SAPIENZA
UNIVERSITÀ DI ROMA

Network Infrastructures

A.A. 2017-2018
Prof. Francesca Cuomo

Carrier Ethernet

- The capacity and flexibility of Ethernet have evolved very quickly over the last decade
- It is now possible to build MAN and WAN solutions based on Ethernet
- SONET/SDH
  - It is a multiplexing transmission carrier system, in which lower bit rate channels are interleaved into a higher level, fixed-length, frame structure
  - Circuit-based, TDM
  - It is optimal for voice traffic, but not for data traffic
    - » It offers a series of time slots for streams of predictable traffic
  - The equipment is speed-specific

Carrier Ethernet

- SONET/SDH (continued)
  - Due to the TDM nature of SONET, carriers can only offer fixed bandwidth services
  - Throughput mismatch issue
    - » A client wants a 100 Mbps service, the carrier must provision a 155 Mbps SONET channel to carry it
  - It is very complex to understand and to implement
    - » High operating cost because of the need for a highly skilled workforce

Carrier Ethernet

- ATM
  - Flexible switching technology
  - It can establish a *virtual path* between users, and can adjust the link to suit different traffic types
- The Ethernet alternative
  - SONET and ATM are complex and expensive
  - Ethernet is more affordable and easier to operate
  - High transmission speeds are now available
    - » 100 Mbps Ethernet, 1 Gbps Ethernet, 10 Gbps Ethernet, 40 Gbps, 100 Gbps
  - Ethernet is much easier to learn and to operate
  - Ethernet is IP-friendly

Ethernet

- Invented by Metcalf at Xerox in 1973, patented in 1976
- IEEE 802.3 standard (1985)
- 10BASE-T (1990)
  - 10 Mb/s half-duplex operation over Unshielded Twisted Pair (UTP) cables (star topology)
- Main advantages
  - Simplicity
  - It has evolved while maintaining backwards compatibility

Ethernet evolution

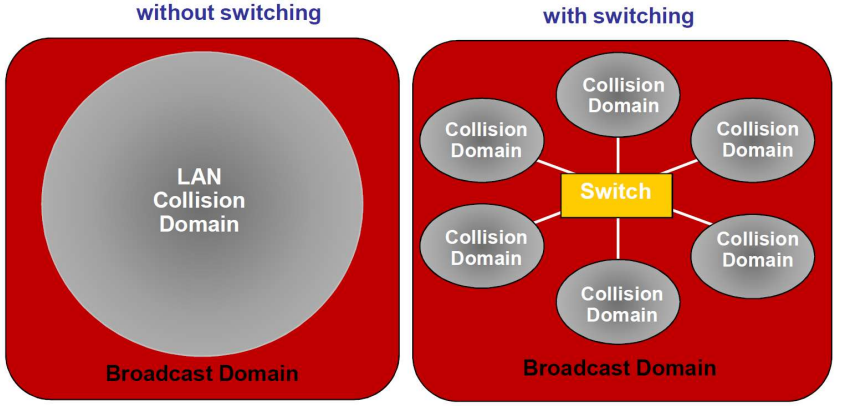
- Simplicity and reliability led to wide acceptance in the LAN market
- Limit on the cable length of Ethernet LANs
  - Ethernet islands proliferated in the business environment
- The switch (1984) allowed multiple Ethernet networks to be transparently interconnected
  - Higher bandwidth efficiency: users that do not communicate often are assigned to different LANs
  - A switch is limited to a single spanning tree
- Virtual LAN (VLAN, 1985)
  - Removes the single spanning tree limitation

Ethernet evolution

- With CSMA/CD the transmission distance has to be reduced as the transmission rate increases
  - There are workarounds but they decrease the efficiency
- Full-duplex Ethernet
  - Point-to-point links
  - CSMA/CD is replaced by a switch
  - Ethernet is no longer distance limited
    - » E.g., 80 km distances are possible with optical fiber links

Swicthed Ethernet

- Switches allow to create larger Ethernet systems by linking multiple collision domains together



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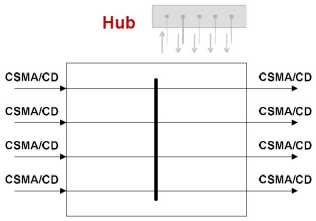
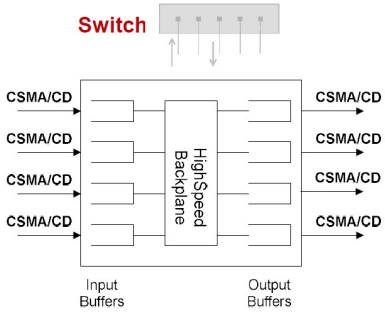
Hubs vs Switches

- An Ethernet Hub
  - does not perform buffering
  - Collisions occur if two frames arrive at the same time



- An Ethernet switch
  - prevents collision
  - Buffers frames
  - Each port is isolated and builds its own collision domain



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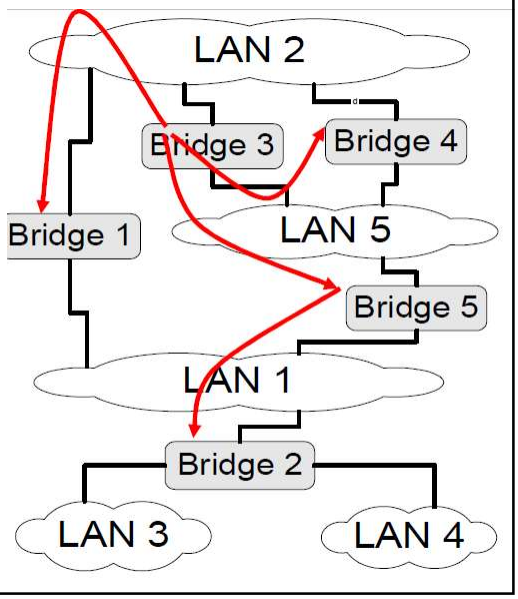
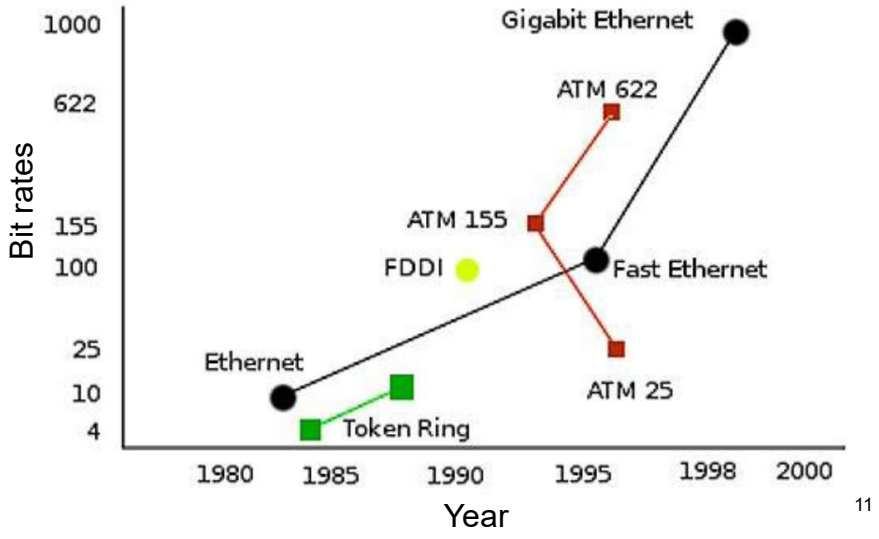
Main processes in a bridge/switch

