Exam March 2018

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Q2:

$b = 350 \text{ kB}$
$= 350 \times 10^3 \text{ B}$

$r = 1.5 \text{ MB/s}$
$= 1.5 \times 10^6 \text{ B/s}$

$M = 20 \text{ MB/s}$
$= 20 \times 10^6 \text{ B/s}$

Maximum burst length

$$S = M \times \frac{b}{M-r} \text{ octets}$$

$$= 20 \times \cancel{10^6} \times \frac{350 \times 10^3}{20 \times \cancel{10^6} - 1.5 \times \cancel{10^6}}$$

$$= 20 \times \frac{350 \times 10^3}{18.5}$$

$$= 378.38 \times 10^3 \text{ B}$$

$$= 378.38 \text{ kB}$$

Q3:

Symbols: $\{0, 1\}$

$P(\text{detect } 1 \mid \text{transmit } 1)$
$= P(\text{detect } 0 \mid \text{transmit } 0)$
$= 0.72$

$P(\text{transmit } 1) = 0.2$

$P(\text{symbol correct} \mid \text{detect } 1)$

$= P(\text{transmit } 1 \mid \text{detect } 1)$

Conditional probability:

$$P(A|B) = \frac{P(A \cap B)}{P(B)}$$

$$P(B|A) = \frac{P(A \cap B)}{P(A)}$$

$$\Rightarrow P(A|B) = \frac{P(B|A)\,P(A)}{P(B)} \quad \text{(Baye's Law)}$$

$\therefore P(\text{transmit } 1 \mid \text{detect } 1)$

$$= \frac{P(\text{detect } 1 \mid \text{transmit } 1) \times P(\text{transmit } 1)}{P(\text{detect } 1)}$$

$$= \frac{0.72 \times 0.2}{P(\text{detect } 1)}$$

$$= \frac{0.144}{P(\text{detect } 1)}$$

$P(\text{detect } 1) = P(\text{transmit } 1 \text{ and detect } 1)$
$\qquad + P(\text{transmit } 0 \text{ and detect } 1)$

$= 0.2 \times 0.72 + (1-0.2) \times (1-0.72)$

$= 0.144 + 0.8 \times 0.28$

$= 0.144 + 0.224$

$= 0.368$

$\therefore P(\text{transmit } 1 \mid \text{detect } 1)$

$$= \frac{0.144}{0.368}$$

$= 0.39.$

Q4:

See random access tutorial solutions.

$$\sum_{k=1}^{\infty} p^{k-1}(1-p) \times k = \frac{1}{1-p}$$

Q5:

Flow 2 gets 4 times bandwidth of Flow 1: $4 = \frac{8}{2}$

Flow 3 gets 2.5 times bandwidth of Flow 1: $2.5 = \frac{5}{2}$

Flow 1 gets 1 times bandwidth of Flow 1: $1 = \frac{2}{2}$

Weights:

$w_1 = 1$

$w_2 = 4$

$w_3 = 2.5$

P	Size	Flow	Weighted size	Start	Finish
1	50	1	50	0	50.
2	80	1	80	50	130.
3	30	1	30	130	160.
4	100	2	25	0	25.
5	150	2	37.5	25	62.5.
6	125	2	31.25	62.5	93.75.
7	480	3	192	0	192.
8	200	3	80	192	272.

Transmission order:

4, 1, 5, 6, 2, 3, 7, 8

Q6:

2 nodes $\Rightarrow$ 2 mini-slots per frame

4 data slots per node $\Rightarrow$ 8 data slots per frame

(a) P(a given node reserves 4 slots)

= P(at least 4 packets arrived at the node during the previous frame)

= 1 − P(less than 4 packets arrived)

$$= 1 - \sum_{k=0}^{3} \frac{\lambda^k e^{-\lambda}}{k!}$$

$$= 1 - e^{-\lambda} - \lambda e^{-\lambda} - \frac{\lambda^2 e^{-\lambda}}{2} - \frac{\lambda^3 e^{-\lambda}}{6}$$

Each node has the same probability and they are independent, so for both nodes we have:

P(all slots reserved)

$$= \left(1 - e^{-\lambda} - \lambda e^{-\lambda} - \frac{\lambda^2 e^{-\lambda}}{2} - \frac{\lambda^3 e^{-\lambda}}{6}\right)^2$$

(b) Expected number of slots used:

$$K = \sum_{k=0}^{7} k \times \frac{(2\lambda)^k e^{-2\lambda}}{k!} + \sum_{k=8}^{\infty} 8 \times \frac{(2\lambda)^k e^{-2\lambda}}{k!}$$

$$= \sum_{k=0}^{7} k \times \frac{(2\lambda)^k e^{-2\lambda}}{k!} + 8\left(1 - \sum_{k=0}^{7} \frac{(2\lambda)^k e^{-2\lambda}}{k!}\right)$$

$\lambda = 2$:

$$K = \sum_{k=0}^{7} k \times \frac{4^k e^{-4}}{k!} + 8\left(1 - \sum_{k=0}^{7} \frac{4^k e^{-4}}{k!}\right)$$

