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IMPLEMENTATION OF MULTIPLE STATIC AND MOBILE SINK NODES FOR ENERGY BALANCING IN A CORPORATE SENSOR NETWORK

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***Abstract*— Wireless sensor consists of spatially distributed autonomous sensors. Sensors are equipped with tiny irreplaceable batteries and it is very difficult to recharge them and sensors are more prone to hotspot phenomenon .These decreases the network lifetime so it is utmost important to design energy efficient algorithm to prolong network lifetime.**

The influence of multiple static sink nodes on energy consumption under different scale networks is first studied and an Energy-efficient Multi-sink Clustering Algorithm (EMCA) is proposed and tested. Then, the influence of mobile sink velocity, position and number on network performance is studied and a Mobile-sink based Energy-efficient Clustering Algorithm (MECA) is proposed and tested. Then by implementation of both static and multiple mobile sink nodes simultaneously is studied and a Static and Multi-mobile-sink Clustering Algorithm (SMCA) algorithm is proposed.

***Index Terms*—Wireless sensor network, hotspot phenomenon, network lifetime**

I. INTRODUCTION

Wireless sensor network is a growing technology which is offering solution to a variety of application areas such as healthcare, military and industry.

Sensors are building blocks of WSN. Sensors usually used for target tracking, environmental monitoring, system control and biological detection.

Corporate sensor network is mainly used for observing the activities of employees.

Many energy efficient routing algorithms and protocols have been proposed to prolong network lifetime for WSN [2].

Some representative technologies to implement a corporate network include: IEEE 802.11, IEEE 1394, Ultra Wide Band (UWB), Bluetooth and ZigBee. ZigBee is highly suitable for implementing home automation networks.

Wireless Sensor Networks (WSNs) are suitable for the corporate environment due to their intrinsic nature including the attributes of self-organizing, infrastructure-less and fault-tolerance. WSNs are usually composed of many sensors and actuators which can sense, process and transmit raw data to a remote sink node (or BS). Typical corporate sensor includes measurement of humidity and temperature, monitoring the activities of employees and healthcare [1].

The components of WSN are sensors, cluster head, base station or sink node. Sensor nodes collects data and sends to a cluster head or to a base station in a multi-hop fashion, that is it first sends data to its nearest sensor, which in turn it sends data to its nearest sensors till it reaches the destination.

In the existing system there will be a single base station, the sensor nodes near to the base station will be busy is forwarding the data, which is sent from far away sensors .These creates a high traffic load among sensor near to the base station .They will consume all their available electric power much earlier than others, which will cause degraded network performance including network partition, isolated nodes and reduced network lifetime, this is called hot spot phenomenon.

Intuitively, the following disadvantages can be reduced if the mobile sink nodes are well deployed and scheduled. First, the hot spot problem can be largely mitigated when the sink nodes move around. Second, energy balancing can be achieved among sensor nodes with prolonged network lifetime. Third, transmission latency can be reduced and throughput can be improved under multiple sink nodes environment. Finally, some isolated nodes or data under sparsely deployed networks can be periodically accessed by mobile sink nodes to improve network performance.

As per sink node deployment strategy, it can be categorized into four classes, namely: single static sink, single mobile sink, multiple static sinks and multiple mobile sinks deployment strategy. In this paper, both multiple static sinks and multiple mobile sinks deployment strategies are studied.

This paper aims to jointly optimize the clustering algorithm and sink node deployment strategy under a corporate sensor network. Two sink mobility based energy-efficient clustering algorithms are first tested. These two algorithms are termed Energy-efficient Multi-sink Clustering Algorithm (EMCA) and Mobile-sink based Energy-efficient Clustering Algorithm (MECA). Then, the influence of multiple sink number, velocity and position on network performance is presented. Since the sink node is more expensive, a mechanism to find the optimal sink number to prevent the overuse of sink nodes is further provided. Then by implementation of both static and multiple mobile sink nodes simultaneously Static and Multi-mobile-sink Clustering Algorithm (SMCA) algorithm has been proposed.

