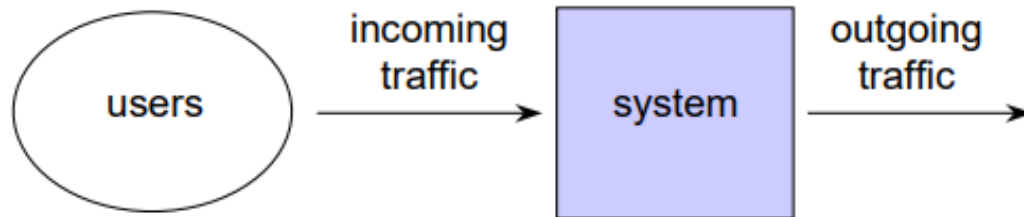# INTRODUCTION
Lecture 1

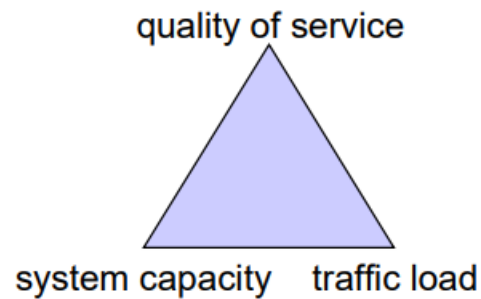Communication Theory III

Eng. (Mrs.) PN Karunanayake

Traffic Concept

Traffic Concept

- Given the system and incoming traffic, what is the **quality of service** experienced by the user?

- Given the incoming traffic and required quality of service, how should the **system be dimensioned**?

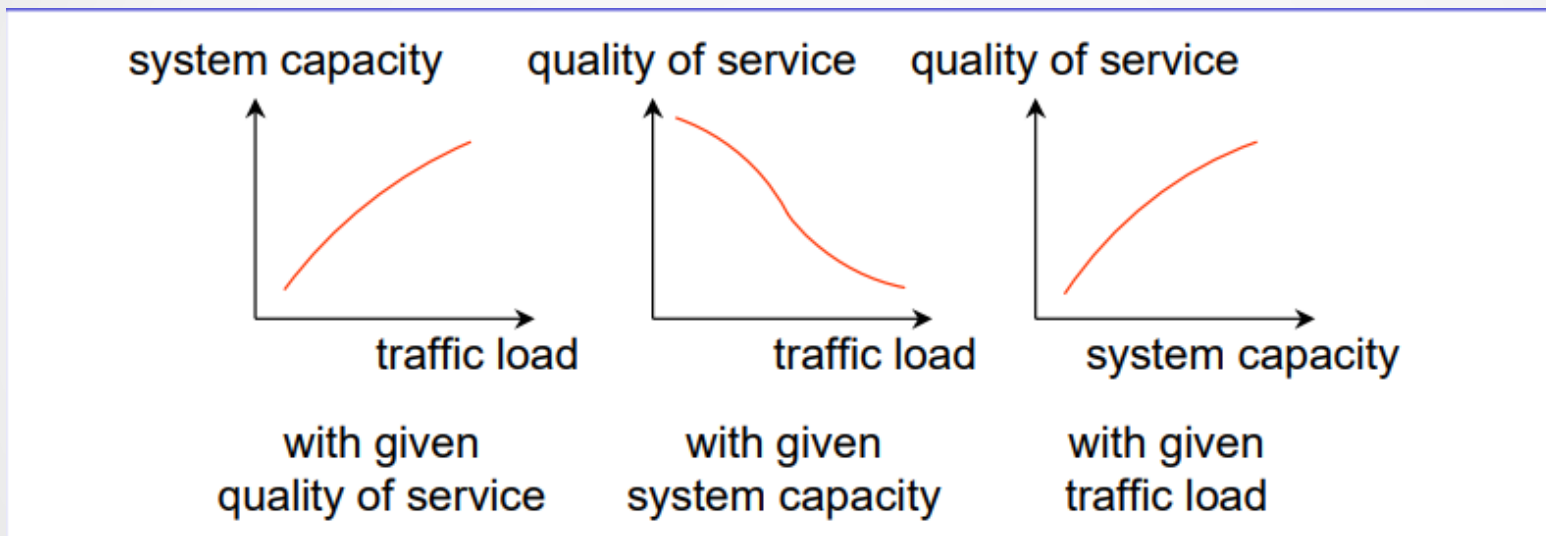- Given the system and required quality of service, what is the **maximum traffic load**?

