Network Security: ARP, IP, TCP, UDP

COMPUTER SECURITY

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During normal operation:

- My laptop always has the same IP address.
  - False
- My laptop always has the same MAC wireless address.
  - True
- VPNs hide my laptops IP from the web site I am visiting.
  - True
- VPNs protect my data from modification between my computer and the destination website.
  - False – VPNs only protect to VPN endpoint
- My ISP (and my VPN) can add and change cookies sent to a website.
  - True – Unless the cookies are encrypted

IP and MAC Addresses

- Devices on a local area network have
  - IP addresses (network layer)
  - MAC addresses (data link layer)
- IP addresses are used for high level protocols
- MAC addresses are used for low level protocols
- How to translate IP Addresses into MAC addresses?

Address Resolution Protocol (ARP)

- Connects the network layer to the data link layer
- Maps IP addresses to MAC addresses
- Based on broadcast messages and local caching
- Does not support confidentiality, integrity, or authentication
- Defined as a part of RFC 826 (IETF, Request For Comments)

ARP Messages

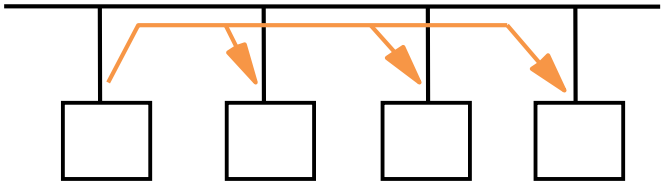
- ARP broadcasts requests of type

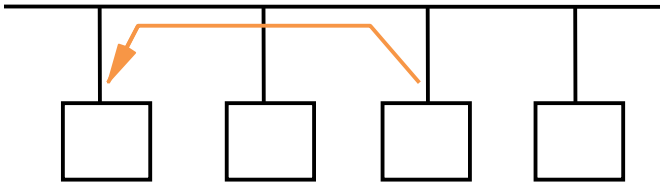
  who has <IP addressC >
  tell <IP addressA >

- Machine with <IP addressC> responds

  <IP addressC > is at <MAC address>

- Requesting machine caches response
- Network administrator configures IP address and subnet on each machine





ARP Cache

- The Linux, Windows and OSX command arp - a displays the ARP table

Internet Address	Physical Address	Type
128.148.31.1	00-00-0c-07-ac-00	dynamic
128.148.31.15	00-0c-76-b2-d7-1d	dynamic
128.148.31.71	00-0c-76-b2-d0-d2	dynamic
128.148.31.75	00-0c-76-b2-d7-1d	dynamic
128.148.31.102	00-22-0c-a3-e4-00	dynamic

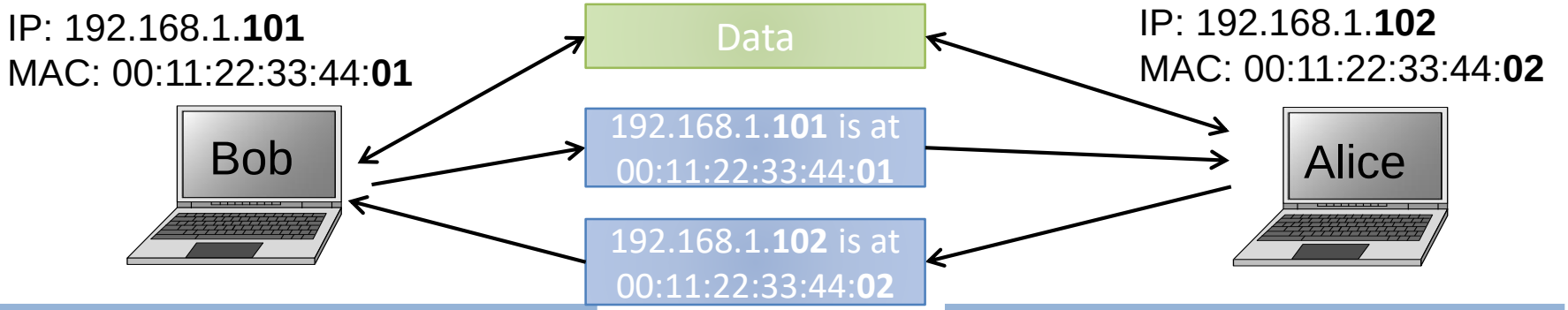
- Command arp –a –d flushes the ARP cache (Windows, Apple?)
- ARP cache entries are stored for a configurable amount of time

ARP Spoofing

- The ARP table is updated whenever an ARP response is received
- Requests are not tracked
- ARP announcements are not authenticated
- Machines trust each other
- A rogue machine can spoof other machines

