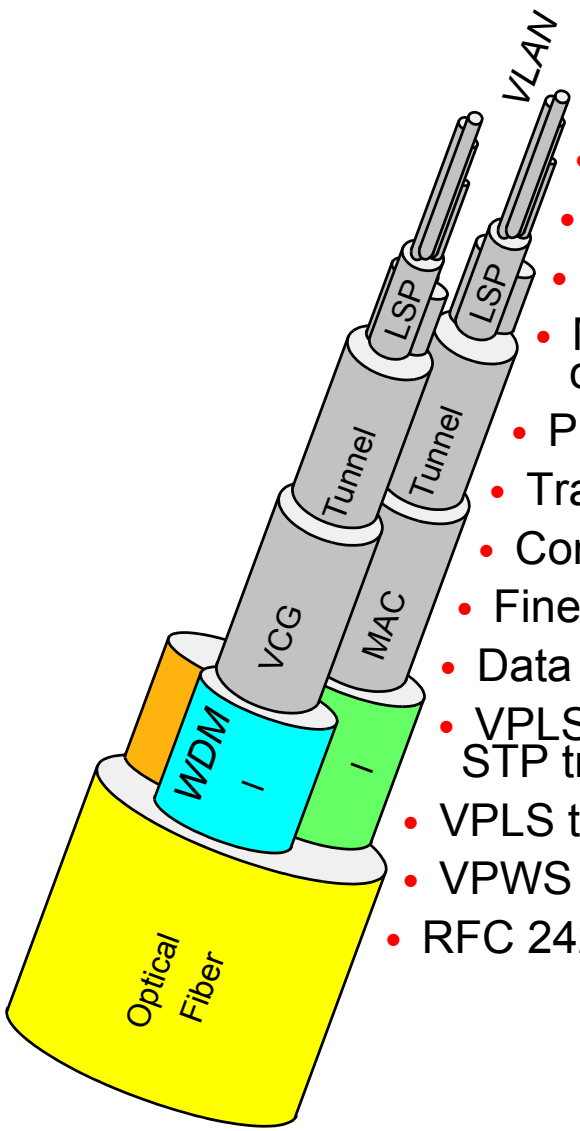


Two architectures are possible:

1. LAN switching: more simple; NG SDH is just a link between the customer switches; can provide only EPL service
2. MAN switching: more flexible; network switches allow a more sophisticated service; can provide all services EPL, EVPL, ELAN, and EVLAN.

However, both require a lot of intervention of central management, and have some of the limitations of layer-2 networks: MAC explosion, continuous learning, VLAN limitations, STP. And an additional MPLS layer is requested to improve scalability, differential QoS & protection.

Ethernet + NG SDH + VPLS = Carrier Ethernet



- Interoperability between different vendors
- Improves scalability up to millions of subscribers
- Service differentiation for QoS provision or advanced traffic engineering
- MPLS paths can be established both dynamically using OSPF and centralised using NMS
- Protection can be set up for end-to-end MPLS paths or LSP
- Transport Layer Independence: MPLS combines SDH, WDM, Fiber, RPR
- Controlled oversubscription is possible using VCG and GFP-F
- Fine granularity integrating MPLS and VCGs
- Data flow separation to provide privacy of each customer's traffic
- VPLS overrides Layer-2 drawback including VLAN limits to 4089, traffic flooding, STP tree topologies, STP slow protection
- VPLS transports multipoint Ethernet traffic
- VPWS transport point to point traffic like FRL, ATM, TDM, PPP
- RFC 2427 and RFC 2684 for FRL and ATM internetworking to Ethernet

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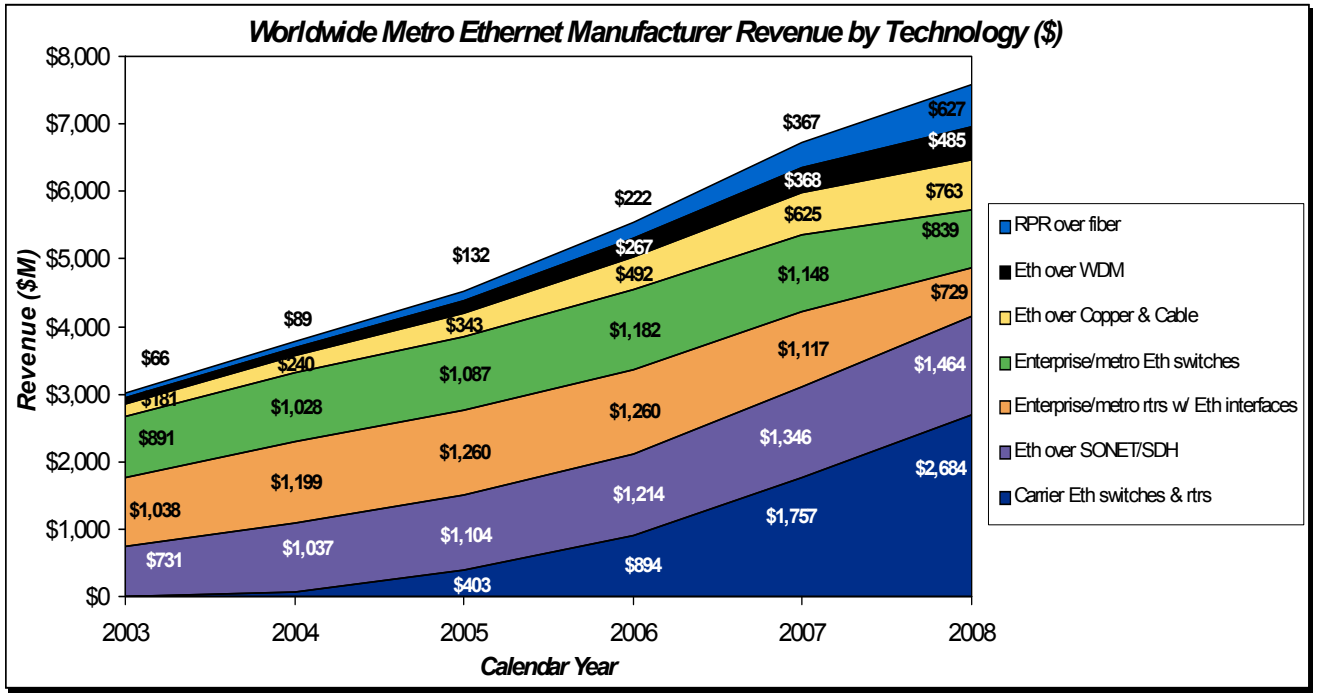
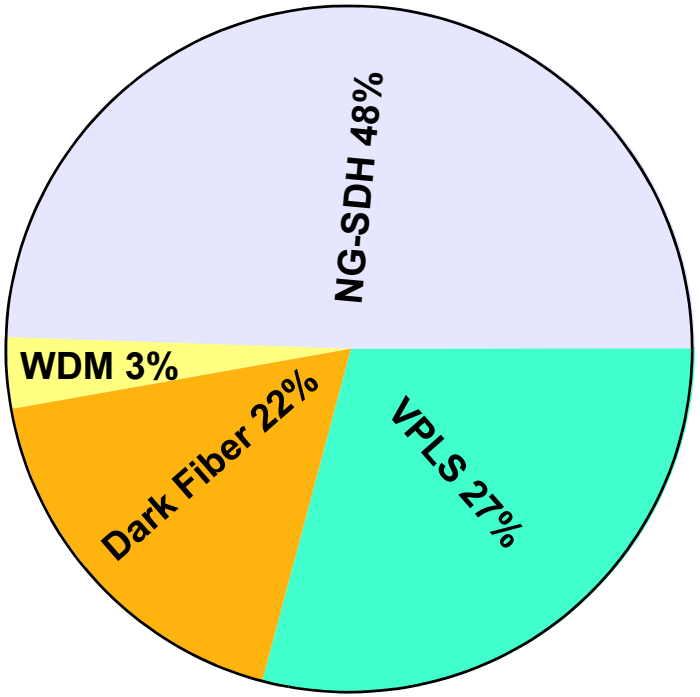
Which Carrier Ethernet



