Telecommunication Networks
15B11EC611

LECTURE: 03

TRAFFIC ENGINEERING

TRAFFIC ENGINEERING (Teletraffic Engineering and Traffic Management)

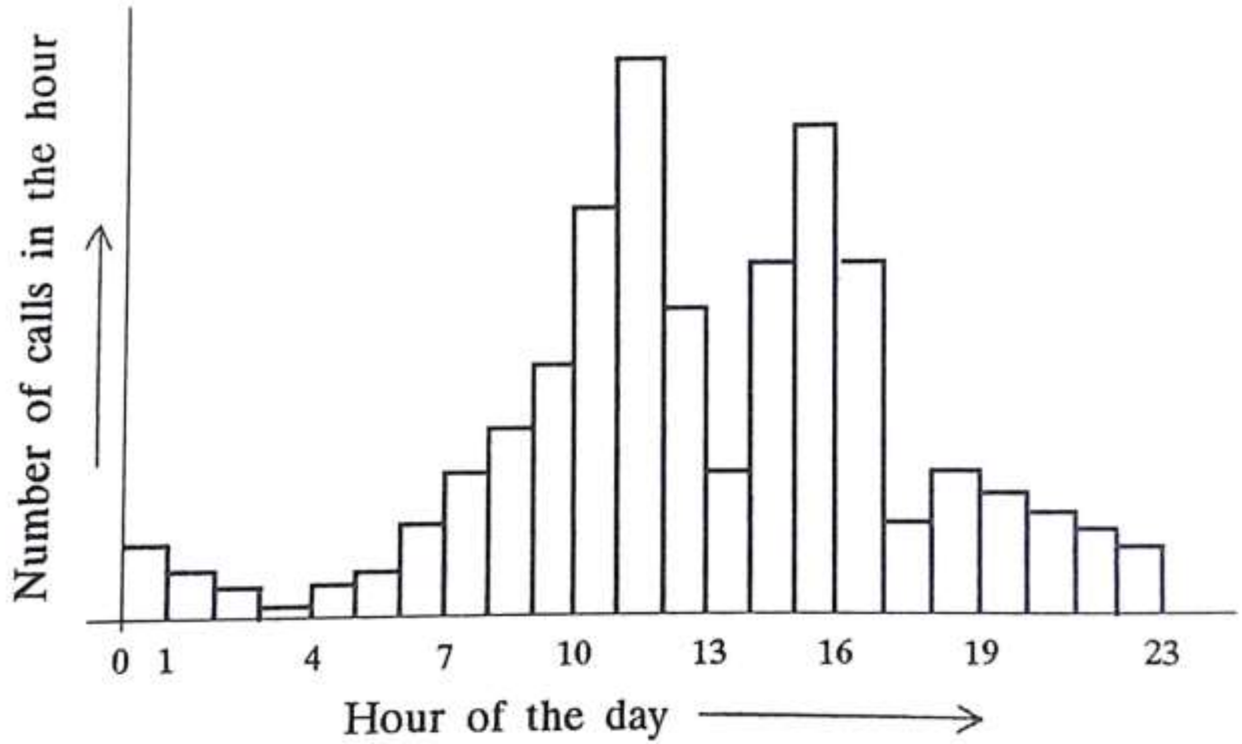
Introduction

- The theory of traffic engineering was originally conceived by A.K. Erlang, a Danish mathematician.
- It provides the basis for the analysis and design of telecommunication networks.
- The task of designing cost effective networks that provides the required quality of service under varied traffic conditions demands a formal scientific basis. Such a basis is provided by traffic engineering.
- Traffic engineering analysis enables one to determine the ability of a telecommunication network to carry a given traffic at a particular loss probability.

