Network and Protocol Security

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Seminario di Complementi di Reti

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Classes of Attacks

We will focus on:

- Unauthorized access and information gathering
- Packet capture and analysis
- Host impersonation
- Denial of Service

Structure of the talk

We will study every class of attack by showing historical examples and techniques, following this order:

- Network access layer
- Internet layer
- Transport layer
- Application layer (and/or protocols)

Information Gathering

- Many successful cyber attacks are social engineering attacks
- Information Gathering is crucial for social engineering
- Possible solutions:
  - Authentication
  - Authorization
  - Security through obscurity (weak)
  - Hardening (requires lots of knowledge)

Service and port scanning

- Pingscan: map hosts of a network using ICMP echo datagrams
- UDP port scanning:
  - Send 0 length packets to every port
  - If ICMP “port unreachable” error is sent back, service is unavailable
- TCP connect() port scanning:
  - Open a connection to every port
  - If handshake is successful, service is alive

Advanced port scanning

Previous techniques are very noisy and easily detectable

- TCP SYN scanning:
  - Attackers sends a SYN packet
  - If the server responds with SYN/ACK packet, the service is available
  - If the server responds with a RST packet, the service is unavailable
  - The attackers reply with a RST packet instead of ACK so that the connection is not open and the event is not logged

Advanced port scanning #2

Many other flags combinations for TCP:

- TCP FIN scanning:
  - Attackers sends a FIN flagged packet
  - If the server ignores the packed, the port is open
  - If the server responds with a RST packet, the service is unavailable
  - Could be done with PSH, URG and even no flags

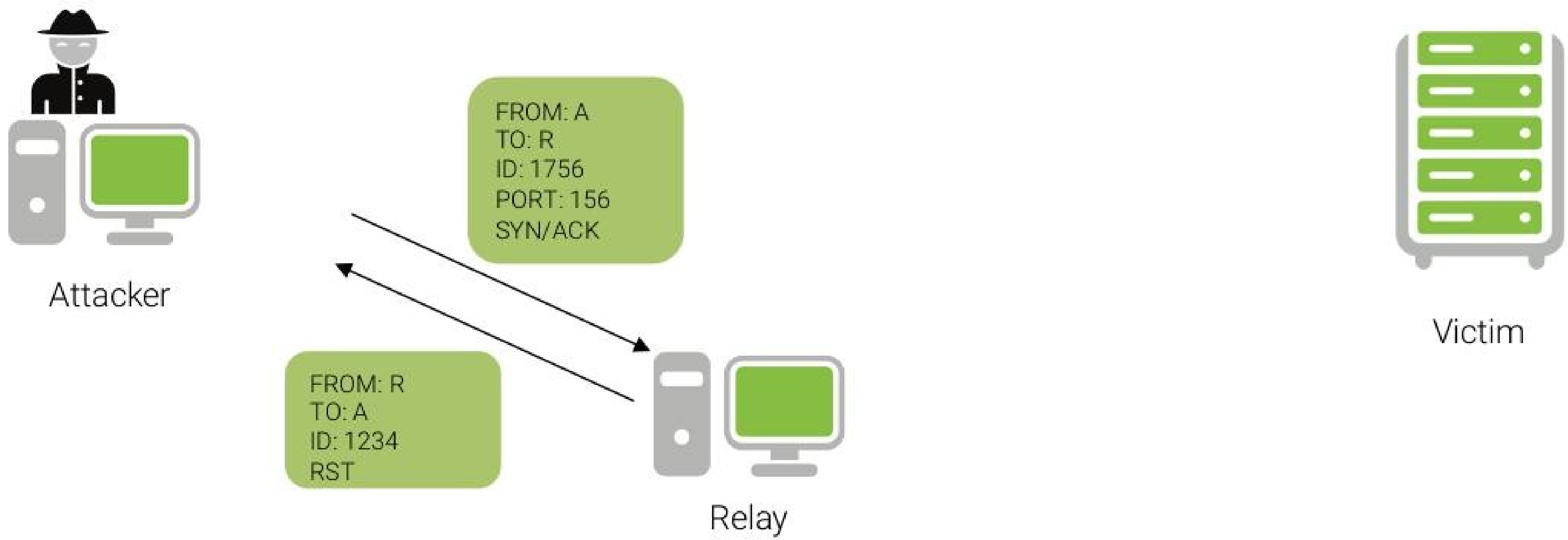
<u>All of these techniques rely on undocumented methods:</u>

<u>the results are not reliable and difficult to reproduce</u>

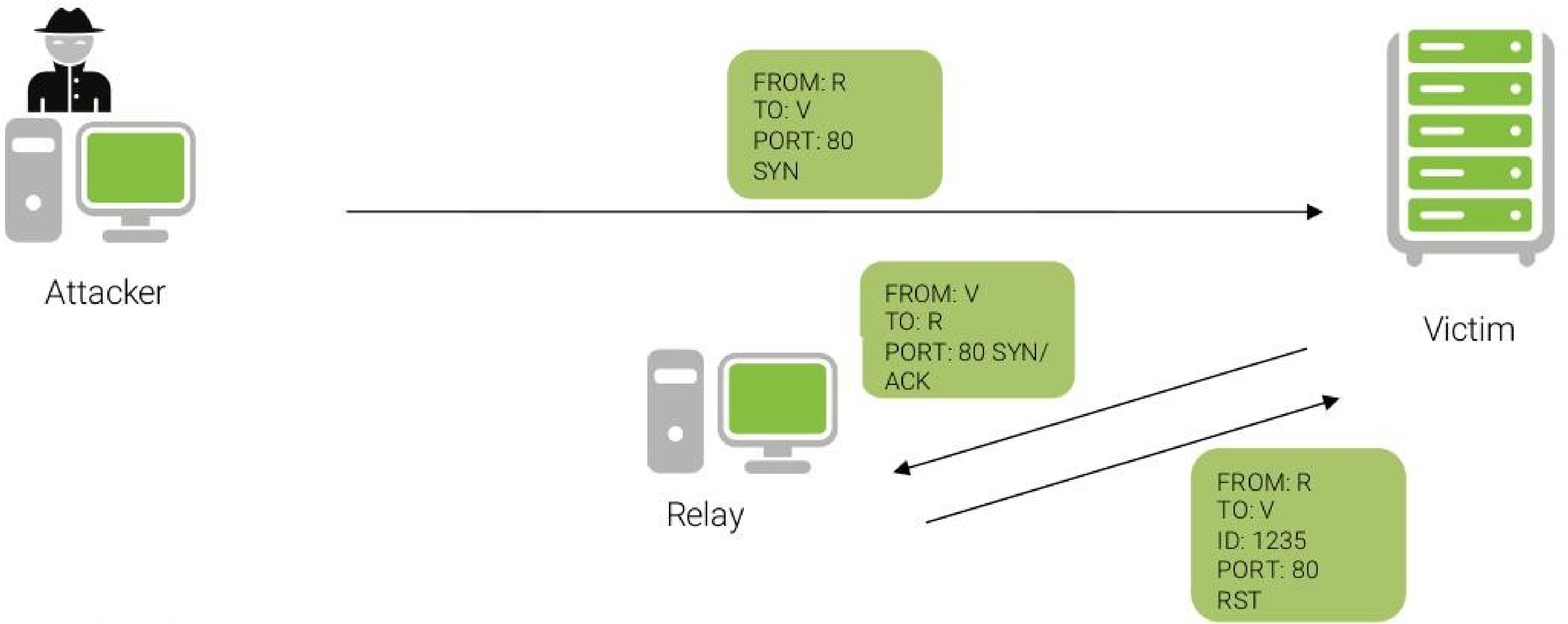
Idle Scanning

- Uses a victim host to “relay” the scan
- The attacker sends spoofed TCP SYN packets to the target
- The packets appear to come from the victim
- The target replies to the victim
  - If the target replies with a SYN+ACK packet (open port) then the victim will send out a RST
  - If the target replies with a RST (closed port) then the victim will not send out any packet
- The attacker checks the IP datagram ID of the victim before and after each port probe
  - If it has increased: port on target was open
  - If it has not increased: port on target was closed

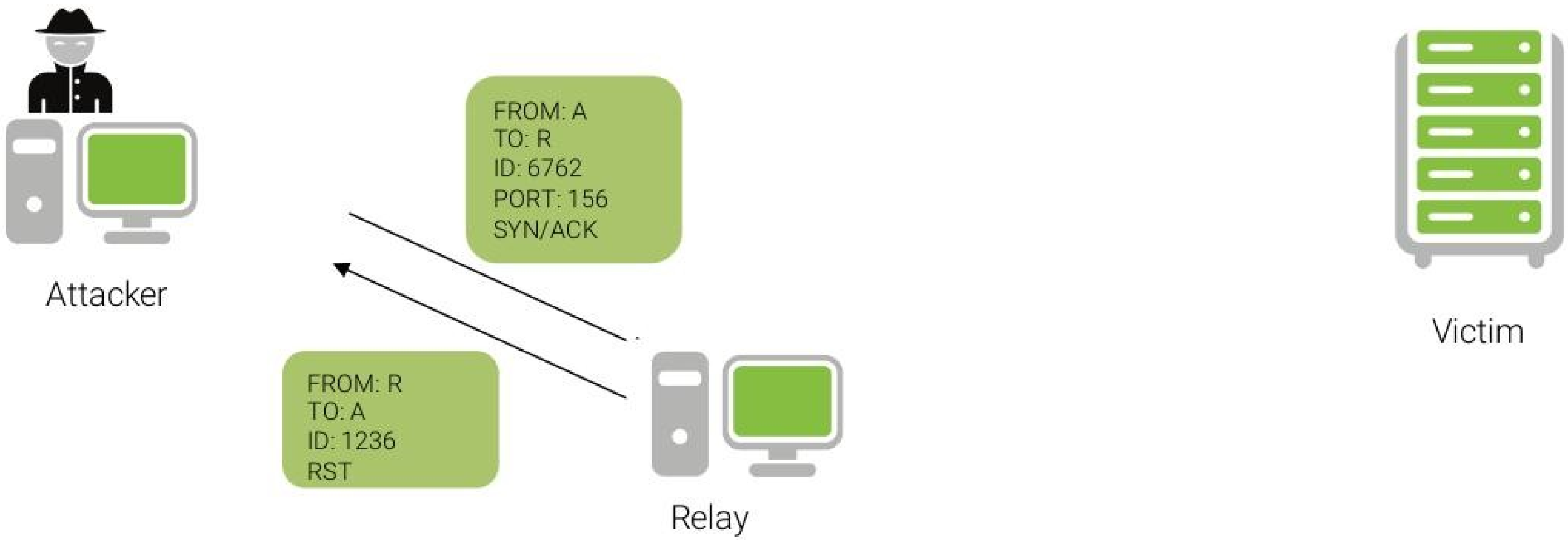
Step 1: determine the relay's initial IP sequence number



Step 2: send a spoofed connection request



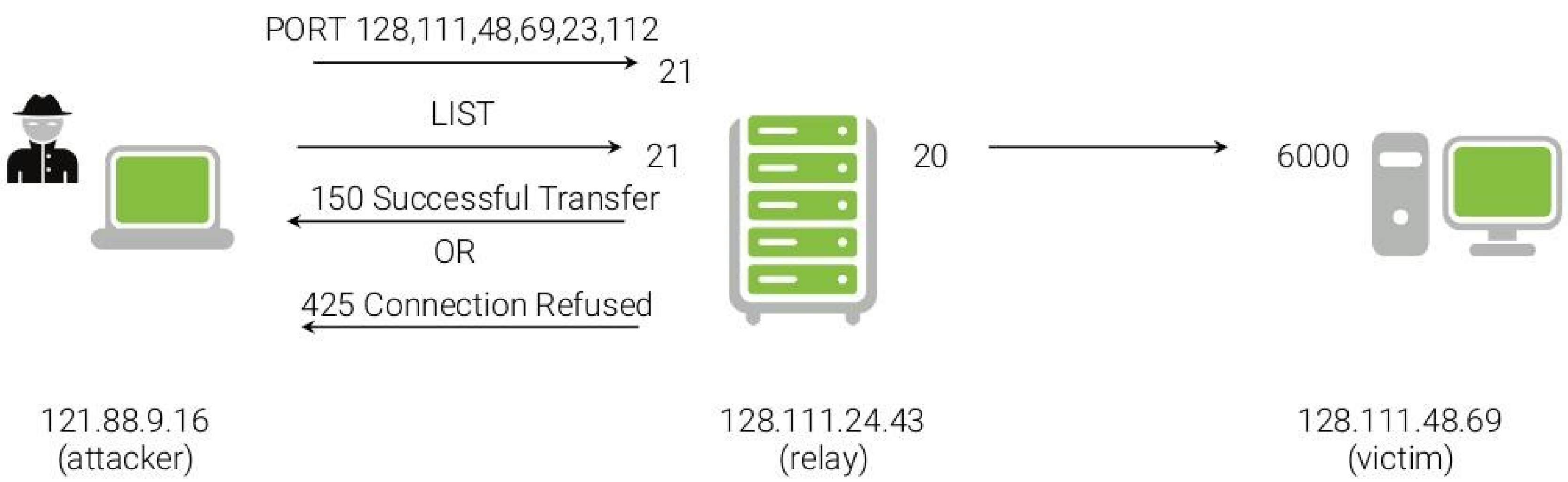
Step 3: determine the relay's final IP sequence number



