Advanced Topics in Communications II (ELCN 456)

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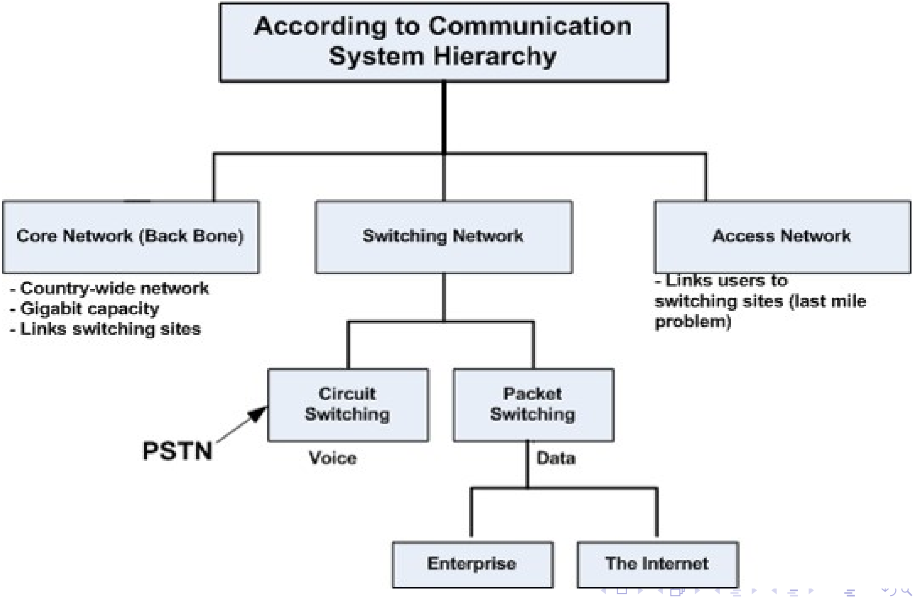
Credit Hours System

Introduction

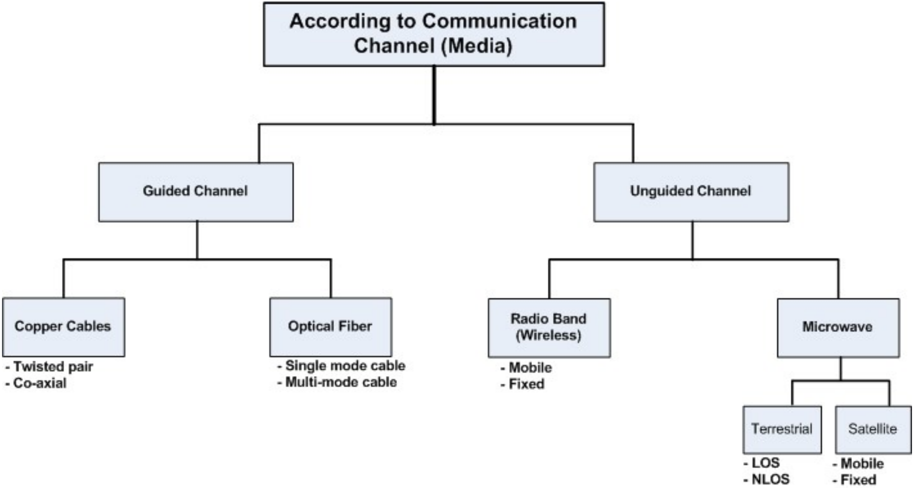
Telecommunication

- Telecommunication deals with the service of providing communications at a distance
- A large business with huge investments
  - Serves a large population with different needs
  - Relies on highly skilled technical personnel
- May be private or open to public access
  The latter are government-owned telephone companies, or private corporations, that sell their services publicly

