Intelligent Information Network

MPLS VPN Security

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Agenda

- Analysis of MPLS/VPN Security
  - Inter-AS VPNs
  - Provider Edge DoS possibility
- Secure MPLS VPN Design
  - Internet Access
- Security Recommendations
- Summary

The Principle: A “Virtual Router”

Virtual Routing and Forwarding Instance

Route Distinguisher: Makes VPN routes unique

```
!
ip vrf Customer_A
  rd 100:110
  route-target export 100:1000
  route-target import 100:1000
!
interface Serial0/1
  ip vrf forwarding Customer_A
!
```

Export this VRF with community 100:1000

Import routes from other VRFs with community 100:1000

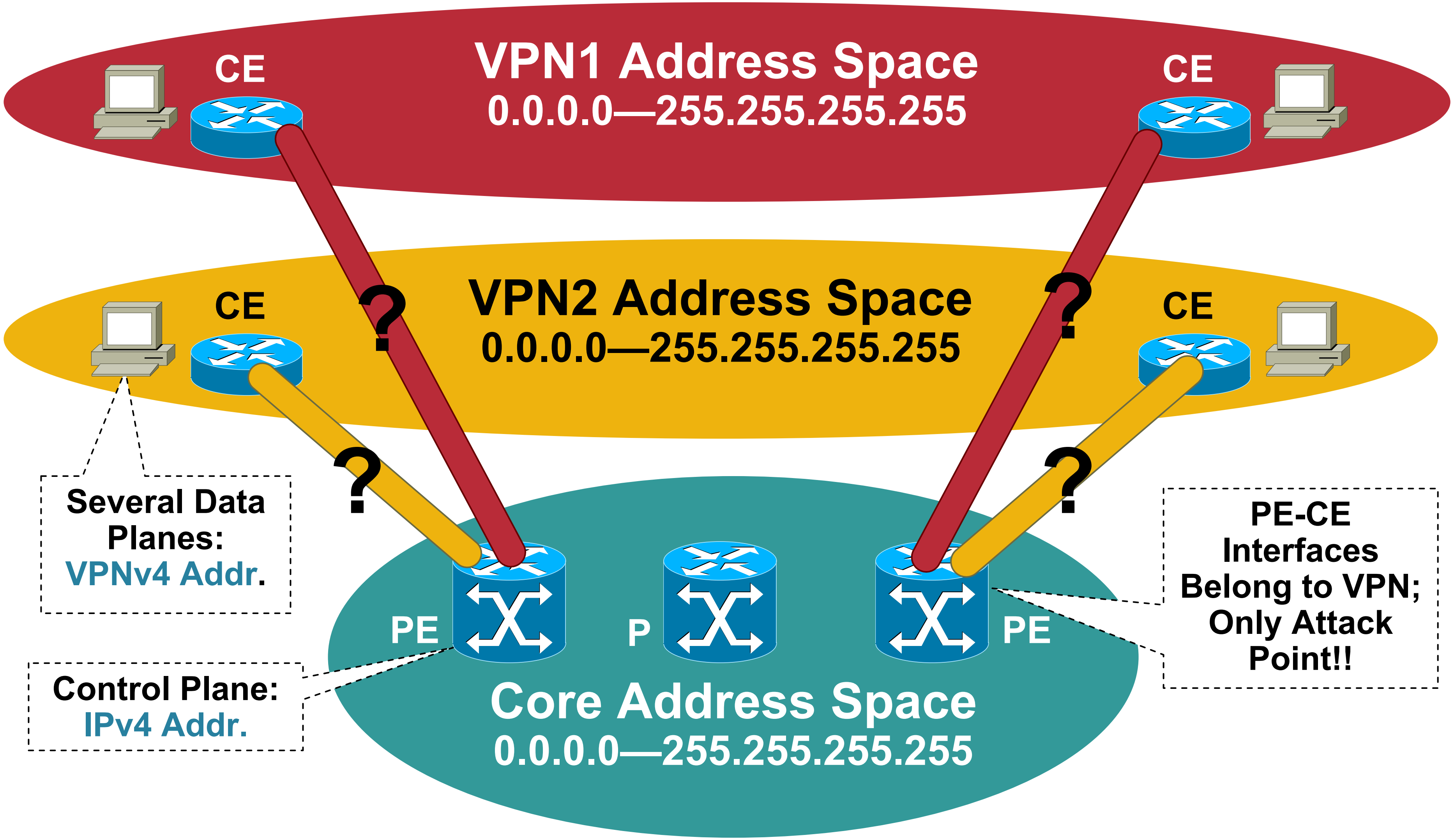
Assign Interface to “Virtual Router”

General VPN Security Requirements

- Address Space and Routing Separation
- Hiding of the MPLS Core Structure
- Resistance to Attacks
- Impossibility of VPN Spoofing

Working assumption: The core (PE+P) is secure

Address Planes: True Separation!

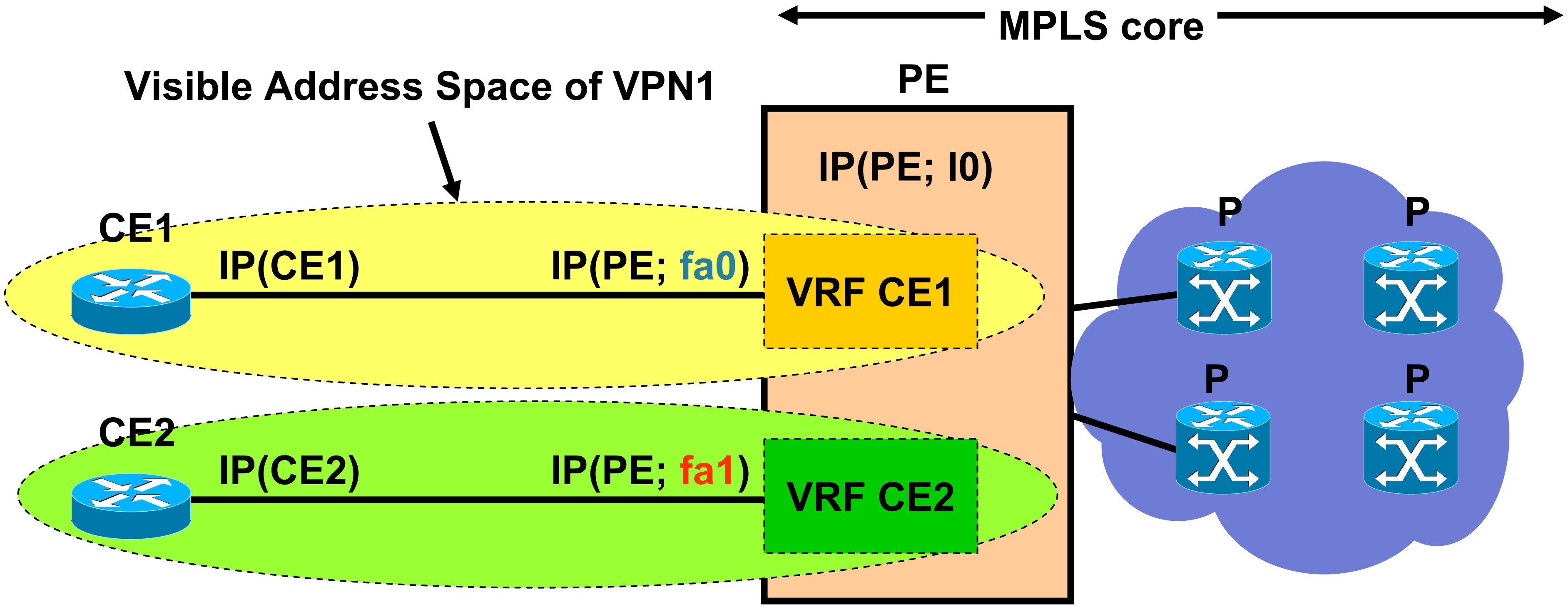


Several Data Planes: VPNv4 Addr.

