IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received November 30, 2019, accepted January 2, 2020, date of publication January 9, 2020, date of current version January 17, 2020.

Digital Object Identifier 10.1109/ACCESS.2020.2965329

Performance Analysis of Modified AODV Routing Protocol With Lifetime Extension of Wireless Sensor Networks

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ABSTRACT Amalgamation of Re-Charging and Load Balancing are introduced here to overcome the problem of quick battery energy depletion and jamming in Wireless Sensor Networks. The primary approach (Re-Charging) is to maintain the desired energy level at each node in the network. The second method guarantees jamming-free communication in the network. To maintain the required energy level of the nodes, the SenCar visits the chosen anchor point along the pre-defined trajectory. At the chosen point, SenCar tests all the nodes within its coverage and re-energize all the nodes that have the energy level below the threshold value (3 Joules). Then, the SenCar moves on to the next anchor point and so on until the pre-defined trajectory completes. Finally, the implementation of the proposed mechanism proves the performance enhancement of Wireless Sensor Networks in terms of Throughput, Energy Level, and Packet Delivery Ratio.

INDEX TERMS Battery re-charging, load balancing, packet delivery ratio, wireless sensor networks.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) is the type of wireless networks in which millions of embedded computers (sensors) interact. Sensors consist of various subsystems such as processors, memory, power supply, radio, sensing subsystem, and actuator. These components require a massive amount of battery power to operate and therefore, due to this reason, the sensors deplete their energy very quickly. This condition leads to a fragmented network, and the data could no longer be fetched from the dead sensors. Hence, to maintain connectivity, such sensors must be recharged before they die to prolong the network lifetime. Thus, a two-way approach of recharging and Load Balancing is proposed for improving further the lifetime of WSNs.

Recent years have experienced an extensive research effort that has resulted in increasing the life span for WSNs. There are two broad categories of research which have been carried out to enhance the network life span. The first category is the conventional methods under which researchers had tried to reduce the power dissipation from the sensor and network aspects. These aspects cover subjects like less energy hardware design, less complicated software execution, and many more. The second category uses recharging techniques to mitigate energy limitation problem in sensors using mechanical, solar, or thermal methods. However, there are various environmental dynamics which disturbs the process of recharging. For illustration, the solar recharging approach using sun radiation is interrupted when the weather is cloudy. Many breakthroughs demonstrate the feasibility of restoring with high efficiency. There are lots of mobile phones which use wireless recharging capability and ensure high proficiency.

SenCar is a multi-functional mobile sensor which arbitrarily visits any node in a network and carries out the function of energy recharging. The Load Balancing is a technique to balance energy consumption of nodes in a fairly equilibrium manner. Therefore, to supply recharging energy to sensors effectively, and to mitigate the problem of congestion due to single route selection, SenCar and Load Balancing are merged. This merged approach is known as Joint Energy Recharging with Load Balancing approach (J-ERLB). This technique will not be affected by any external environmental variations, as the nodes will directly receive energy from SenCar. While traversing the sensors along the pre-defined trajectory, the SenCar will wirelessly re-energize the sensors in an area which can be effectively covered from that sensor to which it is physically attached. The recharging can be

The associate editor coordinating the review of this manuscript and approving it for publication was Tawfik Al-Hadhrami.

done by coupled magnetic resonance. Thus, many advantages can be achieved with the use of SenCar. First advantage is a cost-effective approach, which means that no external power generation equipment would be required for recharging the nodes in a network. Secondly, SenCar will perform a dual function, one to re-energize and others to calculate the remaining energy of a node. This paper aims to formulate a cost-effective solution to the problem and keep on checking the network by varying the number of nodes.

The paper is summarized as follows: Section 2 briefs literature survey for Energy-Efficient techniques and Load Balancing. Section 3 figures out the system description for the proposed approach, while section 4 reveals the J-ERLB model. Section 5 explains the simulation results and statistical comparison between the proposed method and the existing technique. Finally, section 6 concludes the paper.

II. RELATED WORK

This section of the paper surveys the various energy-efficient technologies and models for extending the lifetime and optimizing the performance of WSNs. This section broadly categorizes the literature survey in two parts. In the first part, Recharging techniques or models proposed are discussed, and the second part discusses the Load Balancing techniques. There has been a lot of research for improving the performance of the WSNs, but most of the work concentrates on energy management rather than energy replenishment in WSNs.

