Efficient Mobile Sink Path Scheduling for Clustered based Wireless Sensor Network

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Abstract. WSN (Wireless Sensor Network) has found wide range of adoption in different sector and it is primary component of much real time application such as IoT, Big Data etc. Meanwhile modern application needs scalable real time data access and low latency since they are heterogeneous; however achieving the low latency for real time data causes the energy overhead in sensor device. Moreover, two technique i.e. clustering technique and Mobile sink helps in achieving the scalability and reducing the energy consumption in sensor device, further this causes the energy overhead in rendezvous node and CH (Cluster Head). In order to address this issue several optimization technique were presented for selection of rendezvous node and optimal cluster, the main drawbacks of these techniques are that they are applicable only for the homogeneous network. Hence, to overcome this issue, this research work presents technique EMSPS (Efficient Mobile Sink Path scheduling) technique for heterogeneous WSN, this technique is cluster based. Furthermore, EMSPS introduces the multiple-objective function such as network traffic for CH and rendezvous node selection, coverage time, radio selection strength, connection time and connectivity. EMSPS is evaluated considering the various parameter such as loss of connectivity, first node death, total node death and network lifetime, further comparison has been done with the state-of-art technique by considering the above parameters. Nevertheless, EMSPS provides the satisfactory trade-off between the energy and latency requirement.

Keywords: Clustering, Mobile sink path selection, Energy efficiency, Network lifetime, Rendezvous path node, Wireless sensor network.

1. Introduction

In past few years, several research have been focusing the surveillance application and data gathering from single hop SSN (Stationary Sensor Nodes) using the mobile sink [1][2][3]. In case of surveillance, sensor nodes are deployed to sense the data such as temperature or humidity, further mobile sink is deployed to collect and gather the data in efficient way. Moreover, sink mobility is used for efficient data collection [26] as Mobile sink restricts the detection of it from adversaries in the data collection phase in the sensor field. Moreover, the main aim of the strategy is to choose the trajectory for MS-node, this in terms reduces the message communications throughout the sensor node (static) to MS-node, further this minimizes the detection possibility from adversaries. Meanwhile the sink travels in probabilistically way [27] [28], which favors the least, travelled path so that the network area can be covered faster and reduce the time in network region which leads to large data production. It is highly improbable for the mobile sink to cover whole sensor nodes, hence certain strategies have been adopted for RP (Rendezvous Point)-selection that gathers the data from the adjacent nodes and later deliver it to mobile sink once sink visits them. Furthermore, the approach used [4], [5] restricts the mobile sink movement at the given location, for instance PTV(Public Transport
Vehicles) is restricted to move on to the predefined roads, unconstrained approach [6], [7] is proposed for free movement in the network region.

In [6], author introduced a particular strategy for RP nodes selection through sensor nodes mapping to the given points on Halin graph by considering the residual energy of nodes, WRP(Weighted Rendezvous Planning) [7] proposed selection of most efficient RP nodes and generates the delay bound through giving restriction in travelling distance of MS. Further RP Nodes is determine through assigning the sensor node some weight and senor nodes that carries the higher weight is made as RP nodes, if the distance of MS is less than the given value. However in selection procedure of WRP method [7] weight values are calculated mainly based on the initial information of the sensor nodes and the node directions heads towards the initial point of MS. This generates the routing path which is in the form of set of given initial routing path that constitutes more energy, average hop counts(forwarding) is higher and have non-efficient RP selection. In order to reduce the hop count clustering method has been adopted.

In [8] proposed an efficient energy design for the large network and it adopted the fuzzy based clustering technique, however it failed to provide the efficient network lifetime. Since the CH that are closer to the BS dies instantly. In order to overcome this [9] proposed T2FL (Type2-fuzzy logic) clustering approach, however T2FL considered only the homogeneous network and it is recommended that the routing model should consider the heterogeneous environment and its related application [10], [11], [12] and [13]. Further communicating and accumulating is required for the real time data. [14] proposed data collection model, whereas [15] presented the routing model that adopts the clustering technique, [16] discussed and proposed the data forecasting model for WSN. Similarly [17] and [18] deals with the cross layer technique. Moreover, this technique i.e. [14], [15], [16], [17] and [18] reduces the energy consumption but failed miserably to reduce the data latency, hence to address this [19] presented optimized approach that adopts the evolutionary computing to form the cluster. Further, the wide research in [20] indicated that evolutionary computing causes the more communication overhead in the heterogeneous network. In [21] presented a novel technique for the heterogeneous network based on the tree structure, here the model mainly considers the packet loss rate and link quality to reduce the energy dissipation, and however it did not consider data latency.