Network Traffic Load

- Figure shows the telephone traffic pattern on a working day

- There is little use of network during 0 and 6 hours, when most of the population is asleep

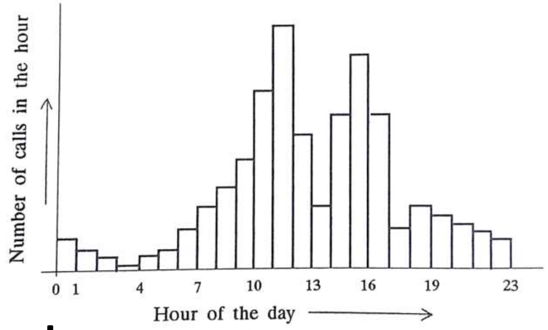


- Large peak around mid-forenoon and mid-afternoon denotes busy office activities

- Low load → Lunch-hour period i.e. 12-14 hours
  → period 17 – 18 hours; people are on the move from office to their residence

- During holidays and festival days, the traffic pattern is different from that shown in Figure

Network Traffic Parameters



Busy Hour (BH)

In a day, the 60-minute interval in which the traffic is the highest.

In Figure, hour 11-12 is BH

BH → vary from exchange to exchange depending on the location and community

BH variations → caused by Stock market activities, weather, natural disaster etc

→To take into account such fluctuations while designing switching networks → three types of BHs are defined by CCITT

1. **Busy Hour (BH):** 1-hour period for which the number of call attempts is greatest
2. **Peak Busy Hour:** The busy hour each day; it usually varies from day-to-day
3. **Time Consistent Busy Hour:** The 1-hour period starting at the same time each day

CCITT: Consultative Committee for International Telephony and Telegraphy

Network Traffic Parameters

- **Not all call attempts materialize into actual conversations for a variety of reasons:**
  - **Line busy**
  - **No answer from the called line**
  - **Blocking in the switching centers**

- ✓ **A call attempt is said to be successful or completed if the called party answers**

Call Completion Rate (CCR)

- **The ratio of the number of successful calls to the number of call attempts.**

- **CCR → should be greater than 0.70, if 0.75 – network is considered excellent**

Network Traffic Parameters

Busy Hour Call Attempts (BHCA)

- The number of call attempts in the busy hour is called BHCA.

Busy Hour Calling Rate (BHCR)

- The average number of calls originated by a subscriber during the busy hour
- Average busy hour calls = BHCA * CCR
- BHCR = (average busy hour calls) / (total number of subscribers)
- Useful in sizing the exchange to handle the peak traffic
- In rural area exchange, BHCR as low as 0.2
- In Business city/urban area exchange, BHCR as high as 3 or more

Network Traffic Parameters

Example 1: **An exchange serves 2000 subscribers. If the average BHCA is 10,000 and the CCR is 60%, calculate the BHCR**

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Solution:

Average busy hour calls = BHCA x CCR = 10000 x 60 / 100 = 6000 calls

BHCR = 6000 / 2000 = 3

Network Traffic Parameters

Day-to-busy hour traffic ratio

- The ratio of BHCR to the average calling rate for the day.
- Useful to know how much of the day's total traffic is carried during the BH
- For rural area → 6 – 7
- For urban area → 20 or more

❖ **The traffic load on a given network may be on**

- The local switching unit
- Inter-office trunk lines
- Other common subsystems (called servers)

Network Traffic Parameters

- The traffic on the network may be measured in terms of the occupancy of the servers in the network.
- Such a measure is called the TRAFFIC INTENSITY (A_0)

- Traffic Intensity (A_0) = {period for which a server is occupied} / {total period of observation (generally one hour)}

- A_0 = Dimensionless

- A_0 is called erlang (E) → to honour the Danish telephone engineer A. K. Erlang

- 1 erlang ➔ a server is said to have 1 erlang of traffic if it is occupied for the entire period of observation

Network Traffic Parameters

Example 2: In a group of 10 servers, each is occupied for 30 minutes in an observation interval of two hours. Calculate the traffic carried by the group.

