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SIMULATION AND ANALYSIS OF RSSI BASED TRILATERATION ALGORITHM FOR LOCALIZATION IN CONTIKI-OS

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Abstract

The recent progress in Wireless sensor networks is contributed by improvisation in research activities in the domain of embedded system and radio communication. Localization is one of the most important challenge in WSNs, in view of the fact that it plays a significant part in many applications, e.g., explore, catastrophe assistance, rescue operations, tracking the target and multiple tasks in smart milieus. Localization of node involves the activity of monitoring events, group discussion between the nearby sensors, routing the necessary information to the destination by keeping network coverage in check. In this research paper, Received Signal Strength Indicator (RSSI) based trilateration algorithm is proposed for localizing a blind node present in the network with minimal localization error. The position coordinates of the blind node is estimated based on the distance estimates and corresponding position coordinates of the anchor nodes present in the network. This work was performed in Contiki-OS with the help of built-in simulator COOJA. Based on the simulation results conducted with random position coordinates, the obtained localization error is found to be approximately 1.9 meters. The obtained error margin though not stringently accurate, but is acceptable, considering the environment in which the nodes are deployed which experiences varying channel characteristics, multipath fading and shadowing

Keywords:

Trilateration, Localization, Contiki OS, COOJA

1. INTRODUCTION

Recent advancements in the field of electronics have led to development of tiny battery powered devices capable of sensing and are termed as sensors. A sensor is a node which processes a physical parameter and converts it into a signal that can be interpreted by the end user. The input data are received by the sensor in WSN, it is stored, processed and the information is forwarded to other nodes. A Wireless Sensor Network (WSN) [1] [2] helps for monitoring environmental parameters such as temperature, pressure, humidity, vibration and sound by means of group of sensor nodes which are capable of handling themselves in a cooperative manner. The advancements in the field of WSN was enthused by military applications such as tracking and surveillance in battlefield and is now being used in many industrial and civilian applications, including inventory management, industrial process monitoring and control, health monitoring, habitat monitoring, home automation etc., [3]. Generally the sensors are posed in antagonistic environment. In such cases it is mandatory to compute their positions in fixed coordinate system [4]. Therefore it is of paramount importance to design efficient localization algorithms that resolve the position of nodes in a network [5]. A nodes location in the network can be decided by itself by receiving the information send periodically from the neighbouring nodes.

Our present work involves the usage of received signal strength indicator (RSSI) and trilateration algorithm for the purpose of localization of sensor nodes. Based on the transmit power, the propagation loss is calculated and the loss can be translated into distance estimate. The greater the distance of the receiver node, the lower is the signal strength. The signal strength is commonly measured in dBm (decibel in reference to one mill watt) or in watts. Theoretically, this signal strength decreases as the inverse of the squared distance, and a known radio propagation model can be used to convert the signal strength into distance. However, in real-world environments, this indication is highly influenced by noises, by obstacles, and by the type of the antenna, which makes it hard to be modelled by a mathematical formula. In these cases, it is normal to make a system calibration, where values of RSSI and distances are previously evaluated in a controlled environment. RSSI is a comparatively inexpensive solution than other devices without any extra devices. Hence, additional hardware is not necessary. RSSI value is quite easy to estimate. The distance estimates can also be obtained from the communication that is taking place in the network [2].

After obtaining the distance estimates, trilateration is performed in order to obtain the position coordinates of the unknown node. In trilateration, using the geometric nature of circles, spheres or triangles the absolute or relative locations of points is decided by the measurement of distances. If a point lies on two circles in two-dimensional geometry, then the centres of the circles and the two radii offer adequate information to slender the possible locations down to two. Auxiliary information may further narrow the potential down to one distinctive location [3].

The goal of the paper is to estimate the position coordinate of a blind node (a node which is unaware of its position) with the help of at least three anchor nodes by using RSSI based trilateration algorithm with an acceptable localization error. The anchor nodes are the nodes whose positions are already known. This work was performed in Contiki-OS with the help of built-in simulator COOJA. Contiki provides sensor network simulations through COOJA. It is a lightweight open source operating system (OS) coded in C for WSN [4].

The rest of the paper is ordered as follows. Section 2.0 gives a background on the work related to this research work. Section 3.0 presents the system overview and Section 4.0 explains the RSSI based trilateration algorithm. Section 5.0 describes the simulation environment and different parameters tested in order to obtain the simulation results. These results are presented in section 6.0. Finally, paper conclusions and ideas for future work are listed in Section 7.0.

