

# SIMULATION & TECHNOLOGY

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*“Most of the time it is impossible to  
understand  
each and every possibility  
in finite lifetime,  
but course to simulation  
solve this problem”*

--Prof. Dr. S. M. Aqil Burney

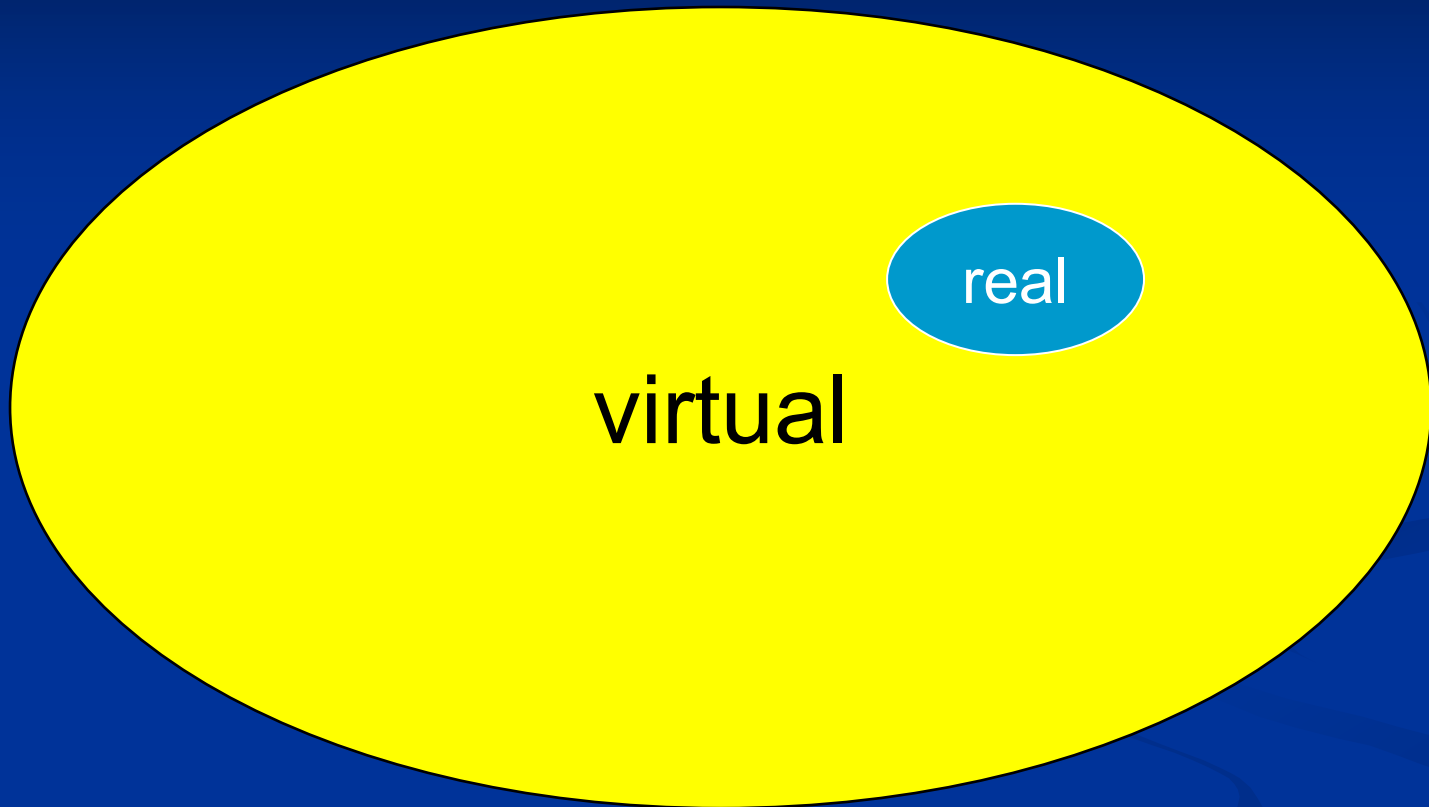
# What is Simulation...?

- Simulation is usually understood as the process of generating reality.
- A dictionary meaning of “to simulate” is  
“Feign,..., pretend to be, act like, wear the guise of, mimic,..., imitate conditions of (situation etc.) with model, for convenience and training...”  
-- Ripley, 1987 & Morgan, 1984

## Monograph on “SIMULATION OF SYSTEMS”

Professor. Dr. S.M. Aqil Burney,  
Department of Computer Science, University of Karachi

# Simulation Dominance



sum total of conscious lives  
(in entire universe, all times)

# What is Simulation...? *Cont'd...*

- A **simulation** is an imitation of some real thing, state of affairs, or process.
- The act of simulating something generally entails representing certain key characteristics or behaviors of a selected physical or abstract system.

# Why Simulation...?

- Test design when cannot analyze
  - System too complex
  - Can analyze only for certain cases  
(Example: Poisson arrivals, very large  $N$ , etc.)
- Verify analysis
- Fast production of results

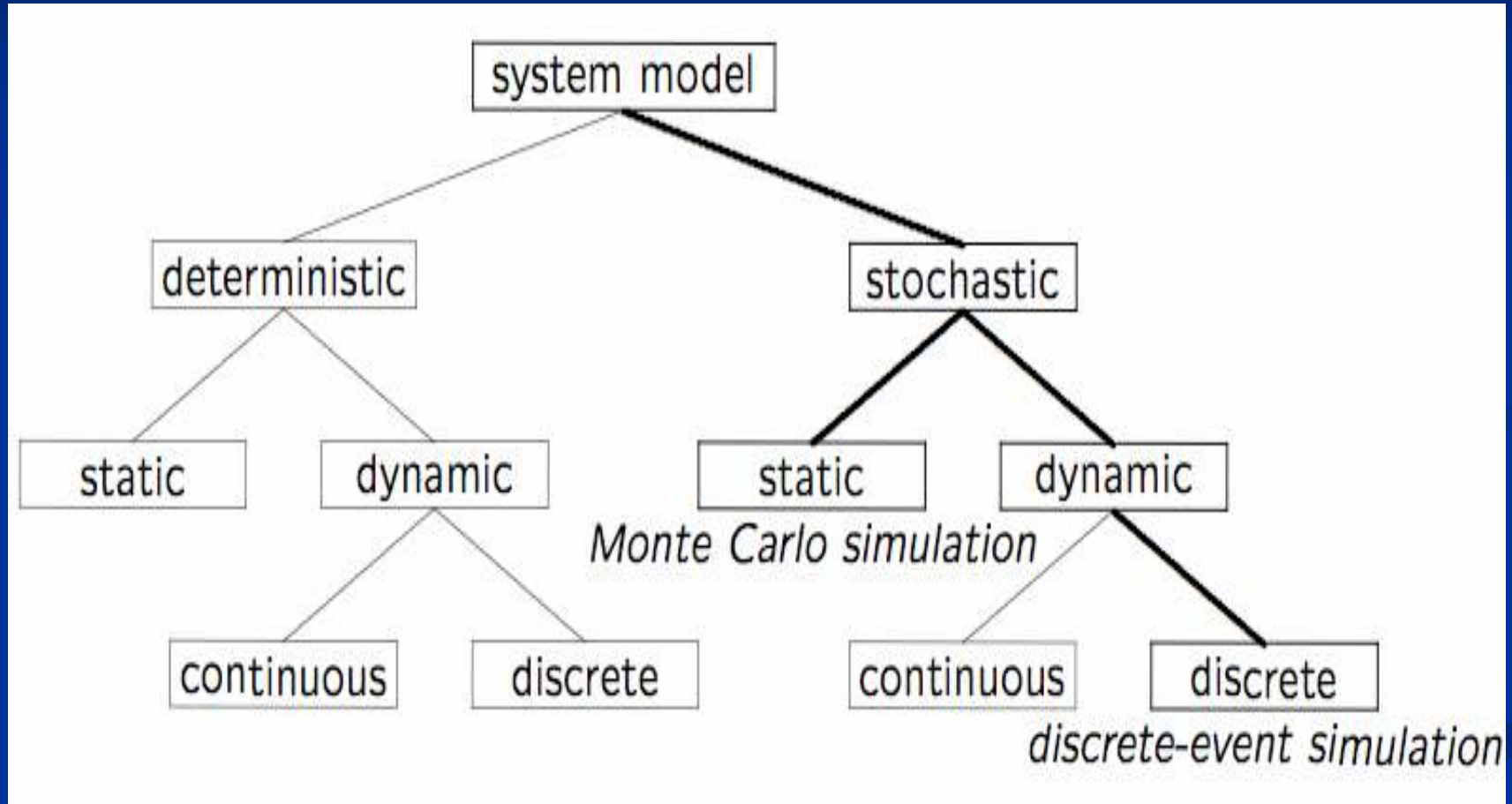
# Simulation Types...

- Deterministic or Stochastic
  - Does the model contain stochastic components?
  - Randomness is easy to add to a DES
- Static or Dynamic
  - Is time a significant variable?
- Discrete or Continuous
  - Does the system state evolve continuously or only at discrete points in time?
  - Continuous: classical mechanics
  - Discrete: queuing, inventory, machine shop models

# Definitions

- Discrete-Event Simulation Model
  - *Stochastic*: some state variables are random
  - *Dynamic*: time evolution is important
  - *Discrete-Event*: significant changes occur at discrete time instances
- Monte Carlo Simulation Model
  - *Stochastic*
  - *Static*: time evolution is not important

# Model Taxonomy



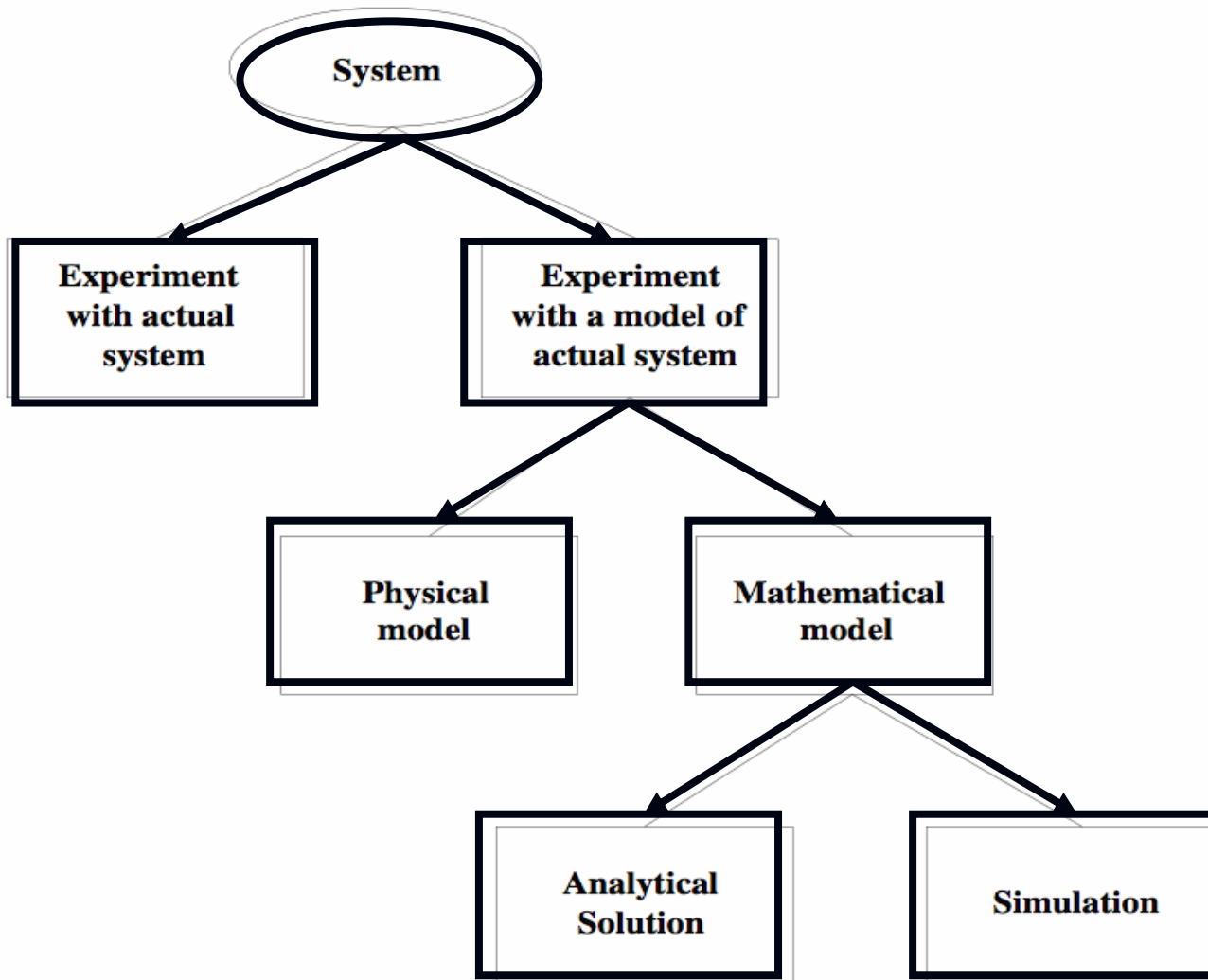
# What is a System...?

