

Computer Networks

EE-5281

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What We Know

- Networks are
 - Experiencing explosive **growth**
 - Providing wide range of **services**
- It is attributed to:
 - **General purpose** nature of computer networks
 - Ability to add new functionality with **software**
 - High performance computers are now **affordable**

and We Know ...

- Connecting mainframes over long-distance telephone lines has turned into a **big business!**
- Lots of **competing players**
 - Computing industry
 - Telephone carriers
 - Service providers, operators, ...
- Global, **ubiquitous**, heterogeneous networking ?
 - Issues of connectivity, service levels, performance, ...

What We Have Learned

- Carefully **identify** what we expect from a network
- Cost-effective connectivity
 - Accomplished through **nested interconnection** of nodes and links
 - Provides **process-to-process** communication services
 - Should offer **high performance** using the metrics like latency and throughput
- This results in a **packet-switched** network

What is Our Approach

- A **layered architecture** as a guideline for design
- **Protocols** are central objects
 - Provides **services** to higher-level protocols
 - Make a message exchange **meaningful** with peers
- **Implement** protocols in software
 - Define **interfaces** to invoke services
 - **Socket** interface between applications and protocols
 - “Similar” interface within the network subsystem

What Next ?

Start with a **simplest** possible network

Two nodes **connected directly**
through some suitable medium

Point-to-Point Links

Reading: Peterson and Davie, Ch. 2

Outline

Hardware building blocks

Encoding

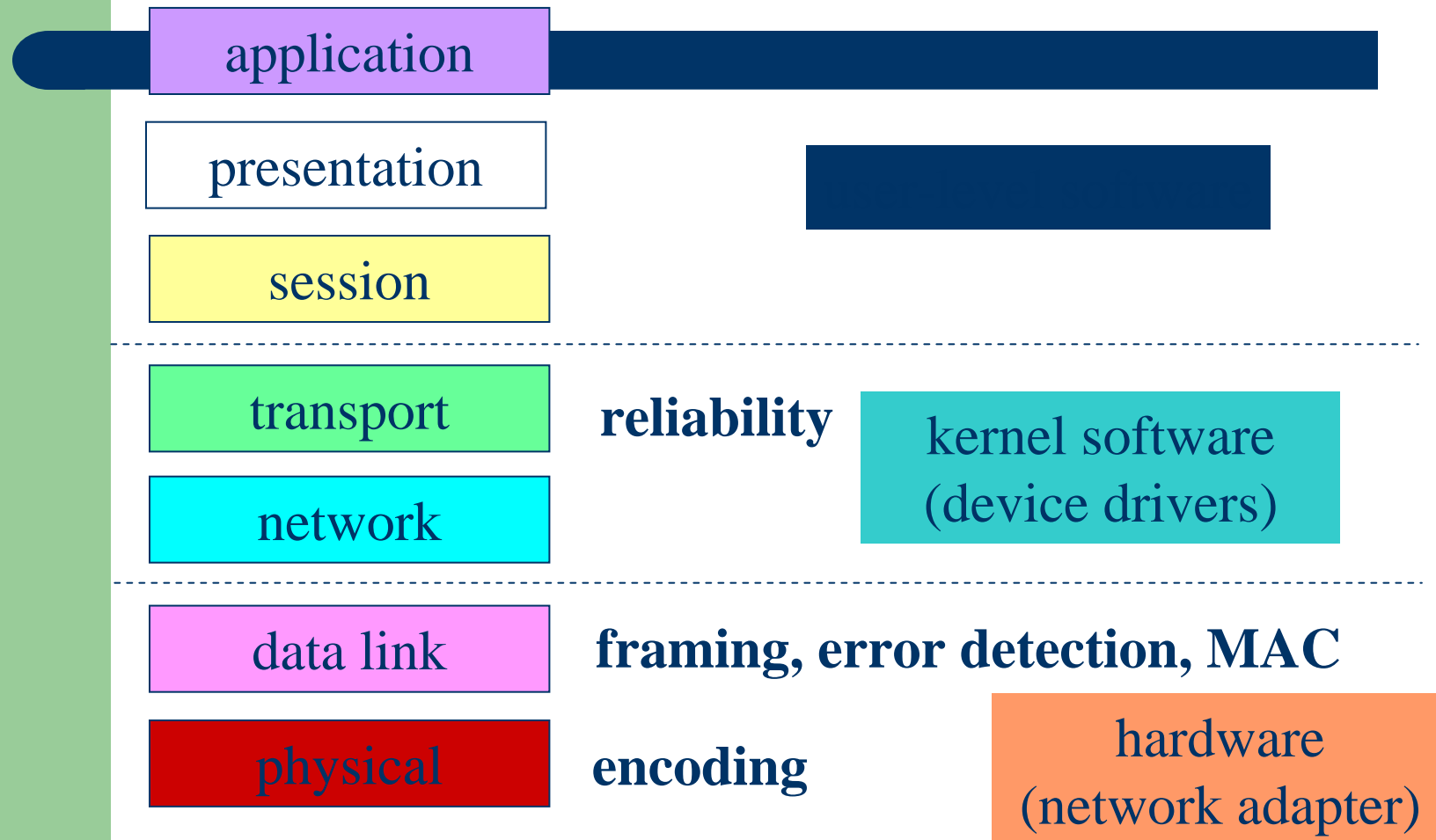
Framing

Error Detection

Reliable transmission

- Sliding Window Algorithm

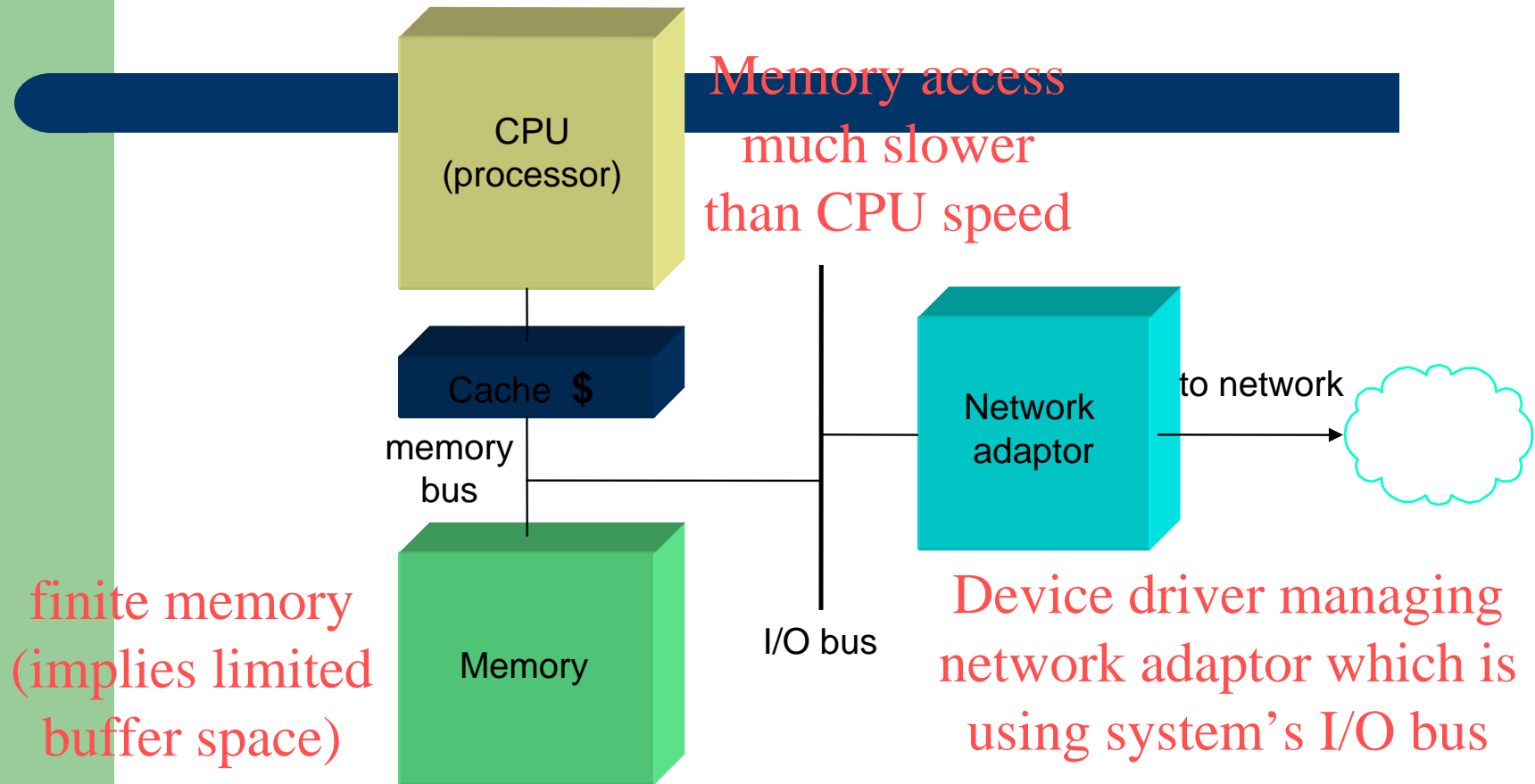
Direct Link Issues in the OSI and Hardware/Software Contexts



