Large Scale Denial of Service Mitigation

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Agenda

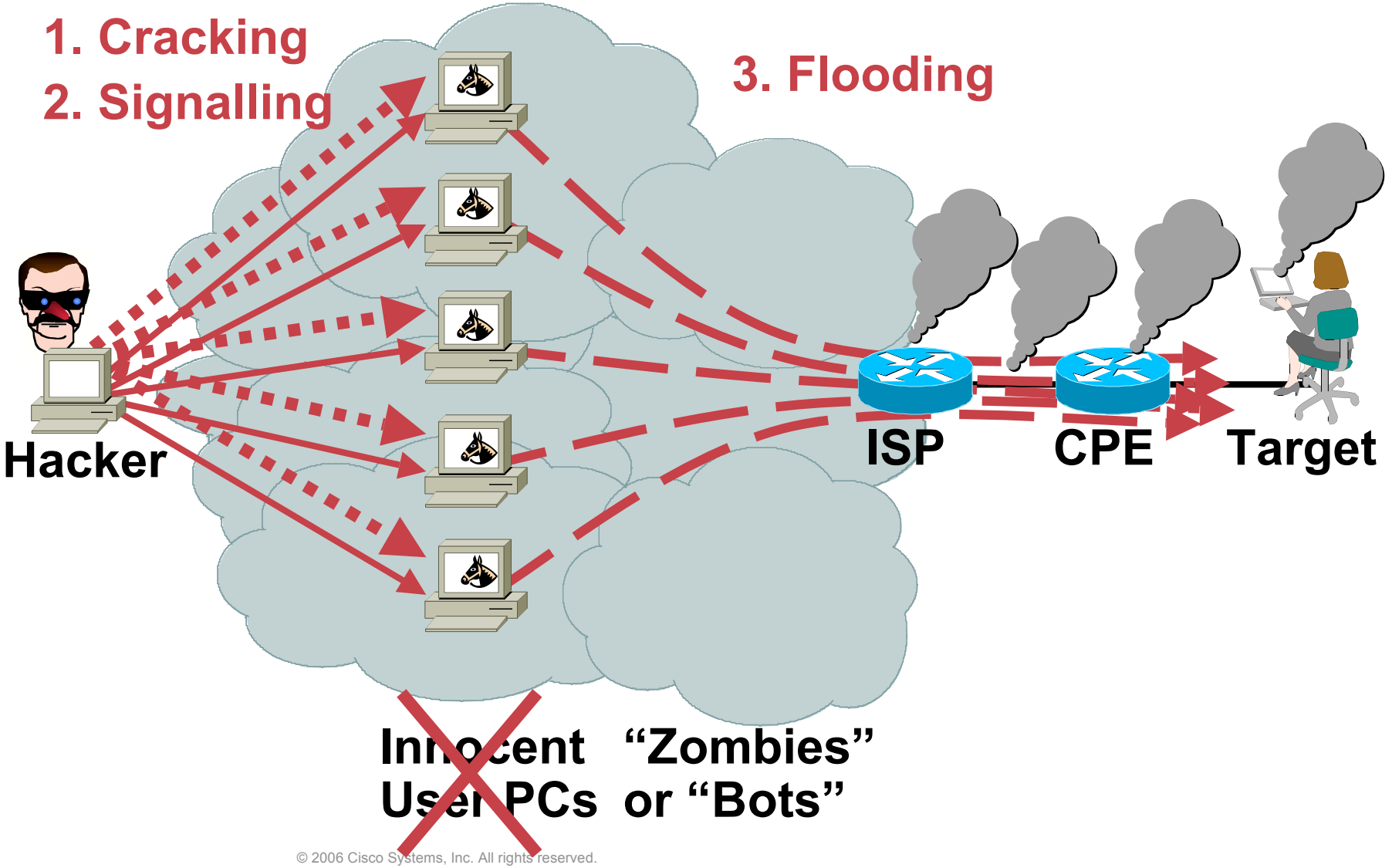
- Introduction
- Prerequisites to Mitigation
- Mitigation
- Large Scale Discussion
- Future Developments

Introduction

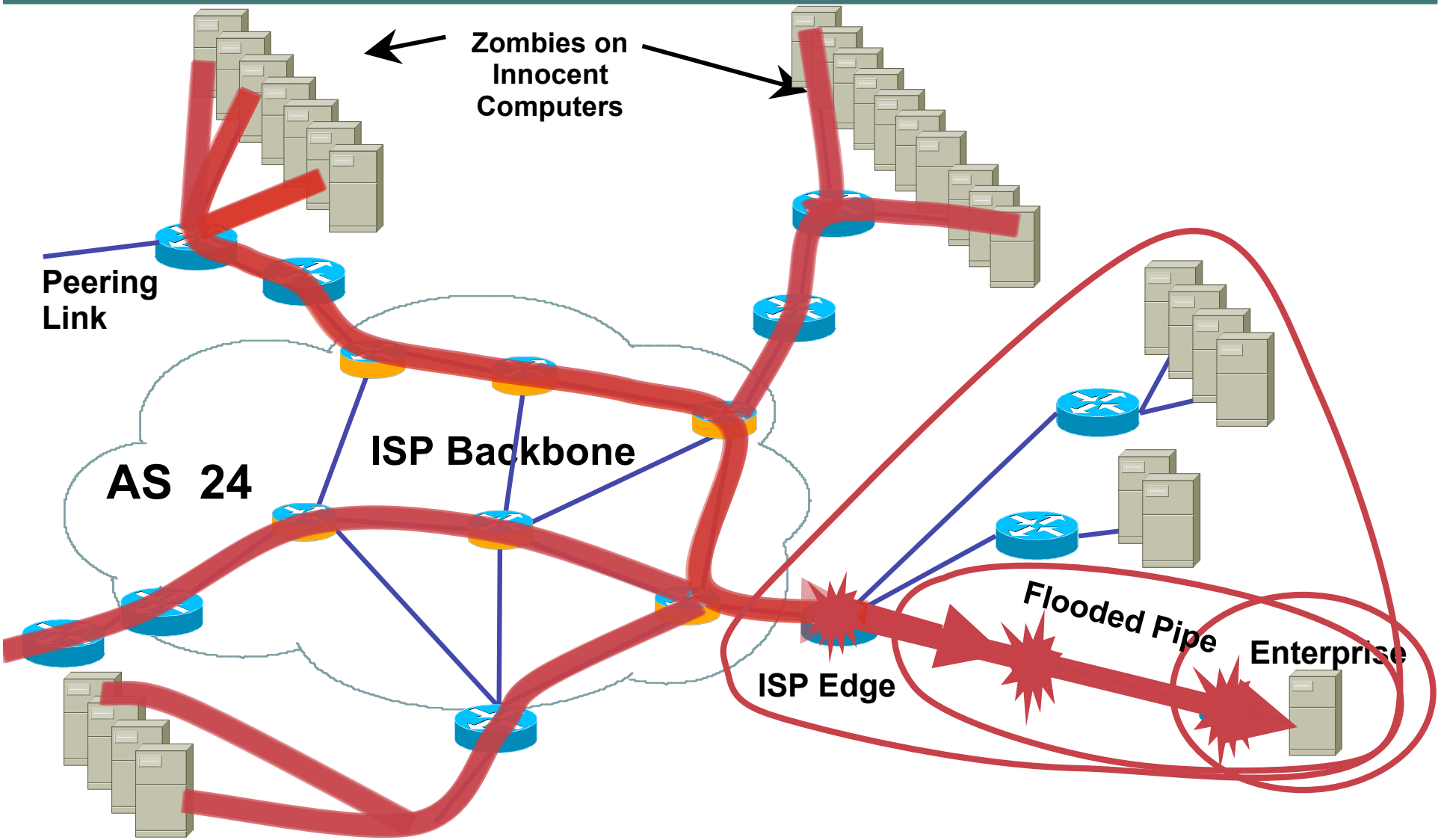
Denial of Service Attacks

- We understand intrusions (patch, patch, patch ;-))
- What about DoS? Do “the right things” and still suffer
- The vast majority of modern DoS attacks are distributed
  - DDos IS DoS
- DoS is often driven by financial motivation
  - DoS for hire :-(
  - Economically-driven miscreant community
- DoS cannot be ignored; your business depends on effective handling of attacks

DoS: The Procedure



An SP View: Denial of Service



Denial of Service Trends

- Multi-path
  - Truly distributed
  - Inbound and Outbound
- Multi-vector
  - SYN AND UDP AND…
- Financial incentive
  - SPAM, DoS-for-hire
  - Large, thriving business
  - Forces us to reassess the risk profile

Infrastructure Security

- All of the techniques talked about today also assume that the infrastructure is available to route and forward packets!
- The infrastructure can either be targeted, or be impacted indirectly

Infrastructure Attacks

- Infrastructure attacks are increasing in both volume and sophistication
  - Sites with Cisco documents and presentations on routing protocols (and I don't mean Cisco.com)
  - Marked increase in presentations about routers, routing and Cisco IOS vulnerabilities at conferences like Blackhat, Defcon and Hivercon
  - Router attack tools and training are being published
- Why mount high-traffic DDOS attacks when you can take out your target's gateway routers?
- Hijacked routers are valuable in the spam world, which has a profit driver
- Router compromise (0wn3d) due to weak password

From Bad to Worms

- Worms have emerged as the new security reality
- Old worms never die!
  - Millions of UPnP and Slammer packets still captured daily
- Most worms are intended to compromise hosts
- Worm propagation is dependant on network availability
- Worms and DoS are closely related
  - Secondary worm effects can lead to denial of service
  - Worms enable DoS by compromising hosts → BOTnets
- Perimeters are crumbling under the worm onslaught (VPN/mobile workers, partners, etc.)
- How do you Assess your backbone's risk?
  - Per flow forwarding
  - Excess capacity
  - SLAs

Worms and the Infrastructure

- Worms typically infect end-stations
- To date, worms have not targeted infrastructure BUT secondary effects have wreaked havoc
  - Increased traffic
  - Random scanning for destination
  - Destination address is multicast
  - TTL and other header variances
- At the core SP level, the aggregate effects of a worm can be substantial
- Worm severity is escalating and evolving

What we are and are not Covering

- **In scope:**
  - **Large-scale attacks: large number of customer impacted, multiple sites**
  - **Collateral damage to the network**
- **Out of scope:**
  - **‘Small scale’ deployments**
  - **Content evaluation techniques**
    - **DDoS needs to cover cases where the content is valid!**
    - **This isn’t going to be an IPS signature discussion**

Prerequisites to Mitigation

Six Phases to Large-Scale Security Incident Response

1. Preparation
2. Identification
3. Classification
4. Traceback
5. Reaction
6. Post mortem

Preparation

Preparation—Develop and Deploy a Solid Security Foundation

- Includes technical and non-technical components
- Encompasses best practices
- The hardest, yet most important phase
- Without adequate preparation, you are destined to fail
- The midst of a large attack is not the time to be implementing foundational best practices and processes

Preparation

- Know the enemy
  - Understand what drives the miscreants
  - Understand their techniques
- Create the security team and plan
  - Who handles security during an event? Is it the security folks? The networking folks?
- Harden the devices
- Prepare the tools
  - Network telemetry
  - Reaction tools
  - Understand performance characteristics

You Are Under Attack: It's Usually Too Late


```
TCP
Local Address          Remote Address         State
-------------------- -------------------- -------
*.*                    *.*                  IDLE
*.sunrpc               *.*                  LISTEN
*.ftp                  *.*                  LISTEN
*.telnet               *.*                  LISTEN
*.finger               *.*                  LISTEN
target.telnet    10.10.10.11.41508          SYN_RCVD
target.telnet    10.10.10.12.41508          SYN_RCVD
target.telnet    10.10.10.13.41508          SYN_RCVD
target.telnet    10.10.10.14.41508          SYN_RCVD
target.telnet    10.10.10.10.41508          SYN_RCVD
target.telnet    10.10.10.15.41508          SYN_RCVD
target.telnet    10.10.10.16.41508          SYN_RCVD
target.telnet    10.10.10.17.41508          SYN_RCVD
target.telnet    10.10.10.18.41508          SYN_RCVD
target.telnet    10.10.10.19.41508          SYN_RCVD
target.telnet    10.10.10.20.41508          SYN_RCVD
*.*                    *.*                  IDLE
```

Output From `netstat -an` on Target Host

Once the Connection Queue Is Full of Waiting-to-Be-Completed Connections, All SYN+RCVDs Get FIFOed out!

Ways to Detect

- Customer call
  - "The Internet is down"
- Unexplained changes in network baseline
  - SNMP: line/CPU overload, drops
  - Bandwidth
  - NetFlow
- ACLs with logging
- Backscatter
- Packet capture
- Network IDS
- Anomaly detection

Network Baselines

- NMS baselines
- Unexplained changes in link utilization
  - Worms can generate a lot of traffic, sudden changes in link utilization can indicate a worm
- Unexplained changes in CPU utilization
  - Worm scans can effect routers/switches resulting in increased CPU both process and interrupt switched
- Unexplained syslog entries
- These are examples
  - Changes don't always indicate a security event!
  - Need to know what's normal in order to identify abnormal behavior

Source vs. Destination Detection

- **Destination detection focuses on the victim**
  - **This if often easy!**
- **How do we distinguish between good and bad sources?**
  - **Furthermore, what about a given source's behavior when it is both good and bad?**
  - **Flash crowds**
- **Comprehensive detection deployments need to take src and dst detection into account**

Classification

- **Classification—understand the details and scope of the attack**
  - **Identification is not sufficient; once an attack is identified, details matter**
  - **Guides subsequent actions**
- **Identification and classification are often simultaneous**

Classification

- **Qualify and quantify the attack without jeopardizing services availability (e.g., crashing a router):**
  - **What type of attack has been identified?**
  - **What's the effect of the attack on the victim(s)?**
  - **What next steps are required (if any)?**
- **At the very least:**
  - **Source and destination address**
  - **Protocol information**
  - **Port information**

Reaction

Reaction—Do Something to Counter the Attack

- Should you mitigate the attack?
  - Where? How?
- No reaction is a valid form of reaction in certain circumstances
- Reaction often entails more than just throwing an ACL onto a router

Traceback

- Operational challenge
  - Know your peers!
  - Use iNOC phone network to communicate with them directly
- Traceback—what are the sources of the attack?
  - How to trace to network ingress points
  - Understand your topology!
- Traceback to network perimeter
  - NetFlow
  - Backscatter
  - Packet accounting
- Retain attack data
  - Use to correlate interdomain traceback
  - Required for prosecution
  - Clarify billing and other disputes
  - Post mortem analysis

Reacting to Attacks

- Many varying reaction mechanisms
- No one tool or technique is applicable in all circumstances
  - Think “toolkit”
  - Automate where possible
  - Don’t forget about the operational costs!
- Choose your techniques wisely

Post Mortem

Post Mortem—Analyze the Event

- The step everyone forgets!
- What worked? What didn't? How can we improve?
- What can be done to build build defense against repeat occurrences
- Was the DOS attack you just handled the real threat? Or was it a smoke screen for something else that just happened?
- What can you do to make it faster, easier, less painful in the future?
- Metrics are important!
  - Resources, headcount, etc.

