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Energy Efficient Data Gathering using Weighted Relay Point based Node Selection for Target Tracking in Wireless Sensor Networks

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Abstract: In wireless sensor network, energy conservation is an important issue for many applications. In target tracking applications, sensor nodes detect a single target simultaneously in multiple clusters and the data collected are usually highly correlated and redundant. Due to minimum no of sensor nodes, it is valuable to reduce the amount of data transmission so that the average sensor lifetime is reduced. To reduce such redundant data and to save energy this paper proposes, Weighted Relay Point based Node Selection (WRPNS) technique. In this approach, we select best set of nodes for tracking mission based on the shortest distance between target and nodes. Among this, a single node is selected as target node which has minimum distance in each cluster. Each node is appointed a weight (distance between nodes and base station) and its remaining energy. In addition, it selects the Weighted Relay Point Node (WRPN) from the table (weight, residual energy). This node is responsible for collecting and aggregating the data from the other target nodes. The aggregated data is then transmitted to its own CH then by WRPN to the base station. Experiment results demonstrate that the proposed approach achieves a significant reduction in power consumption and reduce transmission delay for data transmission and prolongs the network lifetime compared to existing data gathering approach.

Key words: Wireless sensor network · Target tracking · Data gathering · Energy efficiency · Network lifetime

INTRODUCTION

In Wireless sensor network (WSN), we can make easy communication between human and the environment with the help of sensor nodes. WSN is mainly introduced for the detection and observation of an object in an unattended area. The sensors will be deployed in the area where human interaction is not available. These sensors can be used in health care, military applications, industrial applications, remote monitoring etc. Now, introduce the WSN to the target tracking application. In a target tracking WSN, a group of sensor nodes monitor the roaming path of moving targets in the area of deployment. It is difficult to detect the movement of a target, in an unattended environment. But nowadays, by the introduction of WSN to the target tracking application detection is possible. The data is gathered from sensor node then transmitted to sink node (see Fig. 1). We can deploy wireless sensor nodes in an unattended area to create self organizing network and they will interact with the nearby nodes [1]. Detecting and monitoring locations of moving objects are the main process in target tracking.

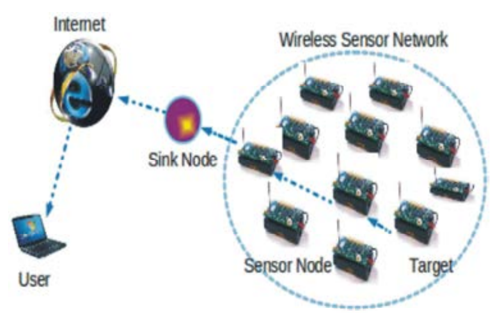

Fig. 1: Data gathering in wireless sensor networks

Tracking is applicable for the real world application such as habitat monitoring, fleet tracking, mobile telephony, traffic control and etc. In data gathering, clustering is an efficient approach to improve the scalability of a large WSN [2], [3]. LEACH is one of the most widely used clustering protocols for WSNs. In a clustered network, for each cluster a Cluster Head (CH) is appointed that manages the other sensor nodes (Cluster Members (CM)). To increase the channel reusability and the network throughput short distance communications are used within the cluster [4], [5]. The CH should be kept in active

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state until replaced by a new selected CH. The selection of CH is performed in periodic manner and the cluster is reselected. In tracking applications, the target moves randomly and the sensing region is largely overlapped. Due to this, the sensor nodes often detect the target in multiple clusters. The nodes sense the data and sendthe sensed data to its own CH. If each cluster aggregate the data and send it to the base station, multiple data transmission may occur with high data redundancy. To address this problem, we propose Weighted Relay Point based Node Selection (WRPNS) for target tracking in WSNs. WRNS dynamically selects weighted relay point node (WRPN) for data aggregation and transmission, focus on reducing the redundant data transmissions, selecting best set of nodes for tracking mission and balancing the energy consumption of each sensor node so as to improve the network lifetime.

The main contribution of this paper includes the following:

- We select best set of nodes for tracking mission that is nearer to the target.
- Weighted Relay Point based node selection is proposed to select the node to gather and aggregate the data.
- We maintain tuple that consists of hop distance and residual energy to select the WRP node.

The paper is organized as follows: Section 2 presents the related work for the proposed paper. Section 3 presents the network model. In section 4 the proposed approach and its modules are discussed. In Section 5 experiment evaluation is presented. In Section 6 conclusion and the future work of the proposed approach is discussed.

