Energy efficiency enhancement in wireless sensor network: ant colony optimization

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ABSTRACT

Wireless sensor networks (WSNs) have received significant scholarly attentionwithin the scientific community lately. The use of small and energy efficient devices with restricted computing capabilities has gained traction in various fields of application, including environmental monitoring, target tracing, and medical health observation. Node localization is a fundamental system parameter in numerous applications. Categorizing hybrid solutions as either range-based or range-free poses a challenge in general. In this article, we aim to simplify the classification process by examining range-based and range-free schemes. There are two distinct classifications of schemes, namely fully schemes and hybrid schemes. Furthermore, we conduct a comparative analysis of the predominant energy efficiency measures in WSN networks and deliberate on prospective avenues for research in WSNs deploying ant colony algorithm.

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1. INTRODUCTION

The enhanced development of wireless sensor networks (WSN) in the 21st century can be attributed to the advancements in micro-electronics systems [1]. WSN has become an indispensable tool for daily users, as it enables the sensing, transformation, and transmission of information. Sensor nodes are typically deployed in diverse spaces, such as war zones where human access is limited [2]. WSN generate significant amounts of data in the form of bits or streams, and these nodes communicate over a specific range of nodes that are organized in an ad-hoc structure and subsequently transmit the acquired data to the sink [3]. WSNs are marked by a number of resource constraints, including limited energy, memory, computational power, and communication capacity [4]. However, the significance of the precise guidelines may not have been given adequate attention. Determining the rank of association rules can pose additional challenges in measurement. Moreover, the present systems may prove inadequate, particularly in cases where multi-level regulations are involved [5]. These regulations pertain to items or topics that originate from the first level of taxonomy, but their placement is determined by factors beyond the confines of a single taxonomy level. Additionally, cross-level regulations, which involve items or topics originating from more than one scientific classification level, would also pose a challenge. Regression analysis is a quantifiable method used to determine the correlation between dependent variables and one or more independent variables [6]. The subordinate factors are those whose attributes are to be predicted, while the free factors are the ones upon which the forecast is constructed [7].

2. REVIEWS OF LITERATURE

Jadon and Dutta [8] presented a pair of heuristic algorithms, local closest first (LCF) and global closest first (GCF), designed to facilitate route planning. The process of route planning in LCF involves the selection of the destination node that is in the closest proximity to the current location of the mobile agent. The terminal sensor node in the pathway is identified as the one farthest from the sinking node. Conversely, the GCF algorithm chooses the target node that has the shortest distance to the sink node. Kim *et al.* [9] proposed MA-based directed diffusion (MADD), which is akin to LCF but diverges in the initial node selection. The MADD algorithm prioritizes the selection of the sensor node that is farthest from the sink as the initial node to be visited by the agent, as opposed to opting for the nearest node to the sink. While LCF, GCF, and MADD have proven to be efficient in smaller networks, they face difficulties when applied to larger networks as the determination of route planning is contingent upon the distance from the source node.

Ci *et al.* [10] proposed the modal analysis of effects and failures (MAEF) approach, which is energy-efficient. The proposed method uses a cluster formation technique to group the sensor nodes. The subsequent procedure involves the identification of a cluster head (CH) for each cluster, which serves to facilitate the process of data collection. Upon completion of data collection, the process of route planning is executed through the utilization of a minimum-spanning tree. Bhardwaj and Pandey [11] implemented the energy efficient and fault-tolerant distributed algorithm for data aggregation in WSNs european free trade association (EFTA) to achieve energy efficiency. The two techniquesemploys a cluster-centric strategy for the purpose of categorizing sensor nodes, whereby clusters are formed and the cluster heads are positioned at the core of their corresponding clusters. Subsequently, the process of data aggregation is initiated, which is succeeded by the identification of pathways connecting every individual cluster head.

2.1. Modified ant colony optimization algorithm with uniform mutation using self-adaptive approach

The ant colony optimization (ACO) algorithm represents a novel meta-heuristic approach extensively employed for various combinational optimization problems, drawing inspiration from the foraging behavior observed in real ant colonies [12]. ACO demonstrates remarkable robustness and offers ease of integration with other optimization methods. In the present study, a highly efficient ACO algorithm employing a uniform mutation operator utilizing a self-adaptive approach has been introduced. The incorporation of the mutation operator aims to enhance the algorithm's ability to overcome local optima [13]. Through the accumulation of the most effective sub-solutions, the algorithm steadily converges towards an optimal final solution. Empirical findings substantiate the superiority of the proposed algorithm over previously suggested approaches [14].

