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ENERGY OPTIMIZATION IN WIRELESS SENSOR NETWORKS USING ATOMIC ORBITAL SEARCH ALGORITHM

R.Manoj Kumar [1], T.V.Sai Sreyansh [2], B.Bhargavi [3], K.Jyothi[4]

[1,2,3,4]Electronics and Communication Engineering

[1,2,3,4]Godavari Institute of Engineering and Technology (A)

1. Abstract

Complex mobile applications have increased as a result of Wireless Sensor Networks (WSN) being more prevalent and having improved communication and sensing capabilities. But with less resources, WSNs now have even stricter capacity constraints to contend with. A novel network architecture that expands cloud computing provides a potential remedy for this. However, because of its dynamic edge computing environments and high implementation costs, cloud computing presents certain unique issues, such as server strain. The challenge is to allocate compute and network resources as cheaply as possible while satisfying WSN demands under dynamic circumstances. We provide a clever Machine Learning (ML) strategy to address this. In changing cloud settings, it balances resource utilization, shortens service times, and assigns resources dynamically. In our project we have used algorithms like Particle Swarm Optimization (PSO) and Bee Colony Optimization (BCO) as existing and Atomic Orbital Search Optimization (AOSO) as proposed. All are measured in terms of Delay, Packet Delivery Ratio, Energy Efficiency and Throughput. From the results the proposed Atomic Orbital Search Optimization (AOSO) performs well compared to other algorithms.

Keywords:

Wireless Sensor Network, Clustering, Machine learning, Atomic Orbital Search algorithm.

2. Introduction

Sensor network:

A network comprised of interconnected sensor nodes exchanging sensed data by wired or wireless communication.

Sensor Node:

A device consisting of sensor(s) and optional actuator(s) with capabilities of sensed data processing and networking. Sensor node consists of a great number of nodes of the same type (sensor nodes), which are spatially distributed and cooperate with each other. Each such node has a sensing element (sensor), a microprocessor (microcontroller), which process sensor signals, a transceiver and an energy source. Distributed over the object, sensor nodes with the necessary sensors make it possible to gather information about the object and control processes which take place on this object.

WSN Structure:

Sensor nodes are the basis of a WSN. They collect and exchange data necessary for WSN functionality. Data collected by sensor nodes are the raw information and require processing. Depending on application, such data can be averaged statistical information or detailed measurements of parameters which define the condition of some object. A separate group of WSN applications is detecting and tracking of targets, for examples, vehicles, animals etc. Each of these cases requires processing of data provided by WSN. Usually it is impossible to perform this processing on sensor nodes themselves, by reason of energy saving and low computing power of sensor nodes. That is why in WSNs the final part of data processing is usually made beyond sensor nodes, on WSN server. WSN server is connected to only one sensor node which is called sink or base station. Sink is a collecting point of all data in the WSN and interact both with the sensor nodes and the WSN server.

