



Performance Modeling of Computer Systems and Networks

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Next Event Simulation

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Sino ad ora non abbiamo considerato il tempo, non c'è simulazione temporale! DE simulation
Next-Event Simulation

Next-Event Simulation (simula il tempo)

Caratterizzata da: (e flessibile)

Next-event simulation is a **more general** approach to discrete-event simulation

- system state (già fatto a liv. concettuale)
 - events
 - simulation clock (tempo c'è)
 - event scheduling (come sono schedulati)
 - event list
- } definiti nella simulazione

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Definitions and Terminology – State

The *state* of a system is a complete characterization of the system at an instance in time

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Algorithm 1.1: how to develop a model

1. Goals and objectives
2. **Conceptual model** (cm)
 - very high level
 - which are the state variables, how they are related, which can be ignored and which not
3. Convert cm into a **specification model** (sm)
 - important: collecting and statistically analyzing data to provide the input models that drive the simulation
4. Convert sm into a **computational model** (cptm)
5. Verification
 - Is cptm consistent with sm?
6. Validation
 - Is cptm consistent with the system being analyzed?
 - Can an expert distinguish simulation output from system output?

lo stato va definito per ciascuno dei 2 livelli

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Definitions and Terminology – State

- **Conceptual model:** *uso linguaggio naturale*
(livello alto) abstract collection of variables and how they evolve over time
- **Specification model:**
collection of mathematical variables together with logic and equations
- **Computational model:** *(traduzione in ling. programmazione)*
collection of program variables systematically updated
- Example *ssq*: the state is number of jobs in the node ← *(a liv. concettuale)*
- Example *inventory system*: the state is current inventory level ← *(a liv. concettuale)*

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Definitions and Terminology - Events

An *event* is an occurrence that may change the state of the system.

By definition, state cannot change except at an event time. *(lo stato cambia SOLO a causa di un evento)*

Each event has an associated *event type*.

- We can define **artificial events** *(do not change system state)* *→ hanno altre finalità, come raccolta dati (es: campionamento statistiche)*
 - Statistically sample the state of the system
 - Schedule an event at a prescribed time
(block arrival flow into the node, an inventory review without orders etc.)

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Definitions and Terminology - Simulation Clock

The *simulation clock* represents the current value of simulated time

- Discrete-event simulations lack definitive simulated time
As a result, it is difficult to generalize or embellish models
 - *snicchiare modello*: ridefinire algoritmo, incastro con altri eventi...
 - Il tempo sarà il clock di simulazione

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P. 66 slide, P. 185 discrete

Definitions and Terminology - Event Scheduling & Event List

scheduler (gestisce eventi, meccanismo avanzamento del tempo)

- a *time-advance mechanism*
to guarantee that events occur in the correct order
(se evento a t_2 e poi t_3 , il clock non passa per t_2)
- *next-event* time advance is typically used in discrete-event simulation

event list (gli eventi stanno in una lista)

- the data structure containing the time of next occurrence for each event type

To build a *next-event* simulation:

- construct a set of state variables
- identify the event types
- construct a set of algorithms that define state changes for each event type

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- *errore grave*: generare tutti gli arrivi prima: simulo 10K recordi, simulo tutti insieme 10K arrivi e poi incastriarli con altri eventi, è una cosa artificiosa/macchinosa ordinarli

Next-Event Simulation

Algorithm 1 *globale di simulazione*

1. **Initialize** - set simulation clock and first time of occurrence for each event type (*inizializzo clock + var + event_i*)
2. **Process current event** - scan event list to determine most imminent event; advance simulation clock; update state (*eseguo algoritmo associato all'evento, consumo l'evento, può generarne altri, sicuro il next event*)
3. **Schedule new events** - new events (if any) are placed in the event list (*se e₀ genera e₁, e' possibile che non portin subito, perché c'è e₂ arrivato*)
4. **Terminate** - Continue advancing the clock and handling events until termination condition is satisfied

Note that the simulation clock runs asynchronously; (Punto 2)
inactive periods are ignored

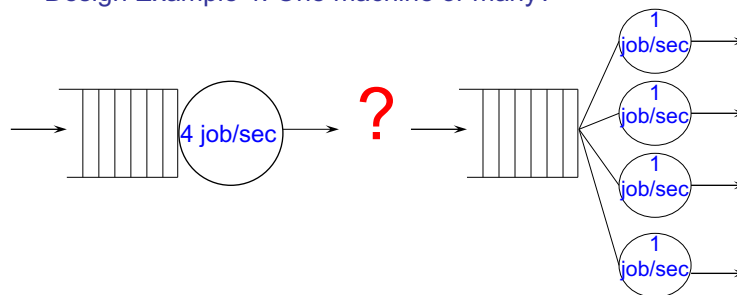
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Model extensions

Design Example 4: One machine or many?



A Multi-Server Service Node

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DE simulation
Next-Event Simulation

come funziona multiserver concettuale (astratto)

Conceptual model: MSQ

Definition 1 (livello concettuale - astratto)
A multi-server service node consists of

- A single queue (if any) *es: B-calling non la ha*
- Two or more servers operating *in parallel*

At any instant in time,

- Each server is either *busy* or *idle*
- The queue is either *empty* or *not empty*
- If one or more servers is idle, the queue must be empty *(se non conservativo)*
- If the queue is not empty, all servers must be busy

vincoli di correttezza

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DE simulation
Next-Event Simulation

Conceptual model: MSQ

linguaggio naturale:

When a job arrives:

- If all servers are busy, the job enters the queue
- Else an idle server is selected and the job enters service

When a job departs: *(termina)*

- If the queue is empty, the server becomes idle
- Else a job is removed from the queue, served by server

Servers process jobs independently

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Conceptual model: Server Selection Rule

Definition 2

The algorithm used to select an idle server is called the **server selection rule**

Come scegliere il server libero,
tra quelli liberi?

Common selection rules:

- *random*: at random from the idle servers
- *in order*: lowest-numbered idle server (uso di più server indice minore)
- *cyclic*: first available, starting after last selected (scelta ciclica)
(circular search may be required)
- *equity*: use longest-idle or lowest-utilized
- *priority*: choose the "best" idle server (modeler specifies how to determine "best")

criteri meno "neutrali",
ma considerazioni
specifiche