Chapter 4
Discrete System Simulation

Prepared By:
Assoc. Prof. Sundar Kunwar
Department of Computer Science and Engineering
Nepal Engineering College

Discrete Event Simulation

- A number used to represent some aspect of the system is called a **state descriptor.**
  - Eg:- no of pages in book, flag value either 0 or 1 and so on.
- Discrete system is a system in which the changes are instantaneous.
- As simulation proceeds, **the state descriptors** change value.
- Each change in the state of system is called as an **event.**
  - For Example, **arrival or departure of a customer in a queue is an event.**
- The simulation of a discrete system is referred to as **discrete event simulation.**

Discrete Event Simulation

- **Applications of discrete event simulation:**
  - It is used by operation research workers to study large complex systems which cannot be studied by analytical method.
  - In inventory control.
  - Study of sea and airport.
  - Steel melting stuffs.
  - Telephone exchanges.
  - Production line.
  - Project scheduling etc.

Representation of time

- There are two different models for moving a discrete system through time.
  - Fixed time step model or **interval oriented model**
  - Event to event(next event) model or **event oriented model**

Fixed time step model v/s next event model:

  - In a fixed time step model a timer or clock is simulated by the computer.
  - This clock is updated by a fixed time interval ꭕ and the system is examine to see if any event has taken place during this time interval.

Representation of time..

In **the next event simulation model**, the computer advances time to the occurrence of the next event. It shifts from event to event.

- The system does not change in between only those points in time are kept track when something of interest happens to the system.

Generation of Arrival Pattern

- Generation of arrival patterns can be done in following two methods:-
- **Trace driven simulation:**
  - Here the sequence of inputs are generated from observations of a running system.
  - Programs monitors are attached to the running system to extract the data with little or no disturbances of the system operation.

Generation of Arrival Pattern..

- **Bootstrapping:**
  - Here the arrival time of the next entity is immediately calculated from the inter-arrival time distribution.
  - The term bootstrapping is used to describe this process of making one entity create its successor.
  - The method requires keeping only the arrival time of the next entity.
  - It is the most preferred method of generating arrival through computer simulation program.

Simulation of Telephone System

- The System has a number of Telephone connecting to a switch board by lines.
- A switch has a number of links which can be used to connect any two lines subject to the condition that only one connecting at a time can be made to each line.
- It assume that it lost call system. A call may be lost because no link is available it is called as a lost call.
- The object of the simulation is to process a given number of calls and determine what proportion are successfully completed block or busy.

- The current state of the system is that lne-2 is connected to line-5 and a line-4 is connected to line-7.
- Each line is treated as an entity and it's availability is an attribute a table of numbers is establish which show the current status of each line.
- A zero in the table means the line is free and where 1 means it is busy.

