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Mobile Sink Node with Discerning Motility Approach for Energy Efficient Delay Sensitive Data Communication over Wireless Sensor Body Area Networks

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Abstract: The sensors nearby the static sink drains their energy resources rapidly, since they continuously involve to build routes in Wireless sensor networks, which are between data sources and static sink. Hence, the sensors nearby the sink having limited lifespan, which axing the network lifetime.The mobile-sink strategy that allows the sink to move around the network area to distribute the transmission overhead to multiple sensor nodes. However, the mobile-sink strategy is often tall ordered practice due to the continuous need of establishing routes between source nodes and the mobile sink (MS) at new position occurred due to its random mobility. In regard to above stated argument, this manuscript proposed a novel energy data transmission strategy which is effective for WSN with mobile sink. Unlike the traditional contributions, which relies on mobile sink with random mobility strategies, the proposal defines a discerning path for mobile sink routing between sectioned clusters of the WSN. The proposal of the manuscript titled "Mobile Sink Node with Discerning Motility Approach (MSDMA) for Energy Efficient Data Communication over WBAN". The method defined in proposed model sections the target network in to multiple geographical clusters and prioritize these clusters by the delay sensitivity of the data transmitted by the sensor nodes of the corresponding clusters. Further, discriminating these clusters by their delay sensitive priority to define mobile sink route. For estimation of the delay sensitive priority of the clusters, set of metrics are proposed. The experimental study carried on simulation to assess the significance of the suggested method. The performance improvement of the suggested method is ascended through comparative analysis performed against benchmark model under divergent metrics.

Keywords: Network Lifespan, Routing Protocol, Energy Efficiency, Motility Management.

I. INTRODUCTION

In current years cloud authorize computing and methods have become widespread. The techniques support the WSNs from lower to upper layer application. This network with abundant sensor nodes does monitors encircle sensor field collectively and these nodes have data storage, transmission, sensation, and processing. The work [1] contributes multiple applications of WSNs in various spheres like military, agriculture, and healthcare.

Still, energy-efficient routing algorithms study is a persuaded research area due to its restricting battery capacity, quantifying ability, storage facility, and data process, however reducing energy consumption and expanding network life span are major WSNs issues that are to be addressed.

Using the multi-hop manner, data is transmitted from sensor nodes to sink node in conventional routing methods. Nonetheless, with the fixed sink node, a few sensor nodes nearby sink transmit extra data than distant nodes which is called energy hole. Further, sensor nodes close to sink does rapid energy consume and perish swiftly; refers the similar sensor nodes as hot nodes.

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Though mobile sink use upsurge network lifespan with curbing energy-hole issue, fetches some other challenges to transmit the data. Unlike static sinks, dynamic network topology hasa shiftingsink where tracking of newest mobile sink location by the sensor nodes is a requisite to transmit data expeditiously. Moreover, considering nodes energy scarcity, broadcasting sink location frequently have to be prevented; it cripples energy preservation concept.

In order to address this issue, the manuscript proposed a novel approach called Mobile Sink Node with Discerning Motility Approach (MSDMA) for delay sensitive data transmission over wireless sensor body area networks. The MSDMA sections the target network in to multiple geographical clusters and defines discerning route for mobile sink. The data transmission is carried in two phases, where initial phase enables data transmission by cluster level sensor nodes to the corresponding cluster head and the second phase enables data transmission by cluster heads to mobile sink. The cluster head selection strategy is adapted from LEACH protocol. The novelty of the proposal is the discerning mobility of MS. The discriminating mobility of sink enables the deterministic time intervals of the sensor node sleep, idle transmission states. Moreover, the discerning mobility limits the energy consumption for signal amplification by cluster heads during the data transmission to the mobile sink which is due to the direct transmission between cluster heads and mobile sink. The priority order of the clusters in sink mobility enables to balance the delay sensitive data transmission.

Further sections of the manuscript explore the review of contemporary models, detailed exploration of the proposed model, experimental study, and summary of the manuscript in respective order.

