Chapter 3 :

Traffic Engineering

جامعة المستقبل- كلية الهندسة والتقنيات الهندسية ات الهندسية

قسم هندسة تقنيات الحاسوب

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Chapter 3

3.1 Trunking and Grade of Service

A- Trunking

- A trunk : is a communications line or link designed to carry multiple signals simultaneously to provide network access between two points. The number of trunks connecting the MSC 1 with another MSC 2 are the number of voice pairs used in the connection.
- One of the most important steps in telecommunication engineering is to determine the number of trunks required on a route or a connection between MSCs. To dimension a route correctly, we must have some idea of its usage, that is, how many subscribers are expected to talk at one time over the route.
- The concept of trunking allows a large number of users to share the relatively small number of channels in a cell by providing access to each user, on demand, from the available channels.
- In a trunked radio system, each user is allocated a channel on a per call basis, and upon termination of the call, the previously occupied channel is immediately returned to the pool of available channels.
- The telephone company uses trunking theory to determine the number of telephone circuits that need to be allocated and this same principle is used in designing cellular radio systems.
- In a trunked mobile radio system,
  - When a particular user requests service and all of the radio channels are already in use, the user is blocked, or denied access to the system.
  - In some systems, a queue may be used to hold the requesting users until a channel becomes available.
- To design trunked radio systems that can handle a specific capacity at a specific "grade of service", it is essential to understand trunking theory and queuing theory.
- The fundamentals of trunking theory were developed by Erlang, a Danish who, in the late 19th century.
- One Erlang represents the amount of traffic intensity carried by a channel that is completely occupied (i.e. 1 call-hour per hour or 1 call-minute per minute).

- Traffic is measured in either:
  - Erlangs,
  - Percentage of occupancy,
  - Centrum (100) call seconds (CCS),

B- The grade of service (GOS):

is a measure of the ability of a user to access a trunked system during the busiest hour.

- The grade of service is a benchmark used to define the desired performance of a particular trunked system by specifying a desired probability of a user obtaining channel access given a specific number of channels available in the system.
- It is the wireless designer's job to estimate the maximum required capacity and to allocate the proper number of channels in order to meet the GOS.
- GOS is typically given as the probability that a call is blocked, or the probability of a call experiencing a delay greater than a certain queuing time.

Traffic intensity is the average number of calls simultaneously in progress during a particular period of time. It is measured either in units of *Erlangs* or *CCS*.

The traffic intensity offered by each user is equal to the call request rate multiplied by the holding time (in hours). That is, each user generates a traffic intensity of A_U Erlangs given by

$$A_U = \lambda H$$

where

H is the average duration of a call (Holding time).
λ is the average number of call requests per unit time.

For a system containing U users and an unspecified number of channels, the total offered traffic intensity A, is given as

$$A = UA_U$$

And

Overflow (O)= (Offered load) – (Carried load)

- *CCS to Erlang conversion*

An average of one call in progress during an hour represents a traffic intensity of 1 *Erlang*; thus 1 *Erlang* equals 1 × 3600 call seconds (36 *CCS*). The Erlang is a dimensionless number.

Example 1

If the carried load for a component is 3000 *CCS* at 5% blocking, what is the offered load?

Solution

$$Offered load = \frac{3000}{(1-0.05)} \approx 3158 CCS$$

Overflow = (Offered load) – (Carried load) = 3158 – 3000 = 158 CCS

Example 2

In a wireless network each subscriber generates two calls per hour on the average and a typical call holding time is 120 seconds. What is the traffic intensity?

Solution

$$A_u = \lambda H = 2 \times \frac{120}{3600} = 0.0667 Erlangs = 2.4 CCS$$

Example 3

In order to determine voice traffic on a line, we collected the following data during a period of 90 minutes. Calculate the traffic intensity in *Erlangs* and *CCS*.

Traffic data used to estimate traffic intensity.

Call no.	Duration of call (s)
1	60
2	74
3	80
4	90
5	92
6	70
7	96
8	48
9	64
10	126

Solution

$$\lambda = \frac{10}{1.5} = 6.667 calls/hour$$

Average call holding time:

$$H = \frac{(60+74+80+90+92+70+96+48+64+126)}{10} = 80\ Sec/call$$

$$A_u = \lambda H = 6.667 \times \frac{80}{3600} = 0.148 Erlangs = 5.33 CCS$$

Example 4

We record data in the Table below by observing the activity of a single customer line during an eight-hour period from 9:00 A.M. to 5:00 P.M. Find the traffic intensity during the eight-hour period, and during busy hour (BH) which occurs between 4:00 P.M. and 5:00 P.M.

Call no.	Call started	Call ended	Call duration (min.)
1	9:15	9:18	3.0
2	9:31	9:41	10.0
3	10:17	10:24	7.0
4	10:24	10:34	10.0
5	10:37	10:42	5.0
6	10:55	11:00	5.0
7	12:01	12:02	1.0
8	2:09	2:14	5.0
9	3:15	3:30	15.0
10	4:01	4:35	34.0
11	4:38	4:43	5.0

Solution

$$\lambda = \frac{11}{8} = 1.375 calls/hour$$

Total call minutes = 3 + 10 + 7 + 10 + 5 + 5 + 1 + 5 + 15 + 34 + 5 = 100 minutes

The average holding time in hours per call is:

$$H = \frac{100}{11} \times \frac{1}{60} = 0.1515 hours/call$$

The traffic intensity is

$$A = \lambda H = 1.375 \times 0.1515 = 0.208 Erlangs = 7.5 CCS$$

The busy hour (BH) is between 4:00 P.M. and 5:00 P.M. Since there are only two calls between this period, we can write:

Call arrival rate = 2 calls/hour

The average call holding time during BH:

$$H = \frac{34+5}{2} = 19.5 \min/call = 0.325 hours/call$$

The traffic intensity during BH is

$$A = \lambda H = 2 \times 0.325 = 0.65 Erlangs = 23.4 CCS$$

Example 6

If the mean holding time in Example 5 is 100 seconds, find the average number of busy hour call attempts (BHCAs).

Solution

A_u = *0.0375 Erlangs = 135 call/sec*

$$\lambda_{BH} = \frac{A_u}{100} = 1.35$$

In a *C* channel trunked system, if the traffic is equally distributed among the channels, then the traffic intensity per channel, A_c, is given as

$$A_C = \frac{UA_U}{C}$$

When the offered traffic exceeds the maximum capacity of the system, the carried traffic becomes limited due to the limited capacity (i.e. limited number of channels).

- The maximum possible carried traffic is the total number of channels, *C*, in *Erlangs*.
- 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 **<u>no queuing</u>** 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