Related Works: There are more kind of network architectures for data gathering in WSNs. In this section a cluster- based WSN alone is discussed. In a cluster based WSN, for example LEACH each cluster involved in aggregation process. Aggregated data will transmit to the sink for the further processing [6]. To increase the network lifetime, A Hybrid Energy Efficient Distributed (HEED) clustering protocol was proposed. It minimizes the control overhead and improves the network lifetime due to the well formation of CHs. This protocol considers both the communication cost and residual energy of nodes while selecting CHs. An efficient clustering aggregation approach was proposed based on data fragments in [7], which improves the network efficiency and reduces the computational complexity. In this approach, a data fragment is any subset of the data that is not divided by any of the clustering results. These approaches focus on fusing data at CHs. For efficient data gathering and to minimize energy consumption CAICS (Coordinated and Adaptive Information Collecting Strategy) approach is proposed. This focus on aggregating the data in a special node called Aggregation node instead of aggregating in CH. It does not provide more efficiency because joint message utility is used for selecting tracking nodes which takes more time [8].

There are different protocols for the efficient communication for the target tracking application. But these approaches do not consider redundancy of data at the sink. For selecting the tracking nodes, the simplest method is selecting the nearest nodes having the shortest distance from the moving object. These methods having easy calculation, but the tracking accuracy results very low [9]. Based on distance from node to sink, the sensor nodes are classified into several layers and in addition the sense region is divided into several clusters [10]. It is suitable only for low dynamic wireless sensor network. There is another method called entropy based selection approach. It is used for increasing the message utility function. This approach results in good tracking accuracy but low computational complex [11].

In clustering approach, some CHs manage large number of sensor nodes that makes the improper formation of clusters. Due to large number of sensor nodes in CHs, CHs died quickly and the division of the network and the overall network performance of the WSN got lowered. A novel differential evolution (DE) based clustering algorithm is proposed for WSNs that prevents quick death of highly loaded CHs to increase the network lifetime [12]. To reduce energy wastage in distance CH node transmission to the sink node multi hop communication has been done between cluster head node to the sink node in Minimum Spanning Tree approach. In addition super CH nodes are created, which aggregate the information from different CHs and transmits it to the sink node [13]. Here, mobility is not considered and network is statics. These approaches take long transmission to send data from every CH to base station.

To determine the sink and CH locations efficiently as well as the data flow in the network mixed-integer linear programming (MILP) model was proposed. This method considers both the location and the energy factors of the sensors while selecting the CHs and neglect the highest-energy sensors [14]. It is not suitable for time critical applications and the location of the CH is not closer to the sink that takes some time delay. DSBCA (Distributed Self-Organization based Clustering Algorithm) is proposed to balance energy and to avoid creating more number of clusters with many nodes [15]. Here communication overhead is occurring. These approaches are not suitable for efficient data gathering.

In contrast, our WRPNS is based on a statically clustered WSN. Here, all the sensor nodes are managed by respective CHs. When the target enters into the region, the CHs will wake up the nodes around the target. The tracking nodes are selected based on the distance between nodes and target. We just simply select the Weighted Relay Point node from the target node set for gathering data and for aggregation process and no prediction is needed.

Network Model: In our approach, a static and clustered WSN is considered. We assume that the base station is placed outside of the network. The sensor nodes in the network will be deployed randomly in a P×Q sensing area. The base station always has infinite power supply. Cluster head (CH) will send the gathered data to the sink. The whole network is organized into clusters. Cluster is formed based on the threshold distance between the neighbor nodes. Each cluster has a single CH and a number of Cluster Members (CMs). CMs are managed by CMs and it selects the CMs based on the information stored in sink. Here we consider that, base station knows the location of all the CMs. CHs are always kept in active state and it is reselected by CMs periodically. Finally, we assume that using any localization algorithm, CH knows the position of its CMs.

Energy required for transmitting and receiving data can be calculated by the equation 1 and 2. The transmission energy and reception energy will be directly proportional to the distance and the path loss component.

$$E_{transmit} = (E_{Tx\text{-}electron} + \varepsilon_{amp} * d^{á}) * n \qquad (1)$$

‘ n’ ->total number of bits that are transmitted.

$$E_{receive} = E_{Rx\text{-}electron} * n \qquad (2)$$

Overall energy for transmitting and receiving data can be calculated by equation 3.

$$E = (2E_{electron} + \varepsilon_{amp} * d^{á}) * n \qquad (3)$$

Weighted Relay Point Node Selection: The proposed WRPNS consists of 1) Tracking nodes selection 2) Weighted Relay Point node Selection and 3) Data transmission. In subsection A, B and C, we will present the details of the above mentioned three phases. After that, we will compare the energy consumption of WRPNS with existing approach in an analytical way and discuss about the experiment evaluation in section 5.

