multiple clocks to better than 10 microseconds RMS. A Network Time Server with a GPS or CDMA receiver and PTP is typically referred to as an óIEEE-1588 GrandMasterô. This paper will describe the basic principles of PTP, various implementations of PTP, measurement methods, and synchronization results using a Tempus LX or Unison GrandMaster Clock.

PTP Synchronization

The protocol defines synchronization messages used between a Master and Slave clock similar to the Server and Client mode used in the Network Time Protocol (NTP). The Master is the provider of time, and the Slave synchronizes to the Master. A Grandmaster is a Master that is synchronized to a time reference such as GPS or CDMA.

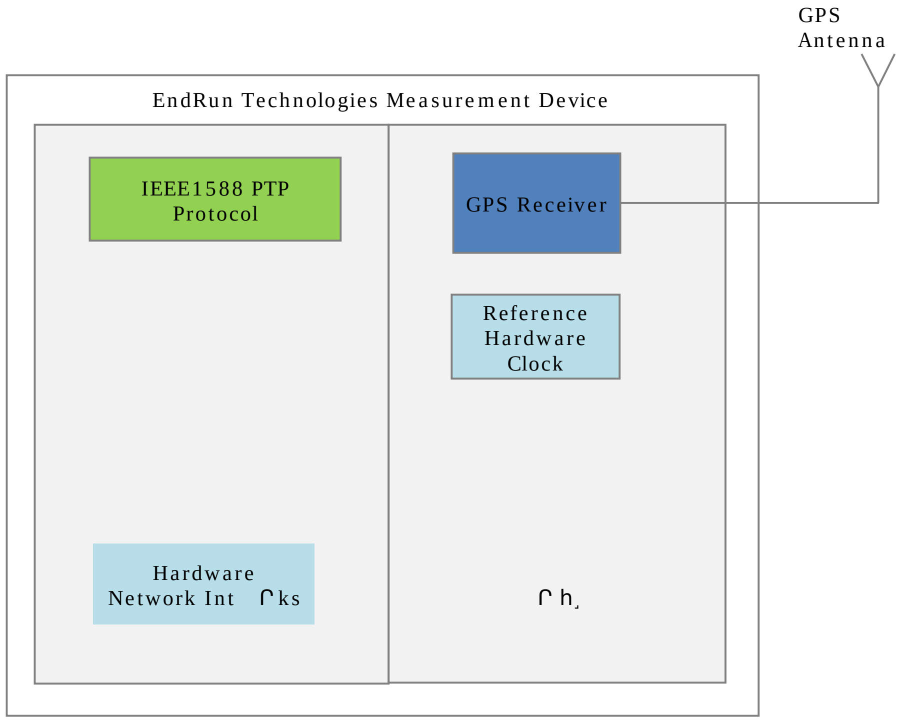
Messages in the protocol include Master sync message, Master delay response message, and the Slave clock

Typical Measurement Methods

The following are two typical measurement methods for determining the accuracy of a PTP Slave synchronized to a PTP Master. Both methods have shortcomings.

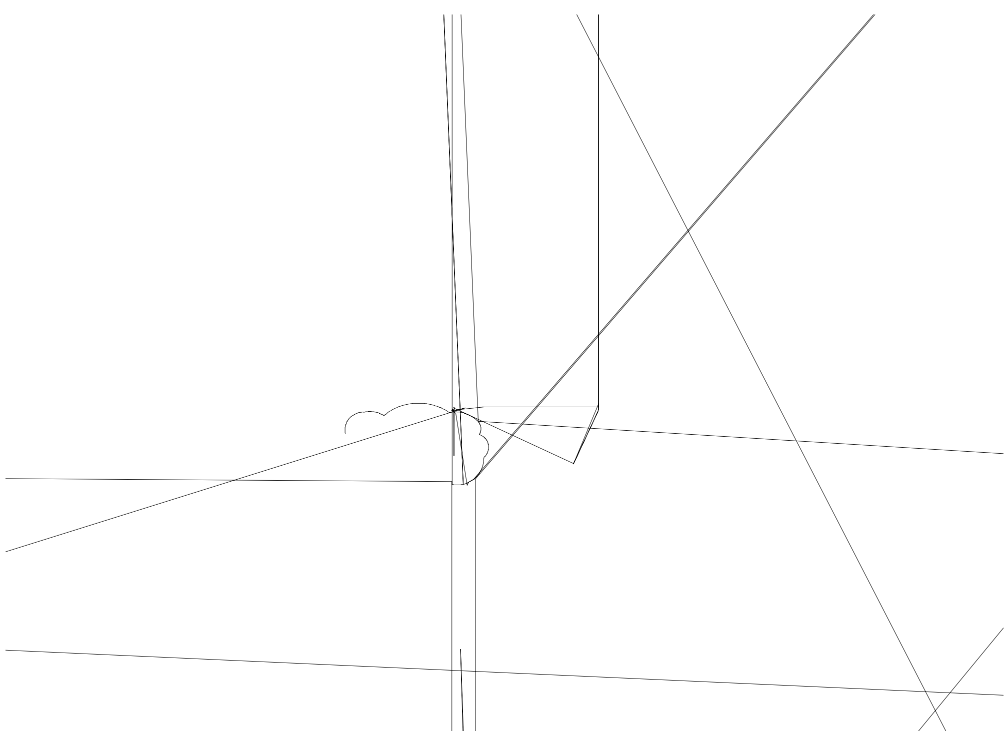
1. Statistics gathered at a Slave is a simple method of understanding synchronization capability, it however does not directly relate to the actual time of the Slave clock.