ARP Normal Operation

- Normal operation
  - Alice communicates with Bob

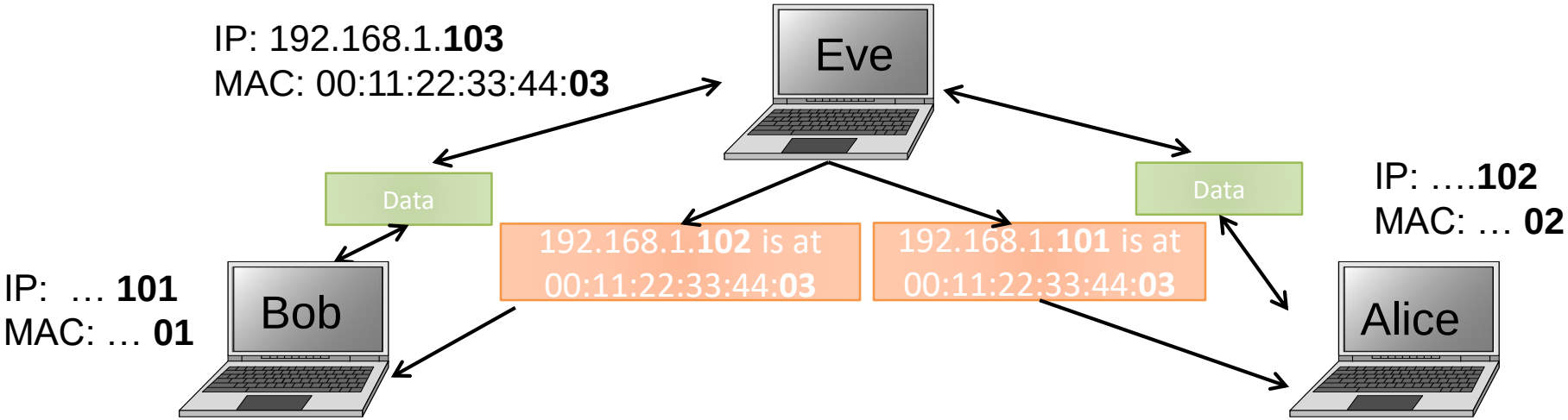


ARP Cache	
192.168.1.**102**	00:11:22:33:44:**02**

ARP Cache	
192.168.1.**101**	00:11:22:33:44:**01**

ARP Poisoning Attack

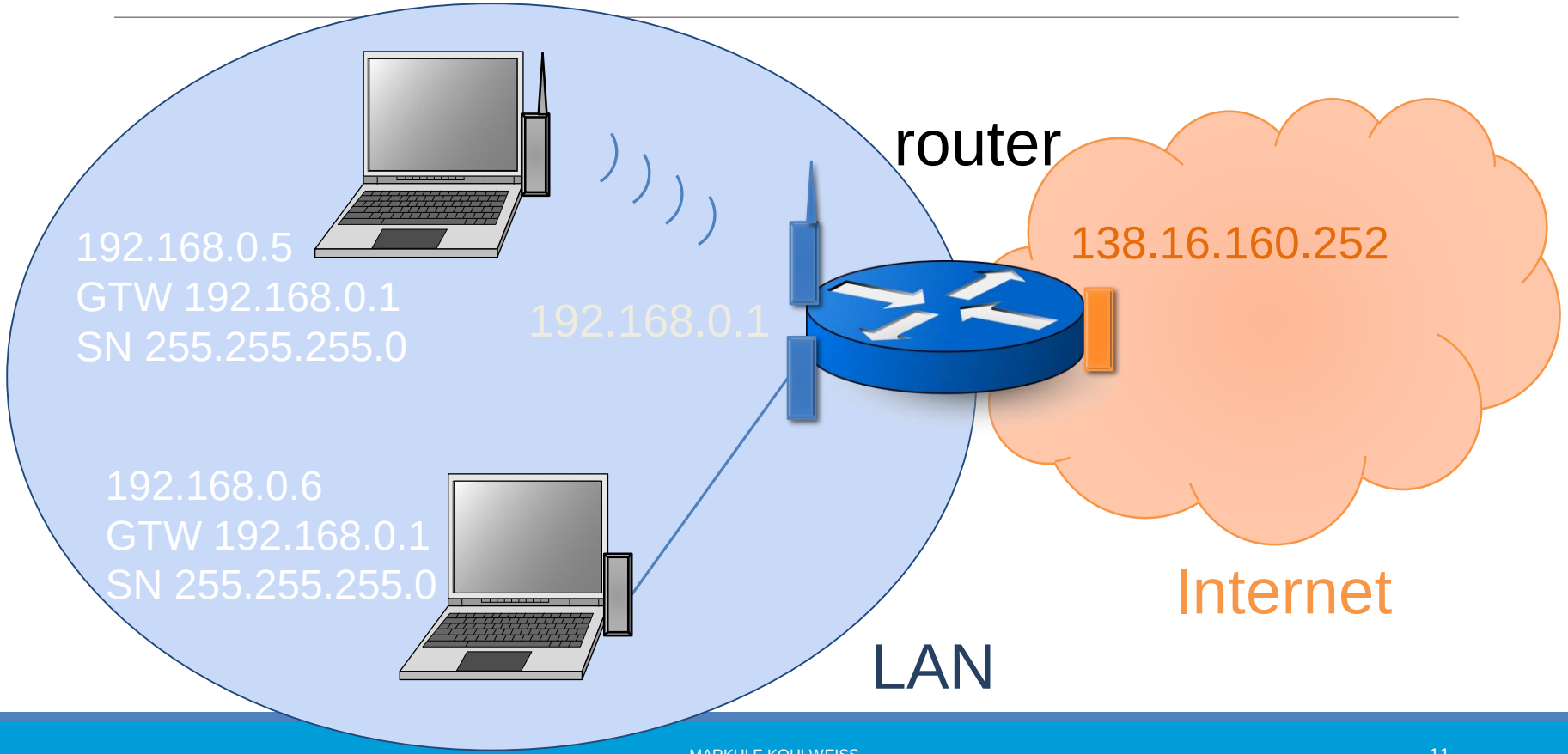
- Man-in-the-middle attack
  - ARP cache poisoning leads to eavesdropping



