15-441 15-641 Computer Networking

Lecture 23 – Security: DOS

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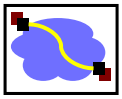
www.cs.cmu.edu/~prs/15-441-F15

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"

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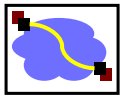
Outline – Part II



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

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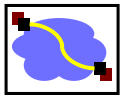
Security Vulnerabilities



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

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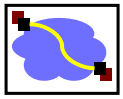
IP-level vulnerabilities



- 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: resources on routers
  - Broadcast for traffic amplification: bandwidth, endpoints

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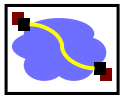
Routing attacks



- 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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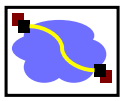
Black-hole Attacks



- 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

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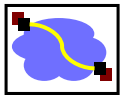
TCP-level attacks



- 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

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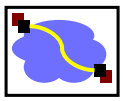
TCP SYN Flooding



- 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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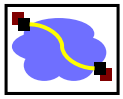
Where do the problems come from?



- Protocol-level vulnerabilities
  - Implicit trust assumptions in design
  - Many protocols were designed at a time that security was not a concern
- Implementation vulnerabilities
  - Both on routers and end-hosts
- Incomplete specifications
  - Often left to the imagination of programmers

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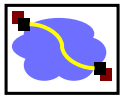
Outline – Part II



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

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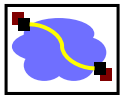
Denial of Service



- 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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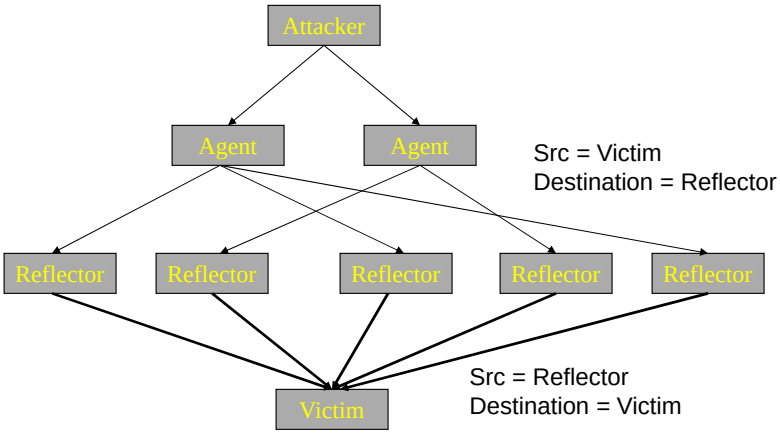
Reflector Attack



Unsolicited traffic at victim from legitimate hosts

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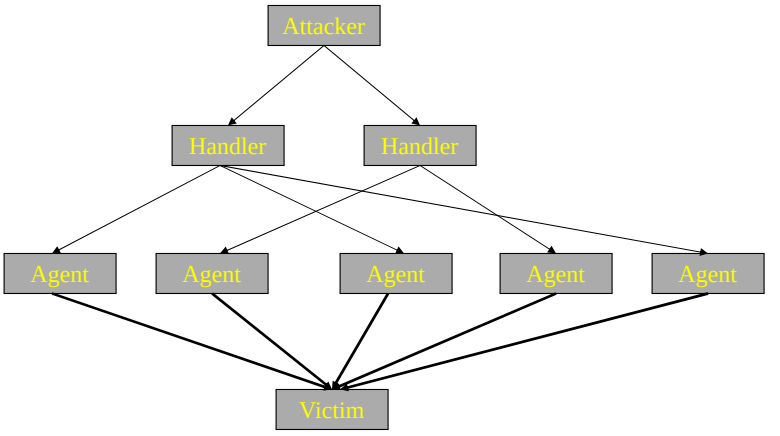
Distributed DoS



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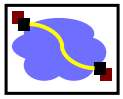
Distributed DoS



- 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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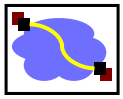
Outline – Part II



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

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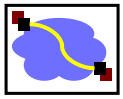
Worm Overview



- 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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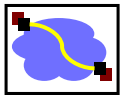
Scanning Techniques



