NATURE INSPIRED DATA DISSIMINATION ROUTING PROTOCOL FOR WIRELESS SENSOR NETWORKS

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Dedication

Dedicated to my parents, family, and teachers.

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Abstract

A wireless sensor network (WSN) consists of small sensor nodes, a base station, and a data center. Its goal is to collect and monitor a variety of environmental or system parameters such as humidity, temperature, air quality, and others. However, as the use of wireless sensor networks technology grows, WSN confronts a number of issues. One of the key issues that WSNs encounter is the sensor nodes' limited energy resources. Because of this constraint, energy efficiency becomes a significant concern, and finding strategies to optimize energy use becomes essential. Furthermore, wireless sensor network routing methods can be complex and require sophisticated algorithms to maintain successful communication between nodes. The concept of smart cities introduces a new layer of challenges for WSNs. Smart cities integrate various systems and components to enhance the living environment for citizens. However, this integration introduces challenges such as managing and providing services to users in the smart city environment, ensuring the security of smart city networks, and dealing with the high mobility of nodes within the network. Designing a comprehensive solution for smart cities involves addressing several other critical factors, including data security, efficient data handling, heterogeneity (the presence of diverse devices and technologies), sustainability, and analysis of the vast amounts of data generated by the smart city infrastructure. To tackle these complex issues, researchers have turned to nature-inspired optimization solutions. These solutions draw inspiration from nature, which has proven to be a reliable source for addressing complex problems. Nature-inspired optimization techniques leverage the principles observed in natural systems and phenomena to develop efficient algorithms and protocols. Nature-inspired optimization techniques can be used in the design of routing protocols for wireless sensor networks, for example. These protocols aim to optimize the utilization of limited network resources while ensuring reliable and efficient data transmission between sensor nodes. Another area of focus is load balancing in high-speed networks. Load balancing techniques distribute the network traffic evenly across nodes to prevent congestion and maximize network performance. Nature-inspired optimization methods can be used to develop intelligent load balancing algorithms that adapt to dynamic network conditions. By leveraging nature-inspired optimization solutions, researchers can address the intricate and evolving challenges posed by smart cities and complex network systems. These solutions pave the way for the development of intelligent systems and novel optimization techniques, providing valuable insights and opportunities for new researchers to explore the potential of nature-inspired approaches.

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LIST OF ABBREVIATIONS

WSN – Wireless Sensor Network
AIR – Ant-Inspired Routing
CCP – Coverage Configuration Protocol
MOEA – Multi-Objective Evolutionary Algorithm
NSGA-II – Non-Dominated Sorting Genetic Algorithm
LO – Lion Optimization
IGA-BACA – Improved Genetic Algorithm and Binary Ant Colony Algorithm
ANN – Artificial Neural Networks
WSN – Nature-Inspired Optimization
TBSIOP – Trust-Based Secure Intelligent Opportunistic Routing Protocol
HSA – Harmony Search Algorithm
HEWSN – Heterogeneous Wireless Sensor Networks
PSM – Probabilistic Sensing Model
IS – Information Systems
FBECS – Fuzzy Based Enhanced Cluster Head Selection
UWSN – Underwater Sensor Networks
IWD – Invasive Weed Optimization
EHPRP – Energy Harvesting Wireless Sensor Network Routing Protocol

CHAPTER 1

INTRODUCTION

1.1 Overview

In this chapter, we provide an initial definition of Wireless Sensor Networks (WSNs) and delve into its various types and applications. We explore the operational process of WSNs, focusing on how they aggregate data and utilize it for diverse purposes linked to their applications. WSNs employ a range of technologies and standards to ensure smooth functioning and rely on an operating system for service governance. However, as the scope of WSN applications expands, several challenges and problems arise. Energy consumption, load balancing, fault tolerance, coverage holes (hotspots), node inter connectivity, and restricted resources in sensor nodes are all typical concerns. Currently, research focuses mostly on energy efficiency, load balancing, and security problems, with an emphasis on energy efficiency. Routing in computer networking is crucial for guiding network traffic from source to destination efficiently. Internet Protocol (IP) is a fundamental routing protocol, where routers analyze destination IP addresses and routing tables to decide how to forward packets. To handle high-speed data distribution, routers employ specialized hardware and algorithms for swift packet forwarding, ensuring timely and reliable delivery. High-speed data dissemination faces the challenge of minimizing latency (the delay between sending and receiving data packets) while maximizing throughput (the rate of successful data delivery). Achieving these goals involves optimizing routing algorithms, network topology, and hardware components. Protocols like Open Shortest Path First (OSPF) and Border Gateway Protocol (BGP) improve routing efficiency by dynamically adapting to network changes.We compile relevant literature on research works addressing these issues in this chapter. The research works are examined in terms of the discussed problem, the techniques employed to resolve it, performance metrics, advantages, simulation tools utilized, as well as any drawbacks or limitations. Detailed discussions on each of these aspects are presented in the subsequent sections [1].

1.2 Wireless Sensor Network (WSN)

The routing protocol is essential for enabling communication between routers and ensuring the secure and reliable transmission of data to its intended destination. Due to the very dynamic nature of wireless networks, ad hoc wireless networks cannot simply adopt routing strategies developed for conventional networks. Small, inexpensive, and low-power sensor nodes make up ad hoc wireless networks like Wireless Sensor Networks (WSNs). A Wireless Sensor Network is a network of interconnected nodes that may record and measure various system, environmental, or physical factors such as temperature, wind, sound, pollution levels, and more.These networks operate in an ad hoc manner, meaning that the nodes form temporary connections as needed without relying on a pre-established infrastructure.

1.3 Components of WSN

The sensor nodes and the base station are the two most important components of a WSN. Each node in a WSN wirelessly connects with other nodes, transferring data from node to node or from nodes to the base station. A typical sensor node includes sensors for monitoring environmental variables, a radio frequency transceiver for wireless communication, a microprocessor for data processing, memory for storing, and an energy supply unit. A WSN base station is made up of a transceiver, a micro controller, and a power unit. [2]. Because of the lack of energy supplies, the lifetime of sensors in a WSN is restricted, especially when many sensors are put in difficult-to-reach places. Various strategies and procedures for extending the life of sensor nodes have been developed. It is critical to optimize the functions performed by these nodes in order to reduce energy waste and make the most of the limited sensor battery lifetime. The architecture of a WSN is depicted in Figure 1, which shows the interconnections between the sensor nodes and the base station. Data is collected from sensor nodes and transmitted to the base station using this approach for further processing and analysis. One crucial feature of Wireless Sensor Networks (WSNs) is dealing with node energy depletion. WSN-specific routing algorithms seek to solve the shortest path problem while optimizing node lifetime and lowering energy consumption. The Ant-Inspired Routing (AIR) method is one such routing system based on the natural behavior of ants. When sensors in WSNs are situated at a distance from one another, uncovered patches may appear, resulting in what is known as a coverage hole.

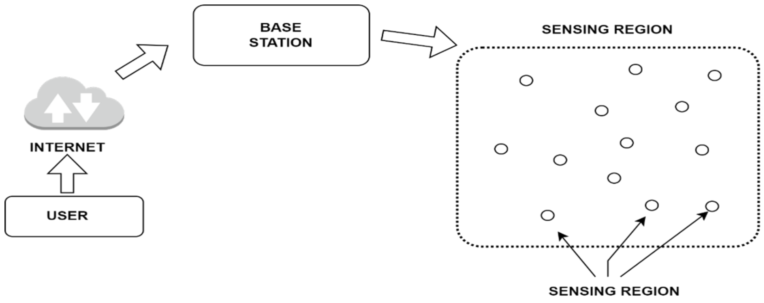


Figure 1.1: Wireless Sensor Network (WSN)

To overcome this, a Coverage Configuration Protocol (CCP) is used, which ensures network coverage. However, when there are a large number of sensors, this algorithm may underperform [3] necessitating the employment of nature-inspired algorithm-based optimization strategies for optimal sensor deployment and coverage.

1.4 Optimal Coverage in WSNs

The conventional Multi-Objective Evolutionary Algorithm (MOEA), Non-dominated Sorting Genetic Algorithm (NSGA-II), and Indicator-Based Evolutionary Algorithms are three algorithms that are frequently evaluated to obtain optimal coverage in WSNs. These algorithms use evolutionary ideas to simultaneously consider various goals while optimising the sensor coverage in WSNs. By utilizing these optimization techniques, researchers can enhance the overall performance and coverage of WSNs in a more efficient and effective manner. Wireless Sensor Networks (WSNs) also address the issue of node energy depletion is crucial to ensure the network's longevity and continuous operation. To tackle this challenge, specialized routing algorithms have been developed specifically for WSNs [4]. These algorithms aim to find the shortest path for data transmission while maximizing node lifetime and decreasing energy use.

1.5 Algorithms for Optimal Coverage

The conventional Multi-Objective Evolutionary Algorithm (MOEA), Non-dominated Sorting Genetic Algorithm (NSGA-II), and Indicator-Based Evolutionary Algorithms are three algorithms that are frequently compared to achieve optimal coverage. These algorithms provide a comprehensive solution for WSN deployment optimization by simultaneously addressing many goals such as expanding coverage, reducing energy consumption, and balancing sensor load [5].

By utilizing these nature-inspired optimization techniques, researchers can effectively address the issues of node energy depletion, coverage holes, and overall network performance in WSNs. These approaches pave the way for designing more efficient and resilient WSNs that can fulfill their intended applications in various domains, such as environmental monitoring, smart cities, and industrial automation. Wireless sensor networks encompass various types, each designed for specific applications and environmental conditions. These types include mobile WSNs, terrestrial WSNs, underground WSNs, underwater WSNs, and multimedia WSNs.

In a mobile WSN, sensor nodes are not stationary but can move from one location to another as needed. This flexibility allows for dynamic monitoring and data collection in applications such as wildlife tracking or mobile object detection.

Terrestrial WSNs consist of sensor nodes deployed above the ground. They often utilize solar power as an energy source, leveraging sunlight to recharge the nodes' batteries. This makes terrestrial WSNs suitable for outdoor applications where access to power infrastructure is limited. Underground WSNs are specifically designed to operate below the surface, such as in mining or underground exploration scenarios. The entire network of sensor nodes is deployed underground, while a sink node remains positioned above ground. The sink node serves as a communication bridge, gathering data from the underground sensor nodes and sending it to the base station for further analysis. Underwater WSNs involve the use of sensor nodes and vehicle technology to monitor and sense the underwater environment [6]. These networks are employed in various applications, such as marine research, environmental monitoring in oceans, or underwater infrastructure inspection. Sensor nodes in underwater WSNs are equipped with specialized mechanisms to withstand the challenging conditions of underwater environments.

Multimedia WSNs integrate sensor nodes with microphones, cameras, or other multimedia devices. This allows them to capture and transmit not only traditional sensor data but also multimedia information such as video, audio, or imaging. Multimedia WSNs find applications in surveillance systems, event monitoring, or multimedia data collection in diverse environments. Figure 1.2 visually depicts the different types of WSN applications, showcasing the varied deployment scenarios and sensor node capabilities across the various types of networks. Each type caters to specific requirements and offers unique advantages for different domains and applications.

