Lecture 20: Link Layer I

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Contents of Chapter 6

- 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

Contents of Chapter 6

- **Introduction to the link layer**
  - The services provided by the link layer
  - Where is the link layer implemented?
- Error-detection and –correction techniques
- Multiple access links and protocols
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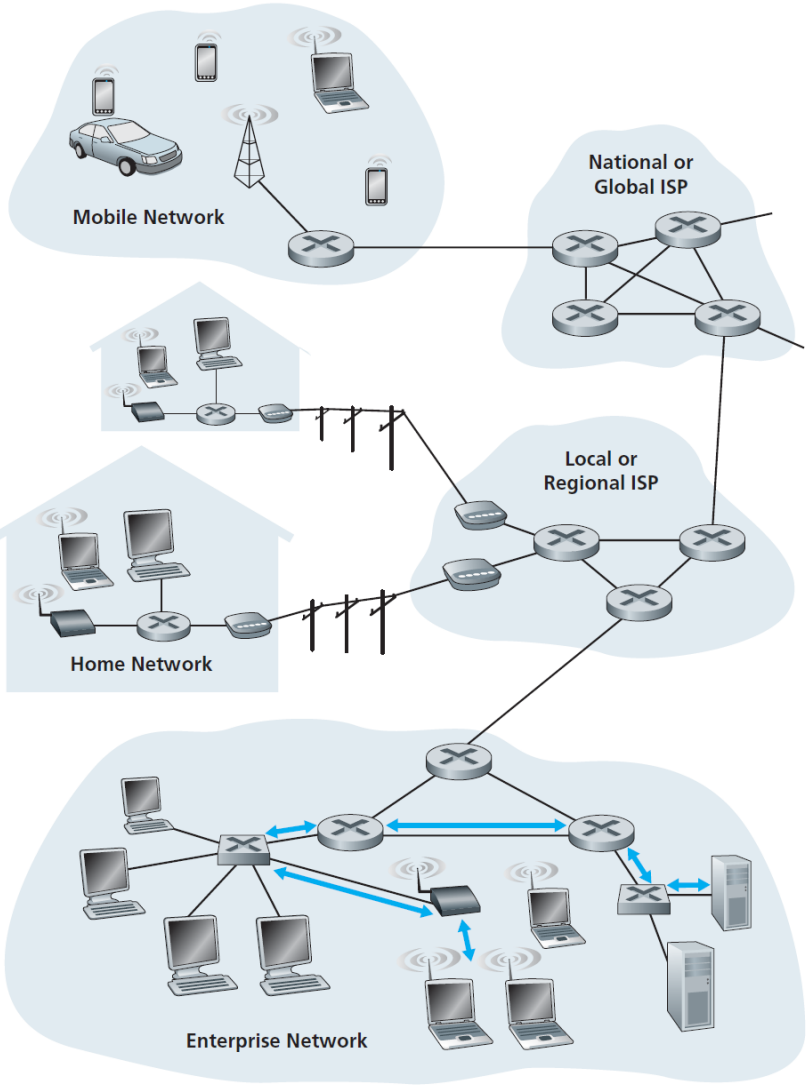
Introduction

- **Types of link-layer channels**
  - Broadcast channels
    - E.g., multiple hosts in wireless LANs, satellite networks, hybrid fiber-coaxial cable (HFC) access networks
  - Point-to-point channel
    - E.g., two routers connected by a long-distance link

Introduction

- **Terminology**
  - **Node**: Any device that runs a link-layer protocol
    - E.g., hosts, routers, switches, and WiFi access points
  - **Link**: A communication channel that connects adjacent nodes along the communication path
  - Link-layer **frames** encapsulate the datagrams.

