Real-Time Entities and Images

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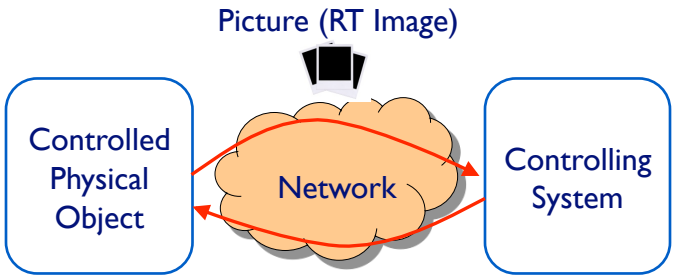
Review Chapter 3

- Clocks
  - **Precision** and **Accuracy** of clocks
  - A **global time** is an abstract notion that is approximated by properly selected microticks from the synchronized local physical clocks of an ensemble.
- Temporal order
  - The reasonableness condition of global time.
  - Two tick difference is sufficient condition to reconstruct temporal order with reasonable global time.

Overview : Observation

- Observation of Real Time Entity
- Temporal Accuracy



How to take a picture?

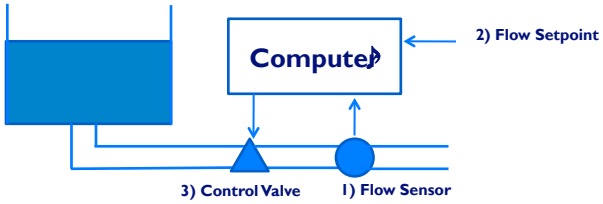
Is this picture valid at this time?

Contents

- Real-Time Entities (RT Entity)
- Observation of RT Entity
  - State Observation
  - Event Observation
- Real-Time Image (RT Image)
- Temporal Accuracy
  - Parametric RT Image (Phase-Insensitive)
  - Phase-Sensitive RT Image
- Permanence and Action delay

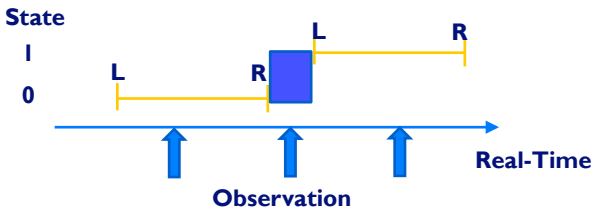
Real-Time Entities

- Definition of Real-Time Entities (RT entity)
  - A state variable of relevance for the given purpose.
  - Located either in the environment or in the computer system.
- Example : Flow of liquid in a pipe
  - 1) the flow in the pipe
  - 2) the setpoint for the flow
  - 3) the intended position of the control valve



Discrete and Continuous RT Entities

- A continuous RT Entity
  - The set of values is always defined.
- A discrete RT Entity
  - Have a discrete value set which remains constant between ***a left event*** (L_event) and ***a right event*** (R_event).
  - In the interval between an R_event and the next L_event , the set of values is ***undefined***.



Observations

- The role of observations.
  - To capture the information about the state of an RT entity at a particular point in time.

$$Observation = <Name, t_{obs}, Value>$$

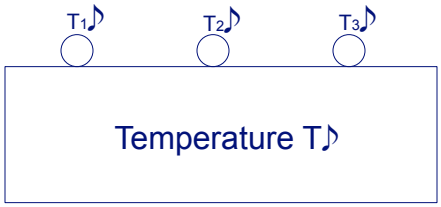
- Classification of Observations
  - Untimed Observation
  - Indirect Observation
  - State Observation
  - Event Observation

Observation Classification (1/4)

- Untimed Observation
  - Without global time, a timestamp generated by the sender is meaningless at the receiver.
  - Receiver use ***the time of arrival*** of the untimed observation message to decide t_{obs}.
  - This t_{obs} may be imprecise (delay and the jitter).

Observation Classification (2/4)

- Indirect Observation
  - Ex) the measurement of the temperature within a slab of steel.
  - May need a mathematical model of heat transfer.

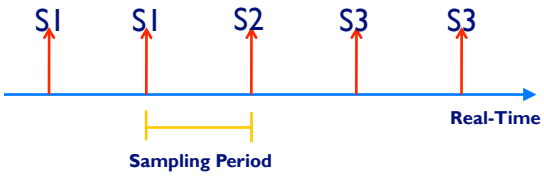


Observation Classification (3/4)

- State observation

Observation = <*Name*, t_{obs}, *Value*>

  - ***Value*** : the state of the RT entity.
  - t_{obs} : the point in real-time when the RT entity was sampled.
  - Every reading of a state observation carries an ***absolute value***.

