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Target Tracking in Wireless Sensor Network

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Abstract:- Wireless Sensor Networks (WSNs) consist of small nodes with sensing, computation, and wireless communications capabilities. In this paper target tracking using dynamic clustering technique has been presented. The dynamic clustering mechanism proposed performs the clustering along the route of the target movement with minimum numbers of sensor nodes to track the target object. The sensors detecting the object need to transmit the sensing data and identification. Sensors forming clusters are termed as core sensors. Within each cluster, the core sensors are selected based on the estimated signal strength since the nodes closer to the targets having larger measurements have a higher probability of becoming core sensors. The core sensors are used to compute the location of a target based on the locations of the neighbouring nodes. These core sensors send this information to the corresponding Cluster Head (CH), using which the target localization is processed. The position of moving object is detected by object moving algorithm. The location is sent to sink from CH node. Target tracking is used in traffic tracking and vehicle tracking.

Keywords: *Target tracking, clustering, localization, core sensor.*

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I. Introduction

The sensor node is a very small device that represents the building blocks of the Wireless Sensor Network (WSN). These nodes are being produced at a very low cost and yet with high levels of sophistication in terms of computing power, energy consumption savings, and multipurpose functionalities when compared with earlier generations of sensor nodes. WSNs are created by deploying a large number of sensor nodes in a certain area, which is usually called the monitored region, for monitoring purposes [10]. Wireless sensor networks are made of connected sensors and each sensor has the capability to collect, process, and store the environmental information and communicate with others through inter-sensor wireless communication. The number of nodes that must be deployed in order to completely cover the whole monitored area is often higher than if a deterministic procedure were used. Networks having stochastically placed nodes, it is enough to activate only the necessary number of sensor nodes, hence energy can be saved at any practical moment. An energy efficient sensor network provides surveillance and target positioning services. By placing K independent sets of sensors on a sensor field, these sets are capable of monitoring the field [2]. Looking at Figure. 1, we can see the architecture of a generic Wireless Sensor Network which examines how the clustering phenomenon is an essential part of the organizational structure [1].

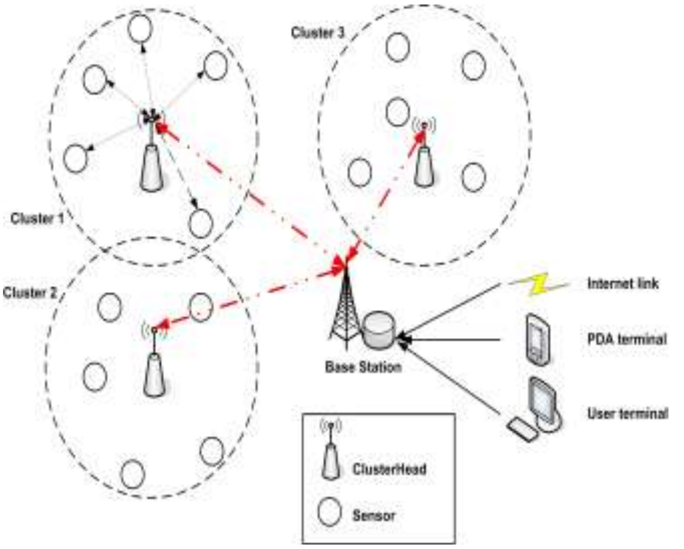

Fig 1 : General Sensor Network Architecture

Object tracking, which is also called target tracking, is a major field of research in WSNs. The main task of an object tracking sensor network (OTSN) is to track a moving object and to report its latest location in the monitored area [10]. , Target tracking aims to detect the presence of a target and compute reliable estimates of the locations while the target moves within the area of interest, and forward these estimates to the base station in a timely manner. It is known that the cluster structure can provide benefits for large scale WSNs. For example, it facilitates spatial reuse of resources to increase the system capacity it also benefits local collaboration and routing. Numerous approaches for object tracking have been proposed. These primarily differ from each other based on the way they approach the following questions: Which object representation is suitable for tracking, which image features should be used, how the motion, appearance, and shape of the object should be modelled. The answers to these questions depend on the context/environment in which the tracking is performed and the end use for which the tracking information is being sought. A large number of tracking methods have been proposed which attempt to answer these questions for a variety of scenarios. Recently, cluster structure is gradually adopted for solving the target tracking problem. A dynamic clustering approach is one that dynamically wakes up a group of nodes to construct a cluster for local collaboration when the target moves into a region. As dynamic clustering only actives the most appropriate nodes in a cluster at one time while keeping other nodes in the sleep state, it is an energy-efficient way for target tracking [11]. The boundary problem will result in the increase of tracking uncertainty or even the loss of the target. Therefore, trade-offs should be taken between the energy efficiency and local collaboration.

