Endpoint Security
Layer 2 Security

November 25, 2014

What this lecture is about:

- Securing hosts inside a network
  - Hosts & servers
- Layer 2 attacks
  - On the network
  - On its devices

Endpoint Security

A secure network is only as strong as its weakest link

Securing “inside” and “outside”

- You know about securing the perimeter of a network against outside threats:
  - ACLs
  - CBAC
  - ZPF
  - TCP intercept
  - IDS/IPS: NIPS
- Internal threats are there, too
  - How well can you control who accesses your internal network?

Big-picture strategy for endpoint security

- NAC (Network Access Control)
  - A solution that requires every endpoint to comply with company policies
  - Non-compliant endpoints are denied access
- Endpoint protection using HIPS
  - Implemented using CSA (Cisco Security Agent)
  - Complemented by IronPort Perimeter Security Appliances
- Network infection containment
  - Before stopping an attack, containment in required
  - Must be an automated process
  - Implemented as a NAC or IPS service

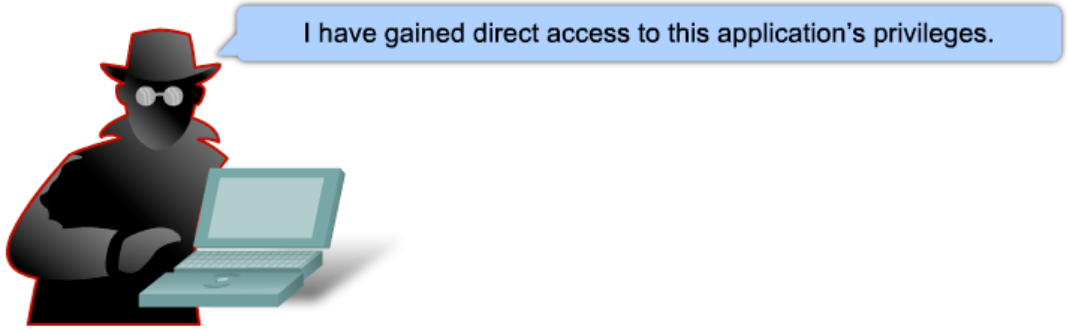
Operating system security

- Protecting an endpoint is protecting its services and applications
- Ultimately, an operating system has full access over a host
- Protecting the operating system becomes a priority

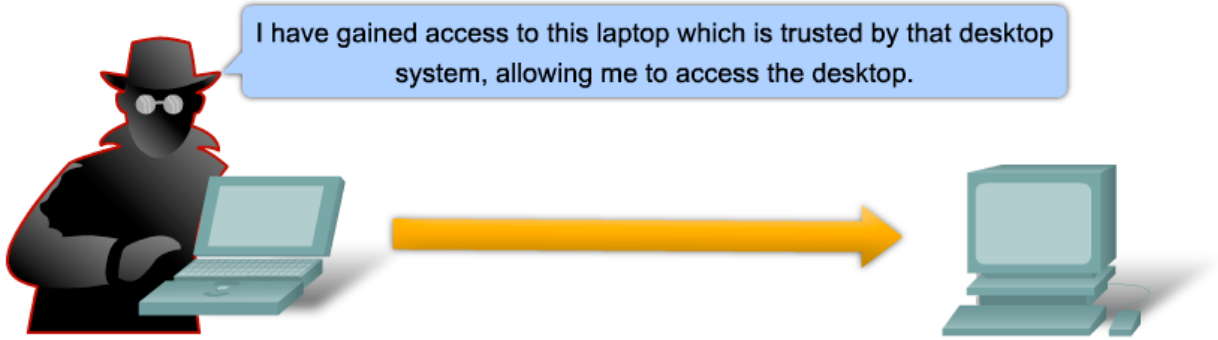
- OS'es have basic security features like:
  - Processes – independent address spaces
  - Privileges – execution must be made from a user account with sufficient privileges
  - Least privilege concept
    - Applies to processes and users, as well

Gaining access: directly and indirectly

- Security must be viewed from a network perspective, too
- Hosts have privileges and can be “trusted”, too



Direct



Indirect

Strategy: NAC – Network Access Control

- NAC provides several features in order to enforce a network security policy:
  - Authentication and authorization
  - Evaluating a foreign device against the policies of the network
  - Quarantining of non-compliant systems
  - Remediation of non-compliant systems

Strategy: NAC – Network Access Control

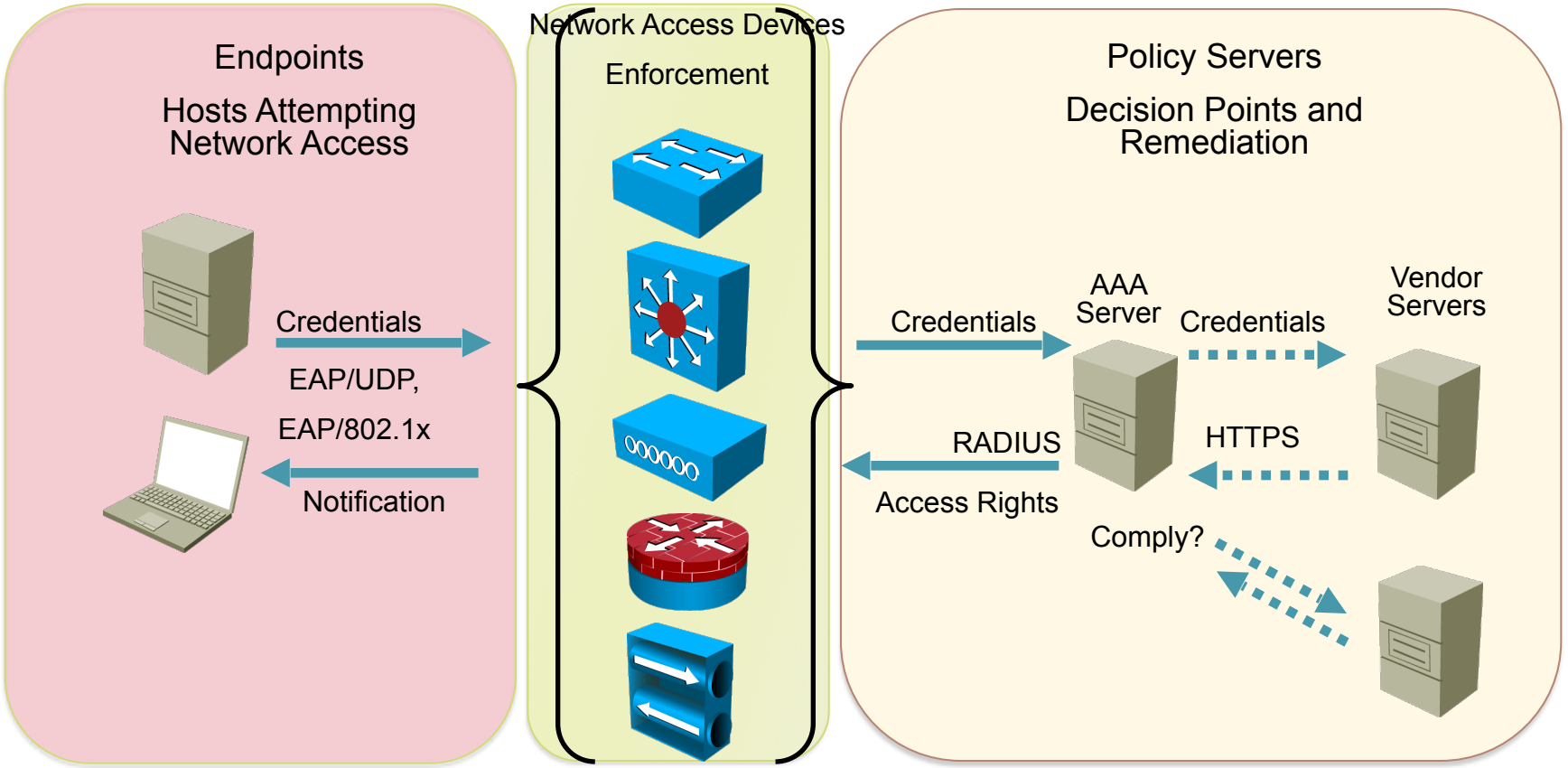
- Purpose: ensure that only authenticated and policy-compliant hosts are given access to the network.
  - Protects against foreign devices such as laptops, PDAs, smartphones
  - Not only “guest” devices, but also devices from your company that have gone off-site and might have become infected
  - These devices can infect a network from inside the perimeter
    - Network Intrusion Prevention System (NIPS) doesn’t help here

Cisco NAC

- Cisco implements NAC in two logical models:
  - NAC framework
    - Distributed solution, for large networks, many network connections and many endpoints.
    - Suited for remote access solutions, too
  - NAC appliance
    - Simplified solution, self-contained
    - Anti-virus and vulnerability updates
    - Can be used on any Cisco platform
    - Turnkey solution

