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Intelligent Energy Aware Routing (IERA) Algorithm based on Dynamic Sink Nodes

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ABSTRACT

The emergence of big data and cloud technology has driven a fast development of wireless sensor networks (WSNs) [1–4]. A sensor node is normally comprised of one or more sensor units, a power supply unit, a data processing unit, data storage, and a data transmission unit [5]. A wireless sensor network is a collection of wireless nodes with limited energy that may be mobile or stationary and are located randomly in a dynamically changing environment. Wireless sensor networks hold the promise of revolutionizing the way we observe and interact with the physical world in a wide range of application domains such as environmental sensing, habitat monitoring and tracking, military defence, etc. [6]. A variety of disciplines uses the WSNs for numerous applications like monitoring of specific features or targets especially in rescue and surveillance applications, medical, engineering and industrial applications and many more. As they are easy to handle because of the small size and is of affordable cost the use of such sensors became common. Besides that they can be deployed in areas like underground, underwater or the normal landscape which made it more feasible. Now a day's everywhere we can see the surveillance equipments which are deployed with sensors. Smart home environments are yet another application. Lot many applications in medical field use WSNs like patient monitoring. Target tracking and war zones extensively rely on these.

The characteristics of low-cost, low-power, and multifunctional sensor have attracted a great deal of research attention, in that sensor nodes can perform intelligent cooperative tasks under stringent constrains in terms of energy and computational resources. However, most previous research work only considers the scenario where a WSN is dedicated to a single sensing task, and such application-specific WSN is prone to high deployment costs, low service reutilization and difficult hardware recycling [7].

In a sensor network, each node acts as both a sensor and router, with limited computing and communications capabilities, and storage capacity. However, in many WSN applications, the deployment of sensor nodes is performed in harsh environments, which makes sensor replacement difficult and expensive [8–10]. Thus, in many scenarios, wireless nodes must operate without battery replacement for a long period of time. Consequently, the energy constraint is vital for the design of WSNs [11]

Routing is an important networking activity as it is the major factor that affects the efficiency of a network in terms of delay, throughput, energy consumption etc. WSNs consist of hundreds and thousands of tiny sensors or motes which are deployed randomly in an area where the sensing of a particular event has to be done. There are a variety of applications which employ WSNs like disaster rescue operations, wild fire protection, war zones, engineering, medical and agriculture fields, robotics etc where the direct intervention of human is comparatively risky or sometimes impossible. In many cases replacing the batteries are also not feasible because of its huge number as well as the restrictions of the deployed region. If one node goes out of power and dies off the entire connectivity can be affected which makes the intention of the network futile. Because of the resource constraint nature, the power backup capabilities are very limited and the only possible way to retain the network connectivity is to efficiently use the available energy so as to extend the lifetime of the entire network. So the proper design of every layer in protocol stack is very important. Network layer activities especially routing can save energy to a great extend because the communication process consumes more energy compared to sensing and other processing activities and hence our focus is on development of an energy efficient routing protocol so as to enhance the life time of the entire network.

In the area of WSNs, energy efficient routing protocols has been always a hot research area but the mobility factor is not addressed in an appropriate level as it is evident that majority of the routing protocols assumes the nodes to be static. But we can find that in most of the applications where wireless sensor networks are involved like disaster applications or medical care etc the nodes can be mobile. So mobility of the nodes i.e. either the source or the sink has to be considered. Literature have shown that mobile sink assisted routing helps to reduce energy consumption to a great extend. Hence we thought of developing an energy efficient routing algorithm which is supported by the mobility of multiple sinks.