II. Related Work

The protocol used for tracking the object is clustering and prediction based protocol (CPBP) [9]. CPBP had base station (BS) tracing as the base for performing the application of moving target in WSN. BS undertakes management of cluster formation, active nodes rotation and part of transmissions needed for tracking the target. In this protocol, all sensors are equipped with 3D cubic antenna that allows them to receive information from long distances at 915 MHz radio frequency. Due to broadcasting nature of BS transmissions, all sensors are capable of hearing transmitted information, but, only the sensors receive information that have been previously triggered and changed their status to awake state; thus, in BS transmissions, only those sensors consume the received energy that are in awake state. Since BS manages the clustering and prediction processes it has a good knowledge of nodes energy level, distance and energy are the two parameters used for clustering algorithm. . Localization and prediction based protocol is basically used for predicting the next location of the target using the proposed protocol the lifetime of the network is increased by preserving the sensor node for a longer time in the network. In this protocol, in order to optimize energy consumption, both frequency and number of sensors involved in target tracking were decreased. An energy-efficient target tracking algorithm [8] has been proposed which minimizes the number of nodes in the network that should be activated for tracking the movement of the target. On detecting a target, the cluster head which detects the target activates an optimal number of nodes within its cluster, so that these nodes start sensing the target. A Markov Decision Process (MDP)-based framework is designed to adaptively determine the optimal policy for selecting the nodes which are localized with each cluster. As the distance between the node and the target decreases, the Received Signal Strength (RSS) increases, thereby increasing the precision of the readings of sensing the target at each node. A clustering-based distributed approach for target tracking has been proposed. Clustering is done in post deployment phase in order to overcome the delay introduced due to clustering after target. In their work, they assume that the target moves by following Gauss-Markov Mobility model proposed in the literature, they formulate the movement of the target in the work. The prediction takes place after the CH detects the target or receives the responsibility of tracking the target from the neighboring CH which was detecting the target before it. The MDP-based algorithm for selecting the nodes runs on each of the CHs. At every state, it would predict the next location of the target using a Kalman Filter. The prediction takes place after the CH detects the target or receives the responsibility of tracking the target from the neighboring CH which was detecting the target before it. After predicting the next location of the target after a time interval of δt, the CH checks whether the target lies within its range or is closer to the neighboring nodes. Once that decision is made, the CH of the cluster which was performing target tracking till then, "hands over" the charge of tracking the target to the closest CH. The aim to obtain a trade-off between the tracking accuracy and the energy consumption it use the cost function to determine the value of Ns, that is, the number of nodes to be selected within a cluster for the target tracking process. A partial information broadcasting scheme (PIBS) [5] proposes a decentralize state estimation and sensor selection problem subject to communication and energy constraints which have been considered. PIBS is formulated as two-layer optimization problem, where at the upper level sensor selection is solved and at the lower level continuous state estimation is solved. Both are solved separately. Random Broadcast (RB) and Good Estimation Broadcast First (GEBF) are proposed by balancing the residual energy among the sensors and reducing time delay. Both can be implemented as decentralized strategy. PIBS with (RB or GEBF) can reduce the energy and bandwidth resource with minor degradation in tracking accuracy as compared to centralized strategy. The PIBS is executed in three steps firstly to detect the moving object, take measurements, and do the pre-processing. Next, a part of sensor nodes broadcast the packets containing local estimates to avoid collisions and others keep silent. Finally, the sensor nodes assimilate the data of the received packets into their local estimates. The key to the PIBS is that not all the sensors broadcast at each time step. An efficient dynamic clustering mechanism which can reduce missing rate by prediction and prolong the lifetime of the whole sensor network by minimizing energy consumption [3]. The energy consumption is mainly reduced in two ways: first, minimizing the number of nodes involved in tracking by constructing cluster dynamically along the target's traveling route. Second, minimizing the communication cost between sensor nodes when forming a cluster. The dynamic clustering mechanism proposed in this paper, performs the clustering along the route of the target movement with minimum numbers of sensor nodes to track the target object. The BS gives the command to all the sensors present in the network. When initialing a cluster, all the sensor nodes in the sensor network are active and can detect the target location after receiving an object tracking command from the base station, and then they will calculate the target moving information by collaborating with other adjacent sensors and volunteer themselves as cluster head. The new cluster head is selected by the former cluster head through broadcasting a confirming packet. After receiving the confirming packet from the former cluster head, the new cluster head will wait for a short random time, and when its timer expires it will broadcast a re-clustering command packet which contains the new scheduling information to the neighboring sensors and then go into listening mode. The neighboring nodes will use the new schedule to detect after receiving this packet, and thus a new cluster is formed. . A cluster head is selected with the consideration of the next possible location of target gained by prediction. When the predicted location of the target is on the boundary of the current cluster, the current cluster head would send a solicitation packet to the sensor nodes around the predicted location, and select the first one which replies the message to be the new cluster head, and send it a confirming packet. When using prediction-based mechanism, the whole energy consumption will be less if the target's moving status changes smoothly, for the accuracy of prediction is affected by the changes of target's movement status. . In multiple target tracking, a sensor node may acquire more than one measurement, these measurements are not only generated by the objects but also possibly from the distributed heap. Hence multiple targets tracking algorithm needs to solve the data association problem, i.e. correctly mapping the measurement and target pairs with the interference introduced by the mass of objects. Extended Kalman Filter (EKF) is the most widely used method for target tracking. In this paper the distance measurements are also considered. Maximum Likelihood estimation [7] which is a measurement conversion method is proposed which resolves the data association problem and then applying standard kalman filtering which then updates the state (position and velocity) of the object. When the object is moving through the sensor area where sensors are located they will detect the object and then form a cluster. From this cluster, one of the sensor nodes is selected as the leader. In target tracking applications, at each time stamp, measurements obtained from numerous sensing nodes are transmitted to the cluster head. After collecting all the information, the leader sensor reports it to the sink node. Maximum Likelihood Estimation (MLE) has drawbacks because of some assumptions that the distance between sensor and the object is very small which is not always true. To overcome this problem, another measurement conversion method is suggested which is Bayesian estimation model. It is a probability based method which resolves the problem formulated by MLE. The algorithms within Bayesian estimation framework include kalman filter. The basic idea is to transform the nonlinear measurement model into a pseudo linear form in the Cartesian coordinates, which estimate the bias and covariance of the converted measurement noise, use of Kalman filter, has better accuracy and consistency in prediction.