Tracking Nodes Selection: To reduce energy consumption and improve tracking accuracy we choose the tracking nodes based on distance from the target. When the target enter into the region, the CH wakeup the sensor nodes which are under the threshold distance in the corresponding cluster. Initially, all the nodes in the cluster are in the detecting state. The CMs are converted from detecting state to tracking state by CH. Node has highest energy will successfully elected as CH. CH will always keeps active for the tracking mission. CH is also responsible to select a set a tracking node based on the shortest distance from the moving object. Here, we reduce the set of nodes for tracking mission. A threshold distance is set for every node in the cluster. The node which has under the threshold distance is selected as active nodes. Among them, a single node is selected for tracking mission by its own CH for each cluster. When the active nodes are selected, the node update the distance

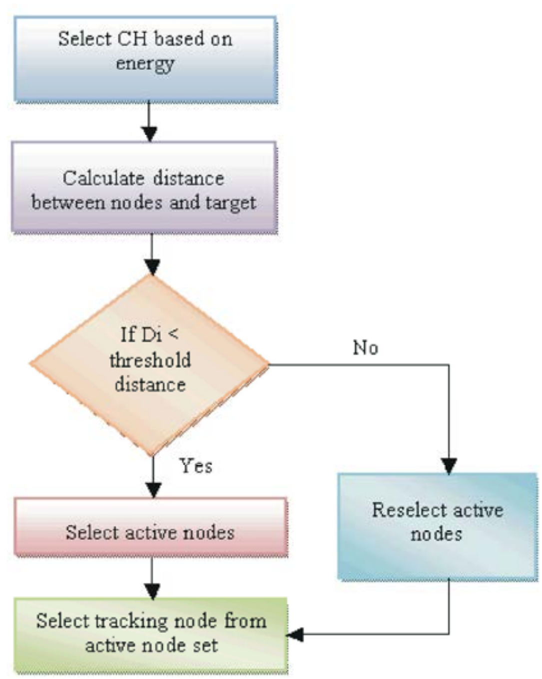

Fig. 2: Tracking node selection

between them to target in its corresponding CH. The CH compare these distance and select a single tracking node which has a minimum distance. The tracking node selection is represented in Fig. 2. Keeping the sensor node in a sleep condition when nothing is to detect will reduce the energy consumption successfully.

A set of nodes which is very nearer to the target will be active for a threshold time and these set of nodes will collects the location and direction details of the moving object. The set can be represented by equation (4).

$$X = [F_a, F_b, F_{c...} F_n] \quad (4)$$

'X' represents the active node set. Based on the distance between node and target, sensor node spends significant energy for every transmission and reception of data. For that reason, we consider that the tracking node selection process selects only the shortest distance path for every transmission of data.

Selection of Weighted Relay Point Node: In our weighted relay point based node selection (WRPNS) approach, we consider the distance factor and energy factor to choose the Weighted Relay Point node (WRPN). We assume that each sensor node is appointed a weight (distance between node and base station), residual energy. Each sensor node maintains a routing table to store these two factors. Now we can select the minimum distance and maximum residual energy from the table. Thus the minimum distance of each sensor node can be defined as the following equation 5.

$$d_{min} = \min(d(F_a\text{-}S), d(F_b\text{-}S), d(F_c\text{-}S)_{...} d(F_n\text{-}S)) \quad (5)$$

'd_{min}' represents the minimum distance between tracking nodes and base station in each cluster.

'$d(F_a\text{-}S)$' represents distance between tracking node F_a to base station S.

The initial energy of the entire node is same. According to the data transmission, the energy consumption may vary. The residual energy of the node can be calculated by equation 6.

$$\text{Residual energy} = \text{Initial energy} - E \quad (6)$$

Here, E can be calculated by equation 3.

