

# Security goals vs attacker's model



Let us consider **confidentiality, integrity and availability**

# Network (in)security

Thierry Sans

# How many of you ...

- have programmed with **sockets** ?
- have taken a **networking course** ?
- have used tools like ?  
**ping, traceroute, ipconfig/ifconfig, nslookup  
netstat, netcat, nmap, wireshark**
- know what is :  
**IP address, port, a canonical hostname  
client, server, router  
switch (or hub), gateway**
- can explain with a fair amount of details :  
**Ethernet, WiFi  
IP, TCP  
ARP, BGP, DNS**

# The Internet

**1980's** - few hosts connected : government institutions and universities

➡ Trustworthy environment

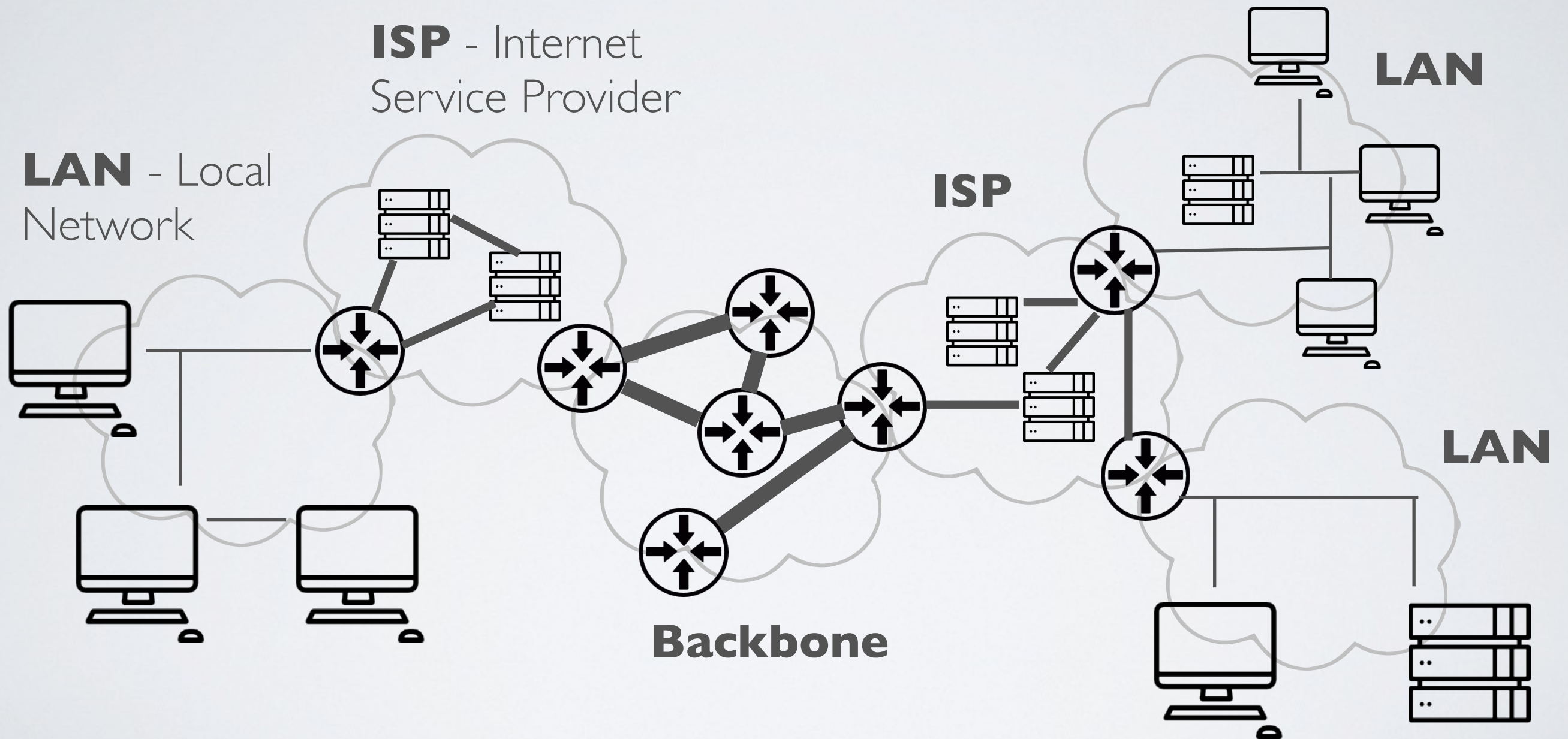
**2019** - ~ 4.2 billion internet users: network of networks

➡ Untrustworthy environment

➡ Internet (and its protocols) was  
**not designed for untrustworthy environment**



# A network of networks

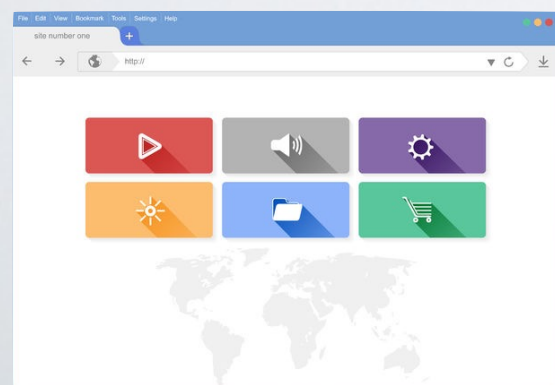


# What is a protocol

## Communication protocol

is an agreement on how communication should take place

- defines the data encoding and/or format
  - defines the message sequence
- ➔ (most) protocols are standards defined by the IETF - The Internet Engineering Task Force

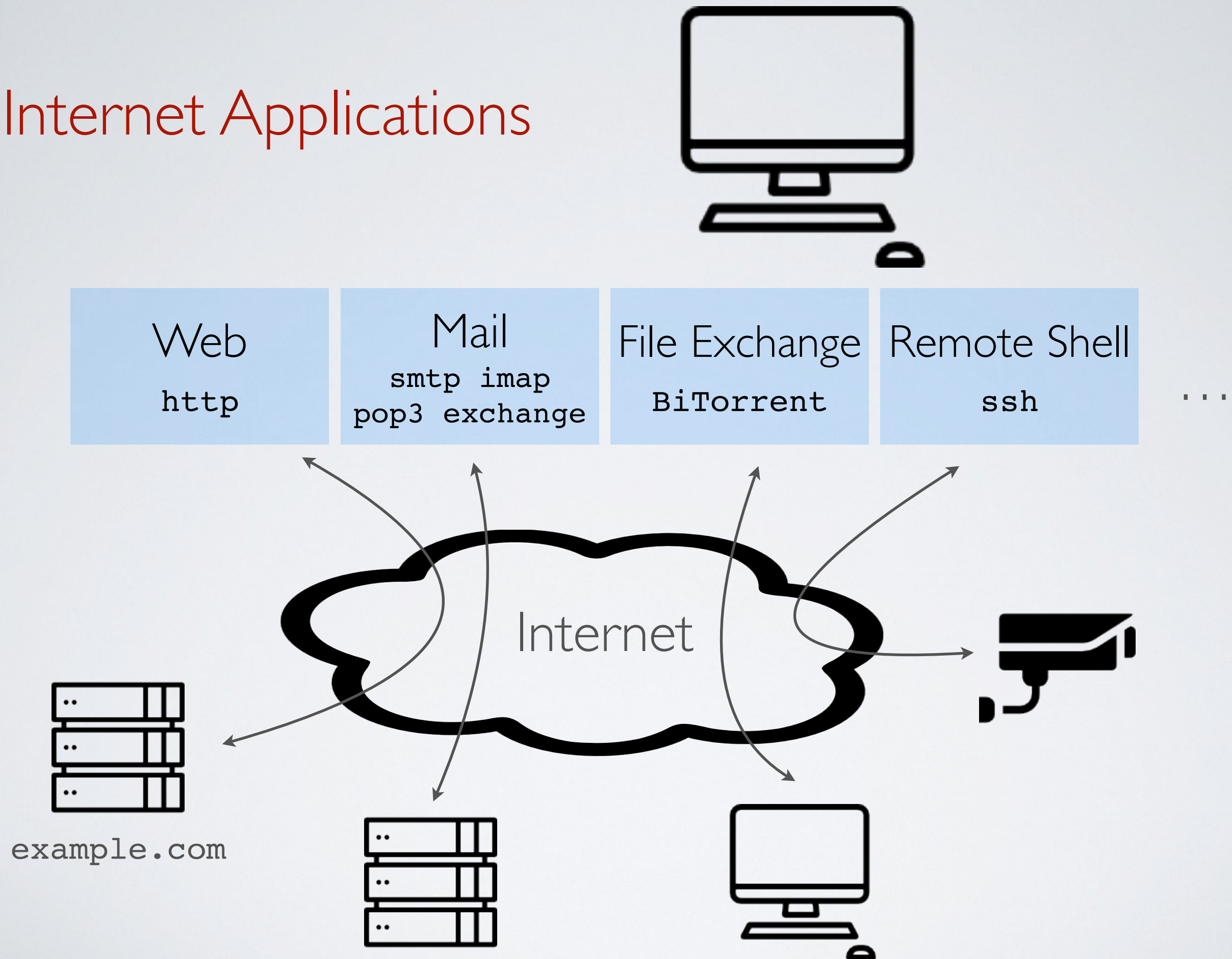


HTTP GET /document.html

HTTP 200 <!DOCTYPE html = ...