- A system is usually considered as a set of inter-related factors, which are described as entities activities and have properties or attributes.
- Processes that cause system changes are called **activities**.
- The state of a system is a description of all entities, attributes and the activities at any time.
- A system may have very large number of states.

# What is a System...?

- The variables or activities of a system are classified as endogenous and exogenous variables.
- Endogenous variables occur within the system, and exogenous variables are found outside the system boundary i.e. those variables in the environment which affect the system.
- A system with exogenous variables is considered as open.
- A system with strict endogenous activities is called a closed system.

# System\*



# Terminology

- Model vs. Simulation (noun)
  - *Model* can be used WRT conceptual, specification, or computational levels
  - *Simulation* is rarely used to describe the conceptual or specification model
  - *Simulation* is frequently used to refer to the computational model (program)
- Model vs. Simulate (verb)
  - *To model* can refer to development at any of the levels
  - *To simulate* refers to computational activity
- Meaning should be obvious from the context

# An ordinary (virtual) family: 'The Sims'





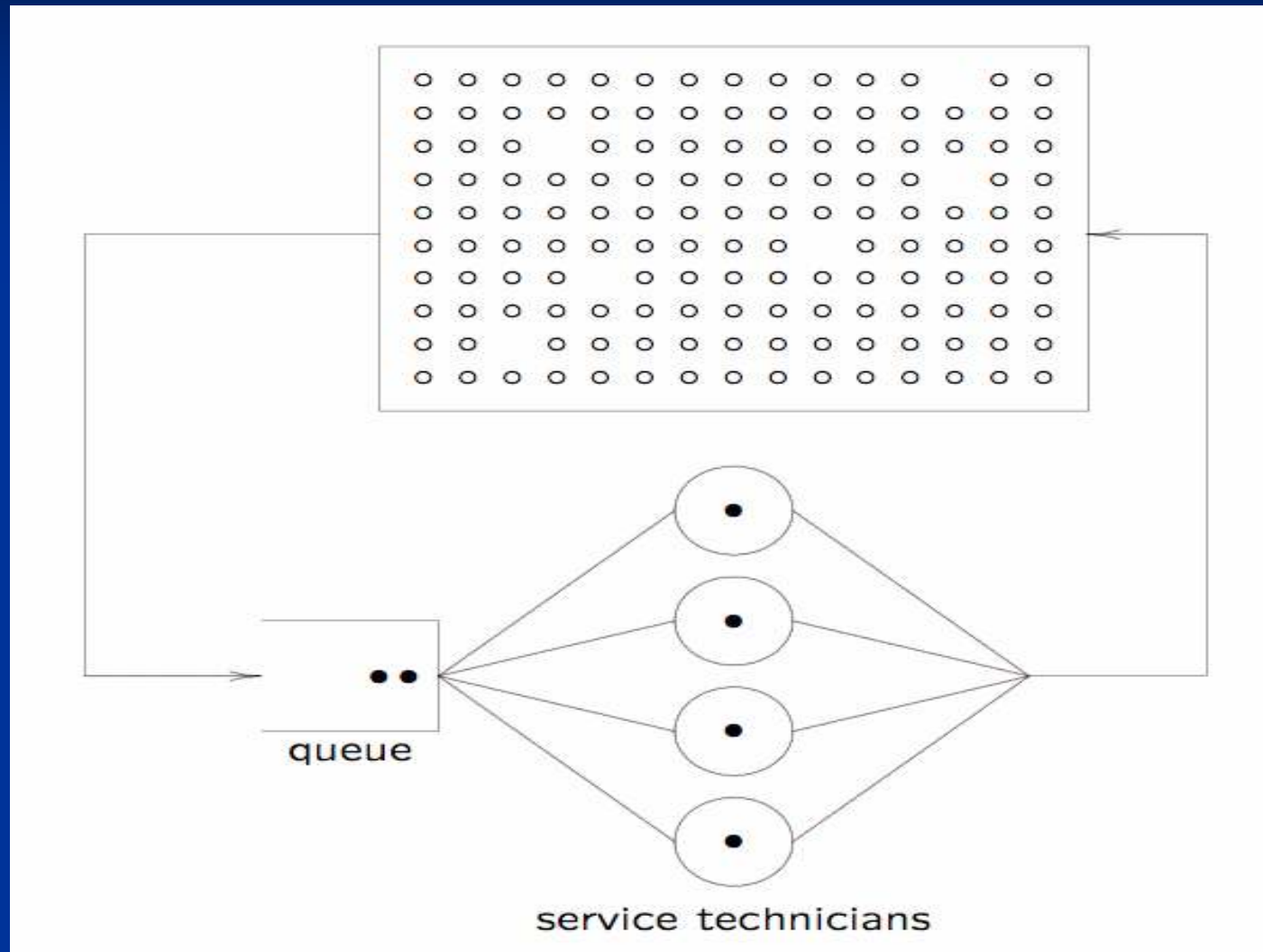


# Example

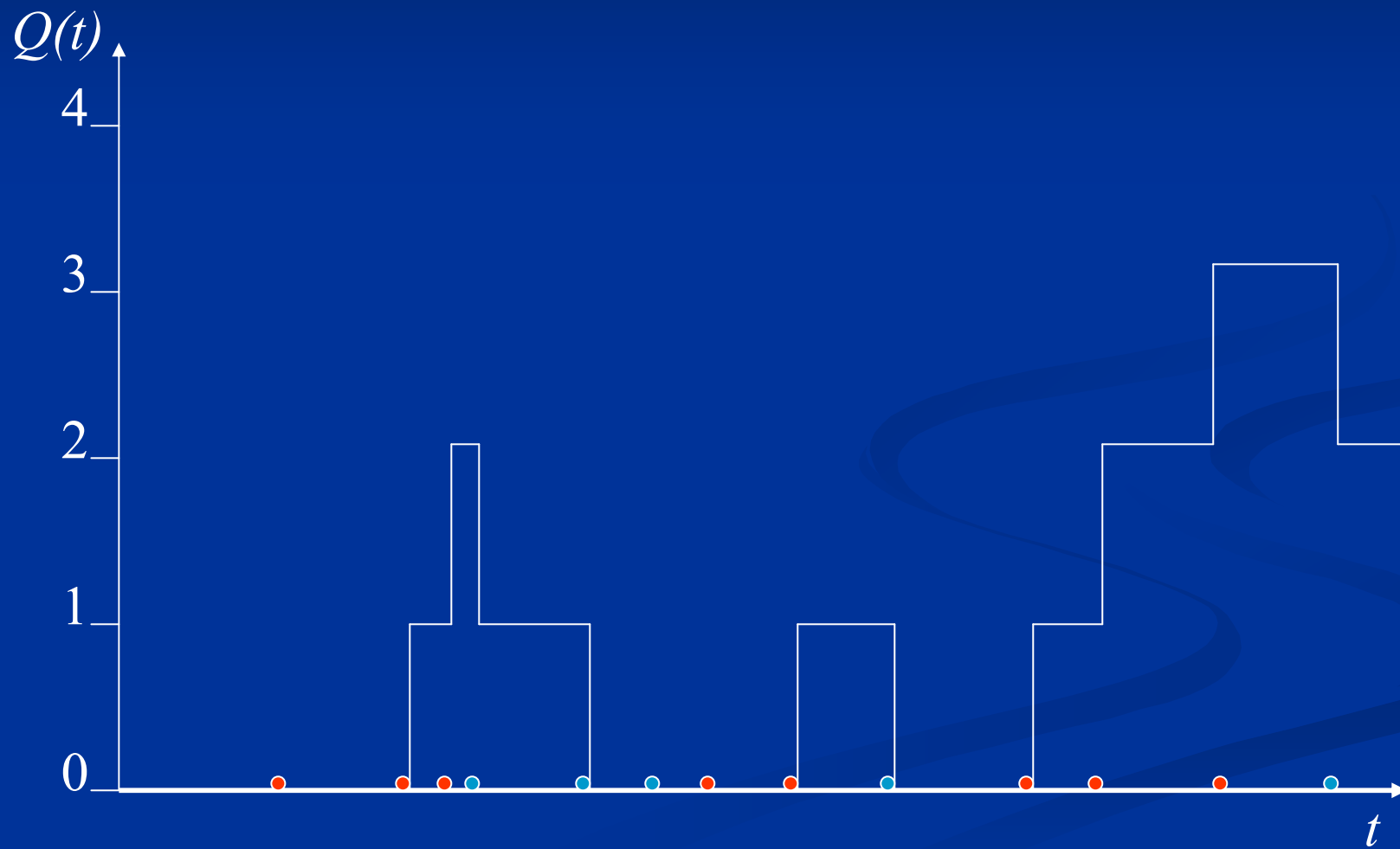
## A Single Server Queuing System

- System to be simulated
  - $A_i$  Interarrival times are I.I.D.
  - $S_i$  Service time are I.I.D.
  - FIFO service
  - Work preserving
- Initial state
  - Empty and idle
  - First arrival after  $A_i$  time units from time 0
- Termination after  $n$  customers left queue.

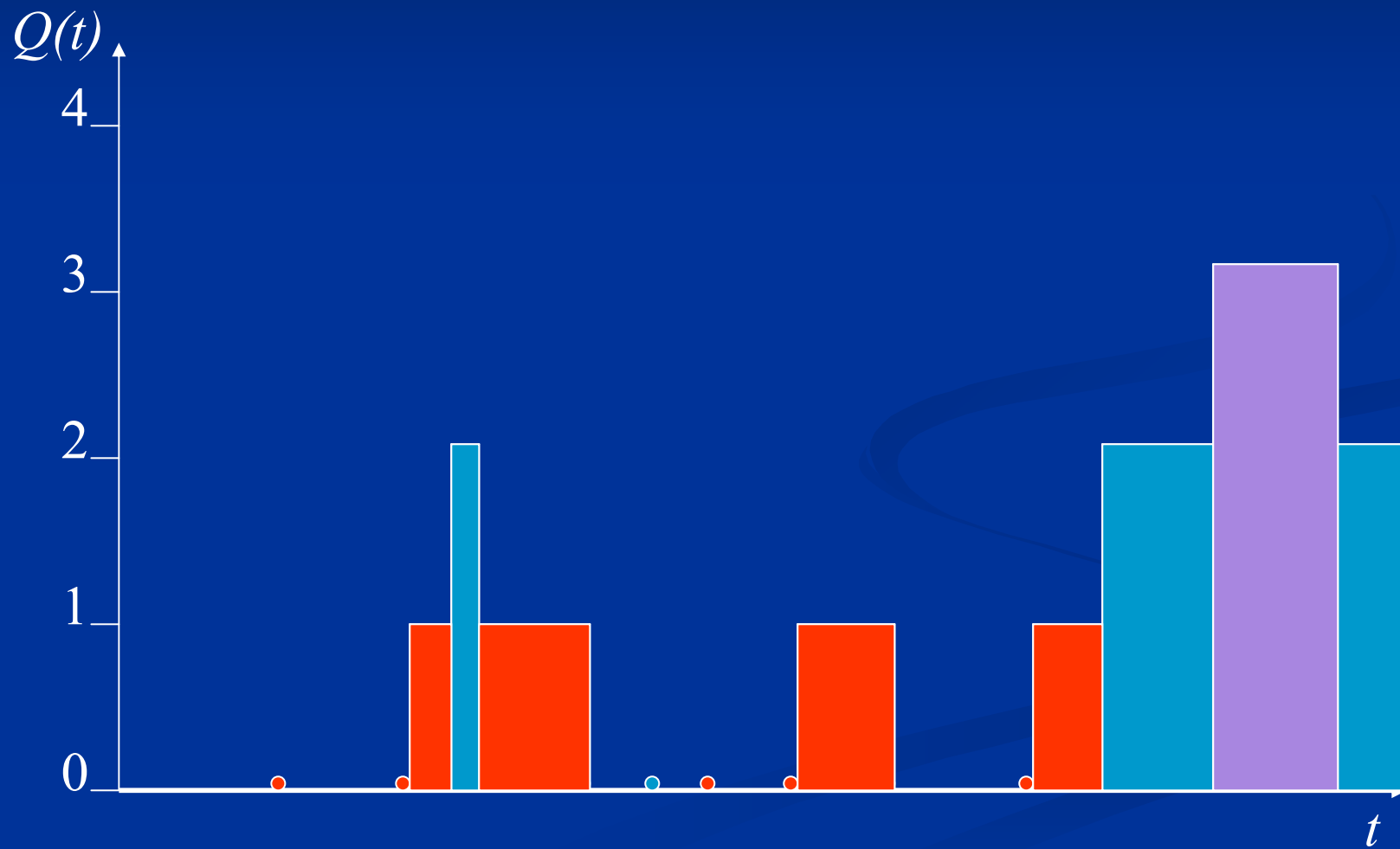
# System Diagram (example)

