Demo: Tracking Vehicles in a Container Terminal

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Abstract

Vehicle tracking system is built for a container terminal. In the system, reference nodes are fixed at known locations. They provide reference locations to a mobile node, which is installed in a vehicle. Received Signal Strength Indicator (RSSI) is measured, and the measured data is gathered in a backend server. The backend server analyzes the data, and estimates the location of the mobile node. Filters are added to handle transient fluctuation in RF environment. SonnoOne mote is made to be used as a mobile node. It contains MG2455 chip from RadioPulse, which combines 8051 MCU and IEEE 802.15.4 radio. We expect the cost will be below $20, and the low cost will enable a large number of mobile nodes to be deployed in a container terminal.

Categories and Subject Descriptors

C.3 [**Special-Purpose and Application-Based Systems**]: Real-Time and Embedded Systems

General Terms

Experimentation, Algorithms

Keywords

Wireless Sensor Networks, Localization

1 Introduction

In a container terminal, there is a need to track the location of trucks. The location information about trucks is helpful in figuring out the overall status of the terminal. Moreover, when a truck moves into a wrong place, the driver can be alerted immediately. Containers are piled as a contiguous block as in Figure 1, and the block is long and narrow. There are many challenges. Up to six containers can be stacked up vertically, forming a huge RF signal barrier. Many trucks and cranes move constantly, and they act as an obstacle. The cost of the system is also a concern. The cost of the mobile node is critical, since a large number of mobile nodes need be deployed. To reduce the cost of the mobile node, a low-cost mote, SonnoOne, is made. This work proposes a tracking system of vehicles, using Wireless Sensor Networks (WSN). The system is tested in Sun-Kwang Incheon Container Terminal. Architecture of the system will be introduced in the next section, and localization algorithm will follow. In the last section, the result will be discussed and the demo scenario will be explained.

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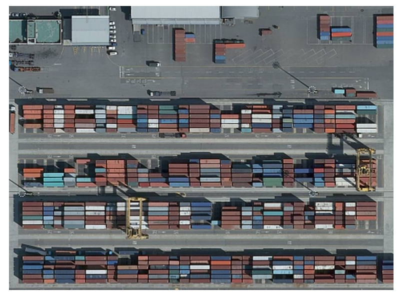

Figure 1. View of a container terminal

2 Architecture

There are three major components in the system: fixed reference node, mobile node, and backend server. Reference nodes are installed at known locations. These fixed nodes work as the location identifier of moving vehicles. Moving vehicles carry mobile nodes. To track vehicles, RSSI is measured, and this information is forwarded to the backend server. The backend server analyzes the signal strength data, and estimates locations of vehicles.

Figure 2 shows the fixed reference node. Wired power will be provided in a real deployment, but during the test deployment, 12V battery is used. The height of the structure is about 3ft. Reflector sheet wraps the pillar for safety. At the top of the structure, there is a small enclosure. Inside the enclosure, there is a Kmote, which is the clone of TelosB [1]. It processes computation and communication, and is implemented using TinyOS.

The mobile node is powered by 24V power outlet of a vehicle. Inside an enclosure, either Kmote or SonnoOne can be used. We made SonnoOne mote which can replace Kmote. SonnoOne mote uses MG2455 [2] chip from RadioPulse. MG2455 is a system-on-a-chip (SOC), and integrates Intel 8051 architecture MCU and IEEE 802.15.4 standard radio. Figure 3 shows SonnoOne mote, and Table 1 shows its specification. Its performance is quite comparable to that of Kmote or TelosB, and TinyOS also runs on it. We designed the connector and the pin layout to match those of Kmote. Therefore, even in other applications, Son-

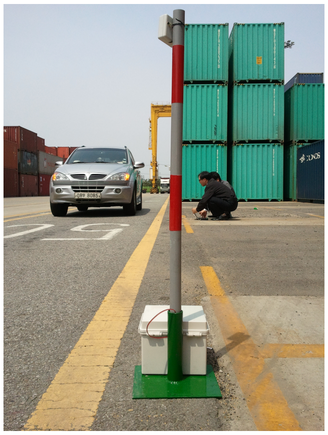

Figure 2. Fixed reference node deployed in Sun-Kwang Incheon Container Terminal

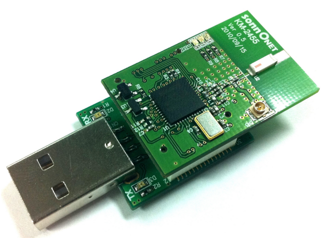

Figure 3. SonnoOne mote contains a RadioPulse MG2455, which combines 8051 MCU and IEEE 802.15.4 radio

noOne can replace Kmote. We expect the cost of SonnoOne can go down to $20. Due to the low cost, a large number of mobile nodes can be deployed in a container terminal. SonnoOne will make the large-scale deployment of WSN more economically feasible.

All the packets and signal strength data are gathered in the backend server. In a real deployment, the backend server will be located in the control center, and data will be forwarded to the control center though LAN installed in a terminal. However, during the test deployment, a laptop is located at the test site. C# is used to implement the backend server.

3 Localization Algorithm

The localization algorithm is based on RSSI. A fixed reference node forms a zone around it. The backend server estimates which zone each mobile node belongs to.

3.1 Overall Algorithm

The basic algorithm is quite simple. A mobile node periodically broadcasts a beacon message. When a fixed reference node receives the beacon message, it includes RSSI in the message, and forwards the message. For example, if three fixed reference nodes hear the beacon message, three packets will be delivered to the backend server. The mobile node belongs to a zone whose fixed reference node has the strongest RSSI. Since there is RF noise, and obstacles block RF signal, RSSI is not stable. We added data processing to the basic algorithm to handle the fluctuation. At the backend server, moving average is used. Sometimes link breaks and a fixed reference node with the strongest RF does not forward packets but continuously remains as the best candidate afterwards. Therefore, timeout is used to remove the outdated fixed reference node from the zone candidate of a mobile node.

Table 1. Specification of SonnoOne mote

System Clock	8MHz or 16MHz
RAM	8KB
Program Memory	96KB
Bandwidth	256Kbps or 512Kbps or 1Mbps

3.2 Filter

The long narrow road between container blocks is one-way, and the network topology is linear there. To take advantage of this terminal-specific condition, two additional filters are added. One filter prevents the abrupt backward movement of a mobile node. Due to noise and blocking, RSSI of the previous fixed reference node sometimes surge, and the mobile node looks like moving backward. This sudden backward movement is filtered. Sometimes vehicles actually do move backward. However, in this case they slowly change the velocity. So only when the degree of change is above the threshold, the backward movement is filtered. The other filter prevents a mobile node from skipping multiple fixed reference nodes. When trucks and cranes block RF signal to fixed reference nodes, RSSI to these nodes becomes weak. Then a mobile node does not belong to a zone of these nodes and suddenly attaches to a fixed reference node a few zones away. The filter forces the mobile node skip only up to a predefined number of zones, and the mobile node reaches the final zone via other zones in the middle.

4 Discussion and Demo Scenario

The system worked well in Sun-Kwang Incheon Container Terminal. Unstable RF environment is alleviated by filters. However, due to some damping effect of filters, there was a little bit of tracking delay between the estimated location and the actual location.

In the demo, the tracking system will be demonstrated. Fixed reference nodes will be installed on a desk. A mobile node will be moved around the desk, simulating the movement of a vehicle. A laptop on the desk will work as a backend server, and show the tracking result. The operation of filters will be explained using example scenarios. SonnoOne mote will also be shown working as a mobile node. Its specification and operation will be explained in detail.

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6 References

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