Kyland solution for IEEE1588 Precision Time Synchronization in Electric Utilities

IEEE1588 v2

In measurement and control systems there is often a need to synchronize distributed clocks. Traditionally, synchronization has been achieved using a dedicated medium to convey time information, typically using the IRIG-B serial protocol. Timing network (IRIG-B) and data network (Ethernet or other bus) exist as two dedicated wiring networks until the technology of NTP (Network Time Protocol) and SNTP (Simple Network Time Protocol) were founded. NTP and SNTP have the advantage of being able to synchronize computers over a local area network. However they do not have the accuracy required for the most demanding substation applications. IEEE1588 v2 has been ratified by the IEEE in March 2008 and has been designed to overcome the inadequacies of previous solutions such as accuracy, scalability and cost. And it can achieve accuracy in the nanosecond range. The electric power industry has recognized that with IEEE1588 v2 there now exists a network based precision time synchronization protocol that is reliable and accurate enough. Table 1 compares each time protocols on accuracy and network character.

Table 1

Time Protocols	Accuracy	Network
IRIG-B (DC)	100 millisecond range	Dedicated timing network
IRIG-B (AC)	100 millisecond range	Dedicated timing network
NTP	Millisecond range	Timing information and data are transferred in a same network
SNTP	Millisecond range	Timing information and data are transferred in a same network
PTP	Nanosecond range	Precision time information and data are transferred in a same network

IEEE 1588 v2 is important for electric utilities because it meets the timing accuracy needs for the applications of today and the future while reducing the cost to install and maintain a separate dedicated timing network. With 1588, the cabling infrastructure requirement is reduced by allowing time synchronization information to be transported over the same Ethernet medium as the data communications.

Figure 1 displays the IRIG-B time synchronization via dedicated wiring in a substation application, and Figure 2 displays the precision time synchronization via Ethernet network.

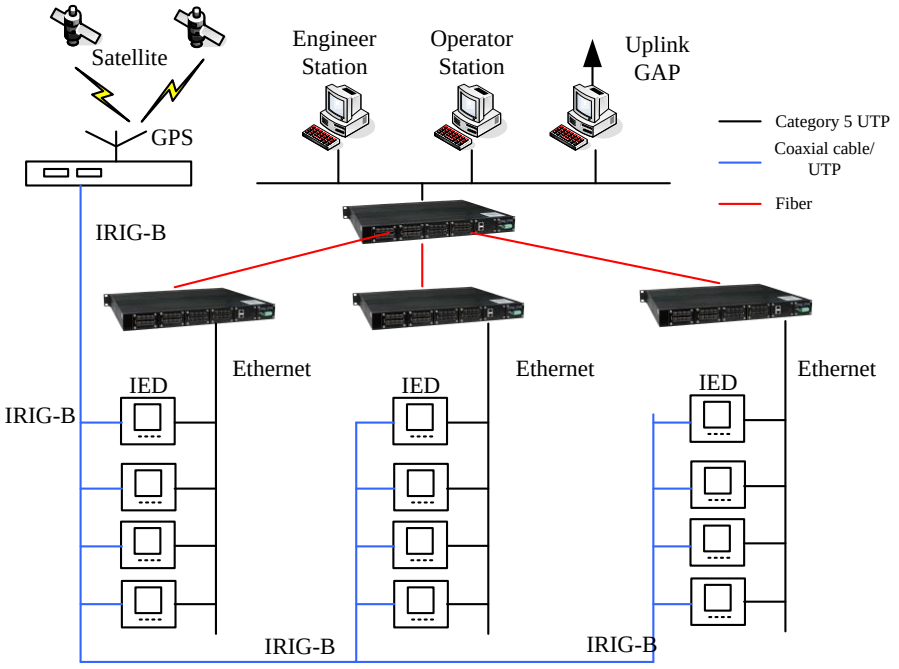

Figure 1: IRIG-B time synchronization via dedicated wiring in a substation application

