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A PRECISE RADIO PROPAGATION MODEL FOR INVESTIGATIONS OF LOCALIZATION ALGORITHMS IN WIRELESS SENSOR NETWORKS USING SIMULATIONS

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In this work, we present a precise radio propagation model that can be used for the simulation of the Link Quality Indicator(LQI) characteristic in wireless communication. The model is very useful for investigations of localization algorithms in wireless sensor networks using simulations. It represents the results of the empirical observations which we obtained in the experiments. Additionally, we show strong and weak aspects of our model.

Keywords: radio propagation model, simulations, wireless networks, localization.

In general, for the analysis and evaluation of an algorithm, simulations are very useful. They save time and help to avoid unnecessary complications with hardware programming. But the simulations alone do not guarantee that the same efficiency will be reached in the real environment. For this reason, subsequent validation of proposed algorithms on the real testbed must follow. Ideally, results from both simulation and experiment must be equal. But in most cases, these results differ significantly due to imperfectness of models, especially those representing difficult multipath propagation environment. Our first validations have shown that this class of models is not close to the reality enough to be used for doubtless evaluation of algorithms and can help only to estimate the trend of produced performance.

To avoid big differences in the comparison of simulation and experimental results, it was decided to replace the model of the environment — proposed by conventional simulation tools like OMNeT++ [1] — with the lookup table that represents data collected in the same environment as the one in which the experiments will be later performed. According to this, we obtain a realistic radio propagation model in form of a table filled with data that was collected empirically.

Next, we describe the simulation platform selected for this research work followed by the description of the experimental testbed, which represents the basis for our lookup table and all further experiments.

Simulation Environment. We use OMNeT++ as a simulation platform in our work.The OMNeT++ simulator represents a reasonable selection since it is a component-based, modular and open-architecture discrete event simulation framework for studying protocols for wired and wireless networks. OMNeT++ is designed to model the communication network and distributed systems. It is a well-established framework with a long history and a very big community [1]. There exist a big number of OMNeT++ extensions that cover specific simulation needs of researchers. One of them is the project MiXiM.

MiXiM is a “mixed simulator” and supports wireless and mobile simulations in OMNeT++. It provides detailed models of the wireless channel (fading), wireless connectivity, mobility models like constant speed, rectangular and circular mobility. Additionally, it provides models for obstacles and many communication protocols mainly at the Medium Access Control (MAC) level. A user-friendly graphical representation of wireless and mobile networks, debugging, a powerful and feature rich tool box, reduced complexity and many other features represent strong aspects of MiXiM that motivate its selection.

Additionally, there will be in the future some comparisons of results obtained in our research work against simulation results of other researches. To enable as fair comparison as possible, OMNeT++ framework was selected since the majority of other studies use this platform as well.

From the project list proposed by MiXiM, we took the standard Indoor Wireless Sensor Network project with ZigBee-based communication stack preprogramed for the mobile nodes. In our investigations, we focus on those localization schemes only that use prepositioned reference nodes (aka anchors). In our simulations and experiments we define the number of anchors as well as the mobile nodes. We use three anchors and a variable number of mobile nodes from 2 to 10 according to specific aspect that will be investigated.

For all simulations, we apply the lookup table as a radio propagation model, which consists of LQI (Link Quality Indicator) values obtained empirically. To collect LQI data, we prepared an experimental testbed, the description of which is given below.

Experimental Environment. The experimental evaluation of algorithms described in this section took place in one of the office rooms in the building 11 at the University of Applied Sciences in Erfurt, Germany. This room is equipped with standard furniture including chairs, bookshelves and desks. It has two windows and represents a dynamic measurement environment where people may walk in and go out of the room during the normal operation of the network, thus modifying the characteristics of the actual radio propagation channel.

The deployed localization system consists of the following main elements:

1. Anchor nodes. For the localization of unknown wireless sensor nodes we use three anchors, i.e. prepositioned reference nodes with known coordinates: A [0;5], B [0;0] and C [5;0].

2. Unknown nodes. These are the nodes that need to be localized. The number of these mobile nodes is changing between 2 and 10 depending on a specific phenomenon investigated experimentally.

3. Sniffer node. There is also a sniffer node, which is connected via an RS232 serial interface to a host computer and forwards the information transferred through the system for monitoring purposes.

Additionally, we need to consider the following major aspects regarding the experimental evaluation:

1. The obtained experimental results should match the simulations as close as possible. For this, the provided simulation platform must reflect the real world.

2. An appropriate path loss model must be created for both simulations and experiments to enable the localization process.