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A traditional corporate network can be modeled as graph G (N, E) where N is the set of all sensor nodes and E is the set of all links (i, j). Here i and j are neighbouring nodes. Node i can communicate directly with its neighbour node j if their Euclidean distance is smaller than its transmission radius.Here, the first order radio model [2], [3] is used as the Energy model. Based on the distance between transmitter receiver, a free space (d^2 power loss) or multi-path fading (d^4 power loss) channel models are used. Each sensor node consumes E_{Tx} amount of energy to transmit a l bits packet over distance d and E_{Rx} for reception, where E_{elec} is the energy dissipated on circuit, and ε_{fs} and ε_{mp} are free space and multi-path fading channel parameters E_{Rx} respectively.

$$E_{Tx}(l, d) = \begin{cases} lE_{elec} + l\,\varepsilon_{fs}\, d^2, d<d_o \\ lE_{elec} + l\,\varepsilon_{mp} d^4, d>d_o \end{cases} \quad (1)$$

$$E_{Rx}(l) = lE_{elec} \quad (2)$$

II.RELATED WORKS

LEACH [3] is one of the most famous hierarchical routing protocols for WSNs, which can guarantee network scalability and prolong network lifetime up to 8-fold than other ordinary routing protocols. The energy can be well balanced among sensors since each sensor takes turn to become the cluster head at different rounds. However, 5% of cluster head nodes are randomly chosen and the cluster heads use direct transmission to send their data to the sink node.

In 2003, Shah *et al* [5] first proposed the basic idea of mobile sinks for WSNs where the authors call them "Data Mules." The Mules use random walk to pick up data in their close range and then drop off the data to some access points. The energy consumption for sensors can be largely reduced since the transmission range is short.

Younis *et al* [6] also investigated the potential of base station repositioning to improve network performance. The authors addressed when, where and how the base station should be moved by checking the traffic density of nodes one hop away from base station as well as their relative distance. A Scalable Energy-efficient Asynchronous Dissemination (SEAD) protocol [7] was proposed to minimize energy consumption in both building a dissemination tree and disseminating data to mobile sinks. When the sink joined the tree, the Steiner tree was built recursively and SEAD found the minimal cost entry to the tree for the sink using unicast. Gandham *et al* [8] tried to use an ILP (Integer Linear Program) to determine the locations of multiple base stations. They aimed at minimizing the energy consumption per node and prolonging the network longevity.

In 2004 - 2005, the idea of multiple mobile sinks for WSNs was further investigated. Akkaya *et al* [4] stated that to find the optimal moving positions for mobile sinks was an NP-hard problem in nature. Oyman *et al* [9] focused on multiple sink location problems and they presented three problems (BSL, MSPOP and MSMNL) depending on design criteria and provided solution techniques. Luo *et al* [10] formulated lifetime maximization as a min-max problem and jointly studied the sink mobility and routing strategy. They claimed that the overall energy is minimized when the mobile were located at the periphery of the circular network. Wang *et al* [11] studied the WSNs with one mobile sink and one mobile relay individually and they claimed that the improvement in network lifetime over the all static network was upper bounded by a factor of four. However, more recently, Shi *et al* [12] proposed theoretical results on the optimal movement of a mobile base station. They showed that when base station location is un-constrained, the network lifetime can be at least (1- ε) of the maximum network lifetime under their designed joint mobile base station and flow routing algorithm. Marta *et al* [13] proposed to change mobile sinks' location when the energy of nearby sensors became low. In that case, mobile sinks had to find new zones with richer sensor energy. The authors claimed that an improvement of 4.86 times in network lifetime was achieved compared to the static sink case. Lee *et al* [14] introduced a single local sink model to minimize total energy cost during geographic routing. The optimal sink location is determined by a global sink and this model was extended to multiple local sinks model to provide scalability. Kim *et al* [15] proposed an Intelligent Agent-based Routing (IAR) protocol to guarantee efficient data delivery to sink node. Mathematical analysis and experimental results were provided to validate the superiority of their proposed protocol in terms of delay, energy consumption and throughput.