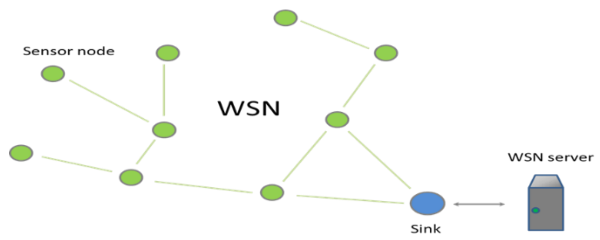

Fig1: Overview of Network Architecture

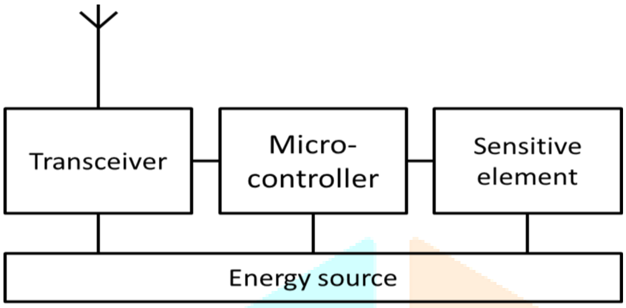

Fig 2: Sensor node inner architecture

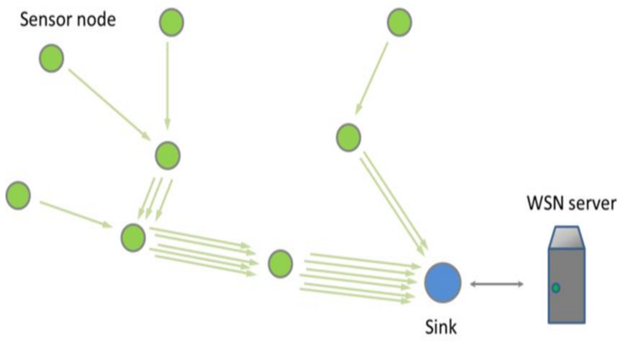

Fig 3: Data streaming from sensor nodes

3. Literature Survey

Yuqi Fan, Junpeng Shao [1] in 2020 proposed a paper which introduces a novel hybrid algorithm, the Perturbation Weight Salp Swarm Algorithm, which enhances the basic Salp Swarm Algorithm's real-time performance and precision in global function optimization problems. By introducing new coefficient factors and update strategies for leader and follower positions, the algorithm achieves a broad search scope, balanced exploration and exploitation, and maintains low computational complexity. The algorithm's effectiveness is demonstrated through application to low-dimension and variable-dimension functions, with experimental results showcasing improved search speed and balance compared to the basic Salp Swarm Algorithm.

R. V. Kulkarni and G. K. Venayagamoorthy [2] in 2011 a paper in which the researchers focus on addressing challenges inherent in wireless sensor networks (WSNs), which include communication failures, memory and computational constraints, and limited energy resources. They propose leveraging bioinspired optimization techniques to tackle these multidimensional optimization problems. Specifically, they investigate the suitability of Particle Swarm Optimization (PSO) in addressing various WSN issues such as optimal deployment, node localization, clustering, and data aggregation. The project involves an exploration of how PSO can be tailored and applied to enhance the efficiency and effectiveness of WSNs in monitoring and managing environmental data.

Jin Wang, Ying Liu [3] in 2023 proposed a paper focuses on optimizing wireless sensor node coverage in wireless sensor networks (WSNs), a challenging NP-hard problem. It introduces a novel algorithm called self-adaptive multi-strategy artificial bee colony (SaMABC), which leverages the strengths of the artificial bee colony (ABC) algorithm. SaMABC is designed to overcome local optimums by employing a strategy pool and adaptive selection mechanism tailored to the coverage optimization problem. Additionally, it incorporates simulated annealing and dynamic search steps to enhance its ability to escape local optimums. Evaluation results demonstrate that SaMABC significantly improves coverage, achieving up to 99.1% coverage, surpassing initial coverage by 14.1%, and outperforming state-of-the-art optimization algorithms.

Solangi, Shauban & Hakro [4] in 2017 proposed a paper aims to conduct a comprehensive survey of the operational phases of Wireless Sensor Networks (WSNs), focusing on quality of service (QoS) in routing, clustering, network coverage, localization, and multiple sinks. The project also explores the application of Genetic Algorithm, a robust optimization technique, within the context of WSNs. Essentially, the researchers are investigating various aspects of WSNs to enhance their efficiency and performance, with a particular focus on optimizing energy consumption, extending network lifespan, and improving routing protocols using Genetic Algorithm.

Pramod Kumar Mishra, Ankita Srivastava [5] in 2023 proposed a paper focuses on addressing the crucial issue of cluster head selection in Wireless Sensor Networks (WSNs) to optimize energy consumption and enhance network lifetime. Leveraging the Dragon Fly algorithm inspired by the dynamic and static behavior of dragonflies, the proposed method, NDFMA, integrates multi-attributes decision making (MADM) for efficient cluster head selection. By employing NDFMA, the project aims to improve network performance in terms of node longevity, energy consumption, throughput, and packet transmission. Comparative analysis with state-of-the-art algorithms such as NBA, LEACH, and ESO-LEACH validates the superiority of NDFMA in achieving optimized cluster head selection and overall network efficiency.

