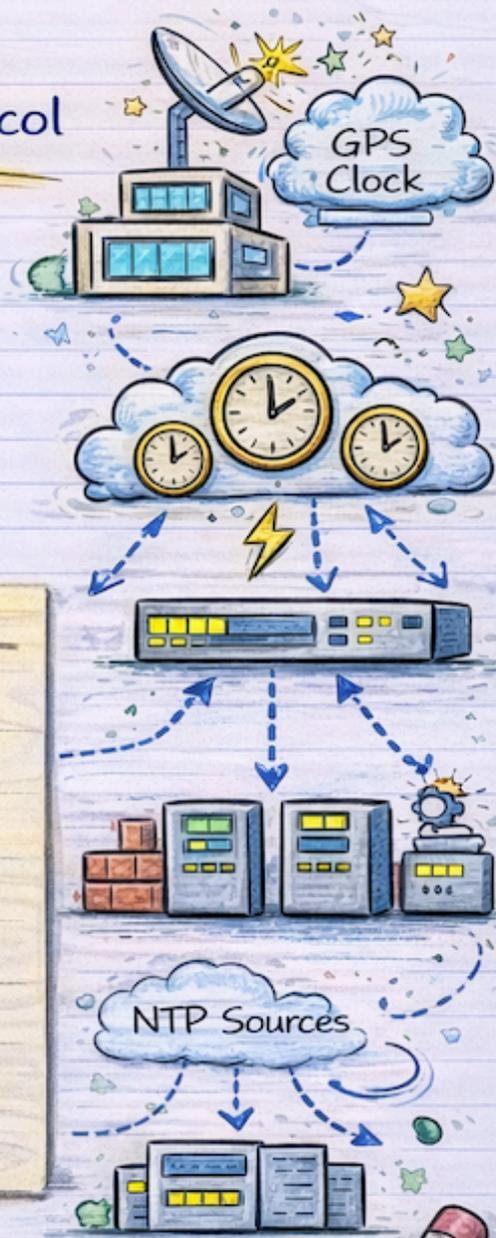


NTP Essentials

A Visual Guide to Network Time Protocol

Covers:

- ✓ NTP fundamentals
- ✓ Stratum hierarchy
- ✓ Timestamp exchange
- ✓ Offset and delay
- ✓ chrony vs ntpd
- ✓ NTP vs PTP
- ✓ Enterprise deployment
- ✓ Troubleshooting



Abhiney Sharma
visualnotes.tech



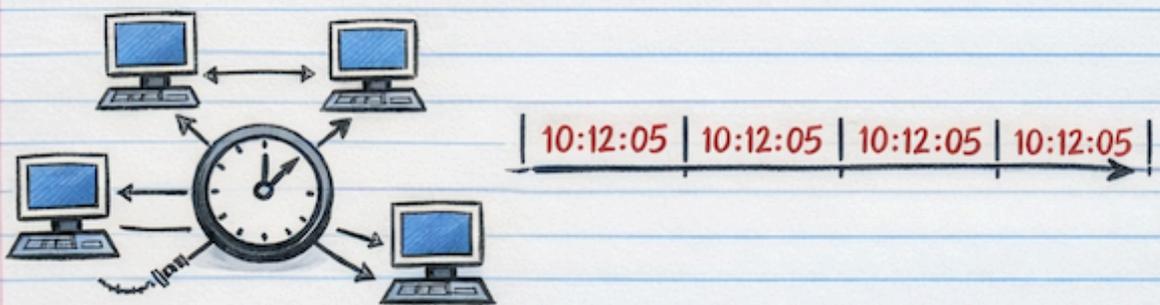
Network Time Protocol (NTP)

Network Time Protocol (NTP) synchronizes system clocks across packet-switched networks.

