2022 International Conference on Industry 4.0 Technology (I4Tech)
Vishwakarma Institute of Technology, Pune, India. Sep 23-24, 2022

Direction Based-Improved Ant Based Routing Algorithm

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***Abstract*—High-efficient routing is a significant component of a network which forms an indispensable part of designing Wireless Sensor Networks (WSNs). A typical WSN environment limits its resources with respect to the power it transmits, the overhead it carries and the energy it is boarded along with. Subsequently, when these WSNs are employed in large numbers to gather data from solitary destinations and targets, few constraints are enforced by itself owing to the fact that sensor nodes in WSNs carry limited energy, a limited computation power and a highly exhaustive storage capacity among themselves. With due credit to this very fact, Swarm Intelligence (SI) algorithms have been brought on the research scene to help administrate and govern the sensor nodes when in action. In this research study, we analyze and weigh the existing advancements in Energy efficiency routing protocols that utilize SI for WSNs and propose our own modification to the Ant Based Routing Protocol, Direction Based-Improved Ant Based Routing Algorithm (DB-IABR). Since the legacy protocol was found to be the trendsetter in terms of energy efficiency, it serves as our benchmark for evaluations that succeed today's innovations. This study uses standard metrics like energy, path hops and the time as the evaluation parameters. The algorithm is compared with its legacy root algorithm Ant Based Routing and Improved Ant Based Routing Protocols.**

Keywords—Wireless Sensor Networks, energy efficient, swarm intelligence, routing protocols, Quality of Service

I. Introduction

High-efficient routing protocol is a significant component of a network which forms an indispensable part of designing Wireless Sensor Networks (WSN). A typical WSN environment limits its resources with respect to the power it transmits, the overhead it carries and the energy it is boarded along with. Over the years, WSNs have gained traction and have entered the status of significant importance in various fields concerning fast data transmission and transfer with little to no disruptions during the transmission. Over the years, the rising demand of WSNs have led to exposing various vulnerabilities and compromises in the networks. Subsequently, when these WSNs are employed in large numbers to gather data from solitary destinations and targets, few constraints are enforced by itself owing to the fact that sensor nodes in WSNs carry limited energy, a limited computation power and a highly exhaustive storage capacity among themselves. Swarm Intelligence (SI) algorithms are techniques that attempt to find solutions for complicated problems which are otherwise difficult, if not extreme to compute otherwise. The main distinguishing feature of SI algorithms lies in its flat-hierarchical structure. Simplistic and straightforward rules are adhered to by the individual nodes without there being any central control structure to monitor which in turn leads to lesser strain and energy demands for particular center nodes otherwise. Ant Colony Optimization (ACO) is a legacy SI algorithm and was introduced since SI's inception. The underlying concept behind ants finding the most optimal food is not randomization, but a very orderly indirect communication that involves the use of release and identification of chemicals they secrete, namely pheromones. The weighted pheromone trail acts as a guide for all the ants to decide which path to take. The problem though, lies with the individual functionalities of each of the nodes. Each Sensor node not only must act as a router, but also must administrate the packet forwarding. Apart from the shortcomings brought in by connectivity of the network system as a whole, the primary problem is to utilize the energy in an efficient manner which in turn helps to extend the lifetime of the network. The aforementioned problem coupled with the reliability factor owing to the delivery of packets within the stipulated time makes it all the more challenging. To cover all this while maintaining its scalability factor and the standard Quality of Services (QoS) parameters is the goal of our research study on WSNs. With due credit to this very fact, SI algorithms have been brought on the research scene to help administrate and govern the sensor nodes when in action. In this research study, we analyze and weigh the existing advancements in energy efficiency routing protocols that utilize SI for WSNs and propose our own modification to the Ant Based Routing Protocol. Since the aforementioned protocol was found to be the trendsetter in terms of Energy efficiency, it serves as our benchmark for evaluations that succeed today's innovations.

