Minufiya University
Faculty of Electronic Engineering
Dep. of Electronic and Communication Eng.

4'th Year

Mobile Communications Theory

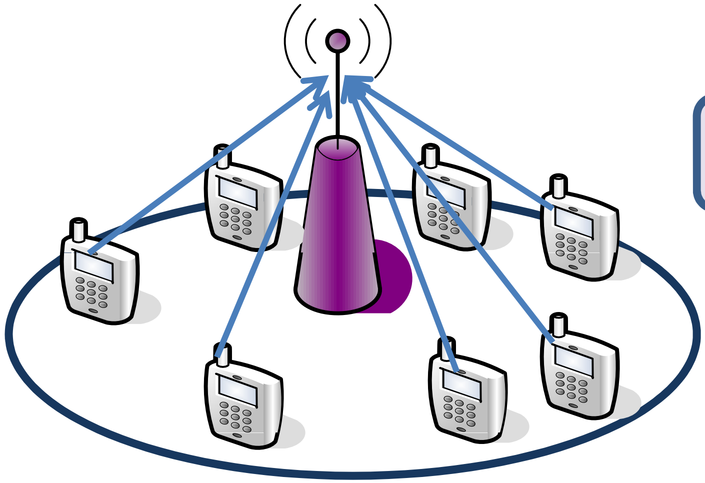
Sheet-1-
Mobile Communications

Prepared by:
Eng. Waleed Saad

Q1 Derive an expression for the throughput of pure- and slotted-ALOHA

Pure Aloha

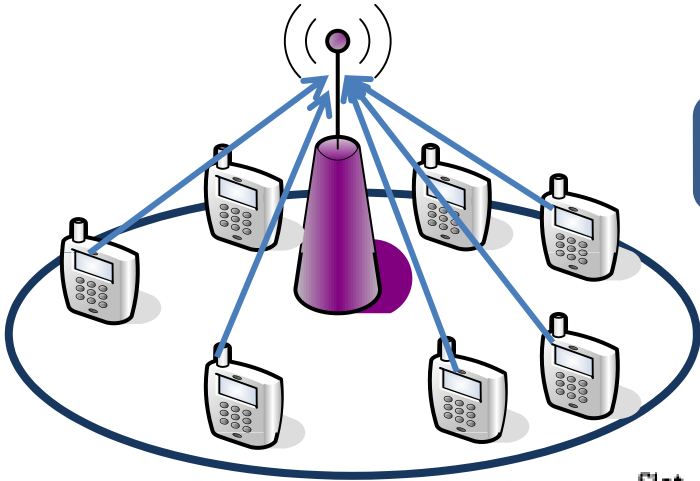
Slotted Aloha



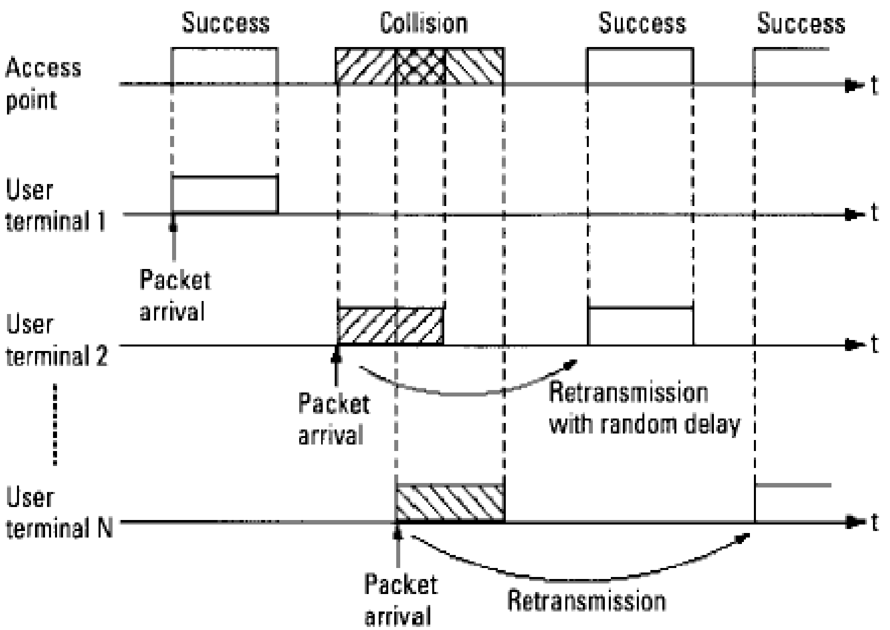
- Infinite number of stations.
- All packets are of constant length "T».
- The channel is noise free.
- The offered load (traffic) "G" is Poisson distribution.