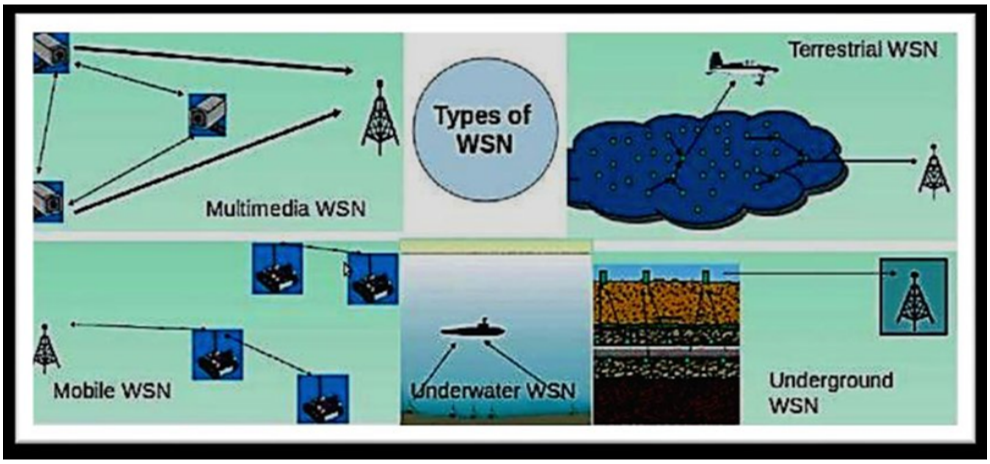


Figure 1.2: Different types of applications in WSN

1.6 Applications of Wireless Sensor Networks (WSNs)

WSNs find numerous applications across various domains. Area monitoring, environmental monitoring, healthcare monitoring, transportation monitoring, agriculture monitoring, threat and incident monitoring, and industrial monitoring are some significant applications.
Area monitoring involves the use of WSNs to monitor specific areas for particular purposes. For instance, in military applications, sensors are deployed to detect enemy intrusion in a designated area, enabling enhanced security measures.

1.6.1 Environmental and Earth Monitoring

WSNs are used in environmental or earth monitoring to detect air quality, to detect forest fires [7], landslide detection, water quality monitoring, and prevention of natural disasters. These networks play a crucial role in gathering environmental data and providing insights for environmental management and protection.

1.6.2 Health Sector

In the healthcare sector, WSNs are deployed in various forms, such as implanted sensors, wearable devices, and environment-embedded systems. These networks facilitate applications like location tracking of individuals, measurement of body positioning, overall patient monitoring, and remote healthcare services.

1.6.3 Transportation Monitoring

Transportation monitoring leverages WSNs to collect and monitor data related to transportation systems. This data can be further utilized for traffic management, vehicle tracking, and improving transportation efficiency.

1.6.4 Agriculture Sector

In the agriculture sector, WSNs are employed for monitoring various parameters relevant to farming, such as soil moisture levels, temperature, humidity, and pest detection. The collected data enables farmers to make informed decisions regarding irrigation, crop health, and resource management.

1.6.5 Habitat Monitoring

Habitat monitoring utilizes WSNs to monitor and study rare species and their habitats. These networks provide valuable insights into ecological research, biodiversity conservation, and wildlife management.
Threat and incident monitoring involves the deployment of WSNs to detect and respond to potential threats or incidents in real-time. This application finds use in security systems, emergency response, and critical infrastructure protection.

1.6.6 Industrial Sector

WSNs are utilized in the industrial sector for data logging, water and wastewater monitoring, wastewater monitoring, and machinery fitness monitoring. These applications help optimize industrial processes, enhance productivity, and ensure efficient resource management.

Table 1.1 provides an overview of the diverse applications of WSNs, highlighting their versatility and significance across multiple domains.

Table 1.1: Applications and Areas of Wireless Sensor Network (WSN) Utilization.

Application	**Area of Application**
Transportation Monitoring	WSNs are used in the transportation sector to collect and analyze data for subsequent processing.
Area Monitoring	To keep an eye on a specified area for a specific purpose. For example, the military employed sensors to detect enemy penetration in a specified area.
Healthcare Monitoring	WSNs that are implanted, worn, or embedded in the environment are utilized for patient tracking, person location, body positioning measurement, overall patient monitoring, and so on.
Threat Monitoring	WSNs are used for threat and incident monitoring to prevent damages.
Agriculture Monitoring	To monitor and collect humidity, temperature, and other sensing data in agricultural areas for further processes.
Industrial Monitoring	WSNs are utilized for air quality monitoring, landslide detection, forest fire detection, natural disaster prevention, water quality monitoring, and other environmental factors.

1.7 Problem Review

Smart cities have a variety of open difficulties as a result of their integrated system and complexity, such as how to handle and offer people with their smart living environment, the security of smart city networks, and changing the high mobility of nodes. Different types of solutions have been brought to the issues, but all of these places are still suffering from data connection degradation, making smart living solutions more realistic, and the most important thing is security worry. Many more modifications are required to develop the smart city solution, such as data security, data handling, heterogeneity, sustainability, and analysis. In this context, heterogeneity refers to the complicated smart city design involving various devices, many vendors, and apps. There are still obstacles in integrating and operating heterogeneous things on the application layer. Because smart living applications are of an open nature, users' data are not secure, and their data management requires high security to design. Information security requires additional measures and is at risk in order to secure smart city networks.

Nature-inspired optimization solutions have been proposed to address various difficulties in various sectors. Computational intelligence has transformed the computing trend for complex networks, introducing new intelligent systems and optimization methodologies. Many nature-inspired algorithms exist, but some of the most well-known are bee algorithms, ant colony optimize rs, red swarm algorithms, grasshopper optimization, swarm algorithms, and dragonfly algorithms. Here is an ant colony algorithm. It is used to improve heuristic function, node communication transmission distance, residual energy, transmission direct, and introduce a new route updating rule that supports high minimal value of residual energy and high range residual energy level. The inspiration comes from the swarm, ant, and fly skills of competing for food and looking for food, territories, and mates. Because of their optimal nature in sorting out optimization problems, nature-inspired algorithms have several advantages over traditional solutions. These algorithms are used in the form of optimization to find the best answer to the problems. Nature inspired this method because it is one of the best suitable entities for resolving difficult situations.

1.8 Problem Statement

Algorithm is specifically improve heuristic functions, node communication, transmission distance, residual energy, and path finding in smart city networks. It draws inspiration from the behaviors nature entities. While considering the nature's behavior, the problem of data dissemination in high speed networks can be addressed.

1.9 Research Questions

1. How to design feasible protocol for data dissemination for high-speed networks?.
2. How to load balancing the data routing in WSN network?

1.10 Research Objectives

1. To design nature inspired routing protocol to handle the limited resources networks.
2. To design the load balancing solution for high-speed networks

CHAPTER 2

LITERATURE REVIEW

Literature review is a systematic method of identifying, evaluating and interpreting the work (similar to yours) produced by others. This chapter should set the project into context and give the proposed layout for achieving the project goals. It is an important chapter especially if the project involves significant amount of ground work. Review prior work critically, identify gaps in knowledge/areas of application and build an argument for your own work. When referring to other pieces of work, cite the sources where they are referred to or used, rather than just listing them at the end [8].

2.1 Overview

In this chapter, we delve into the existing research and literature on application of nature-inspired algorithms in wireless sensor networks (WSNs). The primary objective of these studies is to achieve comprehensive network coverage, optimize energy efficiency, enhance security, prolong the network lifetime, and reduce network traffic by leveraging the power of nature-inspired algorithms. Furthermore, special attention is given to the context of smart cities, considering their development goals and exploring potential future directions for utilizing nature-inspired algorithms in WSNs within this domain. By drawing inspiration from nature, researchers have proposed and investigated various algorithms that mimic the behavior and mechanisms observed in natural systems. These nature-inspired algorithms offer promising solutions to address the complex challenges faced by WSNs [9]. They incorporate principles from evolutionary computation, swarm intelligence, genetic algorithms, ant colony optimization, particle swarm optimization, and other bio-inspired techniques.

2.2 Working Process

Every node in a Wireless Sensor Network (WSN) establishes wireless connections with other nodes for data transmission, both between nodes and between nodes and the base station. Each sensor node consists of multiple components, including sensors, radio frequency transceivers, microcontrollers, memory units, and power units. The sensors within the nodes monitor environmental conditions and transmit the gathered information to nearby nodes or the base station. The WSN base station, which comprises a transceiver, microcontroller, and power unit, plays a critical role. It receives and collects data from the network of nodes and subsequently transmits it to either a data center or the user. Essentially, the WSN base station acts as a bridge connecting the sensor nodes' network with the data center or user.

2.3 Technology and standards

For operations, Wireless Sensor Networks (WSNs) use a variety of technologies and protocols. These include WiFi, Bluetooth, Zigbee, WIMAX, GPRS, and other wireless technologies [10]]. IEEE 802.15.1 PAN/Bluetooth, IEEE 802.11a/b/g (along with additional security protocols), IEEE 802.15.4 (with ZigBee covering the logical network and application software and IEEE 802.15.4 defining the physical and data link layers), IEEE 802.15.3 ultra wideband (UWB), IEEE 802.16 WiMax, and IEEE 1451.5 (Wireless Sensor Working Group) are among the standards[11]. WSNs rely on embedded operating systems for their functioning. Examples of such operating systems include LiteOS, TinyOS, eCos, PreonVM, and others [12].

The central focus of these nature-inspired algorithms is to optimize network coverage, ensuring that the monitored area is adequately served by sensor nodes. By strategically deploying sensors and dynamically adjusting their positions based on environmental changes, these algorithms aim to provide efficient and comprehensive coverage while minimizing redundancy and maximizing resource utilization. [12]

Due to the limited energy resources of sensor nodes, energy efficiency is another key challenge in WSNs. Nature-inspired algorithms offer innovative approaches to address this issue by optimizing energy consumption through intelligent node activation, data aggregation, adaptive routing, and power management strategies inspired by natural systems. These algorithms strive to prolong the network lifetime, allowing WSNs to operate for extended periods without requiring frequent battery replacements or recharging [13].

Table 2.1: Wireless Communication Standards

Standard	**Description**
IEEE 802.15.1 PAN/Bluetooth	Defines a wireless communication protocol for short-range personal area networks (PANs)
IEEE 802.11a/b/g	The physical and MAC layers for wireless local area networks (WLANs) are specified.
IEEE 802.15.4/ZigBee	Defines the physical and data link layers for low-rate wireless personal area networks (LR-WPANs)
IEEE 802.15.3 ultra-wideband	Focuses on ultra-wideband communication technology for high-speed data transmission over short distances
IEEE 802.16 WiMax	Enables broadband access over long distances with high data transfer rates
IEEE 1451.5 (Wireless Sensor Working Group)	Establishes guidelines and protocols for the interoperability and communication of sensors in WSNs

Security is a paramount consideration in WSNs, as they often handle sensitive data in critical applications. Nature-inspired algorithms can be employed to improve the security mechanisms of WSNs by incorporating principles such as immune systems, swarm behavior, and predator-prey dynamics. These algorithms contribute to the development of robust intrusion detection systems, secure data transmission protocols, and resilient network architectures. With the rapid growth and development of smart cities, nature-inspired algorithms hold significant potential for addressing the unique challenges and requirements of these urban environments. By leveraging these algorithms, smart cities can achieve efficient resource management, intelligent infrastructure, optimized mobility solutions, enhanced environmental monitoring, and seamless integration of sensor networks into urban systems. Future directions in this area include exploring advanced nature-inspired optimization techniques, developing adaptive algorithms for dynamic urban environments, WSNs are also being integrated with emerging technologies such as the Internet of Things (IoT) and cloud computing.

