Chapter 3
General Principles in Simulation

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Discrete-Event System Simulation

Outlines

- Concepts In Discrete-Event Simulation
- Able-Baker call center (an example)
- Event scheduling
- Event scheduling example

Concepts In Discrete-Event Simulation

- System
  - A collection of entities (people and machines..) that interact together over time for one or more goals
- Model
  - An abstract representation of a system, usually containing structural, logical or mathematical relationship that describe a system in term of state, entities and their attributes , sets, processes,…
- System state
  - A collection of variables in any time that describe the system
- Entity
  - Any object or component in system that require explicit representation (server, customer,...)
- Attributes
  - The properties of a given customer
- List
  - A collection of associated entities , ordered in some logical fashion (FIFO, priority,…)

Concepts In Discrete-Event Simulation (cont.)

- Event
  - An instantaneous occurrence that changes the state of a system
- Event Notice
  - A record of an event to occur at the current or future time (type and time)
- Event List
  - FEL (future event list)
- Activity (unconditional wait)
  - A duration time of specified length (service time or interarrival time,…)
  - Deterministic, Statistical and functional
- Delay (conditional wait)
  - A duration of time of unspecified indefinite length, which is not known until it ends (customer delay in waiting line)
- Clock
  - A variable representing simulated time

Able-Baker Call center

- System state
  - LQ(t): the number of callers waiting to serve
  - LA(t):0 or 1 indicate Able is idle or busy
  - LB(t):0 or 1 indicate Baker is idle or busy
- Entities
  - Caller
- Events
  - Arrival event, service completion by Able or Baker
- Activities
  - Service time by Able/Baker and Inter-arrival time
- Delay
  - A caller wait in queue until Able or Baker becomes free

Event scheduling

- How does each event affect system state, attributes?
- How activities are defined (deterministic, probabilistic,…)?
- Which events trigger the beginning of each delay?
- What is system state at time 0?

Event scheduling (cont.)

Clock	System state	Attributes	Future Event List (FEL)	Cumulative statistics and counters
t	(x,y,z ,…)		(3,t1) (1,t2) … (4,tn)	