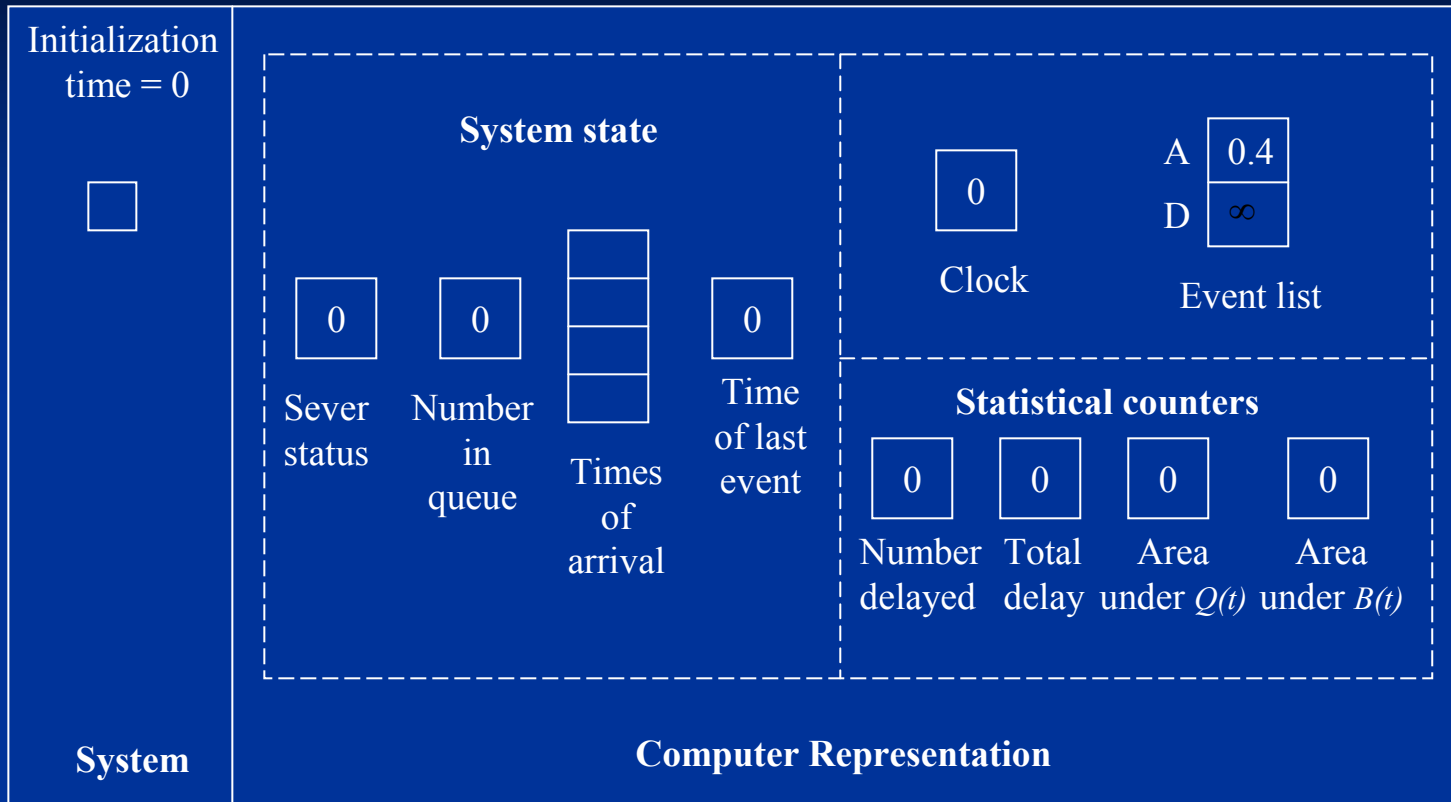


# No. of customers in queue.

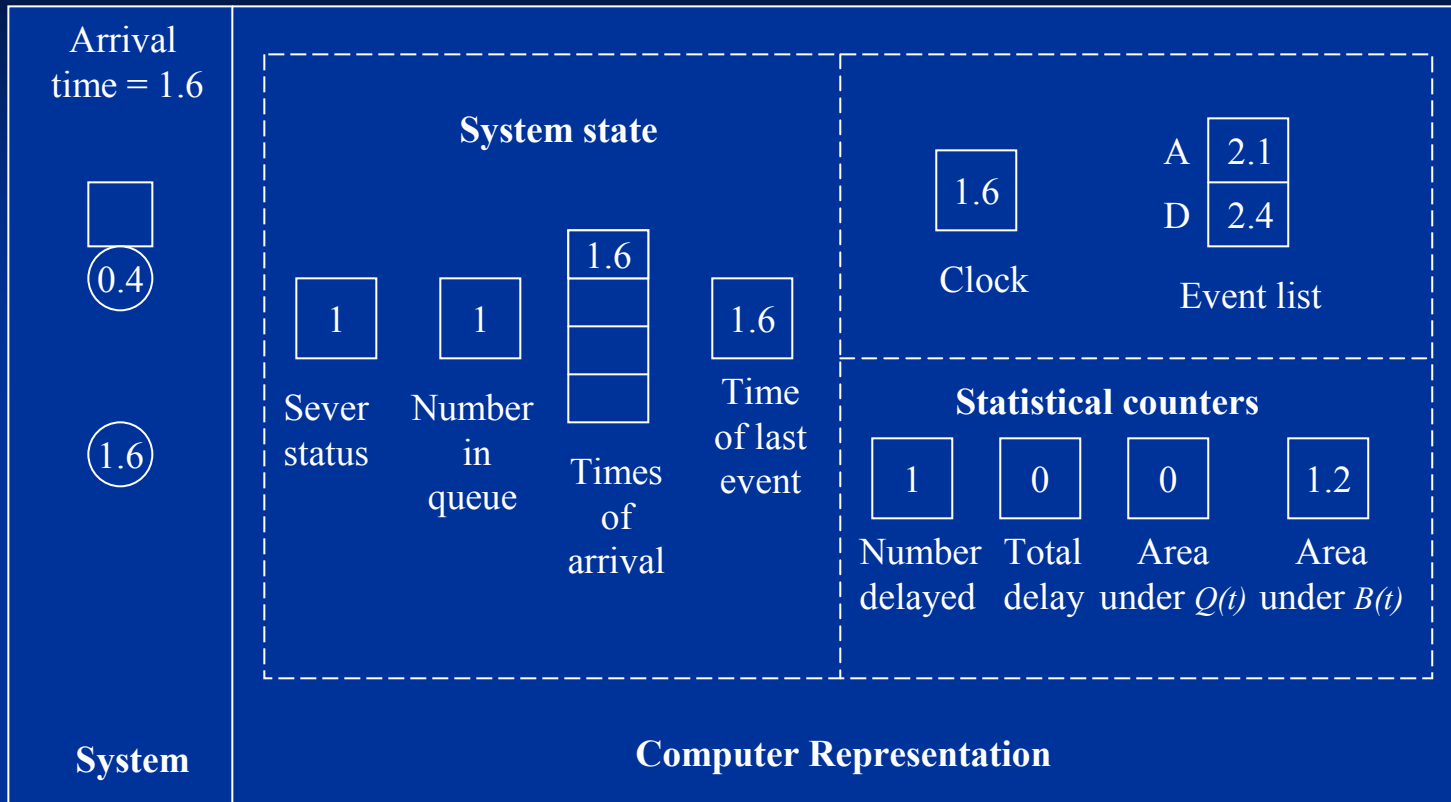


# No. of customers in queue.

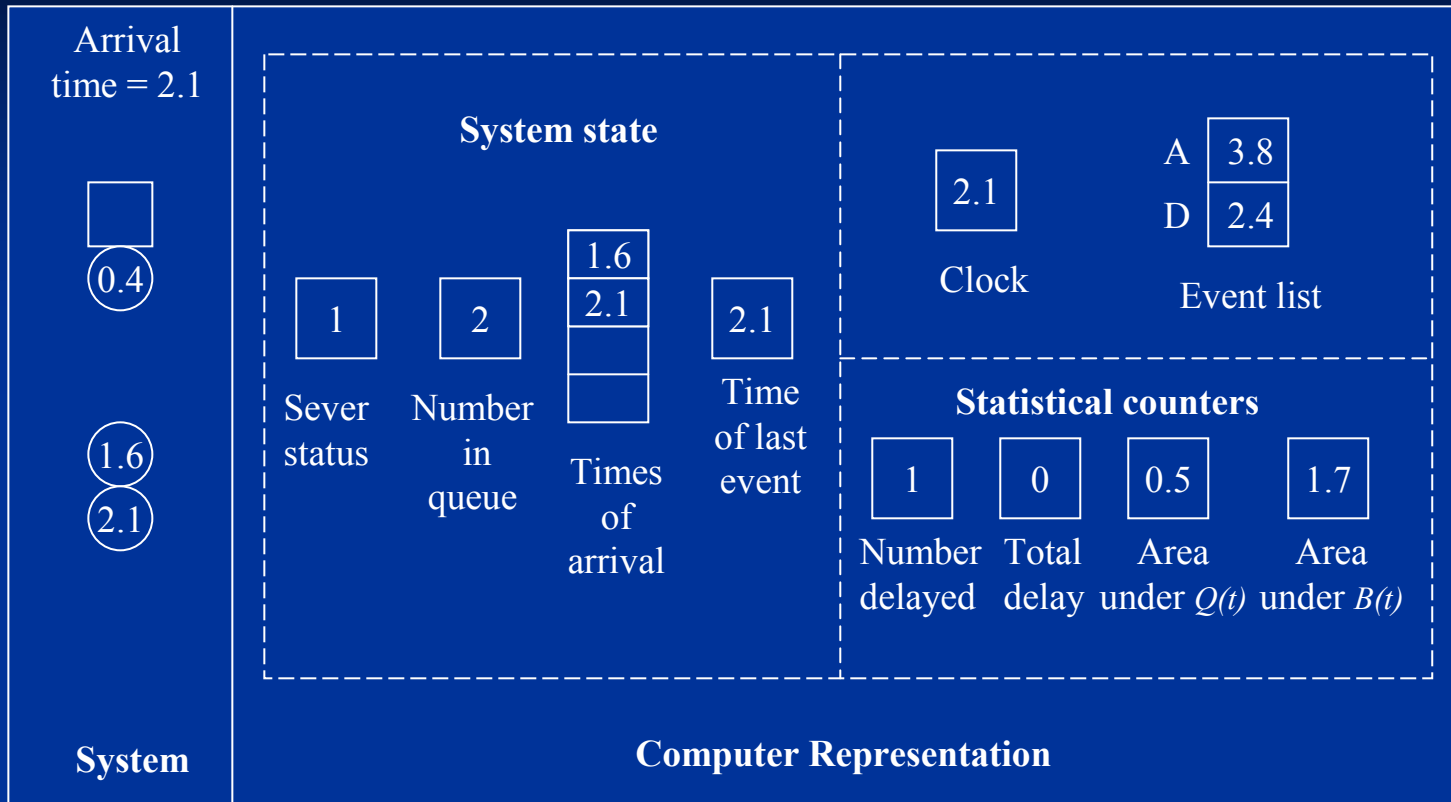




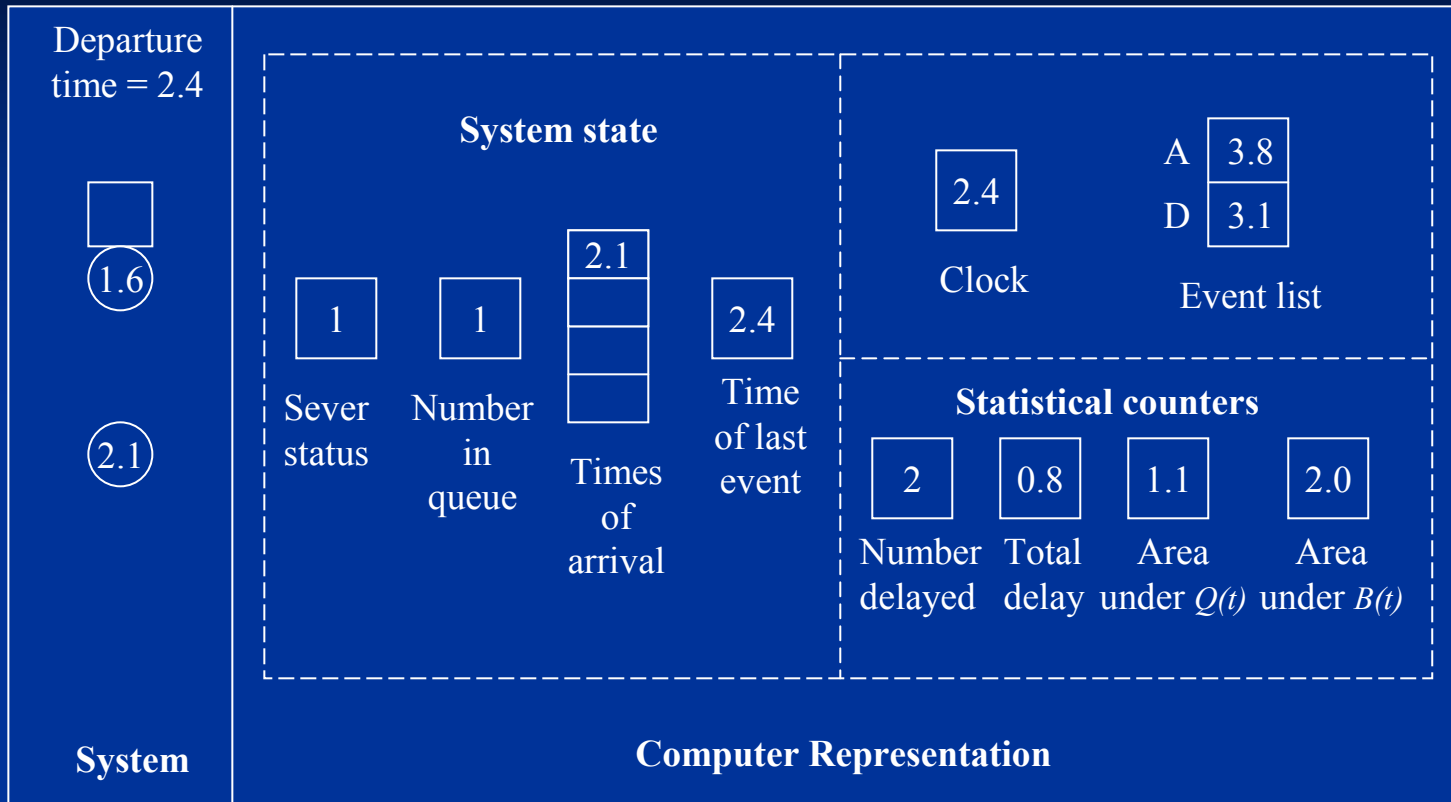
(a)



