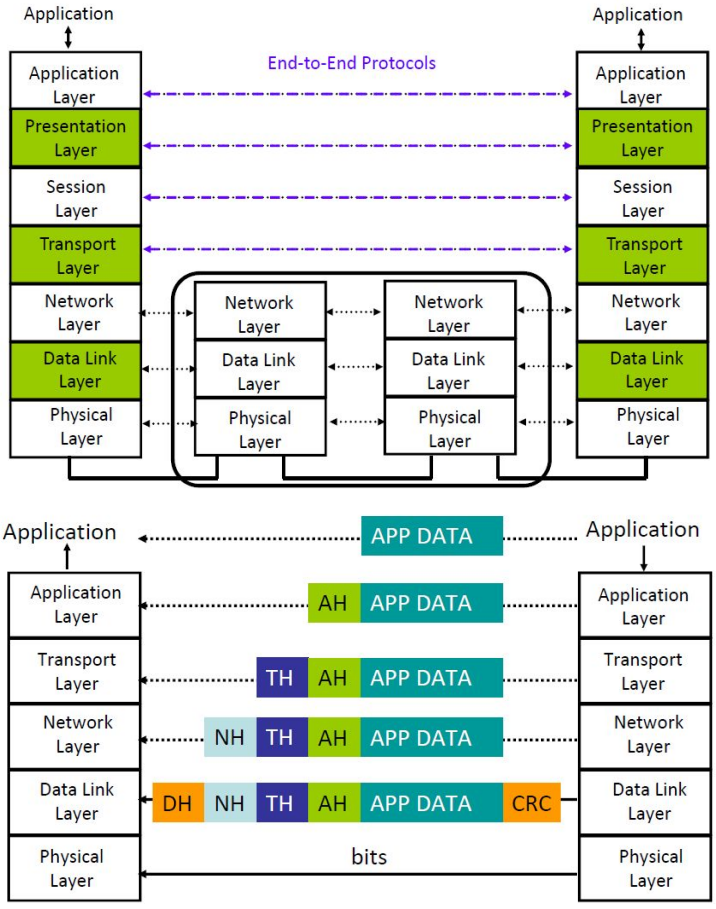
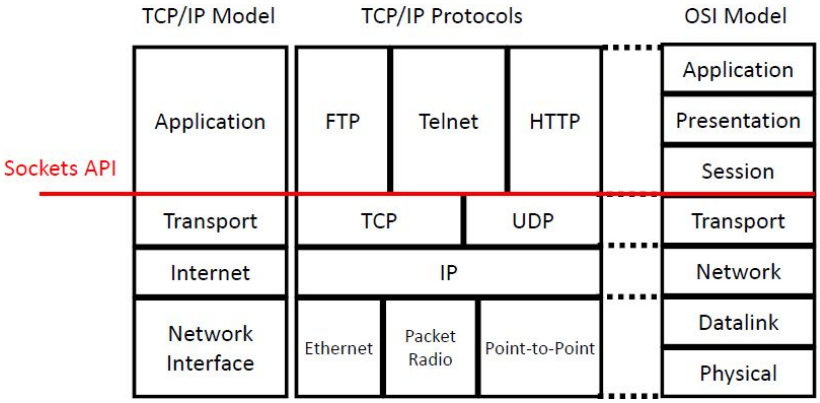
7-Layer OSI Reference Model