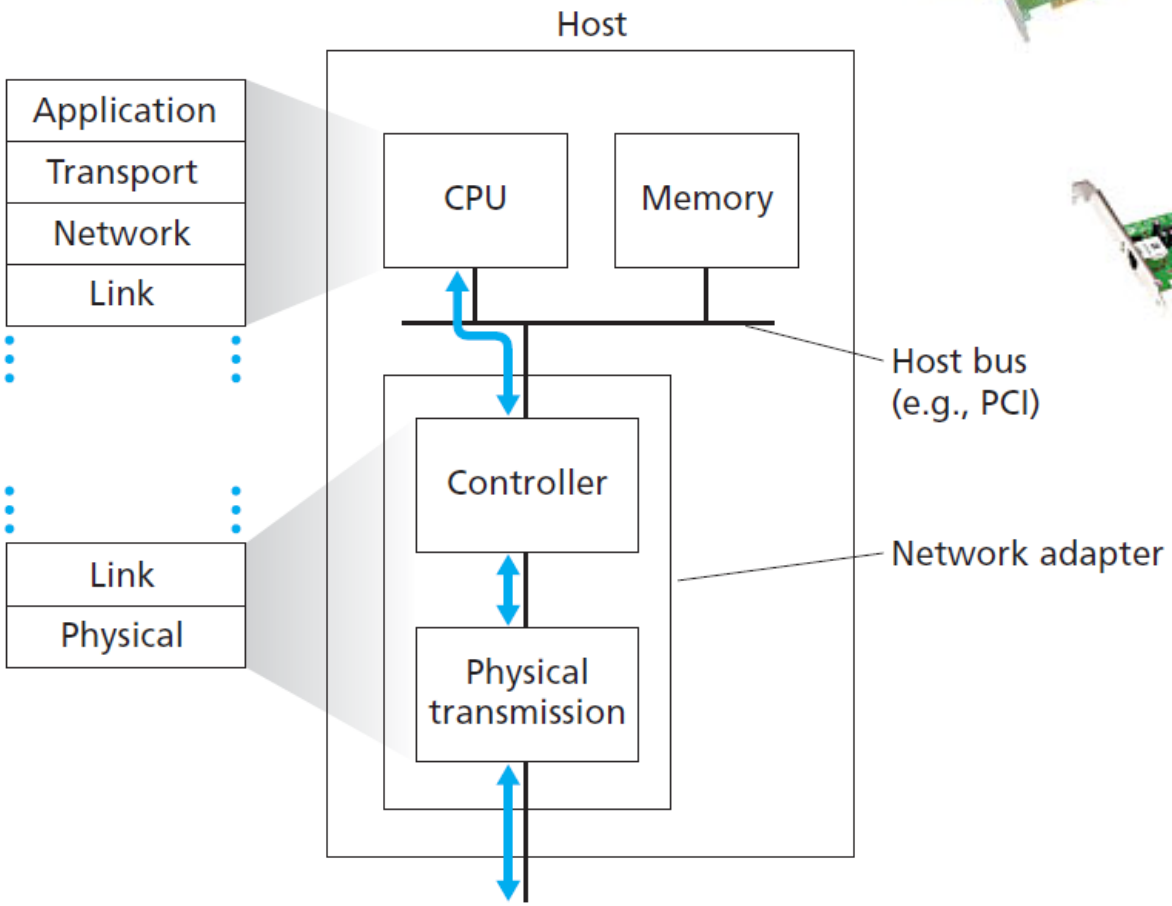


The Services Provided by the Link Layer

- **Framing**
  - Frame = Header field + data field (network-layer datagram)
- **Link access**
  - A medium access control (MAC) protocol specifies the rules by which a frame is transmitted onto the link.
- **Reliable delivery**
  - Often used for links that are prone to high error rates, such as a wireless link
- **Error detection and correction**
  - Error detection: Check whether there are bit errors in the received frame
  - Error correction: Not only detects when bit errors have occurred but also determine exactly where in the frame the errors have occurred (and correct)

Where Is the Link Layer Implemented?

