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An Optimized Cluster Based Localization in Wireless Sensor Networks

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Abstract: Localization in Wireless Sensor Network (WSN) plays a vital role in applications such as military, medical, healthcare, civil and environmental applications etc. Since all the sensor nodes in wireless sensor network are battery powered it is highly required to effectively utilize the sensor nodes in such a way that the lifetime of WSN is higher. Due to the limited availability of battery power in sensor nodes, energy consumption, computation speedup and memory consumption of localization algorithms are to be considered. In this study, a novel Cluster Based approach (CB-TriL) for locating the nodes in WSN is discussed. The proposed approach is energy efficient in nature and high level of accuracy is obtained when compared with other localization techniques.

Key words: WSN, sensor, lifetime, cluster, energy

INTRODUCTION

A wireless sensor network is a group of specializedtransducers with a communications infrastructure for monitoring and recording conditions at diverse locations. Commonly monitored parameters are temperature, humidity, pressure wind direction and speed, illumination intensity, vibration intensity, sound intensity, power-line voltage, chemical concentrations, pollutant levels and vital body functions. A sensor network consists of multiple detection stations called sensor nodes, each of which is small, lightweight and portable. Every sensor node is equipped with a transducer, microcomputer, transceiverand power source. The transducer generates electrical signals based on sensed physical effects and phenomena. The microcomputer processes and stores the sensor output. The transceiver receives commands from a central computer and transmits data to that computer. The power for each sensor node is derived from a battery (Fig. 1).

Wireless sensor networks are:

- Self-configuration, Self-healing, Self-optimization and Self-protection capabilities
- Short-range broadcast communication and multi-hop routing
- Dense deployment and cooperative effort of sensor nodes
- Frequently changing topology due to fading and node failures
- Severe limitations in energy capacity, computing power, memory and transmit power

Localization: Localization determines the physical coordinates of a group of sensor nodes. These coordinates can be global, meaning they are aligned with some externally meaningful system like GPS or relative, meaning that they are an arbitrary “rigid transformation” (rotation, reflection, translation) away from the global coordinate system.

Beacon nodes (also called anchor nodes) are a necessary prerequisite to localize a network in a global coordinate system. Beacon nodes are simply ordinary sensor nodes that know their global coordinates a priori. This knowledge could be hard coded or acquired through some additional hardware like a GPS receiver. At a minimum, three non-collinear beacon nodes are required to define a global coordinate system in two dimensions. If three dimensional coordinates are required, then at least four non-coplanar beacons must be present.

Localization accuracy improves if beacons are placed in a convex hull around the network. By planning beacon layout in the network real improvements in localization can be obtained. The presence of several prelocalized nodes can greatly simplify the task of assigning coordinates to ordinary nodes. But the disadvantage is GPS receivers are expensive. GPS receivers also consume significant battery power which can be a problem for power-constrained sensor nodes. Localization algorithms in wireless sensor network contain three main phases:

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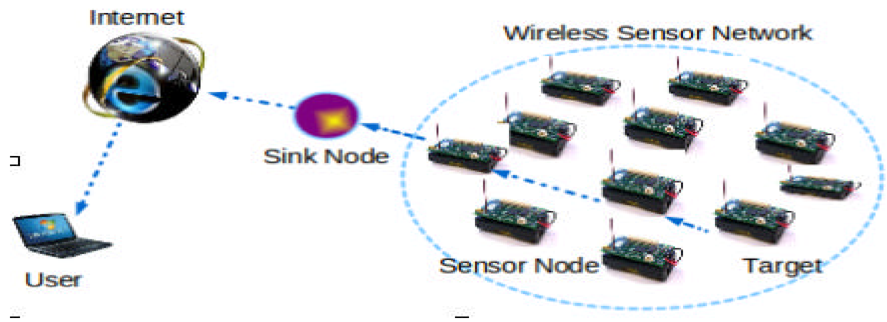

Fig. 1: Illustration of wireless sensor networks

- Distance estimation involves measurement techniques to estimate the relative distance between the nodes
- Position computation consists of algorithms to calculate the coordinates of the unknown node with respect to the known anchor nodes or other neighboring nodes
- Localization algorithm determines how the information concerning distances and positions is manipulated in order to allow most or all of the nodes of a WSN to estimate their position

