



**Network Architectures for Delivering Metro  
Ethernet, IP Video and Legacy Services**  
Globalcomm 2006



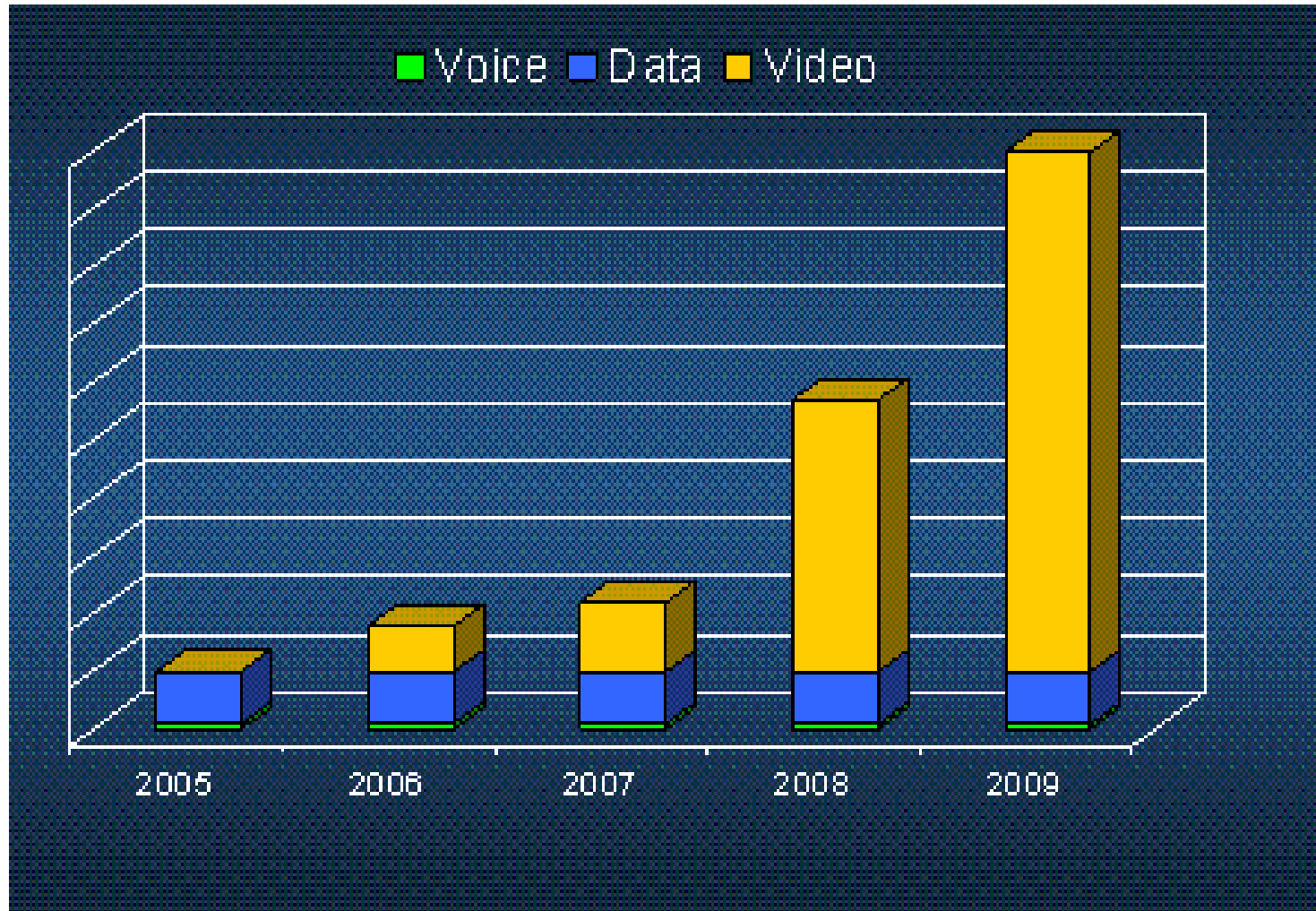
**Rob Schwaber  
Product Marketing  
Manager**



**MUSE Autumn School 2006  
(October 19-20, Bilbao)**

- > Ethernet Services
  - MEF Model: CE, UNI, EVC, MEN
  - Connectivity Services: EPLine, EPLAN, EVPLine, EVPLAN
  
- > Network Architectures and Protocols
  - TDM - SONET/SDH (EoS), PDH (EoPDH)
  - VLAN (Provider Bridging), MAC-in-MAC (Provider Backbone Bridging), MPLS
  - OAM
  
- > Impact of Video/IPTV for network
  
- > Carrying Legacy over Packet, Circuit Emulation

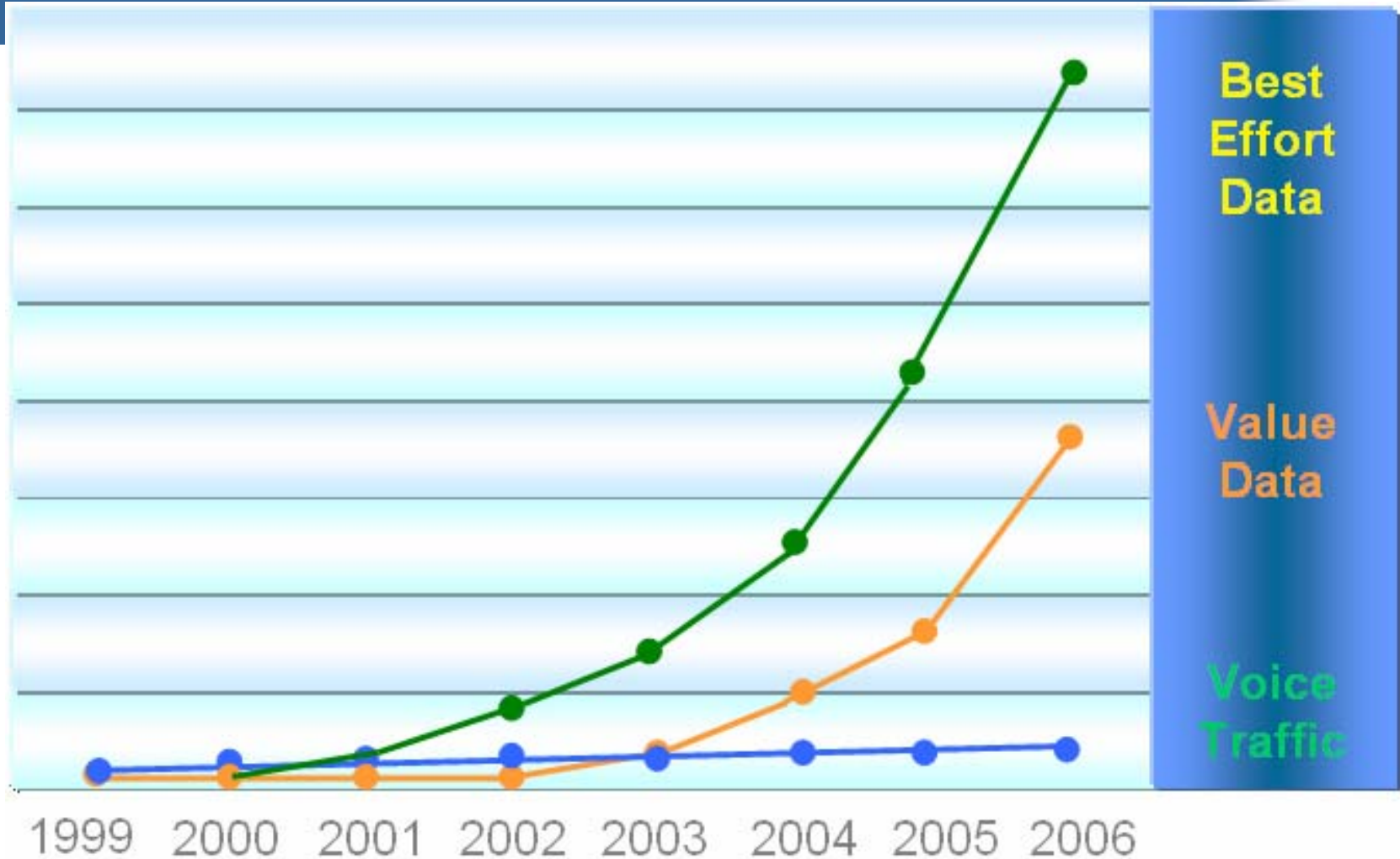
# The Service Mix Is Changing



Source: IPTV Bandwidth Study, March 2006, Bell Labs Research

MUSE Autumn School 2006

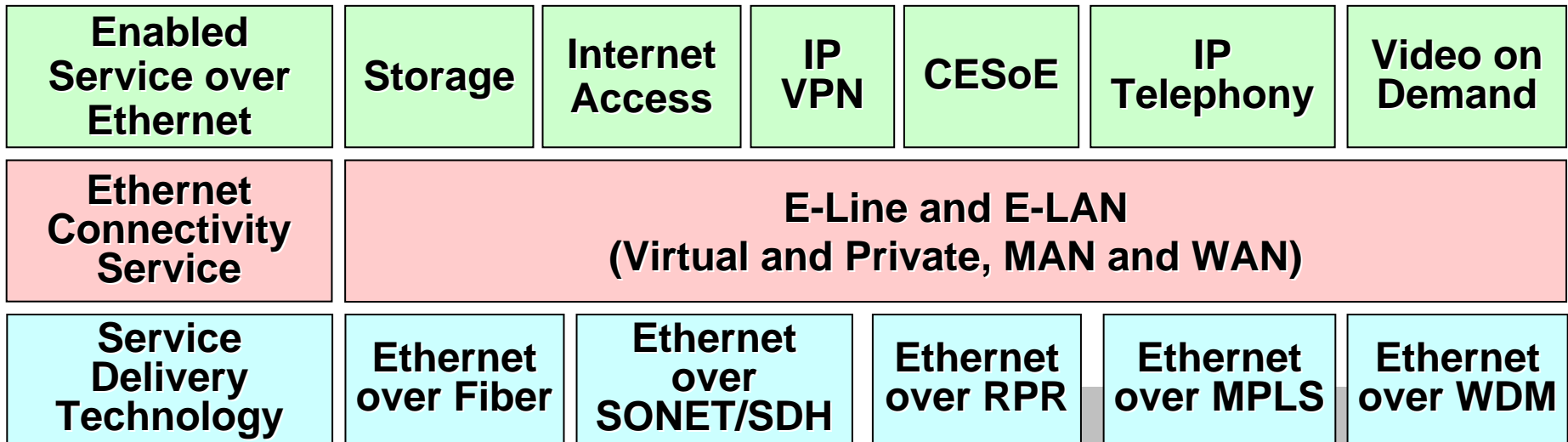
# Data Now Dominates The Network



Merrill Lynch, The Strategy Group, IDC, Vertical, Data Comm, DRW and IDATE March, 2004

MUSE Autumn School 2006

# Ethernet Service Types



Source: Metro Ethernet Forum

# Carrier Survey: Service Rank

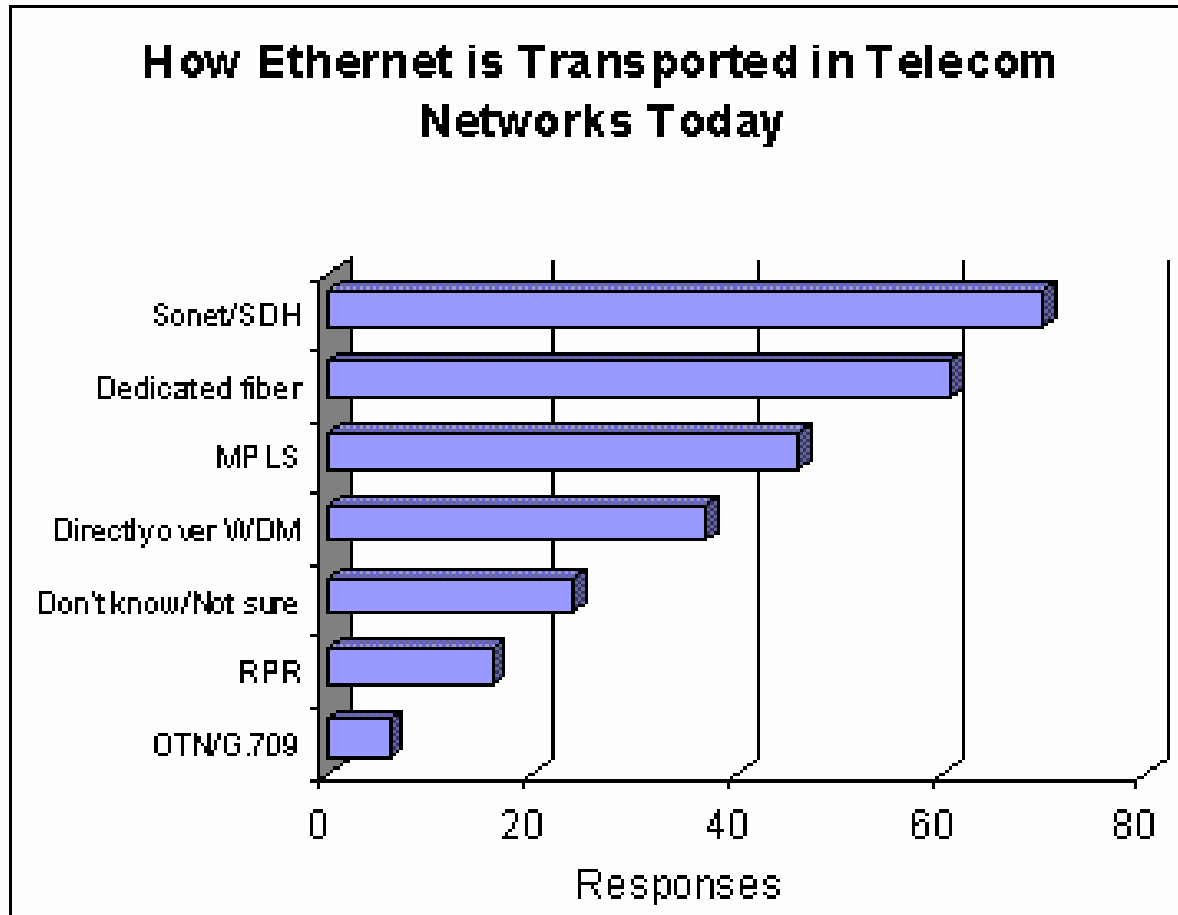


Rank	Transport Service	Score
1	Ethernet Private Line	9.91
2	Mobile Backhaul	9.71
3	Ethernet LAN	9.16
4	FTTx Backhaul	9.08
5	DSLAM Backhaul	8.33
6	TDM Private Line	8.08
7	SAN Transport	6.39



