416 Distributed Systems

Networks review; Day 1 of 2

Jan 11, 2016

Distributed Systems vs. Networks

- Low level (c/go)
- Run forever
- Support others
- Adversarial environment
- Distributed & concurrent
- Resources matter

- And have it implemented/run by vast numbers of different people with different goals/skills

Keep an eye out for…

- Modularity, Layering, and Decomposition:
  - Techniques for dividing the work of building systems
  - Hiding the complexity of components from each other
  - Hiding implementation details to deal with heterogeneity
- Naming/lookup/routing
- Resource sharing and isolation

- Models and assumptions about the environment and components

Today’s Lecture

- Network links and LANs
- Layering and protocols
- Internet design

Basic Building Block: Links

- Electrical questions
  - Voltage, frequency, …
  - Wired or wireless?

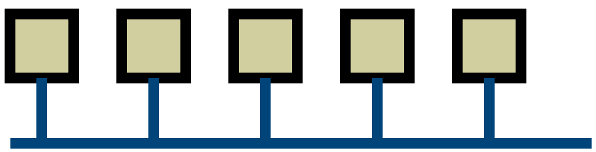
- Link-layer issues: How to send data?
  - When to talk – can either side talk at once?
  - What to say – low-level format?

Model of a communication channel

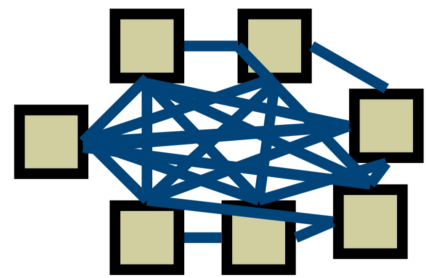
- Latency - how long does it take for the first bit to reach destination
- Jitter - how much variation in latency?
- Capacity - how many bits/sec can we push through? (often termed “bandwidth”)
- Loss / Reliability - can the channel drop packets?
- Reordering

Basic Building Block: Links

- … But what if we want more hosts?



One wire

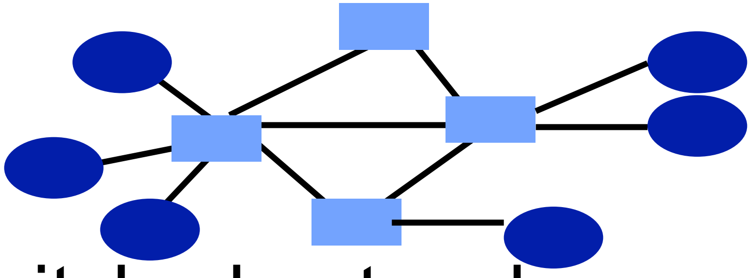


Wires for everybody!

- Scalability?!

Multiplexing

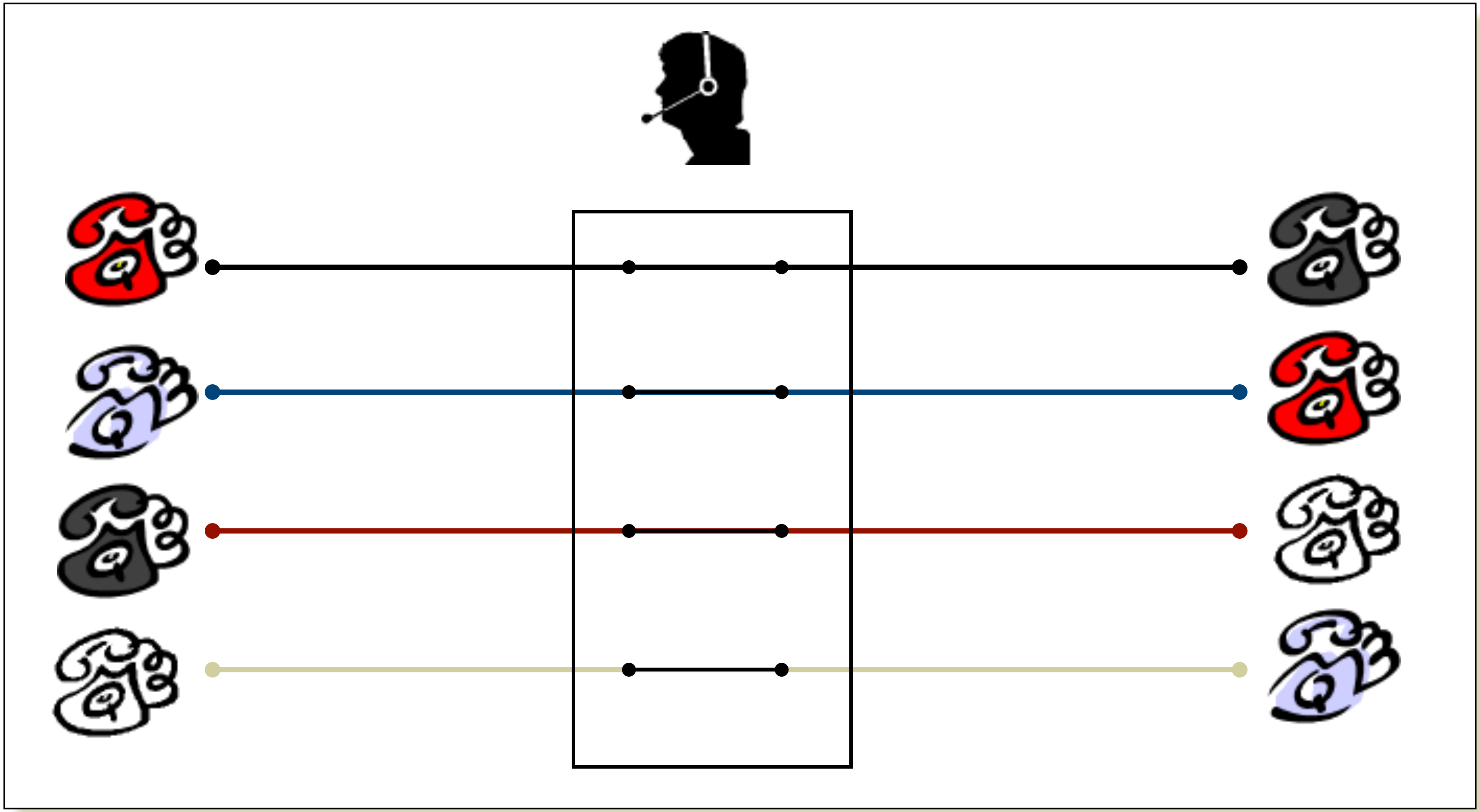
- Need to share network resources



- How? Switched network
  - Party “A” gets resources sometimes
  - Party “B” gets them sometimes
- Interior nodes act as “Switches”

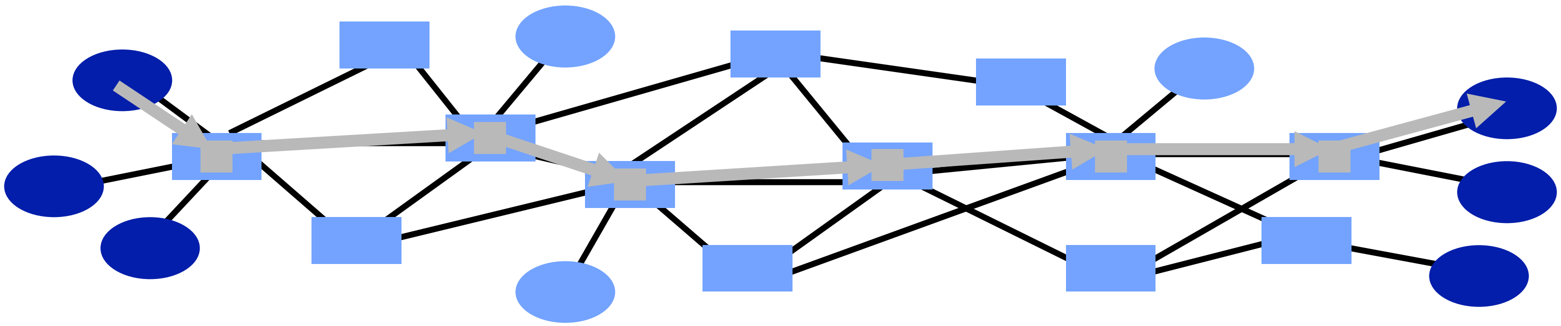
- What mechanisms to share resources?

