Energy Aware Mobile Sink Relocation by Detecting Bottleneck Nodes to Balance Load in WSN

Deepak V Biradar, Nataraj K. R

***Abstract**: WSN consist of tiny light weighted sensors, which have been used in several applications for sensing real-time data, and forward the aggregated data to sink or base station. Since wsn are energy constrain, the key challenging is to extend network lifetime and to balance the nodes energy levels. In multihop routing, the nodes near to a static sink consume more power and become unbalanced due to more energy drain. To alleviate energy problems, mobility of the sink has been accepted as efficient way. Making sink mobile, provided best solution for balancing the network. In this paper we propose a new approach to extend network lifetime by relocating sink node near to bottleneck nodes which limits the network lifetime by disjoint links. The key concept is to target the set of node disjoint links which stops functioning due to low energy level, proposed algorithm finds disjoint links and triggers sink to relocate its position to connect nodes with minimum hop. The extensive simulation has been carried out to analyse proposed system and compared with EASR method*.

Index Terms: WSN, mobile sink, energy efficient routing, sink relocation.

I. INTRODUCTION

Application of WSN has been deployed in many areas like health monitoring, industrial automation, military and mission critical networks. WSN are group of tiny light weighted sensor device, responsible for sensing data from the environment and sending data through intermediate nodes to sink or base station. These sensor nodes are largely distributed in the phenomenon which is left unattended [1][2][3]. Sensors are battery operated, power supply to nodes are limited and cannot be replaced. Due to limited power WSN suffers from energy constrain problems. To enhance the network lifetime of nodes becomes a key challenging issue for WSN [4]. Nodes are randomly deployed over an area, the sensed data has to be forwarded to sink node through intermediate nodes. In order to send and receive the data the intermediate nodes should have high link stability to reach sink. Nodes near to the sink consume more energy, since it collects data transferred from the farther nodes to forward it to sink node [5][6][7]. Due to high energy consumption, nodes near to sink often fails and cannot link to far away nodes. Thus entire network becomes unbalanced and unconnected which leads to node disjoint links and energy hole problem [8-13]. To alleviate energy hole problem sink mobility has been accepted as efficient way to increase network lifetime which reduces the transmission overhead of nodes close to sink. Making sink mobile, disconnects from nodes close to it and balances nodes energy consumption thus preventing from energy hole problem.

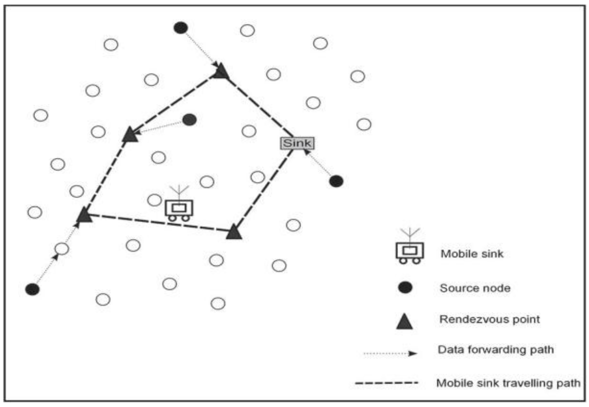

Figure 1: Mobile sink movement to collect data

Fig 1 shows mobile sink visiting feasible site for data collection from nodes. Data routing path are determined by the sink's current position. Sensors need to plan multiple dynamic routes to forward data to sink site feasibly, when sink changes its location. Sink relocation depends on the real-time data generated by nodes. Fundamental problem with mobile sink is how and where to go about collecting sensed data from nodes. In this paper we propose energy efficient sink relocation by detecting the bottleneck nodes which has disjointed links to sink node. Ford Fulkerson algorithm is used to find disjoint links, which triggers sink to relocate its position. Mobile sink balances the energy consumption of nodes while moving across the sensing field. Once the moving path is planned, mobile sink moves near to set of link disjoint nodes and collects data with minimum hop distance. Hence, nodes lifetime can be prolonged and balance the network. The rest of this paper is organized as follows.