II. RELATED WORK

Contemporary literature contributes the researched solutions for the discussing issue: [2], presents the use of the adaptive sensing range concept to deplete energy consumption while expanding WSNs lifespan[3], contributes a centralized solution that resolves the WSN power dearth through scheduling the nodes deployment between active and passive nodes[4], explores an algorithm of a centralized energy conserving scheduling through building max joint sets and later specifying active time period to every joint set[5], introduces the issue of CSC that aims to identify max set covers ensuring the activation of each set various time intervals to preserve power[6], proposes a greedy heuristic which performs the sensors prioritization depending on unconsumed energy of sensors [7], contributes conserving energy directional sensors[8], presents the collaboration of mobile sensors with static sensors[9], introduces failure probability theory of the target coverage issues for expanding system steadfastness along with a greedy algorithm whichcomputes the require number of MRSC efficiently[10], recommends a DOCAthat partitions the big network as several h-hop local networks.

III. METHODS AND MATERIALS

Routing with minimal node energy consumption and "delay sensitive transmissions" are two notable goals of the proposed "Mobile Sink Node with Discerning Motility Approach (MSDMA)". The recommendation is therefore specified in such a way that routing achieves less "control packet overhead," "less idle time of nodes" to efficiently manage energy proficiency. In addition, the goal is to ensure that "delay sensitive data" management conditions are effectively achieved when achieving fault tolerance and improving priority scheduling. The following elements serve as the pivot of the model suggested to achieve the aforementioned goals. Non-overlapped classification of the network is required to ensure that each node in the group is connected towards the other nodes that are important to the group. Each of these groups elects its group head from amongst its members, based on which node has the most energy. Specifically, the LEACH protocol has been tweaked to allow each group to choose the node with the greatest amount of energy available as the group's leader [11]. Energy consumption at a node is now shown as a cumulative total of the energy consumed during idle time, as well as the amount of energy consumed during the transmission process. When receiving and transmitting data, the amount of energy used must be greater than the amount used while the device is idling. However, the power usage during idle time will be larger than during sleep time.

The efficacy of the Control Packets is profoundly significant in terms of handling the energy consumption being less. In contrast to the prevailing models, the nodes are not scheduled to observe the location of the MS, thus, the CPs exchange is driven towards identifying the location of the mobile link surpassing. And this will be happening as nodes tend to transmit data to group head of respective group which later transfers the data which is buffered to MS, while it is accessible in the scope of transmission.

A. Energy Efficiency

At the sensor levels, the energy consumption is categorized into three stages as mentioned below

- Consumption during the tenure of transmission and reception
- Consumption during the tenure of idle time of the sensor

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- Consumption during the tenure of sleep time of the sensor.

During the time of receiving and transmission, the consumption of energy for transferring every aspect of k bits over the distance d (meters) shall be represented as $e_{tx}(k,d)$ and the consumption of energy towards receiving every aspect of k bits shall represent as $e_{rx}(k)$. Egress transmissions consume more energy to transmit k bits over distance d. (meters).

The energy consumption observed over the reception of k signals through the circuit is considered apparent for representing the consumption of energy for receiving every k bits. The energy consumption over idle time is represented as e_{ix}.

Idle time sensor represents how the sensor shall be awakening despite the absence of any transmissions. The consumption of energy in the sensor sleep-time is denoted as e_{sx}. The sensor sleep represents the conditions, wherein the sensor is not active and shall not be listening to the requests of the transmission. Constituting energy consumption at various stages is indicated by $e_{tx} > e_{rx} > e_{ix} > e_{sx}$.

Complete consumption of energy of a sensor is represented using the equation below, wherein the cumulative set of consumption of energy at various stages is depicted.

$$e_c = e_{tx} + e_{rx} + e_{ix} + e_{sx} \quad \text{------ Eq-1}$$

B. Fault tolerance

Among the key limitations of the prevailing models, the fault tolerance issue is an impending aspect, as more often the group head fails to collate data from the sensor's pools within the group, termed as sensor failure. More often the lack of acceptance leading to group head delays leads to increasing waiting time for the message, from sensor failure, and it often ends with receiving terrible message from the respective sensor conditions. Such an activity triggers the conditions of malfunctioning results, thus increasing the complexities of data delivery issues from the select group to MS. Also, more often the data is delivered in terms of resulting groups, falling short for the successful outcome. To address the afore mentioned gaps in the existing models, this manuscript provides significant solutions for procedural collection of data in addressing the limitations discussed above.

