International Journal of Advances in Computer Networks and Its Security– IJCNS
Volume 5: Issue 1 [ISSN : 2250-3757]
Publication Date : 30 April, 2015

Low Overhead Clustering Approach for Long Lifetime Object Tracking Applications

M. Mirsadeghi, A. Mahani, †Y.S. Kavian

***Abstract*—Target tracking is one of the most important applications of wireless sensor networks (WSNs), especially for the urgent event of interest. In this paper we propose a new clustering algorithm beside our accurate prediction mechanism which was proposed previously, that detects and tracks a moving target, and alerts head nodes along the predicted path of the target. The main advantages of proposed clustering algorithms are low transmission overheads with high coverage. Then based on the accuracy of the predictor the best cluster is selected to make more accurate tracking while reducing dramatically the object miss ratio. According to our proposed method in each time instant, only some nodes which, are near to the target and have short distance to the head node, will be selected for tracking and other nodes go to the power saving mode which can strongly reduces the consumed energy.**

***Keywords*—Target tracking, Wireless sensor networks, Cliustering, Coverage, energy efficiency.**

I. Introduction

Target tracking is one of the most important and useful application of WSNs. The use of sensor networks for target tracking faces some problems in which energy constraint is very important. Based on this factor we can classify the object tracking protocols into non-cluster-based [1, 2] and *cluster-based* [3-10] protocols [11]. In the first, each sensor nodes ends data to the sink directly which consumes a lot of energy. While clustering is the most common technique used for energy aware routing in WSNs. Cluster-based target tracking algorithms is divided into two general groups: 1)Static clustering [5-10] and 2) Dynamic clustering [3, 4].

In dynamic clustering, changing the cluster head at the beginning of each tracking process round Consumes more energy and so is not a suitable approach for target tracking purposes. In static clustering the cluster structure changes periodically but all attributes of each cluster such as the size of a cluster, the coverage area, and the cluster members are static for a long period of time until the beginning of the new clustering period. The main parameters whose are considered in clustering phase are 1) low control overhead to have less energy consumption during clustering and 2)good distribution of cluster heads to have high coverage, low number of orphan nodes and low collision between cluster heads as well as reasonable number of CHs. Since orphan nodes transmit directly to the sink and do not participate efficiently in tracking of moving object, so coverage of network has direct effect on missing rate and energy consumption of target tracking system.

Several clustering methods have been proposed so far to achieve such parameters [12-16]. In [12], a gradual cluster head election algorithm is proposed that gradually elects cluster heads according to the proximity to neighbor nodes and the residual energy level at each clustering step. Although this method guarantees high network connectivity and high coverage, the number of cluster heads and their collision in each clustering process round is so high. In [13], a duplication avoidance method is proposed. Each node has a random number generator based on logistic map function and by random updating in each clustering process round, decide to be either a cluster head or not without any communication overheads. In [14], cluster heads are elected based on their probability and residual energy and authors present a new topology control mechanism in which nodes can control their transmission power level. This technique ensures that any elected cluster head is connected under an optimal degree determined the number of neighbors. In [15], a staggered clustering protocol is proposed which selects the high energy node with low communication cost as a cluster head and also considers the load balancing. For CH selection authors in [16] combine fuzzy logic, on demand clustering, non-probabilistic CH election with considering residual energy to reach longer life time.

None of mentioned methods satisfy all of the goals at once. So in this paper a new clustering algorithm with low communication overheads is proposed while has good distribution of cluster heads to increase the quality of tracking. Our proposed clustering method has three steps for CH selection. In the first two steps, CHs are selected without communication overhead and finally some control messages are exchanged between remaining nodes to increase the network coverage.