There are four common methods used in distance estimation technique. They are:

- Angle of Arrival (AoA)-evaluates the relative angles between received radio signals
- Time of Arrival (ToA)-estimates distances between two nodes using time based measures
- Time Difference of Arrival (TDoA)-determines the distance between a mobile station and nearby synchronized base station
- Received Signal Strength Indicator (RSSI)-translates signal strength into distance

Position computation includes the following techniques:

- Lateration-based on the precise measurements to three non collinear anchors. Lateration with more than three anchors called multilateration
- Angulation (or triangulation)-based on information about angles instead of distance

Localization algorithms can be classified into several categories such as:

- Centralized vs distributed
- Anchor-free Vs anchor-based
- Range-free Vs range-based
- Mobile Vs stationary involves

Table 1: Techniques used by range-free and range-based method

Method	Techniques used
Range-free	Local techniques
	Hop-counting techniques
Range-based	Received Signal Strength Indicator (RSSI)
	Time of Arrival (ToA)
	Time Difference of Arrival (TDoA)
	Angle of Arrival (AoA)

The following Table 1 shows the techniques used by range-free and range-based methods.

Clustering: Clustering is the process of grouping physical or abstract objects into classes of similar objects. Cluster is a collection of data objects that are similar to one another within the same cluster and dissimilar to the objects in other clusters. Cluster analysis is the process of finding similarities between data according to the characteristics found in the data and grouping similar data objects into clusters. It is an unsupervised learning method because no predefined classes are used for clustering. Cluster analysis is performed with the help of the following considerations:

- Partitioning criteria
- Separation of clusters
- Similarity measure
- Clustering space

Some of the major clustering approaches are:

Partitioning approach:
- Construct various partitions and then evaluate them by some criterion
- Partition a database D of n objects into a set of k clusters such that the sum of squared distances is minimized
- Typical methods include k-means, k-medoids, CLARANS

Hierarchical approach:
- Create a hierarchical decomposition of the set of data (or objects) using some criterion

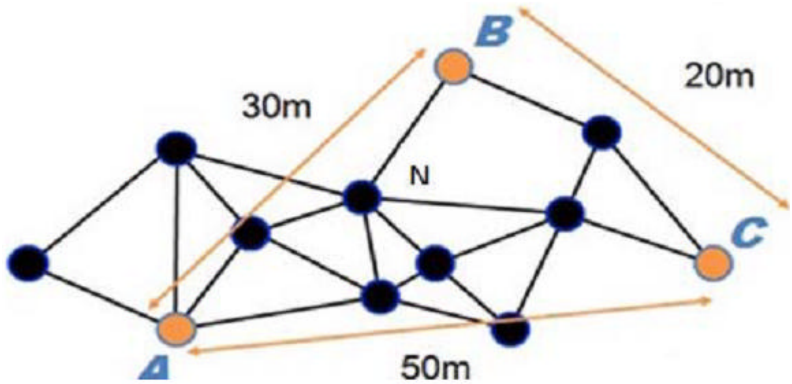

Fig. 2: Network containing 3 beacons

- Use distance matrix as clustering criteria. This method does not require the number of clusters k as an input but needs a termination condition
- Typical methods include Diana, Agnes, BIRCH, CAMELEON

Density-based approach:
- Based on connectivity and density functions
- Typical methods include DBSACN, OPTICS, DenClue

Grid-based approach:
- Based on a multiple-level granularity structure
- Typical methods include STING, WaveCluster, CLIQUE

In general, the number of clusters: k ˜vn/2 for a dataset of n points. Three kinds of measures: External, internal and relative are used to measure the quality of clustering.

External:
- Supervised, employ criteria not inherent to the dataset
- Compare a clustering against prior or expert-specified knowledge using certain clustering quality measure

Internal:
- Unsupervised, criteria derived from data itself
- Evaluate the goodness of a clustering by considering how well the clusters are separated and how compact the clusters are, e.g., Silhouette coefficient

Relative:
- Directly compare different clusterings, usually those obtained via different parameter settings for the same algorithm

HOP algorithm: Initially, each beacon node broadcasts a beacon to be flooded throughout the network containing the beacons location with a hop-count value initialized to one. Each receiving node maintains the minimum hop-count value per beacon of all beacons it receives. Beacons with higher hop-count values to a particular anchor are defined as stale information and will be ignored. Then those not stale beacons are flooded outward with hop-count values incremented at every intermediate hop. Through this mechanism, all nodes in the network get the minimal hop count to every beacon node.

