# CSE 127: Introduction to Security

## Lecture 11: Network Attacks

**George Obaido**

UCSD

Spring 2022

Material from Nadia Heninger, Deian Stefan, Stefan Savage, David Wagner, and Nick Weaver

# Threat modeling for network attacks

Basic security goals:

- **Confidentiality:** No one should be able to read our data/communications unless we want them to.
- **Integrity:** No one can manipulate our data/communications unless we want them to.
- **Availability:** We can access our data/communication capabilities when we want to.

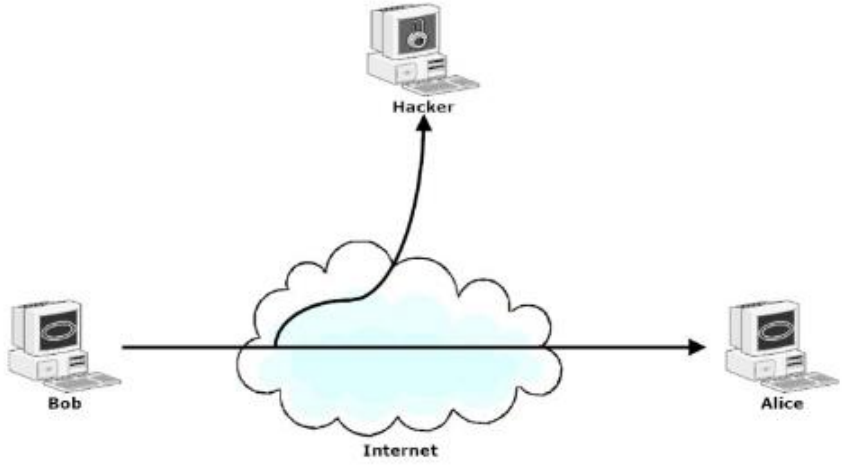
# Threat modeling for network attacks

Attacker capabilities:

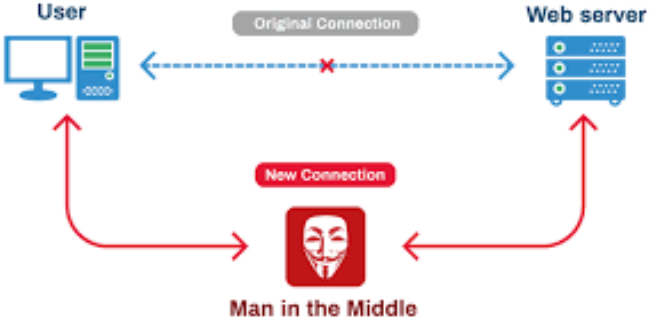
- **Physical access:** Attacker has physical access to the network infrastructure.
- **In path/Man in the middle:** Attacker can see, add, and block packets.
- **On path/Man on the side:** Attacker can see and add packets, but cannot block packets.
- **Passive:** Attacker can see victim's network traffic, but cannot add or modify packets.

# Threat modeling for network attacks

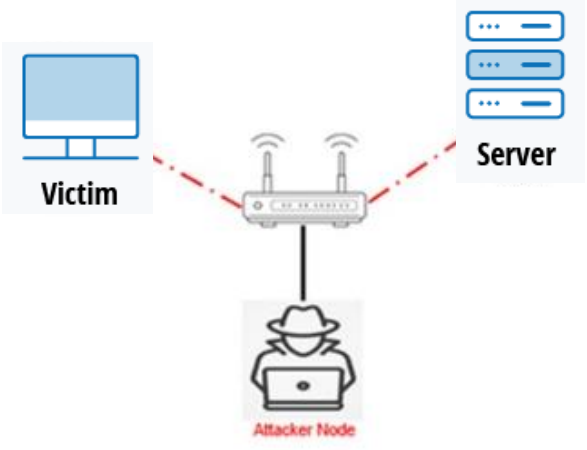
**Physical access**




**Passive attack**

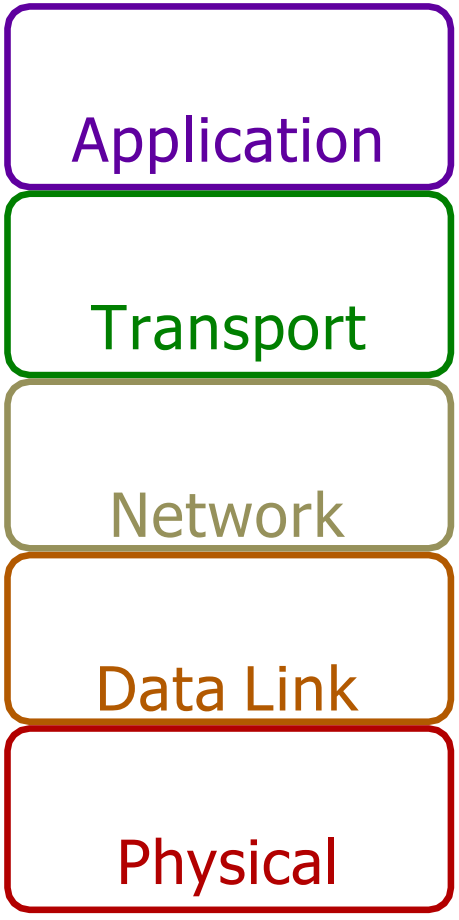



**Man in the middle attack**




**Man on the side attack**

# Different attacks at different layers




- DNS, HTTP, HTTPS
- TCP, UDP
- IP, BGP
- Ethernet, WiFi, ARP
- Physical wires, photons, RF modulation

# Physical



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# Physical/link layer threats

**Eavesdropping:** Violates confidentiality.

Who can see the packets you send?

- Network (routers, switches, access points) see all traffic passing by.

