ITU / BDT- COE workshop

Nairobi, Kenya,

7 – 11 October 2002

Network Planning

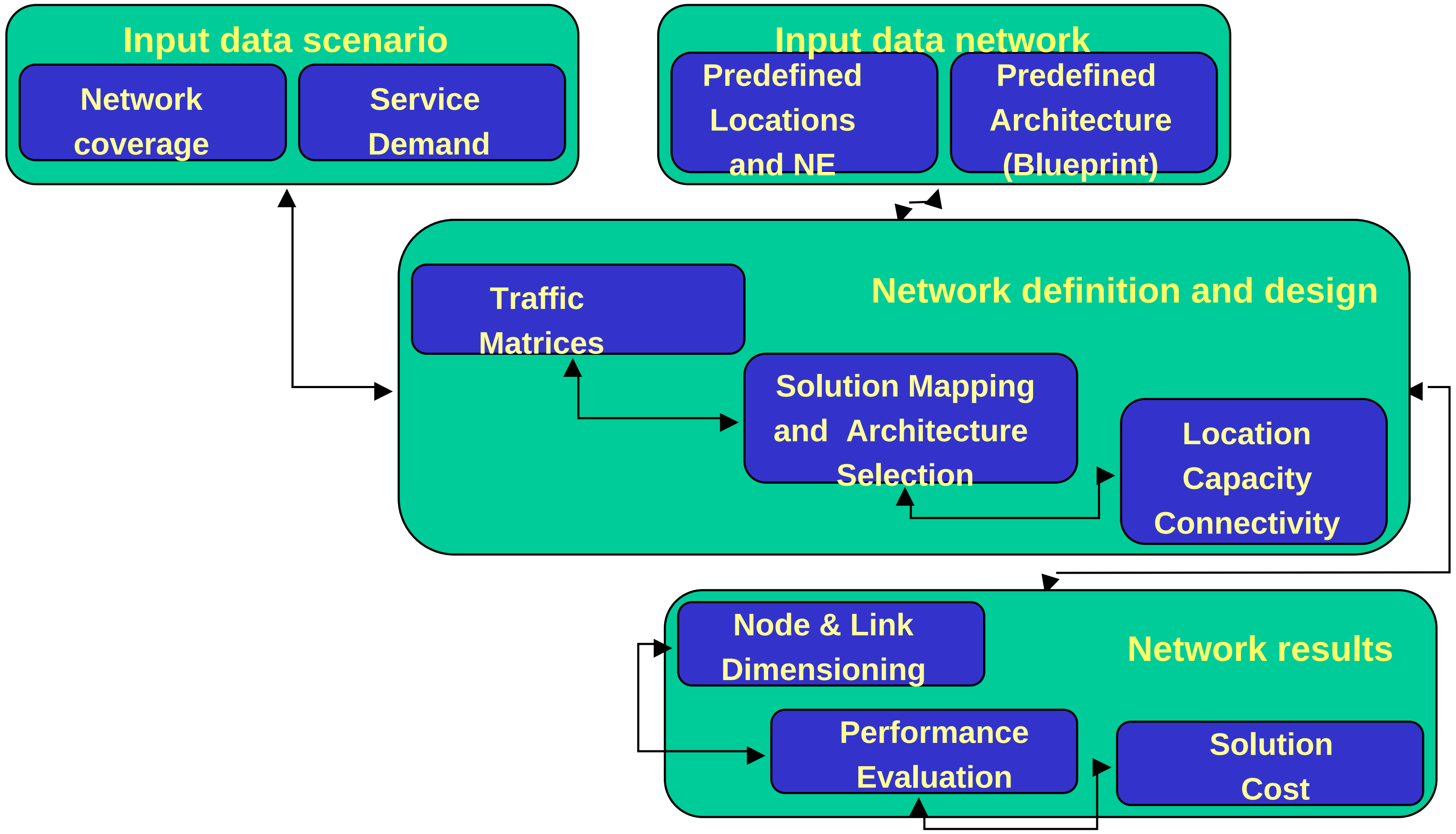
Lecture NP- 3.3

Network Design and Dimensioning

Content Chapter 3.3

- Design process and criteria
- Traffic characterization
- Capacity modeling and dimensioning
- Efficiency increase

Network Design and Dimensioning
The Network Design Process



Network Design and Dimensioning: The Network Design Criteria

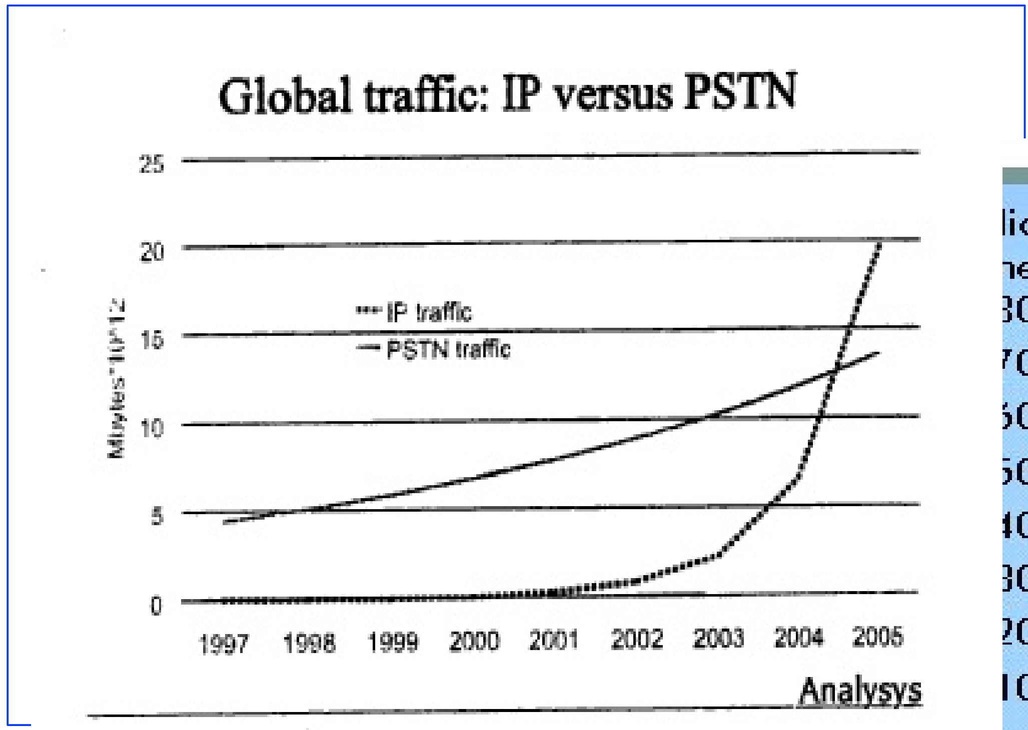
- A) Match realistic service demands and workloads for a given time
  - Node and links loads based on proper **characterization**, measurements and projections
- B) Consider equilibrium between QoS and cost
  - **Statistical behavior** for the flows
  - Traffic modeling for given **quality, efficiency and protection**
  - **Overload** protection and control
- C) Anticipate capacity as a function of service grow rate and needed installation time. **Reserve capacity**
- D) Follow **SLA** when different service classes coexist