SP Community Efforts

Inter-Provider Cooperation

- Increased inter-provider cooperation is required when handling attacks
  - Competitors working together
  - Traceback requires inter-AS work
- Ad-hoc buddy network didn't work
  - iNOC IP phone network
  - NSP-SEC mailing list

NSP-SEC

- **NSP-SEC – Closed Security Operations Alias for engineers actively working with NSPs/ISPs to mitigate security incidents.**
- **Multiple Layers of sanity checking the applicability and trust levels of individuals**
- **Not meant to be perfect – just better than what we had before**
- **http://puck.nether.net/mailman/listinfo/nsp-security**

NSP-SEC: Daily DDOS Mitigation Work

I've been working an attack against XXX.YY.236.66/32 and XXX.YY.236.69/32. We're seeing traffic come from <ISP-A>, <ISP-B>, <IXP-East/West> and others.

Attack is hitting both IP's on tcp 53 and sourced with x.y.0.0.

I've got it filtered so it's not a big problem, but if anyone is around I'd appreciate it if you could filter/trace on your network. I'll be up for a while :/

NSP-SEC-DISCUSS

- **NSP-SEC is where the mitigation takes place. You do not learn anything, you are already expected to know.**
- **NSP-SEC-DISCUSS is the place to learn, consult, work on new mitigation techniques, and lurk (if you want to).**

  http://puck.nether.net/mailman/listinfo/nsp-security-discuss

Technical Efforts

- Security forums and topics at large events
  - NANOG
  - IETF
- Sharing the wealth
  - Service providers are sharing their experience with others
    - UU published traceback technique
    - AOL talked about ISIS migration

What Do ISPs Need to Do?

- Implement Best Common Practices (BCPs)
  - ISP infrastructure security
  - ISP network security
  - ISP services security
- Work with operations groups, standards organizations, and vendors on new solutions
- NSP-SEC mailing list is a great example of inter-provider communication and mitigation

iNOC DBA – Why ?

- ISPs need to coordinate for attacks. They need to talk.
- It is not easy to reach the right contact. The engineer you are trying to reach will not likely pick up the phone.
- Solution: Dedicated NOC Hotline System

  INOC-DBA: *Inter-NOC Dial-by-ASN*

What is the problem?

- **ISPs needed to talk to each other in the middle of the attack.**
- **Top Engineers inside ISPs often do not pick up the phone and/or screen calls so they can get work done. If the line is an outside line, they do not pick up.**
- **Potential solution – create a dedicated NOC Hotline system. When the *NOC Hotline* rings, you know it is one of the NOC Engineer's peers.**

iNOC DBA Hotline

- The iNOC Hotline is used to get directly to peers.
- Numbering system based on the Internet:

  ASnumber:phone

  109:100 is Barry's house.
- SIP Based VoIP system, managed by Packet Clearing House (www.pch.net), and sponsored by Cisco.
- www.pch.net/inoc-dba

How to Participate

- **With your own phones:**

  PCH needs your MAC address, contact info, ASNs, and extension number.

- **With PCH phones:**

  PCH need your contact and shipping address, ASNs, and extension number.

How is iNOC being used today?

- Used during attacks like Slammer
- Coordination during large DoS attacks targeting multi-homed customers
- Many DNS Root Servers are using the iNOC Hotline for their phone communication
- General engineering consultation – SP engineers working on inter-SP issues

More Information

- General information:
  http://www.pch.net/inoc-dba/
- Mailing-list archive:
  http://www.pch.net/resources/discussion/inoc-dba/archive/
- Who's participating:
  http://www.pch.net/inoc-dba/directory/

Exchanges		Carriers		Associations	
LINX	SD-NAP	UUnet	AT&T	ARIN	
PAIX	LAIIX	Sprint	SBC	APNIC	
Equinix	NSP-IXP2		C&W	AOL/T-WRIPE/NCC	
AMS-IX	NOTA	Genuity	RCN	ICANN	
MAEs	OIX	Verio/NTT		TDS	ISC

Mitigation

Capacity as a Solution

- For many types of attacks, a common solution is to add more capacity
- Not every problem gets solved this way
  - Think about collateral damage
- Challenge is to solve all the problems in the most economically feasible way

Data Plane Mitigation

RFC 2827/BCP 38 Ingress *Packet* Filtering

Packets Should Be Sourced from Valid, Allocated Address Space, Consistent with the Topology and Space Allocation

- Our goal here is to bind the problem and reduce the requirements for implementing security

BCP 38: Consequences of No Action

No BCP 38 Means That:

- Devices can (wittingly or unwittingly) send traffic with spoofed and/or randomly changing source addresses out to the network
- Complicates traceback immensely
- Sending bogus traffic is NOT free!

BCP 38 *Packet* Filtering Principles

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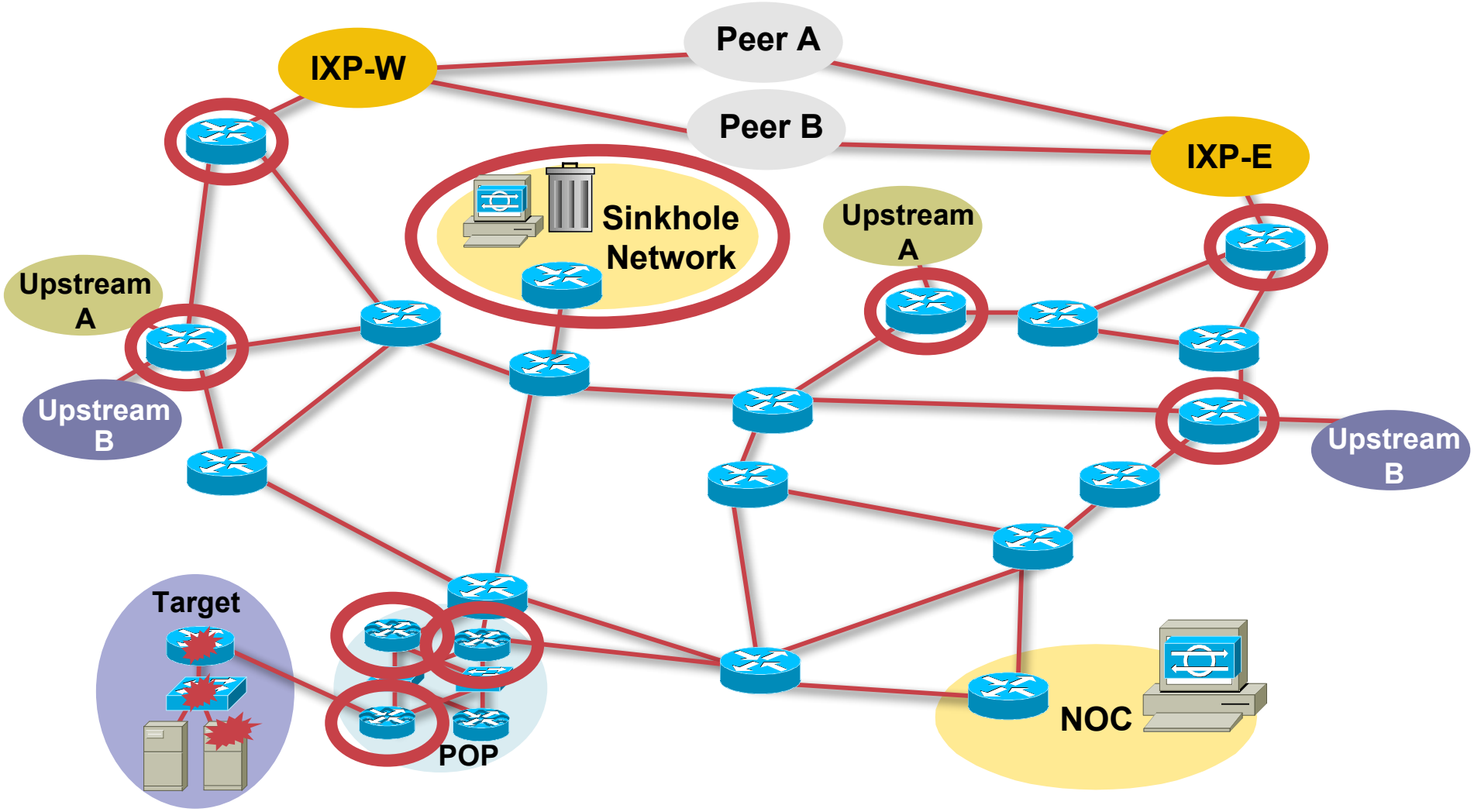
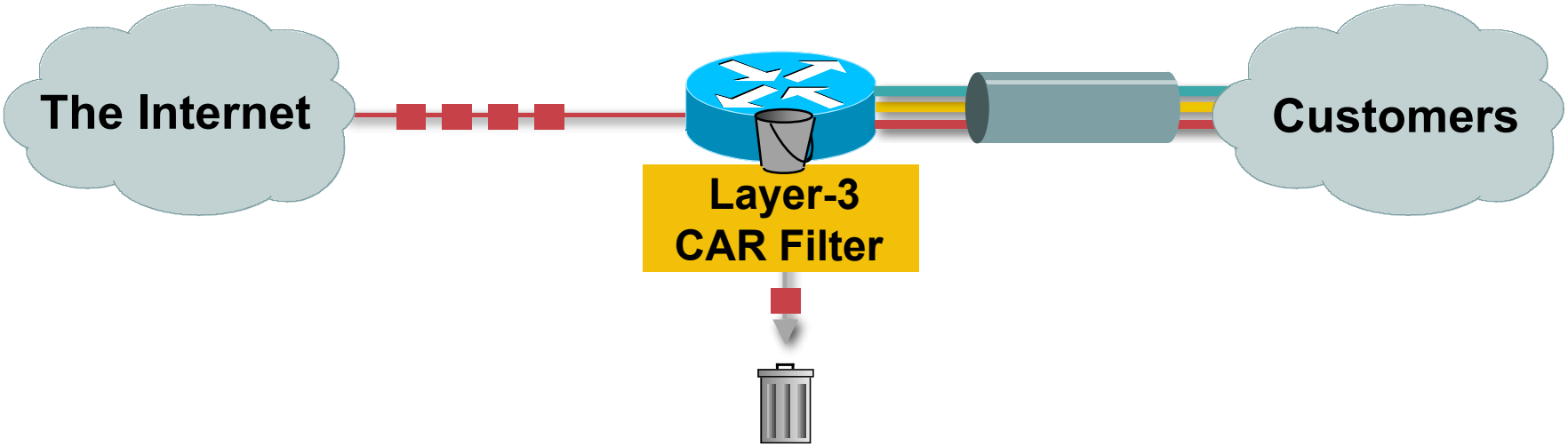
- Filter as close to the edge as possible
- Filter as precisely as possible
- Filter both source and destination where possible

Where to React?



Reacting to an Attack with CAR



- Layer-3 input and output rate limits—specifically input rate limits
- Security filters use the input rate limit to drop *Packets* before they are forwarded through the network
- Aggregate and granular limits

  Port, MAC address, IP address, application, precedence, QOS_ID
- Excess burst policies

Reacting to an Attack with ACLs

- Traditional method for stopping attacks
- Scaling issues encountered:
  - Operational difficulties
  - Changes on the fly
  - Multiple ACLs per interface
  - Performance concerns

ACLs: Deployment Considerations

- How does the ACL load into the router? Does it interrupt *Packet* flow?
- How many ACEs can be supported in hardware? In software?
- How does ACL depth impact performance?
- How do multiple concurrent features effect performance?

