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Time and its role in FDA Systems

Dr. Alexander Apostolov

OMICRON electronics

Los Angeles, USA

www.TRUC.org

Questions

> What are we doing?
> Why are we doing it?
> How are we doing it?

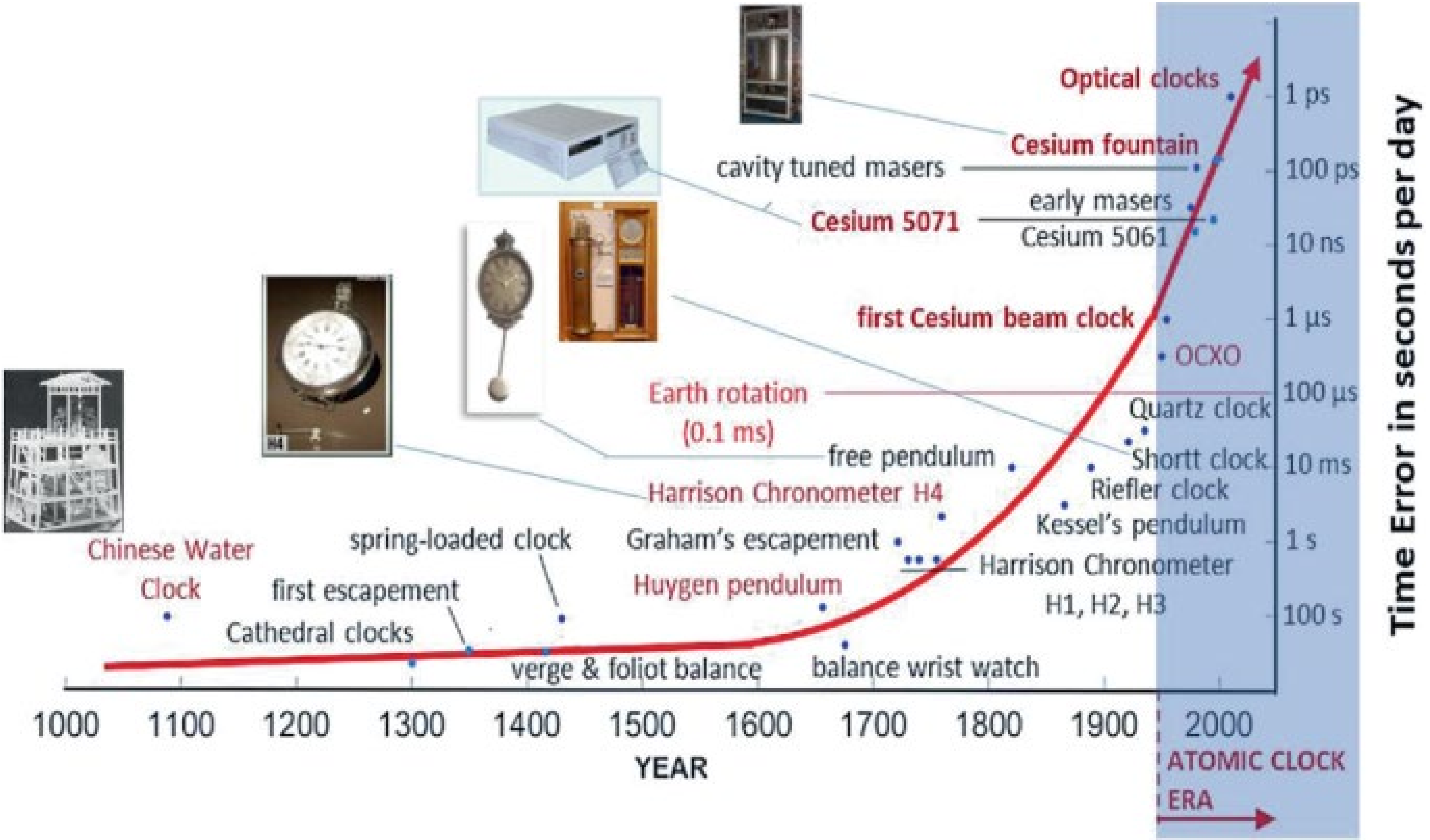
Time definition

- Time is a fundamental concept that plays a central role in both our everyday lives and the physical universe.
- A measure of the duration of events and the intervals between them
- The indefinite continued progress of existence and events in the past, present, and future regarded as a whole
- A point of time as measured in hours and minutes past midnight or noon
- Time as allotted, available, or used
- An instance of something happening

Why do we need time?

