7. NETWORKS AND TELECOMMUNICATIONS

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7.1: Historical Perspective

7.1: Historical Perspective

7.2: Network Concepts

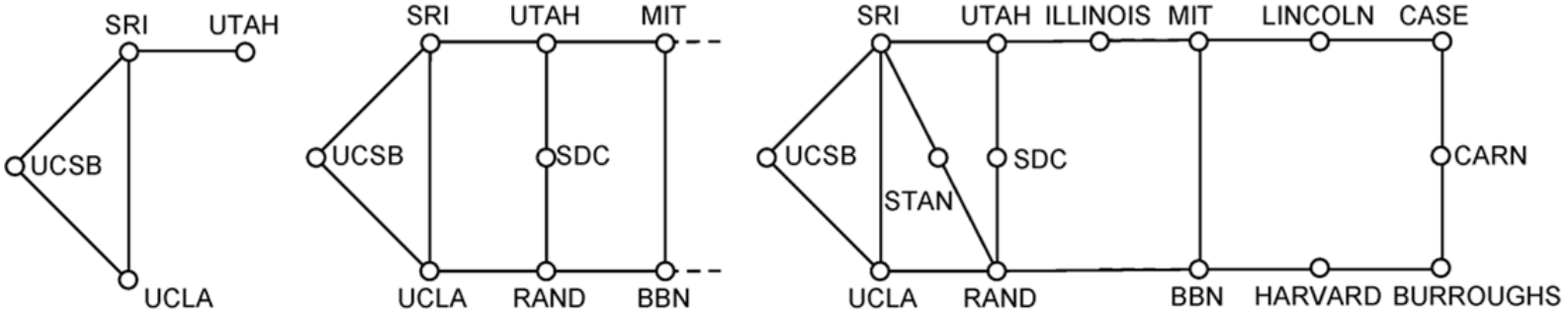
7.3: Network Models

Objectives

- Describe the growth of the internet
- Explain the internet's impact on society
- Explain the internet's impact on economies
- List examples of change that results from the ever-changing internet

From this experimental network …

- ARPANET:1970

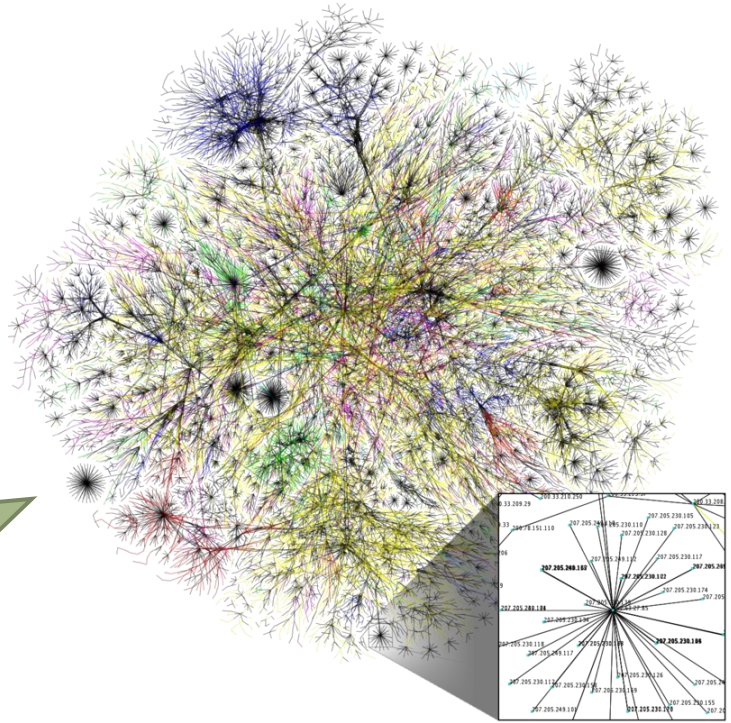


(a) Dec. 1969. (b) July 1970. (c) March 1971.

To the growing internet in 2005…

Number of websites

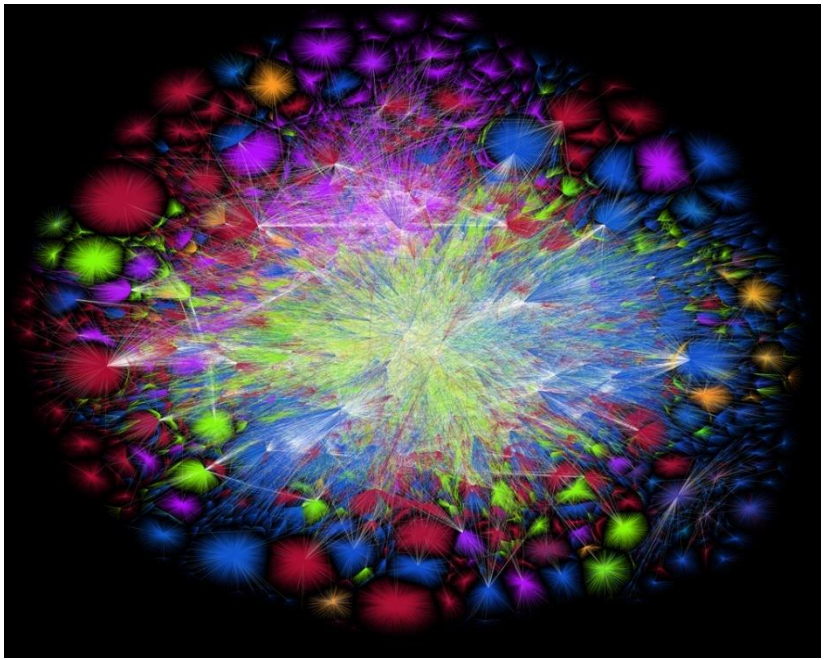
- 1991: 1
- 1993: 130
- 1995: 23,500
- 2000: 17,000,000
- 2005: 64,800,000



To this in 2015!

Number of websites

- 2010: 207 Million
- 2012: 697 Million
- 2014: 969 Million
- 2016: 1 Billion+



An Interconnected World (1)

- Colors show website location
- Connections show routes

North America (ARIN)

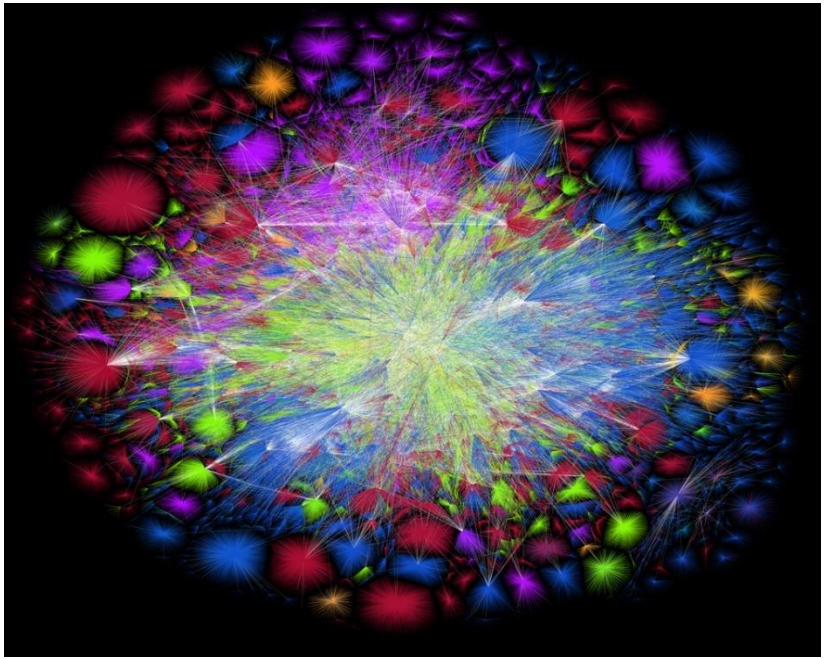
Europe (RIPE)

Latin America (LACNIC)