Hence, to overcome the above-discussed challenges in this research work we proposed efficient MS (Mobile Sink) path scheduling for CWSN, this method considers both i.e. mobile sensor and heterogeneous network. Further EMSPS approach adopts two types of transmission namely cluster based transmission and mobile sink based transmission. At first, this research work efficient CH-selection technique is proposed using the various function objective such as coverage time, radio-SS (Signal Strength), connection time and connectivity. Further, the CH aggregate the collected data from its member and later the EMPS technique designs the MS-path formation along the rendezvous node set to gather the data from CH. In here the transmission, take place either through the rendezvous nodes set or directly. Moreover, the transmission path is formed through the multi objective function and it is similar to CH-selection, later DA (Data Aggregation) is carried out in CH aid to minimize the traffic and improvise the WSN and rendezvous node.

The significance of research are discussed. This paper presented an efficient mobile sink based data collection for clustered based WSN. The EMSPS achieves better energy efficiency (i.e., life time performance) considering varied network scenarios such as first SD death, loss of connectivity and total SD death.

2. Energy Mobile Sink Path Scheduling Model for Clustered based WSN

This section presents an efficient mobile sink path scheduling design for clustered based WSN. The EMSPS model is composed two phased namely setup phase and communication phase. In setup phase, construction of cluster and construction of mobile sink path (MSP) are done for obtaining efficient path between the cluster group (CG) and mobile sink (MS). This phase known as intra cluster and MSP association/transmission. In communication phase, packet are communicated among CG with its respective cluster head (CH), and from CH it is transmitted toward rendezvous node (RN) and mobile sink (MS)/base station (BS). In Fig. 1, the architecture of EMSPS is shown.
a) Setup phase:

In setup phase, first the sensor device (SD) are randomly deployed across predefined area. Then, the sensor devices elects its CH using thresholding parameter. In our work thresholding parameter is multi-objective in nature. The SD with better coverage time, connection time, RSS and connectivity are elected as CH. Then every CH receive packet from its CG and CH aggregates the information and send it to rendezvous path node (RPN). After, MSP transmission are started where RPN receive aggregated packet from the CH and transmit to mobile sink (MS). This work assumes that entire cluster head within the network are well connected to RPN. Similarly, all RPN are well connected with MS that forms a MSP.

b) Intra cluster transmission phase:

This work considered a largely dense WSN which are deployed in random manner in a square area. The position of SD are known in advanced using beacons. The cluster head selection process is initialized. The CH is selected using multi-objective thresholding parameter (TP) $V_n^{CH}$. The multi objective parameter for CH selection are coverage time $\delta f_c(u, u+t)$, connection time $\delta E_c(u, u+t)$, RSS and connectivity $H_n^{CH}$. The TP for selecting CH are obtained considering the SD with maximum CG, residual energy, better connection time, and RSS which can described using below equation

$$V_n^{CH} = \alpha + \frac{O_c^e}{O_m^m} \cdot \frac{F_n^m - F_n^c}{F_n^m} \cdot W_n^m - W_n^c \cdot S_n^m - S_n^c,$$  \hspace{1cm} (1)

Using Eq. (1) the sensor device with maximum $V_n^{CH}$ (i.e., TP) are selected as CH. In Eq. (1) a Boolean parameter $G_c$ is introduced by adding it with multiplicative factor of multi-objective parameter such as residual energy, adjacent SD size, speediness of SD, coverage distance. When $G_c = 1$ then the sensor device was the CH of previous round. Further, if $G_c = 0$ then the SD is having higher chance of getting selected as cluster head for current round in accordance with TP. $O_c^e$ depict the CG size, $O_m^m$ depicts the maximal CG for each round. $F_n^m$ depicts the SD preliminary energy level, $O_m^m$ depicts the maximal amount of CG for each round, $W_n^m$ depicts maximal speediness of SD, $W_n^c$ describes the current speedness of SD, $S_n^m$ depicts the maximal coverage radius(CR) of SD, $S_n^c$ describes the current CR of SD. The proposed TP aid in selecting CH with less mobile nature, with maximal coverage distance (CD) and with high number of CG sensor device. The SD with maximal amount of CG with every cluster (i.e., $N_c$) is obtained using Eq. (4). Along with it is important to obtain the connection time (i.e., packet duration $u^c$) of each SD with respect with to its respective CH. Thus, the anticipated amount of CGs $N_c$ and current CGs size $N_c$ for every round are established using following equation

$$N_f = \frac{O_c - D_l - D_u}{D_l},$$  \hspace{1cm} (2)
where $O_c$ depicts total size of present SD, $D_c$ depicts the cluster head, $D_\text{RPN}$ depicts total number of rendezvous path nodes (RPN). The $O_c$ in Eq. (2) can be computed using following equation

$$O_c = O_u - O_c,$$  \hfill (3)

where $O_u$ depicts the overall size of SD, $O_c$ depicts number of SD dead. Thus, the $N_c$ can be established using following equation

$$N_c = N_f - (N_{ok} + N_c + N_d),$$  \hfill (4)

where $N_{ok}$ depicts newly associated CG from neighbouring cluster in present round, $N_e$ depicts the amount of cluster head is dead, $N_f$ depicts the overall size of CG in sleep state, $N_d$ depicts the total number of SD dead. Thus, for current session length for respective data information $u^g_c$ within every cluster can be obtained using following equation

$$u^g_c = \frac{m_q^c * N}{R_\theta},$$  \hfill (5)

$$u^e_c = \frac{m_q^e * N}{R_\theta},$$  \hfill (6)

where $M_q$ depicts the sie of packet and $R_\theta$ depicts bit rate of a particular communication channel.

