Use of Energy Replenishment Model to Find Optimum Radio Propagation Model in Wireless Sensor Networks

Mohit Angurala, Manju Bala, Sukhvinder Singh Bamber

Abstract**:** ***Unreliability may occur during radio transmissions in Wireless Sensor Networks (WSNs) owing to the rigid constraints on battery power when wireless sensors hold low power radio transceivers. As a result, propagation patterns fluctuates because of which connections becomes unstable. Consequently, a precise radio propagation model is always pivotal for superior communication. Therefore, a Joint Energy Recharging with Load Balancing (J-ERLB) is implemented in WSNs to diversify the lifetime of the network. Moreover, this model is implemented in diverse propagation models to find optimum model for communication. Our numerical findings illustrate the comparison between Free Space Model, Shadowing Model and the Two-Ray Ground. The effectiveness of the proposed model is performed using the NS2 simulator.***

Index Terms**:** ***AODV, Load Balancing, Radio Propagation Model, WSNs.***

I. INTRODUCTION

WSNs are the self-organizing type of network in which different sensors communicate with each other wirelessly to achieve a certain goal. Basically, WSNs work on five major Open Systems Interconnections (OSI) model layers including an Application layer, Transport layer, Network Layer, Data Link layer and Physical layer. Every layer plays a very vital role in WSNs and each layer has different protocols. While the Network layer is responsible for routing, it faces a lot of problems depending upon the type of application, however, in fact, the major challenge is the power saving and limited memory. At the physical layer, data is transmitted in form of a stream of bits which is further used for modulation and data encryption. Although many efficient techniques are proposed in order to maximize the lifetime of the sensor networks still no technique has been proposed so far which can effectively handle both the physical layer and network layer at the same time. To overcome this limitation we have implemented a two-way technique called "J-ERLB" which is responsible for perfectly managing the load at the network layer and efficient radio propagation model is analyzed for WSNs to improve the way, how data is transmitted at the physical layer.

Structure of our research can be formulated as under:

1. J-ERLB approach is implemented in various Radio Models in WSNs. Using this combined approach of recharging and load balancing, the best Radio model among Free Space, Two Ray Ground, and Shadowing can be selected for wireless communication.
2. Implementation of AODV and Radio Propagation model in WSNS to improve the performance at Network layer and Physical layer respectively.
3. Numerical outcomes in form of graphs validate best Radio Model for WSNs.

The remaining part of the paper is organized as follows. Part 2 depicts various literature works for a variety of Radio Propagation Models. Part 3 demonstrates the architecture of the proposed approach and Part 4 reveals about J-ERLB model. Finally, Part 5 is for results and numerical comparison of the proposed approach and traditional approach followed by a conclusion at the last.

II. RELATED WORK

In this part, the review is discussed for various techniques for improving the lifetime of the sensor networks and traditional methods to communicate data from origin to the destination. The overall literature survey is divided into two parts. In the first part, diverse research proposals are explored for traditional methods to prolong the network lifetime at the network layer. In the second part, traditional models or methods are discussed for transferring the data at the physical layer in WSNs.

A. Various Techniques for Improving the Lifetime of the Network at the Network Layer

[1] Proposed single-hop and multi-hop energy efficient for heterogeneous WSNs. In the former type of protocol, the weighted probability is used for electing cluster heads, while in the latter case, the elected cluster heads propel the data packet toward the base station in a multi-hop manner. Further, the author compared these two protocols with existing clustering protocols and analyzed that these protocols extend the lifetime of the network and work better than existing energy efficient clustering technique and energy

Revised Manuscript Received on May 22, 2019.

