LAYERING

September 12, 2020

Layering and Network Architectures

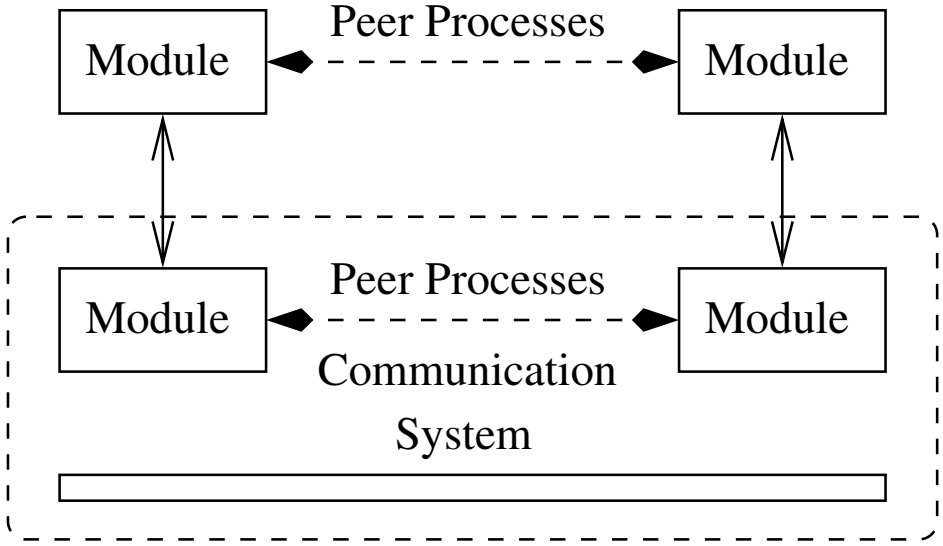
- Design of network is very complex
- Modularity simplifies the design process
- Leads to hierarchy of *modules* where higher level modules are built from lower level in "black box" fashion

Advantages of Layering

- Good design principle in general
- Simple and easy to understand
- Easy to modify and/or adapt to new situations/technologies
- Allows for different solutions for different situations
- Vendor competition

Layering in Networks

- Network provides for communication between two hosts
- Each host has the same hierarchy of modules
- Modules at the same level are called *peers*



- Layer $i-1$ provides *services* to module i
- Services are realized by *protocols*

Two Important Layering Standards

- OSI - Open Systems Interconnection
  - International Standards Organization (ISO), 1983
  - Academically important but largely ignored
- TCP/IP - Transmission Control Protocol/Internet Protocol
  - Invented by Cerf and Kahn, 1974, refined by others
  - TCP/IP is the dominant architecture
  - Practically important but difficult to describe.

OSI
(Open Systems Interconnection)