Cisco NAC framework – distributed solution

- Several devices enforcing different security policies



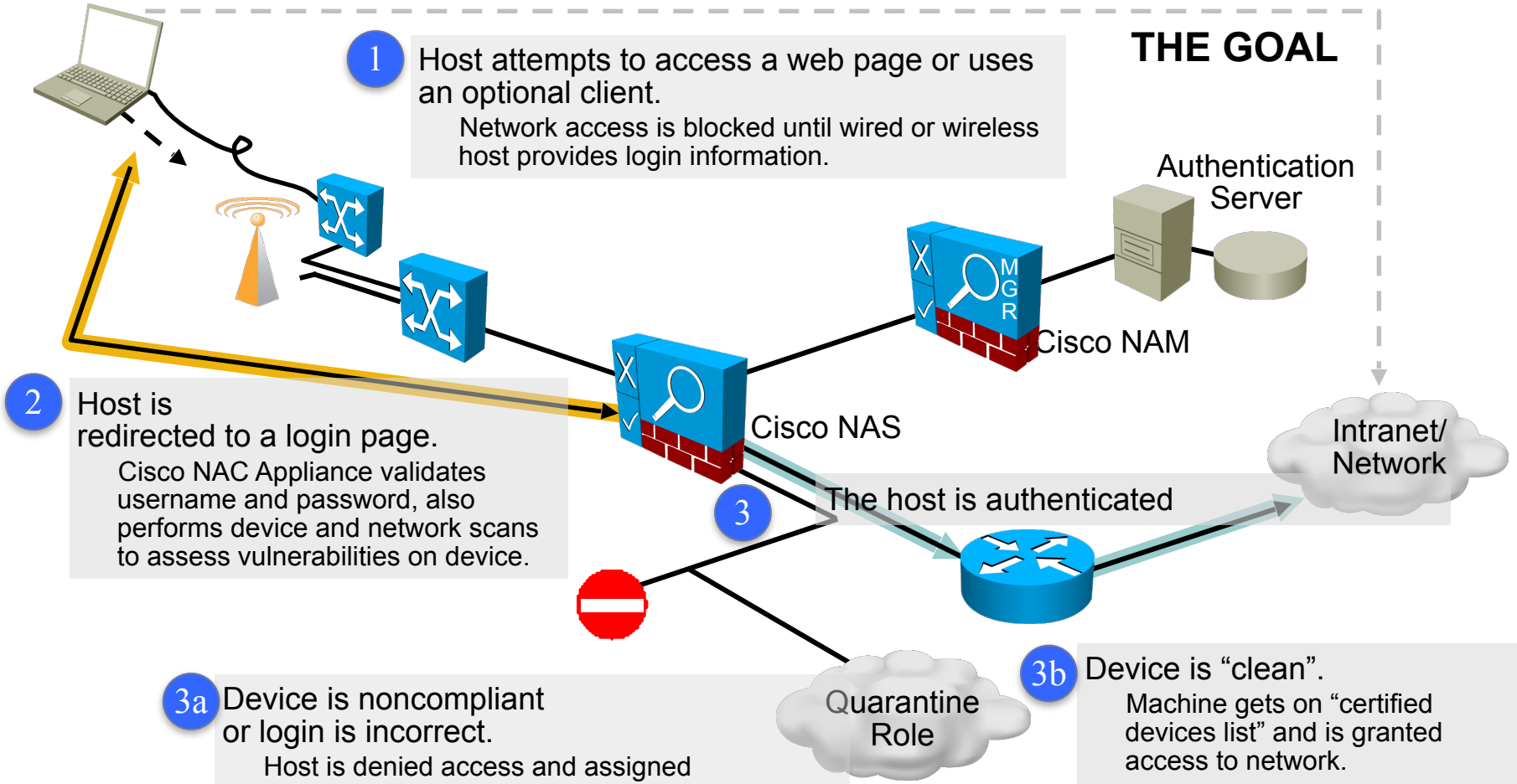
Cisco NAC appliance

- Cisco NAC components:
  - NAS (NAC Appliance Server)
    - Stores network security policies
    - Performs device-compliance checks
  - NAM (NAC Appliance Manager)
    - Administration interface used by support personnel
    - Allows configuration of NAS
  - NAA (NAC Appliance Agent)
    - Software client, runs on endpoint machines
    - Read-only rights over the operating system
    - Performs constant deep inspection and analysis


NAS

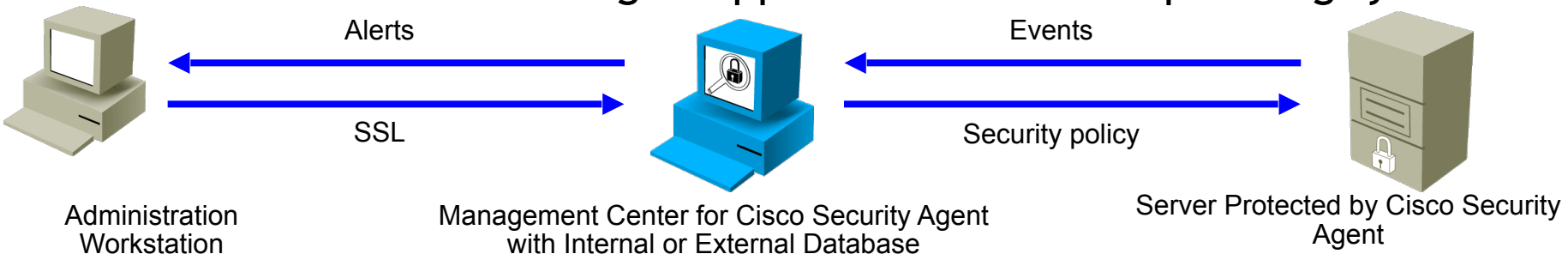
NAM

How does Cisco NAC appliance work?



HIPS solution: Cisco Security Agent (CSA)

- CSA – HIPS solution providing endpoint security
  - Installed on desktop and server systems
- Components:
  - Management center for CSA
    - Administrative interface, maintains logs for alerts sent by clients
  - Cisco Security Agent
    - Installed on host system
    - Continuous monitoring of applications and the operating system



CSA functionality

- When applications require system resources, they make a system call to the kernel

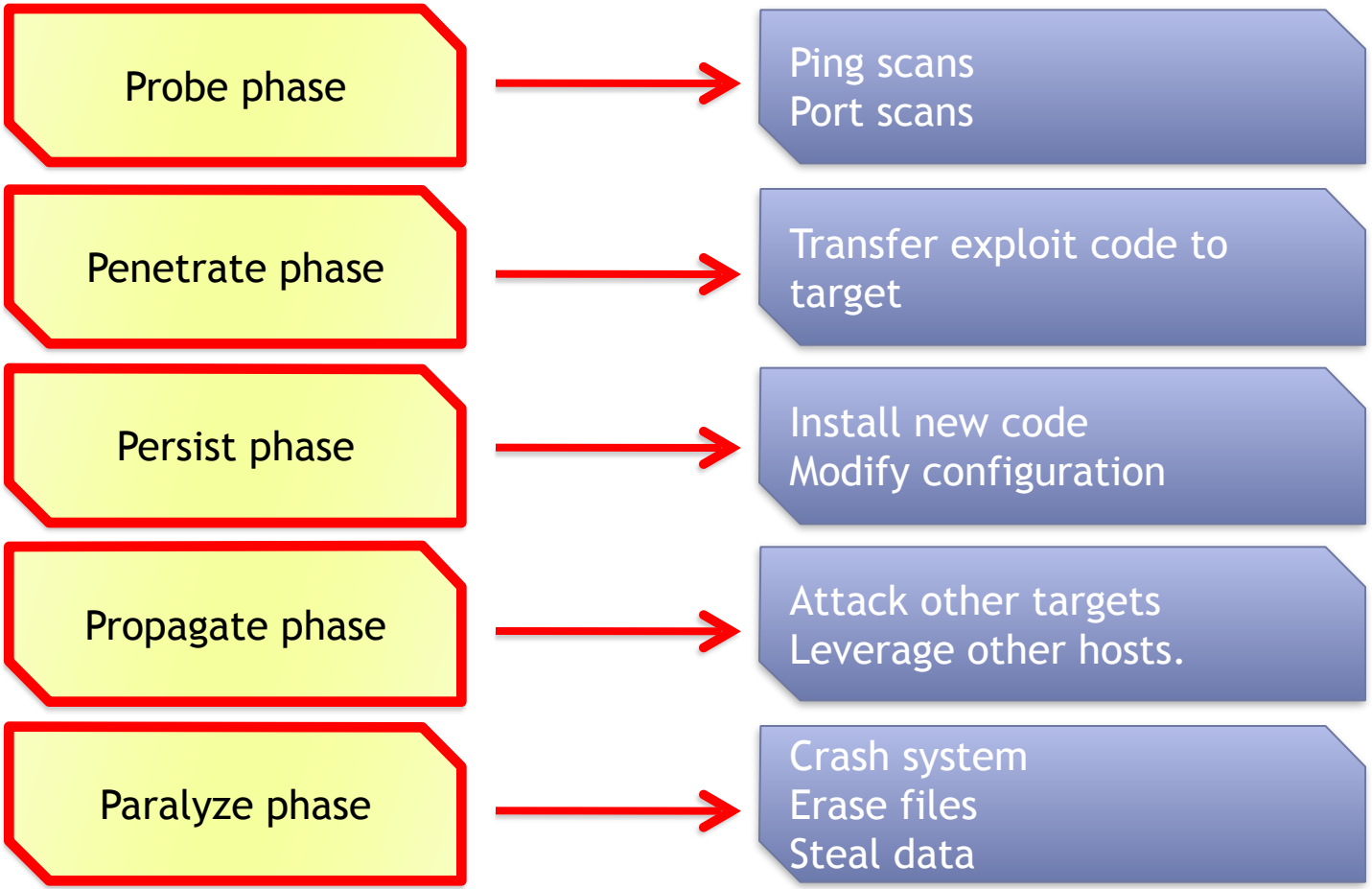
- CSA intercepts system calls and compares them to the system policy
- If the request violates the policy:
  - CSA blocks it
  - Sends an appropriate error message to the application
  - Sends an alert to the Management Center

CSA intercept feature

- CSA intercepts operating system calls using four specialized interceptors:
  - *File system interceptor*: read/write requests to all file systems
  - *Network interceptor*: inspects network traffic; can force limitations to protect from DoS attacks
  - *Configuration interceptor*: read/write requests to the operating system's configuration (like the registry)
  - *Execution space interceptor*: protects the dynamic runtime environment
    - Blocks requests to memory that is not owned by an application

