ACTA PHYSICA DEBRECINA XLVI, 107 (2012)

TIME SYNCHRONIZATION FEASIBILITY TEST ON 1000BASE-T ETHERNET

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Abstract

List mode data acquisition in detector systems with several separate modules may need a precise time stamp synchronization with an accuracy in the sub-microsecond range.

Our goal is to examine the feasibility of a precise synchronization method on 1000BASE-T (Gigabit on twisted pair) Ethernet with simple, commercial off-the-shelf (COTS) components.

I. Introduction

List mode data acquisition in detector systems with several separate modules (clients) may need a precise time stamp synchronization with an accuracy in the sub-microsecond range.

For Local Area Networks, a possible approach is using Precision Time Protocol (PTP), which is able to provide precision timing to distributed embedded devices [1]. But PTP cannot achieve a sub-microsecond accuracy without special, hardware assisted network equipment [2][3].

In contrast to the above solutions our goal is to examine the feasibility of a precise synchronization method with simple, commercial off-the-shelf (COTS) components.

In a previous study [4] we have demonstrated that if 1000BASE-T (Gigabit on twisted pair) Ethernet is used for data acquisition with all clients connecting to the same Gigabit Ethernet switch, then the 125 Mhz Ethernet clock recovered by each client can serve as the shared synchronous clock. In order to synchronize the time stamp counters of the clients, we used special synchronizing broadcast messages. However, using these broadcast packets did not perfectly synchronize the time stamp values: a systematic offset and some random jitter remained.

II. Absolute PD Histogram

Passing through the common switch, the broadcast packets will be delayed by the Packet Delay (PD) plus a Packet Delay Variation (PDV) (see Figure 1). The value of PD and PDV will vary for different switches and even for different ports of a single switch. The PD can be defined in relation to a distinctive reference point of the histogram described below.

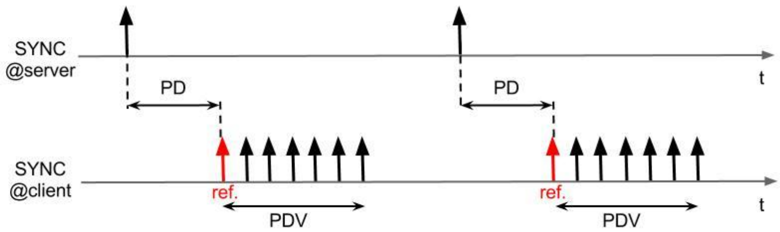

Figure 1: The delay of the broadcast packets

With respect to synchronization (SYNC), a switch port-pair can be characterized by an absolute (hardware synchronous) Packet Delay histogram. After the switch is powered up, with negligible network traffic and a particular average SYNC rate, the histogram exhibits a stable distribution in time. This histogram can be recorded as shown in Figure 2.

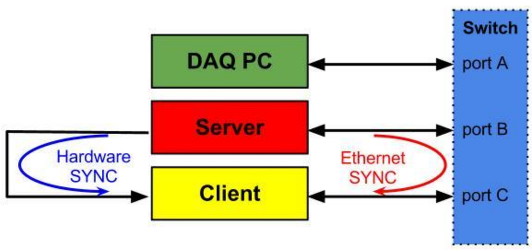

Figure 2: Test setup for recording absolute PD histogram

The SYNC server sends Ethernet SYNC packets to the client through the switch with a constant rate (e.g. 2 kHz average rate). At the same time, together with each sent SYNC packet the server generates a hardware SYNC signal, which provides a common time reference for our test measurement, but not used and not present in a real-life application of our synchronization method. The histogram is based on the arrival time difference of hardware and packet SYNC signals.

III. Test and Result

We have examined two COTS Gigabit switches: an SMC GS24C-Smart and a TP-Link SG1008D switch. For both, absolute PD histograms were taken for each port-pair. Typical histograms can be seen in Figure 3 and Figure 4.

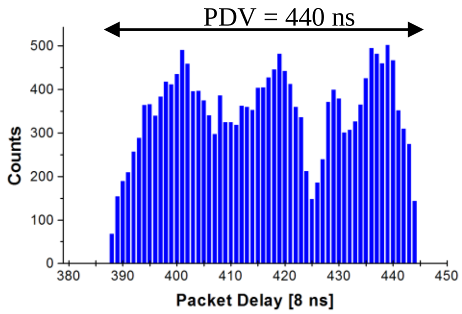

Figure 3: An absolute PD histogram of SMC GS24C-Smart

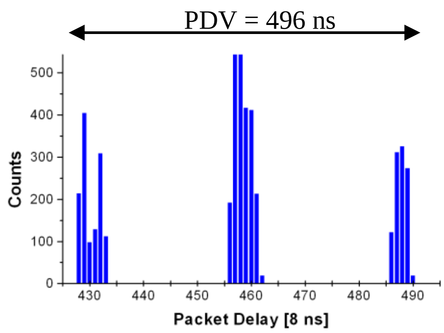

Figure 4: An absolute PD histogram of TP-Link SG1008D

The PD and PDV values that belong to the histograms above are listed in Table 1.

Table 1: PD and PDV values for a particular port-pair of two switches

Switch	PD	PDV
SMC GS24C-Smart	3.1 μs	440 ns
TP-Link SG1008D	3.4 μs	496 ns

Those PD and PDV values remain stable once the cables have been connected and the switch has been powered on. Reconnecting the cables (to the same port-pair) or restarting the switch will result in a PD shift of only ±16 ns. This means that a synchronization accuracy of approximately 500 ns can be achieved by relying only on the PD values.

IV. Conclusions

Our goal was to achieve a synchronization on 1000BASE-T Ethernet, which approximates the theoretical 8 ns accuracy as best as possible. Our method is based on the measurement of the absolute (hardware synchronous) Packet Delay histograms of several port-pairs of Gigabit Ethernet switches. We were able to align the client times with an accuracy of 500 ns.

Further studies are under way to improve the accuracy by using a special algorithm relying on a distinctive part of the Packet Delay histograms.

Acknowledgement

This work was supported by the ENIAC Joint Undertaking under grant agreement # 120209 and the TAMOP-4.2.2/B-10/1-2010-0024 project. The project is co-financed by the European Union and the European Social Fund.

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