The bridging process deals with:

- Frames forwarding from input to output port
- Build and update the database for forwarding decisions
- The spanning tree process
  - » this process is essential in presence of loops



Ethernet evolution



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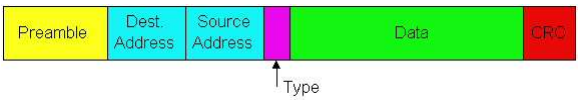
Ethernet frame

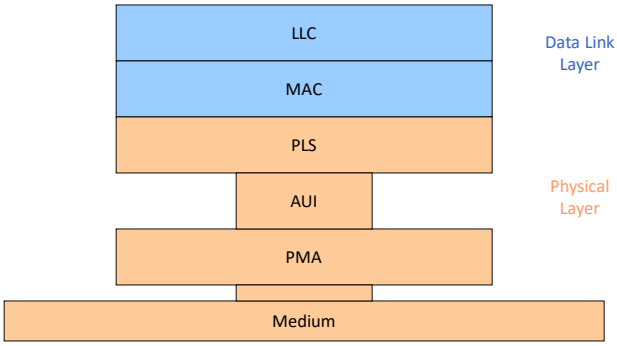
- The frame format DEFINES Ethernet



- Preamble (8 bytes): repeating pattern required for synchronization
- Source & Destination Addresses (6 bytes)
  - Ethernet addresses are globally unique
- Message type / message length (2 bytes)
- Data field (up to 1500 bytes in length)
  - Max frame size 1518 bytes
  - Minimum frame size 64 bytes -> up to 46 bytes padding
- CRC (4 bytes)

Ethernet protocol stack

- Layers 1 and 2 of the OSI model



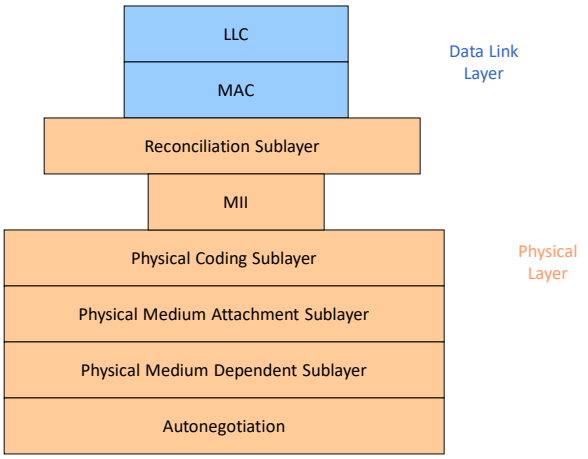
Physical Layer
- PMA: Physical Medium Attachment
- PLS: Physical Signaling Sublayer
- AUI: Attachment Unit Interface

Data link layer
- MAC: Medium Access Control
- LLC: Logical Link Control

Fast Ethernet (IEEE 802.3u, 1995)

- 100 Mbps, extension of the original standard (CSMA/CD)
- Physical layer
  - 100Base-TX (unshielded twisted pair)
  - 100Base-T4 (shielded twisted pair)
  - 100Base-FX (optical fiber)
  - 100Base-SX (optical fiber)
  - 100Base-BX (single mode fiber)
- The physical layer supports autonegotiation
  - It determines the network capability of each device and optimizes transmission parameters (speed, duplex mode, etc.)

Fast Ethernet: protocol stack



- RS maps the serial bitstream of the MAC into the MII
- PCS provides a uniform interface to the RS; it generates CS and CD indications
- PMA performs framing
- PMD maps the physical medium to the PCS

Timing issues in CSMA/CD

- Slot time
  - Derived from the worst-case round-trip delay in the network
  - It is the basic time unit in the backoff algorithm
    - Backoff delays are restricted to integral multiples of the slot time
  - It defines the minimum frame length
- Collision Detection (CD)
  - In case of collision the frame is retransmitted
    - The absence of a collision during transmission is considered by the sender as an implicit acknowledgement
  - Because of the constraint on the minimum frame length, two frames that collide at the receiver **also collide at the transmitter**

Timing issues in CSMA/CD

- The time to transmit a frame must not be less than the round-trip delay
- Any increase in the data rate of a CSMA/CD network must be accompanied by either:
  - a decrease in the maximum distance spanned by the network; OR
  - an increase in the slot time (thus, in the minimum frame size).
- With IEEE 802.3u:
  - data rate: 10 Mb/s -> 100 Mb/s
  - slot time: left unchanged, at 512 bit times (64 Byte)
  - maximum distance: reduced to 205 m
    - acceptable because of increasing network segmentation

Gigabit Ethernet

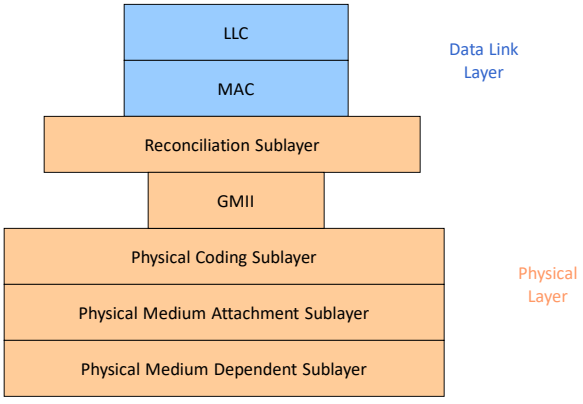
- Need to transfer a large amount of data, possibly over long distances
  - Higher capacity Ethernet is appealing because network managers can leverage their investment in staff skills and training.
- IEEE 802.3z Task force (1997)
  - 1000 Mbps bandwidth
  - IEEE 802.3 Ethernet frame format
  - Half-duplex, full-duplex MAC
  - Backward compatible
- IEEE 802.3z (1998): 1000BASE-X
- IEEE 802.3ab (1999): 1000BASE-T

