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Energy Efficient and Cost Effective Localization using VAN (Virtual Anchor Node) in Wireless Sensor Networks

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***Abstract* – In the field of wireless sensor network, localization is one of the main issues. Localization is a process of finding the location of nodes in a sensor network, which provides the basis for routing, tracking and other communication aspects of network. Hence localization is a significant criterion. In a 2D plane a node requires atleast three anchor nodes location information for localization. One of the main methods to improve localization accuracy is to increase the count of anchor nodes. But this is restricted due to the hardware constraint, cost, and energy consumption and so on. Aim of this paper is to propose an energy efficient and cost effective localization scheme using VAN (Virtual Anchor Node), where a node that wants to localize use controlled flooding technique to get atleast three anchor information. Once any node that receives three anchor nodes information will localize and become VAN that assists other nodes for localization, while the number of AAN (Actual Anchor Node) is same as before. Here the term controlled flooding means, flooding is controlled at two levels; first when request packet reaches VAN. Second, when request packet reaches a node that has stored anchor nodes information but not yet localized. As a result communication overhead is reduced to greater extent.**

***Keywords* – Sensor Network, Flooding, Localization, Actual Anchor Nodes, Virtual Anchor Nodes.**

I. Introduction

Wireless sensor network (WSN) is a large set of tiny sensor nodes deployed in a large field which have sensing, processing and communication features. A specific sensor node called sink node capable of collecting sensed information from which user can get the data via internet [1]. WSN has numerous applications like object tracking, traffic monitoring, soil moisture estimation [2], habitat monitoring, detecting seismic activities, navigating ships and so on. In recent days, researchers have also started exploring smart applications in field of pervasive computing [3] by leveraging embedded processing with WSNs. In these applications locations of sensor node is not only important to application but also for the operations of WSNs.

Localization of a node is finding the location of sensor node. Localization system consists of two components; distance estimation, position computation. The localization algorithm can be categorised into range-based and range-free algorithms. As the name indicates in range-based schemes the range between the nodes is used for localization which may be in terms of distance or angle. In case of range-free schemes instead of using range (distance or angle) between nodes connectivity information is used for localization.

At present, many localization algorithms for sensor networks has been proposed containing minimal number of anchor nodes (which know their position by GPS or by manual configuration) and large number of unknown sensor nodes [4] in which broadcasting of location information is initiated by anchor nodes to its neighbouring nodes and the broadcasting is continued until all unknown nodes receives atleast three anchor nodes information, here it is assumed that all the anchor nodes are neighbour to each other. Since broadcasting is not controlled each node consumes more energy thereby reducing the lifetime of network.

Hence, this paper proposes an energy efficient and cost effective localization algorithm using VAN. Here any node that need to localize floods a request packet to get atleast three anchor nodes information once they localize they become VAN (Virtual Anchor Node) which assists other nodes to localize. Here the flooding is controlled at two levels. First, when request packet reaches VAN. Second, when request reaches a node that has stored anchor nodes information but not yet localized.

The remainder of this paper is organised as follows. Related work is discussed in section II. WSN model, definitions and packet formats used in this paper are discussed in section III. Proposed algorithm is explained in section IV. In section V simulation and results are shown.

II. Related Work

A. Range-free Localization Algorithms

Niculescu and Nath proposed a distributed, hop by hop positioning DV-Hop [5] algorithm. This consists of three steps. First, each node gets a distance to anchor nodes by distance vector exchange. Second, it estimates an average size for one hop, which is deployed as correction to entire network. Finally, all nodes compute location by trilateration method. Later DV-Hop was improved by Hongyan Chen and et al [6], in which they find the average of hopsize and unknown nodes compute distance to anchor node based on hop length and hops. Finally least square method is used to find the position of unknown node.