According to these aspects and considering the difficulty of creating a reasonable indoor propagation model for our simulations, we present a lookup table which includes thousands of LQI values, aka snapshots or fingerprints, which correspond to a set of possible distances between the nodes. After fingerprints are collected, we use the lookup table for simulations and pick up randomly LQI values, according to the distance between the nodes, from the lookup table, instead of calculating them on a very complex model. The main benefit of the lookup table as a form of the radio propagation model is its simplicity and a very close correspondence to the real world.

To collect initial LQI values, a measurement campaign has been conducted. For this purpose we used the wireless sensor nodes, aka ZEBRA2411 modules, from senTecElektronik GmbH. These modules are based on the chip set ZRP1 developed by Freescale Semiconductor [2]. The nodes operate in the 2.4 GHz ISM frequency band and allow wireless communication over a distance of more than 1000 m (line of sight).

ZEBRA contains a micro-controller, the High Frequency (HF) circuitry and a chip antenna with low noise amplifier (LNA) and power amplifier (PA) stages. An integrated Freescale HCS08 MCU serves as the base band controller and operates at 8 MHz. A SMAC (Simple Media Access Control) protocol [3], which is based on IEEE 802.15.4 standard, has been applied for communication between nodes. For the programming of nodes, we use the Metrowerks CodeWarrior development environment from Freescale. Additionally, the ZEBRA modules (Fig. 1) can be connected to a host computer and communicate with it over a simple RS232 connection which can be useful for debugging and can serve as a backbone gateway for monitoring the state of the wireless network.

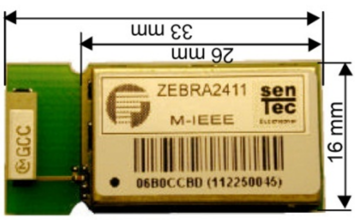

Fig. 1. ZEBRA2411 module developed by Freescale Semiconductor [2]

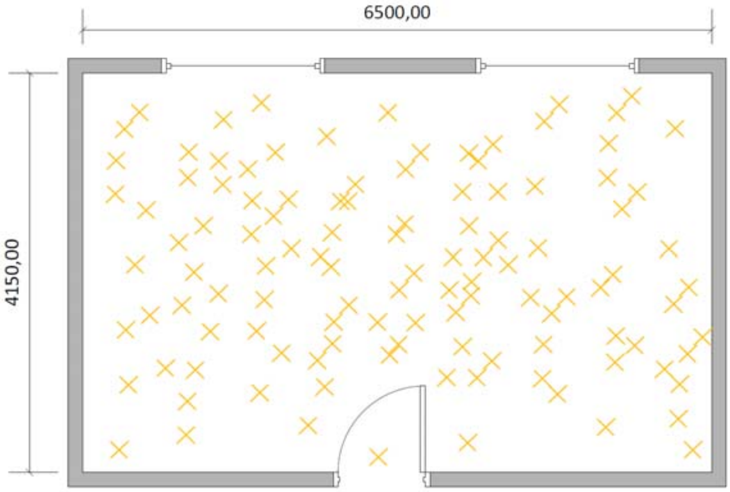

Fig. 2. Ground plan of the office 11.E.24 at the University of Applied Sciences Erfurt, Germany (crosses represent the positions of the nodes during the measurements)

To provide a more realistic view of the real world, all the LQI values for our lookup table were collected in the difficult multipath propagation environments represented by different rooms (with furniture, windows, doors, people coming in and out, etc.) in the buildings 4, 5 and 11 of the University of Applied Sciences in Erfurt, Germany. To collect data, two mobile nodes were placed in randomly selected locations in a room. The distances between the nodes as well as ten first estimated LQI values according to each location were collected before the nodes were moved to other locations. An example of one of the rooms is shown in Fig. 2. Crosses represent the physical positions of the nodes placed randomly. To measure real coordinates of the nodes, as well as the distance between them, Bosch PLR 25 laser rangefinder has been used. This rangefinder provides an accuracy of two millimeters [4].

The scatter plot in Fig. 3 represents the summary of all the collected LQI data showing the dispersion of the measured values for different distances between nodes that were placed indoor as mentioned above. The black crosses show the average values of obtained samples in 10 cm steps. It is important to notice, that LQI values, unlike the signal strength, increase with the distance. Also from the means of samples, it is obvious that we deal with a big uncertainty in the indoor signal propagation, which makes the process of localization very challenging.

