Received: November 17, 2018

International Journal of
Intelligent Engineering & Systems

http://www.inass.org/

Optimized Routing Enhancement for WSN with Balanced Load Mechanism

Mandeep Kaur[1]* **Balwinder Singh Sohi[2]**

[1] *IK Gujral Punjab Technical University, Jalandhar, Punjab, India*
[2] *Chandigarh Group of Colleges, Mohali, Punjab, India*
* Corresponding author's Email: mandeepkaur03@gmail.com

Abstract: Wireless Sensor Networks (WSNs) provides a great support and solution in the field of wireless technologies used in the industrial application. WSN faces serious reliability and load management issue when the power management terminology is enabled to prevent the network from excessive collision. This might result into a very low Packet Delivery Ratio (PDR), reduced network lifetime and high latency. In real time environment, a sensor node may suffer failure due to dust, corrosive agents and due hard weather etc. In that case, if the load increases on sensor node, it requires a reliable sensor node which can share the load. Reliable communication and load balancing among sensor nodes saves undesired consumption in collisions, data resending and data checking. This paper focuses on developing a novel framework enhancing the features of WSN to solve the reliability issue and load balancing problem with broadcast mechanism never used before in this scenario. The proposed framework utilizes a unique combination of Genetic Algorithm-Particle Swarm Optimization and Artificial Neural Network for load balancing architecture. The proposed architecture also utilizes some features of Ad hoc network also but with new terminology so that the packet reaches to the sink in timely fashion and maximum battery and network life along with minimized delay is attained. The proposed framework is evaluated using delay, energy consumption and throughput. One of the recent research works in this area is presented by Liu, Anfeng, et al and the proposed framework is also compared with the results of Liu, Anfeng, et al. By comparing the proposed results with existing, energy consumption of proposed work is reduced with better network lifetime by using the concept of load balancing technique.

Keywords: Network Lifetime, Reliability, Energy efficiency, Delay, WSN, Load balancing.

1. Introduction

In the modern world of technology, real-time industries like factory automation, real-time monitoring system uses Wireless Sensor Network [1] very often. A Wireless Sensor Network is made up of tiny sensors which get power from small batteries. If the network is not properly managed, a node failure may lead to high latency, packet drops and also reduces the lifetime of network [2]. Every source node is listed with a queue in which it stores the requests from other sensor nodes. The key requirements of any WSN application where there is less human intervention is Energy Optimization [3], Network Reliability and on time delivery. The sensor nodes typically get power from small batteries, resulting into limited energy budget frame. The batteries of Nodes can't be charged or replaced once a network is deployed to minimize the cost.

To prevent the batteries, power management is usually employed. WSN includes the power management as a necessary standard [4]. A WSN can be very small consisting of 10 nodes or it can be very big consisting of hundreds/ thousands nodes (Large geographical monitoring). In real time industry, the sensor readings may face failure or drop or a very long latency due to congestion. This paper has tried to solve the following problems in WSN which are [5]:

- Reliability Congestion
- Packet Delivery on Timely fashion.
- Load Balancing

The above section has described the context of the research paper and describes the wireless sensor network following the key requirements with the problems that would be considered for the execution [6].

The architecture of the proposed algorithm is explained in the third section into four steps that is set up of the network, Broadcasting, trust model development and the load balancing. Later the network parameters are being determined. The approach is designed and executed in the next section that is results and discussion. This section explains the results of the parameters, namely, Throughput, Energy, Delay, Collision, Battery Charge, Battery Life, and Network Lifetime for different nodes. The execution of the parameters is taken for with and without broadcasting. The proposed architecture optimizes the reliability and lifetime with the introduction of cache memory and broadcasting concept [8].

The proposed research work has utilized a combination of Genetic Algorithm-Particle Swarm Optimization and Artificial Neural Network (ANN). ANN is comprised of three layers namely input, hidden and an output layer. The input layer is responsible to take the raw data whereas the hidden layer transforms the data into a format which is understandable by ANN. Weight generation mechanism is used to propagate the input data to attain the best training architecture [9]. All the optimization algorithms run over the fitness function designed to attain the maximum goal. GA-PSO is a hard threshold algorithm hence the fitness function is designed in such a manner that only relevant data is selected [10].