In the Old Days…Circuit Switching

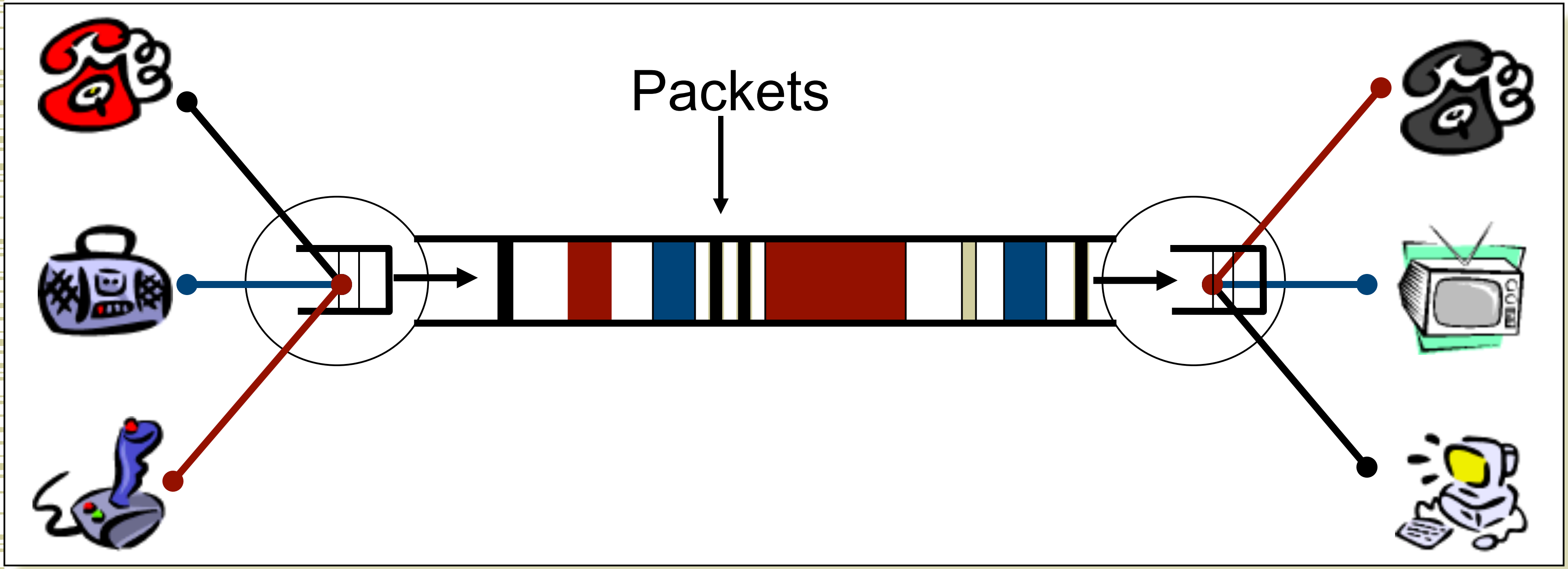


Packet Switching

- Source sends information as self-contained packets that have an address.
  - Source may have to break up single message in multiple
- Each packet travels independently to the destination host.
  - Switches use the address in the packet to determine how to forward the packets
  - Store and forward
- Analogy: a letter in surface mail.



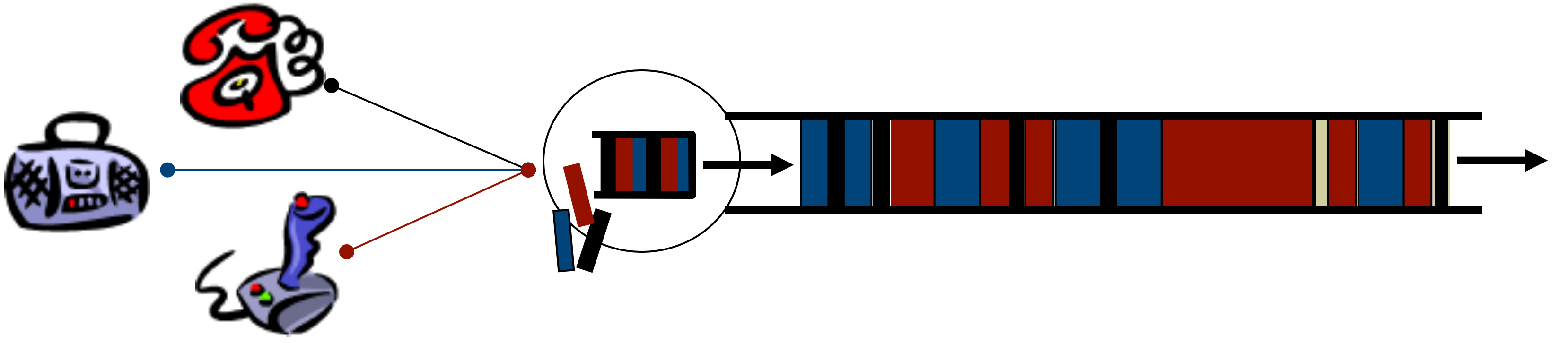
Packet Switching – Statistical Multiplexing



- Switches arbitrate between inputs
- Can send from *any* input that's ready
  - Links never idle when traffic to send
  - (Efficiency!)

What if Network is Overloaded?

Problem: Network Overload

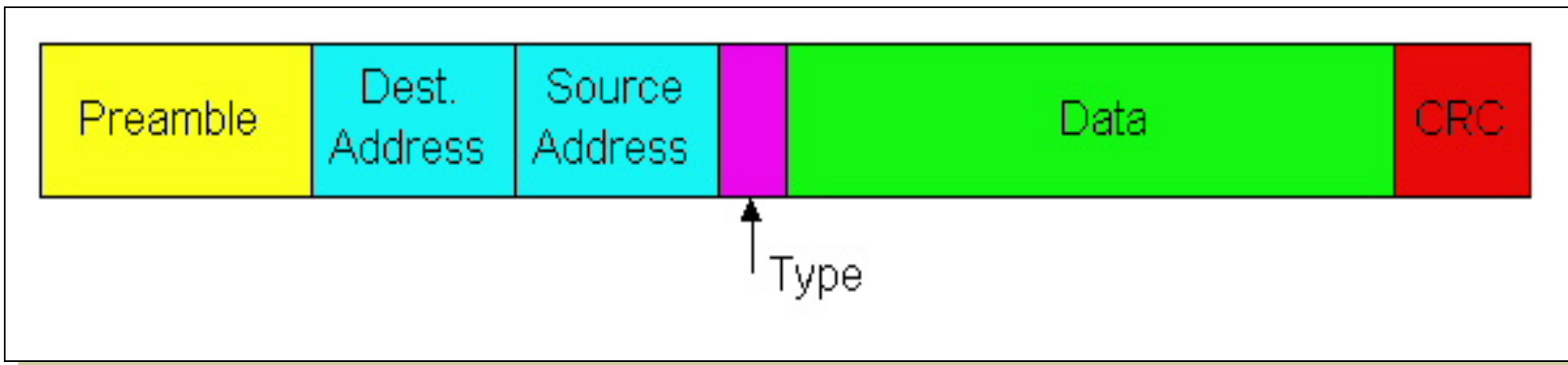


Solution: Buffering and Congestion Control

- Short bursts: buffer
- What if buffer overflows?
  - Packets dropped
  - Sender adjusts rate until load = resources → "congestion control"

Example: Ethernet Packet

- Sending adapter encapsulates IP datagram (or other network layer protocol packet) in Ethernet frame



Ethernet Frame Structure

- Each protocol layer needs to provide some hooks to upper layer protocols
  - Demultiplexing: identify which upper layer protocol packet belongs to
  - E.g., port numbers allow TCP/UDP to identify target application
  - Ethernet uses Type field
- Type: 2 bytes
  - Indicates the higher layer protocol, mostly IP but others may be supported such as Novell IPX and AppleTalk

Ethernet Frame Structure (cont.)

