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EOATR: Energy Efficient Object Tracking by Auto Adjusting Transmission Range in Wireless Sensor Network

S.H. Chauhdary, A.K. Bashir, S.C. Shah and M.S. Park
Internet-Computing Lab, Department of Computer Science and Engineering,
Korea University, Seoul, Korea

Abstract: In this study, we develop EOATR mechanism to track objects by auto adjusting the transmission range of sensors according to the speed of object. The proposed method not only increases the tacking accuracy but also decrease the energy consumption by reducing the number of nodes that participate. Through whole tracking process and minimizing the communication cost, thus can enhance the lifetime of the whole sensor networks. The simulation result shows that our proposed method achieves lower energy consumption and precise object tacking over exciting solutions.

Key words: Wireless sensor network, in-network communication, object tracking, transmission range, energy efficient

INTRODUCTION

A Wireless Sensor Network (WSN) (Akyildiz *et al*., 2002) is consisting of spatially distributed sensor nodes to cooperatively monitor physical or environmental conditions, such as temperature, sound, pollutants and motion. Wireless sensor networks are expected to provide as a key infrastructure for a broad range of applications including crops monitoring, security surveillance, intelligent highway systems and emergent disaster response systems. Because of the sensor's ability of detecting at anytime, anywhere and low price, the object tracking in sensor network has great potential of being widely used in many domains i.e., tracking enemy vehicles, detecting illegal border crossings, tracking the movement of animals in wildlife protection. In such applications, many sensors are involved in collaboration in order to track the object (Zhang and Cao, 2004; Xu *et al*., 2004; Chen *et al*., 2004). An important limitation of sensor network is its limited power source, the most important issue for object tracking in sensor network is to track the object with lowest energy consumption, while maintain better tracking accuracy, thus prolong the lifetime of the whole sensor network.

In general, a node is composed of a sensing component and a communication component. Sensing component is used when sensor detects an object or sense the state of objects and communication module is used when a sensor communicates with another sensor or base station to send or receive data. As shown in Fig. 1, the radio transceiver takes more energy to transmit and receive data (Schugers *et al*., 2002). Transmission can be in two categories (a) Short Distance Transmission (SDT) and (b) Long Distance Transmission (LDT) (Heinzelman *et al*., 2000). In Heinzelman *et al*. (2000), sensors need to communicate with cluster heads to exchange the tracking data and then send back base station which can be regarded as Long Distance Transmission (LDT). While exchanging tracking data on one hop neighbors can be regarded as Short Distance Transmission (SDT). Normally, these long distance transmissions consume more energy consumption. Enabling the local communication among the sensors and make local decisions takes less energy consumption.

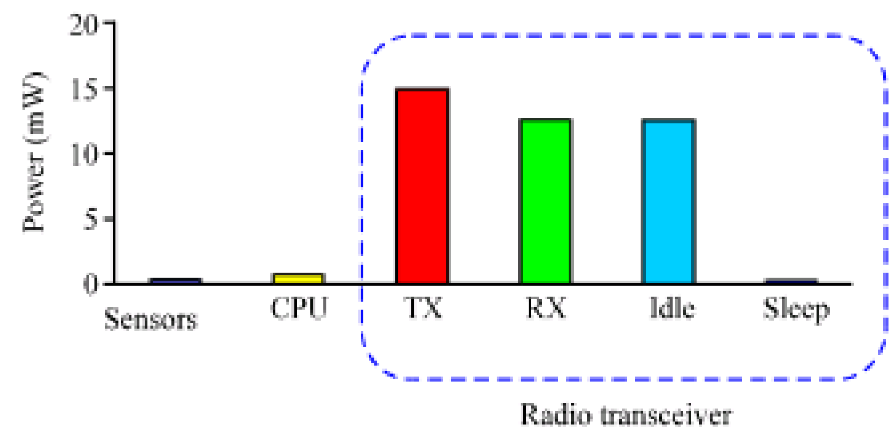

Fig. 1: Power consumption of components. Schurgers *et al*. (2002): Optimizing sensor networks in the energy-latency-dnsity design space, TX: Transmit data, RX: Received data, Idle: Turned on , Sleep: Turned of