Control Plane: IPv4 Addr.

PE-CE Interfaces Belong to VPN; Only Attack Point!!

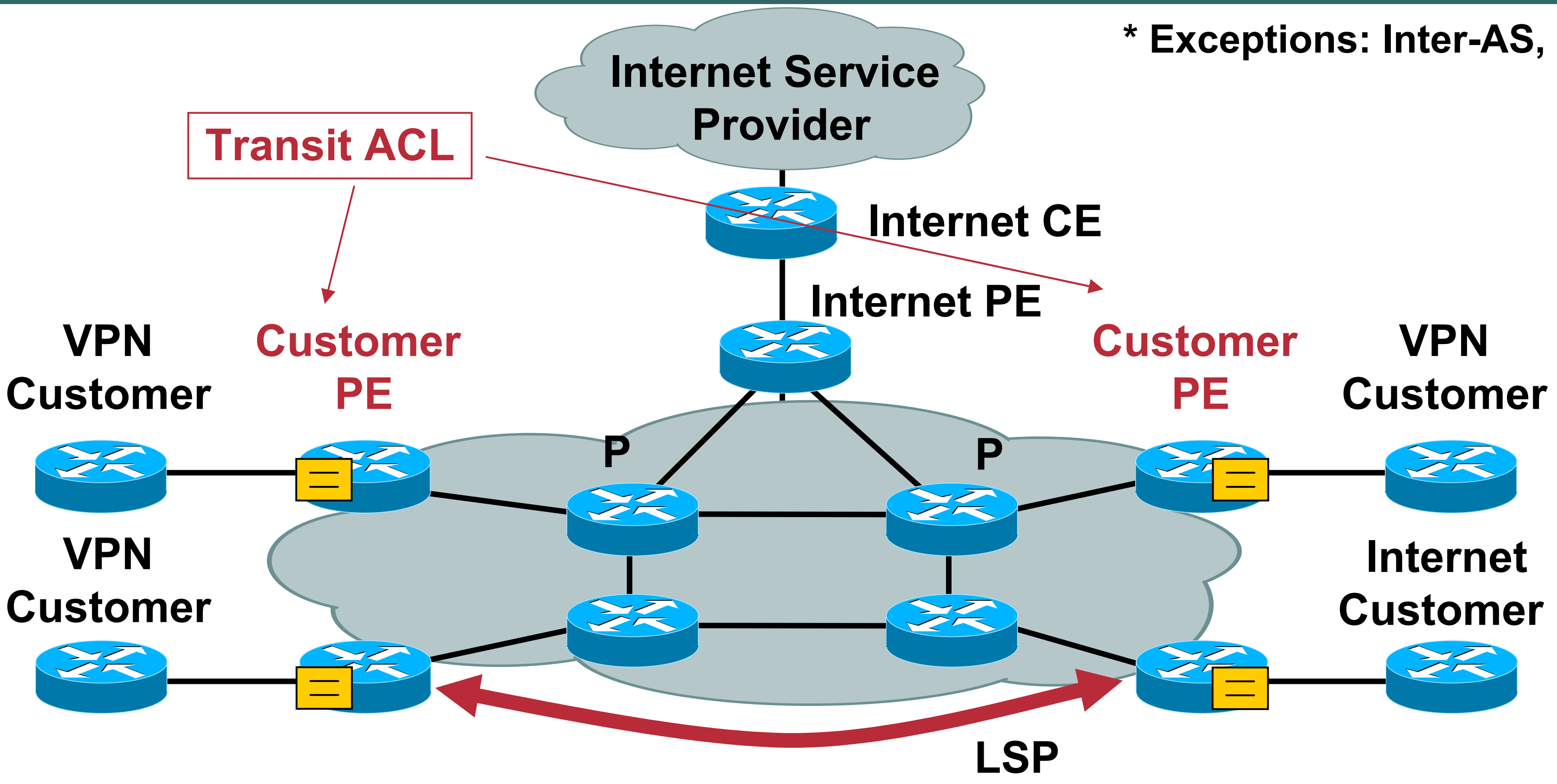
Hiding of the MPLS Core Structure



- **PE interface to CE** – the only point where a VPN can 'see' the core and send packets to the core device; seen and accessible from VPN1 space **only**, **VPN1 cannot see any other interface on the PE**
- **Only PE peer addresses of VPN1 exposed** (-> CE)!
  -> ACL for PE interfaces – for 'receive traffic'
- **IP unnumbered** for PE interfaces – complete hiding of the core from that VPN!
- **P routers** – not reachable from VPN

Protection Against Spoofing

* Exceptions: Inter-AS, CsC



- **Label Spoofing** - Interface between PE and CE – pure IP without labels → labeled packet received from CE, **PE automatically drops it**

→ **Cannot spoof labels from outside!**

- **IP spoofing** – possible, **remains within the originating VPN – RFC2827**

Inter-AS: What are we trying to achieve?

- **An SP should have:**

  100% (full) reachability to all Inter-AS VPNs shared between them (control plane and data plane)

  0% (no) reachability to VPNs that are not shared (control plane and data plane)

- **SP networks should be independent:**

  Must be secured against each other

  Not attackable from outside (other SP, customer, Internet)

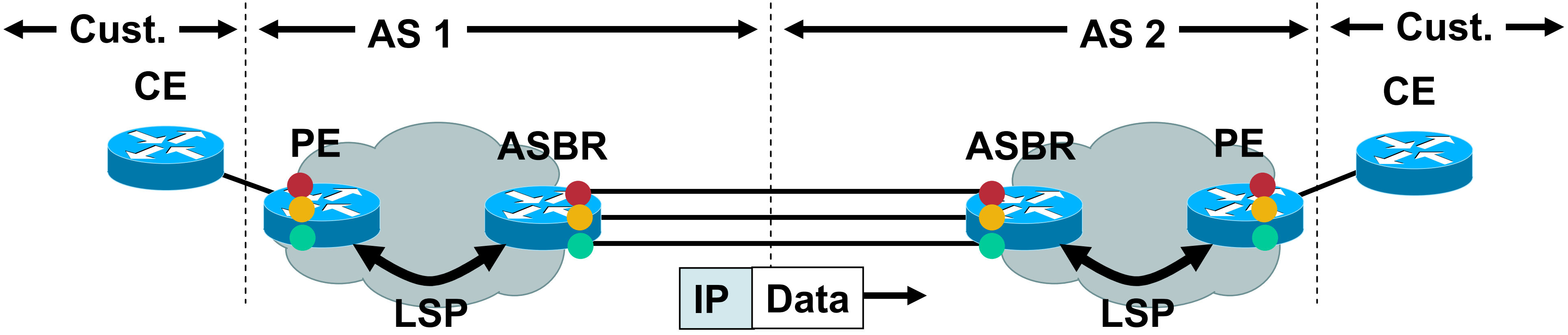
Inter-AS:
What Are We NOT Trying to Achieve?

