


VeEX
The Verification Experts

Ethernet 101

Rev Draft

Agenda

- Terms and definitions
- Layer 1: Ethernet Physical Layer
- Layer 2: Ethernet Data Link Layer
- The Network Layer: Layer 3 (IP)
- The Transport Layer: Layer 4 (UDP and TCP)
- Fundamental of Ethernet Testing
- Key Ethernet Metrics
- Ethernet Testing Standards

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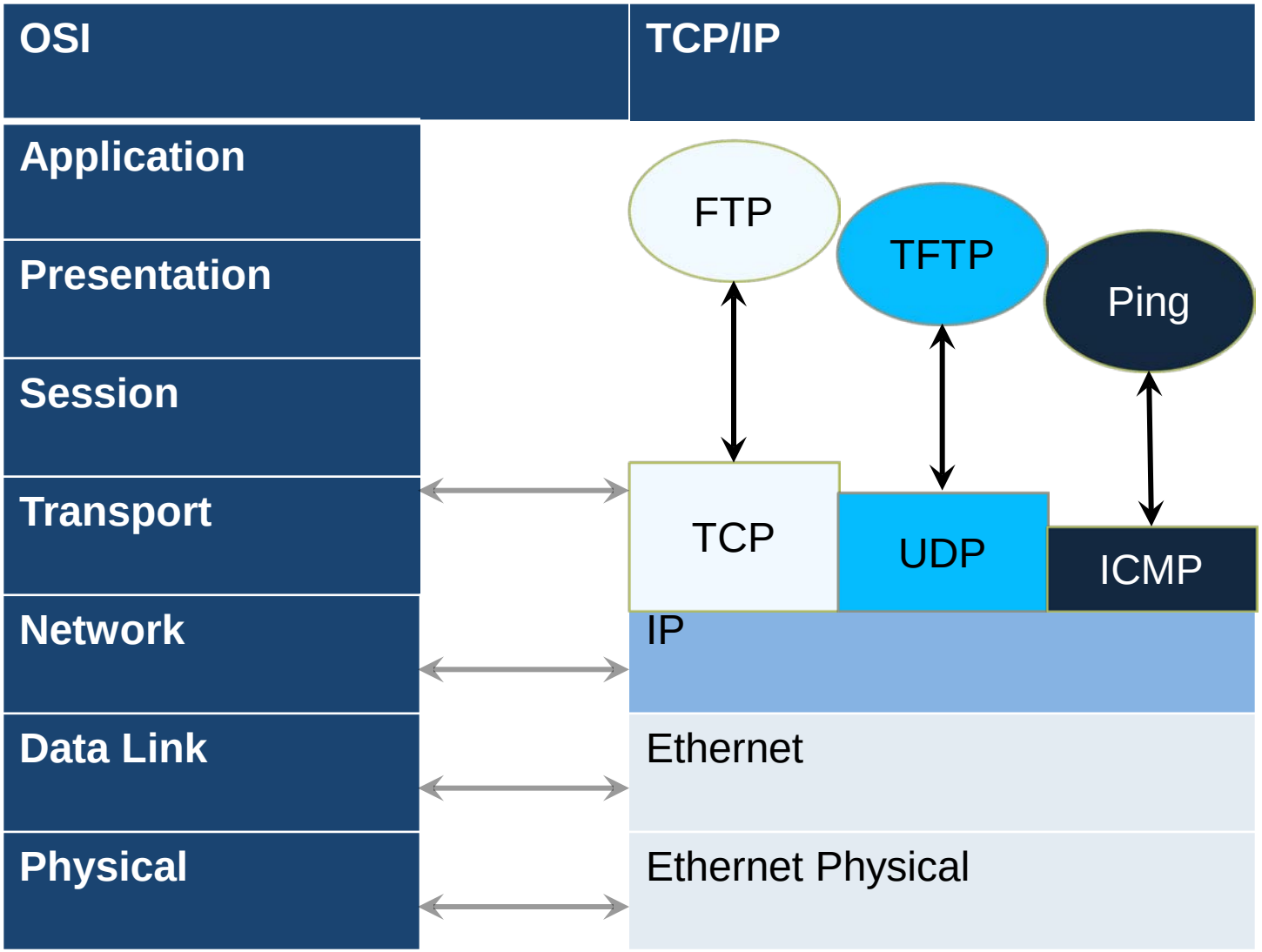
The Basics

The Open System Interconnect (OSI) Model

Layer 7 Application	Interface between OS and user's application software
Layer 6 Presentation	Data representation
Layer 5 Session	Creates a session, handles security
Layer 4 Transport	Reliability of transmission from end to end
Layer 3 Network	End-to-end addressing specific to the network operating system (e.g., routers, routing switches)
Layer 2 Data Link	Access to and from the shared media and addressing on the same physical wire (e.g., bridges, switches)
Layer 1 Physical	Cables, connectors, wires and signaling issues (e.g., repeaters)

OSI Model and TCP/IP



Data Through the TCP/IP Layers

Application: Send an email

Application layer: Email (SMTP)

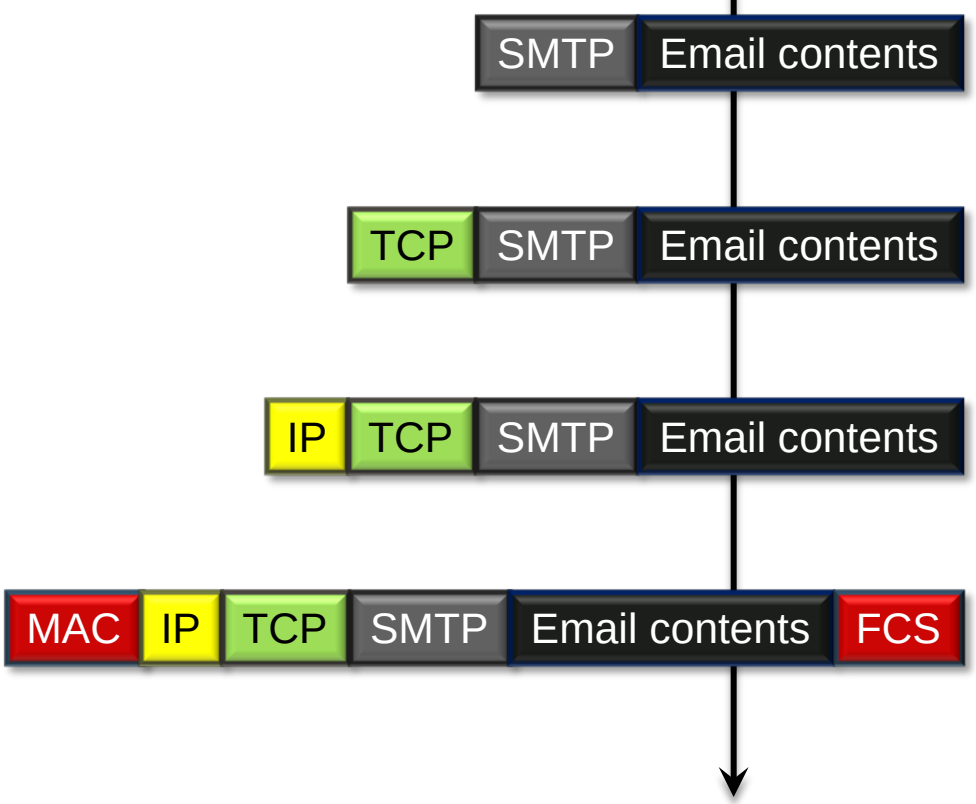
Transport layer: TCP

Network layer: IP

Data link layer: Ethernet

Physical layer: Transmits bits (0s and 1s) on the media

Data Through the TCP/IP Layers



Application: Receive an email

Application layer: Email (SMTP)

Transport layer: TCP

Network layer: IP

Data link layer: Ethernet

Physical layer: Receives bits (0s and 1s) on the media

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Ethernet Physical Layer: Layer 1

10 Mbps and 100 Mbps Standards

	10BASE-T	100BASE-TX
Media	Cat 3, 4, 5 UTP 2 pairs	Cat 5 UTP 2 pairs
Max. segment length	100 m	100 m
Connector	RJ45	RJ45
Standard	802.3 (14)	802.3 (24)