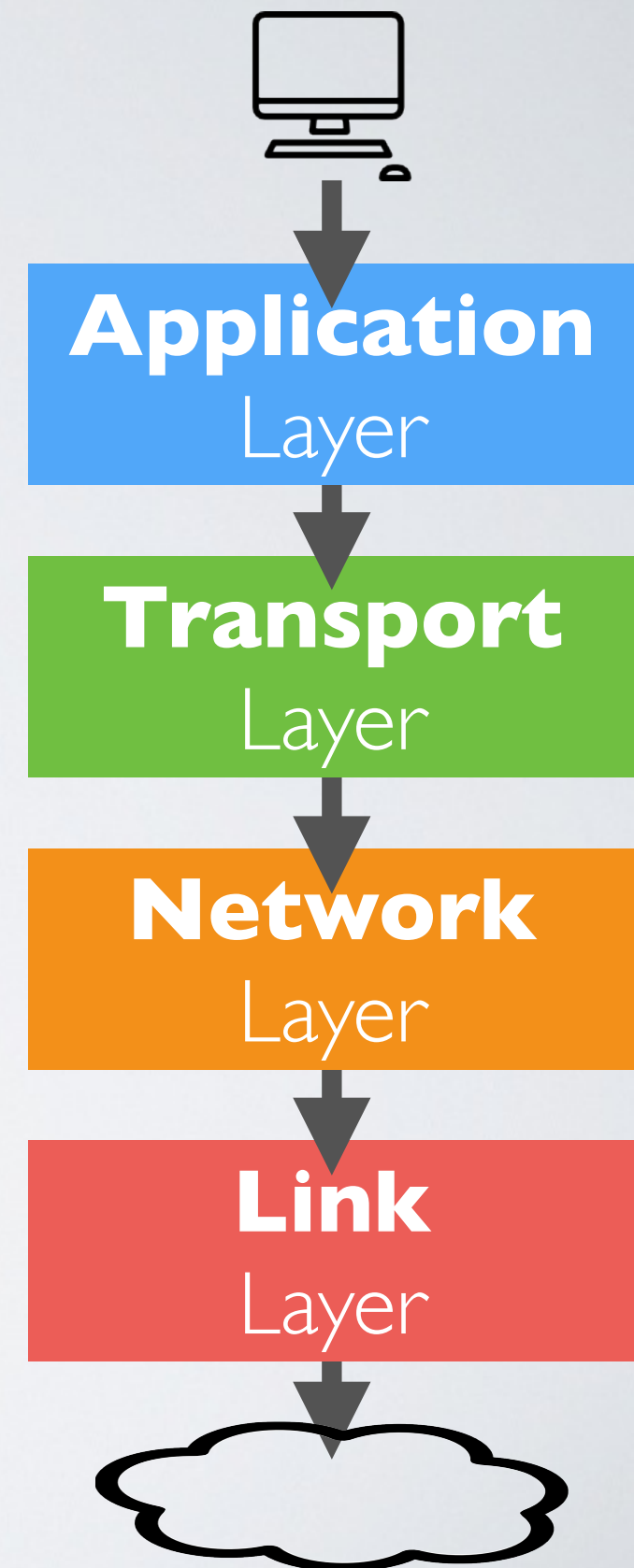
# Internet Applications



# The Internet Protocol Suite (a.k.a the network stack)

Protocols are built on top of each other as layers (modularity and encapsulation)

- How can two programs send messages to each other ?
- How to make sure that messages have been well transmitted ?
- How to route messages through the network ?
- How to encode messages to go through copper, fiber or air ?





confidentiality  
integrity  
availability



The attacker is capable of ...

**Scanning** - survey the network and its hosts

**Eavesdropping** - read messages

**Spoofing** - forge illegitimate messages

**DOS** (Denial of Service) - disrupt the communications

➡ The attacker can target any layer in the network stack

# Link Layer

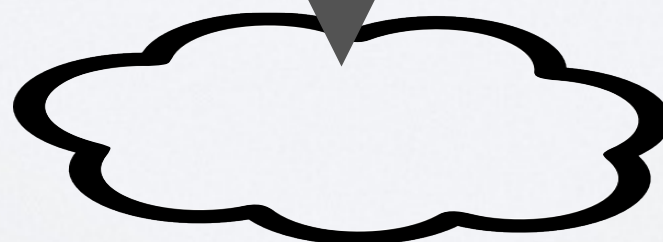
connecting machines together

# Link Layer

Collection of protocols to connect hosts through a medium

- ➡ Defines how information is encoded to go through copper, fiber, air, etc ...

`(message [,recipient])`



# Multiple Interfaces

A host can be connected to several hosts or networks through **multiple interfaces**

- Some are connected to a single host only (Point-to-Point)
- Others are connected to a entire network (BUS)

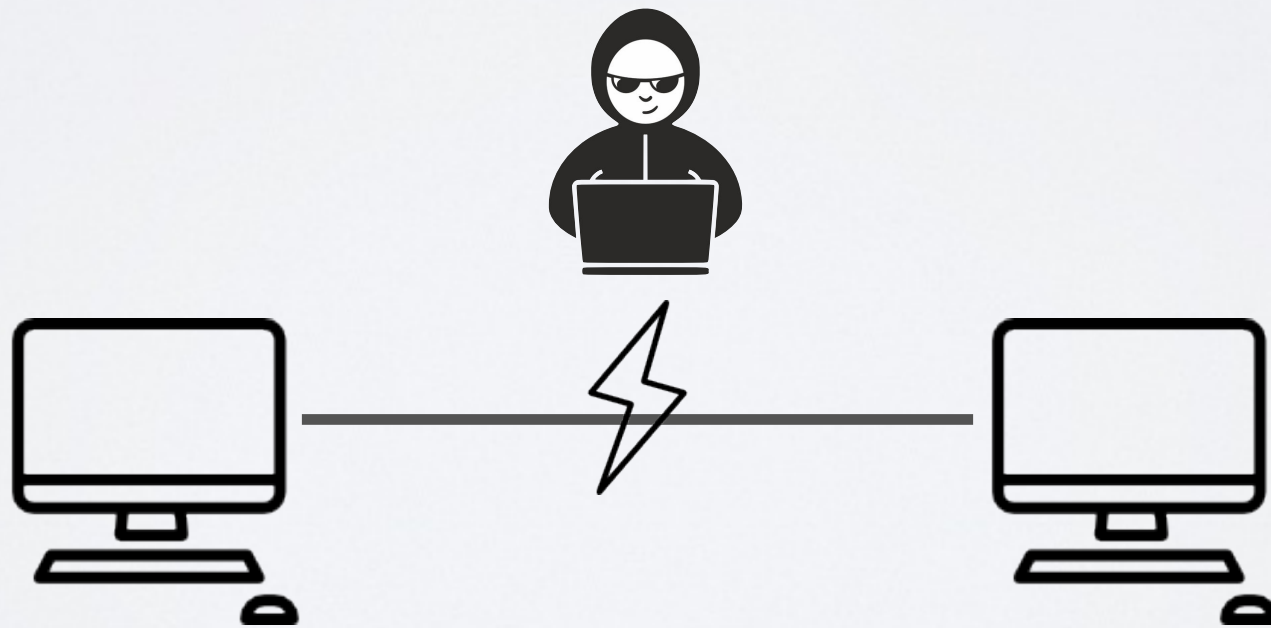




# Point-to-Point Link

Only two hosts are connected at each end of the medium  
e.g. OTN, IRDA, DSL ...

➔ Harder for an attacker to intercept messages

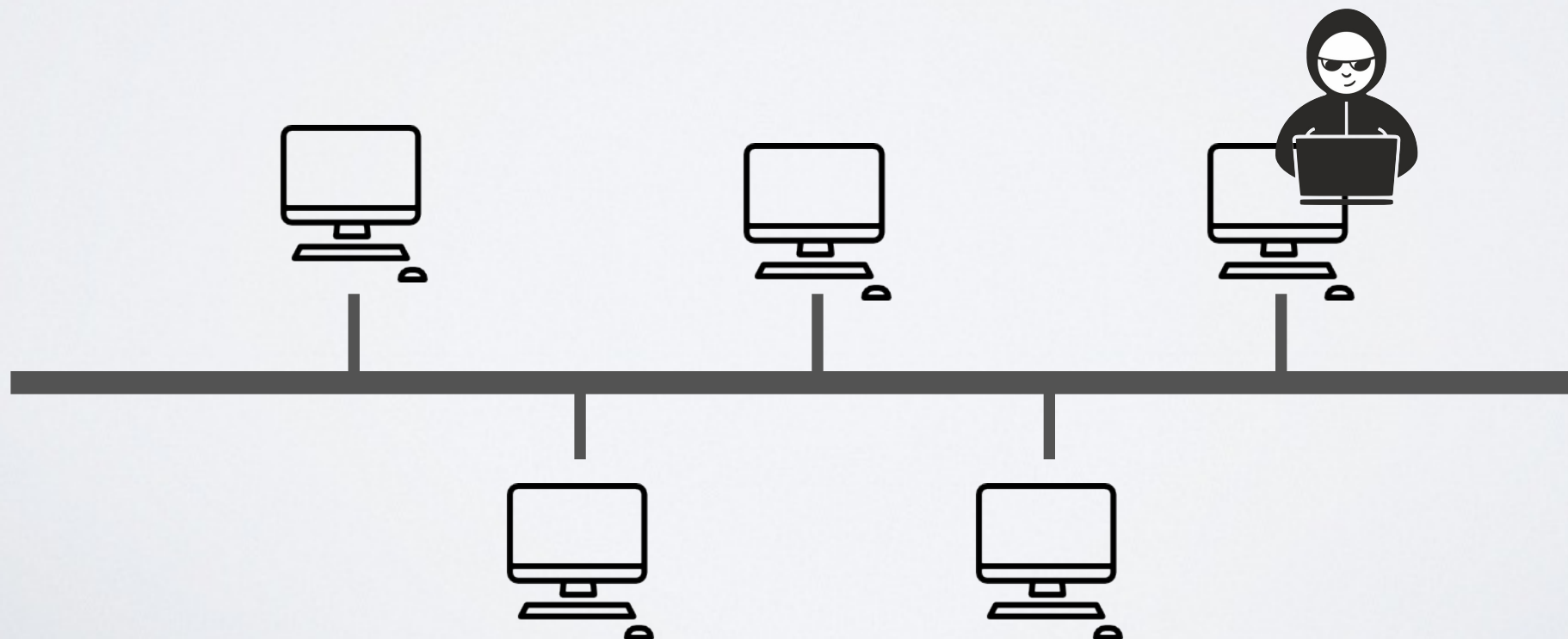


# Bus Link (a.k.a LAN - Local Area Network)

Several hosts are connected to the same medium with a unique physical address called

e.g. Ethernet and WiFi uses MAC  
Media Access Control addresses

- ➔ Easier for the attacker to intercept messages since they are all broadcasted to the same medium





# Packet Sniffing over Ethernet or WiFi

- All messages are transmitted on the medium with the MAC address of the recipient
  - Each network interface only picks messages that correspond to its MAC address
- ➔ An attacker can set its network interface in ***promiscuous mode*** to capture (sniff) all traffic  
e.g. Wireshark



