A Dynamic Clustering Algorithm for Object Tracking and Localization in WSN

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Abstract

A Wireless Sensor Network (WSN) is an assemblage of cooperative sensor nodes acting together into an environment to monitor an event of interest. However, one of the most limiting factors is the energy constrain for each node; therefore, it is a trade-off is required for that factor in designing of a network, while reporting, tracking or visualizing an event to be considered.

In this paper, two object tracking techniques used in Wireless Sensor Networks based on cluster algorithms have been combined together to perform many functions in the proposed algorithm. The benefit of using clusters algorithms can be count as the detection node in a cluster reports an event to the Cluster Head (CH) node according to a query, and then the CH sends all the collected information to the sink or the base station. This way reduces energy consuming and required communication bandwidth. Furthermore, the algorithm is highly scalable while it prolongs the life time of the network.

Keywords: Wireless Sensor networks; Target Tracking, Dynamic Clustering.

1 Introduction

Wireless sensor networks (WSNs) have gained worldwide attention in recent years, particularly with the possibility of production and development of smart sensors in micro-electro-mechanical systems (MEMS) technology. Target tracking is one of the non-trivial applications of wireless sensor network which is set up in the areas of field surveillance, habitat monitoring, indoor buildings, and intruder tracking [1]. In these applications the sensor nodes that can sense the target at a particular time are kept in active mode while the remaining nodes are to be retained in the inactive mode which will save energy until the target approaches them [2]. In order to continuously monitor mobile target, a group of sensors must be turned in active mode just before the target reaches to them. This group of active sensors varies depending on the velocity of the moving target [1].

Power consumption is the key factor in designing any WSN. Plenty of researches have been conducted to achieve a good balance between power consumption and object precision [5 and 6]. In addition, a centralized approach has been introduced when the traditional object tracking methods are applied since the number of node sensors increase in the network; more messages are passed to the sink which consumes extra bandwidth. However, in sensor networks, hundreds, and in some applications, hundreds of thousands of sensors are deployed in a large geographical area so that the phenomenon of interest can be efficiently monitored. Obviously, the network must have a high level of fault tolerance in order to still doing its function adequately [7 and 8].

There are different object tracking techniques that can be used in WSN. These Techniques are categorized based on network architecture, algorithm or technique, type of sensors, and number of targets to be tracked [3]. Network Architecture based classification is further split into Cluster based architecture, decentralized architecture and tree based architecture. The second category which is the classification with respect to the algorithm or the technique used is divided into three groups for the network of sleepy sensors, target reporting, and target chasing. According to the type of sensor classification, the sensor might be either binary sensor or ordinary sensor. Finally; single target or multiple targets can be tracked.

2 Related Works

In this section, a brief discussion on some related works in object tracking protocols in WSN is introduced. Lee *et.al,* proposed a dynamic clustering algorithm that achieves reduction in energy consumption based on prediction result of moving objects as well as to avoid redundant data. Furthermore; the authors present an algorithm that minimizes the overlay area of the cluster and they justify the efficiency of their algorithm by simulation using NS2 [9].

Deldar *et.al*, presented an energy efficient predication based tracking algorithm that selects tracker sensor nodes based on the both energy and distance parameters, and performs localization of the target using trilateration algorithm. The proposed algorithm decreases the network energy consumption and increases the network life time.

Finally, the authors suggest using other localization methods for future work that have lower computation overhead. The authors use OPNET Simulator to verify their algorithm [10].

In Wang *et.al,* the authors implement a novel mobility management protocol that integrates on-demand dynamic clustering into a cluster-based WSN. The proposed algorithm achieves a reasonable tradeoff between energy consumption and local node collaboration as well as solving the boundary problem of cluster-based sensor networks. The authors use MATLAB simulation program to evaluate the performance of their algorithm [11].

In UMA *et.al,* the authors suggest an energy efficient prediction-based clustering algorithm based on LEACH_R algorithm. The new proposed version reduces the number of hops between the transmitter sensor node and the receiver sensor nodes as well as the number of transmitted packets. The Authors' experiment is carried out using NS2 environment. Their algorithm gives better results in both performance and energy consumption [12].

3 Cluster-based Tracking Techniques

Cluster tracking techniques based on the network architecture can be classified under hierarchical network. Hierarchical network is a mesh-based system with multi-hop radio connectivity among wireless nodes. The nodes in the region of an event could monitor and report it back to a sink, and then the sink has the ability to convey its information to the outside world such as laptop, or base station. However, a cluster architecture can be a static one that is formed at the time of the network deployment where each cluster has steady characteristics such as a number of members to which they belong and area that is covered. There are several drawbacks apparent on static clustering; for instance, the failure of static membership has an effect on fault-tolerance. If the Cluster Head dies(CH), the cluster becomes useless and it also prevents sensors in different clusters from sharing information. On the contrary, dynamic clustering offers several advantages; for example, clusters are formed dynamically according to particular triggered events. For example if an event has been detected by a node with sufficient power, the node volunteers to act as a CH. The CH invites others nodes to make them members of that cluster. In this capacity, the sensors do not statistically form a cluster and they may be selected on different clusters at different times [13].