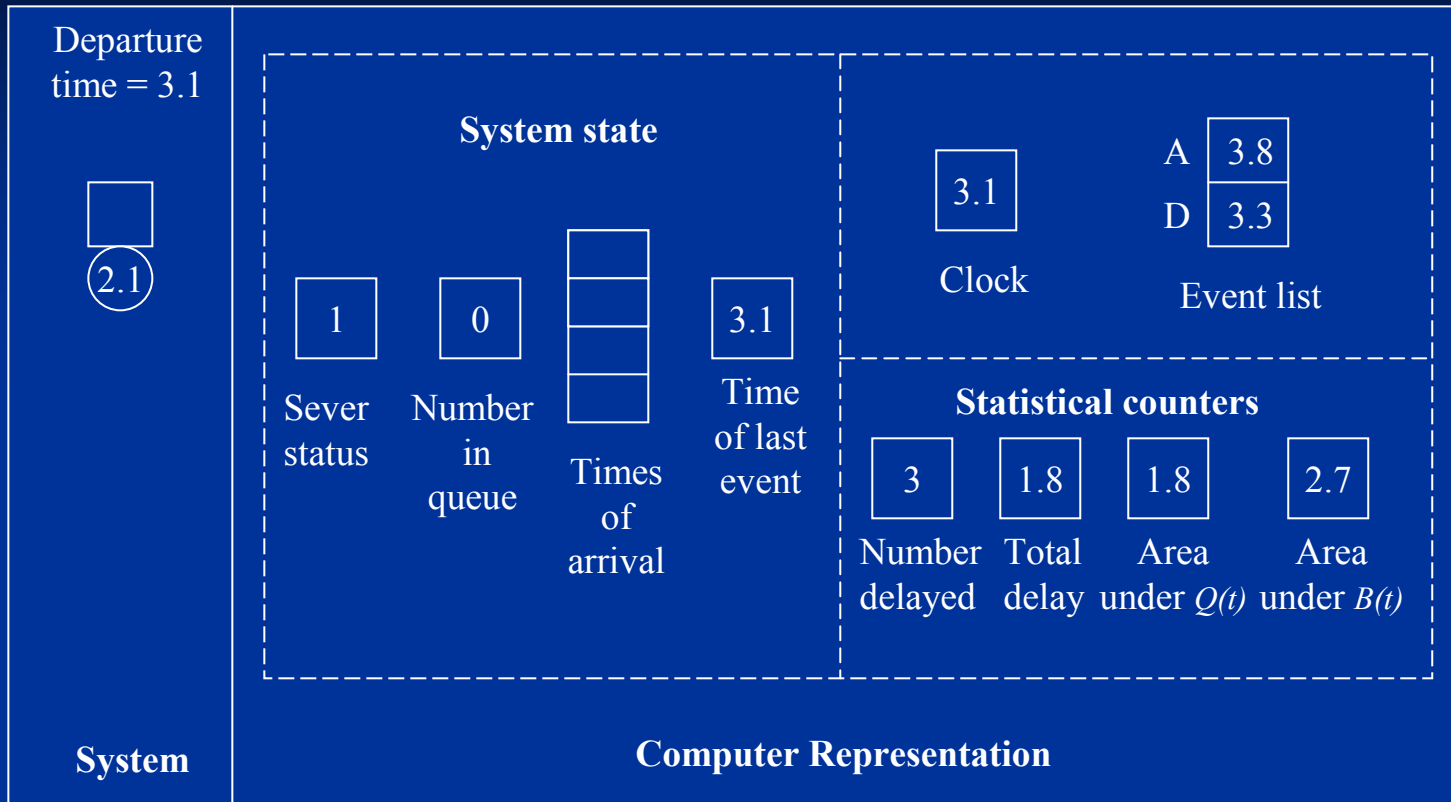
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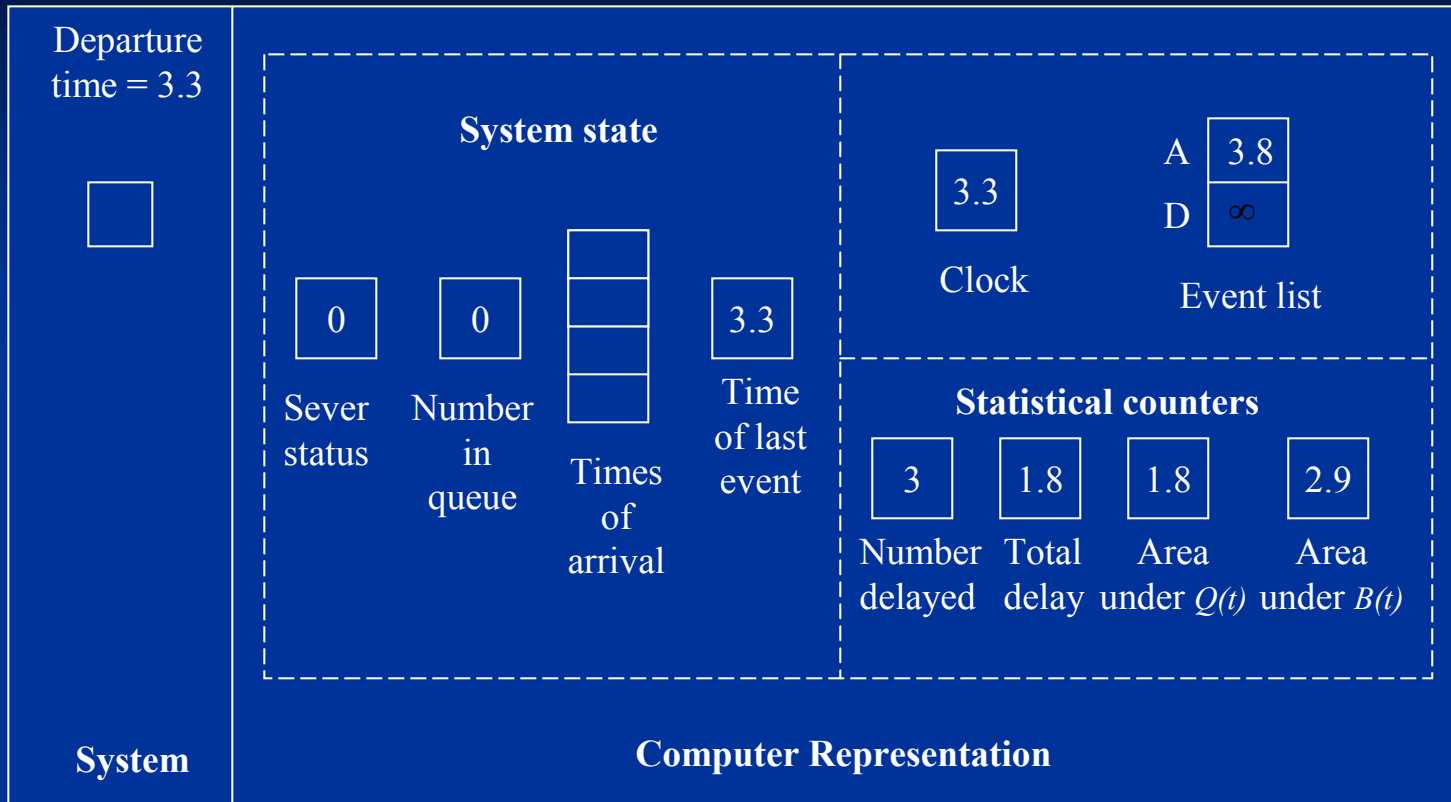
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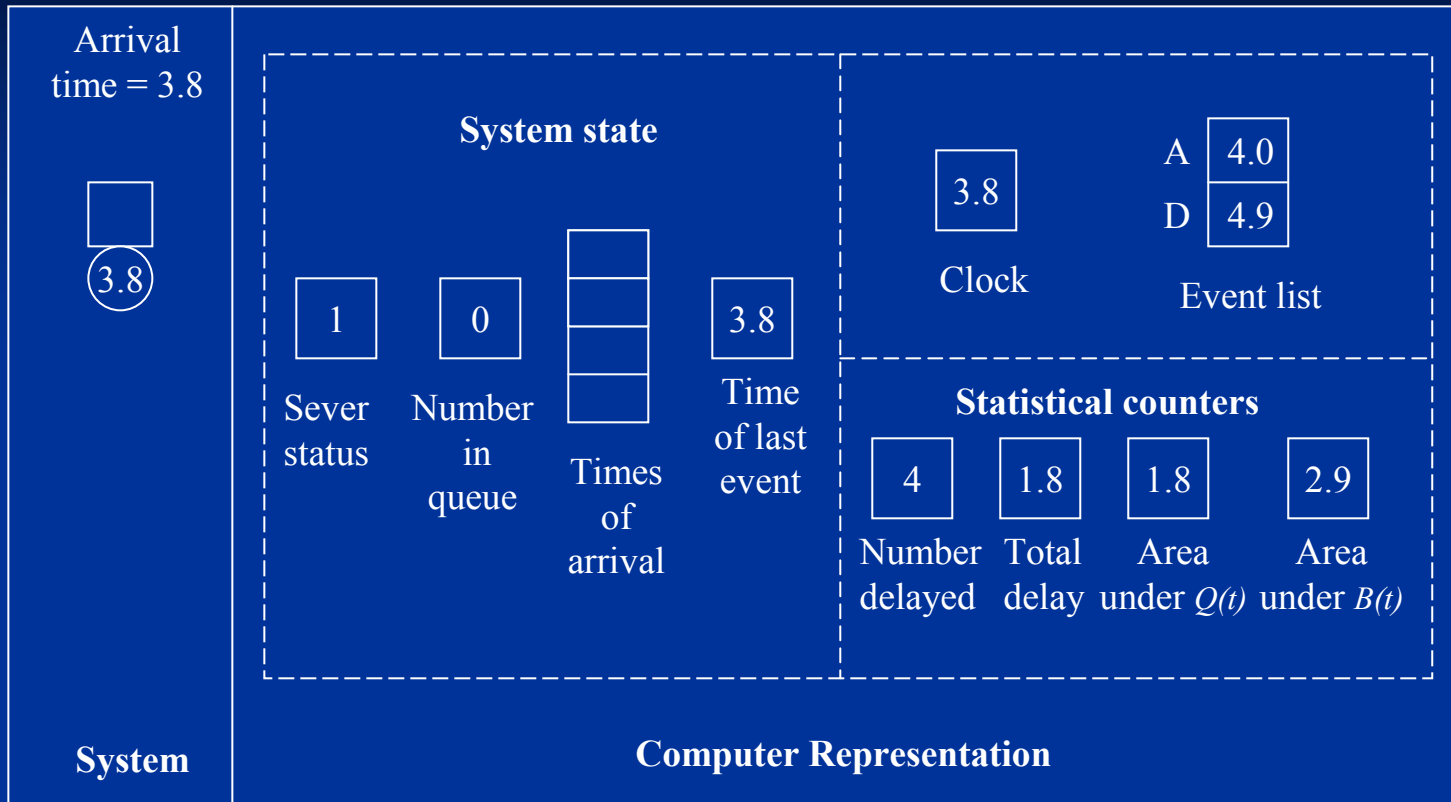
(e)



