Introduction to the course

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1. What is the teletraffic theory?

Multidisciplinary in nature:

- General disciplines:
  - probability theory;
  - theory of stochastic processes
  - statistics.
- Specific disciplines: **parts of operations research:**
  - queuing theory:
  - simulations;
  - traffic modeling;
  - reliability;
  - optimization;

Note: all these allow to create models and analyze them.

1.1. Why teletraffic theory?

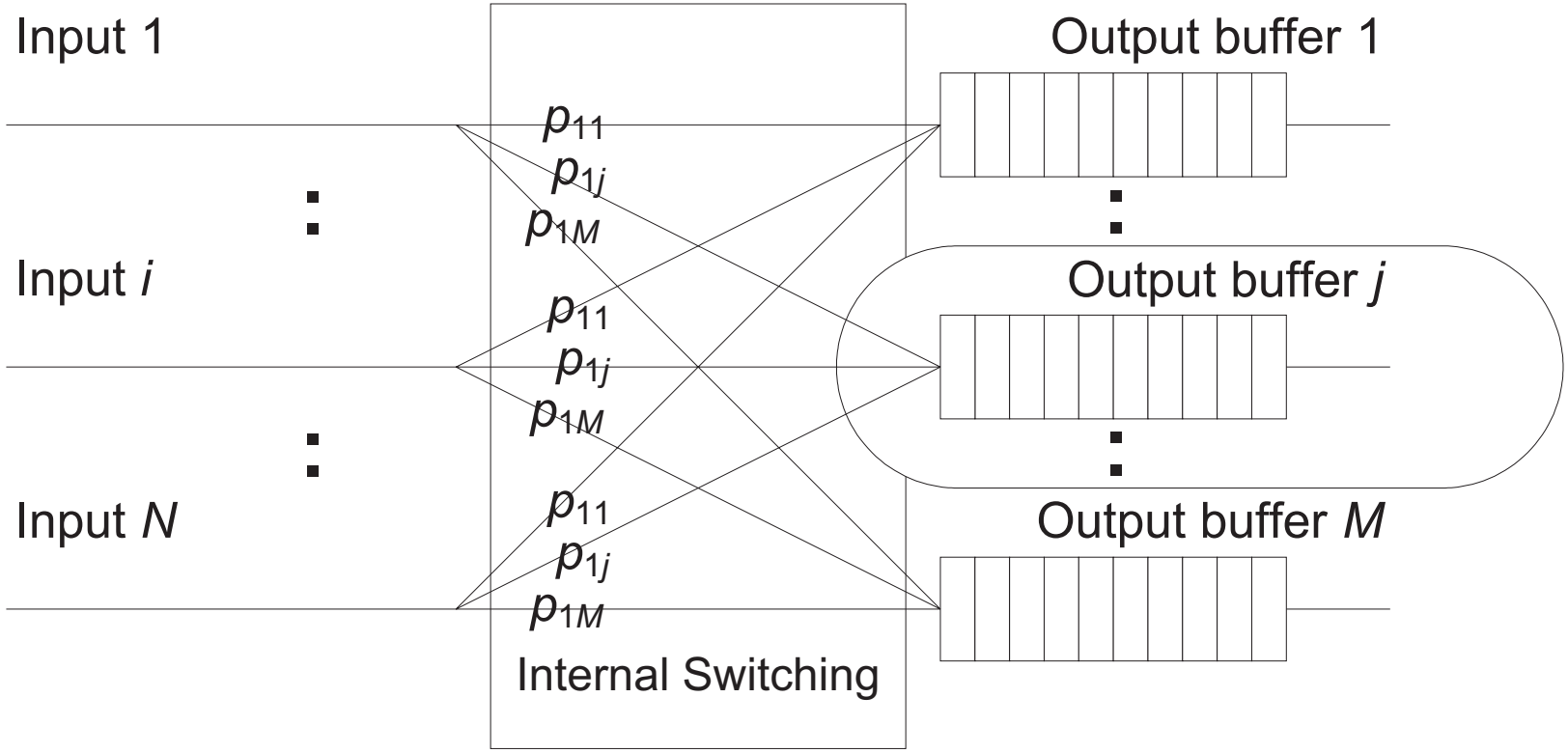
Teletraffic theory is attractive for:

- service providers:
  - how to best distribute service access points to facilitate the users' requests?
  - how many servers are needed to satisfy users' request?
- networks operators:
  - how to best distribute network load?
  - how much buffer space should be assigned to traffic load?
  - what are the optimal link rates?
- vendors:
  - how to best utilize resources of the switching/routing equipment?
  - what kind of improvements should be made to switching equipment?
- end users:
  - what is actual quality of service obtained from the network?

