National University of Computer & Emerging Sciences

CS 3001 - COMPUTER NETWORKS

Lecture 22

Chapter 5

8th November, 2022

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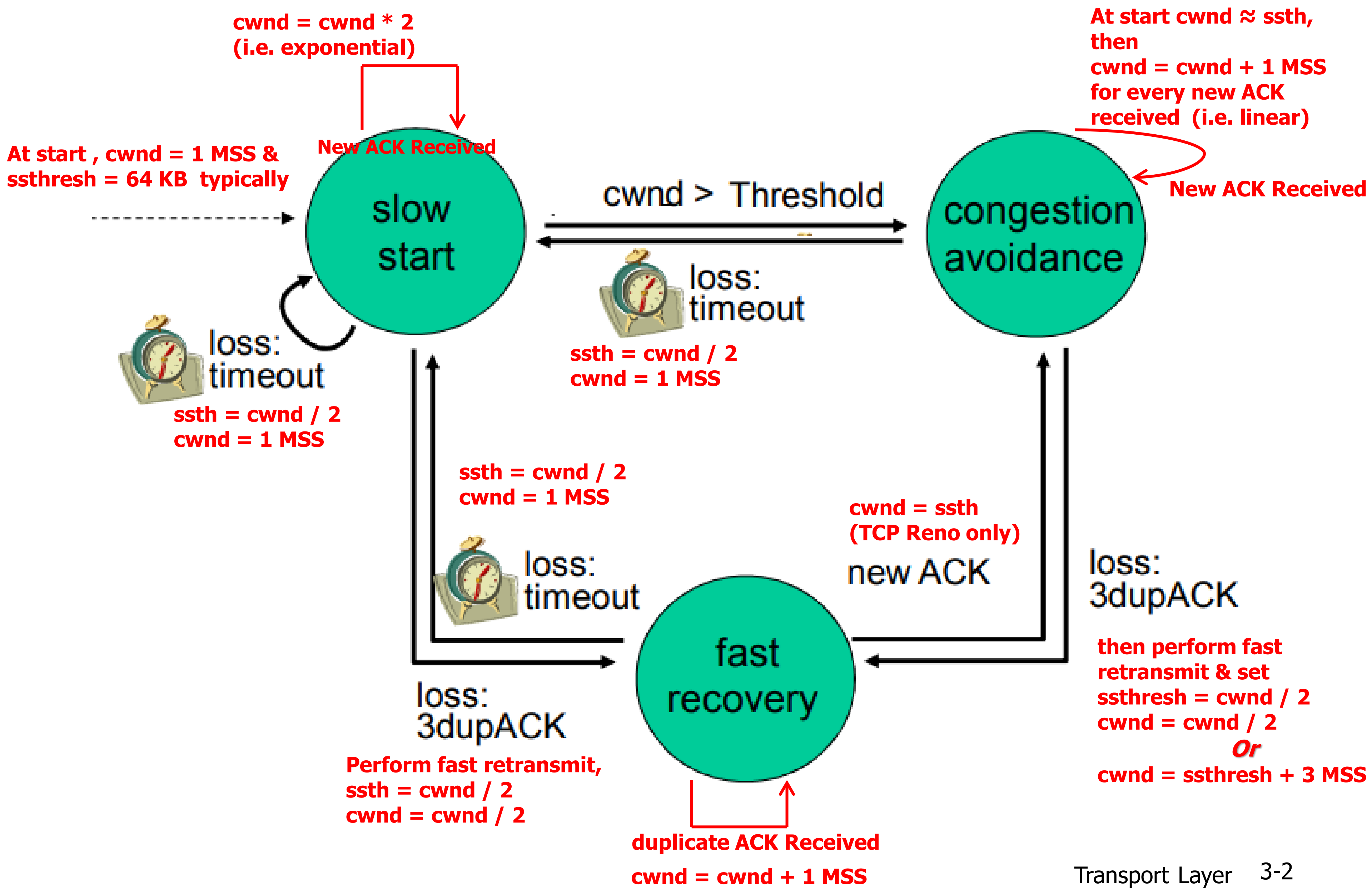
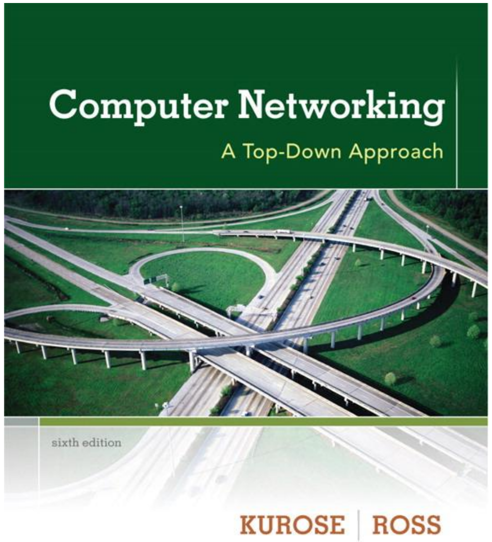
Office Hours: 02:30 pm till 06:00 pm (Every Tuesday & Thursday)

