# CS 194-1 (CS 161) Computer Security

## Lecture 12

## Web Security and Intrusion Detection

October 11, 2006
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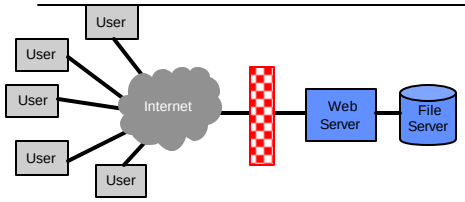
http://cs161.org/

## Review: Firewalls




- Default firewall rule: deny all
- Other firewall rules:
  - allow tcp *:*/out -> <web server IP>:80/in
  - allow tcp *:*/out -> <web server IP>:443/in
  - drop * *:* -> *:*



## Goals for Today

- Web Servers
  - Static and Dynamic Content
- Adding a DMZ to a Firewall
- Secure Topologies
- Intrusion Detection History
- Network-based Host Compromise
- Host-based Network Intrusion Detection
  - Signature-based, Anomaly-based
- Distributed Network Intrusion Detection
  - Honeypots, Tarpits
- An attack against an IDS

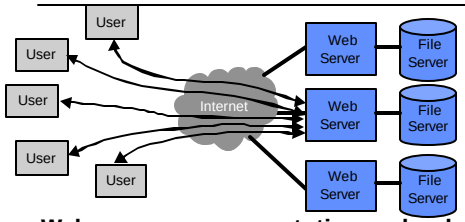


## Polls

- How many people have set up a personal web server?
- How many people have set up a business web server?



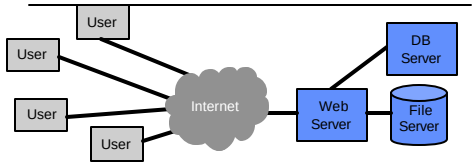
## Web Servers




- Web server serves up static, read-only content from file server
- Scales up by replicating web servers
  - Can use DNS round-robin or load balancer



## Web Servers




- Add a database server for dynamic content
  - DB used to store per-user info or site content
  - Also, used for authentication, read/write actions, e-commerce, …
- Software connector to DB server
  - Object/Java DataBase Connectivity

## Web Servers

- Static content model:
  - Web server uses file server for static content, templates, …
- Dynamic content model:
  - Web server uses database server to retrieve/store dynamic content
- Can have mixtures
  - Ex: Storing dynamic content in FS
  - Ex: Storing static content in DB
- What are the security issues?



## Some Web Server Threats and Attacks

- Replace static content ("defacement")
  - Exploit vulnerability to access Web or File servers
- (Distributed) Denial of Service attack
  - Request large image or emulate complex transaction
- Unauthorized database access
  - Exploit vulnerability (e.g., SQL injection) to read/write database
- Attack server OS or other services
  - Exploit vulnerability to disable server



## Replace Static Content ("Defacement")

- Cracker exploits a vulnerability to gain access to Web or File Servers
- Examples:
  - Flaws in CGI programs
  - Flaws in URL processing
  - Buffer overflows
- Replaces web pages with their own
- May also access protected content



## (Distributed) Denial of Service Attack

- Cracker performs resource exhaustion attack
  - Overwhelm network, CPU, disk bandwidth, …
- Examples
  - Request large image or file
  - POST large image or file (requires many zombies)
  - Emulate complex transaction
- Typically use large number of zombies (1,000's to 100,000's)



## Unauthorized Database Access

- Cracker exploits vulnerability in Web server to DB server connection to read/write database
- Example:
  - Use URL or POST attack to inject SQL code
  - Gain access to Web server, then connect to DB
- Attacks can compromise DB integrity



## Attack Server OS or Other Services

- Cracker exploits vulnerability to gain access to server
  - Many OS and service vulnerabilities…
- Can be a stepping stone to attacking web service or accessing database

