CSE 410/565 Computer Security
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Lecture 18: Network Attacks

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Lecture Overview

- Network attacks
  - denial-of-service (DoS) attacks
    - SYN floods, ICMP floods
    - source address spoofing
    - distributed DoS
  - DNS attacks
  - other types of spoofing
  - session hijacking

DoS Attacks

- Denial of service attacks target at denying availability of some service or resource, including
  - network bandwidth
  - system resources
  - application resources
- Types of DoS attacks

	stopping services	exhausting resources
local	process crashing process killing system reconfiguration	spawning processes to fill process table filling up file system saturating bandwidth
remote	malformed packets to crash buggy services	packet floods

Overview of Network Protocols

- IP: Internet Protocol
  - the main protocol used for routing
  - each IP packet includes the source and destination addresses
  - the protocol is connectionless and unreliable (best effort)
  - TCP and UDP run on top of IP
  - IP is used for routing, data fragmentation and reassembly and error reporting (via ICMP)
- ICMP: Internet Control Message Protocol
  - it is used for network reachability testing and to report errors
  - examples: echo request/reply, destination unreachable and time-to-live exceeded messages

Overview of Network Protocols

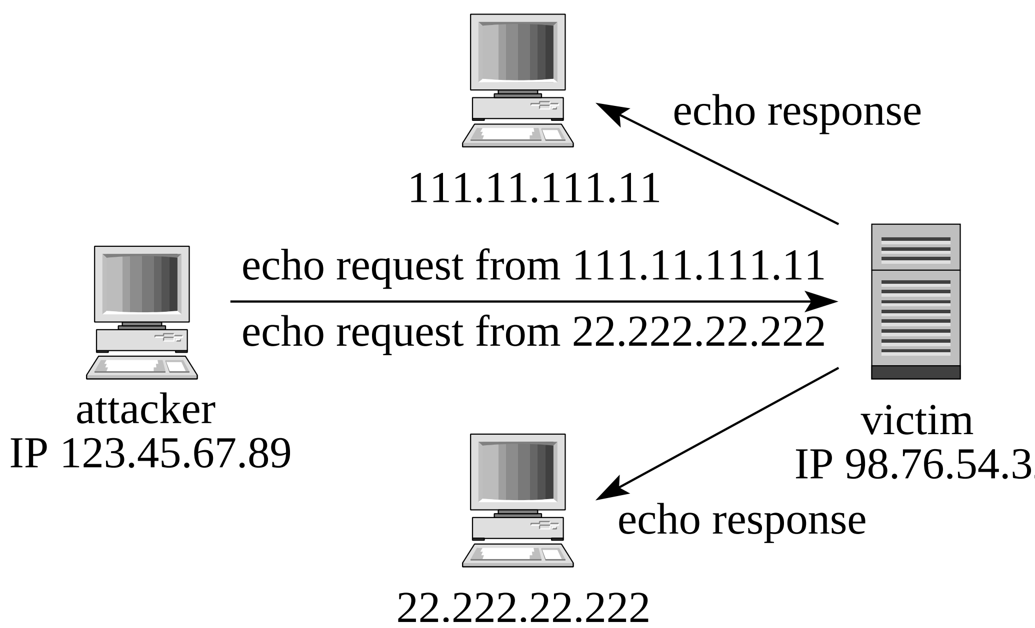
- UDP: User Datagram Protocol
  - transport protocol with minimal guarantees
    - no acknowledgment, no flow control, no message continuation
  - traffic is separated by port number
- TCP: Transmission Control Protocol
  - connection-oriented transport protocol
  - partitions data into packets and reassembles them in correct order at the destination
  - transmission is reliable
    - packets are acknowledged and retransmitted if necessary
  - port numbers are used for different services as well

DoS Attacks

- Basic form of DoS
  - attacker sends a large number of packets through a link or to a particular service
  - the goal is to saturate the network or overload the server
  - most requests from legitimate users will be dropped
  - example
    - attacker sends many ICMP echo request packets to a server
    - the server replies with ICMP echo reply packet
- From attacker's point of view this is unsatisfactory
  - attacker can be easily traced
  - packets sent in response use attacker's resources

