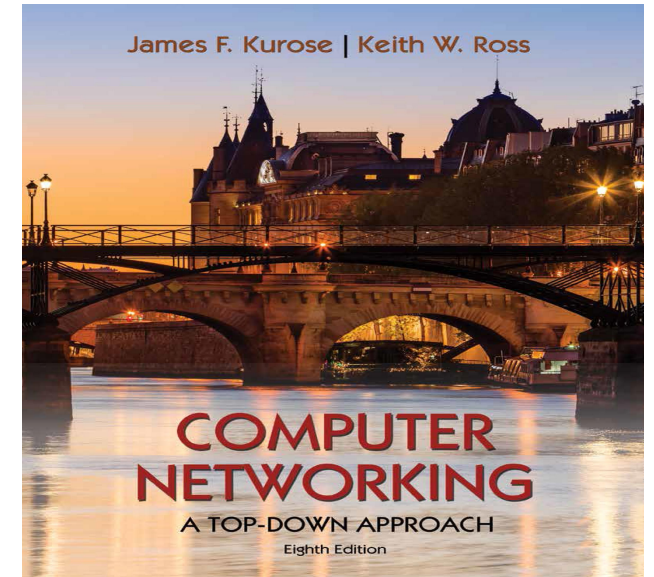


The Link Layer

- Introduction to the Link Layer
- Error-Detection and -Correction Techniques
- Multiple Access Links and Protocols
- Switched Local Area Networks
- Link Virtualization: a Network as a Link Layer
- Data Center Networking
- Retrospective: A Day in the Life of a Web Page Request



Link layer and LANs: our goals

- understand **principles** behind link layer services:
 - error detection, correction
 - sharing a broadcast channel: multiple access
 - link layer addressing
- **practice**: instantiation, implementation of various link layer technologies
 - Ethernet
 - VLANs
 - MPLS
 - data center networks

Link layer, LANs: roadmap

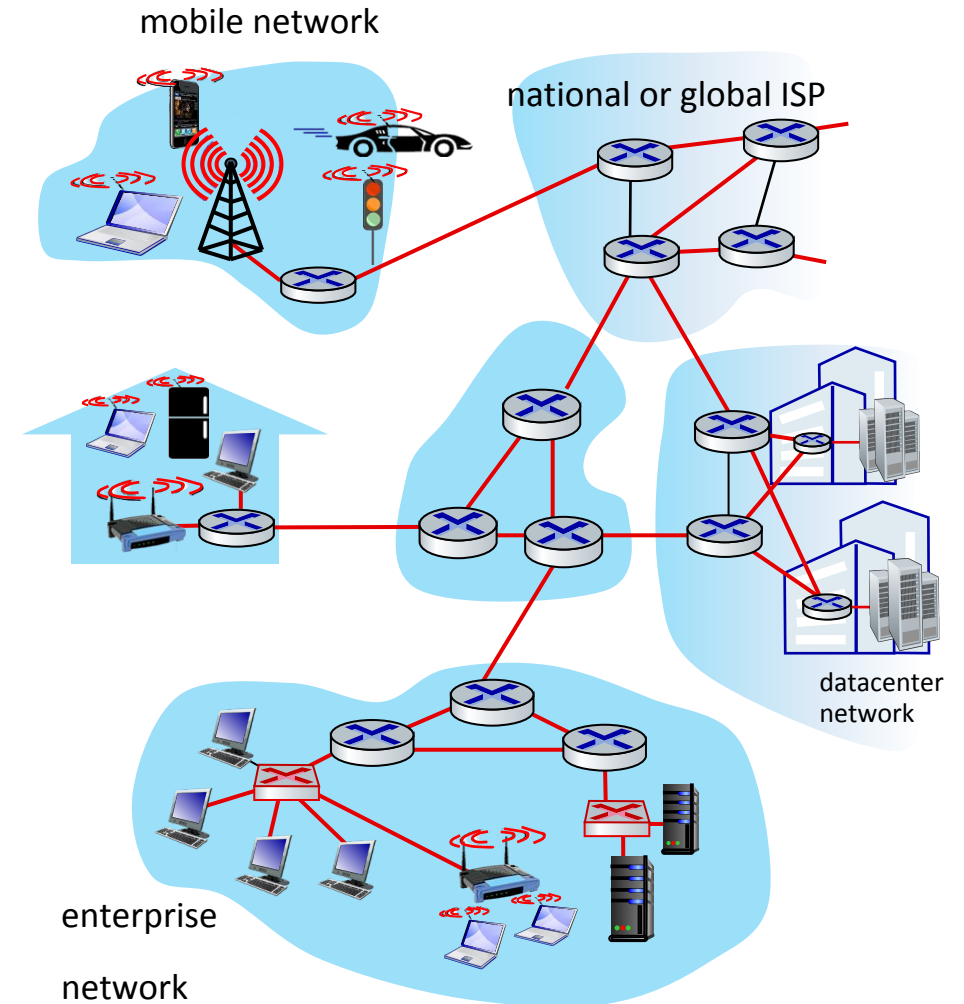
- **introduction**
- error detection, correction
- multiple access protocols
- LANs
 - addressing, ARP
 - Ethernet
 - switches
 - VLANs
- link virtualization: MPLS
- data center networking
- Chapter 1-6 synthesis: a day in the life of a web request

