USING TIME SYNCHRONIZATION TO IMPROVE YOUR PROTECTION & CONTROL SYSTEM

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Today’s Agenda

- Why Do We Need Time Synchronization?
- Time Synch Methods
- Clock Selection

Why Do We Need Time Synchronization?

- In 2011, NIST estimated economic benefits of time synch associated with GPS in the US to be $125 billion
- Every IED's internal clock drifts widely and differently; it is not about absolute time but single reference origin (GNSS)

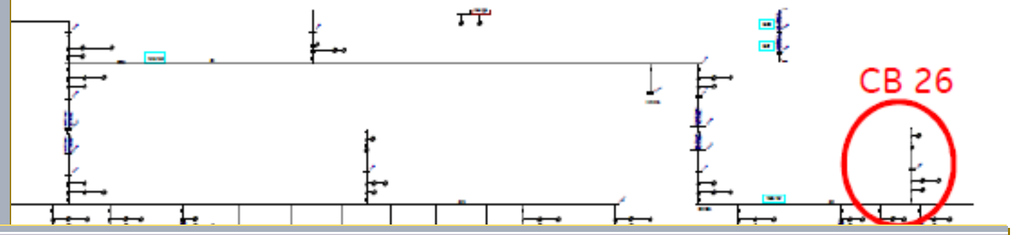
Electrical Grid Time Synch Requirements:

- Sequence of events, post-disturbance analysis (1 ms). NERC recommendation after blackout of 2003, PRC-018-1 requires DME synchronize to within 2ms or less to UTC
- Line current differential
- Synchrophasor (1µs)
- Traveling wave fault detection (300ns). The most demanding roughly
  1-meter error per 3ns of timing error
- Process bus (1µs)

Time Class (IEC61850)	Accuracy (µs)	Phase Angle 60HZ	Fault Location %
T0	10000	216	NA
T1	1000	21.6	7.9
T2	100	2.2	.780
T3	25	.5	.0195
T4	4	.1	.031
T5	1	.02	.008

Case Study: Snake Causes a Distribution Fault

Event	Date	Time	Cause of Event
48	03/20/2014	22:20:49.968	Dropout: Phase Instantaneous OC 1
47	03/20/2014	22:20:49.954	Alarm: Phase B - Arcing Current
46	03/20/2014	22:20:49.953	Dropout: Neutral Time OC 1
45	03/20/2014	22:20:49.953	Dropout: Ground Time OC
44	03/20/2014	22:20:49.945	Input(C) ON-Block Neutral Time OC 1
43	03/20/2014	22:20:49.945	Input(C) ON-Block Ground Time OC
42	03/20/2014	22:20:49.945	Input(C) ON-User Input D / ABB 50D Blk
41	03/20/2014	22:20:49.937	Pickup: Negative Sequence Overvoltage
40	03/20/2014	22:20:49.921	Pickup: Phase B - Phase Time OC 2
39	03/20/2014	22:20:49.921	Pickup: Negative Sequence Time OC



Event	Date	Time	Cause of Event
46	03/22/2014	22:20:10.05	Differential Trip
45	03/22/2014	21:13:33.34	Differential Trip
44	03/22/2014	20:50:10.92	Differential Trip
43	03/21/2014	11:33:29.68	Differential Trip
42	03/21/2014	09:14:34.50	Differential Trip
41	03/21/2014	08:47:18.56	Differential Trip
40	03/20/2014	23:20:33.15	Differential Trip
39	02/11/2014	08:38:36.53	Cont. Power Applied
38	02/11/2014	08:38:35.74	Control Power Lost
37	02/11/2014	08:31:11.56	Cont. Power Applied

Event	Date	Time	Cause
374	03/20/2014	22:00:48.232	Pickup: Ground Ir
373	03/20/2014	22:00:48.232	Pickup: Grou
372	03/20/2014	22:00:48.232	Trip: Phase C - Phase
371	03/20/2014	22:00:48.232	Pickup: Phase C - Phas
370	03/20/2014	22:00:48.232	Trigger Tra
369	03/20/2014	22:00:48.232	Trip: Phase C - Phase
368	03/20/2014	22:00:48.232	Pickup: Phase C - Phas
367	03/20/2014	22:00:48.231	Trigger Data Logger
366	03/20/2014	22:00:48.231	Pickup: Phase C - Phase Time OC 1
365	02/11/2014	07:37:38.182	Trigger Data Logger