Source: Heavy Reading survey of over 60 network operators worldwide, March 2006

# Multiservice Sonet/SDH Market driven by Ethernet

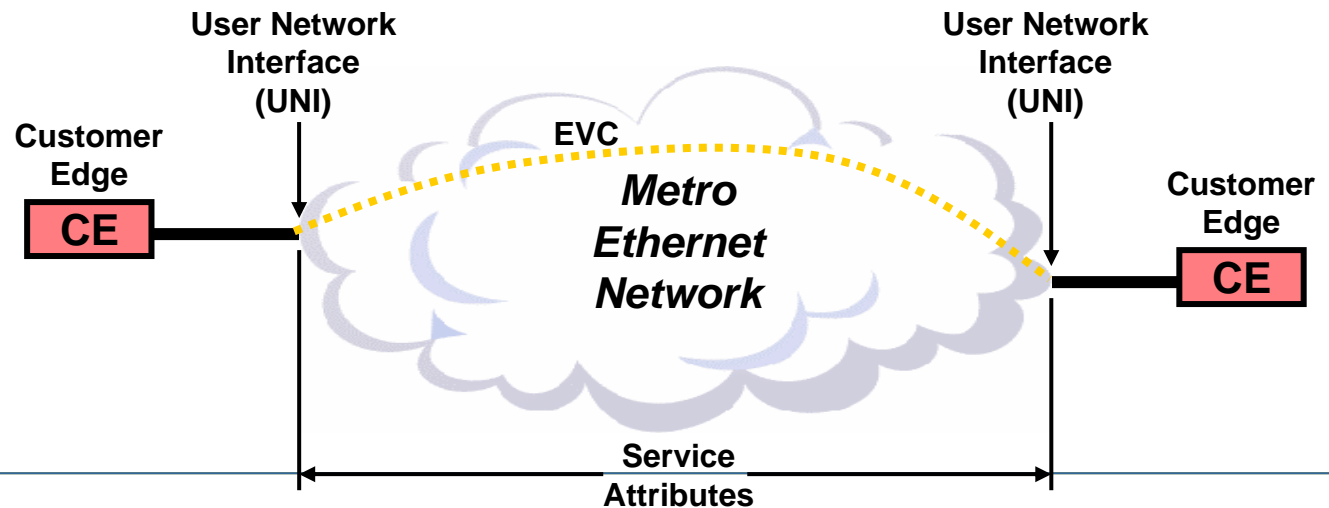


Source: Heavy Reading Survey of 131 Operators Worldwide

# MEF Network Model: Basic Concepts



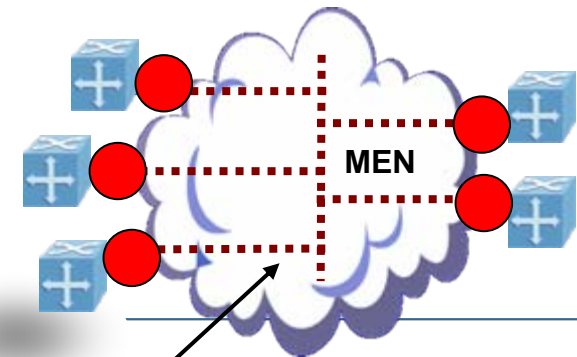
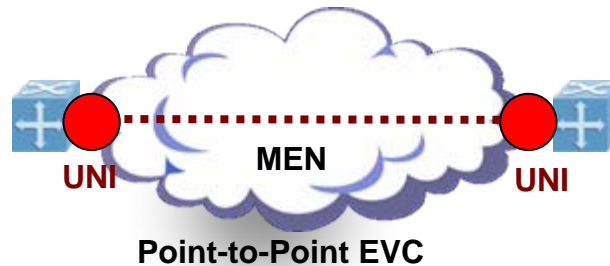
- > CE -- Customer Edge device
  - Enterprise switch (802.1Q bridge) or router
- > UNI -- User Network Interface
  - Supports multiple service classes with different service attributes
- > EVC -- Ethernet Virtual Circuit
  - Instance of association between two or more UNIs
- > MEN -- Metro Ethernet Network
  - May use a variety service delivery technologies



# Ethernet Connectivity Services



	Service (EVC) Type	
Service Identification	E-Line (Point-to-Point)	E-LAN (Multipoint-to-Multipoint)
Private (Dedicated Bandwidth)	EPLine (Private Line Alternative)	EPLAN (Transparent LAN Service)
Virtual (Packet Infrastructure)	EVPLine (Frame Relay Alternative)	EVPLAN (Stat. mux'd TLS)

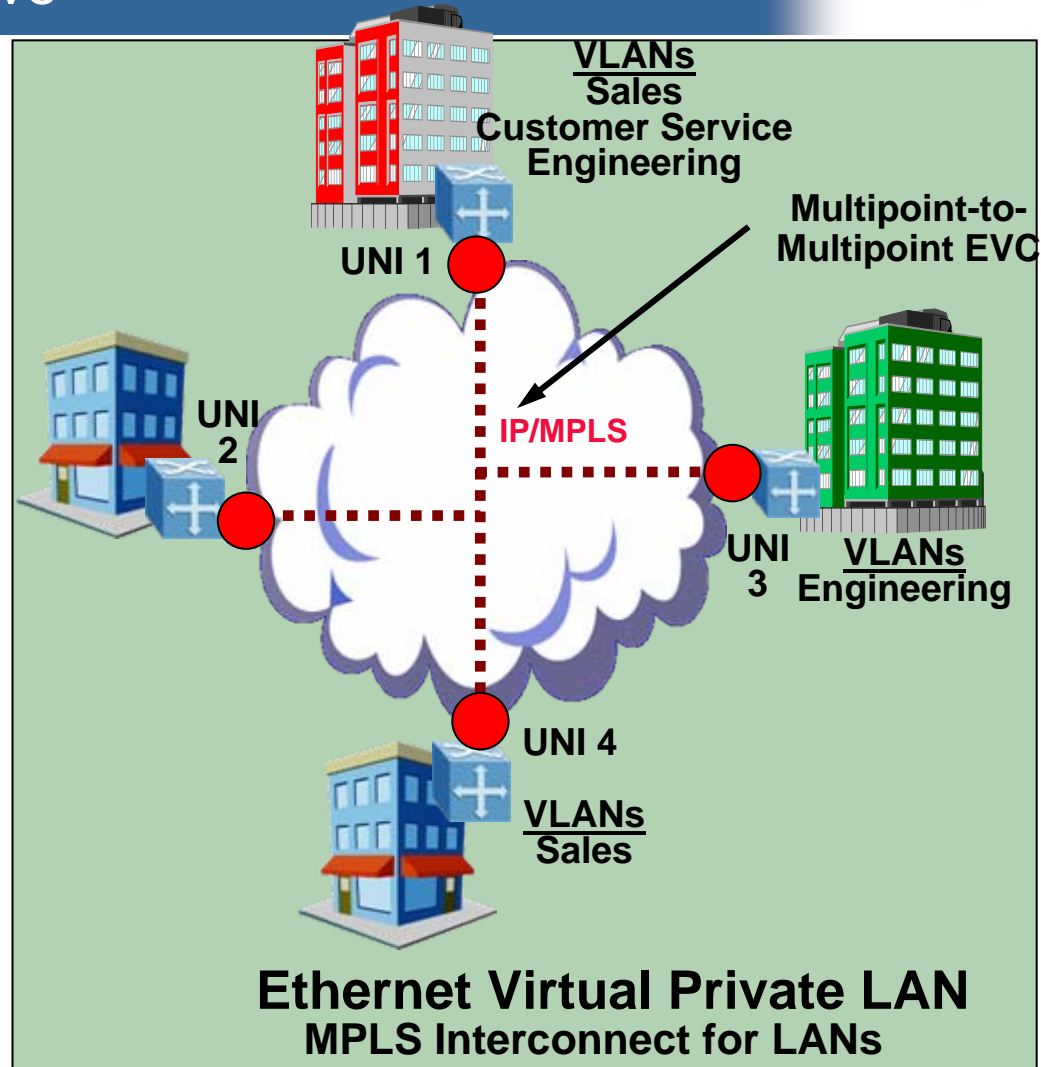


Sources: Metro Ethernet Forum, Light Reading

MUSE Autumn School 2006

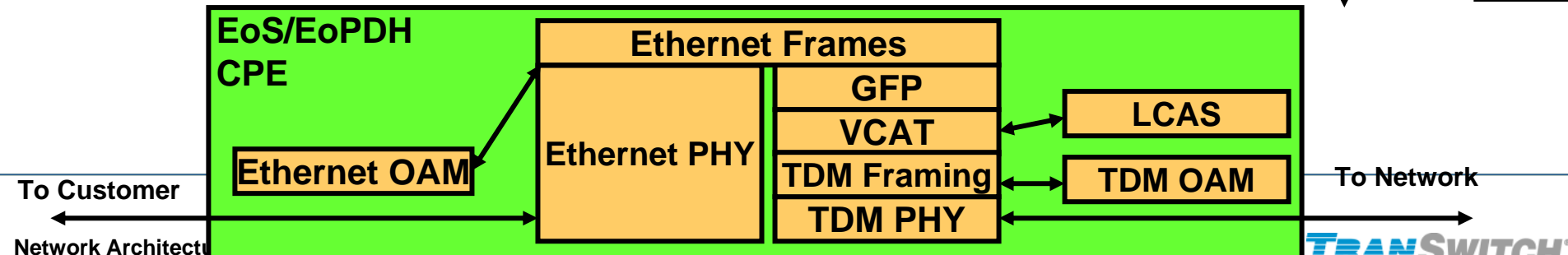
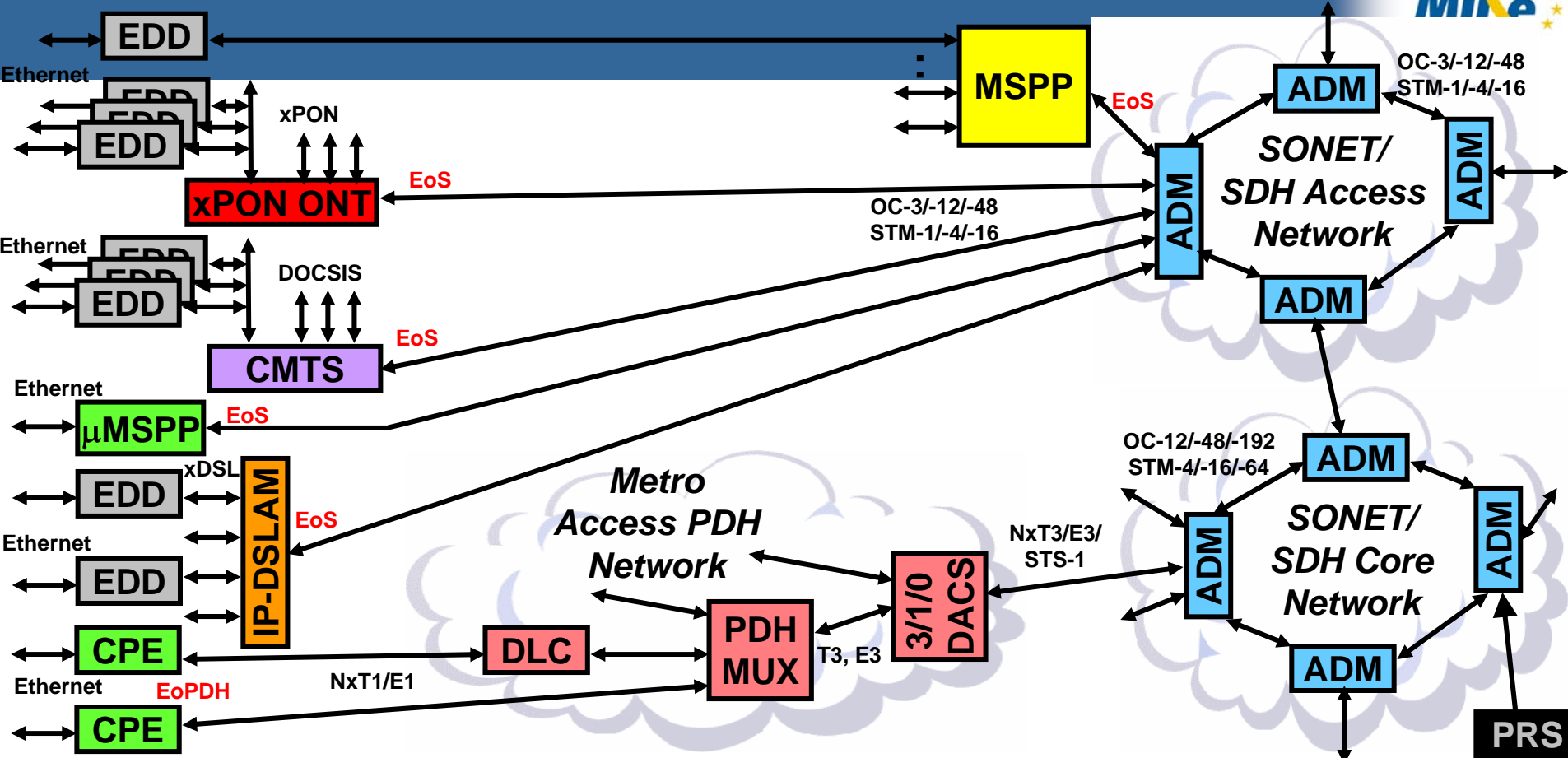
# Ethernet Layer 2 Services: VPLS as a Layer 3 Alternative

- > Multipoint-to-multipoint Layer 2 Ethernet services (VPN) that interconnect many sites as if they were part of a single LAN.
- > Also known as transparent LAN service (TLS) and Ethernet LAN (E-LAN)
- > A premier service providing high bandwidth capacity (greater than T1/E1), multiple QoS levels, scalability and the ability to offer rigorous SLAs.
- > VPLS expands the next-generation VPN service market.

