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Abstract- Recently, wide adoption of wireless sensor networks (WSNs) has been seen for provision real-time and non-real-time application services. Provisioning these application service requires energy efficient routing design for WSN. Clustering technique is an efficient mechanism that plays a major role in minimizing energy dissipation of WSN. However, the existing model are designed considering minimizing energy consumption of sensor device considering homogenous. However, it incurs energy overhead among cluster head. Further, maximizing coverage time is not considered by exiting clustering approach considering heterogeneous network affecting lifetime performance. For overcoming issues of routing data packets in WSN, mobile sink has been used. Here, the sensor device will transmit packet in multihop fashion to the rendezvous and the mobile sink will move towards rendezvous points (RPs) to collect data, as opposed to all nodes. However, the exiting model designed so far incurs packet delay (latency) and energy (storage) overhead among sensor device. For overcoming research challenges, this work present energy efficient mobile sink based routing model for maximizing lifetime of wireless sensor network. Experiment are conducted to evaluate the performance of proposed model shows significant performance in terms of communication, routing overhead and lifetime of sensor network.

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Energy Efficient Mobile Sink based Routing Model for Maximizing Lifetime of Wireless Sensor Network

Naveen Ghorpade [α] & Dr. Vijayakaryhik. P [σ]

Abstract- Recently, wide adoption of wireless sensor networks (WSNs) has been seen for provision real-time and non-real-time application services. Provisioning these application service requires energy efficient routing design for WSN. Clustering technique is an efficient mechanism that plays a major role in minimizing energy dissipation of WSN. However, the existing model are designed considering minimizing energy consumption of sensor device considering homogenous. However, it incurs energy overhead among cluster head. Further, maximizing coverage time is not considered by exiting clustering approach considering heterogeneous network affecting lifetime performance. For overcoming issues of routing data packets in WSN, mobile sink has been used. Here, the sensor device will transmit packet in multihop fashion to the rendezvous and the mobile sink will move towards rendezvous points (RPs) to collect data, as opposed to all nodes. However, the exiting model designed so far incurs packet delay (latency) and energy (storage) overhead among sensor device. For overcoming research challenges, this work present energy efficient mobile sink based routing model for maximizing lifetime of wireless sensor network. Experiment are conducted to evaluate the performance of proposed model shows significant performance in terms of communication, routing overhead and lifetime of sensor network.

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I. Introduction

The increased growth of sensor technologies has led to increased adoption of wireless sensor network (WSN) across various organization for provisioning both non-real-time and real-time application requirement of future wireless sensor network based services [1], [2], [3], and [4].A primary operation of wireless sensor network is to perform accurate sensing and collect resourceful information such as temperature, humidity, etc. for further examination [5]. Further, cloud computing based model, such as Fog-RAN (Fog-Radio area network) [6] and Cloud-RAN [7] enable wireless sensor network with capability of massive storage [8] and processing capability [9]. The senor device are placed in hazardous location where physical monitoring is near impossible such as in oil refinery, space etc. Thus, replacing and recharging of battery of the sensor device [SD] are difficult/impossible. The sensor device sensing operation can either be time driven or event driven where energy loss exponential in nature. The sensory information are generally transmitted directly through base station or through intermediate/neighbouring device. In some case, same sensory information is transmitted toward base station. As a result, affect network energy performance. For addressing data redundancy issues, [10] presented a data aggregation method. Further, [11] showed accurate gathering and routing [12] is needed for provisioning real-time requirement of industrial and commercial application. Performing data aggregation possess several energy efficiency challenges [13]. In [14] presented energy conservation (efficient) model for performing efficient data aggregation. Further, [15] presented hierarchical cluster based routing model namely Hybrid Energy-Efficient Distributed (HEED) and Low Energy Adaptive Clustering Hierarchy (LEACH) for preserving energy of sensor network. However, both LEACH and HEED are not efficient under large density network as they induces energy overhead among cluster head (CH) [16]. Along with, routing data from CH to the base station (BS) is not a feasible solution for such environment [16]. Thus, to minimize overhead among CH and enhance lifetime of sensor network, [17] presented a hop based routing model under clustered network. However, adopting hop based transmission induces communication among CH device and hop device due to channel contention. Further, optimizing channel contention is NP-deterministic.

