Class: 4th

MOBILE COMMUNICATIONS

Lecture 7

Chapter Two

Grade of Service(GOS)

By

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Lecture Outlines

- Queuing
- Grade of Service(GOS)
- Erlang B chart

Teaching Tools:

- White Board, white board marker and eraser

Teaching Methods:

1. Method of lecture.
2. Method of discussion and dialogue.
3. Brain storming

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Queuing

- The AMPS cellular system is designed for a *GOS* of 2% blocking. This implies that the channel allocations for cell sites are designed so that 2 out of 100 calls will be blocked due to channel occupancy during the busiest hour.

There are two types of trunked systems which are commonly used.

1- **no queuing**
2- **queuing**

(1) The first type offers **no queuing** for call requests. That is, for every user who requests service, it is assumed there is no setup time and the user is given immediate access to a channel if one is available. If no channels are available, the requesting user is blocked without access and is free to try again later. This type of trunking is called **blocked calls cleared** and assumes that calls arrive as determined by a Poisson distribution. Furthermore, it is assumed that there are an infinite number of users as well as the following:

(a) there are memoryless arrivals of requests, implying that all users, including blocked users, may request a channel at any time;

(b) the probability of a user occupying a channel is exponentially distributed, so that longer calls are less likely to occur as described by an exponential distribution;

(c) There are a finite number of channels available in the trunking pool. This is known as an M/M/m queue, and leads to the derivation of the Erlang B formula (also known as the blocked calls cleared formula).

The Erlang B formula determines the probability that a call is blocked and is a measure of the *GOS* for a trunked system which provides no queuing for blocked calls.

The Erlang B formula is given by

$$P_r[blocking] = \frac{\frac{A^C}{C!}}{\sum_{k=0}^{C} \frac{A^k}{k!}} = GOS$$

where C is the number of trunked channels offered by a trunked radio system and A is the total offered traffic.

While it is possible to model trunked systems with finite users, the resulting expressions are much more complicated than the Erlang B result, and the added complexity is not warranted for typical trunked systems which have users that outnumber available channels by orders of magnitude.

Furthermore, the Erlang B formula provides a conservative estimate of the *GOS*, as the finite user results always predict a smaller likelihood of blocking. The capacity of a trunked radio system where blocked calls are lost is tabulated for various values of *GOS* and numbers of channels in Table below:

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Capacity of an Erlang B system

Number of channels *C*	**Capacity (*Erlangs*) for *GOS***			
	0.01	**0.005**	**0.002**	**0.001**
2	0.153	0.105	0.065	0.046
4	0.869	0.701	0.535	0.439
5	1.36	1.13	0.9	0.762
10	4.46	3.96	3.43	3.09
20	12	11.1	10.1	9.41
24	15.3	14.2	13	12.2
40	29	27.3	25.7	24.5
70	56.1	53.7	51	49.2
100	84.1	80.9	77.4	75.2

(2) The second kind of trunked system is one in which a **queue** is provided to hold calls which are blocked.