- To synchronize MUs and PMUs to use analog measurements from different locations
- To synchronize recording devices to be able to align the records for fault or disturbance analysis purposes
- To analyze IED operation following fault detection and clearing, or wide area disturbances

Timekeeping history



Timekeeping history

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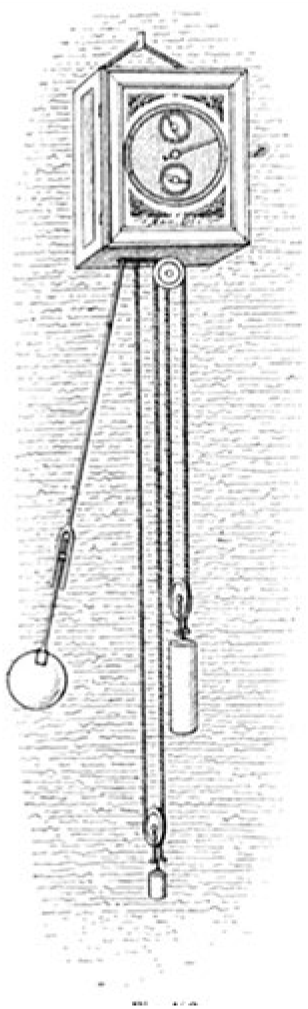


Timekeeping history

Second definition

- The second is the base unit of time in the International System of Units (SI), commonly understood and historically defined as **1⁄86400 of a day**
- It is derived from the division of:
  - 1 day has 24 hours
  - 1 hour has 60 minutes
  - 1 minute has 60 seconds

Second definition

- It wasn't until the invention of atomic clocks, which work by measuring properties of certain atoms, that a really precise measurement of the passing of time became possible.
- Using such clocks the second was defined in 1967 as:
- *The duration of 9,192,631,770 periods of the radiation corresponding between the two hyperfine levels of the ground state of the caesium-133 atom.*

The simplest question

- What time is it?

The answer

- It depends

Time scales

- Greenwich Mean Time (GMT).
- In 1884 the local mean solar time at the Royal Observatory in Greenwich near London was chosen as the international time reference, defining the universal day.
- In 1928 the term Universal time (UT) was introduced referring to the astronomical GMT time with the day starting at midnight.

Time scales

> Starting from 1961 the Bureau International de l'Heure began coordinating UT internationally.

> This time scale is nowadays simply known as UTC (unofficially: Universal Time Coordinated).

Time scales

- UTC second is dependent from the rotation of the earth
- SI second is independent from the rotation of the earth.
- In 1971 named TAI (Temps Atomique International)
- The final implementation of the SI second for UTC took place on 1 January 1972 at 00:00:00 UTC defining an offset of exactly 10 seconds to TAI.

Time scales

- UTC no longer linked to the rotation of earth.
- The rotation of earth is not constant and therefore UTC drifts away from the solar time at Greenwich (UT1).
- To ensure that UTC stays within ± 0.9 s of UT1 it was decided to insert leap seconds.

Time scales

- From 1972 until now a total of 27 leap seconds were inserted resulting in a total offset of 37 s between TAI and UTC.
- Leap seconds can be positive or negative.
- The insertion of a negative leap second reduces the offset between TAI and UTC.

