Security Part One: Attacks and Countermeasures

15-441

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Flashback .. Internet design goals

1. Interconnection
2. Failure resilience
3. Multiple types of service
4. Variety of networks
5. Management of resources
6. Cost-effective
7. Low entry-cost
8. Accountability for resources

Where is security?

Why did they leave it out?

- Designed for connectivity
- Network designed with implicit trust
  - No “bad” guys
- Can’t security be provided at the edge?
  - Encryption, Authentication etc
  - End-to-end arguments in system design

Security Vulnerabilities

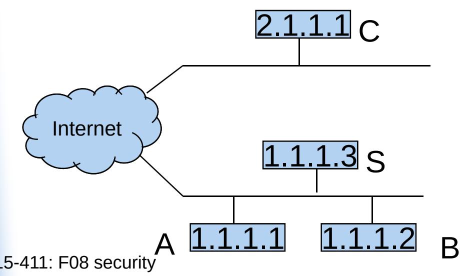
- At every layer in the protocol stack!
- Network-layer attacks
  - IP-level vulnerabilities
  - Routing attacks
- Transport-layer attacks
  - TCP vulnerabilities
- Application-layer attacks

IP-level vulnerabilities

- IP addresses are provided by the source
  - Spoofing attacks
- Using IP address for authentication
  - e.g., login with .rhosts
- Some “features” that have been exploited
  - Fragmentation
  - Broadcast for traffic amplification

Security Flaws in IP

- The IP addresses are filled in by the originating host
  - Address spoofing
- Using source address for authentication
  - r-utilities (rlogin, rsh, rhosts etc..)



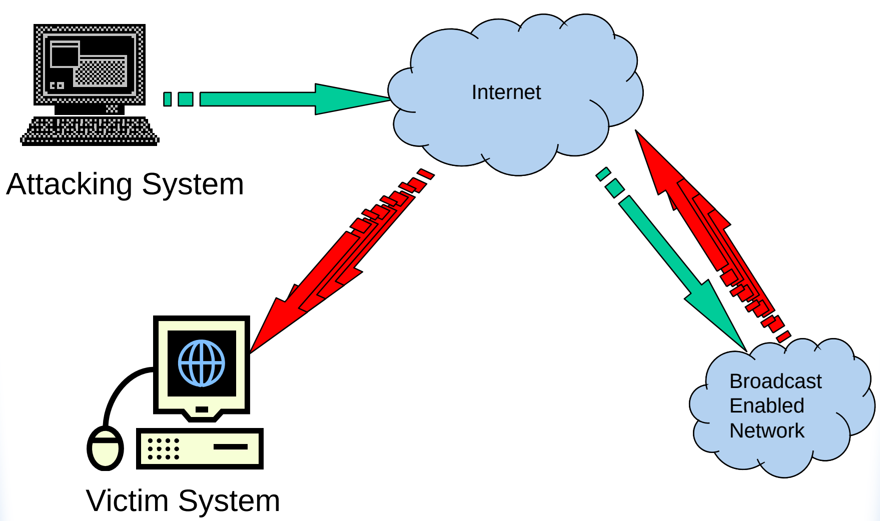
•Can A claim it is B to the server S?

•ARP Spoofing

•Can C claim it is B to the server S?

•Source Routing

Smurf Attack



ICMP Attacks

- No authentication
- ICMP redirect message
  - Can cause the host to switch gateways
  - Benefit of doing this?
    - Man in the middle attack, sniffing
- ICMP destination unreachable
  - Can cause the host to drop connection
- ICMP echo request/reply
- Many more…
  - http://www.sans.org/rr/whitepapers/threats/477.php

Routing attacks

- Divert traffic to malicious nodes
  - Black-hole
  - Eavesdropping
- How to implement routing attacks?
  - Distance-Vector:
  - Link-state:
- BGP vulnerabilities