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efficient heterogeneous clustered technique. [2] Proposed "Maximum Connected Load-balancing Cover Tree" algorithm in which dynamic load balanced trees are formed, so as to accomplish full exposure while retaining the connectivity with the base station. Through the proposed algorithm, a load among various nodes in sensing and transmitting can be shared and therefore energy utilization among nodes is divided equally which further increases the network lifetime. [3] Proposed a J-MERDG approach to attain superior scalability, extended network lifetime and short data collection delay. In the first step, The SenCar moves across various selected anchor points to recharge the dying nodes during the recharge. While the second step involves the data gathering tour in which the SenCar can proficiently collect data from cluster heads and carry the data towards the sink. [4] Proposed a decentralized routing algorithm, called Game Theoretic Energy Balance Routing Protocol (GTEB). This algorithm extends the lifetime of the network by minimizing the energy consumption where the network coverage is large. Further, this approach considers two level approaches, one at the regional level, which uses evolutionary game theory to balance traffic load and other, at the node level, which uses classical game theory to select an optimum node for load balancing in the selected area. [5] Proposed a clustering approach to maintain balanced clusters by considering the value of thresholds for the formation of the cluster. Finally, the results indicate that the proposed method can improve the network lifetime with reduced dead nodes as compared to traditional methods. [6] Proposed a new distributed Ring Routing mechanism which is fairly energy-proficient and commonly known as "mobile sink routing protocol". This protocol is highly appropriate for time-critical applications and aims to reduce the overhead while maintaining the benefits of mobile sinks. [7] Uses sink attributes to increase the lifetime of the network and explores energy efficient clustering techniques and assimilation of spatiotemporal attributes using fuzzy-intervals bound. [8] Proposed a three-layer hierarchy, which follows a dual merged approach of centralized gridding and disseminated clustering. The centralized gridding is used for the upper-level head selection, while the other clustering is used for the lower-level head selection. [9] Proposed an innovative approach to store and retrieve data for WSNs. In order to should be minimized. The proposed technique improves the network lifetime by minimizing the energy consumption with the help of four new algorithms, namely critical-state-data passing algorithm, efficient and energetic wireless recharging algorithm, weighted optimum storage-node placement algorithm, and proficient rule-based node rotation. [10] Proposed a Balanced Load Distribution (BLOAD) scheme to evade energy holes formed because of unequal energy utilization in Under Water Sensor Networks (UWSNs). The proposed methodology enhances the stability period and lifetime of the UWSNs. [11] Proposed a novel graded node deployment strategy that forms the lowest traffic and based on this node distribution, the distributed load-balanced data collection algorithm is designed to send packets in the direction of the sink node via minimum hop routes that further helps to reduce the network traffic. [12] Investigated that many sensor nodes die due to unbalanced load allocation and for this reason, balanced energy consuming and hole alleviating, as well as energy-aware balanced energy consuming and hole alleviating algorithms are proposed.

[13] Proposed a new load balancing method for data communication of WSNs, that utilizes super nodes with additional powerful hardware and superior transmission capability to understand data traffic reorganization. [14] Proposed a method in which a mobile charging is implemented on WSNs. Further, this paper helps in minimizing the recharging cycle time, which contains the traveling time and recharging time. Moreover, the results prove that the charging vehicle took lesser time by using the shortest Hamiltonian cycle. [15] Proposed improved Daubechies wavelet algorithm in order to look for the optimum possible location for the wireless chargers. Further, the algorithm mobilizes the similar chargers in the most excellent position. [16] Introduced the cluster related wireless energy transfer in which, moving the charged vehicle is allowed to roam within the network and re-energize the sensor node's battery in an efficient manner to improve the overall lifetime of a network. [17] Introduced a Corona-based sensor node placement technique that helps to reduce the overall energy diminution of the WSNs. [18] Proposed an LDC-MAC protocol that proficiently handles the data forwarding throughout the sleeping period. Moreover, in the suggested technique, the energy utilization of every sensor nodes in the network is consistent regardless of their remoteness from the base station and hence prevents the formation of energy holes in the network. [19] Used TDMA scheduling for organizing the time slot and thus aims at providing appropriate adroitness in the network. Network adroitness is not just necessary to minimize the packet drop but also helps to slow down the retransmission of similar surplus data. [20] Described the essential conditions for the utilization of bandwidth that makes a routing way out possible and further link bandwidth assessment as well as optimize energy by applying ant colony optimization technique. The first part of the paper analyzed the outcome of the energy-aware routing protocol without implementing the ant colony optimization technique. While, the second part of the paper, used an ant colony optimization on energy consumption to calculate the optimized path bandwidth along with the Bit error rate to verify the performance of a network. [21] Proposed a complex network model to rectify the crisis of heterogeneous node energy in WSNs.

