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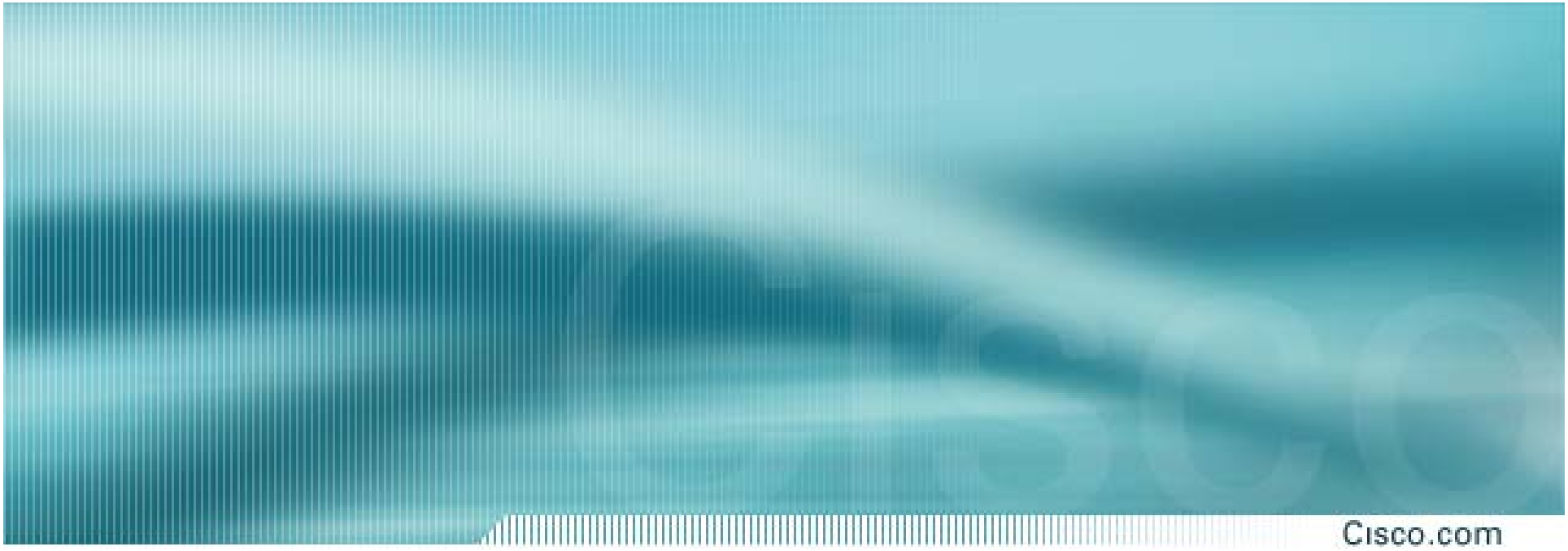

Design Principles for DSL-Based Access Solutions

Thomas Martin

Session SPL-211

Agenda

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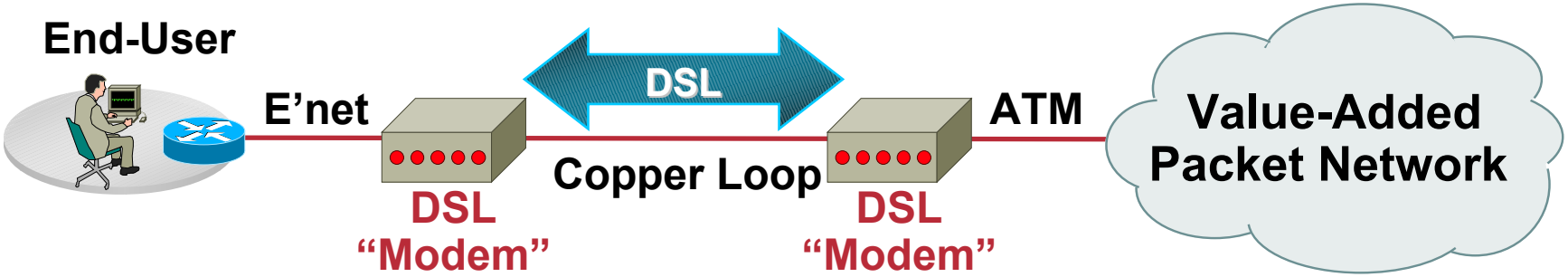
- Digital Subscriber Line Technologies
- Subscriber Connection Models
- Reaching the Services
- Case Studies
- Summary, Question and Answer

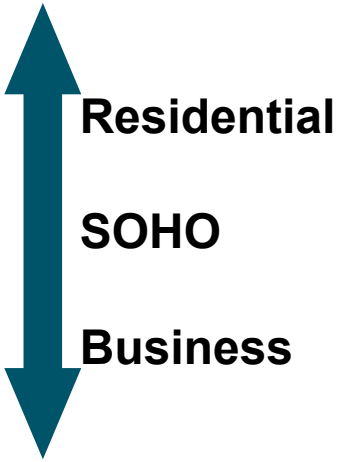
What is Digital Subscriber Line (DSL)?



- DSL is a pair of "modems" on either end of a copper wire pair
- DSL converts ordinary phone lines into high-speed data conduits
- Like dial, cable, wireless, and E1, DSL by itself is a transmission technology, not a complete end-to-end solution
- End-users don't buy DSL, they buy services such as high-speed Internet access, intranet, leased-line, voice, VPN, and video on demand

DSL Modem Technology

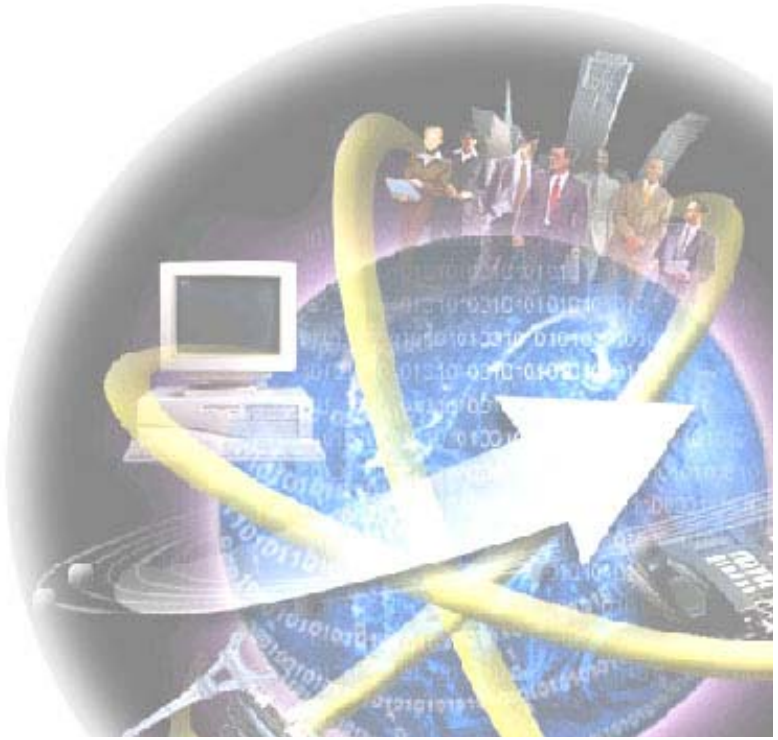
DSL Service	Max. Data Rate Down/Uplink (bps)	Analog Voice Support	Max. Reach (km-feet)
VDSL–Very High Bit Rate	25M/1.6M or 8M/8M	Yes	.9–3,000
ADSL–Asymmetric	8M/1M	Yes	5.5–18,000
G.SHDSL	2.3M/2.3M.	No	8.15–26,000



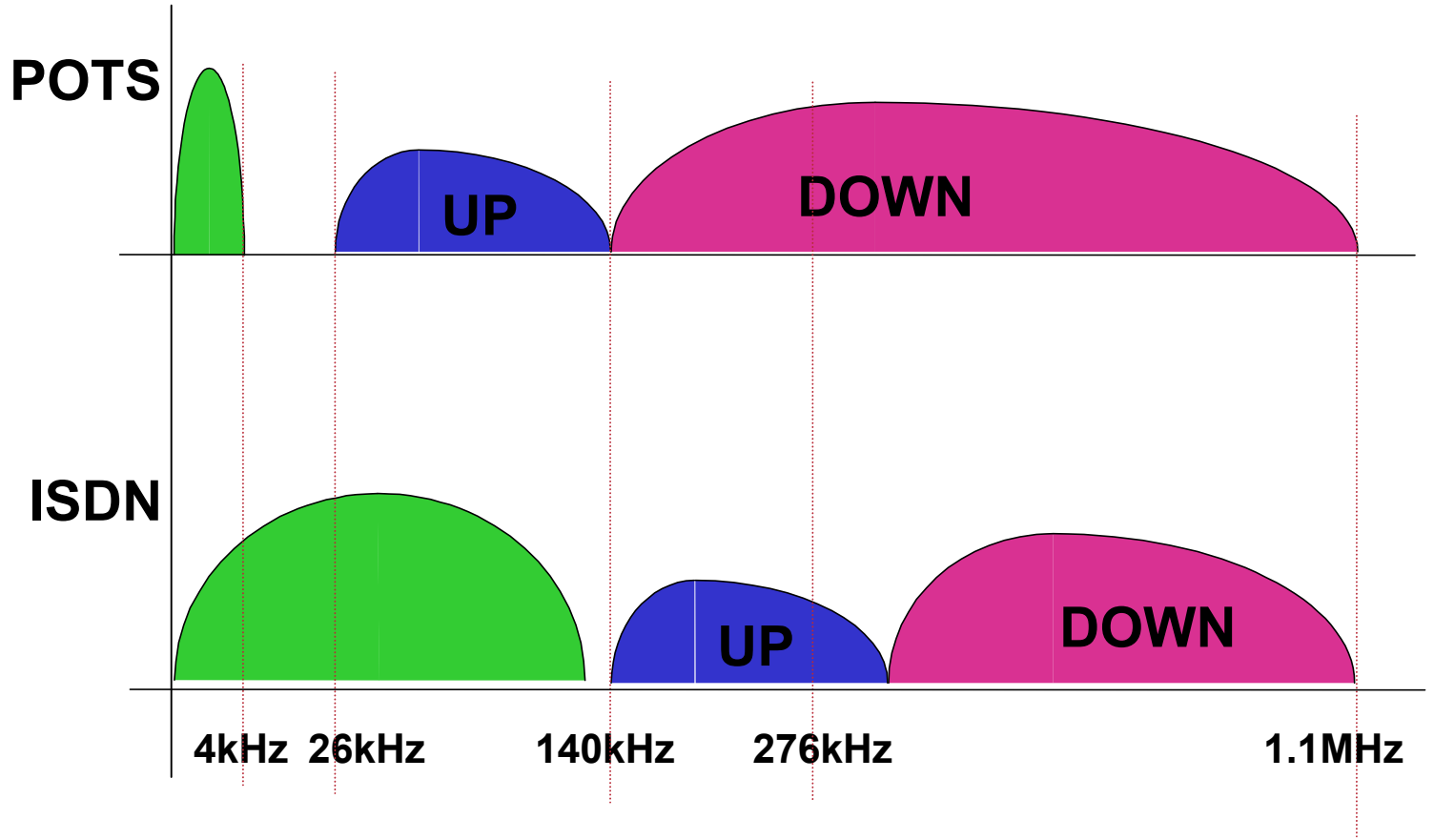
- Trade-off is reach vs. Bandwidth
- Reach numbers imply “clean copper”
- Different layer 1 transmission technologies, need a common upper protocol layer to tie them together

ADSL

- Line sharing – use existing POTS & ISDN lines (small offices and telecommuters)
- Higher downstream bandwidth for video-on-demand and distance learning
- Sufficient upstream bandwidth for videoconferencing
- Can provision for symmetric service with speeds typically up to 640 kbps

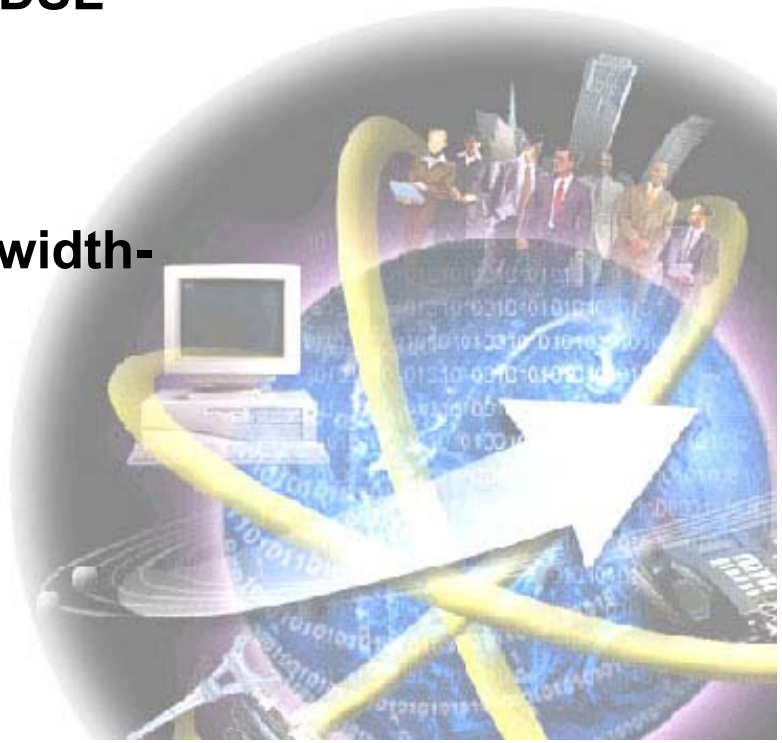


ADSL over POTS or ISDN



G.SHDSL

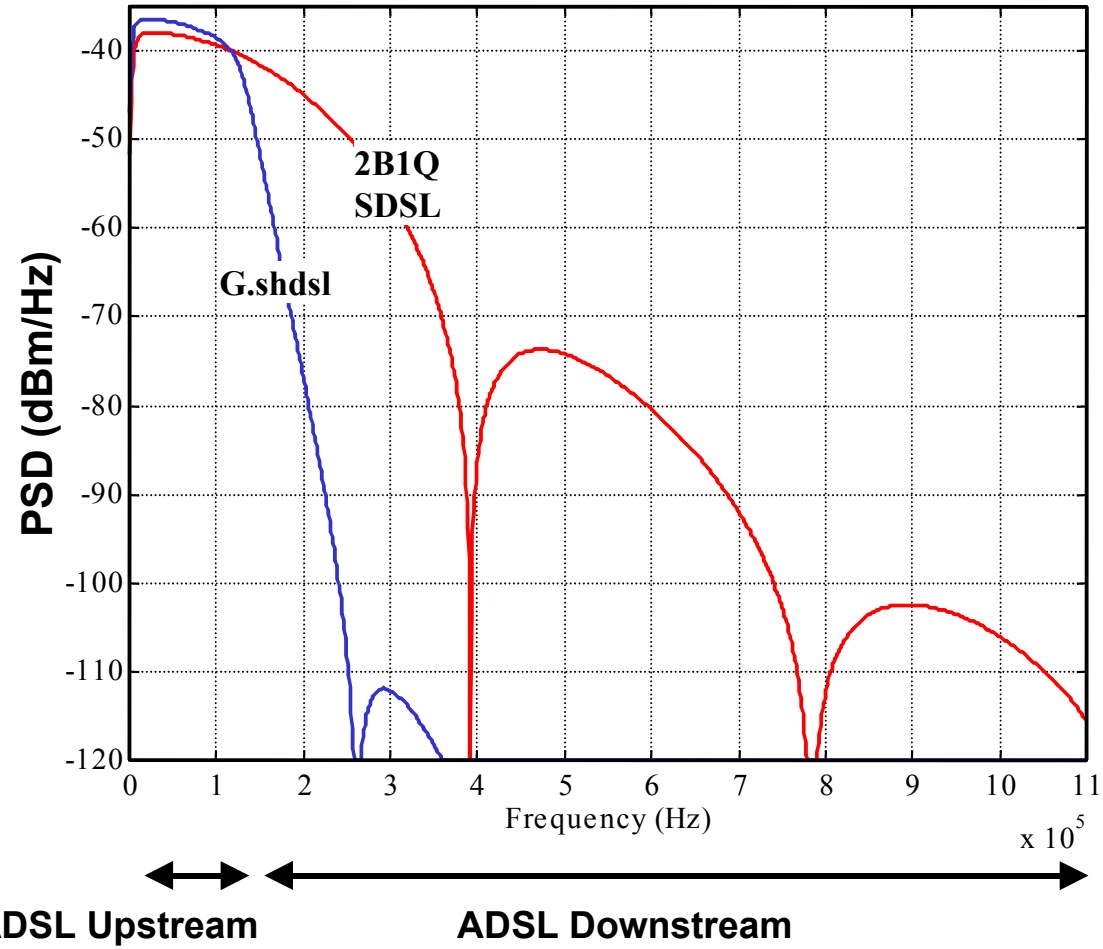
- ITU standard
- Symmetrical service up to 2.3 mbps
- Multirate (192kb/s - 2.3mbps) unlike HDSL
- Spectrally friendly (TC-PAM) with ADSL
- 30% longer reach than SDSL
- Repeatable
- More upstream bandwidth for bandwidth-intensive applications
- Affordable T1/E1 alternative



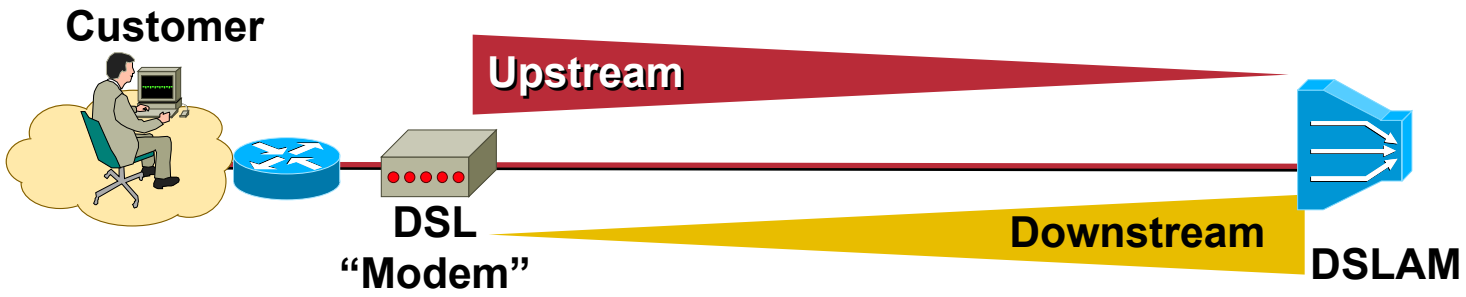
G.SHDSL
Spectral Compatibility

- TC PAM line coding
  - Narrower freq. Band reduces possibility of interference
- Improved Filtering
  - Sharper rolloff of unused bandwidth

PSD: G.shdl vs. SDSL
(768 kb/s example)



Crosstalk



- Downstream power is highest at the DSLAM and lowest at the CPE
- Upstream power is lowest at the DSLAM and highest at the CPE
- If these signals are in different parts of the frequency spectrum then they will not crosstalk, otherwise there will be interference from one signal to the other

Basic xDSL Network Components

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DSL CPE (customer premise equipment) or

ATU-R (ADSL Transmission Unit-Remote)

