ATM and Frame Relay Services over IP/MPLS Networks

APRICOT 2004

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Agenda

- Business and market drivers for MPLS-based convergence
- Reference models
- Terminology and building blocks
- Pseudowires
- ATM and FR Migration to MPLS
- Interworking Layer 2 services with MPLS

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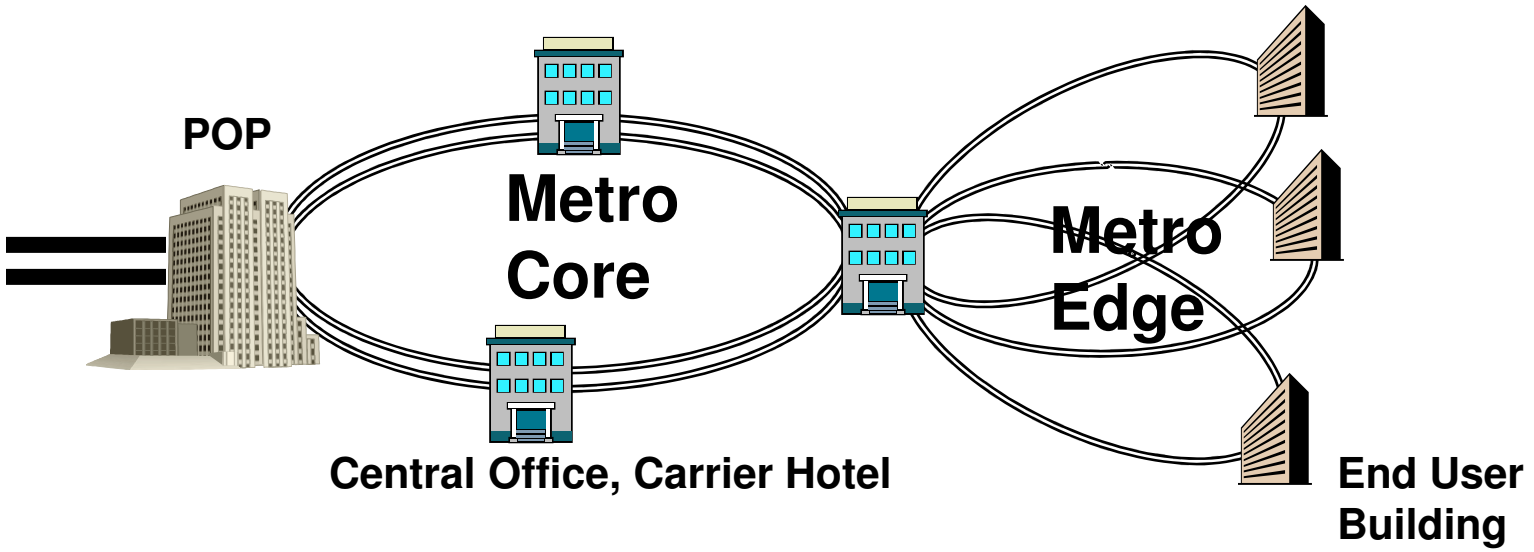
Standards Bodies Discussed

- MPLS and Frame Relay Alliance
  - http://www.mplsforum.org
  - http://www.frforum.com
- Internet Engineering Task Force
  - http://www.ietf.org
- ITU-T
  - http://www.itu.int

Today's Metro Network



- Designed for voice and TDM services
- Based on resilient Sonet/SDH transport (< 50msec protection)
- Carrier class reliability (99.999%)

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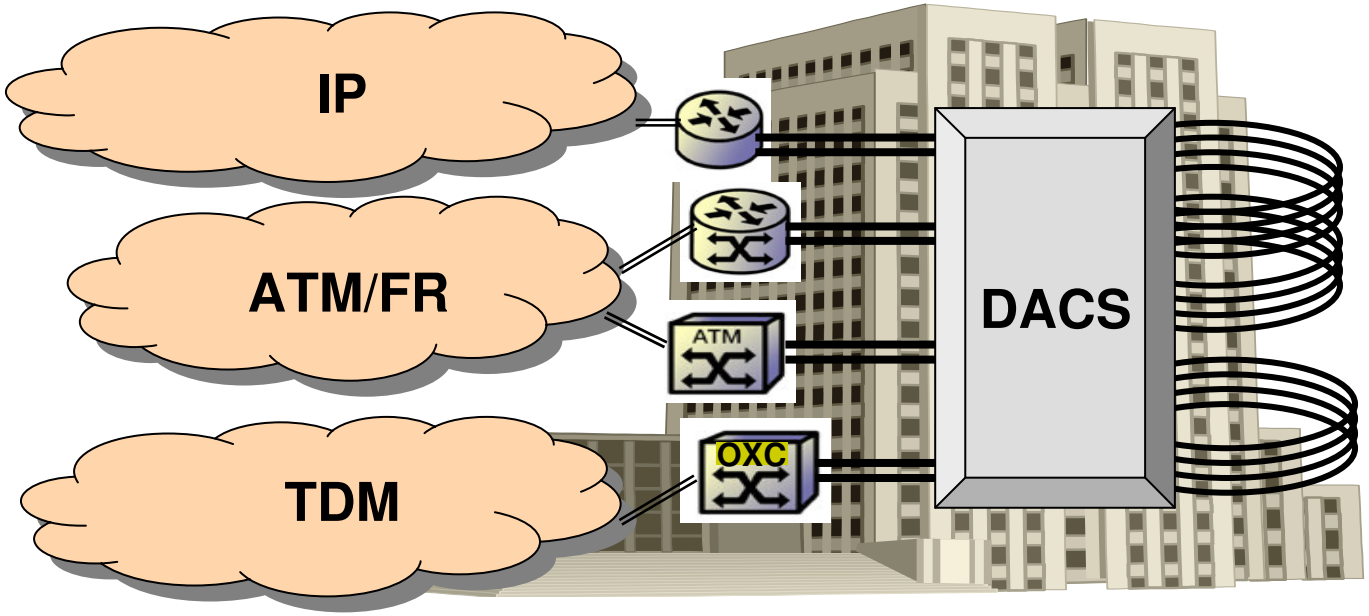
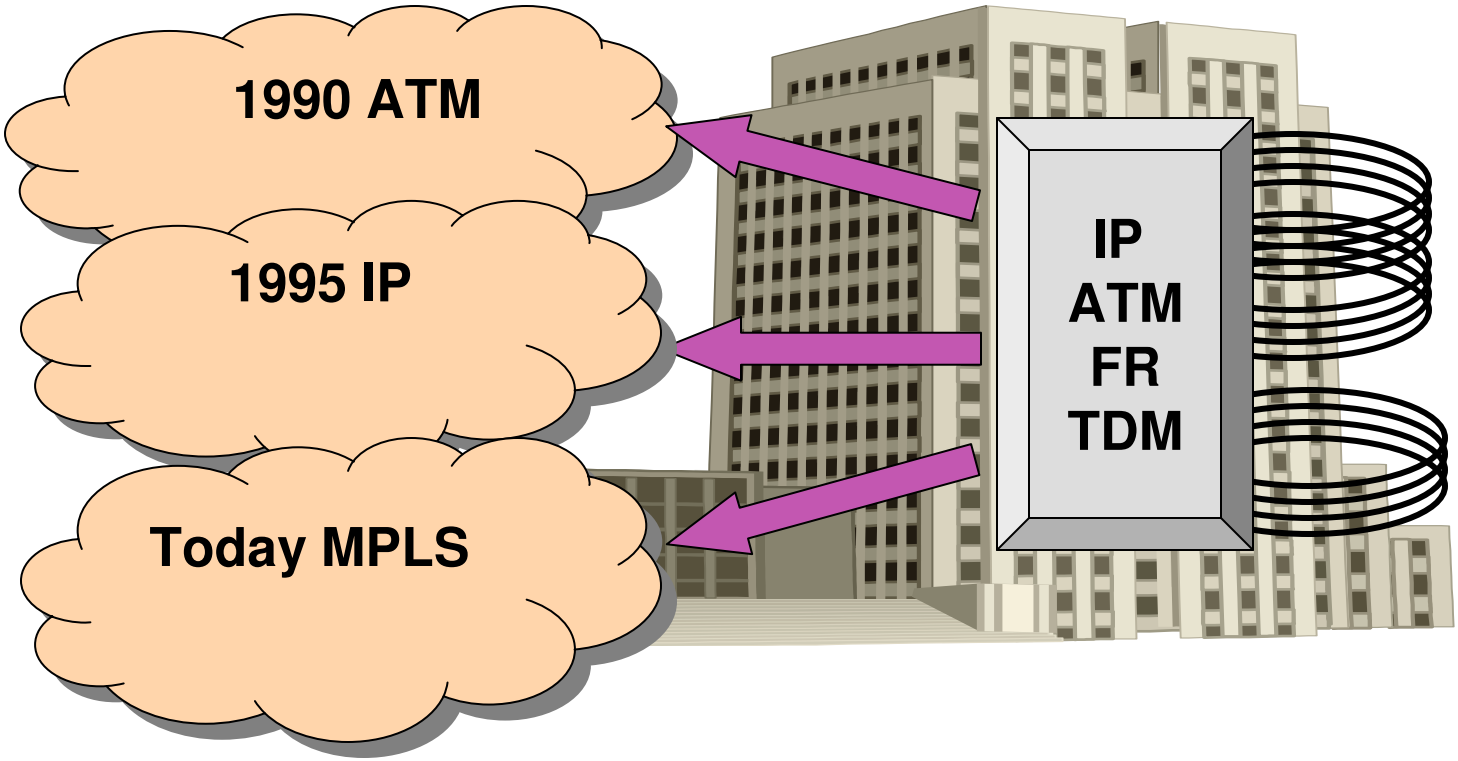
Today's Wide Area Network



- IP network is connectionless best effort
- ATM and Frame Relay network is connection oriented – it supports traffic engineering, Quality of Service (QoS), and Virtual Private Networks (VPNs)
- TDM network is statically provisioned, reliable, supports Service Level Agreements (SLAs)

The Promise of Convergence



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Why MPLS-based Convergence

- MPLS allows service providers to converge into a single infrastructure while offering the service they currently support
- MPLS enables new service offerings and simplifies service provisioning
- MPLS natively supports rapid growth in IP applications and services
- MPLS allows the integration of the emulated services management into common OSS strategy
- Positioned to support integration of packet technologies and optical core

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It Makes Business Sense

Minimize CAPEX	→	**Leverage existing infrastructure** **New service introduction**
Reduce OPEX	→	**Network and services convergence** **Simplifies service provisioning** **Automates operation**
Enables new services	→	**Incremental revenue opportunities** **More focused ROI** **Embraces emerging technologies**

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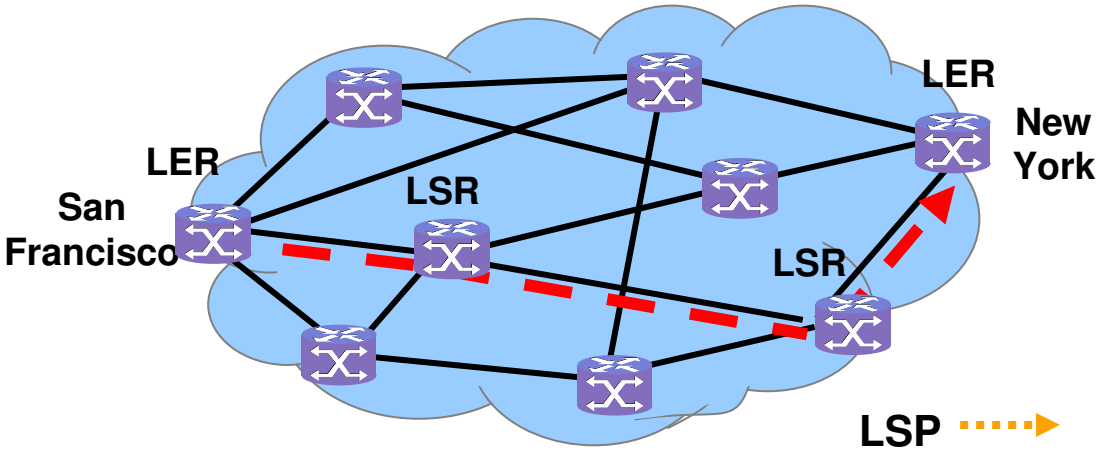
MPLS Terminology

