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# Recursive and ad hoc routing based localization in wireless sensor networks

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ABSTRACT

We consider wireless nodes connected in an ad hoc network where recursion based localization is available and ad hoc routing is deployed. We are interested in studying the possibility to use ad hoc routing to help a mobile (sensor) node in a dense/sparse wireless network to estimate its position by first finding the closest two or three ad hoc reference nodes that are already known their positions then use the position value of the found reference nodes and add the estimated distance using the hop counts of the ad hoc routing to find the estimated position. Our protocol will control which are the nodes that will have to calculate their position using the recursive approach in order to serve as reference points to other nodes in the network. Our proposed algorithm basically includes the improved version of the OLSR protocol mostly about the MPR decision and utilization topics by introducing supplemental selection criteria which are also significant for the localization process. Besides, the first part of the localization is performed with this modified version but at the continuation part, two schemas are used: DV-hop and DV-distance. These two schemas are used in two ways, after finding three anchors to find the position of the related node and if three of the anchors could not be collected then in case of finding anchors. Furthermore, the localized node whose position is detected also assigned as an anchor node in the network. Additionally, we compare our schemas with a recursive position estimation (RPE) algorithm about density, position error and reference point numbers. And t-test is performed in our study for the reference points–densities with p-value of 0.05.



## 1. Introduction

Development in wireless communication technology leads Wireless Sensor Networks (WSNs) to be more accessible for many applications. Meanwhile, localization is an important aspect in WSNs, especially in routing protocol design. For some applications, the localization of a sensor that collects data is as notable as the data itself. In this case, the data must be gathered together with its location information. For this reason, the sensor node should know its own place to be able to determine the exact place of the recovered data. Battlegrounds and catastrophic areas are the most considerable examples of localization needing environments. To be able to examine and monitor an area for different aims, initially, sensors should be positioned. In WSNs, the sensors are positioned in two ways, manually or randomly. In manual sensor node localization, the sensor positions are exactly known. But at the scarped and wild environments, it is difficult to place and measure a sensor manually. Similarly, if a sensor node incorporates global positioning system (GPS) receivers, its exact position is also known but GPS nodes cannot detect and give optimum results in some situations like indoor areas and urban places also these sensors need costly equipments. Therefore, vast networks that contain thousands of nodes, prefer a definite number of nodes to be equipped with GPS. In this case, it is preferred to place sensors as randomly scattering over the related area, thus, areas which are difficult to be reached, can be accessed and discovered easily. The localization procedure's basic steps are; firstly, finding the distance between the unknown node and other (2 or 3 discovered/anchor) nodes. Then, computing the exact coordinates of the unknown node by using these discovered distances. During this procedure, the nodes do not try to discover their location by themselves. In the network, some of the nodes already have their own location information, these nodes are known as anchor nodes and they are used by unknown nodes to discover their positions. In WSNs, information flows occur in a hop by hop manner, thus the distance computation between the unknown node and the anchor is a remarkable problem. For this reason, to accomplish these steps WSN algorithms and protocols that are suitable for multihop network structure should be used [1,2].

One-hop approach is used in WSNs for solving localization problem. In WSNs, nodes with GPS receivers, cooperate with satellites in a one-hop manner. Owing to the high cost of GPS equipments, only some of the nodes, named as anchor nodes are equipped with GPS receivers. The anchor nodes know their locations and they are used to help other 'unknown' nodes to find their locations. To design a low cost network, anchors are scattered as seldom in an area. By using one-hop

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away anchors, effective distance estimation results may not be calculated or with the seldomly scattered anchors, the unknown nodes may not find enough number of anchors between their one-hop neighbors. Therefore, localization with multi-hop attracts great attention recently. Finding distances between anchors and the unknown node that are multiple-hops away from each other is one of the most active research topics in the literature [3].

In this context, researchers focus on most popular and rapidly developing wireless technologies; Wireless Local Area Network (WLAN), Cellular networks, Radio Frequency Identification (RFID) and Wireless Sensor/Actuator Network (WSAN) and they explore potential interactions among them in order to enhance the performance of the indoor localization and mobility management tasks, because both of them will have importance in the future ubiquitous environments. Outdoor positioning systems have proven their potential in the wide range of commercial applications, but to provide successful indoor localization systems more time will be needed, because of the harsh indoor characteristics and requirement for higher accuracy. Also, mobility management in the future heterogeneous wireless networks is much more challenging than in traditional homogeneous networks [4].

In addition to environmental and military applications, mobility in WSNs and localization gain great attention in many areas as in commercial and civil areas. In commercial areas, service robots are designed for nursing at home, providing security at buildings or offices and also servicing in hotels and restaurants for helping community. The main part of the software design of these robots is the localization of their position permanently. Also there are many robot applications for housekeeping for instance, vacuum cleaner robot forms a map of the room with the help of the sensors to be able to traverse the whole room. In civil usage area, there are pothole detectors for streets which are mounted on cars. And as another example, there is a wireless E91 which is the advanced 911 emergency service, when the service is called, the position of the caller is determined with different localization techniques [5–8].