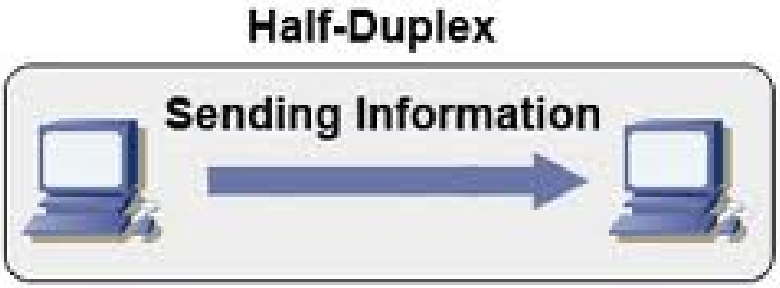
1 Gbps Standards

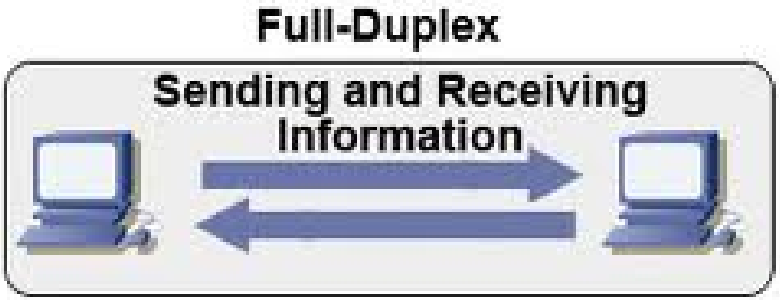
	1000BASE-T	1000BASE-SX	1000BASE-LX	1000BASE-ZX
Media	Cat 5E UTP 4 pairs	850 nm 62.5 or 50 µm Multimode fiber	1,310 nm 50 µm Multimode Or 9 µm Single-mode fiber	1,550 nm Single-mode fiber
Max. segment length	100 m	500 m (50 µm) 220 m (62.5 µm)	10 km (SM) 550 m (MM)	100 km
Connector	RJ45	SC /LC	SC/LC	SC/LC

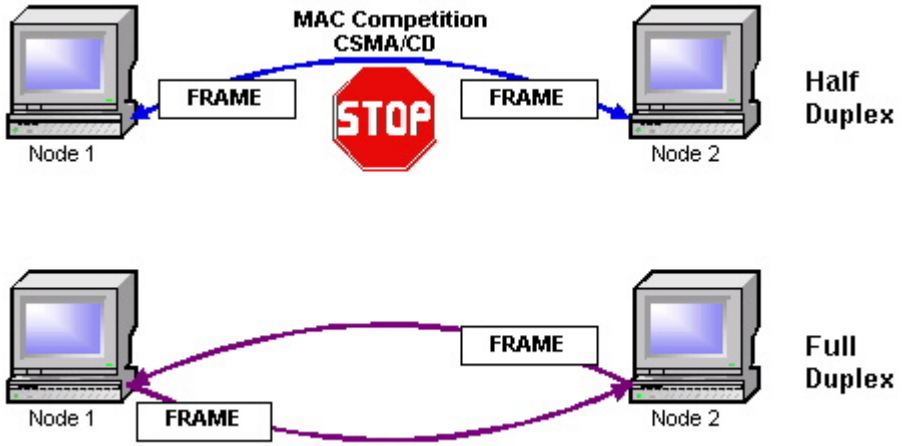
10GE Standards

	10GBASE-SR	10GBASE-LR	10GBASE-ER	10GBASE-SW	10GBASE-LW	10GBASE-EW
Media	850 nm 50 µm Multimode fiber	1,310 nm 9 µm Single-mode fiber	1,550 nm Single-mode fiber	850 nm 50 µm Multimode fiber	1,310 nm 9 µm Single-mode fiber	1,550 nm Single-mode fiber
Max. seg. length	300 m	10 km	30 km	300 m	10 km	30 km
Connector	SC	SC	SC	SC	SC	SC
PHY	LAN	LAN	LAN	WAN	WAN	WAN

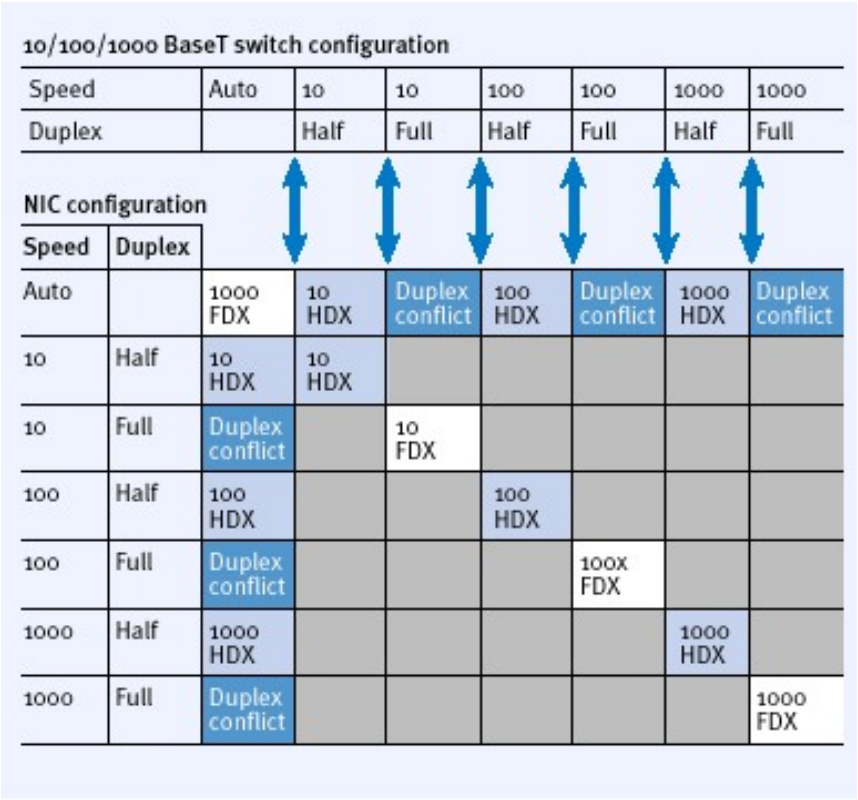
Half Duplex vs. Full Duplex







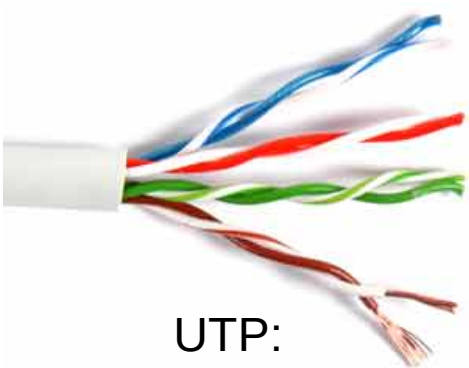
Auto Negotiation Conflict



Local Device Advertised values	Link Partner Advertised values	Local Device Results	Link Partner Results	Comments
AUTO-NEG	AUTO-NEG	100BT/F-DPLX	100BT/F-DPLX	Link at max capability
100BT/F-DPLX	AUTO-NEG	100BT/F-DPLX	100BT/H-DPLX	Problem: Duplex mismatch
100BT/H-DPLX	AUTO-NEG	100BT/H-DPLX	100BT/H-DPLX	Link ok, but link partner defaults to H-DPLX
100BT/F-DPLX	100BT/F-DPLX	100BT/F-DPLX	100BT/F-DPLX	Valid manual configuration
100BT/H-DPLX	100BT/H-DPLX	100BT/H-DPLX	100BT/H-DPLX	Valid manual configuration
100BT/H-DPLX	100BT/F-DPLX	100BT/H-DPLX	100BT/F-DPLX	Problem: Duplex mismatch
10BT	100BT	-	-	Problem: No link
10BT/F-DPLX	AUTO-NEG	10BT/F-DPLX	10BT/H-DPLX	Problem: Duplex mismatch
10BT/H-DPLX	AUTO-NEG	10BT/F-DPLX	10BT/H-DPLX	Link ok, but link partner defaults to H-DPLX
10BT/F-DPLX	10BT/F-DPLX	10BT/F-DPLX	10BT/F-DPLX	Valid manual configuration
10BT/H-DPLX	10BT/H-DPLX	10BT/H-DPLX	100BT/H-DPLX	Valid manual configuration
10BT/H-DPLX	10BT/F-DPLX	10BT/H-DPLX	10BT/F-DPLX	Problem: Duplex mismatch

