Time Synchronization in Short Range Wireless Networks

Filip Gummesson
Kristoffer Hilmersson
{*dat11fgu, dat11khi*}*@student.lu.se*

Highly energy efficient wireless devices has been the trend over the last years. Such devices have made the Internet of Things possible. We have investigated current standards concerning time synchronization and examined the properties that enable efficient time synchronization. With that base, we implemented an algorithm that makes a short range wireless network, consisting of IoT devices, have the same perception of time.

Sensors, like an accelerometer or a thermometer, is used to sense the surrounding environment and report its measured data to some kind of central device, that process the measurements. Say we want to control the indoor climate in a skyscraper. We could guess the temperature and humidity at the beginning of our control sequence, but it would make the system vulnerable to sudden changes, like the sun blazing down on the window. Instead, we deploy sensors in each room and wire them up to our control unit. Now, the system's control unit gets feedback on every move it makes. If the temperature in a room is higher than desired, cooler air gets pumped into the room.

The negative aspect of installing all these sensors would be the cost of wiring. It would probably be more expensive than the sensors themselves. But what if they were communicating wirelessly using Bluetooth low energy?

The answer is not as simple as one would think. The wiring cost would of course disappear, yet another problem arises; each sensors clock need to tell the exact same time as every other sensor's clock. The reason is that the control unit no longer commands a sensor to measure its environment, instead, the sensor decides when to send measurement data to the control unit. The control unit thus has to order these message based on occurrence. To order data from a sensor, its messages have to contain both the timestamp of when it measured its surroundings and the actual sensor data. That is the reason we need to synchronize the sensor clocks.

The Network Time Protocol (NTP) has kept computers in networks in sync within a few milliseconds since the mid-80's. Laptops or desktop computers do not have the same power constraints as a sensor device - a sensor may have to run for years on a single button cell battery. Meaning that a power consuming time synchronization standard, like NTP, has to be replaced with another more power efficient standard or de facto standard.

Reference Broadcast Synchronization (RBS) is a de facto standard with a higher focus on energy efficiency, specifically developed for wireless sensor networks. To explain RBS, you could think of a village where all the residents own a wristwatch and know that the church bell strikes every hour. To make daily life in the village run as smoothly as possible, the villagers has to have the same perception of time.

When the church bell strikes, each villager looks at their wristwatch and notes the time. By using the periodic church bell, the villagers can use the time as a point of reference for comparing their clocks, i.e., translate its own time to another villagers time. The same technique is used in sensor networks. A sensor on each floor has the role as the church, while the other sensors can be seen as villagers.

We propose a minor change to RBS, by introducing a control unit which possesses a translation table to each sensor. Once a sensor measurement is received by the controlling unit, the time in the message is translated to the control units local time.

The results of this project are summarized in the table below:

Table 1: *Number of Sensors in a Network*

Sensors	Mean accuracy	Std. deviation	Max error
2	2.09 ms	1.74 ms	10 ms
3	3.99 ms	2.10 ms	16 ms
4	6.47 ms	2.45 ms	18 ms

The table was generated by running each experiment for three hours. It shows that there is room for improvements, but it still states that it is possible to synchronize a set of nodes using energy efficient devices communicating over Bluetooth low energy. The accuracy of the implementation decreases as more sensors are added to the network.

This report is based on a Master Thesis project by the authors of this article. For further reading, see:

Gummesson,.F and Hilmersson, K. (2016) Time Synchronization in Short Range Wireless Networks.