Packet Filtering Viewed Horizontally

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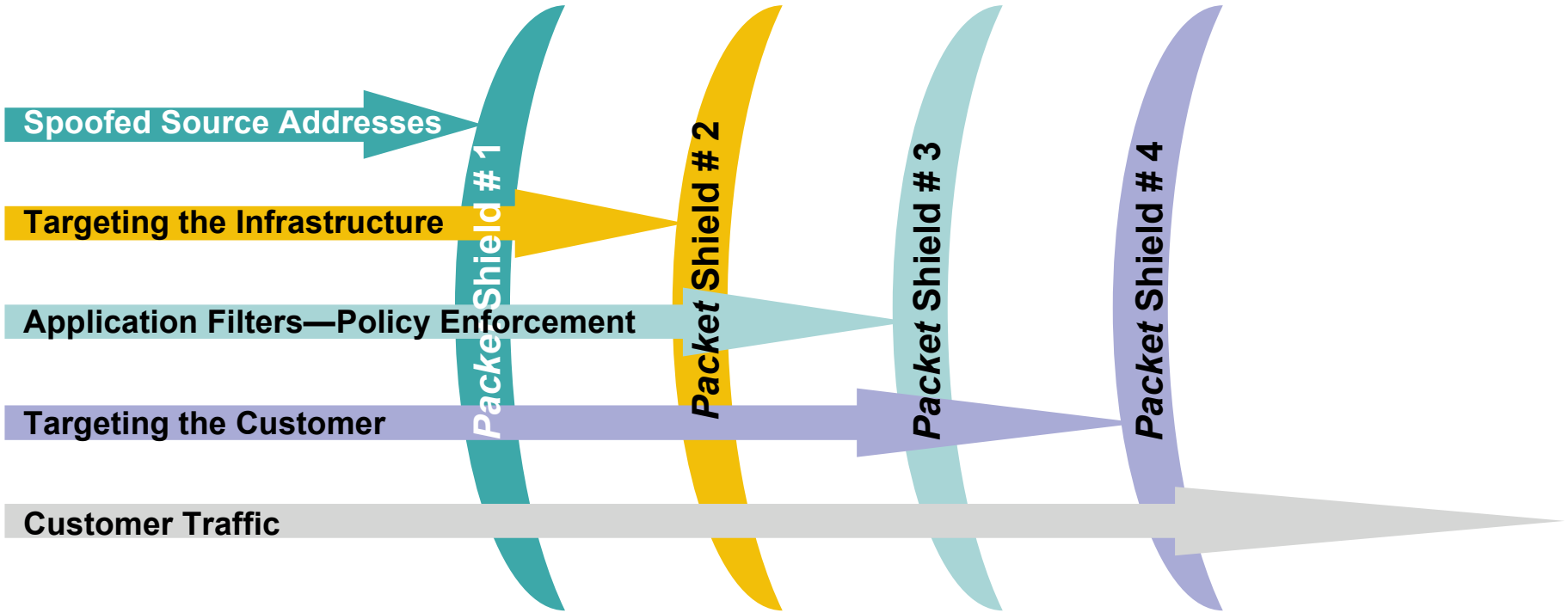
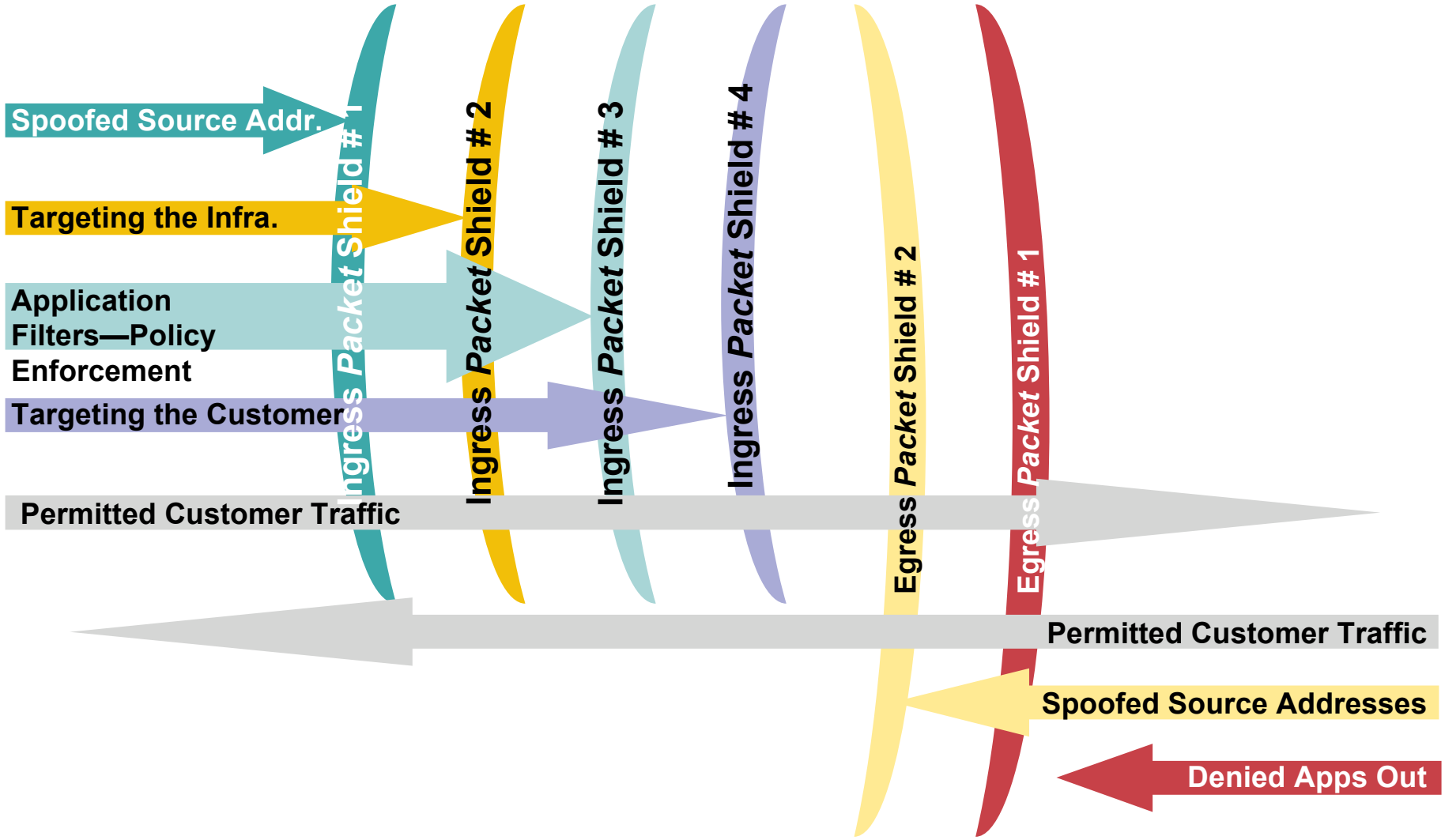


Packet Filtering
Remember to Filter the Return Path



ACL Construction

- **Most common problems:**
  - **Poorly constructed ACLs**
  - **Ordering matters**
- **Scaling and maintainability issues with ACLs are commonplace**
- **Make your ACLs as modular and simple as possible**

ACL Categories: Hybrid Philosophy

Hybrid Permit/Deny

- Anti-spoofing
- Anti-bogon (source)
- Infrastructure
- Explicit deny specific L3
- Explicit deny specific L4
- Incident reaction
- Explicit permit L3 (good traffic)
- Explicit permit L4 (good traffic)
- Explicit deny everything else (auditing)

ACL Summary

- ACLs are widely deployed as a primary containment tool
- Prerequisites: identification and classification—need to know what to filter
- Apply as specific an ACL as possible
- ACLs are good for static attacks, not as effective for rapidly changing attack profiles
- Understand ACL performance limitations before an attack occurs
- Operational efficiencies are important—scripped

The Pros and Cons of ACLs

- **ACLs' key strengths:**
  - **Detailed *Packet* filtering (ports, protocols, ranges, fragments, etc.)**
  - **Relatively static filtering environment**
  - **Clear filtering policy**
- **ACLs can have issues when faced with:**
  - **Dynamic attack profiles (different sources, different entry points, etc.)**
  - **Frequent changes**
  - **Quick, simultaneous deployment on a multitude of devices**
  - **Operationally hard to remove**
- **Because of these weaknesses, another tool was developed—using the control plane to signal the action**

ACL Mitigation: SQL Slammer

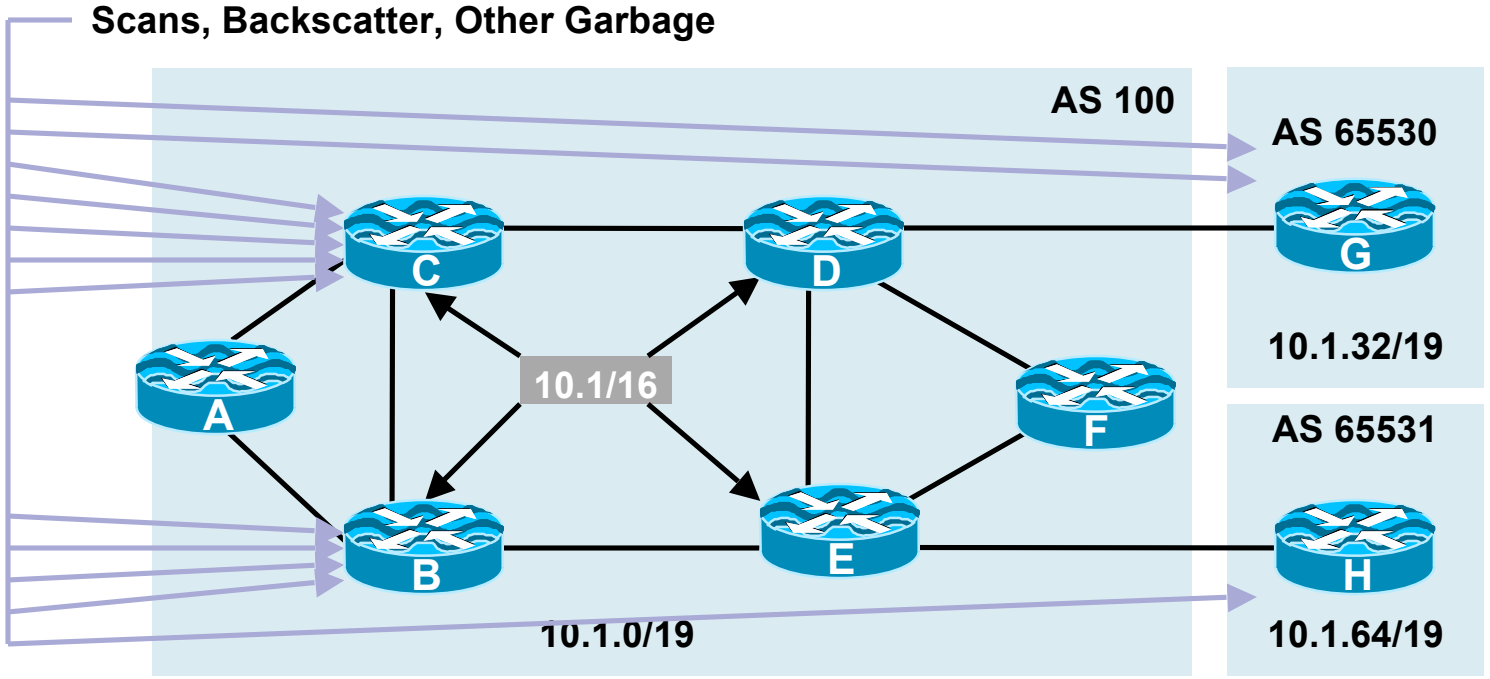
- Slammer Worm
  - Rapidly spreading worm in Jan 2003
  - Targeted vulnerability in MS SQL and MSDE
  - UDP packets destined to port 1434
- Infected not only hosts but networks as well
  - Random scanning
  - Surge in traffic
- ACL here widely used by SP to stop worm traffic
  - Easy, static ACL: deny UDP/1434
  - SP deployed an ACL at their edges
- Philosophical debate: can / should SPs act as the world's firewall?

Blaster: ACLs Were Not Effective

- **Blaster Worm**
  - **Multiple propagation methods, open port: TCP/135, 4444, etc.**
  - **Once in place, worm launched a SYN flood on a specific date**
- **With a high number of infected hosts, a significant DoS attacks was launched**
  - **Effects not only SYN flood target but has collateral effect as well**
- **ACL could help limit the propagation but were not effective at stopping the DoS**
  - **Cannot distinguish between “good” and “bad” SYN**
  - **Large number of hosts, often sending valid and invalid traffic, made per host blocking ineffective**

Reacting with the Control Plane

Routers Drop Data, Often!



- An AS collects all the garbage (backscatter, scans, etc.) destined for 10.1/19, 10.1.96/19, and 10.1.128/17 addresses
- Routers that source those aggregates drop the data to unreachable parts of the networks, and are required to process data, send ICMP unreachables, etc.

Black Hole Filtering

- **Black Hole Filtering or Black Hole Routing forwards a *Packet* to a router's bit bucket**
  - **Also known as "route to Null0"**
- **Works only on destination addresses, since it is really part of the forwarding logic**
- **Forwarding ASICs are designed to work with routes to Null0—dropping the packet with minimal to no performance impact**
- **Used for years as a means to "black hole" unwanted *Packets***

Remotely Triggered Black Hole Filtering

- We will use BGP to trigger a network-wide response to an attack
- A simple static route and BGP will enable a network-wide destination address black hole as fast as iBGP can update the network
- This provides a tool that can be used to respond to security-related events and forms a foundation for other remotely triggered uses
- Often referred to as RTBH

Remotely Triggered Black Hole (RTBH)

- **Configure all edge routers with static route to Null0 (must use “reserved” network)**

  ip route 192.0.2.1 255.255.255.255 Null0

- **Configure trigger router**

  Part of iBGP mesh

  Dedicated router recommended

- **Activate black hole**

  Redistribute host route for victim into BGP with next-hop set to 192.0.2.1

  Route is propagated using BGP to all BGP speakers and installed on routers with 192.0.2.1 route

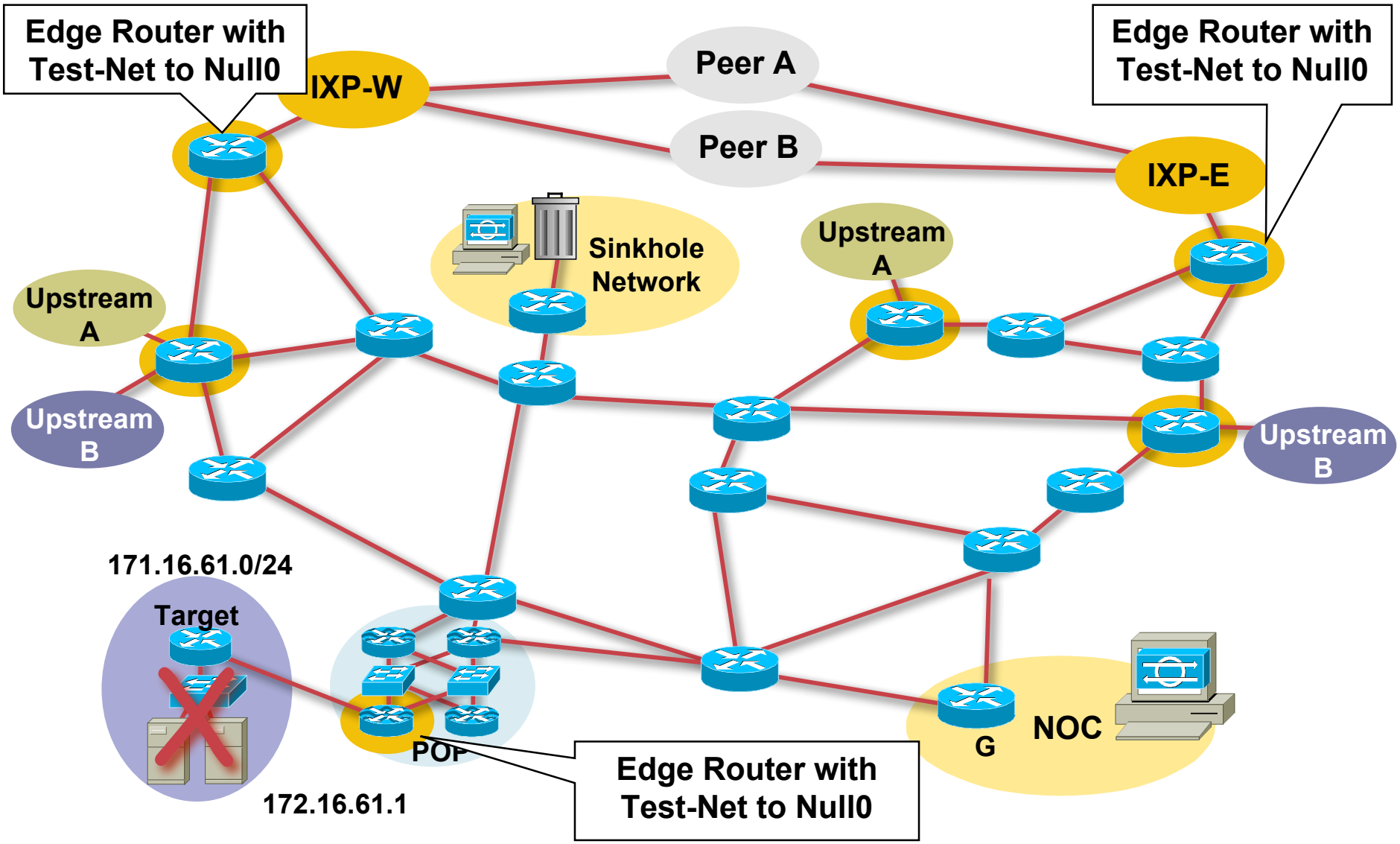
  All traffic to victim now sent to Null0