- Addresses: 6 bytes
  - Each adapter is given a globally unique address at manufacturing time
    - Address space is allocated to manufacturers
      - 24 bits identify manufacturer
      - E.g., 0:0:15:* → 3com adapter
    - Frame is received by all adapters on a LAN and dropped if address does not match
  - Special addresses
    - Broadcast – FF:FF:FF:FF:FF:FF is "everybody"
    - Range of addresses allocated to multicast
      - Adapter maintains list of multicast groups node is interested in

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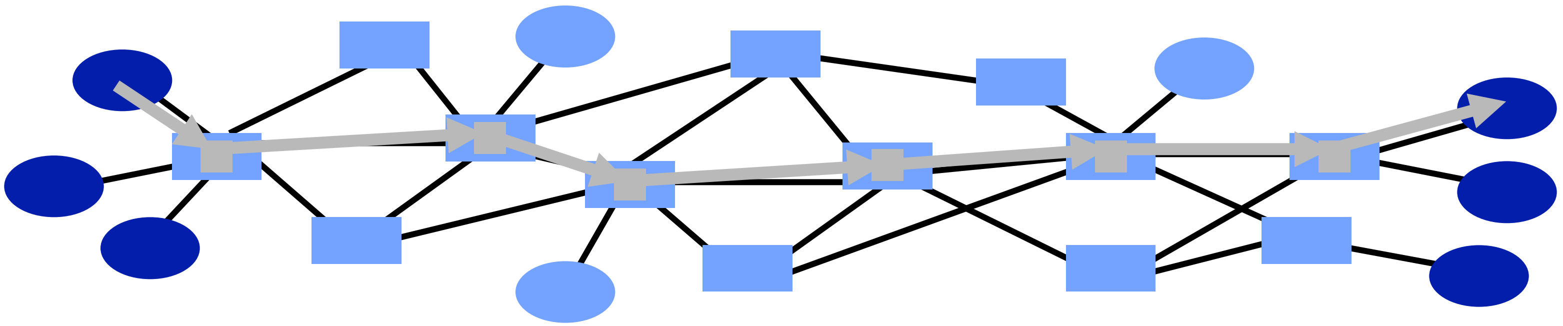
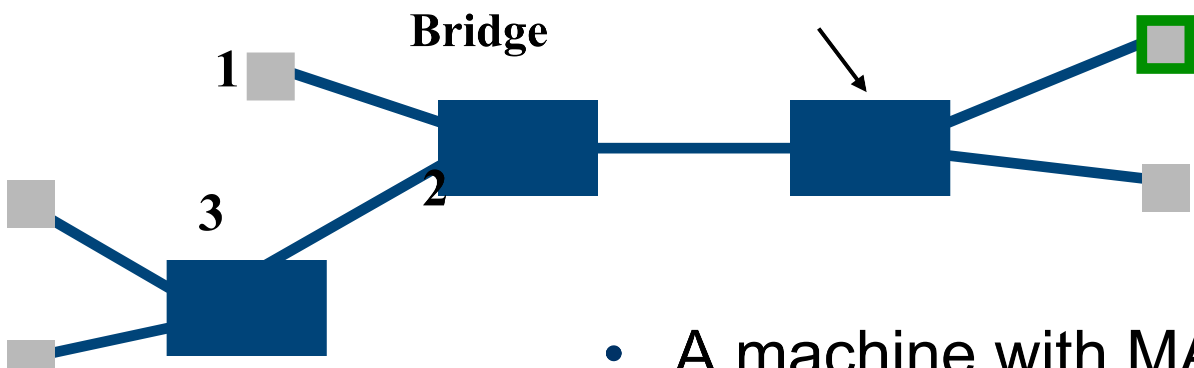


Frame Forwarding

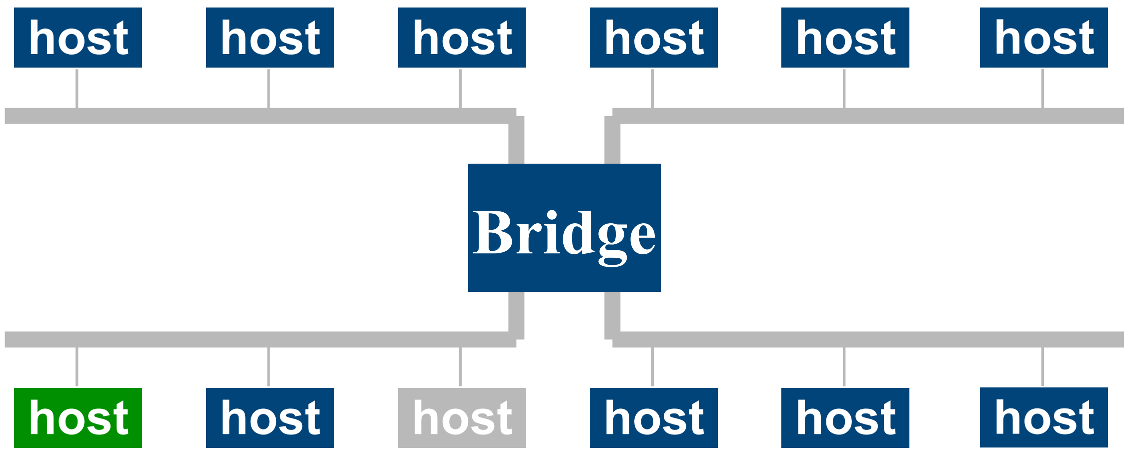


MAC Address	Port	Age
A21032C9A591	1	36
99A323C90842	2	01
8711C98900AA	2	15
301B2369011C	2	16
695519001190	3	11

- A machine with MAC Address lies in the direction of number port of the bridge
- For every packet, the bridge "looks up" the entry for the packets destination MAC address and forwards the packet on that port.
  - Other packets are broadcast – why?
- Timer is used to flush old entries

Learning Bridges

- Manually filling in bridge tables?
  - Time consuming, error-prone
- Keep track of source address of packets arriving on every link, showing what segment hosts are on
  - Fill in the forwarding table based on this information

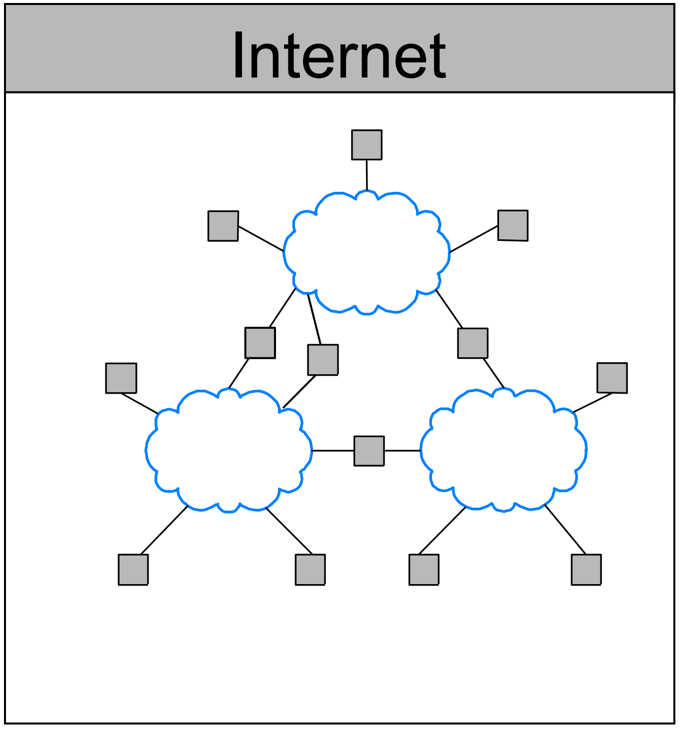


Today's Lecture

- Network links and LANs
- Layering and protocols
- Internet design

Internet

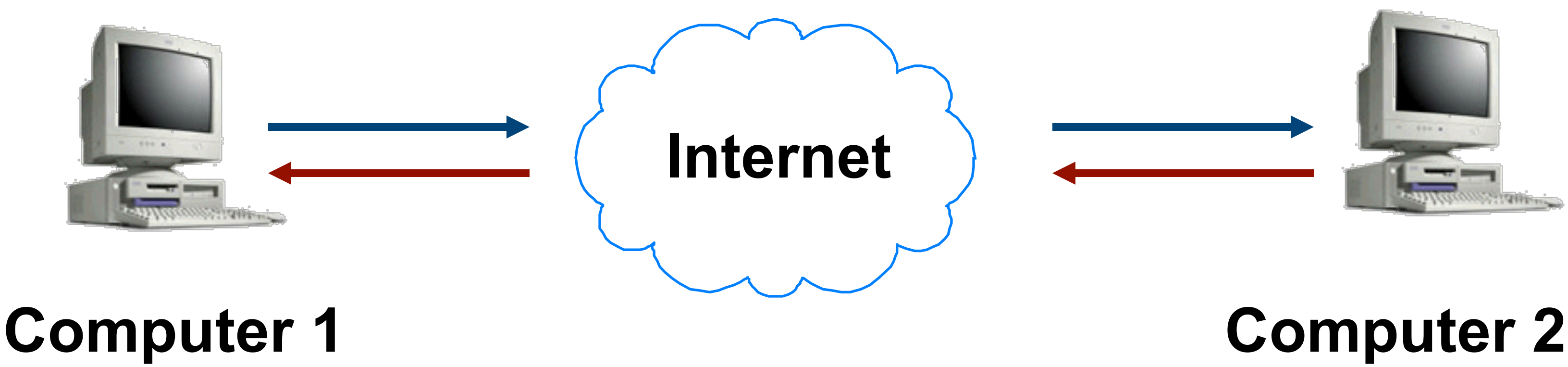
- An inter-net: a network of networks.
  - Networks are connected using routers that support communication in a hierarchical fashion
  - Often need other special devices at the boundaries for security, accounting, ..
- The Internet: the interconnected set of networks of the Internet Service Providers (ISPs)
  - About 17,000 different networks make up the Internet



