CS519: Computer Networks

Lecture 8: Apr 21, 2004

VPNs

VPN Taxonomy

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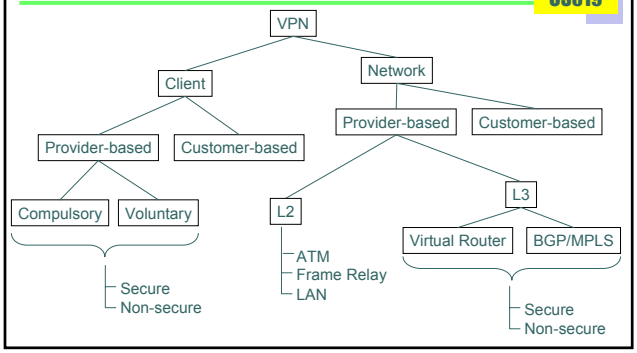

What is a VPN?

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- Making a shared network look like a private network
- Why do this?
  - Private networks have all kinds of advantages
    - (we'll get to that)
  - But building a private network is expensive
    - (cheaper to have shared resources rather than dedicated)

History of VPNs

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- Originally a telephone network concept
  - Separated offices could have a phone system that looked like one internal phone system
- Benefits?
  - Fewer digits to dial
  - Could have different tariffs
    - Company didn't have to pay for individual long distance calls
  - Came with own blocking probabilities, etc.
    - Service guarantees better (or worse) than public phone service

Original data VPNs

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- Lots of different network technologies in those days
  - Decnet, Appletalk, SNA, XNS, IPX, …
  - None of these were meant to scale to global proportions
  - Virtually always used in corporate settings
- Providers offer virtual circuits between customer sites
  - Frame Relay or ATM
  - A lot cheaper than dedicated leased lines
- Customer runs whatever network technology over these
- These still exist (but being replaced by IP VPNs)

VPN Taxonomy

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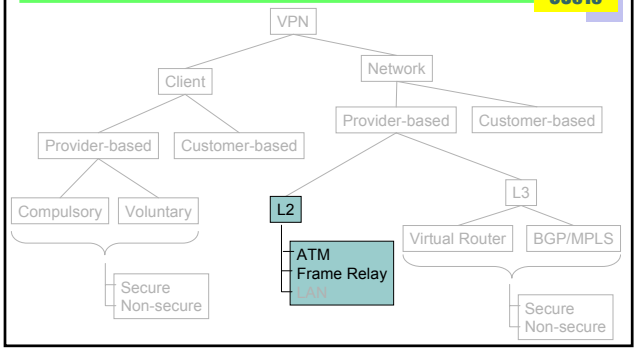

Advantages of original data VPNs

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- Repeat: a lot cheaper than dedicated leased lines
  - Corporate users had no other choice
  - This was the whole business behind frame-relay and ATM services
- Fine-grained bandwidth tariffs
- Bandwidth guarantees
  - Service Level Agreements (SLA)
- "Multi-protocol"

Frame Relay VPN Example

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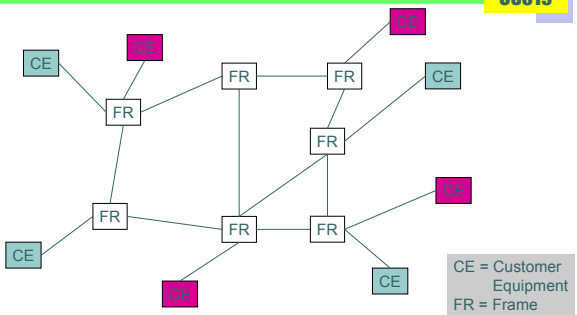

Define circuits CE to CE (for given customer: purple)

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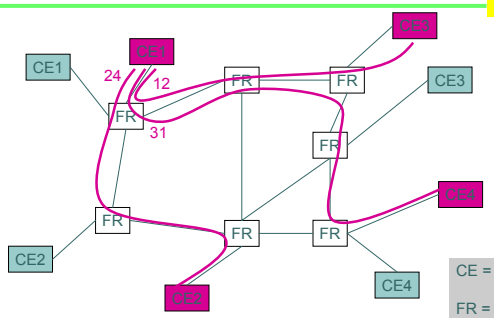

Customer establishes routing tables (per protocol)

