Lecture 7

Recap: Link layer Protocols

Medium Access Control (MAC)

→ broadcast channel

A) Random Access Methods

→ Collisions

→ Methods to reduce collision (CSMA)

→ Methods to reduce the cost of collision (CSMA/CD)

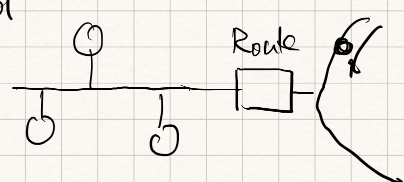
→ Methods to resolve collisions

Binary Exponential Backoff

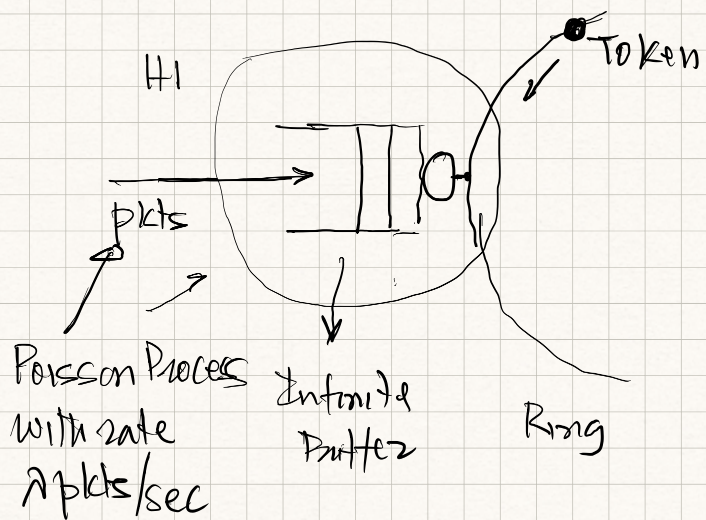
B) Taking Turns

→ Token Ring Protocol

→ Slotted Ring Protocol



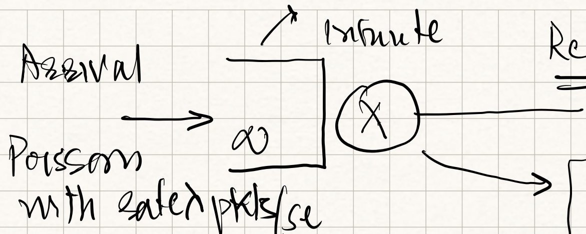
Token Ring Protocol



Service time

⇒ access time
+
transmission time

time to get the token



Recall

M/M/1 queue

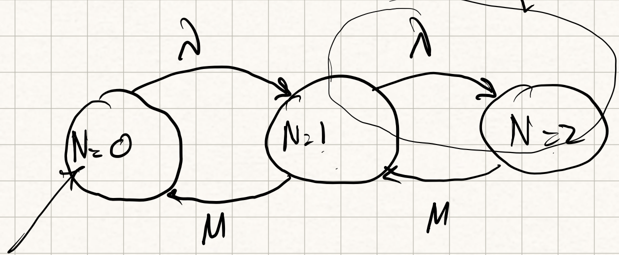
Markovian

[Service time was Exponentially Distribute with rate μ pkts/sec]

$X \sim Expo(\mu)$

$E(X) = 1/\mu$

$Var(X) = 1/\mu^2$



# of pkts in the system

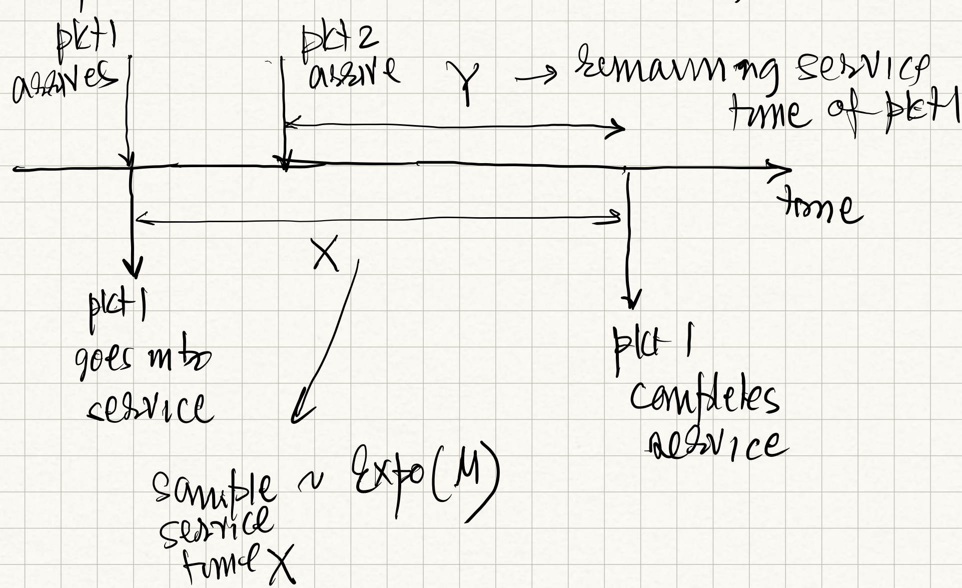
$\rho = \frac{\lambda}{\mu} = \lambda . \bar{x} = \lambda . \frac{1}{\mu}$