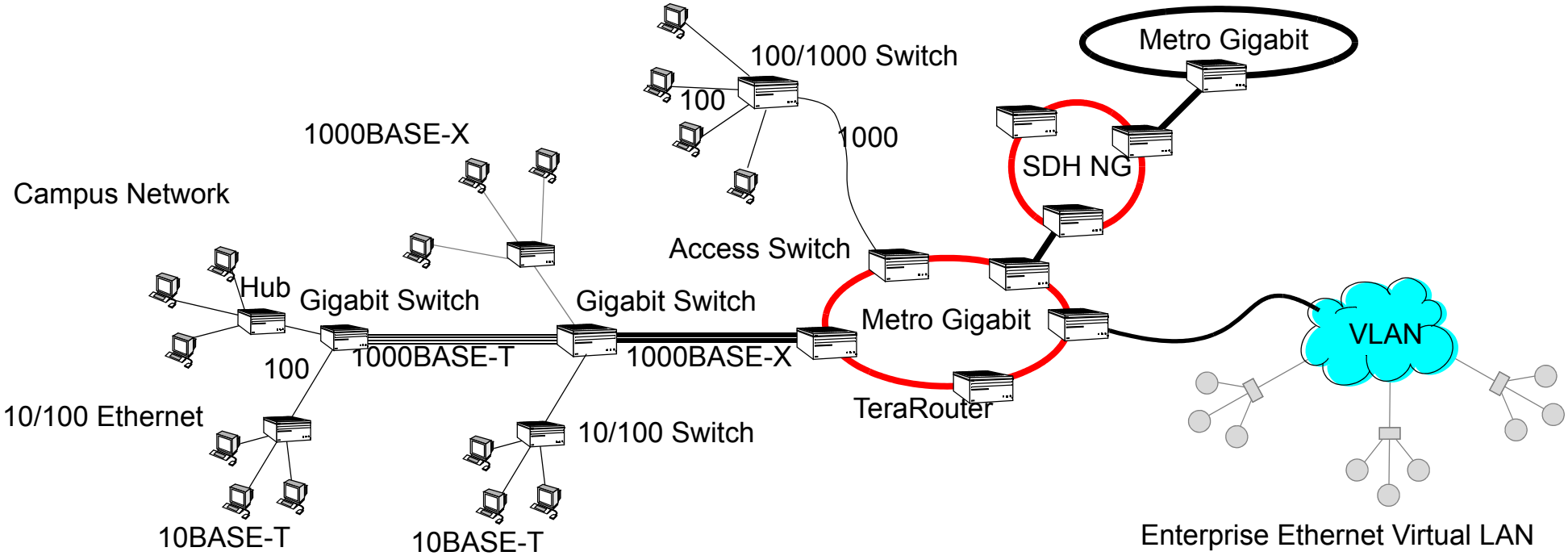
Source: Infonetics – April 2005



Source: Heavy Reading – May 2005

Gigabit Ethernet roll-out

The Testing Challenge



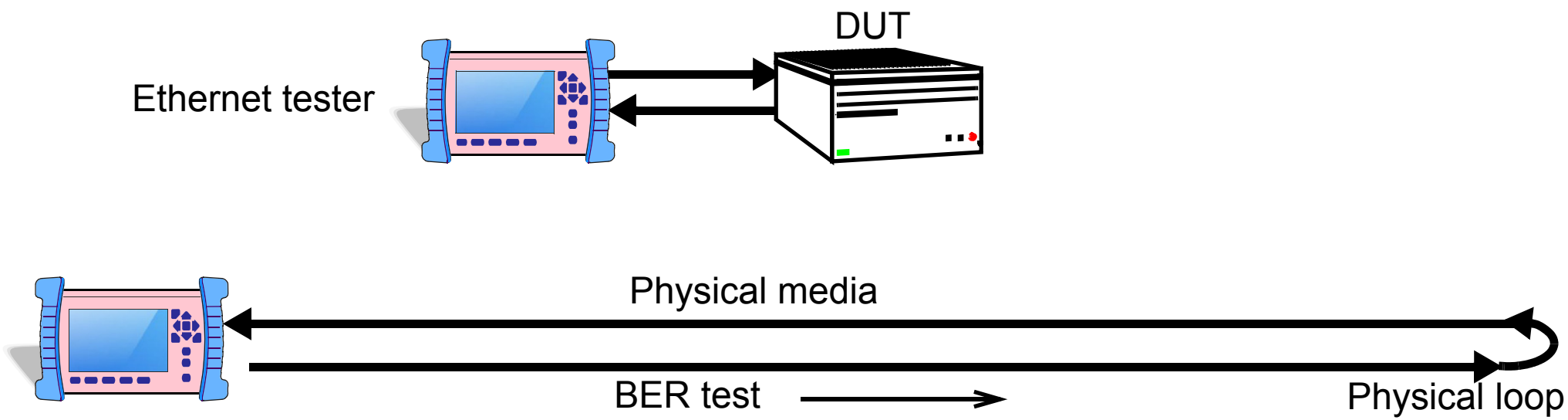
- Approval and Acceptance test, to compare equipment and to verify their correctness
- Installation test, to bring-into-service segments or nodes connected to the links
- Performance test to evaluate the capacity of the network
- Maintenance to guarantee correct network operation, fixing faults and verifying SLA
- Monitoring, analyzing traffic and statistics, enables re-engineering and troubleshooting

Approval and Acceptance

These tests help operators to compare devices from different vendors, with a view to choosing one, and to confirm that they work properly before purchasing them.
Tests can include:

- Physical-Layer Interoperability testing
- Auto-Negotiation testing
- Flow Control and Pause protocol testing
- PCS and PMA testing, including synchronization
- MAC layer testing, including error management and full-duplex verification

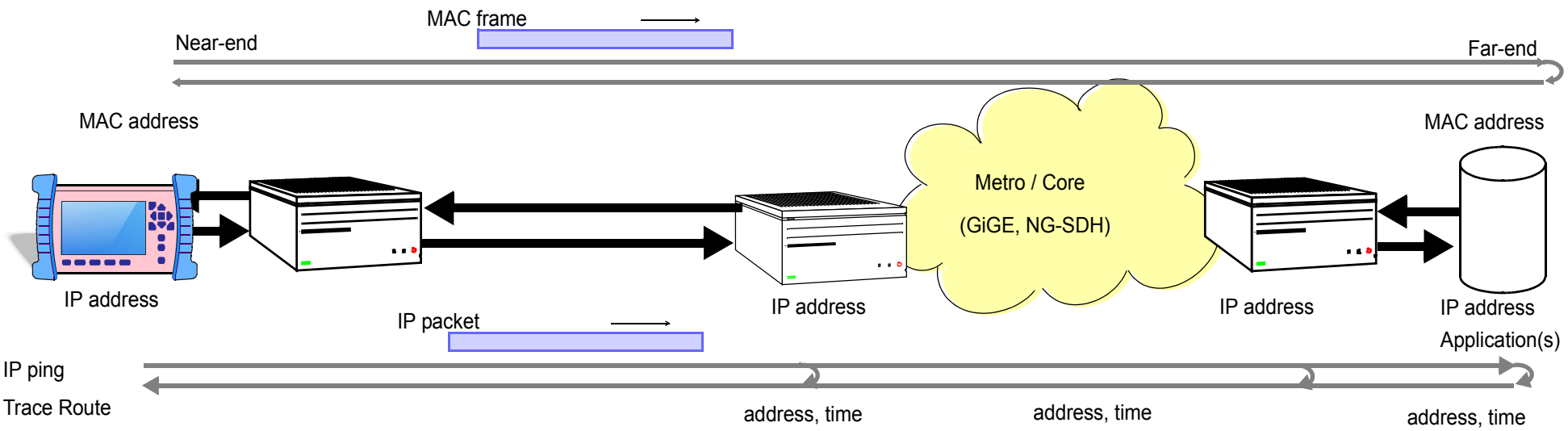
Acceptance Test



This is a benchmark test to verify that a product performs the required functions and meets specified operational parameters. It should include:

1. Physical interfaces: Optical and/or electrical interfaces and frequency tests
2. Cabling test: Fibre Optic or UTP cabling test

Installation test



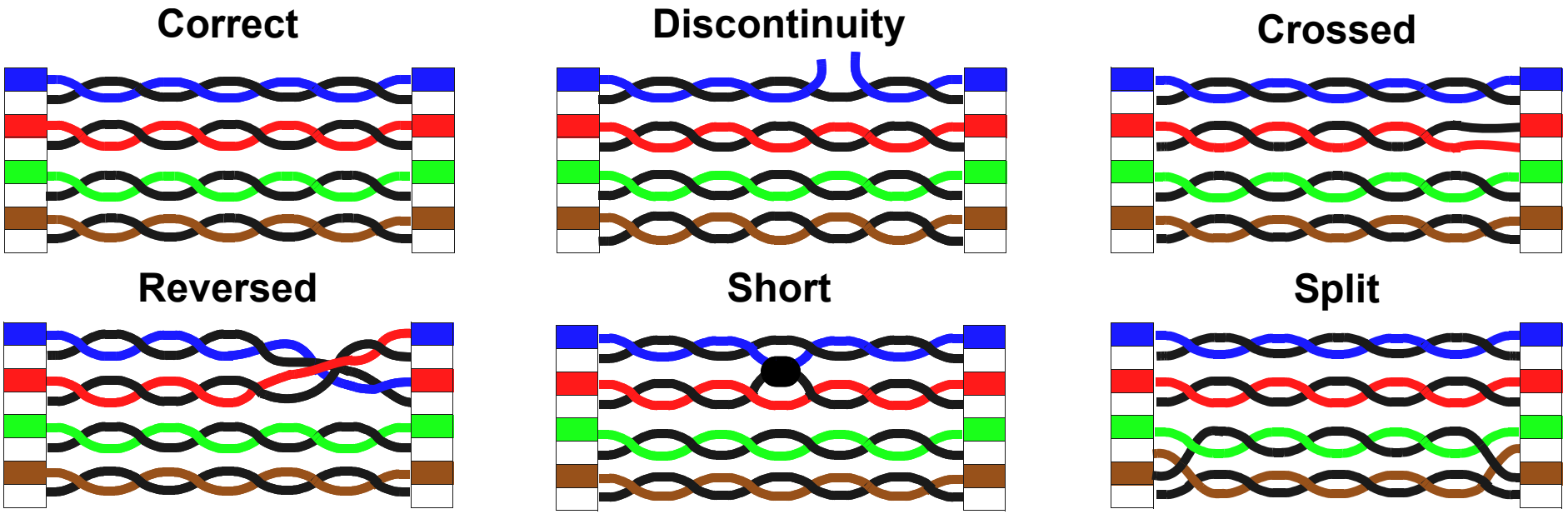
The operations involved are configuration of nodes, continuity and interconnections:

1. Configuration, includes protocol set-up, IP addresses, networks and subnetworks, masks, routing tables, mappings, and encapsulations.

2. Continuity test at:

- Physical layer, by means of a BER test
- MAC layer, by means of MAC frame generation/analysis
- IP layers, by means of Ping and Trace Route

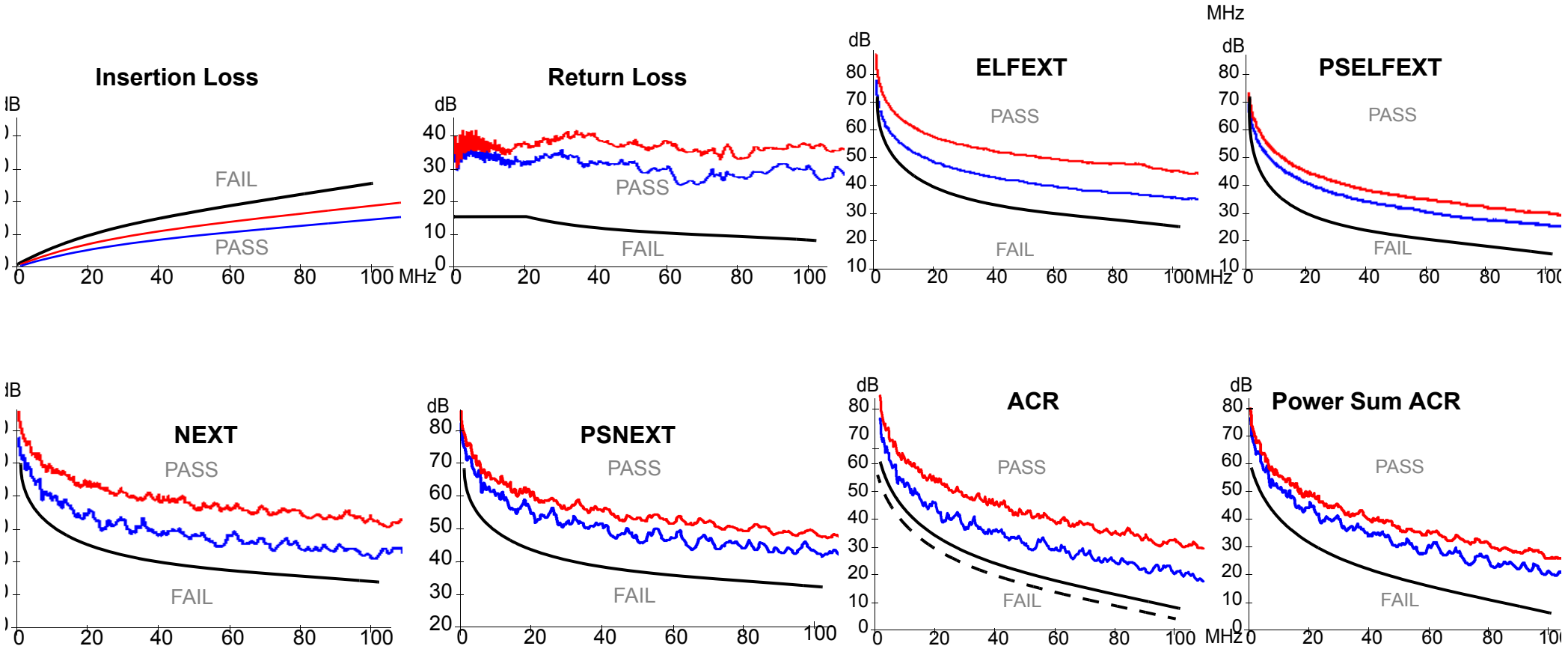
Wiremap Testing for 1000BASE-T



Wiremap is used to identify installation wiring errors, and it should indicate:

- proper pin termination at each end
- continuity to the remote end
- shorts between any two or more conductors
- crossed pairs or polarity swap, split pairs, reversed pairs or pair swap
- shorted pairs and any other miswiring

UTP Cat. 5e Certification



Migration from 10/100BASE-T requires a new certification of the UTP cabling for the new 1000BASE-T applying the new Cat.5e masks

