Real-Time (Paradigms) (1)

1. Temporal Specifications

RT systems are in essence *responsive (reactive)*, i.e. responding to events from the environment (user).

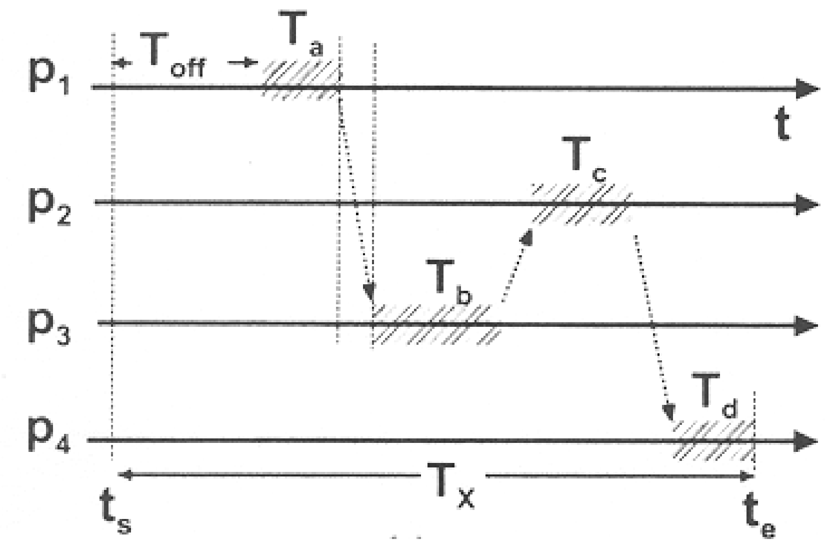
Response Time

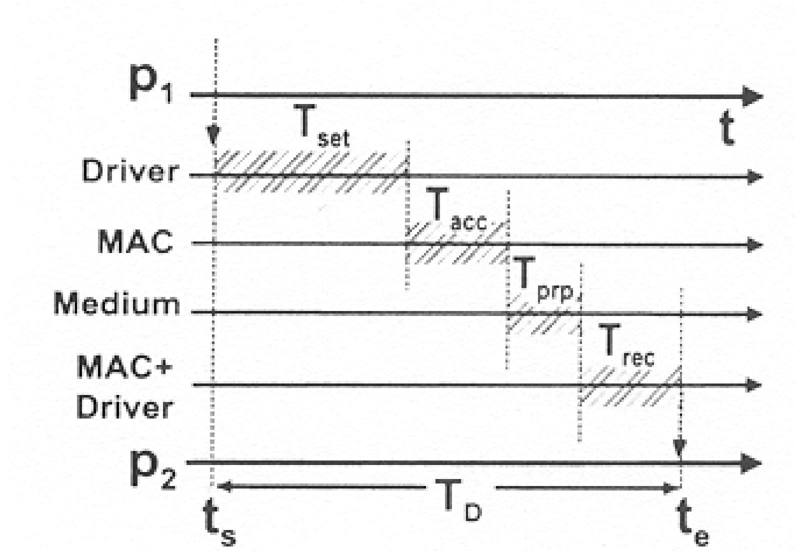
Interval between the occurrence of an input event and the first related output event

Timed Action

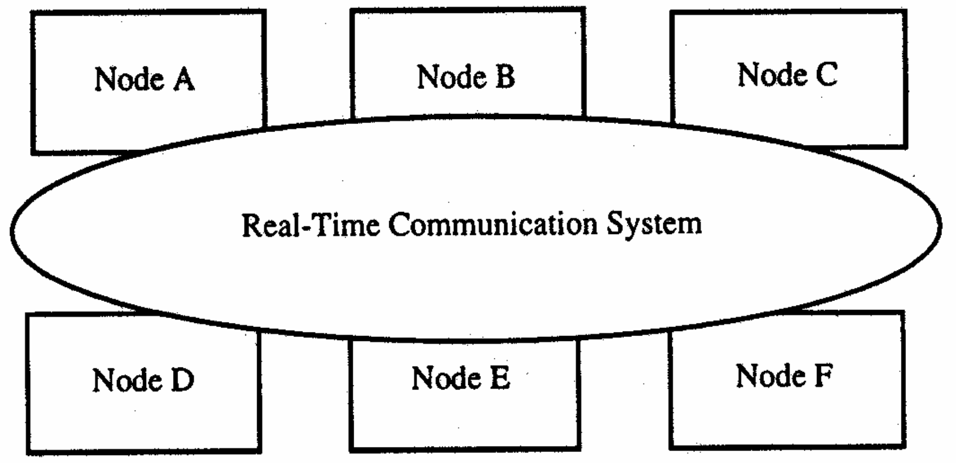
Execution of an operation A such that its termination event happens within an interval T_A from a reference real time instant t_A.