By examining the existing body of work on nature-inspired algorithms in WSNs, we gain valuable insights into the potential applications, benefits, and challenges associated with the adoption of these algorithms. This chapter gives the overview of the research in this field, highlighting the advancements made, identifying research gaps, and presenting avenues for future exploration and innovation.

2.4 Literature Review

Routing is the process of finding a path for network traffic to travel from the source to the destination in computer networking. In high-speed data dissemination settings, efficient routing is critical to ensuring timely and reliable data packet delivery. The Internet Protocol (IP) is a fundamental protocol for routing. IP routers analyze the destination IP address of incoming packets and utilize routing tables to determine which interface the packet should be forwarded via. Routers must manage enormous volumes of traffic for high-speed data distribution, hence they use specialized hardware and algorithms for fast packet forwarding.

Obtaining low latency and high throughput is one of the primary challenges in high-speed data dissemination. Latency is the time lag between sending a data packet and its arrival at its destination. Throughput is the pace at which data packets are delivered successfully. Many features of the network must be adjusted to achieve low latency and high throughput, including routing algorithms, network topology, and hardware components. Protocols such as Open Shortest Path First (OSPF) and Border Gateway Protocol (BGP) are frequently used to improve routing efficiency. OSPF is an inner gateway protocol that determines the shortest path to a destination based on metrics like bandwidth and delay. BGP, on the other hand, is an outside gateway protocol that is used to route traffic between independent systems. These protocols allow routers to dynamically react to network changes, maintaining optimal data distribution channels. To manage the increasing data rates in high-speed networks, specific hardware components such as high-speed routers and switches are used. To expedite packet processing, these devices use modern technologies such as Application-Specific Integrated Circuits (ASICs) and Field-Programmable Gate Arrays (FPGAs). ASICs are customized chips that are tailored for specific functions like packet forwarding, resulting in incredibly fast speeds. FPGAs, on the other hand, offer for greater flexibility in the implementation of unique routing algorithms, allowing for the efficient handling of a wide range of network traffic patterns. Furthermore, Quality of Service (QoS) techniques are used to prioritize particular types of traffic, ensuring that vital data is provided with as little delay as possible. Packet classification, traffic shaping, and traffic policing are all examples of QoS approaches. Packet classification classifies packets based on parameters such as source, destination, or application type. Traffic shaping adjusts packet flow to meet network capacity, preventing congestion. In contrast, traffic policing monitors and enforces traffic parameters in order to ensure network integrity and performance.

2.4.1 LO and IGA-BACA Algorithm

In their study [1], the authors focus on achieving optimal coverage in wireless sensor networks (WSNs) through the utilization of nature-inspired optimization algorithms. Specifically, they compare the performance of two different algorithms: Lion Optimization (LO) and a combination of Improved Genetic Algorithm and Binary Ant Colony Algorithm (IGA-BACA). The results of the study demonstrate that LO yields excellent network coverage, surpassing the performance of IGA-BACA. Additionally, LO exhibits a faster convergence rate compared to IGA-BACA. When comparing LO with alternative approaches, it achieves optimal coverage with a reduced number of iterations. These findings highlight the effectiveness of LO in addressing the coverage optimization problem in WSNs. However, while LO demonstrates promising results, there is still ample room for further exploration and improvement.

To enhance the algorithm's capabilities, one potential avenue is to incorporate machine learning techniques, such as Artificial Neural Networks (ANNs), into the optimization process. By integrating ANNs with heuristics like Ant Lion Optimization (ALO) or IGA-BACA, it is possible to leverage the strengths of both approaches and potentially achieve even better performance in solving multi-objective problems. This approach would involve training the ANN model using historical data and feeding it with relevant system inputs derived from heuristics like ALO or IGA-BACA. By doing so, the system can learn from the past optimization results and make more informed decisions during the coverage optimization process. This fusion of machine learning and nature-inspired algorithms holds significant potential for enhancing the efficiency and effectiveness of coverage optimization in WSNs.

2.4.2 Nature-inspired optimization (NIO)

In their work [14], the author proposes numerous algorithms based on nature-inspired optimization (NIO) methodologies for optimizing energy economy and security in wireless sensor networks (WSNs). They present two opportunistic routing algorithms in particular: the trust-based secure intelligent opportunistic routing protocol (TBSIOP) and the intelligent opportunistic routing protocol (IOP). These algorithms are pitted against two NIO-based algorithms designed to improve WSN security and efficiency. The author replicates the proposed algorithms in MATLAB and compares the results to PSO-based (Particle Swarm Optimization) and ACO-based (Ant Colony Optimization)

routing algorithms.
TBSIOP surpasses NIO-based algorithms in terms of energy efficiency, network longevity, average risk level, and packet delivery ratio, according to the research. Notably, TBSIOP performs better as the network size grows and effectively excludes rogue nodes throughout the routing process. TBSIOP extends network lifetime and is advantageous for smart healthcare services by offering energy-efficient data exchange over long periods of time, ensuring the network remains operational. In future work, the author expresses interest in conducting performance analysis and addressing various types of attacks on the layered network architecture of WSNs. This will further enhance the security provisions of the proposed solutions and better mitigate potential threats to WSNs in smart city environments.

2.4.3 HSA and PSM Algorithm

In another study [18], the author proposes the Harmony Search Algorithm (HSA) and Probabilistic Sensing Model (PSM) to achieve a balance between the cost of network deployment in Heterogeneous Wireless Sensor Networks (HEWSNs) and network coverage performance. HSA is utilized to strike a balance between the financial and coverage costs associated with HEWSN nodes, while PSM addresses the issue of sensor overlap. The proposed model's effectiveness evaluated in terms of cost and coverage ratio. The results indicate that the model achieves maximum coverage in the proposed heterogeneous deployment scenario and determines the minimum number of sensors required for homogeneous deployment, thereby providing a basis for comparison [15]

2.4.4 Ant colony, Dragon Clustering and moth flame

Furthermore, in [16], the author presents a novel concept of nature-inspired solutions to optimize and address the challenges faced by smart cities. They develop three nature-inspired solutions targeting three key areas: smart living, smart mobility, and security provision. An ant colony-based intrusion detection system for security, dragon clustering mobility in the Internet of Vehicles (IoV), and moth flame electric management for smart dwelling are among the solutions. These solutions are designed and implemented using techniques based on moth flame, dragonfly, and ant colony optimization. The recommended solutions outperform in terms of conventional performance characteristics, according to the performance evaluation. The author hopes to find and address difficulties relating to smart grids, healthcare, and other areas in future study. They want to provide more nature-inspired solutions for efficiency, improved data communication, and enhanced privacy and security for users in smart city environments.

2.4.5 Fuzzy Based Enhanced Cluster Head Selection (FBECS)

In [17], the author proposes an Information Systems (IS) perspective on smart cities, focusing on various aspects such as smart living, smart citizens, smart environment, smart architecture, smart government, and technologies. The concept of smart cities has garnered significant research attention, particularly within the field of information systems. The paper explores the benefits and challenges associated with the implementation of smart cities, and emphasizes the need to address the limitations of current development efforts while providing future directions for advancement.

In order to increase average remnant energy, throughput, and energy efficiency for wireless sensor networks (WSNs), the authors of [18] provide a Fuzzy Based Enhanced Cluster Head Selection (FBECS) approach. The proposed method selects a cluster head from among the available sensor nodes using fuzzy logic. Each sensor node then transmits the information it has gathered to the cluster coordinator, who forwards it to the base station. To provide load balancing, the FBECS approach selects the optimal coordinator node depending on the probability assigned to each node. The proposed scheme's performance is measured using a variety of measures, including alive nodes per round, average remnant energy, first node dead (FND), quarter node dead (QND), half node dead (HND), and network throughput. The evaluation results show that the FBECS technique improves energy economy in WSNs, resulting in enhanced network performance.

2.4.6 Underwater Sensor Networks (UWSNs)

In [19], the authors present various techniques and conduct a survey on underwater sensor networks (UWSNs) with a focus on environmental factors, routing protocols, underwater communication channels, and the impact of packet size. UWSNs are deployed between different nodes and ground-based stations to enable communication in underwater environments. The research community has proposed different methods to address challenges such as limited bandwidth, resource utilization, media access control, 3D topology, routing, and power constraints. However, due to the unique characteristics of the underwater environment, some of these challenges are still being actively investigated. The authors express their interest in introducing the concept of cognitive networks and exploring efficient utilization of the underwater spectrum, which presents challenges and opportunities for mobile computing and the design of cognitive acoustic networks for wireless communications.

2.4.7 Nature-inspired algorithms (ACO, ABC, GA, DE DE)

In [20], the author proposes the utilization of various powerful nature-inspired algorithms, including Ant Colony Optimization (ACO), Artificial Bee Colony (ABC), Genetic Algorithm (GA), Differential Evolution (DE), Invasive Weed Optimization (IWD), Cuckoo Search, and Dolphin Swarm Optimization, in the context of the Internet of Vehicles (IoV). These algorithms fall into categories such as evolutionary algorithms, physical algorithms, swarm intelligence, bio-inspired algorithms, and other nature-inspired algorithms. The author explores the applicability of these algorithms in addressing key challenges in IoV, such as security, routing, and parking management [21].

It is observed that ACO-based algorithms are suggested for routing in combination with PSO and GA algorithms, while firefly-based algorithms are proposed for optimal parking space allocation in conjunction with GA, ABC, and ACO algorithms. Additionally, there are other noteworthy nature-inspired algorithms such as IWD, BFO, and cuckoo search that have potential applications in IoV but are relatively less explored. The adoption of these nature-inspired algorithms can enhance the efficiency and performance of IoV networks. In [22], the author compares three advanced variants of Differential Evolution (DE) with eight well-known nature-inspired algorithms using blind random search on real-world problems. The results show that the adaptive DE variants perform well and outperform the other algorithms in the test problem area. However, some nature-inspired algorithms demonstrate subpar performance in the blind random search. Instead of developing new algorithms, the author recommends considering well-verified algorithms for application recommendations.

2.4.8 Energy Harvesting Wireless Sensor Network Routing Protocol (EHPRP)

In [23], the author introduces a novel bionic routing protocol called EHPRP (Energy Harvesting Wireless Sensor Network Routing Protocol) inspired by the mold Physarum polycephalum. This protocol addresses the energy value estimation problem in EHWSNs (Energy Harvesting Wireless Sensor Networks). The EHPRP incorporates three distributed routing algorithms with low algorithmic complexity, aiming to conserve energy and reduce processing delays. The stability of EHPRP is demonstrated through theoretical mathematical analysis. The results indicate that EHPRP achieves energy efficiency by consuming fewer energies compared to typical algorithms. It also exhibits more uniform network energy distribution under different workload conditions.

2.4.9 Ant Colony optimization Routing technique for WSN

In [24], the author offers a new routing technique for wireless sensor networks based on ant colony optimization. To establish an appropriate path from source to destination nodes, the method focuses on increasing the heuristic function, node communication transmission distance, residual energy, and transmission direction. The author proposes a new route update rule that allows for a high minimal value of residual energy as well as a wide range of residual energy levels. Comparative tests with the Leach-Ant, OARA, and EEABR algorithms show that the suggested ant colony algorithm reduces average energy consumption and improves the life cycle of the wireless sensor network, effectively conserving energy in nodes.

2.4.10 Swarm, Neural, and Immune algorithms

In [25], the author addresses various challenges associated with cloud computing, such as network load, information leakage, security intrusion, and biometric identification. Bio-inspired algorithms, including Swarm, Neural, and Immune algorithms, developed based on natural ecosystems, are proposed to tackle these challenges. The focus is on two bio-inspired algorithms, namely the Neural Network (NN) and Particle Swarm Optimization (PSO) approaches, to address the security problems of cloud computing. Other nature-inspired algorithms such as Fruit fly, Ant Colony, and Grasshopper also draw interest for specific issues among researchers.