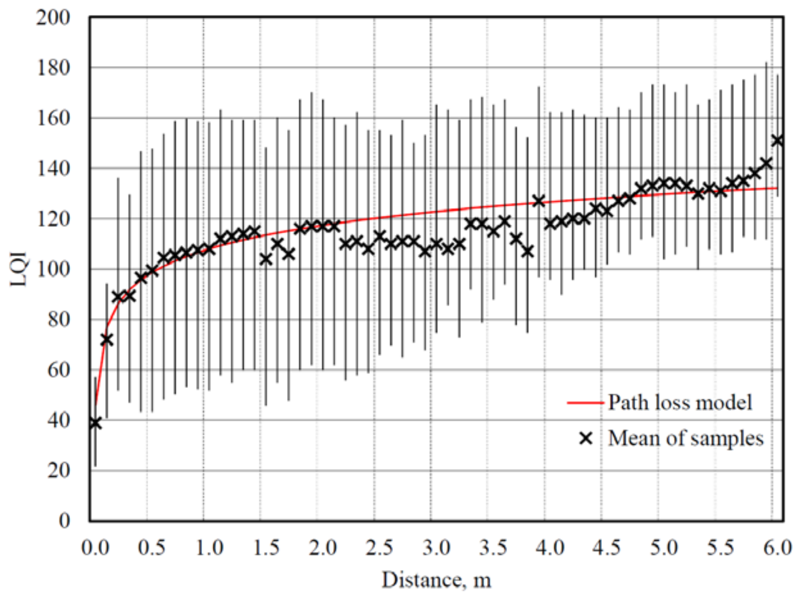

Fig. 3. LQI dispersion

According to the conventional process of localization, we need to estimate distances from the observed LQI values and then use this distances for the position calculation step. There are a lot of studies which propose various signal propagation models even for indoor scenarios. The model which has been applied in this work (the line in Fig. 3) had been found in [5] and adapted to the LQI estimates produced with the hardware platform used in our experiment:

$$L(d) = L_{d_0} + L_p + 10\gamma \log_{10}(d/d_0) + \chi, \quad d \geq d_0$$

where L_{d_0} is the path loss at $d_0 = 0.1$ m; $\gamma \log_{10}(d/d_0)$ is the average path loss with reference to d_0; $\gamma = 3.1$ is the path loss exponent and $L_p = 2.4$ is the penetration loss and both are functions of the measured scenario and working environment; $\chi = 3.6$ is the log-normal shadow fading. For the given scenario the equation and corresponding parameters mentioned above produce the least-square error path loss log-distance model according to the collected LQI values.

The path loss model is used to estimate distances according to the observed LQI values in both simulations and experiments since it was derived from the real measurements. Additionally, we apply the trilateration algorithm to calculate positions according to the given three distances from anchors.

Thus we have presented a radio propagation model which is based on the empirical data. Using this model for simulation purposes will save time since there will be no need to calculate values on a complex mathematical model. Additionally, our model reflects the environment very precisely as it is based on real data. This will help to produce reasonable simulation results.

The weak point of the model is that it is not flexible enough to be applied to any possible environment since it is limited to only some certain working conditions. However, the technique we described in this paper can be applied to any other environment that needs to be simulated.

REFERENCES

1. Nitin G. Palan, Aditi P. Khadilkar. Media Access Control protocolmodeling for Mobile Sensor Network-using OMNeT++ -MiXiM networksimulator // International Conference on Sustainable Energy and Intelligent Systems (SEISCON 2011).— 2011.— P. 641—644

2. Elektronik GmbH senTec. ZEBRA 24XX SM ZigBeeTM Enabled Board for Radio Applications // Product Information 1.7.— May 2007.

3. Freescale-Semiconductor.Simple Media Access Controller (SMAC). User's Guide // SMACRM, Rev. 1.5.— March 2008.

4. Robert Bosch GmbH (Hrsg.).Bosch PLR 25 Digital Laser RangeFinder//http://www.bosch.de/.— latest check: 04. Sep. 2012

5. Alsindi N., Alavi B., Pahlavan K. Empirical pathloss model for indoor geolocation using UWB measurements // Electronics Letters.—2007.— Vol. 43, N 7.— P. 370—372.

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Точная модель распространения радиоволн в пространстве для изучения методом симуляции алгоритмов локализации в беспроводных сенсорных сетях.

В этой работе мы представляем точную модель распространения радиоволн в пространстве, которая может быть применена для симуляции Link Quality Indicator (LQI) параметра в беспроводных сетях. Модель очень полезна для исследования методом симуляции алгоритмов локализации в беспроводных сенсорных сетях. Она представляет собой результат эмпирических наблюдений во время экспериментальных исследований. Также описаны сильные и слабые стороны представленной модели.

Ключевые слова: *модель распространения радиоволн в пространстве, симуляция, беспроводные сети, локализация.*