# The WiFi Cactus @DefCon'19

source: [theoutline.com](http://theoutline.com)





# Network Layer

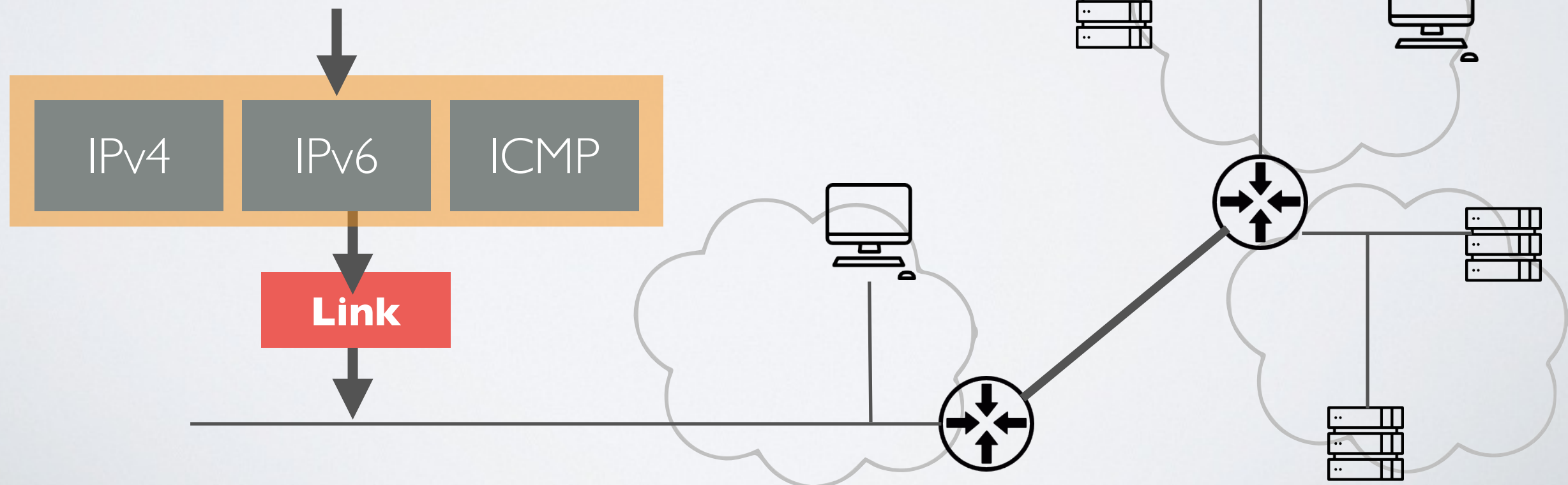
connecting networks together

# The Network Layer

Collection of protocols to connect networks together

- ➔ Defines how messages are routed through the different networks based on IP addresses

(message, IP\_address)



# IP - Internet Protocol

- Each message has the IP address of the issuer and recipient
  - Routers route packet based on their routing table and a default route
- ➡ Best effort protocol

# ICMP - Internet Control Message Protocol

Exchange information about the network

e.g. error reporting, congestion control, network reachability

→ `ping`, `traceroute`



# Host Discovery

~ confidentiality



By default, hosts answer to ICMP echo request messages

➡ An attacker scan an entire network to find IP addresses of active hosts

e.g. **nmap** (does that among other things)

# IP Spoofing

integrity  
availability



- Routers do not validate the source
  - Receiver cannot tell that the source has been spoofed
- ➡ An attacker can generate raw IP packets with custom IP source fields
- e.g. DOS (blackhole) and MITM attacks

# ICMP ping of death (before 1997)

availability



Any host receiving a 64K ICMP payload would crash or reboot

- ➡ 64K bytes payload were assumed to be invalid by programmers
- ➡ An attacker could split a 64K payload, transmit it and would be reassembled by the receiver overflowing a buffer

Security Bulletin

# Microsoft Security Bulletin MS10-009 - Critical

## Vulnerabilities in Windows TCP/IP Could Allow Remote Code Execution (974145)

Published: February 09, 2010 | Updated: February 10, 2010

**Version:** 1.1

### General Information

#### Executive Summary

This security update resolves four privately reported vulnerabilities in Microsoft Windows. The most severe of these vulnerabilities could allow remote code execution if specially crafted packets are sent to a computer with IPv6 enabled. An attacker could try to exploit the vulnerability by creating specially crafted ICMPv6 packets and sending the packets to a system with IPv6 enabled. This vulnerability may only be exploited if the attacker is on-link.



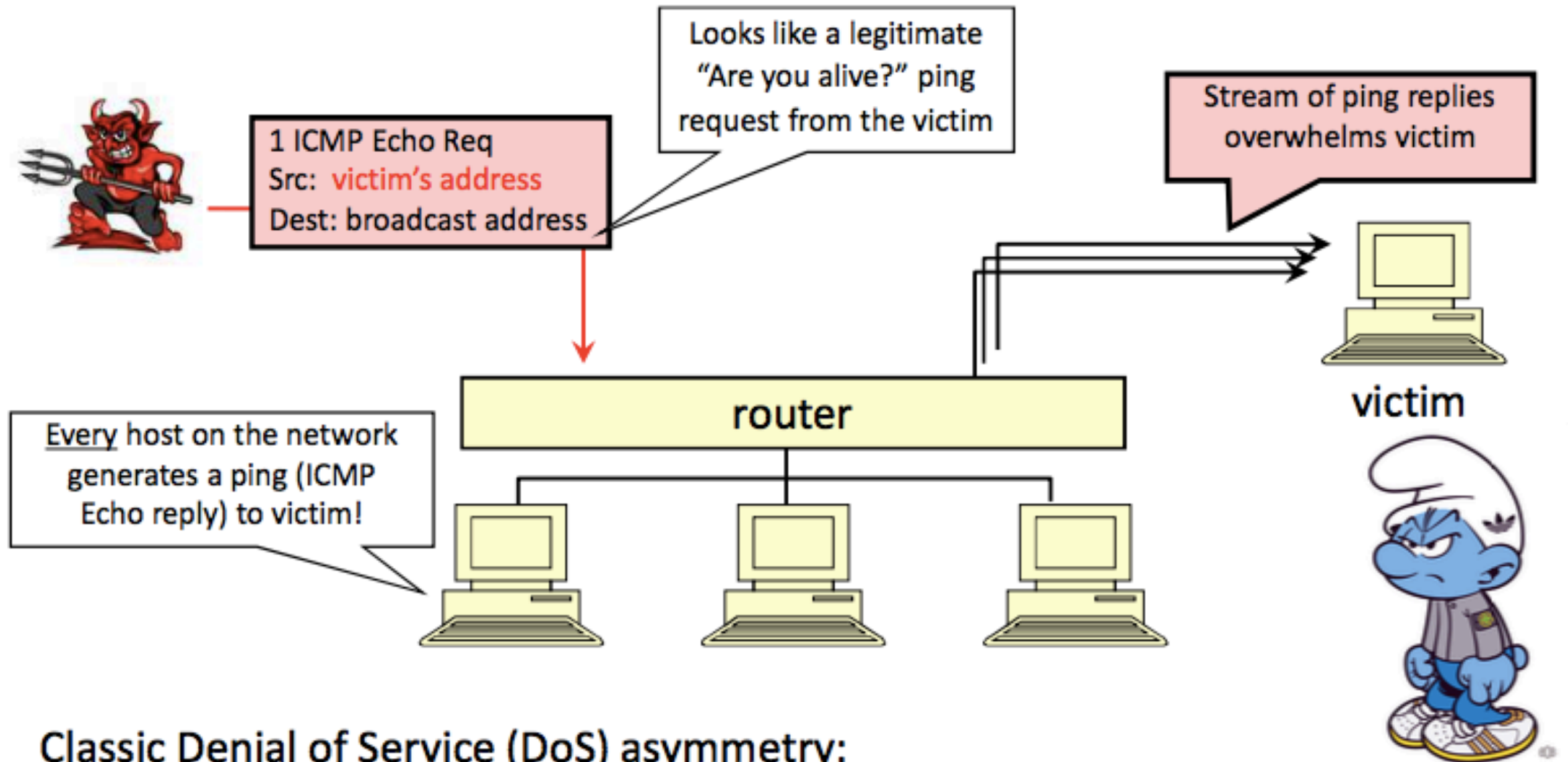
# ICMP Ping Flood

availability



- ➡ An attacker can overwhelm a host by sending multiples ICMP echo requests

# ICMP Smurf Attack - an elaborated ping flood attack



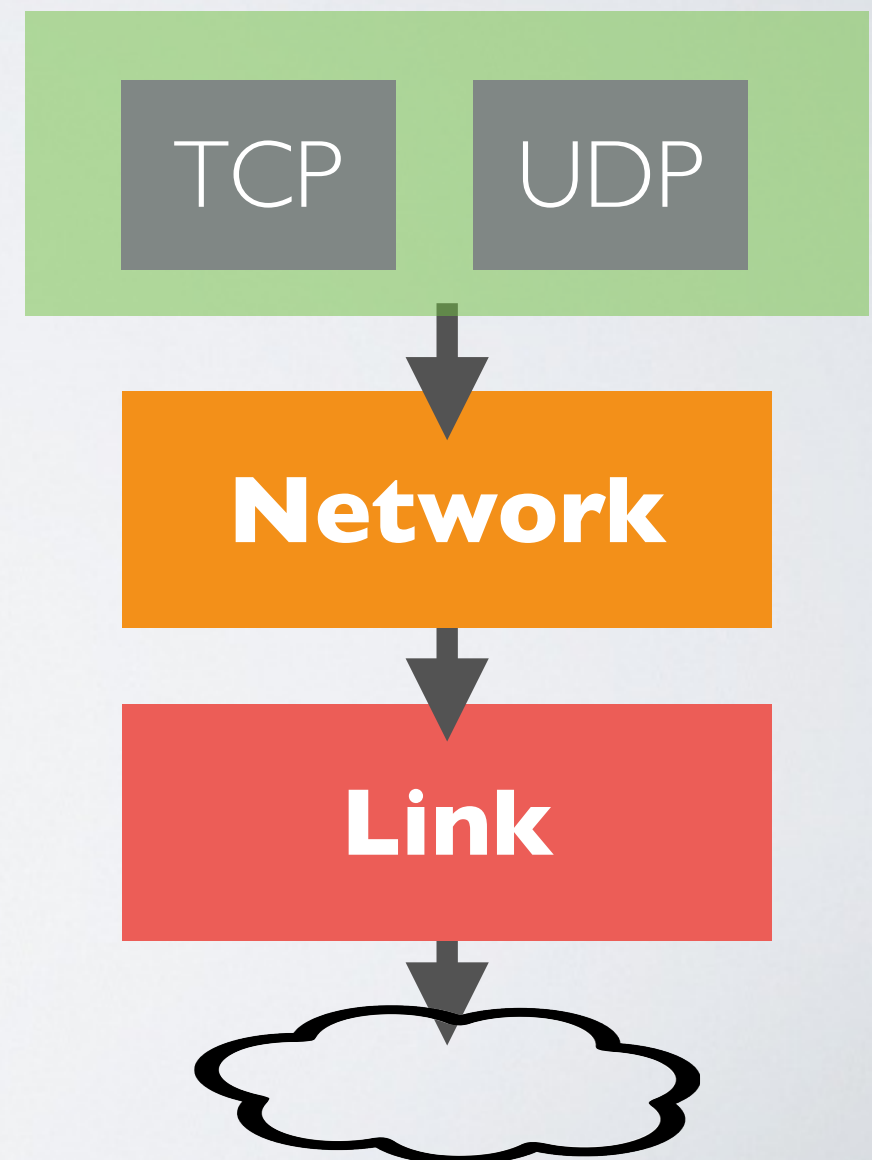
Classic Denial of Service (DoS) asymmetry:  
cheap for attacker, expensive for victim, due to protocol amplification