Summary: TCP Congestion Control (TCP Reno)



Chapter 5
Link Layer



A note on the use of these ppt slides:

We're making these slides freely available to all (faculty, students, readers). They're in PowerPoint form so you see the animations; and can add, modify, and delete slides (including this one) and slide content to suit your needs. They obviously represent a lot of work on our part. In return for use, we only ask the following:

- If you use these slides (e.g., in a class) that you mention their source (after all, we'd like people to use our book!)
- If you post any slides on a www site, that you note that they are adapted from (or perhaps identical to) our slides, and note our copyright of this material.

Thanks and enjoy! JFK/KWR

Computer Networking: A Top Down Approach
6th edition
Jim Kurose, Keith Ross
Addison-Wesley
March 2012

Chapter 5: Link layer

our goals:

- understand principles behind link layer services:
  - error detection, correction
  - sharing a broadcast channel: multiple access
  - link layer addressing
  - local area networks: Ethernet, VLANs
- instantiation, implementation of various link layer technologies

Link layer, LANs: outline

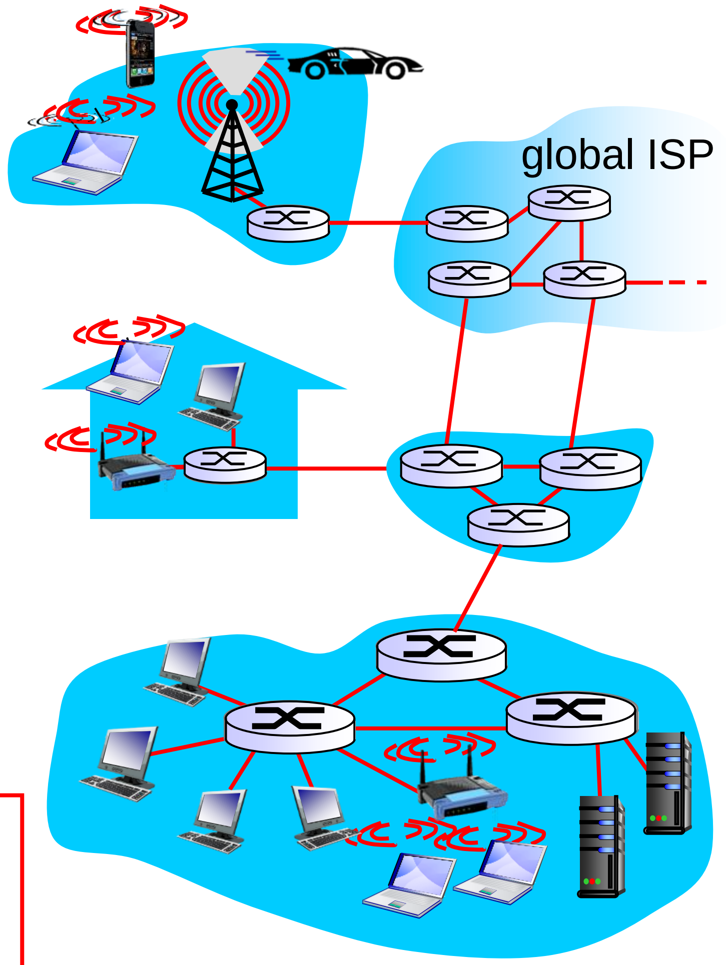
5.1 introduction, services
5.2 error detection, correction
5.3 multiple access protocols
5.4 LANs
- addressing, ARP
- Ethernet
- switches
- VLANS

5.5 link virtualization: MPLS
5.6 data center networking
5.7 a day in the life of a web request