III. Tracking and Proposed Algorithm

In this section, we explain the proposed algorithm for target tracking. In wireless sensor network the performance of the network can be improve by implementing dynamic clustering with the prediction mechanism. It calculates the next possible location of the target which not only be energy efficient but also less error prone to the target missing rate in the network as each time the object is detected cluster is formed.

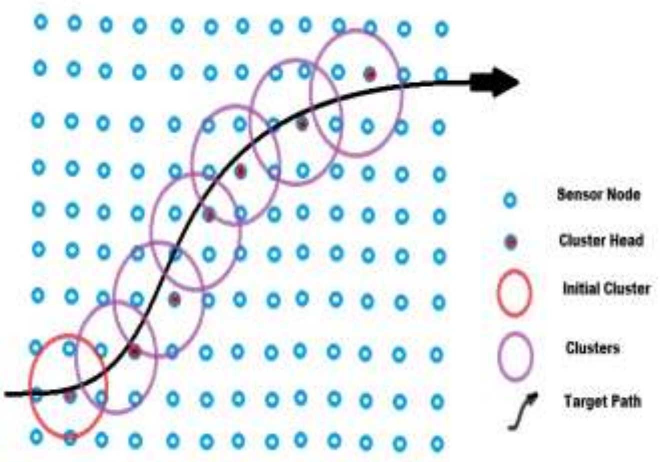

Figure 2 : Object Traversal and its Detection

The figure 2 illustrates the network model structure formed when the object is moving along the sensing region and how the clusters are formed along the traverse path. The dynamic clustering mechanism proposed performs the clustering along the route of the target movement with minimum numbers of sensor nodes to track the target object, thus can reduce the energy consumption and prolong the lifetime of the whole sensor network.

