Locating and Monitoring Emergency Responder using a Wearable Device

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ABSTRACT
When a disaster occurs, activities like search, rescue, recovery, and cleanup are carried out by emergency responders. This paper proposes a new framework for supporting the safety and health of emergency responders by locating their position and monitoring their vital signs using a Wireless Wearable Device. As an initial step towards the development of a wireless wearable tracking and monitoring system for emergency responders, this system uses an iterative localization based scheme, which provides the exact position of each emergency responder, and monitors their vital signs like skin temperature and pulse rate. Any change in the vital signs can be easily sensed and tracked, and could be used to provide warnings when critical events are detected. The system could be used to send early warning alerts and for communication between emergency responders.

Categories and Subject Descriptors
B.2.2 Performance Analysis and Design Aids
B.4.1 Data Communications Devices

General Terms
Algorithms, Measurement, Documentation, Design, Languages, Theory,

Keywords
Incident Commander, Localized node, Monitoring centre, Position estimation, Unlocalized node.

1. INTRODUCTION
In recent years, there has been an increase in natural hazards causing even more loss of human life and infrastructure. In order to reduce the impact of natural hazards on common life, an effective disaster management system is desirable. A key role in effective and efficient disaster management is played by the emergency responders. To support the safety of emergency responders, whilst in dangerous situations, by continuously monitoring their position and sensing their vital signs, is necessary. Locating, tracking, and communicating with emergency responders can be achieved by devising a body sensor system. The system can significantly improve support for organizing and managing the real-time delivery of medical and food supplies to disaster hit people.

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Several environmental factors have an effect on the location accuracy and capability to attain the position of emergency responders. GPS is one of the most popular location tracking system, which needs signals from GPS satellites. In the presence of buildings, forests and dense foliage, the satellite signals might be blocked.

For a large number of emergency responders, a simple solution of adding GPS to all nodes is not a feasible solution. In this paper, we are using a fast and cost effective localization scheme that estimates the position of emergency responder by using RSSI. The proposed system is a wearable device which tracks the emergency responder and monitors the vital signs typically connecting to biomedical sensors and the monitoring device. Here the proposed system ensures that only well trained and properly fit emergency responders are deployed in a disaster area.

The paper is organized as follows: Section II discussed about the related work done in the field of localization and health monitoring. Section III presents the architecture of the proposed system. Section IV describes the localization scheme. Section V demonstrates the simulation of the localization scheme. Section VI summarizes the findings of our analysis.

2. RELATED WORK
Wearable healthcare systems for tracking and monitoring humans are an advanced field in Wireless Sensor Network. In [1], Fei and Yang presented a work which deals with a novel approach of interfacing medical sensors to a RF mote. In [2], [3], [4], [5] the authors presents various architecture of wearable health monitoring systems, which helps to monitor the vital signs of humans.

Locating the position of the sensor nodes is important for location tracking based services in Wireless Sensor Networks. The current approaches and emerging opportunities in localization schemes are presented in [6] and [7]. Many algorithms have been developed to find the nodal position. In [8], the authors present a position estimation algorithm for estimating nodal positions in wireless sensor networks. They have considered the position-based routing and location identification. In [9], the authors proposed a novel framework to detect the position of a sensor node.

In WSN, estimating the node position is very important for location based services. Some of the positioning systems like RADAR [10], APS [11], VORBA [12] make use of approaches based on precise measurements.

Recently several location tracking systems based on Global Positioning System (GPS) have been proposed which is very useful in outdoor environments. Landmark-based approaches [13] usually used GPS for position tracking. As GPS is expensive and is not capable of determining the position of individuals in buildings and dense foliage, an efficient localization technique is needed.

In [14], the authors made an experimental comparison of RSSI-based localization algorithms for indoor wireless sensor networks.

Our work differs from the previous work in that we proposed a system which can track the position of the emergency responder and monitor their vital signs while doing their work.

3. ARCHITECTURE OF ER-TRACK

The proposed system is a wrist worn wireless device which locates the emergency responder, tracks their activity and monitor the vital signs, such as pulse rate, blood oxygen level, blood pressure and body temperature, using biomedical sensors. Locating the emergency responder could be possible with the help of the localization scheme and monitoring the vital signs by using biomedical sensors. The device worn by each emergency responder could provide the safety by continuously monitoring their position and sensing their vital signs to a great extent.

