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1.

a) The failure probability of the network from S to D is:

$$0.01 \times 0.001 \times 0.01 = 0.0000001$$

Therefore, the reliability of the network is: $1 - 0.0000001 = 0.9999999 = 99.99999\%$ (7 9's), which satisfies the requirement.

Minimum downtime per year is: $0.0000001 \times 365 \times 86400 = 3.1536$ (s)

b) i) Denote dispatched packet rates in 3 paths as rA, rB, rC, so rA + rB + rC = 100 kbps / (8 × 125) bits = 100 packets/s

With similar calculation, the service rate of path A, B, C are 100, 150, 120 packets/s respectively.

To have the same average packet delays in each path, we have (after simplified):

$$rA/100 = rB/150 = rC/120$$

Solving this gives us: rA = 27, rB = 41, rC = 32 (after rounding)

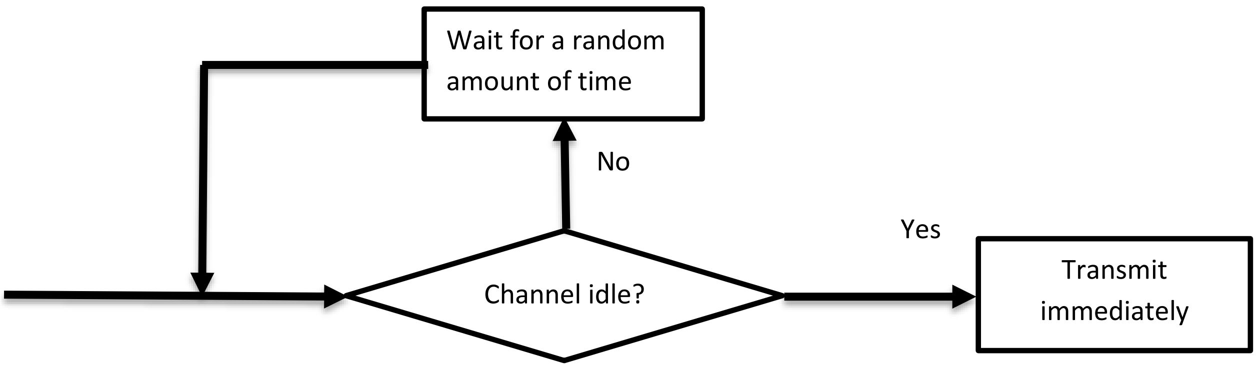
ii) The dispatched rate can never exceed the service rate, which means user can only request playback rate up to: 100 + 150 + 120 = 370 (kbps)

c) The mapping between 7-layer OSI and 3-layer is as follow:

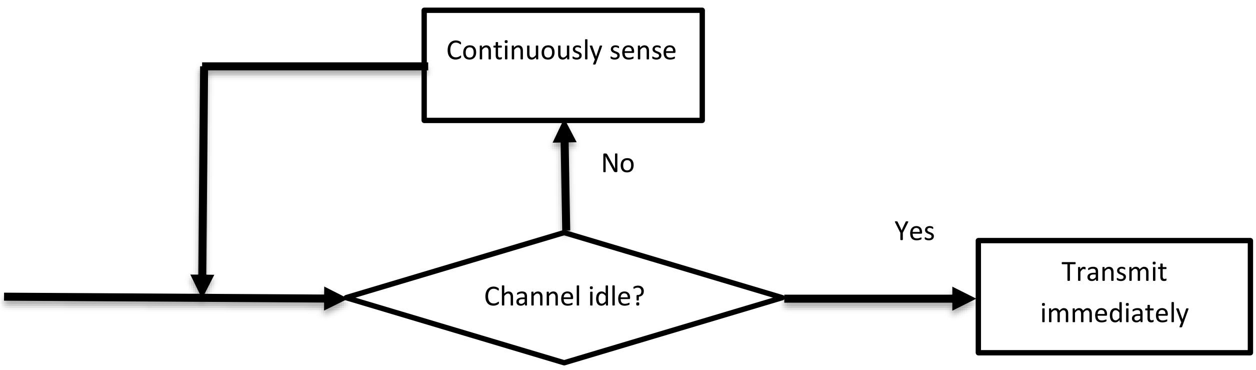
<table>
<tr><td>Application</td><td rowspan="2">Network Service</td></tr>
<tr><td>Presentation</td></tr>
<tr><td>Session</td><td rowspan="3">Network Protocol</td></tr>
<tr><td>Transport</td></tr>
<tr><td>Network</td></tr>
<tr><td>Data Link</td><td rowspan="2">Network Infrastructure</td></tr>
<tr><td>Physical</td></tr>
</table>