Related Works:

Routing is important in the WSN in determining the optimum routing paths of data packets, and there have been a great number of popular routing algorithms for the WSN. Ad hoc On-demand Distant Vector (AODV) [12] was proposed in 1999, and became an IETE standard. It is a routing algorithm in consideration of the distance between the nodes. Its quick adaption to link conditions, low memory usage and low network utilization make the ADOV algorithm popular. However, the number of flooding messages increases significantly thanks to the increasing routing request messages. Clustering protocols can aid in data aggregation through efficient network organization. Low-energy adaptive clustering hierarchy (LEACH) [13] is one of the most well-known WSN hierarchical routing algorithms, which selects the cluster headers (CHs) based on a predetermined probability in order to rotate the CH role among the sensor nodes and to avoid fast depletion of the CH's energy. LEACH operates in two phases, i.e., the cluster setup phase and the steady phase. In the cluster setup phase, the cluster heads are selected and then broadcast to other nodes. In the steady state phase, actual transmission of data occurs. However, the study of LEACH considers only energy consumption in receiving the advertisements from the CHs at each sensor node during the setup phase. The number of the cluster heads varies and the CHs do not have a good distribution. Furthermore, LEACH requires the transmission between the cluster heads and the sink to be completed in a single hop, which consumes a large quantity of energy and disrupts the energy balancing of nodes if the CHs are located far away from the sink. In [14], DF-LEACH is proposed as an improvement of LEACH, which takes into account the distance of the CH to the sink node, and thus saves communications energy. In [14], a hybrid energy-efficient distributed clustering approach (HEED) is proposed. The initial probability for each sensor to become a cluster head is dependent of its residual energy, and the performance results are fairly good. Hausdorff[16] uses a greedy algorithm to select the cluster heads based on residual energy and location information, and this method can significantly prolong the network lifetime. In [17], an unequal cluster-based routing protocol is proposed, which focuses on load balancing in order to address the hot-spot issue. Mottola et al. [18] propose an adaptive energy-aware multi-sink routing algorithm, which is expressly designed formany-to-many communications. In [19], the authors address the issue of load balancing through considering different hop distances for the clusters. EDIT [20] is proposed to select the cluster head based on not only energy but also delay. The traditional routing algorithms are unable to adapt to the flexibility of WSNs. Consequently, we propose a new routing algorithm for the WSN, which can accommodate flexibly and helps achieve better results.

Wang et al in [21] proposes an energy efficient routing protocol where mobile sinks are employed and random deployment of nodes are done. They uses a new version of the Stable Election Protocol wherein the cluster head are selected based on the residual energy of the nodes and the data transmission also is done in a planned manner. This protocol shows good results in balancing the energy of the nodes thereby increasing the lifetime. The authors in [22] tell about the importance of duty cycling and topology management and give an overview of the different protocols used for large level and small level networks. A comparison of the different energy efficient routing protocols is also done.

In [23] the energy consumption of the Direct Communication protocol and Minimum Transmission Energy is assessed and compared LEACH protocol in MATLAB and a through effort is done to emphasize the importance of clustered routing to increase the energy efficiency along with a suggestion for future enhancement i.e. to develop design new energy efficient routing algorithm with a different cluster head selection strategy in order to extend the network life time. In [24] , [25] and [26] a survey of the different energy efficient routing protocols is done mentioning the different strategies adopted by each. These papers in general give an overall idea of the different energy efficient routing protocols. They compile all the different energy efficient routing protocols available in the literature.

The authors in [27] propose a new energy efficient routing protocol for Wireless Body Area Networks where the nodes are static. They use a routing approach by using the intersection of the nodes and find a path to the sink without flooding. Three different stages are used in the proposed scheme where in the first stage the nodes prepare a route and send the advertisement to the neighbours, in the second stage neighboring nodes decision of whether to reply is done and finally in the third stage the information is passed from source to the selected sink node. They claim that the proposed protocol shows better results. But additional hardware requirement of GPS is needed for the nodes to be aware of their current location and that of the sink. Besides that it is assumed all the nodes are aware of their energy levels.

Awwad et al in [28] tells about the issues in the node mobility like packet loss and energy consumption. They propose a protocol called cluster based routing with mobile nodes which proved to be better than the t LEACH Mobile protocol. Here the cluster heads receives data from all the nodes in their cluster when they are free. The proposed one shows improvement by 25% in the case of packet loss when compared with LEACH Mobile protocol. An approach where the location information of the neighboring nodes is exchanged only to the forwarding node sensing data thereby reducing the power usage is done by Kimura, Tomoki, and Iwao Sasase in [29].They use mobile nodes with multiple sinks and does not have multicast routes between them.

