CS225 – Computer Security

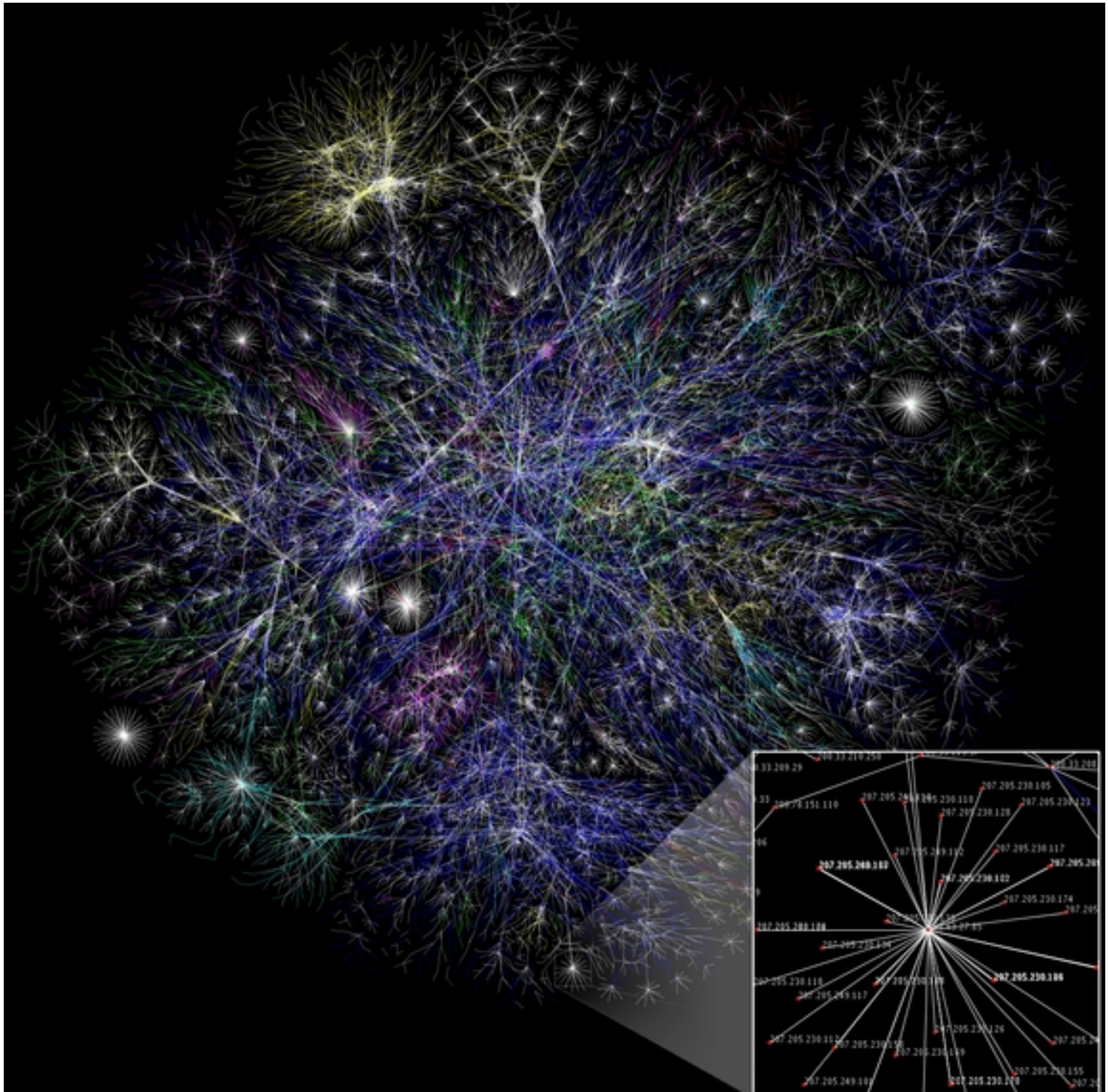
Network Security

slides modified from Zhiyun Qian

History of Network Security

- Initially built for communication between research institutions
  - ARPANET (TCP/IP)
  - First packet sent from UCLA to SRI
- Internet designed without security in mind
  - Including key protocols such as TCP/IP
  - Getting it to work is already an amazing job
- Hard to retrofit security into existing protocols
  - Have to remain backward-compatible
    - E.g., TCP/IP used by every machine now
  - Solutions often are patches or require an additional layer of indirection

How the Internet looks like in 2005

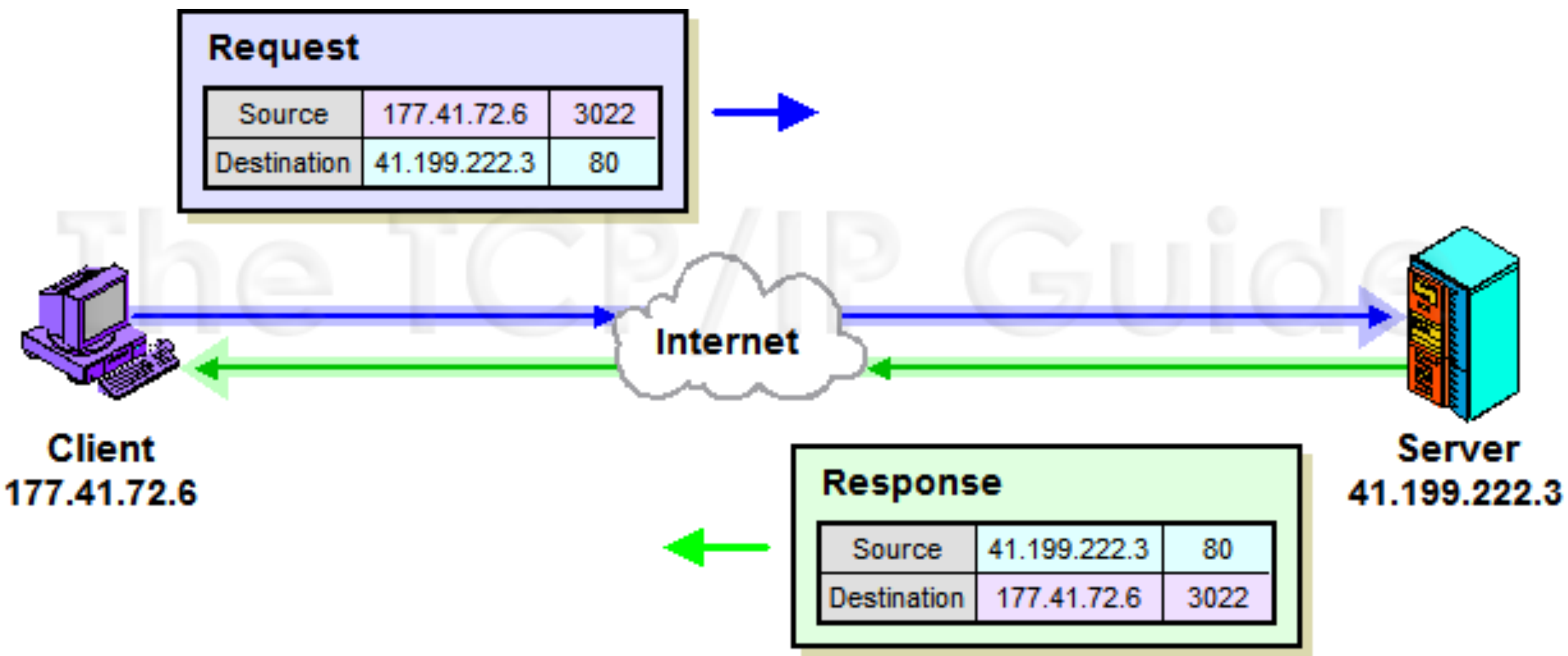


Common network security attacks and their countermeasures

- Packet sniffing and spoofing
  - Encryption (SSH, SSL, HTTPS)
- Finding a way into the network
  - Firewalls
- Denial of Service
  - Ingress filtering, IDS

Quick overview of TCP/IP

- Example:

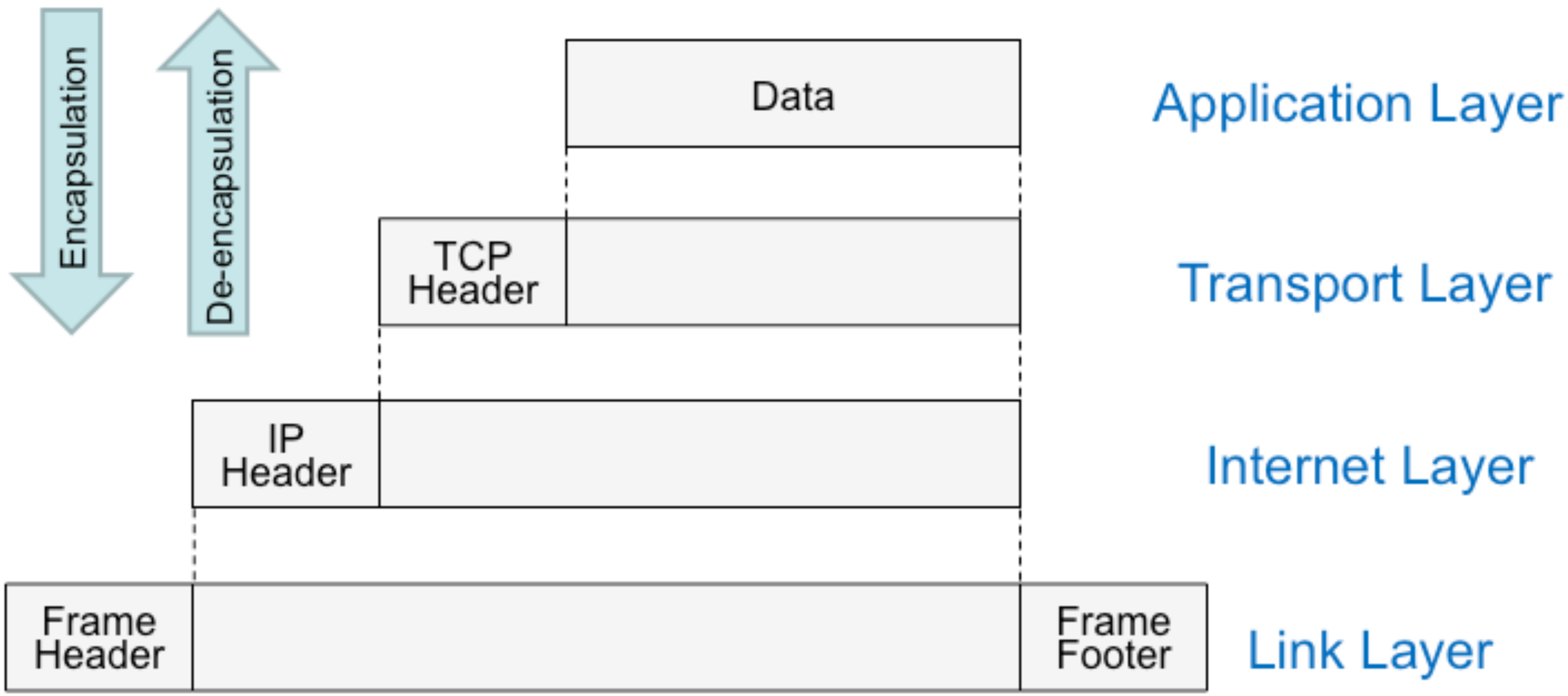


Hosting a web server at TCP port 80

- Network traffic is broken down into “packets” containing information at 4 main layers