As shown in Fig. 2a and b show the communication between nodes as LDT and SDT, respectively. In Fig. 1a

Corresponding Author: Myong-Soon Park, Department of Computer Science and Engineering, Korea University, South Korea Fax: +82-2-927-3797

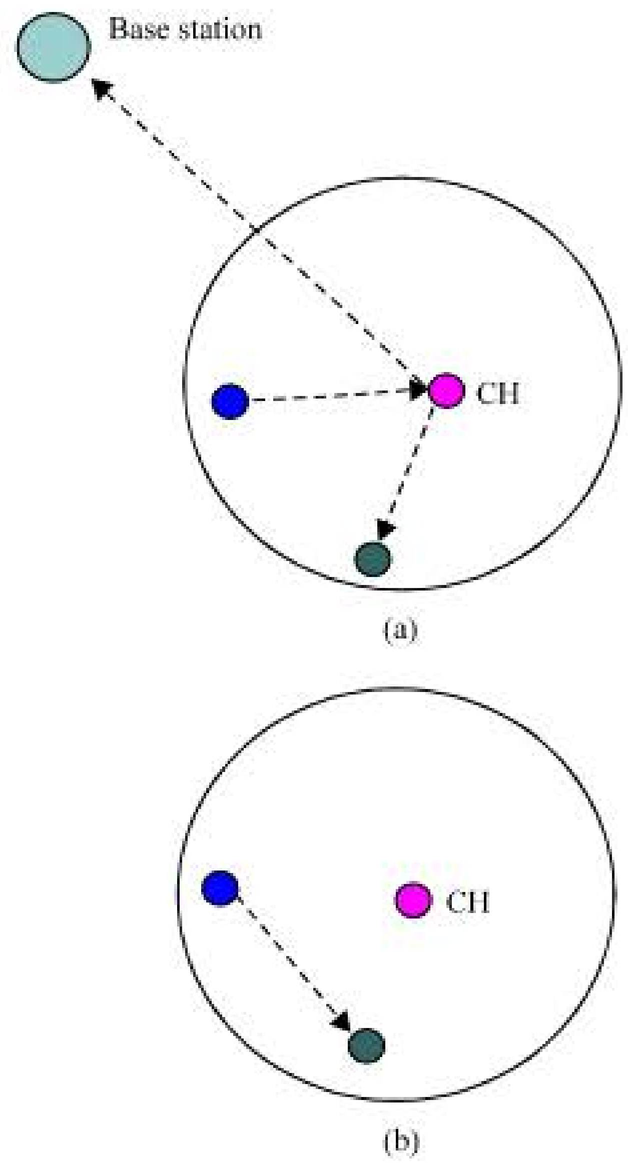

Fig. 2: Communication between in different situations, (a) long distance transmission and (b) short distance transmission

sensor nodes transmits its data to its cluster head to predict the next move of the object and the cluster head sends the latest prediction data to the next sensor node that the object approaches. As in Fig. 1b, sensors don't need to communicate with the cluster head every time for exchange the sense data. Thus, this process method can effectively reduce the long distance transmission between sensor nodes and cluster heads.

The researches about the object tracking can be divided into two major categories (1) centralized schemes and (2) de-centralized schemes. The examples of each scheme are introduced as following:

Centralized scheme: In this kind of scheme, a single centralized point control the entire network scheme. For example in Premon (Heinzelman *et al*., 2000) sensors transfer it's reading to cluster head. The cluster head compile the data from its member nodes and make a tracking decision of the object movement. Then cluster heads wakes up the next cluster head. This all process takes long distance transmission which consumes more energy consumption. Goel and Imielinski (2001) and Chits *et al*. (2003) introduced a method to organize the sensors into clusters and use normal beam or a high beam. When the cluster is active the normal beam is used, whereas high beam is only used when the object is lost. The messages are exchanged between cluster heads. Each cluster head activates the appropriate next cluster before the object arrives, so all this procedure uses long distance transmission and excessive communication which consumes more energy. Jin *et al*. (2006) proposed a dynamic clustering mechanism for object tracking in wireless sensor networks. With forming the cluster dynamically according to the route of moving, the proposed method can not only decrease the missing-rate but can also decrease the energy consumption by reducing the number of nodes that participate in tracking and minimizing the communication cost but they have not consider the clustering time and cost in this approach.

