inst.eecs.berkeley.edu/~cs61c

CS61C : Machine Structures

Lecture 38
I/O : Networks

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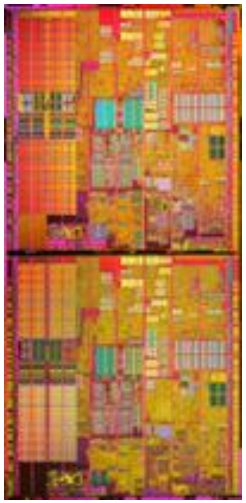
Now "Dual core" processors ⇒



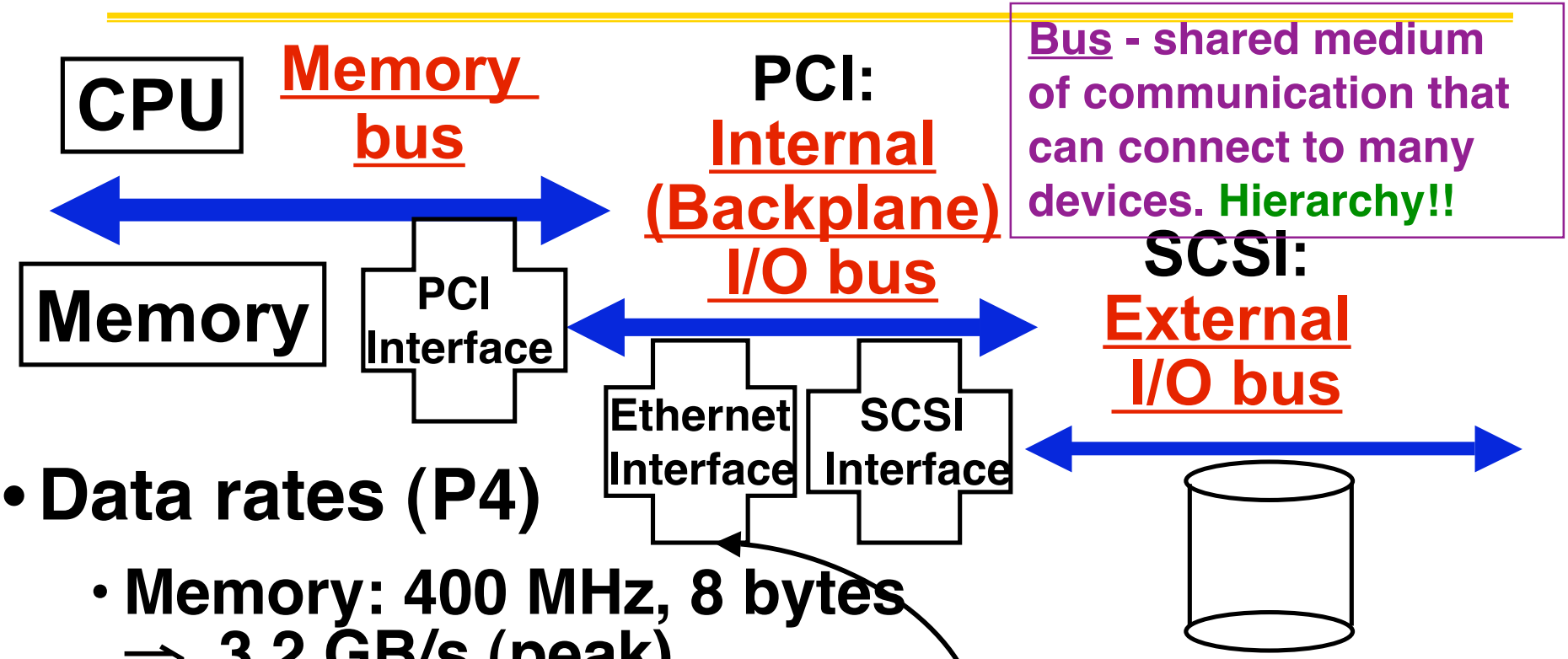
Intel has found a way to achieve more performance out of their chips – go parallel. They've introduced "dual core" technology, i.e., 2 CPUs on a die. This is similar to multiprocessing, but on 1 die.

www.intel.com/technology/computing/dual-core/

I/O Review

- I/O gives computers their 5 senses
- I/O speed range is 12.5-million to one
- Processor speed means must synchronize with I/O devices before use
- Polling works, but expensive
  - processor repeatedly queries devices
- Interrupts works, more complex
  - devices causes an exception, causing OS to run and deal with the device
- I/O control leads to Operating Systems

Buses in a PC: connect a few devices (2002)