ARP Poisoning & ARP Spoofing

- Almost all ARP implementations are stateless
- An ARP cache updates every time that it receives an ARP reply
  - … even if it did not send any ARP request!
- Can “poison” ARP cache with gratuitous ARP replies
- Using static entries solves the problem but it is almost impossible to manage!

From the LAN to the Internet



Edinburgh's IP Space

- Edinburgh is part of the autonomous system (AS786) of Jisc Services Limited, for Joint Information Systems Committee
  - Class B network 129.215.0.0/16 (64K addresses)
- School of Informatics
  - 40 or so sub-networks, class C (/24) with 254 addresses or slightly larger
  - Server machines: 129.215.33.0/24
  - DICE desktop machines: 129.215.24.0/22
  - Laptops without a fixed IP address: 129.215.90.0/23

User Datagram Protocol

- UDP is a stateless, unreliable datagram protocol built on top of IP, that is it lies at the transport layer
- UDP does not provide delivery guarantees or acknowledgments, which makes it efficient
- Can however distinguish data for multiple concurrent applications on a single host
- A lack of reliability implies applications using UDP must be ready to accept a fair amount of corrupted and lost data
  - Most applications built on UDP will suffer if they require reliability
  - VoIP, streaming video, and streaming audio all use UDP

Transmission Control Protocol

- Transport layer protocol for reliable data transfer, in-order delivery of messages and ability to distinguish multiple applications on same host
  - HTTP and SSH are built on top of TCP
- TCP packages a data stream into segments transported by IP
  - Order maintained by marking each packet with sequence number
  - Every time TCP receives a packet, it sends out an ACK to indicate successful receipt of the packet
- TCP generally checks data transmitted by comparing a checksum of the data with a checksum encoded in the packet

Ports

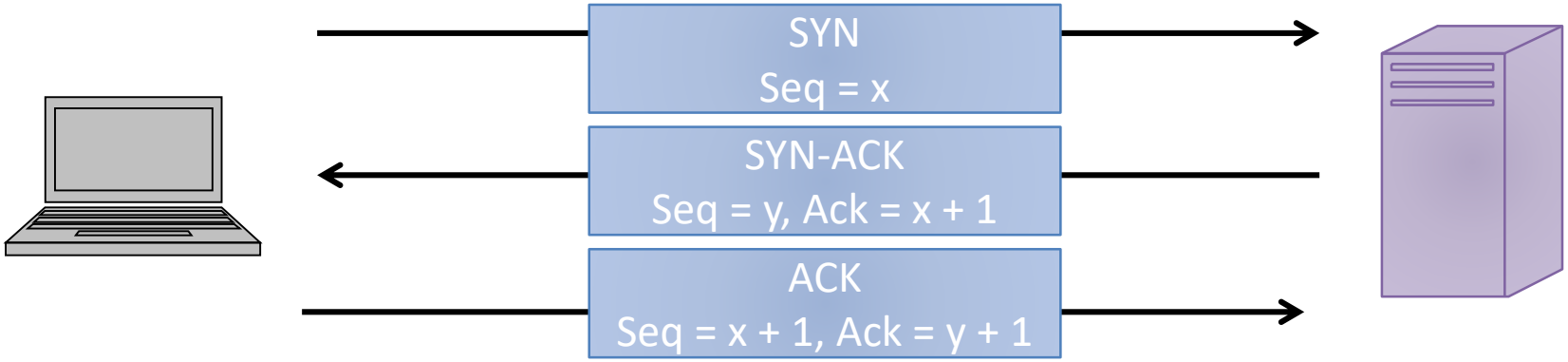
- TCP (& UDP) supports concurrent applications on the same server
- Ports are 16 bit numbers identifying where data is directed
- The TCP header includes both a source and a destination port
- Ports 0 through 1023 are reserved for use by known protocols
  - E.g., HTTPS uses 443 and SSH uses 22
- Ports 1024 through 49151 are known as user ports, and are used for listening to connections

