



SCIENCE OF TIMEKEEPING

Achieving nanosecond accuracy, precision and synchronization

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 #GHCI19

THIRTY METER TELESCOPE

- World's largest optical telescope
- Operational in 2030
- Mauna Kea, Hawaii
- Five countries collaborating
 - USA
 - Japan
 - China
 - India
 - Canada



<https://www.tmt.org/>



ThoughtWorks®

ARCHITECTURE

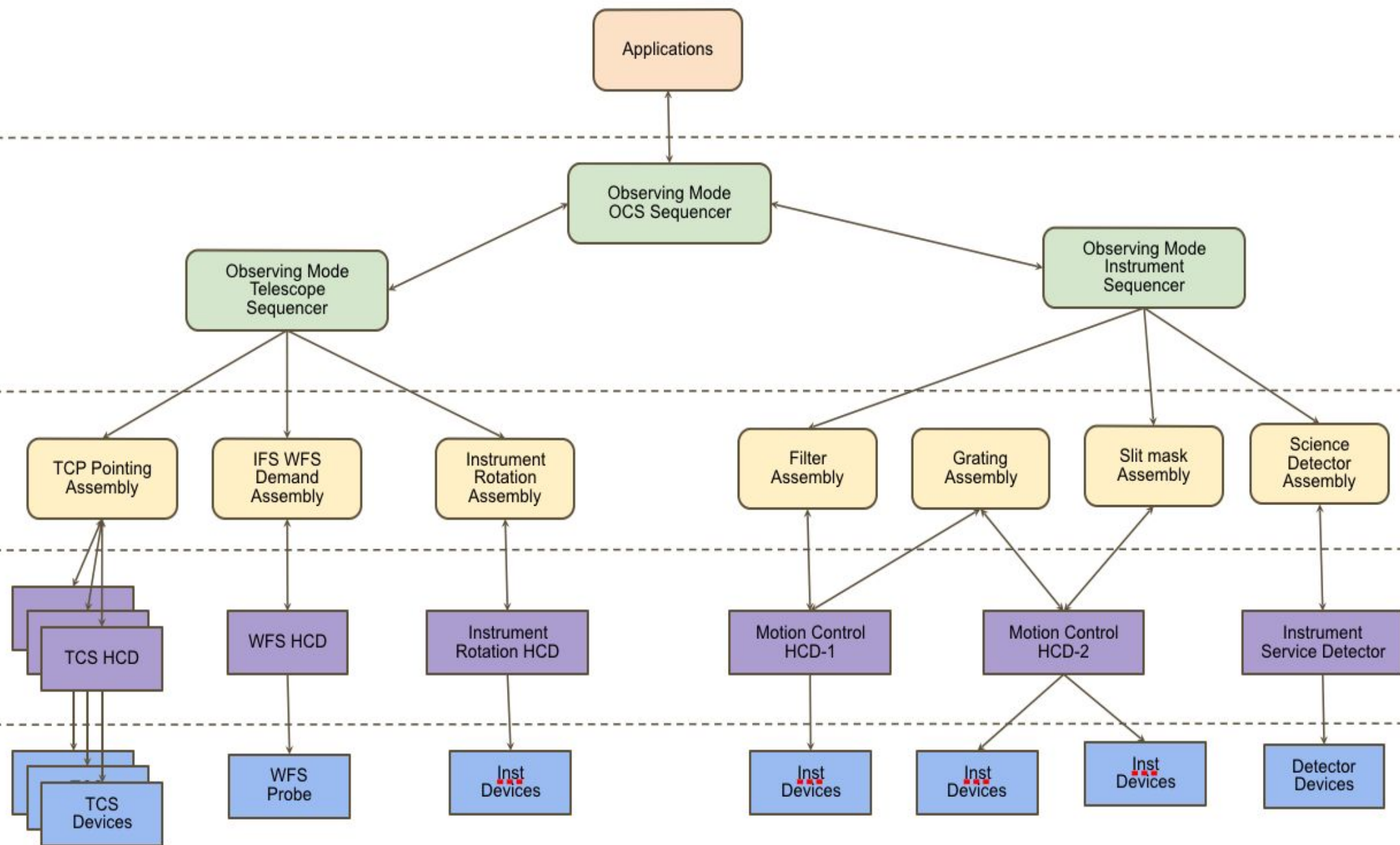
4: Monitoring and Control

3: Sequencing Layer

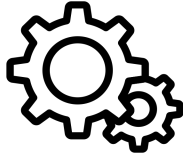
2: Assembly Layer

1: Hardware Control Layer

0: Observatory Hardware



COMMON MIDDLEWARE SERVICES



Config Service



Location Service



Logging Service



Database Service



Time Service



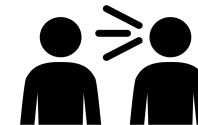