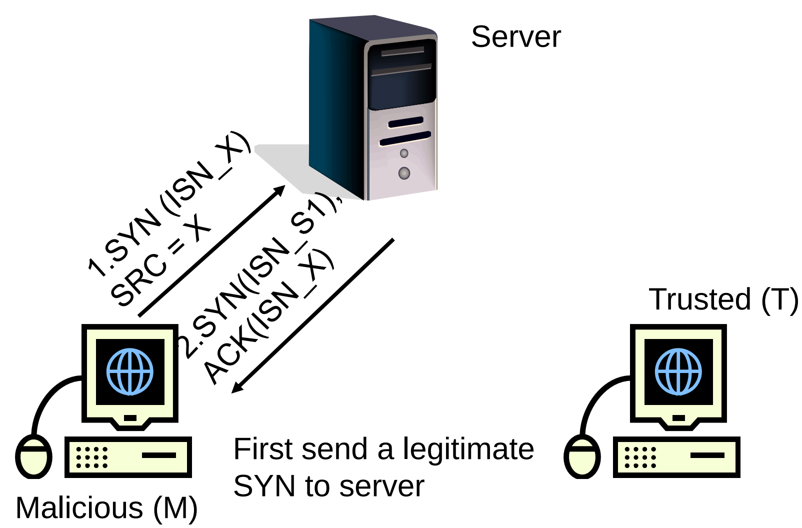
Routing attacks

- Divert traffic to malicious nodes
  - Black-hole
  - Eavesdropping
- How to implement routing attacks?
  - Distance-Vector: Announce low-cost routes
  - Link-state: Dropping links from topology
- BGP vulnerabilities
  - Prefix-hijacking
  - Path alteration

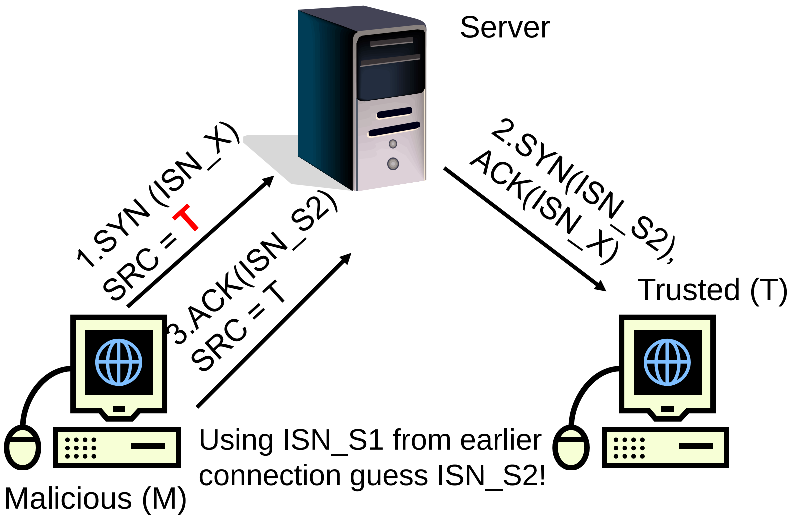
TCP-level attacks

- SYN-Floods
  - Implementations create state at servers before connection is fully established
- Session hijack
  - Pretend to be a trusted host
  - Sequence number guessing
- Session resets
  - Close a legitimate connection

Session Hijack



Session Hijack



TCP Layer Attacks

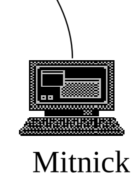
- TCP SYN Flooding
  - Exploit state allocated at server after initial SYN packet
  - Send a SYN and don't reply with ACK
  - Server will wait for 511 seconds for ACK
  - Finite queue size for incomplete connections (1024)
  - Once the queue is full it doesn't accept requests

TCP Layer Attacks

- TCP Session Poisoning
  - Send RST packet
    - Will tear down connection
  - Do you have to guess the exact sequence number?
    - Anywhere in window is fine
    - For 64k window it takes 64k packets to reset
    - About 15 seconds for a T1

An Example

- Finger @S
- showmount –e
- Send 20 SYN packets to S



- Attack when no one is around
- What other systems it trusts?
- Determine ISN behavior