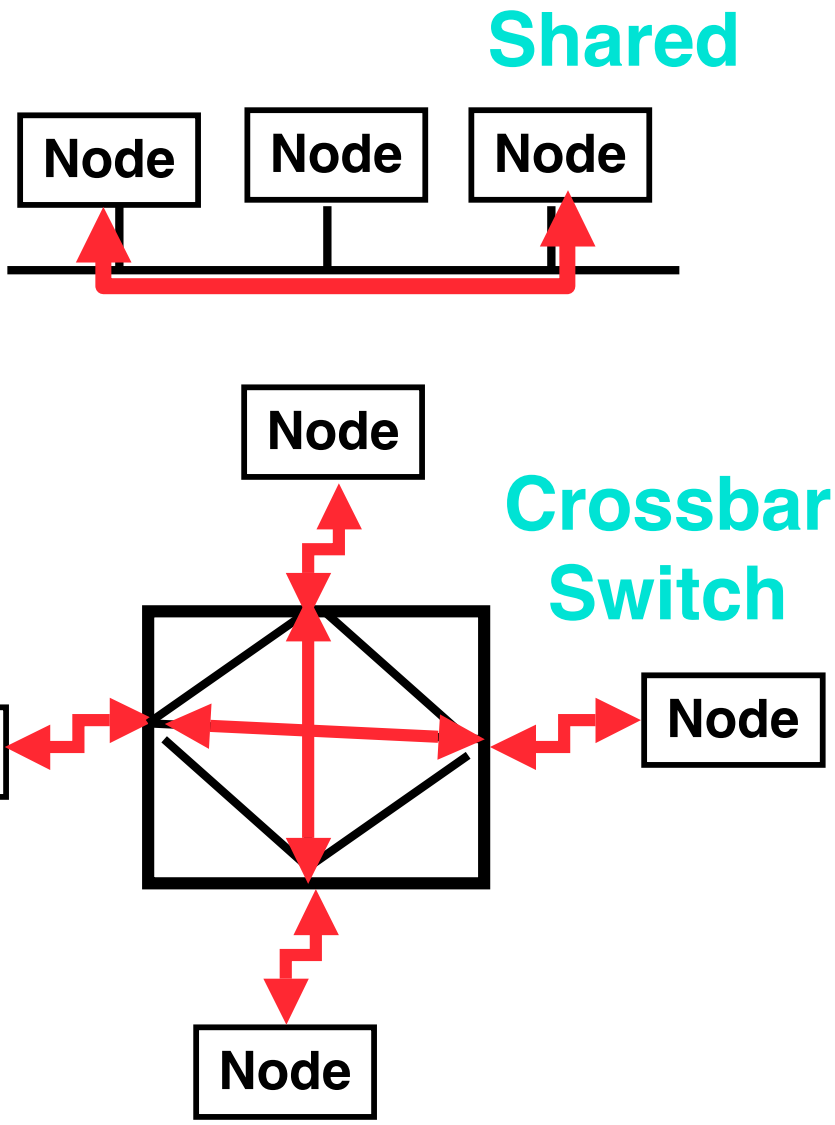


- Data rates (P4)
  - Memory: 400 MHz, 8 bytes
    ⇒ 3.2 GB/s (peak)
  - PCI: 100 MHz, 8 bytes wide
    ⇒ 0.8 GB/s (peak)
  - SCSI: "Ultra4" (160 MHz), "Wide" (2 bytes)
    ⇒ 0.3 GB/s (peak)

Ethernet:
⇒ 0.125 GB/s (peak)

Shared vs. Switched Based Networks

- Shared Media vs. Switched: in switched, pairs ("point-to-point" connections) communicate at same time; shared 1 at a time
- Aggregate bandwidth (BW) in switched network is many times shared:
  - point-to-point faster since no arbitration, simpler interface



Why Networks?

- Originally sharing I/O devices between computers
  (e.g., printers)
- Then Communicating between computers
  (e.g, file transfer protocol)
- Then Communicating between people
  (e.g., email)
- Then Communicating between networks of computers
  ⇒ File sharing, WWW, …

How Big is the Network (2005)?