The TAI & UTC Time Scales

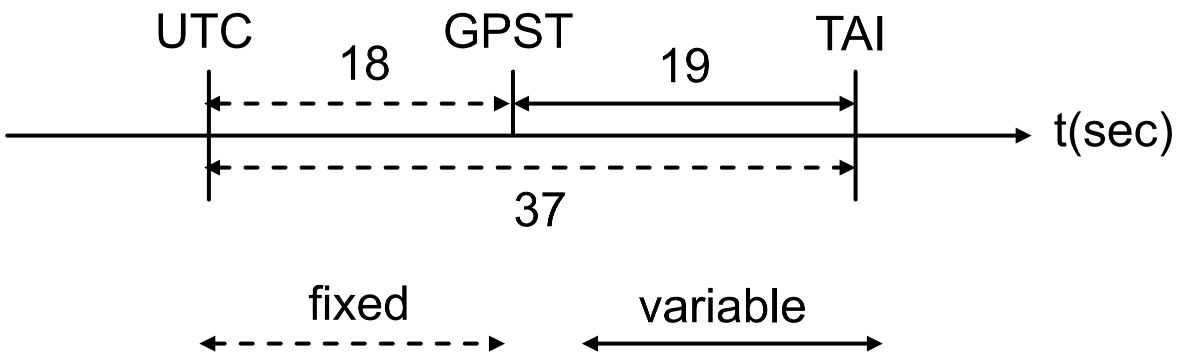
- TAI is based on the absolute second as measured using cesium clocks in many world laboratories and coordinated by BIPM (France).
- UTC is also maintained by these laboratories.
- "Leap seconds" are added to UTC when necessary
- When necessary, leap seconds are always added at the end of December or June.

Time scales

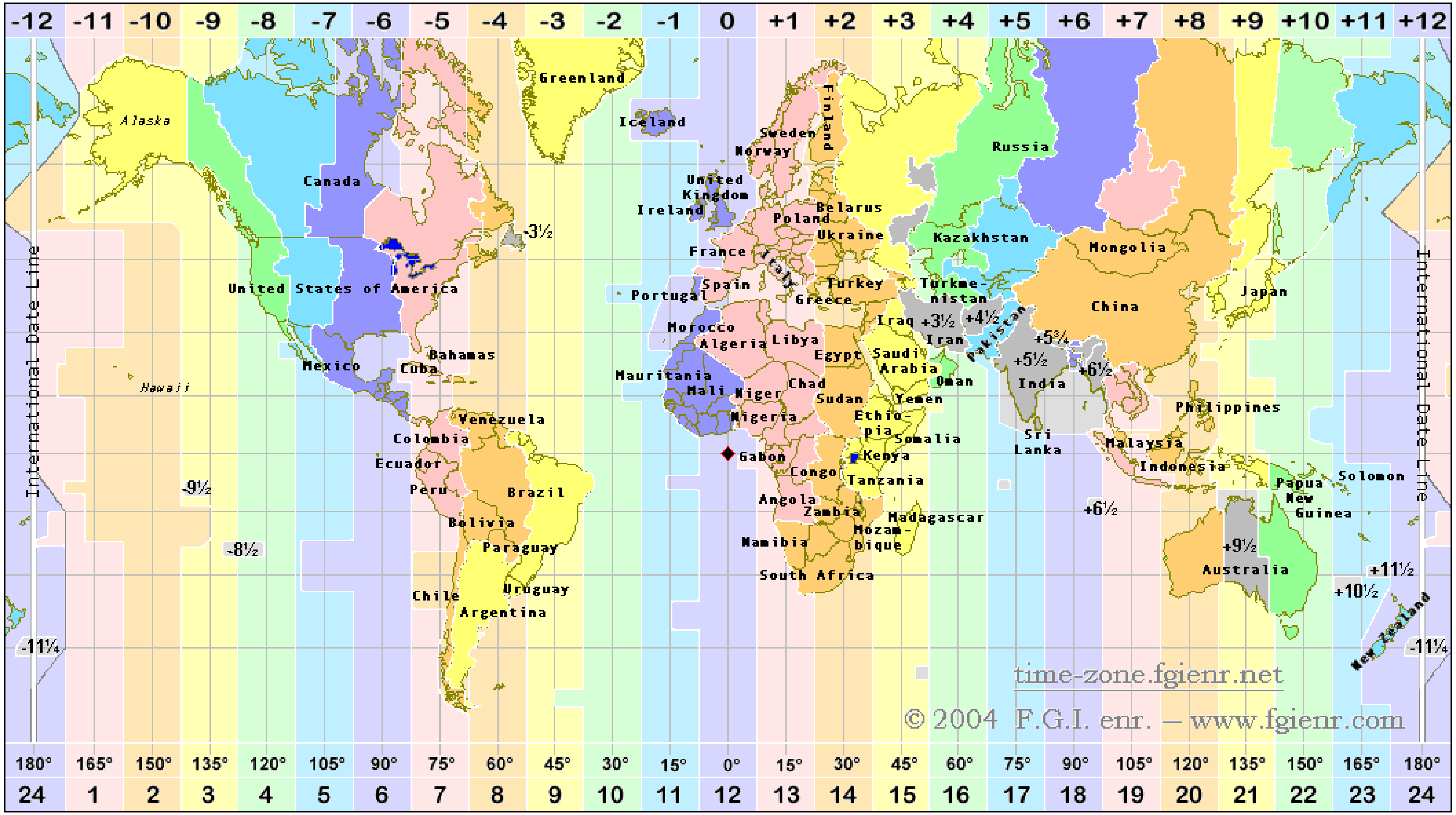
> The GPS time scale (GPST) was started on 6 January 1980 0:00:00 UTC.