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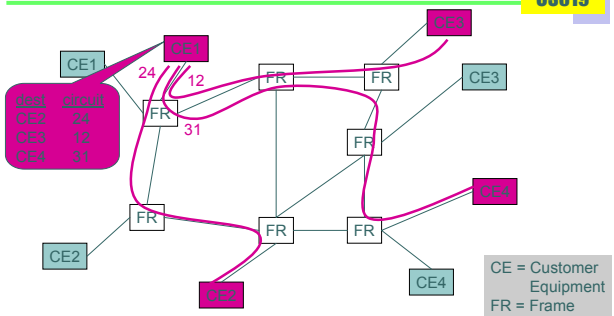

Provider provisions underlying network

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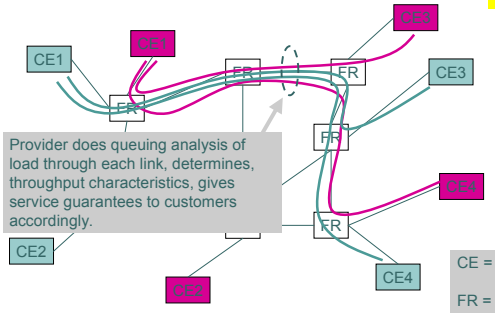

How has the world changed?

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- Everything is IP now
  - Some old stuff still around, but most data networks are just IP
- So, why do we still care about VPNs???

IP VPN benefits

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- IP not really global (private addresses)
  - VPN makes separated IP sites look like one private IP network
- Security
- Bandwidth guarantees across ISP
  - QoS, SLAs
- Simplified network operation
  - ISP can do the routing for you

Client VPNs

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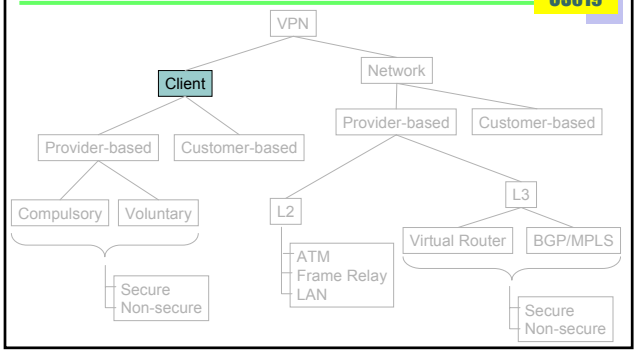

Client VPNs

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- Solves problem of how to connect remote hosts to a firewalled network
  - Security and private addresses benefits only
  - Not simplicity or QoS benefits

Client VPNs

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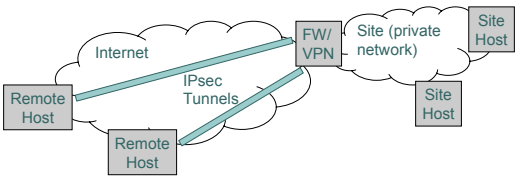
- Solves problem of how to connect remote hosts to a firewalled network



Client VPNs: Configuration

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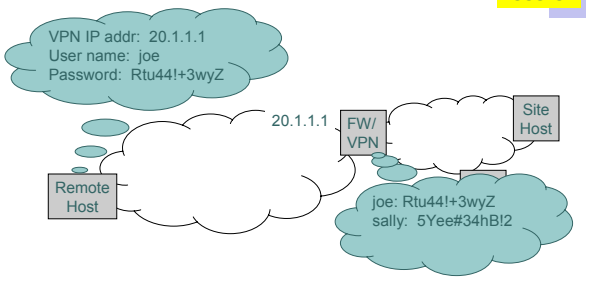

Client VPNs

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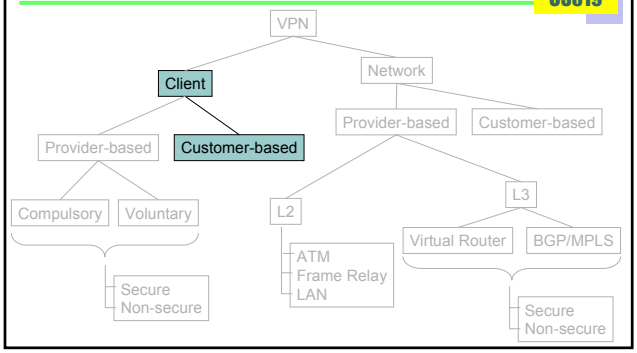

