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# Principles of Indoor Localization and Method for RSSI Measurement

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*Abstract* – **The need of localizing objects indoor and outdoor rises everyday. Since the GPS gained wide popularity more people realized how its advantages can be used. The continuous development of the warehouse environment brought the industry up to a stage where huge variety of robotic systems is used. To be managed in proper order all of these machineries need to know the exact position in the working space for themselves and for the surrounded objects as well. Unfortunately the mass products for positioning are not the best for all purposes. Different cases come to front where is about saving consumption or need of localization where the signals from the global positioning system are not applicable. Here is the place where indoor wireless positioning network can take a place. Using the signal strength value gives an option making it happen. Unfortunately most of the IC for this solution does not provide time-stable and linear RSSI value. This is why we need to use different methods to make the data usable.**

*Keywords* – **Localization, wireless, indoor, industry.**

## I. INTRODUCTION

In our days the new technologies go hand in hand with the industry. The goal that most of the manufactories aim to is a complex of fast transportation, high reliability and effective cost price for all of this.

Whenever indoor localization is needed, some of the problems listed below are faced. It is impossible to use the global positioning system (GPS) while trying to detect indoor objects due to the lack of direct field of vision with the necessary amount of satellites. The GPS modules indeed require higher consumption as well. This may not sound like something to have to pay attention at, but referred to mobile devices with limited power supply its significance raises.

The increasing miniaturization of electronic components and advances in modern communication technologies lead to the development of extreme small, cheap, and smart sensor nodes. These nodes consist of sensors, actuators, a low power processor, small memory, and a communication module. Nodes measure conditions of the environment, precalculate, aggregate, and transmit this data to a base station. Thousands of these nodes form a large wireless sensor network to monitor huge inaccessible terrains. Processor performance and available energy of each sensor node are highly limited by its physical size. Therefore, intensive communication and computation tasks are not feasible. Thereby, algorithms in sensor networks are subject to strict requirements covering reduced memory consumption, communication, and processing time. As a result of the stochastical distribution of all nodes in the deployment phase, a determination of the node's position is required. Determining the position of sensor nodes in wireless sensor networks represents a real challenge. To identify the exact coordinates of sensor nodes (also called unknown nodes or Unknowns) requires measuring a distance e.g., measuring time of arrival (ToA) or time difference of arrival (TDoA). Difficulties concerning time measurement results from synchronization of involved devices as well as the high mathematical effort to calculate the position. Other way for distance estimation is the signal measurement. It can be divided on two basic methods. One is a method giving an account of the minimal transmitted power. The other is focused on the received signal strength. The devices produce different accuracy for those different methods and it is a designer point to decide whether of the devices and the method to be used for satisfaction of the expectations. Measuring the received signal strength (RSS) offers a possibility to estimate distance determination with minimal effort.

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A good localization algorithm should calculate a position as fast as possible and should be resistant to environmental influences as well as imprecise distances. A very good algorithm combining before mentioned conditions is the Weighted Centroid Localization (WCL) in combination with Zigbee.

According to the IEEE Standard 802.15.4-2003 for Low-Rate Wireless Personal Area Networks (LR-WPAN) there are two basic topologies for the wireless networks: star topology and peer-to-peer topology.