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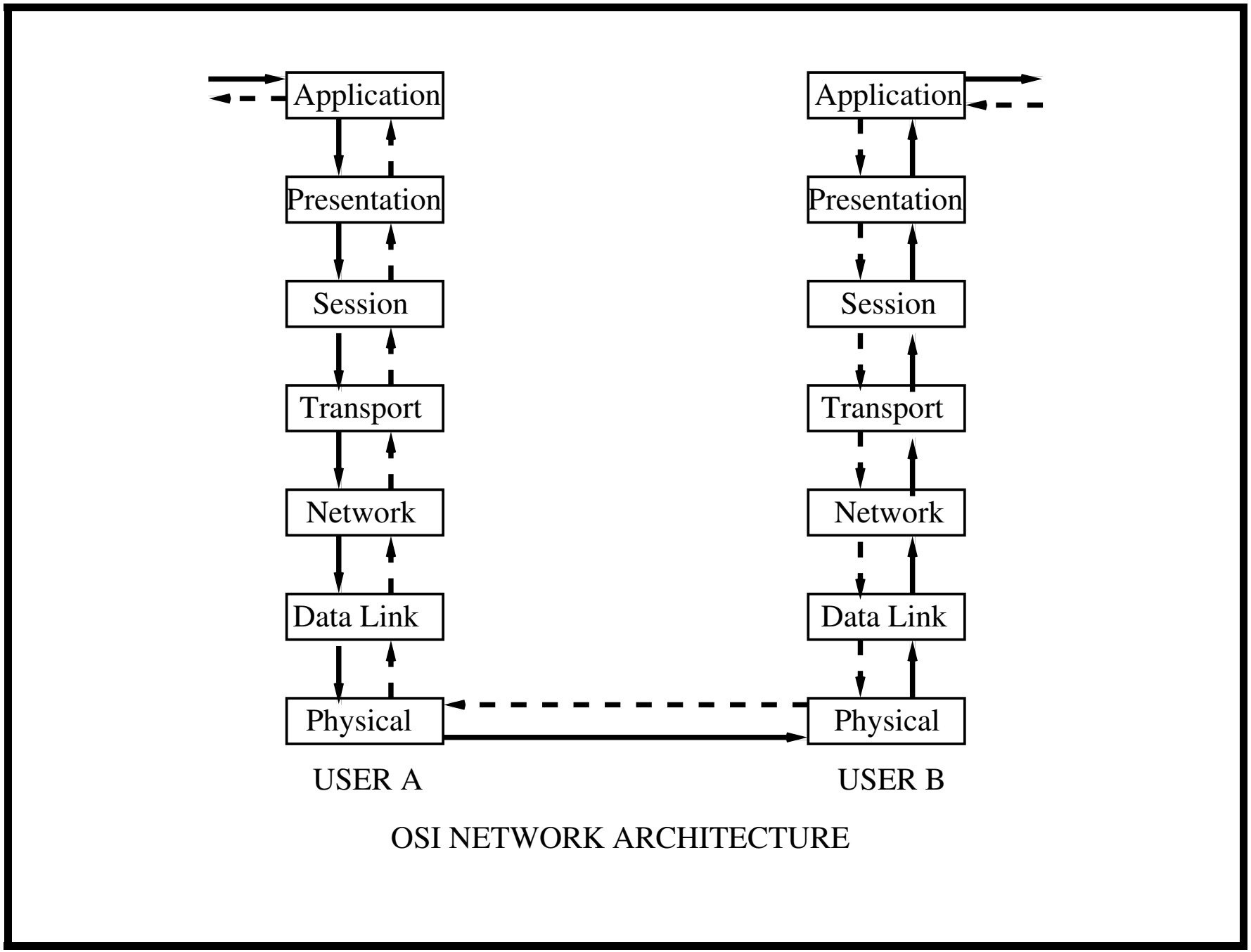
OSI

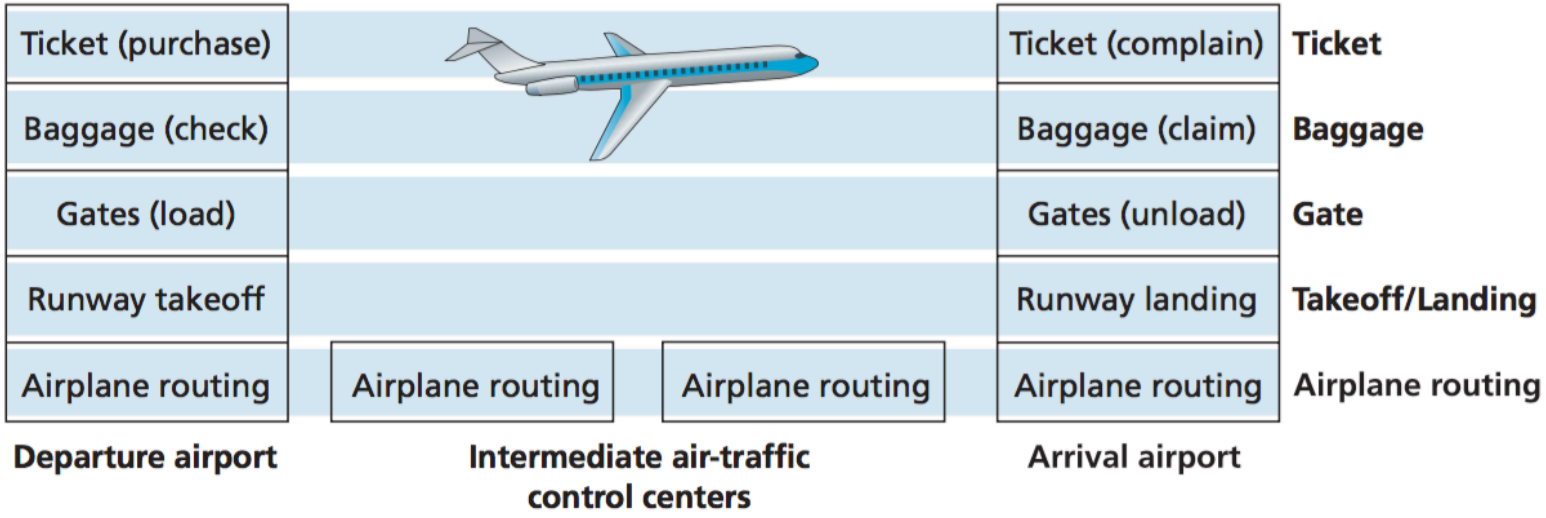
ISO (International Standards Organization) had the following guidelines in mind:

- One layer for each level of abstraction
- Layers perform well-defined functions
- Minimum of information flow between layers (i.e., simple *interfaces*)
- Layers not overloaded with functions
- Layers can be easily standardized



OSI NETWORK ARCHITECTURE

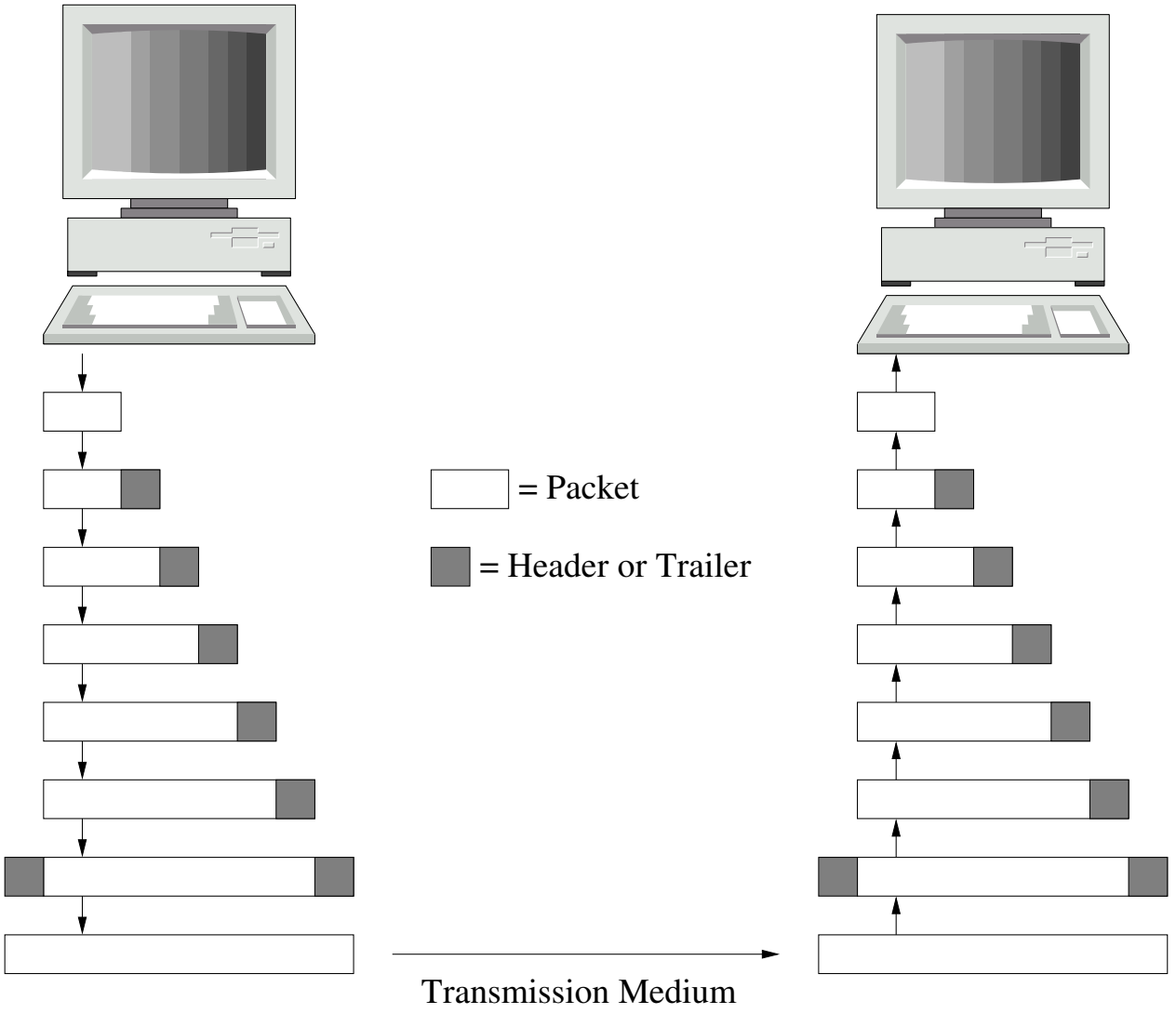
Layering in Airline Industry

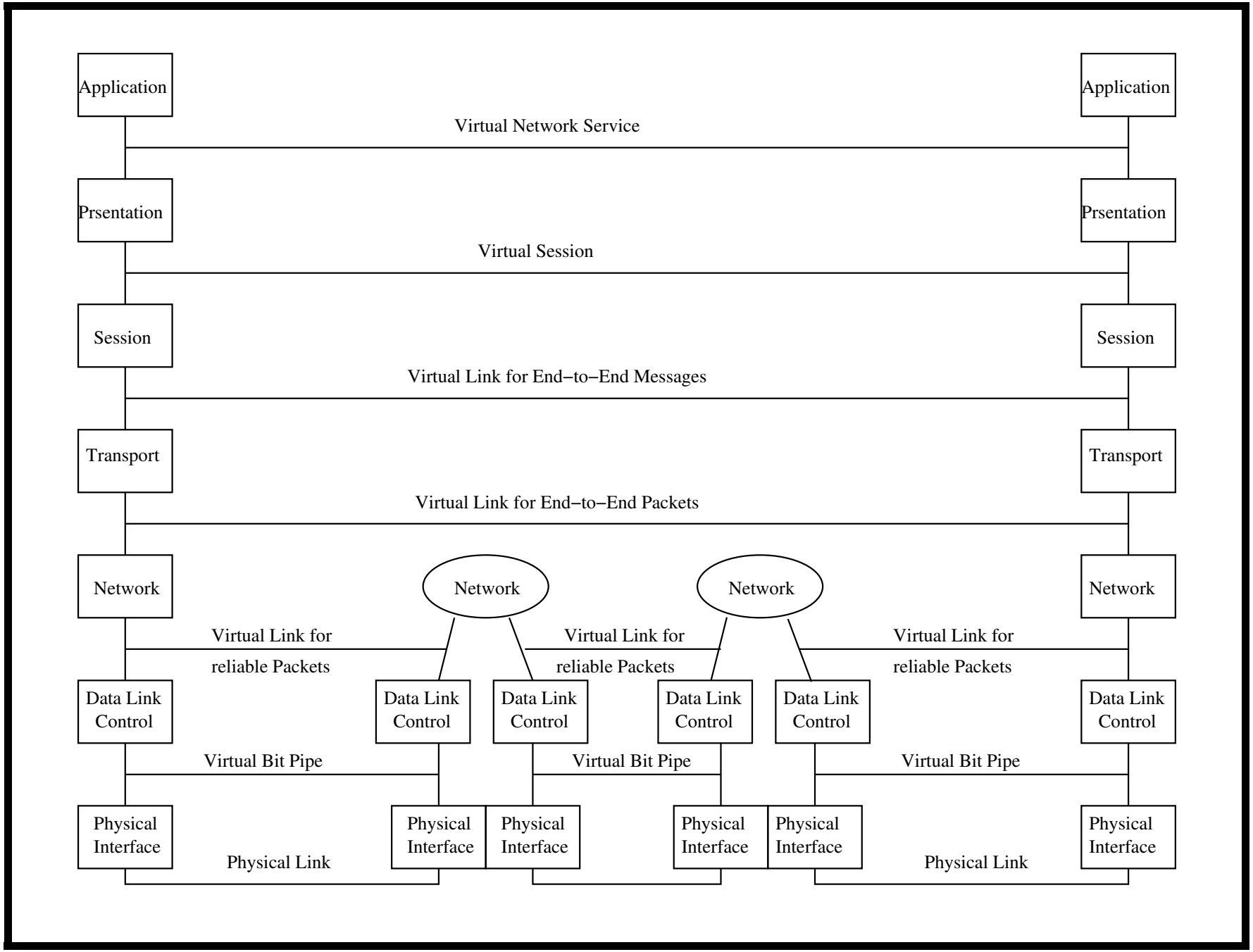


OSI's Seven Layers

- Physical
- Data Link
- Network
- Transport
- Session
- Presentation
- Application