  Layer 4 : Application
  Layer 3 : Transport (TCP)
  Layer 2 : Network (IP)
  Layer 1 : Link/Physical

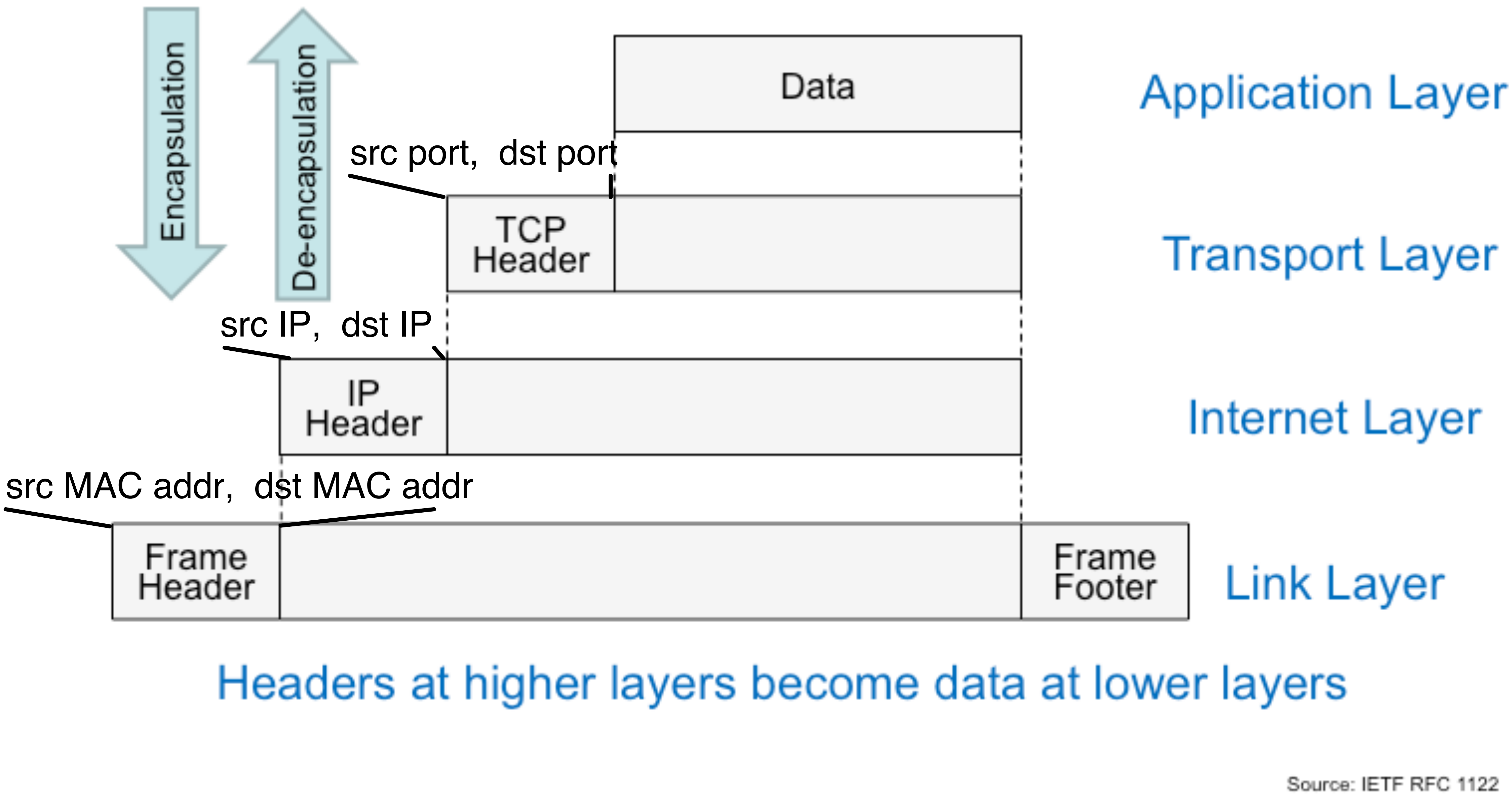
TCP/IP network Layers



Headers at higher layers become data at lower layers

Source: IETF RFC 1122

TCP/IP network Layers



IP Layer

- Responsible for end to end transmission
- Sends data in individual packets
- Maximum size of packet is determined by the networks
  - Fragmented if too large
- Unreliable
  - Packets might be lost, corrupted, duplicated, delivered out of order

IP addresses

- 4 bytes (IPv4)
  - e.g. 163.1.125.98
  - Each device normally gets one (or more)
  - In theory there are about 4 billion available

- But…
  - Basically used up today
  - Therefore, 16 bytes are now used in IPv6 (still not fully functional today)

Routing

- How does a device know where to send a packet?
  - All devices need to know what IP addresses are on directly attached networks
  - If the destination is on a local network, send it directly there

Routing (cont.)

- If the destination address isn't local
  - Most non-router devices just send everything to a single local router (gateway)
  - Routers need to know which network corresponds to each possible IP address

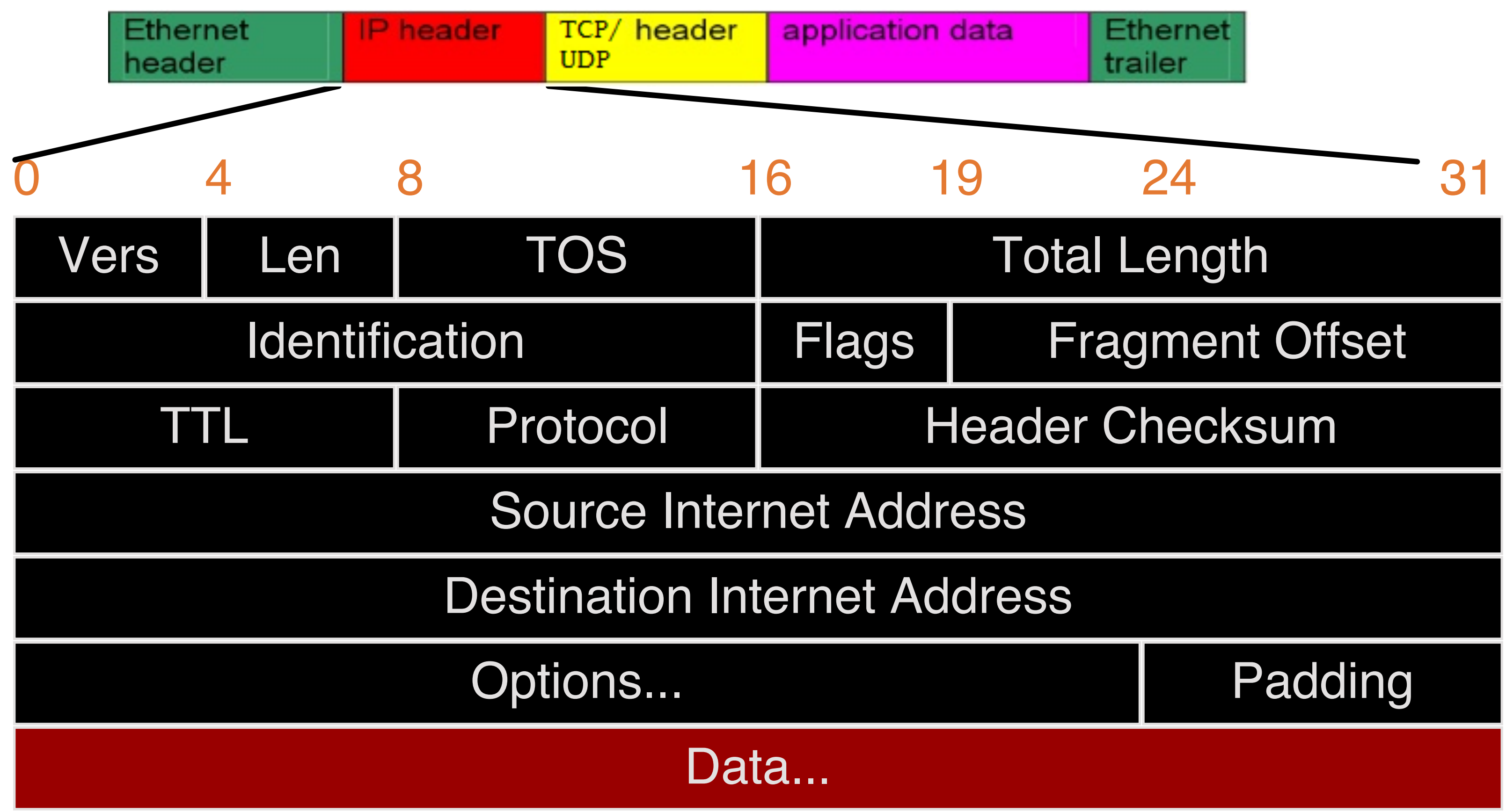
Allocation of addresses

- Controlled centrally by ICANN
  - Fairly strict rules on further delegation to avoid wastage
    - Have to demonstrate actual need for them
- Organizations that got in early have bigger allocations than they really need

IP packets

- Source and destination addresses
- Protocol number
  - 1 = ICMP, 6 = TCP, 17 = UDP
- Various options
  - e.g. to control fragmentation
- Time to live (TTL)
  - Prevent routing loops

