

Network Security - Week 7

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DCC/FCUP

2025

Previously...

- Authentication schemes to withstand attacks
 - Authentication protocols
 - TLS/IPSec
- Encryption and MACs to protect data
 - Key exchange
 - Secure communication via TLS/SSH

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Denial-of-Service (DoS)

NIST security incident handling guide defines DoS as:

“An action that prevents or impairs the authorized use of networks, systems, or applications by exhausting resources such as CPU, memory, bandwidth and disk space”

Denial-of-Service

- A form of attack on the availability of services
- Is often done in a distributed fashion (DDoS)
- *Resource categories* that can be attacked:
 - Network bandwidth
 - System resources
 - Application resources

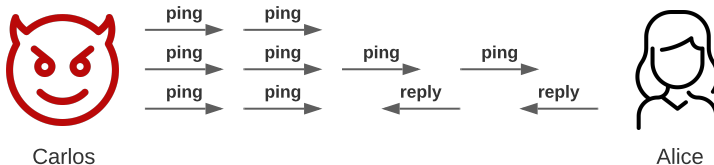
- A form of attack on availability of services
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 - Network bandwidth
 - Relates to the capacity of the network links connecting a server to the Internet
 - For most organizations, this is their connection to their ISP
 - System resources
 - Application resources

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- Is often done in a distributed fashion (DDoS)
- *Resource categories* that can be attacked:
 - Network bandwidth
 - System resources
 - Aims to overload or crash the network handling software
 - Consume resources in the system (e.g. buffers for arriving packets, tables of open connections)
 - Application resources

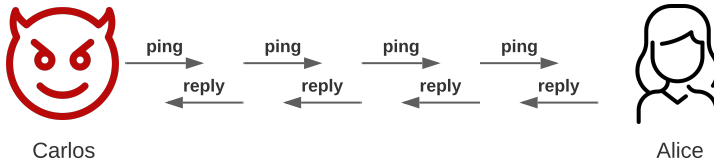
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- *Resource categories* that can be attacked:
 - Network bandwidth
 - System resources
 - Application resources
 - Propose several valid requests to a server within the target system
 - Each request consumes significant resources, limiting the server response ability

Ping Flood attack

Attacker with greater bandwidth...



Alice with greater bandwidth...



DoS Attacks - Flooding ping

The goal of the attack is to **overwhelm** the capacity of the network connection to the victim organization

- E.g. Internet Control Message Protocol echo request packets

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- E.g. Internet Control Message Protocol echo request packets
- Traffic can be handled by higher capacity links on the path, but packets are **discarded** as capacity increases
- Network performance is noticeably affected
- Source of the attack is clearly identified
 - ... unless a spoofed address is used
 - Zombie servers are very useful!



Flooding Attacks - Truly a Classic

- Classified based on the network protocol used
- Goal: to overload the network capacity on some link to a server
- Virtually *any* type of network packet can be used

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ICMP flood

- Ping flood using ICMP echo request packets
- Traditionally, network admins allow these packets into their networks
- A good tool for diagnostics!

UDP/TCP flood

- Direct UDP packets to a specific port number on a system
- ... or TCP packets, depending on the systems of target victim!
- Brute force attack

UPD Flood Attack

- Hacker sends UDP packets to a random port
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Common tool for the job: diagnostic echo service (measure RTTs)

- Respond with UDP packet back to the source
- If service is not running, packet is discarded. ICMP destination unreachable packet returned to the sender
- Achieved its goal of occupying capacity on the link to the server!

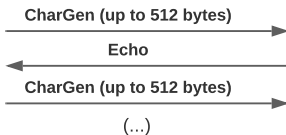
Reflection Attacks

- Attacker sends packets to a known service on the intermediary with a *spoofed* source address on the actual victim
- When the intermediary responds, the reply is sent to the victim
- “Reflects” the attack off the intermediary (reflector)

Goal: To generate enough volumes of packets to flood the link to the target system without alerting the intermediary

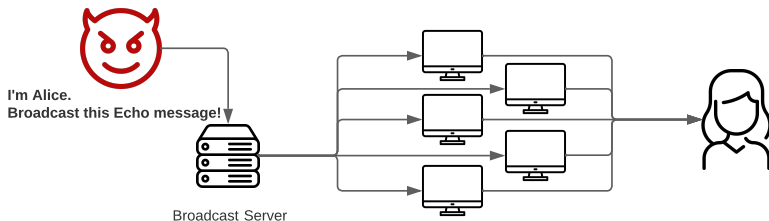
Echo-Chargen

I'm Alice, I'm listening at port 07.
Send me that CharGen nonsense!