OSI: Exchange




Application
Application
Virtual Network Service
Prsentation
Prsentation
Virtual Session
Session
Session
Virtual Link for End−to−End Messages
Transport
Transport
Virtual Link for End−to−End Packets
Network
Network
Network
Network
Virtual Link for
reliable Packets
Virtual Link for
reliable Packets
Virtual Link for
reliable Packets
Data Link Control
Data Link Control
Data Link Control
Data Link Control
Data Link Control
Data Link Control
Virtual Bit Pipe
Virtual Bit Pipe
Virtual Bit Pipe
Physical Interface
Physical Interface
Physical Interface
Physical Interface
Physical Interface
Physical Interface
Physical Link
Physical Link

Physical Layer

- The Physical Layer is concerned with transmission of unstructured bit stream over a physical medium
  - Implements a *virtual bit pipe*
  - Has no idea what the bits mean
- Module that performs these functions is generally called a *modem*

Data Link

- Converts unreliable bit pipe to virtual communication link
  - Sends packets asynchronously but error-free
  - Includes error detection and correction, framing (used to recognize the beginning and end of packet), retransmission strategies
- In broadcast networks there is a special Medium Access Control (MAC) sublayer

Network

- Responsible for establishing, maintaining and terminating connections
  - Routing and congestion control decisions
  - Internetworking
- Most distributed and therefore most complex layer

Transport

- Reliable, transparent data transfer between end points
- Packetization, multiplexing of sessions
- End-to-end flow control and error recovery

Session

- Control of communication between applications
- Load sharing
- Access rights
- Checkpointing for application recovery
- Directory assistance, ie, where services are available

Presentation

- Data encryption
- Data compression
- Code conversion

Application

- What ever is left over and things specific to an application

TCP/IP

TCP/IP is defined by protocols not by layer, although it is convenient to think of it as four layers:

1. Application
2. Host-to-host transport (deals with variable length messages)
3. Internet (transmits datagrams), and
4. Physical (device drivers to perform bit-by-bit transmission).

TCP/IP

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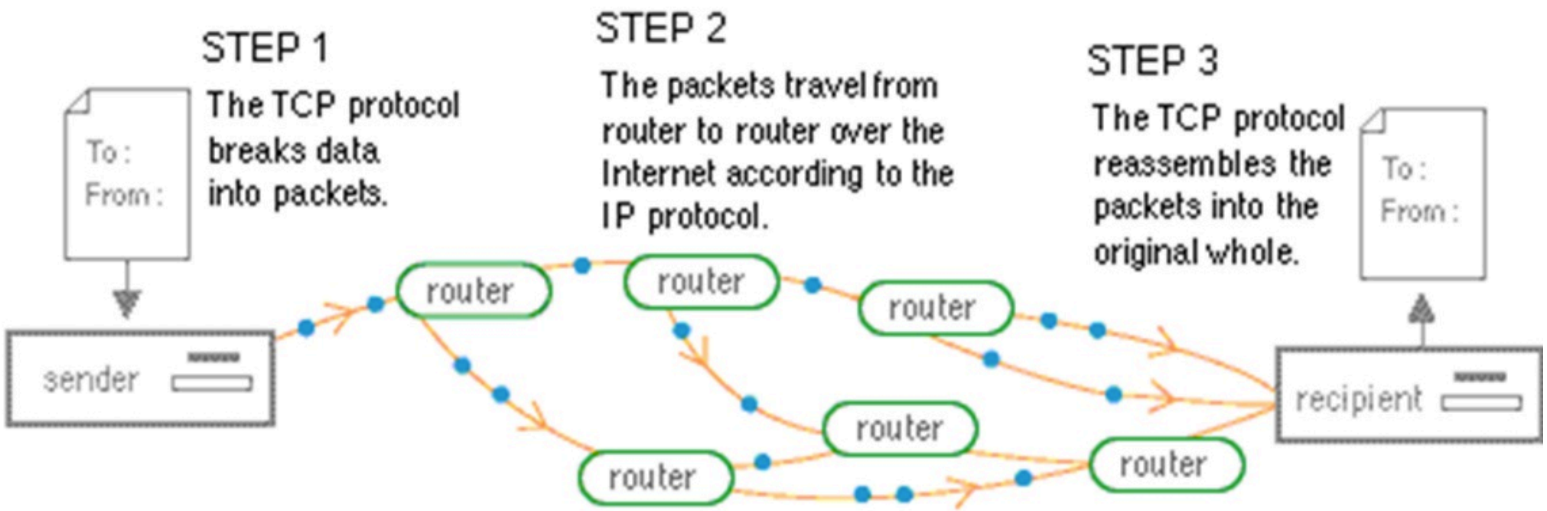
TCP/IP