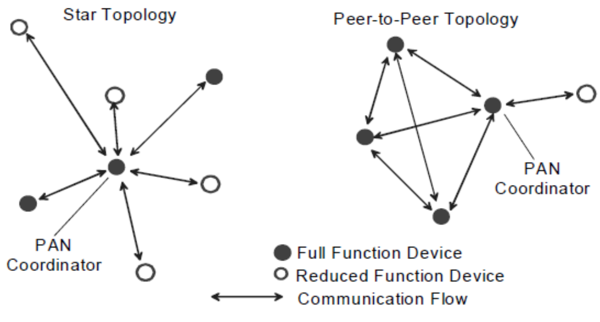


*Fig.1. Basic types of network*

As is shown above the star topology consists of specific controller called PAN coordinator. A device typically has some associated application and is either the initiation point or the termination point for network communications. A PAN coordinator may also have a specific application, but it can be used to initiate, terminate, or route communication around the network. The PAN coordinator is the primary controller of the PAN. All devices operating on a network of either topology shall have unique 64 bit extended addresses. This address can be used for direct communication within the PAN, or it can be exchanged for a short address allocated by the PAN coordinator when the device associates. The PAN coordinator may be mains powered, while the devices will most likely be battery powered. Applications that benefit from a star topology include home automation, personal computer (PC) peripherals, toys and games, and personal health care. The peer-to-peer topology also has a PAN coordinator; however, it differs from the star topology in that any device can communicate with any other device as long as they are in range of one another. Peer-to-peer topology allows more complex network formations to be implemented, such as mesh networking topology. Applications such as industrial control and monitoring, wireless sensor networks, asset and inventory tracking, intelligent agriculture, and security would benefit from such a network topology. A peer-to-peer network can be ad hoc, self-organizing and self-healing. It may also allow multiple hops to route messages from any device to any other device on the network. Such functions can be added at the network layer, but they are not part of this standard. The performance of any routing algorithm will be impacted by the selection of routes over which data is eventually transmitted. Simple routing algorithms that choose the minimum number of hops have been shown to lead to poor network performance in wireless environments.

*A. Received Signal Strength*

Lots of localization algorithms require a distance to estimate the position of unknown devices. One possibility to acquire a distance is measuring the received signal strength of the incoming radio signal. The idea behind RSS is that the configured transmission power at the transmitting device (PTX) directly affects the receiving power at the receiving device (PRX). According to Friis' free space transmission equation, the detected signal strength decreases quadratically with the distance to the sender.

$$P_{RX} = P_{TX} . G_{RX} . G_{TX} \left( \frac{\lambda}{4\pi d} \right)^2 \qquad (1)$$

*PTX* = Transmission power of sender
*PRX* = Remaining power of wave at receiver
*GTX* = Gain of transmitter
*GRX* = Gain of receiver
$\lambda$ = Wave length
*d* = Distance between sender and receiver

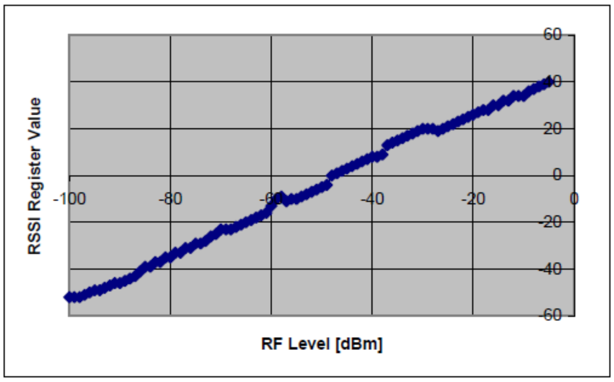


*Fig.2. RSSI vs. RF level*

It can be inferred that the RSSI value as a function of the power of the RF pin is linear and has dynamic range of about 100 dB.

In embedded devices, the received signal strength is converted to a received signal strength indicator (RSSI) which is defined as ratio of the received power to the reference power (PRef). Typically, the reference power represents an absolute value of $P_{Ref}$=1mW.

$$RSSI = 10 \log \frac{P_{RX}}{P_{ref}}, \qquad [RSSI] = dBm \qquad (2)$$

An increasing received power results a rising RSSI. Thus, distance d is indirect proportional to RSSI. In practical scenarios, the ideal distribution of PRX is not applicable, because the propagation of the radio signal is interfered with a lot of influencing effects e.g.

- reflections on metallic objects
- superposition of electro-magnetic fields
- diffraction at edges
- refraction by media with different propagation velocity
- polarization of electro-magnetic fields
- unadapted MAC protocols
- inapplicable receiving circuits.