Client VPNs: Configuration

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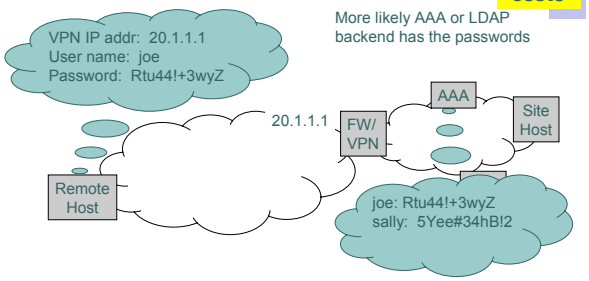
More likely AAA or LDAP backend has the passwords



Client VPNs: Host gets local IP address

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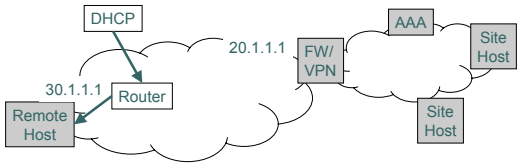

Client VPNs: Host connects to VPN

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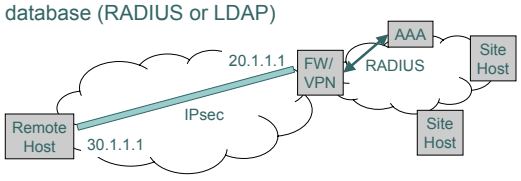
VPN authenticates remote host through backend database (RADIUS or LDAP)



Client VPNs: VPN assigns site address

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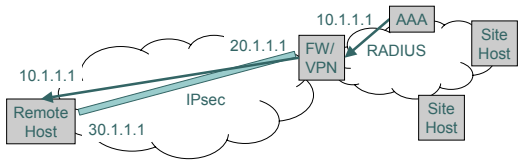
As proprietary enhancement to IPsec, or with PPP (over IPsec)



Client VPNs: Packets tunneled over IPsec

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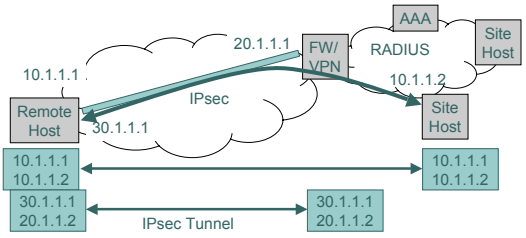

Client VPNs: Packets tunneled over IPsec

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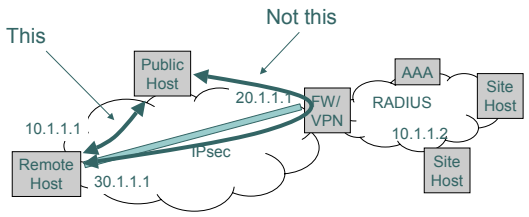
Some VPN clients smart enough to avoid sending non-VPN traffic through the VPN tunnel



IPsec

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- Two parts: Session Establishment (key exchange) and Payload
- IKE/ISAKMP is session establishment
  - Negotiate encryption algorithms
  - Negotiate payload headers (AH, ESP)
  - Negotiate policies
- Keying can be either:
  - Symmetric shared keys
  - Public keys (in certificates)
- Either way, a session key is negotiated by IKE

IPsec Payloads

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- AH: Authentication Header
  - Authenticates each packet but doesn't encrypt
  - Has fallen out of favor (redundant and no more efficient)
- ESP: Encapsulating Security Payload
  - Encrypts (with authentication as side effect)

IPsec transmission modes: Transport or Tunnel mode

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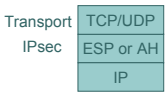
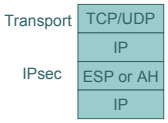


Transport mode. Used when IPsec tunnel is end-to-end. Operates over some of the IP fields, and doesn't work with NAT!



Tunnel mode. Used when IPsec tunnel not end-to-end. Hides the IP identity of endpoints. Operates over inner IP fields…can work with NAT.

