Clock Synchronization in Distributed Systems

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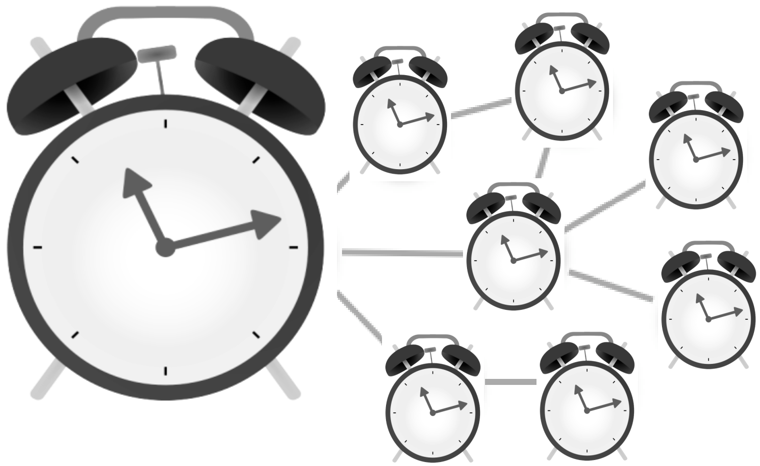

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Outline

- Introduction
- The System Model
- The Lower Bound
- Conclusion

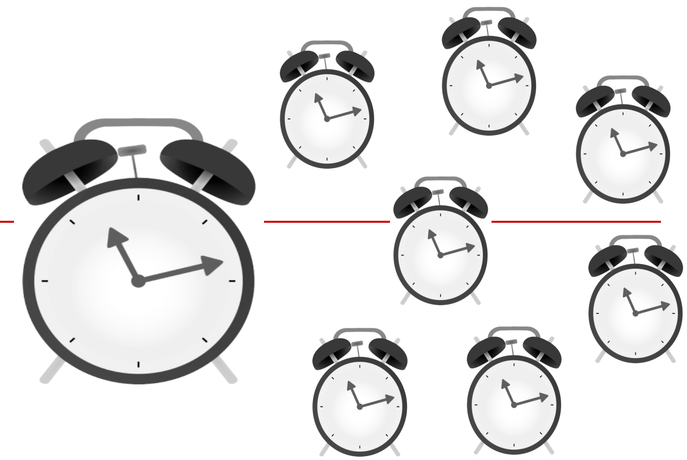
Introduction

- A distributed system consists of a collection of distinct processes (called nodes) which are spatially separated and which communicate with one another by exchanging messages.
- The clocks of the nodes
  - tick at different rates,
  - drift apart,
  - may not remain always synchronized although they might be synchronized when they start.

The Clock Synchronization Problem

- Clock synchronization is the process of ensuring that physically distributed processors have a common notion of time.
- Clock synchronization algorithms are based on
  - exchanging clock information among the nodes
  - eliminate the effects of **non-determinism** in
    - message delay
    - data processing time.

The System Model - I



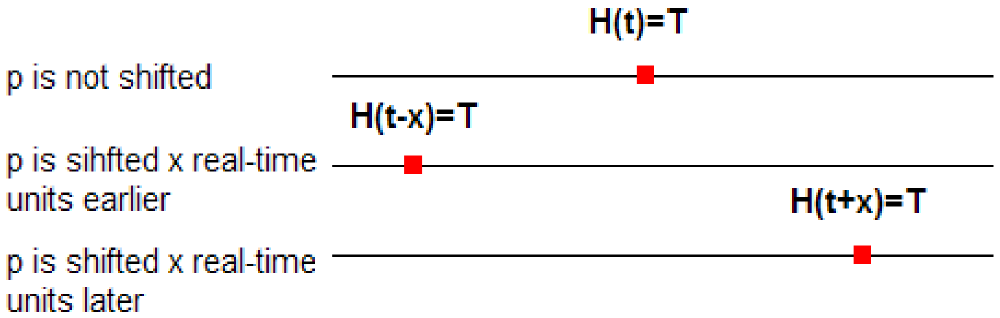
- The Clock Model
  - The Physical Clock $H(t)$
    - Clocks are **perfect** (do not drift)
  - The Logical Clock $L(t)$
- The Communication Model
  - Communication Network $G = \{V, E, L, H\}$
    - Nodes $V = \{1..n\}$
    - Edges $E \in V \times V$
    - Message Delay $L(i,j) \quad H(i,j)$
    - Uncertainty $H(i,j) - L(i,j)$

The System Model - II

- The System Of Nodes With Clocks
  - Events φ
  - History $(\varphi, H(t))$
  - Execution α
    - History for each node
    - Admissable executions
      - All message delays within $[L(i,j), H(i,j)]$
- The Formal Clock Synchronization Problem
  - The **Algorithm** terminates at time t_e
  - At time $t \geq t_e$
    - $|L_i(t) - L_j(t)| \leq \varepsilon$

The Lower Bound - I

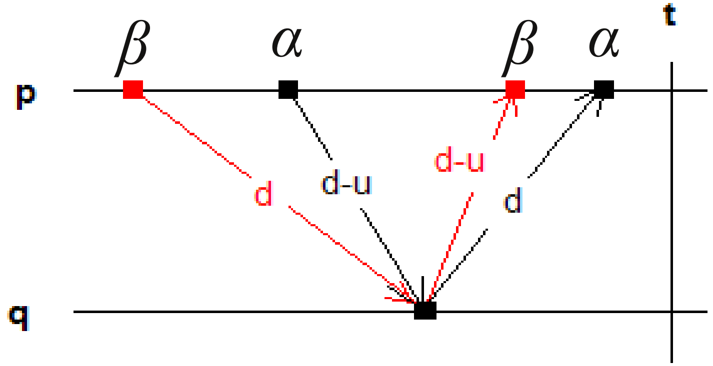
- Shifting



- We have two processors p and q.
- We will create two indistinguishable executions and show that the clock synchronization algorithm must achieve the same precision.

The Lower Bound - II

- Equivalent executions



$$L_q^{\alpha}(t) - L_p^{\alpha}(t) \le \varepsilon$$

$$L_p^{\beta}(t) = L_p^{\alpha}(t) + u \qquad L_q^{\beta}(t) = L_q^{\alpha}(t)$$

$$L_q^{\beta}(t) - L_p^{\beta}(t) = L_q^{\beta}(t) - L_p^{\beta}(t) + u \le \varepsilon$$

$$\varepsilon \ge u/2$$

The worst-case clock synchronization error

Conclusion

- We presented **the lower bound** techniques used for proving the worst-case achievable synchronization in a network with two processors.
- Lundelius and Lynch improved this lower bound for a fully connected network with *n* processors.
  - $u(1-1/n)$
- Biaz and Welch proved that for any communication network, the best achievable synchronization error is a function of the diameter of the network.

Thank you...

Questions?