Recitation 24 12-13-2011

Review:

MAC

Switching

Routing

Transport Layer

Example 1. Given: Three nodes - A, B, C - seek access to a shared channel using slotted Aloha.

Assume the nodes are always backlogged, and the node A has half the probability as the other two, i.e

$P_B = P_C = 2P_A$.

Question. ① If $P_A = 0.3$, what is average utilization

② what value of P_A maximizes the utilization, and

③ what is corresponding maximum utilization?

Solution: utilization is the probability that exactly one user sends

① utilization $u = P(A \text{ xmits}) * P(B \text{ doesn't}) * P(C \text{ doesn't})$

$+ P(B \text{ xmits}) * P(A \text{ doesn't}) * P(C \text{ doesn't})$

$+ P(C \text{ xmits}) * P(A \text{ doesn't}) * P(B \text{ doesn't})$

$= P_A(1-P_B)(1-P_C) + P_B(1-P_A)(1-P_C) + P_C(1-P_A)(1-P_B)$

$= P_A(1-2P_A)(1-2P_A) + 2P_A(1-P_A)(1-2P_A) + 2P_A(1-P_A)(1-2P_A)$ $\quad P_B = 2P_A,\ P_C = 2P_A$

$= 5P_A - 16P_A^2 + 12P_A^3$

$= 5*0.3 + 16*0.3^2 + 12*0.3^3 = \underline{0.384}$

② $u = 5P_A - 16P_A^2 + 12P_A^3$

u is maximized when $\frac{du}{dP_A} = 0$

So: $0 = \frac{du}{dP_A} = \frac{d(5P_A - 16P_A^2 + 12P_A^3)}{dP_A} = 5 - 32P_A + 36P_A^2$

$\Rightarrow P_A = 0.687$ or 0.202

However, ~~$P_B = 2P_A$~~ $2P_A = P_B \leq 1 \Rightarrow P_A \leq 0.5$

So: ~~when $P_A = 0.202$~~,

The value of P_A moxmized utilization is $P_A = 0.202$

③ $U_{max} = 5P_A - 16P_A^2 + 12P_A^3$

$= 5 * (0.202) - 16 * (0.202)^2 + 12(0.202)^3$

$= 0.456$

Eg2) You send a stream of packets of size 1000 bytes each across a network path from Cambridge to Berkeley. You find that the one-way delay varies btw 50ms (in the absence of any queueing) and 125ms (full queue), with an average of 75ms. The transmission rate at the sender is 1Mbps; the receiver gets the packets at the same rate without any packet loss.

(a) What is the mean number of packets in the queue at the bottleneck link along the path (assume that any queueing happens at just one switch)

(b) You now increase the transmission rate to 2Mbps. You find that the receiver gets packets at a rate of 1.6 Mbps. The average queue length does not change from before.

(i) What is the packet loss rate at the switch?

(ii) What is the average one-way delay now?

Solution:

(a) Average ~~delay~~ one-way delay = 75 ms

one-way delay without queueing = 50ms

So: Average queuing delay D = Average one-way delay − one-way delay without queueing

= 75 ms − 50 ms

= 25ms

arrival rate λ = 1 M bps

$= \dfrac{1M \text{ bits/s}}{8000 \text{ bits/packet}}$

= 125 packets/s

1packet = 1000 bytes
= 8000 bits

So: the mean number of packets in the queue

$= \lambda * D$

$= 125$ packets/s $*$ 25 ms

$= 3.125$ packets

b) i) packet loss rate $= \dfrac{\text{sender transmission rate} - \text{Receiver arrival rate}}{\text{Sender transmission rate}}$

$= \dfrac{2M - 1.6M}{2M}$

$= 20\%$

ii) $\boxed{\text{average one-way delay} = \text{one-way delay in the absence of queueing} + \text{average queueing delay } D}$

Use little's Law to calculate D:

N doesn't change. so $N = 3.125$ packets

arrival rate $\lambda = 1.6$ Mbps

$= \dfrac{1.6M \text{ bits/s}}{8000 \text{ bits/packets}}$

1 packet = 1000 bytes

= 8000 bits

$= 200$ packets/s

So: average queueing delay $D = \dfrac{N}{\lambda} = \dfrac{3.125 \text{ packets}}{200 \text{ packets/s}} = 15.625$ ms

So: average one-way delay = one-way delay in the absence of queueing + average queueing delay

$= 50$ ms $+ 15.625$ ms

$= 65.625$ ms

Ex 3: Determine whether the ff statements are True or False:

① There exists some offered load pattern for which TDMA has lower throughput than slotted Aloha.