Department of Electrical Engineering, Shahid Bahonar University of Kerman, Kerman, Iran
Department of Electrical Engineering, Shahid ChamranUniversity of Ahvaz, Ahvaz, Iran

II. Proposed Method

A. Cluster based WSN

Low communication overhead, good distribution of CHs with high coverage, low numbers of orphan nodes and low collision between cluster heads as well as low number of CHs are important metrics in clustering mechanisms. Orphan nodes are nodes that are not covered by any cluster head and so they should stay active all the time, sense the environment continuously and transmit their data to the sink without any positive impact on tracking task. So in the clustering scheme with low coverage, the number of orphan nodes is increased and so the missing rate and energy consumption of target tracking system is increased strongly. Also this high coverage should be achieved by low number of cluster heads to decrease number of direct transmissions to the sink which has negative effect on energy consumption. In this paper to prolong the network lifetime and increase the accuracy of tracking, we propose a new clustering mechanism to have both low transmission overhead and uniform distribution of cluster-heads. We assume that all nodes have an ID number which is unique in the network area and a dynamic ID number that can be changed during cluster head selection. At initial state each node should try to find its neighbors defined as nodes in its communication range. Our proposed method has three steps for CHs selection and cluster creation which describe as follows:

Step1: At the beginning of each clustering process round, the nodes should update their dynamic ID number and also their neighbor's ID. The logistic map function is used to generate random numbers. The function is given by: $p(i+1) = r * p(i) * (1 - p(i))$. Where r is constant and $p(i)$ is a random number. The primary seed is needed to generate the random numbers. In Each clustering process round, nodes should generate a random number to changetheir dynamic ID. Nodes will update theirID number and their neighbor's ID using the following equation: $n(m,i+1) = n(m,i) + RAND$. Where $n(m,i)$ is dynamic ID Number of node m after i^{th} iteration and *RAND* is a random number which is generated through the following formula: $RAND = ceil\,(rand\,(i) * number\ of\ nodes)$.

$rand\,(i)$: Random number (between 0 to 1) in iteration i.

$ceil: MATLAB\ round\ function\ up$

If $n(m,i+1) > number\ of\ nodes$ then:

$n(m,i+1) = n(m,i+1) - number\ of\ nodes$

Because of using the same seed at the beginning which come from design stage, each node will generate the same random number like the other nodes. Now each node should decide whether be the cluster head or not. So a threshold is defined and each node compares their dynamic ID number with the defined threshold. If its ID number was bigger than the predefined threshold (CT_1), the node has a chance to be a cluster head otherwise it will stop the decision process in this phase. Then all of the elected cluster heads inform to their neighbors by *CH_msg*(ID_i) message which includes their unique ID and nodes that don't receive any message are considered as firs step remaining nodes. So the next two steps are done by these remaining nodes.

Step2: Between the first step remaining nodes if its number was smaller than the assumed threshold (CT_2) and was the smallest number among its neighbors, the node will decide to be cluster head otherwise it will stop the decision level and wait for next step. Then the CHs inform to their neighbors by *CH_msg* message and nodes that don't receive any message are considered as second step remaining nodes. So the last step will be done just on these remaining nodes.

Step 3: Despite of previous steps, step3 needs to exchange some control messages among second step remaining nodes. So each node calculates the weight We_i according to equation (1).

$$We_i = (\delta \frac{E_{ri}}{E_{initial}} + \beta \frac{1}{avg(dis)}) \qquad (1)$$

Where, E_{ri} is the remaining energy of node i, $E_{initial}$ is initial energy of node and $avg(dis)$ is average distance of node $i$from all of its neighbors. δ and β are constant values. Each node sets up a timer and waits for a certain time (which is inversely proportional to remaining energy of that node). When the time expires, and the node doesn't hear the *CH_msg* messages from any other sensor nodes, introduces itself as a cluster head candidate by broadcasting the *candidate_CH(NodeID*, *candidate_CH, weight)*, to all nodes within the cluster range. Next, if this particular node has the biggest weight among the candidate CHs, it will become a final cluster head and broadcast a *CH_msg* message within its cluster range.

