Q1a) i)

$$M_0 = \frac{\frac{n_f - n_0}{t_0}}{R} = \frac{1 - \frac{n_0}{n_f}}{1 + \frac{n_a}{n_f} + \frac{2(t_{prop} + t_{proc})R}{n_f}}$$ 3

ii)

$\frac{n_0}{n_f}$ = represents the loss in transmission efficiency due to need to provide headers and CRC 2

$\frac{n_a}{n_f}$ = loss in efficiency due to the time required for the acknowledgment frame 2

$2(t_{prop} + t_{proc})$ = delay due to propagation and processing 2

Q1b) i)
- It is not easy to implement/build hardware that can transmit and detect a collision at the same time
- the adapter might not be able to detect all collision due to the hidden terminal problem 3

ii)
- Reservation protocol: to avoid collision even in the presence of hidden terminals 2

- Since the Request to send / Clear to send exchange can help reduce collisions it also introduces delays.
It might be useful to reserve the channel for transmission of a long data frame (a threshold can be set). 2

- RTS/CTS sequence 4

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Q 2a i) packet marking allows a router to distinguish among packets belonging to different classes of traffic. The router use a policy decision to treat packet differently 4

ii) policing mechanism can be put in place. If the policed application misbehaves, the policing mechanism can take some action (e.g. drop or delay packets that violate criteria), so that the traffic actually entering the network conforms to the criteria 4

iii) A call admission process is needed in which flow declare their QoS requirements and are then either admitted to the network (at the required QoS) or blocked from the network (if the required QoS cannot be provided by the network). 4

Q 2b i) M/M/1 system $T = \frac{1}{\mu - \lambda}$ = average delay of packet waiting in queue and service time.

μ = service rate.

λ = arrival rate.

For a network of queues:

$\gamma \longrightarrow (N, T)$ $\qquad N = \gamma T$

for each queue in this network using Little's

$q_i = \lambda_i t_i$

and for the network 2

$N = \sum_{i=1}^{L} \lambda_i t_i$ $\qquad$ L = number of links (queues) in the network

$\gamma T = N = \sum_{i=1}^{L} \lambda_i t_i$ and for one queue $t_i = \frac{1}{\mu C_i - \lambda_i}$

$\gamma T = \sum_{i=1}^{L} \frac{\lambda_i}{\mu C_i - \lambda_i}$, $F_i = \frac{\lambda_i}{\mu} = x_i$

$T = \frac{1}{\gamma} \sum_{i=1}^{L} \frac{F_i}{C_i - F_i} = \frac{1}{\gamma} \sum_{i=1}^{L} \frac{x_i}{C_i - x_i}$ 2

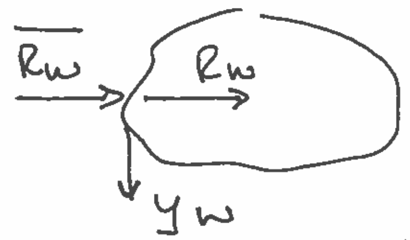
$1/\mu$ = average length of packet [bits/packet]

C_i = transmission speed link i [bits/s]

μC_i = service rate link i [packet/s]

λ_i = arrival rate link i [packet/s]

ii)



2

If we would like to control the flow of packets carried by the network $= R_w$ but at the same time do not reduced to zero; an additional penalty term to $D(C,x)$ will have to form $\left(\frac{a_w}{R_w}\right)^{\alpha}$ 2

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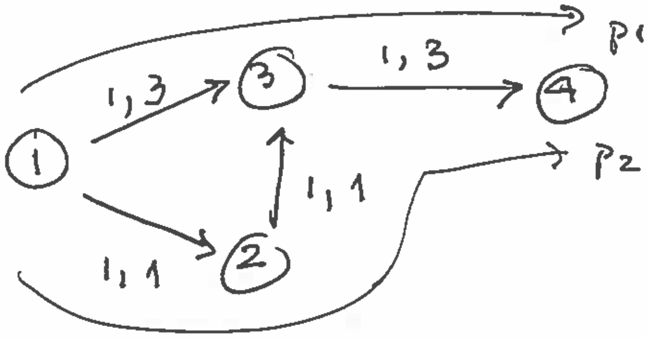
Q3 a) i)

- Foreign agent - mobile node: the mobile node will register with the foreign agent when attaching to the foreign network.
The foreign agent creates a 'care of address" (COA) for the mobile, with the network portion of the COA matching that of the foreign network.
The mobile node will deregister with the foreign agent when it leaves the foreign network 4