- PC NICs, bridge/routers, enterprise routers

DSL access multiplexer) or

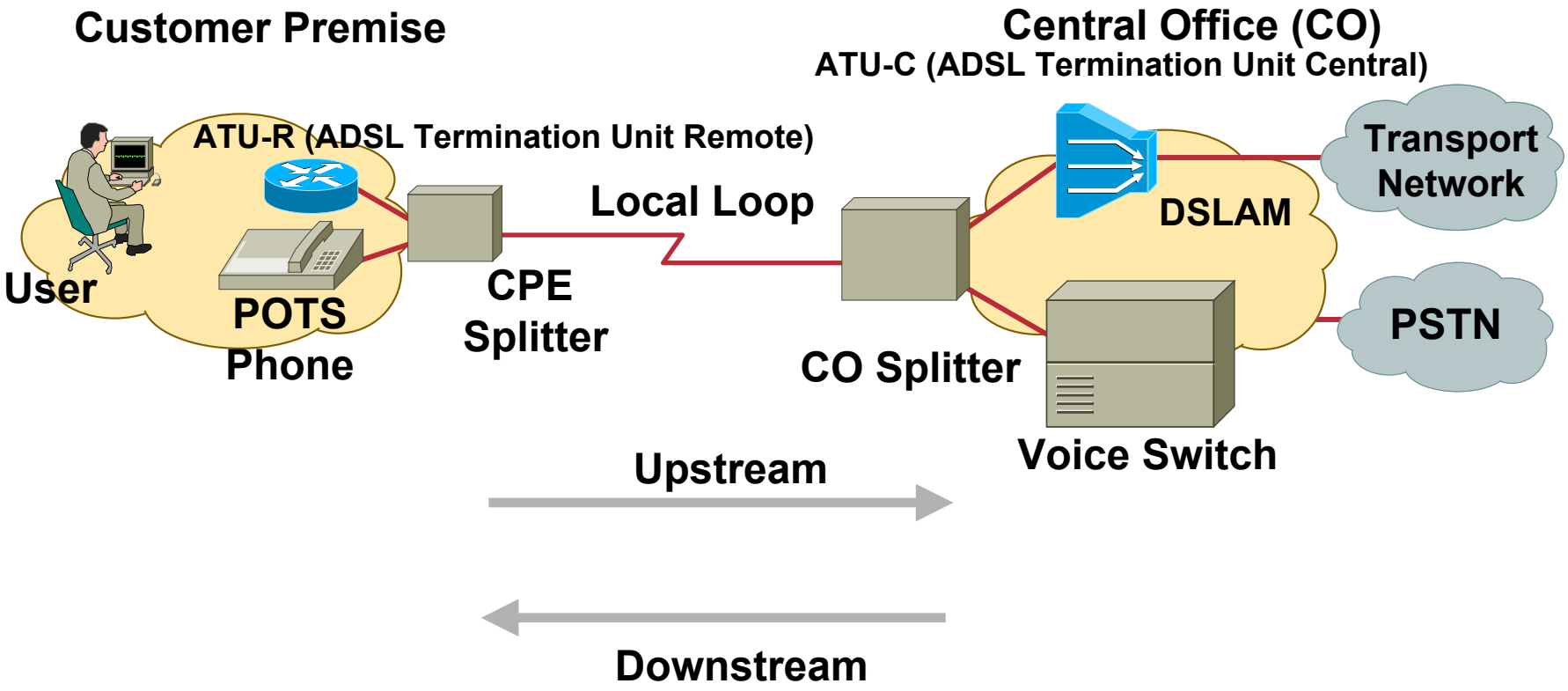
ATU-C (ADSL Transmission Unit-Central)

- Concentrates individual subscriber lines from CPE

Aggregator/service selection gateway

- Concentrates ATM feeds (E1,E3,STM-1) from DSLAMs
- PPP termination, layer 2 and 3 service selection
- On-demand, personalized services
- Accounting and billing

DSL Forum Reference Model



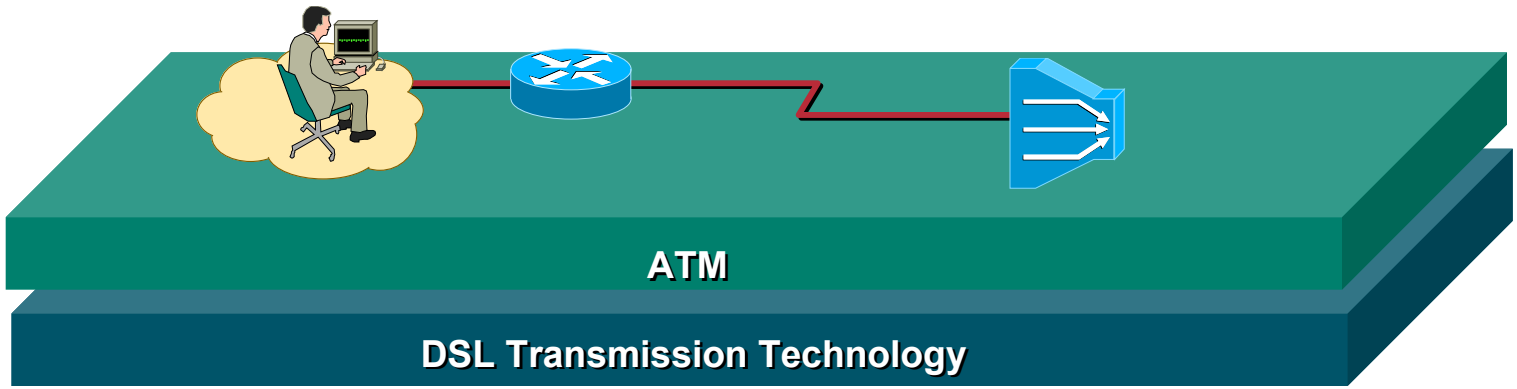
Like Dial, Cable, Wireless, and E1, DSL Is a Transmission Technology

Layer One Considerations

- Reach and quality of copper
- Power dissipation
- Signal to noise ratio
- Error correction algorithms
- Loop testing

ATM Over xDSL

- **Path between CPE and DSLAM uses ATM**
  - **Multiple connection multiplexing**
  - **Built in QoS(quality of service) /CoS (class of service) for newer services**
  - **Layer 2 in the central office**
  - **Proven technology**



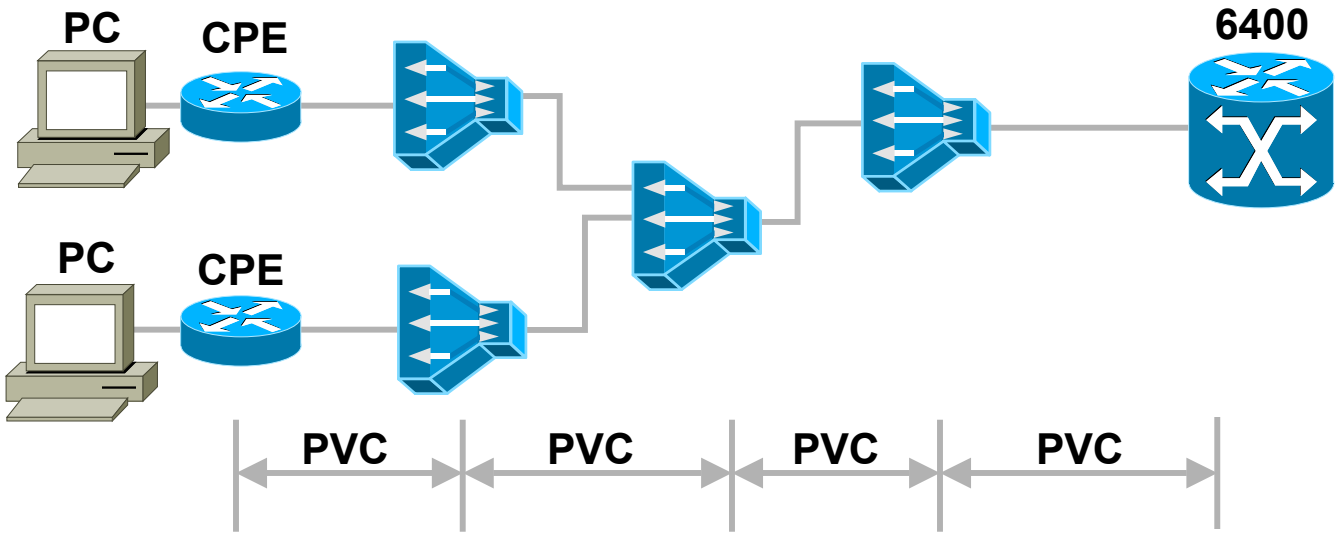
Virtual Channels (VC)

- **PVC (Permanent Virtual Channel)**
  - **Manual mapping of inbound and outbound**

Command syntax:

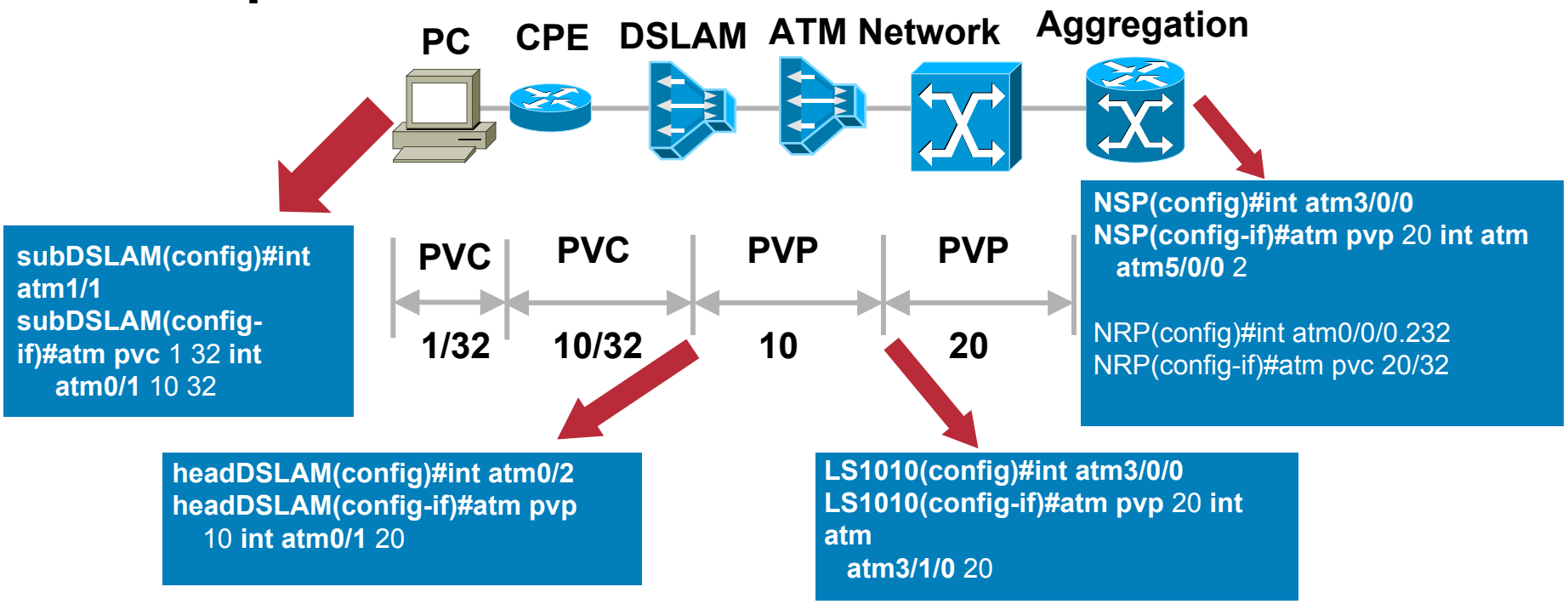
6260(config)#int ATM1/4

6260(config-int)#atm pvc 1 32 int ATM0/1 2 32



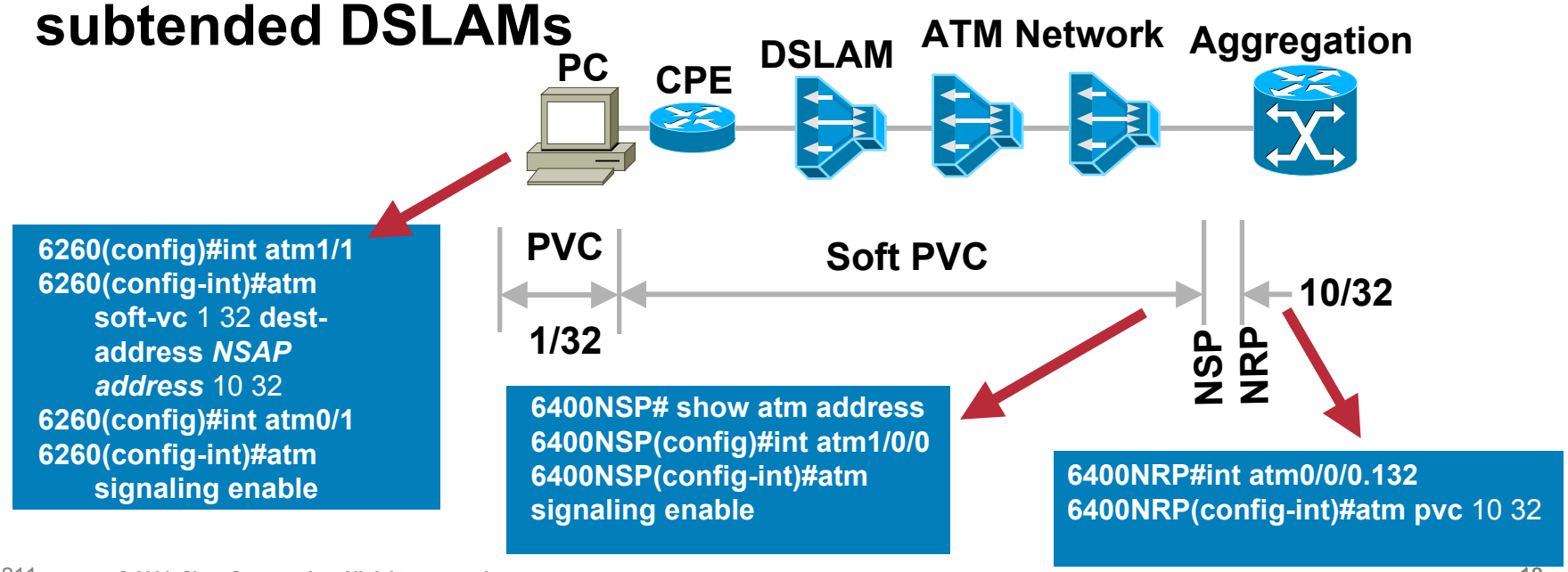
VP Switching

- Allows provisioning of one VP vs. multiple VC cross connects
- Simplifies subscriber provisioning on subtended DSLAMs
- VC depletion not a factor

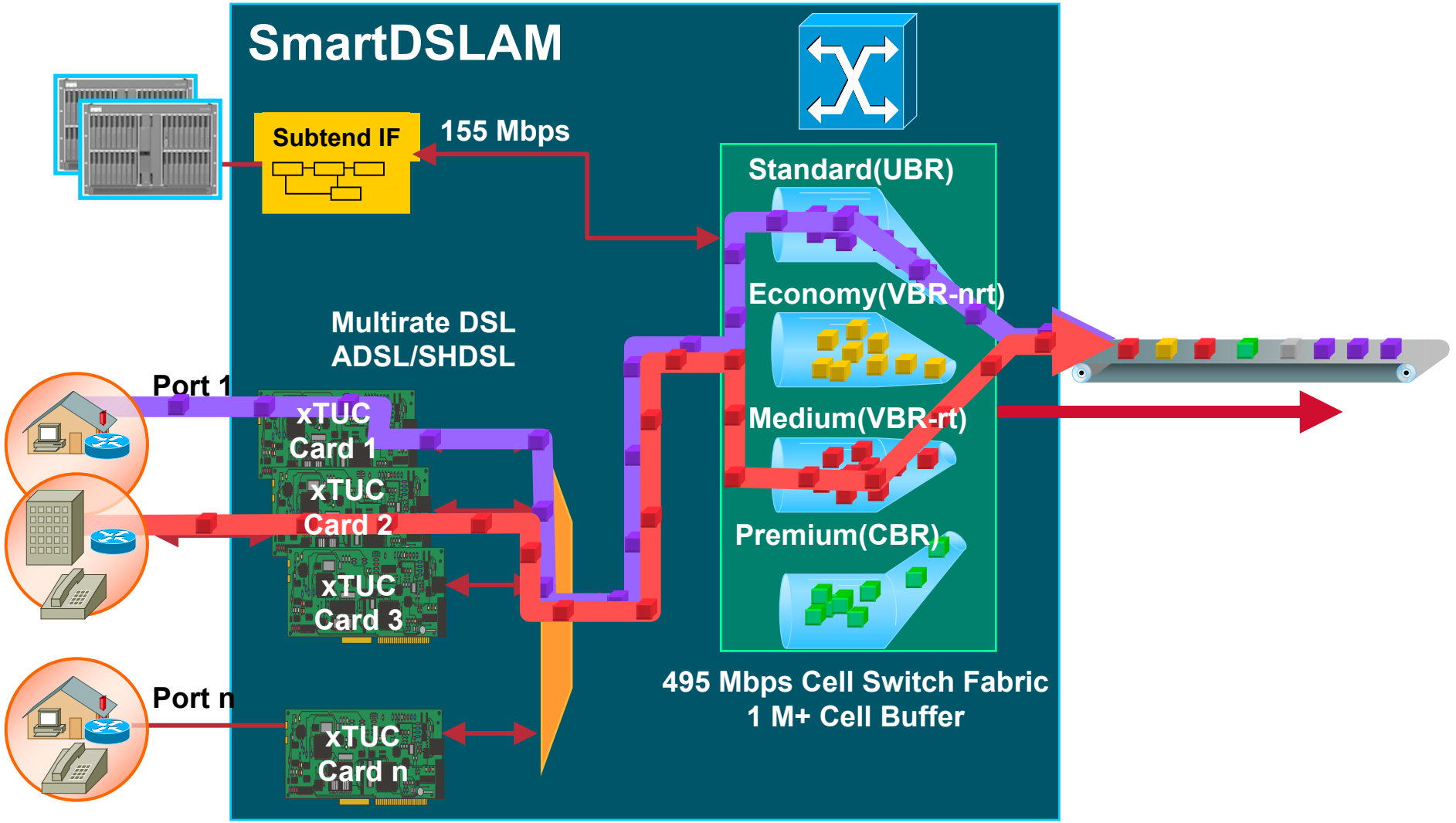


Virtual Channels

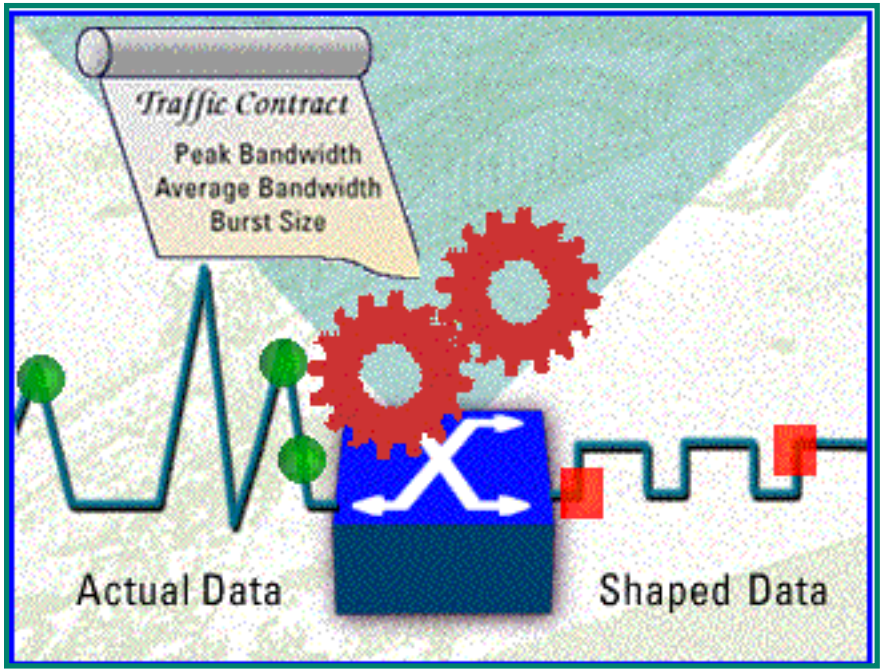
- **Soft PVC's**
  - **Reduce manual configuration steps of PVC at each hop**
  - **Soft PVC will be established only if neighbors discover each other –PNNI signaling support required**
  - **Subscriber provisioning is easier on subtended DSLAMs**