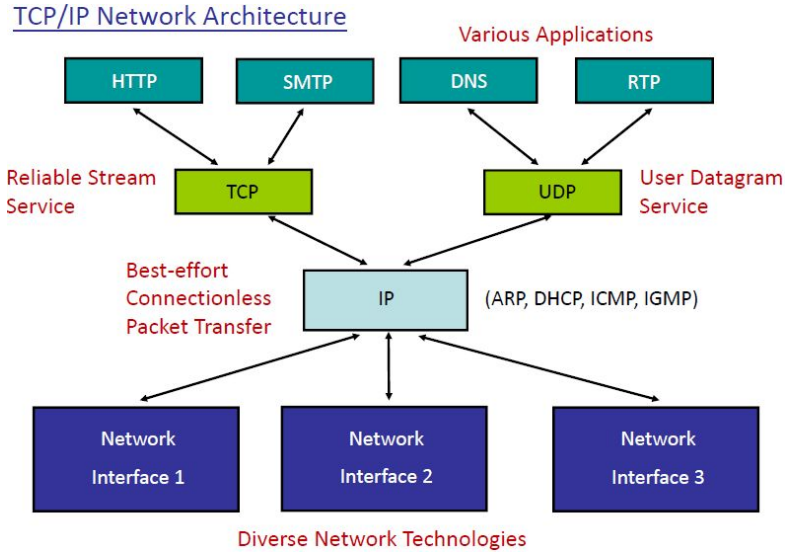
Lecture 2



TCP/IP Network Architecture



TCP/IP Network Architecture



Bit Rate vs. Baud Rate

Lecture 3

- Definitions
  - Bit Rate = # of bits transmitted per second
  - Baud Rate = # of signal transitions per second
- Baud Rate depends on the channel bandwidth
- Bit Rate = (Baud Rate) × (# bits per pulse)
  - It depends on the channel bandwidth as well as the coding scheme
- The bandwidth of a transmission channel (W) is the range of frequencies that is passed by the channel

Multilevel Pulse Transmission

- Assume channel bandwidth of W
- If pulse amplitudes are either -A or +A, then each pulse conveys 1 bit,
  Bit Rate = (2W pulses/sec) × (1 bit/pulse) = 2W bps
- If amplitudes are from {-A, -A/3, +A/3, +A}, then each pulse conveys 2 bits,
  Bit Rate = (2W pulses/sec) × (2 bits/pulse) = 4W bps
- By going with $M = 2^m$ amplitude levels, we achieve
  Bit Rate = (2W pulses/sec) × (m bits/pulse) = 2mW bps
- In the absence of noise, the bit rate can be increased without limit by increasing the pulse level m
- The fastest rate at which (ideal) pulses can be transmitted over the channel (called the Nyquist Rate) is:

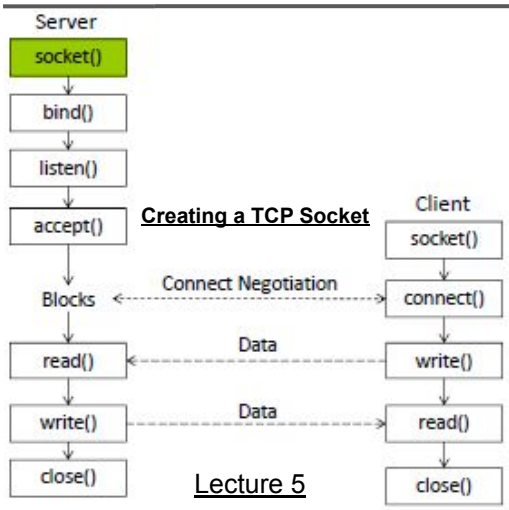
$$r_{max} = 2W \text{ pulses/second}$$

Shannon Channel Capacity $C = W \log_2 (1 + SNR)$ bps

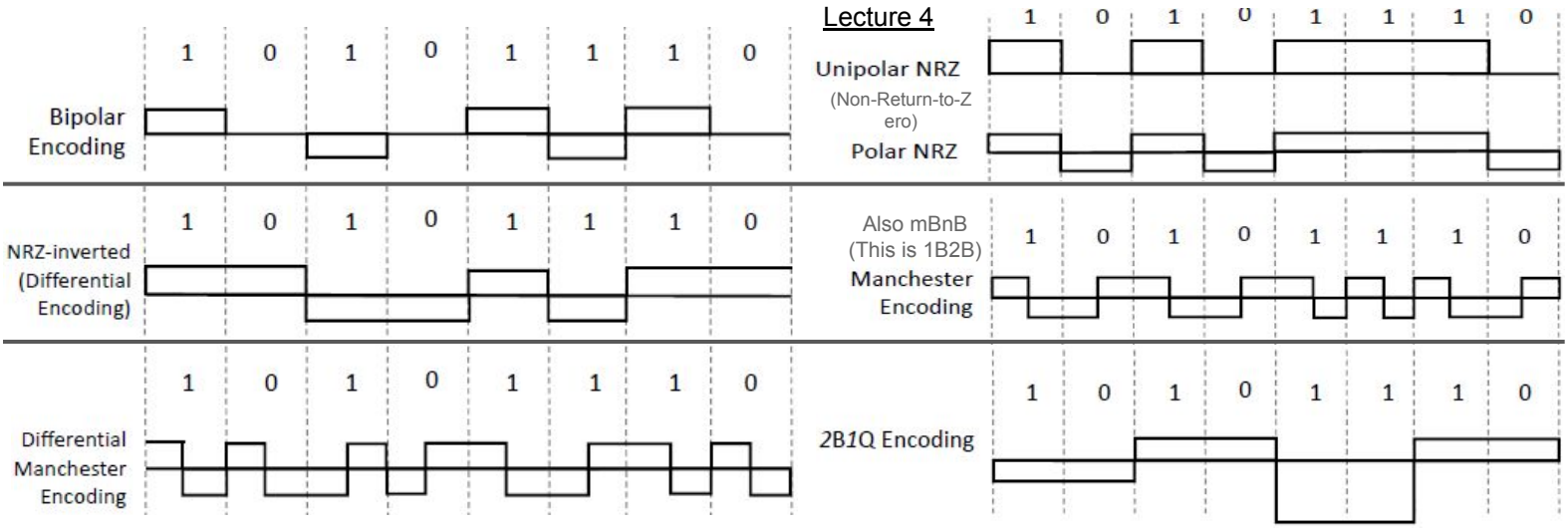
- If transmission rate R > C, reliable communication is not possible
- If transmission rate R ≤ C, arbitrarily reliable communication is possible

Creating a TCP Socket

Lecture 5



Lecture 4

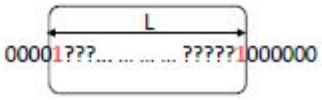


Lecture 5

- Fraction of Undetectable Errors (FUE)
  - FUE = total # undetectable errors / total # valid errors

Error Burst

- Errors can be classified according to:
  - Number of bit error positions: M-bit error
  - Separation of bit error positions: error burst of length L
    - Error starts at bit position i and ends at bit position (i + L - 1)



2B1Q	Previous level: positive	Previous level: negative
Next bits	Next level	Next level
"00"	+A/2	-A/2
"01"	+3A/2	-3A/2
"10"	-A/2	+A/2
"11"	-3A/2	+3A/2

2 bits, one pulse

Lecture 7, 8, 9

Polynomial Encoding

- k information bits define the information polynomial of degree (k – 1)

$$i(x) = i_{k-1}x^{(k-1)} + i_{k-2}x^{(k-2)} + \dots + i_2x^2 + i_1x + i_0$$

- A CRC code is specified by its generator polynomial of degree (n – k) to generate (n – k) check bits

$$g(x) = x^{(n-k)} + g_{n-k-1}x^{(n-k-1)} + \dots + g_2x^2 + g_1x + 1$$

- $x^{(n-k)}\, i(x)$ is the dividend polynomial
- Find the remainder polynomial r(x) of at most degree (n – k – 1)

$$x^{(n-k)}\, i(x) = q(x)\, g(x) + r(x)$$

- Get the codeword polynomial of degree (n – 1)

$$b(x) = x^{(n-k)}\, i(x) + r(x)$$

- All codeword polynomials satisfy the following pattern:

$$b(x) = x^{(n-k)}\, i(x) + r(x) = q(x)g(x) + r(x) + r(x) = q(x)g(x)$$

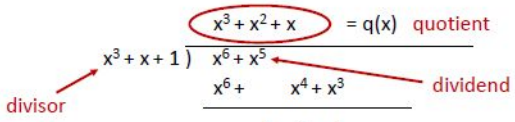
In other words, all codeword polynomials are multiples of g(x)!