A. RECHARGING APPROACH

In the current scenario, energy recharging is being given the ample importance in wireless networks as drainage is becoming a vital issue of concern. Arivudainambi and Balaji [2] gave a mathematical model for calculating the energy used by different sensors in a cluster and energy recharging for gathering details of the sensors to be recharged. Gao and Yang [4] proposed an improved Daubechies wavelet algorithm that finds the optimum possible location for the wireless chargers. Chatterjee *et al.* [6] 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 efficiently to improve the overall lifetime of a system. Jan *et al.* [7] proposed a J- MERDG approach, in two-step approach. In the first step, the recharging tour is performed in which the SenCar is moved across anchor points and recharge the nodes with least remaining energy. In the second step, the data-gathering tour executes, and at that point, the tour evaluates the performance. Pal *et al.* [18] suggested a new way to manage the energy demand in every cluster with the use of Travelling Salesman Problem. Sheikhi *et al.* [20] proposed a limited knowledge charging approach in which each charging station formulates a virtual region using grid cells. The aim of limited knowledge charging is to extend the network lifetime using distinct methods. Han *et al.* [21] divided the network into multiple clusters using the K-means algorithm. In this paper, a semi-Markov model is also proposed for energy prediction to update anchor points in every round of its visit. Dasgupta and Yoon [22] defined an optimization problem known as delay-constrained energy minimization to locate the routes for mobile data collectors. Finally, to find the solution, an integer linear programming problem is created. Militano *et al.* [23] examined the constraints and the benefits of recharging and replacement of sensor nodes in WSNs. The decision points are firstly analyzed, and then it looks for sensors that need to be replenished or replaced. Singh and Kumar [24] reviewed the total examination that has been performed on the basis of three main features: applications, route methods and domains used to create the route. Engmann *et al.* [25] gave the detailed classification of power harvesting methods and systems that are followed. He *et al.* [26] examined dual problems of point provisioning and path provisioning. The former uses the minimum number of readers to guarantee that a stationary label positioned at any place of the network receives an adequate Re-Charging rate for sustained function, while the path provisioning develops the possible mobility of tags.

B. LOAD BALANCING APPROACH

Zhao *et al.* [1] proposed ''Maximum Connected Load-balancing Cover Tree'' algorithm in which dynamic Load Balanced trees forms, to accomplish full exposure while retaining the connectivity with the base station. Dhurgadevi and Meenakshi Devi [3] proposed a new distributed Ring Routing mechanism which is relatively energy-proficient and commonly known as a mobile sink routing protocol. This protocol is highly appropriate for time-critical applications. Wang *et al.* [5] 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 extensive. Liu *et al.* [8] proposed a new and efficient way to increase the lifetime of the network by introducing the feature of Load Balancing in WSN protocol. Ming-hao *et al.* [9] investigated that many sensor nodes die due to unbalanced load allocation, and for this reason, proposed energy-consuming and hole alleviating algorithms. Li *et al.* [10] proposed a novel graded node deployment strategy that forms the lowest traffic. Based on this node distribution, the distributed Load Balanced data collection algorithm is designed. Ahmed *et al.* [11] proposed a new approach towards clustering in which different nodes perform self-organization in a self-configurable pattern, which will help to maximize the network lifetime of WSNs. Singh *et al.* [12] described the necessary conditions for the utilization of bandwidth that makes efficient routing possible and further optimizes energy by applying ant colony optimization technique. Chauhan and Gore [13] 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 system. Barath and Kezi [14] introduced the cooperative-based routing methodology to assure a high-quality performance trade-off among energy effectiveness and reliability of the whole wireless examination structure. Arya and Sharma [15] used TDMA scheduling for organizing the time slot and thus aims at providing appropriate ability to the network. Chen *et al.* [16] proposed a multipath routing protocol, which is one of the efficient ways to save energy. Abd *et al.* [17] proposed a new Load Balancing method for data communication of WSNs that utilizes super-nodes with additional hardware and superior transmission capability to better understand data traffic reorganization. Load Balancing has become one of the essential techniques for managing the traffic load and hence saving the battery. Tunca *et al.* [19] proposed a method based on high energy efficiency called EBCNC (Enhanced-Balanced Compressed Network Coding). Through the technique of data compression, the collected data significantly gets reduced while on the other hand, with the help of the transport mechanism, the efficiency of data collection is maintained.