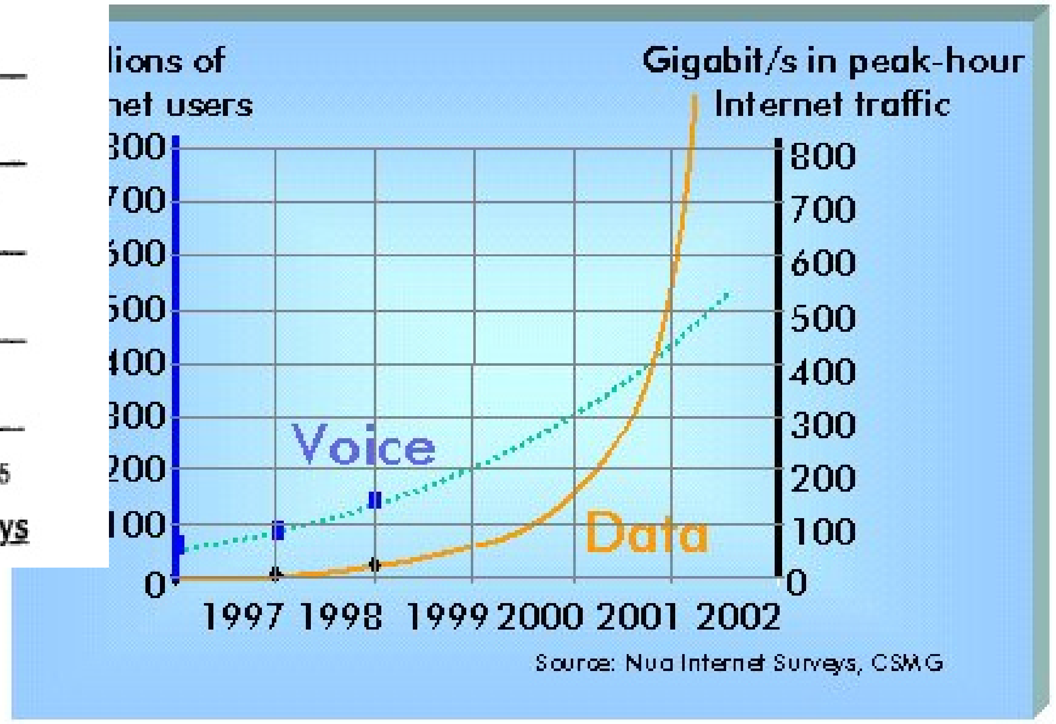
Network Design and Dimensioning:
The 5 basic Traffic activities

- Traffic **Characterization** for services and network flows
- Traffic **Demand** forecasting at the user and Network interfaces
- Traffic **Dimensioning** for all network elements
- Traffic **Measurements** and Validation for key parameters
- Traffic **Management** in focussed and generalized overload

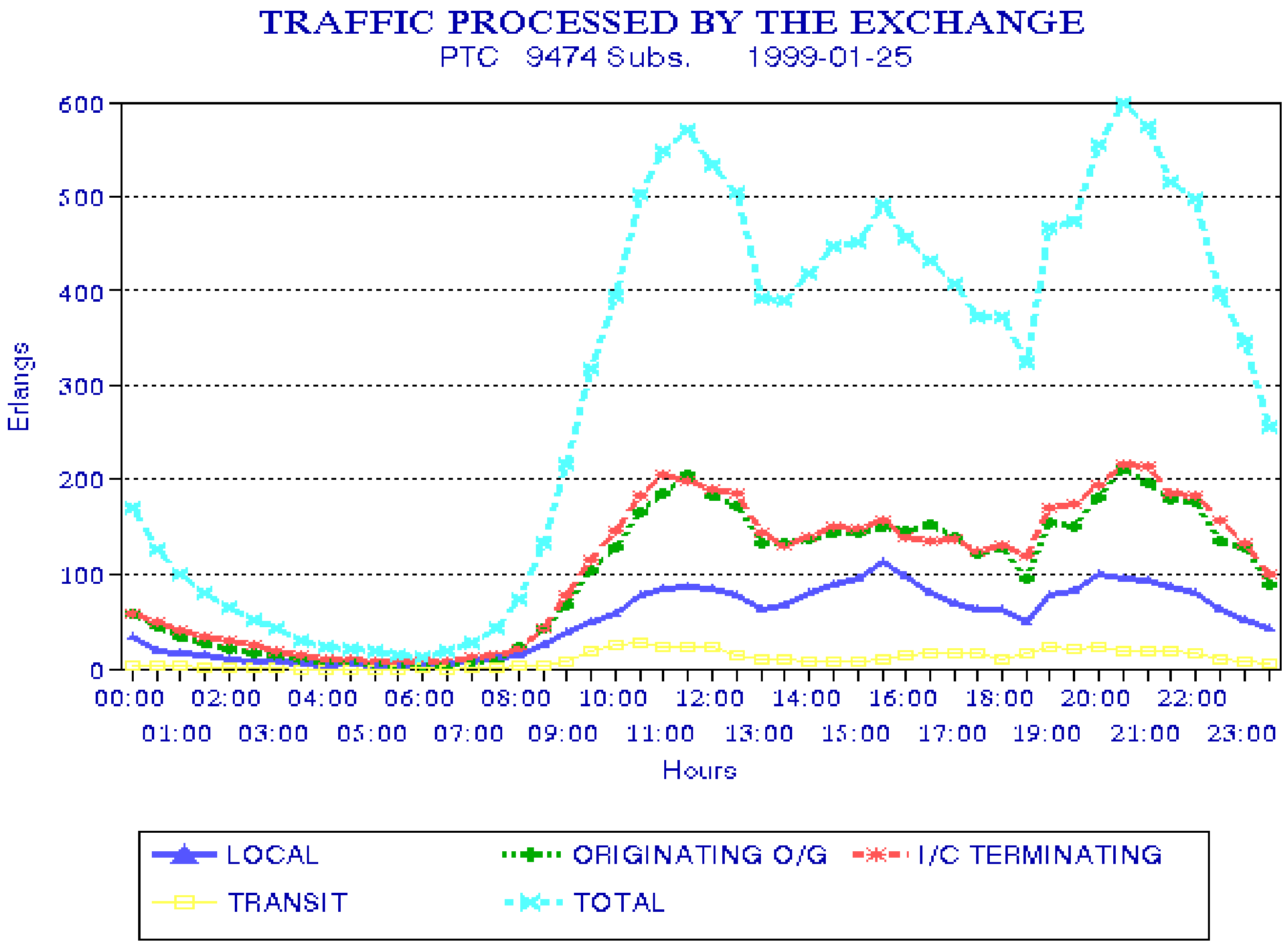
Network Design and Dimensioning: Service and Traffic Demand

- Some examples of published forecasts…. Good enough ??