Command service



Authentication and
Authorisation Service

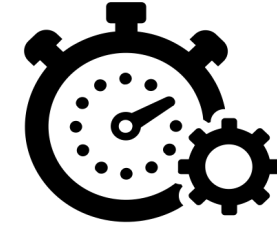


Alarm Service



Event Service

TIME SERVICE



1. Synchronizing all the components with nanosecond accuracy & precision
2. Scheduling tasks at frequency as high as 1 KHz

EVOLUTION OF TIMEKEEPING DEVICES



Sundials and Obelisk (1500 BC)



Stonehenge (3500 BC)



Water Clocks
(16th century BC)



Pendulum Clocks
(16th Century)

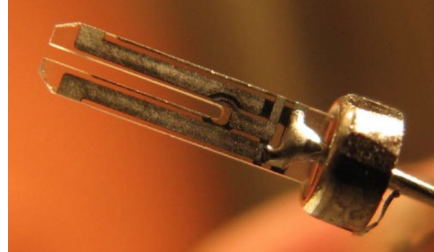


Sea Clocks
(17th Century)

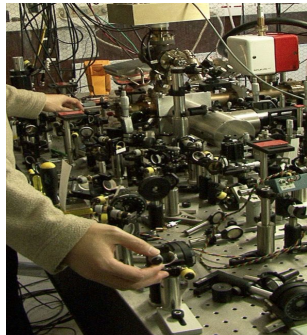
CURRENT AND FUTURE CLOCKS



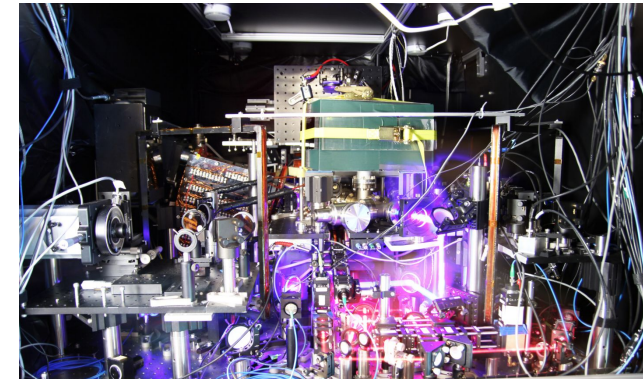
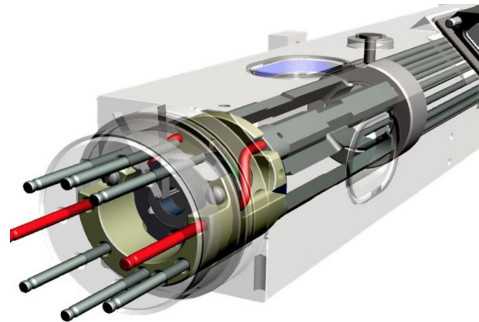
Quartz Crystal Oscillator (1927)



Atomic clocks (1955)