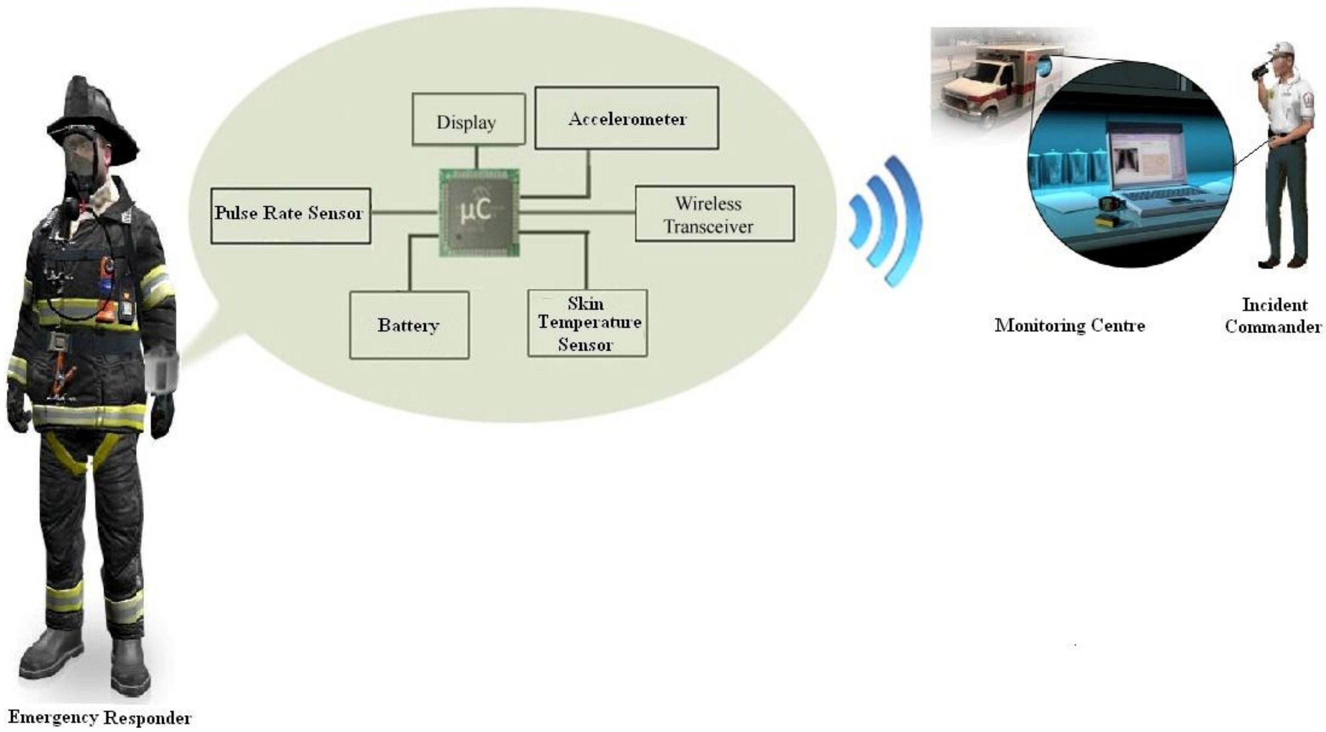

Figure 1: Architecture of the system.

The architecture of the proposed system is shown in the Figure 1. The proposed system employs a fast and precise iterative localization scheme to locate the emergency responder. After locating all the emergency responder, the system communicates with the monitoring centre about the accurate position of each emergency responder. The system also senses the vital sign of each emergency responder, processed it and then transmits it to the Monitoring Centre using a Wireless Transceiver module. The Monitoring Centre contains a server which gathers all the data sent by the device and stored it to the database. The Monitoring Centre is controlled by an Incident Commander, a chief officer who manages the entire emergency responder groups. The Incident Commander is supposed to know the exact position, activity and the health condition of each and every emergency responder. With the help of Wearable Device, the Incident Commander identifies the current position of emergency responder and checks their health condition. If there is any abnormal rise in vital signs is detected, the system generates an alert message and the Incident Commander make a decision to remove the emergency responder from the region. The Wearable Device incorporates a display panel which shows the readings of the vital signs. This assists the responder to know their health. The system allows an efficient communication between emergency responder and Incident Commander.

The proposed system contains a Wearable Device and a Monitoring Centre as shown in the Figure 2.

The Wearable Device is capable of sensing vital signs of emergency responder, such as pulse rate and body temperature, and communicates this to the Monitoring Centre. The Wearable Device contains a Sensing Unit, a Microcontroller and a Wireless Transceiver Module.

