Distributed Computing Module 2 -Lecture 1

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Introduction

- Causality between events is fundamental to the design and analysis of distributed computing
- Usually causality is tracked using physical time.
- In distributed systems, it is not possible to have a global physical time.
- The protocol such as NTP are also not reliable in the case of distributed computation.

Logical Time

- In a system of logical clocks, every process has a logical clock that is advanced using a set of rules.
- Every event is assigned a timestamp and the causality relation between events can be generally inferred from their timestamps.
- The timestamps assigned to events obey the fundamental monotonicity property; that is, if an event a causally affects an event b, then the timestamp of a is smaller than the timestamp of b.

Framework for Logical Clock- Definition

A system of logical clocks consists of a time domain T and a logical clock C. Elements of T form a partially ordered set over a relation $<$.

Relation $<$ is called the *happened before* or *causal precedence*. Intuitively, this relation is analogous to the *earlier than* relation provided by the physical time.

The logical clock C is a function that maps an event e in a distributed system to an element in the time domain T, denoted as $C(e)$ and called the timestamp of e, and is defined as follows:

$$C : H \mapsto T$$

such that the following property is satisfied:

$$\text{for two events } e_i \text{ and } e_j,\ e_i \rightarrow e_j \Longrightarrow C(e_i) < C(e_j).$$

Framework for Logical Clock- Definition

This monotonicity property is called the *clock consistency condition*.

When T and C satisfy the following condition,

$$\text{for two events } e_i \text{ and } e_j,\ e_i \rightarrow e_j \Leftrightarrow C(e_i) < C(e_j)$$

the system of clocks is said to be *strongly consistent*.

Implementation

- Implementation of logical clocks requires addressing two issues: data structures local to every process to represent logical time and a protocol to update the data structures to ensure the consistency condition.
- Each process p_i maintains data structures that allow it the following two capabilities:

1. A local logical clock, denoted by lc_i , that helps process p_i measure its own progress.
2. A logical global clock, denoted by gc_i , that is a representation of process pi 's local view of the logical global time. Typically, lc_i is a part of gc_i .

Framework for Logical Clock- Definition

The protocol ensures that a process's logical clock, and thus its view of the global time, is managed consistently. The protocol consists of the following two rules:

R1: This rule governs how the local logical clock is updated by a process when it executes an event.

R2: This rule governs how a process updates its global logical clock to update its view of the global time and global progress.

Systems of logical clocks differ in their representation of logical time and also in the protocol to update the logical clocks.