- Defined in **RFC 5905**.
- Transport protocol: **UDP**
- Port number: **123**

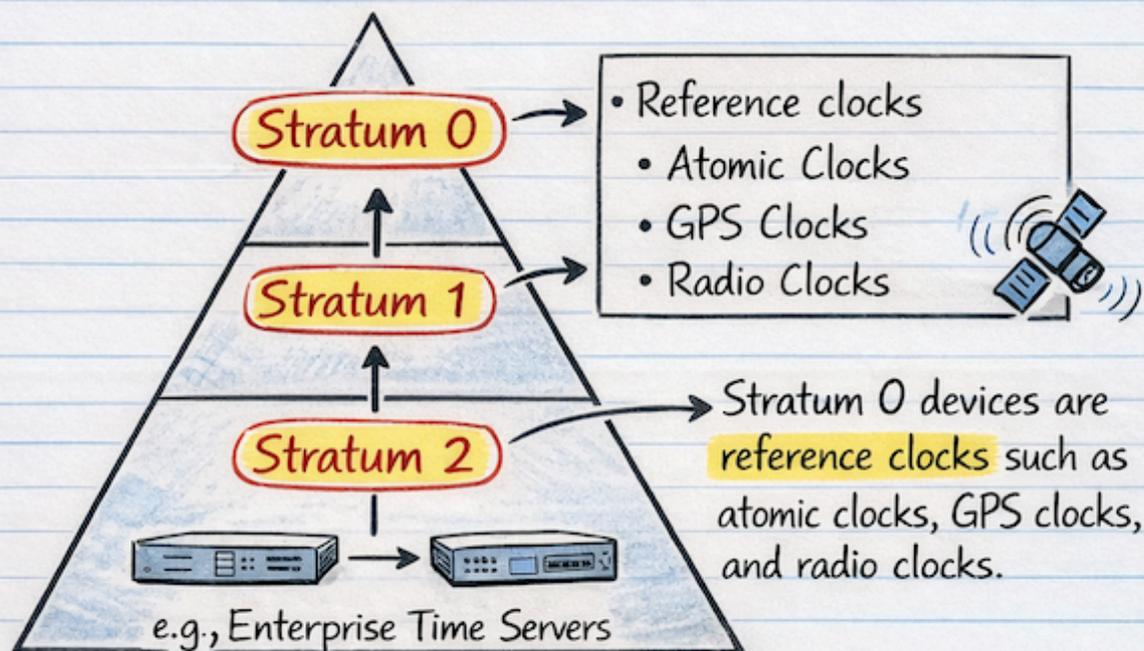
Designed to achieve **millisecond-level** synchronization accuracy over packet-switched networks.

- Provides time synchronization using a hierarchical **time-distribution model**.
- NTP synchronizes systems to **reference time sources** such as GPS and atomic clocks.
- Prevents **clock drift** across **distributed systems**.

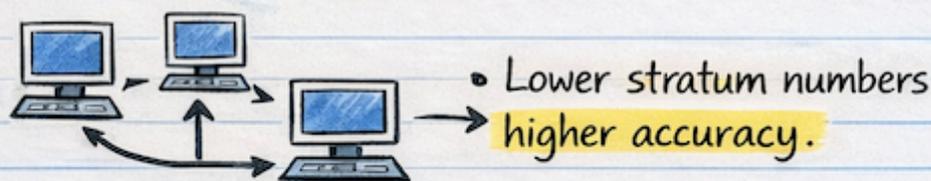


NTP Stratum Levels

- NTP distributes time using a hierarchical stratum model.



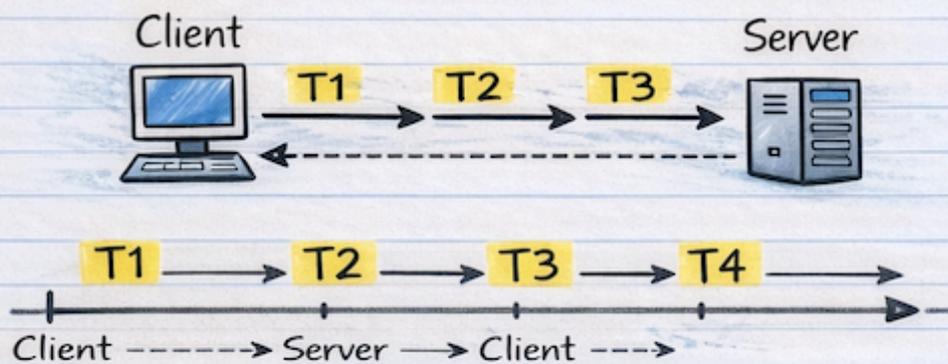
- Stratum 0 devices are reference clocks such as atomic clocks, GPS clocks, and radio clocks.
- Stratum 1 servers synchronize directly from Stratum 0 reference clocks.
- Stratum 2 servers synchronize from Stratum 1 servers.
- Each additional stratum represents another synchronization hop.