Then, once a beacon gets hop-count value to other beacons it estimates an average size for one hop which is then flooded to the entire network. After receiving hop-size, blindfolded nodes multiply the hop-size by the hop-count value to derive the physical distance to the beacon. Figure 2 explains DV-Hop algorithm. In this Fig. 2a-c are beacons. Actual distance between beacons is also mentioned. The beacons calculate the average distance of each hop according to Fig. 3. The average distance can be used to correct the position. The node N is getting its direction from B. The distance can be obtained as specified in Fig. 4.

- $A:(30+50)/(3+4)=11.4\text{m}$
- $B:(30+20)/(3+2)=10\text{m}$
- $C(50+20)/(4+2)=11.7\text{m}$

$N_A=10\times 2=20\text{m}.N_B=10\times 1=10\text{m}.N_c=10\times 2=20\text{m}$

Literature review: Puneet AzadandVidushi Sharma proposed a fuzzy Multiple Attribute Decision-Making (MADM) (Puneet and Vidushi, 2013) approach which was used to select Cluster Heads (CHs) using three criteria including residual energy, number of neighbors and the distance from the base station of the

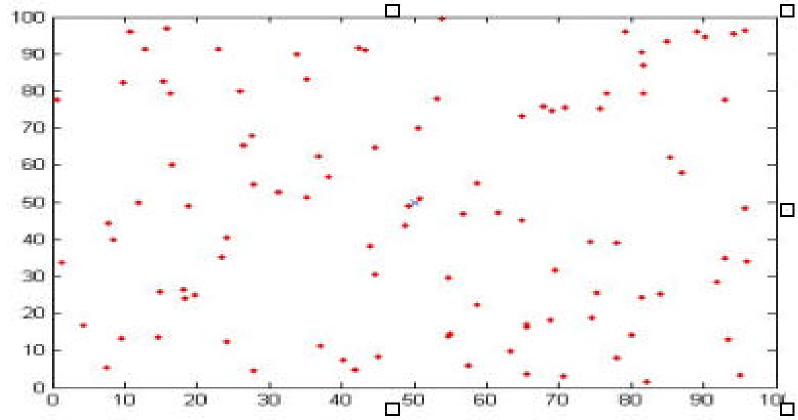

Fig. 3: Random distribution of nodes

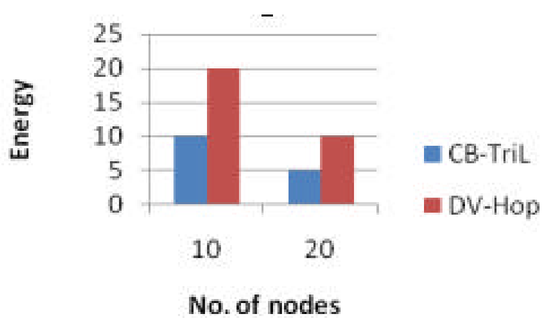

Fig. 4: Energy consumption at nodes

nodes. The CH must remain in active state, while the member nodes can go to sleep mode from time to time. This method was using LEACH protocol for its operation. If the size of the cluster is smaller than the predefined threshold, the cluster merges with the neighboring clusters. The simulation results demonstrated that the proposed approach was more effective in prolonging the network lifetime than the Distributed Hierarchical Agglomerative Clustering (DHAC) protocol in homogeneous environments. It achieved significant energy saving and prolonging network lifetime compared to DHAC protocol.

Carlos Moreno-Escobar, Ricardo Marcel´ýn-Jim´enez Enrique Rodrryguez-Colina and Michael Pascoe-Chalke presented a method to reduce the signaling overhead due to a distributed localization procedure. Each leader solves locally a particular instance of the Multi Dimensional Scaling (MDS) problem. Finally, a minimum set of beacons is selected on each cluster. This method significantly reduced the number of messages exchanged which is an important operation condition for wireless sensor networks. Tracking an object is based on dynamic cluster environment rather than static cluster, this protocol resulted efficient power consumption and efficient localization of nodes with respect to cluster heads.