2. RELATED WORK

Lots of works have already been reported in literature in the domain of localization. A number of techniques have been proposed to achieve the coordinate resolution of the blind node. But these methods have their own pros and cons. Diverse approaches for node localization in WSN have been proposed in [5]. The summary of the techniques proposed by different researchers for the improvement of localization in WSN were also presented. Potential research track and challenges for improving node localization in WSN were also discussed. Localization in wireless sensor networks is classified into two broad categories as centralized localizations and distributed localization.

Centralized localization is fundamentally immigration of inter-node ranging and data connectivity to the centrally controlled base station and then the relocation of resulting positions back to eradicate the predicament of computation in each node. The limitation lies in the communication cost incurred in moving the data back to the base station. In distributed localizations all the related computations are done by the sensors themselves and the sensors communicate among themselves to acquire their locations in the network. It can be further classified into six types. They are beacon-based distributed algorithms, relaxation-based distributed algorithms, coordinate system stitching based distributed algorithms, hybrid localization algorithms, interferometric ranging based localization and error propagation aware localization.

In [6], Oguejiofor et al. proposed trilateration based localization algorithm which is a distributed beacon-based localization algorithm. The method proposed by Oguejiofor et al. uses distance estimation to calculate the 2D position of sensors in the network. This estimation is done with the help of the communicating signal from the source node to the destination node. From the test bed analysis conducted by the authors, it is concluded that whenever the anchor nodes broadcast packets containing their positions and other events, the blind sensor can calculate approximately its distance to the anchor nodes, provided the blind sensor is within the broadcast range. If the blind sensor receives the broadcast packets from at least three anchors per venture, the blind sensor can localize its position.

In [7], M.O. Farooq and T. Kunz presented a study on the contemporary WSN Operating Systems (OS). The rationale behind this review was to emphasize major apprehensions pertaining to OS design in WSNs. The OS for WSNs has been viewed in terms of the architecture of OS, memory management, communication protocols, programming model, resource allocation and sharing, scheduling, support for real-time and non-real-time applications etc., Design strategies for varied components of a WSN-OS have been elucidated in the paper, along with the corresponding advantages and disadvantages. Prospective application domains of different WSN OSs that would assist the network and application designer have been pointed out.

Contiki OS is a portable OS modelled particularly for energy constrained devices. COOJA Simulator is a new sensor network simulator for the Contiki OS. Contiki OS supports pre-emptive multithreading at a per process basis and is built around an event driven kernel. In Contiki OS any simulated application can then be run on a real sensor node unaltered [8] [9].

3. SYSTEM OVERVIEW

This system aims to estimate the position coordinate of a blind node with the help of at least three anchor nodes by using RSSI based trilateration algorithm with an acceptable localization error. The anchor nodes are the nodes whose positions are already known. RSSI measures the signal power at the receiver. Based on the transmit power, the propagation loss is calculated and the loss can be translated into distance estimate. Trilateration technique helps to figure out the centre point with the help of meeting point of three spheres. Similarly, the position of blind node can be obtained by means of meeting point of 3 anchor nodes surrounded by circles for which the distance and position is already known.

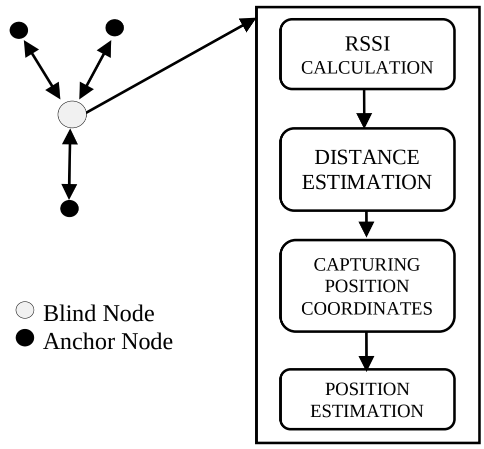

Fig.1. System Architecture

The Fig.1 describes about the system architecture. This architecture involves four steps. First, the blind node calculates RSSI values from at least three neighbouring anchor nodes based on the packets received from them. The RSSI values are obtained by using CC2420 radio transceiver that is fitted in all the sensor nodes. The RSSI register helps to reveal the packet signal strength which comes along with CC2420 radio. Background noise is generated in the absence of transmission. Secondly, based on the RSSI value, the blind node estimates the distance from the three anchor nodes. However, the problem in reality is that the distance estimations are never perfect and it keeps on varying for each and every environment the node is deployed in. Hence, for the simplification purpose, a random position coordinates are chosen by keeping RSSI value in mind and the distance estimate is calculated based on distance formula by keeping the source node at the origin. Now, the obtained distance estimate is mapped with the corresponding RSSI value.

