IT 304
Computer Networks
Autumn 2022

Week 2-Lecture 1

8/8/2022

A host is a device that connects to the network. It can be a desktop computer, laptop, smartphone, etc. The hosting machine contains software that enables it to communicate over the network.

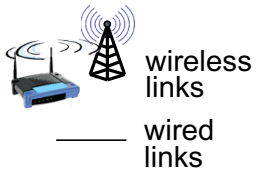
Recap: Network components

- **Network has three main components**
  - ✓ **Computers** (servers and hosts)
    - ✓ Hosts/End systems: hosts files, webpages, other resources
    - ✓ Clients: ask for the resrouces
    - ✓ Servers: give the requested resources
  - ✓ **Network Devices**
    - Devices that interconnect different computers together
  - ✓ **Connectivity**
    - Media that physically connect the computers and network devices

A server is a software or a hardware device that provides services to the other devices in the network. A client is a software or hardware that obtain services of a server. A server can connect multiple clients, and a single client can connect to multiple servers.

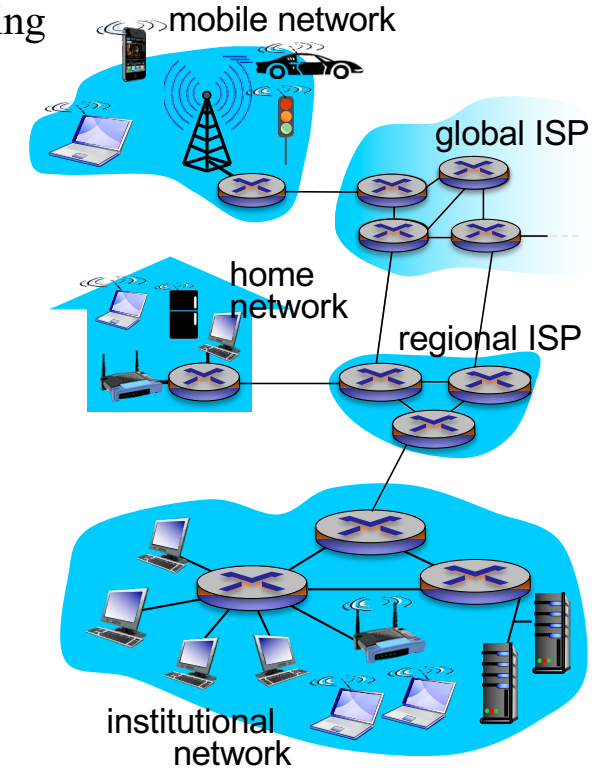
What's the Internet: "nuts and bolts" view

- billions of connected computing devices:
  - *hosts = end systems*
  - running *network apps-Meaning?*



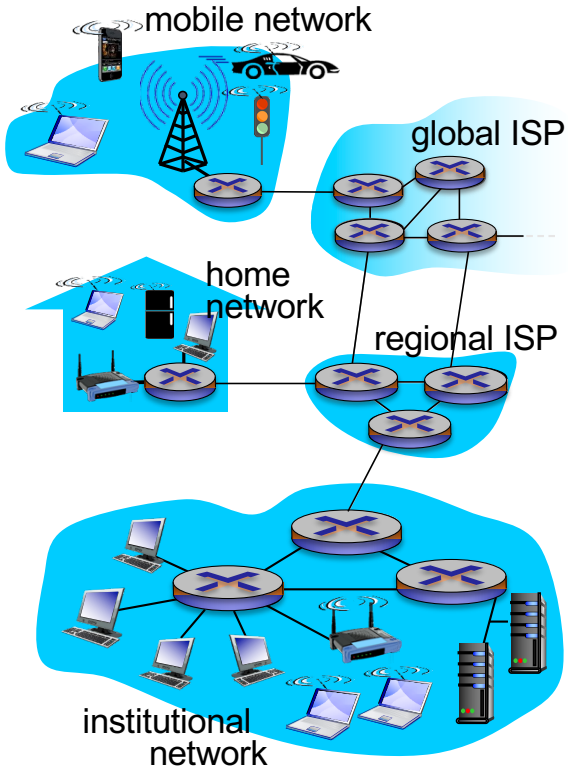
- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate: *bandwidth*

- *packet switches:* forward packets (chunks of data)
  - *routers* and *switches*



What's the Internet: a service view

- *infrastructure that provides services to applications:*
  - Web, VoIP, email, games, e-commerce, social nets, …
- *provides programming interface to apps*
  - hooks that allow sending and receiving app programs to "connect" to Internet
  - provides service options, analogous to postal service



What is a computer network?

