Computer Security: Principles and Practice

Chapter 7: Denial-of-Service Attacks

Denial-of-service

- **Denial of service** (DoS) an action that prevents or impairs the authorized use of networks, systems, or applications by exhausting resources such as central processing units (CPU), memory, bandwidth, and disk space
- Attacks (overload or invalid request services that consume significant resources)
  - network bandwidth
  - system resources
  - application resources

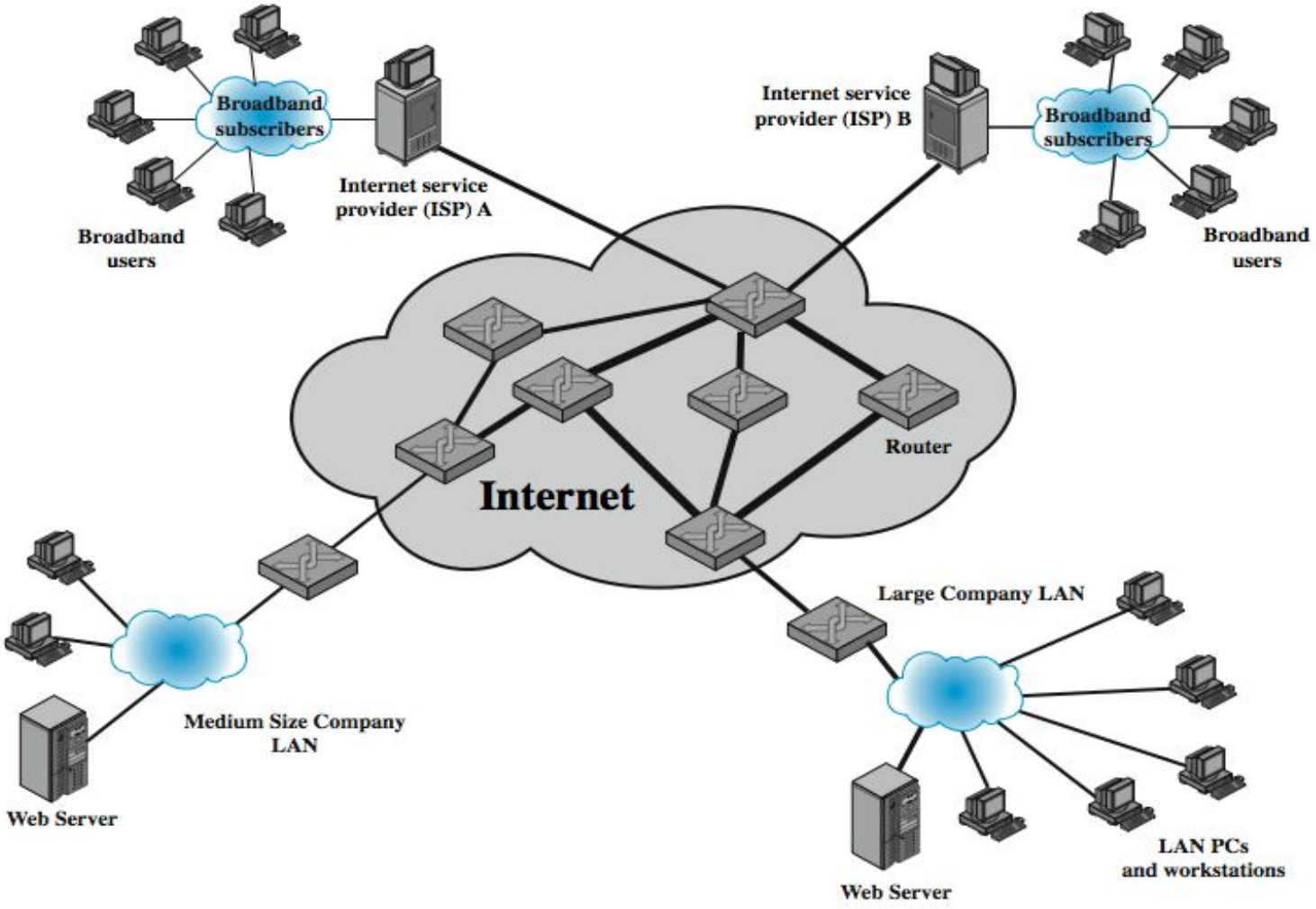
Compromise System Availability

- Have been an issue for some time (25% of respondents to an FBI survey)