- MPLS: Multi Protocol Label Switching
- Label: Local identifier prepended to packets for simplified switching; labels can be stacked for hierarchy
- LSR: Label Switching Router; an IP router that also supports MPLS
- LER: Label Edge Router; an LSR at the edge of the MPLS network
- LSP: Label Switched Path; a unidirectional MPLS connection between LERs
- LDP: Label Distribution Protocol; a protocol used to establish LSPs
- RSVP-TE: Reservation Protocol with Traffic Engineering; a protocol used to establish LSP tunnels used for traffic engineering

MPLS Model



- LSPs are established using RSVP-TE or LDP
- Ingress LERs classify unlabelled IP packets and appends the appropriate label.
- Egress LERs remove the label and forwarding the unlabelled IP packet towards its destination.
- All packets that follow the same path through the MPLS network and receive the same treatment at each node are known as a Forwarding Equivalence Class (FEC).
- Separates packet forwarding from IP routing for traffic engineering and advanced applications

Forwarding Equivalency Class

- Stream/flow of IP packets
  - Forwarded over the same path
  - Treated in the same manner
  - Mapped to the same label
- FEC/label binding mechanism
  - Binding is done once at the ingress
  - For IP packets, usually based on destination IP address prefix
  - FEC is extensible for protocols other than IP, and IP attributes other than destination prefix

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MPLS Features

- Traffic Engineering
  - LSPs can be engineered to meet latency and loss objectives
- Resource reservation for traffic engineered paths
  - Resources can be reserved on a per-LSP basis
- Differentiated forwarding behaviors
  - Forwarding and drop behaviors can be controlled at the LSP level
- Fast reroute
  - MPLS can reroute LSPs around failures in under 50ms
- Graceful restart
  - At control plane, recover the control information on the “down” nodes without disturbing data traffic

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MPLS Issues to be Resolved for Convergence and VPN Services

- Delivering same QoS as existing services provide
- Providing the level of reliability as existing services
- Providing carrier-class resiliency
- Enabling new service offerings for ISPs; converging multiple networks into a single backbone for ILECs
- Network must prove to be scalable, flexible, manageable, and cost-effective
- Migration of existing services to an MPLS infrastructure
- Provide services that end customers want: Layer 2 and 3 VPNs, data separation; service level agreements

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Why Not Use ATM for Convergence?

- ATM was originally optimized for voice transport
- MPLS is optimized for data packet transport
  - Probably already in use for traffic engineering
- Cells are simply fixed length packets and can be carried unchanged across an MPLS network
- Packets are not cells and must be adapted to be carried across ATM – 20-30% overhead
- MPLS label stack provides hierarchy and the ability to provide L2 separation

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Convergence over MPLS History

- Work originally proposed in the IETF in the "Martini" drafts (named after lead author, Luca Martini)
  - Encapsulation (Ethernet, ATM, Frame Relay, HDLC, PPP, TDM, SONET/SDH)
  - Extensions to LDP for L1 and L2 connection setup
- Now resides in two IETF working groups:
  - PWE3 (Pseudo Wire Emulation Edge to Edge)
  - L2VPN (Layer 2 VPNs)
- Related ongoing work in MPLS & Frame Relay Alliance and ITU-T Study Groups 13 and 17:
  - Frame Relay over MPLS Network Interworking
  - ATM over MPLS Network Interworking
  - ATM, FR, & Ethernet Interworking over MPLS
  - ATM and FR to MPLS Signaling Interworking

Challenges at the Edge

- Transparently provide end-to-end support for existing Layer 1 and Layer 2 services
  - Ethernet, ATM, Frame Relay, HDLC, PPP, TDM, SONET/SDH
- While supporting for Layer 3 services
  - IP VPNs, Internet Connectivity
- And enabling new services
  - Ethernet Services
    - Private Line
    - Virtual Private LAN Service (VPLS)
  - Layer Two Interworking

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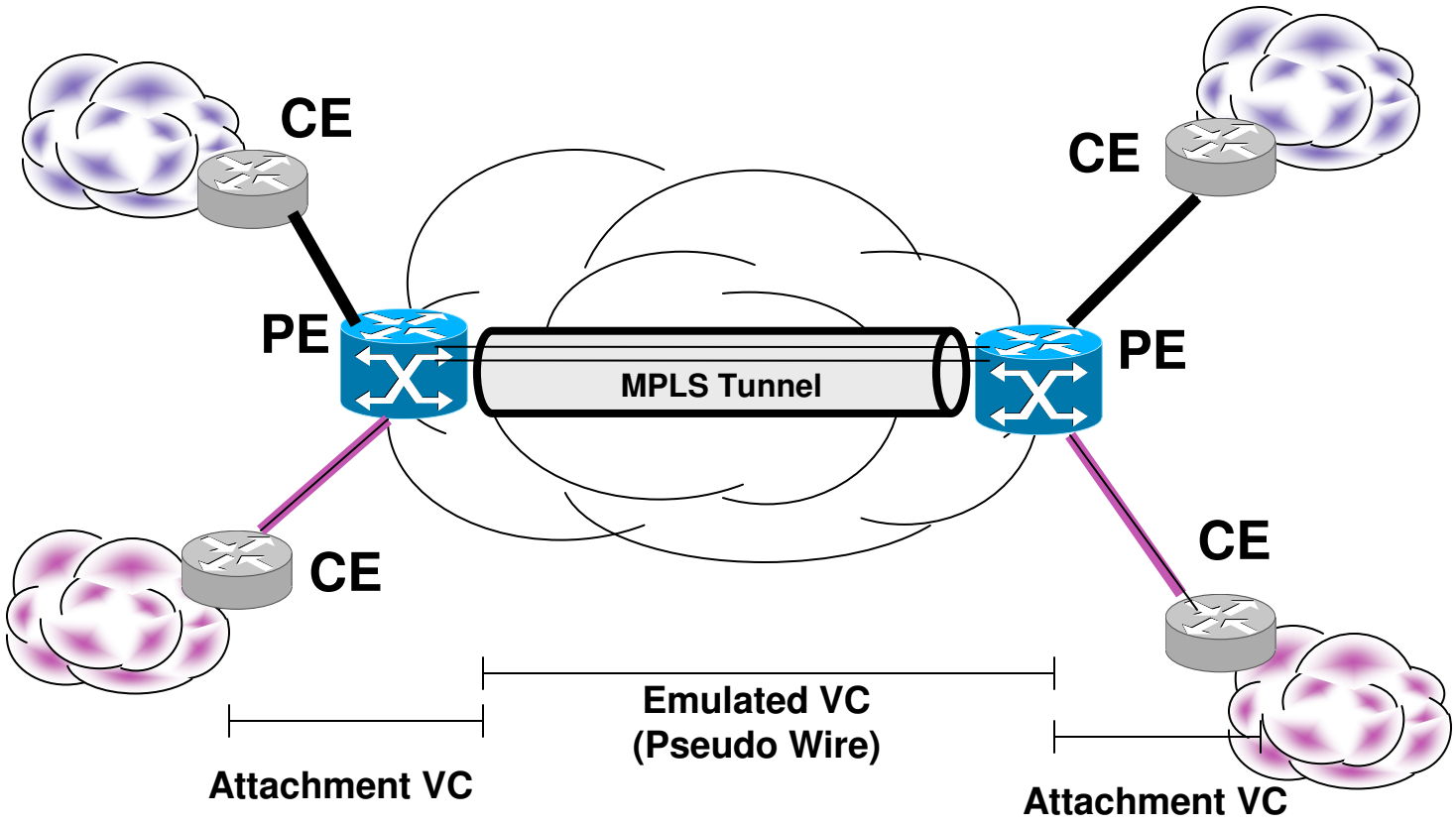
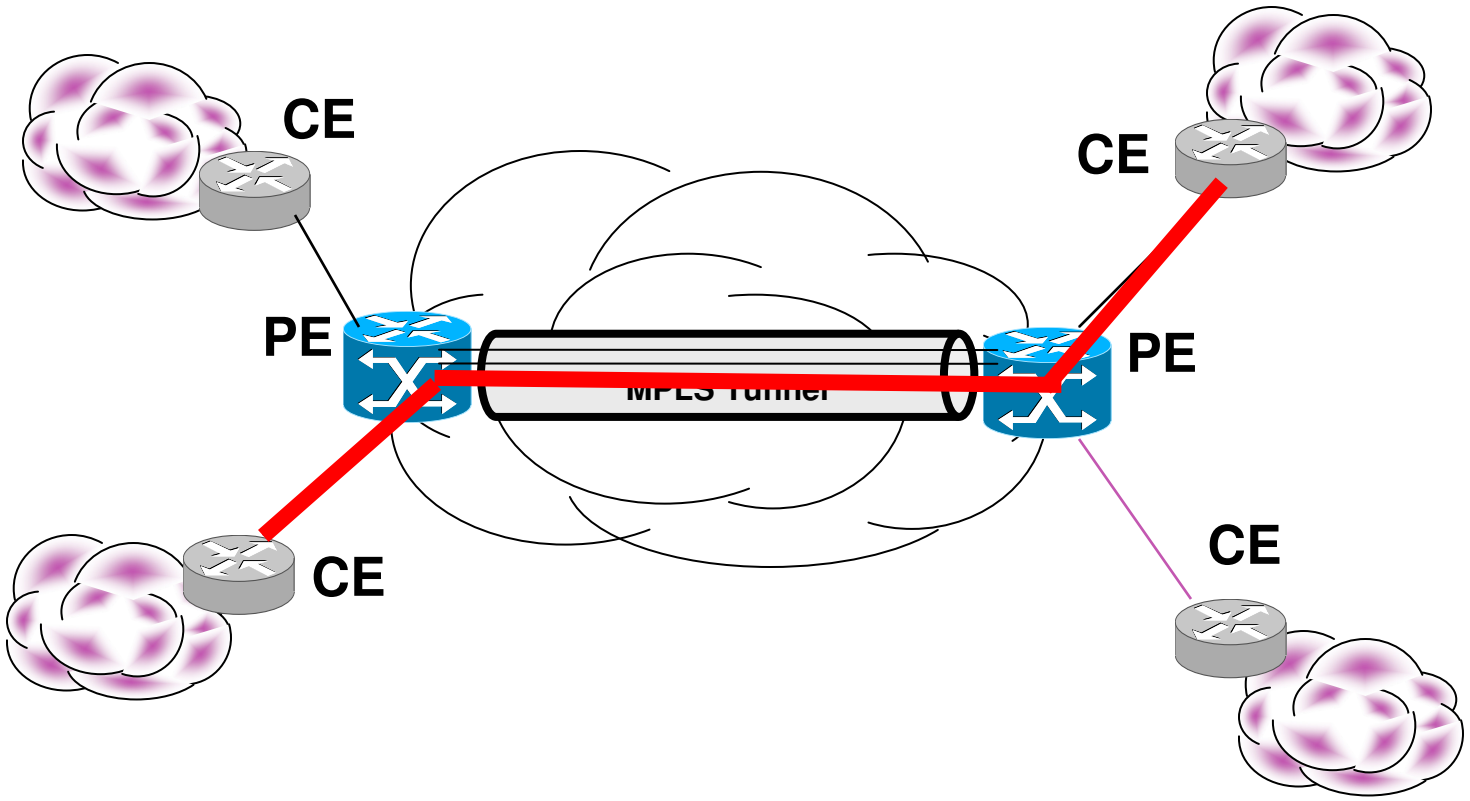
PWE3 Reference Architecture



