15-441 15-641 Computer Networking

Lecture 22 – Security: DOS

Peter Steenkiste

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With slides from: Debabrata Dash, Nick Feamster, Vyas Sekar, and others

Our "Narrow" Focus

- Yes:
  - Creating a "secure channel" for communication (Part I)
  - Protecting network resources and limiting connectivity (Part II)
  - "Network Security"
- No:
  - Preventing software vulnerabilities & malware, or "social engineering".
  - "Software Security"

Security Vulnerabilities

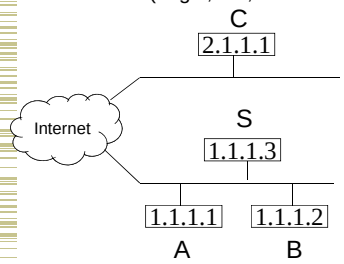
- Exist at every layer in the protocol stack!
- Network-layer attacks
  - IP-level vulnerabilities
  - Routing attacks
- Transport-layer attacks
  - TCP vulnerabilities
- Application-layer attacks

IP-level vulnerabilities

- IP addresses are provided by the source
  - Spoofing attacks
- Using IP address for authentication
  - Should be rare today
- Some "features" that have been exploited
  - Fragmentation
  - Broadcast for traffic amplification

Fun with IP Spoofing

- 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

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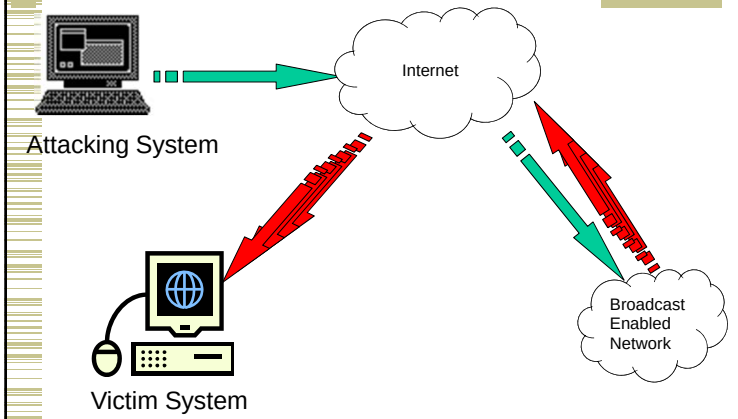
Fun with IP Spoofing (Smurf Attack)



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Routing attacks

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

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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

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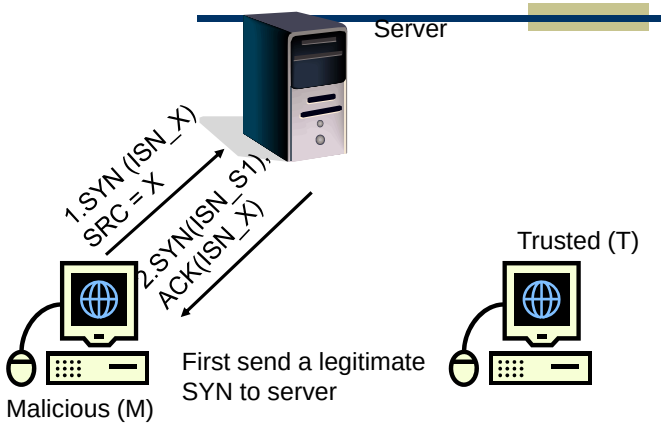
Black-hole Attacks

- All packets to destination network get dropped in network
- Causes:
  - Compromised router drops packets directly
  - Compromised router sends incorrect routing info
  - Maliciously crafted BGP packets
  - Modified BGP packets
  - Dropped BGP packets