Number of energy efficient clustering based method for large wireless sensor network is been presented in recent times. In [18] presented fuzzy based clustering model for large network. However, energy of CH closer to BS drains very rapidly. Thus, affecting lifetime performance of WSN. For addressing, [19] presented type-2 fuzzy logic (T2FL) based clustering model. The T2FL distributes packet load among sensor nodes (SN) aiding lifetime performance improvement of WSN's. However, T2FL cluster model are not designed heterogeneity real-time application requirement of WSN's [20], [21], [22], and [23]. For meeting real-time application requirement [24] presented a data collection method, [25] proposed an energy efficient clustering

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based routing model, [26] proposed data prediction model, and [27], [28] proposed a energy efficient clustering routing design using cross layer design. Recently, many approach has been presented to minimize energy dissipation of sensor device [24], [25], [26], [27], and [28]. However, these model suffers from network coverage issues. Further, [29] presented cluster formation considering coverage problem using evolutionary computing model. However, extensive survey presented in [30] shows using evolutionary computing model under heterogeneous network incurs computation overhead among wireless sensor nodes. in [31], proposed an energy efficient routing model considering packet loss rate and link quality under clustered based heterogeneous sensor network. However, they did not considered improving coverage time. Thus, affecting lifetime performance of WSN's.

For improving network coverage for large heterogeneous network, mobile sink (MS) based routing (data collection) have attained much attention in recent times [34], [35], [36], and [37]. Here, MS will move through the WSN area to gather sensory information from SN. As it is practically impossible (i.e., not efficient) for MS to visit all SN. Recently, number of methods using rendezvous point (RP) selection method is presented. The RP collect the sensory information from sensor node which later send it to MS when the MS visit near them. In [34], [35] presented a fixed rendezvous point. As a result, mobile sink path is very restricted. In [36], [37] presented an unconstrained method where MS can move freely within region of WSN's. In [4], mapped SN to region on a Halin graph (HG) for choosing rendezvous point considering given to the residual energy availability status of the SNs. Similarly, [37] presented a rendezvous point section scheme using weighted rendezvous planning (WRP). The WRP aid in selecting appropriate rendezvous point devices (RPD) while assuring the delay requirement by limiting the travelling distance of the MS. To establish the rendezvous point device, a weight is assigned to each SN. The SN with maximum weight is selected as RPD only if the TD of the MS is smaller than a predetermined threshold. However, throughout the RPD selection process of the state-of-art method [4] and [5], computation of the weight parameter of SN is done using data of preliminary routing paths, whose directions are headed towards a solitary starting point of a MS. Thus, the state-of-art routing model induces higher routing length and affect overall performance of WSN. For overcoming research challenges, this work first present energy efficient mobile sink based routing model for maximizing lifetime of wireless sensor network.

The contribution of research work are as follow. Presenting an optimal rendezvous point selection model for minimizing energy dissipation of sensor nodes and maximizing lifetime of WSN. The proposed model attain significant performance improvement over state-of-art model in terms of communication, routing overhead and lifetime of sensor network.

The manuscript is organized as follows. In section II the proposed energy efficient mobile sink based routing model for maximizing lifetime of wireless sensor network model is presented. The penultimate section presents an experimental study of proposed model over exiting method. The conclusion and future work is discussed in the last section of the manuscript.

II. Energy Efficient Mobile Sink based Routing Model Formaximizing Lifetime of WSN

This section present an energy efficient routing model using mobile sink for minimizing energy consumption sensor device, and maximize lifetime of sensor network. Firstly, we describe the system and channel model of heterogeneous wireless sensor network architecture. Then, we describe the optimal rendezvous point selection and routing model to enhance lifetime of wireless sensor network.