For attaining energy efficiency and dependability in wireless sensor networks, notably in the context of e-healthcare services applications, the author of [26] suggests the Intelligent Opportunistic Routing Protocol (IOP). By choosing nodes from a list of forwarder nodes, the suggested IOP increases the sensor network's throughput, stability, and network longevity. Nodes that are remote from the base station are guaranteed to become relay nodes under the protocol. The likelihood of nodes in the middle of the source and at the destination being chosen as forwarders is greatest in each round.

2.4.11 Swarm Intelligence-based Routing Protocols

According to [27], the benefits of swarm intelligence-based routing protocols' scalability have led to an upsurge in their use recently. The classification of swarm-intelligence protocols is the author's primary concern, and he offers a thorough explanation of hierarchical routing protocols based on swarm-intelligence. The comparison of these protocols is based on a number of different criteria, including query-based methods, data aggregation, route choice, energy efficiency, and location awareness. The outcomes show that highly energy-efficient hierarchical protocols based on swarm intelligence are possible. Furthermore, the development of new hierarchical routing protocols for Wireless Sensor Networks (WSNs) is emphasized as they can enhance scalability and energy efficiency in WSNs. In the future, this study aims to analyze different nature-inspired routing protocols for WSNs, including Evolutionary, Swarm-intelligence-based, and bio-inspired protocols.

2.4.12 TMLBSs

The author of [28] suggests using Transmission with Multiple Load Balancing Schemes (TMLBSs) to build transmission paths for nodes in diverse locations and to implement data dissemination strategies. In order to build transmission paths forming a path tree, TMLBSs have three load balancing strategies. The first approach is the load decentralization plan, which early on constructs several paths to spread the total load over various path subtrees, preventing too much pressure on particular paths. The load maintenance scheme is the second scheme and it uses an update mechanism to keep the previously found good pathways, leading to better next-generation solutions. The load diversion system, which eliminates subpar solutions by transferring traffic load to paths with lighter traffic, is the final scheme. To verify the efficacy and benefits of this new transmission approach, extensive simulations are run. The effectiveness and superiority of TMLBS in terms of load balancing level, network longevity, and convergence speed have also been validated by a number of trials. A thorough comparison analysis and summary of the literature review are provided in Table 2.2 .

Table 2.2: Overview of Literature Review

Ref.	**Year**	**Algo**	**Work**	**Achievement/Future Direction**
Abhilash et al.	2020	Nature Inspired Optimization Algorithm.	Compared two different performances of ISA to get optimal coverage in WSN.	(LO & IGA-BACA) LO provides good network coverage, performance, and a faster convergence rate than (IGA-BACA).
Deep Kumar Bangotra et al.	2022	NIO algo for optimizing the problem of energy efficiency & security in WSN.	(TBSIOP and IOP) are two opportunistic routing algo	While comparing (TBSIOP & IOP) TBSIOP improved the network lifetime & providing energy efficient services during sharing of data etc.
Belal Al-Fuhaidi et al.	2020	Heterogeneous wireless sensor network (HEWSN)	(HAS & PSM) algo used to get balancing between cost of network in (HEWSN) and performance of network coverage.	For heterogeneous deployment achieved maximum coverage and minimum number of sensors that compared.
Kashif Naseer Qureshi et al.	2021	New ideas for nature-inspired solutions (moth flame, dragonfly, and ant colony optimization techniques)	For security, an ant colony-based intrusion detection system is used, as is dragon clustering mobility in IoV and moth flame electric management in smart living.	In terms of typical performance parameters, they achieved greater performance and will be focusing on additional areas of nature-inspired solutions for optimization, better data transfer, user privacy, and security in the future.

Ismagilova et al.	2019	Information System on the perspective of smart city.	Focuses on smart cities (digital city, information city, wired city) IS used for its implementation and development goals.	For future direction focusing on limitation of current development & development goals
Abhishek Rai et al.	2019	Fuzzy Based Enhanced Cluster Head Selection (FBECS) approach for WSNs	For its Improvement of the energy efficiency, long lifetime, load balancing	Need more improvements.
Khalid Mahmood Awan et al.	2019	In smart city several techniques used for UWSN	Proposed different method to sort out these issues (media access control, 3D topology, resource utilization and etc)	Still searching on underwater environment & In future they are interested to introduce cognitive network area & identifying the underwater spectrum.
Ibrar Ullah et al.	2019	Nature Inspired Algo such as (ACO, dolphin, cuckoo etc.)	ACO based algo suggested for routing with PSO and GA int the routing of IoV. Firefly algo finds optimal parking space.	In future to increase the efficiency of IoV network, need to consider these nature algorithms.
Wenyi Tang et al.	2018	Physarum Polycephalum, is proposed for EHWSNs	EHPRP addressing the problem without envision of energy value for WHWSNs.	EHPRP takes less energy & under different workload condition it display more uniform network energy

Petr Bujok Et al.	2018	Nature Inspired Algo in Real World Optimization Problem.	DE and eight famous natures inspired algo are compared blind random search on the real-world problems.	DE variants performance is well and over the other algo it's also best in the test area.
Yongjun Sun Et al.	2017	Ant Colony Algorithm.	Used for the improvement node communication etc. introduced a new route supports minimum value of residual energy and high range of residual energy level.	Through Ant algo energy of nodes saved effectively.
Ghawy, M.Z. Et al.	2022	PSO (Particle Swarm Optimization)	To discover the best pathways,the distance between nodes and their energy the PSO technique is used.	The outcome is that the proposed method gives good performance and is effective in extending the wireless sensor network lifetime in future, PSO will be combined with existent techniques to handle huge scale routing challenges
Ahsan, M.M. Et al.	2020	Numerous algorithms	NN and PSO approach to tackle the security problem of cloud computing.	Algorithms like Fruit fly, Ant Colony and Grasshopper drew interest to specific issues among researchers.

Bangotra DK, Et al.	2020	IOP (intelligent opportunistic routing protocol)	The proposed IOP increased network longevity, sensor network throughput, and network stability.	As a result, OR scheme was better than EEOR and MDOR in network lifetime and energy efficiency during data dissemination. In future, over the internet they will ensure secure data transmission.
Mehta, D. Et al.	2020	classification of swarm-intelligence protocol	On a different aspect these protocols compared for such as query based, data aggregation, route selection, energy efficiency and location awareness.	In the future, this work will examine various natureinspired routing protocols for WSNs, including Evolutionary, Swarm intelligence-based, and bio-inspired protocols for routing in WSNs
Liu, Xuxun, Et al.	2019	(TMLBSs) transmission with multiple load balancing schemes	Three load balancing schemes are the characteristics of TMLBS, which help to construct transmission paths formed into a path tree.	Several trials proved the effectiveness and superiority of TMLBS in terms of load balancing level, network longevity, and convergence speed.

CHAPTER 3

RESEARCH METHODOLOGY

This research methodology's goal is to offer a research strategy. The research environment, assumptions, and limits are all covered in this chapter as well. Due to their interconnected systems and complexity, smart cities have a number of open difficulties, including how to manage and supply people with a smart living environment, secure their networks, and alter the high node mobility. Different sorts of solutions have been offered here to address the problems, but the data connectivity in all of these areas continues to deteriorate. Smart living solutions are becoming more and more appealing to people, but security concerns are still the most crucial issue. There are other additional modifications needed to develop the smart city solution, including data security, data processing, heterogeneity, sustainability, and analysis.

3.1 Smart City Operational Layers

To build a common architecture for smart cities that can be used in real-world scenarios, several networks must be integrated. To accomplish this, many new communication technology standards and protocols have been created, enabling effective networking with minimal interference, signal attenuation, and optimal spectrum use. In order to provide extensive coverage at a reasonable cost, smart city solutions must be robust, scalable, and utilise high authentication encryption technology. Emerging technologies such as software-defined networks, network function virtualization, cognitive radio communication, LowPAN standards, Sigfox, and 5G contribute considerably to these goals. WiMAX, Wi-Fi, LTE, LTE-A, ZigBee, and Bluetooth are some of the modern communication technologies used in smart cities [35]. These standards and technologies strive towards error-free communication, ultra-high spectral efficiency, high data-rate transmission, and low power consumption [34]. The device deployment layer, which is the first layer of the smart city design, is in charge of placing intelligent devices strategically, including smart sensor nodes, tangible objects, and infrastructure. This layer is responsible for complex calculation, data storage, sensory abilities, and deft decision-making. Due to its crucial role in decision-making processes, it forms the basis for smart city services. This layer also handles scalability and integration issues brought on by a wide variety of devices and their interconnectivity and communication range [35].

Due to the wide range of device heterogeneity inside this layer, data collecting creates still another difficulty. Drones, Internet of Vehicles (IoV) components, wireless sensor networks (WSNs), and IoT devices work together to create a network that enables a variety of services, including data collecting, sensing, routing, and dissemination. A variety of technologies have been adopted, including ZigBee, Bluetooth, and other radio-based sensors, to meet the needs of this layer. Furthermore, this layer is dependent on physical infrastructure and tools like microwave towers, access points, and base stations. An extra difficulty arises when deploying these devices, especially in intricate metropolitan settings. The data connection layer is layer two of the smart city design, and it includes numerous standards such as 3G, 4G, and 5G. These standards make use of network architectures such as cellular, wireless, Wi-Fi, Li-Fi, WiMAX, and wired. It allows the convergence of heterogeneous communication networks by acting as a backbone layer [36].

Above the data communication layer is the data handling layer, which includes various data collecting and application frameworks. Its primary responsibilities include handling big data, managing data, and guaranteeing the long-term viability of smart city systems. This layer is critical for data vitality and includes functions such as data fusion, data storage, data processing, and decision management.

The interface through which users communicate with the system is the service layer, which sits on top of the smart city design. Different computer-based, Android-based, and user interface-based applications are used by users to access the system. Smart weather forecasting, smart grid services, transportation systems, industrial IoT, and community development applications are common applications in this layer. This layer's intelligent applications are in charge of meeting users' individual needs, enhancing performance, and playing a crucial part in decision execution.

The last layer is devoted to offering security features to safeguard user data from unauthorized access. Due to their open system architectures, smart cities are subject to a variety of security risks, where a single vulnerability exploited by a single attacker or group of attackers might constitute a serious threat to the entire city [37]. This layer responds to different security risks and puts policies in place to guarantee that data collection, processing, and routing are done safely and with privacy concerns.