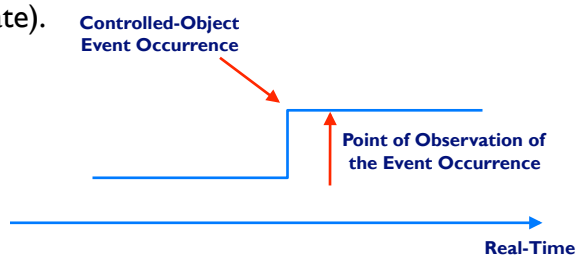


Observation Classification (4/4)

- Event Observation

  Observation = <*Name*, t_{obs}, *Value*>

  - ***Value*** : the change in value between the "old" and the "new" states.
  - t_{obs} : the best estimate of the point in time of the event (Normally, this is the time of the L-event of the new state).

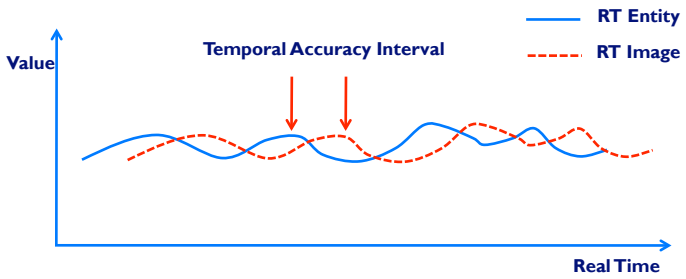


Real-Time Images and Real-Time Objects

- Real-Time Images
  - A ***current*** picture of an RT entity.
  - An RT image is valid at a given point in time if it is an ***accurate*** representation of the corresponding RT entity, both in the ***value*** and the ***time domains*** (***temporal accuracy)***.
- Real-Time Objects
  - A container within a node of the distributed computer system holding an ***RT image*** or an ***RT entity***.
  - A real-time clock with a specified granularity is associated with every RT object.

Temporal Accuracy of RT-Image (1/2)

- The RT-Images have a limited temporal accuracy.
  - How to decide the temporal accuracy interval?♪



Temporal Accuracy of RT-Image (2/2)

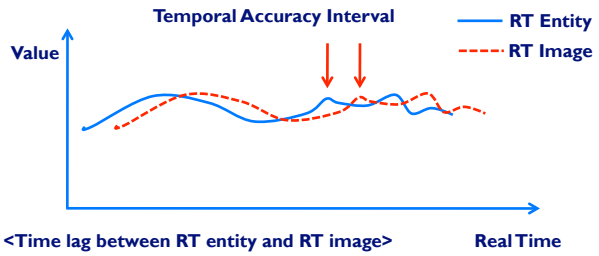
- Temporal Accuracy Interval (***dacc***)
  - Closely related to ***the dynamics*** of the RT entity.
  - During ***dacc***, it is guaranteed that ***the error*** will not exceed the predefined accuracy.♪

Example of Temporal Accuracy Interval (Engine control)

RT Image within Computer♪	Max. Change♪	Accuracy♪	dacc♪
Position of piston within cylinder♪	6000 rpm♪	0.1˚♪	3 usec♪
Position of accelerator pedal♪	100% / sec♪	1%♪	10 msec♪
Engine load♪	50% / sec♪	1%♪	20 msec♪
Temperature of the oil and the coolant♪	10% / minute♪	1%♪	6 seconds♪

Temporal Accuracy : Definition (1/3)

- The relationship between an ***RT entity*** and its associated ***RT image***.
- The ***recent history*** of observations (***RH***$_i$).
  - An ordered set of time points {t_i, t_{i-1}, t_{i-2},…,t_{i-k}}
  - $\exists\, t_j \in RH_i$: *Value*(RT image at t_i) = *Value*(RT entity at t_j)
- Temporal accuracy d_{acc} (or temporal accuracy interval)
  - $d_{acc} = z(t_i) - z(t_{i-k})$



Temporal Accuracy : Definition (2/3)

