Chapter 1 – Introduction

Protocol:

defines the format and the order of messages exchanged between two or more communicating entities, as well as the actions taken on the transmission and/or receipt of a message or other event.

Packet Switching:

Store and Forward Transmission – the packet switch must receive the entire packet before it can begin to transmit the first bit of the packet onto the outbound link

Queuing – if an arriving packet needs to be transmitted onto a link but finds the link busy with the transmission of another packet then the arriving packet must wait in the output buffer/queue

Packet Loss – the buffer space is finite and if it is full with other packets waiting for transmission, then either the arriving packet or one of the already-queued packets will be dropped

Multiplexing in Circuit-Switched Networks: Circuits in a link are implemented with either:

FDM (frequency-division multiplexing) – the link dedicates a frequency band to each connection for the duration of the connection. Each circuit *continuously* gets a *fraction* of the bandwidth. e.g. FM radio stations use frequency spectrum between 88MHz and 108MHz, each station is allocated to specific frequency band

TDM (time-division multiplexing) – time is divided into frames of fixed duration and each frame is divided into a fixed duration of slots. Each circuit gets *all* of the bandwidth *periodically*

Overview of Delay in Packet-Switched Networks:

Nodal Processing Delay : d_{proc} – check bit errors, determine output link, typically < micro sec

Queuing Delay : d_{queue} – time waiting at output link for transmission, depends on congestion level of router

Transmission Delay : d_{trans} – L: packet length (bits) | R: link bandwidth (bps) = L/R

Propagation Delay : d_{prop} – d: length of physical link | s: propagation speed in medium = d/s

Total Nodal Delay : $d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$

Transmission vs Propagation delay :

transmission delay is the amount of time required for the router to push out the packet
propagation delay is the amount of time it takes a bit to propagate from one router to the next, has nothing to do packet's length or transmission rate of the link

(segments between booths are links, toll booths are routers, cars are bits, caravan is the packet)

Highway has toll booth every 100 kilometers

Car travels (propagates) on the highway at a rate of 100km/hour

toll booth services (transmits) a car at a rate of one car per 12 seconds :

d_{tran} = (10 cars) / (5 cars / minute) = 2 minutes OR (10 cars) * 12 seconds = 120 seconds

d_{prop} = 100km / (100km/hour) = 1 hour

62 minutes = time from when caravan is stored in front of a toll booth until stored in front of next toll booth

<u>Layered Architecture</u>:

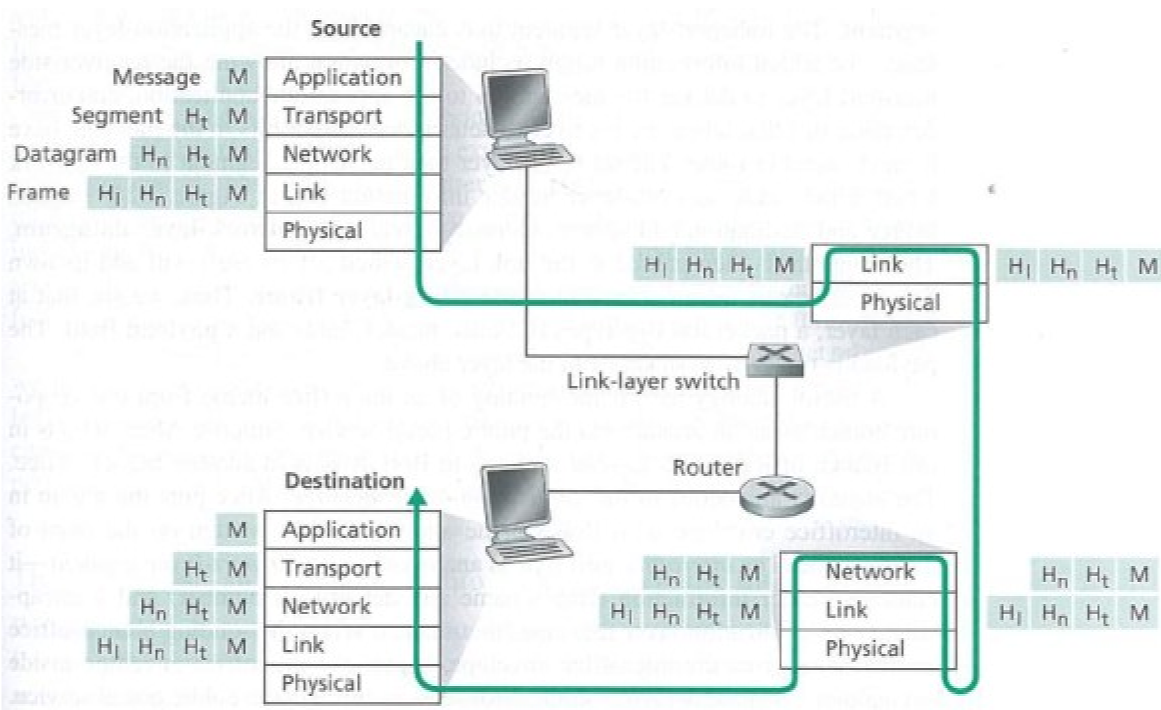
Application – supporting network applications (FTP, SMTP, HTTP)

