Proceedings of ISAP2012, Nagoya, Japan

4D3-5

First Challenge of PTP Time Synchronization Experiment through the Experimental Satellite for Communication, "WINDS"

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1. Introduction

We performed and succeeded in the time synchronization through the experimental satellite for communication, WINDS using PTP [1]. PTP is the protocol for time synchronization which is also called IEEE 1588. It is said that PTP is more accurate than NTP which is popular for us as the time synchronization protocol because of their synchronization algorithm. WINDS is the communication satellite launched by JAXA, JAPAN, 2008. The Japanese WINDS satellite shows the top level bandwidth of Giga bit level. The satellite links are very effective to transfer very heavy contents of the distant e-Medicine and e-Education. We have been supported the construction of Japanese JICA ICT Centre in the University of the South Pacific (USP). The servers connected wirelessly for Medical ICT like e-Medicine must be synchronized within 1 second because the exchange and storage the data is needed to be included accurate time-stamp. Hence, PTP will be of help in such situation.

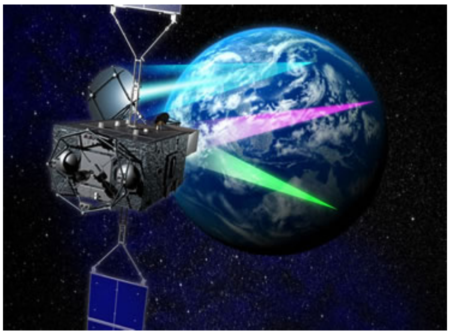

Figure 1: WINDS satellite

2. PTP

PTP is the time synchronization protocol for personal computers binded by hubs or switches and which is defined as IEEE 1588. This protocol is more accurate than NTP, which is most popular for us as the time sycronization protocol. The accuracy of PTP is a few hundreds of nano second or more though that of NTP is a few milli seconds or more. Computers binded by PTP is given roles, one Grandmaster and some Masters and Slaves. Slaves are synchronized with Master exchanging messages like Figure 2 [2]. The left and arrival time of these messages are used for calculating offset and tick rate and the calculation of that is below.

$$\text{Master to Slave difference} = t_2 - t_1 \quad (1)$$

$$\text{Slave to Master difference} = t_4 - t_3 \quad (2)$$

$$\text{One way delay} = \frac{(t_2 - t_1) + (t_4 - t_3)}{2} \quad (3)$$

$$\text{Offset} = \frac{(t_2 - t_1) - (t_4 - t_3)}{2} \quad (4)$$

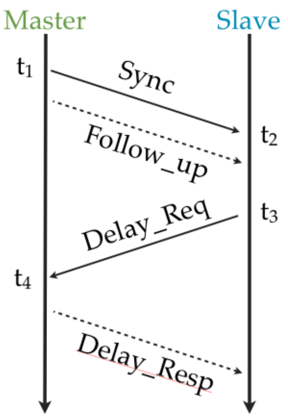

Figure 2: Message Exchange

This calculate is followed as the servo diagram like Figure 3 [3].

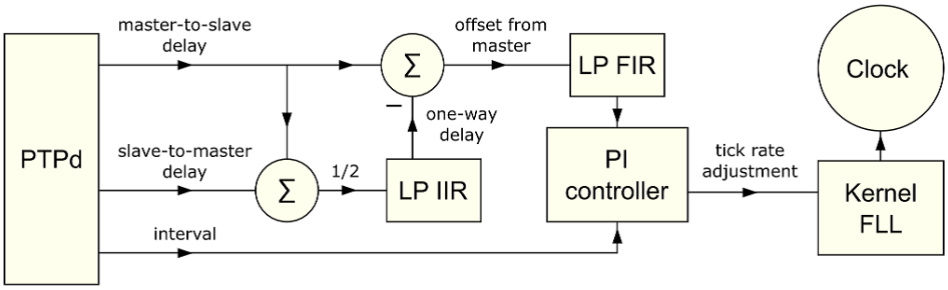

Figure 3: Clock Servo Diagram [3]

3. Experience Environment

Two computers are connected with WINDS, one of that is at YRP (Yokosuka Reseach Park at Yokosuka, Kanagawa, Japan) and another is at KSTC (Kashima Space Technology Center at Kashima, Ibaraki, Japan) like Figure 4 (quoted by JAXA). The round trip time is about 600 ms and the throughput of WINDS is 10 Mbps, best effort. Note that WINDS use TDMA and the round trip time includes the time of dealing the signal, hence, the communication environment is asymmetry. PTP was working in both computers at the experience. It is important that ordinary situation of time synchronization experience's propagation delay of computers is under 1 ms. So, in the situation one-way delay often change, the calculated offset is different from authentic one in the time synchronization protocol. Working PTP in that computers, we measured the offset of them.