3.1 Cluster Formation

A dynamic clustering mechanism is proposed to perform the clustering along the route of the target movement with minimum numbers of sensor nodes to track the target object. Since limited number of sensors are involved in sensing the object the energy consumption is reduced and the lifetime of the whole sensor network is increased. Target tracking starts with the formation of the cluster as the object is detected in the sensing environment. Sensors sensing the object become the members of the cluster depending on the sensed value. The formation of cluster starts as the BS sends tracking command to all the sensors which wakes them up and they sense the environment. The sensors sensing the object forms the cluster depending on the sensed value S_v (sensing value from the sensor node). A threshold value Th is being set by the BS which is the signal strength of the sensors sensing the object. If the sensed values is greater than the threshold value Th, then those sensors form the cluster around the object being tracked and sensed the environment twice again and a solicitation packet containing these three sensed value and their location is sent to the cluster head.

Algorithm 1 Cluster Formation

Let S_v be sensed value of the sensor and Th be threshold value

1. Awake all sensor by sending tracking command.
2. If object sensed
   i. Compare the sensed value with threshold value
      1. If S_v > Th then sensors become Cluster Member(CM)
      2. Else go to sleep
   ii. All sensor sensed object perform sensing twice

   Else
      Go to sleep
3. Finish Sensing 3 times broadcast solicitation packet

Figure 3. Algorithm for forming the cluster

3.2 Cluster Head Selection

Initially the cluster head is selected among the Cluster Member (CM) as one which has the highest sensed value by broadcasting their sensed value to their neighbor. For further tracking process the CH is selected using semi-localized cluster head selection algorithm.

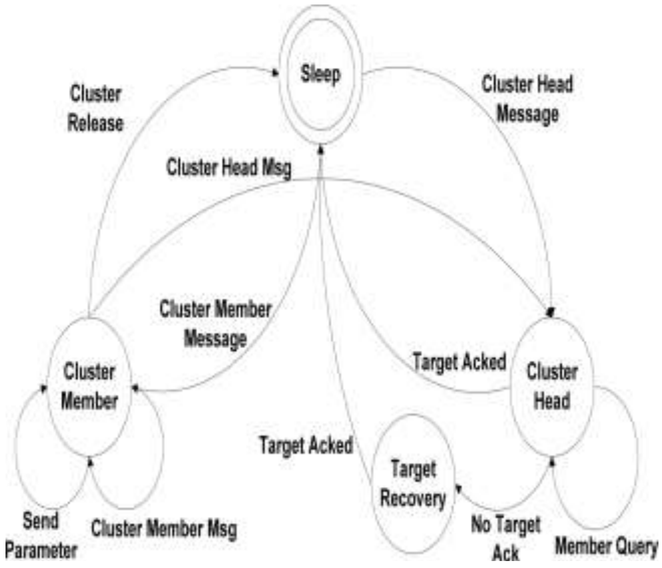

Figure 4. State Diagram of node in semi-localized algorithm

In state diagram of Figure 4 there are four states. First, sensor node waits in the sleep state. If the node is selected as a cluster head, it goes to cluster head state directly. Otherwise, if the node is selected as cluster member, it goes to cluster member state. Other tasks in these states and changing to target recovery state are the same as the distributed algorithm. In this algorithm, current cluster head selects the next cluster head and its cluster members precisely according to predicted location of the target. The grid arrangement of nodes in the network lets the current cluster head to select and wake up the closest node to the predicted target location as next cluster head. In addition to the cluster head, nodes that are able to detect the target in the predicted location are selected as the next cluster's members.

3.3 Target Detection

Target detection is performed in 2 different stages namely Target Localization and Target Tracking. There has been an increasing interest in event source or target localization in the context of WSNs. Among the various methods studied for localization in WSNs, the simplest is the Centroid Estimator (CE), while another approach is based on the classical Maximum Likelihood (ML) estimator. However, both methods do not consider sensor faults and may yield significant estimation errors when faults are present in the field. Tracking techniques, as opposed to the localization techniques discussed previously, usually incorporate a target mobility model and assume a probability distribution for the sensor measurement errors to improve performance. They rely on Bayesian filtering variants, such as Kalman or particle filters, to mitigate the effect of measurement noise and alleviate high localization errors that do not reflect the target's mobility pattern. In general, tracking methods are classified into centralized, decentralized, and distributed approaches. In centralized methods, the sensor measurements are communicated to a central repository, where there is also a processing unit to run the localization and tracking algorithm. In decentralized approaches, a cluster is formed when a target is detected and all the sensors in the vicinity of the target forward their measurements to the cluster head (leader), which is responsible for estimating the target location. In distributed approaches, each node exchanges messages only with its neighbours in the network and runs the tracking algorithm locally by using available measurements from all neighbouring nodes.