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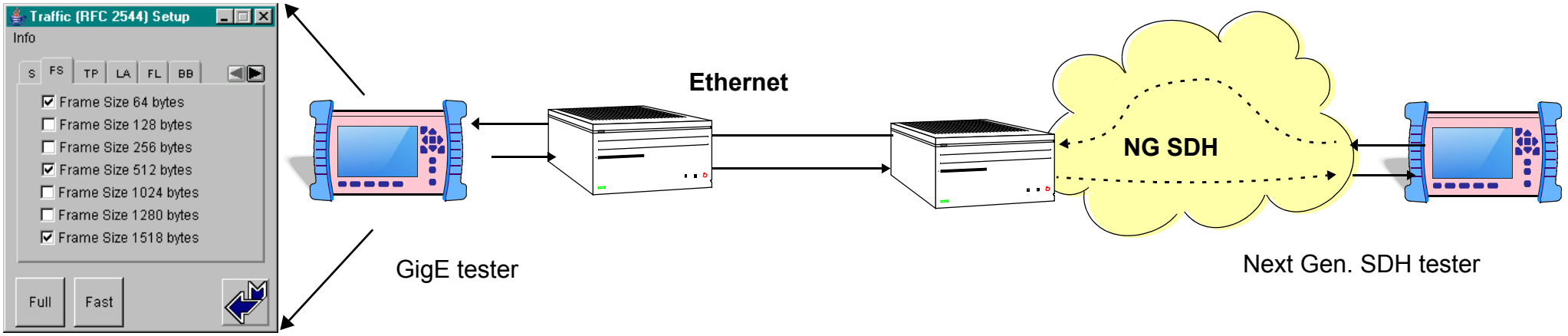
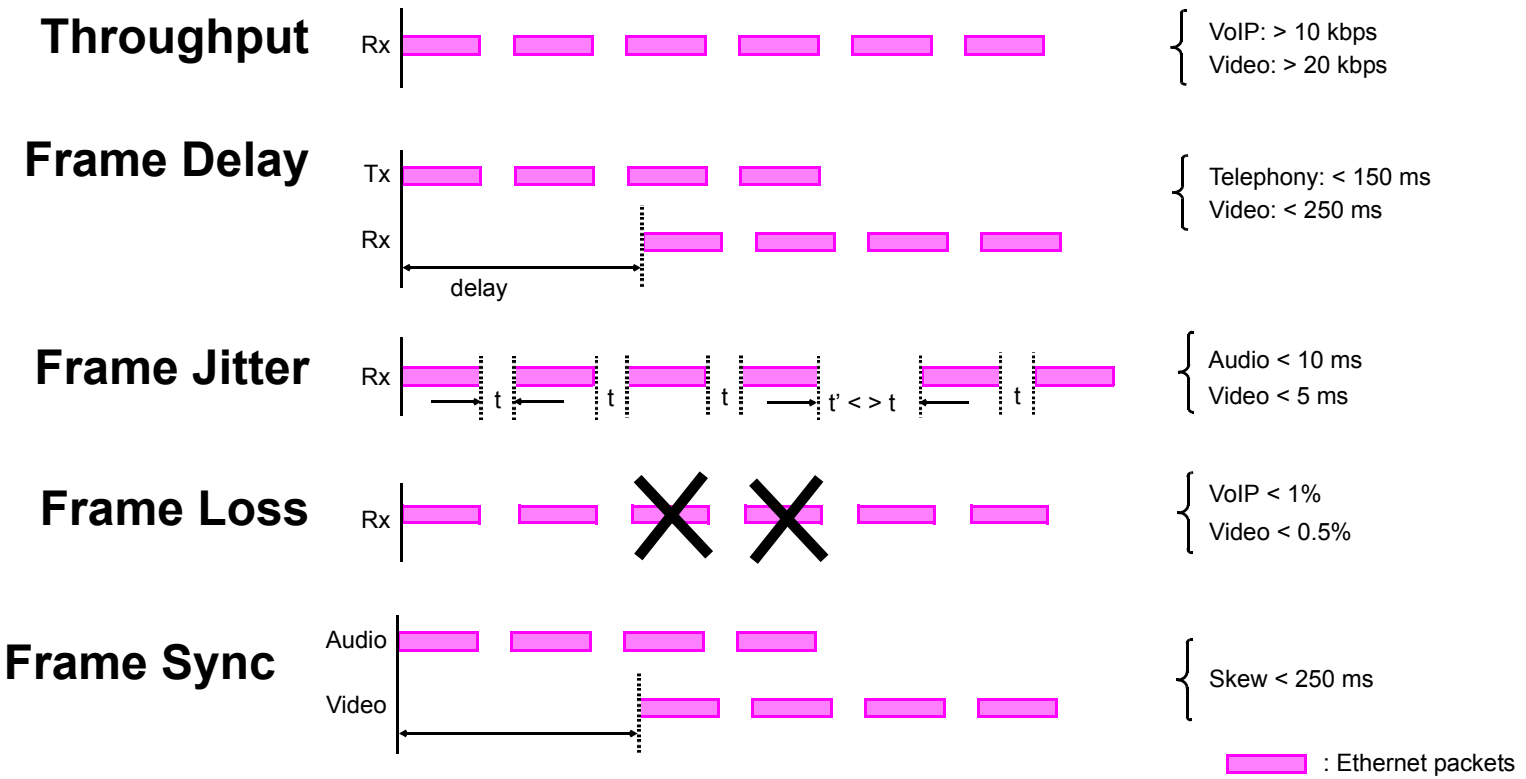
Performance Test by Means of RFC-2544



The RFC-2544, designed to verify the performance of LAN devices, has been adopted to verify network performance by means of the following parameters:

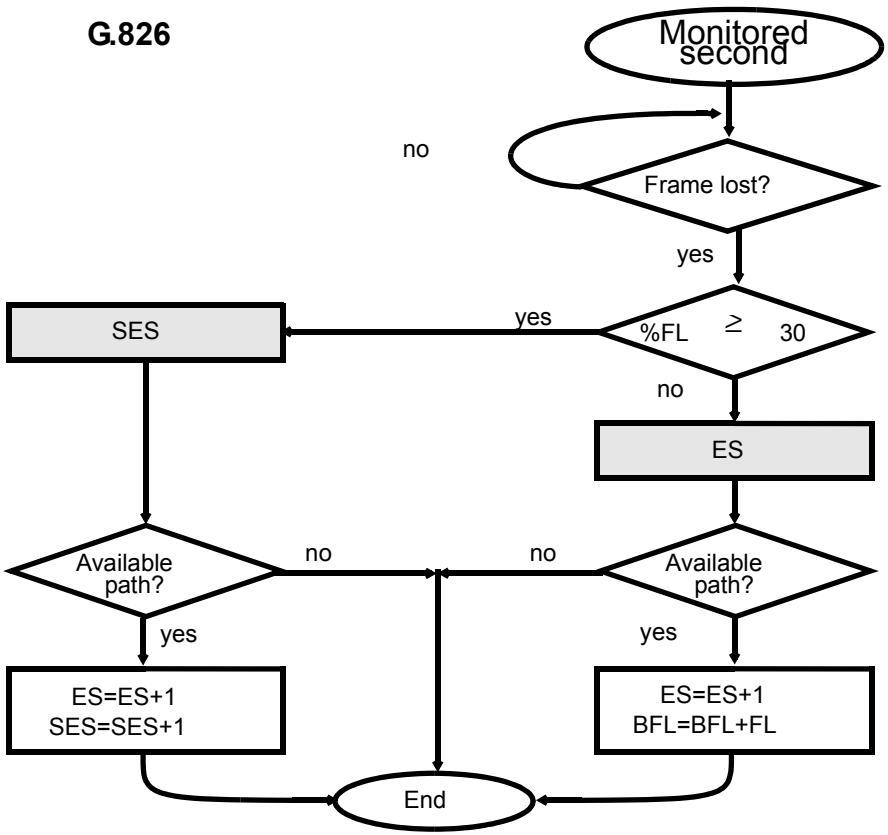
- **Throughput**: the number of bits transmitted per second without losing frames
- **Latency**: the average time that elapses between sending traffic and receiving it
- **Frame loss**: the percentage of the maximum rate at which no frames are lost
- **Burstability or back-to-back**: the maximum number of frames that can be sent in a fixed period of time without frames being dropped
- **Recovery**: characterizes how quickly the network recovers from an overload condition
- **Reset**: the time in which a network or station recovers from a reset