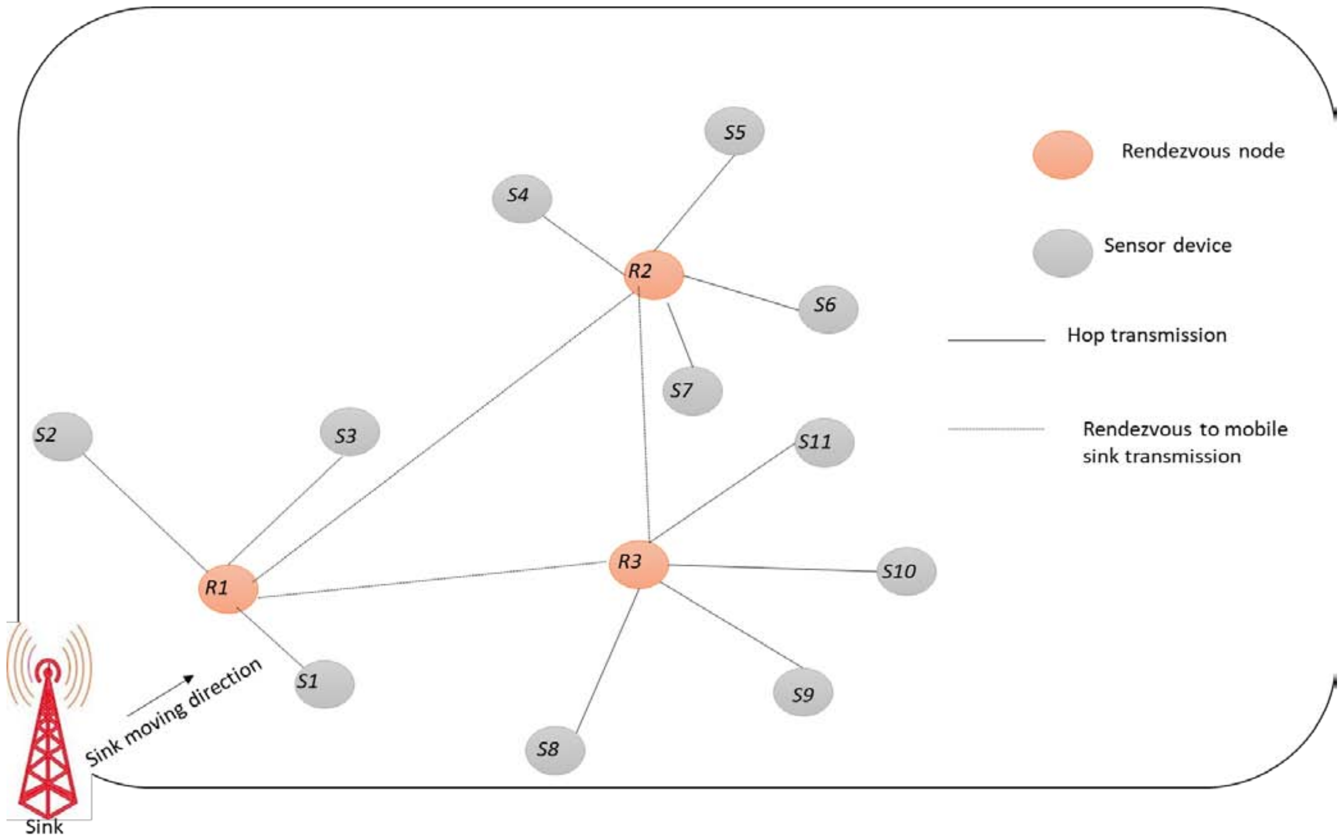

Fig. 1: The Architecture of proposed energy efficient

a) System architecture, channel and transmission optimization model

The architecture of proposed model is show in Fig. 1. From Fig. 1 it can be seen that the rendezvous point closer to base station is composed of less number of rendezvous member we call this as level 1 and rendezvous point little far away from rendezvous node has more number of rendezvous member we call this has level 2. This way the far rendezvous point nodes will have large density of rendezvous member. This deployment method aid in minimizing energy consumption of rendezvous node. Especially, the rendezvous node closer to sink. Thus enhancing coverage time and lifetime of sensor network.

