Choosing the correct Time Synchronization Protocol and incorporating the 1756-TIME module into your Application

By: Josh Matson

Various Time Synchronization Protocols

From the earliest days of networked computing, time synchronization has been important for precise computing applications. Standard clock time is inherently inaccurate and takes on added complexity in a distributed system, in which several computers need to realize the same global time. As the need for more precise time synchronization has increased, several protocols have been developed to control and monitor system time.

Two of the most common protocols governing time transfer are Network Time Protocol (NTP) and Inter-Range Instrumentation Group (IRIG) time code. Although the accessibility of Ethernet is certainly an advantage, it is not always well-suited for precise time-synchronized applications. On an NTP-based LAN, network devices and computer operating systems add latency and jitter that reduce synchronization accuracy to 1 to 2 milliseconds. To compensate for this loss, NTP-based LANs often require separate cabling systems and dedicated clocks. Similarly, the IRIG protocol requires physical modifications, such as a dedicated system of coaxial cables to carry timing signals directly between IRIG B clocks, separate from any data network.

Since it was established over a decade ago, the IEEE 1588-2008 Precision Time Protocol (PTP) has addressed the clock synchronization requirements of measurement and control systems by improving accuracy and reducing cost. Among the many advantages of PTP is the fact that the protocol uses the most readily-available means for network connectivity: IP over Ethernet. Taking advantage of the existing Ethernet infrastructure allows considerable reuse of in-place hardware and cabling, helping to reduce costs for the physical layer. PTP eliminates Ethernet latency and jitter issues through hardware time stamping to cancel out a measured delay between nodes at the physical layer of the network. Accuracy in the range of 10 to 100 nanoseconds can be achieved.

This paper will help clarify how PTP works, its effectiveness in comparison with other protocols, and its cost-effectiveness. The paper will also cover features and capabilities of the 1756-TIME module, as well as its application with NTP and PTP.

NTP vs. IRIG vs. PTP

Because it is ubiquitous, inexpensive, widely available, works well over LANs and WANs, and requires little hardware, NTP has been the most commonly used protocol. However, due to the use of switches and routers on LANs and WANs and the fact that many NTP clients run on non-real-time operating systems, such as Windows or Linux, NTP protocol accuracy cannot be guaranteed (see chart, below right). On the Windows operating system, for instance, clock corrections of 10-50 milliseconds are common, because the system is busy performing tasks it deems more important than timekeeping.

The IRIG protocol would seem to be a better choice, offering accuracy of up to 1–10 microseconds. This time code is often used in precision timing-critical applications: military, aerospace, and power utility instrumentation. Because IRIG systems use dedicated coaxial timing cabling between dedicated hardware clocks, the system has its disadvantages. Most notable of these disadvantages are the added expense of additional hardware and the increased time skew due to the added physical infrastructure required.

PTP, with its innate hardware-assisted time stamping, allows the user to take advantage of the NTP protocol's cost-effectiveness by using existing Ethernet LANs, with accuracy better than that delivered by IRIG clocks. PTP can operate with normal Ethernet network traffic on a LAN with switches, while maintaining synchronization accuracy to the sub–microseconds. IEEE 1588 boundary clocks and transparent switches help achieve 20-100 nanosecond synchronization accuracy.

Protocol	Media	Sync Accuracy
NTP	Ethernet	50-100 milliseconds
IRIG-B	Coaxial	1-10 microseconds
PTP	Ethernet	20-100 nanoseconds

Network Time Protocol (NTP)

Network Time Protocol (NTP) is used to synchronize time across an IP network. It utilizes port 123 as both the source and destination, and runs over the User Datagram Protocol (UDP). The NTP network generally uses a time source such as a radio or atomic clock attached to the main time server, then the NTP server distributes the time across the network.

No more than one NTP transaction per minute is necessary to achieve 1 millisecond synchronization on a local-area network. For larger systems (wide-area networks), NTP can routinely achieve 10 millisecond synchronization. However, the level of synchronization is not guaranteed and can be affected by the infrastructure.