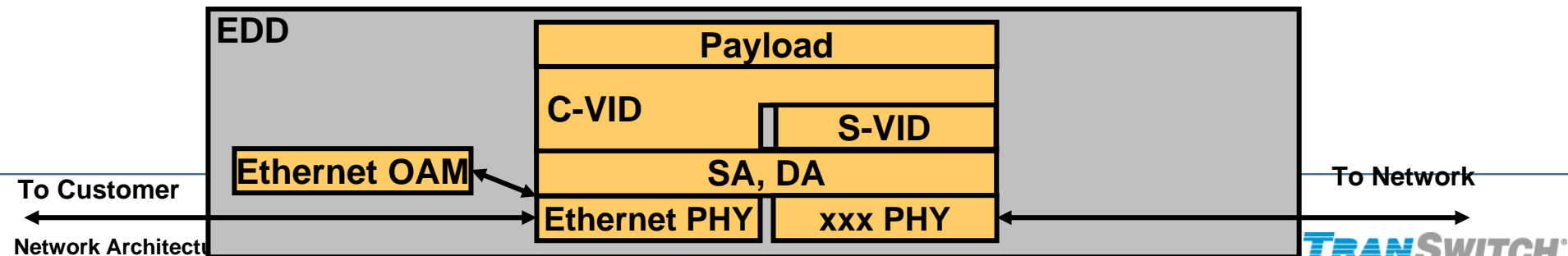
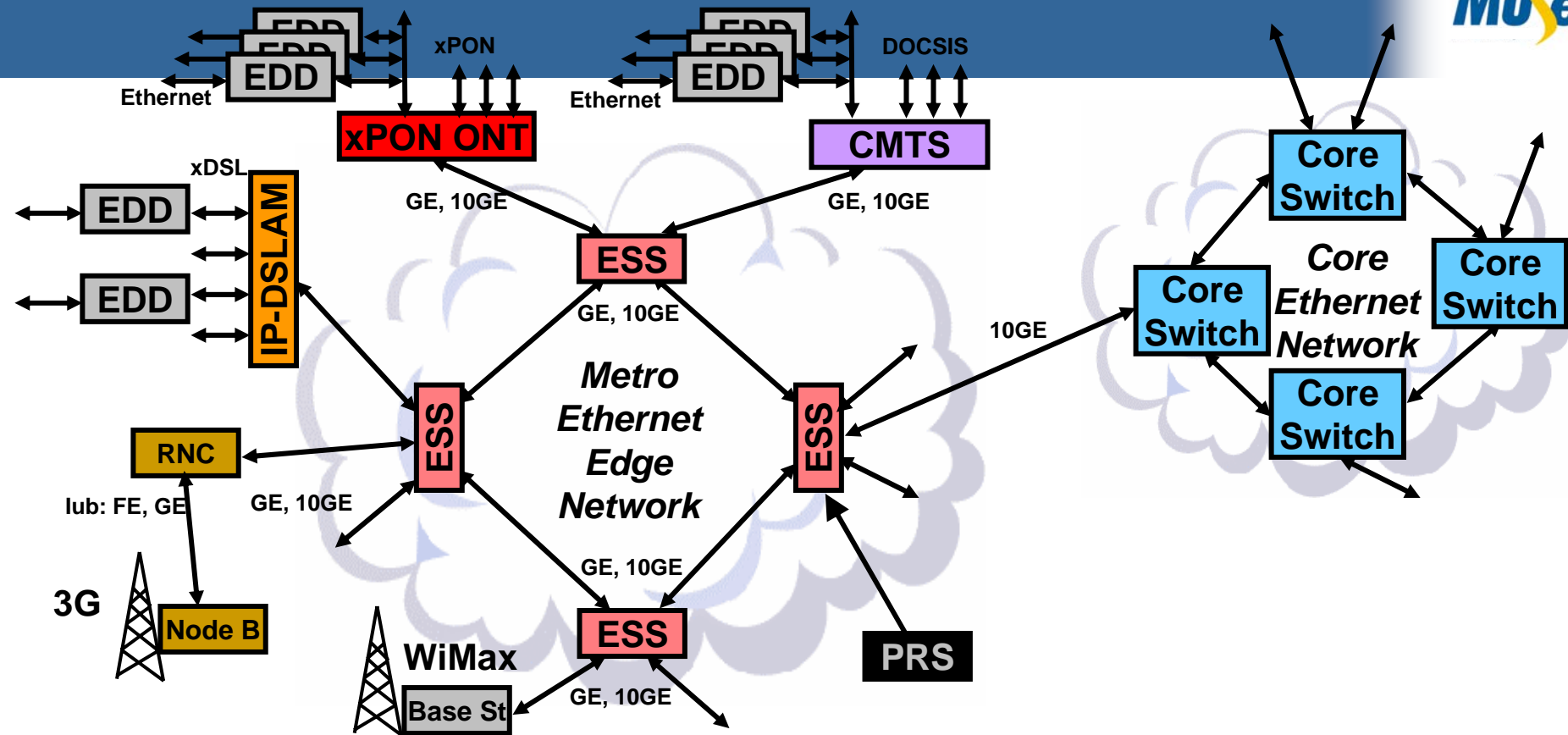


- EVPLINE over MPLS (VPWS)
- EVPLAN over MPLS (VPLS)

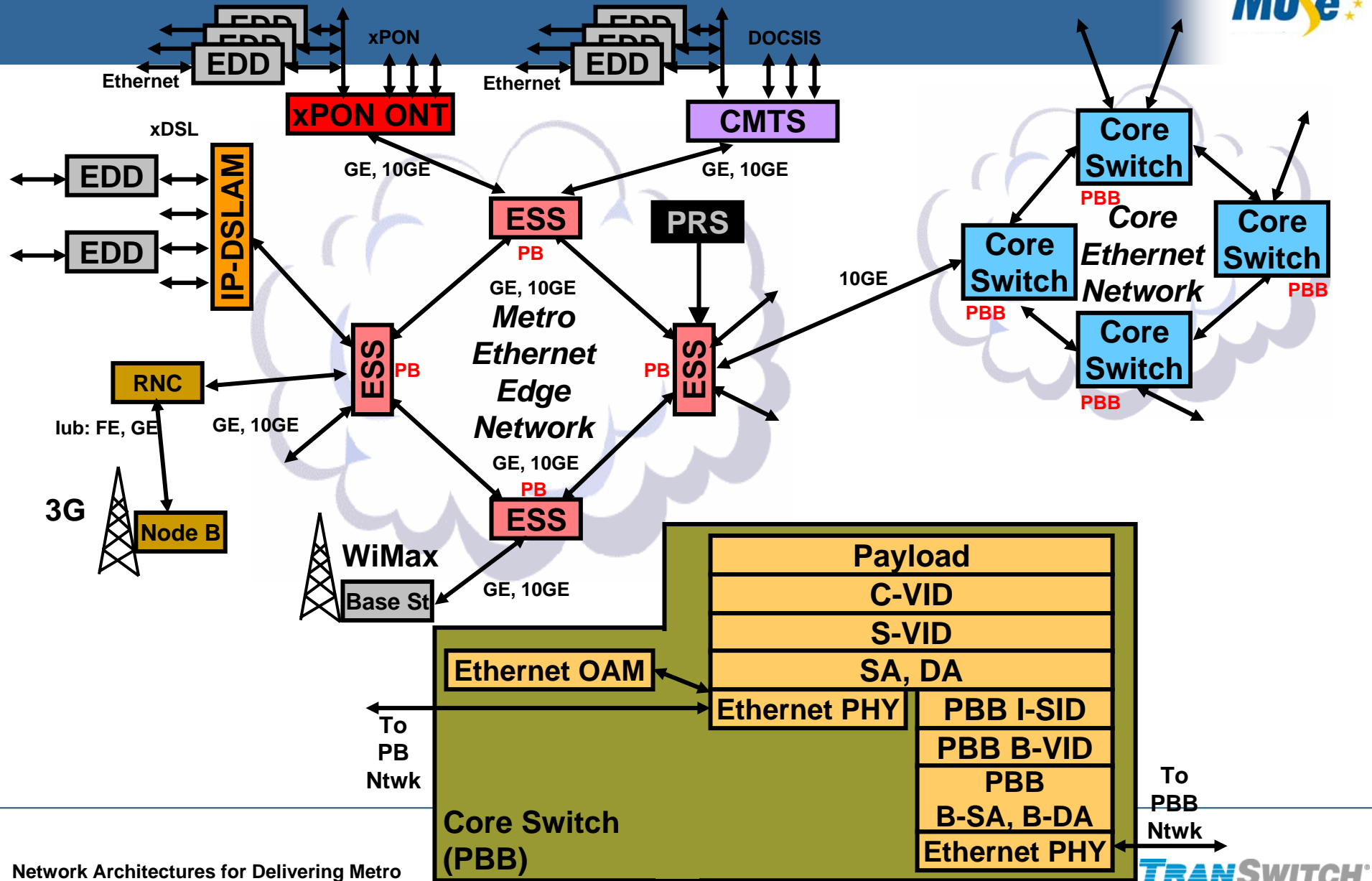
# TDM Architecture and Protocols



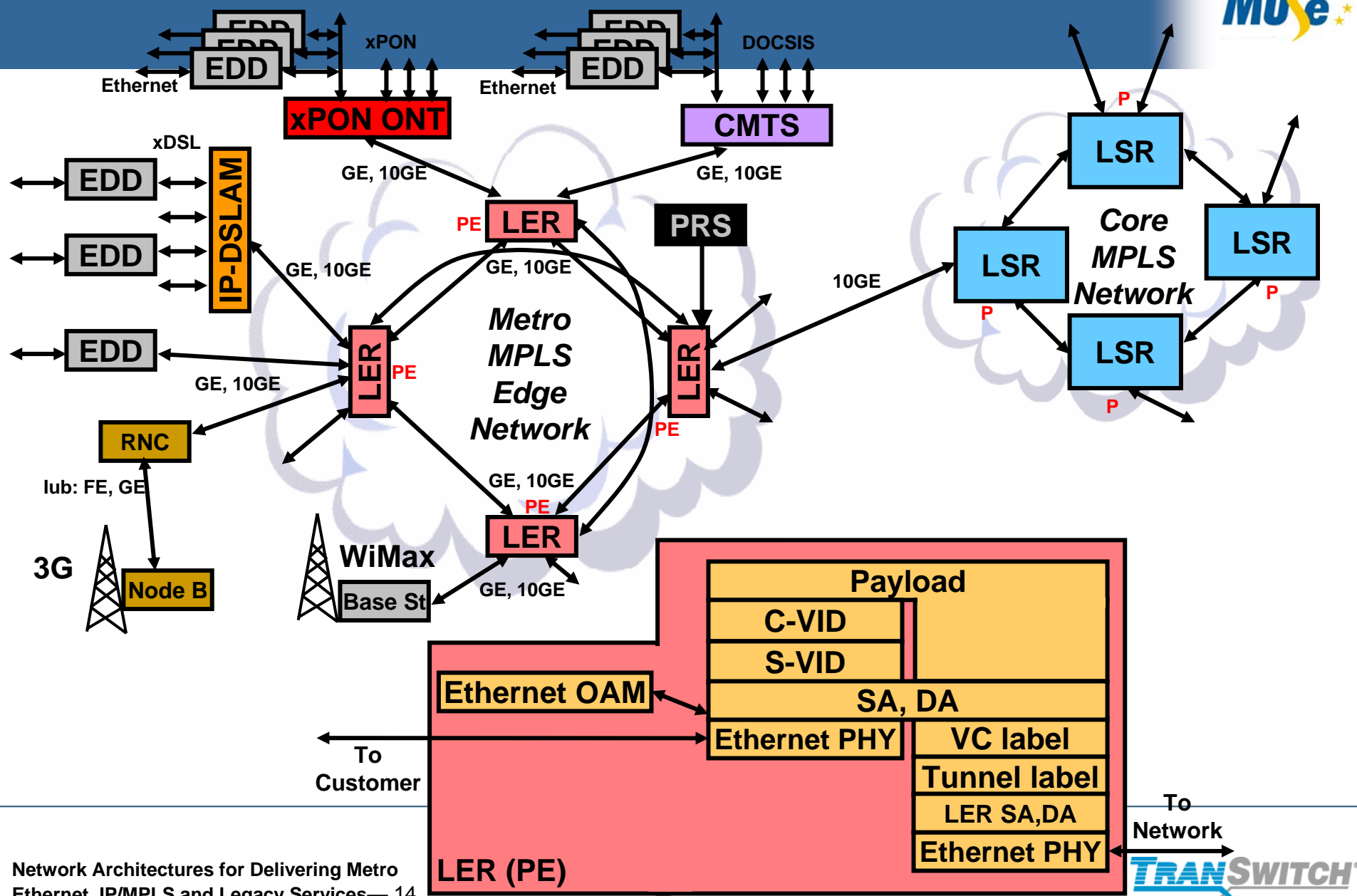
# Q-in-Q (Provider Bridge) Architecture and Protocols