Challenges of an internet

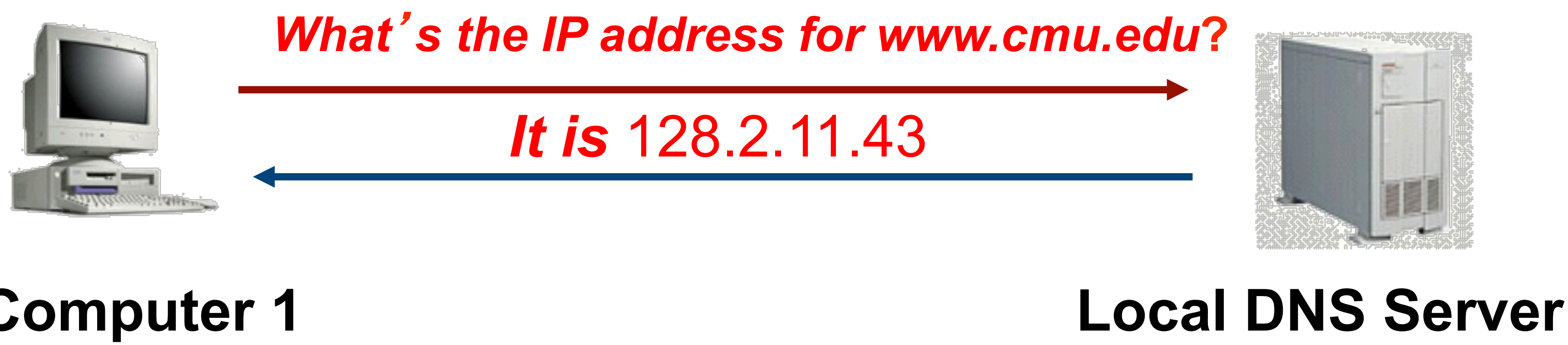
- Heterogeneity
  - Address formats
  - Performance – bandwidth/latency
  - Packet size
  - Loss rate/pattern/handling
  - Routing
  - Diverse network technologies → satellite links, cellular links, carrier pigeons
  - In-order delivery

How To Find Nodes?



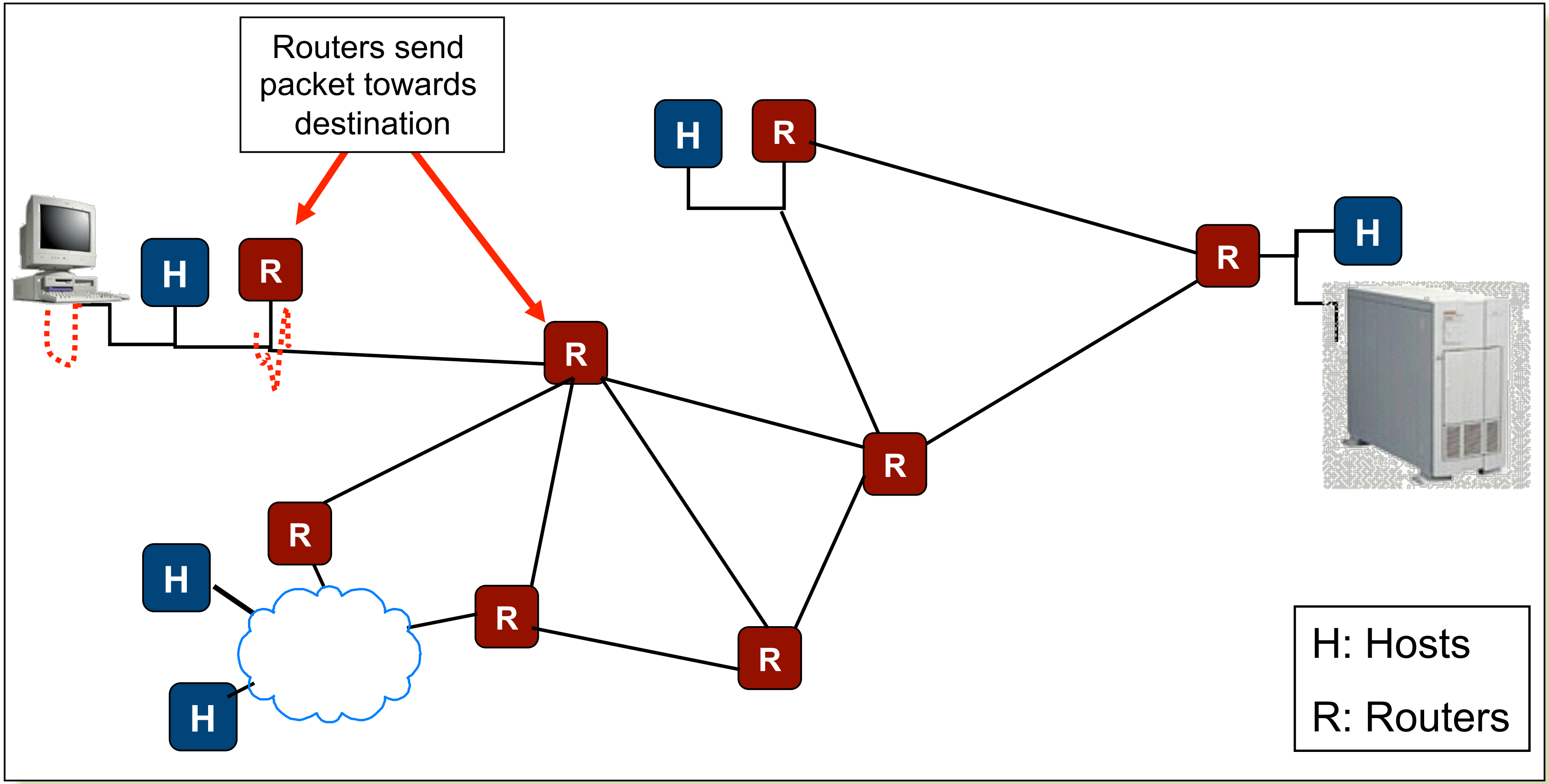
Need naming and routing

Naming



Translates human readable names to logical endpoints

Routing



Routers send packet towards destination
H
R
H
R
R
H
R
R
R
H
R
H
R
H: Hosts
R: Routers

Network Service Model

- What is the *service model?*
  - Ethernet/Internet: *best-effort* – packets can get lost, etc.
- What if you want more?
  - Performance guarantees (QoS)
  - Reliability
    - Corruption
    - Lost packets
  - Flow and congestion control
  - Fragmentation
  - In-order delivery
  - Etc…

Failure models

- Fail-stop:
  - When something goes wrong, the process stops / crashes / etc.
- Fail-slow or fail-stutter:
  - Performance may vary on failures as well
- Byzantine:
  - Anything that can go wrong, will.
  - Including malicious entities taking over your computers and making them do whatever they want.
- These models are useful for proving things;
- The real world typically has a bit of everything.

- Deciding which model to use is important!

Fancier Network Service Models

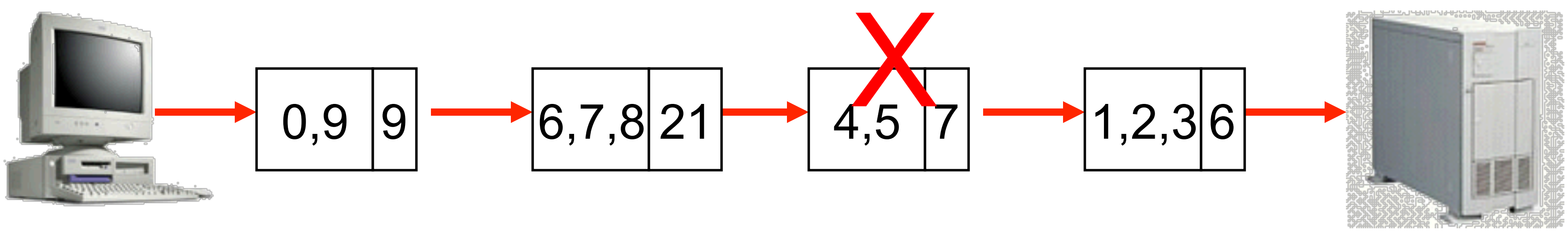
- What if network had reliable, in-order, mostly no-corruption, stream-oriented communication (i.e. TCP)

- Programmers don't have to implement these features in every application
- But note limitations: this can't turn a byzantine failure model into a fail-stop model...

What if the Data gets Corrupted?

