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An Efficient Protocol for Target Tracking in Wireless Sensor Networks (WSNs)

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Abstract

Target tracking is one of the most important applications in wireless sensor networks. In most of objects tracking sensor networks, a general method which is called clustering has been used. The target to be tracked may go unnoticed due to problems like node failures, communication failures amongst nodes and localization errors. Recovery mechanism needs to be initiated to find the exact location of the lost target. Hence, Using Base Station, a new clustering method and new recovery mechanism with virtual grid, we introduce an efficient protocol namely (EBSOTT). Using Base Station as a fundamental element in tracking process, EBSOTT protocol tries to reduce the number of transmitted packets and subsequently, energy consumption in order to meet the current needs of clustering. Also, using virtual grid reduces time of decision which causes to the object retaining and faster recovering. For evaluation, the proposed protocol was compared to the BSOTT algorithm.

Keywords: *Clustering; Location; Recovery; Target tracking; Virtual grid; Wireless sensor network.*

1. INTRODUTION

Wireless sensor networks (WSNs) is a new network paradigm that involve the deployment of hundreds even thousands of low-cost, energy-limited, small, and application-specific sensor nodes to create applications for factories monitoring and control, disaster response, military sensing intelligent house control, and, etc. Energy saving is one of the main challenges in WSNs. It is because of the energy of a sensor node which is limited and replenishment of its battery is usually impossible. So the lifetime of a sensor node is strongly dependent on its battery lifetime and the lifetime of a WSN is directly related to the lifetime of its sensor nodes. Thus, if we can preserve sensor nodes more time in the network, we will increase the network lifetime. Among vast number of WSN applications, target tracking is considered as an important application [1]. It consists of two steps: (a) localization, (b) prediction. The sensor node has limited battery power, and most of the power is consumed in communication [1]. Increased communication may drain the battery, causing node failure. If there are more numbers of failed nodes around, target may go undetected. For next nodes, which were supposed to be active in tracking, may not have the trace of target, causing the situation of loss of target. Other issues like communication failures during transmission of information, localization errors during tracking, and abrupt change in target velocity may also cause loss of target. Following reasons may result in loss of target:

a) Communication failures: Nodes may not be able to communicate due to obstacle like tree, specially in case of forest WSN. Packet loss and delay in response can also be considered in this case.

b) Node failures: As sensor nodes have limited battery power and if they remain active for a long time, battery may drain faster leading to failure. Physical capturing of node and hardware failure are also the reasons of node failure.

c) Sudden change in target speed: As speed of target changes suddenly, the difference between actual and predicted location of target becomes large, resulting in loss of target.

In this paper, Using Base Station, a new clustering method and new recovery mechanism with virtual grid, we introduce an efficient protocol.

Rest of the paper is organized as follows: In section 2, literature survey of clustering algorithms, target tracking and recovery algorithms are presented. In section 3 assumptions during network deployment are presented. In Section 4 we discuss proposed protocol. Simulation and performance comparison between existing and proposed approach is discussed in section 5. Section 6 concludes the paper with summary and future work.

2. LITERATURE SURVEY

WSNs formation has many design challenges like limited energy, network lifetime, secure communication and application dependency etc. Dividing the network into groups of node can be considered as a solution to handle these challenges [2]. Here, only one node is in an active mode from each group and remaining are in sleep mode.

In this manner, less consumption of energy will increase the lifetime of network. Clustering is the suitable solution on increasing the lifetime of WSN. Most works in the related literature propose a cluster based architecture for scalability and robustness [3], [4], [5]. The cluster heads (CHs) are responsible for locally determining the optimal set of sensors that will be activated so that energy spent on tracking is minimized. The nodes are allowed to turn off their radios as long as their measurements satisfy the predictions of the CHs [4]. At a sensor, the energy consumed in transmitting a packet is around twice the energy consumed in receiving it, and the energy consumed in receiving a packet is an order of magnitude higher than the energy consumed per instruction execution [6].

Target tracking approaches can be classified into three categories including tree-based, cluster-based and prediction-based algorithms. Tree-based methods organize the network into a hierarchy tree. Examples of tree-based methods include STUN (Scalable Tracking Using Networked Sensors) [7], DCTC [8] and OCO (Optimized Communication & Organization) [9].

