Sink Relocation Technique for Network Lifetime Enhancement in Wireless Sensor Networks

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Abstract - Sensor networks are dense wireless networks where information is gathered by sensor elements spread out in an interest area. Wireless sensors applications cover large fields such as surveillance and security, target tracking, agriculture, health and military purposes. The main constraint in wireless sensor networks is limited energy supply at the sensor nodes so it is important to deploy the mobile sink at a position with respect to the area of interest, a specific area that is of more interest to the end-user, such that total energy consumption is minimized. The proposed mechanism energy aware sink relocation (EASR) uses information related to the residual battery energy of sensor nodes along with the link constraints of the node to adaptively adjust the transmission range of sensor nodes and the relocating scheme for the sink.

Keywords - mobile sink, sink relocation

I. INTRODUCTION

AWSN consists of small-sized sensor devices, which are equipped with limited battery power and are capable of wireless communications. When a WSN is deployed in a sensing field, these sensor nodes will be responsible for sensing abnormal events (e.g., a fire in a forest) or for collecting the sensed data (temperature or humidity) of the environment. In the case of a sensor node detecting an abnormal event or being set to periodically report the sensed data, it will send the message hop-by-hop to a special node, called a sink node. The sink node will then inform the superv0 is through the Internet. As shown in Fig. 1, sensor node e detects an abnormal event and then it will send a warning message to the sink to notify the supervisor via a predetermined route in path, say $P_{ea} = e - d - c - b - a$. Note that the routing path may be static or dynamic, depending on the given routing algorithm

The applications of Wireless Sensor Networks are broad, such as weather condition monitoring, battlefield surveillance, and inventory etc. In, general, due to the sensory environments being harsh in most cases the sensors in a WSN are not able to be recharged or replaced when their batteries drain out of power.

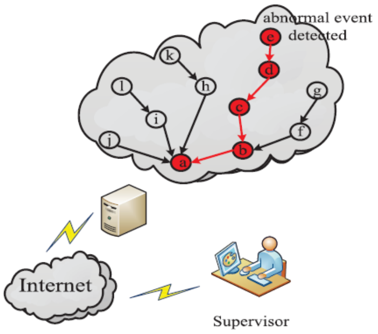


Fig 1: An operating scheme of a WSN

The battery drained out node say cause several problems such as, incurring coverage hole and communication hole problems. Thus, several WSN studies have engaged in designing efficient methods to conserve the battery power of sensor nodes, for example, designing duty cycle scheduling for sensor nodes to let some of them periodically enter the sleep state to conserve energy power, but not harming the operating of the sensing job of the WSN designing energy-efficient routing algorithms to balance the consumption of the battery energy of each sense node or using some data aggregation methods to aggregate similar sensory data into a single datum to reduce the number of transmitted messages to extend he network lifetime of the WSN. In this paper, we propose a sink relocating scheme to guide the sink when and where to move to. Some mathematical performance analyses are given to demonstrate that the proposed sink relocating scheme can prolong the network lifetime of a WSN. We have also conducted simulations to investigate the performance of the EASR method against some traditional methods by numerical simulation. The organization of this paper is as follows. In the next section we will briefly describe some background related to the considered problem, which includes the energy model of a WSN, the energy efficient routing scheme that will be incorporated into the EASR scheme, and the related works of sink relocation.

II. SINK RELOCATION RELATED WORKS

The EASR scheme mainly focuses on when the sink will be triggered to perform the relocation process and where to move to. Besides the sink relocation scheme, the entire operation of the WSNs for environment monitoring also needs to incorporate the routing method for reporting the sensed data from the source to the sink, as well as the energy consumption model. In this section, we will firstly briefly describe the Maximum capacity Path with link capability routing. Then, the energy-aware routing method that is adopted in the EASR method will be illustrated using a numerical example.

This sink relocation method requires mathematical analyses and efficient routing protocols. Özgür B. Akan, proposes Event-to Sink Reliable Transport in Wireless Sensor Networks. He designed reliable event detection using minimum energy usage. This Event-to-Sink Reliable Transport (ESRT) protocol works by controlling the congestion of the network in which multiple event occurrences is accommodated in Wireless Sensor Networks which consumes much more power. Here, the main function is run on sink and minimum functionality is shown at the source end. Hui Wang, describes Network Lifetime Optimization in Wireless Sensor Networks. In this protocol, design of physical, medium access control and routing layers are done in such a way that their network lifetime can be increased by increasing the node duty cycles.