Network Design and Dimensioning: Traffic Characterization



Network Design and Dimensioning: Traffic Forecasting

Service demand Characterization

- By a profile through days in a year/week
- By a busy period within a day
- By superposition of non-coincidence of busy periods (for inter-country traffic in different time zone)
- By aggregation or convolution of flows for different services
- By interest factors between areas (adjusting matrices in the two dimensions ie: Kruithof, affinity, correlation)

Network Design and Dimensioning:
Traffic Characterization

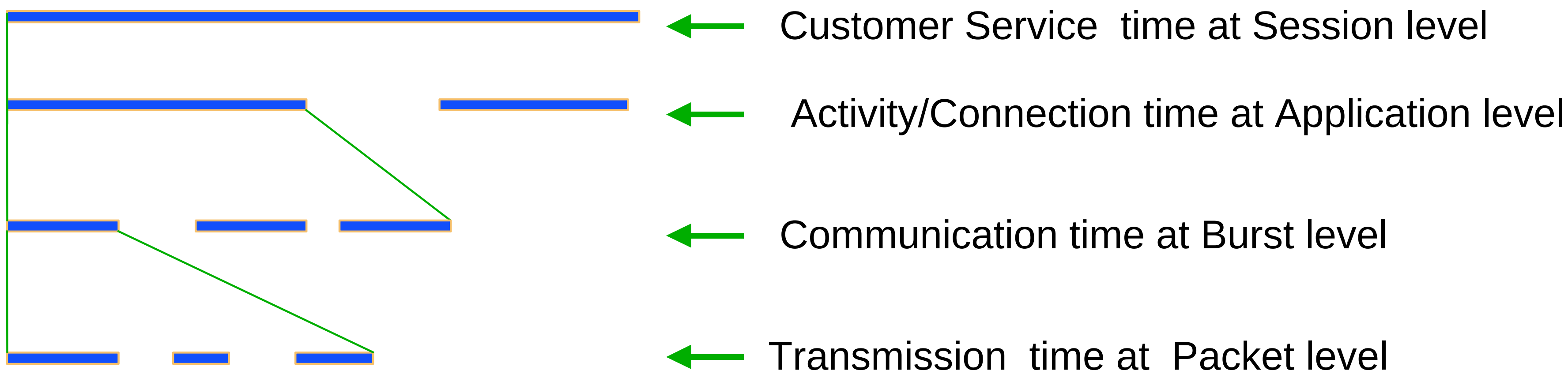
- Traffic Units definition
  - At call, session and packet level
  - Needed additional clarification on the different type of averages and meaning (CBR,SBR, Billed)

- Reference periods
  - Should be common when aggregating services to ensure validity and represent behavior of IP flows
- Statistical laws
  - For calls, sessions and packets

- Aggregation process
  - Considering reference period above and coincidence/non-coincidence of busy periods among services

Network Design and Dimensioning: Traffic network engineering Bottom-up SBR aggregation

- Generalized utilization time and levels per user activity in the busy period : Example for IP



- Aggregated average traffic per level as a weighted average of the services i and customer classes j at that level.

Network Design and Dimensioning: Traffic Architectures to be modeled

To simplify analysis, the following partition is made:

- L1) Global Network Level
  - Overall topological network (access and/or core) including routing procedures and all alternative paths.
- L2) End to End Path or sub-path
  - For different user type scenarios: VoIP to VoIP, VoIP to POTS, etc. and network segments: user to LEX, user to GW, etc.
- L3) Network Elements
  - For Network Nodes
    - LEX, RSU,POP,GW, SS, TGW,IP router, etc.
  - Network Links
    - At functional, transmission and physical levels

Network Design and Dimensioning: Basic methods

- Analytical
  - Loss based ➡ Memoryless ie: Circuit switching, Optical
  - Delay based ➡ "Infinite" memory ie: Computers, Packet
  - Hybrid ➡ Limited memory and/or customer timed-out
- Simulation
  - Discrete events ➡ Call by call, packet by packet, etc
  - Analog ➡ Load flow
- Frequent statistical distributions
  - Poisson, Negative exponential, Lognormal, Hyperexponential, Self-similar, Generalized

Network Design and Dimensioning: Basic methods

- Mathematical processes for the modeling

  - Markov processes ➡ New events function of last system state (easy to be treated)

  - Semi-Markov processess ➡ New events function of oldest states but history resumed with new variables at last state

  - Non-Markovian ➡ New events strongly dependent on all previous states (high complexity for modeling)

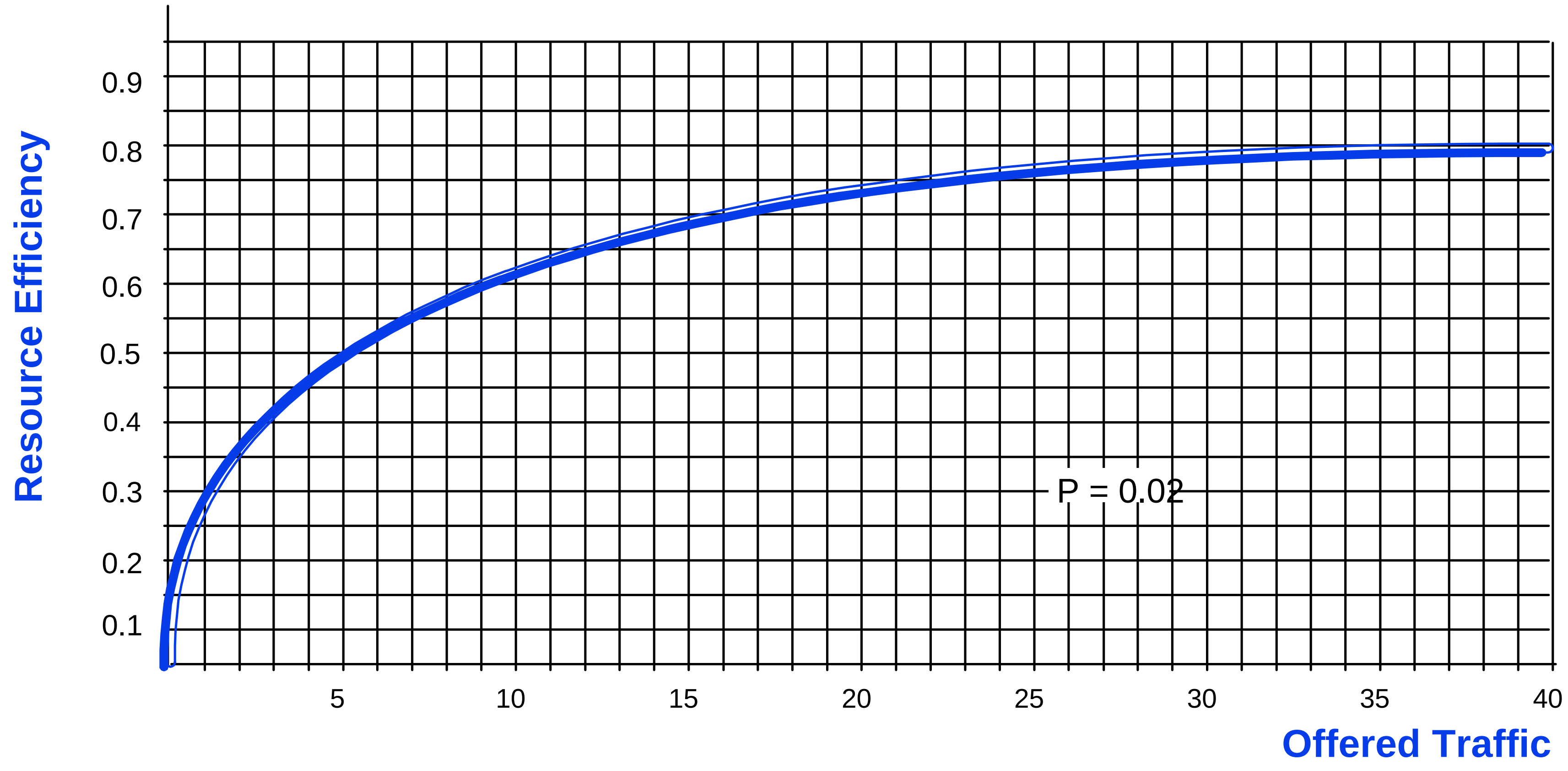
Network Design and Dimensioning: Basic methods