IV. Experimental Results

We evaluate the performance of tracking, the simulation is done on NS2[13]. The experimental setup consisted of 100 nodes deployed in a grid manner in 1000mx1000m. Figure.5 is the topology which we will use in our experiment.

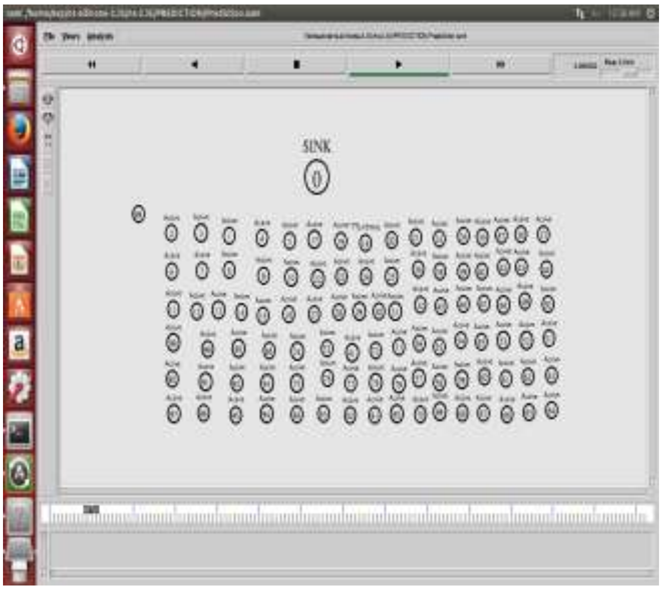

Figure 5. Basic Topology of deployed Sensor Nodes

In the Figure 5 we have created a network in grid fashion with a base station which performs all the processing of the information received from the cluster heads. An object moves randomly from one position to the another and as the target moves its being sensed by the nearest sensors. The distance is calculated from the information received from cluster heads. We have used dynamic clustering approach which uses less energy of the sensor nodes and make it an energy efficient tracking.

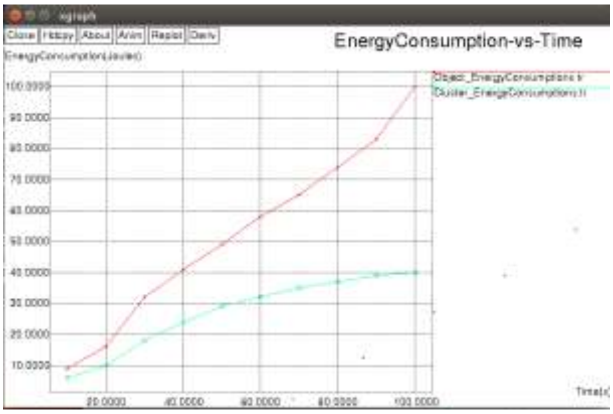

Figure 6. Energy Consumption

The Figure 6 shows how the energy is being consumed by the network nodes as the tracking occurs in the nodes which forms the cluster and it shows how the energy is being optimized. The Figure 7 shows the throughput of the network with the time.

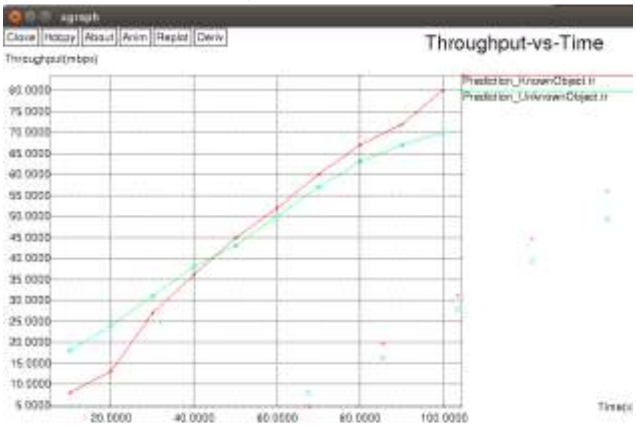

Figure 7. Throughput vs Time

V. Conclusion

An important application of wireless sensor network is target tracking. In this paper, we proposed a new target tracking method which makes it adaptive with target mobility model. In this method, we implemented a dynamic clustering of the nodes as it senses the object. In the other words, the size of waking up area depends on the sensors which sense the target. In our work, we focused on tracking a single object with the network. In our future endeavour, we plan to study the importance of the coverage issues in the model including the data fusion algorithm that would make tracking more accurate.

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