Link layer: introduction

terminology:

- hosts and routers: nodes
- communication channels that connect adjacent nodes along communication path: links
  - wired links
  - wireless links
  - LANs
- layer-2 packet: frame, encapsulates datagram



data-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., Ethernet on first link, frame relay on intermediate links, 802.11 on last link
- each link protocol provides different services
  - e.g., may or may not provide rdt 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

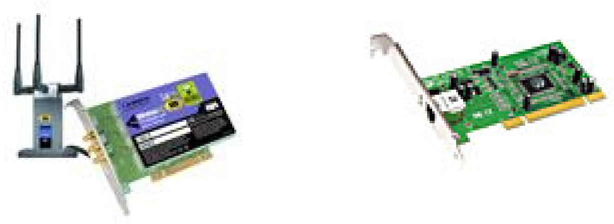
- *framing, link access:*
  - encapsulate datagram into frame, adding header, trailer
  - channel access if shared medium
  - "MAC" addresses used in frame headers to identify source, dest
    - different from IP address!
- *reliable delivery between adjacent nodes*
  - we learned how to do this already (chapter 3)!
  - seldom used on low bit-error link (fiber, some twisted pair)
  - wireless links: high error rates
    - *Q:* why both link-level and end-end reliability?
    - ***A***: Efficiency is improved, i.e. burden taken off of TCP. The goal of correcting an error locally—on the link where the error occurs—rather than forcing an end-to-end retransmission of the data by a transport- or application-layer protocol. Also, even if the link layer is providing reliability, packets could still get lost in intermediate nodes, (e.g. routers etc.)

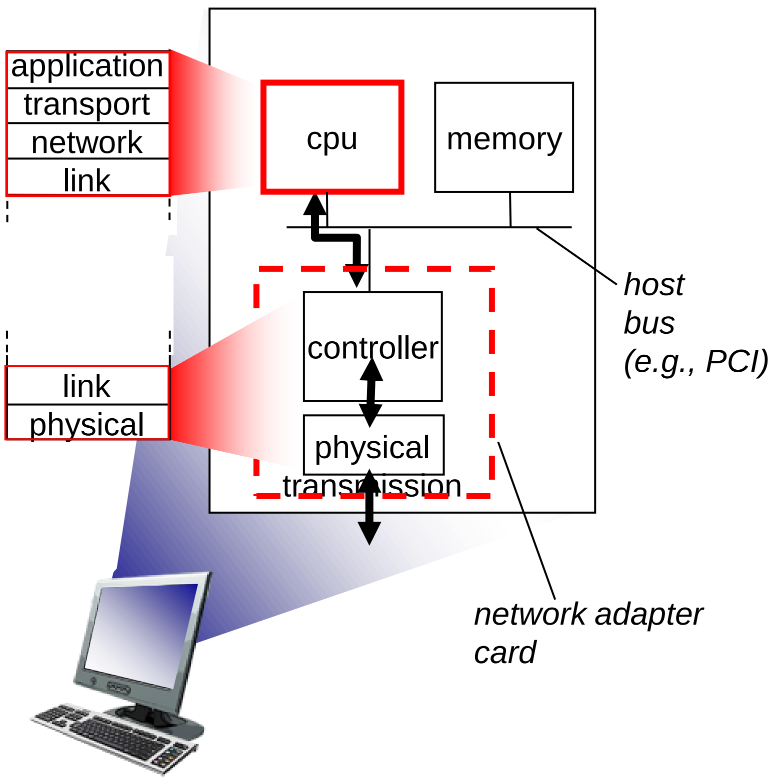
Link layer services (more)

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

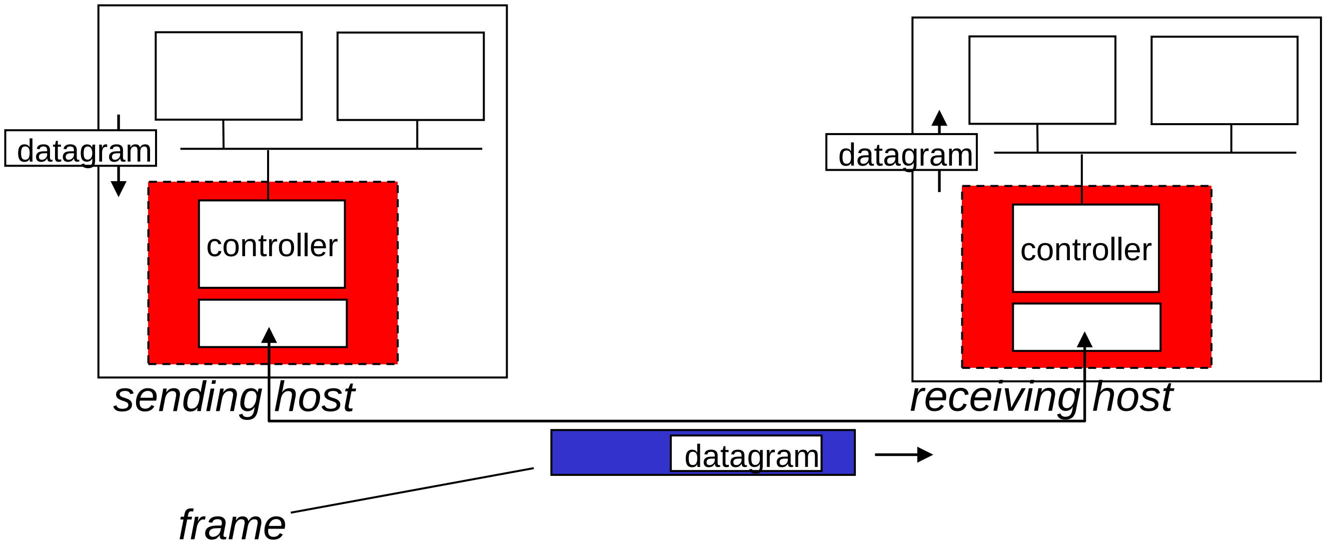
Where is the link layer implemented?

- in each and every host
- link layer implemented in "adaptor" (aka *network interface card* NIC) or on a chip
  - Ethernet card, 802.11 card; Ethernet chipset
  - implements link, physical layer
- attaches into host's system buses
- combination of hardware, software, firmware





Adaptors communicating



- sending side:
  - encapsulates datagram in frame
  - adds error checking bits, rdt, flow control, etc.
- receiving side
  - looks for errors, rdt, flow control, etc
  - extracts datagram, passes to upper layer at receiving side

Link layer, LANs: outline

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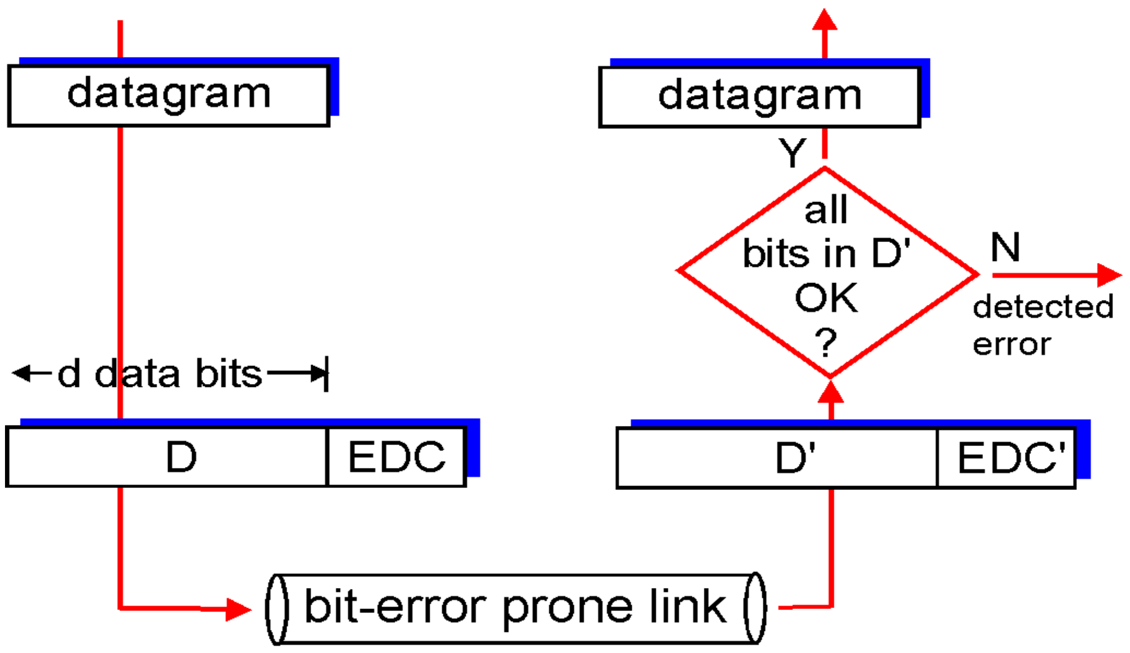
Error detection