Link layer: introduction

terminology:

- hosts, routers: **nodes**
- communication channels that **directly** connect **physically adjacent** nodes: **links**
 - wired , wireless
 - LANs
- layer-2 packet: **frame**, encapsulates datagram

*link layer has responsibility of transferring datagram from one node to **physically adjacent** node over a link*



Link layer: context

- datagram transferred by different link protocols over different links:
 - e.g., WiFi on first link, Ethernet on next link
- each link protocol provides different services
 - e.g., may or may not provide reliable data transfer over link

transportation analogy:

- trip from Princeton to Lausanne
 - limo: Princeton to JFK
 - plane: JFK to Geneva
 - train: Geneva to Lausanne
- tourist = datagram
- transport segment = communication link
- transportation mode = link-layer protocol
- travel agent = routing algorithm

Link layer: services

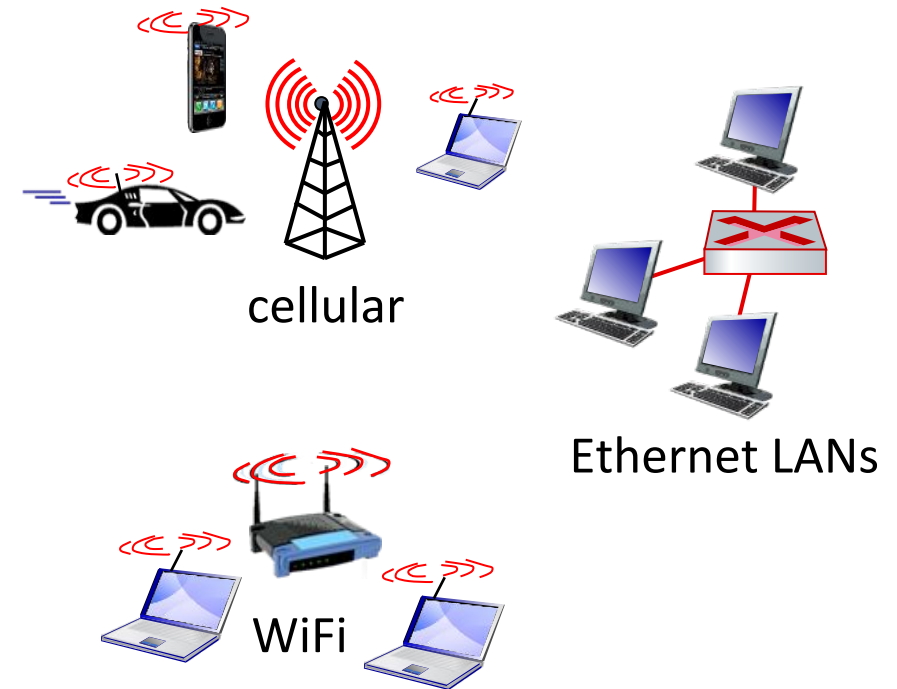
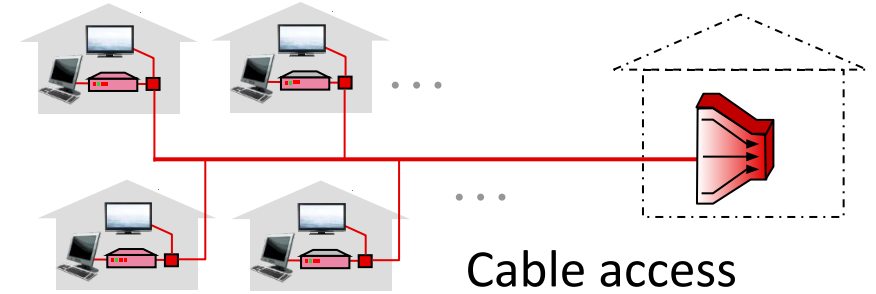
■ framing, link access:

- encapsulate datagram into frame, adding header, trailer
- channel access if shared medium
- “MAC” addresses in frame headers identify source, destination (different from IP address!)