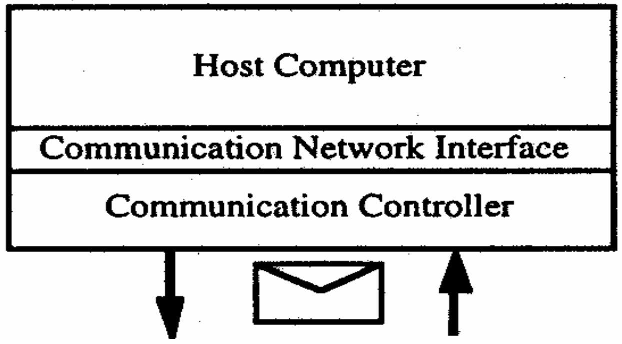
Timing Analysis of an action: (a) Computation (b) Communication





Real-Time (Paradigms) (1a)



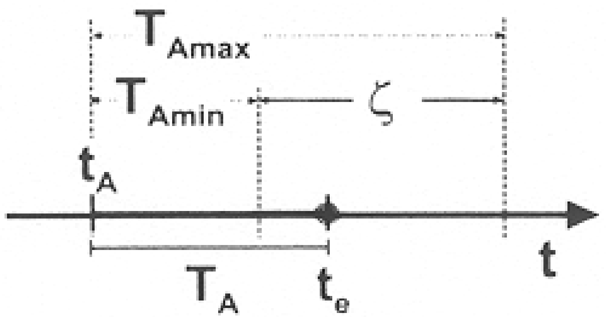


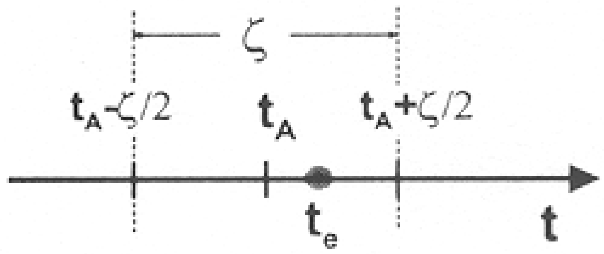
Real-Time (Paradigms) (2)

Jitter

variance in the duration of an action execution or imprecision in the positioning of its termination event.

Example

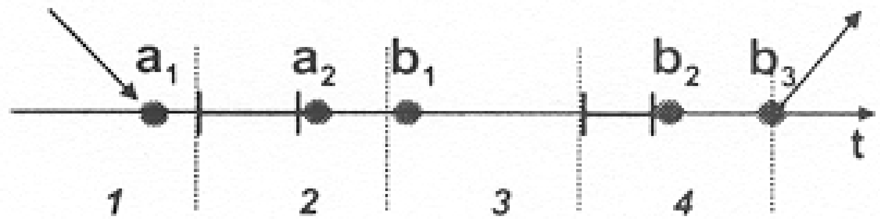




Mainly two approaches of triggering timed actions:

- *event-triggered:* system reacts upon the occurrence of an input event
- *time-triggered:* system reacts upon the command of a clock

Example



Real-Time (Paradigms) (3)

System predictability depends on the predictability of the inputs received from the environment which again depends on the class of application.