② Suppose there are 3 nodes which use a fixed probability of $p = 1/3$ when transmitting on a slotted Aloha network. If all nodes are backlogged, the utilization is $1/e \approx 37\%$.

③ Using contention windows with a CSMA implementation guarantees that a packet will be transmitted successfully (i.e. without collisions) with some bounded time.

Solution:

① TRUE

Proof: (TDMA doesn't work well for unbalanced ~~traffi~~ load)

For example: ~~Throughput~~ There are N nodes. Only 1 nodes is backlogged.

Then, throughput (utilization) of TDMA $= \frac{1}{N}$

Throughput of slotted Aloha ≈ 1 when we set $p \approx 1$

p: the probability that one sends data.

In this case, throughput of TDMA < Throughput of slotted Aloha.

② FALSE

Proof: u = P(node 0 xmits) * P(node 1 doesn't) * P(node 2 doesn't)

+ P(node 1 xmits) * P(node 0 doesn't) * P(node 2 doesn't)

+ P(node 2 xmits) * P(node 0 doesn't) * P(node 1 doesn't)

$= \frac{4}{9} \neq \frac{1}{e}$.

Actally, only N (the number of all nodes) $\to \infty$,

$u \to \frac{1}{e} \approx 37\%$

③ FALSE

Proof:

Recall contention window scheme with CSMA:

CW: current value of the window, cw can vary between CW_{min} and CW_{max}

when a node transmits

picks a number randomly r in [1, cw]

sends packet after r time slots.

If a collision occurs

doubles cw (if $cw < CW_{max}$)

else

halves cw (if $cw > CW_{min}$)

So: contention window only gurantees a transmission attempt within bounded time, but there's no guarantee of success.

(Because all attempts can be collisioned)

Ex 4: Three users X, Y, Z share a link with capacity 1 Mbps.

There are two possible strategies to access the link (1) TDMA and (2) Taking turns.

In "Taking turns" ~ add a latency of 0.05 s before taking the turn. The user can then use the link for as long as it has data to send.

In each of the ff cases, which strategy would you use and why?

(1) X, Y, Z sends a 320 kbits file every second.

(2) X sends 640 kbits file every second, while Y, Z send 80 kbits file every second.

Solution.

① <u>TDMA wins</u>.

Proof: for TDMA, each user gets $\frac{\text{link capacity}}{3} = 333$ kbits bandwidth.

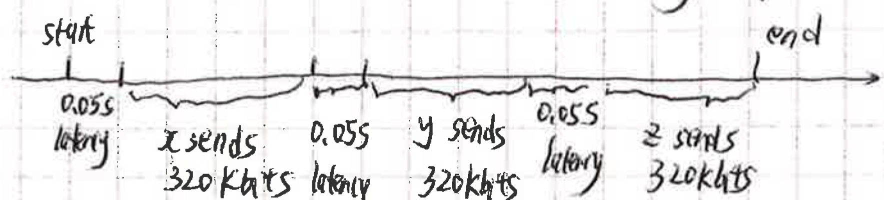
The required bandwidth for each user is

$320 \text{ kbits/s} < 333 \text{ kbits/s}$.

So: TDMA can work well in this case

for "taking turn"

In 1 second, we should do following jobs.



$\text{time} = \frac{\text{data size}}{\text{link capacity}}$

$\frac{320 \text{ Kbits}}{1\text{M bits/s}} = 0.32\text{S}$ $\qquad \frac{320 \text{ kbits}}{1\text{M bits/s}} = 0.32\text{S}$ $\qquad \frac{320 \text{kbits}}{1\text{M bits/s}} = 0.32\text{ S}$

The total time = $0.05 + 0.32 + 0.05 + 0.32 + 0.05 + 0.32 = 1.11\,s > 1s$

So: "taking turn" can't finish its job.

② "Taking turn" wins.