Any Form of Separation Between Inter-AS VPNs (Control or Data Plane) -

- **Interconnection of VPNs is 100%**
- **No firewalling, no limitations, no sanity checks within an Inter-AS VPN**

If an SP Holds VPN Sites in an Inter-AS Set-Up, He Has Full Access to *All* VPN Sites, Also on Other ASes

Inter-AS: Case A
VRF-VRF Back-to-Back



- **Control plane:** No signalling, no labels – interfaces external to AS are pure IP, each ASBR holds its own VRF for the shared VPN

  ASBR - as if a single PE router connecting a CE router (the other ASBR)

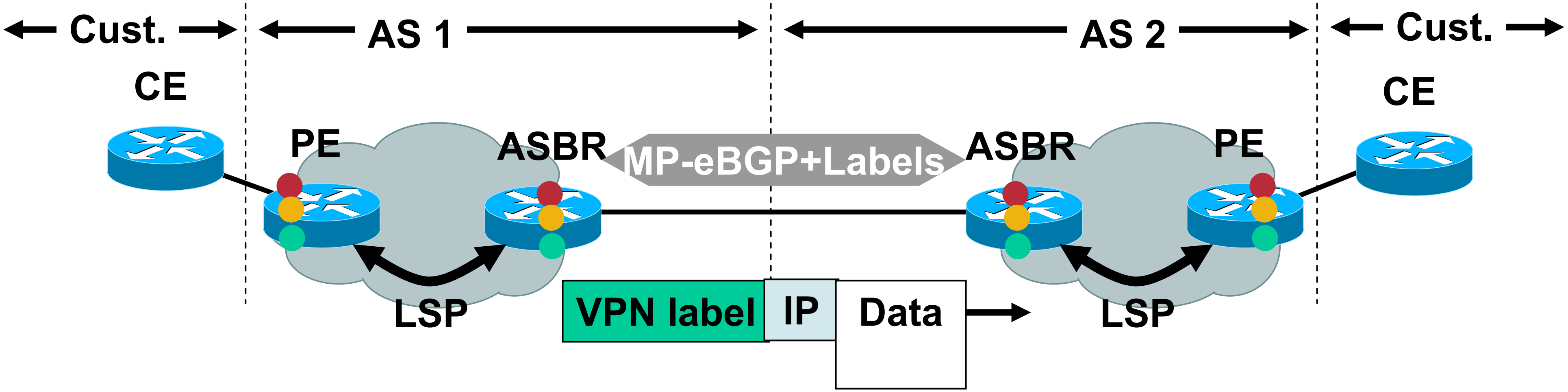
- **Data plane:** IPv4 only, no labels accepted
- Not very scalable

Inter-AS: Case A
Potential Security Issues

- **Accidental misconnection at the ASBR** – SPs have to make sure they are clear about which interface/subinterface connects which VPN
- **Routing issues** –VRFs on both ASBRs will exchange routing for a given Inter-AS VPN
  - ➢ **Routing security**
  - ➢ **Prefix number limited to avoid memory overflow**

- **Security:** as in RFC2547; most secure interconnection model – no labels accepted due to **'PE-CE' analogy**, neighbouring AS cannot see the AS core
- SPs are completely separated, VRF-to-VRF connection, no global routing table connection
- Neighboring ASBR - just an IP interface to MPLS core – **no label spoofing**

Inter-AS: Case B
ASBR exchange labelled VPNv4 routes



- **Control plane:** MP-eBGP between ASBRs, no IGP or TDP/LDP
- Inter-AS VPNv4 routes held in BGP table, not in VRFs
- **Data plane:** one connection between ASBRs – data plane traffic for different VPNs must be kept separate – labelling packets before sending them to the other ASBR (label stack swapped for ASBR VPN label)

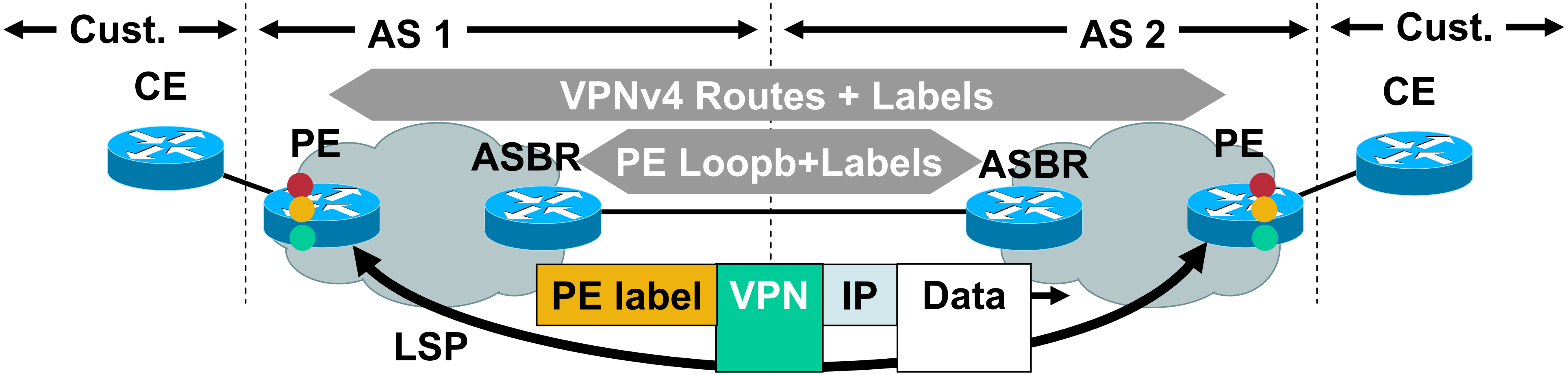
➢ inherent behaviour to MP-eBGP

➢ Better scalability, BGP table size might be an issue

Inter-AS: Case B Potential Security Issues

- **No AS VPN label is checked on ASBRs when forwarding, => possible label spoofing** => data plane not possible to secure completely
    - External interfaces accept labelled packets instead of just IP packets
    - No way for ASBR to check on the VPN membership of the packet, as there is no VRF on ASBR
- **Control plane**: ingress ASBR interfaces – **ACL to filter any IP accept BGP**
- SPs are completely separate
- Visibility – only the neighbouring ASBR, via eBGP