Gigabit Ethernet

Name	Cable	Max. segment	Advantages
1000Base-SX	Fiber optics	550 m	Multimode fiber (50, 62.5 microns)
1000Base-LX	Fiber optics	5000 m	Single (10 μ) or multimode (50, 62.5 μ)
1000Base-CX	2 Pairs of STP	25 m	Shielded twisted pair
1000Base-T	4 Pairs of UTP	100 m	Standard category 5 UTP

- IEEE 802.3u
  - 1000BASE-SX: fiber, short wavelength
  - 1000BASE-LX: fiber, long wavelength
  - 1000BASE-CX: copper, shielded twisted pair
- IEEE 802.3ab
  - 1000BASE-T: copper, unshielded twisted pair

Gigabit Ethernet: protocol stack



- RS maps the serial bitstream of the MAC into the GMII
- The GMII supports 10-, 100-, and 1000-Mbps data rates; it allows any physical layer to be used with a given MAC
- PCS provides a uniform interface to the RS; it generates CS and CD indications; performs autonegotiation
- PMA performs framing
- PMD maps the physical medium to the PCS

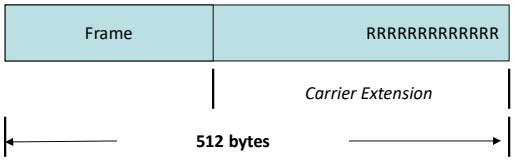
Gigabit Ethernet: MAC

- Gigabit Ethernet can be shared (hub) or switched
- Shared Hub
  - **Half duplex**: CSMA/CD **with MAC changes:**
    - » Carrier Extension
    - » Frame Bursting
- Switch
  - **Full duplex**: Buffered distributor
  - The full duplex mode increases the overall bandwidth as well as the maximum transmission distances

CSMA/CD Extensions

- With a speed of 1000 Mb/s it is no longer possible to leave the slot time unchanged
  - A maximum cable length of 20m would not be very useful!
- The slot time increases from 512 bits to 512 bytes (4096 bit times)
- Problem: to maintain compatibility with Ethernet, the minimum frame size cannot be increased from 64 bytes to 512 bytes
  - Bridged multispeed networks would not work well
- Solution: extend the *carrier event* without extending the frame (**Carrier extension**)

Carrier Extension



- For **10BaseT :** 2.5 km max; **slot time = 64 bytes**
- For **1000BaseT:** 200 m max; **slot time = 512 bytes**
- **Carrier Extension:** continue transmitting control characters [R] to fill collision interval.
  - This allows a minimum-length 64-byte frame to be handled.
- Control characters are discarded at destination.

Carrier Extension

- If the transmitter reaches the end of a frame without detecting a collision, it looks at the frame length
  - If the length is at least one slot time (512 bytes) the transmitter returns a *transmit done* status code to its client
  - If the length is less than one slot time, the transmitter continues transmitting a sequence of special *extended carrier* symbols until the end of the slot time, when it returns the *transmit done* status code
- The carrier extension is *not* part of the frame, and is handled locally within each collision domain
  - However, a collision in the extension will cause the frame to be dropped by the receivers

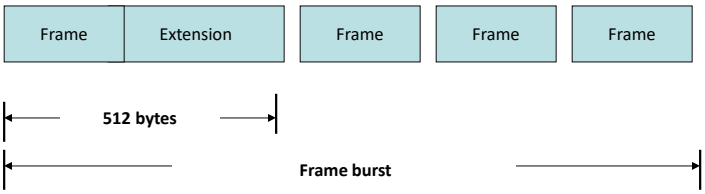
Carrier Extension

- At the receiver, if the total number of incoming bits is below one slot time, the incoming frame is discarded.
- Carrier extension can be very bandwidth inefficient
  - It significantly increases the transmission time for short frames
  - E.g., for a host that generates only 64-byte frames, there would only be a 25% net increase in throughput in comparison with Fast Ethernet
- There is a need to add *pipelining* to the frame transmission process

How to add pipelining?

- Some authors had proposed adopting a go-back-N ARQ protocol
  - Too complex
- A scheme called *packet packing* was considered
  - Combine several frames into a single block, to which carrier extension is applied if it is still too short
  - It is very efficient
  - Requires significant changes to the interface between the MAC layer and its client
    - » No status code after each frame, several unacknowledged frames
    - » The receiver must buffer frames until the end of the slot time

Frame Bursting



- Stations are allowed to send a number of short frames without relinquishing control of the network.
- The first packet is padded to the slot time, if necessary, using carrier extension
  - This ensures that collisions can only affect the first frame of a burst
  - Sender and receiver can retain the one-frame-at-a-time service interfaces
- Subsequent packets are transmitted back to back, with the Minimum Interpacket Gap (IPG), until a *burst timer* (1500 bytes) expires

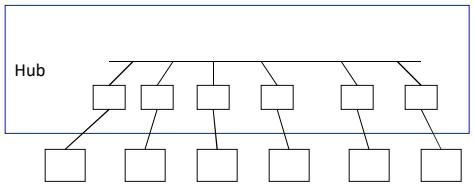
Frame Bursting

1. The transmitter checks if its *burst timer* is running. If not, then the medium is not busy (first frame). The MAC sets a first frame flag, starts its burst timer and starts transmitting. If the frame is less than 512 bytes it will include a *carrier extension*.
2. Right after the carrier extension, the next frame is sent. This happens immediately because the burst timer is already running (clear to send). Now there is no chance of a collision occurring, so this frame is sent *without carrier extension*.

Frame Bursting

- Because of the high speed, flow control is always necessary
  - It is implemented in the PCS, together with autonegotiation
- Note that the decision to allow another frame in the burst is based on the outcome of two tests
  - The transmission must begin before the burst timer reaches a certain value
  - The next frame must be available for transmission before the end of the IPG interval (96 bit)

Buffered Distributor



- A buffered distributor is a new type of 802.3 hub where incoming frames are buffered in FIFOs.
- CSMA/CD arbitration is inside the distributor to transfer frames from an incoming FIFO to all outgoing FIFOs.
- 802.3x frame-based flow control is used to handle congestion.
- All links are full-duplex.

