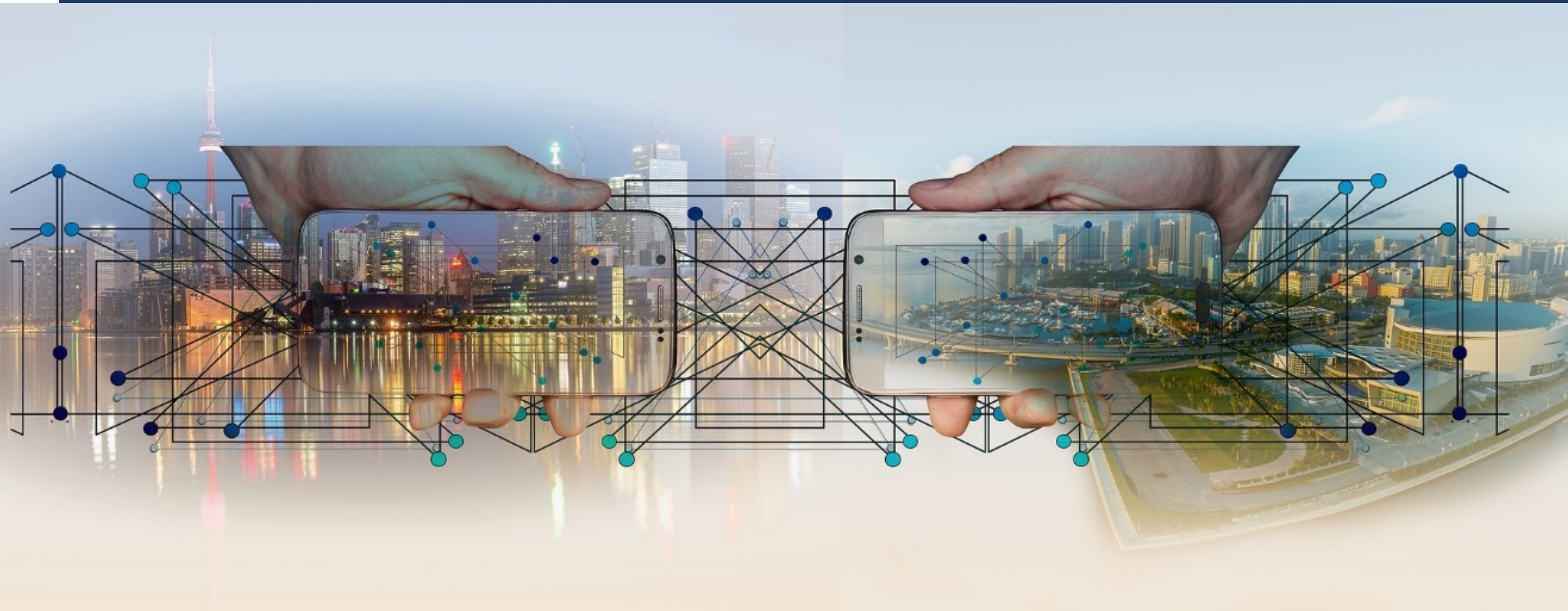
Lecture 1
Overview of Communication Networks and Services



What is Computer Networks?

- A collection of autonomous computers interconnected by a single or multiple technologies
  - Interconnected via:
    - Copper wire
    - Fiber optics
    - Microwaves
    - Infrared
    - Communication satellites, etc.

Services & Applications

- Service: Basic information transfer capability
  - Internet transfer of individual block of information
  - Internet reliable transfer of a stream of bytes
  - Real-time transfer of a voice signal
- Applications build on communication services
  - E-mail & web build on reliable stream service
  - Fax and modems build on basic telephone service
- New applications build on multiple networks
  - SMS builds on Internet reliable stream service and cellular telephone text messaging

What is a protocol?