2.1.1. Fault tolerance

The routing protocol intended for WSN ought to be sufficiently vigorous to deal with the most pessimistic scenario working of the system [15]. The sensor units can bomb because of different reasons, for example, breaking down equipment, programming glitches, disengagement or ecological dangers, for instance, fire or flood. In such a case, medium access control (MAC) and steering conventions together should oblige arrangement of new connections and course [16].

2.2. Enhancing network security using ant colony optimization

Ensuring the security of information within computer networks remains a crucial area of research. To maintain a secure environment, it is essential to have a thorough understanding of the behavior that incoming data exhibits [17]. Network security has emerged as a critical concern for organizations, especially with the growing expertise of hackers and intruders, who have successfully targeted high-profile corporate networks and web services [18]. The advent of artificial intelligence technology has opened up new avenues in the field of networksecurity. Among these approaches, the ant-colony optimization algorithm stands out as an evolutionary learning algorithm capable of addressing complex problems [19]. By incorporating the principles of ACO, network vulnerability detection can be improved, thereby enhancing overall security management [20]. The objective of this study is to apply the ACO algorithm to identify network vulnerabilities and ensure the network's security. Through this application, the performance of network security management can be significantly enhanced [21].

2.3. Ant colony optimization-based routing in wireless sensor networks

2.3.1. Wireless sensor network

WSN describes a group of small-scale micro sensors that are equipped with capability for wireless communication. Similar to many advanced technologies, WSN have their origins in both industrial and military applications [22]. The sound surveillance system (SOSUS) is the first wireless network that aligns with contemporary WSN technologies, designed on subaqueous acoustic sensors [23]. The SOSUS system was equipped with sensors that were strategically placed in both the Pacific and Atlantic Oceans. The defense advanced research projects agency (DARPA) launched the network deep space network (DSN) program in

1980, motivated by the advancements in Internet technology during the 1960s and 1970s, with the aim of developing the necessary hardware for the contemporary internet [24]. The objective was to investigate the design obstacles associated with WSN. The advent of DSN and its entry into the academic sphere via Carnegie Mellon University and the Massachusetts Institute of Technology presented an opportunity for WSN technology to establish a foundation in domestic, educational, and civilian scientific research applications [25]. In quick succession, both public and private entities began implementing sensor technology to track air quality, detect forest fires, predict weather patterns, and mitigate natural disasters, among other applications. During that period, the sensors were distinguished by their large size, high cost, and reliance on proprietary communication protocols [26]. The implementation of WSNs had a significant impact on the industry that employed it. The disproportionate correlation between the high cost and low volume of sensors hindered their widespread adoption [27].

2.3.2. Challenges in designing of wireless sensor network

Energy limitations pose a significant challenge in the design of WSN. These networks are often deployed in remote or inaccessible areas, making it impractical to replace or recharge their batteries. The longevity of the network is directly influenced by its energy efficiency [28]. Consequently, the design of dependable and efficient sensor nodes and routing protocols becomes crucial. Sensor nodes expend energy while performing tasks such as sensing analog data, processing the acquired data, and transmitting it. Moreover, the design of application-specific WSN configurations for various tasks necessitates the ability to sense different types of data [29].

WSNs are deployed to collect valuable information from various fields, utilizing nodes with limited power. The efficient collection of information is of utmost importance in WSNs. These networks are employed in areas with challenging power supply or limited accessibility, as well as in temporary situations where fixed network support is not required. Their ability to be quickly deployed with robust resistance to damage makes them highly versatile [30]. To address the challenges associated with WSNs, a novel technique called bio-inspired mechanism for routing has been proposed. Among the bio-inspired mechanisms, ACO stands out as a dynamic and reliable protocol. ACO facilitates energy-aware and data-gathering routing structures in WSNs, ensuring efficient resource utilization and minimizing energy consumption at individual nodes. This approach effectively mitigates network congestion and prevents rapid energy depletion, thus extending the overall lifespan of the network. The ACO algorithm plays a pivotal role in reducing energy consumption by optimizing routing paths, enabling effective multi-path data transmission, and ensuring reliable communication even in the event of node failures. The primary objective of this research is to maximize the operational duration of the network by facilitating efficient data transmission [31]. This study focuses on the implementation of a WSN and conducts a comparative analysis of its performance with the Ad hoc on-demand distance vector (AODV) routing protocol based on the ant algorithm. Key performance metrics such as packet delivery ratio, throughput, and energy levels are evaluated, demonstrating the superior efficiency of our proposed algorithm compared to AODV.