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Solution:

Traffic carried per server = (occupied duration) / (total duration)
= 30 / 120 = 0.25 E

Total traffic carried by the group = 10 x 0.25 = 2.5 E

Network Traffic Parameters

Example 3: **A group of 20 servers carry a traffic of 10 erlangs. If the average duration of a call is three minutes, calculate the number of calls put through by a single server and the group in a one-hour period.**

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Solution:

Traffic per server = 10 / 20 = 0.5 E

i.e. a server is busy for 30 minutes in one hour

Number of calls put through by one server = 30 / 3 = 10 calls

Number of calls put through by the group = 10 x 20 = 200 calls

Network Traffic Parameters

Another way to measure the Traffic intensity in terms of CENTUM CALL SECOND (CCS)

Centum Call Second (CCS):

- **Represents a call-time product**
- **1 CCS = 1 call for 100 seconds or 100 calls for 1 second or any other combination**

- **CCS as a measure of traffic intensity is valid only in telephone circuits**
- **Erlang (E) is valid for all type of services (like voice, data, and other)**
- **Sometimes Call Seconds (CS) and Call Minutes (CM) are also used as a measure of traffic intensity**
- **Note → 1E = 36 CCS = 3600 CS = 60 CM**

Network Traffic Parameters

Example 4: **A subscriber makes three phone calls of 3 minutes, 4 minutes, and 2 minutes duration in a one-hour period. Calculate the subscriber traffic in erlangs, CCS, and CM.**

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Solution:

Subscriber traffic in erlangs = busy period / total period = (3+4+2)/60 = 0.15 E

Traffic in CCS = 0.15 x 36 = 5.4 CCS

Or Traffic in CCS = ((3+4+2) x 60) / 100 = 5.4 CCS

Traffic in CM = 0.15 x 60 = 90CM

Or Traffic in CM = 3 + 4 + 2 = 9 CM

Subscriber traffic refers to the traffic generated by subscribers who rent telephone lines, while trunk traffic refers to the traffic carried on trunk lines.

Explanation

- **Subscriber traffic**: The traffic generated by subscribers who rent telephone lines
- **Trunk traffic**: The traffic carried on trunk lines, which are telephone lines that connect two exchanges that are far apart
- **Trunk**: A communications line that carries multiple signals simultaneously to provide network access between two points
- **Trunking**: The arrangement of trunks and switches within a telephone exchange

Example

- In a telephone exchange, the number of trunks required is determined by the traffic to be handled.
- In a trunked radio system, each user is allocated a channel on a per call basis.

Network Traffic Parameters

As mentioned, traffic intensity is a call-time product

→ Hence Two important parameters that are required to estimate the traffic intensity or the network load are:

1. **Average call arrival rate, C**
2. **Average holding time per call, t_h** (the amount of time a customer spends waiting on hold with a customer service agent)

In order to calculate the hold time, you need to add the time spent by all callers waiting on hold and divide it by the total number of callers.

Hence, load network, $A = C\,t_h$

traffic intensity is a measure of the average occupancy of a server or resource during a specified period of time, normally a busy hour.

Network Traffic Parameters

Hence, load network, $A = C\, t_h$

Example 5: **Over a 20-minute observation interval, 40 subscribers initiate calls. Total duration of the calls is 4800 seconds. Calculate the load offered to the network by the subscribers and the average subscriber traffic.**

Network Traffic Parameters

Hence, load network, $A = C\, t_h$

Example 5: **Over a 20-minute observation interval, 40 subscribers initiate calls. Total duration of the calls is 4800 seconds. Calculate the load offered to the network by the subscribers and the average subscriber traffic.**

Solution:

Average arrival rate C = 40 / 20 = 2 calls/minute

Average holding time t_h = 4800 / (40 x 60) = 2 minutes/call

Therefore,

Offered load = 2 x 2 = 4 E

Average subscriber traffic = 4 / 40 = 0.1 E

Network Traffic Parameters

we have calculated the traffic in 2 ways:

1. **Traffic generated by the subscribers**
2. **Observation of busy servers in the network**

