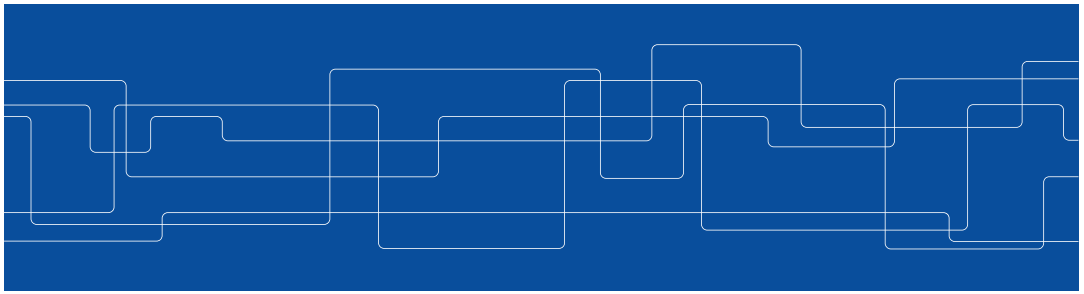
Clocks

Johan Montelius and Vladimir Vlassov



Time

Why is time important?

Correct time

- Who has the correct time?
  - Earth's rotation - UT1
  - one “atomic” clock - UTC
- Even if we all agree, how do we keep nodes synchronized?
  - it takes time to send a signal
  - in between signals nodes will drift
  - how often can we send signals

A correct clock

Drift is change in how well one clock can measure a time interval.

Monotonic is the property that time always moves forward.

Correctness often means monotonic and low drift.

A correct clock might not be synchronized.

How to synchronize

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Synchronization

Accuracy or external synchronization:

- Each node in our network is synchronized with an external (global) source within a bound.

Precision or internal synchronization:

- Every pair of nodes in our network are synchronized within a bound.

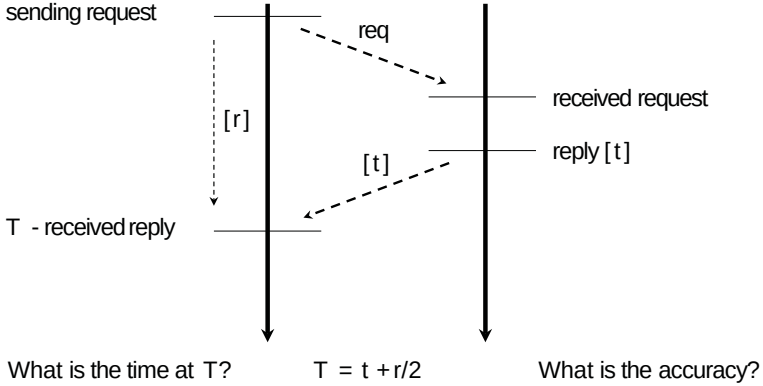
Asynchronous networks

One server is connected to external source and used to synchronize other nodes in the network.

Problem is of course that round-trip times are unknown and that they vary.

A minimum propagation time can be known.

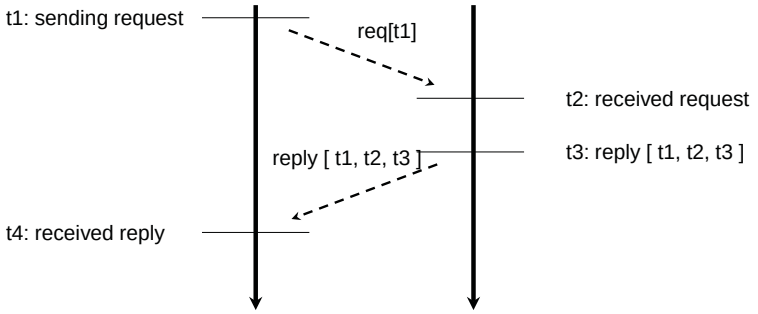
Christian's algorithm (using a time server)



Network Time Protocol (NTP)

- An architecture targeting reliability and wide area networks.
- A hierarchy of servers: stratum-1 connected to external sources.
- Fault tolerant: servers can be degraded to lower stratum if external source is lost, client can connect to secondary servers.
- Several synchronization protocols: LAN multicast, request reply and synchronous.

NTP



Similar to Christian's but with better estimate of delay.
Stateless, no need to record *r*.

Berkeley algorithm

Used to synchronize a network of nodes.

- send requests to all nodes
- collect it and calculate an *average* time T
- send out individual deltas to each node

Summary

Clocks can be synchronized:

- internally
- or to an external source

Synchronization limited by:

- network jitter
- clock drift

Synchronize to UTC (Coordinated Universal Time):

- NTP connected over Internet: a few 10 ms
- local GPS clocks connected to LAN: < 1 ms
- on board GPS clock: few ms to ns