In the literature, there are various algorithms and approaches for object tracking proposed. In this section we provide an overview of the basic algorithms and evaluate them according to the accuracy of tracking and power consumption.

Jang and Dong [14] have proposed a new location tracking scheme based on a static cluster network. The authors balance data accuracy of the tracked mobile objects and the energy efficiency of the network. The proposed scheme was designed to pursue mobile targets using only a portion of the sensor nodes that detected the mobile target. A modified version of the back-off procedure of IEEE 802.11 is used for this purpose. In addition, the authors further addressed data accuracy as controlling the number of nodes by varying the transmission range of the nodes.

The proposed scheme includes two processes; selection and release. It is assumed that all nodes have the same amount of energy and no error of communication and processing. In addition, every node is placed into a position that previously determined through a network and all nodes have either active or sleep status. Whenever a mobile target is detected by nodes surrounding the target, each node selects a random time during the back-off procedure and the node that selects the shortest random time will transmit a DETECT message to its neighbors and starts to track the mobile target, while other nodes stop tracking and they do not reply to any message.

Figure 1 briefly depicts the selection process. In Figure 1 it is assumed that five nodes detect the mobile object at the same time. Therefore, the five nodes trigger the back-off procedure. If node C has the lowest value of back-off times, node C will send a DETECT message to its neighbor nodes and start to track the target. Other nodes A, B, D, and E receive the message from node C, and they stop the back-off procedure.

However, if the target is located out of the sensing range as the target moves, the tracking nodes send a RELEASE message to their neighbors. All the nodes that could detect the release message trigger the back-off procedure, and then a node that has the lowest back-off value is selected as the tracking node. Figure 2 shows the release process. As it depicts, node A is tracking the target. As a result of the target moves and becomes out of the transmission range of node A, node A sends a RELEASE message to its neighbors because it cannot track the target. Until receiving the message, nodes B and C trigger the back-off procedure, and the nodes with the lower value of back-off times will be purse the target.

Freitas *et.al*, *has* stated a model and performance analysis of mobile agents as a target tracking through a wireless sensor network. The authors assume that the sensor nodes are static, whereas developed software to the features of the AFME framework have been implemented as the mobile agents. The algorithms for locating and tracking are accomplished by two types of software agents: Resident Agent (RA) and Collaborative Agent (CA). The RA agents can is fixed in a sensor node, while RA_Coordinator (RAC) is in a coordinator node or RA_SensorNode (RAS) if it is a sensor node. Both of the agents have the ability to communicate with CA agents when these agents are being on the same node. The CA agents could move among the nodes in the network, since they are responsible for keeping tracking and calculating the position of the objects. CA agents can be divided into: CA_Master (CAM) or CA_Slave (CAS). The task of

organizing a cluster can be performed by CAM. On the other hand, CASs have the function of cooperating with the agent CAMs by sending the information so that the location of the target can be calculated and requesting others agents to migrate to another node [15].

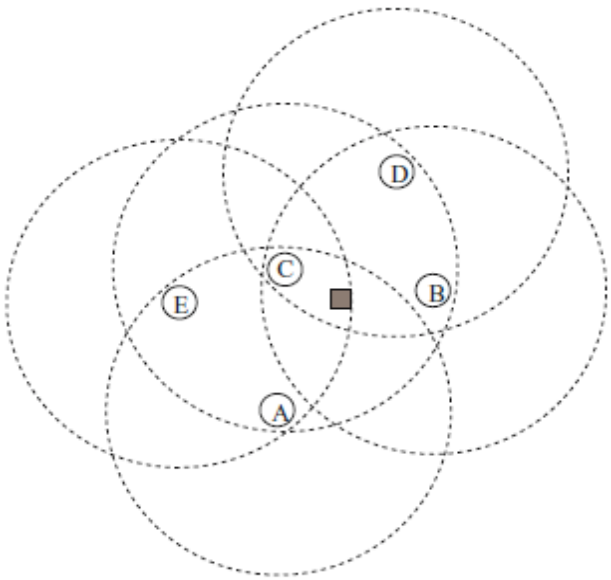

Figure 1: An example to depict the selection process. A circle node represents a sensor node, and a rectangle node represents a mobile target. A dotted circle represents the maximum transmission range of a node [14].