Transport Layer  
end-to-end connection

# The Transport Layer

Collection of protocols to ensure end-to-end connections

- ➡ Allows hosts to have multiple connections through **ports**
- ➡ Allows messages to be **fragmented** into small IP packets
- ➡ Make sure that all packets are received

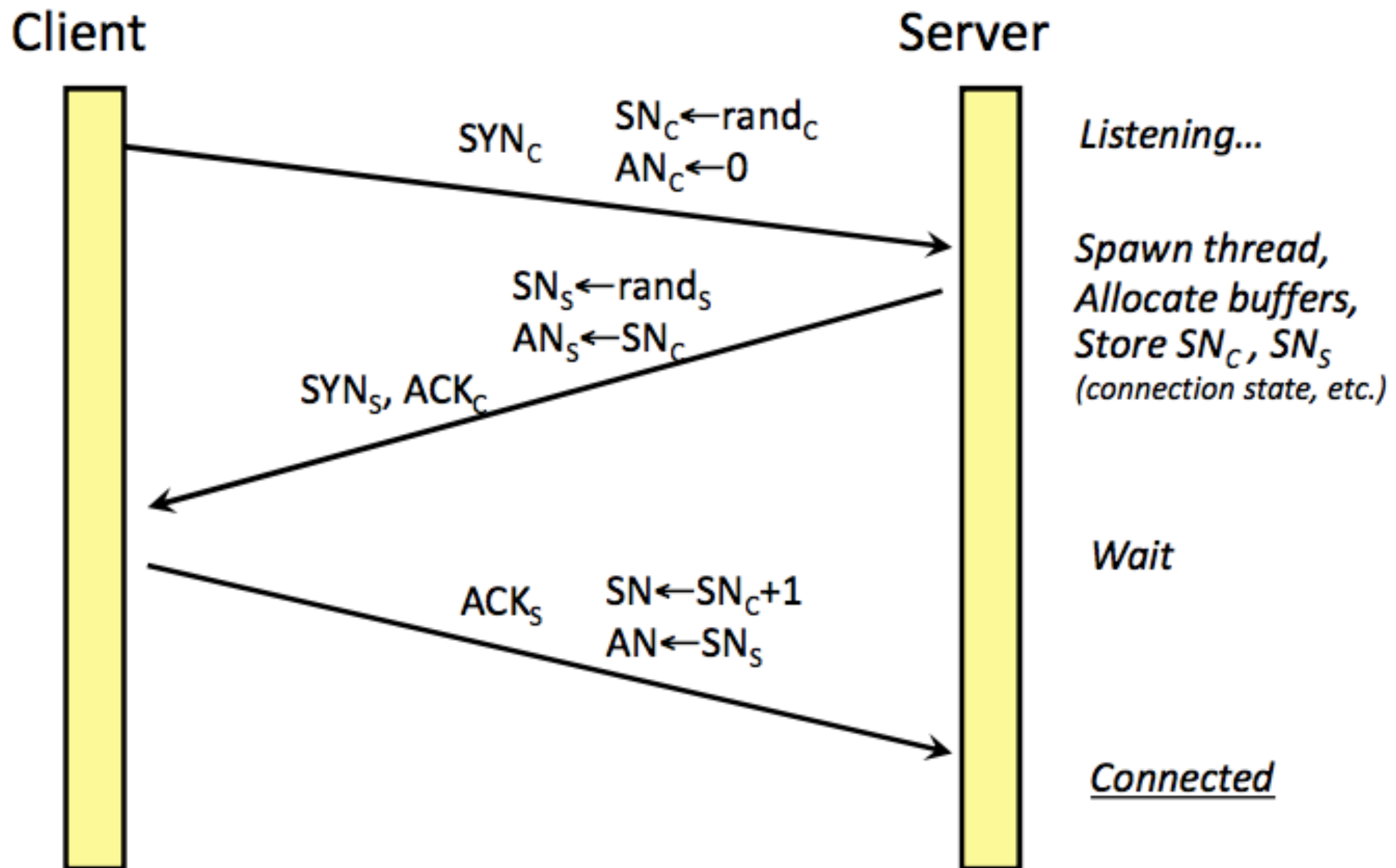




# TCP - Transmission Control Protocol

- The sender divides data-stream into packets sequence number is attached to every packet
  - The receiver checks for packets errors, reassembles packets in correct order to recreate stream
  - ACK (acknowledgements) are sent when packets are well received and lost/corrupt packets are re-sent
- ➡ Connection state maintained on both ends

# TCP “3-way” handshake



# Port scanning

~ confidentiality

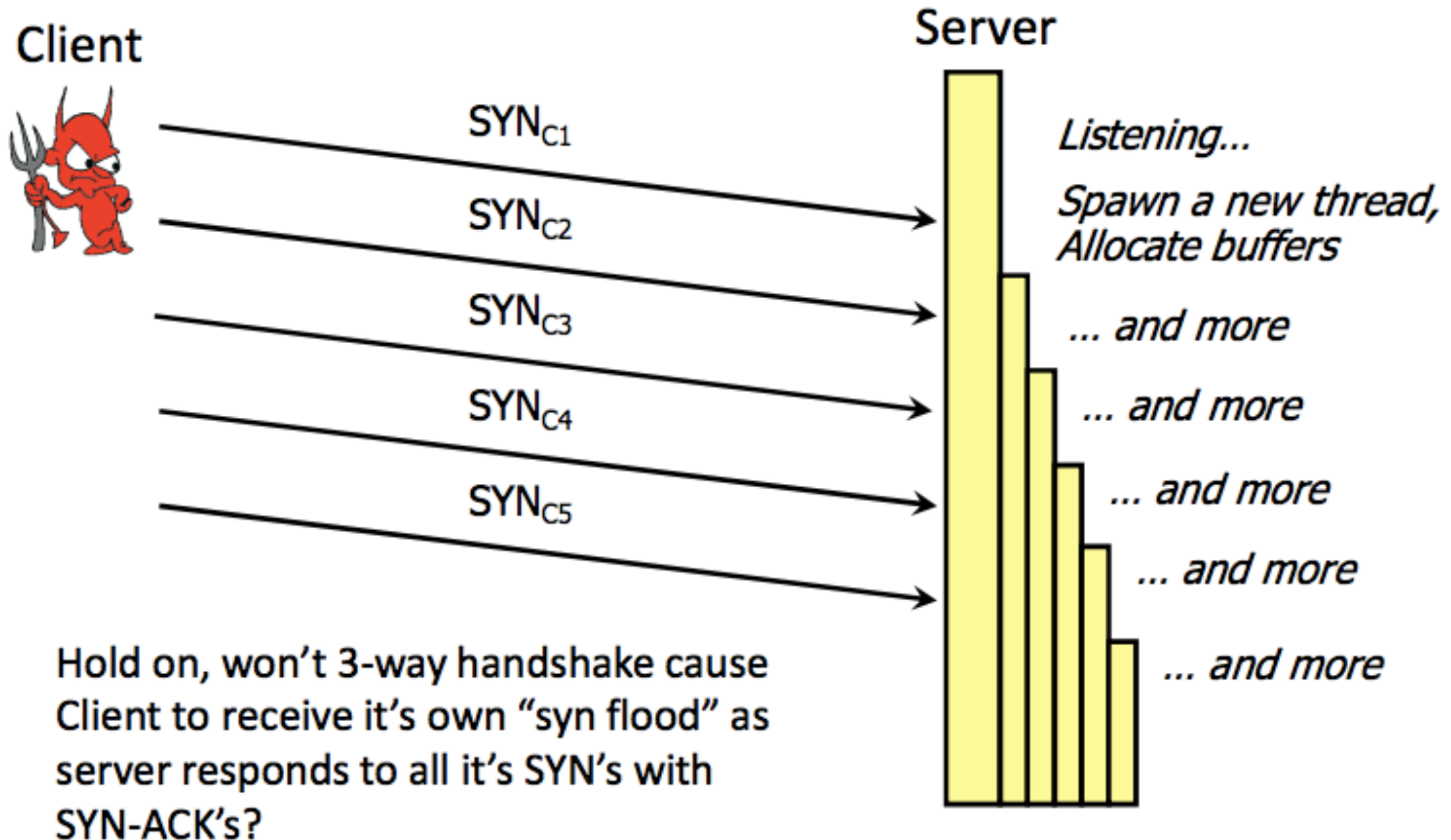


- ➔ Using the “3-way” handshake, an attacker can scan for all open ports for a given host

e.g. `nmap`

# TCP-syn flooding

availability



Note asymmetric effort between attacker client and victim server



availability



# TCP Connection Reset (DOS)

Each TCP connection (i.e each port) has an associated state sequence number

- ➡ An attacker can guess (sniff) the current sequence number for an existing connection and send packet with reset flag set, which will close the connection