Revised Manuscript Received on May 06, 2019

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In Section II describe the related work carried out. Section III and IV describes problem statement and network model. In section V describes the proposed algorithm to find bottleneck node. In section VI the performance of energy analysis and relative simulation are conducted. Finally we draw the conclusion on the proposed scheme in section VII.

II RELATED WORKS

A. W. Khan, [14] proposed Dynamic virtual routes for grid topology to reduce communication cost of mobile sink. Sensing fields are divided to form grid of cells which are same size, cell header are chosen which is center of nodes. In addition, a virtual backbone of nodes structure to cell-header nodes is constructed. The mobile sink visits to sensor field and collects the sensed data by communicating with the border cell-header nodes. To reduce the overall communication cost, the routes reconstruction process includes only a subset of cell-header nodes. Considering the limitations of fixed topology the author **B. Ashutosh Holla [15]** proposed novel routing for mobile sink using ring routing, for real time applications for challenging to extend network lifetime by designing energy efficient route for delivering data. To extend network lifetime in clustering author **JY Chang [16]** proposed energy saving scheme by tree formation to reduce the energy consumption of the nodes with dynamic sorting algorithm for creating tree structure to route the data. This scheme reduces the transmission distances by adopting tree structure and multihop concepts. This scheme also makes efficient routing decision and balances the nodes energy. **W Wen [17]** proposed data collection energy aware path algorithm by selecting particular set of data collection points, which constructs an efficient path and collects data from burden points to transfer data from node to node in energy efficient way.

III PROBLEM STATEMENT

Let us consider WSN, sensor nodes are randomly deployed and generate data periodically. Generated data has to be delivered to sink node within specific time, intermediate nodes are responsible to carry data to sink. To transmit and receive data the link stability between two nodes should be strong enough. Nodes having low energy levels lead in disconnection of links between nodes. Thus increase in transmission overhead in finding alternate route to sink.

IV NETWORK MODEL

Network model consist of n sensor nodes randomly deployed and a mobile sink. Mobile sink possesses infinite energy and unlimited computation resource. Network can be represented DAG graph $G(V,E)$ where $V = \{v_1, v_2 \ldots, v_n\}$ is nodes and E represents the link between two nodes (v_i, v_j) where $v_i, v_j \in V$. Sink node knows all the sensor nodes location and their ID. Sensor nodes are homogenous, has same sensing and sending communication range. Neighbour nodes are responsible to establish path from sender node to sink. The energy model adapted in our approach is node consumption rate is proportional to sensing range and initial energy of nodes may be differing depending on sensing range. Energy consumption of node transmitting m bits over a distance d of receiver is $E_{TX}(m,d)$ and $E_{RX}(m)$ represented

$$E_{TX}(m,d) = E_{elec} \times m + E_{amp} \times m \times d^{\gamma}$$

$$E_{RX}(m) = E_{elec} \times m$$

where, E_{elec} is the energy cost of sensor to transmit one bit. E_{amp} denotes the energy consumption for reliable transmission. Free space propagation model is used and energy cost over free space would be represented as $E_{amp} = \epsilon_{fs}$. Multihop energy cost represented as

$$E_{TX}(m,d) \quad \begin{cases} E_{elec} \times m + E_{amp} \times m \times d^2 \\ E_{elec} \times m + E_{amp} \times m \times d^4 \end{cases}$$

γ is loss of path exponent value $\gamma \in \{2,4\}$ and the distance threshold d_0 is given as $d_0 = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}$ where ϵ_{mp} is the energy cost of amplifier for multihop. When there is no sufficient energy to establish a multihop links to sink, relocation on the sink is trigged.