EDC= Error Detection and Correction bits (redundancy)
D = Data protected by error checking, may include header fields

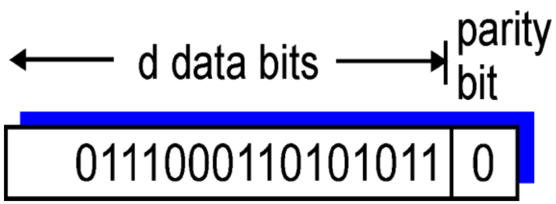
- Error detection not 100% reliable!
  - protocol may miss some errors, but rarely
  - larger EDC field yields better detection and correction (but incur a larger overhead, more computation)



Parity checking (can detect only single bit error, not burst of errors)

single bit parity:

- *d*etect single bit errors

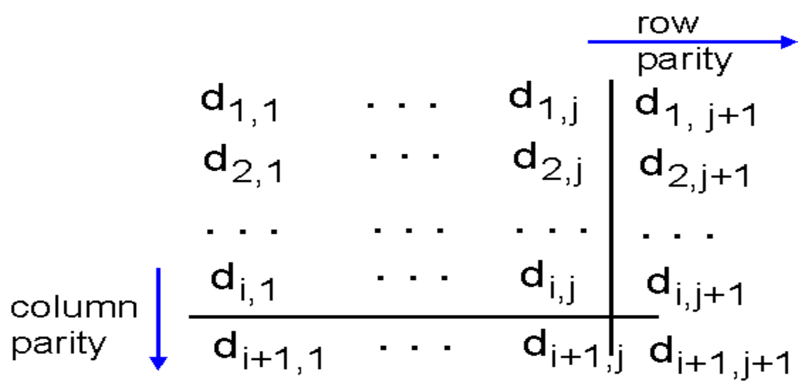


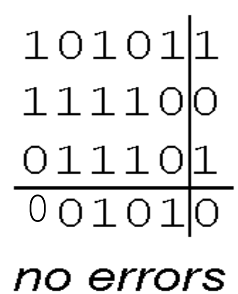
single bit parity:

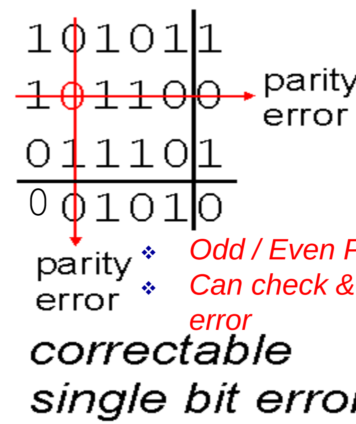
- *Odd / Even Parity Check*
- *Can only check single bit error & discard if error detected, (not correct the error)*

two-dimensional bit parity:

- detect and correct single bit errors







- *Odd / Even Parity Check*
- *Can check & correct single bit error*

Internet checksum (review, primarily performed at the transport layer)

goal: detect "errors" (e.g., flipped bits) in transmitted packet (note: used at transport layer *only*)

sender:

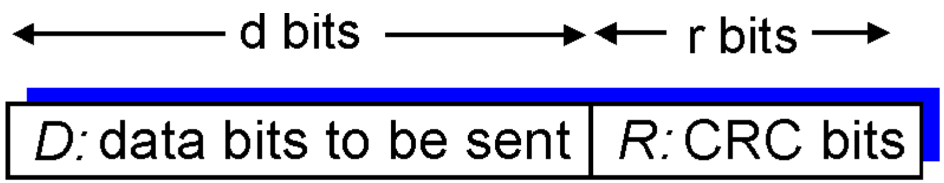
- treat segment contents as sequence of 16-bit integers
- checksum: addition (1's complement sum) of segment contents
- sender puts checksum value into UDP checksum field

receiver:

- compute checksum of received segment
- check if computed checksum equals checksum field value:
  - NO - error detected
  - YES - no error detected. *But maybe errors nonetheless?*

Cyclic redundancy check (aka Polynomial Codes)