CSA security features

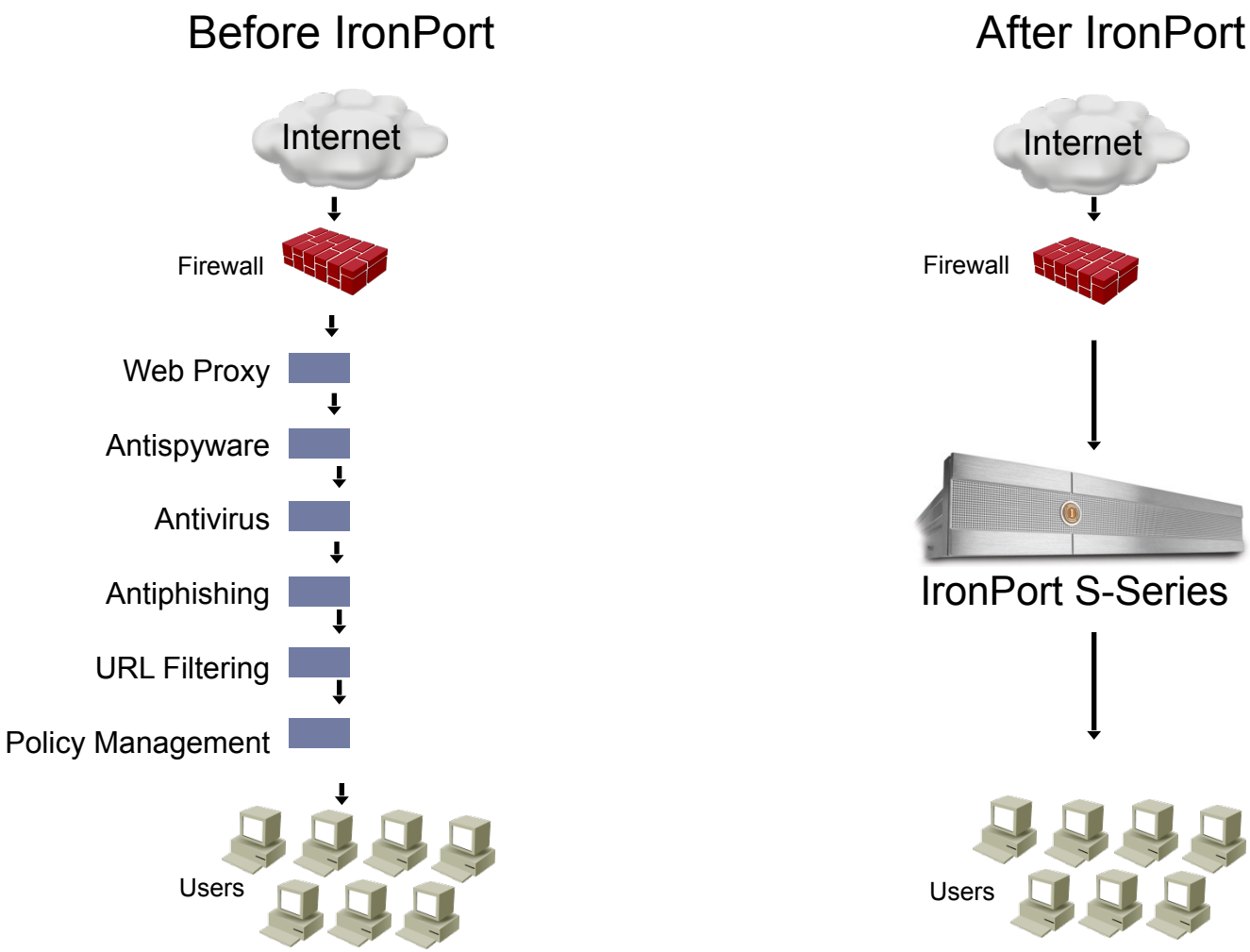
- CSA enables protection against all phases of an attack:



Strategy: IronPort

- Acquired by Cisco in 2007
- Leading provider of anti-spam, anti-virus, anti-spyware appliances
- C-series: *e-mail security*, virus and spam control
- S-series: *web security*, anti-spyware, anti-malware
- M-series: e-mail, web and *organization-specific policies*

Strategy: IronPort combined functionality



Layer 2 security

The lowest link that can prove to be the weakest.

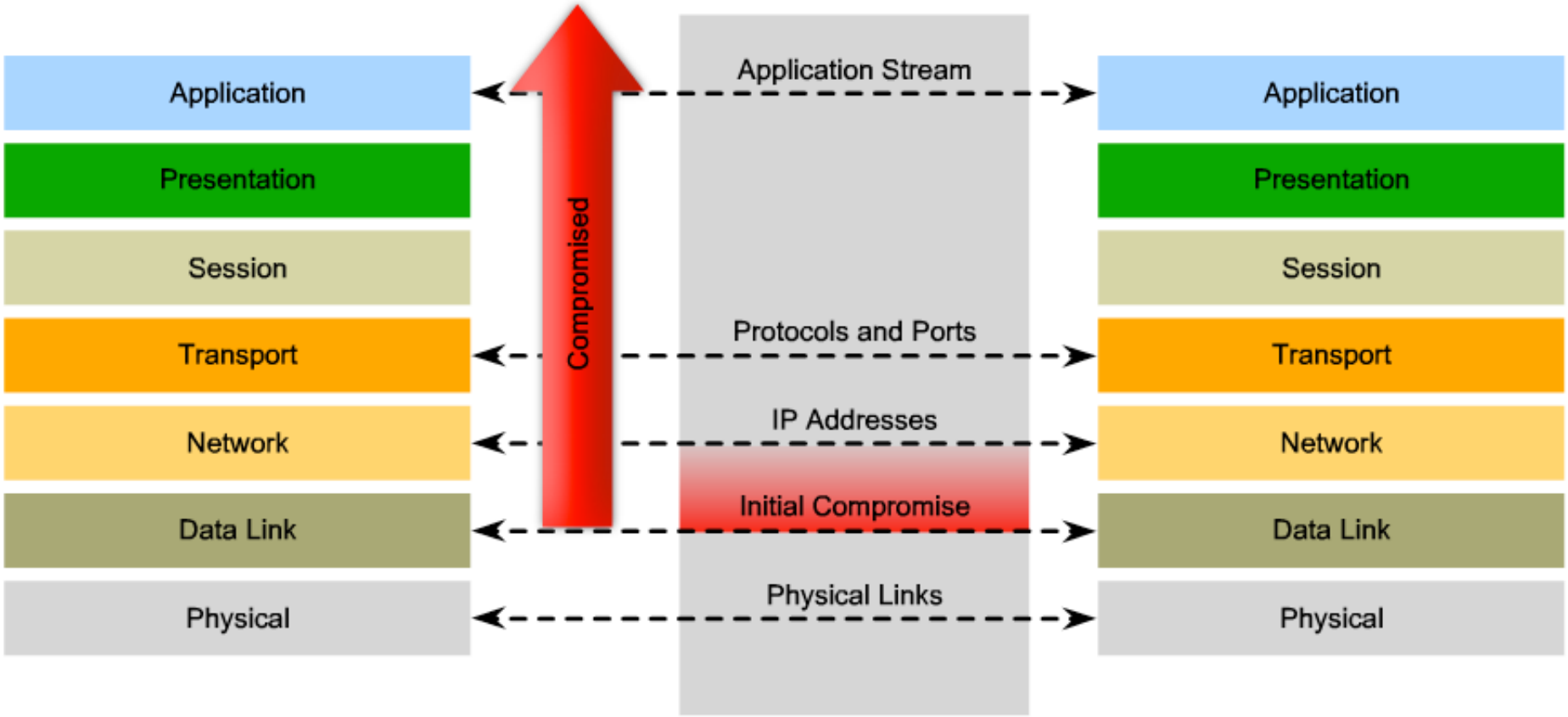
This section will cover:

- Layer 2 attack methods:
  - MAC address spoofing
  - STP manipulation
  - MAC table overflow
  - LAN storms
  - VLAN attacks

- Also, a little brief recap of the LAN technologies

Compromising layer 2 compromises all layers

- If the data link layer is hacked, the other layers will not be aware



Switched networks

- A hub is an intermediary device that forwards data to all ports except the one it was received

- Switches optimize this behaviour:
  - They forward data on specific ports, based on destination MAC addresses
  - So, switches must learn on which port is each MAC address located. The CAM memory stores these mappings
  - How does a switch learn about MAC addresses?

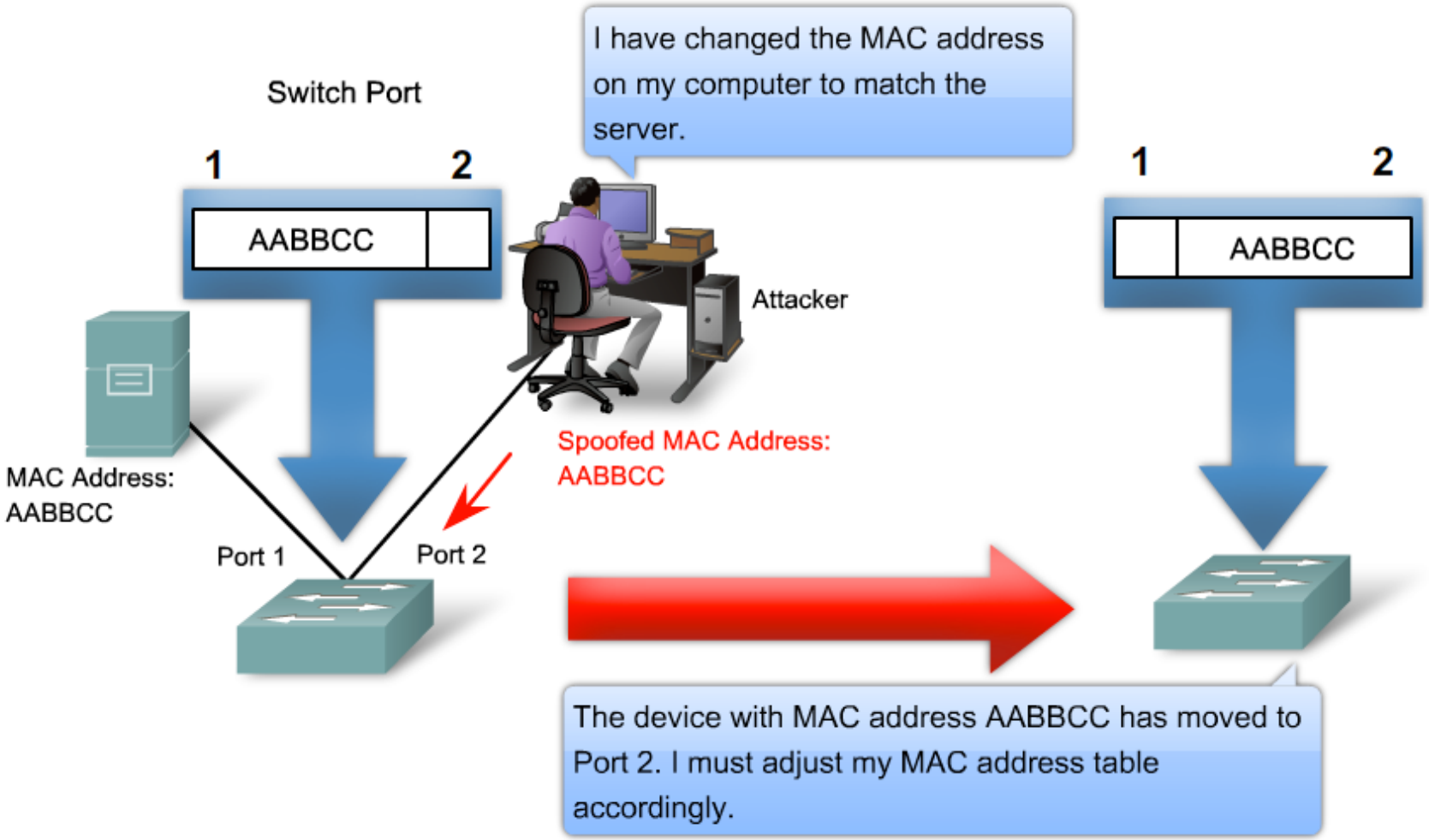
- Can a switch learn a MAC address on more than one port?
- Can a switch learn more than one MAC address per port?
  - Give an example. When?