IP Datagram



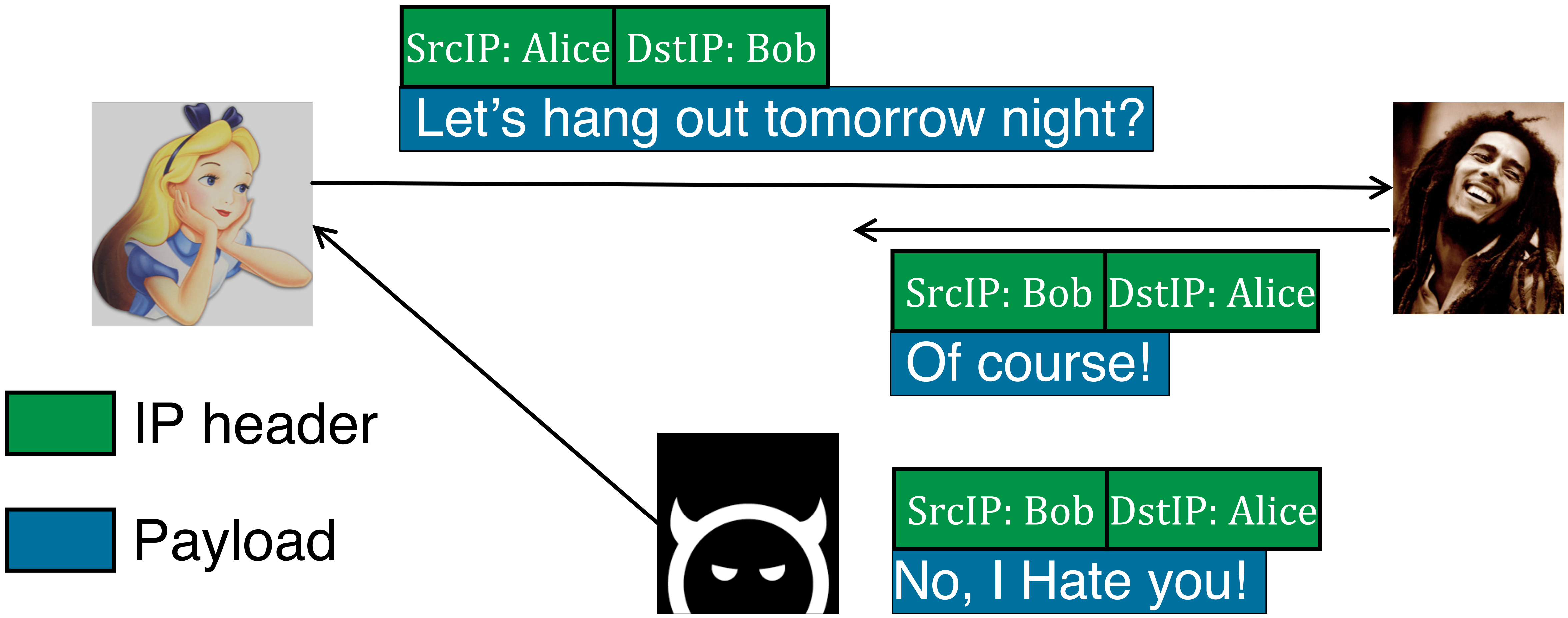
Field	**Purpose**
Vers	IP version number
Len	Length of IP header (4 octet units)
TOS	Type of Service
T. Length	Length of entire datagram (octets)
Ident.	IP datagram ID (for frag/reassembly)
Flags	Don't/More fragments
Frag Off	Fragment Offset

Field	**Purpose**
TTL	Time To Live - Max # of hops
Protocol	Higher level protocol (1=ICMP, 6=TCP, 17=UDP)
Checksum	Checksum for the IP header
Source IA	Originator's Internet Address
Dest. IA	Final Destination Internet Address
Options	Source route, time stamp, etc.
Data...	Higher level protocol data

You just need to know the IP addresses, TTL and protocol #

Problem with IP address

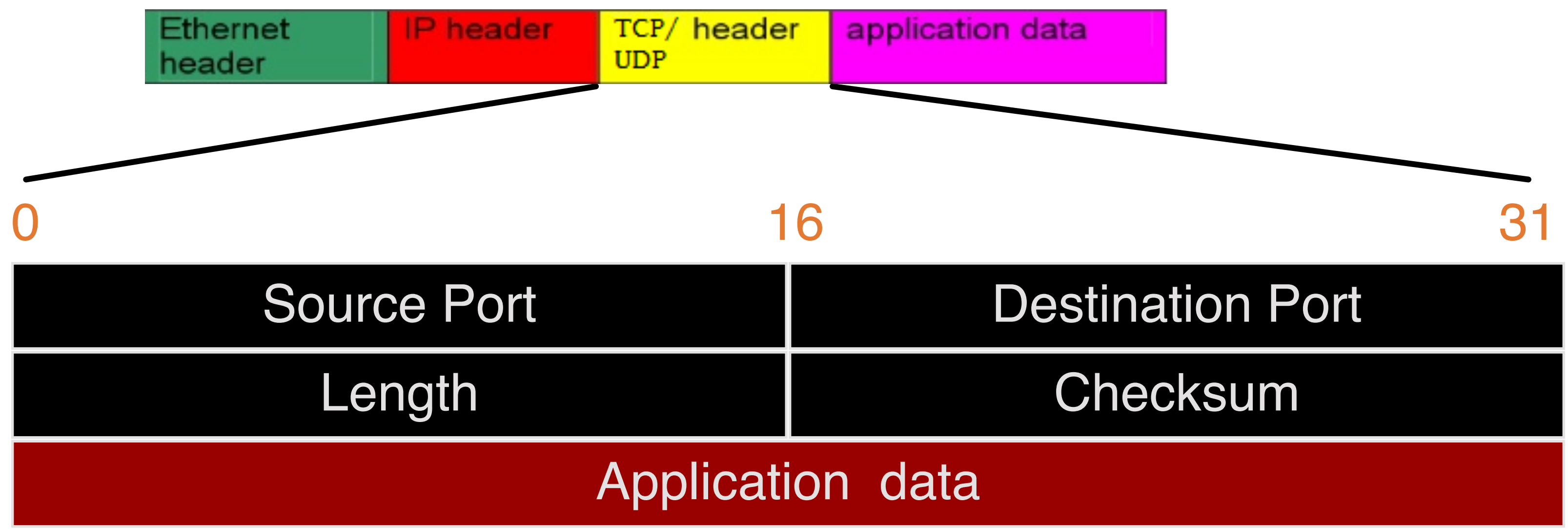
- Source address in a packet can be filled arbitrarily by a host (think of USPS mail)
  - Lack of authentication of packet sources
  - Many vulnerabilities arise because of this



UDP

- Thin layer on top of IP (alternative to TCP)
- Adds packet length + checksum
  - Guard against corrupted packets
- Also source and destination ports
  - Ports are used to associate a packet with a specific application at each end
- Still unreliable:
  - Duplication, loss, out-of-orderness possible

UDP datagram



Field	**Purpose**
Source Port	16-bit port number identifying originating application
Destination Port	16-bit port number identifying destination application
Length	Length of UDP datagram (UDP header + data)
Checksum	Checksum of IP pseudo header, UDP header, and data

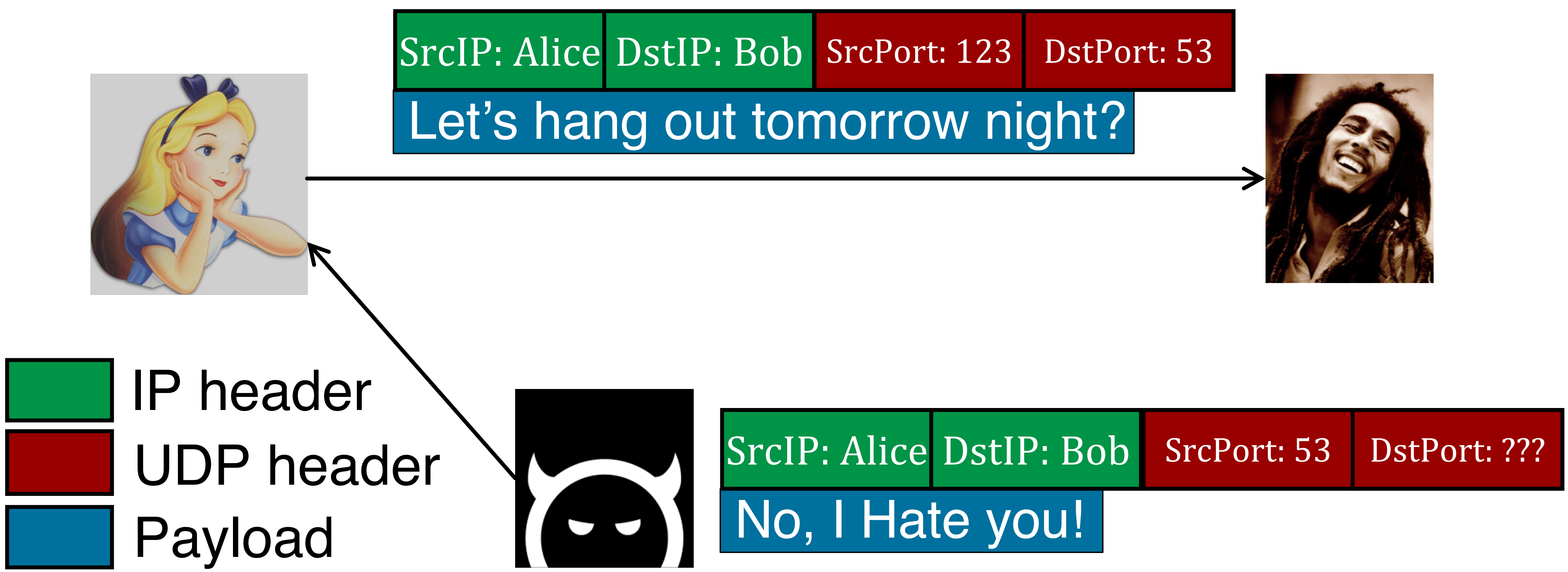
Typical applications of UDP

  - Where packet loss etc is better handled by the application than the network stack
  - Where the overhead of setting up a TCP connection isn't wanted