In cluster-based methods network is divided into clusters. A cluster consists of a cluster head (CH) and member sensor nodes. A CH is responsible for collecting data from its cluster's members, calculates the current target location and sends it to the sink. Cluster-based methods are divided into 2 categories, static clustering and dynamic clustering. In static clustering methods, clusters are formed at the time of network deployment and remain unchanged until the end of network lifetime. But in a dynamic clustering algorithm, clusters are formed dynamically as target moves. Examples of cluster-based methods are presented in [10], [11], [12], [13].

Prediction-based methods are built upon the tree-based and the cluster-based methods, with added prediction models. These algorithms are methods that with a prediction mechanism predict next location of target and with attention to estimated location, only select some nodes that are near to this location for tracking and other nodes remain in sleep mode for energy saving. Examples of prediction-based algorithm are PES (Prediction-based Energy Saving) [14], DPR (Dual Prediction-based Reporting) [15] and DPT (Distributed Predicted Tracking) [16].

Base station (BS) is a powerful energy and computational resource. Using new technologies, such as RFID and new antennas long range transmission with small antenna size, the base station can be used in the tracking process. In this method, base station undertakes management of cluster formation, active nodes rotation and part of transmissions needed for tracking the target.

In this approach ad-hoc ability of WSNs is overlooked to earn energy conservation, facilitated management of WSNs and fault tolerance to failures. In this method, all sensors are equipped with 3D cubic antenna that allows them to receive information from long distances at 915 MHz radio frequency (see Fig. 1) [17]. Since BS manages the clustering and tracking processes, it has a good knowledge of nodes energy level.

All above described tracking algorithms may suffer from loss of target as WSN have limited resources. Causes of loss of target are already discussed. To mitigate these issues, various RMs are proposed by researchers.

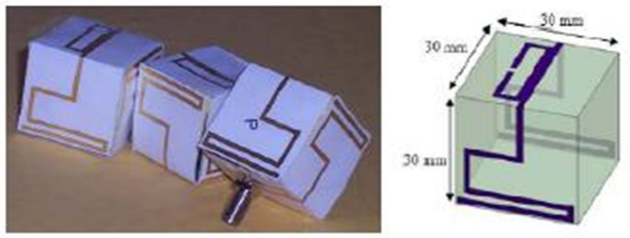

Fig.1. Illustration of the antenna used in the proposed method

RM for wild life tracking is presented in [18] where a simple recovery mechanism for wild life, tracking based on popular places is considered. Popular places, they are the places where animals (targets) frequently visit for water, shelter and rest. If target is lost then by checking their presence at these places recovery can be done. Another RM for wild life tracking using hierarchical clustered WSN is studied in [19]. In paper [20], a lightweight target tracking protocol (LTTP) with three levels of RM is discussed. RM for target recovery using static clustered WSN is discussed in [21]. Also, in this paper, we propose an efficient approach with less communication overhead for successful recovery.

3. Overview

3.1 Assumptions

Our algorithm considers dynamic clustered architecture for target tracking. Following assumptions are made about the sensors and the sensor network in the development of the proposed target tracking algorithm:

1- It is assumed that sensors are binary sensors and each sensor is aware of its own location and they are stationary. Also, BS knows the topology of the WSN.

2- It is assumed that BS is outside of the surveillance field, plugged to an unlimited energy source and capable of long range transmissions through higher transmission power at 915 MHz frequency.

3- Sensing ranges (RS) for all the sensors are the same and communication range (RC) is double the sensing range.

4- All sensors are equipped with 3-D cubic antenna to be able to receive BS packets at 915 MHz from a long distance.

5- All have the same battery power.

3.2 Sensing and Communication Model

In this paper, binary sensors' sensing disk has a radius of RS and binary sensing model is considered [17]. Sensors can detect the target once it enters to the sensing range of the sensor. Formally, the mode is as follows:

$$S_i(T) = \begin{cases} 1, & if\ d(S_i, T) \le R_s(i) \\ 0, & otherwise \end{cases} \quad (1)$$

Where Si (T) is the sensed data of the sensor Si and d (Si, T) is the distance between the sensor Si and the target T. An important assumption made in this paper is equipping sensors with 3-D cubic antenna. Using this antenna, it is possible to have both RFID technology and miniaturized wireless communication equipment at the same time. The frequency of operation lies in the UHF RFID band, 902 MHz–928 MHz (centered at 915 MHz). The ultra-compact cubic antenna has dimensions of 3cm × 3cm × 3cm, which features a length dimension of λ/11. The cubic shape of the antenna allows for "smart" packaging, as sensor equipment may be easily integrated inside the cube's hollow interior.