AH header format

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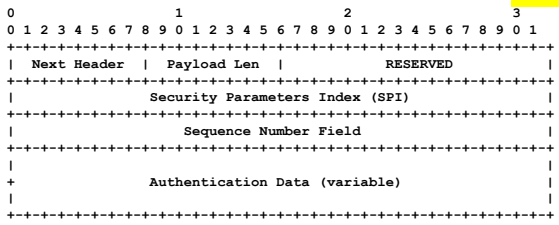

ESP header format

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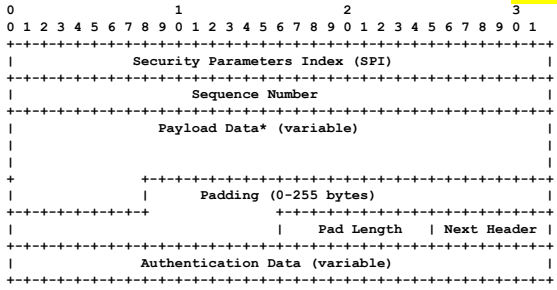

New IPsec transmission modes

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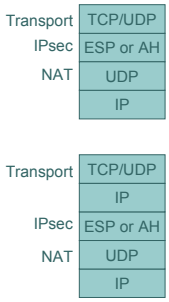

Extra layer of UDP allows IPsec to work over NAT.

Client VPNs

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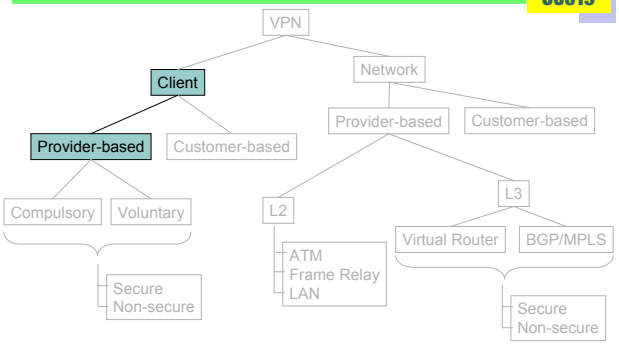

Client VPNs: Host gets local IP address

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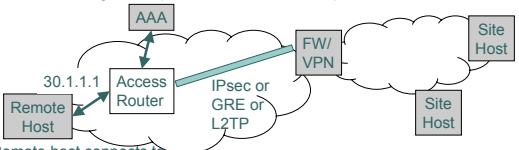
2. If PPP, AAA tells Access Router to tunnel user to VPN. (If not PPP, Access Router uses local configuration.)

3. Tunnel established (or packets forwarded over pre-established tunnel)



1. Remote host connects to Internet (dialup-PPP or PPPoE (cable) or DSL)

Compulsory if Access Router forces tunnel, voluntary if user requests it (through certain NAI). NAI = “user@domain”

Provider-based client VPNs

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- Used for instance when enterprise pays for employee access, wants it to go through enterprise network
  - I know Cisco did this
  - But never used that much
    - Business model didn't take off
  - Used even less now
    - In part because VPN client comes with windows OS???
- The tunneling technology commonly used for roaming dialup though

Network VPNs

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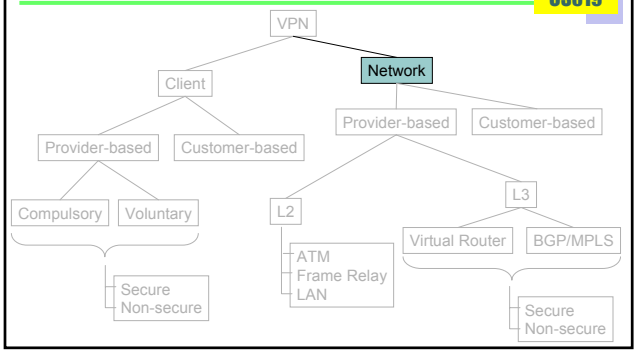

Reiterate network VPN benefits

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- Makes separated IP sites look like one private IP network
- Security
- QoS guarantees
- Simplified network operation

Customer-based Network VPNs

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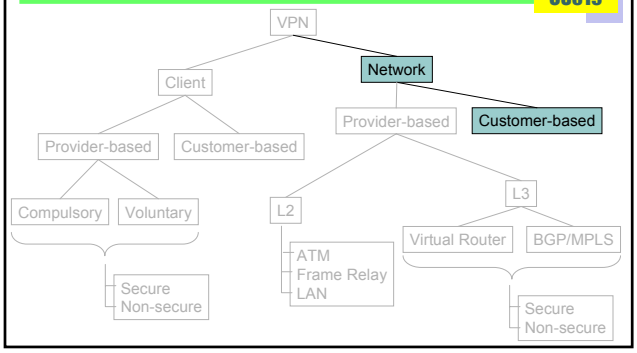