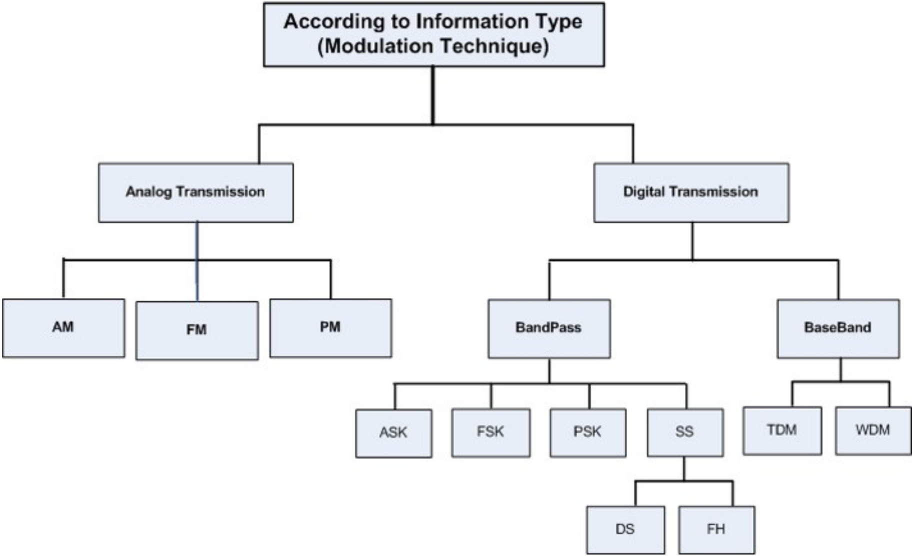
Telecommunication Systems: Classification



Telecommunication Systems: Classification

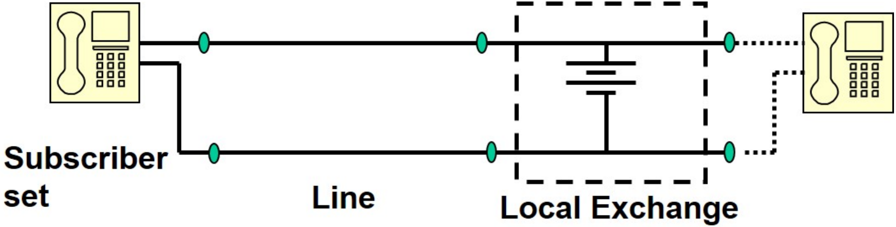


Telecommunication Systems: Classification



Basics of Telephony

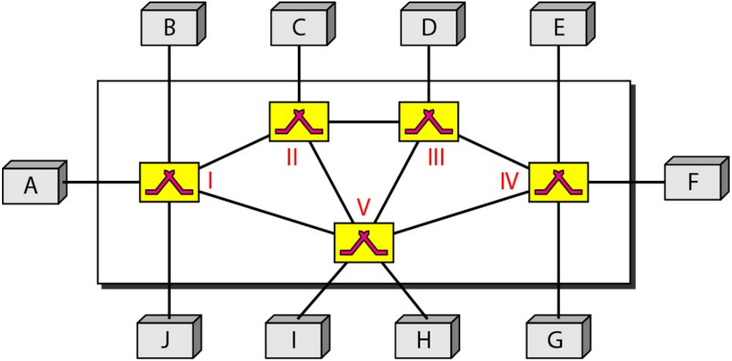
The Central Battery System



- An AC ringing voltage for the telephone bell.
- A DC power for the microphone.
- A signaling action for the call request (call end) as an off-hook or on-hook of the telephone handset.
- The pulsating DC current to signal dialing the number of the called subscriber.