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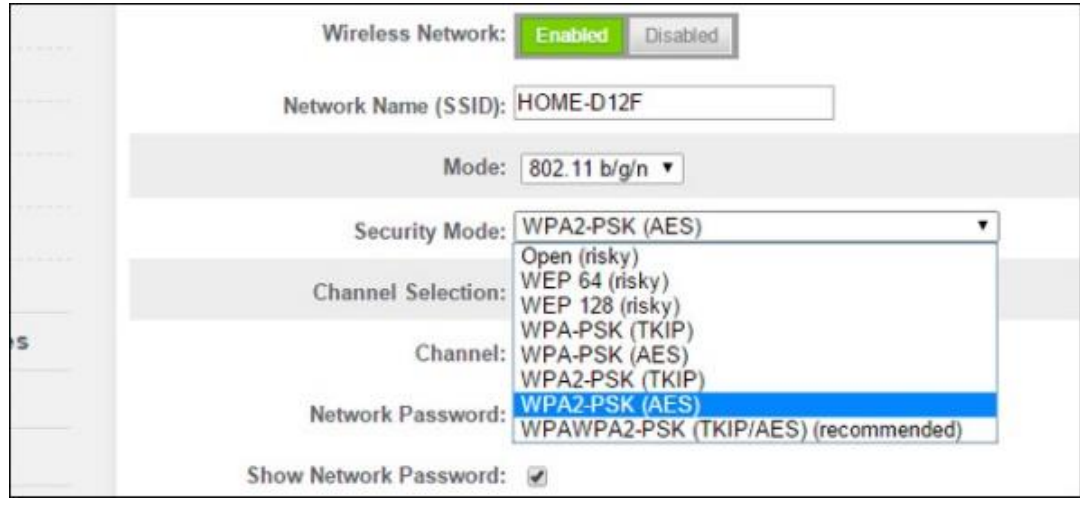
Who can see the packets you send?

- Network (routers, switches, access points) see all traffic passing by.
- Unprotected WiFi network:
- WPA2 Personal (PSK):
- Non-switched Ethernet:
- Switched Ethernet:



# Network eavesdropping

## Tools like tcpdump and Wireshark let you capture local network traffic

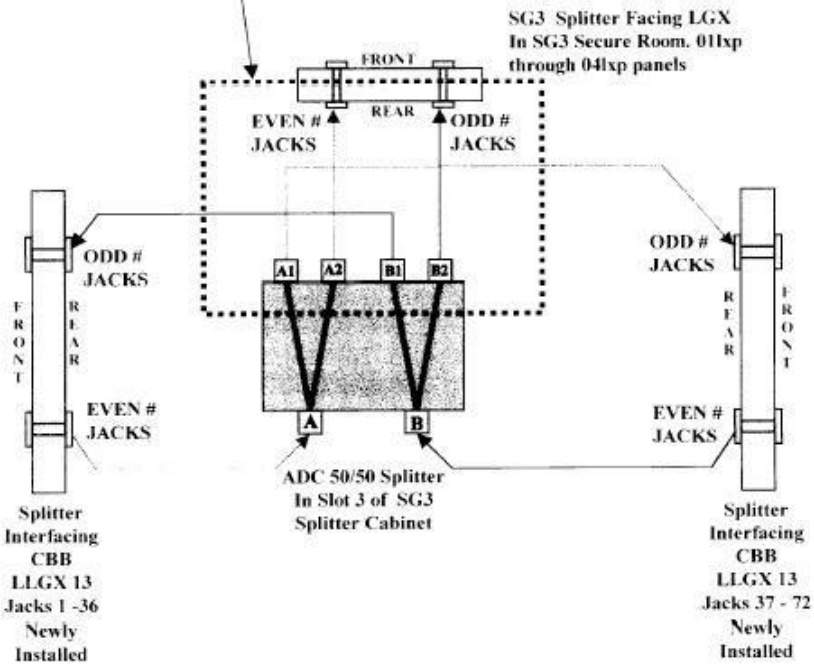
```
$ sudo tcpdump -v -n -i eno1
tcpdump: listening on eno1, link-type EN10MB (Ethernet), capture size 262144 bytes
17:29:41.757880 IP (tos 0x10, ttl 64, id 38565, offset 0, flags [DF], proto TCP (6), length 176)14)
    132.239.15.243.4258 > 66.10.100.54.62681: Flags [P.], cksum 0x3bc5 (incorrect -> 0x2e82), seq 1687079
17:29:41.770734 IP (tos 0x0, ttl 50, id 0, offset 0, flags [DF], proto TCP (6), length 52)
    66.10.100.54.62681 > 132.239.15.243.4258: Flags [.], cksum 0x8e71 (correct), ack 124, win 11736, opti
17:29:41.789239 ARP, Ethernet (len 6), IPv4 (len 4), Request who-has 132.239.15.119 tell 132.239.15.1, le
17:29:41.936864 IP (tos 0x0, ttl 1, id 20121, offset 0, flags [none], proto UDP (17), length 202)
    132.239.15.210.65021 > 239.255.255.250.1900: UDP, length 174
17:29:42.036268 IP6 (hlim 1, next-header UDP (17) payload length: 83) fe80::225:b3ff:fefa:a13d.546 >
ff02
17:29:42.390349 IP (tos 0x0, ttl 64, id 35459, offset 0, flags [DF], proto UDP (17), length 51)
    132.239.15.243.40288 > 172.217.4.138.443: UDP, length 23
17:29:42.419390 IP (tos 0x0, ttl 57, id 0, offset 0, flags [DF], proto UDP (17), length 48)
    172.217.4.138.443 > 132.239.15.243.40288: UDP, length 20
17:29:42.443102 ARP, Ethernet (len 6), IPv4 (len 4), Request who-has 132.239.15.34 tell 132.239.15.1, len
17:29:42.541827 STP 802.1w, Rapid STP, Flags [Learn, Forward], bridge-id 81b0.00:a3:d1:25:06:00.801a, len
        message-age 2.00s, max-age 20.00s, hello-time 2.00s, forwarding-delay 15.00s
        root-id 21b0.3c:08:f6:21:a8:40, root-pathcost 2001, port-role Designated
17:29:43.752250 IP (tos 0x0, ttl 64, id 61970, offset 0, flags [DF], proto TCP (6), length 109)
    132.239.15.243.55866 > 52.37.243.173.443: Flags [P.], cksum 0xbd14 (incorrect -> 0xcfbd), seq
    3280138
17:29:43.788285 IP (tos 0x0, ttl 38, id 43082, offset 0, flags [DF], proto TCP (6), length 109)
    52.37.243.173.443 > 132.239.15.243.55866: Flags [P.], cksum 0x65eb (correct), seq 1:58, ack 57, win
    8
17:29:43.788311 IP (tos 0x0, ttl 64, id 61971, offset 0, flags [DF], proto TCP (6), length 52)
    132.239.15.243.55866 > 52.37.243.173.443: Flags [.], cksum 0xbcdb (incorrect -> 0xab20), ack 58, win
17:29:43.905367 IP (tos 0x0, ttl 128, id 19913, offset 0, flags [none], proto UDP (17), length 414)
    132.239.15.14.17500 > 255.255.255.255.17500: UDP, length 386
17:29:43.907037 IP (tos 0x0, ttl 128, id 59034, offset 0, flags [none], proto UDP (17), length 414)
    132.239.15.14.17500 > 132.239.15.255.17500: UDP, length 386
17:29:43.907052 IP (tos 0x0, ttl 128, id 19914, offset 0, flags [none], proto UDP (17), length 414)
    132.239.15.14.17500 > 255.255.255.255.17500: UDP, length 386
17:29:43.907057 IP (tos 0x0, ttl 128, id 19915, offset 0, flags [none], proto UDP (17), length 414)
    132.239.15.14.17500 > 255.255.255.255.17500: UDP, length 386
```