Lower stratum numbers → higher accuracy.

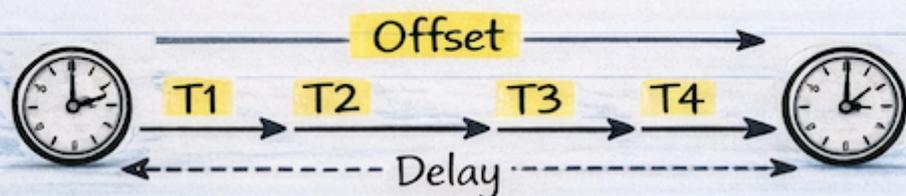
NTP Four-Timestamp Exchange

- NTP synchronizes clocks using a four-timestamp exchange between client and server.
- **T1**: Client transmit timestamp.
- **T2**: Server receive timestamp.
- **T3**: Server transmit timestamp.
- **T4**: Client receive timestamp.
- **Clock offset** and **round-trip delay** are computed from these timestamps.
- **Clock discipline** algorithms adjust system time **gradually**.



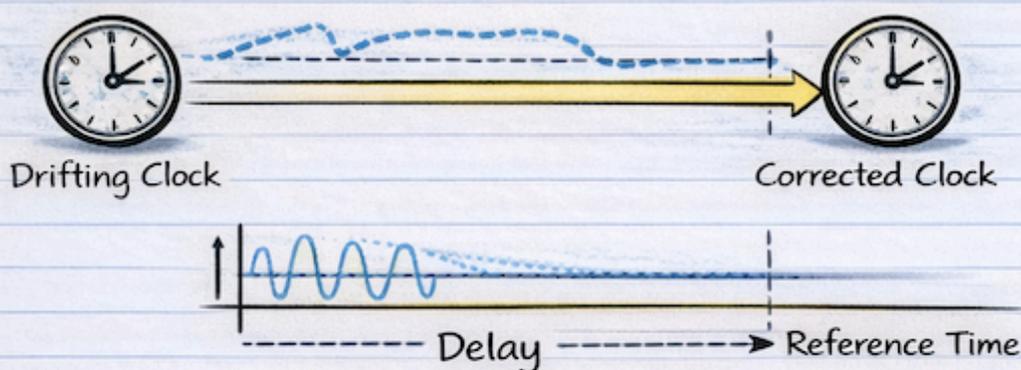
NTP Offset and Round-Trip Delay

- NTP calculates clock offset and round-trip delay using four timestamps.
- $\text{Offset} = \frac{((T2 - T1) + (T3 - T4))}{2}$
- $\text{Delay} = (T4 - T1) - (T3 - T2)$
- Offset represents the time difference between client and server clocks.
- Round-trip delay represents network latency.
- Accurate delay measurement improves synchronization precision.
- These calculations allow the client clock to be corrected.



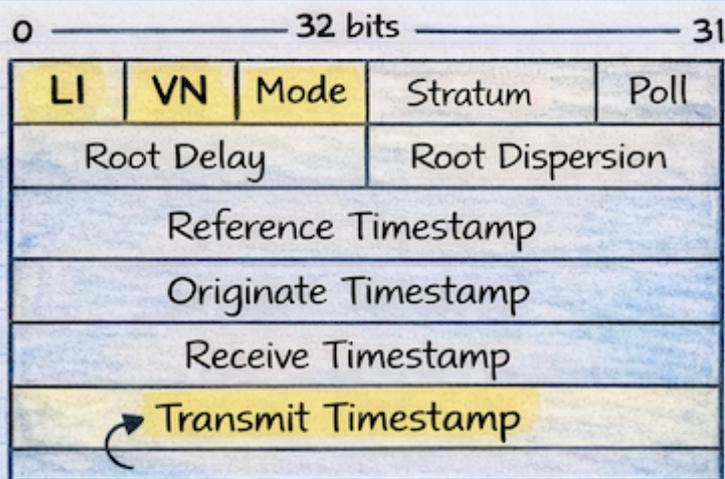
Clock Discipline and Drift

- System clocks drift due to oscillator frequency variation.
- **Clock drift** accumulates when systems run without synchronization.
- NTP uses **clock discipline** algorithms to correct drift.
- Small corrections are applied using **clock slewing**.
- Large time errors may require **clock stepping**.
- **Phase-Locked Loop (PLL)** maintains long-term clock stability.
- Regular synchronization reduces accumulated drift.