Traffic Concept

A triangle with vertices labeled: **quality of service** (top), **system capacity** (bottom left), **traffic load** (bottom right)

- Telephone traffic

  – system = telephone network

  – traffic = telephone calls by everybody

  – quality of service = probability that the connection can be set up, i.e., "the line is not busy"

Relationships between the three factors

Teletraffic Models

Teletraffic models are **stochastic** (**probabilistic**)
– systems themselves are usually **deterministic** but traffic is typically **stochastic**

– "you never know, who calls you and when"

- It follows that the variables in these models are **random variables**, e.g.
  - number of ongoing calls
  - number of packets in a buffer

- Random variable is described by its **distribution**, e.g.
  - probability that there are n ongoing calls
  - probability that there are n packets in the buffer

- **Stochastic process** describes the temporal development of a random variable

Why We Learn TeleTraffic Theory

Network planning
- – dimensioning
- – optimization
- – performance analysis

Network management and control
- – efficient operating
- – fault recovery
- – traffic management
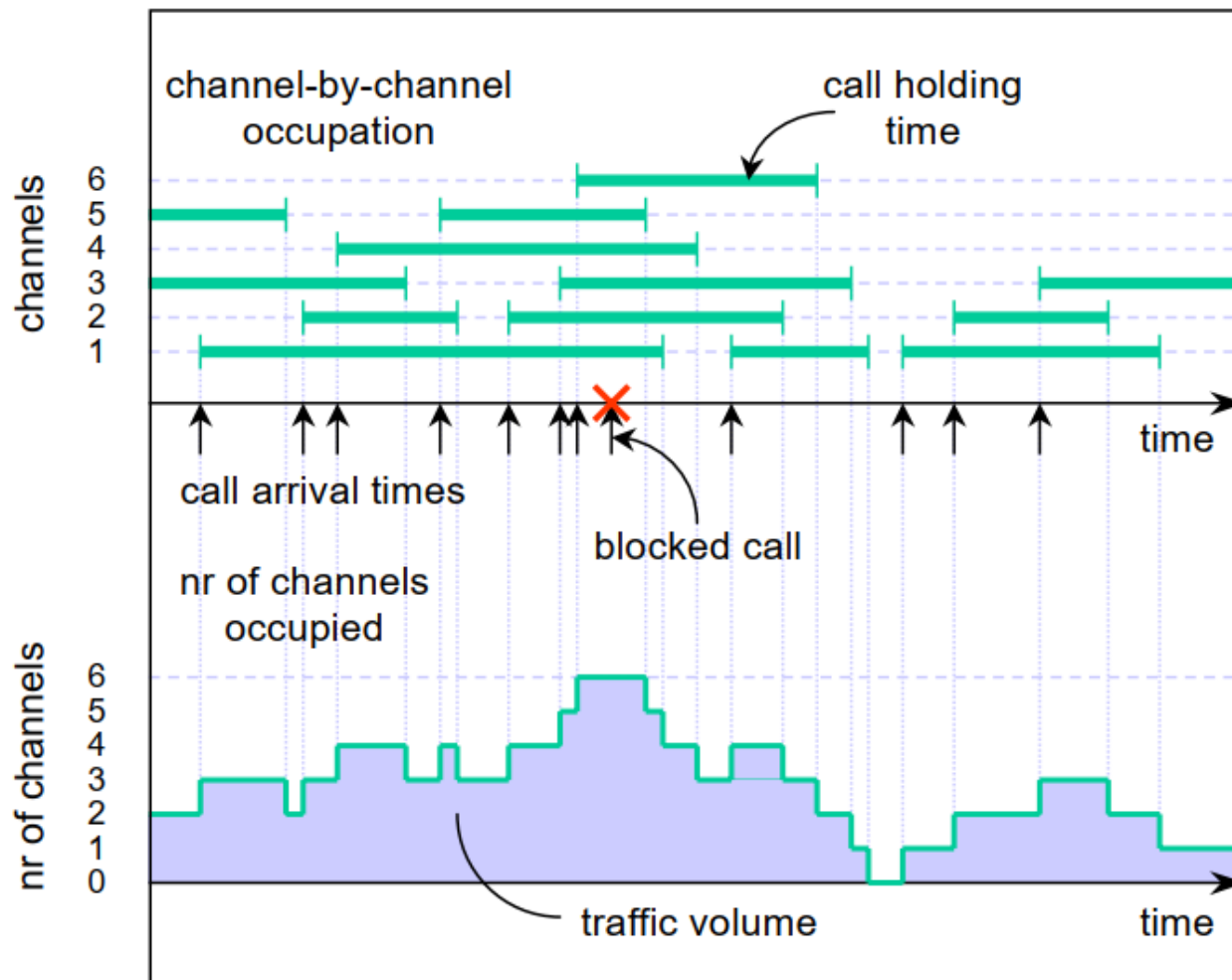- – routing
- – accounting