t1<t2<…<tn

FEL is ordered by event time

Event scheduling/Time-advance algorithm

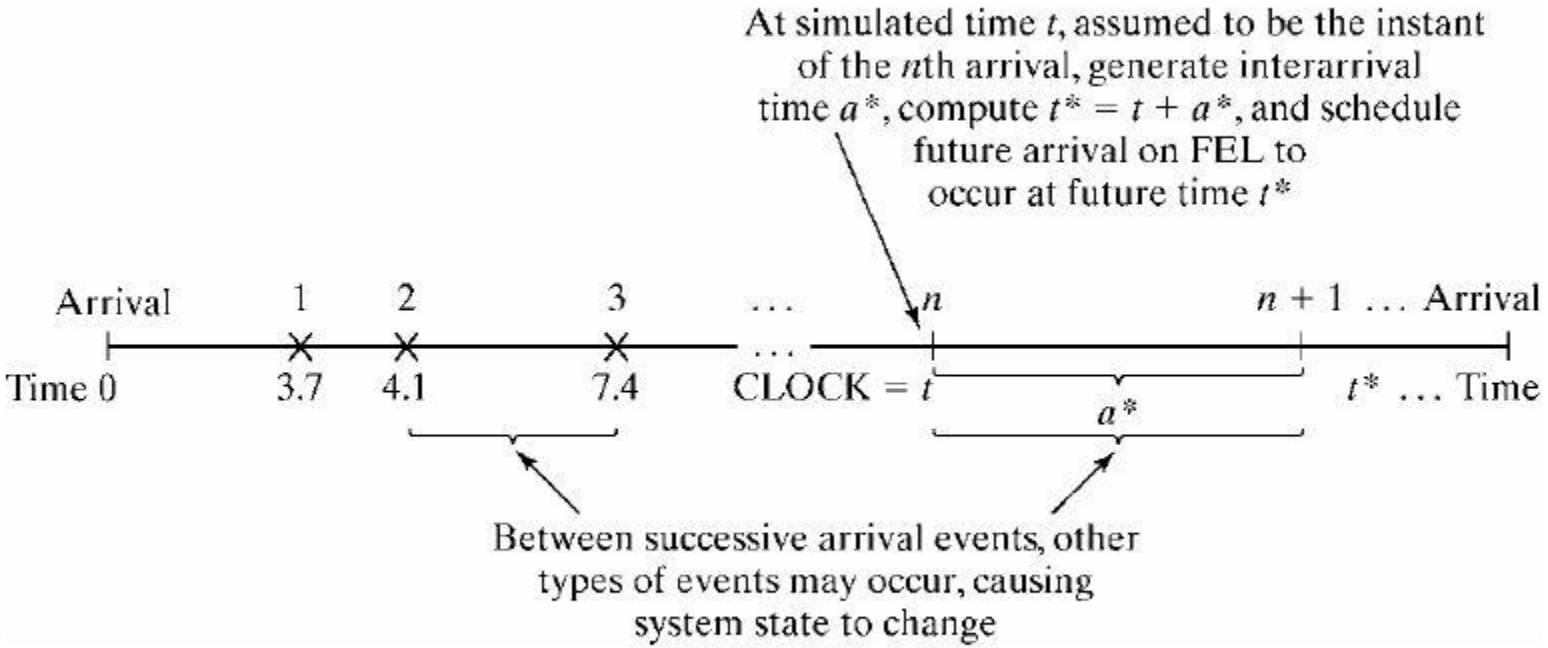
Clock	System state	…	Future Event List (FEL)
t_0	(5,1,6…)		(3,t1) (1,t2) (5,t3) … (4,tn)

- $t2<t^*<t3$

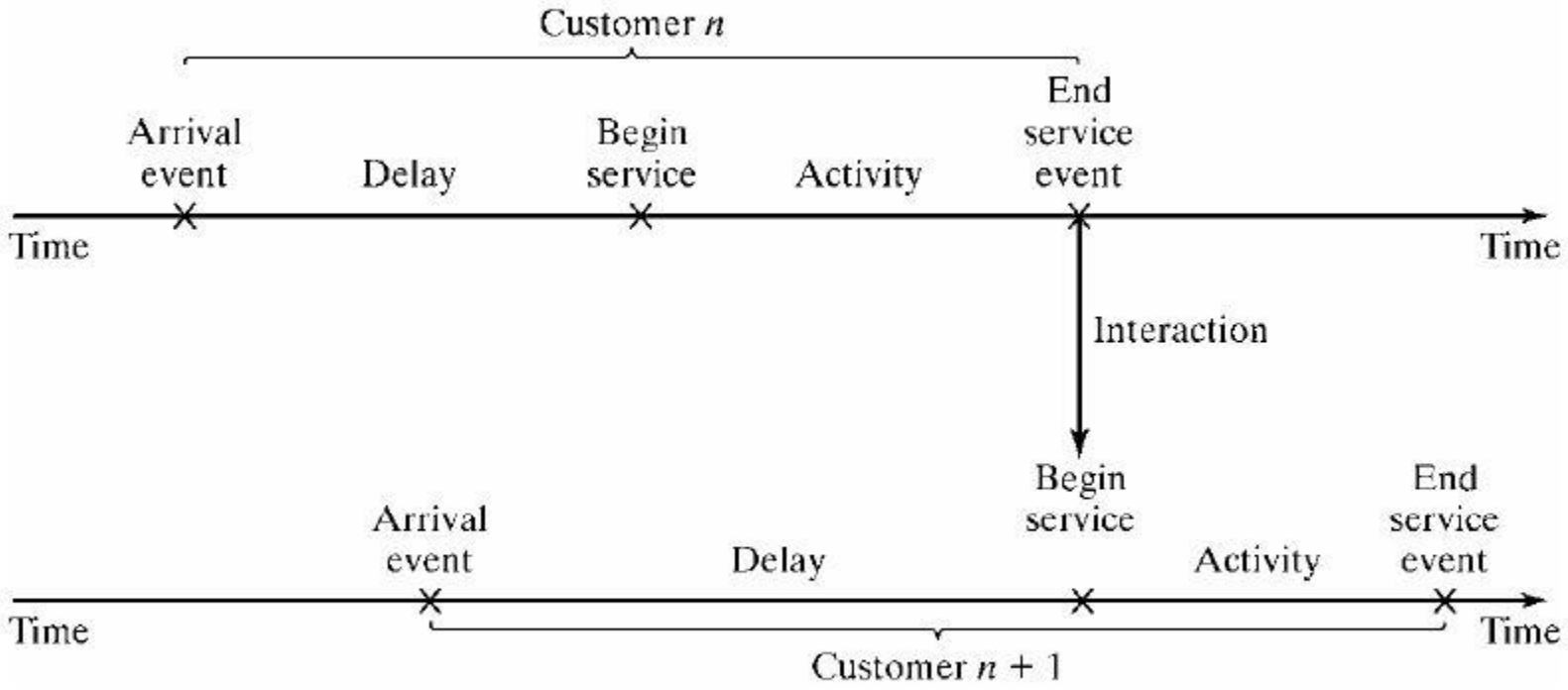
Clock	System state	…	Future Event List (FEL)
t1	(5,1,5…)		(1,t2) (5,t3) … (4,tn)