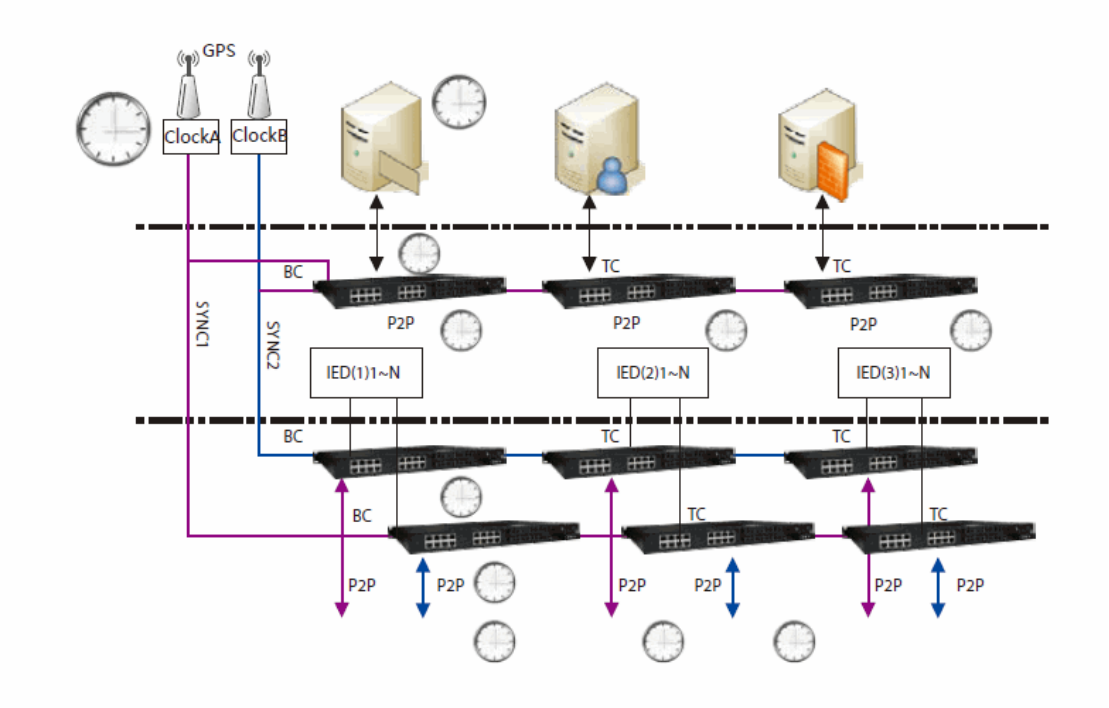

Figure 2: Precision time synchronization via Ethernet network

IEEE 1588 v2 solves following problems:

1. Using an Ethernet network to propagate the timing signals, eliminating the extra cabling requirements of IRIG-B.
2. Using mechanisms that increase accuracy by accounting for switching time and peer to peer propagation delays that occur as the timing signals traverse the network, and the

accuracy achieves nanoseconds range.

3. Using transparent clocks in Ethernet switches that eliminate the need for end-to-end delay measurement, reducing traffic congestion and eliminating switch jitter.

Time synchronization includes frequency synchronization and phase synchronization. The accuracy purely adopting IEEE1588 v2 standard can reach 50ns. If we need to improve the accuracy into a new level, we have to implement synchronous Ethernet technology, and by combining IEEE1588 v2 and synchronous Ethernet technology together, the accuracy of the timing system can be improved to sub 10ns.

Synchronous Ethernet (SyncE)

Over the past two decades Ethernet has become the dominant technology for data transmission, in particular with telecom and wireless providers, due to its simplicity and low cost. However, the asynchronous nature of Ethernet provides certain transmission challenges.

While there are several ways to achieve synchronization over Ethernet, one gaining momentum is Synchronous Ethernet (SyncE). SyncE uses the physical layer interface to pass timing from node to node in the same way timing is passed in SONET/SDH or T1/E1. This gives telecom and wireless providers confidence that networks based on SyncE will be not only cost-effective, but also as highly reliable as SONET/SDH and T1/E1 based networks.

Synchronous Ethernet is a PHY-Level frequency distribution that is achieved through the Ethernet port. This method requires a primary Reference Clock (Ref_Clk) feeding the Ethernet Network. At each node a timing recovery unit will recover this clock, clean it, and use it as the transmit clock to the next node.

Primary standards for Sync-E

- ITU-T G.8261 – Timing and Synchronization aspects in packet network
- ITU-T G.8262 – Timing and characteristics of Sync-E Equipment and slave clock
- ITU-T G.8264 – Distribution of timing through packet networks
- ITU-T G/781 – Synchronization layer functions

Figure 3 illustrates that synchronization does exist in Ethernet on each hop between two adjacent nodes, but it is not passed from hop to hop. Passing synchronization is relatively simple – take the recovered clock from the node receiving synchronization, and with this clock, feed all nodes that are transmitting synchronization (Figure 4).

