

Role of Time in Systems

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View of a System

- **Collection of *active* entities (agents)**
 - **Active Entity**
 - » **State**
 - » **Communication**
 - Exchange information with
 - other entities
 - environment -- non-specific entities
 - » **Actions**
 - Actuators
- **Means for interaction**
- **Hierarchical Views**
 - Aggregation
 - Refinement
- **Observability**
 - States/actions/messages visible
- **System Dynamics**
 - Changes over time

View of Processing

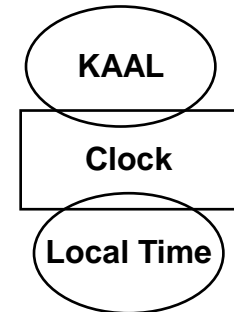
- **Collection of Requests**
- **Request**
 - A collection of activities
 - Defined constraints
 - » Static
 - » Dynamic
- **To meet the processing requirements the requests must be processed meeting all the constraints**

Absolute Time (*Kaal*)

- **Continuous, real number**
- **Universal**
- **Notion of Present, Past and Future**
- **Spatial locality**
- **Kaal at different spatial localities**
 - **Related**
 - » **In quantifiable way**
 - **Relativity Theory**

Physical Time/Local Time

- **As used in a physical system**
- **Related to Kaal through CLOCK**
 - **Physical Device**
 - » **defined local time**
 - » **observable**
 - **Granularity - Tick Time - Finite**
 - **Accuracy is finite**
 - **In a Good clock**
 - » **Relationship with Kaal (Absolute Time) is an invariant**

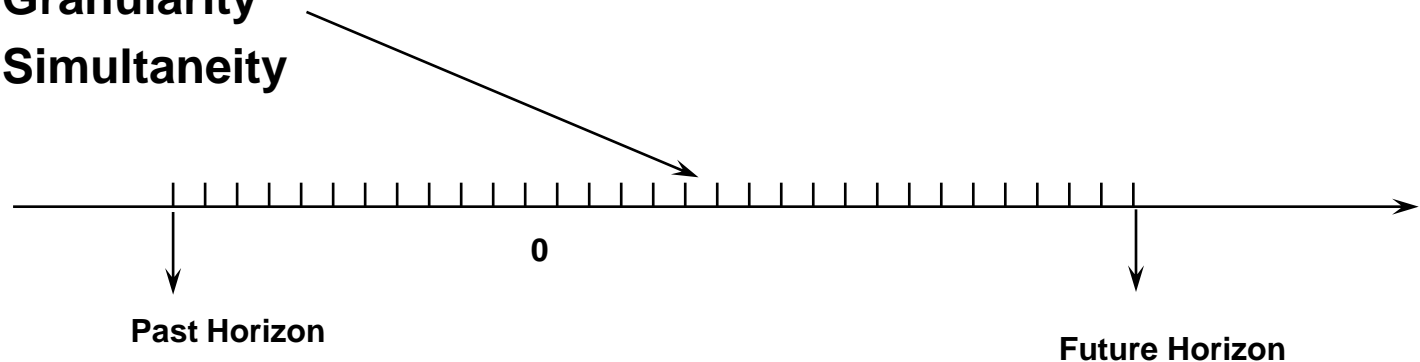


Knowledge of Time

- **Only way of knowing Local Time is by reading the clock**
- **Read the clock**
 - Takes time to read the clock
 - » If fixed, can factor it
 - » If variable, limits the accuracy about the knowledge of time
 - Local Time
- **Only know that the local time is $>$ time read from the clock**
- **If we know the properties of the clock, can relate the time read to Kaal**

Notion of Time in Systems

- **Local Time**
 - When a system is distributed there may be multiple local times in a system
- **Time Horizon**
 - Ignore before and after
- **Time scale**
 - Granularity
 - Simultaneity

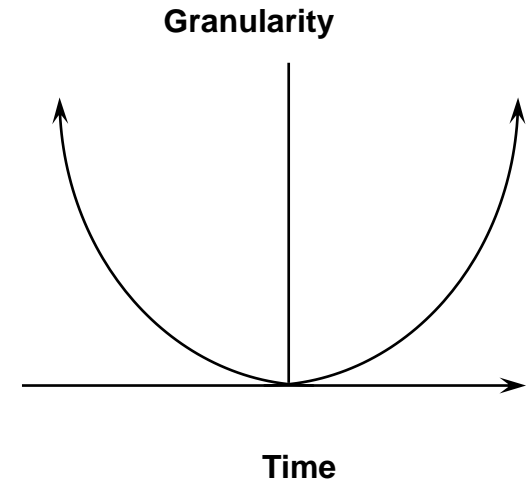


Local Time

- **Specified by a clock**
- **Granularity \geq granularity of clock**
- **Accuracy of representation**
- **Accuracy of observation**
 - **Depends on the variability of reading latency**