Global Navigation Satellite System (GNSS)

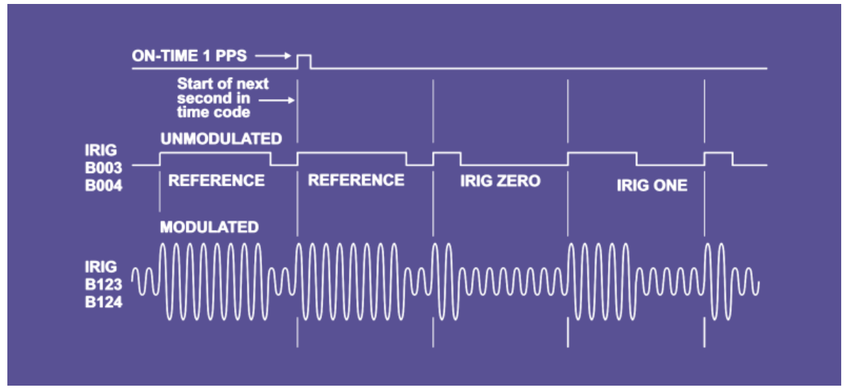
- Composed of GPS (USA), GLONASS (Russia), Galileo (EU), and BeiDou (China) satellite systems
- Currently only GPS and GLONASS are globally available
- GPS + GLONASS allow the receiver to be pinpointed by a group of 48 satellites across the globe
- When used together, increases accuracy with coverage
- GNSS constellations combined reduces the impact from GPS jamming and spoofing

We do not care what the actual time is - we care about event time in reference to single source

Time Synch IRIG-B

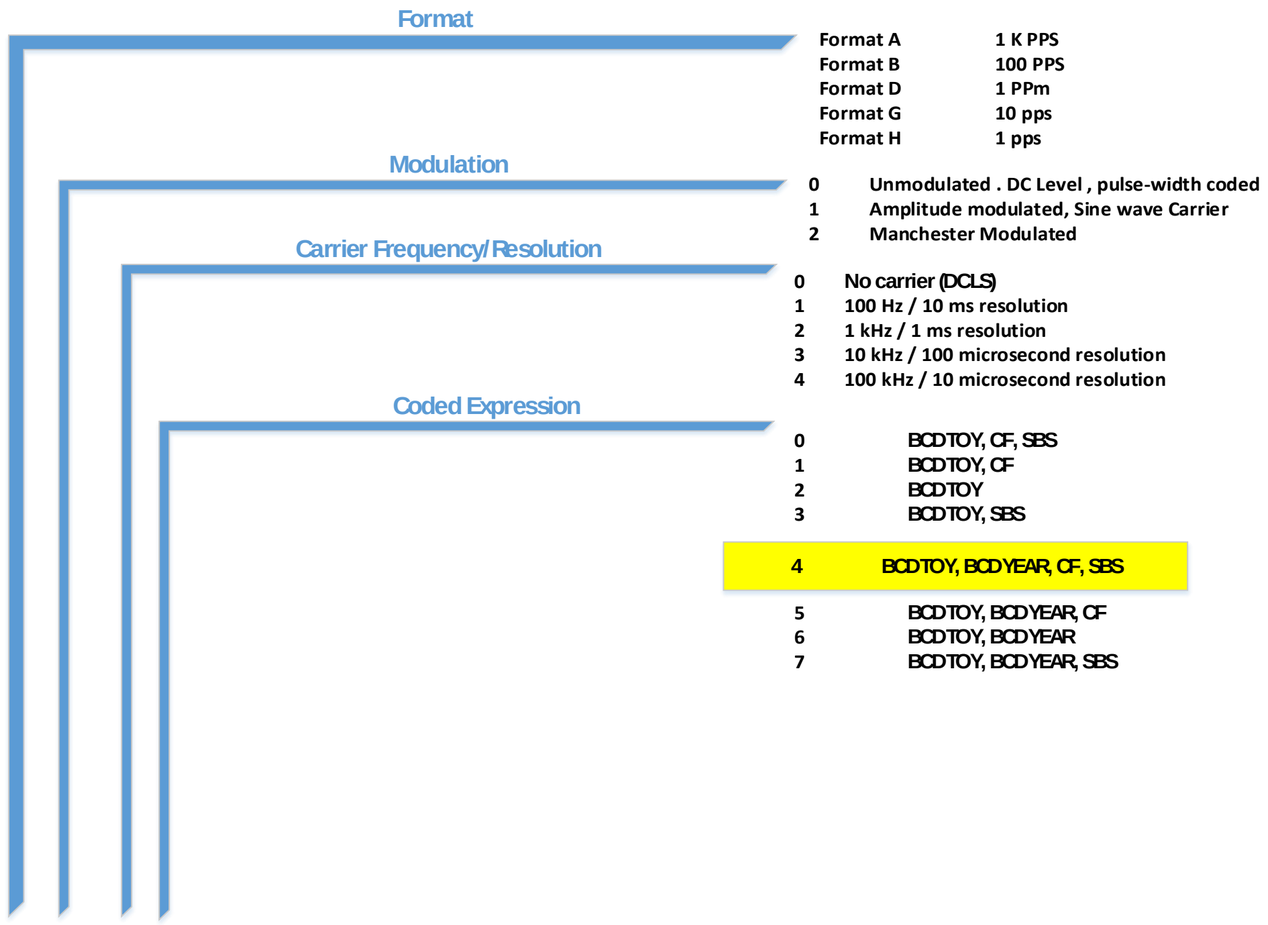
IRIG-B is a timing code:

- Uses voltage pulses on copper wire (modulated or unmodulated)
- Uses light pulses on optical cables
- Pulses indicate time from fractions of a second from midnight, date from January 1, last two digits of year
- Depending on extensions codes from IRIG-B, pulses may also indicate Daylight Savings Time occurrence, time offset from UTC, Time Quality…



Benefits	Disadvantages
• Proven • µs accuracy	• Number of devices • Distance limited by voltage drop (copper) • Redundancy difficult • Requires careful and exclusive wiring design

IRIG-B SIGNAL



BCD – Day of year, hour, minute and second

CF – Time zone, Daylight Saving Time, and year

SBS – Seconds of the day

BCDYear – Year

Time Synch NTP/SNTP

Networking protocol for clock synchronization between devices operating over packet-switched, variable-latency data networks, client-server application.

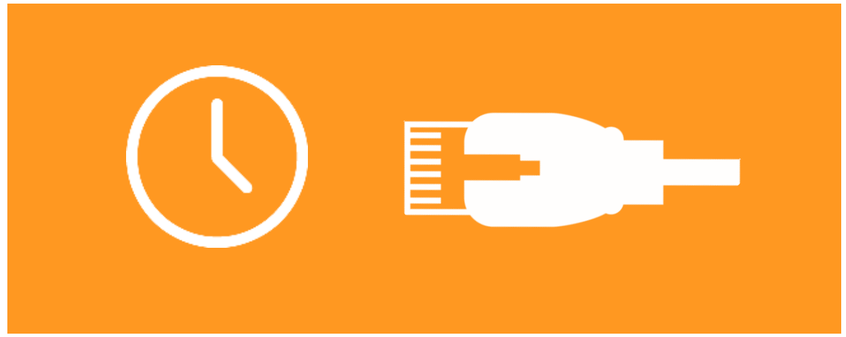
Accurate within millisecond range:

NTP is less accurate because:

- NTP does not compensate to the delay inside the network
- No time stamping at the hardware level

NTP does not recognize time zone and DST.

Time zone and DST may be handled by NTP/SNTP time server (clock).