Efficient dynamic clustering algorithm introduces cluster formation to minimize the overlap area of clusters. This cause to reduce unnecessary data transmissions but efficient re-clustering on every move of object takes considerably much energy consumption (Lee *et al*., 2007).

De-centralized schemes: Drain-And-Balance (DAB) is the first in-network object tracking approach in sensor networks where query messages are not required to be flooded and update messages are not always transmitted to the sink (Kung and Vlah, 2003). However, Kung and Vlah (2003) has two drawbacks. First, a DAB tree is a logical tree not reflecting the physical structure of the sensor network; hence, an edge may consist of multiple communication hops and a high communication cost may be incurred. Second, the construction of the DAB tree does not take the query cost into consideration. Therefore, the result may not be efficient in some cases. Lin *et al*. (2006) developed several tree structures for in-network object tracking which take the physical topology of the sensor network into consideration, which consume more energy. However, in-network processing and communication characteristic of sensor networks has posed new challenges. In this study, we proposed a light weight algorithm, which exploits the common functionalities of sensor nodes i.e., auto adjusting transmission range, short range communication and signal strengths. Using all these functionalizes in well manner way can avoid unnecessary data transmissions and reduce unnecessary energy consumption.

In summary, an accurate and low-cost object tracking is a critical requirement in wireless sensor networks. Existing research efforts on object tracking can be categorized in two ways. In the first category, the problem of accurately estimating the location of an object is addressed (Chits *et al*., 2003). In the second category, in-network data processing and communication for object tracking are discussed to decrease the network cost

(Kung and Vlah, 2003; Zhang and Cao, 2004). In present study, we successfully deal with the trade-off between accuracy and energy efficiency. As in-network communication is always shorter is distance and take less communication cost compare to reporting all reading back to base station.

Earlier, we have developed ETCTR (Chaudhary *et al*., 2008), which is a modest contribution to adopt the in-network communication to over come the energy cost. Chaudhary *et al*. (2008) determined on the basis of radio signal strength identification and velocity of object, the ratio of its auto adjustment of its transmission range. Once there is less transmission range, it's easy to localize the object in less range rather then in a big transmission range. The ETCTR (Chaudhary *et al*., 2008) only consider one object at a time in network and don't help to predict the object direction.

This study is the extension of the earlier study ETCTR (Chaudhary *et al*., 2008). The main contribution includes multiple objects tracking precisely with considerable less communication cost. Our approach involves the common functionalities of sensor nodes for in-network processing which cause to make local decision about objects current location and predict location rather sending information back to cluster head or base station that contains the location, velocity and moving direction of object to make a decision.

PRELIMINARIES

Here, we define and enlist the basic assumptions to ensure our object tracking protocol scheme operational as follow.

- The transmission and sensing range of a sensor have same radius to each other
- The nodes are densely deployed to an extent that their transmission and sensing overlap. This assumption is necessary to ensure there are no holes in RoI (Ahmed, 2005)
- Each sensor node knows its own location by possibly using the Global Positioning System (GPS) (Hofmann *et al*., 1997) or other techniques such as triangulation (Goel and Imielinski, 2001)
- Each sensor can increase and decrease its transmission range to predefine threshold

Tracking model: In present tracking model, sensor nodes can track multiple moving objects at a time. This attribute makes the scope of the paper fundamentally different from single object detection and tracking problem. At a time if there are more than one object in sensor field, objects must have at least two hop distances from each other.

Mobility model: The step size of object movement is less than the smallest hop inside the network at a time. A compromise on this assumption takes a direct effect on the accuracy of the tracking operation.

Idle mode of node: In idle mode, the node only is able to sense/detect presence of some predefined object. It would not be able to transmit and receive information. Idle mode consumes less energy cost compare to active mode.

Active mode of node: In active mode, the node is able to sense/detect the presence of the object. It can transmit, receive the information as well as process the information. Active mode cost more energy compare to idle mode of node.