II. Related Work

A. An Improved Energy-Aware Routing Protocol Using Multi-Objective Particular Swarm Optimization Algorithm

The proposed approach seeks to maximize the overall objectives of the network. The WSN power consumption model is divided into two standard sections. The full use of network power in the assembly stage is like a cluster node spreading a message that informs everyone else. The proposed algorithm uses a land-based strategy. Basically, the target space is divided into areas called text. Writing is the realm of constructed solutions based on objective activities. The steps can be encapsulated as follows. The algorithm checks the speed of each particle while generating meta cubes. Each particle has its memory enabled. The algorithm iteratively computes optimal position and velocity until the memory position is better than the previous positions employing Pareto's law. The advantage of the proposed algorithm is that link-energy is maximized. Due to the specificity of the algorithm, less network parameters are considered while routing which can be modified in future research.

B. Energy Efficient Routing Protocol Using Exponentially-Ant Lion Whale Optimization Algorithm in Wireless Sensor Networks

A novel method Exponentially-Ant Lion Whale Optimization Algorithm was developed to enhance energy efficient routing in wireless sensor networks. The proposed approach facilitates the roadmap process by involving three different phases, namely setup, provincial standing phase and route acquisition phase. In the setup phase, the collection head selection is performed using an ALWO algorithm, which includes ALO and WOA. The ALWO algorithm selects a node as a group head based on the degree of durability that includes delay, and power. Low latency hardness and high node strength are selected as the header. In the stabilization phase, energy recovery and dependency renewal processes are implemented in such a way that the trust factor includes Direct trust (DT), Recommended Trust (RT), and Historical trust (HT). The final stage is the route acquisition phase, in which the appropriate method of data transmission is obtained using the proposed E-ALWO algorithm according to the degree of robustness. The algorithm focuses deeply into routing path optimization and energy consumption. The performance analysis proves the distance, delay and energy consumption to be lowest. Major pitfalls of the proposed method is that the hybridization of the algorithm complicates the algorithm and time and space complexity is not ideal at all. This may result in improper computation.

C. Hybrid Swarm Intelligence Based QoS Aware Clustering with Routing Protocol for WSN

The author builds upon this intuition by introducing a QoS aware Clustering and Routing based technique using Swarm Intelligence (QoSCRSI) algorithm. The proposed algorithm performs a multi-layered clustering. An important detail to note is that logic that shall be dealt with will be fuzzy logic, which means the truth value of any real variable can lie between the closed interval of [0,1]. This logic is employed to handle partiality and not rigidity. Initially, the fuzzy is amalgamated with Glowworm Swarm Optimization (GSO) based Clustering to zone in on the optimal cluster heads. Once the cluster heads are chosen in an optimal way, the author then proposes to select all the possible routes the network can take by employing the Quantum Salp Swarm Optimization Algorithm (QSSA)-based routing techniques (QSSAR). This algorithm satisfies QoS requirements while achieving higher energy efficiency, increased lifetime, less overhead and minimum delay. This comes at the cost of excessive prerequisite data which ultimately leads to redundant data transmission.

D. Energy Optimization using Swarm Intelligence for IoT-Authorized Underwater Wireless Sensor Networks

The given paper proposes a novel routing protocol solution for state-of-the-art Quality of Services (QoS) efficient data transmission and energy efficient data transmission with the help of underwater sensor nodes using Swarm Intelligence (SI). The said protocol is also known as the Energy Optimization using Routing Optimization (EORO) protocol. The EORO employs a forward relay node which is ascertained by the source node using the information provided prior to the routing phase. The given algorithm uses four principal parameters which are used to compute the fitness. Firstly, the residual energy. In addition, the packet transmission ability and node connectivity. Ultimately, the distance. The parameters are strategically selected in order to avoid the packet collisions so as to overcome the problems mentioned previously. The EORO protocol was designed to address and solve existing problems such as void communication or packet collision. Energy consumption was on top of it all, as none of the established protocols could solve it. EORO breaks the given problem into sub problems and solves each one optimally. The energy consumption was broken down to finding the best forward relay node. EORO does just that which enhances the lifetime of the network by maximizing the throughput and reducing the packet loss. Further research can aim to select better relays. The open nature of the algorithm brings compromised security and vulnerabilities that are yet to be resolved.