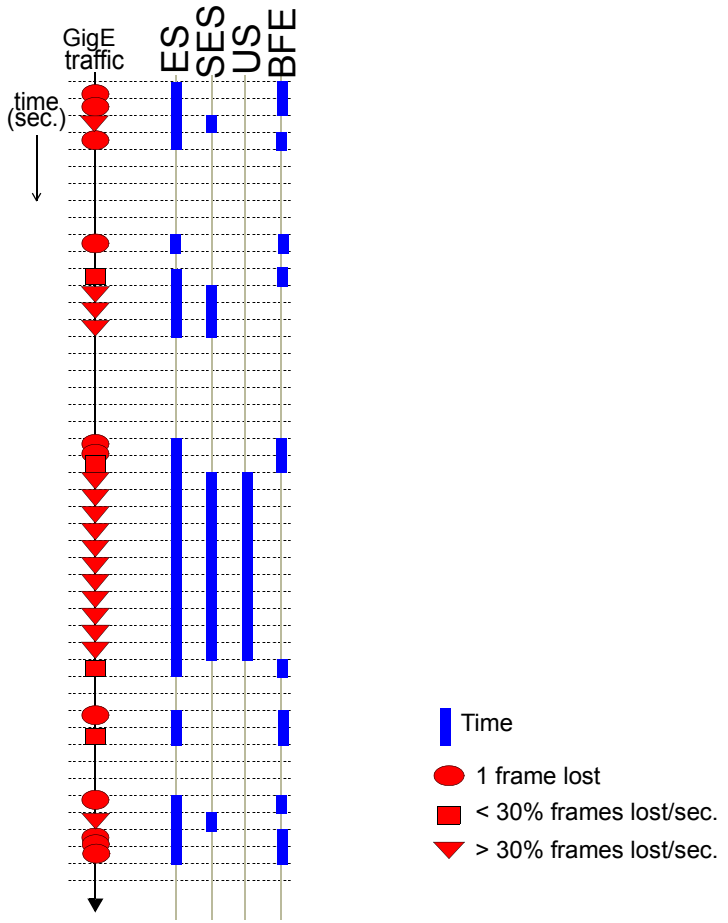
Performance Parameters



- Performance parameters affect the service quality experienced by the subscriber. The MEF has defined availability, frame delay, frame jitter and frame loss
- The objective is to offer a QoS equivalent to the existing data services, FRL or ATM, in order to support data services and voice, video or triple play as well

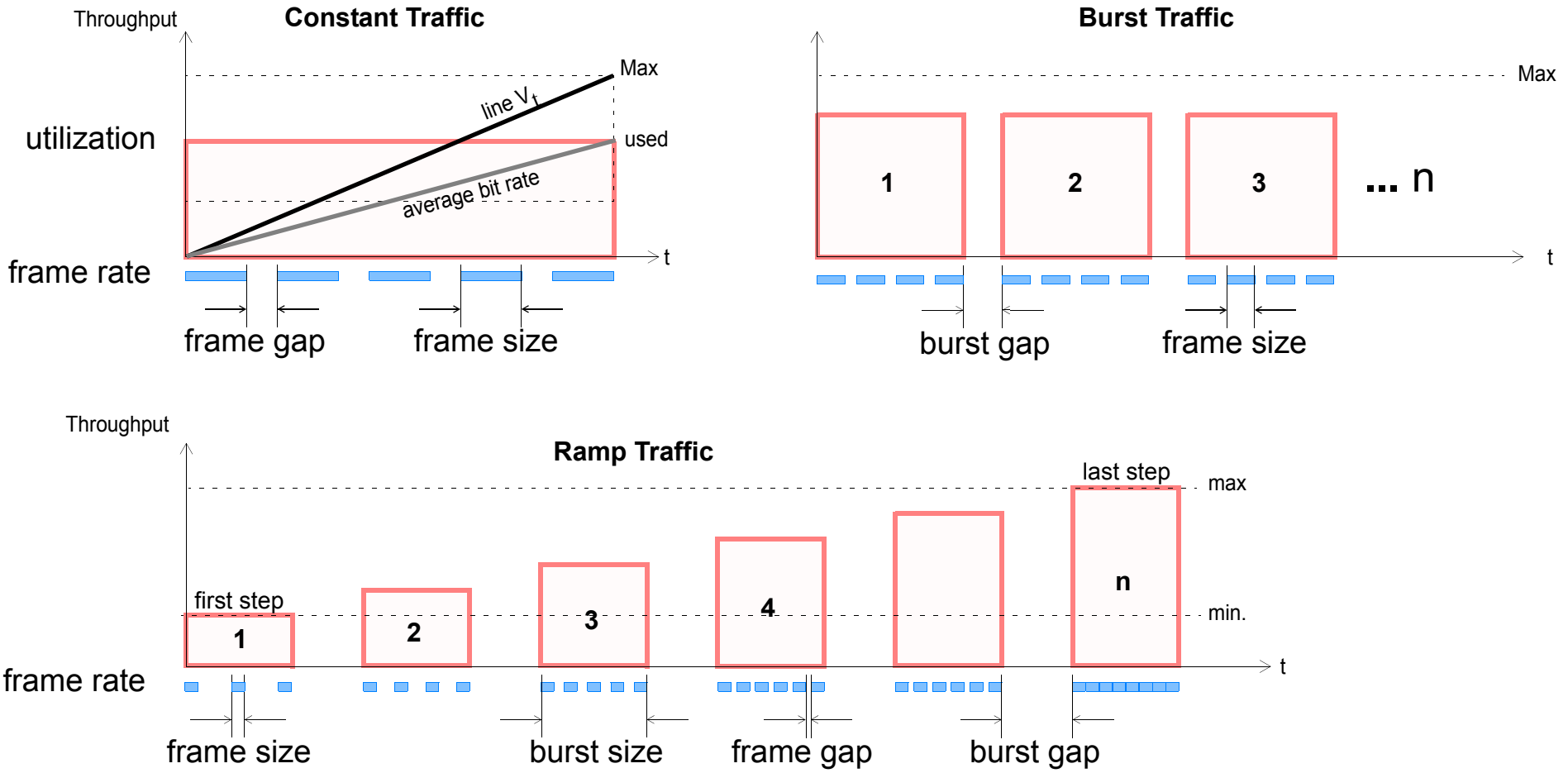
Performance by Means of G.826-Like Test





Trend Communications, matching blocks to frames, has created a 826-like test to measure the performance of Gigabit Ethernet, Errored Seconds (ES), Severely Errored Seconds (SES), Unavailable Seconds (US) and Background Frame Error (BFE).