Wiring and Connectors

RJ45



UTP:
Unshielded Twisted Pairs

LC Connector

SFP

XFP

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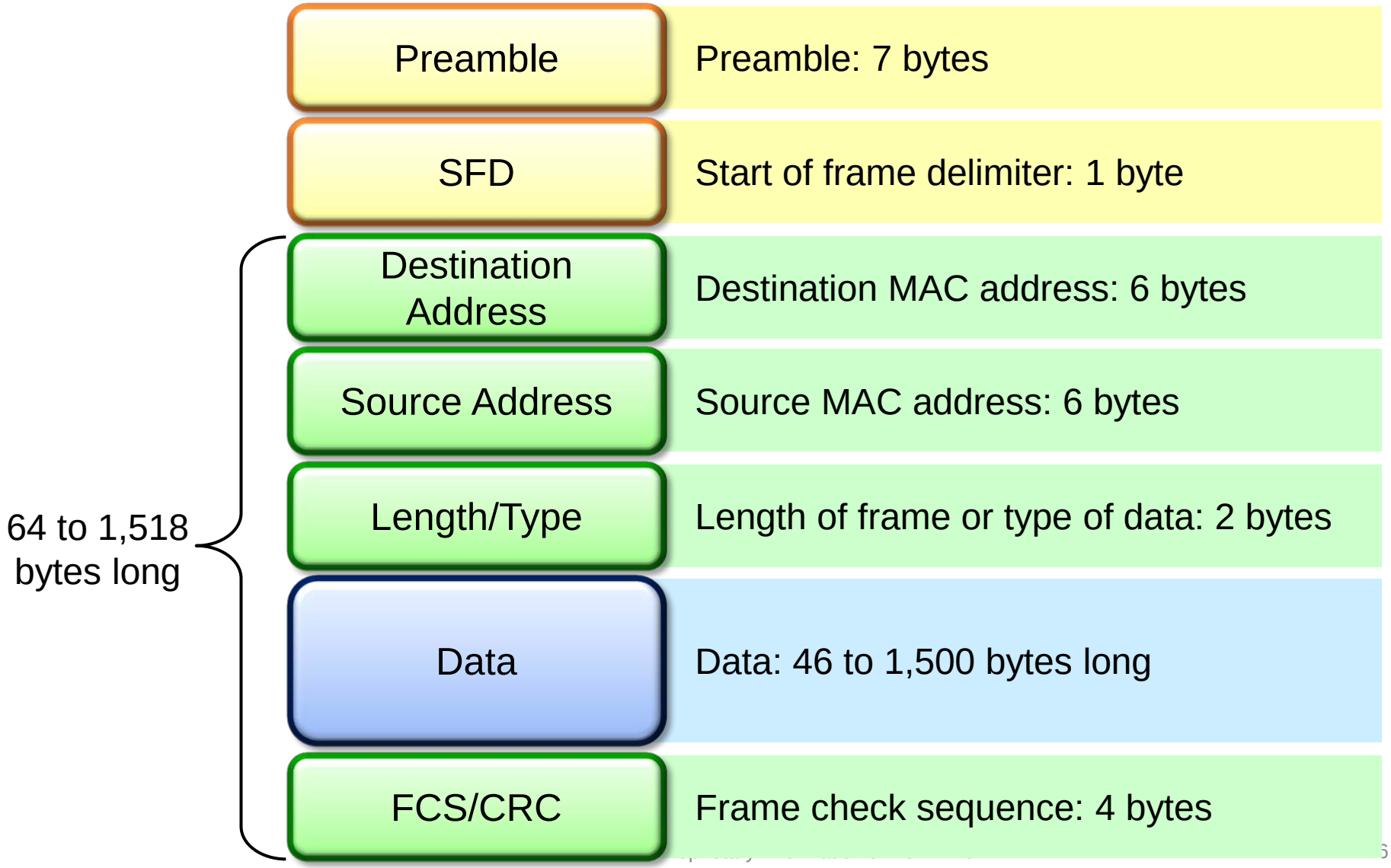
Ethernet Data Link Layer: Layer 2

Ethernet Frame Format



Interpacket Gap

- Interpacket gap = Idle time between transmission of two consecutive frames
- Minimum allowed IPG is 96-bit time:
  - 9.6 nanoseconds at 10 gigabit Ethernet rate
  - 96 nanoseconds at gigabit Ethernet rate
  - 0.96 microseconds at fast Ethernet rate
  - 9.6 microseconds at Ethernet
- If frames are transmitted with minimum IPG, the traffic is transmitted at maximum rate

Frame Rate

- Ethernet frame data size = 64 to 1,518 bytes = 512 to 12,144 bits
- Overhead = 7 bytes (Preamble) + 1 byte (SFD) + 96 bits (IPG) = 160 bits
- Frame rate = Max. data rate / (Data size + Overhead)
  - If max. data rate is 10 Mbps (10B-T) and data size is 64 bytes, frame rate = 14,880 Fps
  - If max. data rate is 100 Mbps (100B-T) and data size is 64 bytes, frame rate = 1,488,095 Fps
  - If max. data rate is 1 Gbps (1000B-X) and data size is 64 bytes, frame rate = 1,488,095 Fps

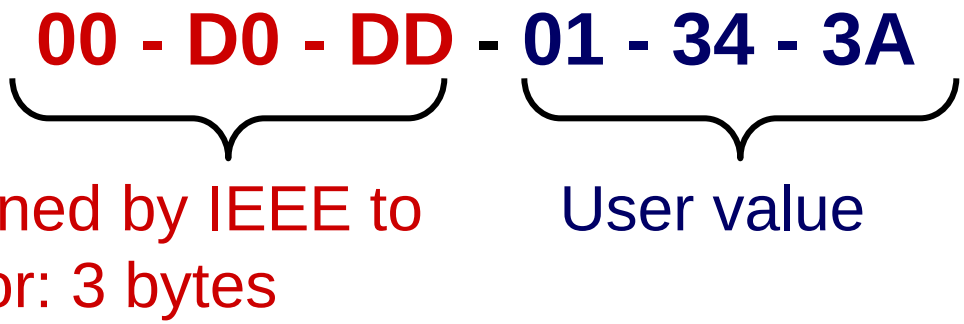
Frame Rate and Efficiency

- In gigabit Ethernet, efficiency increases with frame length
- Also applies to 10BASE-T, 100BASE-TX, and 10 GE

Data size	Overhead per frame	Frames per second	Total bits lost (overhead)	Percentage of bandwidth lost
64 bytes (512 bits)	160 bits	1,488,095	238,095,238	23%
128 bytes (1024 bits)	160 bits	844,594	135,135,135	13%
512 bytes (4,096 bits)	160 bits	234,962	37,593,984	3.7%
1,024 bytes (8,192 bits)	160 bits	119,731	19,157,088	1.9%
1,518 bytes (12,144 bits)	160 bits	81,274	13,003,901	1.3%

MAC Address Format

- MAC address: Unique hardware address associated with each device
- 6 bytes long, in hexadecimal format
- Source MAC address: Identifies who is sending the frame
- Destination MAC address: Identifies the station that should receive the frame