NTP Packet Structure

- NTP packets are 48 bytes without authentication fields.
- Leap Indicator (LI) signals leap second status.
- Version Number (VN) identifies the NTP version.
- Mode field defines client, server, broadcast, or symmetric operation.
- Stratum field indicates distance from reference clock.
- Reference Timestamp records last clock update.
- Transmit Timestamp records packet send time.

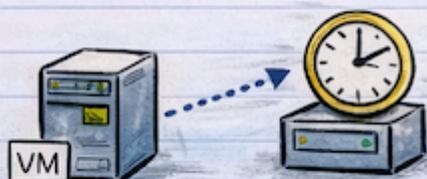


chrony vs ntpd

- ntpd is the traditional Network Time Protocol daemon.
- chronyd is a modern implementation of NTP synchronization.
- chrony synchronizes faster after system startup.
- chrony performs better on virtual machines and unstable networks.
- ntpd is stable for long-running servers with consistent connectivity.
- Most modern Linux distributions use chrony by default.
- Both chrony and ntpd implement NTP clock discipline algorithms.

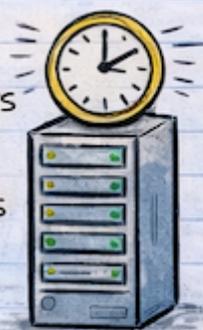
Why chrony?

- Syncs fast after startup
- Ideal for virtual machines



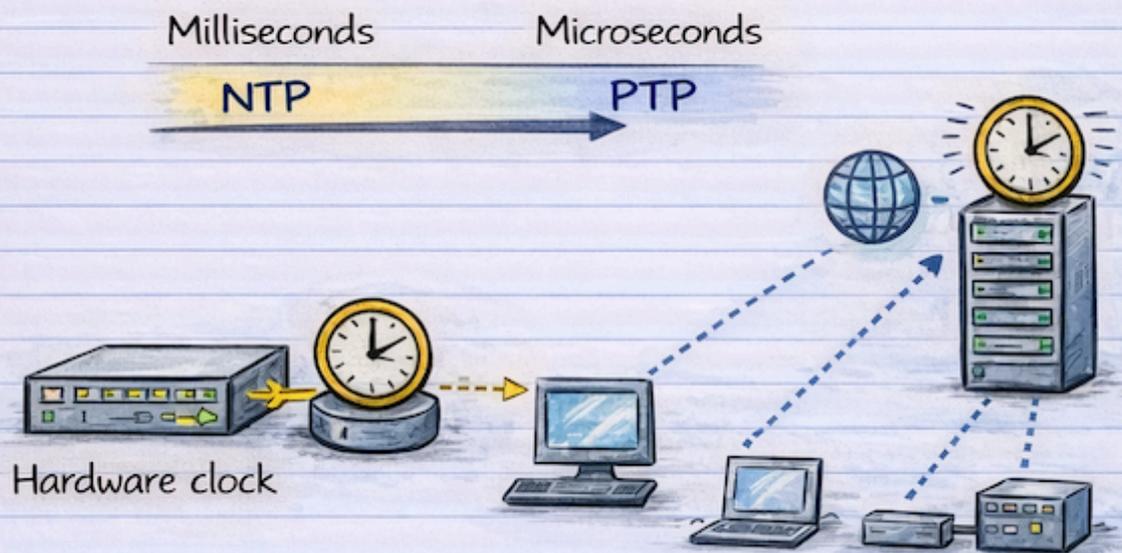
When ntpd?