The rest of the paper is organized in such a manner that section 2 represents the related work which represents the work done in a previous year in the same contrast. Section 3 is the proposed work with results section elaborated and compared in section 4. The paper is concluded in section 5 and a hint of futuristic approaches in this arena is given.

2. Related work

A lot of research work has been done by various researchers working around the globe. Following survey gives a brief review of load balancing mechanisms along with energy minimization algorithms.

Xinming Zhang in 2016 has presented an efficient broadcast protocol for asynchronous wireless sensor networks based on dynamic delegation approach. In this work, energy consumption, delay, and transmission rate is calculated as a performance metrics. The proposed work has used destination node that receives a data packet from an appropriate sender node but there is a problem in the load balancing on nodes according to the data packet. If the data packet is unbalanced then the chances of energy losses are more. In the proposed work, the focus on minimizing the energy consumption rate during the simulation using a broadcast protocol with load balancing mechanism. Felix Dobslaw in 2016 has presented a model based on end-to-end reliability-aware scheduling approaches for wireless sensor networks. In this research, a issue occurs during scheduling. The proposed simulation cannot support multi-channel scheduling. To overcome this type of problem, the author has proposed a load balancing based trust model for scheduling the transmission for multi-users based on reliability and load balancing mechanism using broadcasting protocol. Xingcheng Liu in2015 has proposed joint network-channel coding (JNCC) technique in wireless sensor networks using dynamic energy consumption optimization scheme, but, in this, the time delay is just acceptable and the rate of energy consumption per bits is high due to the lack of an appropriate route set up between the transmitter and receiver. To sort out this problem of the researcher, the researchers have designed a simulation model on the basis of energy consumption by using the trust model approach. In this work, the performance metrics like energy consumption and bit error rate are computed. Yanjun Li in2009 has presented Two hop velocity based routing (THVR) protocol in Wireless Sensor Networks to improve the delivery time. In this work, the researchers have used the velocity based routing algorithm with a trust model to minimize the miss ratio problem. Kuila in 2013 has proposed load balancing clustering based on GA optimization technique whereas in proposed work hybridization of GA and PSO is proposed to enhance network lifetime along with reducing end to end delay. Amir Ehsani Zonouz in 2016 has proposed a reliability, cost, and energy-aware approach in hybrid wireless sensor networks. In this work, the failure of the node occurs during the data packets transmission, so, the rate of packet drop is more and to sort out this problem in proposed work, the researchers have used end-to-end route reliability approach based on the trust model and load balancing mechanism. Saman Siavosh in 2016 has presented Load balanced mechanism using energy efficient clustering protocol for wireless sensor networks. In this research, some important parameters like nodes aliveness, network lifetime and data packets transmission rate are calculated.

One of the major limitations of proposed work is low energy capacity, so, the efficiency of proposed work is dependent on the energy of sensor nodes. To minimize the energy capacity of sensor nodes, some mechanisms such as timing-radio approach, limited control packets approach, and topology control integration approach is provided with the balancing mechanism. Surinder Singh in 2015 has proposed trust and reputation models based wireless sensor networks simulator. In this work, trust and Linguistic Fuzzy Trust Model (LFTM) is used for the simulation of the wireless sensor network system. The researcher has calculated the efficiency of the proposed work on the basis of energy consumption, satisfaction rate and path length which is used for the transmission during the simulation. From this paper, the researchers have observed that with the increment in the sensor nodes, the rate of energy consumption is increased for both trust and reputation models. To minimize this type of problems, newer distribution strategies for the wireless sensor network domain based on the load balancing mechanism is proposed. A. Liu et al. in 2018 has presented a co-operative sensing mechanism for the route discovery process which inspires the proposed algorithm as well.

Sensor nodes are accessed remotely and placed where it is impossible to set up. To utilize the full potential of sensor nodes during the data transmission, we must first address the abnormal sensor nodes of these networks and the resulting technical issues. In this research work, a route optimization mechanism is proposed with the concept of load balancing to overcome the problems of existing WSN routing mechanism. The main problem of existing routing protocols is high energy consumption rate and balancing mechanism of nodes during the data transmission. If we reduce the energy consumption rate, then network lifetime is also improved because network lifetime is a major issue of WSN. There are a lot of work already presented to overcome these problems like optimization technique, fuzzy logic, and classifiers, but due to lack of load balancing concept, the obtained results are not acceptable and needed improvement.