2.3.3. Energy preservation

One of the significant confinements of sensor hubs is the constrained vitality gracefully. The significant part of remaining vitality of these assets imperative small-scale gadgets is expended in finding the neighboring bit and playing out the errands of the two calculations and transmitting data in a remote domain [32]. Further, as the transmission intensity of a remote radio is relative to separate squared or much higher request within the sight of impediments, multi-jump steering devours less vitality than direct correspondence [33]. Be that as it may, multi-jump steering acquaints noteworthy overhead relating with topology the executives and MAC. All things considered, detailing vitality rationing types of correspondence and calculation are basic particularly in a multi jump condition [34].

2.4. Inter-cluster ant colony optimization algorithm for wireless sensor network in dense environment

WSNs have experienced rapid growth due to advancements in information technology. These networks consist of distributed sensor nodes deployed across an area to gather essential information. However, the limited energy capacity of sensor nodes hinders the network’s ability to reach its full potential [35]. Therefore, it is crucial to optimize the gathering and transmission of information to minimize energy dissipation. ACO has emerged as a widely used technique for optimizing network routing protocols. Ant-based routing offers significant potential for enhancing the network’s lifespan. In this research paper, we propose an intercluster ant colony optimization algorithm (IC-ACO) that leverages the ACO algorithm for data packet routing in the network. The primary goal is to minimize the redundancy in data transmission among closely located sensors in densely deployed networks, thereby reducing unnecessary efforts. Simulations were conducted under various network scenarios to evaluate the performance of the IC-ACO algorithm. The results demonstrate the superiority of IC-ACO over the LEACH protocol, showcasing higher energy efficiency, extended network lifetime, enhanced stability period, and increased data packet transmission in densely deployed WSNs [36].

2.4.1. Energy efficiency using leach algorithm

The JCR protocol introduced the LEACH algorithm as the pioneering energy-efficient algorithm for routing in packet-switched networks. This algorithm, which is based on low adaptability and energy efficiency, serves as the foundation for optimizing techniques utilized in our daily lives, engineering, and industrial settings [37]. These optimization techniques find application across various domains, allowing us to minimize costs and energy consumption while maximizing profits, output, performance, and efficiency. Given the limitations imposed by limited resources, time, and financial constraints, optimization becomes crucial in real-world scenarios [38]. However, it should be noted that real-world optimization problems tend to be more intricate, as both parameters and constraints influence the nature of these problems.

2.5. Ant colony optimization: a solution of load balancing in cloud

Cloud computing has emerged as a novel computing paradigm that leverages the Internet for various purposes. It offers numerous advantages but also presents critical challenges that need to be addressed to enhance the reliability of cloud environments. These challenges primarily revolve around load management, fault tolerance, and security concerns within the cloud environment [39]. This research paper focuses specifically on load balancing in cloud computing. Load balancing in cloud computing entails the equitable distribution of workloads across different nodes in a distributed system. The aim is to optimize resource utilization, reduce job response time, and prevent scenarios where some nodes are overloaded while others remain underutilized. Load balancing ensures that each processor or node in the network carries a fair share of the workload at any given time. Various approaches have been proposed to tackle this problem, such as particle swarm optimization, hash methods, genetic algorithms, and scheduling-based algorithms. In this study, we propose a load balancing method based on ACO to address the load balancing challenge in cloud environments [40]. The ACO algorithm offers a promising solution by simulating the foraging behavior of ants to efficiently distribute the workload across nodes. By employing this approach, we aim to achieve better load balancing and improve the overall performance of cloud environments.

2.6. Ant colony optimization for continuous domains

This research paper introduces an extended version of ACO tailored for continuous domains. The adaptation of ACO from its original application in combinatorial optimization to continuous optimization is presented, emphasizing that no major conceptual modifications are required. The general concept, implementation details, and achieved outcomes are discussed. A comprehensive comparison is conducted between the results obtained using the extended ACO and those reported in existing literature for alternative continuous optimization methods, including other ant-inspired approaches and met heuristics initially designed for combinatorial optimization but later adapted for continuous scenarios. The performance, efficiency, and robustness of our extended ACO algorithm are analyzed and evaluated [40].

2.6.1. Proposed approach

The major challenge in WSN is to improve network performance. Here, joint cluster approach, which is the combination of two clustering approach namely energy efficient hierarchical clustering and modified low energy adaptive clustering hierarchy, is used. Thereby increasing the node connection and communication time, it also reduces redundant information. These approaches are widely used as per their ability to work with few error samples to identify the node redundancy.