Virtual Private Wire Service



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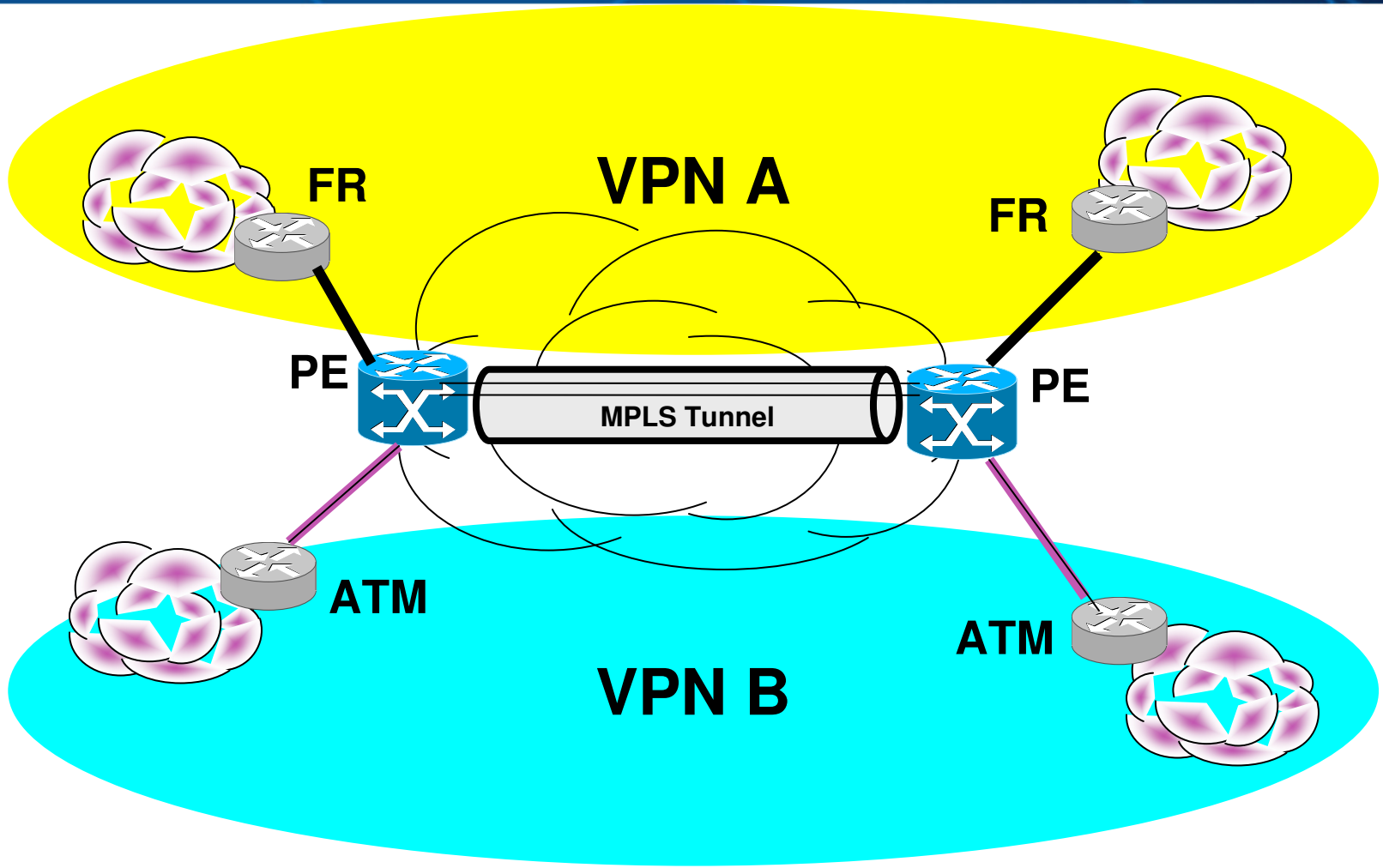
Layer Two Virtual Private Networks



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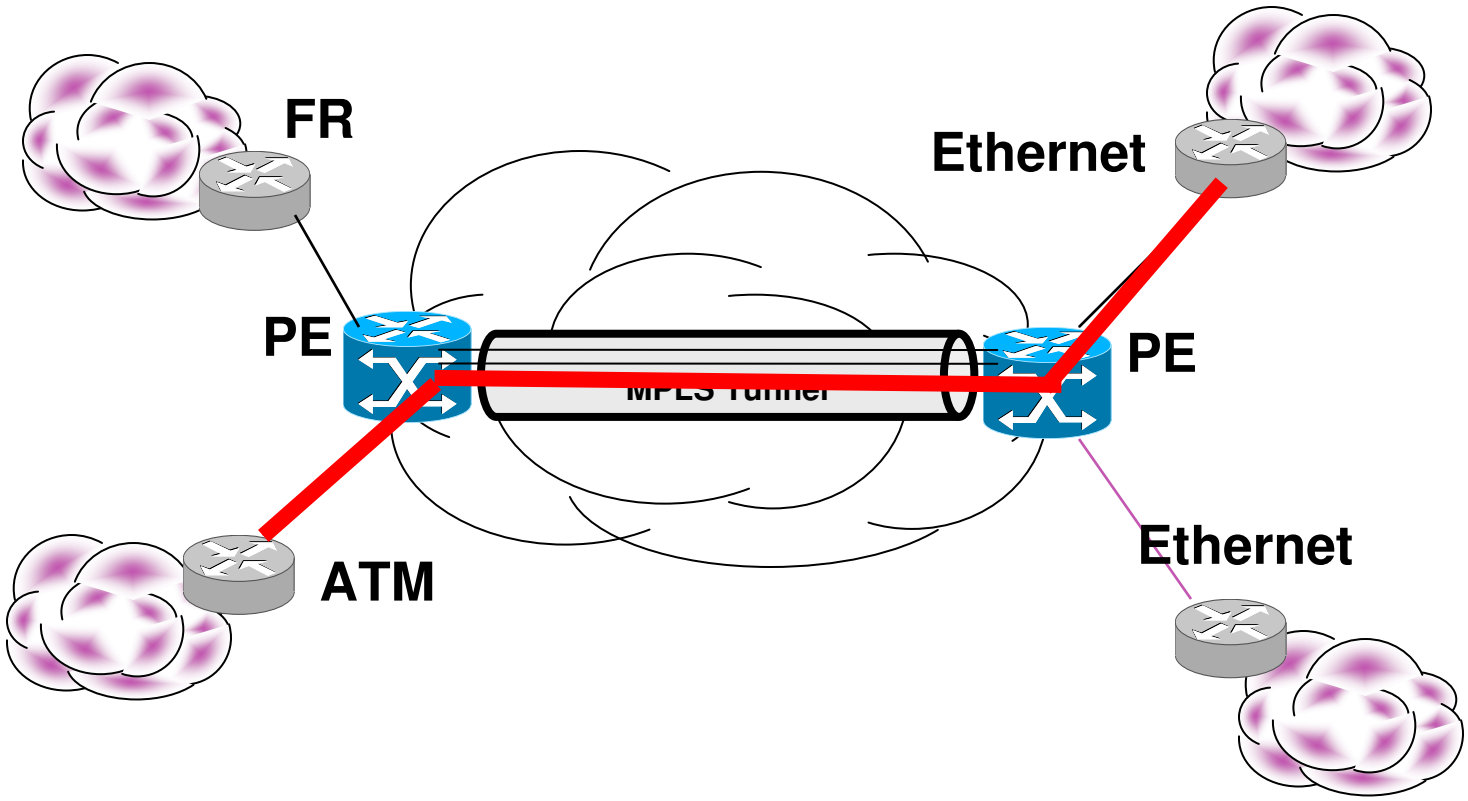
Layer Two Interworking



> PEs include interworking function between L2 protocols

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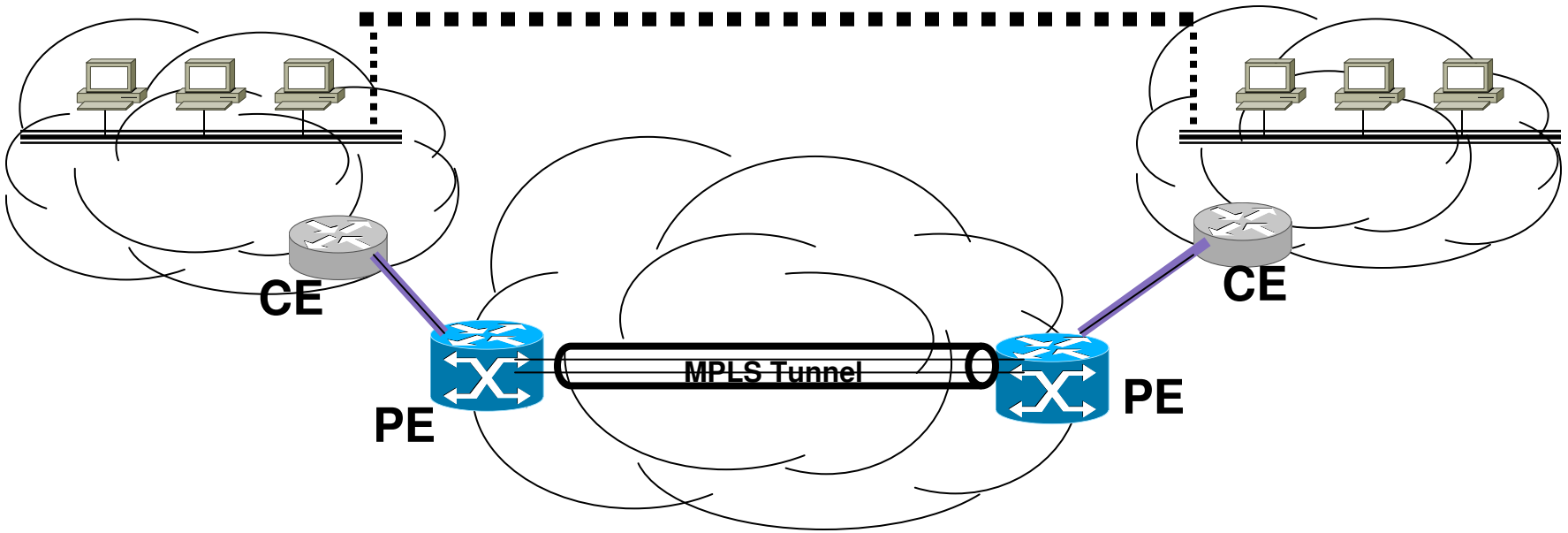
Virtual Private LAN Service (VPLS)