III.TESTED EMCA AND MECA ALGORITHMS

In this section, the influence of multiple static and mobile sink nodes on network performance is studied under different scale hierarchical networks. Two sink mobility based energy efficient clustering algorithms for WSNs are tested, namely an Energy-efficient Multi-sink Clustering Algorithm (EMCA) as well as a Mobile-sink based Energy-efficient Clustering Algorithm (MECA) and Static and Multi-mobile-sink Clustering Algorithm (SMCA) algorithm is proposed

A. *Energy-efficient Multi-sink Clustering Algorithm (EMCA)*

The entire network is divided into several clusters, as depicted in *fig. 1*. In each cluster, there is one Cluster Head (CH) for data collection and the rest of the sensors are called ordinary nodes. The CH is determined by the residual energy among sensors and the CH sends aggregated data to the relevant sink. By adopting clustering or hierarchical routing technique, network scalability and easier management can be guaranteed. If the clustering algorithm is well designed with CHs located in a geographically more uniform way, energy consumption can be well balanced and reduced, causing a much prolonged network lifetime

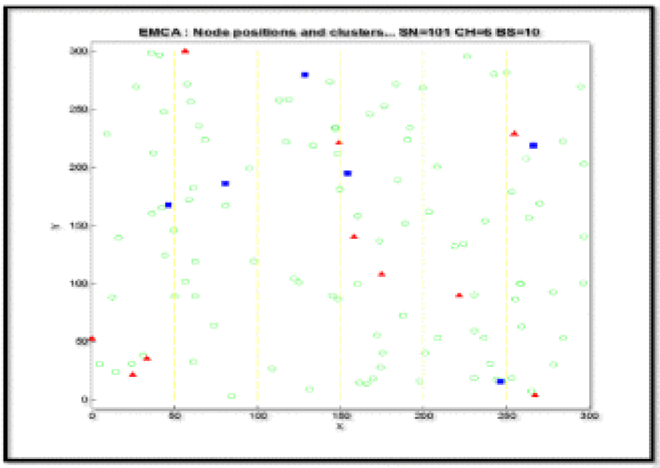

Fig. 1.Cluster formation in EMCA

Cluster
Head Sink
node Sensor
node
Cluster boundary

In EMCA, each cluster head selects an optimal sink to send aggregated data. The reduction and the balancing of the energy consumption is the primary concern. For any CH, the energy required to send data to the B S is represented as:

$$E\,(CH_n,BS_k)=\begin{cases} lE_{elec}+l\,\varepsilon_{fs}\,d(CHn,BS_k)^2, d<d_0 \\ lE_{elec}+l\,\varepsilon_{fs}\,d\,(CHn,BS_k)^2, \; d>d_0 \end{cases} \quad (3)$$

Equation. (3) Shows that the smaller $d(CH_n,BS_k)$ is, the smaller $E(CH_n,BS_k)$ will be. Inter-cluster algorithm can be formulated as to find the *Min* $(d(CH_n,BS_k))$

In many clustering algorithms, such as LEACH, some sensor nodes in the same cluster send data directly to the cluster head. Due to the fact of various locations, certain sensor nodes may consume large amount of energy based on long-distance transmission. Therefore, multi-hop routing is used here. For any member node S_i in a cluster, the energy consumption to send data to its CH_{Si} is represented as:

$$E(S_i,CH_{Si})=\begin{cases} lE_{elec}+l\,\varepsilon_{fs}\,d(S_i,CH_{Si})^2, d<d_o \\ lE_{elec}+l\,\varepsilon_{fs}\,d(S_i,CH_{Si})^2, d>d_o \end{cases} \quad (4)$$

In the meantime, S_i tries to find another sensor node S_j to relay data to save energy by avoiding directly communication with CH_{Si}. To deliver a *l*-length packet to the cluster head,

the energy consumption $E_2\,(S_i,S_j,CH\,Si)$ calculated as (5) and the optimal relay node is determined based on the smallest value of. $E_2\,(S_i,S_j,CH\,Si)$

$$E_2\,(S_i,S_j,CH_{Si})=E_{Tx}(l,d((S_i,S_j))+E_{Rx}(l) +E_{Tx}(l,d((S_i,CH_{Si})) \quad (5)$$

As the multiple sink nodes are randomly deployed then in practice some nodes may consume less energy through sending data directly to the sink rather than to its cluster head

B. *Mobile-sink based Energy-efficient Clustering Algorithm (MECA)*

1) Relocation of sink nodes

In MECA, the moving velocity V of the sink is predetermined. A sink node only needs to broadcast across the network to inform all sensor nodes of its current location P_0 at the very beginning for just one time. Later on, as sensor nodes keep record of the original location of the sink, they can reduce the changed angle θ after a time interval Δt .

$$V=\frac{\theta * R}{\Delta t}$$

$$\theta=\frac{V*\Delta t}{R} \quad (6)$$

As P_0 is known, the new location $P_{\Delta t}$ can be determined after the broadcasting finishes, the mobile sink is ready to

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collect data. Here, the mobile sink is assumed to stay at a site for a period long enough to complete a round of data collection, and then moves to the next position.