In [30] mobile sinks are used and by employing appropriate cluster head for effective communication and routing energy efficiency is claimed by the authors. Both the base station and sensor node mobility is addressed in [31]. They uses cluster head along with two deputy cluster heads for routing and also allows to be dormant state when not in use which achieves more energy efficiency. Taking LEACH as the base, an improvement on that with mobile nodes to achieve better lifetime is done by Nguyen et al in [32].

Xun-Xin, Yuan, and Zhang Rui-Hua in [33] proposes a new energy efficient routing using the sink mobility where the sink moves based on the average energy of the cluster. Here only one sink is mobile. They propose a future enhancement with more mobile sinks along with other normal nodes also given the mobility. For detecting a mobile target a new protocol is proposed by Yu-Chen et al in [34].In mobile target of course chances of path loss or connectivity is possible. According to the proposed protocol the nodes themselves can effectively recover the path and perform energy efficient tracking. The issues in inter cluster communication in large scale networks is addressed in [35]. The authors views that the optimization in the inter cluster head communication is not seriously dealt with in the literature and proposes a new algorithm named Broadcasting Over Cluster Head for better scalable and efficient inter cluster communication. Inter cluster communication using single hop and multihop from the cluster head to the sink is studied and a comparison is done with the existing routing protocols in [36].

Intelligent Energy Aware Routing(IERA) Algorithm

A. Network model

In this paper, we consider the network architecture as shown in Fig. 1. G = (V;L) denotes the directed graph representing the network. V is the vertex set, including one control sever and a number of sensor nodes distributed within the monitoring field randomly. L is the set of directed links. The following assumptions on the sensor network and sensor nodes under consideration in this paper are made:_ We consider a set of _ sensing targets, e.g., temperature, humidity, and so on, which are randomly distributed within the same region of the WSN; _ The resources in a sensor node should be managed, controlled and allocated in an orderly manner in support of various sensing tasks. Besides, to complete different tasks, corresponding programs are stored on the sensor nodes, and the sensor node shall allow application programmers to adjust the sensor functionalities via invoking different programs; Each sensor node has the same ability to operate either in the sensing mode to perceive the environmental parameters or in the communications mode to send data among each other, or directly to the control server, and each node can gather data packets from a cluster member when acting as the control node. And each sensor node is assigned a unique identifier (ID).

- The sensor nodes and control server are stationary after deployment, which is typical for sensor network applications;
- Initial energy is fair to each sensor node, and the network is considered homogeneous;
- All the nodes are left unattended without battery replacement after deployment;
- Nodes are location-unaware, i.e., not equipped with GPScapable antennae or other similar equipment, and each node is assigned a number according to its location;
- The links between the nodes are symmetric. A node can estimate the distance to another node based only on the received signal power;
- The sink node is externally powered.

A simplified model is considered in this paper for communications energy consumption in consideration of path losses. Both the free space (d2 power loss) and multipath fading (d4 power loss) channel models are employed [34], depending on the distance between the transmitter and receiver. Power control can be used to compensate for this loss. If the distance is less than a threshold d0, the free space model is used; otherwise, the multipath model is adopted.

Proposed IERA Algorithm:

According to the literature energy efficiency is dealt by the hierarchical routing category where the concept of clustering is used. We propose an algorithm called Mobile Sink Assisted (MSA) routing which considers the drawbacks of existing algorithms. The detailed concept of the proposed algorithm called Mobile Sink Assisted (MSA) routing along with the assumptions are described in detail below.

Assumptions

According to the design simulation time is given as 50ms initially. There is a static sink and four mobile sinks which are assumed to be rechargeable. Movement of the mobile sinks can be decided by the static sink. As the nodes are assumed to be deployed randomly every time, in order to have a uniform style of movement the mobile sinks are made to move from the centre to the four corners of the deployed rectangular region. The numbers of nodes, area of deployment, initial energy of the nodes, range of the sensors etc can be varied to have an extensive simulation results. We assume sensors are distributed randomly across the network. Mobile sinks can navigate the network to collect the packets and report the data to the static sink. The path for mobile sink is assumed to obstacle free. The mobile sinks are assumed to have higher communication range, so it can reach the static sensor node.