3. Proposed work

The proposed architecture is divided into two parts:

- Routing Optimization
- Load Balancing

3.1 Routing optimization

The setup phase consists of three different node counts: 50,100 and 200. All the wireless sensor nodes have been deployed randomly. To maintain uncertainty into the network, energy node has been provided with random values of energy, battery units, and consumption unit. Now, as in real time scenario, it is obvious that some of the nodes will be in sleep state due to:

- Power management mode
- Critical due to battery issues
- Dead due to environment conditions

The active and sleep states have been designed as follows:

Active-Sleep state of the nodes // description: input;

Function act [f]=Activesleep(n)
n=total nodes
For i=1 to all n
Output:K=round(rand)
If: state of the node [active or sleep]
f[i]= “sleep”;
Else
f[i]= “Active”
Endif
End for

Now, as the nodes will be deployed in the network with random locations to maintain the uncertainty in the network. There would be source and destination which would be involved in the data packet communication. A path is required through which the data packets would be transferred. If a situation is considered when the data has to be transferred for the first time and no node is involved in any communication previously. In such a situation, it is very difficult to choose a path which is secure and fits in the budget.

Let λ be the coverage distance of any node
λ= width * 25/100;
Co_list=[ ]; cov_dist =[ ];
For each n_d in nodelist
x_i= xloc (n_d); // finding the xlocation of the node
y_i= yloc (n_d); // finding the ylocation of the node;
Covcount=0;
For each n_jin the node list
If n_d!= n_j // if both the nodes are not same
x_p= xloc (n_j);
y_p= yloc (n_j);

d = sqrt ((〖x_i-x_p)〗 ^2+(y_i-y_p)^2);
If d<=λ
cov_list [n_d,covcount]=n_j;
cov_dist [n_d,covcount]=d;
covcount=covcount+1;
End if
End for
End for
Cov_list = [Node d, Node p, Node j, Node l]- Node x
Cov_dist = [220,240,250,245];

Now X will transfer the data to the node which is nearest to Node X that is Node d. Furtheron, Node d will follow the same procedure as that of node X. the chain will continue till the destination is not attained. Method B will be followed only when the broadcast response list is empty.

3.2 The trust model

Wireless network faces a latency and load balancing problem due to the absence of a trust model [21]. The network has to select the path every time to transmit the packet data. In this procedure, the network has to always look for available nodes without considering the fact that whether the nodes would be trusts worthy or not. The search and solution process consumes a lot of time and energy, thus increases the battery consumption if the data packet not delivered properly [22]. To avoid such delay in addition to the broadcast concept a trust model is proposed. The key aspects of the trust model are as follows:

If a node X delivers a packet successfully between source S and destination D then the proposed algorithm puts the node into the trust list for the path P(S, D). The node remains in the trust list as long as it does not start consuming energy more than ΔE for the packet transfer.

The proposed architecture in the world involves a monitor system deployed into the network to check the following specification:

If the node X is changing its position from the coordinates (Xx,Yy) to $(\overline{Xx},\overline{Yy})$, but still remains in the coverage set of transferring node as per method B.

If the node X is consuming energy less than ΔE or not is deleted from the trust list. The trust model can be explained as follows:

Let us consider the Figs. 1 (a) and (b). Fig. 1 (a) shows that node X has a node to a different position but still coverable by Node X, in this case, Node X will remain into the trust list as per the trust model.