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In Centroid algorithm [7] unknown node make its coordinates as centroid of anchor nodes that are in its communication range. But due to the asymmetric distribution of anchor nodes the computed position is not so accurate. Further to increase the accuracy Binwei Deng and et al use polygonal centroid and triangle centroid.

Qingiun X and et al proposed pattern driven range-free scheme [8], is mainly suitable for anisotropic network, which is based on the observation that hop count propagated from anchor exhibits multiple patterns under the interference of multiple anisotropic factors.

B. Range-Based Localization Algorithm

Received Signal Strength (RSS) [9] is used to measure the distance between anchor node and unknown node this is based on the fact that radio frequency (RF) signal attenuates while propagating in free space.

Time Difference of Arrival (TDOA) [10], Time of arrival (TOA) [11], and Angle of Arrival (AOA) [12] rely on extra expensive and complex hardware other than the transceiver to get accurate measurements. AOA estimates relative angles between neighbors. TDOA measures difference in arrival of the time of two different signals having different velocities, TOA is similar to TDOA but here only one signal is used.

III. Network Model, Definitions and Packet Formats

A. WSN model

WSN consists of several static sensor nodes and few anchor nodes scattered randomly as shown in Fig 1. Anchor nodes are those whose location information is known previous, either by GPS (Global Positioning System) or by manual configuration. These nodes do not have constraints like energy, battery power, memory as confronted by normal sensor nodes hence they are assumed to wake up all the time. These nodes are identified with unique ID stored in its memory and is sent along the radio signals.

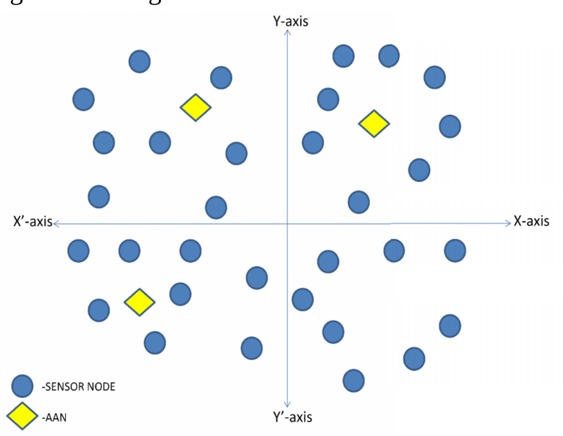

Fig.1.Typical Wireless Sensor Network

B. Definitions and Packet Formats

This subsection defines the keywords used in proposed algorithm along with the network scenario.

Request Packet (req_pkt): This is a query message sent by sensor node to get the location information from AAN or VAN and also from node that has stored anchor information.

Request Node (RN): A node that detects an event and initiates flooding of req_pkt to localize is called request node. For example in Fig 2 nodes n1, n2 and n3 detect the event hence are called request node.

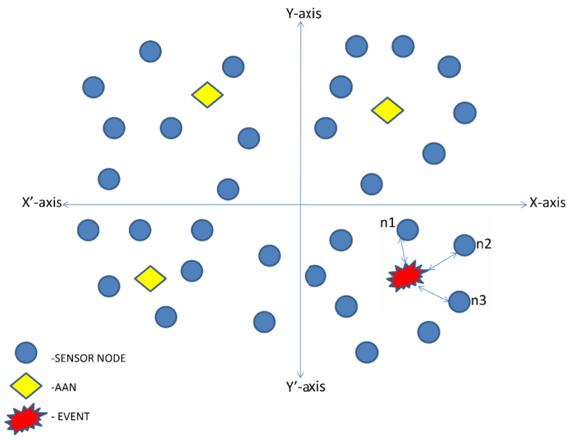

Fig.2. WSN model with event detection

Actual Anchor Node (AAN): Nodes which know their location information in advance either by GPS or by manual configuration. For example in Fig 2 nodes with rhombus shape are AAN.

Virtual Anchor Node (VAN): Node which is localized using AAN. Once they localize they assist other sensor nodes for localization by providing AAN location information.

