B Motivation

- **Important Properties of Computer Systems (Hardware and Software):**
  - ◆ Correctness
  - ◆ User Friendliness
  - ◆ Performance
- **Modern Computer Systems:**
  - ◆ Performance evident (for example Web performance)
    Every user has his own workstation, PC or terminal
  - ◆ Very often minimum performance necessary, e.g. real time systems
  - ◆ Performance important for the acceptance of a computer system
  - ◆ Performance very often important for the decision to buy a computer
- **Methods to improve the Performance**
  - ◆ Measurement, Modeling and Performance Evaluation
  - ◆ **Important**: Design, Developement, Tuning, Comparison of Computer Systems

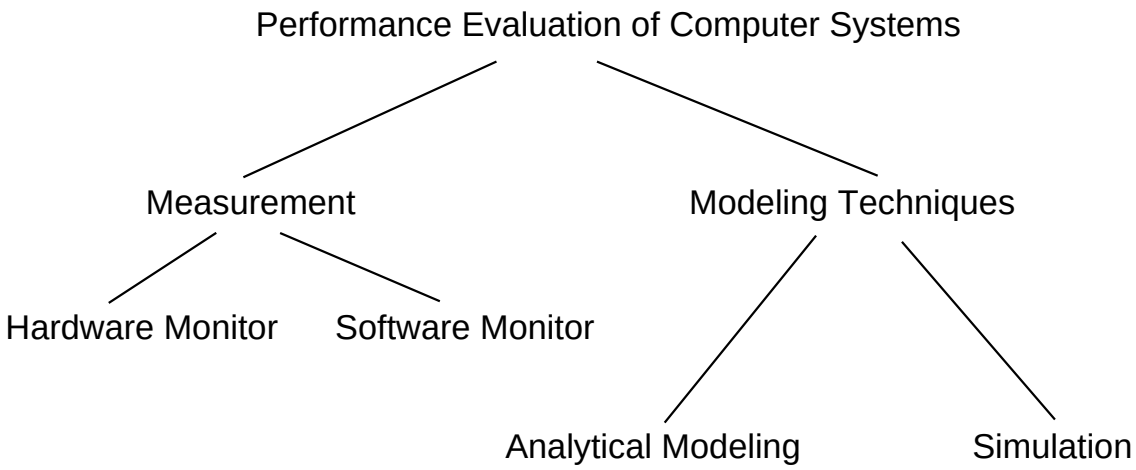
B.1 Performance Measures

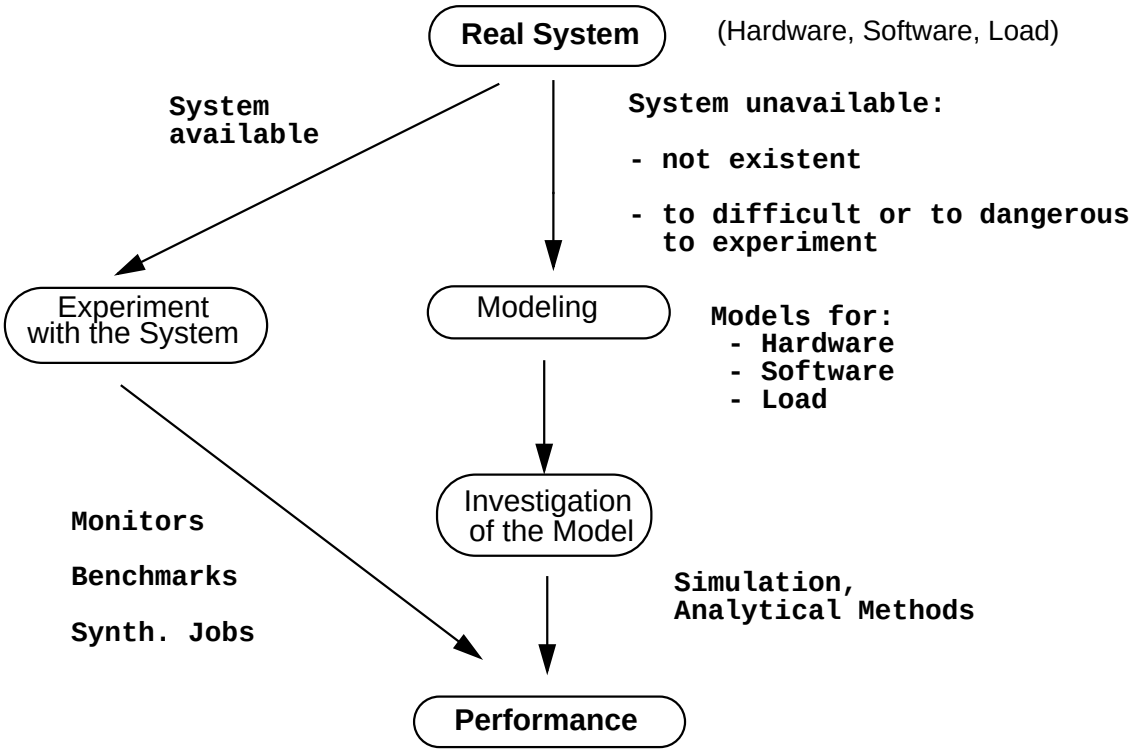
- Response Time, System Time, Sojourn Time
- Throughput
- CPU Utilization
- Utilization of Channels and Peripheral Devices
- Queue Length
- Deadlines
- Speed up
- Availability, Reliability