Problem: Data Corruption

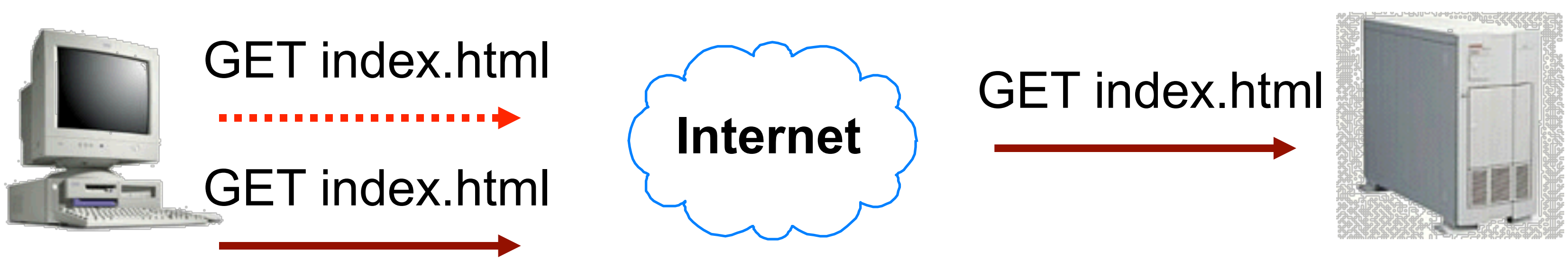
Solution: Add a *checksum*



What if the Data gets Lost?

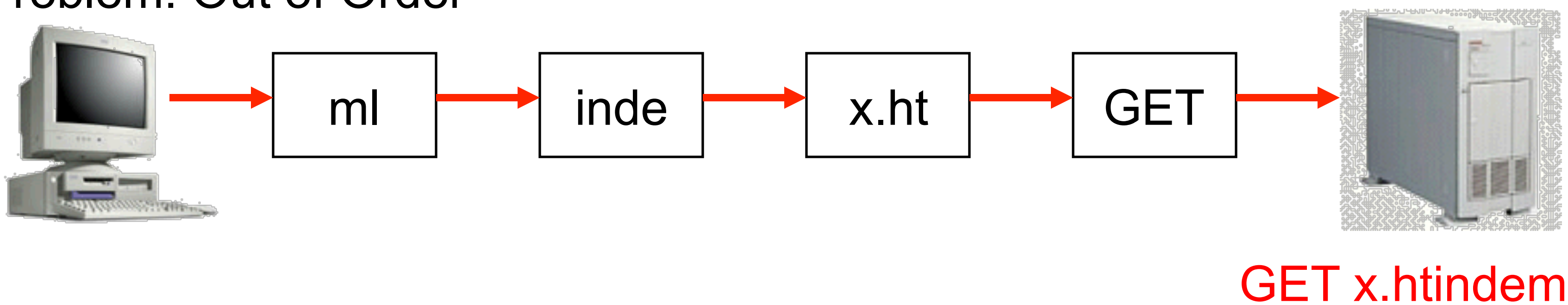
Problem: Lost Data

Solution: Timeout and Retransmit

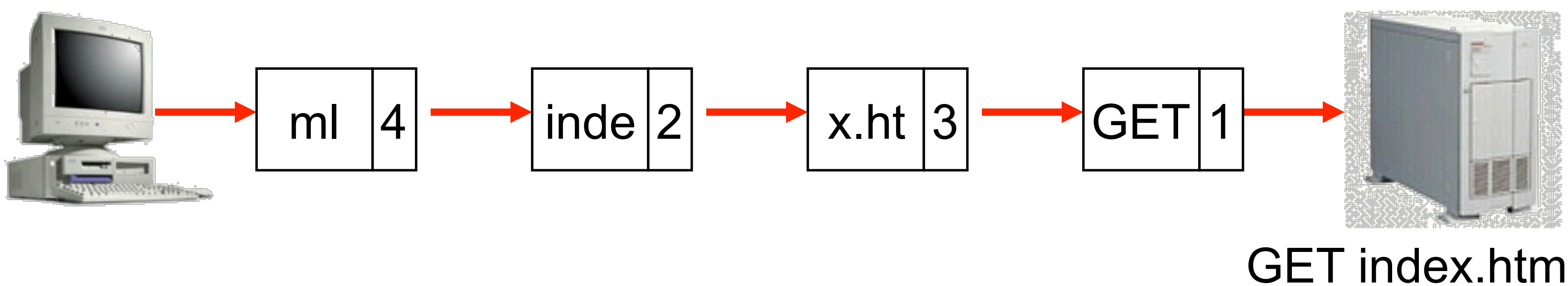


What if the Data is Out of Order?

Problem: Out of Order



Solution: Add Sequence Numbers

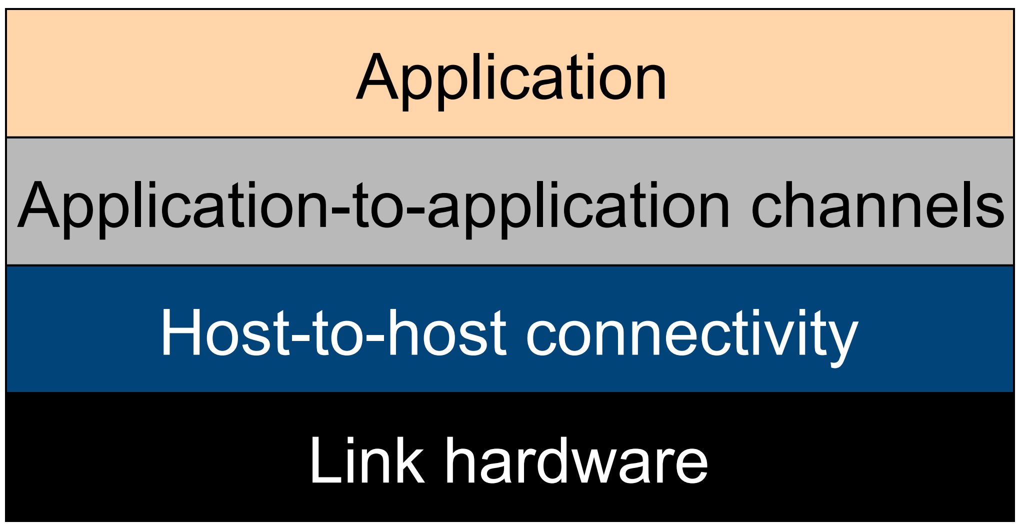


Networks [including end points] Implement Many Functions

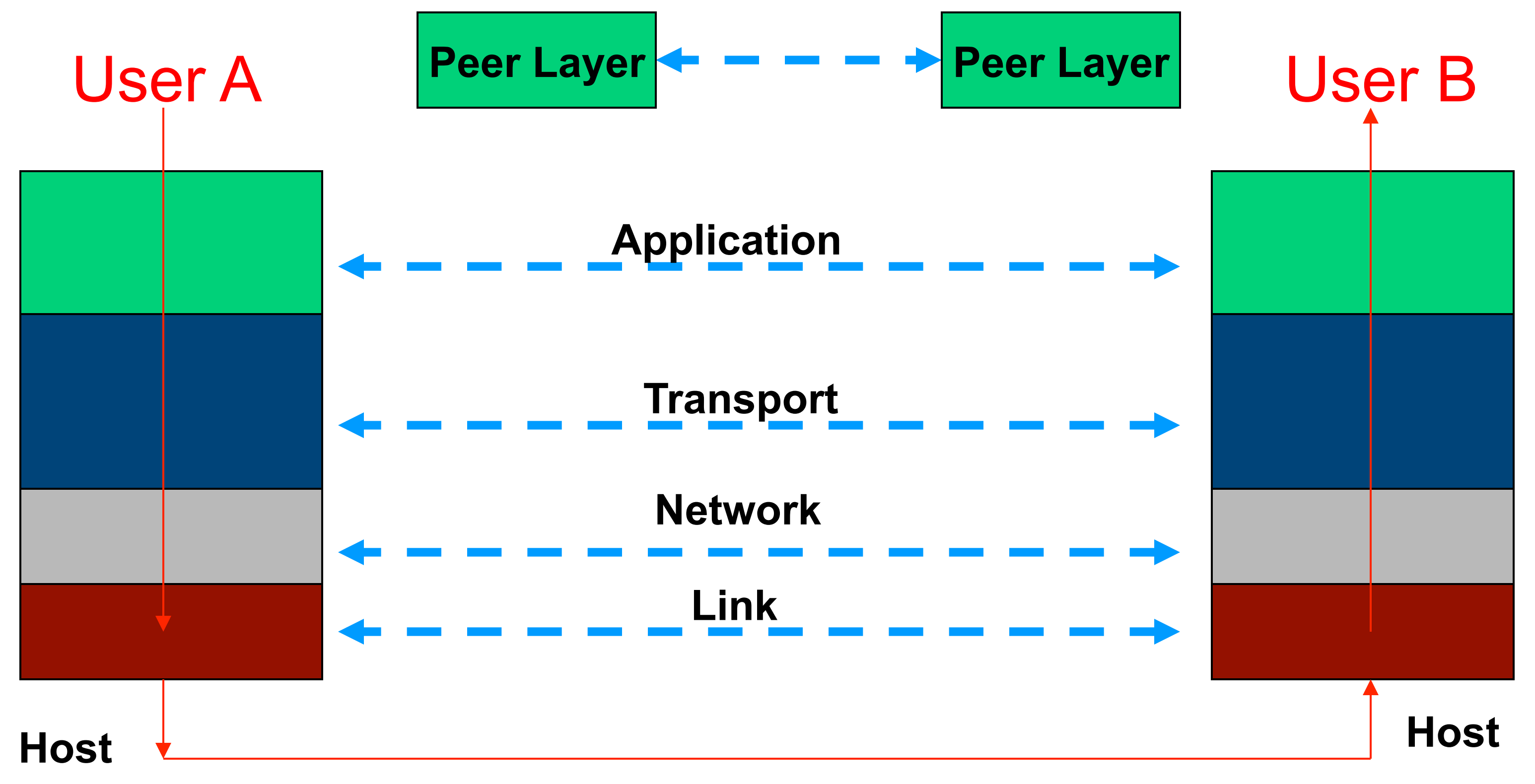
- Link
- Multiplexing
- Routing
- Addressing/naming (locating peers)
- Reliability
- Flow control
- Fragmentation
- Etc….

