Content Chapter 3.3

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

Network Design and Dimensioning: Service and Traffic Demand

- Some examples of published forecasts…. Good enough ??
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 and customer classes at that level.

Traffic Architectures to be modeled

- 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

To simplify analysis, the following partition is made:
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 processes ➞ 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/∞  \(\rightarrow\) Poisson arrival/negative exponential service time/one server/infinite traffic sources
  - M/D/1  \(\rightarrow\) Poisson arrival/constant service time/one server/infinite sources
  - M/M/n/m  \(\rightarrow\) Poisson arrival/negative exponential service time/n servers/m sources
  - M/G/n/∞  \(\rightarrow\) 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:
Basic queuing models:

- **Network dimensioning**
  - Open queues:
    - Without feedback:
    - With feedback:
  - Closed queues

\[ X = (1-p) \lambda_1 = \lambda \]

Network behavior in overload

- Maximum capacity
- Nominal engineering capacity
- Optimal behavior
- Hysteresis cycle
- Unlimited capacity?
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:
Traffic Characterization

![Traffic Characterization Graph](image)
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

Start Time = 26-Apr-1999 00:00:00

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

Call attempts in A

- Failure A - subscriber
- Wrong Network Dimensioning
- Faulty local loop in B
- Busy line in B
- No answer in B

Successful calls in B

Network Design and Dimensioning: Measurements

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

CALLS measured per type of completion

- Completed calls 19.2%
- B-subscriber Failure (busy/no answer) 35.8%
- A-subscriber Failure (wrong dialling, etc.) 13.5%
- Others 0.1%
- Downward exch. failure 22.2%
- Observed exch. failure 9.2%
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