Introduction to Simulation

Refs: Chap1-3, Chap 24 of Raj Jain’s book

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Why simulate?

1. Eg: real-system not available, is complex/costly or dangerous (eg: space simulations, flight simulations)

2. Want to quickly evaluate (kick the tires!) and design alternatives (eg: networking protocols)
   - Can get cool graphs, and leverage lots of existing protocol models

3. Want to evaluate complex functions for which closed forms not available (eg: Monte Carlo simulations, Matlab)

4. Want to animate or graphically visualize complex behavior (Eg: protocol animations, performance graphs, Matlab plots)
Simulators

- Networking stuff: ns-2/nam, SSFnet, Opnet
- Math stuff: Mathematica, Matlab, Maple or Monte-Carlo methods

- For more on simulation: CS has a detailed class on parallel and distributed simulation (PADS)
Simulation vs Measurement/Implementation

1. Real system is more credible, but more complex – lot of auxiliary concerns & murphy’s law strikes often!
   - But simulation must be thought of as a first step to real implementation
   - (I.e. to get a stable design that must be validated by implementation and/or analysis)

2. Measurement of Internet traffic may not be the same as measurement tomorrow (real, but still random samples!)
   - Representative measurement traces can be used to drive simulation (I.e. trace-driven simulation)

3. New emulation platforms: Utah’s emulab (next slide)
   - Takes out the configuration complexity from small/medium sized real experiments!

4. **Bottom line**: mix and match both tools depending upon the problem at hand
Utah Emulab and Click: Emulation and Modular Implementation Platforms

Utah’s **Emulab** Testbed: control & interconnect the kernels of 100s of machines just by using ns-2 scripting!!!
Simulation Lingo

- **“State”:** variables whose values define system state.
  - If a simulation is stopped & restarted – you need to “checkpoint” the state.
  - Hard problem in distributed simulations!

- **“Event”:** Change in system state = event

- **Discrete-event model/simulation:** events are not continuous but take on discrete values
  - All network simulations are of this type!
Deterministic vs Probabilistic Results

- **“Deterministic”:** results the same if you repeat the simulations
  - Usually the case if there is no randomness in the input or in the simulation process/protocols etc

- **“Probabilistic”:** results vary with every run!
  - Eg: similar to your RTT estimation exercise!
  - Random results => cannot make deterministic inferences **EVER**!
    - Multiple (truly random) simulation repetitions needed
    - Get averages, deviations, and to form a confidence interval around results.
Things to remember about Discrete Event Simulation

- The programming model revolves around “events” (e.g., packet arrivals):
  - Events trigger particular sub-routines
    - Huge “switch” statement to classify events and call appropriate subroutine
    - The subroutine may schedule new events! (cannot schedule events for past, i.e., events are causal)
    - Rarely you might introduce new event types
  - Events have associated with them:
    1. Event type, event data structures (e.g., packet)
    2. Simulation time when the event is scheduled
  - **Key event operations:** Enqueue (i.e., schedule an event).
    - Dequeue is handled by the simulation engine
**Discrete Event Simulation: Scheduler**

- **Purpose:** maintain a notion of simulation time, schedule events. A.k.a: “simulation engine”

- **Simulation time ≠ Real time**
  - A simulation for 5 sec of video transmission *might* take 1 hour!

- **Events are sorted by simulation time (not by type!): priority queue or heap data structure**
  - After all subroutines for an event have been executed, control is transferred to the simulation engine
  - The simulation engine schedules the next event available at the same time (if any)
  - Once all the events for current time have been executed, simulation time is advanced and nearest future event is executed.
  - Simulation time = time of currently executing event