2.

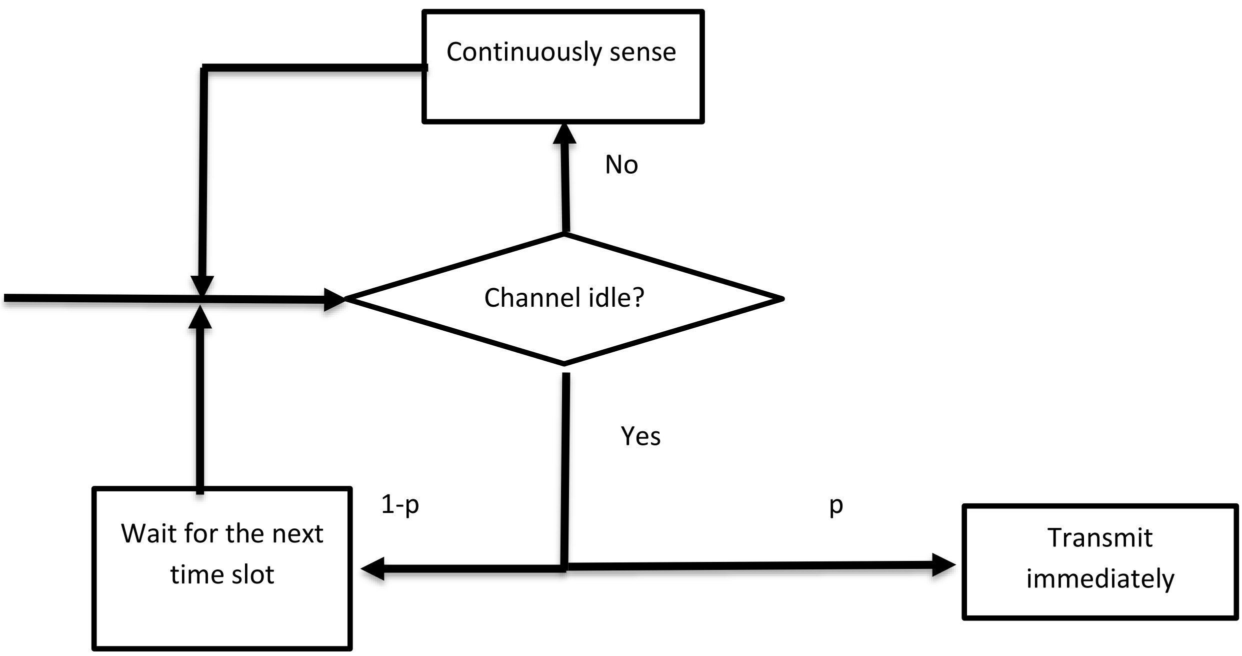
a) i) CSMA non-persistent:



CSMA 1-persistent:



CSMA p-persistent:



ii) non-persistent: reduce collision but might result in longer idle time, longer initial delay

1-persistent: higher chance of collision but reduce idle time

p-persistent: balance between the above 2 flavors

b) i) Denote xyz as the time slots that stations choose. E.g. 111 means all station choose slot 1

There's 8 possible scenarios with equal probability: 111, 112, 121, 122, 211, 212, 221, 222

Out of this 8 possible outcomes, only 6 of them (except 111 and 222) result in 1 station successfully transmit, the other 2 stations has to go to next retransmission window. Note that this station only use 1 slot = ½ the window. Therefore, the channel's normalized throughput is 6/8 × 1/2 = 3/8

For each station, only 2 out of 8 possible outcomes results in its successful transmission. So each station's normalized throughput is 2/8 × 1/2 = 1/8

We can verify that sum of 3 individual's throughput is channel's throughput

ii) We can set station A with p = 1, station B with p = 0 and station C with p = 0.