## Stopping *Some* Attacks

- Replace static content ("defacement")
  - Harden server (latest patch levels, minimum services)
  - Limit data on file server
- (Distributed) Denial of Service attack
  - Add load balancer, DNS round-robin, replicated clusters, …
- Unauthorized database access
  - Harden server (latest patch levels, min. svcs)
  - Sanity check all arguments
- Attack server OS or other services
  - Harden servers (latest patch levels, min. svcs)

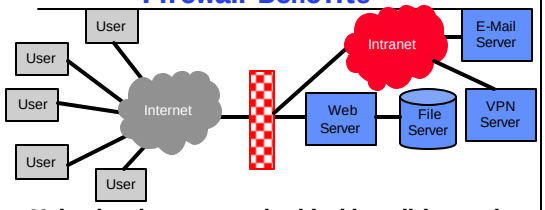


## Problems

- Hard to keep servers up-to-date with patches
  - Zero-day exploits
  - Delays in releasing, retrieving, testing, installing patches
- DDoS attacks still impose load on servers
- Add layered defense
  - Place firewall between Internet and Web server



## Firewall Benefits




- Helps harden servers by blocking all but web traffic
- DDoS attacks: add stateful rules or block zombie IP subnets
  - Doesn't work for all content attacks
- Intranet and e-mail server access?

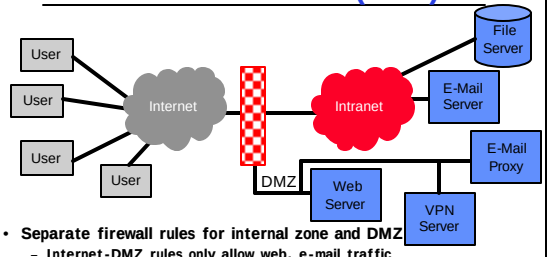


## Firewall Issues

- We can add more rules
  - For access to Intranet, E-mail server, and other "public" servers
- But, what happens if one server or Intranet machine is compromised?
- This is the classic firewall problem:
  - All our machines are now vulnerable!
- Real issue:
  - We need to both protect public servers and Intranet
- Solution: Place public servers in a DMZ



## DeMilitarized Zone (DMZ)

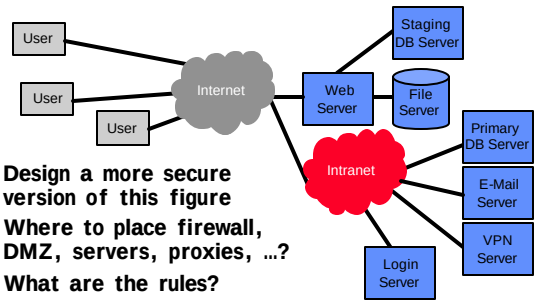



- Separate firewall rules for internal zone and DMZ
  - Internet-DMZ rules only allow web, e-mail traffic
  - DMZ-Intranet rules only allow file, e-mail, remote login *from DMZ*
  - No Internet-Intranet access
- Where to place e-mail server?
  - Add proxy to isolate e-mail access/storage from e-mail forwarding



## Administrivia

## Designing a More "Secure" Topology



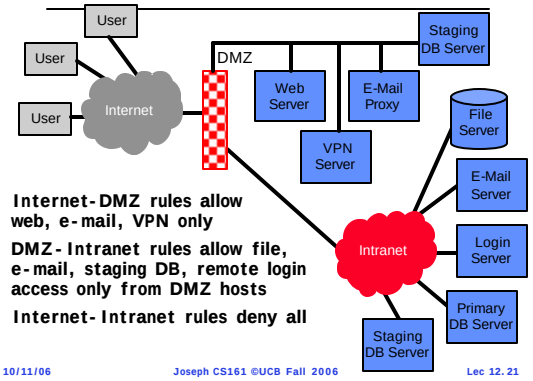

- Design a more secure version of this figure
- Where to place firewall, DMZ, servers, proxies, …?
- What are the rules?