FTP Bounce Scan

- In the FTP protocol uses two stream for control and data
- The PORT command is used by the client to tell the server the address and port to be used when opening a data connection
- The data port need not be in the same host that initiates the FTP commands via the control connection
- Therefore it is possible to instruct a server to open a connection to a third host

Example


PORT 128,111,48,69,23,112
21
LIST
21
150 Successful Transfer
OR
425 Connection Refused
20
6000
121.88.9.16
(attacker)
128.111.24.43
(relay)
128.111.48.69
(victim)

FTP Bounce Attack

- Can be used to execute a TCP portscan
  - The host that appears to be the source of the scan is the FTP server
  - It is possible to scan a host that is behind a firewall exploiting the trust relationship
- Can be used to bypass restrictions and access control

OS fingerprinting

Determine the operating system of a host by examining the reaction to carefully crafted packets, up to the kernel version, and exploit unpatched vulnerabilities

- Wrong answers to FIN TCP packets
- “Undefined” flags in the TCP header of a request are copied verbatim in the reply
- Weird combinations of flags in the TCP header
- Selection of TCP initial sequence numbers
- Selection of initial TCP window size
- Analysis of the use of ICMP messages
- Error rate
  - Amount of offending datagram included
  - TCP options

- OS fingerprinting also can be performed in a passive way using tools such as p0f, ettercap or by performing the same analysis on different protocols

Packet capture and analysis

- The act intercepting and logging traffic over a link, A.K.A. sniffing
- Easier in the case of wireless networks and hubs
- In switched environments, the attacker must convince the switch to send him a copy of the traffic
- Passive form of information gathering
- Depending on network configuration, very hard to detect

Tools

- May protocols sends information in clear:
  - FTP, HTTP, IMAP, XMPP, etc…
- Even if the payload is encrypted, attackers can collect metadata
- Tools:
  - libpcap
  - tcpdump, tcp replay, tcpflow
  - Burp
  - Wireshark

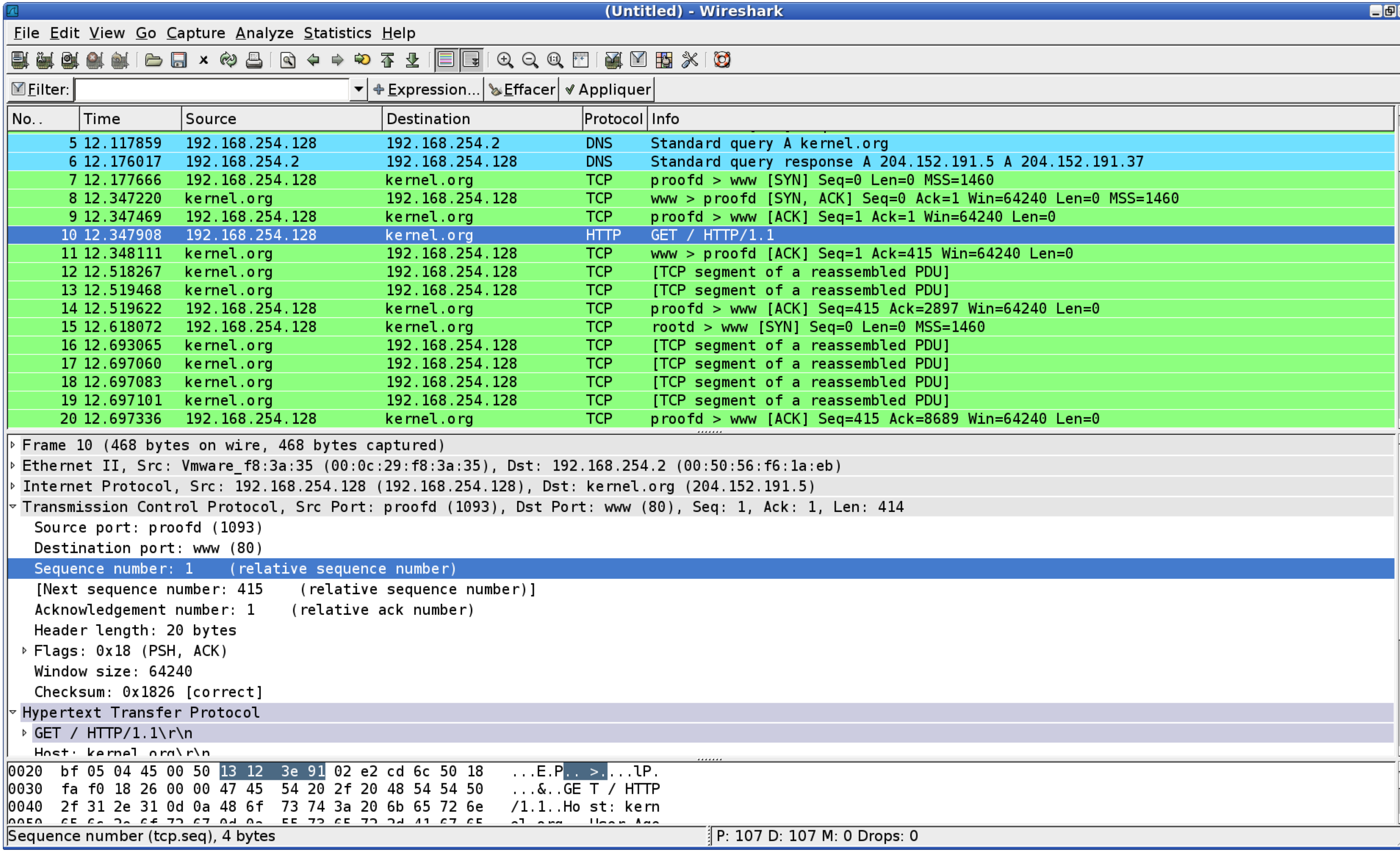
Sniffing in promiscuous networks

- Hubs, wireless networks are susceptible to sniffing
- Network cards can be configured to accept packets sent to different interfaces
  - Promiscuous mode
  - Monitor mode
- Wardriving / wardialing: access points and hosts can be probed without any prior knowledge or physical access

Sniffing in switched Ethernet

Switched Ethernet does not allow direct sniffing

- MAC flooding
  - Switches maintain a table with MAC address/port mappings
  - In some cases, flooding the switch with bogus MAC addresses will overflow the table's memory and revert the behavior from "switch" to "hub"
- MAC duplicating/cloning
  - Attacker reconfigures his/her host to have the same MAC address as the target machine
  - The switch will record this in its table and send the traffic to the attacker machine (or possibly both)


(Untitled) - Wireshark
File Edit View Go Capture Analyze Statistics Help
Filter:
Expression... Effacer Appliquer
No. Time Source Destination Protocol Info
5 12.117859 192.168.254.128 192.168.254.2 DNS Standard query A kernel.org
6 12.176017 192.168.254.2 192.168.254.128 DNS Standard query response A 204.152.191.5 A 204.152.191.37
7 12.177666 192.168.254.128 kernel.org TCP proofd > www [SYN] Seq=0 Len=0 MSS=1460
8 12.347220 kernel.org 192.168.254.128 TCP www > proofd [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0 MSS=1460
9 12.347469 192.168.254.128 kernel.org TCP proofd > www [ACK] Seq=1 Ack=1 Win=64240 Len=0
10 12.347908 192.168.254.128 kernel.org HTTP GET / HTTP/1.1
11 12.348111 kernel.org 192.168.254.128 TCP www > proofd [ACK] Seq=1 Ack=415 Win=64240 Len=0
12 12.518267 kernel.org 192.168.254.128 TCP [TCP segment of a reassembled PDU]
13 12.519468 kernel.org 192.168.254.128 TCP [TCP segment of a reassembled PDU]
14 12.519622 192.168.254.128 kernel.org TCP proofd > www [ACK] Seq=415 Ack=2897 Win=64240 Len=0
15 12.618072 192.168.254.128 kernel.org TCP rootd > www [SYN] Seq=0 Len=0 MSS=1460
16 12.693065 kernel.org 192.168.254.128 TCP [TCP segment of a reassembled PDU]
17 12.697060 kernel.org 192.168.254.128 TCP [TCP segment of a reassembled PDU]
18 12.697083 kernel.org 192.168.254.128 TCP [TCP segment of a reassembled PDU]
19 12.697101 kernel.org 192.168.254.128 TCP [TCP segment of a reassembled PDU]
20 12.697336 192.168.254.128 kernel.org TCP proofd > www [ACK] Seq=415 Ack=8689 Win=64240 Len=0
Frame 10 (468 bytes on wire, 468 bytes captured)
Ethernet II, Src: Vmware_f8:3a:35 (00:0c:29:f8:3a:35), Dst: 192.168.254.2 (00:50:56:f6:1a:eb)
Internet Protocol, Src: 192.168.254.128 (192.168.254.128), Dst: kernel.org (204.152.191.5)
Transmission Control Protocol, Src Port: proofd (1093), Dst Port: www (80), Seq: 1, Ack: 1, Len: 414
Source port: proofd (1093)
Destination port: www (80)
Sequence number: 1 (relative sequence number)
[Next sequence number: 415 (relative sequence number)]
Acknowledgement number: 1 (relative ack number)
Header length: 20 bytes
Flags: 0x18 (PSH, ACK)
Window size: 64240
Checksum: 0x1826 [correct]
Hypertext Transfer Protocol
GET / HTTP/1.1\r\n
0020 bf 05 04 45 00 50 13 12 3e 91 02 e2 cd 6c 50 18 ...E.P.. >....lP.
0030 fa f0 18 26 00 00 47 45 54 20 2f 20 48 54 54 50 ...&..GE T / HTTP
0040 2f 31 2e 31 0d 0a 48 6f 73 74 3a 20 6b 65 72 6e /1.1..Ho st: kern
Sequence number (tcp.seq), 4 bytes
P: 107 D: 107 M: 0 Drops: 0