These effects degrade the quality of the determined RSSI significantly. Thus in many applications, RSSI has a very high variance and low entropy.

*B. Link Quality*

The before mentioned influences during transmission of radio packets reduce the quality of RSSI extremely. Thus, localization of unknowns becomes imprecise. Another method to determine the distance is based on the link quality indicator (LQI) of the transmission. According to IEEE 802.15.4, LQI is a characterization of the strength and/or the quality of a received packet. It must be proportional to signal level (RSSI), a signal-to-noise estimation or a combination of these methods and shall be a value between 0 and 255. By averaging over several LQI values an estimate of the link quality can be obtained and therefore an estimate of the probability of successful transmission is available to the route selection algorithm. In Chipcon's CC2430-based sensor nodes, RSSI is mapped directly to LQI.

The main purpose, exact localization of an object, can be achieved by using enough count of nodes that communicate with the moving objects. The amount of the static point depends on the accuracy that is to be reached. It is impossible and moreover meaningless to build a net with extravagant count of nodes due to the price and the complexity of the system at all. It is up to a particular development to establish the density of the nodes that is suitable for a specific purpose. For this reason the process of localization can be divided on two major parts one is accomplished by the hardware and the mentioned above RSSI while the other is calculated by algorithms. The clue in this case can be divided into two basic parts: one is to acquire more usable and feasible data to work with; the other is to be established the most accurate algorithm that can provide the highest accuracy.

## II. APPLICATION CIRCUIT AND DESCRIPTION

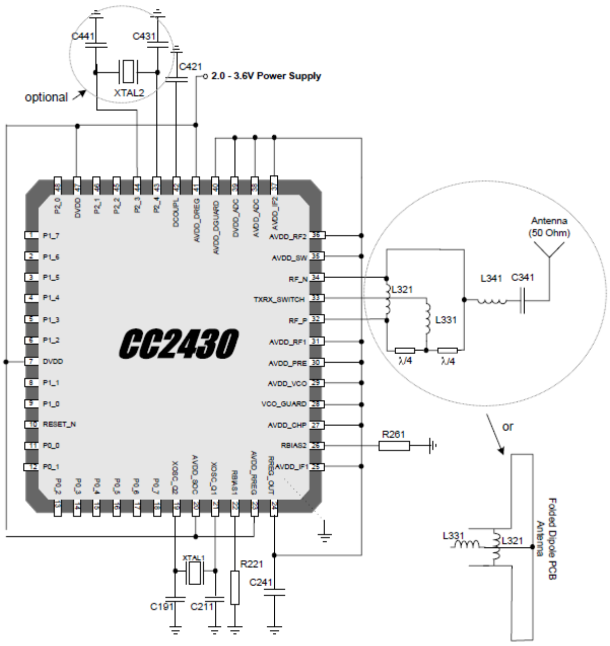


*Fig.3.Basic circuit*

The basic circuit for use of a ZigBee chip CC2430 by Texas Instruments can be viewed as built from three main blocks: digital interface circuit; clock source circuit; radio transmit/receive circuit. By the last block the device can connect and communicate others to transmit data and to measure distance using the built in indicator for received signal strength (RSSI). This indicator will be used as a signal source for the localization.

## III. PRINCIPLES AND ALGORITHM DESCRIPTION

There are some significant difficulties that hinder the proper usage of the RSSI value used to indicate the distance between transmitter and receiver. One is the unstable Time vs. RSSI characteristics.