Algorithm Description

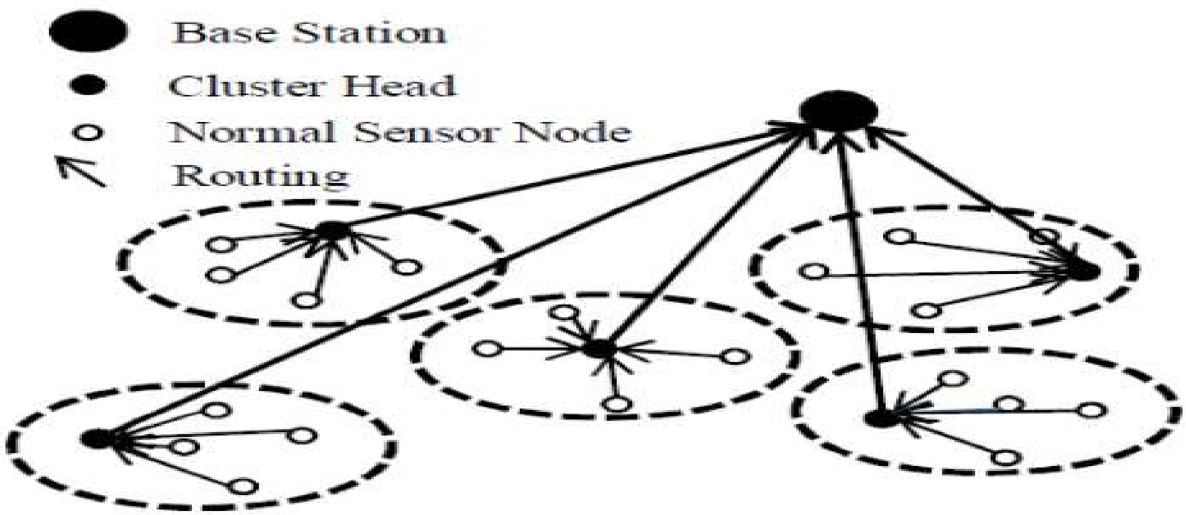
The proposed algorithm consists of three phases namely;

1. Node clustering phase
2. Sink Discovery phase
3. Compilation phase

Detailed explanation of each phase is given in following subsections.

A. ***Node Clustering Phase***

The network is partitioned to clusters using clustering algorithms of LEACH with fewer number of cluster heads possible. Once cluster head nodes are chosen, they broadcast beacon to advertise their presence within their communication range. Based on the received signal strength each non cluster nodes choose their cluster heads to which they belong to. The cluster heads nodes send their information to the static base station also. Because of this arrangement sensor nodes need only low power to transmit their data to the cluster head nodes. The cluster head nodes will aggregate the data and keep it in their memory and wait for mobile sink nodes to reach near them to collect the data. Figure gives the clustering of nodes



B. Sink Discovery phase

Once the static sink receives the cluster head information; it does a path planning to find the optimal number of sensors to navigate the network. The path planning proceeds as follows. From the available cluster heads, static sink picks cluster heads one by one and begins to put in one group till the time the round trip time of travel in that group is bounded by a deadline Td. If the round time exceeds Td then a new group is created. For each group, one mobile sink is allocated. If there are more mobile sinks even after allocating one for each group, the groups are sorted in descending order based on round trip time and mobile sinks are allotted one for group till the number of mobile sink is expired. The rational here is to cover the group with long round trip delay with more mobile sinks.

Once the paths for mobile sinks are decided they are made to move in the path between the cluster heads. If there are more mobile sinks per group, then each mobile sinks is made to start from different nodes.