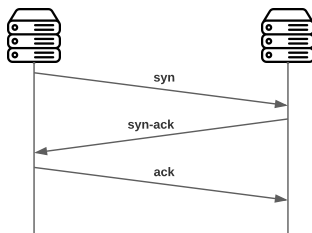
- *Requirement:* Source address spoofing (easy)
- Echo service (port 07) sends back whatever it receives
- CharGen is a character generation service
 - Used for debugging (of course...)
- Huge amounts of data form an endless loop!

Smurf Attack



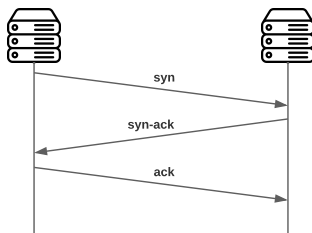
- *Requirement:* Source address spoofing (easy)
- *Requirement:* Access to a server within the network
- Server broadcasts echo “from Alice” to the whole network
- Alice is blasted by echo messages from a bunch of machines

TCP - Establish connection



- 1 A client sends a SYN (synchronize) message
- 2 The server replies with a SYN-ACK message
- 3 The client concludes with a ACK (acknowledge) message

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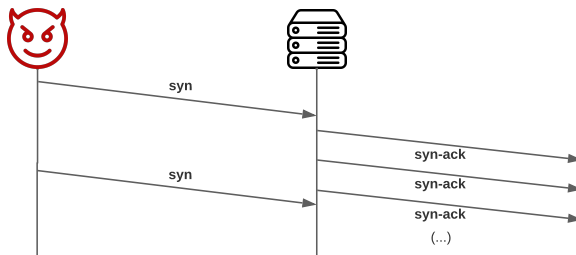


- ❶ A client sends a SYN (synchronize) message
- ❷ The server replies with a SYN-ACK message
- ❸ The client concludes with a ACK (acknowledge) message
 - Channel is only established upon receiving the ACK message
 - Until then, the handshake is on-hold
 - Wasting resources...

SYN Spoofing attack

- Common DoS attack
- Attacks the ability of a server to respond to future connection requests
 - Overflows tables used to manage TCP connections
- Legitimate users are denied access to the server
- An attack on *system resources*, specifically the network handling code in the operative system

SYN Spoofing attack



- Attacker sends SYN with spoofed source
 - Source does not exist, will not reply
- Server replies with SYN-ACK
 - and after time out, sends another, and another...
- Eventually, connection request is assumed to fail
- Until that happens, these occupy table space
- Rinse and repeat
- Mitigation with SYN cookies¹

¹SYN cookies

Kaspersky DoS Report

Kaspersky regularly publishes reports statistical information²

Interesting titbits

- Attacks last longer
 - Average duration of an attack in Q1, 2021: 30 minutes
 - Average duration of an attack in Q2, 2022: 3000 minutes (2 days)
 - DDoS attacks on HTTP(S) in Q3 2022, exceeded those on TCP for the first time

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- New record duration of attack – 41441 minutes (≈ 29 days)
 - Very expensive – machines wear-off and nodes fail
 - Experts wonder about expertise, affiliation and funding of attackers

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- New record duration of attack – 41441 minutes (≈ 29 days)
 - Very expensive – machines wear-off and nodes fail
 - Experts wonder about expertise, affiliation and funding of attackers
- Attacks are down from Q1 to Q2, but increase again on Q3
 - Consistent with the decline of cryptocurrency
 - Stimulates the heating of the DDos market

Methodology

- Use multiple systems to generate attacks
- Attacker uses a flaw in operative system or in a common application to gain access and install a program on it (zombie)