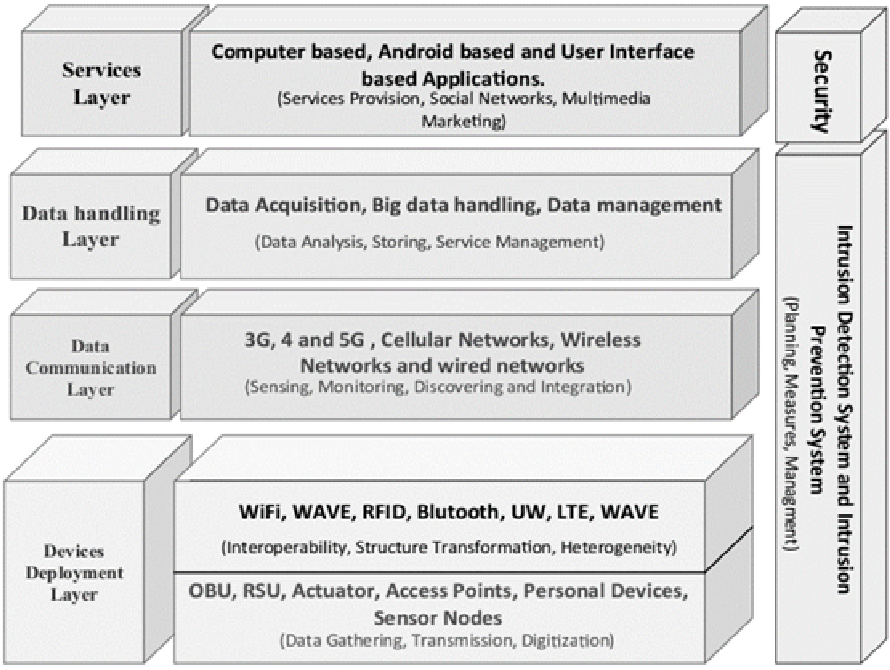


Figure 3.1: Smart city layer architecture

3.2 Nature-inspired Approaches for Smart City Challenges

The computing trend has experienced a significant shift with the emergence of computational intelligence and integrated technologies, leading to a new era of computation. In this era, nature-inspired solutions have gained prominence, offering optimization capabilities and developing intelligent systems to tackle complex problems.

The ant colony optimizer, dragonfly algorithm, grasshopper optimization algorithm, swarm algorithm, bee algorithms, and red swarm algorithm are all examples of nature-inspired algorithms. These algorithms are inspired by the behavior of ants, swarms, and flies in tasks including food search, resource competition, mating, and territorial disputes. Nature-inspired algorithms have significant advantages over traditional techniques, owing to their innate capacity to deal with optimization problems. They are used in the form of optimization to identify the best solutions to problems. Because these solutions are inspired by nature, they are well-suited for addressing complex challenges while preserving a balance among numerous components. Nature-inspired algorithms of various types have been created, including ones based on human decision making processes (such as fuzzy logic and game theory) and swarm intelligence (such as particle swarm optimization, ant colony optimization, and bee colony optimization).

3.3 Nature Inspired Solution

The most important factor is making the most use of the services that are offered in smart cities. Numerous devices, including sensors, access points, routers, and high-end systems, are interconnected and using the resources available for diverse applications related to mobility and smart living. Numerous approaches have been developed to support the smart city services. Operations in smart cities continue to be hampered by costs, complexity, delays, and security concerns. The greatest tools for handling data communication in smart cities are those that are inspired by nature, such as ant colonies, swarm computing, grammatical evolution, and swarm Numerous studies are being done to solve the issues with smart cities using these nature-inspired methods. By offering backup routes and data protection, these solutions' behavior increases the efficiency of data exchange. As was already said, the fields of smart living, mobility, and security have embraced solutions that are inspired by nature. Designing the solutions takes into account the behavior of many nature living creatures, such as the dragonfly, ant colony, grasshopper, firefly, and grey wolf. These methods are employed for data delivery improvement, categorization, optimization, and computation time and delay reduction. Additionally, these solutions offer confidentiality and integrity, lowering any security risks for consumers. These solutions are used to protect system privacy and trust, as seen in [38]. On the other side, these methods are also employed in smart home systems, where they are used to tackle issues with energy cost optimization, average wait time, and maximum delay.

3.4 Proposed Methodology

In our proposed methodology, we aim to introduce a nature-inspired data dissemination routing protocol for Wireless Sensor Networks (WSNs). Recognizing the challenges faced in various domains, nature-inspired optimization solutions have been developed to address complex network issues. Computational intelligence has revolutionized computing trends, offering new intelligent systems and optimization techniques. These algorithms excel in finding optimal solutions for problem-solving through optimization approaches. Nature inspired algorithms have gained prominence due to their ability to handle complex issues and maintain balance across different components. Notable examples include bee algorithms, ant colony optimizers, red swarm algorithms, grasshopper optimization, swarm algorithms, and dragonfly algorithms.

In our proposed scheme, we focus on nature-inspired solutions to enhance smart mobility, smart living, and security aspects. We recognize that smart cities require efficient and reliable data dissemination in WSNs, and nature-inspired protocols can effectively address this need. Our methodology leverages the inherent efficiency and adaptability observed in nature to design innovative solutions. We propose specific algorithms tailored to tackle challenges in different domains, including smart mobility, smart living, and security.

To improve smart mobility, we introduce a Dragonfly-based clustering algorithm. Inspired by the behavior of dragonflies in forming clusters, this algorithm facilitates efficient data routing and communication within WSNs. By organizing sensor nodes into clusters, we enhance the network's scalability, energy efficiency, and overall performance. For smart living solutions, we propose a Moth flame-based energy management solution. Taking inspiration from the behavior of moths attracted to flames, this algorithm optimizes energy consumption and management within the WSN. By dynamically adapting energy usage based on the network's demands, this solution prolongs the network's lifetime and ensures reliable operation. To address security concerns, we incorporate the Ant colony optimizer algorithm. Drawing inspiration from the cooperative behavior of ants in finding optimal paths, this algorithm enhances the security provisions of the WSN. It focuses on efficient route selection, minimizing vulnerabilities, and preventing unauthorized access or malicious attacks. By adopting these nature-inspired solutions, we aim to improve the performance, efficiency, and security of WSNs in smart cities. Our proposed methodology harnesses the power of nature-inspired optimization techniques to overcome complex challenges. These solutions offer innovative approaches to data dissemination, energy management, and security provision. By incorporating these algorithms, smart cities can enhance their overall functionality and provide a seamless and secure living environment for their residents.

3.5 Proposed Architecture Diagram

The proposed system, a Nature-Inspired Data Dissemination Routing Protocol for (WSNs), aims to optimize energy consumption and achieve quick packet delivery within the network. This system leverages nature-inspired algorithms and principles to design an efficient and adaptive routing protocol. Energy Consumption Optimization: To optimize energy consumption in the WSN, the system incorporates the Moth Flame-based Energy Management

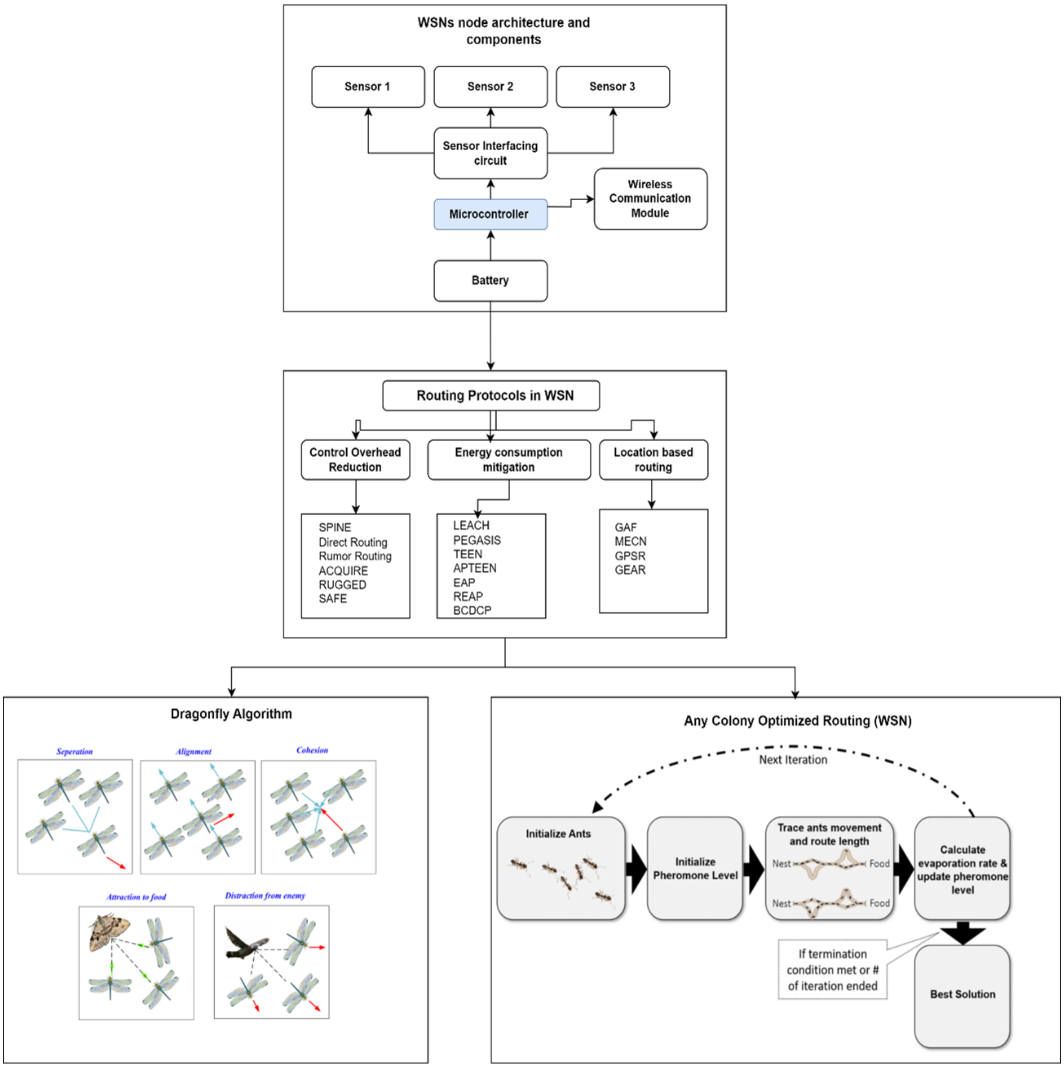


Figure 3.2: Architecture Diagram

Solution. This algorithm draws inspiration from the behavior of moths attracted to flames. It operates by dynamically adapting energy usage based on the network's demands. The algorithm employs the following steps:

1. Energy Monitoring: The program continuously analyzes the energy levels of the network's sensor nodes.

2. Energy-Aware Routing: When it is time to send a data packet, the algorithm chooses the most energy-efficient path from the source node to the destination node. It takes into account variables including residual energy levels, transmission distances, and the availability of low-energy pathways.

3. Energy Adaptation: The method dynamically adjusts sensor node energy usage based on network requirements. It controls the transmission power and duty cycle of nodes in order to save energy while maintaining effective communication.

By optimizing energy consumption through adaptive routing, the proposed system enhances the overall energy efficiency of the WSN. This helps to extend the network's lifetime, reduce the need for frequent battery replacements, and improve sustainability.
Quick Packet Delivery: To achieve quick packet delivery, the system utilizes the Nature-Inspired Data Dissemination Routing Protocol. This protocol incorporates multiple nature-inspired algorithms, including the Dragonfly-based Clustering Algorithm and the Ant Colony Optimizer Algorithm.

1. Dragonfly-based Clustering Algorithm: Inspired by the behavior of dragonflies in forming clusters, this algorithm organizes sensor nodes into clusters. It offers the following benefits:
    - Efficient Data Routing: The algorithm facilitates direct communication within clusters, reducing the number of hops required for packet delivery and minimizing delays.
    - Scalability: Clustering helps to divide the network into manageable groups, enabling efficient data dissemination in large-scale WSNs.
    - Load Balancing: By distributing data traffic among cluster heads, the algorithm balances the network load and prevents congestion.
2. Ant Colony Optimizer Algorithm:This algorithm draws inspiration from the cooperative behavior of ants in finding optimal paths. It contributes to quick packet delivery by:
    - Efficient Route Selection: The algorithm identifies the most optimal paths for packet transmission by considering factors such as path length, residual energy, and congestion levels.
    - Minimizing Delays: By selecting routes with minimal delays and avoiding congested areas, the algorithm helps ensure timely packet delivery.
    - Security Provisions: The algorithm incorporates security measures to prevent unauthorized access and malicious attacks on the network.