Inter-AS Case C: ASBRs Exchange PE loopbacks



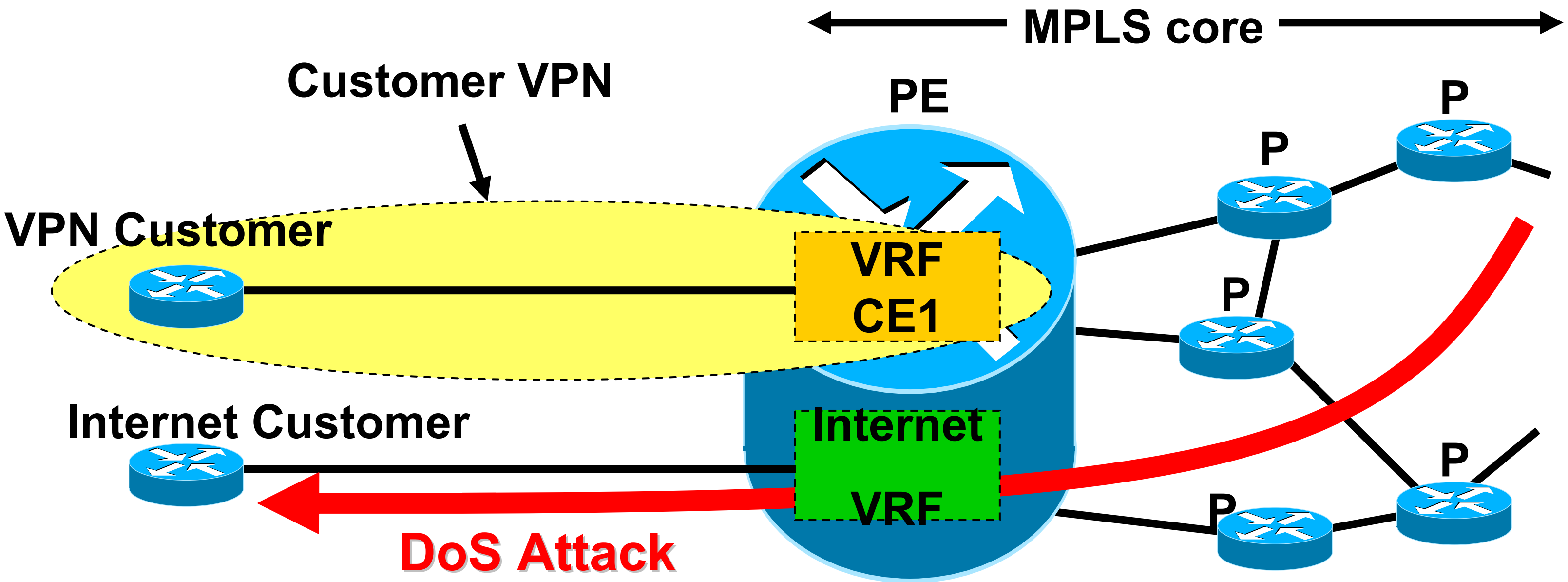
- **Control plane:** PE visibility of both SPs – through Multihop MP-BGP
- ASBR exchange just PE loopback vie eBPG + labels; PEs exchange VPNv4 routes + labels end to end without involving ASBRs => no need to hold VPN specific information, only PE loopbacks and their labels => very scalable
- **Data plane:** PE label + VPN label, ASBRs only as P routers, LSP built from PE in AS1 to PE in AS2

Inter-AS: Case C
Potential Security Issues

- **Security:** SP must be able to reach all PEs of neighbouring AS which hold connections of shared VPNs, issue: ASBR cannot check VPN label, sees only egress PE label, possible VPN label spoofing => probability of mis-insertion
- **Control plane**: ingress ASBR interfaces – ACL to filter any IP accept BGP
- ASBR – no VRF, no VPN routing information => VPN label below egress PE label cannot be checked (e.g. intrusion – no VPN label appended, PHP pops egress PE label at P router, PE receives a pure IP packet – gets routed into SP core)

All these label spoofing attacks carried out by SP, not by customer VPN, as data can be injected at ASBR only!

The Key Issue: Designing a DoS Resistant Provider Edge

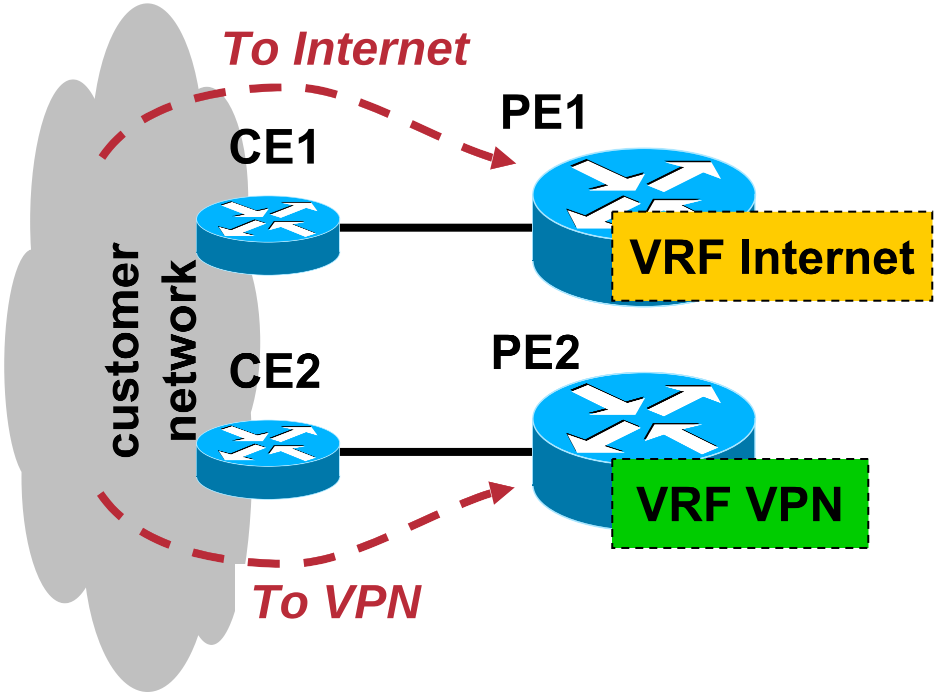


- **Primary prerequisite – IP address visibility**
- **PE has shared CPU / memory / bandwidth resources for different VRFs:**

→ Traffic can affect VPN customer(s) via performance degradation up to complete loss of connectivity

- DoS attacks usually perceived as coming from Internet, however also coming from customer VPNs
- A way to compromise MPLS core – thorough security of PEs crucial to avoid the threat

Today’s Best Practice: DoS Through a Shared PE Solved by Using a different design