Cisco DSLAM Architecture

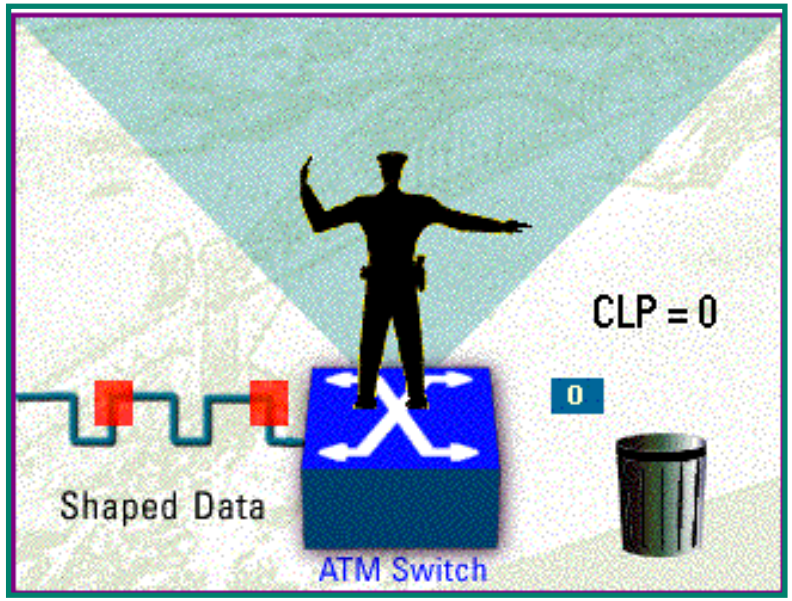


ATM QoS—Traffic Shaping



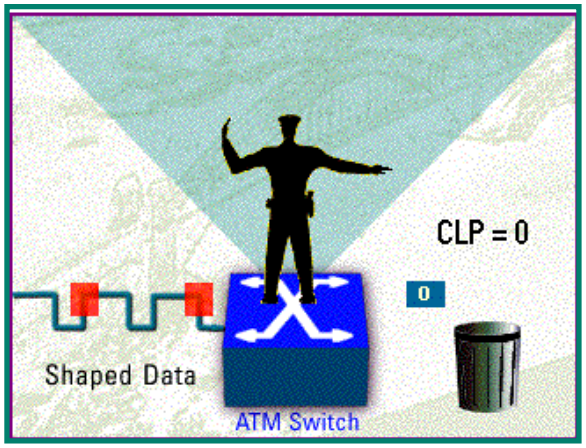
- Used to adhere to the ATM traffic contract
- Uses queues to constrain data bursts, limit peak data rate, and smooth jitter so that traffic will fit within the promised envelope

ATM QoS—Traffic Policing



- Switch measures traffic flow and compares with traffic contract
- If outside of traffic contract, it can set the cell loss priority (CLP) of the offending cells
- Setting the CLP bit makes the cells eligible to be dropped when the switch is congested

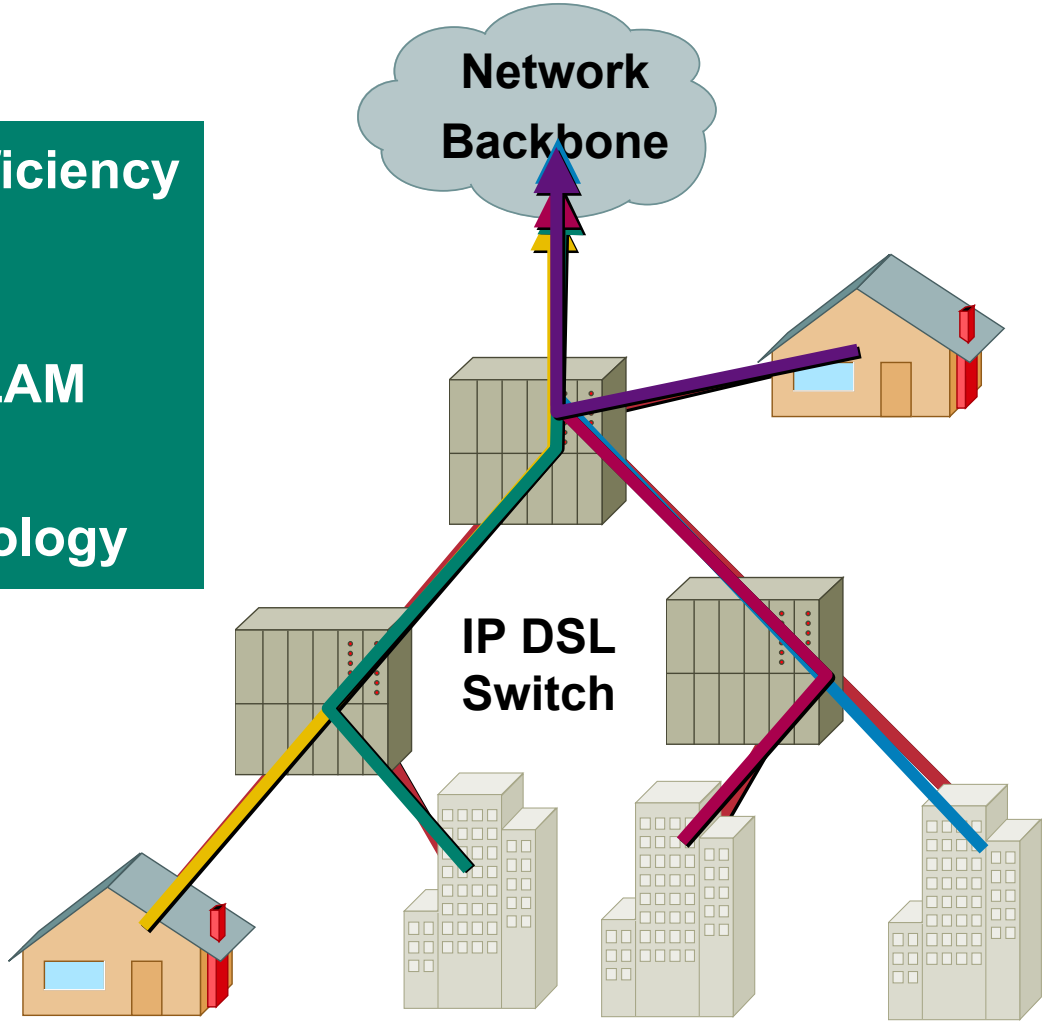
ATM QOS-
Traffic Classes & Priority Queuing



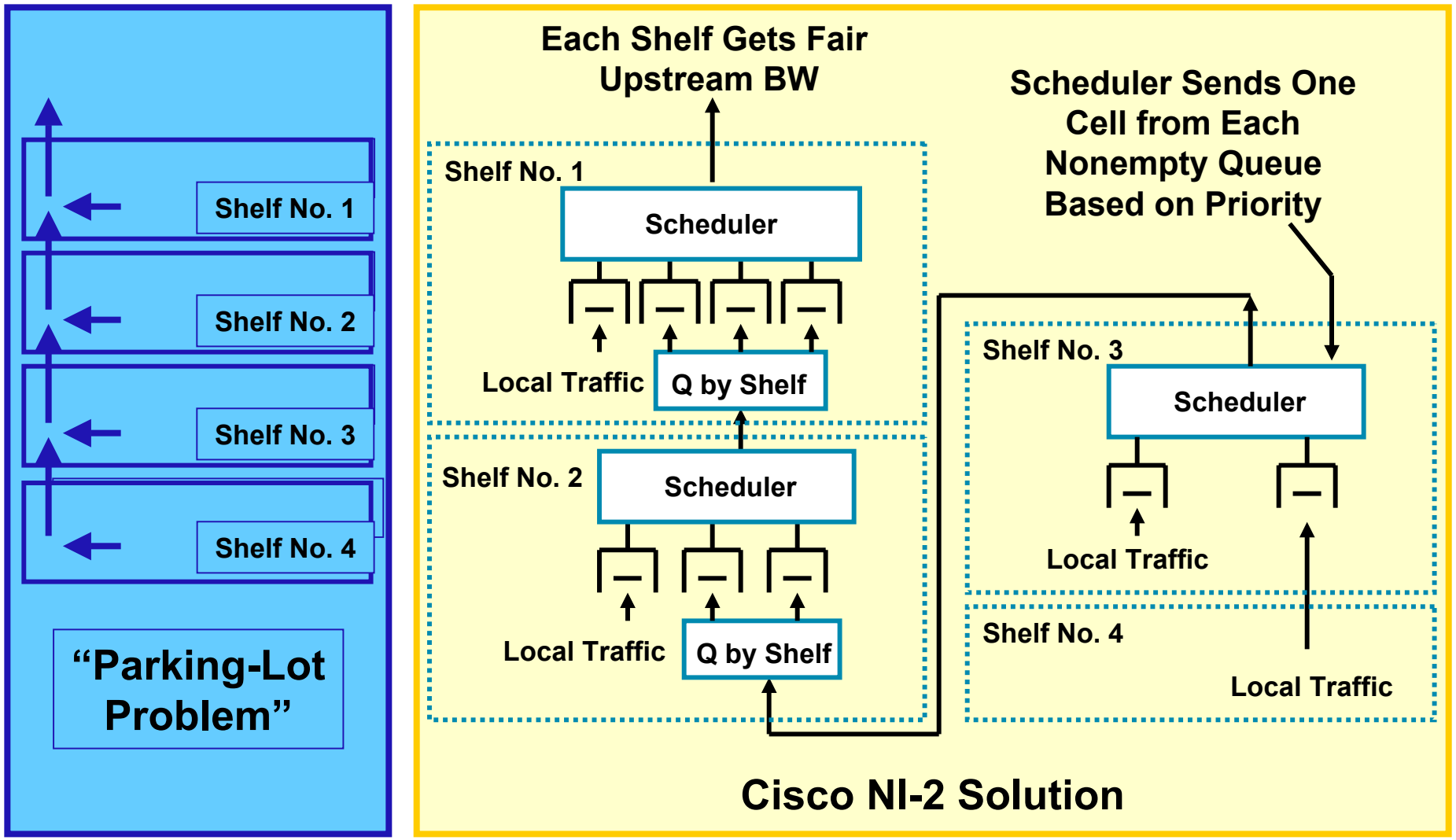
- The switch offers four priority queues, programmable in terms of size and QOS:
  - CBR - for rate-limited services that need guaranteed bandwidth and bounded delay
  - VBR-rt - for delay sensitive voice and video services
  - VBR-nrt - for high-priority data services
  - UBR - for low-priority data services
  - EFCI marking for ABR service support

Subtending

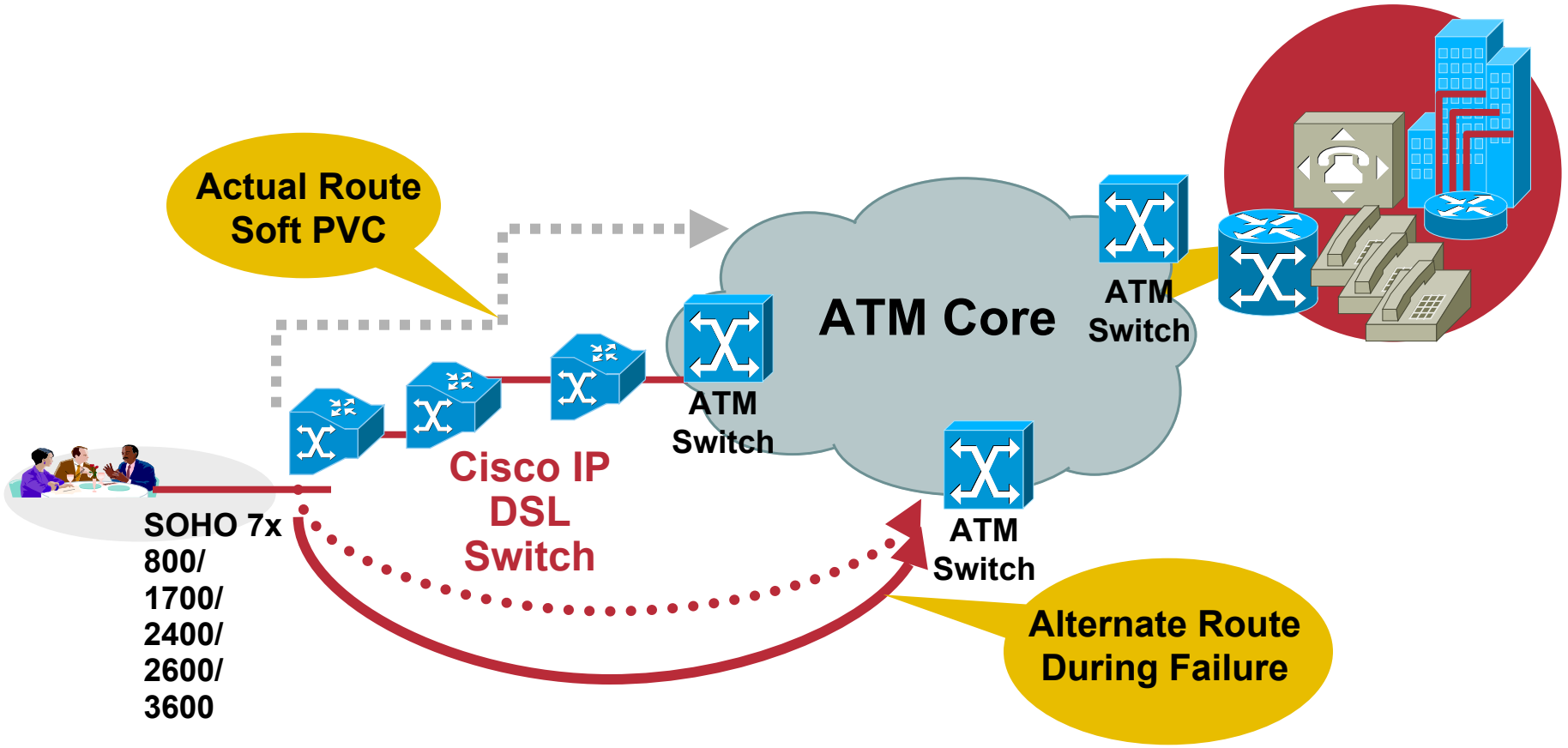
- Increased operational efficiency by sharing the same trunk (STM-1/E3)
- Subtending up to 13 DSLAM (3328 ports) per WAN I/F
- Daisy-Chain or Tree Topology



Subtending Fairness



PNNI Redundancy



Things to Consider at Layer Two

- Ease of subscriber provisioning
- Number of VC's to be switched through the core
- Avoid VC depletion
- Re-routes of VC and availability
- Where and when to do prioritization, policing and shaping, class of service

Agenda

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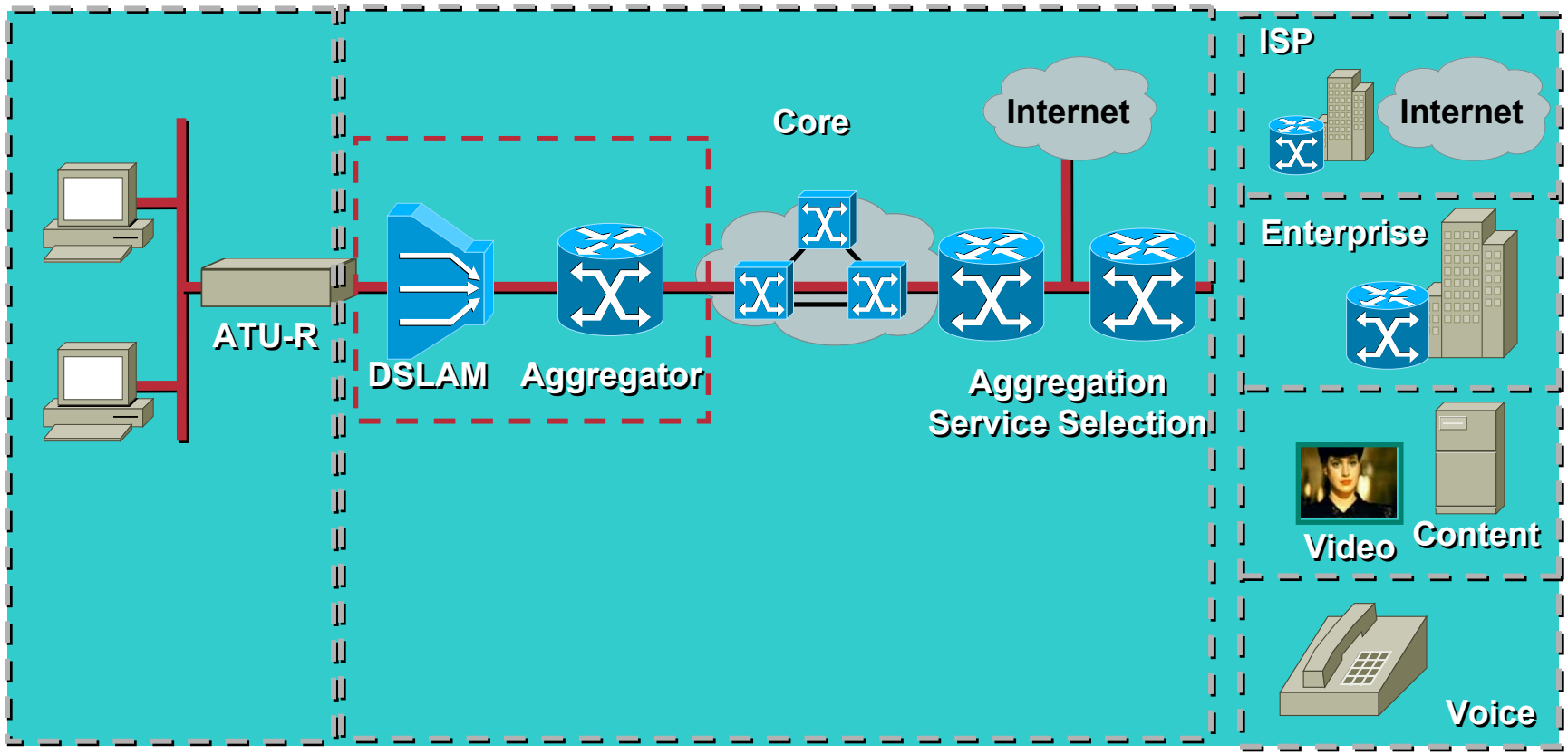
- Digital Subscriber Line Technologies
- Subscriber Connection Models
- Reaching the Services
- Case Studies
- Summary

Functional Segments



CPE; Customer Premise Equipment
NAP; Network Access Provider
NSP; Network Service Provider

Subscriber Connection Models

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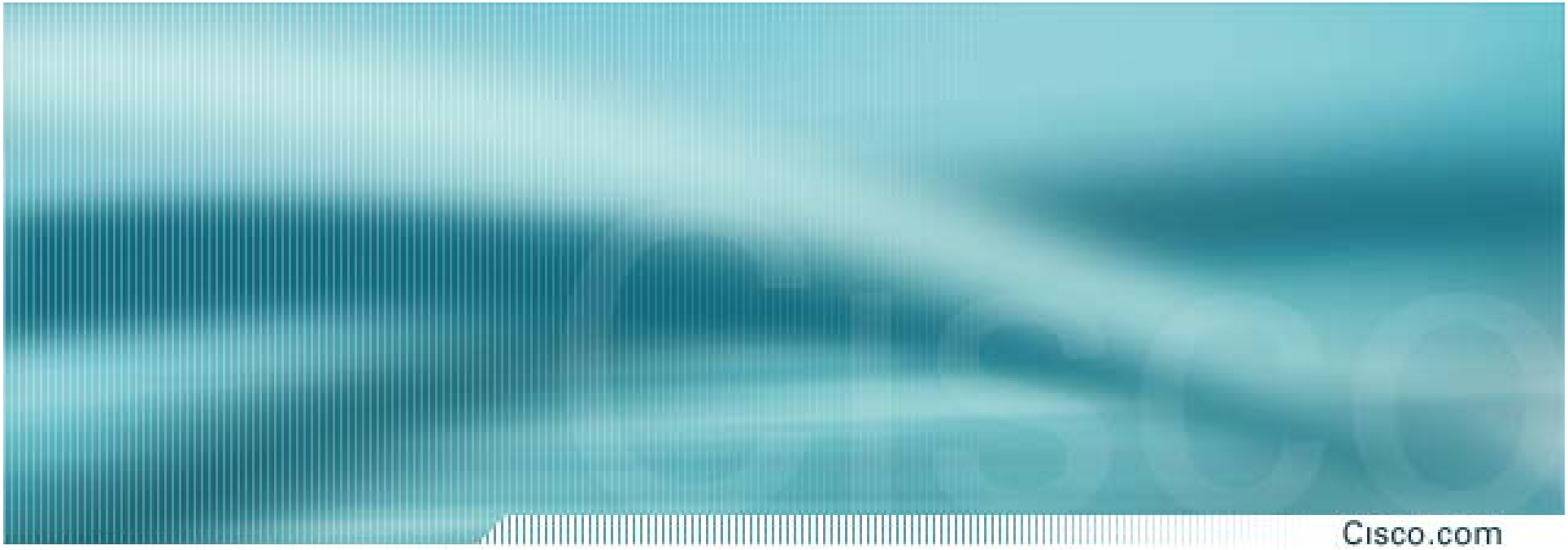
Bridging / RBE	
PPPoE	
PPPoA	
RFC1483 IP routed	