Based on the facts of a literature survey, an observation has been made that the sensors consume extra energy when it communicates with other sensors in a network. Also, the depletion rate is more due to extra burden for transferring the data. Hence, many researchers have proposed several models or techniques to enhance the lifetime of wireless networks and wireless sensors.

III. SYSTEMS DESCRIPTIONS FOR PROPOSED APPROACH

Even though the number of researches in this area has shown excellent performance; still, none of the technique implemented the combined approach of Load Balancing technique along with the recharging feature of SenCar. Load Balancing is a technique to balance the energy dissipation between the nodes in such a way that all the nodes degrade together within a network. In this paper, Load Balancing is performed by considering the queue length of every node in a network. Queue Length is checked, whenever it receives a new route request. If queue length of the node is occupied more than 75% of its total length or size, then the node will not accept the request, but will be diverted to the immediate first neighbour that can handle the traffic request according to the AODV protocol. This helps to avoid congestion in a system to improve the overall lifetime of a network. While, in recharging feature, SenCar is deployed to move across the anchor points. Movement of SenCar includes halts at an anchor points (fixed trajectory path) that are pre-defined so that it can collect the data pertaining to the nodes energy level from all the nearby nodes which falls under the communication range of that particular anchor point. Further, SenCar recharges those sensor nodes which are within the transmission range to half of the initial energy value of node. This increases the overall life span of the sensor node. Thus, the dual technique of Load Balancing and recharging helps to increase the lifetime and to eradicate the congestion in the network. For illustration, the practical application of a SenCar could be a drone, a robot, or any other heavy battery machine which can recharge other sensor nodes deployed in unreachable areas in a network.

Figure 1 demonstrates the architecture of the proposed approach. It consists of a large number of sensor nodes, out of which one node having ample battery storage is designated as a SenCar. Within an area of 1000 * 1000 meters, several sensor nodes are randomly distributed in a region of interest. The used sensor nodes are location-aware, and transmit the data to each other using hop by hop and time-division mechanism. Further, the base station schedules the SenCar to transfer instant energy supplementation to the node having energy less than the threshold. The green-colored nodes depict the full battery status which is initially set as 20 Joule, while the yellow-colored nodes show the average remaining energy (above threshold level and below 50% of initial energy) and red-colored nodes means that the nodes are about to die (that is its energy level is below the threshold value (3 Joules)). Therefore when the state of the node turns to red, SenCar recharges that dying node and change its status to green from red.

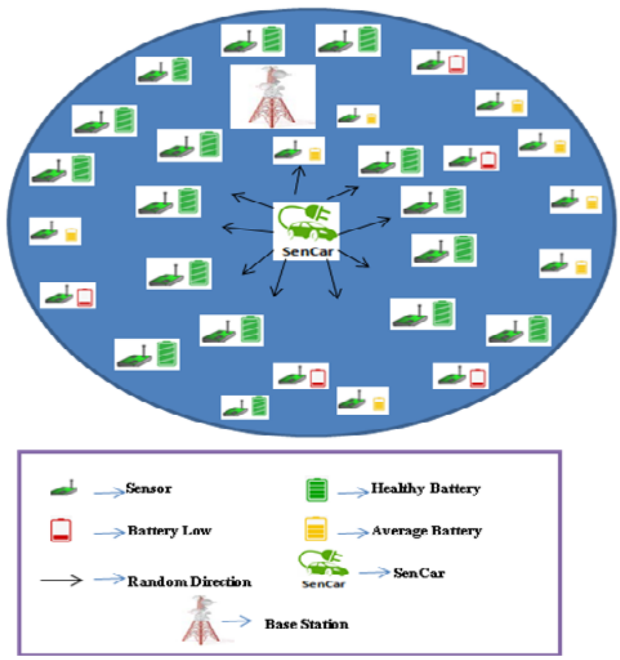

FIGURE 1. Architecture of joint energy replenishment with load balancing (J-ERLB).