An NTP enabled device never synchronizes to a device that is not synchronized itself. Additionally, an NTP enabled device compares the time reported by several NTP devices, and will not synchronize to a device whose time is significantly different than others.

NTP has widely been deployed in enterprise level networks, and should be considered when deploying plant-wide networks requiring synchronized time across multiple Cell/ Area Zones. Because of the absence of PTP enabled network devices at the Manufacturing Zone and higher, the implementation of NTP could be advantageous in the industrial setting. If, for instance, a plant would like to piece together a sequence of events, it is necessary to have a common understanding of time. At the Cell/Area Zone level it may still be best to implement PTP. However, at a higher level, there can be a greater number of devices supporting NTP.

For more information about deploying Network Time Protocol, see this document.

Simple Network Time Protocol (SNTP)

Some devices only support Simple Network Time Protocol (SNTP), which is a simplified, client-only version of NTP. SNTP enabled devices cannot be used to provide time to other devices, they can only receive time from NTP servers. The SNTP enabled devices can achieve synchronization levels within 100 milliseconds.

NTP Server Choice

Many devices have the ability to be an NTP Server, plus there can also be multiple servers on the network. There are also publically accessible NTP servers, which you can learn about by visiting NTP Pool Project.

Most IT departments may have their own NTP server running internally, either on a standalone server, or within a switch or router. All clocks on the LAN can be synchronized to that server. It is acceptable to utilize these existing NTP servers from the Manufacturing Zone (Level 3) up through the Enterprise Network. Note: there is nothing built into the NTP protocol to compensate for multiple hops through a large network. Therefore, the larger the network, the larger the possible a time delay which may be introduced into your system.

IRIG B-122 Protocol

IRIG time codes are another method of time synchronization used in the 1756-TIME module. This module is the only Rockwell Automation product that supports the IRIG standard. For this reason, we typically recommend using NTP or PTP when possible. IRIG also requires additional hardware and cabling, where as the other two methods use Ethernet. IRIG is used primarily when it is necessary to synchronize time across large geographic areas. To date, this system has been implemented primarily in large communication systems, data handling systems, missile and spacecraft tracking, and in large mining operations.

Rockwell Automation uses the modulated IRIG B-122 implementation on the 1756-TIME module for time synchronization. With this implementation, it is possible to achieve synchronization within one microsecond.

Precision Time Protocol (PTP) – IEEE 1588-2008

EtherNet/IP™ uses CIP Sync™ to synchronize device clocks on the Ethernet network. CIP Sync is the name given to time synchronization services for the Common Industrial Protocol (CIP™). CIP Sync uses the IEEE 1588 “Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems,” referred to as Precision Time Protocol (PTP), to synchronize devices to a very high degree of accuracy.

The IEEE 1588 standard specifies a protocol to synchronize independent clocks running on separate nodes of a distributed control system to a high degree of accuracy and precision. The clocks communicate with each other over a communication network. In its basic form, the protocol is intended to be administration-free. The protocol generates a master-slave relationship among the clocks in the system by determining which of the possible sources has the better accuracy. All clocks ultimately derive their time from a clock known as the grandmaster clock.

Once all the clocks in a control system share a synchronized, common understanding of system time, events being monitored in the control system (for example, the ControlLogix™ system) can be time stamped to a very high degree of accuracy.

For more information about Precision Time Protocol, see the Converged Plantwide Ethernet Design and Implementation Guide, and Integrated Architecture and CIP Sync Configuration and Application Technique.