Step 1: Prepare All the Routers with Trigger

- Select a small block that will not be used for anything other than black hole filtering; Test-Net (192.0.2.0/24) is optimal since it should not be in use
- Put a static route with Test-Net—192.0.2.0/24 to Null0 on every edge router on the network

```
ip route 192.0.2.1 255.255.255.255 Null0
```

Step 1: Prepare All the Routers with Trigger



Step 2: Prepare the Trigger Router

The Trigger Router Is the Device That Will Inject the iBGP Announcement into the ISP's Network

- Should be part of the iBGP mesh—but does not have to accept routes
- Can be a separate router (recommended)
- Can be a production router
- Can be a workstation with Zebra/Quagga (interface with Perl scripts and other tools)

Trigger Router's Config

Redistribute Static with a Route-Map

```
router bgp 65535
.
redistribute static route-map static-to-bgp
.
!
route-map static-to-bgp permit 10
match tag 66
set ip next-hop 192.0.2.1
set local-preference 200
set community no-export
set origin igp
!
Route-map static-to-bgp permit 20
```

Match Static Route Tag

Set Next-Hop to the Trigger

Set Local-Pref

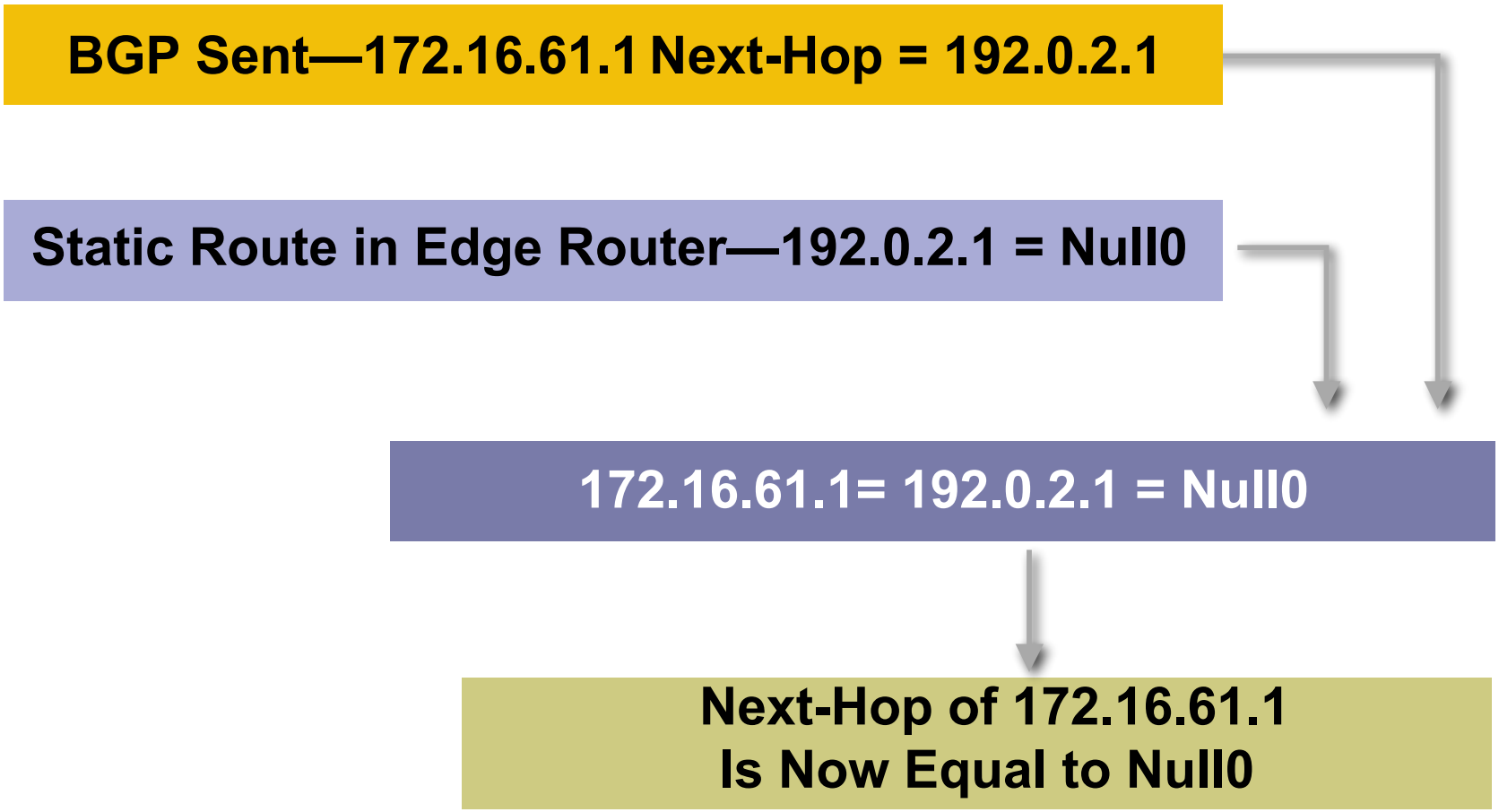
Step 3: Activate the Black Hole

- Add a static route to the destination to be blackholed; the static is added with the “tag 66” to keep it separate from other statics on the router

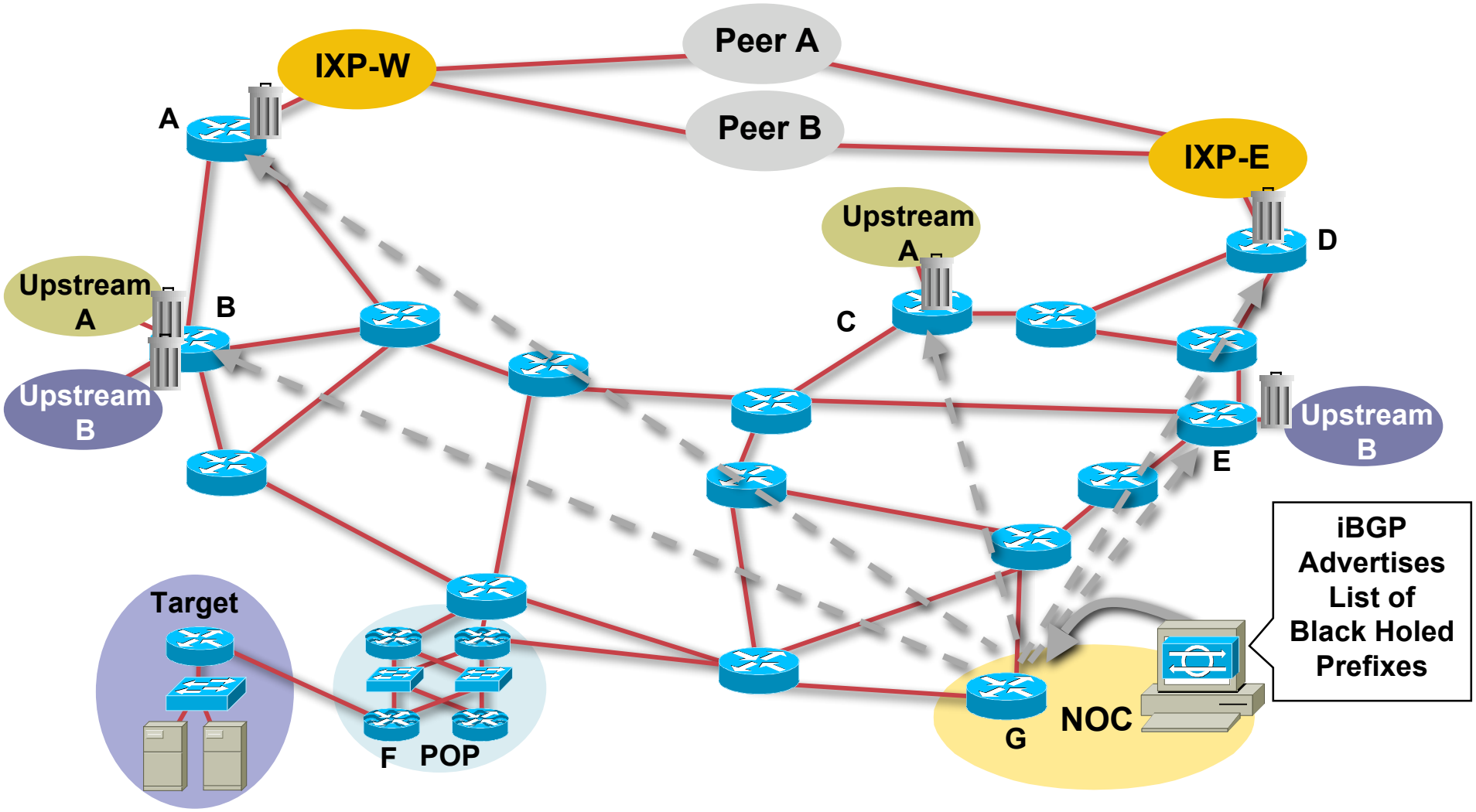
```
ip route 172.16.61.1 255.255.255.255 Null0 Tag 66
```

- BGP advertisement goes out to all BGP-speaking routers
- Routers receive BGP update and “glue” it to the existing static route; due to recursion, the next-hop is now Null0