➤ Performance measures for given system parameters ?

➤ Optimal performance measures for variable system parameters ?

B.2 Overview

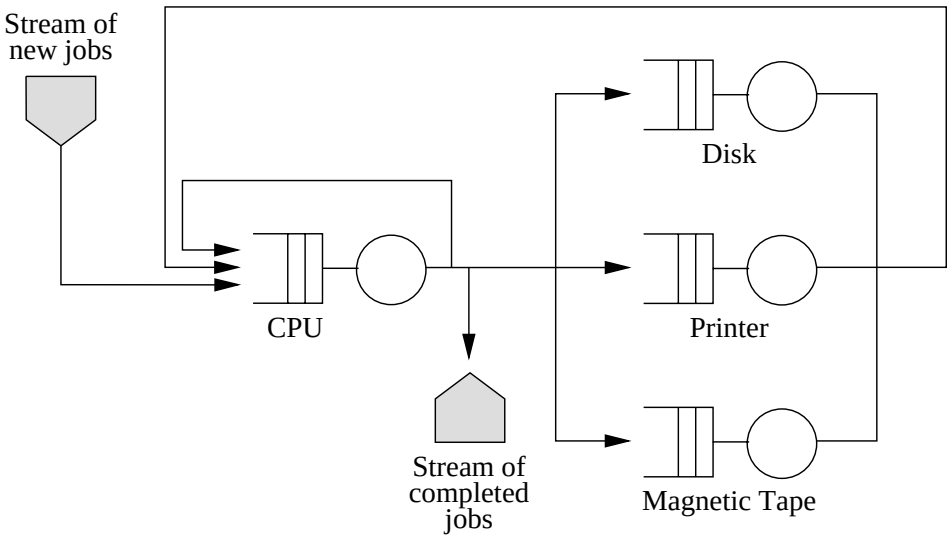




B.3 Model Types

Queueing Network Model:

◆ System described by: Queues, Servers and Edges

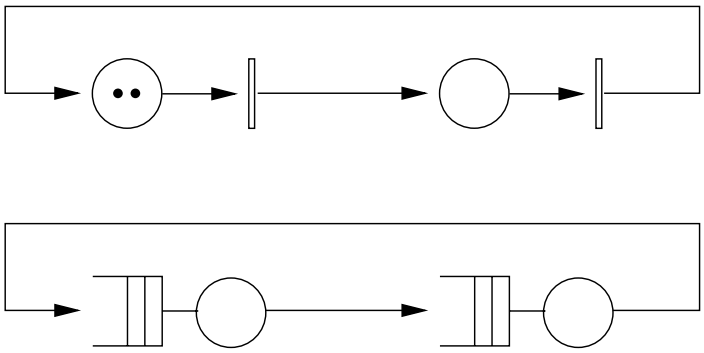


Petri Net:

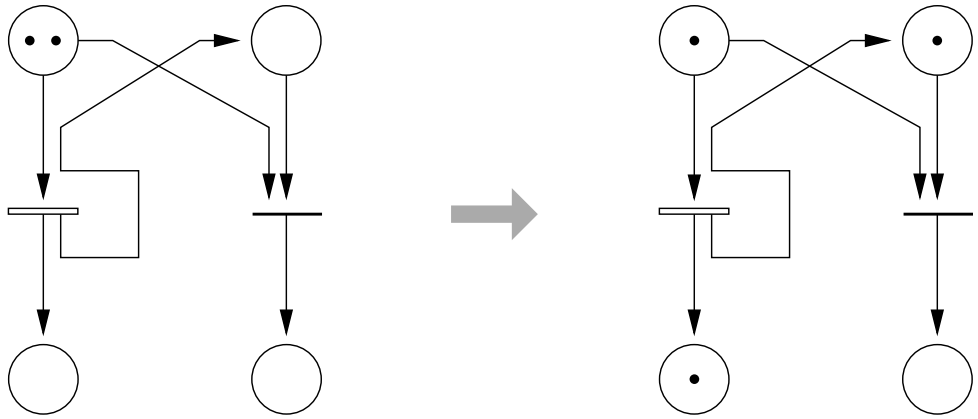
◆ System described by:

- Transitions and Places
- Edges between Transitions and Places or Places and Transitions
- Tokens in the Places

◆ Simple Example:

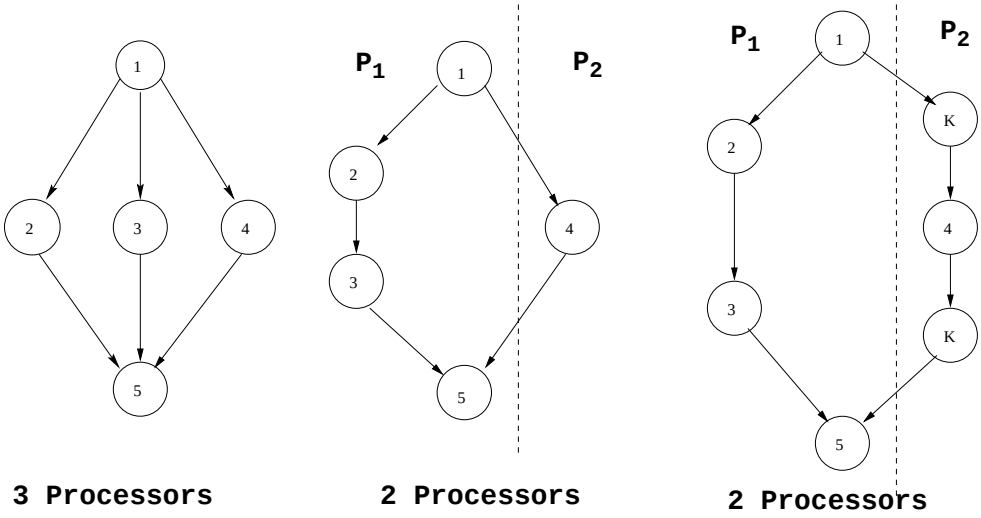


◆ A larger Example:



Precedence Graph:

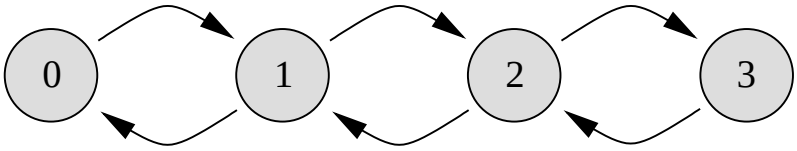
◆ Example: Task composed of 5 Subtasks



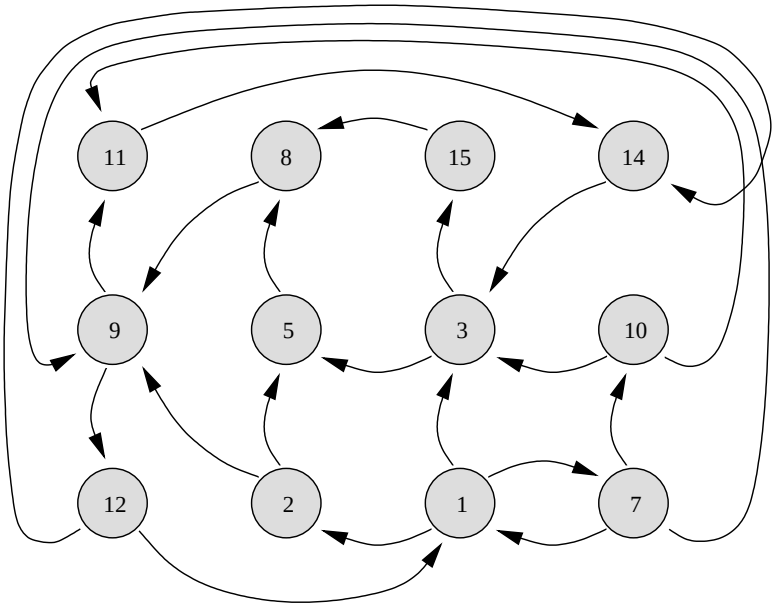
Markov Model:

- System described by:
  - States
  - Transitions between the States

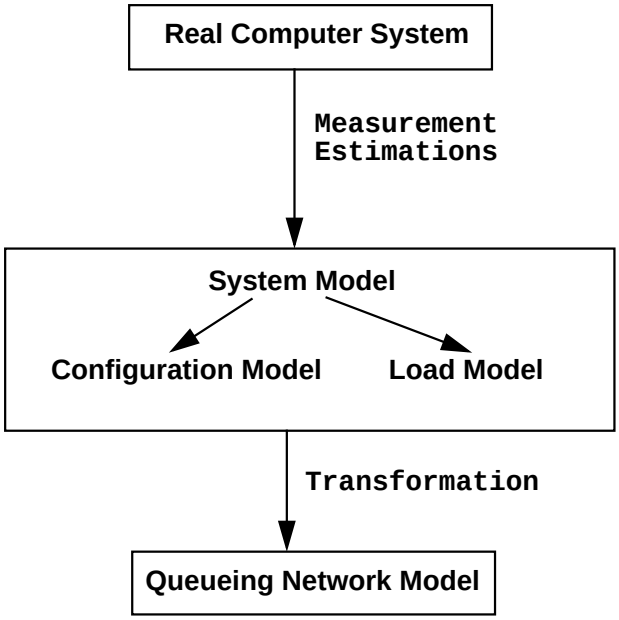
- Simple Example:



- A larger Markov Model:



B.4 Modeling Process



B.5 Investigation of the Model

Simulation

- Simulation of the system behaviour using a software program
  - Simulation program
  - Simulation model
- Programming languages
  - C, C++, JAVA, PASCAL, ...
- Special simulation languages
  - SIMULA, GPSS, ...
- Simulation tools
  - SIMPLEX III, SIMPLE ++, ...
- Advantage: applicable also for very complex systems
- Disadvantage: computing time, difficult for optimations

Analytical Methods

◆ Determination of the function F:

Performance = F(Load, Software, Hardware)
= F(System parameters)

➤ Analytical Modell

◆ Advantage:

➤ Influence of the system parameters is transparent

➤ Optimations are easy to realize

➤ Short computing time

◆ Disadvantage:

➤ It is difficult or impossible to get exact analytical models for complex systems

➤ Solution: Approximate analytical models

Properties of the Model:

◆ Modeling and manipulation of the model is easier, cheaper and faster than the experiment with the real system

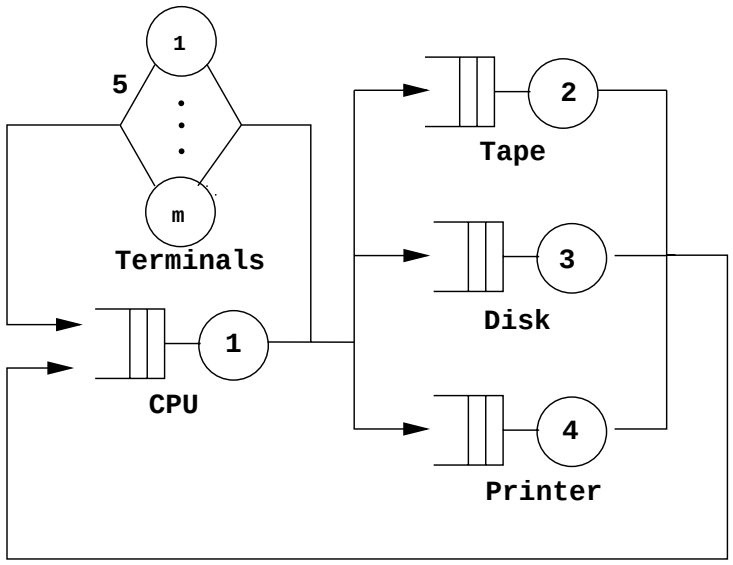
◆ Model should contain all relevant properties of the real system