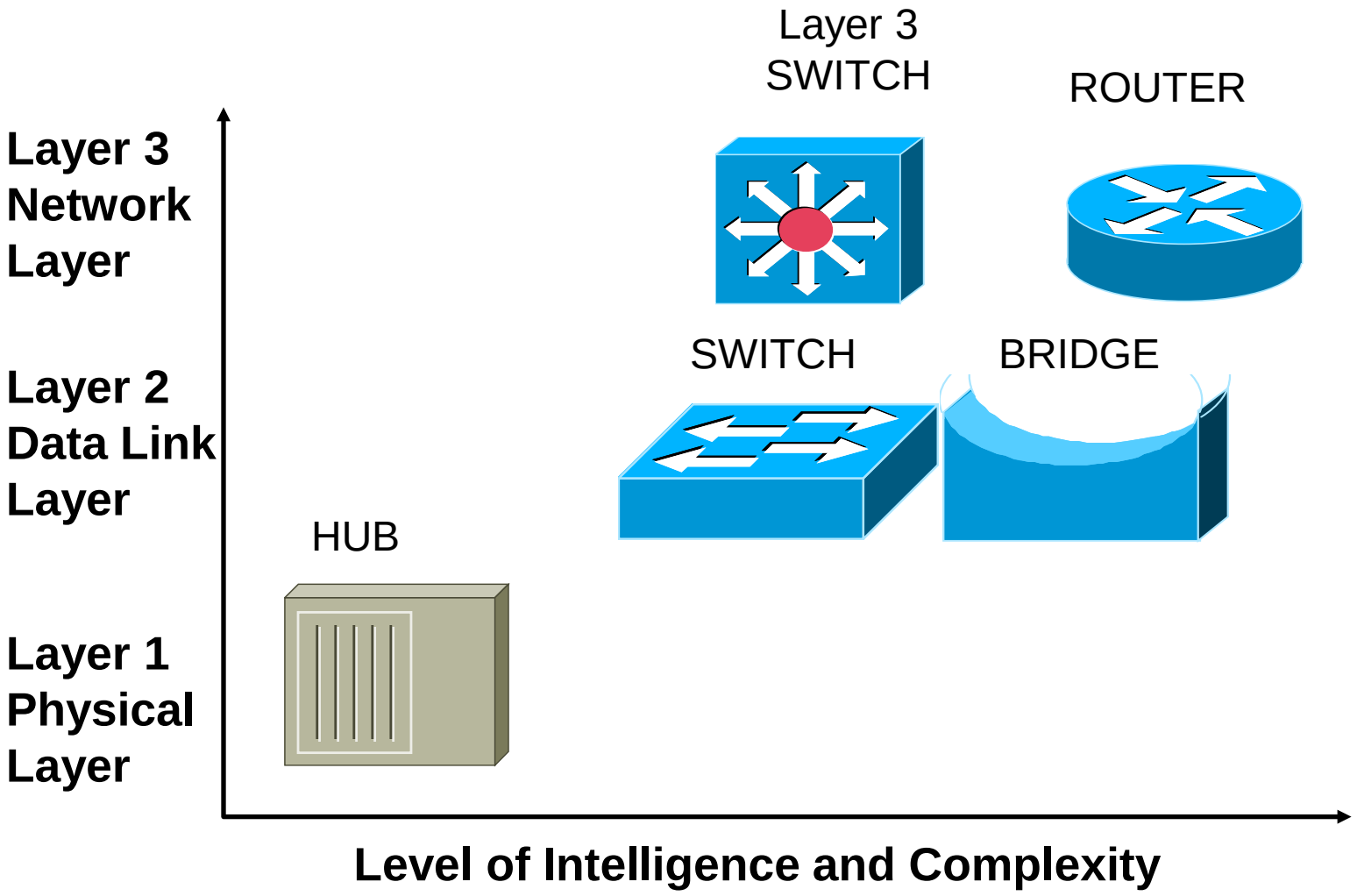


  - Destination MAC addresses: Unicast, broadcast, multicast

Layer 2 Network Equipment

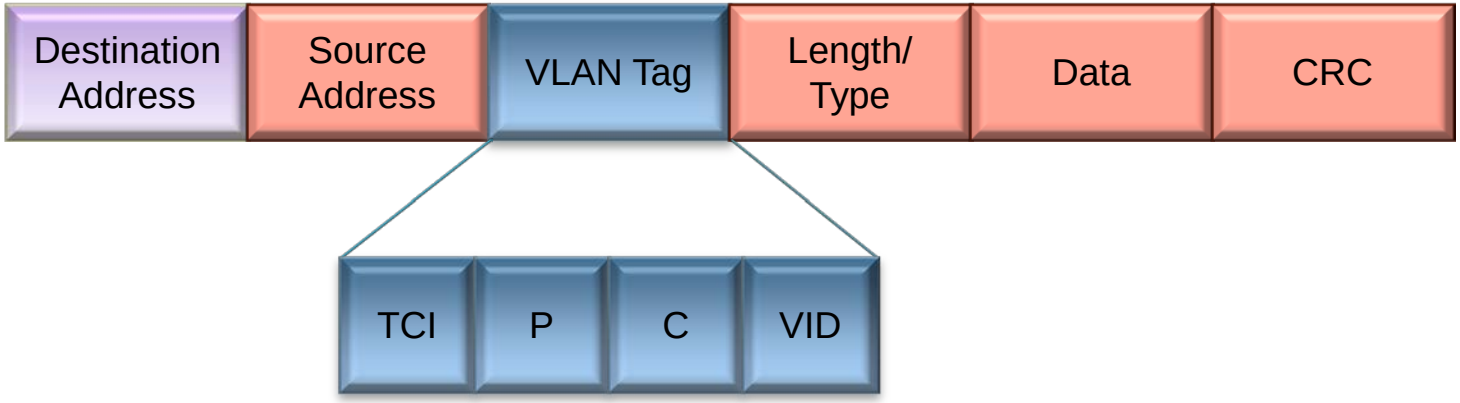
- Layer 2 Switch
- Each physical port provides full duplex bandwidth to each connected device
- Except for multicast and broadcast, traffic only goes to the port where the destination is located

Hubs, Switches and Routers



VLAN – Virtual LAN

- Defined in standard 802.3q
- Why is it needed?
  - Separate broadcast domain per VLAN => increase network performance
  - Router needed for traffic between VLANs => increase security
- Membership indicated by VLAN tag added to Ethernet traffic



Q-In-Q VLAN Stacking

- Defined in standard 802.3ad
- Why is it needed?
  - Service provider can add service VLAN tag (S-VLAN) to traffic already tagged with customer VLAN (C-VLAN)
  - Customer VLAN tag preserved through the network
  - Security ensured by separating customer traffic
- S-VLAN tag added to the C-VLAN tagged traffic

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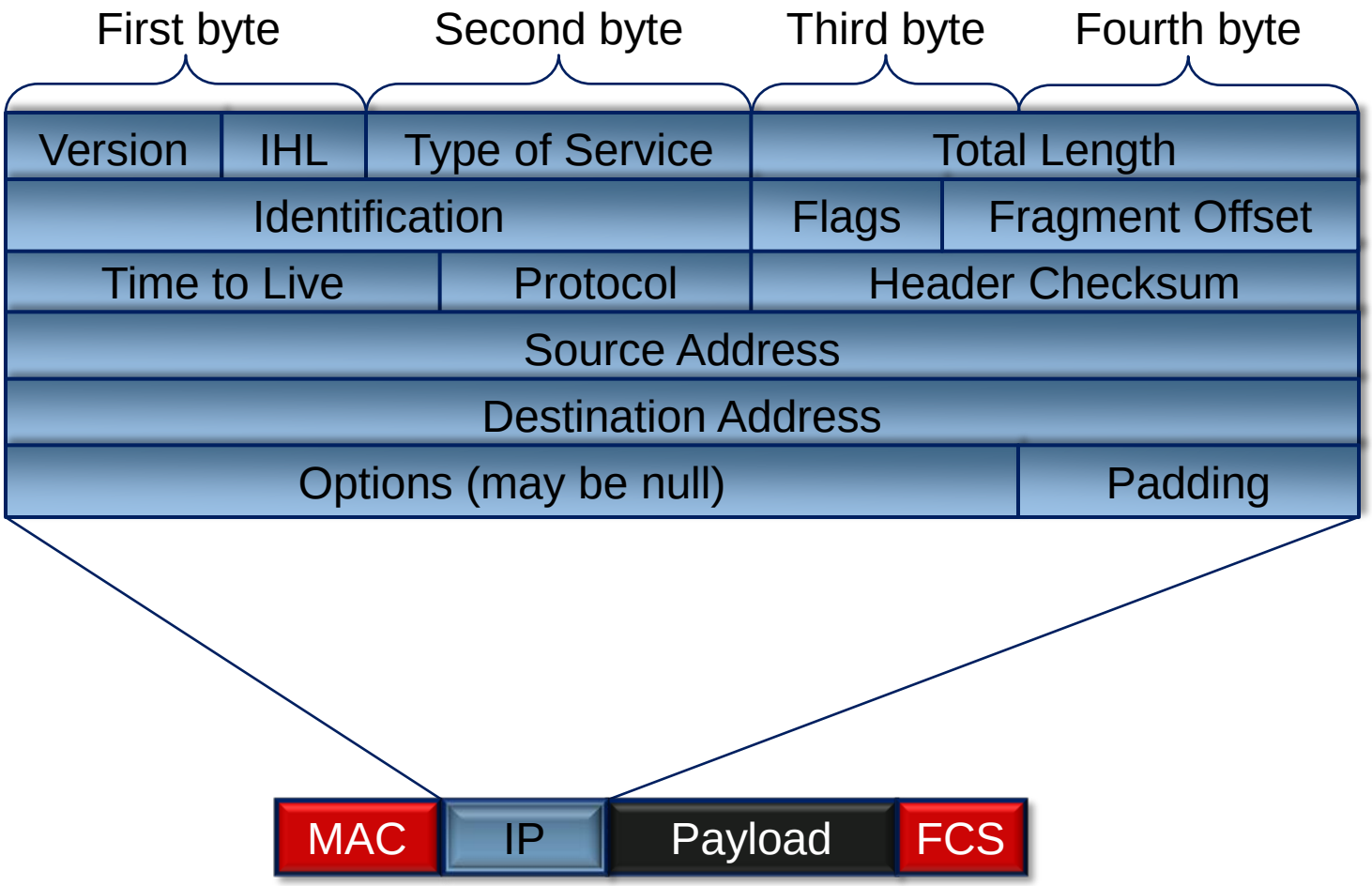
IP Network Layer: Layer 3

IPv4 Header


First byte
Second byte
Third byte
Fourth byte
Version
IHL
Type of Service
Total Length
Identification
Flags
Fragment Offset
Time to Live
Protocol
Header Checksum
Source Address
Destination Address
Options (may be null)
Padding
MAC
IP
Payload
FCS

MAC vs. IP Addresses

- MAC address
  - Directs data through a network
  - Uniquely assigned and burned into the hardware
  - Directs data through TCP/IP internetworking (Internet)
- IP address
  - Directs data through TCP/IP internetworking (Internet)
  - Dynamically allocated or assigned by network administrator
  - Mapped to specific MAC address
  - 32 bits (4 bytes) long: Allows for 4,294,967,296 unique addresses
  - Example IP Address:

    144.232.8.15

Transport Layer (TCP/UDP): Layer 4

TCP

- Transmission Control Protocol: Most widely used transport layer protocol
- Used by most application protocols: HTTP, FTP, Telnet
- Provides the following services:
  - End-to-end connections
  - Multiplexing/demultiplexing
  - Flow control

UDP

- User Data Protocol (UDP): Used for applications that don't need TCP's level of service
  - Trivial File Transfer Protocol (TFTP)
  - Simple Network Management Protocol (SNMP)
  - VoIP
  - IPTV
- Provides simple, connectionless transport layer to allow applications access to IP:
  - Provides simple IP checksum
  - Provides multiplexing/demultiplexing service, allowing multiple processes on each host to share the network