Trade-off:

Guaranteeing system predictability is simpler given a model assuming for regular (periodic) arrival patterns but: potential lack of coverage

Assuming a model accepting irregular (aperiodic) arrival patterns are closer to reality but: designing and proving that such systems are predictable is much more difficult

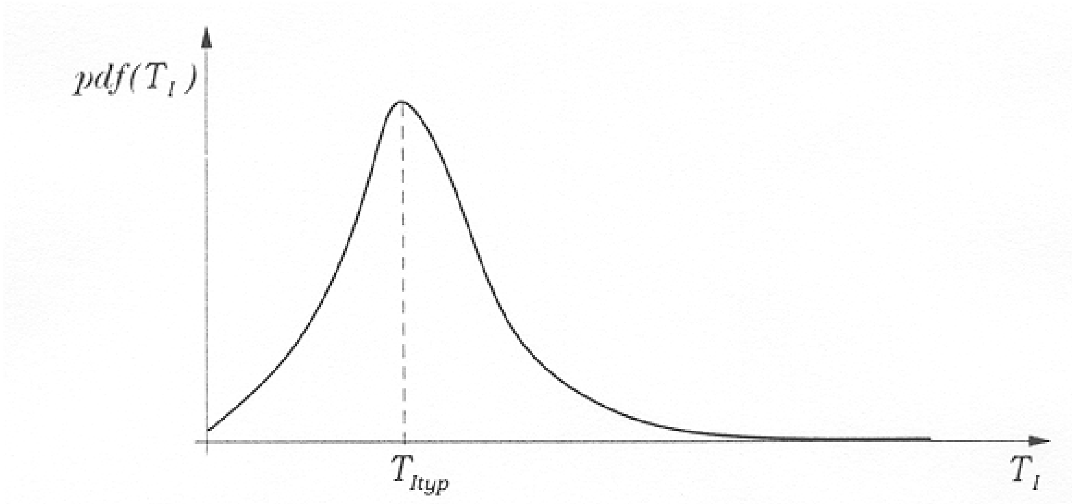
W.r.t the arrival of tasks, 3 types can be distinguished:

Periodic are such where tasks are released regularly at fixed rates (periods).

Aperiodic are such where tasks are released irregularly at some unknown and possibly unbounded rate.

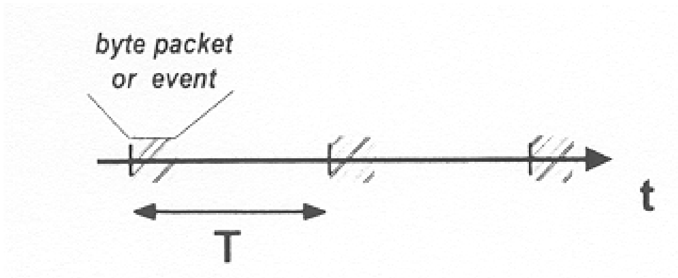
Sporadic tasks are such where tasks are released irregularly with some bounded rate. This rate is characterized by a minimum interarrival period.

Aperiodic Distribution

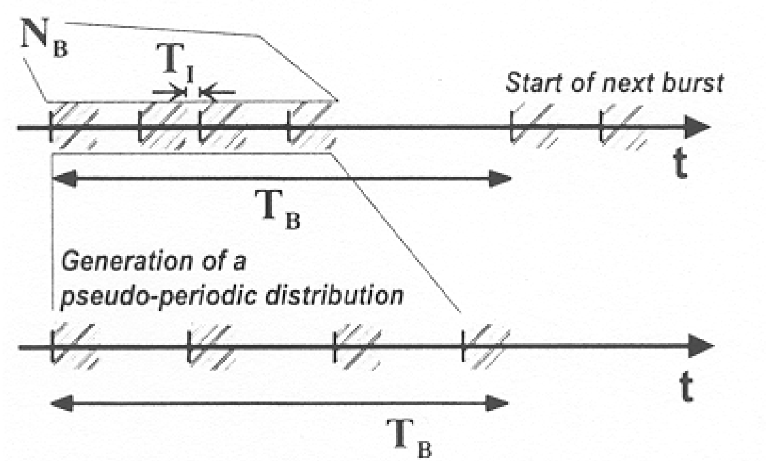


Real-Time (Paradigms) (4)