# Advanced threats: Physical cables can be tapped

*Mathew F. Casamassima, (732) 420-2033, mcasamassima@att.com*

# Splitter to SG3 LGX Connectivity

The Tables in this section give the splitter to SG3 LGX connectivity as shown with in the bounds of this box.



# (TS//SI//NF) FAA702 Operations

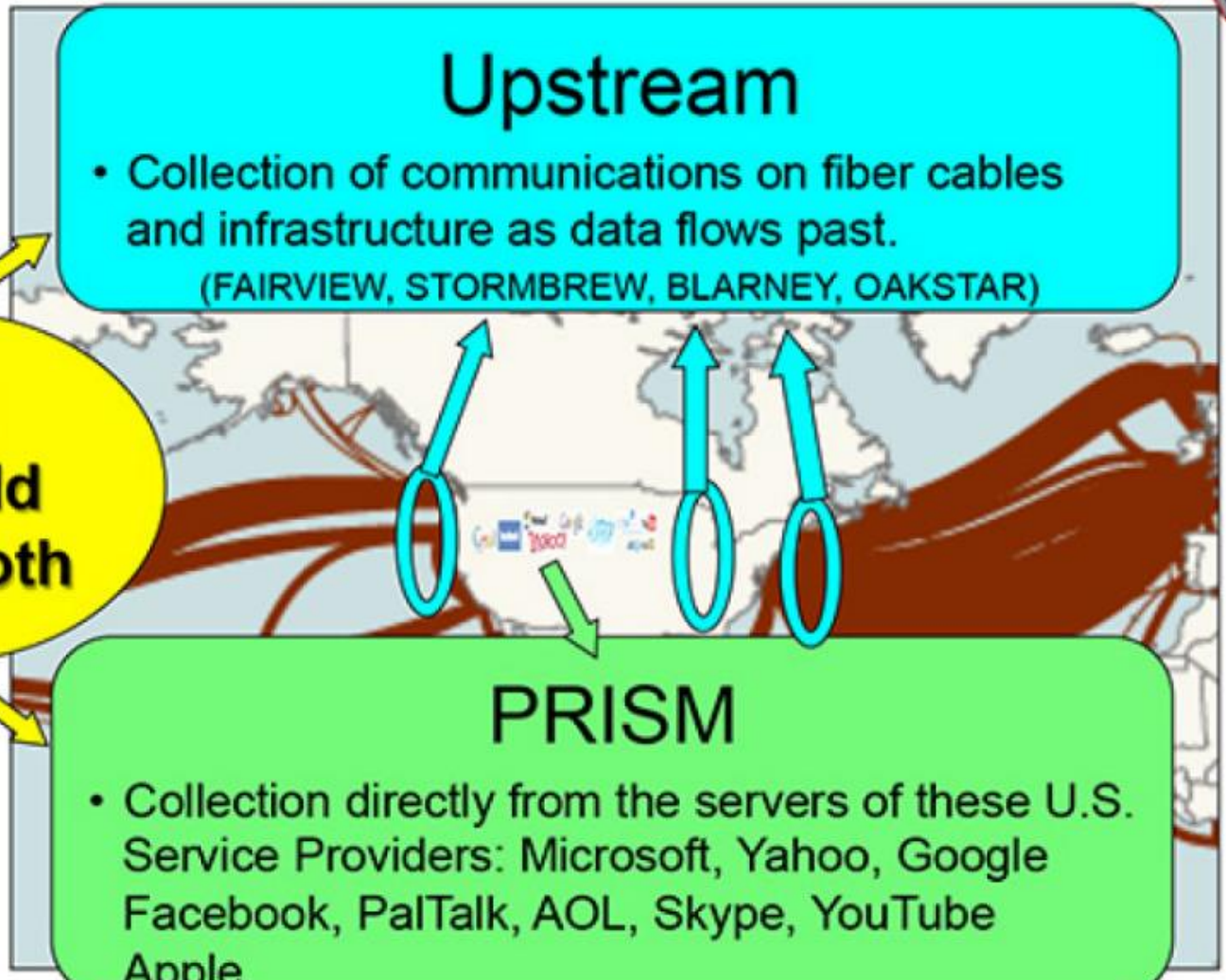
*Two Types of Collection*

## Upstream

- Collection of communications on fiber cables and infrastructure as data flows past.

(FAIRVIEW, STORMBREW, BLARNEY, OAKSTAR)

**You Should Use Both**



## PRISM

- Collection directly from the servers of these U.S. Service Providers: Microsoft, Yahoo, Google Facebook, PalTalk, AOL, Skype, YouTube Apple.

# Optic Nerve

"Optic Nerve was based on collecting information from GCHQ's huge network of internet cable taps, which was then processed and fed into systems provided by the NSA. Webcam information was fed into NSA's XKeyscore search tool, and NSA research was used to build the tool which identified Yahoo's webcam traffic."

