Metro Ethernet – History and Overview

The Greater Chicago Chapter SCTE

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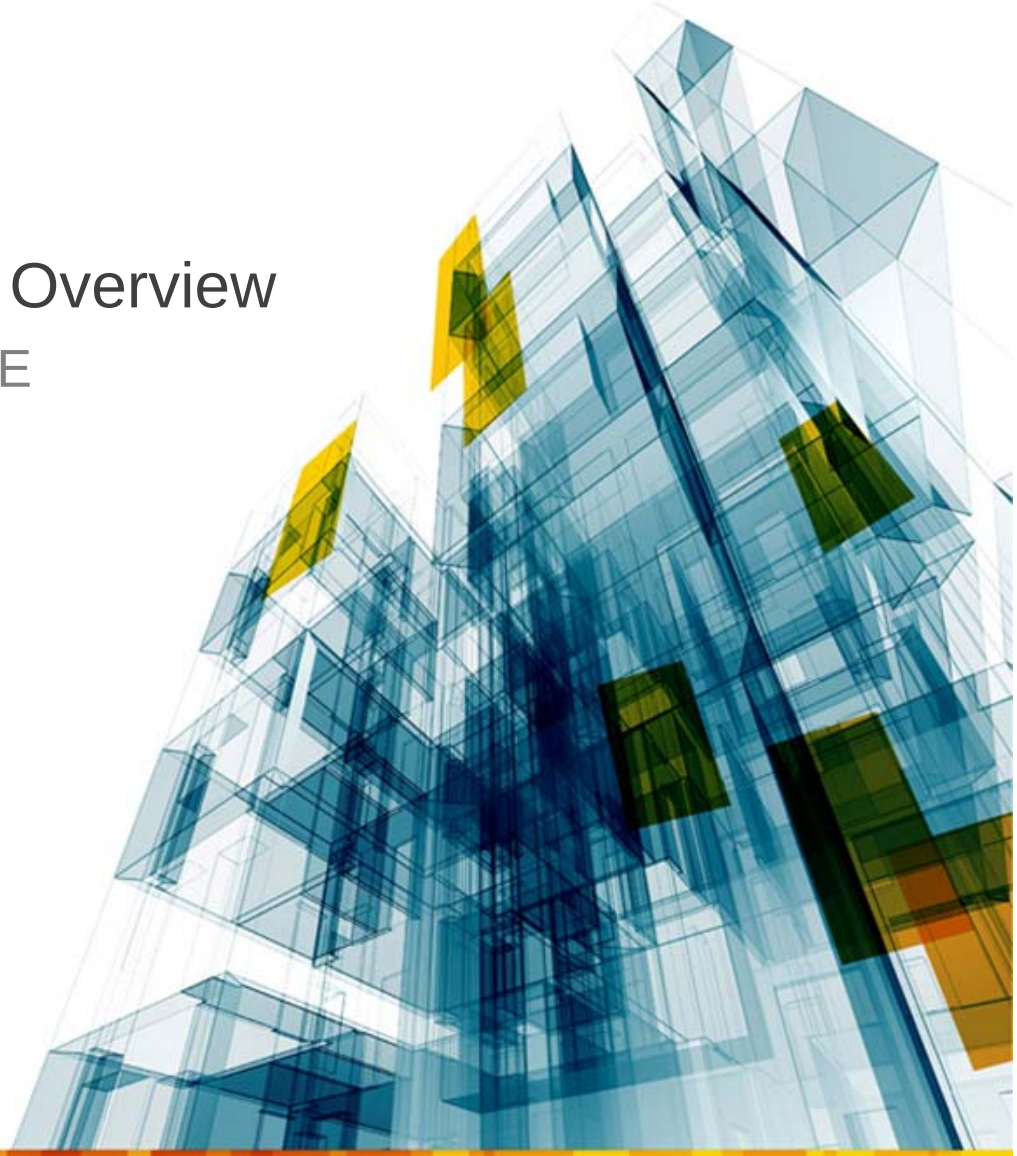

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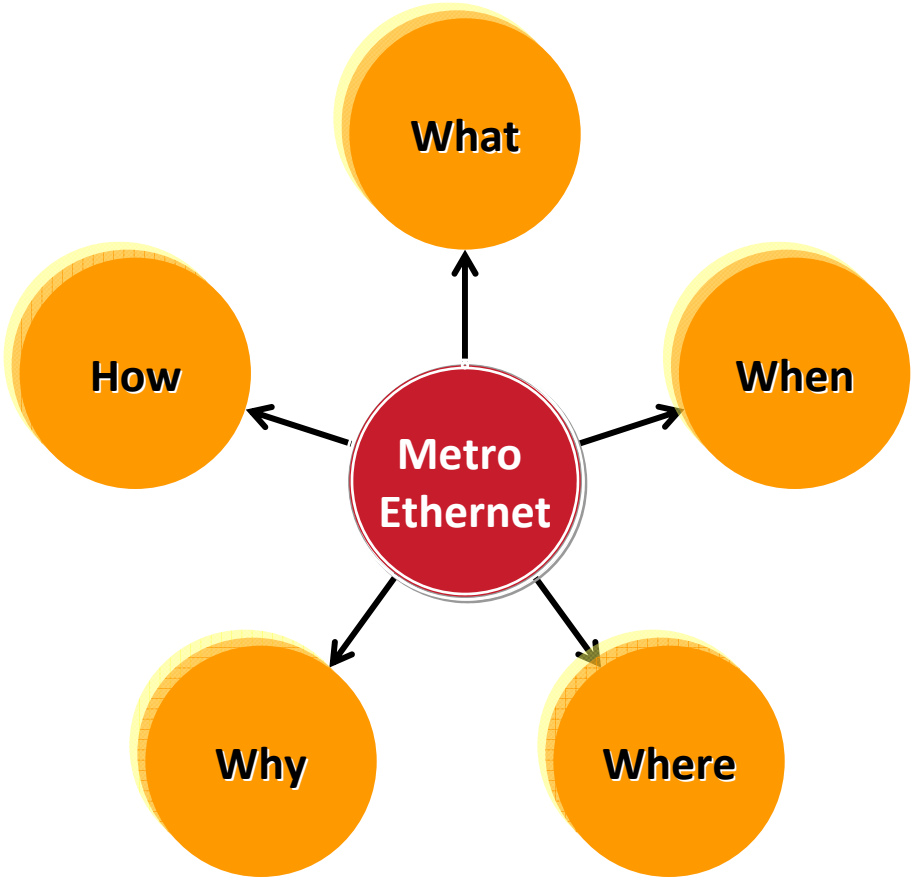
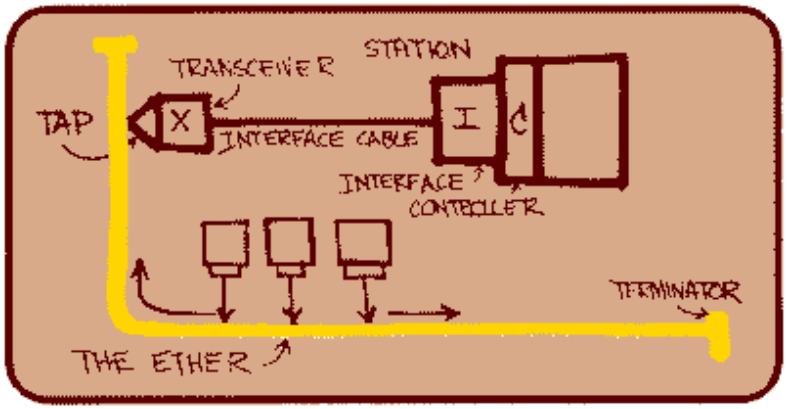


Ethernet — Where it began

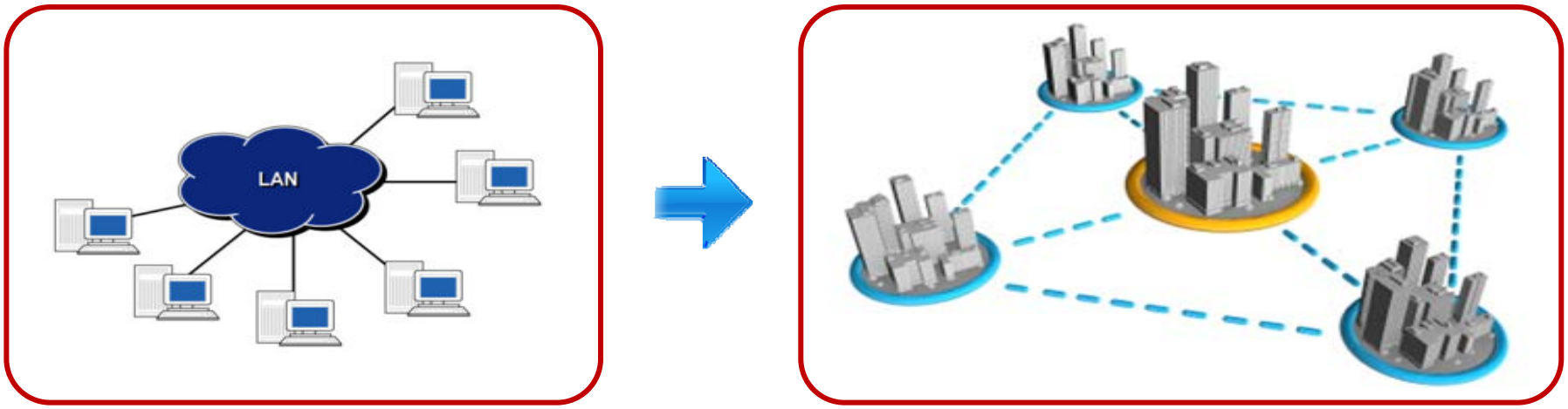
- Robert Metcalfe and David Boggs (working at Xerox PARC in 1973) invented **Ethernet** (which at the time was a standard for connecting computers over short distances)
  - Metcalfe identifies the day **Ethernet** was born as May 22, 1973, the day he circulated a memo titled "Alto Ethernet" which contained a rough schematic of how it would work

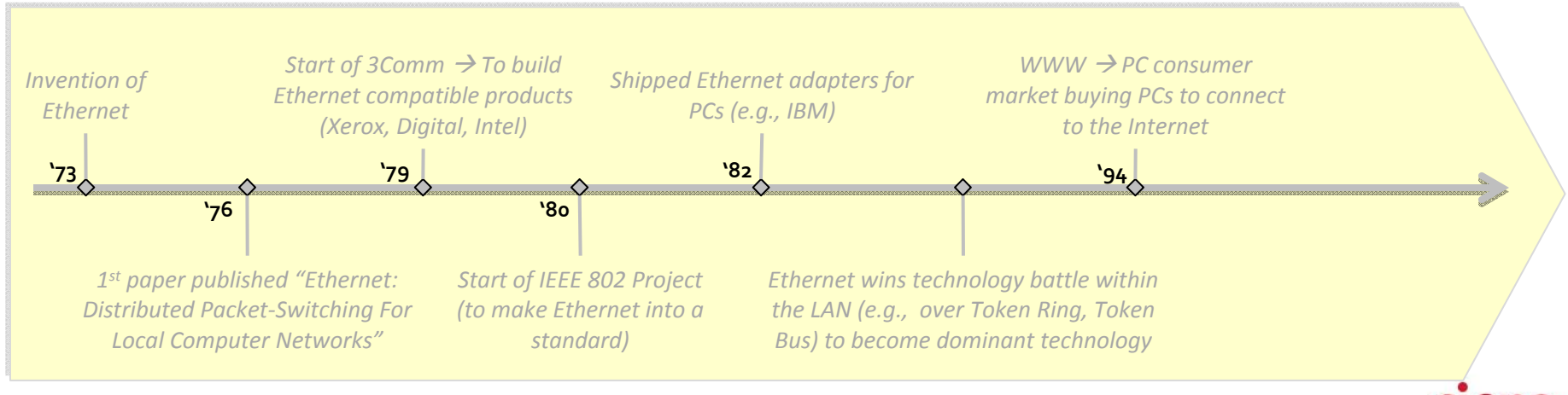


  - Initial **Ethernet** challenges:
    1. The network had to be fast enough to drive the very fast new laser printer
    2. Connect hundreds of computers within the same building
    3. Provide access to the Internet (ARPAnet)