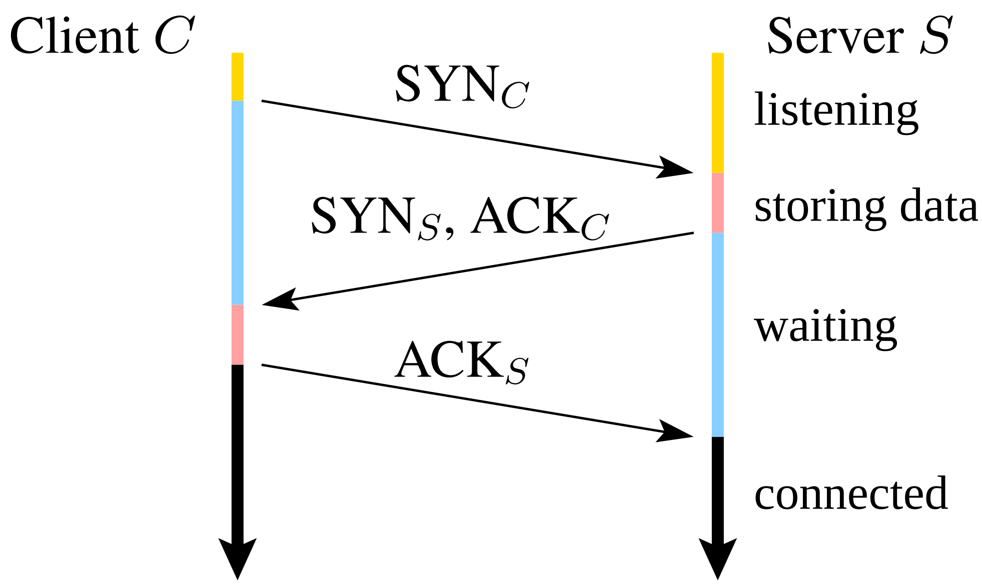
DoS Attacks

- Solution: source address spoofing
  - with sufficient privileges to a machine, the source address in IP packets can be set to anything
  - the source address is set to a randomly chosen address
  - replies from the victim machine are scattered across the internet