Customer-based Network VPNs

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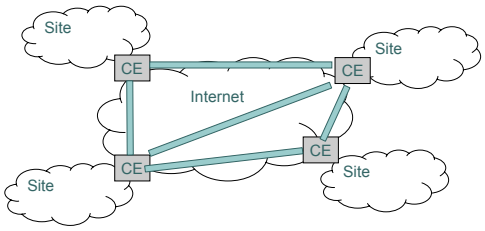

Customer buys own equipment, configures IPsec tunnels over the global internet, manages addressing and routing. ISP plays no role.

Customer-based Network VPNs

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- Great for enterprises that have the resources and skills to do it
  - Large companies
- More control, better security model
  - Doesn't require trust in ISP ability and intentions
  - Can use different ISPs at different sites
- But not all enterprises have this skill

Provider-based Network VPNs (aka Provider Provisioned: PPVPN)

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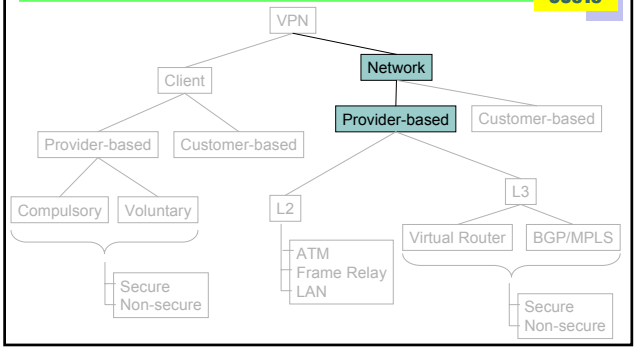

Provider-based Network VPNs

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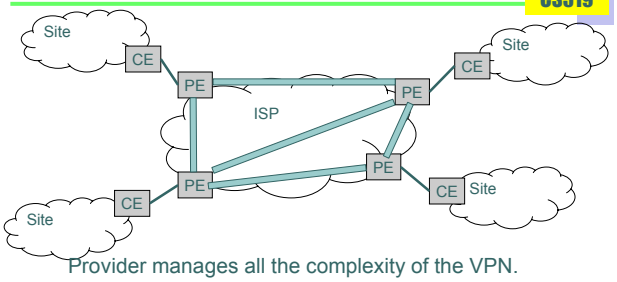

Provider manages all the complexity of the VPN. Customer simply connects to the provider equipment.

Same provider equipment used for multiple customers

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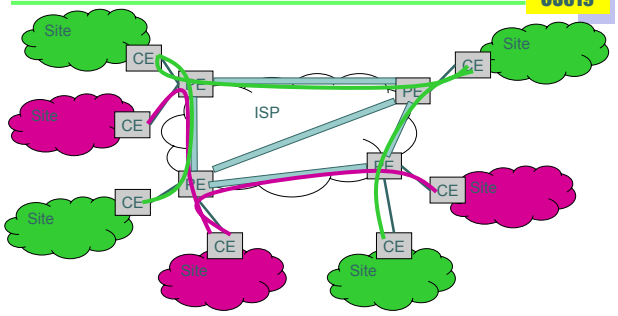

Model for customer

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- Attach to ISP router (PE) as though it was one of your routers
- Run routing algorithm with it
  - OSPF, RIP, BGP
- PE will advertise prefixes from other sites of same customer

Various PPVPN issues

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- Tunnel type?
  - IPsec (more secure, more expensive)
  - GRE etc.
- How to discover which customer is at which PE?
  - Don't want PEs without given customer to participate in routing for that customer
- How to distinguish overlapping private address spaces

BGP/MPLS VPNs (RFC2547)

