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Sensor Networks 700.460

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Continuously Coupled Clocks

1. Introduction

The process of synchronization describes achieving and maintaining coordination among independent local clocks throughout communication between clocks. There are different types of synchronization used for different applications based on different design measures. Those different synchronization schemes can satisfy different needs such as energy efficiency, scalability and application specificity. Continuously-coupled clocks is one type of synchronization which will be discussed in this short summary. The motivation for this study is related to applications such as, cooperative beamforming. [1]

2. Coupled Clocks

Coupled clocks was the first model created in the field of distributed synchronization. A clock is then a time measurement device consisting of an oscillator and an accumulator. [1] The goal of coupled clocks is to drive the second clock to synchronicity with the first one.

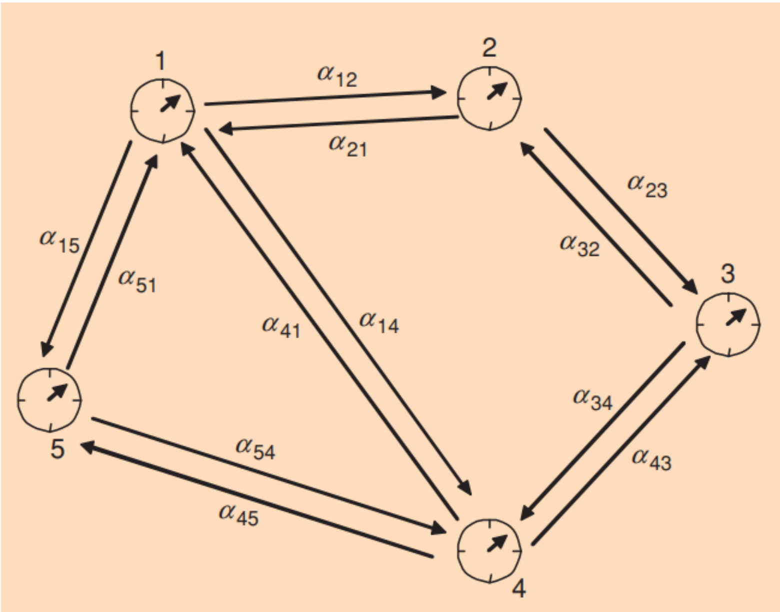

Figure 1: Connectivity Graph.

3. Connectivity Graph

The connectivity graph studies the communication circumstances between different nodes. Figure [1] shows an example of the connectivity graph. We have a system of five different nodes with paths showing the communication lines between each clock and its neighbors. Node 1 for example can receive and send messages to three different nodes (nodes 2, 4 and 5). Each path is given a value of alpha that represents the relative strength of each path for sending and receiving signals in reference with the summation of power signal for all paths combined.

$$\propto ij = \frac{Pij}{P\ total}$$

4. Continuously coupled clocks

Each clock is represented as a node to make it easier to explain and understand. The basic assumption states that each node in a system is capable of transmitting and receiving signals at the same time. Every node transmits a signal proportional to its local oscillator and updates the instantaneous phase based on the signal received from other nodes. This process is referred to as the phase locking mechanism. And the achievement of perfect synchronization between clocks is mainly dependent on the communication environment between them.

$$\Delta\, \emptyset i(t) = \sum \propto ij\ .\ f(\ \emptyset j(t) - \ \emptyset i(t))$$

Where $\emptyset j(t) - \ \emptyset i(t))$ is the phase difference between two nodes, which is then fed to a loop of filters, and to then to the voltage controlled oscillator. Figure [2] illustrates this process in a block diagram consisted of three nodes showing the interior of each node.

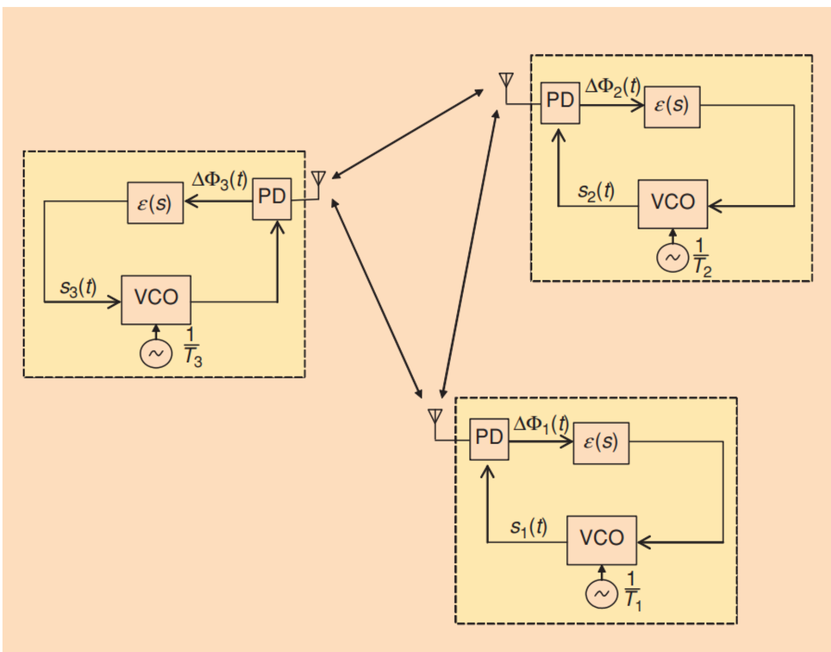

Figure 2: Block diagram of a 3-nodes continuously coupled clock.

5. Kuramotos Model

Kuramoto was the first to propose a mathematical model to explain the synchronization phenomena. It is a standard model that studies the dynamics of oscillators and observes the behaviors. [3] The model basic theory is to find the equilibrium phase or steady state of the system which is the key to find the balance for creating synchronization between clocks. It has been proved that there exists a gain loop value that expresses that stability point. [1] If the system's gain loop is higher than the stability value, the clocks will experience partial synchronization state, which means part of the oscillators won't be in synchronicity. On the contrary, if the system's gain loop is measured lower than the critical value, the clocks will be in an incoherent state.

Bibliography

[1] U. S. Y. B.-N. a. S. H. S. Osvaldo Simeone, "Distributed Synchornization in Wireless Networks," *Signal Processing Magazine,* p. 81, 2008.