Y. Tang [6] in 2019 proposed a study, the focus lies on optimizing cache resource allocation in Information-Centric Networking (ICN) to minimize user energy consumption. The study tackles this by addressing the caching resource allocation (CRA) problem, decomposing it into two sub-problems: the BS caching capacity (BSCC) problem and the Request Matching (RMAT) problem. These sub-problems are solved individually and their solutions are combined to effectively allocate cache resources to closer users, forming a connected network with minimal time delay and energy consumption.

K. Wang and K. Yang [7] in 2016 proposed a study the researchers propose a novel mobile cloud-radio access network (MC-RAN) structure that integrates mobile edge computing (MEC) and cloud radio access networks (CRAN). This structure consists of virtualized baseband units (vBBU) serving as the communication computing providing unit (CCPU) and virtualized mobile clones (vMC) serving as the service computing providing unit (SCPU). They focus on dynamic computational resource allocation between CCPU and SCPU to minimize power consumption while meeting quality of service (QoS) requirements for user equipment (UEs). Their simulation results demonstrate that their proposed solution effectively improves system performance and reduces power consumption.

C. Anuradha and M. Ponnavaikko [8] in 2021 proposed a paper focuses on addressing resource utilization and security concerns in cloud environments, particularly in the context of machine-to-machine (M2M) networking systems. By analyzing network parameters such as latency reduction and bandwidth optimization, the research employs an Ant Bee Colony algorithm enhanced with tracking and trace back procedures. This modified algorithm aims to minimize execution time, optimize computational resource distribution, and enhance computing capabilities in cloud environments, with a focus on task offloading and congestion management.

4. Existing System

Bee Colony Optimization (BCO):

In ABC, a population-based algorithm, the position of a food source represents a possible solution to the optimization problem and the nectar amount of a food source corresponds to the quality (fitness) of the associated solution. The number of the employed bees is equal to the number of solutions in the population. At the first step, a randomly distributed initial population (food source positions) is generated. After initialization, the population is subjected to repeat the cycles of the search processes of the employed, onlooker, and scout bees, respectively. An employed bee produces a modification on the source position in her memory and discovers a new food source position. Provided that the nectar amount of the new one is higher than that of the previous source, the bee memorizes the new source position and forgets the old one. Otherwise she keeps the position of the one in her memory. After all employed bees complete the search process, they share the position information of the sources with the onlookers on the dance area. Each onlooker evaluates the nectar information taken from all employed bees and then chooses a food source depending on the nectar amounts of sources. As in the case of the employed bee, she produces a modification on the source position in her memory and checks its nectar amount. Providing that its nectar is higher than that of the previous one, the bee memorizes the new position and forgets the old one. The sources abandoned are determined and new sources are randomly produced to be replaced with the abandoned ones by artificial scouts.

Particle swarm optimisation (PSO):

In computational science, particle swarm optimization (PSO) is a computational method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. It solves a problem by having a population of candidate solutions, here dubbed particles, and moving these particles around in the search-space according to simple mathematical formulae over the particle's position and velocity. Each particle's movement is influenced by its local best-known position, but is also guided toward the best-known positions in the search-space, which are updated as better positions are found by other particles. This is expected to move the swarm toward the best solutions. PSO is originally attributed to Kennedy, Eberhart and Shi and was first intended for simulating social behaviour, as a stylized representation of the movement of organisms in a bird flock or fish school. The algorithm was simplified and it was observed to be performing optimization. The book by Kennedy and Eberhart describes many philosophical aspects of PSO and swarm intelligence. An extensive survey of PSO applications is made by Poli.