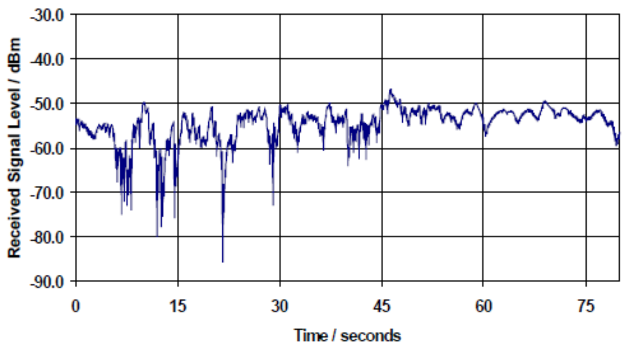


*Fig.4. RSSI time stability*

This disadvantage can be partially avoided by taking the mean RSSI value by multiple measuring in short time terms.

The second major problem is the nonlinear dependency of the RSSI vs. Distance and the huge tolerance that device produces. To convert the curve to a linear slope we use a simple mathematical operation of data converting. By this calculation the one problem that is still to be solved is the low frequency noise in the measured values. This is the reason to use the least square method for the core of a regression function that fits the dependency to a linear and makes it usable

$$A = \Sigma\left(y_i - \left(a.x_i + b\right)\right)^2 = \min \qquad (3)$$

where:

$$a = \frac{\sum x_i . \sum y_i - n.\sum x_i . y_i}{\left(\sum x_i\right)^2 - n\sum x_i^2} \qquad (4)$$

$$b = \frac{\sum x_i . \sum x_i . y_i - \sum y_i . \sum x_i^2}{\left(\sum x_i\right)^2 - n\sum x_i^2} \qquad (5)$$

By converting the data in this way we can finally use the specific data to determine the most linearity characteristic. Ones this is done the rest is most to refer to the IC's specifications.

Unfortunately the results produced from RSSI are significant unrepeatable, in other words if we have all RSSI values and the coordinates we are able to draw the dependency but it might not be the same next time. To avoid we need to have huge statistically collected data. Then we need to establish the most common linear dependencies seen from it. Including them into the system after first couple of measurements we would be able to decide which of the predefined dependencies to be used.

Having the linear dependency of the RSSI vs. Distance we could estimate the position with the maximum allowable accuracy of the IC using the main idea of the Weighted Centroid Localization:

$$P_i^{'}\left(x, y\right) = \frac{1}{n}\sum_{j=1}^{n} B_j\left(x, y\right) \qquad (6)$$

This equation uses only the node's spatial parameters (coordinates) and from this information extracts coordinates for the moving node. Such localization has low accuracy that is why more information is included in the equation below.

$$P_i^{''}\left(x, y\right) = \frac{\left(\sum_{j=1}^{b}\left(w_{ij} . B_j\left(x, y\right)\right)\right)}{\sum_{j=1}^{b} w_{ij}} \qquad (7)$$

The function $w_{ij}$ here is a distance dependant weight function.

More the nodes we use to build the network the better accuracy can be achieved in localizing the object. The localization on other way depends on the shape of the room and presence of moving or other objects that could impede the usable signal necessary for the localization. There are many sources of error during the whole process. The algorithm claims to avoid those mistakes during the estimation. This is achieved by statistics analysis. If RSSI loss suddenly occur while the smooth linear fading or rising was detected few iterations before it can be considered as hindrance object, the measurement is to be