What is Layering?

- Modular approach to network functionality
- Example:



What is Layering?



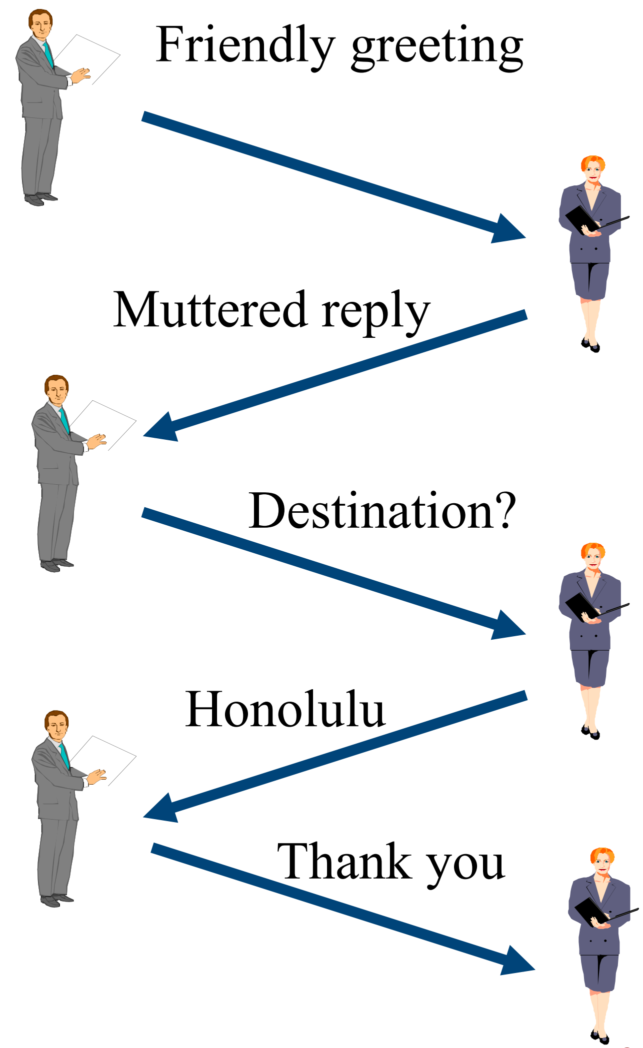
Modular approach to network functionality

Layering Characteristics

- Each layer relies on services from layer below and exports services to layer above
- Interface defines interaction with peer on other hosts
- Hides implementation - layers can change without disturbing other layers (black box)

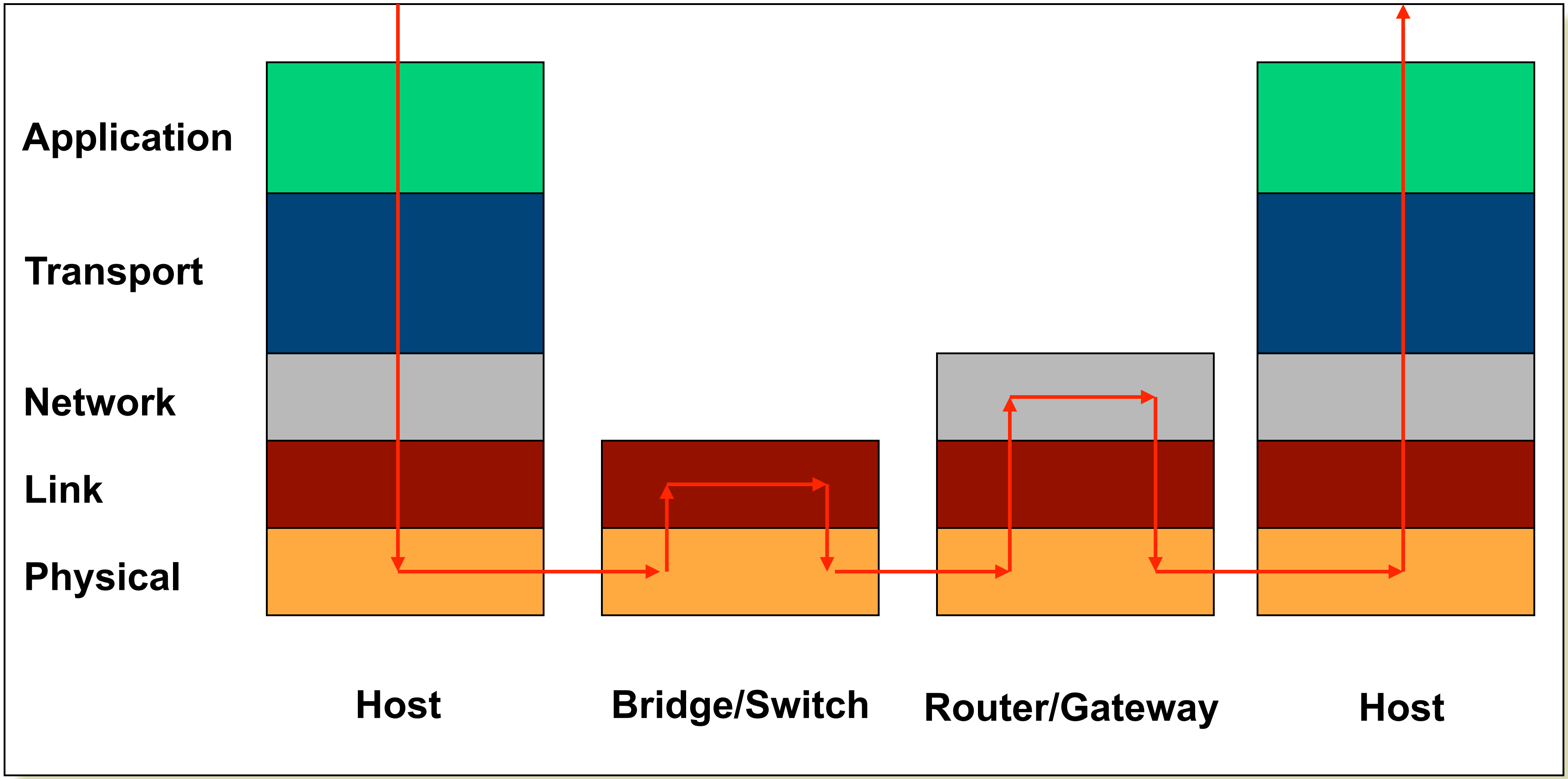
What are Protocols?