PROPOSED ALGORITHM

To describe our algorithm precisely, we have divide it in four major parts EET (external event occurs), ODP (object detection process), OTP (object tracking process) and OPP (object prediction process) as follow:

EET (External event occurs): All the sensor nodes remain in idle state till external event occurs. As it shows in Fig. 3, the deployment of sensor network and object moving toward deployed sensor network, on the presence of the object, few nodes turns to active mode those who get signal strength in their sensing range. On the basis of high signal strength, using the back of time methodology only one sensor becomes source node to track the object.

ODP (Object Detection Process): Subsequent to the selection of source node, it starts to calculate the velocity

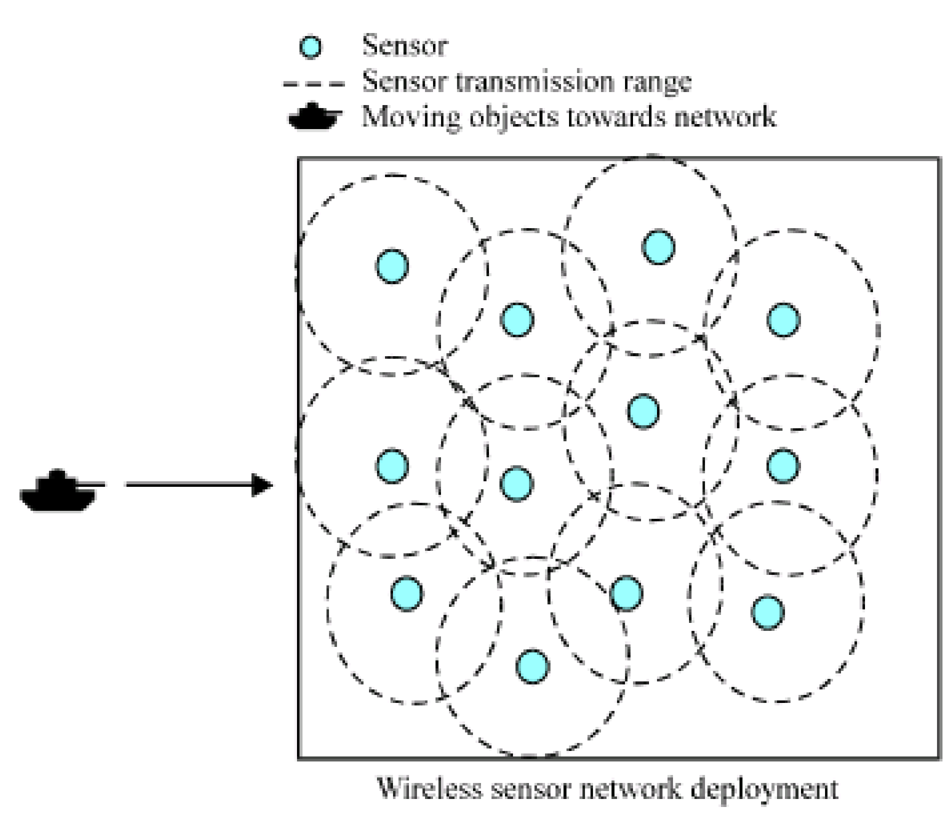

Fig. 3: The network deployment and object approaching towards network

of the object. Deliberate the velocity of the object is key factor in our algorithm because source node decreases its transmission range on the basis of object's average velocity. Source node calculates velocity of the object by calculating the distance from object to source node during a time period. Here, we assume the speed of the object remains constant in every periodic of time. At the time, when an object moves in the sensing range of source node, then source node starts to read the signal strength in-between moving object and itself. On the basis of signal strength source node knows the distance between that object and itself in that specific periodic of time. Source node repeats the same process in next time slot. On the basis of Δss (difference of signal strength in Δt time) source node knows the Δdd (difference of the distance in Δt time), since source node knows the difference of the distance in Δt time between source node and object, it can calculate the average speed of the object.