10-Gigabit Ethernet

- Standards
  - IEEE 802.3ae-2002 (fiber)
  - IEEE 802.3ak-2004 (copper)
  - IEEE 802.3an-2006 (copper twisted pair, 10GBASE-T)
- It only supports full duplex operation (full duplex links, connected by switches)
  - Half-duplex links and CSMA/CD are *not* supported!
- Physical layer: serial and parallel implementation
  - The serial implementation is simpler but requires high-speed logic circuits and technology
  - In the parallel PHY, data are multiplexed on a number of separate streams
    - Parallel cabling or WDM (Wavelength Division Multiplexing)

10 Gigabit Ethernet: MAC

- Similar to Ethernet MAC, but only full duplex
- Half-duplex: low efficiency, distance limitation
  - At 10 Gbps half duplex would not be an attractive option
  - At these speeds most links are point-to-point over optical fibers
- Full-duplex:
  - No contention, the MAC can transmit when it wants
  - The link distance is only limited by the characteristics of the physical medium and devices, power budgets, modulation

10 Gigabit Ethernet: MAC

- Standard Ethernet frame format
  - The link distance does not affect the frame size
  - Minimum MAC frame size: 64 bytes
- Pacing mechanism
  - It allows the MAC layer to support transmission rates lower than 10 Gbps
  - The MAC entity can pause data transmission for an appropriate period of time
    - It can thus provide flow control or rate adaptation
  - Two techniques:
    - Word-by-word hold: the MAC pauses to send a 32 bit word of data upon request from the physical layer
    - IFG stretch: the InterFrame Gap is extended

The Ethernet Family

Ethernet

10	The transmission rate is 10Mbps
Base	Baseband transmission
T	Unshielded Twisted pairs
2	Coaxial cable (thin)
5	Coaxial cable (thick)
F	Optical fiber

Fast Ethernet

Standard	Physical medium
100Base-T4	4 pairs UTP
100Base-T2	2 pairs UTP
100Base-TX	UTP
100Base-FX	Optical fiber

GigaBit Ethernet

Standard	Physical medium
1000Base-SX	Multimode fiber (short wavelenght)
1000Base-LX	Multimode fiber (long wavelenght.)
1000Base-CX	Shielded twisted pair (STP)
1000Base-T	4 pairs UTP full duplex

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Ethernet: the next generation

- IEEE 802.3ba Task Force
- Existing networks are strained by growing bandwidth requirements
- Growth is driven by two factors
  - Bandwidth consuming content is being utilized by an increasing number of users
  - The bandwidth requirements for computing and server applications at the network edge are driven by CPU performance (Moore's law)
- Previously we made 10x leaps in the MAC data rate

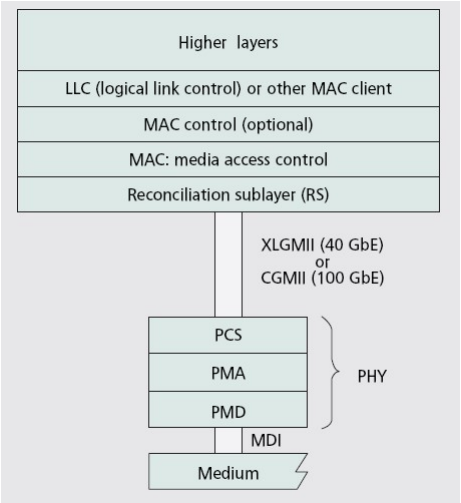
Ethernet: the next generation

- IEEE 802.3ba adopted two new rates:
  - 40 Gb/s for computing and server applications
  - 100 Gb/s for network aggregation applications

	40 GbE	100 GbE
At least 1 m backplane	√	
At least 10 m copper cable	√	√
At least 100 m OM3 multi-mode fiber	√	√
At least 10 km single-mode fiber		√
At least 40 km single-mode fiber		√

Ethernet: the next generation

- Two approaches:
  - Single PCS
  - Aggregation of lower-speed parallel PHYs



Ethernet: benefits

- Simplified network architecture
  - A carrier can provide broadband connection by deploying Ethernet switches linked with fiber cables
  - Eliminate expensive SONET/SDH equipment
- Asynchronous network
  - SONET/SDH requires highly accurate network timing
  - Gigabit Ethernet operates in asynchronous mode
- Ethernet equipment is cheaper
  - Ethernet bandwidth is 85% cheaper than SONET bandwidth
  - Large groups of users and technicians are familiar with Ethernet technology
- Global end-to-end LAN connection
  - No necessity for protocol conversion at the network edge

Ethernet: challenges

- QoS
  - No admission control capability
  - Control on traffic aggregates, not on individual flows
  - Over-provisioning needed to provide delay sensitive apps
    - Possible thanks to the rapid growth in capacity
    - Ethernet is much cheaper than SONET, thus over-provisioning can still be a cost-effective solution
  - Some extensions to Ethernet deal with QoS
    - 802.1p implements QoS at the MAC level:
      - switches can reorder packets based on priority level;
      - eight traffic classes are defined.
  - QoS capability may be provided at the IP layer (IP/MPLS)

Ethernet: challenges

- Network performance monitoring capability
  - The SONET frame has overhead bytes for monitoring the network transmission performance
    - » Detect network degradation, localize faults, take maintenance actions
  - In the Ethernet frame there is no field for performance monitoring
    - » Only frame error check; if a frame is received with errors, Ethernet reports SNMP error messages
    - » This mechanism is very slow: protection/restoration times are on the order of 1 second compared to SONET 50 ms capability
  - The lack of monitoring capability is becoming less critical
    - » Fiber networks are very reliable

Carrier Ethernet

- It is the use of high-bandwidth Ethernet technology for Internet access and for communication among business, academic and government local area networks (LANs).
- It is an infrastructure technology that can be implemented over many different types of Layer 1 transport network technologies.

use the Carrier Ethernet technology within a metropolitan area network (MAN) is known as **Metro Ethernet**

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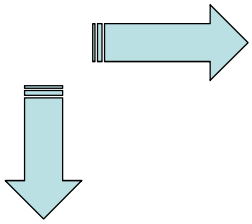
Carrier ethernet versus legacy technologies

Carrier Ethernet



•flexible bandwidth scalability.
•bandwidth can be added simply through remote provisioning up to the Ethernet port speed.
•not necessary to send a service technician to the customer premises.
•additional OpEx savings.
•flexible bandwidth increments
•The ability to add new services using one technology.