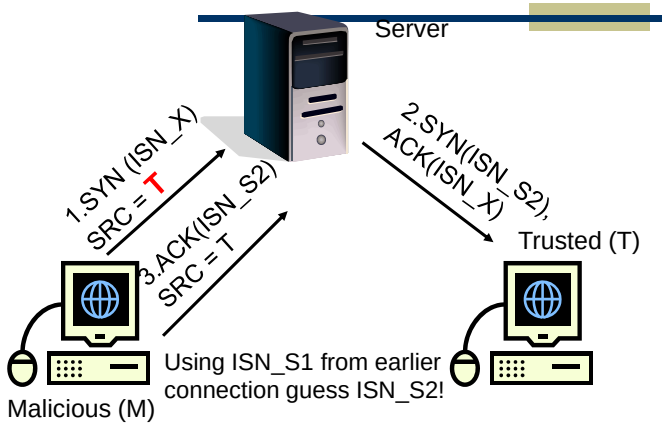
TCP-level attacks

- 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 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 does not accept requests
- The solution is to use SYN cookies
  - The server keeps no state after the SYN
  - Instead, it embeds all the necessary state in the packet as carefully crafted initial sequence number

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TCP 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

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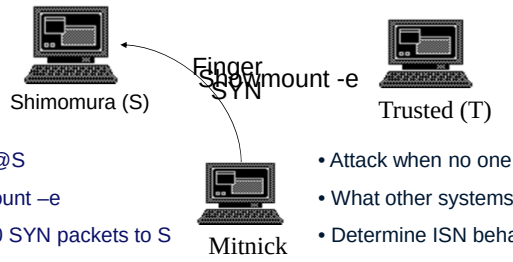
An Example



- 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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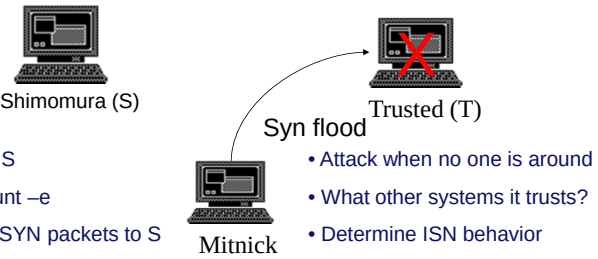
An Example



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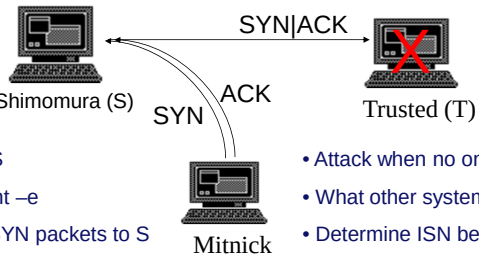

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- Send SYN to S spoofing as T
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- What other systems it trusts?
- Determine ISN behavior
- T won't respond to packets
- S assumes that it has a session with T

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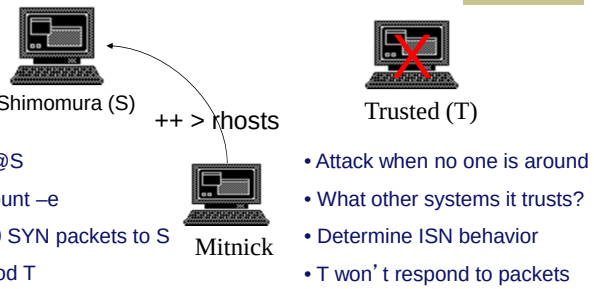
An Example



- Finger @S
- showmount –e
- Send 20 SYN packets to S
- SYN flood T
- Send SYN to S spoofing as T
- Send ACK to S with a guessed number
- 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

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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

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Outline – Part II

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

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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

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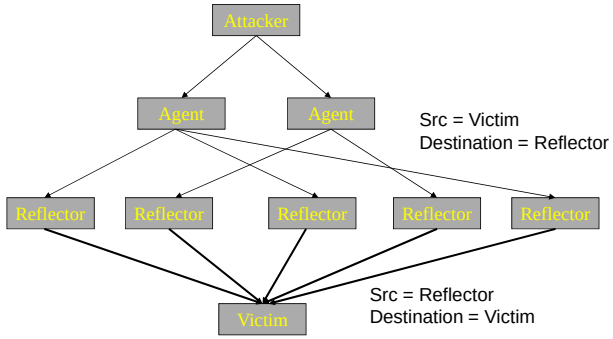
Reflector Attack



