ECE 158A: Data Networks I

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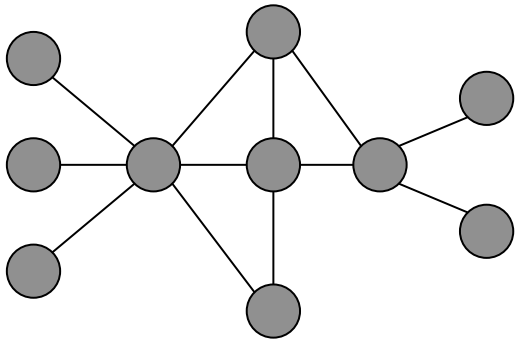
What is a Network?

- A system of links that interconnect nodes in order to exchange information



- We will focus on the INTERNET
- Where nodes are of two types
  - Hosts: Sources and sinks of information
  - Routers: Relay nodes that simply forward information

Packet vs. Circuits

Internet is a packet switching network, a concept introduced by

Leonard Kleinrock in 1961
Back then the current technology was circuit switching
He pointed out the advantages of packet switching in his PhD thesis
Went on to develop this technology at UCLA, ARPA-Net was born…

Relevance of the Internet

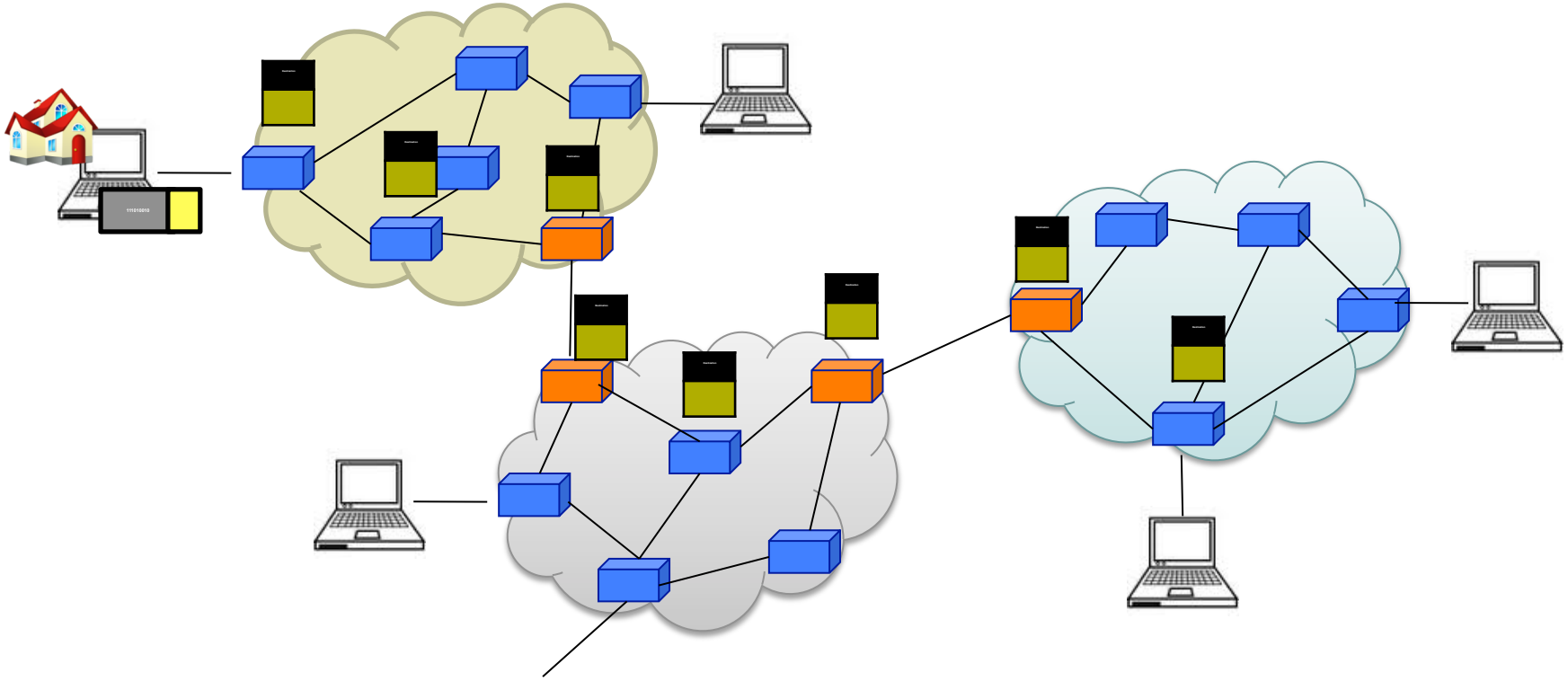
- The Internet changed everything:
  - The way we do business
    - E-commerce, advertising, cloud-computing
  - The way we have relationships
    - Facebook friends, E-mail, IM, virtual worlds
  - The way we learn
    - Wikipedia, MOOCs, search engines
  - The way we govern and view law
    - E-voting, censorship, copyright, cyber-attacks
- The Internet is $$:
  - Many large and influential networking companies
    - Cisco, Broadcom, AT&T, Verizon, Akamai, Huawei, …
  - $120B+ industry (carrier and enterprise alone)
  - Networking central to most technology companies
    - Google, Facebook, Intel, HP, Dell, VMware, …