Legacy technologies (Layer 1 TDM , Layer 2)

•inflexible bandwidth scalability.
•bond multiple circuits together
•upgrade the network and equipment to support a new technology.
•non-linear bandwidth.

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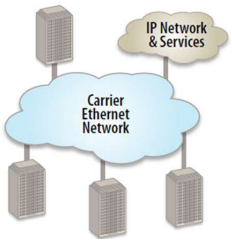
Carrier Ethernet versus Ethernet

Three fundamental aspects differentiate **Ethernet LANs**:

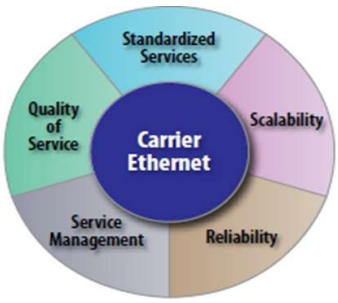
•Each user connects to a dedicated Ethernet port on the LAN.
•The LAN serves one organization.
•The LAN is inside the building.

Three fundamental aspects differentiate **Carrier Ethernet networks :**
•An entire organization connects to a Carrier Ethernet "port" at a given subscriber location.
•The Carrier Ethernet network serves many organizations.
•The Carrier Ethernet network is outside the building across a wide area.



Carrier Ethernet attributes

The MEF (Metro Ethernet Forum) defines Carrier Ethernet based on five attributes :



Carrier Ethernet uses many of the Ethernet LAN technologies but required further augmentation in order to function as a service delivery technology for MANs and WANs .

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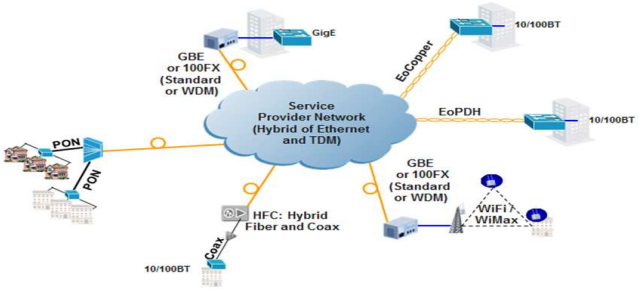
Ethernet over different access network technologies



Active areas in Carrier Ethernet development :

- Ethernet Access for Mobile Backhaul .
- Ethernet over Active Fiber.
- Ethernet over Passive Fiber (PON).
- Ethernet over Copper PDH (E1/DS1).
- Ethernet over Copper DSL.
- Ethernet over Hybrid Fiber Coax (HFC).

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Carrier Ethernet deployement

Carrier Ethernet can be deployed in three ways:

- **Conventional or "pure" Ethernet.**
- **Ethernet over Synchronous Digital Hierarchy (SDH).**
- **Ethernet over Multiprotocol Label Switching (MPLS).**

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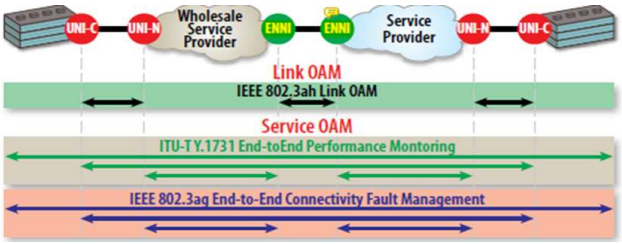
Ethernet OAM (Operations, Administration and Maintenance)

The ability to remotely isolate and diagnose network problems.



Ethernet OAM

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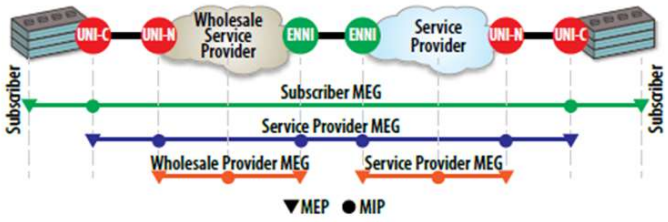
Ethernet OAM



Ethernet SOAM Framework

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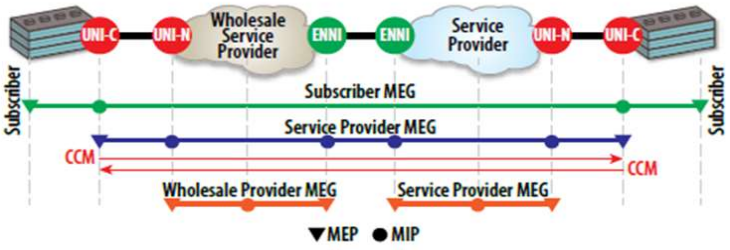
Ethernet OAM

Ethernet Fault Management

Ethernet Service Fault Management:



CCMs across EVC

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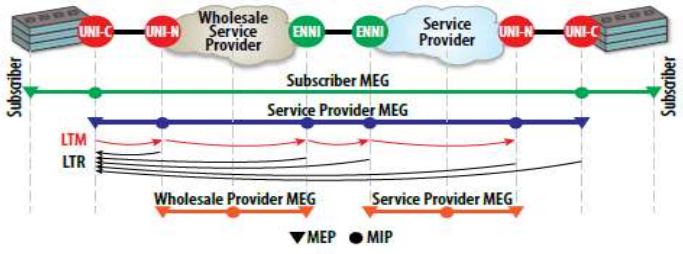
Ethernet OAM

•Link trace



Link Trace

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Ethernet frame format

- A data packet on an ethernet link is called data frame.
- Ethernet was first applied to LANs and then WANs
- Carrier Ethernet is popular because not only it provides high-speeds and low costs, it has the ability to take an Ethernet II frame from LAN and transfer it to a WAN link

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Ethernet frame types

- There are many types of Ethernet frames
- Two of these used on LAN are:
  - Ethernet II
  - Ethernet SNAP

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ETHERNET II FRAME FORMAT

Ethernet_II

Field	Bytes
Preamble	8
Destination Address	6
Source Address	6
Type	2
Data	46-1500
Frame Check Sequence	4

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Ethernet II frame format

- Preamble
  - This is a sequence of 7 bytes or 56 bits of alternating ones and zeros
  - It is used for synchronization
  - It gives components time to detect the signal, and be ready before the frame arrives
  - It was set at this length because it took equipment used to take this long to sync up
  - A preamble is not required for speeds above 10 Mbps ex. In WAN services

