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ZONE LOCALIZATION SYSTEM BASED ON IEEE 802.15.4. RADIO TRANSCEIVERS *

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Abstract. *This paper presents zone localization technique for IEEE 802.15.4 wireless networks, based on a receive signal strength (RSSI) indicator and a ping – pong packet exchange relation between anchors and a moving node. The proposed localization system is intended to be used for indoor localization inside large buildings, warehouses and large ships. Experimental results showed that the precision localization capabilities of an IEEE 802.15.4 are very limited, and rarely useful in real world situations, but can be used in less precise zone localization systems, where pinpointing object position is not imperative.*

Key words: *wireless sensor networks, indoor localization, RSSI, IEEE 802.15.4*

1. INTRODUCTION

Wireless Sensor Networks (WSN) are composed of large number of wireless network entities usually called 'nodes', which are used for monitoring some events within network coverage area. They are largely used in military applications, healthcare, power-metering systems, environmental monitoring, home security and automation.

Every sensor node consists of four basic entities: sensor, microcontroller, wireless radio and battery. Besides sensing functions some nodes in network are designed to relay network traffic between nodes which cannot hear each other and these nodes are known as routers. Some of these routers, called 'base stations' have more advanced functionalities

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to collect measured data from whole network and send it to users using high-level networks, to which base-station nodes are usually connected, such as Ethernet or GPRS.

WSN nodes are usually deployed in ad-hoc fashion within the field, without careful planning. They need to have self-organizing feature which allows them to form wireless sensor networks and communicate with each other. In a topological sense they form a mesh-type network. Certain node will only know relative position of adjacent nodes, without knowing their exact position [1, 2].

There are many WSN applications which require localization of the exact position of a node in network, such as: firefighter tracking, mining, patient-monitoring, intruder-detection, good tracking and etc.

Radio localization of WSN nodes can be achieved by monitoring the one of three parameters of received radio signals: Time of Arrival (ToA), the Angle of signal Arrival (AoA), and the Receive Signal Strength Indicator (RSSI) [3, 4].

The ToA technique is most commonly used with ultrasound, but its usage with standard IEEE 802.15.4 radio transceivers t is practically impossible, because speed of radio propagation (equal to speed of light) is approximately 10^6 times faster the speed of sound. In order to use ToA, nodes would need to have common synchronized clock or some sort of protocol for exchange-timing (two-way ranging protocol [5]).

The AoA technique uses knowledge of an angular separation between two beacons or a beacon and a fixed axis (usually nodes radio antenna axis). AoA can be determined using two common methods: with antenna-array or with estimation of the RSSI ratio between two or more directional antennas on the sensor node [6].

Almost every IEEE 802.15.4 radio transceiver offers RSSI parameter of received packet, so no hardware modification is needed for the proposed method. This method proposes the examining of received signal strength regarding a signal transmitted from a known location. Under optimal conditions (wide-open space) using a free-space signal strength model (inverse-square law), the distances between such nodes can be easily calculated [7]. RSSI can be used during 'profiling' technique where an 'RSSI map' is generated at the initial stage and then combined with RSSI during the active stage [8].

Reflection, scattering, diffraction, attenuation, and other radio propagation properties make RSSI alone, without other parameters, almost impossible to use for distance estimation [9]. For example: if the signals and their reflections reach the receiver during a counter phase, the signals are subtract and the distances between nodes seem to be greater than they are. If the signals reach the receiver during a normal phase the signals are summed up and the distances between nodes seem to be smaller than they are.

In such scenarios, which are more likely in real world applications precise RSSI based localization could not be achieved by usage of commercially available IEEE 802.15.4 narrowband transceivers. Precise RSSI based localization can be achieved using Ultra Wide Band (UWB) transceivers which are introduced by IEEE 802.15.4a standards, but such transceivers are not yet available on the market.

Combining RSSI with the AoA approach for limiting a channel (two-ray, log-normal) gap problem can be avoided but the main drawback of the proposed method is the need for rotational antenna(s) [10].