OTP (Object Tracking Process): Since source node knows the average speed of the object, it starts decreasing its transmission range as an object moves on. The source node keeps checking the signal strength and velocity between object and itself in every given period of time. Whenever source node decides to decrease its transmission rage to certain level, it always updates its one hop neighbor node so that one hop neighbor nodes increase their transmission rage. In this way, we able to avoid the possibility to lost the object and cover the transmission gap. As Fig. 4 shows the decreased transmission of source node and increased transmission of neighbor nodes to predefined threshold after the OTP (Object Tracking Process) it starts the OTP (Object Tracking Process) as follow:

OPP (Object Prediction Process): To process the predicted direction of the moving object, we utilize an ideal hexagon method. Generally, the hexagon topology is known to minimize the overlapping area. The area of a regular hexagon of side length t is given by:

$$A = \frac{3\sqrt{3}}{2}t^2 \simeq 2.598076211t^2$$

It's shown in Fig. 5, source node transmission is divided into 6 triangles. As a source node decreases its transmission range until predefine threshold after that its time to predict object's next moving direction. At that time source node applies the Hexagon topology on its decreased transmission range and use radio signal strength to know the object position in that 6 part of

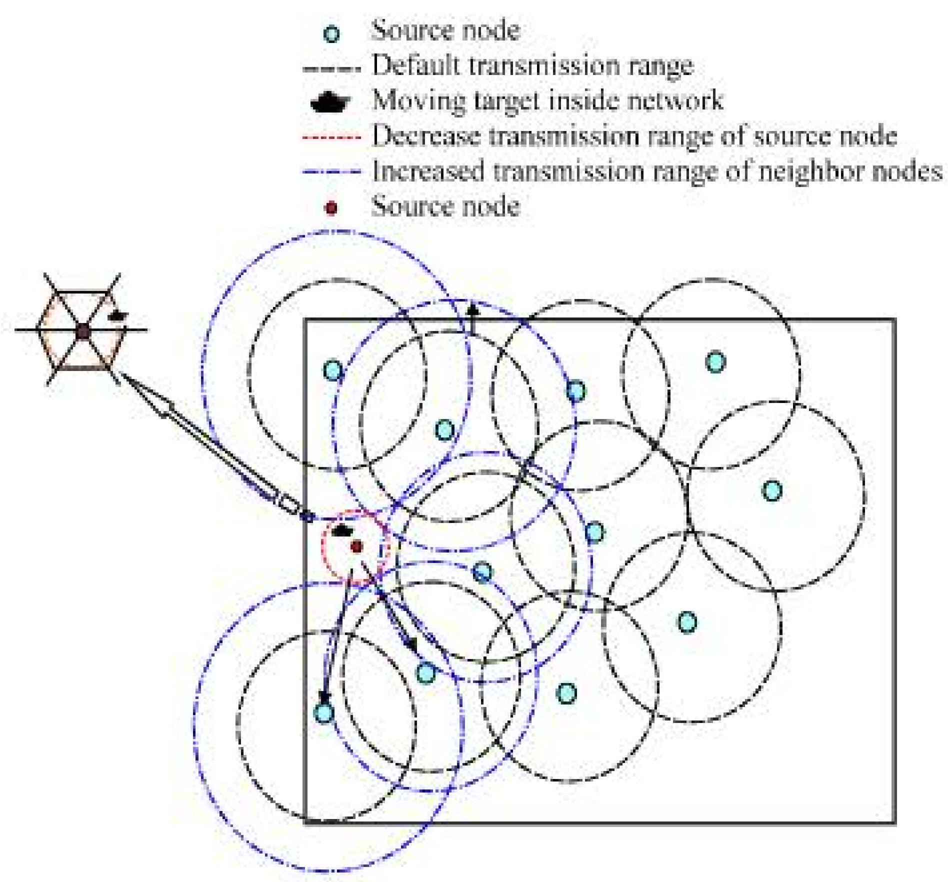

Fig. 4: Decreased transmission of source node and increased transmission of neighbor nodes