> Provides a multipoint bridge service among different CE sites

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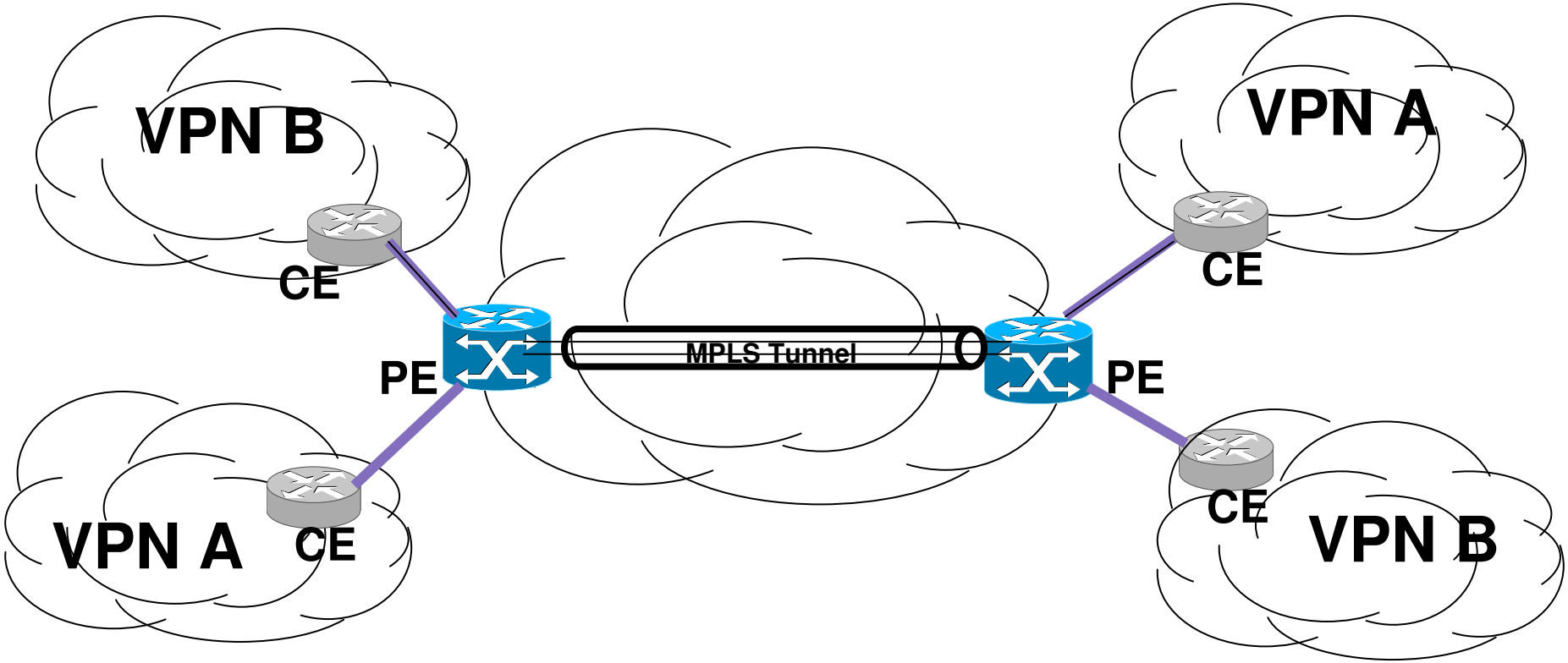
RFC 2547 Layer 3 (BGP/MPLS) VPNs



> Provides private IP connectivity between multiple sites; IP addressing is local to each VPN

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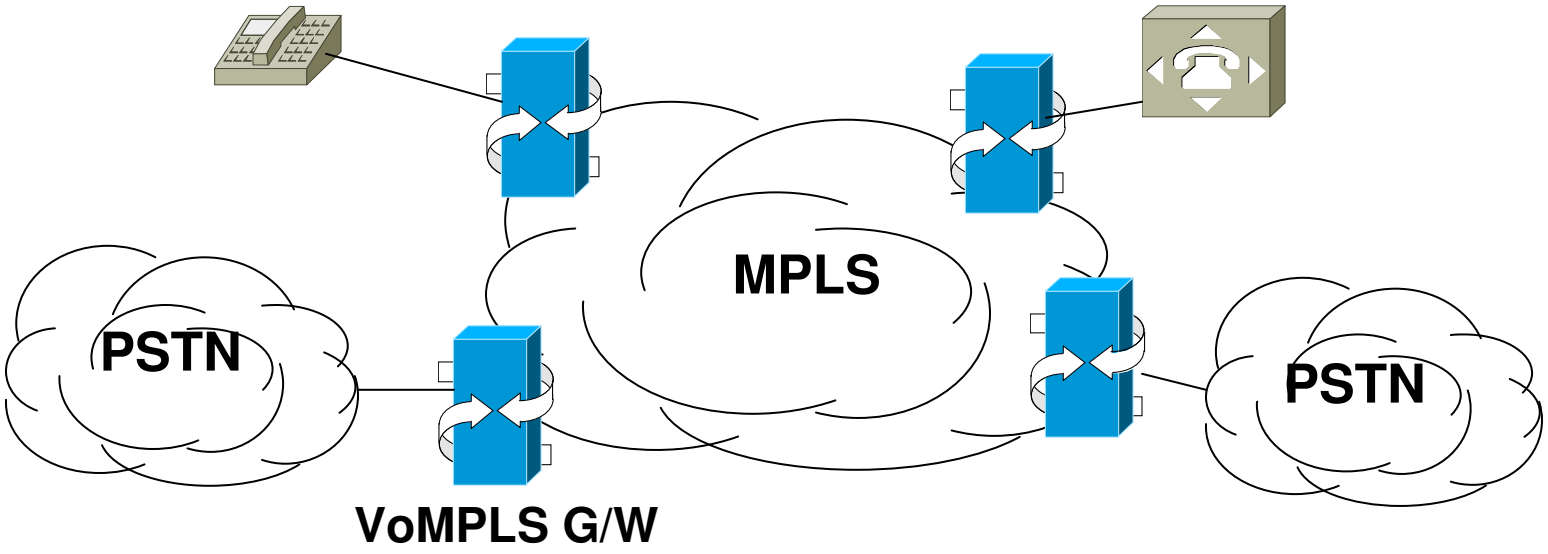
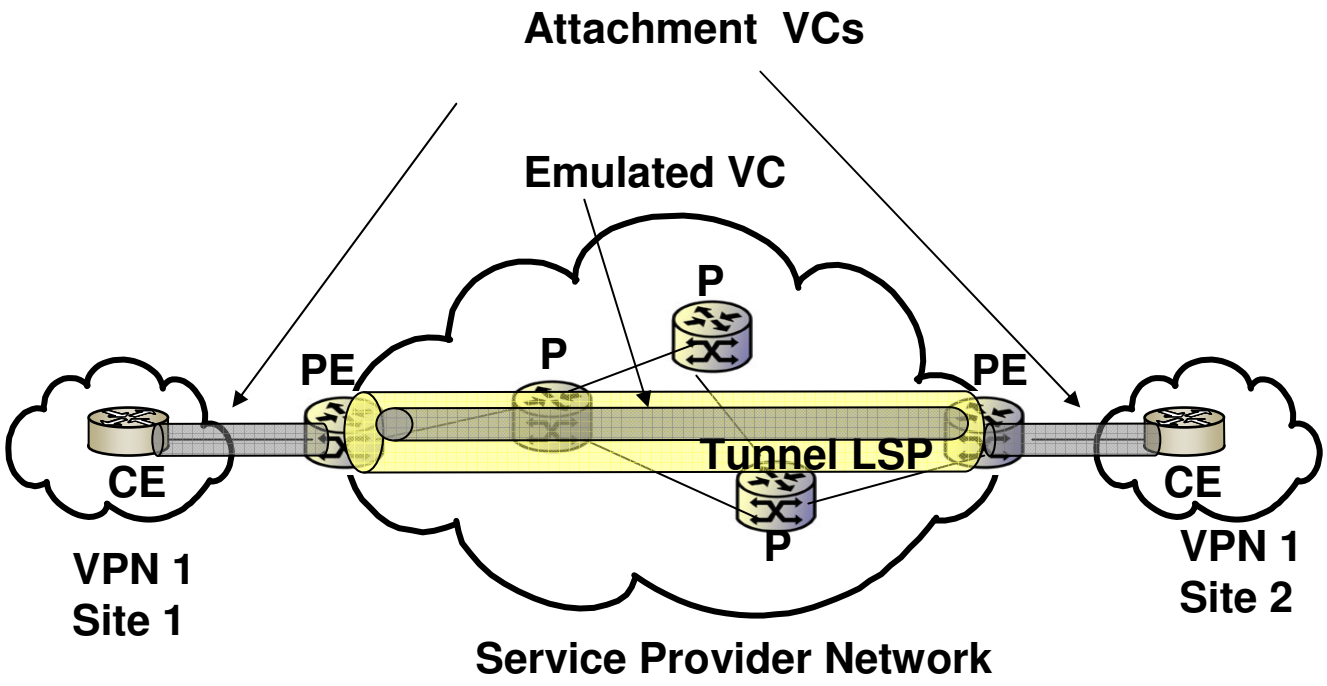
Voice Over MPLS



- Incoming voice protocol such as TDM voice from a PSTN network is terminated at the MPLS network gateway
- Voice sample is mapped directly to MPLS frames at the MPLS network gateway

MPLS Enabled VPNs: Terminology and Building Blocks



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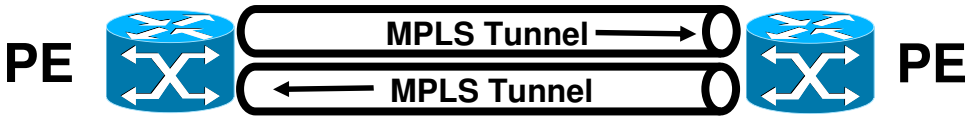
Emulated VC

- Referred to as Pseudo-Wire (PW) in standards
- Two unidirectional inner LSPs contained within unidirectional outer LSPs (traffic engineering tunnels)



- Often abstracted to a single bidirectional end-to-end "connection" for convenience (see previous slide)

Associating ‘Attachment VCs’

- There are two mechanisms for associating the ‘attachment VC’ and distributing the associated labels
  - LDP Extended Discovery, primarily used for Layer 2 VPNs and VPLS
  - Associating and distributing labels with IP VPN routes, used for Layer 3 VPNs, also known as BGP/MPLS or RFC 2547 VPNs