The group head denotes maximum valid time mt_i that consumed by each i^{th} node, which is the, mean of the time consumed during past message transmissions and its "root mean square error". In the case of the waiting time for the group head related to the messages are expected from the sensor being surpassing the data-out-time conditions, for the sensors, it is imperative that the delivery message from the related sensors are unsuccessful, and hence, there is need for furtherance in the procedure.

The notation T_n indicate the residual time of the group head towards gathering data from the whole sensors or the respective group. Also, T_n shall be the cumulative of "data out-time of the group n " that denotes as,

$$T_n = \sum_{i=1}^{|n|} \{t_i\} \quad \text{-------------- Eq-2}$$

// t_i represents the time-taken towards garnering data from i^{th} sensor for resulting group n.

Also, the "data out time" t_i of i^{th} sensor is represented based on the following equation, wherein, the conditions of id sequence.

$$\langle t_i \rangle = \left(\sum_{x=1}^{sid_i} t_x \right) * \left(sid_i \right)^{-1} \quad \text{------------ Eq-3}$$

//denotes that the "average time taken" based on "valid messages" sent by the i^{th} sensor, sid_i representing the conditions of id of sequence constituting to last "valid message" from the i^{th} sensor, t_x is time consumed targeting x^{th} message -delivery.

Priority-Scheduling: The groups constitute the set of sensors and one sensor leading the pack as a group head, accountable for garnering the data from the sensors and transmit them to the MS. Focusing on the conditions of delay sensitivity conditions, the data priority shall be garnered based on the sensor's groups, wherein the proposed model prioritizes the data gathered from sensors, using a systematic approach as mentioned below.

Data collated from sensors in specific group is clustered has stack of arrays of size $\{s \exists s = |n| + 1\}$ thus, the notation $|n|$ represents number of rows in corresponding cluster n . For each array, the 1st column represents the data of the sensor of the cluster n , the 2nd column signifies the priority id of particular sensor, 3rd column of i^{th} row signifies sequence message number essential for buffering in the 1st column of specific row, 4th column denotes the group head "tolerance period", and 5th column indicates that buffered

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message shall be based on comprehension of other messages as collated or non-collated. Also, for the inputs of columns 2, 3, 4, & 5 shall be resourceful for handling the priority rank for respective message, in order that the sequence for the values is indicated based on the columns from minimum- maximum representing the priority rank for the chosen corresponding message. Thus, it helps, in enabling further process more effectively.

However, message from i^{th} sensor, and accordingly the subsequent sequence number shall be implied by one. Based on the last row of array $(|n|+1)^{th}$ is adapted based on the conditions used for buffering the respective levels of data processed by the group heads. In addition, the message listed in i^{th} row of the array effects by priority changes based on the qualities that lead to subsequent conditions in the row of array that is being processed.

The priority condition is treated as maximum if the sensor priority id for a respective message is evident as minimum.

The priority condition is treated as maximum if the specified sequence-id for a corresponding message is minimum.

The group head condition is seen as "tolerance period" when the receiving message for the corresponding sensor is less, and in such instances, the priority shall be seen as higher.

Any further array buffered messages are relied over the corresponding message, the priority shall be perceived as high.

Let Array A of size s buffers messages from sensors of group n . In lines with description mentioned above, array M will be anticipated is shown in (Eq 1):

$$A = \left\{ \begin{array}{l} \{msg_1, id_p, id_s, tp, sts\}, \\ \{msg_2, id_p, id_s, tp, sts\}, ..., \\ \{msg_i, id_p, id_s, tp, sts\}, \\ \{msg_{i+1}, id_p, id_s, tp, sts\}, ..., \\ \{msg_{|n|}, id_p, id_s, tp, sts\}, H(n) \end{array} \right\} \quad \text{.....(Eq 4)}$$

In the equation above, $\{m_i, id_p, id_s, tp, sts\}$ constitutes messages m_i attained from i^{th} sensor of group n , sequence id id_s , "priority id id_p , cluster head tolerance period tp for receiving message m_i ,message need state sts wherein, it indicates 1for dependency , 0 for not dependency .