2) Cluster formation and cluster head selection

As depicted in *Fig. 2*, the whole sensor network is divided into several clusters. When the CH selection begins, the sensor node that is located in the center of each cluster is motivated, like S_i and is regarded as the CH candidate. It broadcasts one message within a neighborhood of radius R .This message aims to motivate other nodes for the competition of the cluster head. It contains the node's id and its residual energy. Only the nodes within the transmission range can receive

the message and become active, whereas the outside nodes remain idle. If any node S_j has larger residual energy than S_i , it becomes the new cluster head candidate and broadcasts new message with its own information to the others. If S_j has equal residual energy with S_i , compare the ID. The node with a smaller ID wins. If S_j has smaller residual energy than S_i , it still broadcasts the message of S_i as soon as the comparison is done, the unselected node becomes idle again. All nodes in the cluster should be compared only once. In this way, the node with the largest residual energy is chosen as the cluster head.

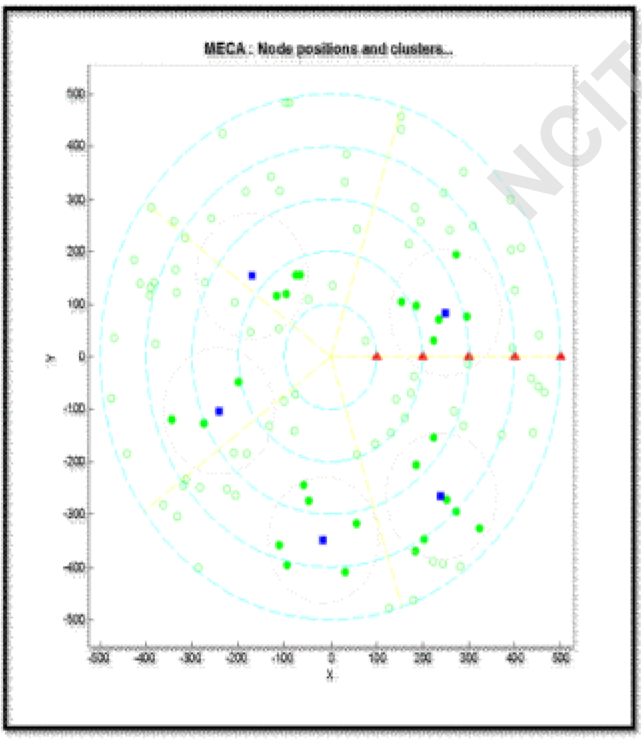

Fig 2.Cluster formation in MECA

Cluster Head
Sink node
Sensor node
Sensor nodes motivated for cluster head selection

3) Hierarchical routing phase

For node S_i in one cluster, the energy consumption cost to send data to its cluster head CH_{Si} is given in (4). In the meantime, S_i tries to find another S_j to relay data which may consume less energy than that through directly communication with CH_{Si} . Since the direction of data transmission can be randomly chosen, various nodes can be chosen, which turn out to cause various energy consumption.

Suppose S_i chooses S_j as its relay node and let S_j have direct communication with the CH_{Si} . To deliver a l –length packet to the CH, the energy consumed by S_i and S_j is shown in (5). Each S_i chooses S_j with the smallest E_2 (S_i, S_j CH_{Si}) as the relay node if necessary:

$$E2\,(S_i\,,\,CH_{S_i}) = \mathrm{Min}(E2\,(S_i\,,\,S_j,\,CH_{S_i})) \qquad (7)$$

Compare (4) and (7), and the smaller one is chosen:

$$E\,(S_i\,,\,CH_{S_i}) = \mathrm{Min}(E1\,(S_i\,,\,CH_{S_i}),\,E2\,(S_i\,,CH_{S_i})) \quad (8)$$