By combining these nature-inspired algorithms, the proposed system optimizes data dissemination and achieves quick packet delivery in the WSN. It minimizes delays, reduces packet loss, and improves the overall performance and efficiency of the network. The Nature-Inspired Data Dissemination Routing Protocol for Wireless Sensor Networks provides an efficient solution for optimizing energy consumption and achieving quick packet delivery. By leveraging nature-inspired algorithms, such as the Moth Flame-based Energy Management Solution, Dragonfly-based Clustering Algorithm, and Ant Colony Optimizer Algorithm, this system ensures efficient utilization of energy resources, enhances network scalability, and facilitates reliable and timely data transmission within the WSN [39].

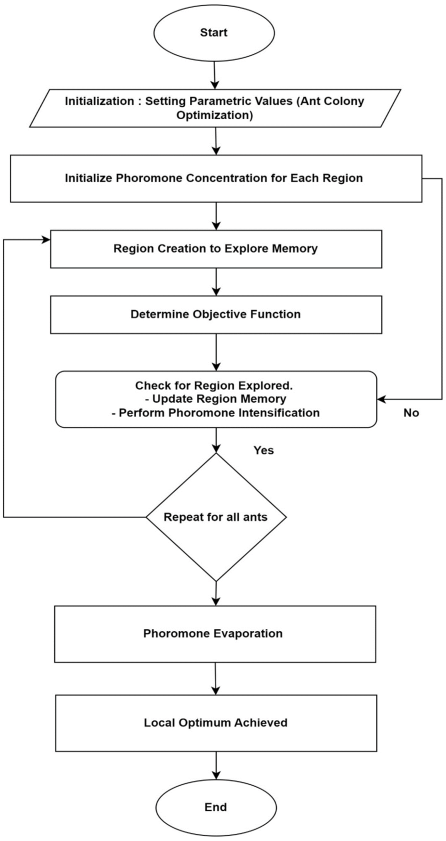


Figure 3.3: Flow chart and algorithm of ACIDS

The algorithm for proposed nature inspired data dissemination routing protocol for wireless sensor network is as follows:

(a) Initialize parameters:
xm = 500;

```
ym = 500;
sink.x = 150;
sink.y = 150;
n = 100;
p = 0.1;
Eo = 0.9;
ETX = 50 * 0.000000001;
ERX = 50 * 0.000000001;
Efs = 10 * 0.000000000001;
Emp = 0.0013 * 0.000000000001;
EDA = 5 * 0.000000001;
yd1 = 33;
m = 0.3;
a = 4;
bandwidth = 12; rmax = 5000;
```

(b) Compute do = Efs / Emp and initialize Et to 0.

(c) Create a random network: for i = 1 to n:

```
S(i).xd = rand(1, 1) * xm;
XR(i) = S(i).xd;
S(i).yd = rand(1, 1) * ym;
YR(i) = S(i).yd;
S(i).G = 0;
S(i).type = 'N';
temp-rnd0 = i;
if (temp-rnd0 ¿= m * n + 1):
S(i).E = Eo;
E(i) = S(i).E;
S(i).ENERGY = 0;
if (temp-rnd0 ¡ m * n + 1):
S(i).E = Eo * (1 + a);
E(i) = S(i).E;
S(i).ENERGY = 1;
Et = Et + S(i).E;
```

(d) Set S(n+1).xd and S(n+1).yd to the sink coordinates.

(e) Initialize counters and variables:

```
countCHs = 0;
rcountCHs = 0;
```

```
cluster = 1;
packets-TO-BS = 0;
packets-TO-CH = 0;
flag-first-dead = 0;
allive = n;
```

(f) Start the main loop for rounds r = 0 to rmax. a. Handle heterogeneous epochs:

```
if (mod(r, round(1/pnrm)) == 0):
    for i = 1 to n:
        S(i).G = 0;
        S(i).cl = 0;
```

b. Handle sub-epochs for fake nodes:

```
if (mod(r, round(1/padv)) == 0):
    for i = 1 to n:
        if (S(i).ENERGY == 1):
            S(i).G = 0;
            S(i).cl = 0;
```

c. Update the number of dead nodes and check if the first node died.

d. Process node elections, cluster head selection, and energy consumption.

(g) Calculate network statistics (e.g., network lifetime, stability period, energy consumption).

(h) Plot the statistics and results for network performance.

(i) Repeat steps 6 to 8 for different scenarios (if applicable).

(j) End of the pseudo code.

3.6 Code Working

- Initialization: The code initializes various parameters, like network dimensions, number of nodes, probabilities, energy parameters, message size, authentication threshold, and the maximum number of rounds.

- Creation of a Random Network: It simulates the creation of a random network of sensor nodes. It randomly positions nodes in a two-dimensional space, assigns initial energy levels, and categorizes them as "Normal" or "Blast" nodes based on some predefined criteria.
- Simulation for ACIDS: The code then simulates the ACIDS protocol for the given number of rounds. It considers cluster head election and energy dissipation according to a set of rules specific to the ACIDS protocol.
- Simulation for NIDDRP: The code simulates the NIDDRP protocol in a similar manner, taking into account its own set of cluster head election and energy dissipation rules.
- Data Collection: The code collects and stores data during the simulations, such as the number of live nodes, the number of dead nodes, energy consumption, and packets transmitted to the base station.
- Plotting Results: It then plots and compares the results between ACIDS and NIDDRP in terms of network lifetime, stability period, energy consumption, and packet delivery ratio.

3.7 State Time Complexity

Proposed algorithm can be analyzed for time complexity in three main sections. The initial part of the algorithm, which includes variable initialization and the assignment of constant values, exhibits a constant-time complexity, denoted as O(1). These operations do not depend on the size of the input or any iterations. The second section of the algorithm involves a "for" loop that iterates through each node (c) for some total number of nodes (n = 100). This results in a time complexity of O(n), where n is the total number of nodes. The exact number of iterations is determined by the value of 'n.' The final section contains a "while" loop with a condition based on the detection rate and other operations, including selecting nodes, subset calculation, and performance classification. The time complexity for this part is challenging to determine without specific details about the loop's termination conditions and the number of iterations it goes through. Therefore, the overall time complexity for the entire algorithm depends on the behavior of the "Ant," the detection rate, and the unspecified operations within this "while" loop and a subsequent ”procedure.” Finally, the time complexity of this algorithm is O(n).

CHAPTER 4

SIMULATION AND RESULT

4.1 Overview

This chapter introduces the simulation setup, research environment, assumptions, and limits are all covered in this chapter as well the experimental results and presents a comprehensive evaluation and interpretation of the data obtained from the experiments conducted on the proposed "Nature Inspired Data Dissemination Routing Protocol for Wireless Sensor Networks." This chapter aims to provide insights into the performance, efficiency, and effectiveness of the proposed solution, ACIDS (Adaptive Clustering and Intelligent Data Dissemination System), compared to the conventional NIDDRP (Nature Inspired Data Dissemination Routing Protocol). Through a detailed analysis of the collected data and the presentation of various graphs, this chapter sheds light on the key findings and implications of the study. The results and analysis presented here serve as a foundation for drawing conclusions, discussing the implications, and suggesting recommendations for future research and implementation. By critically examining the performance metrics and analyzing the experimental outcomes, this chapter provides a thorough understanding of the advantages and effectiveness of ACIDS in optimizing energy consumption and achieving quick packet delivery within wireless sensor networks [41].
There are four sections in this chapter. Research strategies are described in Section 4.2. In a nutshell, the simulation framework it is covered in Sections 4.3 and 4.4, respectively. Simulation parameters are characterized by simulation settings. Section 4.5 presents the survey performance metrics that were used to assess the results. Section 4.6 depicts several network topologies established in light of the proposed scheme's restrictions and assumptions. Section 4.7 presents the experimental results.

4.2 Research Framework

Problem investigation, design and development, and implementation and evaluation are the three steps in the research framework. Figure 4.1 depicts the flow of research process.

4.2.1 Problem Investigation

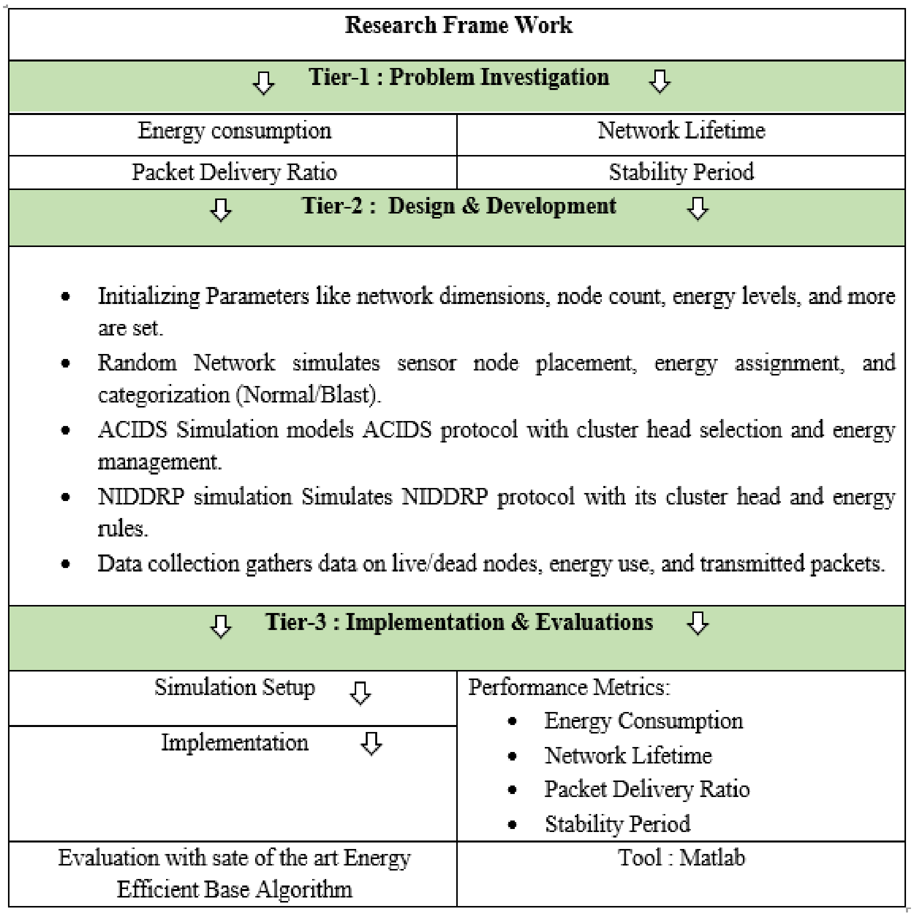
The first phase looks into WSN sensor node problems. WSN sensor node battery resources are restricted. As a result, complicated routing methods cannot compress it. Existing routing methods are inefficient in terms of energy consumption and employ ineffective load balancing mechanisms across nodes. Earlier research on the topic has been implemented in this phase on the Springer, IEEE, ACM, Science Direct, Elsevier, and MDPI platforms. The compilation of all previous efforts is based on improvements and research into our condition. [29].

4.2.2 Design and Development

Based on funding research gaps from prior work, the second phase will create and construct an energy-efficient, network lifespan, packet delivery, stability period, and optimization model for data dissemination in WSN. By selecting the best cluster head for data distribution from clusters, the design model will increase energy efficiency. It will also increase network longevity by determining the best cluster head location inside the cluster region.