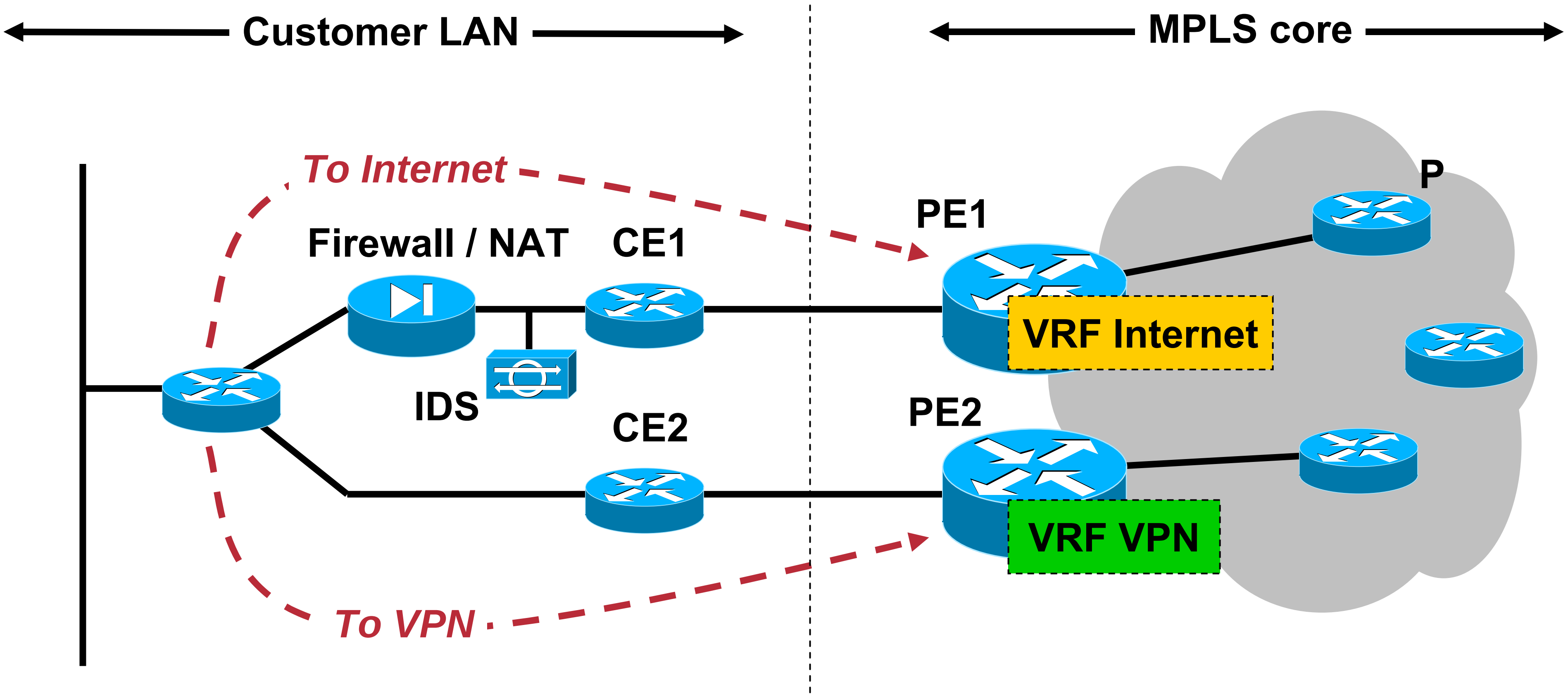
- **Separate VPN and Internet traffic on physically different PE routers**
- **PE routers should contain only VRFs of the same security level. Example:**

  Level 0: Internet

  Level 1: VPN customers

- Internet VPN subject to DoS attack in no different way than other network technologies, i.e. this is not an MPLS-specific issue
- **DO NOT expose PE addresses to Internet at all, or with dynamic routing use limit to routing reachability only – Infrastructure ACL!**

Separate VPN and Internet Access



- Separation
- DoS resistance

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Internet Provisioning on an MPLS Core

Most common VPN user requirement – SP to provide Internet access in addition to VPN connectivity

Two basic possibilities:

1. Internet in global table, either:

   1a) Internet-free MPLS core (using LSPs between PEs)

   1b) Internet routing held by the entire MPLS core (PE and P)

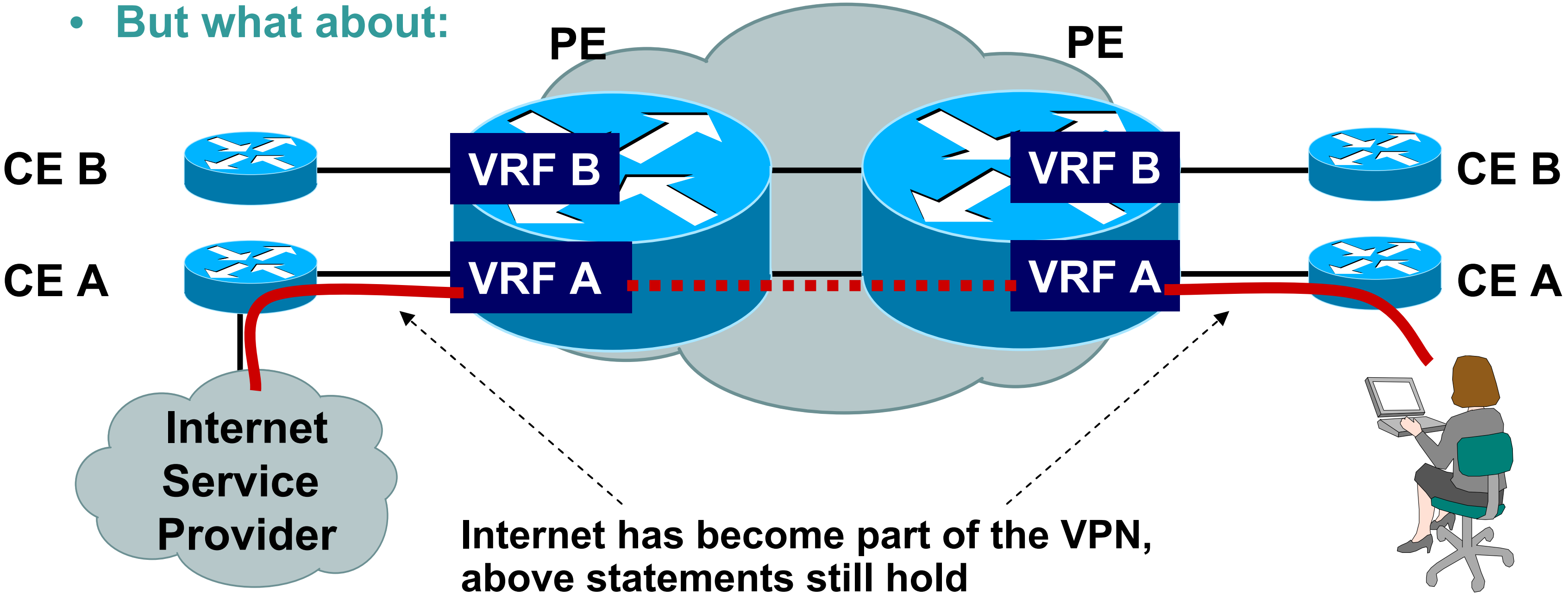
2. Internet in VRF

   Internet carried as a VPN on the core

➢ **Issue – how to design an MPLS core for Internet access such that VPNs remain secure**