> At that date the offset between UTC and TAI was 19 seconds.

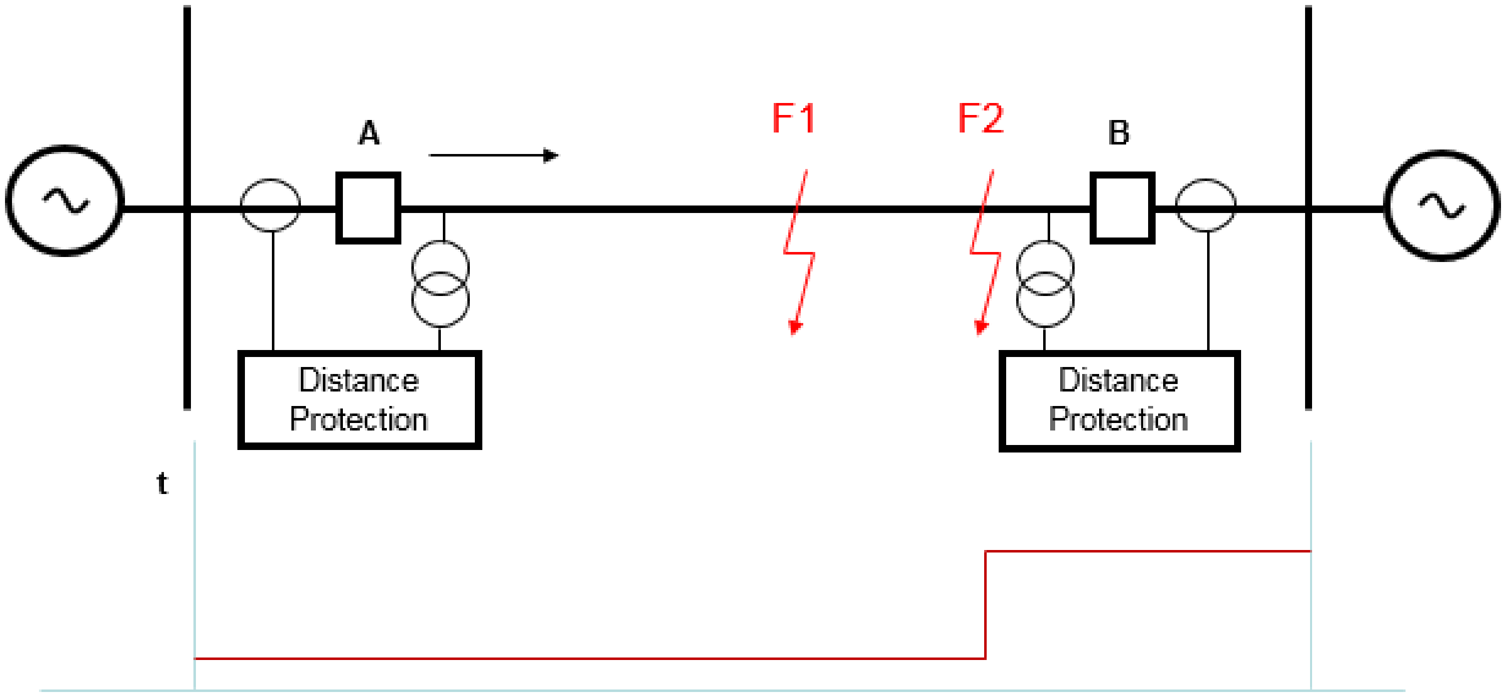
> The GPST is a linear time scale not taking into consideration leap seconds. Therefore the offset between GPST and TAI will remain constant.