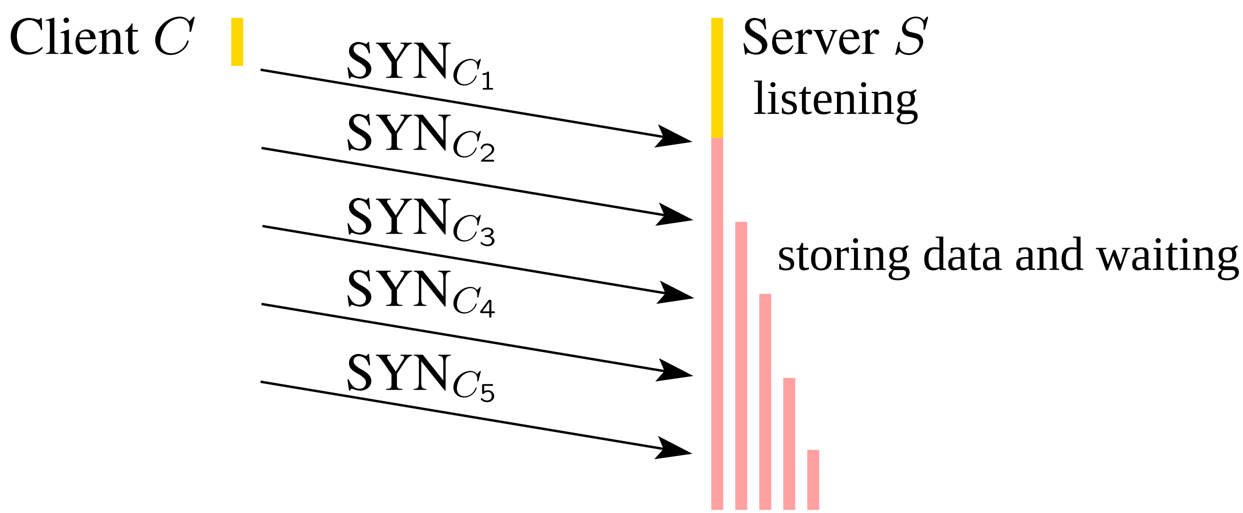
DoS Attacks

- Another way to mount a DoS attack is by TCP SYN flooding
  - uses the fact that a machine has a limit on the number of open connections
  - allows attacker to deny availability with much less traffic
- TCP handshake



DoS Attacks

- TCP SYN flooding attack exploits the fact that server waits for ACKs
  - attacker sends many SYN requests with spoofed source addresses
  - victim allocates resources for each request
    - connection requests exist until timeout
    - there is a fixed bound on half-open connections



DoS Attacks

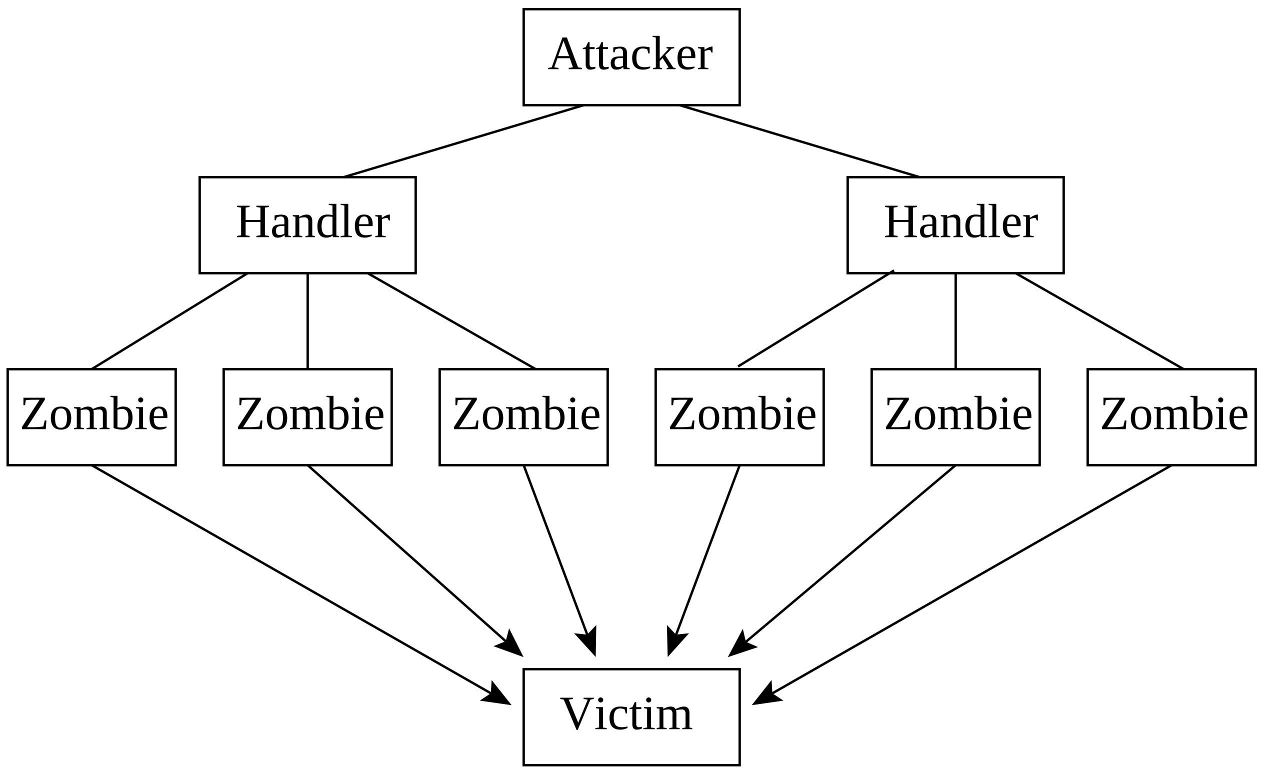
- TCP SYN flooding attack (cont.)
  - resources exhausted $\Rightarrow$ legitimate requests rejected
  - the attack relies on the fact that many SYN-ACK packets will be unanswered
    - an existing host replies to a SYN-ACK packet with RST
    - many IP addresses are not in use
  - the attacker needs to keep sending new SYN packets to keep the table full
- Flooding attacks in general can use any type of packets
  - e.g., ICMP flood, UDP flood, TCP SYN flood
- In any attack with spoofed addresses it is hard to find attacker