E. Multi-Objective Spider Monkey Optimization for Energy Efficient Clustering and Routing in Wireless Sensor Networks

A Multi Objective Spider Monkey Optimization (MOSMO) algorithm was proposed to balance load and improve network lifetime through energy efficient routing and clustering. The algorithm was designed keeping routing, fitness and clustering fitness as primary objectives for optimal routing and clustering. In the proposed algorithm, two fitness functions Fit Routing and Fit clustering are implemented to achieve the mentioned features. For energy efficient routing, an optimal path needs to be selected between gateways and base station. In order to improve energy efficiency, an optimal path between gateways and BS is determined using the Fit Routing function. MOSMO based routing efficiently balances the heavy traffic in the network around the gateways and reduces energy consumption. As the proposed algorithm was designed keeping traffic load, energy and lifetime in mind, it doesn't deal well with security problems.

F. Minimization of Energy Consumption for Routing in High Density Wireless Sensor Networks Based on Adaptive Clone Elite Genetic Algorithm

The paper discusses about a QoS routing algorithm based upon Adaptive Elite Ant Colony Optimization (AEACO) to minimize energy consumption in wireless sensor networks. The effectiveness of the algorithm was assessed through a QoS routing model. It was observed that after few rounds, the energy consumption was reduced by 22.5% and 30.7% on comparing with particle swarm optimization and genetic algorithm, respectively. It also provided a higher convergence than both of the protocols. With the help of the adaptive mechanism introduced in the algorithm, as the number of sensors increases in the network, the demand of transmission increases. Hence, the effect of AEACO in optimization of the routing also increases simultaneously. AEACO algorithm converges quicker and is more effective in finding the optimal path with a lower energy consumption than PSO and GA. The complexity of this algorithm is extremely high as numerous operators and functions are added to achieve an energy efficient routing protocol.

G. Energy-Efficient Heterogeneous Optimization Routing Protocol for Wireless Sensor Network

This paper focuses on different routing protocols and how we can improve them by using cluster heads. The cluster head is chosen with the help of election protocol. Cluster head is also chosen by comparing the power of the network to the node’s residual energy probability function. This increases the node stability at the cost of nodes lifetime. The author gives a new protocol called Multiple Aggregator Multiple Chain. The cluster head gets the information from other nodes and transmits it to the sink node. The load is equally divided over the network and is divided into multiple chains increasing the performance. EE-TDMA-PSO-UFC is superior in terms of end-to-end delay, throughput, and power consumption. Despite this, the algorithm is very generic and may cause security issues.

H. A Hybrid Elephant Herding Optimization and Cultural Algorithm for EnergyBalanced Cluster Head Selection Scheme to Extend the Lifetime in WSNs

A hybrid elephant herding optimization and cultural algorithm for optimal cluster head selection (HEHO-CA-OCHS) protocol is proposed to extend the lifetime while ensuring energy efficient routing in WSNs. Advances in the lifespan of sensory networks depend on the relative energy balancing strength of the network as the process of recharging the batteries is complicated. This energy-saving process can be verified when sensory nodes receive data from local neighbour nodes at a reasonable distance. Along with the primary objective of minimizing energy consumption, it provides and efficient and effective cluster head selection which improves the overall performance of the algorithm. The process is not at all optimized and may cause issues while processing. Hence, the current algorithm needs to be hybridized with another algorithm to achieve the most efficient algorithm.

I. Communication protocols for wireless sensor networks: A survey and comparison

The SENSOR network is a collection of a large number of locally dispersed wireless sensing nodes in the field of sensors. Advanced network metrics topology networks allow sensory nodes to create a wider network to connect and connect to cyberspace in the active world. End-users of data or administrators may then be able to view and respond to events at a specific location. The study focused on the efficient use of energy-saving routes and the energy-saving mechanisms needed to find the routes of data transmission between sensory and sensory sites. Research conducted on wireless nerve networks reveals many desirable areas of social insect communities. The ability to self-organize is named swarm intelligence which happens to be an exceptional field that was formerly labelled as the improvement of rules by encouraging the cooperation of social bodies and other animal societies. Some of the examples of native species' social communities are colonies of ants, bee colonies, termites, bats, and spider monkeys. The simulation results show that Termite Hill has surpassed all other route contracts tested under the same conditions and metrics.