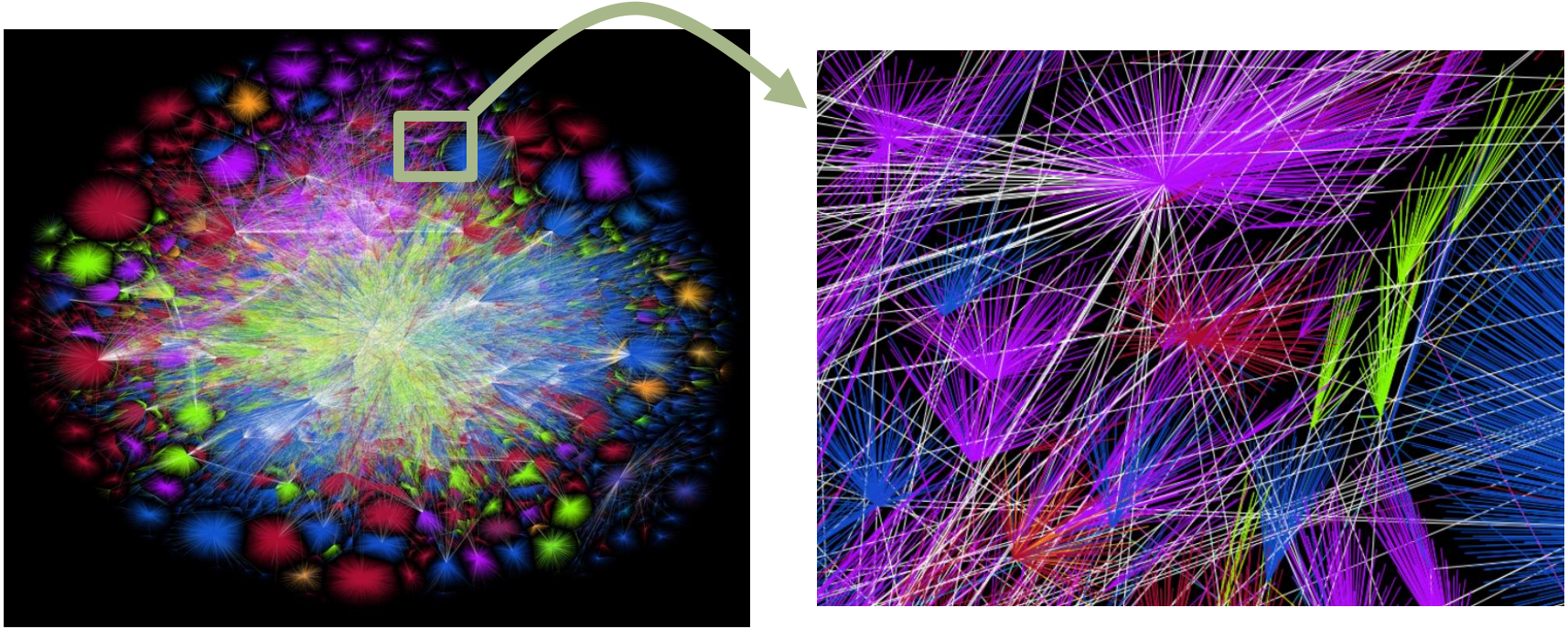
Asia Pacific (APNIC)

Africa (AFRINIC)

"Backbone" (highly connected networks)

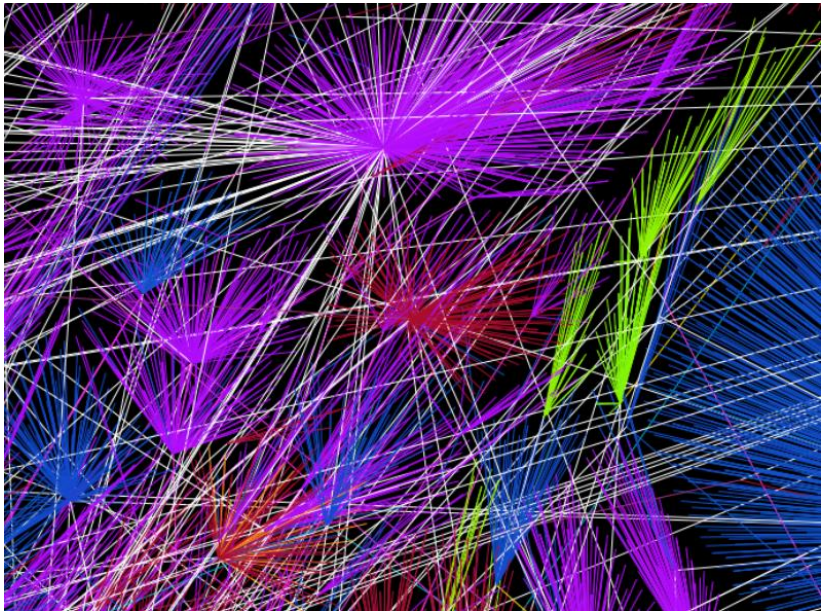


An Interconnected World (2)



The Internet

- Is an everyday institution used at work, home, and on-the-go
- It is vital to our lives



Impact on society

- Enables societies to change
  - Easy access to knowledge
  - Electronic commerce
  - Personal relationships
  - Discussion without censorship

AliExpress

match.com

Tor

Impact on Economies

- An engine of economic growth
  - Access to new markets
  - Online advertising
  - Crowdsourcing; Microloans
  - Transfer of money

Continual Change

- The internet is constantly being re-invented
- Today's internet is different from yesterday's
- And tomorrow's will be different again
- But the fundamentals remain the same

Examples of Changes

- Examples of major changes in the past 1-2 decades

Growth / Technology Driver	Change
Emergence of the web	Content Distribution Networks
Digital songs/videos	Peer-to-peer file sharing
Falling data cost	Voice-over-IP calling
Wireless advances	Mobile devices
Broadband internet	Video streaming

Historical Perspective Summary

- The internet started as an experimental network in the early 1970s
  - The first public website went live in 1991
  - In 2016, there were over 1 billion websites
- The internet changes all aspects of lives
  - Changes to societies and economies
- The internet continues to change and morph

7.2: Network Concepts

7.1: Historical Perspective

7.2: Network Concepts

7.3: Network Models

Objectives

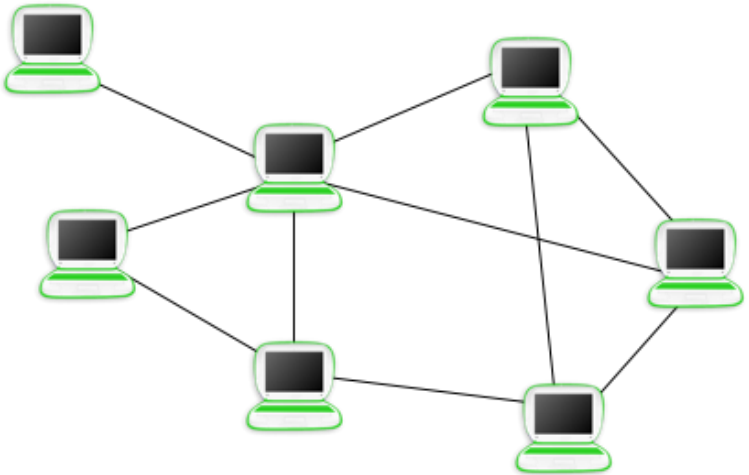
- Explain the function of a computer network
- Describe each network component
- List the major interfaces on a network
- Determine physical and logical network connections
- Describe the types of network by size
- Identify a star network

What is a “network”?

- **Definition**: A way to get “stuff” between 2 or more “things”
- **Examples**: Postal system, phone system, railroad system, highways, roads, and conversations.

Computer Networks (1)

- Two or more computers linked together so they can communicate, share resources, and exchange information



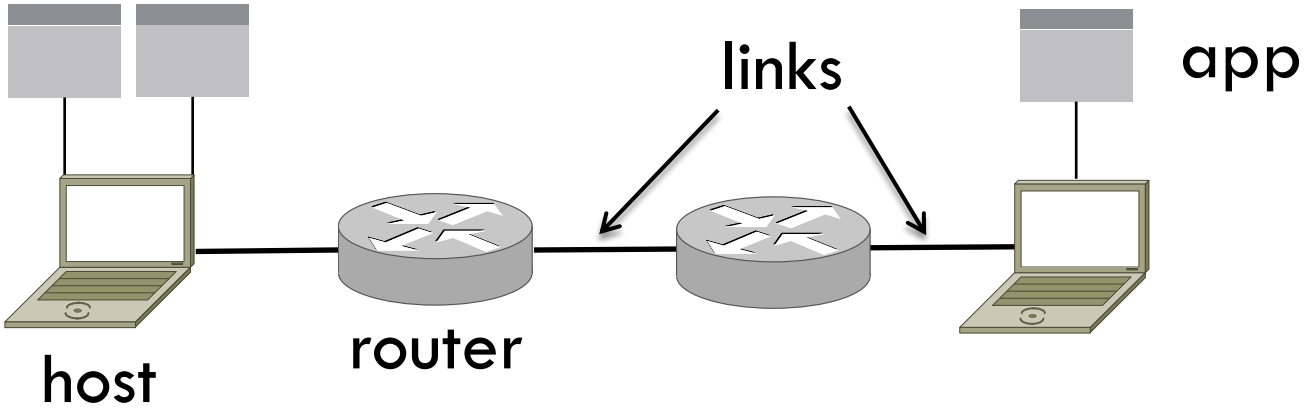
Computer Networks (2)

- Two or more computers linked together so they can communicate, share resources, and exchange information
- Bluetooth creates a two-device network

Example uses of computer networks

- Work:
  - Email, file sharing, printing, …
- Home:
  - YouTube, music, news, video call, e-commerce, …
- Mobile:
  - Voice call, messaging, information access, games …