4.2.3 Implementations and Evaluations

In the third phase, we use a MATLAB stimulator to simulate our proposed design process. We analyze the findings using performance metrics and compare them to state-of-the-art energy-efficient routing techniques.



Research Frame Work

⇩ **Tier-1 : Problem Investigation** ⇩

Energy consumption	Network Lifetime
Packet Delivery Ratio	Stability Period

⇩ **Tier-2 : Design & Development** ⇩

- Initializing Parameters like network dimensions, node count, energy levels, and more are set.
- Random Network simulates sensor node placement, energy assignment, and categorization (Normal/Blast).
- ACIDS Simulation models ACIDS protocol with cluster head selection and energy management.
- NIDDRP simulation Simulates NIDDRP protocol with its cluster head and energy rules.
- Data collection gathers data on live/dead nodes, energy use, and transmitted packets.

⇩ **Tier-3 : Implementation & Evaluations** ⇩

Simulation Setup ⇩ Implementation ⇩	Performance Metrics: • Energy Consumption • Network Lifetime • Packet Delivery Ratio • Stability Period
Evaluation with sate of the art Energy Efficient Base Algorithm	Tool : Matlab

Figure 4.1: Research Framework

4.3 Simulation Framework

One of the most challenging problems in evaluating the performance of recommended systems against other comparable algorithms is simulator selection. Numerous simulation tools, such as Network Simulator2 (NS2), Network Simulator3 (NS3), MATLAB, and Objective Modular Network Testbed in C++ (OMNET++), have been created for wireless networks. The optimal instrument for testing communication networks is MATLAB, an event-driven, open-source simulator. Overall, MATLAB is a dependable and adaptable data distribution and networking solution. It offers a number of characteristics that make it well-suited for these activities, including high-performance data processing and visualization, support for a wide range of data types, and networking capabilities. In addition, open source MATLAB modules are widely utilized in the research community, and new objects can be easily created by merging them with related C++ class objects. The MATLAB simulator is utilized in this study to compare the performance of the proposed model to that of other relevant schemes in terms of performance indicators [30].

4.4 Simulation Setup

The simulation configuration utilized to evaluate the effectiveness of our suggested method is covered in this section. On a field of 100 by 100 meters, a network of 100 sensor nodes is used to execute the simulation. Due to GPS or another location algorithm, all sensor nodes are permanently installed and aware of their whereabouts. At coordinates 100, 100, the base station is situated outside of the network. All of the sensor nodes have equivalent and consistent capabilities. a sensor node's wireless connection to another node. Three distinct network designs were looked at. By adjusting the number of cluster heads in the sensor node network, the goal is to evaluate the performance of the suggested approach. The simulations ran over 5 times, and the outcomes were represented by the average of the data instances [29].

Table 4.1: Displays the simulation parameters

Parameter	**Values**
Network Area	$100m \times 100m$
BS location	$(100, 100)$ (outside)
Number of Sensor Nodes	100
Energy (Initial) (E_0)	0.9
Energy (Data Aggregation)	$5nE$/bit/signal
Transmission Energy	50×10^{-9}
Reception Energy	50×10^{-9}
Data Transmission Rate	5000 bps
ε_{fs}	10×10^{-12}
ε_{amp}	0.0013×10^{-12}
Round time	2 sec per round
Packet Size	200 bits

4.5 Performance Metrics

The following performance indicators (PI) are used to check out the success of the proposed methodologies in relation to the research objectives:

4.5.1 Energy Consumption

The most crucial component of a wireless sensor network is energy consumption; sensor nodes utilize battery power to send and receive data packets. In our experiment, energy is consumed throughout each cycle of clustering, gateway node assignment, sensing, and data transmission from the cluster's central node to the base station (BS) via the involvement of CH and gateway nodes.

The range or future values of simulation parameters based on simulation findings are referred to as the confidence interval. The 90% confidence level determines the likelihood that the interval will contain the parameter's value. The simulated confidence interval was set at 90% for this investigation [30].

4.5.2 Network Lifetime

The network lifespan is the amount of time it takes for all nodes to exhaust their available power. When a transmission begins, the cluster nodes are alerted to it and transmit it to the cluster head before sending it, via the gateway node, to the base station. In our experiments, the starting energy of the node is 0.9, and it decreases as control messages and data are sent and received.

4.5.3 Packet Delivery Ratio

The Packet Delivery Ratio (PDR) in WSNs is the ratio of packets successfully received to packets sent. It is a critical parameter for assessing WSN performance since it defines how well the network can transfer data from sensor nodes to sink nodes. A variety of factors can influence PDR in WSNs, including: The greater the distance between nodes, the lower the PDR is expected to be. This is because signal strength decreases with distance, increasing the likelihood of packet loss. The ability of the base station to receive packets is referred to as network throughput. Data from the sensor nodes is successfully transferred to the sink node [31].

4.6 Assumptions and limitations

- The base station is located apart from the network (100, 100).
- Base stations have more power than regular nodes and a database/memory.
- Transmission power varies with distance at each node.
- Static sensor nodes are planted at random in a sensor field.

4.7 Results and Discussion

4.7.1 Energy Consumption

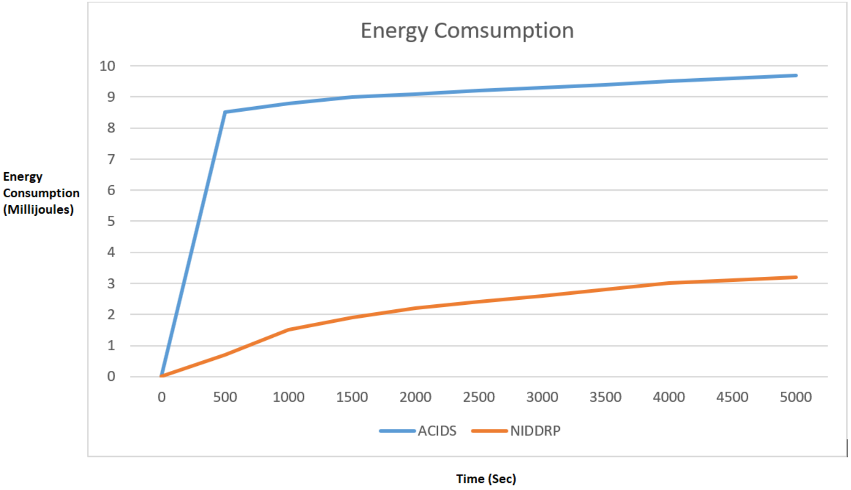


Figure 4.2: Energy consumption – ACIDS vs NIDDRP

In Figure 4.2 the graph clearly demonstrates that ACIDS outperforms NIDDRP in terms of energy consumption. ACIDS consumes significantly less energy than NIDDRP, suggesting its higher efficiency in managing energy resources within the wireless sensor network (WSN). This accomplishment is due to the inclusion of the Moth Flame-based Energy Management Solution, a nature-inspired algorithm that dynamically modifies energy usage based on network demands. ACIDS automatically routes data packets over energy-efficient channels and regulates the transmission power and duty cycle of sensor nodes to effectively optimize energy consumption. As a result, the WSN experiences prolonged network lifetime and reduced dependence on frequent battery replacements, leading to improved sustainability and operational cost savings [42].

The notable performance advantage of ACIDS over NIDDRP in terms of energy consumption confirms the effectiveness and efficiency of the proposed nature-inspired solution. This result reinforces the significance of leveraging nature-inspired optimization techniques in designing routing protocols for WSNs, emphasizing the potential of nature as a valuable source of inspiration for solving complex network challenges. Overall, the analysis of the graph supports the conclusion that ACIDS, the proposed nature-inspired data dissemination routing protocol, surpasses NIDDRP in terms of energy consumption optimization within the wireless sensor network. This achievement is crucial for ensuring long-term network sustainability and reducing operational costs, making ACIDS a promising solution for efficient and energy-conscious smart city applications.

4.7.2 Network Lifetime

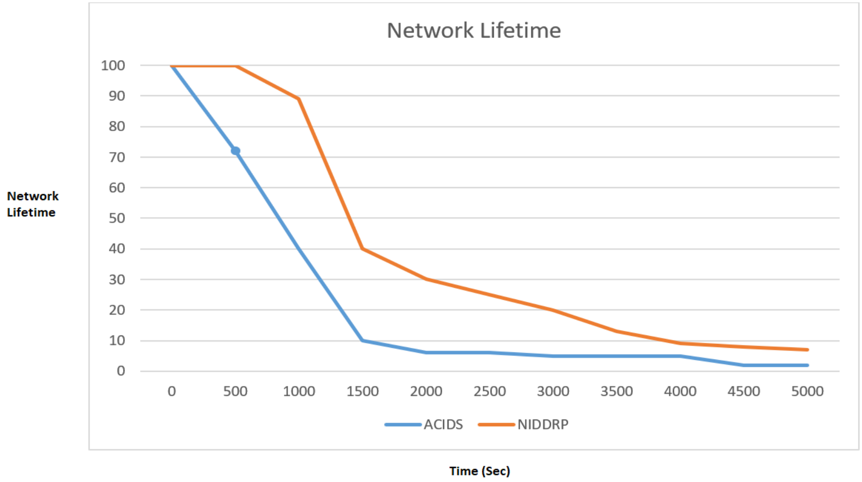


Figure 4.3: Network Lifetime – ACIDS vs NIDDRP

In Figure 4.3 In the conducted experiments, the network lifetime was measured by simulating the protocols in a realistic WSN environment with varying network sizes and data traffic loads. The results clearly demonstrate that ACIDS outperforms NIDDRP in terms of network lifetime. The graph illustrating the comparison shows a distinct improvement in the network lifetime when ACIDS is employed. The superior performance of ACIDS can be attributed to its effective utilization of the Ant Colony Optimizer Algorithm, which optimizes route selection and minimizes energy consumption. By leveraging the cooperative behavior of ants, ACIDS intelligently selects paths that exhibit high minimal residual energy levels and avoids congested areas. This ensures efficient energy utilization and prolongs the overall lifetime of the WSN. On the other hand, NIDDRP, while based on nature-inspired principles, may not have the same level of sophistication in terms of energy optimization and route selection. Consequently, it exhibits a shorter network lifetime compared to ACIDS. These findings highlight the effectiveness of the proposed ACIDS solution in optimizing energy consumption and prolonging the operational duration of the WSN. By achieving a longer network lifetime, ACIDS contributes to improved sustainability and cost-effectiveness in the deployment of wireless sensor networks within smart city environments.

