An Experiment Study for Time Synchronization Utilizing USRP and GNU Radio

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Abstract

Time synchronization is purposed to make the different time realizations of many objects as same as possible. As an initial study on time synchronization, this paper proposes a wireless time synchronization method utilizing SDR (Software Defined Radio). For the purpose, reference pulses are generated and transmitted by a reference USRP (Universal Software Radio Peripheral) based on GNU Radio. The other USRPs are synchronized to the reference pulses for time synchronization. To evaluate the accuracy of the proposed method, sampled data and synchronization error of each slave USRP are compared.

1. Introduction

Time synchronization is a process of aligning to the same time reference between two or more time regions having different time references. Recently, the importance of time synchronization has been increased more than before. Time synchronization has been utilized in various Internet based network services such as finance, communication, medical, weather, and so on (Lee et al, 2013). Previous researches on time synchronization can be categorized into two methods: wired and wireless.

As a typical wired time synchronization method, NTP(Network Time Protocol) has been become the standard for synchronizing time under the Internet environment (Mills, 1992). But NTP is not adequate for precise time synchronization, because its accuracy is only about sub-milliseconds. IEEE 1588 is another standard that provides precise time synchronization with better than one microsecond accuracy. However, IEEE 1588 requires a sensitive hardware approach to provide high-precision synchronization (Guilford, 2005).

For wireless sensor network, several important time synchronization methods have been proposed such as RBS (Reference Broadcast Synchronization) (Elson et al, 2005), TPSN (Timing Sync Protocol for Sensor Network) (Ganeriwal et al, 2003), FTSP (Flooding Time Synchronization Protocol) (Maroti et al, 2004). However, time synchronization methods in wireless environment are performed on sensor nodes having limited energy, performance, and memory. Since these sensor nodes are usually based on low-cost XOs (Crystal Oscillators) with the accuracy from 20 ppm (part per million) to 50 ppm, precise time synchronization is difficult.

Today, time synchronization of considerably many devices is performed by GNSS (Global Navigation Satellite System). Navigation satellites are located about 20,000 km above the earth surface. Satellites are equipped with the atomic clocks employing cesium or rubidium oscillators with the accuracy from 0.0001 ppb (part per billion) to 0.001 ppb. As compared, GNSS receivers are usually equipped with the low-cost clocks employing XOs. For that reason, it is difficult for a GNSS receiver to keep precise time reference depending only on a low-cost XO.

A GNSS receiver acquires and tracks navigation signals from GNSS satellites. After decoding navigation messages and sampling code phase measurements, the receiver can estimate its position and clock error accurately. Then, the clock error of the receiver can be compensated so that the coarse time of the receiver can be aligned to the highly precise GNSS time reference. For that reason, GNSS is very critical part of present high-precision time synchronization systems with low-cost oscillators (Petrov et al, 2016). If GNSS signals cannot be tracked due to harsh environment such as jamming, multipath and signal blockage, the convenient time synchronization method cannot be used. In these cases, a different type of time synchronization method should be established.

As an initial study for non-GNSS wireless time synchronization, this paper proposes a simple synchronization method based on SDR (Software Defined

Radio). In the proposed method, PPS signal is generated and transmitted by a reference USRP (Universal Software Radio Peripheral) with GNU Radio as the reference clock source. The internal clocks of the other slave USRPs are synchronized to the received PPS signal. To evaluate the accuracy of time synchronization, sampled data and synchronized time of each USRP are compared by an experiment.

2. USRP and GNU Radio implementation

USRP is a transceiver for wired or wireless communication. Directly connected to the PC, a USRP is flexible to use in terms of operating frequency by changing a daughterboard mounted on it. As a receiver, a USRP can do the role of an ADC (Analog to Digital Converter) that converts the analog RF signal to the digital baseband signal. Also, as a transmitter, a USRP can do the role of a DAC (Digital to Analog Converter) (Dien et al, 2014).