- Most common models

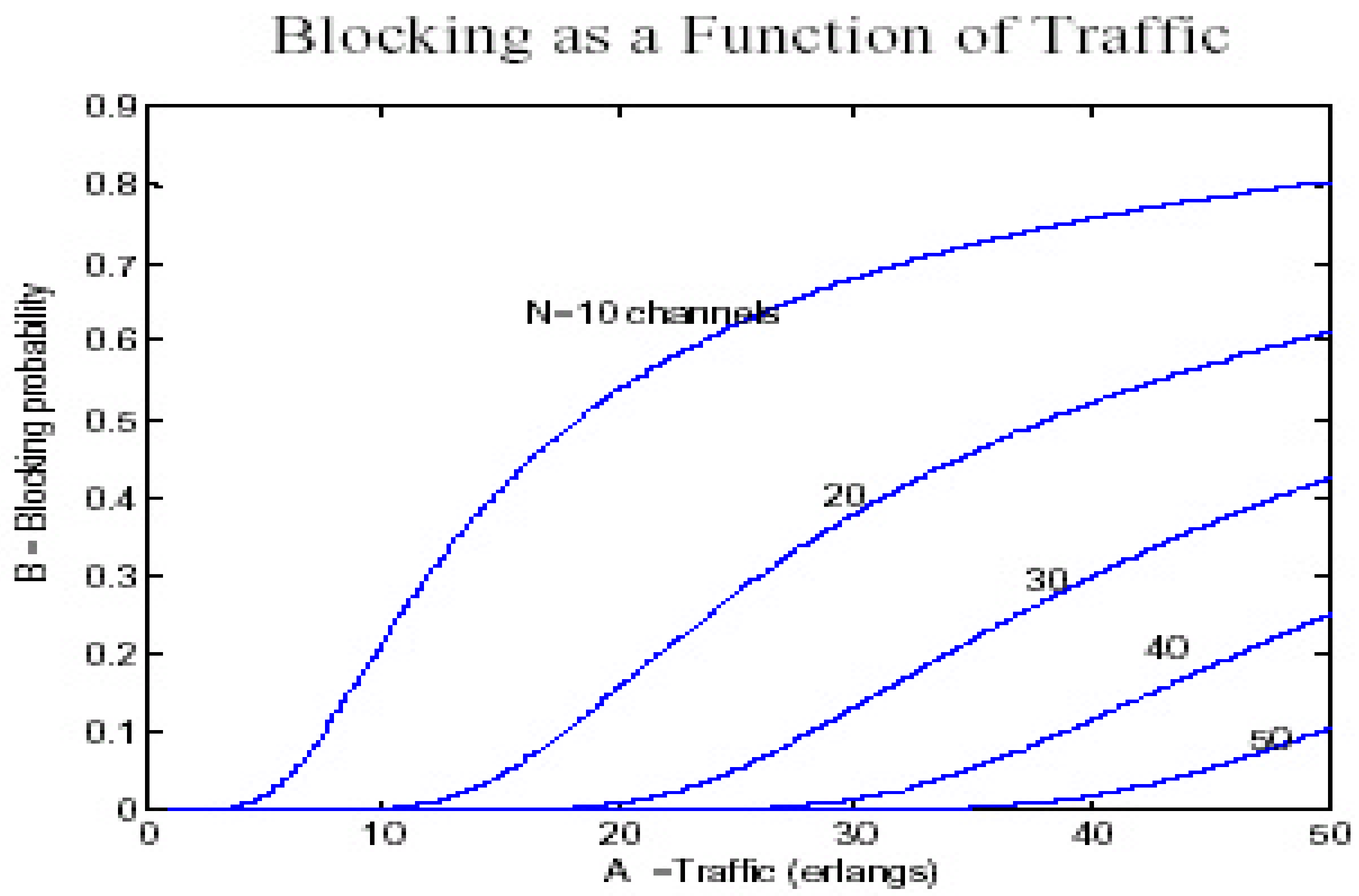
  - M/M/1/∞ ➡ Poisson arrival/negative exponential service time/one server/infinite traffic sources
  - M/D/1 ➡ Poisson arrival/constant service time/one server/infinite sources
  - M/M/n/m ➡ Poisson arrival/negative exponential service time/n servers/m sources
  - M/G/n/∞ ➡ Poisson arrival/generalized service law/n servers/infinite sources

Network Design and Dimensioning:

Impact on efficiency increase for a given quality with traffic and group size (non-linear effect)