Steps of the Performance Evaluation

- Computer system will be modelled using a queueing network model (or another appropriate model type)
- Determination of the system parameters (Measurement, estimation or data from handbooks)
  - Interarrival times
  - Service times
  - Transition probabilities between the components of the model
  - usually random variables (distribution or mean value and variance must be given)
- Calculation of the performance measures from the system parameters using formulas and algorithms, which will be presented and derived in this lecture.

B.6 Examples

Terminal System



◆ System parameters:

- CPU:
  - ➤ Number of processors: 3
  - ➤ Service time 0.5 sec
- Tape:
  - ➤ Service time: 5.0 sec
- Disk:
  - ➤ Service time: 1.0 sec
- Printer:
  - ➤ Service time: 5.0 sec
- Terminals:
  - ➤ Thinking time: 10 sec
  - ➤ Number: 20

◆ Transition probabilities:

$p_{12} = 0.15$

$p_{13} = 0.20$

$p_{14} = 0.15$

$p_{15} = 0.50$

$p_{21} = p_{31} = p_{41} = p_{51} = 1$

◆ Determination of Performance Measures using the Queueing Network Tool **PEPSY** (**P**erformance **E**valuation and **P**rediction **SY**stem)

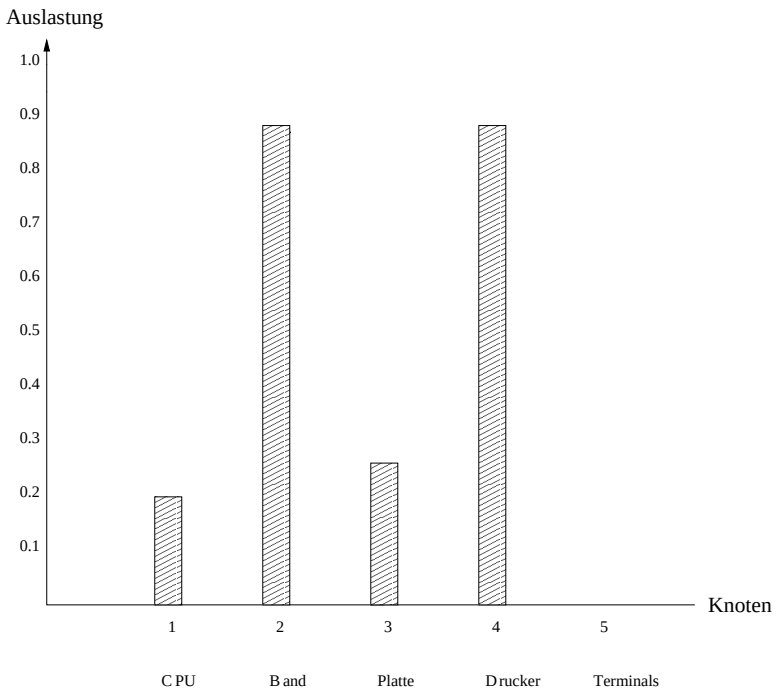
- Performance Measures of the Components (Nodes):

	Service Time	Throughput	Utilization	Queue Length	Response Time
CPU	0.500	1.147	**0.191**	0.005	0.504
Tape	5.000	0.172	**0.860**	2.969	22.262
Disk	1.000	0.229	**0.229**	0.066	1.287
Printer	5.000	0.172	**0.860**	2.969	22.262
Terminals	20.000	0.573	--	0.000	20.000

- Performance Measures of the whole Network:

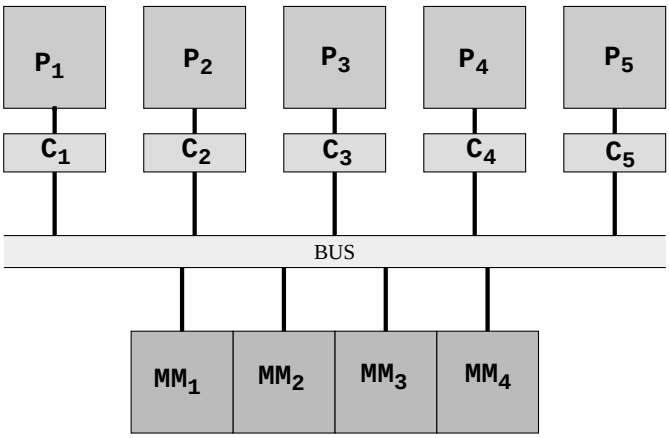
	Throughput	Resp. Time
Network	0.573	34.880

◆ Graphical Representation of the Results:



Multiprocessor System:

◆ Configuration Model:

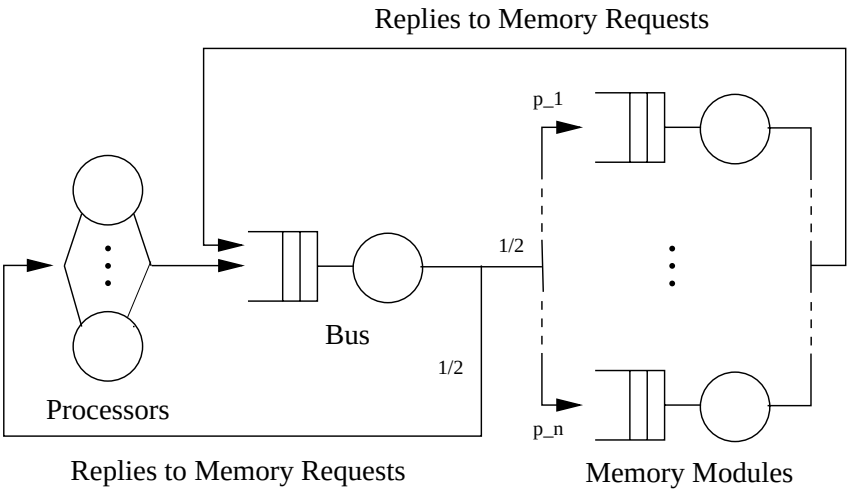


P_n	Processor n
C_n	Cache n
MM_n	Memory Modul n

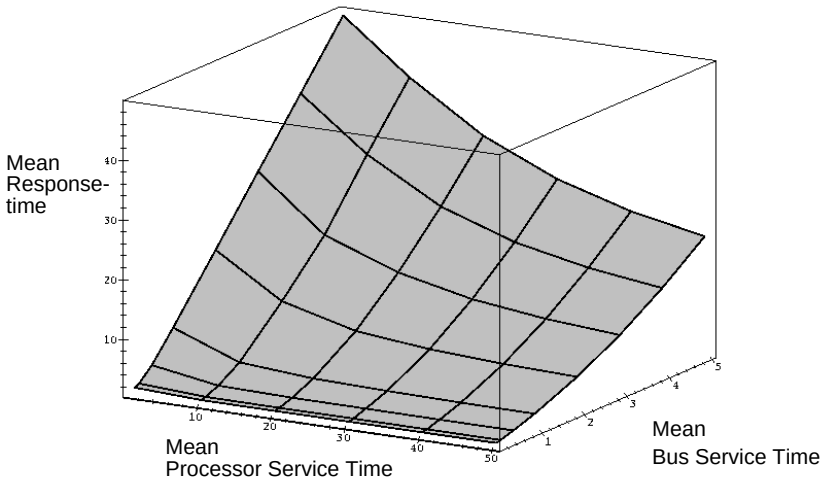
◆ System Parameters:

- ➤ Mean Bus Service Time:
  Mean time the bus is allocated
- ➤ Mean Memory Service Time:
  Mean Time of a memory access
- ➤ Mean Processor Service Time:
  Mean Time between two successive memory accesses
- ➤ Probability p_n of an access to memory modul n

◆ Queueing Network Model:



◆ Mean Response Time for a Memory Access of a Processor:



Mean Memory Service Time = 1