Corresponding to the group n, the head of the group affirms the stacked messages in the array A based on the specified time attained as T_n derived. Messages stacked in terms of array of A is organized as stated in the following description.

The messages shall be ordered in ascending order of priority id and followed by arrangement on the basis of sequence-id in increment proposition. Later in the third stage of sorting, it is organized by increasing sequence of group head tolerance period.

Accordingly, the further arrangement is based on the decreasing sequence of their "dependency state".

The cluster head transmits the messages stacked in array A , based on the priority represented by the priority id of the corresponding messages.

C. Tracing the Mobile-SinkRoute

Sink mobility is indicated as random, and the recommended model MSDMA reflects on the mobility of the sink by groups in terms of transmission centric sensibility. The MS alters over the network is lucrative for managing the data from the group heads towards diverse set of groups. With respective to the above mentioned, the sensibility of transmission for groups is managed by adopting the Likert Scale approach[12], for the metrics, ratio of transmission sensitivity, management of transmission-load factor, and the transmission-ratio.

Insufficient-transmission-ratio (itr **):**This metric represents ratio of insufficient-transmissions buffered at the cluster head levels, which are adjusted to 0 deviations based on the values observed. The metrics are evaluated using the following method for each of the metrics.

The notation IBT represents the "ratio of insufficient-transmissions that are buffered over every period T_m at the group head h of n^{th} group"

The forthcoming period in the estimations are the insufficient buffered transmissions, for T_n at the group head h for the nth group which is assessed using the equation-4 mentioned below.

$$pv = \frac{\sum_{j=1}^{|IBT|} \left\{ ibt_j \exists ibt_j \in IBT \right\}}{|IBT|} \quad \text{.......(Eq 4)}$$

Further, evaluates deviation error in the following (Eq 5)

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$$pe = \frac{\sum_{j=1}^{|IBT|} \sqrt{\left(pv - ibt_j\right)^2}}{|IBT|} \quad \text{--------- Eq-5}$$

$itr = \| pv - pe \|$ // insufficient-buffered-transmission Ratio predicted, for an elective group having its adjustments for 0 deviations and is represented as itr.

Transmission-Sensitivity-Ratio (tsr) **:**The factor tsr denotes the sensitivity towards transmissions of the cluster, which is represented by the transmission of interdependent-data, for the respective cluster. Accordingly, the metric is valued as predictive ration for interdependent transmissions, and the time for respective cluster is adjusted to 0 deviations, in lines with the observed ration of interdependent transmissions, wherein the earlier time periods for respective group are assessed. The metrics values are estimated using the following systematic computation.

The ratio of transmission-sensitivity tsr of the transmissions tc observed for the time T_n for the respective group n, which is assessed using the following approach.

$tsr = \left\| dtc \times tc^{-1} \right\|$ // the notation dtc denotes interdependent transmissions cumulative &indicates tc as transmissions cumulative noticed in time period T_n for definitive category n.

The ratio of transmission-sensitivity predicted for the corresponding cluster denotes by the notation pv for the time T_m prevailed shall be measured as stated in the following approach.

Let the set TSR lists ratio of transmission-sensitivities

$$pv = \frac{\sum_{i=1}^{|TSR|} \left\{ tsr_i \exists tsr_i \in TSR \right\}}{|TSR|} \quad \text{---------- Eq-6}$$

// denotes $|TSR|$ represents number of entries of set TSR, such that the natation $\{tsr_i \exists tsr_i \in TSR\}$ denotes the entry of the set TSR with index i.

Further estimates the transmission-sensitivity prediction error pe of the time interval T_n of the cluster n as stated in equation (7).

$$pe = \left(\sum_{i=1}^{|TSR|} \sqrt{\left(pv - tsr_i\right)^2} \right) * \left(|TSR|\right)^{-1} \text{ ... (Eq 7)}$$

Ratio of transmission-sensitivity predicted shall be estimated to 0 deviations from the observation shall be represented as shown in the equation-8 mentioned below.

$$ptsr = pv - pe \text{ ...(Eq 8)}$$

Transmission load: The metric refers to the scope of predictive transmission load for a chosen time frame T_n for the specific group n, which shall be adjusted for 0 deviations based on the transmission loads from the former time periods for the respective group. Metric shall be assessed based on the following conditions.