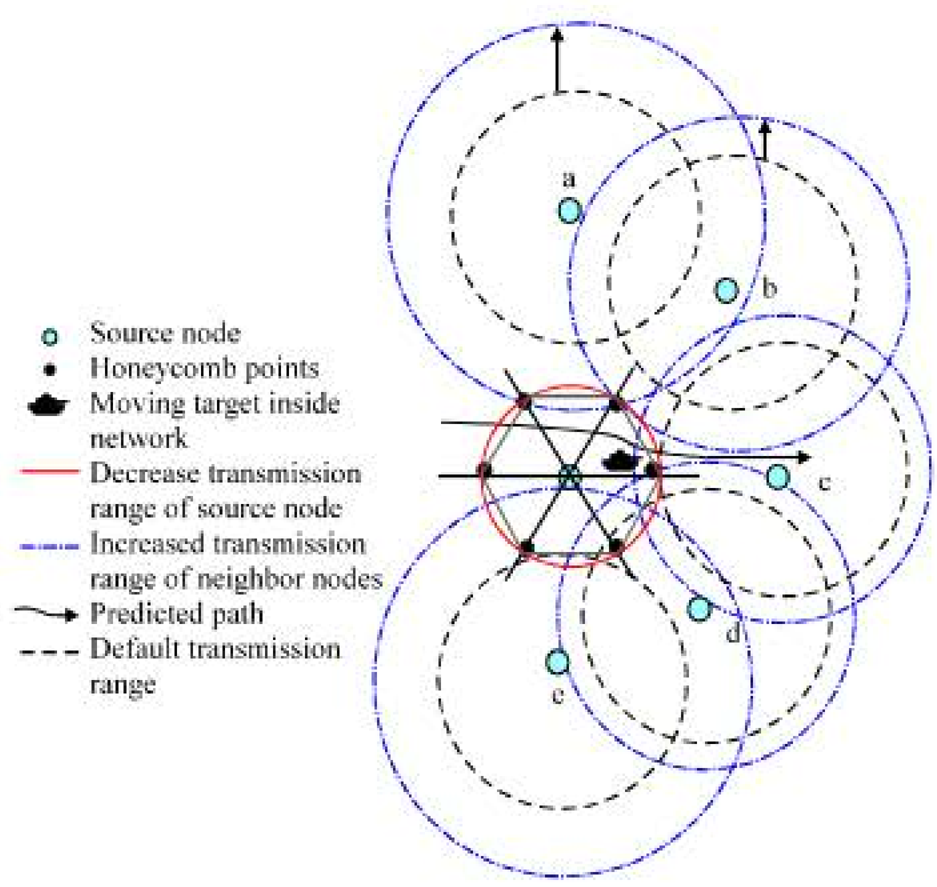

Fig. 5: The closer view of prediction process

Hexagon. As shown in Fig. 5, object appears in one part Hexagon, from that it is possible to know next possible move of the object. Once source node makes a prediction, it includes the speed of moving object along with its direction. Hexagon topology helps source node, to know about possible direction of the objects.

In case of multiple objects: As we assume that if there are more than one object at time in network, objects must have at least two hop distances in between them because if source node will have two objects in its sensing range then it would not be possible to track two objects at a time by adjust sensing according to two objects. But, there is chance, that once two objects are close like two hop count considerably their source nodes can have common neighbors. Source nodes send decreasing TR ratio to its neighbors to increase the TR. So, a neighbor node can receive DDTR (decreasing transmission range rate) message from two source nodes at time or in different time. In such situation neighbor nodes follow the source node with high decreasing transmission range rate. As neighbor node will increase their transmission range in response high decreasing transmission range rat, it will be few chances to have communication hole in network.

SIMULATIONS

In this simulation section, the algorithms that we introduced in related work part is used for comparison with the performance of our EOATR algorithm. The simulation includes efficient dynamic, dynamic clustering and EOATR (Lee *et al*., 2006, 2007). We set up the simulation by NS2 and the Table 1 shows the simulation parameters.

As Fig. 6 shows when the reporting period from nodes to base station is longer, then frequency of reports from cluster heads to the base station gets lower, thus all the algorithms' total energy consumption becomes lower. But in proposed EOATR algorithm, it can minimize the long distance communication between nodes to make a local decision about object movement.

In this way, it reduces the data transmission and the unnecessary reports from the nodes to the base station. Consequently with the proposed algorithm, the total energy consumption of the object tracking in wireless sensor network is always and considerably lower than the other algorithms. And when the reporting period is longer than 7000 msec, the total energy consumption of the four algorithms get very closed to each other. This is primarily because of the exceedingly low frequency of the reports.