V Proposed Sink relocation technique

Assumptions

- Sensor nodes are randomly and uniformly distributed, after deployment nodes are static
- Sink node has unlimited energy, resources and it can be mobile
- Sensor nodes are homogeneous
- Sensor nodes stop functioning when there exist link disjoints
- A set of bottleneck nodes are dead nodes which makes disjoint path to sink

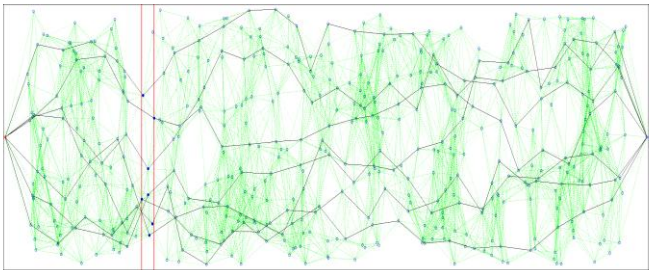

Figure 2: Node connectivity to sink node

Bottleneck Disjoint Algorithm

To detect node disjoint link, ford-fulkerson algorithm is applied to disjoint link between two nodes. Each node V is divided into virtual subnode v_a *and* v_b to extend its lifetime to avoid sensor node working longer than its lifetime. The lifetime of sensor V is given as

$$L_v = \frac{E_v}{0.01 \,.\, r_S^2}$$

Where E_v is initial energy of node. For barrier link coverage, bottleneck nodes can be defined as set of dead nodes which make no longer path from source to sink node and has least remaining energy which cannot make stable link between two nodes. Weakest nodes in WSN are divided into two regions, reachable and non reachable region nodes from source. If sensor node stops functioning, it can be categorize into dead nodes, reachable and unreachable nodes. Each node maintains hop count to reach destination (sink node). A finite reachable node has a multiple hop count, while an unreachable node has an infinite hop count. Set of dead sensor nodes is minimal bottleneck nodes, if it is connected in the chain of reachable at one end and unreachable node at another end. Proposed bottleneck disjoint algorithm is used to determine nodes bottleneck regions to trigger sink relocation near bottleneck regions to collect data.

Bottleneck disjoint algorithm

Input: Nodes list L_n , neighbour node list N and Nodes energy level e
Output: List of disjoint nodes B_{v_n}

- Calculate hop count h_v , $\forall\, v \in L_n$ from source node
- **for** $v \in L_n$ do
- **if** $e_v = 0$ then
- Append v_n dead node list D_n
- **else**
- **if** $h_v < \infty$ then
- Append v_n to list reachable nodes R_n
- **else**
- Append v_n to list unreachable nodes U_n
- **end_ if**
- **end_ for**
- **for** $v_n \in D_n$ do
- **if** $\left(N_{v_n} \cap R_n \neq \emptyset\right) \wedge \left(N_{v_n} \cap U_n \neq \emptyset\right)$ then
- Append v_n to B_{v_n}
- **else if** $\left(N_{v_n} \cap R_n \neq \emptyset\right) \oplus \left(N_{v_n} \cap U_n \neq \emptyset\right)$ then
- **for** $w \in \left(D_n \cap N_{v_n}\right)$ do
- **if** $\left(\left(N_{v_n} \cap R_n \neq \emptyset\right) \wedge (N_w \cap R_n = \emptyset) \wedge\right.$ $Nw{\cap}Un{\neq}\emptyset Nvn{\cap}Un{\neq}\emptyset{\wedge}Nw{\cap}Rn{=}\emptyset{\wedge}$ $Nw{\cap}Un{=}\emptyset$ then
- Append v_n to B_n
- **end_ if**
- **end_ for**
- **else**
- Initialize temporary list $T_n = \emptyset$
- Initialize potential bottleneck list $P_n = \emptyset$
- **for** $v_n \in I$ do
- **if** $v_n \notin P_n$ then
- Append $v_n to\ T_n$
- **while** $(I \cap N_u \setminus T_n) \neq \emptyset, \forall_u \in T_n$ do
- Append all nodes in $(I \cap N_u \setminus T_n, \forall_u \in T_n\ to\ T_n)$
- **end while**
- **if** $B_n \cap N_u = \emptyset, \forall_u \in T_n$ then
- Append u and N_u nodes, $\forall_u \in\ T_n$ to P_n
- **end_ if**
- **end_ if**
- set $T_n = \emptyset$
- **end_ for**
- List all P_n nodes to B_n