Representation TL is based on the count of transmissions observed at distinct conditions for the time periods for a respective group n.

Predictive value pv for a transmission load in the timeline T_n for specific group n is assessed using the equation mentioned below.

$$pv = \frac{\sum_{i=1}^{|TL|} \left\{ tl_i \exists tl_i \in TL \right\}}{|TL|} \quad \text{------ Eq-9}$$

// the depiction $|TL|$ signifies size of set TL, &depiction tl_i refers to i^{th} entry of set TL.

For the current time interval, the predictive error of the load that denotes by the notation pe shall be assessed as,

$$pe = \frac{\sum_{i=1}^{|TL|} \sqrt{\left(pv - tl_i\right)^2}}{|TL|} \text{ ....(Eq 10)}$$

Also, the predictive transmission load ptl, is adjusted based on the 0 deviations observed for the transmission loads as stated in equation-7.

$$ptl = pv - pe \text{ ...(Eq 7)}$$

In terms of improvising the outcome, the predictive values for the metrics are organized in priority manner, wherein the insufficient transmission ratio $(pitr)$, followed by transmission sensitivity ratio $(ptsr)$ taking priority, and at last sequence, the transmission load (ptl) are utilized for assessing the group priority score for the respective group based on the Likert Scale as mentioned in Equation-11.

$$ps = \left(ptl * \left(m - pr_{ptl} + 1\right)\right) + \left(pstr * \left(m - pr_{ptsr} + 1\right)\right) + \left(pitr * \left(m - pr_{pitr} + 1\right)\right). \text{ ..(Eq 11)}$$

In equation above,

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The metrics count denotes by the notation m (m value is 3 in this model)

Priority rank of the metric $pitr$ denotes by the notation pr_{pitr}

Priority rank of the metric $ptsr$ denotes by the notation pr_{ptsr} ,

Priority rank of the third metric p denotes by the notation pr_p .

The priority-score ps of the cluster n chosen for analysis.

Mobility of MS is further assessed based on the following factors. In lines with the mobility, sink chooses the groups constituting maximum priority score values, and the neighbor of the sink having existing location, and persists to visit the neighbor groups for the sequence based on the priority score.

IV. SIMULATION RESULTS

The manuscript presents simulation experiment study to verify the execution of the protocols. Result analysis and comparison with the contemporary protocols, line-based data dissemination (LBDD) [13], railroad [14] & ring routing [15] is performed. Using different speed ranging from5-30 m/s of sink, every experiment is conducted where consumption of various metric factors like the ratio of data-delivery, end-to-end latency conditions, and energy capacity factors. In lines with the parameters mentioned in table -1, an in-depth simulation process is managed for use of Castalia Simulator (v3.2).

Table 1: list of parameters used for the simulation

Name of the parameter	Value
Network cluster	500*500m^2
Total sensor nodes	200
Size of data packet	512 bytes
Size of control packet	32 bytes
Initial energy	1J
δ	5s
Range of speed of the sink	(5,10,15,20,25,30) m/s
Mobility model	Random waypoint
E_{elec}	50nJ/bit
ε^{fs}	10pJ/bit/m^2
ε^{mp}	0.0013pJ/bit/m^4
d0	87m
E_{low}	0.2nj/s
Time of Simulation	600s
MAC protocol	TMAC

A. Average control packet overhead

For building the rendezvous area and sink mobility management, the control packets are transmitted by the sensor node. The Figure 1 represents the control packet energy consumption average based on the different sink speed with multiple protocols. The second proposed protocol has demonstrated less overhead for the control packet than the other protocols projections. This is depicted in the graph presented in the Figure 1.

The inline-node are used to store the data received from the input node in the LBDD approach. In this approach, the data is sent to the sink if the query reaches the inline node. The inundate flooding of the query into the area of the rendezvous leads to raise in the overheads of the control packet. In a single process, the establishment of rail and station in the railroad protocol is done. Nevertheless, exchange of control packet is needed for the process of storing the metadata at station and retrieving location of sink from station. Sink location is stored in all the ring nodes of the ring routing protocol which makes the process of sink location retrieval effortless. The control packet exchange is needed for repairing the ring during the network operation which leads to growth of ring length. Thus, occurs raise in the energy consumption because of increase in the distance either from the sink or source. The first proposed method demands the tree maintenance inside the area of the rendezvous for transmitting the data. Depending on the sink status, the control packets are needed for setting the link whereas the low consumption of control packets overhead is observed in the second proposed method because of less distance average between the cluster of rendezvous and the sink/source when compared to the other protocols.