Traffic Concept

Earlang Concept

• The measurement unit is the erlang, denoted E, from the name of the distinguished Danish engineer **A.K. Erlang** (1878-1929) who established the first fundamental laws of traffic theory.

• *A set of identical resources is said to carry at a given instant, a traffic of N erlangs when N of its units are busy.*

Traffic Concept

If a network receives over a given period permanent demand of 1 call per second, with each call lasting for 3 seconds, the network will continuously have N=3 calls coexisting.

Traffic Concept

Traffic (Traffic intensity) in erlangs is denoted A, and if the number of busy resources is designated as n(t), this gives the following for a period of observation T

$$A = \frac{1}{T} \int_0^T n(t)dt$$

Assumes a sufficient number of resources to carry all the requests presented, and if we call **λ**, the mean number, constant, of requests per time unit and t , the **average occupation time (holding time)** of the resource by each request,

$$A = \lambda t_m$$

Example

Consider a local exchange. Assume that, on the average, there are 1800 new calls in an hour, and the mean holding time is 3 minutes.

1. Calculate the traffic intensity A.
2. If the mean holding time increases from 3 minutes to 10 minutes calculate the traffic intensity.

Blocking

In a loss system some calls are lost and the term **blocking** refers to this event. A call is lost if all n channels are occupied when the call arrives

• There are (at least) two different types of blocking quantities:

1. **Call blocking** B_c
Probability that an arriving call finds all n channels occupied = the fraction of calls that are lost

2. **Time blocking** B_t = probability that all n channels are occupied at an arbitrary time = the fraction of time that all n channels are occupied.

• The two blocking quantities are not necessarily equal
       – If calls arrive according to a Poisson process, then $B_c = B_t$

• Call blocking is a better measure for the quality of service experienced by the subscribers but, typically, time blocking is easier to calculate

Earlang Loss Formula

Let A be the traffic offered to N resources,

Probability of rejection (B) of another request, because of a lack of resources is given by the below equation.

$$E(N, A) = B = \frac{\dfrac{A^N}{N!}}{\displaystyle\sum_{j=0}^{N} \dfrac{A^j}{j!}}$$

Example

Assume that there are $n = 4$ channels on a link and the offered traffic is $a = 2.0$ Erlang. Then the call blocking probability Bc is,