Example Architectures

In our architecture, NTP is used to facilitate time management from Levels 3 through 5. The capability to do this may already be in place in existing Enterprise networks. Between Levels 3 and 2, a conversion from NTP to PTP takes place. This conversion will allow for

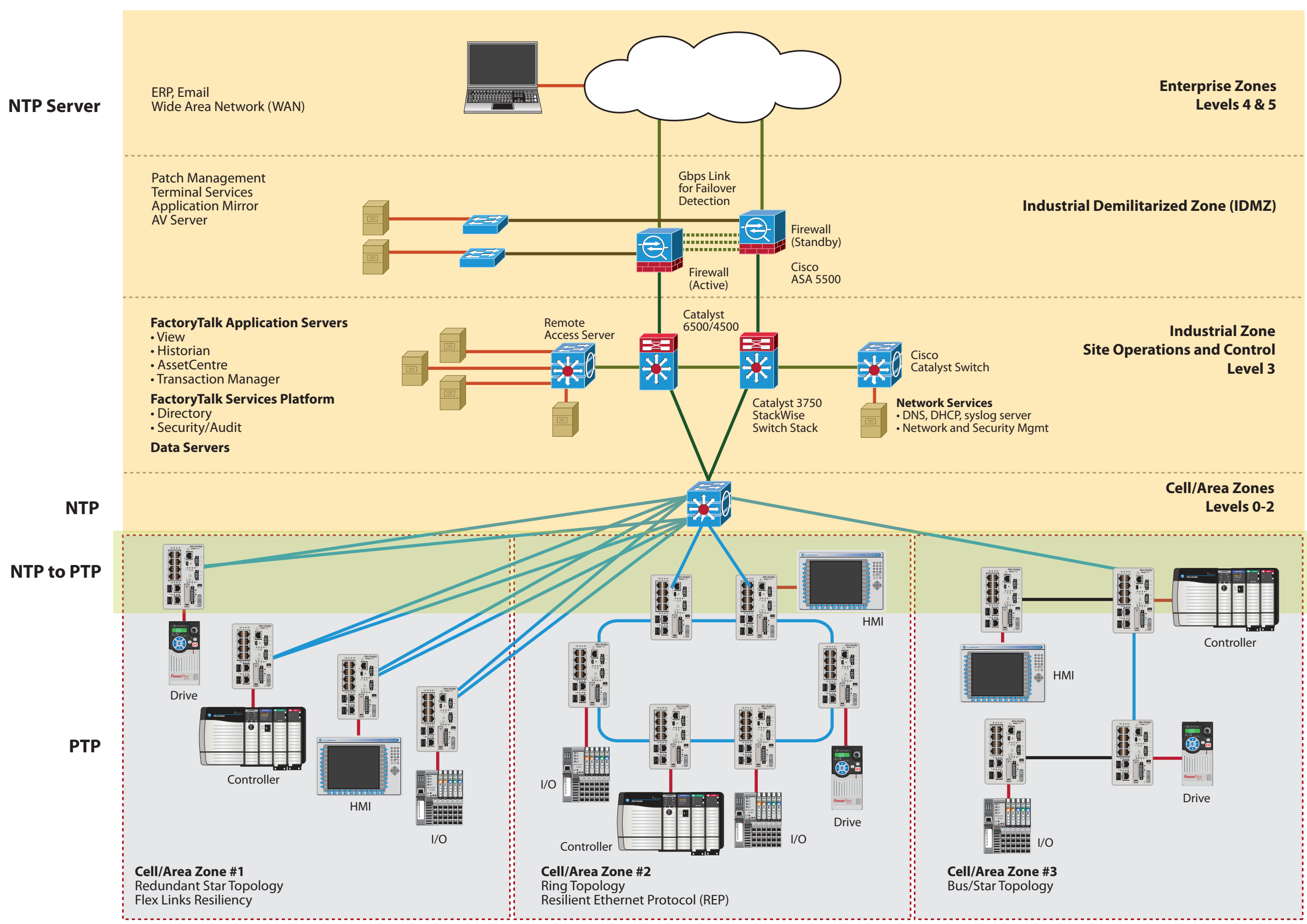


Figure 1

more accurate synchronization at the Cell/ Area Zone level. The plant-wide network will still have similar clocks relative to each other, allowing for plant-wide Sequence of Events to take place. This architecture would be best fit for a plant where an existing NTP server is in place, or for a plant where time synchronization between VLAN's and subnets is necessary, as PTP is not a routable protocol.