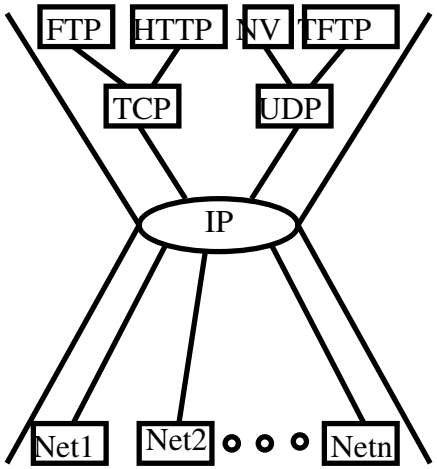
- Physical layer same as OSI
- Network and Data Link combined to form Network Access layer
- Remaining layers are
  - Internet layer
  - Transport layer
  - Application layer
- TCP/IP is not cleanly delineated!

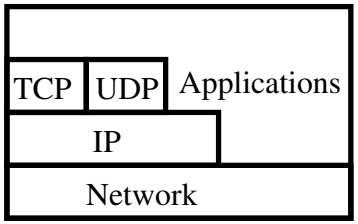
TCP/IP: How it Works



TCP/IP Design

- Looks like a "funnel" with a design that is not clean.





TCP/IP ARCHITECTURE

- But is is very important!

Network Access Layer

- Concerned with data exchange within subnets
- Nothing specified other than the ability to send and receive IP packets
- No distinction made between the Data Link, MAC, internal subnet Network layers

Internet Layer

- Provides connectionless service between hosts
- Receives IP packets from host on any subnet and delivers them to host on any other subnet (possibly out of order)
- The internetworking portion of the OSI network layer
- Routing and congestion control between subnets are the major issues