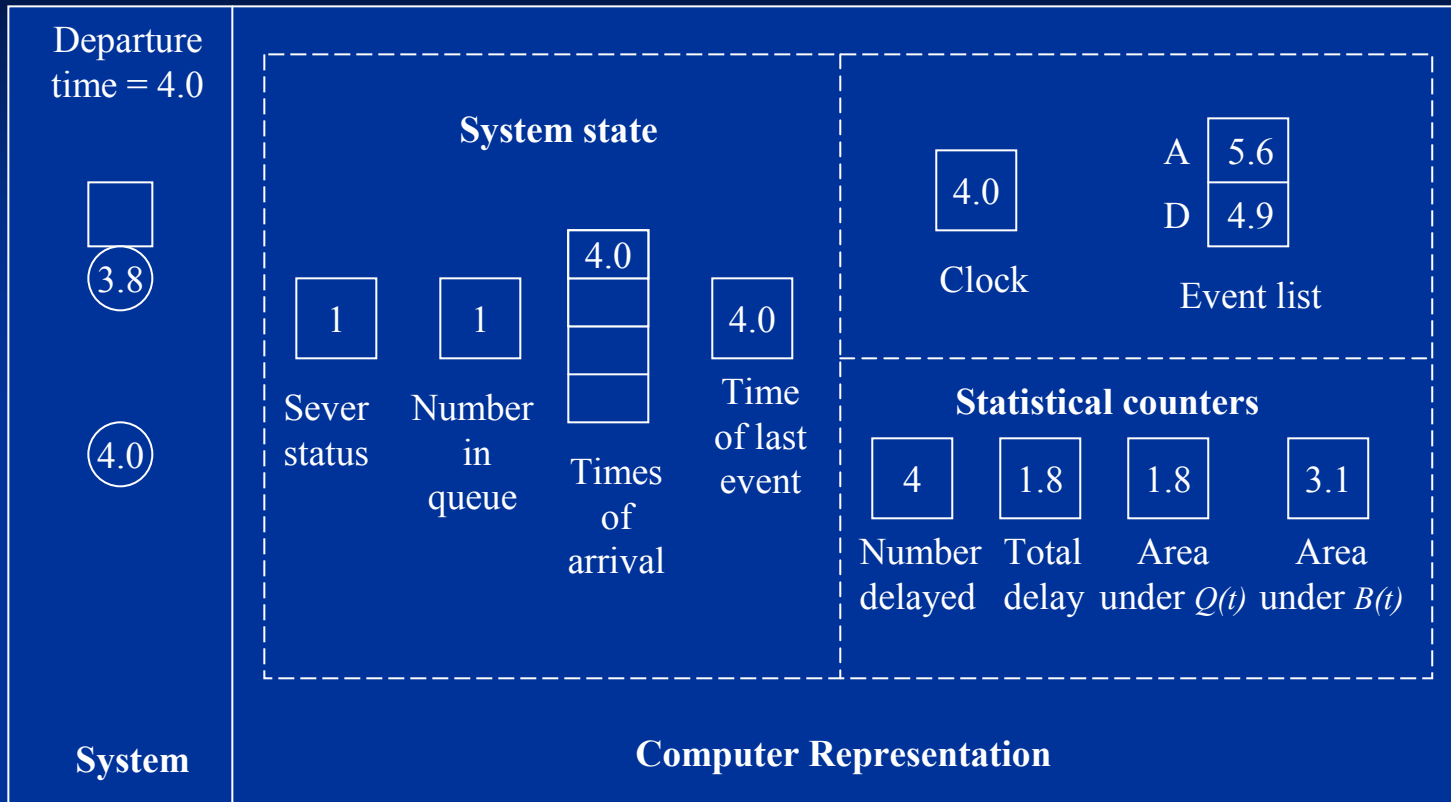
*f)*



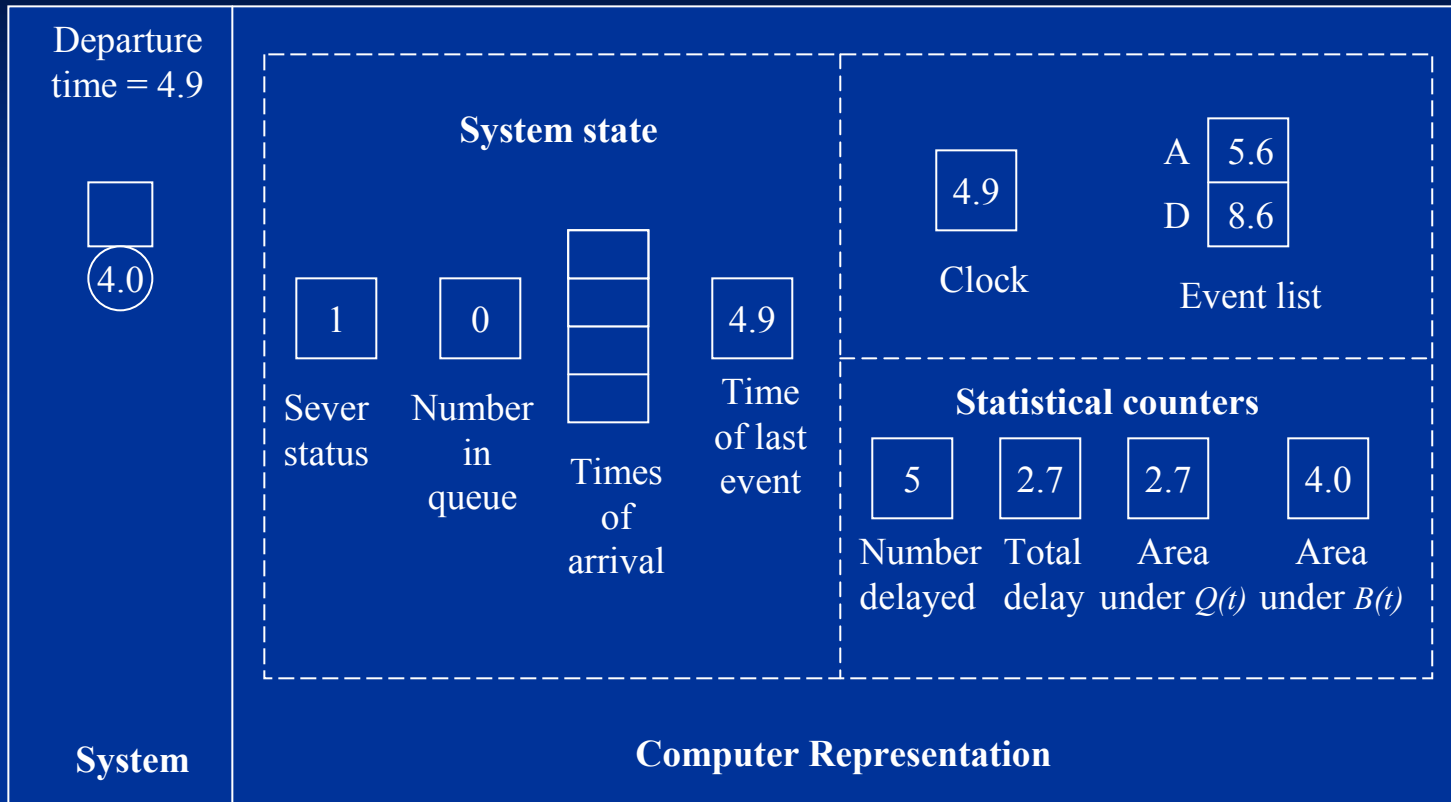
(g)