Time zones


-12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5 +6 +7 +8 +9 +10 +11 +12
Greenland
Iceland
Alaska
Canada
Russia
Finland
Sweden
Norway
United Kingdom
Ireland
Belarus
Poland
Ukraine
Kazakhstan
Mongolia
France
Italy
Spain
Portugal
Greece
Turkey
Turkmenistan
United States of America
China
Japan
Iraq
Iran
Pakistan
Morocco
Algeria
Libya
Egypt
Saudi Arabia
Oman
India
Bahamas
Mexico
Cuba
Hawaii
Mauritania
Mali
Niger
Chad
Sudan
Yemen
Philippines
Venezuela
Nigeria
Ethiopia
Colombia
Somalia
Sri Lanka
Malaysia
Ecuador
Gabon
Kenya
Congo
Indonesia
Peru
Tanzania
Brazil
Angola
Zambia
Madagascar
Papua New Guinea
Solomon
Bolivia
Mozambique
Namibia
Paraguay
South Africa
Australia
Chile
Uruguay
Argentina
New Zealand
International Date Line
-3½ +3½ +4½ +5¾ +5½ +6½ -9½ -8½ +9½ +11½ +10½ -11¼
time-zone.fgienr.net
© 2004 F.G.I. enr. – www.fgienr.com
180° 165° 150° 135° 120° 105° 90° 75° 60° 45° 30° 15° 0° 15° 30° 45° 60° 75° 90° 105° 120° 135° 150° 165° 180°
24 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Distance Protection operation



Time related requirements

- Accuracy - depending on the application
- The time stamp shall be based on an existing time standard (UTC)
- The time model shall be able to track and manage leap seconds
- The time stamp model shall contain sufficient information that would allow the client to compute a date and time

Time related requirements

- The timestamp shall be easily derived from commercially available time sources
- The overall time model shall allow computation of local time and for ½ hour offsets for Local Time.
- It shall indicate whether Daylight Savings is in effect or not.
- The format shall be compact and easily machine manipulated.

Event time definition

- Result of computation (internal or calculated event) - allocation of time (time tagging) shall be done immediately within the time resolution of the clock
- Change of a binary input - the delay of the debouncing procedure has to be considered. The event time shall be locally corrected.
- Change of an analogue input - the delay of the filtering procedure of the input circuit has to be considered. The event time shall be locally corrected.