- Home agent - foreign agent: the home agent receives the datagrams, look at the address destination and if required, forward the datagram to the mobile node in a two-step process.
The foreign agent register the mobile node's COA with the home agent. There is no need to deregister a COA when a mobile moves to a new network 4

ii)
The home agent datagram is encapsulated and forwarded to the correspondent's original datagram with a datagram addressed to the COA
The foreign agent extracts the correspondent's original datagram from the encapsulating datagram, and forward the original datagram to the mobile node 4

Q3 b)
i)



$L_{p_1} = 2 + 6 \qquad L_{p_2} = 3 + 5$ 2

shortest path = path 2

$\sigma_{p_1}^2 = 6$

$\sigma_{p_2}^2 = 5$

The above calculation (sum of variances) is possible due to the fact that the links distribution are independent random variables. 3

ii)
The solution in part i) (sum of variances) will not work for a general cost function $\phi(\sigma_p^2)$.

In this particular case: standard deviations σ_e are not additive

3

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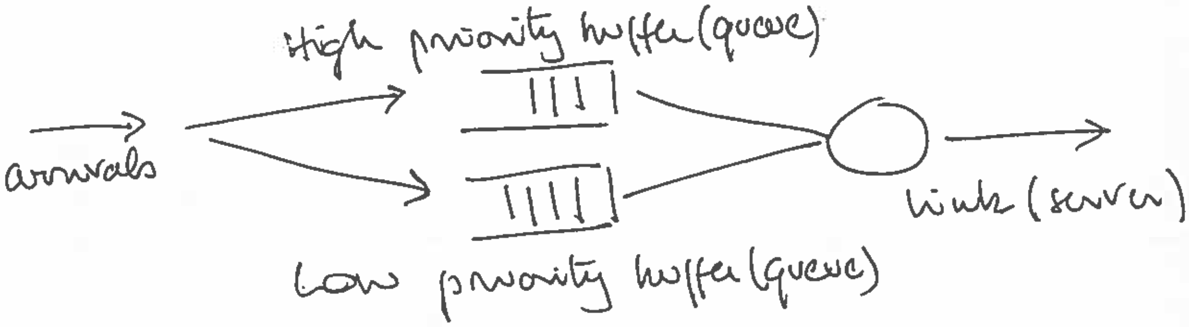
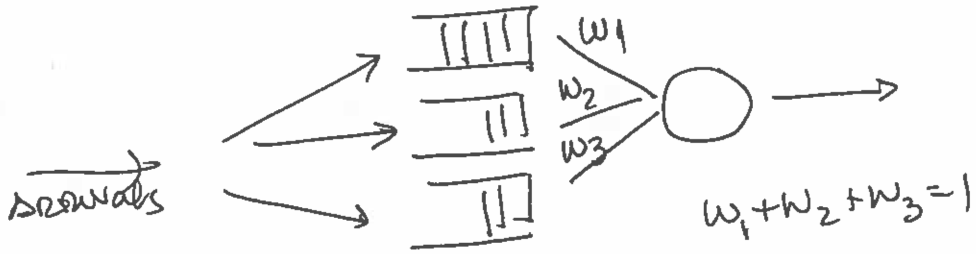
Q4 a) i) Describe and discuss priority queueing systems.



4

ii) The weighted fair queueing discipline is a generalised round Robin.
Each class of packet gets weighted of service in each cycle.



4

Q4 b) i)

$$\frac{\text{Latency}}{\text{Min. latency}} = \frac{2RTT + \frac{O}{R} + P\left[RTT + \frac{S}{R}\right] - (2^P-1)\frac{S}{R}}{2RTT + \frac{O}{R}}$$

$$= 1 + \frac{P\,RTT + \frac{S}{R}\left[P-(2^P-1)\right]}{2RTT + \frac{O}{R}}$$

$$= 1 + \frac{P + \frac{S}{R}\frac{\left[P-(2^P-1)\right]}{RTT}}{2 + \frac{O}{R}\frac{1}{RTT}}$$

$$\leq 1 + P/[2 + (O/R)/RTT]$$

4

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Q4 ii) ii)

$$\frac{\text{Latency}}{\text{Min. Latency}} \leq 1 + \frac{P}{[2 + (O/R)/RTT]}$$

TCP slow start protocol will not significantly increase latency if RTT << O/R.
That is if the round trip time is much less than the transmission time of the object. 4

iii)

R	η_{eff}
28 Kbps	1.003
100 Kbps	1.024
10 Mbps	3.500

For large objects, slow start adds appreciable delay only when the transmission rate is high.
If the transmission rate is low, then the acknowledgements come back relatively fast, and TCP quickly settles down to its maximum rate. 4