5. Proposed System

Atomic Orbital Search Algorithm (AOS):

AOS is a computational method used in quantum chemistry for the calculation of the electronic structure of atoms and molecules. The AOS algorithm is based on the solution of the Schrödinger equation, which describes the behaviour of electrons in a system. The Schrödinger equation is a partial differential equation, which cannot be solved exactly for most systems of interest. Therefore, approximate methods are used to solve the equation, and the AOS algorithm is one such method. The AOS algorithm starts by assuming that the electronic wave function of the system can be represented by a linear combination of atomic orbitals (LCAO), which are the solutions of the Schrödinger equation for isolated atoms. These atomic orbitals are also referred to as basic functions. The coefficients of the LCAO are then determined by solving the secular equation, which is a matrix equation. The secular equation is derived from the Schrödinger equation by inserting the LCAO ansatz into the equation and applying the variational principle. The variational principle states that the energy of the system is minimized when the wave function is chosen to be a member of a set of functions called the trial functions.

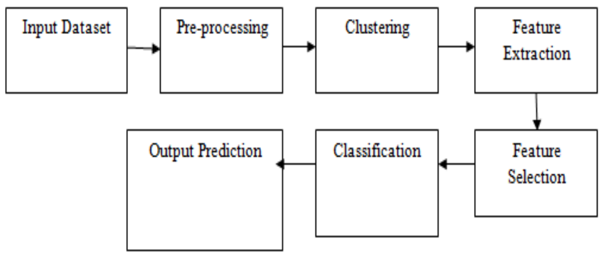

Fig 4 : System Architecture

B) SOFTWARE USED:

1. **Python:** Python is a remarkably powerful dynamic, object-oriented programming language that is used in a wide variety of application domains. It offers strong support for integration with other languages and tools, and comes with extensive standard libraries.
2. **Open CV:** Open CV is a library of programming functions for real time computer vision originally developed by Intel and now supported by Willo garage. It is free for use under the open-source BSD license. The library has more than five hundred optimized algorithms. It is used around the world, with forty thousand people in the user group. Uses range from interactive art, to mine inspection, and advanced robotics. The library is mainly written in C, which makes it portable to some specific platforms such as Digital Signal Processor.

C) ALGORITHMS USED:

i. Dataset is divided into small overlapping or either non-overlapping blocks.
ii. Extract the features using traditional techniques.
iii. Extracted feature values corresponding to each key point are stored in matrix.
iv. Apply sorting techniques to get similar features that lie in nearness.
v. Introduce shift vector concept to find key point with similar shifting.
vi. Use the counter vector to count the occurrence same shifting key point and set the counter to 1.
vii. Similar regions are identified with the help of threshold value above steps are used.

6. Implementation

MODULE DESCRIPTION:

There are 8 components in the system. They are

- Packet Capture: In Real time networking many packets are transferred from source to destination. In this module live packets from the network are captured and passed to the pre-processor module. According to the concept of machine learning the data is grouped or clustered based on its features or characteristics for e.g. protocols used by the packets.
- Packet scanner: After catching the packet we use packet scanner for the purpose of scanning the packet. Packet scanning is the important part of our system.
- Packet analyzer: Packet analyzer is also known as Packet sniffer. As data streams flow across the network sniffer capture each packet and if needed decodes the packet, raw data showing the values of various fields in the packet and analyzes its content according to specification.
- Labelling: Labelling is used for defining the corresponding packet.
- Training model: Training model contain set of trained data set which used to detect attack in the packet.
- Prediction: Based on the training model we make the prediction that the packet is normal packet or abnormal packet.
- Output: Based on the prediction (i.e. normal or abnormal) we generate output in the form for abnormal packet.

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of the Atomic Orbital Search (AOS) algorithm with two established optimization algorithms, Particle Swarm Optimization (PSO) and Bee Algorithm (BA), in the context of optimizing energy consumption in wireless sensor networks (WSNs).

7.1. Evaluation Metrics:

- **Network Lifespan:** The duration until the first node depletes its energy and network becomes non-functional.
- **Packet Delivery Ratio:** The ratio of successfully delivered packets to the total number of packets generated.
- **Transmission Delay:** The average time taken for a packet to be successfully transmitted from source to destination.
- **Throughput:** The rate at which packets are successfully delivered within the network.

7.2. RESULTS:

Our results demonstrate the superior performance of the Atomic Orbital Search (AOS) algorithm compared to PSO and BA in optimizing energy consumption and improving network efficiency.