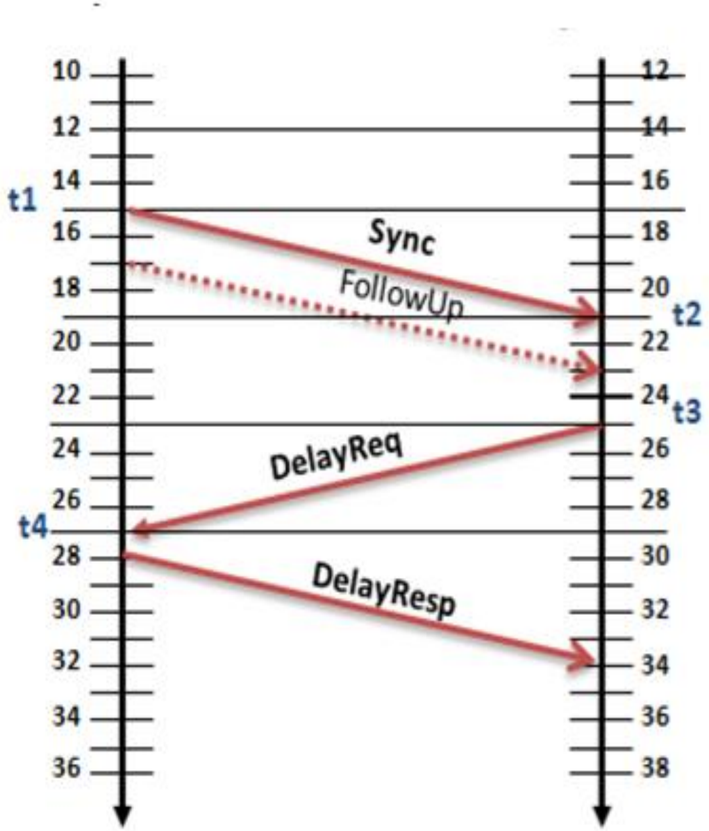


Benefits	Disadvantages
• Uses Ethernet network, usually already installed • Good enough for SOE	• Accuracy in the ms range • Accuracy depends on network traffic • Not sufficient for application as PMU, TWFL, MU, …

Time Synch IEEE 1588 Precision Time Protocol (PTP)

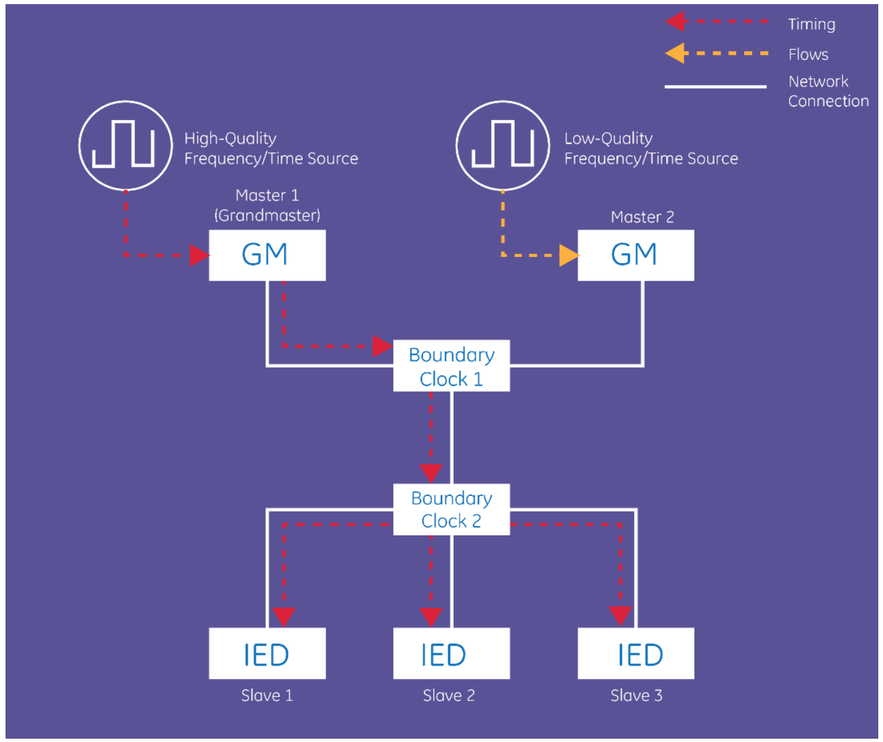
- Nanosecond accuracy possible
- Hardware stamping, more frequent updates
- Best master clock (BMC)
- Redundancy (PRP)

Master Clock



Slave Clock

IEEE 1588 Definitions



GPS Clocks	Eth Switches	End Devices
Grandmaster / Passive Master	Transparent or Boundary	Ordinary

Grandmaster Clock

- Source of time for time sync using PTP

Ordinary Clock

- PTP clock with a single PTP port
- Can be master or slave
- Typically slaves at end device level

