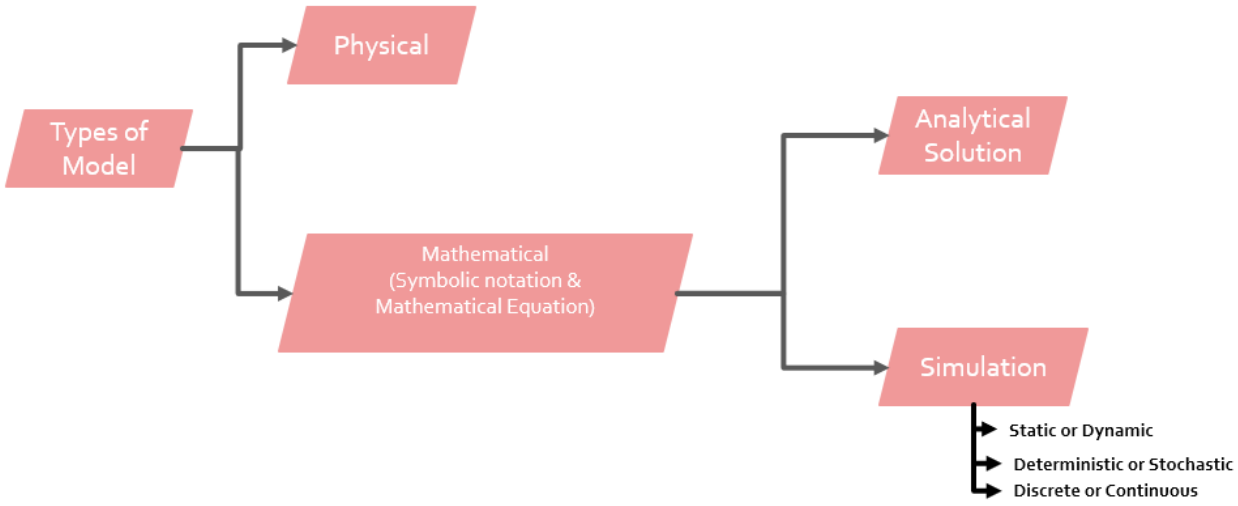
بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