$$B_c = \text{Erl}(4,2) = \frac{\frac{2^4}{4!}}{1 + 2 + \frac{2^2}{2!} + \frac{2^3}{3!} + \frac{2^4}{4!}} = \frac{\frac{16}{24}}{1 + 2 + \frac{4}{2} + \frac{8}{6} + \frac{16}{24}} = \frac{2}{21} \approx 9.5\%$$
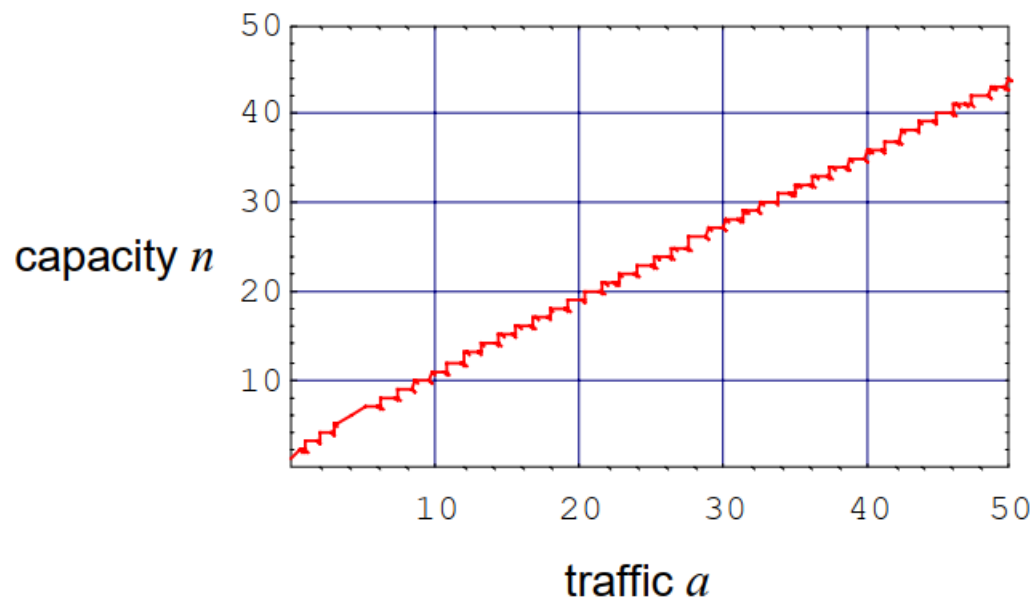
Example

If the link capacity is raised to $n = 6$ channels, calculate the blocking probability.

$$B_c = \text{Erl}(6,2) = \frac{\dfrac{2^6}{6!}}{1 + 2 + \dfrac{2^2}{2!} + \dfrac{2^3}{3!} + \dfrac{2^4}{4!} + \dfrac{2^5}{5!} + \dfrac{2^6}{6!}} \approx 1.2\%$$

Required Capacity vs. Traffic

Given the quality of service requirement that $Bc < 20\%$, required capacity n depends on traffic intensity a as follows:

$$n(a) = \min\{N = 1,2,\ldots \mid \mathrm{Erl}(N,a) < 0.2\}$$

Carried Traffic

The handled traffic by the system considering the traffic offered to it.

$$A_h = A(1-B)$$

Traffic offered & Traffic handled

- traffic offered

- traffic handled (carried)

- Overload

- random nature of traffic offered

- optimise resources

- Call Duration

- *Traffic handled will therefore generally be different from the traffic offered. The rules governing the relationship between these two values form the subject of **quality of service standards**.*
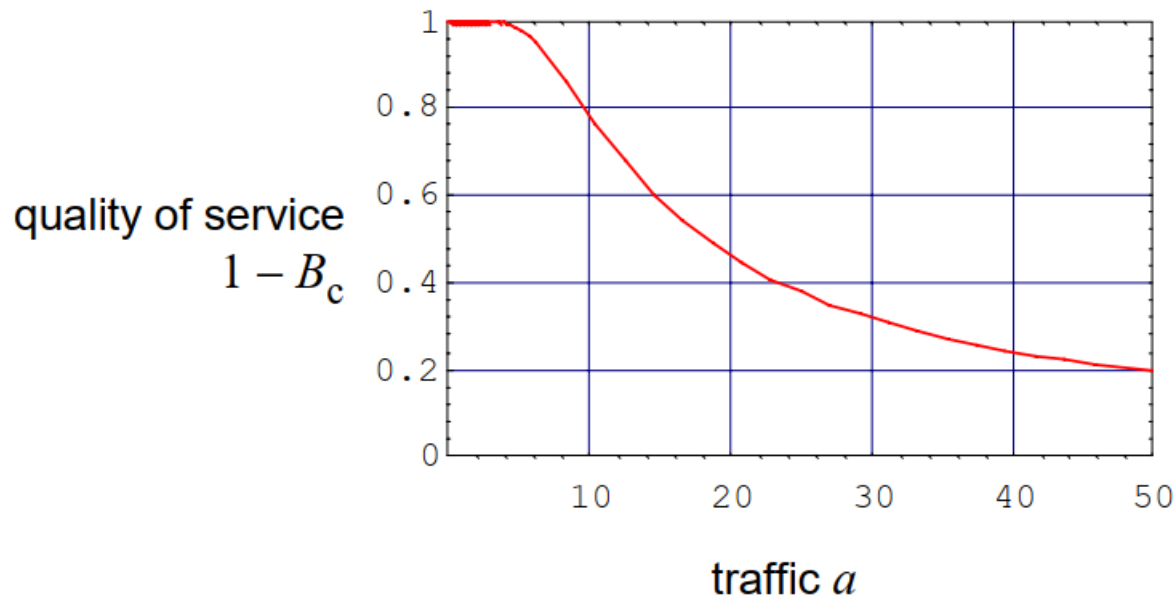
Quality of service