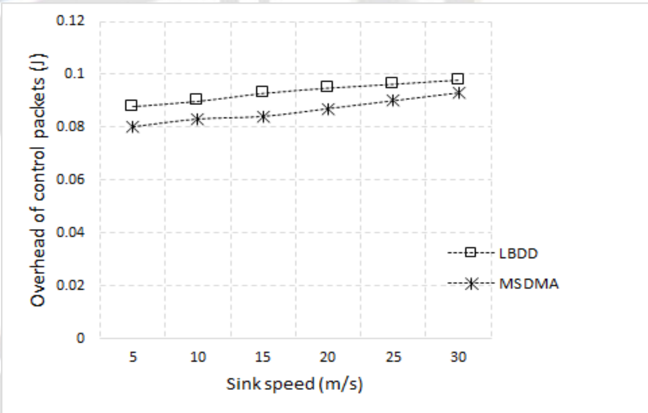

Figure 1: Comparison of overhead of control packet.

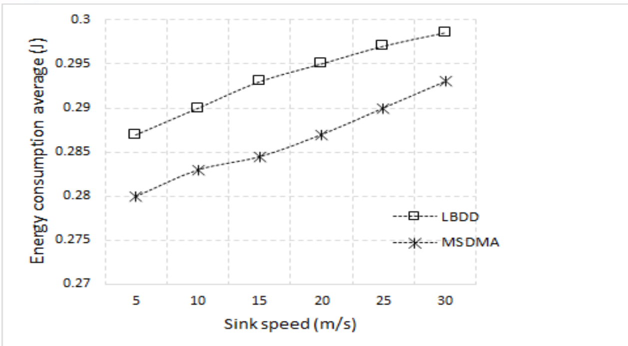

Figure 2: Comparison of energy consumption average.

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B. Average energy consumption

The Figure 2 depicts each node energy consumption for different protocols. Because of high overhead, the consumption of energy is also high in the LBDD approach. From the source, the data is stored and queries of the sink are flooded to cluster of rendezvous. In this approach, the monotonic growth in the energy consumption happen when there is raise in the sink speed. The sink location is no need for the first method, however, the path length average is greater when compared to second method, railroad, and ring routing. Hence, as per the increase of the sink speed, the total energy usage also grows. Like the railroad and ring routing protocols, the average distance of source and sink is equal. Nevertheless, the second proposed method demonstrates superior performance than the other protocols because of low overhead charges of the control packet.

C.Average end-to-end latency

Using varying sink speed, the end-to-end latency average of various protocols is depicted in the Figure 3. This parameter relies on the time taken for finding the location of the sink and diffusing of the data to the sink.Data is transferred directly to backbone tree in 1st model where data is sent to the sink by the tree because of association of the tree with the sink. Subsequently it has a minimal end-to end latency. But soon after receiving the sink location, the data is transmitted by the inline-node in the LBDD protocol. The second method has very low end-to -end latency than railroad and ring routing protocols because of smaller distance among source node & rendezvous area.

D. Packet delivery ratio

Various protocol's data delivery ratio and data reception accuracy rate at the sink is presented in the Figure 4. The first method upholds association of tree and sink, so the ratio of the delivery rate is greater when compared to others. In the LBDD protocol, the inline-node stress the data &transfer data towards sink when the location is found which results in low chances of the data when compared to others. The second proposed protocol has less latency than the railroad and ring routing. Thus, the railroad and ring routing delay the process of data transmission which provides a chance for the sink to shift to another location. This results in the loss of data.

E. Network lifetime

The lifespan of the network is affected by each node energy usage and disproportionate load amongst the sensor nodes. The Figure 5 explicitly depicts that the second proposed protocol has higher lifespan when compared to others. The second method has a lower consumption of control packets and load equal balance amongst the sensor nodes along with route optimization to transmit the data.