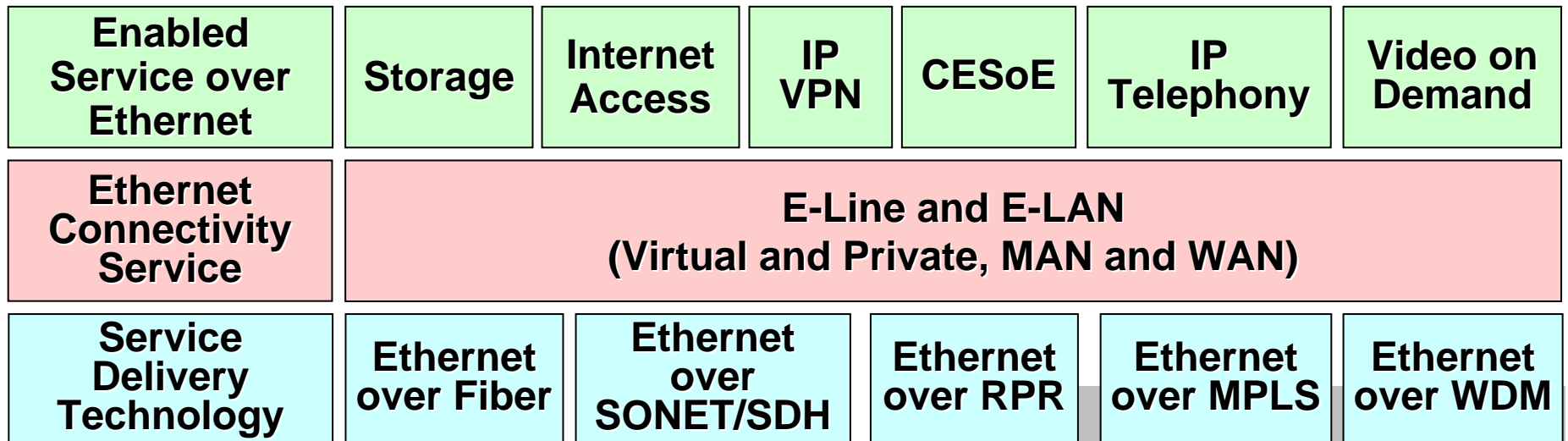
# MAC-in-MAC (Provider Backbone Bridge) Architecture and Protocols



# MPLS Architecture and Protocols

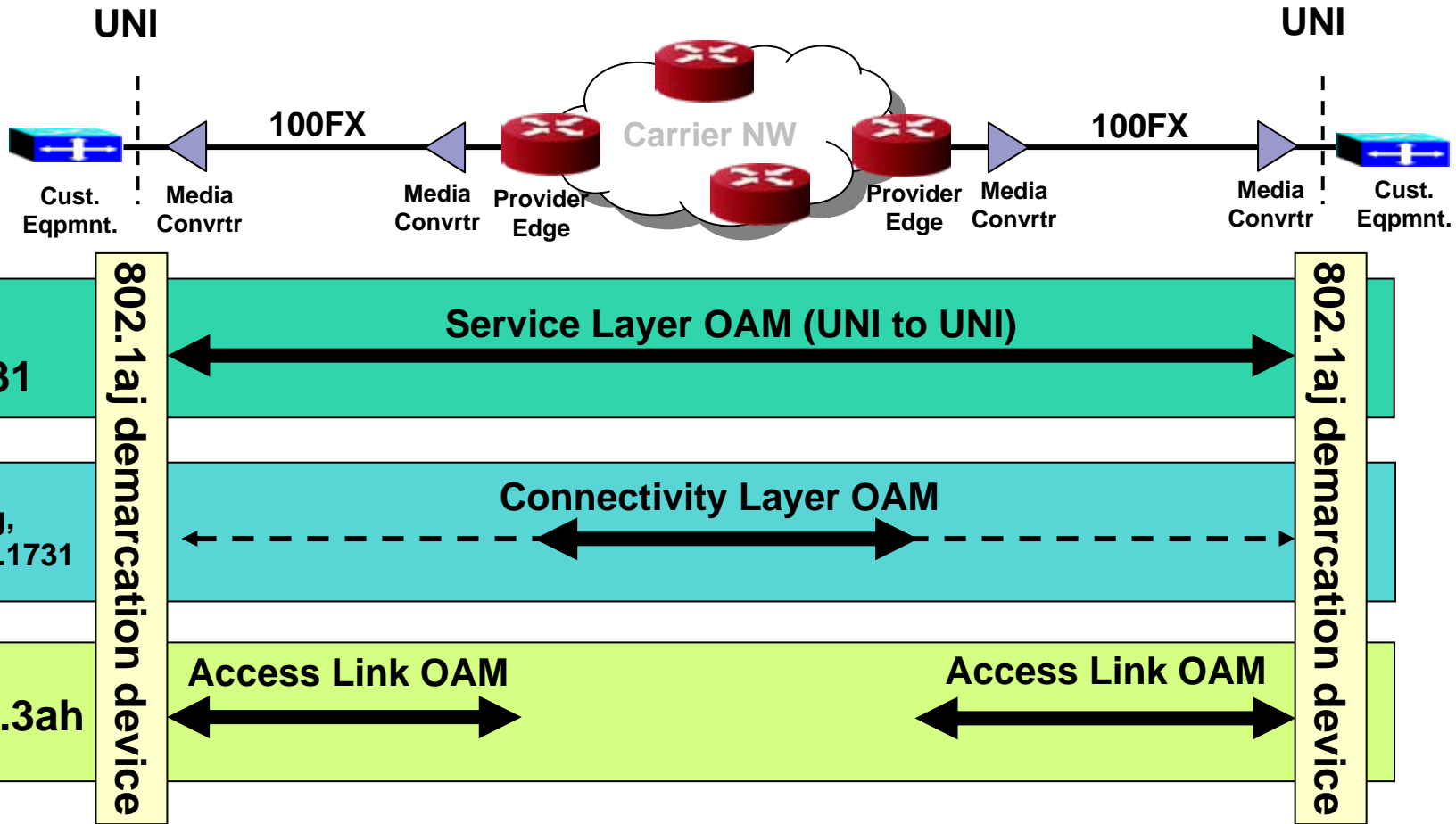


# Ethernet Service Types



Source: Metro Ethernet Forum

# Ethernet OAM Standards



Source: Covaro Networks

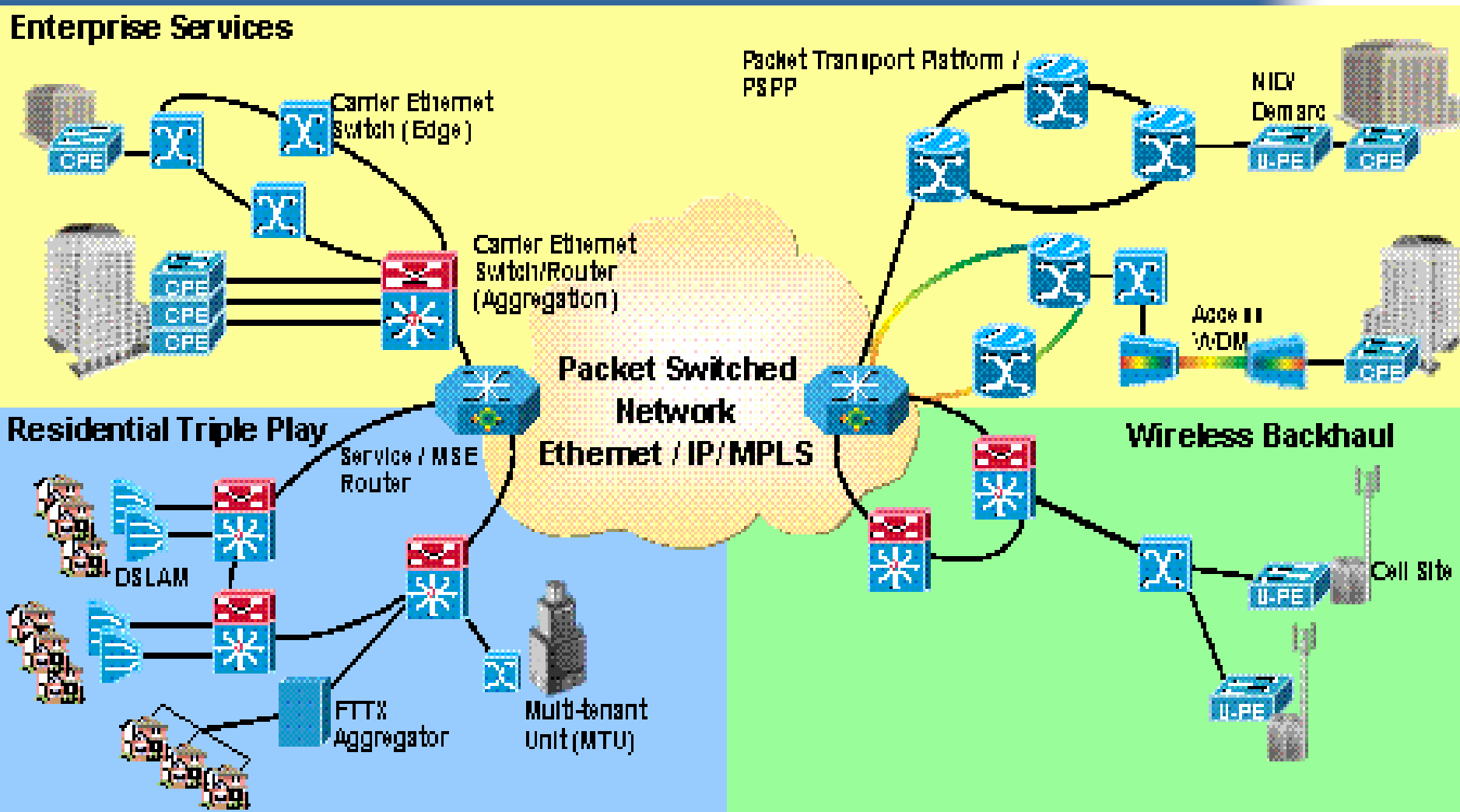
# Ethernet OAM Standards



Services MEF/ITU	Connectivity IEEE 802.1ag, MEF/ITU	Transport/Link 802.3ah (EFM)
Discovery	Discovery	Discovery
Continuity check (keep alive)	Continuity check	Remote failure indication: Dying gasp, link fault & critical event
Loopback (non-intrusive and intrusive)	Loopback	Remote, local loopback
AIS/RDI	AIS	Fault isolation
Traceroute	Traceroute	Performance monitoring with threshold alarms
Performance management		Status monitoring

Source: Covaro Networks

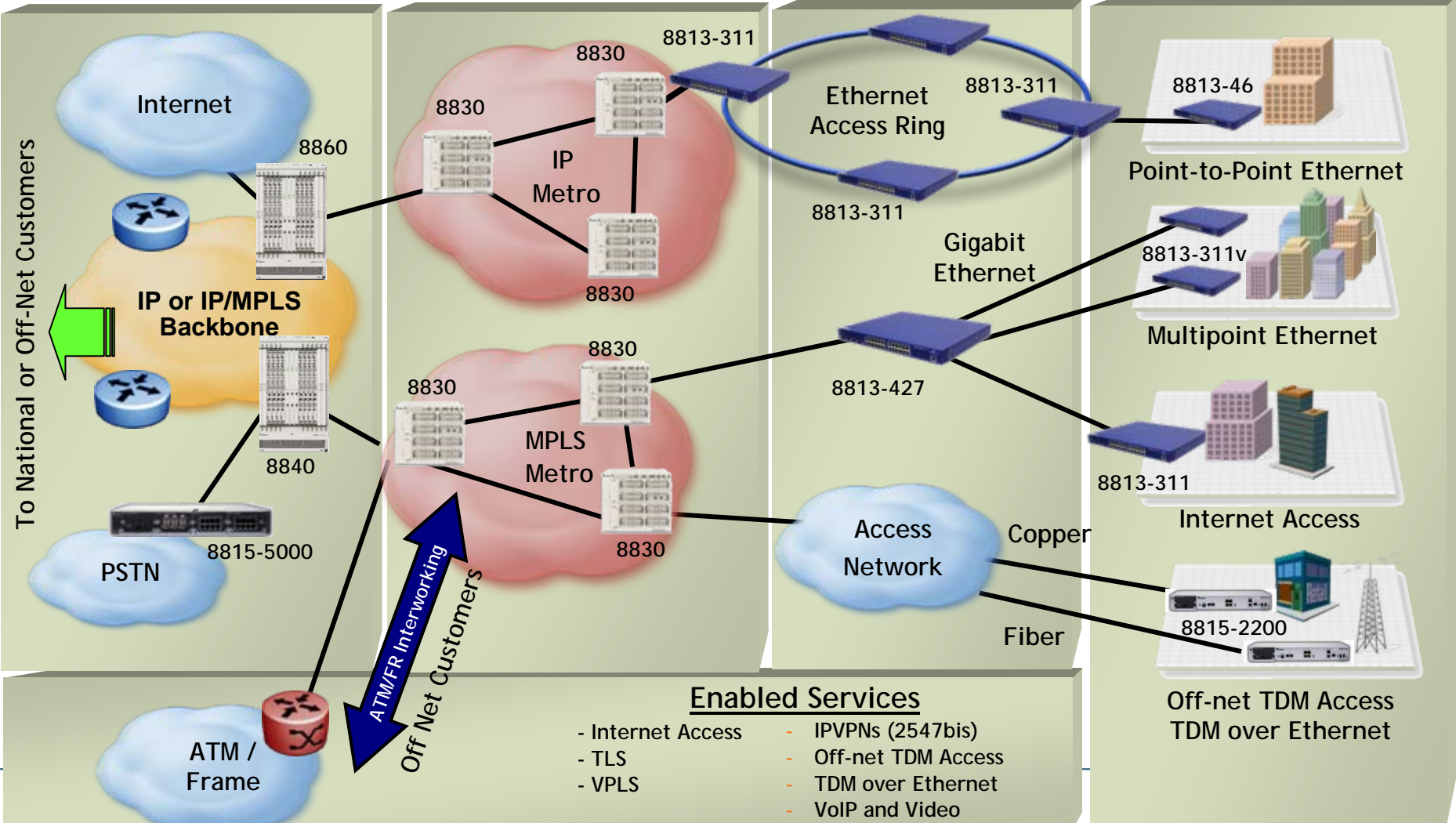
# Transition to Network and Service Convergence