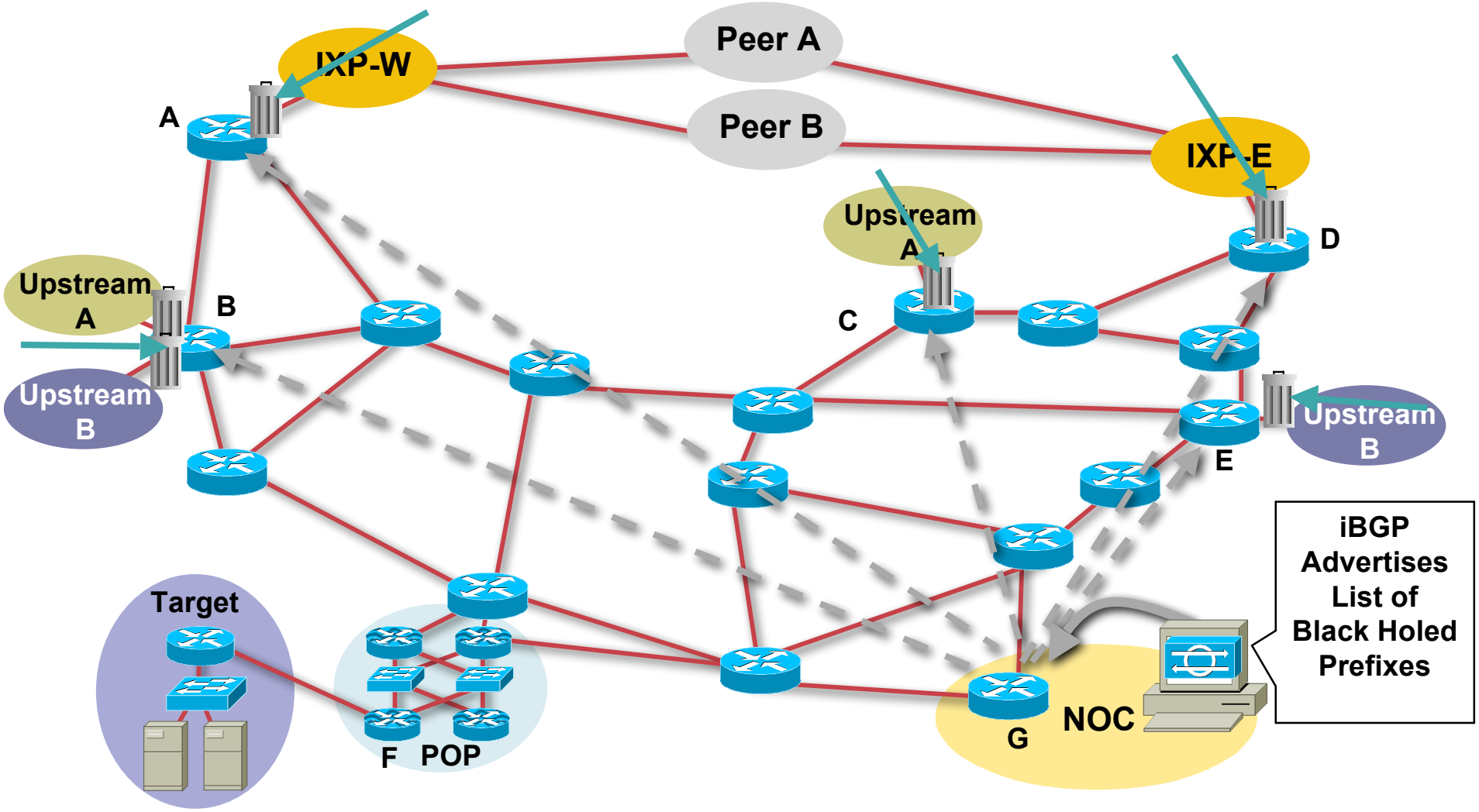
Step 3: Activate the Black Hole



Step 3: Activate the Black Hole



Customer is DOSed (After) *Packet* Drops Pushed to the Edge



Customer Based triggering

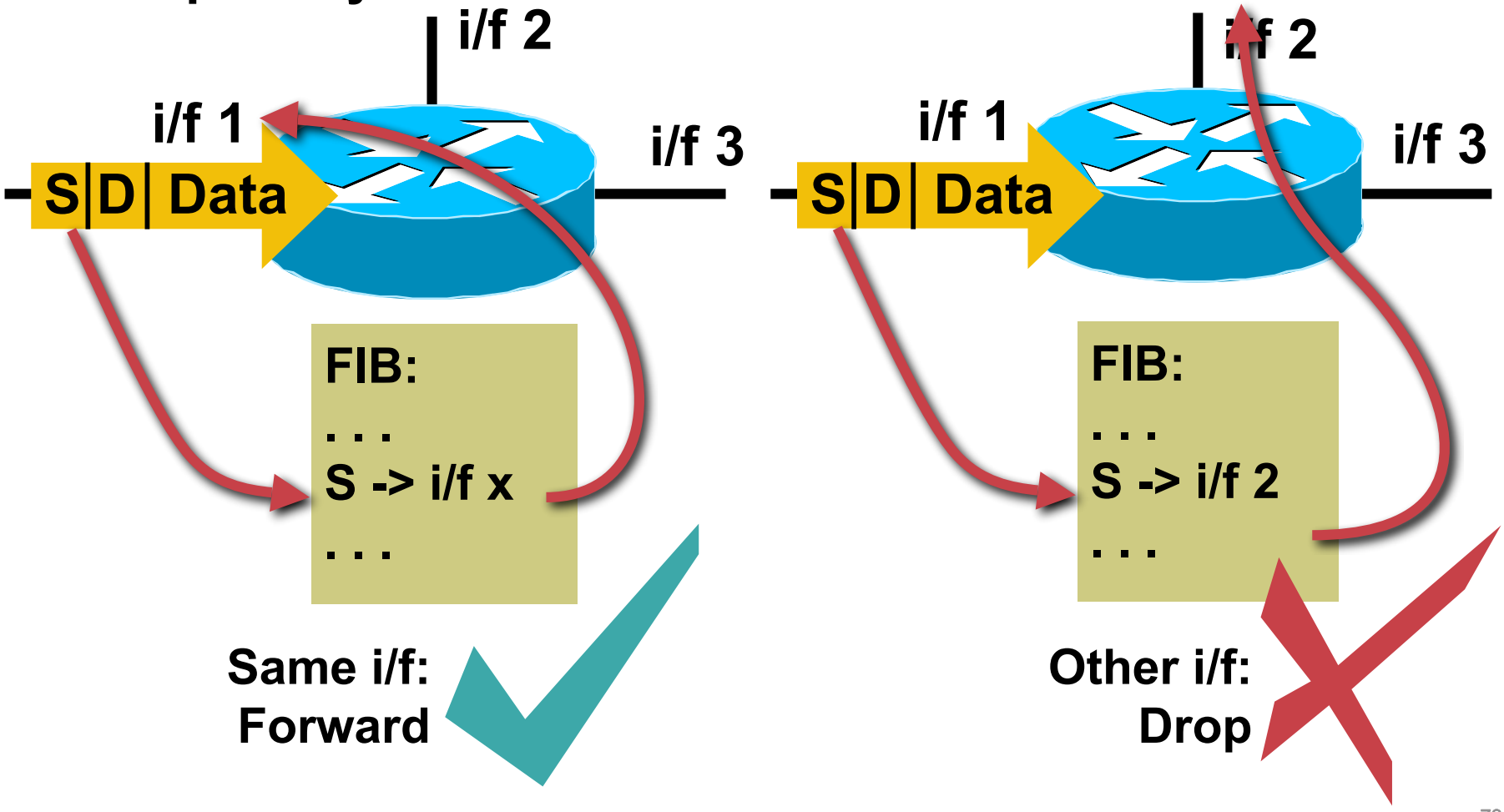
- **Allow your customers to trigger the drops directly**
  - **No call to SP --> they decide when to drop traffic**
  - **Customer injects route that triggers null0 route**
- **Can be offered as a service**
  - **Who detects?**
- **Proper configuration required to ensure that the customer can only trigger drops for appropriate addresses**
  - **You don’t want Customer A dropping Customer B’s traffic!**

RTBH: Triggered Source Drops

- **Dropping on destination is very important**
  - **Dropping on source is often what we really need**
- **Reacting using source address provides some interesting options:**
  - **Stop the attack without taking the destination offline**
  - **Filter command and control servers**
  - **Filter (contain) infected end stations**
- **Must be rapid and scalable**
  - **Leverage pervasive BGP again**

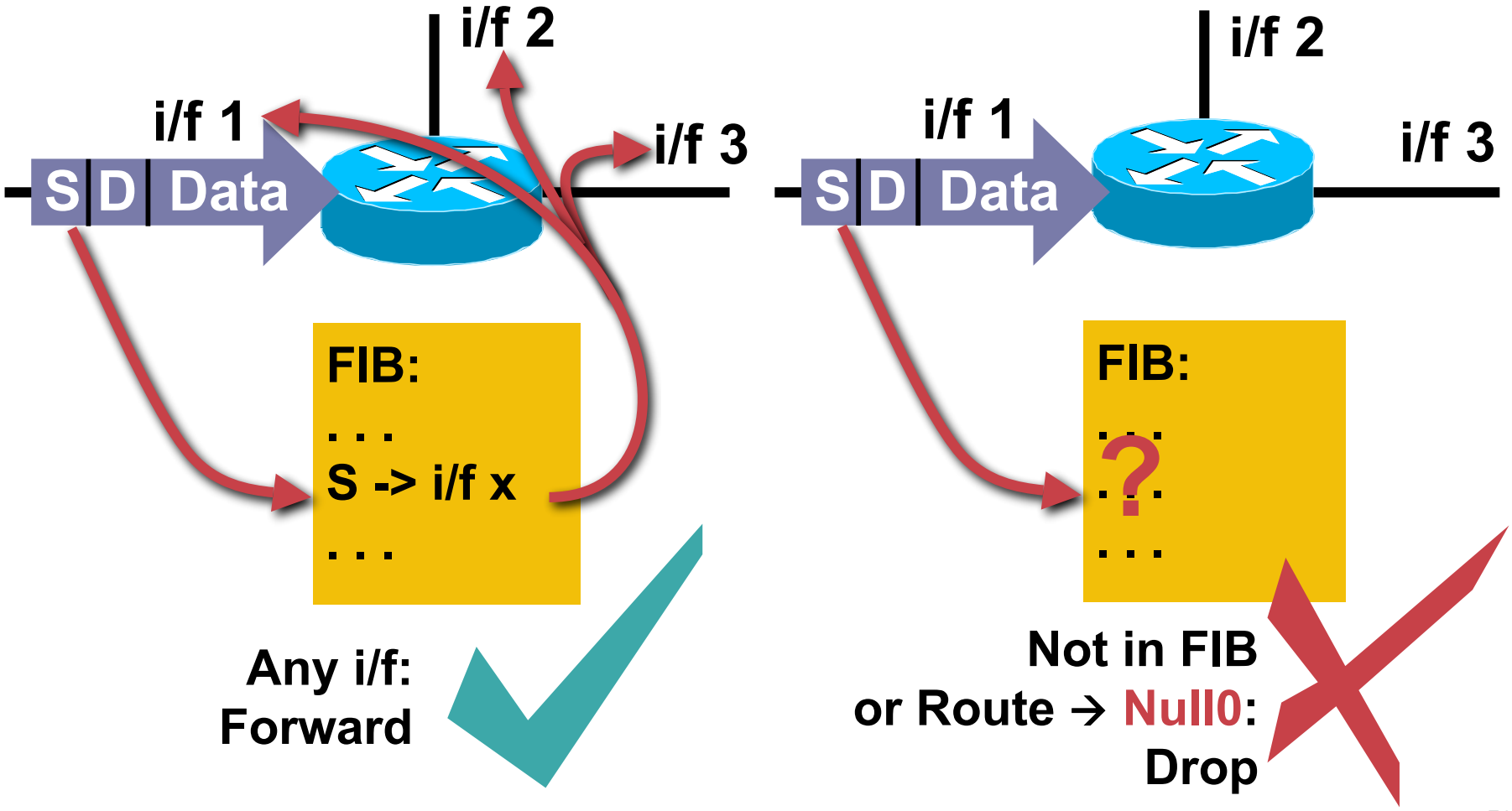
Strict uRPF Check (Unicast Reverse Path Forwarding)

router(config-if)# ip verify unicast reverse-path
or: ip verify unicast source reachable-via rx



Loose uRPF Check

router(config-if)# ip verify unicast source reachable-via any



Source-Based Remotely Triggered Black Hole Filtering

Uses the same architecture as destination-Based Filtering and unicast RPF

- Edge routers must have static in place
- They also require unicast RPF
- BGP trigger sets next-hop—in this case the "victim" is the source we want to drop

Source-Based Remotely Triggered Black Hole Filtering

- **What do we have?**

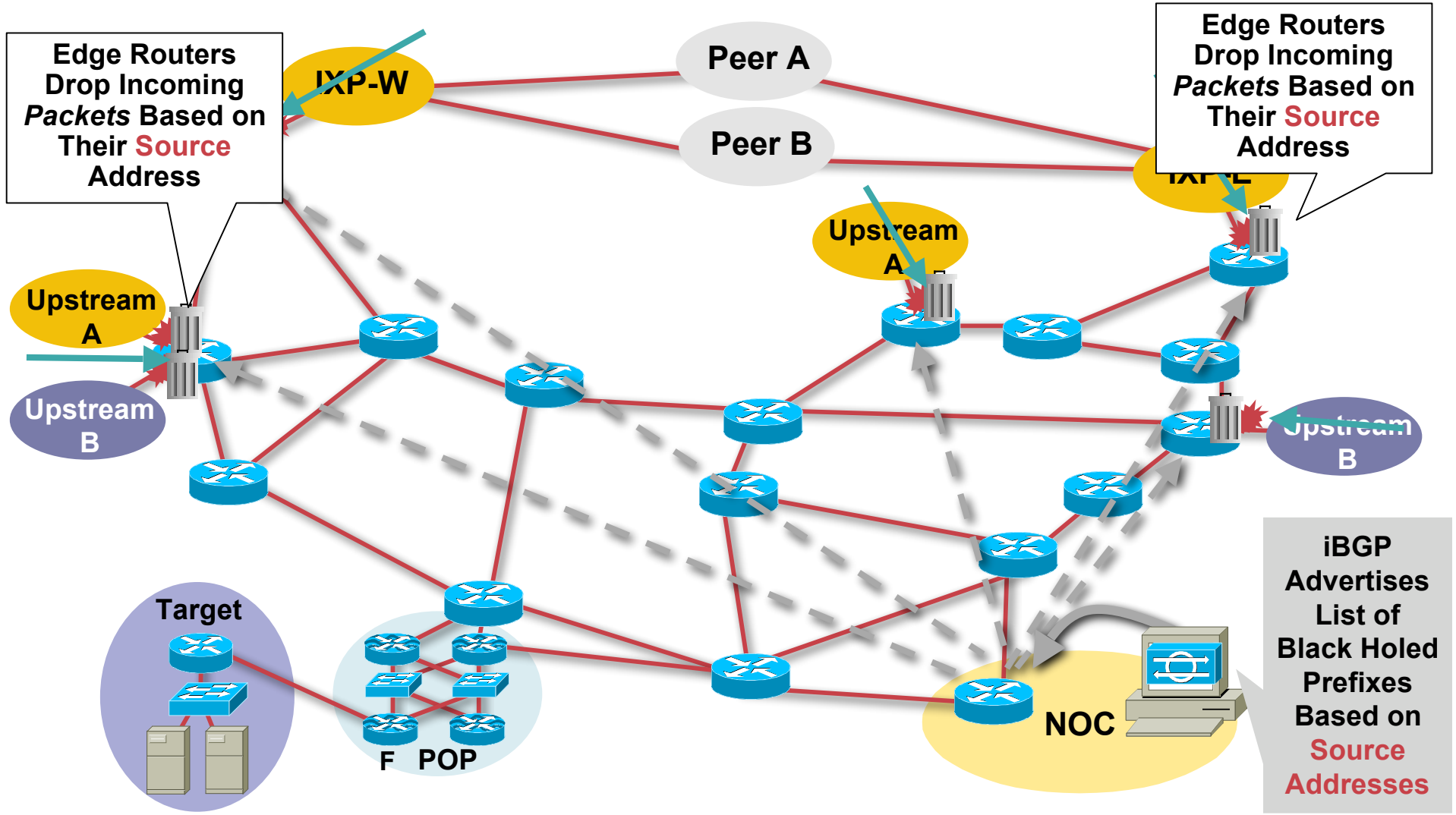
  Black Hole Filtering—if the destination address equals Null0, we drop the *Packet*

  Remotely Triggered—trigger a prefix to equal Null0 on routers across the network at iBGP speeds

  uRPF Loose Check—if the source address equals Null0, we drop the *Packet*

- **Put them together and we have a tool to trigger a drop for any packet coming into the network whose source or destination equals Null0!**

Customer Is DOSed (After) *Packet* Drops Pushed to the Edge



Source Dropping Caution

- Caution: you will drop all *packets* with that source
- Remember spoofing

Community-Based Trigger

- **BGP community-based triggering allows for more fine-tuned control over where you drop the packets**
- **Three parts to the trigger:**
  - **Static routes to Null0 on all the routers**
  - **Trigger router sets the community**
  - **Reaction router (on the edge) matches community and sets the next-hop to the static route to Null0**

Why Community-Based Triggering?