Dongfeng Xie, Qi Sun, Qianwei Zhou, Yunzhou Qiu and Xiaobing Yuan offered a Localized Game theoretical Clustering Algorithm (LGCA) (Xie *et al*., 2013). Each node played a localized clustering game only with its neighbours within a communication radius. This method achieved a better result compared with CROSS and LEACH in terms of network lifetime. LGCA outperforms CROSS and LEACH by properly selecting parameters. This method may be extended by considering residual energy and distance to the BS to ensure that the worthiest node wins the cluster game and the problem of heterogeneous sensor networks is also concerned.

Vinay Kumar, Sanjeev Jain and Sudarshan Tiwari presented taxonomy of energy efficient clustering algorithms (Kumar *et al*., 2011) in WSNs along with LEACH and also timeline and description of LEACH and Its descendant in WSNs. LEACH-HPR introduced an energy efficient cluster head election method using the improved prim algorithm to construct an inter-cluster routing in the heterogeneous WSN.

Tal Anker, Danny Bickson, Danny Dolev and Bracha Hod discussed a novel distributed inference scheme (Anker *et al*., 2008) based on BP for efficient clustering in multi-hop WSN. It selects cluster heads, based on a unique set of global and local parameters which finally achieves, under the energy constraints, improved network performance. Higher throughput was expressed by both data collection rate and time. The advantage is expressed in terms of network reliability, data collection quality and transmission cost.

Puneet Azad and Vidushi Sharma presented a fuzzy decision-making approach for the selection of cluster heads. Fuzzy Multiple Attribute Decision-Making

(MADM) (Puneet and Vidushi, 2013) approach was used to select CHs using three criteria including residual energy, number of neighbors and the distance from the base station of the nodes were considered in order to optimize the number of clusters/cluster heads. Fuzzy TOPSIS technique was used for the selection of cluster heads in WSNs. This method was more effective in prolonging the network lifetime than the Distributed Hierarchical Agglomerative Clustering (DHAC) protocol in homogeneous environments.

Hassan Musafer, Razan Abdulhameed, Eman Abdelfattah and Khaled Elleithy discussed two object tracking techniques for Wireless Sensor Networks based on dynamic cluster algorithms have been combined together to perform many functions in the proposed algorithm. Tracking or localization of an object performed as a response to a query from the base station. The proposed algorithm had efficient power consumption and was highly scalable while it prolonged the life time of the network with respect to cluster heads.

XiaohuiChen, JinpengChen, BangjunLei analysed the shortage of Least Square Localization algorithm (LSL) in WSN_s and then proposed two improved least square algorithms (Chen *et al*., 2012). It was the distance clustering in LSL (LSL-DC) and the distance clustering and minimum related distance in LSL (LSL-DCR). LSL looked for the best function matching of the data in the condition of minimizing the square sum of errors and improved the localization precision.

Biljana Stojkoska, Danco Davcev and rea Kulakov presented a new cluster-based MDS algorithm (Stojkoska *et al*., 2008) for nodes localization in WSN. Each cluster-head created its own local relative map consisting of the nodes in its cluster. All local maps were merged into one global relative map using the best linear transformation. If anchor nodes were presented in the network, this global map can be transformed into global absolute map. The proposed method estimated the nodes location with greater accuracy than MDS-MAP algorithm and less computational intensive if applied on irregular topologies.

Haowen Chan, Mark Luk and Adrian Perrig presented a novel approach (Chan *et al*., 2005) for localization that can satisfy inexpensive off-the-shelf hardware, scale to large networks and also achieved good accuracy in the presence of irregularities and obstacles in the deployment area. This clustering-based approach had many benefits: fully distributed, good accuracy, only three randomly placed sensor nodes knew their geographic position information. It provided accurate position information even in topologies with walls and other concave structures as long as the granularity of the obstacle features was on the same order as the separation between cluster-heads.

Dai *et al*. (2015) proposed a Tree Based Clustering (TBC) multidimensional scaling algorithm for wireless sensor networks with the purpose of overcoming the shortage of classical MDS algorithms in its localization accuracy and computing complexity. The in cluster local coordinates were carried out by applying traditional MDS method after clusters are formed and then mapped into global coordinates. TBC-MDS had better localization coverage and higher accuracy than the traditional MDS based algorithms.

