University Mohamed Khider of Biskra
Faculty of Exact, Natural and Life Sciences
Department of computer Science

Network Simulation

1st year Academic Master

Networks and Technologies of Information and Communication

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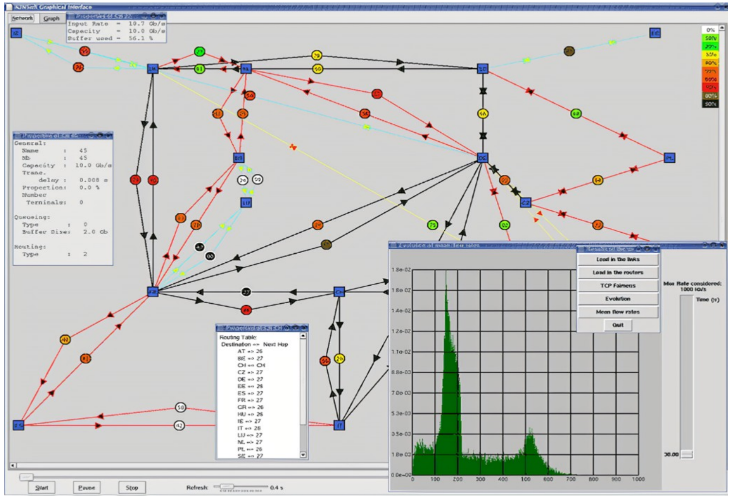
Outline



1) Introduction to Simulation
2) Network modeling
3) Classes of network simulators
   - How to choose a network simulator ?
4) Traffic generation models and queuing theory
5) Principles of simulation
6) Network’s performance evaluation

Introduction

Introduction Definition of Simulation

Many definitions have been attributed to the term “Simulation” in the technical literature:

1. Digital method to solve a problem by imitating reality.
2. Dynamic representation of reality obtained by building a model and manipulating it during a given time.
3. Simulation is used to imitate a real system or process. The act of simulating a system typically involves considering a limited number of key features and behaviors in the physical or abstract system of interest, which is otherwise infinitely complex and detailed.

Introduction Why is simulation important ?

1. Reduce the time needed for tests.
2. Efficient learning tool.
3. Solve real-world problems safely and effectively.
4. Simulation is a good convincing tool.
5. Simulation is an important step in engineering and problem solving and it is undertaken before building a physical prototype.
6. Simulation allows performance evaluation of network mechanisms and complicated systems at low cost.

Introduction Simulation vs Emulation

- The simulation involves the imitation of a process, system, or phenomenon in order to observe and analyze its behavior or performance while emulation replicates the functions of a specific hardware or software environment on a different platform.
- Simulations are often used to model and study real-world scenarios. This is particularly useful for predicting outcomes, understanding complex systems, and training individuals in a risk-free environment. The primary goal of emulation is to enable one system (the emulator) to behave like another system (the emulated).
- Simulation may require emulators of platforms, actors, etc.

Introduction Techniques of simulation

➔ Continuous simulation

- The continuous simulation is a numerical evaluation of a model that represents a physical system where its change over time is continuous according to a set of equations which typically involves differential equations.
- In some systems, the state changes occur all the time, not just at discrete times. For example, the water level in a tank may change all the time. In such cases, “continuous simulation” is more appropriate, although discrete event simulation can serve as an approximation.
- Other examples: Weather Forecasting,Traffic Flow Simulation, Epidemiological Modeling, Financial Modeling, etc.

Introduction Techniques of simulation

➔ Continuous simulation in computer networks

- Continuous simulation in computer networks refers to the process of modeling and analyzing the behavior of network systems over time, in a continuous fashion rather than discrete time steps. This approach allows for the examination of network performance, resource utilization, and other metrics as they evolve dynamically.
- In continuous simulation, various factors such as data transmission rates, network traffic patterns, and protocol behavior are represented using mathematical models or algorithms that can capture the continuous changes in network state.

Introduction Techniques of simulation

➔ Discrete event simulation

- Discrete-event simulation (DES) is a method of modeling systems that change state at discrete points in time, such as arrivals, departures, etc.
- DES tracks the events that occur in the system and updates the system state accordingly.
- DES is a suitable tool for systems with discrete, stochastic characteristics due to its ability to capture randomness, variability, and uncertainty of the system behavior and its components.
- For example, you can use DES to model a queueing system, manufacturing process

Introduction Techniques of simulation

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Introduction Techniques of simulation

➔ Discrete event simulation

A discrete event simulation is characterized by two characteristics:

1. In any time interval, we can find a subinterval in which no event occurs and no state variable changes.

2. The number of events is finite.

Introduction Techniques of simulation

➔ Discrete event simulation in computer networks

Discrete event simulation has many use cases in the context of networking:

- DES allows the simulation of network traffic patterns.
- DES allows developers to simulate the behavior of new protocols in a controlled environment, identifying potential issues and optimizing performance before real-world implementation.
- DES enables the modeling of fault scenarios (e.g., link failures, node failures) to evaluate the network's ability to recover and maintain functionality in such situations.
- Simulation tools such as NS-2, NS-3, OMNeT++, OPNET, etc. are commonly used for discrete event simulation in computer networks.