# UDP - User Datagram Protocol

UDP is a connectionless transport-layer protocol

➡ No acknowledgement, no flow control, no message continuation, no reliability guarantees

e.g. media streaming (VoIP, video broadcasting)

e.g. modern protocols (HTTP 3)

# UDP Flood

availability



When a UDP packet is received on a non-opened port, the host replies with an **ICMP Destination Unreachable**

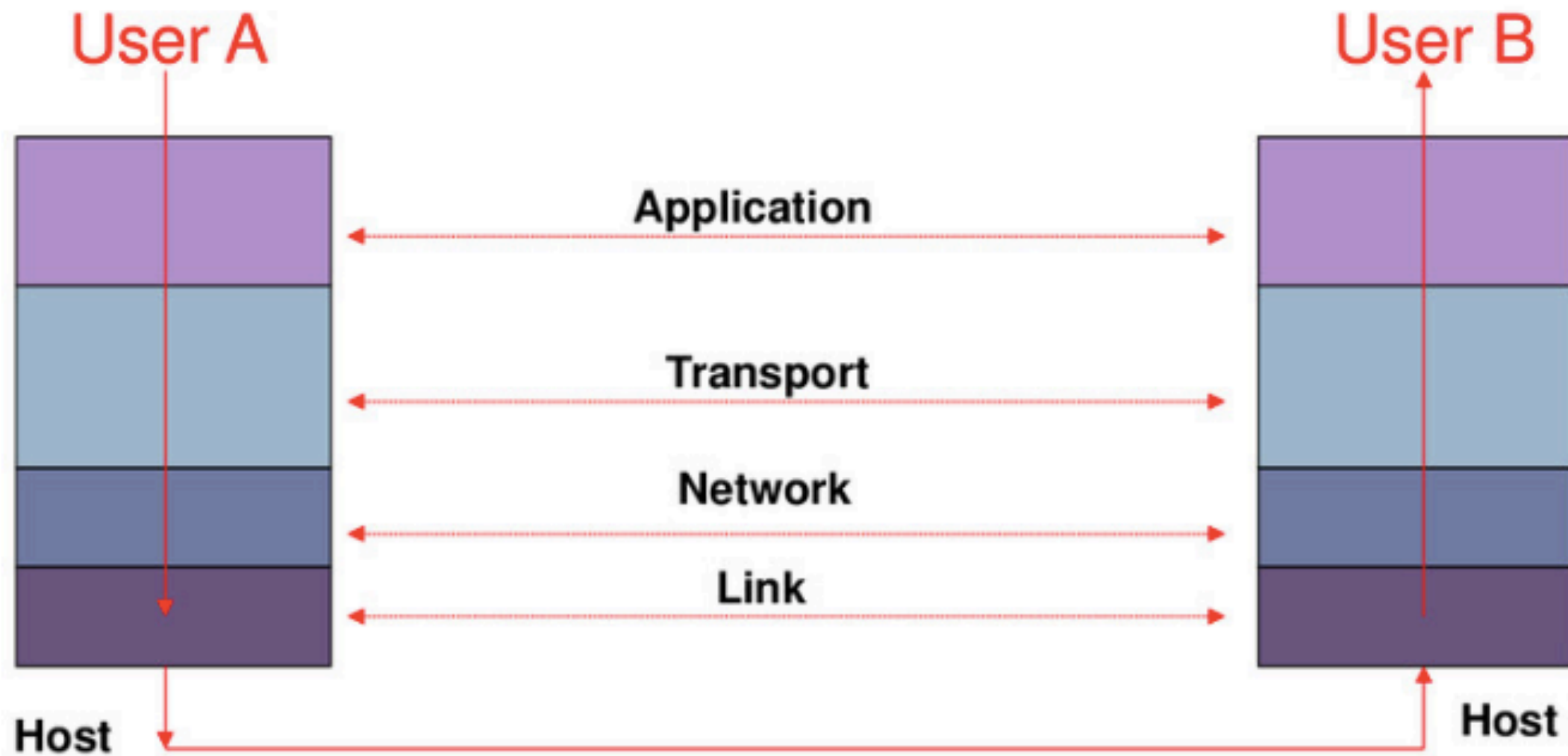
➡ An attacker can send a large number of UDP packets to all ports of a target host

