Week 10: Lecture B

Network Denial of Service

Thursday, October 31, 2024

Announcements

- **Project 3: WebSec** released
  - **Deadline:** Thursday, November 7th by 11:59PM (**next week**)

Project 3: Web Security

Deadline: Thursday, November 7 by 11:59PM.

Before you start, review the course syllabus for the Lateness, Collaboration, and Ethical Use policies.

You may optionally work alone, or in teams of **at most two** and submit **one project per team**. If you have difficulties forming a team, post on **Piazza's Search for Teammates** forum. Note that the final exam will cover project material, so you and your partner should collaborate on each part.

The code and other answers your group submits must be entirely your own work, and you are bound by the University's Student Code. You may consult with other students about the conceptualization of the project and the meaning of the questions, but you may not look at any part of someone else's solution or collaborate with anyone outside your group. You may consult published references, provided that you appropriately cite them (e.g., in your code comments). **Don't risk your grade and degree by cheating!**

Complete your work in the **CS 4440 VM**—we will use this same environment for grading. You may not use any **external dependencies**. Use only default Python 3 libraries and/or modules we provide you.

Project 3 progress

Working on Part 1 — 0%

Finished Part 1, working on Part 2 — 0%

Finished Part 2, working on Part 3 — 0%

Finished with everything! — 0%

Haven't started yet :(— 0%

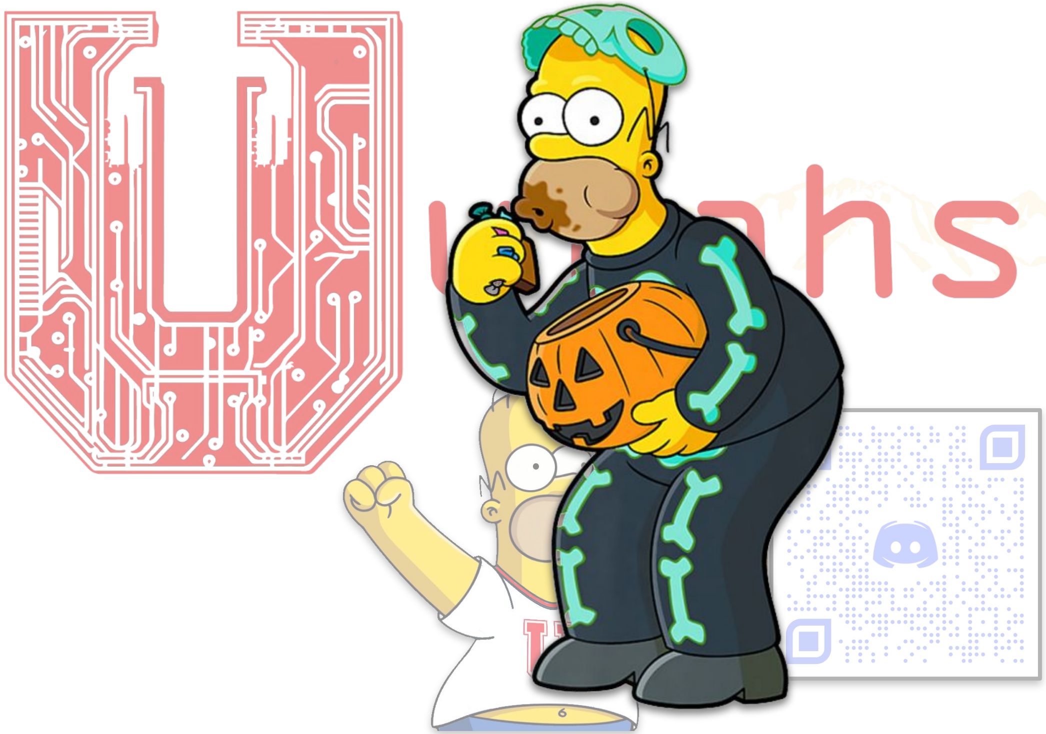
Announcements

utahsec

See Discord for meeting info!

utahsec.cs.utah.edu

Announcements



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Last time on CS 4440…

Application Layer Attacks
HTTP Content Injection
SMTP Header Spoofing
DNS Hijacking

Application Layer Attacks

- **Application Layer:**
  - **???**

Application Layer Attacks

- **Application Layer:** where **network-facing apps** send/receive message
  - Application-specific protocols (message semantics, structure, processing rules, etc.)

- **Attacking the application layer:**
  - **???**

Application Layer Attacks

- **Application Layer:** where **network-facing apps** send/receive message
  - Application-specific protocols (message semantics, structure, processing rules, etc.)

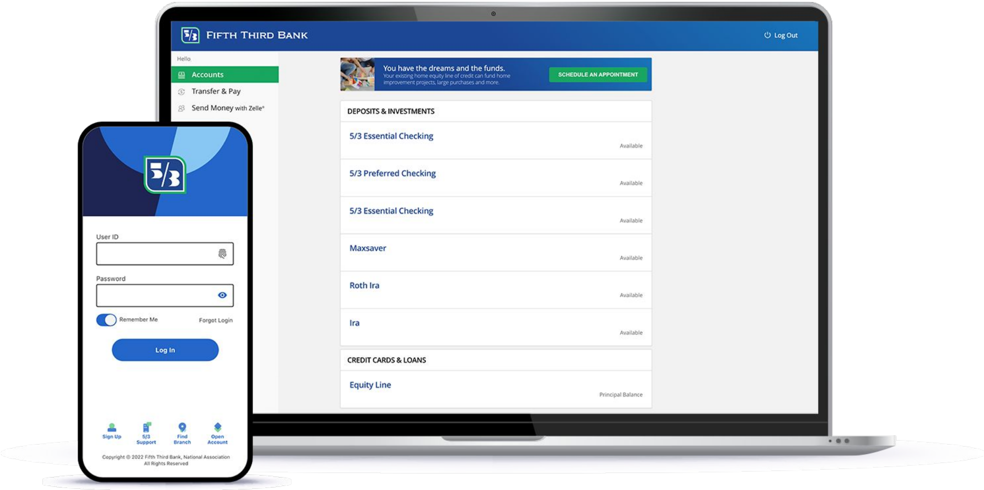
- **Attacking the application layer:**
  - **Command Injection**
    - SQL injection, CSRF, XSS
  - **Denial of Service**
    - Crash a remote application
    - Prevent others from using it
  - **Message Tampering / Sniffing**
    - Injecting data into messages
    - Capturing unencrypted data
  - **Other protocol-specific attacks**

http:// FTP SMTP

McAfee zoom

The HTTP Protocol

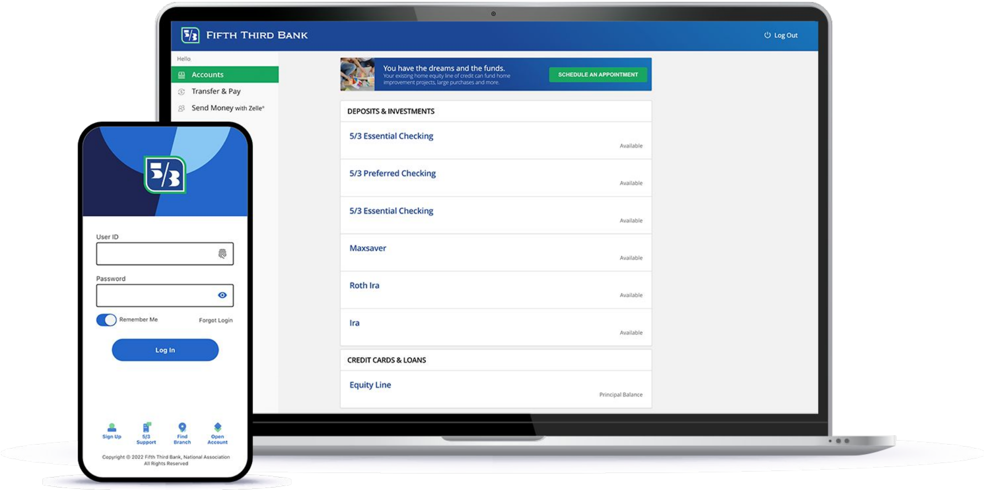
- **What is HTTP?**



The HTTP Protocol

- **What is HTTP?**
  - Protocol for transmitting **hypermedia documents** (e.g., web pages)

- **HTTP’s Characteristics:**
  - Widely used
  - **Simple**
  - **Unencrypted**



HTTP Tampering

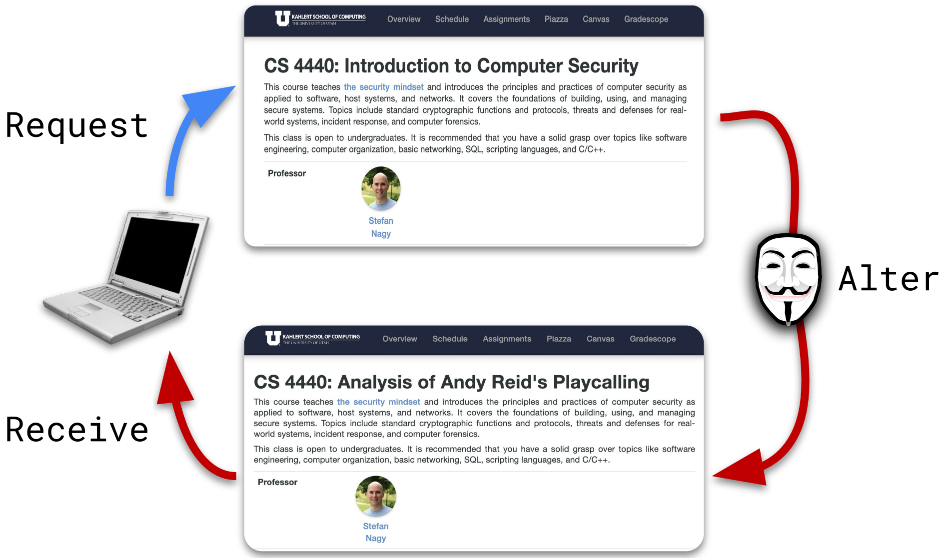
- **Attack: ???**

Request

Alter

HTTP Tampering

- **Attack:** exploit **HTTP's** insecurity
  - **Nothing is encrypted!**
- **Attacker intercepts** requested webpage and **modifies it**
  - User receives modified webpage
- **Attacker capabilities?**
  - Inject malicious **content**
  - Inject malicious **code**



Thwarting HTTP Injection

- **Defenses: ???**

Thwarting HTTP Injection

- **Defenses:** encrypt everything all the time!

Answer: *completely* ditch HTTP!

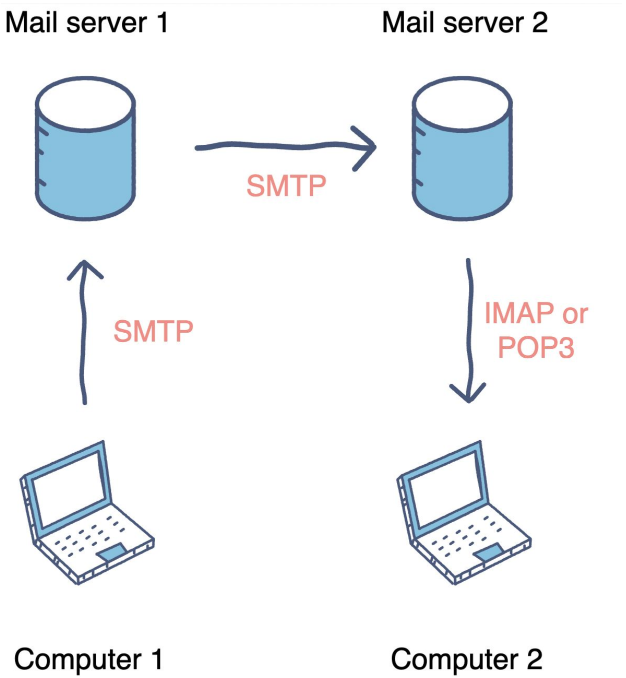
- As web and app developers, enforce strict **HTTPS** compliance
  - Necessary to prevent **HTTPS→HTTP downgrade attacks**

The SMTP Protocol

- **SMTP:** Simple Mail Transfer Protocol
  - Implemented in the **application** layer

- **Characteristics:**
  - Text-based
  - Connection-oriented
  - Uses TCP ports 25/587

- **Security guarantees:**
  - **???**



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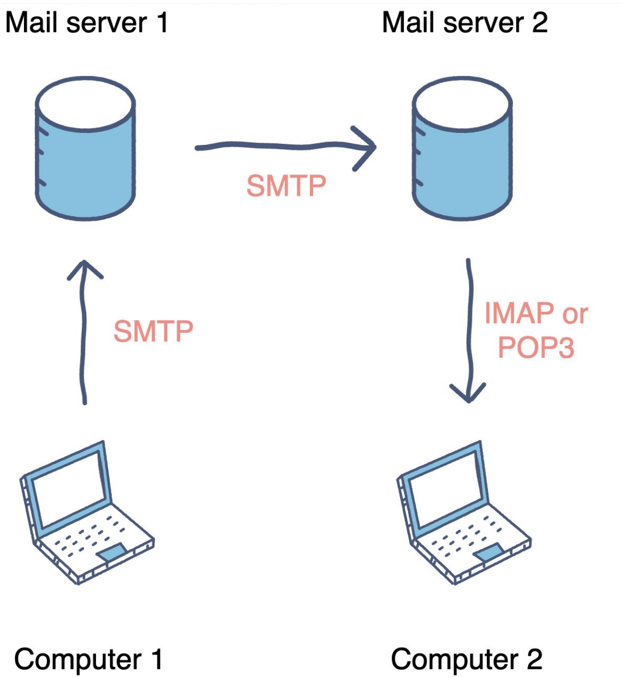
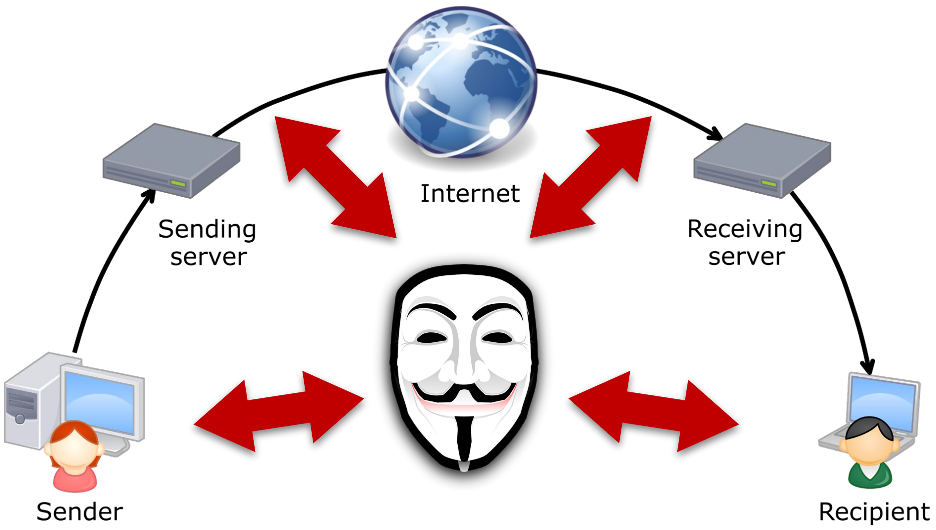
  - Message integrity—**no!**
  - Confidentiality—**no!**
  - Authentication—**no!**



