

# Network Security Architecture

CS461/ECE422

Computer Security I

Fall 2008

# Reading Material

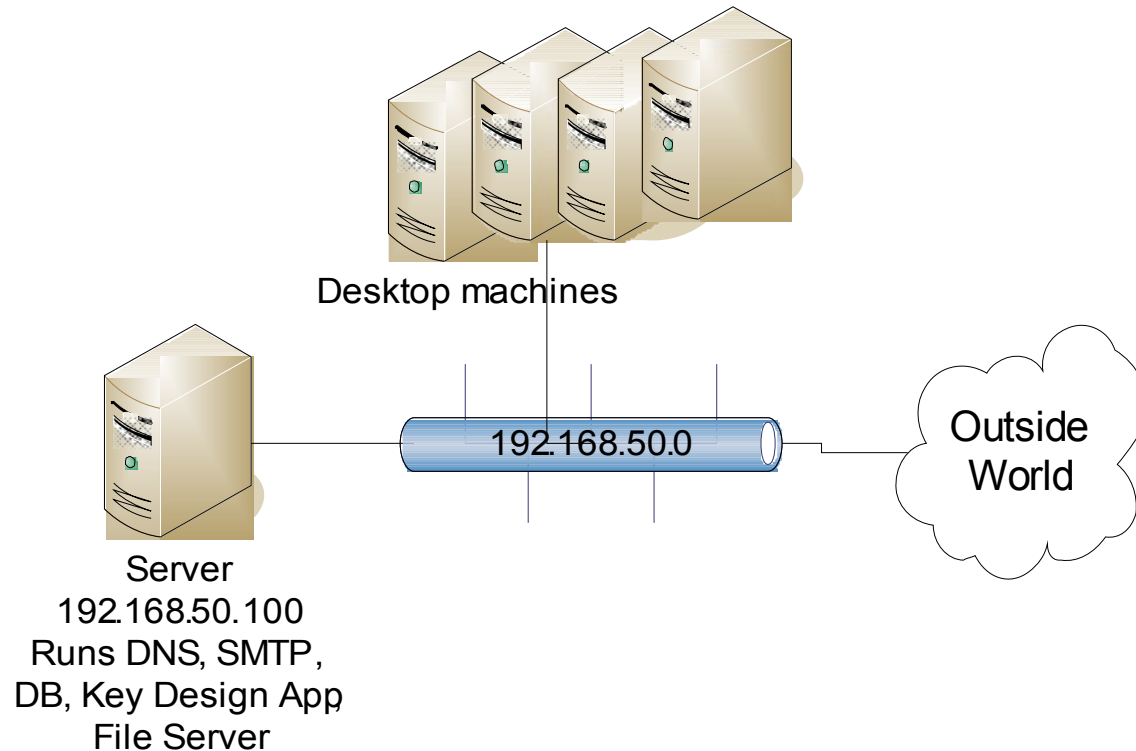
- Computer Security chapter 26.
- “Firewalls and Internet Security: Repelling the Wily Hacker”, Cheswick, Bellovin, and Rubin.
  - New second edition
- “Firewall and Internet Security, the Second Hundred (Internet) Years”  
[http://www.cisco.com/warp/public/759/ipj\\_2-2/ipj\\_](http://www.cisco.com/warp/public/759/ipj_2-2/ipj_)
  - A firewall overview article from 1999

# Overview

- Network Security Architecture
  - Segmentation
  - Wireless
  - Security Domains
  - VPN
- Firewall Technology
  - Address Translation
  - Denial of Service attacks
- Intrusion Detection
- Both firewalls and IDS are introductions.
  - Both are covered in more detail in the Security Lab class.
  - IDS is covered in more detail in 463 – Computer Security.

# Segment

- Separate Functionality
  - Limit infection vectors



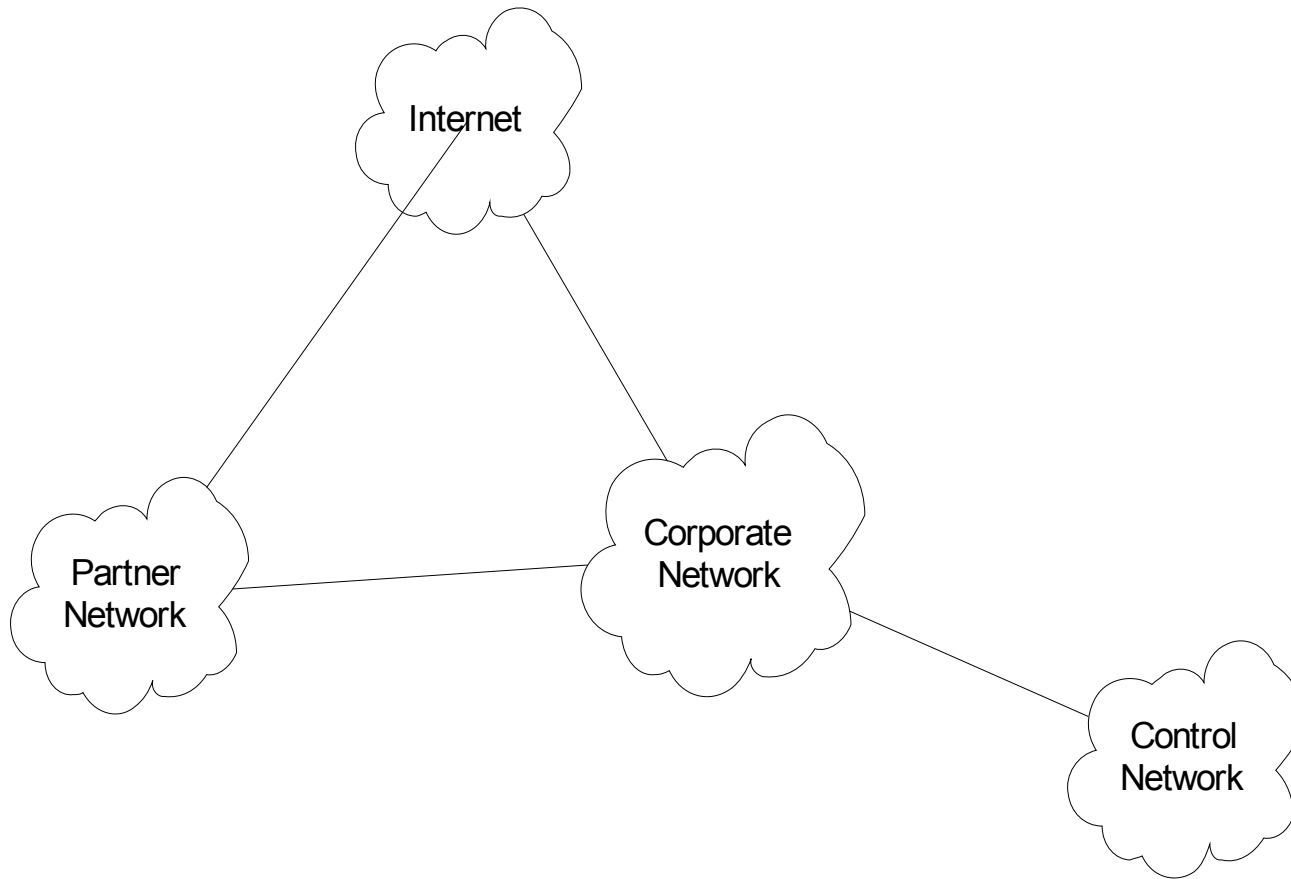
# 802.11 or Wi-Fi

- IEEE standard for wireless communication
  - Operates at the physical/data link layer
  - Operates at the 2.4 or 5 GHz radio bands
- Wireless Access Point is the radio base station
  - The access point acts as a gateway to a wired network e.g., ethernet
  - Can advertise Service Set Identifier (SSID) or not
    - Doesn't really matter, watcher will learn active SSIDs
- Laptop with wireless card uses 802.11 to communicate with the Access Point