Shang *et al*. (2013) presented a new localization method,MDS-MAP that worked well with mere connectivity information. However, it could also incorporate distance information between neighboring nodes when it is available. Through simulation studies it was demonstrated that the algorithm was more robust to measurement error than previous proposals, especially when nodes are positioned relatively uniformly throughout the plane and even yielded relative coordinates when no anchor nodes were available.

Zainalie and Yaghmaee (2008) proposed a clustering algorithm called CFL (Clustering For Localization) (Zainalie *et al*., 2008) and was designed in such a way to consider principle of designing a clustering algorithm in addition to provide an environment for designing a localization algorithm based on clustering. The proposed algorithm used a combined weight function and tried to classify the sensor nodes so that minimum number of clusters with maximum number of nodes in each cluster could be achieved.

Misra and Xue (2007) proposed an efficient scheme (Satyajayant *et al*., 2007) that helped the SNs identify these malicious anchors and discard them from the localization process. CluRoL, a technique that helped each SN to localize itself accurately, using a clustering mechanism that performed clustering of these proximal points. Simulation results indicated that when the malicious anchors were not colluding CluRoL could identify on an average >72% of them. CluRoL performed even better when the malicious anchors were colluding in an attempt to localize an SN at a false position, identifying >85% of the malicious anchors. Manisekaran and Venkatesan (2014) proposed a cluster based architecture for range-free localization in wireless sensor network. An event based localization technique was applied to each cluster that involved straight line scanning of the clusters with deployed multiple sinks. In case if any target node in the cluster was not localized, a distance based localization technique was executed that localized the target node. The proposed technique reduced the overhead and latency and increased the localization accuracy. Performance metrics used were average energy consumption, localization error.

PROPOSED APPROACH

In this study, we present a novel cluster based method for efficient position estimation in wireless sensor network. Based on RSSI and ToA payload is calculated for the nodes in the network. Residual energy and payload of the nodes are considered for clustering. The proposed method follows the steps given below for efficient localization in WSNs:

- Initialize the starting node S
- Broadcast signals from S to all the other nodes in the network
- Calculate payload (W_i) of nodes by considering RSSI and ToA values
- Consider the nodes having higher payload values and also higher residual energy
- Let these nodes be the reference nodes in which $|W_i - W_{i-1}|$>Threshold1
- Let all these reference nodes be the Beacon nodes and form clusters by connecting with their single-hop neighbours
- Apply Trilateration method in each cluster and localize the nodes

SIMULATION RESULT

We have validated our CB-TriL method using simulation. We consider energy consumption, location coverage, accuracy as measurement factors. The experiment region is a square area with the fixed size of 100 X 100 m^2 and the nodes were randomly placed. We deploy 100 sensor nodes in a two dimensional space. The simulation results are presented in Fig. 5.

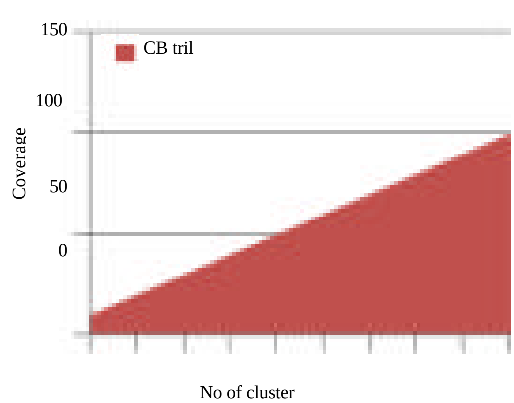

Fig. 5: Location coverahe of nodes

CONCLUSION

In this study, we present a new cluster-based Trilateration method CB-TriL for nodes localization in WSN. In our approach, network is divided into clusters and each cluster has one cluster-head CH for computing local information. Each cluster-head creates its own local relative map which consists of the nodes in its cluster. The results from our experiments, show better results than Trilateration method. Our algorithm estimates the nodes location with greater accuracy with less energy consumption than Trilateration algorithm. Our algorithm has less energy consumption if compared with Trilateration method.

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