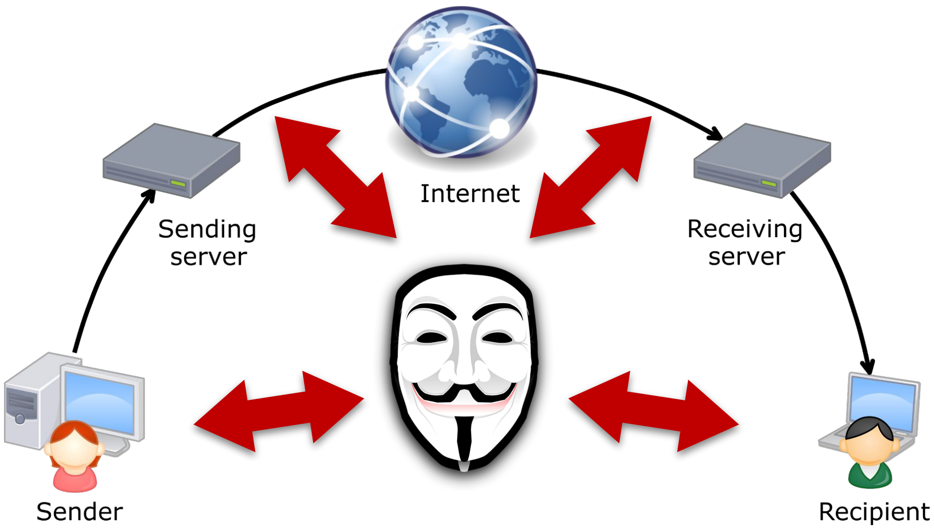
The SMTP Protocol

- No **message integrity**
  - **???**
- No **confidentiality**
  - **???**
- No **authentication**
  - **???**



The SMTP Protocol

- No **message integrity**
  - Tamper with messages
  - Block messages
- No **confidentiality**
  - Find sender/recipient
  - Read message contents
- No **authentication**
  - Spoof sender identity



SMTP Header Spoofing

- **Attack: ???**

```
S: 220 attacker.com SMTP Exim
C: HELO attacker.com
S: 250 Hello attacker.com
C: MAIL FROM: <ceo@company.com>
S: 250 Ok
C: RCPT TO: <bob@company.com>
S: 250 Accepted
C: DATA
S: 354 Enter a message, ending with "." on a line by itself
C: Subject: Download this urgently
C: From: ceo@company.com
C: To: bob@company.com
C:
C: Hi Bob,
C: Please download this urgently: https://some-malicious-link.com
C: Regards
C: .
S: 250 OK
C: QUIT
S: 221 attacker.com closing connection
```

```
To: robertbateman@email.com
Subject: Hi There
From: "Mickey Mouse" <m.mouse@disney.com>
X-Priority: 3 (Normal)
Importance: Normal
Errors-To: m.mouse@disney.com
Reply-To: m.mouse@disney.com
Content-Type: text/plain
```

SMTP Header Spoofing

- **Attack:** spoof SMTP header to **mislead recipient** about sender of the email

```
S: 220 attacker.com SMTP Exim
C: HELO attacker.com
S: 250 Hello attacker.com
C: MAIL FROM: <ceo@company.com>
S: 250 Ok
C: RCPT TO: <bob@company.com>
S: 250 Accepted
C: DATA
S: 354 Enter a message, ending with "." on a line by itself
C: Subject: Download this urgently
C: From: ceo@company.com
C: To: bob@company.com
C:
C: Hi Bob,
C: Please download this urgently: https://some-malicious-link.com
C: Regards
C: .
S: 250 OK
C: QUIT
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```

Fake Sender (MAIL FROM)

Victim (RCPT TO)

Malicious Link

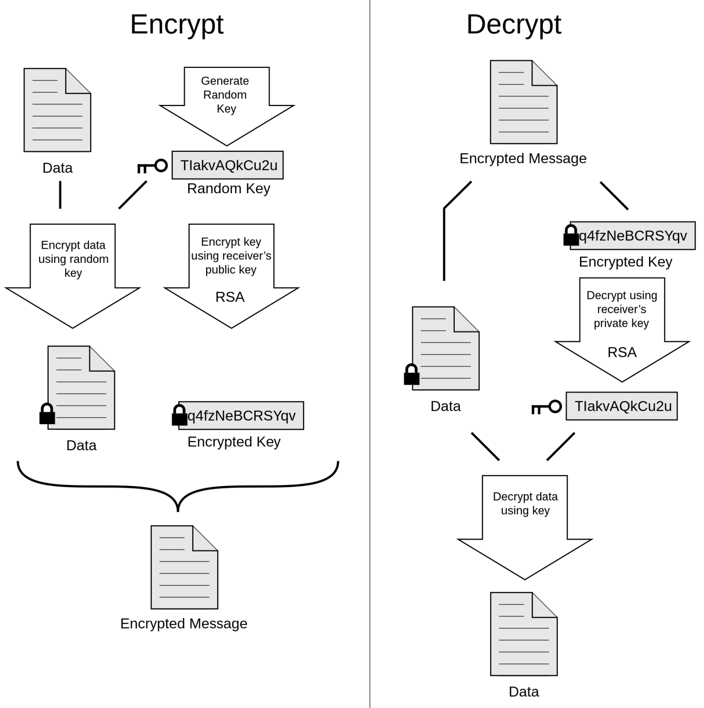
```
To: robertbateman@email.com
Subject: Hi There
From: "Mickey Mouse" <m.mouse@disney.com>
X-Priority: 3 (Normal)
Importance: Normal
Errors-To: m.mouse@disney.com
Reply-To: m.mouse@disney.com
Content-Type: text/plain
```

Thwarting Email Spoofing

- **Defenses: ???**

Thwarting Email Spoofing

- **Checking email bodies**
  - Included links
  - Attached files
  - Text analysis (e.g., known spam campaigns)
- **Checking email headers**
  - Egress server domain registration
    - Check that sender is who it says it is
  - Pretty Good Privacy (PGP)
    - Sender and Receiver authentication
    - Confidentiality
    - Integrity



Identification on the Web

- How do we identify **people**?
  - Social security numbers
  - Passports, drivers licenses
  - Their unique fingerprints

- How can we identify **internet hosts**?
  - **???**

Identification on the Web

- How do we identify **people**?
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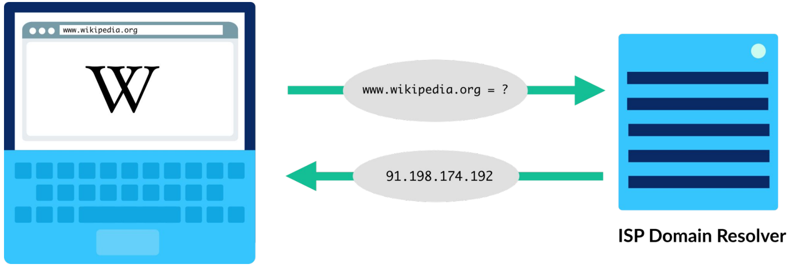
- How can we identify **internet hosts**?
  - **Network layer:** location via **IP addresses**
    - A logical addressing system
    - 32-bit (IPV4) addressing datagrams
  - **What you care about: ???**



Identification on the Web

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  - Social security numbers
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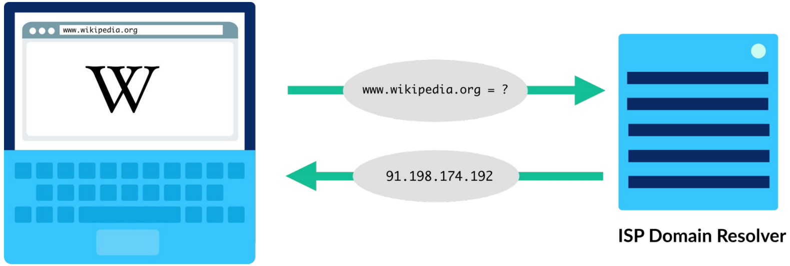
- How can we identify **internet hosts**?
  - **Network layer:** location via **IP addresses**
    - A logical addressing system
    - 32-bit (IPV4) addressing datagrams
  - **What you care about:** the domain name
    - E.g., `www.wikipedia.org`



The Domain Name System

- **Distributed database** implemented in hierarchy of many name servers

- Application-layer **protocol:**
  - Hosts and domain name servers communicate to resolve **domain names**
    - Address–name translation

- **Result:** user requests **???**
  - But their host really gets **???**

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- **Application-layer protocol:**
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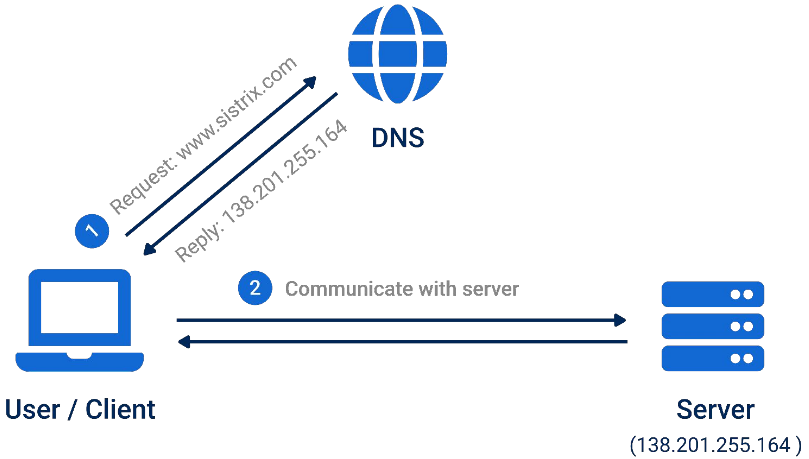
- **Result:** user requests **domain name**
  - But their host really gets its **IP address**
  - Convenient!



The Domain Name System

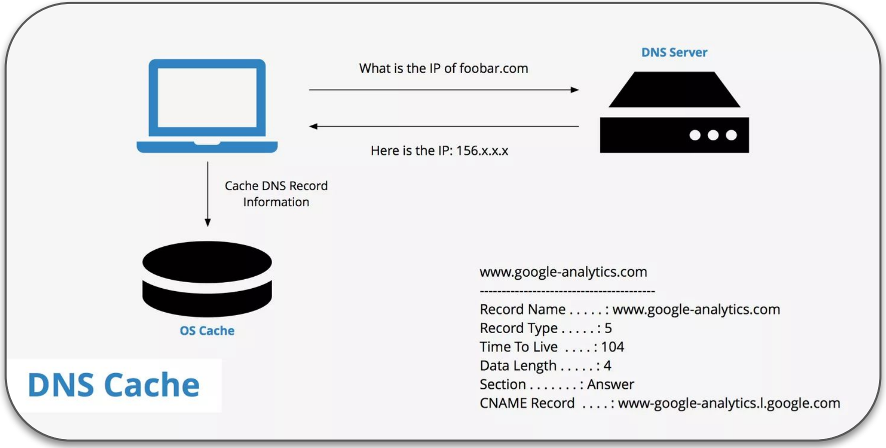
- **How can we optimize DNS resolution?**
  - **???**

The Domain Name System

- **How can we optimize DNS resolution?**
  - **Cache look-ups** to **amortize initial look-up**, reduce system load

- Optimization 1: **???**

- Optimization 2: **???**

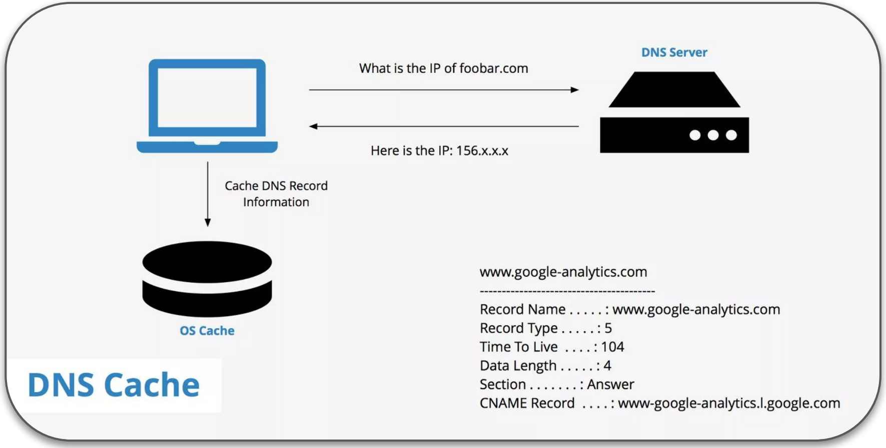


The Domain Name System

- **How can we optimize DNS resolution?**
  - **Cache look-ups** to **amortize initial look-up**, reduce system load

- Optimization 1: **temporal locality**
  - `www.espn.com/page1`
  - `www.espn.com/page2`

- Optimization 2: **popular domains**
  - `google.com`
  - `Facebook.com`



The Domain Name System

```
stefan@cs4440:~$ time nslookup facebook.com
Server:         127.0.0.53
Address:        127.0.0.53#53

Non-authoritative answer:
Name:   facebook.com
Address: 31.13.70.36
Name:   facebook.com
Address: 2a03:2880:f10d:83:face:b00c:0:25de


real    0m0.474s
user    0m0.000s
sys     0m0.015s
```

First Lookup (**non-cached**)

```
stefan@cs4440:~$ time nslookup facebook.com
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```
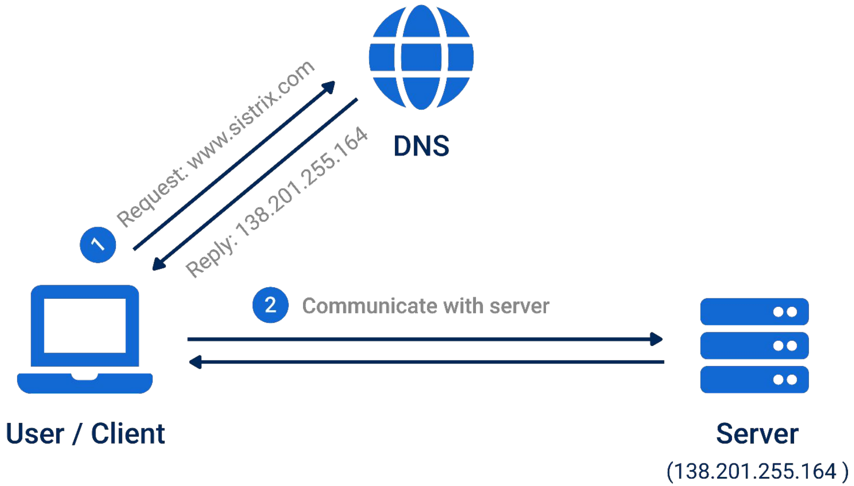

Second Lookup (**cached**)

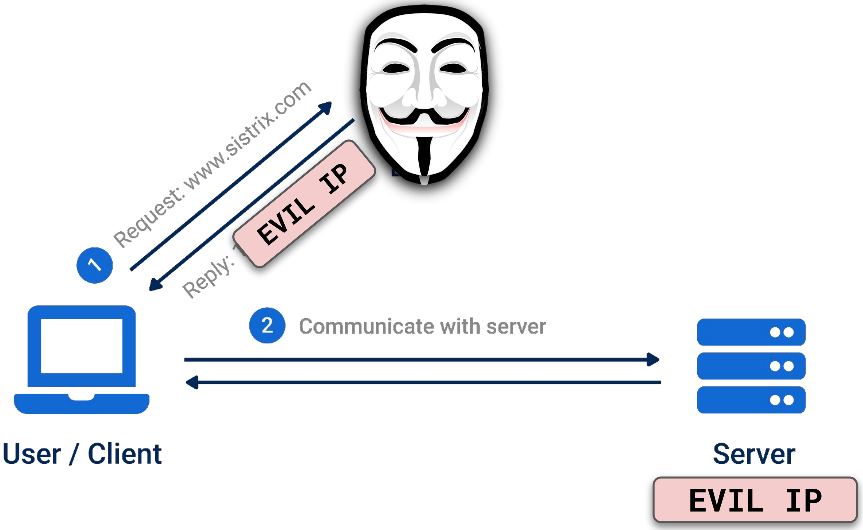
The Domain Name System

- What can an attacker do if they **control a DNS server**?