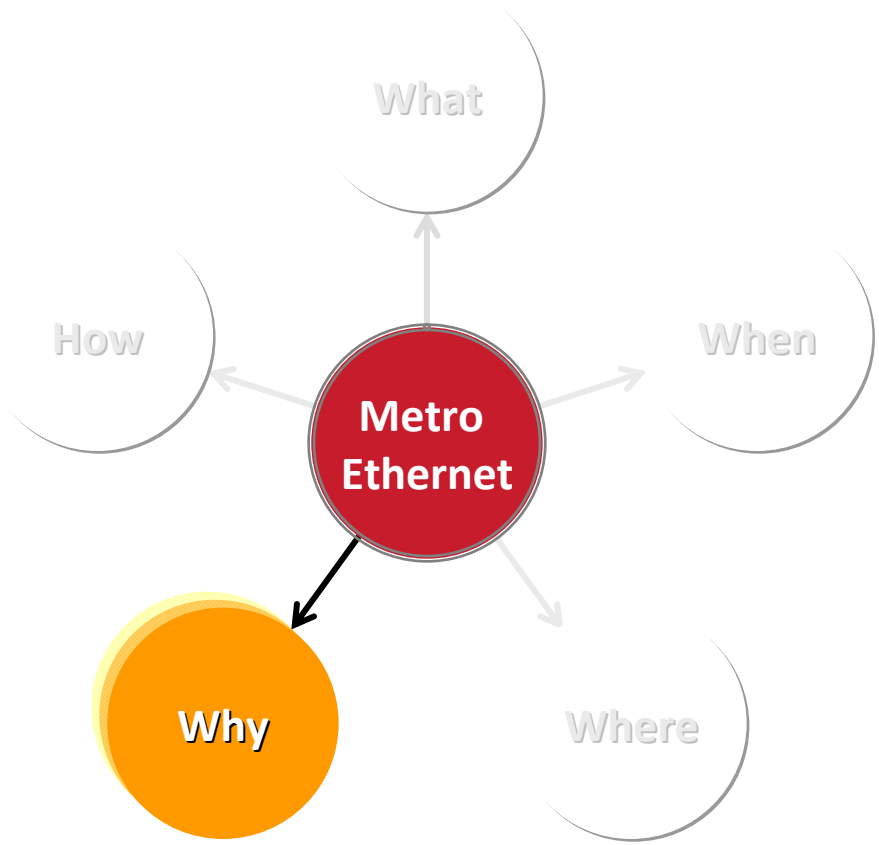
Ethernet — Where it began

- Ethernet continues to evolve from local area network (LAN) applications (using CSMA/CD technology) to metropolitan area network (MAN) applications



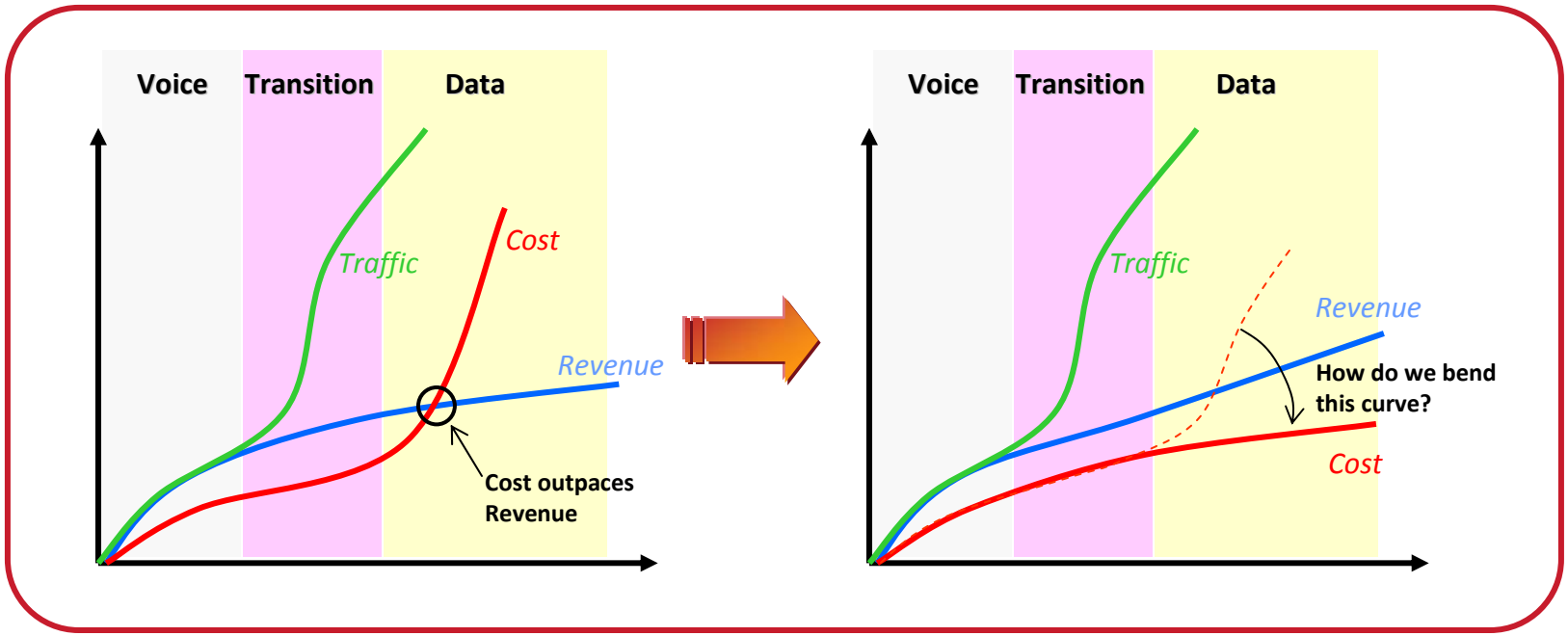


Metro Ethernet - Why?



Why Metro Ethernet?

Service Providers today face a formidable challenge



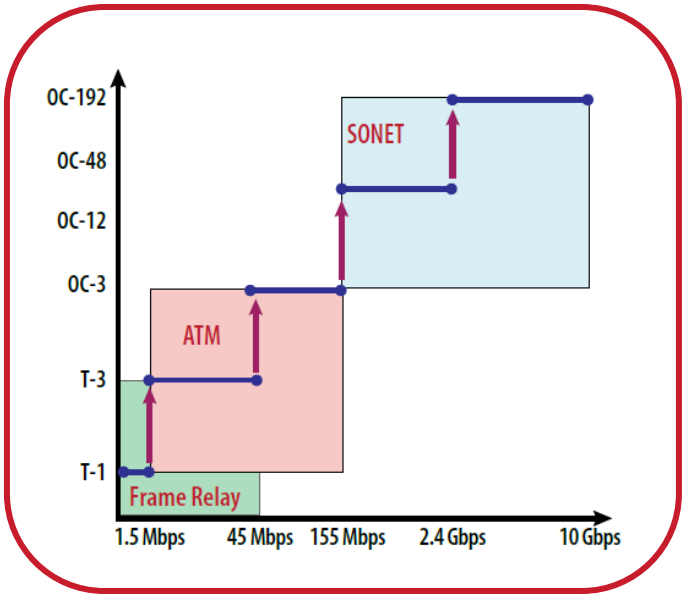
- Packet-based traffic is growing exponentially, but average revenue per user (ARPU) is declining (or flat)
- Average revenue per user is remaining flat (or increasing at a much smaller rate), which is severely impacting the profitability of the Provider's business
- Margin squeeze: Costs increasing faster than revenue
- Moving forward: Must decouple costs from capacity

Why Metro Ethernet?

- Ethernet is a widely deployed cost-effective and well-known technology, and Ethernet interfaces are available on a plethora of data communications/telecommunications devices
- Today, >95% of all data traffic in all enterprise LANs start and end on an Ethernet port
  - As enterprises are looking for network connectivity beyond the walls of their LANs, Metro Ethernet has become an obvious choice both for technical and cost reasons
- In a MAN, Ethernet has the potential to cost-effectively increase network capacity and offer a wide range of service offerings in a scalable, simple, and flexible manner

Why Metro Ethernet?

- Many technologies are used to deliver metro (and wide-area) services
  - Layer 1 TDM technologies used to deliver private line services include T1/T3 copper circuits, and SONET-based optical circuits
  - Layer 2 technologies used to deliver data services over the Layer 1 TDM technologies include Frame Relay, ATM and PPP
  - These legacy technologies provide inflexible bandwidth scalability because the bandwidth is dictated by the technology



NOTE: When a service provider or enterprise needs to add bandwidth, they either bond multiple circuits together or upgrade their network and equipment to support a new technology. This results in non-linear bandwidth that may not be at the bandwidth increment that the subscriber needs or, more importantly, can afford.

- Carrier/Metro Ethernet addresses the limitations of legacy technology by providing flexible bandwidth scalability

Why Metro Ethernet?

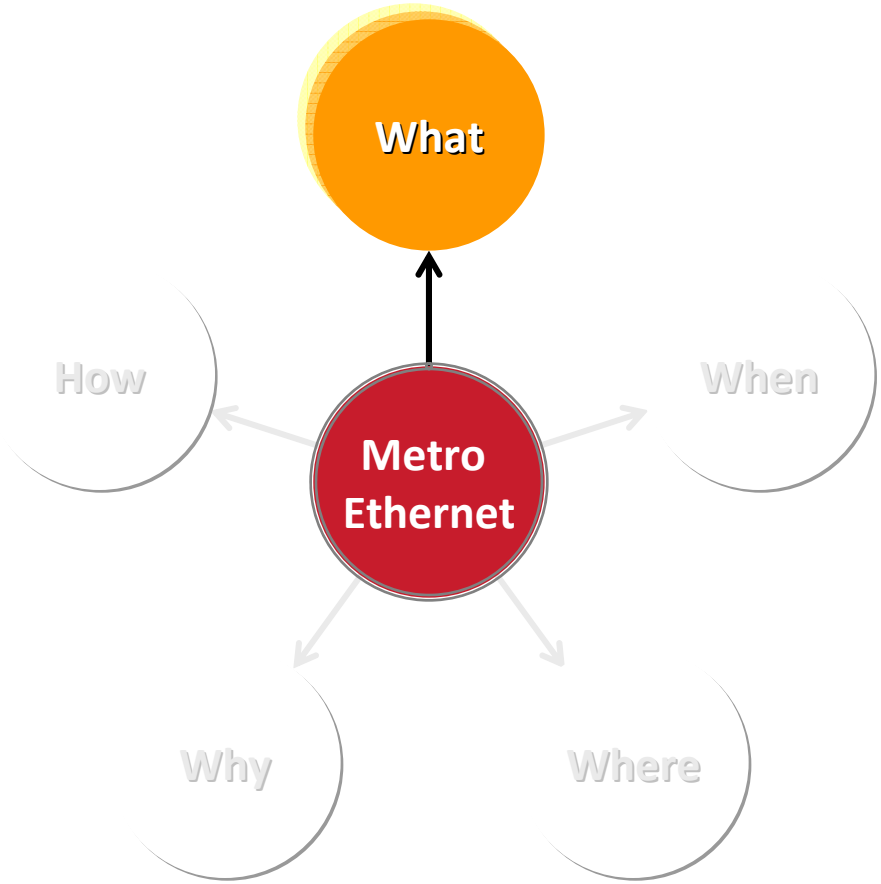
Benefits to the End-User

- Ethernet is ubiquitous in the LAN
- Flexible services and scalability
  - Eliminate over-provisioning
  - No rigid bandwidth limitations
  - Networks readily satisfy growing bandwidth demand
  - 1 Mbps → 1 Gbps → 10Gbps →
- Lower start-up costs
  - CPE costs reduced by mass scale of Ethernet market
- Easy-to-use, plug-and-play technology
- Guaranteed bandwidth with the ability to burst
  - Committed Information Rate (CIR)
  - Excess Information Rate (EIR)

Benefits to the Service Provider

- Multiple revenue streams from a single interface
  - Ethernet Internet Access
  - Ethernet Private Line
  - Ethernet Virtual Private Line
  - Ethernet Virtual Private LAN Service
- Greater revenue potential — granular bandwidth
- Lower capital & operations costs
- Higher customer retention
- Pipes
  - Efficient data transport
  - Economical scalability
- Ports
  - Cost-effective network build-outs

Metro Ethernet – What is it?