J. Improved artificial bee colony metaheuristic for energy-efficient clustering in wireless sensor networks

Energy efficient clustering is classified as an NP-hard optimization problem for Wireless Sensor Networks (WSNs) in general. Swarm Intelligence (SI) techniques are employed to try and find workarounds for this problem. Ant colony optimization, particle swarm optimization and much recently, the artificial bee colony (ABC) optimization has led researches in the right direction by showing desirable properties to solve the problem of optimizing energy efficient clustering process in WSNs. To improve the convergence rate and try to balance out the exploration and exploitation phases. The probability function used was changed to a compact probability density function (cPDF), which only requires a single control parameter, reducing the overhead on all nodes. Maximizing all the capabilities already provided by the metaheuristic, the Energy efficient Bee clustering protocol (EEBC) was proposed to optimally choose cluster heads. The packet delivery ratio and throughput were some parameters among the many that saw a considerable improvement from the classical methods and as much as 70% lesser energy consumption.

K. A Swarm Intelligence algorithm for Routing Recovery Strategy in Wireless Sensor Networks with Mobile Sink

In the proposed algorithm, the optimized multimodal functions will guide the particles to the optimal local area preventing it to jump back out from the area. The method of the proposed ABC algorithm is introduced into the PSO algorithm to search for operators, and the particle searches shall be directed to search in order to make the particles jump out of the local advantages as soon as possible. The algorithm is now incorporated with Fault-tolerant routing protocol to achieve fault tolerance. The ABC-PSO algorithm is used to conduct fast rerouting when path failure is caused by the Sink moving to a new position. Some of the fittest nodes collections shall be adapted to assemble the path with the optimal fitness value using sensor nodes near the original path. The exploration and optimization capacity has been enhanced as observed from simulation results. It provides a better operational efficiency and response capabilities allowing an energy efficient routing protocol.

L. A Multi‐Hop Graph‐Based Approach for an Energy‐Efficient Routing Protocol in Wireless Sensor Networks

The proposed protocol is an inter-cluster multi hop protocol which employs dynamic routing. It is very sophisticated in the sense that it transfers information from one cluster head to another just to reach the base station. The main objective of the protocol is to maintain balance throughout and increase the longevity of the system. The sensor network on which it was tried and tested upon is a group of sensors deployed randomly over a vast area and were constantly under surveillance. The steps followed are as follows, each cluster head makes its decisions by dynamically selecting the subsequent hop for the routing phase. The given selection procedure is governed by a probability function. There are a few assumptions for the given proposed algorithm, which are as follows. To begin with, Sensor nodes are expected to be location aware, in other words, equipped with GPS or similar technologies. Furthermore, the sensed information within each and every individual cluster is heavily correlated. Also, the Base station must also have unlimited energy. The proposed algorithm is Multi-hop graph based approach for an energy efficient routing (MH-GEER) improved the load balancing of the entire system, enhanced the stability and augmented the entire performance in comparison to the LEACH protocol.

M. Swarm Intelligence-Based Bio-Inspired Framework for Wireless Sensor Networks

Tracking capability is effective when reducing power and travel costs across all nodes. SIBER is an example of ant colony adaptation. ACO with WSN achieves better energy savings and minimizes further communication. It uses the delivery method to move the packets into the sink by pushing the ants forward. Most anti-trial strategies do not consider all the limitations of choosing the best route for strength, distance, link quality, and other metrics. The Senor Node Attached Reputation Evaluator (SNARE) is a set of protocols that are directly connected to the network layer.Verification systems and key management keys are the most significant security facilities to provide data security and confidentiality in WSN. In recent years, the use of public-key cryptography in the form of elliptical curve cryptography (ECC) with limited resources has become a preferred method. Encryption is strengthened by entering predefined entry values as data transfers. This makes it tough for external parties to interrupt the network. ECC can also be integrated with another message authentication code (MAC) to improve security.