In order to locate the object, the triangulation algorithm is executed through CAM agent because it has the knowledge of the position of two neighboring nodes. The distance can be calculated by Equation 1.

If are the coordinates of three local nodes are x_1,y_1 , x_2,y_2 and x_3,y_3 then the coordinates of x_0,y_0 can be calculated as follows:

$$P_0 = \begin{bmatrix} x_0 \\ y_0 \end{bmatrix} = A^{-1}.b \qquad (1)$$

Where A: $A = 2.\begin{bmatrix} x_3-x_1 & y_3-y_1 \\ x_3-x_2 & y_{3-y_2} \end{bmatrix}$ (2)

And b: $b = \begin{bmatrix} r_1^2-r_3^2 \\ r_2^2-r_3^2 \end{bmatrix} - \begin{bmatrix} (x_1^2-x_3^2)+({y_1}^2-{y_3}^2) \\ (x_2^2-x_3^2)+({y_2}^2-{y_3}^2) \end{bmatrix}$ (3)

Then, due to the equilateral triangular nodes distribution in the network, the CAM agent can calculate the new position of the node where the agent has to migrate, by using (4).

$$x_4 = x_1 + x_3 - x_2$$
$$y_4 = y_1 + y_3 - y_2 \qquad (4)$$

4 Dynamic Cluster Formation

The necessary equations that are used in implementation of the dynamic cluster network have adopted from [16] and [17]. One of the main characteristic of the dynamic cluster network is that it forms clusters by using a distributed algorithm method. The decisions are made by the individual nodes without any centralized control. The algorithm is designed such that there are a certain number of clusters K during each round. Furthermore, each node has the same energy level. To maintain an acceptable energy level for all the nodes forming the network it requires that each node takes its turn as a cluster head since it is much more energy intensive than being a non-cluster head node.

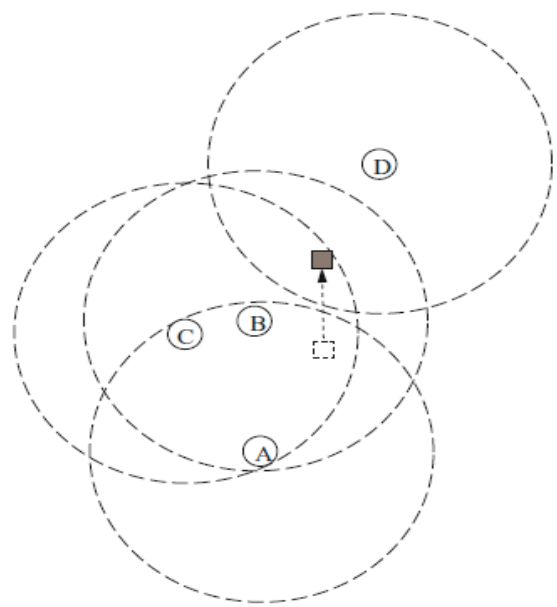

Figure 2: An example depicted the release process. A dashed circle represents the maximum sensing range of a node.

Each sensor i selects itself to be a cluster head at the beginning of round (which starts at time t) with probability $Pi(t)$, which is chosen such that the expected number of cluster head nodes for this round is k. Thus, if there are N nodes in the network

$$E[\#CH] = \sum_{i=1}^{N} P\,i(t) * 1 = k \qquad (5)$$

Ensuring that all nodes are cluster heads the same number of Times requires each node to be a cluster head once in $\frac{N}{k}$ rounds on average. If $Ci\,(t)$ is the indicator function determining whether or not node i has been a cluster head in the most recent $\left(r\ mod\ \frac{N}{k}\right)$ rounds (i.e., $Ci\,(t) = 0$ if node i has been a cluster head and , one otherwise), then each node should choose to become a cluster head at round r with probability

$$P\,i\,(t) = \begin{cases} \frac{k}{N-k*\left(r\ mod\ \frac{N}{k}\right)} & : Ci\,(t) = 1 \\ 0 & : Ci(t) = 0 \end{cases} \quad (6)$$

This will lead to only nodes that are not cluster heads recently, and has more energy than nodes that have recently performed this energy-intensive function, may become cluster heads at round $+1$. The expected number of nodes that have not been cluster heads in the first r rounds is $N - k * (r\ )$. The term $\sum_{i=1}^{N} Ci(t)$ represents the total number of nodes that are eligible to be a cluster head at time t and.

$$E\left[\sum_{i=1}^{N} Ci(t)\right] = N - k * \left(r\ mod\ \ \frac{N}{k}\right) \quad (7)$$