Thus the sensor node with the high residual energy and low weight will have a more chance to be selected as WRP node and when the energy consumption of two or more sensor nodes are same, the sensor node which is

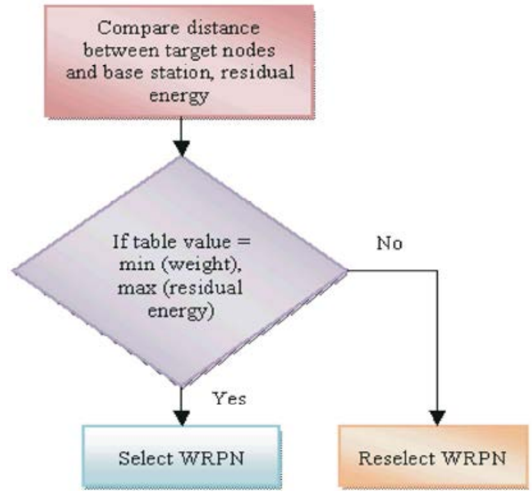

Fig. 3: Weighted Relay Point Node selection

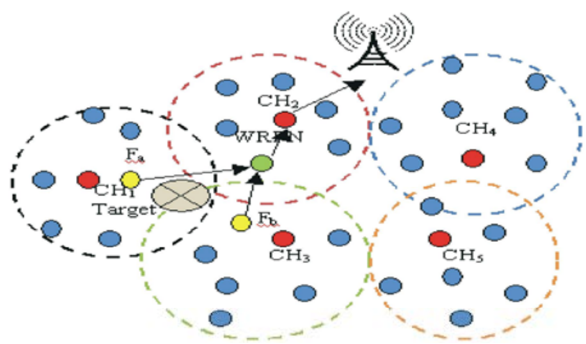

Fig. 4: Network design

more close to the sink node will be likely to be selected as WRPN to forward data. In Fig. 3. WRPN selection is explained.

After completing the selection of WRPN, WRPN will broadcast collect_data message to inform tracking nodes to collect data and then each tracking nodes get the selected information and knows which WRPN it is in. Thus, WRPN of the sensor network are established. The network design is given in below Fig. 4.

Algorithm: The WRPNS Approach

Choosing Tracking Nodes

Set threshold value d_{th}

Calculate distance between node and target -> d_i

if($d_i < d_{th}$)

Select active nodes

else

Reselect active nodes

Update distance between active nodes and target in each CH

```
    if(d_min = min(d_active_nodes and target)) // Compare distance
        elect it as tracking node
        Broadcast("finish_election")
    else
        Reselect tracking node
    end if
end for
```

Selection of Weighted Relay Point Node

```
for each sensor node F_n^D D do
Calculate residual energy, distance between node and base station
Select min(distance), max(residual energy) from table
    if WR = min(d_active_nodes and base station), max(residual energy) ) // from table (WR->Minimum weight and maximum residual energy
        Elect it as WRPN
        Broadcast("finish election")
    else
        Reselect WRPN
    end if
end for
```

Data Aggregation and Transmission

```
for each sensor node F_n^D ? D do
    if F_n^D is WRPN then
        d <- ObtainDistanceToTarget()
        if d < d_th then
        Broadcast("collect_data")
        else //target is out of the defined range
        Broadcast("reselect WRPN")
    end if
    end for
else //the node is not WRPN
    if "collect_data" is received from WRPN then
        TransmitToWRPN(data)
    end if
    end if
    end for
```

Data Transmission: After WRPN is selected, it will send the collect_data message to the nodes F_a, F_b, that is tracking nodes from each cluster. The tracing nodes receive this collect_data message and send collected data to the WRPN without any collision. To avoid collision, we fix a random waiting time for every node. So that, every node is waiting for a particular time period before sending data. These active nodes send the sensed data to the WRPN instead of its own cluster. It avoids long transmission delay and saves energy. The WRPN receive the data from tracking nodes and aggregate it. Then the WRPN send the data to its own CH and the CH forwards the data to the base station. In Fig. 5 the data transmission between sensor nodes is depicted.

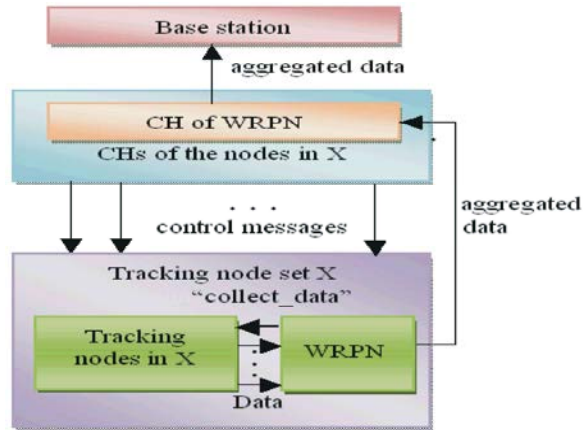

Fig. 5: Data transmission between sensor nodes

We consider distance between nodes to target while selecting active nodes. So that, the node which is nearest to the target is selected for tracking mission. Then from this the node which has the minimum distance in the cluster is selected as tracking node. The number of nodes involved in tracking mission is reduced here compare to the exiting approach. It improves tracking accuracy and encourages fast data transmission. To select WRPN energy factor and distance factor is considered. So that network efficiency is improved. It avoids CH for gathering and aggregating data for every cluster. Here, we can avoid long data transmission. To summarize that, in our proposed approach, the network energy is balanced for all nodes, it avoids long transmission delay and overall network efficiency is improved.