DDoS Attacks

- In all of the above attacks, attacker needs to have substantial resources
  - thus attacks are more effective if carried out from many sources
  - they are called distributed DoS (DDoS) attacks
- DDoS attacks often use compromised computers (zombies)
  - attacker compromised machines and builds a botnet
  - attacker instructs the bots to attack the target machine
  - all communication is often encrypted, can be authenticated
  - zombie machines flood the victim
  - spoofing IP addresses is not necessary since it is hard to trace the attacker from the zombie machines

DDoS Attacks

- DDoS attack illustrated



DoS Attacks

- Other variants of DoS attacks that use additional machines
  - reflection
    - find sites with lots of resources
    - send packets to them with (spoofed) source address of the victim
    - responses flood the victim
    - e.g., echo request $\Rightarrow$ echo response, SYN $\Rightarrow$ SYN–ACK
    - no spurious packets can be observed by other sites
    - attack is harder to detected and defend against
  - amplification
    - also sends packets with spoofed addresses to intermediaries
    - now one original packet generates many response packets

DoS Attacks

- Variants of DoS attacks (cont.)
  - amplification
    - amplification is accomplished by sending a request packet to a broadcast address
    - examples are ICMP echo request packets (smurf program) and UDP packets
    - only connectionless protocols can be used (i.e., not TCP)
  - pulsing zombie floods
    - each zombie is active briefly and then goes dormant
    - zombies take turns in attacking
    - this makes tracing difficult

Defenses Against DoS Attacks

- A significant challenge in defending against DoS attacks is that spoofed addresses are used
- What can be done
  - ingress filtering
    - basic recommendation to check that packets coming from a network have source address within the network's range
    - ISPs are best suited to perform such filtering
    - despite its simplicity and effectiveness, this recommendation is not implemented by many ISPs

Defenses Against DoS Attacks

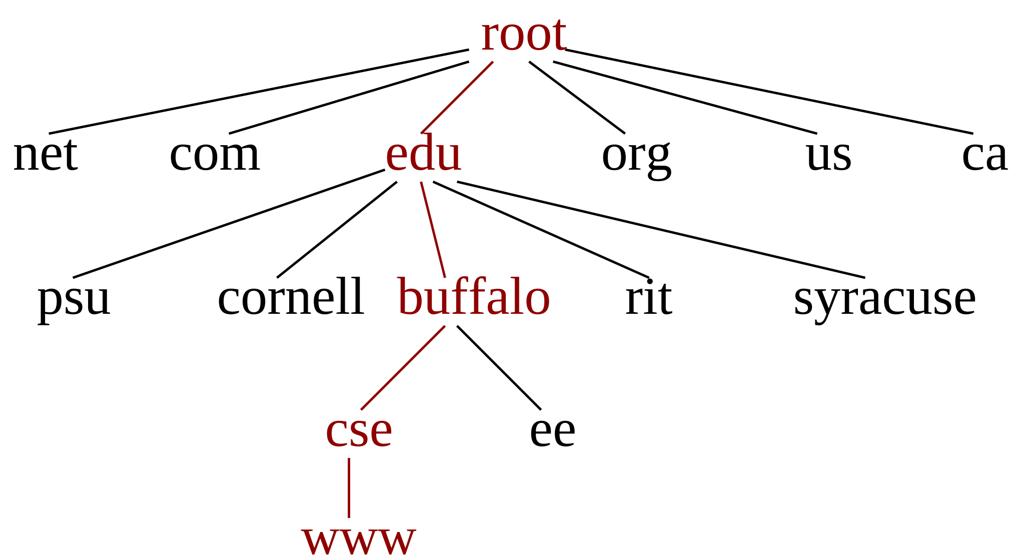
- DoS defenses (cont.)
  - SYN cookies
    - this technique is used to defend against TCP SYN floods
    - after receiving a SYN, information about it is not stored the server
    - instead it is encoded in the SYN-ACK packet
    - upon receiving ACK, server can reconstruct all information
    - disadvantages: increased server computation
  - blocking certain packets
    - many systems block ICMP echo requests from outside of network
    - often IP broadcasts are also blocked from outside