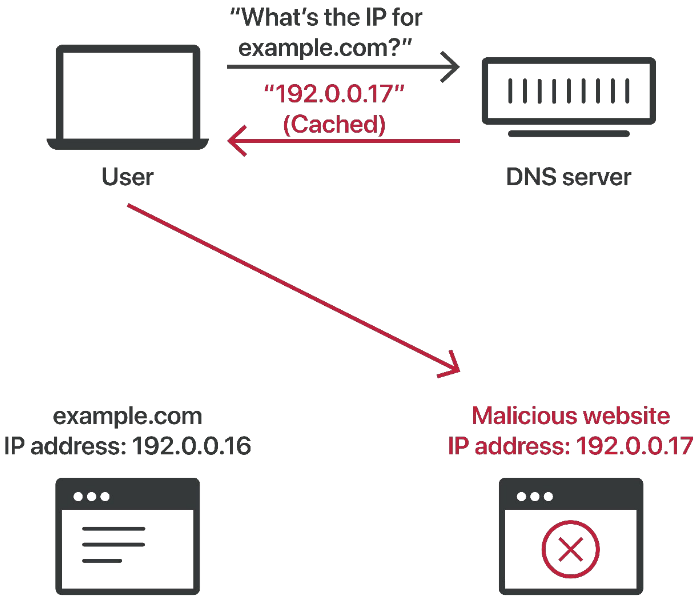
The Domain Name System

- What can an attacker do if they **control a DNS server**?
  - **Control how users of that DNS server view the internet!**
    - Assuming they use domain names



DNS Cache Poisoning

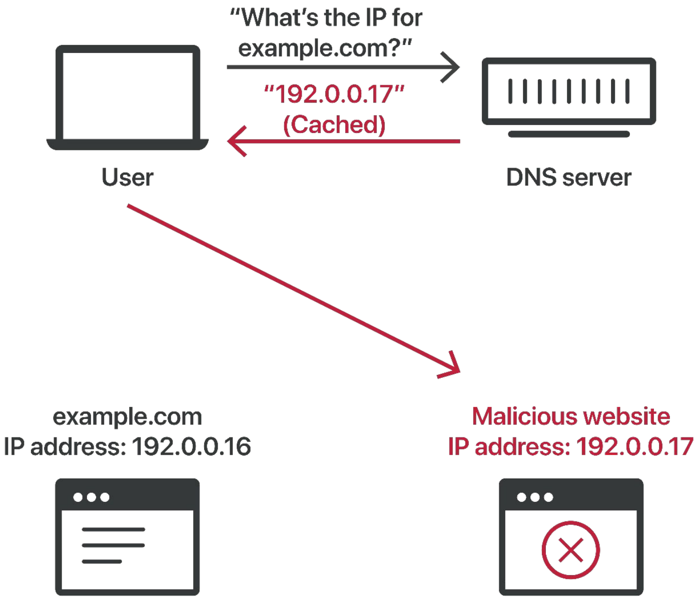
- **Attack: ???**



DNS Cache Poisoning

- **Attack:** pre-empt DNS lookup by **injecting malicious cache** contents
  - Exploits DNS lookup optimization!

- Victim performs cache lookup, instead gets malicious domain IP
  - Attacker can **redirect** the victim's browser to the malicious website



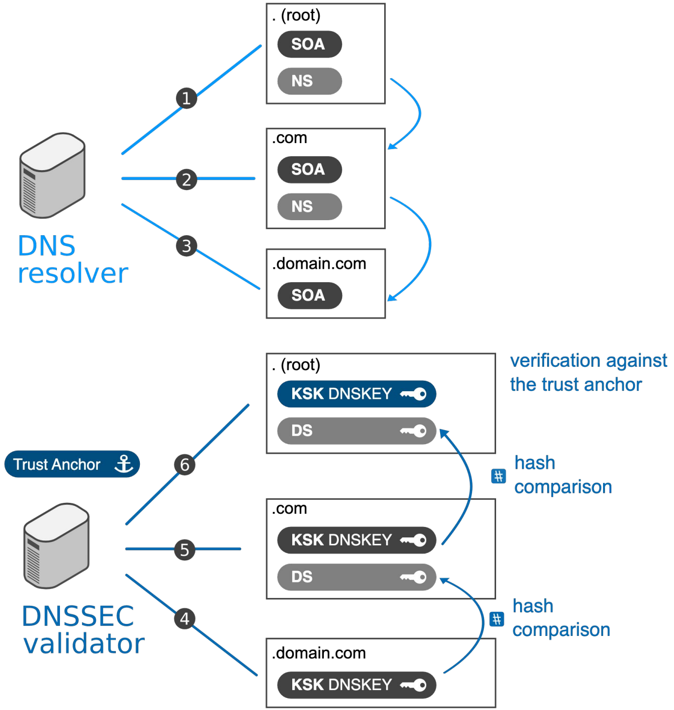
Thwarting DNS Hijacking

- **Defenses: ???**

Thwarting DNS Hijacking

- **DNS-level** authentication
  - DNSSec
  - Public-key crypto to “sign” DNS records

- **Endpoint** authentication
  - Certify that what I am seeing really is bank.com
  - Transport Layer Security (TLS)



Questions?

This time on CS 4440…

Network Availability
Denial of Service (DoS) Attacks
Transport, Link, Network, and Physical DoS

Basic Security Properties

- **Confidentiality: ???**
- **Authenticity: ???**
- **Integrity: ???**
- **Access Control: ???**

Basic Security Properties

- **Confidentiality:** Concealment of information or resources
  - **Attacks: ???**
- **Authenticity:** Identification and assurance of info origin
  - **Attacks: ???**
- **Integrity:** Preventing improper and unauthorized changes
  - **Attacks: ???**
- **Access Control:** Enforce who is allowed access to what
  - **Attacks: ???**

Basic Security Properties

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- **Availability:** Ability to use desired information or resource
  - **Attacks: denial of service**

Denial of Service Attacks

DoS: Denial of Service

- **Goal: ???**

DoS: Denial of Service

- **Goal:** make a service unusable, usually by overloading the server or network

- **How?**

DoS: Denial of Service

- **Goal:** make a service unusable, usually by overloading the server or network

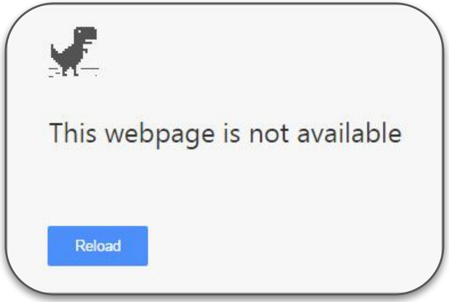
- **How?**
  - Trigger the host to **crash**
    - Application-based DoS
    - Memory corruption
  - Consume host's **resources**
    - TCP SYN floods
    - ICMP ECHO (ping) floods
  - Consume host's **bandwidth**
    - UDP floods
    - ICMP floods

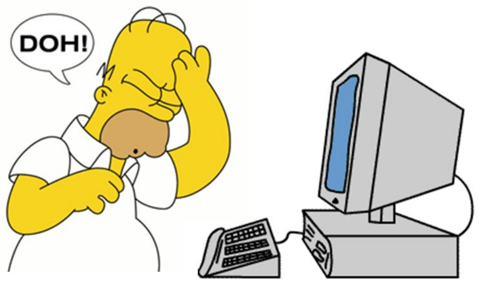
Amazon loses **$66,000 per minute** of downtime

Higher security makes DoS attacks **more likely**

Common DoS Attacks

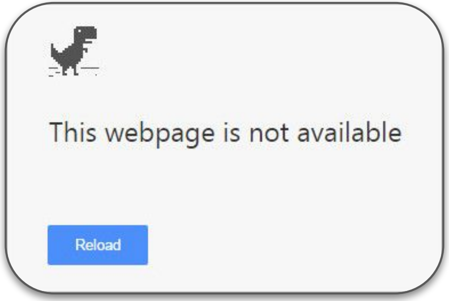
- Locally-induced crash
  - Exploit host's OS or server software bug
- Local resource consumption
  - fork() bomb, fill disk, deep directory nesting
- Deny service to individual hosts
  - Force crash or outage of critical services
- Remotely-induced crash
  - "Magic" packets—ping of death, teardrop
- Remote resource consumption
  - Syslog, SYN, fragment flood, UDP storm

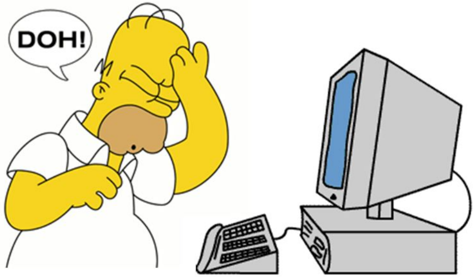




Common DoS Attacks (cont.)

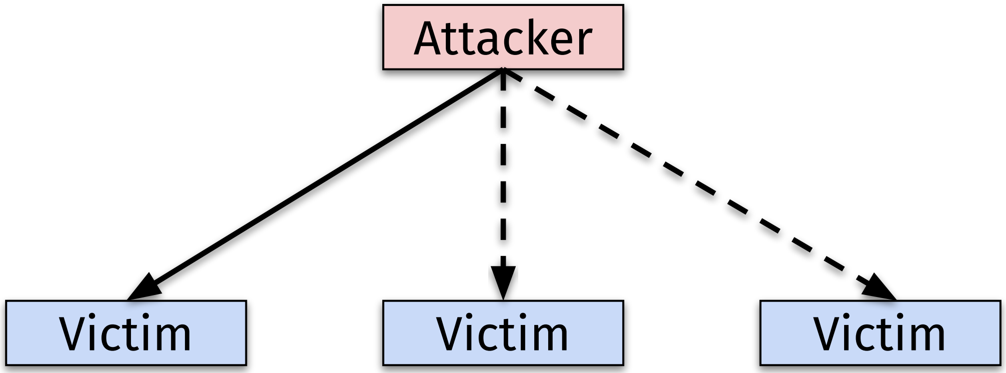
- Deny service to an entire network
  - Target vulnerable links, critical network infrastructure
- Remotely-induced network outage
  - Attacks against routers, DNS servers
  - Redirected routes—forged routing information
- Remote network congestion
  - Remote control of compromised hosts (“zombies”)
    - Allows for coordinated flooding
    - Distributed Denial of Service (DDoS)





Simple DoS Attacks

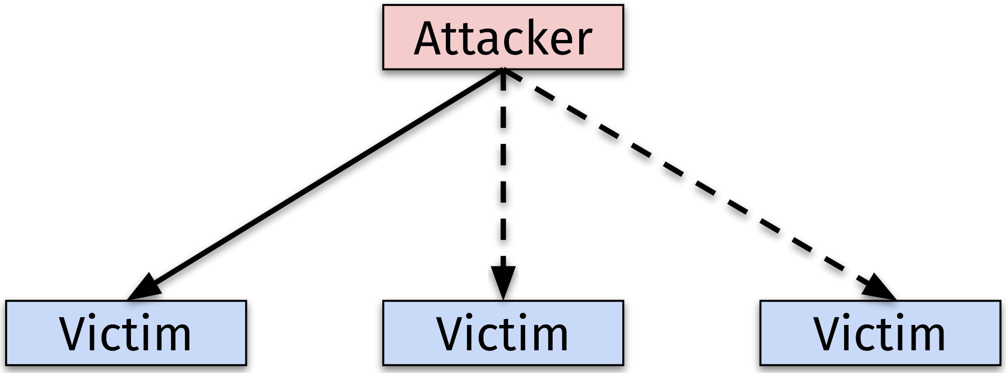
- Attacker spoofs their source address to hide origin
- **Defenses:**
  - ???