- Communications between computers requires very specific unambiguous rules
- A protocol is a set of rules that governs how two or more communicating parties are to interact
  - Internet Protocol (IP)
  - Transmission Control Protocol (TCP)
  - HyperText Transfer Protocol (HTTP)
  - Simple Mail Transfer Protocol (SMTP)

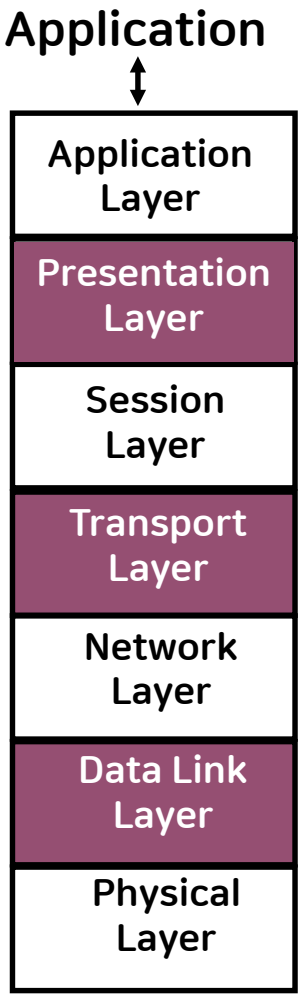
What is a communication network?

- The equipment (hardware & software) and facilities that provide the basic communication service
- Virtually invisible to the user; Usually represented by a cloud

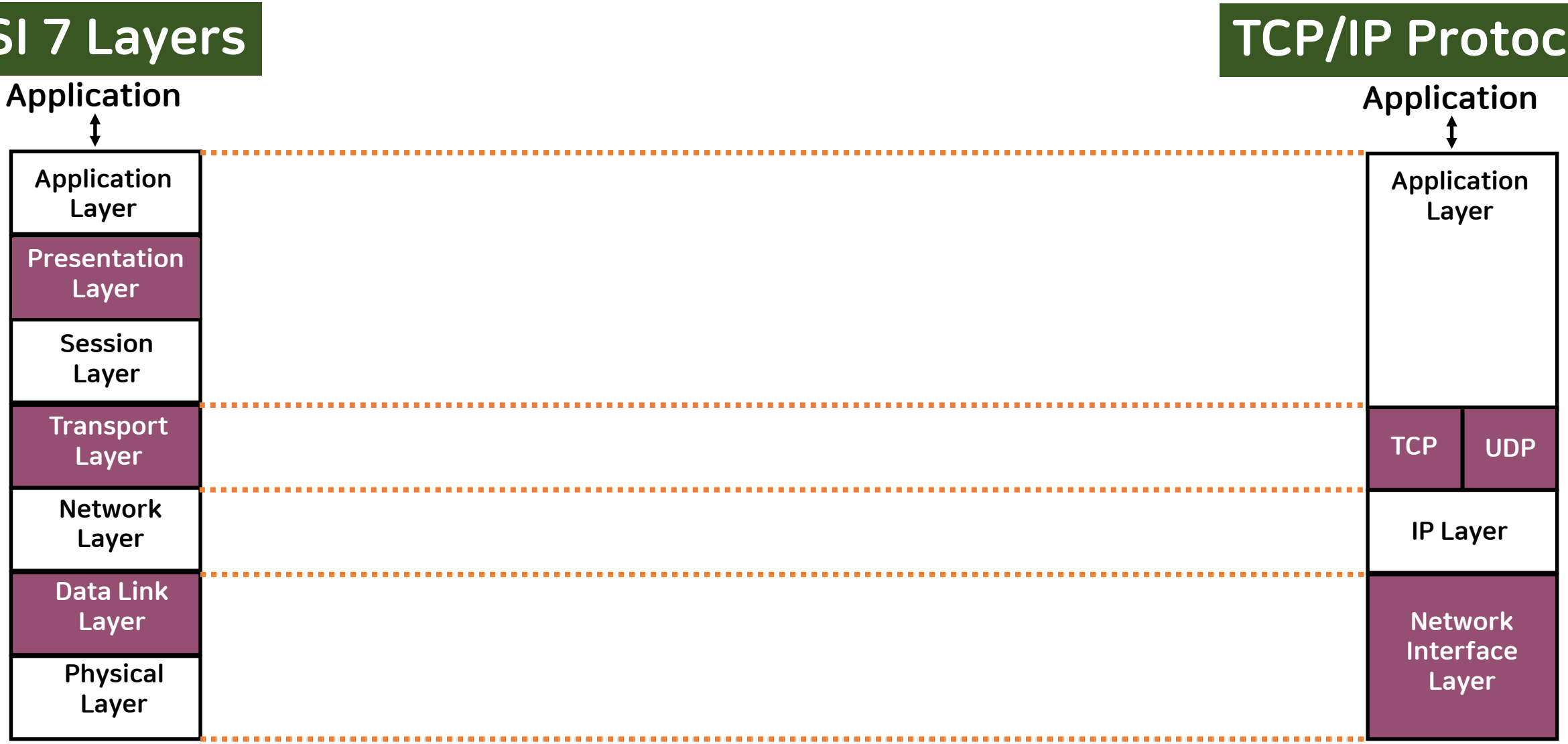
- Equipment
  - Routers, servers, switches, multiplexers, hubs, modems, …
- Facilities
  - Copper wires, coaxial cables, optical fiber
  - Ducts, conduits, telephone poles …