2. System Definition and Hardware Used

Large warehouses and ships normally have specific areas where GPS or GPS localization cannot be used, because of lack of services caused by Faraday cage effect. Therefore, within wider indoor areas like those regarding communication, the localization of personal or other entities (goods, warehouse robots) is crucial.

System is composed from base stations and mobile nodes. Hardware used in this research is based on our faculty developed wireless sensor node called SPaRC Mosquito [11]. SPaRC Mosquito is a modularly built WSN node with LPC1768 Cortex M3 microprocessor. It uses MRF24J40MA IEEE 802.15.4 compliant radio transceiver, which can be easily replaced with more powerful radio transceiver MRF24J4MB or MRF24J40MC, in order to increase node's radio range. SPaRC Mosquito is powered by two AA batteries and has TC77 temperature sensor and photo-resistor. Besides regular role of sensor node, the node can act as base station by adding expansion-board which provides Ethernet connectivity, as it was used for base-station (Fig. 1.).

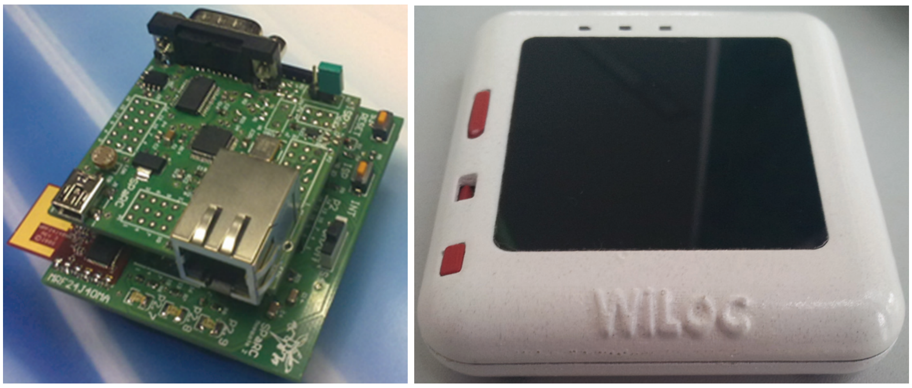

Fig. 1. SPaRC Mosquito base-station and mobile WiLoc node

Mobile node is also based on SPaRC Mosquito WSN node, with LCD display (for displaying messages to user) and headphones connectors. The prototype supported three LEDs – red, green, and blue for various 'silent messages'. WiLoc mobile node is battery powered pocket sized device. (Fig. 1).

3. RSSI Experimental Results

As stated in [7, 8] the measured RSSI values are greatly impacted by reflections from object bigger than a signal carrier's wavelength, therefore the measured RSSI values are basically useless for precise distance measurement in 2.4GHz band.

In order to confirm that thesis, we prepared a simple test. Two anchor nodes were placed about 20 meters apart within a long narrow arena at the faculty. Transmitting node was placed at the exact middle and transmitted four packets every 250 ms, during eight hour test. The anchor nodes measured the RSSI values and these values were forwarded to the personal computer. During the experiment we aggregated the measured data into 100 000 samples (with averaging) – (Fig. 2).

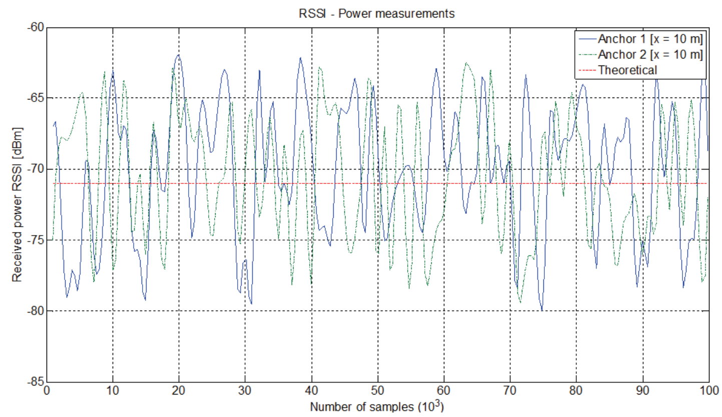

Fig. 2. RSSI values measured during the initial experiment.