Simple DoS Attacks

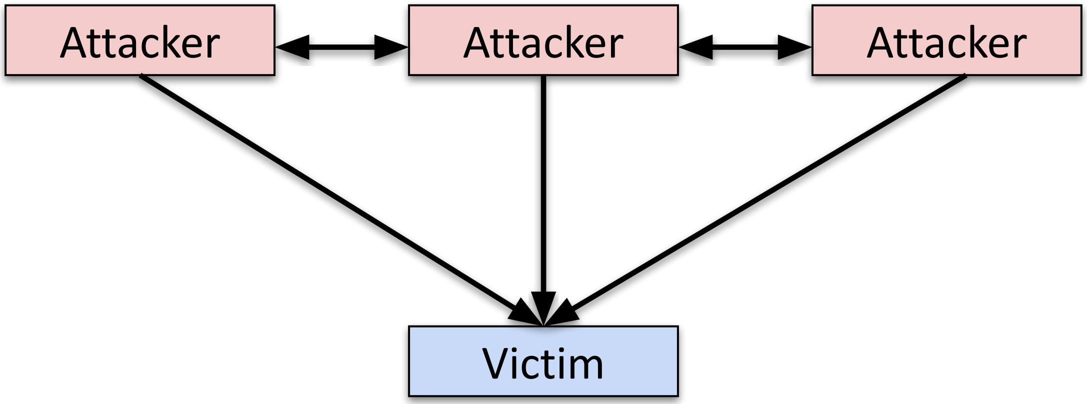
- Attacker spoofs their source address to hide origin

- **Defenses:**
  - Block source IP address
  - Firewall
  - ISP-level blocking
  - Ignore requests

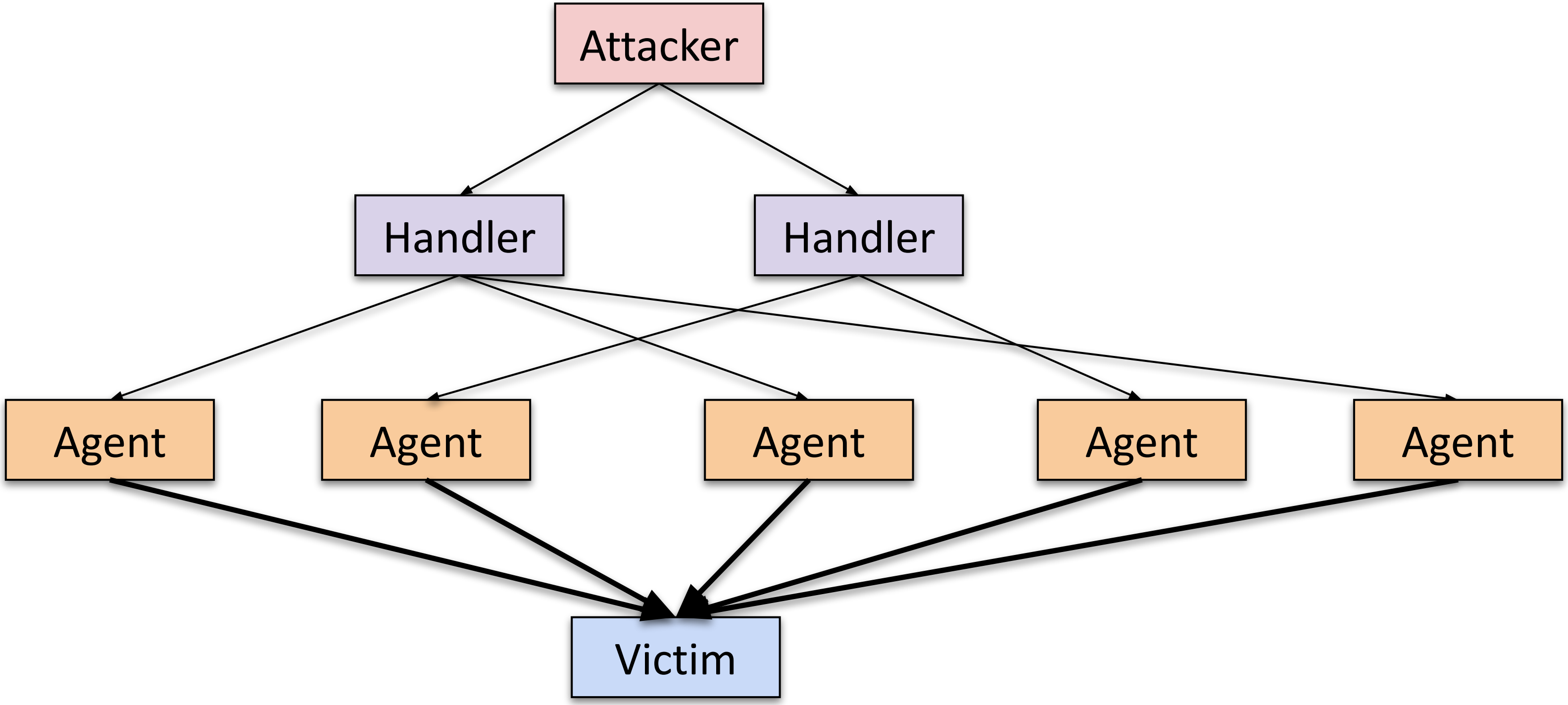


Coordinated DoS Attacks

- Multiple willing attackers coordinate an attack on victim(s)
  - Same source-spoofing techniques as before
  - Harder to deal with



Distributed DoS Attacks (DDoS)



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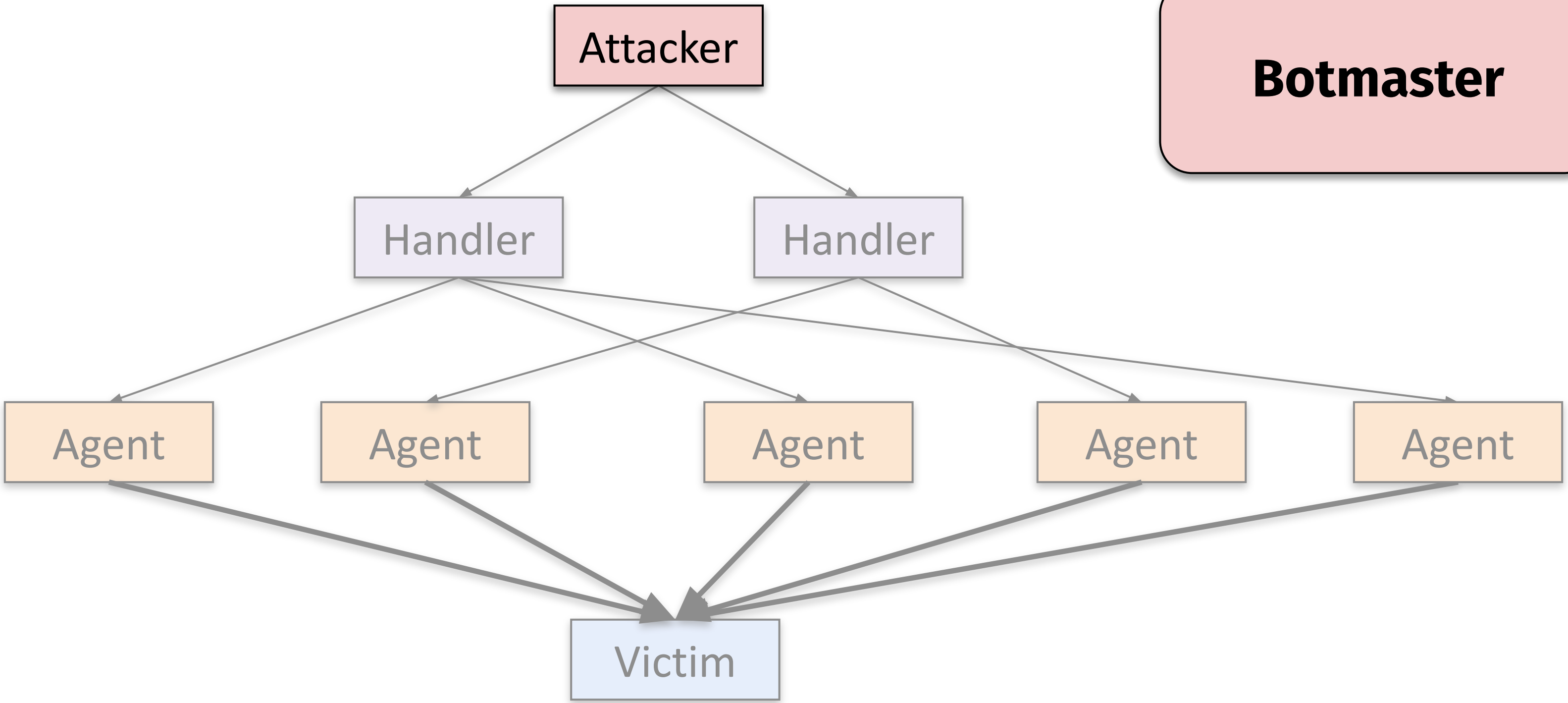
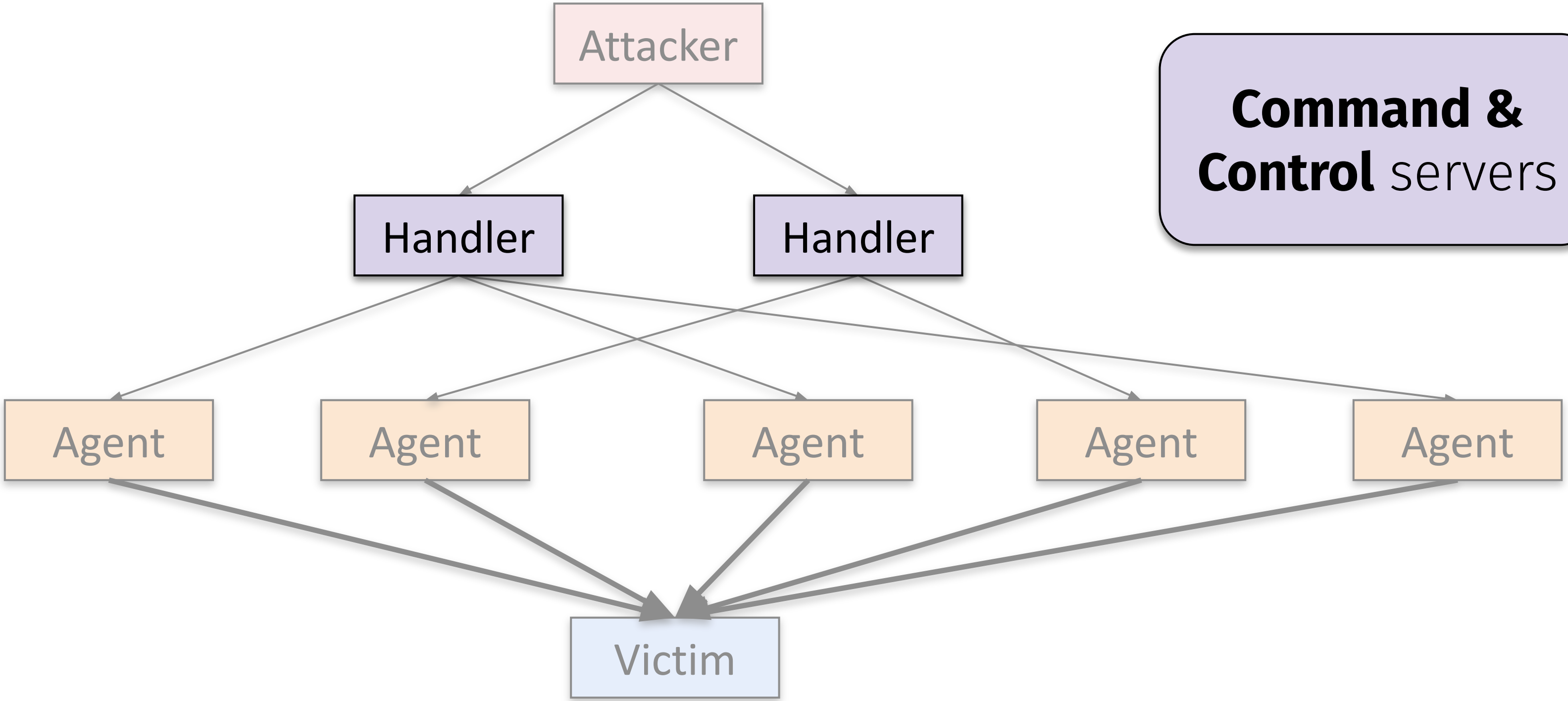


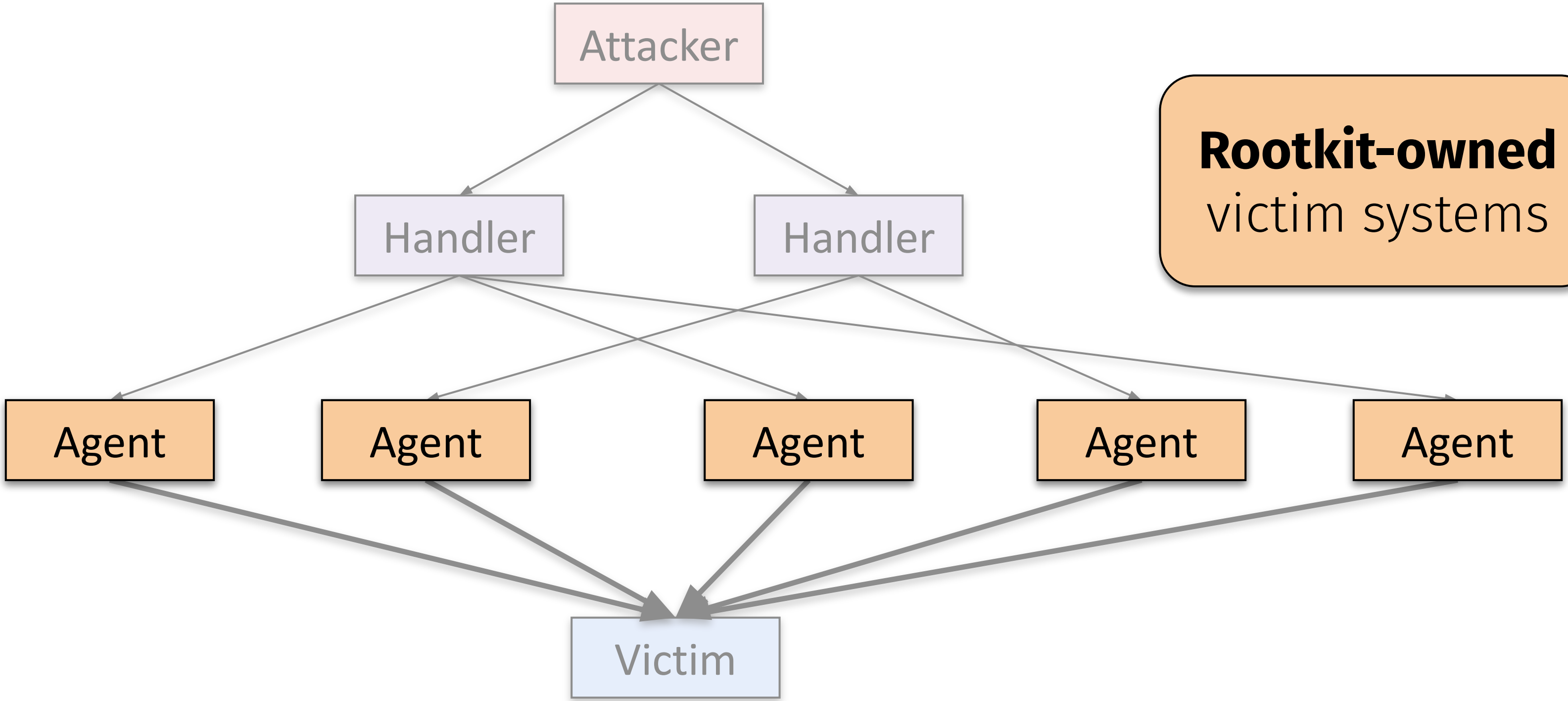
Botmaster

Distributed DoS Attacks (DDoS)



Command & Control servers

Distributed DoS Attacks (DDoS)



Rootkit-owned victim systems

Timeline of a DDoS Attack

- **Goal:** compromise a large number of machines to form a botnet
  1. Attacker identifies **exploitable hosts** with scanners or other techniques
  2. Attacker **gains control** over systems via exploits, password cracking, etc.
  3. Attacker installs **rootkit**
  4. Attacker **remotely instructs** compromised machines to **attack the target**

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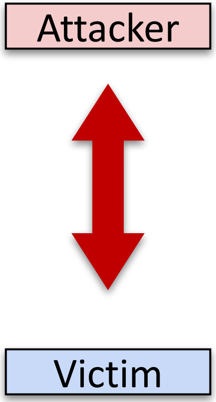

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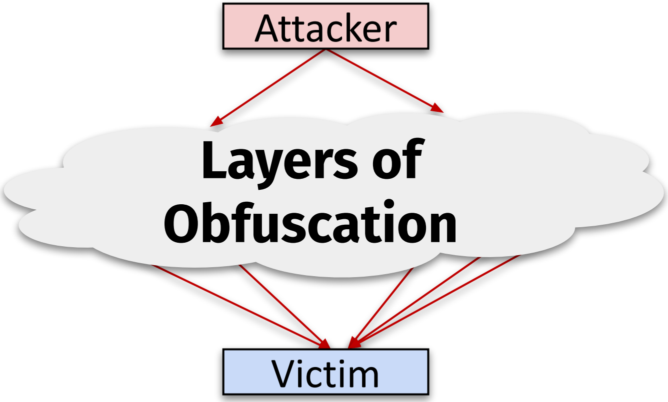

Victim never sees the true **attacker**

Real DDoS Botnets

The Mirai botnet explained: How teen scammers and CCTV cameras almost brought down the internet

Mirai took advantage of insecure IoT devices in a simple but clever way. It scanned big blocks of the internet for open Telnet ports, then attempted to log in default passwords. In this way, it was able to amass a botnet army.