## Design



## One Solution




- Internet-DMZ rules allow web, e-mail, VPN only
- DMZ-Intranet rules allow file, e-mail, staging DB, remote login access only from DMZ hosts
- Internet-Intranet rules deny all



## Web Security Summary

- Public servers are vulnerable to attack
  - OS and services
- Eliminate unnecessary services
- Apply all patches
- Use a DMZ to provide layered defense
  - Place server/proxy in DMZ
  - Place database/file/"real" servers in Intranet
  - Deny all default for Internet-Intranet traffic



## Intrusion Detection History

- Detecting attempts to penetrate our systems
  - Used for post-mortem activities
  - Related problem of extrusion (info leaking out)
- In pre-network days (centralized mainframes)…
  - Primary concern is abuse and insider information access/theft
  - Reliance on logging and audit trails
- But, highly labor intensive to analyze logs
  - What is abnormal activity?
  - Ex: IRS employees snooping records
  - Ex: Moonlighting police officers



## Network-based Host Compromises

- How do remote intruders gain access?
- They attempt network-based attacks that exploit OS & app bugs
  - Ex: Denial of service, spyware install, zombie, …

## Host-based Net Intrusion Detection

- At each host, monitor all incoming and outgoing network traffic – for each packet:
  - Analyze 4-tuple and protocol
  - Examine contents
  - …
- Challenge: Separate "signal" from "noise"
  - *Signal* is an attack (intrusion)
  - *Noise* is normal "background" traffic
  - Assumption: can separate signal and noise…



## Some Challenges

- What is normal traffic?
  - Server, desktop, PDA, PDA/phone, …
  - My normal traffic ? your normal traffic
  - Lots of data for servers
- Why do we need sufficient signal and noise separation?
  - To avoid too many false alarms!
- What happens if signals are missed?
  - Possible intrusion!



## Some Common False Positives

- Proximity probes
  - Website load balancers will probe your machine for proximity
  - Connect to website hosted by mirror-image.com, and >10 load balancers in 6 countries probe your machine
- Stale IP caches
  - Using dynamic IP addresses, you may get the "old" address of someone who was running a P2P app
  - Peers continue to try to "re-connect"
- Web posts with dynamic IP addresses
  - Spiders crawl machine currently using IP address