The criteria used to determine rejection rates, or allowable response times, which are generally specified in international standards, are the bases of the concept of quality of service (QoS).

Required Quality of Service vs. Traffic

Given the capacity $n = 10$ channels, required quality of service $1 - Bc$ depends on traffic intensity a as follows:
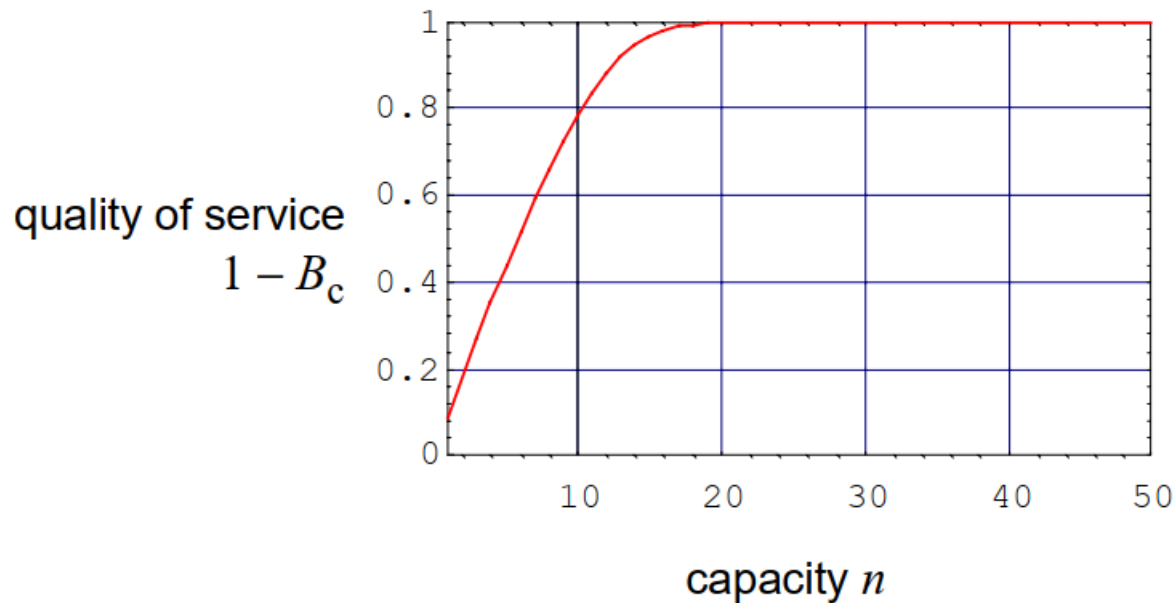
$$1 - B_c(a) = 1 - \text{Erl}(10, a)$$