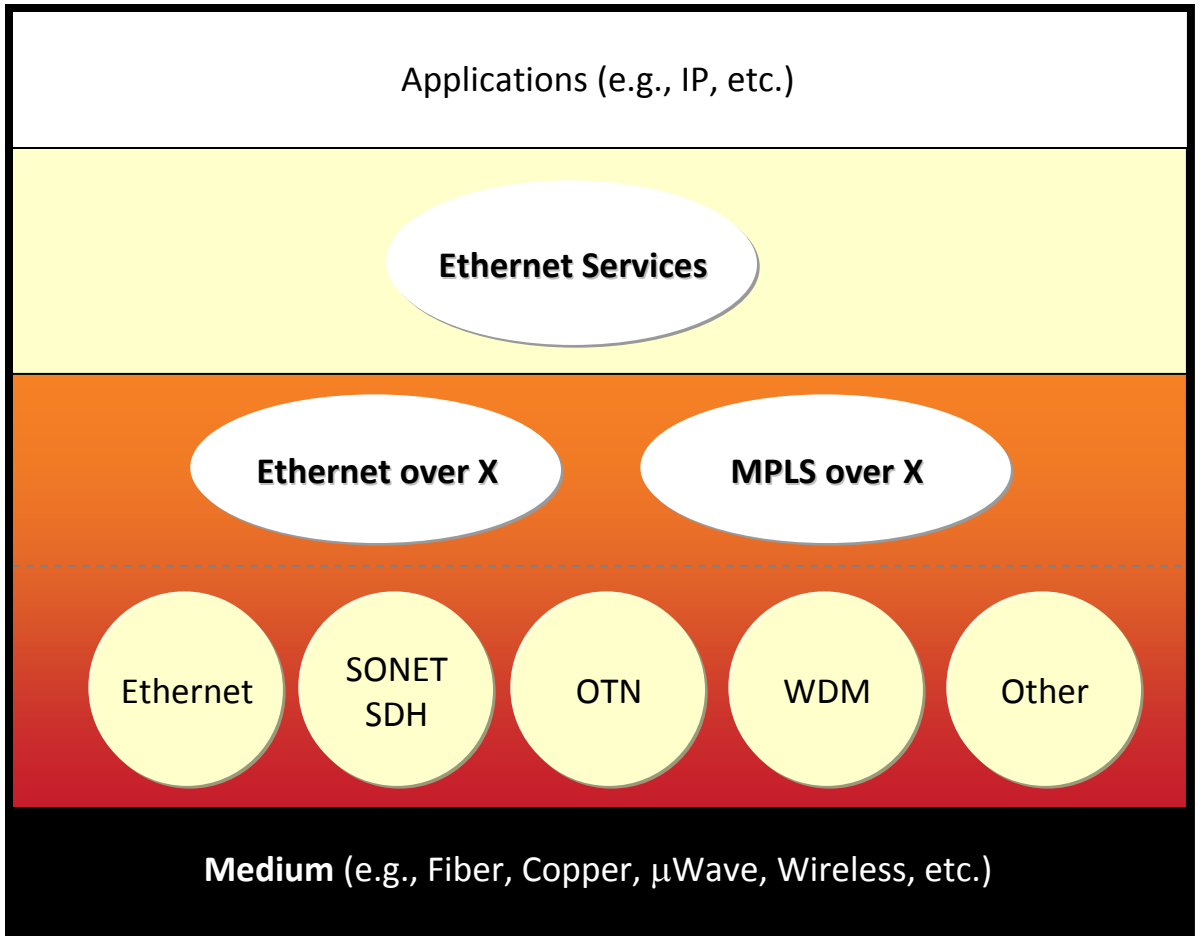


What is Metro Ethernet?

- Metro Ethernet …
  - The use of **Carrier Ethernet** technologies in a metropolitan area network (MAN), which is used to connect
    a) End users and businesses to a wide area network (WAN) and the Internet
    b) Corporations, academic institutions and government agencies (in large cities) to branch offices or offices to an Intranet
- Metro Ethernet System …
  - Consists of a collection of connected of Layer 2 and Layer 3 switches and/or routers
- Metro Ethernet Network …
  - The network that bridges or connects geographically separated enterprise LANs while also connecting across the WAN or backbone networks that are generally owned by Service Providers
  - The MEN provides connectivity services across Metro geography utilizing Ethernet as the core protocol and enabling broadband applications

What is Metro Ethernet?

- Metro Ethernet is really about how to **transport** Ethernet Services



What is Carrier Ethernet?

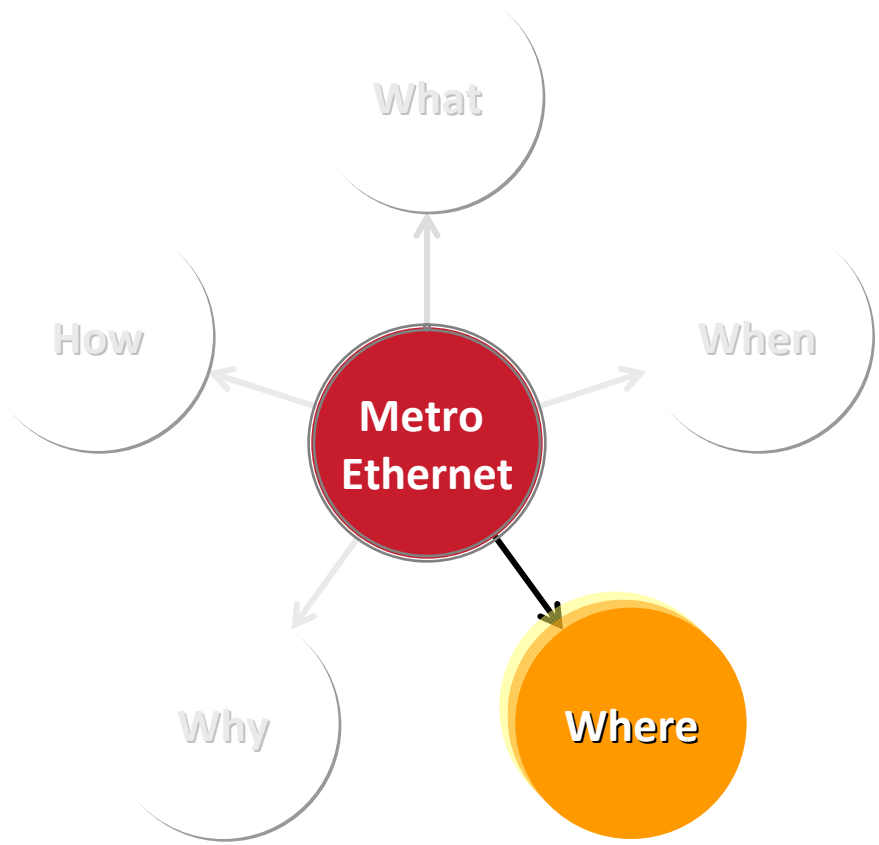
- Carrier Ethernet is a term used to refer to extensions to Ethernet to enable service providers to provide Ethernet services to customers and to utilize Ethernet technology in their networks
- According to the Metro Ethernet Forum, **Carrier Ethernet** is defined as a ubiquitous, standardized, carrier-class Service and Network defined by five attributes that distinguish it from LAN-based Ethernet:

1. **Standardized Services**: Customers can receive a wide range of standardized yet improved services, including converged network services, over existing equipment
2. **Scalability**: Can be implemented in bandwidth from 1Mbps to 10Gbps and beyond, from access to global coverage
3. **Reliability**: The network can quickly detect and recover from incidents without impacting users
4. **Quality of Service**: Wide choice of SLAs for end-to-end performance of business and residential services
5. **Service Management**: The ability to monitor, diagnose and centrally manage the network with standards-based systems and operations management.

What is Carrier Ethernet?

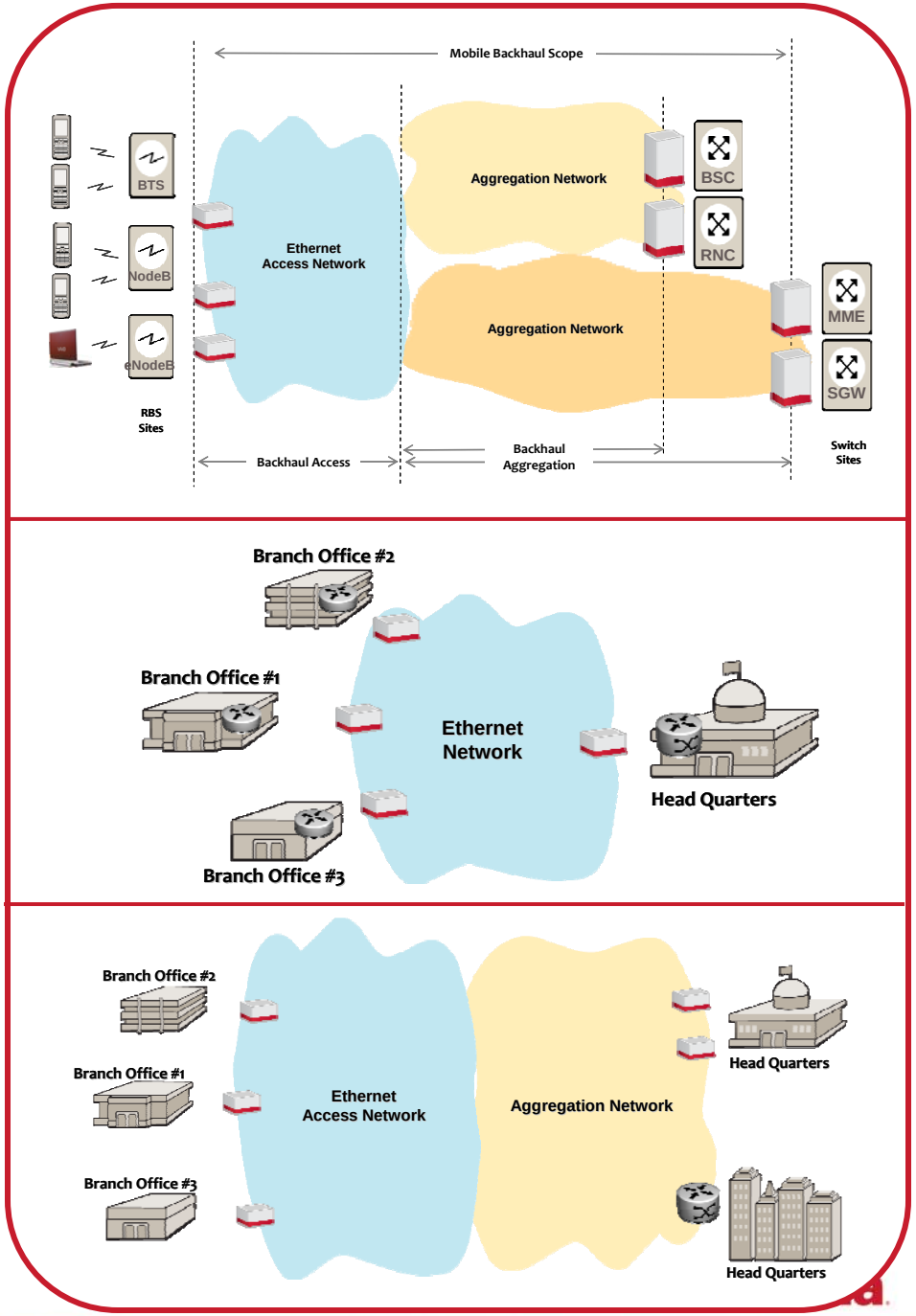
- We need to beef up Ethernet to be Carrier grade
- **WHERE** can we apply Metro Ethernet?
- **HOW** can we address?
  1) Scale & Performance
  2) Reliability/Resiliency
  3) Quality of Service
  4) Manageability
  5) Standardized Services

Metro Ethernet - Where?

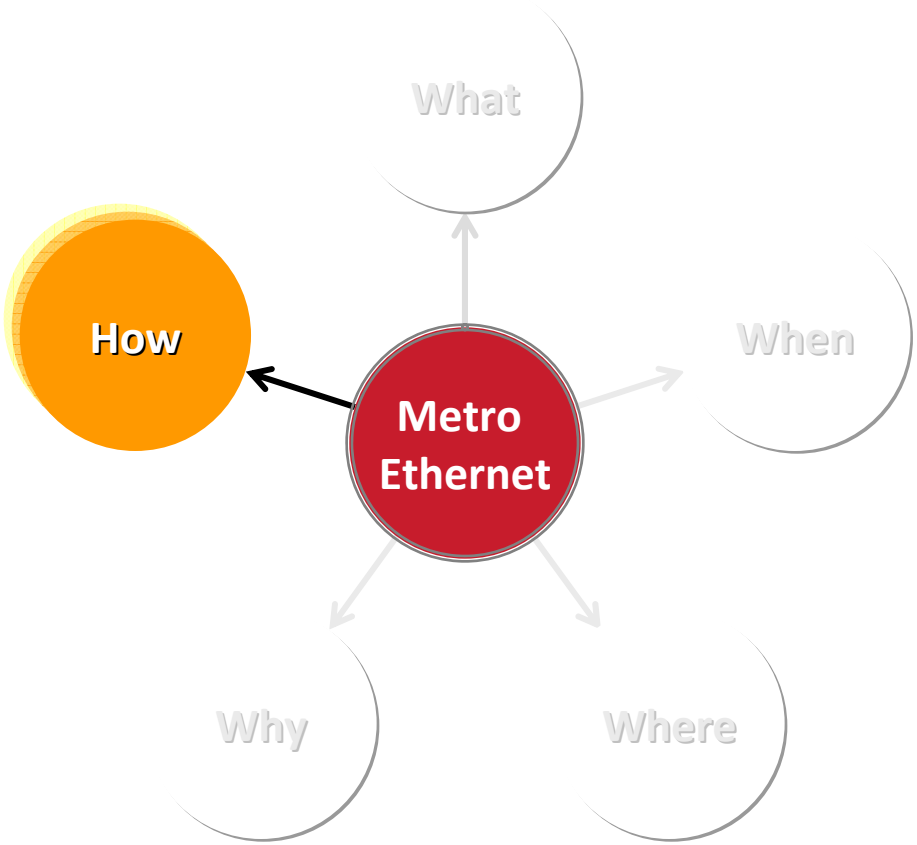


Metro Ethernet – Where?