3.1 Sensing Unit

The Sensing Unit in the Wearable Device contains a Pulse Rate Sensor, Skin Temperature Sensor and an Accelerometer.

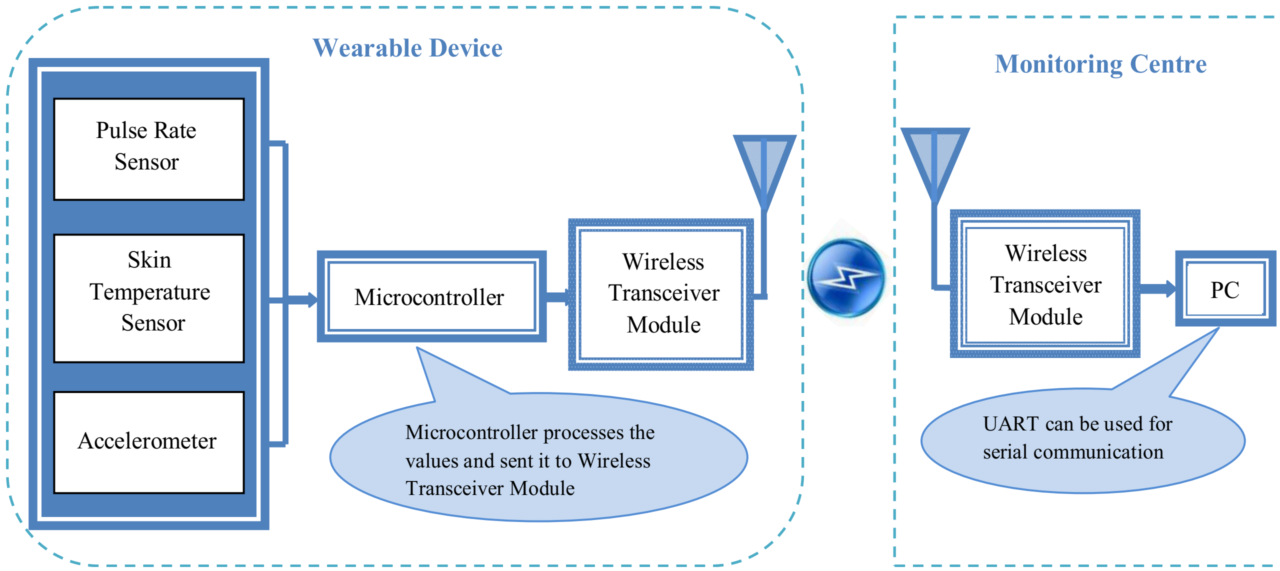

Figure 2: Block diagram of the system.

The main functionality of the Sensing Unit is Vital Sign Monitoring. Vital Sign Monitoring is necessary to identify the vital signs and symptoms of emergency responders as they work. Monitoring and assessing the emergency responder's vital signs helps the Incident Commander to determine the health condition of each emergency responder and to know when and whether protective measures should be provided.

3.1.1 Pulse Rate Sensor

The Pulse Rate Sensor works on the principle of light modulation by blood flow through finger at each pulse. It consists of a Finger Probe, a Microcontroller and a Display as shown in Figure 3.

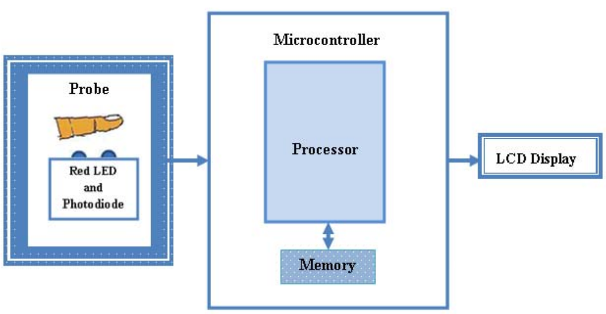

Figure 3: Block diagram of Pulse Rate Sensor.

The Finger Probe uses a Super Bright Red LED and a Photodiode to measure the pulse rate by sensing the change in blood volume in a finger artery. When a finger is placed in the Probe, the Super Bright Red LED emits the light through the finger. By using the Super Bright Red LED, the maximum light emitted must spread in finger and is detected by the Photodiode.