~30 Computers in 273 Soda

~525 in inst.cs.berkeley.edu

~6,400 in eecs&cs .berkeley.edu

(1999) ~50,000 in berkeley.edu

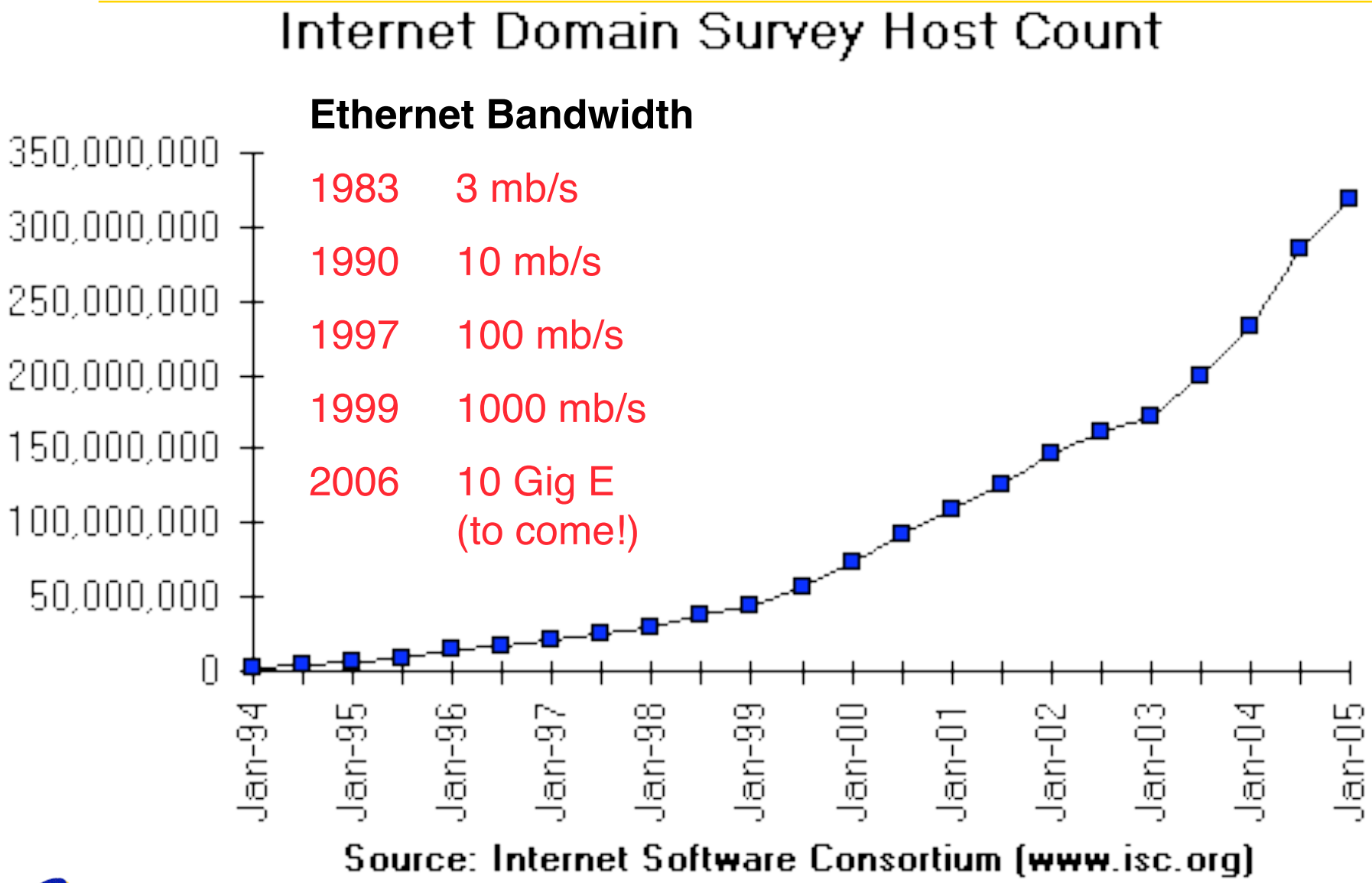
~9,000,000 in .edu

~217,000,000 in US
(.net .com .edu .arpa .us .mil .org .gov)

~318,000,000 in the world

Source: Internet Software Consortium: www.isc.org

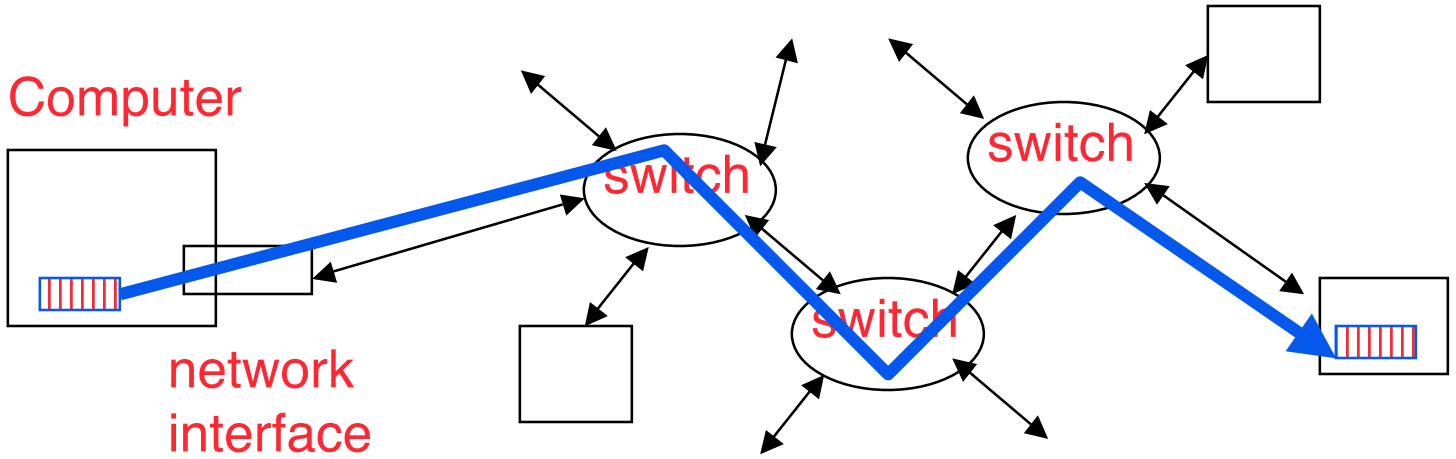
Growth Rate



en.wikipedia.org/wiki/10_gigabit_ethernet

What makes networks work?

- **links** connecting **switches** to each other and to computers or devices



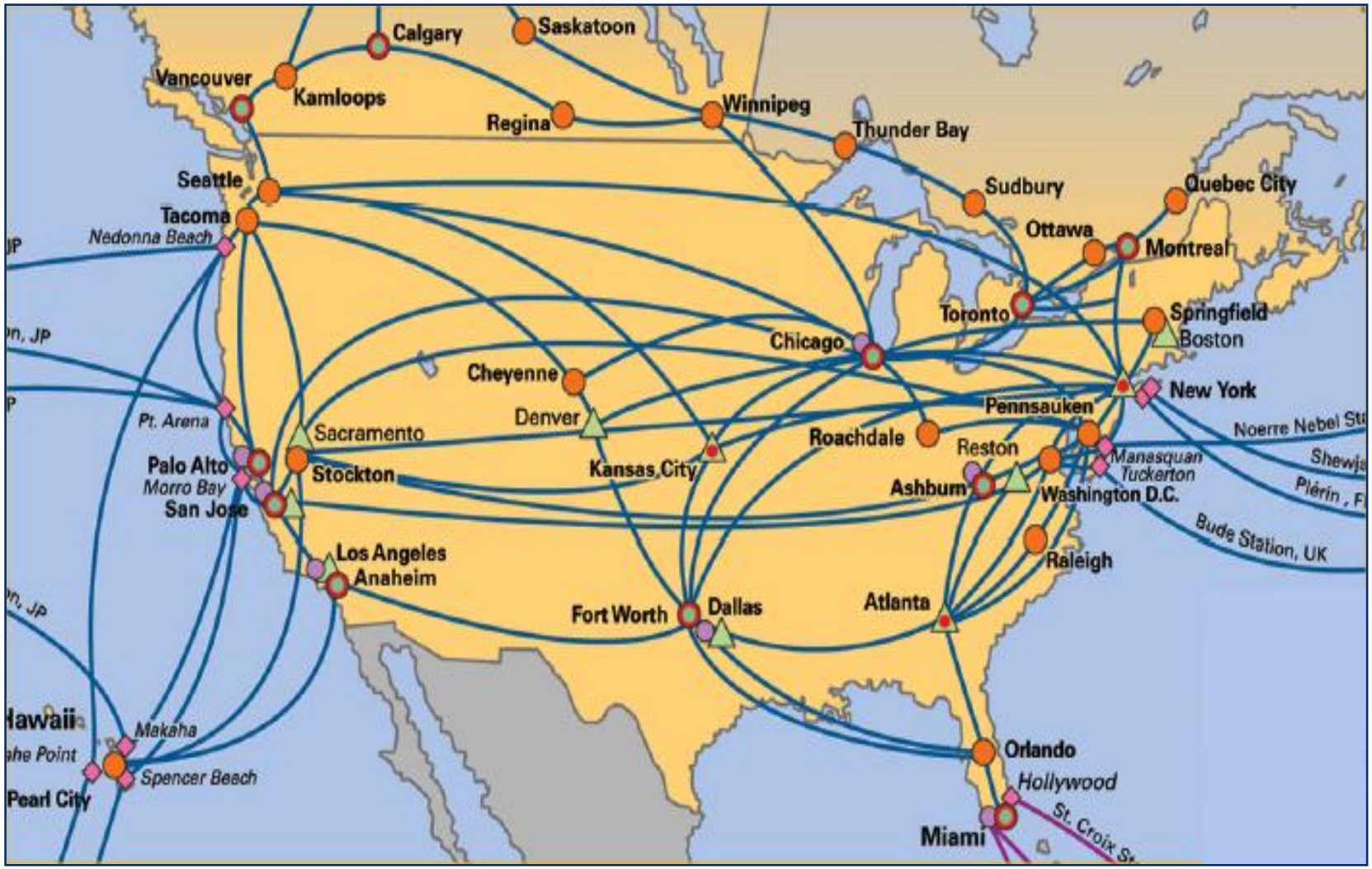
- ability to **name** the components and to **route** packets of information - messages - from a source to a destination