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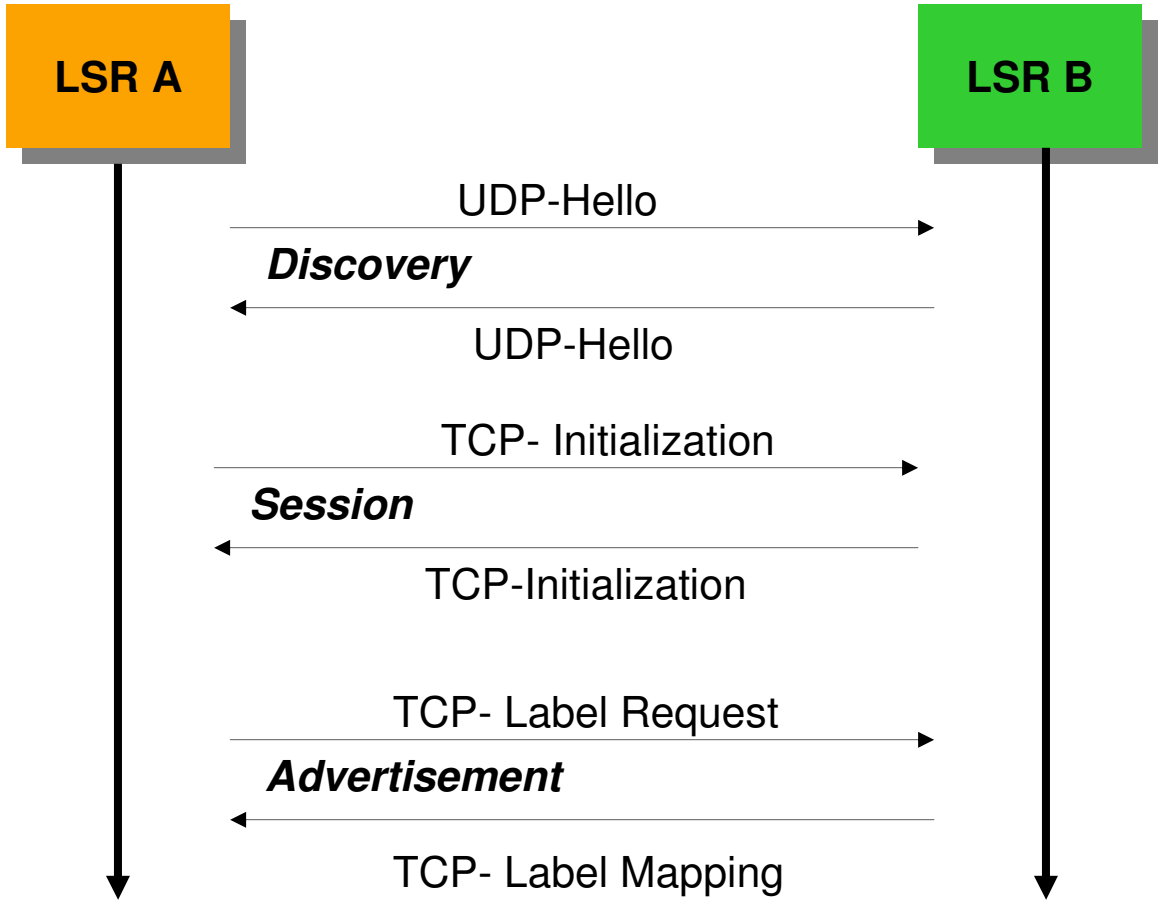
LDP Message Exchange



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LDP Extended Discovery

- Enables LSRs that are not directly connected to engage in LDP label distribution (targeted session)
- LDP Extended Discovery which uses Targeted Hello messages sent to specific LSRs, rather than only directly connected LSRs
- Defined in RFC 3036; extended for PWE3 signaling in draft-ietf-pwe3-control-protocol-05.txt

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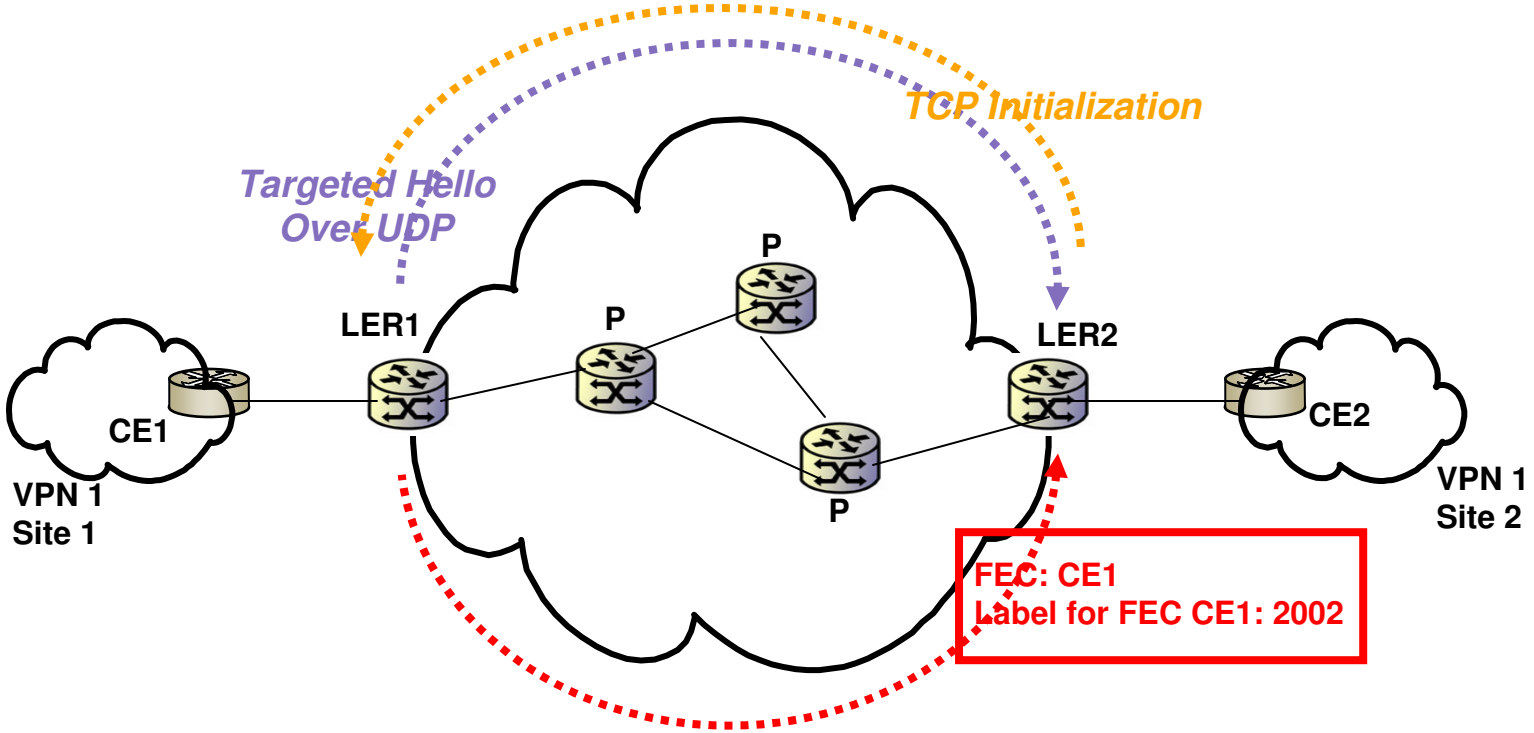
LDP Extended Discovery



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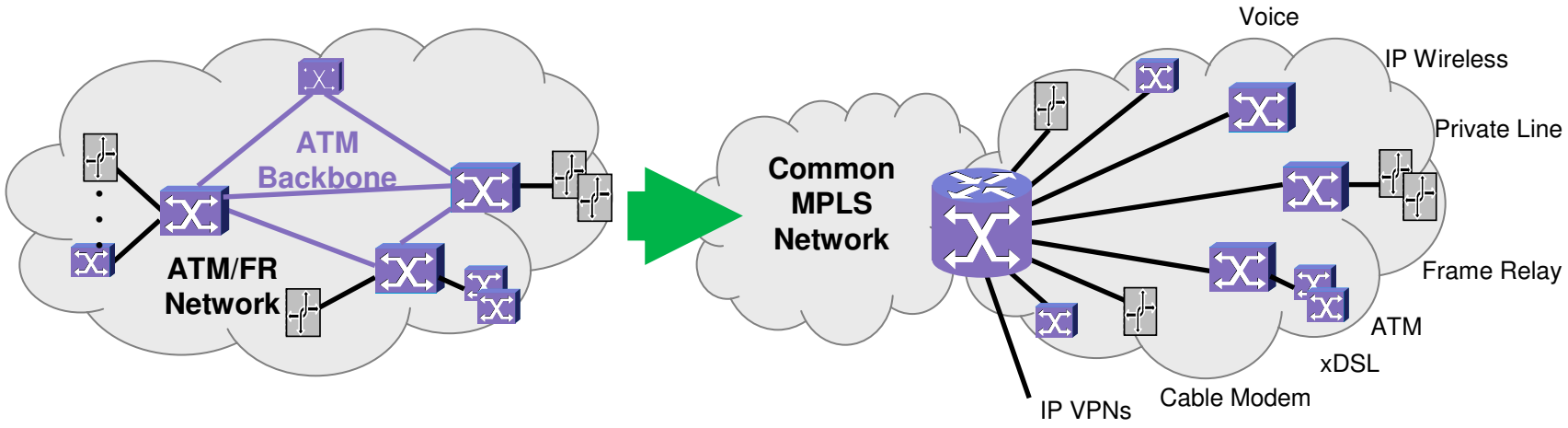
Motivations for Moving to ATM and Frame Relay Services to MPLS



- Scale ATM/FR network aggregation and connection capacity to support traffic growth
  - Free-up I/O slots on existing switches for services
- Migrate to higher capacity IP/MPLS-based switches and backbone
- Add new IP-based VPN and VPLS services
- Reduce CAPEX and OPEX by using one backbone for all services

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ATM Over MPLS

- Encapsulation defined in the IETF by draft-ietf-pwe3-atm-encap-04.txt and in the ITU-T by Recommendations Y.1411 (cell mode) and Y.1412 (frame mode)
- Definitions are identical
- Four modes:
  - One-to-one and N-to-1 Cell Modes
  - AAL5 Frame PDU and SDU Modes
- Cell mode differences:
  - One-to-one cell mode more efficient, but can only transport one ATM VC per MPLS LSP and has variable-length header
  - N-to-one can transport multiple ATM VCs per MPLS LSP and has fixed-length header
- AAL5 SDU Mode is more efficient; AAL5 PDU Mode includes AAL5 trailer and FCS

