Time Error Analysis of SOE System Using Network Time Protocol

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1. Introduction

To find the accuracy of time in the fully digitalized SOE (Sequence of Events) system, we used a formal specification of the Network Time Protocol (NTP) Version 3[1], which is used to synchronize timekeeping among a set of distributed computers.

Through constructing a simple experimental environments and experimenting internet time synchronization, we analyzed the time errors of local clocks of SOE system synchronized with a time server via computer networks.

2. Network Time Protocol

The NTP, now published as Internet Standard Protocol, is used to organize and maintain a set of time servers and transmission paths as a synchronization subnet. NTP is built on the Internet Protocol (IP) and User Datagram Protocol (UDP), which provide a connectionless transport mechanism; however, it is readily adaptable to the other protocol suites. It is evolved from the Time Protocol and ICMP Timestamp Message, but is specially designed to maintain accuracy and reliability, even when used over typical Internet paths involving multiple gateways and unreliable networks.

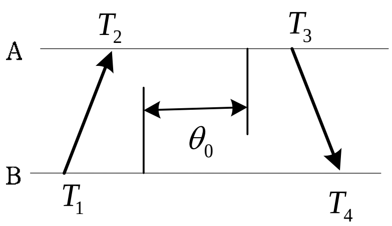

Figure 1. measuring delay and offset

3. Calculating Time Errors

In practice, errors due to stochastic network delays usually dominate. In general, it is not possible to characterize network delays as a stationary random process, since network queues can grow and shrink in chaotic fashion and arriving traffic is frequently bursty. Nevertheless, it is a simple exercise to calculate bounds on clock offset errors as a function of measured delay. Let $T_2 - T_1 = a$ and $T_3 - T_4 = b$. Then, the roundtrip delay δ and clock offset θ of B relative to A are:

$$\delta = a - b \text{ and } \theta = \frac{a+b}{2}.$$

The true offset of B relative to A is called θ_0 in Figure 1. Let x denote the actual delay between the departure of a message from A and its arrival at B. Therefore, $x + \theta_0 = T_2 - T_1 \equiv a$. Since x must be positive in our universe, $x = a - \theta_0 \geq 0$, which requires $\theta_0 \leq a$. A similar argument requires that $b \leq \theta_0$, so surely $b \leq \theta_0 \leq a$. This inequality can also be expressed

$$b = \frac{a+b}{2} - \frac{a-b}{2} \leq \theta_0 \leq \frac{a+b}{2} + \frac{a-b}{2},$$

Which is equivalent to

$$\theta - \frac{\delta}{2} \leq \theta_0 \leq \theta + \frac{\delta}{2}.$$

The inequality can be written

$$\theta - \varepsilon_\theta - \frac{\delta + \varepsilon_\delta}{2} \leq \theta_0 \leq \theta + \varepsilon_\theta + \frac{\delta + \varepsilon_\delta}{2},$$

where ε_θ is the maximum offset error and ε_δ is the maximum delay error derived (See [1] for deriving bounds on delay and offset errors).

The quantity $\varepsilon = \varepsilon_\theta + \frac{\varepsilon_\delta}{2}$, called the dispersion, defines maximum error in the inequality. Thus, the correctness interval I can be defined as the interval

$$I = [\theta - \frac{\delta}{2} - \varepsilon, \theta + \frac{\delta}{2} + \varepsilon],$$

in which the clock offset $C = \theta$ is the midpoint. By construction, the true offset θ_0 must be lie somewhere in this interval.

4. Experiment and Analysis

Figure 2 shows two kinds of time synchronization experiments with time servers as follows:

- time synchronization per one minute between the primary time server in KRISS(Korea Research Institute of Standards and Science) and the secondary time server
- time synchronization per one minute between the secondary time server and the client

As a result, we produced a delay, a clock offset, and a dispersion for each of two experiments as shown in Figures 3, 4, 5, 6, 7, and 8. Figure 5 and Figure 6 shows the main cause of deviations between dispersions of the secondary time server and the client is due to the instability of delays and offsets.