Allows for More Control on the Attack Reaction

- Trigger community #1 can be for all routers in the network
- Trigger community #2 can be for all peering routers; no customer routers—allows for customers to talk to the DOSed customer within your AS
- Trigger community #3 can be for all customers; used to push a inter-AS traceback to the edge of your network
- Trigger communities per ISP peer can be used to only black hole on one ISP peer's connection; allows for the DOSed customer to have partial service

(Source-Based) RTBH

- **Advantages:**
  - No ACL update
  - No change to the router's configuration
  - Drops happen in the forwarding path
  - Frequent changes when attacks are dynamic (for multiple attacks on multiple customers)
- **Limitations:**
  - Source detection and enumeration
  - Attack termination detection (reporting)
  - Resource utilization: finite resources
  - Effects all traffic, on all triggered interfaces, regardless of actual intent

Attack Example: Mitigation W/ Control Plane

- Botnet Controllers are commonly blocked with RTBH – disrupting the communication channel between attacker and his bots
- Works better the nearer you are to the bot controller
- This prevents the attacker from modifying the attack and lets the target of the attack defend itself – by say changing their IP address in DNS.
- Attacks may use multiple controllers, or switch controllers quickly – RTBH lets an operator react just as quickly

Attack Example: Mydoom - RTBH was problematic

- Mydoom.C
  - Spread as a Virus Attached to email
  - DDoS payload attacked on specific date
  - Opened 14 tcp connections/sec
  - Made one GET request (GET/) on each connection
- Size and Scope
  - Over 1 million concurrent attackers
  - 5 Gigabytes + of traffic peak
  - Attack lasted for several months
- Why RTBH was problematic
  - Would block sources completely – not allow patching
  - Proxies would be blocked… including all hosts behind it
  - Telling who was a good vs bad source just on opening tcp connections is problematic with most telemetry systems

Dedicated Devices

Network IDS/IPS
Overview

- Content inspection technology
- Originally designed to prevent ‘intrusion’ type attacks
- Content filtering can directly apply to DDoS attacks
  - Some DoS attacks use perfectly legitimate content!
  - Performance problematic – not optimized for DDoS
- IPS assume that you are inline and see both directions…

Network IDS/IPS

- False positives: system mistakenly reports certain benign activity as malicious; also called false alarms
- False negatives: system does not detect and report actual malicious activity
- For many, false positives are the bane of IDS technology
- Additionally, you require a signature in order to stop the attack

Firewalls
Modern Stateful Firewall: The Security Keystone

What It Is

- Sometimes called a hybrid
- Combines features of other firewall approaches such as:
  - Access control lists
  - Application-specific proxies/inspections
  - Stateful inspection
- Plus features of other devices:
  - Web (HTTP) cache
  - Specialized servers
    - SSH, SOCKS, NTP
  - Most include VPN, some include IDS

Pros and Cons

- Pro: Pretty high performance in modern implementations
- Pro: Application layer gateway services provide application security while resolving the NAT issue
- Con: Does not provide complete session termination, as would a full proxy
- Con: Actively tracks the state of incoming connections—a DoS issue

Load Balancers

- **Stateful by design**
  - **-One to many**
  - **-Distributes capacity**
- **Some have DDoS features being added**
  - **-Syn Cookies**
  - **-Basic Behavior Recognition**
- **Require inline/symmetry to work**
- **Since load balancers are stateful, problems can occur when an attack uses a protocol without inherent state (e.g. UDP)**
  - **-Not so good with DNS!**

Given Everything Said, What Remains?

- Raise the bar! Stop ONLY bad traffic
- In asymmetric environments, especially across peers, packet spoofing is still problematic
- Detection of exactly “who” is attacking is problematic
- Doing all this in the core requires specialized hardware, which has scaling and availability problems

Packet Scrubbing Technologies

Shunting the packets

Scrubbing the packets

Formal Requirements for a Core Security Device

- **Need to avoid state**
  - **Constant state tracking leaves us vulnerable to DDoS attacks**
- **Doesn't rely on signatures**
  - **If I get an attack with no signature, I cannot block it**
  - **Possibly can use signature-like filters, however, after the fact**
- **Doesn't have to be in-line when it isn't needed**
- **Scales easily**
- **Doesn't require traffic symmetry**
  - **The Internet is a very asymmetrical place!**

Define Packet Scrubbing

- **Packet scrubbers have the following core characteristics**
  - **Classification**
  - **Source verification**
  - **Measurement**
  - **Recognition**
  - **Enforcement**

  A reference architecture for packet scrubbing is presented later

Packet Scrubbers: Details

- Scale by using traffic shunting and anycast
- Packet scrubbing

  1) Validate incoming traffic to make sure it comes from the source IPs that are in the SRC IP field of the *Packet*

  2) Evaluate these validated sources against a baseline and then recommend either further processing or dropping for sources that misbehave
- Availability is the key security metric!

  Pad thresholds to reduce likelihood of false positives

  Better to stop 90% of the attack than 110%

  Implement content filtering only when necessary

Packet Scrubbing Via Shunts

- **Advantages:**
  - **Not on critical path during normal operation**
  - **Anomaly-based detection with base lining**
  - **Optimized for high-performance blocking**
  - **Is resistant to state limitations of most other devices**
- **Limitations:**
  - **Not designed to stop single-*packet* attacks**
  - **Inherent is an assumption of a “destination” being protected**
  - **Resource utilization: finite resources in the scrubber complex**
  - **Requires up-front network engineering to implement**

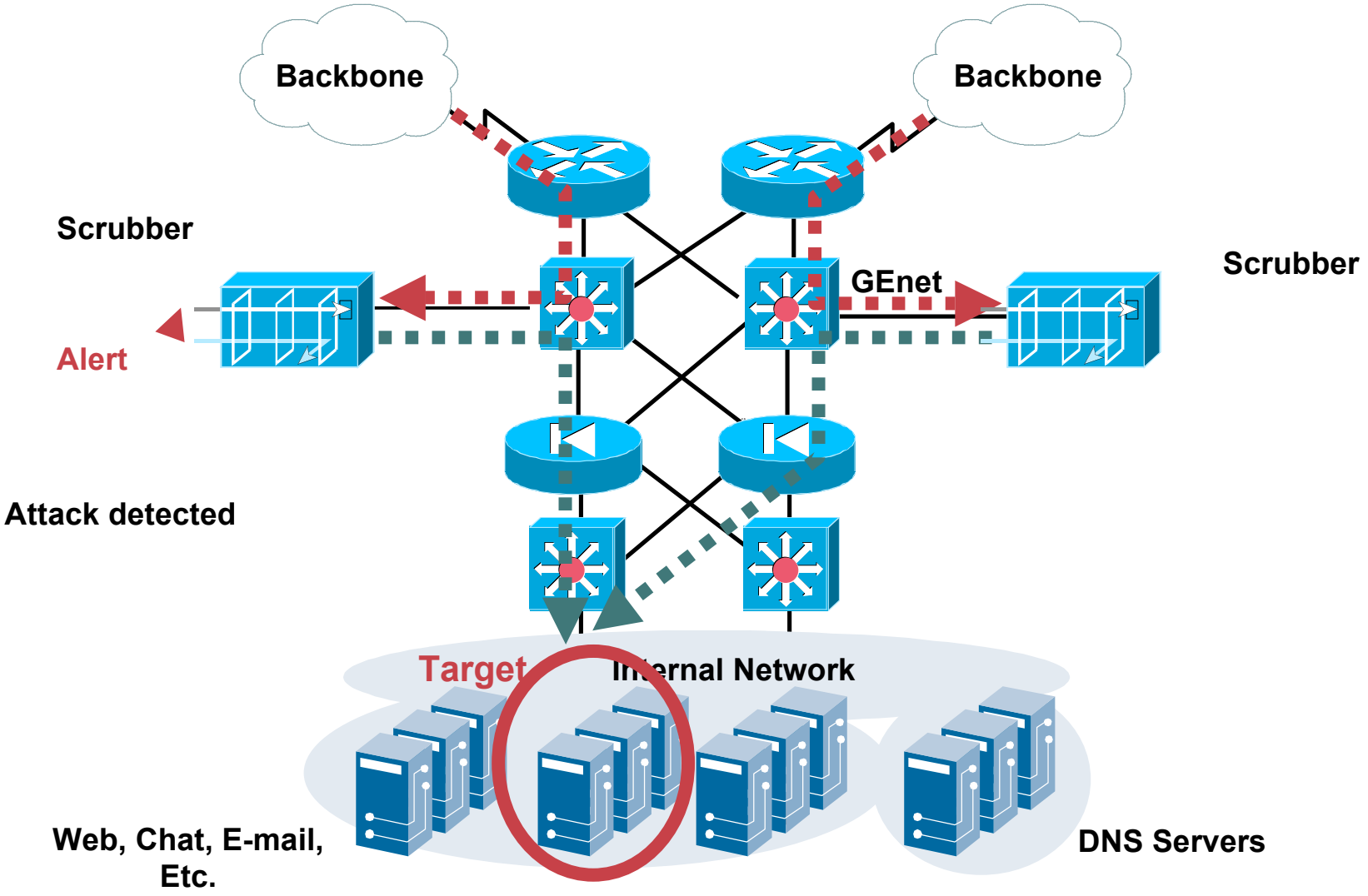
Traffic Shunts

- Intercept and shunt traffic to the mitigation device—the “scrubber”
- Return good traffic back to the customer
- Need to avoid forwarding loops—means some sort of tunneling

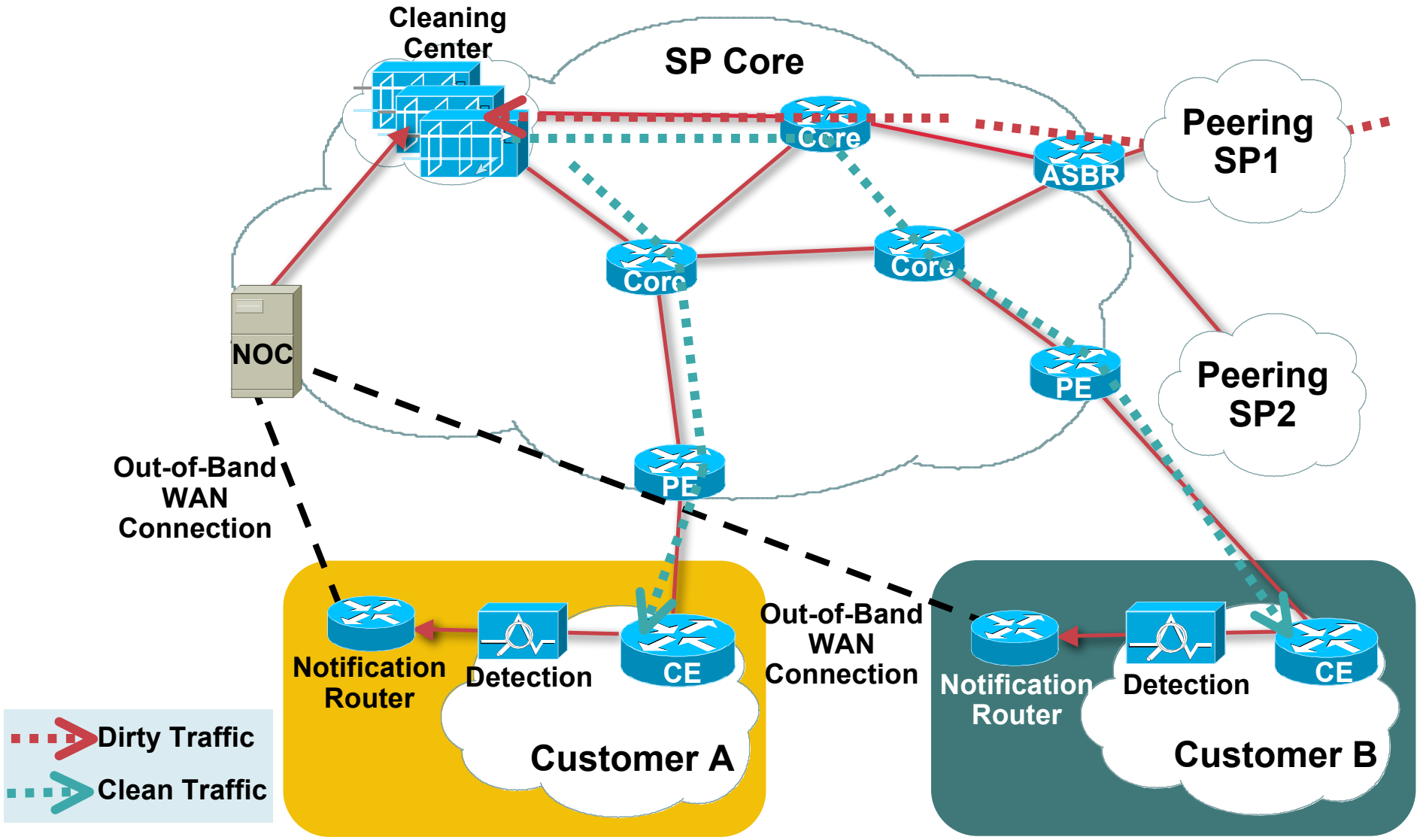
Shunts in the Data Center

- **All devices on the same subnet**
  - **Either scrubber-driven or configured in router**
  - **May use remotely triggered shunt trick**
  - **→ All traffic in core to target goes to the scrubber**
- **Optionally, you can use VLANs to avoid loops**
  - **Bypassing the "modified" router is trivial with VLANS and .1Q trunking**

Hosting/SP Data Center



Packet Scrubbing in the Core: The Cleaning Center



Shunts in the Backbone: Scrubbing Centers

- **Question is: how many?**
  - **Most national providers have decided to start with two**
  - **Geographic redundancy**
  - **Adequate incoming bandwidth in key locations**
  - **Limit the backhaul of traffic across expensive links**
- **Once you decide on where, then the hard part starts**
  - **Getting traffic to and from the center(s)**