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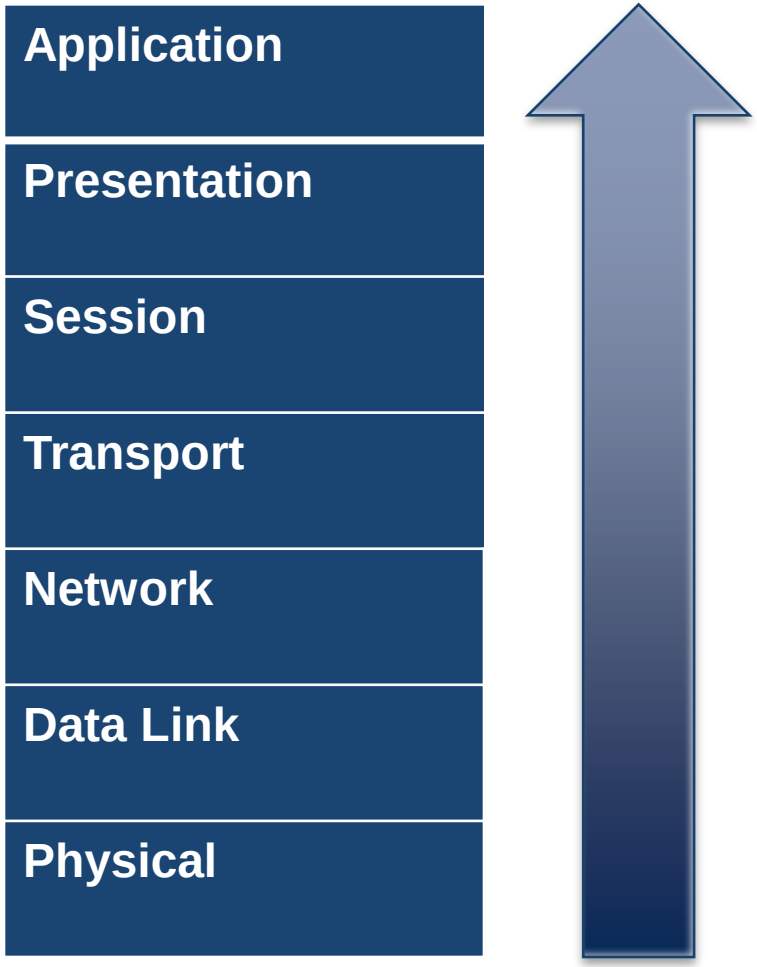
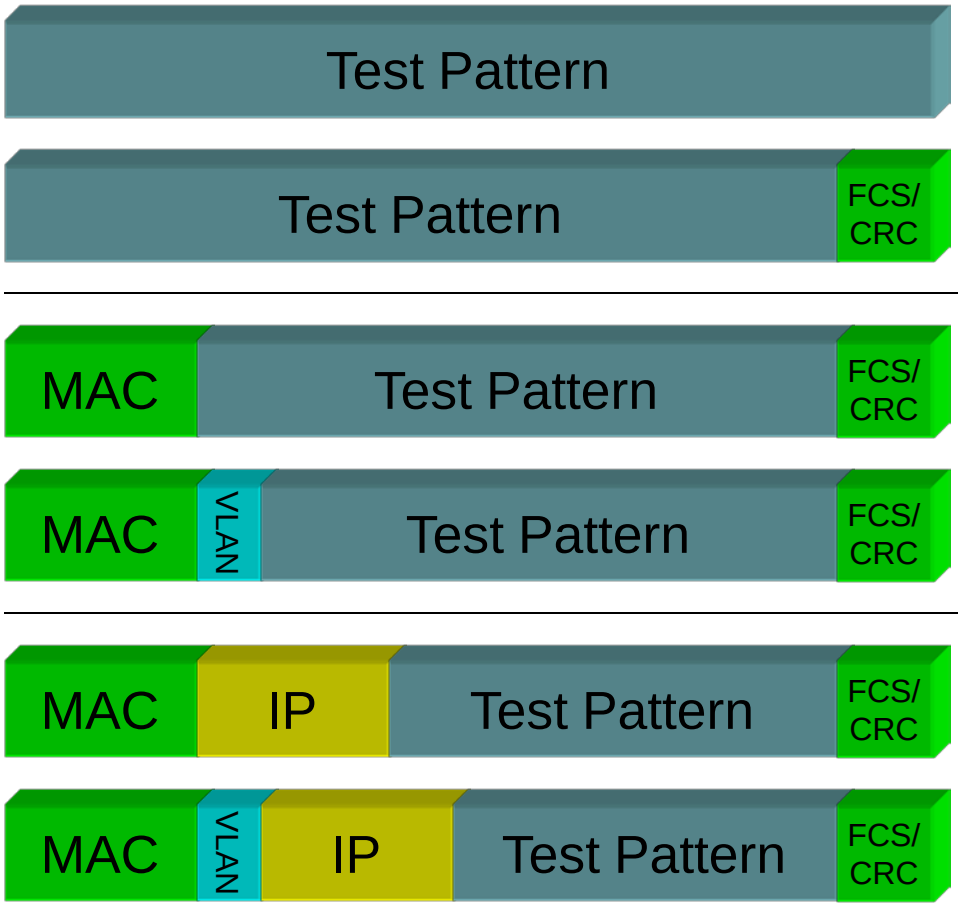
Fundamentals of Ethernet Testing

Before Testing



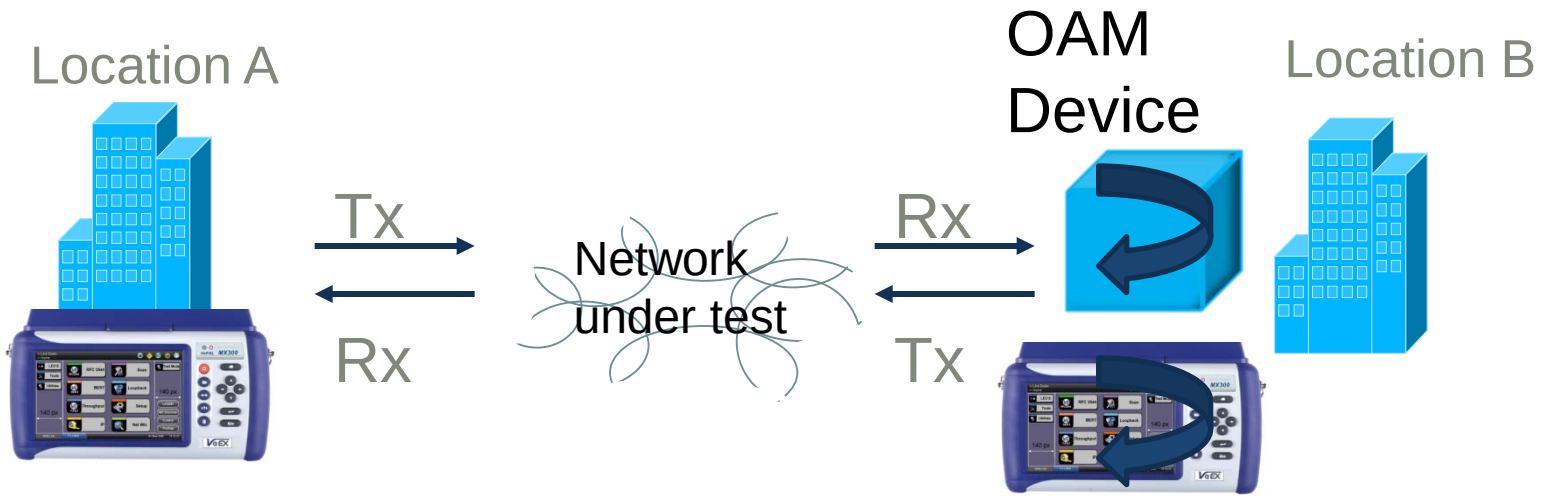
- Determine at what layer you'll be testing:
  - Layer 3: Routed network
    - Need valid source (static or DHCP) and destination IP addresses
    - Need Valid Gateway IP address
  - Layer 2: Network switches
    - VLAN?
    - Need to configure MAC address source and destination in test traffic
  - Layer 1:
    - Copper or Fiber?
    - 850,1310,1550nm?
    - 10,100,1000BaseT?
    - Auto-negotiation or fixed?

Test Layers

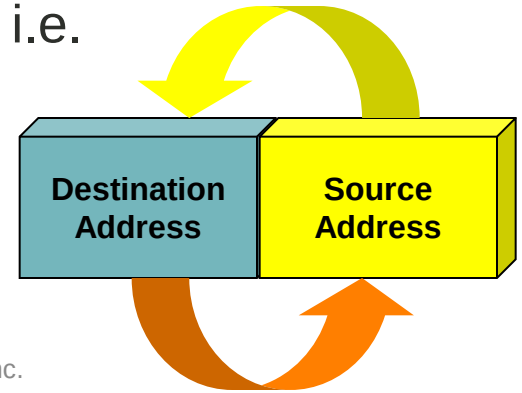


- Layer 1: Unframed
- Layer 1: With CRC
- Layer 2: MAC Frame
- Layer 2: MAC + VLAN
- Layer 3: MAC + IP
- Layer 3: MAC + VLAN + IP

