Localization of Sensors by Base Station in Wireless Sensor Networks

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Sensors in a Wireless Sensor Network are typically deployed at random. In order to establish the network, the position of the sensors is required to be localized. Once this activity is complete, a routing algorithm is used to establish the network. Whilst many methods have been contemplated in the past, this paper presents a method to find the exact location of sensors using Received Signal Strength Indicator (RSSI) values coupled with triangulation techniques. Further, these computations can be undertaken by the base station thereby reducing considerable energy and computational overheads for an otherwise resource hungry wireless sensor network.

Keywords: WSN, Sensor Localization, Triangulation Technique, Energy Consumption Reduction

Introduction

Wireless Sensor Networks are one of the emerging computing technologies which have displayed maximum research potential and are now gradually inching from the concept stage and lab trials into to a practical and commercially viable reality. An application field of inhospitable environs like underground mines1 is what has been chosen as the forerunner in the Wireless Sensor Networks applications. Wireless Sensor platforms are now equipped with a variety of environmental monitoring sensors for acoustic sensing, temperature sensing, pressure sensing, humidity measurements and also lately video capture. Newer applications include long term monitoring of undersea coral reefs2, Cardiac applications3 and wireless filter monitoring system for compressed air4. As the data increases, the capturing and transmitting of it becomes complex. So the sensors must be capable of retaining the energy, transmitting the voluminous and complex data, and must logically decide the optimal path or route for data exchange. Optimal deployment of sensors, their routing, data fidelity and integrity with energy conservation to maximize network life thus become the key research areas.

Methods of localization

Localization is the process of identifying the position of the deployed sensors in the Region of Interest (ROI) so as to establish a routing algorithm. Use of Global Positioning System (GPS) is not a very useful approach in WSNs where the number of sensors are large and rather than absolute position, the relative position with respect to a reference within or outside the network is of interest. Research in localization can be broadly categorized in two techniques namely the range based localization and range-free localization. The range based techniques use radio signal strength, triangulation and trilateration to estimate the position of the node. In range free system, the nodes are aware if the nodes in the vicinity, their approximate physical range and location estimate. This system typically does not rely on radio signal strengths and do not require the hardware for the same. This paper concentrates on the range free localization. In range free schemes some of the nodes are aware of their positional data. Such nodes are termed as anchors while the rest are called as normal nodes. Anchors are static while the normal nodes may be static or dynamic. The normal nodes acquire the positional information of the anchor nodes and then compute their own positions with the anchors. This process involves no exchange of ranging information and hence relatively low cost sensors can be utilized to establish the network. The environment also is not able to disturb the connectivity information between the nodes which make such a network more robust compared to the range based scheme. In5, a heterogeneous network is considered which contains the nodes with the well-known location information. Here, the anchors beacon their position to the neighbors. The neighbors keep

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track of the received beacons. A simple centroid model is used to approximate the listening nodes location with the help of the proximity information. This protocol is referred as centroid algorithm\textsuperscript{6,7} make the anchors flood their location information to the network rather than utilizing single hop broadcasts. A running hop count is maintained at each node along the way of the broadcast. Nodes compute their location based on hop count and average distance per hop from a particular anchor. The authors term this method as DV-Hop. A similar algorithm, Amorphous Positioning algorithm uses offline hop-distance estimates, improving location estimations through the neighbor information exchange.

The author has also proposed the coordinate system with the available local information for ad hoc sensor networks\textsuperscript{8}. Mobile Anchor Positioning uses a scheme where anchor nodes are used for localization of sensor nodes without using additional hardware\textsuperscript{9}. Annealing –Differential Evolution with Mobile Anchor Positioning approach proposed by\textsuperscript{9} is also quite promising towards improving localization accuracy. Range free localization using fuzzy logic\textsuperscript{10} is another approach to optimize the localization problem. The anchor positioning (APIT)\textsuperscript{11} scheme is proposed, which is optimal in an environment having irregular radio patterns and random node placement. The method also has a low communication overhead. Variety of application scenarios have been checked also with focus on error handling and trapping. The results illustrate that the range-free schemes are suitable to support the various applications in field of wireless sensor networks and they are accurate with a slight degradation in performance.