Storm: the largest botnet in the world?

Timely spam blasts help spread highly aggressive malware

A tiny botnet launched the largest DDoS attack on record

A small but powerful army of just 5,000 devices generated a record-breaking web attack.

DDoS or legitimate traffic?

DDoS or legitimate traffic?

reddit

u/TheRealAndyReid

"OMG… **Joe's in KC** serves the BEST **brisket sandwich**"

DDoS or legitimate traffic?

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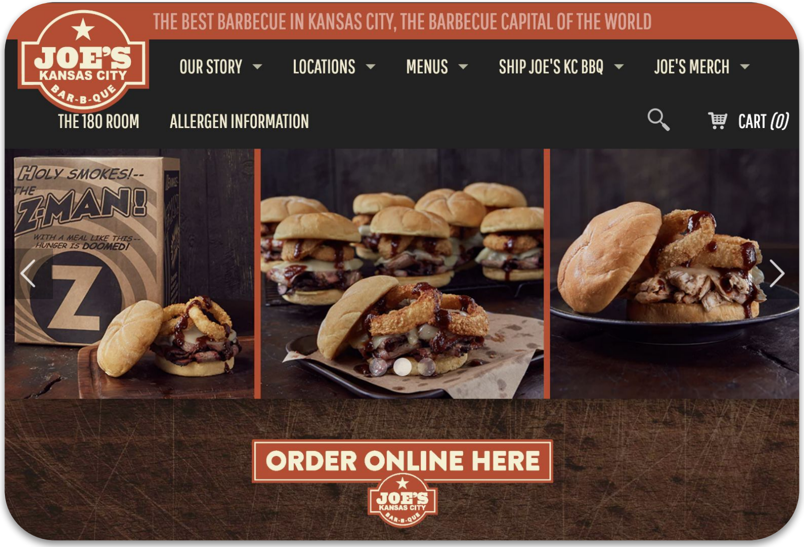
https://www.joeskc.com/



DDoS or legitimate traffic?

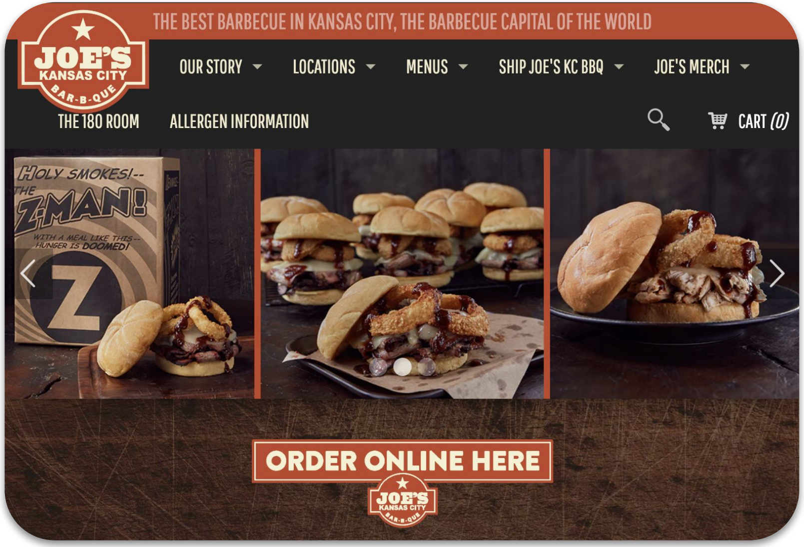
reddit u/TheRealAndyReid

"OMG… **Joe's in KC** serves the BEST **brisket sandwich**"

"Click!"

"Order now!"

https://www.joeskc.com/



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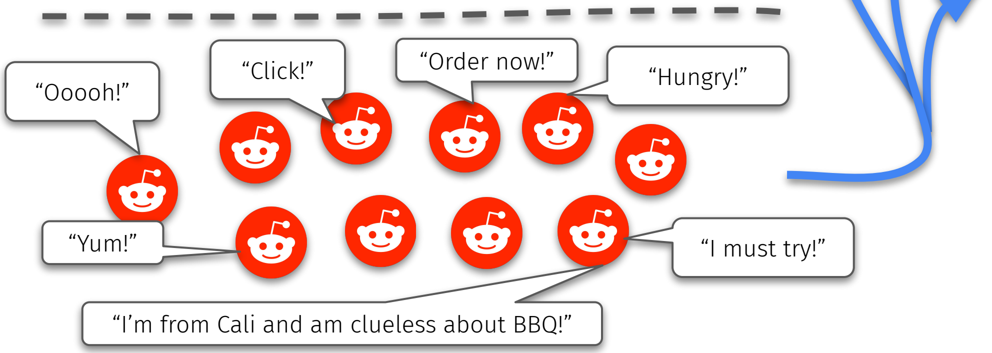

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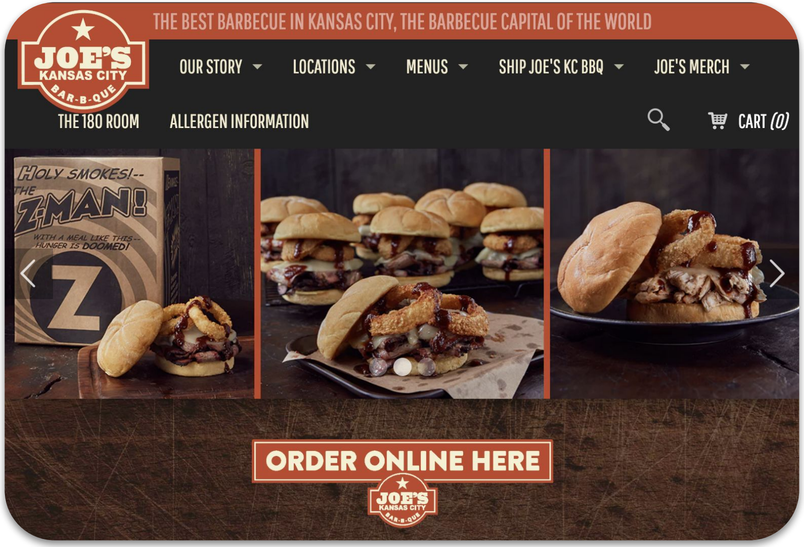
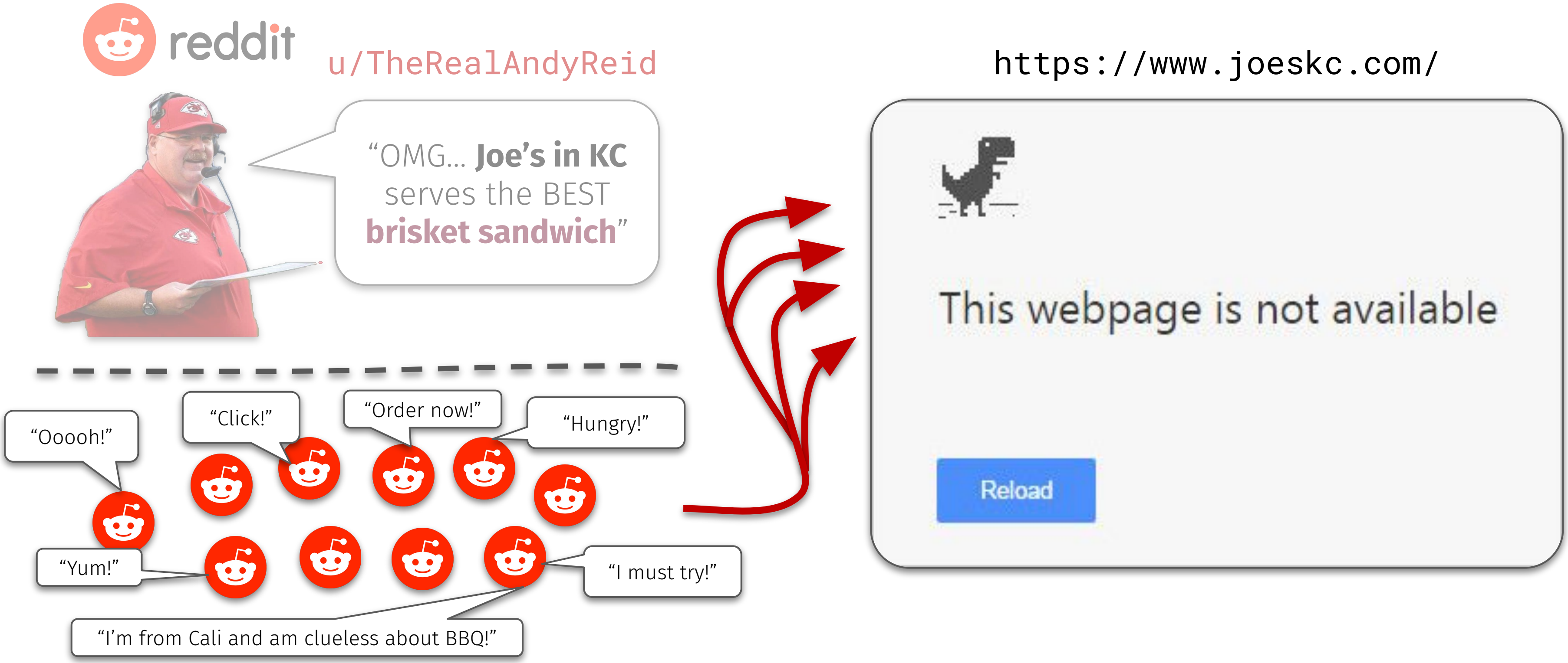


DDoS or legitimate traffic?



DDoS or legitimate traffic?

- How can we differentiate between **Flash Mob traffic** and **DDoS traffic**?

DDoS or legitimate traffic?

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- **Flash Mob traffic**
  - Many clients using service legitimately
  - “Slashdot Effect”, “Reddit Hug of Death”
    - Traffic dies down when the network is flooded
  - Sources in flash crowd are clustered
    - Usually by location (e.g., USA)

What Does Slashdot Effect Mean?

The slashdot effect refers to a temporary surge in traffic to a website, which can occur when a high-traffic website posts a link to smaller site or blog, thus directing an unprecedented surge in traffic. If the traffic increase is very large, it slow the site down or make it unreachable. The site is then considered to have been "slashdotted."

It's when someone posts a link to a website saying "Everyone, look at this website!" and everyone *does*. This puts so much traffic on the site in question's servers that they get overloaded and crash, causing the site to be inaccessible until the amount of traffic dies down a bit.

DDoS or legitimate traffic?

- How can we differentiate between **Flash Mob traffic** and **DDoS traffic**?

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    - Traffic dies down when the network is flooded
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    - Usually by location (e.g., USA)

- **DDoS traffic**
  - Attack does not end when host crashes
  - Scattered locations (e.g., entire world)

> **What Does Slashdot Effect Mean?**
>
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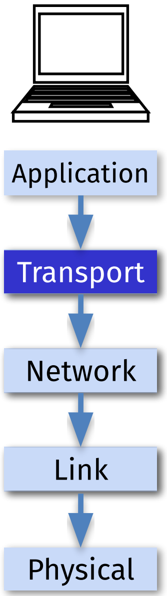
Questions?

Transport Layer DoS

Recap: The Transport Layer

- **What does it facilitate?**
  - **???**

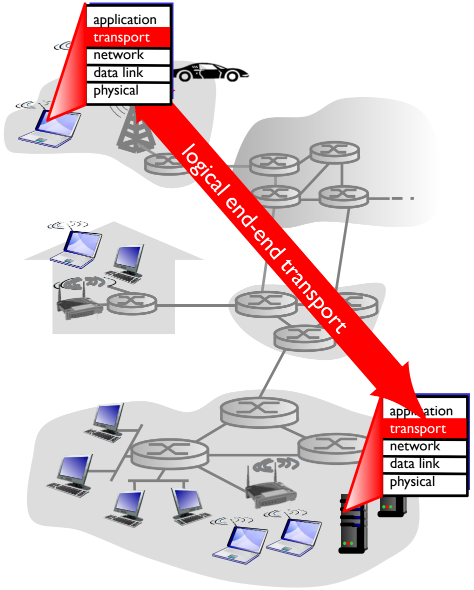
- **Key protocols?**
  - **Protocol 1: ???**
    - **Characteristics: ???**
  - **Protocol 2: ????**
    - **Characteristics: ???**

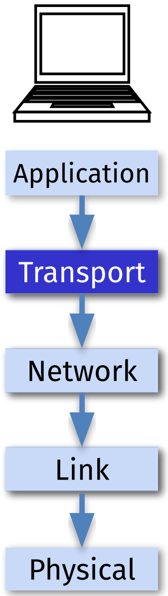


Recap: The Transport Layer

- **What does it facilitate?**
  - Communication between apps on different hosts

- **Key protocols?**
  - **Protocol 1: TCP** (Transmission Control Protocol)
    - **Characteristics: slow/complex** but **reliable**
  - **Protocol 2: UDP** (User Datagram Protocol)
    - **Characteristics: fast/simple** but **unreliable**





The TCP Three-way Handshake

- **Recall:** TCP is a **connection-oriented** protocol
  - Initiate with three-way "handshake": **SYN**, **SYN-ACK**, **ACK**