IP Over AAL5

- **Multiple methods exist for encapsulating IP packets in AAL5 PDUs (Protocol Data Units)**
  - **RFC 1483 (MPOA) bridging and routing (RFC 2684)**
  - **PPP over ATM (RFC 2364)**
  - **PPP over Ethernet (RFC 2516)**
  - **RFC 1577 (classical IP over ATM)**
- **Different approaches yield different service offerings, architecture choices**



RFC1483(2684)bridging

(based on RFC1483 bridging)

Bridging Implementation

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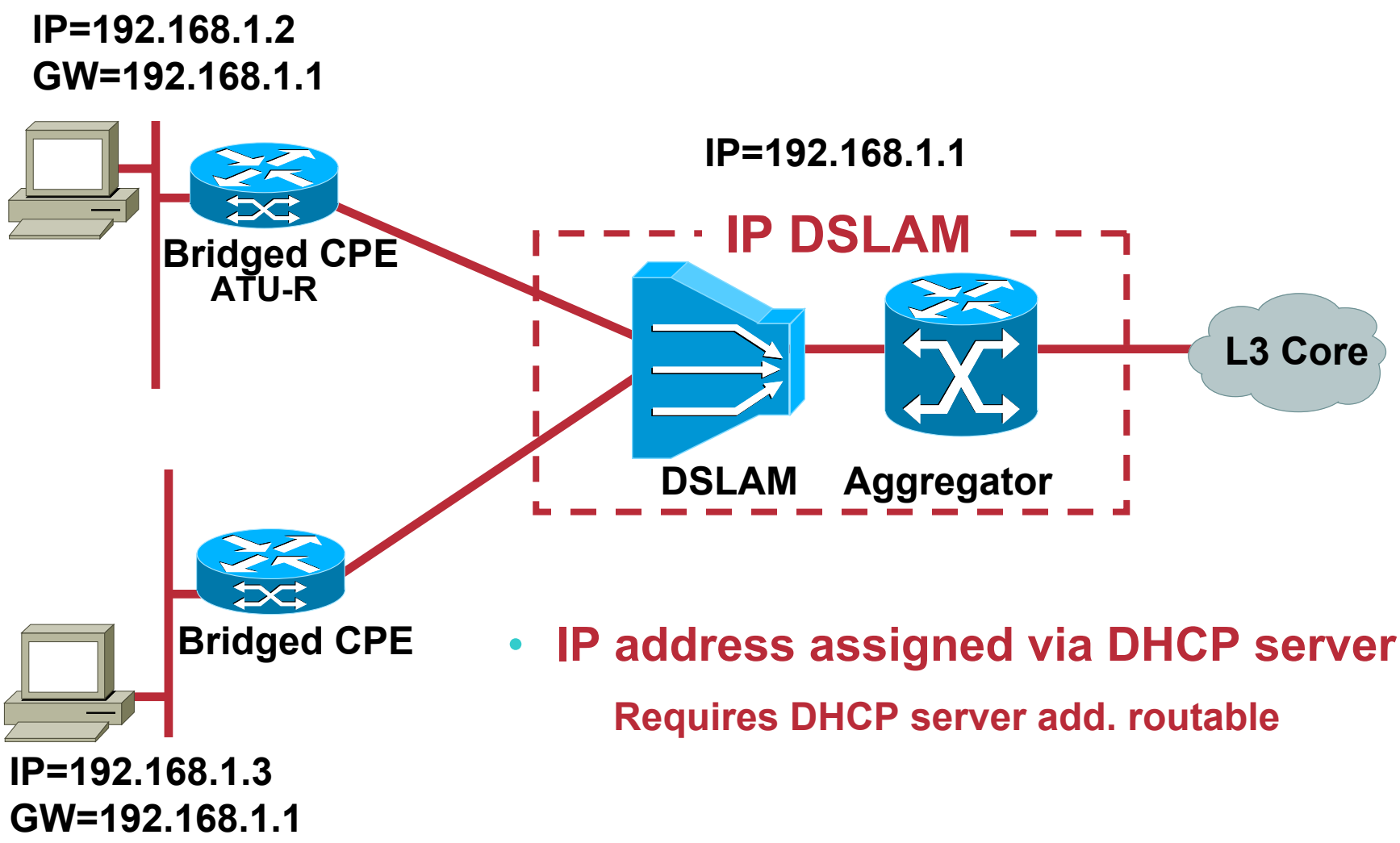
- CPE—RFC 1483 (now RFC 2684) bridging
- Aggregation/termination
  - Integrated Routing Bridging (IRB)
  - Routed Bridge Encapsulation (RBE)
- Core
  - Usually ATM, if no aggregation used
  - With VC aggregation, typically IP or IP+ATM

Typical RFC1483 bridging Architecture



- IP address assigned via DHCP server
  - Requires DHCP server add. routable

How Does RFC1483 Bridging Work?

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- Subscriber traffic is carried in a BPDU (Bridged Protocol Data Unit)
- The ATM interface is treated as a bridged interface

Protocol Stack—RFC 1483 Bridging

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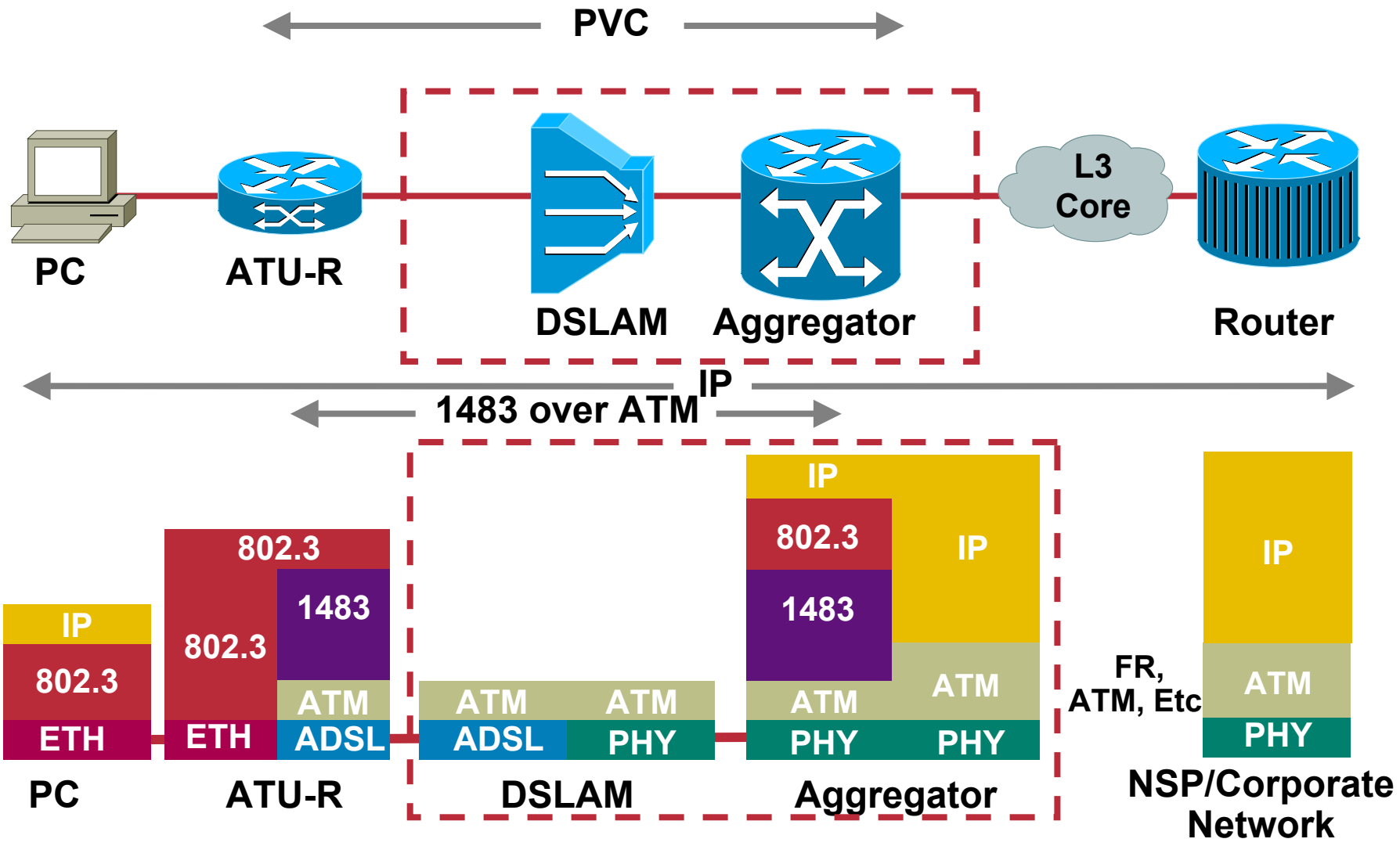


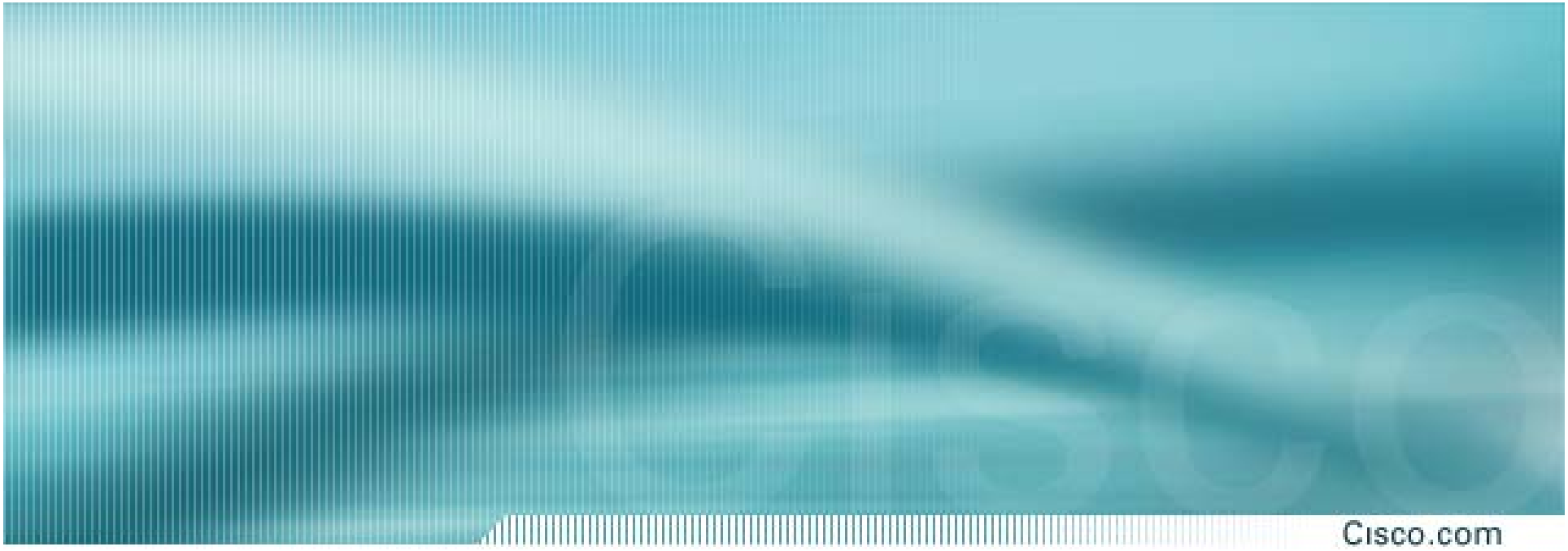
Bridging - Pros & Cons

PROS

- Simple to understand
- Minimal CPE configuration
- Multiprotocol support (IP/IPX/..)

CONS

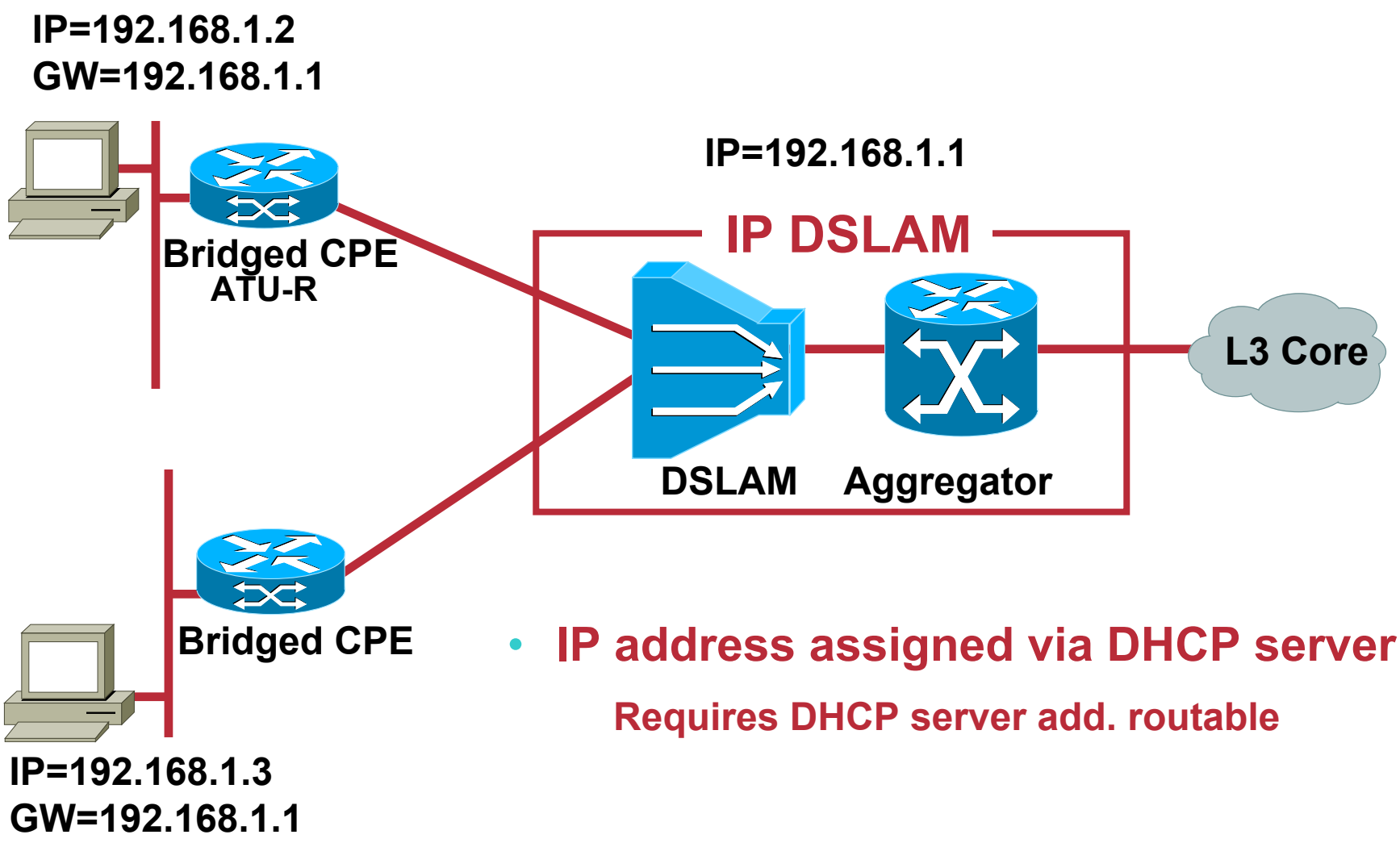
- heavy use of broadcasts - prone to broadcast storms
- No accounting and Authentication
- In wholesale Scenario, NAP needs to provide IP address.
- Bridgegroup limitation in IOS (255)
- IP Address hijacking



Route Bridge Encapsulation
RBE

(based on RFC1483 bridging)

Typical RBE Architecture



- IP address assigned via DHCP server
  - Requires DHCP server add. routable

How Does RBE (Routed Bridge Encapsulation) Work?

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- Subscriber traffic is carried in a BPDU (Bridged Protocol Data Unit)
- The routed-bridge ATM interface is treated as a routed interface;
- For packets originating from the subscriber end
  - Ethernet header is removed
  - Packet forwarded based on Layer 3 information
- For packets destined to the subscriber end
  - Ethernet Header applied
    Destination IP address is checked on the packet
  - Outbound interface is determined from routing table
  - ARP (Address Resolution Protocol) table is checked for the destination Mac address, if none found than ARP request sent out on the destination interface only

RBE IP Address Management

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- IP addresses provided by DHCP
  - Server can be
    - On NAP network
    - On NSP network
- If using DHCP relay, the remote server must be reachable and must have a return route

RBE - Pros & Cons

PROS

- Highly Scalable and Better Performance than bridging(IRB).
- Avoids IP Hijacking, ARP Spoofing and Broadcast Storms.
- Efficient Way to control no. of hosts behind CPE
- Configuration- less CPE
- Support existing Bridged CPE.
- Simple Implementation/ Provisioning
- L3 Service Selection (SSG/SSD)

CONS

- Consumes more IP address if used with numbered Interfaces
- No accounting (unless using L3 SSG) and Authentication
- In wholesale Scenario, NAP needs to provide IP address.
- No CPE management unless IP Add is provided to the CPE

When To Use RBE/Bridging?

- Bridged CPE's are the CPE's of choice for residential services, no management required
- If the ATU-R is very simple and can only perform RFC1483 (now RFC 2684) Bridging.
- The NAP/NSP does not want to maintain the client software on the subscriber computer.
- Only one PVC from the Subscriber CPE to the NAP. No requirement for routing on multiple PVC's.