Binary sensors have minimal assumptions about sensing capabilities. At this frequency long range transmission for BS is possible. However, sensors use 2.4 GHz for inter sensor transmissions and merely BS uses 915 MHz to send its data in one-hop and for long range. Fig. 2 shows how BS transmit command message to lead the clustering, and CH replies target location hop by hop. Binary reporting, smart sensors also can act as binary sensors. So, proposed tracking algorithm is applicable to both binary and smart sensor networks.

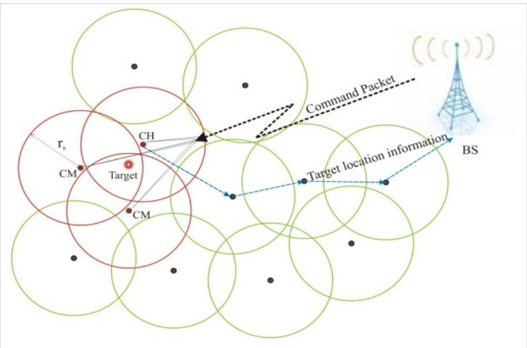

Fig.2. Illustration of the BS and sensors communication

3.3 Localization

Assuming target T has the coordinate of (XT, YT), all the sensors located in a circle centered at the point (XT, YT) with a radius RS can detect the target. Generally, the centroid of the sensors that can detect the target can be a fair approximation for target location. The location of the target can be estimated using the centroid approach [17]:

$$\begin{cases} \bar{X} = \frac{1}{n_{sd}} \sum_{i=1}^{n_{sd}} X_i \\ \bar{Y} = \frac{1}{n_{sd}} \sum_{i=1}^{n_{sd}} Y_i \end{cases} \quad (2)$$

Where (X_i, Y_i) S_i and is the coordinate of the sensors and the number of sensors that detect the moving target respectively. The estimated coordinate of the target T is $(\bar{X}, \bar{Y})$.

4. PROPOSED ALGORITHM

Our algorithm is divided into two stages, clustering and recovery.

4.1 Clustering

Clustering is one of the most needed important operations of aggregation and data fusion. Dynamic clustering algorithms problem is that when target frequently changes its location, reclustering must be invoked and with the course of time communicative overhead imposed by clustering, which makes clustering to lose the initiative. In our proposed algorithm clustering overhead is minimized by using BS. Whenever reclustering is needed, BS broadcasts a command message to announce the new CH and cluster members (CMs). The base station uses the following methods to select the cluster heads and cluster members. In this method, BS calculates, for each node that can sense the target, a selection parameter as follows:

$$\text{selection}_i = \frac{energy_\text{i}}{{distance_i}^2} \quad (3)$$

In this relation $distance_i$ is the distance of node i from previous location of target, and $energy_i$ is the remaining energy of nod i. Then, active CH selects three or five (cluster number) nodes that have maximum selection parameter as tracker sensor nodes in the next interval time. Using both of these parameters, distance and energy, for tracker sensor node selection algorithm caused that nodes with lower energy remain more time in network and so network lifetime increases. Especially in situations that target remains in a cluster for a lot of time or target traverses a route several times or target moves slowly, using proposed tracker sensor node selection algorithm can prolong network lifetime significantly.

Then, BS forms a command packet including clustering information such as CH and CMs IDs and transmits the packet over the WSN through a long range transmission. It is noticeable that BS sends its data in one hop at 915 MHz and with a high power. Also, sensors use 3-D cubic antennas to receive BS data. Activated sensors of the field receive the packet and extract the information target new location. BS decide which sensor must be the new CH. BS lets the sensors to be informed of the new CH and CMs. If any node failure causes missing the target, recovery operation is invoked. This phase continues until BS finds the target.

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4.2 Recovery

Recovery mechanism needs to be initiated to find the exact location of the lost target. In this paper, we are proposing an efficient recovery mechanism. In this method, the sensor network environment is divided cells with dimensions of 100 × 100. Each sensor node is located within this field, resulting in one of these cells. The BS estimates target location and saves which cell is the target location. Detail of recovery process is as given below:

Step 1: The last cell, which the target is located, is saved in a list.
Step 2: We search target in the list.
Step 3: If the target was found, therefore, the recovery process is finished.
Else
Step 4: All its neighboring cells are add to the list.
Step 5: Go to Step 2.