B. Target Tracking Mechanism

At the beginning, all nodes are in sleep mode in which just can listen to communication channel to check messages. Once cluster heads receive an alarm message from the sink, wake up and sense the environment. If they cannot find the object, wake their members up to sense the environment and find it. Each cluster head that object is in its cluster, stays active and other nodes go back to sleep mode. For the first tracking round the active cluster head wakes all of its members up to sense the object but for the next periods that in each time step it should find the best sensor nodes for object tracking. The cluster head is responsible of doing necessary computation and finding the best sensor nodes. Then sends a wake up message to them, and if object is going to leave its cluster, it should inform the next cluster head and send a wake up message and necessary current position information of object to that CH. Cluster heads send their information to the sink for the period of T second and clustering is repeated after period of T_0 second in which $T_0 \gg T$.

III. Simulation Results

In this section we focus on tracking just one moving object to evaluate our proposed clustering methods and analyze the

TABLE1: parameters for energy consumption model

E_{elec}	$50\ nJ/bit$
E_{DA}	$5\ nJ/bit/signal$
E_{sense}	$22mW$
ϵ_{mp}	$0.0013\ pJ/bit/m^4$
ϵ_{fs}	$10\ pJ/bit/m^2$
d_0	$87\ m$
Data packet size	2000 *bits*
δ	0.8
β	5
Permanent counter threshold	75
Temporary counter threshold	2
CT_1	150
CT_2	50

effect of it on energy efficiency and quality of target tracking via MATLAB, although this method is able to track more than one object. In fact we have two steps of simulation. In the first step, five clustering methods named ECPF [16], DAC [13], GCA [12], SCP [15] and TCAC [14] that are described in section 1, are considered to compare with our proposed clustering method. In second step, the performance of our proposed algorithm for target tracking is evaluated through simulations. We will study the effect of clustering on target tracking performance. Show that using suitable clustering mechanism can decrease energy consumption of network and has direct effect on accuracy and energy efficiency of tracking system.

A. *Simulation Environment*

The network area is $200 * 200\ m^2$ in which 200 sensor nodes with initial energy of $1\ Joule$, are uniformly distributed. All sensor nodes are similar and have standard deviation of measurement noise $\sigma_\theta = 1^\circ$, sensing range $R_{sensing} = 35$ meters and communication range $R_{communication}$ =50 meters. But when CHs wants to send data to the sink, they can increase their communication range. The sink is located out of the area $(x = 100, y = 250)$ and the packets send to the sink every T=0.5 second and all attributes of object and predictor are the same as [17]. The energy consumption model for communication is discussed in [18], in which the consumed energy of transmitter node is:

$$\begin{cases} if \quad d > d_0 E_t = lE_{elec} + l\varepsilon_{mp} d^4 + lE_{DA} \\ if \quad d \le d_0 E_t = lE_{elec} + l\varepsilon_{fs} d^2 + lE_{DA} \end{cases}$$

Where E_{DA} is the energy for data aggregation in head nodes, E_{elec} is the dissipated per bit to run the transmitter or receiver circuit, ε_{fs} and ε_{mp} depend on the transmitter amplifier model, d is distance, d_0 is threshold distance and l is the packet length. The consumed energy for receiver nodes E_r is as follows: $E_r = lE_{elec}$. The table 1 contains simulation parameters.

B. *Step1: Static Clustering Comparisons*

In this step we have a comparison between the simulation results of different static clustering methods. We run each method for 1000 rounds and suppose that in each clustering process round all nodes are active, sense the environment and send their information to the cluster heads. Then all the cluster heads send the data packet to the sink. The results show that our proposed method has better condition in comparison with other methods.