Mobile Sink Scheduling

When the disjoint link found by the bottleneck algorithm, relocation of sink takes place. Travelling of mobile sink depends on the shortest route to reach disjoint node regions. To travel in shortest path we utilize minimum spanning tree algorithm for sink movement. Spanning tree contains undirected graph, is a set of edges between nodes terminals. Scheduling of mobile is done after forming tree, which reduces infinite possible sites to finite set of sites.

Sink scheduling Algorithm

Input : V vertices and edges of nodes

Output : G spanning tree graph for V

- V_x $\leftarrow$ sort V by non-decreasing x
- if $V_{n_i} \subset V_x$ then
- EdgeGraph $\left(V_{n_i}\right)$;
- end if
- V_y $\leftarrow$ sort V by non-decreasing y
- if $V_{n_i} \subset V_y$ then
- EdgeGraph $\left(V_{n_i}\right)$;
- end if
- $V_{x+y} \leftarrow$ sort V by non-decreasing $x + y$
- if $V_{n_i} \subset V_{y+x}$ then
- EdgeGraph $\left(V_{n_i}\right)$;
- end if
- $V_{x-y} \leftarrow$ sort V by non-decreasing $x - y$
- if $V_{n_i} \subset V_{y-x}$ then
- EdgeGraph $\left(V_{n_i}\right)$;
- add edges to edge connection graph connect G_v
- end_ if

VI PERFORMANCE EVALUATION

Evaluation of the proposed algorithm is discussed in this section, proposed algorithm is compared with EASR technique. In EASR sink relocation is done on the basis of residual energy levels of nodes and adjusting node transmission range, this scheme mainly focuses on maximum capacity path to route data. This scheme has a disadvantage of link quality estimation, which connects to sink node. It only considers energy levels as threshold values and triggers sink relocation.

Proposed scheme is simulated on event driven simulation tool NS2 simulator which an open source tool. Parameters used in simulation are listed in below table.

Parameters	Values
Deployment Layout	Random
Deployment Area	1000 x 1000
No of nodes	80
Bandwidth	2Mb
Mobility Model	Random Mobility Model
Traffic Type	CBR
Transmission Range	35 mts
Initial Energy	10,20,30 Joules
Propagation Model	Tworayground
MAC Type	802_11

Table 1: Simulation Parameters

Simulation is carried out on different scenario, the nodes are uniformly distributed using random distribution. Nodes are assigned with initial energy. Sink node is placed randomly, which collects sensed data from nodes. Each node assumes to know their position and distance to sink node. Barrier coverage of node is estimated by link stability between two nodes. Stronger the link makes more connectivity to sink node. Sensor node stops functioning when it has disjoint links due to less energy level. Proposed bottleneck algorithm finds the bottleneck regions, where nodes have a set of disjoint link to sink. Triggers sink to relocate its position to bottleneck regions. Below figure 3 shows the comparison of EASR and Bottleneck disjoint method in link connectivity to sink node.

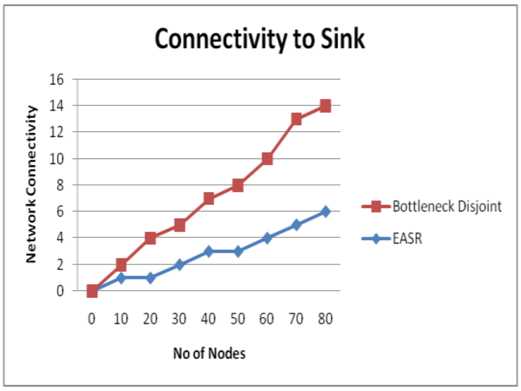

Figure 3: Network Connectivity graph

Network lifetime performance is compared with EASR by varying initial energy on different rounds. The proposed bottleneck disjoint scheme outperformed the EASR in relocating sink to bottleneck regions. EASR only considers varying energy levels of nodes, but not the link stability. The simulation is carried by varying transmission range and no of nodes accordingly. By varying transmission range the routing overhead is minimized. The overhead comparison graph is shown in below figure 4.