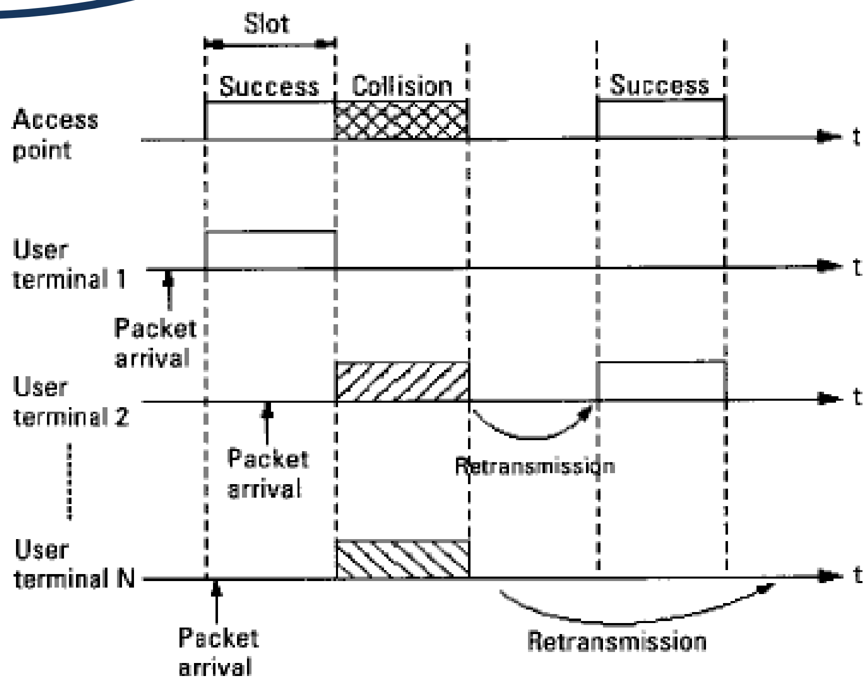
Q1 Derive an expression for the throughput of pure- and slotted-ALOHA

Pure Aloha



Slotted Aloha





Q1 Derive an expression for the throughput of pure- and slotted-ALOHA

Pure Aloha

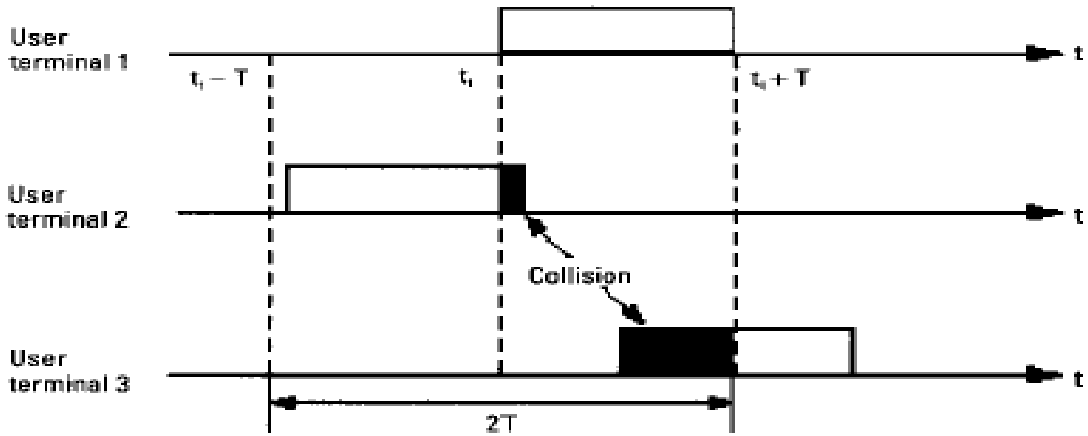
the probability to generate n packets in the period t → $P_n(t) = \frac{e^{-\lambda t}(\lambda t)^n}{n!}$

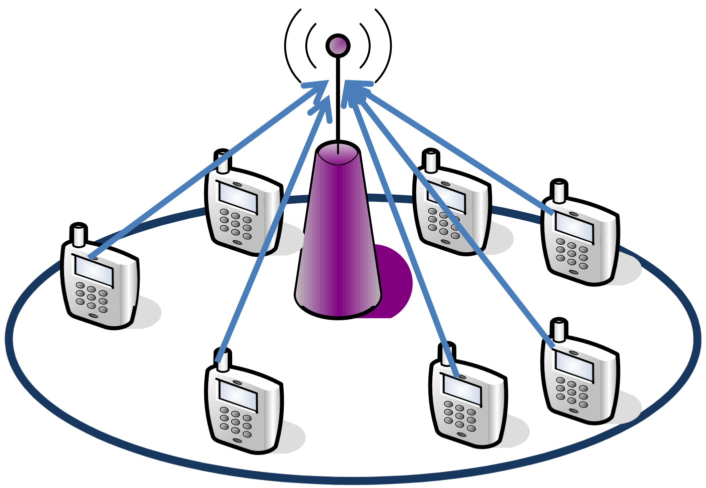
λ the expected number of packets to generate in a unit time

$G = \lambda\tau$

Probability of successful transmission of a packet from a user to the access point = prob. not to generate any packets within 2T

$$P_{succ} = P_0(2\tau) = \frac{e^{-2\lambda\tau}(2\lambda\tau)^0}{0!} = e^{-2\lambda\tau} = e^{-2G}$$