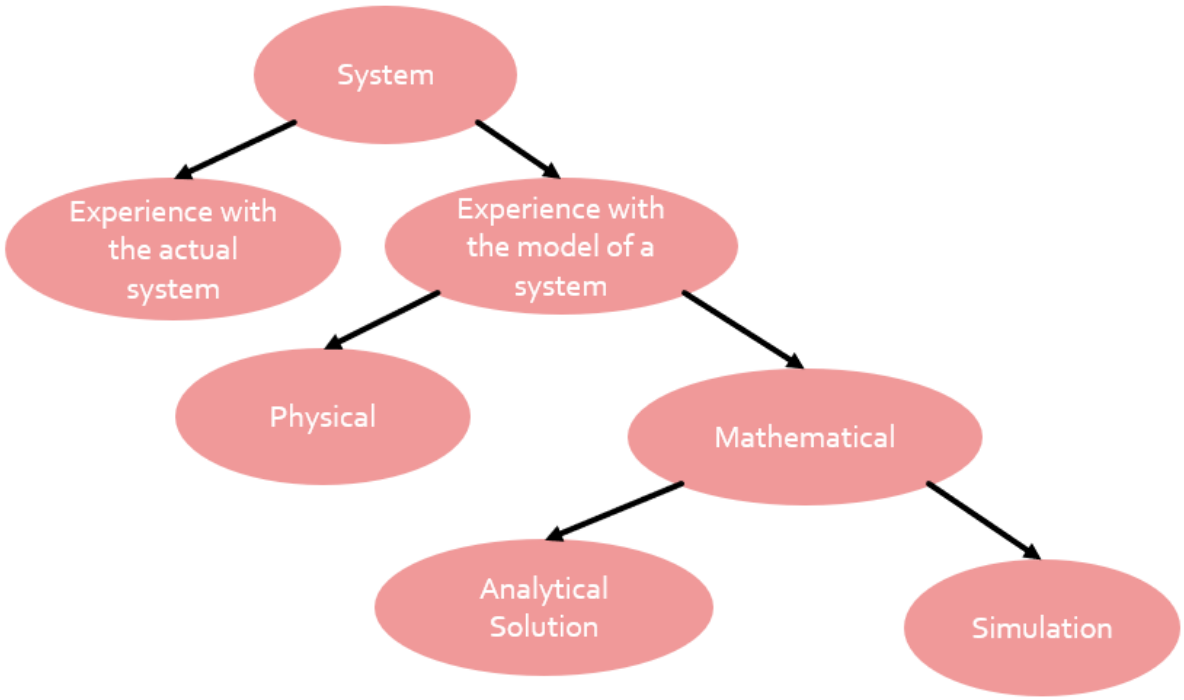
Lecture: 02

Model of System

A model is a representation of a system for the purpose of the system.



Way to Study a System



Created by
Shahadat Hossain
Lecturer, Dept of CSE
City University

Simulation Models

- Static Vs Dynamic
- Deterministic Vs Stochastic
- Continuous Vs Discrete

Note: We have to Think at the top level of any system before start simulation.

Discrete Event Simulation

Discrete Event Simulation: The state variables change instantaneously at separate point of time.

Time advance Mechanism:

- Next-event Time advance
- Fixed-increment Time advance

Next Event Time Advance

We consider the next event time advance approach for the single server queuing system.

t_i = time of arrival of i^{th} client

$A_i = t_i - t_{i-1}$ = inter arrival time between $(i-1)^{th}$ and i^{th} arrival of client

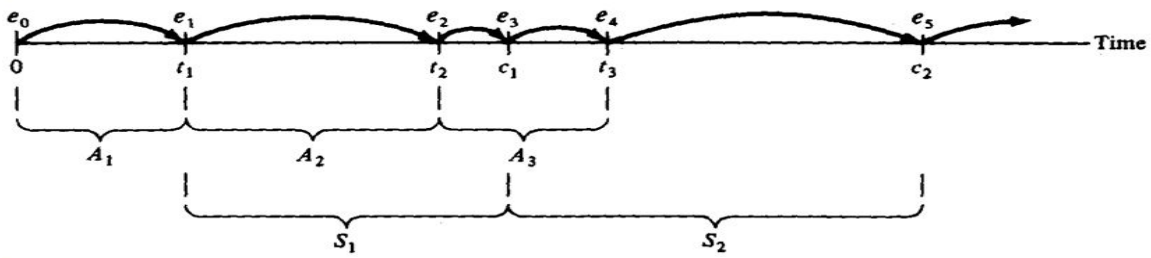
S_i = the actual time server spends serving i^{th} client

D_i = Delay in the queue of i^{th} client (wastage of time)

$C_i = t_i + D_i + S_i$ = Time the i^{th} client complete service and departs

e_i = time of occurrence of i^{th} event of any type (e_0 =0)