Client: SYN

The TCP Three-way Handshake

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Client: SYN

Server: SYN-ACK

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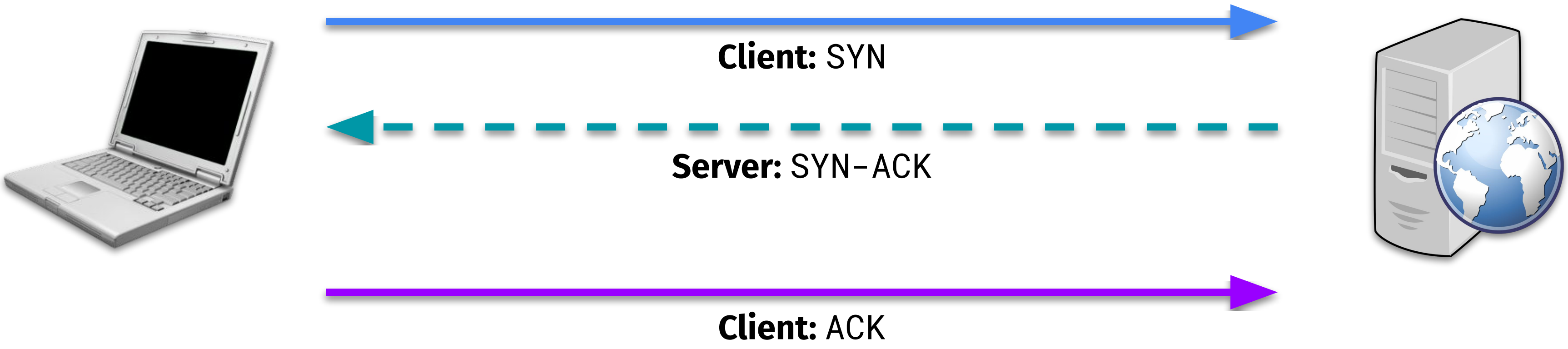
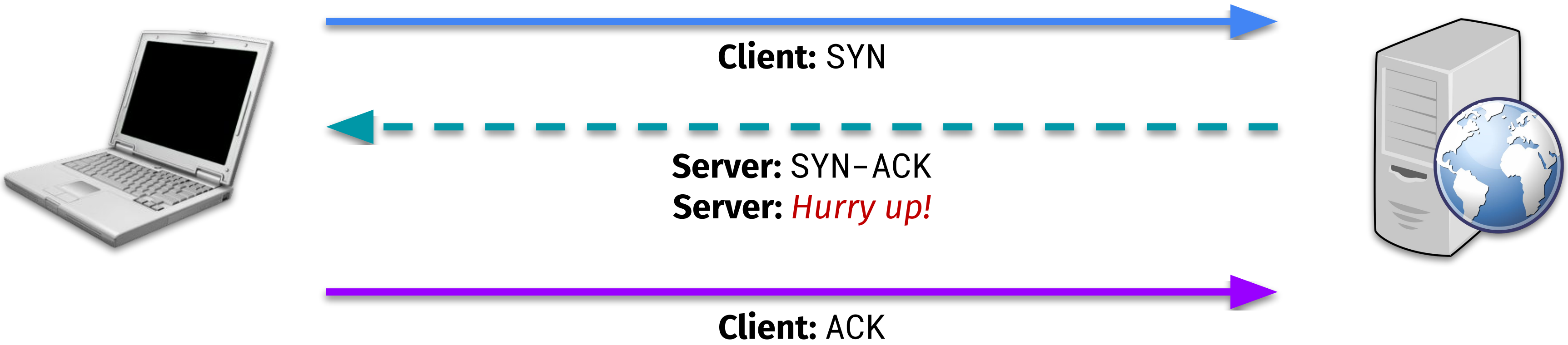


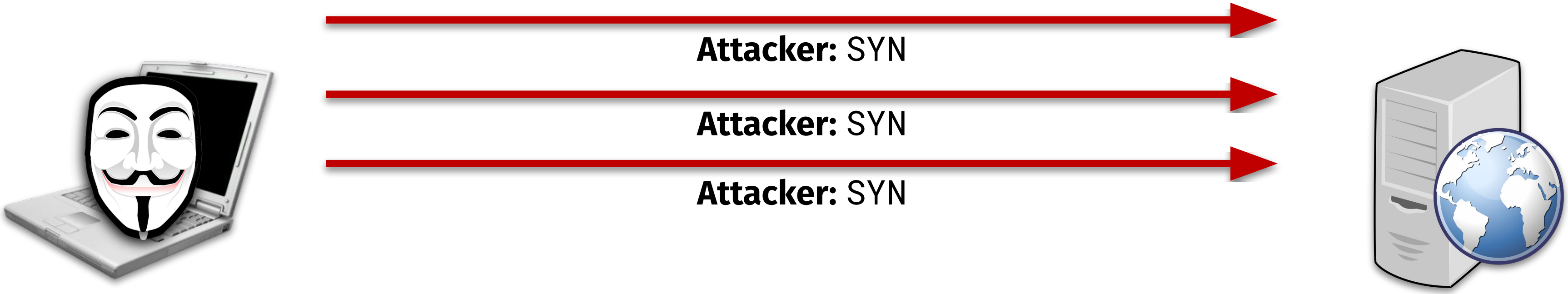
The TCP Three-way Handshake

- **Recall:** TCP is a **connection-oriented** protocol
  - Initiate with three-way “handshake”: **SYN**, **SYN-ACK**, **ACK**
  - **Server waits until client responds with ACK**



SYN Flooding Attack

- **Attack:** **spam SYN packets** to server, with **spoofed origin** address



SYN Flooding Attack

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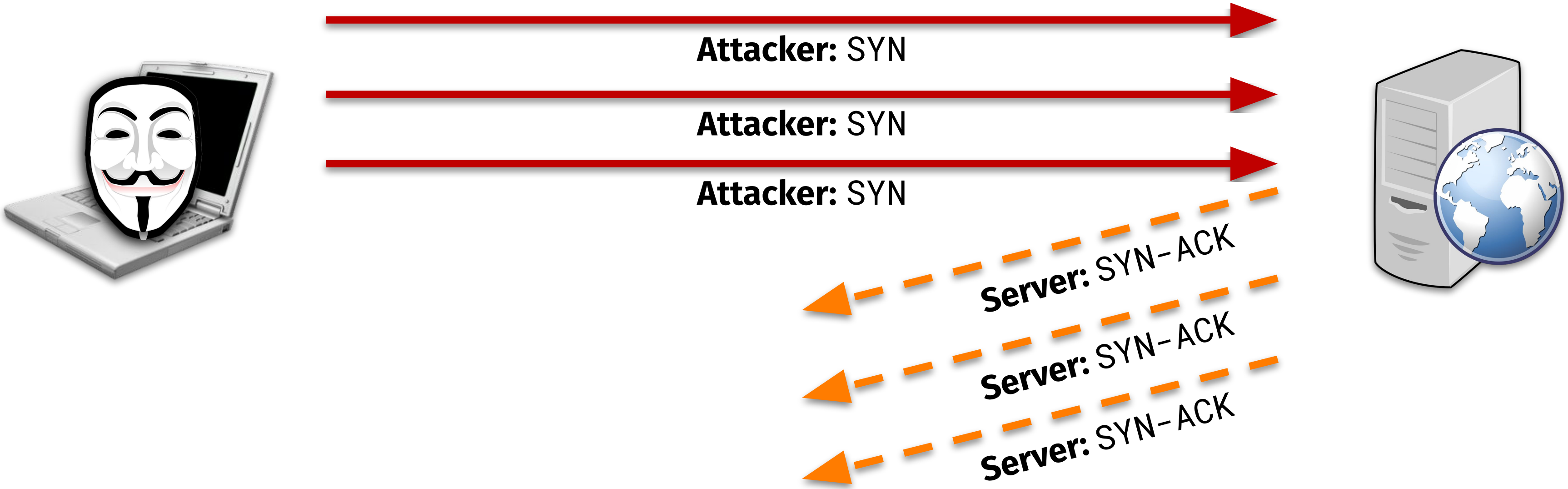

SYN Flooding Attack

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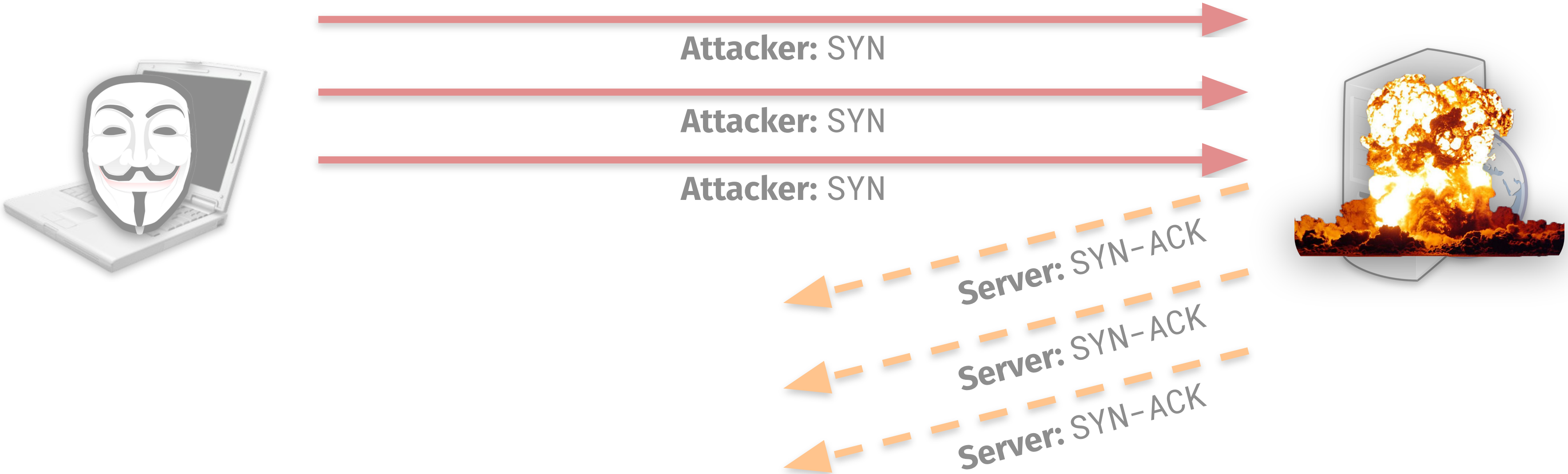

Thwarting SYN Flooding

- **Attack:** **spam SYN packets** to server, with **spoofed origin** address
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How can we **prevent** SYN flooding?

Attacker: SYN

Server: SYN-ACK

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Server: SYN-ACK

Thwarting SYN Flooding

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How can we **prevent** SYN flooding?

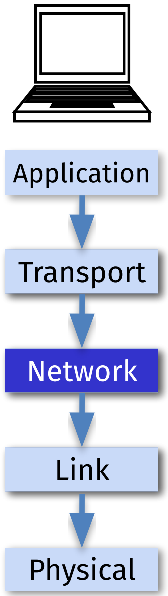
Incorporate **state**—use **SYN cookies!**

Questions?

Network Layer DoS

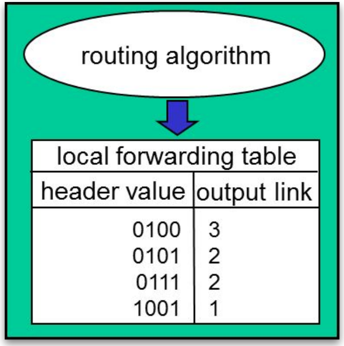
Recap: The Network Layer

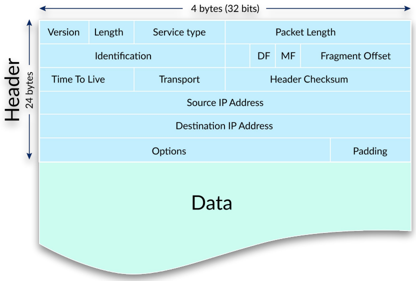
- **What does it facilitate?**
  - **???**
- **Key functions?**
  - **Function1: ???**
  - **Function1: ???**
- **Addressing?**
  - **???**

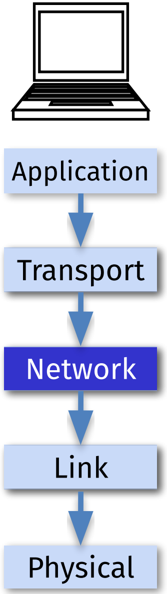


Recap: The Network Layer

- **What does it facilitate?**
  - Sending of data from host on one network to another
- **Key functions?**
  - **Function1: Routing:** (find the shortest path for a packet)
  - **Function1: Forwarding** (send packet on to the next hop)
- **Addressing?**
  - **IP addressing** (logical addressing)

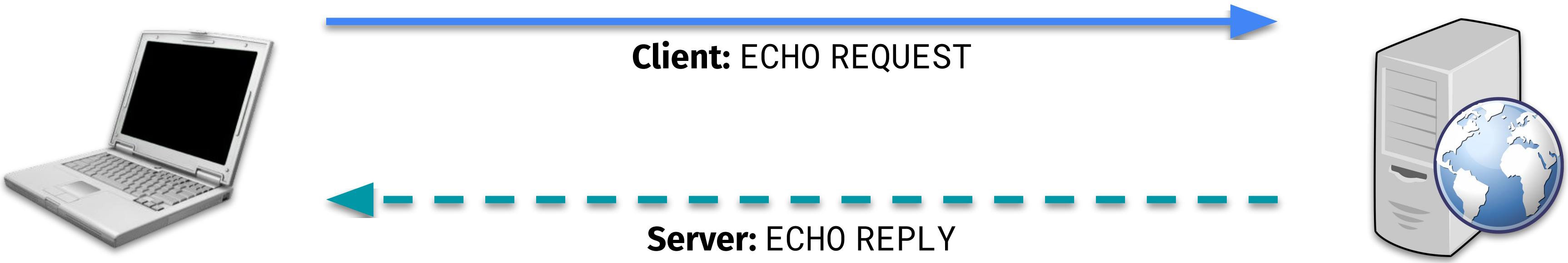






ICMP: Internet Control Message Protocol

- **ICMP:** pings to determine whether a system is **connected to the Internet**
  - Analogous to **"Hello, are you still there?"**



ICMP Smurf Attacks

- **Attack:** takes advantage of **broadcast-enabled hosts** to **amplify** attack