This paper assumes the charging model used in [26]. SenCar is considered as a power transmitter and the other nodes as the power receivers. The transmission power of the SenCar is denoted by $S_{tr,}$ and N_{re} means the received power by the node. The relationship between S_{tr} and N_{re} is depicted as:

$$S_{tr} = \frac{G_{tr} G_{re} \eta \mathrm{Nc} \mathrm{N}_{re}}{Lp} \left(\frac{\alpha}{4\pi(d+\beta)} \right)^2 \tag{1}$$

In the above equation (1), η is rectifier efficiency, N_c is the congestion within a network, Lp is polarization loss, d is the distance between the SenCar and the receiver, G_{tr} is transmitter antenna gain and β is the constant used for Friis' Free Space short distances, and G_{re} is receiver antenna gain. Equation (1) can be simplified to:

$$S_{tr} = \frac{\sigma}{(d+\beta)^2} \quad (2)$$

where, $\sigma = \frac{G_{tr} G_{re} \eta \mathrm{Nc} \mathrm{N}_{re}}{Lp}\left(\frac{\alpha}{4\pi}\right)^2$ and experimental values for σ is 4.32×10^{-4} and β is 0.2316.

Equation (2) can further be simplified and analyzed as:

$$S_{tr} \propto \frac{1}{d^2} (\text{Where } \sigma \text{ and } \beta \text{ being constants}) \quad (3)$$

As the data communication in the WSN takes place, the energy level of the participating nodes start decreasing mainly due to the factors: energy consumed during transmission mode, energy consumed during reception mode, energy consumed during idle mode, energy consumed during sleep mode and energy consumed during transition mode. Thus the average energy at the node can be calculated as:

$$TEC = EC_{tr} + EC_{re} + EC_{id} + EC_{sl} + EC_{tp} \quad (4)$$

where TEC is total energy consumption, EC_{tr} is the energy consumption during transmission mode, EC_{re} is energy consumption when receiving a packet, EC_{id} is the power consumption when node is idle, EC_{sl} is the energy consumption during sleep mode and EC_{tp} is the amount of power consumption during the transition power mode. Equation (5) indicates total energy consumption of a single node. Therefore, the energy consumption of all the nodes (TE) in a network is calculated by following formula:

$$TE = \sum_{i=0}^{n} TEC_i \quad (5)$$

Thus, the formula used for calculating the remaining energy is as follows:

$$AVGRE = \frac{\sum_{i=0}^{n} IE - \sum_{i=0}^{n} TE}{N} \quad (6)$$

In the above equation IE is the initial energy supplied to each node in a network.

Further, as the data communication in the network proceeds, the delays get introduced due to the various transmission impairment factors (attenuation, distortion & noise) and the increased traffic i.e. congestion. Congestion here means delay. The delay can be calculated as:

$$Delay = \frac{1}{N} \sum_{n=1}^{N} (\mathrm{Re}n - Sen) \quad (7)$$

where, N is received number of data packets, Re_n is the time at which nth data packet is received and Se_n is the time during which nth data packet is sent.

However, there are some important considerations for evaluating the effectiveness of the proposed approach such as delay, and average remaining energy. The delays may occur during the transmission process which includes the transmission delay, the propagation delay, queuing delay, and processing delay. The transmission delay is the time taken to transmit bits in the form of packet. which is the time taken by the packets to reach from one end of the link to the other end, queuing delay is the delay in which packets wait in the buffer of a router buffer before being transmitted and the processing delay is experienced by the packet when routing tables is consulted by routing to decide where to forward the packet. The average end-to-end delay can be calculated by adding each delay for successive packet and then it is divided by the number of successively received packet (6). Further, Average Energy Consumption (AEC) also depends upon the number of nodes in a network as average remaining energy is inversely proportional to the number of nodes in a network (6). This AEC can be calculated if the value of total energy consumed by all the nodes in a network is known (5). The total energy consumption is the summation of energy consumed during the transmission mode, receiving mode, idle mode, sleep mode and transition power mode (4).

IV. J-ERLB (PROPOSED MODEL)

This section presents the implementation of a proposed J-ERLB mechanism in case of WSNs. Here, it has been assumed that the nodes are randomly deployed and then 2-way approach for recharging and Load Balancing is applied to increase network lifetime. The J-ERLB model will not only improve the lifetime of the WSN; but also balance the load and improve the PDR and throughput of the system.

A. PROBLEM FORMULATION

A Collaborative approach of energy replenishment and Load Balancing to improve the performance and extend the lifetime of WSNs using modified SenCar.