Speaking of Distributed Denial of Service

Methodology

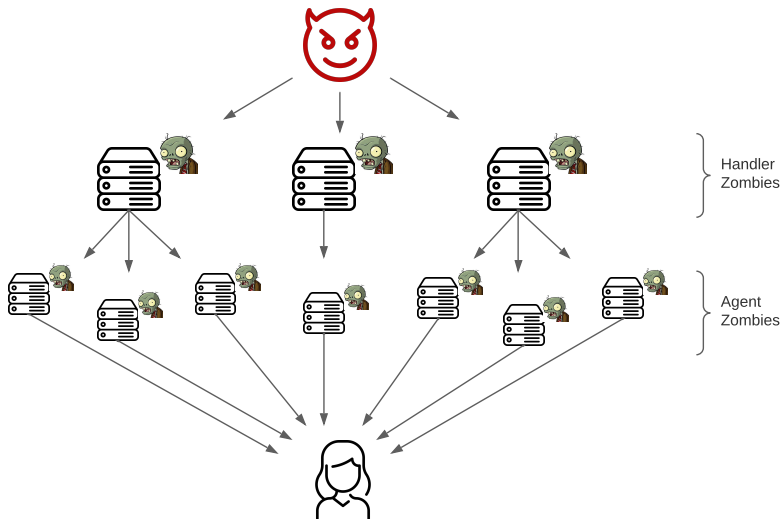
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- This method can be applied to gain access to large collections of such systems, which are then used to perform attacks (*botnet*)



DDoS Control Hierarchy



A network of computers infected with malicious software (a.k.a. malware) that allows them to be controlled by an attacker (zombies)

- Botnets are used to commit a variety of cybercrimes
 - Spam; Scams; Hacks; DDoS

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Attack-as-a-Service

- Command and Control servers (C&C) are responsible for commanding infected computers
- Allows the attacker (bot-herder) to put the botnet to use
- Services of botnets can be provided to paying customers
 - The larger the botnet, the more powerful the cybercrime
 - More computational power; more messages can be sent in parallel

HTTP Flood

- Attack that bombards Web servers with HTTP requests
- Typically DDoS
 - Requests come from many different hosts
- Consumes considerable resources
- Spidering
 - Start from an HTTP link and follow all links on a Website recursively

Going back to attacks - HTTP

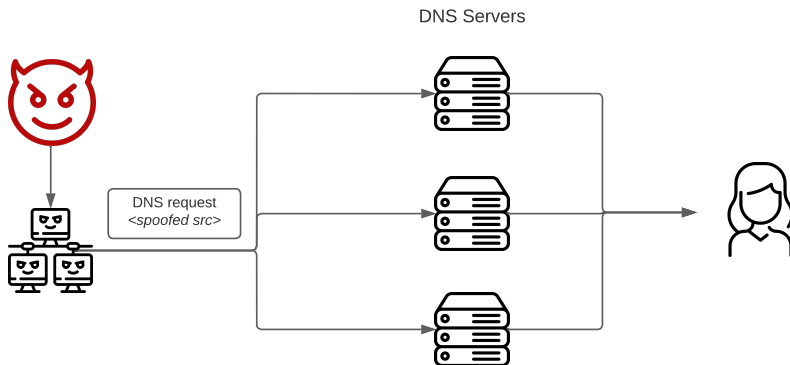
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Slowloris

- Send *legitimate* HTTP requests that never complete
- Exploits techniques to support parallel processing of requests
- Blocks all threads for establishing connections
- Current intrusion detection/prevention solutions relying on signatures do not recognize slowloris

DNS Amplification Attack



DNS Amplification Attack

- Use DNS requests with spoofed source IP address being the target
 - Alice, in the previous picture
- Exploit DNS behavior to convert a small request to a much larger response
 - Argument “ANY” produces large responses
 - 60 byte request can lead to a 512-4000 byte response
- Attacker sends request to multiple well connected servers, flooding the target
 - Only needs a moderate flow of request packets
 - ... Thus hard to detect
 - ... And also effective against DNS servers

Mitigating DNS Amplification

Not a lot of choices...

- A volumetric attack - large volumes of traffic are generated
 - Pressure is not only on the victim, but also on the surrounding infrastructure
- ISP may *blackhole* traffic (next!)

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Alternatives

- Reduce the total number of open DNS resolvers
- Restricting a DNS resolver to only respond to queries from *trusted* sources
- Have ISPs actively detect spoofed IP addresses
 - Ingress Filtering (Whitelist/Blacklist for IP addresses)
 - Collaborative ISP DDoS detection (not always possible...)

DDoS Blackhole Routing

- Traffic is routed into a null route and is lost.
 - From legitimate and illegitimate sources
 - The goal is to prevent a service from being flooded
- An aggressive countermeasure to blocking DDoS attacks
- Often **too severe a measure**

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Shutting down Youtube

In 2008 Youtube was down after Pakistan Telecom's use of blackhole routing^a

- Dutch cartoon depicting images deemed improper led to a government order to shut down a specific video
- Blackhole routing applied to *all* users trying to access Youtube.
- Pakistan Telecom shared this route with worldwide ISPs: all Youtube-bound traffic went through Pakistan telecom, which would then be dropped.