How are communication networks designed and operated?

OSI Reference Model



OSI Reference Model & TCP/IP Protocol Stack



Communication Network Architecture

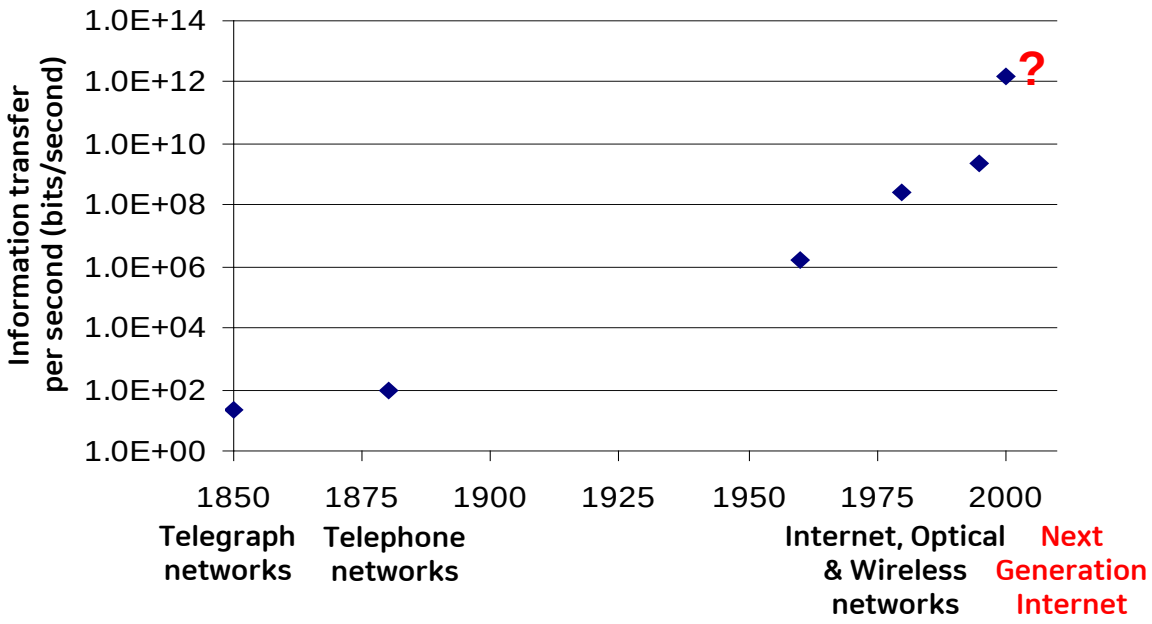
- *Network architecture*: the plan that specifies how the network is built and operated
- Architecture is driven by the network services
- Overall communication process is complex
- Network architecture partitions overall communication process into separate functional areas called *layers*