Thus all the nodes in the network will maintain approximately equal energy to each other after every rounds .Using (6) and (7), the expected number of cluster heads per round is

$$E[\#CH] = \sum_{i=1}^{N} P\,i(t) * 1 = \left(N - k * \left(r\ mod\ \ \frac{N}{k}\right)\right) * \frac{K}{N-K*\left(r\ mod\ \frac{N}{k}\right)} = k \quad (8)$$

The probability for becoming a cluster head is based on the assumption that all nodes start with an evenly distributed amount of energy, and that all nodes have data to send during each frame. The other case where nodes have different amounts of energy, in this case the nodes with more energy should be cluster heads more often than the nodes with less energy, to ensure that all nodes die at approximately the same time. This can be achieved by setting the probability of becoming a cluster head as a function of a node's energy level relative to the aggregate energy remaining in the network, rather than purely as a function of the number of times the node has been cluster head, thus

$$Pi(t) = \min\left\{\frac{Ei(t)}{Etotal\ (t)}k, 1\right\} \quad (9)$$

Where $Ei(t)$ is the current energy of node and is the current energy of node and

$$Etotal(t) = \sum_{i=1}^{N} Ei\ (t) \quad (10)$$

Using these probabilities, the nodes with higher energy are more likely to become cluster heads than nodes with less energy. The number of cluster head nodes is

$$E[\#\ CH] = \sum_{i=1}^{N} Pi(t) * 1 = \left(\frac{E1(t)}{Etotal} + \cdots + \frac{EN(t)}{Etotal}\right)k = k \quad (11)$$

4.1 Energy Consumption

To transmit a l bit message at a distance, the radio hardware energy dissipation expends [16] and [17]

$$ETx(l,d) = ETx - elec(l) + ETx - amp(l,d) = \begin{cases} lEelec + l\mathcal{E}f_s d^2\ ,\ d < d0 \\ lEelec + l\mathcal{E}mpd^4\ ,\ d \geq d0 \end{cases} \quad (12)$$

And to receive this message, the radio expends:

$$E\ Rx\ (1) = E\ Rx - elec\ (l) = l\ Eelec \quad (13)$$

The energy dissipated in the cluster head node during a single frame is

$$EcH = lEelec\left(\frac{N}{K} - 1\right) + lEDA\frac{N}{K} + lEelec + l\mathcal{E}mpdto^{\ 4}\ BS \quad (14)$$

Where l is the number of bits in each data message is, d_{toBS}^{1} is the distance from the cluster head node to the BS, and we have assumed perfect data aggregation. While the energy used in each non-cluster head node is

$$Enon - CH = lEelec + l\mathcal{E}f_s d_{toCH}^{2} \quad (15)$$

Where d_{toCH}^{1} is the distance from the node to the cluster head? The area occupied by each cluster is approximately $\frac{M^2}{K}$. Therefore, in this case

$$E_{non}\ - CH = lE_{elec} + lef_s\ \frac{1}{2\pi}\ \frac{M^2}{K} \quad (16)$$

The energy dissipated in a cluster during the frame is

$$E_{cluster} = E_{CH} + \left(\frac{N}{K} - 1\right)E_{non} - CH \approx E_{CH} + \frac{N}{k}\ E_{non} - CH \quad (17)$$

And the total energy for the frame is

$$E_{total} = kE_{cluster} = l\ (E_{elec}N + E_{DA}N + k\mathcal{E}_{mp}\ d_{toBS}^{4} + E_{elec}\ N + \mathcal{E}_{f_s}\ \frac{1}{2\pi}\ \frac{M^2}{k}\ N) \quad (18)$$

The optimum number of clusters can be found using

$$K_{opt}\ = \frac{\sqrt{N}}{\sqrt{2\pi}}\sqrt{\frac{\mathcal{E}_{fs}}{\mathcal{E}_{mp}}}\frac{M}{d_{toBS}^{2}} \quad (19)$$

5 Simulation Parameters

The following assumptions are made for the purpose of the simulation scenarios in this paper:

1. Sensor nodes are randomly spread in a region.
2. Sensor nodes are homogenous and a unique id has given for each node throughout the network.
3. The position of the node is fixed after it has been deployed; whereas CHs are randomly and continuously reelected.
4. Single-hop or multi-hop communication between nodes and CHs.

Table 1: Simulation parameters

Parameters	Values
Area	(100m,100m)
Nodes number	100
Energy for each node	0.5J
BS location	(50m,175m)
Packet CH size	200 Bits
Packet BS size	6400 Bits
Energy for transmitting (E_{TX})	50nJ / Bit
Energy for receiving (E_{RX})	50nJ / Bit
Energy for data aggregated (E_{DA})	5nJ / Bit
Energy consumptions of power amplifier in free space (ε_{fs})	10pJ/Bit/m^2
Energy Consumptions of power amplifier in Multi-path fading (εmp)	0.0013pJ/Bit/m^4

6 The proposed algorithm

We propose in this paper a new approach for tracking a mobile object based on a dynamic cluster network. Obviously, there are several drawbacks apparent on static clustering as discussed earlier.