- ***Coverage & energy consumption***

Table 2 compares the coverage ratio, number of orphan nodes and all energy consumption of all the methods in the whole working duration. As shown in table 2, when clustering method has high coverage it means that the number of orphan nodes is reduced and so the energy consumption of network would be reduced. According to the table 2, all nodes in our proposed method are covered by the selected cluster heads and there aren't any orphan nodes

- ***Network lifetime***

According to figure 1, in our proposed scheme its lifetime is more than other clustering methods. The life time of clustering algorithms are dependent on numbers

TABLE 2. Comparison of coverage rate, ratio of orphan nodes and energy consumption

Method	Coverage Ratio (%)	Orphan Nodes	Energy Consumption (%)
Proposed scheme	86	0	32
ECPF	88	0	38.2
DAC	55	22	54.5
GCA	91	0	64.2
SCP	43	27	72
TCAC	36	40	76

of cluster heads, coverage and number of orphan nodes, in which all of them are optimized in our proposed method.

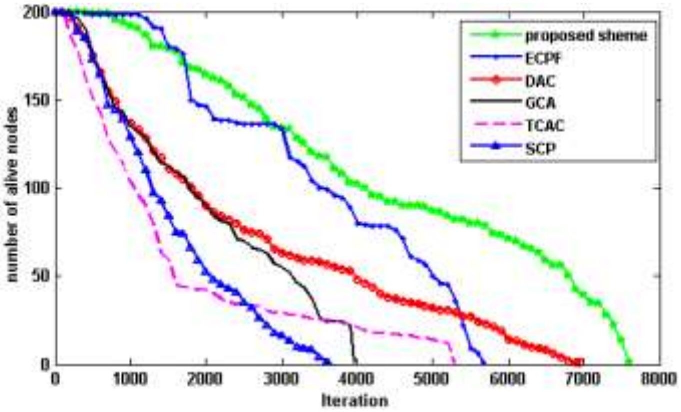

Figure 1. Comparison of network lifetime

C. *Step2: Target tracking results*

In this step the performance of our novel clustering algorithm for target tracking is evaluated. We employ the proposed clustering scheme in target tracking system and consider the accuracy and energy efficiency of target tracking and it will compare with three other clustering methods, ECPF, DAC and SCP.

- ***Missing ratio& Energy Consumption***

Our clustering method reduces the missing rate of object. In target tracking, when the object lost, cluster heads should sense the environment to find the lost object, and orphan nodes are always active Therefore as depicted in figure 2, network coverage and the numbers of orphan nodes influence the missing rate of object. Based on figure 2, our proposed clustering that has high coverage and doesn't have any orphan nodes, leads to low missing ratio in target tracking.

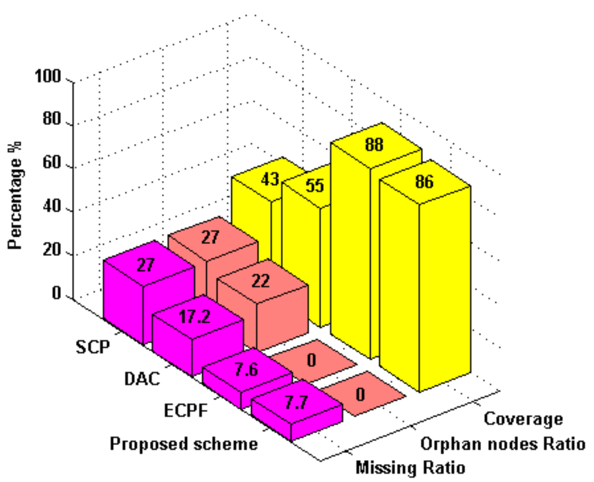

Figure 2. Comparison of Missing rate based on network coverage and orphan nodes ratio

Figure 3 illustrates all energy consumption of target tracking system in different clustering methods. As shown in figure 3, network with high coverage, low number of orphan nodes and low missing ratio reduces the energy consumption and our proposed clustering scheme has the lowest energy consumption during target tracking period.