- DNS
- VoIP
- Some games

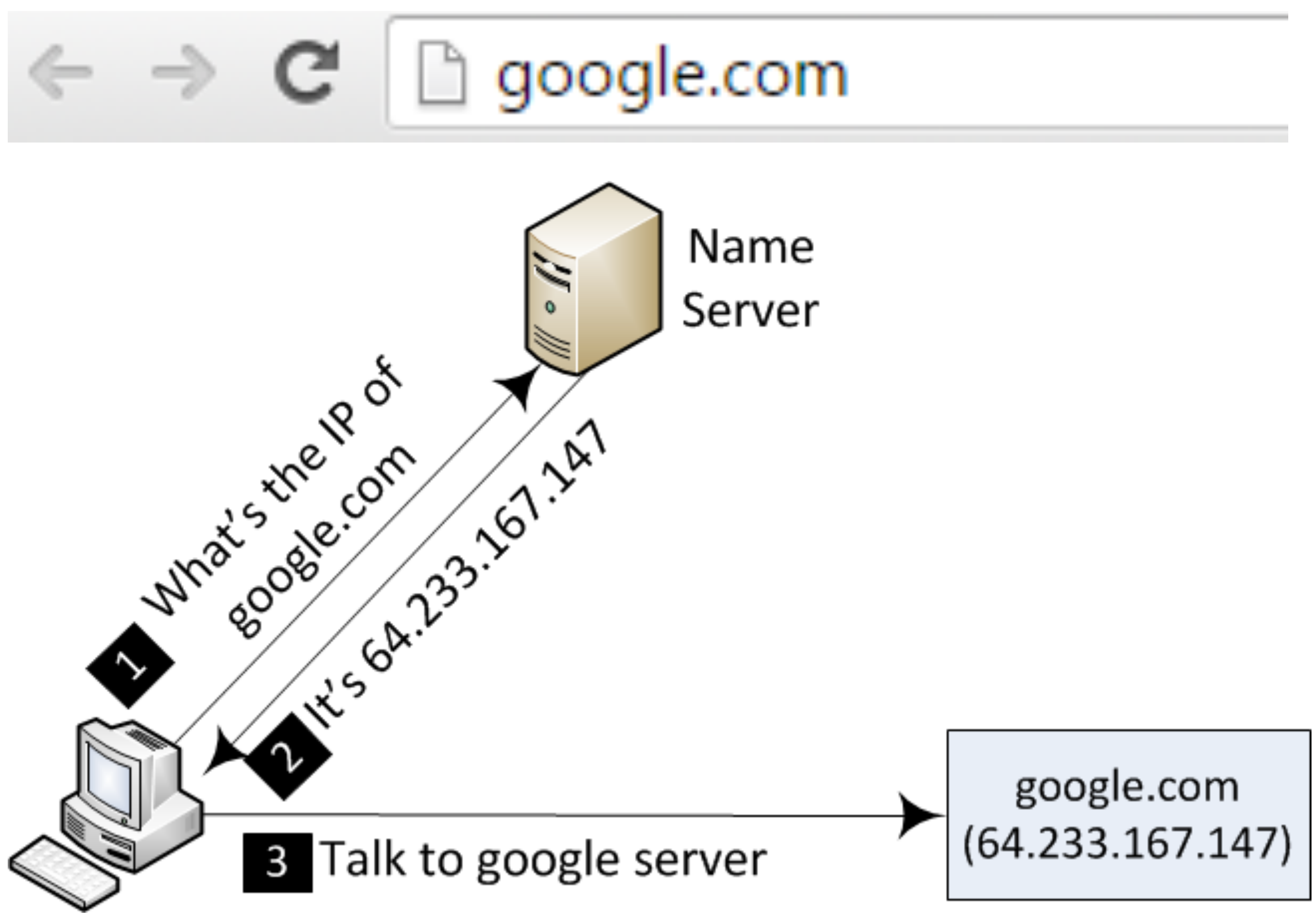
IP Spoofing against UDP

- Need to guess the port number…



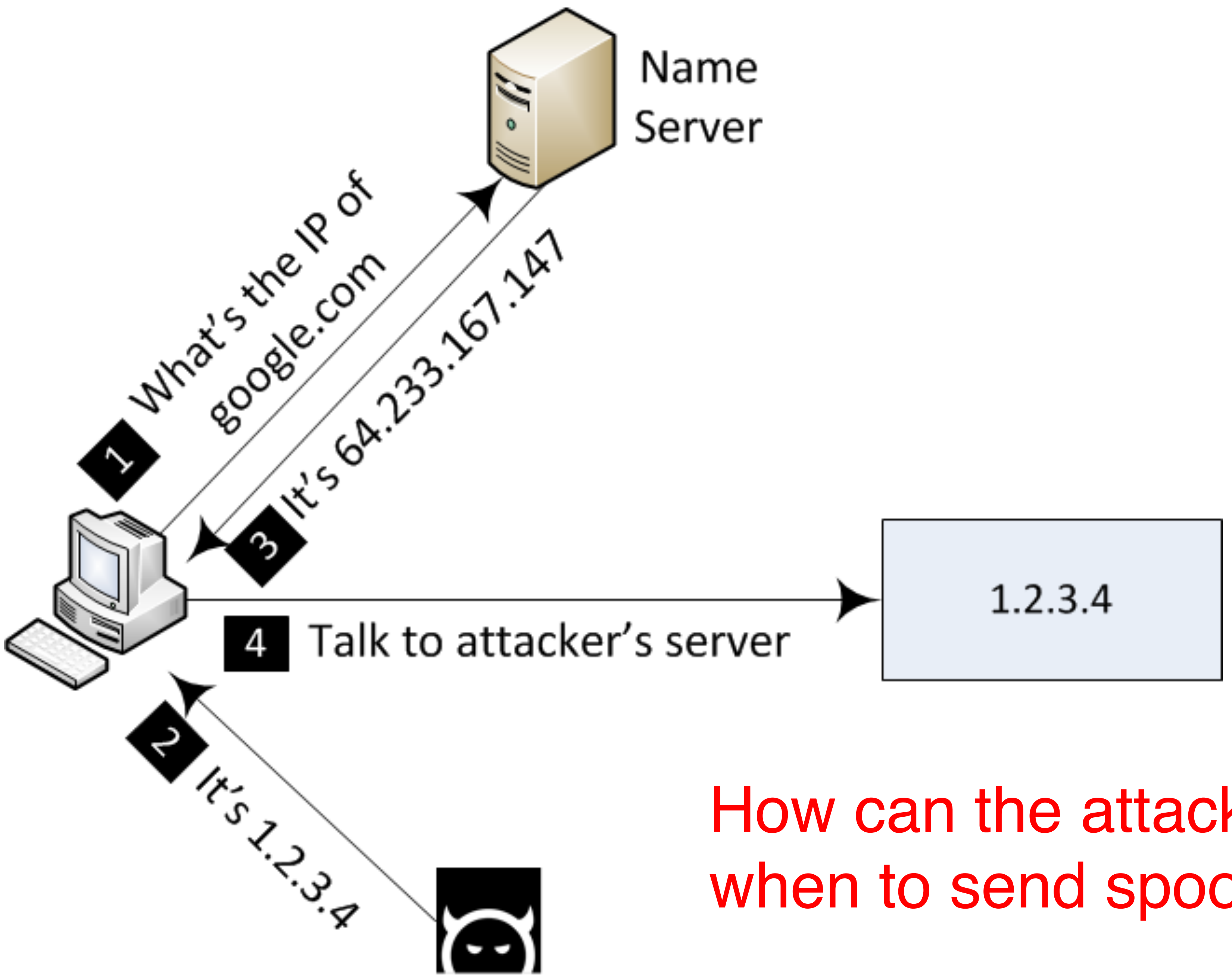
DNS Protocol – Application Layer Protocol

- Mapping between domain name (human readable) and IP addresses



DNS Poisoning Attack

- Attacker can spoof its source IP as name server's IP



How can the attacker know when to send spoofed packet?

TCP

- Reliable, full-duplex, connection-oriented, stream delivery
  - Interface presented to the application doesn’t require data in individual packets
  - Data is guaranteed to arrive, and in the correct order without duplicates
    - Or the connection will be dropped
  - Imposes significant overheads

Applications of TCP

- Most things!
  - HTTP, FTP, SMTP…

- Saves the application a lot of work, so used unless there's a good reason not to

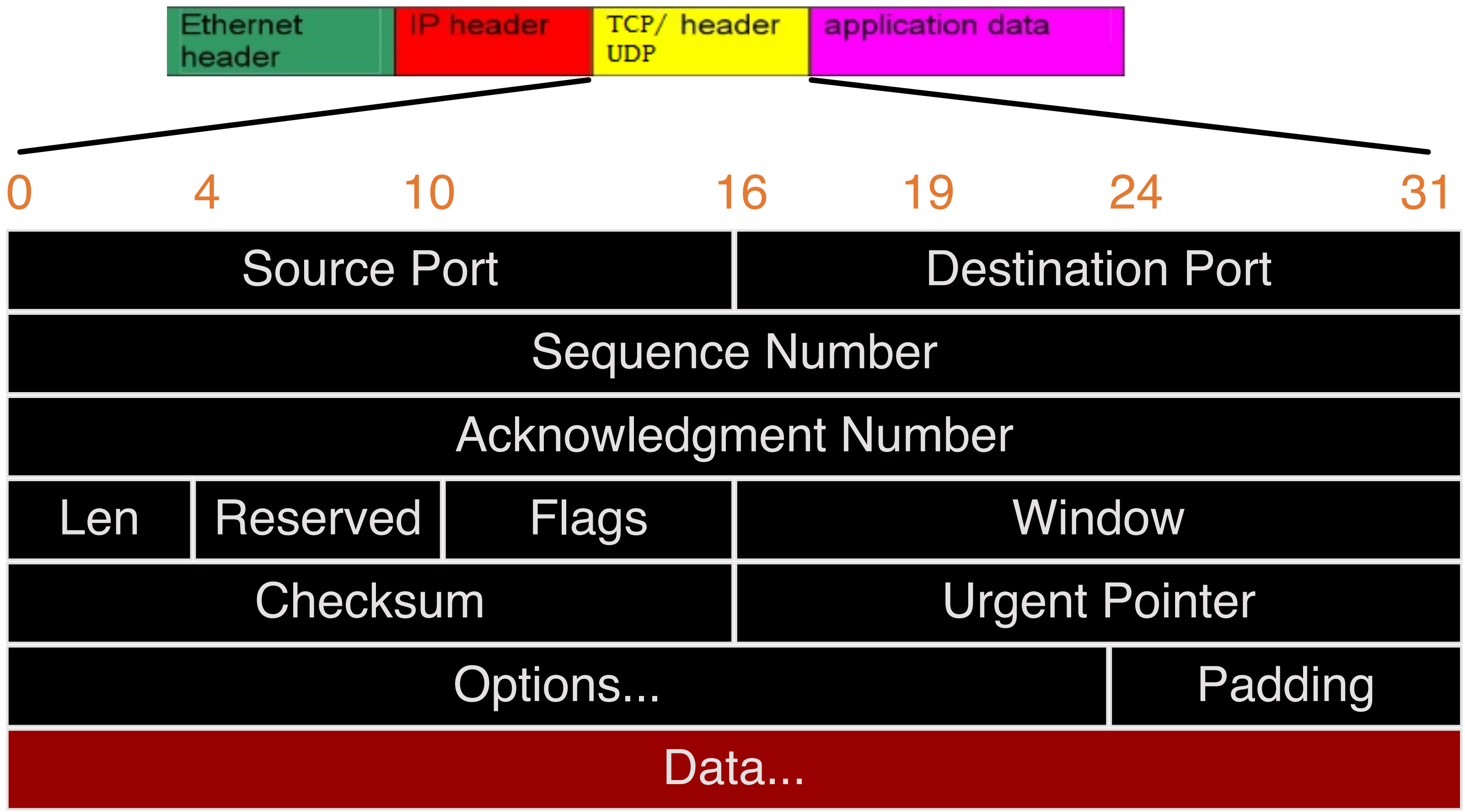
TCP implementation

- Connections are established using a three-way handshake
- Data is divided up into packets by the operating system
- Packets are numbered, and received packets are acknowledged
- Connections are explicitly closed
  - (or may abnormally terminate)

TCP Packets

- Source + destination ports
- Sequence number
- Acknowledgement number
- Checksum
- Various options

