Computer Time Synchronization Aspects

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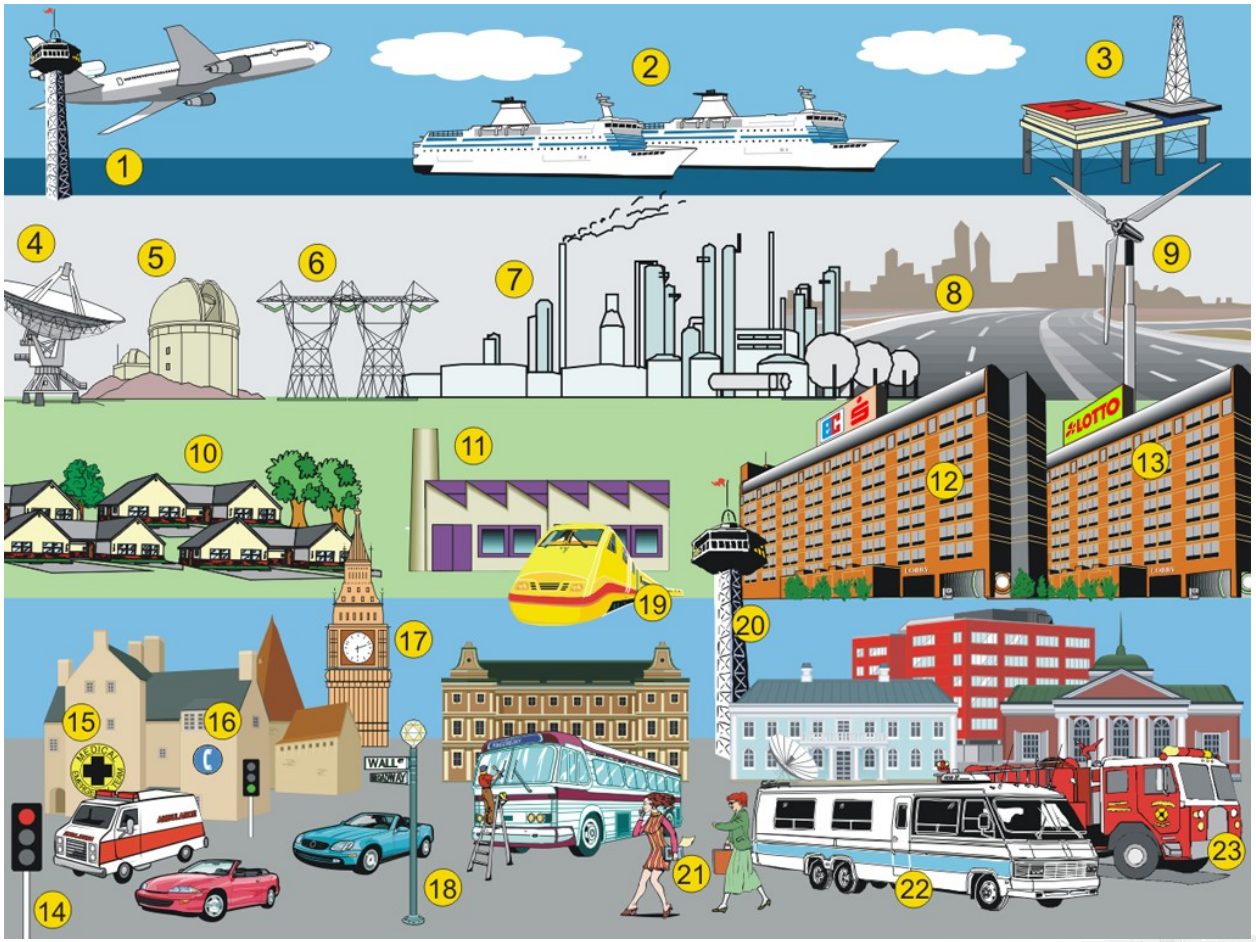
Agenda

- Some Basics
- Network Time Protocols
- Ways to Distribute Time
- Accuracy considerations

Who Needs Time Synchronization?