^a<https://www.cloudflare.com/learning/ddos/glossary/ddos-blackhole-routing/>

Back to Amplification Attacks

Protocol	Bandwidth Amplification Factor	Vulnerable Command
DNS	28 to 54	see: TA13-088A [4]
NTP	556.9	see: TA14-013A [5]
SNMPv2	6.3	GetBulk request
NetBIOS	3.8	Name resolution
SSDP	30.8	SEARCH request
CharGEN	358.8	Character generation request
QOTD	140.3	Quote request
BitTorrent	3.8	File search
Kad	16.3	Peer list exchange
Quake Network Protocol	63.9	Server info exchange
Steam Protocol	5.5	Server info exchange
Multicast DNS (mDNS)	2 to 10	Unicast query
RIPv1	131.24	Malformed request
Portmap (RPCbind)	7 to 28	Malformed request
LDAP	46 to 55	Malformed request [6]
CLDAP [7 ^{cf}]	56 to 70	—
TFTP [23 ^{cf}]	60	—
Memcached [25]	10,000 to 51,000	—
WS-Discovery	10 to 500	—

- Commands to UDP protocols elicit very large responses
- Depending on the protocol, this is a nice way to upscale attacks
- Table based on the NCAS analysis (source)

NTP Amplification Attacks

An innocuous service for clock synchronization...

- Same MO as previous attacks:
 - 1 Find a service that has a good reply-to-request ratio
 - 2 Spoof source IP to forward packets to the victim
 - 3 Profit!

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Concretely...

- Use MONLIST to get the peers list
- Generates the last 600 IP addresses connected to the NTP
- Send those to Alice

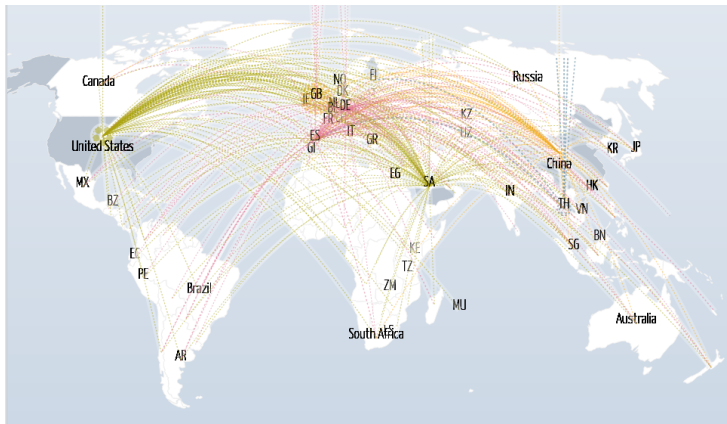
Simple Service Discovery Protocol

Used by Universal Plug and Play to advertise and search for services/devices over the network

- Attack is based on a UDP request over M-SEARCH
- Can request ssdp:all - i.e. all services that a given device offers
- Uses by default multicast address for destination, but can be set to use unicast
- Open on the WAN side (available over the internet)
- Post from Cloudflare describes how this “Stupidly Simple” attack can be used to generate a 100Gbps DDoS

Denial-of-Service Monitoring

Digital Attack Map presents data gathered and collected by the ATLAS system (330 ISP, over 130Tbps of global traffic)



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According to the website and its references

- 150\$ are sufficient to acquire a week-long DDoS attack on the black market
 - Attacks are cheaper and more powerful
- More than 2000 daily DDoS attacks can be observed world-wide
 - Sources, Destinations, Types and Duration all over the place
- 1/3 of all downtime incidents can be attributed to DDoS attacks
 - They may not be elegant, but they are effective

Denial of Service

- Denial of Service attacks aim to disrupt system resources
- The common tactic is to overwhelm the network
 - Flooding ping; Echo Chargen; Smurf Attack; SYN Spoofing

Wrap up

Denial of Service

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Botnets and Attacks

- Corrupted machines zombified to help with attacks
- Botnets are hierarchical systems of zombies
- Used to upscale attacks

Wrap up

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Countermeasures

- Hard to counteract
- Requires proactive policies and spoofing prevention
- And a good back-up plan for when they happen

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