$= 3.557 + 8 \times 0.051$

$= 3.557 + 0.409$

$= 3.966$

$$\text{Utilisation} = \frac{3.966}{\underbrace{0.1 \times 2}_{\text{mini-slots}} + \underbrace{8}_{\text{data slots}}}$$

$$= \frac{3.966}{8.2}$$

$= 0.48$

Q7:

Video calls: Poissen, $\frac{1}{\lambda} = 1.4s$

GBR, 480×10^3 bps per call

Call length average: $4 \times 60 + 30 = 270s$

Web: 60 concurrent sessions on average

non-GBR

Total capacity: 100×10^6 bps

(a) $\frac{100 \times 10^6}{480 \times 10^3} = 208$

(b) Erlang system, $N = 208$

$h = 270s$

$\lambda = \frac{1}{1.4}$

$= 0.714$ calls/s

$A = \lambda h$

$= 270 \times 0.714$

$= 192.857$

$P_B = \frac{A^n}{\quad}$

$$\frac{n!}{\sum_{j=0}^{n} \frac{A^j}{j!}}$$

$$= \frac{\left((192\,857)^{208}\right)/208!}{\sum_{j=0}^{208} \frac{(192.857)^j}{j!}}$$

$(= 0.016)$

(c) Carried video call traffic:

$A_C = A(1 - P_B)$

$= 192.857(1 - 0.016)$

$= 189.77$ simultaneous calls on average

Average capacity used for video calls:

$= A_C \times 480 \times 10^3$

$= 189.77 \times 480 \times 10^3$

$= 91090.286 \times 10^3$

$= 91.090286 \times 10^6$ bps

Average capacity available for web traffic

$= 100 \times 10^6 - 91.090286 \times 10^6$

$= 8.91 \times 10^6$ bps

$= 8.91$ Mbps $= 0.15$ Mbps per connection

(d) Increase, as then some capacity will be reserved for web traffic.

Q9:

Max allowed delay for control data:

10 ms

Logging data $\lambda_\ell = 400$ pk/s

avg. length = 2000 B

Control traffic: $\lambda_c = 500$ pk/s

avg length = 200 B

Data rate per channel: 8×10^6 bits/s

(a) Logging channel:

non-persistent CSMA

$$S = \frac{G}{1+G} \quad \text{(Normalised offered load)}$$

Normalised offered load

$$G = \frac{2000 \times 8 \times 400}{8 \times 10^6}$$

$$= 0.8$$

Normalised throughput:

$$S = \frac{0.8}{1+0.8}$$

$$= \frac{0.8}{1.8}$$

$$= 0.44$$

Control channel:

1-persistent CSMA

$$G = \frac{200 \times 8 \times 500}{8 \times 10^6}$$

$$= 0.1$$

$$S = \frac{Ge^{-G}(1+G)}{G+e^{-G}}$$

$$= \frac{0.1 \times e^{-0.1}(1+0.1)}{0.1 + e^{-0.1}}$$

$$= \frac{0.0995}{1.0048}$$

$$= 0.099$$

(b) Data rate to centralised controller: 5×10^6 b/s

Arrival rate for control packets:

$$S = 0.099 \Rightarrow \lambda_c' = \frac{0.099 \times 8 \times 10^6}{200 \times 8}$$

$$= 495 \text{ pk/s}$$

Arrival rate for logging traffic:

$$S = 0.44 \Rightarrow \lambda_\ell' = \frac{0.44 \times 8 \times 10^6}{2000 \times 8}$$

$$= 220 \text{ pk/s}$$

FCFS:

$$\lambda = \lambda_\ell' + \lambda_c'$$

$$= 495 + 220$$

$$= 715 \text{ pk/s}$$

Average packet length

$$L = 2000 \times \frac{220}{715} + 200 \times \frac{495}{715}$$

$$= 615.38 + 138.46$$

$$= 753.3846$$

$$\mu = \frac{5 \times 10^6 \text{ bs}^{-1}}{753.3846 \times 8 \text{ b}}$$

$= 829.082$

$$\rho = \frac{\lambda}{\mu}$$

$$= \frac{715}{829.082}$$

$= 0.86$

Priority queueing:

$$\rho_c = \frac{\lambda_c}{\mu_c}$$

$$\mu_c = \frac{5 \times 10^6 \ bs^{-1}}{200 \times 8 \ b}$$

$= 3125$ pk/s

$$\rho_c = \frac{495}{3125}$$

$= 0.1584$

(c) Delay bound for M/M/1:

$$P(T_R \leq t) = 1 - e^{-\mu(1-\rho)t}$$

$t = 10 \times 10^{-3}$ s

$\rho = 0.86$

$\mu = 829.082$ pk/s

$P(T_R \leq 10 \times 10^{-3})$

$= 1 - e^{-829.082(1-0.86) \times 10 \times 10^{-3}}$

$= 1 - e^{-1.16}$

$= 0.69$

Priority queueing:

$\rho = 0.1584$

$\mu = 3125$ pkt/s

$P(T_R \leq 10 \times 10^{-3})$

$= 1 - e^{-3125(1-0.1584) \times 10 \times 10^{-3}}$

$= 1 - e^{-26.3}$

$= 1 - 3.8 \times 10^{-12}$

≈ 1.0