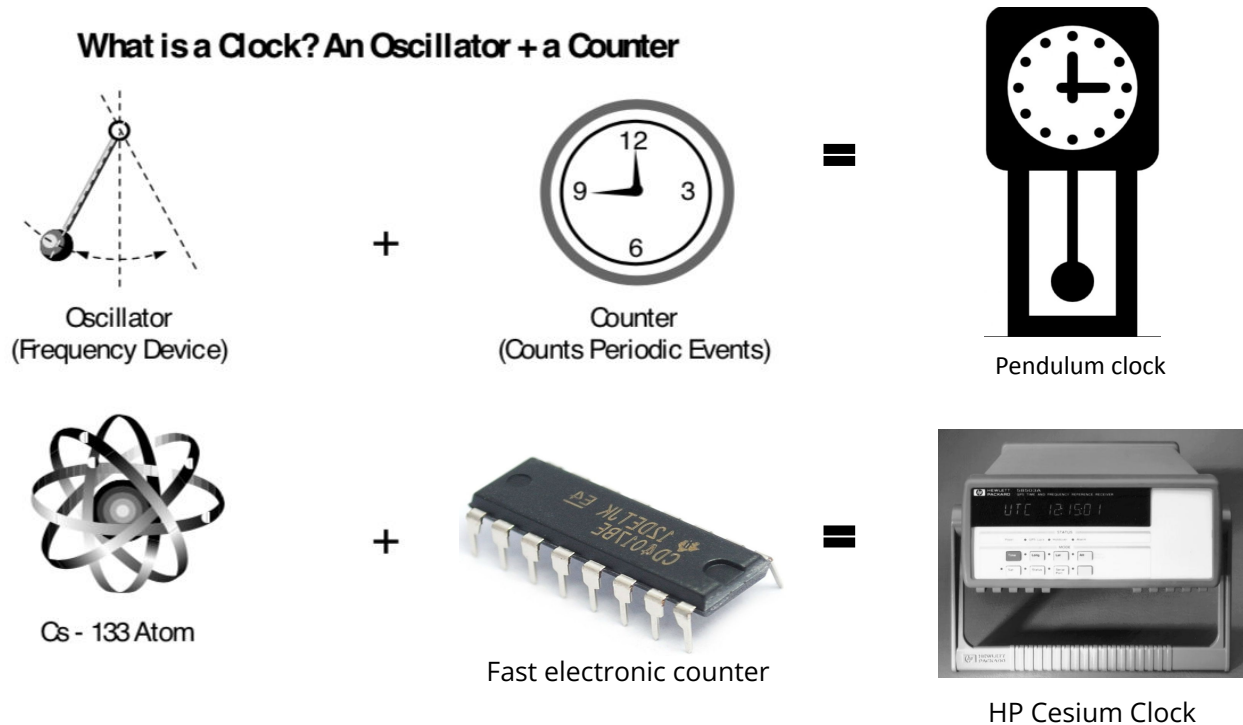


Quantum Clock (2010)



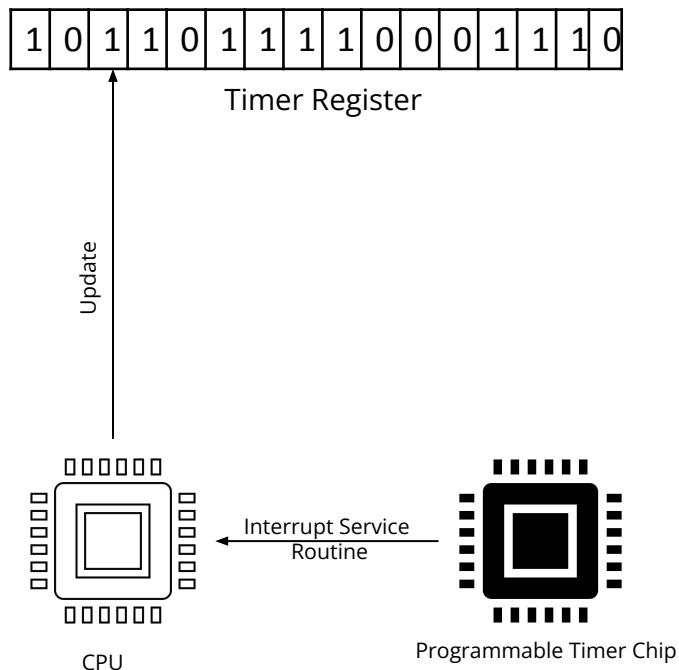
Optical Clock

WHAT IS A CLOCK



A Second is defined as 9,192,631,770 cycles of a Caesium atomic clock

COMPUTER CLOCKS



- The higher the number of bits in register, the better the resolution and range (64 bits = nano resolution)
- The “epoch” is used to define the zero
- Time update frequency depends on the Interrupt Service Routine
- Popular interrupt frequencies are 1024 Hz, 1MHz or higher
- The value added every timer interrupt is frequently referred to as tick
- There is an additional Realtime(Hardware) Clock that keeps track of time when the system is off