In MECA, the sink node changes its location overtime. Therefore, some nodes may consume less energy through sending data directly to the sink rather than to its cluster head. So it is necessary to compare E (S_i ,CH_{Si}) and $E(S_i$, $BS)$ and decide the final route. In summary, the clustering algorithms in this paper can be viewed as to find The

$Min\,(E(S_i\,,CH\,),\,E(S_i\,,\,BS))$

IV) PROPOSED SMCA ALGORITHM

A) *Static and Multi-mobile-sink Clustering Algorithm (SMCA)*

Here both multiple mobile BS_m and static sink nodes BS_s are deployed. Suppose, whenever mobile sink BS_m node appears near to it then cluster head CH_{Si} , if that CH_{Si} finds the distance between its mobile sink is less than static sink BS_s it directly forwards packet to mobile sink node. Thus, energy is saved. Sensor nodes will calculate least distance which is required to forward the packets. Sensor nodes calculates the minimum energy required with the help of this formula

$Min\ (E\ (S_i,\ BS_m),\ E\ (S_i,\ BS_s))$

Fig 3.Routing in SMCA

Cluster Head
Mobile Sink node
Sensor node
Static sink node

V.PERFORMANCE EVALUATION

A. Test Environment

Consider the following parameters, there are 100 Sensor nodes deployed in a [500,500] network with multiple sink nodes placed either inside or along periphery of the area. The maximum transmission radius is assumed to be 120 meters Each sensor node transmits the collected data to a sink either directly or in a multi-hop fashion.

TABLE I. The following network parameters are initially assumed

Parameter name	**value**
Network size	[300,300] to [500,500]
Num of nodes(N)	100
Radius(R)	120m
Packet length(l)	6 bits
Initial energy(E_0)	0.5 Joule
Energy consumption on circuit	50nJ/bit
Free space channel parameter	$10pJ/bit/m^2$
Multi-path channel parameter	$0.0013pJ/bit/m^4$

B) EMCA performance analysis

i) Performance analysis total energy consumption

100 sensor nodes are randomly deployed. As illustrated in the *fig. 1* .Here whole network is divided into several clusters By, changing the number of sink node and the number of cluster total energy consumption can be evaluated .It can be seen that total energy consumption units decreases as the number of sink node increases .when 3 or 4 sinks are deployed The decreasing rate of energy consumption becomes relatively small even if more sink nodes are added later.

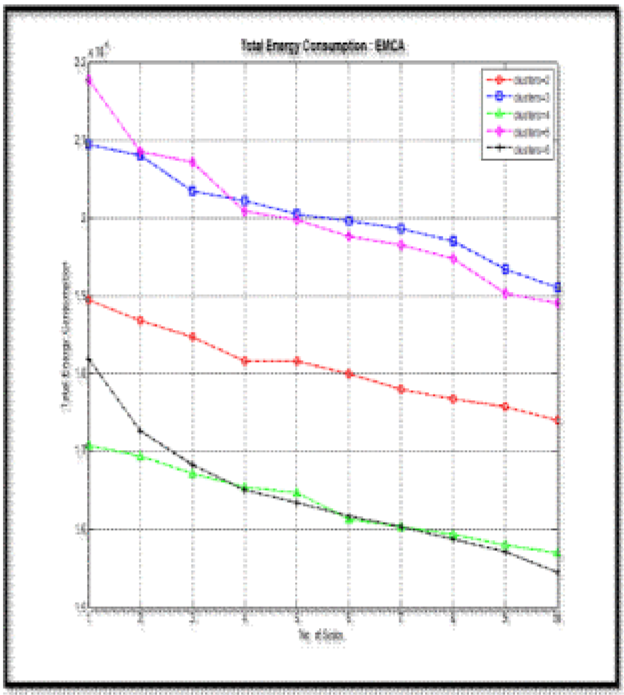

fig 4.graph of total energy consumption

C) MECA performance analysis

i) performance analysis of single sink mobile node by varying its velocity

The influence of single mobile sink node moving under different strategy is studied.

Fig. 5 illustrates, changing the velocity of sink node influences the energy consumption of the sensor network.