Transport Layer

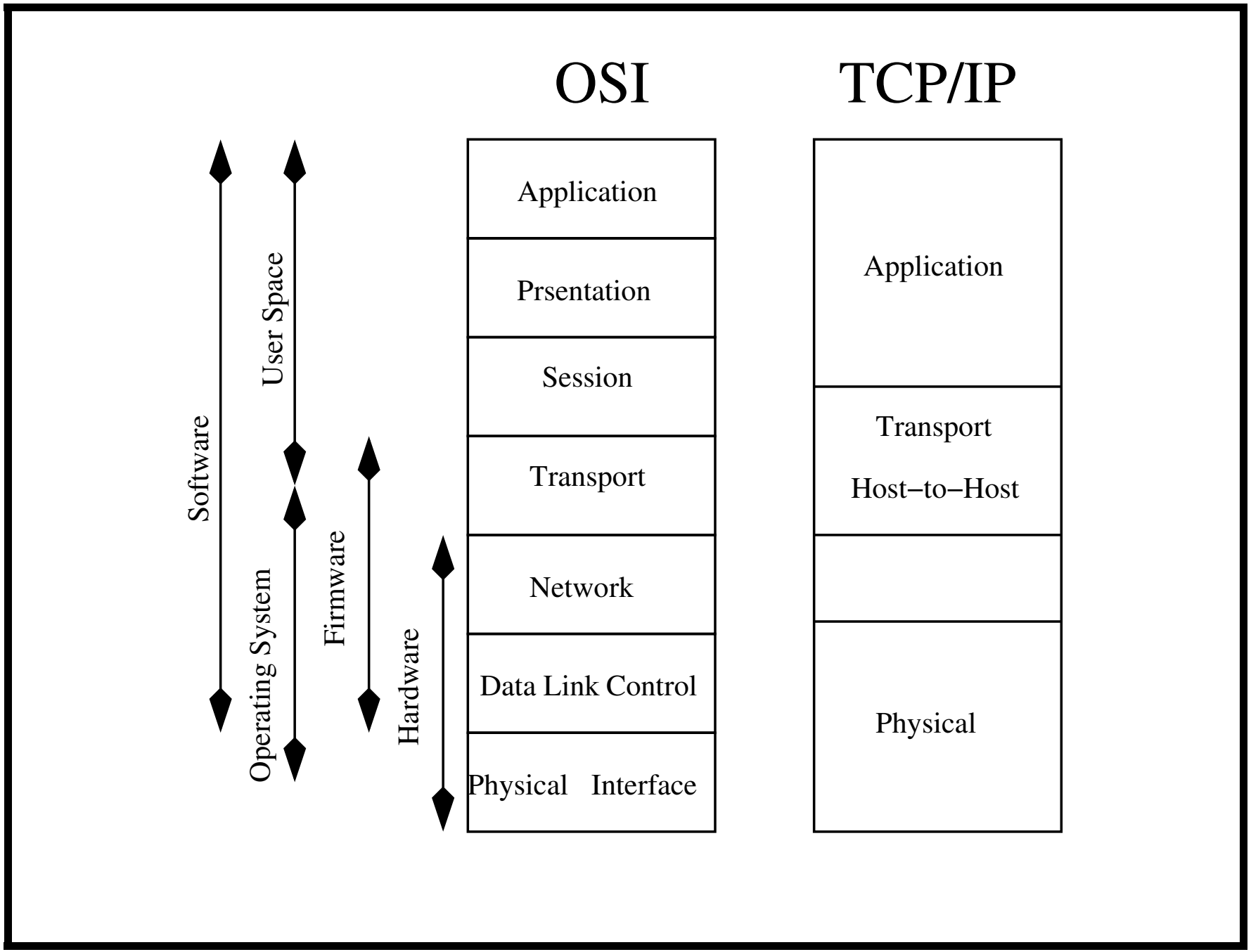
- Similar to OSI transport layer (packetization, error recovery)
- Provides two end-to-end protocols
  - TCP - Transmission Control Protocol - reliable connection-oriented service with flow control
  - UDP - User Datagram Protocol - unreliable connectionless service

Application Layer

- No presentation or session layers
- Examples of application layer protocols are
  - Telnet,
  - FTP,
  - SSH,
  - E-mail,
  - HTTP.

Comparison of OSI and TCP/IP

- OSI
  - Clean, thought out, explicit OO design
  - Not biased towards any protocol
  - Good for discussion but bad for implementation (too many layers)
- TCP/IP
  - Dirty afterthought to already developed protocol
  - Lower layers unspecified
  - Sloppy but practical


OSI
TCP/IP
Application
Prsentation
Session
Transport
Network
Data Link Control
Physical Interface
Application
Transport
Host–to–Host
Physical
Software
User Space
Operating System
Firmware
Hardware

Current and Future Trends

September 12, 2020

Robustness of Layering

- Keep in mind that layering is meant to provide guidance in computer network design.
- It is used in "copy, adapt, and use" manner:
  - *copy:* because you copy from older designs
  - *adapt:* because you modify designs in a new computer network, and
  - *use:* because you use it in the new network.
- Layering is "present" but"invisible" in all networks current and future.
- As such layering has proved to be robust.
- In some instances you can avoid layering when you design "overlay" networks. Nevertheless your network design "exists" between some of the OSI layers.