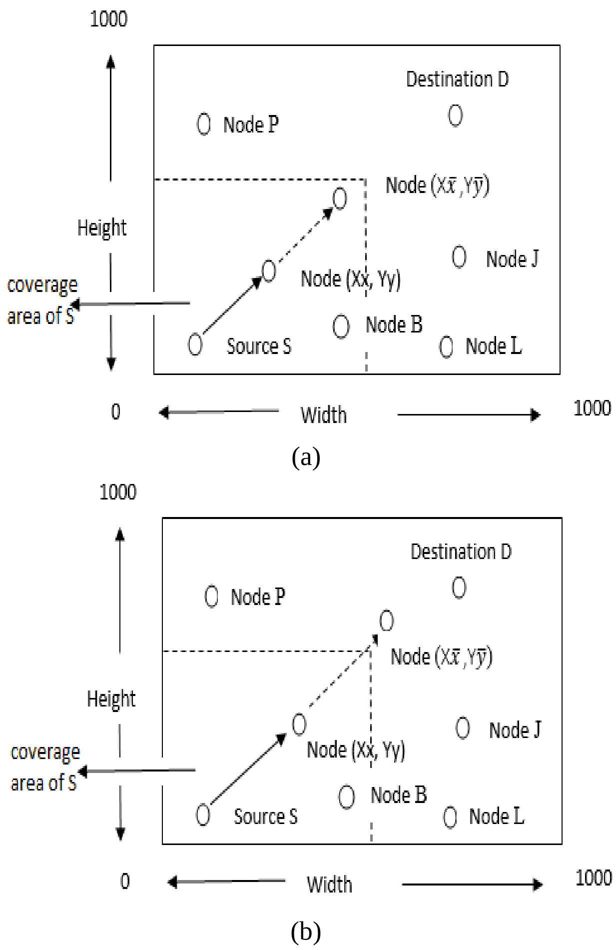

Figure. 1 Examples: (a) node inside the coverage area and (b) node outside the coverage area

In Fig. 1 (b) the Node X move to a new position and it is now it out of the coverage area of Node X in such a scenario it will be deleted.

3.3 The loading balancing

The load balancing mechanism is adapted from one of the previous works done by the author itself. In this framework, the sensor node is assumed to be a processing node with multiple processing units. Each processing unit is computed with processing cost and the minimum processing cost element is selected as a transfer node unit.

The proposed work also utilizes a hybrid structure of GA and PSO for route optimization [23].

Function Optimized Route= Optimize_Hybrid(Nodes.architecture)
Define nodes properties

1. all_x=Node.architecture.x // X coordinates of nodes
2. all_y= Node.architecture.y // Y coordinates of nodes
3. Defined coverage range, Cov_range=[ ]

4. **For i=1 to Total_Nodes**
5. **For j=1 to Total_Nodes**
6. $dist = sqrt((all\_x(i) - all\_x(j))^{\wedge}2 + (all\_y(i) - all\_y(j))^{\wedge}2)$ // Calculate distance between nodes using distance formula
7. **End** for
8. **End** for
9. Source, identify_source( );
10. Destination, identify_destination ( );
11. initial_population_ga= Node . Count;
12. mutation_initial_value=.5
13. cross_over=" linear" ;
14. ga.optimset={ Population , Mutation , Crossover , fitness function }.
15. Find_Node_next_hop =ga.fitness.value();
16. **If node.fitness_accepted**
17. Add node to path;
18. **End** if
19. **If (Path.finalized)**
20. ttl= length.Path(); // total elements
21. **For i=1 to ttl**
22. intial_velocity = random;
23. initial_displacement=random;
24. find_pso_fit(initial,velocity ,initial_displacement,route_path_elements)
25. find_best_fit(pso_fitness)
26. **If satisfied (sendpacketthrough)**
27. **End**if
28. **End** for
29. **End**title.

The above mentioned algorithm is a hybrid algorithm and is designed by using the concept of GA and PSO to optimize the route discovery mechanism based on the fitness function.

4. Results and discussions

This section explains the results obtained after the evaluation of the proposed work. The results have been shown in form of graphs and tables. From the above graph, as shown in Fig. 2 and Table 1, it can be concluded that using broadcasting method throughput values has been enhanced w.r.t. without broadcasting method. It has been seen that without broadcasting method maximum throughput is 87.41. On the other hand, throughput attained by the broadcasting algorithm is 88.17.Ina similar fashion; Fig. 3 represents the throughput with the broadcast.

Table 1. Throughput evaluation without broadcasting

No. of Iterations	**Throughput with 50 nodes**	**Throughput with 100 nodes**	**Throughput with 150 nodes**
1	85.85	86.38	86.94
2	85.98	86.82	87.41
3	86.73	86.14	86.96

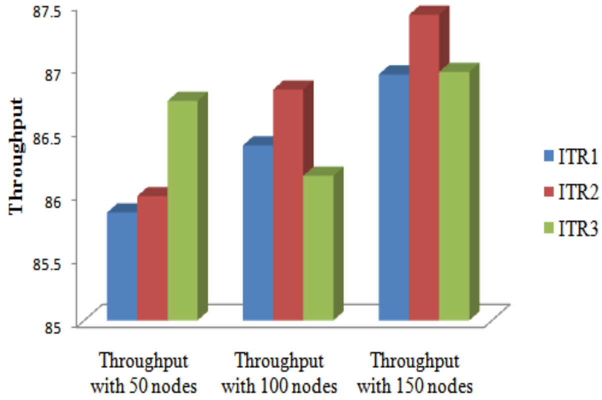

Figure. 2 Throughput with 50, 100 and 150 nodes without broadcasting

Table 1. Throughput evaluation with broadcasting

No. of Iterations	**Throughput With 50 Nodes**	**Throughput With 100 Nodes**	**Throughput With 150 Nodes**
1	87.23	88.34	89.45
2	87.46	88.23	89.43
3	87.34	87.89	88.22

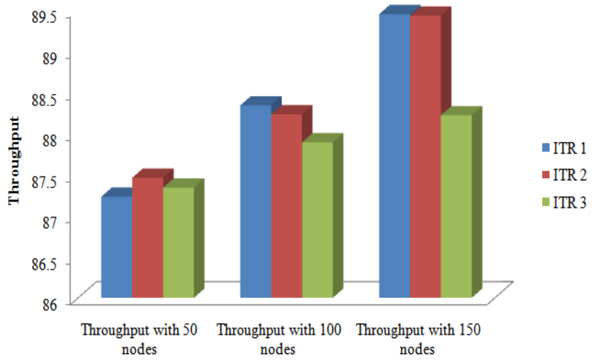

Figure. 3 Throughput with 50, 100 and 150 nodes with broadcasting

Table 2. Energy without broadcasting

No. of Iterations	**Energy with 50 node**	**Energy with 100 nodes**	**Energy with 150 nodes**
1	12.63	11.75	10.22
2	13.44	11.93	10.89
3	14.52	12.32	10.53

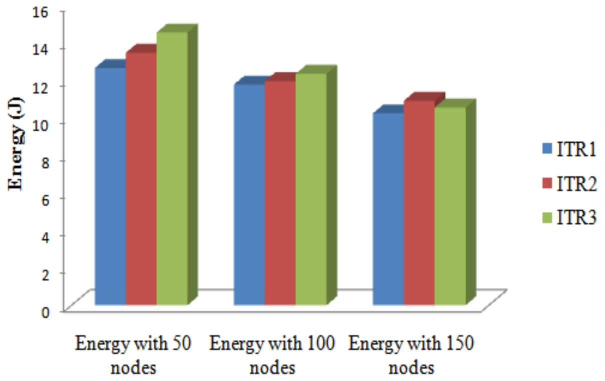

Figure. 4 Energy with 50, 100 and 150 nodes without broadcasting

Table 3. Energy consumption with broadcast

No. of Iterations	Energy with 50 node	Energy with 100 nodes	Energy with 150 nodes
1	6.43	4.35	3.29
2	8.47	5.38	3.32
3	8.95	5.96	4.33

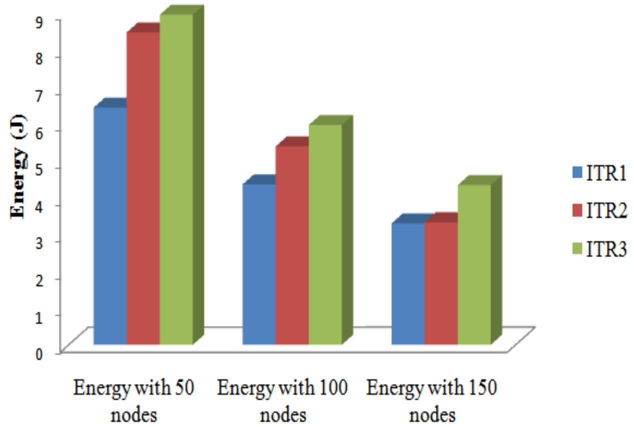

Figure 5. Energy with 50, 100 and 150 nodes with broadcasting

Energy consumption is the total utilized energy for transmission of data packets from source to destination. The result as shown in Fig. 4 and Table 3, the low energy consumption using the broadcasting method and the average value for without broadcasting is 13.53 J for 50 nodes, 12.00 J for 100 nodes and 10.54 J for 150 nodes. Fig. 5 represents the energy consumption of the network with respect to the broadcast.

Figs. 6 and 7 represent the delay of the network with respect to with and without the broadcast in the network. Tables 5 and 6 represent the numeral values of delay for with and without broadcast. The tables clearly depict that the delay with broadcast is less as compared to the delay without broadcast.

Table 4. Delay without broadcasting

No. of Iterations	Delay with 50 nodes	Delay with 100 nodes	Delay with 150 nodes
1	17	23	29
2	19	25	35
3	21	29	41

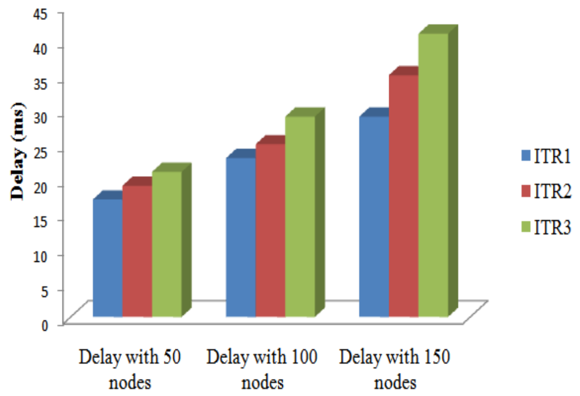

Figure. 6 Delay with 50, 100 and 150 nodes without broadcasting

Table 5. Delay with broadcast

No of Iterations	Delay with 50 Nodes	Delay with 100 Nodes	Delay with 150 Nodes
1	12	18	24
2	14	19	26
3	18	21	32

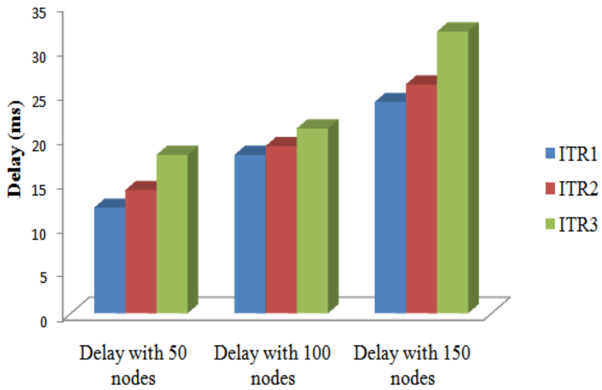

Figure. 7 Delay with 50, 100 and 150 nodes with broadcasting

Table 7. Network Lifetime without broadcasting

No. of Iterations	Network Lifetime with 50 nodes	Network Lifetime with 100 nodes	Network Lifetime with 150 nodes
1	3.2	4.6	5.1
2	2.3	4.1	4.9
3	2.1	3.2	4.7

Received: November 17, 2018

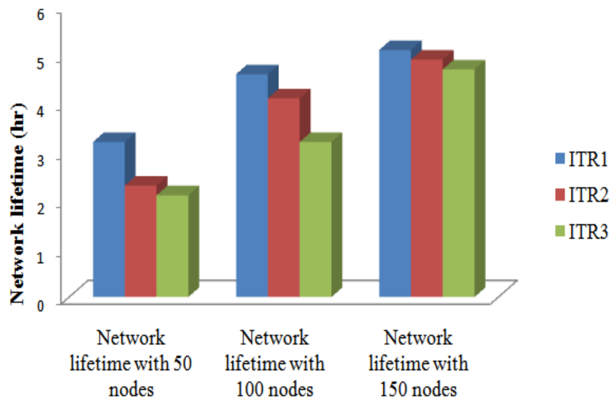

Figure. 8 Network lifetime with 50, 100 and 150 nodes without broadcasting

Table 8. Network lifetime with broadcast

No of Iterations	Network Lifetime with 50 Nodes	Network Lifetime with 100 Nodes	Network Lifetime with 150 Nodes
1	6.5	7.8	8.9
2	6.3	7.3	8.6
3	6.2	7.1	8.2

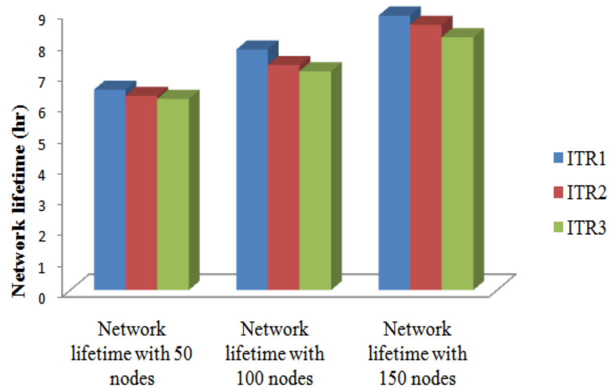

Figure. 9 Network lifetime with 50, 100 and 150 nodes with broadcasting

Figs. 8 and 9 represent the network lifetime with respect to with and without the broadcast in the network. Tables 7 and 8 represent the values of Network Lifetime for with and without broadcast. The tables clearly depict that the Network Lifetime with broadcast is more as compared to the Network Lifetime without broadcast. In Fig.10, the delay of the proposed framework is improved by 35% as compared to previously implemented algorithms. In Fig.11, The throughput of the proposed algorithm is 2-4% more as compared to previous architectures. Fig. 12 is depicting the comparison of energy consumption and it has been seen that the proposed framework is reduced by 38.19%.

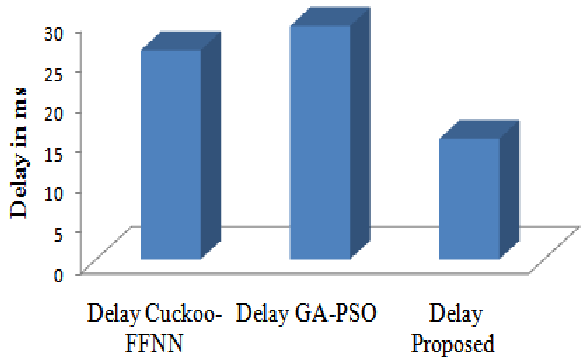

Figure. 10 Delay comparison

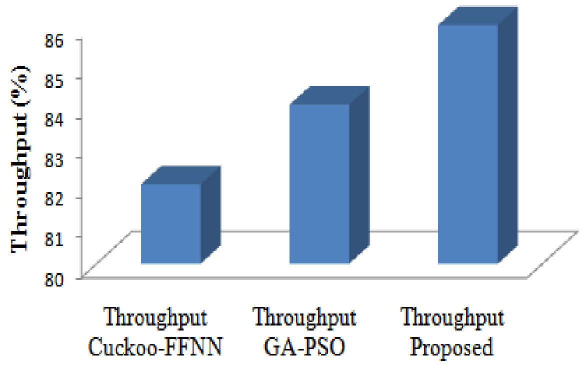

Figure. 11 Throughput comparison

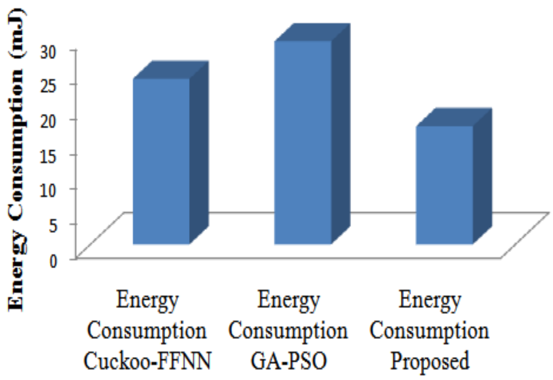

Figure. 12 energy consumption comparison

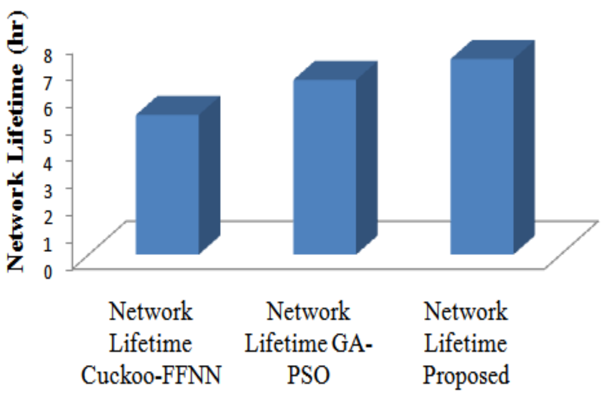

Figure. 13 Network lifetime

 DOI: 10.22266/ijies2019.0430.23

Fig. 13 is depicting the comparison of network lifetime and it has been seen that the proposed framework is increased by 13.19%.