- Layering, protocols, and encapsulation as means of **abstraction** (61C big idea)

Typical Types of Networks

- Local Area Network (Ethernet)
  - Inside a building: Up to 1 km
  - (peak) Data Rate: 10 Mbits/sec, 100 Mbits /sec,1000 Mbits/sec (1.25, 12.5, 125 MBytes/s)
  - Run, installed by network administrators
- Wide Area Network
  - Across a continent (10km to 10000 km)
  - (peak) Data Rate: 1.5 Mb/s to 10000 Mb/s
  - Run, installed by telecommunications companies (Sprint, UUNet[MCI], AT&T)
- Wireless Networks (LAN), ...

The Sprint U.S. Topology (2001)



Upcoming Calendar

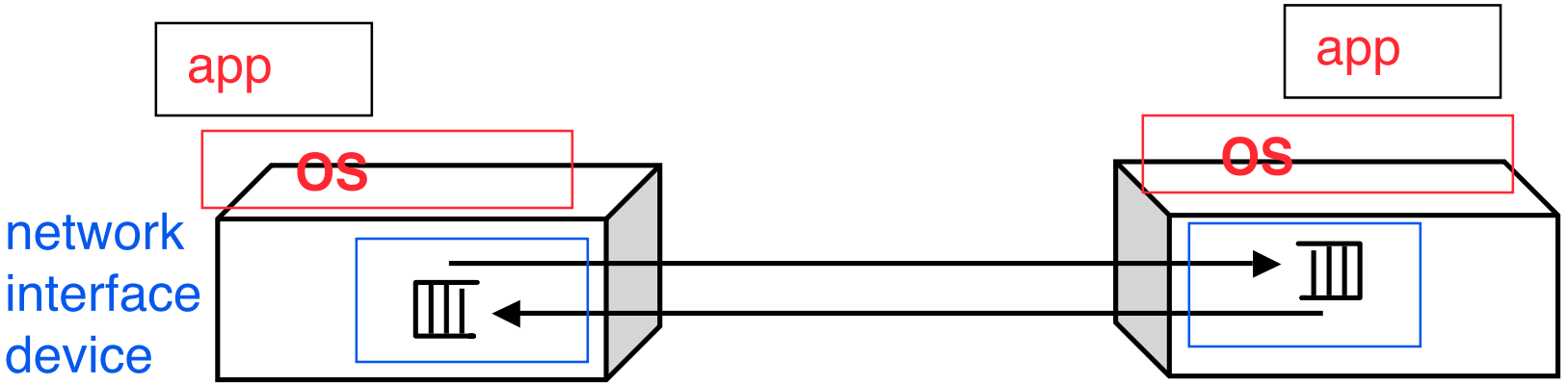
Week #	Mon	Wed	Thu Lab	Fri
#14 This week	I/O Basics	I/O Networks	I/O Simulation (No Dan OH)	TA Casey I/O Disks
#15 Next week	Perfor-mance I	Perfor-mance II	I/O Networks	TA Andy TBD
#16 Last Week o' Classes Sun aft Review	LAST CLASS Summary Review & HKN Evals			FINAL EXAM SAT 05-14 @ 12:30pm

Administrivia

- Remember, Dan will be at the Faculty Retreat and not have OH tomorrow
  - He WILL have OH today right after lecture

ABCs of Networks: 2 Computers

- **Starting Point: Send bits between 2 computers**



- **Queue (First In First Out) on each end**
- **Can send both ways ("Full Duplex")**
  - **One-way information is called "Half Duplex"**
- **Information sent called a "message"**
  - **Note: Messages also called packets**

A Simple Example: 2 Computers

- What is Message Format?
  - Similar idea to Instruction Format
  - Fixed size? Number bits?