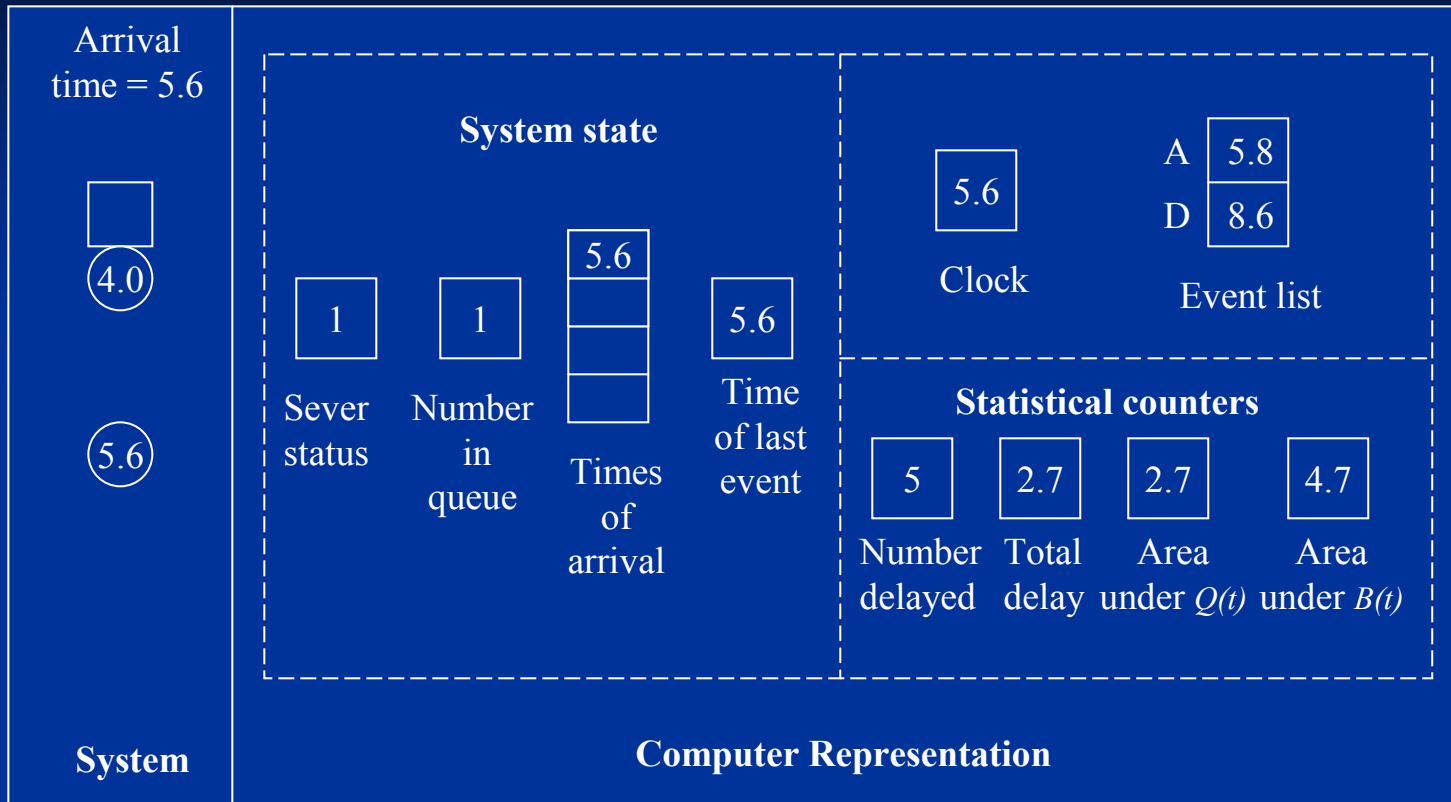
(h)



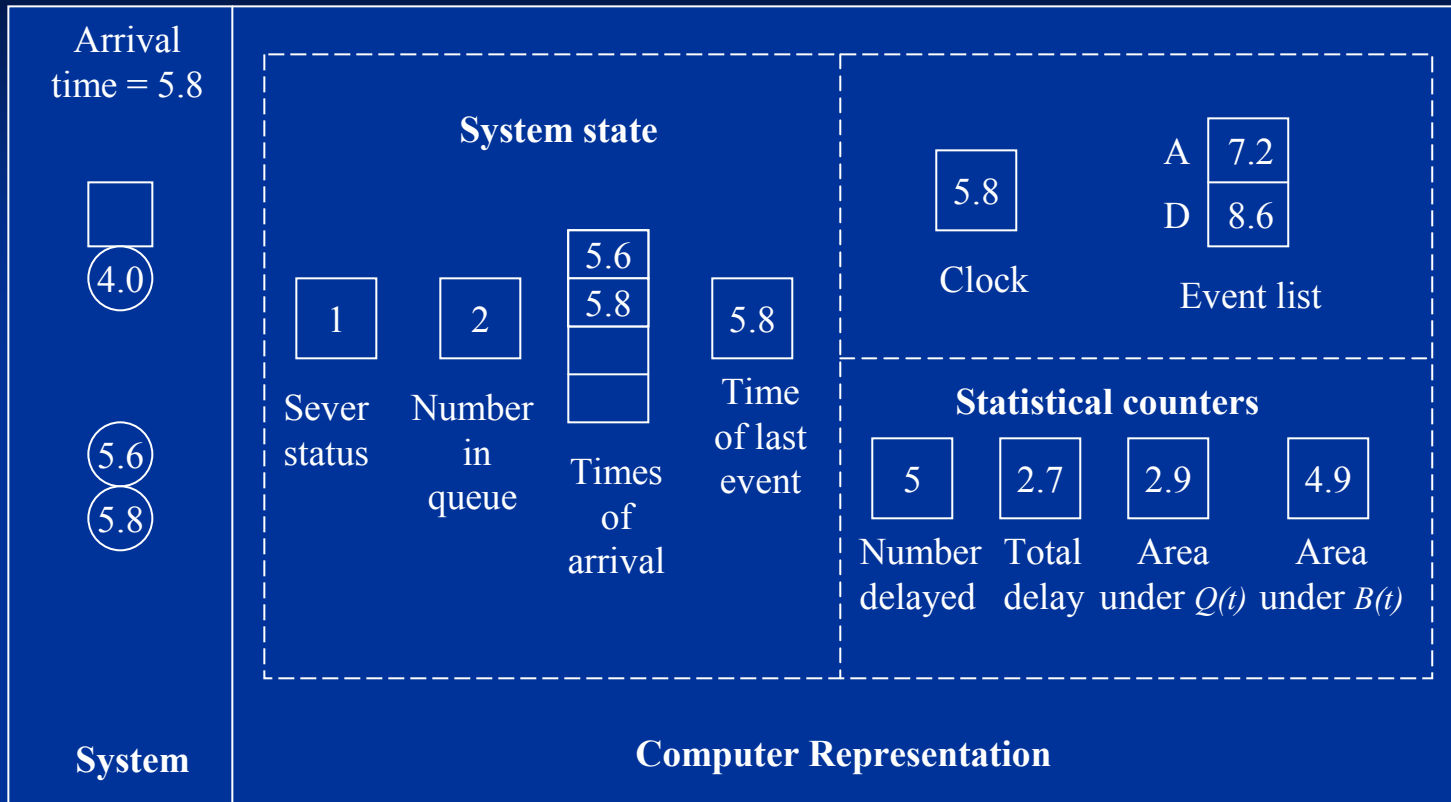
(i)



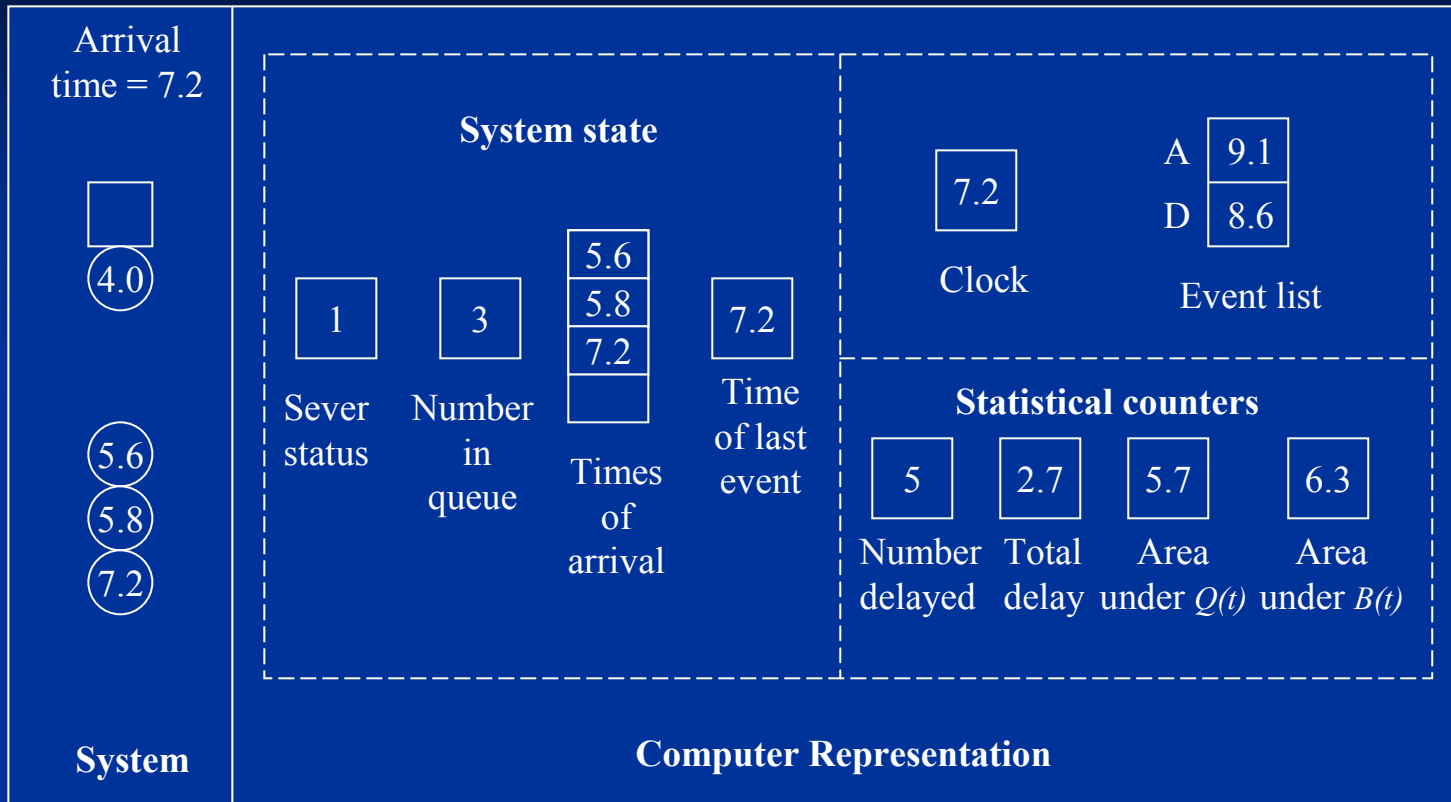
(i)