1. Air Traffic Control
2. Research Vessels
3. Oil Production
4. Satellite Communication
5. Observatories
6. Power Substations
7. Power Plants
8. Toll Charging Systems
9. Wind Energy Plants
10. Public Infrastructure
11. Production Flow
12. Banks, Cash Terminals, Stock Exchange, Data Centers
13. Lottery
14. Traffic Management
15. Operation Coordination
16. Event Management
17. Wall Clocks
18. Lighting Control
19. Railway Time Table
20. Radio Broadcasting
21. Mobile Communication Call Data Records
22. Outside Broadcast Van
23. Emergency

World Time vs. Local Time

- World has been divided into 24 time zones
- Time zones usually differ by 1 hour
  - A few regions have local times 15, 30, or 45 minutes off
- Time zone borders often follow borders of countries
- Many countries are in a single time zone
  - People often don't care about the time zone
- Large countries span several time zones
  - People are used to account for different times in different zones
- Time zones are derived from common world time (UTC)

Computer UTC vs. Local Time (1)

- Computer system time is usually kept as UTC
- Converted to local time according to user preferences (configuration)
- On Windows usually only a single time zone setting
- On Unix/Linux even single processes can run with different time zone settings
- Switching to/from daylight saving (DST) is done by the operating system

Computer UTC vs. Local Time (2)

- Time synchronization only adjusts UTC system time
- If UTC time is correct then local times are also correct
- Time zone parameters and DST are not job of time synchronization software
- Time zone rules stored on the client
- New tzdist protocol coming to simplify update of time zone rules on clients

System Time Resolution

- On some operating systems limited to timer tick
  - Windows XP / Server 2003: about 16 ms
  - Windows Vista / Server 2008: 1 ms
  - Windows 8 / Server 2012: sub-microsecond resolution
  - Reading system time yields same time during timer tick!
- Other operating systems provide better resolution
  - Linux / Unix: microseconds or even nanoseconds
  - Reading system time yields always different time stamps
- Nanosecond **resolution** does not necessarily mean nanosecond **accuracy**, but high resolution is a precondition for high accuracy.

Computer Time Synchronization Aspects (1)

- Where do I get the time from? At which accuracy?
  - Radio clock
  - Time server / network
- Which ways exist to get the time?
  - PCI card: Can get the current time always, immediately
  - Serial: Wait for time string. When sent? Transmission delay?
  - Network: Send query, wait for reply
  - Compensate network delay and other transmission delays

Computer Time Synchronization Aspects (2)

- Resolution of the local system time
- Stability of the on-board system clock
  - Quartz frequency offset, drift with temperature, virtualization
- Time synchronization software
  - Which resolution is supported?
  - Is transmission delay compensated?
- How is system time adjusted? Set periodically? Smoothly?
- **Very important**: Handling of Leap Seconds by OS or client

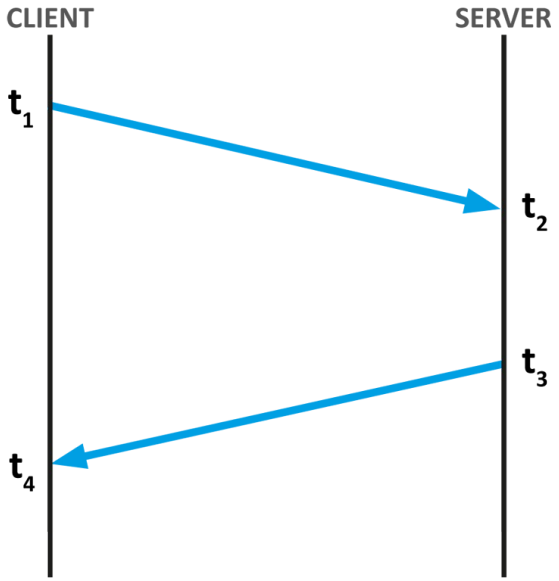
Network Time Synchronization Protocols

- Network Time Protocol (NTP)
  - Invented later in the 1980s, 0.2 ns resolution → supports high accuracy
  - Current protocol version is v4, compatible with older versions
  - Standard protocol for time synchronization in Unix/Linux, and Windows
  - Reference implementation available as free software
- Precision Time Protocol (PTP/IEEE1588)
  - v1 from 2002, v2 from 2008, v2 is not compatible with v1
  - Nanosecond resolution, eventually yields some nanoseconds accuracy under specific conditions (e.g. hardware timestamping on **every** node)
  - Open source implementation available