Maintenance Test

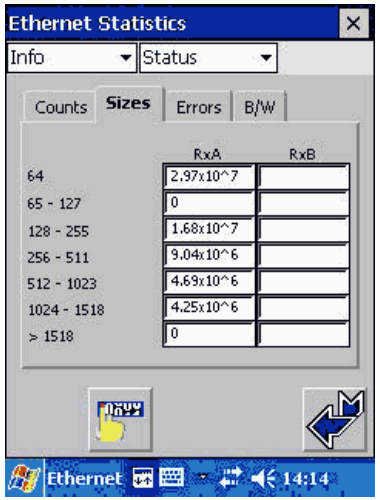


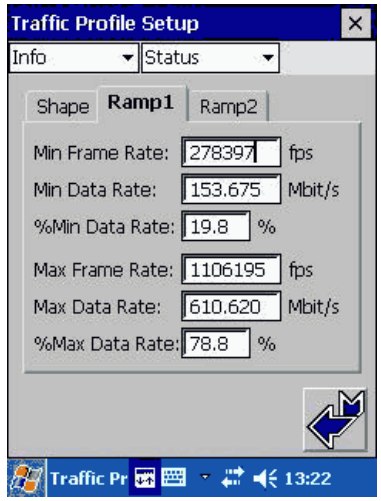
A number of tests that allow for the verification of carrier-class services, SLA, and troubleshooting of faults once the network is in service

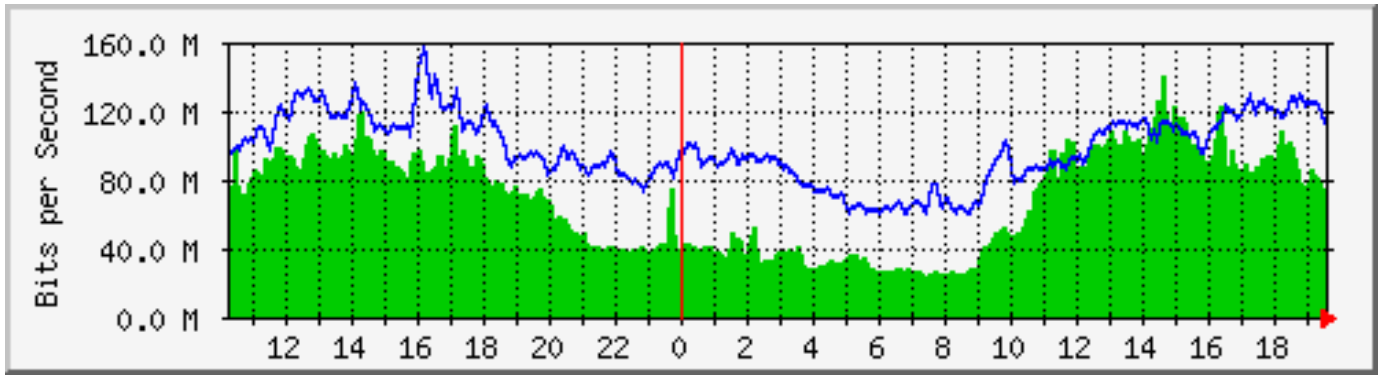
Monitoring Test

Traffic statistics are an important source of information to plan and re-engineer services.

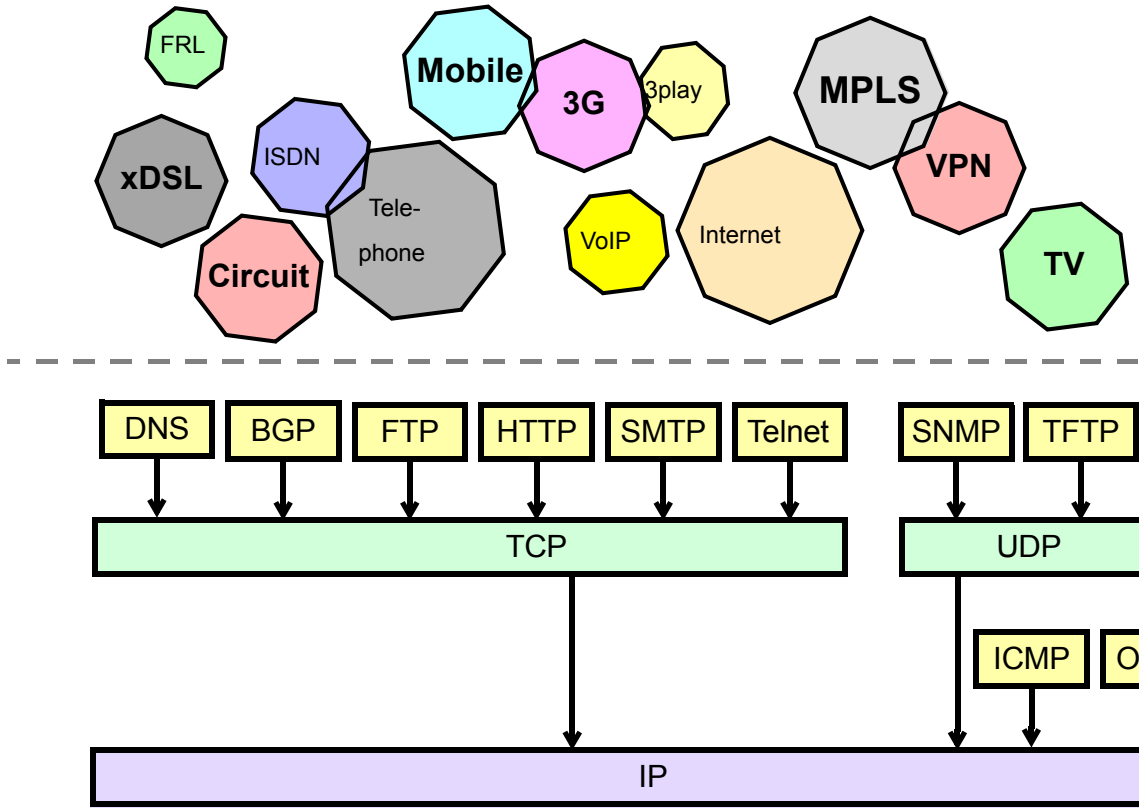
The Ethernet level can include a large number of parameters, such as *Common Address*, *Packet sizes*, *Pattern*, *Counts*, *Sizes*, *Errors*, *Delays*, *Utilization*, etc.





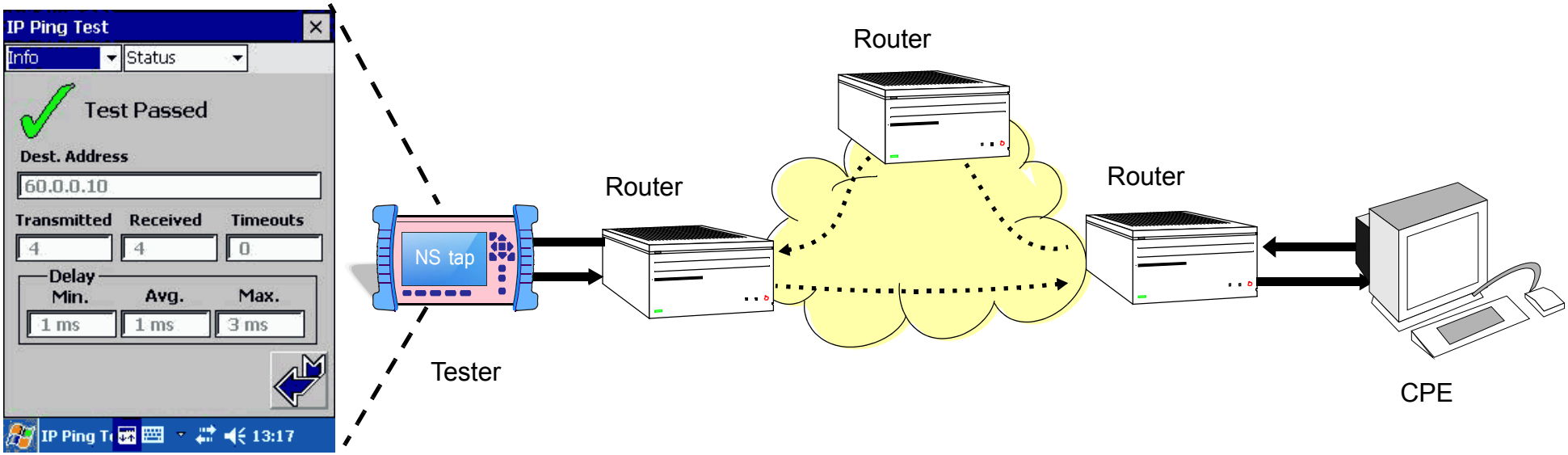


Higher-Layer Testing



There are many hardware and software tools that can carry out all types of tests on the higher layers based on TCP/IP. These tests vary from simple connectivity tests, such as IP ping, up to detailed traffic statistics and tracing.