Defenses Against DoS Attacks

- DoS defenses (cont.)
  - limiting packet rates
    - certain types of packets such as ICMP are rather rare in normal network operation
    - limiting their rate can help mitigate attacks
  - packet marking
    - a router marks a small number of packets with its ID
    - for high volume traffic, packets will be marked by most servers on their path to the victim
    - path to the attacker can be reconstructed
    - effectiveness of this technique depends on its wide usage
  - general good security practices

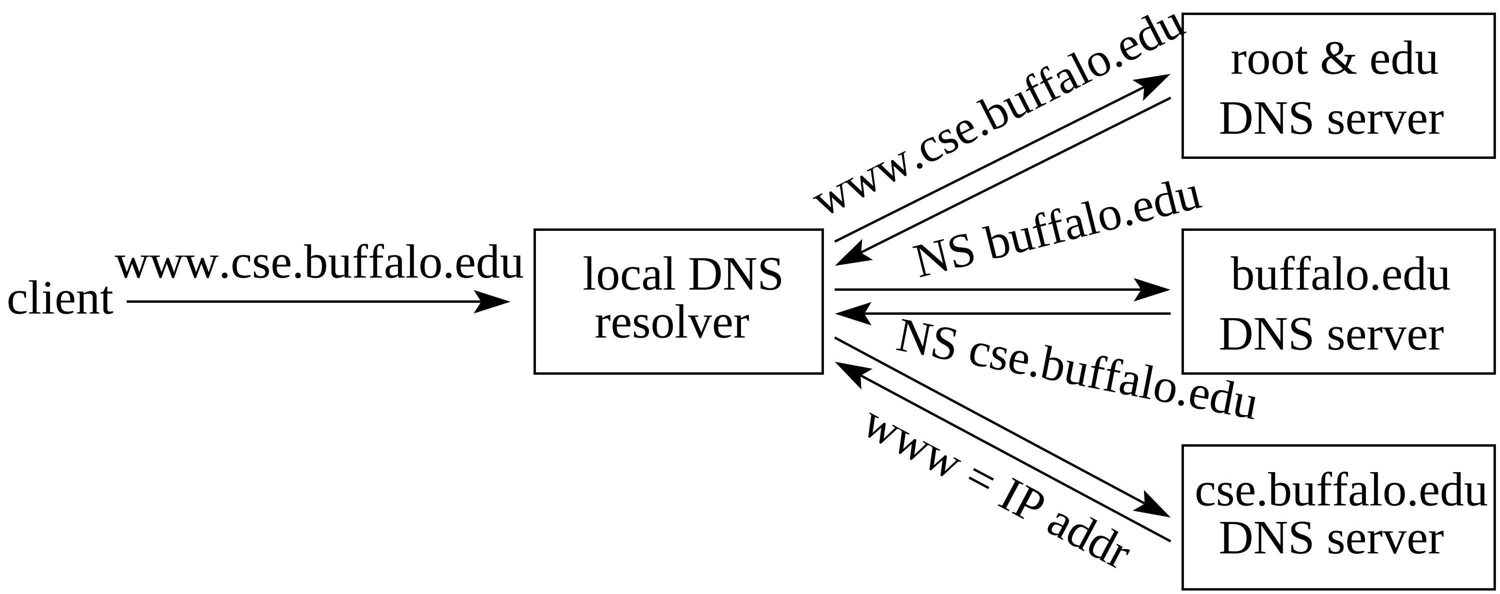
DNS

- Domain Name System (DNS) allows to map symbolic names to IP addresses