For smaller architectures where an existing NTP server may not be present, and where there is only one subnet and VLAN, the following architecture would be appropriate. In this system the 1756-TIME module sits between the Cell/Area Zones and the rest of the plant. The TIME module acts as both the PTP Grandmaster for the entire VLAN/Subnet, as well as the NTP server for the rest of the plant. Since the clock on the TIME module will be more accurate than that found on a computer, this system will have an overall more accurate clock. Again, it is important to note that this architecture is only appropriate for systems with a single subnet and VLAN, as PTP is not routable.

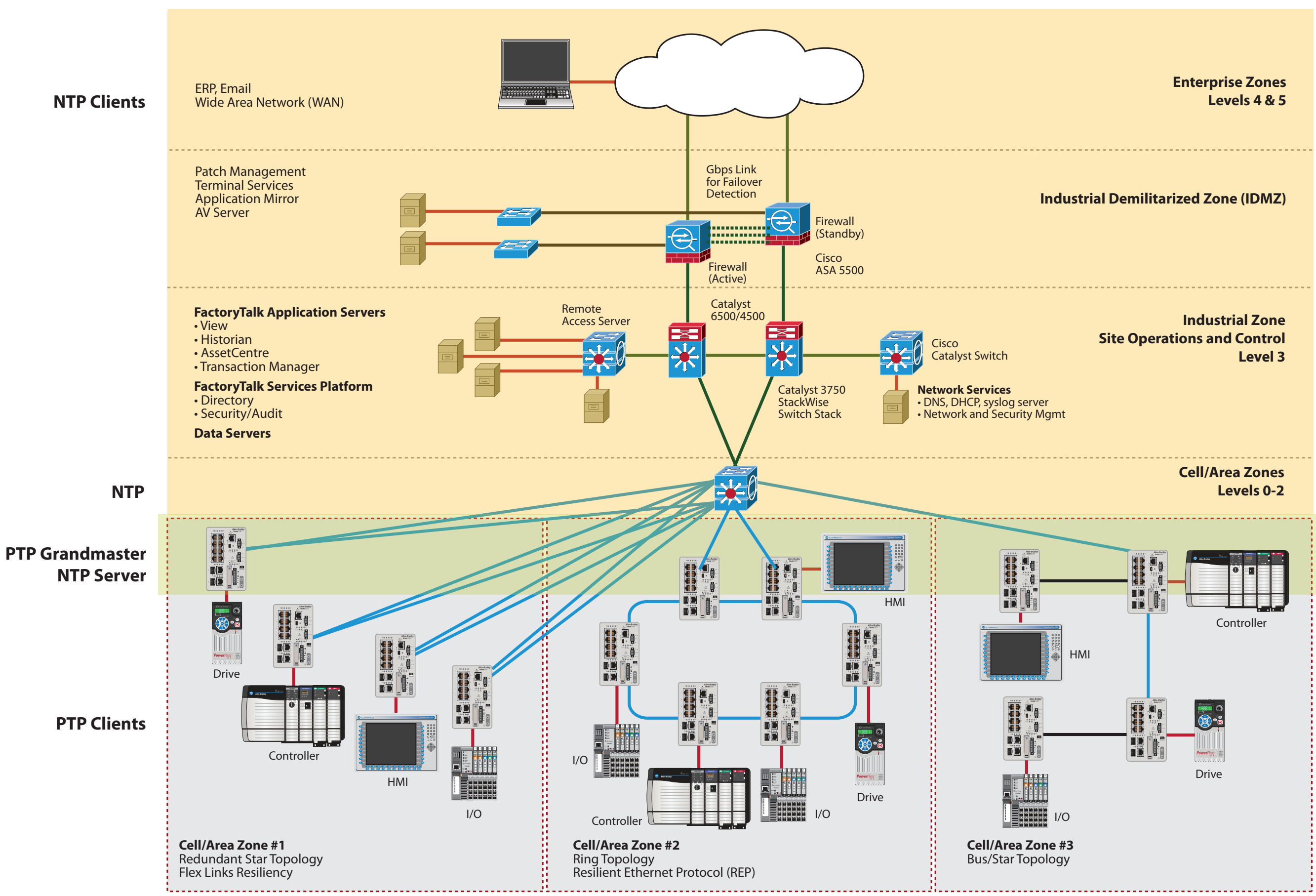


Figure 2

Utilizing 1756-TIME Module NTP Client Functionality

Thus far, the discussion has been on achieving time synchronization across the plant floor by utilizing NTP. However, the NTP mechanism is not extremely accurate, so it may not always be the best solution for all situations. For instance, at the Cell/Area Zone level, a CIP Motion™ system may be implemented. For CIP Motion, it is necessary to implement PTP, which requires a grandmaster. In order to still utilize the NTP time already propagating through the plant, you have to convert NTP to PTP at the Cell/Area Zone level.

As you can see in the following drawing, you can utilize the dual port embedded switch on the front of the 1756-TIME module as the conversion point for NTP to PTP.