# Security Mechanisms

- MAC restrictions at the access point
  - Protects servers from unexpected clients
  - Unacceptable in a dynamic environment
  - No identity integrity. You can reprogram your card to pose as an “accepted” MAC.
- IPSec
  - To access point or some IPSec gateway beyond
  - Protects clients from wireless sniffers
  - Used by UIUC wireless networks
- 802.11i
  - Authentication and integrity integral to the 802.11 framework
  - WEP, WPA, WPA2

# Security Domains



# Perimeter Defense

- Is it adequate?
  - Locating and securing all perimeter points is quite difficult
    - Less effective for large border
  - Inspecting/ensuring that remote connections are adequately protected is difficult
  - Insiders attack is often the most damaging



# Virtual Private Networks

- A private network that is configured within a public network
- A VPN “appears” to be dedicated network to customer
- The customer is actually “sharing” trunks and other physical infrastructure with other customers
- Security?
  - Depends on implementing protocol

# Multiple VPN Technologies

## SSL

- Confidentiality? Yes
- Data integrity? Yes
- User authentication? Yes
- Network access control? No
- In addition, limited traffic

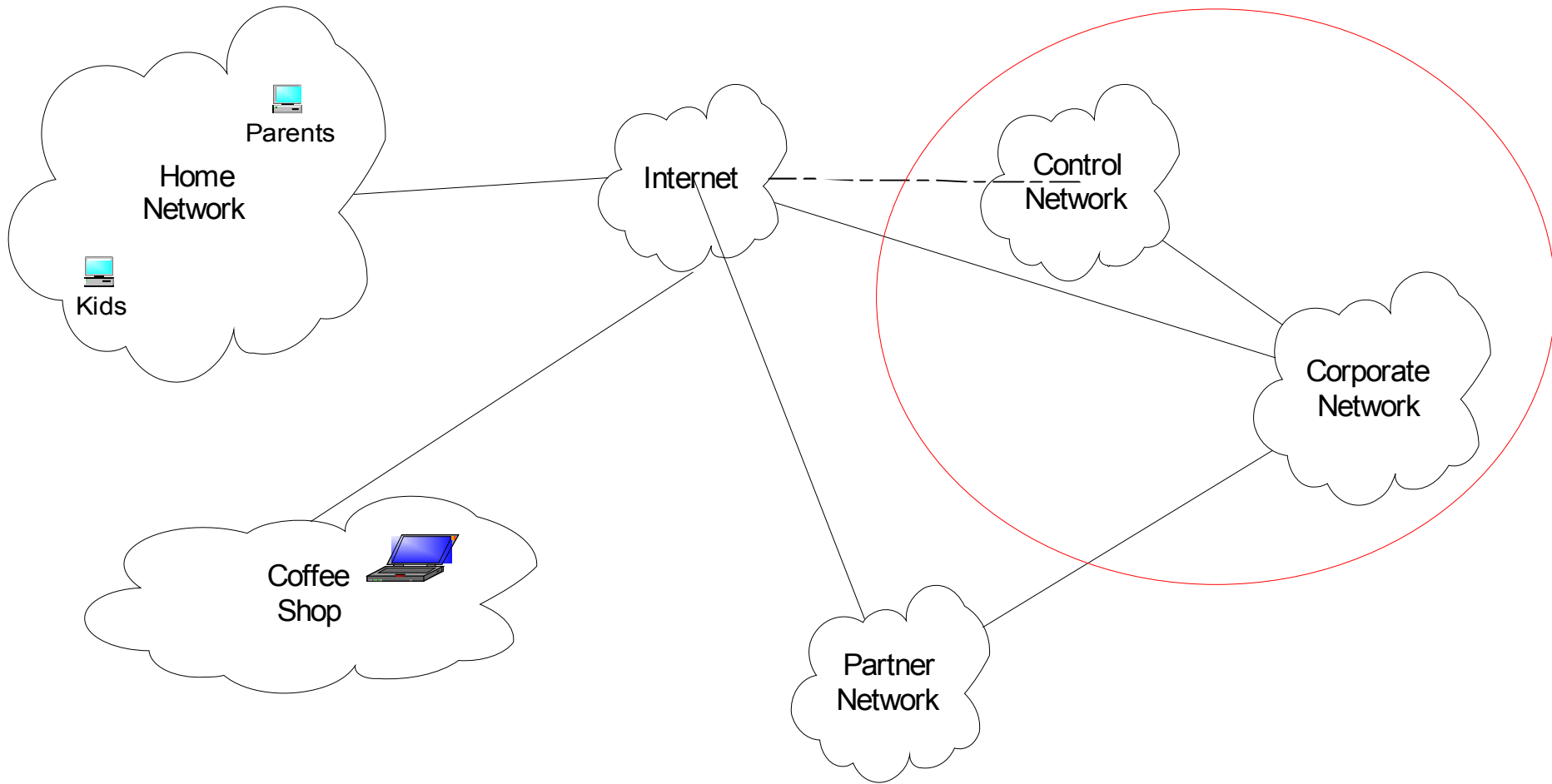
## IPSec

- Confidentiality? Yes
- Data Integrity? Yes
- User Authentication? Yes
- Network access control? Yes
- Client configuration required.

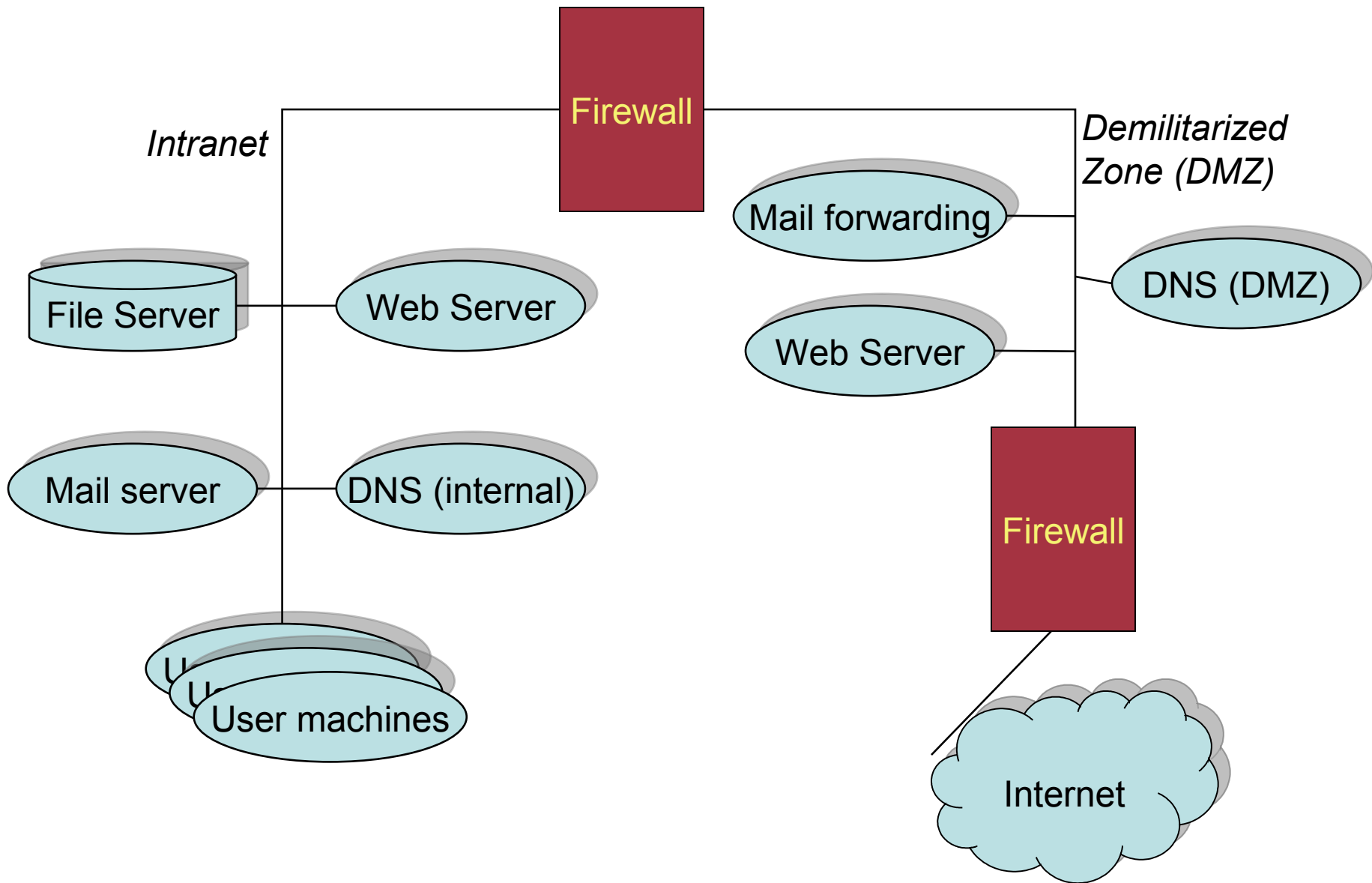
## VLAN – Layer 2 tunnelling technology

- Confidentiality? No
- Data Integrity? No
- User authentication? Yes
- Network access control? Yes
- Not viable over non-VLAN internetworks

# Security Domains with VPNs

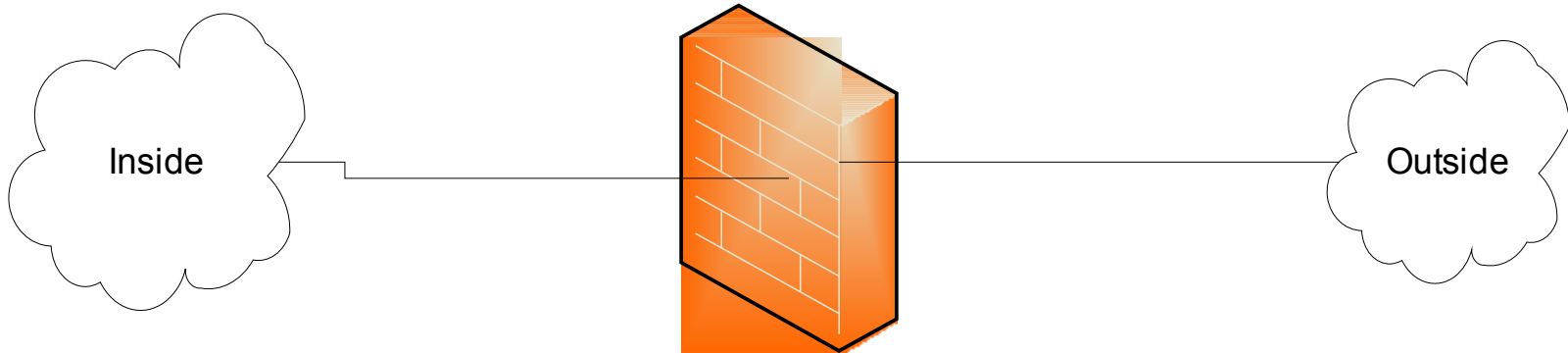


# “Typical” corporate network



# Firewall Goal

- Insert *after the fact* security by wrapping or interposing a filter on network traffic



# Application Proxy Firewall

- Firewall software runs in application space on the firewall
- The traffic source must be aware of the proxy and add an additional header
- Leverage basic network stack functionality to sanitize application level traffic
  - Block java or active X
  - Filter out “bad” URLs
  - Ensure well formed protocols or block suspect aspects of protocol

# Packet Filter Firewall

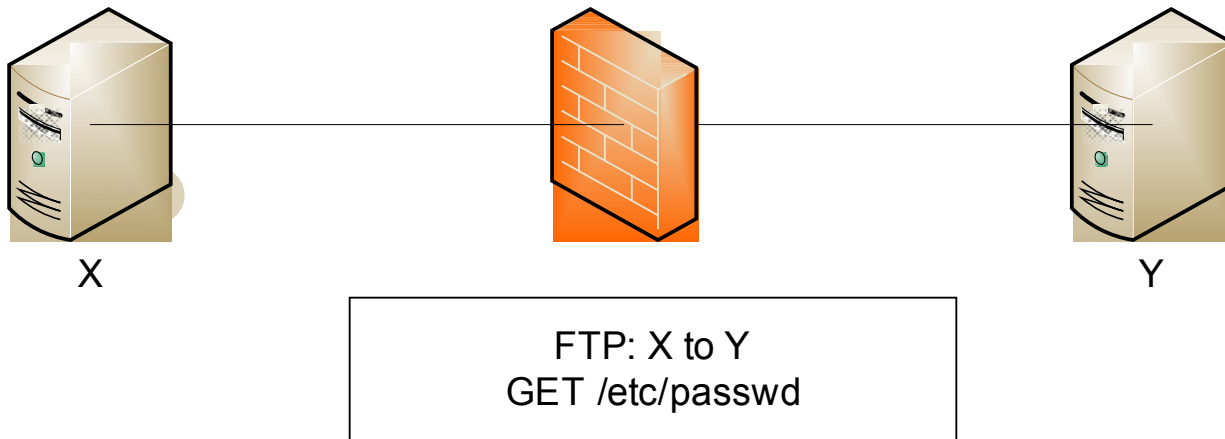
- Operates at Layer 3 in router or HW firewall
- Has access to the Layer 3 header and Layer 4 header
- Can block traffic based on source and destination address, ports, and protocol
- Does not reconstruct Layer 4 payload, so cannot do reliable analysis of layer 4 or higher content

# Stateful Packet Filters

- Evolved as packet filters aimed for proxy functionality
- In addition to Layer 3 reassembly, it can reconstruct layer 4 traffic
- Some application layer analysis exists, e.g., for HTTP, FTP, H.323
  - Called context-based access control (CBAC) on IOS
  - Configured by fixup command on PIX
- Some of this analysis is necessary to enable address translation and dynamic access for negotiated data channels
- Reconstruction and analysis can be expensive.
  - Must be configured on specified traffic streams
  - At a minimum the user must tell the Firewall what kind of traffic to expect on a port
  - Degree of reconstruction varies per platform, e.g. IOS does not do IP reassembly



# Traffic reconstruction



GET command causes  
firewall to dynamically  
open data channel initiate  
from Y to X

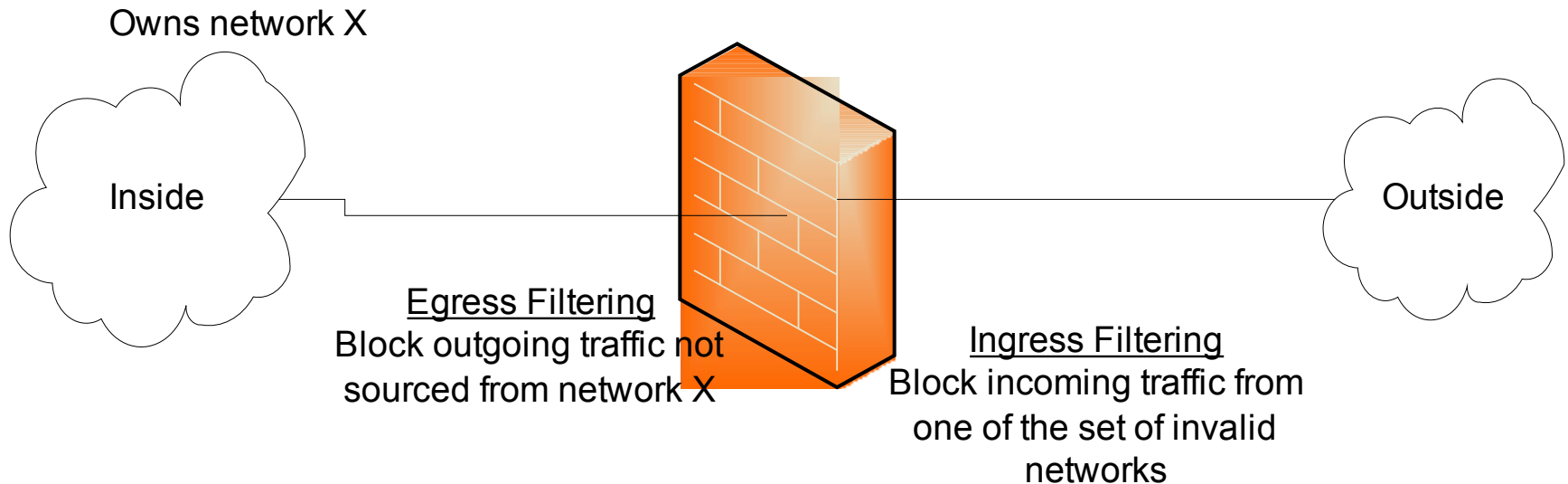
Might have filter for files to  
block, like /etc/passwd

# Access Control Lists (ACLs)

- Used to define traffic streams
  - Bind ACL's to interface and action
- Access Control Entry (ACE) contains
  - Source address
  - Destination Address
  - Protocol, e.g., IP, TCP, UDP, ICMP, GRE
  - Source Port
  - Destination Port
- ACL runtime lookup
  - Linear
  - N-dimensional tree lookup (PIX Turbo ACL)
  - Object Groups
  - HW classification assists

# Ingress and Egress Filtering

- Ingress filtering
  - Filter out packets from invalid addresses before entering your network
- Egress filtering
  - Filter out packets from invalid addresses before leaving your network



# Denial of Service

- **Example attacks**
  - Smurf Attack
  - TCP SYN Attack
  - Teardrop
- **DoS general exploits resource limitations**
  - Denial by Consumption
  - Denial by Disruption
  - Denial by Reservation

# TCP SYN Attack

- Exploits the three-way handshake

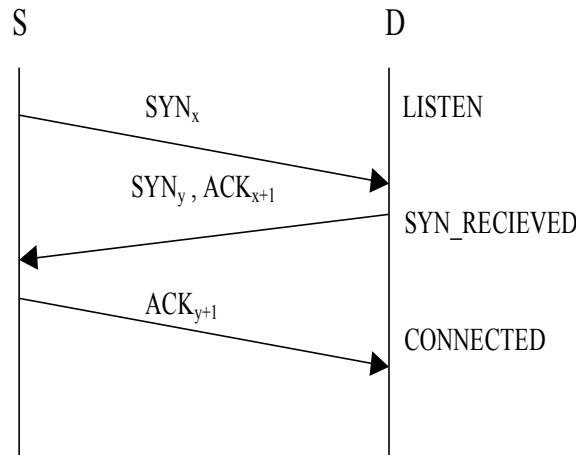


Figure 1. Three-way Handshake

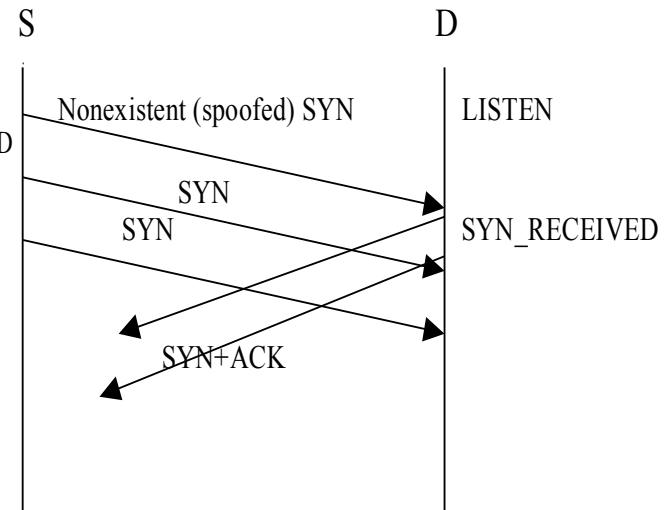


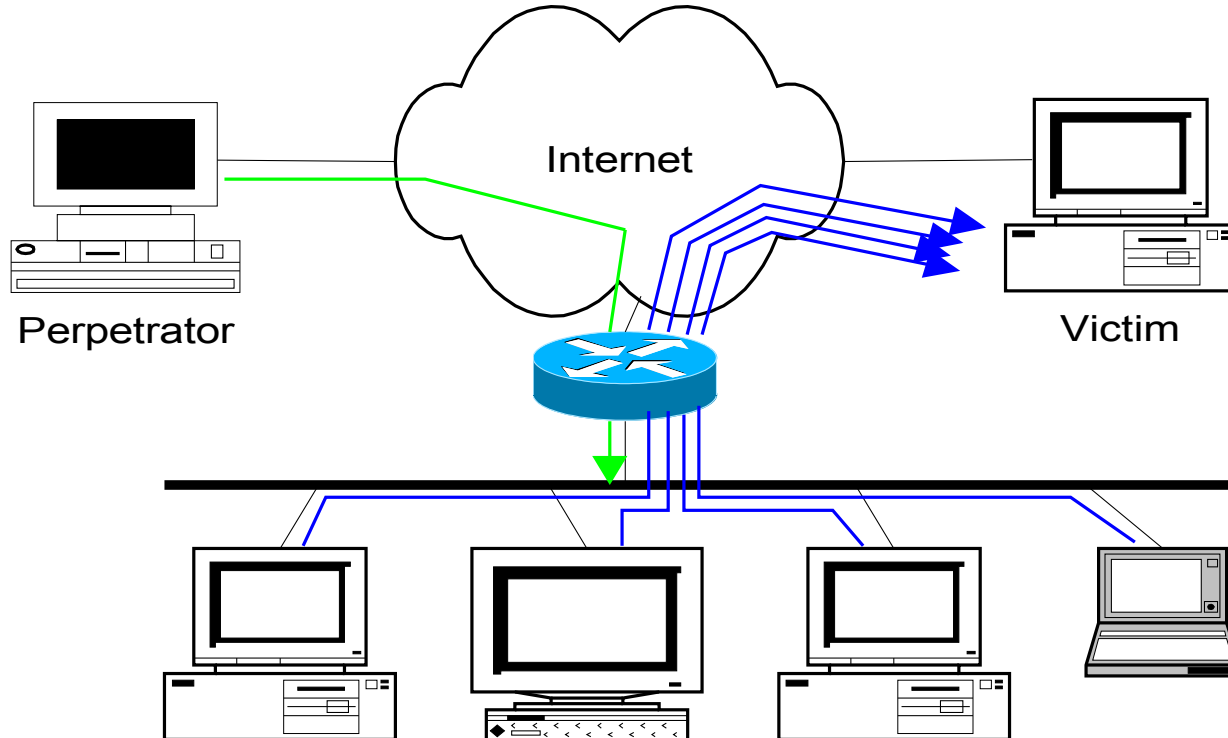
Figure 2. SYN Flooding Attack

# TCP SYN Attack Solutions

- Intermediate Firewall/Router
  - Limit number of half open connections
- Ingress and egress filtering to reduce spoofed addresses
  - Does not help against DDoS bot networks
- Reactively block attacking addresses
  - Generally expensive to acquire technology to do fast enough
- Fix Protocol - IPv6

# “Smurf”

- ICMP echo (spoofed source address of victim)
- Sent to IP broadcast address
- ICMP echo reply



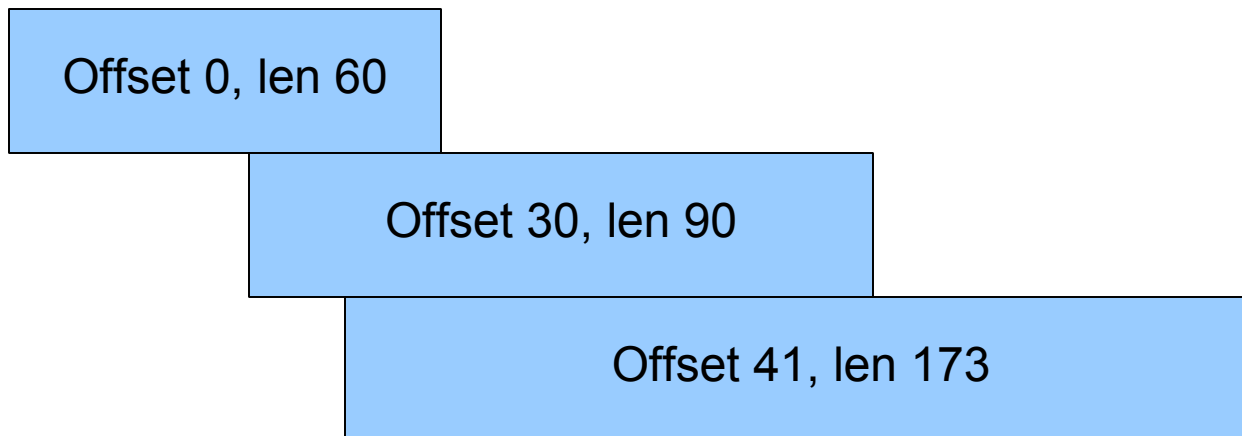
# Smurf Issues

- Amplification attack
  - Small effort on attacker results in big impact on victim
- Victim fails unexpectedly under high load
  - May just stop responding
  - May stop performing normal security checks
- Exploiting protocol failure
  - Fixed in IPv6
- Old attack
  - Blocked by most firewalls



# Teardrop Attack

- Send series of fragments that don't fit together
  - Poor stack implementations would crash
  - Early windows stacks



# Address Translation

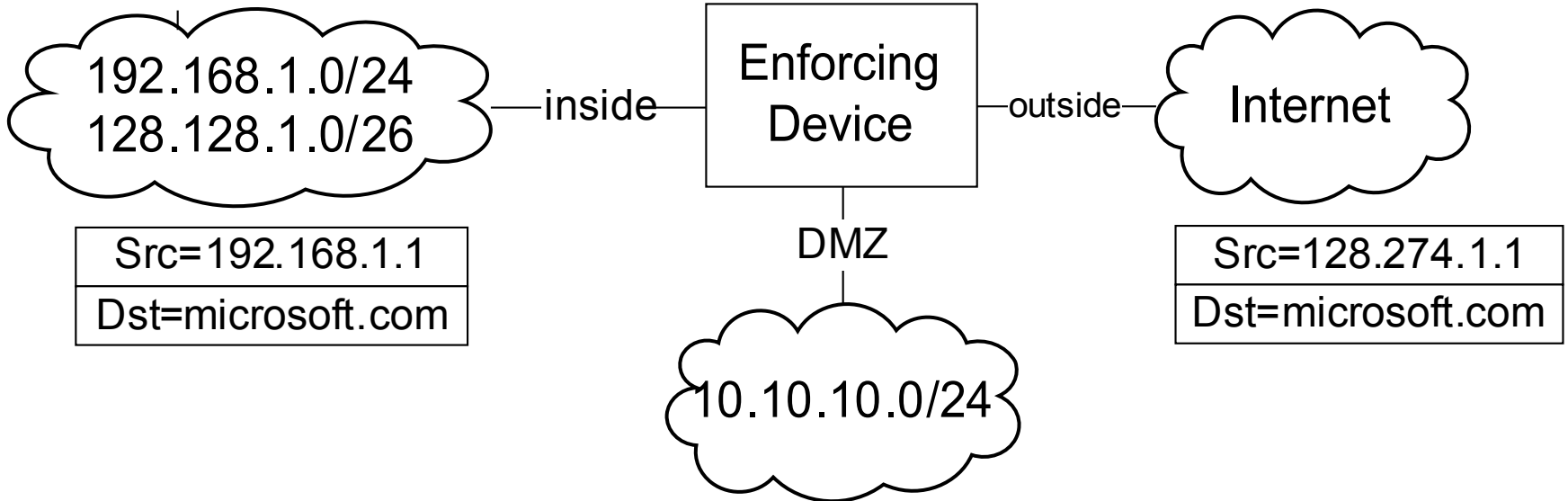
- Traditional NAT RFC 3022 Reference RFC
- Map real address to alias address
  - Real address associated with physical device, generally an unroutable address
  - Alias address generally a routeable associated with the translation device
- Originally motivated by limited access to publicly routable IP addresses
  - Folks didn't want to pay for addresses and/or hassle with getting official addresses
- Later folks said this also added security
  - By hiding structure of internal network
  - Obscuring access to internal machines
- Adds complexity to firewall technology
  - Must dig around in data stream to rewrite references to IP addresses and ports
  - Limits how quickly new protocols can be firewalled

# Address Hiding (NAPT)

- Many to few dynamic mapping
  - Packets from a large pool of private addresses are mapped to a small pool of public addresses at runtime
- Port remapping makes this sharing more scalable
  - Two real addresses can be rewritten to the same alias address
  - Rewrite the source port to differentiate the streams
- Traffic must be initiated from the real side

# NAT example

Hide from inside to outside  
192.168.1.0/24 behind 128.274.1.1  
Static map from inside to DMZ  
192.168.1.5 to 128.274.1.5