- An agreement between parties on how communication should take place
- Module in layered structure
- Protocols define:
  - Interface to higher layers (API)
  - Interface to peer (syntax & semantics)
    - Actions taken on receipt of a messages
    - Format and order of messages
    - Error handling, termination, ordering of requests, etc.
- Example: Buying airline ticket

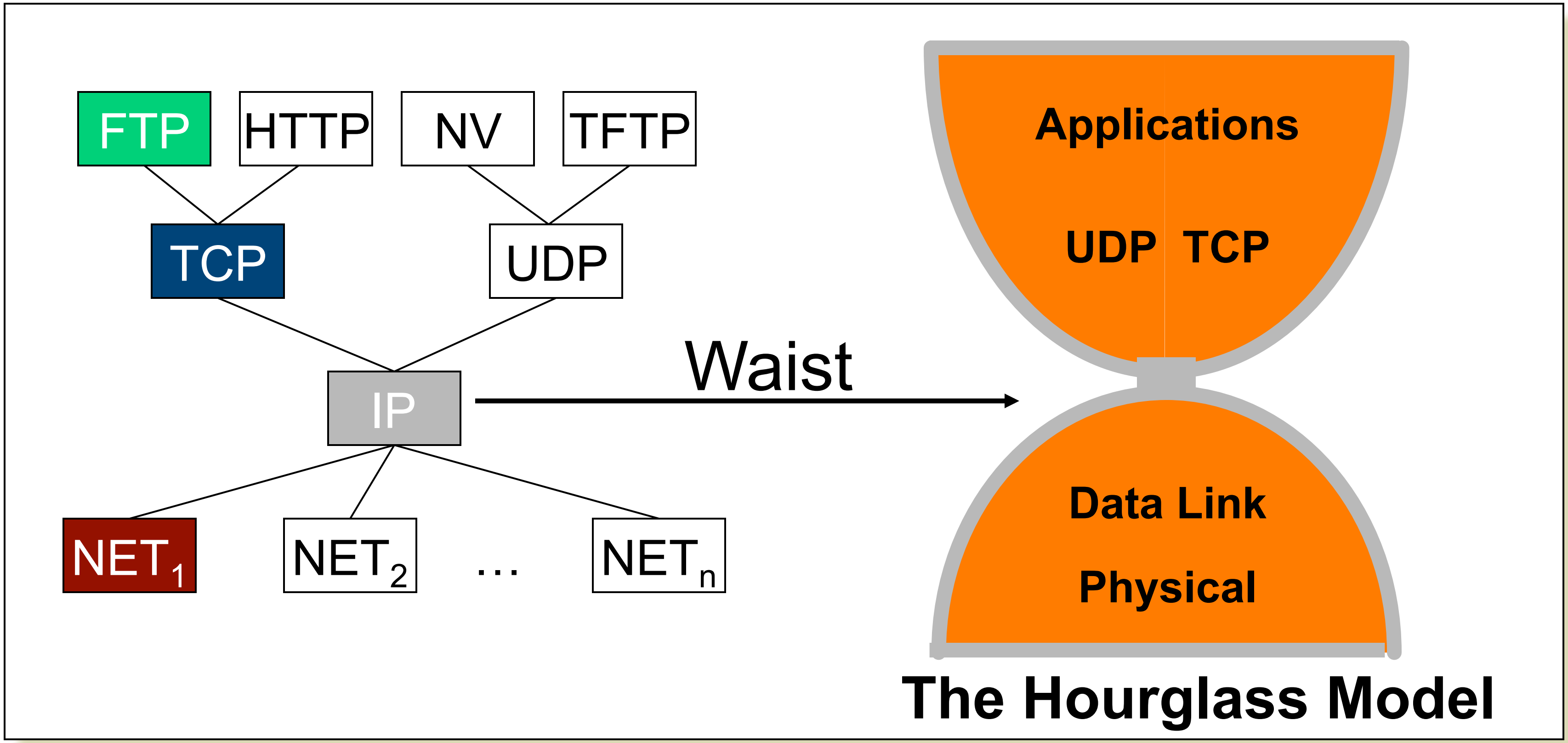


IP Layering

- Relatively simple

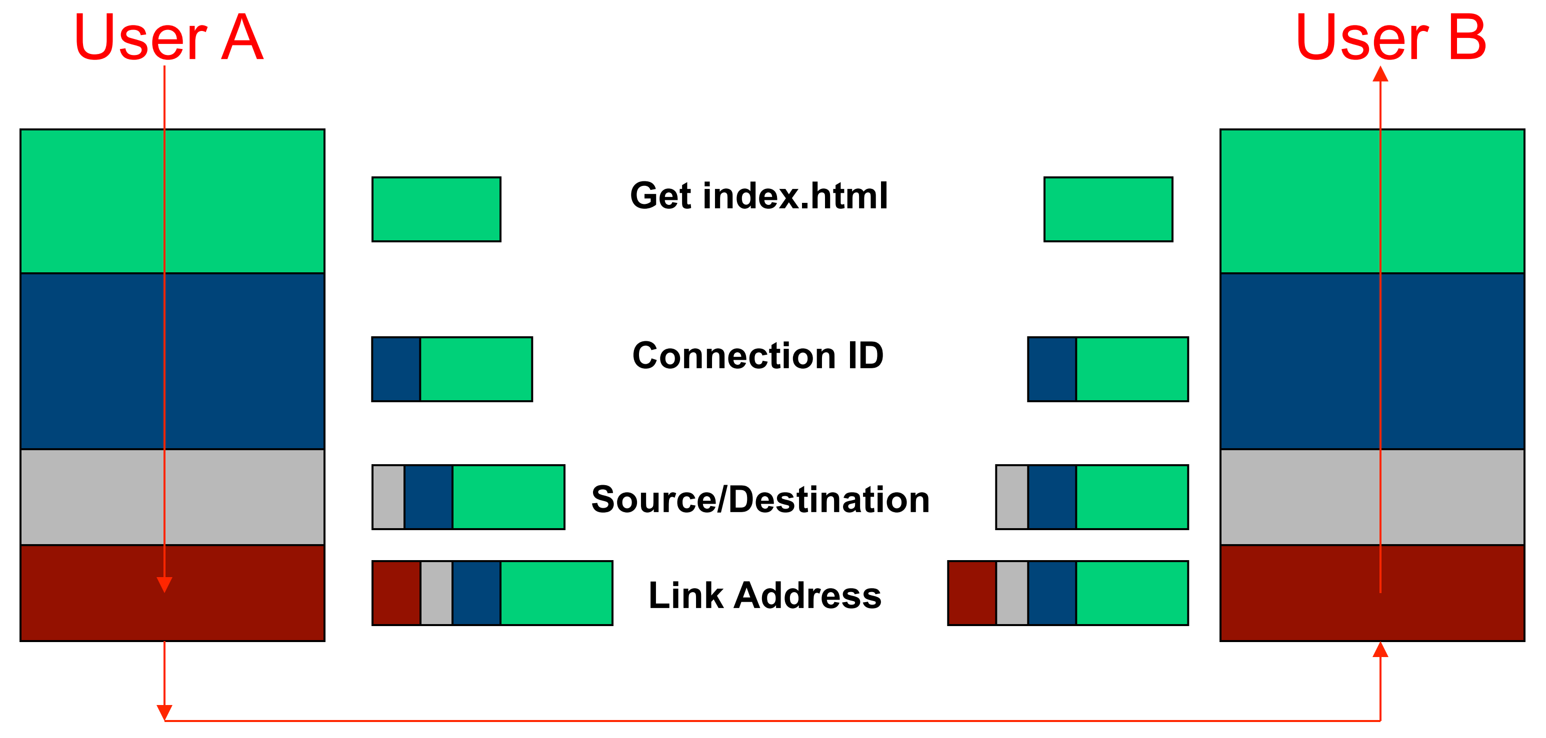


The Internet Protocol Suite



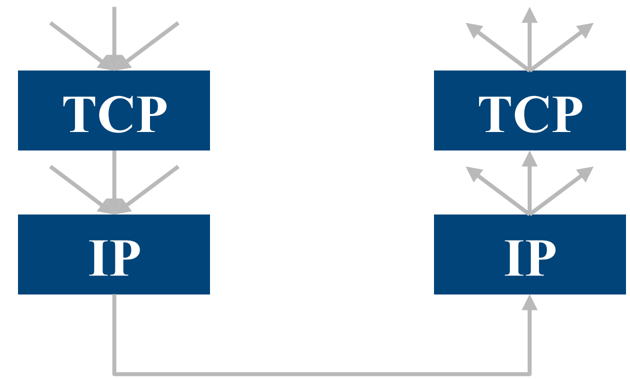
The waist facilitates interoperability

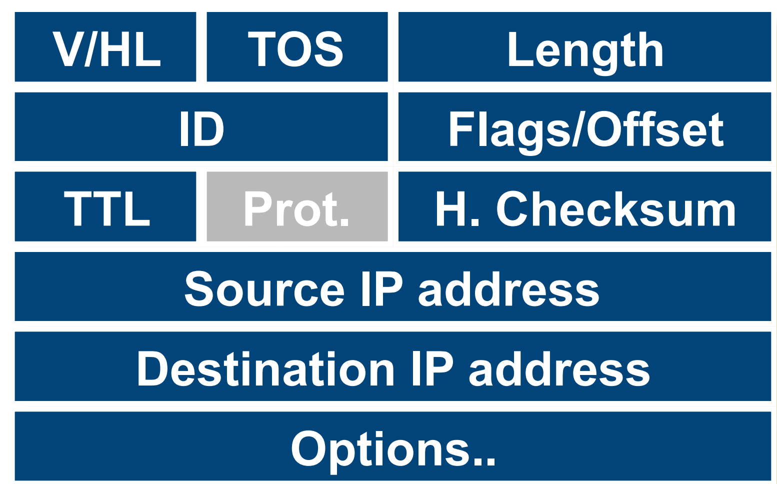
Layer Encapsulation



Multiplexing and Demultiplexing

- There may be multiple implementations of each layer.
  - How does the receiver know what version of a layer to use?
- Each header includes a demultiplexing field that is used to identify the next layer.
  - Filled in by the sender
  - Used by the receiver
- Multiplexing occurs at multiple layers. E.g., IP, TCP, …