PPP (Point to Point Protocol) Implementation

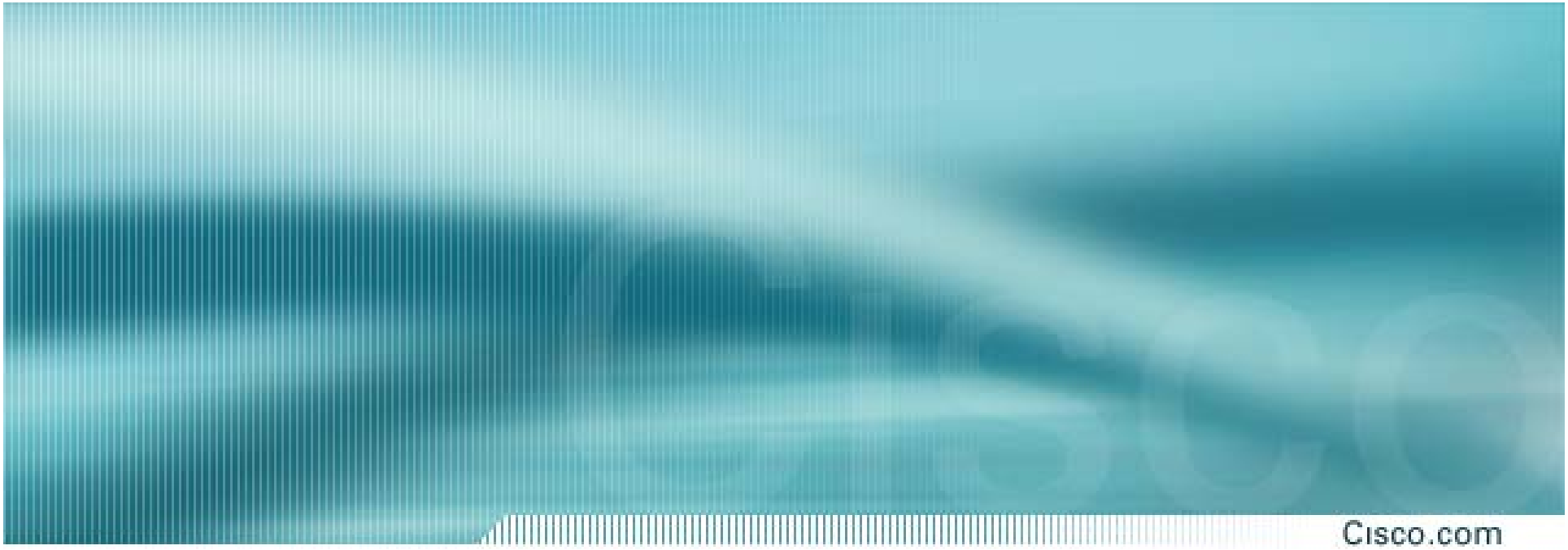
- Three access methods:
- Subscriber

  PPPoE, PPPoE, L2TP client
- Aggregation

  PPP sessions terminated

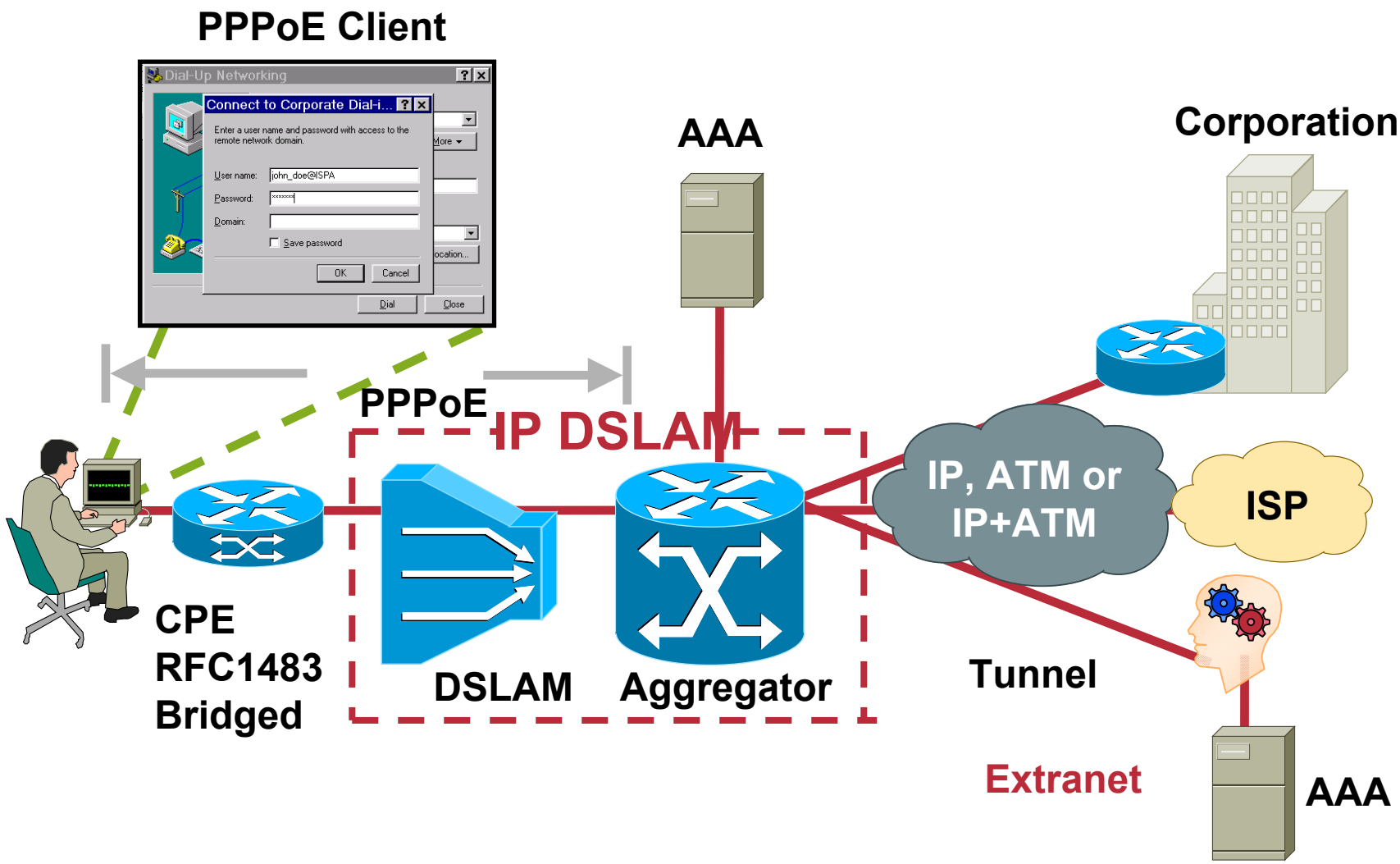
  PPP sessions tunneled over to NSP
- Core

  End–to–end ATM PVC, PPP terminated at NSP IP, ATM or IP+ATM; (L2TP, L2F, MPLS/VPN)

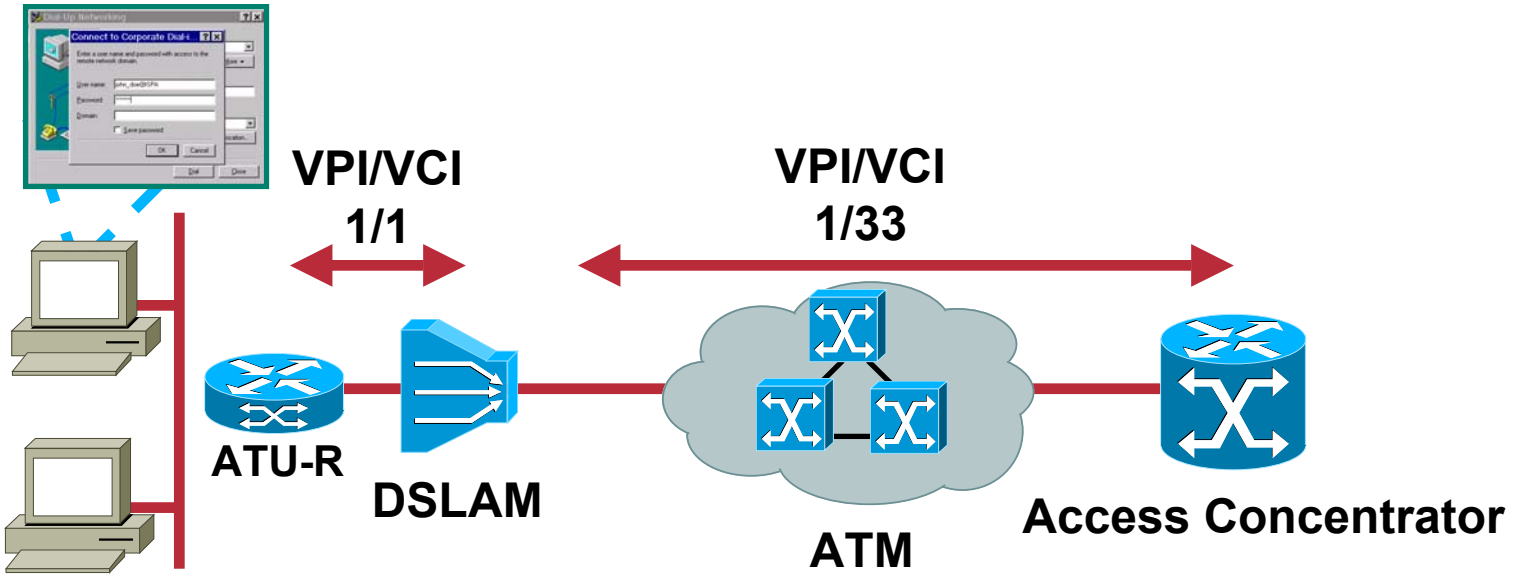


PPP over Ethernet
PPPoE

Typical PPPoE Architecture



How Does PPPoE Work?



PADI (PPPoE Active Discovery Initiation)

PADO (PPPoE Active Discovery Offer)

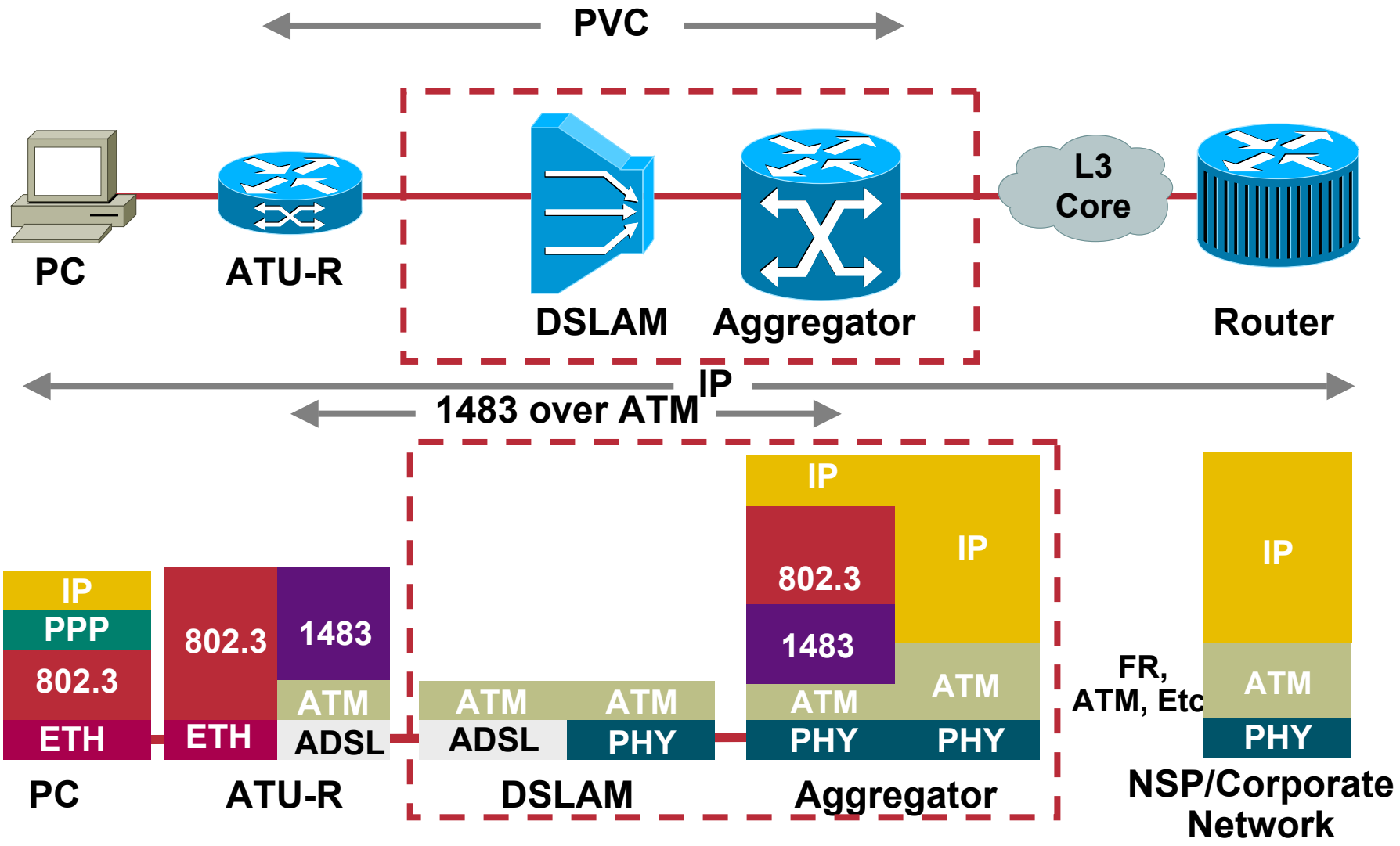
PADR (PPPoE Active Discovery Request)

PADS (PPPoE Active Discovery Session) ID

LCP(Link Control Protocol)/IPCP (IP Control Protocol)

Rfc 2516;
Ethernet Traffic Is
Bridged from the PC
Host to the Access
Concentrator

Protocol Stack—PPP Over Ethernet



PPPoE IP Address Management

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- **Same as PPP in dial mode**

  Address can be assigned to host by NAP (Network Access Provider) if session terminated, or by NSP (Network Service Provider) if tunneled

- **IP addresses assigned by RADIUS**

  Local or proxy

- **IP address assigned from pool**

  Local or from radius

- **The Ethernet NIC on the PC does not need an IP address to start the PPPoE session**

PPPoE - Pros & Cons

PROS

- Configurationless CPE
- Support existing Bridged CPE
- Multiple Sessions Per VC
- Per Session Authentication and Accounting
- NAP can offer VPN Services using PTA-MD or L2TP Tunneling.
- Service Selection possible at subscriber CPE and also support for Web Selection
- Oversubscription possible by enabling idle and session timeouts

CONS

- Requires Client Software on the hosts, increases maintenance
- Sparse PPPoE Client support for Non Windows based Operating Systems

When to Use PPPoE

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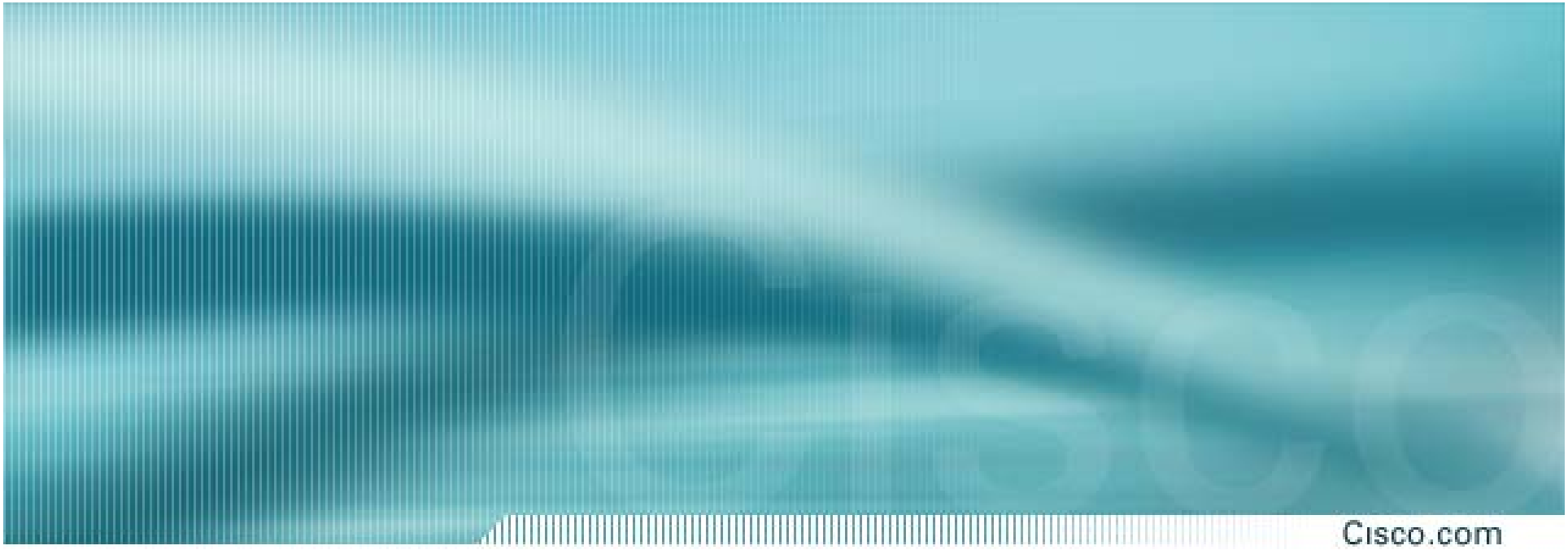
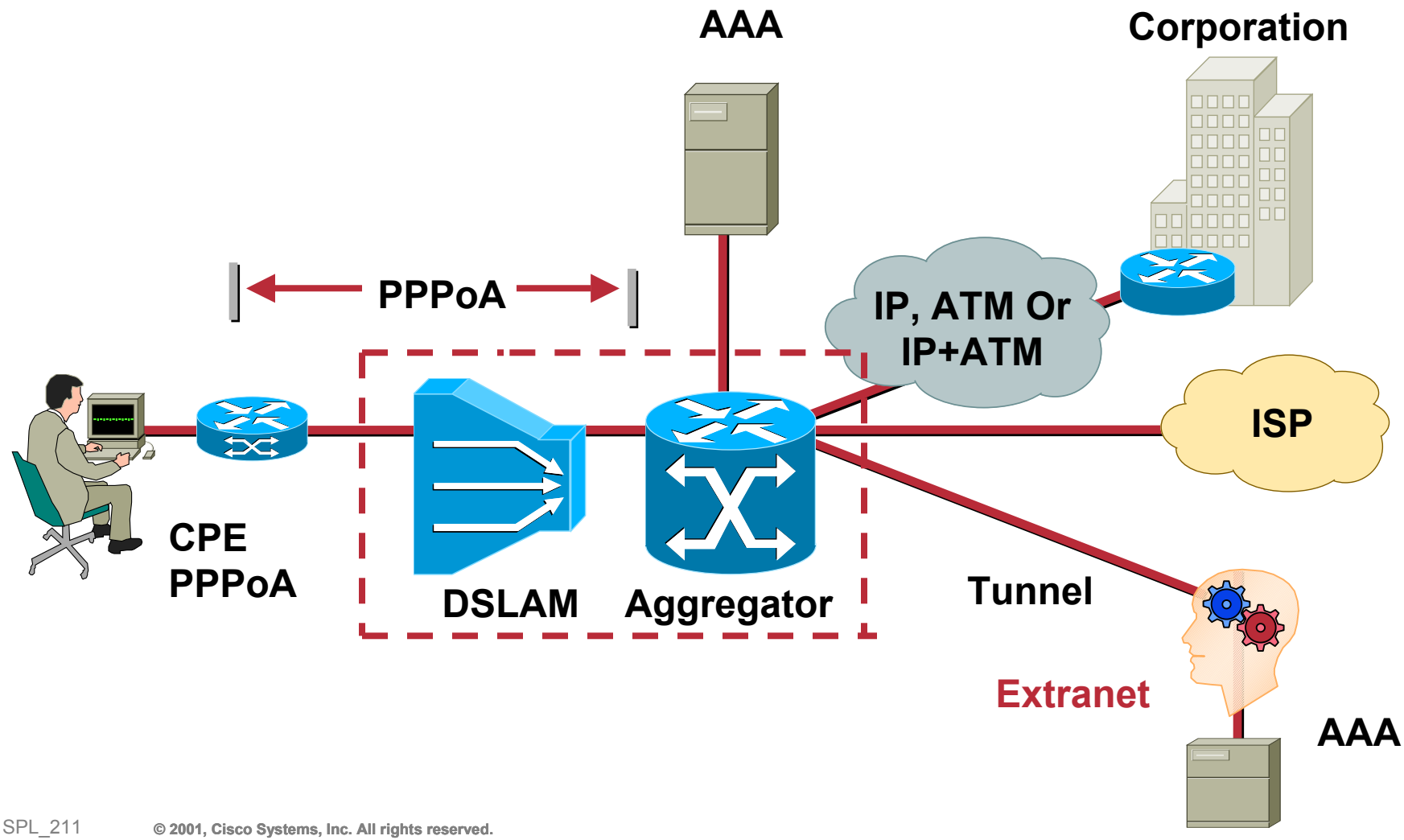
- Low cost, bridged CPE are the CPE's of choice for residential subscribers
- Service Provider is willing to maintain host software at Subscriber end
- Dynamic L2/L3 service selection
- Offer VPN services using L2TP
- No Routing Required on the CPE between Multiple PVCs
- "Dial-like" PPP-based service



PPP over AAL5
PPPoA

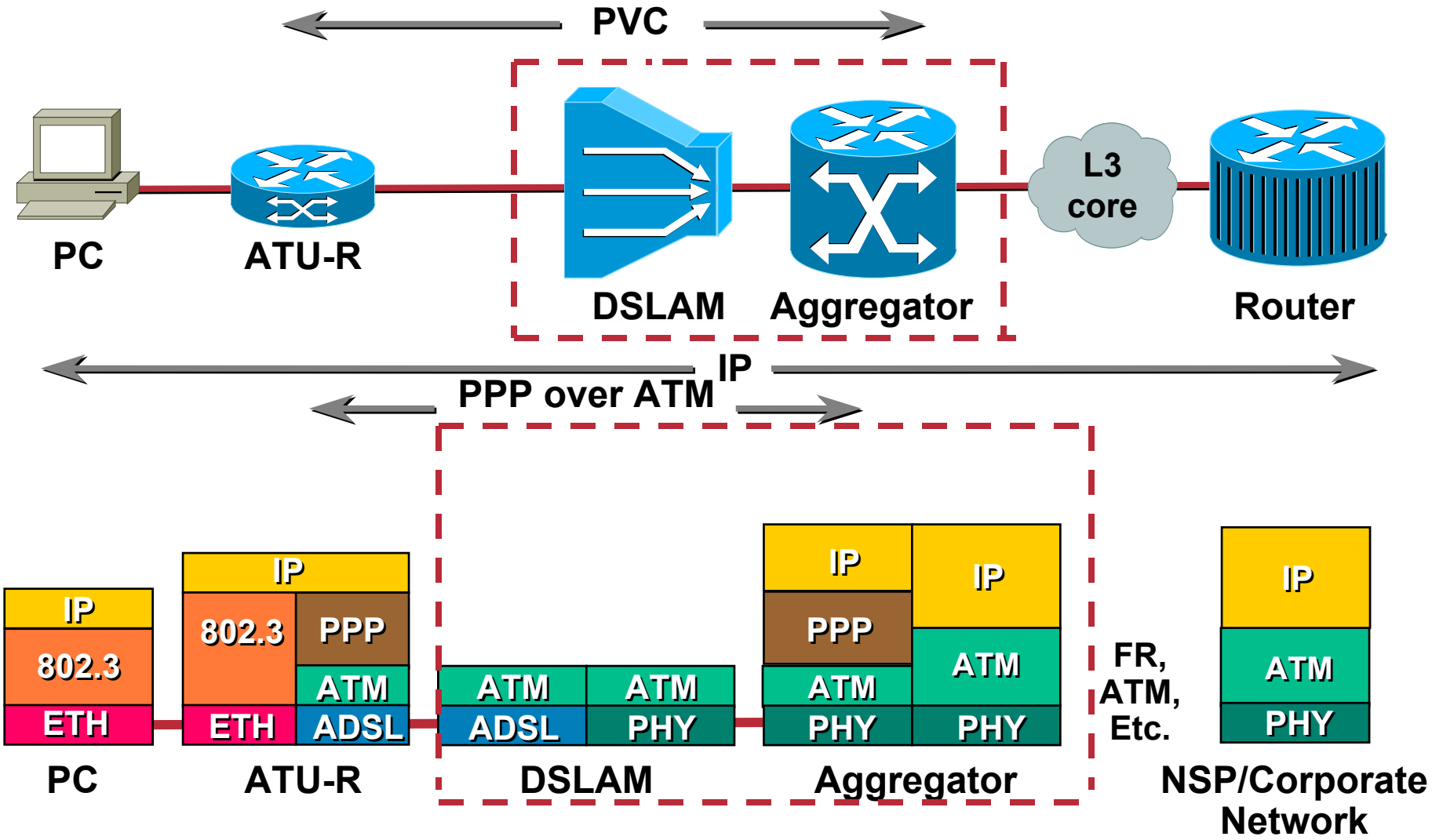
Typical PPPoA Architecture



How Does PPPoA Work?