Classic DoS attacks

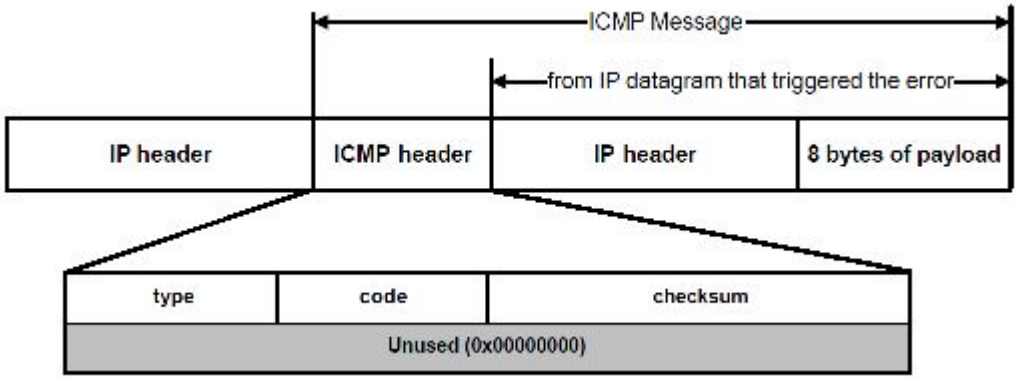
- Flooding ping command
  - Aim of this attack is to overwhelm the capacity of the network connection to the target organization
  - Traffic can be handled by higher capacity links on the path, but packets are discarded as capacity decreases
- Source of the attack is clearly identified unless a spoofed address is used
- Network performance is noticeably affected

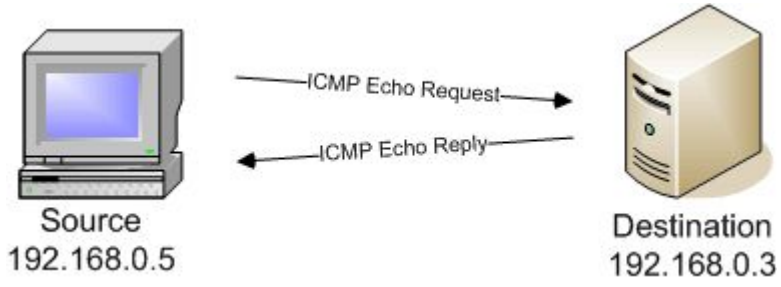
Classic DoS attacks



Internet Control Message Protocol (ICMP)

- The Internet Control Message Protocol (**ICMP**) is one of the main IP protocols; it is used by network devices, like routers, to send error messages (e.g., a requested service is not available or a host or router could not be reached)





The host must respond to all echo requests with an echo reply containing the exact data received in the request message

Source address spoofing

- Use forged source addresses
  - Usually via the raw socket interface on operating systems
  - Makes attacking systems harder to identify
- Attacker generates large volumes of packets that have the target system as the destination address
- Congestion would result in the router connected to the final, lower capacity link
- Backscatter traffic
  - Advertise routes to unused IP addresses to monitor attack traffic

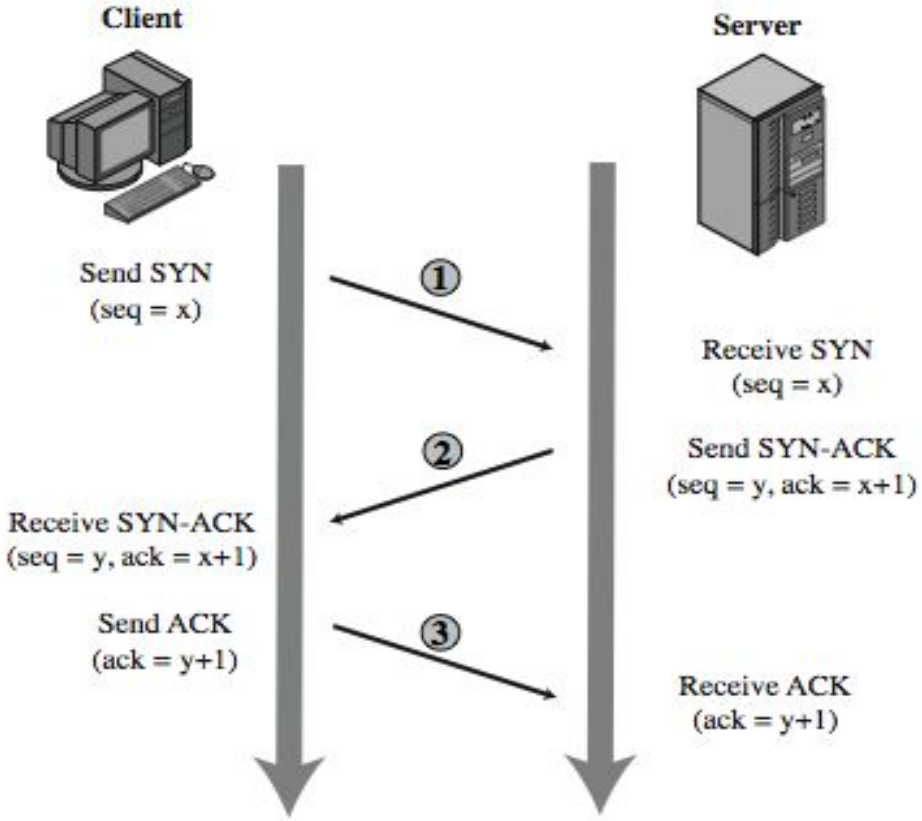
Backscatter traffic

- Security researchers (Honeypot Project) advertise blocks of unused IP addresses (no real/legit uses)
- If ICMP/connection request is made, this is most likely from attackers
- Monitoring unused IP addresses provides valuable info on the type and scale of attack