When the heart pumps blood through the blood vessels, the finger becomes slightly more opaque. So less light will be detected by the Photodiode. With each pulse, the Photodiode signal varies and this variation is converted in to electrical pulse. This signal is amplified and triggered through an amplifier which outputs +5V logic level signal. Operational Amplifier (OpAmps) is used to filter the signal and amplifies them to appropriate voltage level.

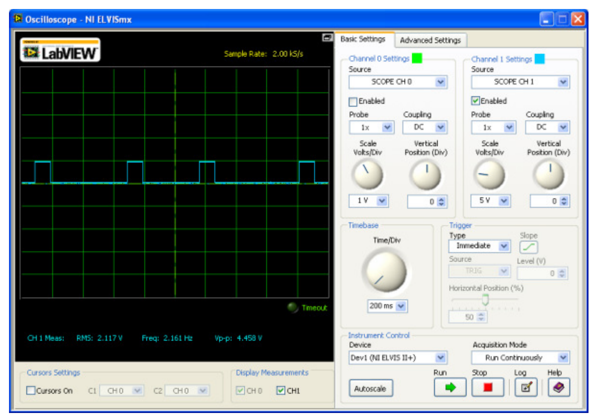

Figure 4: Digital Pulse Wave obtained from the Finger Probe.

A Microcontroller is used for processing the digital pulse obtained from the Finger Probe. The output of the Finger Probe, as shown in the Figure 4, is directly connected to the digital input pin of the Microcontroller to measure the Beats Per Minute (BPM) rate.

A LCD is used for displaying the BPM rate.

The steps for detecting the Pulse Rate:

1) Initialize the microcontroller.

2) Connect the sensor to the digital input pin of the microcontroller.
3) Acquire the readings from the Probe by placing the finger, and saved it to the Memory.
4) Initialize a counter, which stores the duration between two pulses. Initially counter is zero. Delay for 10ms so that the sensor does not listen to any noise.
5) Start counting the counter values from 10ms since there is a delay after pulse.
6) If signal is high, wait for 1msec and keep incrementing the counter for each 1ms.
7) If signal is high, wait for 1msec and keep incrementing the counter for each 1ms.
   Now counter will have time in ms between two high edge pulse.
8) Pulse Rate Calculation

$$bpm = 60000/duration \quad (3)$$

   where *bpm* is the beats per minute and *duration* is the value stored in the counter.
9) Display the reading in BPM

The working voltage for the Pulse Rate Sensor is +5V DC.

3.1.2 Accelerometer

An accelerometer is used as a sensor to give more information on the activity/state of the emergency responder. The accelerometer is capable of measuring changes in vertical and horizontal axis. The main functionality of the Accelerometer is Activity Tracking.

Activity Tracking: Once the system locates the emergency responder, it starts tracking their activity using acceleration sensor integrated in the system. This information can be helpful for the health analysis of the responder.

3.1.3 Skin Temperature Sensor

The Skin Temperature Sensor is mounted in the wrist worn device, and positioned in such a way that it has direct contact with the skin, allowing the sensor to measure the external temperature of the emergency responder's body.

3.2 Microcontroller Unit

The Microcontroller is used to processes the sensing values from the Sensing Unit. The processed values are sending to Monitoring Centre using Wireless Transceiver Module

3.3 Wireless Transceiver Module

The Wireless Transceiver Module is used for communication between the Wearable Device and the Monitoring Centre.

The Monitoring Centre contains a Personal Computer or Laptop for monitoring the emergency responder's vital values and a Wireless Transceiver Module for receiving the vital values from the Wearable Device. The main functionalities of the Monitoring Centre are Health State Analysis and Emergency Detection.

Health State Analysis: The health analysis of each and every emergency responder could be done by the Monitoring Centre. All the information regarding each emergency responder is available there. The information concerning to the vital signs of each emergency responder will be wirelessly available to the monitoring centre from the Wearable Device.

Emergency Detection: The monitoring centre verifies the vital reading of each emergency responder. If the system notices any sign of abnormality in emergency responder, an alert mechanism is initiated and if required, emergency responder should be removed from the location.

4. LOCALIZATION SCHEME FOR ER-TRACK

The main focus of the system is to facilitate a large number of emergency responder networks with location tracking capabilities in a fast, effective and low cost manner. The main intention of the localization scheme is to locate and track the emergency responder in harsh environments A Wearable Device with a localization module will efficiently estimate the position of each emergency responder and minimize the probability of error.