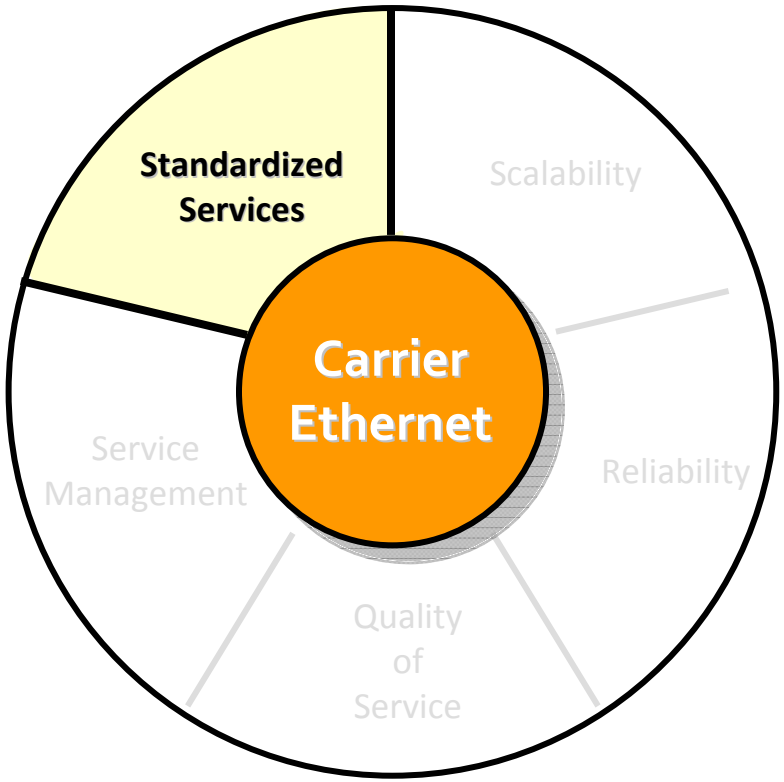
- The Metropolitan Area Network
- The applications enabled by a Metro Ethernet network include Ethernet Layer 2 networking and Ethernet access to IP (Layer 3) services
  - Site-to-site Layer 2 VPNs
  - Ethernet Private Line
  - Wholesale Ethernet access
  - 3G/4G cell site Mobile Backhaul
  - Ethernet access to IP services
  - Delivery of Private Cloud services
  - Residential services



Metro Ethernet - How?



Standard Ethernet Services

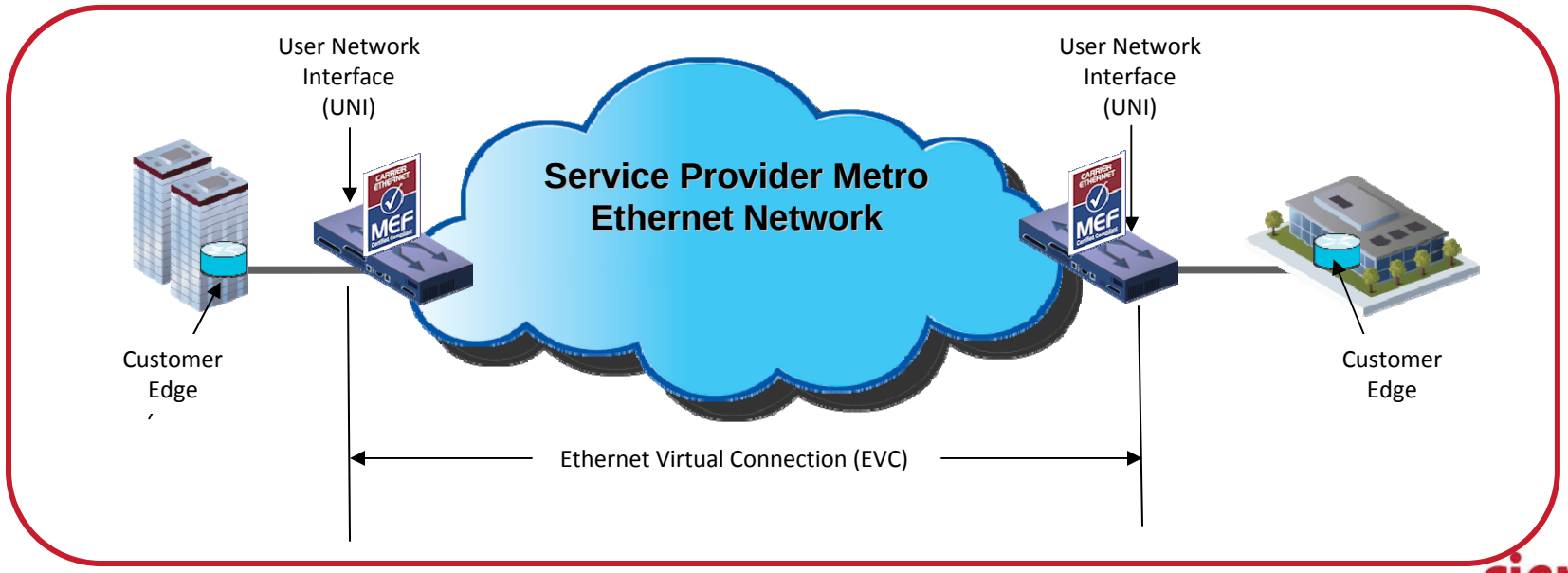


Standard Ethernet Services

- The Metro Ethernet Forum is actively defining the scope, concepts, and terminology for deploying Ethernet services in the metro
- Other standards bodies, such as the Internet Engineering Task Force (IETF), have also defined ways of scaling Ethernet services through the use of MPLS
  - While the terminologies might slightly differ, the concepts and directions taken by these different bodies are converging
- For Ethernet services, the MEF defines a set of attributes and parameters that describe the service and SLA that are set between the metro carrier and its customer

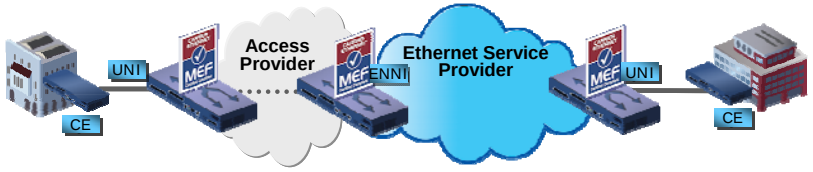
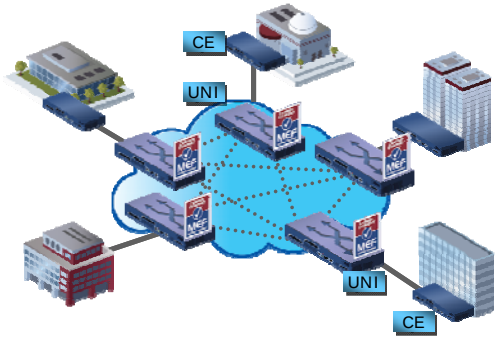
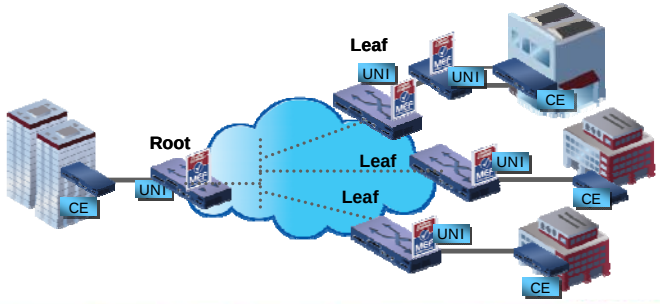
What is an Ethernet Service?

- An Ethernet service is provided by the Metro Ethernet provider
  - Customer's (subscriber) services extends from UNI to UNI
  - CE attaches to the network at the UNI using standard Ethernet interfaces
- Services are defined from a subscriber perspective
  - As such services can be supported over a variety of transport technologies and protocols in the MEN (such as SONET/SDH, DWDM, MPLS, GFP, Ethernet, etc.)
  - However, from a subscriber-perspective, the network connection at the subscriber side of the UNI is Ethernet
- Connectivity between UNIs is an Ethernet Virtual Connection (EVC)

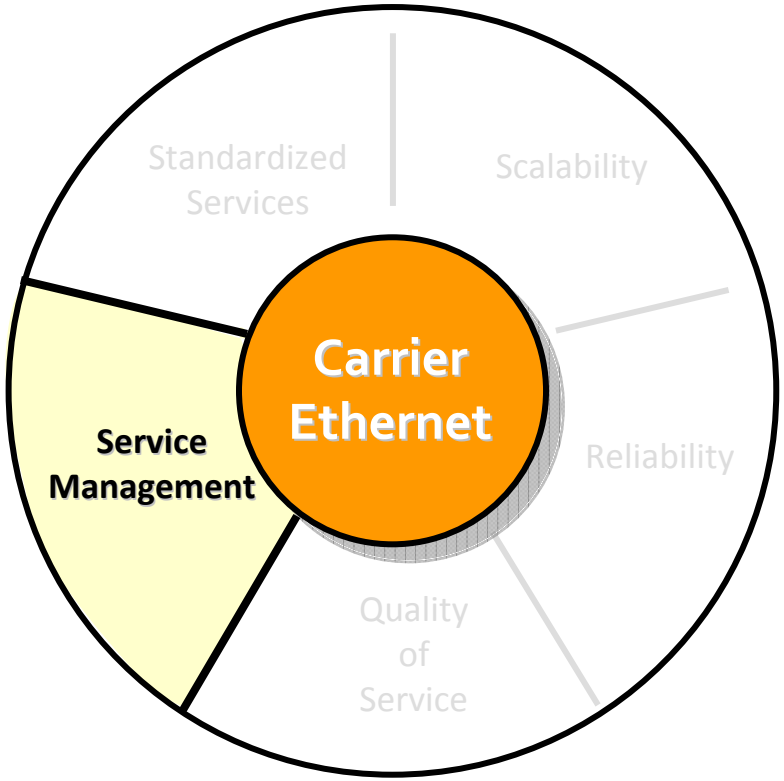


MEF Defined Ethernet Services

- Standard MEF service (E-Line, E-Access, E-Tree, E-LAN) definitions can be supported by various Ethernet networking technologies
- E-Service variants include
  - Port-Based (*All-to-One Bundling*)
  - VLAN-Based (*Service Multiplexed*)
- Enables a Service Provider to deliver services efficiently over standardized equipment
- Provides greatest flexibility to meet range of user needs

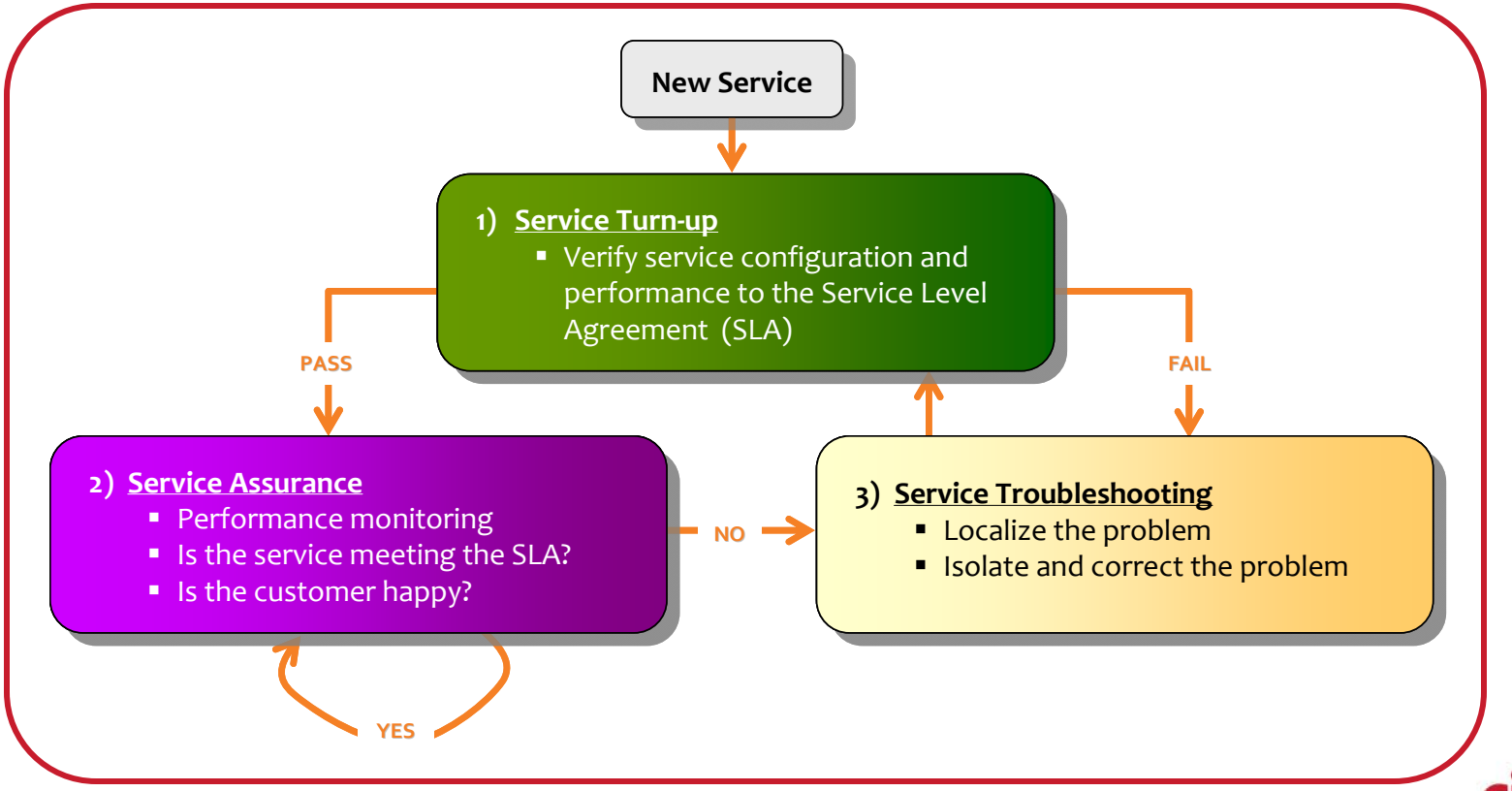
Service Type	Service Network Reference
E-Line *(Point-to-point EVC)*	
E-Access *(OVC)*	
E-LAN *(Multipoint-to-multipoint EVC)*	
E-Tree *(Rooted multipoint EVC)*	