ICMP Smurf Attacks

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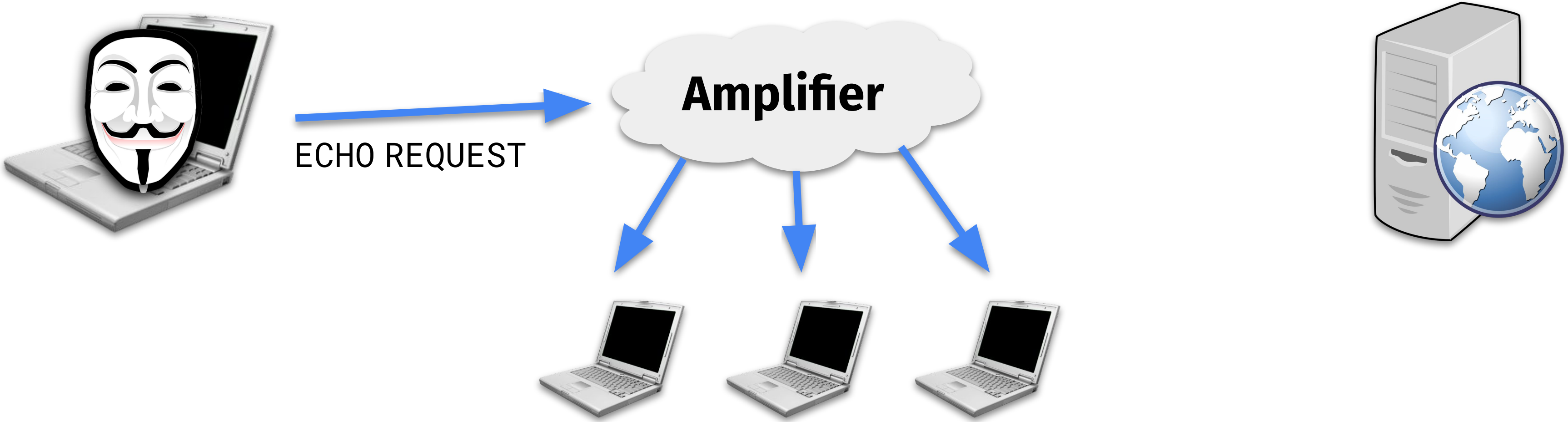
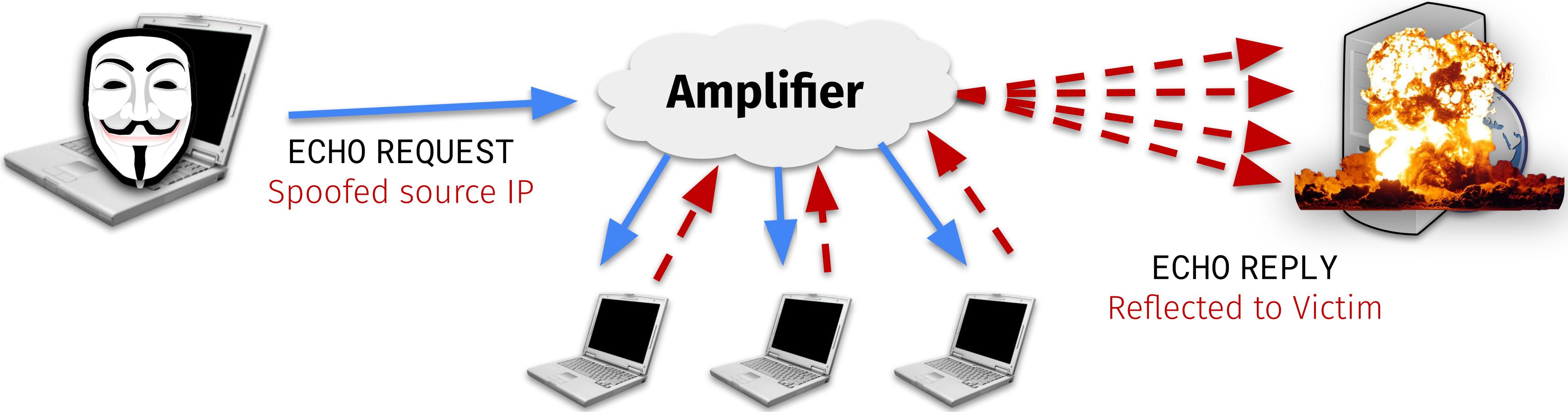


ICMP Smurf Attacks

- **Attack:** takes advantage of **broadcast-enabled hosts** to **amplify** attack
- Attacker spams **spoofed-source** ICMP requests, **reflected to victim's** IP



Advanced DoS Strategies

- **Reflection:**
  - IP spoofing to redirect response to a victim
- **Amplification:**
  - Technique that increases the amount of traffic or packet size that the victim sees versus what the attacker originally sent
- Common in **real-world DDoS attacks**
  - Harder to detect (source obfuscation)
  - Harder to thwart (changing sources)

ICMP Ping of Death Attack

- **Internet Protocol:** IPV4 packets should be **less than 65,536 bytes**
  - Packets can be sent in **fragments** and **reassembled** by receiver

IP Header	ICMP Header	ICMP Data
20 bytes	8 bytes	65,508 bytes

ICMP Ping of Death Attack

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  - Many historical computer systems **could not handle larger packets**

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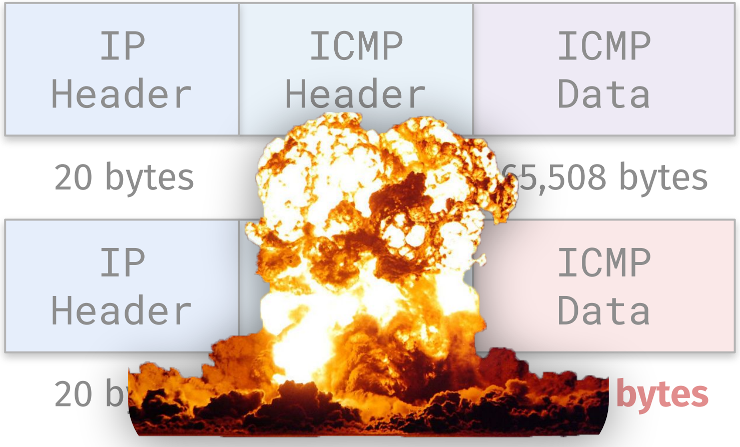
- **Result:** crash by **buffer overflow**
  - Can't serve clients until restart!



Thwarting ICMP-based DoS

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- **Attack:** sen
  that **reasse**
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How can we **prevent** ICMP attacks?

Thwarting ICMP-based DoS

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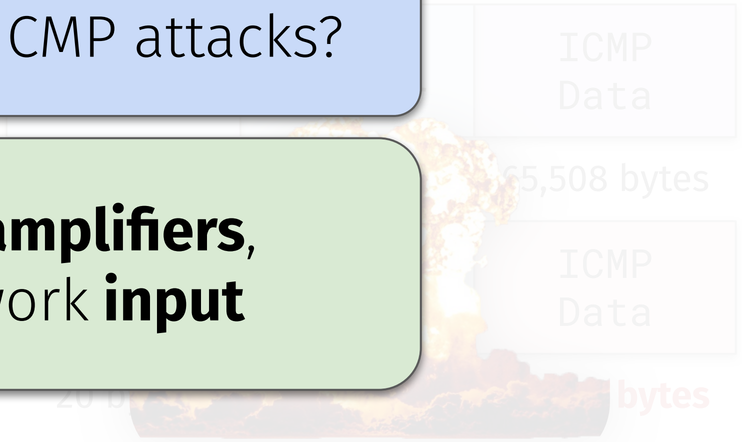
  - Can't serv…



How can we **prevent** ICMP attacks?

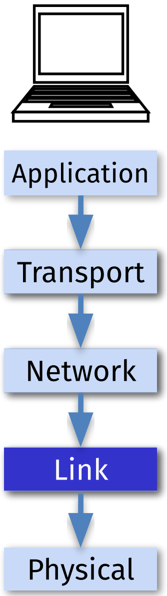
Secure any open **amplifiers**, and **sanitize** network **input**

Questions?

Link Layer DoS

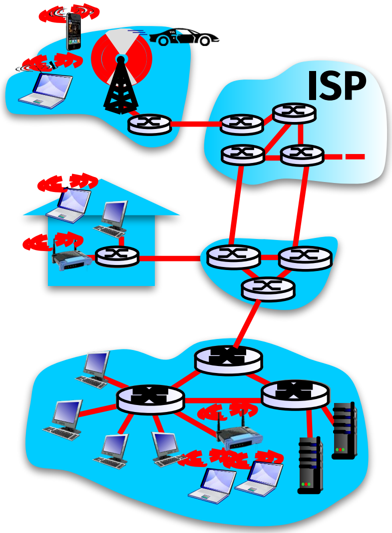
Recap: The Data Link Layer

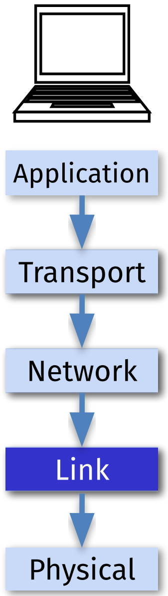
- **What does it facilitate?**
  - ???
- **Addressing?**
  - ???
- **Authenticity?**
  - ???



Recap: The Data Link Layer

- **What does it facilitate?**
  - Responsible for the node-to-node delivery of data
- **Addressing?**
  - MAC addresses
    - Physical identifier for hardware
- **Authenticity**?
  - **No—MAC addresses can be changed!**





ARP: Address Resolution Protocol

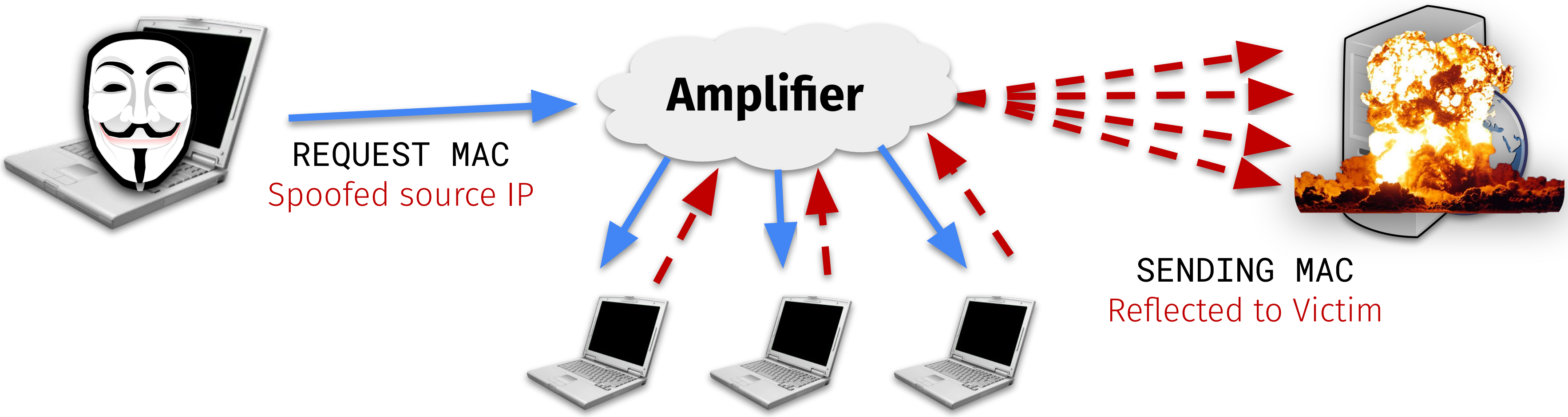
- **ARP:** query to **resolve the MAC address** given a desired host IP
  - How we know which **physical** address to transmit data to from its logical address

Client: `REQUEST MAC for IP 192.168.1.1`

Server: `SENDING MAC 00:B0:D0:63:C2:26`

ARP Flooding Attack

- **Attack:** same idea as **ICMP Smurfing**; **spoof source to victim** and spam away!
  - Victim gets overwhelmed by ARP replies and bandwith crashes



Thwarting ARP Flooding

- **Attack:** same idea as **ICMP Smurfing**; **spoof source to victim** and spam away!
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How can we **prevent** ARP flooding?

Thwarting ARP Flooding

- **Attack:** same idea as **SYN flood**; spoof source to victim and spam away!
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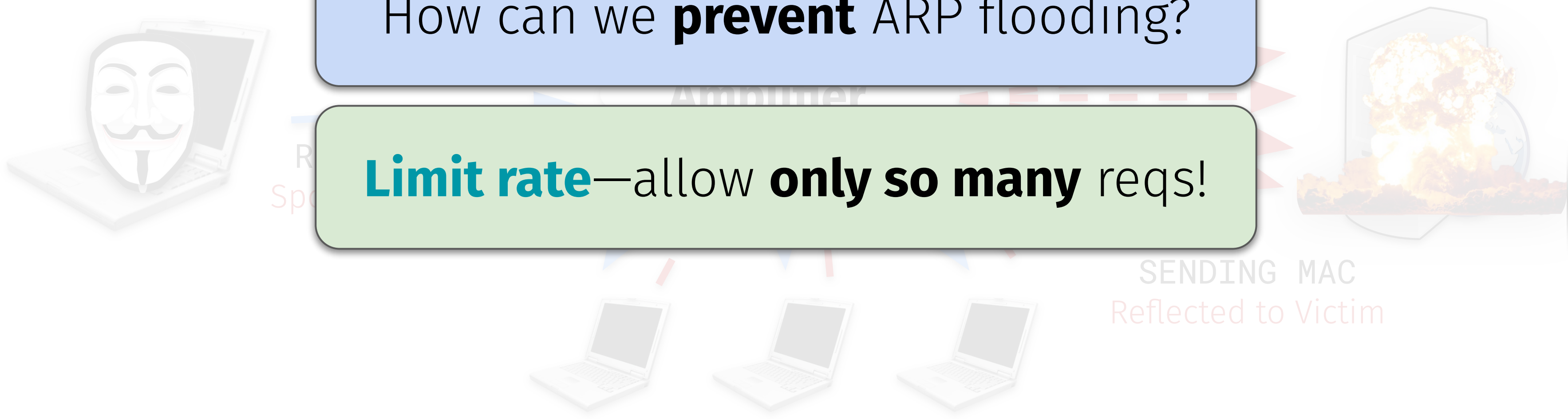


How can we **prevent** ARP flooding?

Limit rate—allow **only so many** reqs!

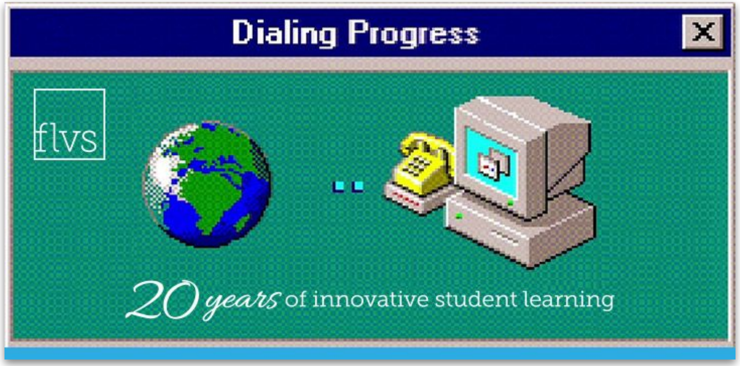
Physical Layer DoS

Recap: Physical Layer

- **What is it?**

Recap: Physical Layer

- **What is it?**



Physical Layer DoS

Russian Spy Submarines Are Tampering with Undersea Cables That Make the Internet Work. Should We Be Worried?

A massive cable attack is probably an over-hyped scenario, at least for a country with as many redundant cables as the United States pitted against a limited number of Russian special-operations submarines.