e.g *Low Orbit Ion Cannon*

# The TCP/IP Stack

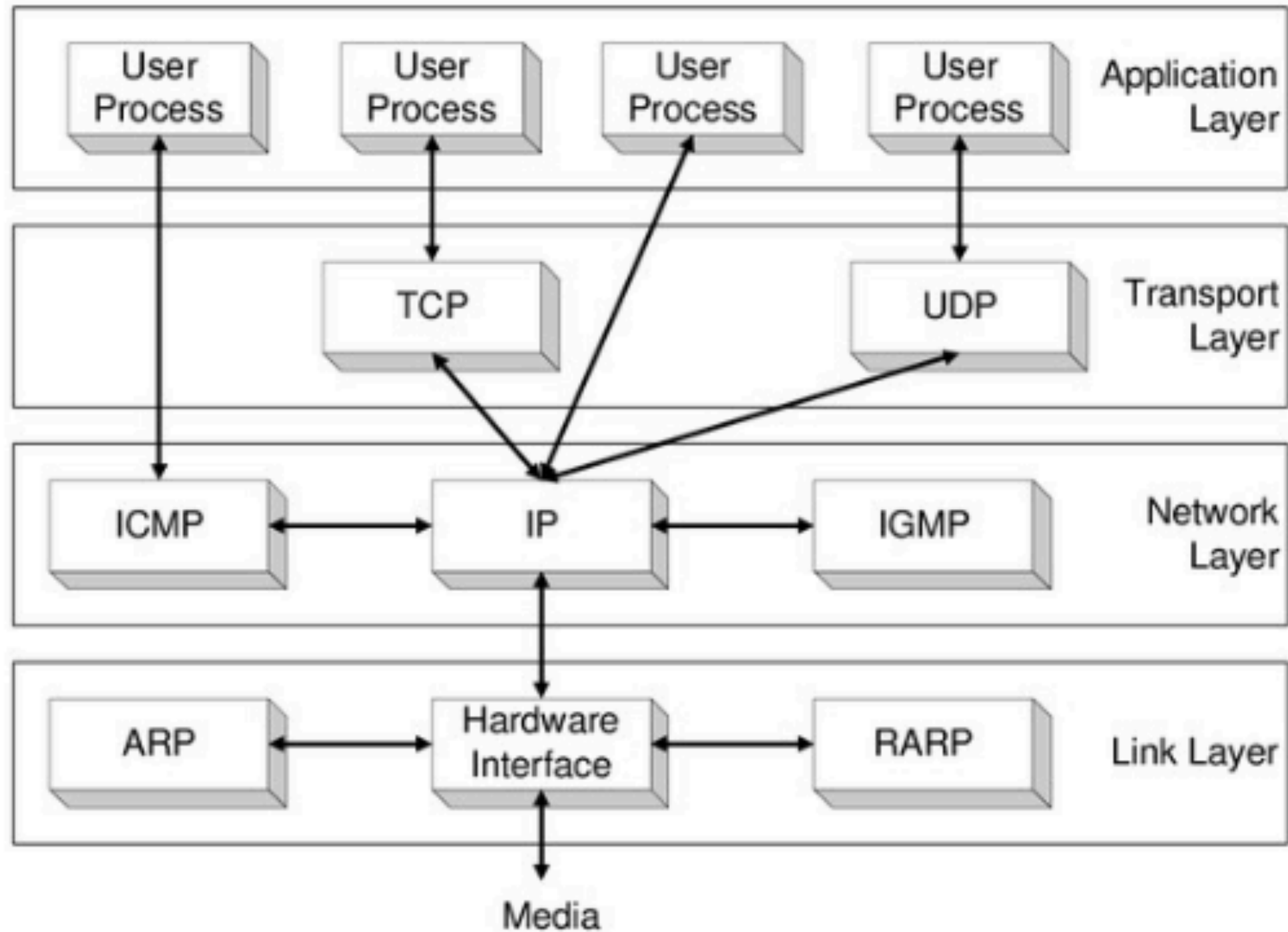


# Layering

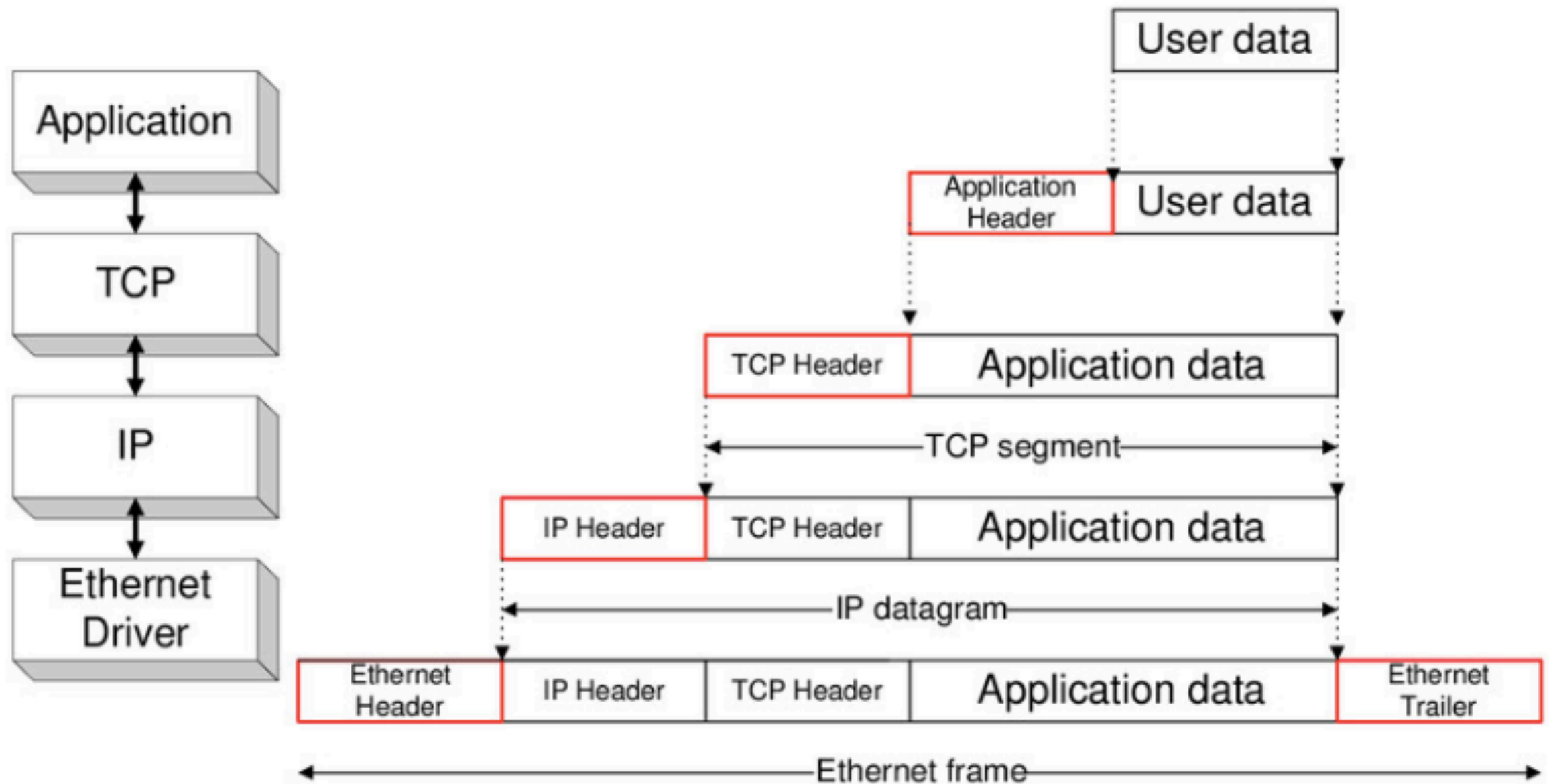


Layering: technique to simplify complex systems

# TCP/IP



# Data encapsulation



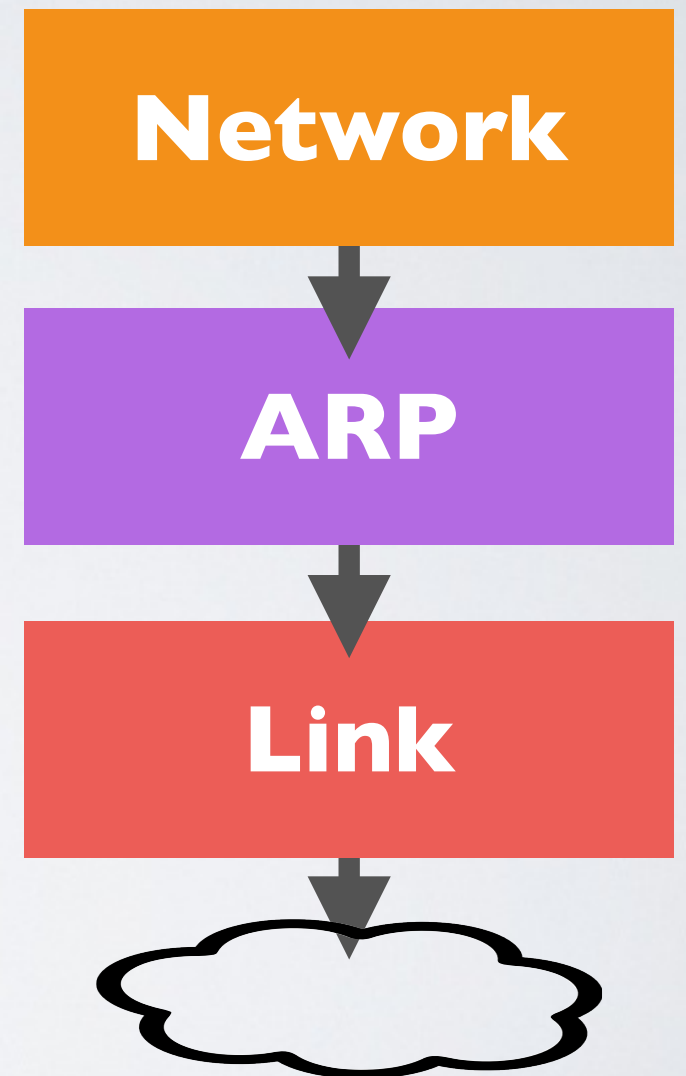
# Special Protocols



# ARP - Address Resolution Protocol

Each host has an ARP table that contains mapping between MAC and IP addresses

- ➡ Host broadcasts their own IP address and MAC address to others to build their ARP table



# ARP Cache Poisoning

integrity  
availability



- ➔ An attacker can broadcast fake IP-MAC mappings to the other hosts on the network

e.g. DOS and MITM attacks

# BGP - Border Gateway Protocol (a.k.a routing)

Each router has a routing table to IP messages

BGP is the protocol for establishing routes

- ➡ Routers advertise the best route to other nearby routers depending on the state of the network

# Route hijacking

confidentiality  
availability



- ➔ An attacker can advertise fake routes  
e.g. DOS (blackhole) and MITM attacks



# Pakistan's Accidental YouTube Re-Routing Exposes Trust Flaw in Net



A Pakistan ISP that was ordered to censor YouTube accidentally managed to take down the video site around the world for several hours Sunday.

Source: Wired

# DNS - Domain Name Server

Internet applications relies on canonical hostname rather than IP addresses

DNS servers translates domain names into IP addresses

- ➡ DNS servers form a distributed directory service by exchanging information about domains and other DNS servers



# DNS Cache Poisoning

confidentiality  
availability

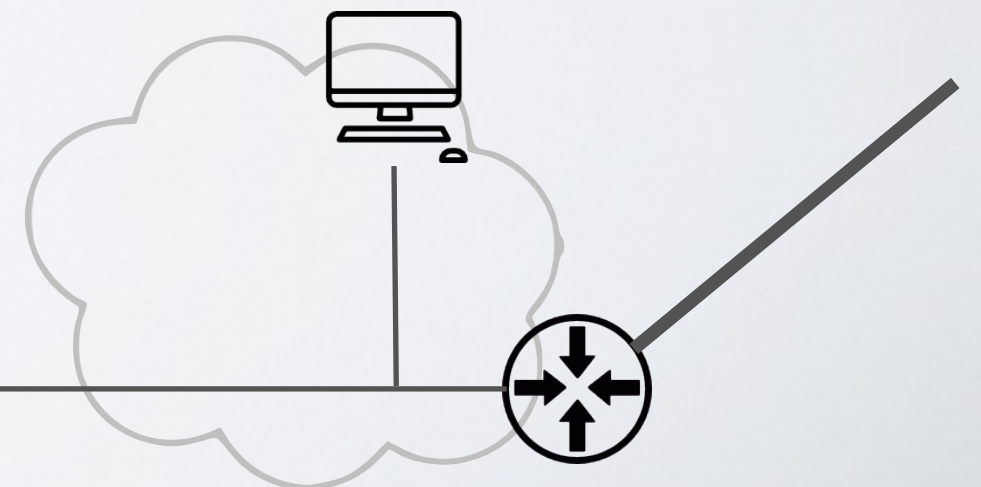
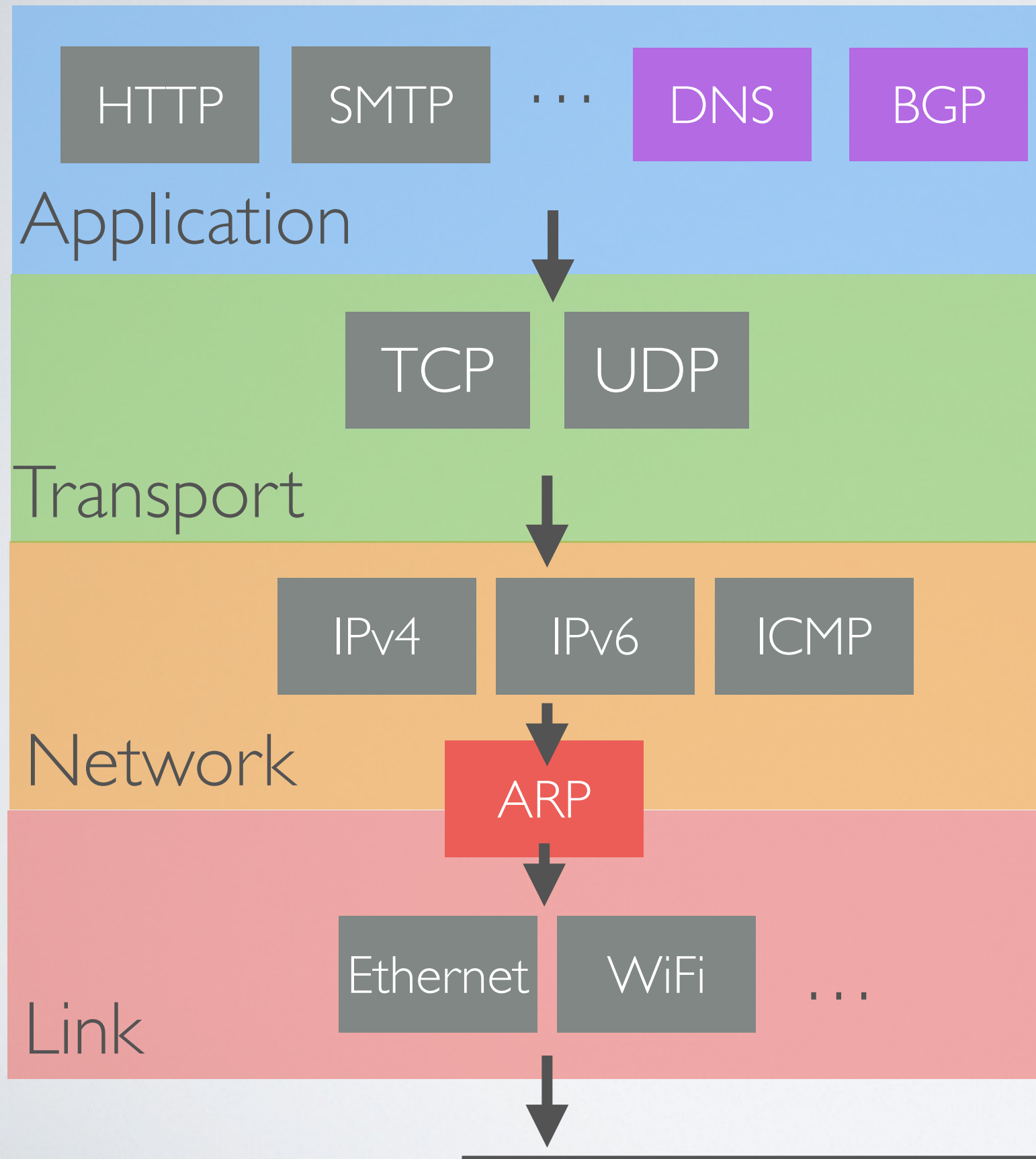


- ➔ An attacker can advertise fake DNS information  
e.g. DOS and MITM attacks

# Summary



# The Protocol Stack



confidentiality  
integrity  
availability



The attacker is capable of ...