Using our recovery process causes that less number of nodes participates in recovery operations, therefore, nodes consume less energy and will increase the network lifetime. As a result, our mechanism works as follows:

At the beginning of this algorithm, all nodes are in sleep mode except border nodes. When a border node finds a target in its sensing range, it waits for a random time called back off time to avoid collision. Then, the border node sends its sensed data to the BS. Upon receiving sensed data from border nodes, BS estimates target location. According to the clustering algorithm presented in this section, the BS selects the cluster heads. Since, all sensors autonomously return to sleep mode after a period of time, BS needs to trigger CH and CMs to awaken them and make them ready for receiving command message. BS broadcasts command message containing new CH's ID, over the WSN to inform sensors about the new CH, subsequently other awakened sensors that are not CH will be CMs. Sensors work in two distinct modes shown in Fig. 3 [17].

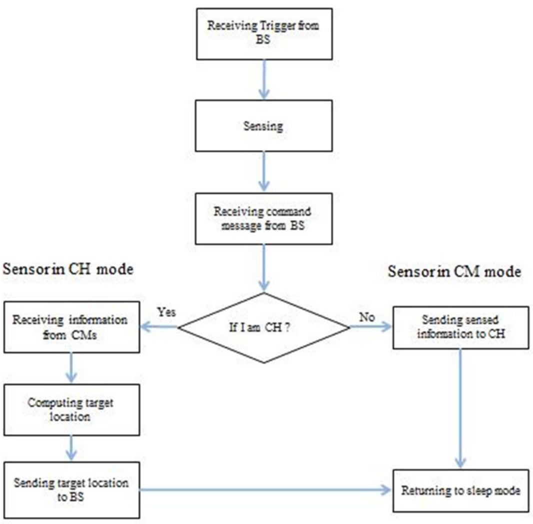

Fig.3. Working stages for sensors.

However, if new CH and the latest CH are the same, BS won't transmit any command message indicating that everything is as the same. Then, the very last CH again is CH for the new round, CMs just transmit their sensed data. Once a member detects the target, it sends its scan data (its location and the time finding the target) to the CH. CH performs data fusion to get the location of the target, and reports to the BS periodically. Receiving tracking information from sensor field, BS starts to evaluate target location. Then, if target is not in the sense range of the current CH, BS dismisses current CH and choose a new CH as mentioned before. So far BS leads tracking process. However, any failure needs to be handled. In this case presented recovery operation is invoked .If BS succeeds to capture the target, then tracking process starts from the beginning, otherwise BS does recovery process until it finds the target or reach to end the of the network lifetime. Fig. 4 shows working stages of the BS in two conditions; normal condition and target miss condition.

Being triggered by BS, sensors change their state to sensing state and wait to receive command message. After receiving command message, they check to see if they have been announced as CH or not. If a sensor is not announced as CH, then it is CM. CM broadcast sensed information and CH receives the information from all CMs. Then, CH computes exact location of the target using (2). Finally, CH sends target location to BS. Due to energy conservation, CH and CMs return to sleep mode at this point.