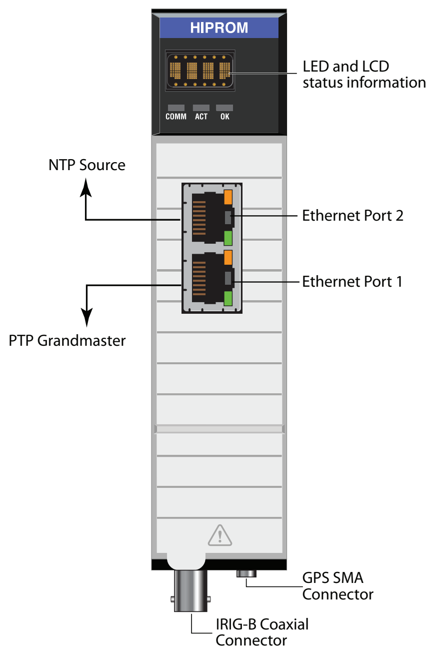
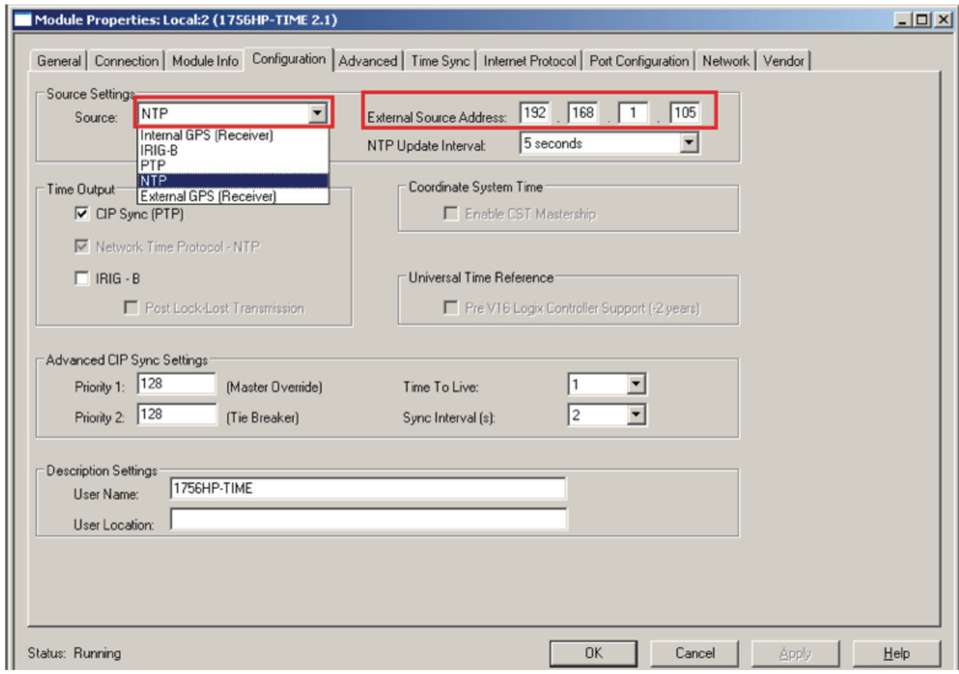
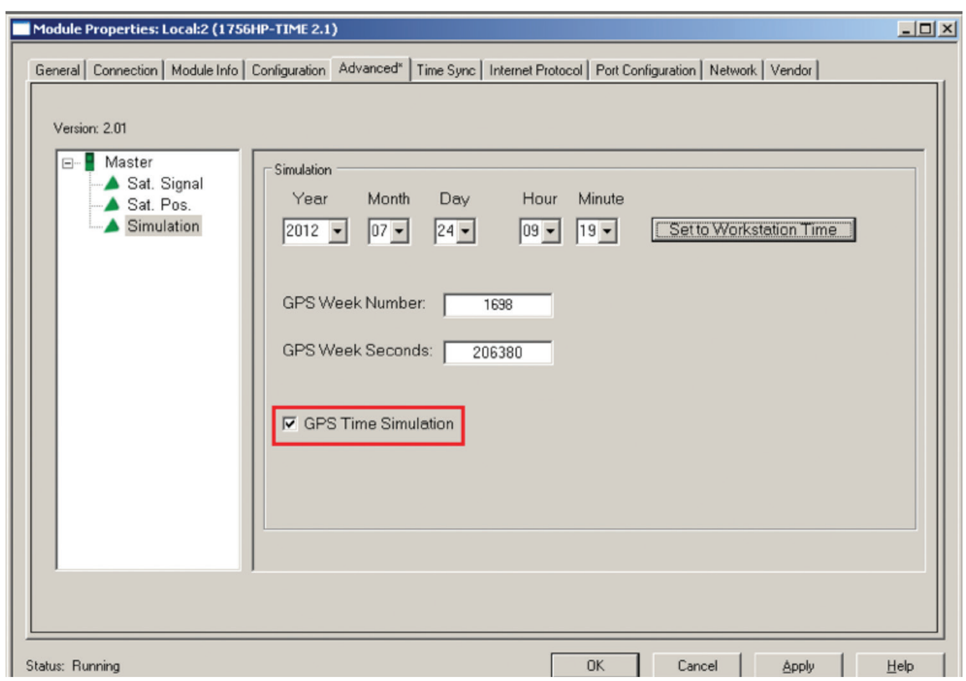


Figure 3 - 1756HP-TIME Module

This conversion can be achieved by utilizing the 1756-HPTIME module, along with its NTP Client capability. When configuring the HPTIME Module choose NTP as the source, rather than GPS. Then insert the NTP server IP address into the module. You can also force priority for CIP Sync Grandmastership from this tab.



In order to bypass the GPS mechanism in the 1756-HPTIME module, it is necessary to put the module into "Simulation Mode," which can be found in the Advanced Tab, as seen below:



www.rockwellautomation.com

Power, Control and Information Solutions Headquarters

Americas: Rockwell Automation, 1201 South Second Street, Milwaukee, WI 53204-2496 USA, Tel: (1) 414.382.2000, Fax: (1) 414.382.4444
Europe/Middle East/Africa: Rockwell Automation NV, Pegasus Park, De Kleetlaan 12a, 1831 Diegem, Belgium, Tel: (32) 2 663 0600, Fax: (32) 2 663 0640
Asia Pacific: Rockwell Automation, Level 14, Core F, Cyberport 3, 100 Cyberport Road, Hong Kong, Tel: (852) 2887 4788, Fax: (852) 2508 1846

Publication ENET-WP030A-EN-E – May 2013