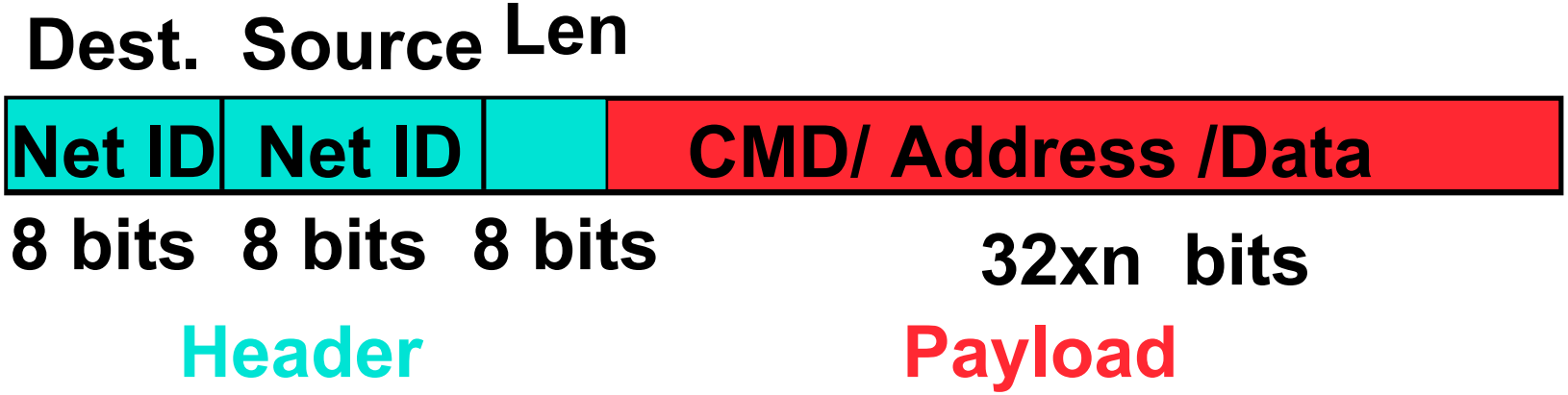
8 bit

32 x Length bits

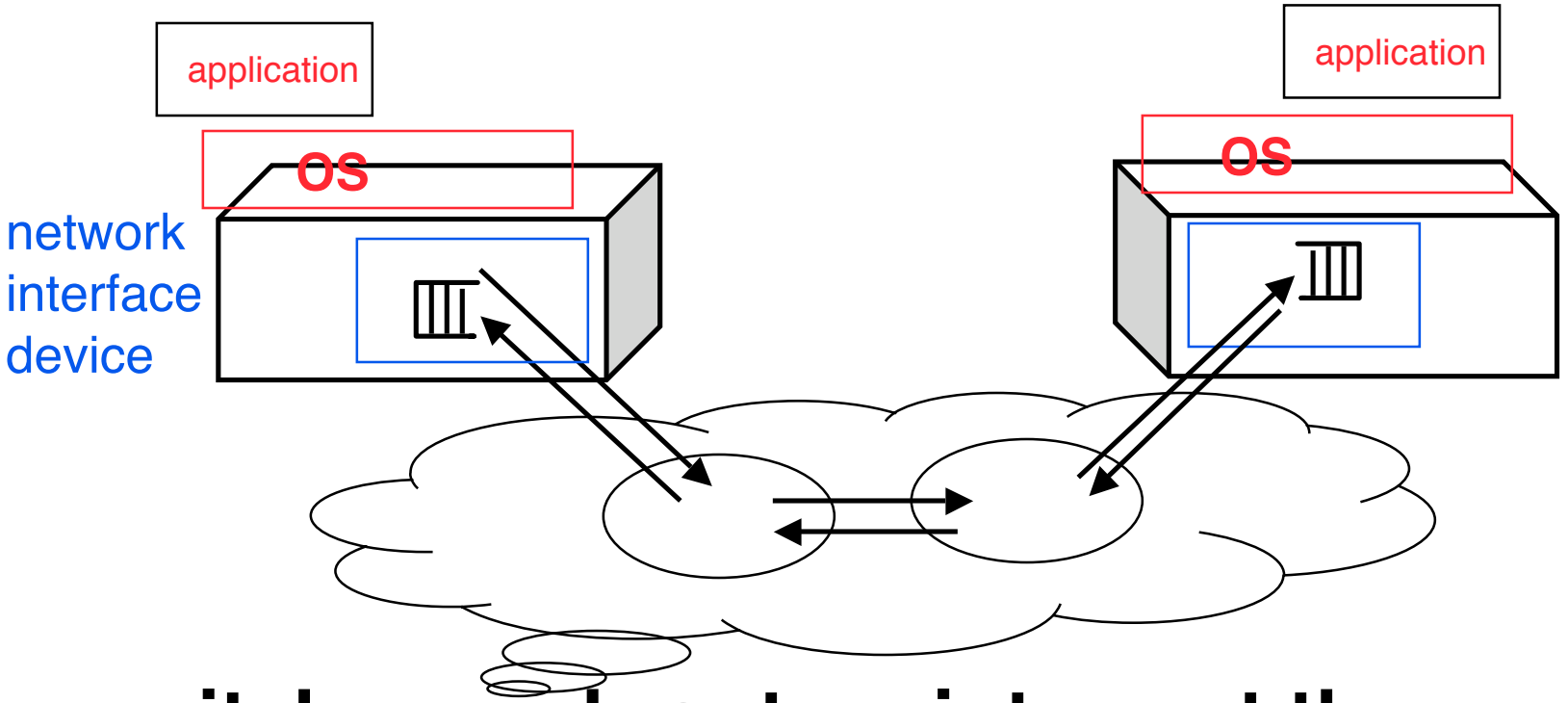
- Header(Trailer): information to deliver message
- Payload: data in message
- What can be in the data?
  - anything that you can represent as bits
  - values, chars, commands, addresses...

Questions About Simple Example

- What if more than 2 computers want to communicate?
  - Need computer "address field" in packet to know which computer should receive it (destination), and to which computer it came from for reply (source) [just like envelopes!]