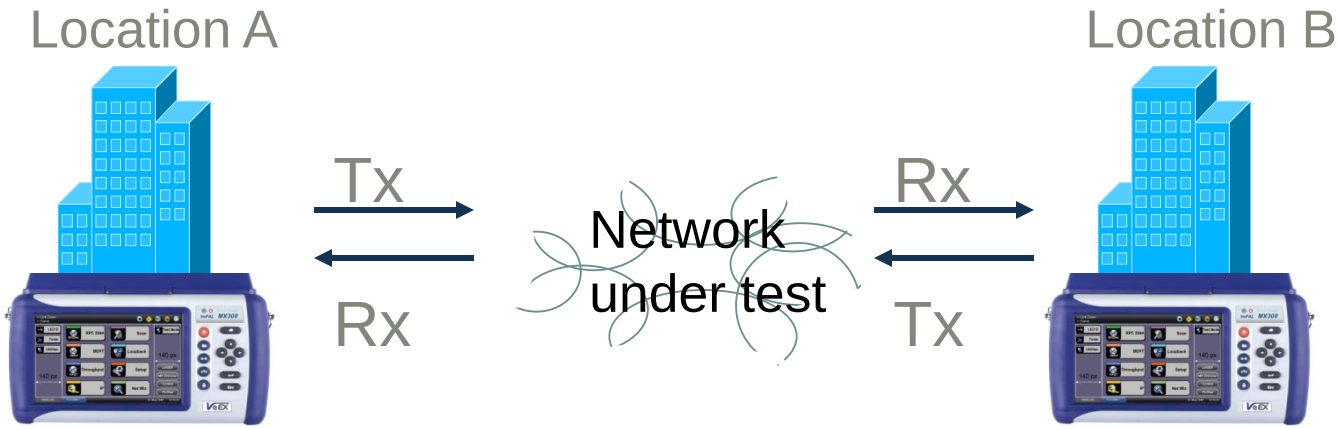
Loopback testing



- Remote Loopback testing to remote VeEX tester or Ethernet OAM capable device.
- Layer 2 and Layer 3 testing requires “smart loop” i.e. test set can swap MAC and IP address fields



Peer to Peer Testing



- Both testers generate test traffic and display measurements.
- Traffic can be symmetrical or asymmetrical
- Remote control from a single unit

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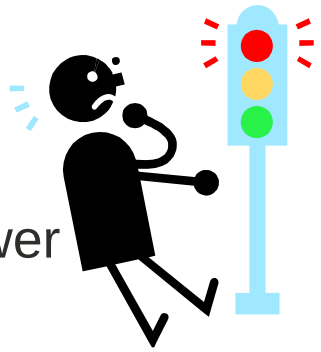
Key Ethernet Metrics

Key Ethernet Metrics

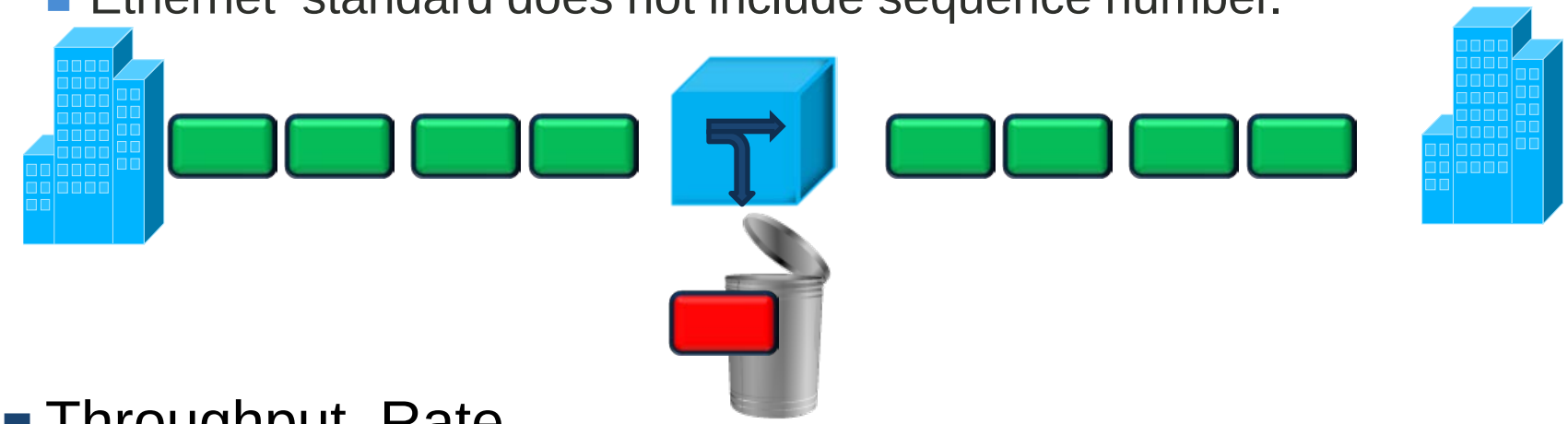
- Link Status
  - Link Up/Down
  - For copper link need to verify speed 10/100/1000Mbps and Full/Half duplex
    - ALL modern equipment supports full duplex =
    - If you get half-duplex link verify the settings
  - For fiber link need to verify wavelength or optical power



- CRC errors
  - Frame check sequence detects bit errors

Key Ethernet Metrics

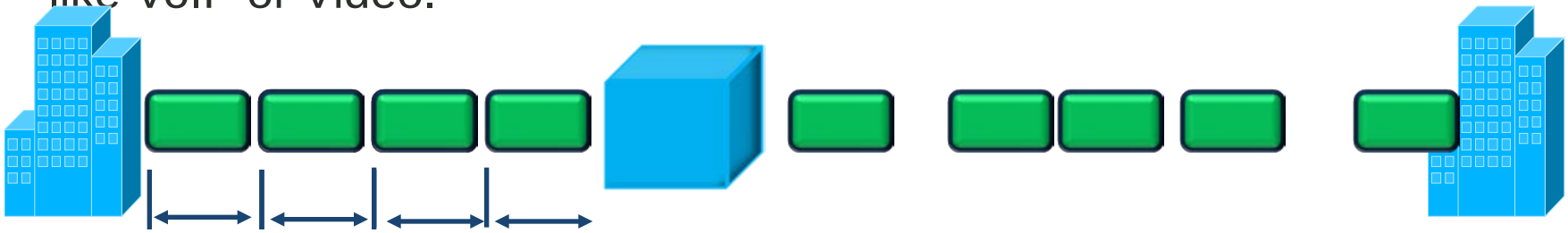
- Frame Loss
  - Network Equipment drops errored frames
  - To detect frame loss , the test frames need to include a sequence number tag.
  - Ethernet standard does not include sequence number.



- Throughput Rate
  - What is the maximum data rate that your network can handle?
  - Congested equipment will drop frames

- Frame Transfer Delay
  - round trip or 1-way delay important for time-sensitive applications (example mobile backhaul signaling traffic)
  - 1-way delay requires time synchronization

- Jitter – Frame Delay Variation
  - Metric used for jitter sensitive applications that require constant rate like VoIP or Video.



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Ethernet Test Standards

RFC2544 and Y.1564 (SAM)

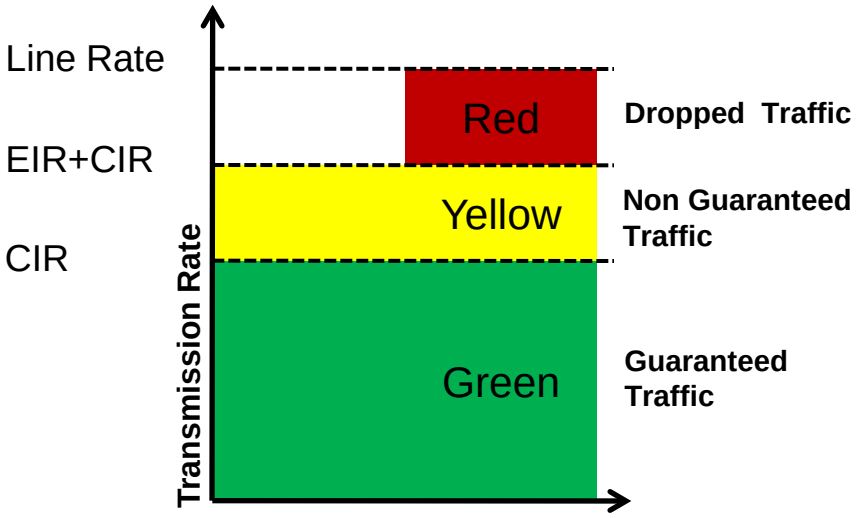
- RFC2544: IETF standard "*Benchmarking Methodology for Network Interconnect Devices".* The test suite includes: Throughput, Latency, Frame Loss and Back-to-back (burst) test.
- ITU-T Y.1564 defines an out-of-service test methodology
  - Service Activation Test Methodology (SAM)
  - Users can assess the proper configuration and performance of an Ethernet service prior to customer delivery.
  - In particular, Y.1564 is aimed at addressing and solving the deficiencies of RFC 2544
- Benefits to the User
  - Total test time is drastically reduced - Services are being tested over a longer duration simultaneously, and all the SLA parameters are also measured simultaneously.
  - Results reporting - clear and simple "Pass/Fail" indication in Green/Red. This is for each test, each service, with a global indication.

Y.1564 versus RFC2544

	RFC2544	Y.1564
Key Test Objective	Device performance	Network Service verification/activation
Service validation	One service at a time	Multiple services simultaneously
Throughput	Yes	Yes
Latency	Yes	Yes
Frame Loss	Yes	Yes
Burstability	Yes	Yes
Packet Jitter	No	Yes
Multiple Streams	No	Yes
Test Duration	Long (serialized test procedure)	Short (simultaneous test/service)
Test Result	Link performance limit	Related to SLA, fast, simple, Pass/Fail

CIR and EIR Definitions

- **Committed Information Rate (CIR):**
  - Guaranteed maximum rate at which the customer can send frames that are assured to be forwarded through the network without being dropped.
- **Excess Information Rate (EIR):**
  - Maximum rate above the CIR at which the customer can send frames that will be forwarded on a best effort basis, but may be dropped in the event of congestion within the network. Traffic beyond CIR + EIR will be dropped when it enters the carrier's network.