ICMP analysis

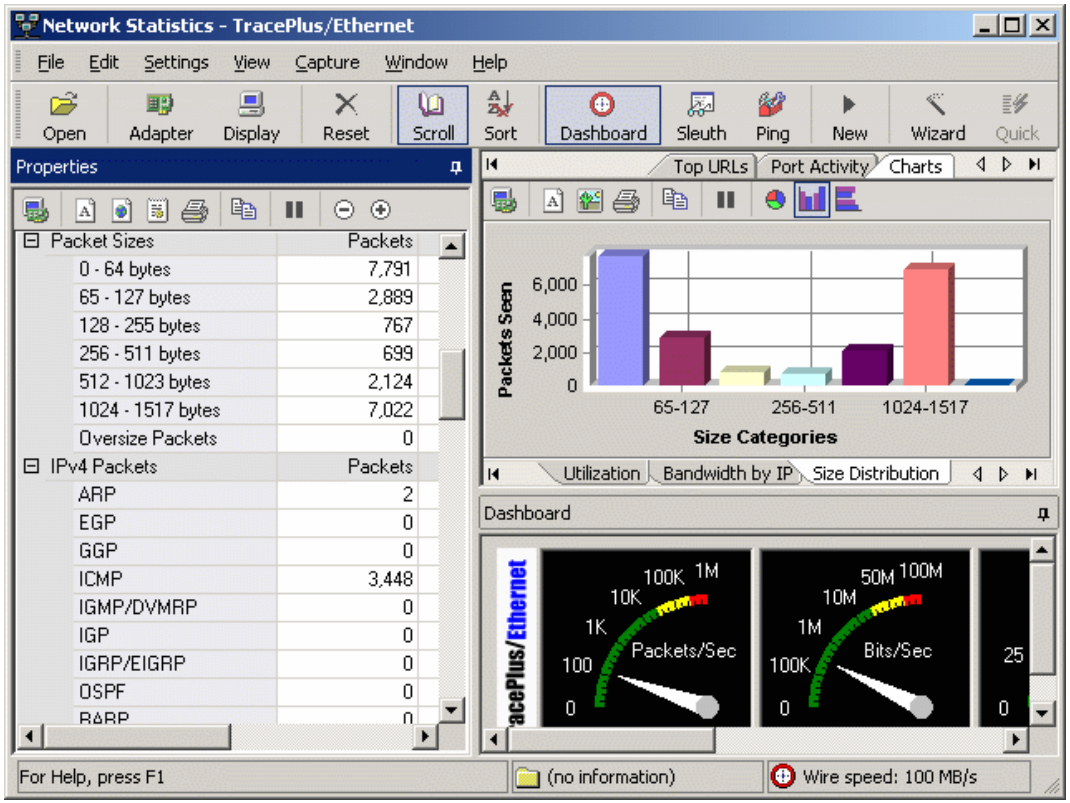


The *Internet Control Message Protocol* (ICMP) works closely with the TCP/IP used for error reporting and analysis, transferring messages (not data!) from routers and stations, and for reporting network configuration and performance problems.

The most popular ICMP applications are:

- IP Ping
- Trace Route

Ethernet Monitoring and Troubleshooting



Therea many tools, even freeware, to monitor Ethernet / IP traffic with advanced functions for *traffic capture and analysis*. Network administrators can use these tool to *troubleshoot* their network, developers might use it to *debug* protocol implementations. Functions like traffic filtering on- and off-line, by MAC/IP address, IP address range, name, protocol type, or by any value at byte offset, capture and trending for both shared and switched environments. It can be attached to a remote probe, and this way you can manage remote networks.

Observer: Network Monitoring and Troubleshooting

Observer can monitor Ethernet (10/100/1000), providing measurements, traffic filtering on- and off-line, by MAC/IP address, IP address range, name, protocol type, or by any value at byte offset, capture and trending for both shared and switched environments. It can be attached to a remote probe, and this way you can manage remote networks.

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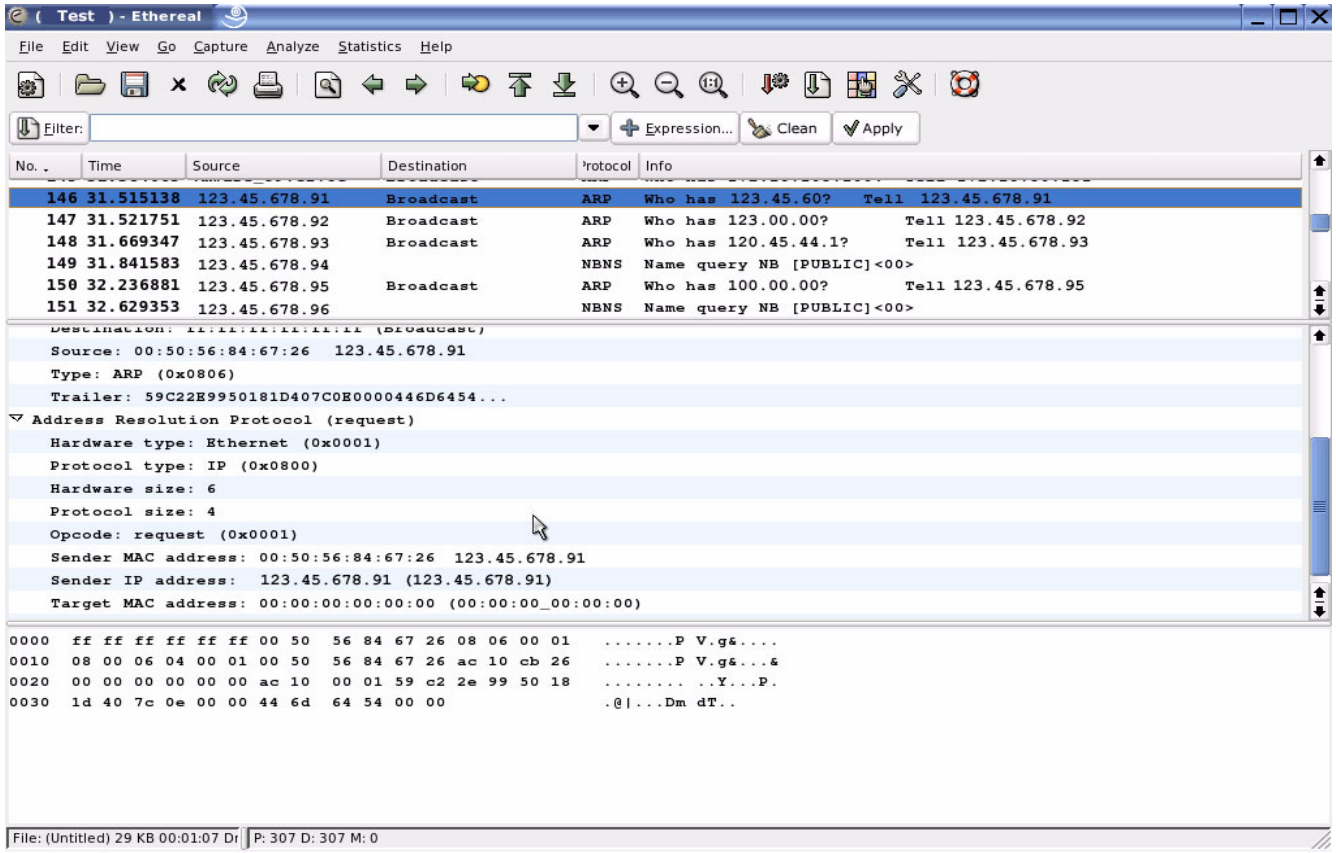
Ethereal: a Freeware Solution



You can use Ethereal for both *capture* and *analysis*. Network administrators can use this tool to *troubleshoot* their network, developers might use it to *debug* protocol implementations, and if you work in network security, you can use this tool to solve *security* problems.4

Conclusions

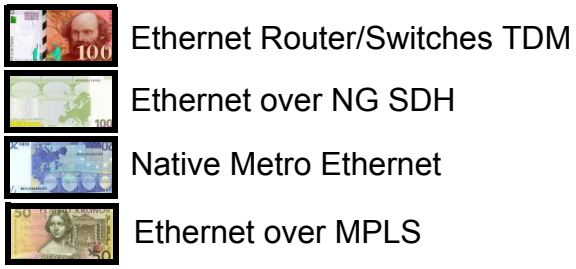
Could it Be the Universal Telecom Service?

