Name______________________

Student Number____________

Department of Electrical and Electronic Engineering
ELEN 90061 Communication Networks

Part 2 Mid-Semester Test - September 2020

Authorised materials:

Open book Test

All test papers shall be submitted online at the end of the examination. The late submission will be subject to penalty.

Instructions to students:

The marks for each question are indicated in brackets after the question. The total marks of Part 2 for this examination are 24.

You may use the spare empty pages to write your solutions. It is very important to properly note down the question number before the solution.

Part 1

1. There are on average 2 packets per second arriving in a node that can be modelled as Poisson process. Within 10 seconds, the probability to see 50 packets is
(A) 1.2e-7, (B) 2.3e-8, (c) 7.6e-9, (d) 6.9e-10

Answer:
The formula for Poisson distribution is:

$$P(X=k)=\frac{(\lambda t)^k \boldsymbol{e^{-\lambda t}}}{k!}$$

Accordingly, $P(X=50)=\frac{20^{50}\boldsymbol{e^{-20}}}{50!}=7.6e^{-09}$

1a. There are on average 3 customers arriving per second in a post office that can be model as Poisson process. Within 20 seconds, the probability to see 50 customers is
(B) 2.4e-3, (B) 2.3e-2, (c) 2.7e-4, (d) 3.4e-5

Answer:

$$P(X=50)=\frac{60^{50}\boldsymbol{e^{-60}}}{50!}=0.0233$$

(2 marks)

2. Consider a packet-switched communication network that has link bandwidth of 1 Gb/s, each user consumes 50 Mb/s, and each user is only active 20% of the time. Assume, FDMA is used. For 22 users, what is the blocking probability of the network?
(A) 3.4e-15, (B) 4.6e-3, (C) 3.7e-14, (D) 4.4e-2

Answer:

$$P(user\ is\ active)=p=\frac{20}{100}=\frac{1}{5}$$

Blocking occurs if there are 21 and 22 users in the system because the system can handle 20 users at any given time.
Therefore,

$$n=22$$

$$P(k=21)=\binom{n}{k}p^k(1-p)^{n-k}=3.69e^{-14}$$

$$P(k=22)=4.194e^{-16}$$

$$P(k=21)+P(k=22)=3.7329e^{-14}$$

2a. Consider a packet-switched communication network that has link bandwidth of 1 Gb/s, each user consumes 20 Mb/s, and each user is only active 50% of the time. Assume, FDMA is used. For 52 users, what is blocking probability of the network?
(A) 4.1e-14, (B) 1.2e-14, (C) 4.5e-2, (D) 3.2e-2

Answer:
The blocking means there are 51 & 52 users.

$P_{51} = \binom{52}{51} (50\%)^{51} (1-50\%)$

$P_{52} = \binom{52}{52} (50\%)^{52}$, **(2 marks)**

$P_b = P_{51} + P_{52} = 1.2e^{-14}$

3. Laptop A has just received a file from Laptop B within the same LAN via Ethernet Switch C. Select correct statements below:
   (A) At Laptop B, only the application, transport and network layers are involved for the file transfer.
   (B) At Switch C, physical, link, and network layers are involved for the file transfer.
   (C) At Laptop A, all the layers from physical to application layer are involved for the file transfer.
   (D) A should have the entry of B in its ARP table, and B also should have the entry of A in its ARP table after completion of the file transfer.

(2 marks)

Answer:
(A) False. All the layers are involved.
(B) False, Switch only involves link layer and below.
(C) True.
(D) True. Since the transaction has already completed, which means both A and B should have each other in the ARP table.

4. Which is the CRC bit pattern for data [1011101] using generator [10001]?

Answer:

```
          101
10001 ) 1011101
        10001
        -----
          11001
          10001
          -----
           1000
```

CRC bit = [1000]

4a. Which is the CRC bit pattern for data [1011001] using generator [10001]?

Answer:

```
              101
10001 | 1011001
        10001
        -----
         11101
         10001
         -----
          1100
```

, CRC bits = [1100]

(2 marks)

5. Consider the queuing systems:
   (A) The average number of customers upon arrival and average number of customers upon departure may be different in a general queuing system.
   (B) In queuing systems where both arrival and serving process can be considered as Poisson, number of customers upon arrival and number of customers upon departure are identical when in steady state.
   (C) If the arrival process is not memoryless, the queuing process cannot be modelled as Markov Chain
   (D) If a random process is continuous instead of discrete-valued, it can still be modelled by Markov Chain.

(3 marks)

Answer:

(A) True
(B) True
(C) True, Markov chain only models memoryless process.
(D) False. Markov chair can only model discrete-value random process.

Part 2

(1) A clinic has 10 beds. When beds are fully occupied, there is a waiting room (practically infinitely large) to hold the overflow patients. Assume both patient arriving and usage of bed can be modeled as Poisson process, and on average there are 40 patients arriving each day, and each patient will spend 5 hours using the bed for the treatment before leaving.

   (i) How much time on average does each patient have to stay in the waiting room before being brought bed for treatment?

   (3 marks)

   (ii) What is the probability to find 15 patients in the clinic?

   (2 marks)

   (iii) What is the probability that a patient does not need to wait and can go directly to the bed for the treatment upon arrival?