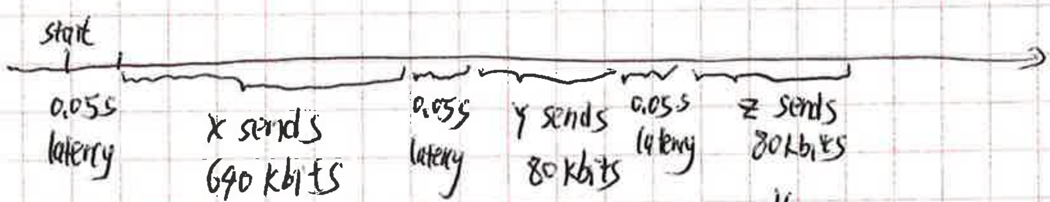
Proof: for TDMA, each user still gets 333 kbits/s bandwidth.

However, user X requires 640 kbits/s bandwidth.

So. X's ~~band~~ requirement can't be met.

for "taking turn"

In 1 second, we should do following job.



Time = $\frac{\text{data size}}{\text{link capacity}}$

X: $= \frac{640\text{kbits}}{1\text{Mbits/s}} = 0.64s$

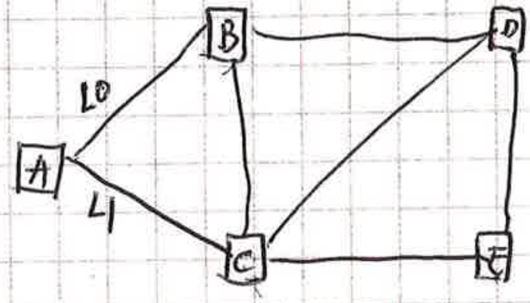
Y: $= \frac{80\text{ kbits}}{1\text{mbits/s}} = 0.08s$

Z: $= \frac{80\text{kbits}}{1\text{mbits/s}} = 0.08s$

The total time = $0.05 + 0.64 + 0.05 + 0.08 + 0.05 + 0.08 = 0.95\,s < 1s$

So: "taking turn" can finish its job in this case.

Example 5: Consider a network with topology shown below.



Suppose the final routing table for node A using Dijkstra's algorithm is as below.

Node	Link	cost
A	—	0
B	L0	5
C	L1	6
D	L0	7
E	L1	9

Assume: the costs obey two constraints.

① all costs are integer ≥ 1

② each shortest path is unique. i.e, there aren't two possible shortest paths between any two nodes

Question: Please make the most specific deduction about ~~each~~ ~~link's cost~~ ~~link~~ cost of link (A−B, B−C, A−C, B-D, C-D, C-E, D-E)

i.e.: give the exact cost if that can be determined, or, indicate ≥k if you determine that k is a lower bound on the possible link cost.

Solution:

① Look at entry (B, L0, 5)

A — B is the shortest path between A and B. $\Rightarrow$ Linkcost(A B) = 5

② Look at entry (C, L1, 6)

A-C is the shortest path between A and C $\Rightarrow$ Linkcost(A C) = 6

Besides, The following path cost > 6:

$A \xrightarrow{5} B - C > 6 \Rightarrow$ Linkcost(B, C) ≥ 2

③ Look at entry (D, L0, 7)

Three possible paths

$A \xrightarrow{5} B - D$ $\Rightarrow$ Linkcost(B,D) = 2

$A \xrightarrow{5} B \xrightarrow{\geq 2} C - D$ Impossible

$A \xrightarrow{5} B \xrightarrow{\geq 2} C - E - D$ Impossible.

Besides. The following path cost > 7

$A \xrightarrow{6} C - D \Rightarrow$ Link cost (C, D) ≥ 2.

④ Look at (E, L1, 9)

Two possible paths

$A \xrightarrow{6} C \xrightarrow{\geq 2} D - E \Rightarrow$ Linkcost(DE) = 1. However, then cost($A \xrightarrow{5} B \xrightarrow{2} D \xrightarrow{1} E$) is the shortest between AE then, which is impossible.

$A \xrightarrow{6} C - E \Rightarrow$ Linkcost(CE) = 3

Besides. The following path cost > 9.

$A \xrightarrow{5} B \xrightarrow{2} D - E \Rightarrow$ Linkcost(DE) ≥ 3.

So: Final result:

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