Binary Polynomial Arithmetic

Addition: $(x^7 + x^6 + 1) + (x^6 + x^5) = x^7 + (1 + 1)x^6 + x^5 + 1 = x^7 + x^5 + 1$

Multiplication: $(x + 1)(x^2 + x + 1) = x^3 + x^2 + x + x^2 + x + 1 = x^3 + 1$

Division:



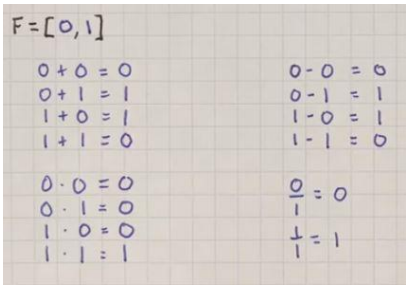
$x^5 + x^4 + x^3$

$x^5 + x^3 + x^2$

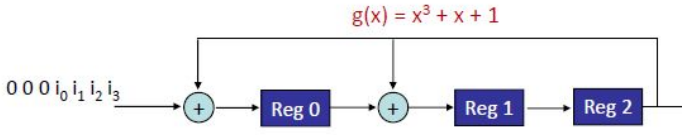
$x^4 + x^2$

$x^4 + x^2 + x$

$x = r(x)$ remainder



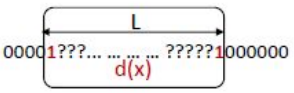
Shift-Register Circuit Implementation



Clock	Input	Reg 0	Reg 1	Reg 2
0	-	0	0	0
1	$1 = i_3$	1	0	0
2	$1 = i_2$	1	1	0
3	$0 = i_1$	0	1	1
4	$0 = i_0$	1	1	1
5	0	1	0	1
6	0	1	0	0
7	0	0	1	0
	Check bits:	$r_0 = 0$	$r_1 = 1$	$r_2 = 0$

Error Detection Capabilities

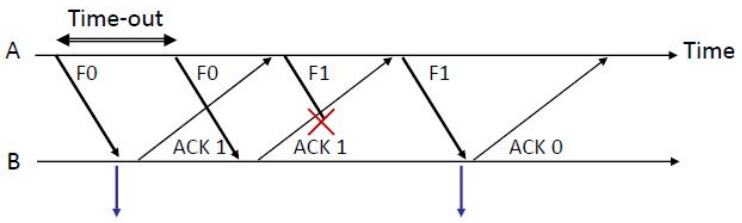
- For Error Bursts of Length L:
  - For error burst starting at bit location i and ending at bit location (i + L - 1)
    - $e(x) = x^{i+L-1} + \dots \dots + x^i = x^i\, d(x)$ where $d(x) = x^{L-1} + \dots \dots + 1$



  - g(x) has degree (n – k)
    - L < (n – k + 1)
      - g(x) cannot divide d(x) because deg(d(x)) < deg(g(x))
      - Can detect all such error bursts
    - L = (n – k + 1)
      - d(x) is divisible by g(x) if and only if d(x) = g(x)
      - Fraction of such error bursts that are undetectable is $(½)^{(n-k-1)}$
    - L > (n – k + 1)
      - Fraction of such error bursts that are undetectable is $(½)^{(n-k)}$

1. Stop-and-Wait ARQ (S&W)

- The transmitter and receiver work on the delivery of one frame at a time through alternation of actions
  - *Essential Components:* ACK, timeout, sequence numbering

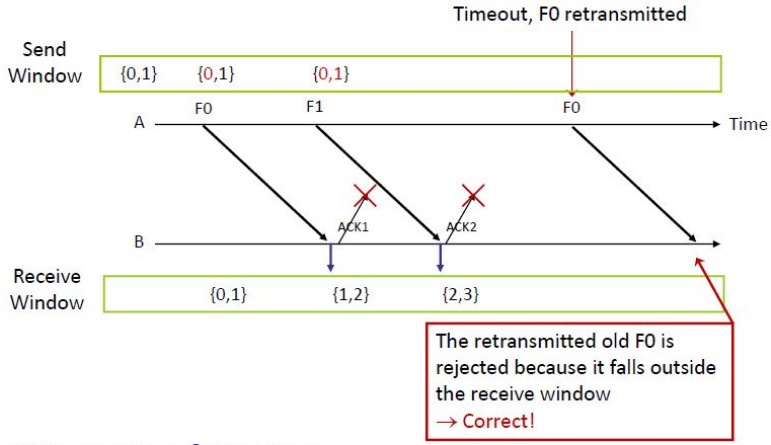


SR Protocol

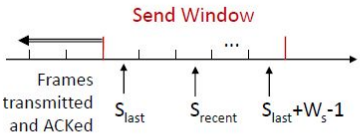
- *Essential Components:* ACK, NAK, timeout, sequence numbering
  - NAK is sent when an error-free out-of-sequence frame is received
  - ACK is sent for all other error-free frames
  - Both ACK and NAK acknowledge reception of all prior frames
- Frame in error is retransmitted upon
  - Timeout or reception of NAK
  - Only the frame in error is retransmitted