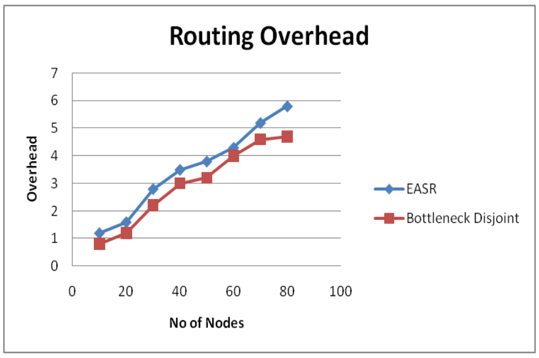

Figure 4: Routing overhead

Energy consumption of EASR and proposed bottleneck disjoint method is compared by varying energy levels at different rounds. The number of nodes and transmission range are varied, the bottleneck disjoint method outperforms in balancing the nodes energy and increase in the network lifetime. In the figure 5 shows the energy consumption by varying initial energy of the nodes.

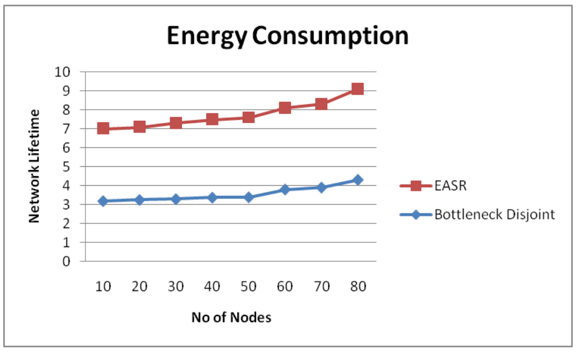

Figure 5: Energy Consumption

In figure 6 shows the improvement in network lifetime, by varying transmission ranges of nodes. Extending the transmission rates increases neighbour nodes and efficient data transmission.

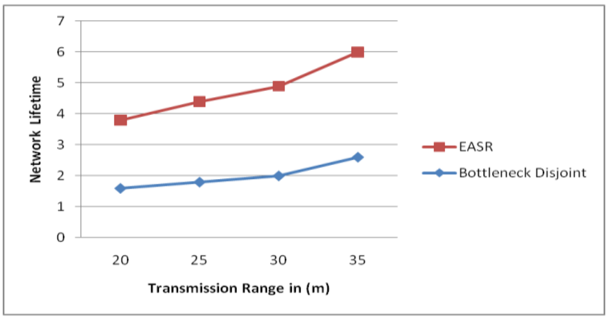

Figure 6: Varying transmission range

VII CONCLUSION

Depleting energy of nodes will significantly affect network lifetime. If the link between two nodes is unstable, the communication to sink gets failure thus reducing the performance of overall network.

Detecting this unstable link and relocating sink node to set of disjoint link regions enhances network lifetime and balances node energy levels. In this paper an energy efficient sink relocation method by detecting bottleneck region of node is proposed, this approach uses ford-fulkerson algorithm to find the set of disjoint links in the network. This triggers the sink to relocate its position to regions and collect data efficiently. The travelling of the mobile sink is defined by the shortest spanning tree algorithm to avoid mobile sink travelling in infinite loop. The simulation results shows the better performance compared to EASR method of sink relocation.