Telecommunication Systems: Elements

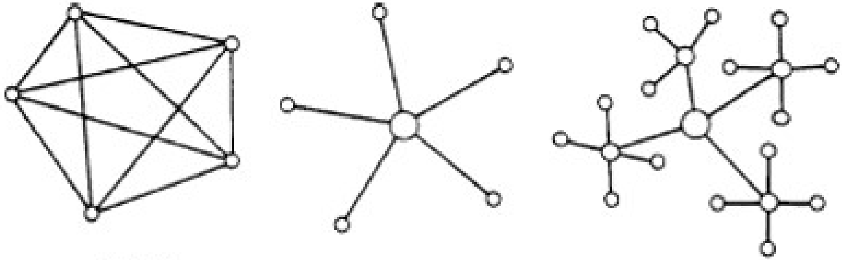
- End System
- Transmission System
- Switching System
- Signaling System



- Subscriber
- Call
- Trunk - Junction
- Subscriber lines - Lines - Local loops
- Concentration
- Local Exchange - Central Office
- Local Area - Toll Area - Long Distance
- A **network** is a grouping of interworking telephone exchanges

Telecommunication Networks: Configuration

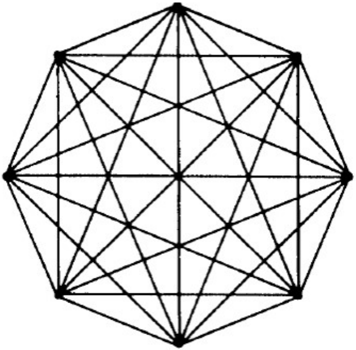
- A network in telecommunications may be defined as a method of connecting exchanges so that any one subscriber in the network can communicate with any other subscriber
- There is a number of different ways to interconnect switches



(A) Mesh (B) Star (C) Double star

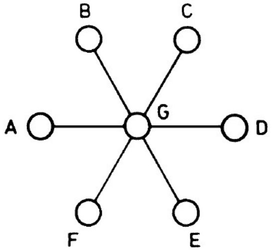
Configuration: Fully Connected Mesh

- Every switch (exchange) is connected to all other switches (or nodes)
- Very robust: a number of possible alternative routes
- Complexity increases with the increase of nodes
- Used when there are comparatively high traffic levels between exchanges



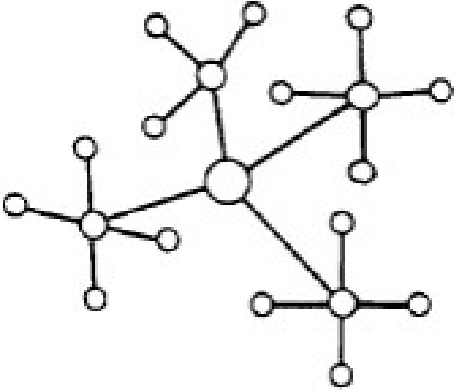
Configuration: Star

- Utilizes an intervening exchange, called a **tandem exchange**, such that each and every exchange is interconnected via a single tandem exchange
- Probably the least survivable but has least complexity
- One of the most economic connections
- May be applied when traffic levels between exchanges are comparatively low

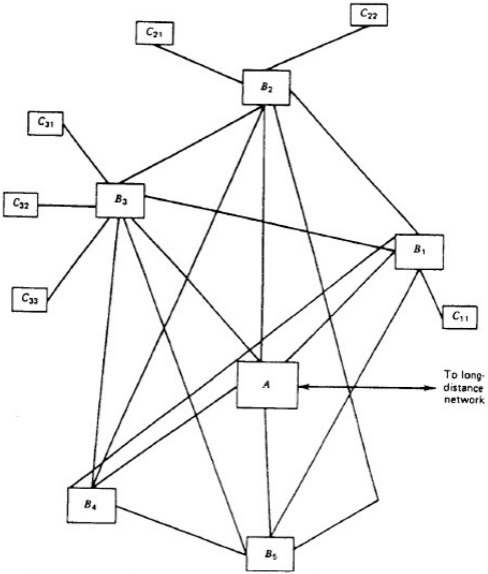


Configuration: Double Star

- Sets of pure star sub-networks are connected via higher-order tandem exchanges
- Used to decrease the complexity of mesh connections