Parts of a Network

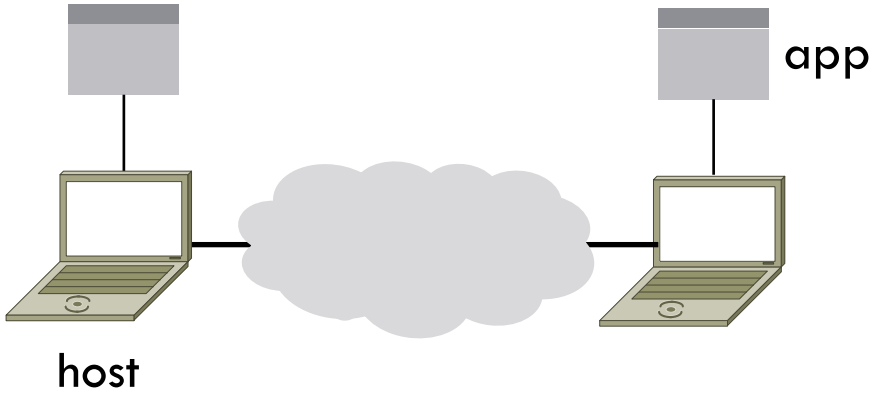


Component Names

Component	Function	Example
Application, or app, user	Uses the network	Chrome, WhatsApp
Host, or end-system	Supports apps	Laptop, mobile
Router, or switch, hub …	Relays messages between links	DSL modem, access point
Link, or channel	Connects nodes	Wires, wireless

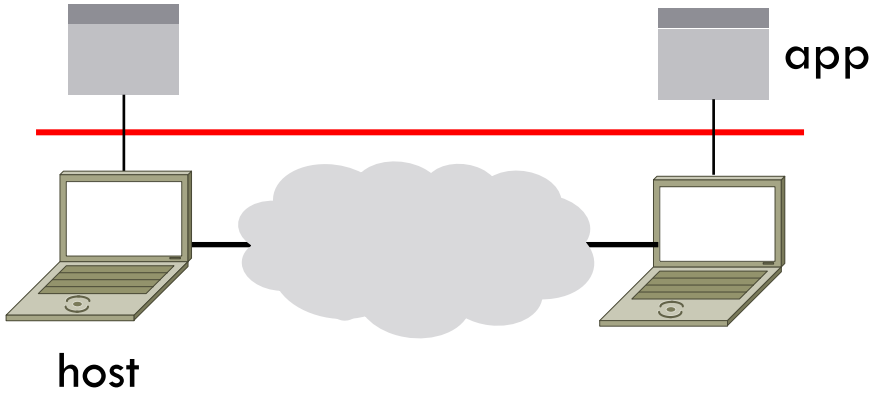
Key Interfaces (1)

- Between (1) apps and network, and (2) network components



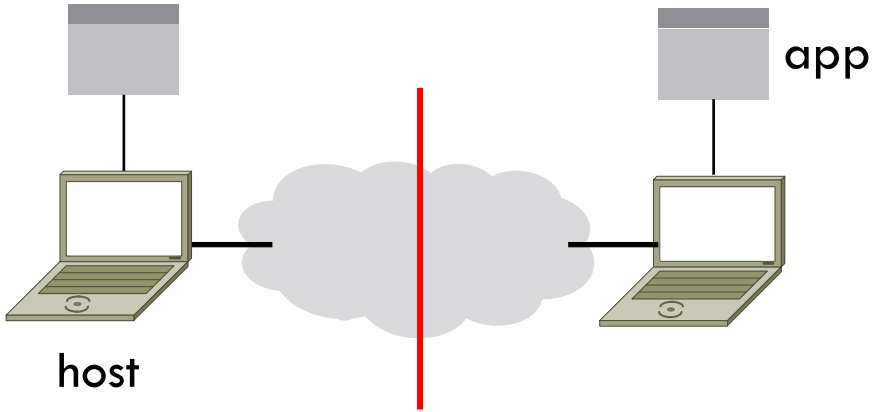
Key Interfaces (2)

- Network-application interfaces define how apps use the network



Key Interfaces (3)

- Network-network interfaces define how nodes work together



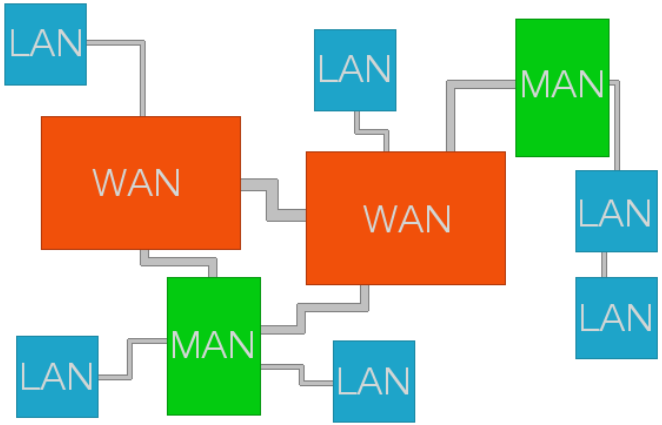
Example Networks

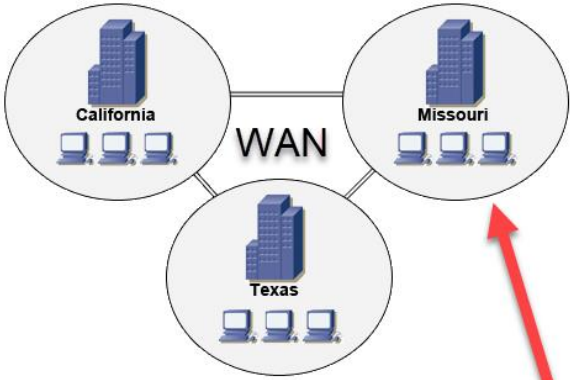
- WiFi (802.11)
- Ethernet
- ISP (Internet Service Provider)
- DSL model
- Mobile phone / cellular (2G, 3G, 4G)
- Bluetooth
- Satellite ...

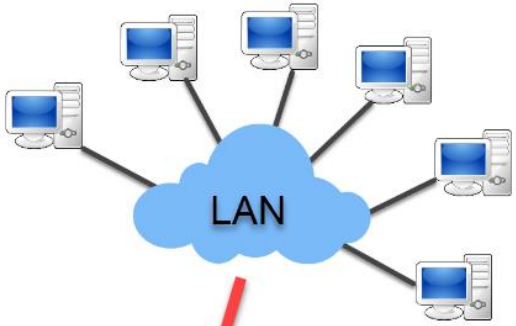
Network names by scale

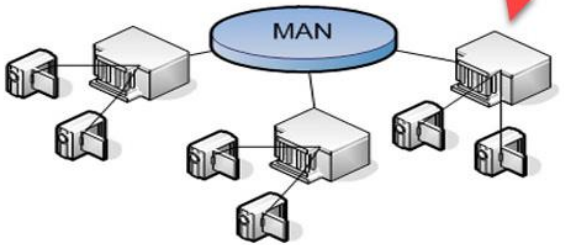
Scale	Type	Example
Vicinity	PAN (Personal Area Network)	Bluetooth (e.g., headset)
Building	LAN (Local Area Network)	WiFi, Ethernet
City	MAN (Metropolitan Area Network)	Cable, DSL
Country	WAN (Wide Area Network)	Large ISP
Global	The Internet (network of all networks)	The internet!