2.6.2. Energy efficient hierarchical in WSN

The energy efficient hierarchical clustering is a decentralized and randomized clustering algorithm designed to enhance the longevity of the network. Its objective is to establish a hierarchy of cluster heads by organizing the sensor nodes (SN). Each cluster head (CH) collects and aggregates data from the SN within their respective clusters, subsequently transmitting the accumulated data to the designated sink. The algorithm consists of two stages: the initial single-level clustering and the subsequent multilevel clustering.

2.7. Research gaps and issues

2.7.1. Distributed network

In a WSN, effective packet forwarding among nodes is a collaborative process, making each node function as a router. Consequently, routing becomes a crucial aspect to consider. This dissertation focuses on addressing routing challenges within ad hoc networks. This section will also delve into additional issues prevalent in WSN networks.

2.7.2. Dynamic topology

Wireless sensor nodes in a network exhibit self-organizing behavior, leading to a dynamic and ever-evolving network topology. Consequently, routing protocols tailored for such networks must demonstrate adaptability to effectively accommodate the fluctuations in topology. Some of this protocol features enable users to adapt to heavy traffic network load by only using active nodes in every communication path. Mostly this protocol is also considered power saving protocol due to its ability to bypass unused nodes time by time. This protocol has its leverage in expansion and security, where the network path can be changed on the go and its static nature also changes the internet protocol (IP) address time to time which will be secure.

2.7.3. Power awareness

The issue of power awareness assumes paramount importance due to the battery-powered nature of nodes within ad hoc networks, especially when deployed in challenging and hostile environments. Consequently, it becomes imperative to develop protocols that prioritize efficient power management, aiming to conserve battery life and enhance the overall energy efficiency of the network. In essence, these protocols must embody a power-aware approach to address the rigorous power requirements of nodes in ad hoc networks.

2.7.4. Addressing scheme

The dynamism of the network topology necessitates careful consideration when designing the addressing scheme. It becomes crucial to implement a robust addressing scheme that can accommodate the constant changes in the network structure. In the context of a dynamic network topology, an addressing scheme that ensures ubiquity and eliminates duplicate addresses becomes essential. While cellular networks employ mobile IP with a centralized base station responsible for node addressing, such a scheme is not suitable for ad hoc networks due to their decentralized nature. Therefore, alternative addressing schemes need to be devised to effectively handle the unique characteristics and requirements of ad hoc networks.

2.7.5. Network size

Ad hoc networks offer appealing opportunities for commercial applications, including data sharing in conference halls, meetings, and similar contexts. Nonetheless, it is crucial to consider that the underlying protocols introduce a notable latency factor that imposes a stringent limitation on the network’s scale. The delay inherent in these protocols establishes a strict upper threshold for the size of the network, necessitating careful planning and optimization to ensure efficient and reliable communication within the network.

2.7.6. Security

Guaranteeing security within an ad hoc network is a critical consideration, particularly in deployment scenarios like the battlefield. The three fundamental objectives of security, namely confidentiality, integrity, and authenticity, pose significant challenges due to the equal participation of every node in the network. In our research, we address the security concerns surrounding secure routing in WSNs and examine the complexities involved.

2.8. Wireless sensor networks: design challenges

Figure 1 shows the organization of sensor nodes in a WSN. The effective implementation of a WSN necessitates adequate planning and optimal design considerations. WSNs’ deployment demands expertise in software development, information processing, electronic systems, and embedded system design. These diverse areas of technology exhibit distinct characteristics, highlighting the need for a comprehensive examination of the interplay between these factors in the design process. This study provides a thorough survey of the key factors that influence the design and performance of WSNs.

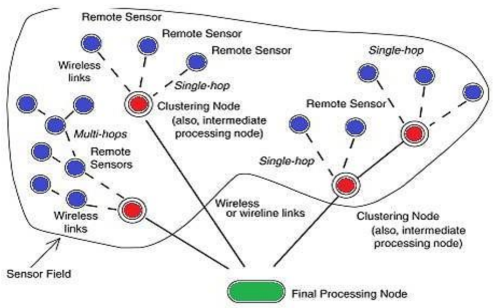

Figure 1. A schematic representation of a sensor node

2.9. Sensor network topology

WSNs' network topology optimization poses significant challenges due to dense sensor network with high risk of failure resulting from power drain or physical damage. Designing the network topology in advance is often impractical, requiring data gathering and communication to adapt to the irregular and dynamically changing topology. WSNs' sensor nodes network framework is typically distributed across a sensor deployment. The nodes are separately equipped with data collection and routing capabilities to relay information to the base station and end users. Data is transmitted back to the end users through a multi-stage decentralized architecture, utilizing the receiver nodesas intermediate nodes. The interaction between the receiving nodes and the scheduler node is facilitated by the network.