A set of network elements connected together, that implement a set of protocols for the purpose of sharing resources at the end hosts

- **Three important components**:
  - **Core infrastructure:**
    - A set of network elements connected together
  - **Protocols:**
    - Needed to use the network
  - **Purpose:**
    - Sharing resources at the end hosts (computing devices)

What do computer networks do?

A computer network delivers data between the end points/hosts

- **One and only one task**: Delivering the data

- This delivery is done by:
  - Chopping the data into **packets**
  - Sending individual packets across the network
  - Reconstructing the data at the end points

Evolution of three components of computer networks!

- Infrastructure, protocols, purpose

Data delivery as a fundamental goal

- Support the logical equivalence of **Interprocess Communication (IPC)**
  - Mechanism for "processes on the same host" to exchange messages
- Computer networks allow "processes on two different hosts" to exchange messages
- Clean separation of concerns – Division of roles
  - Computer networks deliver data
  - Applications running on end hosts decide what to do with the data
- Keeps networks simple, general and application-independent

1. A network consists of

A. End hosts

B. Network core devices

C. Links

D. All of the above

E. None of the above

2. Is there a difference between host and an end system?

A. Yes

B. No

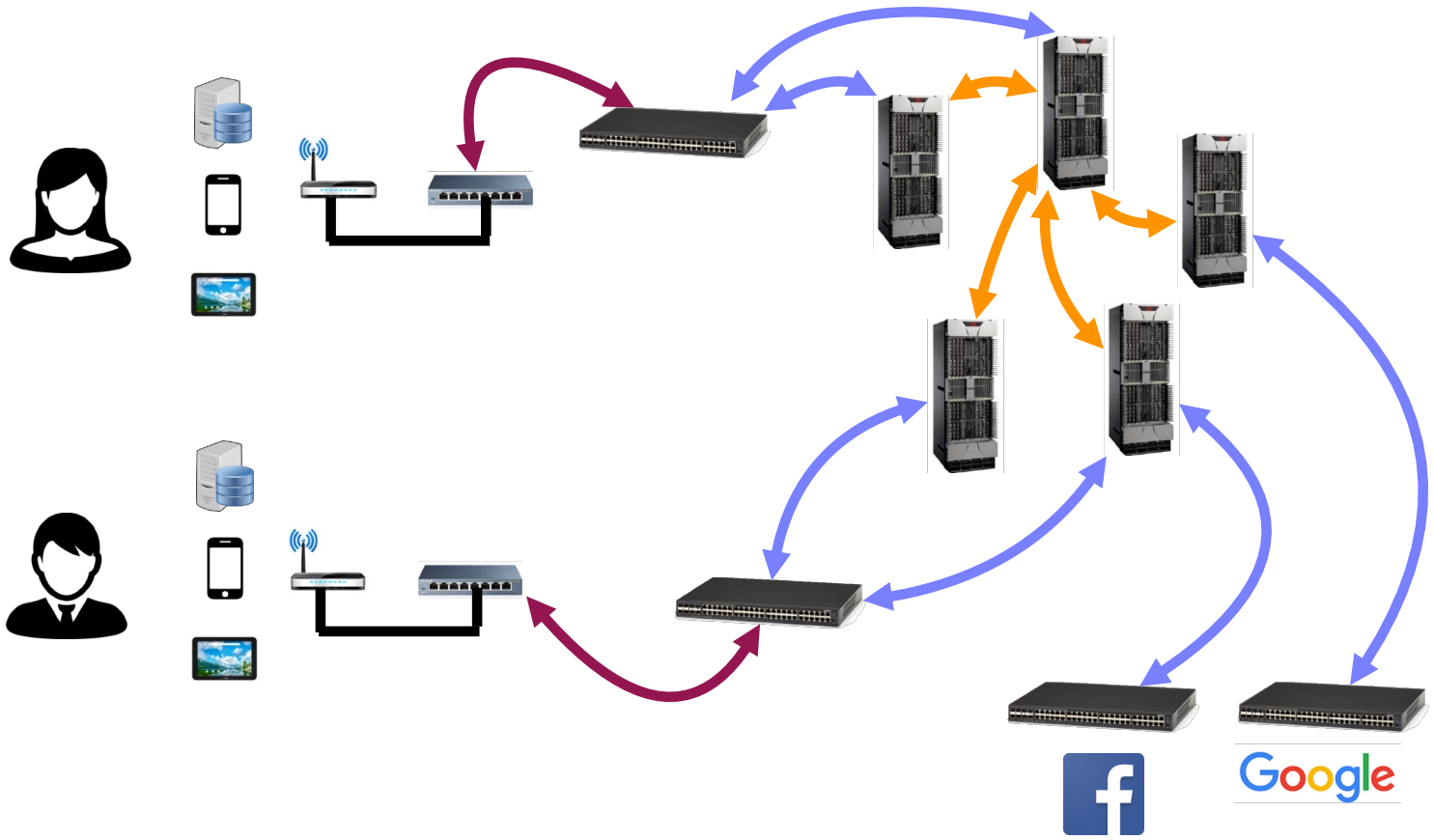
3. The Internet provides

A. Best effort service

B. Guaranteed service

What do computer networks look like?

End hosts, switches/routers, links



Chapter 1: roadmap

1.1 what *is* the Internet?

1.2 network edge

- end systems, access networks, links

1.3 network core

- packet switching, circuit switching, network structure

1.4 delay, loss, throughput in networks

1.5 protocol layers, service models

1.6 networks under attack: security

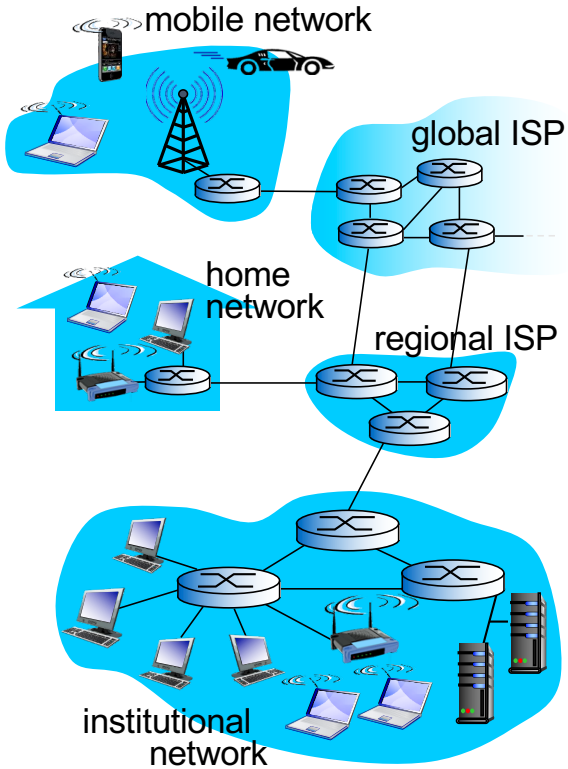
1.7 history

A closer look at network structure:

- *network edge:*
  - hosts: clients and servers
  - servers often in data centers

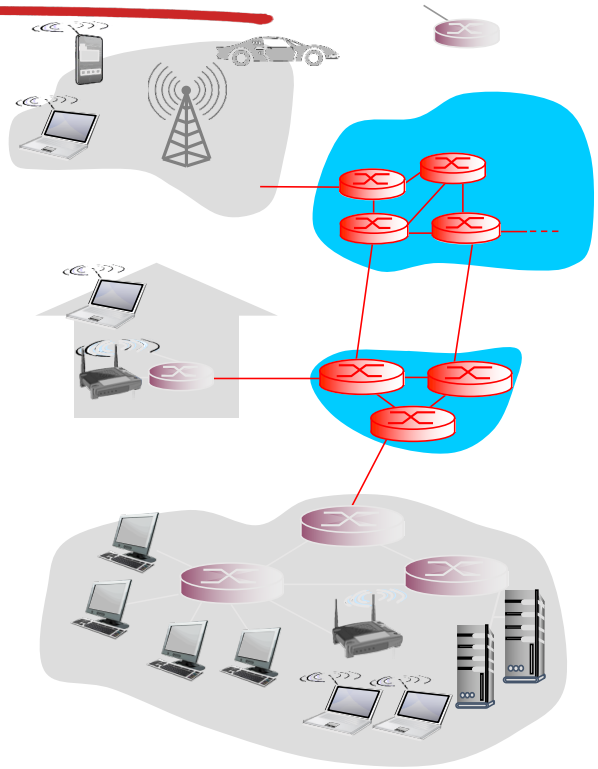
- *access networks, physical media:* wired, wireless communication links

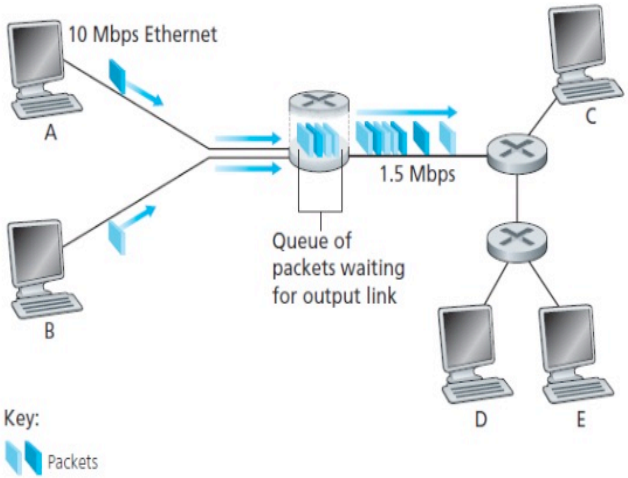
- *network core:*
  - interconnected routers
  - network of networks



The network core

- mesh of interconnected routers
- packet-switching: hosts break application messages into *packets*
  - forward packets from one router to the next, across links on path from source to destination
  - each packet transmitted at full link capacity





Architectural principles, design goals and performance objectives in wired networks

- **What tasks get done?**
  - What is delivered (packets, files, …)?
  - What are the semantics (reliability, ordering, …)?

- **Where do tasks get done?**
  - At the network elements? At the end-hosts?
  - How do end hosts interface with network elements?
  - How do different network elements interface with each other?

- **How tasks get done?**
  - What protocols and algorithms do each of these use?
  - How to achieve various performance objectives (latency, etc.)?

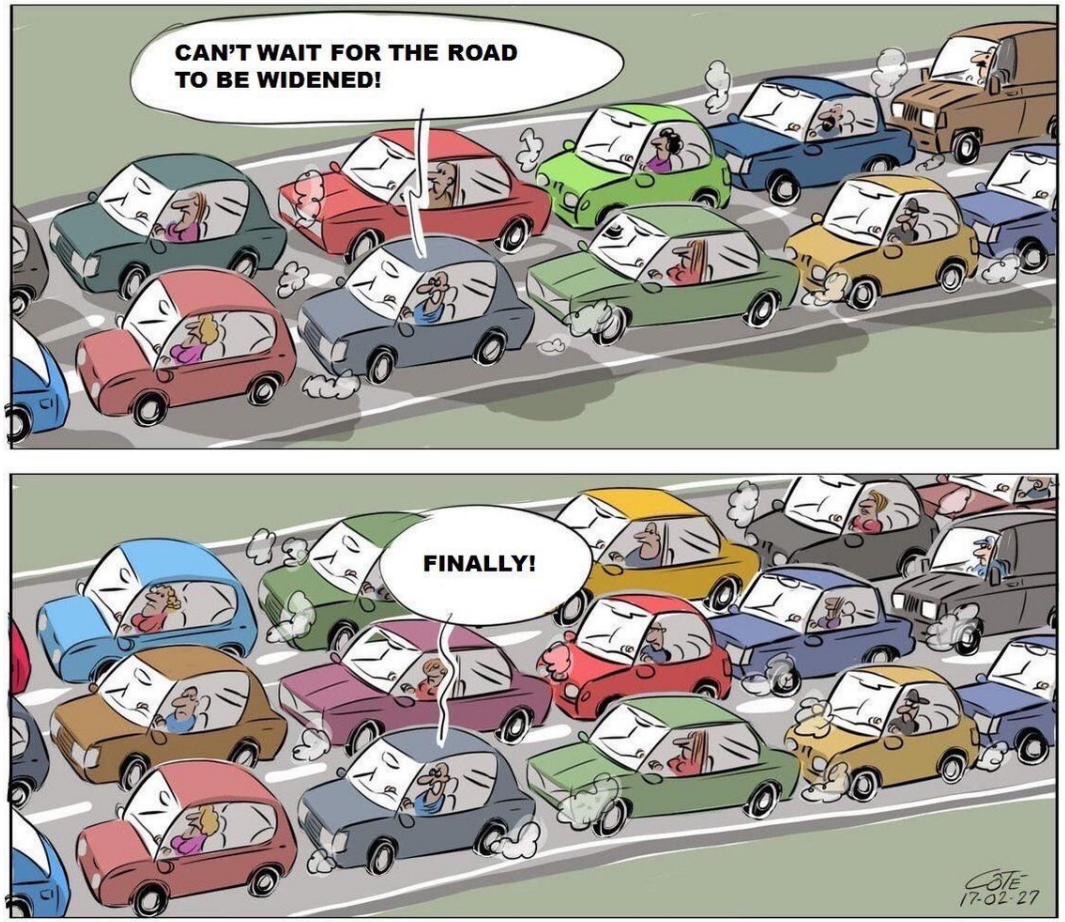
Many mechanisms: What do we mean by …

- Locating a destination? →Naming, Addressing
- Finding path to the destination → Routing
- Sending data to the destination → Forwarding
- Failures, reliability,etc..→ Congestion control

What are the performance metrics?

Capacity

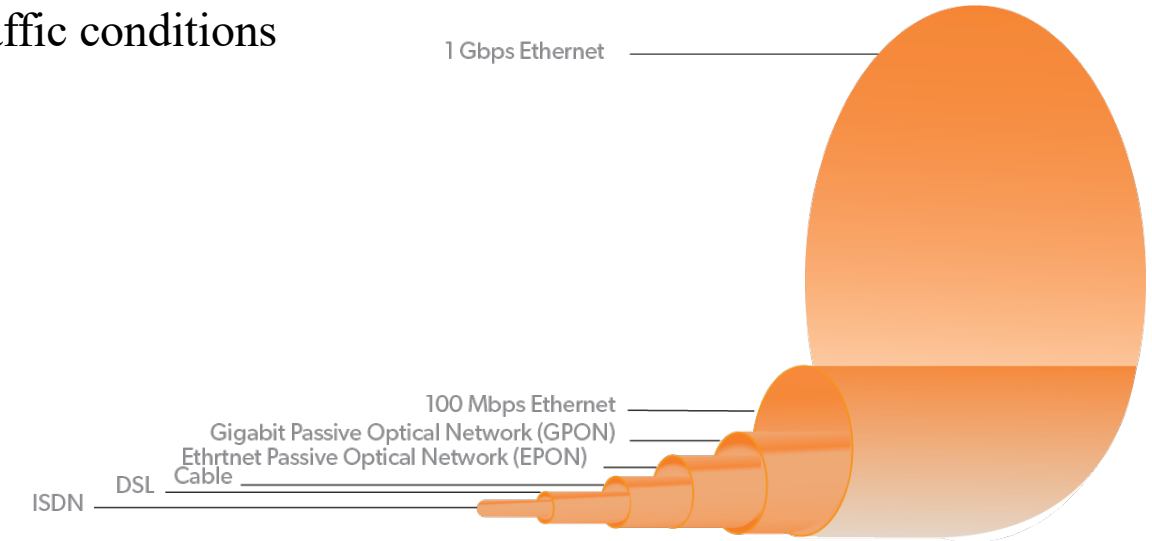
- How wide is the road?
- How fat is the tunnel?
- How many cars can fit at a time?
  - One, two, three…?



Performance metrics in computer networks!

Capacity is Bandwidth: Number of bits sent per unit time (bits per second, or bps)

- Depends on
  - Hardware
  - Network traffic conditions

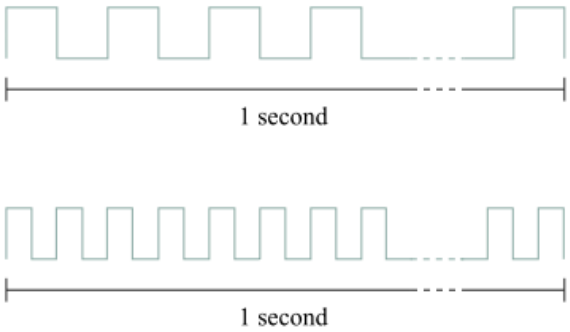


Ref [1]

Ref [1]: https://www.elandcables.com/the-cable-lab/faqs/faq-what-is-bandwidth-in-cables

- Each bit is a pulse of some width.
- For example, each bit on a
  - 1-Mbps link is **1 µs** wide
  - 2-Mbps link is **0.5 µs** wide,

- The narrower each bit can become, the higher the bandwidth.
  - This means more bits can get inside the tunnel
  - So MORE DATA CAN FLOW WITHIN A TIME



Time taken is Propagation delay: Time for one bit to move through the link (seconds)

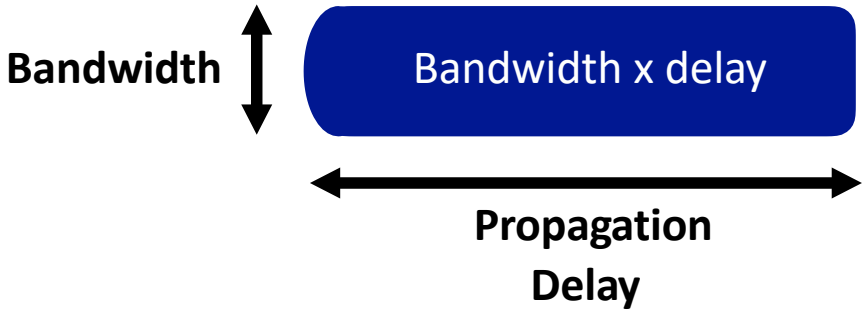
- Depends on
  - Hardware
  - Distance between machines

Propagation Delay

Bandwidth-delay product (BDP)

Number of bits "in flight" at any point of time (bits)

- Bits sent, but not received



- Same city over a slow link
  - Bandwidth: ~100Mbps
  - propagation delay: ~0.1ms
  - BDP = 10,000 bits (1.25KBytes)
- Between cities over fast link:
  - Bandwidth: ~10Gbps
  - propagation delay: ~10ms
  - BDP = 100,000,000 bits (12.5MBytes)

Access network means
A. The communication links
B. The routers and switches
C. A
D. B
E. Neither of them

Bandwidth is
A. The number of bits sent per unit time
B. Size of the data generated

Traffic conditions impact both bandwidth and delay
A. True
B. False

Google celebrates its birthday on September 27, although no one really knows the exact date when it was founded. Started by two Stanford college friends, Larry Page and Sergey Brin, in 1998, it is a multi-billion dollar enterprise now. The name comes from a simple misunderstanding when they were searching for another, actual, word that existed in academia and meant a particular number. What word is that and what number does it denote?

Googol, 1 followed by 100 zeros

Gmail was launched by Google on April 1, 2004, which led many to believe it was an April Fool's joke. Before this service the term 'G-mail' already existed from as early as 1998. This was used online by fans of a certain fictional obese cat, and the original G-mail was known as "e-mail with cattitude". What does the G stand for in the original G-mail?

Garfield

When Page and Brin built the first server rack for Google at Stanford, they were looking for a cabinet to house it that was easy to assemble and disassemble. The server contained ten 4GB hard disks and two cooling fans. What colourful and bountifully found system did they use to build the server stack?

Lego bricks

Who is the father of the Internet?

Vincent Cerf

Why study computer networks?

#1: Has transformed and more importantly, is transforming everything!

- **Industry: core to and creator of many large and influential companies**
  - Google, Facebook, Apple, Cisco, Juniper, Akamai
- **Communication**
  - Email, messenger, phones, VoIP, …
- **Travel**
  - AirBnB, Uber, Maps, …
- **Health**
  - Digital health, remote diagnostics, ….
- **Entertainment**
  - Netflix, Prime
- **Relationships**
  - Facebook, Instagram, Snapchat, the list is endless…

Why study computer networks?

#2: To learn how to design for scale!

- **Tremendous scale**
  - 51% of world population
  - 1.24 trillion unique web pages
  - Every **second**, approximately
    - > 2 million emails
    - > 40000 Google search queries
    - > 6000 Tweets
- **Introduced the phrase "Internet Scale"**

Why study computer networks?

#3: To learn how to design for diversity!

- **Communication latency:** Microseconds to seconds
- **Bandwidth:** 1Kilobits/second to 100Gigabits/second
- **Packet Loss:** 0-90%
- **Technology:** Wireless, satellite, optical, copper, …
- **End hosts:** Sensors, cell phones, computers, servers, datacenters, …
- **Applications:** **www,** voice, video, gaming, remote medicine
- **Trust models:** selfish (users), malicious (attackers), greedy (companies), …

And yet, everything needs to work in tandem!

Recap: Packet switching summary

- **Goods:**
  - Easier to handle failures
  - No resource underutilization
    - A source can send more if others don't use resources
  - No blocked connection problem
  - No per-connection state
  - No set-up cost
- **Not-so-goods:**
  - Unpredictable performance
  - High latency
  - Packet header overhead

Recap: Deep dive into one link: packet delay/latency

- **Consists of six components**
  - Link properties:
    - Transmission delay
    - Propagation delay
  - OS internals:
    - Processing delay
    - Queueing delay
  - Traffic matrix and switch internals:
    - Processing delay
    - Queueing delay
- First, consider transmission, propagation delays
- Queueing delay and processing delays later in the course