Simulation of Telephone System

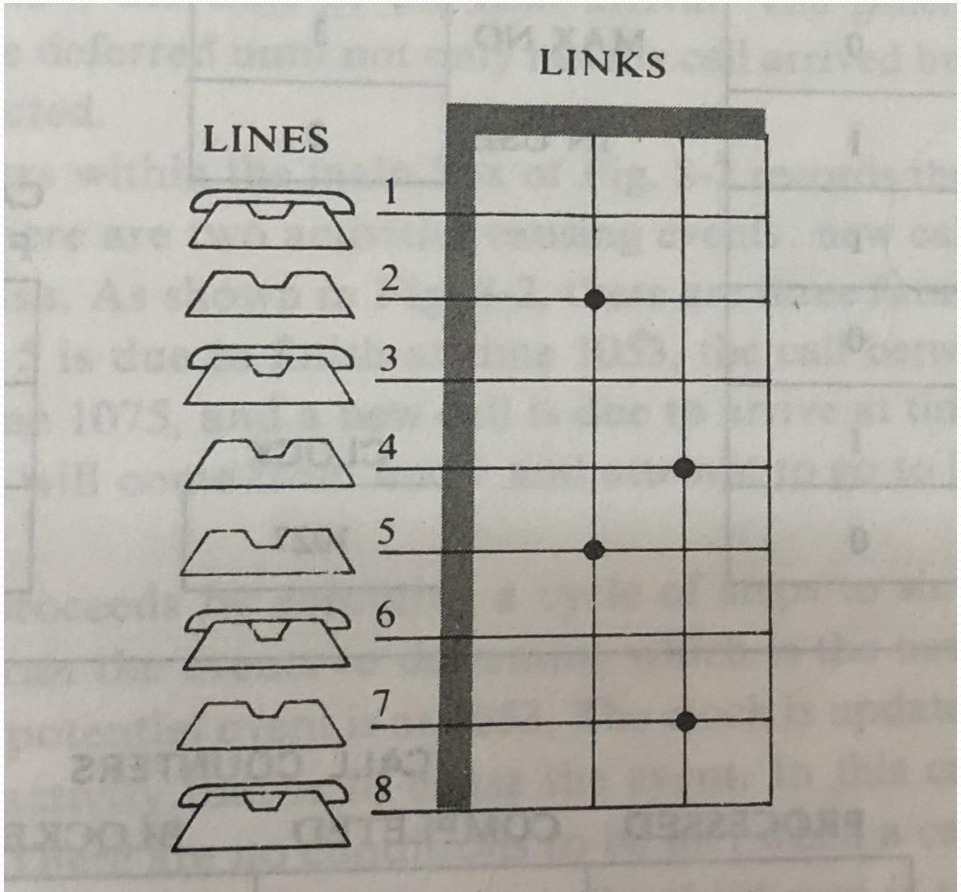


Figure 8-1. Simple telephone system.

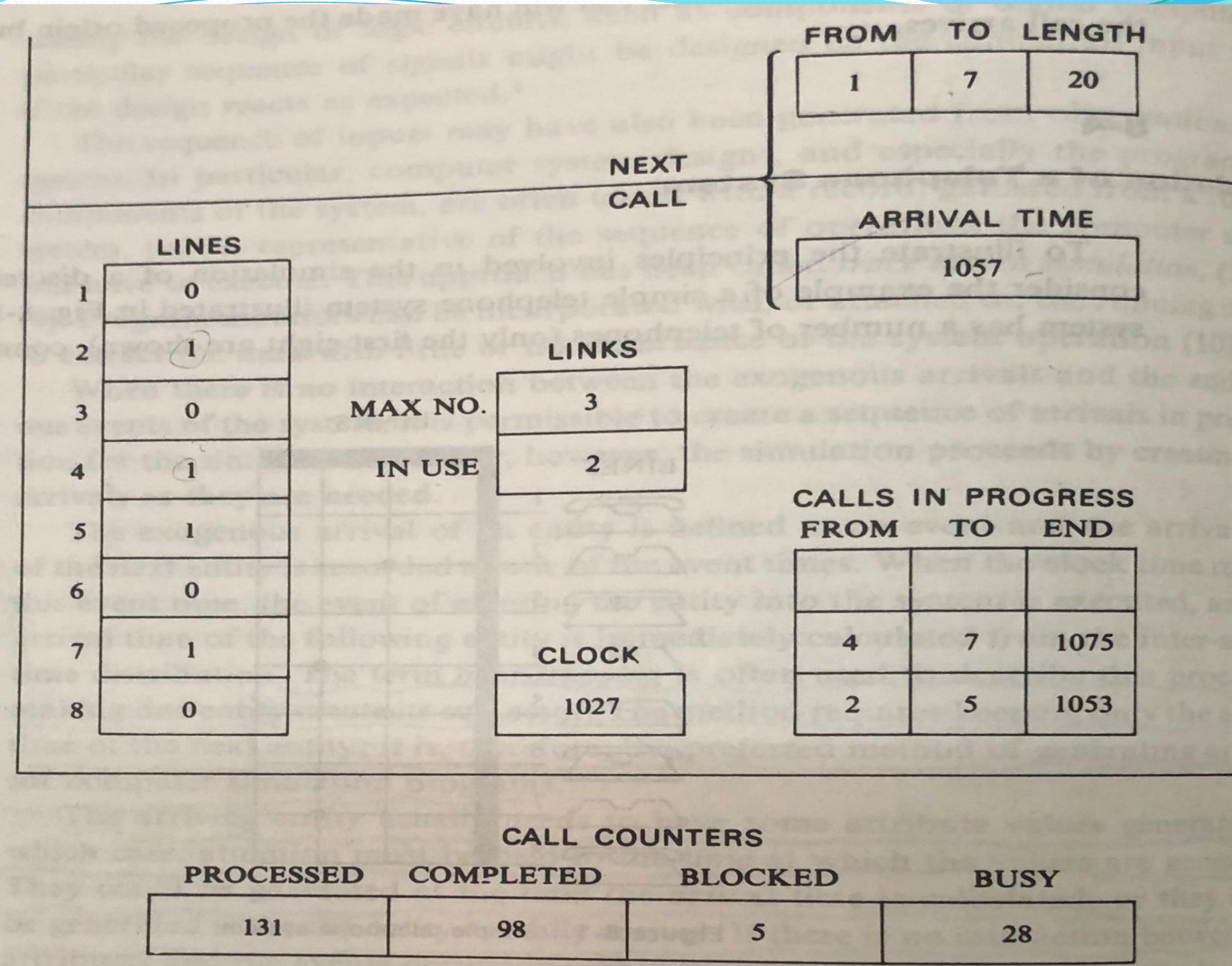


Figure 8-2. System state-1.