After obtaining the distance of three anchor nodes, its respective positions are captured by the blind node. By knowing the distance estimate and position of three anchor nodes, the blind node performs trilateration algorithm for estimating its position estimates. The trilateration algorithm performs translation and rotation method for the calculation purpose. This work is performed in Contiki-OS with the built-in simulator COOJA.

4. RSSI BASED TRILATERATION ALGORITHM

The RSSI based trilateration algorithm is used for finding the position coordinates of the blind node. The algorithm involves 2 steps, viz., Distance Estimation and Position Estimation

4.1 DISTANCE ESTIMATION

The distance estimation involves calculation of RSSI values from the anchor nodes and based on that value, the corresponding distance estimate is calculated by the blind node. The RSSI values are obtained by using CC2420 radio transceiver that is fitted in all the sensor nodes. The mathematical formulation is given as follows:

$$\text{RSS} = \text{RSS\_VAL} + \text{RSS\_OFFSET [dBm]} \quad (1)$$

where, RSS_OFFSET is approximately -45 and RSS_VAL is the power received by the CC2420 radio transceiver [10]. Using RSSI value, the distance estimation is done as follows. Assuming that the transmission power P_{tx}, the path loss model, and the path loss coefficient α are known, the receiver can use the received signal strength P_{rcvd} to solve for the distance d in a path loss equation like,

$$d = ((C \times P_{tx}) / P_{rcvd})\wedge \alpha. \quad (2)$$

4.2 POSITION ESTIMATION

The position estimation involves the process of obtaining the position of respective anchor nodes and with the help of its corresponding distance estimates; the position of blind node can be calculated. The function node_loc_x and node_loc_y helps to find the position of anchor nodes. It gives the functionality like having GPS on node and can access their location information to send to other node.

The Position estimation is done using trilateration algorithm. The Fig.2 depicts the flow chart of trilateration algorithm.

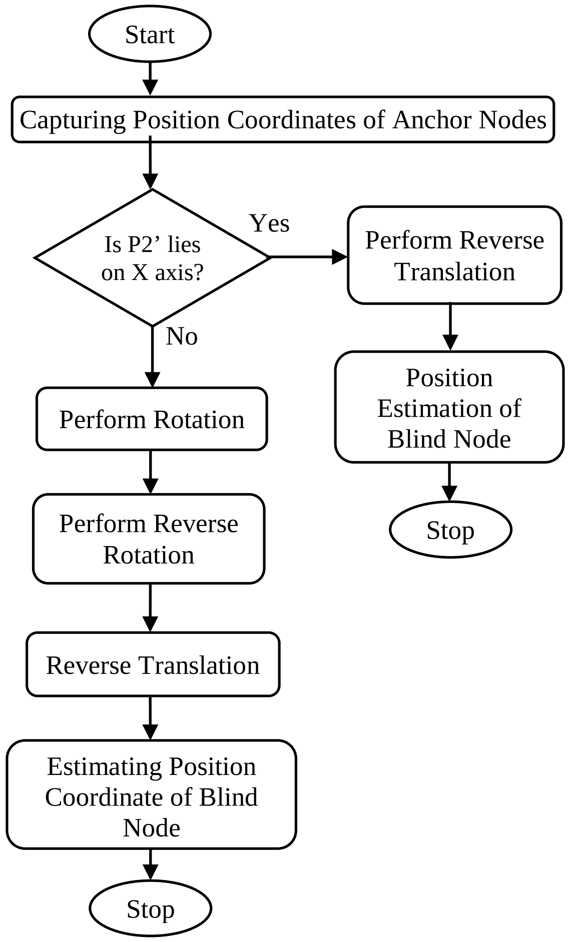

Fig.2. Trilateration Algorithm

5. SIMULATION ENVIRONMENT

Simulations were performed using Contiki-OS v-2.7 and emulated sky motes. The proposed algorithm was simulated in Contiki's built-in simulator COOJA. The environment is set to unit disk graph medium (UDGM): distance loss for the deployment of sky motes in the network. Upto four nodes were deployed for the purpose of simulation that includes a blind node (also called as sink node) and three anchor nodes. The transmission range and interference range is set to 50 and 100 meter respectively. Enable viewing of actual positions of deployed nodes in the network in order to compare with the estimated position obtained in the mote output area. The deployed anchor nodes should be within the transmission range of the blind node in order to enable transmission of packets.