B. DETERMINISTIC SOLUTION

This section proposes an optimal solution to the problems formulated above. The proposed 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 will randomly move across the network to calculate the remaining energy of each sensor node in network. The SenCar will compare the value of remaining energy with the threshold energy level. If the value of the calculated energy level of a node is below the threshold value, then the SenCar will recharge that specific node with half amount of value (10 Joules). But, if the energy level of the node is above the threshold value, then the SenCar will move to the next anchor point node in the network. As shown in Fig.1: the red nodes (dying nodes) are those nodes which are having lesser energy than the threshold value, yellow indicates an intermediate level of energy, and green indicates the healthy level. The following pseudo-code depicts the working of the first phase:

If N[R] = TRUE
Recharge node

Else

Move to next node randomly and check its status

The second phase and third phase shows, how a path is established between a sender and receiver in the routing protocol. It checks if the queue size at a node is less than 75%, then only it will be used for transferring the data. Otherwise, a new path gets chosen. This is how the Load Balancing gets performed. The discussion for the proposed solution is through the following algorithms:

Phase 1 (Recharge module)

R_tour() /*This function is used to re-energize the dying nodes*/
{
for(0 to n) check_node_energy ( ) /*This function is used to re- energize the dying nodes*/
{
if(node_energy<threshold) /*This is a condition where level of energy is compared with the threshold value*/
{
recharge_node();/*This this function will reset the energy of the node to a certain level*/
}
}
}

Phase 2 (Path establishment routine in routing protocol)

send_request (destination_id); / Node initiates path discovery to transmit data*/*
Recv_request(packet) / When request is received at a node*/*
{
if(index==packet_destination || route_available()) / Condition is matched here*/*
{
send_reply(queue length); / Reply packet is sent with queue length of the node*/*
}
else
{
forward_packet() / Packet is sent with queue length of the node*/*
}
}
Recv_reply(Packet) / Forward path is established after receiving reply*/*
{
add_route(); / Path is added in routing table with queue length*/*
}

Phase 3 (Path selection routine)

select_path (destination) / Path selection is done based on queue length*/*
{
*if(path_queue_length<0.75*max_queue_length)/* Packets in queue should be less than 75% of max queue length for path to be used */*
{
return path; / Path is returned*/*
}
}

V. SIMULATION RESULTS AND PERFORMANCE ANALYSIS

A. SIMULATION ENVIRONMENT AND PARAMETERS USED

This section discusses the result comparison between AODV with SenCar and AODV with SenCar Load Balanced. In this section, simulation has been performed to check the performance of the proposed J-ERLB method. The parameters used for experimentation are shown in Table 1. The transmission range of each node is 6 meter, and every node is randomly distributed in an area of 1000 m × 1000 m. SenCar moves at a speed of 0.5 m/s and Omni-Directional antenna type is used as it provides consistent coverage in all direction, which directional antenna cannot. The initial energy of each node is 20 J. Also, the size of a data packet is 128 bit. Table 1 shows some of the specification implementations of J-ERLB:

TABLE 1. Scenario details.

Name of Parameter	Selection
Area	1000 * 1000 m
Speed of SenCar	0.5 m/sec
Data Packet Size	512 kb
Initial Energy of SenCar	500 J
Default Queue Length for Load Balancing	50
Threshold Queue Length for Load Balancing	35
Antenna Type	Omni-Directional
Propagation Model	Two-Ray Ground
Initial Energy	20 J
Average Energy	10 J
Threshold Energy	3 J

In this section, the effectiveness of the proposed model is evaluated based on the numerical values achieved in the case of SenCar_LoadBalanced and SenCar. Following parameters have been used to test the effectiveness of the proposed model:

Packet Delivery Ratio PDR is the number of packets actually received by the receiver in comparison to the packets delivered by the source in a single attempt.

Figure 2 depicts the PDR of the SenCar with Load Balanced technique and without Load Balanced tech-

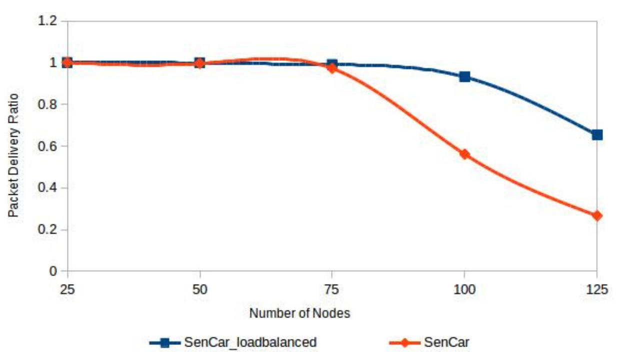

FIGURE 2. PDR with SenCar and SenCar_LoadBalanced.