An iterative algorithm is also proposed for large planar networks. Here, to address the problem of network lifetime Time Division Multiple Access technique is adopted. Ankit Thakkar, elaborates on Cluster Head Election for Energy and Delay Constraint Applications of Wireless Sensor Network and proposes cluster formation that results in good performance with respect to energy and delay constraints of the network In this cluster formation, cluster head collects and aggregates the data from member nodes and send it to the other cluster head or the base station, thus achieving good scalability.

Efficient routing protocol should control the energy consumption of the network and they should reduce the complexity of the network. During communication between sensor nodes, these protocols should minimize the transfer delay occurring at the nodes. In this paper, we have compared various energy efficient routing protocols by maintaining better. So these routing protocols should also concentrate on all these parameters to select the shortest path such that it should increase the network lifetime.

MAXIMUM CAPACITY PATH

A sensor node in the layered network may have multiple shortest paths to reply the sensing data to sink. For example, consider a layered network N of G as shown in Fig.2. The number beside each node represent sits available energy..

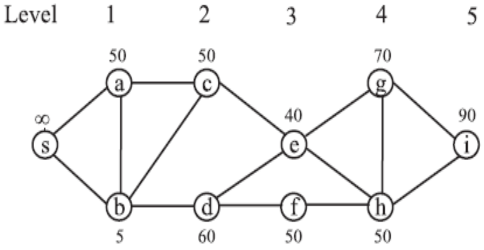


Fig 2: Example of path selection in the layered network

When sensor node e at level 3 has a data packet to send, it has three routing paths: e-c-a-s, e-c-d-sand e-d-b-s. Suppose that node e selects a neighbor node with maximum available energy as its forwarder, say node d. That is, node e selects path e-d-b-s to forward the data. However, the available energy of node b is very low and the node b will run out of its energy rapidly.

In order to avoid this fault, we proposed a path selection scheme, called as maximum capacity path scheme, for each sensor node to select a routing path with maximum capacity to sink. Let $c(v)\geq 0$ denote the available energy of node u inv and assume that $c(s)=\infty$. Define the capacity of a routing path P= v_u, v_1,….v_k, s as minimum node energy in P. The maximum capacity path scheme is to determine a maximum capacity path from a specified sensor node to sink in the layered network. For example, as shown in Fig. 1, the capacities of paths are: e-c-a-s, e-c-d-s and e-d-b-s. 50, 5 and 5 respectively. Thus, the maximum capacity path scheme will select path as forwarding path e-c-a-s for node e. That is, node e sends data packets along path e-c-a-s. In general, suppose that sensor node v has k in-bound links $(v,u_1),(v,u_2),\ldots\ldots,(v,u_k)$.Let p(w) denote the maximum capacity value of maximum capacity path P from node w to sink s. Thus, sensor node v selects node u* as forwarder to forward its data such that $p(u^*)=\max\{p(u_1),\ldots, p(u_k)\}$.Then, node v updates its p(v) by $p(v)=\min \{c(v),p(u^*)\}$. In this proposed work the routing is done taking link cost into consideration along with the node battery levels.

III. ENERGY AWARE SINK RELOCATION TECHNIQUE

In the EASR method, we incorporate the technique of energy-aware transmission range adjusting to tune the transmission range of each sensor node according to its residual battery energy. In the case of the residual battery energy getting low after performing rounds of message relaying and environment sensing tasks, then its transmission range will bet used to be small for energy saving. Moreover, the relocating decision made by the sink will take the MCP [9] routing protocol, (which has been described in the previous section) as the underlying message routing in order to gain the merit of prolonging network lifetime. Although the EASR method can be incorporated with any existing routing method, we chose the MCP as the underlay in grouting method to limit the above influence since the only parameter of the MCP is the same as the decision parameter of the proposed EASR method; that is the residual battery energy of the sensor nodes. The proposed EASR consists of two components, the energy-aware transmission range adjusting and the sink relocation mechanism that are described as follows.

ENERGY-AWARE TRANSMISSION RANGE ADJUSTING

In general, a larger transmission range set for a sensor node will increase the number of neighbors and consequently enhance the quality of the energy-aware routing; however, it also bring the drawback of longer distance message relaying ,which will consume more battery energy of a sensor node. On the contrary, for a shorter range of communication, although it does not help too much for routing, it can conserve the usage of the residual battery energy. In the proposed method, the transmission range adjusting will depend on the residual battery energy of a sensor node. We classify sensor nodes into three types by the ’healthy’ state of their battery and adjust their transmission range accordingly. Let B be the battery energy value when the battery energy is full in the beginning and r (u) denotes the current residual battery energy of a sensor node u $\in$V. In the case of $0 \le r(u) < B/3$(and $B/3 \le r(u) < B/2$), then sensor node u belongs to type I (and II) sensor node and we set its transmission range to $\gamma/4$ (and $\gamma/2$), respectively, where γ denotes the initial transmission range of a sensor node. For the case of $/2 \le r(u) \le B$, the sensor node u is very healthy for its battery energy (type III node) and we set its transmission range to γ. Intuitively, a ’healthy’ sensor node can adapt a larger transmission range to shorten the routing path, while a sensor node with only a little residual battery energy can tune the transmission range to be small to conserve its residual energy. Thus an adaptable transmission range adjusting mechanism can enlarge the lifetime of a sensor node and the network lifetime.