ABCs: many computers



- switches and routers interpret the header in order to deliver the packet
- source encodes and destination decodes content of the payload

Questions About Simple Example

- What if message is garbled in transit?
- Add redundant information that is checked when message arrives to be sure it is OK
- 8-bit sum of other bytes: called "Check sum"; upon arrival compare check sum to sum of rest of information in message. `xor` also popular.

Math 55 talks about what a Check sum is…

Questions About Simple Example

- What if message never arrives?
- Receiver tells sender when it arrives (ack) [ala registered mail], sender retries if waits too long
- Don't discard message until get "ACK" (for ACKnowledgment);
  Also, if check sum fails, don't send ACK

Observations About Simple Example

- Simple questions such as those above lead to more complex procedures to send/receive message and more complex message formats
- Protocol: algorithm for properly sending and receiving messages (packets)

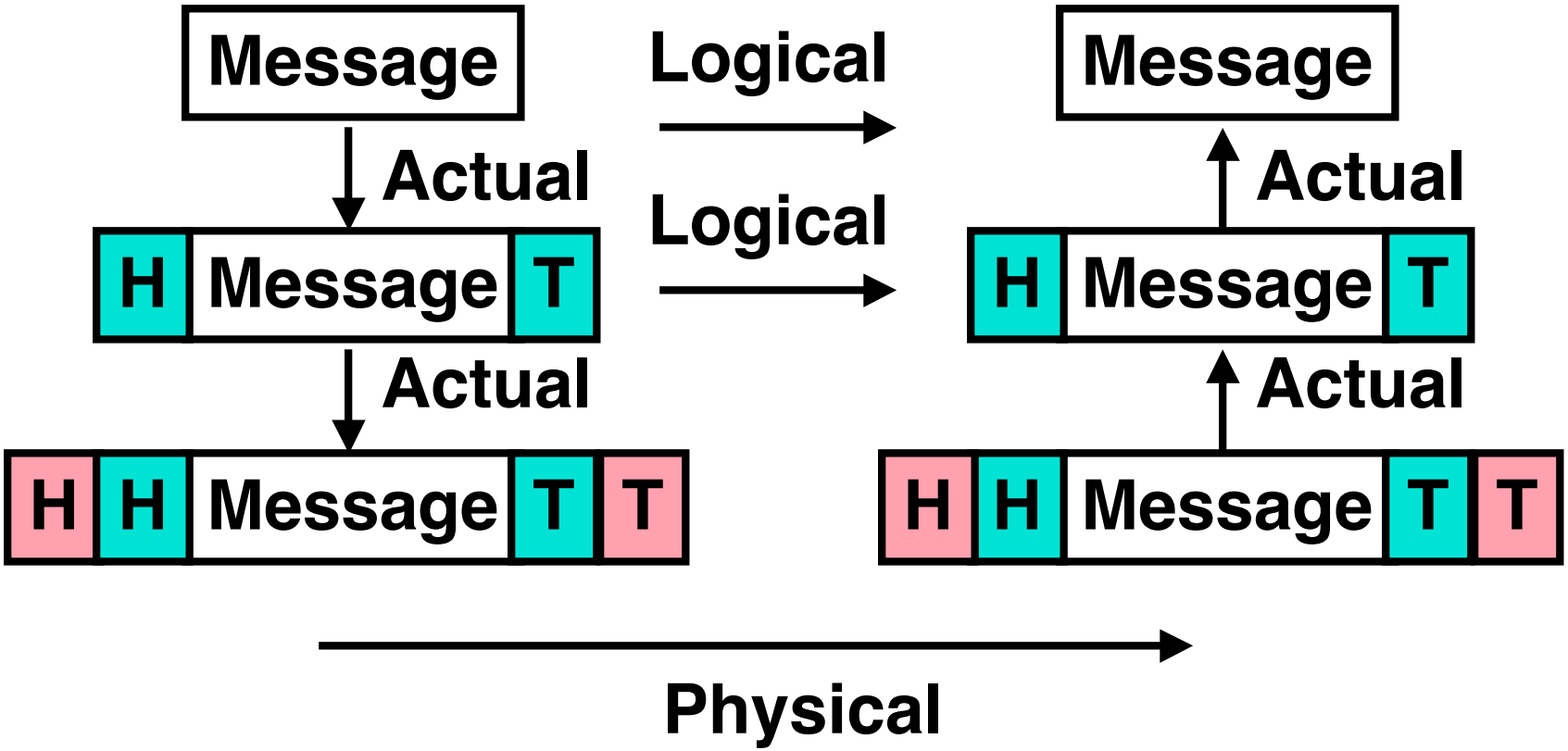
Software Protocol to Send and Receive

- SW Send steps
  - 1: Application copies data to OS buffer
  - 2: OS calculates checksum, starts timer
  - 3: OS sends data to network interface HW and says start
- SW Receive steps
  - 3: OS copies data from network interface HW to OS buffer
  - 2: OS calculates checksum, if OK, send ACK; if not, delete message (sender resends when timer expires)
  - 1: If OK, OS copies data to user address space, & signals application to continue

Protocol for Networks of Networks?

- Internetworking: allows computers on independent and incompatible networks to communicate reliably and efficiently;
  - Enabling technologies: SW standards that allow reliable communications without reliable networks
  - Hierarchy of SW layers, giving each layer responsibility for portion of overall communications task, called protocol families or protocol suites
- Abstraction to cope with complexity of communication vs. Abstraction for complexity of computation

Protocol Family Concept



Protocol Family Concept

- Key to protocol families is that communication occurs logically at the same level of the protocol, called peer-to-peer…