SYN spoofing

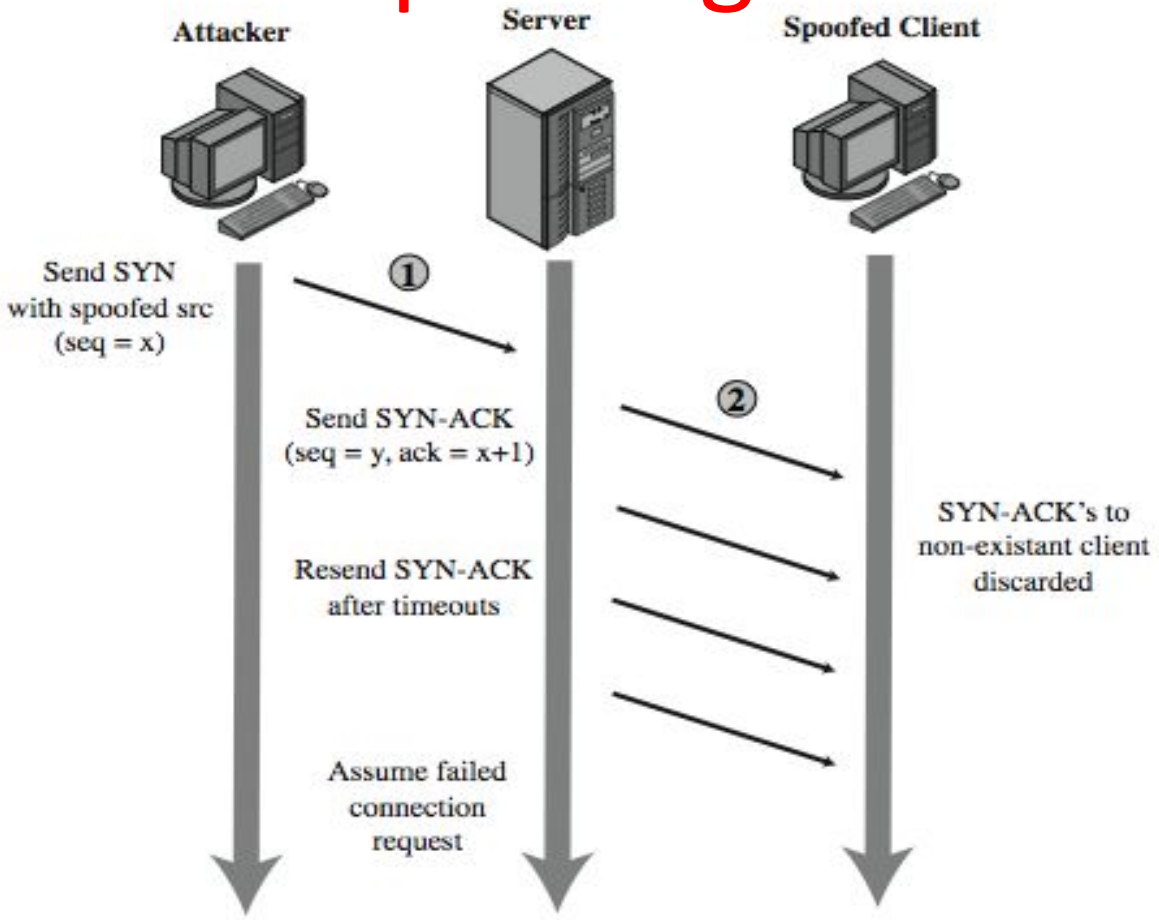
- Common DoS attack
- Attacks the ability of a server to respond to future connection requests by overflowing the tables used to manage them
- Thus legitimate users are denied access to the server
- Hence this is an attack on system resources, specifically the network handling code in the operating system

TCP connection handshake



syn/ack pkts
y= server seq#
x= client seq#

SYN spoofing attack



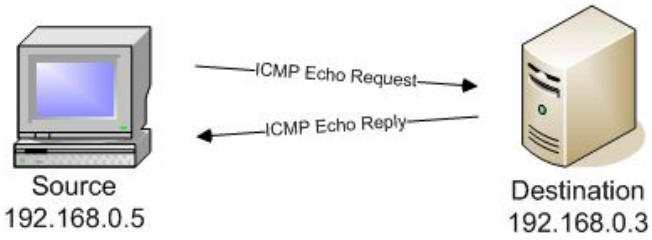
assumption: most connections succeed and thus table cleared quickly