– The Guardian 2/27/14

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– The Guardian 2/27/14

27. Unfortunately, there are issues with undesirable images within the data. It would appear that a surprising number of people use webcam conversations to show intimate parts of their body to the other person. Also, the fact that the Yahoo software allows more than one person to view a webcam stream without necessarily sending a reciprocal stream means that it appears sometimes to be used for broadcasting pornography.

28. A survey was conducted, taking a single image from each of 323 user ids. 23 (7.1%) of those images contained undesirable nudity. From this we can infer that the true proportion of undesirable images in Yahoo webcam is $7.1\% \pm 3.7\%$ with confidence 95%.

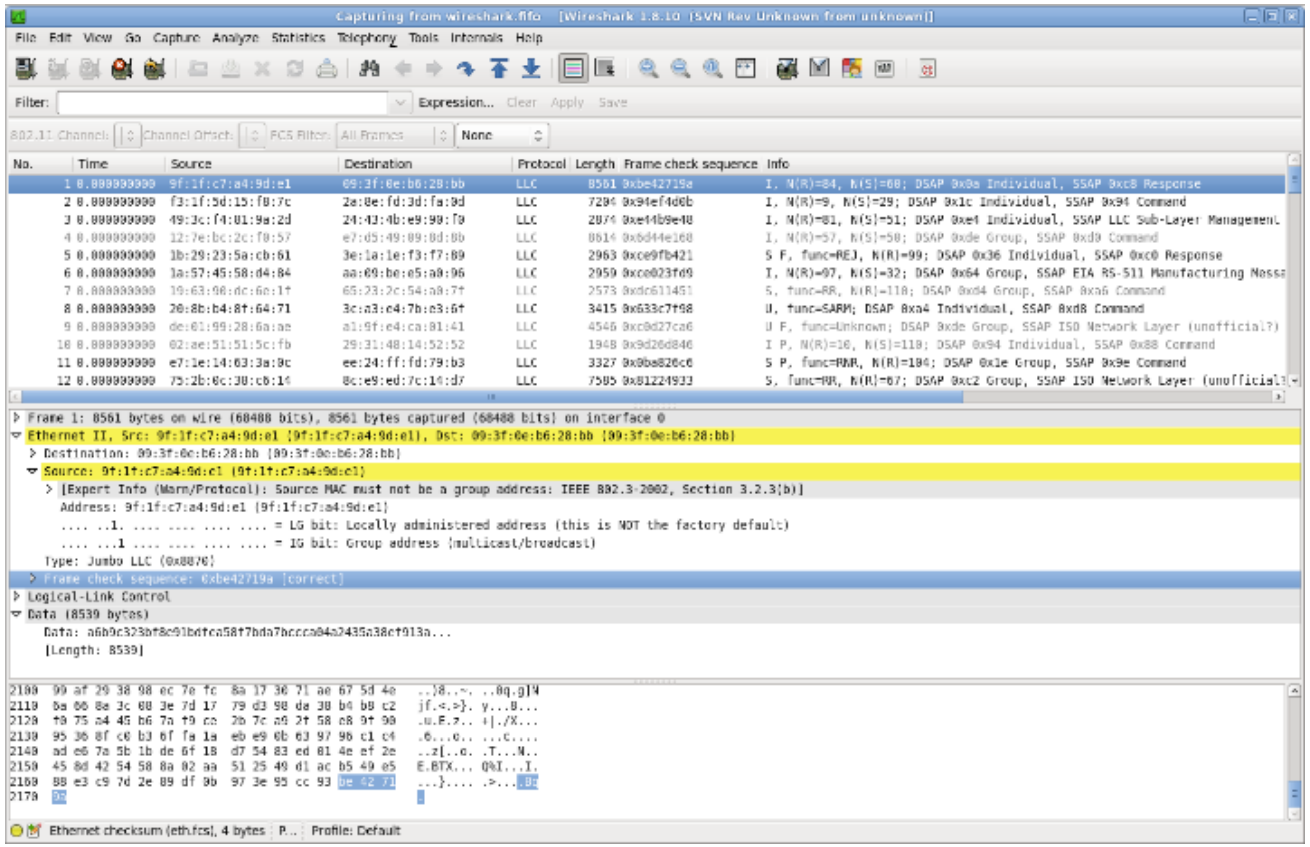
# Advanced threats: Physical cables can be tapped

Trevor Paglen, NSA-Tapped Undersea Cables, North Pacific Ocean, 2016

# Physical/link layer threats

**Injection:** Violates integrity.

- Ethernet packets are unauthenticated: attacker who can inject traffic can create a frame with any addresses they like.



Which attack happens when there is a third party that's monitoring and controlling a conversation between two parties, with the latter completely unaware of the situation?

A. SQL Injection

B. Man in the middle

C. Physical access

D. Off-path

E. None of the above

Which attack happens where an attacker has sufficient access to observe and inject traffic which through timing/bandwidth is consumed by the victim before the legitimate reply arrives but cannot block packets?

A. Man on the side

B. Man in the middle

C. Physical access

D. Off-path

E. None of the above

# Data-Link



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# Packet injection: ARP spoofing

- Recall: ARP used to map IP addresses to MAC addresses on local network

```
$ sudo tcpdump -v -n -i eno1
tcpdump: listening on eno1, link-type EN10MB(Ethernet), capture size 262144 bytes
17:29:47.455929 ARP, Ethernet (len 6), IPv4 (len 4), Request who-has 172.16.15.1
    tell 172.16.15.151, length 46
```

- ARP requests broadcast to local subnetwork
- Anyone can send an ARP response
- Attacker on local network can impersonate any other host.

# Physical/Data-link layer threats

**Jamming:** Violates availability.

- Physical signals can be overwhelmed or disrupted.
- Radio transmission depends on power and distance.

# Radio jamming: P25 law enforcement radios

Figure 1: Motorola XTS5000 Handheld P25 Radio

By careful synchronization, a jammer that attacks only the NID subfield of voice traffic can reduce its overall energy output so that it effectively has *more than 14dB of average power advantage* over the legitimate transmitter.

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Figure 1: Motorola XTS5000 Handheld P25 Radio

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Figure 7: Girltech IMME, with modified firmware

While any CC1110 board for the correct frequency range is sufficient, we used the *GirlTech IMME,* a commercial toy intended for pre-teen children to text message one another without cellular service. Presently priced at $30 USD, the package includes a handheld unit and a USB adapter, either of which may be used with our P25 client (for an aggregate price of $15 per jammer).