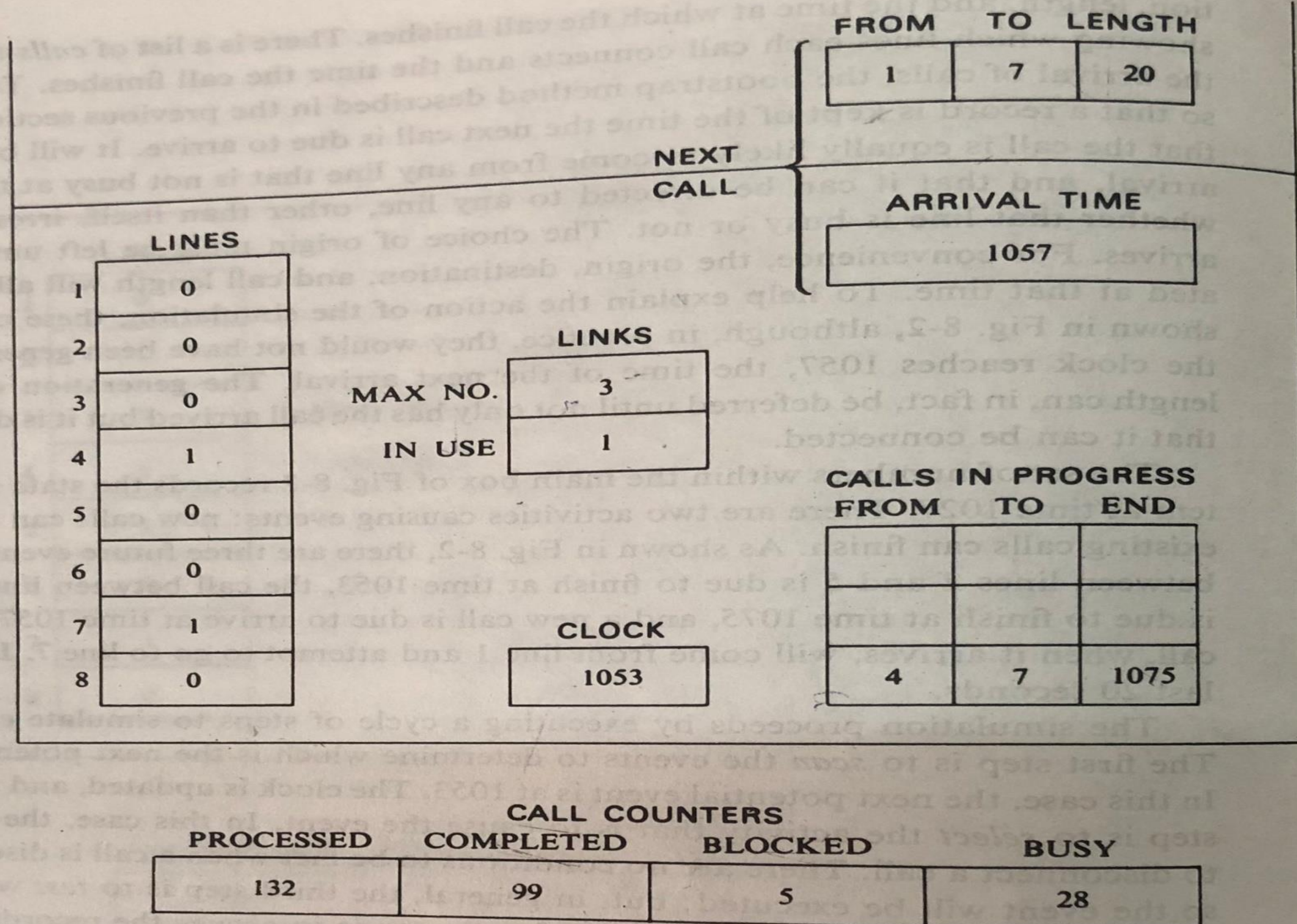


Figure 8-3. System state-2.