SYN spoofing attack: attacker's source

- Attacker often uses either
  - random source addresses (addresses that may not exist)
  - or that of an overloaded server (that may not send a RST)
  - to block return of (most) reset packets
- Has much lower traffic volume
  - attacker can be on a much lower capacity link
- Objective: uses addresses that will not respond to the SYN-ACK with a RST

Types of flooding attacks

- Classified according to the network protocol used
- Objective: to overload the network capacity on some link to a server
- Virtually any type of network packet can be used
- *ICMP Flood*
  - Uses ICMP packets, eg ping (echo) request
  - Typically allowed through, some required



- *UDP Flood*
  - Alternative uses UDP packets to random ports (even if no service is available, attacker achieves its goal)
- *TCP SYN Flood* (SYN spoof vs SYN flood)
  - Sends TCP SYN (connection request) packets
  - Focuses on volume attack

UDP packet

- User Datagram Protocol (UDP) is a component of the IP suite and allows computer applications to send messages
- A UDP can be directed at practically any service (port); if service is unavailable, the packet is discarded but the attacker objective is achieved

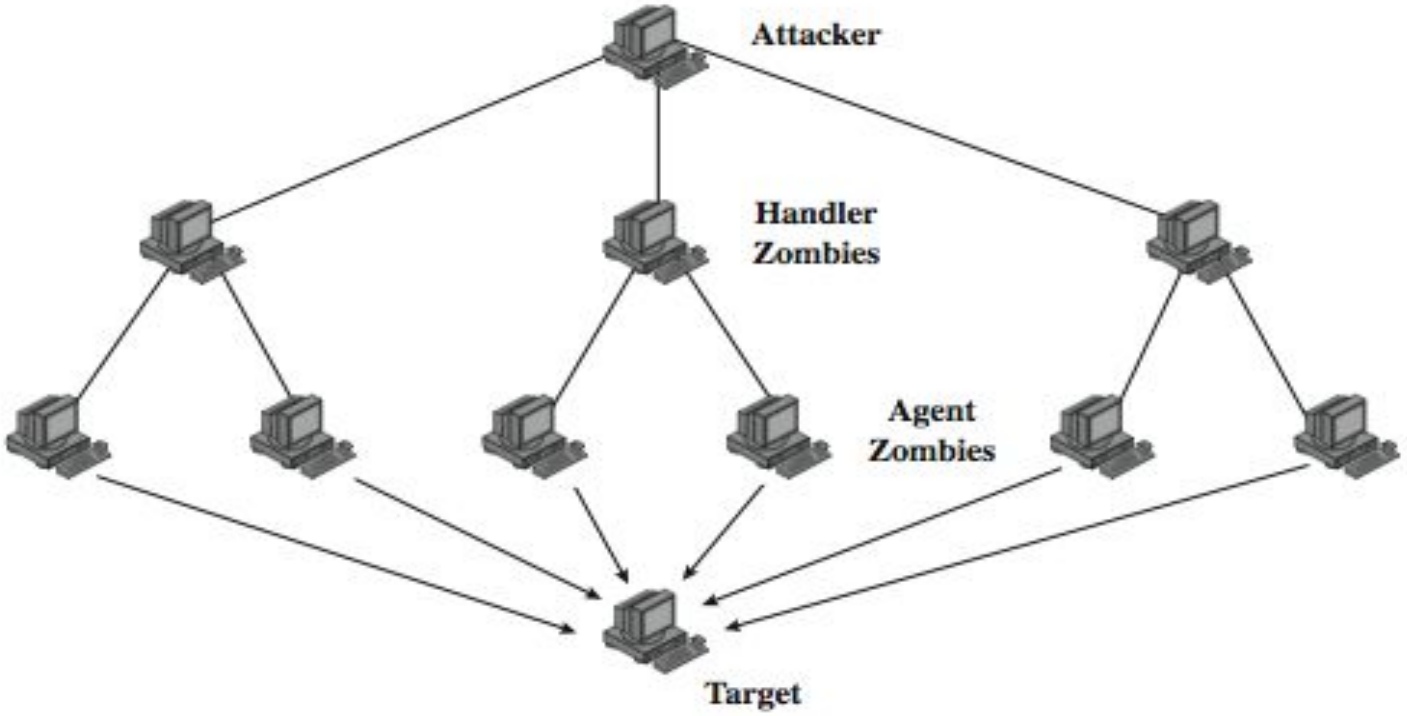
Offset (bits)	Field
0	Source Port Number
16	Destination Port Number
32	Length
48	Checksum
64+	Data ⋮

Distributed DoS attacks

- Have limited volume if single source used
- Multiple systems allow much higher traffic volumes to form a distributed DoS (DDoS) attack
- Often compromised PC's/workstations
  - Zombies with backdoor programs installed
  - Forming a botnet
- Example: Tribe Flood Network (TFN), TFN2K
  - did ICMP, SYN and UDP floods