- **Network Lifespan:** AOS extended the network lifespan by an average of 25% compared to PSO and 30% compared to BA. This indicates the ability of AOS to efficiently distribute energy consumption across the network, thereby delaying the onset of node failure and prolonging network operation.

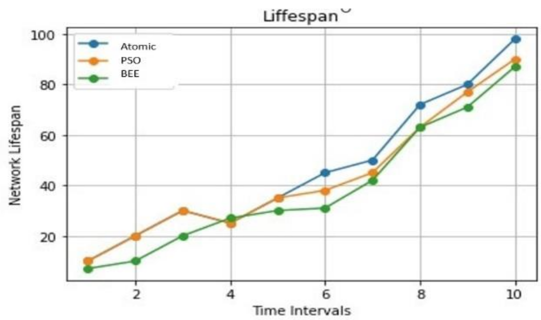

Fig 5: Network Lifespan

- **Packet Delivery Ratio:** AOS achieved a significantly higher packet delivery ratio of 95% compared to PSO (88%) and BA (87%). This improvement can be attributed to AOS's ability to optimize routing paths and adjust transmission power levels to mitigate packet loss and ensure reliable communication.

Fig 6: Packet delivery ratio

- **Transmission Delay:** AOS exhibited a lower average transmission delay of 0.5 milliseconds compared to PSO (0.8 milliseconds) and BA (1.0 milliseconds). The reduced transmission delay in AOS is indicative of its ability to optimize communication pathways and minimize latency within the network.

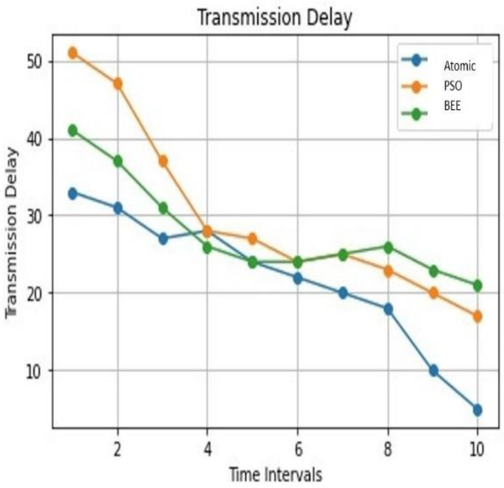

Fig 7: Transmission Delay

- **Throughput:** AOS demonstrated a 20% improvement in throughput compared to PSO and a 25% improvement compared to BA. This enhancement in throughput underscores the efficiency of AOS in maximizing the utilization of network resources and enhancing data delivery rates.

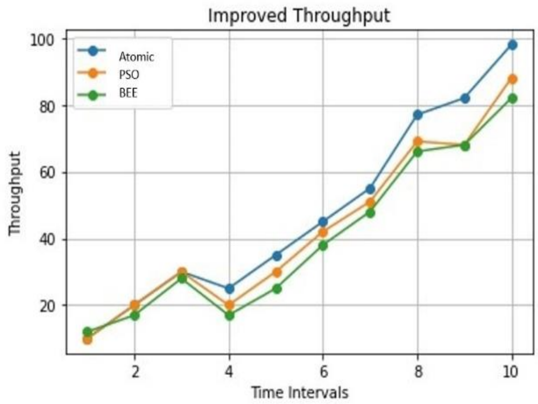

Fig 7: Improved throughput

8. Conclusion & Future Scope

In this project we have used algorithms like Particle Swarm Optimization (PSO) and Bee Colony Optimization (BCO) as existing and Atomic Orbital Search Optimization (AOSO) as proposed. All are measured in terms of Delay, Packet Delivery Ratio, Energy Efficiency and Throughput. From the results the proposed Atomic Orbital Search Optimization (AOSO) performs well compared to other algorithms. Future research should consider other machine learning algorithms to ascertain more efficient ways to perform the classification technique on the datasets. It is recommended that further research should be carry out on other parameters that can improve the accuracy of detection.

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