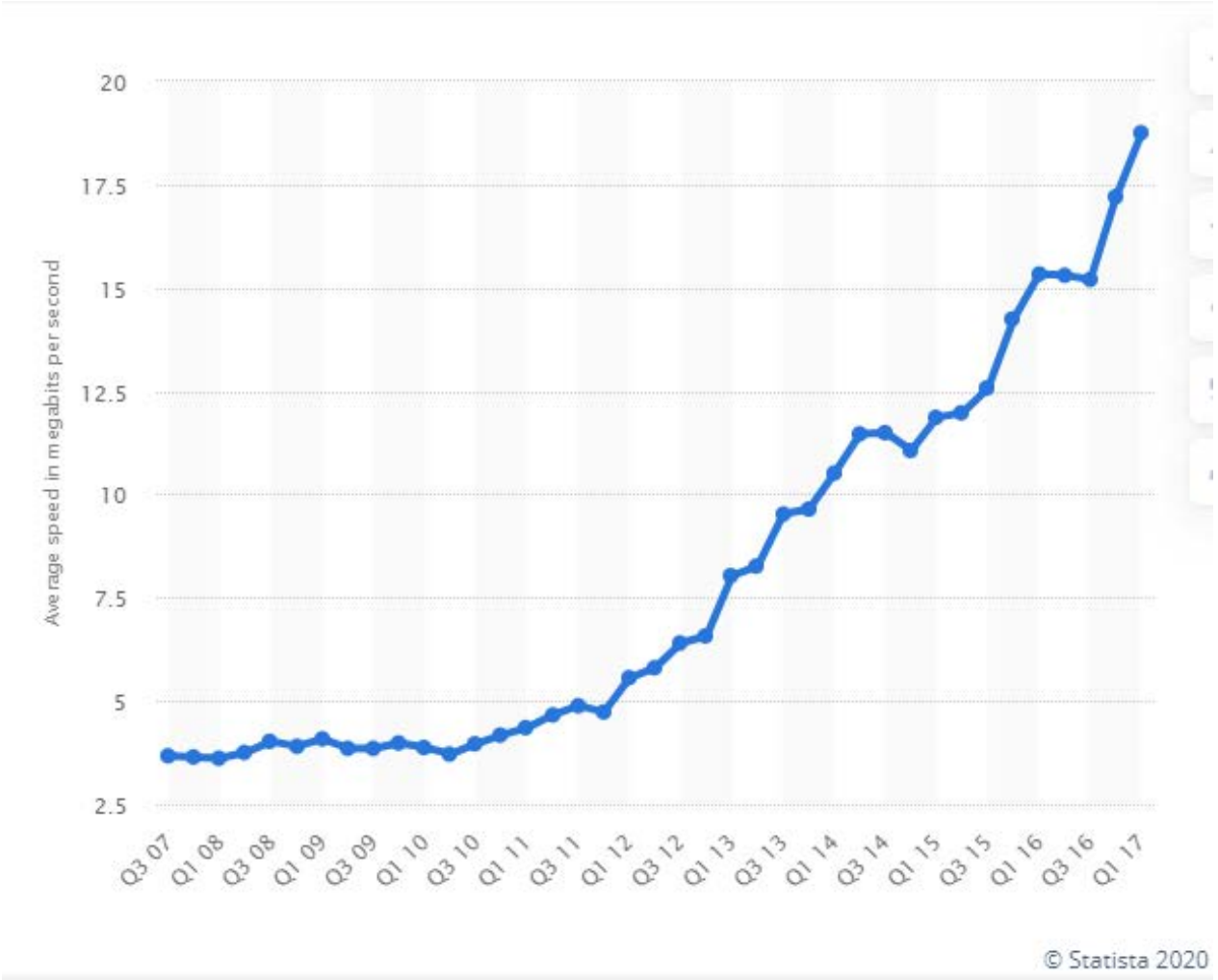
Next we will trace evolution of three network architectures: telegraph, telephone, and computer networks