c) Mobile sink path construction and Rendezvous path node transmission:

For construction of mobile sink path (MSP), RPN are utilized. The role of RPN is to collect the aggregated data from cluster head and transmit to MS. The RPN is selected by BS. Similar to CH selection method i.e., using Eq. (1) the RPN nodes are selected. For achieving better packet transmission and energy efficiency performance, the RPN is selected using TP similar to Eq. (1). The multi-objective parameter considered are packet duration, connection time, coverage time, and connectivity. The RPN node is chosen within one-hop neighbor of CH. This is done to reduce overhead of CH and as well as improve packet transmission performance with better energy efficiency of WSN. Then by combining all RPN the MSP is constructed. Thus, the RPN for establishing MSP is done considering residual energy level, present coverage, mobility status of SD using following equation

$$U_{\gamma \mu}^{\theta} = I_V + \left(\frac{F^\theta_o - F^\theta_\mu}{F^\theta_o} \times \frac{W^\theta_o - W^\theta_\mu}{W^\theta_o + W^\theta_\mu} \times \frac{S^\theta_o - S^\theta_\mu}{S^\theta_o + S^\theta_\mu}\right),$$  \hfill (7)

where $I_V$ depicts the hop size of $\gamma$ with respect to BS in MSP, $\gamma$ are utilized to establish adjacent device in MSP, $F^\theta_o$ depicts the preliminary energy level of SD, $F^\theta_\mu$ depicts the present energy level of $\mu$, the parameter $\mu$ are utilized it establish the RPN considering adjacent or next hop SD, $W^\theta_o$ depicts the maximal speediness of SD, $W^\theta_\mu$ depicts current speediness of $\mu$, $S^\theta_o$ depicts maximal CR of SD, $S^\theta_\mu$ depicts the current CR of SD.

The usage of RPN aid in minimizing overhead of communication (i.e., packet transmission) and energy overhead (i.e., energy incurred for hop transmission) of WSN. For enhancing the network lifetime (NL) of WSN every round a new RPN and CH is chosen. Further, it should be noted RPN does not take part in sensing operation. As a result, the RPN does not belong to any of the cluster and does affect communication of any CG. Post establishing MSP the data are collected by mobile sink from each RPN node. For MSP communication spectrum model presented in [24] are used. The proposed EMSPS model achieves better lifetime performance when compared with existing model which is experimentally shown below.

3. Experiment result and Discussion

Experiment result and discussion are presented here. The performance of EMSPS over existing model is evaluated in terms of network lifetime performance. Network lifetime performance is evaluated considering varied sensor device size considering first SD death, total SD death, and loss of connectivity (LOC). For simulating SENSORIA simulator is used. The EMSPS and LEACH [23] are modelled using C# programing
language and incorporated into SENSORIA simulator [25]. This work consider LEACH as a baseline model as most of the existing model has considered it. Thus, a proper comparative analysis can be done over existing model [8], [9], [19], [21], and [22]. The simulation parameter considered for performance evaluation is presented in Table 1.

### Table 1. Simulation parameter used for experiment analysis

| Simulation parameter                  | Configured value          |
|---------------------------------------|---------------------------|
| Number of sensor device               | 400, 800, and 1200        |
| Network size                          | 50 * 50                   |
| Number of mobile sink                 | 1                         |
| Transmission range                    | 5 meters                  |
| Sensing range                         | 3 meters                  |
| Packet size                           | 2000 bits                 |
| Bandwidth                             | 5000 bit/sec              |
| Packet communication delay            | 0.1 seconds               |
| Sensor device initial energy          | 0.1 J to 0.2 J            |
| Communication idle energy (Eelec)     | 50 nj/bit                 |
| Radio energy consumption (Emp)        | 50 nj/bit                 |
| Radio amplification energy            | 100 pJ/bit/m²             |

a) **Lifetime performance evaluation considering varied device under First SD death, Total SD death, and LOC:**