On contrary, if we make a tracking network as a dynamic cluster, which all nodes are homogeneous, we will be able to form some clusters to be responsible for tracking, according to triggered particular events. Meanwhile other clusters will be responsible to convey the messages to the sink. In fact, if we have the decision to construct a cluster, we will make nodes randomly close to each other to reduce the power consumption, through multiple radio connectivity. In this way, the shortest distances between nodes, the lowest power consumption and the longest life time for the network are achieved. The proposed algorithm can be explained in the following steps.

1. After constructing the network, which is randomly deployed on a particular area and election of CHs, the sensor nodes are being involved to detect a mobile object.
2. If there is a target detected by some nodes that belong to a specific cluster, the cluster randomly points to any of the detecting nodes with sufficient energy to track the mobile object, while the other sensor nodes that belong to different clusters go to sleep mode except CHs in order to forward a report to the base station through multiple CHs if it is needed. There are two types of CHs in the proposed algorithm either primary, if the CH is close enough to be elected by the network or secondary.
3. Another feature of the algorithm that enhances its performance is that the tracking CH will select only one node for tracking or three suitable nodes for localization and decide the reporting schedule relying on the target speed.

To evaluate the performance of the algorithm, simulation experiments were carried by Matlab environment. We present in the next paragraphs snapshots that demonstrate the deployment phase of the network and phases of formation cluster heads, determining nodes that belong to each CH, informing the base station about network construction, and establishing tracking process.

As it has shown in Figure 3, the formation of the network includes only homogenous nodes that are randomly distributed in a square area, and then an election of CHs takes place in order to determine the number of CHs and to assign particular nodes to each CH. Figure 4 shows the CHs and the nodes included in each CH. After the structure of the network has been formed, a report regarding to that formation has to be forwarded to the base station. However, the base station decides based on on the number of hops in each cluster and the number of member nodes fit in each cluster, if the positions of CHs have plausible locations.

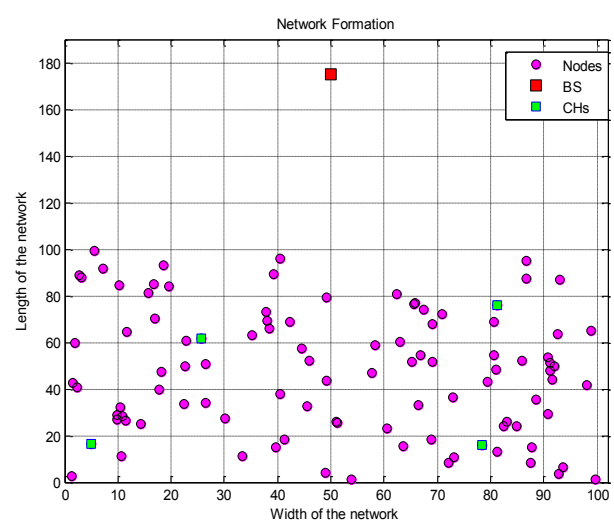

Figure 3: Network formation in a square area

The network is tested under the assumption that all nodes provide periodically their sensing information to the CHs and the CHs inform the base station with the collected information. Also, it is important to mention that during a specific period or round, the process of reelection CHs could be conducted in the network according to triggering an event of interest. Figure 5 depicts the life time of the network. The figure shows that the life time of the network is steady until approximately 400 rounds and then the number of live nodes falls to reach almost zero after 800 rounds. Alternatively, Figure 6 shows the number of dead nodes during the life time of the network. It is clear that there are no dead nodes before 400 round. However, the dead nodes increase to reach 90 nodes at roughly 800 rounds.

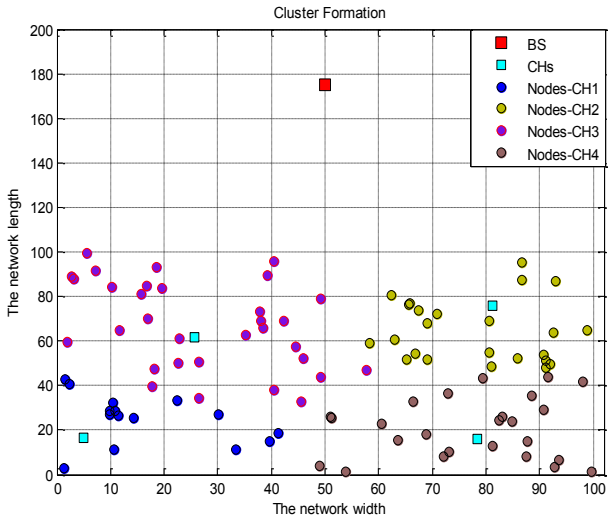

Figure 4: Election cluster heads.