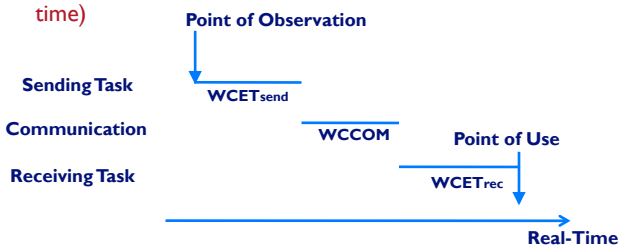
- Setting a temporal accuracy interval d_{acc}.
  - Determined by the dynamics of the RT entity considering the worst-case error.
  - If the RT entity changes its value quickly, a short accuracy interval must be maintained.
  - Ex) Engine control
    - Position of accelerator pedal : Max. Change 100%/sec, Accuracy 1% -> 3*msec*
    - Temperature of the oil and the coolant : Max. Change 10%/min, Accuracy 1% -> 6 seconds
- A time point t_{use}
  - When the result of a computation using an RT image is applied to the environment.
  - For the result to be accurate, it must be based on a temporally accurate RT image.

$$z(t_{obs}) \le z(t_{use}) \le (z(t_{obs}) + d_{acc})$$

$$z(t_{use}) - z(t_{obs}) \le d_{acc}$$

Temporal Accuracy : Definition (3/3)

- Phase-Aligned Transaction
  - An RT transaction consisting of the following tightly synchronized tasks
    - The sender(observing node) with $WCET_{send}$ (Worst-case execution time)
    - The message transmission with WCCOM (Worst-case communication delay)
    - The computational task at receiver with $WCET_{rec}$ (Worst-case execution time)

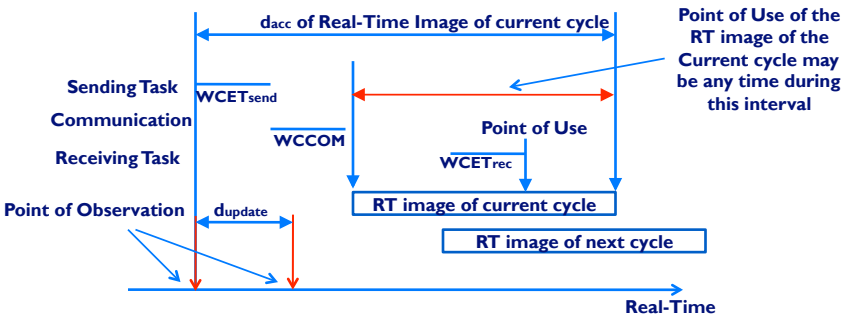


Temporal Accuracy : Parametric RT Image (1/2)

- Assumption for Parametric RT Image
  - An RT image is updated ***periodically*** by a ***state observation*** with an update period d_{update}.
  - The transaction is phase aligned at the sender.
- Parametric RT Image
  - The RT image parametric or phase insensitive if
  - $d_{acc} > (d_{update} + WCET_{send} + WCCOM + WCET_{rec})$
- The property of parametric RT Image
  - A parametric RT image can be accessed at the receiver at any time without having to consider the phase relationship between the incoming observation message and the point of use of the data.

Temporal Accuracy : Parametric RT Image (2/2)

- Illustration of Parametric RT Image
  - $d_{acc} > (d_{update} + WCET_{send} + WCCOM + WCET_{rec})$



Temporal Accuracy : Phase-Sensitive RT Image

- Phase-Sensitive RT Image
  - The RT image at the receiver is called ***phase sensitive*** if

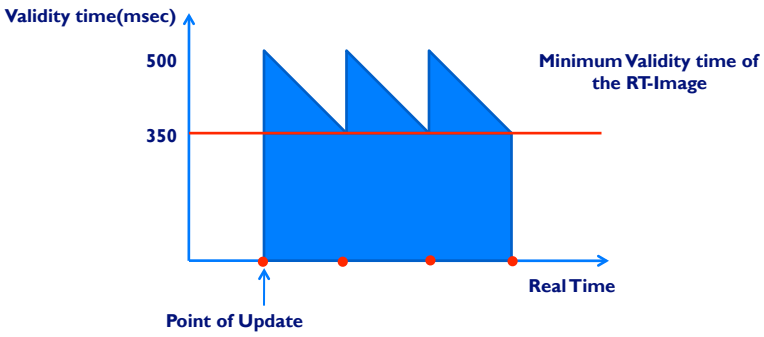
    $d_{acc} \leq (d_{update} + WCET_{send} + WCCOM + WCET_{rec})$ ***and***