B. Various Traditional Approaches for Transferring Data at Physical Layer

[22] Investigated and clarified the dependency of channel capacity on antenna element beamwidth in a Spatial Division transmission technique which uses two-ray fading. Further, a simple calculation model is used with an antenna radiation pattern, which takes beamwidth pressure as well as the reflection coefficient

of the ground surface into consideration. [23] Suggested a three dimensional model, in which a parabolic wave equation technique is changed to incorporate the effects of Rayleigh dispersion as well as absorption by dust particles to observe microwave signals proliferate in a sand and dust storm [24] Said that wide research has not been done on communication modeling for normal short as well as tall-grass surroundings for the aim of wireless sensor use. This investigated deployment of wireless sensors in different applications such as following the grazing habit of cows on the grass or finding sporting activities. This investigation gives empirical path loss techniques for wireless sensor placements in grass surroundings. The recommended models are linked with theoretical methods to find out their defects in forecasting path loss among the sensor nodes situated in natural grass environment. [25] Proposed an efficient cross-layer reliable retransmission scheme in IEEE 802.15.6 with no extra control overheads. The proposed method not only looks for the data of the sensor nodes with ineffective transmission frames to keep back retransmission resources but also increases the success probability to resend frame. [26] Said that sensible sensor nodes are utilized to examine the path loss effects of WSNs at 2.425 GHz in a ground protected by snow at a different height from the ground. Further, the developed models are compared with the existing path loss models to disclose their accuracy between sensor nodes equipped in snowy areas. [27] Gave an outline of the experimentally licensed propagation models and quantitative association of propagation models for WSNs. [28] Found that through the examination of the received signal strength indicator and packet loss rate, the received signal strength drops as the transceiver nodes distance increases. [29] Used particle swarm optimization to improve the basic centroid based localization algorithm. [30] Found that the throughput gain given by the successive interference cancellation method expands with the increase in a number of users in WLAN.

III. ARCHITECTURE FOR THE PROPOSED APPROACH

Based on the above-related work, an observation is made that static sensor close to the sink node are prone to use a large amount of energy. Hence, the depletion rate is much large in such a case. On the basis of such facts, many researchers proposed a number of models or techniques to enhance the lifetime of the wireless networks and wireless sensors. For illustration, [3], [14] used mobile data collector for gathering data from nearby sensors and recharge them if necessary. Although similar kind of researches has shown good performance, still none of the technique implemented the load balancing technique along with the wireless recharging feature of SenCar. In the below Fig. 1, n1 is taken as SenCar as it has larger battery status as compared to other nodes. It will keep on traversing all the network in a random way and recharge the node which has battery status less than the threshold value.

In the above Figure, n is a number of nodes and n1 is reserved for SenCar node. The green colored nodes depict the full battery status whilst the yellow colored nodes show the average remaining energy and red colored nodes indicate that the nodes are about to die. Therefore, when the status of the node turns out to be red, at that point SenCar recharges that dying node and re-energize to green color.

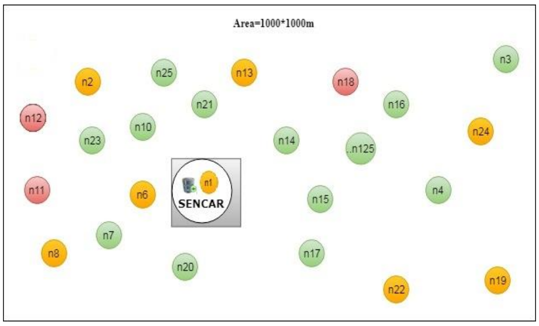

Fig.1. Architecture of Joint Energy Replenishment with Load Balancing (J-ERLB)

IV. J-ERLB (PROPOSED MODEL)

This section represents an efficient implementation of J-ERLB in case of WSNs. Further, in this research, a two-way approach is given to increase the lifetime of the entire network. This two-way approach of recharging and load balancing will help improve the network lifetime in a better and proficient manner.