   (3 marks)

   (iv) Upon arrival, a patient sees there are total 14 patients in the clinic, how long in total does he need to stay in the clinic on average ?

   (4 marks)

This can be considered as M/M/m, $m = 10$

$\lambda = 40$, $\bar{x} = 5\text{hr} = \frac{5}{24}$ day, $\mu = \frac{24}{5}$ /day

$\rho = \lambda/(\mu m) = \frac{40}{\frac{24 \times 10}{5}} = \frac{40}{48} = \frac{10}{12} = 5/6$

(i) $p_0 = \left[\sum_{k=0}^{m-1} \frac{(m\rho)^k}{k!} + \left(\frac{(m\rho)^m}{m!} \right) \left(\frac{1}{1-\rho} \right) \right]^{-1} = 1.8e^{-4}$

$\bar{N}_q = \frac{(m\rho)^m \cdot \rho \, p_0}{m! \, (1-\rho)^2} = 2.44$

$T = \frac{\bar{N}_q}{\lambda} = \frac{5.38}{40} = 0.06 \text{ day} = 1.46 \text{hr}$

(ii)

$$P_0 = \left[\sum_{k=0}^{m-1} \frac{(m\rho)^k}{k!} + \left(\frac{(m\rho)^m}{m!}\right)\left(\frac{1}{1-\rho}\right) \right]^{-1}$$

$$P_k = P_0 \cdot \frac{(m\rho)^k}{m!\, m^{k-m}}, \quad k=15, \; m=10$$

$$\rho = \frac{5}{6}$$

$$P_{15} = 0.033$$

(iii) Erlang C formula

$$P[\text{queueing}] = \frac{\left(\frac{(m\rho)^m}{m!}\right)\left(\frac{1}{1-\rho}\right)}{\left[\sum_{k=0}^{m-1} \frac{(m\rho)^k}{k!} + \left(\frac{(m\rho)^m}{m!}\right)\left(\frac{1}{1-\rho}\right)\right]}$$

$\cdot P(\text{Not wait}) = P_{NW} = 1 - P[\text{queueing}]$

$P[\text{queueing}] = 0.4876 = 0.49$

$P_{NW} \doteq 0.51$

(iv) The effective service rate = $m\mu$ =10*(24/5)=48 patients/day

The effective service time seeing by the waiting patients =1/48 (day)=0.5 hr
Namely, one patient will leave every 0.5 hour on average

There are 12 patients in total in the clinic, meaning 2 patients waiting, and 10 in bed. We know that one patient will leave every 0.5 hour on average.
So the waiting time would (2+1)x0.5=1.5 hour, adding the service time once the patient is in bed is 5 hr. So the total time T=W+X=1.5+5=6.5 hr

(3) Consider the link layer in Internet Protocol Stack.

(i) Which architecture does modern Ethernet LAN migrate to, star, hub or switch? Explain why it is so.

(2 marks)

(ii) Does Ethernet switch still need CSMA/CD to resolve collision?

(2 marks)

(iii) Can Ethernet switch be used in wireless LAN? Explain your answer.

(2 marks)

(iv) In a LAN, 10 users that are sending their data (or packets) via shared medium using slotted ALOHA protocol, and the data generated at each user is modelled iid.

(1) If each user has packets to send with a probability of 20% in each slot, what is the efficiency of the network.

(2 marks)

(2) If each user has packets to send with a probability of 20% in each slot, what is the probability **that a specific user** will be able to successfully transmit its data in its 2^{nd} trial.

(2 marks)

(3) What is the maximum efficiency of this slotted ALOHA network with 10 users?

(2 marks)

Answer:

(i) Switch. When the speed gets higher, the delay becomes significant, and the shared medium efficiency will decrease rapidly. So the dedicate collision-free switch is used for high-speed Ethernet.

(ii) No. Switch is collision-free. Each user is in its own collision-domain.

(iii) No. Wireless LAN is broadcast, but Ethernet switch is point-to-point.

(iv)

(1) efficiency = P[successful transmission]

$= P_s = M \times (1-p)^{M-1} \cdot p$

$= 10 \times (1-20\%)^9 \times 20\% = 0.27 = 27\%$

(2) Successful in 2nd trial means Not successful in 1st trial, but succeful in 2nd trial

$P[\text{success for specific user}] = P_s'$

$= (1-p)^{M-1} \cdot p =$

$P_s' = 0.0268$

$P[\text{success in 2nd trial}] = P[\text{fail in 1st trial}] \cdot P[\text{success in 2nd}] = (1-P_s') \cdot P_s'$

$= 0.0261$

(2) The efficiency E is:

$$E = M(1-p)^{M-1}p$$

$$lnE = lnM + (M-1)ln(1-p) + lnp$$

$$\frac{dE}{E\,dp} = -\frac{M-1}{1-p} + \frac{1}{p} = 0 => \frac{1}{p} = \frac{M-1}{1-p} => \frac{1}{p} - 1 = M - 1 => p = \frac{1}{M}$$

system

Maxium efficiency of this Aloha

would $P = \frac{1}{M} = 10\%$

$$E = M \times (1 - 10\%)^{M-1} (10\%) , M = 10$$

$$\doteq 0.39 ,$$