This work considers heterogeneous WSN i.e., let's consider classes of sensor device such class A, class B. Class A are represented as sensor device that performs operation such as sensing. These device are low cost and tiny devices which are deployed across sensing region. The sensor are grouped together to form a rendezvous points. Class B sensor device is more powerful and has higher computing capability than Class A device which depicted as rendezvous node. The class B device collects and aggregates sensory data from its member and transmit toward sink/base station through set of hop/intermedia rendezvous node device.

Let consider there are N and O nodes that are randomly deployed in a network and their position are known. Each sensor device are connected/associated with one rendezvous node device and generates mean packet load of α bits/sec and transmit to the rendezvous node, which further routes to the mobile sink nodes (which in this work we considers as the $(M+1)^{th}$ rendezvous node directly or through intermediated rendezvous node devices. Further, this work considers the rendezvous node consumes much higher energy than its sensor devices. Since, rendezvous node is active all the time and at the same time the member device are in sleep state. As a result, this work aimed to minimize energy consumption of rendezvous node device. As it aid in enhancing network coverage resulting in better lifetime of wireless sensor networks.

This work considers Rayleigh fading model to characterize the channel among rendezvous node and also among rendezvous node and the base station. Therefore the channel gain y among sender and receiver for communication is obtained as follows

$$i(y) = M(e_0)\left(\frac{y}{e_0}\right)^{-o}\beta \qquad (1)$$

where $M(e_0)$ is the path loss component of e_0 which can be computed as follows

$$M(e_0) = \frac{H_u H_s m^2}{16\pi^2 e_0^2} \qquad (2)$$

where H_u is the antenna gain of the sender, H_s is the antenna gain of the receiver, β is a normalized arbitrary

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parameter that depicts the variation in the fading process, m is the wavelength of the frequency carrier, o is the path loss exponent. The β is arbitrary and is considered to be exponentially distributed, and the received signal is also arbitrary. Therefore, perfect reception of a signal is assured through probabilistic manner. Hence we needed that $P\{f_s \geq \delta\} \geq \gamma_m$ for ideal reception, where f_s is the energy of obtained signal, δ is predetermined energy threshold, and γ_m is the expected link ideal parameter.

Let consider d_j as the cumulated hop routing load attained by the j^{th} rendezvous node (bit/seconds) for $j = 1, \dots, O$. The rendezvous pointing optimization vector is expressed as follows

$$d = (d_1, \dots, d_O). \quad (3)$$

An important to be seen here is that the number of sensor device associated with rendezvous node ji.e., the size of rendezvous point j, is expressed as follows

$$\frac{d_j}{\alpha}. \quad (4)$$

For $j \in \{1,2,3, \dots, O\}$ and $k \in \{1,2,3, \dots, O+1\}$, with $j \neq k$, let w_{jk} be the rendezvous routing load that is transmitted from rendezvous node j to rendezvous node k. The routing optimization matrix $\boldsymbol{S}$is the $O * (O+1)$ matrix of elementw_{jk}, $j = 1, \dots, O$ and $k = 1, \dots, O+1$. This work considers$w_{jj} = 0$. The objective of this work is to maximize coverage time by establishing an optimized routing matrix $\boldsymbol{S}'$ and rendezvous point vectord'. Let consider Q_j as the mean energy consumption of the j^{th} rendezvous node. Then, the Q_j is expressed as follows

$$Q_j = f_{recv}\left(d_j + \sum_{1 \leq k \leq O, k \neq j} w_{kj}\right) + f_{trns}\left(\sum_{1 \leq k \leq O+1, k \neq j} w_{jk}\right) + \sum_{1 \leq k \leq O+1, k \neq j} w_{jk}\, f_{ujk}, \quad j = 1, \dots, O \quad (5)$$

where f_{trns} are the circuit energy per bit dissipated in transmitting data, f_{recv} are the circuit energy per bit dissipated in receiving data, and f_{ujk} is the energy dissipated from rendezvous node j to rendezvous node k. Let us assume that e_{jk} as the distance among rendezvous node j and k, therefore using Eq. (1) the received energy per bit can be expressed as follows

$$f_{recvjk} = f_{trnsjk}\, M(e_0)\left(\frac{e_{jk}}{e_0}\right)^{-o} \beta. \quad (6)$$