- **Based on RFC 2364 (PPP over AAL5)**
  - **VC multiplexed PPP, LLC (Link Layer Control) encapsulated PPP**
- **CPE and aggregation goes through;**
  - **LCP (Link Control Protocol) negotiation**
  - **Authentication phase**
  - **IPCP (IP Control Protocol)**
- **Aggregation configured similar to dial-in Services**
  - **Assigns IP address to the CPE via local pool, dhcp, local radius or proxy radius**
  - **Establishes a 32-bit host route**

Protocol Stack—PPP Over ATM



PPPoA IP Address Management

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- **CPE is smarter and more complex**
  - **CPE can do Port Address Translation (PAT)/DHCP, to conserve IP address**
  - **IP address gets assigned to CPE**
  - **IP subnet feature, allows to prevent**
  - **NAT (Network Address Translation)**
- **PPPoA sessions can be terminated on NAP (Network Access Provider) or tunneled out using L2x**
  - **If terminated IP address provided by NAP**
  - **If tunneled, by the LNS (L2TP Network Server)**
- **IP address allocation same as PPPoE**

PPPoA - Pros & Cons

PROS

- Per Session Accounting and Authentication
- VPI/VCI Authentication
- Manageable CPE
- IP address Conservation if CPE configured for NAT/PAT.
- Secured VPN access by using L2x at NAP
- L2/L3 Service Selection (SSG/SSD)

CONS

- Single Session Per VC
- Can not work with L3 Service Selection if PAT is being implemented at CPE, because SSG requires IP address per host objects
- Limited per User Accounting (Multiple Users per CPE)

When to Use PPPoA

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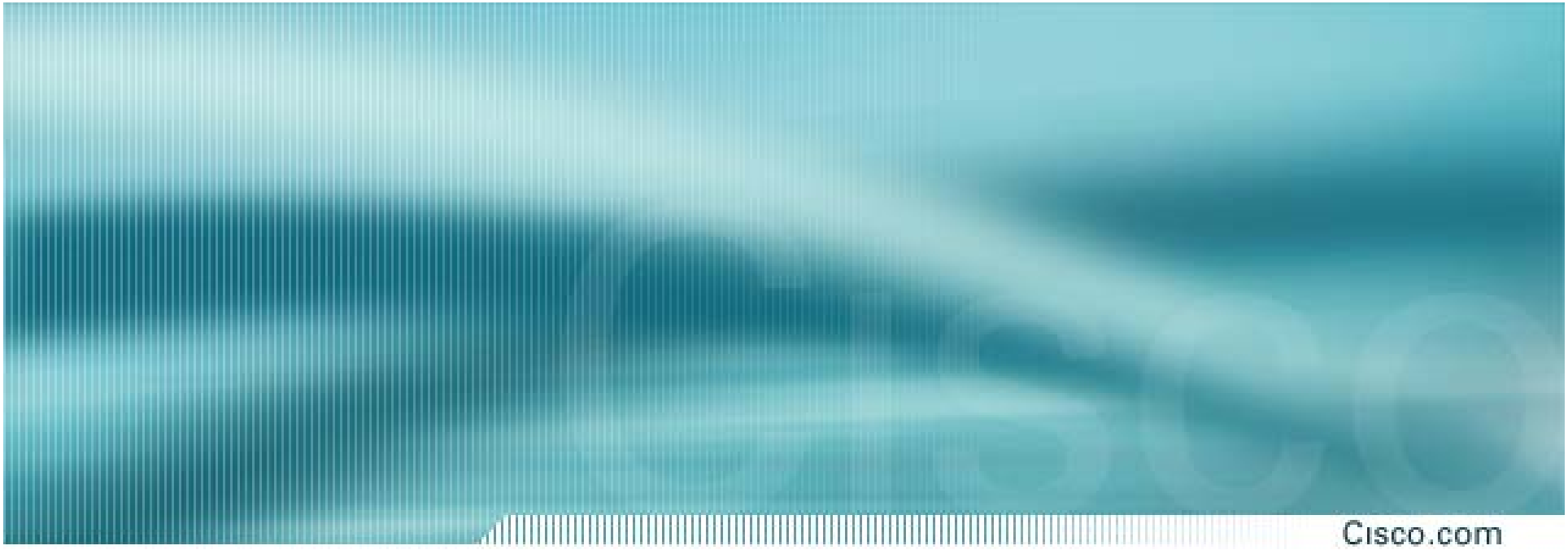
- No host-based special software
- Per Session Authentication and Accounting
- Intelligent CPE

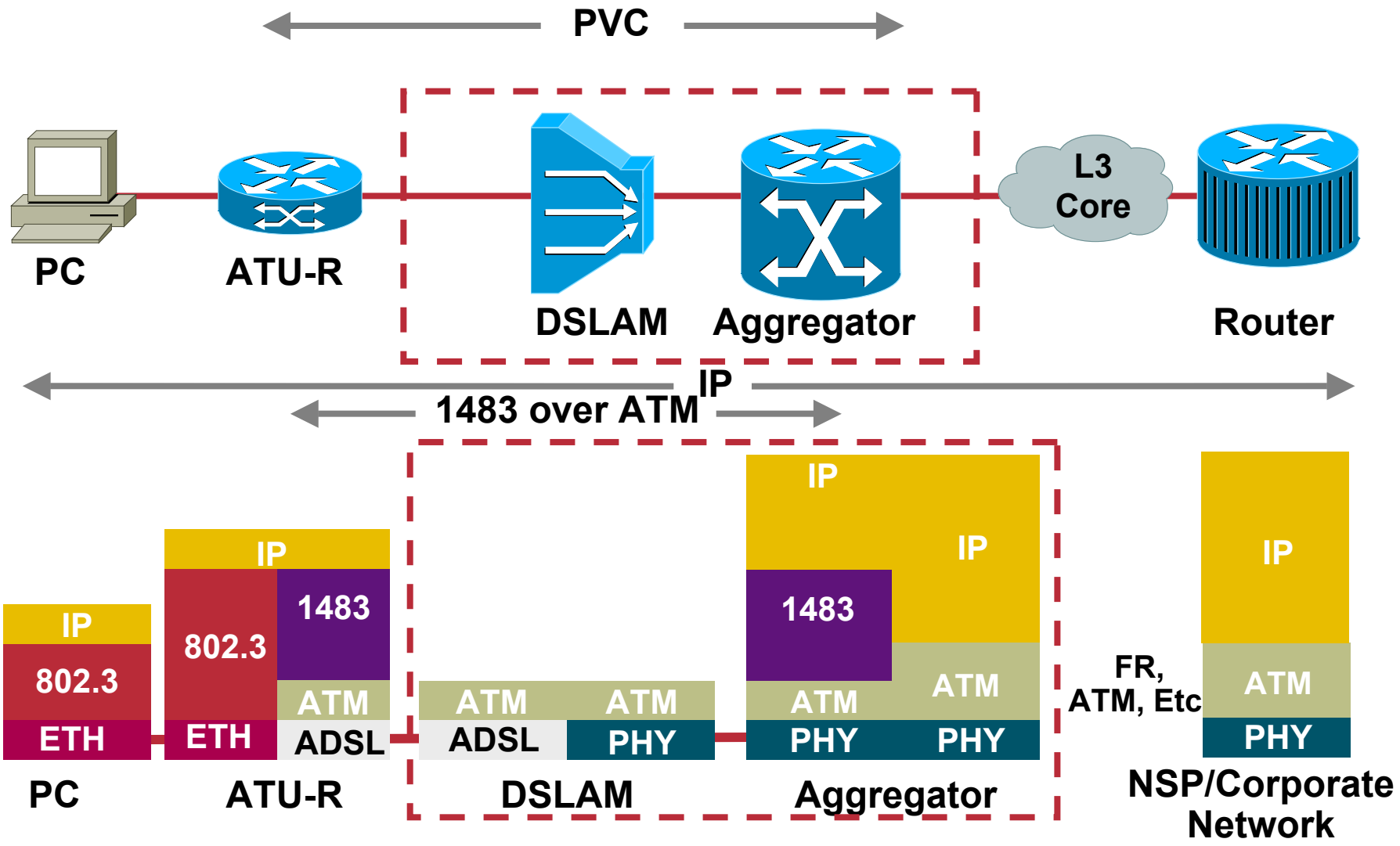
  access-lists
- If Closed User Group is required

  VPI/VCI authentication



RFC2684 (RFC1483) Routed

Protocol Stack — RFC1483 IP Routing



Routing Implementation

- **CPE**

  CPE in routing mode, single or multiple subnet behind CPE

  Routing protocol support

- **Aggregation**

  Learns subscriber routes through routing protocol or static routes

- **Core**

  Typically,IP or IP+ATM (MPLS/VPN)

When To Use RFC1483 IP Routing?

- Routing implemented mainly for enterprise customers.
- If access provider wants to offer VPN services to enterprise, or different ISPs.

RFC1483 IP Routing – Pros & Cons

PROS

- Best Approach to Provide Enterprise VPNs.
- Manageable CPE
- Accounting Possible through Netflow
- IP address Conservation if CPE configured for NAT.
- Firewall feature set, to avoid DoS attacks.
- Can have more than one subnet behind the CPE.
- L3 Service Selection (SSG/SSD)

CONS

- CPE to be configured for Routing, Requires Routing understanding, and increases Maintenance and Provision Costs for Service Provider.
- No Authentication unless used with Web Selection (L3 SSG/SSD).

Subscriber Connection Models Summary

Bridging / RBE	**Bridged CPE, No Client Software required, no Authentication & Accounting**
PPPoE	**Bridged CPE, Client Software required, Authentication & Accounting via Radius**
PPPoA	**„intelligent“ CPE required, no Client Software, Authentication & Accounting via Radius**
RFC1483 IP routed	**„intelligent“, routed CPE required, „leased-line“ like IP Service**

Agenda

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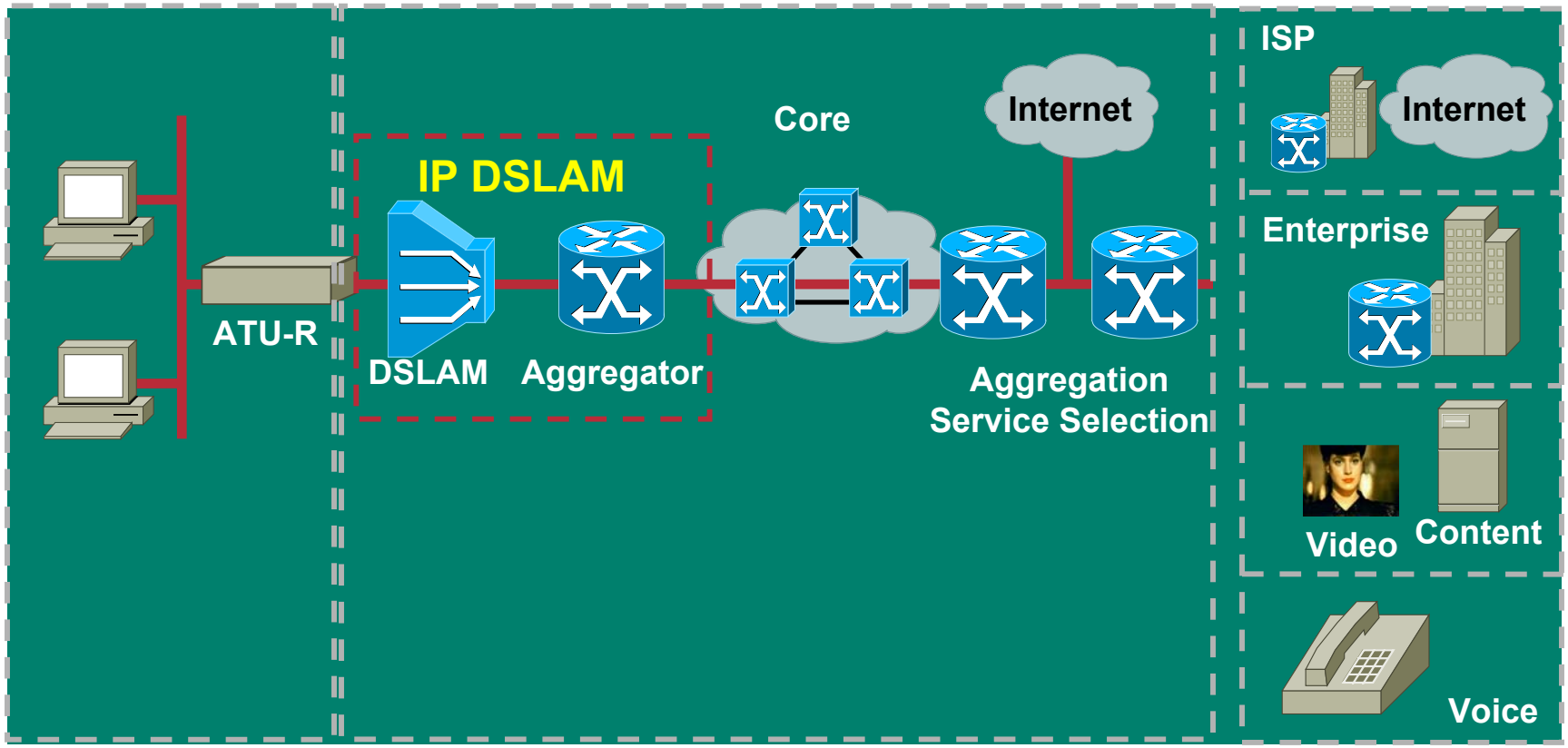
- Digital Subscriber Line Technologies
- Subscriber Connection Models
- Reaching the Services
- Case Studies
- Summary

Functional Segments



CPE; Customer Premise Equipment
NAP; Network Access Provider
NSP; Network Service Provider

Getting Across the Core

- **Depends on what type of subscriber connection is used**
  - **PPP can be carried to Service Provider using L2TP (Layer Two Tunneling Protocol)**
  - **PPP sessions can be terminated on NAP (Network Access Provider) aggregator and traffic provided to Service Provider on L2 PVC or L3 interface**
  - **Bridged and routed traffic delivered across L3 core**

Design Considerations for Different Service Architectures

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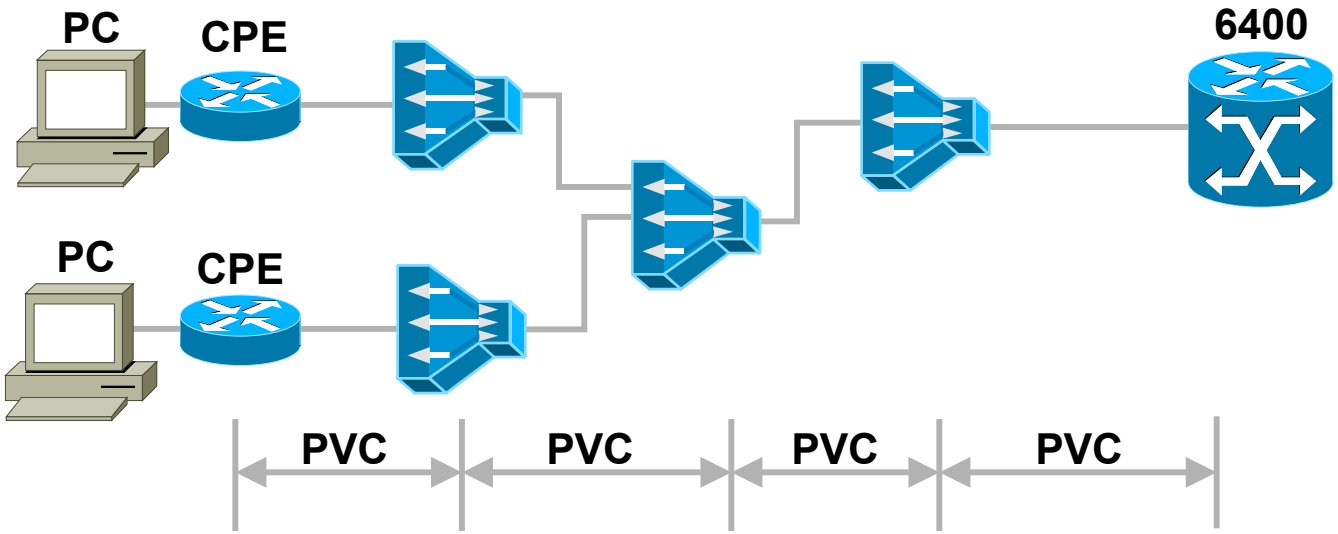
- End to end VC model
- RBE/1483 terminated and put in MPLS/VPN
- RBE/1483 terminated and routed out
- PPPoX terminated and routed out
- PPPoX tunneled into L2TP
- PPPoX terminated and put in MPLS/VPN

End to End VC Model



- No. of VCs required to switch through the core
- Possible VC depletion issue
- Could be tackled by aggregation, VP switching
- Subscriber connection model depends on the NSP
- Bandwidth management, SLA, QoS applied on ATM VC
- SPVC, PNNI eases provisioning, availability

RBE/1483routed—Routing Out

- Subscriber traffic must be terminated on the Aggregator
- Accounting per subscriber difficult without Netflow
- Usage of routing protocols and its considerations
- IP addressing allocation, overlapping IP address
- How to keep the traffic separate without introducing MPLS/VPN
- Applications (retailers or wholesalers)

