

Network Overview

What is the question you concern about networks?

- When people talk about a “better” network, what do they actually mean?
- “Faster” networks
 - The speed of the networks sometimes is a very general measure. Typically, if we just talk about the physical/network transmission capability, it often refers to **data rate or throughput**, measured in bitrate (bits per second, bps), and it’s usually measured as kbps (10^3), Mbps (10^6), Gbps (10^9), and Tbps (10^{12}).
 - However, users rarely experience a network simply as “bits per second.”
 - However, we sometimes link the network speed unintentionally with the **experience of using** a network application or opening a website. Therefore, the speed includes more than just the data rate. For example, faster networks (a.k.a. network applications or websites) have **lower latency**, as the server responds more quickly to a request; fast networks have **lower error rates**, such as bit error rate or packet loss probability, so there will be fewer retransmissions, and the networks are faster; or the network has **higher availability**, so the network is more reliable and is less likely to be down, letting users feel that the networks are fast.
- Ubiquity
 - the service can be provided everywhere
 - “everywhere” means more than WiFi + Cellular. Today’s Internet may reach a device through: Ethernet, WiFi, fiber/cable, 4G/5G, low-power IoT networks, **non-terrestrial networks (satellites)**
- Lower monetary **cost**
 - can access fast and reliable networks everywhere with low cost
- Improved **user experience** (low complexity)
 - easy to use. Ideally, applications work without users having to understand what network is underneath them.
 - Modern networking tries to make heterogeneous networks appear seamless. A phone may move among WiFi, 5G, and other access technologies while applications expect communication to continue.

Categories of Networks

- Wide Area Network (WAN)
 - A computer network spanning a large geographical distance (regions, countries, continents, and the world)
 - The Internet is a network of networks.
- Local Area Network (LAN)
 - A computer network that extends over a limited area, such as a residence, school, laboratory, university campus, or office building.

- Its network equipments and interconnections are locally managed (Ethernet, WiFi).
- Access Network
 - The network that physically connects a host to the first router on a path toward the rest of the Internet (aka, connect the subscribers to the service providers)
 - Hosts: desktops, laptops, smartphones, tablets, TVs, watches, AR/VR headsets, IoT sensors, vehicles, robots, ...
 - the most prevalent types: Fiber to the home (in Gbps) , cable (using the cable television company's existing cable television infrastructure, in Mbps), DSL (digital subscriber line, provided by the same local telephone company that provides local phone access, using exiting phone line, in Mbps), and Satellite broadband (in Mbps)
- Core Network
 - backbone, high-capacity network that interconnects access networks and other networks.
 - routers forwarded packets across theses interconnected networks: device (your laptop) -> access network (Colby campus network) -> ISP/core (Colby's ISP) -> other networks (Google's network) -> destination (a Google server)
- Cellular Data Networks
 - extending the Internet to cellular subscribers
 - smartphones are able to connected to Internet
 - cellular technology generation
 - 5G: higher capacity, lower latency possibilities, massive device connectivity
 - 5G-Advanced: a shift from "make 5G faster" toward "make the network smarter and more efficient." 3GPP (3rd Generation Partnership Project) Release 18 explicitly introduced AI/ML support for NG_RAN (next generation radio access network) use cases like network energy saving, load balancing, and mobility optimization. AI/ML enables networks from reactive to predictive.
- Non-Terrestrial Networks (NTN)
 - Cellular networking is expanding beyond terrestrial cell towers
 - communication through Low Earth Orbit (LEO) satellites, Medium Earth Orbit (MEO) satellites, and Geostationary satellites is part of NTN.
 - devices -> terrestrial base station OR satellite -> Internet
 - Why would we want satellite connectivity? (better coverage)
 - What problems might satellites introduce? (delay, mobility, limited spectrum, power constraints, cost). Active networking research problems.
- Datacenter Networks
 - Large Internet/cloud companies, like Google, Microsoft, Facebook, and Amazon, operate enormous data centers.

- A data center is composed of 10's to 100's of thousands of servers, concurrently supporting many distinct cloud applications (e.g., search, email, web services, videos, cloud computing, databased, storage)
- Servers are worker bees in a data center. They include CPU, memory, and disk storage.
- A datacenter network interconnects its servers with each other and interconnects the data center to the Internet.
- AI is changing datacenter networking.
- High needs of accelerators (1000 GPUs) for model training require “fast” networks among several servers equipped with multiple GPUs. The intermediate data are needed across servers for training, therefore, the network that interconnect the servers are expected to be extremely high bandwidth, very low latency, low packet loss, predictable performance, congestion control, load balancing.

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Disclaimer: Notes adapted from the textbook and online resources.