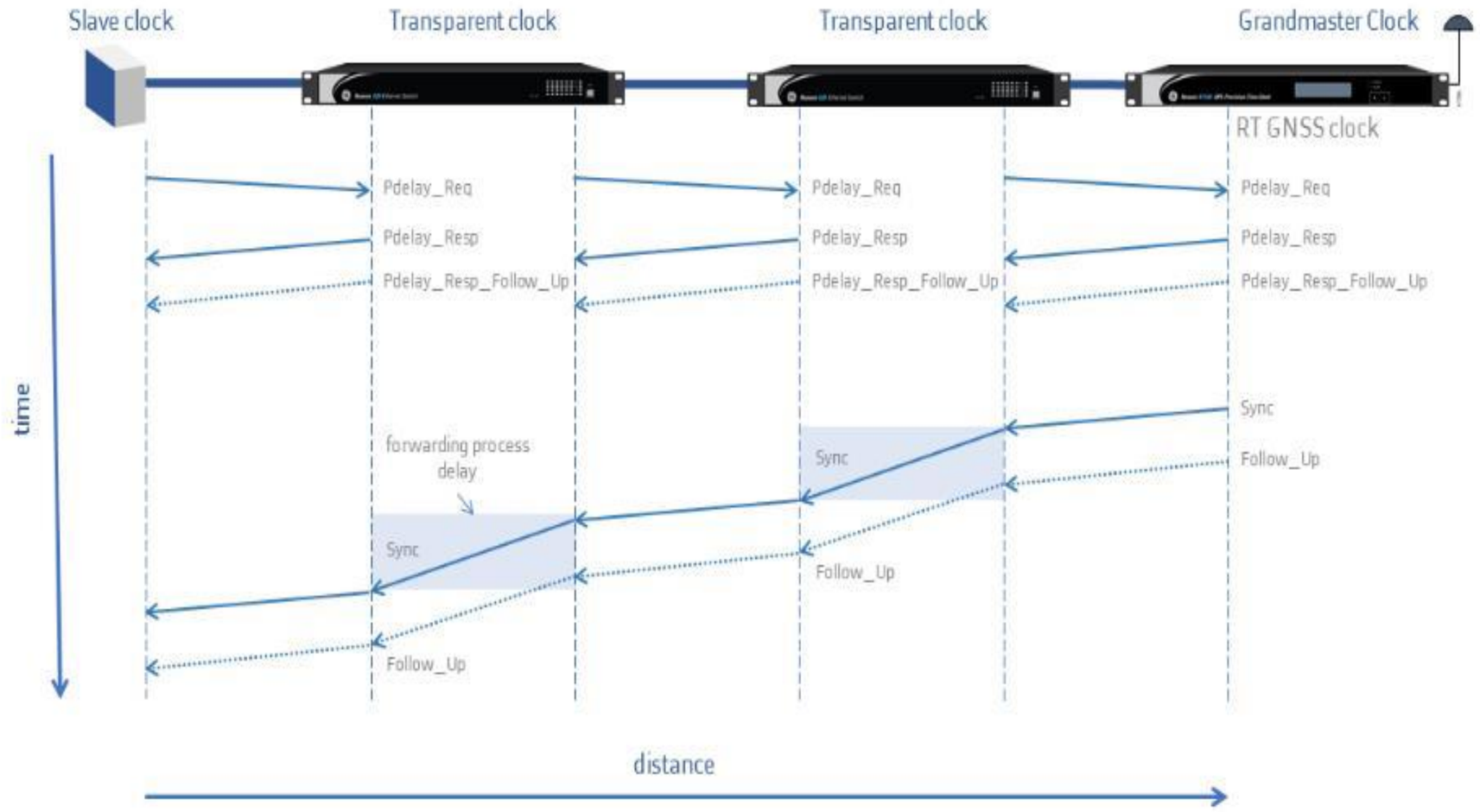
Boundary Clock

- Multiple PTP ports (1x slave, others master)
- Can be master and slave
- Publish Sync pulses in case masters are lost

Transparent Clock

- Corrects the time of messages going through it
- Update time interval field in PTP messages