General Network Time Transfer (1)

Example: NTP protocol

t1: Client sends request packet to server
t2: Server receives request packet from client
t3: Server sends reply packet to client
t4: Client receives reply packet from server



→ Four timestamps from one packet exchange

→ Timestamps from server are server time

→ What's the offset between server time and client time?

→ How long did the request and reply packet travel on the network?

→ High accuracy if the network delays are the same in both directions

General Network Time Transfer (2)

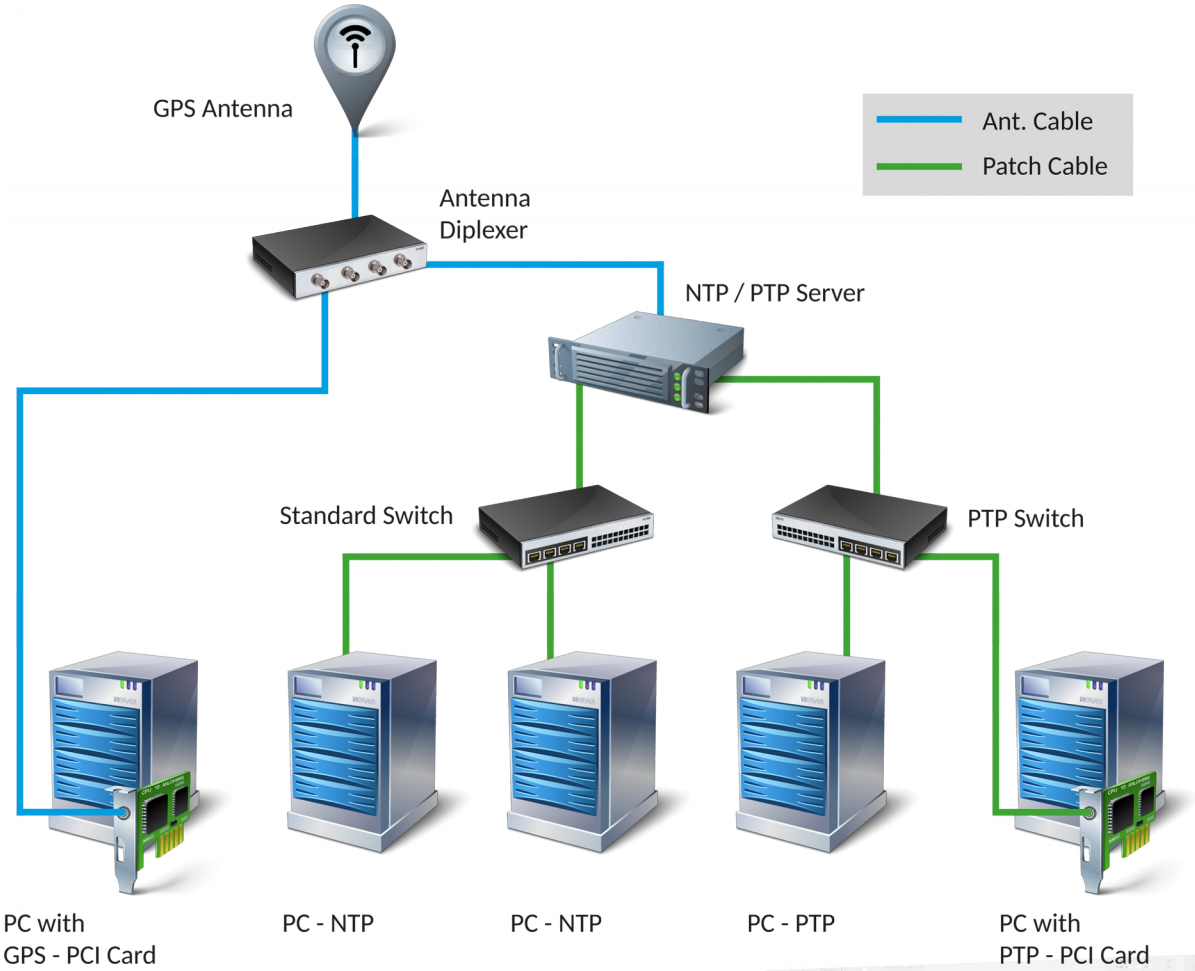
- Network delays are not constant → **filtering** required on the **client** !
- Achievable accuracy does not only depend on the accuracy of the server,
- It depends strongly on the implementation of the **client software**.
- When talking about NTP or PTP distinguish between protocol and implementation.