LAN, MAN, WAN Relationship



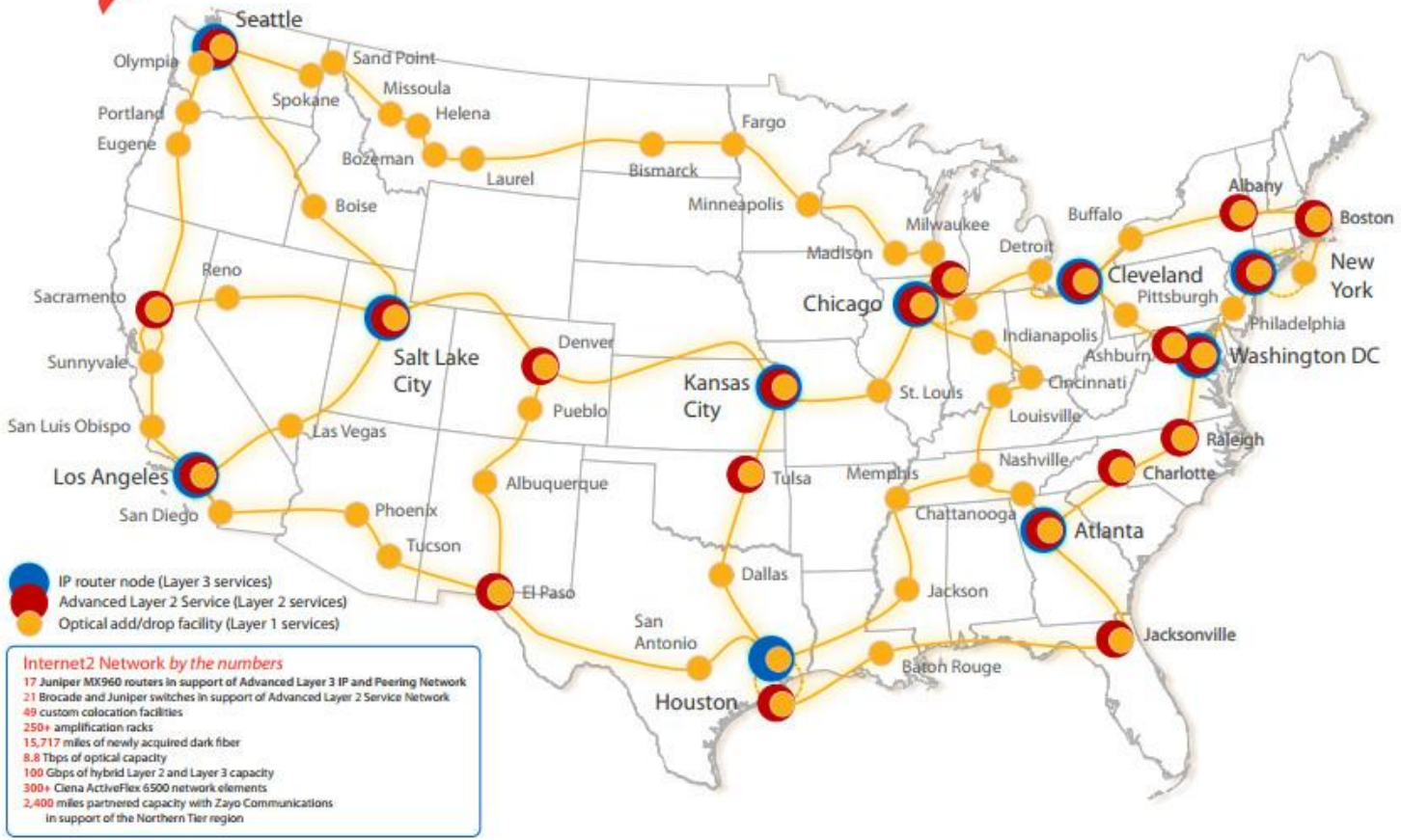






Internet2 Network Infrastructure Topology

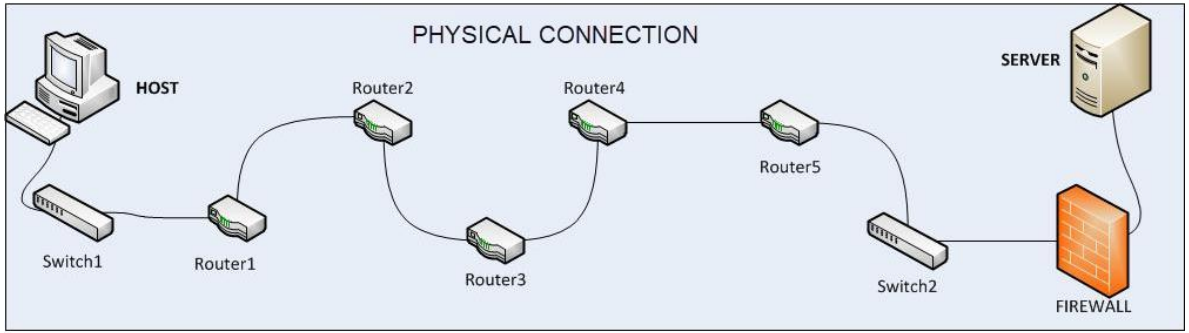
March 2013

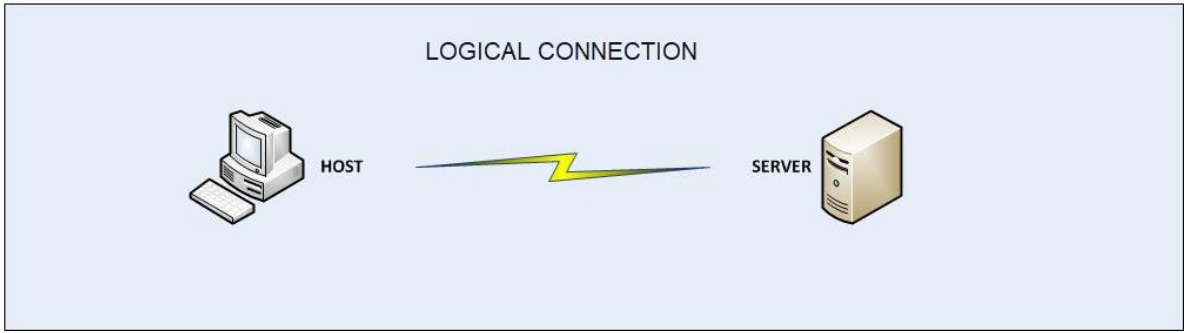


Internet2 Network *by the numbers*

- **17** Juniper MX960 routers in support of Advanced Layer 3 IP and Peering Network
- **21** Brocade and Juniper switches in support of Advanced Layer 2 Service Network
- **49** custom colocation facilities
- **250+** amplification racks
- **15,717** miles of newly acquired dark fiber
- **8.8** Tbps of optical capacity
- **100** Gbps of hybrid Layer 2 and Layer 3 capacity
- **300+** Ciena ActiveFlex 6500 network elements
- **2,400** miles partnered capacity with Zayo Communications in support of the Northern Tier region