MPLS Core Without Internet Connectivity

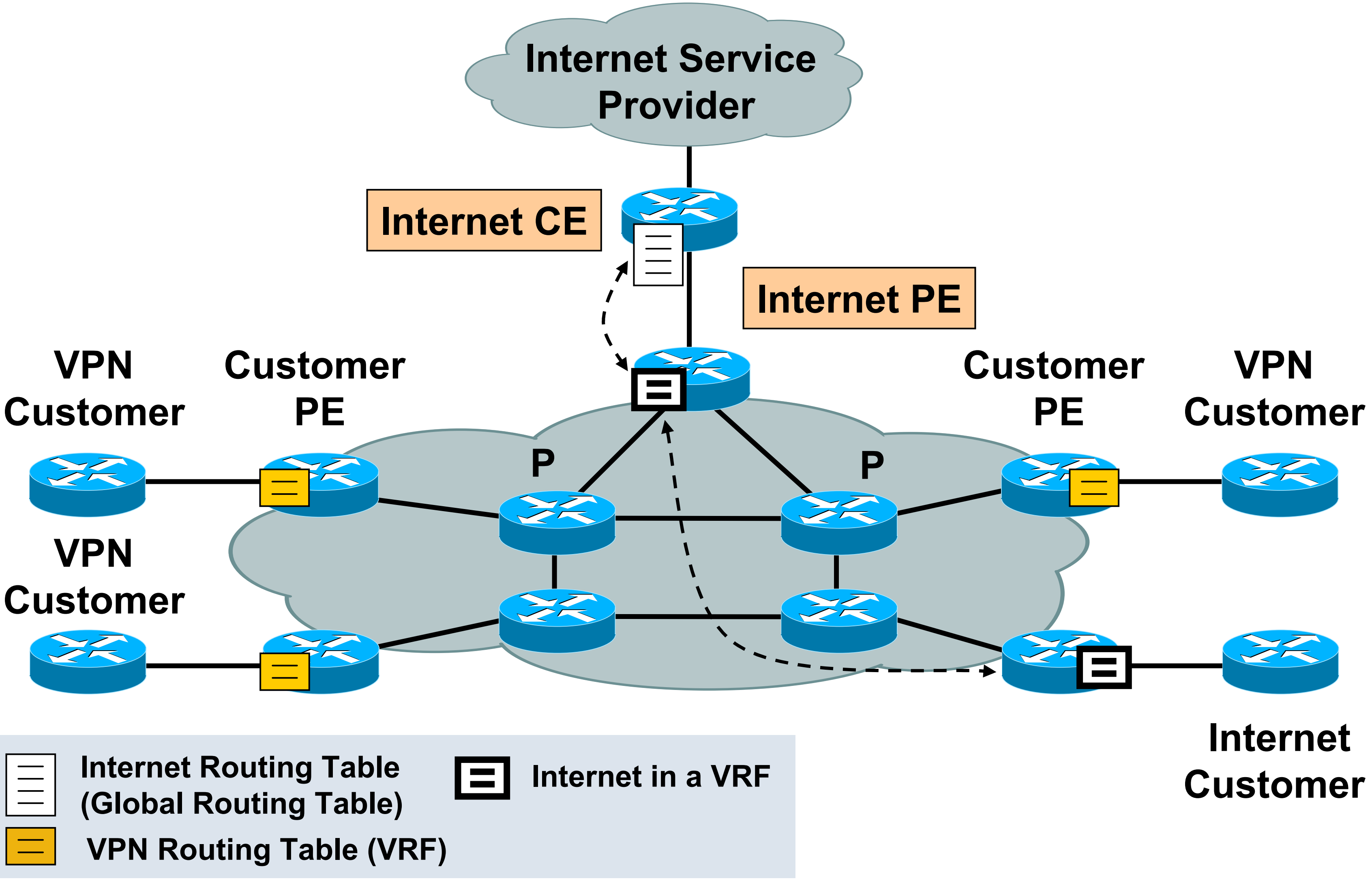
- MPLS Core – no connection to the Internet; only VPNs connect to the core, **P not reachable, also PE** (except in case seen below)
- Pure MPLS VPN service considered "most secure" – well secured against intrusions and DoS attacks from the outside (core invisible from the outside)
- VPN Spoofing impossible, **VPNs not reachable from the outside**
- **But what about:**



Internet has become part of the VPN, above statements still hold

- DoS attack within such VPN – no immense threat as **access capacity of VPN A can be limited by configuration**