In Fig. 7, we can see that, when the object's movement status changes smoothly and running time increases, the total energy consumption relatively decrease compare to dynamic clustering and efficient dynamic clustering as running time increases the power consumption ratio increases. That is because in this method, one sensor at a time involves to track the moving object, controlling transmission range and its one hop neighbor sensors.

As shown in Fig. 8, comparison between the original and predicted path as general behavior. It illustrate that object location prediction is very close to the actual one, it is because in every time period object speed is being consider constant and $\Delta t'$ is kept smaller, where the object's bending nature can be measured at every time instant. As the hexagon topology chooses the next source node at before last movement of object moving from one TR to next TR and closest one. It is discussed before that prediction is made and then neighbor sensors of source node are activated accordingly, even if the prediction is not accurate but still it is close enough to the actual position of the object where the object lies with-in the of the neighbor sensors, chosen by using hexagon topology.

Table 1: Simulation parameters

Parameters	Default setting
Terrain	500×500 m
No. of nodes	200
Simulation duration	200 sec
Reporting period	1s
Transmission energy	600 mW
Receiving energy	300 mW
Objects moving speed	5 ~ 10 m sec^{-1}
Objects moving duration	0.5 sec
Monitoring/transmission of each node	20 m

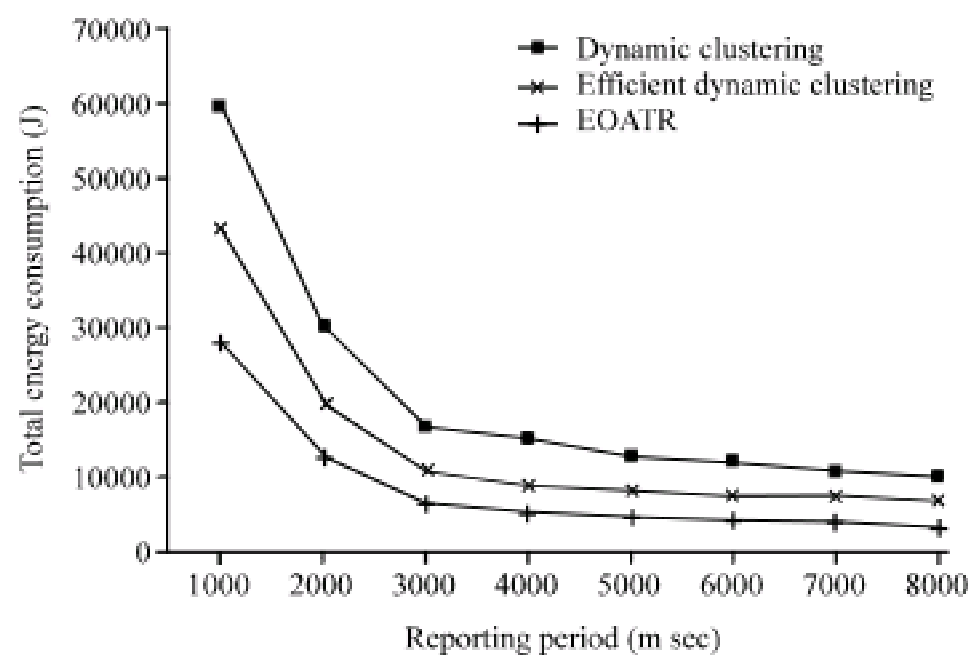

Fig. 6: Total energy consumption with different reporting period

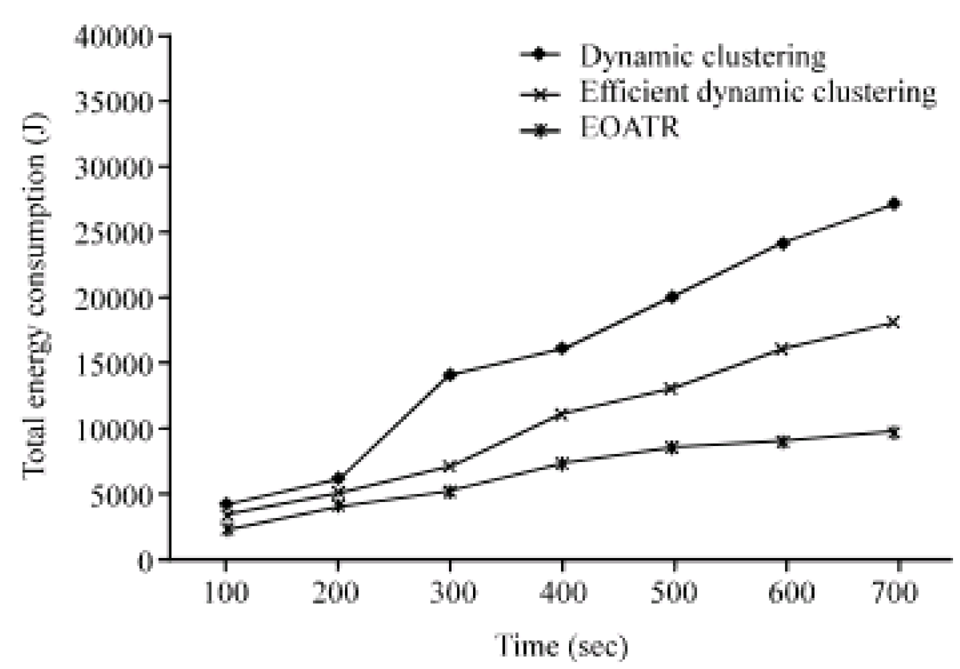

Fig. 7: Comparison of total energy consumption

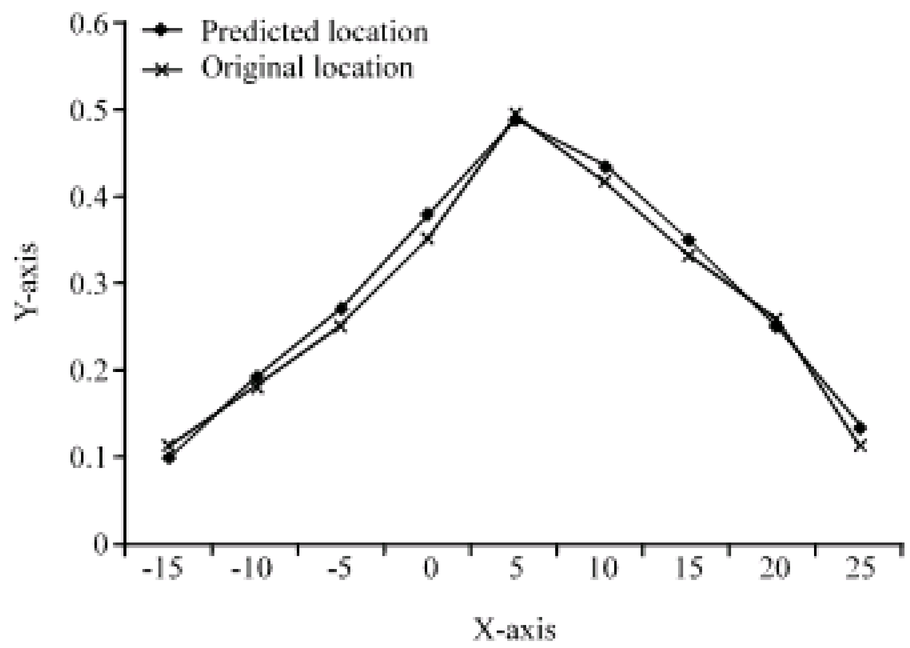

Fig. 8: Comparison between the original and predicted path as general behavior

CONCLUSION

In this study, we have developed efficient way to automatically control the transmission range of sensor to track moving objects. Adjusting the transmission range allows for small amount of messages to be transmitted and enable short range of communication, which cause considerable less energy consumption. Precise prediction enhance the overall life time of network and accuracy in tracking. The simulation shows that proposed algorithm can effectively improve the performance in moving objects tracking application. Proposed algorithm is able to reduce the energy consumption by reducing unnecessary communication cost.

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