DDoS control hierarchy

Attacker sends one command to the handler zombies;
the handler forwards to other handlers, agents

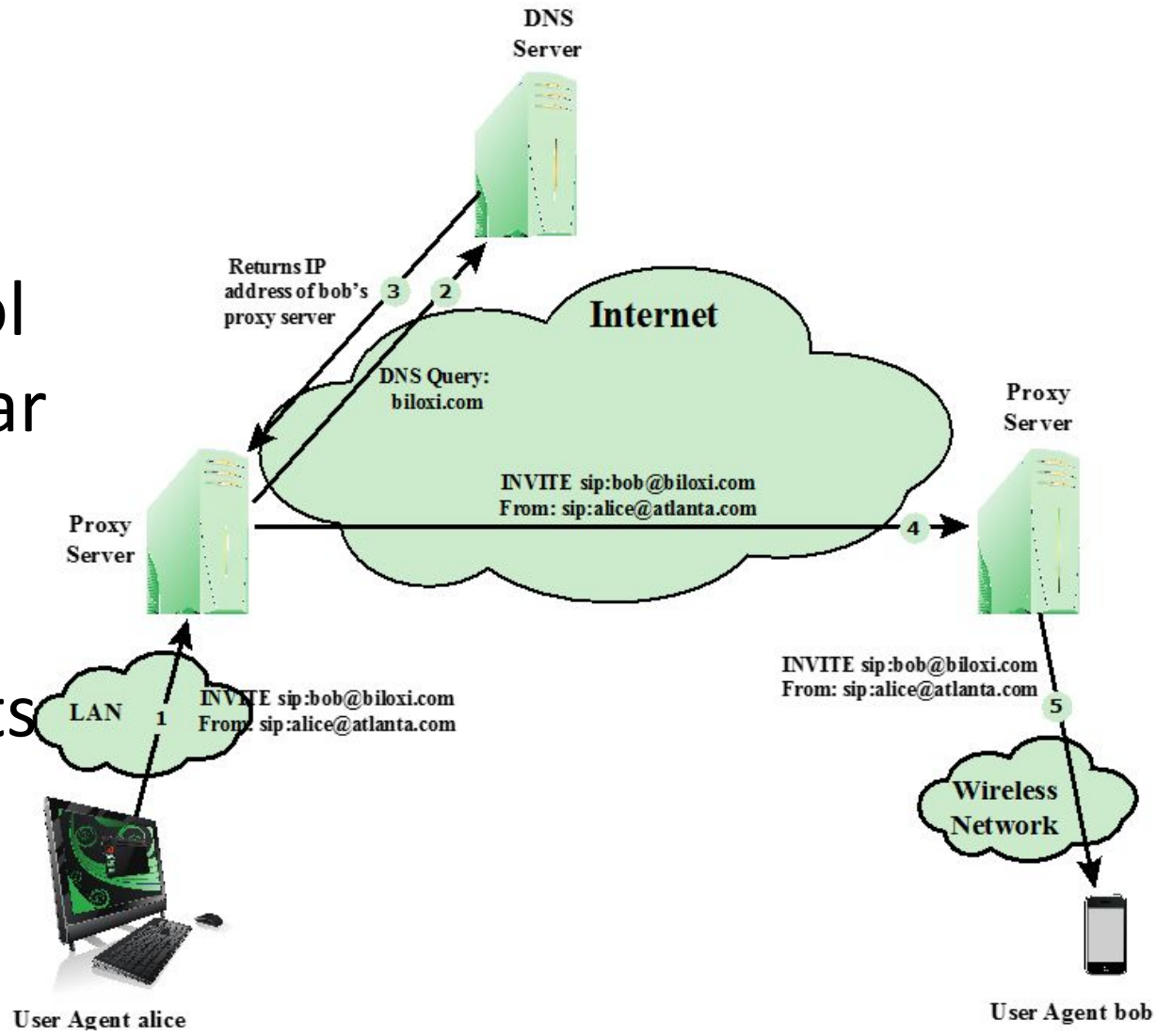


Application-based bandwidth attacks

- Force the victim system to execute resource-consuming operations (e.g., searches, complex DB queries)
- VoIP Session Initiation Protocol (SIP) flood (see Figure 7.5): attacker sends many INVITE requests; major burden on the proxies
  - server resources depleted while handling requests
  - bandwidth capacity is consumed

SIP invite scenario

- Standard protocol for VoIP telephony
- Text-based protocol with a syntax similar to that of HTTP
- Two types of SIP messages: requests and responses