Periodic Distribution



Sporadic Distribution



burst period T_B: lower bound for the interval between the start of two consecutive bursts

burst length N_B: upper bound of number of events occurring in one burst

inter-arrival time T_I: lower bound for the interval between the occurrence of two consecutive events

Utilization Factor

measure of percentage a resource is used over a given time interval

Real-Time (Paradigms) (5)

2a. Entities and Representatives

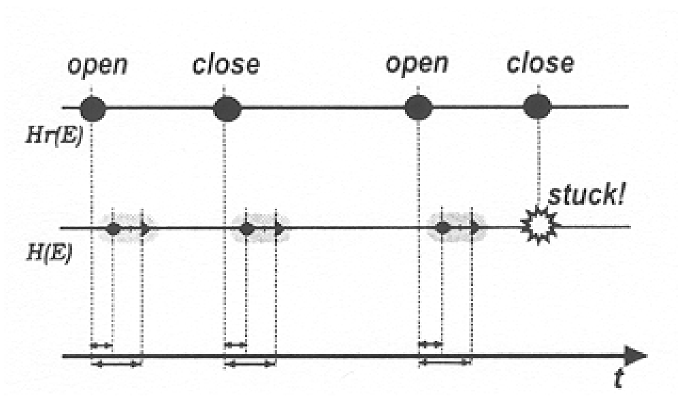
RT entity: element of the environment the state of which can be read or written, but not both

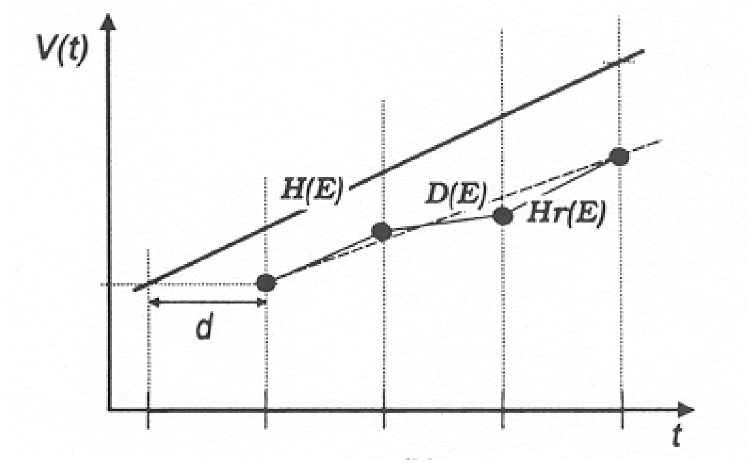
Representative: element of the (controlling) computer system which observes or acts on a RT entity´s state

The state of a RT entity is not accurately reflected in its representative at all times during system evolution!

---> A representative emulates its RT entity with an error in the value of state, or in the time where this state holds, or both.

Examples for RT Entity - Representative Relationship





Real-Time (Paradigms) (6)

2b. Time-Value Duality

Time-Value entity: RT entity E the value V of which depends on time, i.e. $V = E(t)$

For operations using time-value entities to be correct, two problems must be solved:

1. ensuring the correct observation of
   - the instantaneous value of the RT entity and
   - its positioning in the timeline, i.e. the corresponding time of the value
2. ensuring the correct use of the observation, i.e. using the observed value while it is still valid

ad 1)

Given a known V_0, observation $(r(E_i)(t_i), T_i)$ is *consistent in the value domain*, if and only if $v_i <= V_0$

Given a known Z_0, observation $(r(E_i)(t_i), T_i)$ is *consistent in the time domain*, if and only if $\zeta_i <= Z_0$

A set of observations is *mutually consistent*, if they are consistent and the timestamps of all observations fall within a given interval Z_m (also called *relative validity interval* in the context of databases)

ad 2)

Given a known V_a, observation $(r(E_i), T_i)$ is *temporarily consistent at* $t_a >= T_i$,

if and only if $|E_i(t_a)-E_i(T_i)| <= V_a$ (also called *absolute validity interval* in the context of databases)

The first problem addresses the consistency property w.r.t. the observation event, the second one deals with the evolution of the consistency of its value over time, a specific characteristics of time-value entities.