MAC spoofing

- The way switches learn MAC addresses is a vulnerability by itself

- Hosts can use another MAC address to impersonate another device and “fool” the switch
  - The switch receives frames with the spoofed MAC address
  - It look at the source address and learns it on a different port.
    - The switch updates its CAM table and maps the old MAC address on the new port
  - Frames destined to the target host are now sent to the attacking host

Example: MAC address spoofing



MAC address table overflow attack

- A switch stores MAC-port mappings in its CAM memory
  - Which, of course, is limited…
- Flooding a switch with many fake (spoofed) source MAC addresses will fill up this memory
  - Having its memory full, the switch cannot learn new MAC addresses
  - What does a switch do when it does not have the destination MAC address in its memory? (what would YOU do?)
- The switch will start acting like a hub
- Any attacker will be able to sniff traffic between any two hosts in the network

STP quick recap

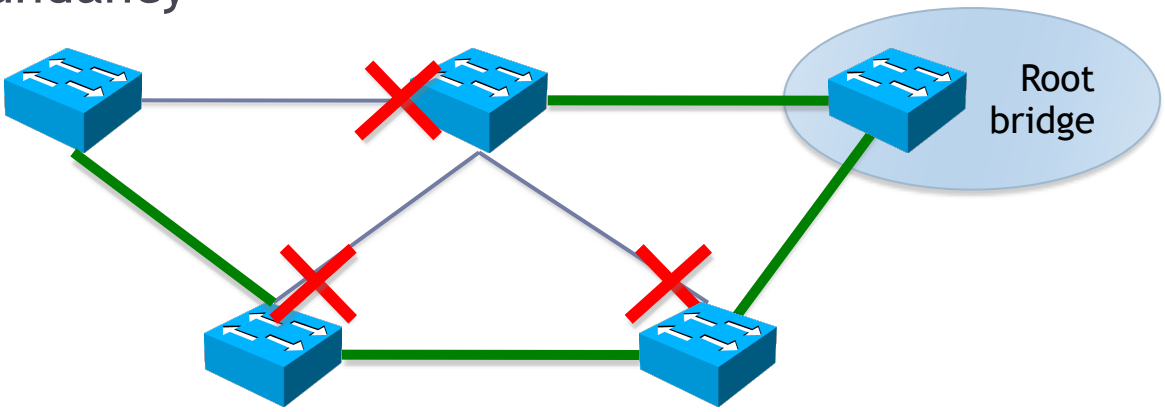
- STP = Spanning Tree Protocol
- A Protocol that Spans Trees over your local network ☺

- The MAC address learning method used by switches does not work if there is a loop in the network
- Also, loops in a LAN can cause:
  - Data cycling indefinitely in the loop
  - MAC address table inconsistency

- STP creates a loop-free topology (a tree) covering all your switches
- Traffic will flow only on the tree's links

STP facts

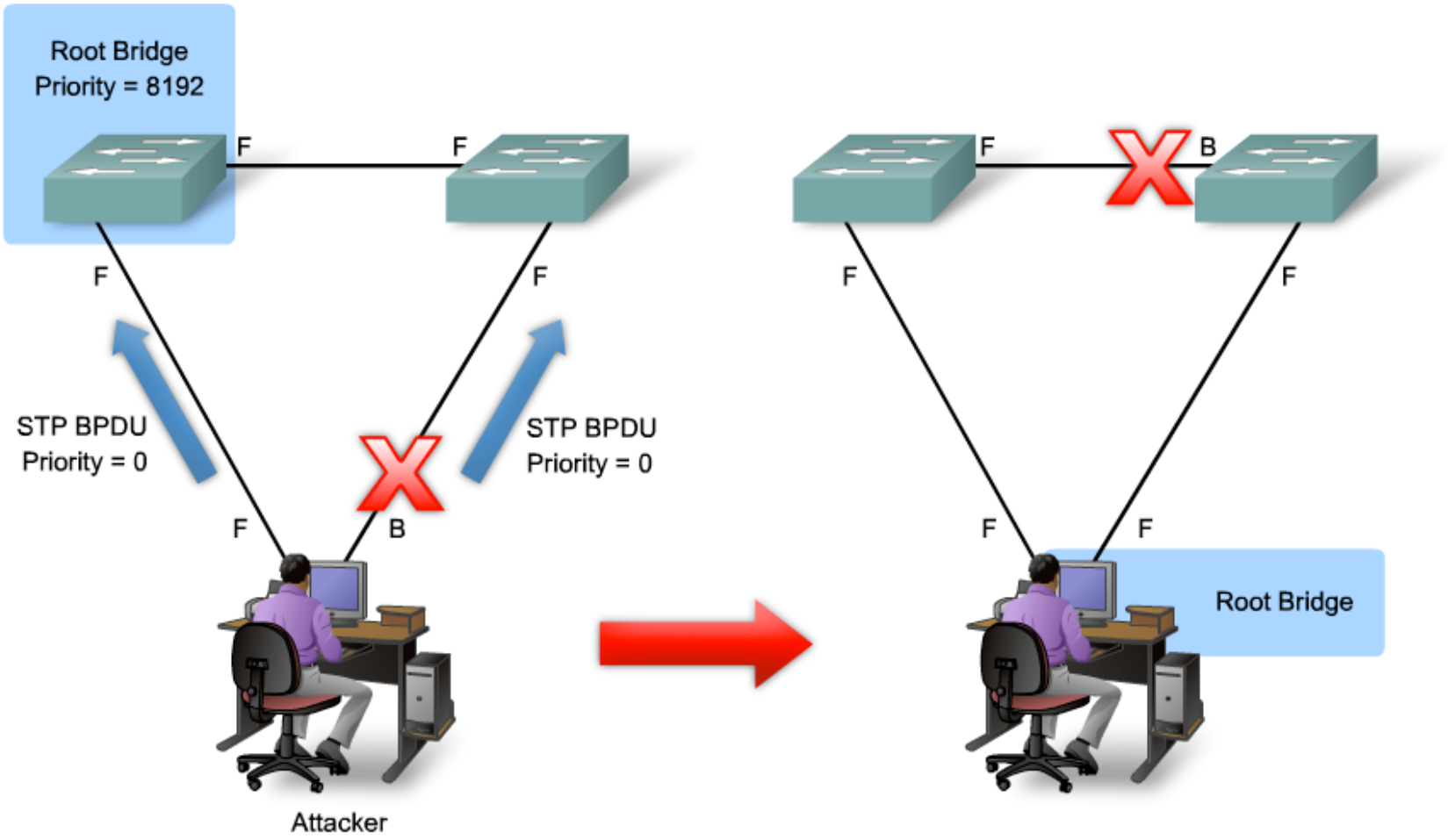
- Switches in STP are called “bridges”
- A root bridge is elected based on:
  - Lowest configured priority
  - If the above are equal, the lowest MAC address is the tie breaker (now, if THOSE are equal you’ve got bigger problems…)
- STP shuts down switch ports in order to create a loop-free path
- In case of failures, closed ports will be opened again
  - Thus, ensuring redundancy



STP manipulation attacks

- The election process for the root bridge is carried out using BPDUs
  - A BPDU (Bridge Protocol Data Unit) is a small piece of data exchanged between adjacent switches every 2 seconds
  - It contains relevant data for STP election ad stability
- Sending false BPDUs can change the logical topology of the network
  - Attackers can send false BPDUs to make themselves the root bridges and to be able to receive all traffic traversing the network

STP attack: sending the lowest priority: 0



LAN storm attack

- Broadcasts are vital for a network to function properly.
  - Example protocols: ARP, DHCP
- But flooding a network with broadcast traffic degrades network performance
- Broadcast storm: flooding the network with excessive broadcast traffic
  - Why is this possible?

    Because switches forward broadcasts out on all their ports

Mitigating LAN storms

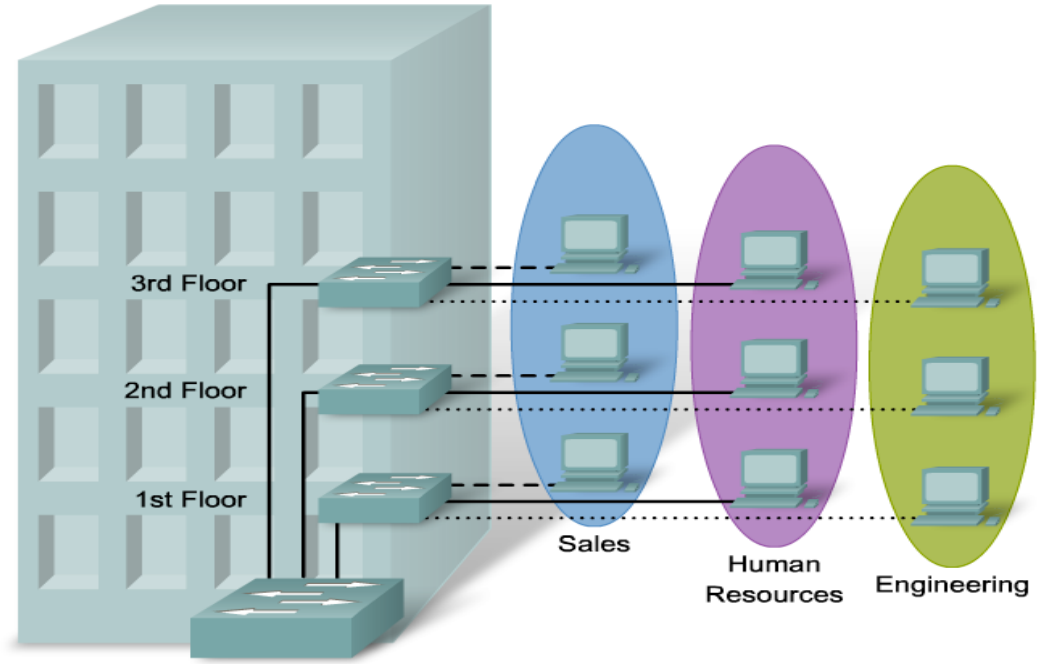
- Broadcasts cannot be eliminated from the network
- Solution: Storm control (traffic suppression)
  - Monitors unicast, multicast and broadcast traffic on an interface
  - Compares the amount of traffic to a predefined threshold
  - If the number of incoming packets is too high, traffic is blocked
    - Storm control unblocks traffic after a period of time

