CS 925

Lecture 22

Network-based Time Synchronization

Tuesday, April 23, 2024

Time transfer

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- *You need precise time…*
  … so I write the current time on Post-it note and take it to you …
- The key issue is time transfer and the key challenge is the latency of the communication

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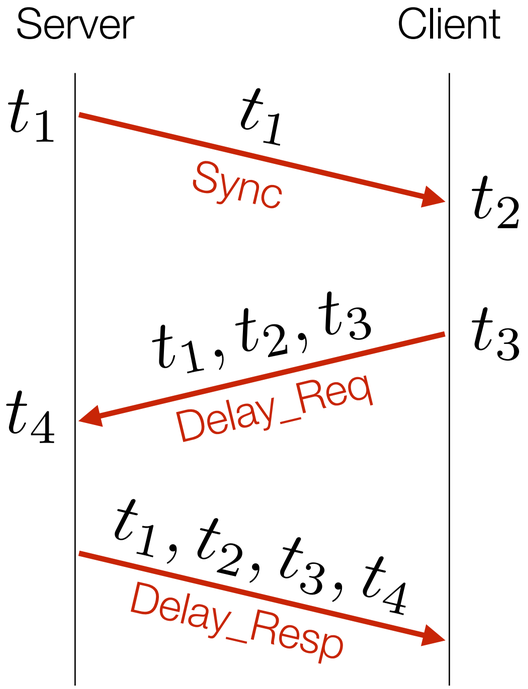

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$$Offset = (t_2 - t_1) - \frac{RTT}{2}$$

Time transfer - example

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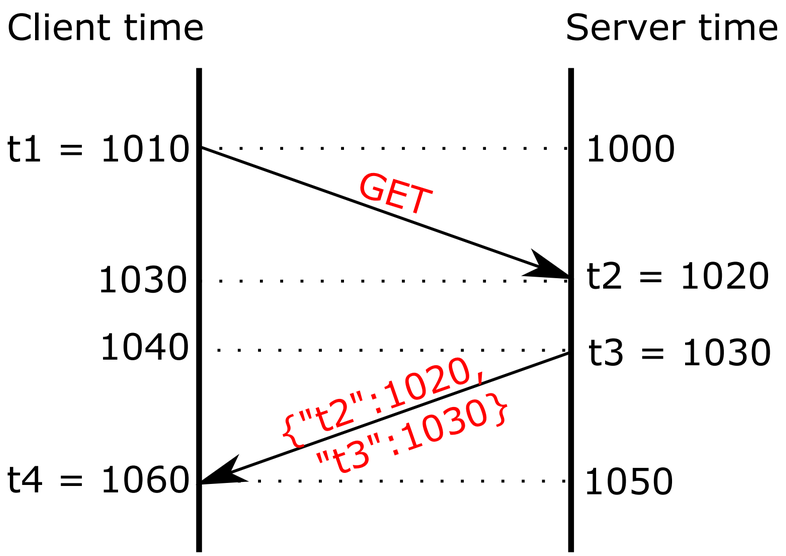

RTT = (1060 - 1010) - (1030 - 1020) = 40 units

Offset = (1010 + 40/2) - 1020 = 10 units

The client clock is 10 units ahead of the server clock

Time transfer - example

$$RTT = (t_4 - t_1) - (t_3 - t_2)$$

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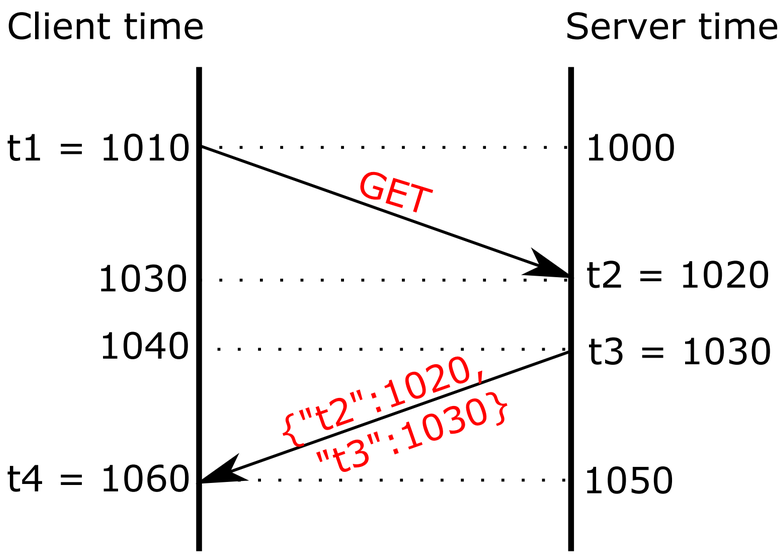
Assumption!
Sometimes not true
in real systems