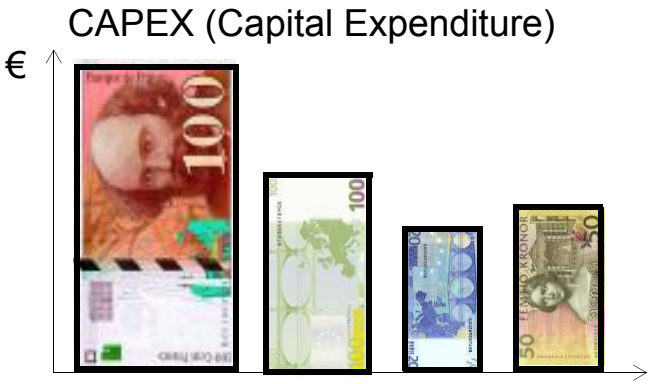
- Easy to use
  - Well understood
  - Highest availability
- Cost effective
  - A lot of competition, which means low cost
  - Elder equipment can be re-developed
- Flexible
  - Packet-oriented: best granularities
  - High scalability from 10 Mbit/s, up to 10 Gbit/s
  - Many topologies, point-to-point, multipoint, LAN, MAN, WAN
- Market-driven standard
  - During the past 30 years
  - New standards continuously appearing, i.e. local loop, carrier class, etc.
  - Why Carrier-class? > To occupy the PDH, FRL and ATM markets.

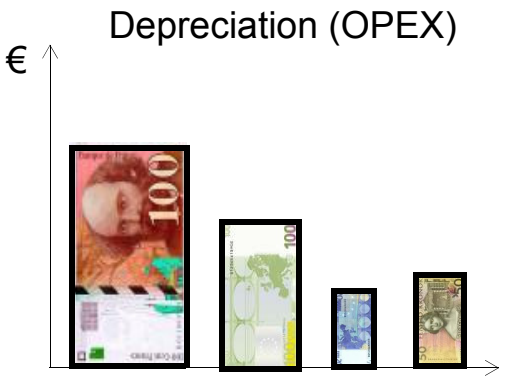
Ethernet Main Services

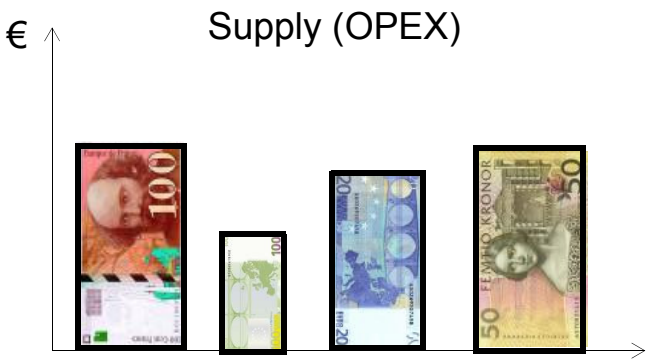
Application	IP Telephony	Host/Server Storage	IP VPN	Video on Demand	Datacom	Internet Access	Transport DSLAM
Service	E-line and E-LAN						
Infrastructure	Ethernet over fibre	Ethernet over DWDM	Ethernet over RPR	Ethernet over MPLS	Ethernet over NG SDH		

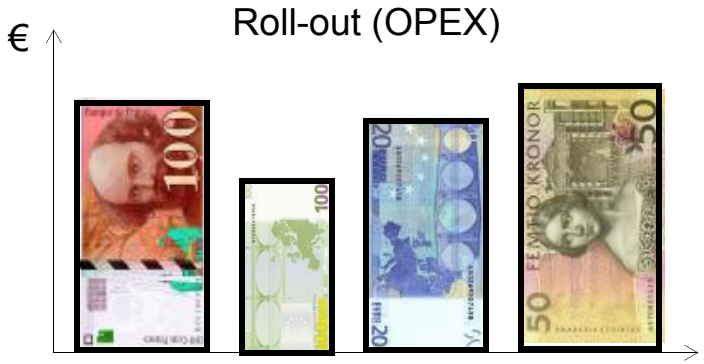
Ethernet Cost Evaluation

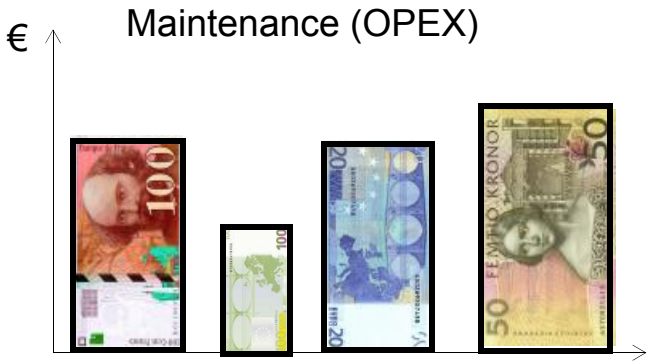












Capex: Equipment cost, software, acceptance test, cabling, upgrading

Opex: Depreciation: low capex results in low depreciation, and high capex in high depreciation

Supply: licences, leased lines and networks, contracts

Set up: installation, cabling certification, synchronization, etc.

Maintenance: Monitoring, troubleshooting

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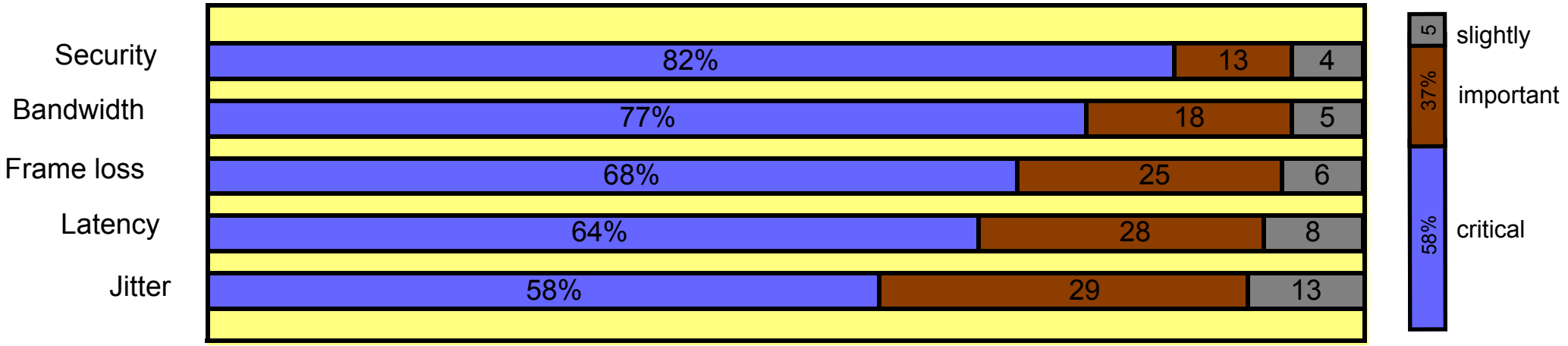
Good, But Still Some Challenges Ahead



(Source: Heavy Reading)

Ethernet is the choice for a large number of customers - for any size of business and budget

The best benefits are mentioned above, however, some features are still under way:

- Market penetration in Metro and WAN
- Services Management including proper O&AM
- Carrier-class services
- SLA monitoring
- End-to-end restoration

That's al

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