$W_s + W_r \leq 2^m$

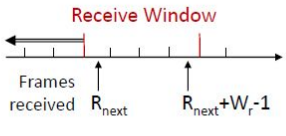
- Example: 2-bit (m = 2) sequence numbering, $W_s = W_r = 2$



SR Transmitter & Receiver



1. If an error-free ACK or NAK with $R_{next} \in [S_{last}, S_{recent}+1]$ arrives, send window slides forward: $S_{last} = R_{next}$
2. When timer for a frame expires or when a NAK arrives, transmitter retransmits the corresponding frame only



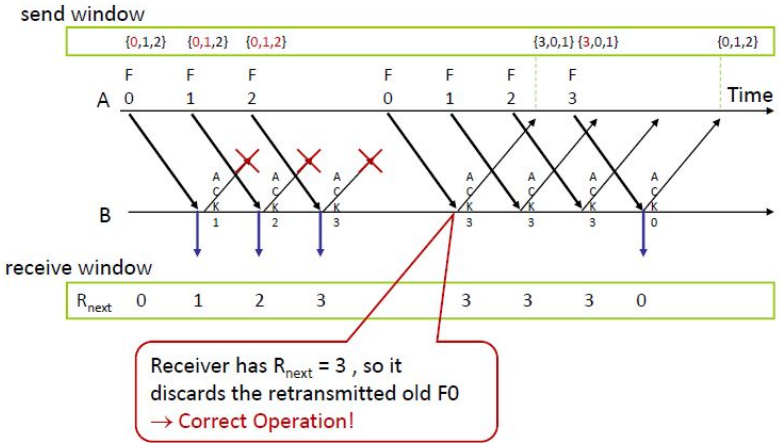
1. Receiver only accepts error-free frames with sequence number $\in [R_{next}, R_{next}+W_r-1]$
2. When frame with sequence number R_{next} arrives, R_{next} is incremented to a proper value $\Rightarrow$ receive window may slide forward by more than one
3. Erroneous frames and error-free frames with sequence number $\notin [R_{next}, R_{next}+W_r-1]$ are discarded
4. NAK is sent when an error-free out-of-sequence frame is received
5. ACK is sent for all other error-free frames received

2. Go-Back-N ARQ (GBN)

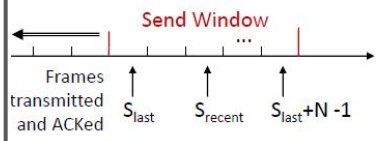
- GBN improves S&W by keeping the channel busy when the transmitter waits for acknowledgment from the receiver
- *Essential Components:* ACK, timeout, sequence numbering
  - ACK acknowledges reception of all prior frames implicitly
- Upon timeout:
  - Frame in error and all subsequent frames are retransmitted

$N + 1 \leq 2^m$

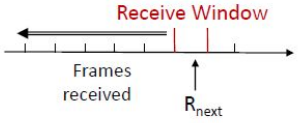
- Example: 2-bit (m = 2) sequence numbering suffices for Go-Back-3 (N = 3) ARQ