Configuration: Mesh-Star Hybrid



Traffic Engineering

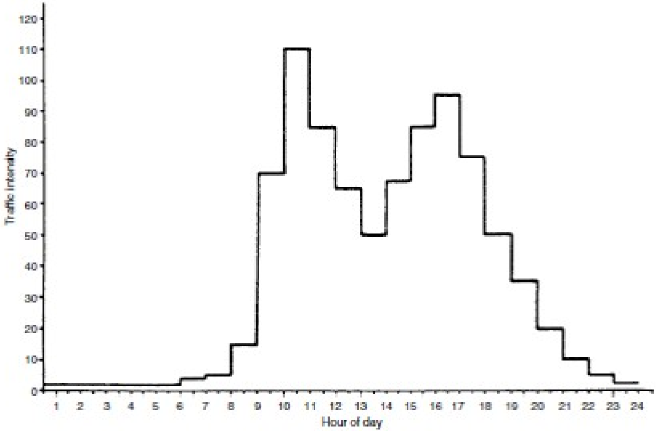
Traffic Engineering

- **Traffic** is a term that quantifies usage
- It is most important in telecommunication engineering to determine the number of trunks required on a route/connection between exchanges
- This is called **dimensioning** the route
- Dimensioning a route requires having some idea of its usage, i.e. how many people will wish to talk at once over the route

Traffic Engineering: Terminology

- **Usage** may be defined by two parameters
  - **Calling rate:** the number of times a route or traffic path is used per unit period (the call intensity per traffic path during the busy hour)
  - **Holding time:** the duration of occupancy of a traffic path by a call
- **Traffic path:** a channel, time slot, frequency band, line, trunk, switch, or circuit over which individual communications pass in sequence
- **Carried traffic:** the volume of traffic actually carried by a switch
- **Offered traffic:** the volume of traffic offered to a switch

- **Busy Hour (BH):** the continuously 60 - minute period during which the traffic volume or number of call attempts is highest



Traffic Engineering: Terminology

- **Traffic Density:** represents the number of simultaneous calls at a given moment
- **Traffic Intensity:** represents the average traffic density during a 1-h period. Used in the calculation for dimensioning of switches
- **Erlang:** The unit of measuring traffic intensity
  1 Erlang = a 60-minute call in one hour
- **Centrum-Call-Seconds (CCS):** the number of 100-call-seconds in a busy hour. It is a measure of the unit call (UC)
  1 Elrang = 36 CCS $\Rightarrow$ Call-minutes (Cm), Call-hours (Ch)
- **Time congestion:** the decimal fraction of an hour during which all trunks are busy simultaneously
- **Call congestion:** the number of calls that fail at first attempt (lost calls)

Traffic Measurement

- **Telephone traffic:** the aggregate of calls over a group of trunks with regard to the duration of calls as well as their number
- **Traffic measurements used for long-term** network planning are usually based on the traffic in the busy hour (BH)
  Usually based on observations/studies
- The traditional traffic measurements on trunks during a measurement interval are:
  - **Peg count:** calls offered
  - **Usage:** traffic carried (in CCS or Erlangs)
  - **Overflow:** call encountering all trunks busy
- **Traffic measurements for short-term** network management purposes are usually concerned with detecting network congestion.

Traffic Measurement

- **For short-term calculations;**
  - Calls carried, peg count, and overflow count can be used to calculate
    - attempts per circuit per hour (ACH)
    - connections per circuit per hour (CCH)
  - These measurements are calculated over very short time periods (e.g., 10-min intervals)
- The traffic flow, A, is expressed as:

$$A = C \times T$$

where,

C = number of calls originated during a period of one hour

T = the average holding time, given in hours

Call Blockage - Grade of Service

- The telephone system resources are designed on the basis of BH assumptions
- When the number of calls for which the system is designed are encountered, the system is assumed to handle them properly
- However, extra calls may be encountered during the BH that exceed the allocated resources
- A design tradeoff must be made in such a way that not too many calls will be blocked but at the same time this is done in an economical way