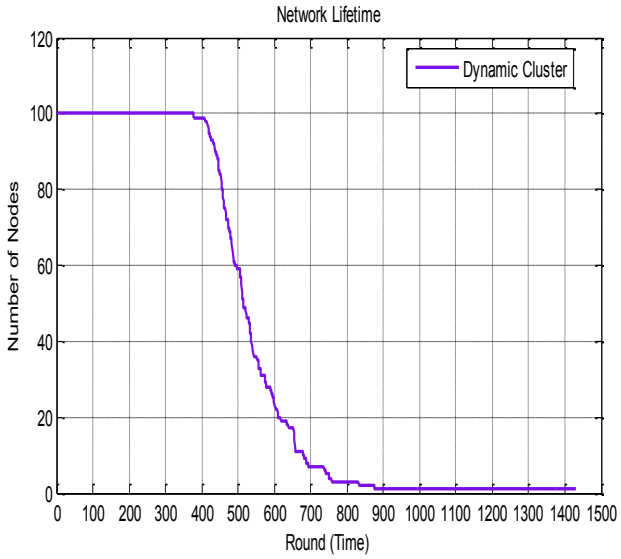

Figure 5: The network lifetime.

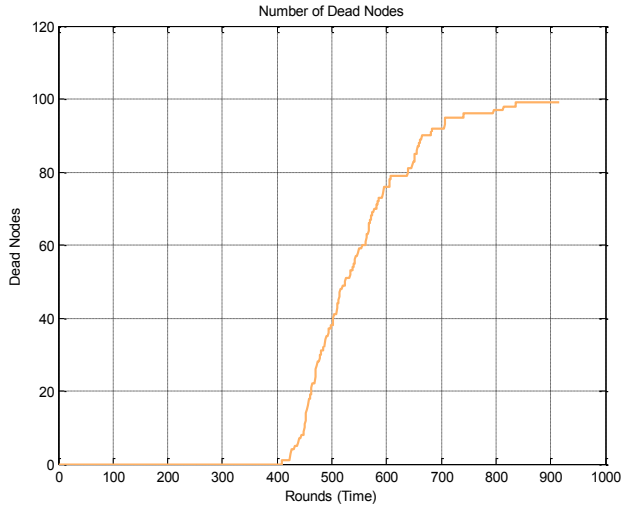

Figure 6: The number of dead nodes during the network lifetime.

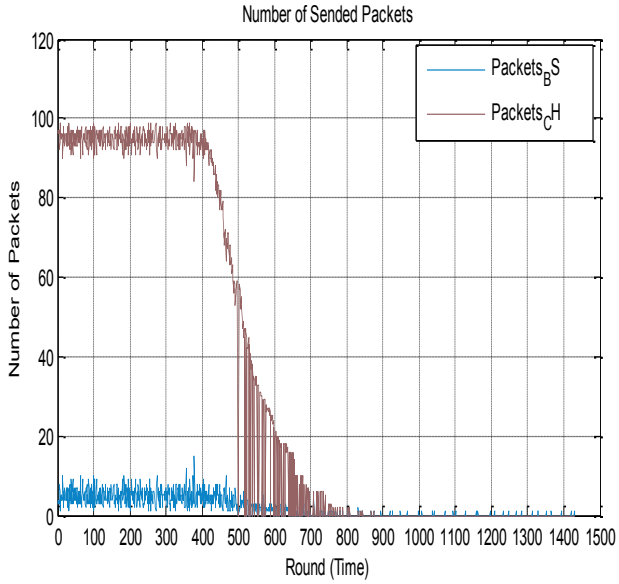

Figure 7: The number of transmitted packets to the BS and CHs.

Additionally, the number of packets arrived to the CHs and to the base station in measured. Figure 7 shows that the number of packets reached to the BS are much less than the packets reached to the CHs during the lifetime of the network. Thus, the number of packets decreases dramatically when the number of dead nodes increases roughly after 700 rounds.

Figure 8 and Figure 9 show the process of tracking a mobile object. Once a query from the base station is sent to detect a target, all CHs inform the sensor nodes in the network to get involved by scanning the environment. If a target is detected by some nodes in a cluster, the cluster will randomly choose a node with sufficient energy to track the target. When the speed of the target is detected by

the base station, the sleep packet protocol is applied on the network except for CHs and the detected node. However, if the target moves outside the radio range of the node, a release message is sent from the detected node and the tracking algorithm of is invoked.