Created by
Shahadat Hossain
Lecturer, Dept of CSE
City University

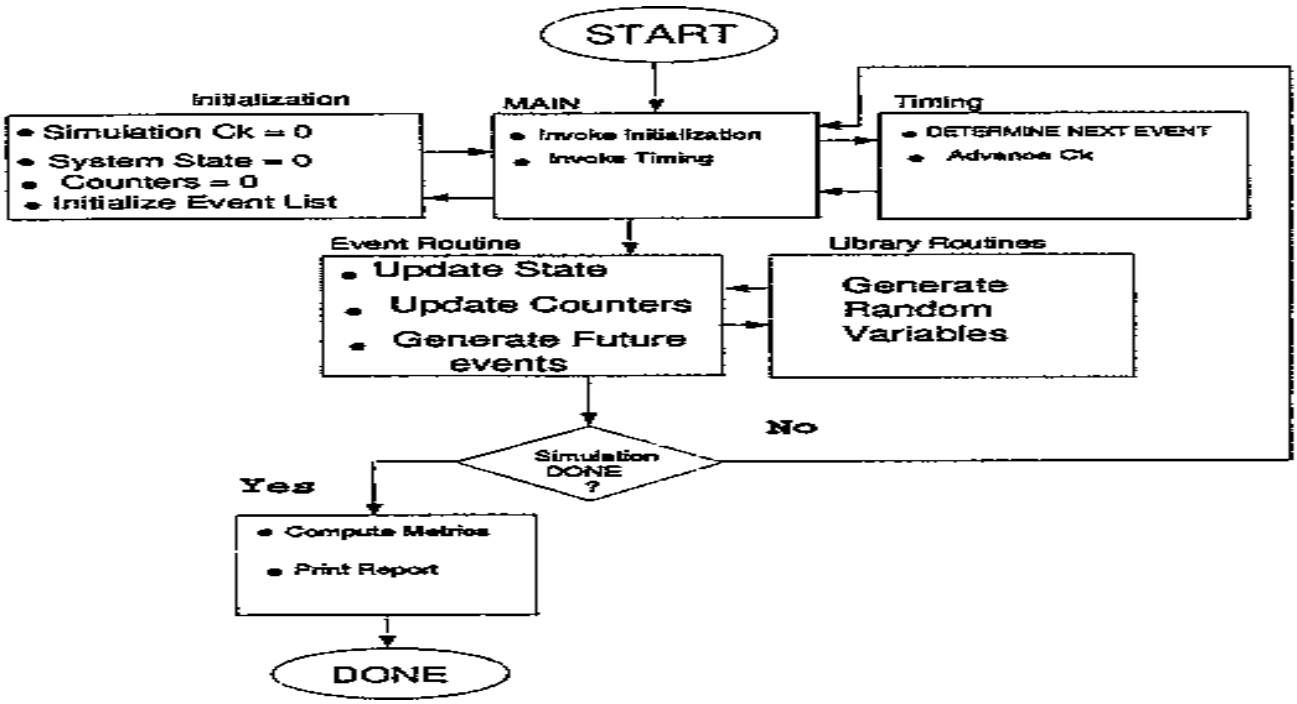


Components of Discrete Event Simulation

- **System State:** The collection of state variables necessary for to describe the system at the particular time.
- **Simulation Clock:** A variable which will give us current value of simulation time.
- **Event List:** A list containing the next time when each type of event will occur.
- **Statistical Counter:** Variables use for starring or recording statistical information of the system performance.
- **Initialization Routine:** A sub program to initialize the simulation model at time Zero 0.
- **Timing Routine:** A sub program that determines the next event from the event list and then advance the simulation clock to the time when that event is to occur.
- **Event Routine:** A sub program that update the system state when a particular type of event occurs. (there is one event routine for each event type)
- **Library Routine:** A set of Sub program that used to generate random observation from probability distributions that were determined as part of simulation model.
- **Report Generator:** A Sub program that computes estimates (from the Statistical counters) of the desired measures of performance and produce a report when the simulation ends.
- **Main Program:** A Sub program that invoke the timing routine to determine the next event and then transfer control to the corresponding event routine to update the system state appropriately. The main program may also check for termination & invoke the report generator when the simulation is over.

Created by
Shahadat Hossain
Lecturer, Dept of CSE
City University

Flow of Control (for the next-event-time-advance approach)



Simulation of Single Channel Queue/ Single Server Queue

Problem-1:

1. You have only one checkout counter
2. Customer arrives at this checkout counter at random from 1 to 8. Each possible value of inter arrival time has the same probability of occurrence as shown in the Table 1.
3. The service time varies from 1 to 6 minutes with the probabilities shown in Table 2.
4. The problem is to analyze the system by simulating the arrival and service of 20 customer.
5. Random value for time between arrivals- 913,727,015,948,309,922,753,235,302,109,093,607,738,359,888,106,212,493,535
6. Random value for service time- 84,10,74,53,17,79,91,67,89,38,32,94,79,05,79,84,52,55,30,50

Created by
Shahadat Hossain
Lecturer, Dept of CSE
City University

Solution:

Table-1

Time between Arrival (min)	Probability	Cumulative Probability	Random Digit Assignment
1	0.125	0.125	001-125
2	0.125	0.250	126-250
3	0.125	0.375	251-375
4	0.125	0.500	376-500
5	0.125	0.625	501-625
6	0.125	0.750	626-750
7	0.125	0.875	751-875
8	0.125	1.000	876-1000

Table-2

Service Time (min)	Probability	Cumulative Probability	Random Digit Assignment
1	0.10	0.10	01-10
2	0.20	0.30	11-30
3	0.30	0.60	31-60
4	0.25	0.85	61-85
5	0.10	0.95	86-95
6	0.05	1.00	96-100

Created by
Shahadat Hossain
Lecturer, Dept of CSE
City University

Table-3

Customer	Time Since Last Arrival (Inter arrival Time)	Arrival Time	Service Time	Time Service Begins	Time Customer Waits in a queue	Time Service Ends	Time Customer Spend in System	Idle time of Server
1	0	0	4	0	0	4	4	0
2	8	8	1	8	0	9	1	4
3	6	14	4	14	0	18	4	5
4	1	15	3	18	3	21	6	0
5	8	23	2	23	0	25	2	2
6	3	26	4	26	0	30	4	1
7	8	34	5	34	0	39	5	4
8	7	41	4	41	0	45	4	2
9	2	43	5	45	2	50	7	0
10	3	46	3	50	4	53	7	0
11	1	47	3	53	6	56	9	0
12	1	48	5	56	8	61	13	0
13	5	53	4	61	8	65	12	0
14	6	59	1	65	6	66	7	0
15	3	62	4	66	4	70	8	0
16	8	70	4	70	0	74	4	0
17	1	71	3	74	3	77	6	0
18	2	73	3	77	4	80	7	0
19	4	77	2	80	3	82	5	0
20	5	82	3	82	0	85	3	0
Total	**82**		**67**		**51**	**85**		**18**

Average Inter arrival time: $\frac{82}{20} = \mathbf{4.1}$

Average Waiting Time: $\frac{51}{20} = \mathbf{2.55}$

Average number of Customer in Queue or, Probability of Customer in Queue: $\frac{12}{20} = \mathbf{0.6}$

Average Service Time: $\frac{67}{20} = \mathbf{0.35}$

Average time spend in the counter: Avg Waiting time + Avg Service Time =2.55+0.35= **2.90**

Probability of idle server: $\frac{Total\ idle\ time}{Total\ run\ time} = \frac{18}{85} = 0.211 \sim \mathbf{0.2}$

Created by
Shahadat Hossain
Lecturer, Dept of CSE
City University

Utilization of counter: $\frac{End\ time - Idle\ time}{End\ time} = \frac{85-18}{85} = 0.788 \sim \mathbf{0.8}$

Utilization 80%

Problem-2:

1. Consider a Clothing store cash counter
2. For the following data (time in minutes) simulate the system and answer the following question. Assume the first customer arrives at time t=0.
3. Calculate the average delay in queue
4. Calculate utilization of the server.

Inter Arrival Time (min)	0	8	6	1	8	3	8	7	2	3
Service time(min)	4	1	4	3	2	4	5	4	5	3

Solution:

Customer Number	Interarrival Time	Arrival Time	Service Time	Service time Begin	Service Time Ends	Waiting Time	Idle Time
1	0	0	4	0	4	0	0
2	8	8	1	8	9	0	4
3	6	14	4	14	18	0	4+5=9
4	1	15	3	18	21	3	0+9=9
5	8	23	2	23	25	0	2+9=11
6	3	26	4	26	30	0	1+11=12
7	8	34	5	34	39	0	4+12=16
8	7	41	4	41	45	0	3+16=19
9	2	43	5	45	50	2	0+19=19
10	3	46	3	50	53	4	0+19=19
Total					**53 min**	**9min**	**19min**
Average Delay Time in the queue						**9/10=0.9**	
Utilization $= \frac{End\ time - Idle\ time}{End\ time}$						$\frac{53-19}{53} = 0.64$ or, 64%	

Created by
Shahadat Hossain
Lecturer, Dept of CSE
City University