Performance Evaluation

Simulation Results: In the experiments, we demonstrate the energy efficiency of WRPNS by comparing to the existing approach, by means of simulations carried out on NS2. The performance metrics include the network load (the number of packets transmitted), the energy consumption for data transmission and the network lifetime.

Fig.6 shows the execution time of the CAICS and WRPNS approach. When the execution time increases the nodes number also increases. The execution time increases because it needs more computations for more sensor nodes. The execution time of the WRNS is lesser than the CAICS because the existing approach uses joint

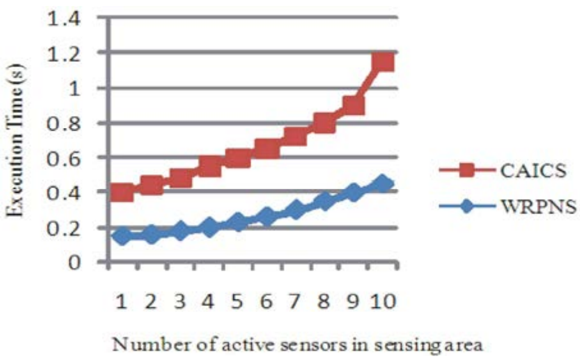

Fig. 6: Number of active sensors Execution time

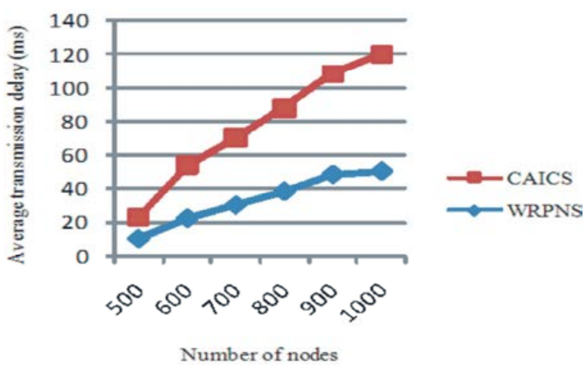

Fig. 7: Number of nodes Vs Average transmission delay

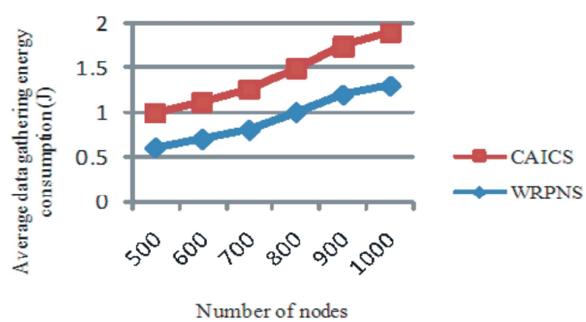

Fig. 8: Average data gathering energy consumption Vs Number of nodes

information utility to select nodes for tracking mission. From figure it has higher computational complexity and achieves more accuracy.

Fig. 7 shows that our WRPNS achieves lower energy consumption compared to CAICS approach. In CAICS, it consists of more than one tracking nodes for each cluster. But in WPRNS we reduce the number of nodes for tracking mission. We maintain a routing table to select minimum distance between node and target, residual energy and WRPN is selected. So the overall network efficiency is high in WRPNS.

Fig. 8 shows the transmission delay increases with the network size. In CAICS approach, the selection of nodes cause increase in delay. The delay of WRPNS is shortest because WRPN selects a single node for each cluster for tracking mission.

The depicted graphs show that our proposed approach is more efficient that the existing approach.

CONCLUSION

This paper proposes a Weighted Relay Point Node Selection (WRPNS) for target tracking. In WRPNS an efficient node selection algorithm is proposed. Here, we select tracking nodes for efficient target tracking. It selects a single node as a tracking node for each cluster so that the number of nodes in tracking mission is minimized. Moreover WRP node is selected to send the aggregated data to the node that is nearest to the base station. The node which has the minimum distance from the node to base station and has highest residual energy is selected as WRP node. Simulation results showed that our WRPNS approach outperforms existing works in terms of energy consumption and data transmission delay. Network lifetime also increases in our proposed approach compared to the existing approach. In future, we planned to provide efficient data gathering algorithm for multiple target tracking and in addition we will also provide this in a security manner.

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