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Time transfer protocols

- Software-only solution:

  Network Time Protocol (NTP)

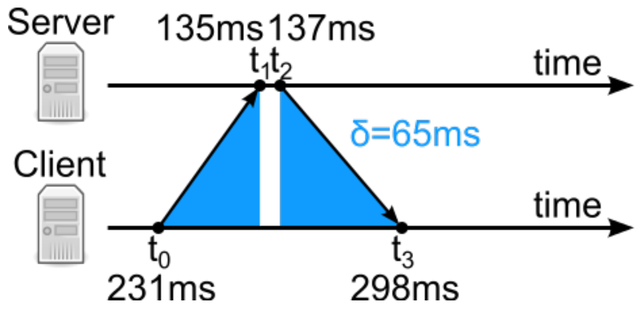
- Hardware-assisted solutions:

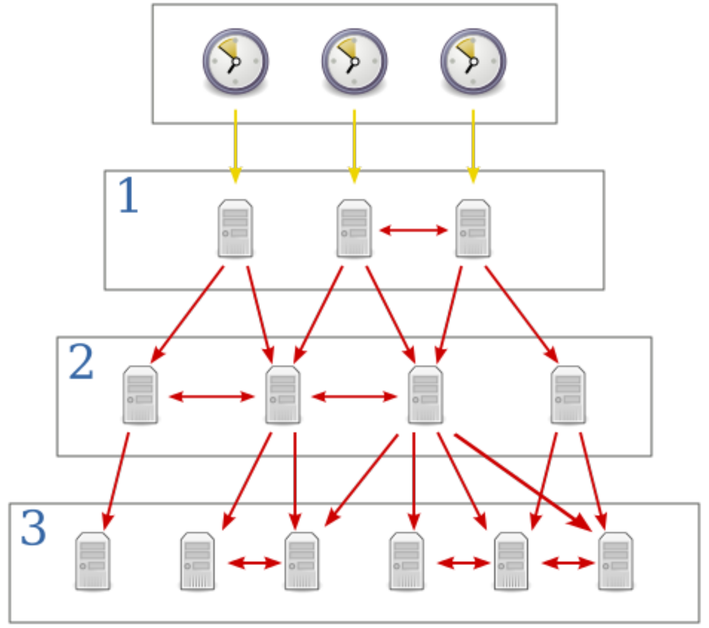
  IEEE 1588 Precision Time Protocol (PTP)

  White Rabbit

NTP

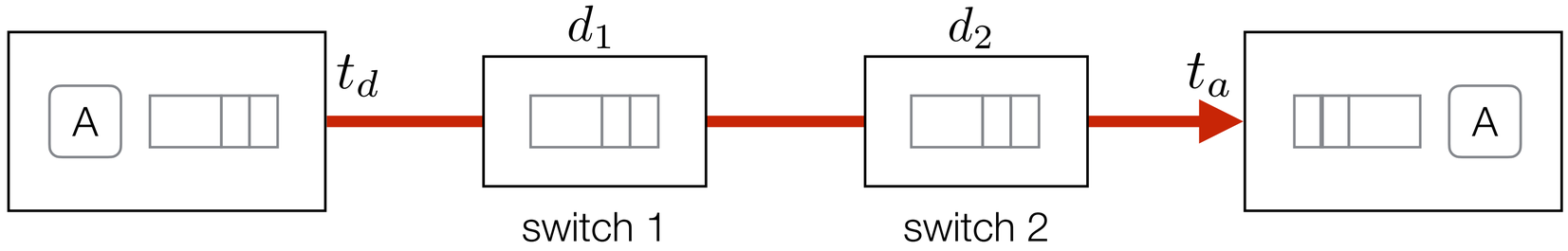
- Network Time Protocol (NTP)
- One of the fundamental Internet protocols
- Current version (NTPv4): RFC 5905 is from 2010
- Clock strata
- Implemented and enabled by default by most operating systems