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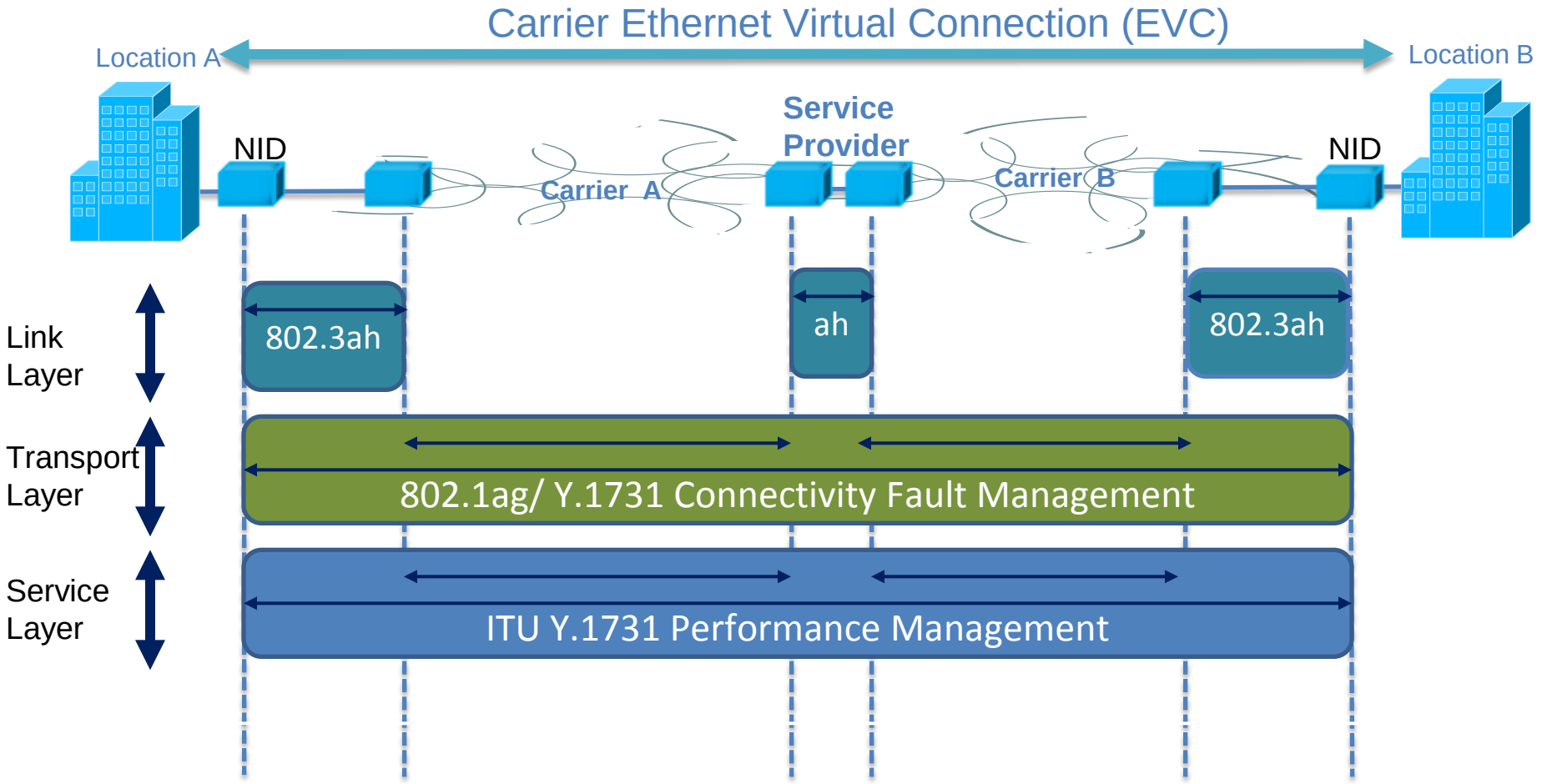
Ethernet OAM

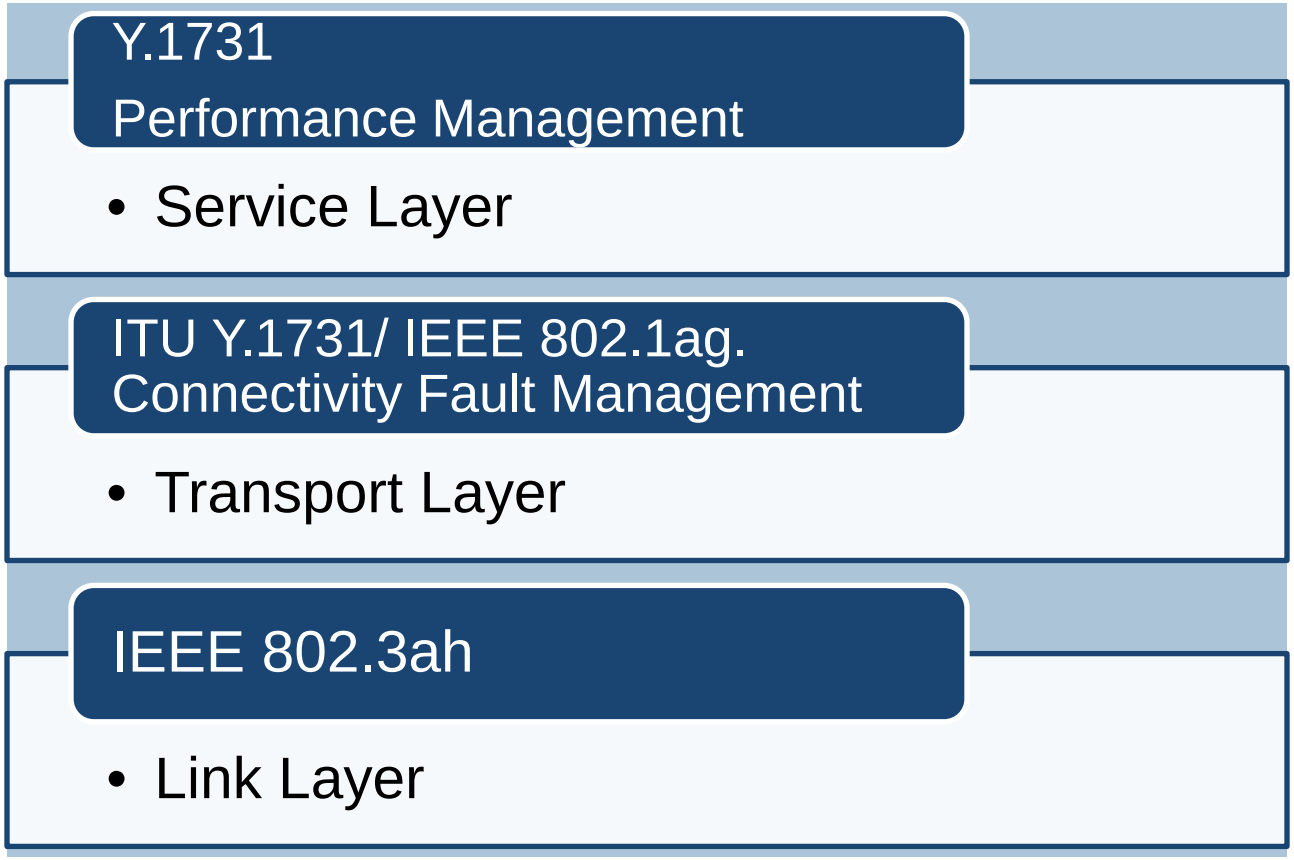
Ethernet OAM Overview

- Ethernet originated as a Local Area Network (LAN) technology
  - A small number of co-located stations, were all managed by a single entity so E2E performance was never a real concern
- “Carrier Class Ethernet” radically changed the situation;
  - Networks need to be managed and monitored by service providers in order to guarantee SLAs
  - Ethernet MANs need to support automated defect detection and performance measurement
- Three Ethernet OAM protocols have emerged;
  - IEEE 802.3ah EFM link-layer OAM
  - IEEE 802.1ag Connectivity Fault Management
  - ITU-T Y.1731 OAM Functions and Mechanisms for Ethernet networks
- The different OAM solutions are complementary