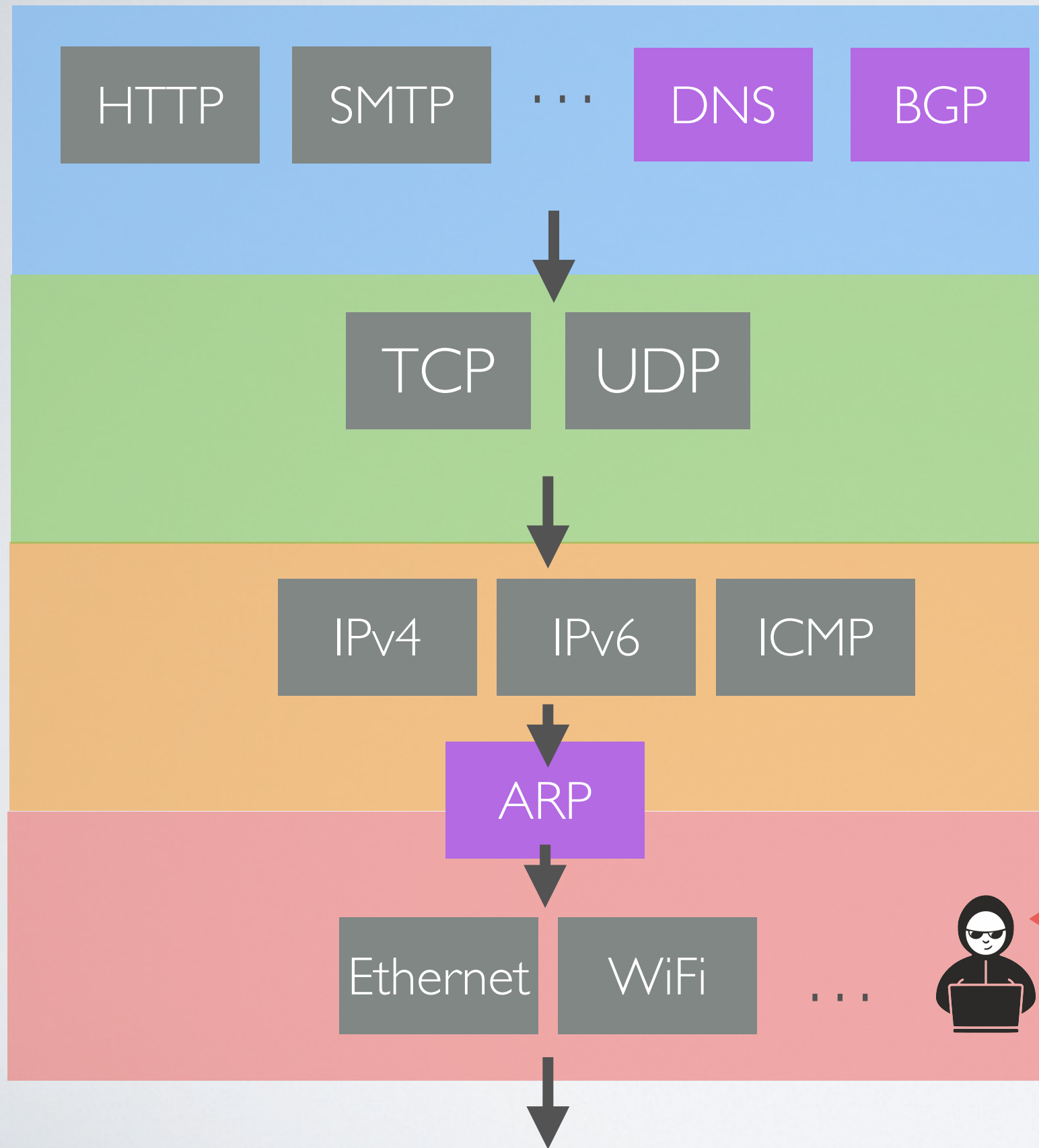
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**Eavesdropping** - read messages

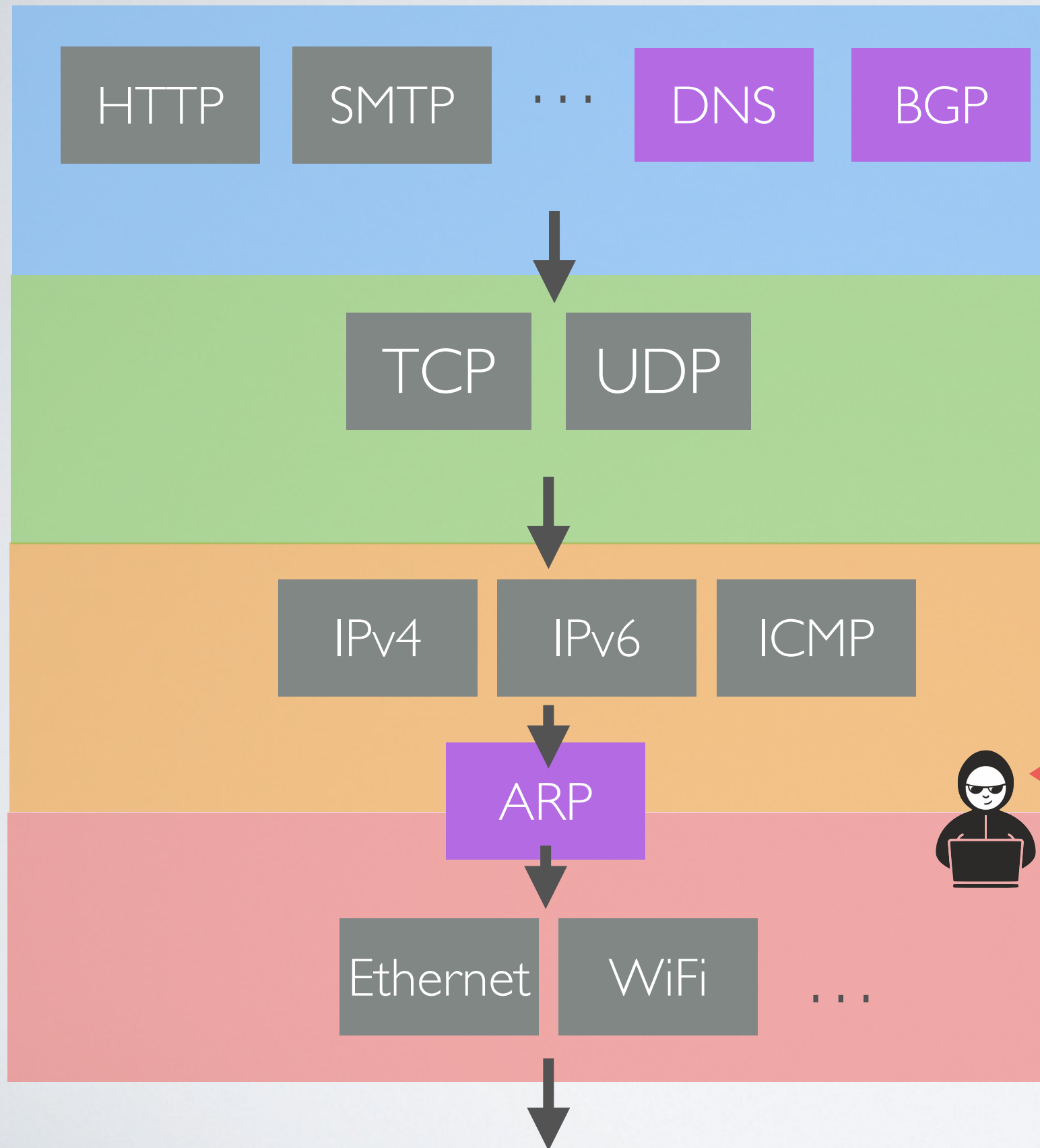
**Spoofing** - forge illegitimate messages

