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Energy Optimized Routing Protocol Based on Binary Particle Swarm Optimization Successive Interference Cancellation for WSN

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Abstract: ***A large variety of Wireless Sensor Network (WSN) applications encourage researchers to develop and improve protocols and algorithms for rising challenges. During data transmission, energy consumption is main issue because sensor nodes have limited energy capacity. In fact, WSN needs load balancing algorithms that keep use of the limited energy source to route the collected data to the receiving node. While considering adhoc network in sensitive areas, one amongst the necessary aspects to consider is energy as a result of while sending information all communicating nodes exhausts its battery life. For mobile nodes in adhoc situation one and only one source of energy is battery. As compared to single path multipath routing helps to find best path that needs less energy and enhances the network life. In this paper an energy efficient routing protocol is proposed. In routing algorithm, route that have shortest path among multipaths chosen by particle swarm optimization algorithm. Among these shortest paths, that path is chosen that need minimum route selection parameter. The proposed algorithm is based on selection of energy efficient paths from multiple shortest SIC path from source to destination. For selection Binary Particle Swarm Optimization (BPSO) algorithm is applied. The Binary Particle Swarm Optimization (BPSO) algorithm selects energy efficient route among different shortest paths. The k-shortest route is selected on the basis of bandwidth and minimum SIC. The performance of the proposed algorithm is compared with multipath Ad hoc On-Demand Distance Vector (AODV) routing protocol and concluded that BPSO optimized energy efficient path is more efficient with respect to remaining energy of the network. The result is analyzed with variable number of packets send.***

Keywords: ***Binary Particle Swarm Optimization, Energy Efficiency, Multipath Routing, Wireless Sensor Network.***

I. INTRODUCTION

Recent developments in wireless ad hoc technologies have enabled wireless sensor networks to establish spontaneous connections between devices with or without infrastructure [1]. With the advent of sensor-based smart mobile devices, WSN has become an integral part of the Smart City infrastructure and the Internet of Things. Smart devices can be customized by WSN and automatically configured.

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Sending, receiving and sharing data in a very small space [2]. Despite the interesting applications of WSN, these systems still face many challenges and limitations that must be explored further before commercializing WSN.

The main limitations of the WSN network design are:

- Limited battery life and duration
- Quality of service
- Configurations without infrastructure and dynamic network topologies
- Node mobility
- Wireless reliability
- Functionality of variable nodes
- Routing scalability
- Multicast support and security threats [3].

Therefore, the routing protocol plays an important role in these networks and WSN restrictions persist in the development of the latest routing protocols to modify the efficient transmission of packets in wireless support, particularly when the origin and destination is not adjacent. The routing protocol should select the best path between the pairs of source-destination nodes in terms of energy consumption and quality of service measurements, such as available bandwidth, average end-to-end delay, packet loss and average noise. The following is a reminder of this document. Various approaches to high-speed, ad hoc and bandwidth multi-hop routing algorithms were explored and applied to reduce latency, delay and bandwidth of the connection and to ensure a guaranteed level of connection performance application sensitive to service quality. Multipath routing is more promising in ad hoc networks as a result of it offers further options like load equalization, fault tolerance and better throughput [4].

The availability of multiple paths between an origin and a destination is used to acquire the subsequent benefits:

- Fault Tolerance: The introduction of redundancy within the network or the provision of backup ways to be employed in the event of a fault are styles of introducing fault tolerance at routing level in mesh networks. To the present end, some techniques is applied as packet recovery [5], if the particular path is interrupted.
- Improved throughput: In a network, some connections might have limited bandwidth. Single-route routing might not offer enough bandwidth for a connection. Therefore, using multiple paths at the same time to route information is a good approach to meeting the bandwidth necessities of some applications.

II. LITERATURE REVIEW

Abdelkader et al. [1] proposed a multipath routing algorithm based on the residual energy of the network. This setting is based on the number of hops in each node to find the easiest path and place it in the routing table. The main idea of this algorithm comes from the ant colony optimization (ACO).

Chrispen et al. [2] the author proposes a new protocol called Efficient Power Aware AODV. This work is a combination of two previously proposed works which are a modification of the normal functioning of the widely used and well-known ad-hoc remote vector routing protocol.

Tejaswini [3] focused on the design of SIC routing protocol aiming at achieving high overall throughput compared to that of the hop count routing. A comparison of hop count routing and SIC routing is developed with respect to various parameters. The introduction of SIC improves the path bandwidth and high throughput.

Waheb A. Jabbar et al. [5] proposed a power-efficient routing schemes for WSNs proposed to reduce energy consumption when transmitting and receiving packets during communication.

Shanti Rathore et al. [6] proposed the ACO based multipath congestion control technique with varying the queue according to load in dynamic network. The AOMDV is additionally balance the load by providing different path however not skilled at each condition. The AOMDV is provides the multiple path for knowledge causing.

Neung-Um Park [7] investigate the impact of node speed and transmission range on hello intervals in terms of network throughput. Through simulations for a mobile ad-hoc network using AODV routing protocol, researchers showed that the hello interval to maximize the network throughput can be determined as a function of node speed and transmission range.

Nisheeth et al. [8] proposed an EEPR protocol (Energy Efficient Path Routing) that reduces the variance of the residual energy of the nodes and increases the duration of the WSN network. The protocol selects a path based on the min-max formulation to find the residual energy path to reduce the variation in energy consumption. As a consequence, the duration of the WSN network also increases. It also chooses the path that is energy efficient and with maximum stability and reliability.

Annapurna et al. [9] proposed a more recent variant of the AODV routing protocol that addresses the key issues in WSN, such as adaptability and energy efficiency. This is done by evaluating the energy values of the nodes and transmission packets along the path of the less drained nodes, thus making the network adaptable. Performance evaluation in terms of network duration, throughput, packet speed and end-to-end delay is performed using simulation tools such as NS2 / QualNet.

A significant challenging concern on designing system structures of ad hoc network applications is to design and develop an efficient routing protocol. The existing routing protocols worked on single routing path to transmit data. The disadvantages of the previous technique are that for each of the routes lot of control packets are wasted in case of route failure or retransmission and the energy consumed is very high.

III. METHODOLOGY

Due to the limited amount of energy in the sensor nodes, the analysis of the energy consumption of the WSN is very important. The proposed algorithm may be scalable and energy-efficient. The route selection is dependent on minimum SIC and remaining energy. In distance-based routing protocol, energy consumed is very high due to fact that the energy required for transmission and Euclidean distance are directly proportional to energy consumed hence as the number of links are high the energy consumed is high.

Therefore, in this research work, for determining optimized route in multipath routing protocols and High Throughput routing with the Successive Interference Cancellation (SIC) is proposed. For this approach the proposed algorithm contributes to define multiple routes between a destination node and the source node by selecting a subset of all existing routes. In routing algorithm, route that have shortest path among multipaths selected by Binary Particle Swarm Optimization algorithm as PSO techniques can generate high-quality solutions within shorter calculation time and stable convergence characteristics. So, for optimization among multi-paths is done with PSO algorithm in this work.

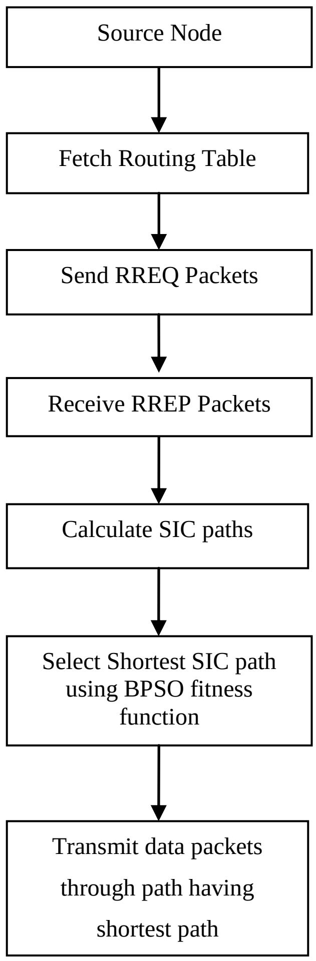

Fig. 1. Proposed Algorithm Flow Chart

A. Proposed Flow Chart

The flow chart of proposed algorithm is discussed below:

- Step 1: Send RREQ from source node

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- Step 2: Receive route reply from neighbor nodes using SIC values
- Step 3: Establish different paths from source to destination
- Step 4: Calculate shortest path based on SIC value and remaining energy of the nodes in the path using Binary Particle Swarm Optimization
- Step 5: Select multiple shortest path from network
- Step6: Select one among different shortest paths whose selection parameter value is minimum.
- Step 7: Forward Data packets

1) Fetch Routing Table and Route Request

After initialization of simulation scenario, the source node fetches the routing table for transmission. If the routing table doesn't contain the path to destination node then it sends the route request to all its neighboring nodes.

2) Route Reply

After route request from source node, neighboring node checks its routing table, if found the path to destination node then it sends it to the source node otherwise it requests to its neighboring node. In this way different paths to destination node is selected.

3) Successive Interference Cancellation (SIC) Calculation

The SIC routing algorithm first finds the one neighbor path to destination node and then each of the intermediate node acts like a source node. After finding the neighbor nodes, path having lowest SIC value is chosen using BPSO algorithm.
This process is repeated until threshold time expires or until destination is reached. Once the time expires min hop routing algorithm triggers that find the proper link to destination. Like that multiple routes are discovered. Then the route which has lowest SIC value is chosen as the best route.
For calculating the SIC Source Node, Destination Node Transmission Range and power loss acts as an input. The SIC selection parameter is estimated as below in equation:

$$R_{sp} = \frac{P(tx)d^{-\alpha}(i,j)}{\sum_{k=1}^{N} P(tx)d^{-\alpha}(i,j)+ \sigma^2} \quad (1)$$

Where, P(tx) = Transmission Power
d-α (i,j) = Distance between node i and j
σ = Power level of noise
α = Path loss components

4) Particle Swarm Optimization based Shortest Path Selection

The steps for BPSO algorithm is discusses as:

- Step 1: (Initialization) In this phase, initially initialize the random SIC paths. These set of paths are considered as a string of length N.
- Step 2: (Fitness) Further, fitness value of each particles/SIC paths in each set is calculated. The fitness value determines the global maximum value out of all paths. These values determine the local best value among set of paths and further global best value among all sets.
- Step 3: (Update) After finding best fitness value, velocity of each SIC paths are updated.
- Step 4: (Construction) Position of each particles are further updated.
- Step 5: (Termination) Finally, if termination condition is satisfied or reached then iteration is stopped, otherwise repeat step 2.

Feature Selection (Binary particle swarm optimization) Algorithm

- Begin, initialize the parameters, No of particles (N_p), Maximum Iteration (Itr_{max}), Cognitive factor (C_1), Social Factor (C_2), Maximum Particle Velocity (vel_{max}), Minimum Particle Velocity (vel_{min})
- Initialize N_p
- Calculate fitness function of all particles, $F_f(N_p)$
- Initialize P_{best} and G_{best}
- for t = 1: Itr_{max}
- Calculate the inertia weight I_w as

$$W = W_{max} - (W_{max} - W_{min})(\frac{t}{Itr_{max}}) \quad (2)$$

W_{max} and W_{min} are the maximum and minimum inertia weight
t=number of iteration

- for i = 1 : N_p
- for d = 1 : D
- Update the velocity of particles (V_{t+1})

$$Vel_{new} = Vel_{old} + C1 * R1 * (P_{best} - Present\_Position) + C_2 * R_2 * (G_{best} - Present\_Position) \quad (3)$$

$$Present\_Position = Present\ Position + Vel_{old} \quad (4)$$

- Convert the velocity into probability value

$$S(Vel_{t+1}) = \frac{1}{1 + \exp(-Vel_{t+1})} \quad (5)$$

- Update the position of particle, X t+1 id using Equation (6)

$$Present_{Position_{t+1}} = 1, if\ S(Vel_{t+1}) > rand$$
$$Present_{Position_{t+1}} = 0, otherwise \quad (6)$$

- increment d
- Calculate fitness function of new particles, $F_f(N_{t+1})$
- increment i
- Update the P_{best} and G_{best}
- increment t

In this proposed algorithm the best path is chosen according to fitness value which is according to the minimum SIC to be travelled by a data up to base node as well as energy of the node.

Fitness Function

To find optimize path using BPSO, need to find the fitness value of each path.

$$Fitness_{val} = SIC(i,j) + Used_{energy(i)} + Used_{energy(j)} \quad (7)$$

This fitness value will be used to select the local best and global best for PSO. The path having minimum fitness value will be the best optimal solution.

5) Data transmission

After finding the best route to destination, then data transmission is performed through this route.

In condition of route failure or delayed transmission, the packets are transmitted through, another best route selected through PSO-SIC algorithm.

The benefit of this algorithm is that it gives optimal path as well as saves some alternative optimal paths in case of route failure or retransmission.

6) Energy Calculation

While considering adhoc network in sensitive areas, one of the important aspect to consider is energy because while transmitting data all communicating nodes exhausts its battery life. For mobile nodes in adhoc scenario one and only one source of energy is battery.

While it is known that nodes consume energy in transmitting mode, receiving mode, sleep and idle mode. In transmitting and receiving mode, nodes drains their power most as compared to idle or sleep mode because nodes are constantly in active state. When node sends packet or data at that time many Ad-hoc routing protocols and mobility models are available, each having different characteristics and scenario so each may consume different amount of energy, so the best one is who sends packets at successful rate with consuming minimum energy [10].

Transmission Mode

In this energy consumption mode energy consumed by the node to transfer the packets or data, in this the amount of energy is rely upon the quantity of packets being send by that node, massive the quantity of packets thus large amount of energy is consumed. Generally, the transmitted power is represented by Tx.

$$P_t = T_x / T_t \text{ Watts} \tag{8}$$

Where P_t is power consumed in transmission mode T_x is energy consumed in transmission, T_t is time to consume that energy.

Receiving Mode

In this energy is consumed in receiving mode, because in this mode nodes are receiving packets from sender. The power in receiving mode can be given as:

$$P_r = R_x / T_x \text{ Watts} \tag{9}$$

Where P_r is the power at receiver node in Watt, R_x is the energy in receiving mode.

Idle Mode

In this node neither sends nor receives packets so it is called as idle mode. Still it consumes energy the reason is that the node has to continuously check and update their status table to intimate that any new node added in network.

The amount of energy consumed by node in idle mode is less than the energy consumed in sending or receiving mode because in idle mode the actual communication among node is not going on. So power in idle mode is nearly equal to power in receiving mode. $P_i = P_r$.

Overhearing Mode

When node receive packets that are not destined to it then it is a overhearing node and it may consume energy in receiving those packets, it is undesirable energy consumption, the power consumption in overhearing mode is given as

$$P_{over} = P_r \tag{10}$$

Where P_{over} is power consumed in overhearing mode and Pr is power consumption in receiving mode.

The main target of adding Energy model is to calculate energy in transmission, receiving, idle and overhearing mode. If consumed energy is minimum then the lifetime of network is longer because all nodes get energy from battery.

In WSN, the radio energy dissipation model is a simple model of wireless energy consumption. The transmitter circuit dissipates the energy needed to operate the transmission electronics and power amplifiers. The receiver circuit dissipates energy to operate only the electronics of the receiver [11].

Depending on the distance between transmitter and receiver, multiple fade and free space channel patterns are used. The free space model (loss of power d^2) is mainly used for communication, while the power loss model d^4 is used for communication between nodes. The threshold distance is greater than or equal to d_0. The radio energy consumed by the transmitter to transmit a 1bit message at a distance d is:

The radio energy consumed by the transmitter to transmit a 1bit message at a distance d is:

$$\begin{aligned} E_{Tx}(I,d) &= E_{Tx-elec}(I) + E_{TX-amp}(I,d) \\ &= IE_{elec} + IE_{amp}d^4, d \end{aligned} \tag{11}$$

And energy consumed by the receiver is:

$$E_{Rx}(I) = E_{Rx-elec}(I) = IE_{elec} \tag{12}$$

Where,

E_{elec} = Per bit energy consumed to execute transmitter and receiver

E_{fs} = amplifier energies for free space

E_{amp} = amplifier energies for multipath models

The Advantages of Proposed Approach are End to End Delay is less, Energy consumption is reduced due to fact that the routes that are discovered are very less. The algorithm takes route selection parameter based on power requirement and bandwidth requirement of the route to pick the forwarding nodes or forwarding link hence the throughput is high because the route chosen is dependent not only on distance as well as on selecting best route among multiple paths.

IV. RESULT ANALYSIS

In this research work the MATLAB tool is used to simulate and verify the validity of PSO optimized multipath routing protocol. The result analysis is performed in two cases. The first case is with variable number of packets whereas second case is with variable number of nodes.

A. With Variable Number of Packets (Homogeneous WSN)

For simulation environment we have assumed WSN consisted of 100 sensor nodes and nodes are randomly distributed in the 100*100m area. The simulation parameters are given below in table I.

Table-I: Parameters with Variable Packets for Homogeneous WSN

Parameter Name	Values
Network Area	100*100
Number of nodes	100
Packet Size	4000 bits
No. of packets	1-500
Initial Energy, E_O	.5J
Transmitter Energy, ETX	50nJ/bit
Receiver Energy, ERX	50nJ/bit
Amplification Energy for short distance, Efs	10pJ/bit/m^2
Amplification Energy for long distance, Emp	0.0013pJ/bit/m^2

According to proposed algorithm following results are analyzed as following:

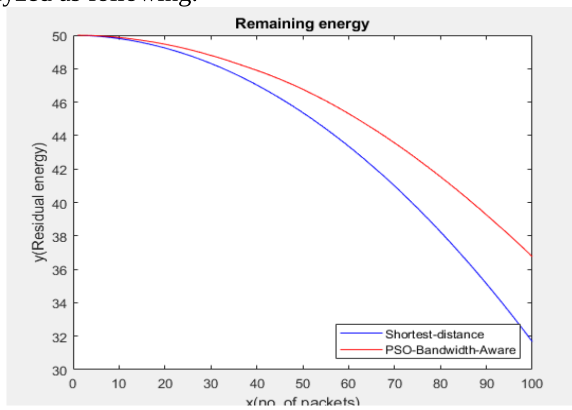

Fig. 2. Residual Energy Analysis with 100 Packets for Homogeneous WSN

In figure 2, the result analysis is performed for 100 packets for Homogeneous WSN and it is concluded that BPSO optimized multipath routing protocol outperforms better as compared to shortest distance routing protocol (AODV). The graph states that the residual energy is approx. 10%-12% more in proposed algorithm as compared to the existing work.

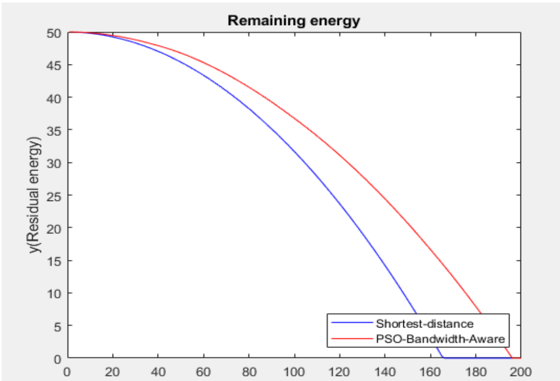

Fig. 3. Residual Energy Analysis with 200 Packets for Homogeneous WSN

In figure 3, the result analysis is performed for 200 packets for Homogeneous WSN and it is concluded that BPSO optimized multipath routing protocol outperforms better as compared to shortest distance routing protocol (AODV). The graph states that the residual energy is approx. 10%-12% more in proposed algorithm as compared to the existing work.

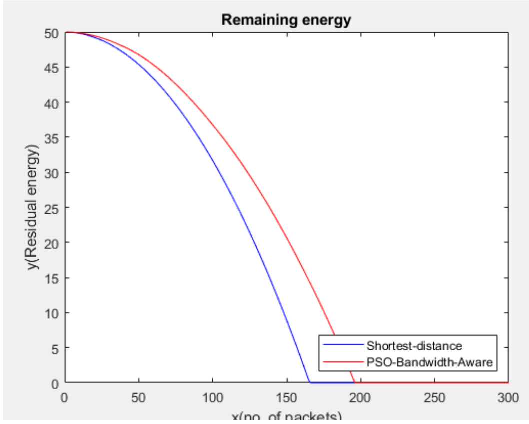

Fig. 4. Residual Energy Analysis with 300 Packets for Homogeneous WSN

In figure 4, the result analysis is performed for 300 packets for Homogeneous WSN and it is concluded that BPSO optimized multipath routing protocol outperforms better as compared to shortest distance routing protocol (AODV). The graph states that the residual energy is approx. 10%-12% more in proposed algorithm as compared to the existing work.

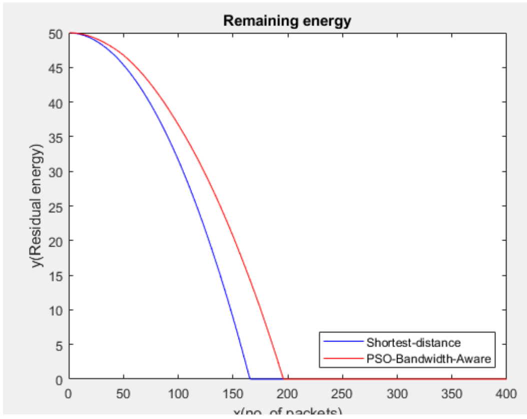

Fig. 5. Residual Energy Analysis with 400 Packets for Homogeneous WSN

In figure 5, the result analysis is performed for 400 packets for Homogeneous WSN and it is concluded that BPSO optimized multipath routing protocol outperforms better as compared to shortest distance routing protocol (AODV). The graph states that the residual energy is approx. 10%-12% more in proposed algorithm as compared to the existing work.

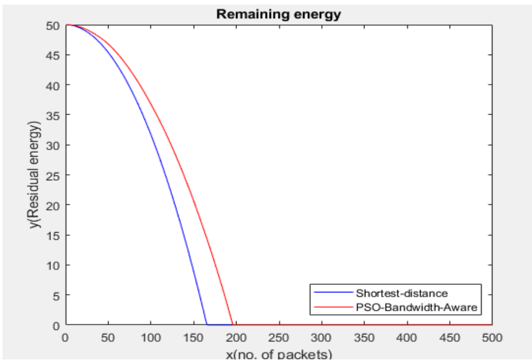

Fig. 6. Residual Energy Analysis with 500 Packets for Homogeneous WSN

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In figure 6, the result analysis is performed for 500 packets for Homogeneous WSN and it is concluded that BPSO optimized multipath routing protocol outperforms better with respect to shortest distance routing protocol (AODV). The graph states that the residual energy is approx. 10%-12% more in proposed algorithm as compared to the existing work.

B. With Variable Number of Nodes (Homogeneous WSN)

For simulation environment we have assumed Homogeneous WSN consisted of variable sensor nodes and nodes are randomly distributed in the 100*100m area but packets are fixed. The simulation parameters are given below in table 5.2.

Table-II: Simulation Parameters for Variable Nodes for Homogeneous WSN

Parameter Name	**Values**
Network Area	100*100
Number of nodes	100-500
Packet Size	4000 bits
No. of packets	100
No. of paths	10
Initial Energy, E_O	.5J
Transmitter Energy, ETX	50nJ/bit
Receiver Energy, ERX	50nJ/bit
Amplification Energy for short distance, Efs	10pJ/bit/m^2
Amplification Energy for long distance, Emp	0.0013pJ/bit/m^2

According to proposed algorithm following results are analyzed as following:

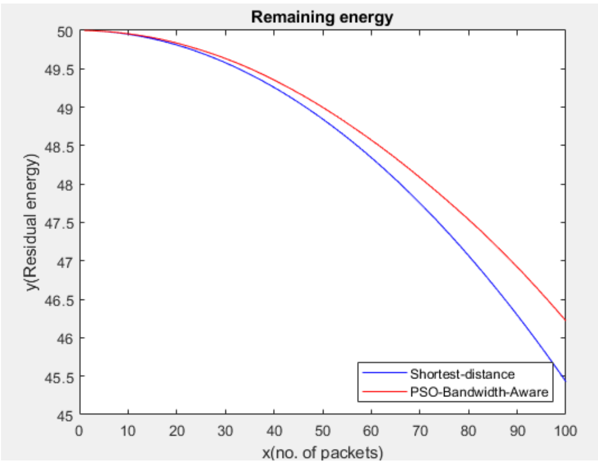

Fig. 7. Residual Energy Analysis with 100 Nodes for Homogeneous WSN

In figure 7, the result analysis is performed for 100 packets and 100 nodes for Homogeneous WSN and it is concluded that BPSO optimized multipath routing protocol outperforms better as compared to shortest multipath routing protocol. The graph states that the residual energy is approx. 8-10% more in proposed algorithm as compared to the existing work.

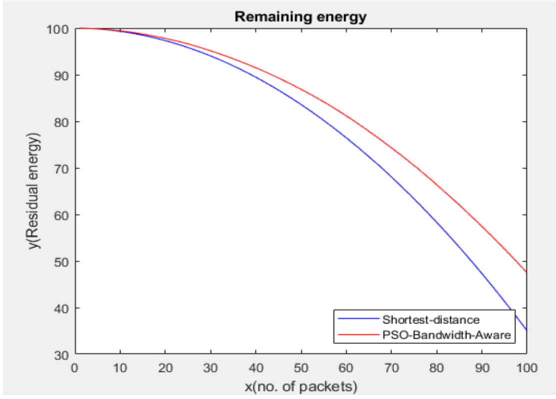

Fig. 8. Residual Energy Analysis with 200 Nodes for Homogeneous WSN

In figure 8, the result analysis is performed for 100 packets and 200 nodes for Homogeneous WSN and it is concluded that PSO optimized multipath routing protocol outperforms better as compared to shortest multipath routing protocol. The graph states that the residual energy is approx. 8-10% more in proposed algorithm as compared to the existing work.

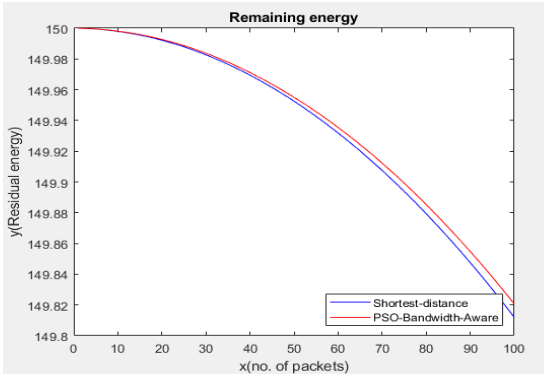

Fig. 9. Residual Energy Analysis with 300 Nodes for Homogeneous WSN

In figure 5.8, the result analysis is performed for 100 packets and 300 nodes for Homogeneous WSN and it is concluded that PSO optimized multipath routing protocol outperforms better as compared to shortest multipath routing protocol. The graph states that the residual energy is approx. 8-10% more in proposed algorithm as compared to the existing work.

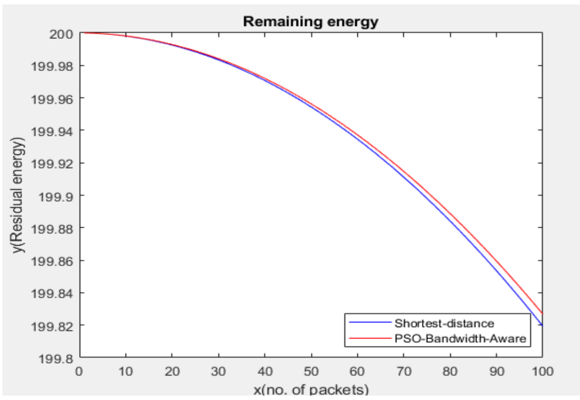

Fig. 10. Residual Energy Analysis with 400 Nodes for Homogeneous WSN

In figure 5.9, the result analysis is performed for 100 packets and 400 nodes for Homogeneous WSN and it is concluded that PSO optimized multipath routing protocol outperforms better with respect to shortest multipath routing protocol. The graph states that the residual energy is approx. 8-10% more in proposed algorithm as compared to the existing work.

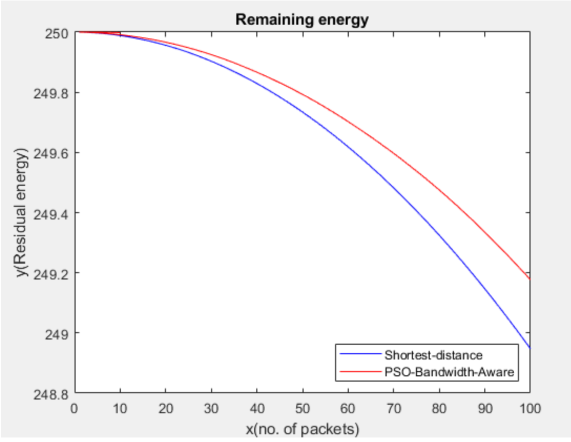

Fig.10. Residual Energy Analysis with 500 Nodes for Homogeneous WSN

In figure 10, the result analysis is performed for 100 packets and 500 nodes for Homogeneous WSN and it is concluded that PSO optimized multipath routing protocol outperforms better as compared to shortest multipath routing protocol. The graph states that the residual energy is approx. 8-10% more in proposed algorithm as compared to the existing work.

V. CONCLUSION

In this research an energy efficient multipath routing algorithm is proposed. This algorithm is used to find optimum path among all shortest path discovered which utilizes the minimum energy of nodes and thus wireless network remains for long time span. In this research work routing protocol, called PSO-SIC, that has high throughput and would actively explore SIC opportunities for multipath routing algorithm for wireless networks. The methodology analytically compute the available bandwidth of a given path with SIC that achieves significant throughput gain over other protocols.

The proposed algorithm uses SIC value as well as energy of nodes as a parameter to find optimum paths using Binary Particle Swarm Optimization. Among these selected paths, only one optimum path is selected which reduces the energy requirement and have minimum SIC value of the network. The BPSO algorithm selects energy efficient route among different shortest SIC paths. The k-shortest route is selected on the basis of bandwidth.

The performance of the proposed algorithm is compared with multipath AODV routing protocol and concluded that PSO optimized energy efficient path is more efficient with respect to remaining energy of the network. The result analysis states that the residual energy is approx. 8-12% more in proposed algorithm as compared to the existing work.

Due to the limited amount of energy in the sensor nodes, the analysis of the energy consumption of the WSN is very important. The proposed algorithm may be scalable, energy-efficient and may reduce packet drop ratio. In future proposed algorithm would be enhanced with concept of secure, energy-efficient, scalable and reliable algorithm.

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