## Lots and Lots of Data!!

- Network trace from Win2K desktop

```
ZoneAlarm Logging Client v3.7.202
Windows 2000 -5.0.2195 -Service Pack 4-SP
type,date,time,source,destination,transport
FWIN,2004/01/15,13:17:38 -8:00 GMT,216.183.33.67:42645,128.32.168.229:6129,TCP (flags:S)
FWOUT,2004/01/15,13:18:00 -8:00 GMT,128.32.168.229:5000,68.26.217.204:5000,UDP
FWIN,2004/01/15,13:42:38 -8:00 GMT,61.178.60.11:0,128.32.168.229:0,ICMP (type:8/subtype:0)
FWIN,2004/01/15,13:42:48 -8:00 GMT,62.177.227.10:0,128.32.168.229:0,ICMP (type:8/subtype:0)
FWIN,2004/01/15,13:48:12 -8:00 GMT,128.32.41.80:1040,128.32.168.229:38293,UDP
FWIN,2004/01/15,13:58:30 -8:00 GMT,24.224.253.230:2446,128.32.168.229:6129,TCP (flags:S)
FWIN,2004/01/15,14:04:40 -8:00 GMT,80.116.4.42:0,128.32.168.229:0,ICMP (type:8/subtype:0)
FWOUT,2004/01/15,14:04:44 -8:00 GMT,128.32.168.229:5000,68.26.217.204:5000,UDP
FWIN,2004/01/15,14:07:36 -8:00 GMT,210.217.129.194:3598,128.32.168.229:1433,TCP (flags:S)
FWIN,2004/01/15,14:15:00 -8:00 GMT,128.32.30.70:0,128.32.168.229:0,ICMP (type:8/subtype:0)
FWIN,2004/01/15,14:23:20 -8:00 GMT,80.56.148.243:0,128.32.168.229:0,ICMP (type:3/subtype:1)
FWIN,2004/01/15,14:41:48 -8:00 GMT,194.23.44.215:0,128.32.168.229:0,ICMP (type:8/subtype:0)
FWIN,2004/01/15,14:43:08 -8:00 GMT,61.64.246.192:0,128.32.168.229:0,ICMP (type:8/subtype:0)
FWOUT,2004/01/15,14:43:16 -8:00 GMT,128.32.168.229:5000,68.26.217.204:5000,UDP
FWIN,2004/01/15,15:02:00 -8:00 GMT,128.32.168.21:0,128.32.168.229:0,ICMP (type:8/subtype:0)
FWIN,2004/01/15,15:06:28 -8:00 GMT,81.185.244.166:0,128.32.168.229:0,ICMP (type:8/subtype: 0)
FWIN,2004/01/15,15:43:46 -8:00 GMT,217.255.55.163:0,128.32.168.229:0,ICMP (type:8/subtype: 0)
FWOUT,2004/01/15,15:44:16 -8:00 GMT,128.32.168.229:5000,68.26.217.204:5000,UDP
FWIN,2004/01/15,15:50:06 -8:00 GMT,65.78.10.110:3071,128.32.168.229:3410,TCP (flags:S)
FWIN,2004/01/15,15:59:42 -8:00 GMT,202.42.49.198:0,128.32.168.229:0,ICMP (type:8/subtype:0)
FWIN,2004/01/15,16:07:40 -8:00 GMT,68.22.89.249:4088,128.32.168.229:1433,TCP (flags:S)
FWIN,2004/01/15,16:08:36 -8:00 GMT,193.95.219.45:0,128.32.168.229:0,ICMP (type:3/subtype:1)
FWIN,2004/01/15,16:23:50 -8:00 GMT,67.37.40.15:4299,128.32.168.229:3410,TCP (flags:S)
FWOUT,2004/01/15,16:24:16 -8:00 GMT,128.32.168.229:5000,68.26.217.204:5000,UDP
```



## Trace Analysis

- ZoneAlarm Logging Client v3.7.202
- Windows 2000-5.0.2195-Service Pack 4-SP
- type,date,time,source,destination,transport
- FWIN,2004/01/15,13:17:38 -8:00 GMT,216.183.33.67:42645,128.32.168.229:6129,TCP (flags:S)
- FWOUT,2004/01/15,13:18:00 -8:00 GMT,128.32.168.229:5000,68.26.217.204:5000,UDP
- FWIN,2004/01/15,13:42:38 -8:00 GMT,61.178.60.11:0,128.32.168.229:0,ICMP (type:8/sub
- FWIN,2004/01/15,13:42:48 -8:00 GMT,62.177.227.10:0,128.32.168.229:0,ICMP (type:8/subtype:0)
- FWIN,20 GMT,128

b2b-33-67.ip.granderiver.com

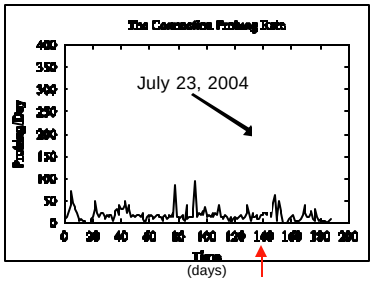
"ping" probe

Used by the Dameware remote admin sw (old versions have a bug allowing unauthorized login). Dameware also installed by some viruses