2.10. Networking architecture for WSNs

Sensors are typically distributed across a grid, each equipped with data collection and routing capabilities to relay information to the receiving nodes and consumers. Data is transmitted back to theusers through a multi-stage peer-to-peer architecture, utilizing the receiver as an intermediate node. Information exchange between the receiver node and scheduler node is facilitated through the Internet.

2.10.1. Quality of service

QoS parameters including data handling capacity, delay, accuracy, information transmission errors, unreliable data channels, network element failures, and dropped packetsare crucial considerations. Achieving QoS in WSNs is challenging due to power and processingconstraints. Furthermore, the desired QoS varies depending on the application. Event-driven systems prioritize reliable and error-free data delivery within an acceptable delay, especially for events of significance, rather than periodic information. Improving throughput is another critical factor where routing protocols employing multiple paths prove more suitable. Real-time applications demand the timely delivery of data.

2.10.2. Security

Managing WSNs' security is a complex task owing to the use of wireless networking, limited power and processing resources, small node sizes, unknown topologies in scattered deployments, and the heightened risk of physical attacks on unattended sensors. Confidentiality, integrity, authenticity, and availability are essential for securing WSN operations [40]. In contrast to legacy networks, sensor vertices are physically placed outdoor, making them susceptible to elements and human activities. Conventional security schemes are often unsuitable for WSNs due to resource limitations and low energy budgets. Additionally, security requirements vary across applications. Most security mechanisms employ keys to provide security. Key management involves key generation, distribution, and revocation in the event of compromised keys. However, key usage increases computational complexity, leading to higher energy consumption. These factors highlight the need to address security threats and protection in WSNs differently.

2.11. Proposed algorithm

2.11.1. Artificial ants

The proposed algorithm utilizes ant-based routing algorithms, employing artificial ants or agents address intricate challengescompared to real ants. The agents possess additional capabilities:

- Memory: agents can remember their path and backtrack using the same route.
- Pheromone deposition: agents deposit pheromones based on the effectiveness of the solution produced. For example, the quality can be evaluated based on the duration of the ant's path.
- Limited perception: agents are not completely blind and can perceive more than just pheromones. Local information influences their decision-making, aiding in solving shortcut problems.

To illustrate the behavior of artificial ants, we describe their role in AntNet, a routing solution for a telecommunications network. In this case, the network is fully connected, allowing any node to be reached from any other node. These artificial ants likely to find the path from source to destination using local information. After each successful travel loop the information is updated successfully. This approach also deals with the problem of multi hop jumping by fixing its route to a single network.

2.11.2. Ant colony optimization

Initially designed by [6], is a metaheuristic primarily used for discrete optimization problems. However, its applicability extends to certain continuous methods discussed in the subsequent paper. ACO is mainly used to observe the movement of the ants to one locality to other in order to reach target in less time. Where they first start to move randomly, this approach opens up multiple routes from location to location. ACO is widely used to minimize one of the main causes of routing failure by pheromone value comparison at each point, so that duplications cannot cause errors.

3. METHOD

3.1. Technique 1

Each ant is allocated a transmitter source node, initiating their journey towards the sink node through ad-hoc routing. The construction of a single ant-based solution involves the following steps:

- In case the node has already been visited during the current iteration, then the path taken by a previous ant should be followed.
- If necessary, utilize a node selection rule.
- Choose the shortest route if all the neighbouring paths have been visited.
- In the absence of any adjacent nodes, backtrack to the previous node.
- In the event that there are no adjacent nodes and the preceding node is not operational, terminate the programafter recording the network's lifespan.
- The process of transmitting a packet involves the current node sending the packet to the selected node, followed by both nodes updating their residual energy. In the event that the current node is lacking the necessary energy for transmission, the attempt will fail. To maintain the network and avoid transmission failures, an energy check is conducted during node selection [18]-[29].

3.2. Technique 2

Ants initiate their journey from the collector node towards their respective emitter nodes, following the paths discovered in the forward pass. Before reaching their transmitting nodes, the algorithm repeats the following steps:

- Retrieve the antecedent node in the path solution.
- Proceed with packet transmission.
- In the event of transmission failure, ensure the network is operation and discontinue the activity of the ant.
- The process of node selection during the forward pass can be modulated through the deposition or evaporation of pheromone on the corresponding edge.