Hardware Building Blocks

- Nodes
 - **Hosts**: general-purpose computers
 - **Switches**: typically special-purpose hardware
 - **Routers** (connecting networks): varies
- Links
 - Copper **wire** with electronic signaling
 - Glass **fiber** with optical signaling
 - **Wireless** with electromagnetic (radio, infrared, microwave) signaling

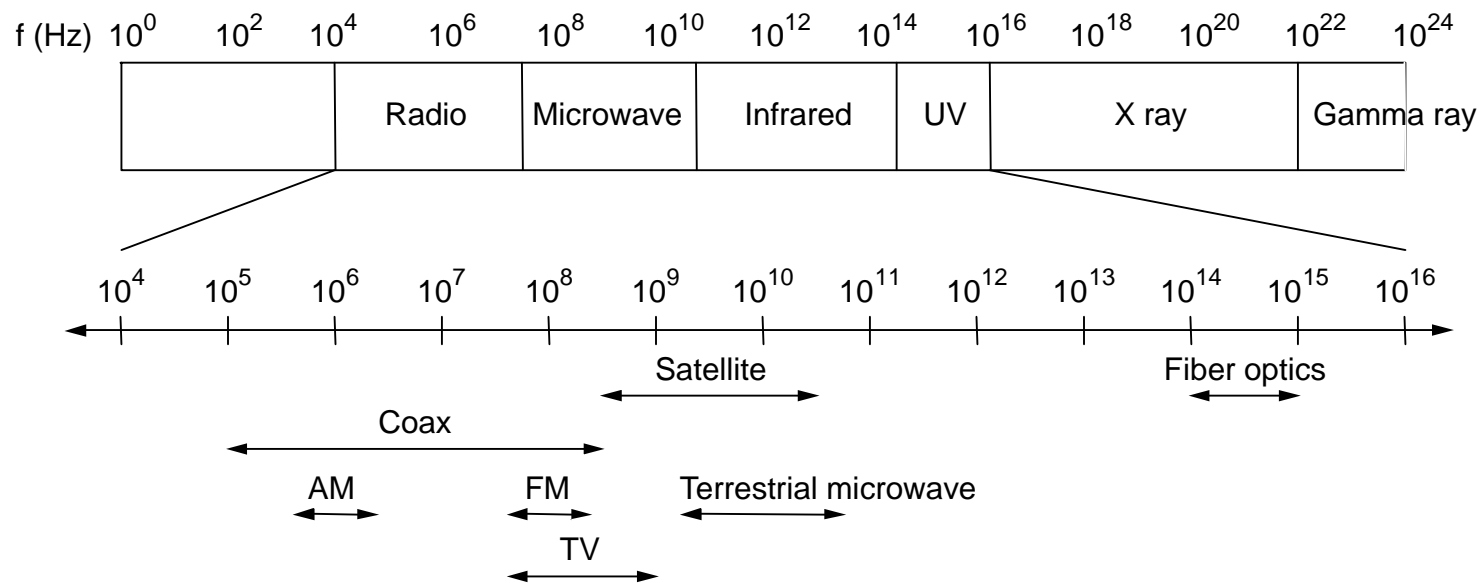
Nodes – A Workstation Architecture



Links

- Physical media
 - twisted pair cable
 - coaxial cable
 - optical fiber
 - space
- Media is used to propagate **signals**
- Signals are electromagnetic waves of certain **frequency**, traveling at speed of light