nique. The graph shows that the PDR is .6528 with the LoadBalanced technique (SenCar_LoadBalanced) while it is .266 without the Load Balanced feature in a SenCar which uses AODV for routing in the network. Initially all nodes are fully energized and number of nodes is also comparatively less, the PDR is quite high and comparable. But with the increase in time and number of nodes, the performance of the SenCar without Load Balancing falls drastically because the nodes start entering the red zone (energy level starts falling below threshold value of 3 Joules) as the traffic congestion due to fixed path selection leads to high utilization of energy among the nodes for transmission. Thus the SenCar's own battery gets depleted after a period of time which further leads to packet drop and hence PDR also drops in accordance with (3).

Moreover, the transmission of energy by SenCar also depends on the distance between the nodes and the anchor point. Only those nodes will receive the energy from SenCar which are within the transmission range of anchor point and with the increase in the distance, the range of transmission declines sharply and becomes low which can be ignored if value of distance is less than a threshold value, that is $S_{tr} = 0$ if $d > 100$ meter. This is general transmission range of a sensor node in WSNs.

Therefore, the energy transmission of SenCar purely depends upon the network congestion and the distance. This makes it costly or impossible to re-charge the nodes due to SenCar's own battery depletion problem and as a result of it, the energy level of the node falls below the threshold value. The sensor node is unable to transmit the data as the required minimum level of energy is missing as a consequence the PDR falls.

While in the case of Load Balanced SenCar routing; the SenCar randomly moves to any node in the network and as the network size increases, the Load Balancing feature divides the load to less congested route. In this way, nodes within a network consumes less energy and hence the SenCar would be able to work for longer period of time as it would find less nodes with red zone, which further leads to less packet drops with high PDR outcome. The re-energizing mechanism first of all calculates the energy level of the node and re-energizes it to half of its capacity so that it's life can be extended (recharge module) in both cases of SenCar without Load_Balanced and SenCar with Load_Balanced as shown below:

```
/* If N[R] = TRUE
Recharge Node
Else
move to next node randomly and check its status *//*
R_tour() {
for(0 to n) check_node_energy ( )
{
if(node_energy<threshold)
{
recharge_node();
}}}
*/
```

Then the Load Balancing feature detects the traffic load on that node. If the waiting queue is already occupied to 75% of its total length, then the traffic from that node is partly shifted to the neighboring nearest node that can accommodate load (Path Selection routine):

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

Throughput

Throughput is the number of predefined data units successfully received at the receiver from the total number of actually transmitted data units from source to the destination over a specified time period. Consequently, to calculate the throughput for a network or a network segment, the data units successfully received by all the nodes individually for specific time duration are summed up. Figure 3 illustrates the throughput of SenCar (Without Load Balancing) and the SenCar_LoadBalanced (with Load Balancing).

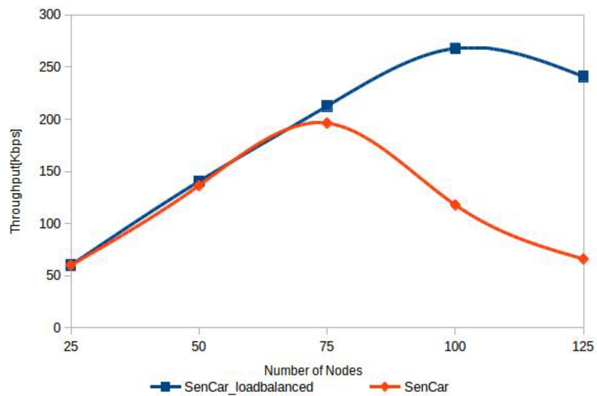

FIGURE 3. Throughput for SenCar and SenCar_LoadBalanced.

Here, the SenCar starts along the predefined trajectory from the first anchor point. It recharges the anchor point and all the nodes under its administration and moves on to the next anchor point without focusing on the traffic on the node(s) while being recharged. As more is the traffic on the node more will be the energy consumption at that particular node (4). Hence many of the nodes get quickly depleted and may sometimes die-off before they are recharged. Since many of the nodes get quickly depleted or die-off, so unable to transmit/receive the data units which ultimately leads to the downfall in the throughput.