**DOS** (Denial of Service) - disrupt the communications

➡ The attacker can target any layer in the network stack

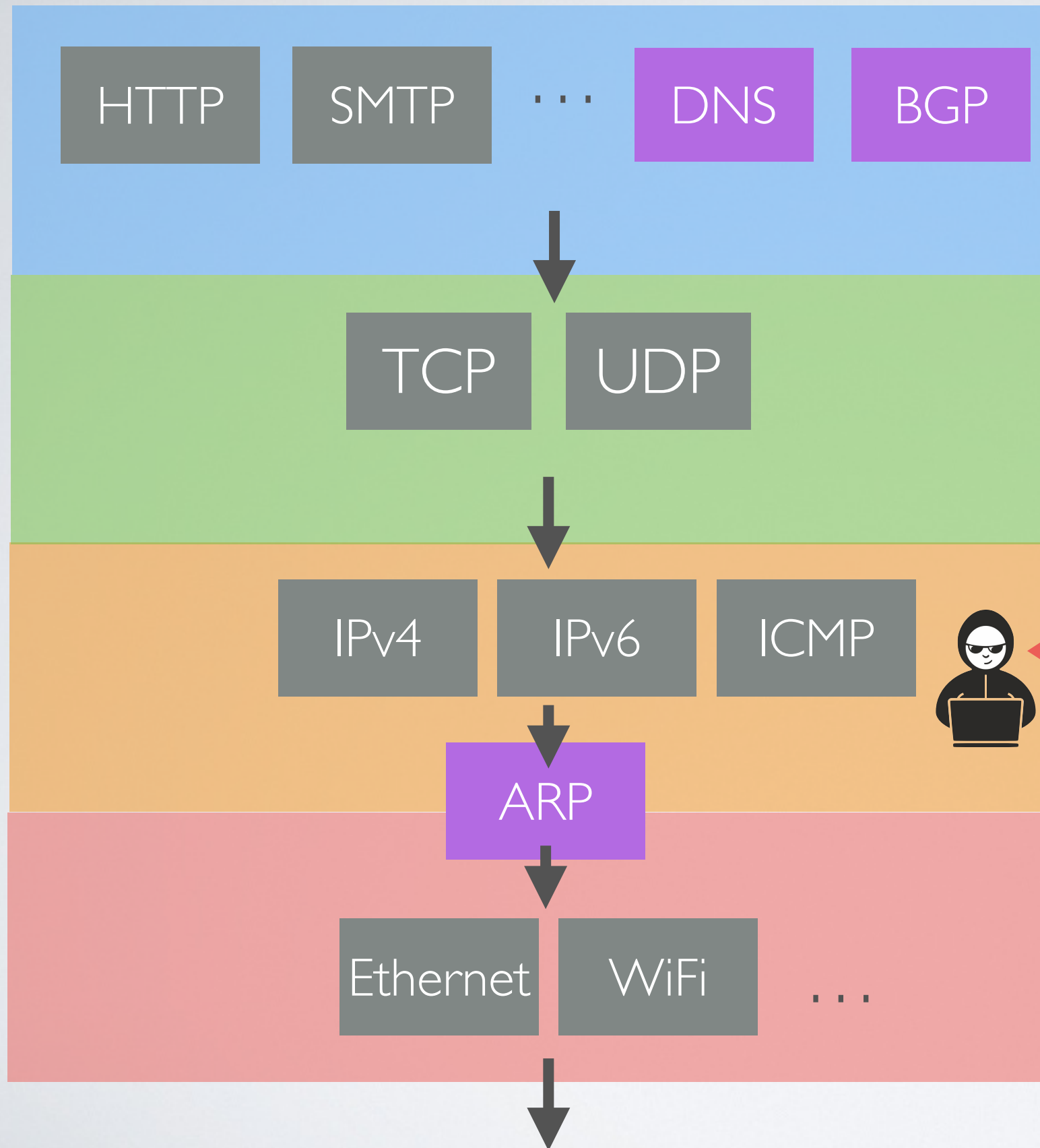


Packet Sniffing (eavesdropping)

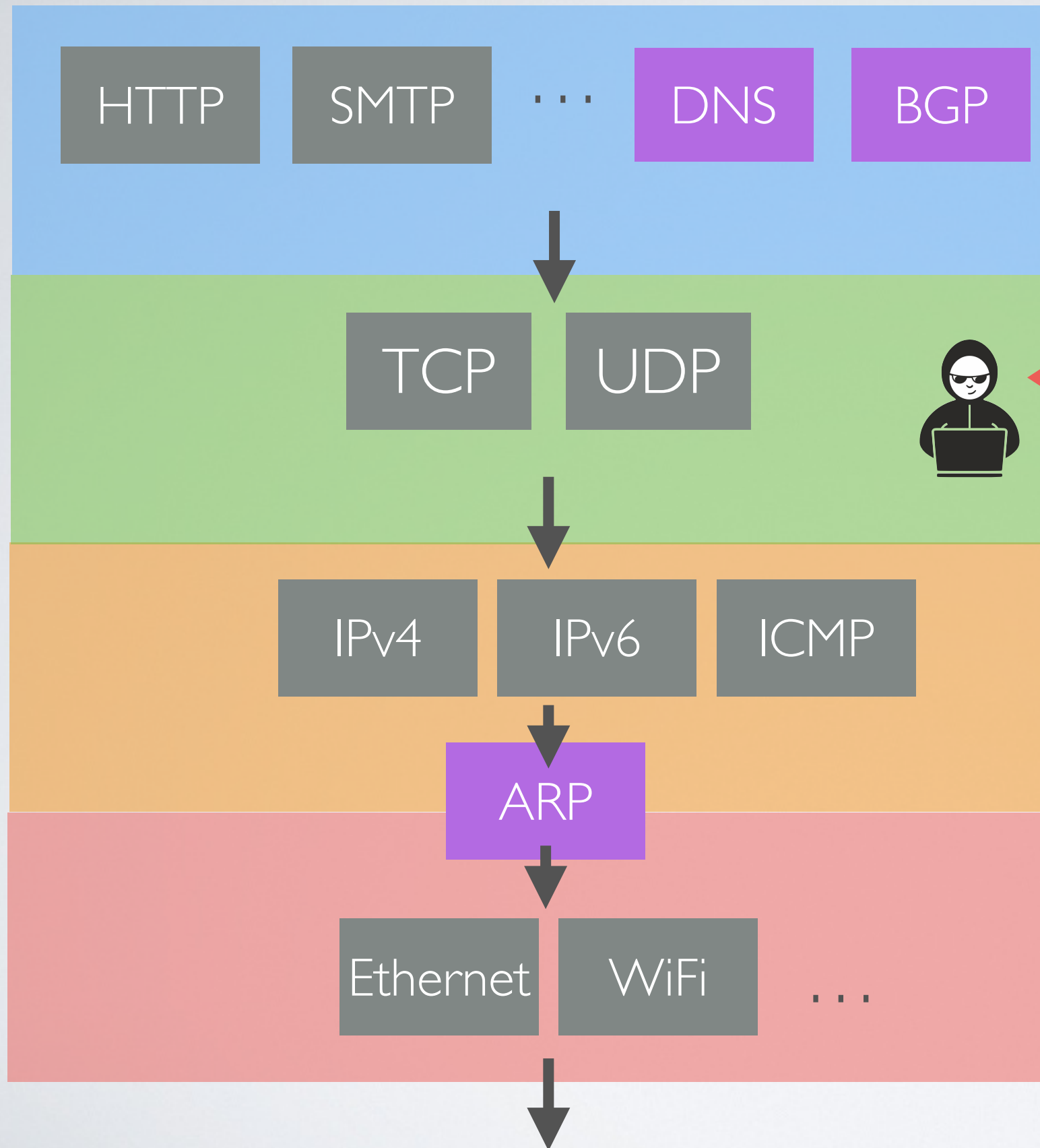


ARP-cache poisoning (spoofing)

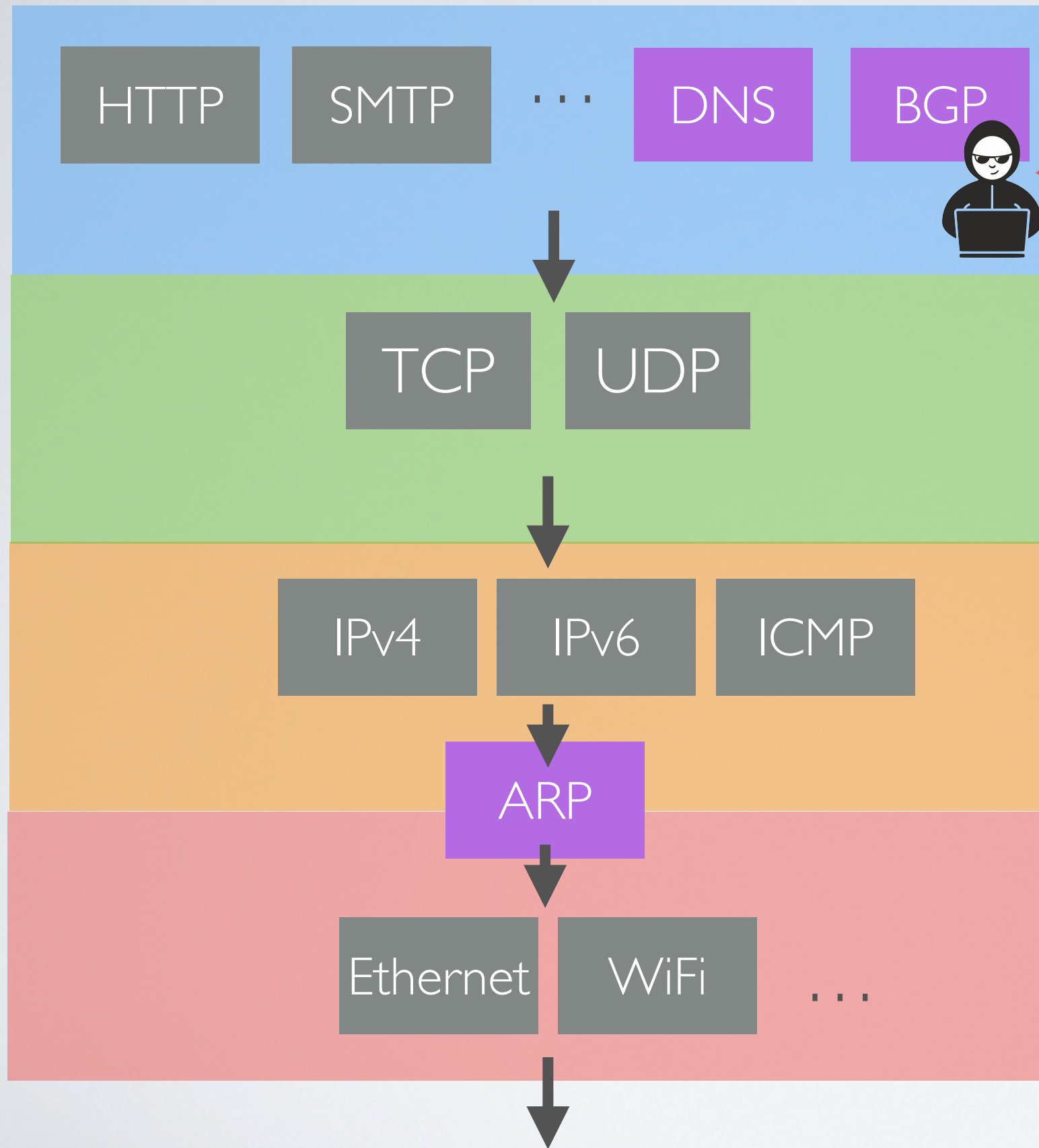




- Host discovery (scanning)
- IP forgery (spoofing)
- ICMP Ping flooding (DOS)



- Port scanning (scanning)
- TCP forgery (spoofing, DOS)
- TCP-syn flooding (DOS)
- UDP flooding (DOS)



- Route Hijacking (spoofing, DOS)
- DNS-cache poisoning (spoofing, DOS)