Synchronization requirements

- 1 ms is not sufficient for all applications
- An absolute accuracy of 1 µs or better is required for:
  - Sampled Values
  - Synchrophasor measurements
  - Travelling Wave Fault Location

Time performance classes

Time Performance Class	Accuracy	Purpose
T1	± 1 ms	Time tagging of events
T2	± 100 µs	Time tagging of zero crossings and of data for the distributed synchrocheck. Time tags to support point on wave switching
T3	± 25 µs	Time performance classes for instrument transformer synchronization
T4	± 4 µs	
T5	± 1 µs	

Time sources

GNNS (space-based global navigation satellite system)

Time synchronization methods

Time Synchronization Method	Typical Accuracy	Distribution	Ambiguity
IRIG-B	10 µs - 1 ms	Separate wiring	1 year (100 years with extension)[7]
DCF 77 (digital)	1 µs – 100 ms	Separate wiring	100 years
1PPS	< 1 µs	Separate wiring	1 second
Serial ASCII	1 ms	Separate wiring	None
NTP	1 ms - 10 ms	Ethernet (IEC 61850 Bus)	None
PTP (IEEE 1588)	< 1 µs	Ethernet (IEC 61850 Bus)	None

PTP

- IEEE 1588-2002 introduced a network based time synchronization method for applications in LANs that require a higher accuracy than the one provided by the Network Time Protocol (NTP).
- New version IEEE 1588-2008 (PTPv2) introduced several novelties that simplified the practical application of PTP. Not backwards compatible to IEEE 1588-2002 which definitely delayed roll out of PTP.

PTP

- PTP utilizes a continuous timescale based on TAI.
- PTP epoch is 1 January 1970 00:00:00 TAI.
- Time stamps are defined as a combination of a 48 bit integer number (for seconds) and a 32 bit integer number (for nanoseconds).
- With these numbers all points in time for the next 8.9 million years can be time stamped with a nanosecond resolution

Transparent clock

- Transparent clock is an Ethernet switch with PTP capability.
- It timestamps PTP packages at ingress and egress. From these time stamps the residence time of the package inside the switch is calculated and written into a field the respective data package or a follow up message.

Boundary clock

- Boundary clock is a clock that has ports in two or more domains. The boundary clock synchronizes to a grandmaster in one domain and acts as a grandmaster in all other domains. It is used to time synchronize two or more separate networks infrastructures to one grandmaster without the need of bridging data packages between the networks

Clock types in IEC 61850-9-3

- **Slave-only clock:**
  The port(s) of a slave-only clock are always in the slave state. It will lock itself to the grandmaster of the network. In case that no grandmaster is present it will remain in the slave state and never announce itself as a grandmaster.

Clock types in IEC 61850-9-3

> **Grandmaster-only clock:**
> A grandmaster-only clock announces itself as a grandmaster. If it is the best clock in the network it will become the grandmaster. Otherwise it will switch its ports to passive. A grandmaster-only clock will always lock only to its primary time reference (e.g. GPS) but never to another grandmaster in the network.