Host impersonation

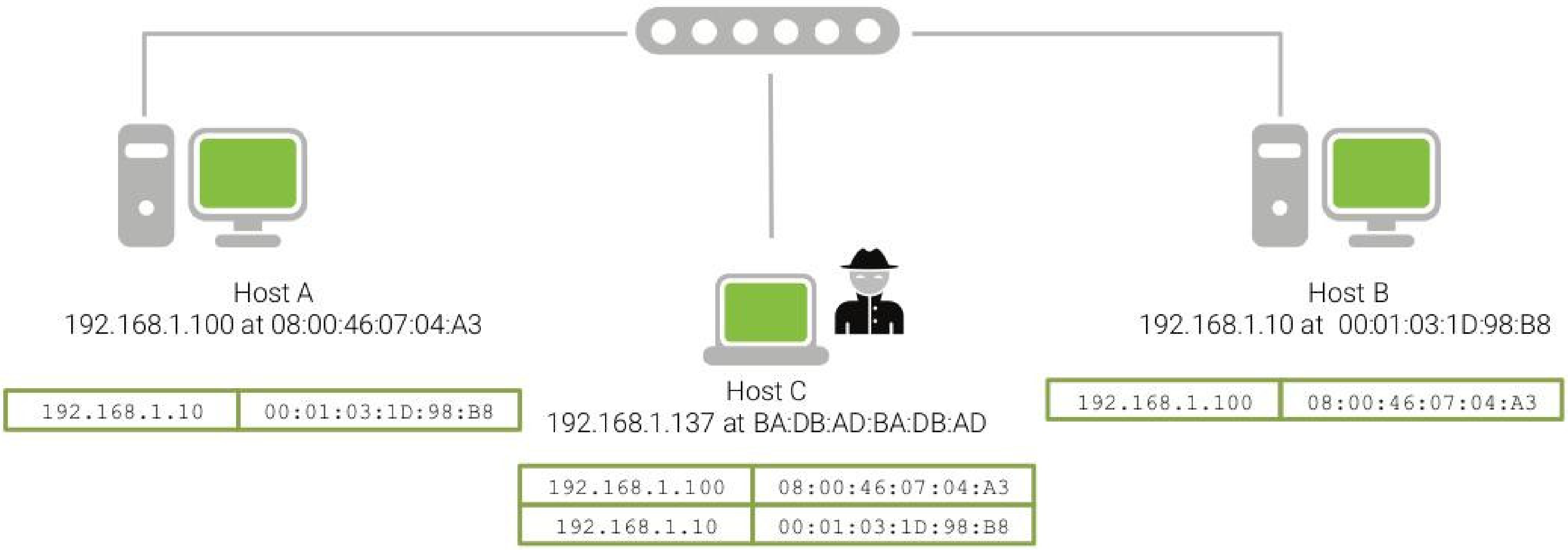
- The attacker disguises himself as the known source or the destination host of the communication
- It manipulates the protocol by forging the data used for routing and access
- Also known as spoofing
- Particularly effective in the absence of authentication and identity verification

ARP spoofing

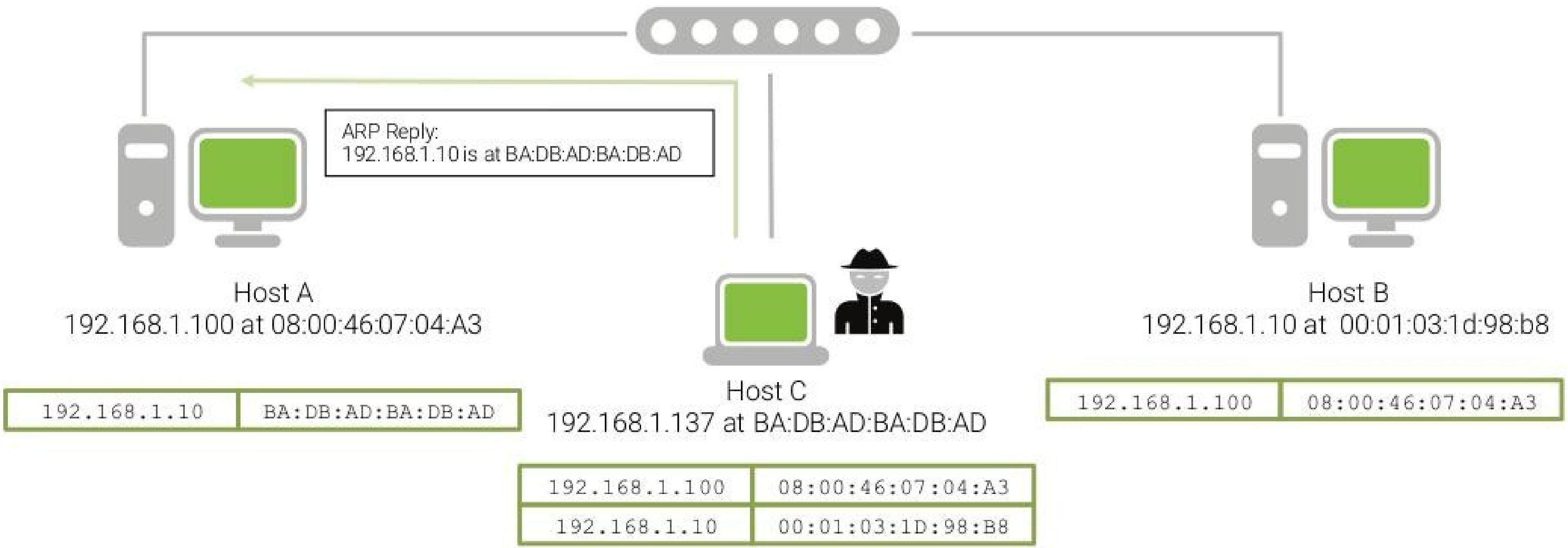
Sniff and manipulates traffic between two hosts in a switched environment

- The attack leverages the stateless nature of the ARP protocol
  - Replies without a request will be accepted
- The attacker host sends spoofed ARP messages to the two victim hosts, poisoning their cache
- The victim host sends their IP packets to the attacker host
  - The attacker host acts has a router
  - Continuously monitor and resend spoofed ARP replies

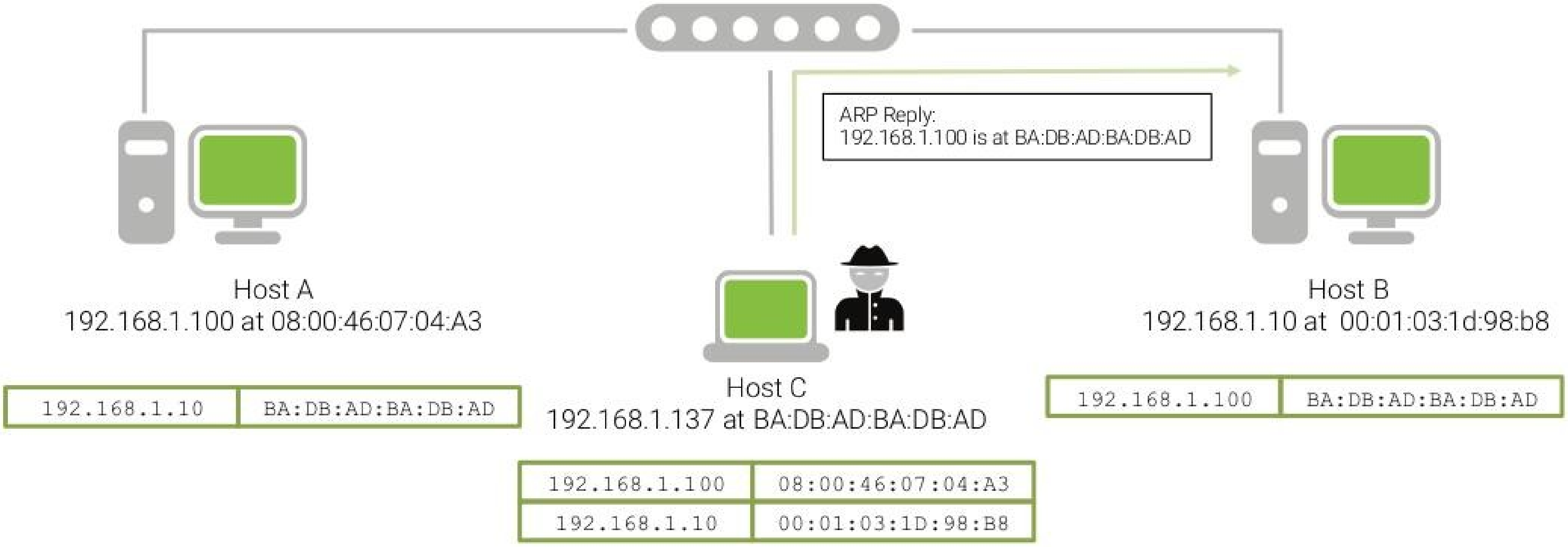
Poisoning the ARP table #1



Poisoning the ARP table #2



Poisoning the ARP table #3



ARP Spoofing Defense

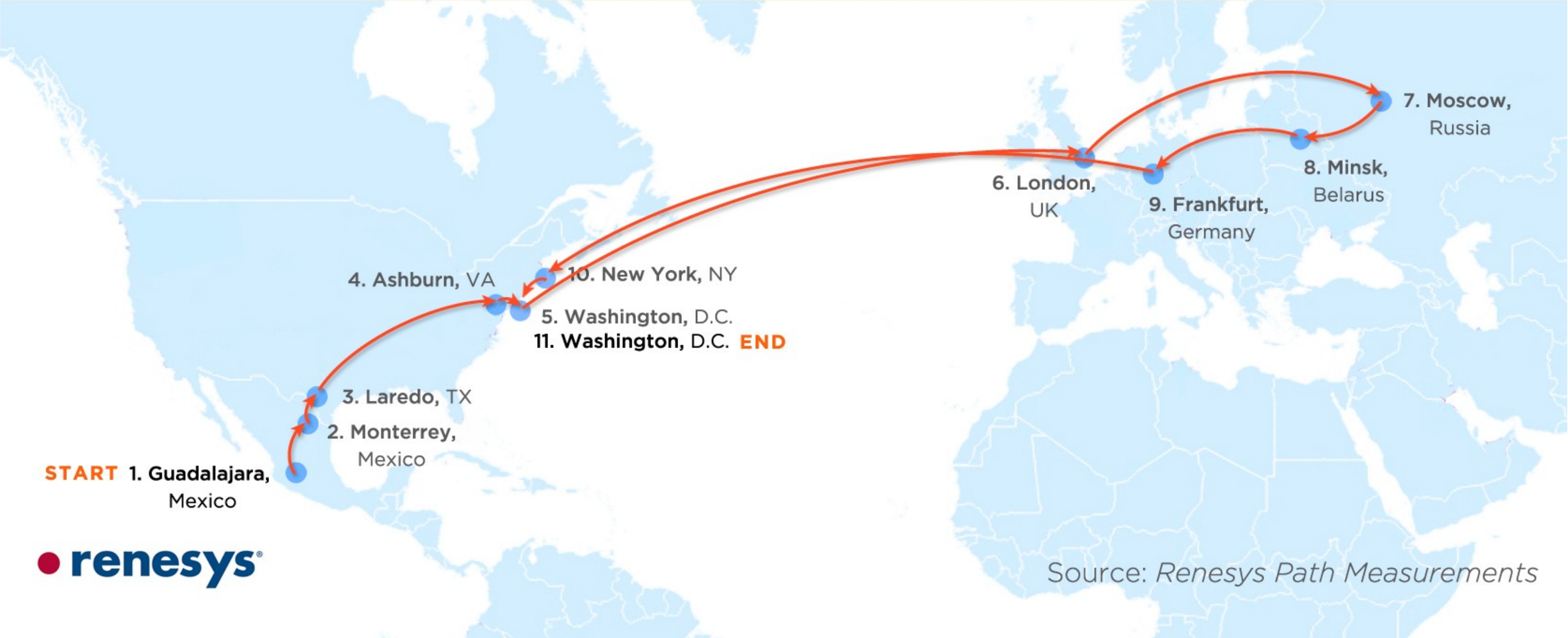
- Static ARP entries
  - The ARP cache can be configured to ignore dynamic updates
  - Difficult to manage in large deployments
  - Could be used for a subset of critical addresses (e.g., DNS servers, gateways)
- Cache poisoning resistance
  - Ignore unsolicited ARP replies (still vulnerable to races)
  - Update on timeout (weak)
- Monitor changes (arpwatch)
  - Listen for ARP packets on a local Ethernet interface
  - Keep track for Ethernet/IP address pairs
  - Report suspicious activity and changes in mapping

BGP Rerouting

- BGP stores many paths for a given destination
- Best path is chosen in relation to a list of attributes: granular control over which AS gets the traffic
- Malicious nodes can advertise false attributes

  - Weight
  - Local Preference
  - Originate
  - AS Path length
  - Origin Code
  - MED
  - eBGP vs IBGP
  - Shortest IGP to next BGP
  - Oldest Path
  - Router ID
  - Neighbor IP Address
  - Others depending on vendor

Traceroute Path 1: from Guadalajara, Mexico to Washington, D.C. via *Belarus*



IP Spoofing

- Used to impersonate sources of security-critical information
- IP spoofing is used to exploit address-based authentication in higher-level protocols
- Many tools available
  - Protocol-specific spoofers (DNS spoofers, NFS spoofers, etc)
  - Generic IP spoofing tools (e.g., hping)
  - Libraries: libnet, scapy