3.3. Simulation tool

The objective of this study was to assess the effects of Ant-Net routing on MANETs. We used the network simulator (NS) software to simulate multiple scenarios of MANETs and incorporated energy parameters. In order to compare the conventional AntNetMANETs and our suggested improvements, we created a new protocol that attracts data packets selectively before discarding them. We then conducted simulations using this protocol. In the following chapter, we introduce NS and outline our specific contributions to the field.

3.4. Network simulator (NS2)

The NS program is a simulation tool that employs an event-centric architecture as shown in Figure 2. Developed by the University of California, Berkeley it comprises a diverse set of network elements such as protocols, applications, and traffic source patterns. The program is a crucial component of the VINT project's software suite, which has been the recipient of funding from DARPA since 1995.

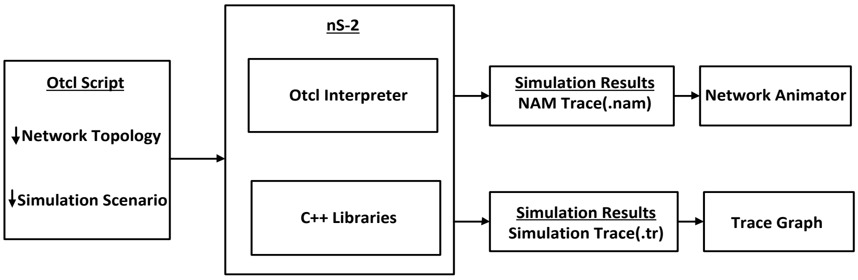

Figure 2. Network simulator

At the simulation layer, NS utilizes the object-oriented tool command language (OTcl) programming language for the interpretation of user simulation scripts. OTcl is a programming language that enhances the Tcl language by providing object-oriented features while ensuring compatibility with the C++programming language. At the uppermost layer, NS functions as a mediator for Tcl scripts supplied by the user, operating in tandem with C++algorithms.

3.5. Performances matrices

When evaluating the operational effectiveness of routingprotocols, performance metrics play a crucial role. Among the selected metrics, the following parameters demonstrate the performance of the routing protocol:
- Packet delivery ratio (fraction): this metric assesses the ratio of incomingpackets to the aggregate packetstransmitted as shown by (1).

$$PDF= (P_r/P_s) \quad (1)$$

here, 'P_r' represents the aggregate incoming packets, while 'P_s' represents the aggregate transmitted packets.
- Average delay: this metric measures the time required for a packet transmission in a MANET as shown by (2).

$$D= (T_r-T_s) \quad (2)$$

'T_r' denotes the packet's receive time, and 'T_s' represents the time when the packet was sent.
- Normalized load: this metric calculates the ratio of forwarded packets to data transfers in a single simulation and reports routing congestion per unit of data successfully delivered to the target node.

4. RESULTS AND DISCUSSION

Table 1 shows the simulated parameters output environment for 10s pause time. In this Table 1, it can be observed that simulated environment is of area 500×500 meter. Each packet is capable of delivering maximum of 512-byte load from one node to another. The total simulation time is done for 100 seconds which is following Mac/802.11 protocol. Overall, the given parameters are calculated in NS-2 simulator by testing AntNet routing protocol. For sufficient transmission of information, it is assumed that a total of 20 nodes are taken into account. Initially, all the nodes transmission speed is varied in between 10 to 40 m/s.

Table 1. Simulation parameter values for 10s pause time

Parameters	Value
Simulator	NS-2
Routing protocol	AntNet
Number of nodes	20
Area	500m× 500m
Packet size	512byte
Simulation time	100s
Pause time	10.0
Traffic type	CBR
Mac protocol	Mac/802.11
Speed	10 to 40 m/s

4.1. Performance metrics analysis with varied maximum speeds using xgraph

The main emphasis of this section is the assessment of the performance of the Ant Net routing scheme. To accomplish this, we carried out simulations and studied the impact of modifications in energy parameters and mobility on the system. Our goal was to assess the comprehensive performance metrics while taking into account a spectrum of maximum speeds ranging from 10 to 40 m/s.

The simulator interface captured in Figure 3 exhibits the successful delivery 20 packets. The averages for each parameter that was previously discussed were averaged and then compared to the performance of the ant colony system (ACS) algorithm. The simulation was conducted with specific parameters in place: the packet delivery ratio (PDF) was represented along the Y-axis, and the maximum speed (in m/s) was shown along the x-axis. The data transmission was conducted within the range of 10 m/s to 40 m/s. The red line in the graph represents the performance of AntNet, while the green line shows the efficient data delivery achieved through the use of the current AntNet routing algorithm.