**Proposed methodology**

Once the sensors are deployed, to establish a network the initial action is to find out the positions of these sensors. This activity is called localization. In order to make the measured data significant, finding the location of the sensor nodes is crucial. In the present study have been undertaken using simulations. The sensors were deployed randomly in the ROI. The sensors have been assumed to have fully charged battery and all the sensors are assumed to have the same battery capacity. The rate of change of Received Signal Strength Indicator (RSSI) vs distance is also assumed to be identical for all the sensors. The changes in the RSSI values with distance is measured by the real mote Figure 1. The base station is connected to the laptop which receives the data from the other mote. For the experiment, the position of the sender mote is changed in a range from one to fifty meters. This experiment is done in outdoor and the nesC programming in TOSSIM with the real sensors Figure 2.The change in the RSSI with distance is shown in Figure 3. The sensors as soon as they are deployed transmit their identity as beacons. All the nodes are programmed to aggregate the RSSI value for the nodes from which they are receiving transmission in a Table 1. The Table 1 has node name and the corresponding RSSI value. This activity will cease within 10 seconds of deployment and all the sensors will then become passive listeners. The data aggregated in the 10 seconds duration will be stored in the memory of the sensors. Once the base station receives information on all the nodes, localization
The algorithm is run to finalize the positions of all nodes. The positions are estimated based on mapping the sensors based on their relative RSSI values from other sensors which can be solved as simple algebraic equations. The Algorithm 1 used for the location of the sensors. The base station then identifies the clusters and cluster heads based on predefined algorithm and transmits this information back to all the nodes through the clusters.

Algorithm 1: Get Location - GETLOC( )

- Input : Distance based on RSSI
- Output: location of a node

1. Get the distance between the nodes based on RSSI values
2. Form the equations based on the distance
3. Define origin
4. Solving the equations to find the location
5. Calculate the values of the location of nodes
6. Return

The energy consumption would be minimum for localization and clustering as the sensors will be active only for the initial phase of 10 seconds and then only when the beacon message is received from the nodes, the sensors again go into active transmission. The process also enables the clustering/selection of clusterhead activity to be undertaken by the base station thereby reducing this overload from the sensor nodes. Complex algorithms can also be employed at the base station where abundant computation capability is available.

Results

The approach used for localizing the sensor mote uses a simple calculation for solving the equations. The memory requirement of this approach is comparatively less as it does not include complex calculations or requirement of the previous readings. The Average Location Error (ALE) is calculated as shown in equation one.

\[
ALE = \frac{\sum\sqrt{(X_{cal} - X_r)^2 + (Y_{cal} - Y_r)^2}}{N}
\]  

The ALE is calculated as difference of calculated values of X and Y location as \( X_{cal} \) & \( Y_{cal} \) with the real values \( X_r \) and \( Y_r \) divided by the total number of sensors nodes as N. Figure 4 shows the graph of the ALE (m) Vs the number of sensors nodes of the proposed method vis a vis other methods. The method proposed in the paper removes a considerable computational overhead from the sensors. The entire localization and subsequent actions like routing, identification of cluster heads etc. is now undertaken by the base station which is assumed to have sufficient energy and computational resources. Further as can be seen from Figure 4 the ALE has reduced for the proposed method.

Conclusions

The paper presents a simplistic method of localization of sensors using a novel method in which the base station aggregates the RSSI values of all sensors as soon as they are deployed. The base station maps the sensors on the geographical area and also undertakes clustering and cluster head selection. This would considerably reduce the energy as well as computation overhead of the individual sensors. A real time and a considerably advanced and complex control on routing and fault tolerance can be executed through the base station. Extremely complex algorithms also can be executed at the base station. Real time connectivity to a remote location through a cloud backbone also can be established.
References