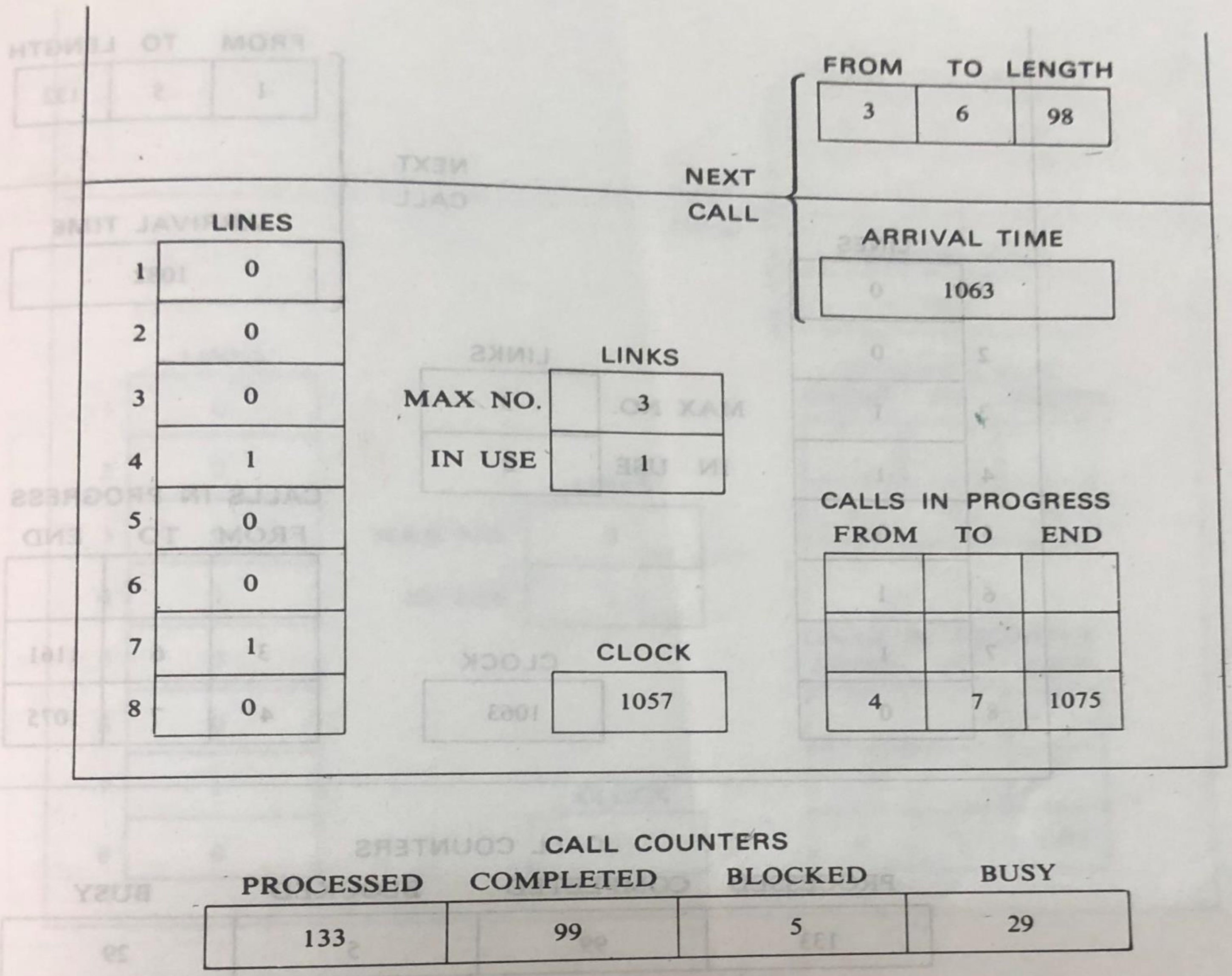


Figure 8-4. System state-3.

Simulation of Telephone System..

- To keep track of event the number of representing currently the clock time 5 1027.
- The unit of time is taken to be in second. There is a list of call in progress showing which line call is connected and the time each call finishes.
- The arrival of call is generated by the boot strapping technique.
- There are 2 activities causing event.

    1. New calls can arrive
    2. Existing calls can finish

Simulation of Telephone System..

- There are 3-future events :
  - • The call between lines 2 and 5 is due to finish at time 1053.
  - • The call between line 4 and 7 is due to finish at time 1075.
  - • A new call is due to arrive at time 1057.

The simulation proceeds by exhibiting a cycle of state to simulate each event.

Steps:- 1. Find the next potential event.

2. Select an activity.

3. Test if the event can be executed.

4. Change the system event.

5. Gather statistics.

The simulation will be run until a given number of calls have been processed or until the simulation time has elapsed.

Simulation of Telephone System..

- Delayed Call
  - Suppose the telephone system is modified so that cannot be connected are not loosed instead the wait until they can be connected, they have called as delayed calls.
  - To keep records of these delayed calls a delayed call list is made.
  - When a call completely ends, it is necessary to check the delayed call list to see if a waiting call can be connected.