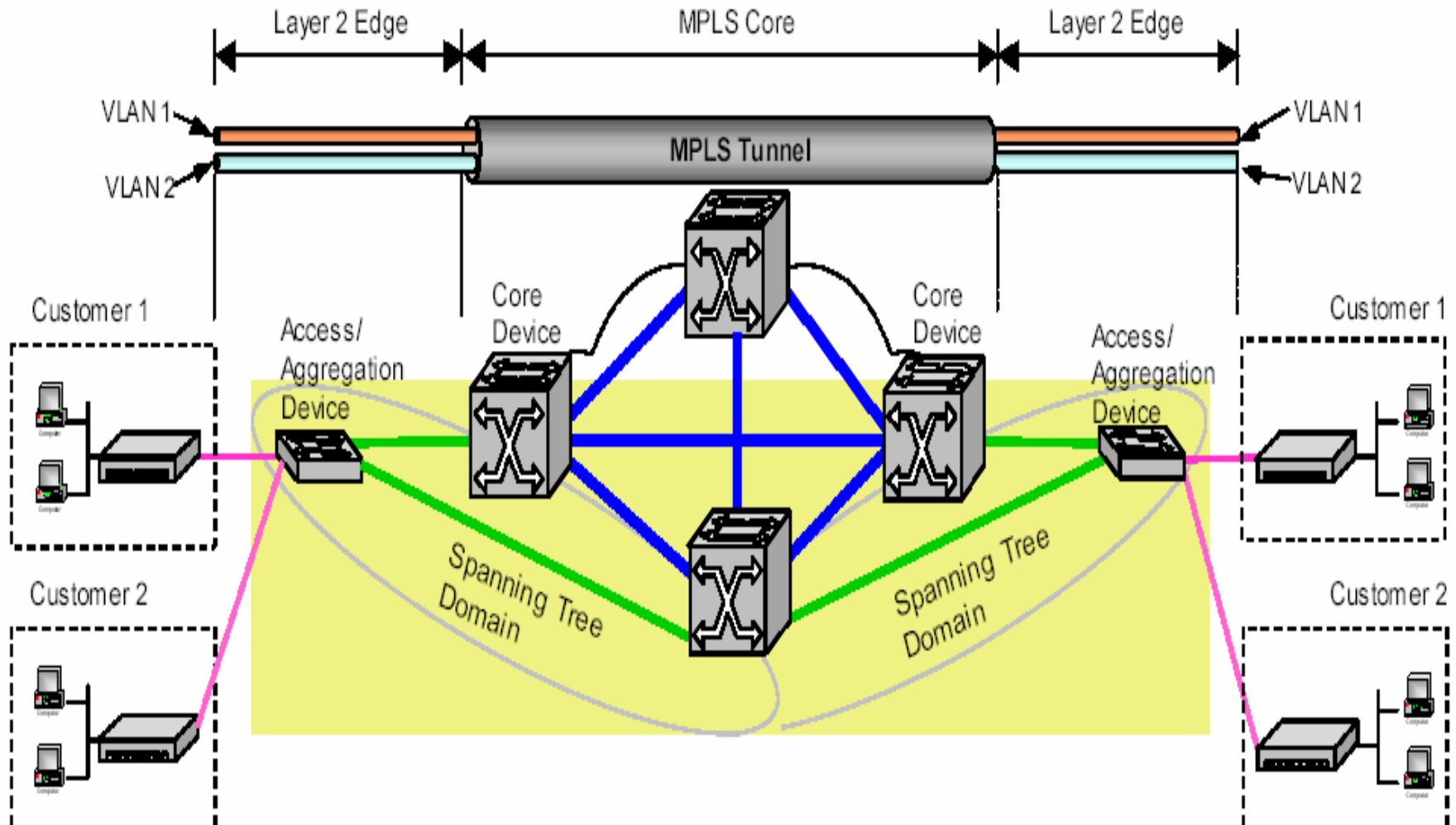


# Example End to End Services Network Architecture

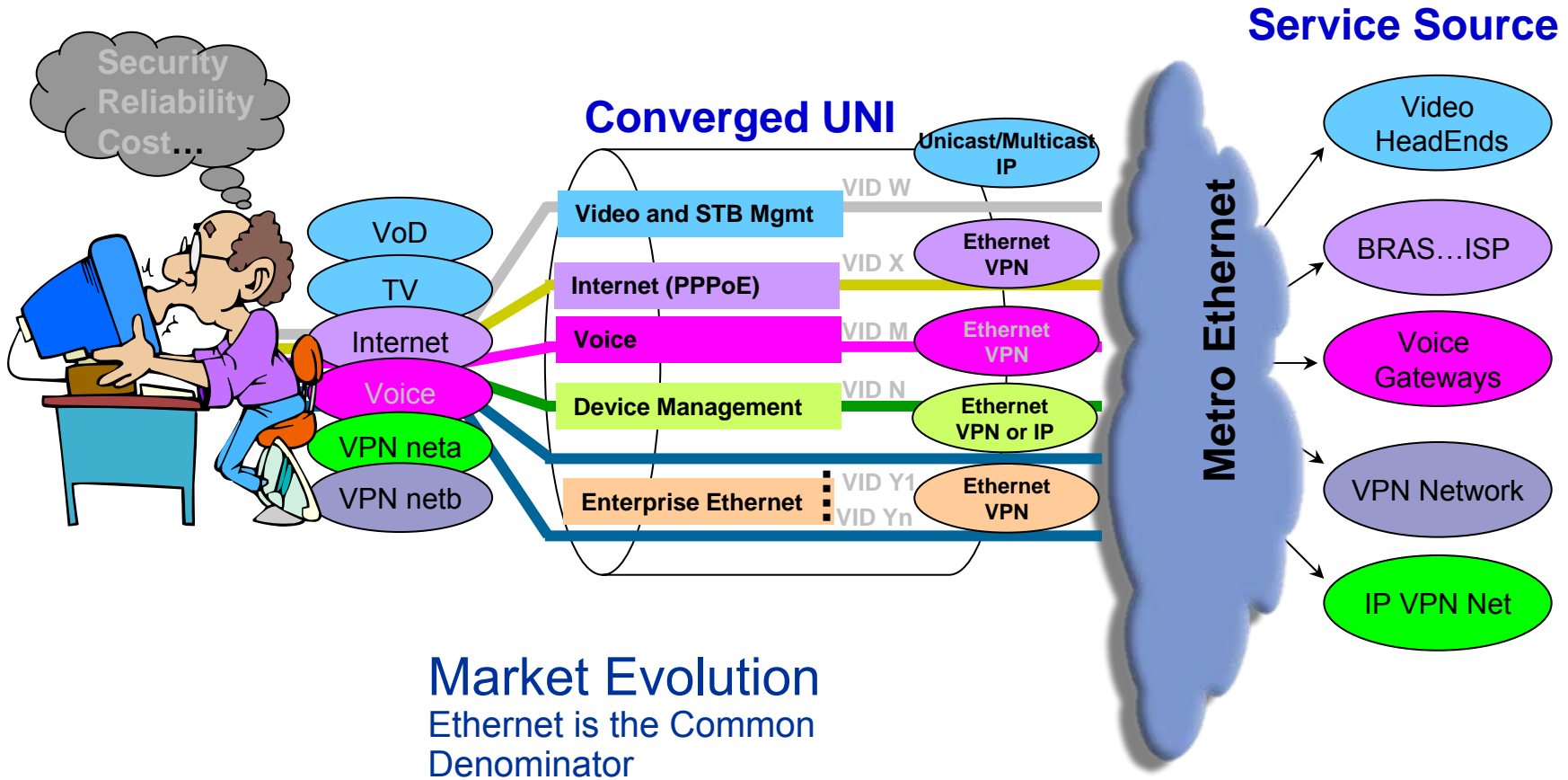
Core                      Aggregation                      Access                      Customer Premises



# Ethernet Aggregation, Service Separation



# Ethernet UNI allows for Triple Play Convergence



# Reasons for shift to Layer 2 VPN (Ethernet, MPLS)-1



- **Facilitates easy migration of MPLS from Core to access network**
- **Rapid service creation and provisioning at Layer 2**
- **L2 gear (interfaces) generally lower cost than Layer 3**
- **Robust Layer 2 service offering capability;**
  - P2P and MP2MP EVCs for L2VPN services
  - Rooted MP EVCs for multicast video distribution
  - Application and L3 protocol transparency
  - Services and subscriber scalability (beyond Layer 3 achievability)
- **EVC's & PWE3, multiple services over a single port**
- **Virtual switching (PB), faster, cheaper than L3 routing (no extensive longest exact match look ups required)**

# Reasons for shift to Layer 2 VPN (Ethernet, MPLS)-2



- **MPLS tunnels to carry multiple EVC's, more efficient to provision and manage bundles**
- **Capability for E-LAN using VPLS (mpt-mpt)**
- **H-VPLS (Hierarchical); allows for larger scale mesh, reduce signaling overhead and reduces routing updates**
- **Better service aggregation capability of IP at Layer 2 (without adding router hops...)**
- **Improved resiliency, faster convergence, split domains for RSTP/MSTP**
- **Protocols & mechanisms exist to avoid previous limitations;**
  - **#CE-VLAN's in WAN (.1Q),**
  - **# services/users,**
  - **# MAC addresses,**
  - **better segmentation of RSTP domains (PBB)**
  - **mechanisms for QoS/CoS and guaranteed SLA's end to end**

# Forces Driving Carriers to Support IPTV



- Intense service provider **competition** (Telcos vs MSOs)
- Creation of “**Customer Stickiness**” through triple play bundling
- IP Video represents significant increase in **per service revenue for Telco’s**
- **Recent Video over Internet announcements/offerings:** Google-YouTube, Yahoo, AOL, Apple, Disney, Starz, NBC, News Publishers, NBA, Major League Baseball, CinemaNow, MovieLink....
- New **internet video** emerging as a parallel **HUGE** source of new content



ool 20



# IP Video Services



- > Broadcast Video (BTV)
  - **National and regional/local broadcast channels**
  - **Multicast: bandwidth consumed depends on number of channels**
  - **Combination of SD and HD content, moving to HD over time.**
  
- > Video on Demand (VOD), Stored Video
  - **Network-stored, subscription-based, typically 10%-20% peak utilization**
  - **Unicast: per viewer channel, very high utilization**
  - **PVR; network-based PVR. with FF, RW, Stop, and Pause options**
  
- > IPTV Integrated Communication
  - **Integrated telephony services: incoming call notification, caller ID, call logging**
  - **Voice/videoconferencing**
  - **Integrated Internet services: TV Web browsing, instant messaging, email**
  
- > IPTV Gaming
  - **Single-user and multi-user gaming**
  - **TV-based gambling, karaoke, etc.**
  
- > IPTV Advertising
  - **Traditional broadcast ads, local ad insertion; two-way subscriber feedback**
  - **Integrated with telecommerce for purchase on demand**

# QoS: IPTV Video Traffic Stream Characteristics



- **Asymmetric bandwidth, flows are uni-directional except for control signaling (IGMP/PIM, RTSP)**
- **Broadcast video: one channel = one IP Multicast group**
- **Delay when switching between channels (multicast groups) mostly due to MPEG**
- **Ratio of *I*, *P* and *B* pictures (frames) in MPEG stream (GOP) is determined by the nature of the video stream**
- **Delay due to short I-frame gap or high proportion of I-frames in GOP (I-frame is reference picture in MPEG-2 protocol)**
- **IP multicast: latency for leave/join of channel groups is usually kept very low**



# QoS: IPTV Video Traffic Stream Characteristics



- Video has variable bit rate by nature and needs high bandwidth
- Sustained throughput orders of magnitude greater than data or VOIP
- Packet-layer IP Video streams hard to shape
- Frame loss: Dropping packets affects quality because each frame is highly compressed and STB cannot compensate
- Video call admission control (CAC) can cause denied session requests
- Timing between packets is crucial; jitter compensation is important (STB's ~150ms)
  - Needs to be corrected at receiver to ensure continuous video play-out
- Availability: one lost multicast source means hundreds of thousands of outages
  - Need rapid failover and redundant sources
- QoS is extremely important when assessing an IPTV architecture
- Video over IP streams are sensitive to packet loss

# Network Bandwidth Requirements IPTV

Many agree the key to IPTV success lies in VoD and interactive services like education, games and shopping, rather than merely another outlet for regular broadcasts.