Electromagnetic Spectrum



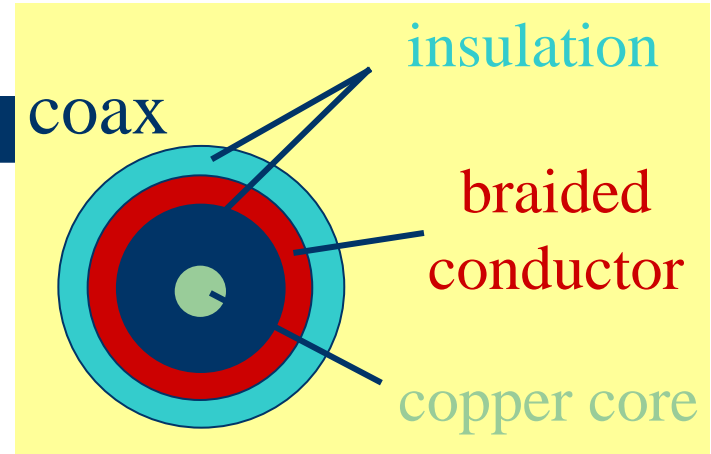
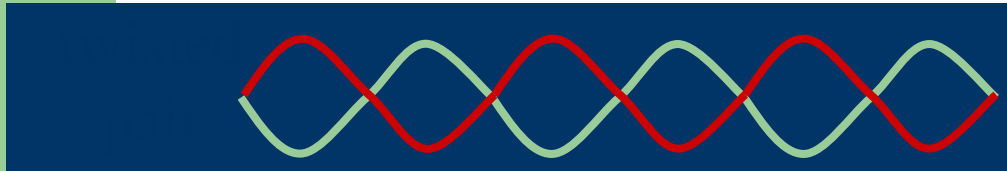
$$\begin{aligned}
 \text{Wavelength} &= \text{speed/frequency} \\
 &= 2 \times 10^8 / 300 \\
 &= 667 \text{ meters}
 \end{aligned}$$

Signals Over a Link

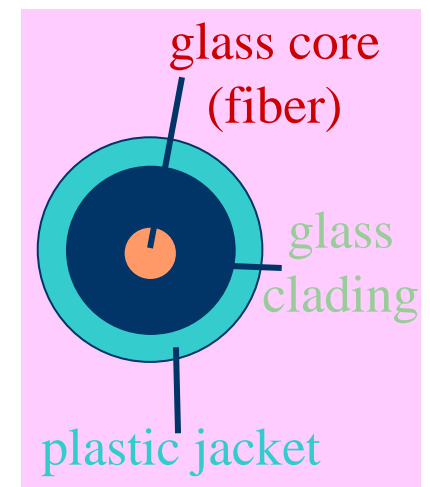
- Signal is **modulated** for transmission
 - varying freq/amp/ph to receive distinguishable signals
- Binary data (0s and 1s) is **encoded** in a signal
 - make it understandable by the receiving host
- Bit streams may be **transmitted** both ways at a time on a point-to-point link
 - full-duplex
- Sometimes two nodes must alternate link usage
 - half duplex

Which Link to Use ?

- Cables
 - same room / building / site



Cable	Typical Bandwidths	Distances
Cat-5 twisted pair	10-100 Mbps	100 m
Thin-net coax	10-100 Mbps	200 m
Thick-net coax	10-100 Mbps	500 m
Multimode fiber	100 Mbps	2 km
Single-mode fiber	100-2400 Mbps	40 km



Which Link to Use ?