TCP Packet Format

Bit Offset	0-3	4-7	8-15	16-18	19-31
0	Source Port			Destination Port	
32	Sequence Number				
64	Acknowledgment Number				
96	Offset	Reserved	Flags	Window Size	
128	Checksum			Urgent Pointer	
160	Options				
>= 160	Payload				

Establishing TCP Connections

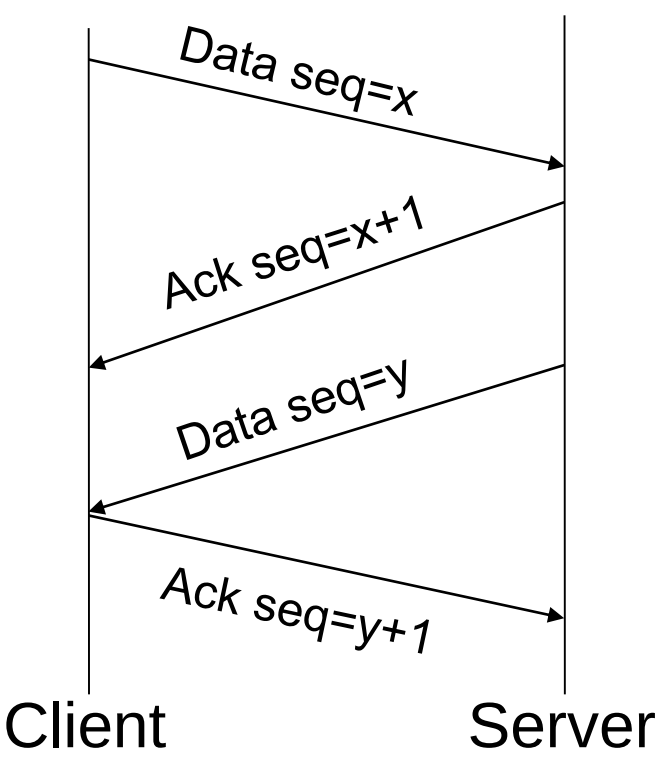
- TCP connections are established through a three-way handshake.
- The server generally is a passive listener, waiting for a connection request
- The client requests a connection by sending out a SYN packet
- The server responds by sending a SYN/ACK packet, acknowledging the connection
- The client responds by sending an ACK to the server, thus establishing connection

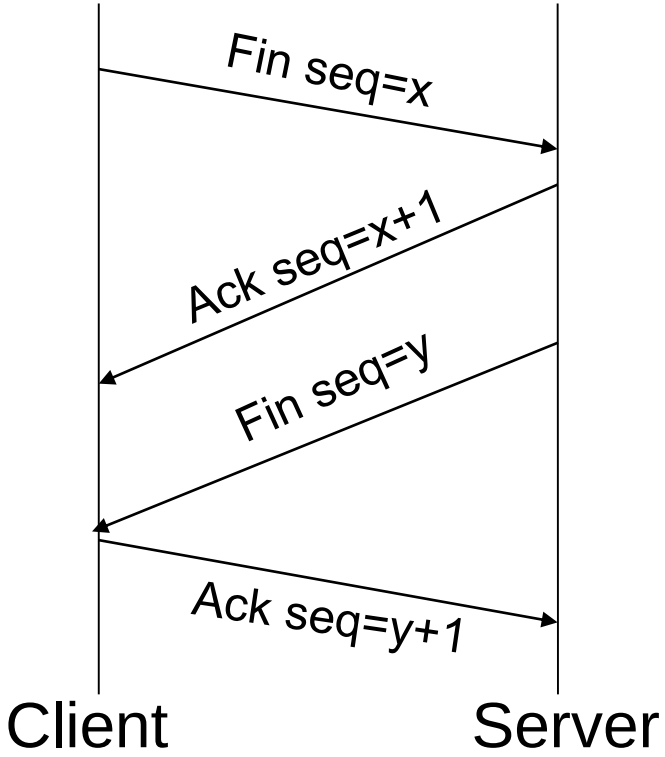


TCP Data Transfer

- During connection initialization using the three way handshake, initial sequence numbers are exchanged
- The TCP header includes a 16 bit checksum of the data and parts of the header, including the source and destination
- Acknowledgment or lack thereof is used by TCP to keep track of network congestion and control flow and such
- TCP connections are cleanly terminated with a 4-way handshake
  - The client which wishes to terminate the connection sends a FIN message to the other client
  - The other client responds by sending an ACK
  - The other client sends a FIN
  - The original client now sends an ACK, and the connection is terminated