GBN Transmitter & Receiver

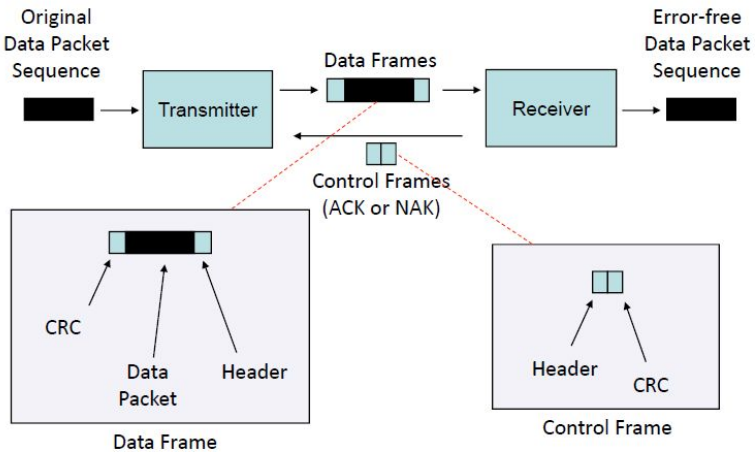


1. Transmitter waits for error-free ACK with: $R_{next} \in [S_{last}, S_{recent}+1]$
2. When such ACK arrives, send window slides forward: $S_{last} = R_{next}$
3. When timer expires for S_{last}, transmitter go-back-N to retransmit S_{last} and all subsequent frames



1. Receiver only accepts error-free frame with sequence number R_{next}
2. When such frame arrives, R_{next} is incremented by one, meaning that receive window slides forward by 1: $R_{next} = R_{next} + 1$
3. Erroneous frames and error-free frames with sequence number $\neq R_{next}$ are discarded
4. ACK is sent for each error-free frame received

Automatic Repeat reQuest (ARQ)



Advantages of LAN (Local Area Network)

- **Resource Sharing:** Computer resources like printers, modems, DVD-ROM drives and hard disks can be shared with the help of local area networks. This reduces cost and hardware purchases.
- **Software Applications Sharing:** It is cheaper to use same software over network instead of purchasing separate licensed software for each client a network.
- **Easy and Cheap Communication:** Data and messages can easily be transferred over networked computers.
- **Centralized Data:** The data of all network users can be saved on hard disk of the server computer. This will help users to use any workstation in a network to access their data. Because data is not stored on workstations locally.
- **Data Security:** Since, data is stored on server computer centrally, it will be easy to manage data at only one place and the data will be more secure too.
- **Internet Sharing:** Local Area Network provides the facility to share a single internet connection among all the LAN users. In Net Cafes, single internet connection sharing system keeps the internet expenses cheaper.

Disadvantages of LAN

- **High Setup Cost:** Although the LAN will save cost over time due to shared computer resources, but the initial setup costs of installing Local Area Networks is high.
- **Privacy Violations:** The LAN administrator has the rights to check personal data files of each and every LAN user. Moreover he can check the internet history and computer use history of the LAN user.
- **Data Security Threat:** Unauthorised users can access important data of an organization if centralized data repository is not secured properly by the LAN administrator.
- **LAN Maintenance Job:** Local Area Network requires a LAN Administrator because, there are problems of software installations or hardware failures or cable disturbances in Local Area Network. A LAN Administrator is needed at this full time job.
- **Covers Limited Area:** Local Area Network covers a small area like one office, one building or a group of nearby buildings.

Advantages of MAN (Metropolitan Area Network)

- Extremely efficient and provide fast communication via high-speed carriers, such as fibre optic cables.
- It provides a good back bone for large network and provides greater access to WANs.
- The dual bus used in MAN helps the transmission of data in both directions simultaneously.
- A MAN usually encompasses several blocks of a city or an entire city.

Disadvantages of MAN

- More cable required for a MAN connection from one place to another.
- It is difficult to make the system secure from hackers and industrial espionage(spying) graphical regions.

Advantages of WAN (Wide Area Network)

- Covers a large geographical area so long distance business can connect on the one network.
- Shares software and resources with connecting workstations.
- Messages can be sent very quickly to anyone else on the network. These messages can have picture, sounds or data included with them(called attachments).
- Expensive things(such as printers or phone lines to the internet) can be shared by all the computers on the network without having to buy a different peripheral for each computer.
- Everyone on the network can use the same data. This avoids problems where some users may have older information than others.

Disadvantages of WAN

- Need a good firewall to restrict outsiders from entering and disrupting the network.
- Setting up a network can be an expensive, slow and complicated. The bigger the network the more expensive it is.
- Once set up, maintaining a network is a full-time job which requires network supervisors and technicians to be employed.
- Security is a real issue when many different people have the ability to use information from other computers. Protection against hackers and viruses adds more complexity and expense.