This beacon based localization scheme begins with placing a group of beacon nodes. Beacon nodes are nodes whose position is known. The exact position of each emergency responder is computed with the help of the beacon nodes. Each and every emergency responder determines their position with the help of these predefined positioned beacon nodes. These position estimate values are transmitted to the Monitoring Centre for further proceedings. The Incident Commander checks the current position of each emergency responder and starts tracking them.

The major assumptions are:
i. Area of the region is known,
ii. Few beacon nodes with predetermined position,
iii. All unlocalized nodes are deployed randomly.

The main aim of this scheme is to localize the unlocalized nodes using the least amount of beacon nodes. Unlocalized nodes are those nodes whose coordinates have to be estimated.

Our localization scheme is an RSSI based position estimation which computes the (x,y) coordinates of each unlocalized node based on the coordinates of localized nodes (x,y). A nodes position is estimated by minimizing the difference between the actual and the estimated distance, and thereby make it possible for a node to estimate their (x,y) coordinates. Each node estimates the distance of its neighbor using RSSI method. The traffic in the network is limited to those nodes which are in the communication range of the localized nodes.

Consider a region with 'n' beacon nodes whose x and y coordinates are xActual and yActual. In the initial phase, beacon nodes (with their predefined position) are placed in the region. The 'n' unlocalized nodes labeled 1, 2, …., n are placed randomly at unknown distinct locations in the region. Initially, the beacon nodes estimate the position of some unlocalized nodes. After knowing their positions, these newly localized nodes act as localized nodes. Localized nodes are those nodes which recognize their position. . Newly localized nodes can propagate their x and y coordinates among other nodes and assisting other unlocalized nodes to compute their coordinates. The information exchange between localized nodes and unlocalized nodes is facilitated with these coordinates. The localized nodes send their location values to all unlocalized nodes in their range. Using these transmitted location values, unlocalized nodes determine their position. As every unlocalized node can estimate its distance from the localized node, this localization scheme offers good performance at low complexity.

During localization, the information is passed within the neighborhood of a node, which results in high communication efficiency.

4.1 Position Estimation

In this RSSI based position estimation, every node has a maximum transmission range of 'R'. Each node communicates with their neighbor using received signal strength. Based on this measured signal strength, the distance between the nodes is estimated. Each node determines its distance to its neighboring nodes and shares it with them. The measured signal strength between two nodes contains the information about the distance between those nodes.

Let d_{ij} be the actual distance to the localized node 'i'. Suppose the actual position of an unlocalized node 'j' is (x_j, y_j) and it is going to acquire the distance d_{ij} to the i^{th} localized node whose position is (x_i, y_i), $1 \leq i \leq n$. Then the distance between nodes 'i' and 'j' is

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \qquad (2)$$

The actual and estimated position for node 'i' is x_i and x_j and for node 'j' is y_i and y_j respectively.

This node level distance estimation reduces the network traffic drastically. Once distance estimate of each unlocalized nodes are obtained, the position estimation could be done to determine their locations. To determine the location, we compute the coordinates of unlocalized nodes with respect to the localized nodes.

5. SIMULATION RESULTS

The localization scheme simulation is done in Matlab. We consider a sensor network with the area size 40 ×40 square areas. The basic simulation takes four beacon nodes and forty unlocalized nodes which uses a RSSI method. The traffic in the network is limited to those nodes which are in the communication range of the localized nodes.

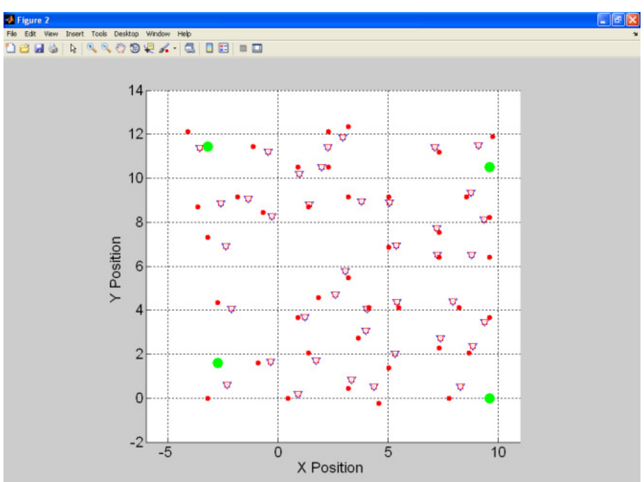

Figure 6. Actual and estimated positions of nodes are shown.