Network Architecture Evolution

- Telegraph Networks
  - Message switching & digital transmission
- Telephone Networks
  - Circuit Switching
  - Analog transmission → digital transmission
  - Mobile communications
- Internet
  - Packet switching & computer applications
- Next-Generation Internet
  - Multiservice packet switching network

Network Architecture Evolution





[Source] https://www.statista.com/statistics/616210/average-internet-connection-speed-in-the-us/
https://ourworldindata.org/internet

Classification of interconnected processors by scale.

Interprocessor distance	Processors located in same	Example
1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

Metric Units

Exp.	Explicit	Prefix	Exp.	Explicit	Prefix
10^{-3}	0.001	milli	10^{3}	1,000	Kilo
10^{-6}	0.000001	micro	10^{6}	1,000,000	Mega
10^{-9}	0.000000001	nano	10^{9}	1,000,000,000	Giga
10^{-12}	0.000000000001	pico	10^{12}	1,000,000,000,000	Tera
10^{-15}	0.000000000000001	femto	10^{15}	1,000,000,000,000,000	Peta
10^{-18}	0.000000000000000001	atto	10^{18}	1,000,000,000,000,000,000	Exa
10^{-21}	0.000000000000000000001	zepto	10^{21}	1,000,000,000,000,000,000,000	Zetta
10^{-24}	0.000000000000000000000001	yocto	10^{24}	1,000,000,000,000,000,000,000,000	Yotta

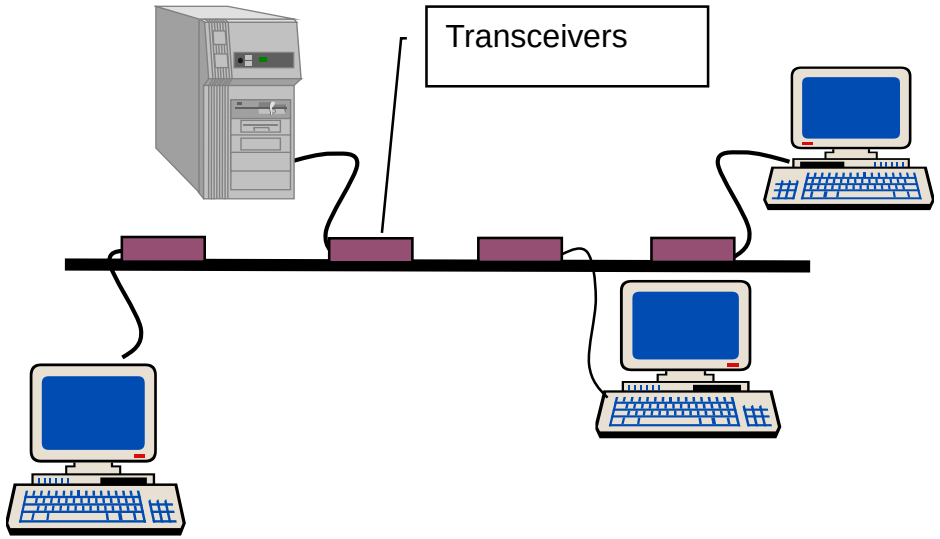
The principal metric prefixes.