Ethernet Service Management



Ethernet Service Management

- Carrier Ethernet provides a comprehensive standardized suite of protocols to allow the Service Provide to monitor, diagnose, and centrally manage the network, using standards-based vendor independent implementations
- Let's examine how Carrier Ethernet can provided full coverage of a representative service management OAM cycle



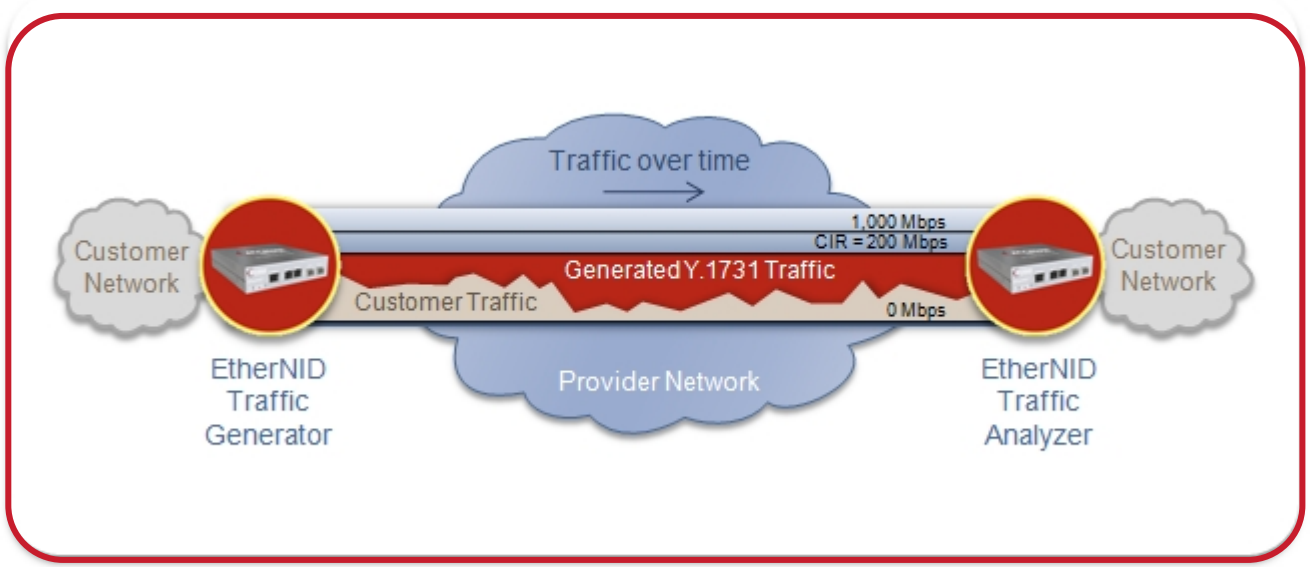
Ethernet Service Management – Service Turn-Up

Service Turn-Up

- IETF RFC 2544 (Benchmarking Methodology for Network Interconnect Devices)
  - Provides a methodology for measuring throughput, latency, frame loss and back-to-back (burstability) for the purpose of verifying the design of network equipment
- ITU-T Y.1564 (Ethernet Service Activation Test Methodology)
  - Serves as a network service level agreement (SLA) validation tool, ensuring that a service meets its guaranteed performance settings in a controlled test time
  - Can ensure that all services carried by the network meet their SLA objectives at their maximum committed rate, proving that under maximum load network devices and paths can support all the traffic as designed
  - Performs medium and long-term service testing, confirming that network element can properly carry all services while under stress during a soaking period
- IETF RFC 5357 (TWAMP: Two-Way Active Measurement Protocol)
  - Provides a flexible method for measuring round-trip IP performance among any two devices in a network.
  - It measures core and edge IP performance through cooperation between the routers and switches in the Network
  - Connects use TCP and uses UDP packets for testing

Ethernet Service Management – Service Benchmarking

- Service/Networking “benchmarking” provides an initial view of the service/network performance of the Ethernet service being newly introduced within the Service Provider’s network
  - Throughput
  - Latency
  - Jitter
  - Etc.
- This view is sometimes referred to as the “birth certificate” of the newly introduced service (or network connection)



Ethernet Service Management – Service Assurance

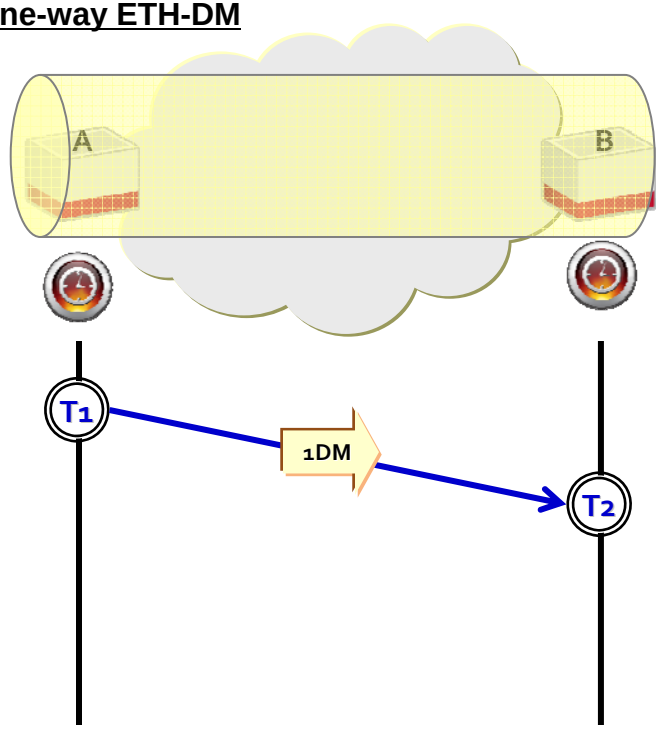
Service Assurance

- ITU-T Y.1731 (OAM Functions and Mechanisms for Ethernet based Networks)
  - Service frame delay and delay variation (jitter) measurements
  - Service frame loss measurements
  - Service availability
  - Service connectivity validation
- ITU-T Y.1564 (Ethernet Service Activation Test Methodology)
  - Service performance (e.g., frame delay, delay variation (jitter), throughput) that can be compared to initial service activation results
- IETF RFC 5357 (TWAMP: Two-Way Active Measurement Protocol)
  - Service frame delay and delay variation (jitter) measurements
  - Service frame loss measurements

Ethernet Service Management – Performance Monitoring

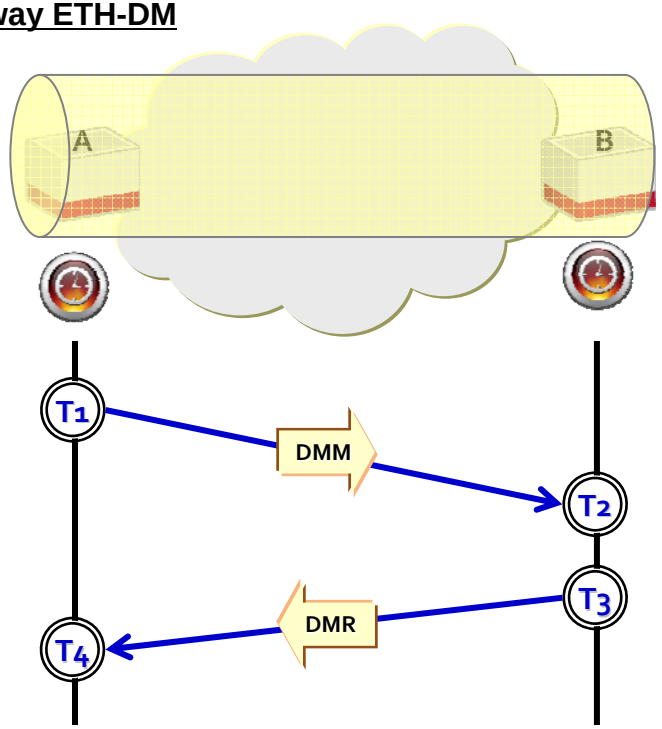
- ITU-T Y.1731 defined protocols to support service latency and inter-frame delay variation (a.k.a., jitter) measurements

One-way ETH-DM



- 1DM PDU is Tx from local to remote device
- One-way (`local → remote`) computed by |T2-T1| at remote

Two-way ETH-DM

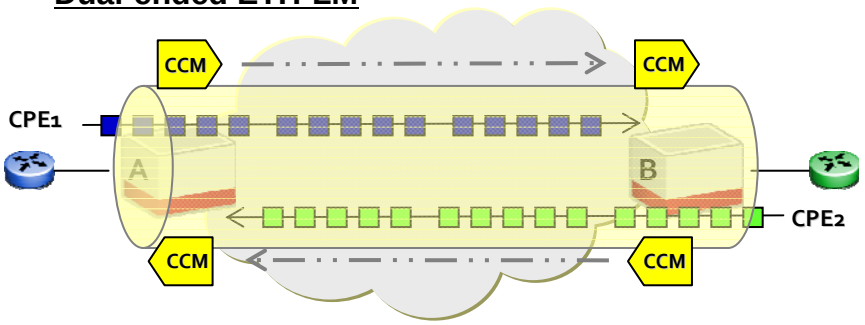


- DMM PDU is Tx from local to remote device, and remote "reflects" DMM PDU by Tx DMR PDU back towards local
- One-way (`local → remote`) computed by |T2-T1|
- One-way (`remote → local`) computed by |T3-T4|
- `Round trip` computed by |T4-T1|-|T3-T2|

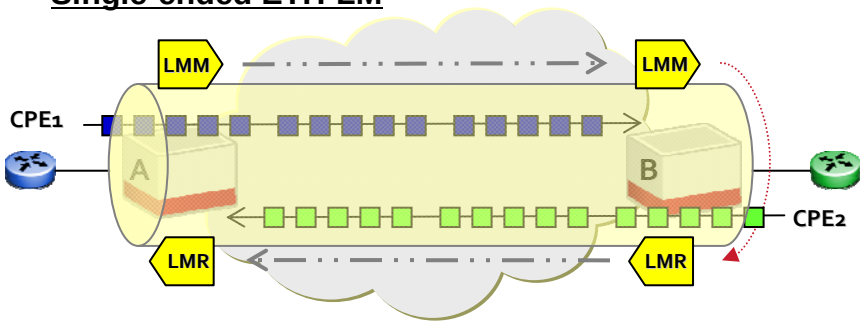
Ethernet Service Management – Performance Monitoring

- ITU-T Y.1731 defined protocols to support service frame loss measurements

Dual-ended ETH-LM

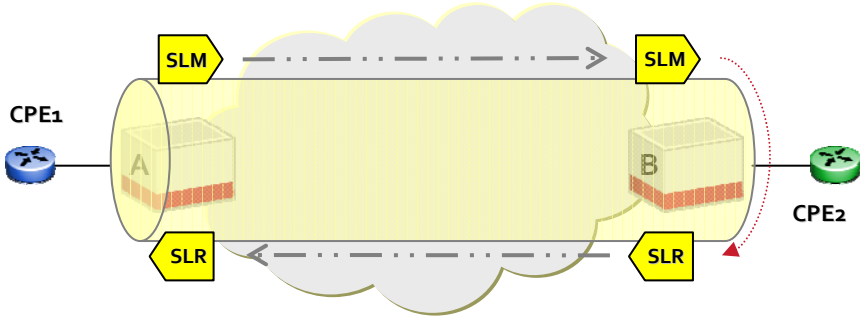


Single-ended ETH-LM



- PDUs contain actual client frame Rx/Tx counters, associated with the service
- Frame loss (`local` and `remote`) measurements reflect that of actual service flow, over duration