Required Quality of Service vs. Capacity

Given the traffic intensity $a = 10.0$ erlang, required quality of service $1 - B_c$ depends on capacity n as follows:

$$1 - B_c(n) = 1 - \mathrm{Erl}(n, 10.0)$$

Load profiles

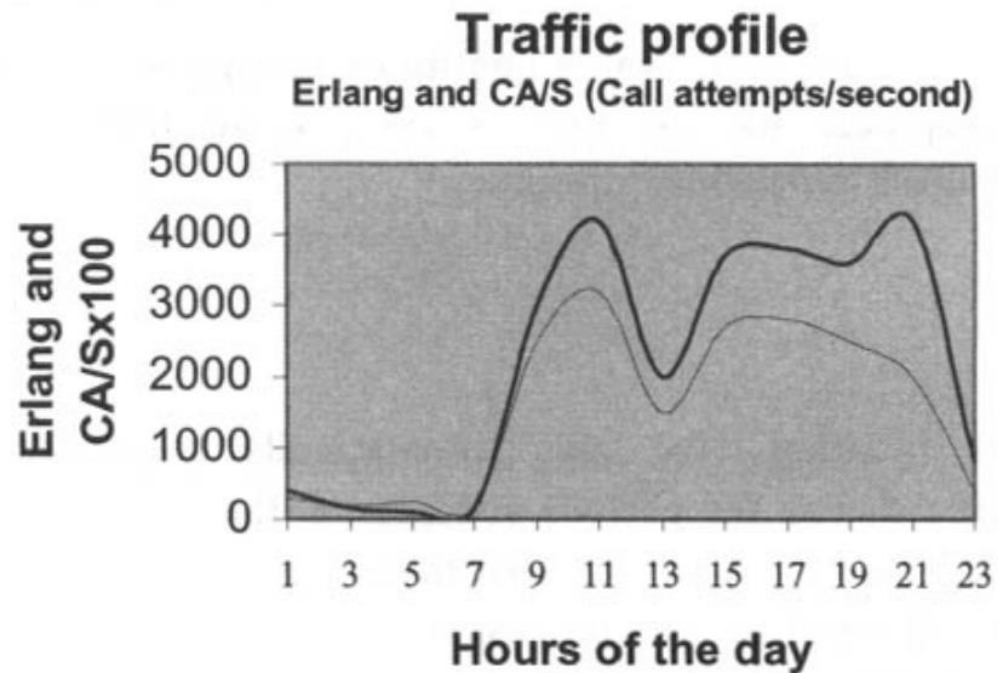●During a particular day demand may disappear at certain times and then reappear, with different load levels.

●For example

●- With morning traffic, the low intensity hours at midday and then afternoon and evening traffic.

●- Internet traffic of professional users during the daytime, and of residential users in the evening.

●The concepts here are **peak hours** and **low intensity hours**, which periods may not necessarily be the same for different networks and even for different parts of the same network.

Load Profile Example

Traffic profile
Erlang and CA/S (Call attempts/second)

Stationarity

●To size and evaluate the quality of service, that there is a certain stability in the characteristics of the demand arrival processes over given periods of time.

The concept of Busy Hour Call Attempts (BHCA)

- Number of requests per time unit.

- In telephony the unit is the number of busy hour call attempts (BHCA). A call attempt (CA) is an attempt to set up a call which may be successful or not.

- **Traffic intensity in erlangs and BHCA load**

$$N_{BHCA} = \frac{A_{Erlang}}{\tau_{sec\,onds}} 3600$$

Where τ is the mean duration of the request in seconds.

User Plane and the Control Plane

●The user plane consists of resources carrying "useful" information at user level (voice, image, data, files, etc.).

●User plane will be primarily concerned with load in erlangs (erlangs of calls, of kbit/s, etc.) and the associated resources will be mainly at the transport level.

●The control plane will consist of resources in charge of setting up calls, signalling exchanges, observations, network management and network operation.

●Control plane will be mainly concerned with BHCA demand (calls, transactions, etc.) and the associated resources will mainly be handling processors and signalling links.

Characterisation of traffic

● Why we need a Characterisation of traffic?

    - To identify the resources necessary for satisfactory traffic flow.