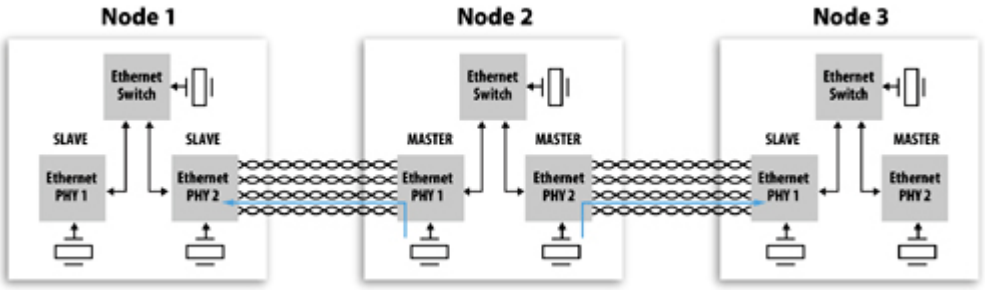

Figure 3: Physical layer timing in traditional Ethernet

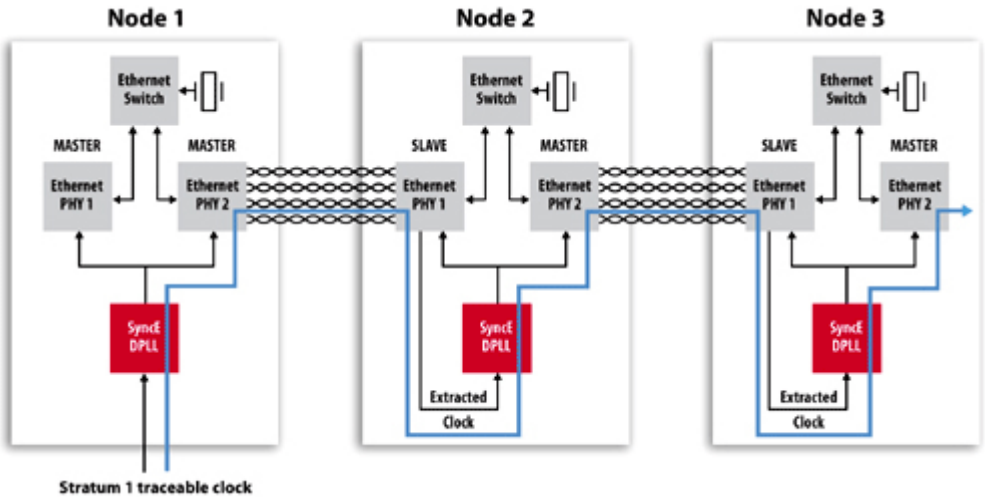

Figure 4: Physical layer timing in synchronized Ethernet

The biggest advantage of Kyland precise clock synchronization solution compared with other vendors is that this solution supports not only IEEE1588 v2, but also synchronous Ethernet with a reliable hardware-based technology. Figure 5 illustrates Kyland's solution on precision time synchronization via SyncE.

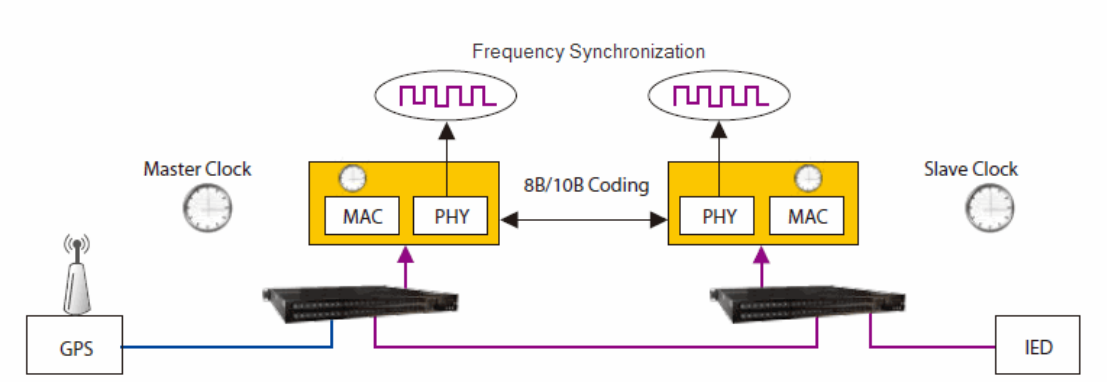

Figure 5: Precision Time Synchronization via SyncE

The synchronous Ethernet technology realizes the frequency synchronization in physical layer, and IEEE1588 v2 only need to adjust the phase inaccuracy. This can reduce the network protocol messages, and reduce the network traffic efficiently.

