PHYSICAL CLOCK SYNCHRONIZATION: NEWTWORK TIME PROTOCOL (NTP)

Centralized systems do not need clock synchronization, as they work under a common clock. But the distributed systems do not follow common clock: each system functions based on its own internal clock and its own notion of time.The time in distributed systems is measured in the following contexts:

- The time of the day at which an event happened on a specific machine in the network.
- The time interval between two events that happened on different machines in the network.
- The relative ordering of events that happened on different machines in the network.

Clock synchronization is the process of ensuring that physically distributed processors have a common notion of time.

Due to different clocks rates, the clocks at various sites may diverge with time, and periodically a clock synchronization must be performed to correct this clock skew in distributed systems. Clocks are synchronized to an accurate real-time standard like UTC (Universal Coordinated Time). Clocks that must not only be synchronized with each other but also have to adhere to physical time are termed **physical clocks**. This degree of synchronization additionally enables to coordinate and schedule actions between multiple computers connected to a common network.

Basic terminologies:

If C_a and C_b are two different clocks, then:

- **Time:** The time of a clock in a machine p is given by the function $C_p(t)$,where $C_p(t)= t$ for a perfect clock.
- **Frequency:** Frequency is the rate at which a clock progresses. The frequency at time t of clock $C_a$is$C_a'(t)$.
- **Offset:**Clock offset is the difference between the time reported by a clockand the real time. The offset of the clock C_a is given by $C_a(t)- t$. Theoffset of clock C a relative to C_b at time $t \geq 0$ is given by $C_a(t)- C_b(t)$

- **Skew:** The skew of a clock is the difference in the frequencies of the clockand the perfect clock. The skew of a clock C_a relative to clock C_b at timet is $C_a'(t)$- $C_b'(t)$.
- **Drift (rate):** The drift of clock C_a the second derivative of the clockvalue with respect to time. The drift is calculated as:

$$C''_a(t) - C''_b(t).$$

Clocking Inaccuracies

Physical clocks are synchronized to an accurate real-time standard like UTC (Universal Coordinated Time). Due to the clock inaccuracy discussed above, a timer (clock) is said to be working within its specification if:

$$1 - \rho \leq \frac{dC}{dt} \leq 1 + \rho.$$

ρ- maximum skew rate.

1. Offset delay estimation

A time service for the Internet - synchronizes clients to UTC Reliability from redundant paths, scalable, authenticates time sources Architecture. Thedesign of NTP involves a hierarchical tree of time servers with primary serverat the root synchronizes with the UTC. The next level contains secondaryservers, which act as a backup to the primary server. At the lowest level isthe synchronization subnet which has the clients.

2. Clock offset and delay estimation

A source node cannot accurately estimate the local time on thetarget node due to varying message or network delays between the nodes.This protocol employs a very common practice of performing several trialsand chooses the trial with the minimum delay.

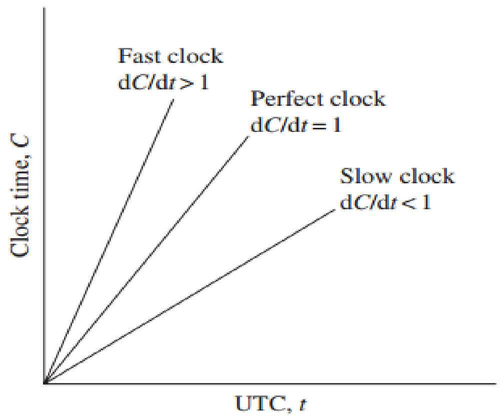
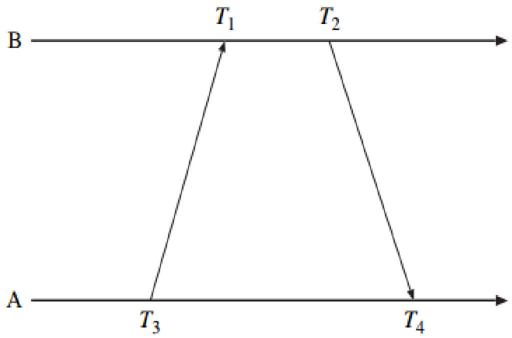


Fig : Behavior of clocks



Figa) Offset and delay estimation between processes from same server

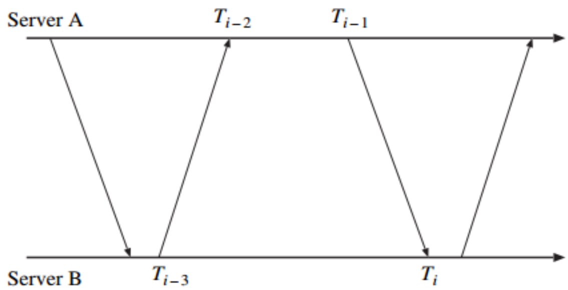


Fig b) Offset and delay estimation between processes from different servers

Let T1, T2, T3, T4 be the values of the four mostrecent timestamps. The clocks A and B are stable andrunning at the same speed. Let a = T1 − T3 and b = T2 − T4. If the networkdelay difference from A to B and from B to A, called **differential delay**, is small, the clock offset θand roundtrip delayδ of B relative to A at time T4are approximately given by the following:

$$\theta = \frac{a+b}{2}, \quad \delta = a - b$$

Each NTP message includes the latest three timestamps T1, T2, andT3, while T4 is determined upon arrival.