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Implementation of Embedded Testbeds Using USRP and GNU-Radio for Performance Measurement and Analysis of PPS and PCO-Based Time Synchronizations

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ABSTRACT

In wireless networks, time synchronization is one of the key functions for the MAC and the physical layer because it is important to accurately transmit data by maintaining the order and consistency of transmission between nodes. The time synchronization can be divided into centralized and distributed methods and there are many synchronization schemes. However, there are little testbeds for comparing and analyzing various time synchronization schemes in a real environment. Most papers analyze the proposed time synchronization algorithm by simulation, and some testbeds are also configured for the proposed scheme only. In this paper, the authors build embedded testbeds using USRP and GNU-Radio. The two typical methods of the centralized and decentralized time synchronizations, PPS, and PCO-based schemes, respectively, are implemented on the testbeds and their performances are measured and analyzed in the real environment.

KEYWORDS

Embedded Testbed, Firefly, GNU-Radio, Pulse Coupled Oscillator, Pulse per Second, Signal Processing, Software-Defined Radio, Time Synchronization, USRP

INTRODUCTION

In a typical computer, time is determined by the frequency of the oscillator that generates the event periodically. The oscillators differ in the accuracy from board to board due to the surrounding environment and various variables. Therefore, time synchronization is used to maintain the order

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and consistency of transmission between nodes by eliminating time differences between two or more boards.

In wireless networks, time synchronization is one of the key functions for the MAC (Medium Access Control) and Physical layer because the difference in time between nodes causes a degradation of the network performance due to an incorrect operation of the MAC protocol.

The time synchronization can be divided into centralized and distributed methods and there are many synchronization schemes. However, there are little testbeds for comparing and analyzing various synchronization schemes in a real environment. Most papers analyze the proposed time synchronization algorithm by simulation, and some testbeds are also configured for the proposed scheme only.

In (Chang, Y. J., Ingram, M. A., & Frazier, R. S. 2010) authors proposed time synchronization for cooperative transmission. The testbed is composed of USRP and GNU-radio. However, the testbed is for the clustered environment and it is hard to experiment the other schemes. In (Aloi, G., Loscrì, V., Borgia, A., Natalizio, E., Costanzo, S., Pace, P., Massa, G. D., & Spadafora, F. 2011) authors use Simulink and USRP to implement testbed. However, because the testbed is for radar system, it has low scalability to experiment the time synchronization for the radio system. In (Crossley, P. A., Guo, H., & Ma, Z.) authors proposed time synchronization using GPS and IEEE 1588 and build testbed to experiment the proposed scheme. The testbed is based on GPS antenna.

In this paper, we build embedded testbeds using two hardware and software SDR (Software Defined Radio) platforms, USRP (Universal Software Radio Peripheral) and GNU-radio, respectively. Also, as representative central and distributed time synchronization, PPS (Pulse Per Second) and PCO (Pulse Coupled Oscillator) based time synchronization, respectively, are implemented on the testbeds. The experimental results show the performances of the PPS and PCO based time synchronizations and they are compared.

RELATED WORKS

PPS-based Centralized Time Synchronization

PPS (Pulse Per Second)-based time synchronization is a scheme in which one or more reference nodes generates a pulse to all the nodes with every predetermined period. The receiving nodes detect the valid signal and perform time synchronization.

Figure 1 shows an example of PPS-based time synchronization. Let $S_{threshold}$ be the threshold of the reference signal which the receiving nodes recognize the signal and the T_p be the predetermined period of the reference signal. The reference node generates a reference signal its power exceeding $S_{threshold}$ with every T_p, which is the predetermined period of the reference signal. Then the other three receiving nodes detect the valid signal using $S_{threshold}$ and perform time synchronization at the detection point.

PCO-Based Distributed Time Synchronization

PCO (Pulse Coupled Oscillator)-based time synchronization is a scheme in which process is based on the mathematical model of synchronization via firefly.

Mirollo-Strogatz firefly model is a self-synchronization of distributed nodes with certain rules. Figure 2 represents the interaction between two PCOs which follows the synchronization model. Let T_f be the time period of oscillators. The oscillator of node i has the phase variable $\Phi_i(t)$, which is increased as follows.

$$\frac{d\Phi_i(t)}{dt} = \frac{1}{T_f} \tag{1}$$