The channel's throughput will be 1/2 as 1 slot is used surely. Station A ½ window surely, which means its individual throughput is 1/2. Station B and C's throughput is 0 since they doesn't use any slot.

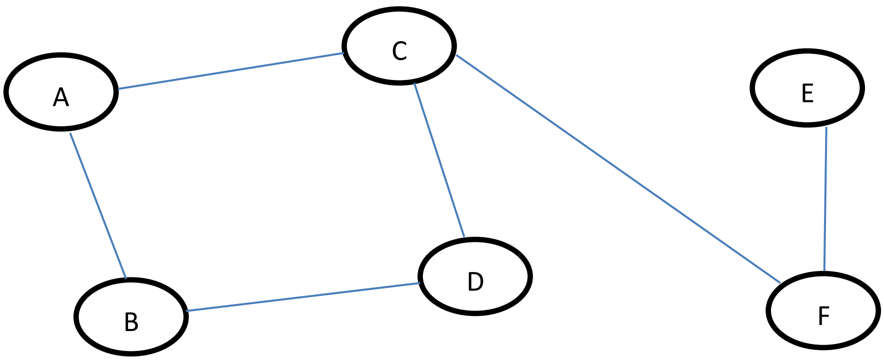
iii) We can see that the above scheme does increase the throughput but is not equally distributed between 3 stations. The objective now is high throughput and equal distribution. So we set transmission probability of each station to 1.

Denote n as number of slots in the window. For each station, it transmits successfully when 2 other stations choose 1 of n-1 other slots, so the probability is $\frac{(n-1)^2}{n^2}$. The individual throughput is $\frac{(n-1)^2}{n^3}$. We can check that this equation is maximized when n = 3.

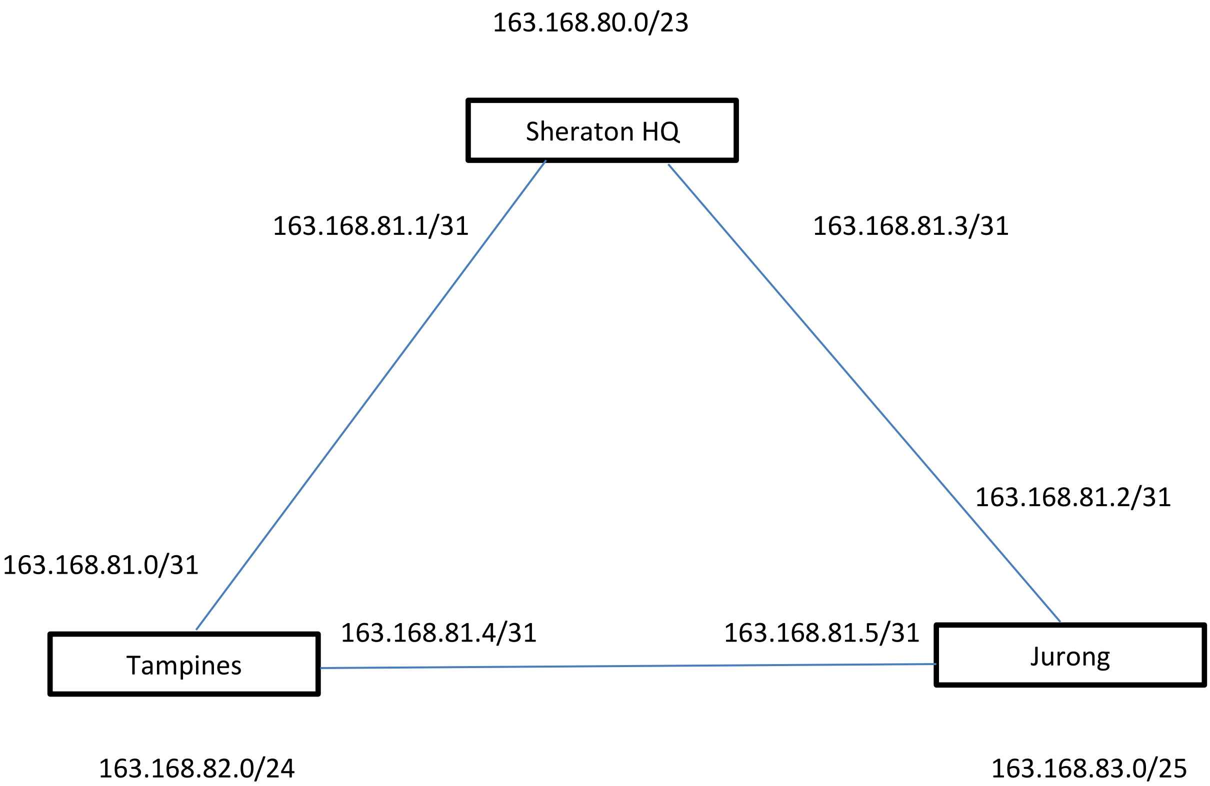
Each station's throughput is then 4/27 and the channel's throughput is 4/9