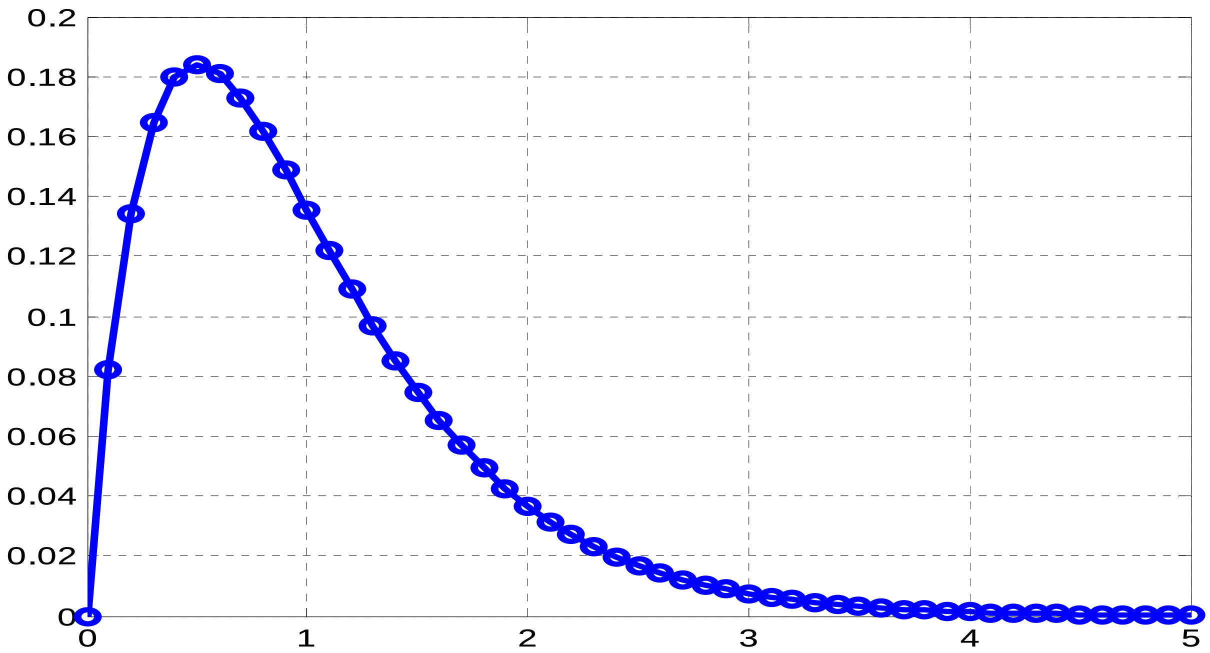


Q1 Derive an expression for the throughput of pure- and slotted-ALOHA

Pure Aloha

The throughput "S": **The expected number of packets that are transmitted at the access point successfully .**

$$S = GP_{succ} = Ge^{-2G}$$



Q1 Derive an expression for the throughput of pure- and slotted-ALOHA

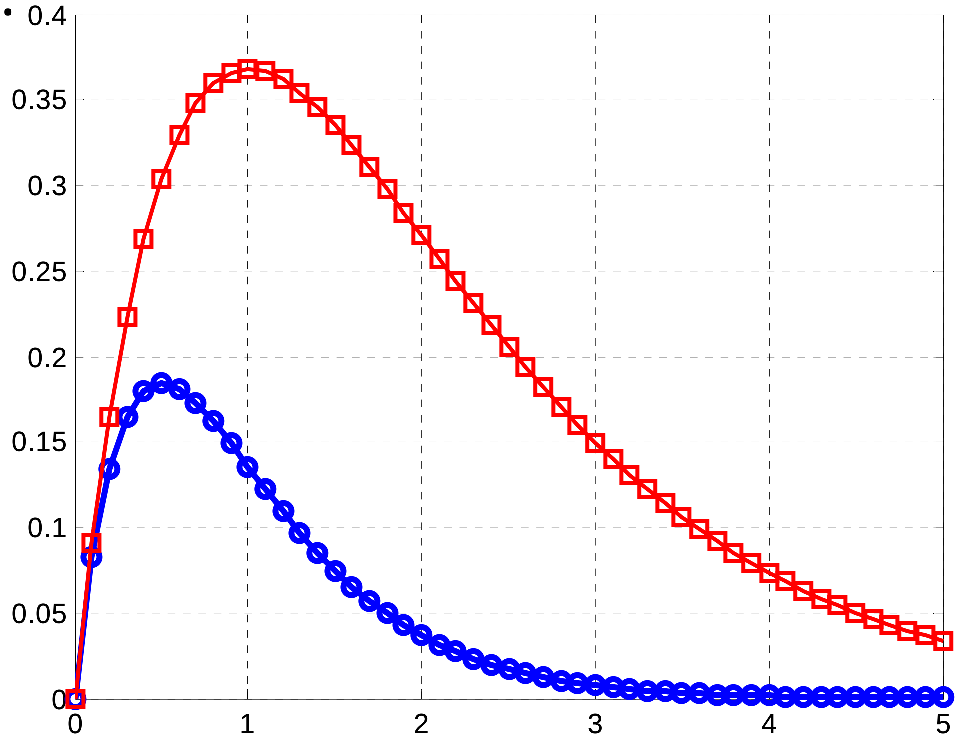
Slotted Aloha

Probability of successful transmission of a packet from a user to the access point = prob. not to generate any packets within T

$$P_{succ} = P_0(\tau) = \frac{e^{-\lambda\tau}(\lambda\tau)^0}{0!} = e^{-\lambda\tau} = e^{-G}$$