Time Synch P2P 2 Steps, Transparent Clock



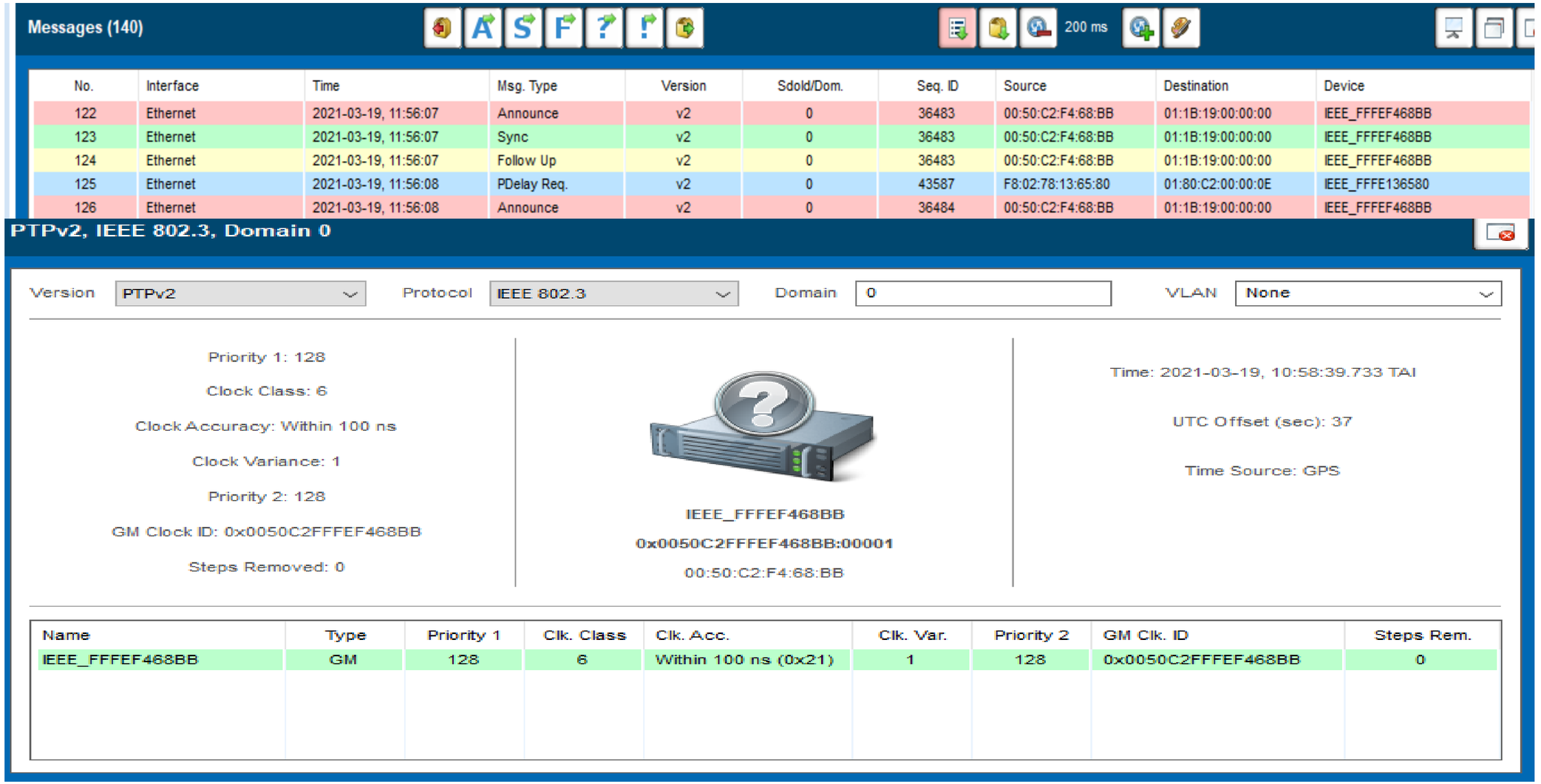
Time Synch Best Master Clock (BMC)

Announce Messages includes the following attributes with the following priority:

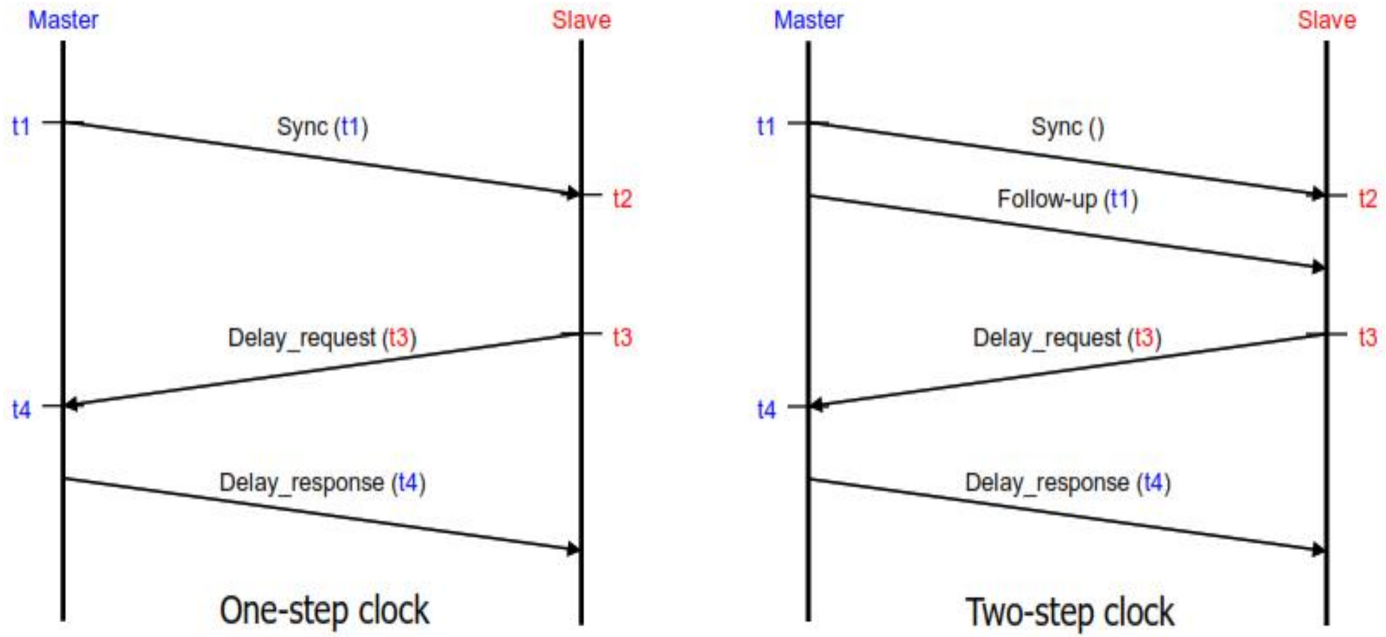
- Priority 1: This is an 8-bit user settable value. The lowest number wins
- ClockClass: This enumerated list of clock states, for example, a GrandMaster clock (GPS sync) would have more class than free running on
- Clock accuracy: This enumerated list range of accuracy to UTC, for example 30-100 ns
- Clock Variance: Represents its stability based on observation of its performance over time
- Priority 2, same as priority 1 but lower in the decision-making tree
- Clock Identity: A universally unique numeric identifier for the clock. Typically constructed based on a device's MAC address serves as tie-breaker

Master Clock listens to Announce Message and compares (based on the above criteria) its own clock with other clocks and decides if it will be a master or slave to the other clock

IEEE 1588 Precision Time Protocol Announce Message



Time Synch IEEE 1588 Precision 1 Step Versus 2 Steps



Delay Mechanism

- End-to-end: Measurement of delay across the network between master clock and slave clock.
- Peer-to-peer: Measurement of delay only between master and slave clocks as neighbors.

All power profiles require P2P. E2E is more suitable if devices in the network do not support PTP