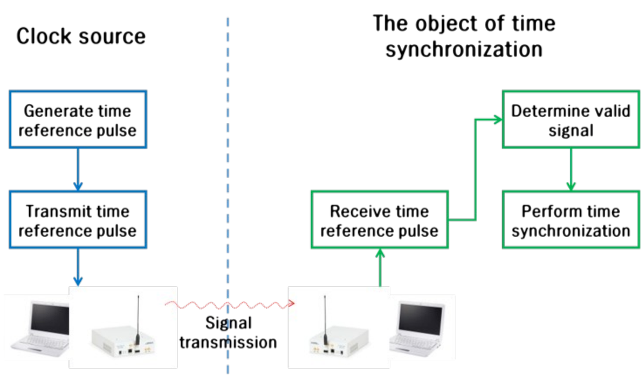

Figure 1: The overall time synchronization process

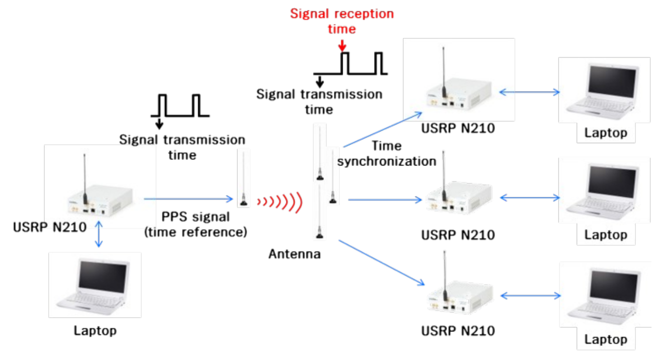

Figure 4: Experiment configuration

GNU Radio is based on the open source that provides a GUI (Graphic User Interface) type of GRC (GNU Radio Companion). It can be used as the SDR development toolkit for various wireless communication system. GRC provides many block-type signal processing modules. User can add or modify the C++ and python related to each module flexibly (Park, 2010).

To synchronize the time between the reference USRP and the other slave USRPs, the clock source of the reference USRP generates PPS (Pulse Per Second) signal. Each slave USRP receives the PPS signal and checks the maximum amplitude and the rising edge to determine exact timing. Time synchronization process is illustrated in Figure 1.

As shown in figure 1, the reference USRP generates the PPS signal and multiplies it with carrier frequency. After that, the carrier modulated PPS signal is transmitted by the antenna. The slave USRP receives the modulated PPS signal and down-converts it to the baseband. By comparing the amplitude of the received signal and the predetermined

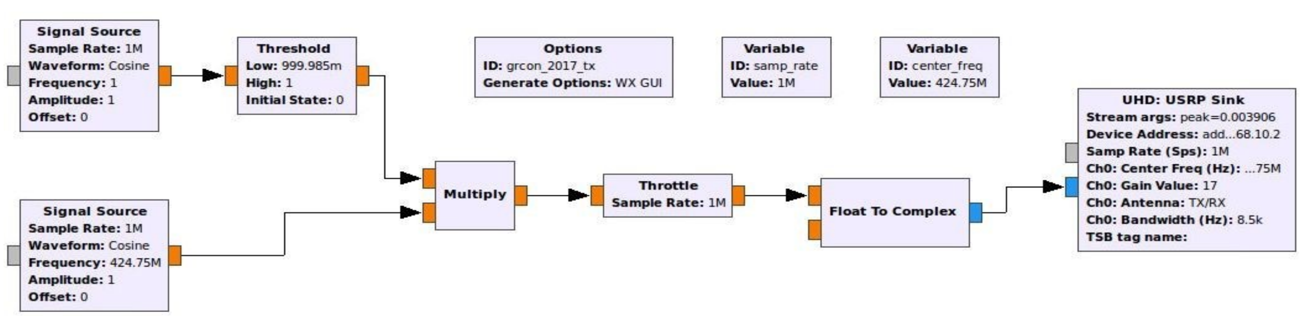

Figure 2: GNU Radio companion block diagram of reference USRP

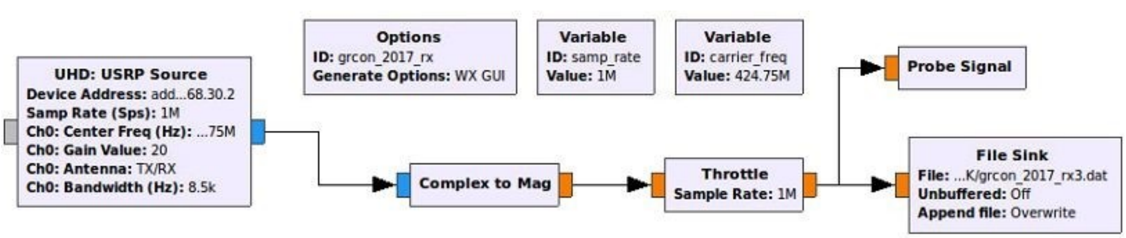

Figure 3: GNU Radio companion block diagram of slave USRP

threshold, the validity of the received signal is checked and the reference time is extracted.

The block diagram of the reference and slave USRPs constructed by GNU Radio companion are illustrated in Figure 2 and Figure 3, respectively. Experiment configuration is illustrated in Figure 4.

3. Experiment

An experiment was performed to evaluate the accuracy of time synchronization between USRPs. For this purpose, N210 model of Ettus Research was utilized as a reference USRP. Since N210 uses a SBX daughterboard, carrier frequency should be used in the 400~4400 MHz frequency band. Therefore, an ISM(Industry-Science-Medical) frequency band antenna was used to transmit signals. Each USRP is connected to a laptop computer for control and manipulation.

For experiment, the carrier signal of 424.75 MHz frequency was used to modulate PPS signal. Sampling rate of 1 Msps(Mega Sample Per Second) was used for analog to digital or digital to analog conversion. The experiment was performed on May 5, 2017 from 1:28 to 1:37 for 10 minutes (600 epochs).