Call Blockage - Grade of Service

- Grade of service (GOS) expresses the probability of encountering blockage during the BH
- GOS = number of lost calls/Total no. of offered calls
  Therefore, GOS is the probability that a call offered to the group will find available trunks already occupied on first attempt
- This probability depends on a number of factors
  - the distribution in time and duration of offered traffic
  - the availability of trunks in a group to traffic sources (full or restricted availability)
  - the number of traffic sources [limited or high (infinite)]
  - the manner in which lost calls are handled

- Telephone-call originations in any particular area are random in nature Originating calls or call arrivals at an exchange were found to follow a **Poisson distribution**
  Poisson distribution is fundamental to traffic theory
  Most of the common probability-distribution curves are two-parameter (mean, variance) curves

$$\text{VMR} = \alpha = \frac{\sigma^2}{\mu}$$

$$\begin{aligned} \alpha &< 1 \Rightarrow \text{smooth traffic} \\ \alpha &> 1 \Rightarrow \text{rough traffic} \\ \alpha &= 1 \Rightarrow \text{random traffic} \end{aligned}$$

Availability

- It is convenient to describe switches in terms of inlets and outlets in traffic engineering
- When a switch has full availability, each inlet has access to each outlet
- With limited availability, not each free outlet can be reached by inlets

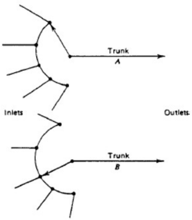


Figure 1.5A. An example of a switch with limited availability.

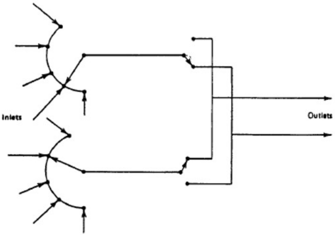


Figure 1.5B. An example of a switch with full availability.

Infinite and Finite Sources

- Traffic sources are assumed infinite or finite
- For infinite traffic sources
  - The probability of call arrival is constant, does not depend on the state of occupancy of the system
  - It also implies an infinite number of call arrivals, each with an infinitely small holding time
- Finite sources
  - The number of sources offering traffic to a group of trunks or circuits is $\lll$ the number of circuits
  - The arrival rate is proportional to the number of sources that are not already engaged in sending a call

Handling of Lost Calls

- **Lost calls cleared (LCC):** if an idle sever is not immediately available, a call is cleared from the system
- **Lost calls held (LCH):** if an idle sever is not immediately available, the call is held for an interval = the holding time
- **Lost calls delayed (LCD):** if an idle sever is not immediately available, the call is queued until an idle server is available

Traffic Characterization

Traffic Formulas

- Dimensioning a route means that we want to find the number of circuits that serve the route
- Several Formulas have been devised to determine that number of circuits based on the BH traffic load
- Factors that determine which formula to use are:
  - Call arrivals and holding time distribution
  - Number of traffic sources
  - Availability
  - The way of handling of lost calls

Traffic Formulas

Traffic Formula Selection Guide

Typical Applications	Number of Sources	Blocked-Call Disposition	Holding-Time Distribution	Traffic Formula
Final trunk groups in North American PSTN	Infinite	Held	Constant or exponential	Poisson
Trunk groups and other nondelayed server pools	Infinite	Cleared	Constant or exponential	Erlang B
Delayed server pools	Infinite	Delayed	Exponential	Erlang C
Small PBX or remote switch trunk groups	Finite	Held	Constant or exponential	Binomial
Small line concentrators	Finite	Cleared	Constant or exponential	Engset