3.

a)



b) 480, 178 and 78 computers would need 9, 8 and 7 bits respectively. So, we arrange IP address as follow:



Note that in real life, a company wouldn't allocate that much of public IPs to their computers for cost and security reason. Most of their computers will get private (local) IP and will be behind 1 or more routers.

c)

Vendor A: number of fragments on each frame is (3020 – 20)/(1020 – 20) = 3

The packet loss rate is $1-(1-0.01)^3=0.0297$

Vendor B: number of fragments on each frame is (3020 – 20)/(520 – 20) = 6

The packet loss rate is $1-(1-0.002)^6=0.0119$

So we choose vendor B with lower packet loss rate.

4.

a) Option 1: time to transmit 24 segments is: (1000 × 8 × 24)/1e9 = 0.000192, much smaller than RTT

Therefore, the throughput is 24/(2 × 0.1) = 120 (segments per second)

Option 2: time to transmit 12 segments is: (1000 × 8 × 12)/1e10 = 0.0000192, much smaller than RTT

Therefore, the throughput is 12/(2 × 0.1) = 60(segments per second)

We can see that option 1 give a higher throughput. In fact, TCP throughput depends mostly on RTT and maximum segments sent without ACK, given that transmission bandwidth is already fast enough, which is mostly the case.

b) 3 missing AN from B is 100, 100 and 180

c) Notice that our computer and www.ntu.edu.sg are not in the same subnet. The same thing holds for the pair of our computer and our configured DNS server. So the table should be as follow:

Destination's MAC	Source's MAC	Destination's IP	Source's IP	Comment
FF-FF-FF-FF-FF-FF	9C-8E-99-3E-EF-68	155.69.143.254	155.69.142.177	ARP broadcast to find MAC of default gateway
9C-8E-99-3E-EF-68	00-80-45-32-FA-B5	155.69.142.177	155.69.143.254	ARP reply from default gateway, so ARP cache now has default gateway's MAC address
00-80-45-32-FA-B5	9C-8E-99-3E-EF-68	155.69.146.254	155.69.142.177	Send DNS request to DNS server, but it is not in the same subnet, so send to default gateway's MAC
9C-8E-99-3E-EF-68	00-80-45-32-FA-B5	155.69.142.177	155.69.146.254	DNS reply
00-80-45-32-FA-B5	9C-8E-99-3E-EF-68	155.69.7.173	155.69.142.177	Send ping request to www.ntu.edu.sg. Again, the request is forward to default gateway
9C-8E-99-3E-EF-68	00-80-45-32-FA-B5	155.69.142.177	155.69.7.173	Ping response