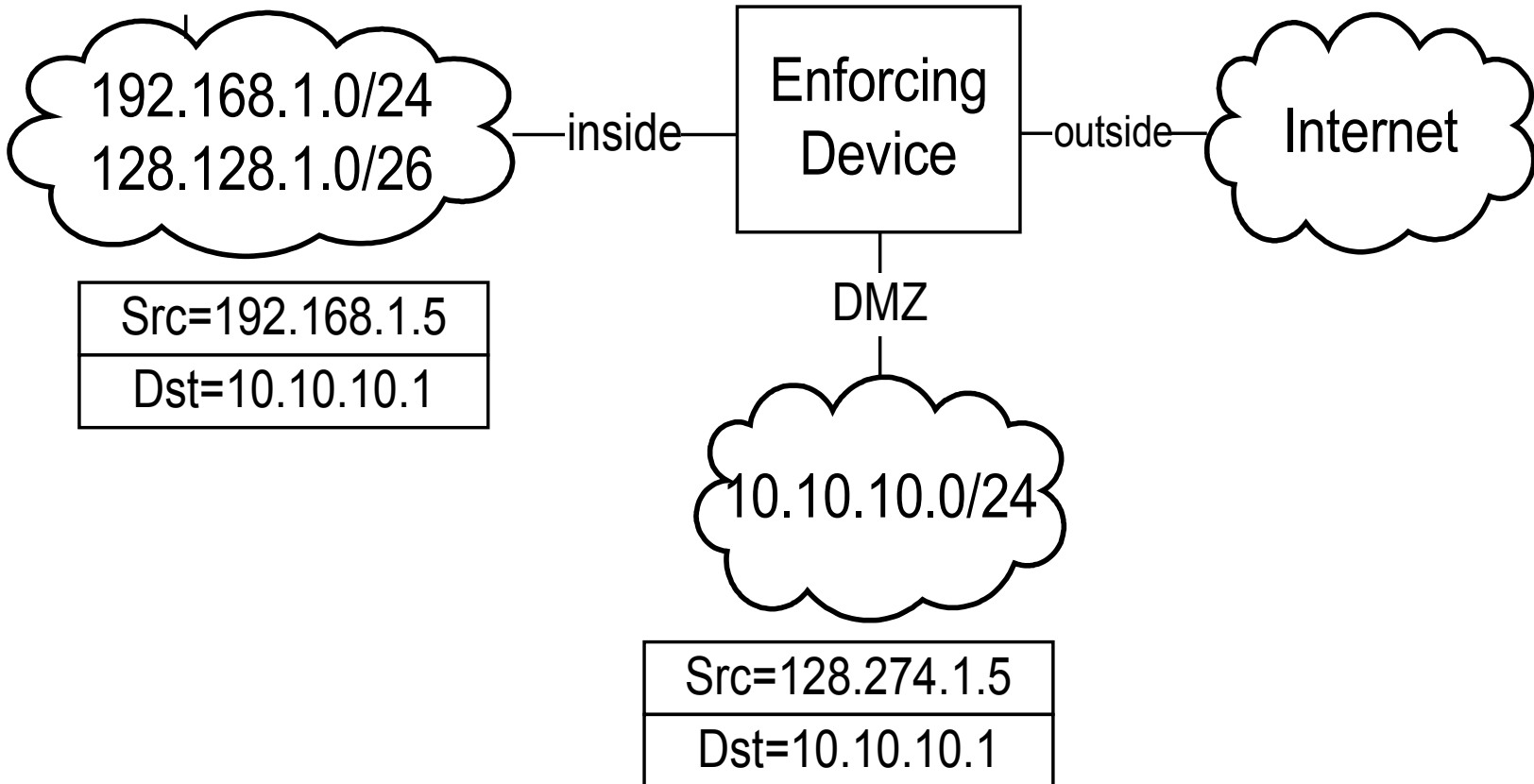


# Static Mapping

- One-to-one fixed mapping
  - One real address is mapped to one alias address at configuration time
  - Traffic can be initiated from either side
- Used to statically map out small set of servers from a network that is otherwise hidden
- Static port remapping is also available

# NAT example

Hide from inside to outside  
192.168.1.0/24 behind 128.274.1.1  
Static map from inside to DMZ  
192.168.1.5 to 128.274.1.5



# FW Runtime Characteristics

- Firewalls track streams of traffic
  - TCP streams are obvious
  - Creates pseudo UDP streams for UCP packets between the same addresses and ports that arrive near enough to each other
- Processing first packet in stream is more expensive
  - Must evaluate ACLs and calculate address translations
  - Subsequent packets get session data from a table

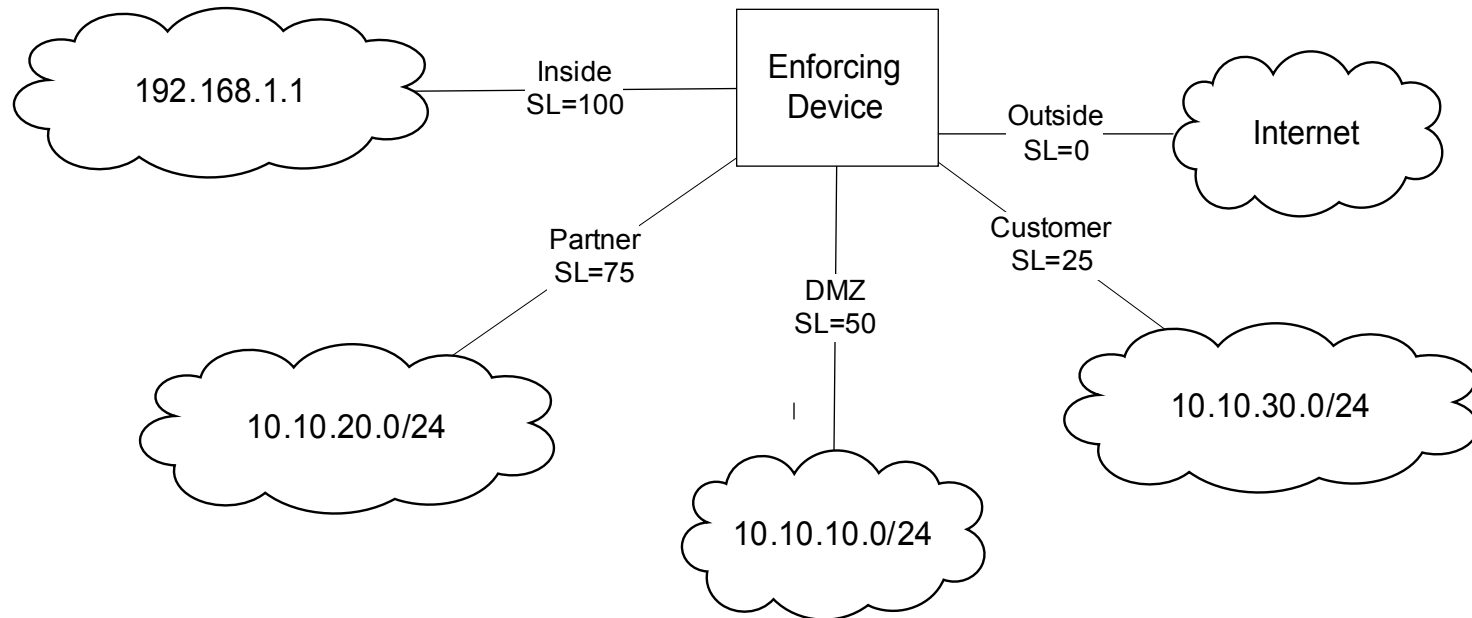
# Multi-legged Firewalls

- Historically firewalls have protected inside from outside
  - Still true for the most part with personal and home firewalls
  - No longer sufficient for larger enterprises
- PIX security level solution
  - Outbound = traffic from low security level interface to high security level interface
  - Inbound = traffic from high security level interface to low security level interface
  - Different requirements for inbound and outbound traffic
- IOS divides interfaces into inside and outside groups
  - Address translation can only be defined between inside and outside groups
- Routing conflicts with address translation
  - Address translation specifies both interfaces
  - Must be evaluated before the routing, better be consistent