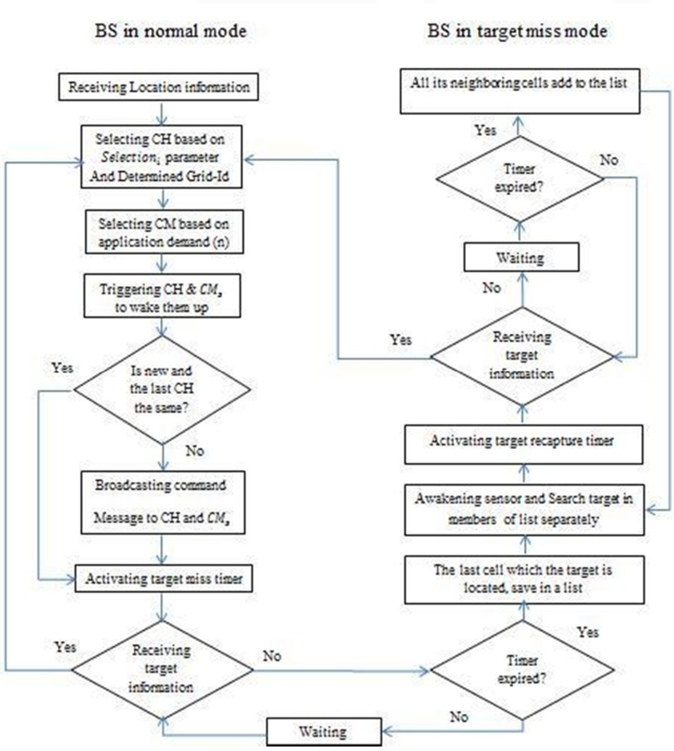

Fig.4. Working stages for base station (BS).

5. SIMULATION

In this section, using computer simulation, we evaluate performance of proposed algorithm and compare our proposed method with BSOTT [17]. In this review, all algorithms have been simulated in two different cluster member numbers. In fact we changed cluster members from 3 to 5, to investigate impact of this variant on different network parameters. Our simulation has been done in c# simulator (Microsoft Visual Studio 2010). Three below parameters for evaluate performance of our algorithm with others.

1- Network lifetime: The time that the first node of network dies.
2- Energy consumption of nodes.
3- Transmitted Packets.

5.1 Simulation Environment

The EBOSTT algorithm described in the previous section was simulated a wireless sensor network consisting of a set of sensor nodes randomly deployed in a field of 1000×600 m2. The sensor network environment is divided into cells with dimensions of 100 × 100. Each sensor node is located within this field, resulting in one of these cells (see Fig. 5).

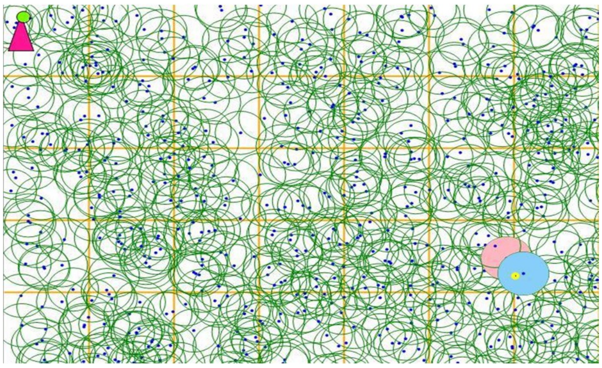

Fig.5.Simulation environment.

Also, the simulation model is considered a network which the number of its nodes is varied between 1000 and 4000. Each sensor node is able to detect the existence of nearby moving target communicate with other sensor nodes in the vicinity and do some simple computation. Target is moving with the maximum velocity of V_{max} =10 m/s and target motion model is a random waypoint. Basic information of each sensor node is considered as Table1 [22].

Table1: Basic information of each sensor node.

Parameters	Value of parameters
sensing range (R_S)	30 (m)
communication range (R_C)	60 (m)
initial energy	3 J
transmission and reception energy	0.175 J
sensing energy	1.75 µJ

5.2 Simulation Results

In this section, we evaluate performance of our algorithm and compare our algorithm with BSOTT in the network lifetime, average energy consumption of nodes and transmitted packets. Performance of the proposed algorithm was compared with cluster members 3 and 5 with changing the number of nodes.

5.2.1 Network Lifetime

For more comparison, we run our simulation in many different scenarios, with different node number and two different cluster member numbers, and calculate the network lifetime. We considered time that the first node of network dies as network lifetime. Fig. 6 shows effect of increasing number of sensors and cluster members respectively on the network lifetime. As this diagram shows, network lifetime in proposed algorithm is more than BSOTT and this time increases as the nodes number of network increase.

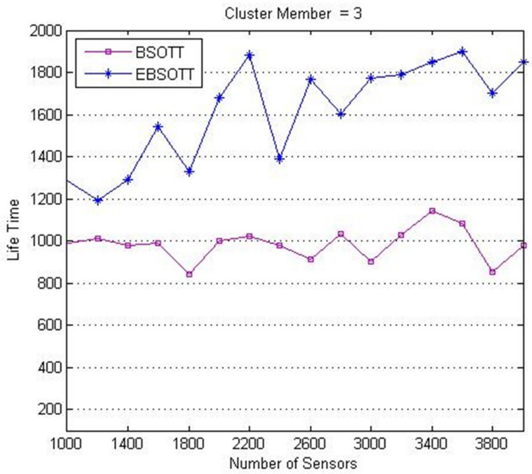

Fig.6. Effect of number of sensors on network life time.