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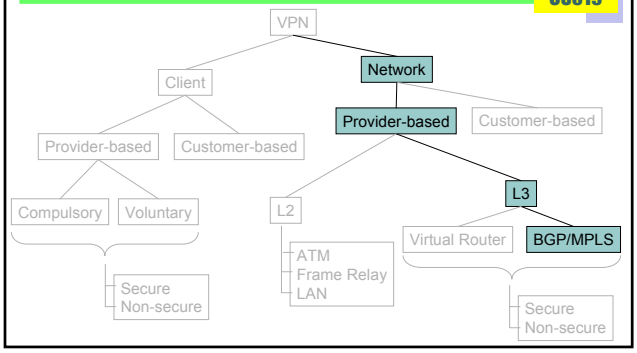

BGP/MPLS VPNs (RFC2547)

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- Cisco invention
  - Leverage Cisco's investment in both BGP and MPLS (Multi-Protocol Label Switching)
- What is MPLS?
  - Link-layer technology
    - Tags like circuit switching
    - But with some IP awareness
  - How Cisco killed Epsilon
  - Initially marketed as high performance switching
  - Later became "traffic engineering" and VPN

Recall this frame-relay traffic engineered L2 VPN…

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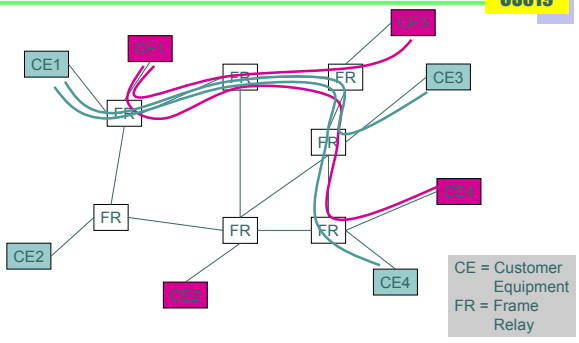

ISPs historically used L2 networks in their core

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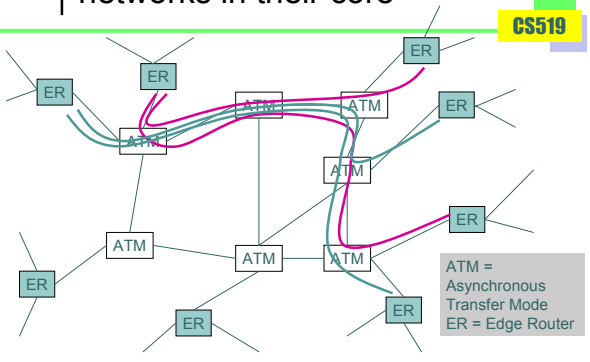

Logically, ISPs were structured like this

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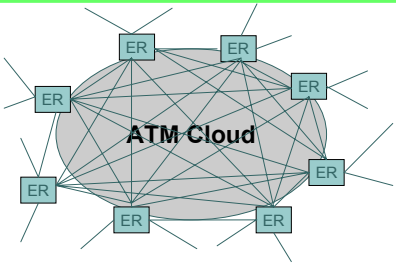

Every router was "adjacent" to every other

Why L2 (ATM)?

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- ATM was, at least until 4-5 years ago, faster than IP forwarding
- ATM switches were better matched to the underlying SONET transmission links
- It was easier to traffic engineer based on virtual circuits than based on destination IP address
- IP wasn't the only network protocol

But there were problems…

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- ISPs had 100's of routers, each of which logically had a link to all others
  - Was difficult to manage and run routing over all of these logical links
  - Scaled poorly
- Basic idea of MPLS was to elevate ATM intelligence to L3, while doing switching at L2!
  - Epsilon business model…

MPLS tried to get the best of both worlds

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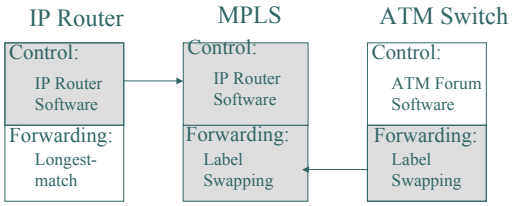
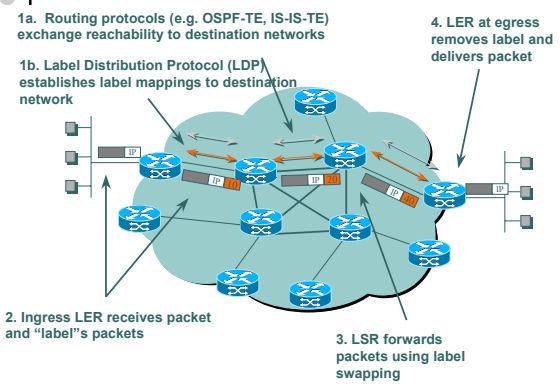