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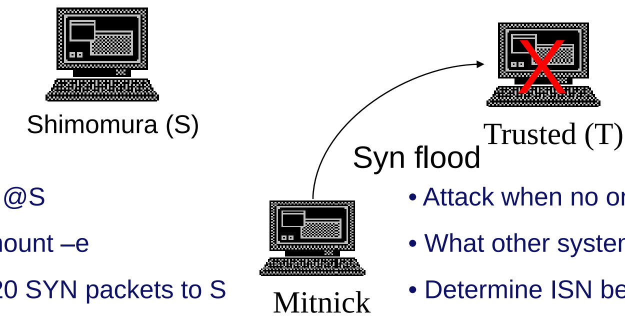

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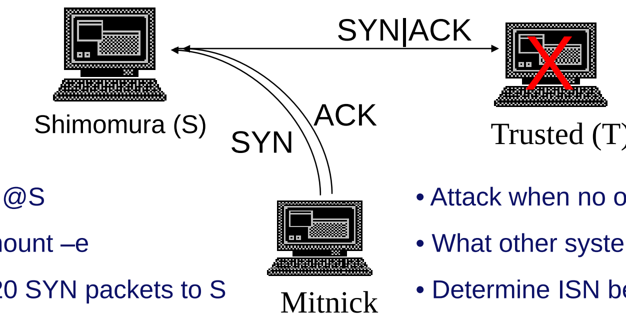

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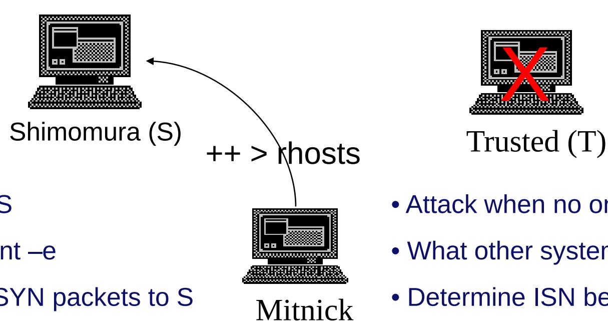

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- Send "echo + + > ~/.rhosts"

- Attack when no one is around
- What other systems it trusts?
- Determine ISN behavior
- T won't respond to packets
- S assumes that it has a session with T
- Give permission to anyone from anywhere

Where do the problems come from?

- Protocol-level vulnerabilities
  - Implicit trust assumptions in design
- Implementation vulnerabilities
  - Both on routers and end-hosts
- Incomplete specifications
  - Often left to the imagination of programmers

Outline

- Security Vulnerabilities
- ***Denial of Service***
- Worms
- Countermeasures: Firewalls/IDS

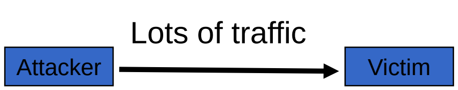
Denial of Service

- Make a service unusable/unavailable
- Disrupt service by taking down hosts
  - E.g., ping-of-death
- Consume host-level resources
  - E.g., SYN-floods
- Consume network resources
  - E.g., UDP/ICMP floods

Simple DoS

•Attacker usually spoofs source address to hide origin

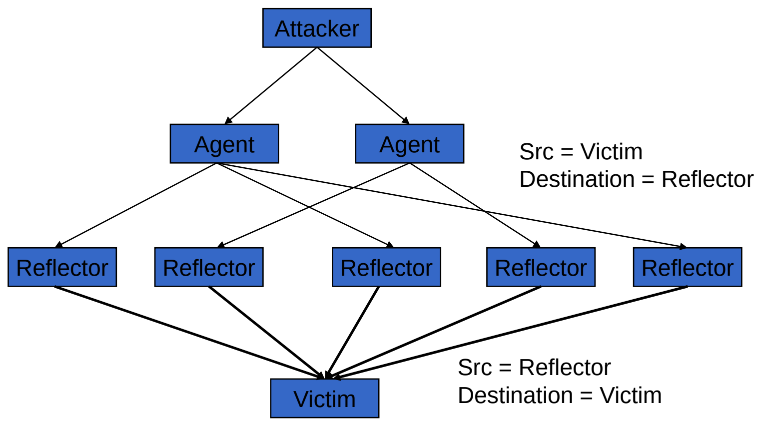
•Aside: Backscatter Analysis
  •When attack traffic results in replies from the victim
  •E.g. TCP SYN, ICMP ECHO



