Clocks, order of events

Source:

- IB Distributed System
- y2014p5q7

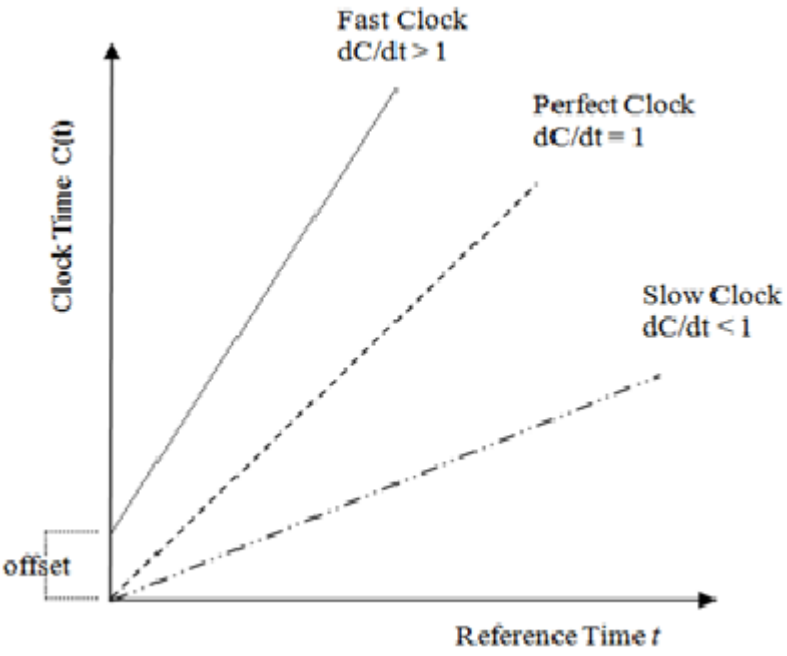
Clock	Physical	Logical
measure	seconds	events with causality
example	analogue/mechanic digital: Quartz (drift) Atomic, GPS	Lamport Vector

Physical Clock

Time-of-day and Monotonic

Physical Clock	Real Time	Monotonic
since	a fixed date time	arbitrary point (start-up)
correction	$slew \implies step$	always slew *forward*
behaviour	human readable; compare ts among nodes if sync	measure elapsed time on a single node
usage	certificate time	measure intervals / timeouts

Synchronization



The time of a clock in a machine p is $C_p(t)$, frequency/rate of a clock is $C'_p(t)$