The throughput "S": The expected number of packets that are transmitted at the access point successfully .

$$S = GP_{succ} = Ge^{-G}$$



Q2

Derive expression for maximum throughput for:

(i) P-ALOHA

(ii) S-ALOHA

Pure Aloha

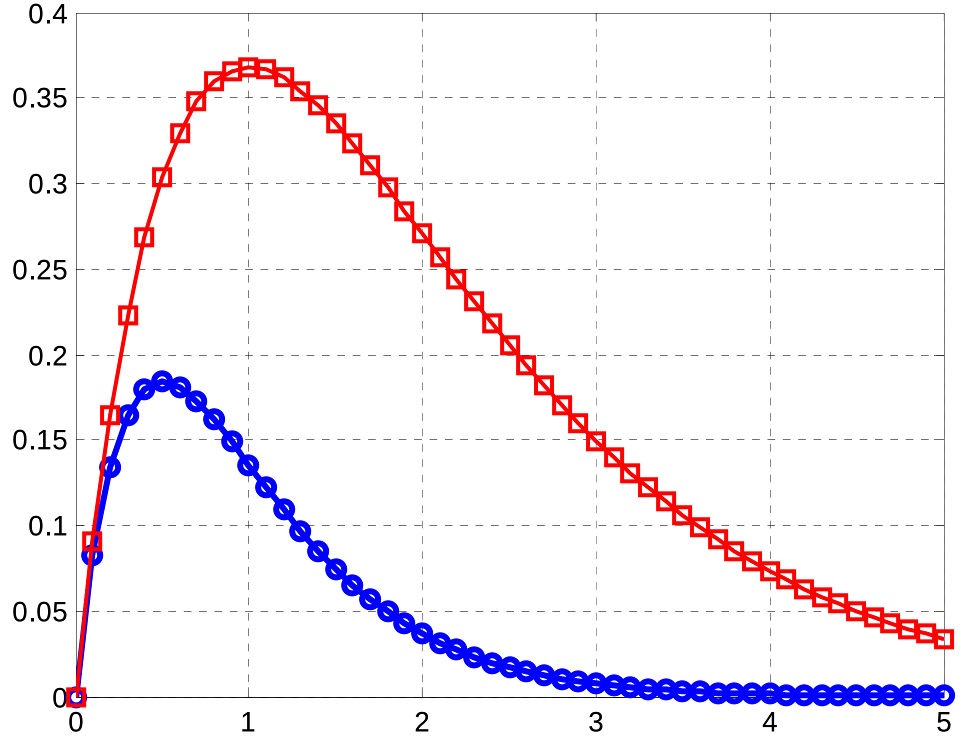
$$S = GP_{succ} = Ge^{-2G}$$

$$S^* = \frac{1}{2e} \approx 0.184, \quad \text{when} \quad G^* = \frac{1}{2}.$$

Slotted Aloha

$$S = GP_{succ} = Ge^{-G}$$

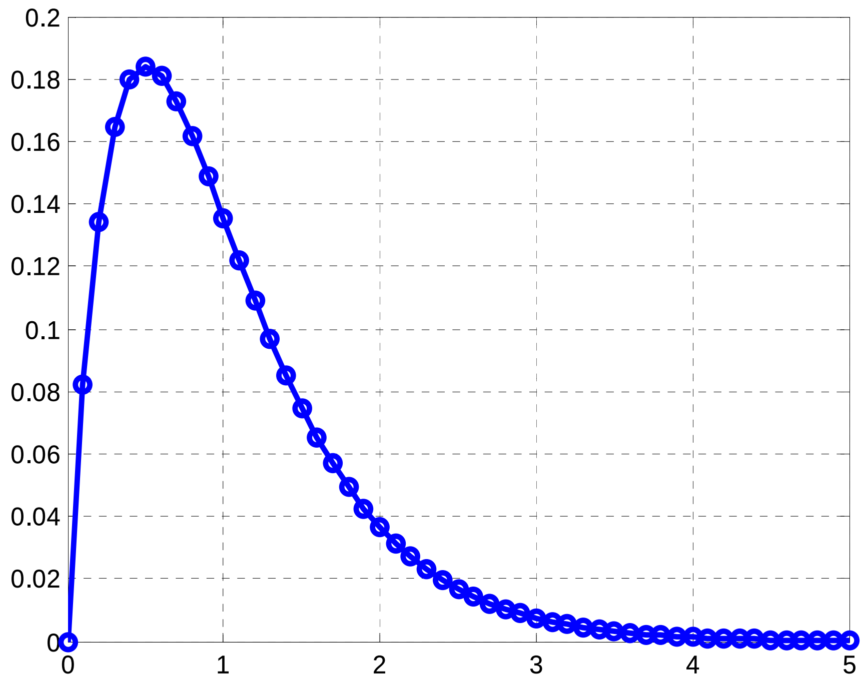
$$S^* = \frac{1}{e} \approx 0.368, \quad \text{when} \quad G^* = 1.$$