  …but is implemented via services at the next lower level

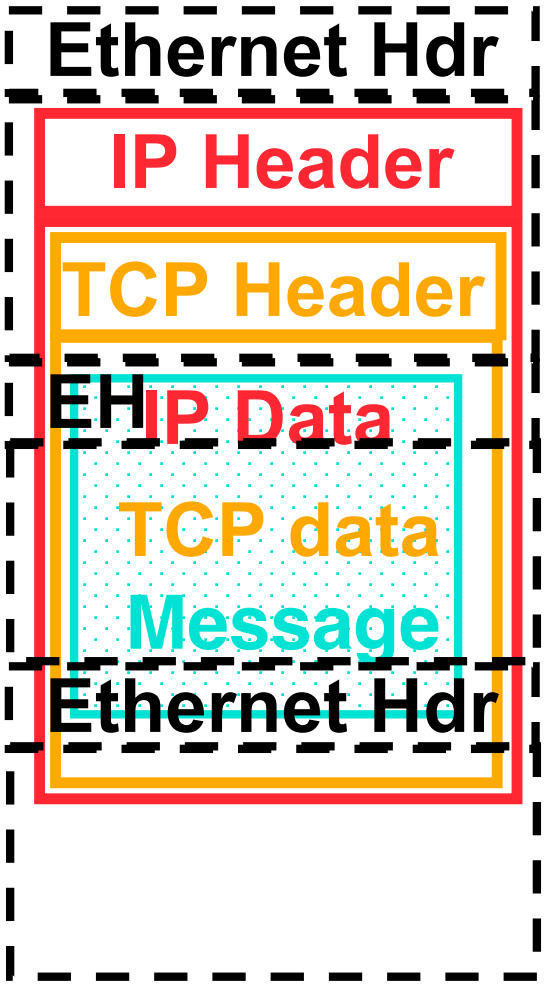
- Encapsulation: carry higher level information within lower level "envelope"
- Fragmentation: break packet into multiple smaller packets and reassemble

Protocol for Network of Networks

- Transmission Control Protocol/Internet Protocol (TCP/IP)
  - This protocol family is the basis of the Internet, a WAN protocol
  - IP makes best effort to deliver
  - TCP guarantees delivery
  - TCP/IP so popular it is used even when communicating locally: even across homogeneous LAN

TCP/IP packet, Ethernet packet, protocols

- Application sends message
- TCP breaks into 64KiB segments, adds 20B header
- IP adds 20B header, sends to network
- If Ethernet, broken into 1500B packets with headers, trailers (24B)
- All Headers, trailers have length field, destination, ...



Overhead vs. Bandwidth

- Networks are typically advertised using peak bandwidth of network link: e.g., 100 Mbits/sec Ethernet ("100 base T")
- Software overhead to put message into network or get message out of network often limits useful bandwidth
- Assume overhead to send and receive = 320 microseconds (μs), want to send 1000 Bytes over "100 Mbit/s" Ethernet
  - Network transmission time: 1000Bx8b/B /100Mb/s = 8000b / (100b/μs) = 80 μs
  - Effective bandwidth: 8000b/(320+80)μs = 20 Mb/s

Peer Instruction

(T / F) P2P filesharing has been the dominant application on many links!

Suppose we have 2 networks, Which has a higher effective bandwidth as a function of the transferred data size?

- BearsNet
  TCP/IP overhead 300 μs, peak BW 10Mb/s
- CalNet
  TCP/IP overhead 500 μs, peak BW 100Mb/s

TRUE

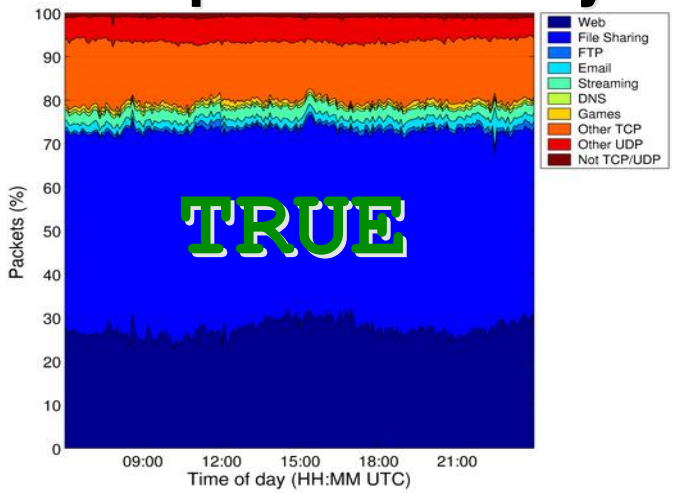
1: B always
2: C always
3: B small
   C big
4: B big
   C small
5: The same!

FALSE

6: B always
7: C always
8: B small
   C big
9: B big
   C small
0: The same!

Peer Instruction Answer

2002 Sprint Gateway link `http://ipmon.sprint.com/`



Dominates at small sizes

Dominates at big sizes

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	TRUE
1:	B always
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	FALSE
6:	B always
7:	C always
8:	B small C big
9:	B big C small
0:	The same!

And in conclusion…

- Protocol suites allow heterogeneous networking
  - Another form of principle of abstraction
  - Protocols ⇒ operation in presence of failures
  - Standardization key for LAN, WAN
- Integrated circuit ("Moore's Law") revolutionizing network switches as well as processors
  - Switch just a specialized computer
- Trend from shared to switched networks to get faster links and scalable bandwidth