Clock	System state	…	Future Event List (FEL)
t1	(5,1,5…)		(1,t2) (4,t*) (5,t3) … (4,tn)

Generation Arrival Stream by Bootstrapping



Two customer processes interaction in single server queue



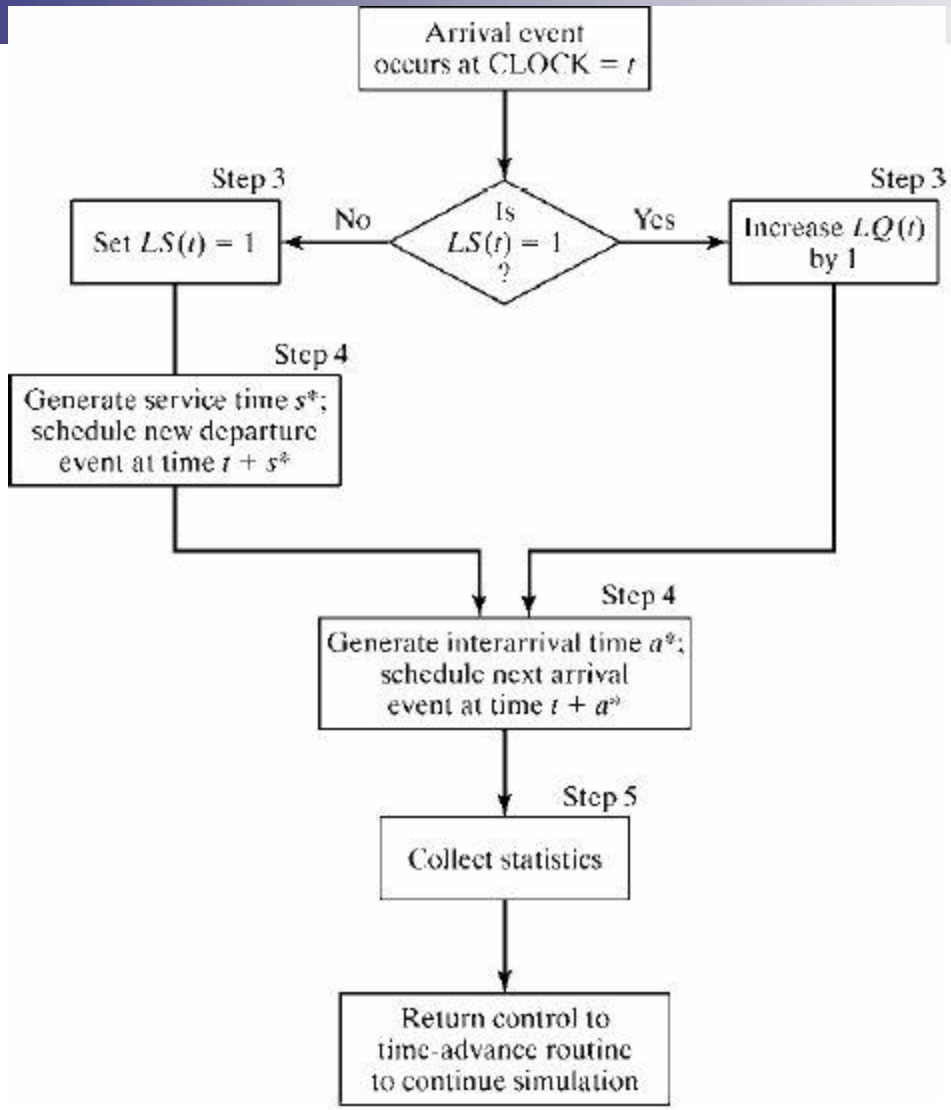
The stop time of simulation