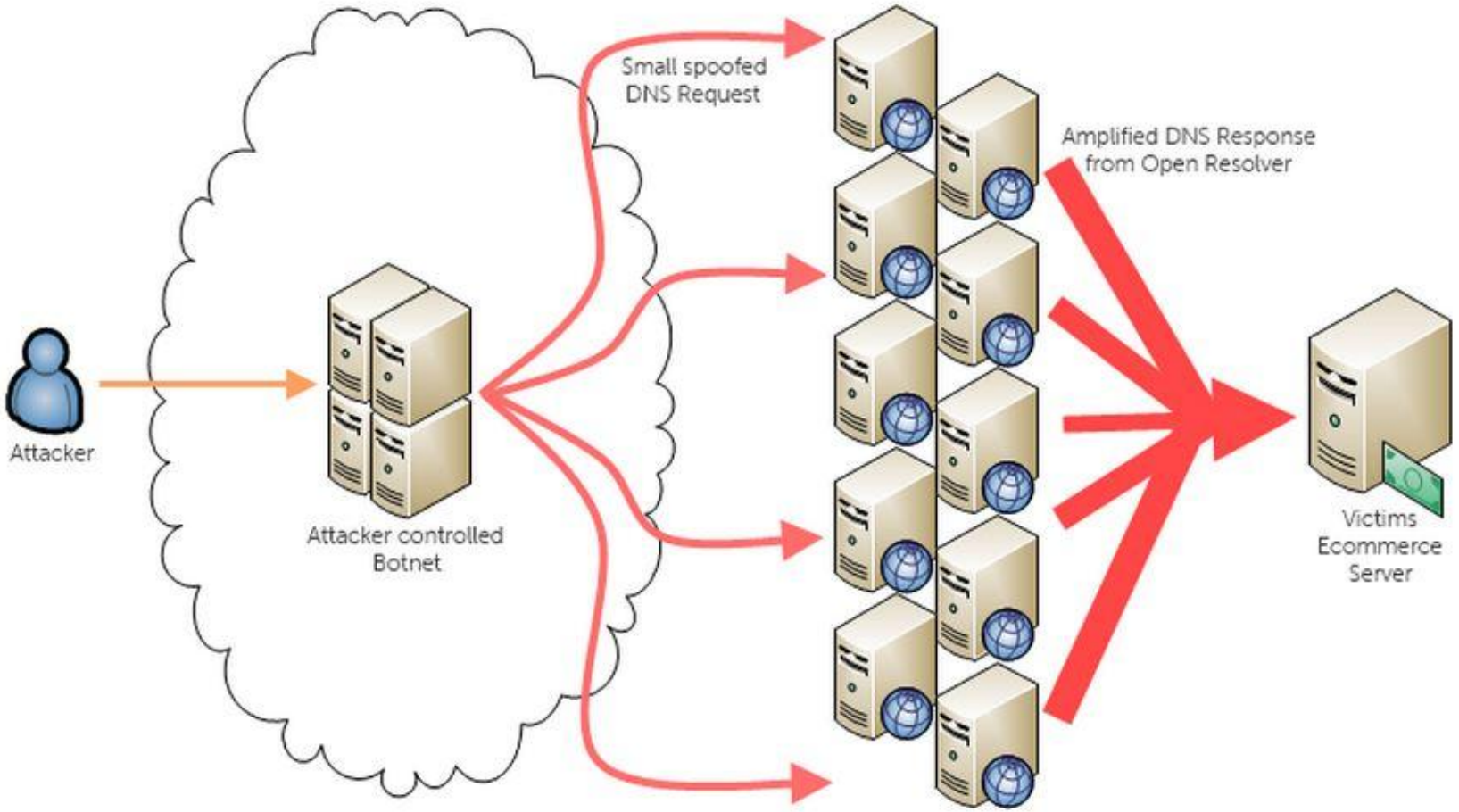
HTTP-based attacks

- *Slowloris*: On each connection, it sends an incomplete request that does not include the terminating newline sequence. Existing intrusion detection and prevention solutions that rely on signatures to detect attacks will generally not recognize Slowloris
  - Attempts to monopolize by sending HTTP requests that never complete
  - Eventually consumes Web server's connection capacity
  - Utilizes legitimate HTTP traffic
- *Spidering*: Bots starting from a given HTTP link and following all links on the provided Web site in a recursive way