Time Granularity

- **Human notions of time**
 - non-uniformity of time scale
- **Machine notions of time**
 - Uniform time scale
 - Models of dynamics
 - » Differential Equation Models
 - Uniform notion of time
 - Granularity
 - » greater than the granularity of the clock used
- **Should we use the non-uniform time granularities in systems?**
 - Used to some degree today



Fusion

- **All interactions requires temporal coordination as well as spatial coordination**
 - Interactions are physical exchange of information/signals
- **The control of interactions is through the use of local time but takes place in absolute time**
- **Fusion of local time is required**
 - Commonality of units, scale, origin, etc.

Fusion

- **When two active entities have to interact**
 - **Must have common notion of local time**
 - » **From the knowledge of T_A , A should be able to infer T_B with reasonable accuracy**
 - » **Use**
 - **Common clock**
 - **Synchronized clock**
 - **Execute special protocol for coordination**

Buffers

- **Entities which can hold a signal for some time**
 - Fixed time
 - When cleared
- **Buffers are the primary means of providing one directional temporal matching**
 - A places information in the buffer
 - » B can pick it up *any* time after that
- **Use of buffers increases latencies and delays**

Temporal Locality: Simultaneity

- **What A and B consider to be simultaneous**
- **May be within the granularity of their clocks**
- **Simultaneity should carry with it the time scale/granularity**

Distributed System

- **Has multiple localities**
- **Each locality has a local time**
- **Distributed system must maintain time fusion for all localities (*temporal consistency*)**
- **Inaccuracies in time fusion**
 - Longer delays - lower throughputs
 - Larger buffers
 - etc.

Coordination

- **Activities of multiple autonomous units have to be coordinated**
 - **WHY????**
- **A key to all systems**
- **Coordination of**
 - **Two**
 - **More than two**

Modes of Coordination

- **Event based**
 - A causes an event E which is visible to B
- **Time based**
 - Agree to carry out a coordinated action at prearranged time

Event Based Coordination

- **Event visible to A and B**
 - Example - signal sent by A to B
- **Signal takes time to propagate from A to B**
- **B must be monitoring the signal for it to see**
 - A can not make B to do anything unless B is listening
 - If B starts monitoring after A sends the signal, it is lost
 - And B must have some temporal coordination before they get in the event based coordination mode

Event Based Coordination

- **Most monitoring is done in a loop with finite latency**
 - There are delays of transfer of signal and the latency of monitoring cycle
- **Handshake protocols may confirm to A that B saw the signal**
 - Cause additional latency
- **Most software systems used Event based coordination**
- **Buffers may be used to account for delayed detection of signal (temporal Matching)**

Time Based Coordination

- **A and B must have a common notion of local time**
 - Time Fusion
 - Knowledge of drift and drift correction
- **Must prearrange the time, T_{AB} , for coordinated action**
 - Arrangement must be completed before T_{AB}
 - » It may be dynamic
- **Most hardware systems use time based coordination**
 - Clock Based synchronous circuits
- **Buffers may be used for temporal matching**

Coordination

- **With the same clock resolution**
 - Time based coordination can be
 - » temporally more accurate
 - » require less overhead of messages and signals
- than event based coordination

Coordination among Multiple Agents

- **The complexity of Event based schemes increases as the number of agents increases**
 - **Communication medium**
 - » **Point to Point**
 - Many messages- sequential or in parallel
 - » **Broadcast**
- **Complexity of Time based schemes remains the same**

Hierarchical Decomposition

- **When decompose a system, time scale may have to be modified**
- **Time granularity may also change**

What takes time

- **Agent uses ITS resources to carry out an activity**
- **Use of resources takes time**

Role of Time

- **Time conveys a lot of information**
- **In order to use time effectively**
 - **Need a characterization of the resource/time requirements of activities**
 - » **Operations carried out by active entities**
 - **When shared resources are used**
 - » **need knowledge of**
 - **Resource management policies**
 - **Resource constraints**
- **Explicit representation of time adds significantly to the capabilities of a system**