Ethernet Local Area Network

- In 1980s, affordable workstations available
- Need for low-cost, high-speed networks
  - To interconnect local workstations
  - To access local shared resources (printers, storage, servers)
- Low cost, high-speed communications with low error rate possible using coaxial cable
- Ethernet is the standard for high-speed wired access to computer networks

Ethernet Medium Access Control

- Network interface card (NIC) connects workstation to LAN
- Each NIC has globally unique address
- Frames are broadcast into coaxial cable
- NICs listen to medium for frames with their address
- Transmitting NICs listen for collisions with other stations, and abort and reschedule retransmissions

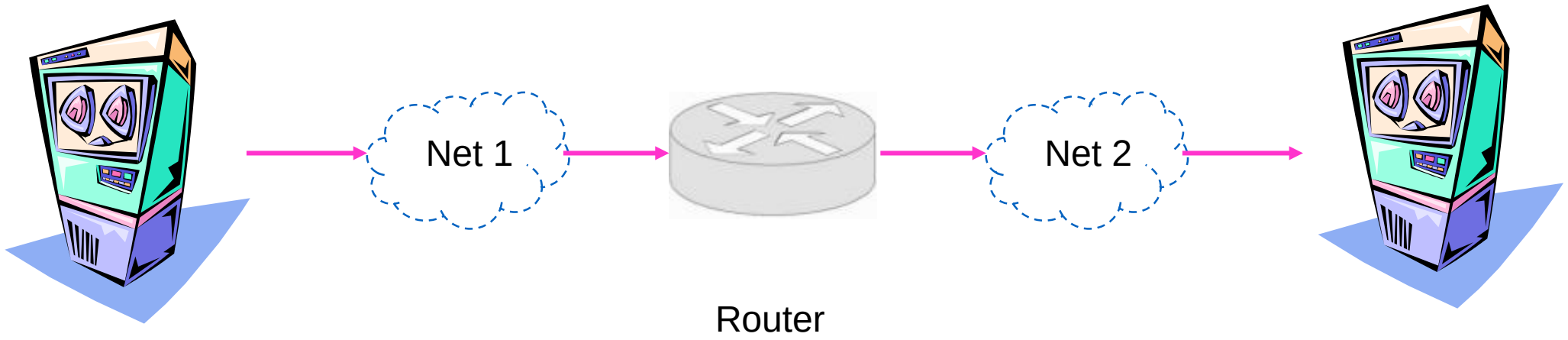


The Internet

- Different network types emerged for data transfer between computers
- Each network has its protocols and is possibly built on different technologies
- *Internetworking protocols* required to enable communications between computers attached to *different* networks
- *Internet*: a network of networks

Internet Protocol (IP)

- *Routers (gateways)* interconnect different networks
- Host computers prepare IP packets and transmit them over their attached network
- Routers forward IP packets across networks
- *Best-effort* IP transfer service, no retransmission



Names and IP Addresses

- Routing is done based on 32-bit IP addresses
- Dotted-decimal notation
  - 128.100.11.1
- Hosts are also identified by name
  - Easier to remember
  - Hierarchical name structure
  - tesla.comm.utoronto.edu
- Domain Name System (DNS) provided conversion between names and addresses

Internet Applications

- All Internet applications run on TCP or UDP
- TCP: HTTP (web); SMTP (e-mail); FTP (file transfer; telnet (remote terminal)
- UDP: DNS, RTP (voice & multimedia)
- TCP & UDP incorporated into computer operating systems
- Any application designed to operate over TCP or UDP will run over the Internet!!!

Standards

- New technologies very costly and risky
- Standards allow players to share risk and benefits of a new market
  - Reduced cost of entry
  - Interoperability and network effect
  - Compete on innovation
  - Completing the value chain
    - Chips, systems, equipment vendors, service providers
- Example
  - 802.11 wireless LAN products

Standards Bodies

- Internet Engineering Task Force
  - Internet standards development
  - Request for Comments (RFCs): www.ietf.org
- International Telecommunications Union
  - International telecom standards
- IEEE 802 Committee
  - Local area and metropolitan area network standards
  - https://en.wikipedia.org/wiki/IEEE_802 (As of February 2019)
- Industry Organizations
  - MPLS Forum, WiFi Alliance, World Wide Web Consortium