CNN Exclusive: FBI investigation determined Chinese-made Huawei equipment could disrupt US nuclear arsenal communications

Physical Layer DoS

Russian Spy Submarines Are Tampering with Undersea Cables That Make the Internet Work

A massive cabl
as many redun
Russian specia

Iran blocks capital's internet access as Amini protests grow

Social media platforms have also been cut off in areas of Tehran and Kurdistan as videos of dissent go viral

CN ed
Chinese-made Huawei equipment could disrupt US nuclear arsenal communications

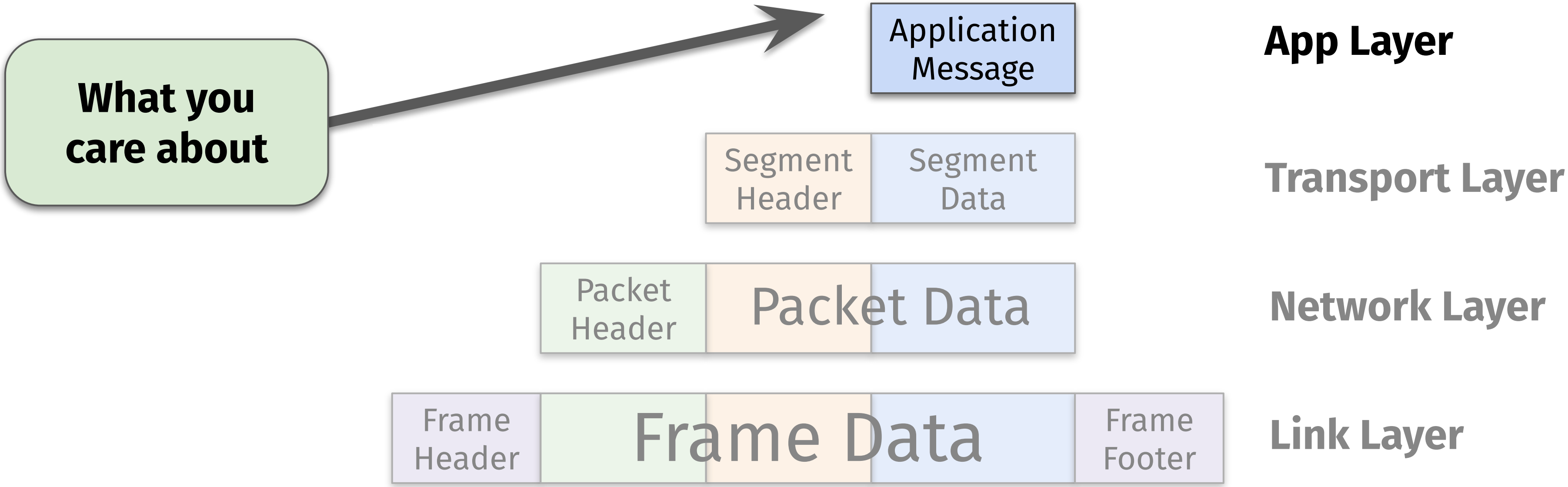
Thwarting Physical Layer Attacks

Questions?

Analyzing Network Packets

Recap: Internet Packet Encapsulation

- How packets are generated and sent



Recap: Internet Packet Encapsulation

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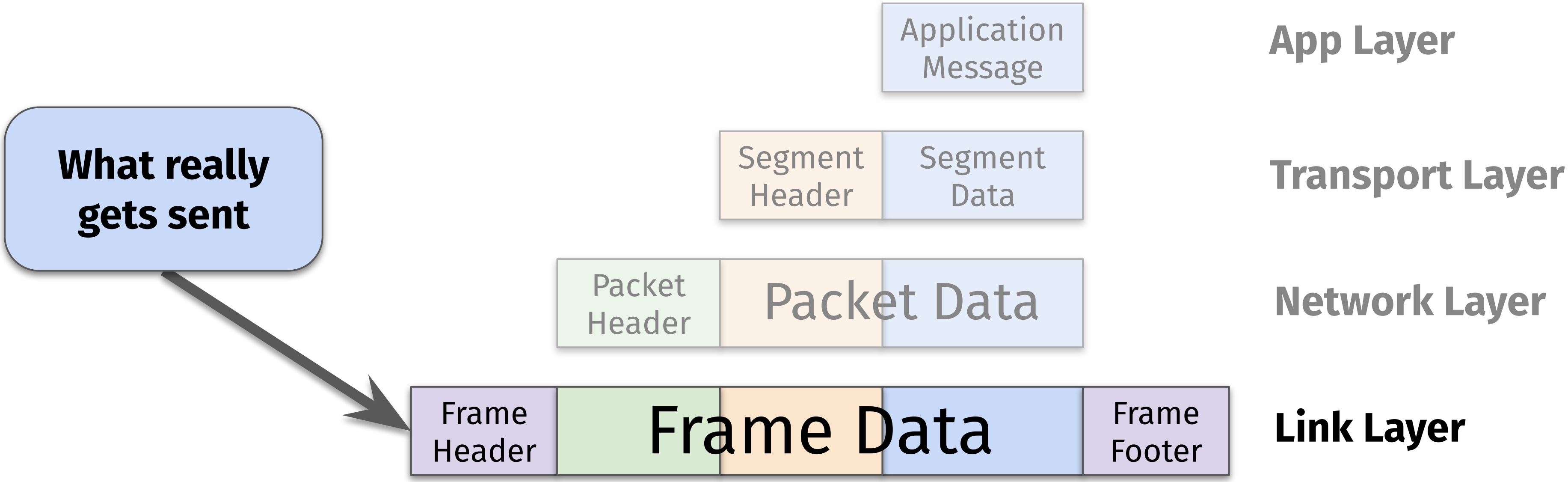


Recap: Internet Packet Encapsulation

- How packets are generated and sent

Application Message

App Layer

What really gets sent

How can we **detect and thwart** different **attacks** on network layers?

Transport Layer

Packet Header | Packet Data

Network Layer

Frame Header | Frame Data | Frame Footer

Link Layer

Tools of the Trade

- **Packet Analyzers:**
  - Tools for dissecting network packets
- Packet Analyzers allow you to:
  - Identify unusual packets
  - Characterize network activity
  - Pinpoint **malicious traffic**
- The basis of modern-day network security (e.g., firewalls, antivirus)

SNORT®

scapy

Wireshark

PcapPlusPlus

Familiarity with packet analysis tools?

I eat NetSec CTF challenges like a kid eats candy on Halloween. 🧙

0%

Some (e.g., Wireshark, DPKT, Scapy, or something else)

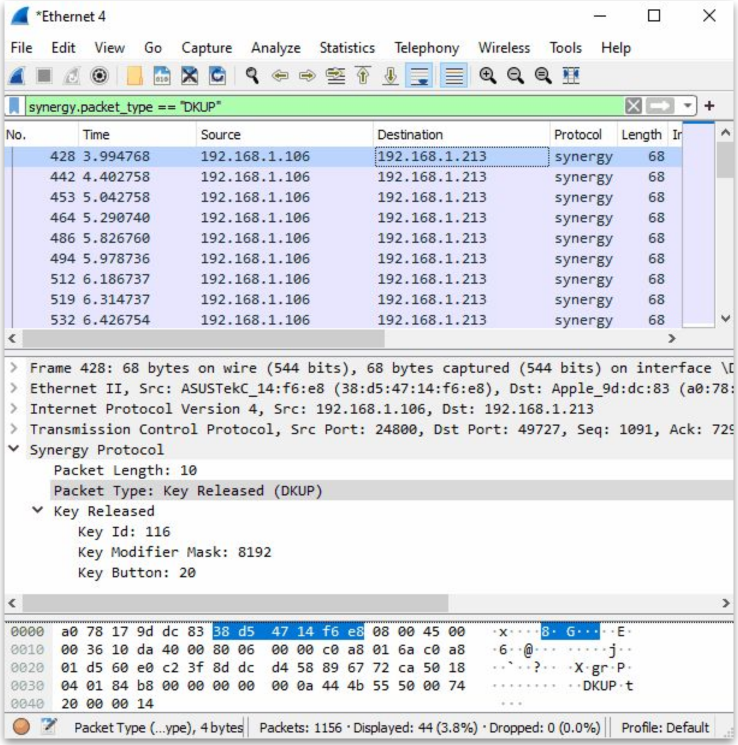
0%

None (but that's totally okay!)

0%

Tools of the Trade: Wireshark

- A "graphical interface" for manual packet analysis
  - Completely **open-source and free**
- General workflow:
  - Load up a PCAP (packet capture)
  - Wireshark will display each packet
  - Inspect particular fields of interest



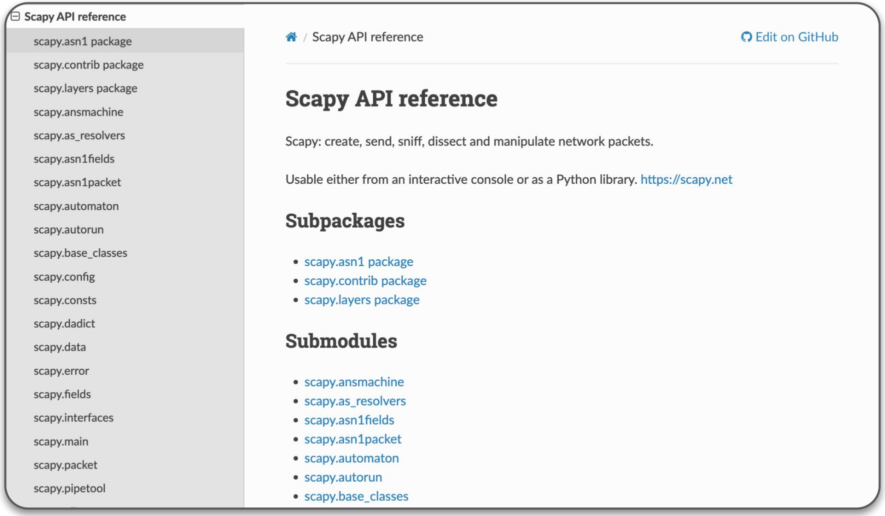
Tools of the Trade: Wireshark

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	10.0.0.2	10.128.0.2	TCP	54	3341 → 80 [SYN] Seq=0 Win=512 Len=0
2	0.003987	10.128.0.2	10.0.0.2	TCP	58	80 → 3222 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MSS=1460
3	0.005514	10.128.0.2	10.0.0.2	TCP	58	80 → 3341 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MSS=1460
4	0.008429	10.0.0.2	10.128.0.2	TCP	54	3342 → 80 [SYN] Seq=0 Win=512 Len=0
5	0.010233	10.128.0.2	10.0.0.2	TCP	58	80 → 3220 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MSS=1460
6	0.014072	10.128.0.2	10.0.0.2	TCP	58	80 → 3342 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MSS=1460
7	0.016830	10.0.0.2	10.128.0.2	TCP	54	3343 → 80 [SYN] Seq=0 Win=512 Len=0
8	0.022220	10.128.0.2	10.0.0.2	TCP	58	80 → 3343 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MSS=1460
9	0.023496	10.128.0.2	10.0.0.2	TCP	58	80 → 3219 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MSS=1460
10	0.025243	10.0.0.2	10.128.0.2	TCP	54	3344 → 80 [SYN] Seq=0 Win=512 Len=0
11	0.026672	10.128.0.2	10.0.0.2	TCP	58	80 → 3218 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MSS=1460
12	0.028038	10.128.0.2	10.0.0.2	TCP	58	80 → 3221 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MSS=1460
13	0.030523	10.128.0.2	10.0.0.2	TCP	58	80 → 3344 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MSS=1460

```
▸ Frame 2: 58 bytes on wire (464 bits), 58 bytes captured (464 bits)
▸ Ethernet II, Src: 42:01:0a:f0:00:01 (42:01:0a:f0:00:01), Dst: 42:01:0a:f0:00:17 (42:01:0a:f0:00:17)
▸ Internet Protocol Version 4, Src: 10.128.0.2, Dst: 10.0.0.2
▾ Transmission Control Protocol, Src Port: 80, Dst Port: 3222, Seq: 0, Ack: 1, Len: 0
    Source Port: 80
    Destination Port: 3222
    [Stream index: 1]
    [TCP Segment Len: 0]
    Sequence number: 0    (relative sequence number)
    [Next sequence number: 0    (relative sequence number)]
    Acknowledgment number: 1    (relative ack number)
    0110 .... = Header Length: 24 bytes (6)
  ▸ Flags: 0x012 (SYN, ACK)
    Window size value: 29200
    [Calculated window size: 29200]
    Checksum: 0x4268 [unverified]
    [Checksum Status: Unverified]
    Urgent pointer: 0
  ▸ Options: (4 bytes), Maximum segment size
  ▸ [Timestamps]
```

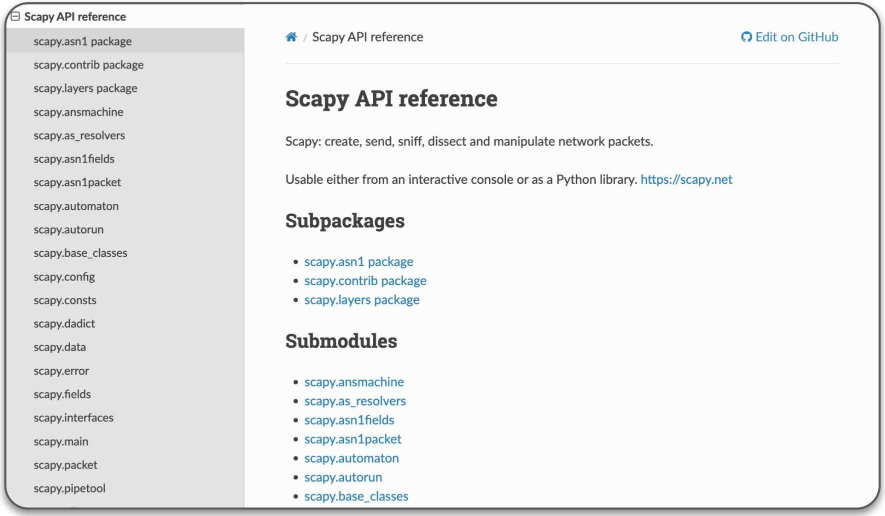
Tools of the Trade: Scapy

- Python API for programmatic packet capture and analysis
  - Think of it as “Wireshark in API form”
  - **Project 4:** you will use Scapy to write your own packet analysis scripts



Tools of the Trade: Scapy

- Python API for programmatic packet capture and analysis
  - Think of it as “Wireshark in API form”
  - **Project 4:** you will use Scapy to write your own packet analysis scripts
- We’ll provide the PCAP traces…
  - You’ll write code to analyze them!
  - **Examples:**
    - **Detecting attacks** on a network
    - Finding **user credentials**
    - Sniffing a user’s **browsing history**



Questions?

Next time on CS 4440...

Passwords and Secure Authentication