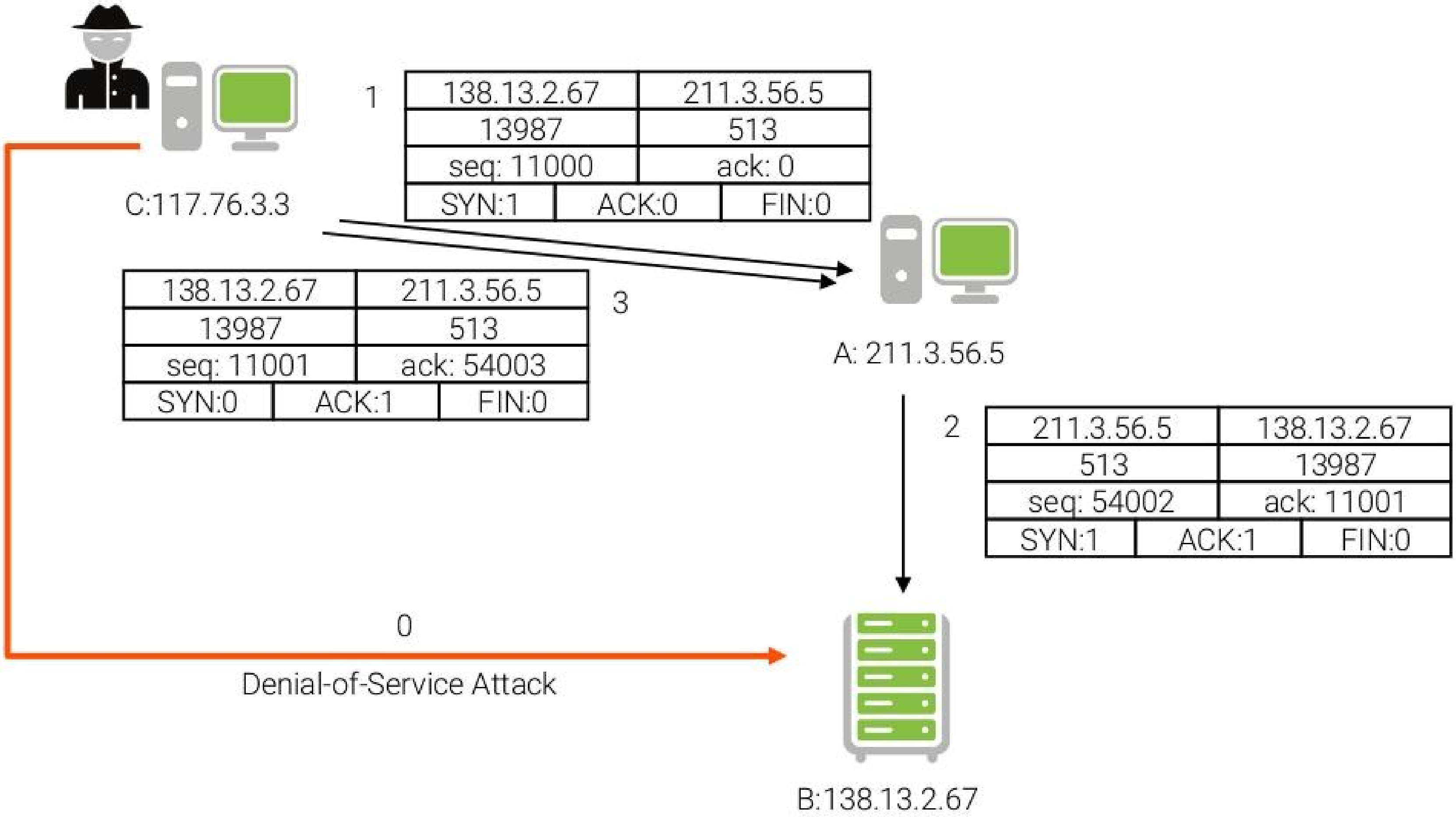
Blind IP Spoofing

- The attacker sends an IP datagram with the address of some other host as the source address
- The attacked host replies to the impersonated host
- Usually the attacker does not have access to the reply traffic
- Can be used to exploit misconfigurations

TCP Spoofing

- Alice trusts Bob
- Eve wants to impersonate Bob with respect to Alice in opening a TCP connection
- Eve kills Bob (flooding, crashing, redirecting) so that Bob does not send annoying RST segments
- Eve sends a TCP SYN segment to Alice in a spoofed IP packet with Bob's address and seq num Ss
- Alice replies with a TCP SYN/ACK segment to Bob with seq num Sc. Bob ignores the segment: dead or too busy
- Eve does not receive this segment but to finish the handshake it has to send an ACK segment with Ss + 1 as the ack number
- Eve eavesdrop the SYN/ACK segment
- Eve guesses the correct sequence number Sc

Example



1
138.13.2.67 | 211.3.56.5
13987 | 513
seq: 11000 | ack: 0
SYN:1 | ACK:0 | FIN:0
C:117.76.3.3
3
138.13.2.67 | 211.3.56.5
13987 | 513
seq: 11001 | ack: 54003
SYN:0 | ACK:1 | FIN:0
A: 211.3.56.5
2
211.3.56.5 | 138.13.2.67
513 | 13987
seq: 54002 | ack: 11001
SYN:1 | ACK:1 | FIN:0
0
Denial-of-Service Attack
B:138.13.2.67

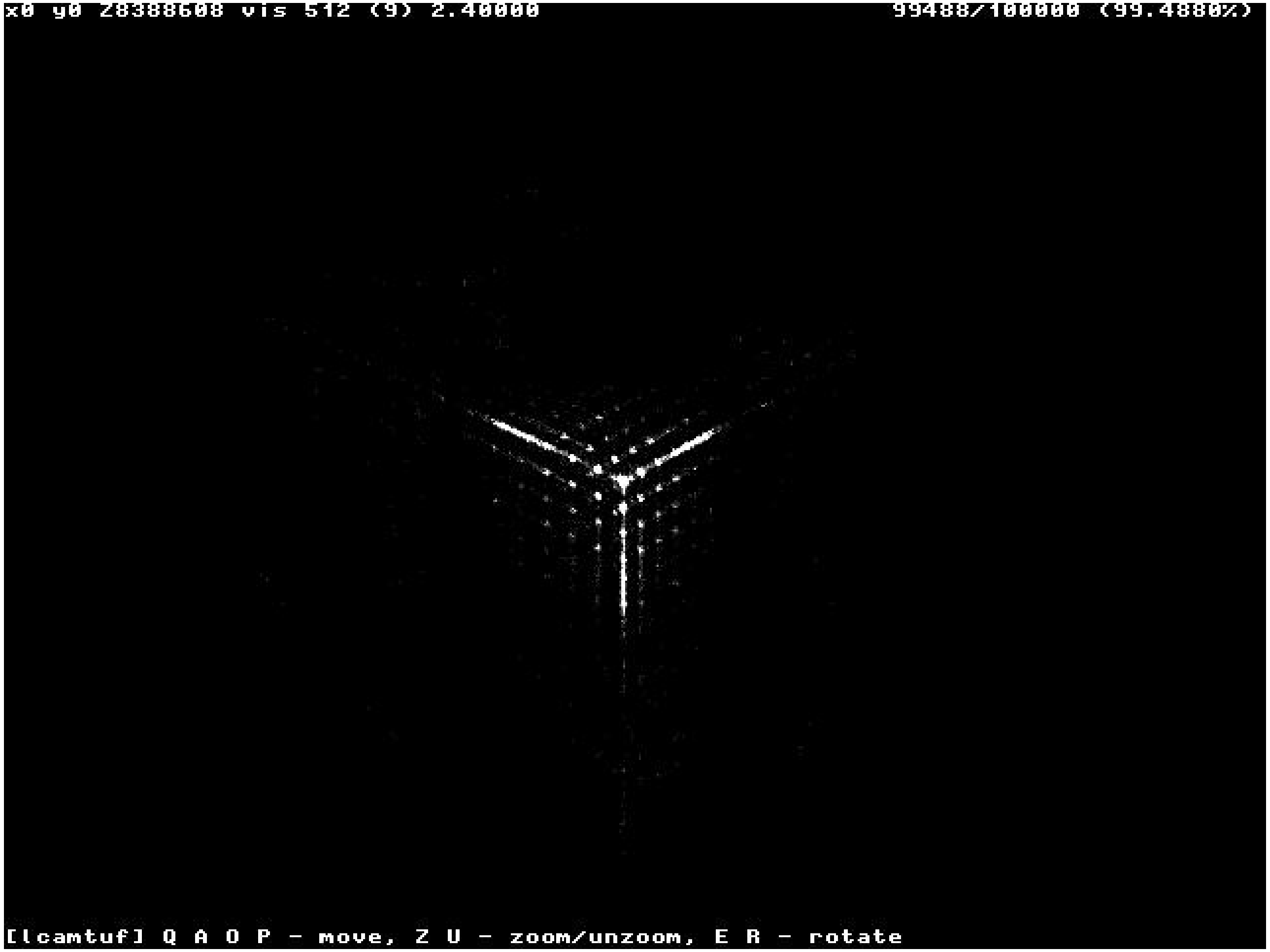
The Kevin Mitnick Attack

- 1992, Kevin Mitnick wanted to access Tsutomu Shimomura's X-Terminal computer
- Shimomura’s terminal was accepting connection only from a trusted IP 125.126.127.128
- Mitnick killed 125.126.127.128 by DOS’ing (we will see later this attack)
- He knew beforehand by “guess and retry” that: $Seq^{th+1} = Seq^{th} + 128\,000$
- Made a spoofed TCP three way handshake and successfully guessed the correct seq num
- The TCP payload contained: “echo + + >> /.rhost”

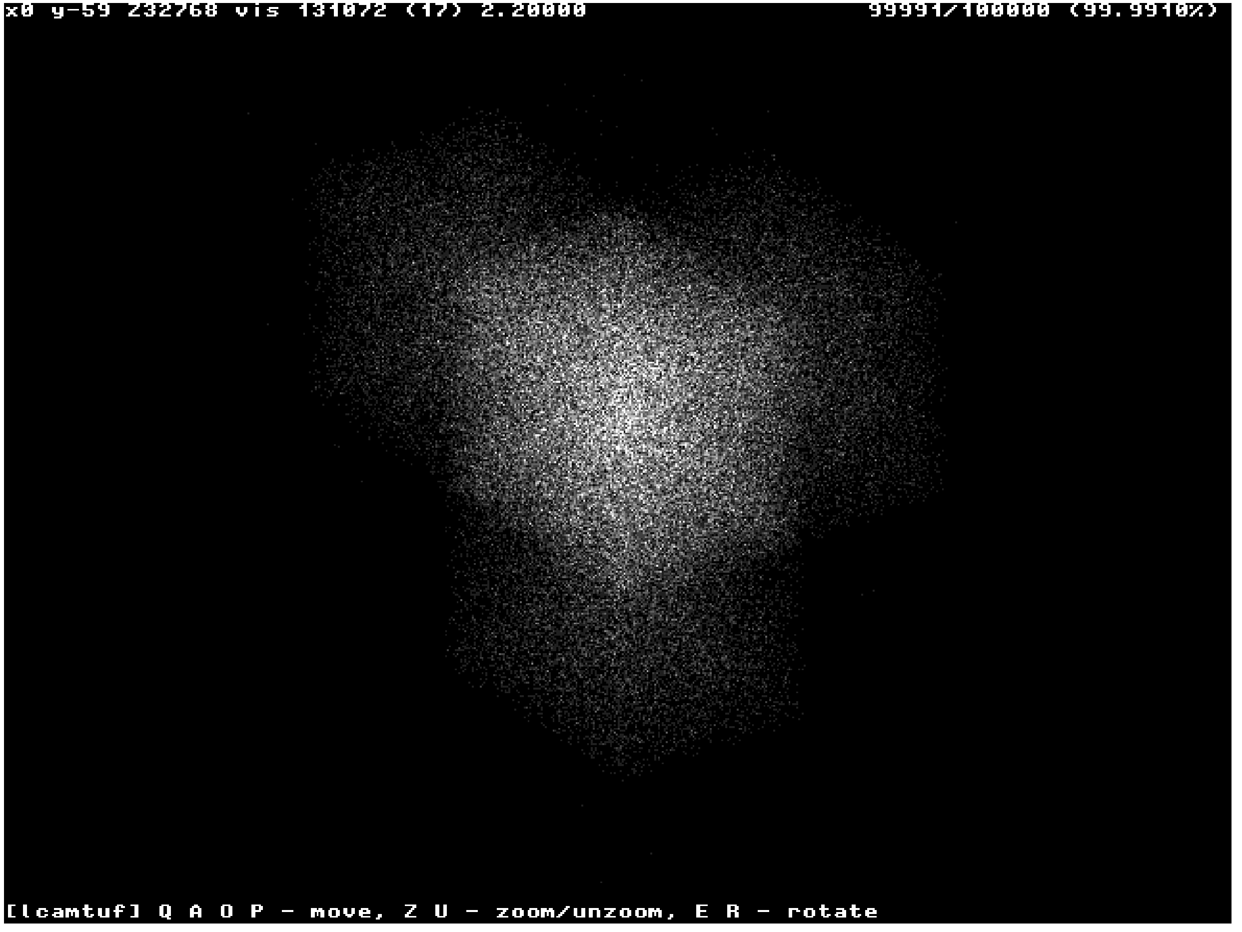
Guess the right Sequence Number

- RFC 1948 defines way to improve sequence number generation
- Some implementations are not compliant / unpredictable
- Michal Zalewski’s paper “Strange Attractors and TCP/IP Sequence Number Analysis” and its update “One Year Later”
- He build a graph using a composition of the values seen recently in a series of sequence numbers:
  - x[n] = s[n-2] – s[n-3]
  - y[n] = s[n-1] – s[n-2]
  - z[n] = s[n] - s [n-1]