- Network adapter



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  - Parity checks
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  - Cyclic redundancy check (CRC)
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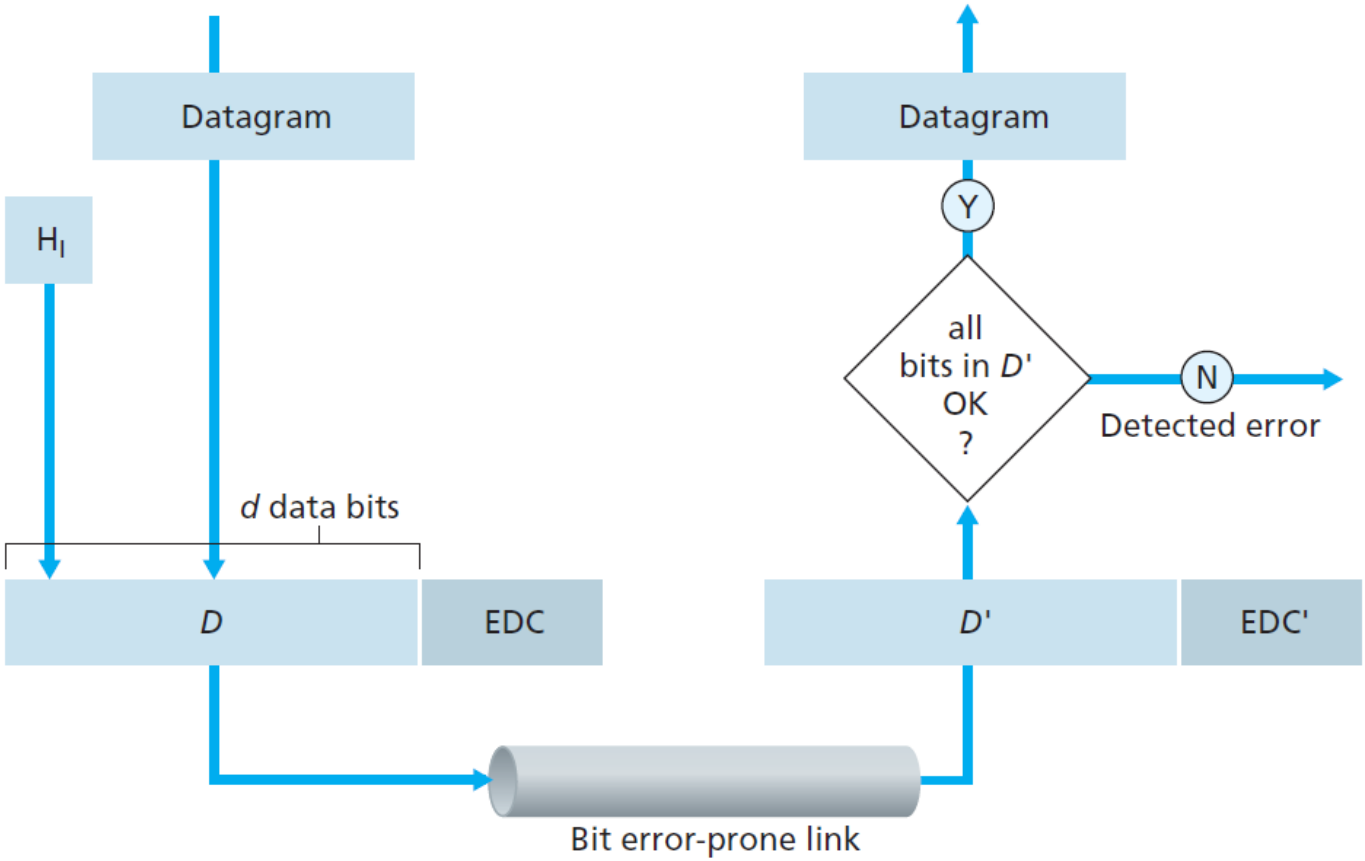
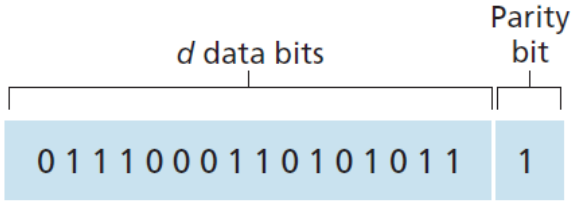
Error-detection and Error-correction

- Error-detection and –correction scenario

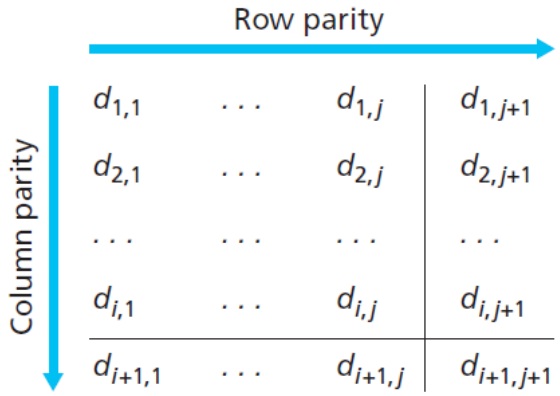


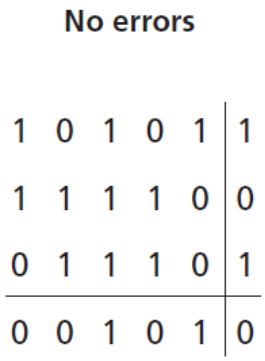
Parity Checks

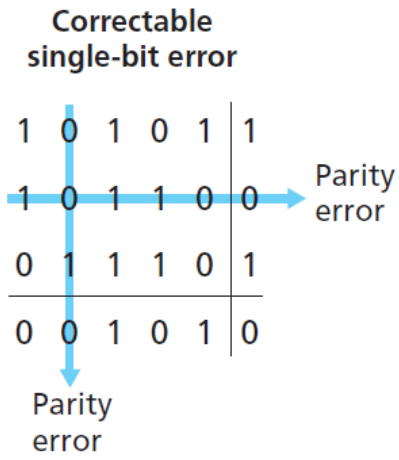
- **One-bit parity scheme**
  - **Even**: The sender includes one additional bit and chooses its value such that the total number of 1s is even.
  - **Odd**: The sender includes one additional bit and chooses its value such that the total number of 1s is odd.