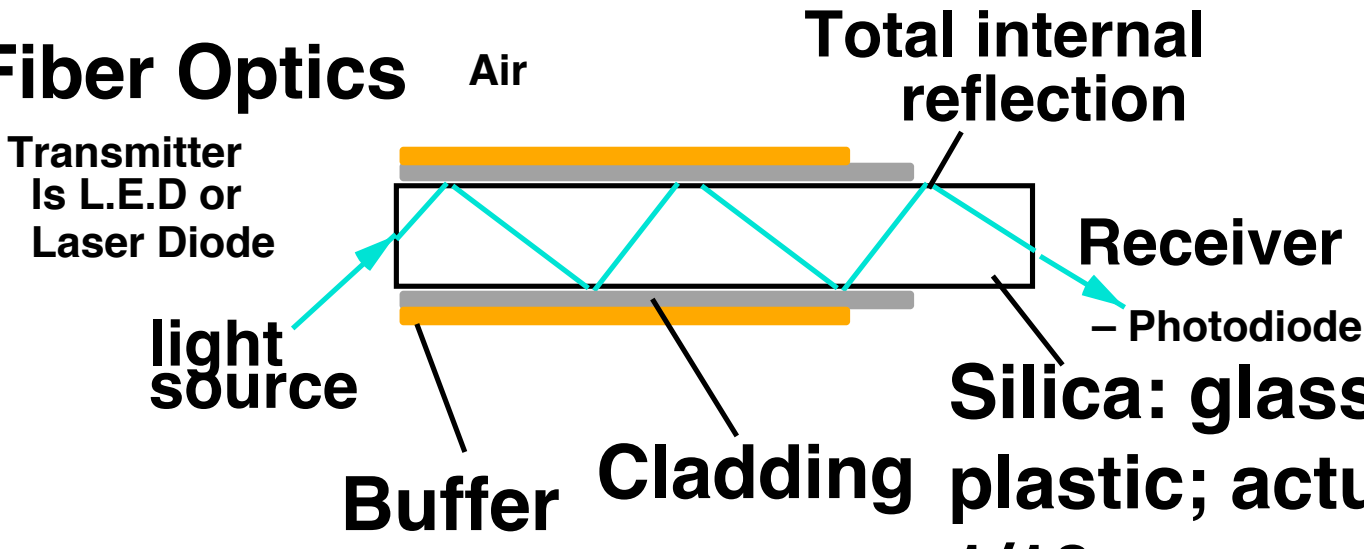
[Bonus] Example: Network Media

Twisted Pair ("Cat 5"):

Copper, 1mm think, twisted to avoid antenna effect

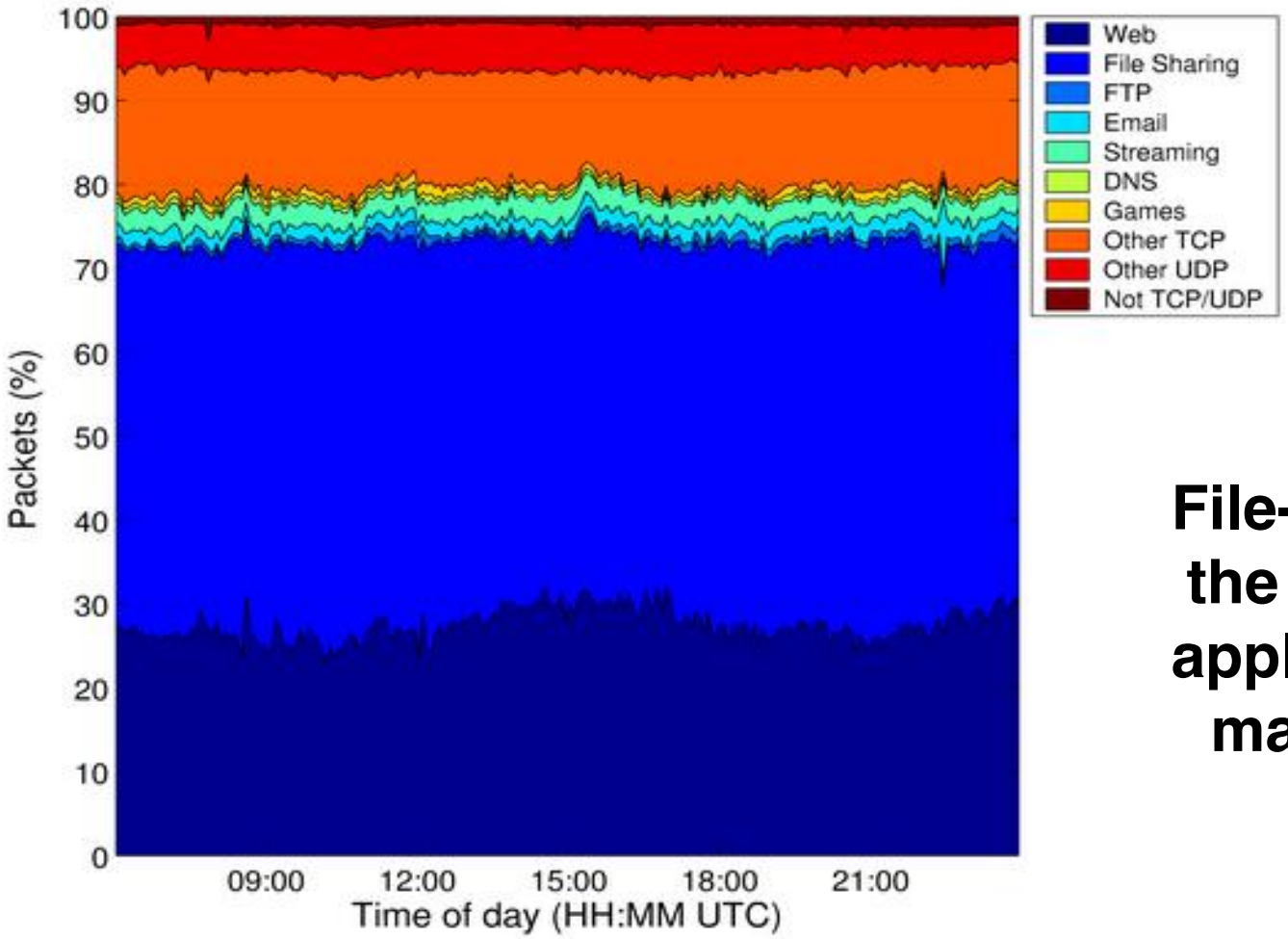
Light:
3 parts are cable, light source, light detector

Fiber Optics



Silica: glass or plastic; actually < 1/10 diameter of copper

[Bonus] Backbone Link App Composition



File-sharing is the dominant application on many links!