- At time 0 the simulation stop time is specified, T_E
- Run length T_E is determined by the simulation itself.
  - The time of occurrence of some specified events

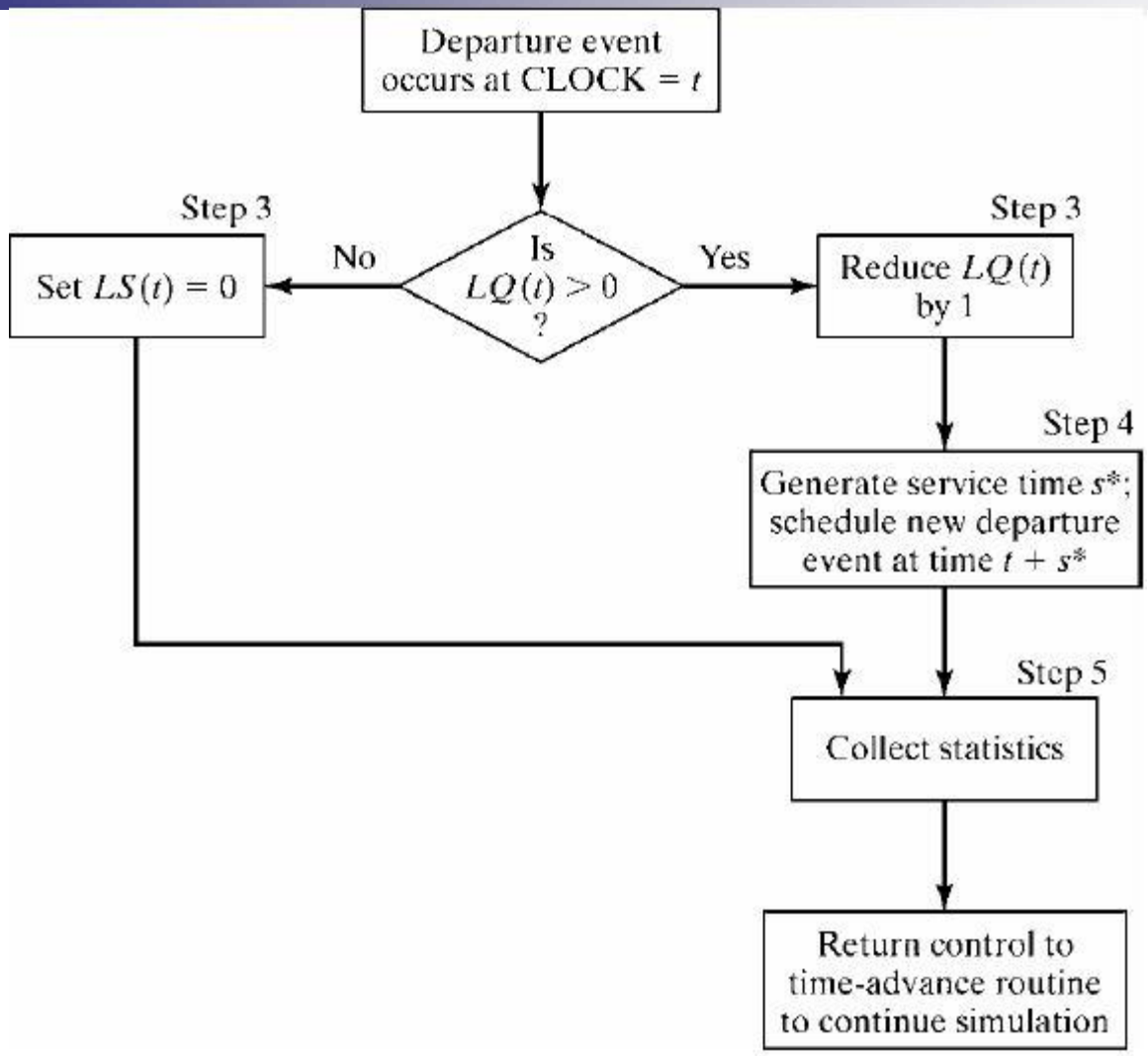
Event Scheduling example (Grocery Center)