Reply Packet (rep_pkt): This is a message sent as a response to reply packet, which contains anchors location information. This is sent by AAN or VAN and also node containing AAN information but not localized.

Packet Formats:

Request Packet (req_pkt): The fields of the packet are as shown in Fig 3. **Type** field indicates packet is request or reply packet, value **1** indicates request and **0** reply packet. **Source_ID** indicates the node that has initiated flooding on detection of event. **Path** indicates path traversed by req_pkt. **TTL** indicates amount of time required to send and receive a req_pkt and rep_pkt. The value for this derived from relation d/s, where "d" is hop count distance and "s" is speed of network. **Hop Count Limit** specifies the number of hops req_pkt is allowed to broadcast

Type	Source_ID	Path	TTL	Hop Count Limit

Fig.3. Request Packet Format

Reply Packet (rep_pkt): The fields of packet are as shown in Fig 4. Value for type field is **0**. **Anchor_ID** contains ID of anchor node that responses to request packet. **Path** indicates the path traversed by request packet through which anchor node will send reply packet back to RN. **Anchor's Location value** specifies location information of anchor node.

Type	Anchor_ID	Path	TTL	Anchor's Location Value

Fig.4. Reply Packet Format

Data Table: The location information received by RN after sending the req_pkt is stored in table called Data Table. The fields are as shown in Table 1. **Anchor Node ID** specifies the ID of anchor node. **X co-ordinate** and **Y co-ordinate** field specifies (X,Y) co-ordinate values for its corresponding anchor node along with hop distance from RN to anchor node which is specified in **Hop Distance** field.

Table 1: Structure of Data Table

Anchor Node ID	X Co-ordinate	Y Co-ordinate	Hop Distance
1	70.3	10.5	5
2	19.2	15.9	3
3	35.4	10.6	2

IV. PROPOSED ALGORITHM

A. Overview

Fig 5 consists of combination of both anchor nodes and normal sensor node that need to be localized and it also shows the occurrence event in the vicinity of node n1, n2 and n3. Now these nodes need to localize. So these nodes construct req_pkt and starts flooding to its neighboring nodes to get location information of anchor nodes. The process of flooding will take place until hop count limit value becomes NULL or TTL value becomes NULL. During the flooding of req_pkt, if it is received by AAN node it replies with its location information via the rep_pkt along the reverse traversed path of req_pkt for RN.

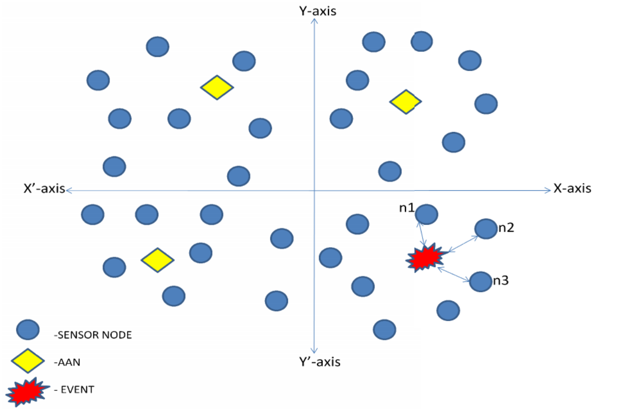

Fig.5. WSN model

And this anchor information is stored in all the nodes that are encountered along the reverse traversed path of req_pkt for RN. Further these nodes assist other nodes for localization by providing stored anchor information. These nodes also localize when they get minimum three anchor information. Once any node localize it becomes VAN and assist remaining nodes to localize and store AAN information in its data table as shown in Table 1.

The RN node does this process until it receives minimum of three anchor information which is necessary requirement for the localization of node, and is localized by any range-based localization technique.