● The traffic characteristic is defined in terms of **services** (call types, bit rate characteristics), **use** (penetration of subscribers) and flow distribution over the different branches of the network.
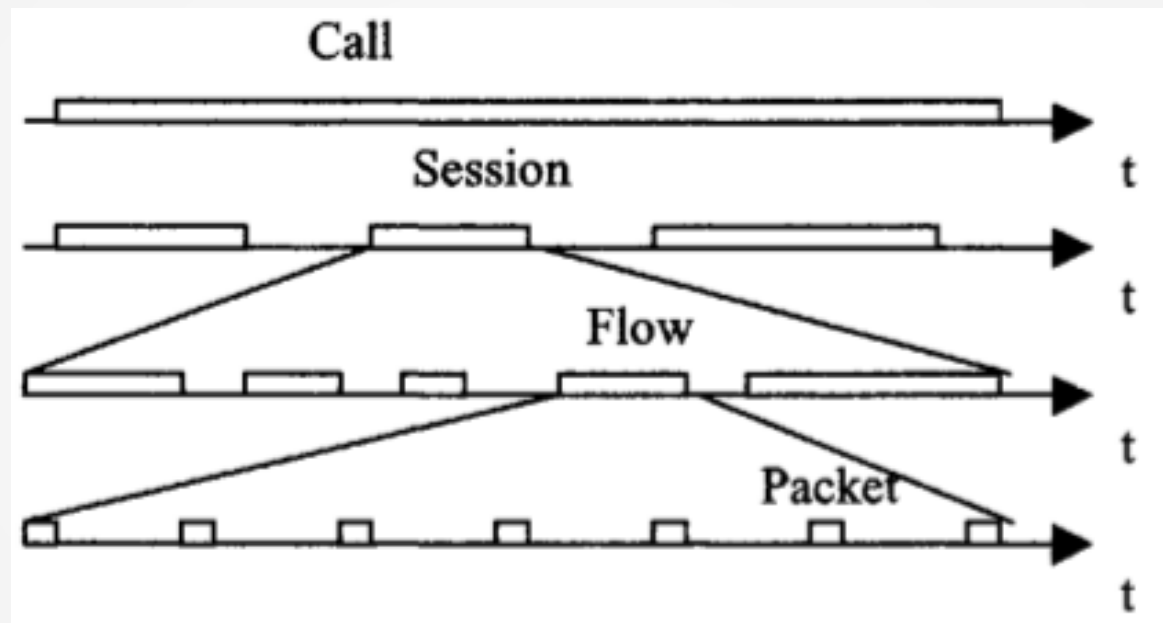
Characterisation of services

- Traditional circuit networks, the characterisation of a service:

  - Call arrival law (usually Poisson)

  - A call duration (exponential law with a mean value in the order of a few minutes)

  - A constant bit rate (e.g. 64 kbit/s)

- Resources used: in this case, as many 64 kbit/s channels

Characterisation of services

● The voice service in a packet network:

● packet flows of fixed length

● Variable bit rate (with an inter-arrival time that is to be defined)

● Constant bit rate.

The flows of a given service observed at different levels

Traffic mix

- Defines different user categories with different user profiles which leads to penetration rate and the service utilisation rate.

- - Professional users

- - Residential users

- - Small and Large business users

- Ex.: Telephone calls on fixed or mobile network, VoIP session, video, web, on the packet network, etc.

Traffic mix

●Based on the penetration rate and utilisation rate of each services, it is possible to determine the traffic mix of an average user.

●For an example, an average user may have a traffic of 0.1 E in mobile telephony, 0.1 E in telephony on IP, and 0.2 E of web browsing.

Network level traffic matrix

● In a network, the nodes are connected by links.

● The capacity of the links are decided by the amount of traffic handled by the links.

From \ To	A	B	..	i	j	Total outgoing
A	x_{AA}	x_{AB}	..	..	..	O_A
B	x_{BA}	x_{BB}	..	..	..	O_B
..	..	..	..	..	..	..
i	..	..	..	x_{ii}	x_{ij}	O_i
j	..	..	..	x_{ji}	x_{jj}	O_j
Total incoming	I_A	I_B	..	I_i	I_j	T

Thank You!