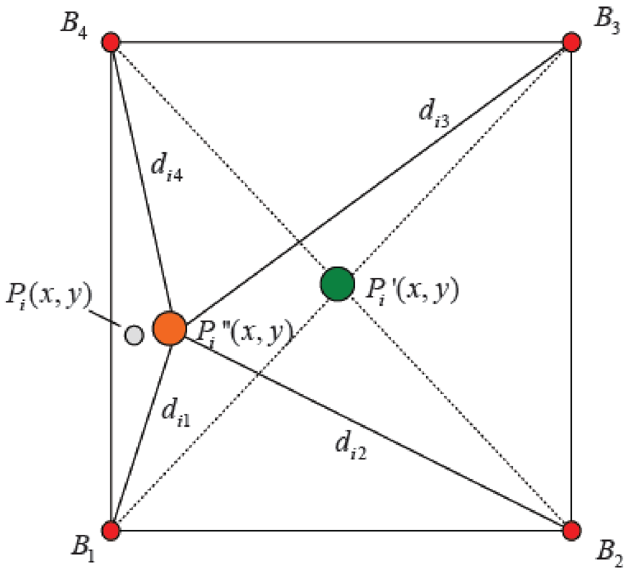


*Fig.5.Basic scheme of node position*

excluded and repeated after when the register value change. The method used to detect the node position referred to some predefined coordinates can be described by example of how the springs work. Thus the closer to the FFD is the node the stronger the signal is. Measuring the data from more than three statistic nodes could localize the moving node with high accuracy.

## IV. RESULTS

In this chapter some simulation results are shown. The data is software generated regarding to the mentioned above features of ZigBee devices. The dependency of the RSSI[dB] value vs. distance[m] is given with the chart below:

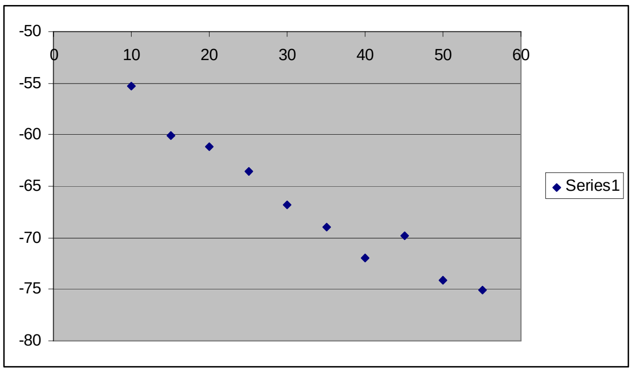


*Fig.6. RSSI vs.distance*

Extending this result statistic produces a high nonlinear curve. This non-linearity makes the results hard to work with due to this we need to convert them in a way to make them more comfortable for further usage. Converting of theses data gives the next step into the measuring and establishing.

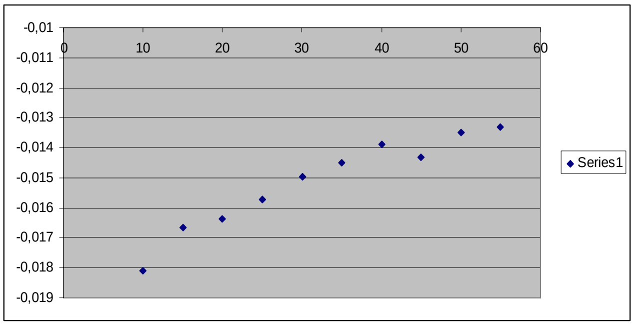


*Fig.7. Converted RSSI vs. distance results*

Now the results are increasing in way that is to be closer to linear but is still not what we aimed to. Here we start with the least squares method and extract the linear shape that would make the results usable to work with.

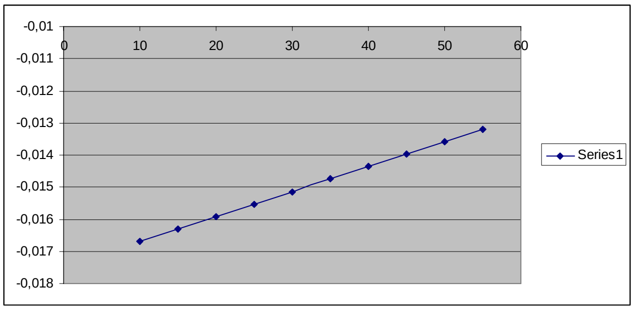


*Fig.8. Converted RSSI vs. distance to linear results*

## V. CONCLUSION

The accuracy given by the method of converting data as shown above and use of the Weighted Centroid Localization algorithm needs more investigations. It depends on many different components as specific characteristic of the ZigBee chip series used to build a particular device; the data result randomness; the antenna type and position are important as well. There is still much work to be done before we can tell the localization using ZigBee meets our expectations.

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