A. J-ERLB Scenario Details

The implementation of J-ERLB shown in table 1, considers the following scenario details:

Table1: Scenario details

Name of Parameter	Selection
Area	1000*1000
Mac	802.11
Initial Energy	20 J
Number of Nodes	25, 50, 100, 125

B. J-ERLB in WSNs

On the basis of above-mentioned scenarios, simulations are performed and the results are gathered. The J-ERLB model will not only improve the lifetime of the wireless sensor network, rather it will balance the load and improve the packet delivery ratio and throughput in the network. This model is designed to overcome various pitfalls of the WSNs. We first formulated a problem, and then we gave the optimal solution to mitigate the problem.

a) Problem Formulation

In this section, three major problems are identified in WSNs as follows:

- More traffic congestion at the gateway nodes.
- More consumption of power by battery operated sensor nodes.

Both these problems are the major hurdle for WSNs. Hence a proper deterministic solution is

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needed which can mitigate these two problems in an efficient manner.

b) Deterministic Solution

This section proposes an optimal solution for above-mentioned problems. In this model, two techniques are merged together in order to enhance the network lifetime. The proposed solution is discussed with help of the following algorithm:

```
Phase I

R_tour()
{
for(0 to n)
check_node_energy()
{
if(node_energy<threshold)
{
recharge_node();
}
}
}

Phase II

//Path Eshtablisment routine in routing protocol
send_request(destination_id);
Recv_request(packet)
{
if(index==packet_destination || route_available())
{send_reply(queuelength);
}
else
{forward_packet()}
}
Recv_reply(Packet)
{
add_route();
}

Phase III

//path selection routine
select_path(destination)
{
if(path_queue_length<0.75*max_queue_length)
{
return path;
}
}
```

The Algorithm is divided into three phases. The First Phase represents the recharging of sensor nodes having energy less than the threshold level. In this case, the SenCar randomly moves across the network to calculate the remaining energy of all the nodes in a network. Once the calculation is done at each point, the SenCar will now recharge the dying node with half amount of energy if the energy is below the threshold. Otherwise, SenCar will randomly move to the next node in a network. As shown in Figure 1, the red nodes (dying nodes) are those nodes which are having lesser energy than the threshold value while green indicates healthy level and yellow indicates an intermediate level of energy. The following equation depicts the working of the first phase:

$$\left\{ \begin{array}{ll} \text{If } N[R] = \text{TRUE} & \text{Recharge node} \\ \text{Else} & \text{Move to next node randomly and check its status.} \end{array} \right\}$$

The second phase and third phase shows how a path is established between a sender and receiver in the routing protocol and checks if the size of queue length of a node is less than 75% then it will be used for transferring the data, otherwise a new path will be chosen. Therefore, this is how the load balancing will be performed. The next section discusses the result comparison between AODV with SenCar and AODV with SenCar and load balancing.

V. PERFORMANCE AND RESULT COMPARISON

In this section, the effectiveness of the proposed model is evaluated on implementing the J-ERLB model on various radio propagation models and best model is evaluated based on different parameters such as Packet Delivery Ratio, Throughput, Average End-to-End Delay, Average Remaining Energy, and Normalized Overhead.