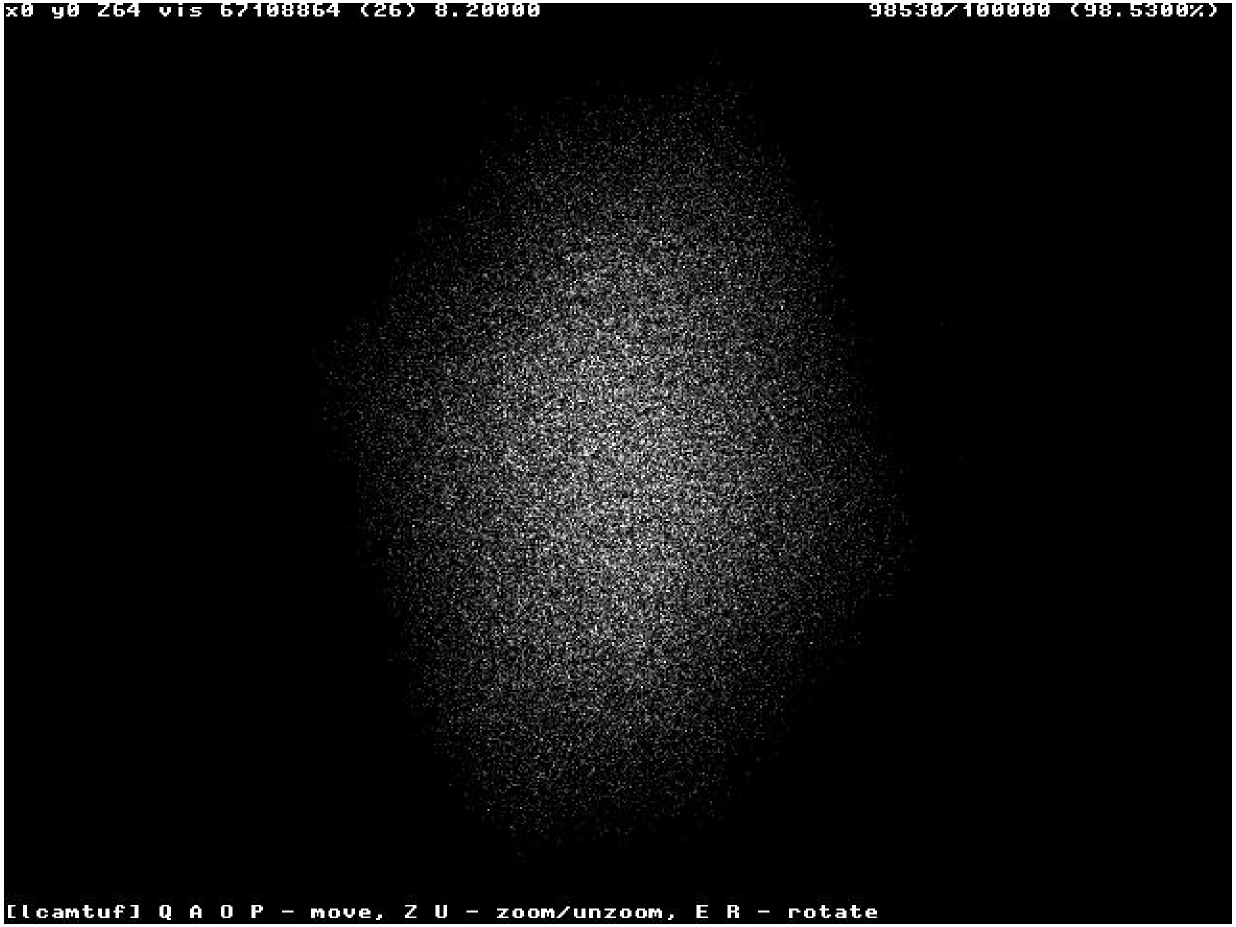
Windows 95


x0 y0 28388608 vis 512 (9) 2.40000
99488/100000 (99.4880%)
[lcamtuf] Q A O P - move, Z U - zoom/unzoom, E R - rotate

Windows 2000 and XP



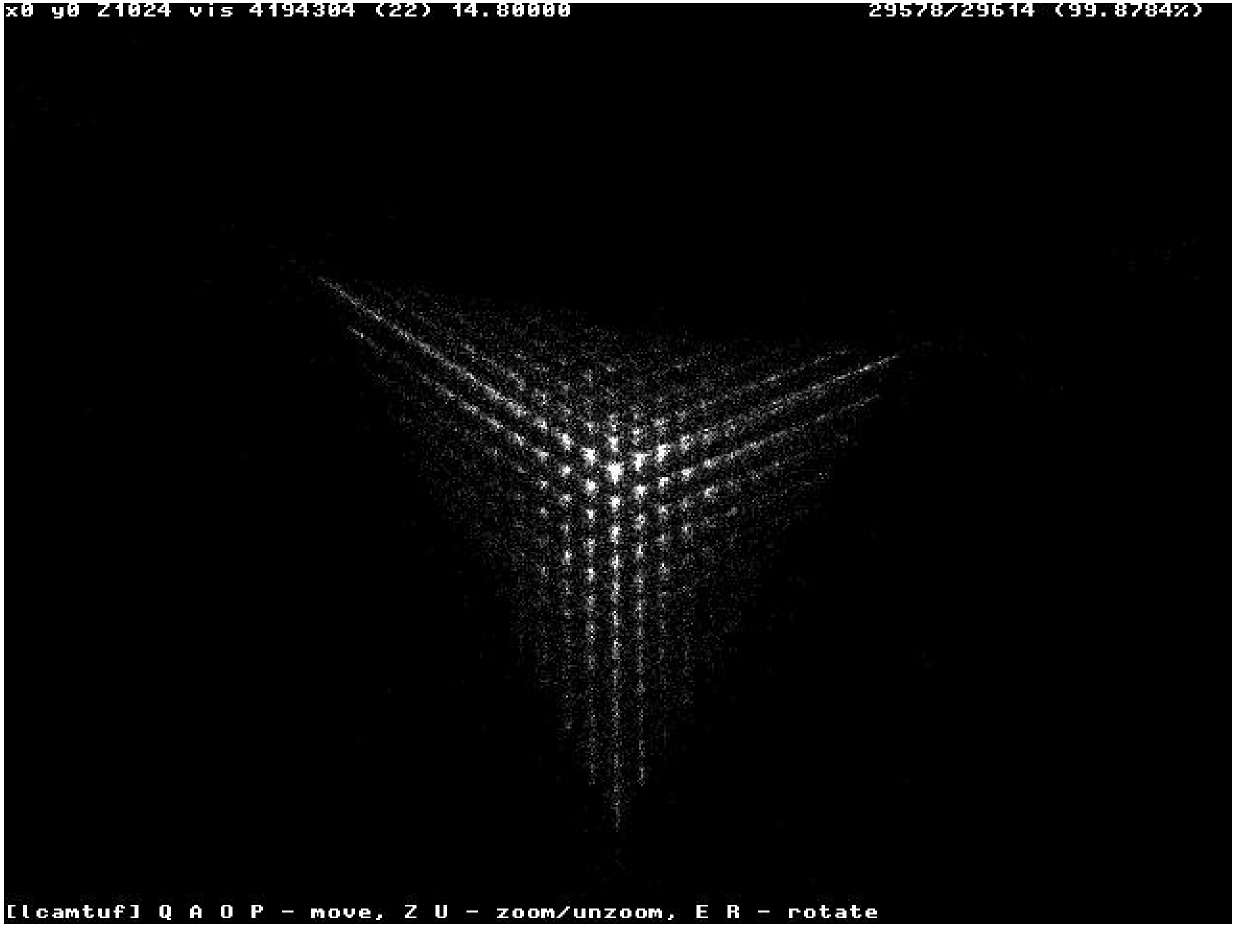
Linux (<Kernel 2.X)



FreeBSD

)0 y0 Z0 vis 2147483648 (33) 0.00000
100000/100000 (100.0000%
[lcamtuf] Q A O P - move, Z U - zoom/unzoom, E R - rotate

Cisco IOS



x0 y0 Z1024 vis 4194304 (22) 14.80000
29578/29614 (99.8784%)
[lcamtuf] Q A O P - move, Z U - zoom/unzoom, E R - rotate

Cisco IOS (one year later)

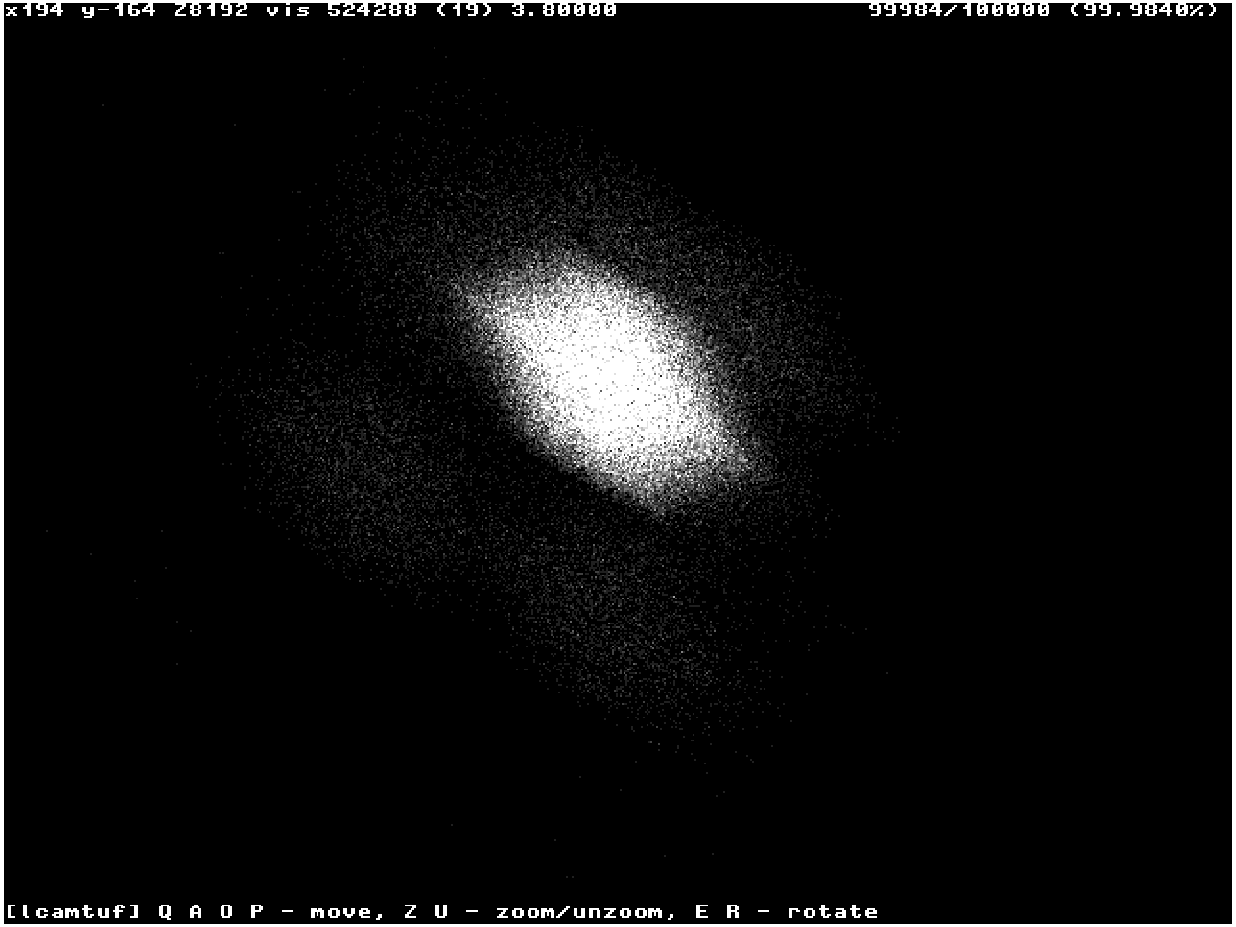
Mac OSX


x0 y0 Z1 vis 2147483648 (32) 0.00000
99996/100000 (99.9960%)
[lcamtuf] Q A O P - move, Z U - zoom/unzoom, E R - rotate