- Stable for long-running servers
- Good on consistent networks



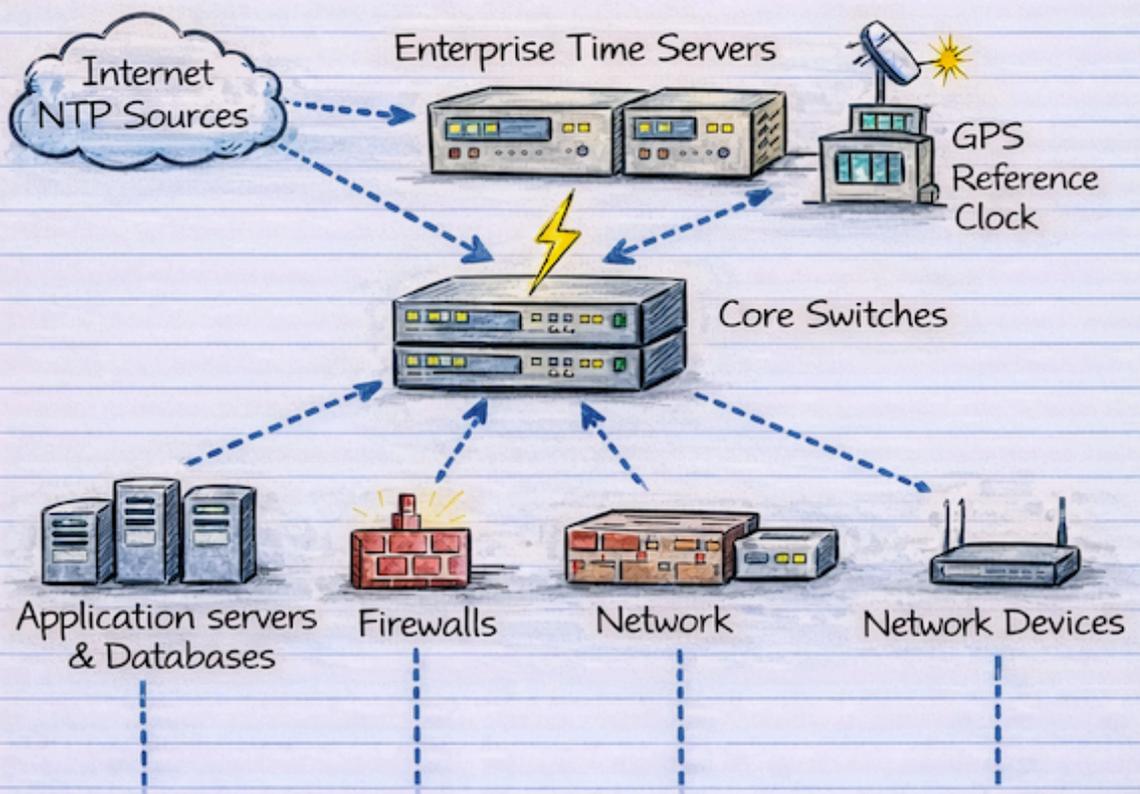
NTP vs PTP

- NTP provides millisecond-level time synchronization.
- PTP provides microsecond or sub-microsecond synchronization.
- PTP is defined in IEEE 1588.
- PTP uses hardware timestamping for high precision.
- NTP operates over general-purpose IP networks.
- PTP is used in telecom, financial trading, and industrial automation.
- Both protocols synchronize distributed system clocks.



Enterprise NTP Architecture

- Enterprise networks deploy internal NTP servers for reliability.
- Internal NTP servers synchronize from trusted external time sources.
- Reference sources may include GPS clocks or public NTP pools.
- Core infrastructure devices synchronize from internal NTP servers.
- Application servers and databases synchronize from internal sources.
- Redundant NTP servers prevent single points of failure.
- Hierarchical synchronization improves stability and accuracy.



NTP Troubleshooting

- Verify synchronization status using NTP monitoring commands.
- `ntpq -p` displays NTP peers and synchronization state.
- `chronyc sources` shows active time sources.
- Check system time using the `date` command.
- Ensure UDP port 123 is reachable across the network.
- Multiple NTP sources improve synchronization reliability.
- Large clock offsets may indicate network delay or server issues.