Backscatter Analysis

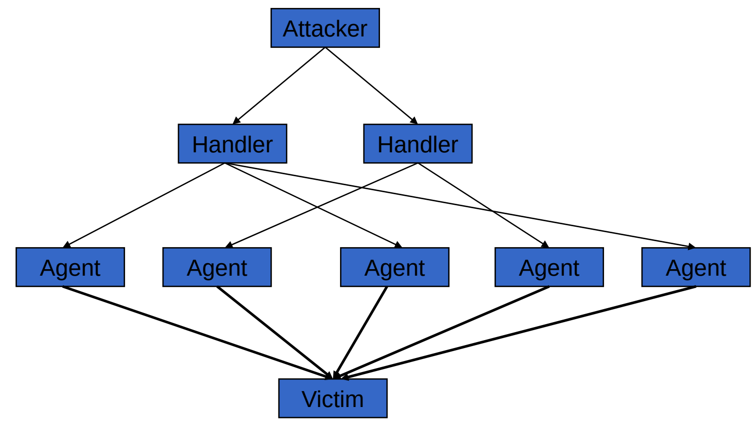
- Attacker sends spoofed TCP SYN packets to www.haplessvictim.com
  - With spoofed addresses chosen at random
- My network sees TCP SYN-ACKs from www.haplessvictim.com at rate R
- What is the rate of the attack?
  - Assuming addresses chosen are uniform
  - (2^32/ Network Address space) * R

Reflector Attack



Unsolicited traffic at victim from legitimate hosts

Distributed DoS



Distributed DoS

- Handlers are usually high volume servers
  - Easy to hide the attack packets
- Agents are usually home users with DSL/Cable
  - Already infected and the agent installed
- Very difficult to track down the attacker
  - Multiple levels of indirection!
- Aside: How to distinguish DDos from flash crowd?

Outline

- Security, Vulnerabilities
- Denial of Service
- ***Worms***
- Countermeasures: Firewalls/IDS

Worm Overview

- Self-propagate through network
- Typical Steps in worm propagation
  - Probe host for vulnerable software
  - Exploit the vulnerability (e.g., buffer overflow)
    - Attacker gains privileges of the vulnerable program
  - Launch copy on compromised host
- Spread at exponential rate
  - 10M hosts in < 5 minutes
  - Hard to deal with manual intervention

Scanning Techniques

- Random
- Local subnet
- Routing Worm
- Hitlist
- Topological

Random Scanning

- 32-bit randomly generated IP address
  - E.g., Slammer and Code Red I
  - What about IPv6?
- Hits black-holed IP space frequently
  - Only 28.6% of IP space is allocated
  - Detect worms by monitoring unused addresses
    - Honeypots/Honeynet

Subnet Scanning

- Generate last 1, 2, or 3 bytes of IP address randomly
- Code Red II and Blaster
- Some scans must be completely random to infect whole internet

Routing Worm

- BGP information can tell which IP address blocks are allocated
- This information is publicly available
  - http://www.routeviews.org/
  - http://www.ripe.net/ris/

Hit List

- List of vulnerable hosts sent with payload
  - Determined before worm launch by scanning
- Boosts worm growth in the slow start phase
- Can evade common detection techniques

Topological

- Uses info on the infected host to find the next target
  - Morris Worm used /etc/hosts , .rhosts
  - Email address books
  - P2P software usually store info about peers that each host connects to

Some proposals for countermeasures

- Better software safeguards
  - Static analysis and array bounds checking (lint/e-fence)
  - Safe versions of library calls
    - gets(buf) -> fgets(buf, size, ...)
    - sprintf(buf, ...) -> snprintf(buf, size, ...)
- Host-diversity
  - Avoid same exploit on multiple machines
- Network-level: IP address space randomization
- Host-level solutions
  - E.g., Memory randomization, Stack guard
- Rate-limiting: Contain the rate of spread
- Content-based filtering: signatures in packet payloads

Outline

- Security, Vulnerabilities
- Denial of Service
- Worms
- ***Countermeasures: Firewalls/IDS***

Countermeasure Overview

- High level basic approaches
  - Prevention
  - Detection
  - Resilience
- Requirements
  - Security: soundness / completeness (false positive / negative
  - Overhead
  - Usability

Design questions ..