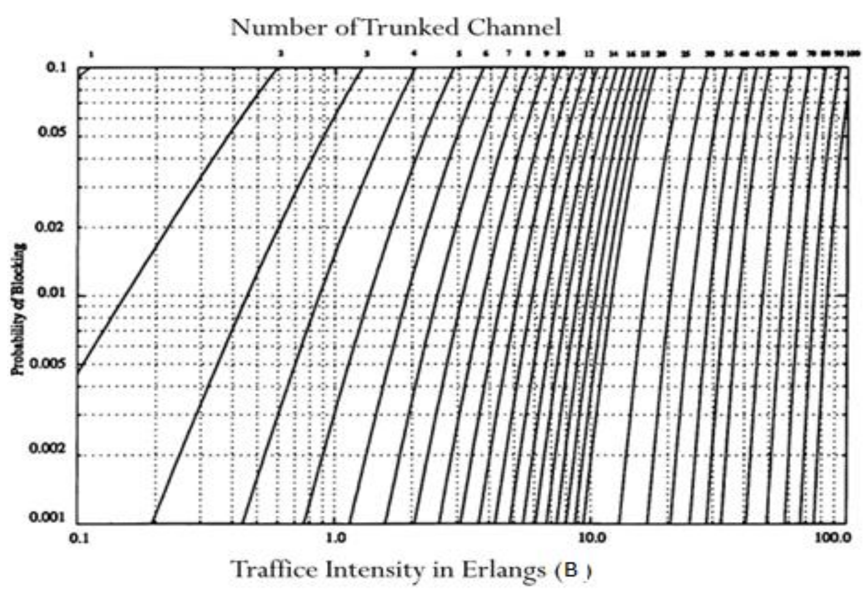
- If a channel is not available immediately, the call request may be delayed until a channel becomes available.
- This type of trunking is called **Blocked Calls Delayed**, and its measure of *GOS* is defined as the probability that a call is blocked after waiting a specific length of time in the queue.
- To find the GOS, it is first necessary to find the likelihood that a call is initially denied access to the system.

Grade of Service(GOS):

The likelihood of a call not having immediate access to a channel is determined by the *Erlang C formula*

$$P_r[delay > 0] = \frac{A^C}{A^C + C!\left(1 - \frac{A}{C}\right)\sum_{k=0}^{C-1}\frac{A^k}{k!}}$$

- If no channels are immediately available the call is delayed, and the probability that the delayed call is forced to wait more than *t* seconds is given by the probability that a call is delayed, multiplied by the conditional probability that the delay is greater than *t* seconds.



Example 1

How many users can be supported for 0.5% blocking probability for the following number of trunked channels in a blocked calls cleared system?

a. 5
b. 10

Assume each user generates $A_U = 0.1$ *Erlangs* of traffic.

Solution

(a) From Erlang B chart, we obtain $A \approx 1$

Therefore, total number of users, $U = A/A_U = 1 /0.1 = 10$ users.

(b) From Erlang B chart, we obtain $A \approx 4$

Therefore, total number of users, $U = A/A_U = 4 /0.1 = 40$ users.

<u>Example 2</u>

How many users can be supported for 0.5% blocking probability for the following number of trunked channels in a blocked calls cleared system? (a) 1, (b) 5, (c) 10, (d) 20, and (e) 100. Assume each user generates 0.1 *Erlangs* of traffic.

Solution

From the table of the capacity of an Erlang B system, we can find the total capacity in *Erlangs* for the 0.5% *GOS* for different numbers of channels.

By using the relation $A = UA_U$, we can obtain the total number of users that can be supported in the system.

(a) Given $C = 1$, $A_U = 0.1$, $GOS = 0.005$

From Erlang B chart, we obtain $A = 0.005$

Therefore, total number of users, $U = A/A_U = 0.005 /0.1 = 0.05$ users.

But, actually one user could be supported on one channel. So, $U = 1$

(b) Given $C = 5$, $A_U = 0.1$, GOS = 0.005

From Erlang B chart, we obtain $A = 1.13$

Therefore, total number of users, $U = A/A_U = 1.13/0.1 = 11$ users.

(c) Given $C = 10$, $A_U = 0.1$, GOS = 0.005

From Erlang B chart, we obtain $A = 3.96$ *Erlangs*

Therefore, total number of users, $U = A/A_U = 3.96/0.1 \approx 39$ users.

(d) Given $C = 20$, $A_U = 0.1$, GOS = 0.005

From Erlang B chart, we obtain $A = 11.10$

Therefore, total number of users, $U = A/A_U = 11.1/0.1 = 110$ users.

(e) Given $C = 100$, $A_U = 0.1$, GOS = 0.005

From Erlang B chart, we obtain $A = 80.9$

Therefore, total number of users, $U = A/A_U = 80.9/0.1 = 809$ users.