The first step in the localization simulation is to place the beacon nodes in known location. The second step in the simulation is to place the unlocalized nodes. The output of the localization simulation shows the position estimation of nodes (see Figure 6). That is the estimation of coordinates of each unlocalized nodes based on coordinates of localized nodes. The small dots, as shown in Figure 6, are unlocalized nodes whose position is unknown and coordinates have to be estimated. The big dots are beacon nodes and the inverted triangles show the estimated position of unlocalized nodes (see Figure 6).

Using the four beacon nodes, the position of some unlocalized nodes is determined. After getting the position, these newly localized nodes provide their location information to the unlocalized nodes within their range and start assisting them to determine their estimate position. This process continues in the succeeding localization process.

6. CONCLUSION

This paper presents Wireless Wearable Device architecture with a location tracking scheme, for tracking and monitoring emergency responders. The localization scheme presented estimates the distance of emergency responders to their neighbors using localized nodes. Since the traffic in the network is limited to those emergency responders who are in communication range, the distance estimation can perform efficiently, reducing the network traffic significantly. By implementing such a fast and effective localization scheme, the location information of the emergency responder can be easily tracked. This scheme can fulfill our main objective of providing a cost-effective and care efficient context aware monitoring system for emergency responder's. The RSSI based localization scheme is relatively inexpensive and consumes low power considering its operation and can easily be implemented in hardware. This system helps to increase disaster relief capabilities and the safety of emergency responders.

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8. REFERENCES

[1] Fei Hu, and Yang Xiao, 2009. Congestion-Aware, Loss-Resilient Bio-Monitoring Sensor Networking for Mobile Health Applications in *Proceedings of IEEE on Areas of Communication*.

[2] Pandian, P. S., Safeer, K. P, Pragati Gupta, D. T. Shakunthala, Sundersheshu, B. S., and Padaki, V. C., 2008. Wireless Sensor Network for Wearable Physiological Monitoring in *Journal of Networks*.

[3] Nuria Oliver, and Fernando Flores-Mangas, 2006. HealthGear- A Real-time Wearable System for Monitoring and Analyzing Physiological Signals in *Proceedings of IEEE on Wearable and Implantable Body Sensor Networks*.

[4] Hongliang Ren, Max Q.-H. Meng, and Xijun Chen, 2005. Physiological Information Acquisition through Wireless Biomedical Sensor Networks in *Proceedings of the 2005 IEEE International Conference on Information Acquisition*.

[5] David Malan, Thaddeus Fulford-Jones, Matt Welsh, and Steve Moulton, 2004. CodeBlue: An Ad Hoc Sensor Network Infrastructure for Emergency Medical Care in *Proceedings of the MobiSys Workshop on Applications of Mobile Embedded Systems (WAMES 2004)*.

[6] Amitangshu Pal, 2010. Localization Algorithms in Wireless Sensor Networks: Current Approaches and Future Challenges, In *Network Protocols and Algorithms*.

[7] Nader Moayeri, Jalal Mapar, Tompkins, S., and Pahlavan, K., 2011. Emerging opportunities for localization and tracking, in *IEEE Wireless Communications*.

[8] Ohta, Y., Sugano, M., and Murata, M 2005. Autonomous localization method in wireless sensor networks in *Third IEEE International Conference on Pervasive Computing and Communications Workshops*.

[9] Simon Wong, K. F., Ivor W. Tsang, Victor Cheung, Gary Chan, S.H., and James T. Kwok 2005. Position Estimation for Wireless Sensor Networks in *Proceedings of IEEE GLOBECOM*.

[10] Paramvir Bahl, and Venkata N. Padmanabhan 2000. RADAR: An In-Building RF-based User Location and Tracking System in *Proceedings of Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies, INFOCOM*.

[11] Dragos Niculescu, and Badri Nath, 2003. Ad-Hoc Positioning System (APS) using AoA in *Proceedings of IEEE INFOCOM '03*.

[12] Dragos Niculescu, and Badri Nath, 2004. VOR Base Stations for Indoor 802.11 Positioning in *Proceedings of the 10th ACM MOBICOM*.

[13] Dragos Niculescu, 2003. DV based positioning in ad hoc networks in *Telecommunication Systems*.

[14] Giovanni Zanca, Francesco Zorzi, Andrea Zanella, and Michele Zorzi, 2008. Experimental comparison of RSSI-based localization algorithms for indoor wireless sensor networks in *Proceedings of the workshop on Real-world wireless sensor networks*.