Poster Abstract: MODEL – Moving Object DEtection and Localization in Wireless Networks Based on Small-Scale Fading

Qingming Yao, Hui Gao, Bin Liu, and Fei-Yue Wang
Laboratory of Complex Systems and Intelligence Science
Institute of Automation, Chinese Academy of Sciences
{qingming.yao, hui.gao, bin.liu, feiyue.wang}@ia.ac.cn

ABSTRACT

This paper presents a new Moving Object Detection and Localization (MODEL) system, which is based on the small-scale fading of RF signal strength and independent from the salient characteristics of both the device and the sensor. We first validated the feasibility of applying small-scale fading effects to moving object detection and localization through experimental analysis. Then, we introduced MODEL: an embedded network system which adopts an easily-realized Rolling-Window algorithm. We applied the Region-Partition method to determine the position of the moving object, and concluded that the precision of the object position is dependant upon the density of participating nodes. MODEL is also scalable to other wireless network infrastructures and adaptable to various environments without the need for complex and time consuming training.

Categories and Subject Descriptors

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

General Terms

Experimentation, Measurement, Algorithms

Keywords

Received Signal Strength, Small-Scale Fading, Moving Object Detection, Localization

1. BACKGROUND AND MOTIVATION

Recent years have witnessed a wide range of research conducted on Received Signal Strength (RSS) based position systems. Almost all such systems like RADAR [1] *et.al* require a physical device being attached to the person or object to be positioned, which is impractical in many scenarios. More recently Youssef *et. al* [3] proposed the concept of device-free passive localization in which the tracked entity does not need to carry any physical devices. However, all mentioned systems neglect the fact that the movement of an object, even slight, would have an obvious impact on the RSS, namely, the Small-Scale Fading effect(SSF). We conclude through numerous experimental analyses that the SSF effect caused by the movement of objects is measurable and therefore can be applied to the detection and localization of moving objects.

*This work was support in part by the MOST Grant 2006CB705500, NNSFC Grants 60334020, 60621001, and CAS Grant 2F05N0.

SenSys'08, November 5–7, 2008, Raleigh, North Carolina, USA.
ACM 978-1-59593-990-6/08/11.

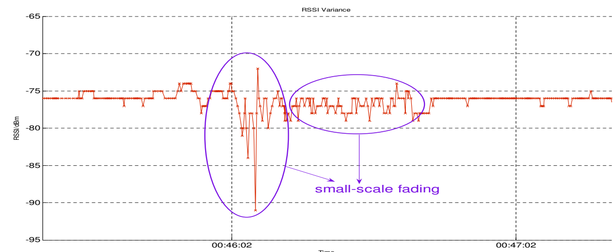

Figure 1: Small-Scale Fading Effects

2. MODEL

2.1 Mechanism

Electromagnetic wave propagation suffers from two types of signal strength fading, namely the large-scale fading and the small-scale fading. The large-scale fading is caused by a gradual loss of signal power due to transmitter-receiver separation distances while the small-scale fading refers to the rapid fluctuations of the amplitudes, phases, or multipath delays of a radio signal over a short period of time or travel distance. In small-scale fading, the RSS may vary by as much as three or four orders of magnitude (30 or 40 dB) when the receiver moves by a mere fractional order of a wavelength. Physical factors in the radio propagation channel which influence SSF include multipath propagation, speed of the mobile, speed of the surrounding area and the transmission bandwidth of the signal [2]. Therefore, moving objects in a wireless network, which will incur a surrounding area speed and multipath propagation, may have a distinct effect on the RSS of the signal transmitted in the network, as shown in Fig.1. Experimental results show that this effect mainly depends on the distance between the object and the wireless node. This characteristic could be utilized to implement moving objects detection and localization.

2.2 Testbed

Fig.2 shows our experimental testbed, which includes the 8th floor of our building and an open playground nearby. We used a ZigBee network which operates in 2.4 GHz band with a coordinator, several routers and end devices. Each node consists of a PIC microcontroller and RF chip cc2420. The RF chip cc2420 provides a dynamic RSSI range from -100 dBm to 0 dBm with an +/-6 dBm accuracy. The omnidirectional inverted-F PCB antenna is used to obtain a more stable performance.