Introduction Techniques of simulation

➔ Components of Discrete event simulation

All discrete event simulations have the following components **(1)**:

- **Input routine**: Routine that obtains input parameters from the user and provides them to the model.
- **State variables:** Variables that together completely describe the state of the system.
- **Initialization routine:** routine responsible for initializing the values of the different state variables, global variables and statistical variables at the start of the simulation program.

Introduction Techniques of simulation

➔ Discrete event simulation

All discrete event simulation All discrete event simulations have the following components **(2)**:

- **Event queue**: list containing all pending events (in the future). The implementation of the list of events and the functions to be performed on it can significantly affect the effectiveness of the simulation program.
- **Event routines:** Routines that manage the occurrence of events. If an event occurs, its corresponding event routine is executed to update the state variables and event queue appropriately.
- **Simulation Clock**: A global variable that represents simulated time. Simulation time can be advanced by time-driven or event-driven methods.

Introduction Techniques of simulation

➔ Discrete event simulation

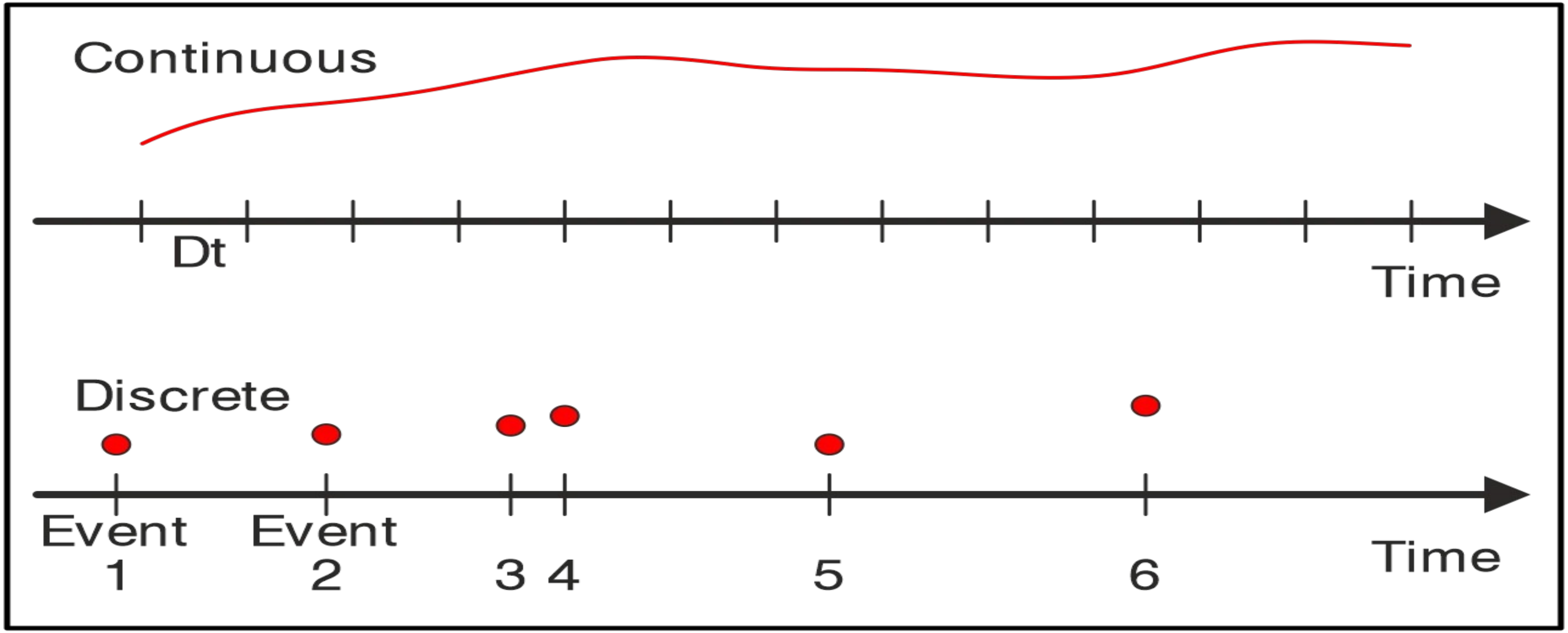
All discrete event simulation All discrete event simulations have the following components **(3)**:

• **Report generation**: routine responsible for calculating the results and printing them to the end user.