The initial experiment showed that RSSI was an unreliable distance evaluator, not even if the data were averaged and the most inaccurate measurements eliminated. According to [9] there is no 'best' channel model for indoors EMR-spreading, which would acknowledge reflecting, scattering, and other phenomena.

As stated in [12], a log-normal channel model can be selected for the sake of simplicity in regard to computational complexity. Distance from this model can be calculated as:

$$d = d_0 \cdot 10 \frac{P_0 - P_r}{10 \cdot n} \tag{1}$$

Where d is the calculated distance, d_0 stands for default distance where measuring power P_0 (in our case 1m and -71.5dBm); P_r the received power at distance d, n stands for the terrain factor [12]. From the results (Fig. 3.) we can be seen that the relative distance error rose by up to 170%, confirming the thesis in [12].

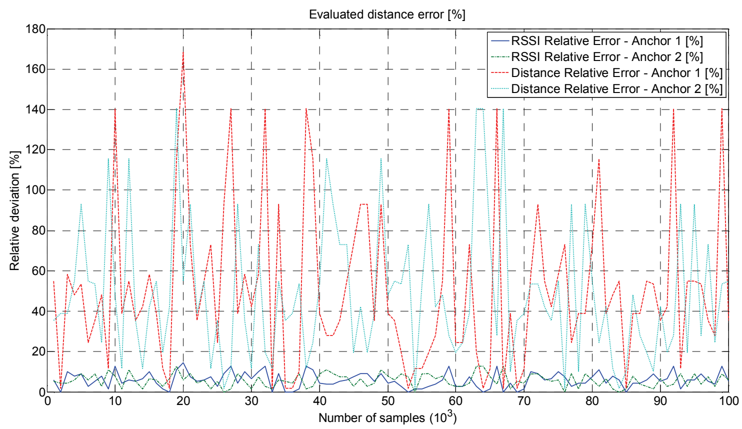

Fig. 3. Relative deviation in percents of measured RSSI values and distances.

4. PING-PONG RSSI ALGORITHM

As stated previously- RSSI cannot be used for estimating distances amongst two nodes. Instead of the estimated distance we have created 'Zones' and inside these zones are 'Sectors' (Fig. 4).

The general idea behind the solution is to define within which sector of which zone the subject is present – not to pin point its location. At the end of the experiment we had managed to pin-point users into sectors with size 1.5 x 1.5 m.

The general idea behind the algorithm is when the subject with mobile node enters the zone, one of anchors transmits ping packet to the subject, containing data such as the ping-power level, ping-channel, and ping ID. The ping data is transmitted in burst mode – five messages are sent every 250ms, where IEEE 802.15.4 CSMA/CA is used for avoiding possible collisions.

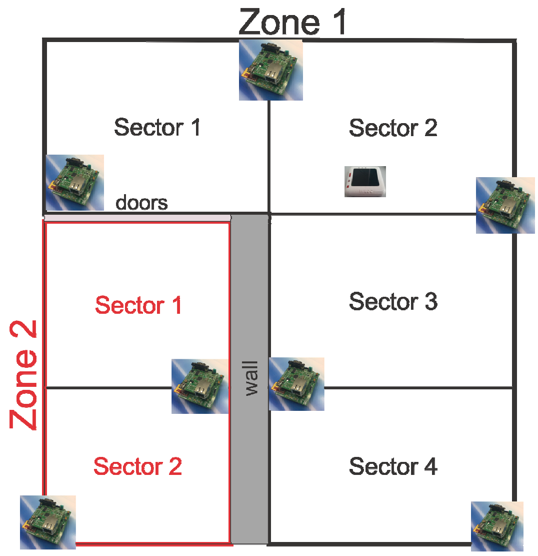

Fig. 4. Zones and sectors

The mobile node retransmits received ping packets to anchors. The anchors receive these pong messages and calculate the RSSI value from received packet. When the RSSI value has been calculated the 'location data' is transmitted to the central computer connected via Ethernet. The algorithm then calculates the RSSI power and ping count and decides to which sector the subject belongs. The weight of ping data and RSSI value now has to be taken into consideration (Eq. 2.):

$$d_{vector} = RSSI \cdot w_{RSSI} + PingCnt \cdot w_{PingCnt} \tag{2}$$

Research shows that weight optimization could not be determined by suitable algorithm. It can be obtained by experimental measurements at given location.