A. Packet Delivery Ratio

The first parameter, the packet delivery ratio is the number of packets received to the number of packets sent. In Fig. 2, the proposed model, J-ERLB is implemented on free space, Two Ray ground and shadowing radio propagation models and results indicate that when the number nodes is 25, the Packet Delivery Ratio performed better in case of Free Space model with value as 1, whilst, the Two Ray Ground and the Shadowing performed in a similar way with value 0.9998. Further, when the number of nodes is increased to 50, The Free Space model and Two Ray Ground generated the similar value of Packet Delivery Ratio with value 1, whereas the value of Shadowing remained unchanged. Again, when the number of nodes is increased from 50 to 75, the value of packet delivery ratio is 1 in Free Space model, while Two Ray Ground and Shadowing have values 0.9927 and 0.9996 respectively. Finally, when the number of nodes is increased to 100 and 125, then there is a sharp decrease in the value of packet delivery ratio in case of Two Ray Ground that is 0.8721 and 0.5874, while Free Space holds the value of 1 and 0.9999 for 100 and 125 numbers of nodes respectively. On the other hand, the value of packet delivery ratio in case of Shadowing is 0.9854 and 0.9975 respectively. Hence, overall packet delivery ratio shows the best results for Free Space radio model than other two models.

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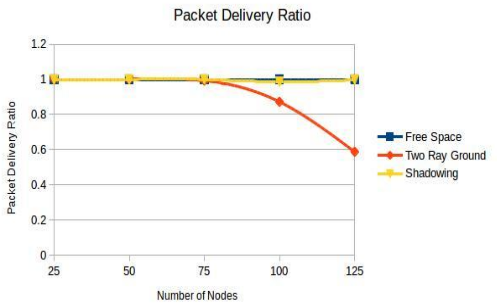

Fig.2. Packet Delivery Ratio for various radio propagation models

B. Throughput

Throughput is defined as the speed at which data is sent in a network. Fig. 3 illustrates the values calculated when the proposed model that is J-ERLB is implemented on various radio propagation models. In the first case when a number of nodes are 25, the value of Throughput is more in Free Space model that is 60.11, while Two Ray Ground, as well as Shadowing, has 60.1 and 60.9 respectively. Further, when a number of nodes are 50, the value of Two Ray Ground and Free Space is same that is 140.99, while Shadowing has a value of 140.97. Again, when a number of nodes are 75, the values of the Free Space and Shadowing is 216.17 and 216.07 respectively and for Two Ray Ground it's 214.6. At last, when the number of nodes is increased to 100 and 125, there is a quick decrease in value to 257.37 and 216.79 respectively for Two Ray Ground model. While for Free Space model values are 295.08 and 369.02 respectively and for Shadowing, values are 290.8 and 368.15 respectively.

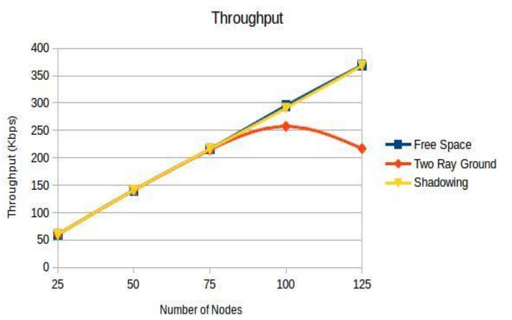

Fig.3. Throughput comparison for various radio propagation models

C. Average End to End Delay

The average delay is least in case of Free Space with a value of 2.35 while Shadowing experience maximum delay with value 2.879 and Two Ray Ground has less delay than Two Ray Ground with a value of 2.656. This is the case when a number of nodes are 25. But when the number of nodes is increased to 50 and 75, then the values noticed in the case of Free Space model are 3.287 and 6.058 respectively. While values in the case of Two Ray Ground are 7.606 and 7.082 respectively and for Shadowing, the values are 3.554 and 5.140 respectively. Further, when the number of nodes is gain increased to 100 and 125, the minimum delay is noticed for Free Space model with values 5.674 and 14.961 respectively while for Two Ray Ground there is a rapid boost in value that is 16.4616 and 1705.7. This is the point where the maximum delay is experienced. Finally, Shadowing has value 10.818 and 19.008 respectively.

