High Performance NTP Server using FPGA

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Introduction The demand for accurate time information, which is used to adjust the internal clocks of PCs and servers, is currently increasing. A network time protocol (NTP) is commonly used for this purpose, and the number of access to existing servers is increasing rapidly. We developed a high-precision and high-throughput hardware NTP server using a field programmable gate array (FPGA). This hardware is designed only for a stratum-1 NTP server, which simply puts timestamps based on an accurate external clock. Our NTP server works as fast as the wire-speed of Gigabit Ethernet and has a timestamp accuracy of 8 nano-seconds even in full-traffic. Due to the server's high performance, no overload or crack protection methods are required.

Hardware NTP server We have implemented the minimum functions needed for a public NTP server, including an NTP unicast response in both IPv4 and IPv6. To achieve high-speed operation, our NTP server processes the incoming Ethernet frame directly using a hardware pipeline. In this pipeline, (1) source and destination fields of MAC address, IP address, and port number are swapped; (2) timestamps and some server status information are written; and (3) checksum and CRC are recalculated, then its output is returned as the NTP response. The integer part of a timestamp is just a count of 1 PPS rising edge, with an initial value was set to NTP time using a PCI bus. The fraction is calculated from a 250 MHz counter value using a hardware multiplier.

The basic operation of this server is shown in Figure 1, and our implementation in a PCI card is shown in Figure 2. Figure 3 shows the internal block diagram of the server.

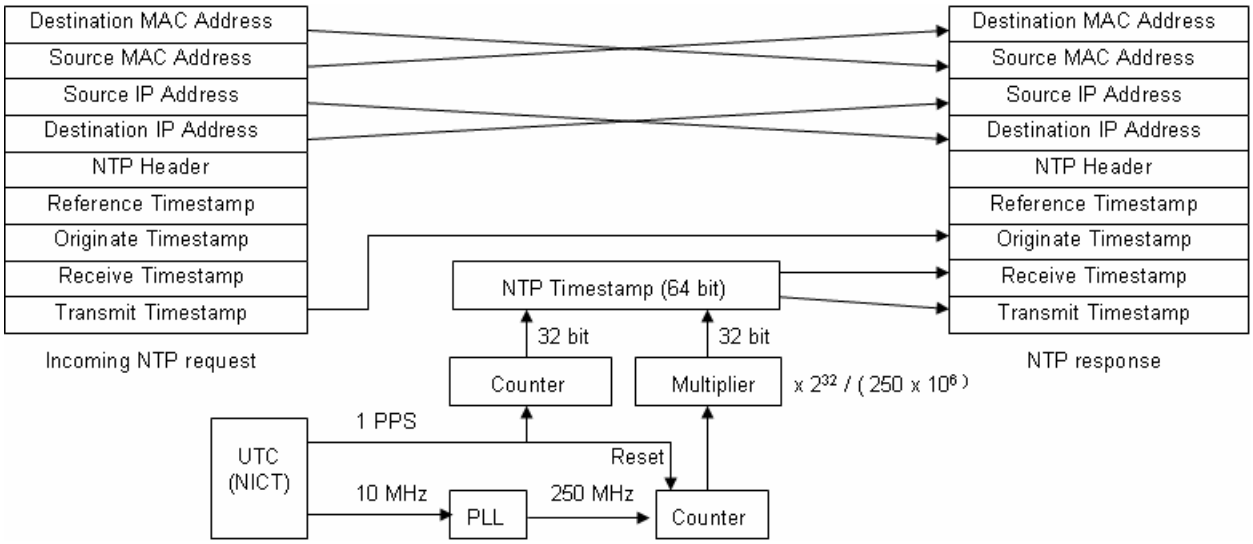

Figure 1. Basic operation of our NTP server

Figure 2. Hardware NTP server

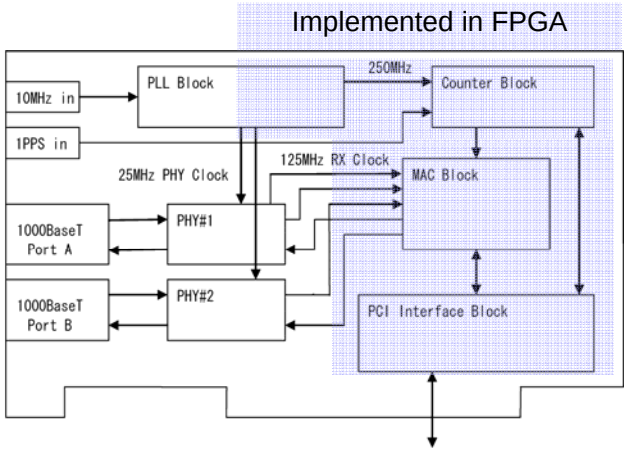

Figure 3. Block diagram

Experiment Results Since our NTP server works at the wire-speed of a Gigabit Ethernet, there is no server overload and no timestamp jitter greater than the transmit clock cycle of a Gigabit Ethernet even in full traffic. We also implemented an NTP client function in the same hardware, which can be used for measuring the timestamp offset of NTP servers as shown in Figure 4. The measured results of an ordinary ntpd and the hardware server are shown in Figure 5.

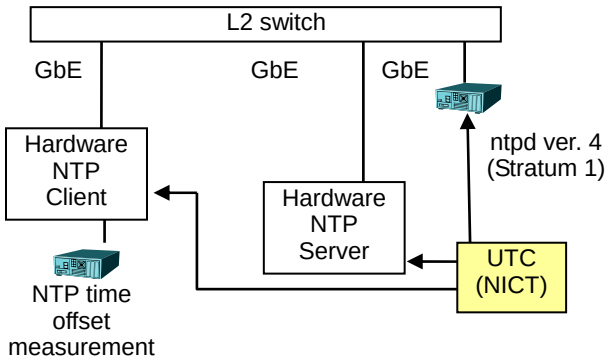

Figure 4. Offset measurement

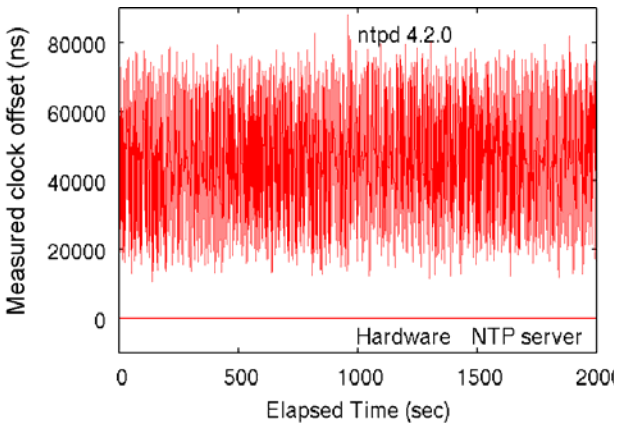

Figure 5. Measured offset

Summary We developed a high-precision and high-throughput hardware NTP server using an FPGA. Though limited in function, the server is sufficient for a stratum-1 NTP server using an accurate external clock exclusively.

To disseminate standard time, we started a public NTP service (ntp.nict.jp) using our servers and UTC (NICT) signals. This server has the significant advantages of requiring no overload or crack protection. This server can be used for precise time-transfer within a building or metropolitan area with an accuracy of approximately 100 ns.