Q3 Calculate throughput S for P-ALOHA network. If the offered traffic G is 0.75

Pure Aloha $S = GP_{succ} = Ge^{-2G}$

$$S = 0.75 \times e^{-2 \cdot 0.75}$$
$$= 0.1673$$
$$S = 16.73\ \%$$



Q4

S-ALOHA channel has an average 10% of the slots idle.

i. What is the offered traffic G?
ii. What is the throughput?
iii. Is channel overloaded or under loaded?

For slotted ALOHA channel,

(a) Probability of single transmission during a slot time is = e^{-G}.

$$10\ \% = e^{-G}$$

$$0.1 = e^{-G}$$

$$\Rightarrow \quad -G = -2.3$$

$$\therefore \quad G = 2.3$$

(b)

$$S = G * e^{-G}$$

$$= 2.3 * e^{-(2.3)}$$

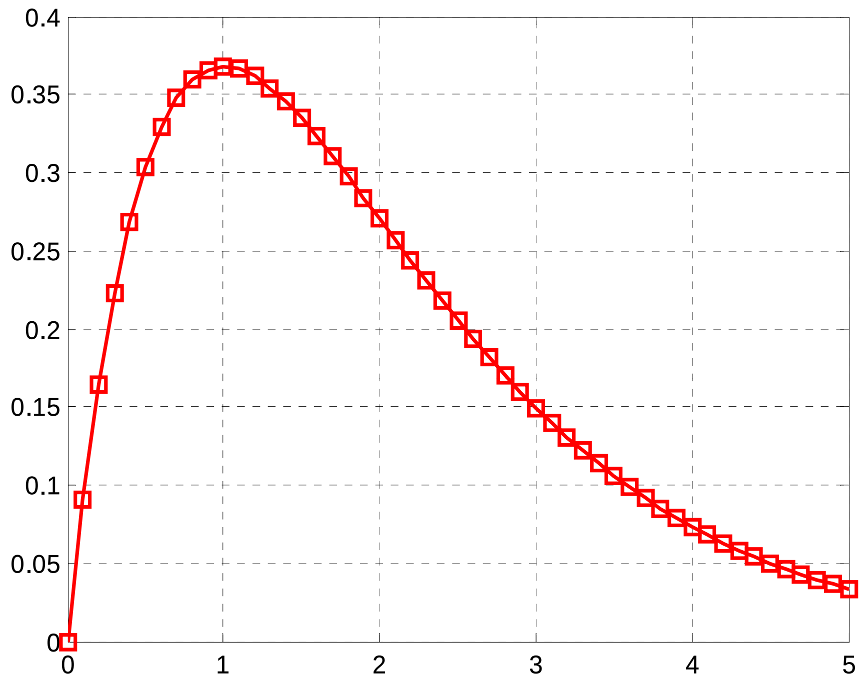
$$= 0.23$$

(c) For slotted ALOHA, S is maximum at $G = 1$.