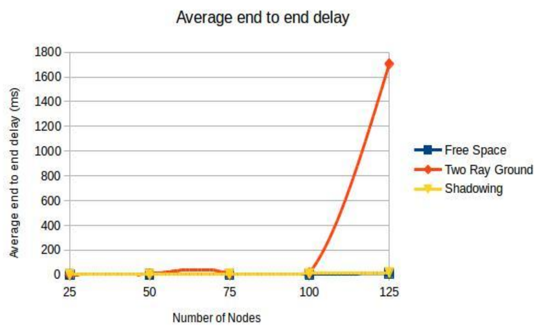

Fig.4. Average End to End Delay comparison

D. Average Remaining Energy

The values collected suggest that average remaining energy is optimum for free space model when number of nodes is either 75 and 100, the values are 7.999 and 5.842 respectively while at this point average remaining energy is less for Two Ray Ground model as well as Shadowing with values 6.627 and 7.244 respectively in former and 6.604 and 5.233 respectively for later. Further, when a number of nodes are 25, 50 and 125, Shadowing outperforms other two radio propagation models with values 12.274, 9.057 and 9.954 respectively. Free Space models experience remaining energy values like 8.603, 3.520 and 3.285 respectively and Two Ray Ground has values like 8.031, 6.588 and 7.267 respectively.

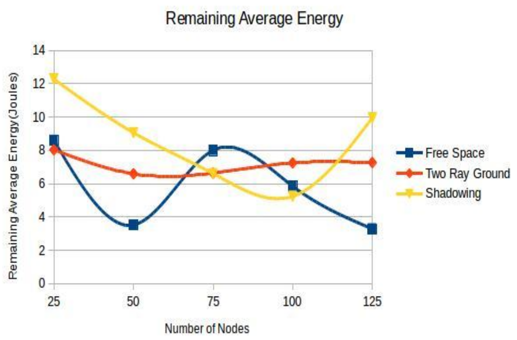

Fig.5. Average Remaining Node Energy

E. Normalized Overhead

In this parameter also the maximum overhead is in case of Two Ray Ground with value 6.26, while the other two models that is Free Space model and Shadowing has values as 0.245 and 0.433 respectively. Further, when a number of nodes are 25 and 50, the values achieved for Shadowing are 0.079 and 0.173 respectively. While for Two Ray Ground the values minimum that is 0.061 and 0.102 respectively and for Free Space models, the values are 0.064 and 0.109 respectively. Again when a number of nodes are 75 and 100, the values for Shadowing is 0.223 and 0.349 respectively. While another model that is Two Ray Ground model has outcomes as 0.14 and 0.402 that is, this model has the least values among the other two models. Finally, Free Space has numerical values of 0.153 and 0.192 respectively.

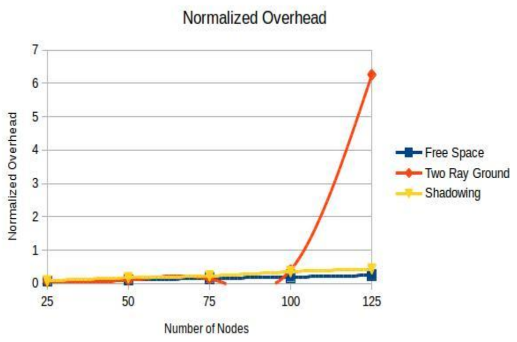

Fig.6. Normalized Overhead

Therefore all the five parameters strongly depict that Free Space model and Shadowing performs better in almost all the performance metrics.

VI. CONCLUSION

In this research work, path loss models are analyzed for J-ERLB models in the NS2 simulator and the best model is evaluated based on different performance metrics. The study shows a comparison between the three path loss and results suggest that Free Space Model and Shadowing model outperform the Two-Ray Ground model. This happens because of the reflection as due to reflection, the receiving node gets reflected signal with low signal strength which further causes packet drops in a network.

In Future work will include to explore the performance of the framework on more diverse propagation models and to find optimal among them. Further, to make existing routing protocol more energy efficient so that in case the node runs out of energy, then the second SenCar could be used as a backup.

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