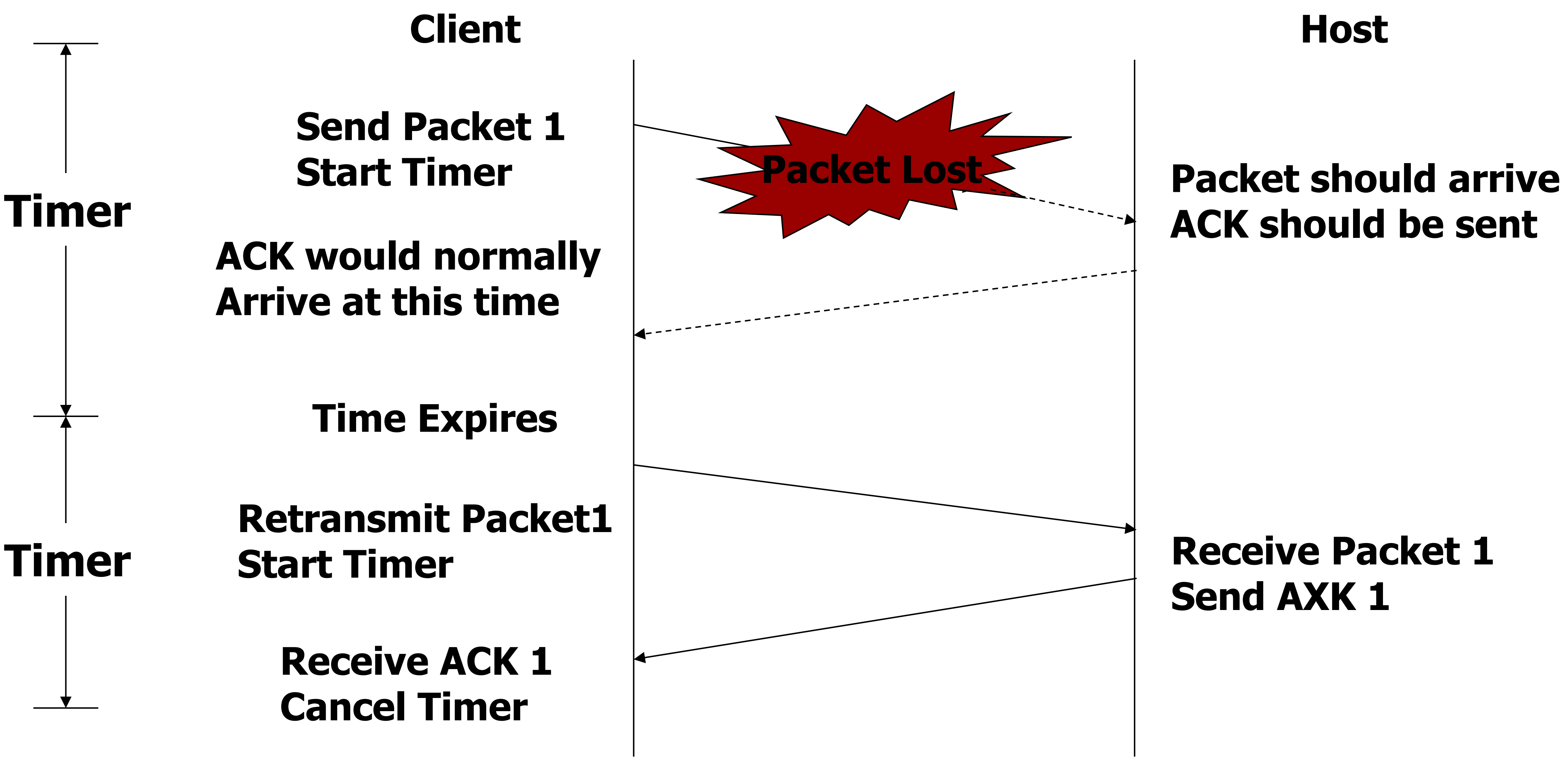
TCP Segment



Field	**Purpose**
Source Port	Identifies originating application
Destination Port	Identifies destination application
Sequence Number	Sequence number of first octet in the segment
Acknowledgment #	Sequence number of the next expected octet (if ACK flag set)
Len	Length of TCP header in 4 octet units
Flags	TCP flags: SYN, FIN, RST, PSH, ACK, URG
Window	Number of octets from ACK that sender will accept
Checksum	Checksum of IP pseudo-header + TCP header + data
Urgent Pointer	Pointer to end of “urgent data”
Options	Special TCP options such as MSS and Window Scale

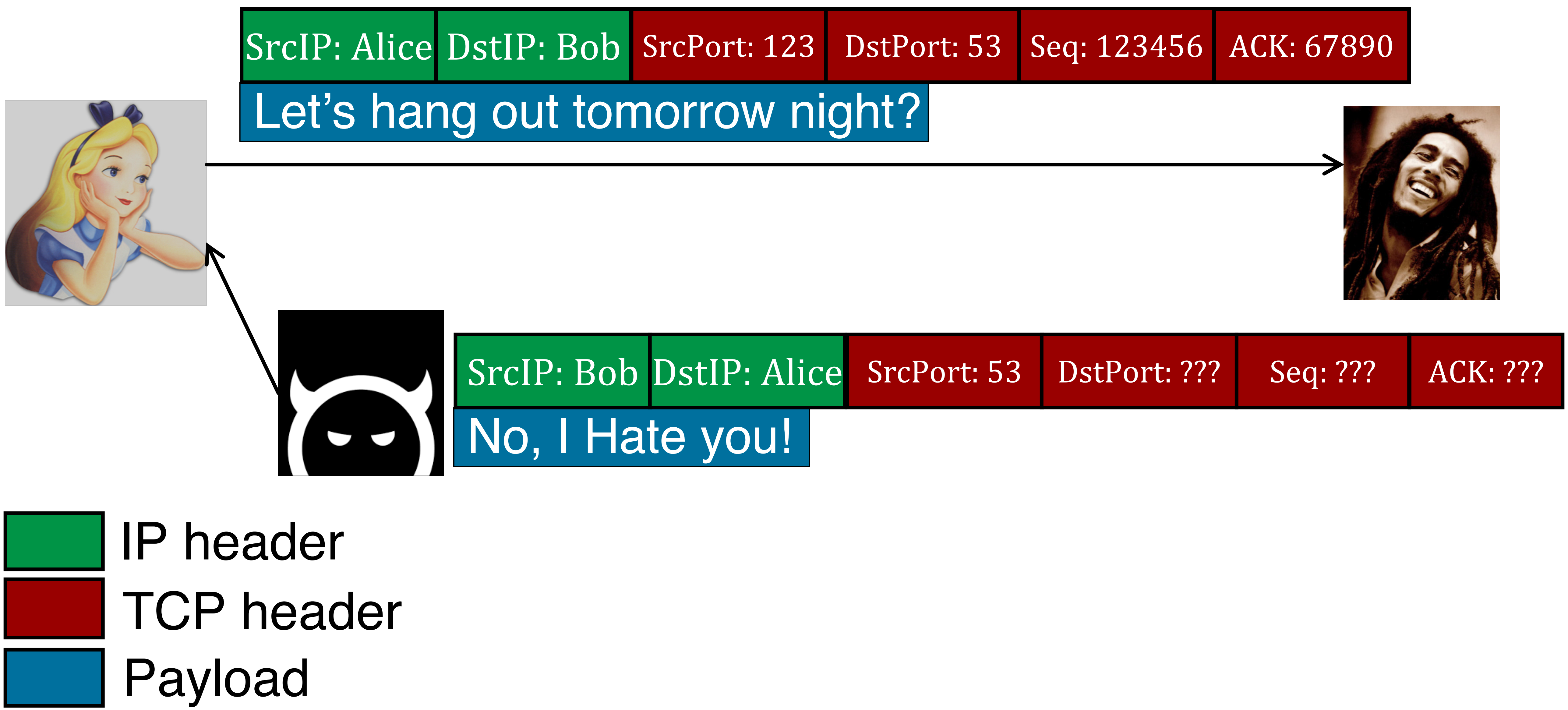
You just need to know port numbers, seq and ack are added

TCP : Data transfer



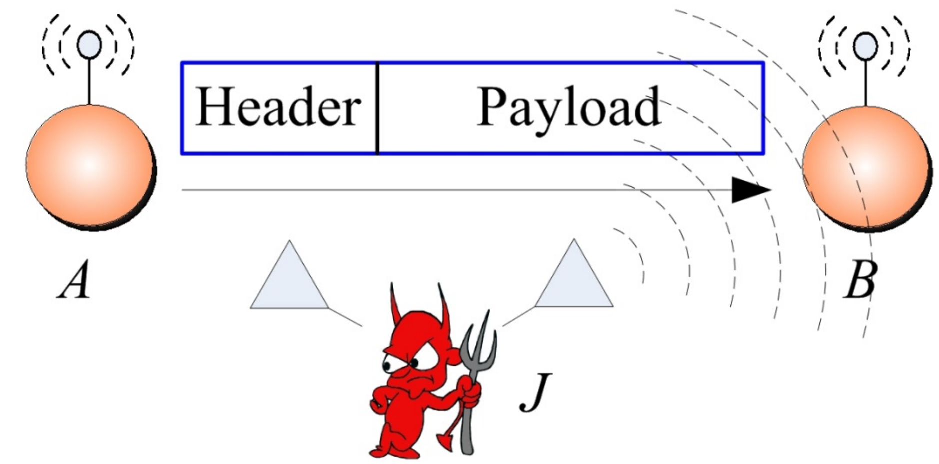
IP Spoofing against TCP

- Need to guess the port number, sequence number, and acknowledgement number!

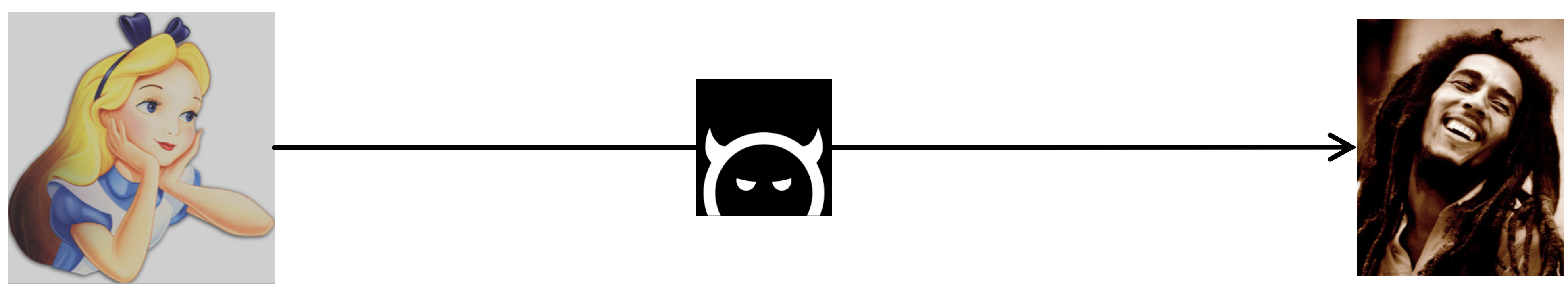


Common Threat Models in Networks (targeting confidentiality and integrity)

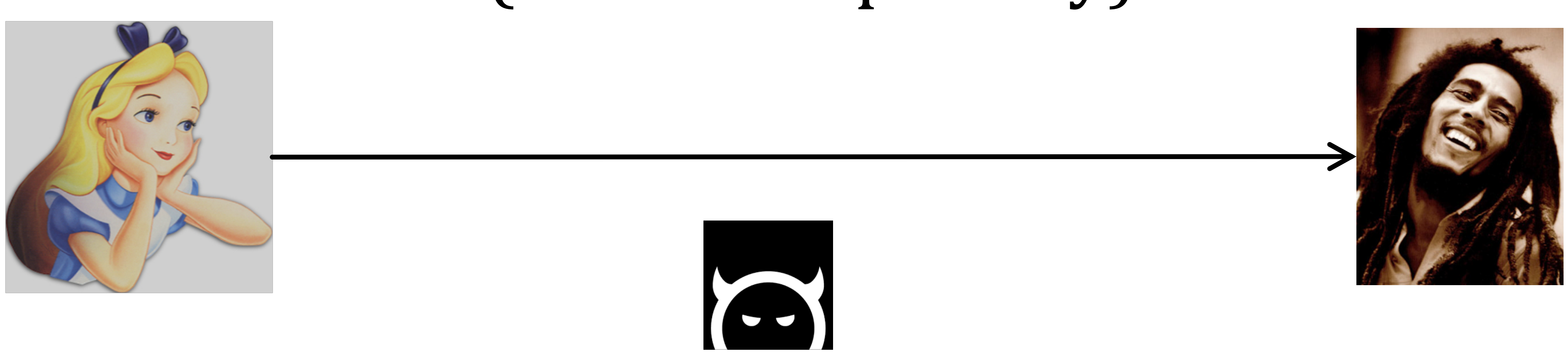
- Passive Eavesdropper
  - Read (and at most Insert)



- Man-in-the-middle (MITM)
  - On the communication path (compromised router)
  - Arbitrary Read/Write capability (modify, drop, etc.)