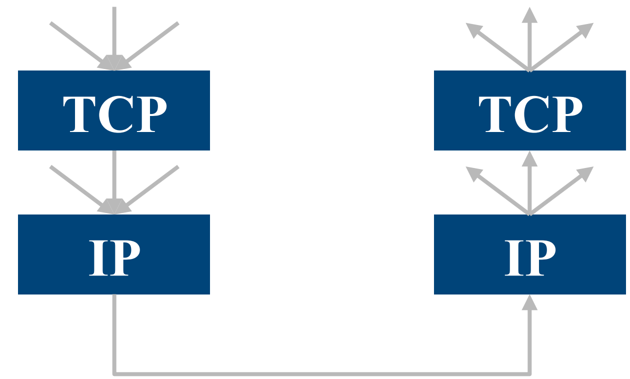
Multiplexing and Demultiplexing

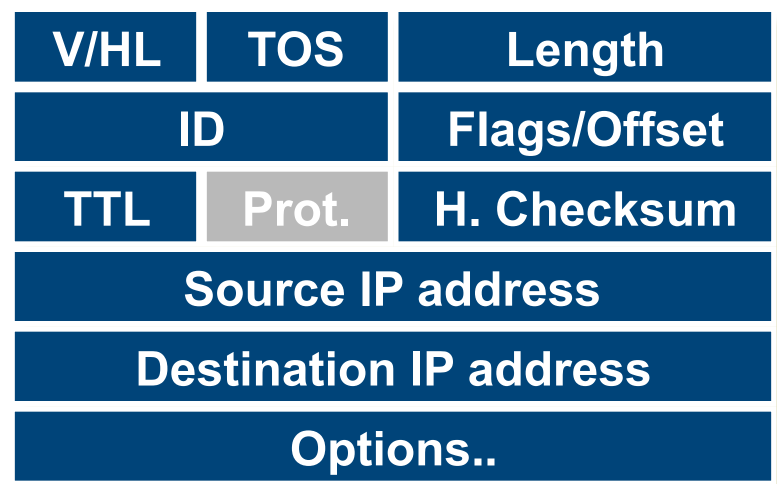
List of IP protocol numbers

From Wikipedia, the free encyclopedia

This is a list of IP numbers **used in the *Protocol* field of the** IPv4 hea

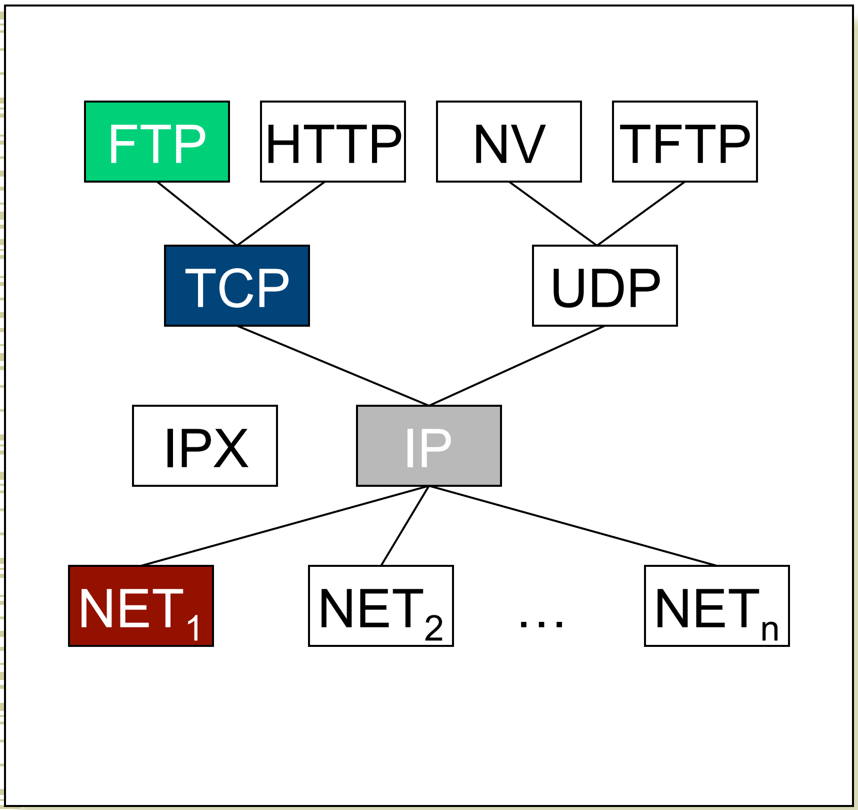
Decimal	Hex	Keyword	
0	0x00	HOPOPT	IPv6 Hop-by-Hop Option
1	0x01	ICMP	Internet Control Message Prot
2	0x02	IGMP	Internet Group Management F
3	0x03	GGP	Gateway-to-Gateway Protocol
4	0x04	IP-in-IP	IP in IP (encapsulation)
5	0x05	ST	Internet Stream Protocol
6	0x06	TCP	Transmission Control Protocol
7	0x07	CBT	Core-based trees
8	0x08	EGP	Exterior Gateway Protocol
9	0x09	IGP	Interior Gateway Protocol (any their IGRP))
10	0x0A	BBN-RCC-MON	BBN RCC Monitoring
11	0x0B	NVP-II	Network Voice Protocol
12	0x0C	PUP	Xerox PUP
13	0x0D	ARGUS	ARGUS

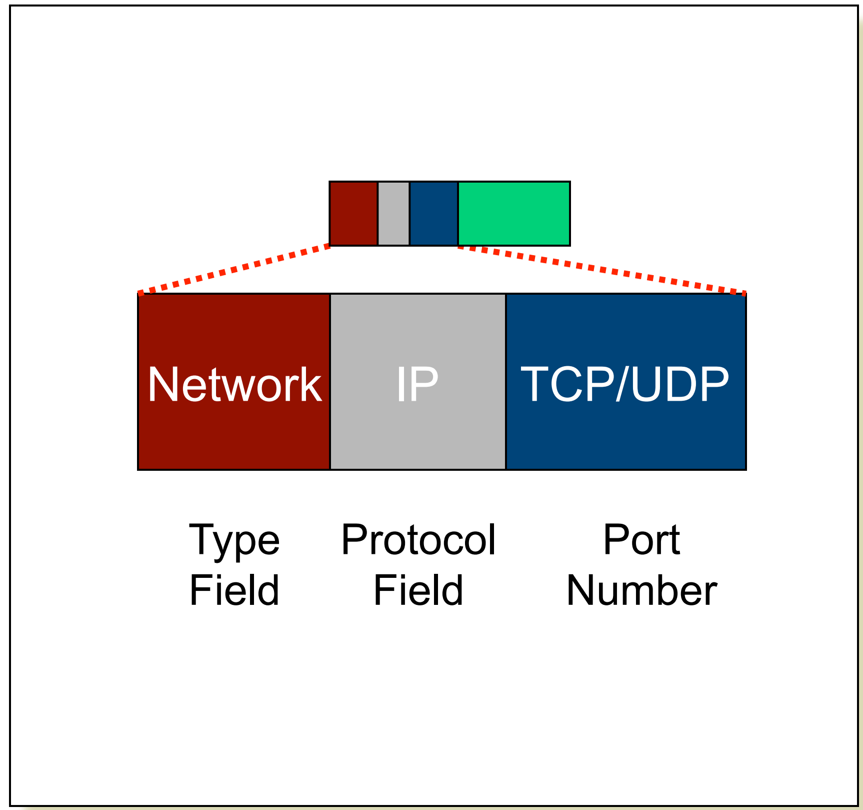




Protocol Demultiplexing

- Multiple choices at each layer





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Goals [Clark88]

0 **Connect existing networks**

   initially ARPANET and ARPA packet radio network

1. Survivability

   ensure communication service even in the presence of network and router failures

2. Support multiple types of services
3. Must accommodate a variety of networks
4. Allow distributed management
5. Allow host attachment with a low level of effort
6. Be cost effective
7. Allow resource accountability

Goal 1: Survivability

- If network is disrupted and reconfigured…
  - Communicating entities should not care!
  - No higher-level state reconfiguration

- How to achieve such reliability?
  - Where can communication state be stored?

	Network	Host
Failure handing	Replication	“Fate sharing”
Net Engineering	Tough	Simple
Routing state	Maintain state	Stateless
Host trust	Less	More