Current and Future Trends

- High Speed Networking
- Mobility
- Virtual Machines
- Intelligent Agents
- Ubiquitous Computing
- Pervasive Computing
- Wireless/Ad-hoc/Sensor Networks
- Satellite Networks
- Quantum Networks

High Speed Networking

- Integration of voice, video, data
- Optical media
- ATM (Asynchronous Transfer Mode)
- Gigabit Ethernet
- Trend towards "smart" networks

Mobility

- Wireless - untethered, eg, cordless phone
- Nomadic - geographic flexibility, e.g., extension phone
- Mobile - user in motion, e.g., car phone
- From wireless LAN to Teledesic (Satellite)

Virtual Machine Layer

- A layer between transport and application built into operating systems (JAVA).
- Network computers
- Functionality in the network not at the desktop
- Dynamic deployment of applications solves "Who goes first" problem

Intelligent Agents

- Autonomous active software
- Making appointments
- Suggesting purchases
- Intelligent search engines

Ubiquitous Computing

- Anytime, anywhere computing
- Computers as common as TVs and telephones
- Wearable computers? (Cyberborg)
- Virual Reality Apps (e.g., Augmented Reality)
- Convergence of computing and communications

Satellite Networks: SpaceX[a]

- September, 3, 2020: 12th batch of satellites launched.
- Has launched 715 Starlink satellites so far.
- Plans to put nearly 12,000 satellites in orbit and possibly expand to as many as 42,000.
- Goal is to provide internet around the world, particularly in areas where access has so far been unreliable or nonexistent.
- How fast data travels from the satellites to customers, and then back to the rest of the internet?
- Tests indicate download speeds higher than 100 Mbs per second. SpaceX has promised that Starlink will eventually be able to provide Gbs speeds once more satellites are operating.

[a]New Scientist, Sep 11, 2020

Quantum Networks

- Quantum networks are more secure than regular networks, because they rely on the quantum properties of photons, rather than computer code that can be cracked.
- Can build quantum networks using multiplexing "entanglement": a quantum property that links a pair of photons, so that measuring one of them instantly influences the measured state of the other, regardless of distance.
- Rather than connecting users one-to-one, multiplexing entanglement splits photons from a single laser according to their wavelength.
- Each wavelength can hold a data stream, meaning the system could support between 50 and 100 users with existing hardware
- Despite this, building one is still expensive.

Exercises[a]

1. What are some reasons for using layering?
2. What are some reasons for using layered protocols?
3. Is there a reason when building a new network architecture to design it from scratch?
4. In what sense is the principle of layering robust?
5. What is the principal difference between connectionless communication and connection-oriented communication?
6. The Internet is roughly doubling in size every 18 months. Although no one really knows for sure, one estimate put the number of hosts on it at 100 million in 2001. Use these data to compute the expected number of Internet hosts in the year 2020. Do you believe this? Explain why or why not.

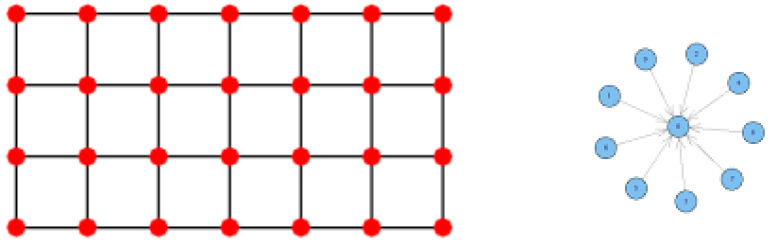
[a] Not to hand in!

7. IoT (Internet of Things) has the ability to connect everything to the internet. What layers of PSI would be affected the most and why"
8. List two advantages and two disadvantages of having international standards for network protocols.
9. Make a list of activities that you do every day in which computer networks are used. How would your life be altered if these networks were suddenly switched off?
10. The subnet below was designed by Paul Baran (RAND Corporation) to withstand a nuclear war!

How many bombs would it take to partition the nodes into two

disconnected sets? Assume that any bomb wipes out a node and all of the links connected to it.

11. Same as Exercise 10 for the two networks depicted below.



12. Assume that a bomb wipes out only a link (and the vertices adjacent to this link survive). Consider the networks depicted in Exercises 10 and 11. How many bombs would it take to partition the nodes into two disconnected sets?

13. Wireless networks are easy to install, which makes them inexpensive since installation costs usually far overshadow equipment costs. Nevertheless, they also have some disadvantages. Name a few of them.

14. Recall the network types discussed: from High Speed, Mobile, Virtual, Intelligent Agents, Ubiquitous, Pervasive, to Wireless/Ad-hoc/Sensor and Social Networks. Which layer(s) are most used in each type of network?[b]

15. Each of the network types listed in this lecture represents a class of networks with its own design philosophy. Search the internet under each name and identify its characteristics, positive aspects and drawbacks.

[b] Must have good understanding of network technologies to answer this question.