- more powerful error-detection coding
- view data bits, D, as a binary number
- choose r+1 bit pattern (known as generator), G (the most significant (leftmost) bit of G is required to be a 1; pre agreed between sender & receiver)
- goal: choose r CRC bits, R, such that
  - <D,R> exactly divisible by G
  - receiver knows G, divides <D,R> by G. If non-zero remainder: error detected!
  - can detect all burst errors less than r+1 bits
- widely used in practice (Ethernet, 802.11 WiFi, ATM)



bit pattern

$$D * 2^r \quad \text{XOR} \quad R$$

mathematical formula for this bit pattern

CRC example (Read textbook pages # 443, 444, 445)

want:

$D \cdot 2^r$ XOR $R = nG$

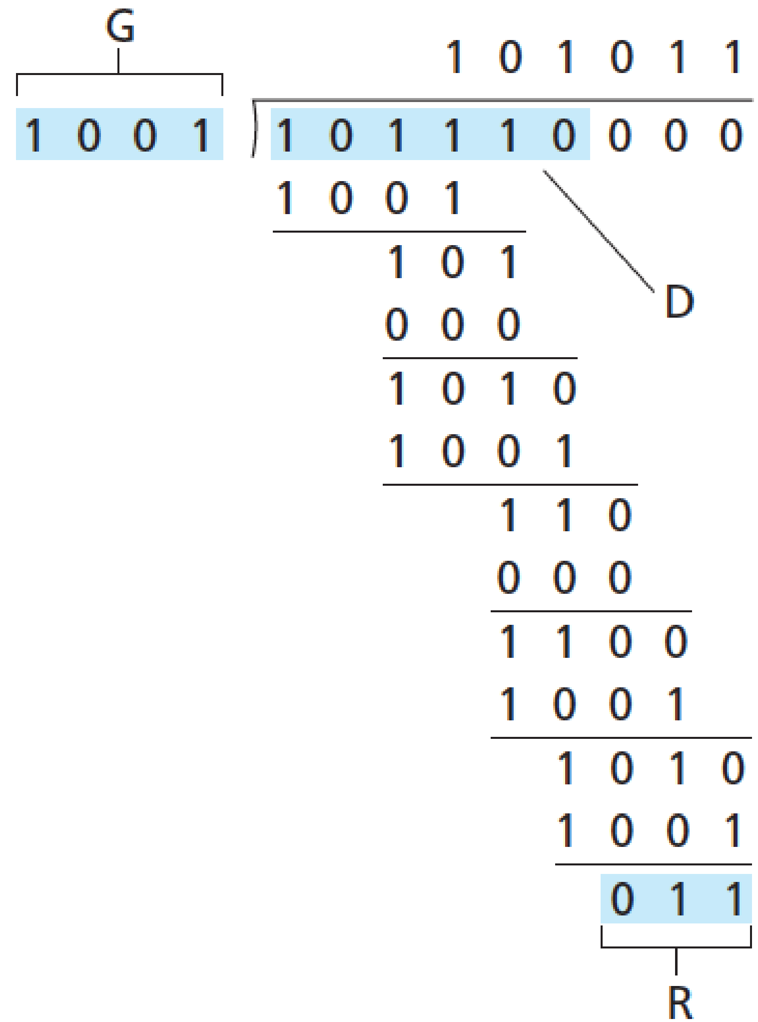
equivalently:

$D \cdot 2^r = nG$ XOR R

equivalently:

if we divide $D \cdot 2^r$ by G, want remainder R to satisfy:

$$R = remainder\left[\frac{D \cdot 2^r}{G}\right]$$



Cyclic Redundancy Check (CRC) – Example Video

- For revision of CRC discussed in the Class, please watch and review my video shared via Google Classroom. (Please watch the complete video, where I explain & solve an example of CRC step by step in detail.)

Very Important Example !!!!!!!

Assignement # 4 (Chapter – 4)

- *4th Assignment will be uploaded on Google Classroom on Tuesday, 8th November, 2022, in the Stream - Announcement Section (not the Classwork Section)*

- *Due Date: Thursday, 17th November, 2022 (Handwritten solutions to be submitted during the lecture)*

- *Please read all the instructions carefully in the uploaded Assignment document, follow & submit accordingly*

GOOD LUCK IN YOUR EXAMS

knock 'em out with your GENIUS!