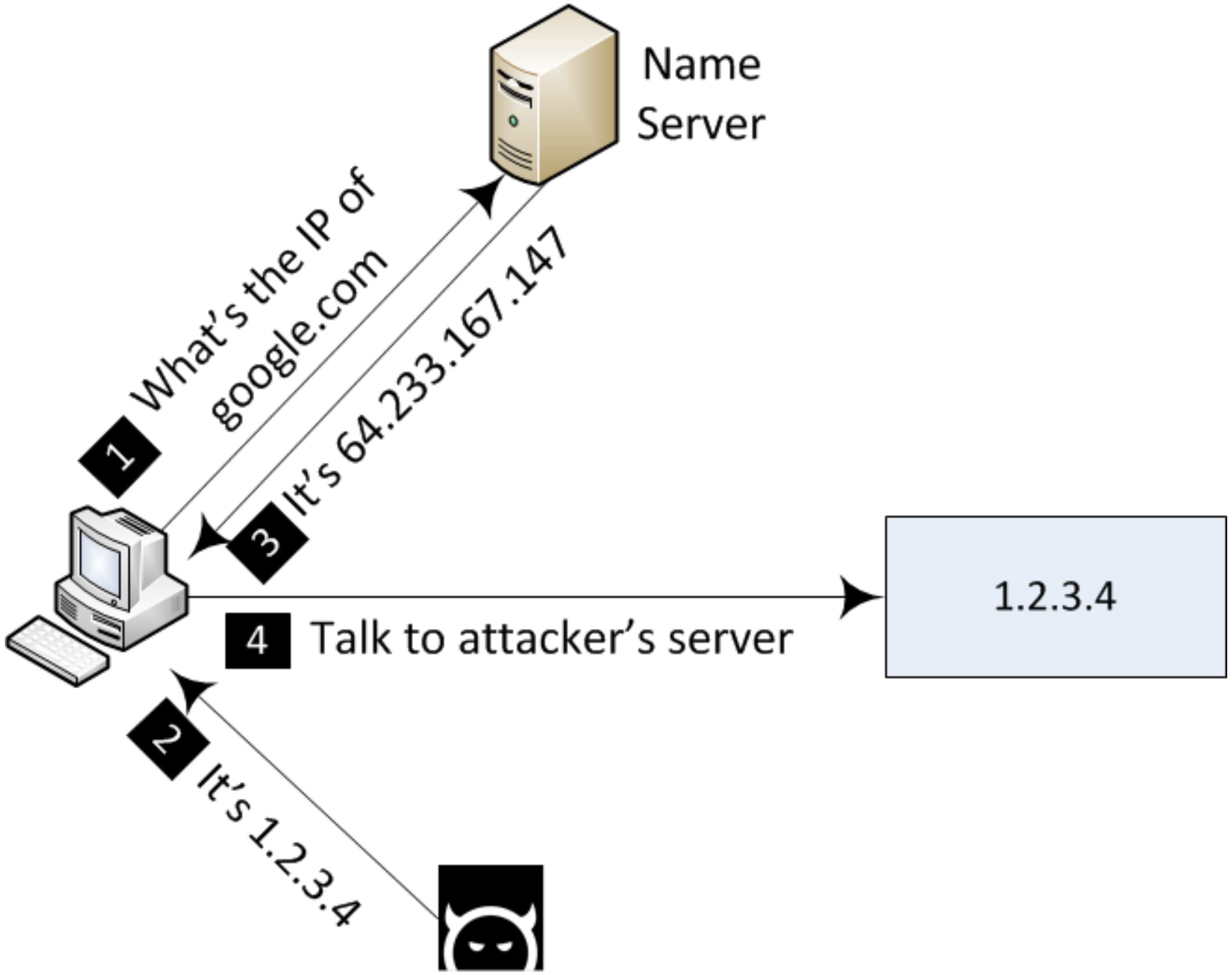


- Off-Path attacker (no read capability)



Passive Eavesdropper

- Read (at most insert)
- Can an attacker launch DNS poisoning attack?

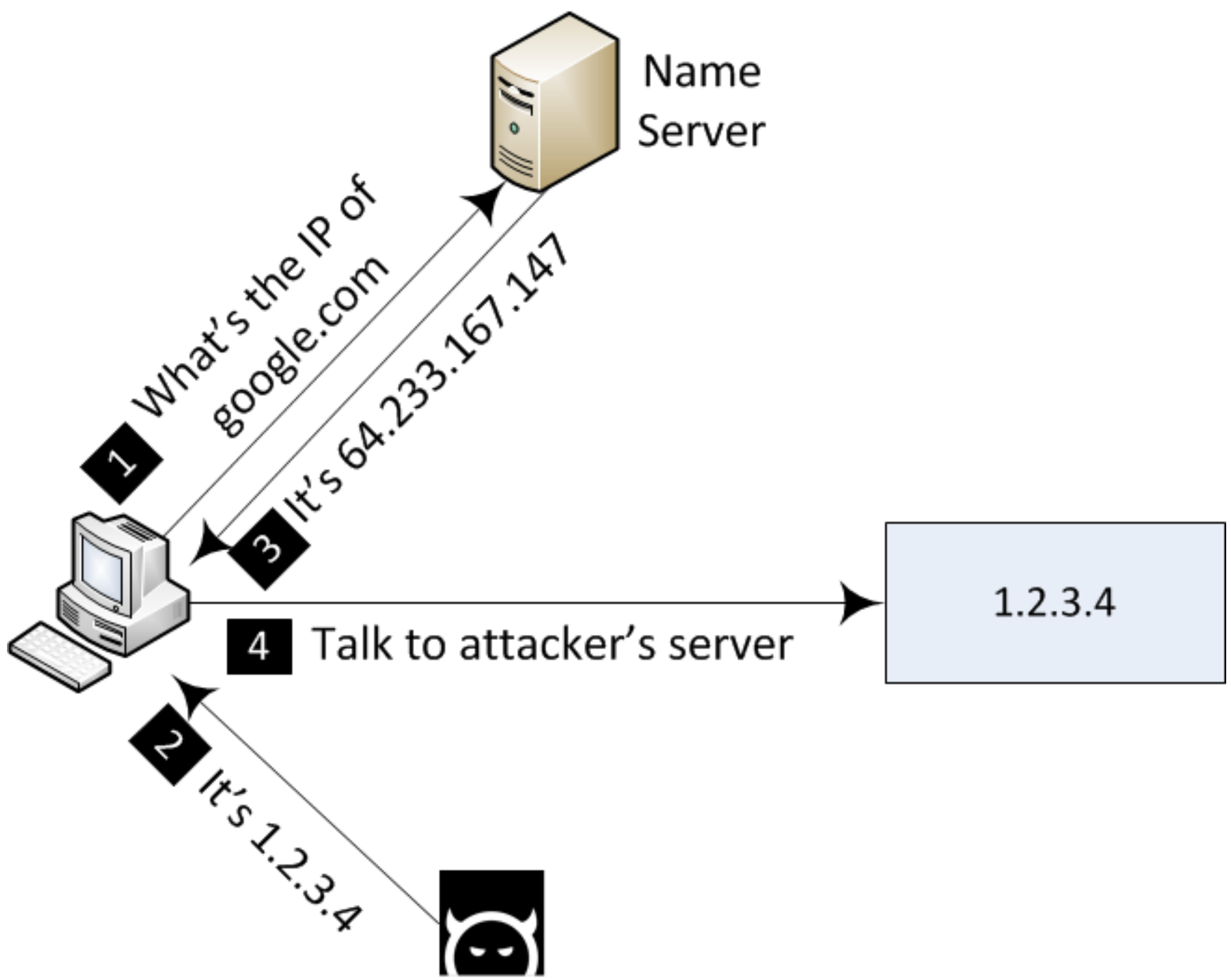


IP Spoofing against UDP (review)