# Four Legged FW

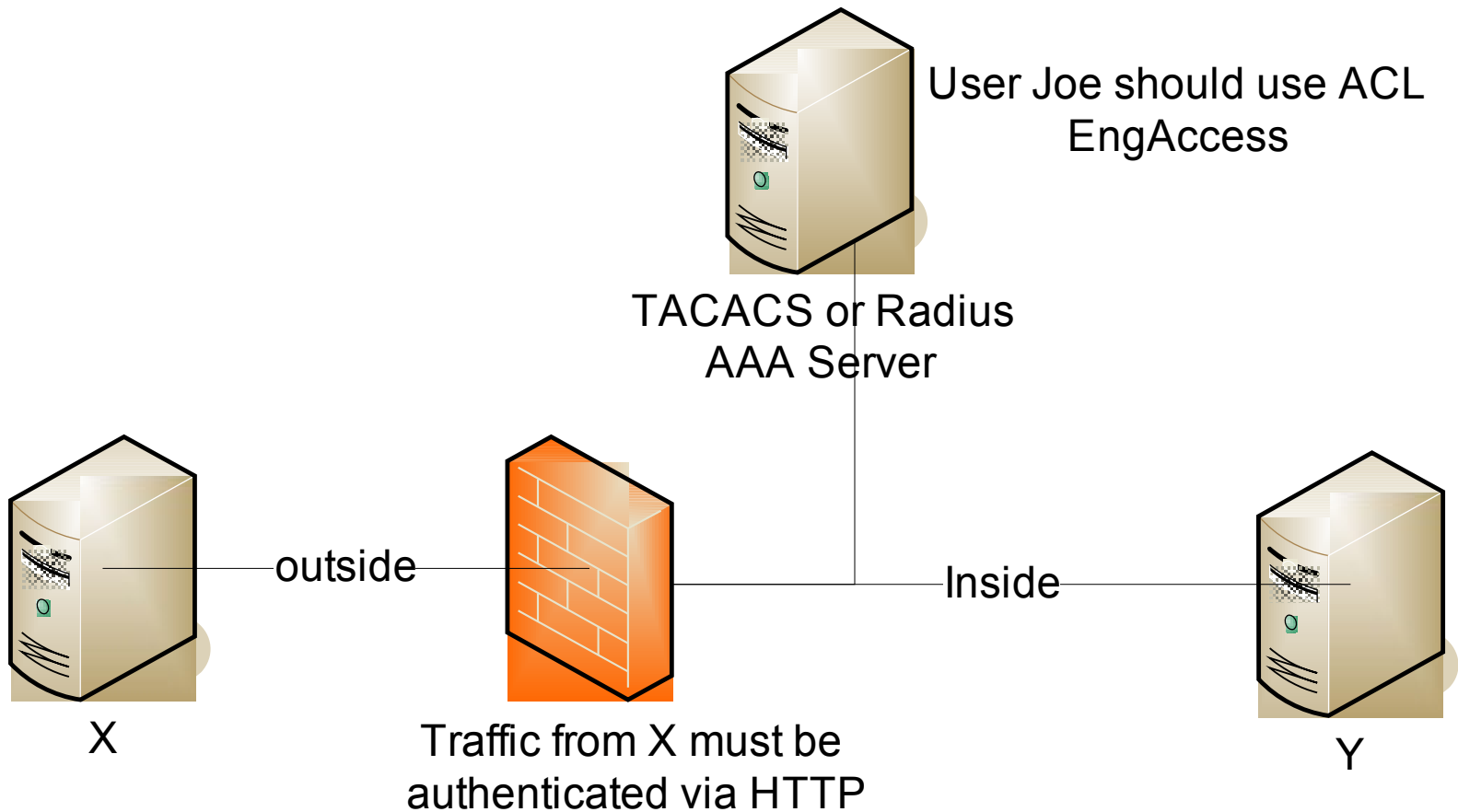
- Static translation from DMZ to Customer
  - 10.10.10.10.1 to 128.1.1.1
- But routing table wants to route 128.1.1.1 from DMZ to outside interface
  - Static translation interface selection will win



# Identity Aware Firewall

- Use TACACS+ or Radius to authenticate, authorize, account for user with respect to FW
  - For administration of FW
  - For traffic passing through FW
    - PIX cut-through proxy allows authentication on one protocol to cover other protocols from same source
- Authorization for executing commands on the device
- Download or enable ACL's
- XAuth to integrate AAA with VPN authentication and other security mechanisms

# AAA Scenario



# Is the Firewall Dead?

- End-to-end security (encryption) renders firewalls useless
  - Tunnels hide information that firewalls would filter or sanitize
  - With IPSec decrypting and re-encrypting is viable
- Blurring security domain perimeters
  - Who are you protecting from whom
  - Dynamic entities due to DHCP and laptops
  - More dynamic business arrangements, short term partnerships, outsourcing
- Total Cost of Ownership (TCO) is too high
  - Managing firewalls for a large network is expensive
- Perhaps personal or distributed firewalls are the answer?
  - “Implementing a Distributed Firewall”  
<http://www1.cs.columbia.edu/~angelos/Papers/df.pdf>

# Intrusion Detection

- Holy Grail: Detect and correct “bad” system behavior
- Detection can be viewed in two parts
  - Anomaly detection: Use statistical techniques to determine unusual behavior
  - Mis-use detection: Use signatures to determine occurrence of known attacks
- Detection can be performed on host data (HIDS), network data (NIDS), or a hybrid of both

# Intrusion Handling

- Preparation for attack
- Identification of the attack
- Containment of the attack
  - Gather information about the attacker
  - Honeypots
- Eradication
  - Broadly quarantine the system so it can do no more harm
  - BGP blackholing
  - Tighten firewalls
  - Cleanse the corrupted system
- Followup phase
  - Gather evidence and take action against the attacker

# Honey Pots

- Reconnaissance for the good guys
- Deploy a fake system
  - Observe it being attacked
- Resource management
  - Cannot be completely passive
    - Must provide enough information to keep attacker interested
  - Must ensure that bait does not run away
- Scale
  - Host, network, dark address space

# IDS Architecture

- Agents run at the lowest level gathering data. Perform some basic processing.
- Agents send data to a Director that performs more significant processing of the data. Potentially there is a hierarchy of agents and directors
  - Director has information from multiple sources and can perform a time-based correlation to derive more significant actions
- Directors invoke Notifiers to perform some action in response to a detected attack
  - Popup a window on a screen
  - Send an email or a page
  - Send a new syslog message elsewhere.
  - Adjust a firewall or some other policy to block future action from the attacker



# Data Sources

- Direct data
  - Network packets
  - System calls
- Indirect data
  - Syslog data, Windows event logs
  - Events from other intrusion detection systems
  - Netflow information generated by routers about network traffic

# Mis-use/Signature Detection

- Fixed signatures are used in most deployed IDS products
  - E.g., Cisco, ISS, Snort
- Like virus scanners, part of the value of the product is the team of people producing new signatures for newly observed malevolent behavior
- The static signature mechanism has obvious problems in that a dedicated attacker can adjust his behaviour to avoid matching the signature.
- The volume of signatures can result in many false positives
  - Must tune the IDS to match the characteristics of your network
  - E.g., what might be unusual in a network of Unix systems might be normal in a network of Windows Systems (or visa versa)
  - Can result in IDS tuned too low to miss real events
  - Can hide real attacks in the mass of false positives

# Example Signature

- Signature for port sweep
  - A set of TCP packets attempting to connect to a sequence of ports on the same device in a fixed amount of time
- In some environments, the admin might run nmap periodically to get an inventory of what is on the network
  - You would not want to activate this signature in that case