■ reliable delivery between adjacent nodes

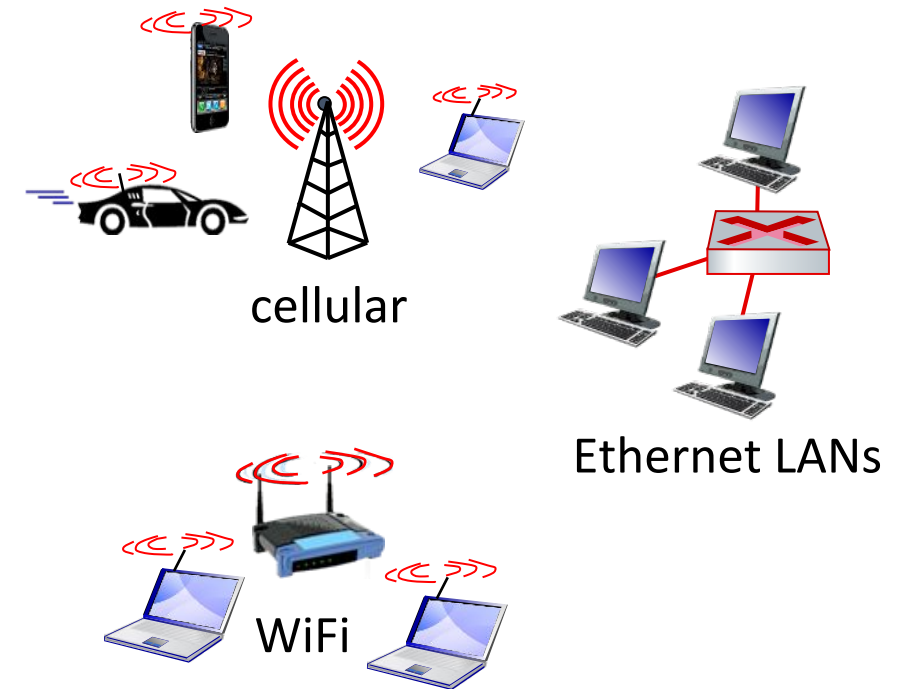
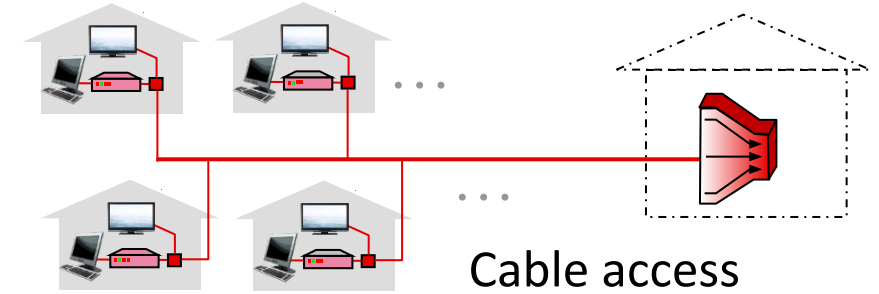
- we already know how to do this!
- seldom used on low bit-error links
- wireless links: high error rates
 - Q: why both link-level and end-end reliability?