Transport – transports application-layer messages between application endpoints (TCP, UDP)

Network – routing of datagrams from source to destination (IP, routing protocols)

Link – data transfer between neighboring network elements (Ethernet, 802.111 (WiFi))

Physical – bits "on the wire"



<u>Throughput in Computer Networks</u>:

Throughput – rate at which something is processed

Instantaneous throughput – Host A transmits to Host B across network. At any *instant* of time is the rate (in bits/sec) at which Host B is receiving the file.

Average throughput – file consists of F bits and the transfer takes T seconds for Host B to receive all F bits then average throughput = F/T bits/sec

Rate of server = R_s | Rate of client = R_c | the lowest one is the throughput

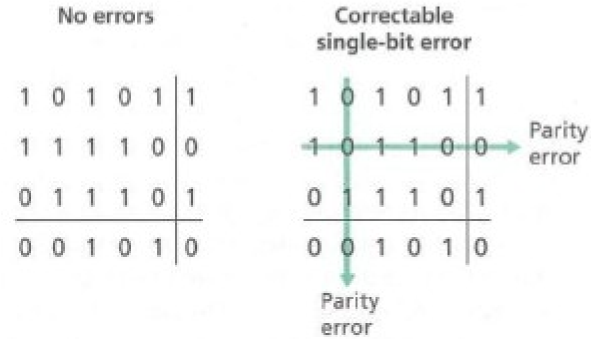
Chapter 6 - Data Link Layer

Data Link Layer – breaks user data from higher layer into data frames and transmits them sequentially over the physical layer's communication channel. Ensures that data is correctly transmitted (detects transmission errors and loss of data packages)
sits on top of physical layer in OSI Reference Model

Error Detection and Correction Techniques:

Parity Checks

2D even parity check: can detect bit error at a specific position but NOT correct



Checksum

Bits are treated as integers and the sum is kept track of and used to detect errors. Low packet overhead but provide weak protection against errors

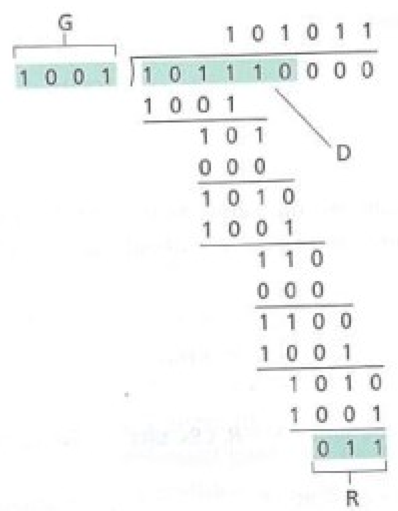
CRC

Detect all burst errors (mostly used in Ethernet)

Polynomial = $x^5 + x^3 + x + 1$ = 101011

XOR division

Remainder = CRC code



Example:

D = 101110

d = 6 (number of data bits)

G = 1001 (generator) = $x^3 + 1$

r = 3 (highest power in G)