VLANs and VLAN attacks

- A VLAN (Virtual LAN) is a logical broadcast domain within a switched network
  - Multiple VLANs appear as different subnets
  - Allow segmentation of the LAN without using routers
  - Hosts cannot communicate between VLANs without a routing-capable device (router, layer 3 switch)
- VLANs are a simple way to securely isolate groups of hosts inside a LAN
- Attempting to gain access to another VLAN is a type of a VLAN attack

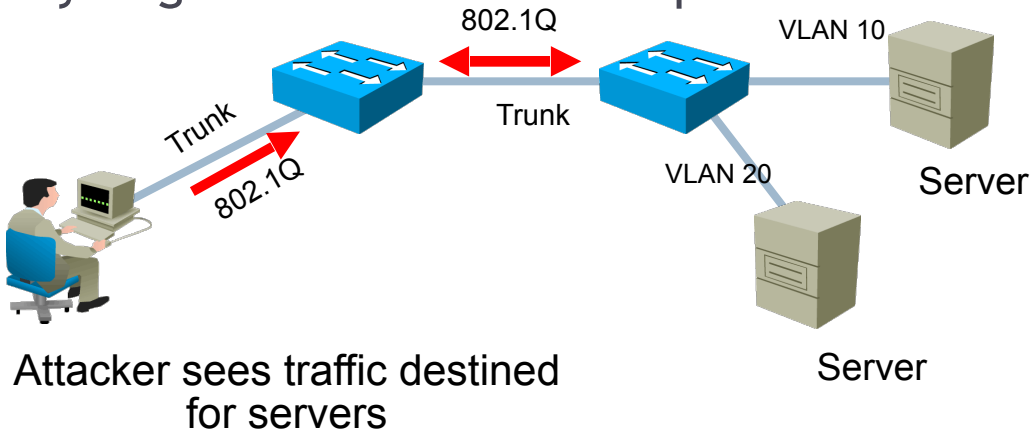
VLAN extensibility

- VLANs are not restricted to a single geographical location
  - Inter-switch links that carry more than one VLANs are called trunk links
    - Common trunking protocol: IEEE 802.1q (“dot1q”)
  - Ports that connect hosts to a single VLAN are called access ports



VLAN hopping attacks

- End-users (their hosts) are always members of a single VLAN
- Accessing another VLAN, other than the one assigned to your switch port, is called VLAN hopping
- Method: establish your own trunk link with the switch
  - The trunk link can transport any VLAN
  - DTP (Dynamic Trunking Protocol) is active by default and will automatically negotiate a trunk when possible

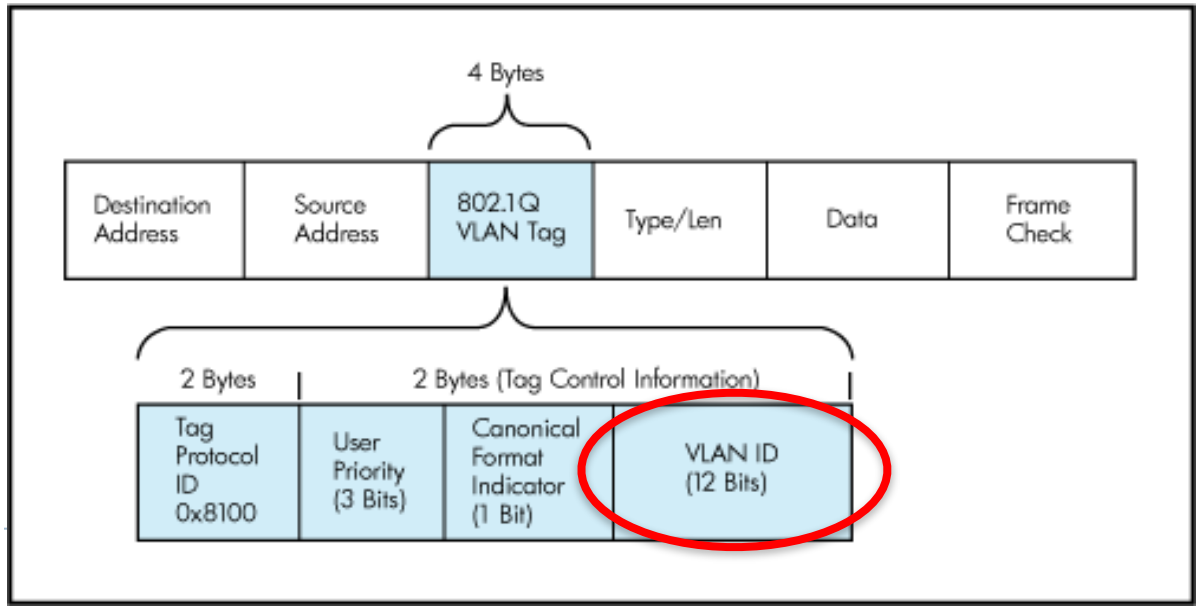


VLAN hopping mitigation

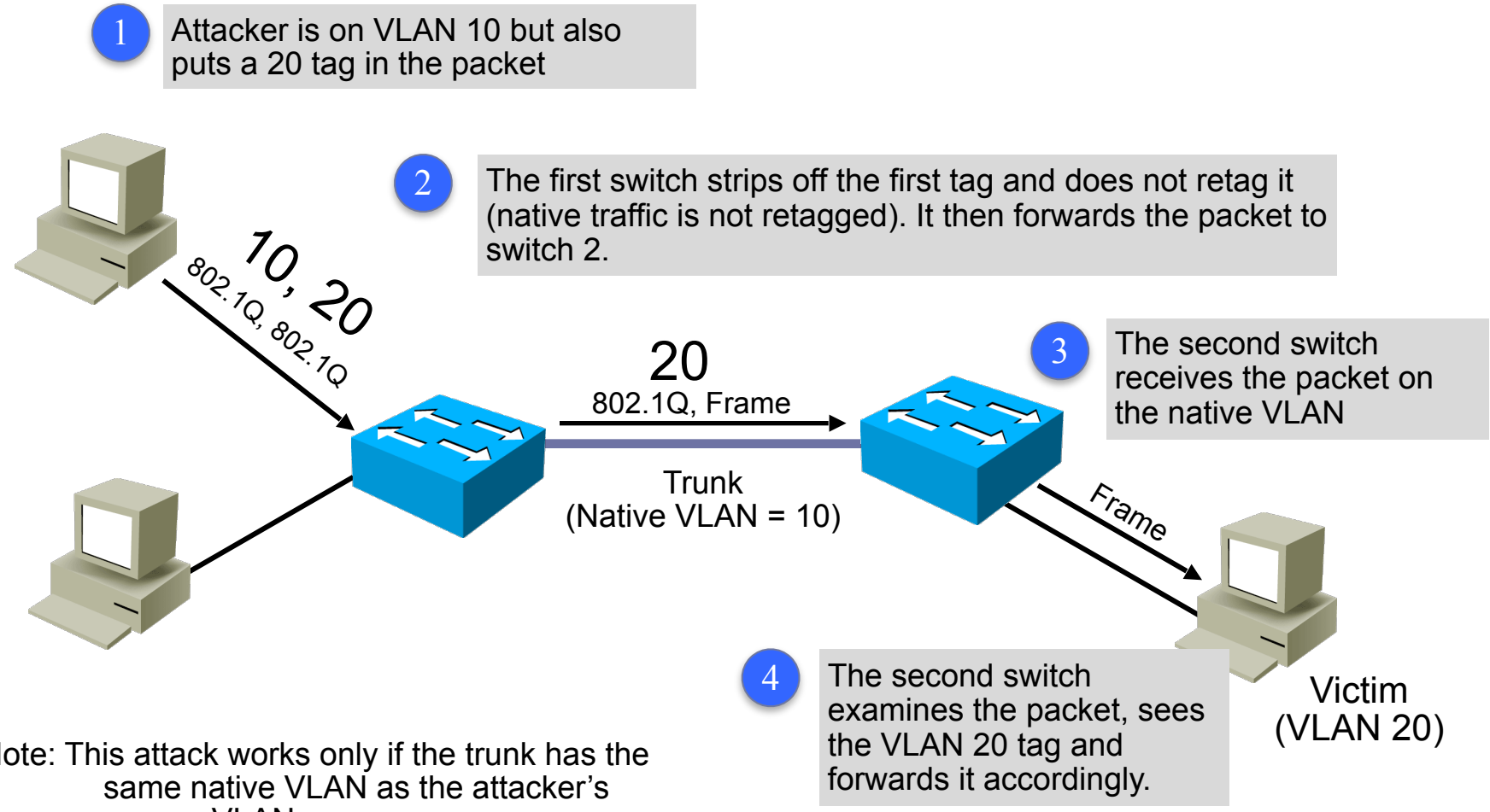
- Unwanted trunk links can be created using:
  - A host that acts like a switch and sends DTP negotiation frames
  - A normal switch, owned by the attacker
- Solution:
  - Disable DTP on ports that do not require trunking
    - Negotiation of a trunk will not be possible any more
  - Preferably, manually enable trunking where needed

Trunks and native VLANs

- When passing over a trunk, a frame must retain its VLAN information
  - So that the end switch will know to which VLAN it belongs to
  - "Tagging" a frame with its VLAN information is done using the dot1q protocol
  - If a frame does not have a tag, it is considered to belong to the "native VLAN" of the trunk link



VLAN hopping: double-tagging



Note: This attack works only if the trunk has the same native VLAN as the attacker's access VLAN.