N. An Enhanced PSO-Based Clustering Energy Optimization Algorithm for Wireless Sensor Network

The given research paper proposes a Particle Swarm Optimization (PSO) based clustering energy optimization algorithm which helps to form clusters, select cluster heads using centralized and distributed methods interchangeably with the support of a static sink node. PSO is a population-based algorithm and a metaheuristic built upon Swarm Intelligence (SI). The sink or base station (BS) broadcasts information to all the sensor nodes present in the network. The proposal optimizes average distance and average energy of all the system nodes. New particles are generated from the existing particles. All the parameters are calculated all over again from the newly generated particles. Finally, the fitness value is calculated again.

III. Proposed Methodology

1. For every sensor node, an ant is cast away with a set objective, namely a forward ant, to discover a viable route till the base node, or the sink. Each of these nodes saves its respective IDs into the memory. Each ant carries its own memory. The naming legend is as follows:
   a. *M – Memory*
   b. *K – Sensor node*
   c. *N – Number of entries*
   d. *D – Possible destination*

2. The Ant Colony Optimization (ACO) is pre-configured with a probability function that assists the node in selecting the next hop node in the course of action. The standard formula is as follows:

$$P_{i,j} = \frac{(\tau_{i,j})^{\alpha}(\eta_{i,j})^{\beta}(\lambda_{i,j})^{\gamma}}{\Sigma\left((\tau_{i,j})^{\alpha}(\eta_{i,j})^{\beta}(\lambda_{i,j})^{\gamma}\right)} \text{ where } \eta_{i,j} = \frac{1}{L_{i,j}} \quad (1)$$

P_k (r, s) – Probability pertaining to ant K being selected from node r to node s.
τ – Routing table at every node containing the quantity of pheromone trail on the edge (r, s).
λ – Cosine Similarity function between two vectors.
E(s) – A visibility function also calculated as $E(s) = \frac{1}{C_s - E_s}$
C_s – initial energy level of Node s
E_s – Actual energy level of Node s
α, β – parameters in charge of correlation between trail and visibility
L – Cost required for the respective route

a. The given probability function compromises with visibility in turn for the actual trail intensity. Visibility means the higher energy nodes must be chosen with a higher probability. Trail intensity is defined as that a heavy traffic-inflicted edge *(r, s)* in this case is highly desirable.

3. The ant which was cast away, is set to reach the sink. Upon doing so, the forward ant is now converted to a backward ant. The ant is now given the objective which is to identify, follow and update the very same pheromone trail it used for traversing during the time it was a forward node. The information for the same is stored in the memory.

4. Before the backward ant, K returns back to its original position, the source node along the same path, the sink is tasked with the calculation of finding the quantity of pheromone the ant might theoretically drop along the way of the return expedition. The standard formula is given as follows:

$$\Delta\tau = \frac{1}{C_{av} - \left[\frac{E_{min} - N_j}{E_{av} - N_j}\right]} \quad (2)$$

C_{av} is the initial arithmetic mean of the energies of all sensor nodes.
E_{min} is the minimum energy of the route used by the forward ant. E_{av} is the average energy of the route used by the forward ant.

i. Point to note is that both E_{min} and E_{av} are considered for the route the forward ant uses to reach its destination, the sink.
ii. Both the parameters depend on the nodes present in the said path. The values are also closely correlated to the energy consumed by those nodes during the packet exchange process.
iii. Certain cases might have the value of E_{min} lesser than the quantity of nodes visited but at any point of time, the value of E_{av} ≥ number of nodes visited
iv. N_j at any point of time is defined as the nodes visited by the forward ant at that particular instant
v. The intuition behind this very calculation is to filter out the optimized routes. For e.g., a route with 15 nodes can absolutely have the same average energy as a route with just 3 nodes. Calculating the amount of

pheromone that might be lost in due process by treating it as a function of energy and quantitative number of nodes is the key difference between this algorithm and the conventional approach of ACO which only considers the number of nodes.