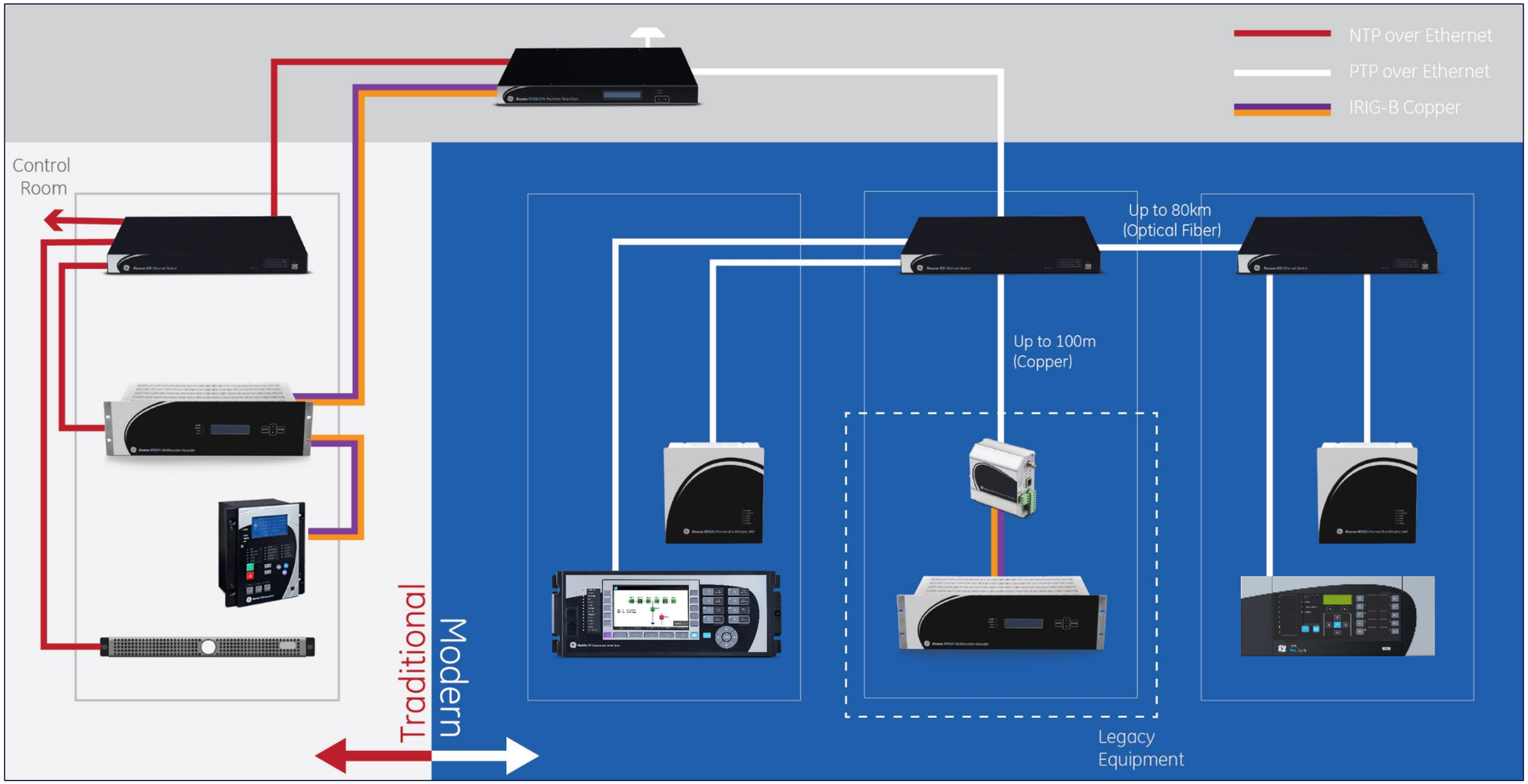
PTP Power Profiles

Those items not allowed in power profile:

- Use of non-TAI time stamps
- End-to-end path delay determination mechanism
- Unicast operation
- Other message rates

	IEEE C37.238:2011 PTP Power Profile	IEEE C37.238:2017 PTP Power Profile	IEC 61850-9-3 PTP Profile for Power Utility Automation
Network Protocol	Ethernet Layer 2	Ethernet Layer 2	Ethernet Layer 2
Delay Mechanism	Peer-to-Peer (P2P)	Peer-to-Peer (P2P)	Peer-to-Peer (P2P)
Operation Mode	One Step	One or Two Step(s)	One or Two Step(s)
Sync / Announce Message Interval	1 per second / 1 per second	1 per second / 1 per second	1 per second / 1 per second
TLV messages	Required	Optional	Optional
Grandmaster Priority	#1 and #2 = 128 Equal for all Grandmaster	Selectable, allowing to choose the best grandmaster for holdover conditions	Selectable, allowing to choose the best grandmaster for holdover conditions

Traditional x Modern Time Synch



Considerations for Clock Selection

- Support for GNSS (jamming and spoofing)
- Supports IRIG-B , NTP, PTP simultaneously (legacy and new devices)
- Supports for PRP (redundancy)
- Full range power and redundant power supply
- SNMP support for remote status of the clock v1,v2,v3
- Software-based licensing for adding more features
- Software configurable
- TCXO internal oscillator in case signal to satellite lost
- Locked relay contact
- No internal battery

Conclusions

- Time synchronization is not optional - it is a critical functionality in protection and control
- IEEE 1588 Time Synchronization protocol allows for sub-microsecond time synch and more robust redundancy than is required for application such as process bus, traveling wave
- Ethernet communication is the backbone of modern substations. With 1588 Time Synchronization protocol, it is that much more important
- As we modernize our infrastructure, we need to ensure newly sourced clocks and switches meet legacy and new technology needs

QUESTIONS ?