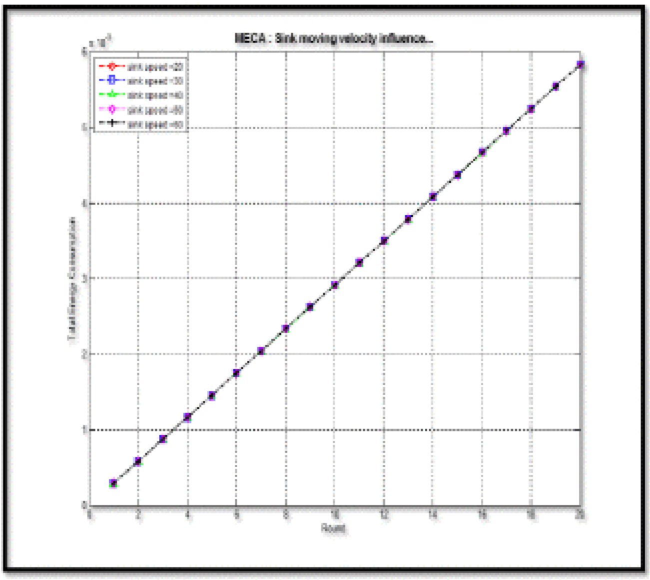

Fig 5.sink moving velocity influence

ii) performance analysis of single sink mobile node by varying its position

Fig.5 illustrates the influence of position of a sink node Moving in a different radius(1/5R,2/5R…)

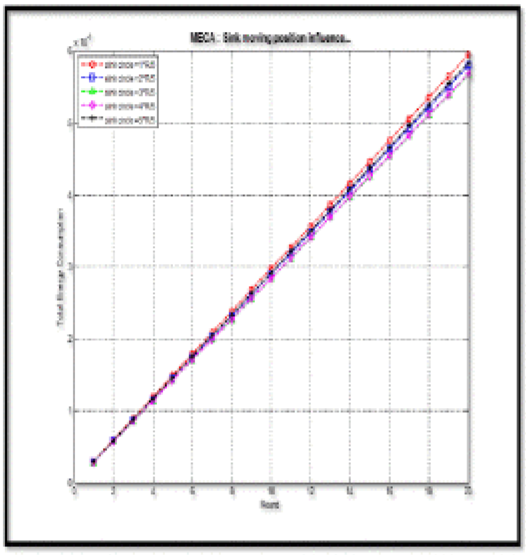

Fig 5.sink node position influence

It can be seen that single mobile sink velocity and position have little influence on energy consumption of sensor node due to the average distance square being similar to the single moving sink regarding the random sensor network topology

iii) influence of multiple mobile sink number on energy consumption by varying number of sink nodes

It can be seen from *fig.7* that as the number of sink nodes increases total energy consumption decreases but, it is necessary to find the optimal sink number for improving sensor network lifetime.

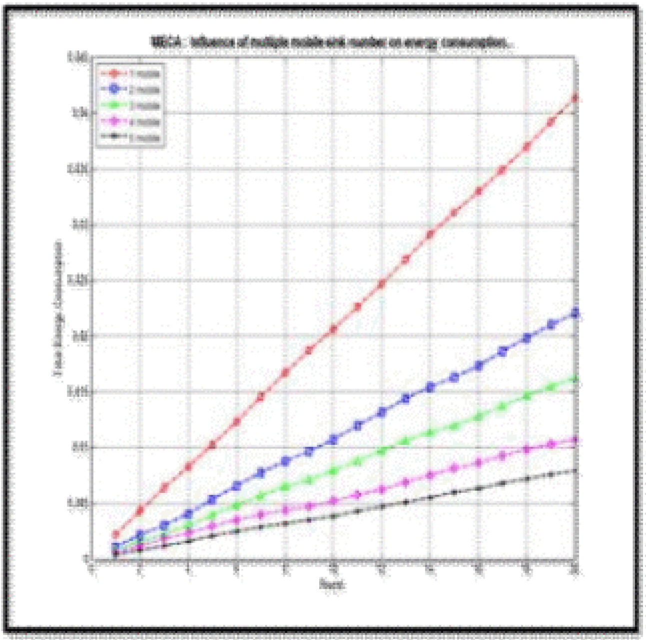

Fig 7.influence of multiple sink number on energy consumption

VI. CONCLUSION

The main focus of this project is balancing energy among sensor nodes and to improve the network lifetime of sensor network. Therefore two algorithms EMCA and MECA is proposed and tested another algorithm SMCA has been proposed.

Fig 6.Sink moving position influence

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