OAM Network Overview

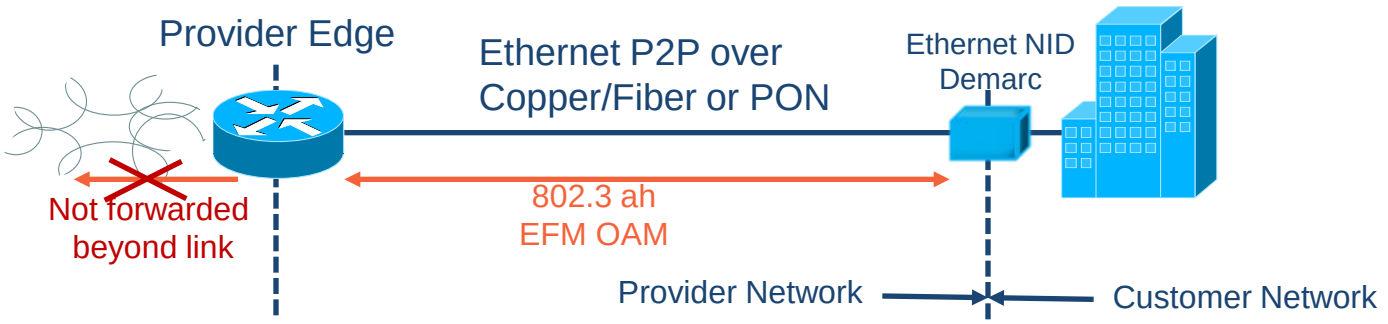


OAM Building Blocks



EFM OAM 802.3ah

- Defined in IEEE 802.3 standard clause 57
- Developed for EFM (Ethernet in the First Mile) i.e. last segment before customer
- First mile = Direct point-to-point links between provider and customer, or point-to-multipoint PONs
- Link Layer OAM is not forwarded beyond the link
- Slow protocol limited to 10 frames per second
- Not mandatory for backward compatibility with older Ethernet equipment

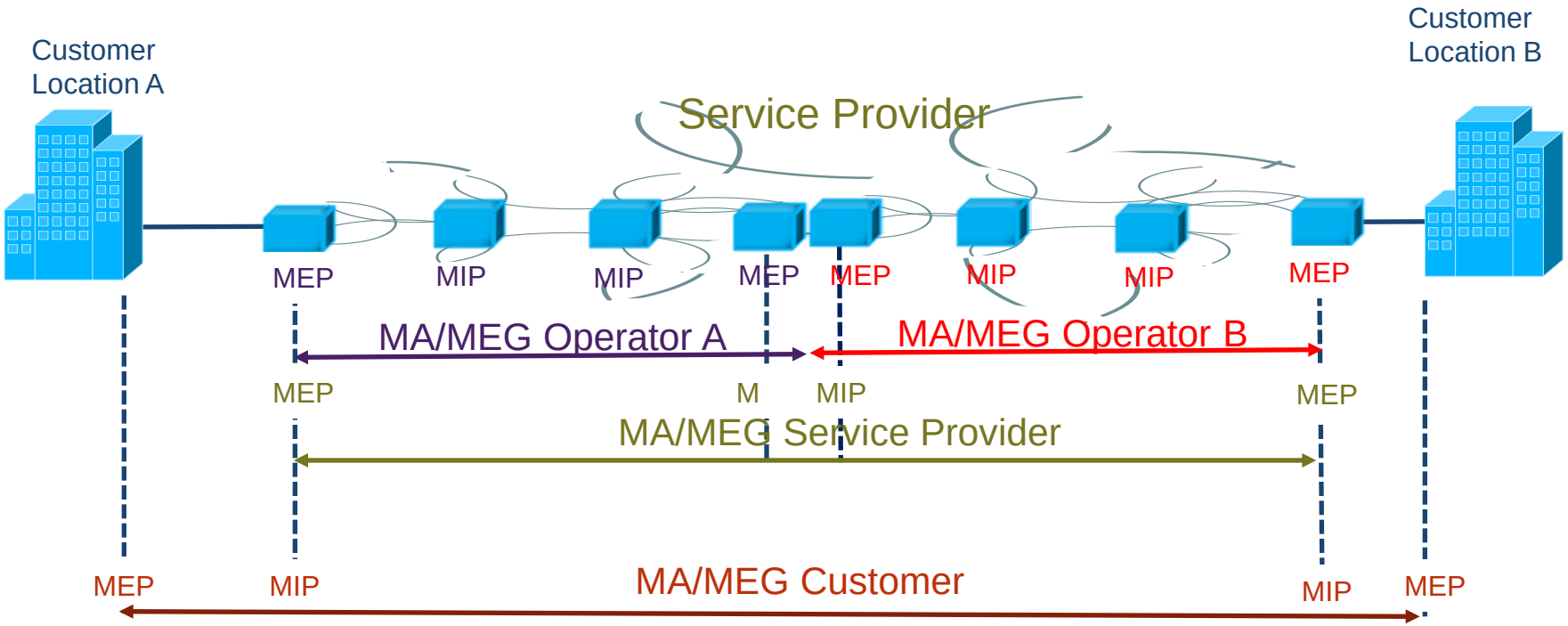


802.3ah Functions

Discovery	Information about OAM entities capabilities, configuration, and identity are exchanged
Remote Failure Indication	Notification of critical link failures: •Link Fault: receive path broken •Dying Gasp: unrecoverable local fault (e.g. power failure, reboot, reset) •Critical Event: severe error condition
Remote Loopback	Loopback request command for link performance testing and fault isolation
Performance Monitoring	Link events threshold crossing notification
Performance Monitoring	Transfer of Ethernet counters and stats via MIB querying mechanism
Proprietary extensions	Mechanism to add proprietary extensions for organization or vendor specific use

802.1ag/Y.1731 Multi-domain Overview

- Network separated into multiple maintenance domains run by separate management entities

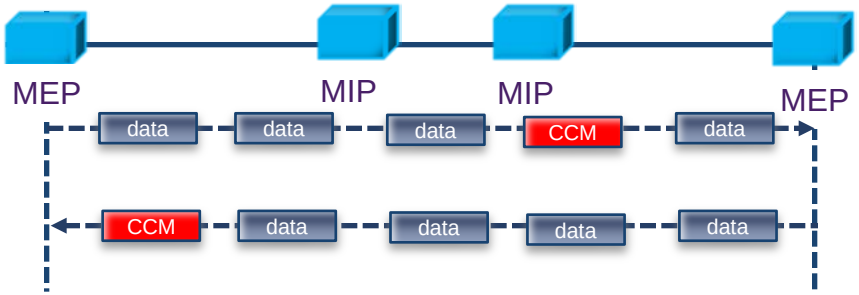


CFM Functions

802.1ag/Y.1731 Connectivity Fault Management Functions:

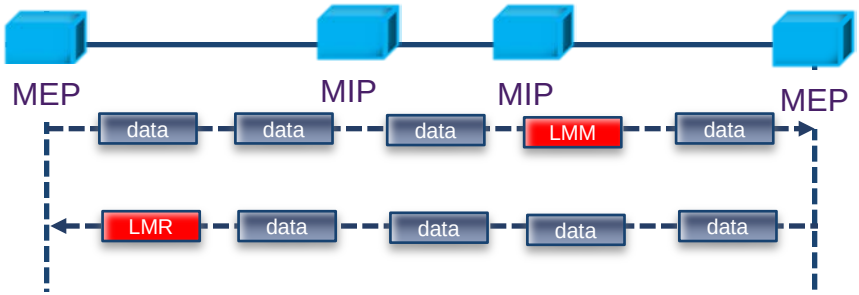
- Fault Detection – Continuity Check:
  - CCM “heartbeat” messages transmitted at a configurable periodic interval by MEPs
- Fault Notification – RDI
  - Upon detection of fault condition, MEP encodes RDI flag in CCM message
- Network/Path Discovery – Link trace message
  - Equivalent to “traceroute” test. MIPs and MEPs along the path send a response
- Fault verification and isolation – Loopback
  - Verify connectivity to a specific point in the message. Equivalent to “ping” test

- Dual ended Frame Loss Measurement



CCM frames contain frame counters

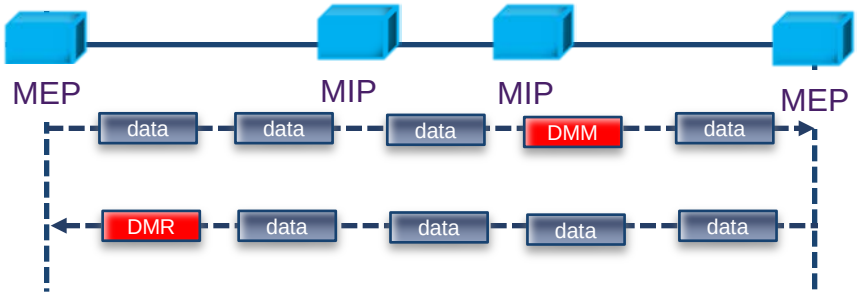
- Single ended Frame Loss Measurement



LMM frames contain frame counters

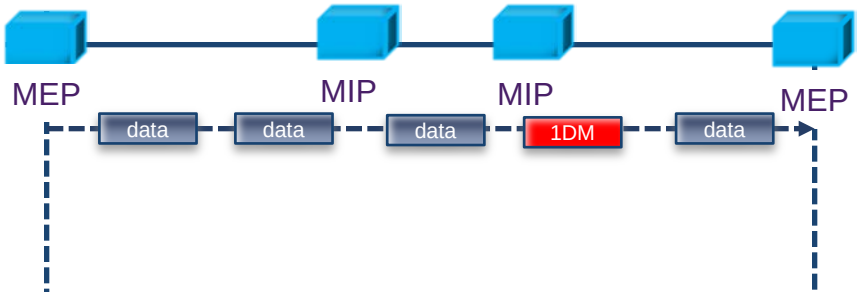
Performance Management

- Dual ended Frame Delay Measurement



DMM and DMR frames contain timestamp info

- Single ended Frame Delay Measurement



1DM frames contain timestamp info

Thank you.

Any questions?