The simulation was conducted with random position coordinates of the anchor nodes and the resulting actual and estimated position coordinates of the blind node is noted down. Based on the readings obtained, the localization error can be calculated as follows.

$$\text{Localization Error} = ((x_2\text{-}x_1)^2 - (y_2\text{-}y_1)^2) \wedge 0.5 \quad (3)$$

where, (x_1,y_1) and (x_2,y_2) are the actual and estimated position coordinates of the blind node respectively. The simulation was repeated for more than 100 times and the obtained readings were tabulated. The overall localization error was obtained by finding the average of all the list of obtained localization error during the simulation.

6. RESULTS AND ANALYSIS

In this section, we show the results of the performance of the RSSI based trilateration algorithm in networks obtained from the simulation performed using the COOJA simulator. The parameter observed is the localization error. Consider the position coordinates of the deployed 3 anchor nodes as node 2 (35, 32), node3 (18, 73) and node 4 (68, 65). Node 1 is designated as the blind (sink) node and its actual position coordinate is node1 (42, 51).

The steps involved in RSSI based trilateration algorithm are shown in sequence of snapshots taken during the simulation. The Fig.3 presents the capturing of RSSI values and distance estimation. The anchor nodes send packets to the blind node and based on the power of the signal at the receiver, the blind node calculates the RSSI values of the respective anchor nodes. Based on the RSSI value, the corresponding distance of anchor nodes are estimated by the blind node. Here, in this case, the RSSI and the distance estimate of anchor node 2 as read by the blind node is given as - 44 and 20 meter respectively.

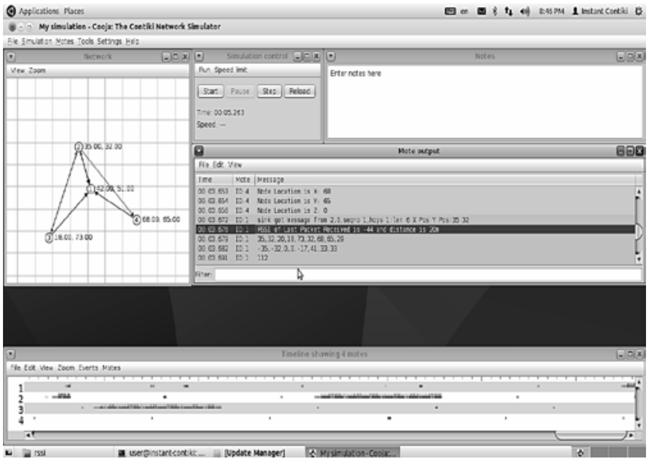

Fig.3. RSSI and distance estimation

The Fig.4 shows obtaining of anchor nodes position by the blind node. For calculating the position coordinates of blind node, apart from distance estimates of the anchor nodes, its corresponding position coordinates are needed. The position coordinates of the anchor nodes are sent to the blind node. From the above example, the location of anchor nodes 2, 3 and 4 as displayed by the Mote output window; as shown as (35, 32, 0), (18, 73, 0) and (68, 65, 0) respectively.