2. Hardware measurements comparing a Slave to a Master using lab equipment (i.e. time interval counter or oscilloscope) are valid techniques only if both the Master and Slave clocks provide 1 pulse per second (PPS) outputs as illustrated in Figure 3. This method can measure the difference between the phase of the 1PPS pulses. While this is valid it lacks the major time of day (days, hours, minutes, seconds) and can have an une Mp p ΨM ՐMp ՐςՐpЎM ςω εΨ M



GPS and CDMA Master-Slave Test Configurations

The test network was configured with a Tempus LX Grandmaster clock, the network element, and the PTP Slave Measurement Device (see Figure 5). The two test configurations (GPS and CDMA) are shown independently for a clear understanding of the network configuration (see Figures 6 and 7). With GPS, the measurements are considered to be in common view. Both of the GPS antennas are on the same roof within two meters of each other. With CDMA, the measurements are not in common view and an added CDMA base station offset uncertainty is introduced. The PTP clock configurations were defaulted at two second sync rates. The data collected was for a minimum of 24 hours on the LAN with typical daily use network loading.



Measurement Analysis

The analysis of the time synchronization is a combination of the Tempus LX Grandmaster clock reference source (GPS or CDMA), the network element that affects Packet Delay Variation (PDV) and the Slave clock implementation.

The greatest variation is due to the network element affecting PDV. In this case PDV is the difference in packet delay from the Grandmaster to Slave, from one packet to the next. PDV is caused by a combination of distance between the Master and Slave, and the queue delay of the switches affected by network traffic.

The following plots shown include the PTP Slave offset from the GPS Grandmaster (Figure 8) and the Histogram of the PTP Slave locked to the GPS Grandmaster (Figure 9). The Slave measured by the GPS time compare shows a 5.24 microseconds RMS synchronization with a 1 microsecond mean offset.

Figures 10 and 11 show the PTP Slave offset from the CDMA Grandmaster and the Histogram of the PTP Slave locked to the CDMA Grandmaster. The Slave measured by the GPS time compare shows a 9.72 microseconds RMS synchronization with a -8.47 microseconds mean offset. This offset is attributed to the uncertainty of the distance to the CDMA base station and it is not in common view to GPS.

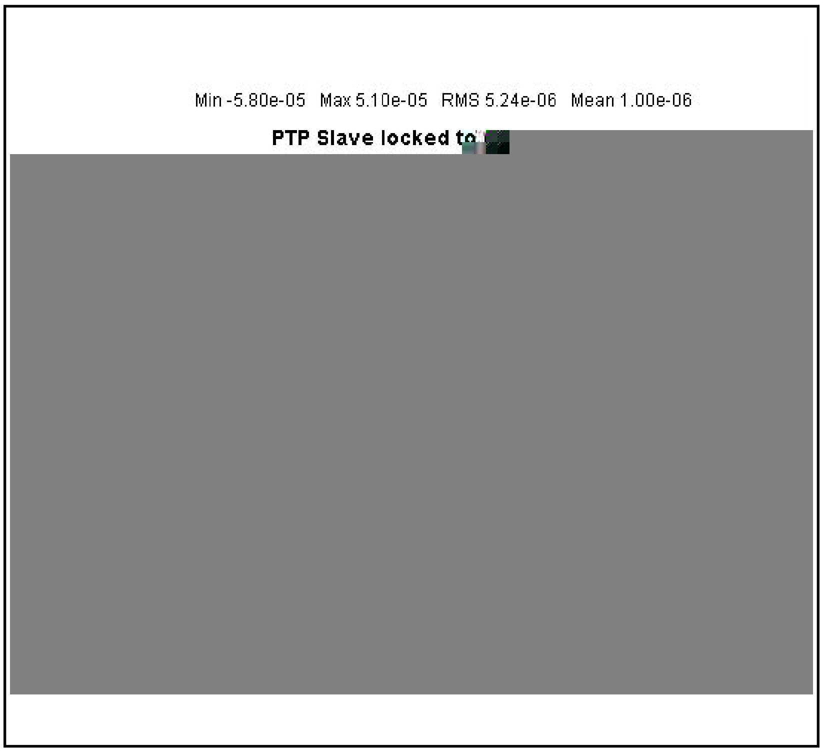


Figure 8. PTP Slave Locked to Tempus LX Grandmaster (GPS)