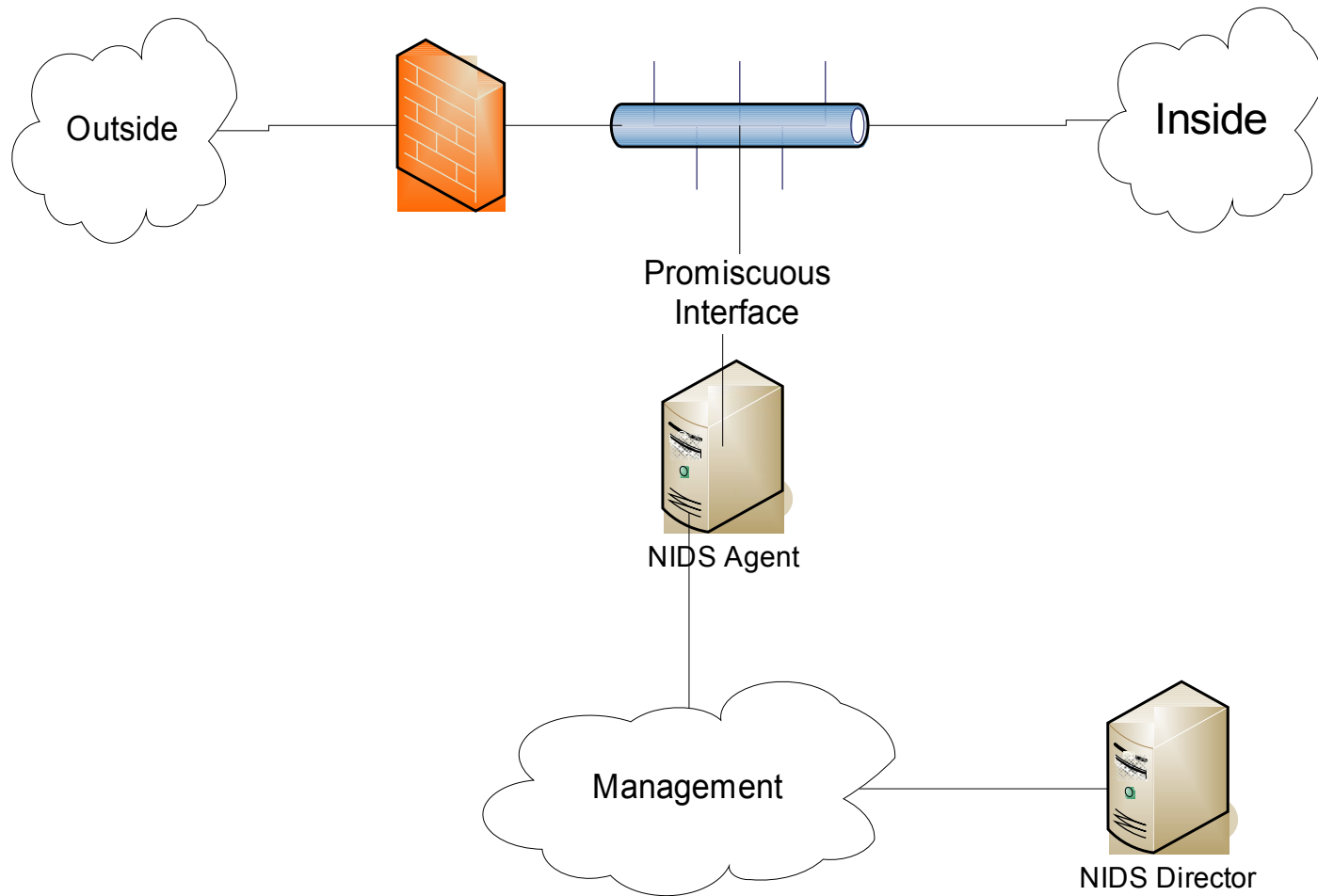
# Anomaly/statistical detection

- Seems like using statistics will result in a more adaptable and self-tuning system
  - Statistics, neural networks, data mining, etc.
- How do you characterize normal?
  - Create training data from observing “good” runs
    - E.g., Forrest’s program system call analysis
  - Use visualization to rely on your eyes
- How do you adjust to real changes in behaviour?
  - Gradual changes can be easily addressed. Gradually adjust expected changes over time
  - Rapid changes can occur. E.g., different behaviour after work hours or changing to a work on the next project

# Host Based IDS

- Tripwire – Very basic detection of changes to installed binaries
- More recent HIDS. Look at patterns of actions of system calls, file activity, etc. to permit, deny, or query operations
  - Cisco Security Agent
  - Symantec
  - McAfee Enterccept

# Classical NIDS deployment



# NIDS Remediation Options

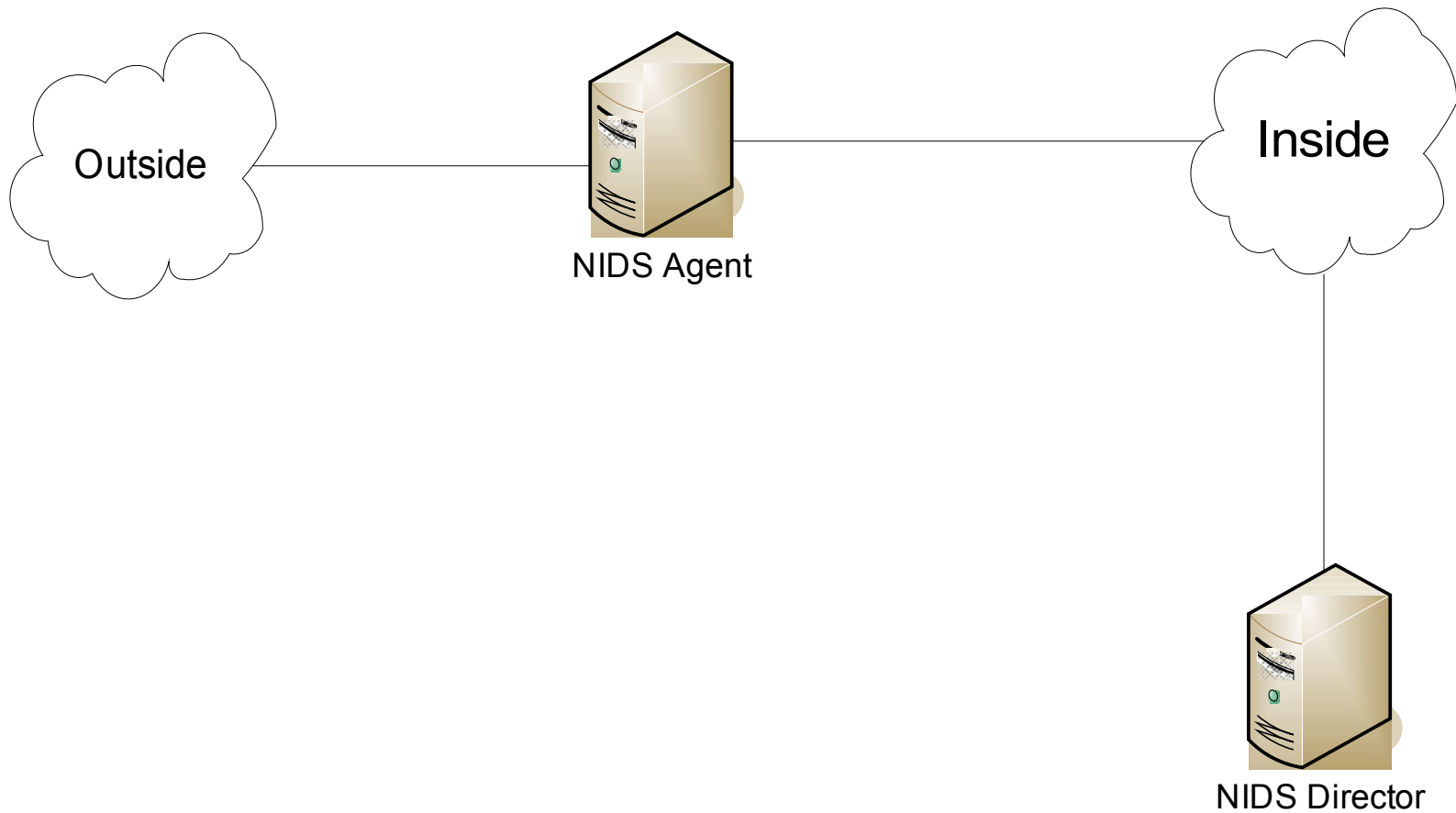
- Log the event
- Drop the connection
- Reset the connection
- Change the configuration of a nearby router or firewall to block future connections

# Intrusion Protection Systems (IPS)

- Another name for inline NIDS
- Latest buzz among the current NIDS vendors
- Requires very fast signature handling
  - Slow signature handling will not only miss attacks but it will also cause the delay of valid traffic
  - Specialized hardware required for high volume gateways
- When IDS is inline, the intrusion detector can take direct steps to remediate.
- If you move IDS into the network processing path, how is this different from really clever firewalling?



# Network IPS scenario



# Summary

- Identification of security domains basis of perimeter security control
  - Firewall is the main enforcer
- Intrusion detection introduces deeper analysis and potential for more dynamic enforcement
- Intermediate enforcement can handle some Denial of Service attacks