- perfect clock $\Leftrightarrow C_p(t) = t$

Clock skew / offset

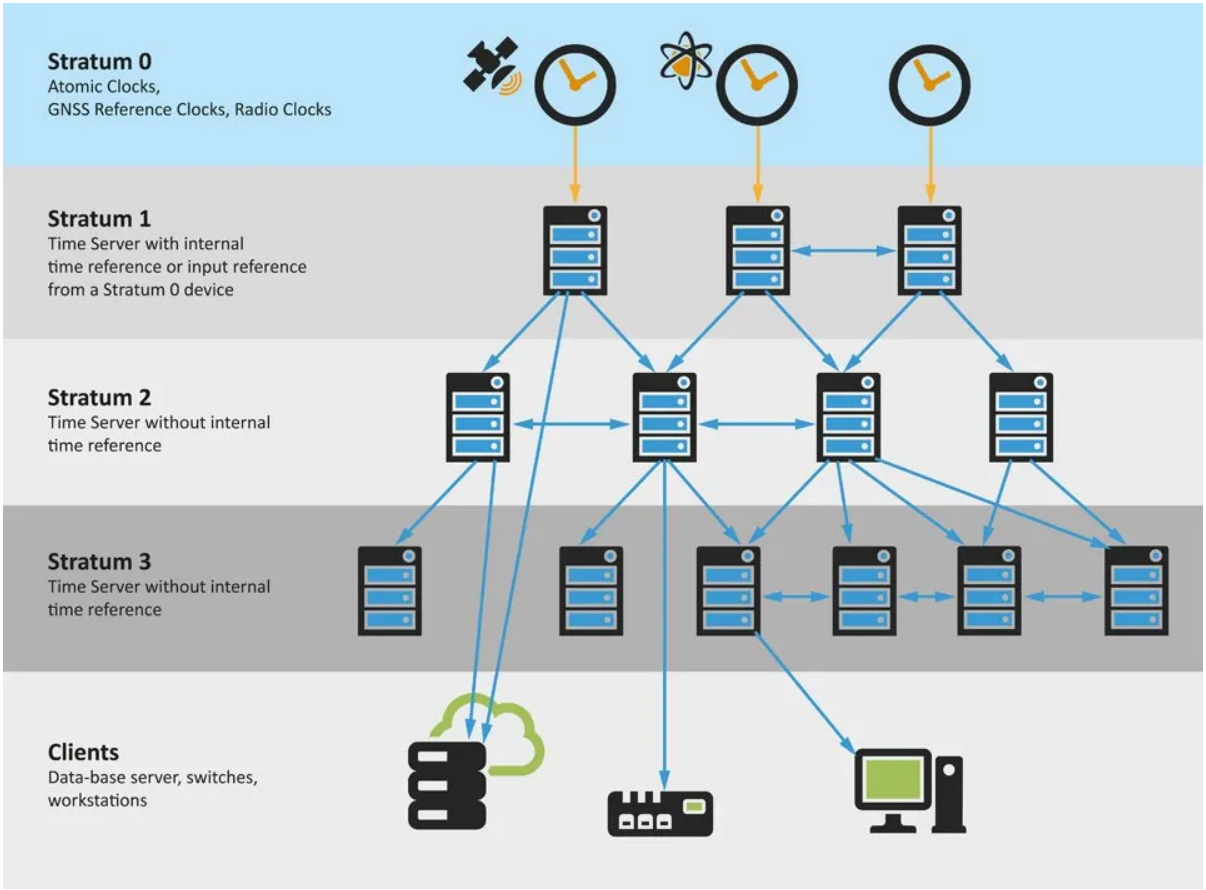
- the difference between the time on two clocks
- skew $\Delta_s = C_a(t) - C_b(t)$ (ms)
- measure: RTT δ, Cristian's Algorithm wiki
    - assumption:
        - symmetric latency
        - not consider the derivative of the clock (i.e. drift) or higher derivatives
- correction
    - as Δ_s increases, $slew \implies step \implies panic$

Clock drift

- the difference of clock rate of oscillations / ticks
- drift $\Delta_d = C'_a(t) - C'_b(t) = \Delta_s(t_1) - \Delta_s(t_2)$ (ms/day, parts per million)
    - affected by temperature, etc.
- measure: Cristian's Algorithm twice
    - assumption
        - symmetric latency
        - not considering the second or higher derivatives of the clock

NTP / PTP (Stratum 0-2)

- Less accurate synchronization
    - Time source (higher stratum)
    - Assumption of Cristian's Algorithm



Logical Clock

- causal / happen-before dependency $e_1 \to e_2$
  - e_1 and e_2 occurred at the same node, different by execution time
  - e_1 is sending message to e_2
  - transitivity, $\exists e_3.(e_1 \to e_3) \wedge (e_3 \to e_2) \implies e_1 \to e_2$.
  - (strict) partial order, asymmetric, undefined when race condition has occurred $e_1 || e_2$
- logical clock timestamp is consistency with causal dependency
  - But lamport may not get causal dependency of events back from logical timestamps.

$$e_1 \to e_2 \implies T(e_1) < T(e_2)$$

	Lamport	**Vector**
format	$(N(e), L(e))$ (i, Seq)	$\langle N_1, ..., N_n \rangle$ $V(e) = \langle t_1, ..., t_n \rangle$
order	$total \prec$	$partial < \|\|$
timestamp	scalar	vector
	$\implies$	$\iff$
initial	$(i, 0)$	$\langle 0, ..., 0, ..., 0 \rangle$
event occur	$(i, t) \to (i, t+1)$	$T_V[i] := T_V[i] + 1$

	Lamport	Vector
$receive(t'/T', m)$	$t := max(t, t') + 1$	$T_V := max_j(T_V, T')$ $T_V[i] := T_V[i] + 1$