Gathering statistics

- The statistics of interested variables has to be gathered during simulation and the selection variables depend on the nature of our simulation studies.
- For example
  - **Counts,**
  - **Summary measures,**
  - **Utilization, Occupancy**
  - **Transit times etc.**

Gathering statistics

- **Counts:**
  - are number of entities or events. e.g. No. of devices, No. of links, Blocked call events etc.
- **Summary measures:**
  - Extreme values, Mean and standard deviations etc. For example Maximum links in telephone system.
- **Utilization:**
  - Fraction or percentage of time that some entities get engaged.
- **Occupancy: -**
  - Links available to use. - Fractions or percentage of a group of entities on average.
- **Distribution:**
  - Distribution of important values, such as waiting time in SSQM.
- **Transit time:**
  - Time taken for an entity to move from one part of the system to the other part.

Counter and Summary statistics

– Counters are the basis for most statistics.

– Counters are used to accumulate totals or recorded current values of some level. In Telephone System Simulation (TSS),

Examples:

(a) Maxima/Minima

– Whenever new value is generated, it can be compared with the maxima or minima. If the generated value is new maxima/minima, the previous record have to be changed.

(b) Mean

$$Mean\ (m) = \frac{1}{N} \sum_{r=1}^{N} X_r$$

Where, N is the total number of observations and X_r is the r^{th} observed value.

(c) Standard deviation (from mean)

$$\sigma = \left[\frac{1}{N-1} \sum_{r=1}^{N} (m - X_r)^2 \right]^{\frac{1}{2}}$$

Measuring utilization and occupancy

- Utilization is a statistics that gives a measure of the load on some entity (Variables).
- For example, in TSS what fraction of item i.e. individual line was engaged or busy during the simulation run.
- In single server queuing model, the server utilization i.e. the proportion of time the server is busy.

Let, a line becomes busy at time t_b and becomes free at time t_f where $t_f < t_b$, then the interval $t_f - t_b$ is added to a counter. By the end of simulation run, we can

calculate the utilization (U) using the ratio of accumulated total to the total time (T) i.e.