Why (Special Agent) Johnny (Still) Can't Encrypt: A Security Analysis of the APCO Project 25 Two-Way Radio System Clark et al. 2011

# Network



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# Network layer threats

**Spoofing:** Set arbitrary source address.

- IP packets offer no authentication.
- Source address in IP set by sender.
- Do you need to be a MITM attacker?

# Network layer threats

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- IP packets offer no authentication.
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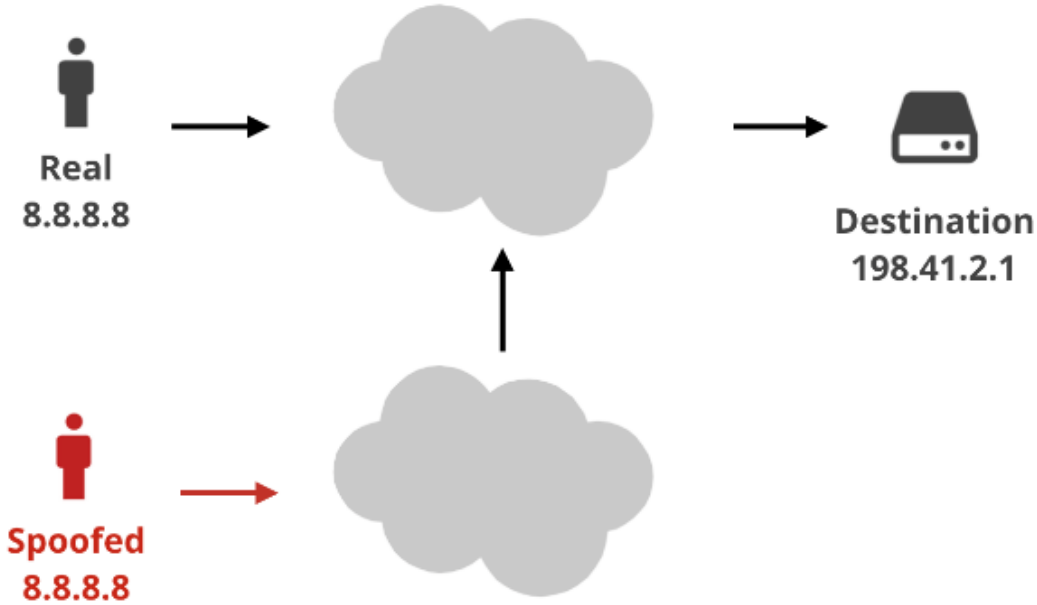


# Example: DHCP response spoofing

- Recall: DHCP used to configure hosts on network.

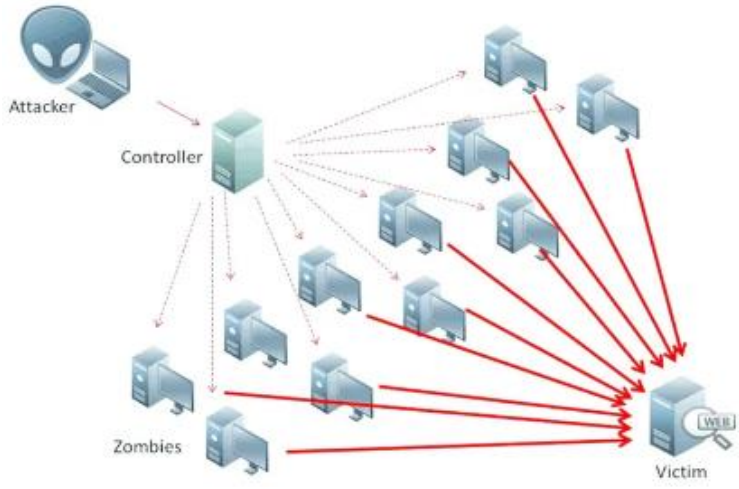
# Example: DHCP response spoofing

- Recall: DHCP used to configure hosts on network.
- DHCP requests broadcast to local network.
- Local attacker can race real server for response, set victim's network gateway and DNS server to attacker-controlled values.
- Allows attacker to act as invisible man-in-the-middle and relay victim's traffic.

# Network layer threats

**Set arbitrary destination address:**
No authentication of traffic sender at network layer

Applications:




- **Network scanning:**
  - Example tools: nmap, zmap, shodan
  - IPv4 has $2^{32}$ possible addresses, possible to enumerate all of them.
  - Send traffic to a port on some protocol, if you get a response then there is a live service.

- **Unwanted trafic:**
  - Denial of service attacks: overwhelm recipient with traffic

TECH \ FACEBOOK \ INSTAGRAM

81

# Facebook is back online after a massive outage that also took down Instagram, WhatsApp, Messenger, and Oculus

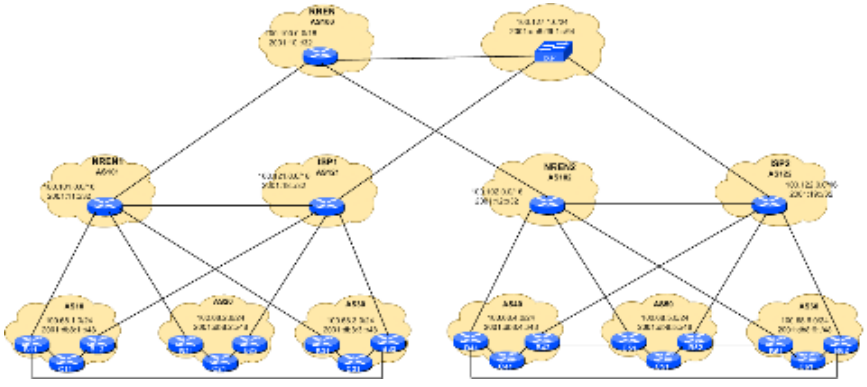
*'Networking issues' took the sites down just before noon ET*

By Richard Lawler and Alex Heath | Updated Oct 5, 2021, 2:28pm EDT

# Network layer threats

**Misdirection:** BGP hijacking.

- Recall: BGP protocol manages IP routing information between networks on the internet.
- Each BGP node maintains connections to a set of trusted neighbors.