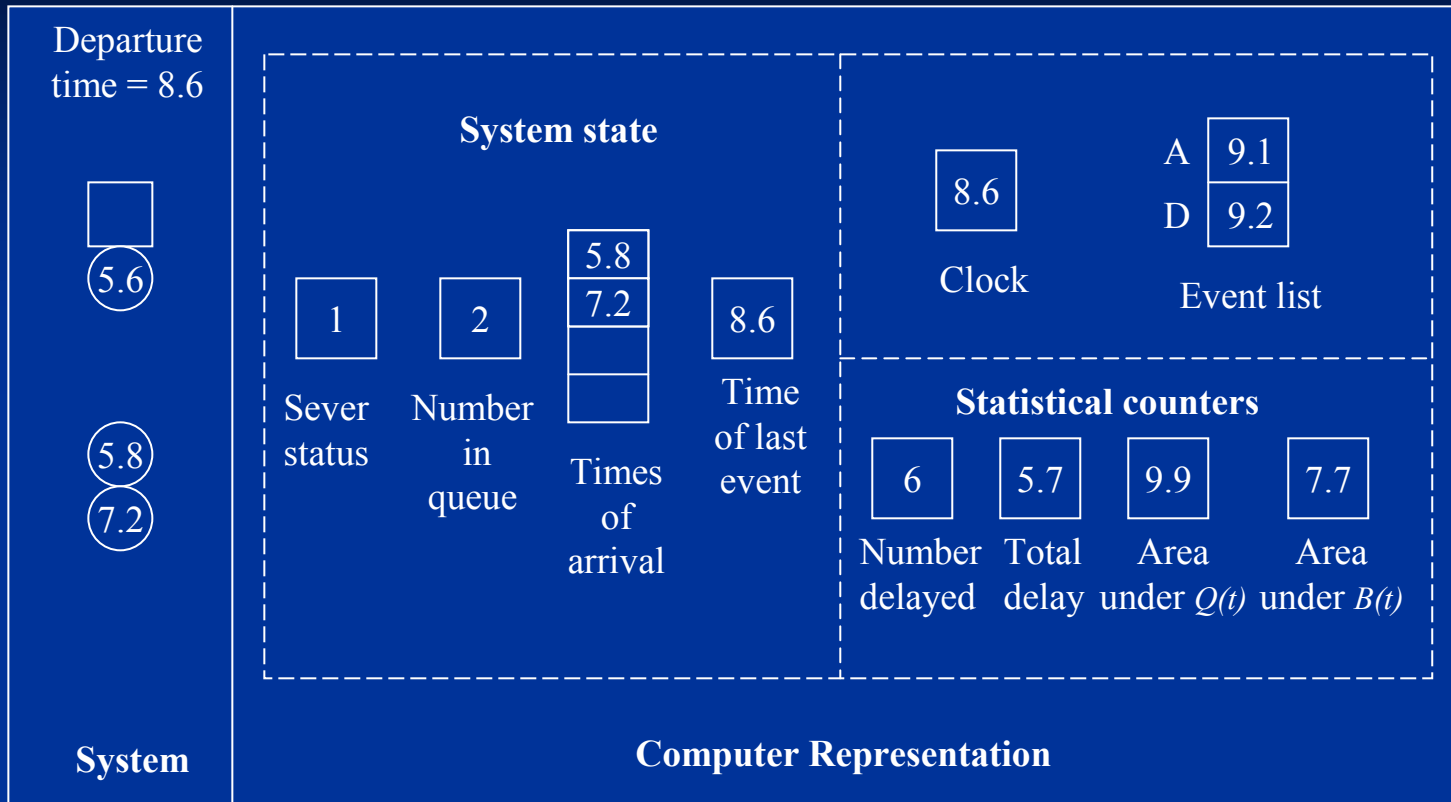
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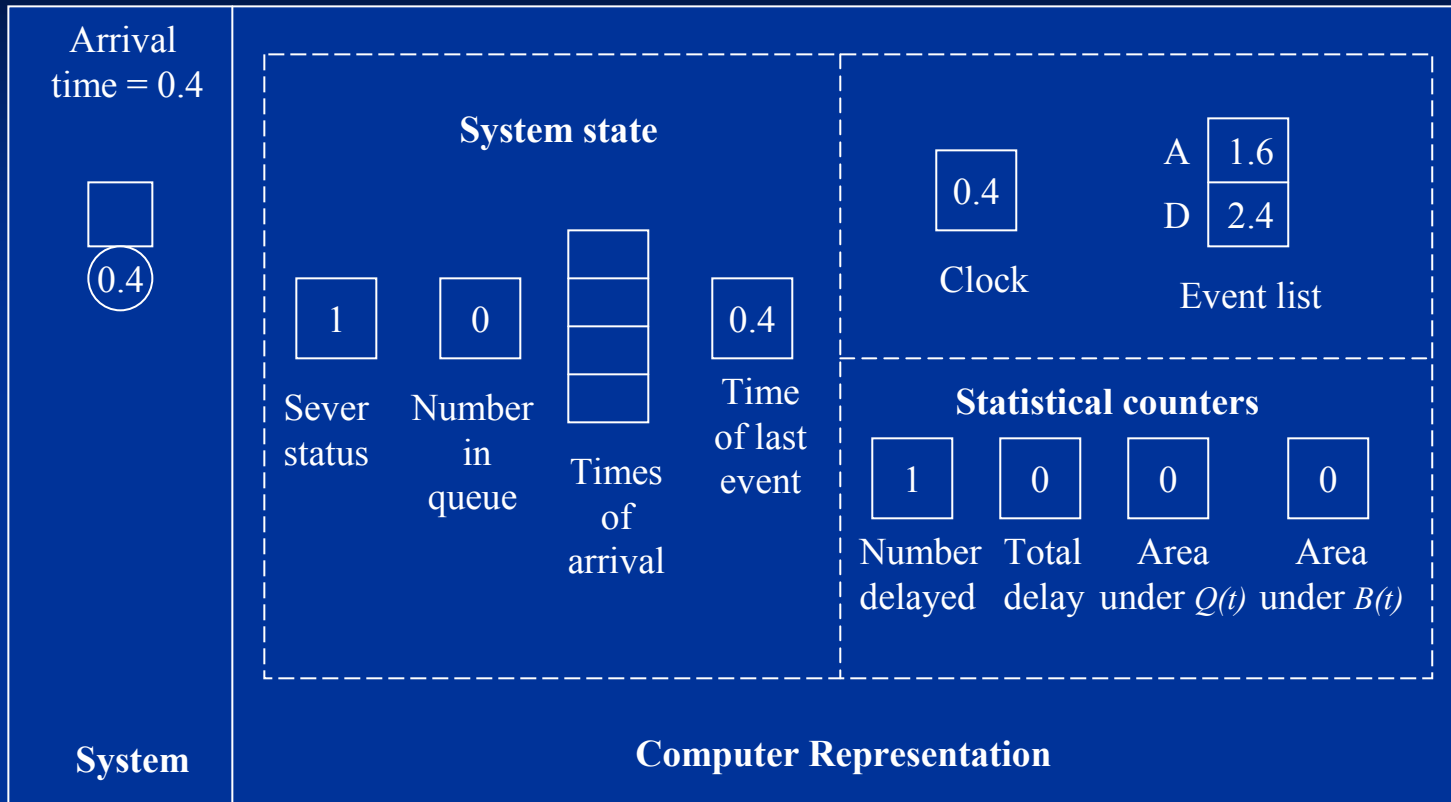
(l)



(m)



(n)



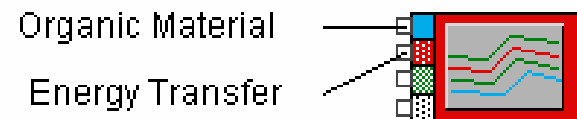
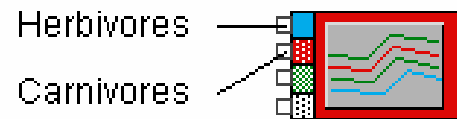
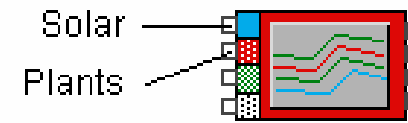
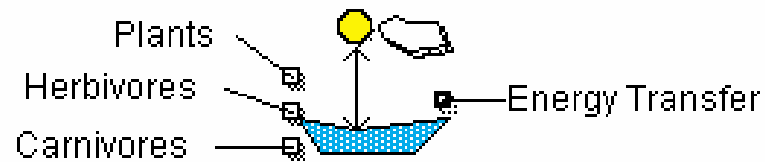
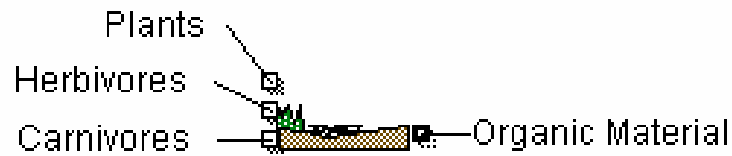
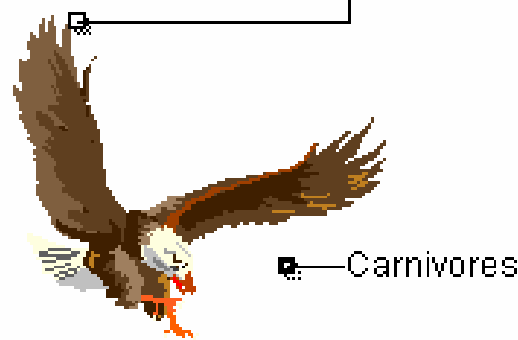
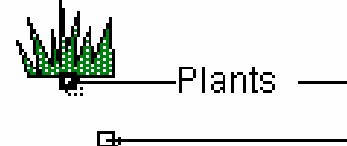
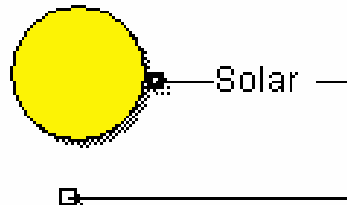
(b)

# Example Systems...

- Extend Demos
  - Eco System
  - Bank Teller System
  - Local Area Network
  - Proof Animation

# Eco System

Season:



# Eco System

Description: This model shows the annual cycles of solar energy, plants, herbivores, carnivores, sediment, and energy transfer to the environment in a lake ecosystem. As you run the model, you should notice the cyclical nature of the solar energy and its effects on the other components.

Particulars: There is a mathematical relationship between each of the system components listed above. The following equations describe this relationship.

$$\text{solar} = 95.9(1.0 + 0.635 \sin(2 \pi \text{time}))$$

$$\frac{d(\text{plants})}{dt} = \text{solar} - 4.03 \text{ plants}$$

$$\frac{d(\text{herbivores})}{dt} = 0.48 \text{ plants} - 17.87 \text{ herbivores}$$

$$\frac{d(\text{carnivores})}{dt} = 4.85 \text{ herbivores} - 4.65 \text{ carnivores}$$

$$\frac{d(\text{organic})}{dt} = 2.55 \text{ plants} + 6.12 \text{ herbivores} + 1.95 \text{ carnivores}$$

$$\frac{d(\text{energy})}{dt} = 1.00 \text{ plants} + 6.90 \text{ herbivores} + 2.70 \text{ carnivores}$$

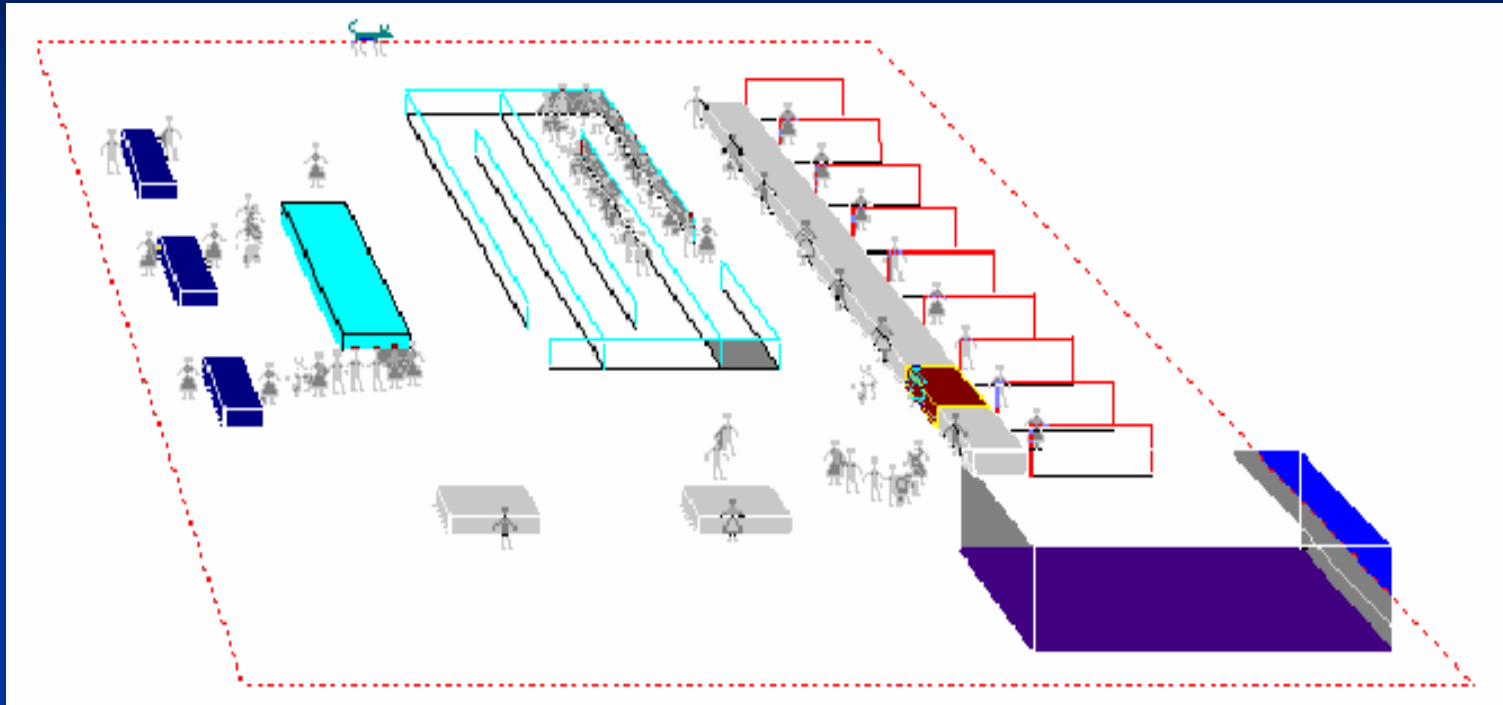
These components are measured in energy content per square centimeter. Hierarchical blocks are used to calculate each one of the above equations. The notebook is used to display the graphs of the various system variables.