Internet in a VRF



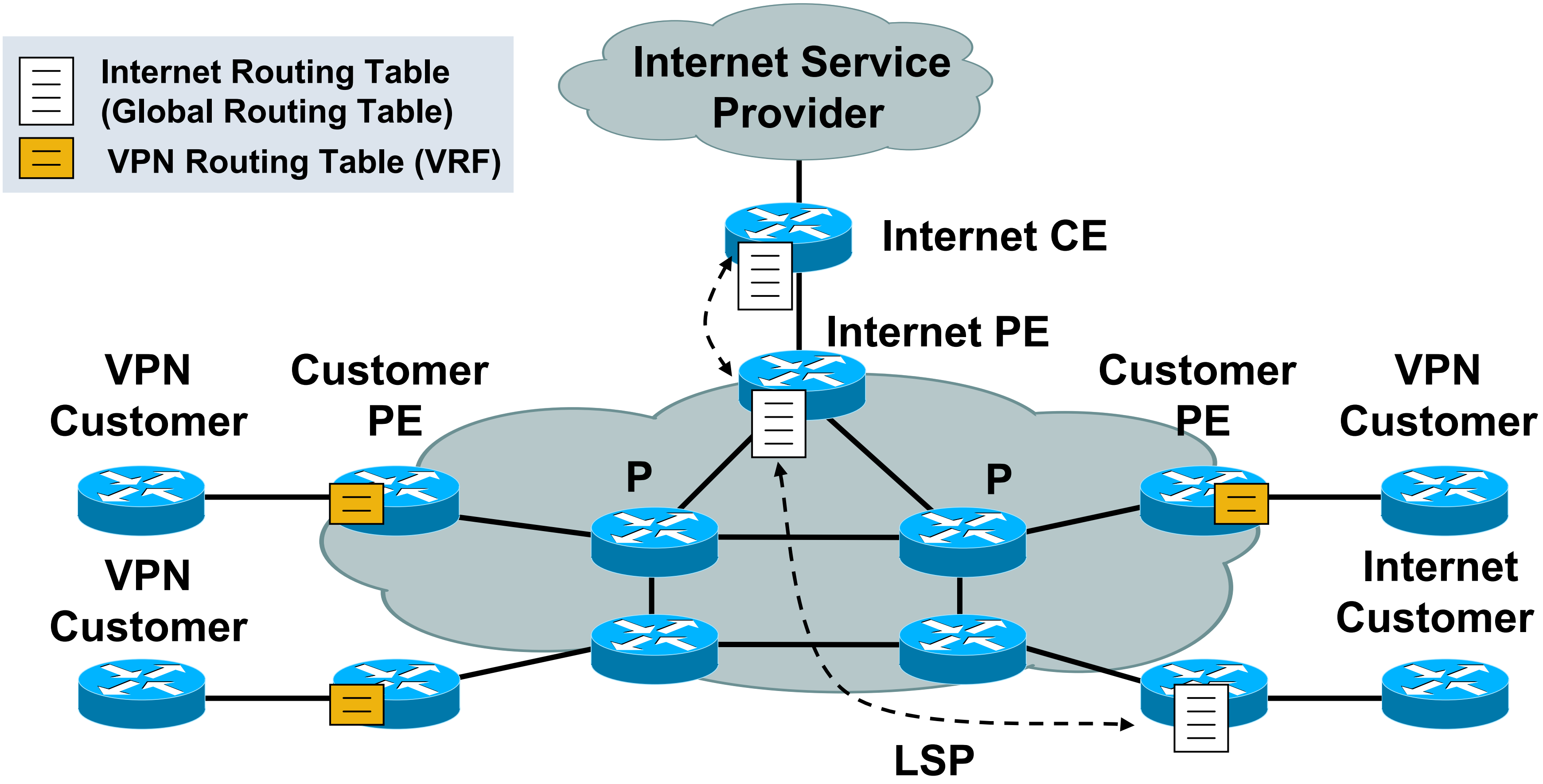
Internet in a VRF – Security Features

- Internet is handled just the same as a VPN, **Customer VPNs not reachable from Internet VPN**
- The core is secure against attacks from the outside as the Internet has no access to the core – **P not reachable**
- Spoofing is impossible between VPNs and Internet in a VPN
- Internet VPN – possibility of DoS of higher magnitude – **PE can be reachable from Internet if not secured properly**

➢ Customer VPNs must not be affected -> provide sufficient capacity in the core OR use QoS to prioritize VPN traffic over Internet traffic

➢ **Scalability Issue** – a prefix held in a VRF requires about three times as much memory as a prefix held in the global table => additional memory required

Internet in the Global Routing Table Using LSPs Between PEs



- **Ingress PE - iBGP next hop - Egress PE loopback**

  Next hop to egress usually has label, LSP is used to reach egress PE

  P routers do not need to know Internet routes (nor run BGP, only IGP and LDP)

Internet in the Global Routing Table Using LSPs Between PEs - Recommendations

- In this model PE routers have to carry routes for P routers in their IGP
- Traffic coming from the outside into a PE router's global routing table will have normally a route to the P routers (P reachable unidirectionally)
- LDP and iBGP threatened via attacks against TCP – **usage of MD5 authentication as a solution**

➢ use **Infrastructure ACLs** to prevent packets from outside reach the inside of the core

➢ use **Receive ACLs** and **Control Plane Policing** to protect the control plane of a single platform

➢ **Consider using NSAP addresses in core – IS-IS**

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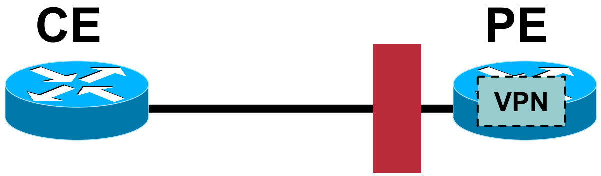
Securing the Core: Infrastructure ACLs



In MPLS:
PE address
belongs to VRF!

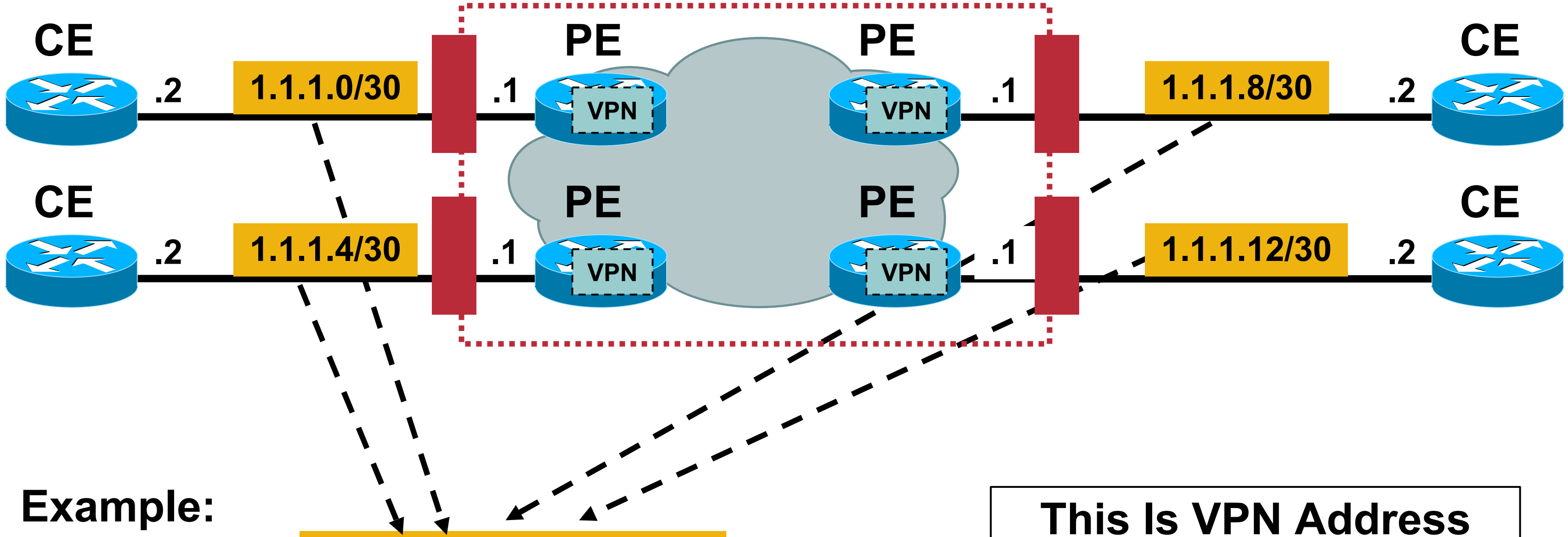
- Intended to filter data **destined** for network infrastructure equipment, i.e. what protocols and addresses **can access** critical infrastructure equipment
- On all reachable PE VRF interfaces:

  deny ip any <PE – CE address space>

  permit ip any any

  exception: routing protocol from CE only and all transit traffic
- Idea: Protecting the Core
- DoS: traffic over router theoretically enables DoS, **primary threat – traffic destined for RP**
- **iACLs also to deny** source private address space, reserved addresses, SPs own address space - **antispoofing**

Securing the Core: Infrastructure ACLs



- **Example:**

  deny ip any 1.1.1.0 0.0.0.255

  permit ip any any

This Is VPN Address Space, Not Core!

- **Caution:** This also blocks packets to the CE's!

  Alternatives: List all PE i/f in ACL, or use secondary i/f on CE

Securing the Core:
PE-CE routing protocol security

In order of security preference:

1. **Static: If no dynamic routing required**
(no security implications – no fabricated routing updates, less CPU impact, possible sniffing not revealing routes due to no updates**)**

2. **BGP: For redundancy and dynamic updates**
(many security features – prefix filtering, route dampening, one BGP process, multiple address-families (per customer/VRF), redistribution at PE not necessary into iBGP**)**

3. **IGPs: If BGP not supported**
(limited security features – PE peering address known, no ‘neighbor’ definition, use iACLs**)**

Routing Security: Neighbor Authentication and BGP TTL

- **Use static routing between CE and PE where possible**

  no errant routes announced, no routing data crossing the ‘wire’, no CPU impact

- Routers authenticate each time a routing update is exchange between them – reliable information received from a trusted source

  Verification through MD5 hash

- Supported: BGP, ISIS, OSPF, EIGRP, RIPv2, LDP
- **MD5 for LDP –** label spoofing protection, enable also on MP-iBGP

Control of Routes from a BGP Peer

- **Injection of too many routes – possible attack at routing table stability, CPU and memory:**

  Potential DoS attack, leading e.g. to CEF disabling or reload

- **Control with "maximum prefix" command**

  After exceeding the number – BGP peering disabled, neighbor down

From This Neighbor…

… Accept Max 45 Prefixes, Then Reset Session …

```
router bgp 13
  neighbor 140.0.250.2 maximum-prefix 45 80 restart 2
```

…Log a Warning at 80% (of 45),…

…and Restart the BGP Session After Two Min.