Transmitted code = D + R

Hamming Code – Error Detection and Correction

Determine k : $2^k >= m + k + 1$ (m = message bit length)

k = number of parity bits to add (at position 1, 2, 4, 8, etc)

m = 8

$2^4 >= 8 + 4 + 1$

Transmitted messages length = 8 + 4 = 12

12	11	10	9	P8	7	6	5	P4	3	P2	P1

P1: [1, 3, 5, 7, 9, 11]

P2: [2, 3, 6, 7, 10, 11]

P4: [4, 5, 6, 7, 12]

P8: [8, 9, 10, 11, 12]

Slotted ALOHA

each node attempts to transmit a frame in a slot with probability ‘p’

Assume there are N nodes

the probability that a given slot is ‘successful’ is defined by a node transmitting with ‘p’ and [N-1] nodes not transmitting with (1-p)

The probability of a given node having success

$p(1-p)^{N-1}$

For N nodes, the probability of success

$N * p(1-p)^{N-1}$

CSMA/CD – Estimation of Conditional Probabilities

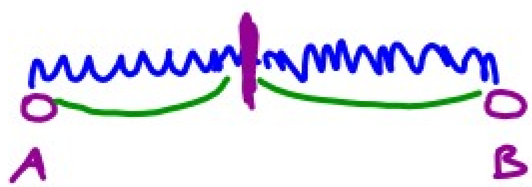
Carrier Sense Multiple Access / Collision Detection

carrier sensing – node listens to channel before transmitting and waits if a frame from another node is currently being transmitted into the channel. The node continues to wait until it detects no transmissions. (listen before speaking)

collision detection – listens to channel while transmitting and if another node is detected transmitting an interfering frame, it stops transmitting and waits a random amount of time to recheck if there is an interfering frame being transmitted.
(stop talking if someone else is talking)

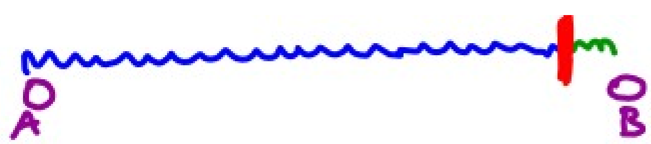
2 Nodes A and B.

1



T: 10:00AM, A and B start transmitting (blue)
T: 10:30AM, Collision (purple line)
T: 11:00AM, Collision signal sent back to A and B (green)