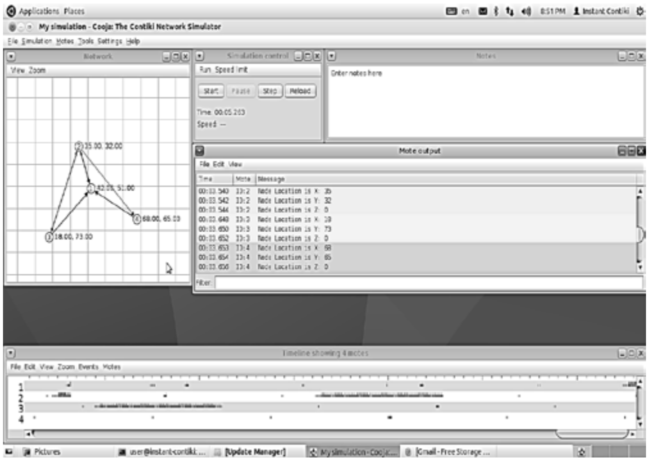

Fig.4. Obtaining anchor nodes position

The Fig.5 depicts the position estimation of the blind node. The position estimation is performed using trilateration. It can be done by knowing the position coordinates and corresponding distance estimates of the anchor nodes. From the above example, the blind node's position is estimated to be (42, 50). While, in comparison with the actual position i.e. (42, 51), the localization error is found to be approximately 1 meter.

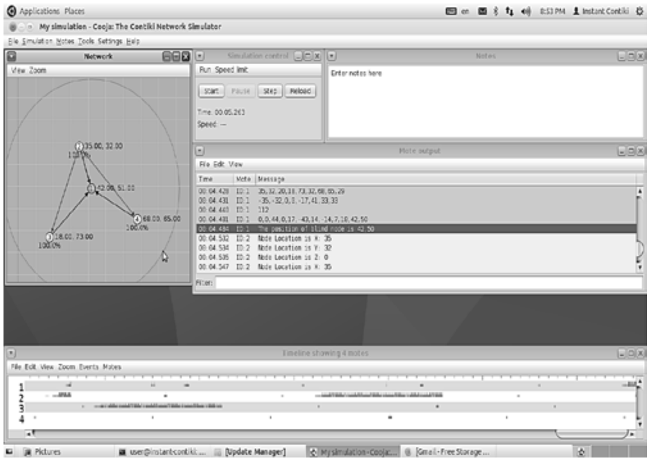

Fig.5. Position estimation

The simulation was repeated for over 100 rounds with random position coordinates and localization error was calculated for each round and tabulated. The overall localization error obtained through this experiment was found to be 1.9 meters. The obtained error margin is not accurate enough. But, considering the environment in which the nodes are deployed which experiences varying channel characteristics, multipath fading and shadowing, the obtained localization error is acceptable. Simulations of twenty rounds are shown in the tabulation for understanding purpose.

Table.1 Localization Error Calculation

Simulation	**Position Coordinates**		
Round	**Actual**	**Estimated**	**Localization Error (m)**
1	(39,43)	(40,53)	1
2	(54,29)	(55,29)	1
3	(73,52)	(72,53)	1.414
4	(31,33)	(33,34)	2.236
5	(90,27)	(91,29)	2.236
6	(58,33)	(58,35)	2
7	(109,109)	(108,108)	1.414
8	(83,107)	(83,104)	3
9	(43,50)	(44,49)	1.41
10	(3,96)	(7,94)	4.47
11	(26,51)	(27,50)	1.41
12	(10,80)	(12,77)	3.6
13	(32,81)	(32,79)	2
14	(60,86)	(59,83)	3.16
15	(55,60)	(54,59)	1.41
16	(49,42)	(50,43)	1.41
17	(67,49)	(67,47)	2
18	(107,47)	(108,46)	1.41
19	(88,84)	(88,85)	1
20	(61,74)	(63,74)	2

The variation in error is due to varying channel conditions in wireless environment.

7. CONCLUSION AND FUTURE WORK

A RSSI based trilateration algorithm was developed for the purpose of estimating the position coordinates of the blind node based on the distance estimate and position coordinates of the anchor nodes deployed in the network. This work was performed in Contiki-OS with the help of built-in simulator COOJA. Based on the simulation results obtained, the overall localization error was approximately found to be 1.9 meters. The obtained error margin is not accurate enough. But, considering the environment in which the nodes are deployed which experiences varying channel characteristics, multipath fading and shadowing, the obtained localization error is acceptable. This work can be further extended in the future by improving the positional accuracy of blind node by considering distance measurements from more than three anchor nodes, resulting in using multilateration method. The positional accuracy of a sensor node heavily depends on the accuracy of the distance estimation based on the RSSI value. Since RSSI values does not remain constant even when sender and receiver node does not move, hence for improving the accuracy of distance estimation, RSSI values are taken continuously for extended period and averaged out to obtain a good distance estimate resulting in improving the positional accuracy of the blind node.

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