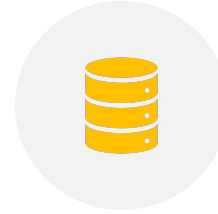
TIME PROTOCOLS



NETWORK TIME
PROTOCOL (NTP)
~100 μ S



PRECISION TIME
PROTOCOL (PTP)
~100 NS



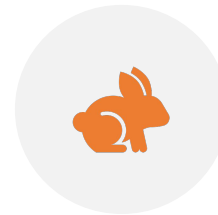
DATACENTER TIME
PROTOCOL (DTP)
~ 25 NS



PULSE PER SECOND
(PPS) ~10 NS



GLOBAL POSITIONING
SYSTEM (GPS)
~ 5 NS



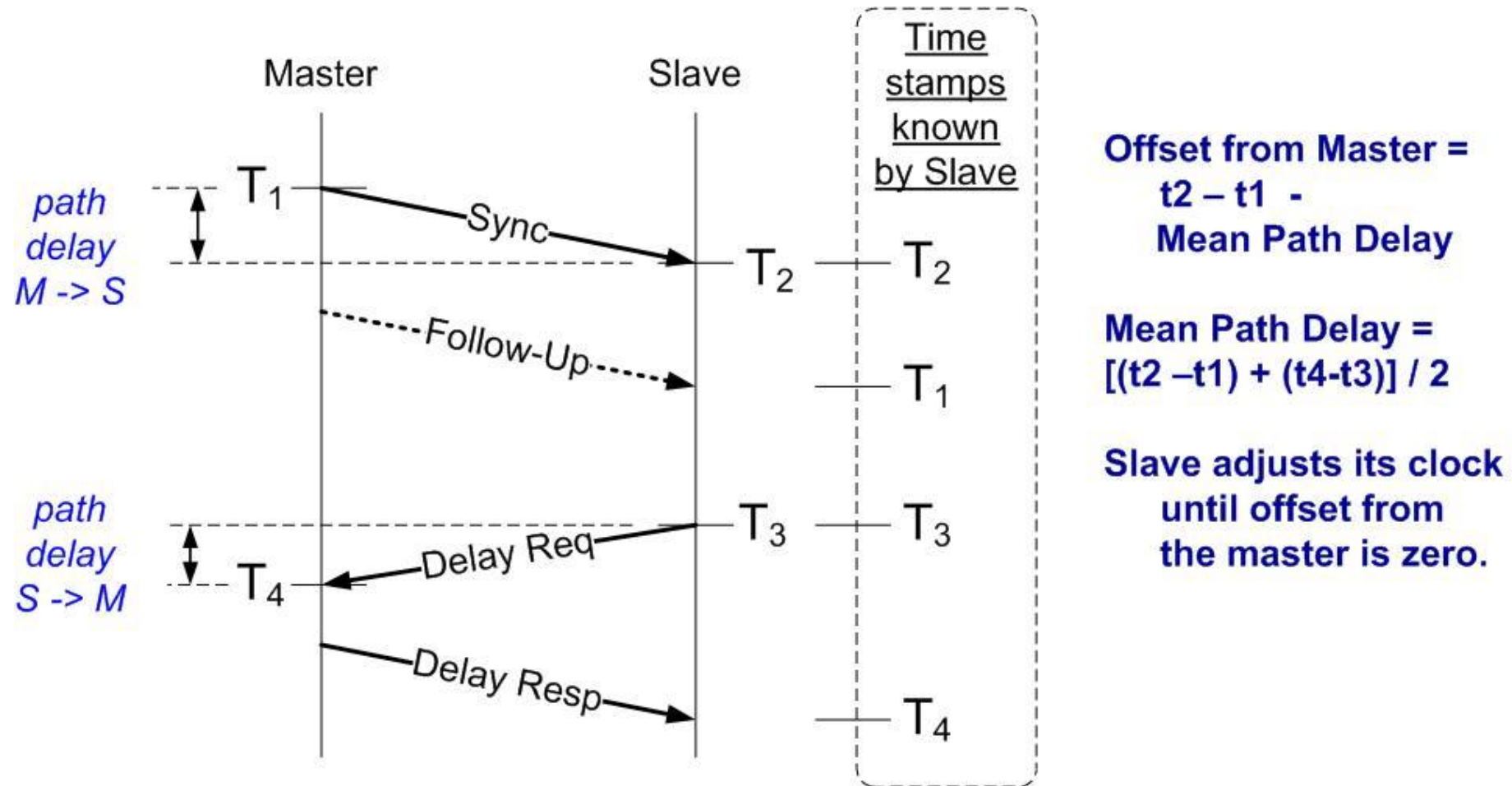
WHITE RABBIT (WR) –
SUB-NS (PS)