Telecommunications magazine May 2006

Number of channels	Standard TV MPEG-2 4Mb	HDTV MPEG-2 20Mb	HDTV MPEG-4 12Mb
100	400Mbps	2Gbs	1.2Gbs
200	800Mbps	4Gbs	2.4Gbs
300	1.2Gbs	6Gs	3.6Gbs
500	2Gbs	10Gbs	6Gbs

# Network Bandwidth Requirements IPTV



## VOD: Unicast

**Bandwidth required in the aggregation and distribution networks to carry on-demand streams is much greater than what is required for broadcast services and scales with the number of subscribers. Peak utilization rates have large impact on network. Availability (redundancy) may be compromised**

**Example: MPEG-2 compressed standard-definition content to 50,000 on-demand subscribers at a 10% peak take rate requires about 19 Gbps of capacity.**

## BTV: Multicast

**Amount of bandwidth required in the access/distribution networks scales with the number of channels. Must have high availability (redundant transport paths).**

**Example: Broadcast TV that uses MPEG-2 for 300 channels of standard-definition content requires more than 1 Gbps of capacity in the distribution network to handle worst-case usage patterns.**

# High Speed Internet (HSI) and Video Services Differences



## IP Video

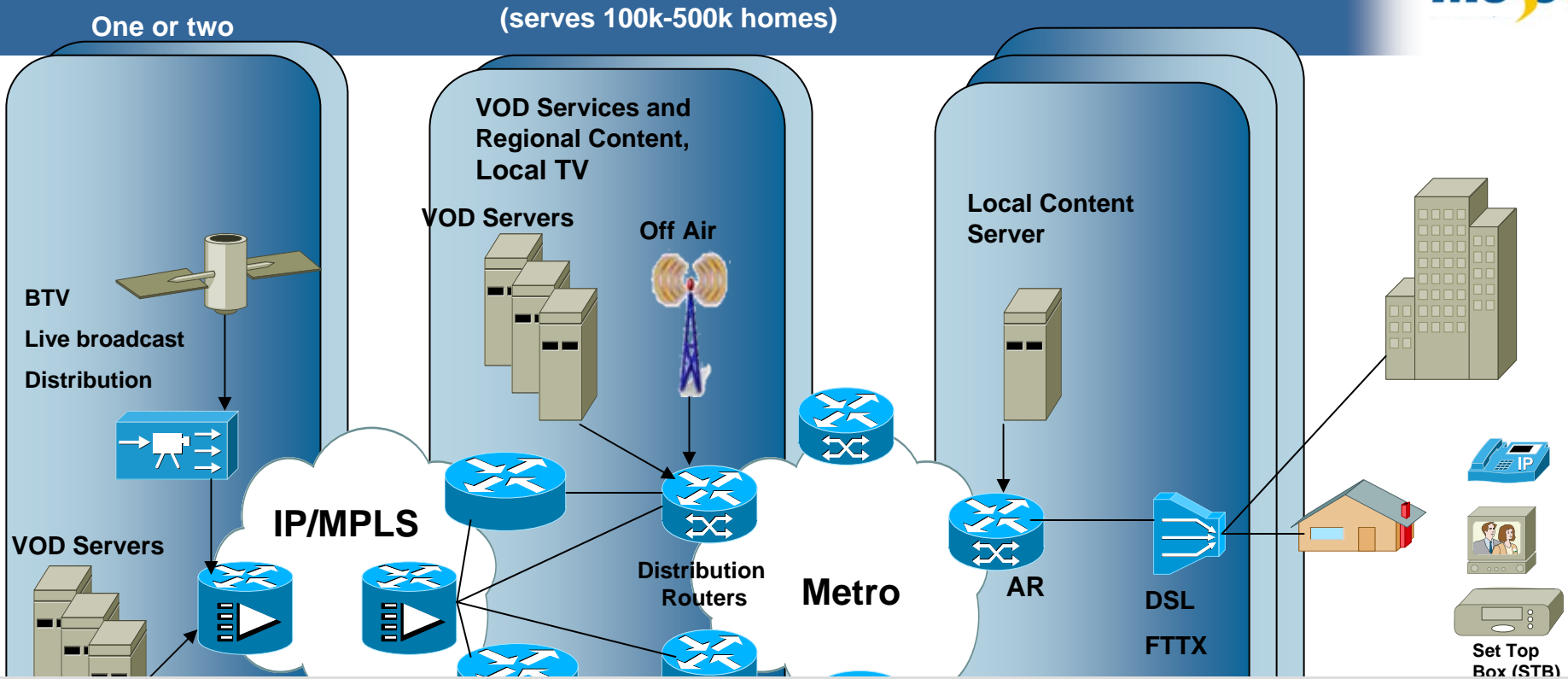
1. Application hosted by service provider (Telco)
2. Measurement: QoE - Quality of Experience (not parameter based) on a per service basis
3. Cannot shape easily, drops severely affect application, TCP cannot fully compensate for encoding
4. Application guarantees, must support difficult Broadcast and unicast requirements & video CAC
5. QoS same for all classes of users, Quality may differ with tiered service, SD & HD
6. Transport SLA is transparent and lies underneath application QoE, end users don't care
7. Authenticated by application-aware middleware as part of EPG & DRM (Microsoft TV IPTV)



## HSI

1. Application hosted by third party, not service provider
2. Measurement: SLA enforcement per BP's (CIR/PIR/EIR, latency, jitter, loss) on a per subscriber basis
3. Traffic can be shaped over CIR, drops tolerated, leverage TCP back-pressure servers
4. Residential HSI: Best Effort, no application guarantees, Business VPN: SLA's (for PIR/CIR, jitter, delay and loss), but no application guarantees
5. QoS is dynamic and different per subscriber (BoD), use shaping
6. Transport SLA must be enforced per subscriber
7. Authenticated by Network (PPPoE, 802.1x) not application

# Basic IP Video Architecture



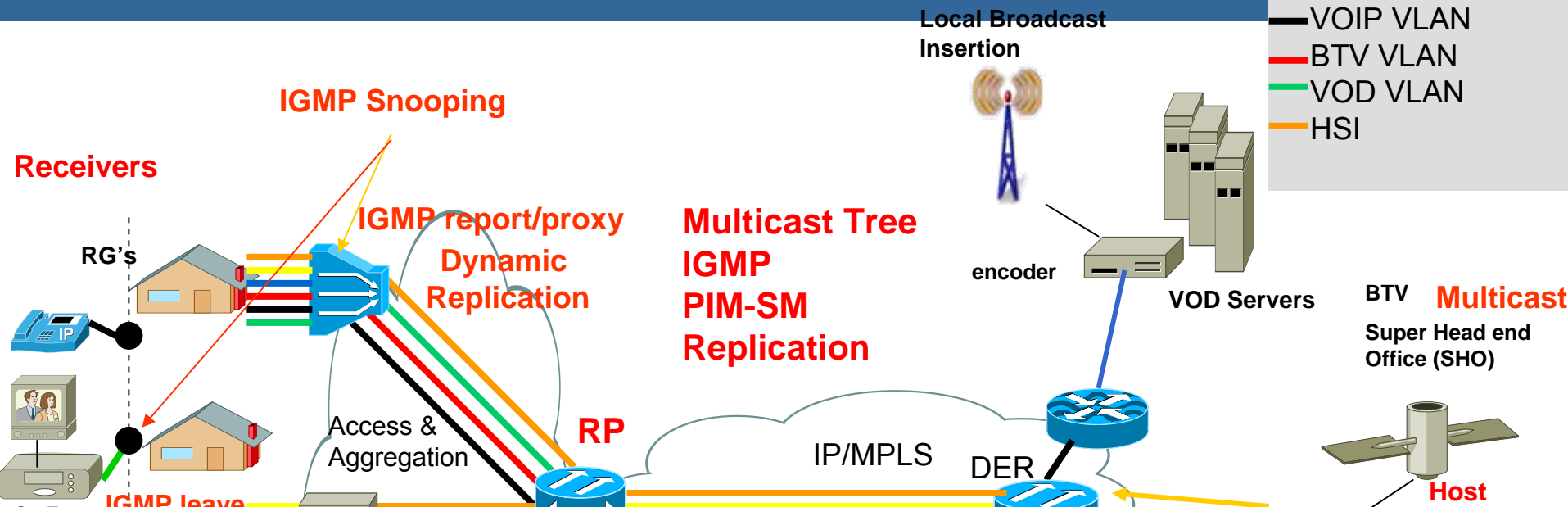
**Optimal designs use Layer 3 in the aggregation router, places IP multicast capabilities in the aggregation layer. Provides many advantages for service providers.**

- Local content insertion: more easily change video source
- Containment of MAC address scaling (from Distribution/Core)
- Reduces wasted replication bandwidth that layer 2 aggregation would spawn

# Transport Networks Using Multicast



- SIP session setup
- VOIP VLAN
- BTV VLAN
- VOD VLAN
- HSI



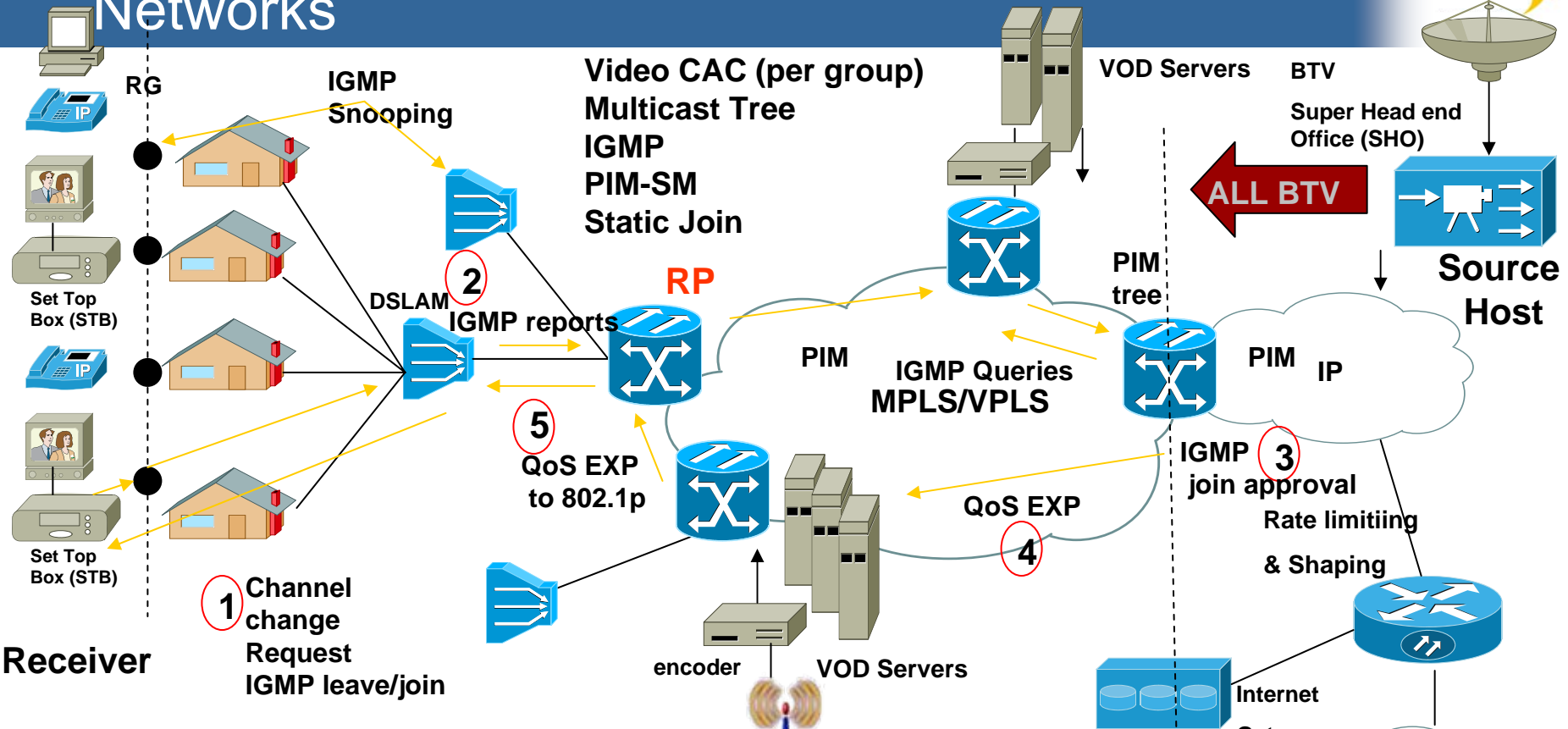
**IGMP runs at Layer 3 and is used by IP hosts and multicast routers to establish multicast group memberships. Multicast routers send Host Membership Queries to discover which host groups have members, Hosts respond to a Query by generating Host Membership Reports**

**IGMP Snooping: method by which Layer 2 devices (Switch/DSLAM..) can “listen in” on Layer 3 IGMP conversations between hosts and routers for group join/leave messages. This reduces signaling overhead and flooding from hosts.**

**PIM protocol runs between routers building multicast shared trees rooted per group at an RP (Rendezvous Point). PIM-SM generally scales fairly well for wide-area. PIM Snooping also reduces overhead in messaging between nodes.**