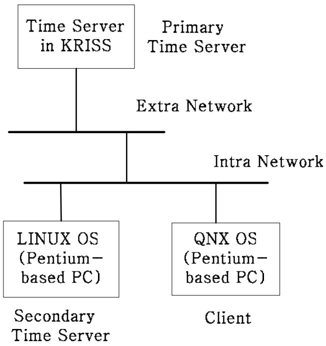

Figure 2. experimental environment

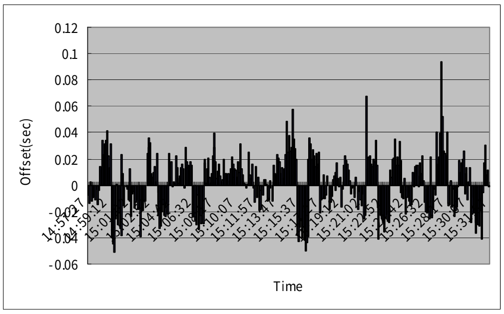

Figure 3. offset of secondary time server

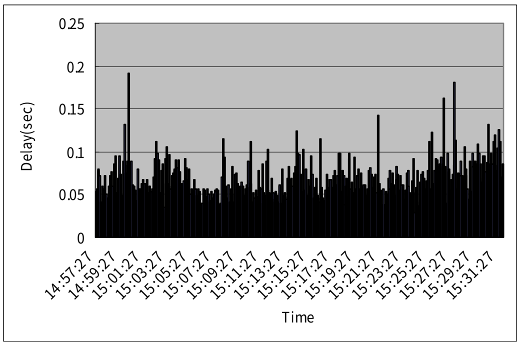

Figure 4. delay of secondary time server

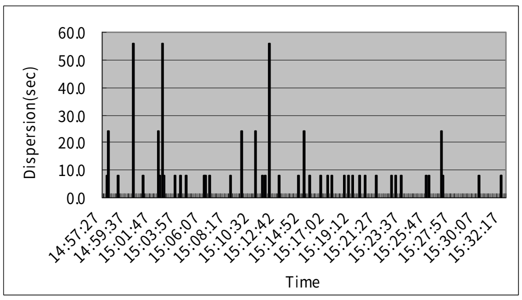

Figure 5. dispersion of secondary time server

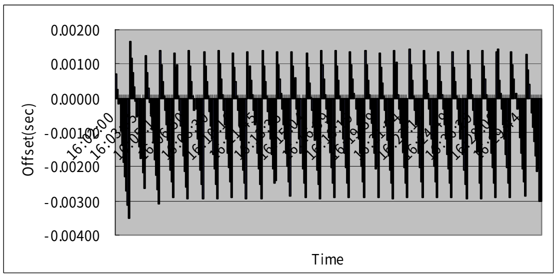

Figure 6. offset of client

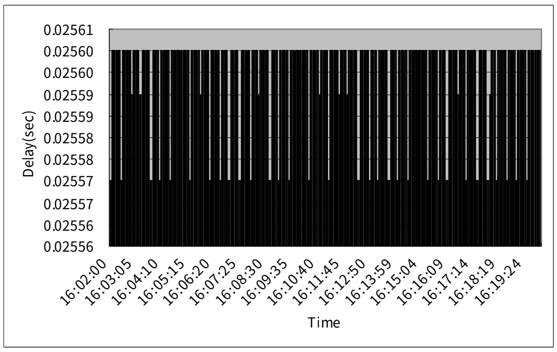

Figure 7. delay of client

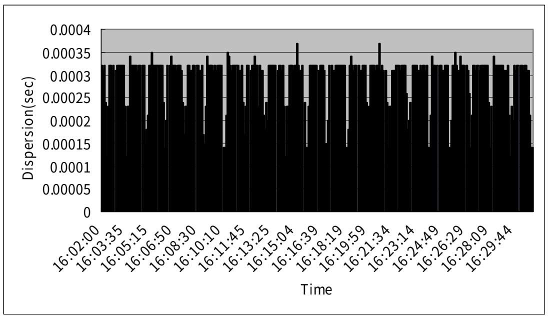

Figure 8. dispersion of client

5. Conclusions

We performed the analysis of time errors arising in the generation and processing of NTP timestamps and the calculation of delays and offsets.

The analysis of the dispersions by the experiment shows that the errors of delays and offsets contribute to the time errors of the fully digitalized SOE system.

Finally, we have concluded that the time accuracy of SOE system can be improved through the stability of delays and offsets.

REFERENCES

[1] Mills, D.L. Network Time Protocol (version 3) specification, implementation and analysis. Network Working Group Report RFC-1305, University of Delaware, March 1992.