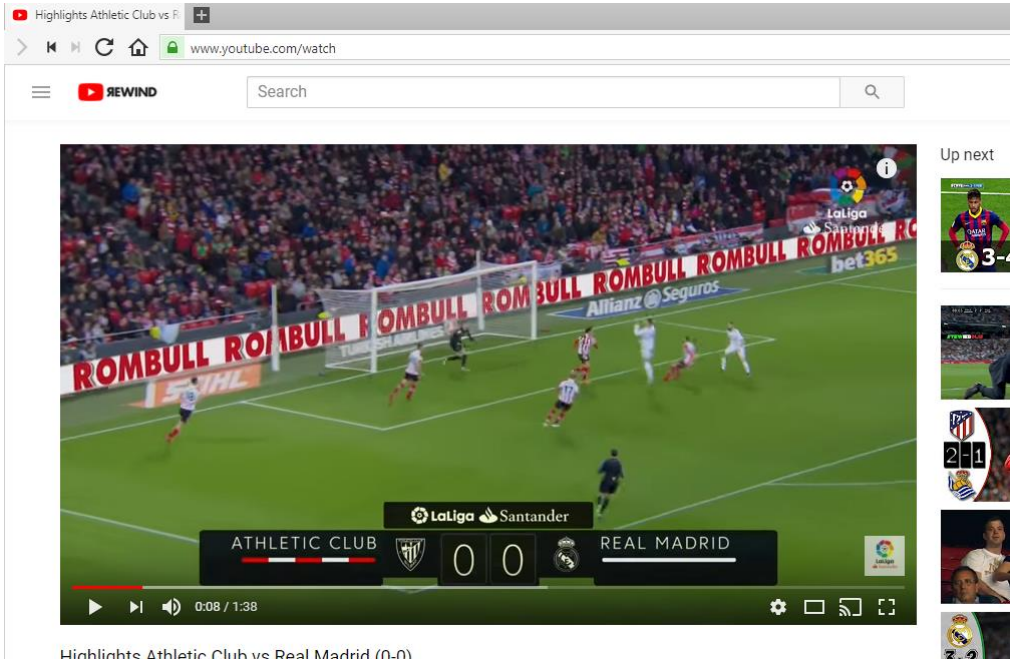
Physical vs. Logical Connection



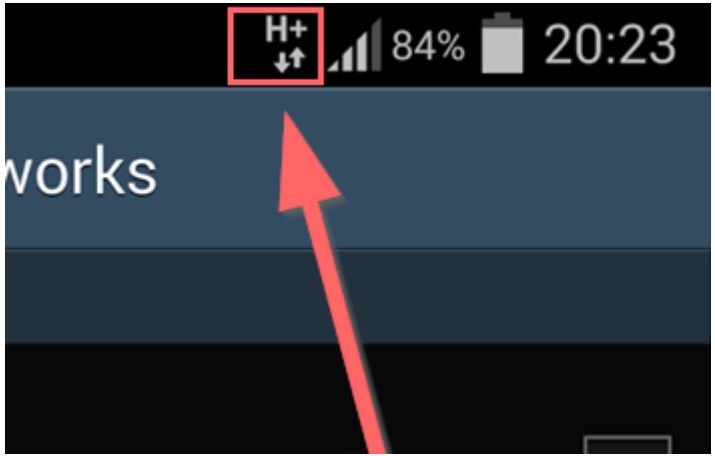


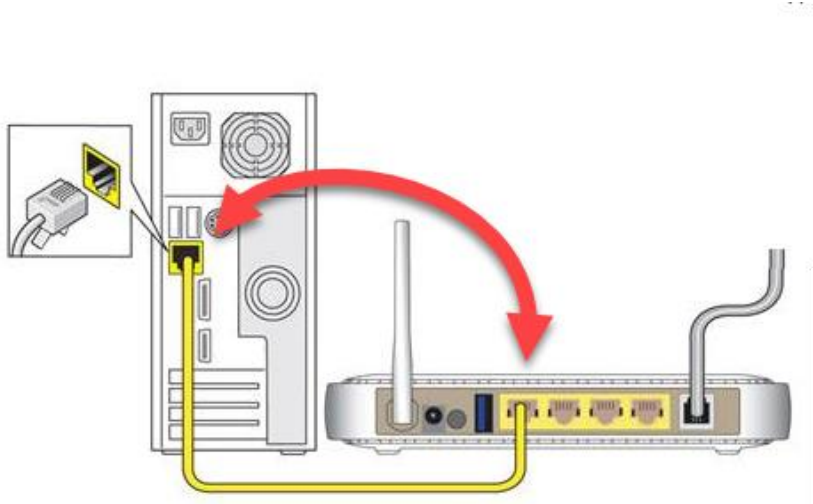
Logical Connection

- Software or virtual connection
- End-to-end connection

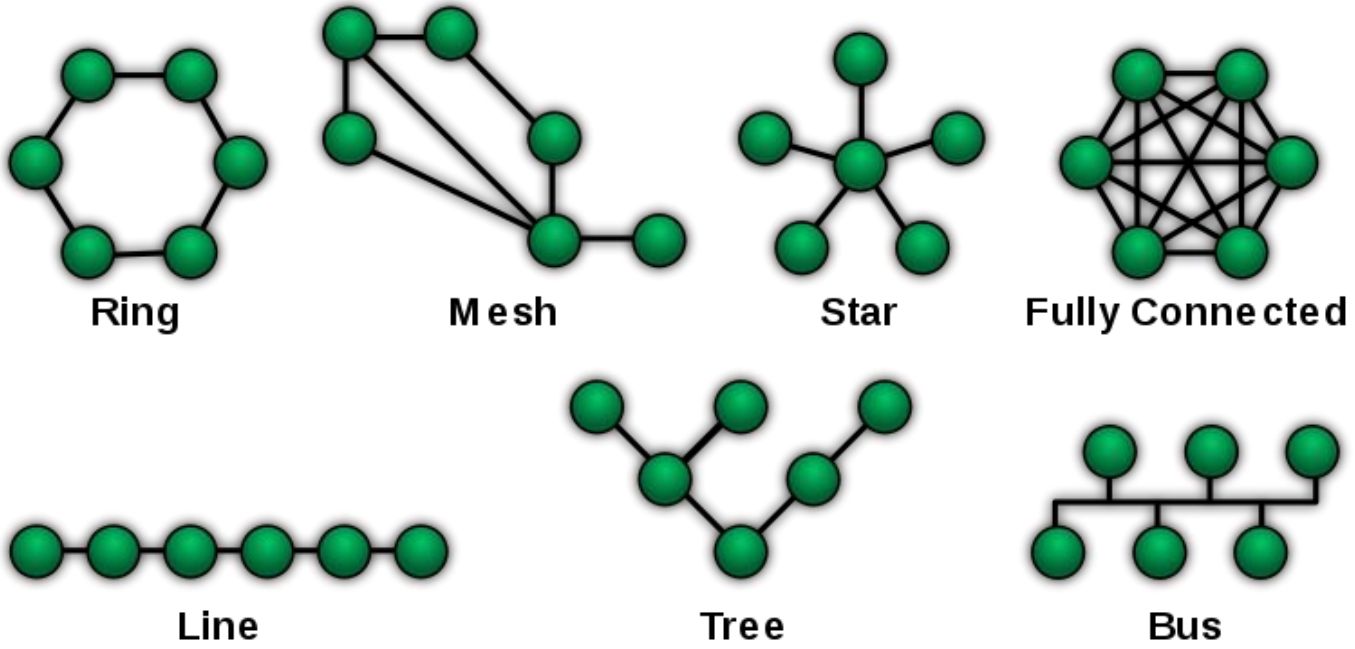


Physical Connections



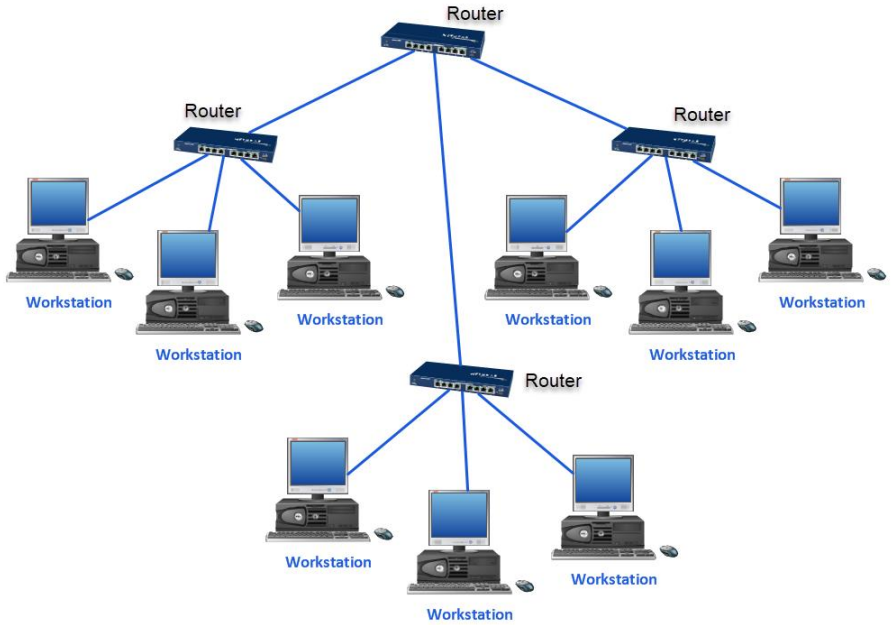


Network Topology

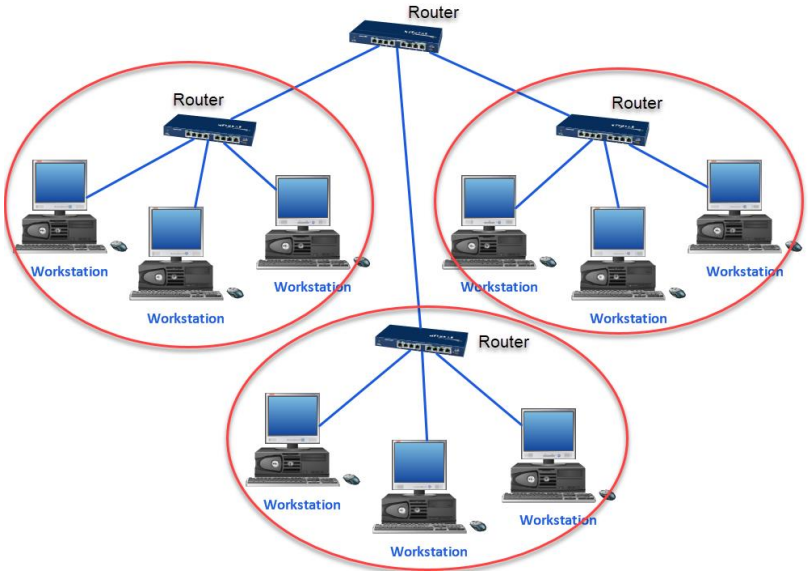


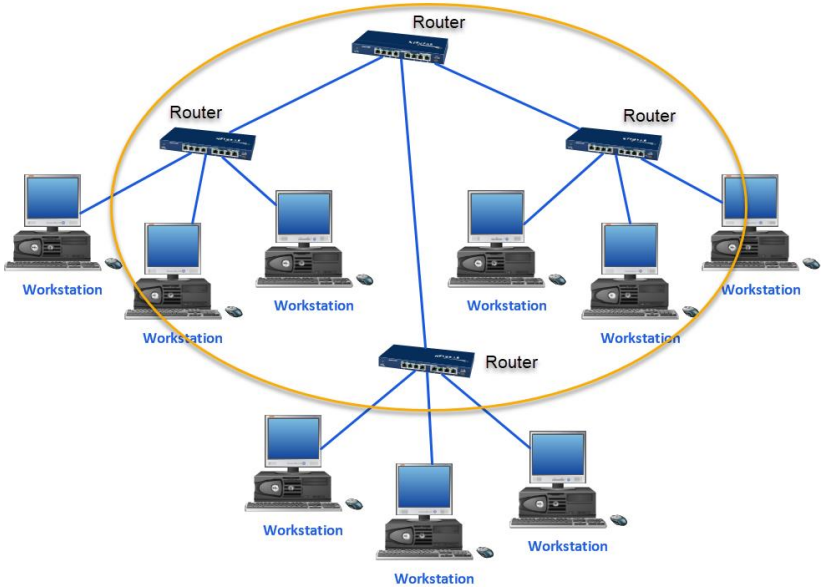
Star Network Topology

- The star topology is the most common type of network used today



Star Network Topology





Network Concepts Summary

- A computer network is two or more computers linked together to exchange information
- Network components
  - Applications, hosts, routers, and links
- Application-Network and Network-Network interfaces
- Physical connection is real; Logical connection is virtual
- Scale of networks: WAN, MAN, LAN, PAN
- A star network is the most common network topology

7.3: Network Models

7.1: Historical Perspective

7.2: Network Concepts

7.3: Network Models

Objectives

- List the five network layers
- Explain how the first four layers deliver the data
- Define protocols

Computer Networking Models

- Network models help to understand different layers of a network
- Each layer describes a particular level of network communication
- The layers start from an overview perspective and work towards a detailed level