Reflection attacks

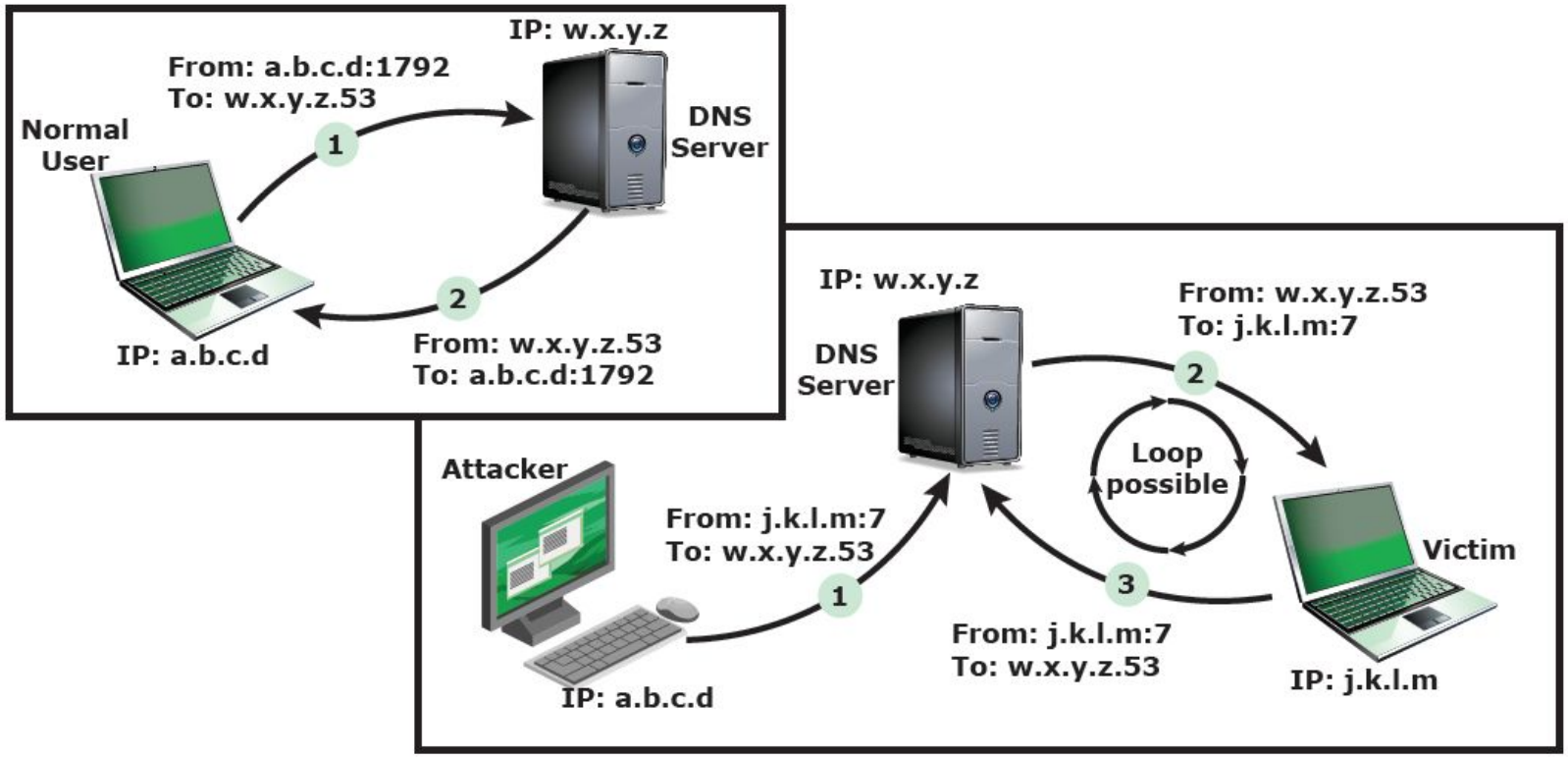
- Attacker sends packets to a known service on the intermediary with a “spoofed source address” of the actual target system
- When intermediary responds, the response is sent to the target
- “Reflects” the attack off the intermediary (*reflector*)
- Goal is to generate enough volumes of packets to flood the link to the target system without alerting the intermediary
- The basic defense against these attacks is blocking spoofed-source packets