- Neighbors share routing information.
- Routes are not authenticated: malicious or malfunctioning nodes may provide incorrect routing information that redirects IP traffic.

**GOVERNMENT OF PAKISTAN**
**PAKISTAN TELECOMMUNICATION AUTHORITY**
**ZONAL OFFICE PESHAWAR**
Plot-11, Sector A-3, Phase-V, Hayatabad, Peshawar.
Ph: 091-9217279- 5829177 Fax: 091-9217254
www.pta.gov.pk

NWFP-33-16 (BW)/06/PTA February ,2008

Subject: **Blocking of Offensive Website**

*Reference:* *This office letter of even number dated 22.02.2008.*

I am directed to request all ISPs to immediately block access to the following website

URL: http://www.youtube.com/watch?v=o3s8jtvvg00

IPs: 208.65.153.238, 208.65.153.253, 208.65.153.251

Compliance report should reach this office through return fax or at email peshawar@pta.gov.pk today please.

**Deputy Director**
(Enforcement)

To:

1. M/s Comsats, Peshawar.
2. M/s GOL Internet Services, Peshawar.
3. M/s Cyber Internet, Peshawar.
4. M/s Cybersoft Technologies, Islamabad.

Apr 24, 2018, 02:10pm EDT

# A $152,000 Cryptocurrency Theft Just Exploited A Huge 'Blind Spot' In Internet Security

**Thomas Brewster** Forbes Staff

Cybersecurity

*Associate editor at Forbes, covering cybercrime, privacy, security and surveillance.*

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# Transport



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# TCP threats

Recall:

- TCP session identified by (source address, source port, destination address, destination port)
- TCP packets identified by sequence number that determines where in stream they are placed.

**On-path injection**

- Connection hijacking: If an on-path attacker knows ports and sequence numbers, can inject data into the TCP connection.
- RST injection: Attacker can inject RST into connection to immediately stop it, will be accepted if sequence number is within acceptable window.

# Great Firewall of China

- China does extensive monitoring of all cross-border network traffic and blocks many international services and sites
- Collection of network techniques and policies called the "Great Firewall"
- Most famously: RST injection based on IP/host blocking and deep packet inspection for blacklisted keywords
- Multi-decade arms race on censorship circumvention
- **Circumvention techniques:** HTTPS, VPNs, proxies, traffic obfuscation, domain fronting, refraction networking

GREATFIRE.ORG

SEARCH TEST URL TEST KEYWORD FAQ NEWS

All

# WE ARE UNDER ATTACK

Submitted by charlie on Thu, Mar 19, 2015

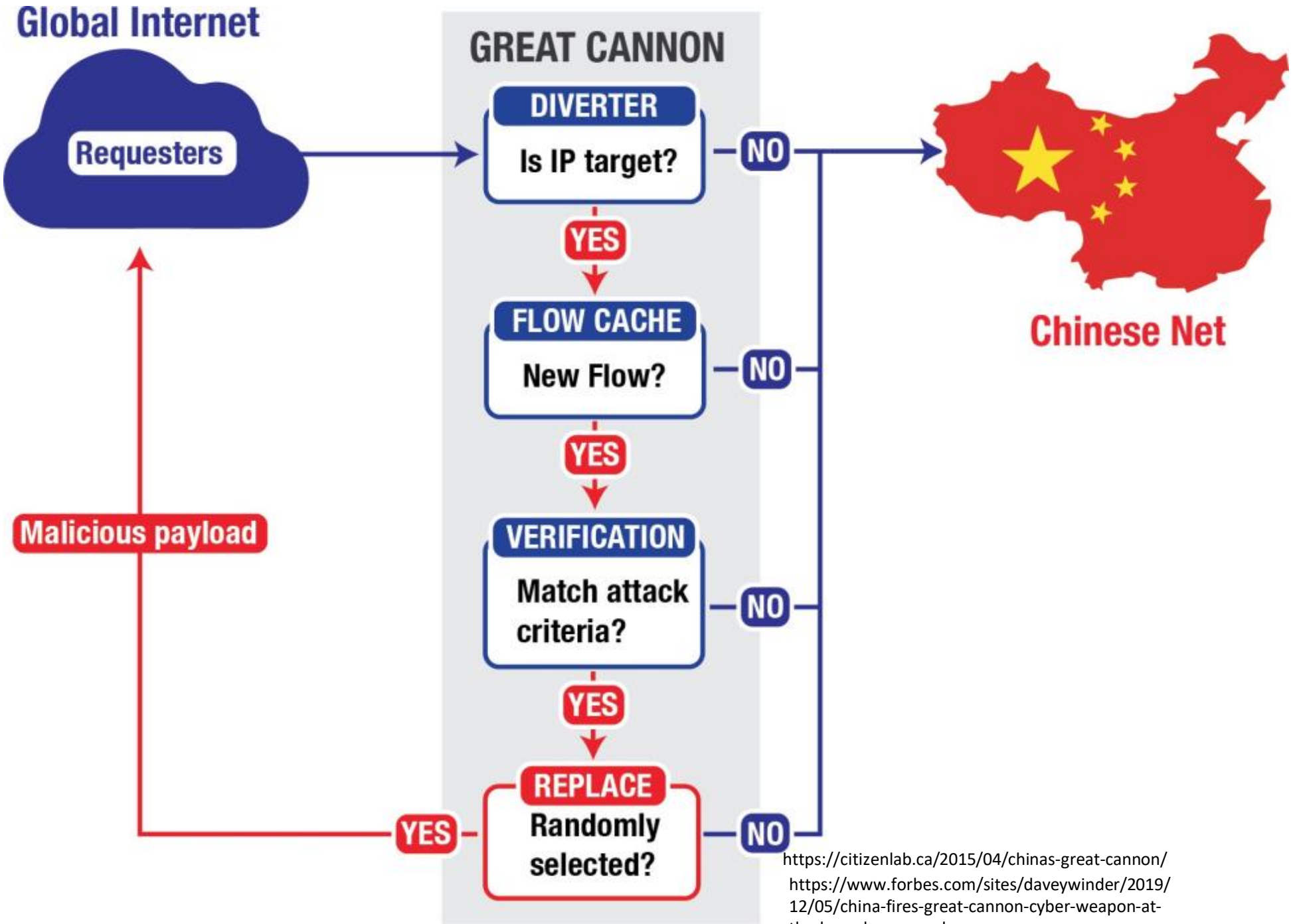
We are under attack and we need help.