C. Compilation phase

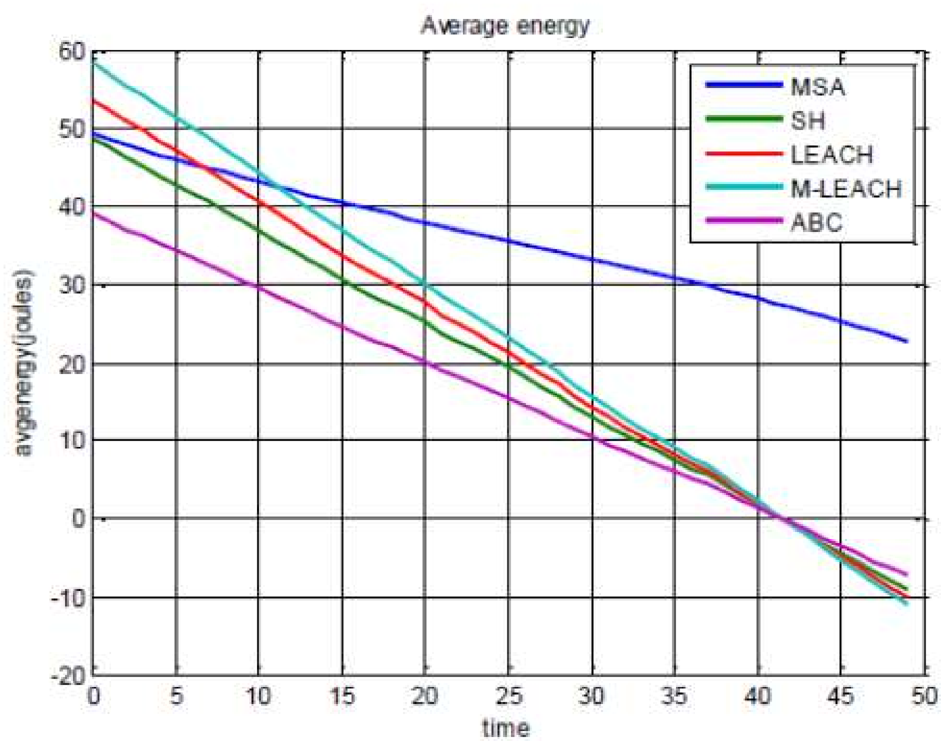
The mobile sink once reaches a cluster head node, will advertise a beacon which requests the cluster head node to give all the data stored to the mobile sink. The cluster head node will forward all the aggregated data to the mobile sink. The mobile sink node will forward the data to the static sink. The static sink forwards the data to any application which needs to process the data. Node deployment is done randomly and they are assumed to be homogeneous. Clusters are formed based on the received signal strength and the general behavior of the nodes. The residual energy of the nodes is also taken into consideration. The mobility of the sink nodes plays a vital role in reducing the energy consumption. We are assuming that the sink nodes are rechargeable. The cluster heads will decide the time slot for each node to send data to it which will be aggregated and passed on to the nearest mobile sink. The mobile sinks collects all the sensed data from the cluster heads aggregates it again and finally pass on to the static sink from where the user can get the information. The two ways aggregation process still minimizes the need for each cluster head to transmit to the sink which again reduces the energy consumption.

V. SIMULATIONS AND RESULTS

In this section, the performance of our proposed method is evaluated via computer simulations. The network lifetime is the time span from deployment to the instant, when the network is considered nonfunctional [39]. In periodic data collection applications, the proper definition of lifetime is the time span between the start of network operation and the time when first node the dies. The simulation models and programs are developed in MATLAB.

Table 1: Simulation Parameters

No.of Nodes	200
Area of simulation	100*100 m
Range of Sensor	10 m
Location of sink	(100,5000
Initial Energy at sensor	50 Joules
Transmission Energy	.5 Joules
Receiving Energy	.2 Joules
No of mobile sink	4
No of static sink	1
Data Packet Length(bits)	150
Broadcast packet length(bits)	50



CONCLUSION

Energy efficiency enhancement is always a matter of concern in wireless sensor networks. In our paper an energy efficient routing algorithm with mobile sinks called IERA routing is proposed with the details about the implementation and simulation results. Extensive simulations have proved that the proposed one gives much better performance than the existing protocols like shortest hop, LEACH, modified LEACH and Artificial Bee Colony algorithms in terms of life time, the average energy of nodes, packet delay and the average packet delivery ratio.

The real time implementation of this algorithm will serve many applications to save energy to a greater extend. The future work will be dealt in the area of finding optimal path for the movement of the sinks so as to save energy of the nodes by reducing the number of hops which can enhance the lifetime of the entire network.

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