REFERENCES

1. Muhammad Azman Miskam , Azwan bin Nasirudin and Inzarulfaishaam Abd. Rahim"Preliminary Design on the Development of WSN for Paddy Rice Cropping Monitoring Application in Malaysia", European Journal of Scientific Research, Vol.37 No.4 (2009), pp.649-657.
2. R. Min, et al., " Low Power Wireless Sensor Networks", in the Proceedings of International Conference on VLSI Design, Bangalore, India pp.205-210, January 2001.
3. J.M. Raabaey, "PicoRadio supports ad hoc ultra-low-power wireless networking," IEEE Computer, Vol. 33, pp. 42-48, July 2000.
4. I. Akyildi Sankarasubramaniam, and E. Cayirci, "A survey on sensor networks," IEEE Commun. Mag., vol. 40, no. 8, pp. 102–114, Aug. 2002.
5. J. Lian, K. Naik, and G. B. Agnew, "Data capacity improvement of wireless sensor networks using non-uniform sensor distribution," Int. J. Distrib. Sens. Netw., vol. 2, no. 2, pp. 121–145, Apr.–Jun. 2006.
6. J. Li and P. Mohapatra, "An analytical model for the energy holes problem in many-to-one wireless sensor networks," in Proc. 62nd IEEE Veh. Technol. Conf., Dallas, TX, USA, Sep. 2005, vol. 4, pp. 2721–2725.
7. J. Luo and Hubaux, "Joint mobility and routing for lifetime elongation in wireless sensor networks," in Proc. IEEE INFOCOM, Miami, FL, USA, Mar. 2005, vol. 3, pp. 1735–1746.
8. S. Basagni, and Z. K. Wang, "Controlled sink mobility for prolonging wireless sensor networks lifetime," Wireless Netw., vol. 14, no. 6, pp. 831–858, Dec. 2008.
9. J.-W. Kim and D.-S. Eom, "An intelligent agent-based routing structure for mobile sinks in WSNs," IEEE Trans. Consum. Electron., vol. 56, no. 4, pp. 2310–2316, Nov. 2010.
10. W. Liang, J. Luo, and X. Xu, "Prolonging network lifetime via a controlled mobile sink in wireless sensor networks," in Proc. IEEE GLOBECOM, Miami, FL, USA, Dec. 2010, pp. 1–6.
11. B. Naazir and H. Hasbullah, "Mobile sink based routing protocol (MSRP) for prolonging network lifetime in clustered wireless sensor network," in Proc. ICCAIE, Kuala Lumpur, Malaysia, Dec. 2010, pp. 624–629.
12. S. Mottaghi and M. R. Zahahbi, "Optimizing LEACH clustering algorithm with mobile sink and rendezvous nodes," AEU-Int. J. Electron. Commun., vol. 69, no. 2, pp. 507–514, Feb. 2014.
13. M. R. Jafri, N. Javaid, A. Javaid, and Z. A. Khaan, "Maximizing the lifetime of multi-chain PEGASIS using sink mobility," World Appl. Sci. J., vol. 21, no. 9, pp. 1283–1289, Mar. 2013.
14. A. W. Khan, A. H. Abdulah, M. A. Razzaque, and J. I. Bangash, ``VGDRA: A virtual grid-based dynamic routes adjustment scheme for mobile sink-based wireless sensor networks," IEEE Sensors J., vol. 15, no. 1, pp. 526_534, Jan. 2015.
15. B. Ashutosh Hola, "Data gathering in Wireless Sensor Network using optimum mobile sink path", Wireless Communications Signal Processing and Networking (WiSPNET) 2017 International Conference on, pp. 425-429, 2017.
16. JY Chang "An Efficient Tree-Based Power Saving Scheme for Wireless Sensor Networks With
17. Mobile Sink" IEEE Sensors Journal , Volume: 16 , Issue: 20 , Oct.15, 2016.
18. W.Wen "EAPC: Energy-Aware Path Construction for Data Collection Using Mobile Sink in Wireless Sensor Networks" IEEE Sensors Journal 10.1109/JSEN.2017.2773119.

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