Likely in response to a recent story in the Wall Street Journal (WSJ), we've experienced our first ever distributed denial of service (DDoS) attack. This tactic is used to bring down web pages by flooding them with lots of requests – at the time of writing they number 2.6 billion requests per hour. Websites are not equipped to handle that kind of volume so they usually "break" and go offline.

This kind of attack is aggressive and is an exhibition of censorship by brute force. Attackers resort to tactics like this when they are left with no other options.

We are not equipped to handle a DDoS attack of this magnitude and we need help. Some background:

**https://www.theverge.com/2015/3/19/8257191/china-anti-censorship-great-firewall-free-weibo**

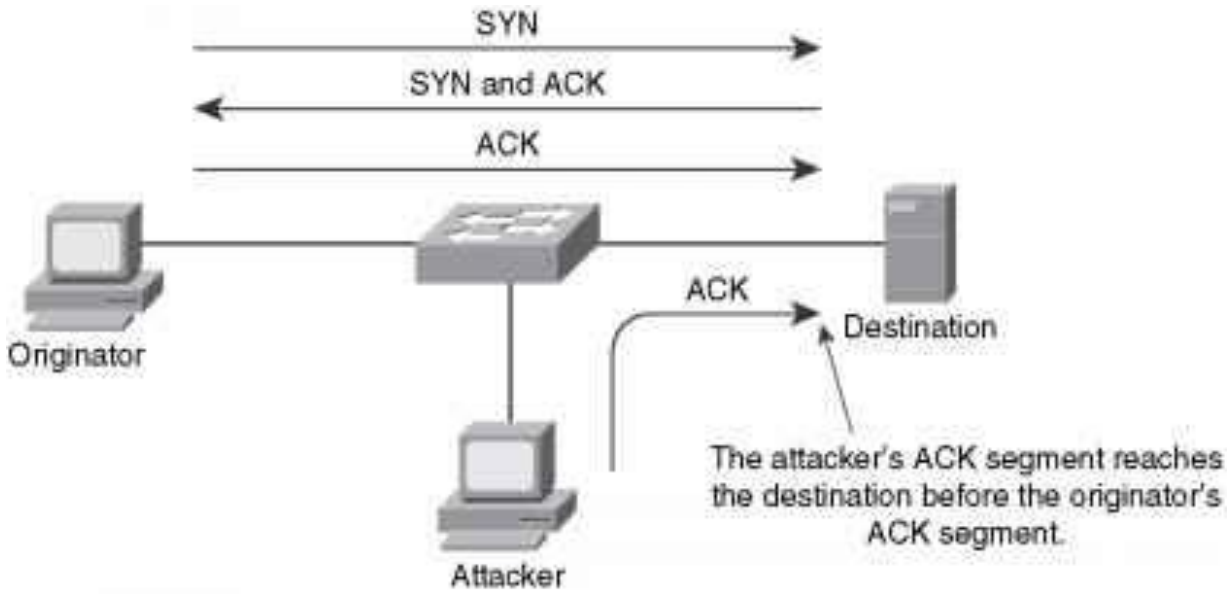



https://citizenlab.ca/2015/04/chinas-great-cannon/
https://www.forbes.com/sites/daveywinder/2019/12/05/china-fires-great-cannon-cyber-weapon-at-the-hong-kong-pro-democracy-movement/?sh=5e2c86f47c85

# TCP threats

**Blind spoofing**: Can an off-path attacker convince a victim to open a TCP connection with a spoofed host?

- Attacker forges the initial TCP handshake SYN message from an arbitrary source.
- The attacker cannot see the SYN-ACK response so does not learn the responder's sequence number.



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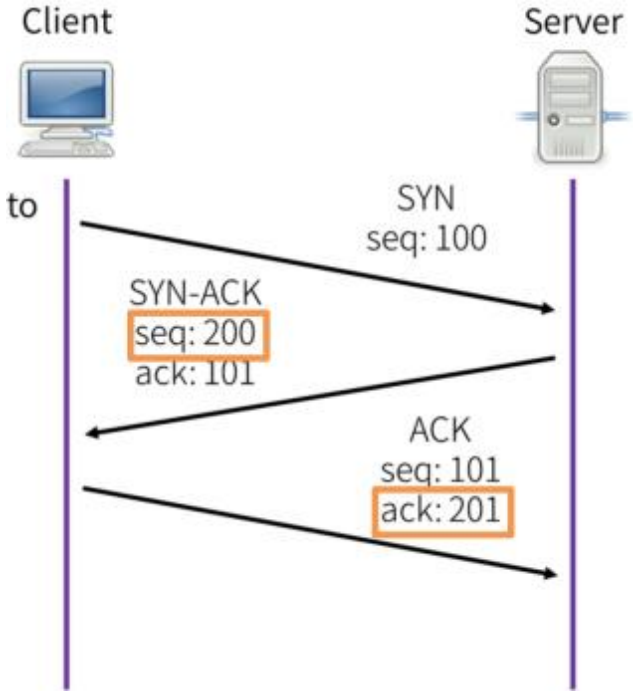
- Attacker forges the initial TCP handshake SYN message from an arbitrary source.
- The attacker cannot see the SYN-ACK response so does not learn the responder's sequence number.
- Initial TCP spec: initial sequence number based on local clock: easy to brute force
- Mitigation: use random ISN: $2^{-32}$ chance of guessing correctly.



Which type of attack happens where a malicious actor sends falsified ARP (Address Resolution Protocol) messages over a local area network. This results in the linking of an attacker's MAC address with the IP address of a legitimate computer or server on the network.

A. ARP Spoofing

B. DNS Spoofing

C. DHCP Spoofing

D. BGP Hijacking

E. None of the above

Which attack affects most ISPs and happens when attackers maliciously reroute Internet traffic.