By using Rayleigh channel model, the link ideal parameter can be described as follows

$$\gamma_m = \mathcal{P}\{f_{recvjk} \geq \delta\} = \mathcal{P}\left\{\beta \geq \frac{\delta}{f_{trnsjk}\, M(e_0)}\left(\frac{e_{jk}}{e_0}\right)^{o}\right\} = f^{-\frac{\delta e_{jk}^{o}}{f_{trnsjk}\, M(e_0) e_0^{o}}} \quad (7)$$

From Eq. (7), we can describe f_{trnsjk} as follows

$$f_{trnsjk} = \varphi e_{jk}^{o}, \quad j \neq k \quad (8)$$

where φ is a constant that can be expressed as definition as follows

$$\varphi = \frac{-\delta}{M(e_0) e_0^{o} \log \gamma_m} \quad (9)$$

The Eq. (5) can be written considering for $j = 1, \dots, O$, as follows

$$Q_j = f_{recv}\left(d_j + \sum_{1 \leq k \leq O, k \neq j} w_{kj}\right) + \sum_{1 \leq k \leq O+1, k \neq i} w_{jk}\left(f_{trns} + \varphi e_{jk}^{o}\right) \quad (10)$$

Let $F_j$depicts the initial energy of the j^{th} rendezvous node, $j = 1, \dots, O$. This work consider an optimization problem to maximize coverage time as follows

$$max_{\{d,S\}} min\left\{\frac{F_1}{Q_1}, \frac{F_2}{Q_2}, \dots, \frac{F_O}{Q_O}\right\}. \quad (11)$$

When rendezvous nodes are deployed with equal energy, that is,

$$P_j = P\ \forall\ j, \quad (12)$$

The optimization problem of Eq. (11) can be rewritten as follows

$$min_{\{d,S\}} max\{Q_1, \dots, Q_O\} \quad (13)$$

For solving optimization problem of Eq. (13), packet load composed by all the rendezvous node considering certain instance period of time must be identical to load produced by all the sensor devices in the same instance period of time.

b) Optimal rendezvous point selection and routing model

This section present rendezvous point optimization technique for wireless sensor network. Let $d' = (d_1', \dots, d_O')$ be the optimal rendezvous pointing vector outcome. For $j = 1, \dots, O$, rendezvous node j is given $N_j' = d_j'/\alpha$ sensor devices. The sensor device allocation is carried out in sequential manner, i.e., one at a time. A corresponding sensor device is allocated to the nearest rendezvous node j, provided that number of SD to rendezvous node j is not greater than $N_j^{'}$. If it exceed then next nearest rendezvous node is considered and so on. The algorithm for obtaining optimal rendezvous pointing is presented in algorithm 1.

Algorithm 1: Optimal rendezvous pointing selection algorithm

Input: $d^{;} = d^{'} = (d_1^{'}, \dots, d_O^{'})$

Expected outcome: $V_1, \dots, V_O$

Initialize: $V_1 = \cdots = V_O = \emptyset$ (rendezvous point sets)

Start: For $j = 1$ to N

For $k = 1$ to O

Set y_{jk} to distance among sensor device j and rendezvous node k

End for

Iteration: $l = arg_{\{k\}} \min\{y_{jk}, k = 1, \dots, O\}$

If $d_l^{'} > 0$

$$d_l^{'} = d_l^{'} - \alpha$$

$$V_l = V_l + \{l\}$$

Else

$$y_{jl} = \infty$$

go to iteration

End if

End for

End:

This work consider routing considering shortest path root towards rendezvous node device to mobile sink through number of hop devices. For minimizing hop count which varies for different transmission. As a result, this work considers quality of communication using parameter γ_q for computing probability of positive end-to-end reception. Fordifferent roots of L paths experience different fading, the root reliability γ_u must be at least $\gamma_q^{\frac{1}{L}}$. Considering the shortest hop case, the packets are routed through nearest rendezvous node closer to the next level j towards the base station. This work considers energy balanced rendezvous point based routing design that balance energy of different rendezvous nodes. The communication radius of rendezvous point can be obtained as follows

$$\frac{1}{2}(s_1 - s_0), \dots, \frac{1}{2}(s_L - s_{L-1}), \tag{14}$$

is the important to energy dissipation at different level rendezvous nodes. Thus, by purposely regulating the size of rendezvous point in different levels, a more balanced energy dissipation at different rendezvous nodes is attained, which aided in enhancing coverage time of WSN. Thus improving lifetime of WSNs which is experimentally proven below.

III. Simulation Result and Annalysis

This section present performance evaluation of proposed model over exiting method considering lifetime, communication overhead and routing overhead. The experiment is conducted using windows 8 operating system, I-7 Intel Pentium processor, 64-bit, 8 GB RAM. Experiment evaluation is done using SENSORIA simulator [32] for proposed and existing model. Here we compared our result with base LEACH protocol [11]. The LEACH and proposed model is modelled using Dot Net framework 4.5 and C# programming language. The LEACH has been widely used comparison protocol across various exiting approaches [11]. As a result, this work consider LEACH protocol as a case study for comparison. The simulation parameter used for experimental analysis is described as follows, the network size is set to 100m × 100m, the sensor device is varied from 500, 1000, 1500 and 2000, one base station is consider which is placed at the edge of the network, initial energy of sensor device is set between (heterogeneity) 0.1 to 0.2 Joules (j), Idle Energy Consumption (Eelec) is set to50 nj/bit, and Amplification Energy (Emp) is set to100 pJ/bit/m2. The range of transmission is set to 5 m and sensing range is set to 3 m, Data Packets Length is set to 5000 bits, Transmission Speed is set to 100 bit/s, Bandwidth is set to 10000 bit/s, Data processing delay is set to 0.1 s.

a) Lifetime performance analysis considering total sensor node death

This section describes performance attained by proposed model over existing model considering total sensor device death. Here the sensor device is varied from 500, 1000, 1500, and 2000 and experiment are conducted to evaluate lifetime performance and the result is graphically represented in Fig. 2. The result shows proposed model improves lifetime performance by 69.09%, 76.22%, 82.96%, and 83.83% over existing

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protocol considering 500, 1000, 1500, and 2000, sensor device respectively. An average lifetime performance improvement of 78.02% is attained by proposed model over existing considering total sensor device death. The overall result attained shows scalable lifetime performance considering varied network density.

