Development of Time Synchronized Wireless Sensor Network

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Network based wireless sensing has become an important area of research and various new applications for remote sensing are expected to emerge. When a sensor network is used for vibration measurement and modal analysis, all the data measured at different wireless sensor nodes need to be aligned with a common clock. The difference of the clock among nodes can be misunderstood as a phase shift of vibration, which seriously affects the modal analysis of the building vibration.

In this paper, we introduce a newly developed time synchronized wireless sensor network system. The system employs IEEE 802.11 standard based TSF counter and sends the measured data with the counter value. It enables consistency on common clock among different wireless nodes.

In order to evaluate the scalability effect on accuracy of the time synchronization, simulation studies were conducted. IEEE 802.11 standards based TSF partially depends on a stochastic manner. It may happen that the node whose clock is fastest cannot be given the chance to propagate one’s clock. This could increasingly occur as the size of IBSS (Independent Basic Service Set) becomes larger, and it affects the precision of clock synchronization of multi-node. Therefore, we examined the stochastic effect on synchronization precision by using the Monte Carlo simulation method.

We ran a simulation that corresponds to 90 minutes elapse of time and made 100 times of simulation trials by randomly selecting clock speed of attending nodes. Fig. 1 shows the simulation result when 20 nodes are arranged in daisy chain configuration so that radio waves can reach only two adjacent nodes (right and left nodes). The median value in 20-node case is 410 $\mu$sec and 99.9% of the data maintain less 267 $\mu$sec in 20-node.

We also made experiments in a three-story reinforced concrete building. For the experiments, newly developed wireless nodes as shown in Fig. 2 was used. The nodes were arranged to communicate two-hop transmission, i.e. the end-to-end communication packets are relayed via the middle node. For the wireless transmission, we used 802.11 g standard based device. Wired signal lines, to which rectangular wave voltage was supplied to generate hardware interrupt, were connected to all nodes for the reference purpose. Every moment when the voltage of square wave stepped up, an interrupt occurred and TSF timer count was obtained and recorded in the interrupt handler routine.

After the measurement, the difference between the fastest TSF count and the slowest TSF count at each recorded set was calculated. Fig. 3 shows the experimental result. The most frequent value was around 25 $\mu$sec and it well matched that of the simulation result.

From the results of simulations and experiments, it is concluded that the developed system can be sufficiently applicable for vibration measurement.

![Fig. 1. Maximum clock offset in 20 nodes](image1)

![Fig. 2. Wireless node with external antenna](image2)

![Fig. 3. Maximum clock offset with three wireless nodes](image3)