While several TC(Transparent Clock) are connected in cascades,
The time drift in one cascade $\Delta t = Tdelay * \delta f$
Δt: the time drift between the PTP message resident time and the switch transmission delay.
Tdelay: message's resident time.
δf: Time frequency's drift between TC and GMC(Grand Master Clock).

We assume δf=1ppm.

When the network load is small, Tdelay = 1 to 5 ms, Δt=1ms*1ppm=1ns, this is the best situation. But while the network load is huge, Tdelay =50 to 600ms, Δt=600ms*1ppm=600ns. If we have 5 cascades, the total time drift will be 5*600ns=3us

So during the PTP transparent clock transmission, it is proved that adjusting the switch's own atomic clock according to the master clock is absolutely necessary. Without this function, time drift will occur during the switches transmitting the timing signals coursing the failure of whole timing system for all IEDs and end devices.

Kyland Solution for Precision Time Synchronization

According to IEEE1588 v2 and IEC61850, Kyland developed its own full solution for smart grid including PTC2000 series of precision time source, PTC1000 series of user terminal precision time card and clock convertor, SICOM3024PT series of industrial Ethernet switch supporting precision time synchronization.

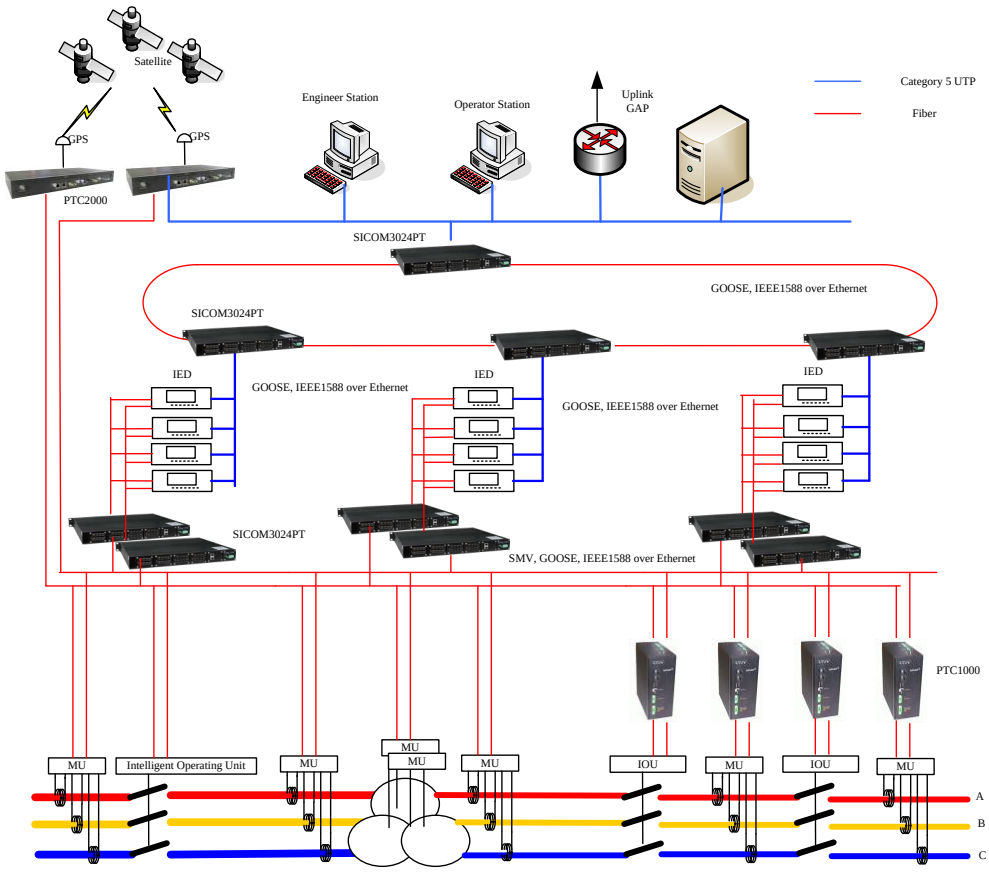

Figure 6: Kyland full solution for precision time synchronization

PTC2000 Series 1588 GMC

PTC2000 Series 1588 GMC can obtain precision time information from GPS and Beidou satellite navigation system and bring this precision time information into industrial Ethernet with a precision of nanosecond range.

Each PTC2000 can support two 1588 cards which can be used as two master clocks simultaneously or one as master clock the other as backup master clock. Each 1588 card can support one 100Base-FX or 10/100Base-TX port, one IRIG-B (DC) port, and one PPS output port.