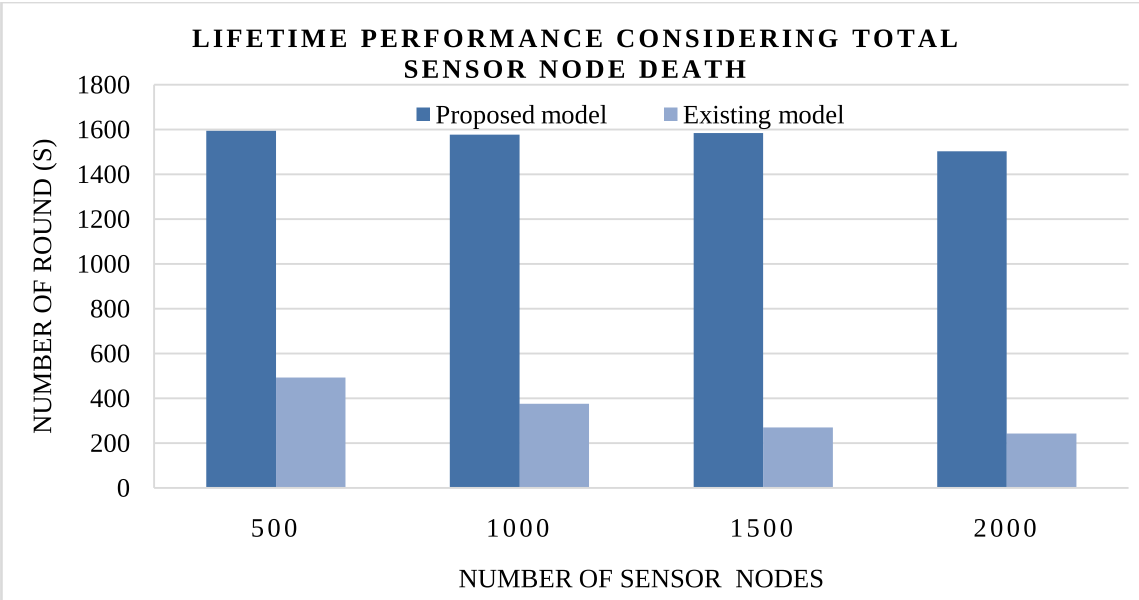

Fig. 2: Lifetime performance considering total sensor node death

b) Communication overhead and Routing/transmission overhead performance evaluation considering varied sensor device

This section studies communication overhead and routing overhead performance attained by proposed model over existing model [11]. For experiment analysis, the sensor device is varied from 500, 100, 1500, and 2000 and experiment are conducted and the result is graphically shown in Fig. 3. The outcome shows, proposed model reduces computation overhead by 32.74%, 26.25%, 48.644%, and 41.88% over existing model considering 500, 1000, 1500, and 2000 sensor device, respectively. An average communication overhead reduction of 37.37% is attained by proposed model over existing model. Similarly, experiment are conducted to evaluate routing overhead performance by varying sensor device from 500, 100, 1500, and 2000 and result is graphically shown in Fig. 4. The outcome shows, proposed model reduces routing overhead by 51.62%, 44.06, 45.08%, and 51.93% over exisitng considering 500, 1000, 1500, and 2000 sensor device, respectively. An average routing overhead reduction of 48.17% is attained by proposed model over existing model.

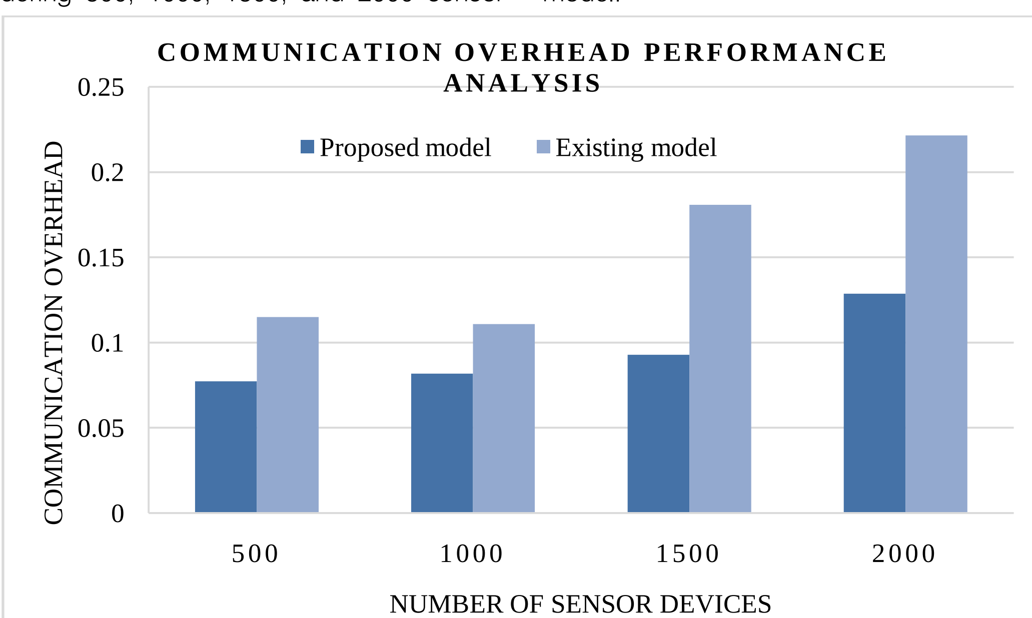

Fig. 3: Communication overhead performance evaluation for varied wireless sensor nodes