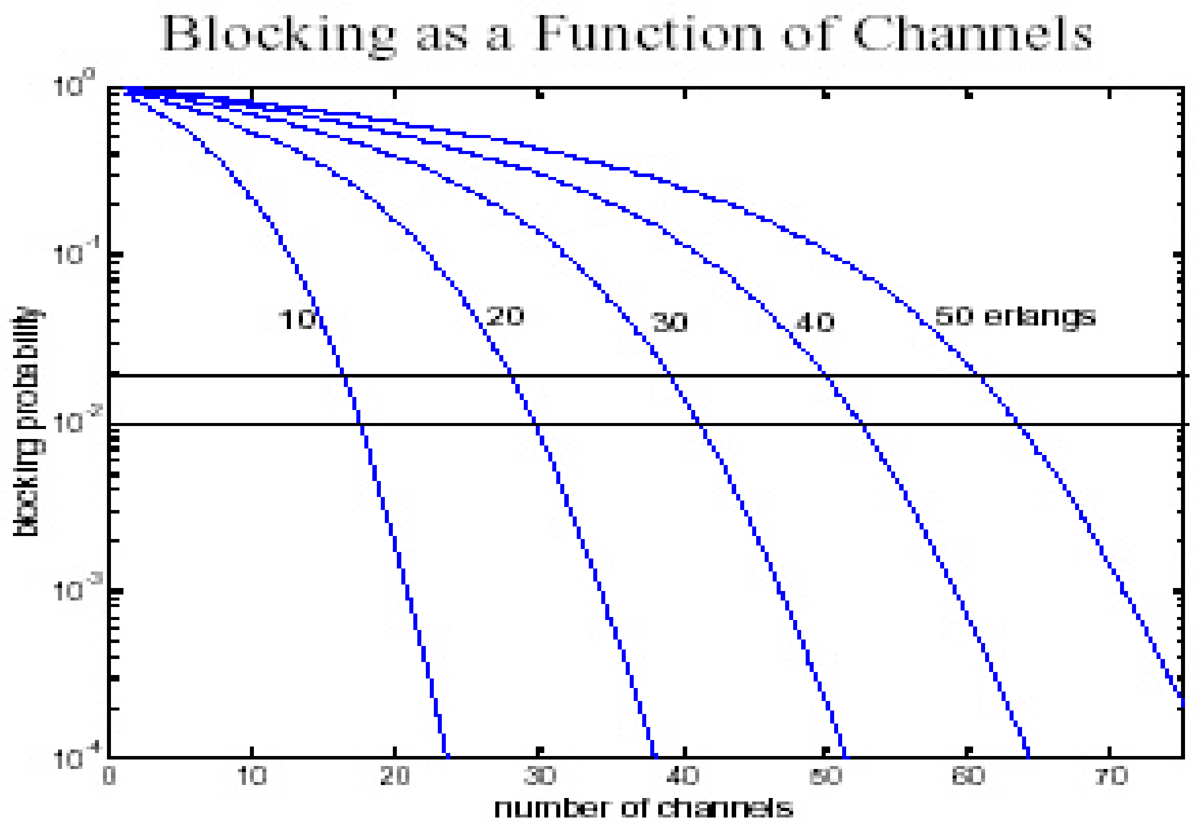


Network Design and Dimensioning: Typical dimensioning curves

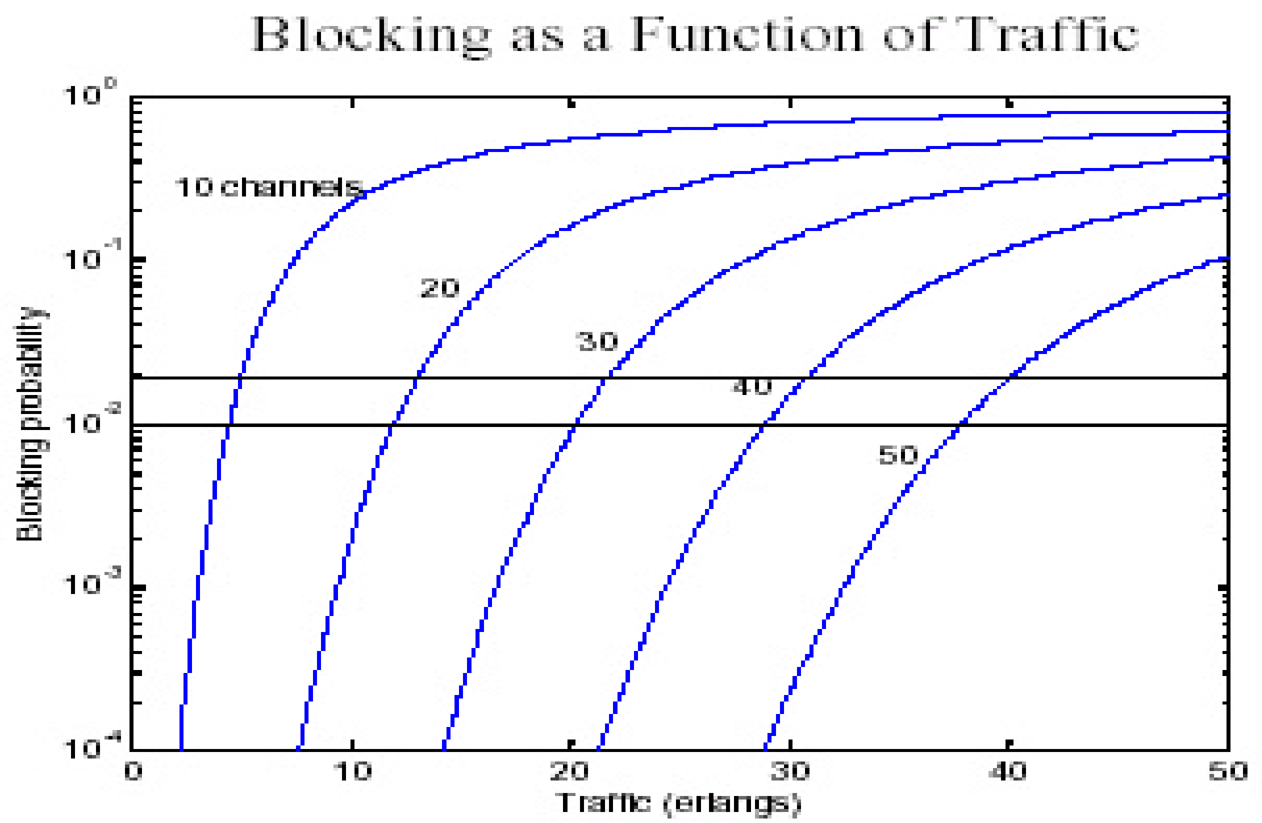


Erlang.jpeg

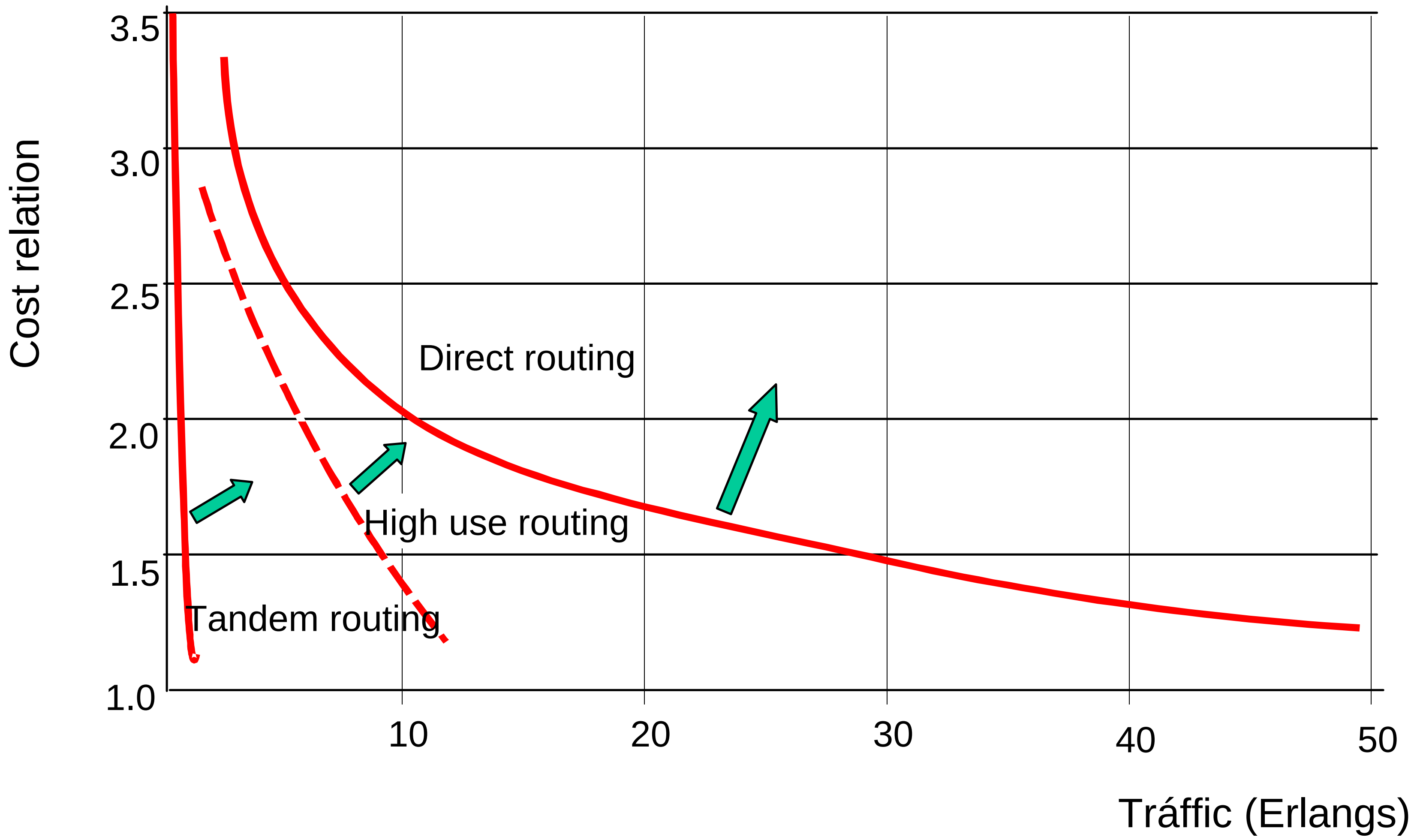
Network Design and Dimensioning: Typical dimensioning curves