## Analyzing Host-based Trace Data

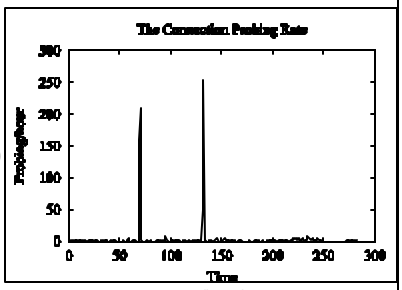
- TCP connection probes on port 445
- Day 0 is 2003/03/04




MSBlaster Worm

## MSBlaster in Detail

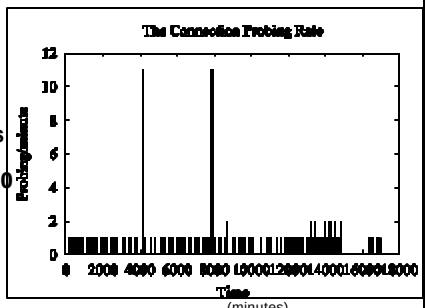
- TCP 445 probes/hr
- Hour 0 is 15:20 on 2003/07/20






## MSBlaster in More Detail

- TCP 445 probes / 10 min
- Minute 0 is 15:20 on 2003/07/20






## Example Common Attack

- Port scanning a host
  - Trying to connect/send data to different ports/protocols: sequential scan of host
  - Nmap tool (http://www.insecure.org/nmap/)
    - » Determines OS/hostname/device type detection via service fingerprinting (ex: SGI IRIX has svc on TCP port 1)
    - » Determines what svc is really listening on a port and *can even determine app name and version*
    - » Operates in optional obfuscation mode
- How to detect attack?



## Intrusion Detection Using Signals

- This is a misuse detection problem
  - Similar problem to virus detection
  - "Match what you know"
- High-level solution:
  - Collect info about attack methods and types
    - » 4-tuple/protocol
    - » Packet contents
  - Create and look for signatures
    - » Slammer packet, port scan, …



## Intrusion Detection Using Noise

- This is an anomaly detection problem
  - Need to learn normal behavior
  - "Match what's different"
- High-level solution:
  - Try to identify what is normal traffic
    - » Common 4-tuple/protocol
  - Heuristic: Look for major deviations (outliers)
    - » Ex: unusual target port, source addr, or port sequence (scan)
  - Apply AI: Statistical Learning Techniques



## Signature Detection

- Language to specify intrusion patterns
  - 4-tuple/protocol and potential intrusion values
    - » Ex: External host → file server (port 110, 135, …)
    - » Ex: Internal workstation → external P2P host
  - Packet contents
    - » Could be single or multiple packets (stream reconstruction)
  - Sequence of 4-tuple/protocol and packets
    - » Also, model of protocol/app finite state machine
- Lots of state in pattern matching engine
- Example rule:
  - `alert tcp any any -> myip 21 (content:"site exec"; content:"%"; msg:"site exec buffer overflow attempt";)`

## Signature Detection

- Snort tool (http://www.snort.org/)
  - 2 million downloads, 100,000+ active users,
- Advantages
  - Very low false positive (alarm) rate
- Disadvantages
  - Only able to detect already known attacks
  - Simple changes to attack can defeat detection
    - » Ex: Scan every even port, then every odd port…



## Anomaly Detection

- Analyze normal operation (behavior), look for anomalies
  - Uses AI techniques: Statistical Learning Techniques
  - Compute statistical properties of "features"
    - » 4-tuple, protocol, packet contents, packets/sec, range of port numbers, …
  - Report errors if statistics are outside of "normal" range



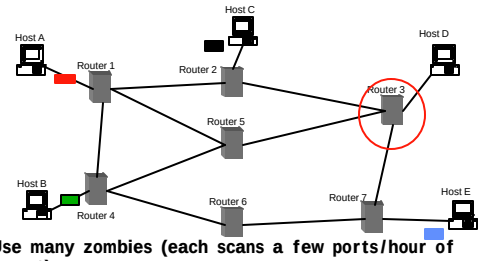
## Anomaly Detection

- Advantages
  - Can recognize "evolved" and new attacks
- Disadvantages
  - High false positive rate (alarms)
  - May have delayed alarm
  - Some attacks can hide in "normal" traffic
  - SLT requires training on known good data
  - Hard to capture protocol state behavior (FSM)
  - Problems when what's "normal" changes
    - » Ex: flash crowds