TCP Data Transfer and Teardown





SYN Flooding

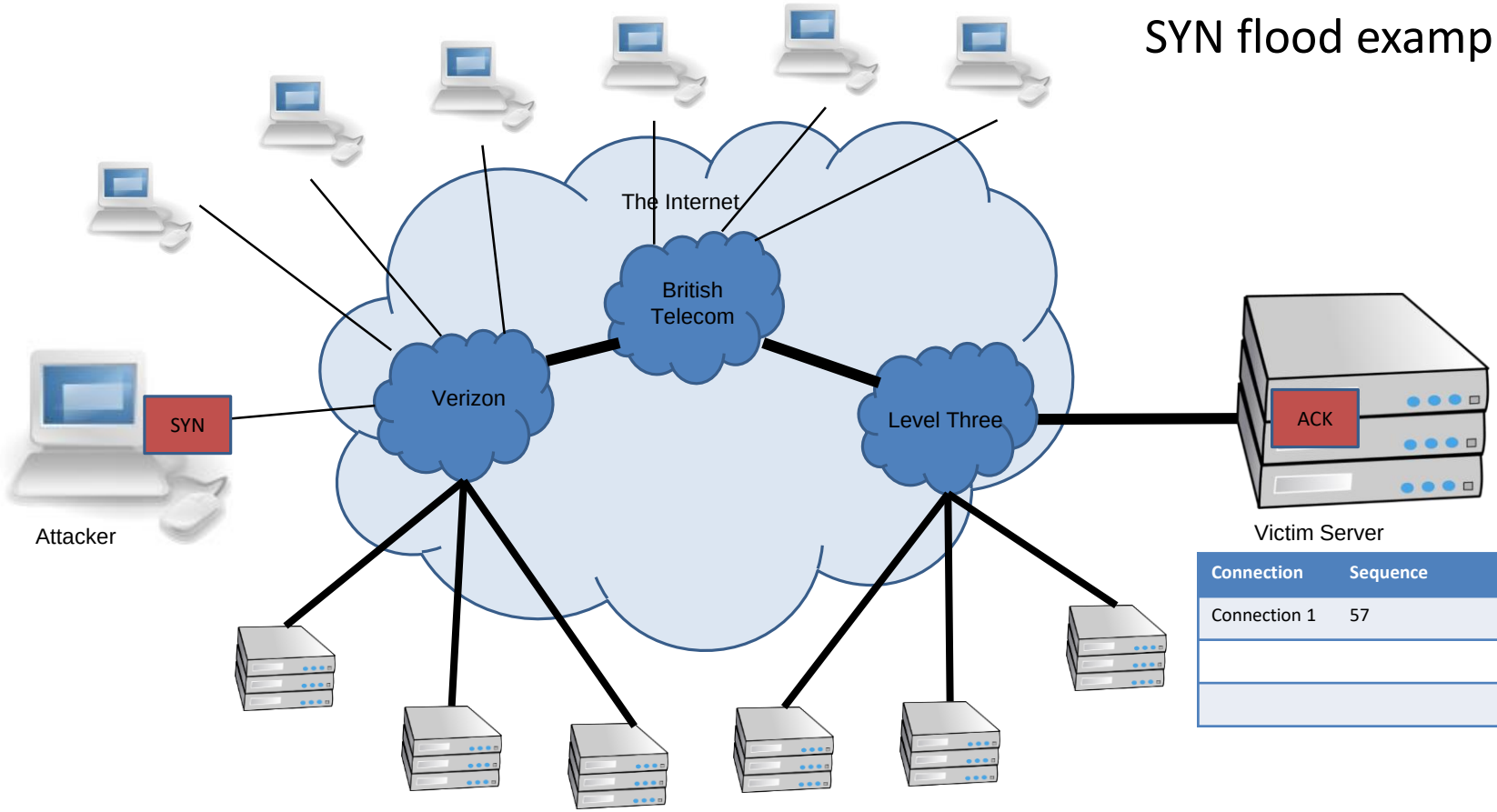
Send tons of requests at the victim and overload them.

- Basic three-part handshake used by Alice to initiate a TCP connection with Bob.

$$
\begin{aligned}
A \rightarrow B: &\quad \text{SYN}, X \\
B \rightarrow A: &\quad \text{ACK}, X+1;\ \text{SYN}, Y \\
A \rightarrow B: &\quad \text{ACK}, Y+1
\end{aligned}
$$

- Alice sends many SYN packets, without acknowledging any replies. Bob accumulates more SYN packets than he can handle.