- ***Evaluation Parameter (Gama)***

Here a new parameter named *gama* is introduced to compare the mentioned tracking methods. Five variables are considered to calculate *gama*: Normalized numbers of orphan nodes ($orph_n$), normalized numbers of cluster heads (CH_n), coverage ratio (cov), tracking error ratio (er) and energy consumption ratio (en):

$$gama = \frac{1}{cov} + CH_n + orph_n + en + er \qquad (2)$$

According to equation 2 the best method has lower value of *gama*. In figure 4 the value of *gama* in each time step for such methods is drawn. As is clear *gama* in our method, is lower most of the time.

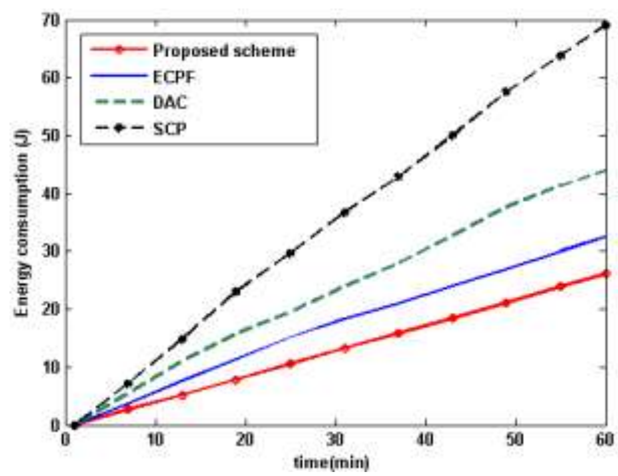

Figure 3. Energy consumption of network for target tracking application

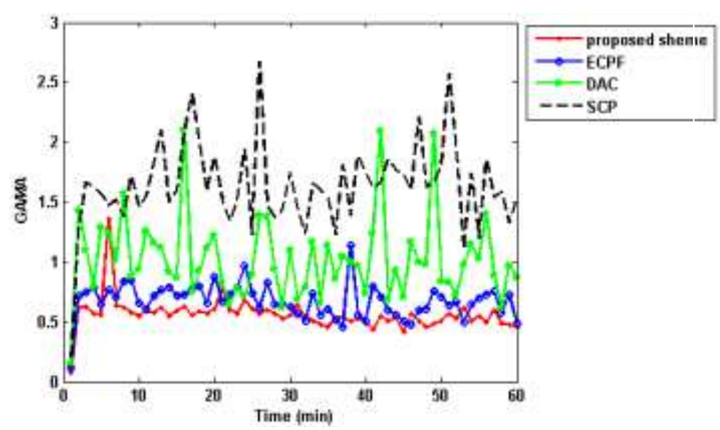

Figure 4. Comparison of gama for 60 minutes

IV. Conclusion

In this paper we present a novel clustering based target tracking in wireless sensor networks. A static clustering approach and prediction mechanism is used to decrease energy consumption and prolong the lifetime of network. We introduce a new high coverage clustering scheme which increases accuracy and energy efficiency of target tracking system. The main idea of proposed clustering method is based on our previous work [15] which has zero overhead. Here we have only 0.04% extra overhead while the coverage ratio increases about 31% and the energy consumption of tracking system reduces about 9%. Also in comparison with ECPF and GCA, we have 2% and 5% reduction in coverage respectively but consumed energy reduces about 6.2% and 32.2.Simulation results show that our new clustering scheme reduces the energy consumption of tracking system because it has high coverage, low CH selection's overhead and zero number of orphan nodes.

References

[1] Y. Xu, J. Winter, and W. C. Lee, "Prediction-based strategies for energy saving in object tracking sensor networks", Proceedings of the Fifth IEEE International Conference on Mobile Data Management (MDM'04), USA, January, 2004.

[2] H.W. Tsai, C.P. Chu, T.S. Chen, "Mobile object tracking in wireless sensor networks", Journal of Computer Communications, vol. 30, no. 8, 2007.