5. DEMO APPLICATION

The demo application was prepared in C#, using .NET framework 3.5. The application gathered data and computed the node position.

The triangle in Fig.5 represents the floor-plan of *Mare Informatica* Company's headquarters building in Pisa, where the project's demonstration was made. Inside the triangle there is one mobile node (blue circle with ID = 0x11) which was tracked throughout localization zones. The information and parameters, such as building maps, anchor node positions, ping and RSSI weights are imported into application in form of XML files. This feature provides that the application can be fully customized and reconfigured without need for compilation.

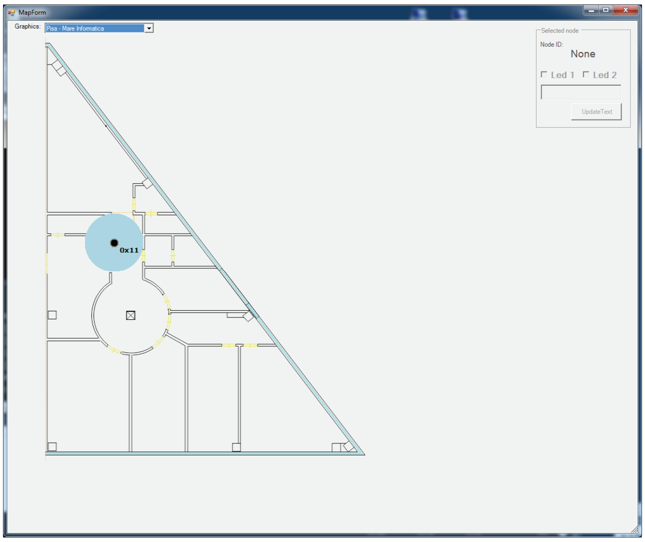

Fig. 5. Running demo at "Mare Informatica –Pisa"

6. CONCLUSION

RSSI parameter can only be used for localization purposes inside buildings in combination with other techniques. As shown in proposed paper, some sort of localization can be done via ping-count and RSSI parameters but only if we consider such parameters as the number and positions of necessary anchor nodes and optimal weight settings.

The proposed technique can be only used within static scenarios – not many objects are moved once the weights were set. Relying on our experience we believe that this technique is useless for more than 5 or 6 subjects within one zone. If there were be more subjects present the communication would start to be interfered with, resulting in poor RSSI and ping - measurements. Many subjects within one zone means several moving objects that change the reflection and scattering conditions, which would then impact on RSSI values, and so on.

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SISTEM ZA ZONSKU LOKALIZACIJU ZASNOVAN NA IEEE 802.15.4 RADIO PRIMOPREDAJNICIMA

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Ovaj rad predstavlja tehniku za zonsku lokalizaciju u IEEE 802.15.4 bežičnim mrežama, zasnovanu na indikatoru prijemne snage signala i razmeni ping-pong poruka između fiksnih čvorova i pokretnog čvora. Predstavljeni system, namenjen je za lokalizaciju unutar velikih zgrada, skladišta i brodova. Eksperimentalni rezultati pokazuju da su mogućnosti precizne lokalizacije sa IEEE 802.15.4 primopredajnicima veoma ograničene i da se teško mogu reaalizovati u praksi, ali se sa zadovoljavajućom tačnošću mogu koristiti u zonskoj lokalizaciji, kod koje precizna pozicija objekta nije imperativ.

Ključne reči: *bežične senzorske mreže, lokalizacija unutar objekata, Indikator prijemne snage signala, IEEE 802.15.4*