- System State
  - LQ(t),LS(t)
- Entities
  - The server and customer are not explicitly modeled
- Events
  - Arrival (A), Departure (D), Stopping event (E=60)
- Event notices
  - (A,t), (D,t) , (E,60)
- Activities
  - Inter-arrival time, service time
- Delay
  - Customer time spent in waiting queue

Execution of the arrival event



Execution of the departure event



Simulation Table

clock	System state		Future Event List	Comment	Cumulative Statistics	
	LQ(t)	LS(t)			B	MQ
0	0	1	(A,1)(D,4)(E,60)	First A occures (a*=1) schedule next A (s*=4) schedule first D	0	0
1	1	1	(A,2)(D,4)(E,60)	Second A occures:(A,1) (a*=1) schedule next A (Customer delayed)	1	1
2	2	1	(D,4) (A,8)(E,60)	Third A occures:(A,2) (a*=6) schedule next A (Two customer delayed)	2	2
4	1	1	(D,6) (A,8)(E,60)	First D occures:(D,4) (s*=2) schedule next D (Customer delayed)	4	2
6	0	1	…	…	6	2

Computing Mean Response Time (cont.)

- Entities
  - (Ci,t), representing customer Ci who arrives at time t
- Event notices
  - (A,t,Ci), the arrival of customer Ci at future time t
  - (D,t,Cj), the departure of customer Cj at future time t
- Set
  - “CHECKOUT LINE” the set of all customers currently at the checkout counter, ordered by time of arrival
- Response time
  - CLOCK TIME-attribute “time of arrival”
- S:sum of customer response time
- ND: all number of customers that currently are departure
- F:Total number of customers that spend more than 5 minutes in system

Simulation Table

clock	System state		CHECKOUT LINE	Future Event List	Cumulative Statistics		
	LQ(t)	LS(t)			S	N_D	F
0	0	1	(C1,0)	(A,1,C2)(D,4,C1)(E,60)	0	0	0
1	1	1	(C1,0)(C2,1)	(A,2,C3)(D,4,C1)(E,60)	0	0	0
2	2	1	(C1,0)(C2,1) (C3,2)	(D,4,C1) (A,8,C4)(E,60)	0	0	0
4	1	1	(C2,1) (C3,2)	(D,6,C2) (A,8,C4)(E,60)	4	1	0
6	0	1	…	…	9	2	1

Structure of a simulation system