Erlang B Formula

- Calculates the probability of blockage at the switch due to congestion or to all trunks busy (ATB)
- This formula assumes the following
  - Traffic originates from an infinite number of sources
  - Lost calls are cleared assuming zero holding time
  - The number of trunks or servicing channels is limited
  - Full availability exists (i.e. every source has equal access to every server)
- This is expressed as grade of service (GOS) or the probability of finding x channels busy

Erlang B Formula

- Erlang B formula is given as:

$$E_B(N) = \frac{\frac{A^N}{N!}}{\sum_0^N \frac{A^i}{i!}}$$

where,
E_B is the grade of service or the probability of finding N channels busy
$N =$ number of trunks or servicing channels
$A =$ mean offered traffic in Erlangs

Waiting Systems (Queuing) - Server-Pool Traffic

- Server-pools are groups of traffic resources, e.g. signaling registers, that are shared
- Service requests that cannot be served immediately are placed in a queue and served on a FIFO basis
- Server-pool traffic is directly related to offered traffic, server holding time and call-attempt factor
- It is inversely related to call-holding time

Waiting Systems (Queuing) - Server-Pool Traffic

- Server-pool traffic is calculated as:

$$A_s = \frac{(A_T \times T_s \times C)}{T_c}$$

where,
A_s = Server-pool traffic in Erlangs
A_T = Total traffic served in Erlangs
T_s = Mean server-holding time in hours
T_c = Mean call-holding time in hours
C = Call-attempt factor (dimensionless)

Waiting Systems (Queuing) - Server-Pool Traffic

- Total traffic served refers to the total offered traffic that requires the services of the specific server pool for some portion of the call
- The mean server holding time is the arithmetic average of all server holding times for the specific server pool:

$$T_s = aT_1 + bT_2 + cT_3 + \cdots$$

where,
$T_s =$ mean server-holding time in hours
$T_1, T_2, \cdots =$ Individual server-holding times in hours
$a, b, c, \cdots =$ Fraction of total traffic served $(a + b + \cdots = 1)$

Example

Determine the mean receiver-holding time for a central office (CO) where subscribers dial local calls using a 7-digit number and toll calls using an 11-digit number. Assume that 70 percent of the calls are local calls, the remainder are toll calls, and that the typical signaling register holding times of following table are applicable.

Dialed Digits	1	4	7	10	11
Local Receiver (sec)	2.3	5.2	8.1	11	12

$$T_s = (0.7)(8.1 \text{ sec}) + (0.3)(12.0 \text{ sec}) = 9.27 \text{ sec}$$

- Call-attempt factors are dimensionless numbers that adjust offered traffic intensity to compensate for call attempts that do not result in completed calls.
- Therefore, call-attempt factors are inversely proportional to the fraction of completed calls as follows:

$$C = \frac{1}{k}$$

where,
C = Call-attempt factor (dimensionless)
k = Fraction of calls completed (decimal fraction)

Waiting Systems (Queuing) - Server-Pool Traffic

Table 1-2 Typical Call-Attempt Dispositions

Call-Attempt Disposition	Percentage
Call was completed	70.7
Called subscriber did not answer	12.7
Called subscriber line was busy	10.1
Call abandoned without system response	2.6
Equipment blockage or failure	1.9
Customer dialing error	1.6
Called directory number changed or disconnected	0.4

Example

Determine the server-pool traffic in CCS and Erlangs for the telephone system of the previous example, assuming total offered busy-hour subscriber traffic of 2000 CCS, a call-attempt factor of 1.5, and a mean call-holding time of 3 minutes (180 seconds).

$$A_s = (2000 \text{ CCS})(1.5)(9.27 \text{ sec})/(180 \text{ sec}) = 154.5 \text{ CCS} = 4.29 \text{ Erlangs}$$

Alternate Routing

- If trunk groups were made so large
  - All offered traffic would be carried
  - The trunk group would not be economical
- Therefore, routing is used instead
- Only high-usage trunk groups are provided with alternate routes

Thank You

Questions?

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