A complex engineering system

- Of enormous scale
- Diverse
- Constantly evolving
- Prone to failures
- Highly constrained design

IP: the “glue” of the internet

- The Internet ties together different networks
  - >18,000 ISP networks



- Hosts and routers are tied together by IP (Internet Protocol), a single common interface between users and the network and between networks

Hierarchical addressing

- Each node attached to the network has an IP address, 32 bits usually written in decimal format a.b.c.d. Usually dynamically assigned by the Internet provider (via Dynamic Host Configuration Protocol)
  - 169.229.60.32 (i.e, 10101001.11100101.00111100.00100000)
- DNS is a distributed directory system that translates names into IP addresses
- IPV6 expands to 128 bits

Why so gigantic numbers?

- Need to accommodate:
- 2.4 Billion users (34% of world population)
- 1 Trillion unique URLs
- 294 Billion emails sent per day
- 1 Billion smartphones
- 937 Million Facebook users
- 2 Billion YouTube videos watched per day

Constant Evolution

- 1970s:
  - 56kilobits/second “backbone” links
  - <100 computers, a handful of sites in the US
  - Telnet and file transfer are the “killer” applications

- Today
  - 100+Gigabits/second backbone links
  - Routers switch 10Terbits/sec
  - 5B+ devices, all over the globe
  - 20M Facebook apps installed per day

Can it fail?

- To send a message, **all** components along a path must function correctly
  - software, modem, wireless access point, firewall, links, network interface cards, switches,…
  - Including human operators
- Consider: 50 components, that work correctly 99% of time → 39.5% chance communication will fail
- Yet, the Internet is extremely robust globally (despite some claims that we will discuss…)

A successful Architecture

- Very successful system design:
  - The early Internet pioneers came up with a solution that was successful beyond all imagining
  - Several enduring architectural principles and practices emerged from their work decades later!
- The Internet offers us a lesson in how to reason through the design of a very complex system
  - What are our goals and constraints?
  - What's the right prioritization of goals?
  - How do we decompose a problem?
  - Who does what? How?
  - What are the interfaces between components?
  - What are the tradeoffs between design options?