In the literature, localization algorithms are proposed with many titles like centralized/distributed, one hop/multihop and range based/range free methods. Most familiar of them are multihop, DV-hop and DV-distance methods. In DV-hop method, the number of hops are found between all of the nodes and anchors in the network because it is a hop-by-hop method for localization. The nodes share their tables' information with their neighbors. When an anchor receives information from another anchor, it can estimate the correction value which is one hop average distance. The correction value is used by the nodes to find their distances with the anchors. The other well known algorithm is DV-distance. In DV-distance algorithm, estimated ranges between neighbors are used for finding the distance between the node and an anchor. By using these estimated ranges, the node may estimate the Euclidean distance to a farther anchor in the multihop structure. DV-distance method produces better results with the increasing number of nodes in the network. Eventually, in the DV-distance method, the radio signal strength is used to discover the distances between neighbor nodes for more delicate results than DV-hop method [9]. In single hop, the nodes find their positions by directly corresponding with anchor nodes between their neighbors. RADAR, Cricket and SpotON are the examples of a single hop localization technique [10–12].

Furthermore, mobile ad-hoc protocols are examined under three categories: proactive, reactive and hybrid. In proactive routing protocols, the changing topology should cope with permanently varying already known routes and in addition to known routes, new routes are found and updated. Because of these updates, bandwidth is wasted. The well known proactive routing protocols are Optimized Link-State Routing (OLSR) and Destination Sequenced Distance Vector (DSDV). In our study we utilized the OLSR protocol. In the OLSR, in addition to the basic proactive routing protocol structure, its most remarkable diversity is about its topology construction and message flow usage. For instance, for update procedure of topology, periodic messages are sent to definite neighbors in the network instead of sending to the whole neighbors around [13–16].

The rest of the paper is organized as follows. In Section 2, the utilized localization techniques are given. In Section 3, constructed system architecture is presented together with the examined and developed protocol structure. In Section 4, we detailed our study with the proposed algorithm. Section 5, includes our performance evaluation with presented solutions. Eventually, in the last section, the conclusion with final remarks is given.

## 2. Multi-hop localization techniques

### 2.1. DV-hop algorithm

In localization with connectivity based DV-hop, initially distance is estimated then by the help of the estimated distances, location is estimated. Distance estimation of a sensor node to every anchor is performed over a multi-hop connection. Next, by the multilateration technique, the sensor node decides its location by using estimated multihop distances. The multi-hop distance estimation of anchors and the sensor node is provided by multiplication of the minimum hop count and the average hop distance [17].

To collect the minimum hop count between anchor nodes and sensor nodes, the data that includes anchor nodes' position information is broadcasted with controlled flooding to the sensor nodes. So, the sensor node gathers the coordinates of each anchor node together with a variable that implies the number of hops from the broadcasting anchor to the arriving sensor node.

The gathered hop count data is stored by the sensor node and exchanged in between the neighbors of sensor nodes as position messages. Thus, with the position message, an anchor node estimates the average distance for a single hop. The average distance is computed as follows.

$$AvgDistance_i = \frac{\sum_{j=1,j\neq i}^{M}\sqrt{\left(x_i-x_j\right)^2+\left(y_i-y_j\right)^2}}{\sum_{j=1,j\neq i}^{M}h_{ij}} \tag{1}$$

where, $(x_i, y_i)$ and $(x_j\ , y_j)$ are the locations of anchor $i$ and anchor $j$ identifies the number of anchors, $h_{ij}$ is the hop count of $i$ and $j$.

In the network, an anchor node broadcasts its average distance to sensor nodes and other anchor nodes. And the sensor node uses the broadcasted average distance data to compute its estimation distance with the anchor node by multiplying it with the total number of hops for every anchor node using Eq. (2) that is given as

$$d_j = AvgDistance_i \times h_j. \tag{2}$$

Eventually, unknown sensor node's position is computed with triangulation or multilateration equations [18,19]. DV-hop is restricted to the geometric circumstances of anchor nodes, thus it is a kind of an anchor node based localization algorithm [20].

### 2.2. DV-distance algorithm

Another well known localization algorithm is DV-distance algorithm. In DV-distance positioning algorithm, anchor nodes broadcast to the whole network their location information that includes the anchor's position, node ID and RSSI. Then with utilizing the RSSI model, the distance from the adjacent nodes is computed by the nodes, thus they count the cumulative distance. Next, a correction factor is computed with the true distance between anchor nodes, when an anchor node receives the cumulative distance to other anchor nodes.