$$U = \frac{1}{T}\sum_{r=1}^{N}\left(t_f - t_b\right)_r$$

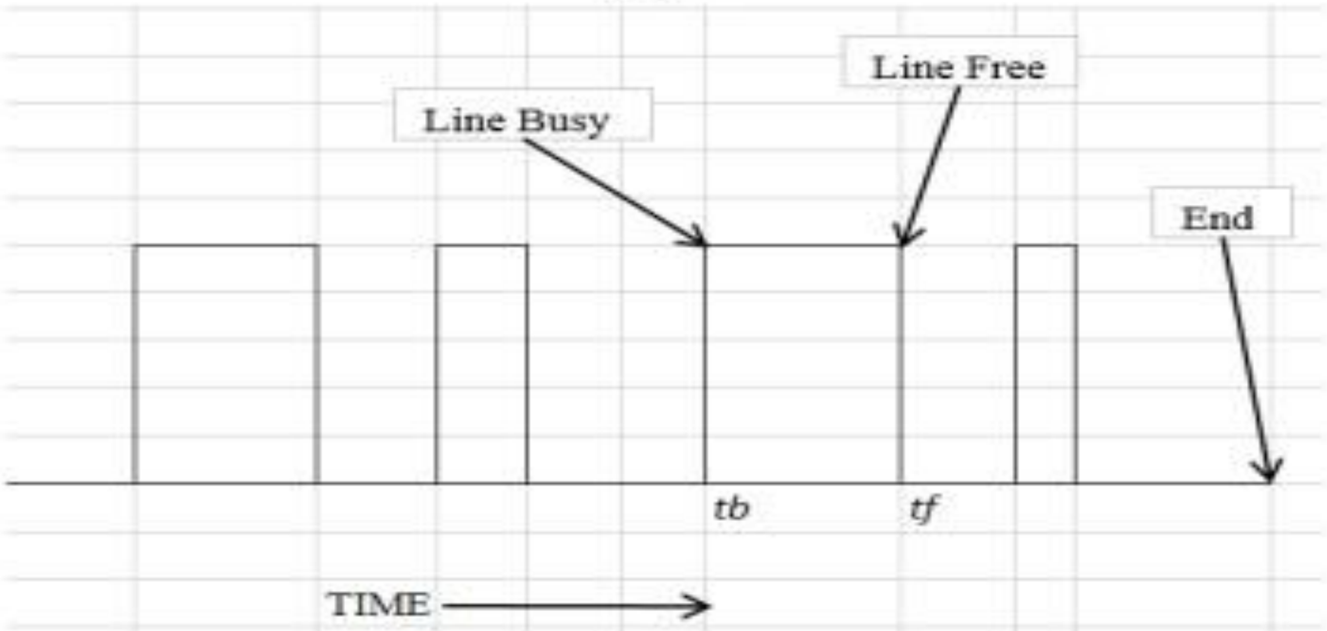


Fig. Utilization of a link in TSS

Furthermore, among m number of links, we may be interested to calculate the average number of links in use. To obtain this, we must have to keep records of currently busy links and the time when it get changed. If the busy number changes at time t_r to the value n_r then, at the time of the next change t_{r+1}, the quantity $n_r(t_{r+1} - t_r)$ must be calculated and added to the accumulated total. The average number in use (A) then calculated over the period T is calculated from:

$$A = \frac{1}{T}\sum_{r=1}^{N} n_r\left(t_{r+1} - t_r\right)$$

Recording distribution and Transit

After recording simulation statistics, we may be interested in finding the distribution of concerned variables from their counts i.e. how many times the value of the variable falls within the specified class or intervals. To obtain this, we need to accumulate the count of the variables in predefined intervals. This is done by adding 1 to the count of its interval at every new observation.

Normally, some uniform intervals are defined and tabulated with the following specifications:

(a) The lower limit of tabulation
(b) The interval size
(c) The number of intervals

The above terms are illustrated in the following diagram.