1.2. Why all these disciplines?

Classic problem: dimension the buffer of the hypothetical router given a known load:

- determine the buffer space and the link rate;
- assume that routing is static.



The step-by-step procedure:

Represent arrival traffic on each input link:

- measure arriving traffic;
- determine and measure important statistics;
- choose an appropriate model;
- fit parameters to obtain model.

Define superposition of processes entering the queue at the output port:

- use properties of models to get superposed traffic:
  - for example: superposition of homogenous Poisson processes is again Poisson;
  - for example: superposition of Markovian processes is again Markovian.

Analyze the queue under defined load:

- propose and analyze queuing system for a set of output parameters;

Determine required buffer space and link rate share:

- formulate and solve the inverse task.

Represent arrival traffic on each input link:

- we have to know: probability, stochastic process, statistics, traffic modeling;

Define superposition of processes entering the queue at the output port:

- we have to know: probability, stochastic process, statistics, traffic modeling.

Analyze the queue under defined load:

- we have to know: queuing theory, simulations, reliability theory;

Determine required buffer space and link rate share:

- we have to know: queuing theory, optimization methods.

1.3. Two approaches

Analytic approach:

- traffic modeling;
- queuing theory;
- optimization.

Simulation approach:

- traffic modeling;
- simulations.

Advantages of simulations:

- less restrictive assumptions: works well when analytical approach does not help.

Shortcomings of simulations:

- not suitable for optimization tasks.

1.4. Aims of the course

Why to take 'Traffic modeling and network simulation techniques'::

- sufficient for performance evaluation purposes;
- can be useful in isolation:
  - especially: those who have minor in telecommunication.

This course is also connected with:

- 'Teletraffic theory part I: Queuing theory' is up for fall 2006;
- 'Teletraffic theory part II: Performance evaluation' is up for spring 2007;
- Basically, all of these are a part of what we call performance evaluation!

Aims of the 'Traffic modeling and network simulation techniques' are to:

- give basic knowledge of supplementary disciplines:
  - probability, stochastic processes, statistics.
- give a comprehensive introduction to simulation techniques:
  - how to develop you own trusted simulations?
- give overview of traffic in circuit-switched and packet-switched networks:
  - what are the trends of the traffic in the Internet?
  - why Poisson models does not hold for packet networks?
  - what traffic parameters are important for network dimensioning?
- give a comprehensive introduction to modern traffic modeling techniques:
  - what are the classic models for circuit-switched networks?
  - what are the modern models of traffic in packet-switched network?

2. Outline of the course

Outline of the 'Teletraffic theory I: queuing theory':

- **Lecture 1:** Introduction to the course
  - objectives of the course;
  - motivation to study simulations and traffic modeling;
  - basic notations;
  - parameters of interest.
- **Lecture 2:** Reminder of probability theory
  - definitions of probability;
  - combinatorial analysis, conditional probabilities;
  - PDF, pdf, PF, moments, functions of RV;
  - useful continuous-time distributions: uniform, exponential etc.;
  - useful discrete-time distributions: geometric, phase-type etc.

- **Lecture 3:** Reminder of stochastic processes
  - definition, overall description;
  - classification: strict and second order stationary, ergodicity:;
  - moments and autocorrelation function;
  - Markov property;
  - continuous and discrete-time Markov chains, properties;
  - birth-death processes.
- **Lecture 4:** Reminder of statistics
  - representing statistical data;
  - point estimators;
  - interval estimators;
  - fitting data to distributions: moments matching;
  - testing hypothesis: Smirnov's, Kolmogorov's and χ^2 tests.

- **Lecture 5:** Introduction to simulations:
  - motivation to use simulation;
  - classifications of simulations;
  - discrete-event simulations;
  - examples.
- **Lecture 6:** Design of discrete-event simulations
  - discrete-event simulations;
  - event advance design: sequential lists and linked lists;
  - unit-time advance design;
  - activity-based simulation;
  - examples.