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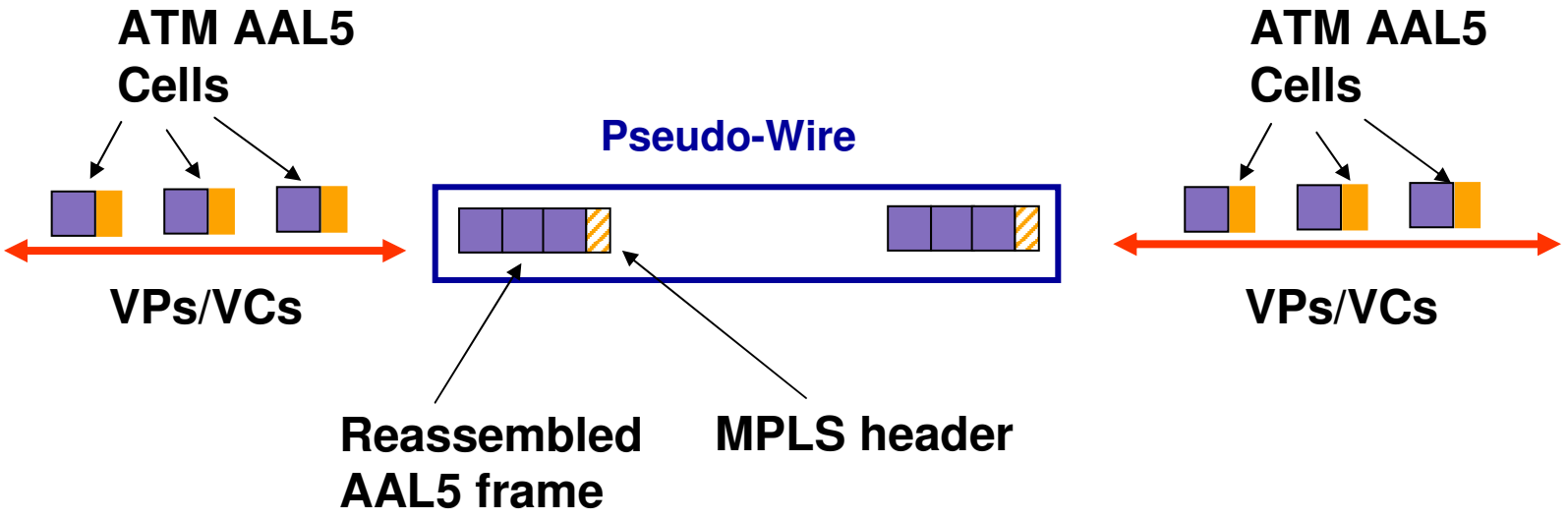
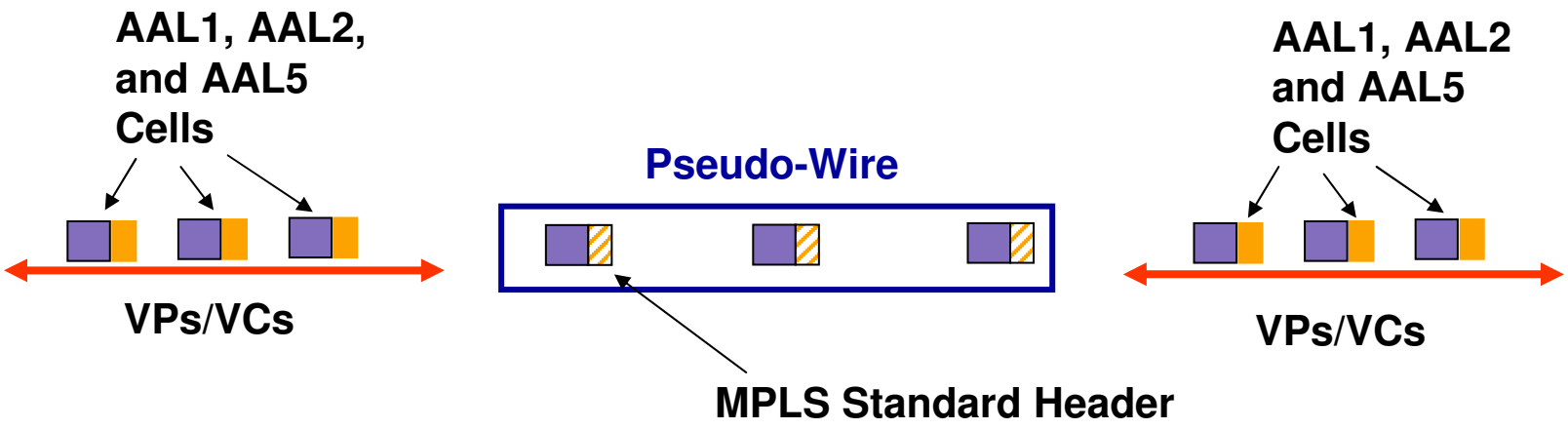
ATM Over MPLS: AAL5 Frame Mode



- SDU Mode: Includes entire AAL5 PDU (payload, pad and trailer)
- PDU Mode: Only includes the AAL5 SDU payload

ATM Over MPLS: Cell Mode



- One-to-One mode: uses different cell encapsulation & header formats for VCC and VPC services
- N-to-One mode: uses 4 octet ATM header to encapsulate all services (VCC and VPC)
  - Cells of one or more VCCs or VPCs per MPLS LSP
  - Sole required encapsulation mode for ATM cells

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Frame Relay over MPLS

- Encapsulation defined in the IETF by draft-ietf-pwe3-frame-relay-01.txt and in the ITU-T by X.84 – definitions are identical
- The FR PDU is transported without the FR header or the FCS for efficiency
  - Draft in the IETF to allow optional FCS retention and transmission - draft-ietf-pwe3-fcs-retention-00.txt
- The BECN, FECN, DE and C/R bits are carried across the network in the encapsulation header; LERs may change the BECN and FECN bits to reflect MPLS network congestion

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Mapping ATM QoS to MPLS

- QoS is a significant ATM/frame relay service attribute – particularly those with SLAs
  - End-to-end absolute characteristics
  - Standard ATM class of service: CBR, VBR-RT, VBR-NRT, UBR, ABR
- MPLS Network support
  - Traffic engineered path with allocated bandwidth
  - Specify how traffic is relatively treated at each LSR (Per Hop Behavior - PHB)
    - Queue management, policing, shaping, scheduling, congestion management
    - Use MPLS header EXP field (3 bit) to convey information
    - LSR maintains mapping from EXP to PHB

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Mapping ATM QoS to MPLS

- Focus of MPLS QoS standards work on support of IP QoS (Diffserv)
  - Standard PHBs: Expedited Forwarding (EF), Assured Forwarding (AF),
    Default - best effort
  - Convey Diffserv information using:
    - E-LSP: EXP infers PHB scheduling class; single LSP supports up to 8 behavior aggregates (BA)
    - L-LSP: Label infers PHB scheduling class (up to different 64 PHBs); separate LSP for single FEC/BA pair

Mapping ATM QoS to MPLS

- MPLS is capable of providing the hard QoS that ATM traffic requires
  - Control Plane: required signaling work underway (ATM-MPLS Signaling Interworking Implementation Agreement)
  - Data plane:
    - ATM-like per-flow queuing, policing, shaping and scheduling can be applied to forwarding over MPLS LSPs (leverage ATM experience)
    - IETF RFC 3496 for ATM Service Class-aware traffic engineering
- Service provider defines how ATM QoS is supported in a MPLS network using a combination of:
  - Traffic Engineering + PHBs + Signaling Interworking + Traffic Management

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Connection Admission Control

- Connection Admission Control (CAC)
  - U[illegible]ailability and rese[illegible]
  - S[illegible]ate functions in ATM/FR and MPLS domains
  - P[illegible]ision ATM/FR CAC information (bandwidth, del[illegible]ell/packet lo[illegible]ents, …) associated with a VC int[illegible]omain

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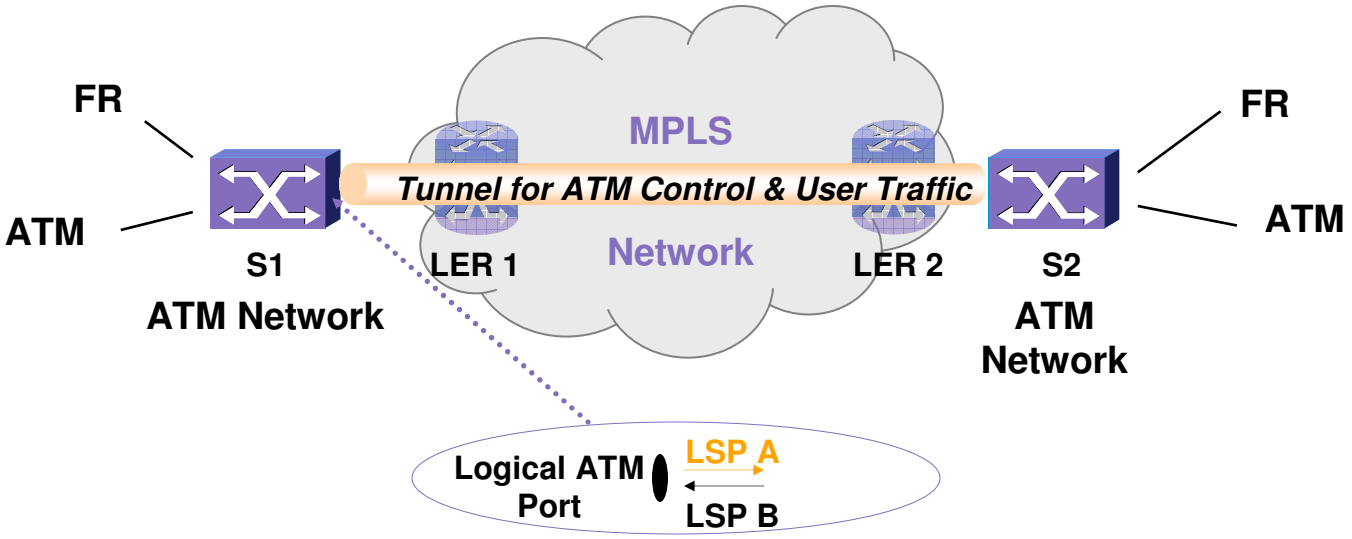
ATM-MPLS Network Interworking



- MPLS network appears as a tunnel to the ATM network for traffic transport
- Tunneling function for control and user traffic
- Pair of transport LSPs modeled to ATM signaling/routing as a logical ATM port

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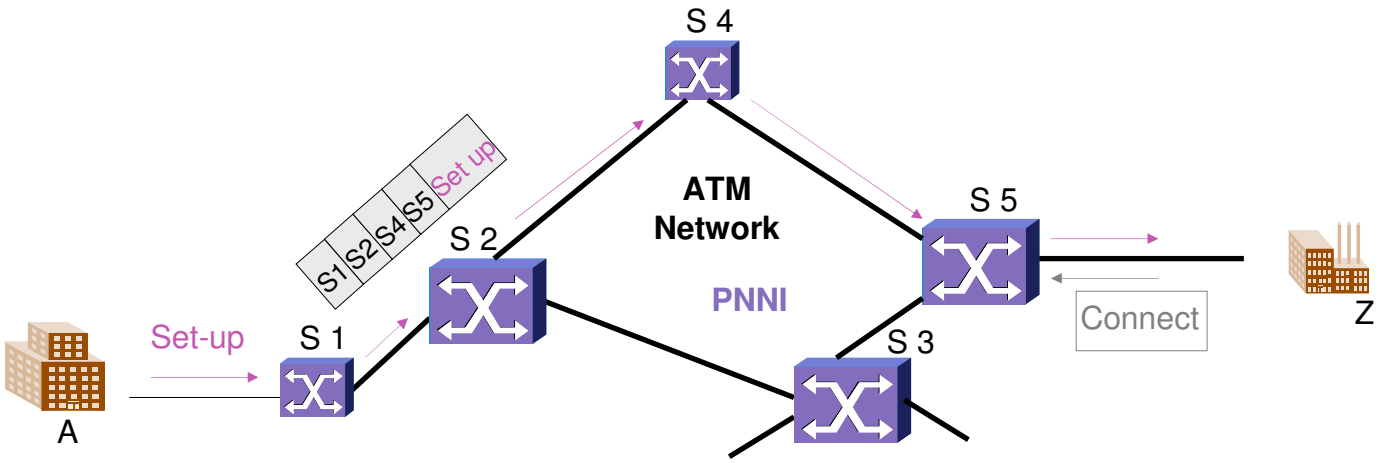
Provisioning ATM Service - Today



- PNNI network using SPVCs
- Provision endpoints on service provider network
- Source node selects path