Network Delays Affecting Time Synchronization

- Delays in routers and switches
- Processing time of packets on server and clients
- IRQ latencies of high performance NICs
  - Interrupt coalescence
- Hardware Timestamping can reduce variable network delays
- Required on every network node to get highest accuracy

➔ Use PTP with special PTP-aware switches

Time Distribution (1)



Time Distribution (2)

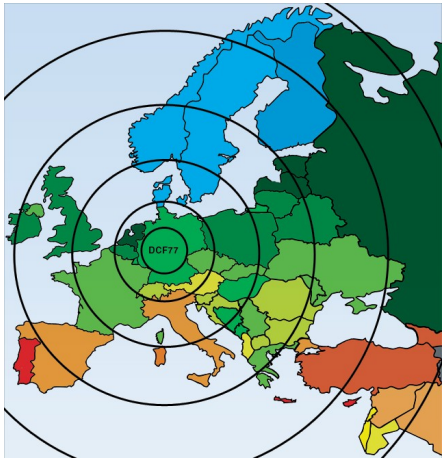
- GPS card in each server, multiple GPS antennae
  - High accuracy
  - High cabling efforts for antennae
- GPS card in each server, single GPS antenna with diplexer(s)
  - High accuracy
  - Only single cable to antenna, but special antenna cables to each GPS card

Time Distribution (3)

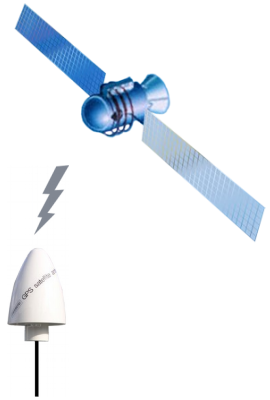
- Single, GPS controlled NTP/PTP time server
  - Provides high accuracy to clients
  - Single antenna cable required
  - NTP with good accuracy for “normal” servers
  - PTP with highest accuracy for special requirements
  - PTP PCI cards get high accuracy into a server
  - PTP-aware switches required for high accuracy
  - Standard patch cables instead of special antenna cables

- In any case limited accuracy with virtual machines

Times Sources



- Long Wave Receivers
  - DCF-77, MSF, WWVB
  - Single transmitter per system
  - Varying signal propagation delay, low bandwidth
  - Millisecond accuracy only



- Satellite Systems
  - GPS, GLONASS, Galileo, Beidou
  - Multiple satellites per system
  - Propagation delay can be measured and compensated
  - Sub microsecond accuracy internally

Charactersistics Affecting Time Accuracy

- Protocol
- Transmission
- Operating System
- Hardware
- Virtual Machines vs. Physical Machines

Conclusion

- Timekeeping accuracy depends on many facts
- Required accuracy depends on applications
- Higher accuracy requires higher effort, and thus solutions are usually more expensive
- Ask the experts for support in finding the solution which best meets the requirements of your application

Contact / Questions

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Thanks for your attention!