Main Features:

- Time stamp precision reaches about 50ns.
- Supports two 1588 cards simultaneously.
- Regulating clock precision reaches 0.1μ s/h
- Supports one PPS output.
- Supports Synchronous Ethernet
- Card structure, easy for combination.

GMC Features:

- Synchronous interval 1, 2, 8, 16 and 64s.
- Sending packet: 100 Delay_Req per second
- Delay&not_Req Cache: 256 time stamps
- Time stamp precision: 10ns

Protocols:

- IEEE1588 v2
- G.8261, G.8262

Management:

- CLI, WEB, SNMP management

PTC1000 Series 1588 Slave Clock Source

PTC1000 is a small PTP client specially designed for time and frequency synchronization applications in small size network such as industrial Ethernet control, labs, base stations and etc. PTC1000 brings the revolutionary evolutions of time synchronization brought by IEEE1588 into all kinds of terminal devices and equipments. PTC1000 can act as an Ordinary Clock, synchronized by PTP master clock, offering precision time information in PPS,

IRIG-B, RS232 and 10MHz NTP for all kinds of PLC, fault oscillograph, and transmission line protection equipments.

PTC1000 also supports powerful web management functions and network clock monitoring functions. Through web browser, not only detail device working status can be monitored, all the device settings can also be configured, and firmware upgrades is supported.

According to customer's requirements, PTC1000 Series 1588 Slave Clock supports two models: PTC1000A in Din Rail, and PTC1000B in PCI embedded card.

	PTC1000A	PTC1000B
Photo		
Features	● Supports IEEE1588 v2 ● Outputs PPS and 10MHz frequency, synchronization precision is better than 100ns. ● Outputs IRIG-B (DC), synchronization precision reaches 1μs. ● RS232 management interface	● Supports PCI interface, software driver can support general OS. ● Supports IEEE1588 v2 ● Outputs PPS and 10MHz frequency, synchronization precision is better than 100ns. ● Outputs IRIG-B (DC), synchronization precision reaches 1μs. ● RS232 management interface
Protocols	● IEEE1588 v2 ● G.8261, G.8262 ● NTP	● IEEE1588 v2 ● G.8261, G.8262 ● NTP
Management	SNMP management\WEB\CLI	CLI

SICOM3024PT Precision Time Synchronization Industrial Ethernet Switch

SICOM3024PT is a precise clock synchronization solution of IEC61850 compliant managed industrial Ethernet switch specifically designed to operate stably in electrically harsh and climatically demanding utility substation and industrial environments. It offers up to 24 100Base TP/fiber ports, 4 Gigabit SFP slots or 10/100/1000Base-T(X) ports. The redundant function of optical fiber network, independent entire network management channel, dual redundant power supplies function, and entire network real-time management system provide multiplex guarantee for reliable operation of the system.

Features

1. Supports 4 Gigabit SFP slots or 10/100/1000Base-T(X) ports, 24 100Base TP/fiber ports
2. Supports IEEE1588V2, Boundary Clock (BC), E2E Transparent Clock (TC-E2E), P2P Transparent Clock (TC-P2P)
3. Time source automatic selection
4. Supports G.8261 Synchronization industrial Ethernet standard
5. Supports DT-Ring protocols (recovery time<50ms), RSTP/STP (IEEE802.1w/d) redundant protocols
6. Advanced ring topology protocol avoiding broadcast storm
7. Supports IGMP Snooping, port trunking, port mirroring, QoS, VLAN, ACL
8. Real time temperature detecting and alarming, alarm value can be set
9. System operation log's writing and uploading
10. Supports port speed limitation, and special broadcast storm control
11. Supports precise real time clock
12. IP and MAC address confliction detection
13. Unicast attack detection
14. Safe MAC and port binding function, supports static FDB
15. Bandwidth configuration controls port bandwidth properly
16. Improves network monitoring ability through RMON (group 1, 2, 3 and 9)
17. Supports multiple management functions including CLI, TELNET, WEB, SNMP V1/V2 and OPC
18. EMC industrial level 4, specially designed for harsh electromagnetic interference environment
19. Abundant power supply options, dual redundant power supplies
20. Support relay alarm output port alarming the loss of power
21. Operating temperature: -40 to 85℃ (-40 to 185℉)
22. Ribbed aluminum case for heat dissipation (patent), fanless design
23. Rack-mounting (19 inch 1U/2U) installation
24. IP40 protection class
25. Unified management software for SICOM series: Kyvision3.0