PPPoX Terminated—Routed Out

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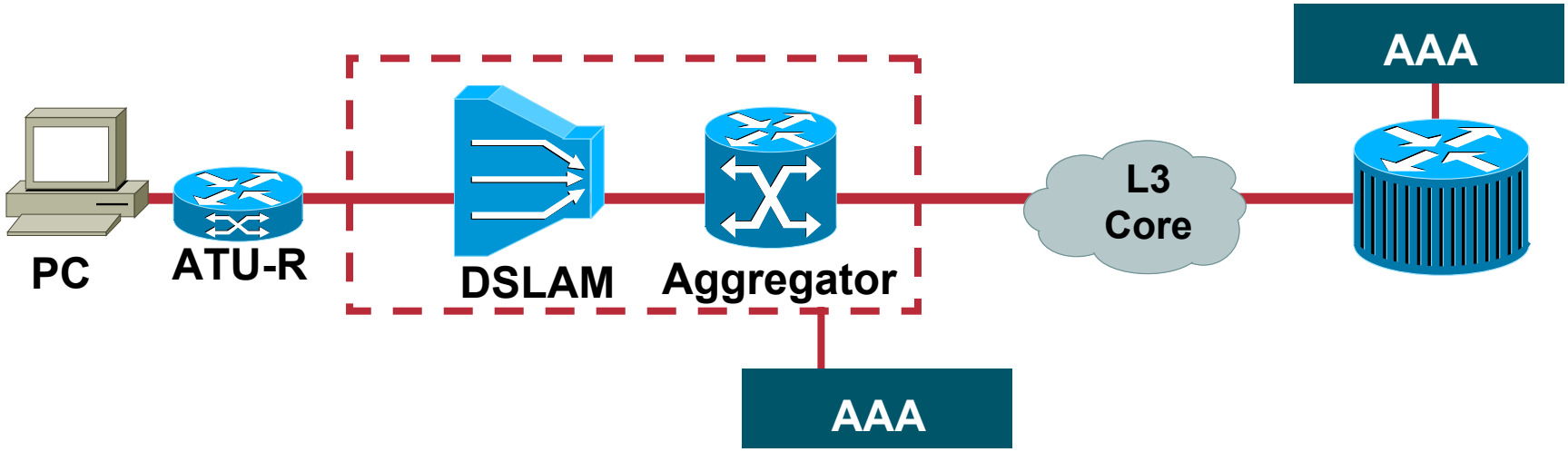
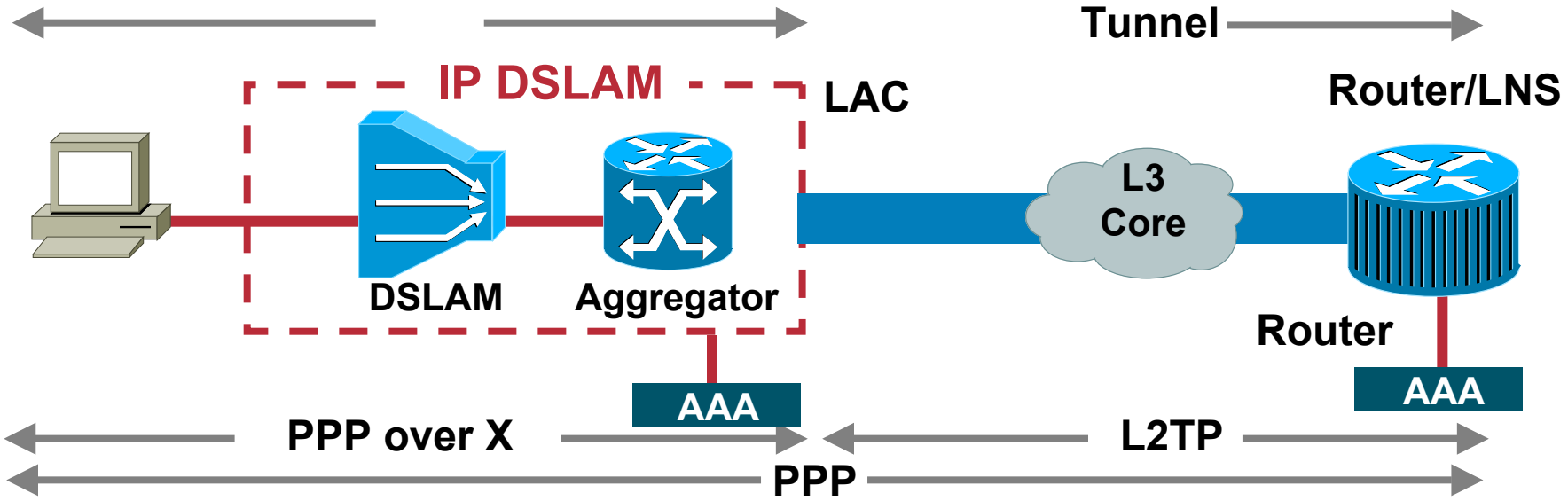


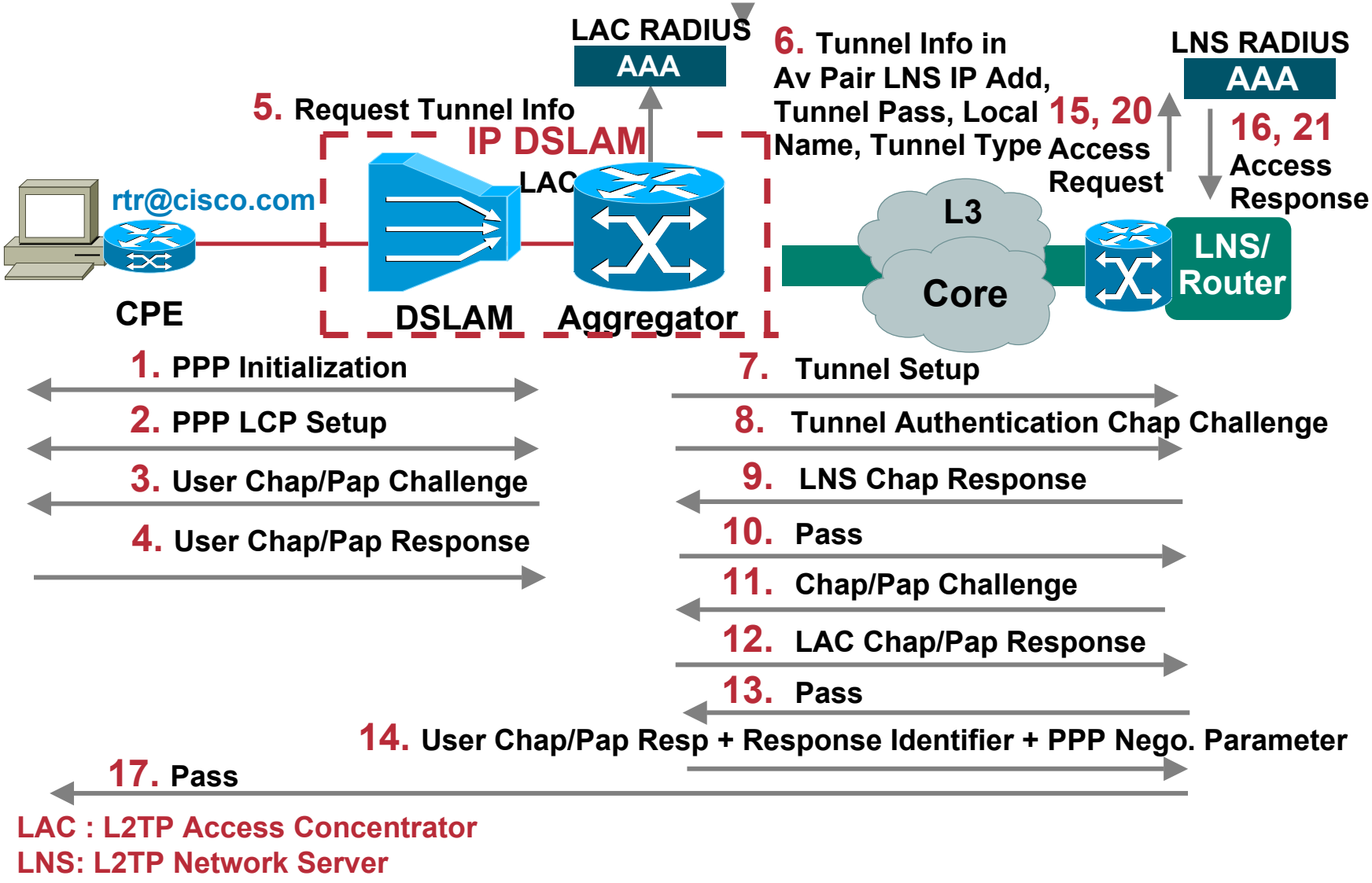
- AAA via Radius
- IP address allocation
- Wholesaler's challenged with IP address management
- Where to perform the aggregation?
- Route summarization

PPPoX Tunneled Using L2TP



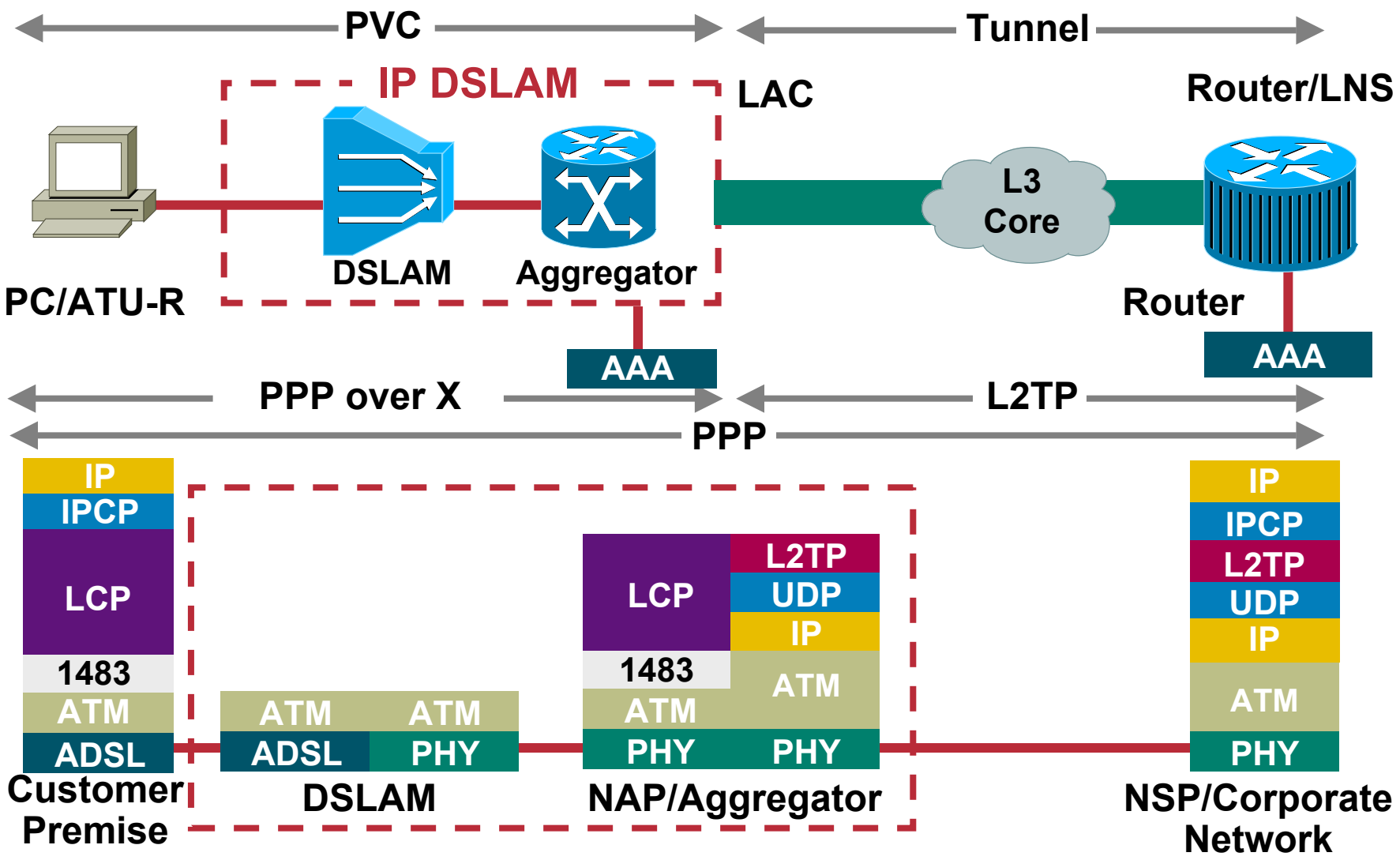
- Wholesaler need not worry about the IP address management
- No. of tunnels and no. of sessions per tunnel
- Where to perform LAC?
- Redundant links for LNS
- Routing between LAC and LNS
- Provisioning for new LAC

Layer Two Tunneling Protocol (L2TP) Overview and Call Flow

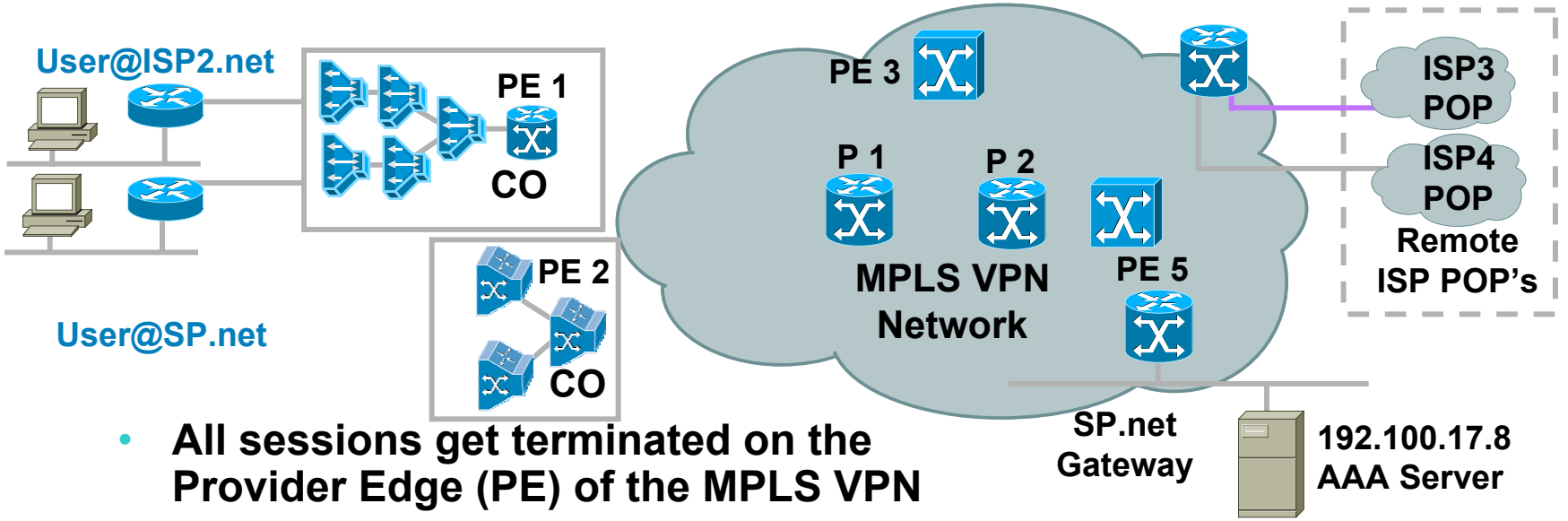


LAC : L2TP Access Concentrator
LNS: L2TP Network Server

Protocol Stack—L2TP



Any (RBE, 1483 Routed, PPPoX) Into MPLS/VPN



- All sessions get terminated on the Provider Edge (PE) of the MPLS VPN
- IP address allocation
- Identification of VPN
- Number of VPN,number of routes per VPN
- Total number of global routes on a PE
- Provider Edge (PE)—Customer Edge (CE) routing protocol and provisioning
- Hub and spoke vs. fully mesh topology

Agenda

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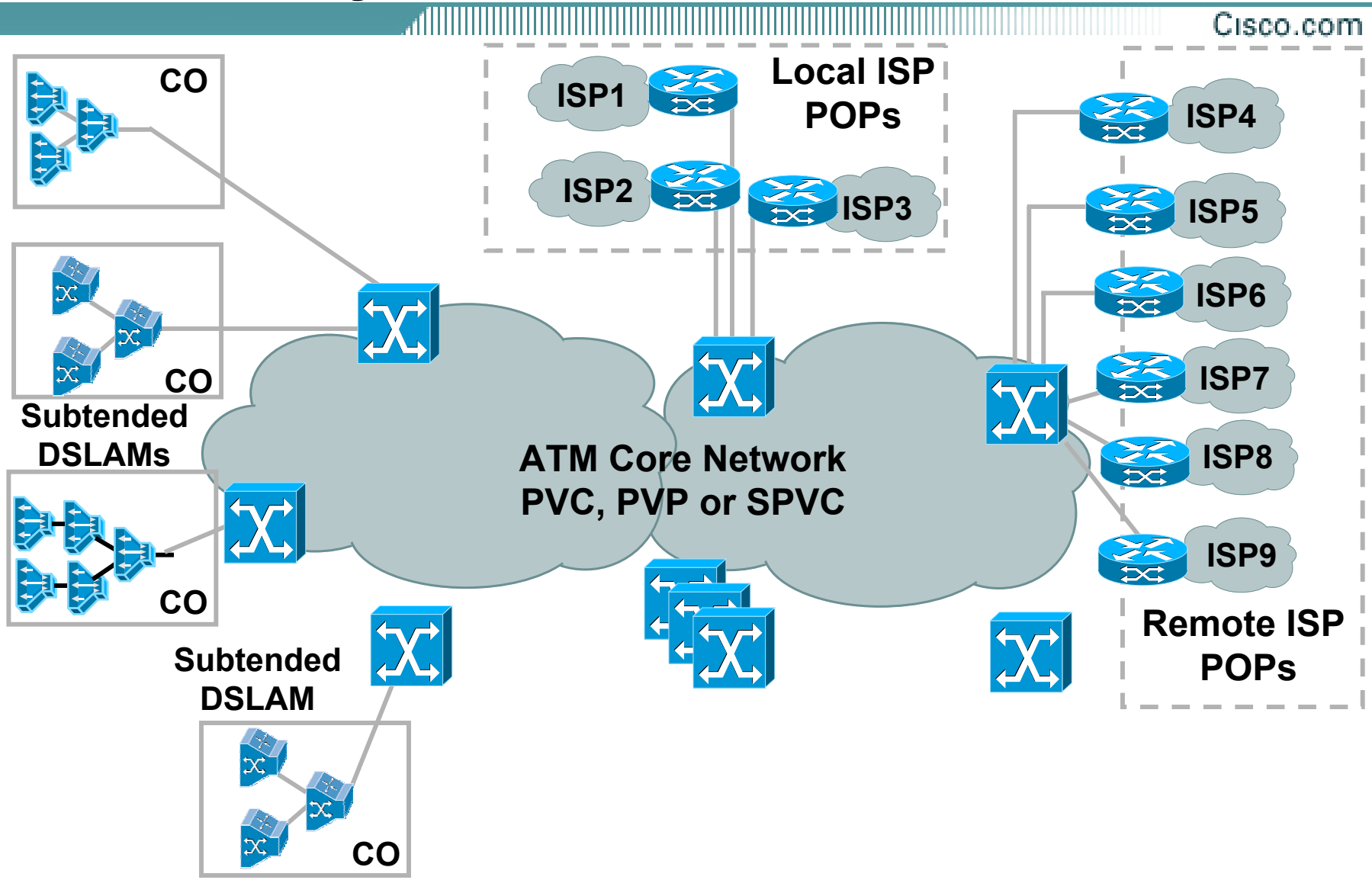
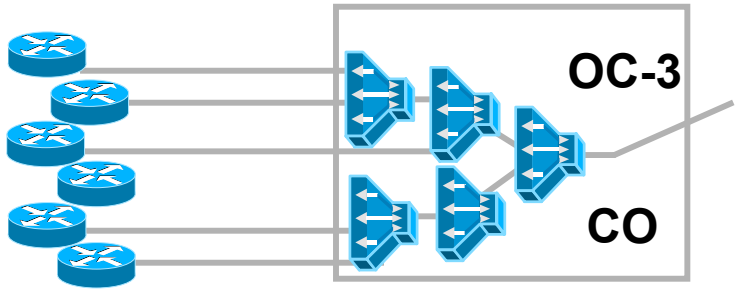
Case Study 1

- Customer is a Network Access Provider (NAP), regulated side of an ILEC
- NAP can not handle any L3 info
- Wants to offer services to 500,000 residential subscribers at 128 Kbps upstream and 784 Kbps downstream
- Maximum concentration at each CO is 2000

Network Architecture — Case Study 1



Design Consideration — Case Study 1



- 2000 subscribers per CO, total= 250 CO
- Each CO consideration:

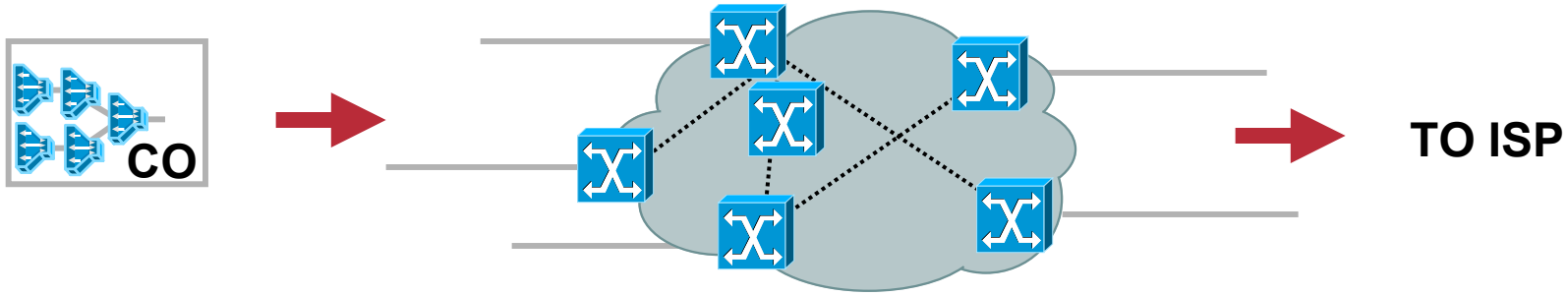
  No. of DSLAMs, subtending, trunk capacity, power dissipation, availability