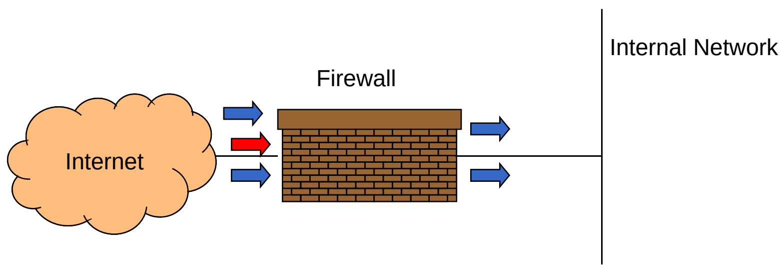
- Why is it so easy to send unwanted traffic?
  - Worm, DDoS, virus, spam, phishing etc
- Where to place functionality for stopping unwanted traffic?
  - Edge vs. Core
  - Routers vs. Middleboxes
- Redesign Internet architecture to detect and prevent unwanted traffic?

Firewalls

- Block/filter/modify traffic at network-level
  - Limit access to the network
  - Installed at perimeter of the network
- Why network-level?
  - Vulnerabilities on many hosts in network
  - Users don’t keep systems up to date
  - Lots of patches to keep track of
  - Zero-day exploits

Firewalls (contd…)

- Firewall inspects traffic through it
- Allows traffic specified in the policy
- Drops everything else
- Two Types
  - Packet Filters, Proxies



Packet Filters

- Selectively passes packets from one network interface to another
- Usually done within a router between external and internal network
- What/How to filter?
  - Packet Header Fields
    - IP source and destination addresses
    - Application port numbers
    - ICMP message types/ Protocol options etc.
  - Packet contents (payloads)

Packet Filters: Possible Actions

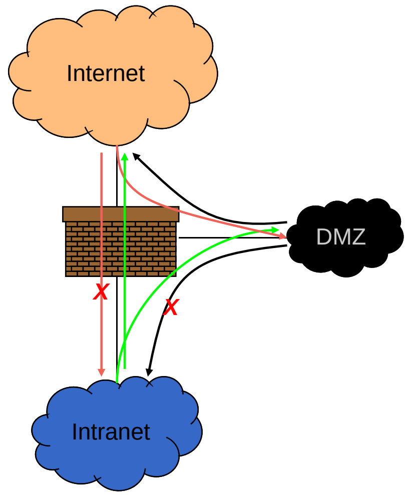
- Allow the packet to go through
- Drop the packet (Notify Sender/Drop Silently)
- Alter the packet (NAT?)
- Log information about the packet

Some examples

- Block all packets from outside except for SMTP servers
- Block all traffic to/from a list of domains
- Ingress filtering
  - Drop pkt from outside with addresses inside the network
- Egress filtering
  - Drop pkt from inside with addresses outside the network

Typical Firewall Configuration

- Internal hosts can access DMZ and Internet
- External hosts can access DMZ only, not Intranet
- DMZ hosts can access Internet only
- Advantages?
  - If a service gets compromised in DMZ it cannot affect internal hosts



Firewall implementation

- Stateless packet filtering firewall
- Rule → (Condition, Action)
- Rules are processed in top-down order
  - If a condition satisfied – action is taken

Sample Firewall Rule

Allow SSH from external hosts to internal hosts

Two rules

Inbound and out

How to know a p

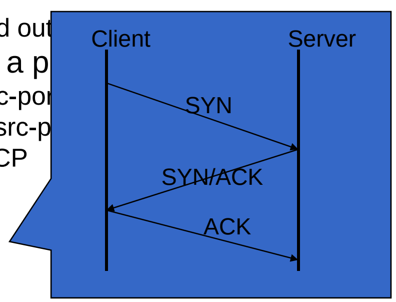
Inbound: src-por

Outbound: src-p

Protocol=TCP

Ack Set?