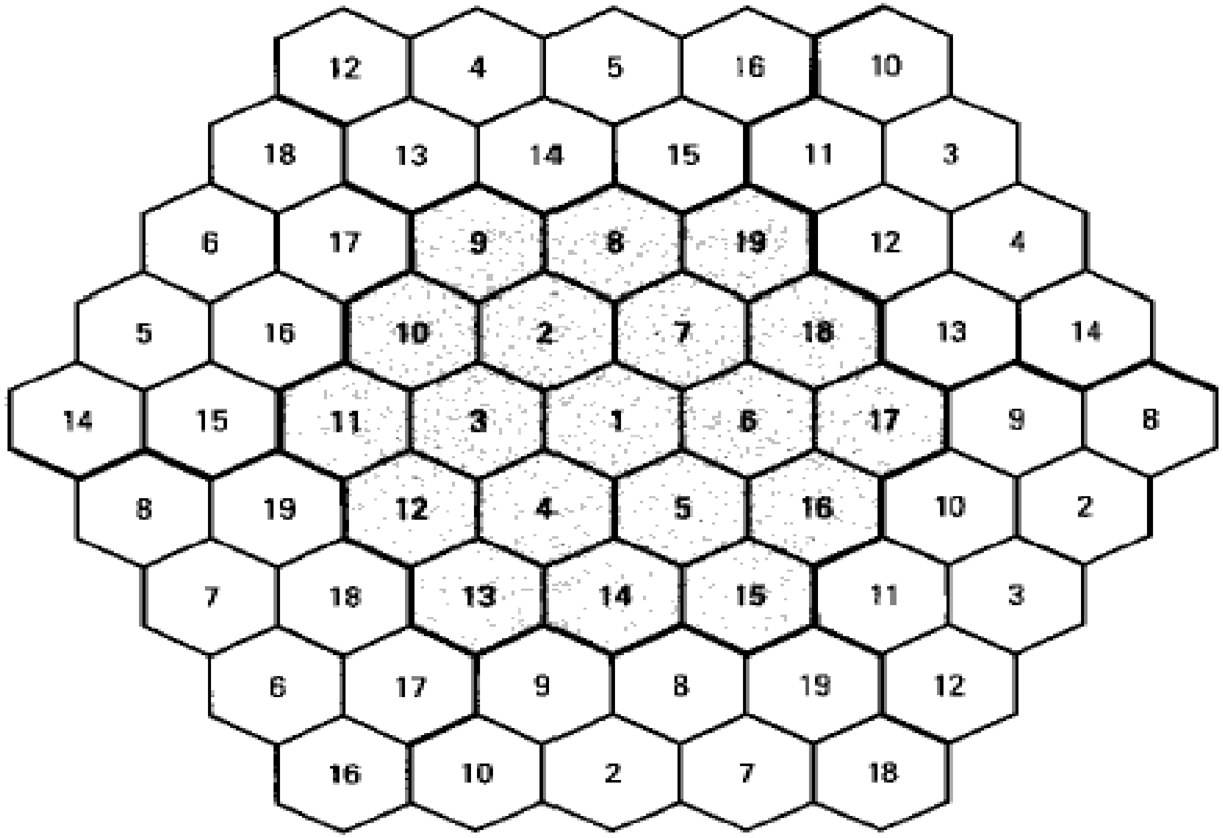
Here $G = 2.3$ and

$$S = 0.23$$

It is beyond $G = 1$, hence it is overloaded.



Q5 Derive expression for cluster size and Reuse distance for Hexagonal cellular system.



Cellular system structure

Q5 Derive expression for cluster size and Reuse distance for Hexagonal cellular system.

From the geometry of the figure, $OA = R$ and $AB = R/2$.

Then, $OB = OA + AB = R + R/2 = 3\,R/2$.

Then, in right-angled $\Delta\, OAP$,

$OP = OA \sin 60^{\circ} = (\sqrt{3}/2)R$

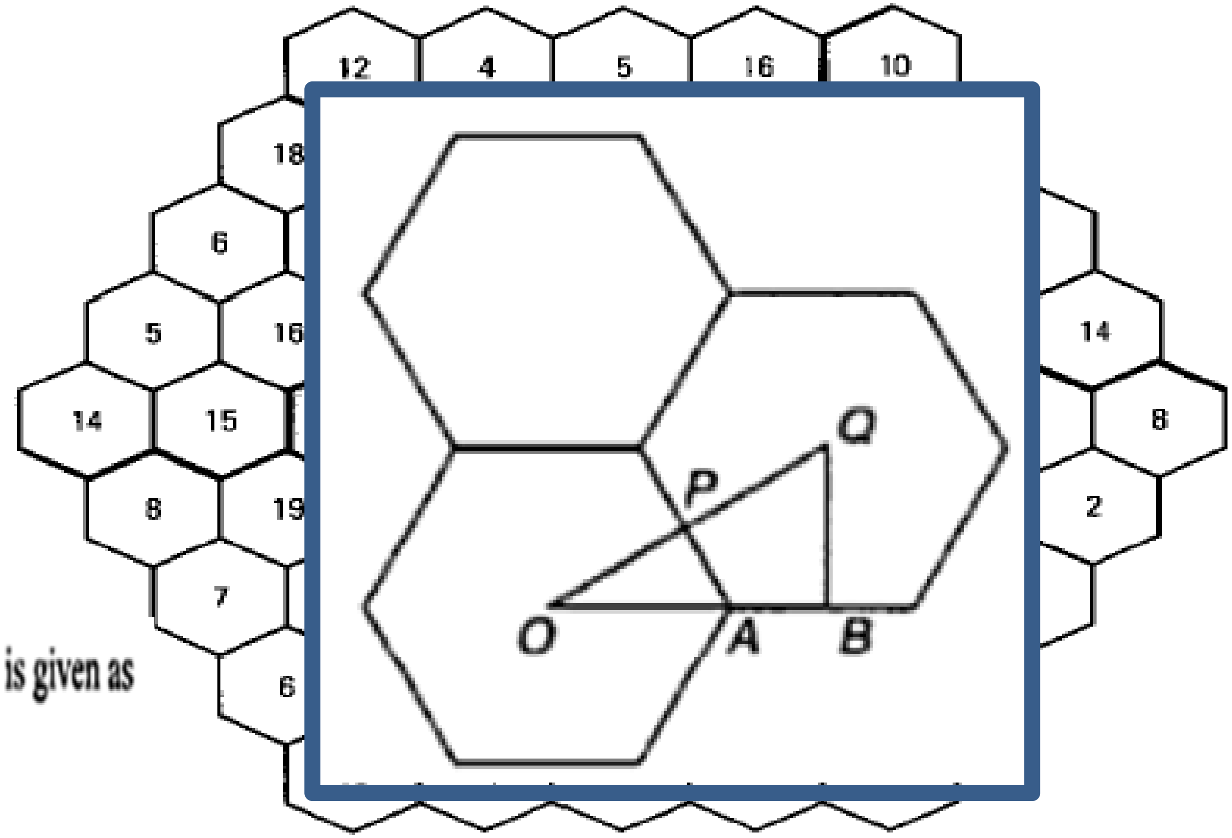
$OQ = OP + PQ$ (where $OP = PQ$)

Therefore, $d = [(\sqrt{3}/2)R] + [(\sqrt{3}/2)R]$

Hence, $d = \sqrt{3}R$

The area of a cell (the small hexagon) with radius R is given as

$A_{small\ hexagon} = (3\sqrt{3}/2) \times R^2$



Cellular system structure

Q5 Derive expression for cluster size and Reuse distance for Hexagonal cellular system.