B. Algorithm

The nodes in sensor network localize by using the anchor information. Any node that detects an event initiates flooding the req_pkt to its neighboring nodes within its transmission range. Every node checks its memory when it receives new req_pkt, if it is already present it will discard else store in memory and decrease hop count value by one and again floods to its neighboring nodes that are within its transmission range. Like this flooding of req_pkt takes place until RN gets three anchor nodes information. For example in Fig 6 n1 initiates flooding of req_pkt which is reached to three different AAN. These anchor nodes send back their location information via rep_pkt along the reverse traversed path of req_pkt for RN. While traversing back, anchor information is stored in each of the nodes encountered in that path to RN. Once RN gets three anchor nodes information i.e. AAN1, AAN2 and AAN3 it is localized by using any range-based localization technique and node will become VAN which assists other nodes for localization.

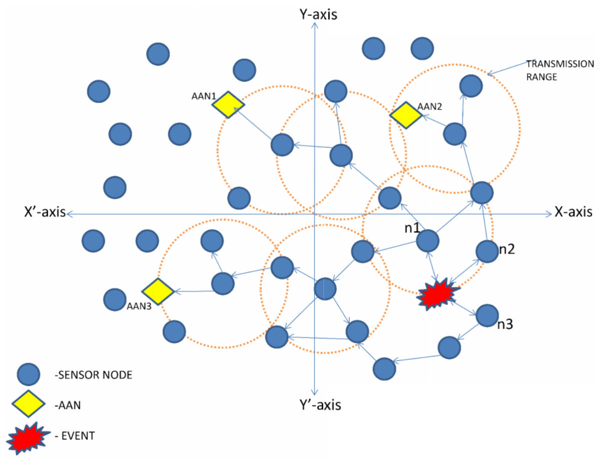

Fig.6. Localization using flooding

Fig.7 clearly depicts that a RN n1 become VAN when it localizes by get AAN1, AAN2 and AAN3.

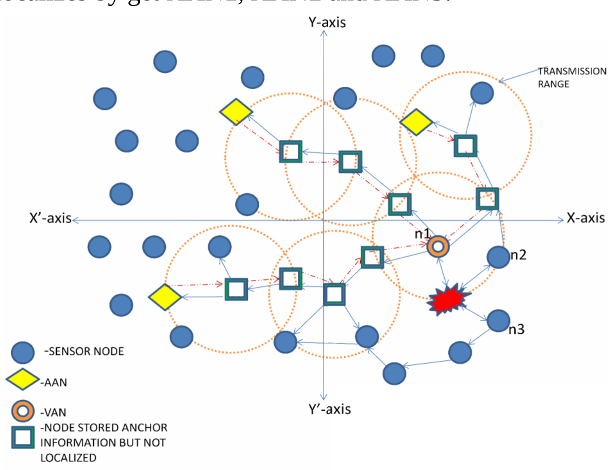

Fig.7. Request node getting three anchor information

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Further, when any VAN receives the req_pkt without being flooding to it neighboring it constructs rep_pkt through which AAN information is sent to RN and is as shown in Fig 8.

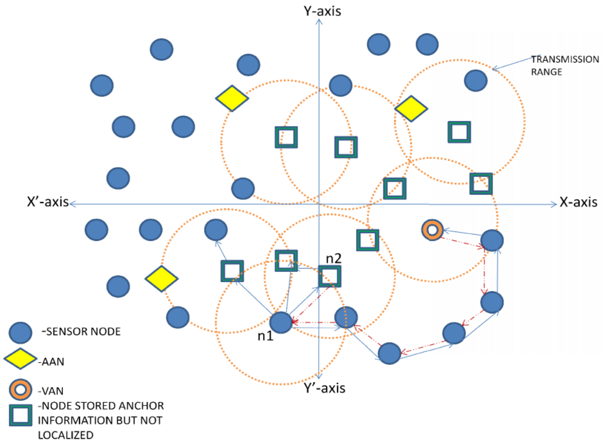

Fig.8. Node getting AAN from VAN and also from node that has stored anchor information

If the req_pkt is received by any node that has stored anchor information previously during rep_pkt traversing back RN, it also initializes rep_pkt and is sent back to RN with reference to req_pkt and is as shown in Fig 8.