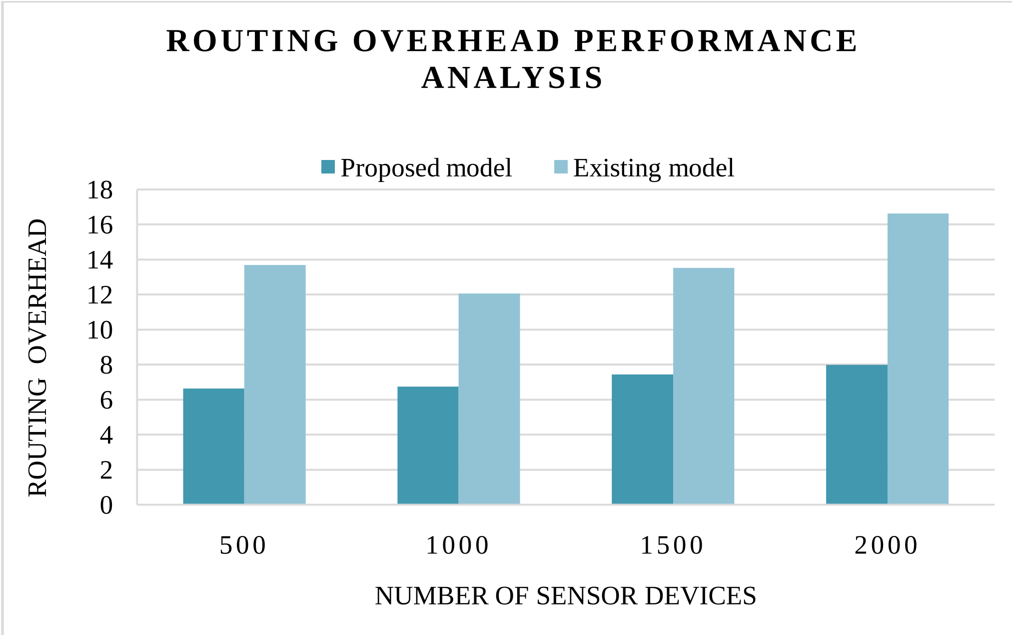

Fig. 4: Routing overhead performance analysis for varied wireless sensor nodes

c) Result and discussion over state-of-art technique

This paper conducted experiment evaluation considering various performance parameter such as communication overhead, routing overhead, and network lifetime considering total sensor device death. This section particularly evaluate lifetime performance attained by proposed and various state-of-art technique over LEACH protocol [11].The model presented in [18] attain a lifetime performance improvement of 25.0%, [19] by 50.0%, [29] by 55.0%, [31] by 44.0%, [33] by 15.0%, and proposed model by 78.02% over LEACH [11]. From overall result attained shows proposed model attain significant lifetime performance enhancement over various existing model [18], [19], [29], [31], and [33]. Our model brings minimize energy consumption of rendezvous node, enhancing coverage time aiding in lifetime performance improvement of WSNs. Thus will aid in provisioning real-time application service that requires energy efficient design.

IV. Conclusion

Building energy efficient design for provisioning real-time and non-real-time application services in WSN is challenging. Extensive survey carried out shows number of approaches has been presented lately to enhance energy efficiency of sensor network. Among them mobile sink based routing design play an important role in enhancing performance of sensor network. However, design mobile sink based routing model with minimal latency and higher energy efficiency is challenging. To overcome research challenges, this manuscript presented an Energy Efficient Routing Optimization model using mobile sink. Further, routing optimization is carried out and shortest path based routing is considered for attaining good trade-off between minimizing energy and maximizing lifetime of sensor network. Experiment are conducted to evaluate performance of proposed model over exiting model. The result shows proposed model improves lifetime performance of 78.02% considering total sensor device death. Further, the proposed model reduces communication overhead and routing overhead over exiting model by 37.37%, and 48.17% respectively. The overall result attained shows scalable lifetime, communication overhead and routing overhead performance considering varied network density.

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