    $d_{acc} > (WCET_{send} + WCCOM + WCET_{rec})$
  - The phase relationship between the moment at which the RT image is updated, and the moment at which the information is used, must be considered.
  - Significantly more complicated scheduling of tasks than using parametric RT images.
- Dealing with Phase-Sensitive RT Image
  - It is good to minimize the number of Phase-Sensitive RT Image.
  - Need a tradeoff

    (e.g. Increase the update frequency versus Communication load)

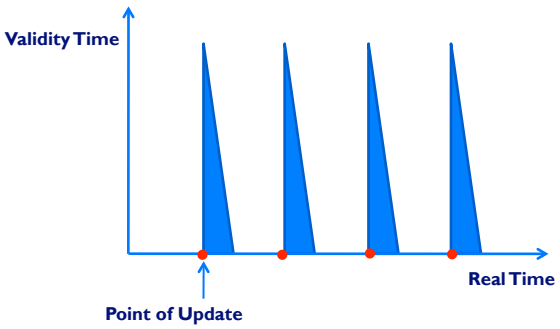
Classification of RT-Images(1)

- Phase-Insensitive RT Image
  - ***At all points*** in time the RT-Image can be assumed to be ***temporally accurate*** for *at least* ***dacc*** time units into the future.



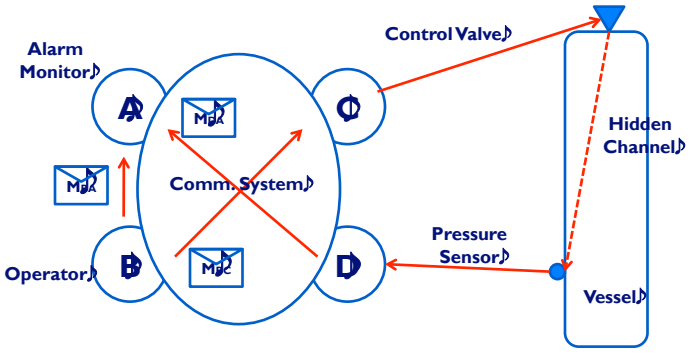
Classification of RT-Images(2)

- Phase-Sensitive RT Image
  - A user task need to check whether the RT-image is valid at the point of use. (may need state estimation)♪



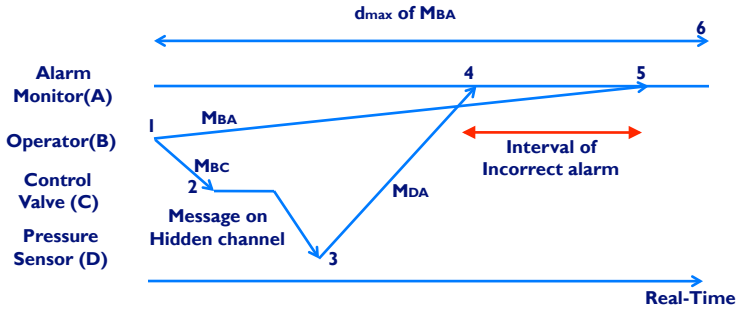
Permanence

- Permanence
  - A relation between ***a particular message*** arriving at a node and the set of all messages that have been sent to this node before this particular message.♪



Permanence

- Action delay
  - The time interval between the start of transmission of a given message and the point in time when this message becomes permanent at the receiver.
  - The receiver must delay any action on the message until after the action delay has passed to avoid an incorrect behavior♪



Other issues

- State Estimation
  - A technique to extend the temporal accuracy interval of an RT image.
- Idempotency
  - The effect of receiving more than one copy of a message is the same as receiving only a single copy.
  - Used to implement fault tolerance.
  - The state message is idempotent, but the event message is not.
- Replica Determinism
  - Fault-tolerance.
  - Facilitate the system test.

Summary

- A Real-Time entity : Continuous or Discrete.
- An observation of an RT entity : <*Name*, t_{obs}, *Value*>
  - State Observation
  - Event Observation
- A Real-Time Image is a current picture of an RT entity.
- Temporal accuracy
  - Parametric RT image (Phase-insensitive RT image)
  - Phase-sensitive RT image
- A particular message needs permanence with action delay.