  - the name space is hierarchical



DNS

- Hierarchical service
  - root name servers are for top-level domains
  - authoritative name servers are for sub-domains
  - local name resolvers contact authoritative servers when they don't know a name

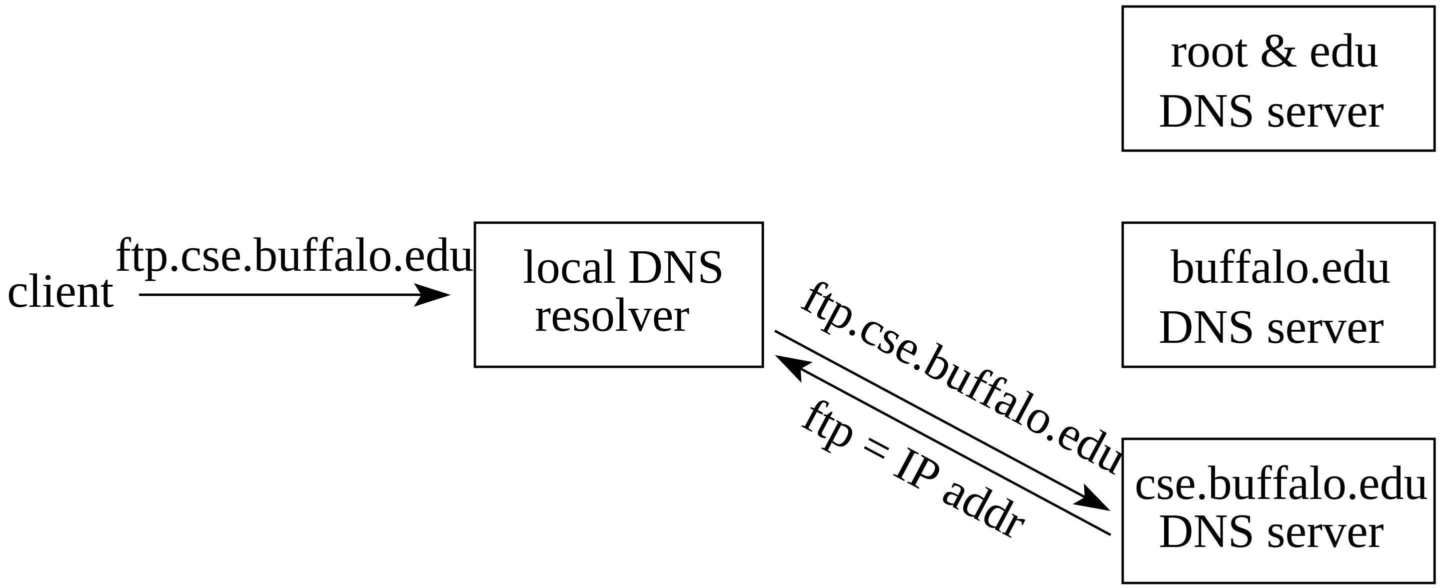


DNS

- DNS resource records
  - "A" record supplies host IP address
  - "NS" record supplies name server for domain
- DNS cashing
  - DNS responses are cached
    - quick response for repeated translations
    - useful for finding servers as well as addresses
  - negative results are cached
    - save time for nonexistent sites, e.g., misspelling
  - cashed data periodically time out