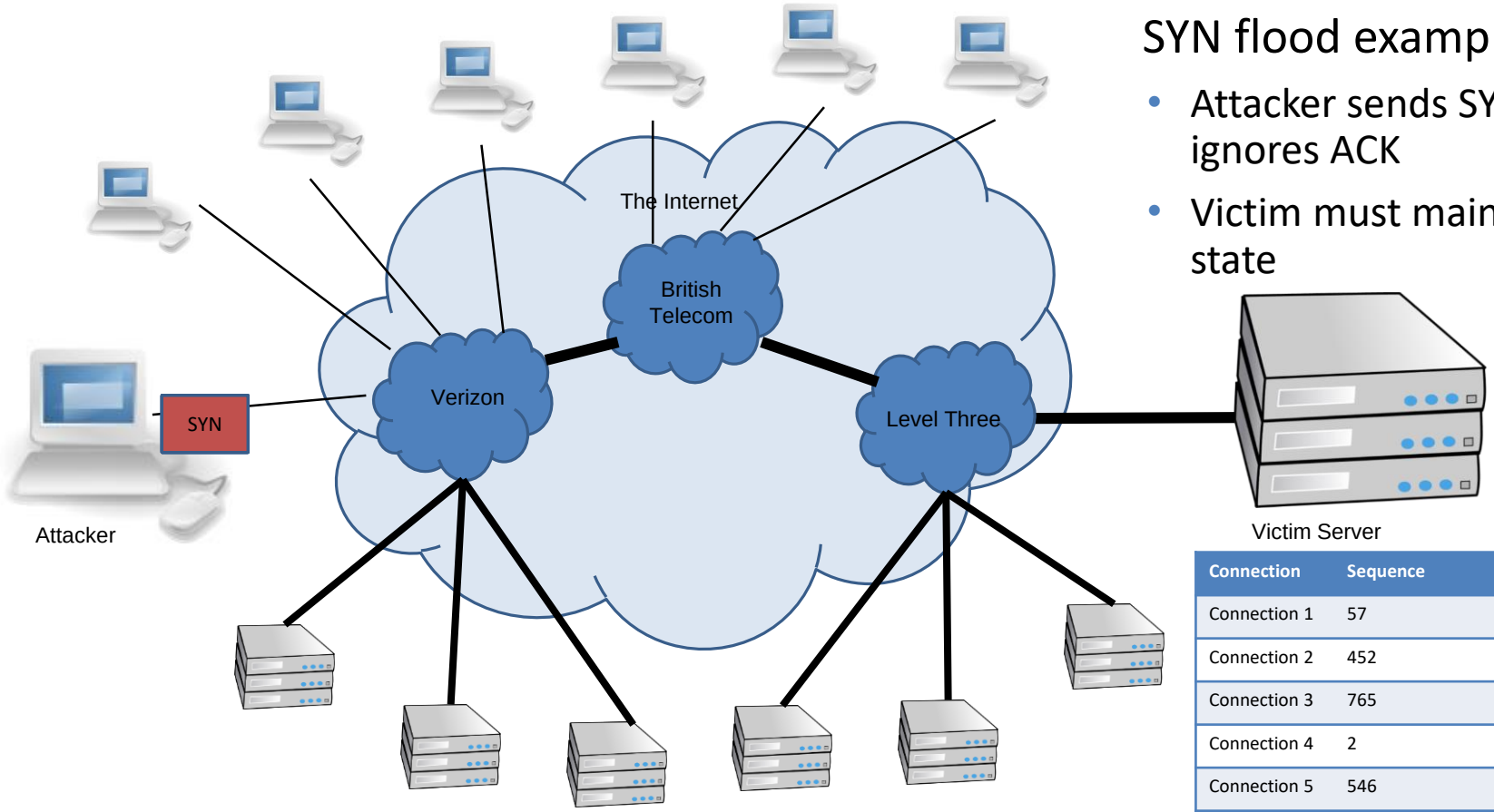
SYN flood example



Connection	Sequence	IP
Connection 1	57	1.1.1.1

SYN flood example

- Attacker sends SYN and ignores ACK
- Victim must maintain state



Connection	Sequence	IP
Connection 1	57	1.1.1.1
Connection 2	452	1.1.1.1
Connection 3	765	1.1.1.1
Connection 4	2	1.1.1.1
Connection 5	546	1.1.1.1
Connection 6	97	1.1.1.1
Connection 7	56	1.1.1.1
Connection 8	15	1.1.1.1

SYN Flooding

- Problems
  - Attribution – attacker uses their own IP which could be traced
  - Bandwidth – attacker uses their own bandwidth which is likely smaller than a server's
- Effective against a small target
  - Someone running a game server in their home
- Not effective against a large target
  - Company website