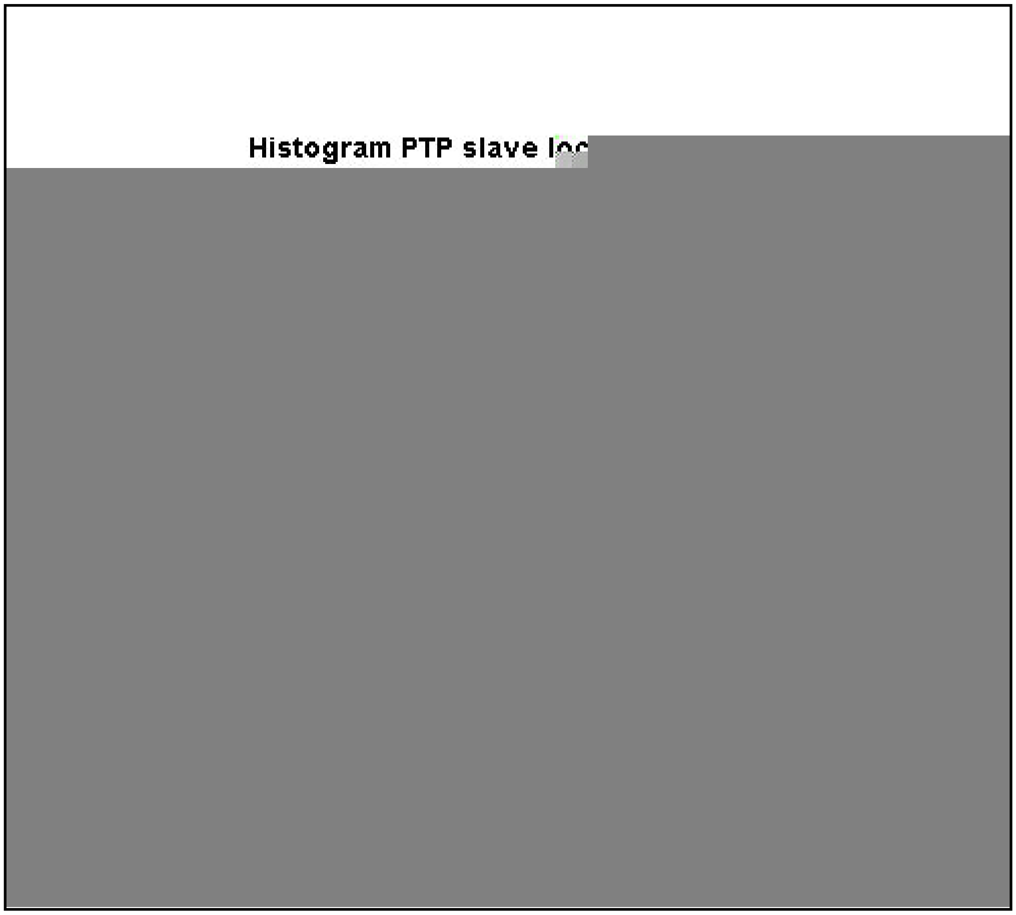


Figure 9. PTP Slave Locked to Tempus LX Grandmaster (GPS)

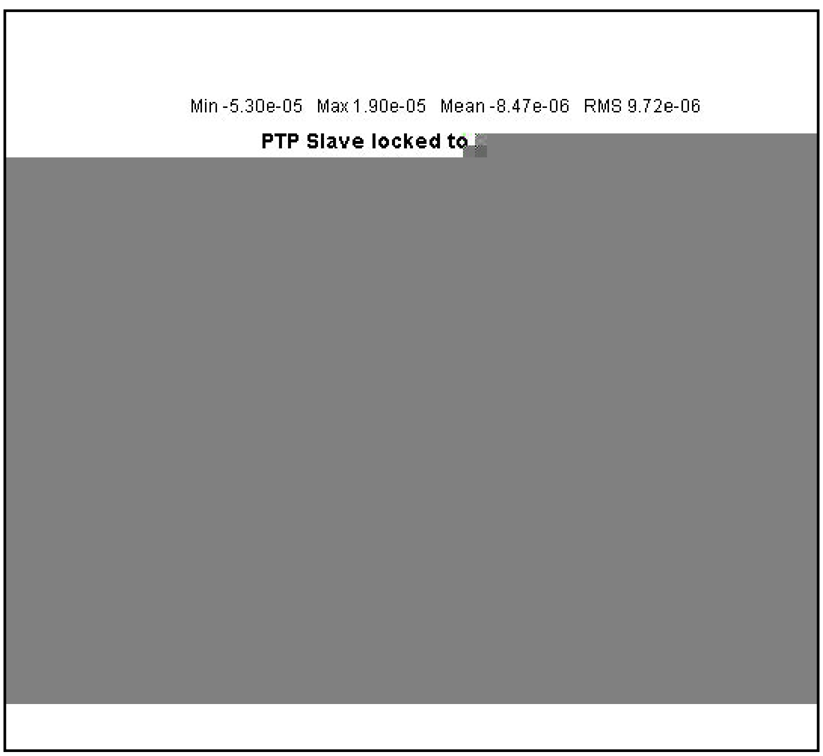


Figure 10. PTP Slave Locked to Tempus LX Grandmaster (CDMA)