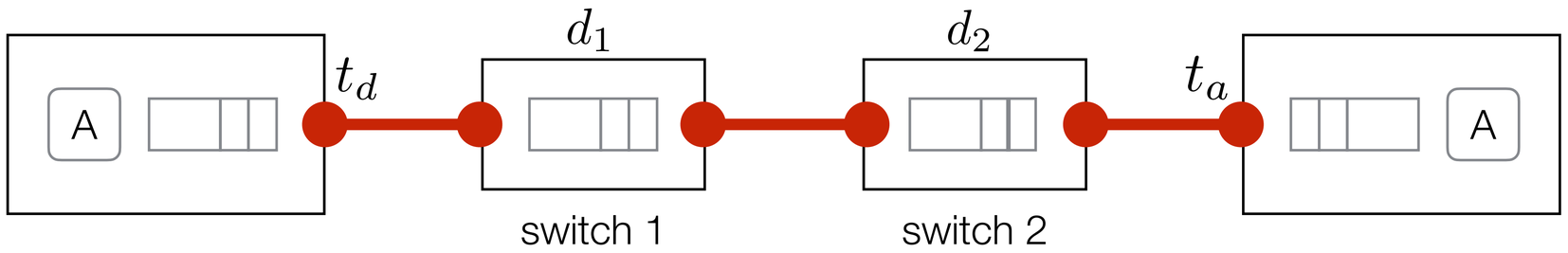


IEEE Std 1588

- Precision Time Protocol (PTP)
  - initial version: IEEE Std 1588™-2002
  - “current” version: IEEE Std 1588™-2008 (a.k.a. v2)
  - new version: IEEE Std 1588™-2019 (a.k.a. v2.1)
- Takes advantage of hardware support
  - precise packet arrival and departure timestamp
  - allows for compensation of delay encountered within a switch



IEEE Std 1588



- Link latency:
  - "constant" on links
  - variable at endpoints and switches due to queueing
- Variable components can be eliminated:

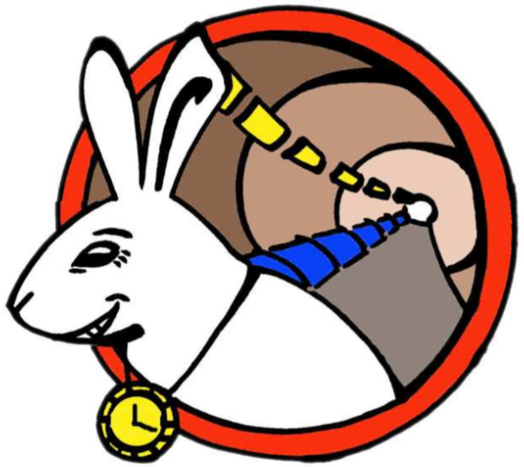
$$t_a - t_d - \sum_{i=1}^{N} d_i$$

Key Components

- Node types (“clock” = IEEE Std 1588 aware node)
  - ordinary clocks (OC)
  - boundary clocks (BC)
  - transparent clocks (TC)
- End to End (e2e) and Peer to Peer (p2p) modes
- Use of multicasting
- MAC or IP as underlying protocols
- Best Master Clock (BMC) algorithm
- Application domain specific profiles

White Rabbit

- A project from CERN, supported in the latest version of IEEE Std 1588
- Goals: sub-nanosecond accuracy, flexibility, predictability and reliability, robustness, open source hardware and software
- Means:
  - Synchronous Ethernet for syntonization
  - IEEE 1588 Precision Time Protocol



Achievable accuracy

- Continental distances:
  - GNSS (GPS, Glonass, BeiDou, Galileo): 1 µs is easy, 50 ns is possible, <10 ns very hard
  - NTP (Network Time Protocol): milliseconds
- Within a LAN:
  - IEEE1588: 1 µs easy, 50 ns with care, few ns hard
  - White Rabbit: 100 ps accuracy, 10 ps jitter