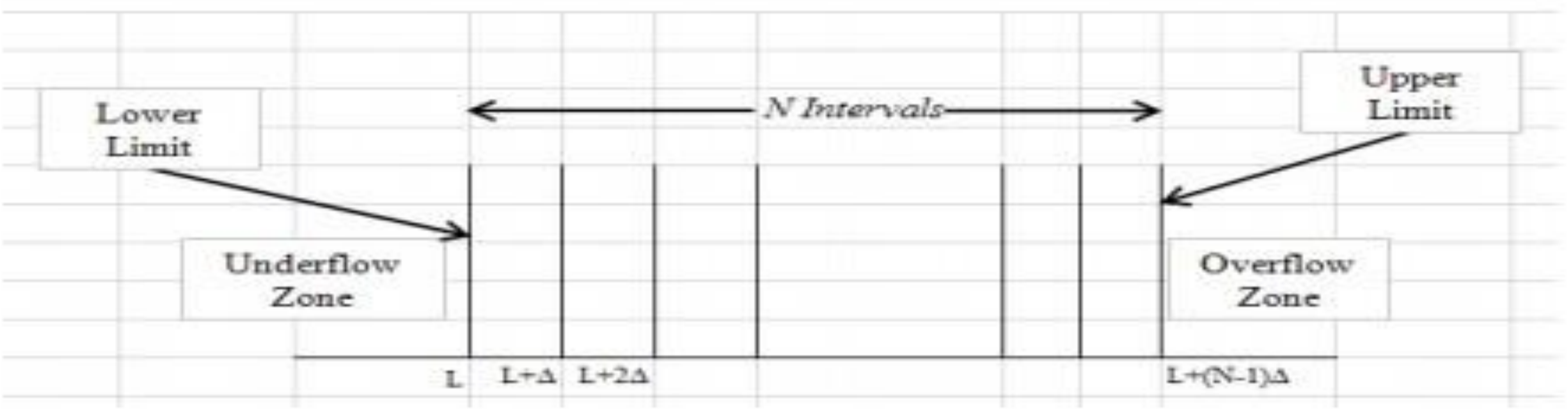


Fig. Definition of distribution table

Discrete Simulation Language

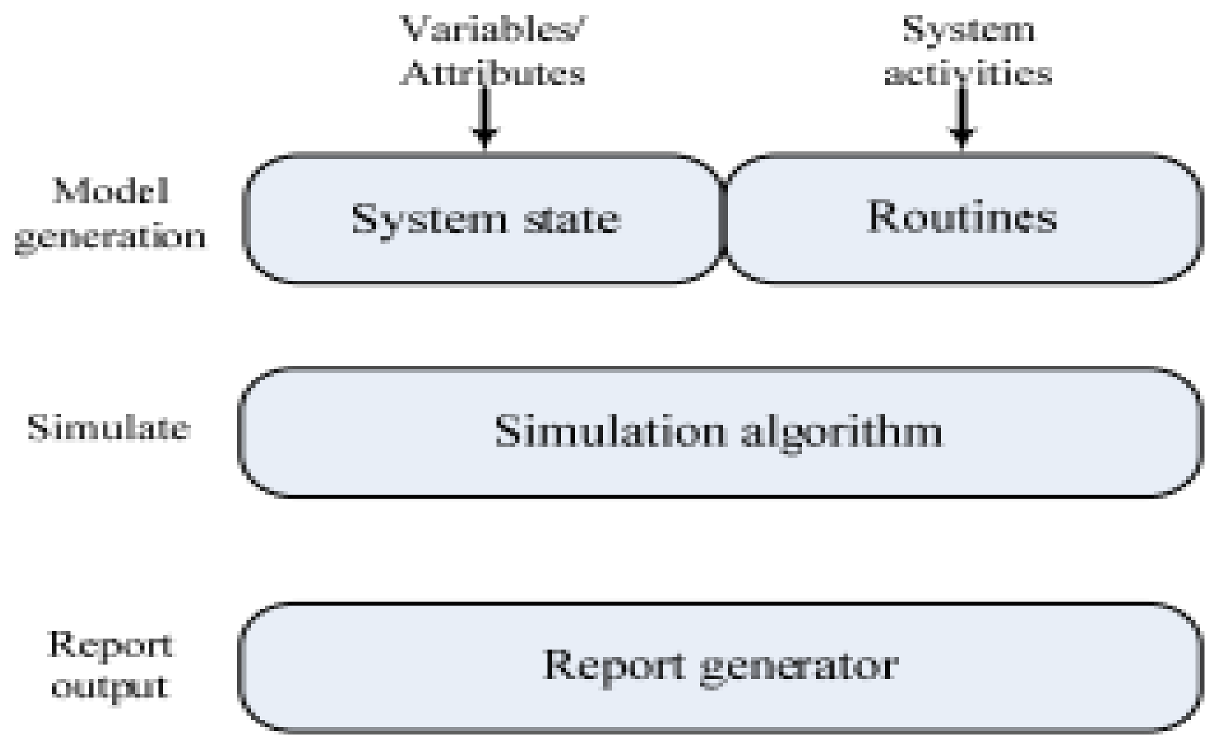
https://en.wikipedia.org/wiki/List_of_discrete_event_simulation_software

Software	Publisher	Description	Last Updated
WITNESS	Lanner Group Ltd.	Discrete event simulation with VR available on desktop and cloud	July 07, 2017
VisualSim	Mirabilis Design Inc.	Model-based system architecture exploration of electronics, embedded software and semiconductors based on timing, power consumption and functionality	June 11, 2017
SIMUL8	SIMUL8 Corporation	Object-based simulation software	March 22, 2016[13]
Simio	Simio LLC.	An object oriented discrete event and agent based simulation software	July 1, 2017[12]
SimEvents	MathWorks	Adds discrete event simulation to the MATLAB/Simulink environment.	September 14, 2016[11]
Simcad Pro	CreateASoft, Inc	Dynamic discrete and continuous simulation software. Visual Interface with no coding environment.	August 11, 2016[10]
ProModel	ProModel, Inc.	A discrete-event simulation tool that also allows modeling of continuous processes.	November 15, 2017[9]
Plant Simulation	Siemens PLM Software	Software that enables the simulation and optimization of production systems and processes.	May 19, 2016[8]
MS4 Modeling Environment	RTSync Corporation	A general purpose DEVS methodology based software environment for discrete event and hybrid models.	July 23, 2015[7]
GPSS	Various	A discrete event simulation language. Different implementations are available through vendors.	Various
GoldSim	GoldSim Technology Group LLC	Combines system dynamics with aspects of discrete event simulation, embedded in a Monte Carlo framework.	September 21, 2015[6]
FlexSim	FlexSim Software Products, Inc.	A discrete event simulation software with a drag-and-drop interface for modeling simulations in 3D.	April 9, 2018[5]
ExtendSim	Imagine That Inc.	A general purpose simulation software package.	February 13, 2015[4]
Enterprise Dynamics	INCONTROL Simulation Solutions	A simulation software platform to model and analyze virtually any manufacturing, material handling and logistics challenge.	July 18, 2018[3]
Care pathway simulator	SAASoft Ltd.	A discrete event simulation program specifically designed for service industries e.g. healthcare.	Unknown
AutoMod	Applied Materials	A discrete event simulation package for manufacturing, distribution and material handling systems	May, 2017
Arena (software)	Rockwell Automation	A discrete event simulation program that also allows modeling of continuous processes.	August 14, 2017[2]
AnyLogic	The AnyLogic Company	A general purpose multimethod modeling tool.	October 27, 2017[1]