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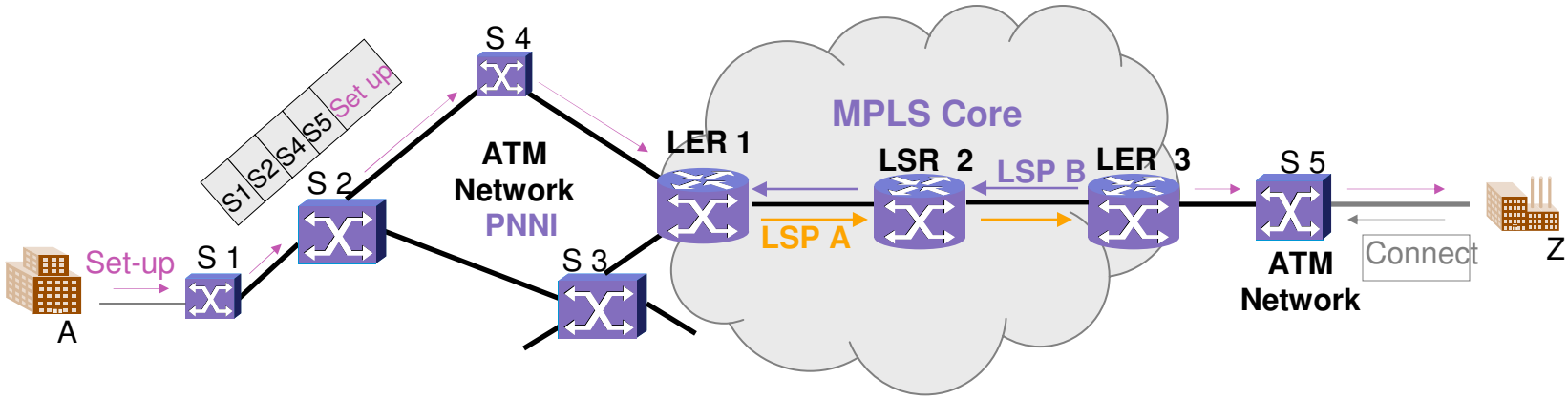
Provisioning ATM Service with MPLS Core



- Provision ATM endpoints on service provider network
- ATM source node selects path
- Provision cross-connect of bi-directional VCs into uni-directional LSPs

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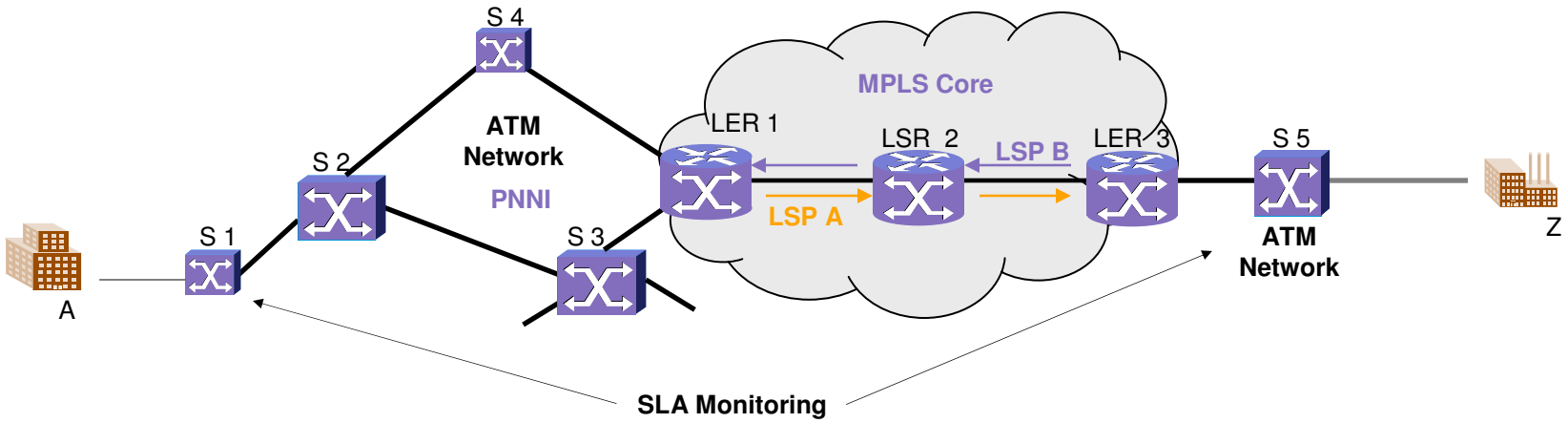
SLA Monitoring



- Service specific monitoring continues at edge
  - Current Customer Network Management (CNM) tools continue in use by businesses
    - Performance monitoring
    - Configuration of specific resources
- MPLS network is transparent

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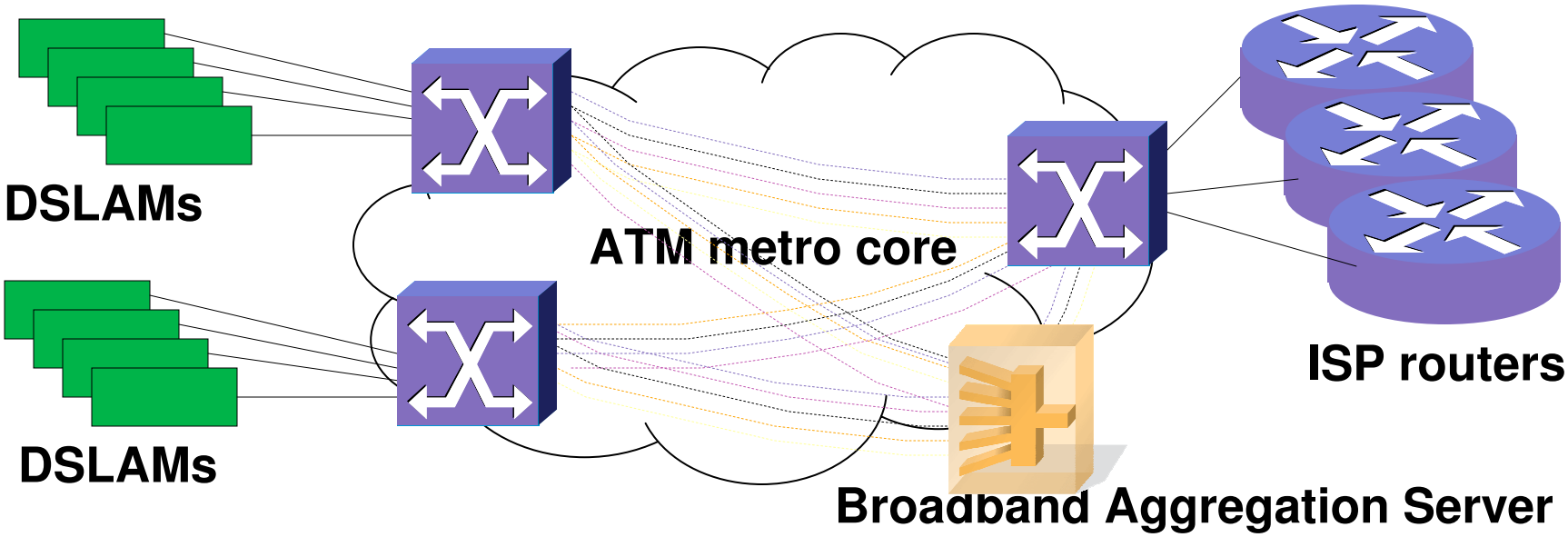
Metro DSLAM backhauling
Existing models



- DSLAM backhaul is mainly based on ATM transport today
- PVC or PVP based, both models require high meshing and intensive provisioning
- L2 access and core technology dependent implementation

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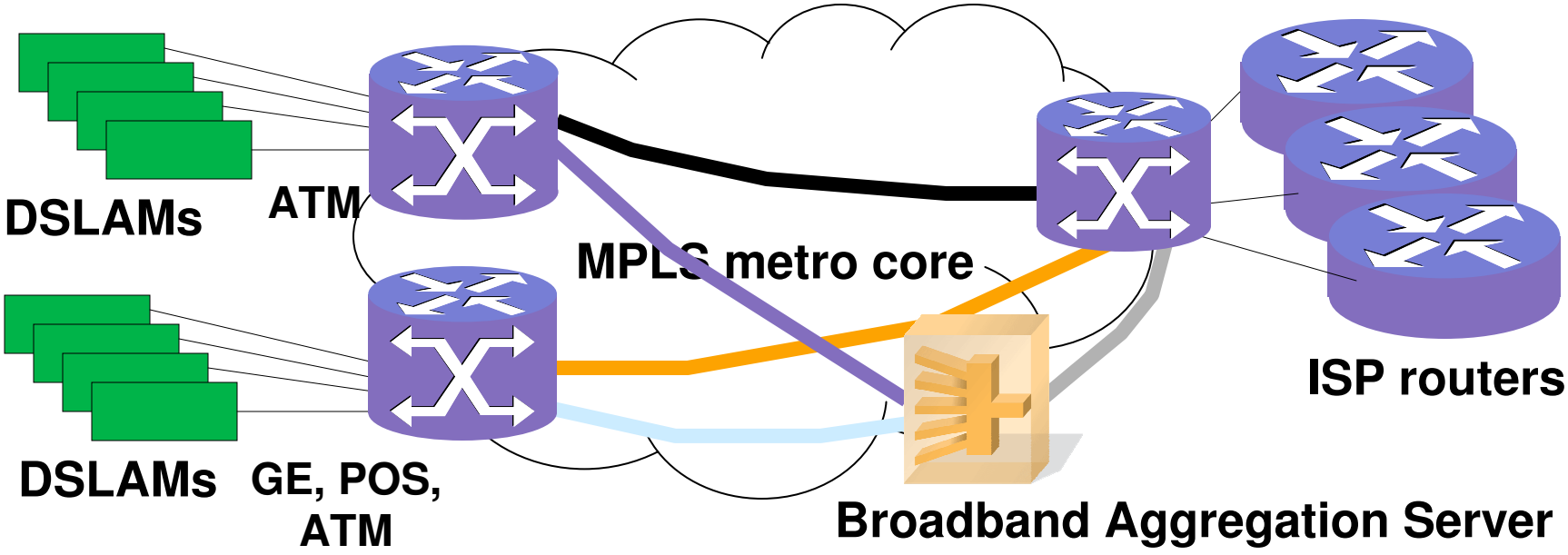
Metro DSLAM backhauling
MPLS model



- LSPs interconnect routers, switches and BASes
- Simplified metro transport because of limited number of core LSPs – reduced operational efforts
- Multiple L2 technologies in the access and in the core
- Simplified DSLAM provisioning (plug & play for new end users)

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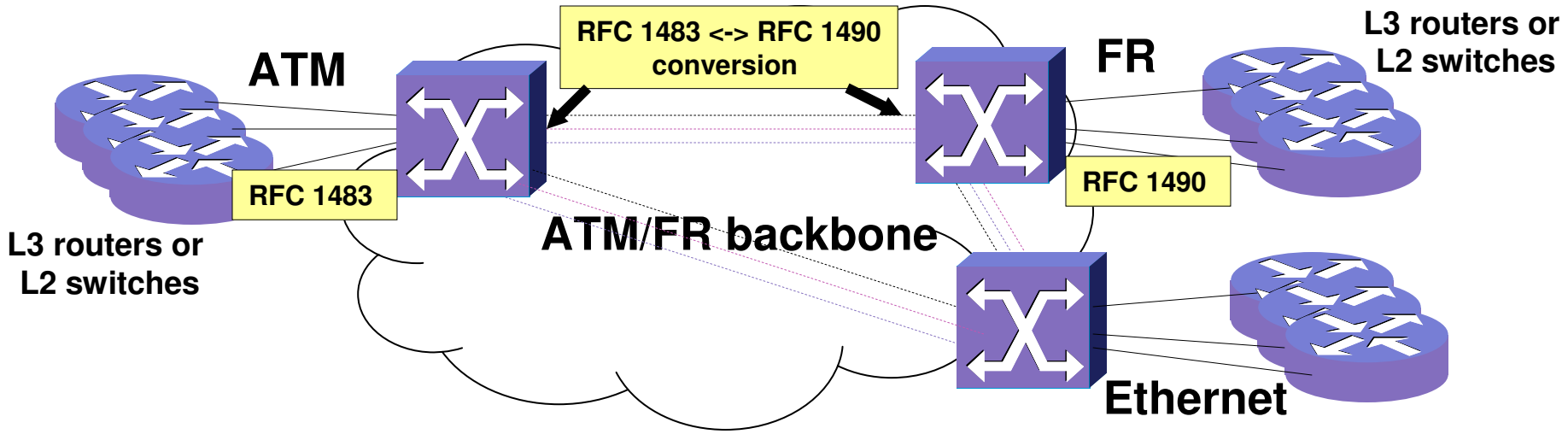
Layer 2 Service Interworking over MPLS