MPLS Operation



Original business model failed

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- Simple reason:
  - People figured out how to make IP fast…as fast as ATM
- MPLS spent a long time looking for a reason to exist
  - Finally found it in MPLS-BGP PPVPNs

Basic difficulty with PPVPN: private addresses

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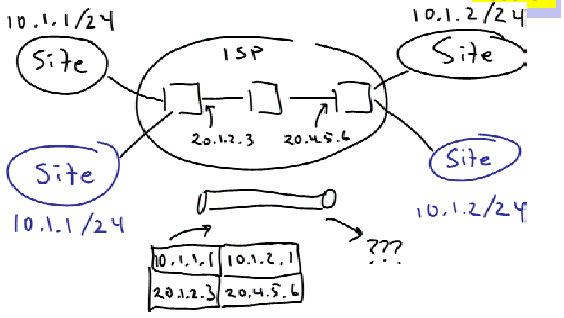

MPLS Label identifies VPN

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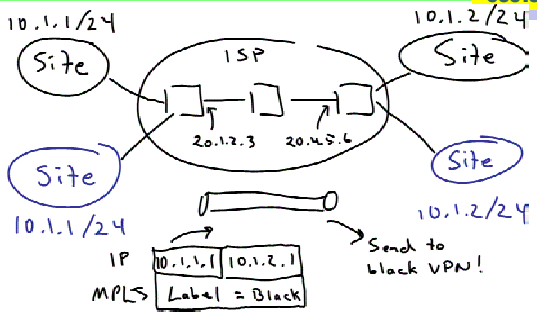

How BGP/MPLS VPNs work

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- BGP updates normally carry a set of IP prefixes in the routing path
- With MPLS VPN, they carry a VPN identifier, and an MPLS tag
  - VPN identifier distinguishes overlapping address
  - MPLS tag says how to encapsulate customer's IP over MPLS
- Within MPLS, the tag both routes the packet and identifies the customer
- Tunnels are typically not secure
  - Customer assumes provider links are physically secure

A few more MPLS details

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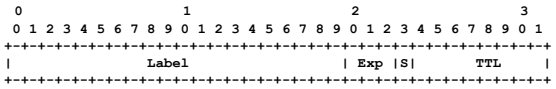
- Headers are stackable
- Uses variant of RSVP for establishing label values
- Also used these days for Traffic Engineering
  - Because can route on source and dest
  - Allows per-customer Service Level Aggrements



Virtual Router based L3 VPNs

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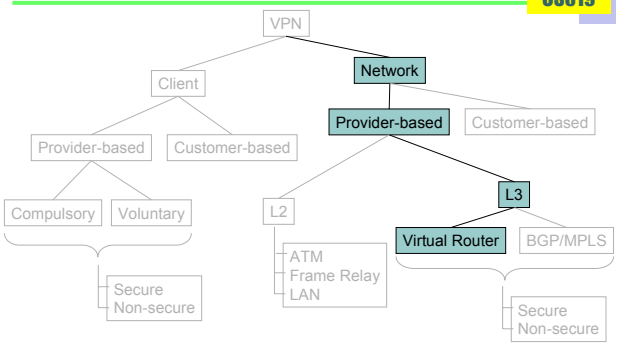

Virtual Router based L3 VPNs

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- BGP/MPLS gave Cisco a huge advantage
  - Because Cisco was the BGP and MPLS expert
- Competitors' counter argument:
  - No need to couple routing technology with tunneling technology…they are separate issues
  - Simpler to use virtual routers

What is a virtual router (VR)?