A. ARP Spoofing

B. DNS Spoofing

C. DHCP Spoofing

D. BGP Hijacking

E. None of the above

# Application



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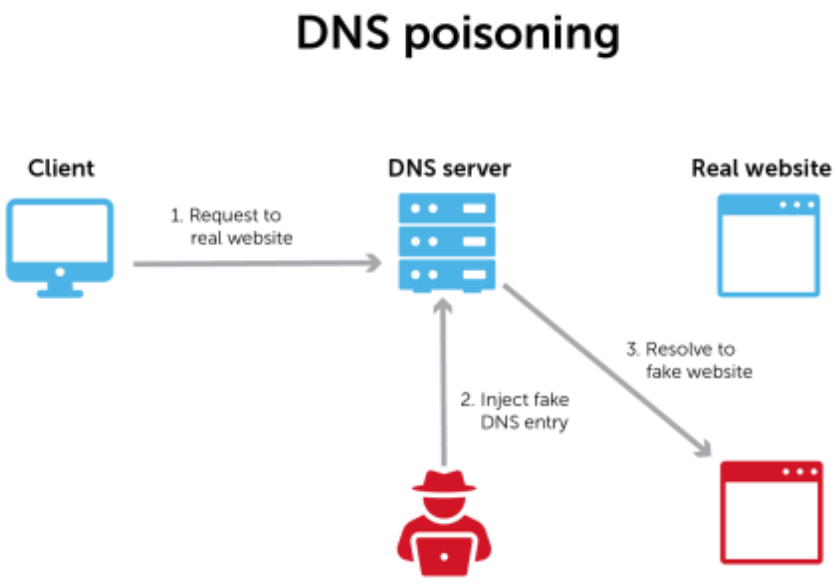
# Application layer threats: DNS spoofing

Recall:

- DNS maps between domain names and IP addresses.
- Responses cached to avoid query times.

DNS Threat Models:

- **Malicious DNS server:** Any DNS server in query chain can lie about responses.



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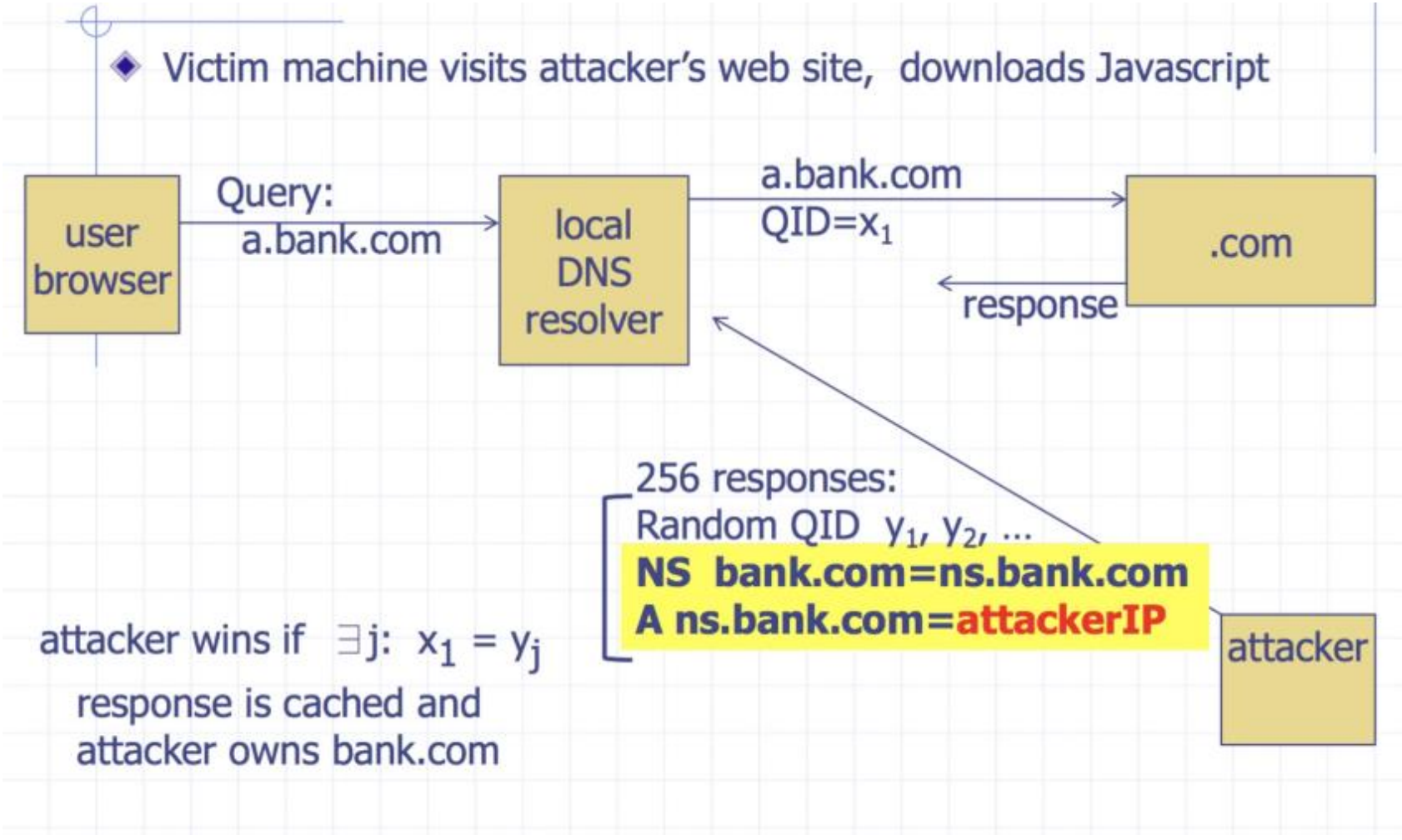
- **Malicious DNS server:** Any DNS server in query chain can lie about responses.
- **Local/on-path attacker**: Can impersonate DNS server and send a fake response.
- **Off-path attacker:** Can try to forge response: needs to match 16-bit query ID.
  - Original spec: query ID increments with each request.
  - How can you attack this?

# DNS spoofing: 2008 Kaminsky attack




- Birthday bound: attacker expects to succeed after $2^8 = 256$ lookups
- Mitigation: randomize source port

**Conclusion:**

- Internet built from protocols that assumed trustworthy network operators.

- Next lecture: How to add security after the fact.