- Today ATM and FR networks carry mostly IP traffic
- Hub and spoke configurations involve high speed hub location and low speed spokes
- RFC1483/1490 bridged and routed interworking is required to provide conversion for different L2 protocols
- Fully meshed PVC architecture is required to provide L2 or L3 VPNs – O(n*2) PVC provisioning

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Existing FR/ATM Service Interworking

- RFCs 1483/2684 and 1490/2427 allow multiprotocol transport over ATM and FR networks
- FRF.8.2 FR/ATM interworking specifies multiprotocol identification translation
  - FR/ATM interworking is possible with preservation of the encapsulated information

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Layer 2 Service Interworking over MPLS

- L2 transport over MPLS is based today on the point-to-point approach
- Existing point-to-point solutions address only one L2 protocol at a time; i.e., no interworking at L2 is currently defined
- MPLS&FR Alliance currently working on specifying Ethernet/ATM/FR interworking over MPLS networks
  - Will allow interworking between different L2 endpoints
  - Allow the use of L2 endpoint technology that makes the most sense:
    - Best technology to meet BW and QoS requirements
    - Take advantage of tariffs and local loop availability

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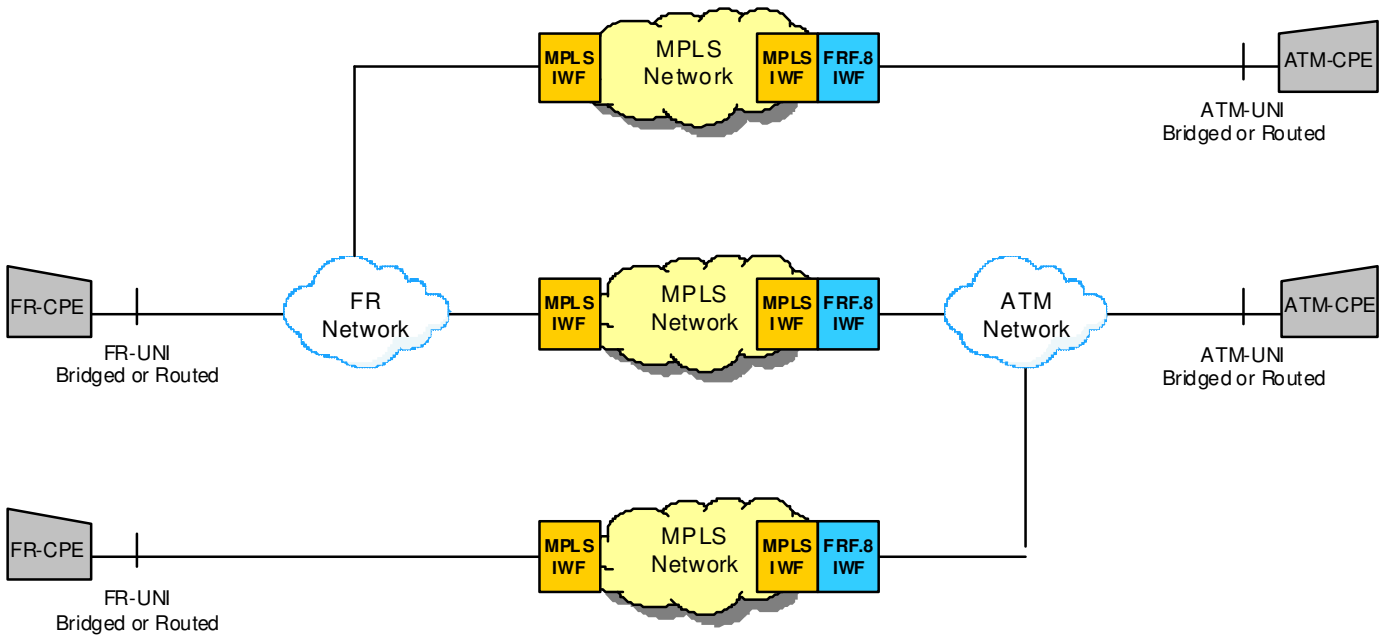
Layer 2 Service Interworking Cases



- **MPLS & FR Alliance working on three cases:**
  1. **General FR/ATM interworking with MPLS in the middle (see above)**
  2. **Bridged Ethernet over FR or ATM to Ethernet**
  3. **IP over FR or ATM to IP over Ethernet**

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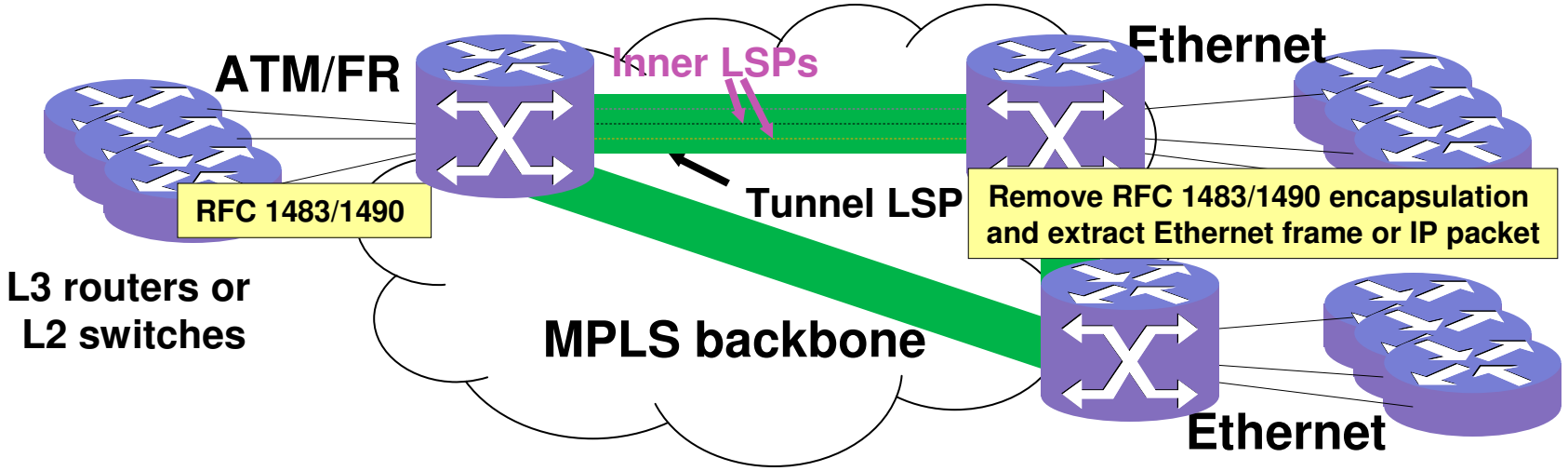
FR/ATM to Ethernet Interworking Using L2 VPN



- Point-to-point configuration
- Two cases:
  - Bridged Ethernet over FR or ATM is interworked with native Ethernet
  - IP over FR or ATM is interworked with IP over Ethernet (requires ARP Mediation)

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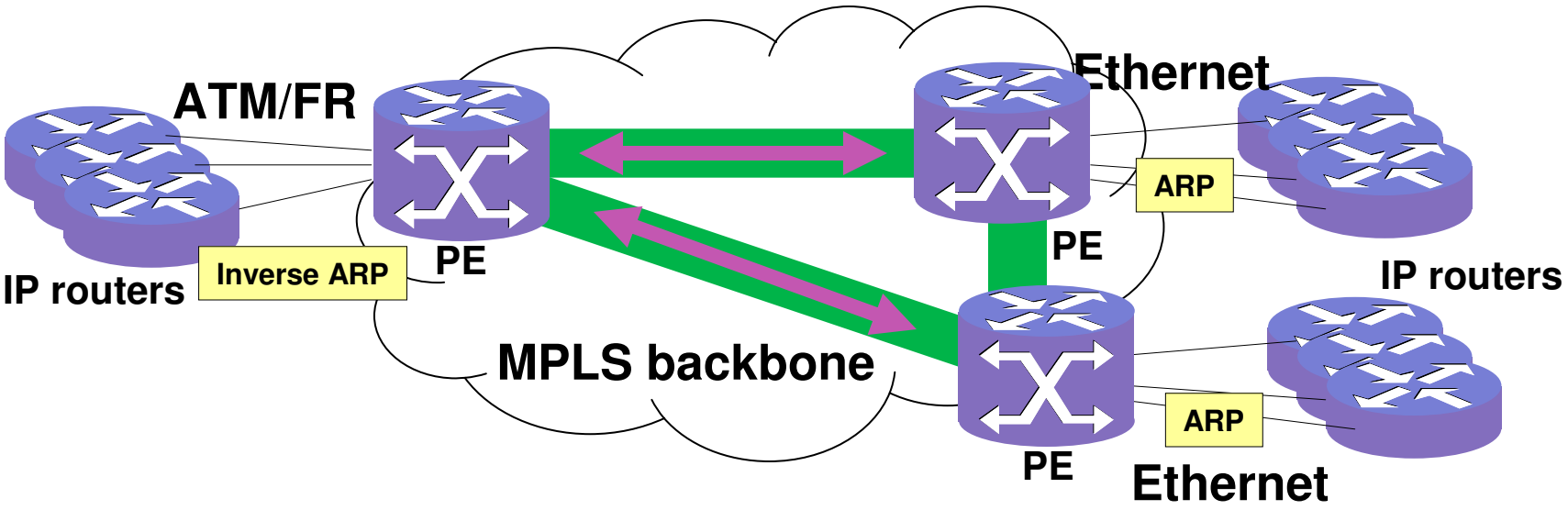
Address Resolution Protocol Mediation

- Different IP address resolution protocols are used depending on the access circuit L2 technology
- IP over Ethernet uses ARP as defined in RFC 826
  - Matches Ethernet MAC address with an IP address on Ethernet LANs
- IP over FR uses Inverse ARP as defined in RFC 2390
  - InARP is used for point-to-point technologies
  - Matches a pt-to-pt circuit with the IP address
- IP over ATM uses ATMinARP as defined by RFC 2225
  - Similar in functionality to FR InARP, but different packet format
- If two different technologies are used on the access circuits of the same connection, the address resolution protocols used at both circuit ends will not interoperate
- FRF.8.2 defines the mediation between RFCs 2225 and 2390
- Mediation between RFCs 826 and 2390 or 2225 is defined in draft-shah-ppvpn-arp-mediation-02.txt

ARP Mediation (cont.)



- PE performs ARP mediation function
  - Discovers attached CE addresses
  - Distributes learned IP addresses to the remote PEs
  - Notifies CE about learned remote CE IP addresses

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Standards Online

- Free documents:
  - IETF RFCs can be found at http://www.ietf.org/rfc/
  - IETF Internet Drafts can be found at http://www.ietf.org/internet-drafts/
  - MPLS Forum Interoperability Agreements can be found at http://www.mplsforum.org/
  - Frame Relay Forum Interoperability Agreements can be found at http://www.frforum.com/
- Documents requiring payment:
  - ITU-T recommendations can be found at http://www.itu.int (three free downloads per year per email address)

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