- Need to guess the port number…

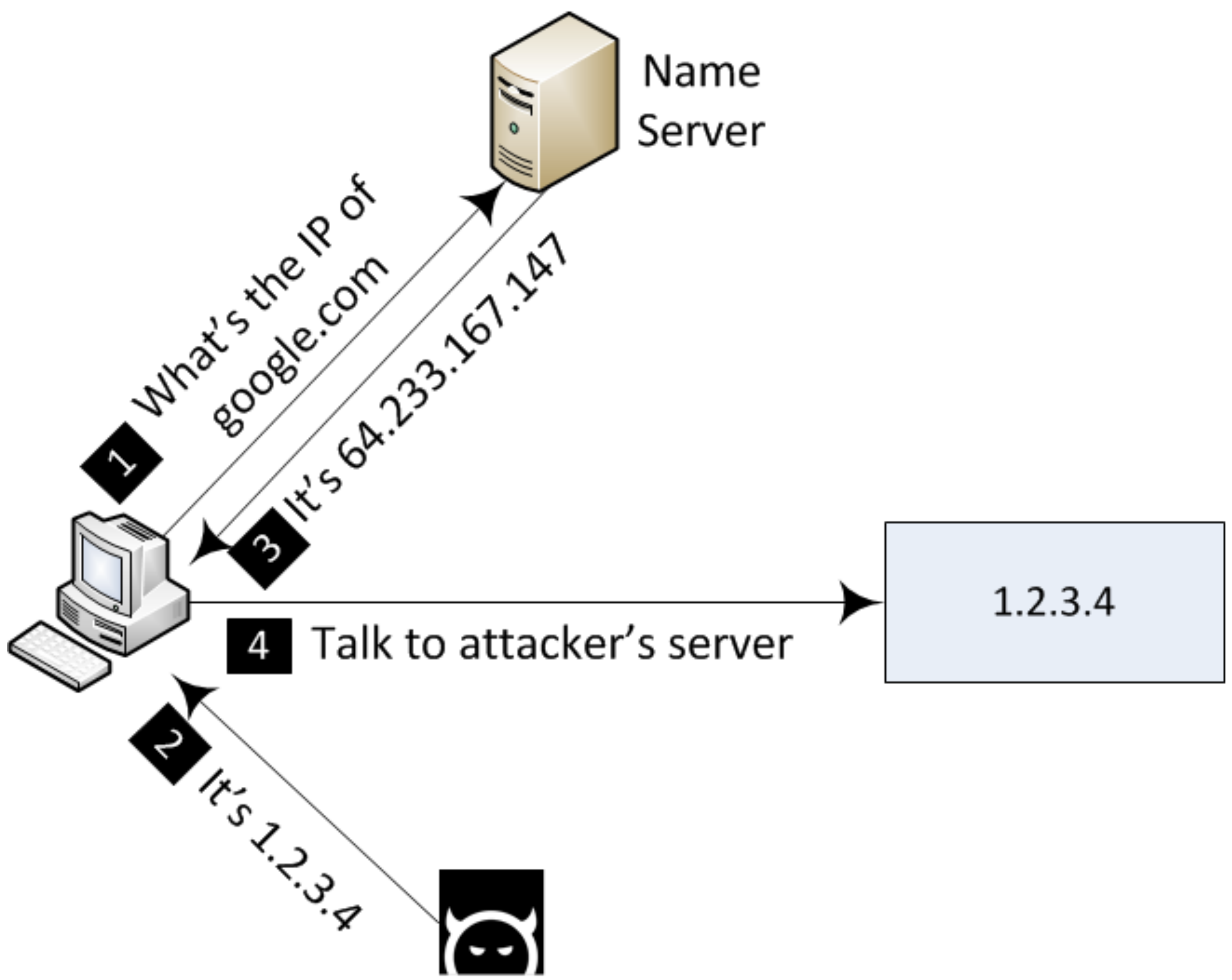
Man-in-the-middle (MITM)

- Arbitrary Read/Write capability (modify, drop, etc.)
- Can an attacker launch DNS poisoning attack?



Off-Path Attacker

- No read. Can insert.
- Can an attacker launch DNS poisoning attack?



Common network security attacks and their countermeasures

- Packet sniffing and spoofing
  - Encryption (SSH, SSL, HTTPS)
- Finding a way into the network
  - Firewalls
- Denial of Service
  - Ingress filtering, IDS

Finding a way into the network -- Scanning

```
Host 192.168.2.1 appears to be up.
MAC Address: 00:04:E2:34:B6:CE (SMC Networks)
Host 192.168.2.79 appears to be up.
MAC Address: 00:11:11:5B:7A:CD (Intel)
Host 192.168.2.82 appears to be up.
MAC Address: 00:10:5A:0D:F6:D7 (3com)
Host 192.168.2.198 appears to be up.
MAC Address: 00:10:DC:55:89:27 (Micro-star International)
Host 192.168.2.199 appears to be up.
MAC Address: 00:C0:4F:36:33:91 (Dell Computer)
Host 192.168.2.200 appears to be up.
MAC Address: 00:0C:41:22:CC:01 (The Linksys Group)
Host 192.168.2.251 appears to be up.
MAC Address: 00:0F:66:75:3D:75 (Cisco-Linksys)
```

Does That Matter?

- The number of computers an organization has roughly corresponds to the number of people in it
- How large is your competitor?
- (How many computers does Google have in its data centers? They won’t say.)

Does That Matter?

- If they identify a service that has a known vulnerability (e.g., buffer overflow), they can launch the corresponding exploit

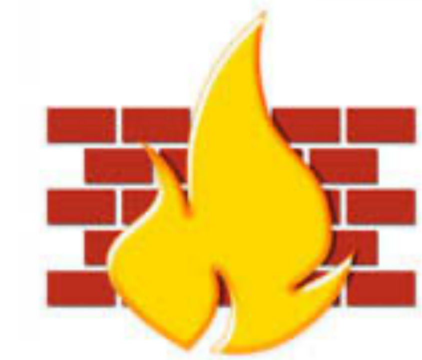
```
$ nmap -Pn www.cs.ucr.edu

Starting Nmap 6.40 ( http://nmap.org ) at 2015-11-17 20:03 UTC
Nmap scan report for www.cs.ucr.edu (169.235.30.15)
Host is up (0.00033s latency).
rDNS record for 169.235.30.15: thoth.cs.ucr.edu
Not shown: 996 closed ports
PORT     STATE SERVICE
22/tcp   open  ssh
80/tcp   open  http
111/tcp  open  rpcbind
5666/tcp open  nrpe
```

Firewalls

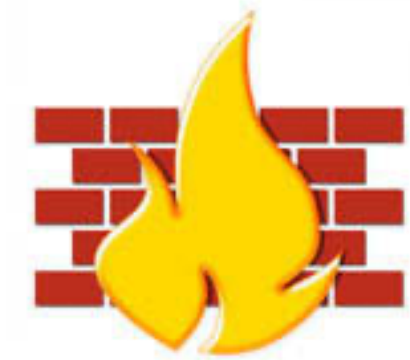
- Basic problem – many network applications and protocols have security problems that are fixed over time
  - Difficult for users to keep up with changes and keep host secure
  - Solution
    - Administrators limit access to end hosts by using a firewall
    - Firewall is kept up-to-date by administrators

Firewalls



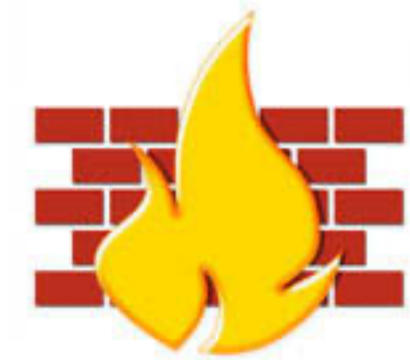
- A firewall is like a castle with a drawbridge
  - Only one point of access into the network
  - This can be good or bad
- Can be hardware or software
  - Ex. Some routers come with firewall functionality
  - ipfw, ipchains, pf on Unix systems, Windows XP and Mac OS X have built in firewalls

Firewalls



- Used to filter packets based on a combination of features
  - These are called packet filtering firewalls
    - There are other types too, but they will not be discussed
  - Ex. Drop packets with destination port of 23 (Telnet)
  - Can use any combination of IP/UDP/TCP header information
- But why don’t we just turn Telnet off?

Firewalls



- Here is what a computer with a default Windows install looks like:
  - `135/tcp open loc-srv`
  - `139/tcp open netbios-ssn`
  - `445/tcp open microsoft-ds`
  - `1025/tcp open NFS-or-IIS`
  - `3389/tcp open ms-term-serv`
  - `5000/tcp open UPnP`

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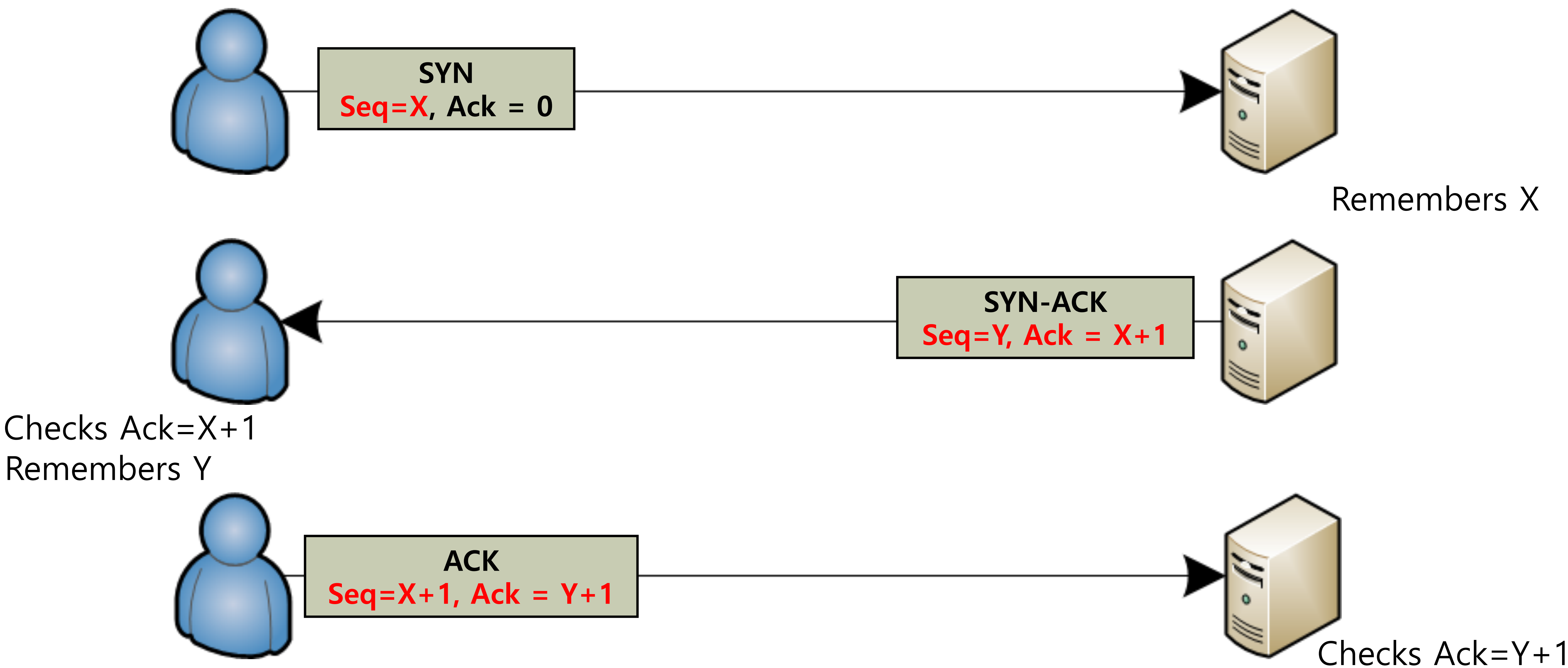
Denial of Service

- Purpose: Make a network service unusable, usually by overloading the server or network
- Many different kinds of DoS attacks
  - SYN flooding
  - SMURF
  - Distributed attacks

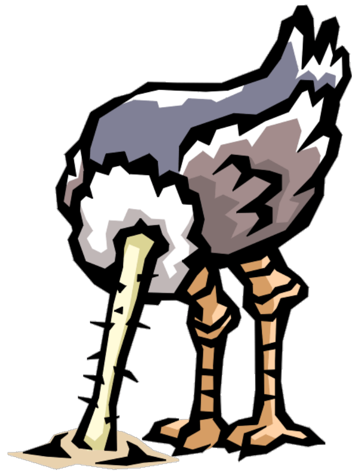
TCP Three-way handshake



Denial of Service

- SYN flooding attack
- Send SYN packets with bogus source address
  - Why?
- Server responds with SYN ACK and keeps state about TCP half-open connection
  - Eventually, server memory is exhausted with this state