HP-UX


x-119 y-59 24096 vis 1048576 (20) 0.60000
99988/100000 (99.9880%)
[lcamtuf] Q A O P - move, Z U - zoom/unzoom, E R - rotate

HP-UX (one year later)



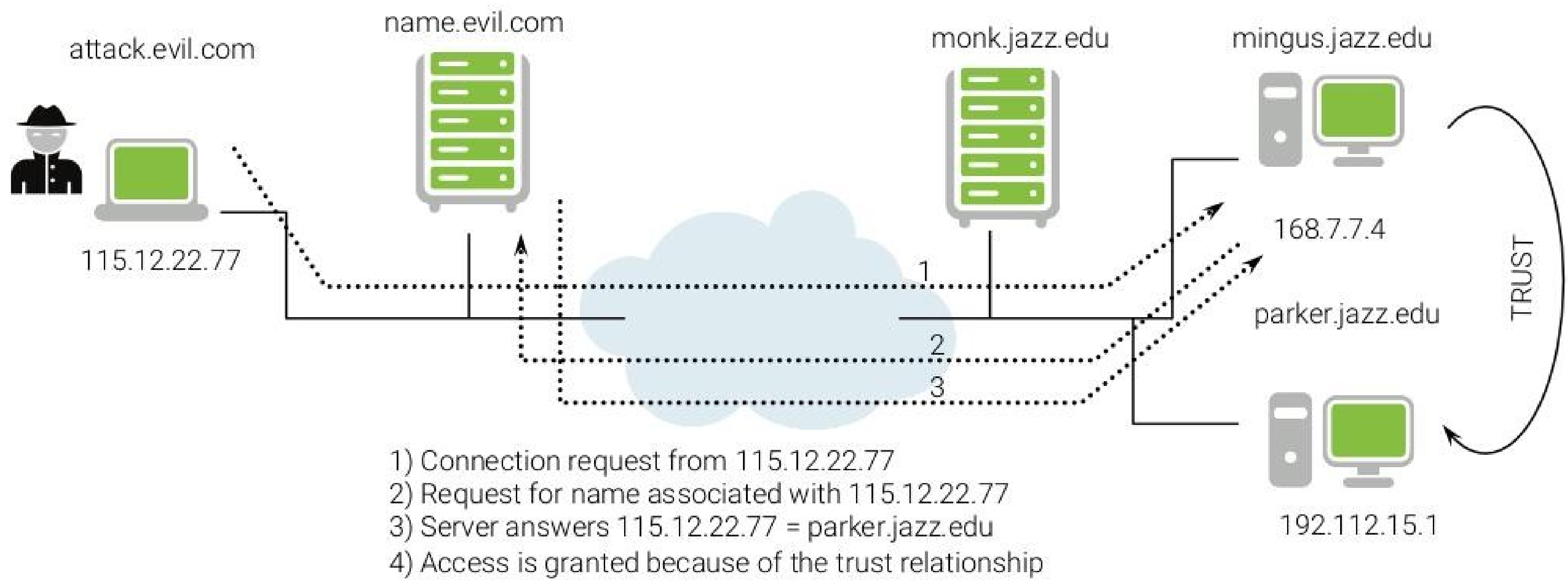
IRIX


x0 y0 216384 vis 262144 (18) 2.20000
99988/100000 (99.9880%)
[lcamtuf] Q A O P - move, Z U - zoom/unzoom, E R - rotate

DNS Spoofing

- Alice and Bob have a trust relationship
- Eve controls a malicious DNS server
- Eve sends a requests to Alice from her IP
- Alice requests the domain name associated to Eve’s IP
- Eve’s DNS server replies with Bob’s domain name
- Access is granted

Example

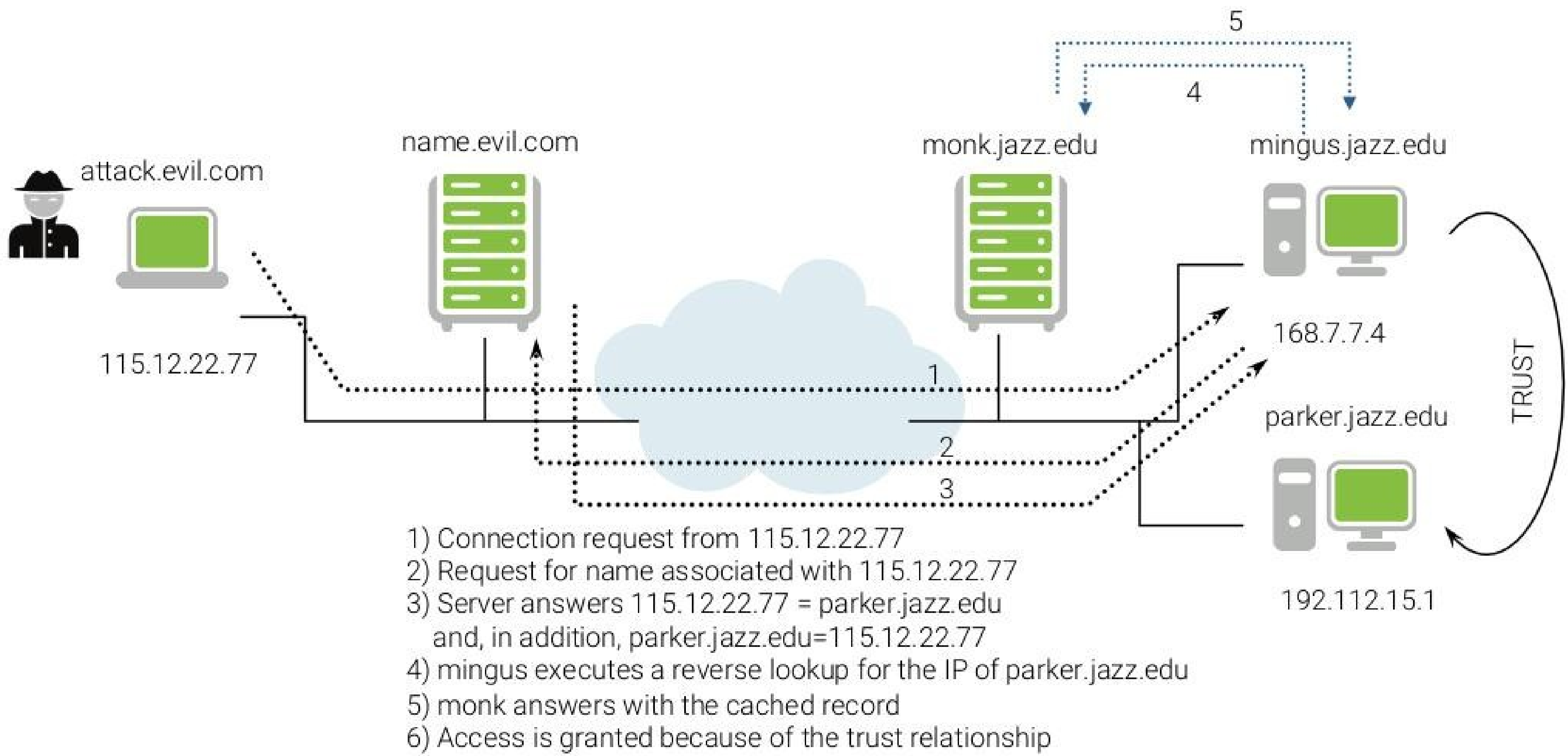


attack.evil.com
name.evil.com
monk.jazz.edu
mingus.jazz.edu
115.12.22.77
168.7.7.4
parker.jazz.edu
TRUST
192.112.15.1
1
2
3
1) Connection request from 115.12.22.77
2) Request for name associated with 115.12.22.77
3) Server answers 115.12.22.77 = parker.jazz.edu
4) Access is granted because of the trust relationship

DNS Spoofing: countermeasure

- Alice could do a double reverse lookup: ask Bob's authoritative DNS for the real IP and it will get a mismatch with Eve's IP
- In that scenario Eve could either:
  - spoof a UDP packet and race for the reply
    - Techniques for guessing the right
  - poison the DNS cache:
    - Some DNS implementations accept additional commands with a request

Example

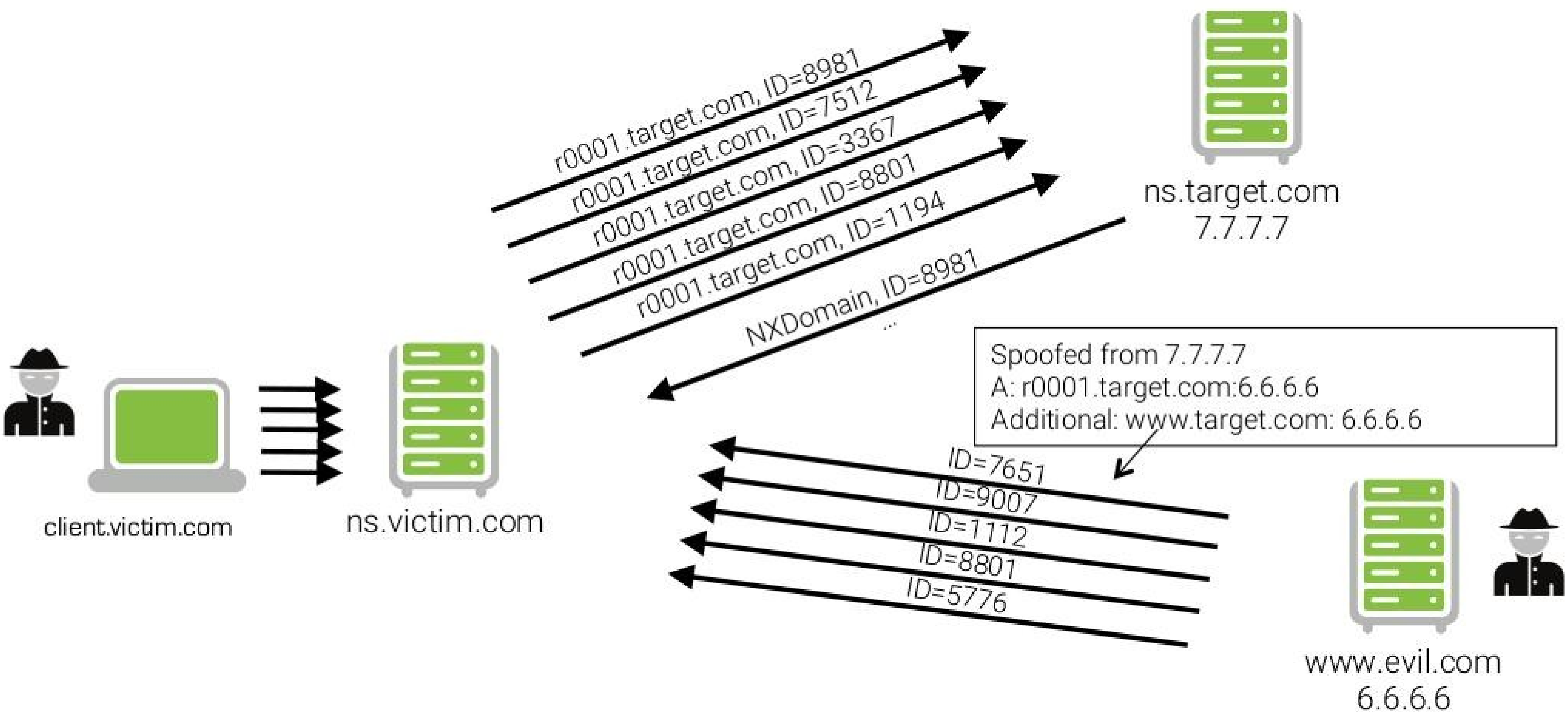


5
4
attack.evil.com
name.evil.com
monk.jazz.edu
mingus.jazz.edu
115.12.22.77
168.7.7.4
1
2
3
parker.jazz.edu
TRUST
192.112.15.1
1) Connection request from 115.12.22.77
2) Request for name associated with 115.12.22.77
3) Server answers 115.12.22.77 = parker.jazz.edu
and, in addition, parker.jazz.edu=115.12.22.77
4) mingus executes a reverse lookup for the IP of parker.jazz.edu
5) monk answers with the cached record
6) Access is granted because of the trust relationship