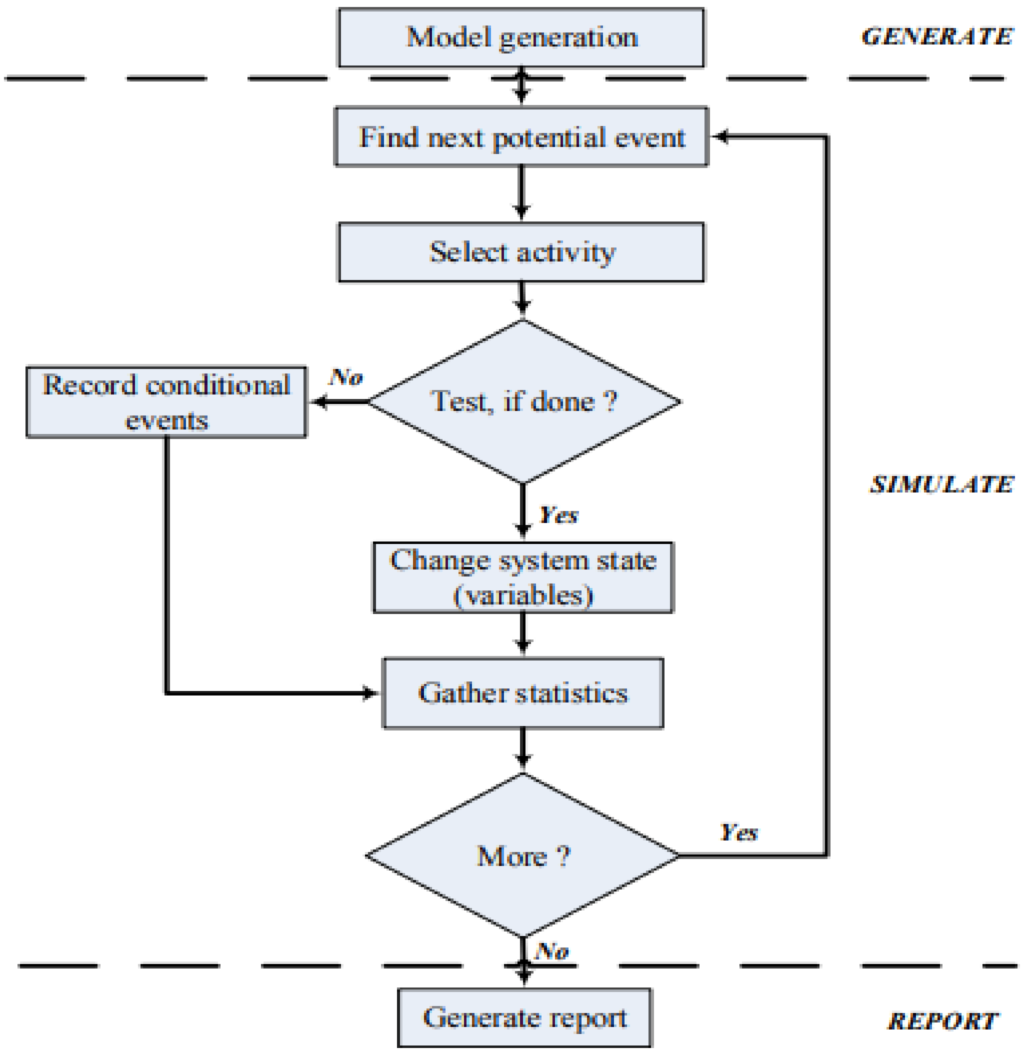
Simulation Programming Tasks

- There are three main tasks to be performed:
  - **1. Model generation:** This part includes model generation and initialization. A set of variables for system representation is to be created to show the status of the system state at all the time which is known as system image (state). Some procedures are also to be defined to represent the activities involved in the system which updates the system variable in run time.
  - **2. Model simulation:** A simulation algorithm has to be employed to carry out the simulation task. This procedure executes the cycle of predefined actions during simulation.
  - **3. Report generation:** A report generator gathers the statistics of interested variables and generates the simulation report in an organized way.

Simulation Programming Tasks



Simulation Programming Tasks



Assignment

- What is state descriptor and discrete even in discrete system simulation? Explain with suitable example.
- How is time represented in discrete system simulation?
- How are arrival patterns generated in discrete system simulation?
- What is lost and delay call system? Explain the simulation of telephone system with necessary state diagrams.
- What are the tasks to be performed in simulation programming? Also list out the activities to be performed in execution of simulation algorithm with neat diagram.
- Write short notes on:
  - Gathering Statistics
  - Counter and Summary Statistics
  - Measuring Utilization and Occupancy
  - Recording Distribution and Transit Time
  - Discrete Simulation Language