## BREAK

## Super Stealthy Port Scanning




- Use many zombies (each scans a few ports/hour of target)
  - Each zombie is assigned many machines to scan
- Fast to scan both one machine, and many
- Very hard to detect at targets!



## Distributed Intrusion Detection

- Place appliance in the network at choke point or, *share results across machines*
- Apply signature or anomaly detection across larger data set
- Advantages:
  - Easier to detect stealth probes of large number of machines
- Disadvantages:
  - Large amount of data to communicate

## Honeypots

- Closely monitored network decoys
- May distract adversaries from more valuable machines on a network
- May provide early warning about new attack and exploitation trends
  - Enables in-depth examination of adversaries during and after exploitation



## Honeypots

- Can simulate one or more network services on one or more machines
  - Can have virtual cluster of machines
- Causes an attacker to think you're running vulnerable services that can be used to break into the machine
  - Can log access attempts to those ports, including the attacker's source IP and keystrokes
  - Can watch attacker in real-time and trace back/forward
- Provides advanced warning of an attack
  - Could use to automate generation of new firewall rules



## Tarpits

- A very,very sticky honeypot…
- Set up network decoy
  - For each port we want to "tarpit," we allow connections to come in, but don't let them out
- Idea:
  - Slow down scanning tools/worms to kill their performance/propagation because they rely on quick turnarounds
  - Might also give us time to protect real hosts



## Example Tarpit Implementation

- Accept any incoming TCP connection
- When data transfer begins to occur, set TCP window size to zero, so no data can be transferred within the session
- Hold the connection open, and ignore any requests by remote side to close session
- Attacker must wait for the connection to timeout in order to disconnect



## Tarpits

- Advantages
  - Can customize for specific worms
    - » Ex: analyze incoming packets to port 80 and only tarpit web connections from worms – look for "cmd.exe" (CodeRed) or "default.ida" (Nimda)
- Disadvantages
  - Might trap valid host
  - Can cause some operating systems to crash



## Intrusion Prevention Systems

- We can detect intrusions, so why not automatically cut off network connections to compromised hosts?
- Intrusion Prevention Systems do this
- But, what if we're wrong…
  - Possible Denial of Service – trick IPS into thinking host is compromised
  - Turn off access our airline reservation server when a fare deal causes very high/different traffic patterns

## Witty Worm

- March 04: Attacked the IDS
- Targeted a buffer overflow vulnerability in several of a vendor's IDS products
- Deletes a randomly chosen sectors of hard drives over time killing system
- Payload contained phrase:
  - "(^.^) insert witty message here (^.^)"



## Witty's Many Firsts

- First widely propagated Internet worm with a destructive payload
- First worm with order of magnitude larger hit list than any previous worm
- Shortest known interval between vulnerability disclosure and worm release – 1 day
- First to spread through nodes doing something proactive to secure their computers / networks
- Spread through a population almost an order of magnitude smaller than that of previous worms



## Intrusion Detection Systems Summary

- Ongoing arms race between attackers and detection technologies
- Real challenge is false positive rate
  - Renders most IDS useless – alerts ignored
- Adaptive, anomaly detection is promising, but still lacking
- IPS products are still immature and problematic
- IDS products are now targets



## Summary

- Avoiding attacks against public servers:
  - Eliminate unnecessary services
  - Apply all patches
  - Use a DMZ to provide layered defense
- Intrusion detection is hard!
  - Crying wolf syndrome
  - Immature products
  - We need new adaptive techniques
- Ongoing arms race between attackers and defenders