Spoofing: forged TCP packets

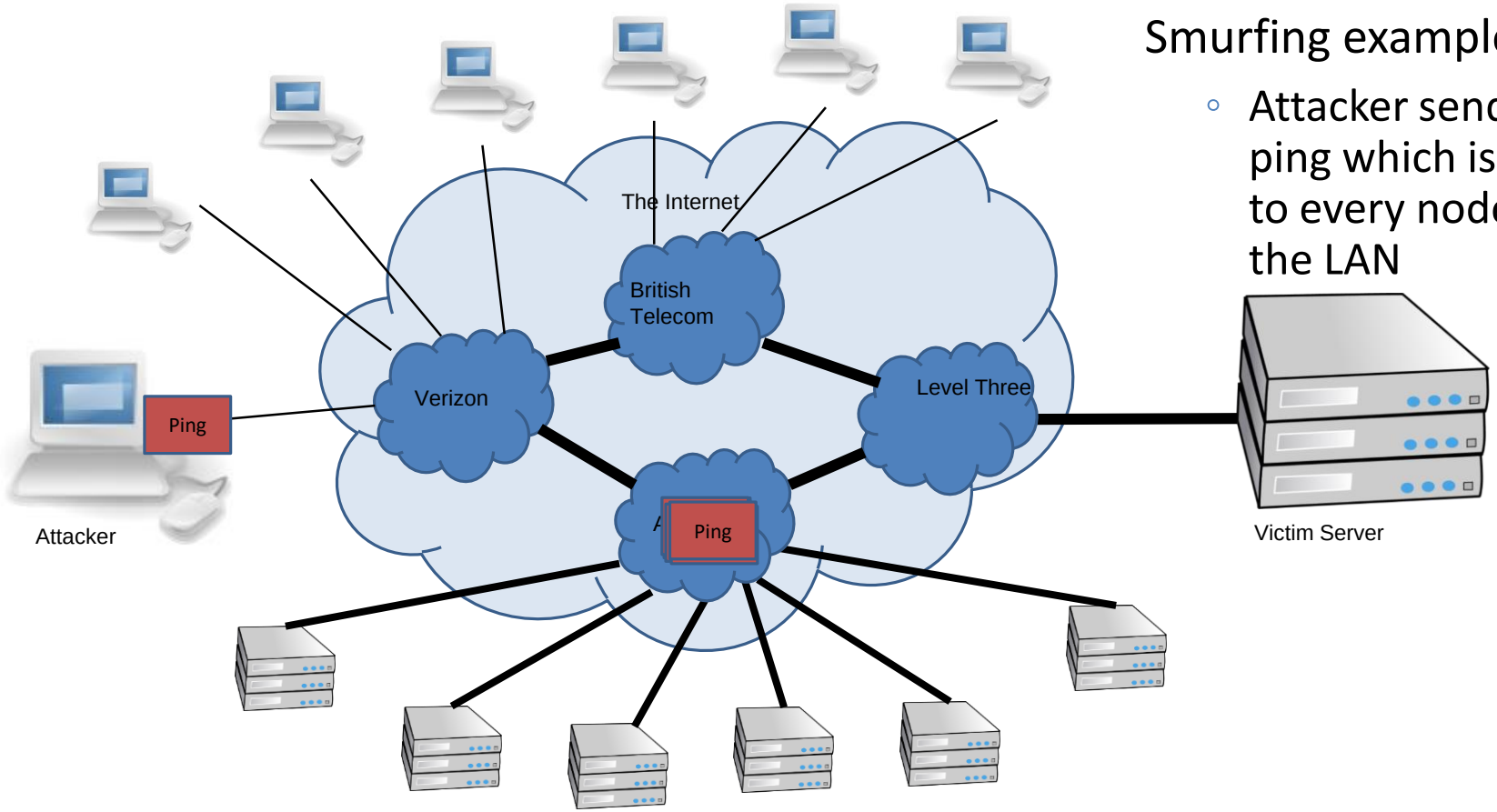
- Same as SYN flooding, but forge the source of the TCP packet
- Advantages:
  - Harder to trace
  - ACKs are sent to a second computer, less attacker bandwidth used
- Problems:
  - Ingress filtering is commonly used to drop packets with source addresses outside their origin network fragment.

Smurfing (directed broadcast)

- The smurfing attack exploits the ICMP (Internet Control Message Protocol) whereby remote hosts respond to echo packets to say they are alive (ping).
- Some implementations respond to pings to broadcast addresses.
- Idea: Ping a LAN to find hosts, which then all respond to the ping.
- Attack: make a packet with a forged source address containing the victim's IP number. Send it to a smurf amplifier, who swamps the target with replies.