In [13] it is stated that the amount of energy consumption during flooding is given by

$E_{total}=(E_{rx} * \text{avg number of neighbors} + E_{tx}) * N$ -------(1)

Equation 1 implies that total energy consumption directly depends on neighboring nodes (N) and average number of nodes.

Since the main objective of proposed algorithm is to have energy efficient and cost effective localization algorithm, energy efficiency is achieved by performing controlled flooding due to this communication overhead gradually decreases as number of nodes that provide AAN information increases in network without increasing the count of AAN and is done at two levels. First, at VAN i.e when req_pkt is received by VAN, flooding does not takes instead it replies with AAN stored in it. Second, when req_pkt is received by nodes that has stored anchor information but not localized, flooding does not takes place instead it replies with AAN stored in it. Since minimal number of anchor nodes is used hence it is cost effective.

Algorithm:

1. **for** all the event detected nodes
2. **do**
3. call "initialization req_pkt" procedure
4. RN floods req_pkt;
5. **if** req_pkt is received by normal node*
6. call "unprocedure"
7. **end if**
8. **if** req_pkt is received by AAN
9. call "initialization rep_pkt" procedure
10. rep_pkt sent back to RN with reference to path field and store anchor information in each of these encountered nodes;
11. **end if**
12. **if** req_pkt is received by VAN
13. call "initialization rep_pkt" procedure
14. rep_pkt is sent back to RN with reference to Path field;
15. **end if**
16. **end do**
17. **if** RN do not get three anchor nodes and WT Equals to zero
18. H++;
19. perform flooding until RN gets three anchor Values;
20. **else**
21. RN localizes by any range based technique;
22. **end if**
23. end for

1. **initialization req_pkt ()**
2. Type= 1;
3. Source_ID = RN's ID
4. Path = RN's ID;
5. TTL= d/s;
6. Hop Count Limit= H;
7. **end initialization req_pkt ()**

1. **initialization rep_pkt ()**
2. Type= 0;
3. Anchor_ID =anchor node's ID;
4. Path= path field of req_pkt;
5. TTL=d/s;
6. Anchor co-ordinate value= (x,y) co-ordinates of Anchor node;
7. **end initialization rep_pkt ()**

1. **unprocedure ()**
2. **if** Source_ID is present in memory
3. discard req_pkt;
4. **else**
5. store req_pkt;
6. **end if**
7. **if** it contains any anchor information
8. call "initialization rep_pkt"
9. rep_pkt is sent back to RN with reference to rep_pkt's path field;
10. **end if**
11. **end unprocedure ()**

*normal node is node that needs to localize and doesn't contain any AAN information.

V. Simulation and Results

This section evaluates the performance of the proposed scheme. A grid area of 500 x 500 with 100 sensor nodes and 3 anchor nodes are considered.

The following performance metrics are considered for evaluation of proposed scheme.

Localization Ratio: is a ratio of number of nodes localized successfully to number of nodes deployed and

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the graph is as shown in Fig 9. The number of event detected nodes (RN) is plotted in x-axis and VAN ratio in y-axis. The RN becomes VAN after localization, the number of VAN increases with increase in event detected nodes.

Energy efficiency: is the amount of energy used by nodes for localizing. Fig 10 shows the energy consumption by network during localization. It clearly depicts energy consumption gradually decreases, this is due to the fact that as the number of nodes that provide anchor information increases flooding is controlled.

Localization convergence time: is a time taken by unknown node to localize. Fig 11 shows localization convergence time. It clearly depicts that as number of RN increases the time taken to localize decreases. This is because as RN increases VAN also increases i.e. location providing nodes also increases.