ETH-SLM



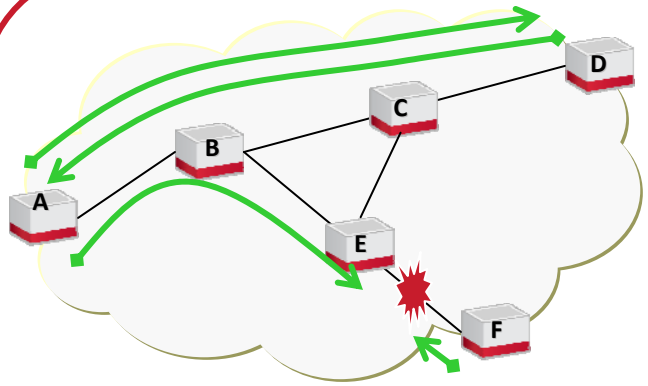
- PDUs are generated (i.e., synthetic traffic) which contain counters of PDU traffic Tx/Rx
- Frame loss (`local` and `remote`) measurements reflect that of synthetic traffic

Ethernet Service Management – Service Trouble Shooting

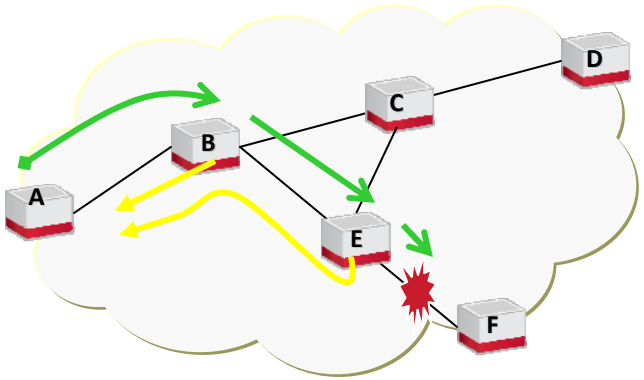
Service Trouble Shooting

- IEEE 802.1ag (Connectivity Fault Management)
  - Service connectivity validation (via CCMs)
  - Loopback and Linktrace
- IEEE 802.3ah (OAM Link Fault Management)
  - Loopback, dying gasp, link fault notifications, etc.
- ITU-T Y.1564 (Ethernet Service Activation Test Methodology)
  - Service performance (e.g., frame delay, delay variation (jitter), throughput) that can be compared to initial service activation results

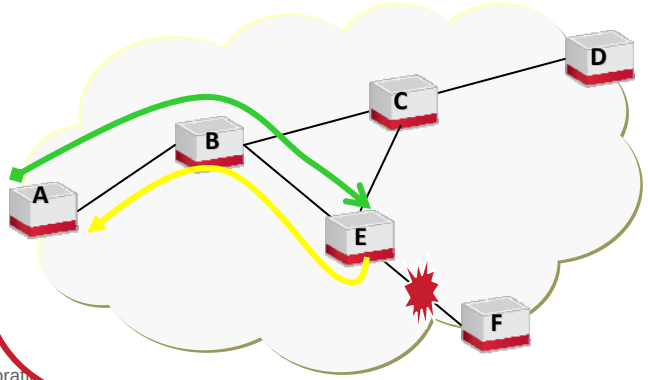
Ethernet Service Management – Fault Management



Continuity check messages (CCMs) dispatched over service to detect continuity and connectivity faults within service connection

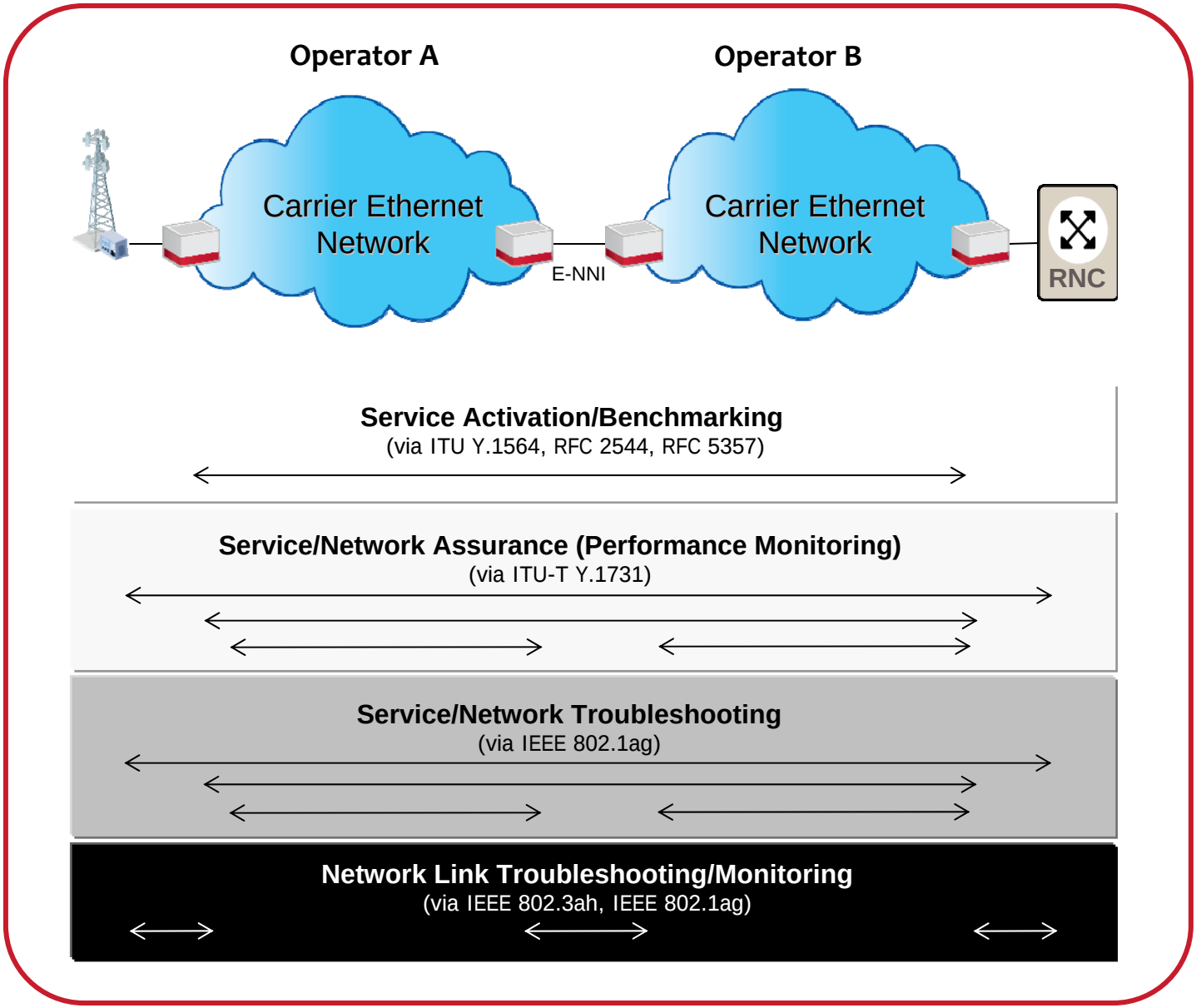


Link trace protocol (LTM/LTR) can be used to provide [path] trace of nodes and hop count within service connection

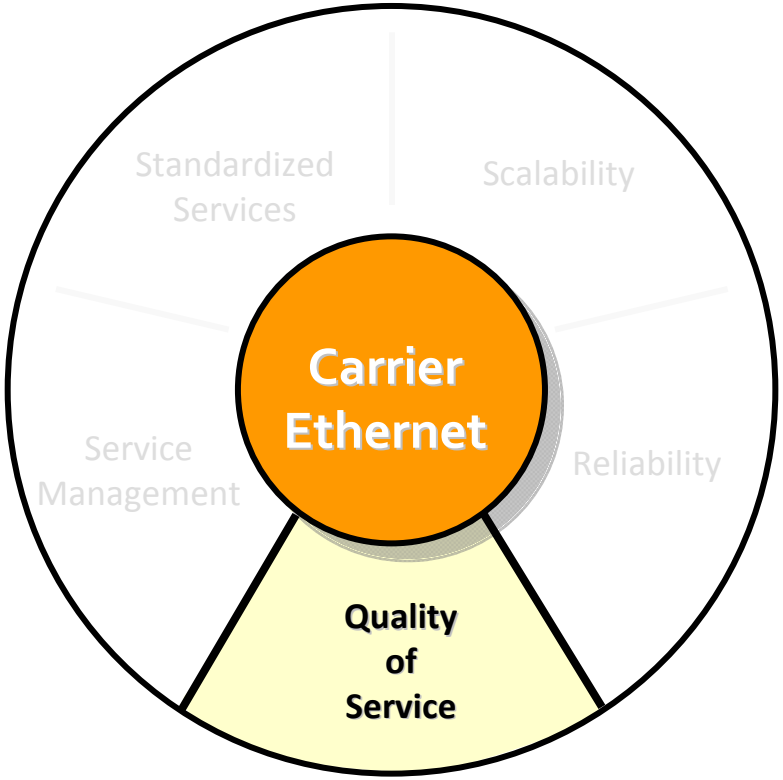


Loopback protocol (LBM/LBR) can be used to validate connectivity between nodes and provide fault isolation within the service connection

Ethernet Service Management — Network Perspective



Ethernet Quality of Services



Ethernet Quality of Services

- Quality of Service (QoS) is a mechanism that allows service providers to offer different classes of service to their customers
  - Enables Ethernet service providers to offer, monitor and enforce Service Level Agreements (SLAs) for Ethernet services
    - There is typically a monetary correlation between a higher class of service (e.g., mission critical application) versus a lower class of service (e.g., best effort IP applications) that can be provided
  - Class of services may have different service-network performance characteristics, which match the requirements for voice, video, or data applications over a converged Ethernet network
    - Service frame loss tolerances
    - Service frame latency and jitter tolerances
    - Service availability tolerances
    - Network bandwidth access tolerances (both committed and on a best effort basis)

- Carrier Ethernet supports qualitative delivery of critical enterprise applications, which demand strict adherence to specific performance levels outlined in SLAs

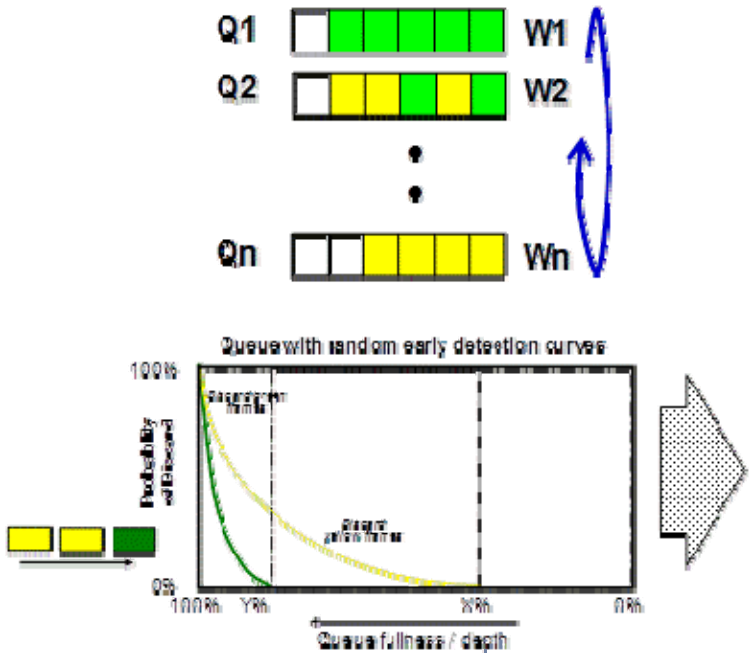
Ethernet Quality of Services

1. Rich service flow classification for QoS treatment spanning layer 1 up to layer 4+
   - Ingress port, TCP/UDP port, etc.
   - Service identifiers (e.g., VIDs, labels, etc.)
   - Priority (e.g., p-bits, DSCP, etc.)
   - Addresses (MAC, IP, etc.)
   - Etc.