THE SINK RELOCATION MECHANISM

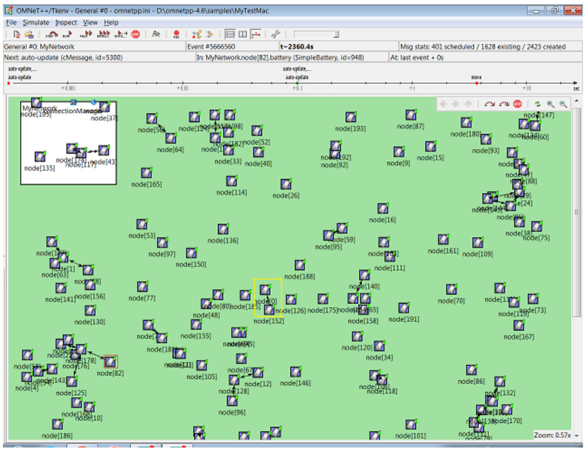
This mechanism consists of two parts. The first is to determine whether to trigger the sink relocation by determining whether a relocation condition is met or not. The second part is to determine which direction the sink is heading in and the relocation distance as well. For the relocation condition, the sink will periodically collect the residual battery energy of each sensor node in the WSN. After the collecting process is completed, the sink will use the MCP routing protocol to compute the maximum capacity path $P*_{us}$ with respect to each sensor neighbor u of sink s. For each maximum capacity path $P*_{us}$, we denote the maximum capacity value with respect to $P*_{us}$ as $c(P*_{us})$. Let the collection of the sensor neighbors of be N. Then the relocation condition will be met when one of the following conditions occurs: (1) when one of the capacity values $c(P*_{us})$ with respect to the sensor neighbor u in N drops below B/2; or (2) the average residual battery energy of the neighbor set drops below B/2. That is, when either the condition occurs, which means the residual energy of the nearby sensor nodes of the sink become small or the residual energy bottleneck of some routing paths falls below a given threshold (B/2). Then the sink relocation mechanism will be performed to relocate the sink to a new position, which can enlarge the network lifetime. In the case of the sink having to relocate, it will firstly determine the positions of the moving destination. The moving destination has 4 candidate positions, S_{C1} , S_{C2} , S_{C3}, and S_{C4} ,which are located in the right, up, left, and down direction γ distance away from the current position of the sink . Let the neighbor subset Ni with respect to each moving destination candidate S_{Ci} ($1 \le i \le 4$) be the collection of sensor nodes that is located within the circle centered at node S_{Ci} with radius γ , respectively. Let a weight value w_i that is associated with each neighbor subset N_i, $1 \le i \le 4$ be

$W_i = \min\{c(P*_{us})/ u£N_i\}$, where $c(P*_{us})$ denotes the maximum capacity value of $P*_{us}$

Then, the relocating position $S_{Ci}*$ will be chosen from S_{C1} ,S_{C2} , S_{C3}, and S_{C4} , such that the weight value w_i* with respect to $S_{Ci}*$ is the maximum value among w_i ($1 \le i \le 4$). Now the sink s will relocate itself to position $S_{ci}*$. Intuitively, the weight value w_i of a candidate position represents the residual energy lower bound among the bottleneck value of the routing paths to the sink when the sink relocate itself to the candidate position S_{Ci}. Thus the EASR method will drive the sink to the candidate position with the greatest w_i value among the four candidate positions by adopting ’healthy’ routing paths to transmit the message to enhance the network lifetime. After the sink relocates to the new position, the above processes (the residual battery energy collecting, the relocating condition checking) will be iteratively performed. In the case of their location condition once again being met, then the relocation process will also be invoked again.