Network Design and Dimensioning: Typical dimensioning curves

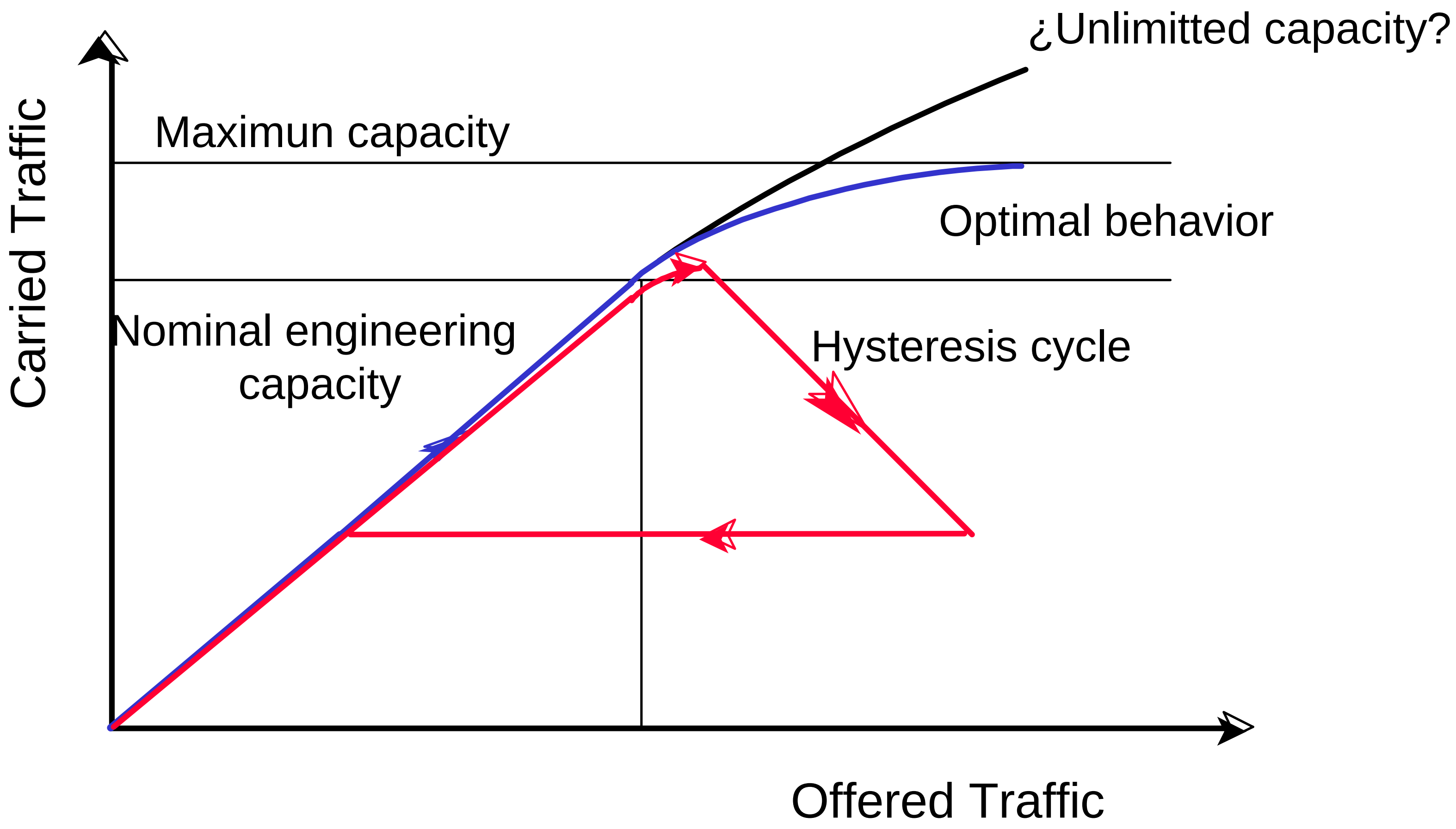


Network Design and Dimensioning:
Simplified design criteria



Network Design and Dimensioning:

Network behavior in overload



Network Design and Dimensioning: Traffic Measurement and Validation

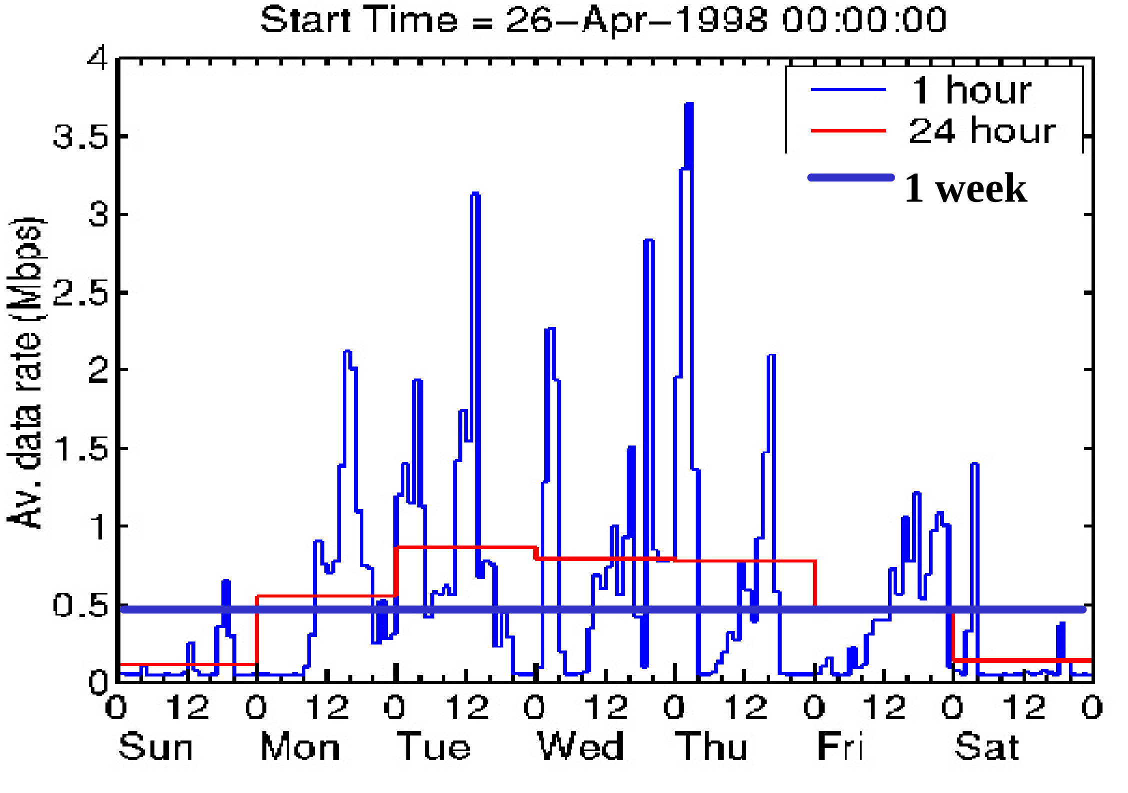
- For **Overall Network** and network **Paths/sub-paths** including parameters used in the network dimensioning and performance
  - By internal measurements. May alter original flows and overload systems and memory due to the high volume of information)
  - By statistical stratified sampling to solve the previous problems (recommended)
- For **Network Nodes and Links** including more detailed system parameters
  - Following harmonized measurement period for statistical significance
- Result analysis and validation
  - For all defined 3 levels (network, path and NE) and parameters used in the dimensioning and SLA/QoS