- **Two-dimensional parity scheme**







Checksumming Methods

- **Internet checksum**
  - Transmitter
    - Calculate the 1s complement sum of 16-bit integers
    - Obtain the 1s complement of the sum
  - Receiver
    - Check the checksum by taking the 1s complement of the sum of the received data (including the checksum) and checking whether the result is all 1 bits.
  - In the TCP and UPD protocols, the Internet checksum is computed over all fields (header + data).
  - In IP, the checksum is computed over the IP header.
  - Implemented in SW

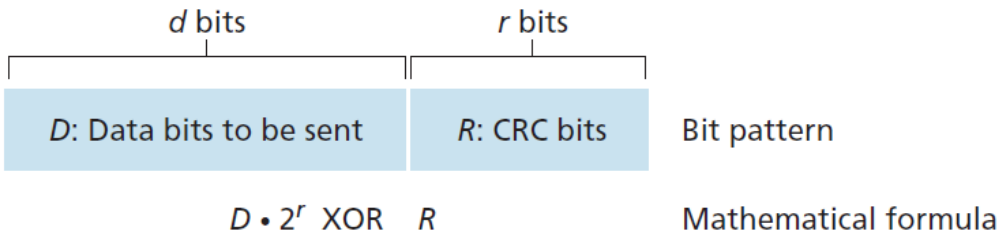
Cyclic Redundancy Check (CRC)

- **The sender**
  - Choose r additional bits, and append them to D such that the resulting $d+r$ bit pattern is exactly divisible by generator G using modulo-2 arithmetic.
- **The receiver**
  - Divide the $d+r$ received bits by G
  - If the remainder is nonzero, the receiver know that an error has occurred.
- **All CRC calculations are done modulo-2 without carries or borrows.**
- **How to calculate R?**

$$D \cdot 2^r \text{ XOR } R = nG$$

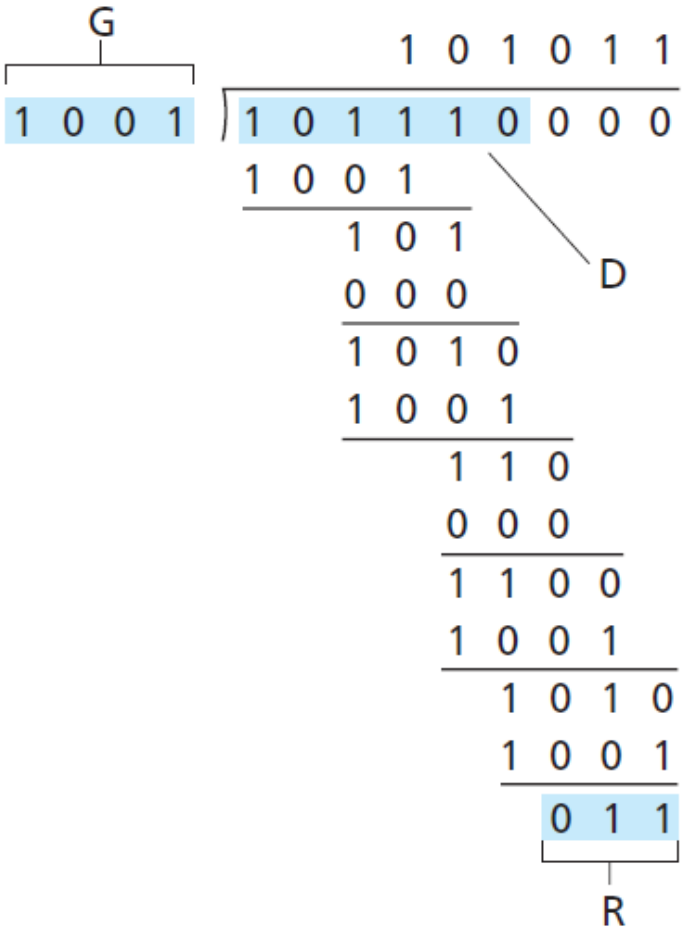
$$D \cdot 2^r = nG \text{ XOR } R$$

$$R = \text{remainder}\frac{D \cdot 2^r}{G}$$



Cyclic Redundancy Check (CRC)

- **Example (*D*=101110, *d*=6, *G*=1001, *r*=3)**



- Transmitted bits: 101110011