A Never-ending Story

- Better analytical understanding has developed over time
- Many new limitations/problems have emerged
- New requirements have emerged:
  - Mobility, reliability, many more nodes (Internet of Things), …
- Researchers in networking today are still debating improvements and solutions…

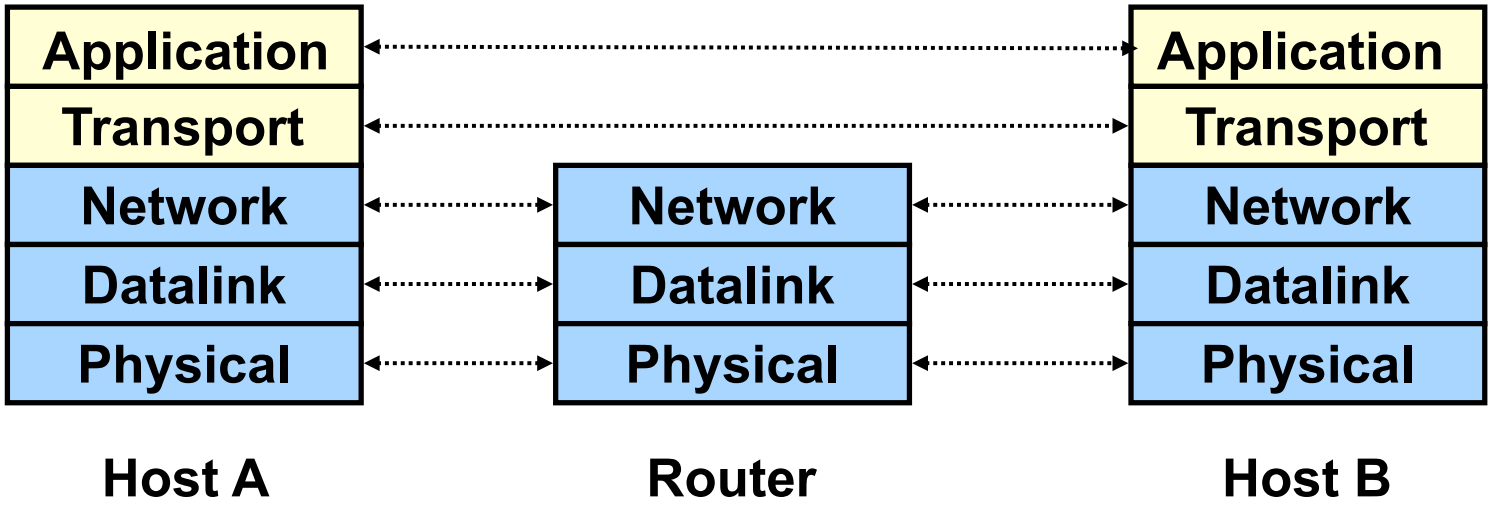
Now is your turn to carry the torch!

Course Syllabus

- Basic concepts and key design principles:
  - Packet vs circuit switching,
  - TCP-IP
  - Hierarchical shortest path routing
  - Flow and congestion control
- The Internet protocol stack:
  - Application: HTTP, FTP…
  - Transport: TCP
  - Routing: IP
  - MAC: WiFI, Ethernet, LTE
- Ideas rather than implementation details

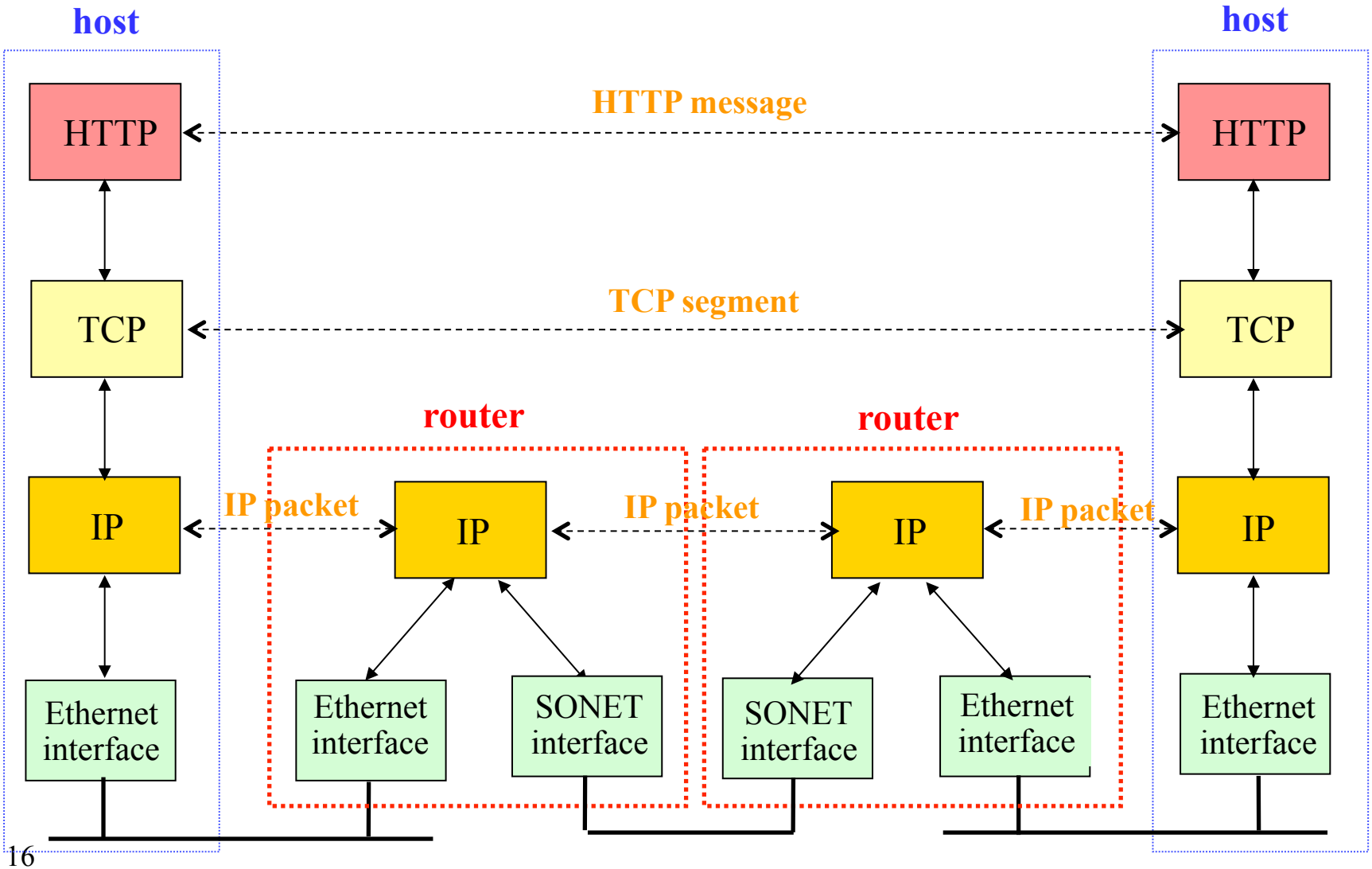
Open System Interconnection (OSI)

- Conceptual model of the International Organization for Standardization (ISO)
- Each layer accomplishes different tasks
- Well defined interfaces across layers



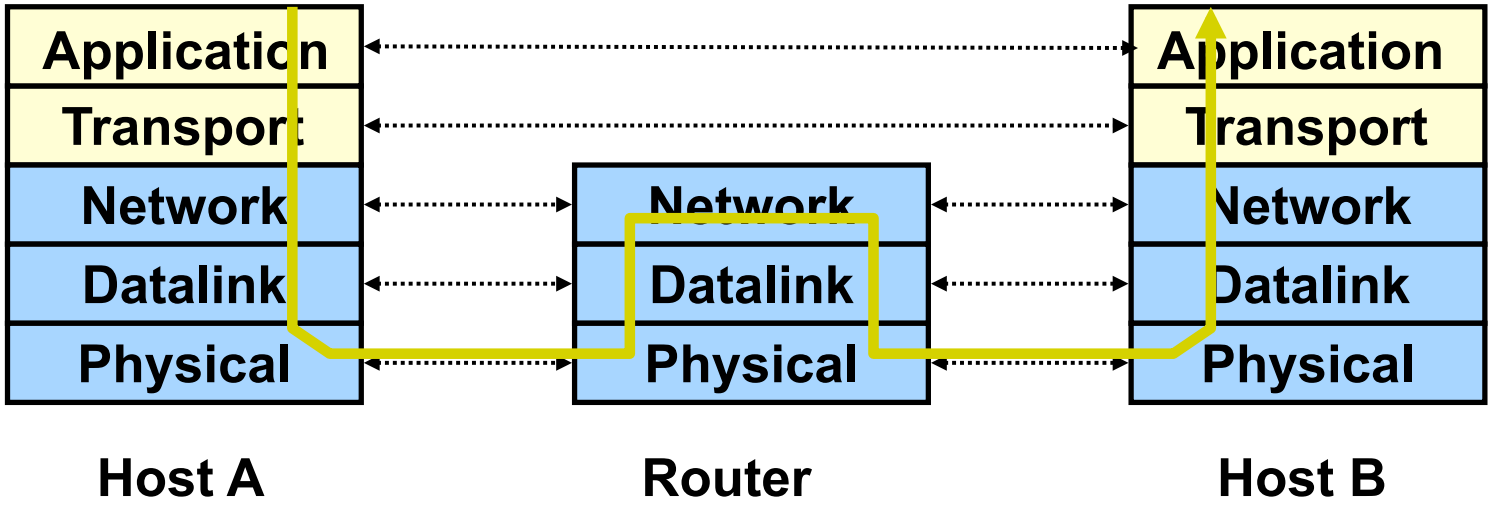
- Layers interacts with peer's corresponding layer

Internet Protocol Stack

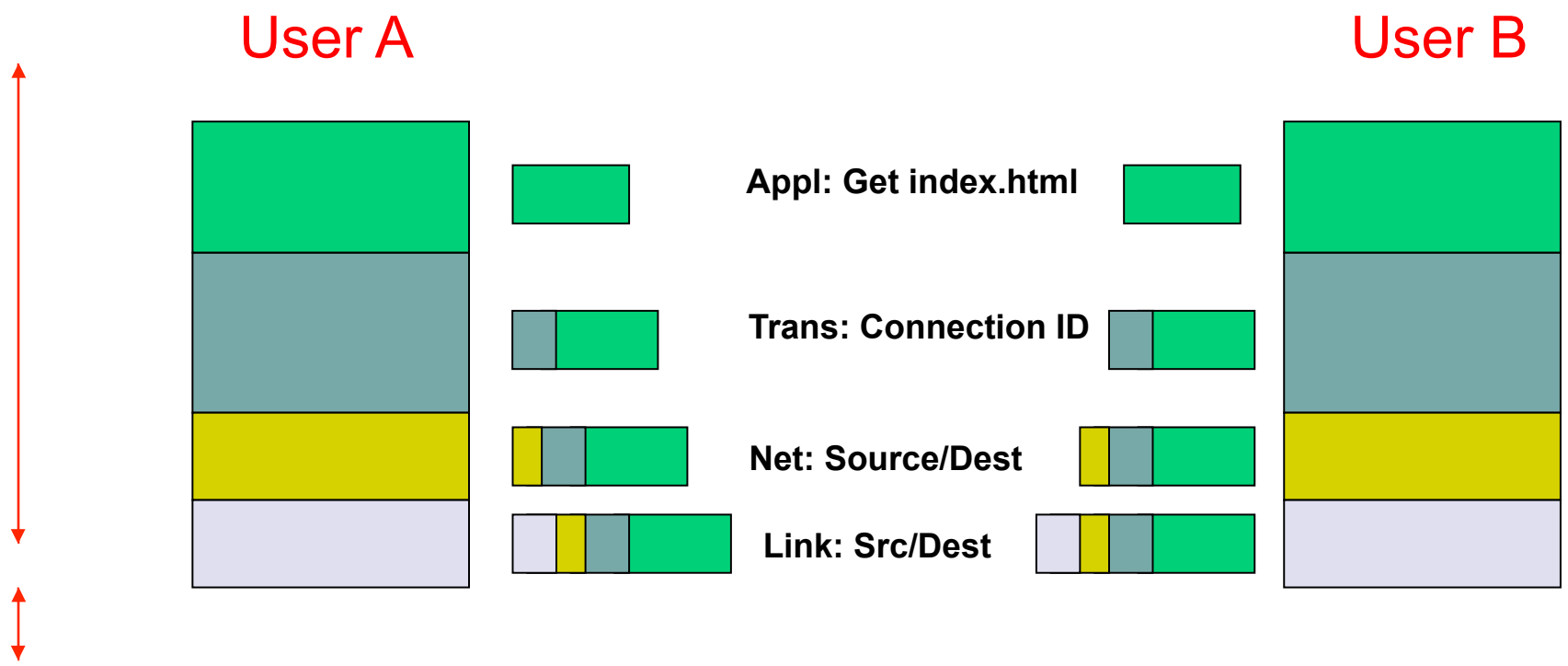


Open System Interconnection (OSI)

- Lower three layers implemented everywhere
- Top two layers implemented only at hosts
- Communication goes down to physical network
- Then from network peer to peer
- Then up to relevant layer



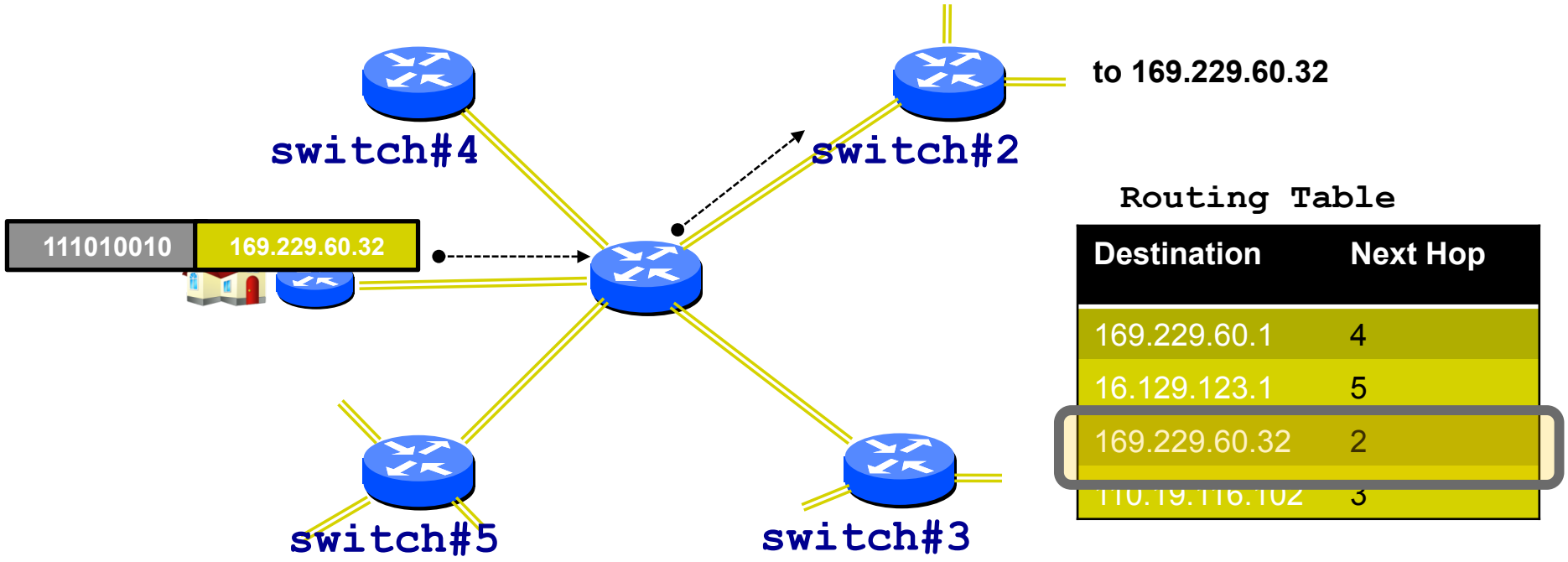
Encapsulation



Common case: 20 bytes TCP header + 20 bytes IP header + 14 bytes Ethernet header = *54 bytes overhead*

Routers Forward Packets

- Routers determine the next hop for a packet based on the destination IP address
- Routing algorithms ensure packets follow the shortest path from source to destination
- Each router constantly update a routing table specifying the next hop for each destination address



Error, Flow, and Congestion Control

Applications

…built on…

Reliable (or unreliable) transport

…built on…

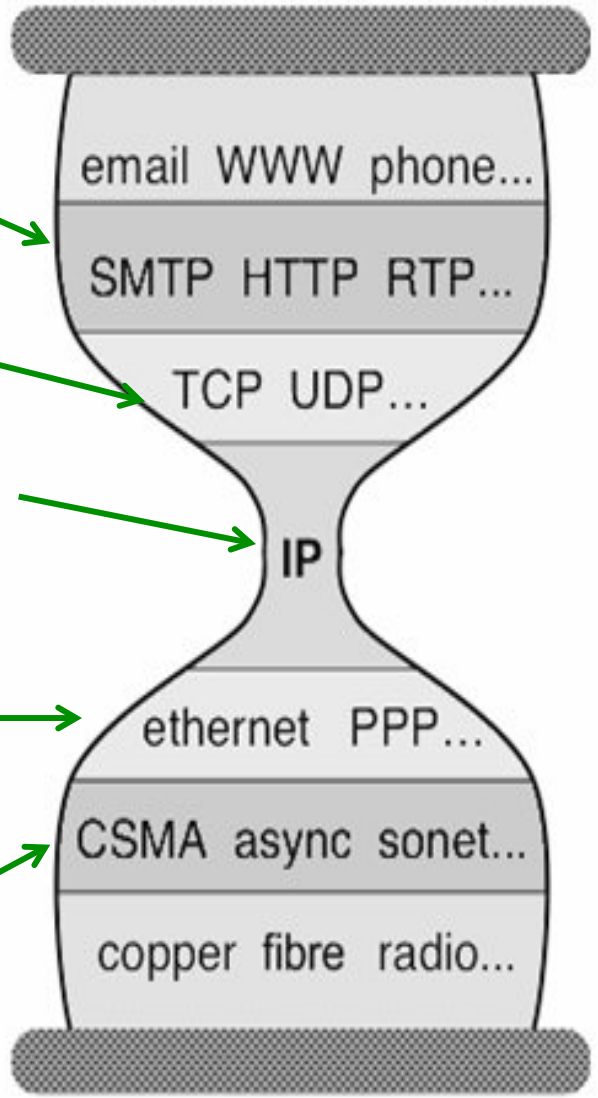
Best-effort global packet delivery

…built on…

Best-effort local packet delivery

…built on…

Physical transfer of bits



Summary

- Each host has a 32-bit IP address. DNS translates names to addresses
- Hosts arrange information into packets. Each layers adds a header
- Routers forward packets based on destination IP address using routing tables
- The source/destination hosts perform error, flow, and congestion control