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Ethernet II frame format

- SFD - Start Frame Delimiter
  - Also part of the preamble is a sequence of 1 byte or 8 bits having the bit configuration 10101011 that indicates the start of the frame
- Destination Address
  - This is the MAC address of the station the message is for
- Source Address
  - This is the MAC address of the sending station
- Type
  - EtherType code in hexadecimal, indicates the protocol type that the frame is destined for at the network layer, such as
    - » 0800 for TCP/IP
    - » 8137 for IPX
- Data
  - This is the important stuff and has a maximum size of 1500 bytes

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Ethernet II Frame Format

- FRS - Frame Check Sequence
  - This is used for error checking
  - When the source station assembles a MAC frame, it performs a CRC calculation on all the bits in the frame from the Destination MAC Address through the Pad fields
  - The source station stores the value in this field and transmits it as part of the frame
  - When the frame is received by the destination station, it performs an identical check

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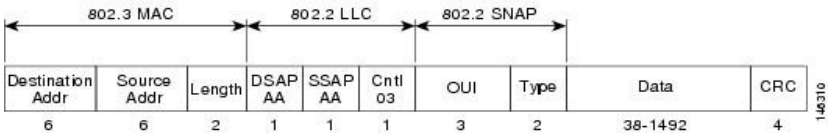
Ethernet SNAP Frame

•The other type of frame commonly seen on an Ethernet based local area network is a SNAP or Subnetwork Access Protocol frame

•The SNAP frame allows EtherType codes to be used with all IEEE 802 protocols, as well as supporting proprietary protocols



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802.3 MAC Sublayer

- The 802.3 MAC sublayer contains the layer 2 address fields
- The length field shows the amount of data in the frame

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802.2 LLC Sublayer

- It contains the following main fields

  DSAP SSAP Control
  - The LLC sublayer consists of addressing information
  - The control field contains command, response, and sequence number information
  - There are three types of frames
    - » I Frames
    - » Supervisory Frames
    - » Unnumbered Frames

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802.2 SNAP Sublayer

- The OUI field identifies who is responsible for the protocol that will follow
- The PID or type field indicates what protocol should be used

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Why Ethernet?

The Evolution

Higher Bandwidth	Quality of Service	LAN Extension	Economics	Resiliency
Started as 10 mbps Ethernet	QoS mechanisms	Port-based services	Lower per port cost	No single point of failure
Evolved to 100 Mbps and 1Gbps	IP Prec/DSCP	Transparent connectivity	OPEX/CapEx reduction	Quick failure recovery
Now available as 10Gbps Ethernet	802.1P (CoS)	L2 protocol tunneling	IT staff already trained	Provides link and node failure protection
	MPLS EXP LLQ	Access agnostic	No expensive upgrades	
	Congestion avoidance			
	Scheduling			

The Result: Carrier Ethernet Network

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Virtual LAN - VLAN

- A Virtual LAN is a method of creating independent **logical networks** within a single
- **physical network infrastrucure**
- or in other words…
- A Virtual LAN is a **logical segmentation of a broadcast domain** (switched network) into different broadcast domains

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Why VLANs

Advantages:

- Reduces the broadcast traffic and increases network security (both of which are hampered in case of single large broadcast domain)
- Reduces management effort to create subnetworks
- Reduces hardware requirement, as networks can be logically separated instead of physically separated
- Increases control over multiple traffic types

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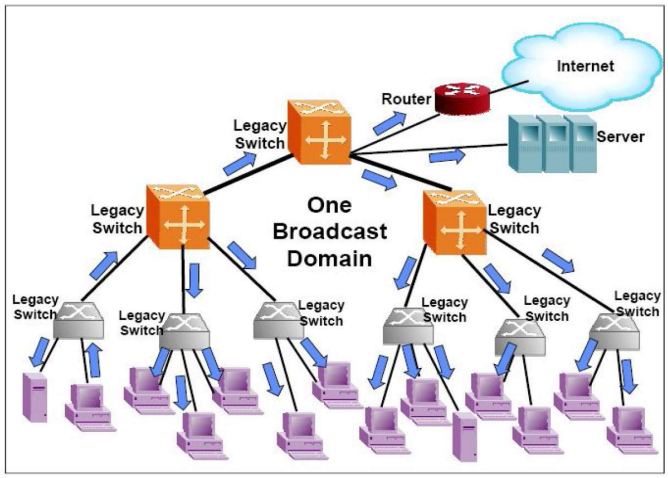
One broadcast domain



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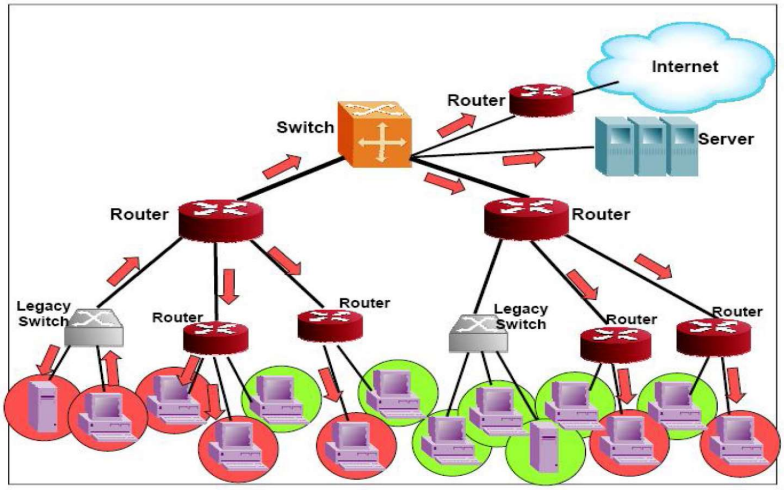
A possible solution: use of routers



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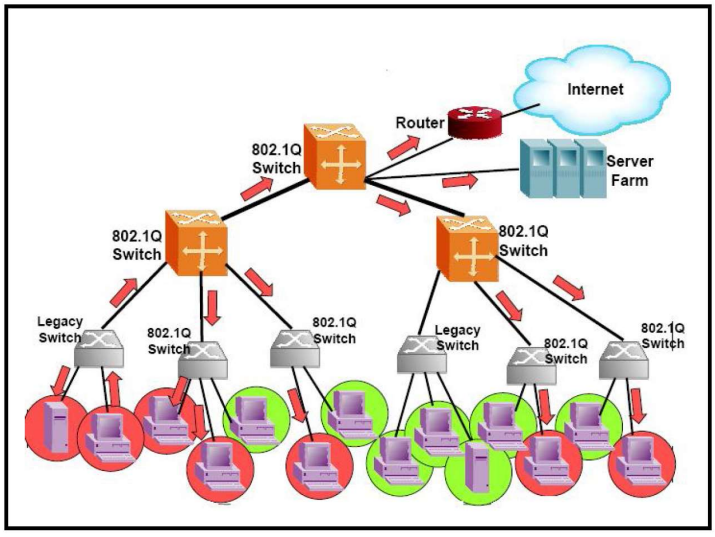
An easyer solution: use VLANs