N = 1 pkt ⇒ the pkt is being transmitted

New arrival ⇒ state goes to N = 2

Reason why we donot consider the remaining time of the pkt in service is because of the Exponential distribution of the service

Exponential distribution is Memoryless



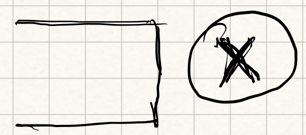
$Y \sim \text{Expo}(M) \rightarrow X$ is memoryless distribution

Service time follows any other distribution (other than Exponential) then we have to consider the remaining service in the state description

$\Rightarrow$ Token Ring System

$X \sim \text{Gen}(\bar{x}, x_{var})$ — $E(X)$, $Var(X)$

Arrival Process $\rightarrow$



Poisson with rate λ pkts

Infinite buffer

Generally distributed service time

M | G | 1 ← 1 server

Markovian ← M

G ← General service

State of the system at any time t: (N_t, R_t)

N_t: # of pkts in the system

R_t: Remaining time of the pkt in service

$\Rightarrow$ This is much harder to solve

But you can solve it

$\bar{q}$: Average number of pkts in the system

$$= \rho + \rho^2 \frac{(1 + C_b^2)}{2(1-\rho)}$$

$\rho = \lambda \cdot$ mean service time

$= \lambda \cdot \bar{x}$

C_D^2 = Coefficient of Variation

$$= \frac{Var(X)}{(E(X))^2}$$

$X \sim Expo(\mu)$ $\quad C_D^2 = \frac{1/\mu^2}{1/\mu^2} = 1$

$$E(N) = \bar{q} = \rho + \frac{\rho^2(1 + C_D^2)}{2(1-\rho)}$$

Service time has higher C_D^2
$\Rightarrow$ higher average queue length

as $\rho \to 1$ $\quad E(N) \to \infty$

- We have always derived the queue length $E(N)$. How do we derive $E(D)$ where D is the <u>delay faced by a pkt</u>

↳ waiting time in the queue + service time

<u>Little's Law</u>

$$\boxed{E(D) \cdot \lambda = \underbrace{E(N)}}$$

Average # of pkts left behind by a departing pkt

average # of pkts seen by a departing pkt = average number of pkts seen by an arriving pkt

True

PASTA property

↳ Poisson Arrivals see Time Averages

$$E(D) = \frac{1}{\lambda} E(N)$$

For M|M|1 queue

$$E(D) = \frac{1}{\lambda} \cdot \frac{\rho}{1-\rho} = \frac{1/\mu}{1-\rho}$$

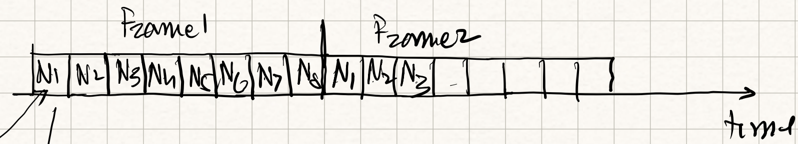
$\rho = \lambda/\mu$

For M|G|1 queue

$$E(D) = \frac{1}{\lambda}\left[\rho + \frac{\rho^2(1+C_b^2)}{1-\rho}\right]$$

Channel Partitioning

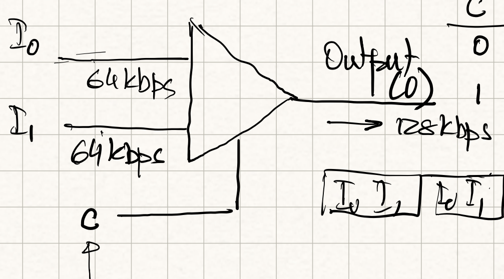
Time Division Multiplexing



Slot

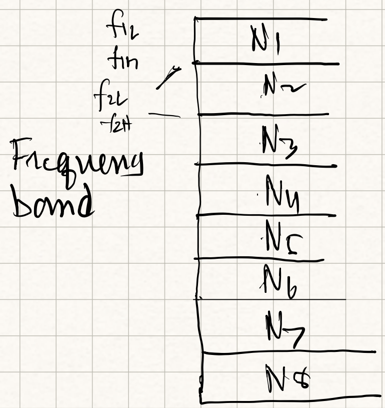
Each slot is assigned to a specific source/host/node

Multiplexer



C	Output (O)
0	I_0
1	I_1

Frequency Division Multiplexing



→ Combine FDMA & TDMA

⇒ done in LTE & 5G

Review

- → Simple
- → Decentralized (No single point of failure)
- → Suppose R bps is the data rate of the link. If only 1 node is transmitting then it should get R bps (high utilization requirement)
- → If m nodes are transmitting then each node should get R/m bps on the average (fairness requirement)