Network Design and Dimensioning:

Examples for impact by reference time period

Measurements for Data traffic at SERC IP LAN - Australia (ITC'99)

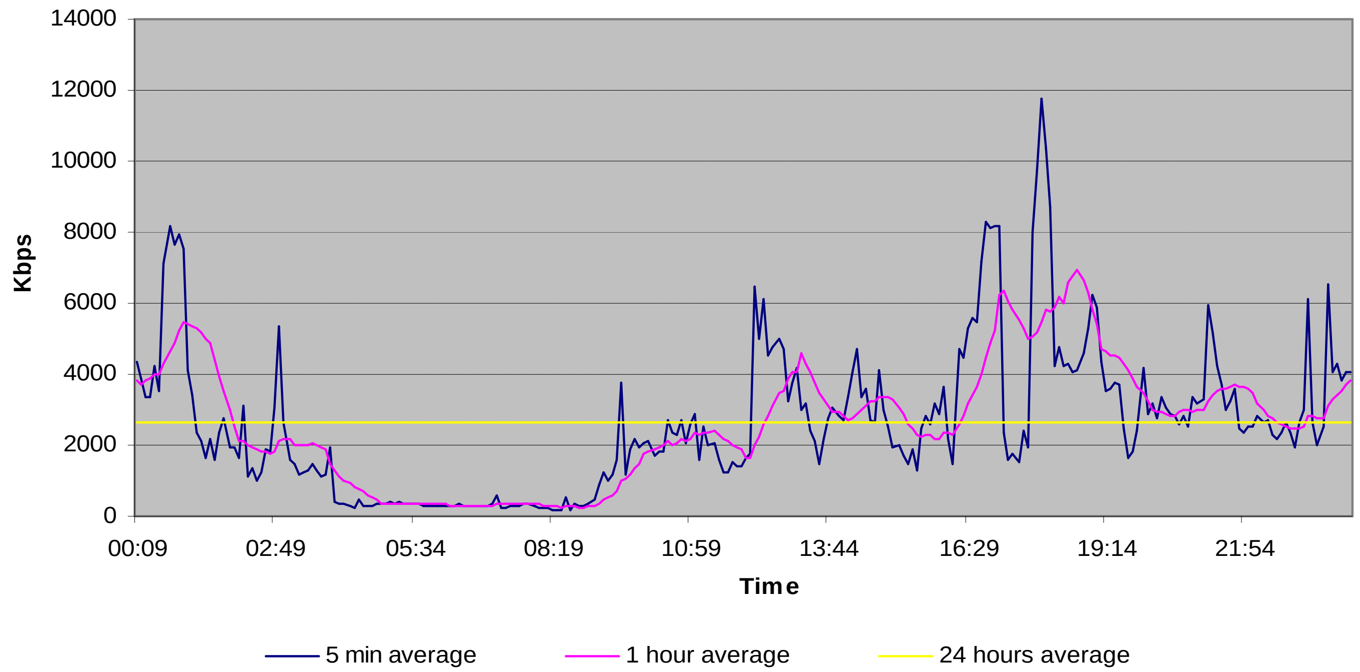
Mean data rate



Network Design and Dimensioning:
Example of time-scale measurements and issues

Variation per measurement averaging period

ENST campus measurements in 2001



- Impact of averaging period
  - 2:1 ratio between “5 min” and “1 hour”
  - 2:1 ratio between “1 hour” and “24 hours”

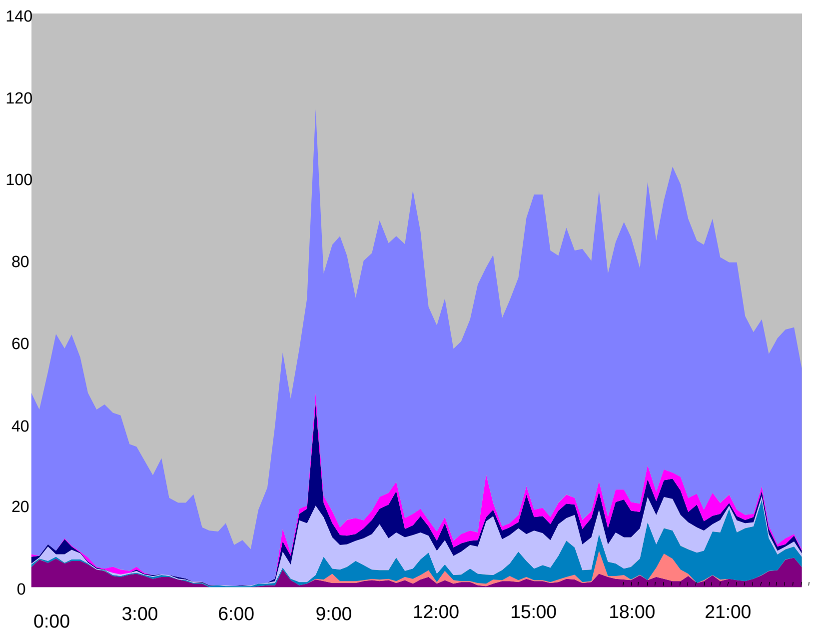
Network Design and Dimensioning:

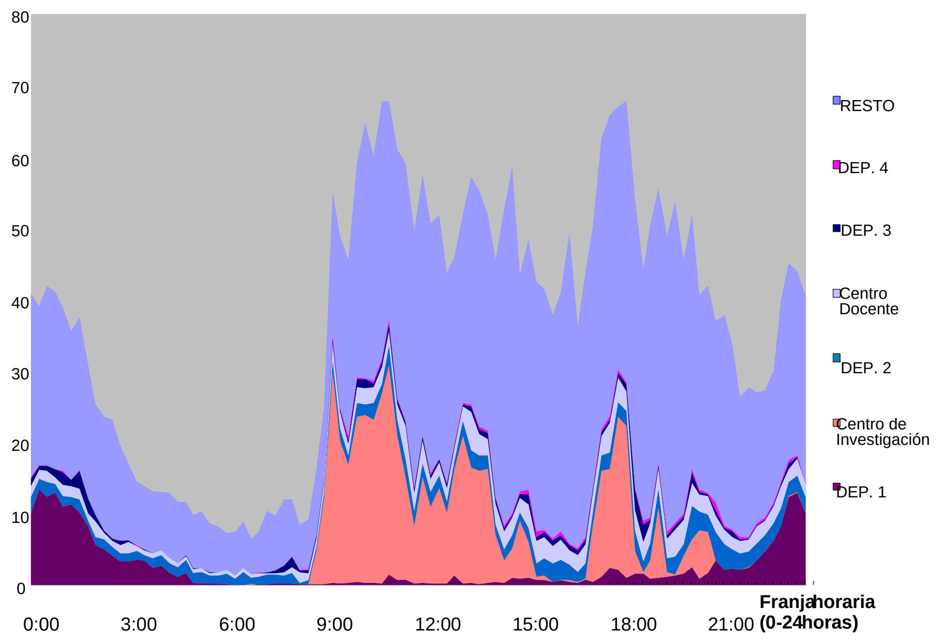
Examples for behavior per user class

Example of I/O hourly variation per user class in a region

IP/ATM Internet National Backbone - Red IRIS Spain by UPM (IFIP'99)