For experiment, four USRPs were installed where one USRP was used as the reference unit and the other three USRPs were used as the slave unit. Each set consists of USRP N210, laptop computer and 424 MHz UHF antenna. Distance between the reference USRP and each slave USRP was approximately 5 meters.

Figure 5 and Figure 6 show the configurations of the reference USRP and slave USRPs, respectively.

As the experiment result, time synchronization error of each USRP is illustrated in Figure 7. Table 1 summarizes the mean value of time synchronization error and its RMSE (Root Mean Square Error) of each USRP. In table 1, it can be seen that time synchronization error ranges from tens to hundreds of microseconds. Thus, it can be understood that wireless time synchronization is possible by USRPs but a lot more works need to be done in the future.

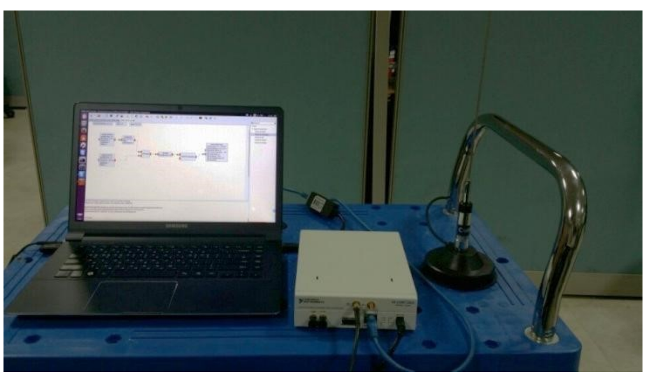

Figure 5: Configuration of reference USRP

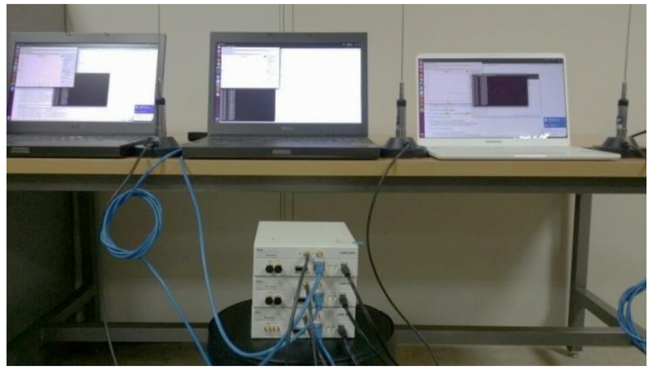

Figure 6: Configuration of slave USRPs

Table 1: Comparison of synchronized time error

Unit : μ sec

	USRP Rx1	USRP Rx2	USRP Rx3
Mean	94.99	84.08	204.9
RMSE	67.95	65.97	126.8

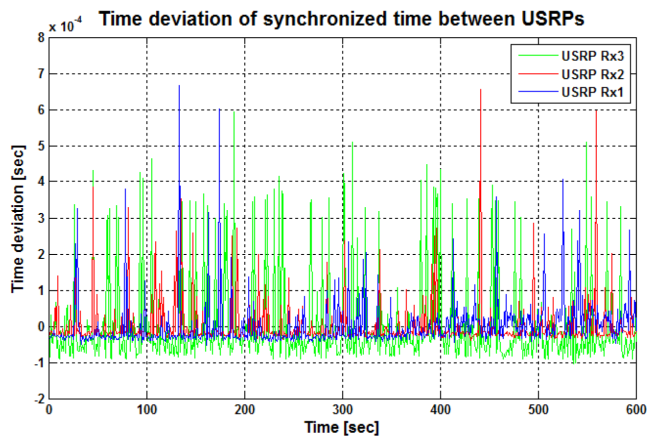

Figure 7: Time deviation of synchronized time on USRP

During the experiment, it was found that different synchronization accuracies occurred between different USRPs operating at the same sampling rate. This result seems to be caused by performances of laptop computers connected to each USRPs. Therefore, improving the performance of the host computer might improve the accuracy of time synchronization. It would be possible by increasing the sampling rate of USRPs since their time resolution can be improved through the reduced interval between samples.

4. Conclusion

In this paper, we proposed a simple wireless time synchronization method. In the absence of a precise atomic clock source, reference pulses are generated and transmitted by a reference USRP based on GNU Radio.

The other slave USRPs are synchronized to the reference pulses for time synchronization. By an experiment, the accuracy of the proposed method was evaluated. It was shown that the proposed method can be used for wireless synchronization with the accuracy ranges from tens to hundreds of microseconds. Thus, it can be understood that wireless time synchronization is possible by the proposed method but a lot more works need to be done in the future. In the near future, the effects of improving the performance of host computers are increasing sampling rate of USRPs are planned to be studied.

Acknowledgements

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