Let 'd' be the distance between two adjacent cells and 'D' be the distance from the centre of the cell under consideration to the centre of a nearest cochannel cell.

ΔXYZ

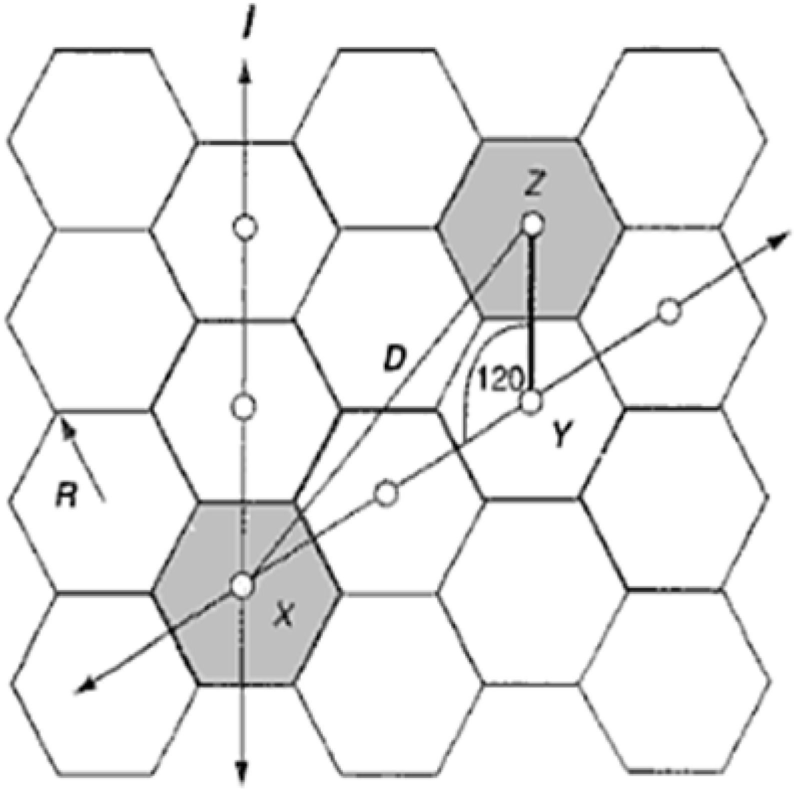
$$XZ^2 = XY^2 + YZ^2 - 2 \times XY \times YZ \cos 120°$$

$$\text{Or, } D^2 = (i \times d)^2 + (j \times d)^2 - 2 \times (i \times d) \times (j \times d) \cos 120°$$

$$\text{Or, } D^2 = (i \times d)^2 + (j \times d)^2 - 2 \times (i \times d) \times (j \times d) \times (-½)$$

$$\text{Or, } D^2 = (i \times d)^2 + (j \times d)^2 + (i \times d) \times (j \times d)$$

$$\text{Or, } D^2 = d^2 (i^2 + j^2 + i \times j)$$



$$D^2 = 3 \times R^2 \times (i^2 + j^2 + i \times j)$$

Q6

(a) Assume a cellular system of 32 cells with a cell radius of 1.6 km, a total spectrum allocation that supports 336 traffic channels, and a reuse pattern of 7. Calculate the total service area covered with this configuration, the number of channels per cell, and a total system capacity. Assume regular hexagonal cellular topology.

(b) Let the cell size be reduced to the extent that the same area as covered in Part (a) with 128 cells. Find the radius of the new cell, and new system capacity.

Comment on the results obtained.

(a) To calculate total service area, number of channels per cell, and system capacity

Total number of cells in service area = 32 (given)

Radius of a cell, $R = 1.6$ km (given)

Step 1. *To calculate area of a regular hexagonal cell*

Area of a regular hexagonal cell, $A_{cell} = 3\sqrt{3}/2 \times R^2$

Therefore, $A_{cell} = 3\sqrt{3}/2 \times (1.6\text{ km})^2 = 6.65\text{ km}^2$

Step 2. *To calculate total service area*

Total service area covered = no. of cells in total area × Area of a cell

Hence, **total service area covered** = 32 × 6.65 = **213 km²**

Step 3. *To calculate number of channels per cell*

Total number of available traffic channels = 336 (given)

Frequency reuse pattern (cluster size) = 7 (given)

Hence, **number of channels per cell** = 336/7 = **48**

Step 4. *To calculate total system capacity*

Total system capacity = number of channels per cell × number of cells

Hence, **total system capacity** = 48 × 32 = **1536 channels**

Q6

(a) Assume a cellular system of 32 cells with a cell radius of 1.6 km, a total spectrum allocation that supports 336 traffic channels, and a reuse pattern of 7. Calculate the total service area covered with this configuration, the number of channels per cell, and a total system capacity. Assume regular hexagonal cellular topology.