Fig. 7 illustrates effect of cluster members on the network life time. Increasing cluster members again leads to growth of message transmission. Hence, cluster head battery drains mush faster and it shortens the lifetime.

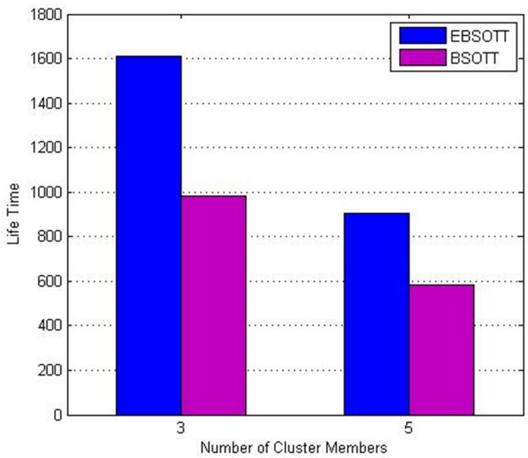

Fig.7. Effect of cluster members on network life time.

5.2.2 Energy Consumption

The second parameter that has been studied in this research is energy consumption. Almost in all WSN's applications energy consumption is considered and regardless of the fact that which parameter is improved, energy consumption must be kept low. Moreover, energy consumption should not depend on number of sensors since this dependency limits scalability of the network. Fig. 8 shows that not only proposed algorithm consumes less than its rivals energy, but also slope of the diagram indicates that there is no significant dependency between number of sensors and energy consumption in our algorithm as opposed to BSOTT.

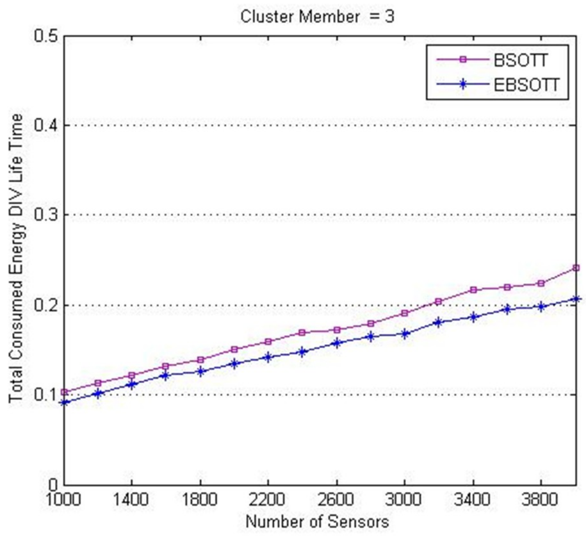

Fig.8. Effect of number of sensors on energy consumption.

In Fig. 9, relation of cluster members and energy consumption has been taken into consideration. There are two facts in Fig. 9. First, increasing cluster members leads to more energy usage. Second, BSOTT algorithm has more energy disposal in all two cases than proposed method.

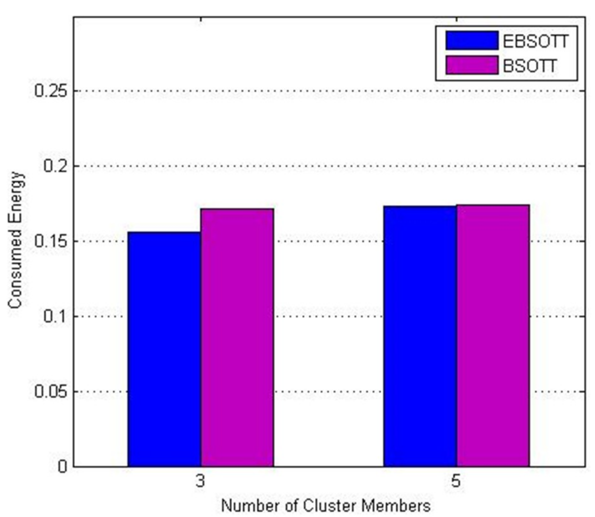

Fig.9. Effect of cluster members on energy consumption.