Problems?



Rule	Dir	Src Addr	Src Port	Dst Addr	Dst Port	Proto	Ack Set?	Action
SSH-1	In	Ext	> 1023	Int	22	TCP	Any	Allow
SSH-2	Out	Int	22	Ext	> 1023	TCP	Yes	Alow

Default Firewall Rules

- Egress Filtering
  - Outbound traffic from external address → Drop
  - Benefits?
- Ingress Filtering
  - Inbound Traffic from internal address → Drop
  - Benefits?
- Default Deny
  - Why?

Rule	Dir	Src Addr	Src Port	Dst Addr	Dst Port	Proto	Ack Set?	Action
Egress	Out	Ext	Any	Ext	Any	Any	Any	Deny
Ingress	In	Int	Any	Int	Any	Any	Any	Deny
Default	Any	Any	Any	Any	Any	Any	Any	Deny

Packet Filters

- Advantages
  - Transparent to application/user
  - Simple packet filters can be efficient
- Disadvantages
  - Usually fail open
  - Very hard to configure the rules
  - May only have coarse-grained information?
    - Does port 22 always mean SSH?
    - Who is the user accessing the SSH?

Alternatives

- Stateful packet filters
  - Keep the connection states
  - Easier to specify rules
  - Problems?
    - State explosion
    - State for UDP/ICMP?
- Proxy Firewalls
  - Two connections instead of one
  - Either at transport level
    - SOCKS proxy
  - Or at application level
    - HTTP proxy

Proxy Firewall

- Data Available
  - Application level information
  - User information
- Advantages?
  - Better policy enforcement
  - Better logging
  - Fail closed
- Disadvantages?
  - Doesn't perform as well
  - One proxy for each application
  - Client modification

Intrusion Detection Systems

- Firewalls allow traffic only to legitimate hosts and services
- Traffic to the legitimate hosts/services can have attacks
- Solution?
  - Intrusion Detection Systems
  - Monitor data and behavior
  - Report when identify attacks

Classes of IDS

- What type of analysis?
  - Signature-based
  - Anomaly-based
- Where is it operating?
  - Network-based
  - Host-based

Signature-based IDS

- Characteristics
  - Uses known pattern matching to signify attack
- Advantages?
  - Widely available
  - Fairly fast
  - Easy to implement
  - Easy to update
- Disadvantages?
  - Cannot detect attacks for which it has no signature

Anomaly-based IDS

- Characteristics
  - Uses statistical model or machine learning engine to characterize normal usage behaviors
  - Recognizes departures from normal as potential intrusions
- Advantages?
  - Can detect attempts to exploit new and unforeseen vulnerabilities
  - Can recognize authorized usage that falls outside the normal pattern
- Disadvantages?
  - Generally slower, more resource intensive compared to signature-based IDS
  - Greater complexity, difficult to configure
  - Higher percentages of false alerts

Network-based IDS

- Characteristics
  - NIDS examine raw packets in the network passively and triggers alerts
- Advantages?
  - Easy deployment
  - Unobtrusive
  - Difficult to evade if done at low level of network operation
- Disadvantages?
  - Fail Open
  - Different hosts process packets differently
  - NIDS needs to create traffic seen at the end host
  - Need to have the complete network topology and complete host behavior

Host-based IDS

- Characteristics
  - Runs on single host
  - Can analyze audit-trails, logs, integrity of files and directories, etc.
- Advantages
  - More accurate than NIDS
  - Less volume of traffic so less overhead
- Disadvantages
  - Deployment is expensive
  - What happens when host get compromised?

Summary

- Security vulnerabilities are real!
  - Protocol or implementation or bad specs
  - Poor programming practices
  - At all layers in protocol stack
- DoS/DDoS
  - Resource utilization attacks
- Worm/Malware
  - Exploit vulnerable services
  - Exponential spread
- Countermeasures: Firewall/IDS