Source G1  
icast  
rvers  
ITCH

# Flexibility in Handling IPTV Broadcasts in Networks



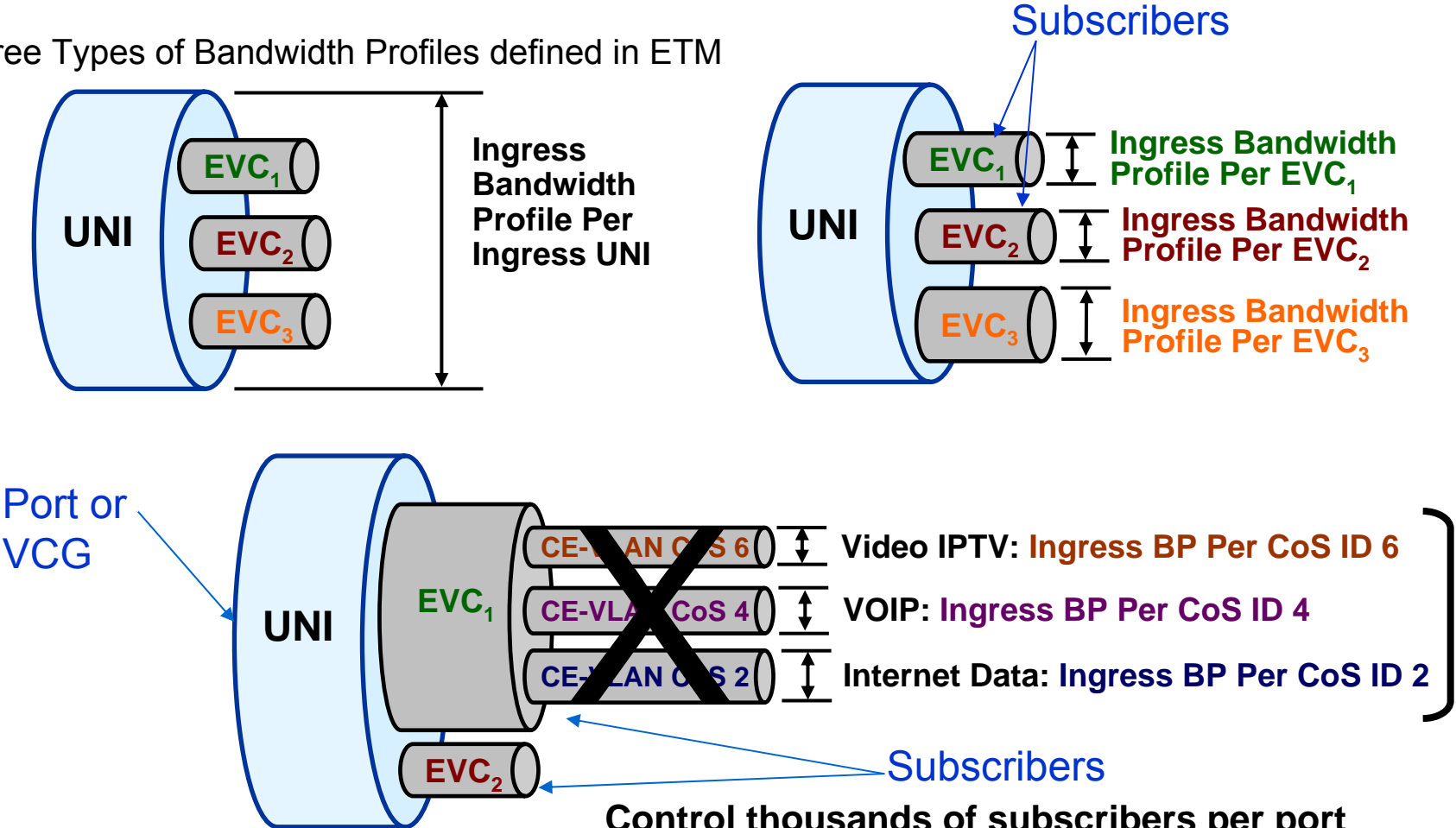
**Join Latency-**The time it takes for data to begin flowing after an application issues a command to join a multicast group  
**Leave Latency-**The time it takes for data to stop flowing after an application issues a command to leave a multicast group

**Static Join:** much reduced latency for channel change signaling or replication, high bandwidth, need statistical analysis for #channels, # subscriber & channel frequency

# IPTV Challenges: Hierarchical QoS w/Bandwidth Profiles

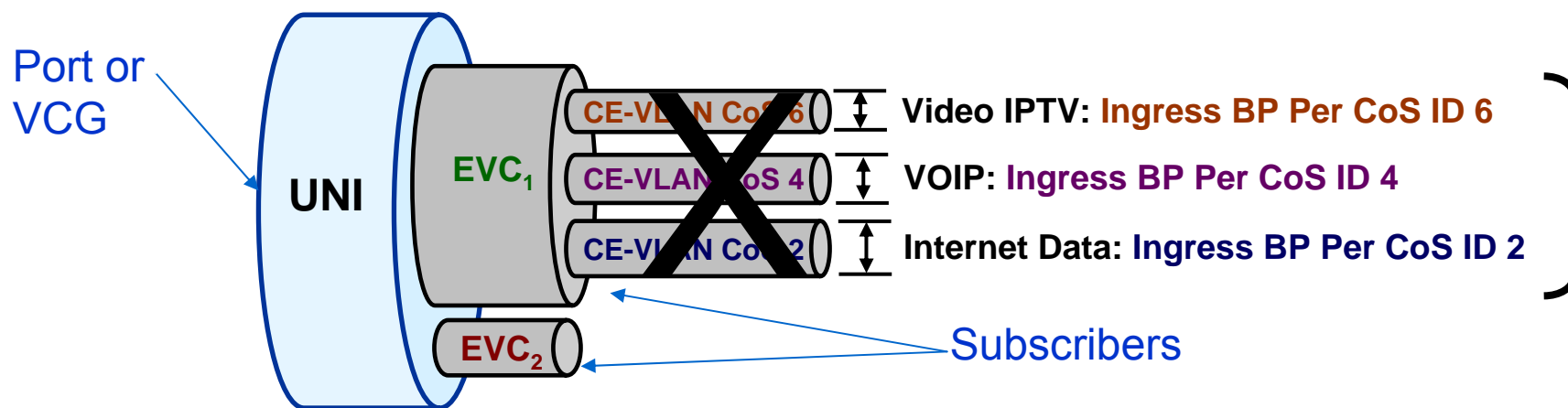
**Carriers must assure the bundle or face customer churn!**

Three Types of Bandwidth Profiles defined in ETM



**Control thousands of subscribers per port  
Control multiple levels of QoS per subscriber  
Provide bandwidth control per application**

**Carriers must assure the bundle or face customer churn!**



**Control thousands of subscribers per port  
Control multiple levels of QoS per subscriber  
Provide bandwidth control per application**

Adapted from **METRO** Ethernet Forum

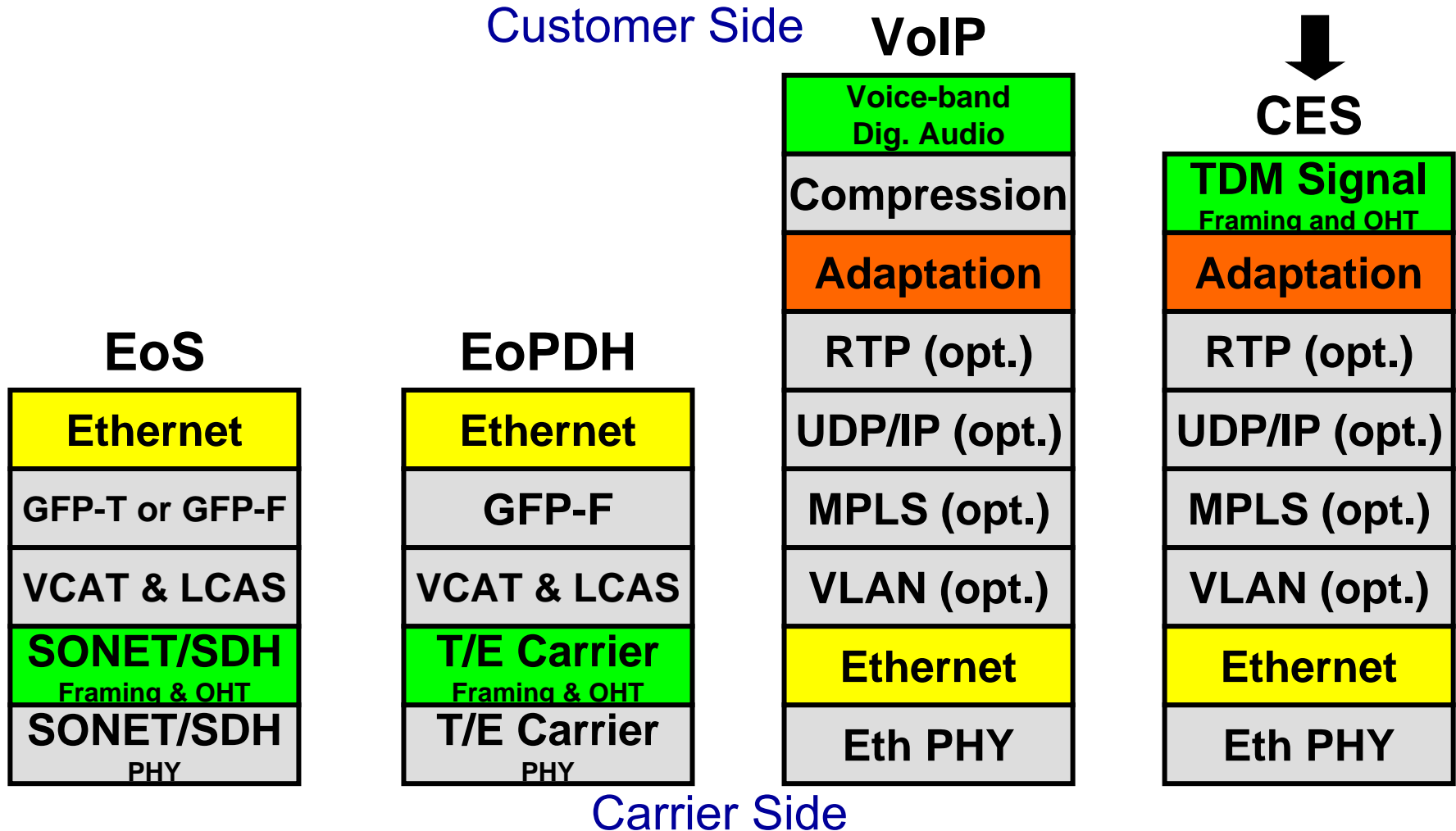
# Metro IP Video Services Summary



- **IPTV**
  - Huge revenue opportunity and challenge for all carriers
  - IPTV subscriber will be different
  - IP Video QoE for subscriber requires underlying robust QoS mechanisms
- **IP Video traffic**
  - More demanding and difficult than voice, VOIP or HSI data
  - Peak VOD may have enormous impact on transport networks
- **Intelligent Ethernet and IP/MPLS tools for QoS and Multicast**
  - Targeted to be future transport bedrock for IP video
  - Flexible Traffic Management with granular per service BP's for SLA's
- **Broadcast strategies and network topologies**
  - Network solutions (node placement) will be centered on support for VOD Unicast and BTV Multicast applications
  - Optimal design trade-offs needed for delay and bandwidth
- **Triple Play traffic mix -- need intelligent choices to "Assure the Bundle"!**
  - Hybrid Transport Solution using Layer 2/3 with interworking

- > Circuit Emulation Services (CES) Rationale and Basic Model
- > CES Specifications and Standards
- > Clock Recovery Options
- > CES for Sync-over-Packet

# TDM Convergence Technologies



# Voice Evolution



Circuit Switching	Packet Switching	
PSTN	ATM	IP/MPLS/Et
Leased-Line Service	Circuit Emulation Service	Circuit Emulation Service
Switched Voice Service	VoATM (ATM LES)	VoIP



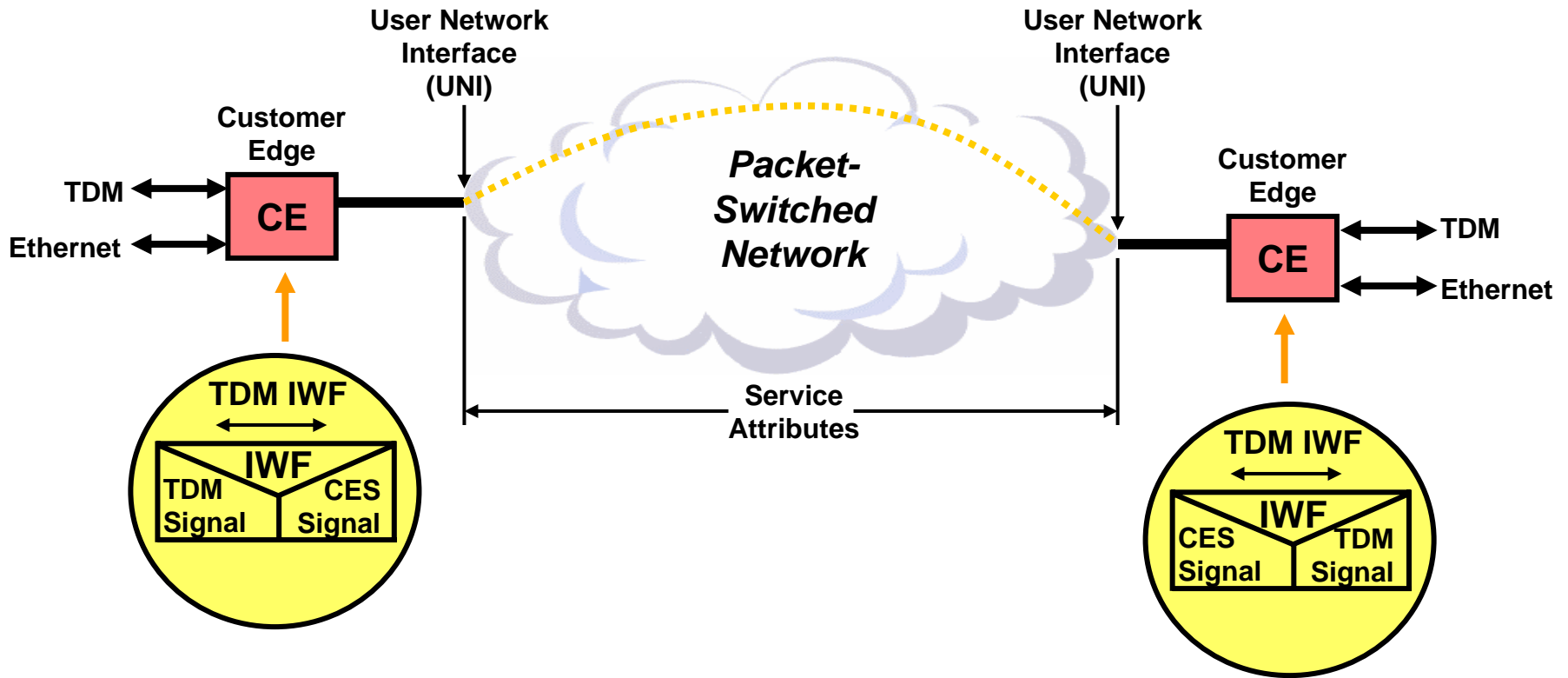
## Carrier

- Cellular Backhaul
- Leased Lines
- Private Lines
- SS7 Transport
- Sync-over-Packet