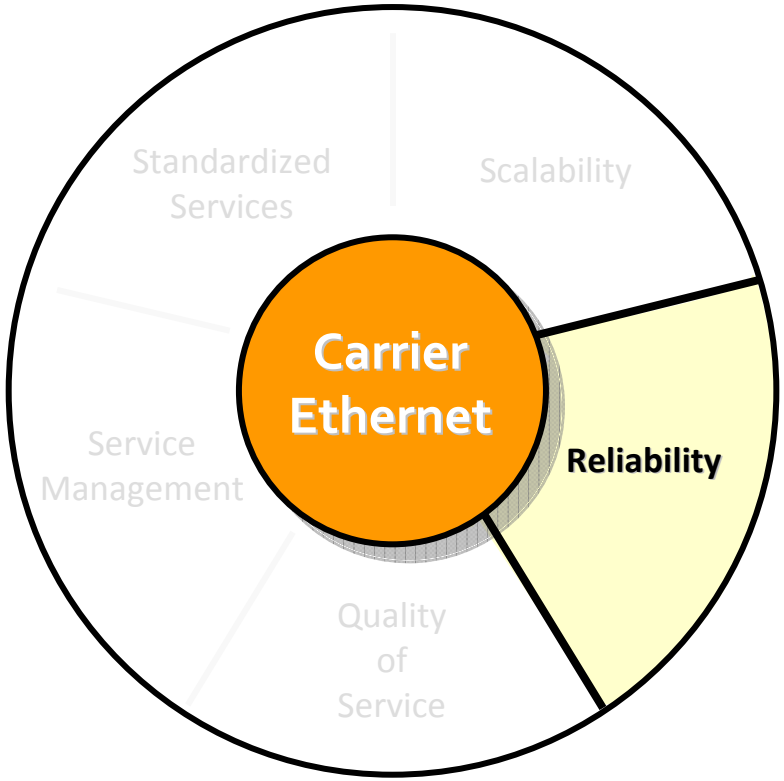
2. Sophisticated service traffic policing
   - Application of defined service bandwidth profiles: {CIR/EIR, CBS/EBS}
   - Ingress metering (dual rate, 3 color) in service bandwidth increments

3. Sophisticated CoS queuing and scheduling
   - Egress shaping in service BW increments
   - Dual rate, 3 color shaping
   - Random early discard congestion management/avoidance
   - Strict and/or WFQ scheduling

4. Performance monitoring of service traffic performance characteristics via Y.1731
   - Frame-loss, frame-delay, frame-delay-variation, and availability measurements



Ethernet Reliability/Resiliency



Ethernet Reliability/Resiliency

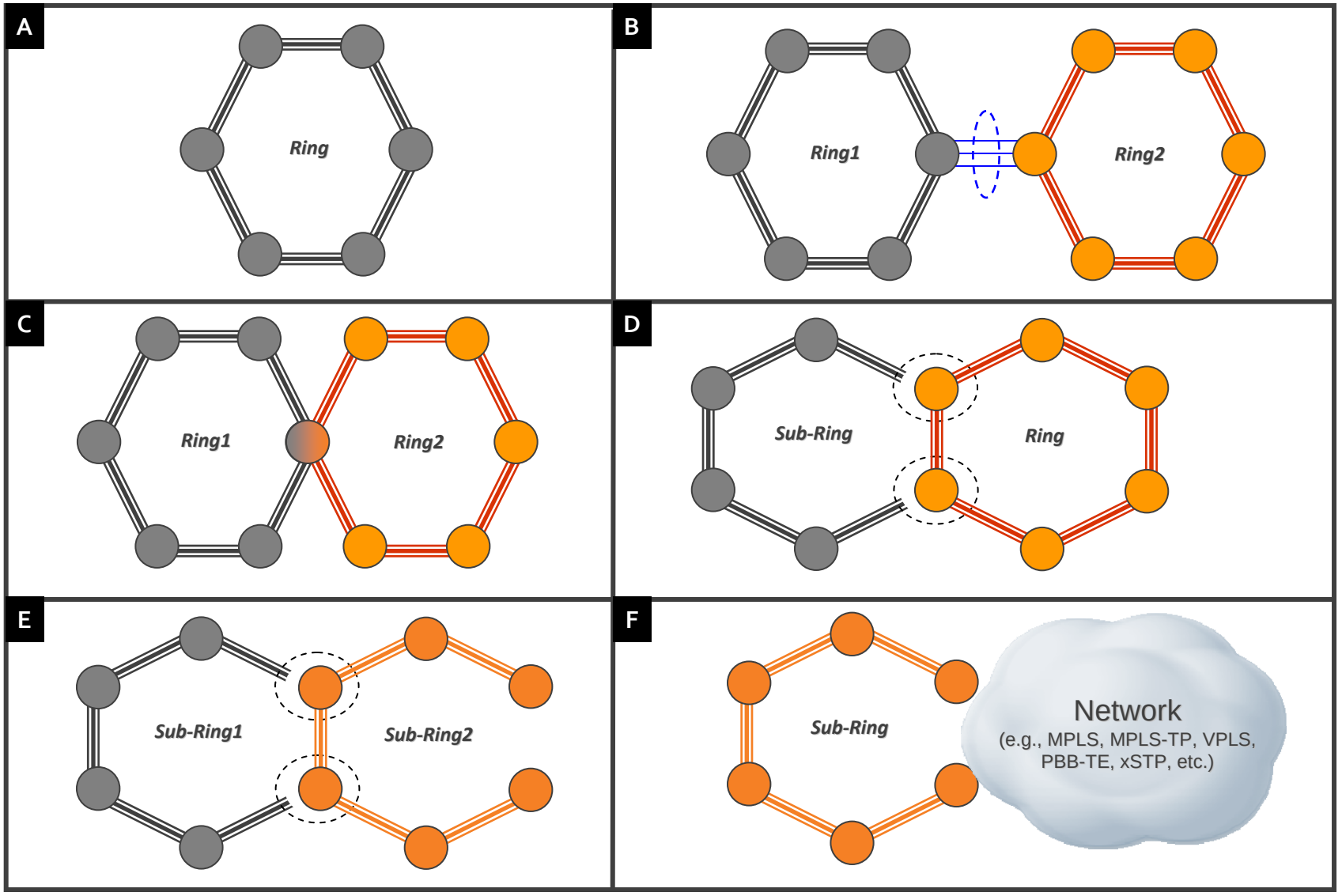
- Because carrier networks often support mission-critical applications and services for large-scale customers, there is a need for reliable, resiliency, and restoration properties for carrier services
- Carrier-grade reliability/resiliency must provide the following:
  - Complete service-level protection against faults and failures in the underlying infrastructure used for the delivery of carrier services, network paths, network links, and node devices
  - Resiliency to ensure the impact of failures is local, not widespread, and does not affect other users or applications
  - The ability for the network to detect and recover from incidents with negligible impact to user traffic flows
  - The ability to support the most demanding performance and availability requirements
  - Rapid recovery time when problems do occur (as low as 50ms)
- Rapid and automatic detection of infrastructure faults and service failures is vital to the operation of a Service Provider's network
- Availability tolerances of the network is often bounded by service level agreements (SLAs)

Ethernet Reliability/Resiliency

- IEEE Bridged network domains (802.1Q) can be protected via the spanning tree protocol (e.g., STP/RSTP/MSTP)
  - However, service restoration performance and level of network scale can be a concern
- IEEE 802.1aq (Shortest Path Bridging) introduced a more scalable and resilient bridging domain solution which leverages an IS-IS control protocol
  - Provides service restoration in sub-seconds to below 100 milliseconds
  - Scales for large topologies (e.g., ~1K bridges)
  - Utilizes (multiple) shortest paths
  - Reuse all existing Ethernet OAM (802.1ag/Y.1731)
- IEEE 802.1Qay (PBB-TE) and ITU-T G.8031 (Ethernet Linear Protection), provides deterministic sub-50ms protection for services with a linear topology
- ITU-T G.8032 (Ethernet Ring Protection) provides deterministic sub-50ms protection for Ethernet services with point-to-point and/or multipoint topologies
- LAG and MC-LAG provides link and nodal redundancy and resiliency

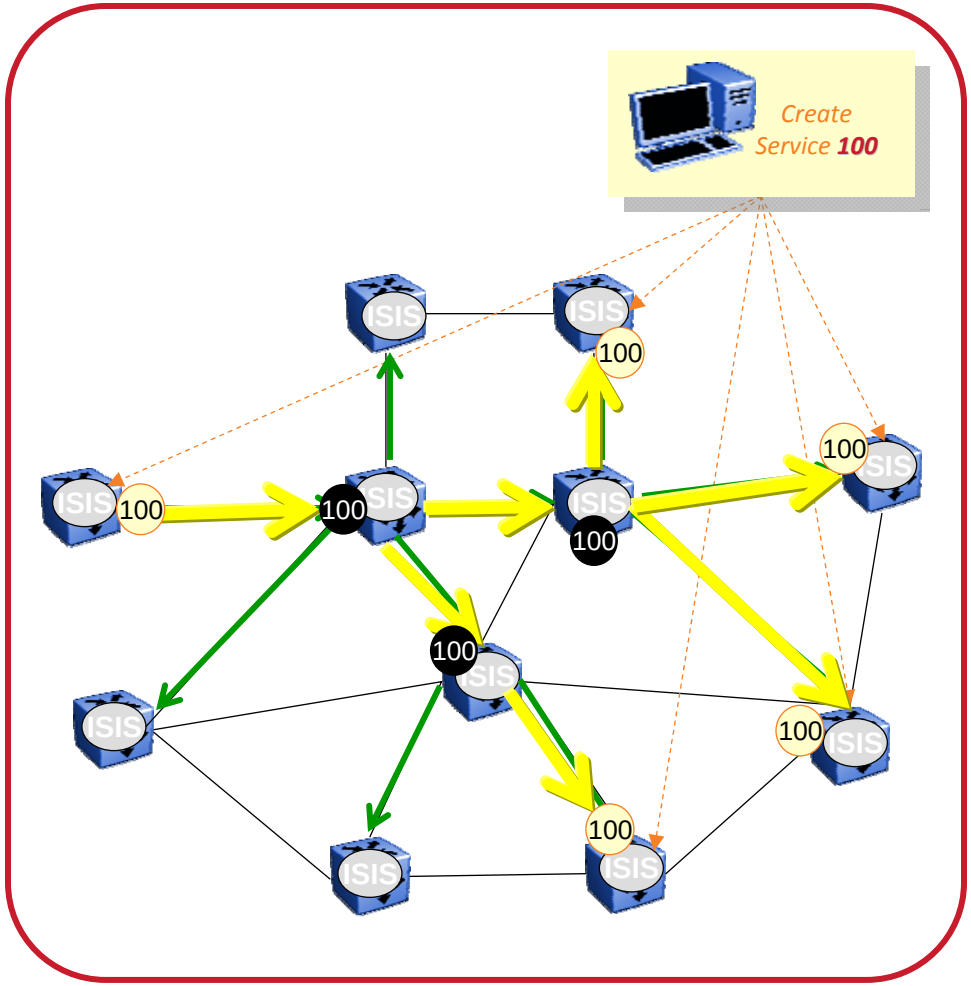
NOTE: MPLS within a Metro Network also provides a plethora of resiliency options (inclusive of MPLS FRR, MPLS-TP automatic linear protection switching, etc.)

ITU-T G.8032 — Network Protection Strategies

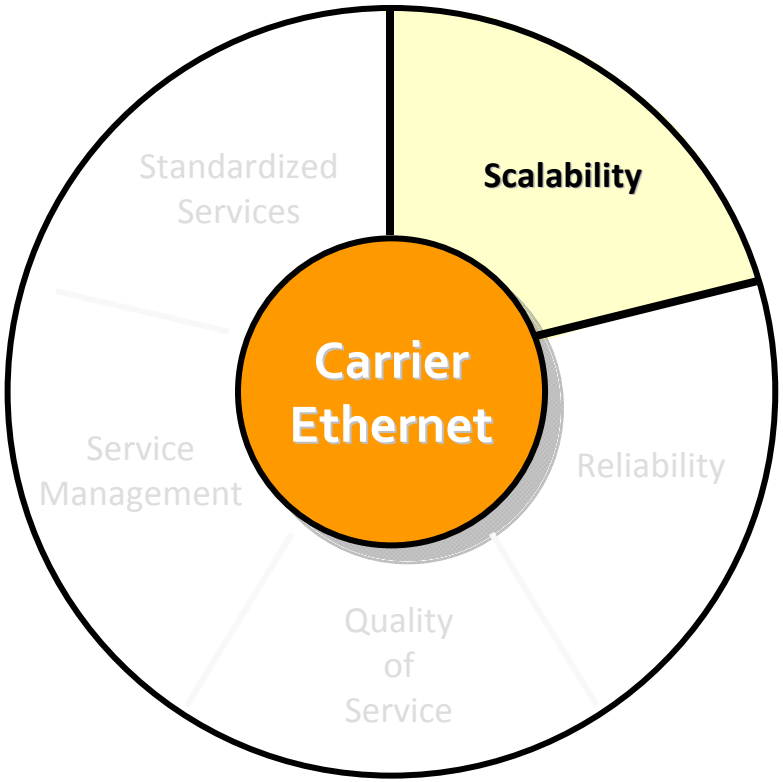


IEEE 802.1aq — Shortest Path Bridging

1. Discover network topology
   - Link state routing protocol IS-IS is used as a natural L2 routing protocol
   - Each node/link is automatically discovered
2. IS-IS nodes automatically build trees from itself to all nodes
   - Shortest path tree based on link metrics
   - No blocked links
   - Loop freeness provided
   - Symmetric datapath between any two nodes provides closed OAM system
   - Unicast path now exists from every node to every other node
3. Use IS-IS to advertise new services communities of interest
   - MAC and ISID information added to standard IS-IS advertisements
4. When nodes receive notice of a new service and they are on the shortest path, update FDB
   - ISID/Service specific entries