Clock types in IEC 61850-9-3

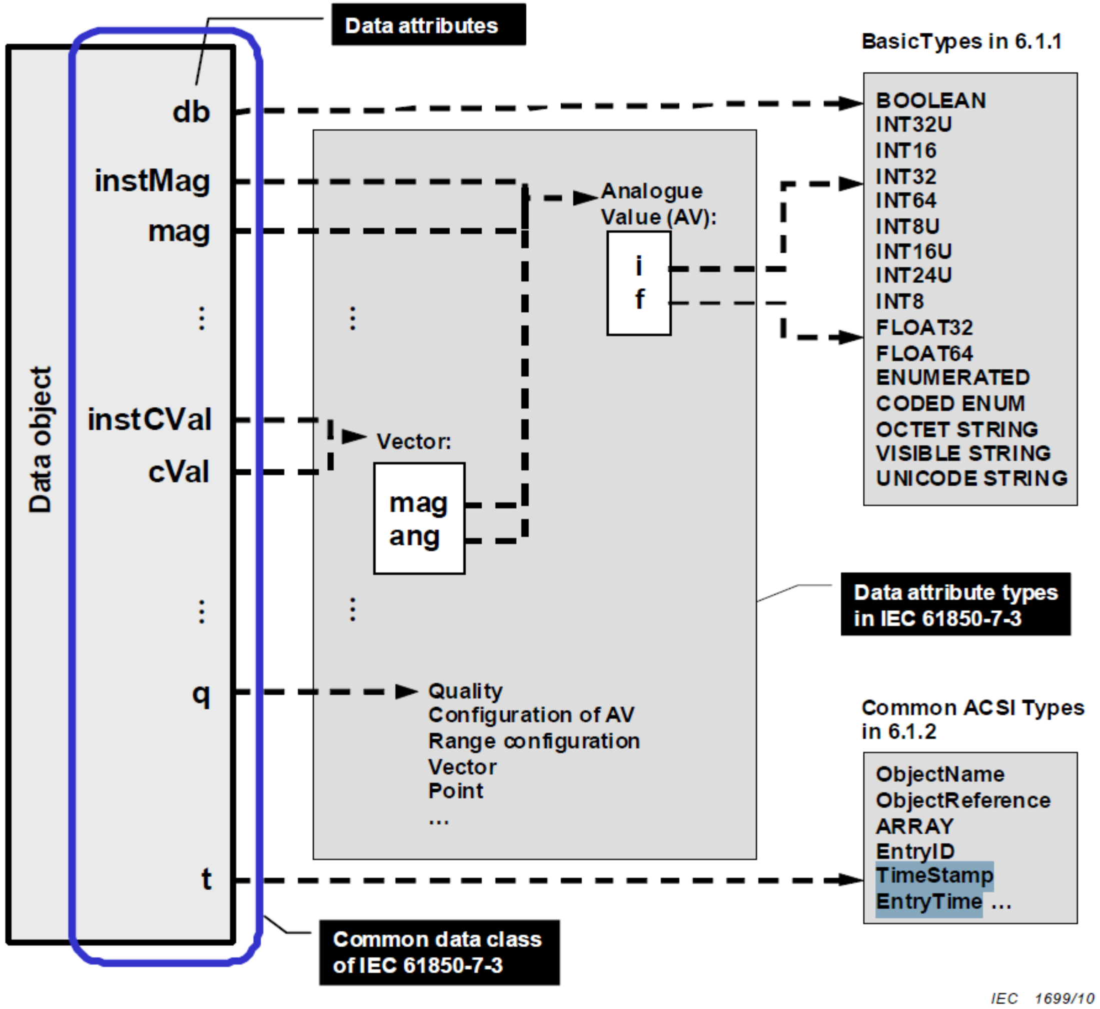
> **Grandmaster-capable clock:**
> A grandmaster-capable clock can switch its ports either to the master or the slave state. Further on a grandmaster-capable clock does not necessarily require a primary time reference. In case that all grandmaster-only clocks in a network are malfunctioning or are switching to hold-over, a grandmaster-capable clock equipped with an accurate internal oscillator can become grandmaster of the network.

Time synchronization classes

Time synchronization class	Accuracy [□s]	Phase angle accuracy for 50 Hz [°]	Phase angle accuracy for 60 Hz [°]	Fault location accuracy[b] [%]
TL[a]	> 10 000	> 180	> 216	n.a.
T0	10 000	180	216	n.a.
T1	1 000	18	21,6	7,909
T2	100	1,8	2,2	0,780
T3	25	0,5	0,5	0,195
T4	4	0,1	0,1	0,031
T5	1	0,02	0,02	0,008

[a] TL stands for time synchronization "low".[b]