Configuring Layer 2 Security

Here come the commands…

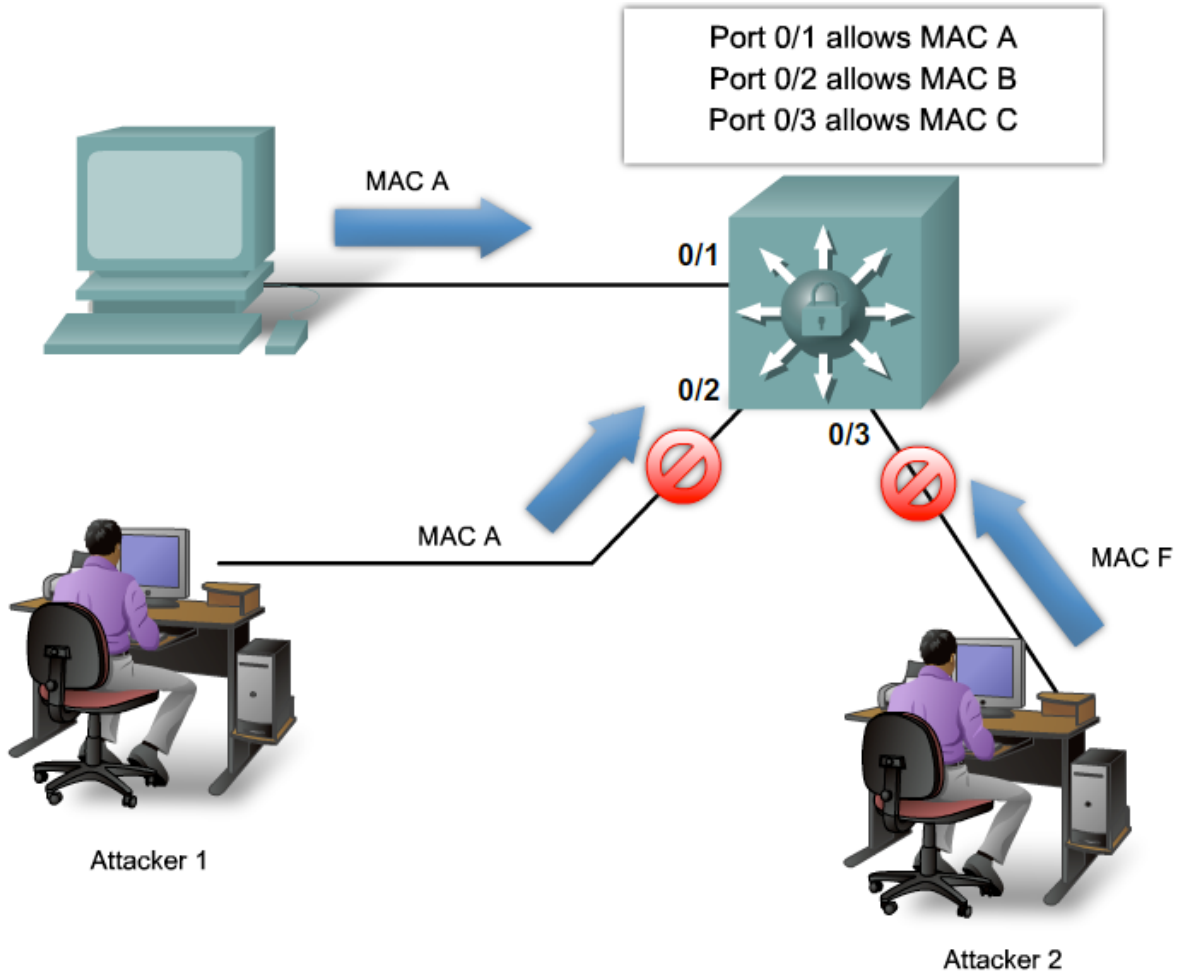
Overview

- Overview of this section:
  - Configuring port security
  - Verifying port security
  - Configuring BPDU Guard and Root Guard
  - Configuring Storm Control

Port security

- Port security is a feature that allows you to:
  - Configure the maximum number of MAC addresses a switch can learn on a certain port
  - Statically configure the allowed MAC addresses
- All incoming frames using disallowed MAC addresses are dropped by default
- Protects against:
  - Unauthorized expansion of the network
  - Foreign hosts or switches becoming members of your network

Port security example



Configuring port security

- Changing the interface mode to access: [access != trunk]

```
S1(config)#interface FastEthernet 0/24
S1(config-if)#switchport mode access
```

  - The default mode on a switch port (interface) is dynamic auto, which will use DTP to try and dynamically negotiate a trunk on the link
  - Port security cannot be enabled on dynamic auto ports

- Activating port security on the interface:

```
S1(config-if)#switchport port-security
```

- Set the maximum number of MAC addresses that can be learned on the interface:

```
S1(config-if)#switchport port-security maximum 3
```

Configuring port security MAC addresses

- Specifying one or more MAC addresses that are associated on the interface:

```
S1(config-if)#switchport port-security mac-address
0026.08de.f22e
```

  - We still have only a maximum of 3 MAC addresses on the interface
  - Configuring one MAC address leaves the other 2 to be dynamically learned
  - The first MAC address of a sending host will be recorded

Configuring port security actions

- The action that is to be taken by the switch port when an invalid source MAC address is detected on the port is called violation

- Setting the violation mode:

```
S1(config-if)#switchport port-security violation ?
  protect   Security violation protect mode
  restrict  Security violation restrict mode
  shutdown  Security violation shutdown mode
```

- Setting the violation mode is optional
  - The default is to shut down the port

Port security violation modes

- Protect
  - Frames with unknown source addresses are dropped.
  - Until you remove some secure MAC addresses or increase the maximum allowed number of addresses to let them pass.
  - No notifications are sent.
- Restrict
  - Frames with unknown source addresses are dropped.
  - Until you remove some secure MAC addresses or increase the maximum allowed number of addresses to let them pass.
  - Security Violation counter is incremented
  - SNMP traps are sent, syslog messages as well.
- Shutdown
  - Completely shuts down the interface.
  - The port is set in the error-disabled state.
  - The port has to be manually brought up.
  - Sends the same notifications as in Restrict mode.

Witnessing a “shutdown” violation ☺

- A port shutting down after receiving one more MAC address than the maximum allowed:

```
2d17h: %PM-4-ERR_DISABLE: psecure-violation error detected on Fa0/1, putting Fa0/1 in
 err-disable state
2d17h: %PORT_SECURITY-2-PSECURE_VIOLATION: Security violation occurred, caused by MAC
 address 0019.e792.8321 on port FastEthernet0/1.
2d17h: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to
 down
2d17h: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to down
```

- Checking port state:

```
SW3(config-if)#do sh ip int brief | incl 0/1
FastEthernet0/1        unassigned      YES unset  down  down
```

- Checking for the error-disabled state:

```
SW3#show int fa 0/1
FastEthernet0/1 is down, line protocol is down (err-disabled)
  Hardware is Fast Ethernet, address is 001a.6cf8.8c01 (bia 001a.6cf8.8c01)
```

Recovering from a “shutdown” violation

- Do not attempt the following:

```
SW3(config)#int FastEthernet0/1
SW3(config-if)#no shutdown
```

- …as it will have the following “effect”:

```
SW3(config-if)#do sh ip int brief | inc 0/1
FastEthernet0/1  unassigned  YES unset  down  down
```

- Err-disabled state is not **really** a “shutdown” mode of the interface. Recover by shutting down the interface and bringing it up again:

```
SW3(config-if)#shutdown
SW3(config-if)#no shutdown
2d17h: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed
state to up
2d17h: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
```

- Or, even better, automate this to recover after 60 minutes:

```
SW3(config)#errdisable recovery cause psecure-violation
SW3(config)#errdisable recovery interval 60
```

The “sticky” ones…

- Dynamically learned MAC addresses are lost after the switch reloads
  - They will be learned again but this could be a security risk
- You can make all dynamically learned MAC addresses “sticky”
  - MAC addresses will still be dynamically learned
  - But they will be automatically saved in the running config

```
SW3(config-if)#switchport port-security mac-address sticky
```

- The running-config will automatically include:

```
SW3#sh run | include sticky
switchport port-security mac-address sticky
switchport port-security mac-address sticky 0019.e792.8321
```

Aging port security entries

- Configuring aging:

```
SW3(config-if)#switchport port-security aging
```

- Setting the number of minutes after which the entries will age out:

```
SW3(config-if)#switchport port-security aging time 15
```

- Setting the type of aging:

```
SW3(config-if)#switchport port-security aging type ?
  absolute    Absolute aging (default)
  inactivity  Aging based on inactivity time period
```

  - Absolute: entries will age out after 15 minutes
  - Inactivity: entries will age out after 15 minutes of inactivity from the specific MAC address

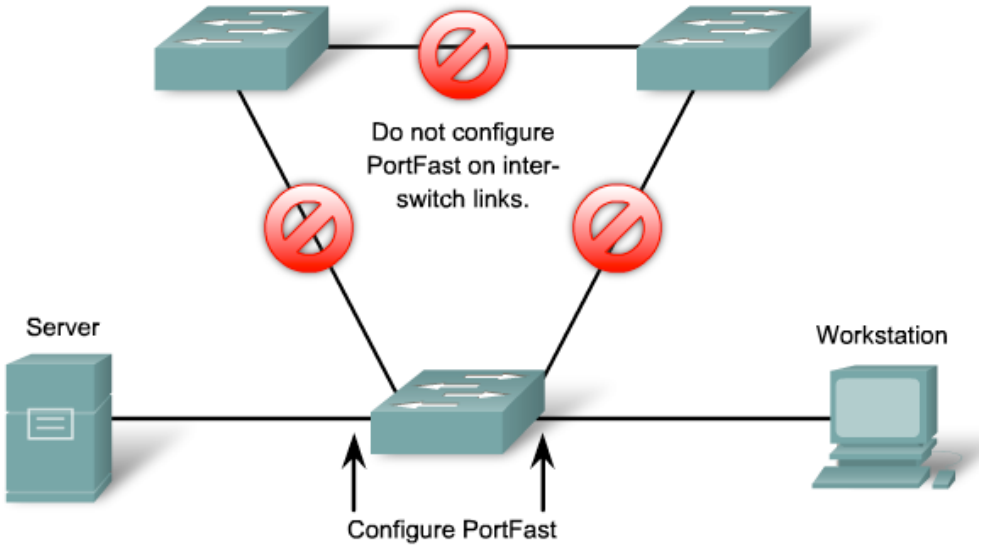
Verifying port security

```
SW3#show port-security
Secure Port  MaxSecureAddr  CurrentAddr  SecurityViolation  Security Action
                (Count)       (Count)          (Count)
---------------------------------------------------------------------------
      Fa0/1              3            3                  0         Shutdown
     Fa0/22              3            1                  0          Protect
---------------------------------------------------------------------------
Total Addresses in System (excluding one mac per port)     : 2
Max Addresses limit in System (excluding one mac per port) : 8320
```

- Showing all learned or configured addresses:

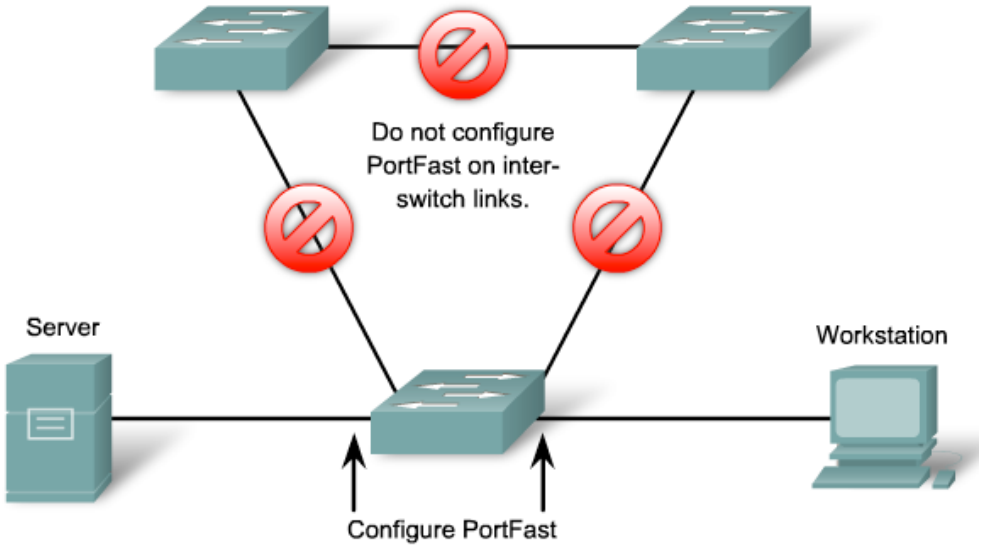
```
SW3#show port-security address
          Secure Mac Address Table
------------------------------------------------------------------------
Vlan    Mac Address       Type                  Ports   Remaining Age
                                                            (mins)
----    -----------       ----                  -----   -------------
   1    0019.e792.8321    SecureSticky          Fa0/1         -
   1    0025.bcdc.17b6    SecureConfigured      Fa0/1        11
   1    001b.9035.f118    SecureDynamic         Fa0/22        -
------------------------------------------------------------------------
```

PortFast



- STP takes time to converge and goes through several states
- The PortFast feature can be enabled on access links to avoid STP calculations on them
  - They are not included in the STP tree, anyway

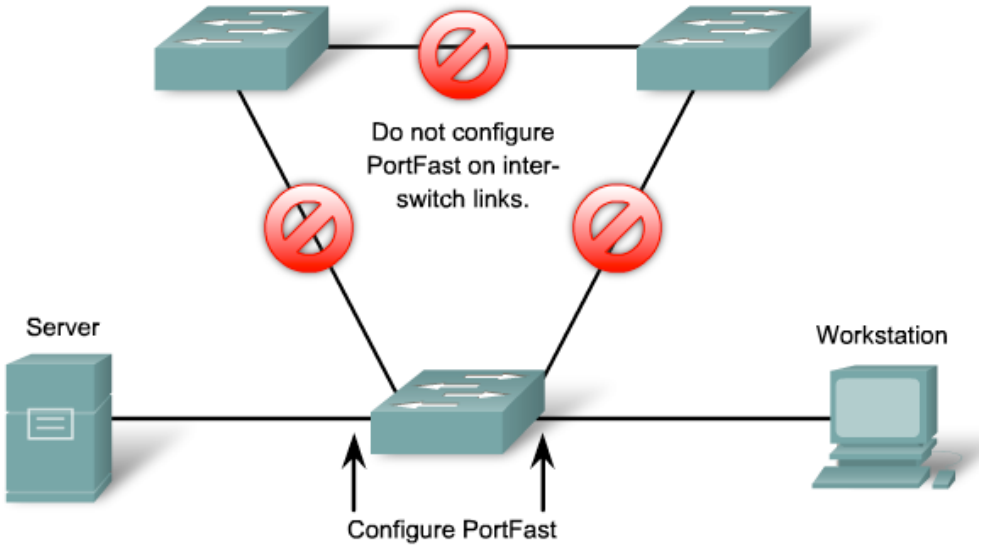
Configuring PortFast globally



- Configuring PortFast on all non-trunking ports at once:

```
SW3(config)#spanning-tree portfast default
```

Configuring PortFast at interface level



- Enabling PortFast for a specific interface:

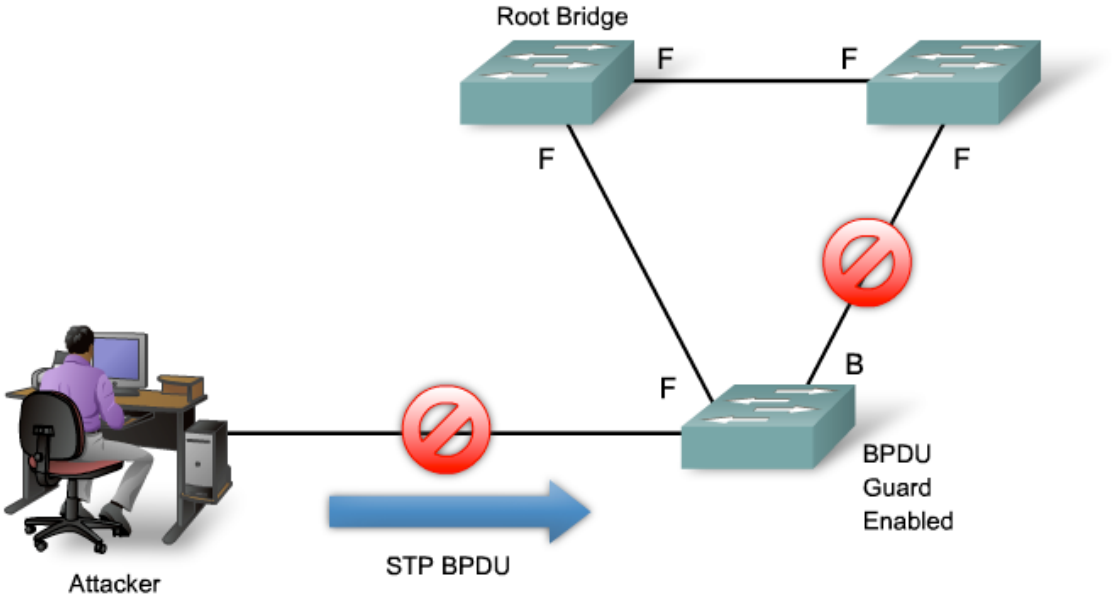
```
SW3(config-if)#spanning-tree portfast

%Portfast has been configured on FastEthernet0/1 but will only
 have effect when the interface is in a non-trunking mode.
```

- Proof that PortFast cannot work on trunk links

Configuring BPDU guard

- BPDU guard protects the network by blocking BPDUs on ports where they should not be received
  - This way the network topology remains predictable
  - Intruders cannot alter the root bridge of the STP tree
  - Access ports should have BPDU guard enabled



Configuring BPDU guard

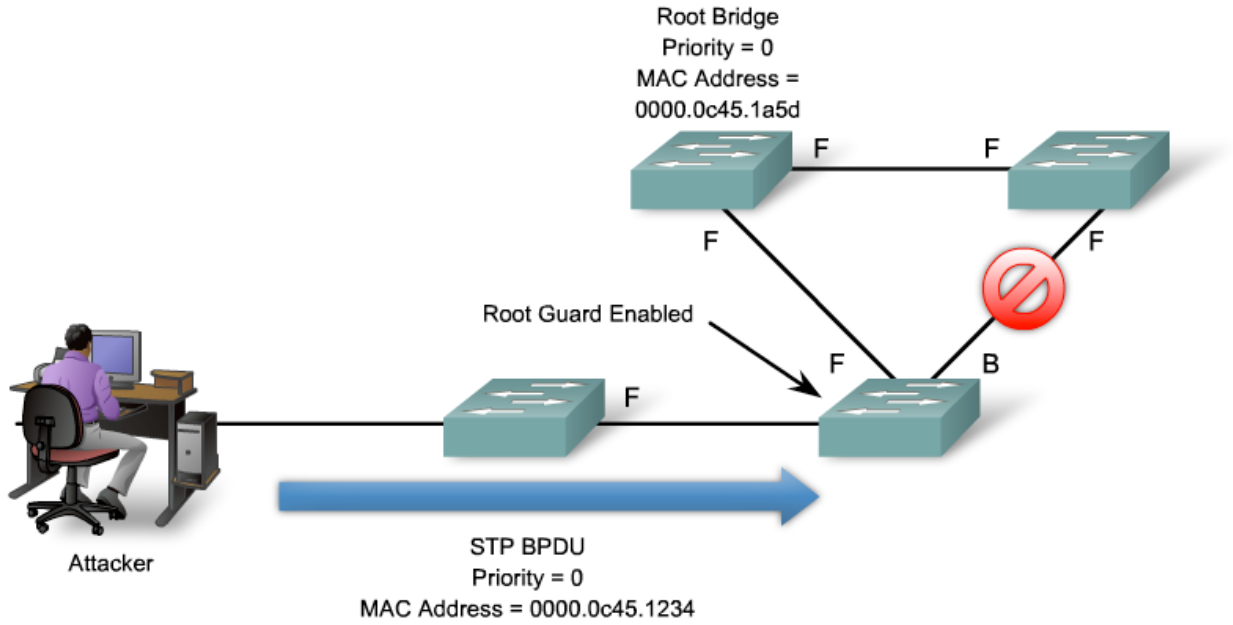
- BPDU guard is a PortFast feature
  - By default, BPDU guard will shut down the port if a BPDU is received
- Enabling BPDU guard globally on the switch:

```
SW3(config)#spanning-tree portfast bpduguard default
```

- Verifying:

```
SW3#show spanning-tree summary
Switch is in pvst mode
Root bridge for: VLAN0001
Extended system ID           is enabled
Portfast Default             is enabled
PortFast BPDU Guard Default  is enabled
Portfast BPDU Filter Default is disabled
Loopguard Default            is disabled
[…output ommited…]
```

Root guard



- An attacker can send spoofed BPDUs in an attempt to become the root
- The device connected to the switch port can participate in STP as long as it does not try to become the root
- Root guard puts the port in the root-inconsistent state
  - It automatically recovers when the offending BPDUs stop

Configuring Root guard

- Configuring Root guard on the interface:

```
Switch(config-if)#spanning-tree guard root
00:16:27: %SPANTREE-2-ROOTGUARD_CONFIG_CHANGE: Root guard
enabled on port FastEthernet0/1.
```

- Root guard should be configured on ports that do not lead to the root switch

- To view port states use:

```
Switch#show spanning-tree inconsistentports
```

- BTW: sending BPDUs with a priority of 0 does not guarantee that you will become the root bridge
  - Some other switches might exist, with 0 priority and a lower MAC address