This section evaluate network lifetime performance of EMSPS over existing model considering first SD death, Total SD death, and LOC. Fig. 2 shows network lifetime performance outcome achieved by EMSPS over LEACH considering varied SD under first SD death. An NL performance enhancement of 81.86%, 87.89%, and 89.17% is attained by EMSPS with respect to LEACH for SD size of 400, 800, and 1200, respectively. An average NL performance enhancement of 86.306% is attained by EMSPS with respect to LEACH under first SD death. Similarly, Fig. 3 shows network lifetime performance outcome achieved by EMSPS over LEACH considering varied SD under total SD death. An NL performance enhancement of 77.68%, 80.82%, and 82.41% is attained by EMSPS with respect to LEACH for SD size of 400, 800, and 1200, respectively. An average NL performance enhancement of 80.306% is attained by EMSPS with respect to LEACH considering total SD death. Then, Fig. 4 shows network lifetime performance outcome achieved by EMSPS over LEACH considering varied SD under LOC. An NL performance enhancement of 81.57%, 85.63%, and 86.07% is attained by EMSPS with respect to LEACH for SD size of 400, 800, and 1200, respectively. An average NL performance enhancement of 84.42% is attained by EMSPS with respect to LEACH considering LOC.
From result achieved it can be described EMSPS is very efficient considering highly dense and are adaptive to varying SD size when compared with existing approaches. Majority of traditional model evaluate NL performance considering total SD death. Nonetheless, evaluating NL considering first SD death is also very significant as it affects the connectivity of WSN. Thus, this work carried out NL performance evaluation of EMSPS over existing model [8], [9], [19], [21], and [22] considering first SD death, total SD death, and LOC as shown in Table II. From result attained it can be seen them EMSPS attain better NL performance considering different case. The significant outcome of EMSPS is achieved because of efficient selection of
CH and RPN. The RPN aid in reducing the overhead of CH and usage of mobile sink aid in improving energy efficiency of WSN.

Table 2. Performance Comparison of network lifetime achievement over LEACH

| Author name                  | Methodology/algorithm used                                                   | Lifetime improvement achieved over LEACH considering total node death | Lifetime improvement achieved over LEACH considering first node death | Lifetime improvement achieved over LEACH considering loss of connectivity |
|------------------------------|--------------------------------------------------------------------------------|-----------------------------------------------------------------------|-----------------------------------------------------------------------|------------------------------------------------------------------------|
| P. Nayak et al., [8]         | Fuzzy logic based LEACH.                                                       | 25.0%                                                                | 50.7%                                                                | -                                                                      |
| P. Nayak et al., [9]         | Type-2 Fuzzy Logic LEACH.                                                      | 50.0%                                                                | -                                                                    | -                                                                      |
| W. Twayej et al., [19]       | Self-organizing cluster head to sink algorithm (SOCHSA) using discrete particle swarm optimization (DPSO) and genetic algorithm (GA). | 55.0%                                                                | -                                                                    | -                                                                      |
| Z. Hong et al., [21]         | Clustering-tree topology control algorithm based on the energy forecast (CTEF) for heterogeneous WSN. | 44.0%                                                                | -                                                                    | -                                                                      |
| H. K. Deva Sarma et al., [22]| Energy Efficient and Reliable Routing for mobile WSN.                         | 15.0%                                                                | -                                                                    | -                                                                      |
| EMSPS                        | Efficient mobile sink path scheduling with energy efficient CH and rendezvous node selection for mobile and heterogeneous WSN. | 80.303%                                                              | 86.306%                                                             | 84.42%                                                                |

4. Conclusion

Energy efficient WSN with low latency is the ideal and desired model for the real time processing of modern BigData application. Further mobile sink and clustering based approach plays an important part in reducing the energy consumption and hence enhancing the network lifetime. Moreover the main drawback of these techniques i.e. state-of-art technique are energy overhead in CH, the energy overhead occurs due to longer transmission range as it reduces the RN-energy in the heterogeneous network and mobile sink. Nevertheless, several application such as IoT and Big data requires the low latency, since these applications have been designed by considering the heterogeneous network and only certain research has been carried out. Hence, in this research work a novel methodology names EMSPS is presented that reduces the energy consumption as well as latency. Furthermore, EMSPS uses the MOF (Multiple Objective Function) such as network traffic for hop-node selection and Cluster Head selection, coverage time, Radio Signal Strength, Connection Time and connectivity. Further EMSPS is evaluated through comparing with LEACH; EMSPS outperforms LEACH by considering several parameters such as death of first sensor node, connectivity loss. Further evaluation analysis shows that the improvisation of EMSPS over leach is 84.42 80.303% and 86.306% in terms of connectivity loss, first node death and total number of dead node respectively. Thus the outcome clearly shows the marginal improvement of EMSPS over state-of art technique when parameters such as connectivity loss, first node death and total number of node is considered. Future would consider evaluation considering other performance parameter such as communication overhead, latency etc. Along with, will consider evaluating hop count impact of energy efficiency of mobile sink with and without clustered based WSN.
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