DNS Poisoning

- Remote DNS cache poisoning through hijacking requires the attacker to guess the 16-bit ID value used to match requests to replies and the source port used in the request
- It can be shown that with ~200 replies, we have 50% possibilities to guess the right ID (Kaminsky attack)
  - ID used to be sequential and it is now random
  - Source port is most of the time not random

Kaminsky Attack



Denial of Service

- Making a network resource unavailable to its intended users
- Usually happens by overloading the resources (flooding)
- Could happen by exploiting misconfiguration (crashing)
- Real world example: Protesters crowding Burger King at Palazzo Nuovo

Denial of Service, the easy way

- Wireless networks are particularly vulnerable to DOS attacks
- Manipulation of control frames:
  - Attacker can send a disassociation request to nodes on a wireless network and continue to send disassociation messages whenever they retry
- Frequency interference

Historical Example

Datagram Fragmentation:

- When a datagram is encapsulated in lower level protocols (e.g., Ethernet) it may be necessary to split the datagram in smaller portions
- This happens when the datagram size is bigger than the data link layer MTU (Maximum Transmission Unit)
- Fragmentation can be performed at the source host or at an intermediate step in datagram delivery
- If the datagram has the “do not fragment” flag set, an ICMP error message is sent back to the originator

Fragmentation

- If the datagram can be fragmented:
  - The header is copied in each fragment
    - In particular, the “datagram id” is copied in each fragment
  - The “fragmentation offset” field contains the position of the fragment with respect to the original datagram expressed in 8-byte units
  - The “total length field” is changed to match the size of the fragment
  - Each fragment is then delivered as a separate datagram
  - If one fragment is lost the entire datagram is discarded after a timeout

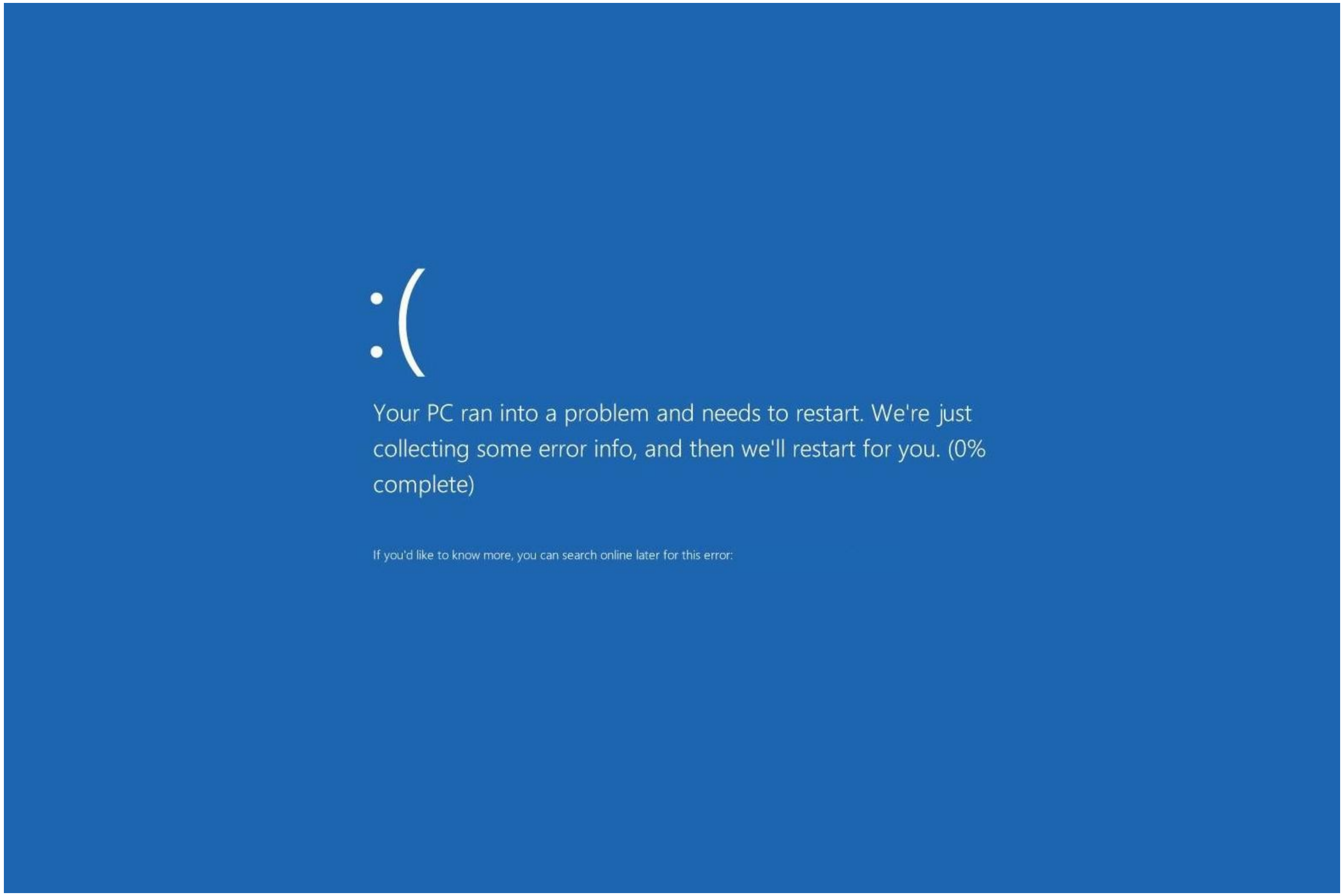
Fragmentation attack

The ping of death:

- The attacker modifies the offset of the last segment such that the total size of the reassembled datagram is bigger than the maximum allowed size
  - A kernel static buffer is overflowed, causing a kernel panic
- In other scenarios fragmentation can be used as a form of evasion because some firewalls don’t reassemble packets

Ping of Death: IPv4 – WinNuke

History repeats itself: IPv6

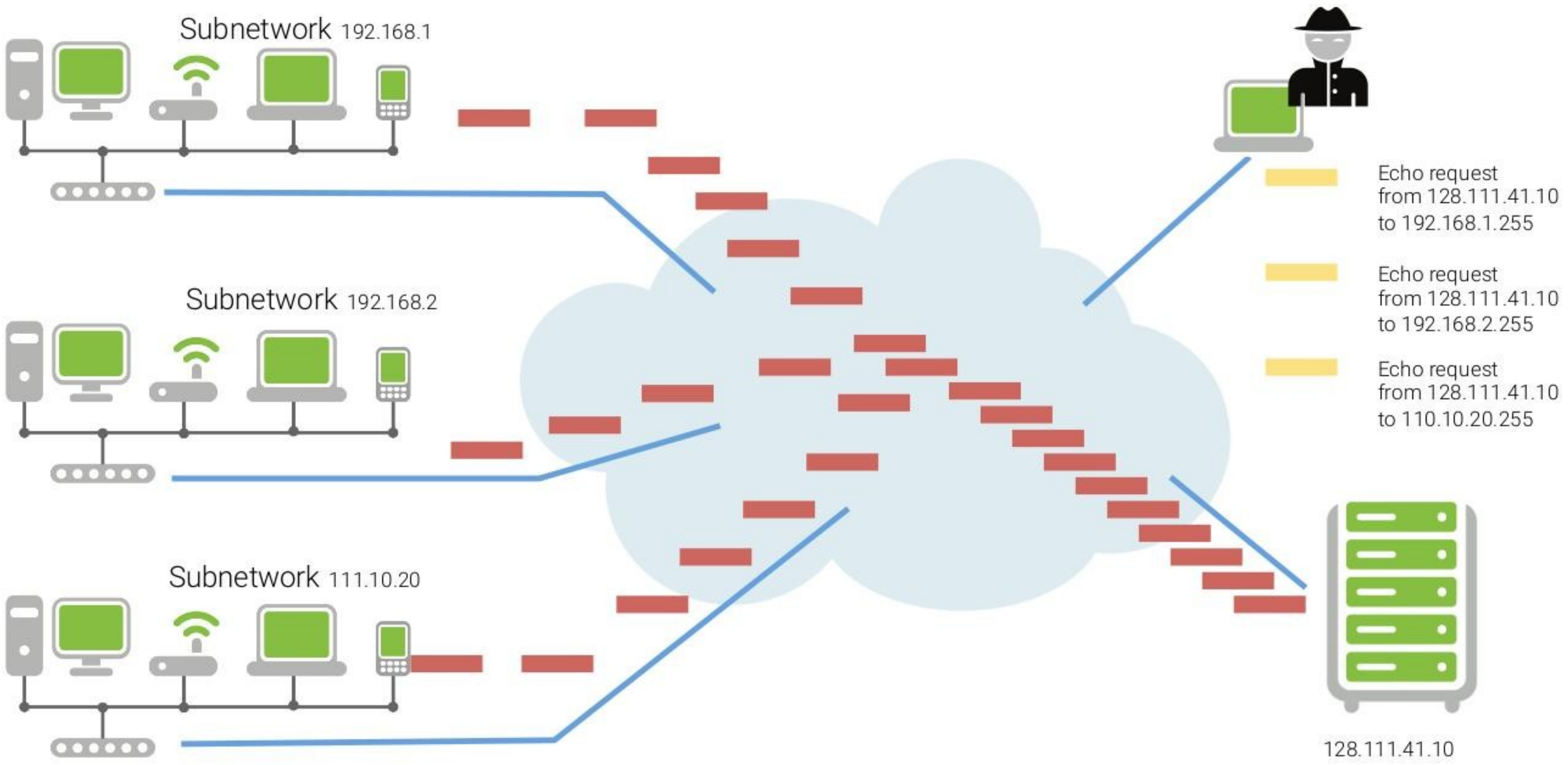


ICMP

Smurf Attack

- 1990, a small attacker versus a crowded network
- Forged ICMP packets with:
  - victim’s spoofed source IP
  - Network broadcast address as destination
- Effective because:
  - Broadcast addresses were in the standards until 1999
  - Routers were accepting packets from the outside even if the IP belonged to an host inside the network
  - A similar attack can be done with UDP

Smurf attack



Exploiting ICMP again

- ICMP defines “destination unreachable” and “redirect” packets
- An attacker forges a ICMP packet that is sent to a router
- The router subsequently reconfigures the routing table
- Traffic gets hijacked and nodes could be cut out from the network

Exploiting the state

- Many protocols are not stateless
- State consumes resources even when the links are idle
  - Memory for the socket descriptor
  - Transactional and pending state
  - Process or thread to manage the connection
  - Memory associated with the data in the TCP stream that has not yet been acknowledged
  - Database and file locking