Reflection attacks



Reflection attacks

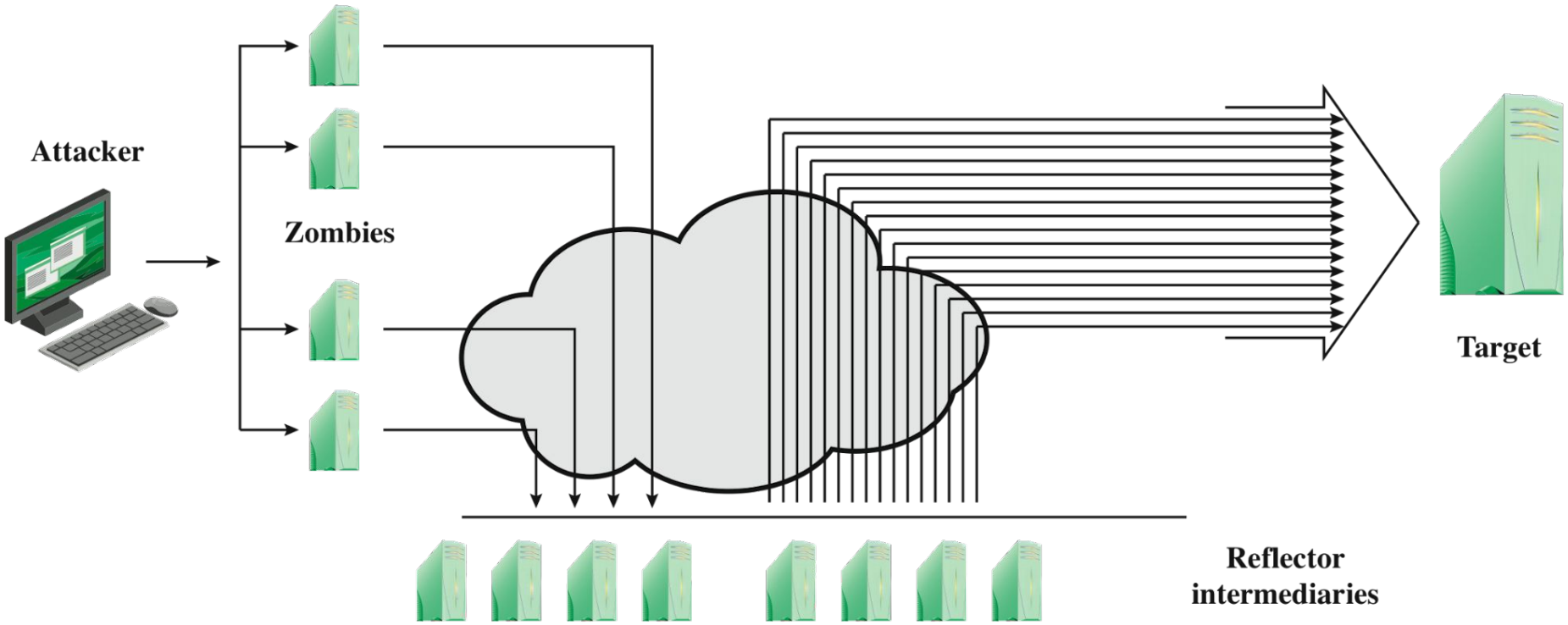
- Further variation creates a self-contained loop between intermediary and target (attacker spoofs using port 7 requiring echoes)
- Fairly easy to filter and block



DNS amplification attacks

- Use packets directed at a legitimate DNS server as the intermediary system
- Attacker creates a series of DNS requests containing the spoofed source address of the target system
- Exploit DNS behavior to convert a small request to a much larger response (amplification)
- Target is flooded with responses
- Basic defense against this attack is to prevent the use of spoofed source addresses

Amplification attacks



Can take advantage of broadcast address of some network

Four lines of defense against DDoS attacks

- Attack prevention and preemption (before attack)
- Attack detection and filtering (during the attack)
- Attack source traceback and identification (during and after the attack)
- Attack reaction (after the attack)

DoS attack prevention

- Block spoofed source addresses
  - On routers as close to source as possible
- Filters may be used to ensure path back to the claimed source address is the one being used by the current packet
  - Filters must be applied to traffic before it leaves the ISP's network or at the point of entry to their network
- Use modified TCP connection handling code
  - Cryptographically encode critical information in a cookie that is sent as the server's initial sequence number
  - Legitimate client responds with an ACK packet containing the incremented sequence number cookie
  - Drop an entry for an incomplete connection from the TCP connections table when it overflows

Attack prevention

- Rate controls in upstream distribution nets
  - On specific packets types e.g. some ICMP, some UDP, TCP/SYN
  - *Impose limits*
- Use modified TCP connection handling
  - Server sends SYN *cookies* when table full (reconstruct table data from the cookie from legit clients)
  - Selective or random drop when table full

Attack prevention

- Block IP directed broadcasts
- Block suspicious services and combinations
- Manage application attacks with a form of graphical puzzle (captcha) to distinguish legitimate human requests
- Use mirrored and replicated servers when high-performance and reliability is required

Responding to attacks

- Good incidence response plan
  - Details on how to contact technical personal for ISP
  - Needed to impose traffic filtering upstream
  - Details of how to respond to the attack
- Implement anti-spoofing, directed broadcast, and rate limiting filters
- Ideally have network monitors and IDS to detect and notify abnormal traffic patterns

Responding to attacks

- Identify type of attack
  - Capture and analyze packets
  - Design filters to block attack traffic upstream
  - Or identify and correct system/application bug
- Have ISP trace packet flow back to source
  - May be difficult and time consuming
  - Necessary if planning legal action
- Implement contingency plan
  - Switch to alternate backup servers
  - Commission new servers at a new site with new addresses
- Update incident response plan

Summary

- Introduced denial of service (DoS) attacks
- Classic flooding and SYN spoofing attacks
- ICMP, UDP, TCP SYN floods
- Distributed denial of service (DDoS) attacks
- Reflection and amplification attacks
- Defenses against DoS attacks
- Responding to DoS attacks