Networking Models

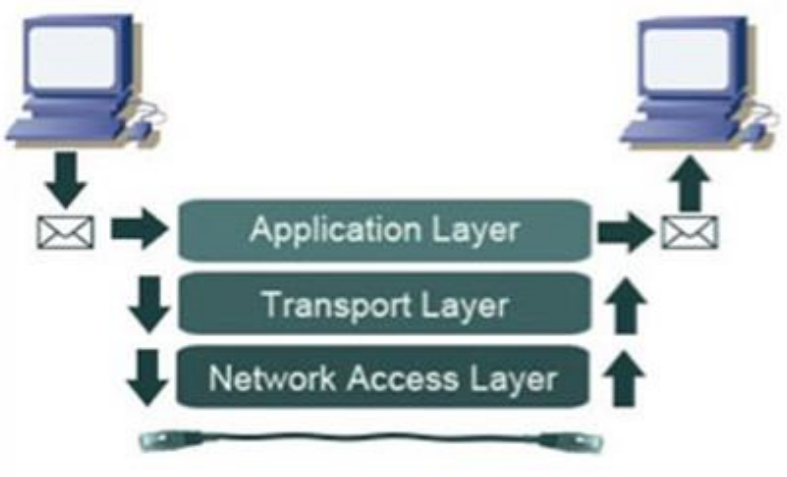
OSI 7-Layer Model	
7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Data
1	Physical

Simplified Layer Model
Application
Transport
Network
Data
Physical

DOD 3-Layer Model
Application
Protocol
Local Network (LAN)

Model Purpose

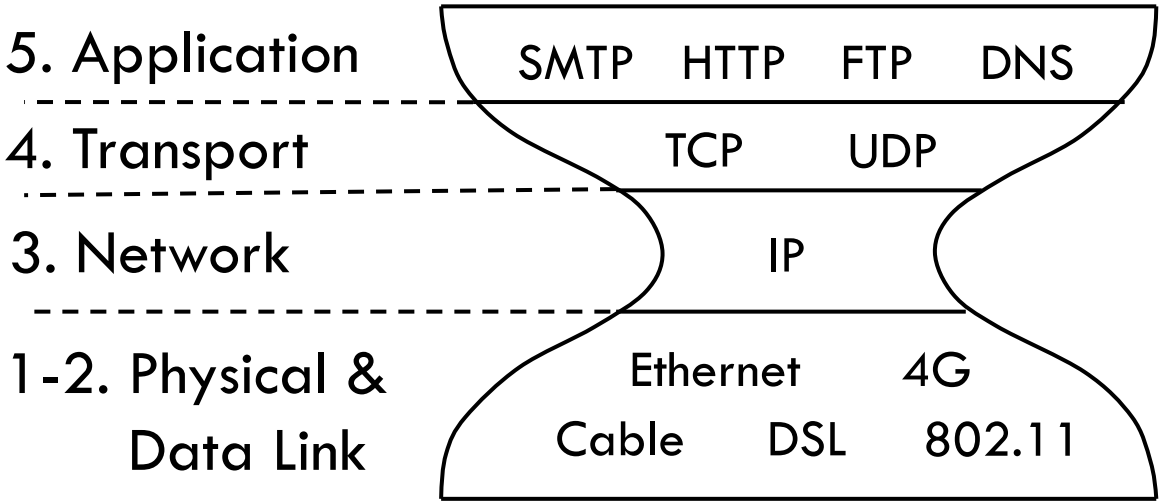
- Shows how the data (a webpage, an email) get from the server to your computer



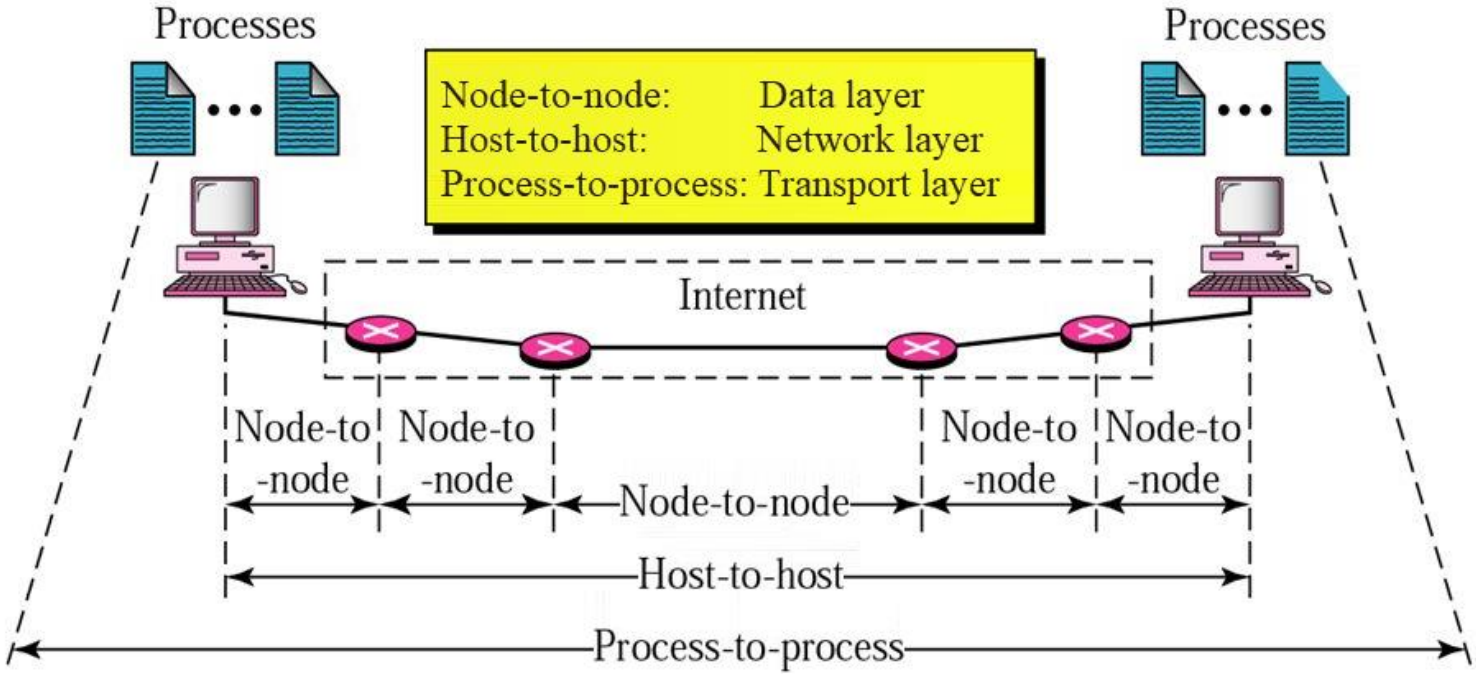
Protocol Concepts

- Protocols are sets of rules
- Network protocols answer these questions:
  - What do you want to do? (Application)
  - Where are you going? (Addressing)
  - How do you get there? (Media types)
  - Did you get there? (Acknowledgments, Error checking)