Traffic generated by the subscribers → may exceeds the network capacity → Hence

- **There are two ways to handle the overload traffic**

  a) **Overload traffic may be rejected without being serviced → calls are lost → Loss systems → Automatic telephone exchange (LOSS SYSTEMS)** eg. Circuit switched

  b) **Overload traffic may be held in queue → calls are delayed → Delay systems → operator-oriented manual exchange (DELAY SYSTEMS)** eg. Store & forward

Registers user request & establishes connection as soon as network facilities become available

	Loss system	Delay system
Performance parameters	Grade of Service (GOS) and Blocking probability (P_B)	Service delays
Traffic models used for studying	Blocking or congestion models	Queuing models

Grade of Service and Blocking Probability

Grade of Service (GOS)

- In loss systems, the traffic carried by the network is generally lower than the actual traffic offered to the network by the subscribers. The overload traffic is rejected.

- The amount of traffic rejected by the network is an index of the quality of service offered by the network. This is termed grade of service.

- GOS is defined as the ratio of lost traffic to offered traffic

- GOS = $(A-A_0) / A$, A = Offered traffic, A_0 = Carried traffic, $A-A_0$ = Lost traffic

Offered traffic = average no. of calls generated * average holding time per call
Carried traffic = average occupancy of servers in the network

- the value of GOS should be small for better service

- In India, GOS = 0.002 → 2 calls may be lost in every 1000 calls

Grade of Service, GoS

- Grade of Service is a measure of the probability that a percentage of the offered traffic will be blocked or delayed.
  - the ability to interconnect users
  - the rapidity with which that connection is made
- Commonly expressed as the fraction of calls or demand that
  - fails to receive immediate service (blocked calls)
  - is forced to wait longer than a given time (delayed calls)

For example, if GOS = 0.05, one call in 20 will be blocked during the busiest hour because of insufficient

Blocking probability (P_B):

- ✓ P_B defined as the probability that all the servers in a system are busy.

- ➢ In a system with equal number of servers and subscribers:
  - GOS = 0, as there is always a server available to a subscriber
  - $P_B \neq 0$, as all the servers are busy at a given instant

- ➢ The fundamental difference between GOS and PB:
  - GOS is a measure from the subscriber point of view, whereas
  - PB is a measure from the network or switching system point of view

GOS	P_B
Measure from the subscriber point of view	Measure from the network or switching system point of view
GOS is arrived at by observing the number of rejected subscribers calls	P_B is arrived at by observing the busy servers in the switching systems
GOS is called Call Congestion or Loss probability	P_B is called time congestion

Subscriber viewpoint: GOS = call congestion = loss probability

Network viewpoint: Blocking probability = time congestion

Example 6: A call processor in an exchange requires 240 millisecond to complete 1 process of the call (call processing time or call service time).What is the BHCA rating for the processor. If the exchange is capable of carrying 900E of traffic, what is the CCR? Also calculate the GOS of the system. Assume call holding time (total time complete a call-all the processes) is 2 minutes.

Call processing time (tp) = 1hr / Busy Hour Call Attempts (BHCA)

Busy Hour Calling Rate (BHCR) = Average BH calls / Total no. of subscribers = BHCA x CCR / N

CCR = No. of successful calls (carried traffic) / No. of call attempts (offered traffic)

Offered traffic (A) = Total calls (BHCA) x Call duration / observation time

Example 6: A call processor in an exchange requires 240 millisecond to complete 1 process of the call (call processing time or call service time).What is the BHCA rating for the processor. If the exchange is capable of carrying 900E of traffic, what is the CCR? Also calculate the GOS of the system. Assume call holding time (total time complete a call-all the processes) is 2 minutes.

Solution: BHCA = 1 hr / call processing time = 3600 s / 240 ms = 15,000

Given, Carried traffic = 900 E

Offered traffic = (BHCA X call duration) / observation time
= (15000 X 2) / 60 = 500 E

CCR = carried traffic / offered traffic = 900 / 500 = 1.8

But CCR > 100% not possible, so CCR = 1 Ans

GOS = (offered traffic – Carried traffic) / offered traffic = (500 – 900) / 500 = – 0.8

GOS ≠ -ve So GOS = 0 Ans