5.2.3 Transmitted Packets

Number of transmissions during tracking process in the field of WSN is an important factor mostly known as radio silence. Number of transmitted packets must be kept low for both energy and radio silence reasons. Number of transmitted packets in the proposed method is less than the BSOTT. Transmitted packets shown in Fig. 10 is an average number and shows the ratio of actual transmitted packets to network life time.

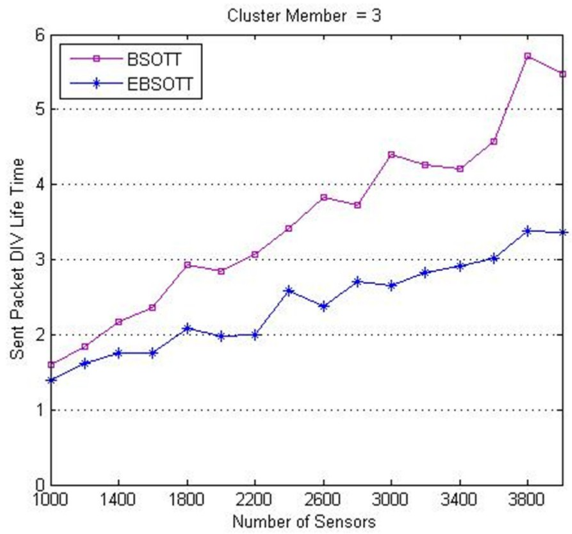

Fig.10. Effect of number of sensors on transmitted packets

Obviously raising cluster members results in more message exchange between cluster head and cluster members to form and manage a cluster. Thus, the more member a cluster have, the more transmissions it needs (Fig .11).

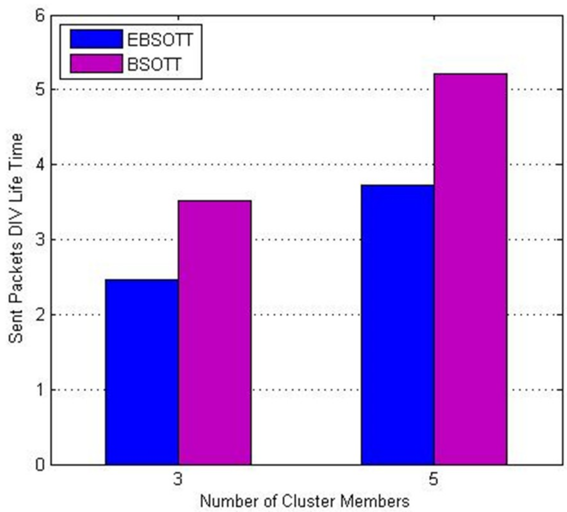

Fig.11. Effect of cluster members on transmitted packets.

6. CONCLUSION AND FUTURE WORK

In this paper, we investigated the feasibility of using BS as a central element and virtual grid in tracking process.

It improves virtual grid ideas to divide each network into M×N square area and use the nodes in each grid, so that the less number of sensors can be used in recovery operations. This method for target tracking led to reduce energy consumption and increase the network lifetime too. This scheme reduces the number of transmitted packets. The density of the sensor nodes in the network has some impacts on energy consumption and number of transmitted packets. In the future studies, we will focus on prediction methods to improve the proposed algorithm.

REFERENCES

[1] F. Martincic, and L. Schwiebert, Introduction to Wireless Sensor Networking. In Ivan Stojmenovic (Ed.): Handbook of Sensor Networks: Algorithms and Architectures, John Wiley & Sons, 2005, pp. 22 – 61.

[2] P. Kumarawadu, D. J. Dechene, M. Luccini, and A. Sauer, “Algorithms for Node Clustering in Wireless Sensor Networks: A Survey,” Information and Automation for Sustainability, 2008, ICIAFS 2008, 12-14 Dec, pp. 295 - 300.

[3] O. Garcia, A. Quintero, and S. Pierre, “Profile-based energy minimisation strategy for Object Tracking Wireless Sensor Networks,” IEEE International Conference on Wireless and Mobile Computing Networking and Communications, 2006, pp. 372 - 379.

[4] P. Beyens, A. Nowe, K. Steenhaut, “High-density Wireless Sensor Networks: a new Clustering Approach for Prediction-based Monitoring,” EWSN 2005, Proceedings of the Second European Workshop on Wireless Sensor Networks, Istanbul, Turkey, 2005, pp.188 – 196.