Getting Traffic to and from the Scrubbing Center

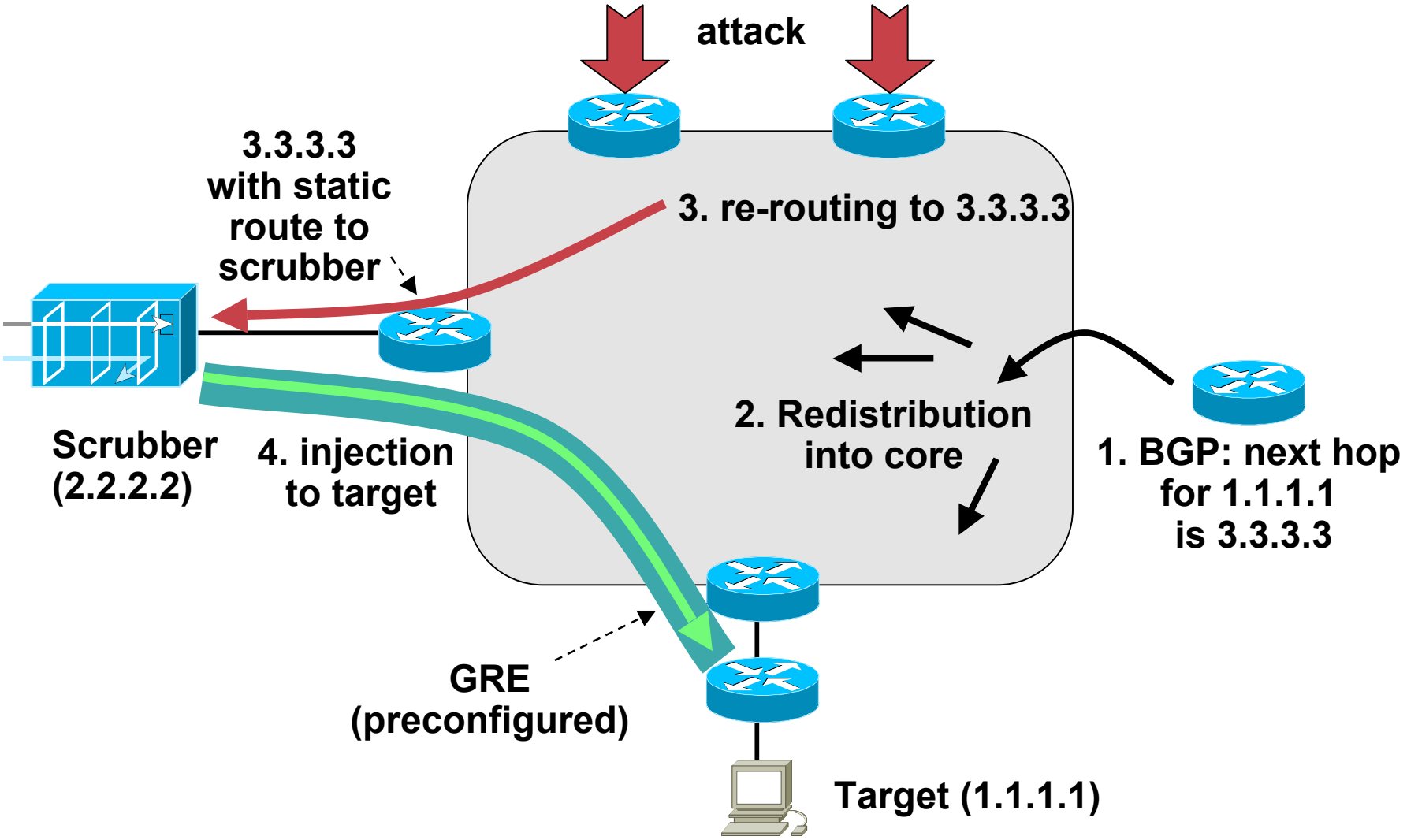
- **GRE**
  - Requires GRE start
  - Requires GRE endpoint
- **MPLS VPN shunt**
  - Requires a single MPLS VPN for injection, for all customers
  - Easy config, no performance hits
  - Works if peering PEs also connect potential victims
- **MPLS proxy egress LSP**
  - Requires MPLS, but not VPN.
  - Very simple, easy config
  - But: Does not work if peering PEs connect potential victim

Option 1:
IP Core and GRE injection

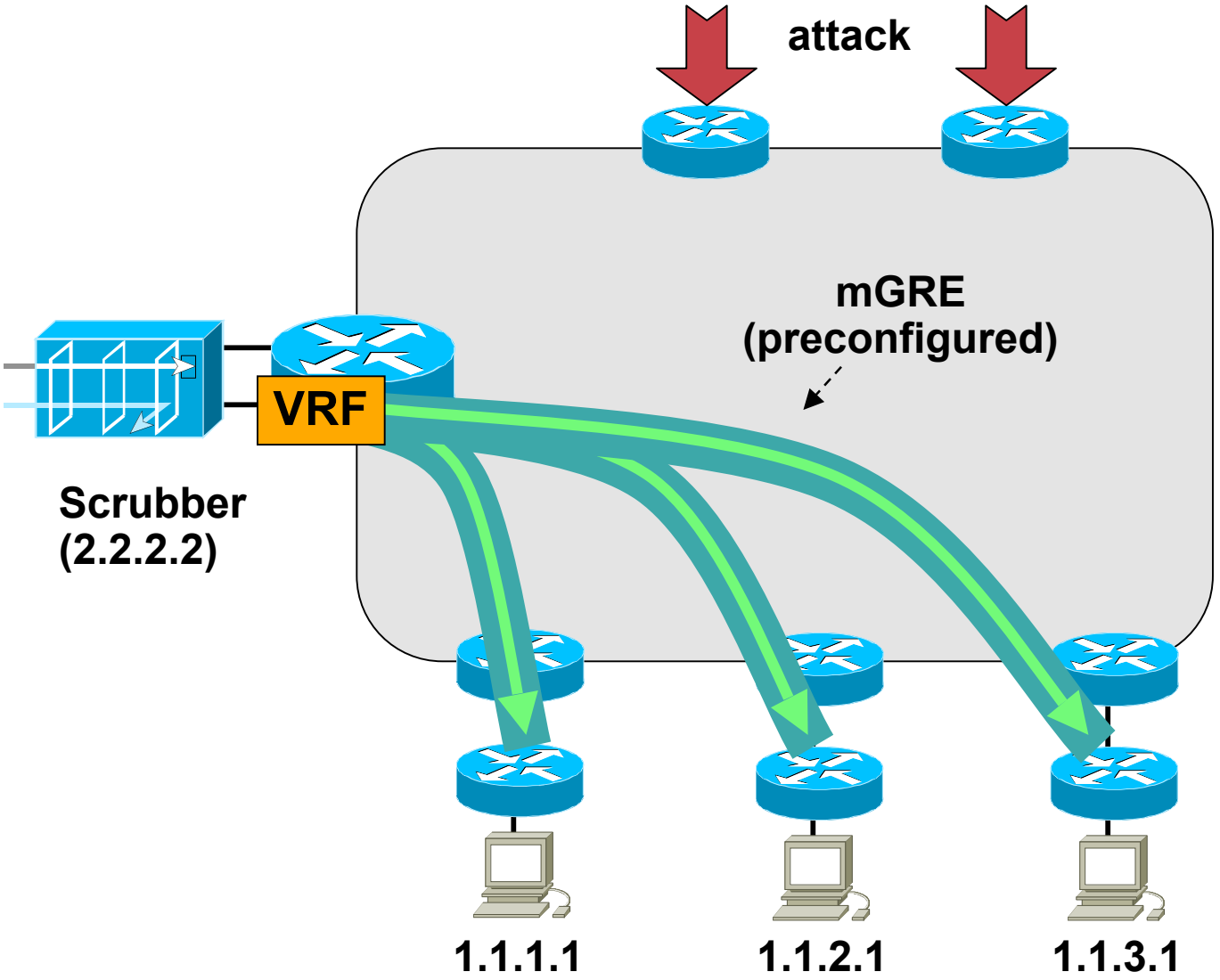
IP Core and GRE Injection

- **Core routes "target" IP to the scrubber**
  - **Either scrubber driven or configured in router**
  - **May use remote triggered shunt trick**
  - **→ All traffic in core to target goes to the scrubber**
- **Injection into GRE tunnel**
  - **Bypassing the "modified" core routing**
  - **GRE starts on scrubber, terminates on CPE, which has "clean" routing to target**

IP Core and GRE Injection
Triggered by a router or other device



mGRE Injection: Simplified Hub Config!

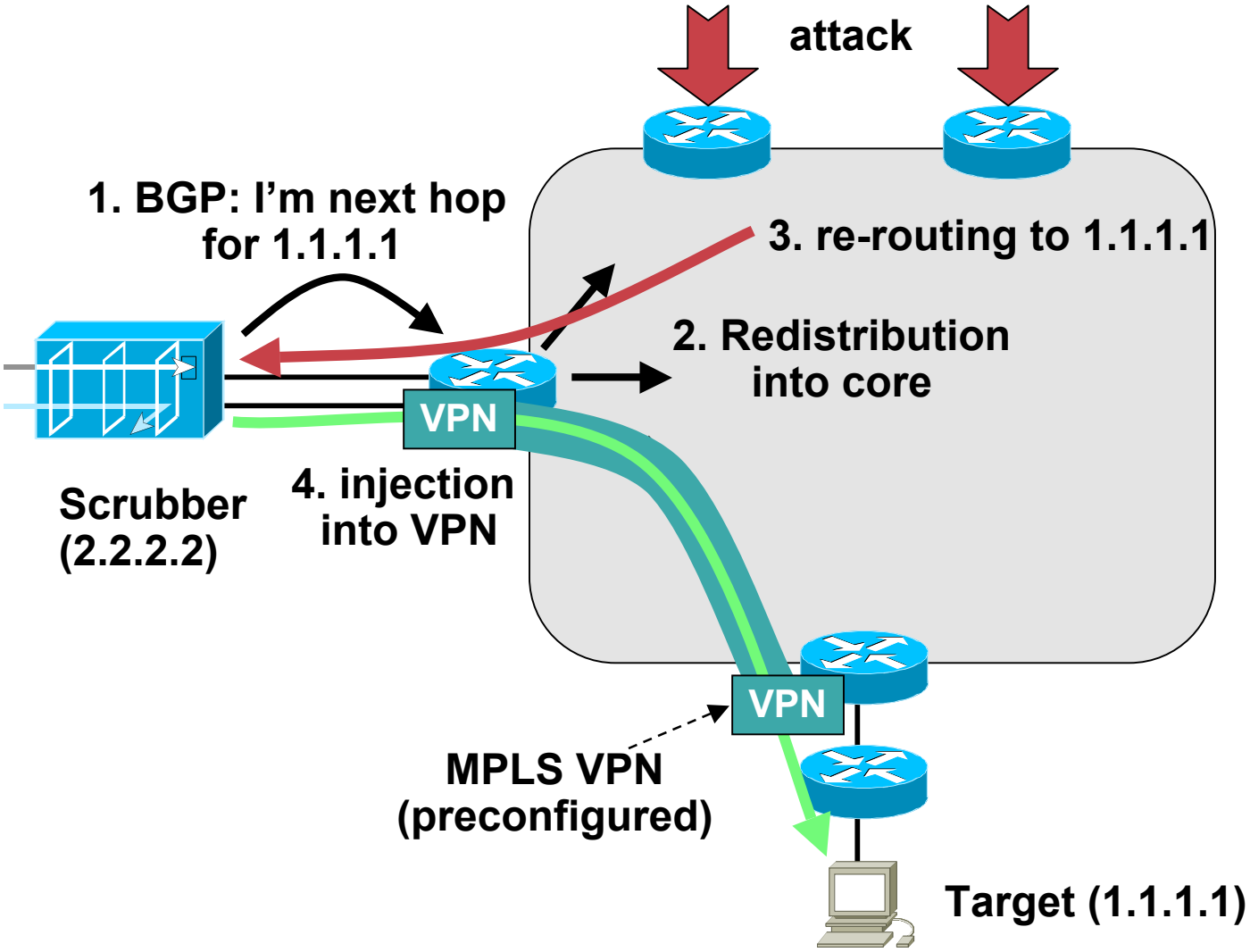


IP Core + GRE

- **Easy to deploy:**
  - **Core remains untouched**
  - **GRE tunnel invisible to core**
- **GRE might have performance impact**
- **GRE endpoint required:**
  - **PE?**
  - **CE?**