Denial of Service

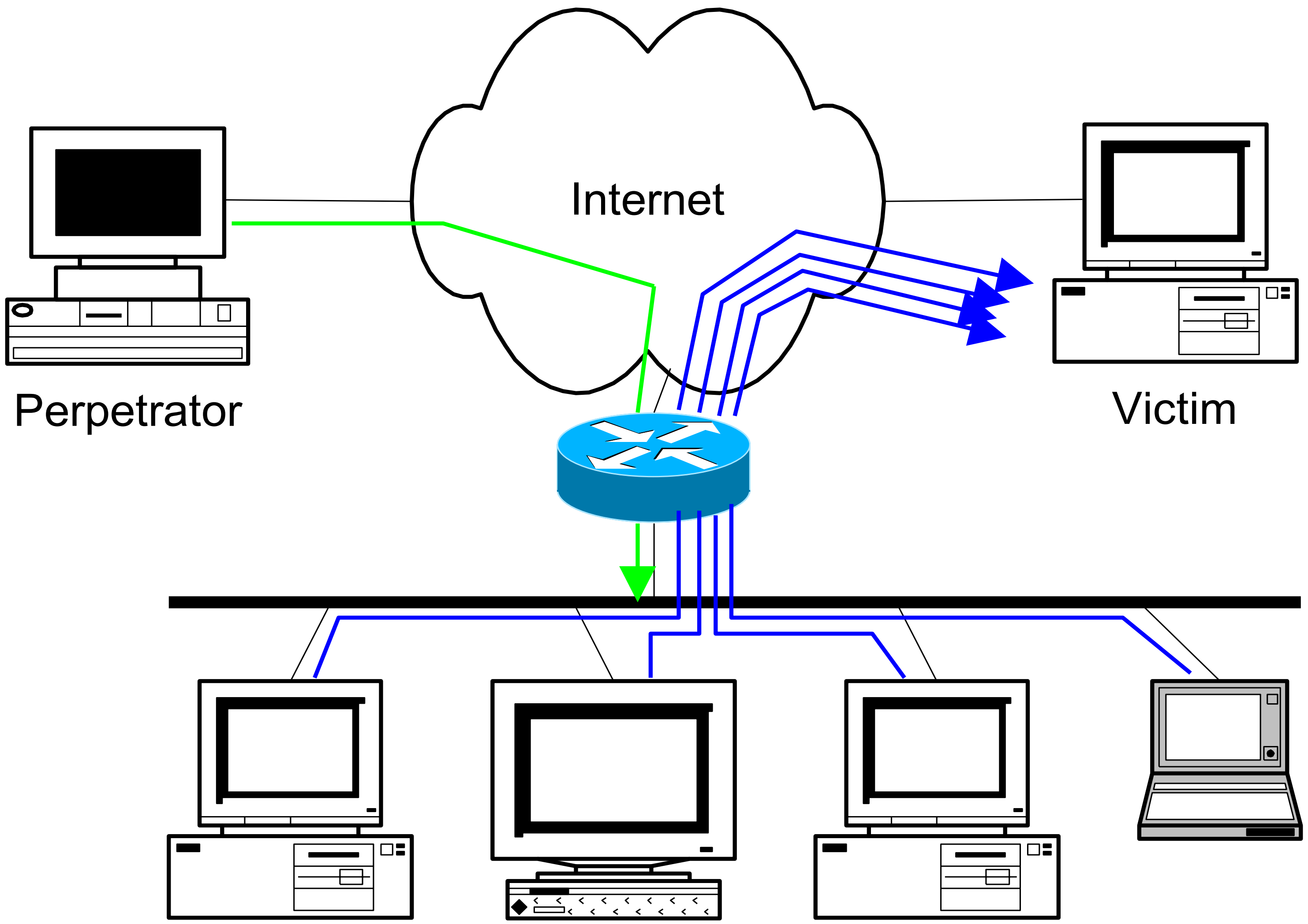


Denial of Service

- SMURF
  - Source IP address of a broadcast ping is forged
  - Large number of machines respond back to victim, overloading it

Denial of Service

ICMP echo (spoofed source address of victim)
Sent to IP broadcast address
ICMP echo reply



State Holding Attack

Assume stateful TCP policy

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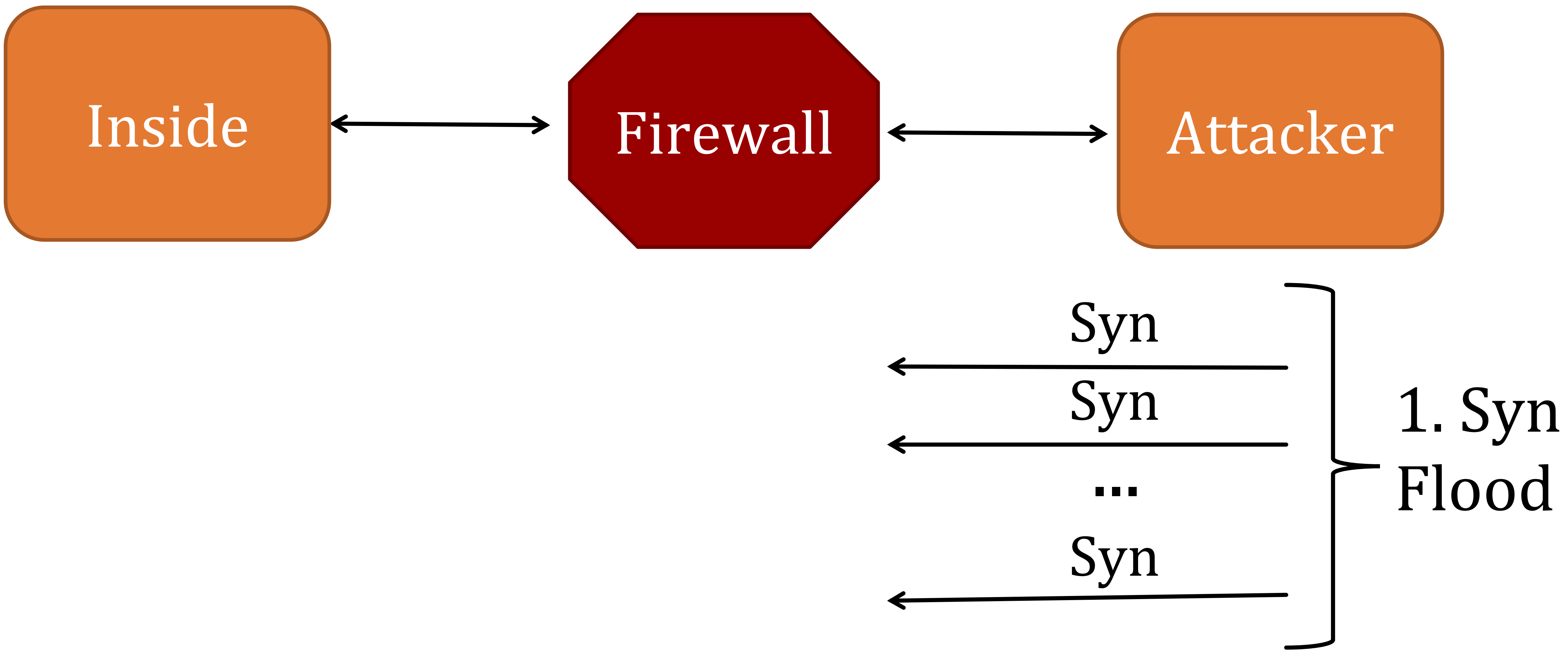
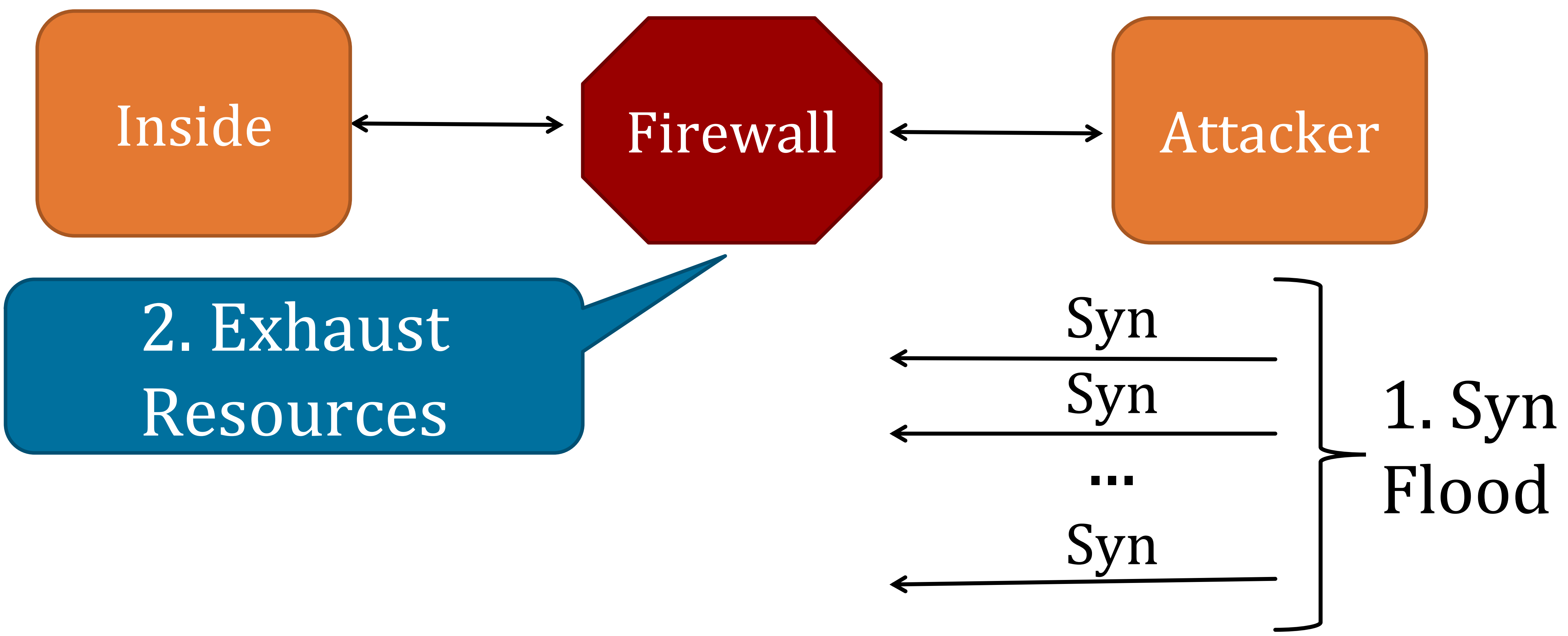


State Holding Attack

Assume stateful TCP policy



State Holding Attack

Assume stateful TCP policy