Configuring storm control

- Example scenarios for configuring storm control:
  - Block broadcast packets over 75.55% of the interface's capacity:

```
sW(config-if)#storm-control broadcast level 75.55
```

  - You can specify upper and lower threshold levels

  - Block multicast packets that go over 5Mbps:

```
sW(config-if)#storm-control multicast level bps 5000000
```

  - Configure the interface to shut down (err-disabled) when either storm control violation occurs:

```
sW(config-if)#storm-control action shutdown
```

  - The default is to filter broadcasts

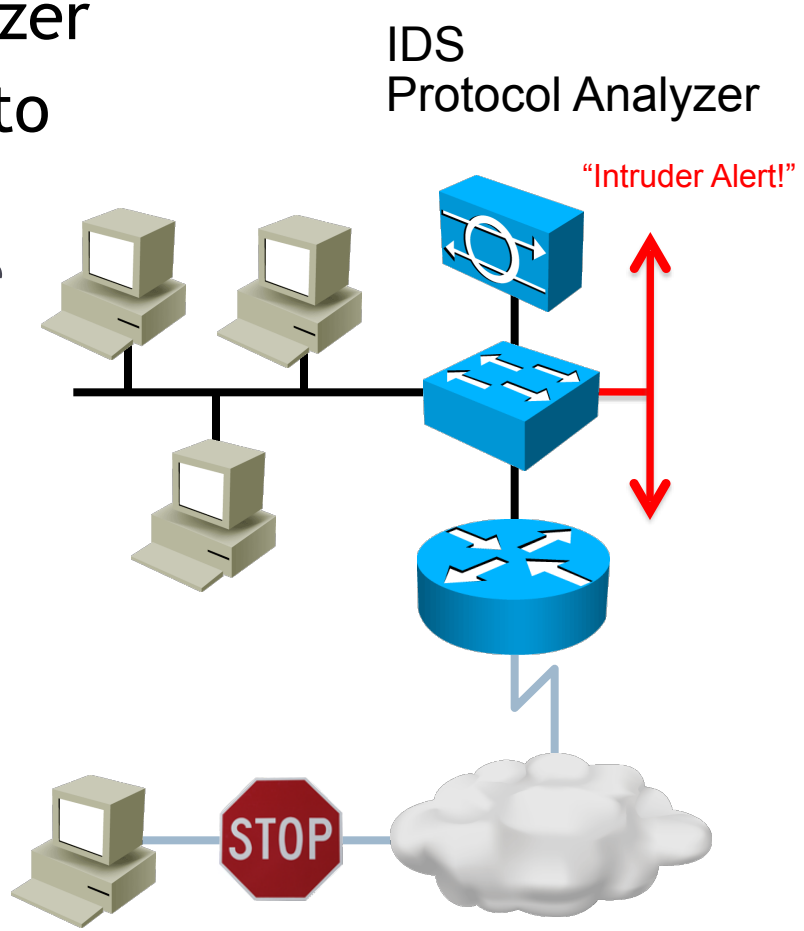
Verifying storm control

- Show storm control status:

```
SW3# show storm-control
Interface    Filter State   Upper        Lower      Current
---------    ------------   ----------   ---------  ---------
  Gi0/1        Forwarding     20 pps       10 pps     5 pps
  Gi0/2        Forwarding     50.00%       40.00%     0.00%
<output omitted>
```

Monitoring with SPAN

- SPAN = Switched Port ANalyzer
- A SPAN port mirrors traffic to another port
  - Monitors the entire interface (port) or a single VLAN
  - Monitors inbound and/or outbound traffic
- Ideal deployment for IDS systems
- Does not affect normal switching operation



Configuring SPAN – Example #1

- The “monitor session” command:
  - Setting the source interface to monitor:

```
Switch(config)# monitor session 1 source interface
gigabitethernet0/1
```

  - Setting the destination interface, where traffic will be mirrored:

```
Switch(config)# monitor session 1 destination interface
gigabitethernet0/2 encapsulation replicate
```

  - The “encapsulation” parameter tells the switch to mirror traffic while retaining the same encapsulation method

Configuring SPAN – Example #2

- The following example monitors only two VLANs:
  - Mirror only received traffic on VLAN 10:

```
Switch(config)# monitor session 1 source vlan 10 rx
```

  - Mirror only sent traffic on VLAN 20:

```
Switch(config)# monitor session 1 source vlan 20 tx
```

  - The destination is still an interface:

```
Switch(config)# monitor session 1 destination interface
FastEthernet 0/1
```

Viewing SPAN configuration

- Use the “show monitor” command to view configuration info about all monitor sessions:

```
#show monitor session 1
Session 1
---------
Source Ports:
    RX Only:        None
    TX Only:        None
    Both:           Fa0/2
Destination Ports: Fa0/3
```

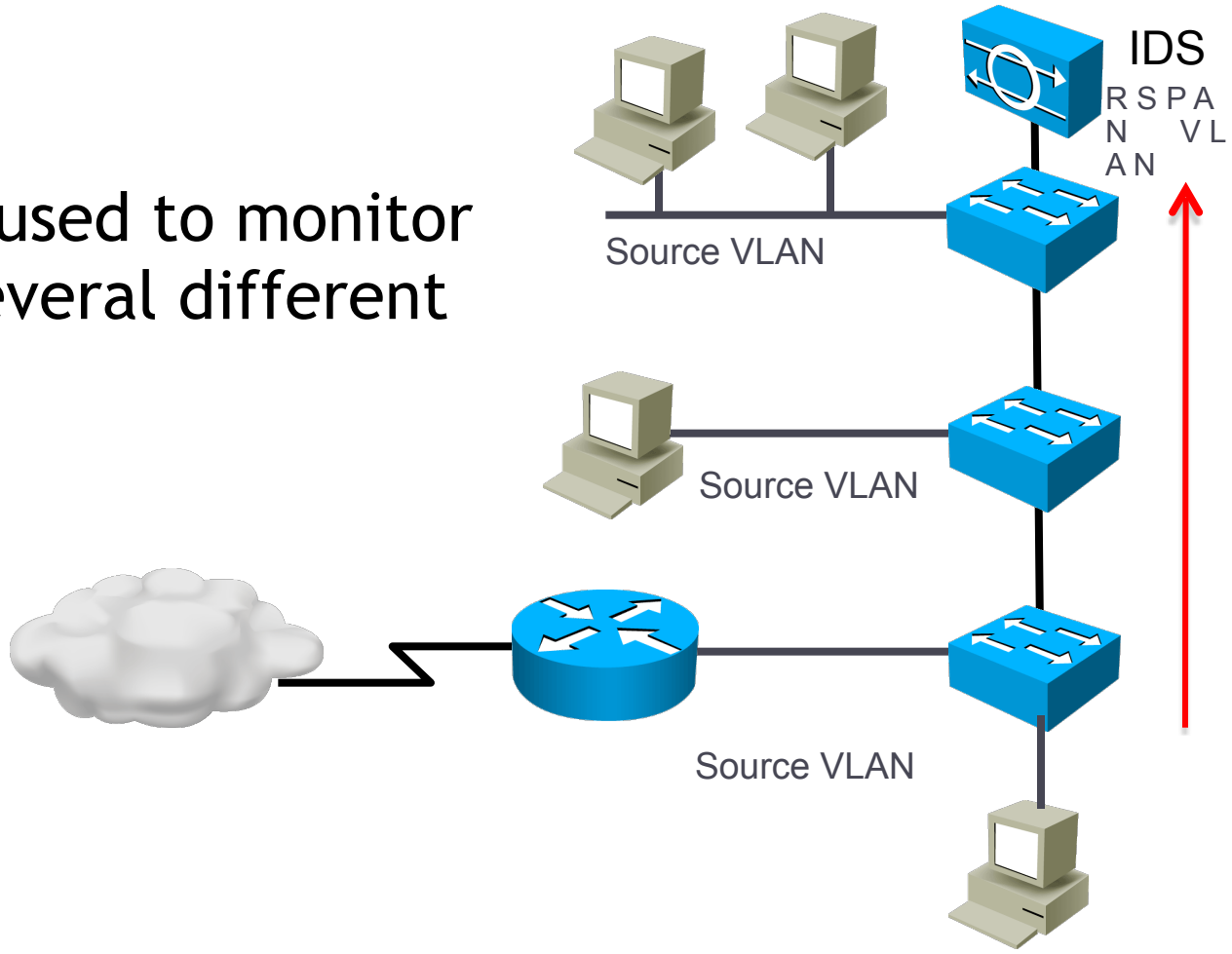
Monitoring with RSPAN

- RSPAN = Remote SPAN
- SPAN mirrors traffic between ports on the same switch
- RSPAN mirrors traffic to a port on a different switch

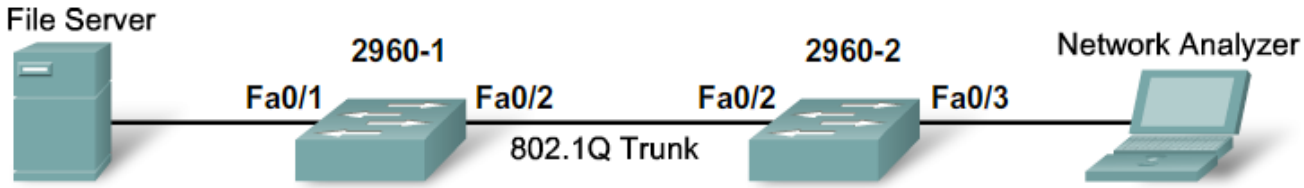
- This way, traffic from multiple switches can be mirrored to a single destination
  - Multiple traffic flows can be monitored at the same time
  - Using the same IDS

RSPAN deployment

- RSPAN can be used to monitor traffic from several different VLANs



Configuring RSPAN



- Create the RSPAN VLAN on both switches:

```
2960-1(config)# vlan 100
2960-1(config-vlan)# remote-span
2960-1(config-vlan)# exit
```

- Configure RSPAN source ports and VLANs:

```
2960-1(config)# monitor session 1 source interface FastEthernet 0/1
2960-1(config)# monitor session 1 destination remote vlan 100
  reflector-port FastEthernet 0/2
2960-1(config)# interface FastEthernet 0/2
2960-1(config-if)# switchport mode trunk
```

- Configure RSPAN traffic to be forwarded:

```
2960-2(config)# monitor session 2 source remote vlan 100
2960-2(config)# monitor session 2 destination interface FastEthernet
0/3
2960-2(config)# interface FastEthernet 0/2
2960-2(config-if)# switchport mode trunk
```

"Security depends not so much upon how much you have, as upon how much you can do without.."

Joseph Wood Crutch