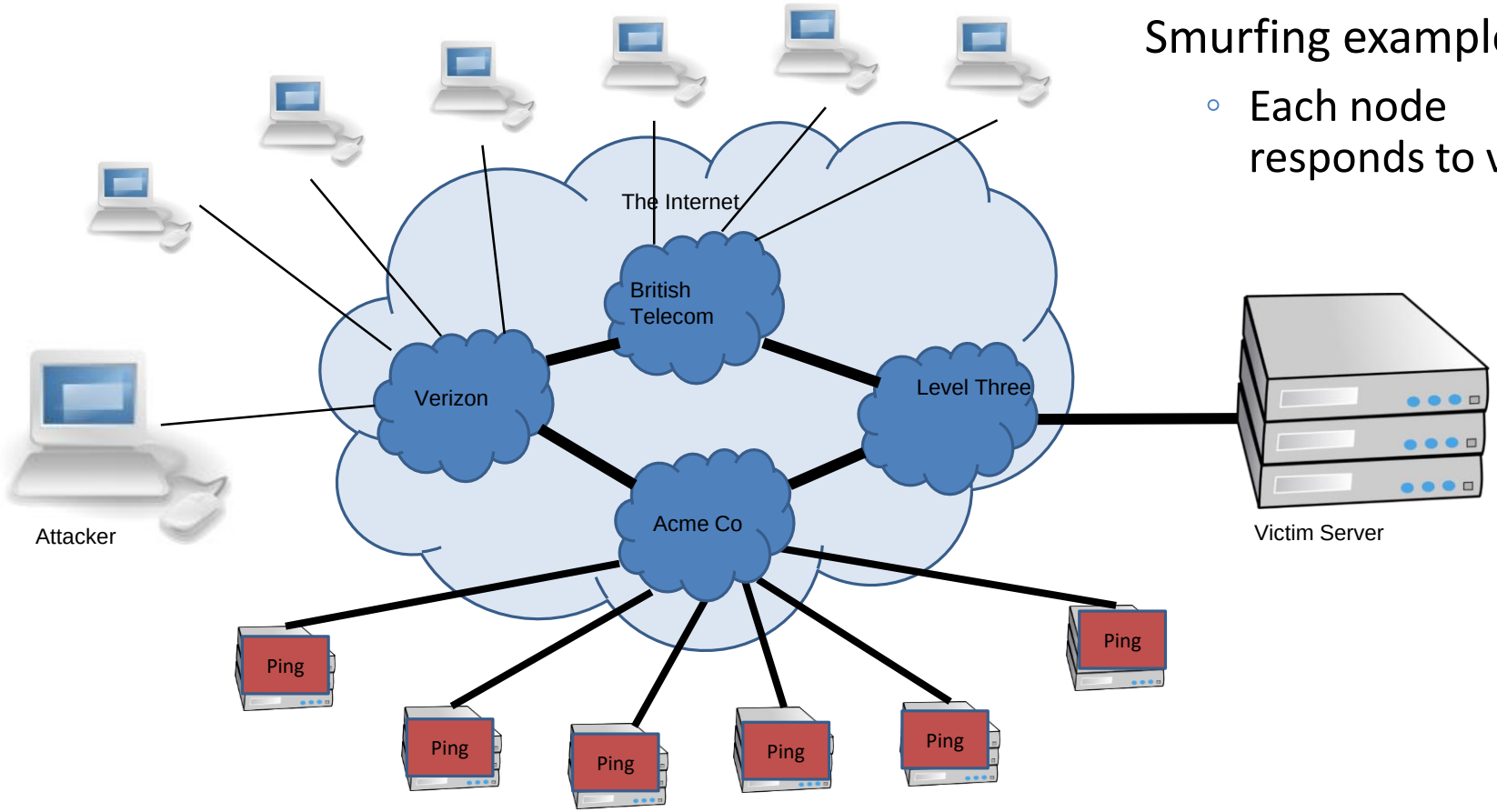
Smurfing example

- Attacker sends 1 ping which is sent to every node on the LAN



Smurfing example

- Each node responds to victim



LANs that allow Smurf attacks are badly configured. One approach is to blacklist these LANs.

powertech

Smurf Amplifier Registry (SAR)
http://www.powertech.no/smurf/

Current top ten smurf amplifiers (updated every 5 minutes)
(last update: 2016-01-17 23:31:02 CET)

Network	#Dups	#Incidents	Registered at	Home AS
212.1.130.0/24	38	0	1999-02-20 09:41	AS9105
204.158.83.0/24	27	0	1999-02-20 10:09	AS3354
209.241.162.0/24	27	0	1999-02-20 08:51	AS701
159.14.24.0/24	20	0	1999-02-20 09:39	AS2914
192.220.134.0/24	19	0	1999-02-20 09:38	AS685
204.193.121.0/24	19	0	1999-02-20 08:54	AS701
198.253.187.0/24	16	0	1999-02-20 09:34	AS22
164.106.163.0/24	14	0	1999-02-20 10:11	AS7066
12.17.161.0/24	13	0	2000-11-29 19:05	not-analyzed
199.98.24.0/24	13	0	1999-02-18 11:09	AS6199

2457713 networks have been probed with the SAR
56 of them are currently broken
193885 have been fixed after being listed here

Distributed Denial of Service (DDoS)

A large number of machines work together to perform an attack that prevents valid users from accessing a service.

Common examples:

- Slashdot effect – a large number of valid users all try and access at once.
- Botnets
- Amazon web services

What We Have Learned

- ARP protocol
- ARP poisoning attack
  - MitM attack on a LAN
- Transport layer protocols
  - TCP for reliable transmission
  - UDP when packet loss/corruption is tolerated
- Lack of built-in security in network protocols
  - Security can be incorporated into application layer (SSL)

Questions