PRECISION TIME PROTOCOL (PTP)

ABOUT PTP

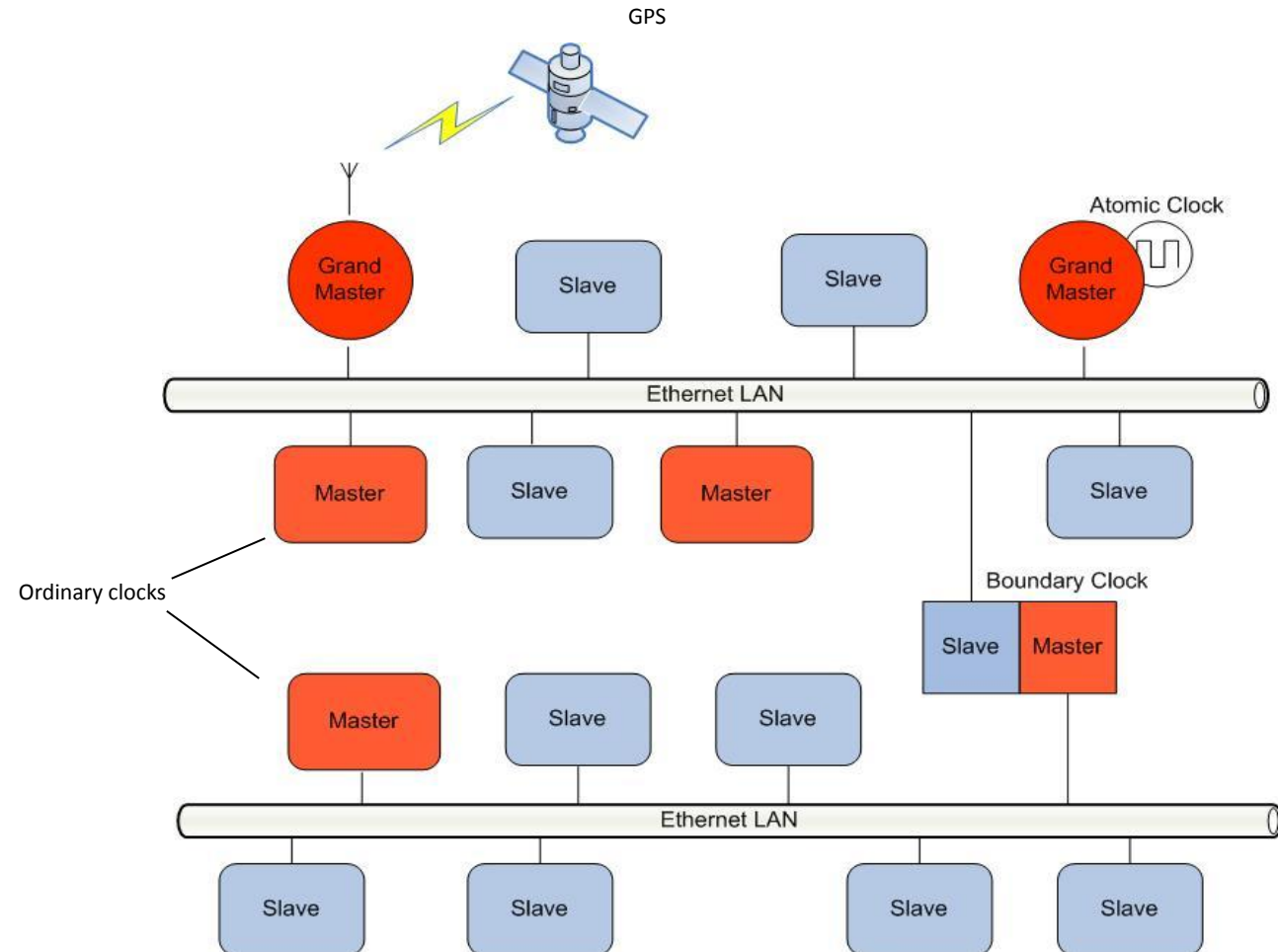
- “Precision Clock Synchronization Protocol for Networked Measurement and Control Systems”
- Originally defined in 2002 as IEEE 1588-2002
- Revised in 2008 as IEEE 1588-2008, PTP Version 2, improves accuracy, precision and robustness.
- Microsecond and submicrosecond accuracy

HOW PTP WORKS?