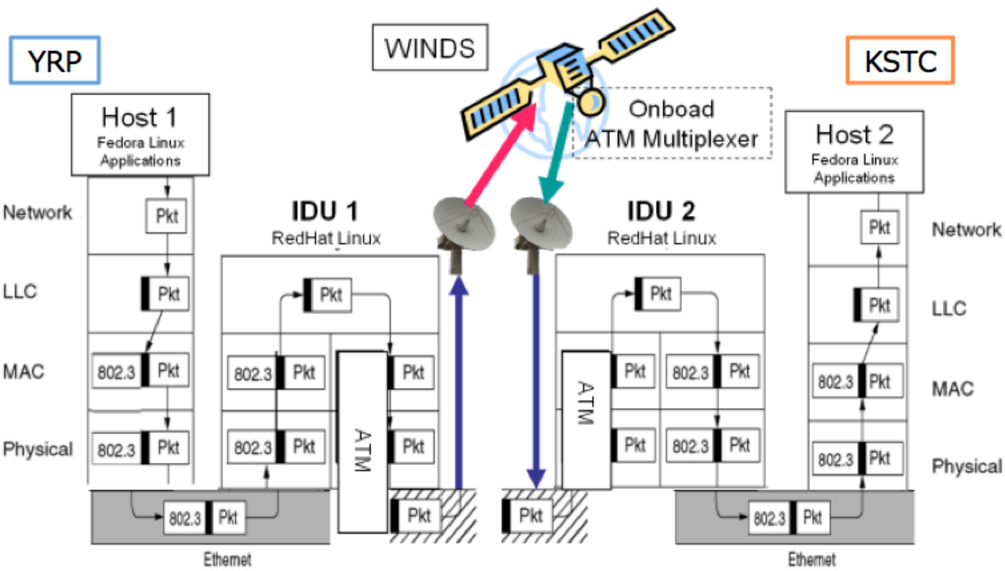

Figure 4: WINDS, YRP, and KSTC (quoted by JAXA)

4. Experimental Result

The result of this experience measuring the offset of two computers for close to two hours, one of that is at YRP and another is at KSTC, which is connected through WINDS and working PTP in them is

Figure 5. Below is the result from this data calculated by LSM.

$$y = 3.6009 \times 10^{-5} t + 8.2353 \times 10^{-3} \pm 1.1996 \times 10^{-2} \text{ [sec]} \quad (5)$$

where y [sec] is the offset of two computers and t [min] is the lapsed time of the experience. And the accuracy of this is 6.0015×10^{-7} [sec/sec]. It shows that estimated offset of the result is 1 ms or more. In general, PTP presents under 1 ms offset. For example, in the situation Figure 6 is the result of our indoor PTP time synchronization experiment measuring for close to sixteen hours. The estimated equation of the measured wave in this figure by LSM is below and the accuracy of this wave is 4.9085×10^{-11} [sec/sec]. We presented such result to the conferences [4] [5].

$$y = 2.9451 \times 10^{-9} t - 4.5015 \times 10^{-5} \pm 5.3692 \times 10^{-5} \text{ [sec]} \quad (6)$$