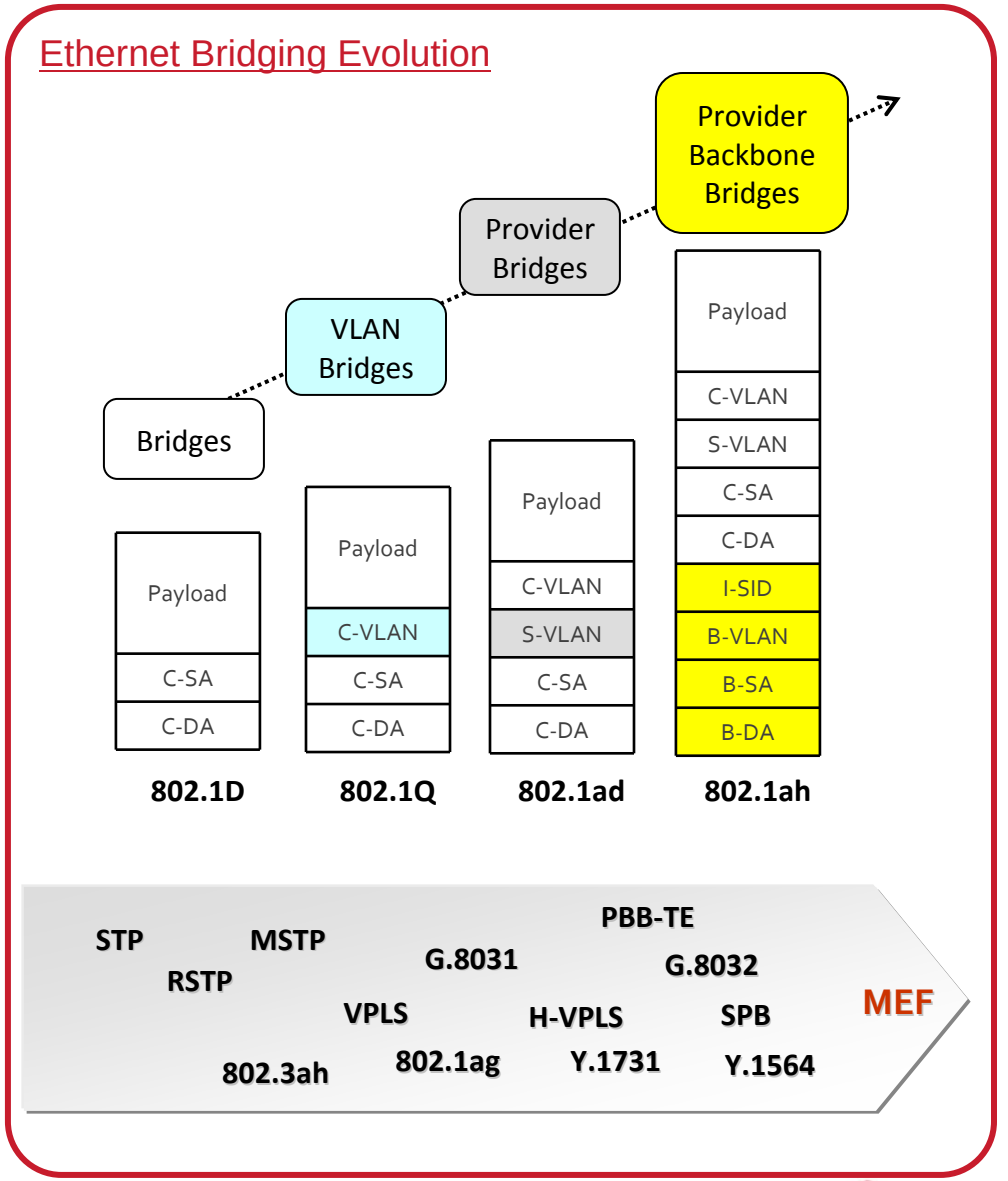
Ethernet Service Scalability



Ethernet Service Scalability

- Ethernet bridging (802.1) technologies have improved service scaling from 802.1D to 802.1Q (customer virtual LANs), to 802.1ad (provider bridged networks with 4K service instances), to 802.1ah (provider backbone bridged networks with 16M service instance scaling)

- Evolution of control protocols to manage the connectivity of the evolving networks from STP to RSTP to MSTP, PBB-TE (sub-50ms protection switching), G.8032 (sub-50ms service restoration), and SPB (shortest path bridging)

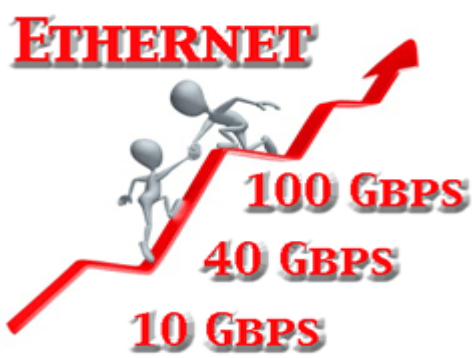


Ethernet Service Scalability

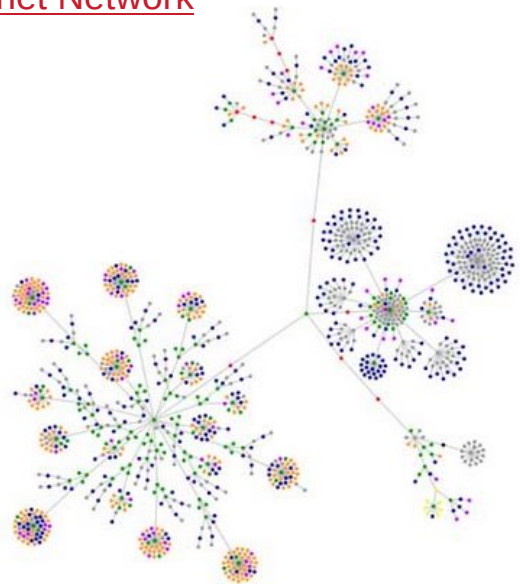
- Ethernet bandwidth capability continues to grow
  - 10M, 100M, 1G, 10G, 40G, 100G and beyond (e.g., 400G, Terabit Ethernet, etc.)

- These enhancements are meeting the scaling demand to sustain and accommodate growth within a Service Providers network
  - The ability for millions to use a network that is ideal for the widest variety of business, information, communications and entertainment applications with voice, video and data
  - Spans access, metro to national & global services over a wide variety of physical infrastructures implemented by a wide range of Service Providers

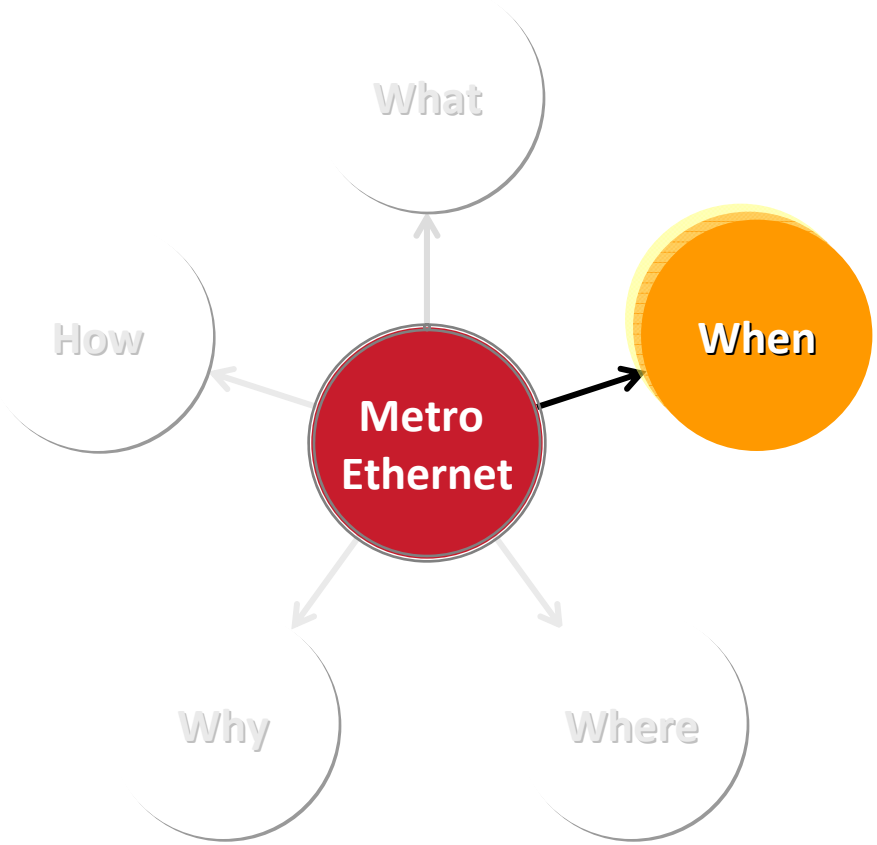
Ethernet Bandwidth Growth



Ethernet Network

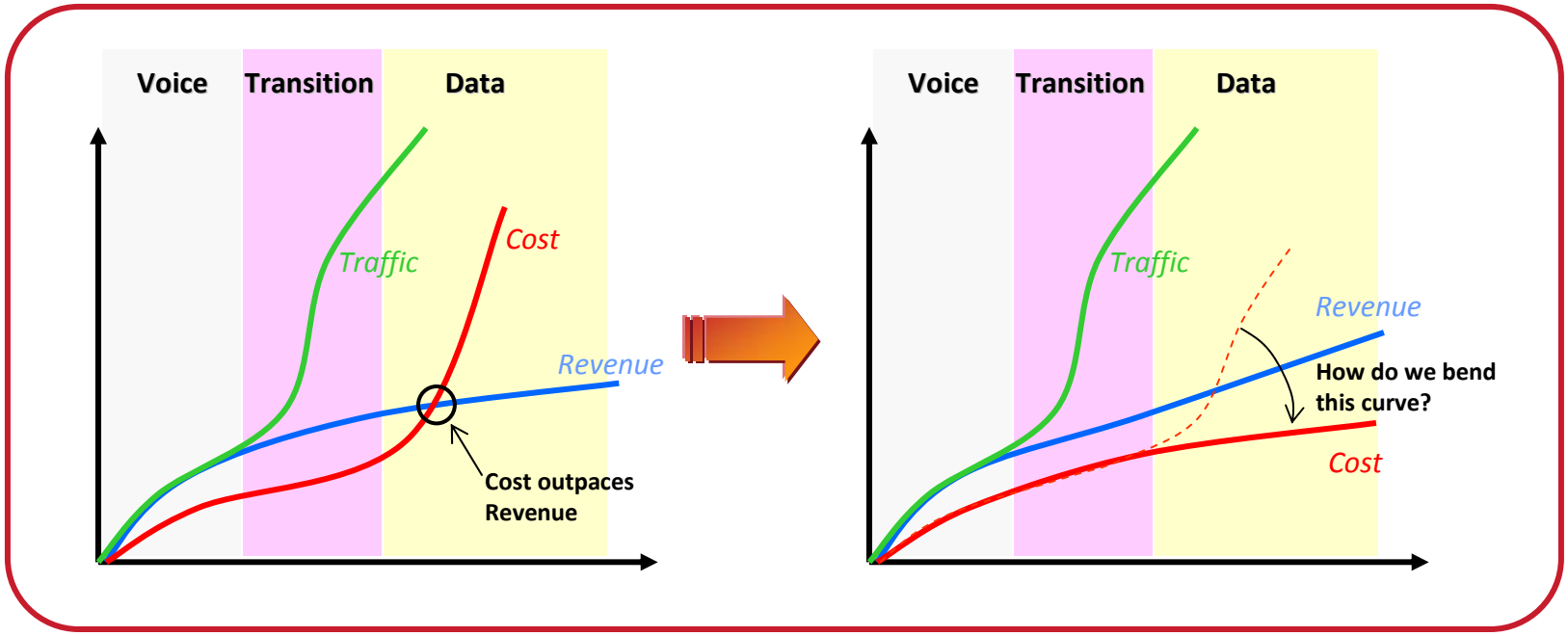


Metro Ethernet - When?



Metro Ethernet – When?

- Now!



- **Metro Ethernet** is a key ingredient to bend the *cost* curve and favorably increase *revenue* opportunities for Internet Service Providers

Thank you