Data types in IEC 61850



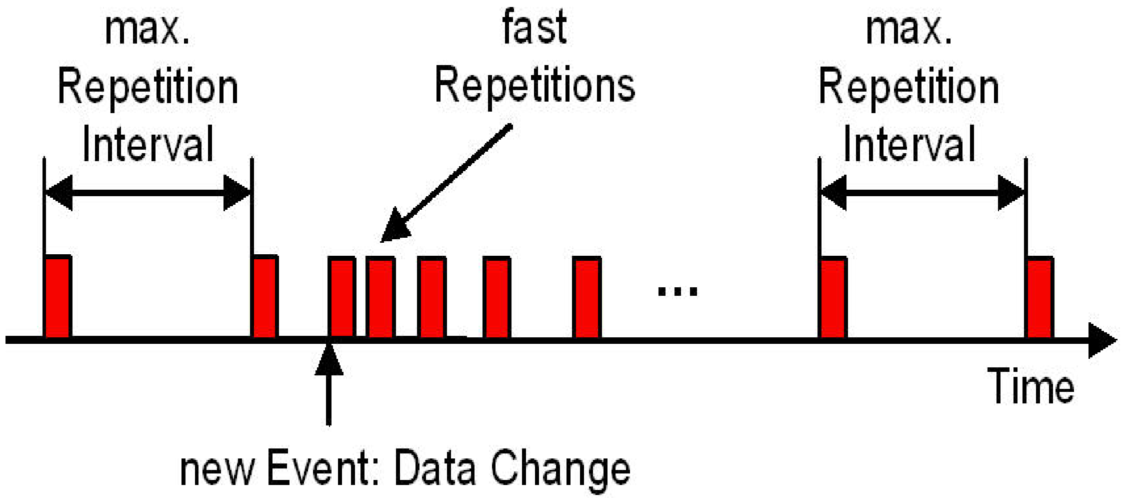
Time related attributes

- A common attribute of data objects is ***t***, representing a time stamp or an entry time related to a change of the value of the data object
- Another time related attribute in the model is **FractionOfSecond** representing the fraction of the current second when the value of the **TimeStamp** has been determined.

Time related attributes

- The **TimeQuality** is an attribute in the object models that provides information about the time source of the sending device and includes information about:
- LeapSecondsKnown
- ClockFailure
- ClockNotSynchronized
- TimeAccuracy

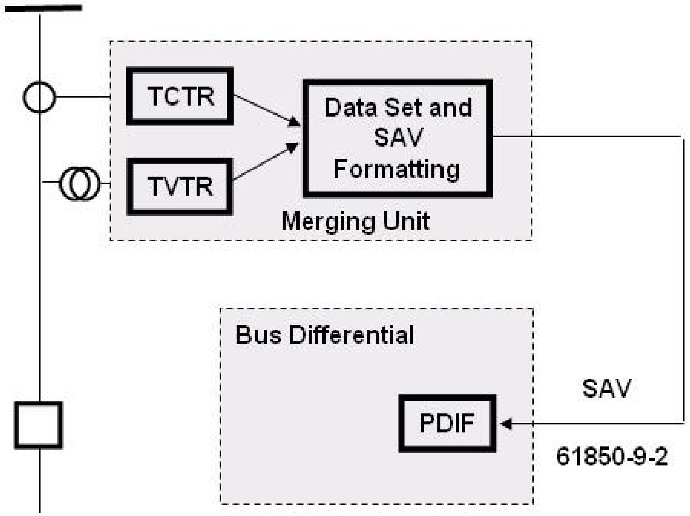
Time in GOOSE model

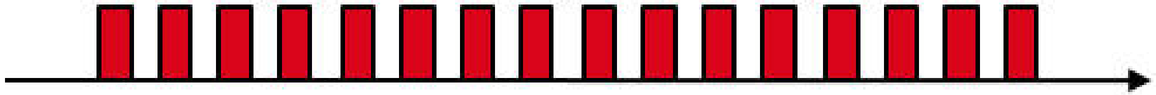


Time in GOOSE message

GOOSE message		
Parameter name	**Parameter type**	**Value/value range/explanation**
DatSet	ObjectReference	Value from the instance of GoCB
GoID	VISIBLE STRING129	Value from the instance of GoCB
GoCBRef	ObjectReference	Value from the instance of GoCB
T	TimeStamp	
StNum	INT32U	
SqNum	INT32U	
Simulation	BOOLEAN	(TRUE) simulation | (FALSE) real values
ConfRev	INT32U	Value from the instance of GoCB
NdsCom	BOOLEAN	Value from the instance of GoCB
GOOSEData [1..n]		
Value	(*)	(*) type depends on the appropriate common data classes (CDC).

Time in SV communications





Transfer Time