The simulator interface shown in Figure 4 portrays the successfultransfer of 20 packets. The performance of the ACS algorithm was compared to the averages of each parameter mentioned previously. The simulation parameters were set as follows throughout the experiment: the maximum velocity along the x-axis (in meters per second) and the delay along the Y-axis. Data transmission occurred within the range of 10 m/s to 40 m/s. The green line illustrates the effective data delivery of the existing AntNet routing algorithm, while the red line represents that of AntNet. It is essential to note that the modified AntNet algorithm resulted in lower delays compared to the original AntNet.

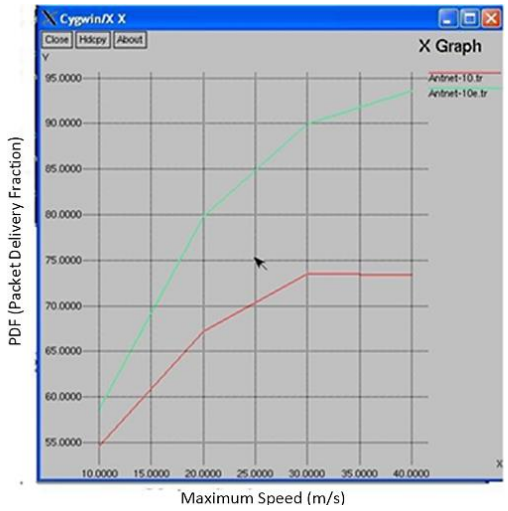

Figure 3. PDF v/s maximum speeds

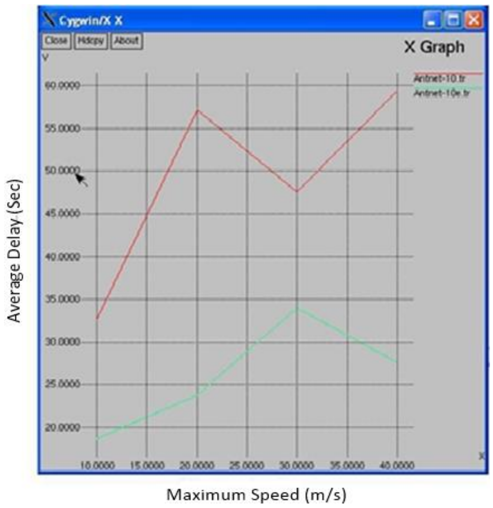

Figure 4. Average delay v/s maximum speed

The simulator interface displaying the successful transmission and receipt of 20 is depicted in Figure 5. We calculated the averages for each parameter discussed and conducted a performance comparison using the ACS algorithm. All experiments were conducted using simulation parameters with the maximum speed (in m/s) on the x-axis and the network load on the y-axis. Data transmission occurred within the range of 10 m/s to 40 m/s. The red line corresponds to the performance of AntNet, while the green line represents the efficient data delivery achieved by the existing AntNet routing algorithm. It is noteworthy that the modified AntNet algorithm led to a reduction in network load. Table 2 shows the simulated parameters output environment for 1 to 4s pause time.

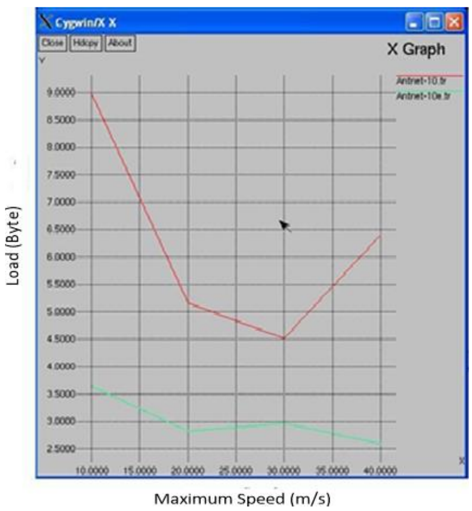

Figure 5. Load V/s maximum speed

Table 2. Simulation parameter values for 1 to 4s pause time

Parameters	Value
Simulator	NS-2
Routing protocol	AntNet
Number of nodes	20
Area	500m×500m
Packet size	512byte
Simulation time	100s
Pause time	1.0 to 4.0s
Traffic type	CBR
Mac protocol	Mac/802.11
Speed	10 m/s

In Figure 6, the simulator interface displays the successful transmission 20 packets, with the averages for each parameter discussed previously calculated. A performance evaluation was conducted, comparing the results with those of the ACS algorithm. The simulation parameters were fixed throughout the experiments, with the pause time (in seconds) depicted on the x-axis and the PDF on the y-axis. The data was transmitted within the time span of 1 to 4 seconds. The performance of AntNet is illustrated by the red line, while the green line indicates the efficient data delivery achieved by the current AntNet routing system.