  Trunk capacity—based on over subscription of 1:20, requires an STM-1

  Applying QoS and fairness in subtended DSLAM

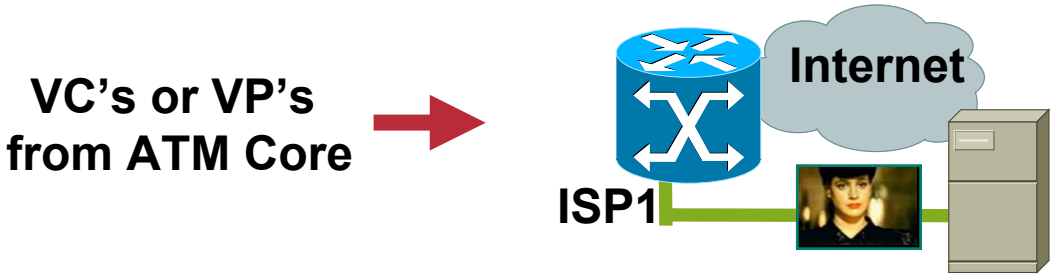
  CPE provisioning

Design Consideration — Case Study 1



- **Total No. of VC's to be switched through the core= 500,000, getting across the core**
  - **Lot of provisioning of VCs**
  - **Options: Pure VC switching using SPVC or PVP**
  - **Trunks to ISP should be based on no. of subscribers and their average data rates**

Design Consideration — Case Study 1



- **ISP, final destination considerations**

  Terminate/aggregate high no. of VC's, requires ATM capabilities and high throughput

  Operation and maintenance consideration of individual subscriber VC's

  Usage of service selection gateway

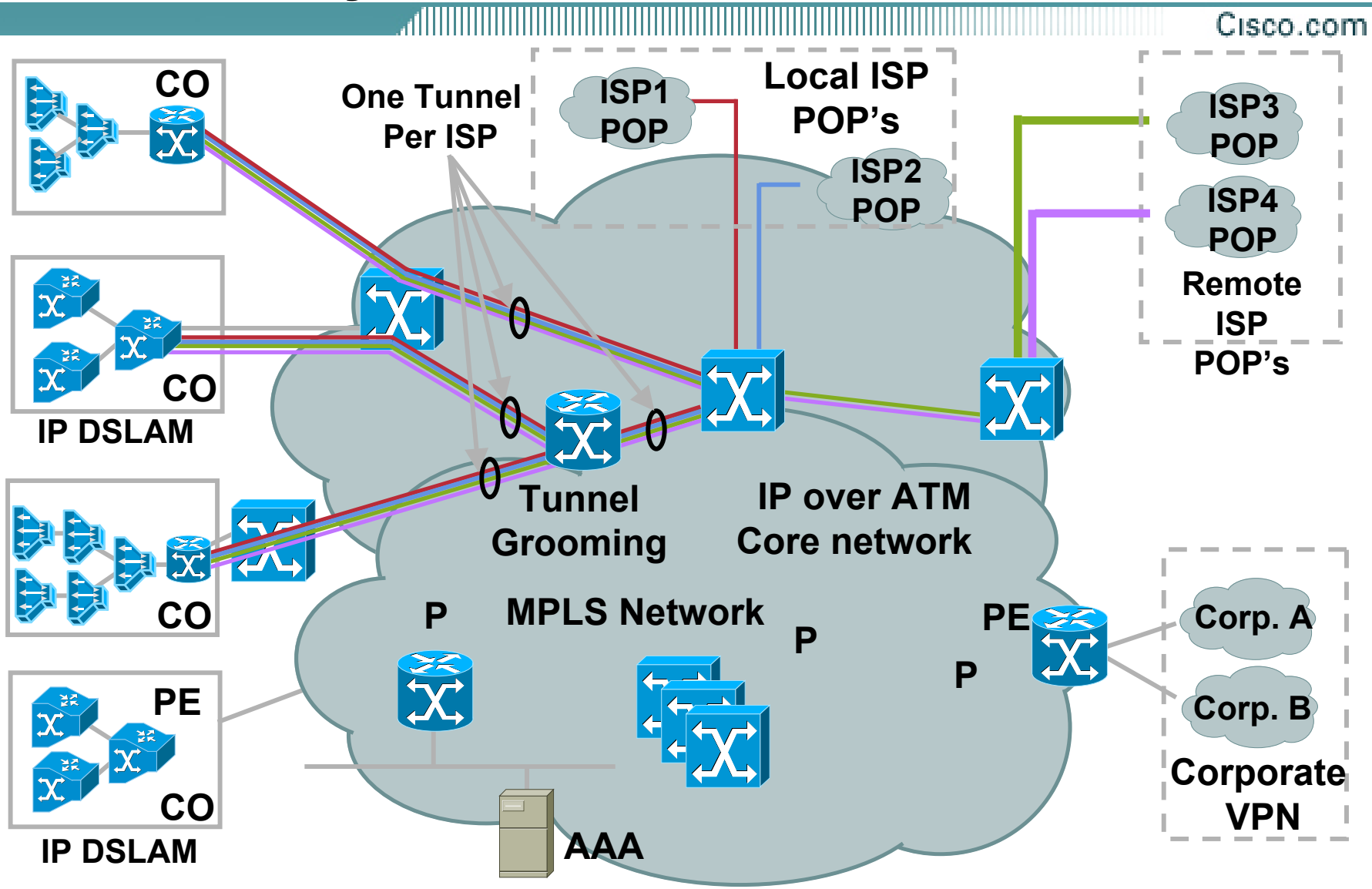
  CPE, access encapsulation

  IP address allocation

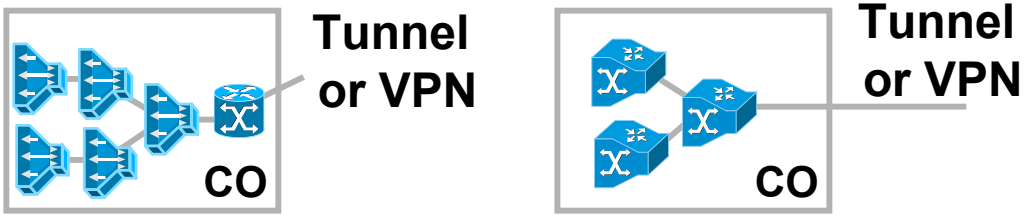
Case Study 2

- Customer is from an unregulated side of an ILEC
- Wants to offer local ISP services as well as wholesale residential services to 100 other regional ISP's
- Customer also wants to offer business VPNs to corporations
- Number of subscriber and concentration per CO remains unchanged from the previous case study

Network Architecture — Case Study 2

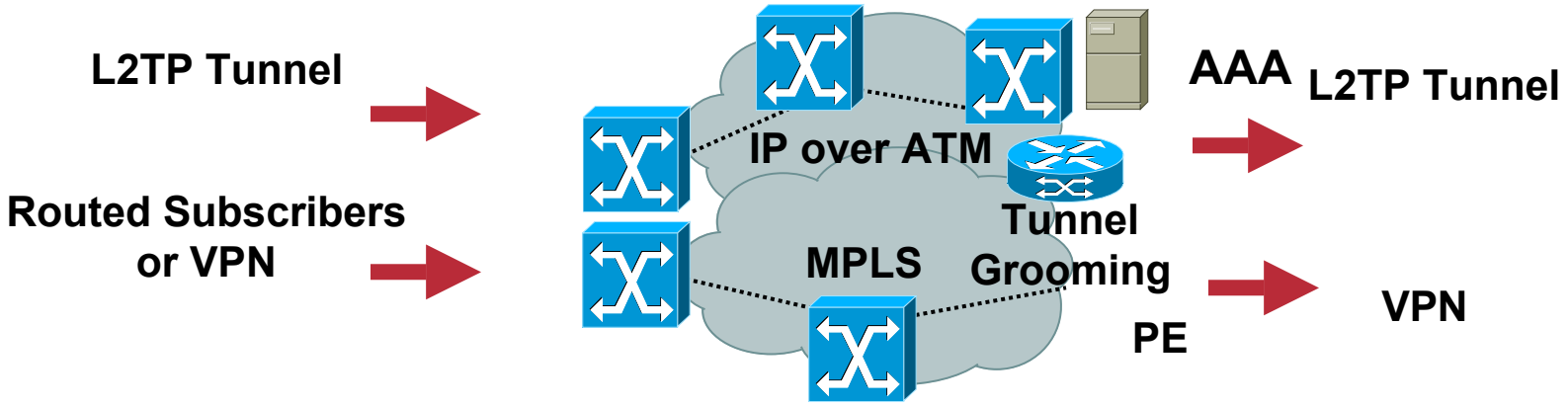


Design Consideration — Case Study 2



- **CPE considerations**
  - Subscribers belonging to retail customer can use any access encapsulation, bridging more suitable
  - Bridging allows for the NAP to allow subscribers belonging to different ISP to use PPPoE
- **CO consideration**
  - No. of CO remains the Same= 250
  - Aggregating at the edge, will enable the core to scale, each aggregation device aggregates max 5000 sessions, throughput
  - Local subscribers connections terminated and routed out, customer can inject content and use caching by terminating the subscriber connections and providing IP at the edge
  - Subscribers belonging to different ISP tunneled out; each Aggregate device potentially may require to support 100 tunnels (may vary)
  - VPN subscribers are placed in their respective VPN at the edge
    - VPN information is provided by either radius, or specified locally
  - How the radius servers are reached- direct or proxy?

Design Consideration — Case Study 2



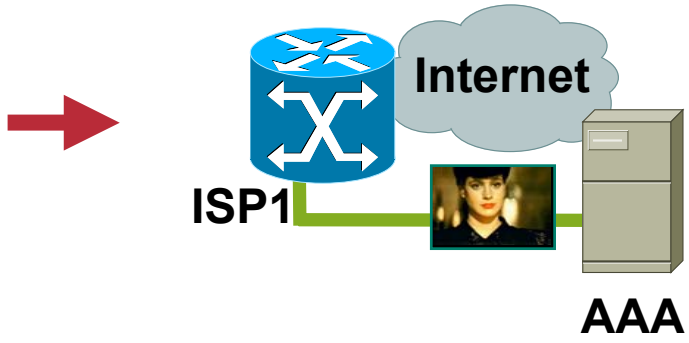
- **Core consideration**

  No. of VCs to be switched through the core reduced to 100 * 250= 2500 (compared to 500,000 in previous case) for subscribers belonging to other ISP

  Routing between different L2TP Network Server (LNS) and L2TP Access Concentrator (LAC), probable tunnel grooming

Design Consideration — Case Study 2

Tunnels, VPN or Routed in Aggregated VCS



- ISP or final destination

  No. of tunnels (250) and No. of sessions to be terminated

  LNS redundancy

  IP address allocations

  Throughput

Agenda

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- Digital Subscriber Line Technologies
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- Summary , questions and answers

Things To Consider

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- **Identify the business model**
  - Wholesale vs. retail, corporate access/VPN vs. residential
- **Who is providing the IP addresses?**
  - Is it NAP or NSP or enterprise?
  - Tunneling is an easy way to support last 2 options
- **Do addresses overlap?**
  - They nearly always do in residential scenarios
- **How is the NSP reached from the NAP?**
- **Is host-based software acceptable?**
  - If not, no PPPoE

Things To Consider

- Network management, provisioning/billing
- Traffic engineering for bandwidth allocation and QoS, SLA (Service Level Agreements)
- Geographical distribution of PoPs and aggregation
- NSPs hardware requirements for terminating tunnels and PPP sessions
  - Includes interface type
- Over subscription
  - Within NAP cloud
  - NSP interface speed; subscriber interface speeds

Recommended Reading

Cisco.com

- **SPL 210—Deploying Next Gen DSL Network**
- **White Papers on Various Access Architectures available:**

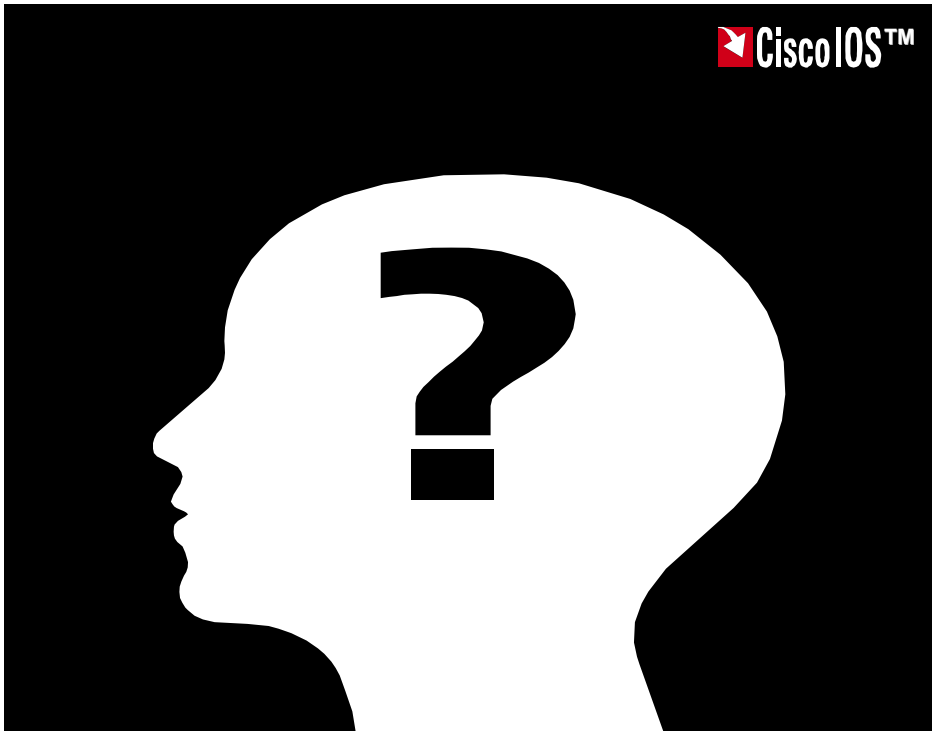
  http://www.cisco.com/warp/customer/794/pppoe_arch.html

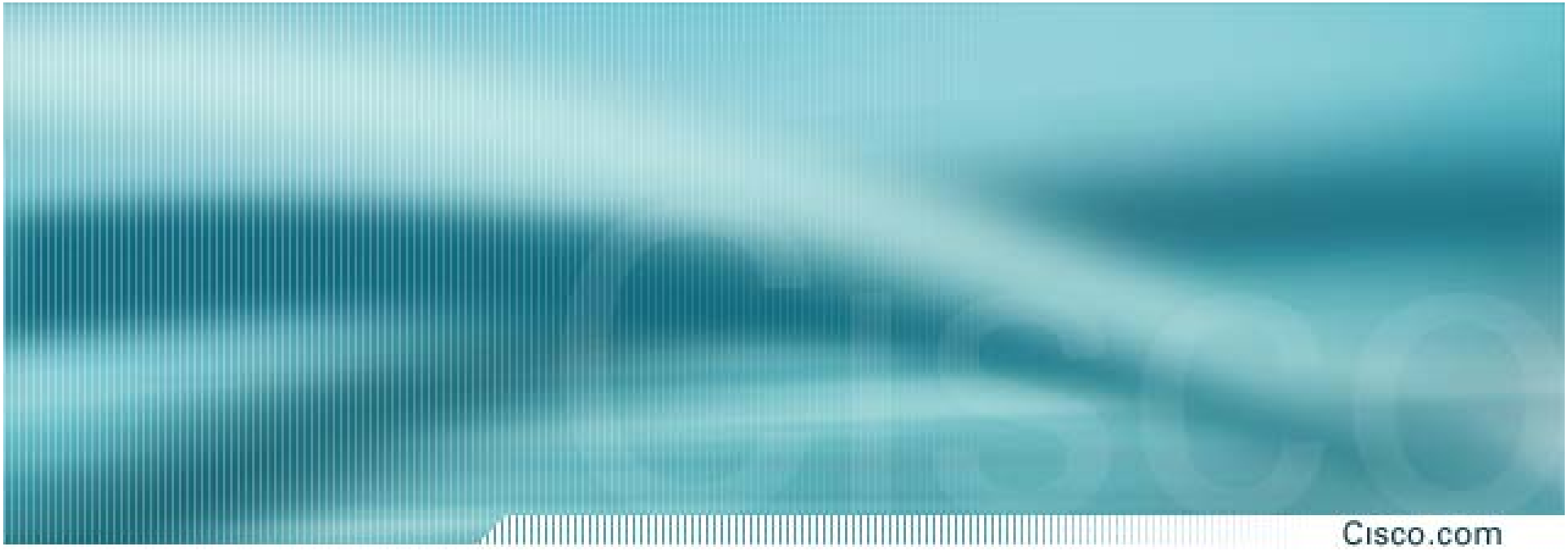
  hthttp://www.cisco.com/warp/customer/794/pppoa_arch.html

  hthttp://www.cisco.com/warp/customer/794/routed_bridged_encap.html

  http://www.cisco.com/warp/customer/794/rfc_brdg_arch.html

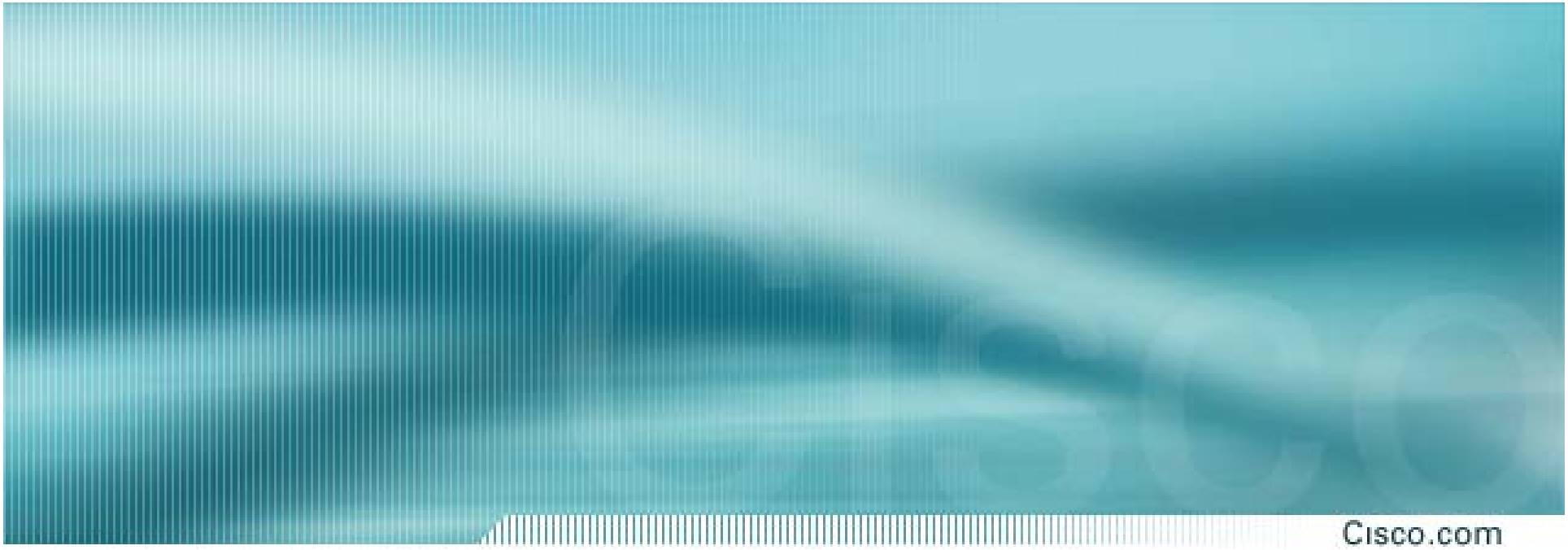
Questions, Comments?





Design Principles for DSL-Based Access Solutions

Session SPL-211



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