Finally, the proposed algorithm support localization by involving three nodes to evaluate equation (1) by the base station. Figure 10 shows the how the target localization and two CHs send their information to the BS.

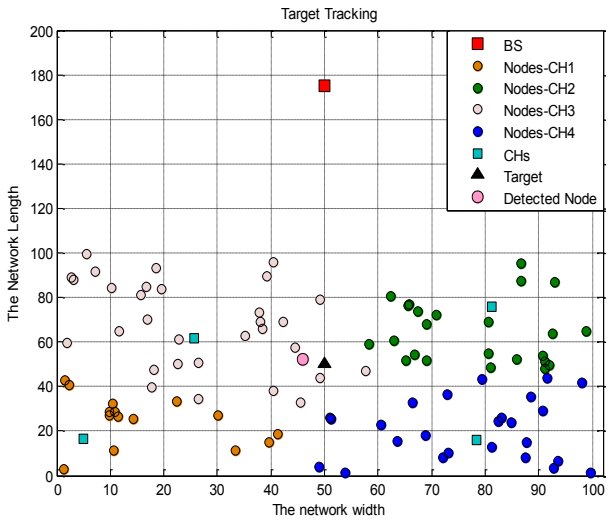

Figure 8: Target detection by the network and highlight the detected node.

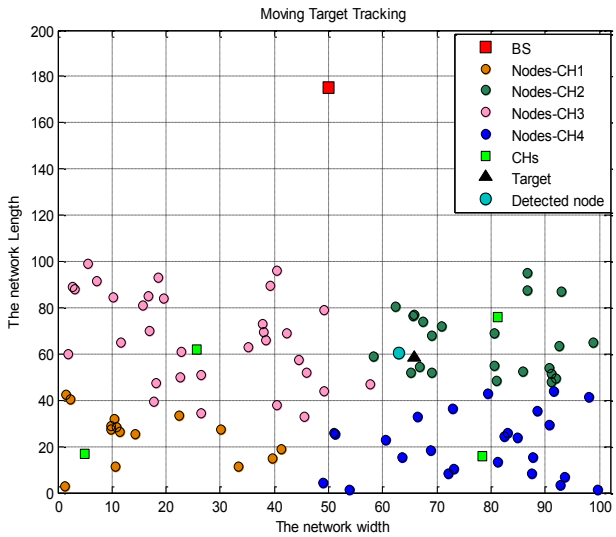

Figure 9: Tracking the moving target through the network and highlight the detected node.

7 Conclusion

Two object tracking techniques were presented in this paper based on dynamic clustering algorithms. A combination of the two techniques is proposed to improve the performance of dynamic cluster. TO demonstrate the performance of the proposed algorithm, Matlab environment was used to present this illustration. Various factors such as the accuracy of tracking and the power consumption were considered in the simulation tests. It was demonstrated that the proposed algorithm provides many functions such as tracking or localization of an object as a response to a query from the base station. Also, since we proposed that tracking an object is based on dynamic cluster environment rather than static cluster, our protocol has resulted efficient power consumption and efficient localization of nodes with respect to cluster heads. Furthermore, the sleep packet protocol is considered in the proposed algorithm which implies that only one node is appointed from the CH to track the object. However, the different speeds of the moving object are not examined in the proposed algorithm but it is considered a random movement for the mobile object. We are planning to extend this protocol in the future to consider the aped and directions of the moving nodes and how such factors can affect the algorithm performance.

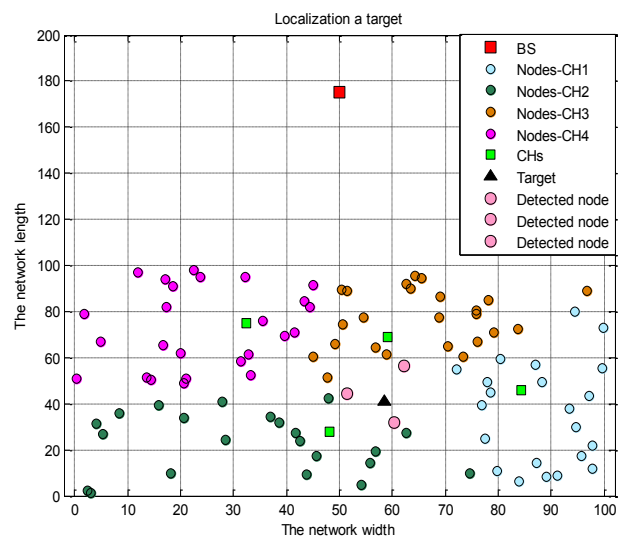

Figure 10: Target localization through the network and highlight the detected nodes.