[3] Z. Kuk Liu, Z. Liu, "A Dynamic Clustering Protocol for Wireless Sensor Networks", IEEE International Conference on Computational and Information Sciences, 2011.

[4] X. Sheng, X. Changfeng, S. Zhangsong, "An Adaptive Target Tracking Scheme for Binary Wireless Sensor Networks", IEEE International Conference on Electronics, Communications and Control, pp. 121-124, september 2011.

[5] A.M. Khedr, W. Osamy, "Effective target tracking mechanism in a self-organizing wireless sensor network ", Journal of Parallel and Distributed Computer, No. 71, pp. 1318–1326, 2011.

[6] F. Deldar, M.H. Yaghmaee, "Designing a Prediction-based Clustering Algorithm for Target Tracking in Wireless Sensor Networks",International Symposium on Computer Networks and Distributed Systems (CNDS),February 2011.

[7] J. Teng, H. Snoussi,C. Richard, "Prediction-basedProactive Cluster Target Tracking Protocol for Binary Sensor Network", IEEE International Symposium on Signal Processing and Information Technology, pp. 234-239, December 2007.

[8] Z. Wang, W. Lou, Z. Wang, J. Ma, H. Chen, "A Novel Mobility Management Scheme for TargetTracking in Cluster-Based Sensor Networks", Springer-Verlag Distributed Computing in Sensor Systems, vol. 6131, pp. 172-186, 2010.

[9] Z. Wang, W. Lou, Z. Wang, J. Ma, H. Chen, "A Hybrid Cluster-Based Target Tracking Protocol for Wireless Sensor Networks", International Journal of Distributed Sensor Networks, Hindawi Publishing Corporation, Article ID 494863, 2013.

[10] X.Wang, J.J.Ma , S.Wang , DW. Bi, "Cluster-based Dynamic Energy Management for Collaborative Target Tracking in Wireless Sensor Networks", Sensors, vol. 7, no. 7, pp. 1193-1215, 2007.

[11] S. Tyagi, N. Kumar,"A systematic review on clustering and routing techniques based upon LEACH protocol for wireless sensor networks", Journal of Network and Computer Applications, vol. 36, Issue 2, March 2013

[12] S.H. Lee, S. Lee, H. Song, H.S. Lee, "Gradual Cluster Head Election for High Network Connectivity in Large-Scale Sensor Networks", IEEE International Conference on Advanced Communication Technology, pp. 168-172, 2011.

[13] A. Mahani, M.H. Askari-Hemmat, Y.S. Kavian, "Duplication Avoidance for Energy Efficient Wireless Sensor Networks", 8th IEEE, IET International Symposium on Communication Systems, Networks and Digital Signal Processing, 2012.

[14] D.P. Dahnil, Y.P. Singh, C.K. Ho, "Topology-controlled adaptive clustering for uniformityand increased lifetime in wireless sensor networks", The Institution of Engineering and Technology, Vol. 2, Iss. 4, pp. 318–327, 2012.

[15] A.K. Tripathy, S. Chinara, "Staggered Clustering Protocol: SCP an Efficient Clustering Approach for Wireless Sensor Network", IEEE World Congress on Information and Communication Technologies, 2012.

[16] M. Mirsadeghi, A. Mahani, M. Shojaee, "A Novel distributed Clustering Protocol using fuzzy logic", International conference on Electronics, Telecommunications and Computers CETC 2013, Lisbon, Portugal, December 2013.

[17] M.Mirsadeghi, A.Mahani, "Energy Efficient Fast Predictor for WSN-Based Target Tracking", annals of telecommunications springer publisher, Online available, March 2014.

[18] W. B. Heinzelman, A. P. Chandrakasan, H. Balakrishnan, "An Application-Specific Protocol Architecture for Wireless Microsensor Networks", IEEE Transactionon Wireless Communications, vol. 1, Issue 4, pp. 660-670, October 2002.