Protocols examples for each layer

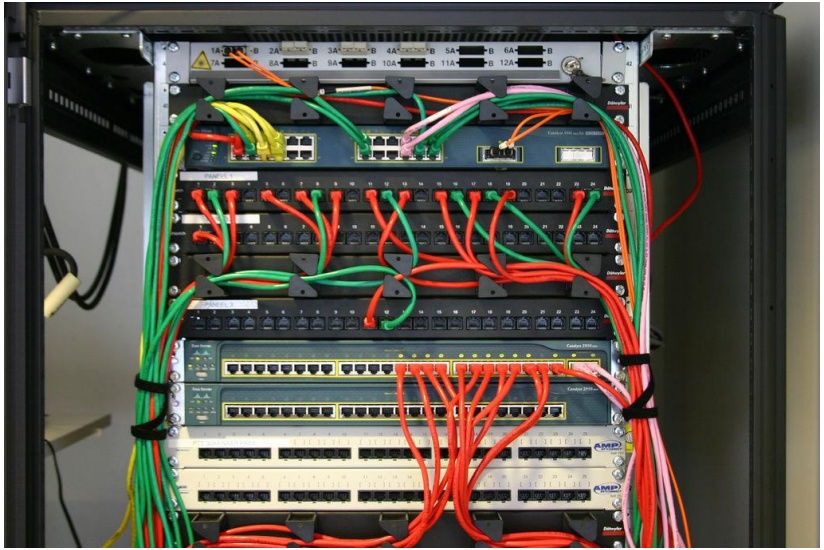


Data Delivery Overview

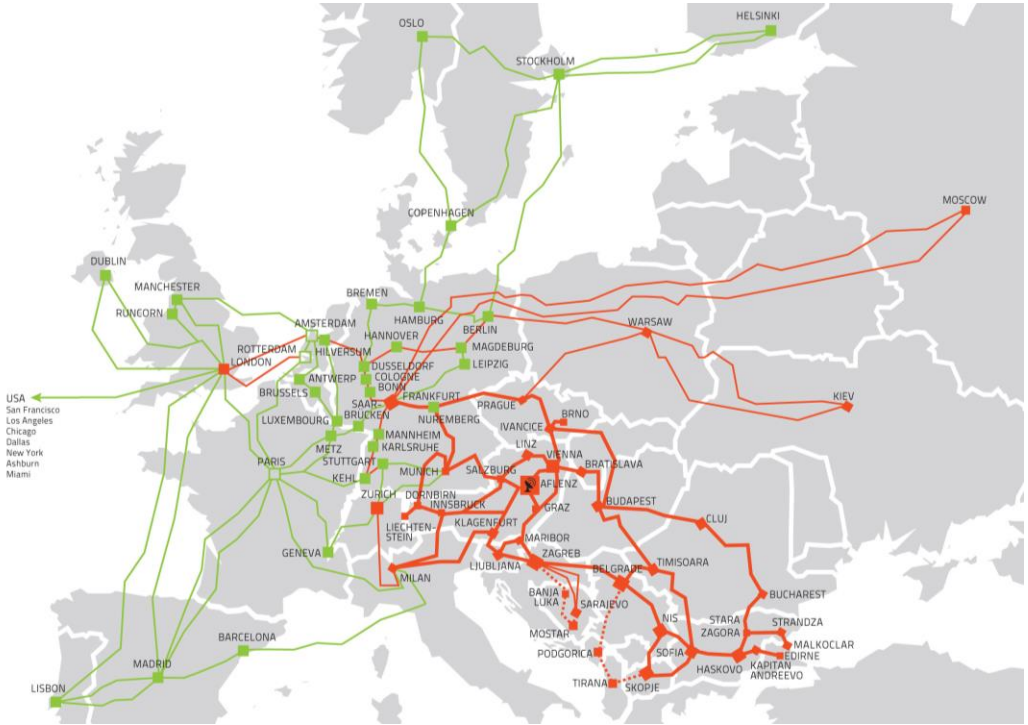


Layer 1: Physical

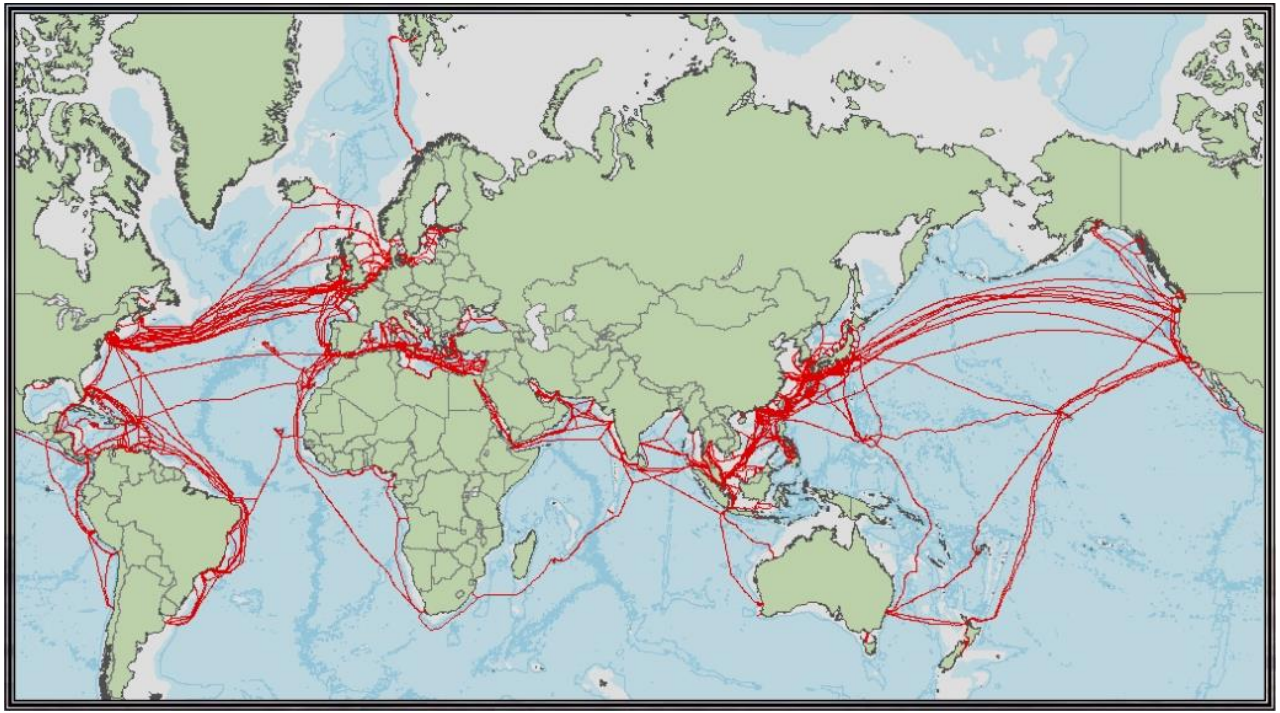
- **Function:** Transmit data by an electric voltage, radio frequencies, or light over a physical medium
- Examples include cables, routers, and antennas



A physical network in Europe

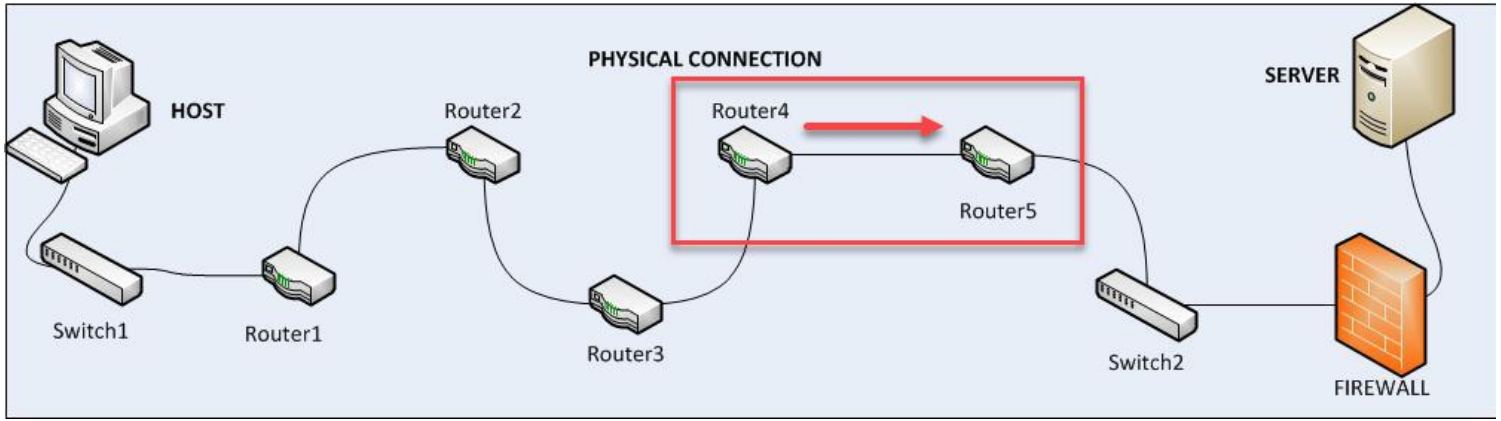


Submarine Fiber Optic Telecommunication



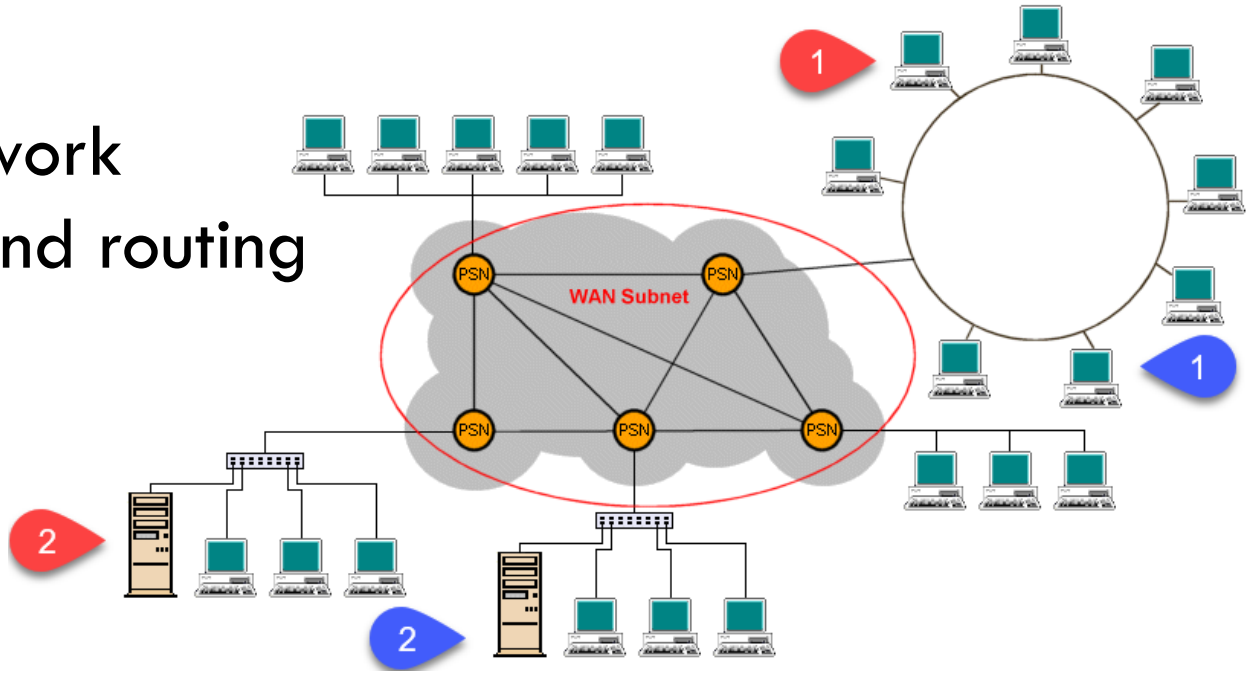
Layer 2: Data

- **Function:** Reliably transmit **data frames** between two nodes connected by a physical layer (node-to-node)