- Leased lines
 - across city / country
 - dedicated link from the telephone company
 - appears, but **may not be a single link !!!**

Service:	DS1/T1	DS3	STS-1	STS-3	STS-12	...	STS-48
Bandwidth:	1.5M	44.7M	51.8M	155M	622M	...	2.5G
(bps)							

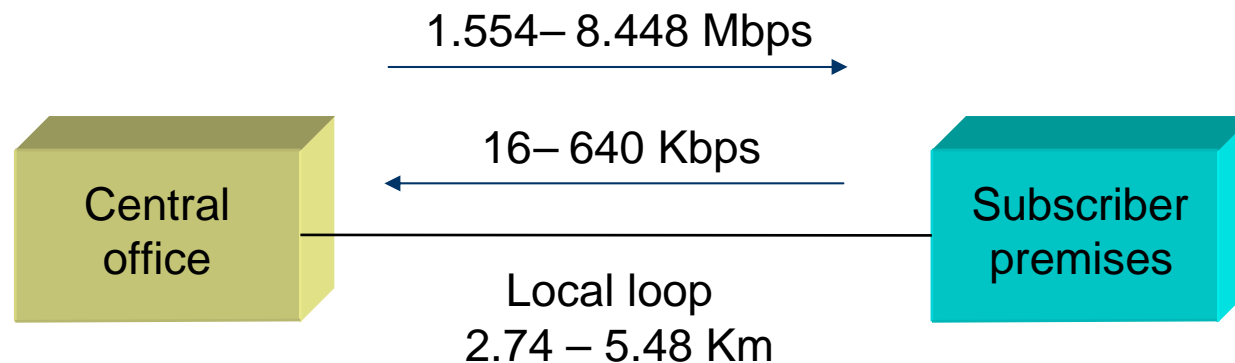
Which Link to Use ?

- Last-mile links
 - most economical
 - home to network service provider
 - to take benefit of an **existing** network

Service:	POTS	ISDN	xDSL	CATV
Bandwidth: (bps)	28.8 - 56 K	64 - 128 K	16 K - 55.2 M	20 – 40 M

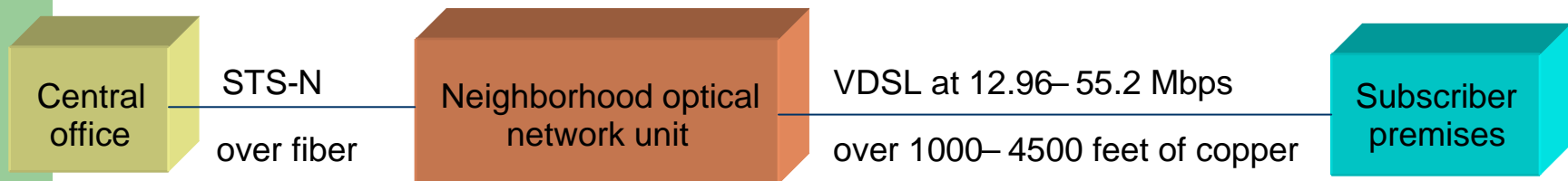
ADSL (Asymmetric Digital Subscriber Line)

- Connects the subscriber to the central office via the **local loop**
- Bandwidth depends on length of local loop



VDSL (Very high data rate DSL)

- Connects the subscriber to the optical network that reaches the neighborhood
- Runs over **short distances**
- Symmetric



CATV

- Uses existing cable TV (CATV) infrastructure
 - reaches 95% of households in U.S.
- Single CATV channel has **bandwidth of 6 MHz**
- Can be used in asymmetric way
- Currently achieves on a single channel:
 - 40 Mbps downstream (100 Mbps theory.)
 - 20 Mbps upstream
- Multiple access on **shared channel** (IEEE 802.14)

Optical Communication

- Higher bandwidths
- Superior attenuation properties
- Immune from electromagnetic interference
- No cross-talk between fibers
- Thin, lightweight and cheap (the fiber, not the optical-electrical interfaces)

Wireless Links

- Satellite links

- Provide a grid of medium- and low-orbit satellites
 - Geosynchronous satellite 600-1000 Mbps
 - Low Earth Orbit (LEO) array ~400 Mbps
- Targeted at voice communication \Rightarrow modems
- Teledesic supports 1440 16 kbps satellite-to-earth channels (~2 Mbps); 155.5 Mbps intersatellite channels

- Radio and infra-red frequency links

- 11 Mbps rates, 2.4 GHz band, distances of 50-150 meters
 - 5.2 GHz band, > 55 Mbps: HIPERLAN-1, IEEE 802.11a
- Bluetooth piconets: Infrared links, 1 Mbps, 10 meters