IV. SIMULATION AND RESULT ANALYSIS

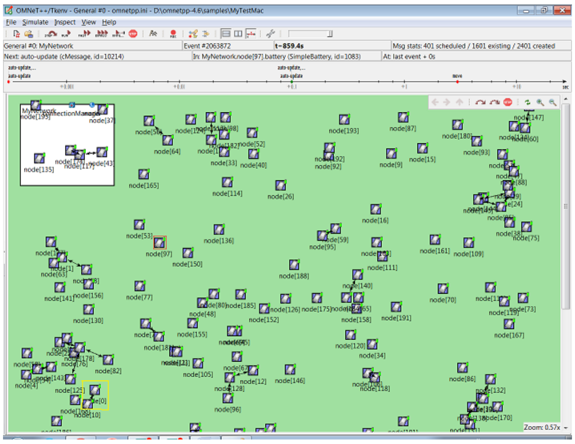
The scenarios taken for the comparison of the EASR and its improved version is based on the number of nodes taken per scenario and the simulation area. The stationary sink scheme assumes that the sink is not capable of moving and remains stationary at all times. In these simulations, the proposed method and the previous methods all adopt the MCP routing protocol as the underlying routing for message reporting, during path computations, network topology was assumed to be ”frozen.


OMNeT++/Tkenv - General #0 - omnetpp.ini - D:\omnetpp-4.6\samples\MyTestMac

General #0: MyNetwork | Event #5666560 | t=2360.4s | Msg stats: 401 scheduled / 1628 existing / 2423 created

Next: auto-update (cMessage, id=5300) | In: MyNetwork.node[82].battery (SimpleBattery, id=948) | At: last event + 0s

Fig 3: Position of sink before relocation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General #0: MyNetwork | Event #2063872 | t=859.4s | Msg stats: 401 scheduled / 1601 existing / 2401 created

Next: auto-update (cMessage, id=10214) | In: MyNetwork.node[97].battery (SimpleBattery, id=1083) | At: last event + 0s

Fig 4: Position of sink after relocation

Fig 3 and Fig 4 shows the position of sink before and after relocation. The comparison factor is the network lifetime of a WSN, for which the network lifetime is defined to be the number of message reporting rounds performed before the first sensor node drains out its battery energy. The simulation environment settings are as follows. We assume that the sensor nodes are all stationary after the deployment, but the sink is capable of moving except for the stationary sink scheme.

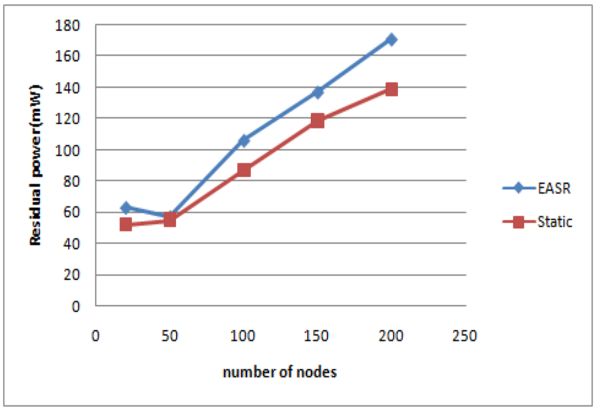

Fig 4: Network lifetime comparisons with varying number of nodes

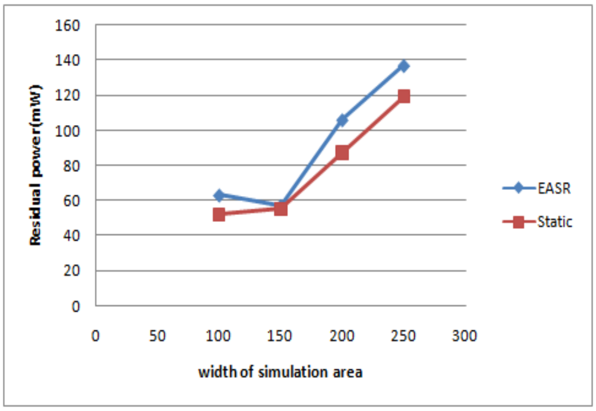

Fig 5: Network lifetime comparisons with varying width of simulation area

As shown in this figure, the improved technique outperforms the EASR for any instance of the number of sensor nodes. Show the simulation results for simulation scenario when the size of the simulation area and the transmission range vary, respectively.

V. CONCLUSION

In this paper, we have analyzed and compared sink deployment techniques in wireless sensor networks and only very few works such as energy aware sink relocation consider all the major objectives like threshold, area coverage and connectivity. A reloadable sink is approach for prolonging network lifetime by a voiding staying at a certain location for too long which may harm the lifetime of nearby sensor nodes. We conclude that by taking link stability into consideration for the MCP routing protocol we further enhanced the network lifetime of the wireless sensor network.

VI. REFERENCES

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