In order to overcome the problem of extra traffic on certain nodes, the SenCar_LoadBalanced in addition to the recharging the anchor point and its dependant nodes, checks the amount of traffic at each node(s) that is recharged. If the traffic on the node recharged is more than 75 % of the total queue length of that node then some of the traffic is shifted to the immediate neighboring node that can handle the traffic. And the traffic on that particular node is reduced to below the 75 % of its total queue length. In doing so the waiting time on the transmitting or intermediate node(s) get reduced drastically due to shorter queue lengths. In other words delays are reduced according to (7).

If delays are reduced, means more number of data units can be transmitted / received per unit time. Therefore the throughput is increased as proved in the Fig: 3.

B. AVERAGE REMAINING ENERGY

Average Remaining Energy is defined as the amount of energy left with a node when the data transmission has finished. In wireless recharging sensor networks, most of the power is used during the transmission/reception processes.

With the increase in the number of nodes, the average remaining energy (AVG_{RE}) decreases (6). Therefore, to prevent the nodes from dying and to keep them in the active state for the longer durations (desirable in WSNs) recharging and Load Balancing are required at regular intervals of time.

Now the SenCar moves along designated trajectory and recharges the anchor nodes on the First Come First Served Basis (FCFS) till it drains out. Thus, not able to complete the designated trajectory most of the times due of the scarcity of energy. As a consequence most of the far-off nodes get depleted and die-off because not recharged on time and the excessive data transmission (maximum energy utilized during EC_{tr} and EC_{re}).

On the other hand the SenCar_LoadBalanced moves along the designated trajectory. Stops at the anchor point. It first of all checks the energy level of the anchor node (recharges it to its half of its initial value, if required). Secondly, it checks the traffic at that anchor point. If the traffic is more than 75% of its queue length, it redirects some of the traffic to the neighboring node so that the traffic on the node falls below the 75% of its queue length. Thus, reducing the EC_{tr} and EC_{re} (4) on that anchor node by redirecting some of the traffic to some other node. Since the transmissions and receptions are reduced by diversion of traffic, the average remaining energy (AVG_{RE}) is prolonged which keep the anchor point in the active state for longer time period. This process is repeated for all the nodes in the cluster of that anchor point, after that the SenCar_LoadBalanced moves on to the next anchor point and ultimately completes the designated trajectory. Hence the SenCar_LoadBalanced is better able to cater the WSN as proved in the Figure 4.

Therefore all the three parameters depict that AODV SenCar_LoadBalanced shows better performance as compared to the ordinary SenCar.

VI. CONCLUSION

To circumvent the ill effects of Sensor Nodes, the dual approach of energy replenishment and Load Balancing are proposed for the WSNs. Explicitly, a SenCar is implemented in the rechargeable WSNs, which moves to pre-defined anchor points along the designed trajectory and recharge the positioned sensors by means of wireless power transmissions. SenCar first of all measures the remaining energy level of the sensor nodes within its range. Then, in two-step approach, the entire WSN is analyzed to finalize the anchor points and define the trajectory. In the primary step, the desired energy level at each node in the network is maintained. Then, in the secondary step, congestion free communication within the network is maintained. In this way, every Sensor Node regulates the data speed, and routing on its own such that the whole network's resources are optimally used and lifespan is extended. Finally, extensive statistical outcomes reveal that the proposed dual approach can efficiently sustain continuous network operations and improve the performance as well as life-time.

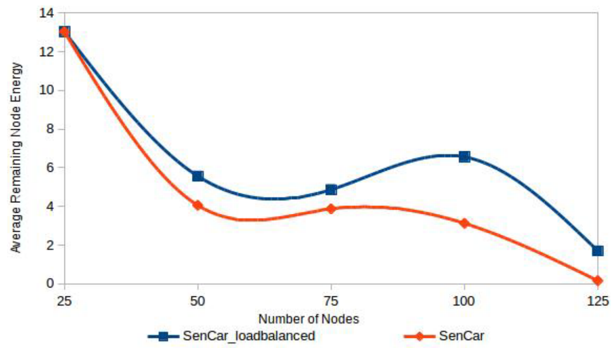

FIGURE 4. AVG_{RE} for SenCar and SenCar_LoadBalanced.

FUTURE WORK

The work presented still suffers from some issues which can be further improved:

- Self depletion of battery is the main drawback of the WSNs. A novel technique for minimizing / halting automatic depletion can be implemented to overcome this problem.
- Cellular nature of SenCar can be implemented to improve the performance of the SenCar itself.

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