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- Separate logical router within a single physical router
  - Runs its own routing algorithm
  - Has its own FIB (Forwarding Information Base)
- Basic idea: Incoming tunnel identifies which VR is intended
  - If GRE, then GRE key field
  - If IPsec, then IPsec SPI field
  - If L2TP, then L2TP key field
- This is how overlapping addresses are distinguished

VR approach has discovery issues

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- No standard way to configure tunnels and discover which PEs attach to which customers
  - All manually configured (via management system)
- Various proposals exist
  - Via BGP, OSPF, DNS, an LDAP database, and even IP multicast

Layer 2 LAN VPNs

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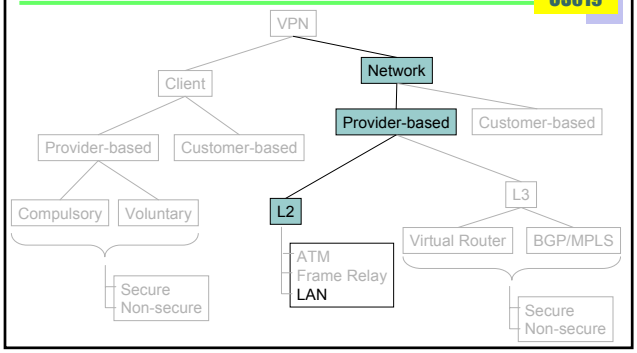

Layer 2 LAN VPNs

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- Model is for PE to look like LAN to CE
- CE broadcast over LAN reaches only other CEs of the same customer
  - Thus customer can run OSPF over LAN in standard way
  - Supports multicast
  - Multi-protocol
- Uses VLAN (Virtual LAN) tags to distinguish customers
- Advantages over FR and ATM are:
  - Ethernet is more common interface
  - Supports broadcast/multicast

What is a VLAN?

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- A “virtual LAN”: makes a single physical look like multiple LANs
- Virtual LAN and priority capabilities are provided by 802.1Q/p:
  - a VLAN tag is provided by 802.1Q to identify VLAN membership
    - Limited to 4096 VLANs – this is a potential scalability issue
  - the VLAN tag has a 3-bit priority field that allows 8 possible service classes (matches DiffServ’s 8 possible classes)

Why VLANs?

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- LAN scalability:
  - limits broadcast domains (limits broadcast storms);
  - also limits multicast, chatty protocols, etc., reducing overall network traffic.
- Network efficiencies: traffic flows from different VLANS can be segregated
- Allows non-physical grouping of nodes that share similar resources
- Allows easy changing of LAN membership
- Reduces the amount of level 3 (IP) routing
- Security: limits snooping; authentication required (via GVRP) to join VLAN

More to the point

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- Ethernet has gotten very fast
  - GigE common
  - 10gig Ethernet coming (optical)
- We can put much more on an Ethernet, so we need to segregate
- These days, site networks are composed of ethernet switches and VLANs, not routers and subnets!

Typical site configuration (from Cisco)

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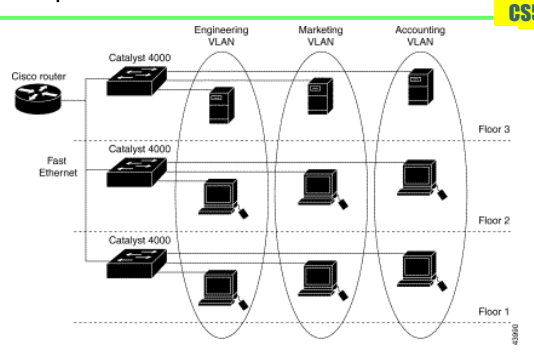

VLAN Header

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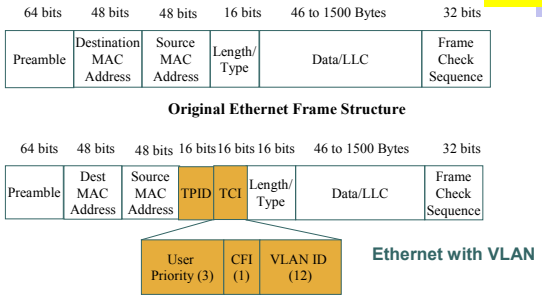

Meta-Point: Its all about tunnels!

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- In this lecture we saw a lot of tunnels
  - IPsec, MPLS, GRE, L2TP
- I said before that the Internet has two ways to scale:
  - Hierarchy and caching
- It has a third way:
  - Tunnels!

Tunnels are scalable

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- Tunnels prevents the “middle” from having to know details of the “edge”
  - But in a manner that is more flexible than hierarchy
  - Hierarchy forces a structure from the middle (top)
  - Tunnels “cut through” the middle transparently
- Tunnels have been introduced piecemeal
  - We still don’t have a coherent architecture for them . . .