DNS

- DNS lookup using cache



DNS

- DNS is susceptible to cache poisoning attacks
  - change IP address in cache to redirect URLs to fraudulent sites
    - this attack is called pharming
  - example
    - www.yahoo.com NS ns.evil.org (delegate to evil.org)
    - ns.evil.org A 1.2.3.4 (address for evil.org)
  - if resolver looks up www.yahoo.com, the address 1.2.3.4 will be returned
  - the attack is more dangerous than phishing attacks
    - in phishing, users receive email with link to fraudulent website
    - pharming requires no email solicitation, all users go to a wrong address

DNS

- DNS cache poisoning
  - the problem is DNS messages are not authenticated
  - some DNS poisoning attacks in the past
    - in January 2005, the address of a large ISP Panix was redirected to a site in Australia
    - in November 2004, Google and Amazon users were sent to Med Network Inc., an online pharmacy
- There are also attacks on DNS reverse address lookup and DNS implementations
  - example: reverse query buffer overrun in BIND releases 4.9 and 8
    - could gain root access, abort DNS service

DNSSEC

- Domain Name System Security Extensions (DNSSEC) was developed to protect integrity of DNS records
  - all DNS responses are authenticated
    - a server signs all answers it provides
    - this prevents forgery such as DNS cache poisoning
  - DNSSEC is specified in IETF RFCs 4033, 4034, 4035, and others
  - DNSSEC is being deployed slowly due to its perceived overhead
  - see dnssec.net and other resources for more information

Other Attacks

- Address resolution protocol (ARP)
  - primarily used to translate IP addresses to Ethernet MAC addresses
  - each host maintains a table of IP to MAC addresses
- ARP spoofing (or ARP poisoning)
  - send fake ARP messages to an Ethernet LAN (no authentication)
    - this causes other machines to associate IP addresses with attacker's MAC
  - defenses
    - static ARP table
    - DHCP snooping (access control based on IP, MAC, and port)
    - detection: Arpwatch, reverse ARP

Other Attacks

- Session hijacking attacks
  - host-based session hijacking
    - with root privileges can read and write to local terminal devices
  - network-based session hijacking
    - often performed against TCP
- What harm can be done
  - data injection into unencrypted server-to-server traffic such as email exchange, DNS zone transfers, etc.
  - data injection into unencrypted client-to-server traffic such as ftp file downloads and http responses
  - denial of service attacks such as resetting a connection

Other Attacks

- TCP session hijacking
  - each TCP connection has an associated state
    - client and server IP and port numbers, sequence numbers
  - the problems is that it is not difficult to guess state
    - port numbers can be standard
    - sequence numbers are often chosen in a predictable way
- TCP sequence numbers
  - need high degree of unpredictability
    - attacker who knows initial sequence numbers and amount of traffic sent can estimate likely current values
    - send a flood of packets with likely sequence numbers

Other Attacks

- TCP sequence numbers (cont.)
  - packets can be injected into existing connection
  - some implementations are vulnerable
- DoS vulnerability
  - if attacker can guess sequence numbers for an existing connection, it can send a RST packet to close connection (DoS)
  - naively, success probability is $1/2^{32}$ (32-bit numbers)
  - most systems allow for a large window of acceptable sequence numbers resulting in much higher success probability
  - attack is most effective against long lived connections such as BGP

Defenses

- Cryptographic network protection
  - protocol level solutions
    - adding authentication to protocols would solve many problems (various types of spoofing and poisoning)
    - perceived as too expensive for current internet speeds/volumes
  - solutions at network layer
    - use cryptographically random initial sequence numbers, IPsec
    - can protect against session hijacking/data injection and DoS using session resets
  - solutions above transport layer
    - tools such as TLS and SSH
    - protect against session hijacking, but not against RST-based DoS

Conclusions

- DoS attacks are common and result in substantial losses
  - a number of defenses are effective, but no perfect solution exists
- DNS attacks can also have a large impact
- Manipulating other protocols and information transmitted on the network can result in various types of other attacks