In MODEL, the end devices sends broadcasts and extracts the RSS of received broadcasts, while routers relay messages

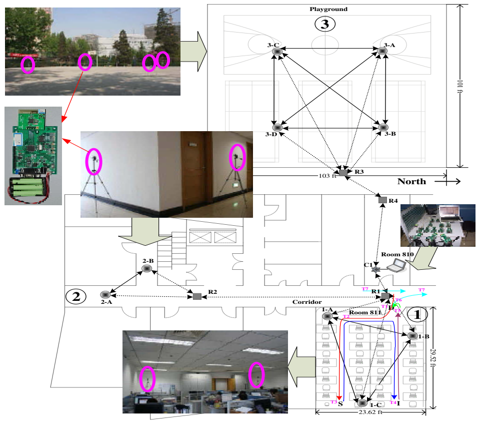

Figure 2: Testbed and Experiment Scenarios

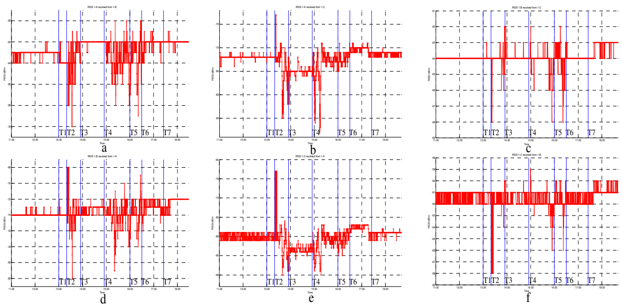

Figure 3: Measurement Results in Scene 1

between the coordinator and end devices. The coordinator exchanges network information with a PC through a serial port, and the PC then provides detection and position information.

3. PRELIMINARY EXPERIMENTS AND RESULTS

3.1 Experiments and Analysis

To reveal the relationship between moving objects and the subsequent SSF effects, we designed the following experiments under Situation 1: a person enters the room at time T_1, moves to position S at constant speed, then to position I after stopping for one minute, backs to the door, closes it and walks away, finally another person passes by the door and opens it at T_7 . The RSS received by each node is shown in Fig.3. The following conclusions can be drawn after data analysis:

- The RSS is either quite stable (Fig 3.c) or varies around a certain value in static environments (Fig 3.f).
- The closer to the node an object is, the more obvious the effect is (Fig 3.b, the variance range is about 10 dB).
- A "still" person near a node can affect the RSS significantly.
- A change of environment may affect the mean value of the RSS, but results in small fluctuation which is different from that of moving objects.
- The experiment results above have been verified by successful repetition in all situations.

Detection refers to identifying whether or not there are objects or persons in an area of interest or not. In order

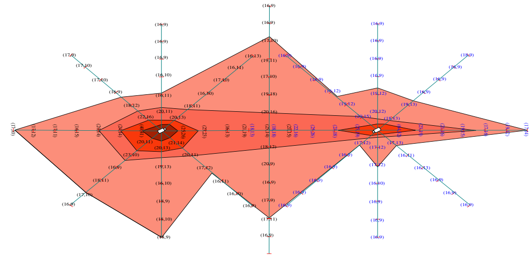

Figure 4: Contour Map

to detect the moving object, the proposed algorithm should extract the obvious variance of RSS while filtering interference from unstable nodes and any environmental change. To perform localization, the relationship between the variance of the RSS and the physical distance should be determined.

3.2 Rolling-Window Based Detection

We propose the rolling-window algorithm based on Equation (1) which is computation efficient for embedded systems.

$$V_n = \sum_{i=0}^{w-1} |R_{n-i} - R_{n-i-1}| + \sum_{j=2}^{w-1} |R_n - R_{n-j}| \qquad (1)$$

Where V_n, R_n and w represent the the variance of RSS at time n, measured RSS value at time n, and the window width respectively. The first term considers rapid fluctuations while the second term can eliminate small fluctuations. The wider the window is, the larger V_n is and the more accurate our detection. However, this accuracy is gained at the cost of a greater time delay. When the width of the window is $w = 6$, the performance is proven to an accuracy of 100% accuracy in Situation 1 with average 0.2 seconds delay under a 10 Hz sample rate.

3.3 Region-Partition Based Localization

Experiment results show that the RSS variance is inversely proportional to the distance between the moving object and the transceiver, so a contour map representing this relationship can be constructed. In the map, the physical space can be partitioned into contiguous regions, each of which corresponds to a certain RSS variance level. Fig.4 shows the contour map of a pair of transceivers in Situation 3, we then constructed four contiguous partitions according to those measurements. When the nodes are of sufficient density, the position of objects can be inferred from overlapped contour maps with a higher accuracy.

4. FUTURE WORK

Large scale networks with high node density need to be implemented in order to obtain a fine-grained contour map for better localization accuracy. More experiments in different environments will be taken to evaluate the performance of our system.

5. REFERENCES

[1] P. Bahl and V. N. Padmanabhanr. Radar: an in-building rf-based user location and tracking system. In *IEEE INFOCOM*, pages 775–784, 2000.

[2] T. S. Rappaport. *Wireless Communications Principles and Practice (2nd Edition)*. Prentice Hall, 2001.

[3] M. Youssef, M. Mah, and A. Agrawala. Challenges: device-free passive localization for wireless environments. In *MobiCom '07*, pages 222–229, 2007.