8 References

[1] Bhatti, S and Jie Xu, "Survey of Target Tracking Protocols using Wireless Sensor Network," The Fifth International Conference on Wireless and Mobile Communications, pp. 110-115, Cannes/La Bocca, French Riviera, France, August 23-29, 2009.

[2] Hua-Wen Tsai, Chih-Ping Chu and Tzung-Shi Chen, "Mobile Object Tracking In Wireless Sensor Networks," Computer Communications, Volume 30, Issue 8, pp. 1811–1825, 2007.

[3] Mohsin Fayyaz, "Classification of Object Tracking Techniques in Wireless Sensor Networks," Wireless Sensor Network, Volume 3, Number 4, pp.121-124, 2011.

[4] Ameer Ahmed Abbasi and Mohamed Younis, "A Survey on Clustering Algorithms for Wireless Sensor Networks," Computer Communications, Volume 30, Issues 14–15, pp. 2826–2841, 2007.

[5] Sung-Min Lee, Hojung Cha and Rhan Ha, "Energy-aware location error handling for object tracking applications," Computer Communication, volume 30, issue 7, pp. 1443-1450, 2007.

[6] Yingqi Xu and Wang-Chien Lee, "On localized prediction for power efficient object tracking in sensor networks," In Proceedings of the 23rd International Conference on Distributed Computing Systems Workshops, pp. 434–439, Province RI, USA, 29-29 May, 2003.

[7] G. Hoblos, M. Staroswiecki, A. Aitouche, "Optimal design of fault tolerant sensor networks," In proceeding of: Control Applications, 2000. Proceedings of the 2000 IEEE International, pp. 467-472, Anchorage, Alaska, USA September 25-27, 2000.

[8] Ian Akyildiz and Mehmet Can Vuran, Wireless Sensor Networks. John Wiley and Sons, 2010.

[9] In-Sook Lee, Zhen Fu, WenCheng Yang and Myong-Soon Park, "An Efficient Dynamic Clustering Algorithm for Object Tracking in Wireless Sensor Networks," DCDIS series B ,Vol.14(S2),Complex system and application-Modeling Coontrol and Simulation, pp. 1484-1488, 2007.

[10] Fatemeh Deldar and Mohammad Hossien Yaghmaee, "Energy Efficient Prediction-based Clustering Algorithm for Target Tracking in Wireless Sensor Networks," International Conference on Intelligent Networking and Collaborative Systems, Thessaloniki, Greece, pp. 315-318, 24-26 Nov. 2010

[11] Zhibo Wang, Wei Lou, Zhi Wang, Junchao Ma and Honglong Chen, "A Hybrid Cluster-Based Target Tracking Protocol for Wireless Sensor Networks," International Journal of Distributed Sensor Networks, Volume 2013.http://dx.doi.org/10.1155/2013/494863

[12] UMA, G.V and Charanya D, "Tracking of moving object in wireless sensor network," International Journal of Computer & Communication Technology, Volume-3, Issue-5, 0975 – 7449, 2012. http://interscience.in/IJCCT_Vol3Iss5/2.pdf

[13] Arvind Rapaka and Sanjay Madria, "Two energy efficient algorithms for tracking objects in a sensor network," Wireless Communications & Mobile Computing, Volume 7, Issue 6, pp. 809 – 819, 2007.

[14] Jang K. and Dong Y., "Location Tracking for Wireless Sensor Networks," In preceding 7th International Conference Next Generation Teletraffic and Wired/Wireless Advanced Networking, pp. 306–315, Petersburg, Russia, 2007.

[15] Edison Pignaton de Freitas, Bernhard Bösch, Rodrigo S. Allgayer, Leonardo Steinfeld, Flávio Rech Wagner, Luigi Carro, Carlos Eduardo Pereira, and Tony Larsson, "Mobile Agents Model and Performance Analysis of a Wireless Sensor Network Target Tracking Application," Smart Spaces and Next Generation Wired/Wireless Networking: 11th International Conference, pp. 274- 286, Berlin Heidelberg, 2011.

[16] Wendi B. Heinzelman, Anantha P. Chandrakasan, , and Hari Balakrishnan, "An Application-Specific Protocol Architecture for Wireless Microsensor Networks," IEEE transactions on wireless communications, vol. 1, no. 4: pp. 660 - 670, 2002.

[17] Georgios Smaragdakis, Ibrahim Matta and Azer Bestavros, "SEP: A Stable Election Protocol for clustered heterogeneous wireless sensor networks," http://www.cs.bu.edu/techreports/pdf/2004-022-sep.pdf