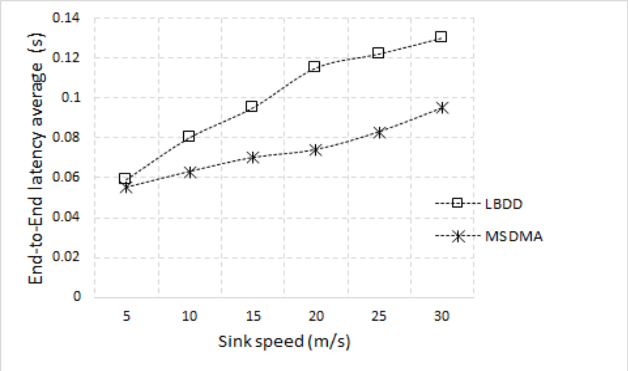

Figure 3: Comparison of end-to-end latency average

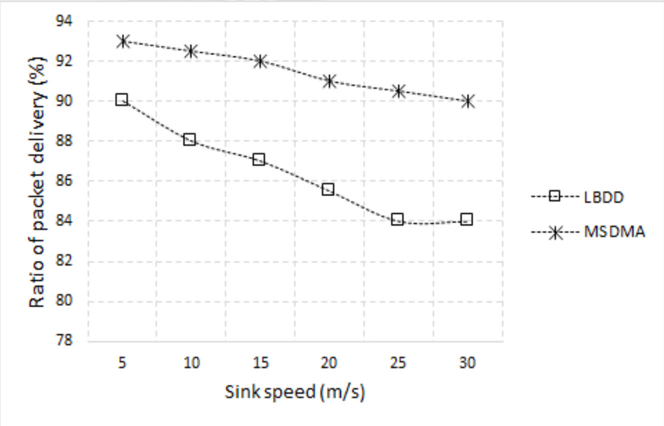

Figure 4: Comparison of ratio of packet delivery

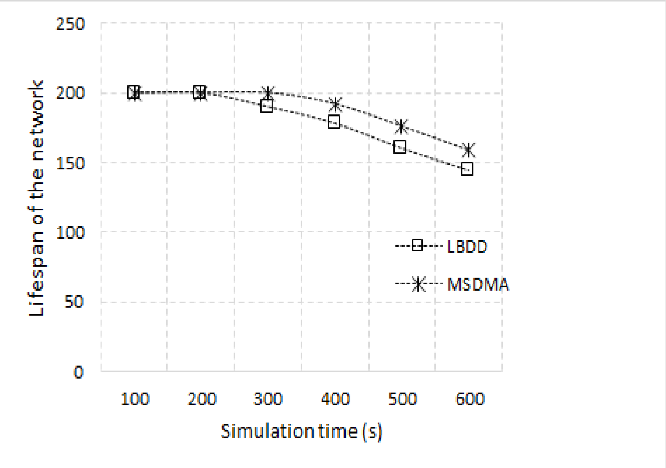

Figure 5 Comparison of lifespan of the network.

V. CONCLUSION

The goal of the model addressed in this book is to achieve optimality in terms of energy consumption over the wireless network domain utilizing the mobile sink strategy. In light of the previous solutions, the model provided in this paper, which considered a mobile sink with random mobility, is a selective

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method for dealing with the sink mobility aspects. The model's basic principle is to divide the network into various areas and select an optimum sensor as an agent from each zone, which can aid in establishing a connection between the sensors in that region and the mobile sink. As a result, the method is known as MSDMA (Mobile Sink Node with Discerning Motility Approach), and it is designed to help with energy-efficient delay-sensitive data transfer across wireless networks.

The goal of determining the selective way between mobile sink and route to prioritized regions. Alternative criteria such as transmission load, insufficient transmissions ratio, as well as transmission sensitivity can be used to define area priority. By comparing the model to current benchmark modes like LBDD, the model's performance efficacy is promoted through energy, latency, packet overhead, network lifespan, and data delivery ratio (Line based data dissemination). The experimental research of the model relates to the model's effectiveness as well as its great scalability potential. The contribution in this publication aids in a better understanding of future study in terms of various methodologies and determining the best path to take when dealing with movable sink route solutions.

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