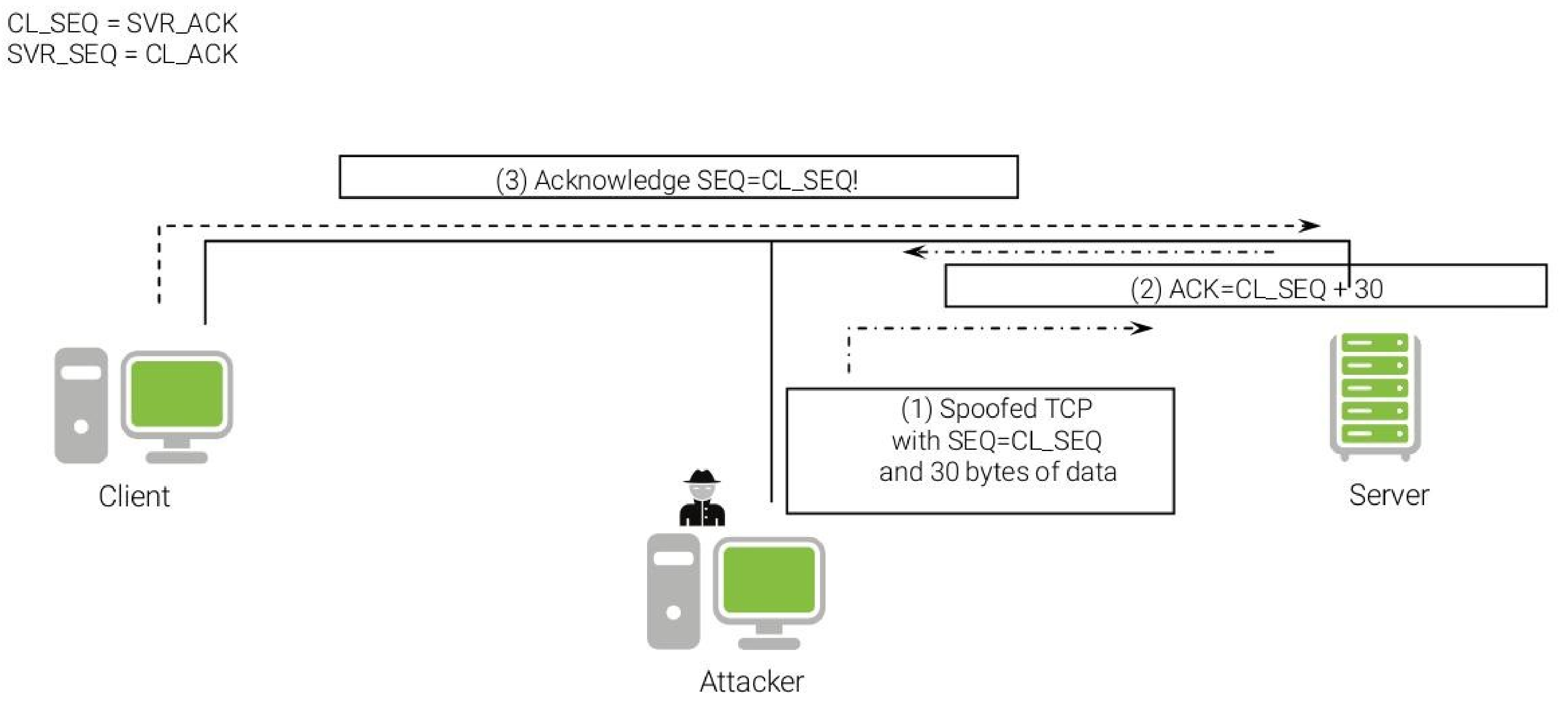
ACK Storm

- The attacker has some knowledge of the state and waits until the connection is “quiet”
  - All the transmitted data have been acknowledged (by both endpoints)
- The attacker injects the data in the stream
  - “Desynchronizes” the connection
- The receiver of the injected data sends an acknowledgment to the apparent sender
- The apparent sender replies with an acknowledgement with the “expected” sequence number
- The receiver considers this as out-of-sync and sends an an acknowledgement with the “expected” sequence number

ACK Storm #2

- ACK messages with no data are not retransmitted in case of loss
- The “ACK storm” continues until one message is lost
- Any subsequent attempt to communicate will generate an ACK storm
- ACK storms can be blocked by the attacker using ACK packets with the right numbers

ACK Storm #3

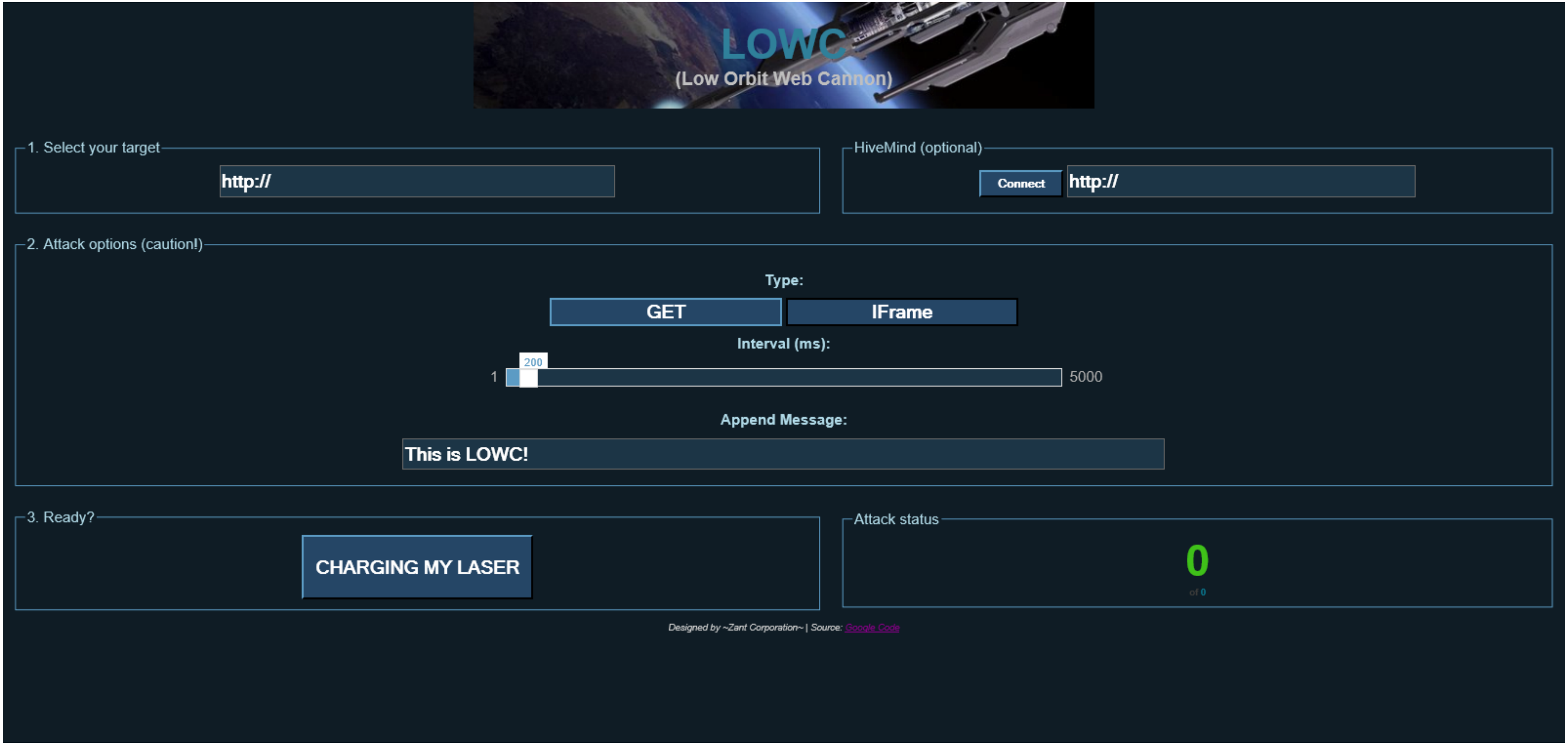


CL_SEQ = SVR_ACK
SVR_SEQ = CL_ACK
(3) Acknowledge SEQ=CL_SEQ!
(2) ACK=CL_SEQ + 30
(1) Spoofed TCP
with SEQ=CL_SEQ
and 30 bytes of data
Client
Server
Attacker

SYN Flooding

- Attacker starts handshake with SYN-marked segment
- Victim replies with SYN-ACK segment
- Attacker stays silent
  - the source IP of the attacker can be spoofed, since no final ACK is required
  - the attack vector could be a slow link (TOR) because few resources are used
- A host can keep a limited number of TCP connections in half-open state. After that limit, it cannot accept any more connections
- Mitigated by SYN cookies (that requires way less state)

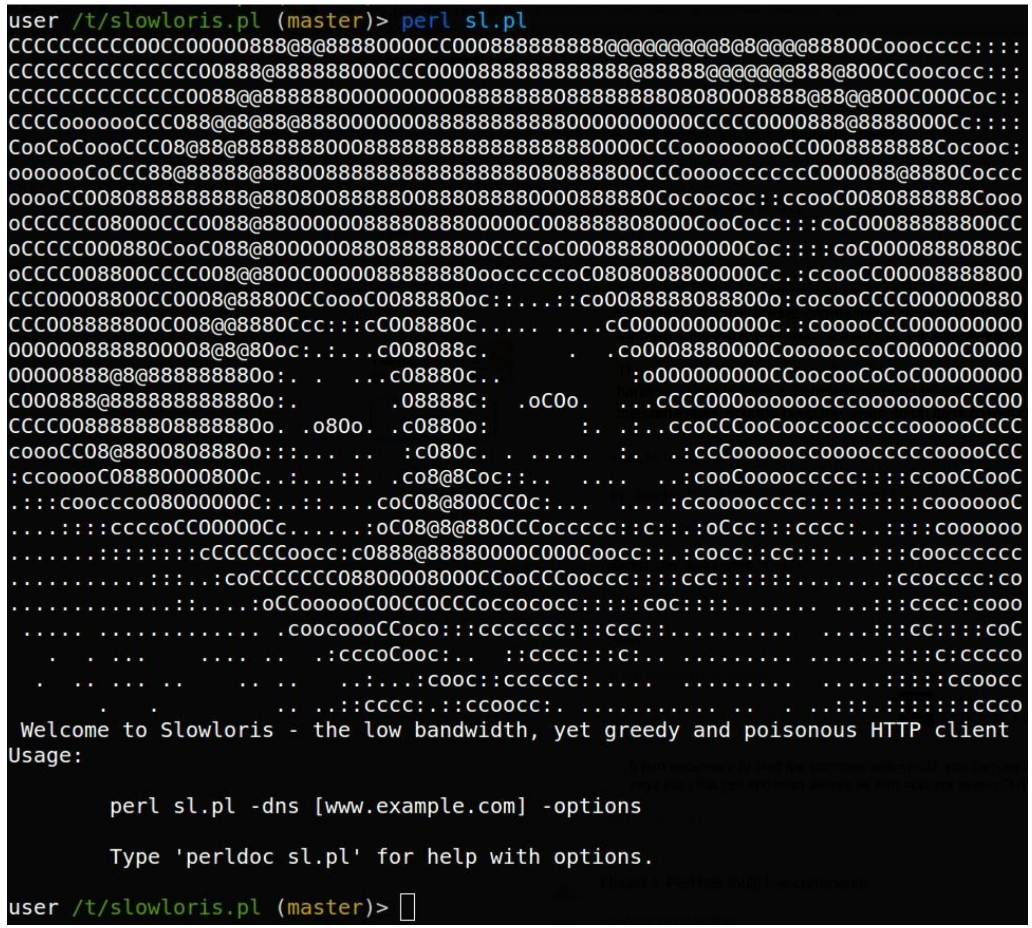
LOIC


LOWC
(Low Orbit Web Cannon)
1. Select your target
http://
HiveMind (optional)
Connect
http://
2. Attack options (caution!)
Type:
GET
IFrame
Interval (ms):
200
1
5000
Append Message:
This is LOWC!
3. Ready?
CHARGING MY LASER
Attack status
0
of 0
Designed by ~Zant Corporation~ | Source: Google Code

HTTP POST Attack

- Legitimate HTTP POST header
  - “Content-Length” up to 2GB
- The actual message body is transmitted at an extremely slow rate.
- Many of this sessions are opened until logical resources are exhausted
- Difficult to distinguish and filter

SlowLoris


user /t/slowloris.pl (master)> perl sl.pl
Welcome to Slowloris - the low bandwidth, yet greedy and poisonous HTTP client
Usage:
perl sl.pl -dns [www.example.com] -options
Type 'perldoc sl.pl' for help with options.
user /t/slowloris.pl (master)>