Unsolicited traffic at victim from legitimate hosts

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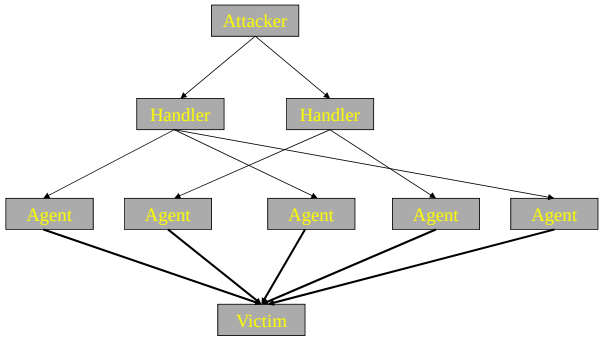
Distributed DoS



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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?

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Outline – Part II

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

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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

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Scanning Techniques

- Random
- Local subnet
- Routing Worm
  - Uses information about allocated addresses from BGP
- Hitlist
  - Provide list of vulnerable hosts
- Topological
  - Exploit information on the infected hosts

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Random Scanning

- 32-bit randomly generated IP address
  - E.g., Slammer and Code Red I
  - What about IPv6?
- Hits black-holed IP space occasionally
  - Some percentage of IP space reserved
  - Detect worms by monitoring unused addresses
    - Honeypots/Honeynet

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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

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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

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Outline – Part II

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

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Countermeasure Overview

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

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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?

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Firewall Motivation

- 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 do not keep systems up to date
  - Lots of patches to keep track of
  - Zero-day exploits

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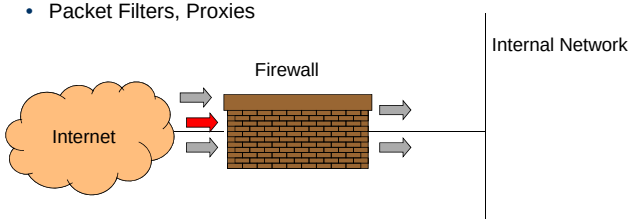
Firewalls Design

- Firewall inspects traffic that flows through it
- Allows traffic specified in the policy
- Drops everything else (“default off”)
- Two Types
  - Packet Filters, Proxies



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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)

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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

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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

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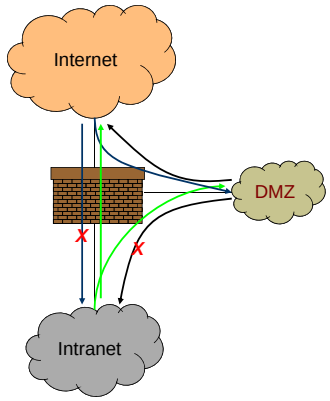
Typical Firewall Configuration

- 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



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Firewall implementation

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

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Sample Firewall Rule

Allow SSH from external hosts to internal hosts

- Two rules
  - Inbound and outbound
- How to know a packet is for SSH?
  - Inbound: src-port>1023, dst-port=22
  - Outbound: src-port=22, dst-port>1023
  - Protocol=TCP
- Problems?

Rule	Dir	Src Addr	Src Port	Dst Addr	Dst Port	Proto	Action
SSH-1	In	Ext	> 1023	Int	22	TCP	Allow
SSH-2	Out	Int	22	Ext	> 1023	TCP	Allow

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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

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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?

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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

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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

Summary – Part II

- 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

Resources

- Textbook: 8.1 – 8.3
- Wikipedia for overview of Symmetric/Asymmetric primitives and Hash functions.
- OpenSSL (www.openssl.org): top-rate open source code for SSL and primitive functions.
- "Handbook of Applied Cryptography" available free online: www.cacr.math.uwaterloo.ca/hac/