Mbytes





Network Design and Dimensioning: Measurements utility

- To analyse end to end flow completion rates

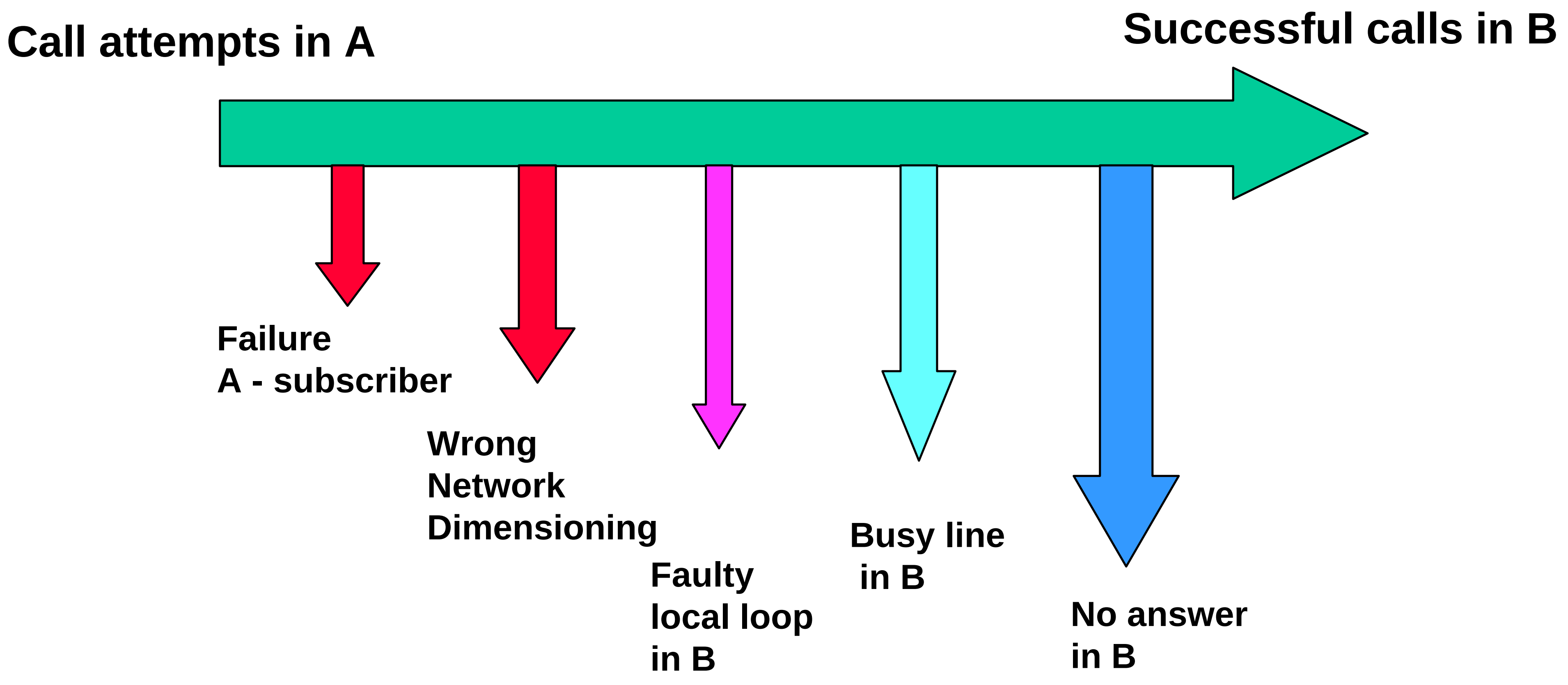
- To follow up and to analyse the occupancy rates
  - for each type of systems (local exchange, primary/secondary main cables, distribution cables)
  - for each elementary service area

- To detect the bottlenecks and saturation level

- To determine the lost revenues due to waiting list in each area

- To classify areas by priority depending on the profitability of projects of extensions.

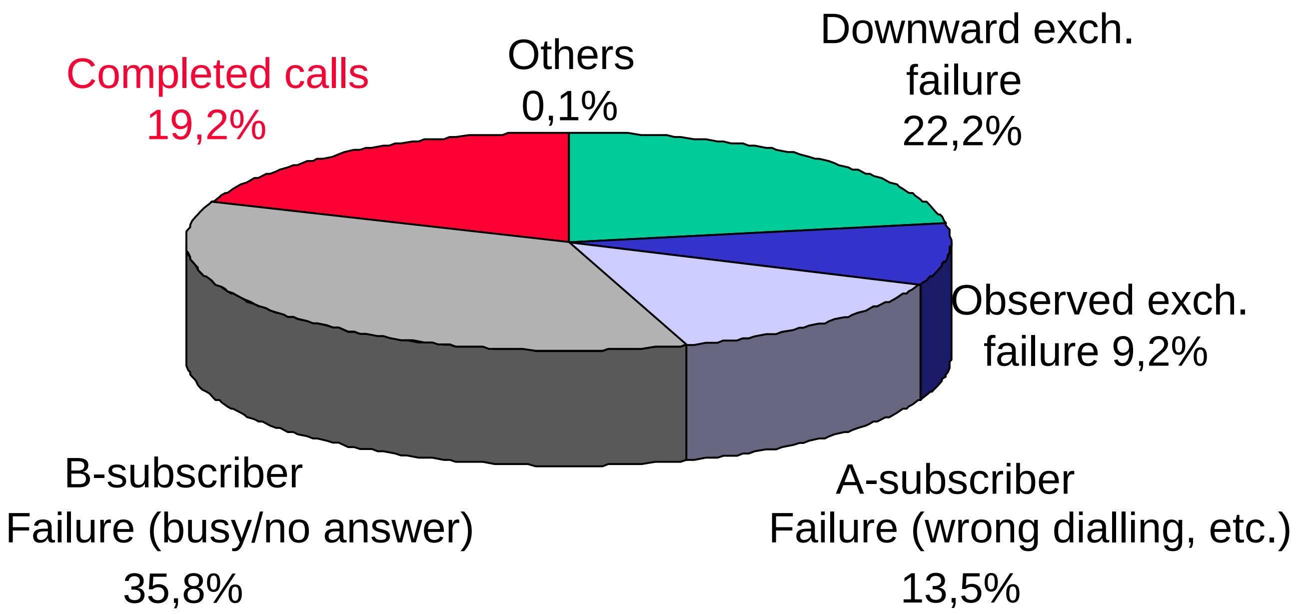
Network Design and Dimensioning: Improvement of traffic efficiency



Network Design and Dimensioning: Measurements

GLOBAL EFFECTIV., FROM EXG. LEVEL MEASUREMENTS IN A LOW EFFICIENCY SCENARIO

CALLS measured per type of completion



Network Design and Dimensioning: Example for performance objectives

- Overall end to end success billed calls: > 70 %
- Average trunk call success rate during office hours: 95%
- Percentage of exchanges achieving a minimum success rate of 95% for calls to and from individual exchange areas: 95%
- Max number of customer reported faults per 1000 mainlines and year (average): 150
- Delivery time for installations in permanent dwellings within 5 working days: 90%
- Fault clearing time for telephone service in permanent dwellings no later than one working day after being reported: 90%

Network Design and Dimensioning: Network Challenges and Trends

- Provide High Capacity and Scalability for the expected demands at any location
- Benefit in all layers from the large Economy of Scale provided by new technologies ie: DWDM
- Provide Flexible Topologies and Architectures able to evolve for changing flow patterns and demands
- Provide sufficient Connectivity and Protection to ensure Survivability to unexpected events
- Reach Low cost for low density customers varying five orders of magnitude between different scenarios