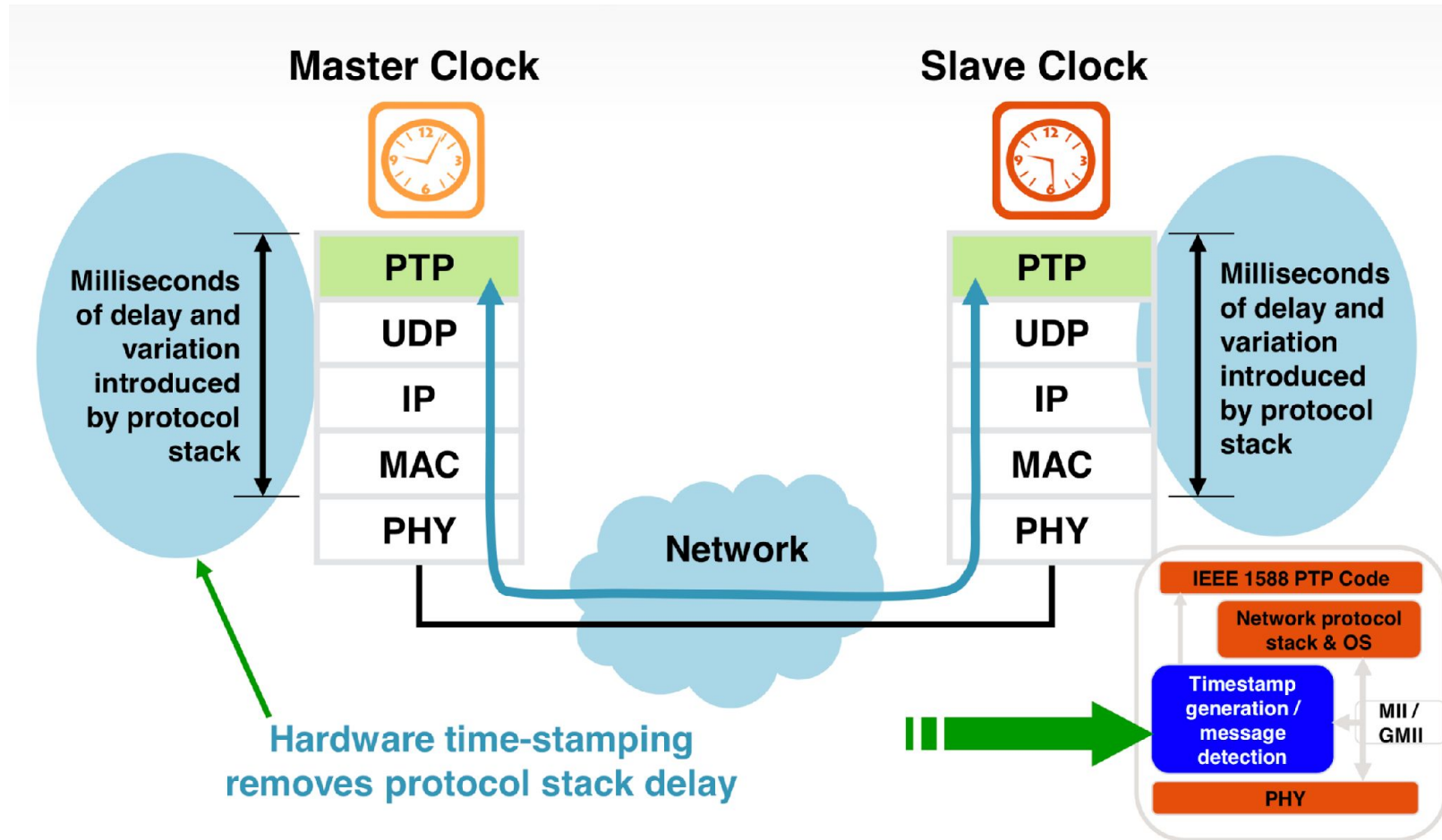


PTP TOPOLOGY

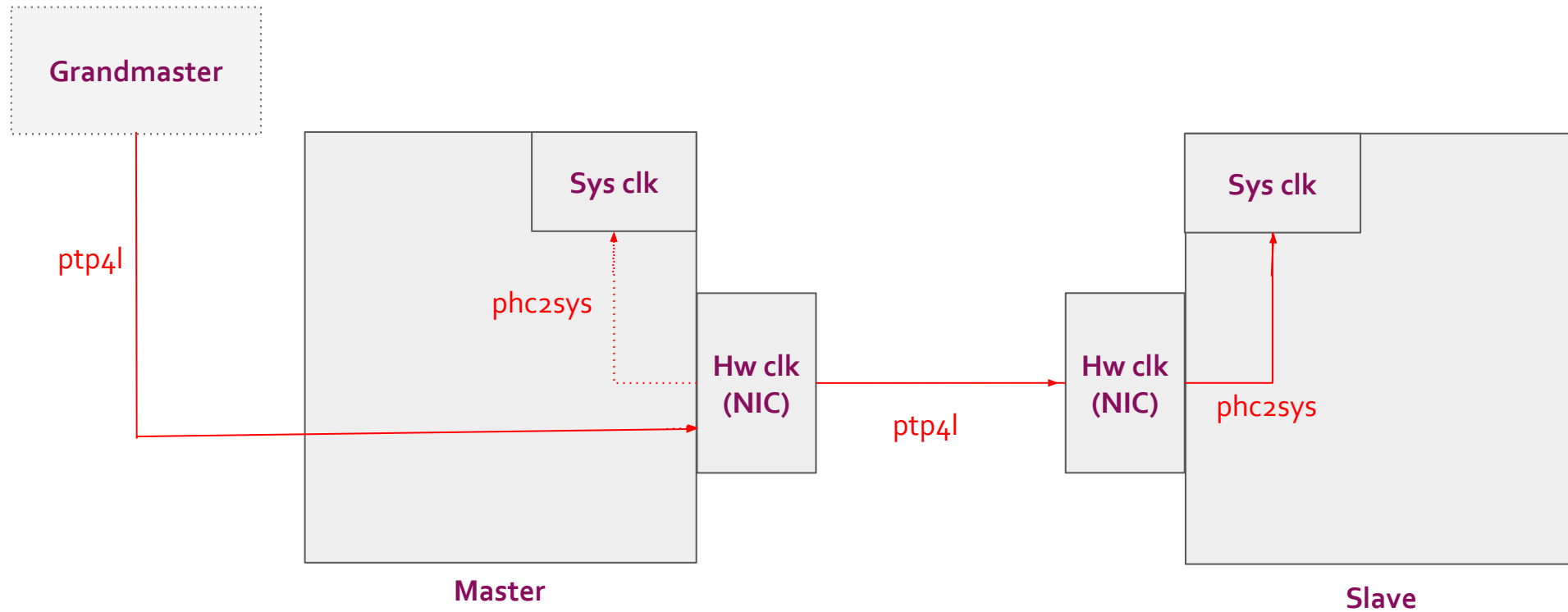
1. Grandmaster
2. Master
3. Slave
4. Ordinary Clock
5. Boundary Clock
6. Transparent Clocks