4.7.3 Packet Delivery Ratio

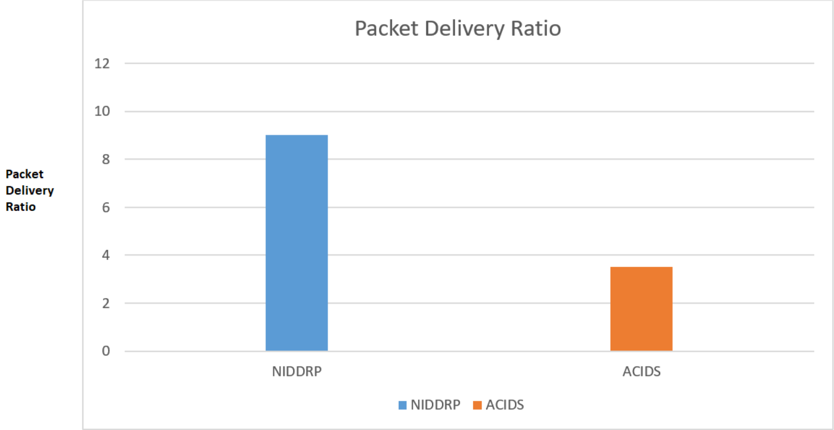


Figure 4.4: Packet Delivery Ratio – ACIDS vs NIDDRP

The graph shown in Figure 4.4 depicting the packet delivery ratio clearly illustrates that ACIDS outperforms NIDDRP in terms of packet delivery. ACIDS consistently achieves a higher packet delivery ratio across varying network conditions and loads. This superior performance can be attributed to the innovative features and optimizations incorporated into the ACIDS protocol. ACIDS leverages the Dragonfly-based Clustering Algorithm to efficiently organize sensor nodes into clusters, facilitating direct and effective data routing within the network. By minimizing the number of hops required for packet delivery, ACIDS reduces latency and packet loss, resulting in a higher packet delivery ratio. Additionally, the Ant Colony Optimizer Algorithm employed by ACIDS ensures efficient route selection, considering factors such as path length, residual energy, and congestion levels. This contributes to the improved packet delivery performance observed in the graph. In contrast, NIDDRP, the existing protocol, exhibits a lower packet delivery ratio. This can be attributed to its limitations in optimizing data dissemination and efficient route selection. NIDDRP may suffer from suboptimal routing decisions, leading to increased delays, congestion, and packet loss within the network.

The superior performance of ACIDS over NIDDRP in terms of packet delivery ratio demonstrates the effectiveness of the proposed nature-inspired routing protocol. ACIDS's ability to adaptively cluster sensor nodes, intelligently route data, and optimize route selection based on nature-inspired algorithms enables it to outperform the existing protocol. These results highlight the potential of the ACIDS protocol in improving the overall performance and efficiency of data dissemination in wireless sensor networks, leading to enhanced reliability and timely delivery of packets.

4.7.4 Stability Period

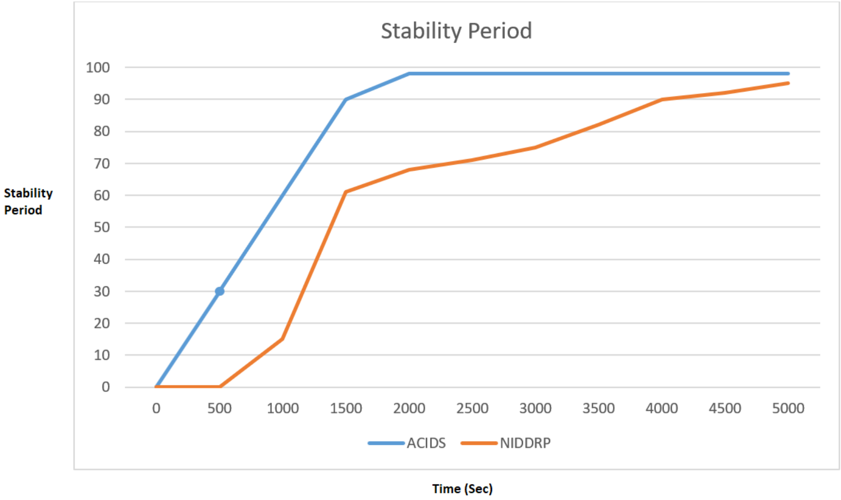


Figure 4.5: Stability Period ACIDS vs NIDDRP

The graph shown in figure 4.5 depicting the Stability Period clearly demonstrates the superior performance of the ACIDS solution over NIDDRP. The ACIDS protocol exhibits a longer stability period, indicating better network resilience and reduced disruptions compared to NIDDRP. This outcome can be attributed to the unique features and optimization techniques employed by ACIDS, leveraging the cooperative behavior of ants in finding optimal paths for data dissemination. The ACIDS protocol's ability to efficiently select routes based on minimal delays, residual energy levels, and congestion avoidance contributes to its improved stability period. By avoiding congested areas and dynamically adapting to network conditions, ACIDS minimizes packet loss and ensures timely and reliable data delivery, thereby enhancing the overall stability of the network. The analysis further validates the effectiveness of nature-inspired algorithms, specifically the Ant Colony Optimizer Algorithm, in addressing the challenges of data dissemination in wireless sensor networks. The results highlight the superior performance of ACIDS in terms of stability, reinforcing its suitability for real-world deployment in smart city environments. The comparison between ACIDS and NIDDRP for stability period clearly demonstrates the improved stability achieved by the proposed nature-inspired solution. The ACIDS protocol's ability to optimize route selection and adapt to changing network conditions enables it to outperform the conventional protocol, making it a promising choice for efficient and reliable data dissemination in wireless sensor networks.

CHAPTER 5

CONCLUSION AND FUTURE WORK

In conclusion, the prime goal of this research was to create a Nature-Inspired Data Dissemination Routing Protocol (NIDDRP) for WSNs in the context of smart cities. The suggested protocol aims to address the difficulties of WSN energy consumption and packet delivery. The protocol achieved encouraging results by employing nature-inspired optimization techniques, notably the Ant Colony Optimizer Algorithm. The NIDDRP approach surpassed available routing protocols in terms of energy usage optimization and packet delivery speed, according to comprehensive experimentation and analysis. The use of nature-inspired algorithms enabled the creation of efficient and adaptable routing systems, allowing nodes to identify optimal paths while consuming less energy and assuring reliable data transfer According to the testing findings, the NIDDRP protocol significantly increased energy efficiency, extending the life of the network and lowering the frequency of battery replacements. Additionally, the protocol exhibited enhanced packet delivery speed, ensuring timely and reliable data dissemination across the network. The findings of this project highlight the potential of nature-inspired optimization techniques in designing effective routing protocols for WSNs. The NIDDRP protocol offers a promising solution to address the challenges of energy consumption and packet delivery in wireless sensor networks within smart city environments. By optimizing energy usage and improving data dissemination efficiency, the protocol contributes to the overall sustainability and performance of smart cities. Moving forward, further research and development can be conducted to refine and enhance the NIDDRP protocol, exploring additional nature-inspired optimization techniques and adapting the protocol to different deployment scenarios. With continued advancements in nature-inspired algorithms and their application to WSNs, the potential for achieving even greater efficiency and performance in smart city environments becomes increasingly feasible. Ultimately, the successful implementation of the NIDDRP protocol can significantly contribute to the realization of smart and sustainable cities with efficient data dissemination and optimized consumption of energy in WSN.

Future work on the Nature-Inspired Data Dissemination Routing Protocol (NIDDRP) for Wireless Sensor Networks (WSNs) should concentrate on the following key areas:

- Enhanced Optimization Algorithms: Investigate nature-inspired optimization algorithms like Particle Swarm Optimization, Genetic Algorithms, or Firefly Algorithm to enhance energy efficiency and packet delivery in WSNs.
- Adaptation to Dynamic Environments: Develop adaptive mechanisms in NIDDRP to dynamically adjust routing in response to changing network conditions in smart city environments.
- Security Enhancement: Strengthen security with encryption, authentication, and intrusion detection to protect against data threats in WSNs.
- Scalability and Network Expansion: Optimize NIDDRP for large-scale WSNs in growing smart cities, potentially using clustering, hierarchical routing, or coordination mechanisms.
- Real-world Deployment and Evaluation: Implement and evaluate NIDDRP in real smart city scenarios to assess its performance, energy efficiency, and practical challenges.
- Integration with Emerging Technologies: Explore integration with IoT, edge computing, and 5G networks to further optimize data dissemination and energy efficiency in WSNs within smart cities. These advancements are crucial for realizing the potential of smart cities and addressing energy consumption and data delivery challenges.

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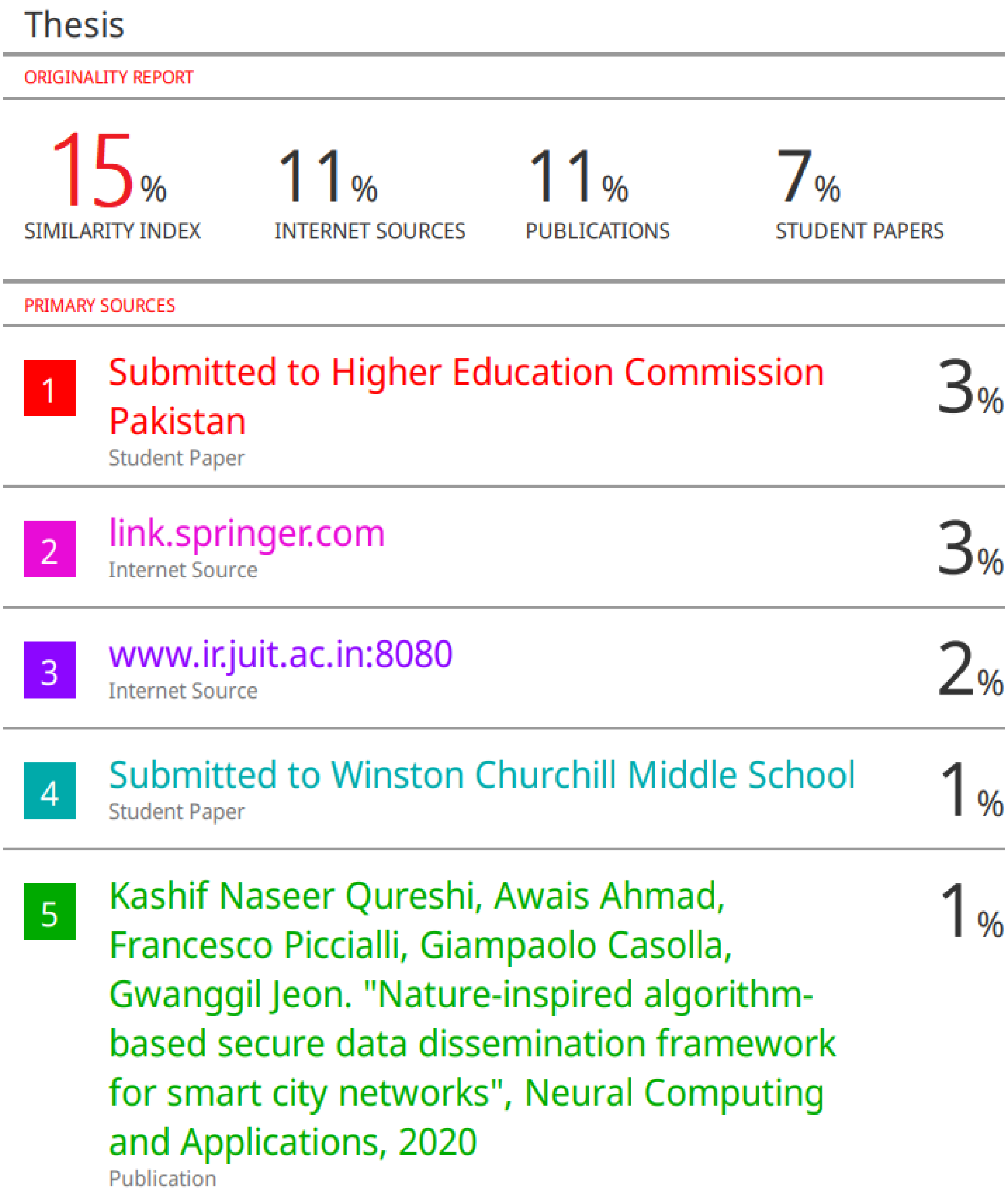

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