5. Let's assume a node 'r'. The moment r encounters a backward ant from another node, say 's', which is the neighboring node of r, the routing table is updated with the following formula

$$\tau(r,s) = (1-p)\tau(r,s) + \left[\frac{\Delta\tau}{\phi B_{dk}}\right] \quad (3)$$

φ is a coefficient.
B_{dk} is the distance covered by the backward ant, where d and k are also symbols. K is the Ant.
p is also a coefficient and (1-p) indicates the quantity of pheromone evaporated since the last time it was updated in the routing table namely τ (r,s).

i. The main motive behind doing so is to distribute pheromones much more optimally, as nodes near to the sink will obviously have more quantity of pheromone left, and hence this will ensure that the nodes further away search for better solutions and routes.
ii. The main plus point of this method is it works exceptionally well for dynamic nodes, and if the sink node can move, the adaptation of pheromone levels will take place much quicker than otherwise.

6. The complete journey marks an end as shown in Fig.1, when the backward ant reaches its initial position. Upon doing so, the objectives are successfully met and so the backward ant is then removed. Multiple ants are employed iteratively to reach the optimal solution.

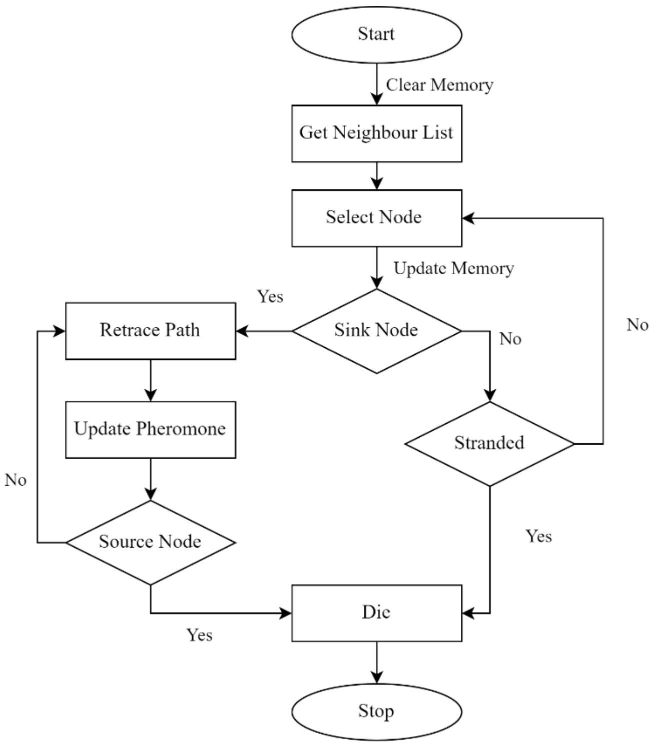

Fig. 1. Proposed Methodology

IV. Experimental Results and Observations

A. Experiment Environment

Each particular source and sink will be transmitting a total of 50 packets between each other. To emulate the real-life network connections as close as it can get, we will be having 3 pairs of sources and sinks at any point of time which will be transmitting 50 packets. As explained before, our algorithm incorporates a factor of vector direction similarity raised to the power of gamma, another parameter. To display our algorithm's effectiveness gamma is assumed to be 1 which means that the direction heavily influences the probabilistic deciding function in line to Table I.

We will be using the Python package Matplotlib to visualize all the nodes in real time. The edges are coloured red by default. For every successful packet transmitted, the simulation colours the selected path with blue colour for better visibility. Towards the end of every code run, the simulation calculates the average unsuccessful packet transmission Attempts, average selected path length and average energy levels.

By intuition, our model aims to achieve lower unsuccessful transmission attempts, a shorter path length on an average and higher energy levels, and by doing so, fulfilling the objectives of our study, energy conservation using Swarm Intelligence algorithms in Wireless Sensor Networks.

