Research on Computer Time Synchronization

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***Abstract*—Network time server and PCI timing card are two important devices of computer time synchronization. So it is necessary to research the features of them. In this paper, the two methods which synchronize accurate time to the computer based on the two devices were described. An effective PPS measurement method which shows synchronization accuracy and delay of each was made by using the computer parallel port. By comparing the results of two methods of synchronizing time, the different delay characteristics are analyzed in windows operating system environments. A more accurate synchronization can be achieved by reducing delay which can get a better the delay characteristics and delay compensation.**

I. INTRODUCTION *(HEADING 1)*

With the rapid development of computer technology, the time synchronization accuracy of computer which is synchronized by UTC has a direct impact on safe working or trading in some industries, especially in the financial, communications, transportation, military and other important fields. Therefore, the accuracy of computer time synchronization is very important, and an effective test method is an important guarantee for the time synchronization accuracy of computer [1].

At present, there are three most commonly used methods of computer time synchronization: serial port, computer bus and network time synchronization method.

- Based on the serial port-RS232 method. In the three time synchronization methods, the time synchronization accuracy of this method is the worst, about a hundred milliseconds.
- Based on computer bus method. This method usually is based on the ISA bus or PCI bus, it's time synchronization accuracy is less than one millisecond.
- Network time synchronization method. The traditional network time synchronization method is largely affected by network conditions. The accuracy is usually about a few milliseconds to hundreds of milliseconds. However, some new protocols of network time synchronization have the better accuracy of computer time synchronization, such as the IEEE1588 [2].

TABLE I. CONTRASTION OF COMPUTER TIME SYNCHRONIZATION ACCURACY BY USING COMMONLY METHODS

Interface Type	Synchronization Accuracy	Software Method
Serial Port	About 100ms	Application Programming
ISA Bus	Less than 1ms	Driver programming
PCI Bus	Less than 1ms	Driver programming
Ethernet Interface	1ms-100ms	Using Network Time Protocal

The method based on RS-232 has a low timing precision, and most computers do not support the ISA bus. So, this paper focuses on the two computer time synchronization methods in which network time server and PCI timing card are used respectively.

II. PRINCIPLES OF COMPUTER TIME SYNCHRONIZATION

A. PCI timing card

By using the computer PCI bus technology, PCI timing card can provide high precision time synchronization, generally better than 1ms. PCI timing card is a timing module that based on the PCI bus. It can receive and maintain a high-precision time outside the computer. By reading or writing the PCI timing card through the PCI bus, the computer could be achieved time synchronization with the time of clock source (GPS time or user-defined high-precision clock).

As a result of the independence time was maintained by the PCI timing card, and it was not affected by the computer's operating system, so this method can provide higher accuracy of the computer time synchronization. Block diagram of its work is shown as follows:

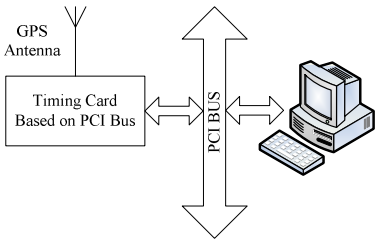

Figure 1. Block diagram of PCI timing card work

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B. *Network Time Protocol*

The Network Time Protocol, or NTP, is the most widely used method for transmitting time information across the internet.

A computer can be synchronized using NTP by running client software, which may be a small program running in the background or built into other software such as the operating system. The client sends periodic time requests across the Internet or an internal network to one or more specified servers. Each call to a server results in an exchange of time-stamped packets of data that allow the client software to estimate the network delay and the rate offset between the client computer's clock and the server, and uses this information to adjust the clock. Repeated calls to a number of servers allow the client software to ignore responses from those that send a time significantly different from the others, and to average the results from those that appear to be corrected [3][4][5]. The principle of its work is shown in figure below:

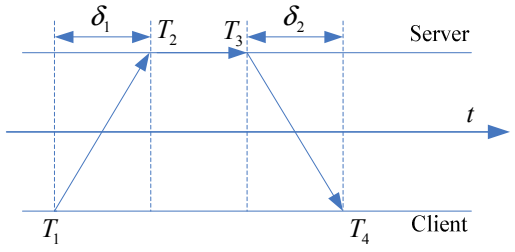

Figure 2. The principle of NTP work

T_1: The time that client requesting the time service ;

T_2: The time that server receiving the request;

T_3: The time that server sending the Reply;

T_4: The time that client receiving the Reply;

δ_1: The transmission delay of the request information;

δ_2: The transmission delay of the reply information;

Now known T_1, T_2, T_3, T_4, in order to adjust client clock θ can be solved:

$$\begin{cases} T_2 = T_1 + \theta + \delta_1 \\ T_4 = T_3 - \theta + \delta_2 \\ \delta = \delta_1 + \delta_2 \end{cases} \quad (1)$$

If the transmission delay of the request information is equal to the transmission delay of the reply information, namely δ_1 is equal to δ_2, they can be solved:

$$\begin{cases} \theta = \dfrac{(T_2 - T_1) - (T_4 - T_3)}{2} \\ \delta = (T_2 - T_1) + (T_4 - T_3) \end{cases} \quad (2)$$

So θ and δ are not related to the amount of time which is spent when server processes the request. By the above two formulas, the computer time error can be obtained.