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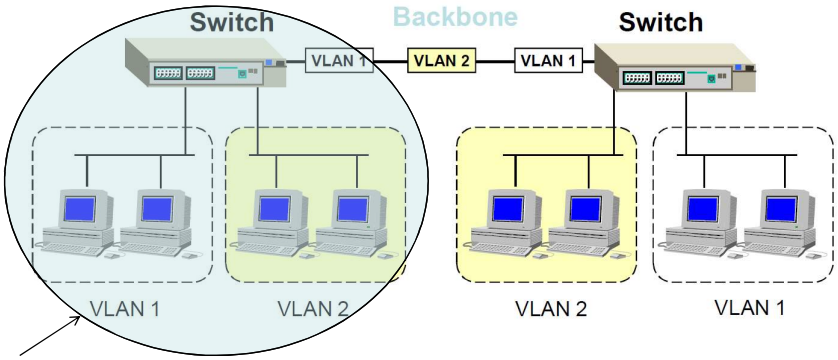
Inter-switch VLANs

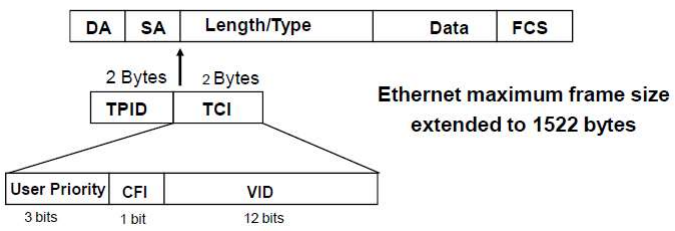
- Sharing VLAN among switches is achieved by inserting a tag with a VLAN identifier in each frame (802.1Q VLAN standard specification)



Intra-switch VLANs are achieved by having Switch Ports grouped into different broadcast domains

VLAN Tagging Scheme: IEEE 802.1Q

- **Tag Protocol Identifier (TPID)**: identifies the frame as a tagged frame
- **Tag Control Information (TCI)** with the following fields:
  - **User priority**: carries priority information based on the values defined in the 802.1p standard
- **Canonical Format Indicator (CFI)**: allows Source Routing control Information to be specified
- **VLAN identifier (VID)**: uniquely identifies the VLAN to which the frame belongs



Quality of Service

- QoS allows to guarantee parameters like
  - Bandwidth
  - Packet loss rate
  - Maximum delay
  - Maximum jitter
- Examples of typical service class definitions:
  - Gold: Guaranteed Bandwidth, very low packet loss rate, Minimum jitter ➔ suitable for VoIP and Video Boadcast
  - Bronze: No guarantees ➔ suitable for Data transmission (data packets can be re-transmitted in case of loss)
  - Network Control: Most important traffic, highest priority

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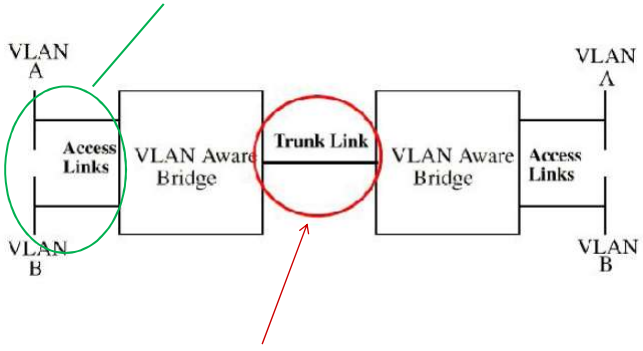
Access and Trunk links

- Access links are untagged for VLAN unaware devices
- The VLAN switch adds tags to received frames and removes taggs
- when transmitting frames



A trunk link attaches two VLAN switches
It carries tagged frames only

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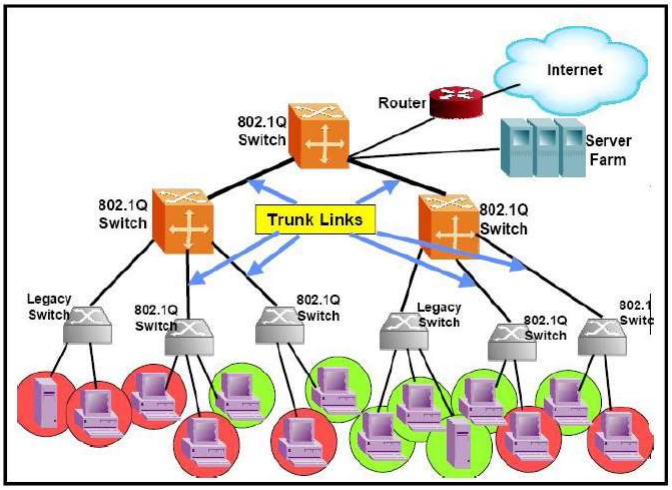
Trunk links



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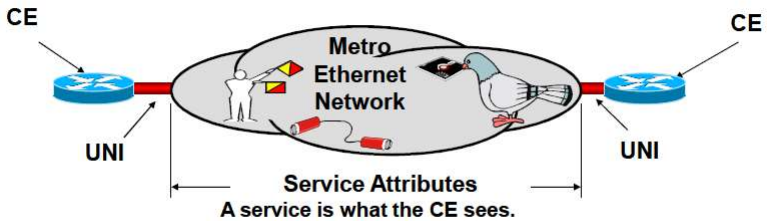
Ethernet service model defined by MEF

- **CE can be**
- – router
- – IEEE 802.1Q bridge (switch)
- **UNI (User Network Interface)**
- – Standard IEEE 802.3 Ethernet PHY and MAC
- – 10Mbps, 100Mbps, 1Gbps or 10Gbps
- **Metro Ethernet Network (MEN)**
- – May use different transport and service delivery technologies
- • SONET/SDH, WDM, RPR, MAC-in-MAC, Q-in-Q, MPLS
- **Service frame**
- – With IEEE 802.1Q tag (up to 1522 bytes)
- – Without IEEE 802.1Q tag (up to 1518 bytes)



A service is what the CE sees.
The technology used inside the MEN is not visible.