## Enterprise

- Private Lines
- TDM PBX Migration to PSN
- MTU TDM Service
- Sync-over-Packet

# Basic CES Model

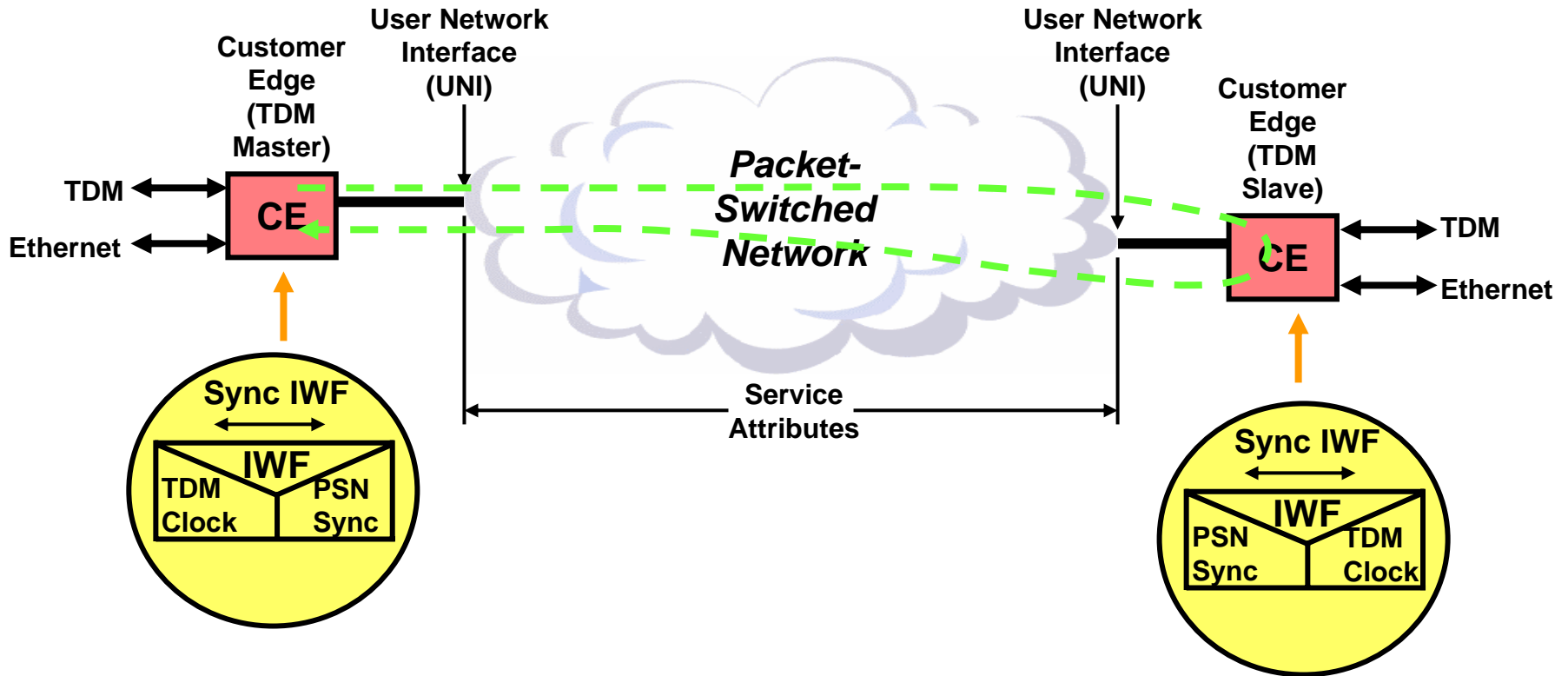


# CES Standards: The IETF PWE3 Specs

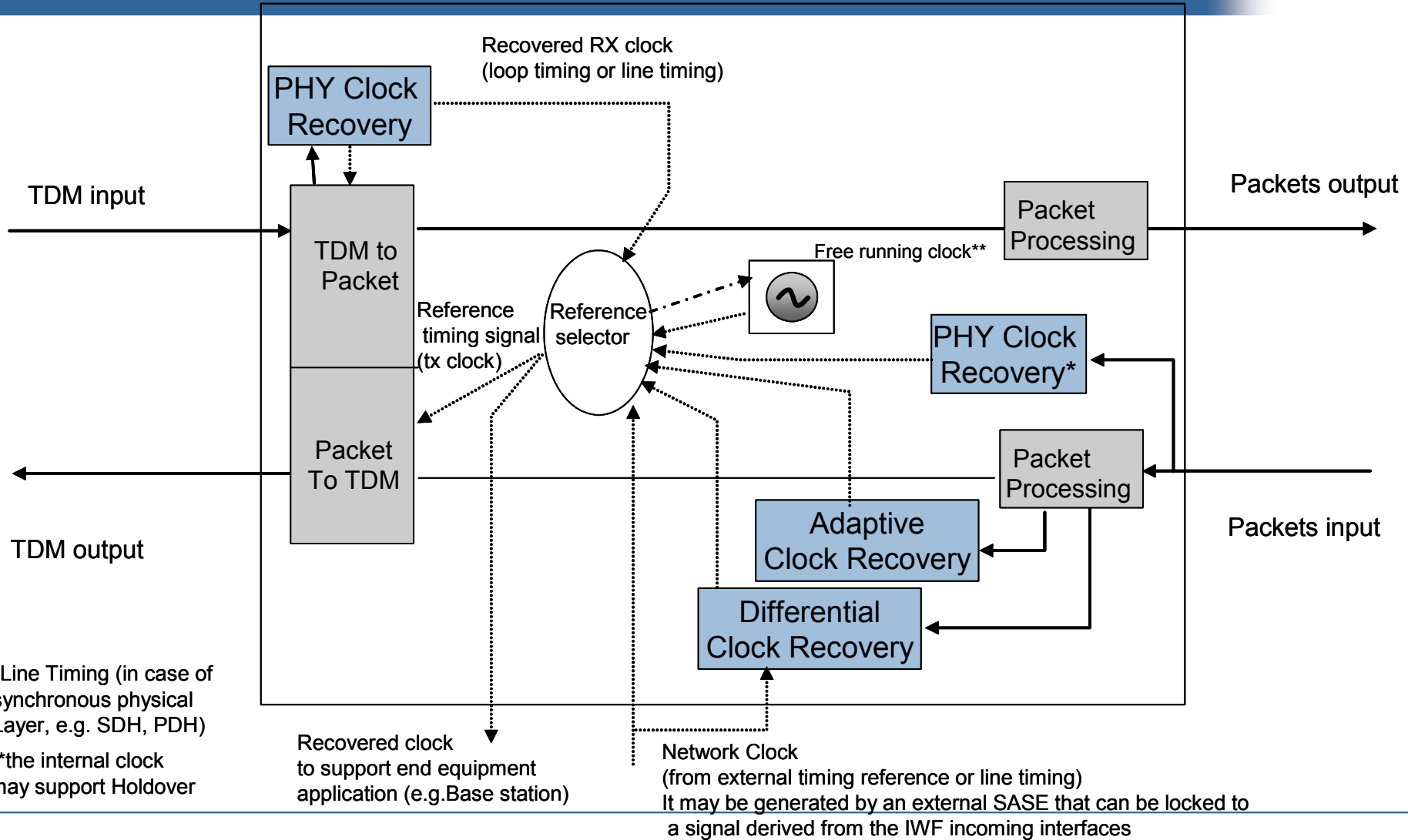


- > TDMoIP
  - Derived from ATM AAL, AAL2
  - Unstructured, structured
  - Full and fractional
  - For T1, E1, T3, E3
  - 35,000+ ports in operation
  
- > SAToP
  - Derived from part of earlier TDMoIP drafts
  - For simple unstructured T1, E1, T3, E3
  
- > CESoPSN
  - For structured T1, E1
  
- > CEP
  - For SONET/SDH frames and VCs

# Clock Recovery Modes, Technologies, Limitations



# IWF Synchronization Functions (Packet to TDM direction)



# Wireless Sync Requirements are Very Tight!



- > GSM, WCDMA, and CDMA2000 require frequency accuracy of 0.05 ppm at air interface
- > CDMA2000 requires time synchronization at +/- 3 $\mu$ s (+/-10 $\mu$ s worst case)
- > WCDMA TDD mode requires 2.5 $\mu$ s time accuracy between neighboring base stations (i.e. +/- 1.25 $\mu$ s of UTC)

# Sync-over-Packet Applications



- > Wireless
- > IPTV
- > Video conferencing
- > VoIP pt-pt
- > VoIP on conference bridges
- > FAX
- > Modem
- > Dealerboard public address
- > Home A/V: e.g. 10 nsec required for stereo speakers

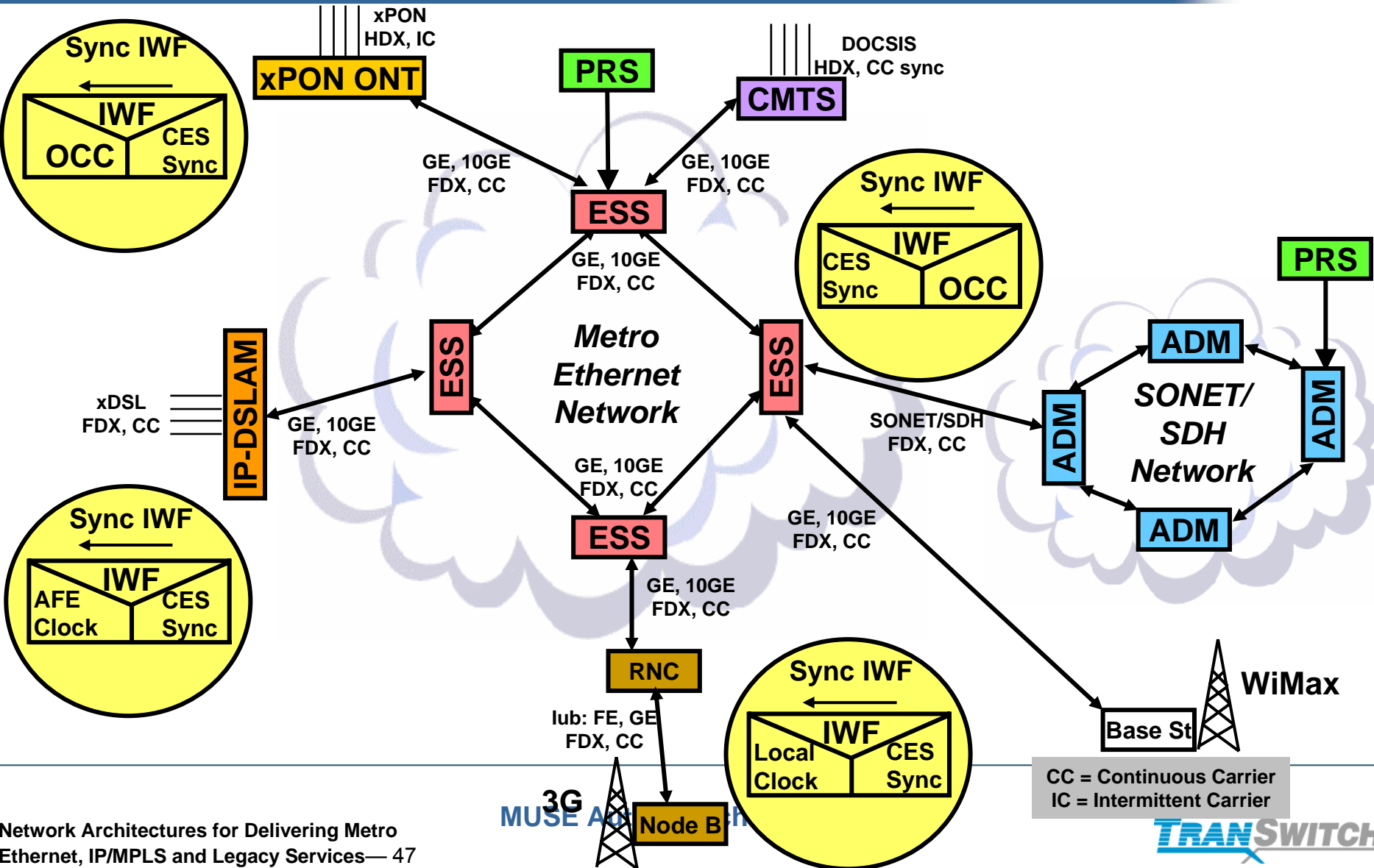
>**CES applications I showed previously usually require PSN-derived sync plus the TDM payload itself.**

>**But providers and OEMs are awakening to the fact that the requirement for transport of reliable sync does not go away when we transition from circuit to packet networks.**

>**CES-based sync is one option for transporting sync over packet networks, but it's one of the most mature.**

***Applications may require low latency more than sync.***

# Sync-over-Packet Network View



## *CES over Ethernet, IP, and MPLS...*

- *Is here*
- *Is well-defined*
- *Is in demand*
- *Can be implemented in several ways*
- *Can be leveraged for use as a sync-over-packet technology*