III. TESTING TIME SYNCHRONIZATION THEORY

For the computer, it is very difficult how to assess the performance of time synchronization, so that there is more than one method to test the quality of time synchronization. They provide different information and have different considerations. There are two methods commonly used to test the time synchronization- Software reported test method and PPS (Pulse Per Second) synchronization test method [6].

A. *Software Reported Test*

This method relies on the report for PTP (point-to-point network protocol-based connection) stack which shows the quality of time synchronization. This means that the results of software testing method have the same constraint as the PTP algorithm itself. The main restrictions on PTP algorithm is that send path can not be corrected and the receive path length is different. The error that is introduced by the PTP algorithm need be considered for the results of analysis. After testing in the method, the error of the accuracy is a large value, typically around tens of microseconds.

B. *PPS Synchronization Test*

For analysis of time synchronization, the most common way is to observe the second pulse signal. For many older systems, the way is the only successful time synchronization methods. But, for computers, device driver programming is a better method. When the second of the computer system time is changing, the computer's PPS signal is generated through the computer's parallel port, and then the time interval between it and UTC PPS is measured [7]. PPS method test is shown as below:

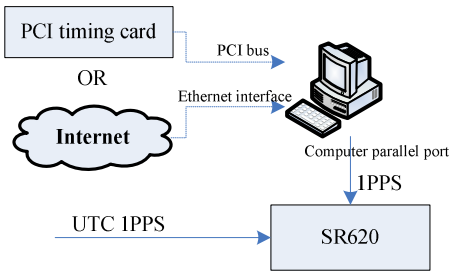

Figure 3. Pulse Per Second Synchronization Test

The main advantages of this measurement method is that it can effectively sample the error of time synchronization per second, and the result of computer time synchronization can directly be observed by using oscilloscope. The method also has certain disadvantages. In spite of the method in which the PPS is generated through device driver programming, but it is still affected to some extent by the operating system. The method will add an additional error, usually around tens of nanoseconds.

IV. CONCLUSION

The results of computer time synchronization through the two methods which by using Pulse Per Second Synchronization Test is shown as follows:

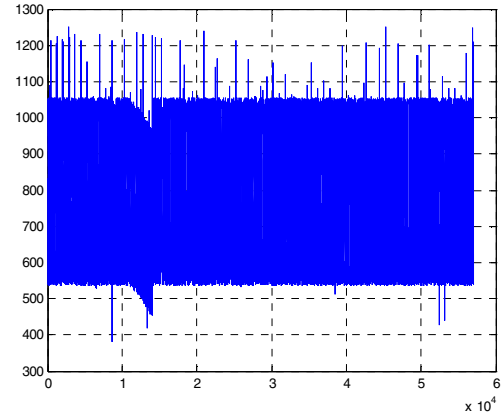

Figure 4. The result of PCI timing card test

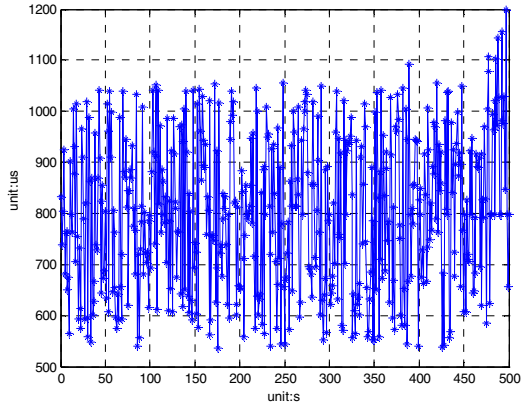

Figure 5. Drawing of partial enlargement for Figure 4

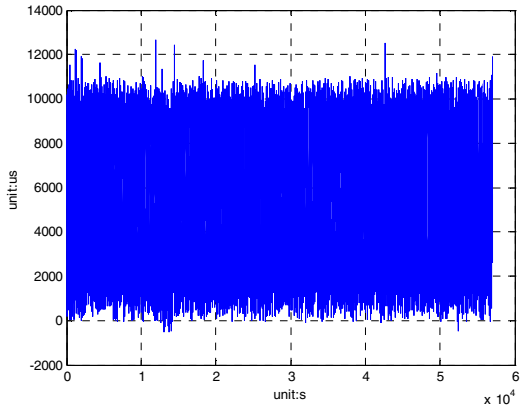

Figure 6. The result of NTP test

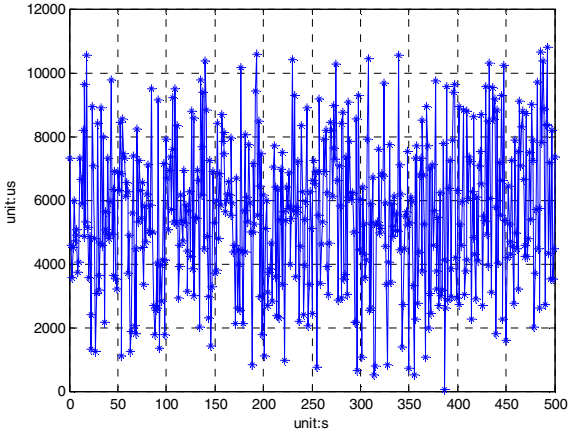

Figure 7. Drawing of partial enlargement for Figure 6

TABLE II. THE RESULTS OF TEST

	Mean	1-σ Standard Deviation	Number of Samples
PCI timing card	794.48us	150.28us	57000
NTP	5.44ms	2.29ms	57000

According to the above test results, It can be concluded that the Bus-based PCI timing card has much higher accuracy of time synchronization than the web-based NTP method.

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