TABLE I. Simulation Parameters

Simulation Parameters	**Value**
Initial Node Energy	10 joules
Idle Node Dissipation Energy	0.1 joules
Maximum Transmission Range of a Node	5
Total Packets Transmitted	150
α	0.7
β	0.3
γ	1

B. Test Results

Table II compares the performance of the proposed algorithm to the legacy algorithm and an improved version of the legacy algorithm. On observation of results, it's found that the proposed utilizes the lowest amount of energy making it more energy efficient while being able to achieve other improvement in factors like network lifetime, path hops, path length and many more. The following figures demonstrate the average energy of nodes throughout the experiment duration, path hops and the path length each packet takes to reach its destination node, and finally, the time taken for every packet in each of the three algorithms we will be using for a comparative analysis, namely, Ant Based Routing (ABR), Improved Ant Based Routing (IABR) and Direction Based Improved Ant Based Routing (DB-IABR).

TABLE II. PERFORMANCE COMPARISON OF PROPOSED PROTOCOL WITH EXISTING PROTOCOLS

Algorithm	ABR	IABR	DB-IABR
Network Lifetime (ms)	82	80	85
Avg Path Hops	3.29	3.25	3.04
Avg Path Length (m)	6.4	6.54	5.74
Average Time Taken (ms)	34.57	34.2	31.95
Average Energy Level (J)	0.34	0.4	0.48
Average Energy per Packet (J)	0.81	0.83	0.78

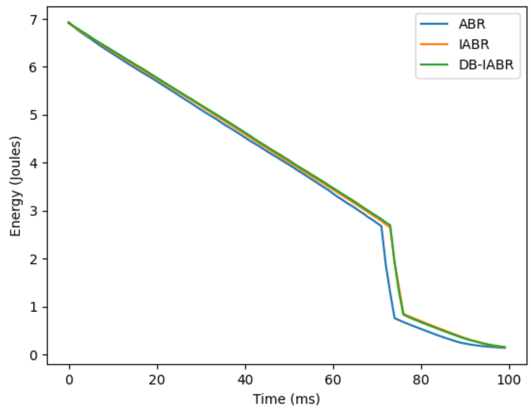

Fig. 2. Average Energy of Nodes

From the Fig. 2 above, we can see that the average energy in the nodes of DB-IABR hold up for longer than its counterparts' nodes which shows a higher energy consumption in the legacy algorithms. Our model successfully implements Energy conservation and when implemented for real life applications, the conservative approach of consuming energy will pay dividends.

From the Fig. 3 below, it is evident that nodes incorporating an ABR approach on an average take the path with longer hops owing to a greater energy consumption model. IABR on the other hand is quite consistent with the path selection but due to the extra energy consumption, the nodes die out quicker. IABR model must then reconfigure the shortest path for the nodes to use. The reason behind abrupt jumps in the IABR path hops graph. DB-IABR on the other hand consistently outperforms the IABR while maintaining its energy judiciously. Another key point to note from the graph is that the lifetime of DB-IABR outlives the other two algorithms which justifies the small extension of the graph after 250 as well.