Control of Routes from a BGP Peer: Logging

```
6d22h: %BGP-4-MAXPFX: No. of prefix received from 140.0.250.2 (afi 2)
   reaches 37, max 45

6d22h: %BGP-3-MAXPFXEXCEED: No. of prefix received from
   140.0.250.2 (afi 2): 46 exceed limit 45

6d22h: %BGP-5-ADJCHANGE: neighbor 140.0.250.2 vpn vrf
   VPN_20499 Down BGP Notification sent

6d22h: %BGP-3-NOTIFICATION: sent to neighbor 140.0.250.2 3/1
   (update malformed) 0 bytes  FFFF FFFF FF
```

VRF Maximum Prefix Number

- **Injection of too many routes:**

  Potential memory overflow

  Potential DoS attack

- **For a VRF: Specify the maximum number of routes allowed**

In This VRF…

… Accept Max 45 Prefixes,…

```
ip vrf red
 maximum routes 45 80
```

…and Log a Warning at 80% (of 45),…

PE-Specific Router Security

- **PE Control Plane hardening – Receive traffic**
  - L3 routing environment (authentication, max number of prefixes…)
  - Infrastructure ACLs
  - Protection ACLs (anti-spoofing, etc.)
- **PE Data Plane Hardening**
  - Use **uRPF Strict mode** on each interface of the PE routers' CE-facing interfaces and on the CE routers' PE-facing interfaces

Attacking a CE from MPLS (other VPN)

- **Is the CE reachable from the MPLS side?**

  -> only if this is an Internet CE, otherwise not!
  (CE-PE addressing is part of VPN!)

- **For Internet CEs:**

  Same security rules apply as for any other access router.

MPLS hides VPN-CEs: Secure!
Internet CEs: Same as in other networks

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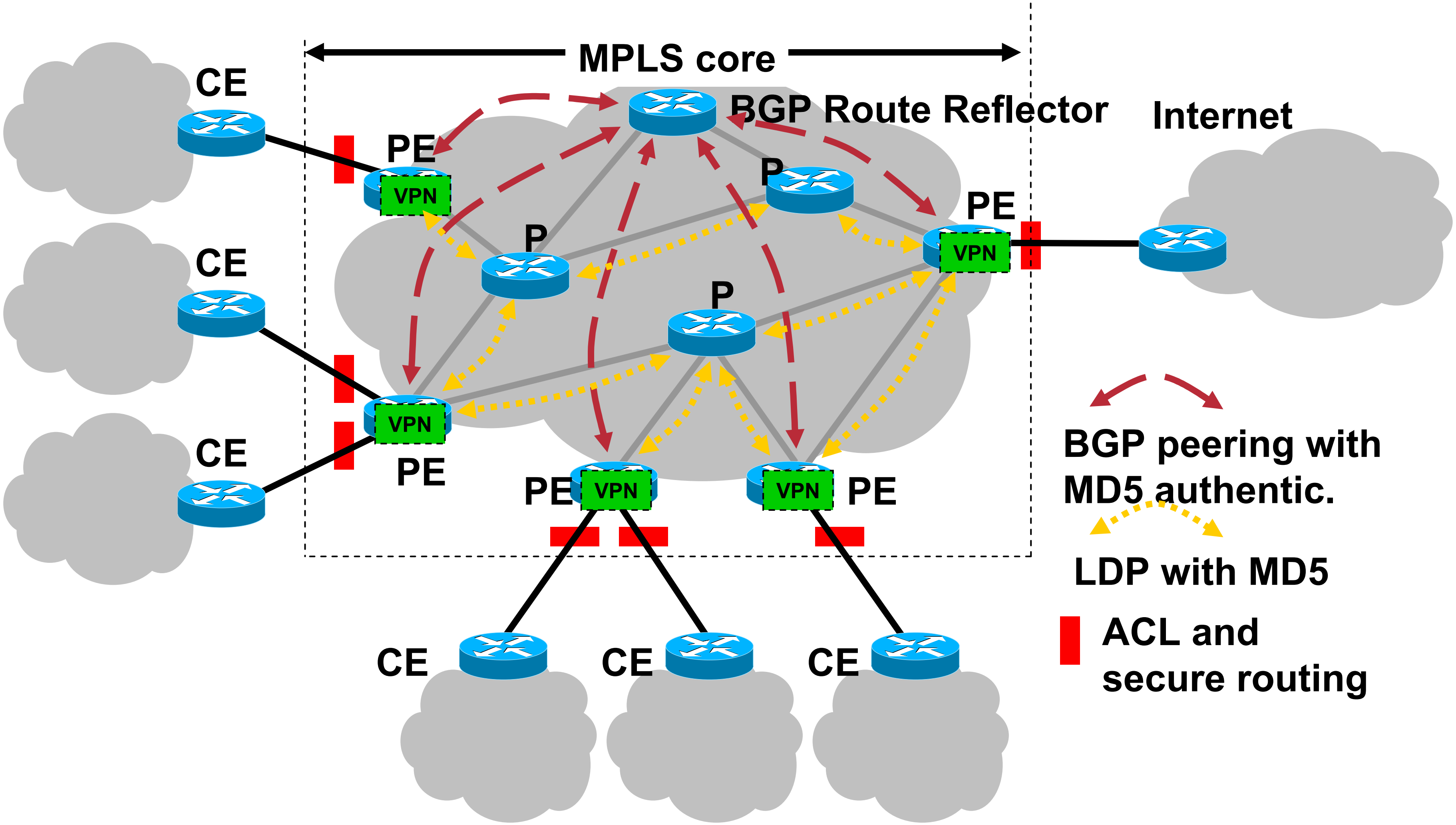
Securing the MPLS Core: Wrap-Up



MPLS core

BGP Route Reflector

Internet

CE

CE

CE

PE

PE

PE

PE

PE

P

P

P

VPN

VPN

VPN

VPN

VPN

CE

CE

CE

BGP peering with MD5 authentic.

LDP with MD5

🟥 ACL and secure routing

MPLS Security Overview

1. Don’t let packets into (!) the core

   → No way to attack core, except through routing, thus:

Still “open”: routing protocol

2. Secure the routing protocol

   Neighbor authentication, maximum routes, dampening, …

Only attack vector: Transit traffic

3. Design for transit traffic

   QoS to give VPN priority over Internet

   Choose correct router for bandwidth

   Separate PEs where necessary

Now only insider attacks possible

4. Operate Securely

Avoid insider attacks