Reference:

Pegden, et al, Introduction to Simulation using SIMAN, McGraw-Hill, 1990

Williams, R. B. (1971), Computer Simulation of Energy Flow in Cedar Bog Lake, Minnesota based on Classical studies by Lindeman, in Systems Analysis and Simulation in Ecology, B. C. Patten, Editor, Academic Press.

# Bank Model... *an example*



A bank line is the "classic" discrete event simulation. This example shows the operations of a small bank. Customers require the services of a teller, loan agent, customer service agent, or the bank manager. This bank also has a limited parking lot. If a customer arrives, and the lot is full, the customer will "balk" or not enter the bank.

Try changing the available number of tellers, loan agents, and service agents to see the effect on the queue lengths and the utilization.

# Bank Teller System

Bank operations

Exit

Enter

Customer service

Manager

Tellers

Loans

Copyright (c) 2000 Imagine That, Inc.

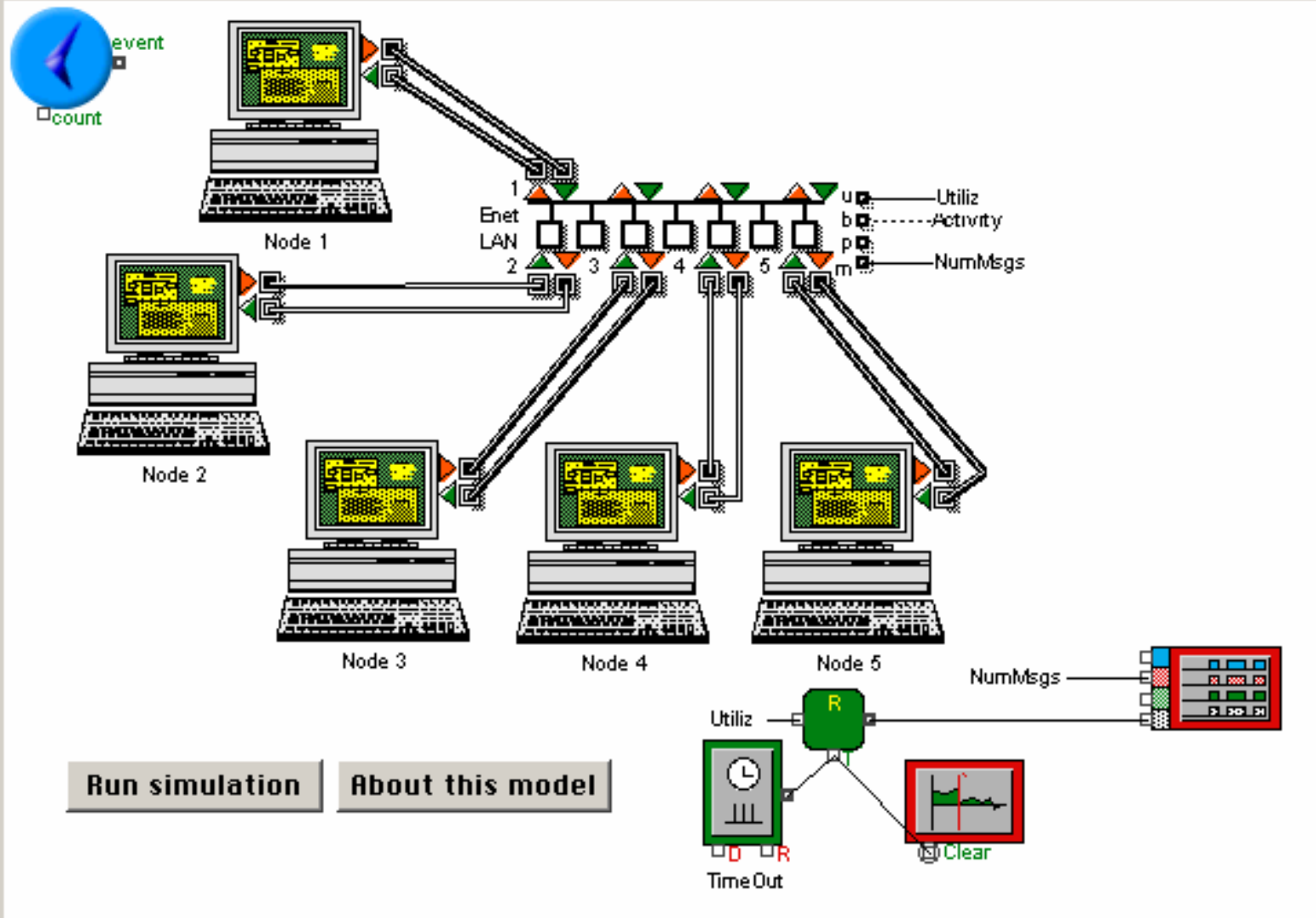
	Available	Max	Utilization
Tellers:	<input type="text" value="3"/>	4	0.8298
Loan agents:	<input type="text" value="2"/>	3	0.702
Service agents:	<input type="text" value="2"/>	2	0

Change these and resume simulation

Run simulation

About this model

# Local Area Network



# Random Generator

- Make sure you can regenerate your random sequence, or debugging is **hell**.
- For long simulations, use 32 bit pseudo random generator. 16 bit is too short!

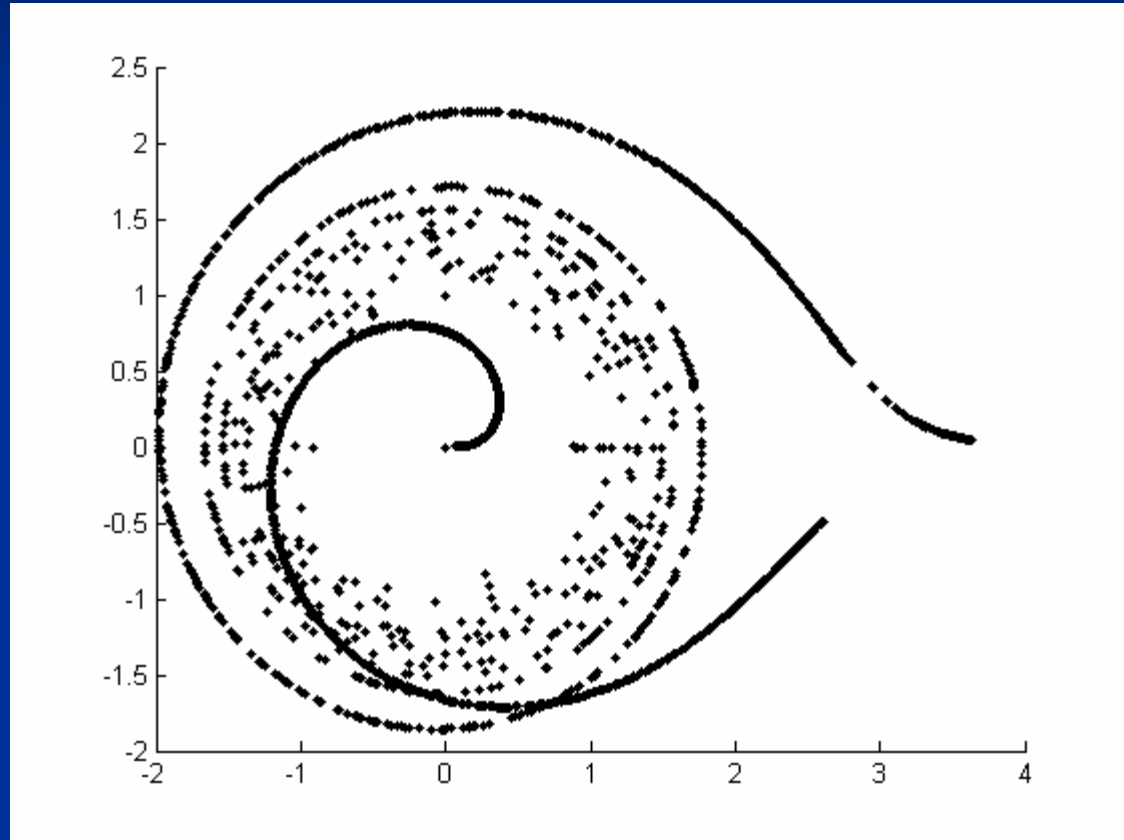
# A good pseudo random generator

```
float myrand()
{
    b32 = (314159269*b32 + 453860245);
    if (b32<0)
        b32 = -b32;
    return(0.00000000046566128730 * b32);
}
```

# Simulation of normal distribution using BOX-MULLER algorithm based on Congruential random number simulation

## MATLAB CODE FOR $XI = (65 * XI-1 + 1) \bmod 2048$

```
n=input(' No Of Iteration ')
seed=input(' Seed Value ')
u1=rand(n,1);
for i=1:n,
    x1i=mod(65 * (seed+1),2048);
    seed=x1i;
    u1i=x1i/n;
    theta=2*pi*u1i;
    u2i=1-u1i;
    E2i=-log(u2i);
    r=sqrt(2*E2i);
    x=r*cos(theta);
    y=r*sin(theta);
    xt(i)=x;
    yt(i)=y;
    xtt=xt';
    ytt=yt';
    hold on;
    plot(xtt,ytt,'p')
end
```



## “SIMULATION & MODELLING LABS”

Professor. Dr. S.M. Aqil Burney, Department of Computer Science, University of Karachi

## Important Steps in Building a Simulation Model

1. Define an achievable goal
2. Create a diverse team with different skills

### Skills Needed:

- Knowledge of system
- Model building
- Data collection
- Statistical (input/output data representation)
- Managerial.

3. Model the appropriate level(s) of detail

- Define boundaries of the system,
- Some characteristics of the environment may need to be included
- Control tendency to model in great detail well understood parts of the system
- Neglecting less known parts .

## **Important Steps in Building a Simulation Model**

4. Develop a plan for model verification

5. Develop a plan for model validation

Insure the model represents the system under investigation

6. Develop a plan for statistical output analysis

# Advantages of Simulation

- Most complex, real-world systems with stochastic elements cannot be accurately described by a mathematical model that can be evaluated analytically. Thus, a simulation is often the only type of investigation possible.
- Simulation allows one to estimate the performance of an existing system under some projected set of operating conditions.
- Alternative proposed system designs (or alternative operating policies for a single system) can be compared via simulation to see which best meets a specified requirement.

# Advantages of Simulation

- In a simulation we can maintain much better control over experimental conditions than would generally be possible when experimenting with the system itself.
- Simulation allows us to study a system with a long time frame--- e.g. an economic system---in compressed time, or alternatively to study the detailed workings of a system in expanded time.

# Disadvantages of Simulation

- Each run of a stochastic simulation model produces only estimates of a model's true characteristics for a particular set of input parameters. If a "valid" analytic model is available or can be easily developed, it will generally be preferable to a simulation model.
- Simulation models are often expensive and time-consuming to develop.
- If a model is not a "valid" representation of a system under study, the simulation results, no matter how impressive they appear, will provide little useful information about the actual system.

# Disadvantages of Simulation

- In some studies both simulation and analytic models might be useful. In particular, simulation can be used to check the validity of assumptions needed in an analytic mode.
- On the other hand, an analytic model can suggest reasonable alternatives to investigate in a simulation study.

## Software Packages (Tools) for simulation

- **C++ Libraries:**
- **SimKit:** For discrete Events Simulations
- **Dex:** Dynamic Experimentation Tool Kit used for dynamic multi-body simulation
- **Labview:** It Enables interfacing with various laboratory devices
- **SIGMA:** It provides graphical simulation environment
- **Matlab & SIMULINK:** These are leading languages for technical computing
- **FLASH**
- **Professional Visio**
- **Dream weaver**

# Books on Modelling & Simulation

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*Questions...?*