Option 2:
MPLS VPN Shunt

MPLS VPN Shunt

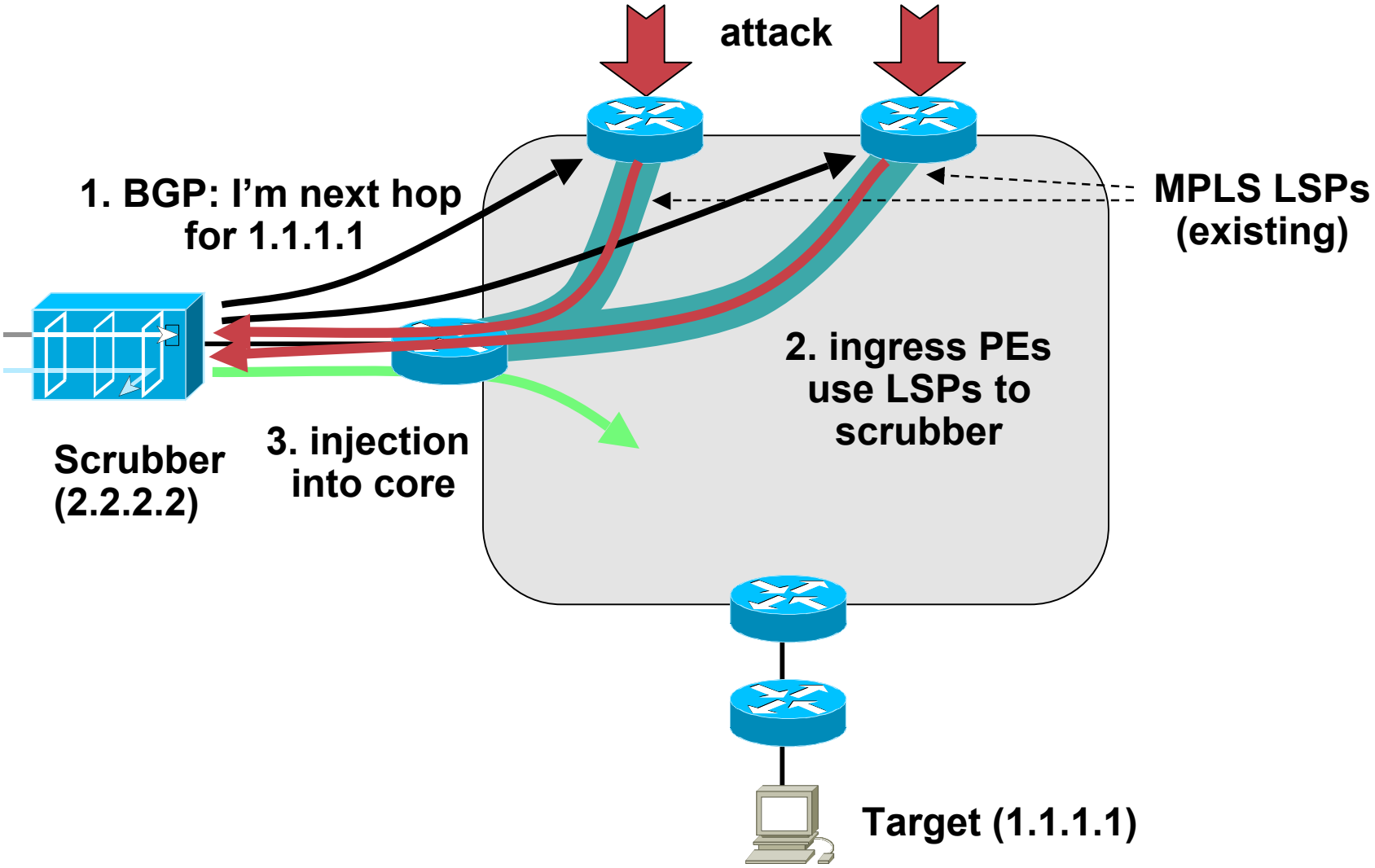


MPLS VPN Shunt

- **Easy to deploy:**
  - **Core remains untouched, injection VPN pre-configured**
  - **Need one VPN only**
  - **VPN invisible to core**
- **No performance impact**
- **No need to touch CPE**
- **But: MPLS VPN required on core**

Option 3:
MPLS Proxy Egress LSP Shunt

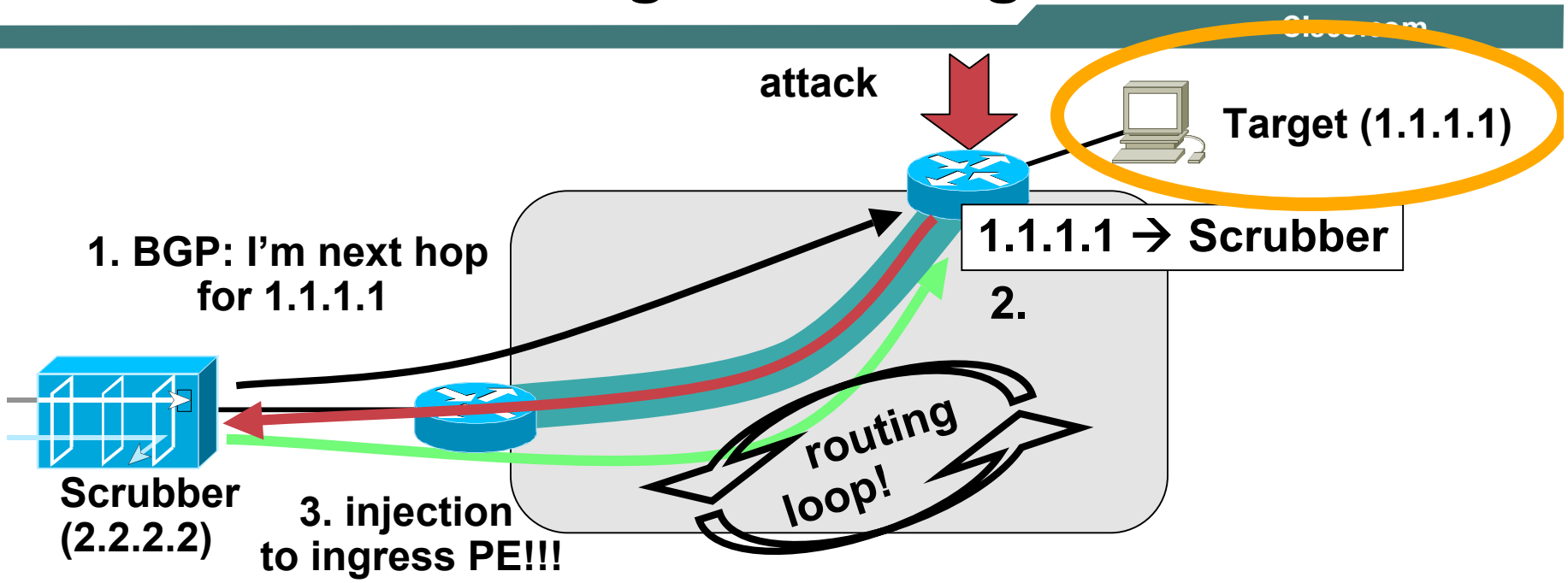
MPLS LSP Shunt



MPLS Proxy Egress LSP Shunt

- **Preparation: scrubber loopback is in IGP → LSPs exist to the scrubber**
  - **Filtering PE acts as "proxy", popping the label, sending IP only**
- **Scrubber peers with ingress PEs (and only with ingress PEs!)**
  - **Scrubber is iBGP "next hop" for victim (on ingress PEs).**
  - **→ Network sends traffic to the victim to the iBGP next hop**
  - **→ Follows the LSPs to the scrubber (pre-established)**
- **Filtering PE does not route this traffic, but label switches**
  - **→ Routing table unchanged, still pointing to victim**
  - **→ Scrubber sends cleaned traffic to the filtering PE**
  - **→ Traffic goes onto LSP to egress PE**

MPLS LSP Shunt:
Cannot have "Targets" on Ingress PE!



- Ingress PE: Routing to "target" now → Scrubber

  Cannot reach directly connected Target any more!
- Careful! Routing loop with several Gig of traffic!!!!
- Workaround: PE based communities (a bit risky…)

MPLS LSP Shunt

- Using existing LSPs from ingress PEs to scrubbing center
  - Only config: static route on filtering PE to scrubber loopback
- Scrubber iBGP peers with all ingress PEs
- Other PEs (including egress PE) maintain normal routing to target
- No performance impact
- No need to touch CPE
- But: ingress PE must not connect the victim!
  - Otherwise: Routing loop. Workarounds:
    - Use MPLS VPN method! or communities per PE
- MPLS required, but not MPLS VPN

Shunting and DDoS: Summary

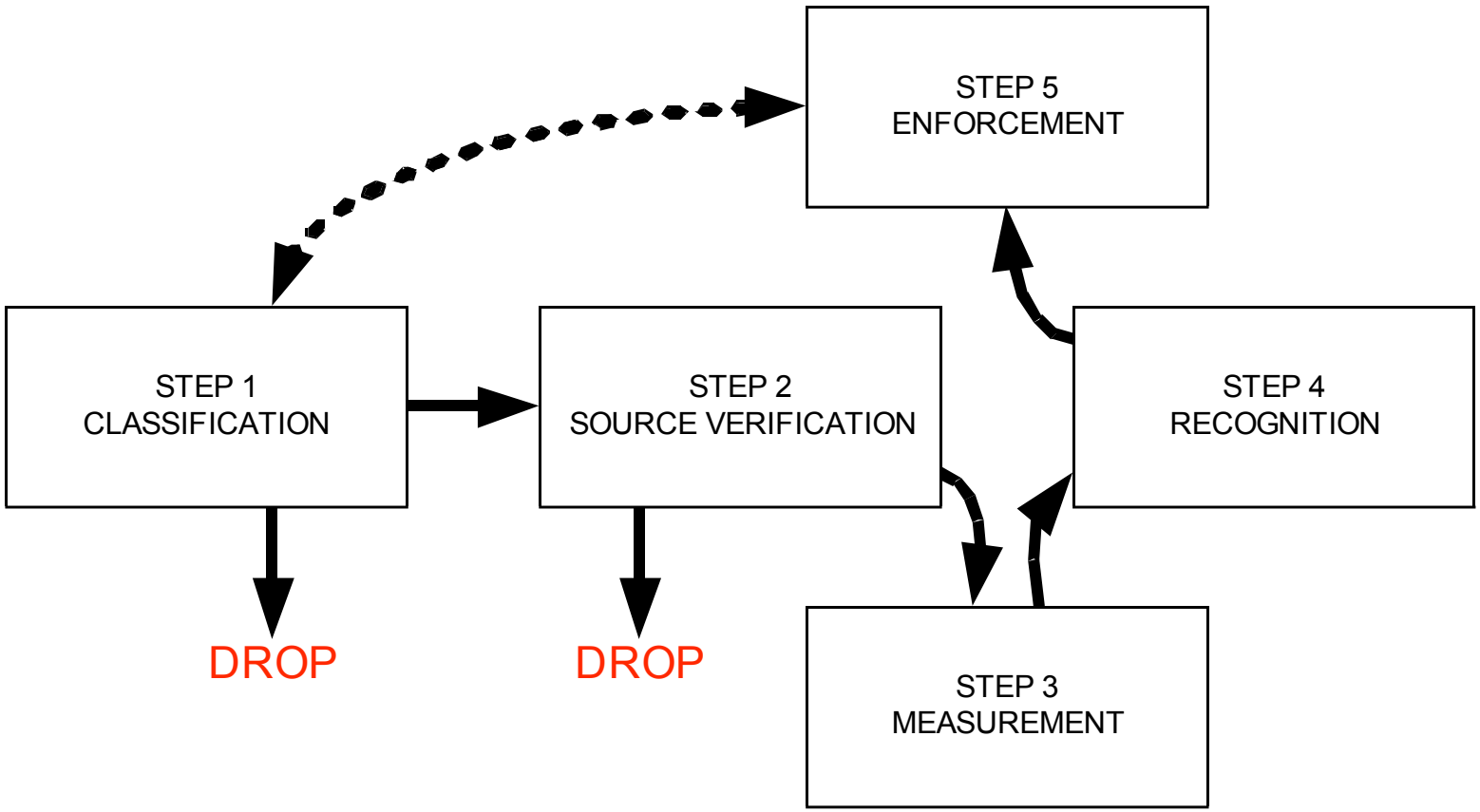
- Many options for deployment:
  - One or several scrubbing centers
    - For several centers: Static or anycast
  - Trigger by scrubber, Arbor, other devices (BGP speakers)
  - Either re-direction or injection must bypass normal routing table
  - Options: GRE, MPLS VPN, MPLS LSPs, other tunnels, …
- Highly scalable
  - Several scrubbing centers
  - Several scrubbers in each

A Reference Architecture for Mitigation

Mitigation Reference Architecture

- Alternative to a “Product Pitch”
- Goal is to define a standard for DDoS technologies to be judged
- This is a implementation guide based on the requirements outlined in the previous section
- A five step architecture that addresses all the functional components in modern DDoS mitigation technologies

Mitigation Reference Architecture



Mitigation Reference Architecture

- **Step 1: Classification**
  - **Classifies traffic for future inspection**
  - **Implements 'inline' enforcement:**
    - **blocking malicious sources**
    - **blocking malicious content**
- **Step 2: Source Verification**
  - **Defeats spoofed attacks**
  - **Must operate at 'line rate' or will be vulnerable to DoS**

Mitigation Reference Architecture

- **Step 3: Measurement**

  Counts the traffic

  – **Can be on the resource itself**

  – **Can be on an offline device like a NetFlow collector**

- **Step 4: Recognition**

  Uses input from measurement to determine who is an attacker

  Suggests to Enforcement who to block

- **Step 5: Enforcement**

  Informs classifier what to block

  Gets information back from classifier when attack is over

Future Developments

A Look at How We Got Here

- **End-to-end principle**
  - **Network devices should not replicate end system functions**
  - **Corollary: Every IP address on the Internet is supposed to be able to communicate to every other IP address**
  - **Controlling this behavior is the key challenge**
- **Attacks are getting smarter based on economically motivated factors**
- **Attack frequency is determined by two factors:**
  - **Background malicious activity**
  - **Financial opportunity**

The Right and Wrong Way to Control Traffic

Cisco.com

- Today there is a natural, accepted mechanism for blocking traffic—filtering ports!
- This leads to a situation where applications avoid filtering by using common ports of other applications (e.g. Port 80 for P2P)
- Now the security professional decides to invest in deep *Packet* inspection technologies
- This will lead to a situation where applications start using encryption to avoid detection
- Imagine everything encrypted over 443!

  This isn't as far away as you might think.

Operational Security and Encryption

Cisco.com

- **Two ways today to mitigate attacks**
  - **Packet content evaluation: evolving to content filtering**
  - **Flow-behavior analysis: and anomaly recognition**
- **Encryption prevents effective use of either mechanism**
  - **How can you evaluate the content—classify it, police it, etc.**
  - **All encrypted traffic tends to look alike, behaviorally**
  - **Since decryption usually requires CPU, it in itself usually makes a system more vulnerable**

An Alternative Model to Port Blocking

- Classify, and mark p*ackets*
- Once marked, treat traffic in three to four broad buckets:
  - Control
  - High quality
  - Best effort
  - Bulk traffic
- DiffServ as a strategic security tool!
- Classification is the key!

Summary

Summary

- Implementing DDoS mitigation in large, complex environments is non trivial
- A mitigation system requires both security and networking resources – can't be done with one alone!
- A variety of tools are available- these must be integrated into your Operational environment

Thank You!

Questions?

References

- **ISP Essentials**
  ftp://ftp-eng.cisco.com/cons/isp/
- **Team Cymru**
  http://www.cymru.com/
- **Nanog Security Curriculum**
  http://www.nanog.org/ispsecurity.html
- **Cisco DDos Protection Solution**
  http://www.cisco.com/cdc_content_elements/networking_solutions/service_provider/ddos_protection_sol/
- **DDos Links**
  http://www.honeypots.net/incidents/ddos-mitigation
- **ICMP Backscatter Traceback**
  http://www.secsup.org/Tracking/
- **Customer Triggered Blackholes**
  http://www.secsup.org/CustomerBlackHole/