(b) Let the cell size be reduced to the extent that the same area as covered in Part (a) with 128 cells. Find the radius of the new cell, and new system capacity.

Comment on the results obtained.

(b) Total number of available cells = 128 (given)

Total service area = 213 km^2 (as calculated in Step 2)

Step 5. *To determine area of new regular hexagonal cell*

Area of a regular hexagonal cell = total service area / number of cells

$= 213 \text{ km}^2 / 128 = 1.66 \text{ km}^2$

Step 6. *To find radius of new smaller cell, R*

Area of a regular hexagonal cell = $3\sqrt{3}/2 \times R^2$

But, $3\sqrt{3}/2 \times R^2 = 1.66 \text{ km}^2$ (as calculated in Step 5)

Or, $R = 0.8$ km

Hence, **radius of new smaller cell, $R = 0.8$ km**

Step 7. *To find new system capacity*

New system capacity = number of channels per cell × number of cells

New system capacity = 48 × 128

Hence, **new system capacity = 6144 channels**

Q7

A mobile communication system is allocated RF spectrum of 25 MHz and uses RF channel bandwidth of 25 kHz so that a total number of 1000 voice channels can be supported in the system.

(a) If the service area is divided into 20 cells with a frequency reuse factor of 4, compute the system capacity.

(b) The cell size is reduced to the extent that the service area is now covered with 100 cells. Compute the system capacity while keeping the frequency reuse factor as 4.

(c) Consider the cell size is further reduced so that the same service area is now covered with 700 cells with the frequency reuse factor of 7. Compute the system capacity.

Comment on the results obtained.

Number of available voice channels, $N = 1000$ (given)

Step 1. *To determine the cluster capacity*

We know that in a cellular system based on frequency-reuse concept, all the given available channels, that is, 1000, are allocated to each cluster uniformly.

Therefore, each cluster can serve 1000 active users simultaneously.

In other words, the capacity of a cluster = 1000

(a) *To compute the system capacity for given K*

Number of cells covering the area = 20 (given)

Frequency reuse factor or cluster size = 4 (given)

Step 2. *To determine number of clusters*

Number of clusters = number of cells/cluster size

Therefore, number of clusters = 20/4 = 5

Step 3. *To determine the system capacity*

The capacity of a cluster = 1000 (as calculated is Step 1)

Number of clusters = 5 (as calculated is Step 2)

Thus, number of channels in all 5 clusters = 1000 × 5 = 5000

Hence, **the system capacity = 5000 users**

Q7

A mobile communication system is allocated RF spectrum of 25 MHz and uses RF channel bandwidth of 25 kHz so that a total number of 1000 voice channels can be supported in the system.

(a) If the service area is divided into 20 cells with a frequency reuse factor of 4, compute the system capacity.

(b) The cell size is reduced to the extent that the service area is now covered with 100 cells. Compute the system capacity while keeping the frequency reuse factor as 4.

(c) Consider the cell size is further reduced so that the same service area is now covered with 700 cells with the frequency reuse factor of 7. Compute the system capacity.

Comment on the results obtained.

(b) To compute new system capacity for increased number of cells.

Number of cells covering the area = 100 (given)

Frequency reuse factor or cluster size = 4 (given)

Step 4. To determine number of clusters

Therefore, number of clusters = 100/4 = 25

Step 5. To determine new system capacity

Thus, number of channels in all 25 clusters = 1000 × 25 = 25000

Hence, **the new system capacity = 25000 users**

Q7

A mobile communication system is allocated RF spectrum of 25 MHz and uses RF channel bandwidth of 25 kHz so that a total number of 1000 voice channels can be supported in the system.

(a) If the service area is divided into 20 cells with a frequency reuse factor of 4, compute the system capacity.

(b) The cell size is reduced to the extent that the service area is now covered with 100 cells. Compute the system capacity while keeping the frequency reuse factor as 4.

(c) Consider the cell size is further reduced so that the same service area is now covered with 700 cells with the frequency reuse factor of 7. Compute the system capacity.

Comment on the results obtained.

(c) To compute new system capacity for increased number of cells and cluster size.

Number of cells covering the area = 700 (given)

Frequency reuse factor or cluster size = 7 (given)

***Step 6.** To determine number of clusters*

Therefore, number of clusters = 700/7 = 100

***Step 7.** To determine new system capacity*

Thus, number of channels in 100 clusters = 1000 × 100 = 100,000

Hence, **the new system capacity = 100,000 users**

Comments on the results It is observed that as the number of cells covering a given service area is increased, the number of clusters having all available number of channels increases. This results into significant increase in the number of active users in the system or the system capacity. Hence, it is concluded that frequency reuse enhances system capacity.