Localization Error: is amount of error involved in location information of dislocated node. It is given by relation.

$$\text{Localization Error} = \frac{\sum (Xe - Xi)^2 + (Ye - Yi)^2}{\text{No.of Sensor Nodes}} \quad \text{---(2)}$$

where (Xe, Ye) is estimated location of sensor node and (Xi, Yi) is true location of sensor nodes.

Fig 12 shows a graph of number of triggered nodes in x-axis and error in percentage on y-axis. It clearly depicts as the total number of nodes deployed in a network increases the error decreases.

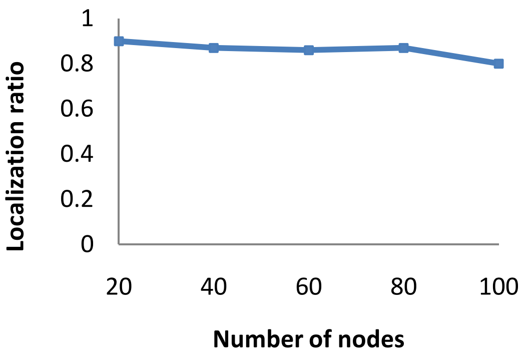

Fig.9. Localization Ratio

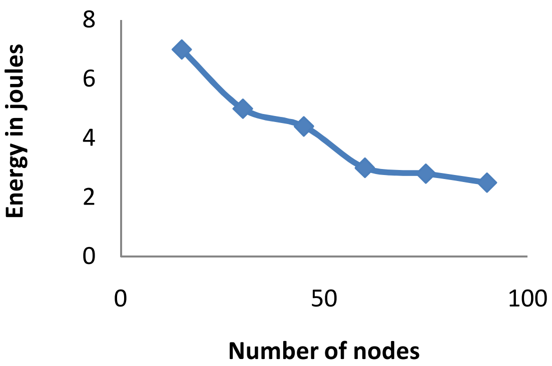

Fig.10. Energy Efficiency

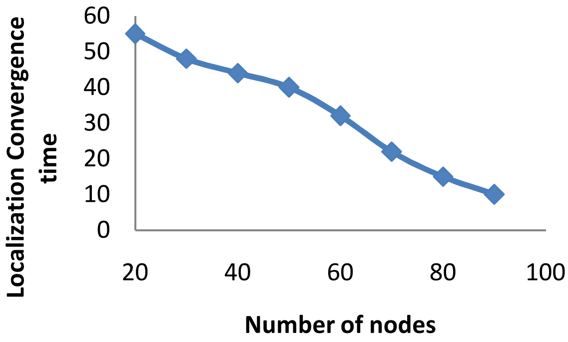

Fig.11. Localization Convergence Time

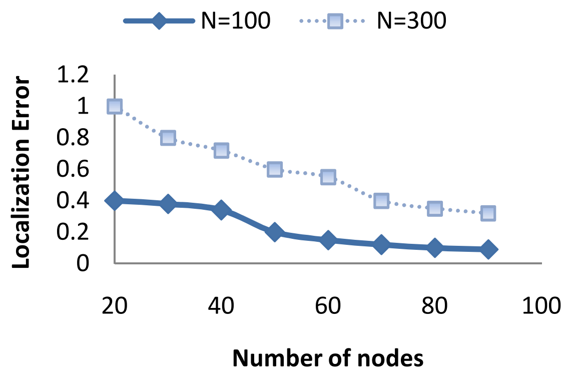

Fig.12. Localization Error

VI. Conclusion

The main objective of the proposed scheme is to achieve energy efficiency and cost efficient. Energy efficiency is achieved by performing controlled flooding, and is done at two levels. First, at VAN. Second, at nodes those have anchor information but not localized i.e. when request packet received by any one of these nodes flooding does not takes place, due to this communication overhead is gradually reduced as VAN increases in network. It is cost effective because all nodes in the network localize with minimal number of anchor nodes.

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