The proposed framework is also compared with the early developed frameworks by the same author [22, 23]. Where nodes were taken between 10 to150 based on different scenarios. Figs. 10, 11, 12 and 13 represent Average Delay, Throughput, Energy Consumption and Network Lifetime of the proposed algorithm and previously implemented structures of the same author.

The proposed framework is also compared with Liu, Anfeng et al. [7, 2018] taking the parameter of distance from sink. The first comparison is made on the base of delay between hops evaluated against the distance to sink.

In Fig.14, the maximum delay proposed by Liu, Anfeng is 14 ms for 100 m of distance from the sink whereas for the same constraints, the proposed work takes 2ms lead. The second parameter is an end to end delay plotted against the distance to sink.

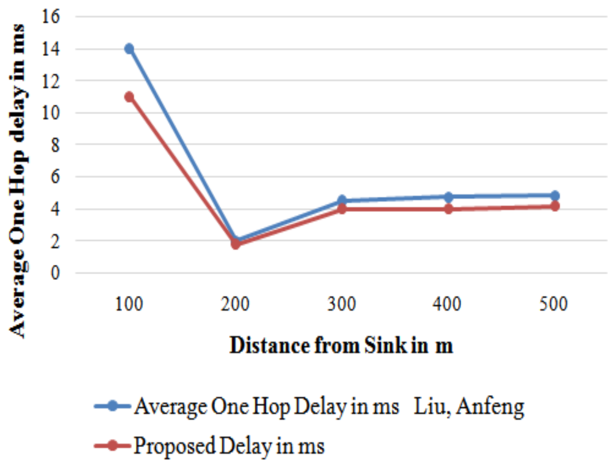

Figure. 14 Average one hop delay

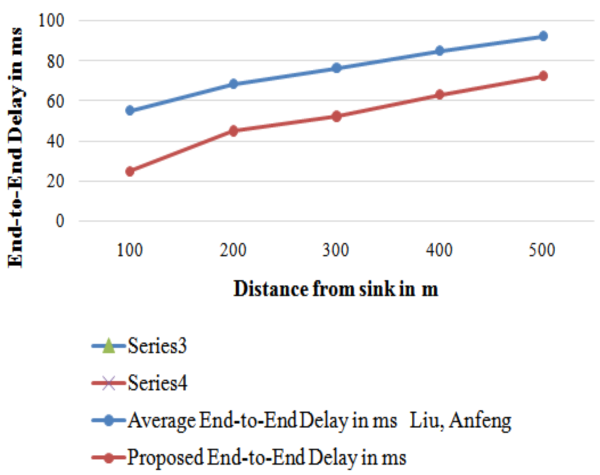

Figure. 15 End-to-end delay

The average End-to-End Delay for Liu, Anfengis 72.1 ms for the distance ranging from 100-500 meters from the sinkwhereas for the same configuration the proposed framework is 52.4 ms. The comparison of the proposed work has been drawn according to the QoS parameters of the conventional researches in [22, 23] based on Delay, network lifetime, throughput and energy consumption as per nodes whereas the comparison of proposed work of average one hop delay and end to end delay as per distance from sink node is with [7].

5. Conclusion

In recent years, the various number of WSN based real applications have been increased rapidly. In a real time environment, basically, some features are required i.e. high throughput, less energy consumption, reduced delay, high network lifetime and good battery life. The proposed research work has tried to optimize the lifetime and reliability by in introducing the concept of broadcast and cache memory to it. The proposed algorithm also included a trust model due to which the extra time and to search nodes for the transfer of data is saved. The proposed work model utilized the architecture of optimization along with load balancing the computed parameters displays a good growth of 20-30 % in each region. The proposed algorithm results are also compared with the previous implemented algorithmic structures of the same author and it is marked that the proposed algorithm of this paper stands an improvement of 10-12 % in each segment of QoS parameters. The proposed framework is also compared to Liu, Anfeng et al. The proposed results show improvement of 2ms in the hop to hop delay whereas an average of 15ms in the end to end delay for a total distance from sink ranging from 100-500 meters. The current research work has opened a lot of futuristic gates in terms of the usage of the Swarm Intelligence in this structure. Usage of Firefly would be also interesting to monitor. Variations in Neural Network structure may surprise the user.

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