- **Lecture 7:** Generation of random numbers
  - importance of the problem;
  - basic approach;
  - generation of uniformly distributed random numbers;
  - tests for uniform generators: independence and uniformity;
  - generation of random numbers with arbitrary distribution.
- **Lecture 8:** Collection of data and data analysis
  - exogenous and endogenous variables;
  - transient and steady-state simulations;
  - measures of central tendency;
  - measures of variability;
  - analysis for steady-state simulations;
  - data-collection techniques;
  - estimation for transient simulations.

- **Lecture 9:** Variance reduction techniques
  - how to achieve a given accuracy in simulations;
  - antithetic variates technique;
  - control variates technique;
  - validation of the simulation model.
- **Lecture 10:** ns2 network simulator
  - overview and history of development;
  - ns2 architecture;
  - simulations;
  - supplementary tools: nam, xgraph;
  - example.

- **Lecture 11:** Traffic concept and measurements
  - traffic concept;
  - traffic in circuit-switched networks;
  - traffic in packet-switched networks;
  - traffic measurements;
  - recent observations of Internet traffic;
  - notes on ergodicity, stationarity and traffic modeling.
- **Lecture 12:** Renewal traffic models and their properties
  - point processes;
  - classifications of point processes;
  - notes on analytical tractability;
  - renewal point processes;
  - exponential-based processes: Erlang, hyperexponetial, Cox, phase-type;
  - general renewal processes.

- **Lecture 13:** Non-renewal traffic models and their properties
  - markovian models: IPP, SPP, MMPP, MAP, BMAP, IBP, SBP, D-MAP, D-BMAP;
  - autoregressive models: AR(p), MA(q), ARMA(p, q), DAR(p), GBAR;
  - fluid-flow traffic models: MMFP;
  - deterministic models: rt, b, $rt + b$;
  - long-range dependent and self-similar models: FARIMA(p, d, q), FBM.
- **Lecture 15:** Traffic modeling in circuit-switched networks
  - basics of circuit-switched networks;
  - call arrival process to a telephone exchange;
  - call arrival process between telephone exchanges;
  - notes on service processes

- **Lecture 16:** Traffic modeling in packet-switched networks
  - basics of packet-switched networks;
  - applications in packet switched networks;
  - modeling single sources: voice, video, data;
  - modeling aggregated traffic;
  - notes on stationarity of aggregated traffic.

2.1. Important information

Pay attention:

- Lectures will be given once a week:
  - Every Wednesday starting from 30.08.2006;
  - Room TB222, time 16:00 – 17:45.
- Two assignments:
  - contain tasks similar to those ones which will be given at exam;
  - will be available at the course page soon.
- exam date: 30.11.2006:
  - usually there are three attempts to pass exam;
  - check O-INFO system;
  - you have to sign for exam at O-INFO.

2.2. Expected knowledge and references

Knowledge necessary to attend the course:

- all information necessary to understand the content of the course will be given;
- knowledge of probability, stochastic processes and statistics is advantageous.

Literature:

- lecture notes will be available at the course page;
- traffic modeling:
  - circuit-switched networks: V.B. Iversen 'Teletraffic Engineering Handbook';
    - freely available at: http://www.tele.dtu.dk/teletraffic/
  - packet-switched networks: research sources, e.g. http://researchindex.org/
- simulations:
  - H. Perros, 'Computer Simulation Techniques – The Defnitive Introduction':
    - freely available at: www.csc.ncsu.edu/faculty/perros/simulation.pdf
  - any book on discrete-event simulations that you may find in library.

2.3. Credit points

Credit points:

- one can earn up to 6 CPs:
  - minimum: 4 CPs;
  - maximum: 6 CPs.

How you get it:

- 4 CPs: pass of exam only;
  - this is base;
  - you may not attend lectures, exercises, assignments!
- No CPs for attendance of lectures:
- 2 CPs: assignment (1 CP per each).

Important note: if you fail to pass exam you get nothing!

2.4. Personal information

Lectures:

- Dmitri Moltchanov;
- e-mail: moltchan@cs.tut.fi;
- course pages:
  - official: http://www.cs.tut.fi/kurssit/TLT-2706/;
  - unofficial: http://www.cs.tut.fi/~moltchan/modsim/: will be updated more frequently.