- Random: generate random addresses
- Local subnet: generate last 1, 2, or 3 bytes of IP address randomly
- 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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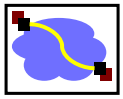
Random Scanning



- 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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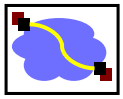
Some proposals for countermeasures



- 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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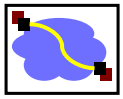
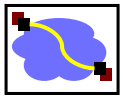
Outline – Part II



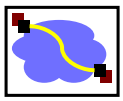
- Security, Vulnerabilities
- Denial of Service
- Worms
- ***Countermeasures: Firewalls/IDS***

Countermeasure Overview



- High level basic approaches
  - Prevention
  - Detection
  - Resilience
- Requirements
  - Security: soundness / completeness
    - Manage false positive / negative tradeoff
  - Overhead
  - Usability
- Where to place functionality: edge vs core

Firewall Motivation



- Block/filter/modify traffic at the perimeter of the network
  - Limit access to the network and all hosts/devices
- Why network-level?
  - Vulnerabilities on many hosts in network
  - Hosts/devices are very heterogeneous
  - Users do not keep systems up to date
  - Lots of patches to keep track of
  - Zero-day exploits

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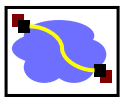
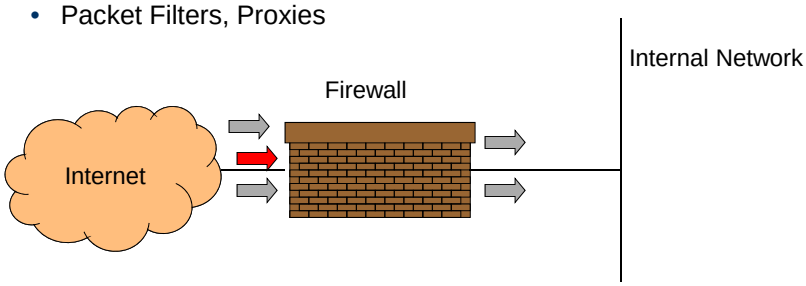
Firewalls Design



- 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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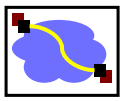
Packet Filters



- Selectively passes packets from one network interface to another
  - Options: forward, drop, or forward + log
- 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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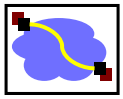
Some examples



- 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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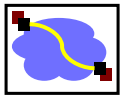
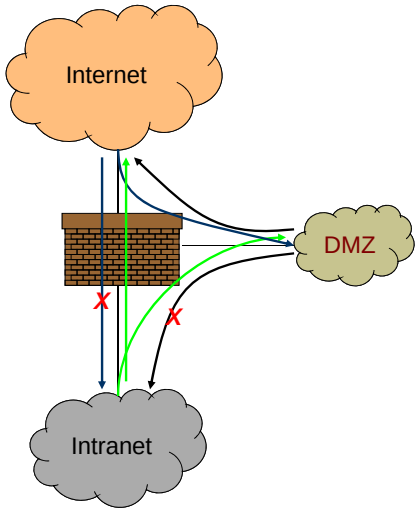
Typical Firewall Configuration



- Internal hosts can access "Demilitarized Zone" (DMZ) and Internet
- External hosts can access DMZ only, not Intranet
- DMZ hosts can access Internet only
- Advantages?
  - A compromised service in DMZ it cannot affect internal hosts



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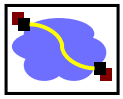
Packet Filter Implementation



- 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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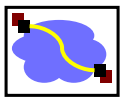
Sample Firewall Rule



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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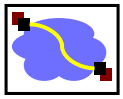
Default Firewall Rules



- Default rules are placed at end of the list – after “Allow” 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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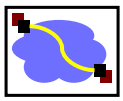
Packet Filters



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

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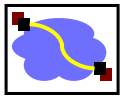
Alternatives



- 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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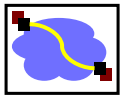
Intrusion Detection Systems



- Traffic to the legitimate hosts/services can have attacks
- Intrusion detection system monitors traffic and traffic patterns
  - Looks for unusual behavior
  - Compares with known attacks, e.g., list of signatures based on attacks observed elsewhere
  - Block or report attacks

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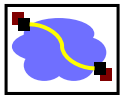
Summary – Part II



- 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

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