2



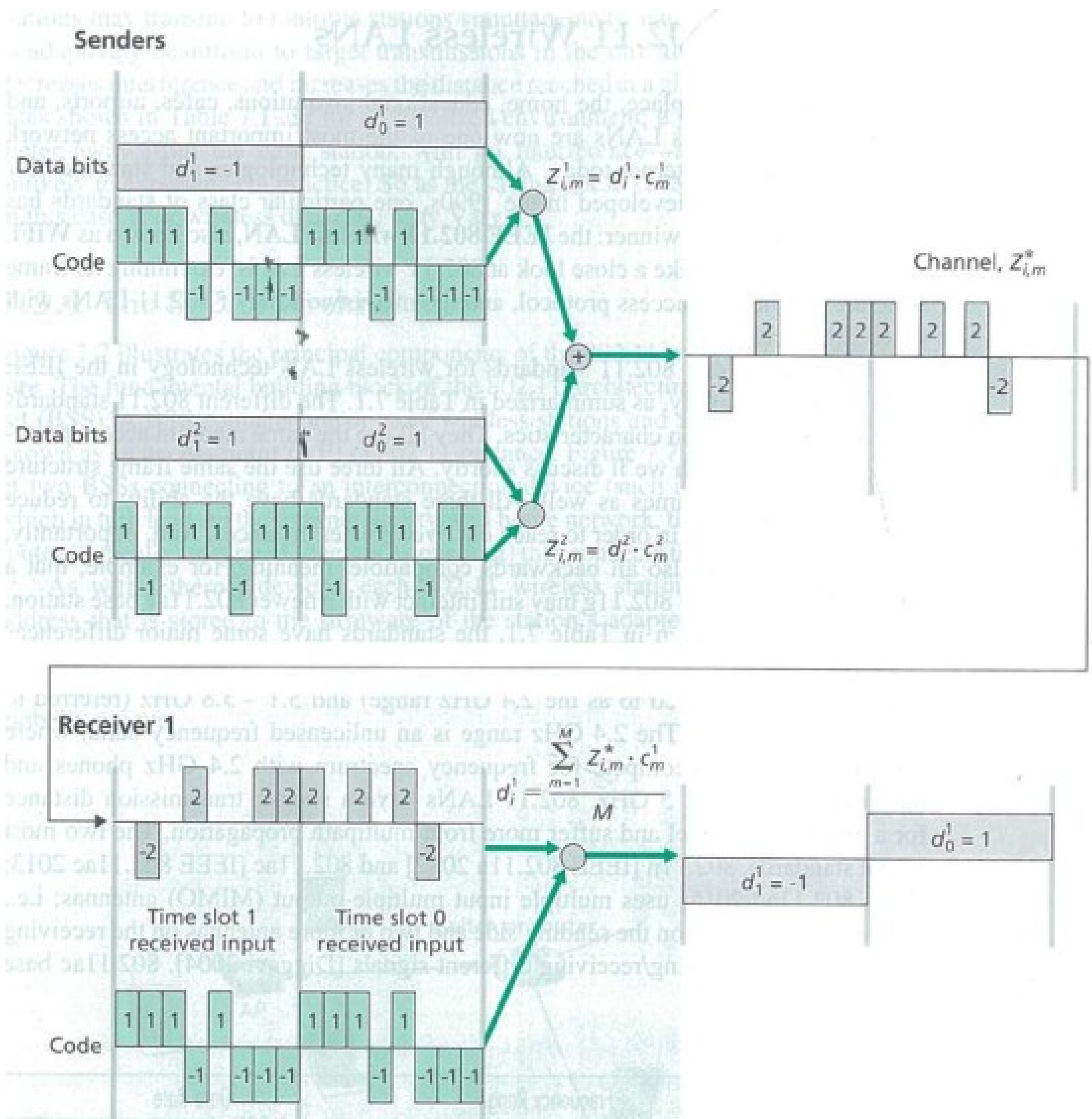
T: 10:00AM, A has started transmission
T: 10:59AM, B has started transmission
T: 11:00AM, Collision has been detected
T: 11:01AM, B hears its collision signal
T: 11:59AM, A will hear its collision signal
(since A’s transmission traveled 59 minutes, it must wait 59 minutes to hear back

Chapter 7 – Wireless Networks

<u>CDMA</u>:

Code Division Multiple Access – each bit being sent is encoded by multiplying the bit by a signal (the code)

Code (1, 1, 1, -1, 1, -1, -1, -1) * d_1 then (1, 1, 1, -1, 1, -1, -1, -1) * d_0



The 802.11 Architecture, Active and Passive Scanning in Wireless Networks:

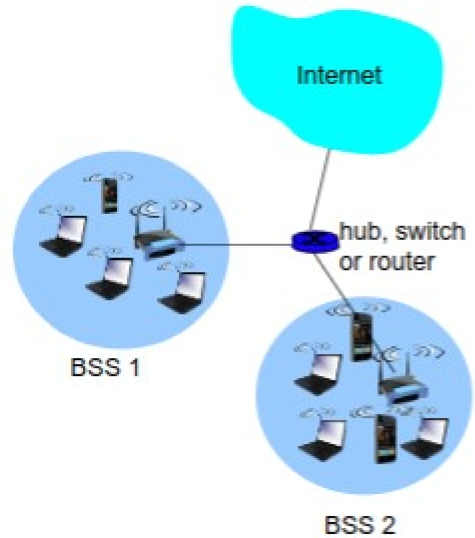
Architecture –

BSS – basic service set

AP – access point

Passive Scanning – scanning channels and listening for beacon frames

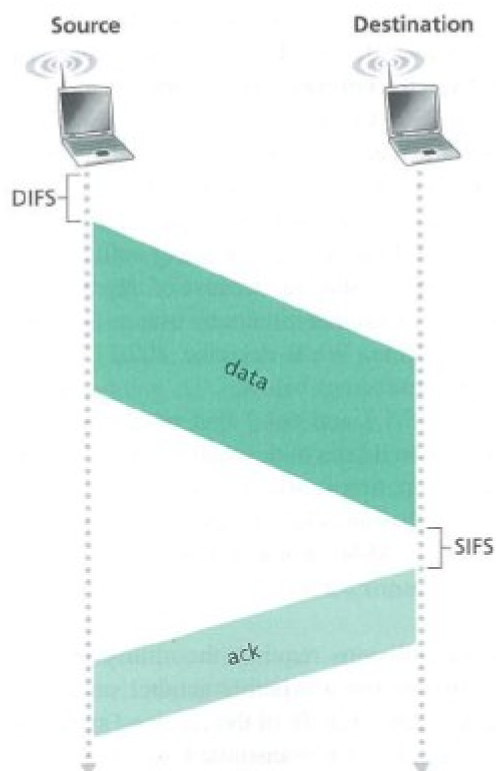
Active Scanning – broadcasting a probe frame that will be received by all Aps within the wireless device's range



802.11 MAC Layer CSMA/CA Protocol:

SIFS (short inter-frame spacing) – when destination station receives a frame, it waits a short period of time then sends back acknowledgment frame

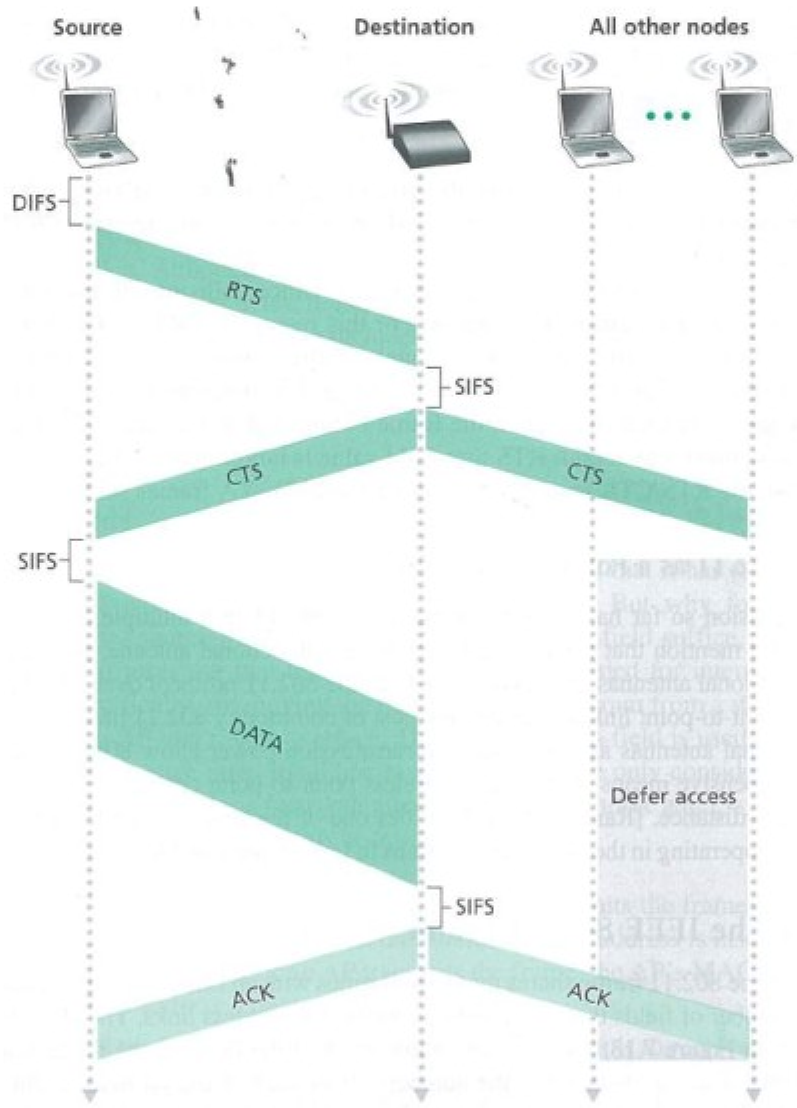
DIFS (distributed inter-frame space) – if the station senses the channel is idle then after a short period of time it transmits



CTS and RTS:

short control frame to reserve access to a channel
CTS – clear to send

RTS – request to send



Hidden Terminal Problem: