NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

NTU IOT RESEARCH GROUP

WANDS wireless and networked distributed sensing group

CE3005 Computer Networks

Part 1 - Tutorial 3 - LAN and Wireless Protocols: CSMA/CD, Backoff, and Throughput Analysis

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if you have questions

Q1: Carrier Sense Multiple Access with Collision Detection

The CSMA/CD specification for a medium is given below:

(a) Maximum cable length per segment is 200 meters and the propagation delay is 1 μsec per 100 meters.

(b) Maximum number of stations per segment is 20.

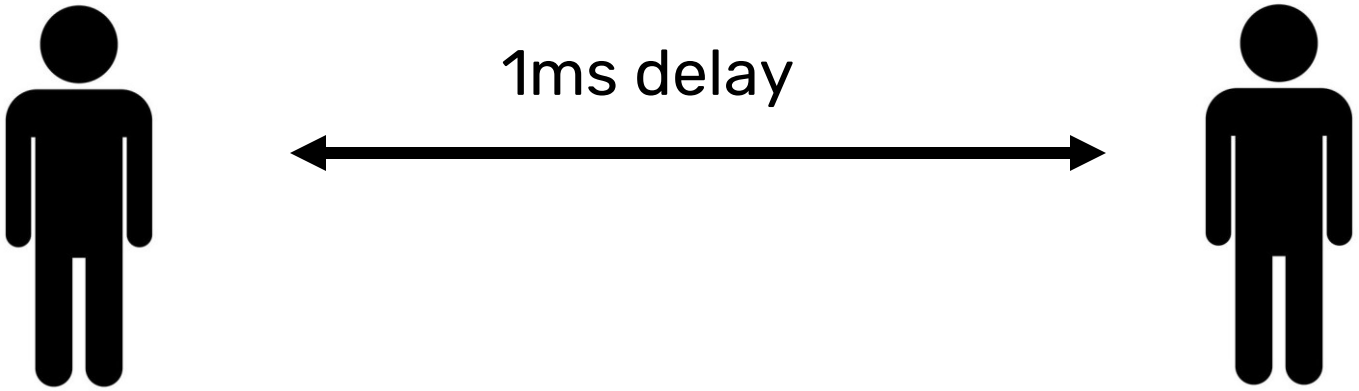
(c) Maximum number of repeaters between any two segments (or say, between any two stations) of a LAN is 4. Delay through each repeater is 2 μsec.

Determine the minimum frame size required for correct operation of the CSMA/CD protocol if the network is run at 20 Mbps.

Carrier Sense Multiple Access with Collision Detection.

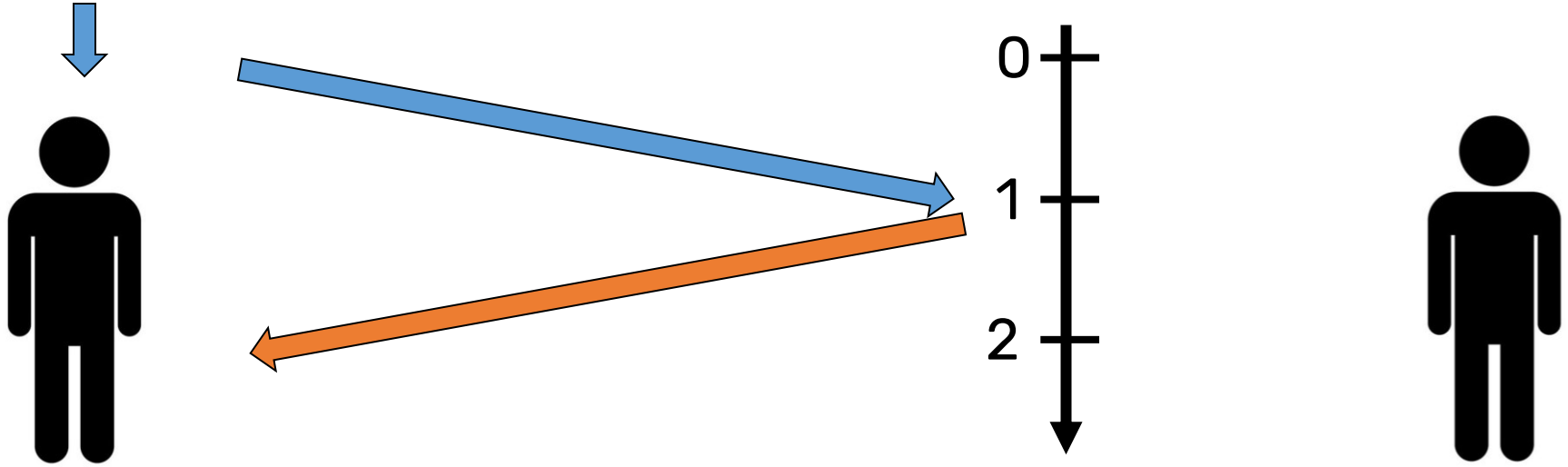
Q1: Detection

Question: How long does it take to detect a collision (worst case)?



Q1: Detection

Question: How long does it take to detect a collision (worst case)?



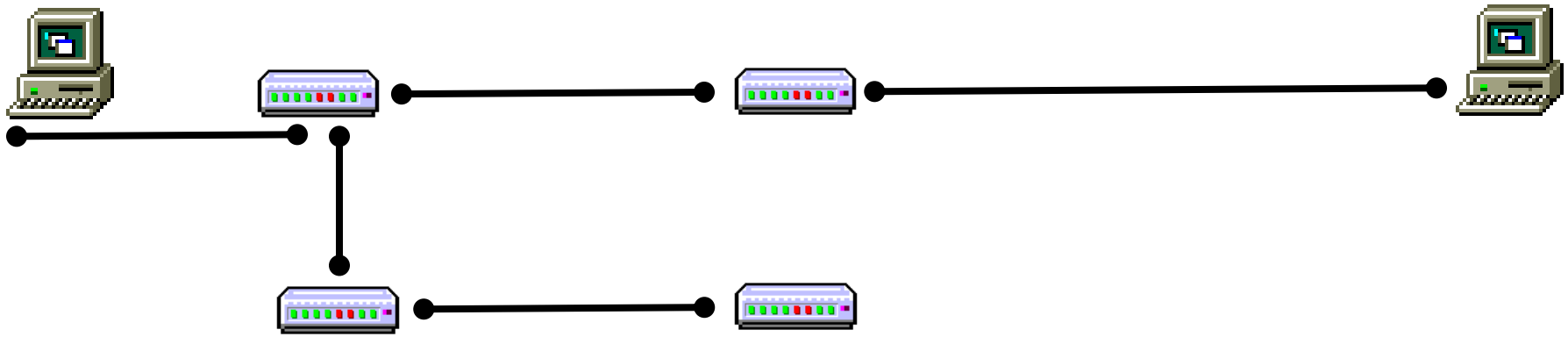
B speaks right when A's sound arrives

Q1: Minimal Worst Case Setup?

(a) Maximum cable length per segment is 200 meters

(b) Maximum number of stations per segment is 20.

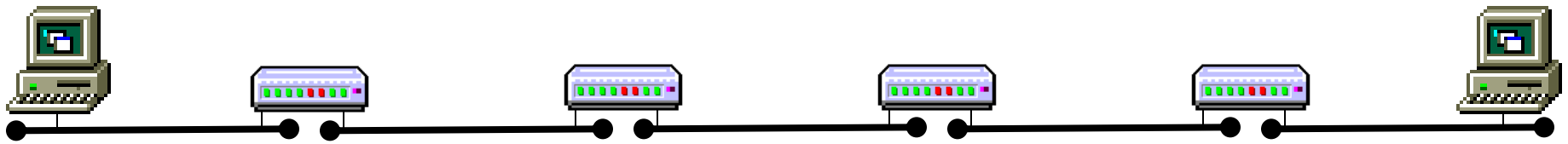
(c) Maximum number of repeaters between any two segments (or say, between any two stations) of a LAN is 4.



Q1: Delay

..and the propagation delay is 1 μsec per 100 meters.

..delay through each repeater is 2 μsec.



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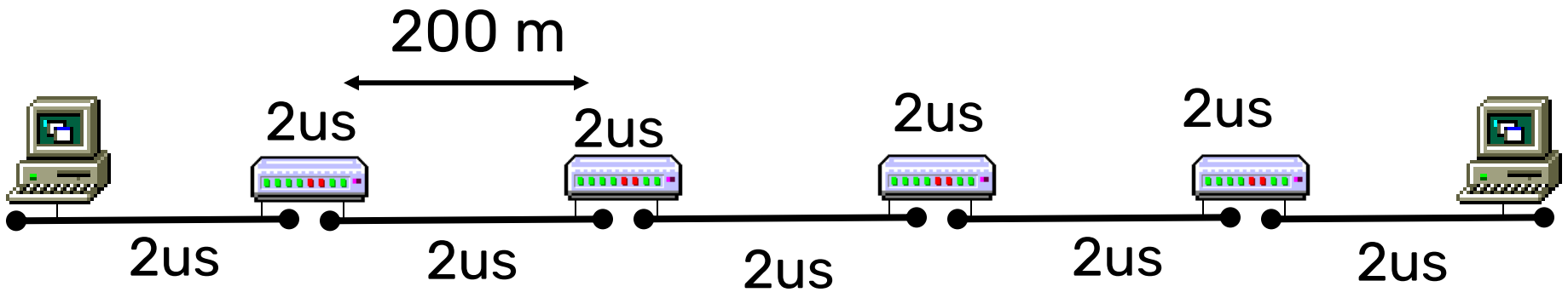


9*2us = 18us -> *2 = 36us

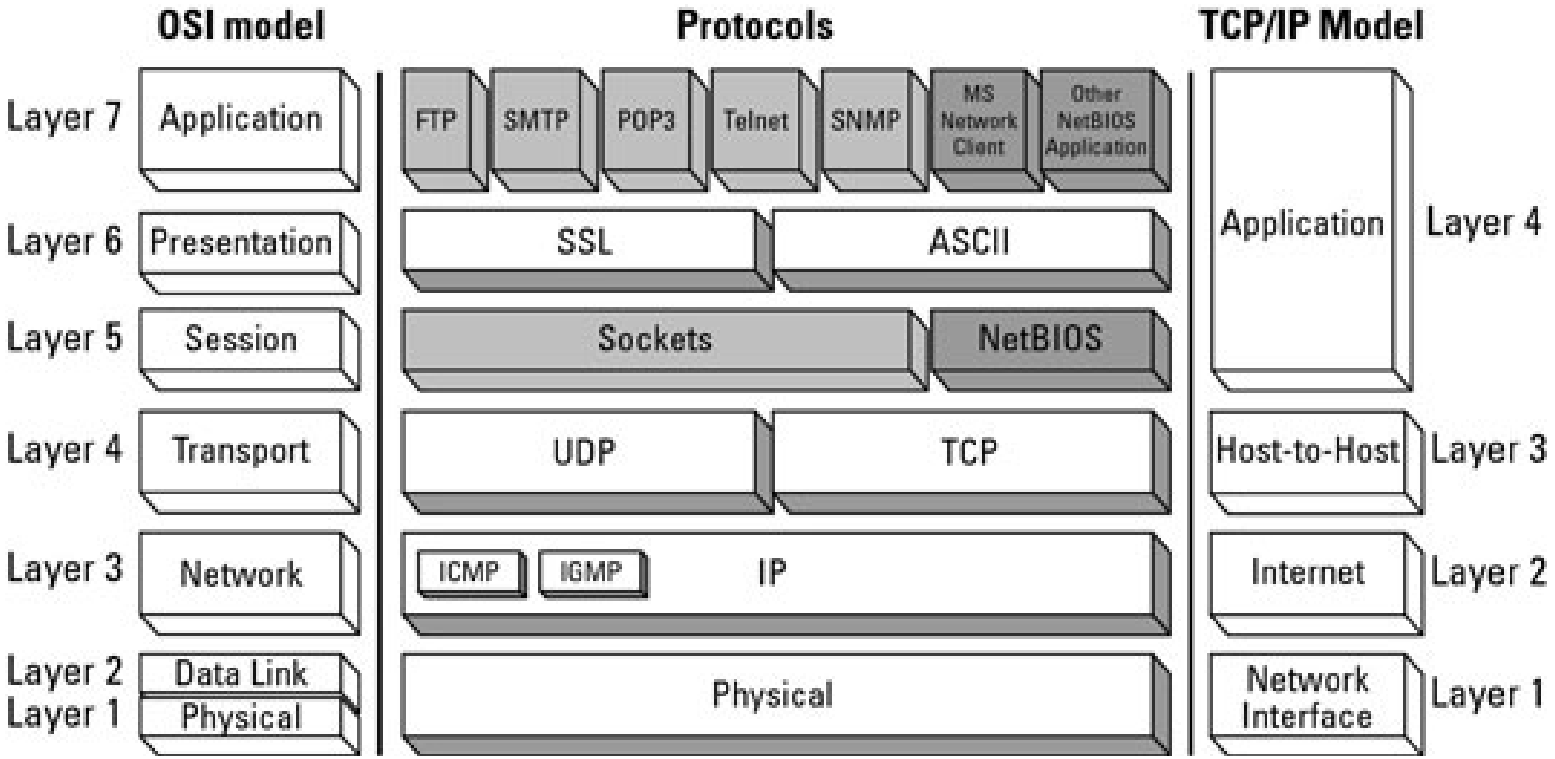
Q1: Minimum Frame Size

Minimum frame size (tx time) = 36 us

at 20Mb/s, for a time period of 36 us, the number of bits can be transmitted is:

36us * 20Mb/s = 720 bits

Which Layer are we working on?



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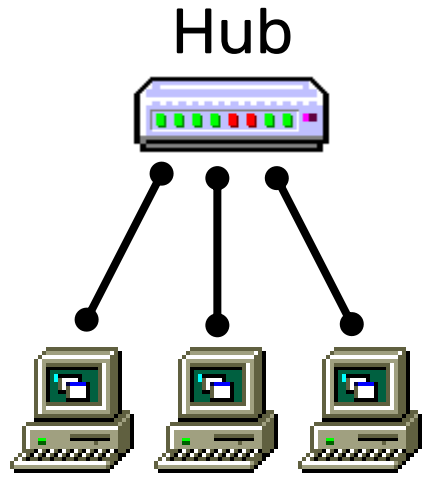
Q2: Binary Exponential Backoff (BEB)

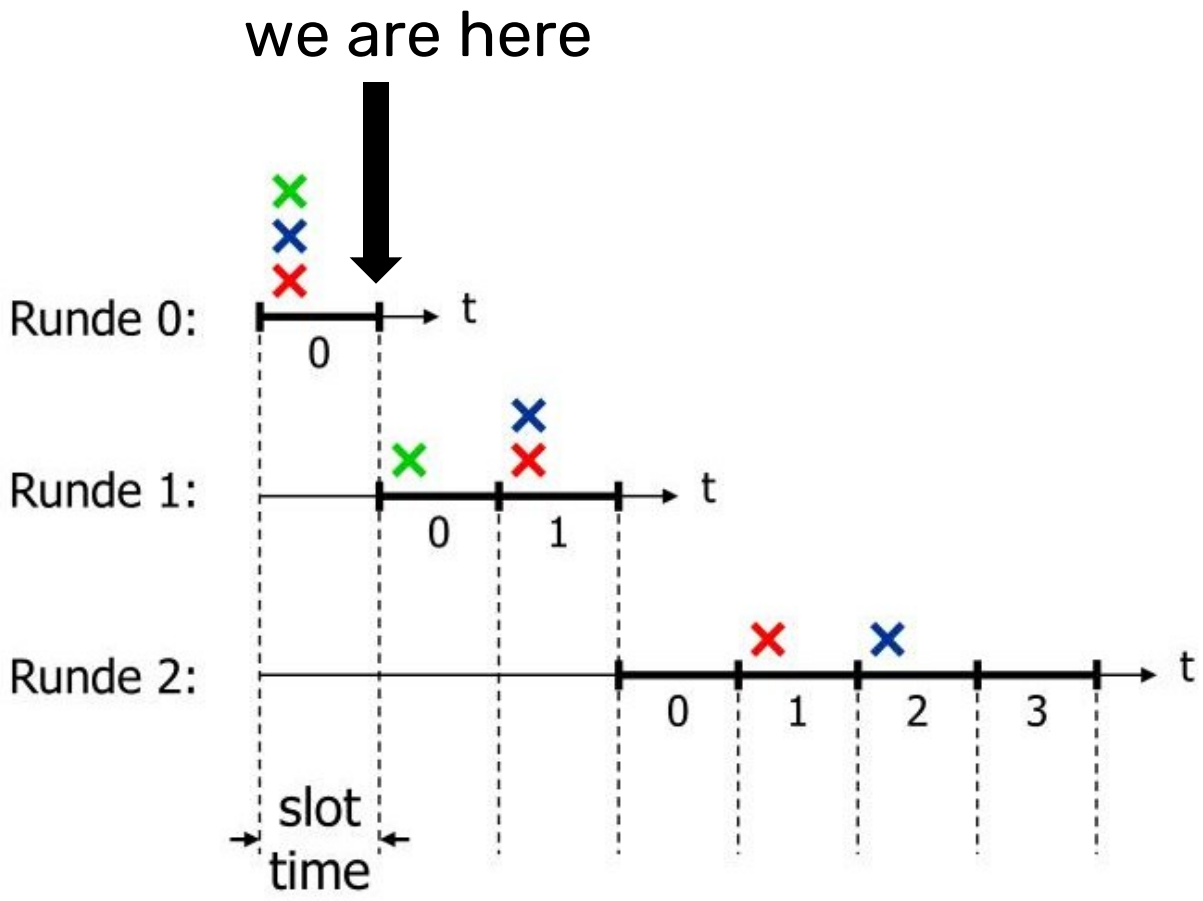
PROBLEM:
Three stations involved in a collision in an attempt to access an Ethernet LAN. Calculate the probability that the next event on the channel is also a collision.



Next event can be either:
- a successful transmission
or
- a collision.

(Hint: *if nothing happens on the first retrial time slot, it does not count as an event.*)

Q2



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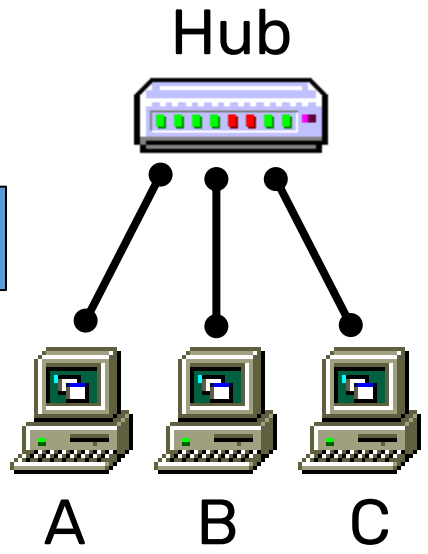
Q2: Cases for next event is a collision

we are here



(Hint: *if nothing happens on the first retrial time slot, it does not count as an event.*)

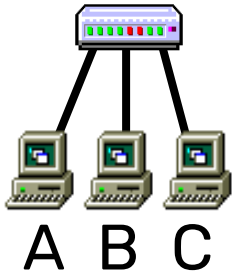
Q2: Cases for next event is a collision

we are here

collision

slot 0	slot 1
A, B, C	
A, B	C
A, C	B
C, B	A
not an event	A, B, C

Hub



(Hint: *if nothing happens on the first retrial time slot, it does not count as an event.*)

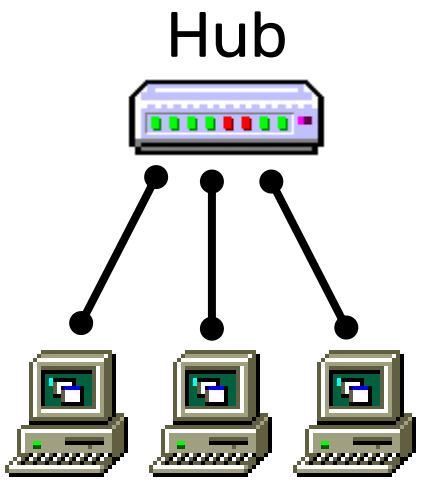
Q2: Binary Exponential Backoff (BEB)

= Prob (All choose slot 0 or 1) + Prob (Two choose slot 0)

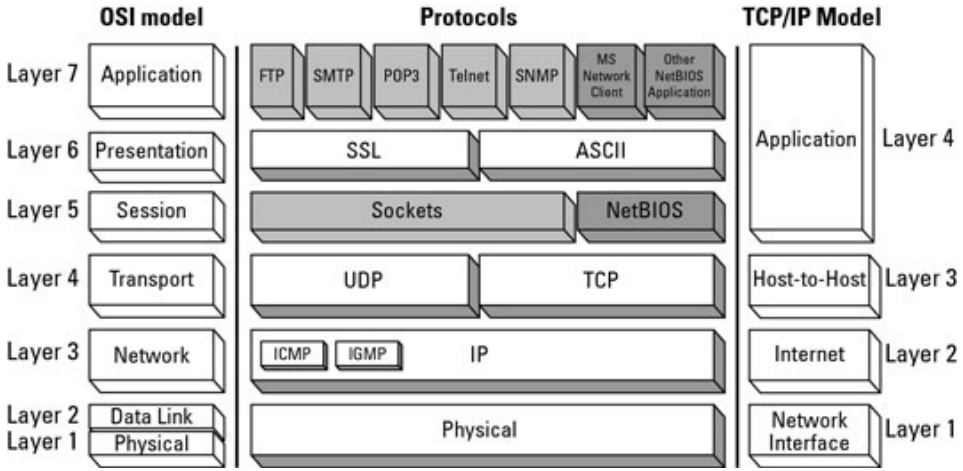
= Prob (A=0, B=0, C=0) + Prob (A=1, B=1, C=1)
+ Prob (A=1, B=0, C=0) + Prob (A=0, B=1, C=0)
+ Prob (A=0, B=0, C=1)

= (0.5 x 0.5 x 0.5) x 5 (since A, B, & C are independent)
= 0.625

Hub vs Switch?



Hub vs Switch?



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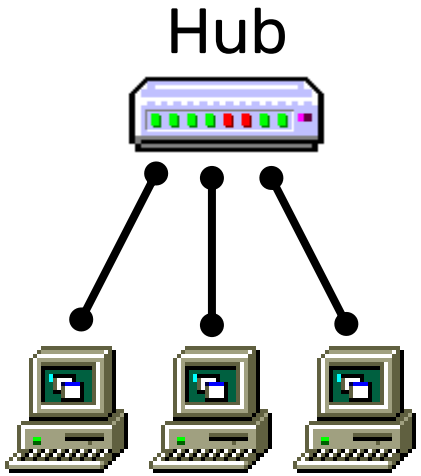


Q3

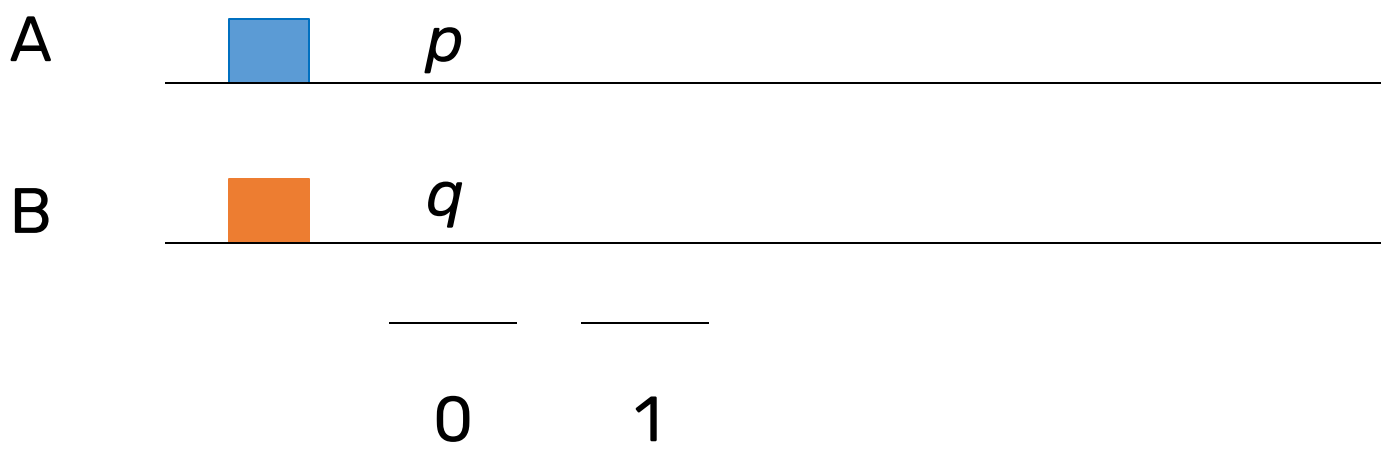
In a local area network using the CSMA/CD protocol, a **Modified Binary Exponential Backoff scheme** is used if a collision is detected in the channel.

Assume that two stations (A and B) are transmitting and their frames collide in one time slot. Each of them will retransmit its data frame over a window of size 2 slots.

Station A retransmits in slot 0 with probability of p and station B retransmits in slot 0 with probability of q.

Q3

i) If $p = 1/3$ and $q = 2/3$, what is the probability that the first event in the channel will be a success?



Q3(i)

i) If $p = 1/3$ and $q = 2/3$, what is the probability that the first event in the channel will be a success?

A	B	Probability	Success?
0	0	$p*q$	?
0	1	$p*(1-q)$	?
1	0	$(1-p)*q$	?
1	1	$(1-p)*(1-q)$	?

$p = 1/3, q = 2/3$

Q3(i)

A	B	Probability	Success?
0	0	$p*q$	No
0	1	$p*(1-q)$	Yes
1	0	$(1-p)*q$	Yes
1	1	$(1-p)*(1-q)$	No

$p = 1/3, q = 2/3$

Pr(first event is success) = p*(1-q)+(1-p)*q
= 1/3*1/3 + 2/3 *2/3
= 5/9

Q3(ii)

ii) How would you maximize the probability that the first event in the channel will be a success, by choosing proper values for *p* and *q*?

Pr(first event is success) = p*(1-q) + (1-p)*q

To maximize the throughput, one can choose
(i) p = 0, *q* =1
OR
(i) p =1 , *q* = 0

Idea: i.e. in case of a collision device 0 starts immediately, device 1 waits one slot, ..

Problem in practice:
- we typically do not know the number of participants
<- this would add some extra overhead,

Q3(ii)

$$y = p(1-q) + q(1-p) = p + q - 2pq$$

$$\begin{cases} \dfrac{\partial y}{\partial p} = 1 - 2q = 0 \\ \dfrac{\partial y}{\partial q} = 1 - 2p = 0 \end{cases} \Rightarrow \begin{cases} p = 0.5 \\ q = 0.5 \\ y = 0.5 \end{cases}$$

Check boundary conditions:

p=0, q=0, y=0

p=0, q=1, y=1

p=1, q=0, y=1

p=1, q=1, y=0

Q4

Suppose that an 11-Mbps 802.11b WLAN is transmitting 64-byte frames back-to-back over a radio channel with a bit error rate of 10 –7.

How many frames per second will be damaged on average?

Q4

1) 1 frame: 512bits & bit error rate: p = 10−7

2) Pr[all 512bits transmitted w/o error] = (1 – p)512 = 0.9999488

Q4

1) 1 frame: 512bits & bit error rate: $p = 10^{-7}$

2) Pr[all 512bits transmitted w/o error] = $(1 - p)^{512}$ = 0.9999488

3) Pr[frame damaged] = 1 - 0.9999488 = 0.0000512

Q4

1) 1 frame: 512bits & bit error rate: $p = 10^{-7}$

2) Pr[all 512bits transmitted w/o error] = $(1 - p)^{512}$ = 0.9999488

3) Pr[frame damaged] = 1 - 0.9999488 = 0.0000512

4) #frames per second: $11 \times 10^6 / 512 = 21{,}484$.

Q4

1) 1 frame: 512bits & bit error rate: $p = 10^{-7}$

2) Pr[all 512bits transmitted w/o error] = $(1 - p)^{512}$ = 0.9999488

3) Pr[frame damaged] = 1 - 0.9999488 = 0.0000512

4) #frames per second: $11 \times 10^6 / 512$ = 21,484.

5) Pr[frame damaged] * #frames per second = 0.0000512 * 21484 = 1.0999808
=> ~1 damaged frame per second

Q5

You are commissioned to design an experimental wireless network for SCE to support its 100 wireless devices. You have decided to adopt a multi-access reservation protocol (MARP) for frame transmission in the data link layer. Specifically, each transmission cycle consists of two phases:

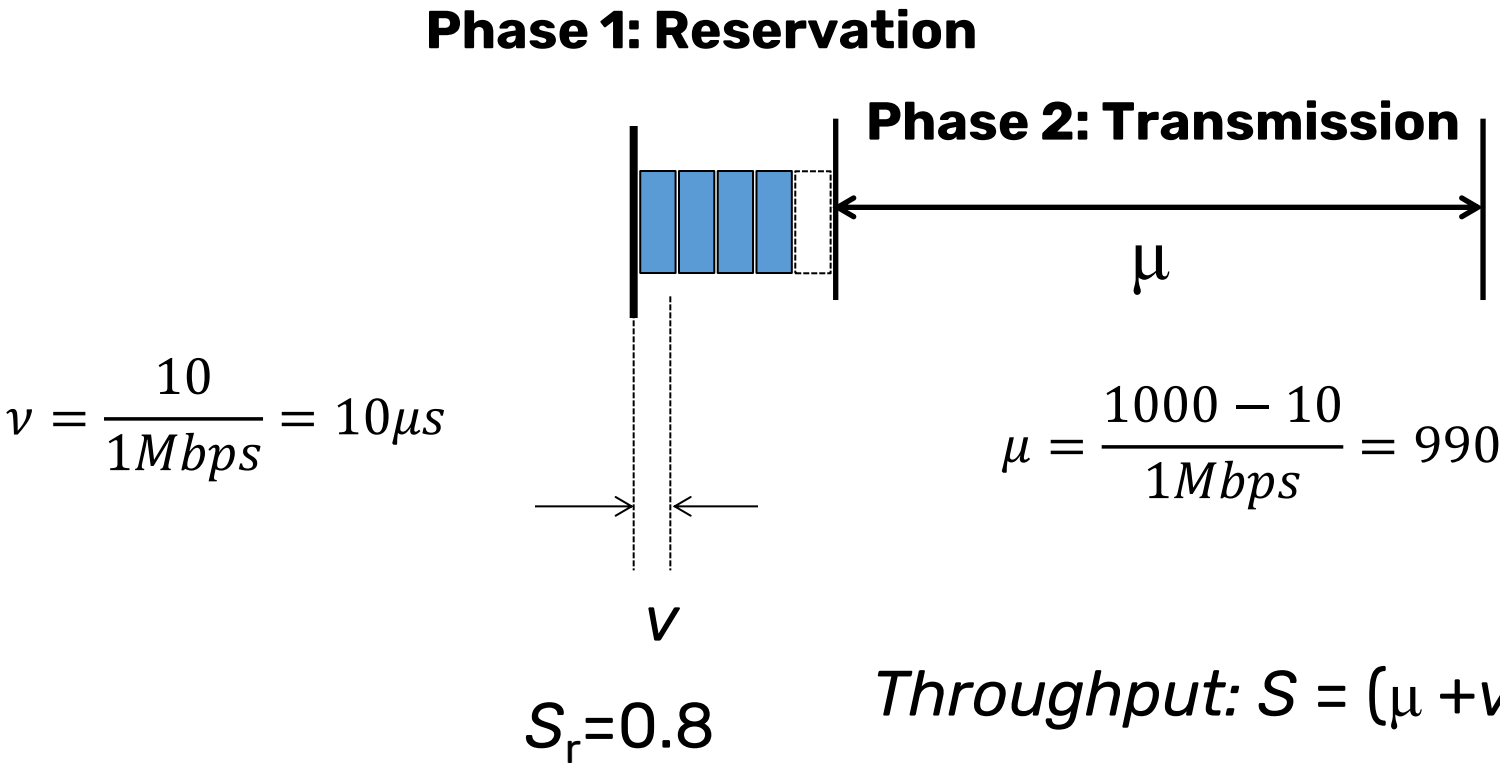
1) a reservation phase In the reservation phase, a chosen MAC protocol is used for transmission stations to reserve the channel;

2) the transmission phase, the station that successfully reserves the channel transmits one frame.

The data rate in the wireless channel is 1 Mbps. The length of the data frame is 1000 bits, among which the reservation frame carries 10 information bits.

Q5(i)

If the MAC protocol used in the reservation phase has a utilization of 0.8, what will be the throughput of the MARP?



$$v = \frac{10}{1Mbps} = 10\mu s$$

$$\mu = \frac{1000 - 10}{1Mbps} = 990\mu s$$

S_r=0.8

Throughput: $S = (\mu + v) / (\mu + v/S_r)$

$$S = \frac{1000}{990 + \frac{10}{0.8}} = \frac{1000}{1002.5} = 99.75\%$$

Q5(ii)

(ii) Assume that the **slotted Aloha protocol** is used in the reservation phase.

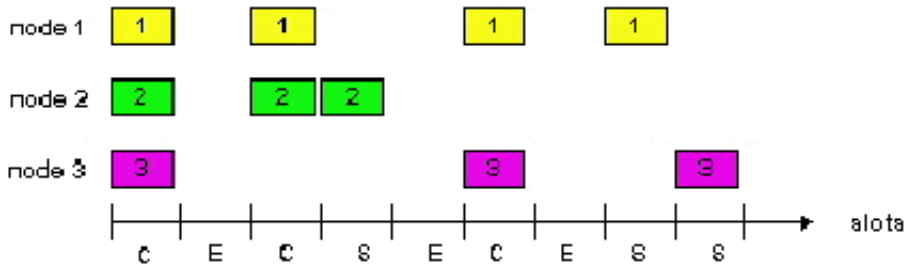
The utilization for the slotted Aloha protocol is Ge^{-G}, where $G = np$
- n is the number of stations
- p is transmission probability

Calculate an optimal transmission probability to maximize the throughput of the MARP, and the corresponding maximum throughput?

Q5(ii)

Slotted Aloha

- time is divided into equal size slots (= pkt trans. time)
- node with new pkt: transmit at beginning of next slot
- if collision: retransmit pkt in future slots with probability p, until successful.



Success (S), Collision (C), Empty (E) slots

5: DataLink Layer 5a-21

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Q5(ii)

Calculate an optimal transmission probability to maximize the throughput of the MARP, and the corresponding maximum throughput?

In order to maximize the utilization, it is equivalent to maximize $S_r = Ge^{-G}$.

$$\frac{dS_r}{dG} = e^{-G} - Ge^{-G} = 0 \Rightarrow G^* = 1$$

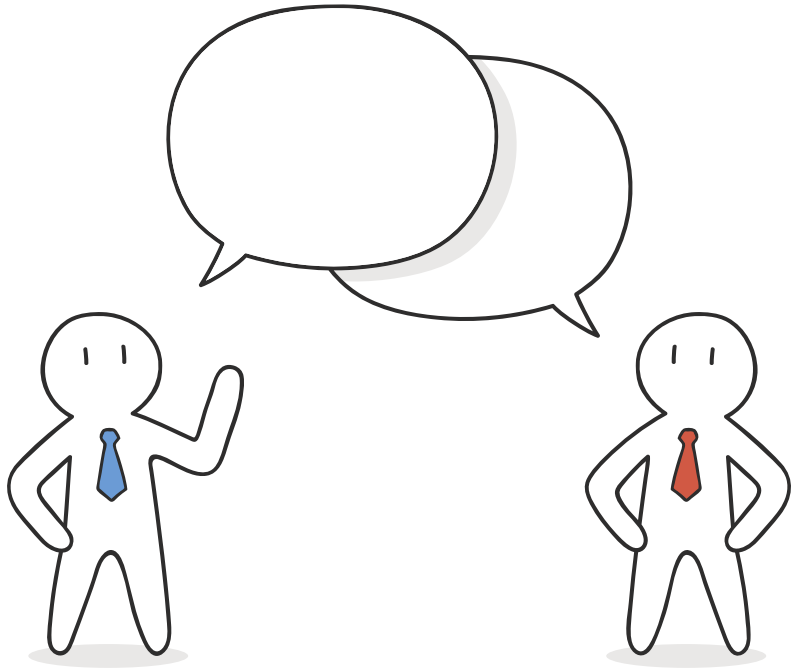
In this case, $p^* = \frac{G^*}{n} = 1/100 = 0.01$,

$S_{r,\max} = 1/e$

The maximum utilization is derived as

$$S_{\max} = \frac{\mu+\nu}{\mu+\nu/S_{r,\max}} = \frac{1000}{990+10e} = 98.31\%$$

Questions?



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