Link layer: Single hop reliability
Transport layer: Complete path reliability



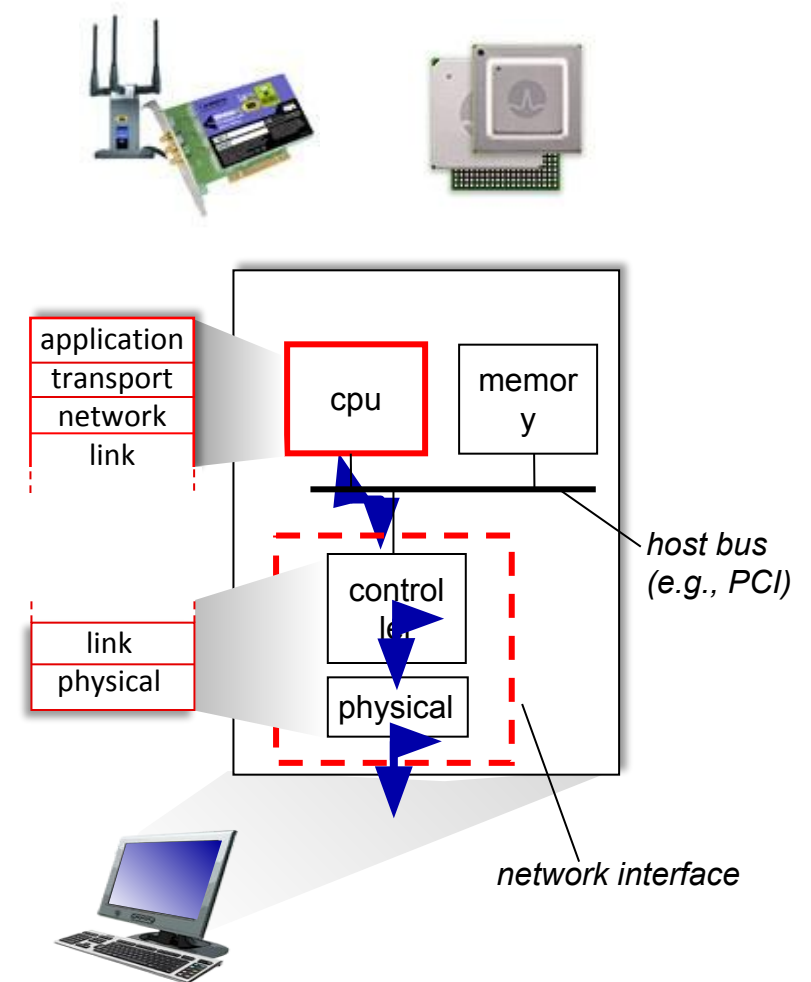
Link layer: services (more)

- **flow control:**
 - pacing between adjacent sending and receiving nodes
- **error detection:**
 - errors caused by signal attenuation, noise.
 - receiver detects errors, signals retransmission, or drops frame
- **error correction:**
 - receiver identifies *and corrects* bit error(s) without retransmission
- **half-duplex and full-duplex:**
 - with half duplex, nodes at both ends of link can transmit, but not at same time

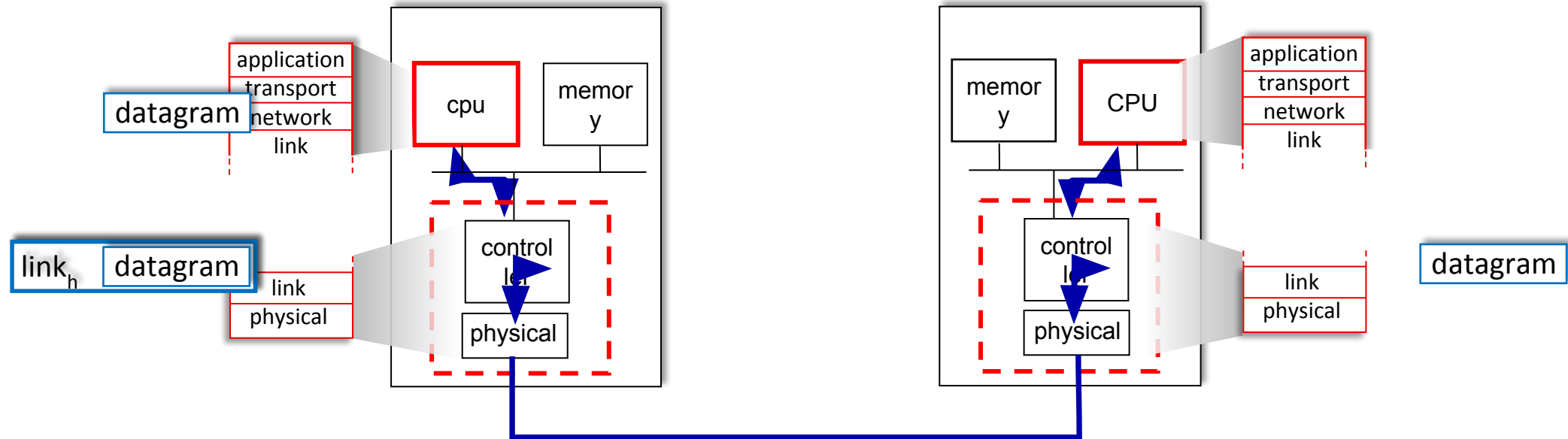


Host link-layer implementation

- in each-and-every host
- link layer implemented on-chip or in network interface card (NIC)
 - implements link, physical layer
- attaches into host's system buses
- combination of hardware, software, firmware



Interfaces communicating



sending side:

- encapsulates datagram in frame
- adds error checking bits, reliable data transfer, flow control, etc.

receiving side:

- looks for errors, reliable data transfer, flow control, etc.
- extracts datagram, passes to upper layer at receiving side