• **Main program:** the program where the other routines are called. The main program calls the initialization routine; The input routine runs different iterations, finally calls the report generation routine and completes the simulation.

Introduction Techniques of simulation

➔ **Continuous simulation VS Discrete event simulation**



Introduction Techniques of simulation

➔ Continuous simulation VS Discrete event simulation

	Continuous simulation	**Discrete event simulation**
Changes in the system to simulate	Continuous changes over time.	No changes occur between events
Primary characteristic	Time	Events
Time tracking	Models track the system continuously over time	Models jump from event to event in time.

Introduction Techniques of simulation

➔ The combination of CS and DES

- In some cases, we may need to combine discrete-event simulation (DES) and continuous simulation (CS) to create a more comprehensive and realistic model for hybrid systems, mixed systems, or multiscale systems.
- For example, we can use a discrete-event model to simulate the discrete events and a continuous model to simulate the continuous state changes within each event.
- Alternatively, we could use a continuous model to simulate the overall system behavior and a discrete-event model to simulate the specific system components or subsystems.
- We can use hybrid simulation software that can integrate both discrete-event and continuous simulation methods.

Introduction Techniques of simulation

➔ The combination of CS and DES in computer networks

- Even in communication networks, hybrid simulation is possible and allows comprehensive evaluation and study of network performances and behavior.
- We can use CS for tracking overall energy consumption of the network over the whole simulation time. On the other hand, we can use DES for tracking function-based energy consumption.
  - In the same context, DES can be also used for simulation battery depletion with each node, which will happen at discrete times.
- Constant network traffic can be simulated with CS, while DES is used for the simulation of random traffic.

Introduction Techniques of simulation

➔ Monte carlo simulation

- It is a classic simulation technique that has no time axis.
- Monte Carlo simulation is used to model probabilistic phenomena that do not change over time, or to evaluate non-probabilistic expressions using probabilistic techniques.
- It is a computational procedure in which a performance measure is estimated using samples drawn randomly from a population having appropriate statistical properties.
- Random sampling is essential for Monte Carlo simulation, using probability distributions to generate uncertain outcomes estimates.

Introduction Techniques of simulation

➔ Monte carlo simulation

- Monte Carlo simulation generates random inputs and uses the inputs to determine a numerical value of the performance measure.
- Examples of Monte carlo simulation:

  -- Finance, -- Risk Analysis,

  -- Engineering, -- Healthcare,

  -- Physics, -- Climate Modeling,

  -- Game Development, etc.

Introduction Techniques of simulation

➔ Monte carlo simulation

- In the context of networking, it can be applied in various ways (1):
  - **Performance Evaluation:** Monte Carlo simulation can be used to evaluate the performance of network protocols, algorithms, or architectures. By simulating various scenarios with different parameters and random inputs, we can assess the performance metrics such as throughput, latency, and packet loss.
  - **Reliability Analysis:** It can be utilized to analyze the reliability and availability of network systems. By modeling the failure probabilities of network components and simulating the network behavior over time, one can estimate the reliability metrics and identify potential points of failure.

Introduction Techniques of simulation

➔ Monte carlo simulation

- In the context of networking, it can be applied in various ways (2):
  - **Capacity Planning:** Monte Carlo simulation can aid in capacity planning for network resources such as bandwidth, storage, or processing power. By simulating the network traffic patterns and resource utilization under different conditions, one can optimize resource allocation to meet performance requirements.
  - **Risk Assessment:** It can be employed to assess the risks associated with network security, such as the likelihood of a cyber attack or data breach. By modeling various attack scenarios and simulating their impact on the network infrastructure, one can evaluate the effectiveness of security measures and develop mitigation strategies.

Introduction Techniques of simulation

➔ Monte carlo simulation

- In the context of networking, it can be applied in various ways (3):
    - **Protocol Design:** Monte Carlo simulation can assist in the design and optimization of network protocols. By simulating the protocol behavior in diverse network environments and under varying conditions, one can identify potential bottlenecks, optimize protocol parameters, and improve overall network performance.
- Monte Carlo simulation provides a flexible and powerful tool for analyzing complex network systems, identifying performance bottlenecks, and optimizing network designs.