Figure 7 illustrates the simulatorinterface displaying the successful transmission 20 packets. The values for each discussed parameter were calculated. We conducted a comparative analysis of its performance against the ACS algorithm. Throughout the experiments, the simulation parameters were configured with the pause time (in seconds) represented on the x-axis and the PDF on the y-axis. The data transmission occurred within the range of 1.0 second to 4.0 seconds.

The successful transmission of 20 packets is shown on the simulator interface in Figure 8. We calculated the averages for each parameter that was discussed. As part of our performance comparison with the ACS algorithm, we configured the simulation parameters with the pause time (in seconds) on the x-axis and the network load on the y-axis. The data transmission occurred between 1.0 second and 4.0 seconds. The performance of AntNet is represented by the red line, while the efficient delivery of data using the existing AntNet routing is indicated by the green line. Additionally, the modified AntNet algorithm resulted in a decrease in network load, which is noteworthy.

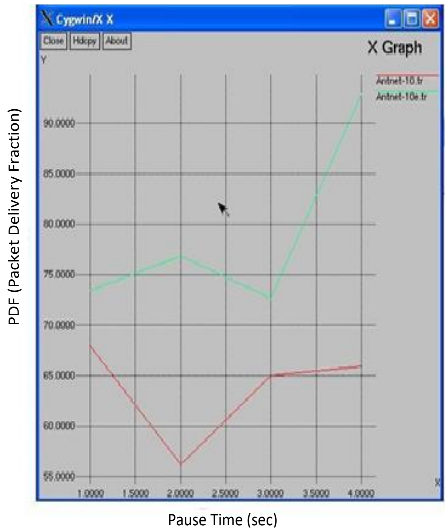

Figure 6. PDF V/s pause time

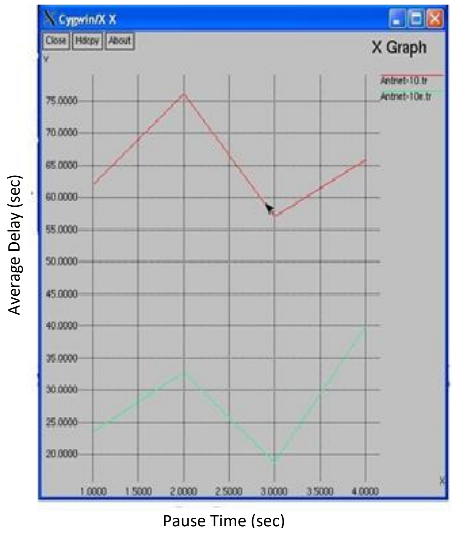

Figure 7. Average delay V/s pause time

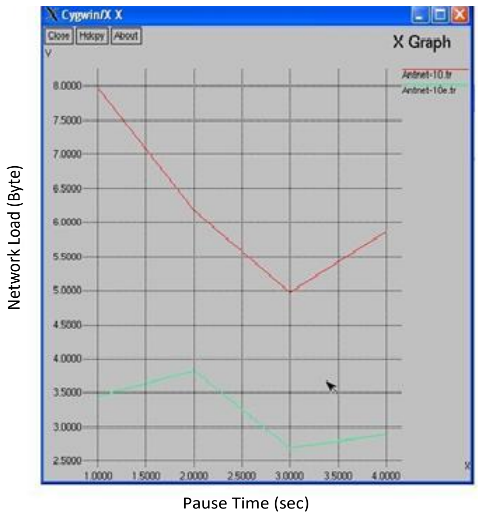

Figure 8. Network load V/s pause time

5. CONCLUSION

The article delves into the various domains whereWSNs can be applied. It sheds light on the difficulties that arise with creating sensor nodes and establishing a wireless communication infrastructure. The issue of network lifetime due to energy limitations poses a significant obstacleWSNs' routing. One possible solution is the implementation of mobile base stations, which can extend the network's longevity by evenly distributing stored energy, in contrast to stationary base stations which face major constraints. Furthermore, the article emphasizes the research challenges that come with developing WSNs for contemporary applications. Future investigations will investigate the efficacy of the AntNet algorithm in dynamic networks, such as ad hoc wireless networks. Multiple ACO will be employed to tackle the problems of stagnation and congestion. The upgraded version of ACO can recognize several optimal outgoing interfaces, rather than just one path, which leads to increased network capacity and the possibility of exploring new and better paths, especially in topologies that change frequently. Employing this technique will distribute the traffic from overloaded links to other preferred links, which will enhance the network's throughput and resolve stagnation problems.

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