[5] K. Wu, J. Harms, and E. Elmallah, “Profile-Based Protocols in Wireless Mobile Ad Hoc Networks,” 26th Annual IEEE International Conference on Local Computer Networks (LCN'01), 2001, pp. 568 - 575.

[6] S. Goel, and T. Imielinski, “Prediction-based monitoring in sensor networks: taking lessons from MPEG,” ACM Computer Communication Review, October 2001, Vol. 31, No.5, pp. 70 – 83.

[7] H. T. Kung, and D. Vlah, “Efficient Location Tracking Using Sensor Networks,” Proceedings of 2003 IEEE Wireless Communications and Networking Conference (WCNC).

[8] W. Zhang, and G. Cao, “DCTC: Dynamic Convoy Tree-Based Collaboration for Target Tracking in Sensor Networks,” IEEE Transactions on wireless communications, VOL. 3, NO. 5, september 2004.

[9] S.P.M. Tran, and T. A. Yang, “OCO: Optimized Communication & Organization for Target Tracking in Wireless Sensor Networks,” Proceedings of the IEEE International Conference on Sensor Networks, Ubiquitous, and Trustworthy Computing, 2006.

[10] W.P. Chen, J.C. Hou and L. Sha, “Dynamic Clustering for Acoustic Target Tracking in Wireless Sensor Networks,” Proceedings of the 11th IEEE International Conference on Network Protocols, 2003.

[11] J. Chen, Ch. Zang, W. Liang, and H. Yu, “Auctionbased Dynamic Coalition for Single Target Tracking in Wireless Sensor Networks,” Proceedings of the 6th World Congress on Intelligent Control and Automation, June 21 - 23, 2006, Dalian, China,2006 IEEE.

[12] K.T. Soe, “Increasing Lifetime of Target Tracking Wireless Sensor Networks,” PROCEEDINGS OF WORLD ACADEMY OF SCIENCE, ENGINEERING AND TECHNOLOGY, AUGUST 2008, VOL, 32.

[13] E. Olule1, G. Wang, M. Guo, and M. Dong, “RARE: An Energy-Efficient Target Tracking Protocol for Wireless Sensor Networks,” International Conference on Parallel Processing Workshops, 2007 IEEE.

[14] Y. Xu, J. Winter, and W.C. Lee, “Prediction-based Strategies for Energy Saving in Object Tracking Sensor Networks,” International Conference on Mobile Data Management, 2004 IEEE.

[15] Y. Xu, J. Winter, and W.C Lee, “Dual Prediction-based Reporting for Object Tracking Sensor Networks,” First Annual International Conference on Mobile and Ubiquitous Systems: Networking and Services, 2004 IEEE.

[16] H. Yang and B. Sikdar, “A Protocol for Tracking Mobile Targets using Sensor Networks,” Proceedings of IEEE Workshop on Sensor Network Protocols and Applications, 2003 IEEE.

[17] R. P. Khajei, M. hoseinzadeh, S. Ghatei, “An Extensive Study on Base Station Based Target Tracking in WSNs,” IJSSST, 2010, Vol. 12, No. 2, pp.46–53.

[18] F. Lalooses, H. Susanto and C.H. Chang, “An Approach for Tracking Wildlife Using Wireless Sensor Networks,” The International Workshop on Wireless Sensor Networks (NOTERE 2007), IEEE, Marrakesh, Morocco, 2007.

[19] F. Lalooses, H. Susanto, and C. H. Chang, "Recovery Target Tracking in Wildlife," Wireless and Optical Communication, Montreal Canada, Nov. 2005.

[20] H. Yang and B. Sikdar, “Lightweight target tracking protocol using ad-hoc sensor network,” Vehicular Technology Conference, 2005, VTC 2005-Spring. 2005 IEEE 61st, VOL. 5, June 2005, pp. 2850- 2854.

[21] A. Khare, K.M. Sivalingam, "On recovery of lost targets in a cluster-based wireless sensor network," Pervasive Computing and Communications Workshops (PERCOM Workshops), 21-25 March 2011, pp.208-213.

[22] M. Guo, E. Olule, G. Wang and S. Guo “Designing energy efficient target tracking protocol with quality monitoring in wireless sensornetworks,” The Journal Supercomput, 2010, VOL. 51, 131 – 148.