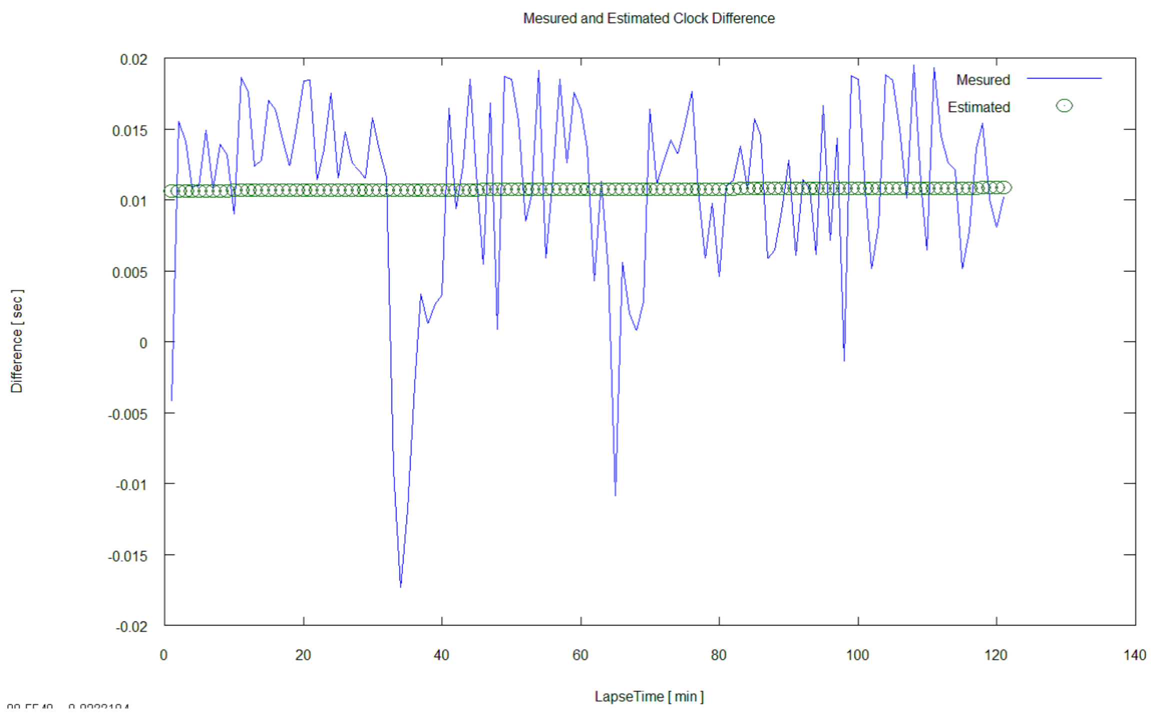

Figure 5: Clock Difference between Master and Slave through WINDS

5. Discussion

The reason the offset of the experiment is worse than that of indoor experiment is result from the difference of the up and down throughput. And below is the explanation of that according to equation(4).

$$\begin{aligned} D' &= D + \Delta\tau && (7) \\ t_2 - t_1 &= D + O && (8) \\ t_4 - t_3 &= D + \Delta\tau - O && (9) \\ \therefore O_m &= \frac{(t_2 - t_1) - (t_4 - t_3)}{2} && (10) \\ &= O - \frac{\Delta\tau}{2} && (11) \end{aligned}$$

where D is the one way delay from YRP to KSRP, D' is the one way delay from KSRP to YRP, $\Delta\tau$ is the difference of D and D' , O is the real offset of the two computers, O_m is the measured offset of the two computers, and t_1, t_2, t_3, t_4 are according to Figure 2. In the end $-\frac{\Delta\tau}{2}$ results in the error of the offset.

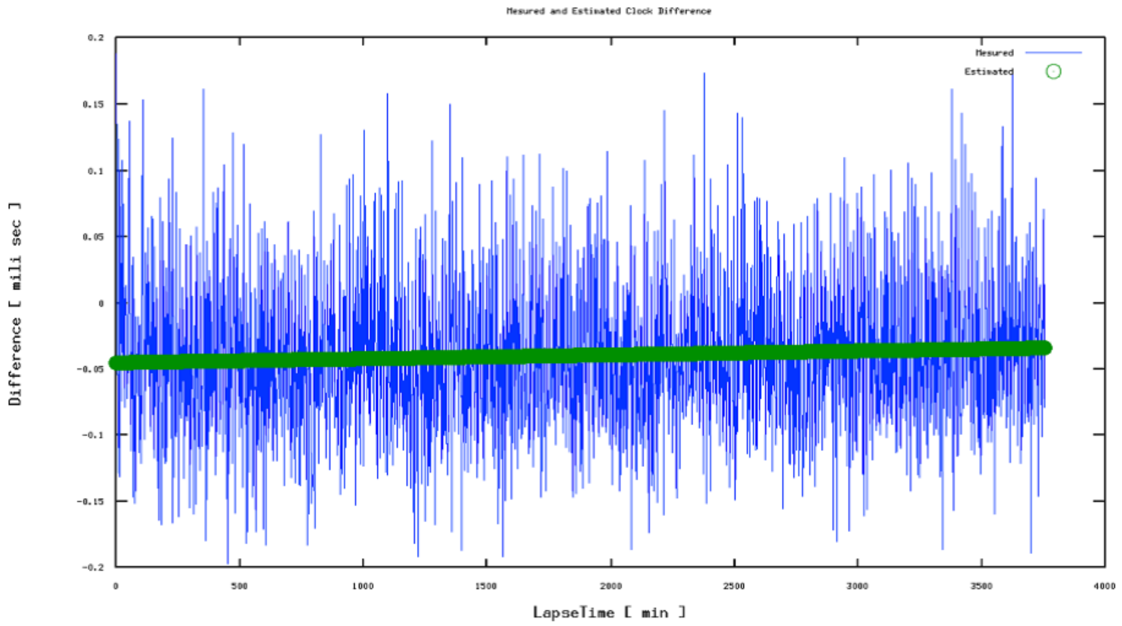

Figure 6: Clock Difference between Master and Slave in the Lab.

6. Conclusion

We successflly performed the PTP time trasfer experiment through WINDS Satellite. The precision and offset of measured results on our WINDS experiment are 6.0015×10^{-7} [sec/sec] and 8.2353×10^{-3}[sec], respectively. In the event we found that in the situation one way delay change as time lapse such as satellite communication the offset result from PTP time synchronization is larger than that in the situation two computers connected with wired line. In the future satellite communication will be more popular than now the time synchronization protocol correcting the pseudo offset will be needed for the application needed accurate time synchronization.

References

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