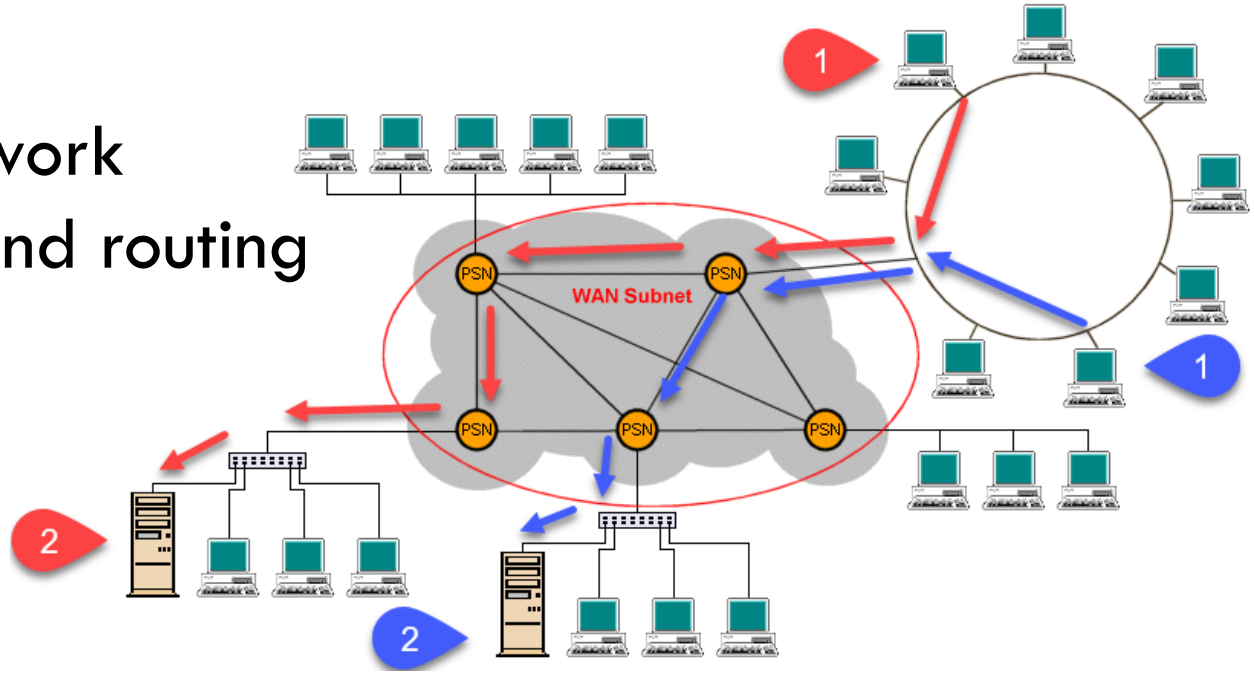
Layer 3: Network (1)

- **Function:**
  Provides network addressing and routing (host-to-host)



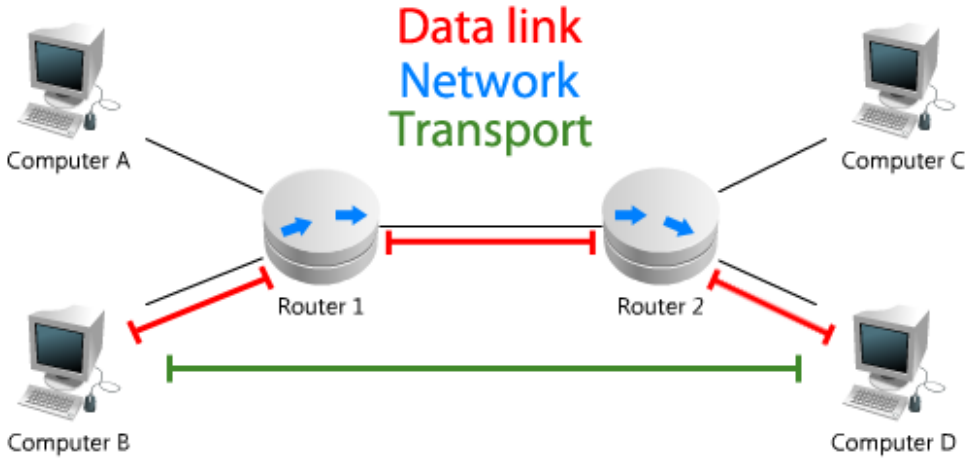
Layer 3: Network (2)

- **Function:**
  Provides network addressing and routing (host-to-host)
- Directs the data to the next node



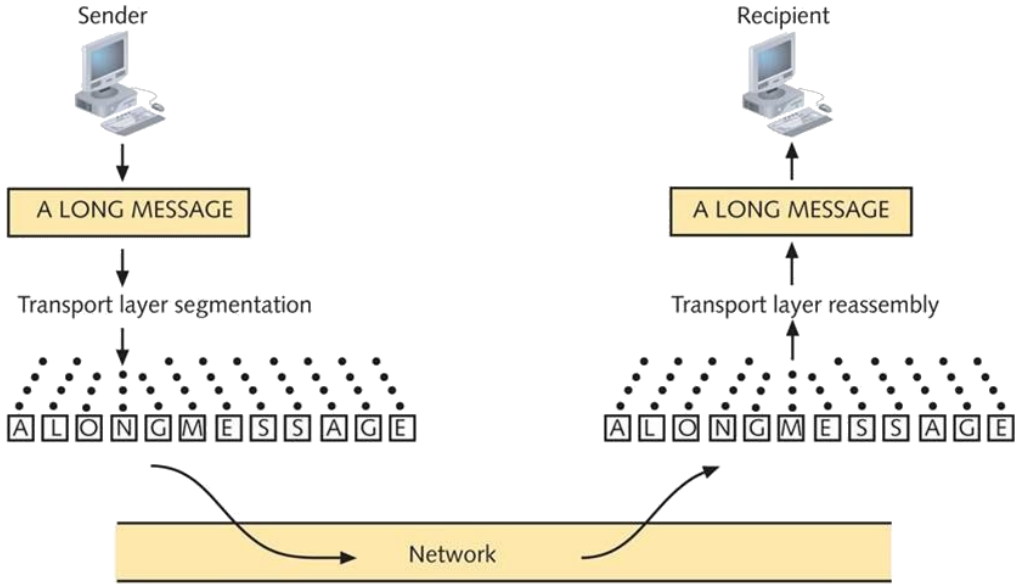
Layer 4: Transport (1)

- **Function:** Provides end-to-end connections and reliability
- Moves data from the sender to the receiver (process-to-process)



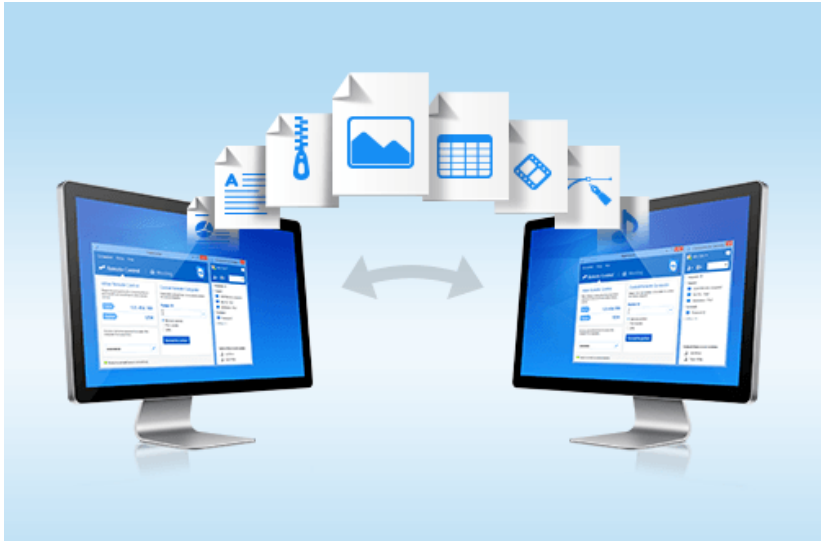
Layer 4: Transport (2)

- Segmentation and Reassembly



Layer 4: Transport (3)

- The delivery of a complete file from the process on one computer to the process on another computer is the job of the transport layer.



Layer 5: Application Layer

- **Function:** Provides application services to users and programs (application-to-application)
- Builds distributed "network services" on transport services
  - Examples: Web, domain name service (DNS), file transfer services, email services, and video streaming
  - Protocols: HTTP, DNS, FTP, SMTP, and RTP
- Access network services through computer applications
  - Examples include web browsers, messaging clients, email clients

Network Models Summary

- The Simplified Layer Model describes how a network operates
  - physical, data, network, transport, and application
  - communicate using protocols, which are a set of rules

Physical	Transmits data using physical properties
Data	Sends data node-to-node
Network	Directs data from host-to-host
Transport	Delivers data from process-to-process
Application	Builds distributed networks, such as WWW, file transfer, and video streaming

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