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Technologies for Carrier Ethernet Services

- **MEF defines service models, put requirements, but does not define the transport technologies**
- **Legacy transport technologies:**
  - WDM : it uses wavelenghts
    - » Bandwidth wasting for low bit rate EVC
  - SDH: it uses Virtual Circuits and GFP
    - » Expensive …and circuit technology
- – ATM: ATM LAN Emulation service (ATM LANE)
    - » Packet technology..but expensive
- – IP/MPLS: Virtual Private LAN Service (VPLS)
    - » Packet technology ..but still expensive for metro area
- **Emerging transport technologies:**
  - Ethernet-based technology: Provider Bridge (PB), Provider Backbone Bridge
  - (PBB), and Provider Backbone Bridge – TE (PBT)
  - MPLS-based technology: T-MPLS

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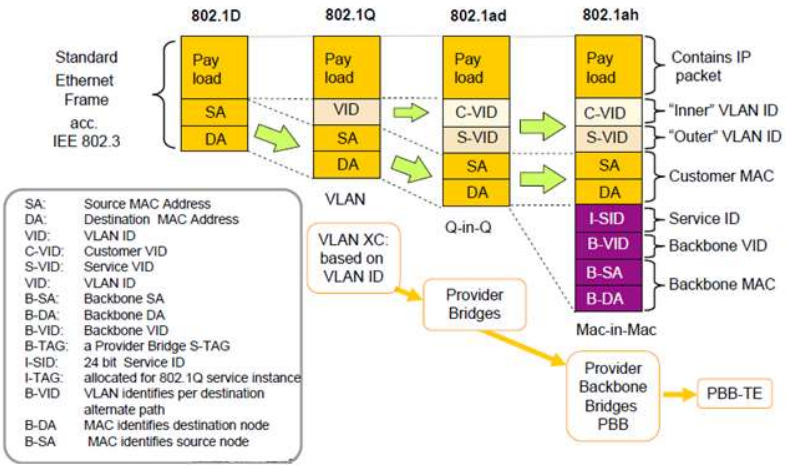
Evolution of Ethernet Hierarchy



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802.1ad Provider Bridge (Q-IN-Q)

The Concept
- Adding another layer of 802.1Q
- The purpose - expanding the VLAN space by tagging the tagged packets
- The expanded VLAN space allows the service provider to provide certain services, such as Internet access on specific VLANs for specific customers, and yet still allows the service provider to provide other types of services for their other customers on other VLANs.

Frame without VLAN Tag Header

Destination address	Source address	Type / Length	Data	CRC

Frame with single VLAN tag header 802.1Q

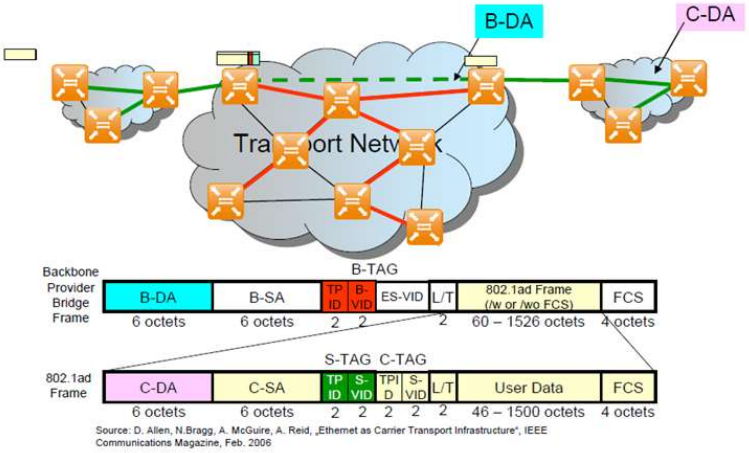
Destination address	Source address	C-VLAN	Type / Length	Data	CRC

Frame with double VLAN tag header 802.1ad

Destination address	Source address	S-VLAN	C-VLAN	Type / Length	Data	CRC

Support of 4K S-VLAN x 4K C-VLAN = theoretical 16 Mill VLAN

802.1ah – provider backbone bridging (PBB)



Source: D. Allen, N.Bragg, A. McGuire, A. Reid, „Ethernet as Carrier Transport Infrastructure", IEEE Communications Magazine, Feb. 2006

- Add a **transport hierarchy** "MAC in MAC" encapsulation
- **No learning** of customer MAC addresses in the middle of the network
- Transport spanning **TREES** instead
- Use **global** meaning of tag (**B-DA** (**48 bit**) and **B-VID** (**12 bit**))

Comparison of the schemes

Encapsulation method	MAC address table containment	Scalability	Priority bits	Transition / Evolution	Localization of impact of duplicate MAC	Localization of impact of provider ST control	Signaling	Min. overhead (Byte)
VLAN stacking	No	Combin. of VID: Yes Provider: No	Yes	Yes	No	No	Needed	2
MAC stacking	Yes	Yes 16 million	Yes	Yes	Yes	Yes	Optional	20
MPLS	Yes	Yes 16 million	Yes	Partially (cost)	Yes	Yes	Yes	8

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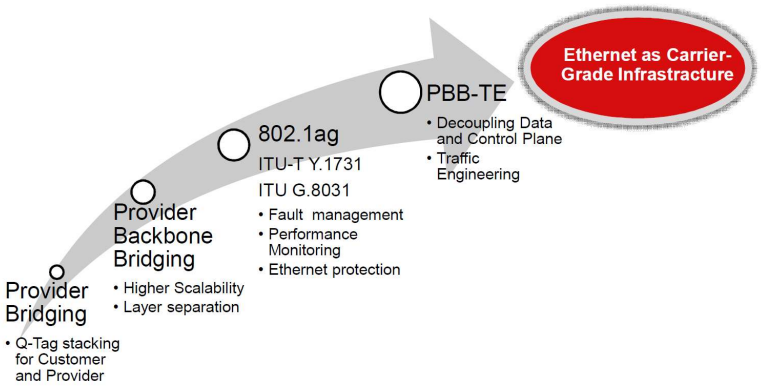
Ethernet evolution summary



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  - http://metroethernetforum.org/
- Ethernet in the First Mile
  - http://www.**ethernet**inthe**firstmile**.com/