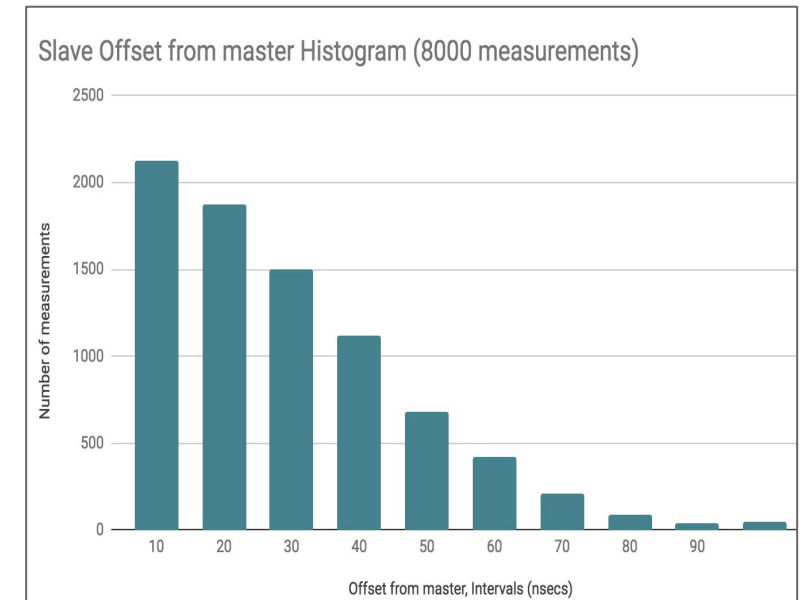
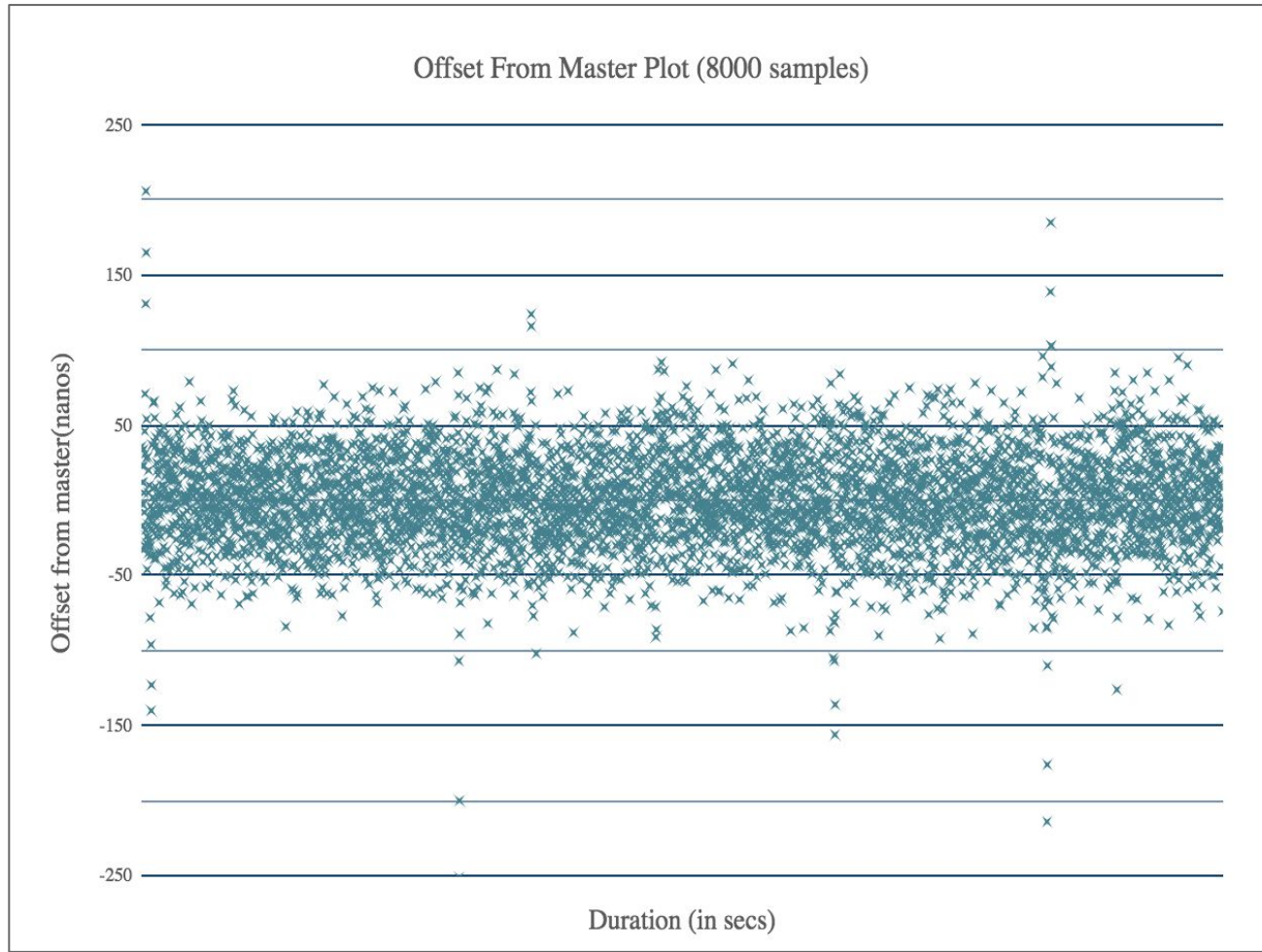
SOFTWARE & HARDWARE TIMESTAMPING



PTP HARDWARE TIMESTAMPING



TESTS AND ANALYSIS



CHALLENGES

- No expertise on Time domain
- Lack of suitable hardware for testing
- No proper documentation for PTP
- Asking questions on forum and waiting for experts to answer
- Agony of relying on native calls



Thank
you