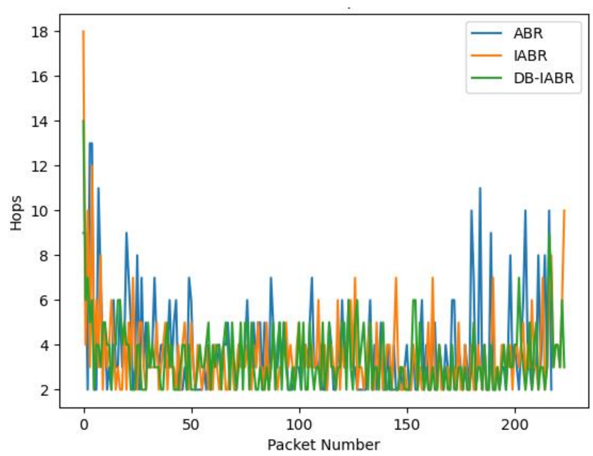

Fig. 3. Average Path Hop

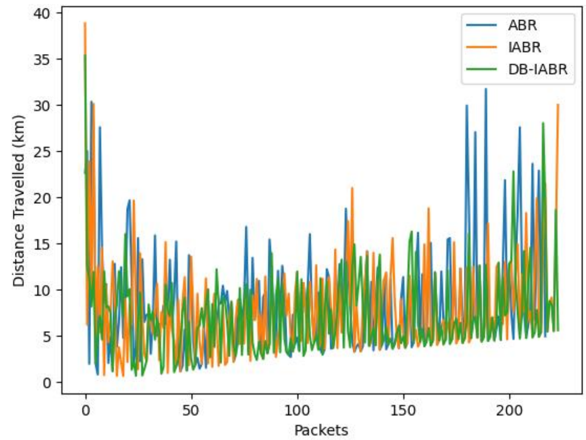

Fig. 4. Average Path Lengths

From Fig. 4, we can conclude the other important parameters that are otherwise often overlooked such as the path length. Path length helps gauge whether the algorithm neglects other parameters in its quest of achieving lesser energy consumption through the course of the experiment. DB-IABR consistently provides the packets with the shortest path and naturally, the path with least hops on an average.

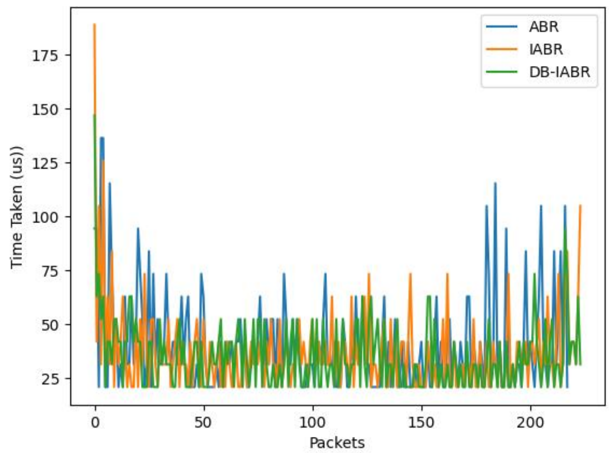

Fig. 5. Average Time Taken

In Fig. 5, the time taken for each packet to reach the destination is demonstrated. This is slightly correlated to the path length and hops which would signify that if the path chosen has shorter length, it would naturally take lesser time to deliver. As expected from the calculations and previous results, the DB-IABR outperforms the legacy algorithms, ABR and IABR, by consistently taking less time for delivering the packets while conserving energy at the same time. This is a testament to the importance of the direction factor in the probabilistic function used to choose the path for each node.

V. Conclusion and Future Work

ACO comes with an inherent quality of being able to be redesigned to build inspired metaheuristic algorithms. Some new fronts for continuing research on ACO include frameworks and models that employ different optimization strategies with a new take on combinatorial probabilities. The DB-IABR successfully negated the threat of excess consumption of energy during subsequent execution of the algorithm, but at the same time it came with certain trade-offs. In order to achieve the global optimum in the shortest possible time without excess loss of energy, our model compromises on the security aspect. Future research can aim to improve the security standpoint of this particular model and achieve security along with minimum energy consumption. For the precision ACO provides, it also uses up more resources than a normal algorithm does. Since the given model is resource-intensive, questions about adaptability start arising. In future, DB-IABR can be optimized further and by doing so, ensure that the model's application is not limited by the availability of resources in the experimental setting. For being a legacy Swarm Intelligence Algorithm, the ACO is highly complex. Owing to this fact, any algorithm built on top of the same is difficult to improvise further. Open-ended innovations along the ACO for Wireless sensor networks (WSN) are highly encouraged to build upon the strengths of both the given systems to maximize the desired results. WSNs are at the forefront of wireless transmission and are soon gaining traction in various fields. It poses additional features due to the resource-constrained nature. Energy consumption is at the root of most inadequate resource problems. The main aim of our proposed model was to employ an algorithm that helps us to overcome the excess energy consumption, which was very well accompanied with the help of Swarm Intelligence algorithms. The results of our experiments indicate that coupling WSN with ACO helps overcome the energy consumption problem which in turn helps give the WSN a prolonged lifetime and achieve low-cost solutions for different use cases.

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