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# Revolutionizing Green IoT: Exploring Evolutionary Algorithms, Trends, and Future Frontiers

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**Abstract: -** The Internet of Things (IoT) represents a significant advancement in Information and Communication Technology (ICT). IoT facilitates the integration of systems ranging from small-scale to large-scale. The Internet of Things comprises billions of interconnected devices, forming a vast network of gadgets. The number of Internet-connected devices has rapidly grown as a result of recent technological developments, which have raised the demand for resources. This has drawn attention to IoT due to its low energy consumption. The demand for energy efficiency led to the emergence of Green IoT. In the Green IoT, several optimization approaches are employed to reduce the consumption impact of the negative effects of human activity on the environment. This paper outlines IoT devices, their components, and their applications. This paper presents a comprehensive literature review of methods for reducing energy use along with an overview and evaluation of various optimization algorithms. The Green IoT and its applications are also discussed. Furthermore, this study explores IoT applications in the healthcare sector and discusses associated challenges.

**Keywords**: IoT, Green IoT, Optimization, Medical IoT, Energy conservation, Sustainability, Medical domain

## 1. Introduction

The Internet of Things has been characterized as the combination and communication of intelligent devices (things)[1]. IoT's dominance facilitates the creation of new technologies and applications. A network of physically linked objects that can detect, monitor, and communicate both inside an organization and within its supply chain[2]. It is a system of digitally networked physical objects that offer flexibility, transparency, information tracking and flow to speed up the planning, management, and coordination of supply chain processes. Connecting sensors and other real-time modules enable the transmission of detected data to centralized repositories, where it is aggregated, stored, and made accessible to people with the proper access privileges. When there are a lot of communication devices, the Internet of Things (IoT) capabilities that use wireless technologies are very different from those of traditional networking systems[3].

Power System Technology
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Because each IoT device finds and sends data to a different IoT server, IoT-based traffic isn't usually very high. However, the data generated by several devices may have some effect on how the network works. So, the networks will run safely and sustainably for a very long time without any help from people.

IoT has created several environmental issues, the most prominent of which are the increases in e-waste creation, energy consumption, and CO2 emissions[4]. It has become essential to effectively handle the threats and challenges posed by the IoT to avoid any possible negative environmental repercussions of recent technological breakthroughs. These challenges essentially consist of increasing energy consumption, the generation of electronic waste, greenhouse gas emissions, notably CO2, the use of non-biodegradable materials for Internet of Things devices, and the use of non-renewable and organic raw materials[5]. G-IoT is an important future development of IoT that has to do with green technology and the economy[6]. G-IoT is predicated on the IoT's clean energy and reliability tenets. The phrase "green IoT" refers to an energy efficient IoT strategy for minimizing or eliminating the greenhouse impact caused by currently running applications[7]. Green IoT aims to improve the well-being of both people and the environment by a lot by using new sustainable technologies. G-IoT is already required and has the potential to completely change society while also improving the health of the environment. The newest technology, the G-IoT, focuses on minimizing or eliminating negative impacts on the environment and human health[8].

The Internet of Things (IoT) is a major step forward in the fields of information and communication. There are now a lot more devices than just smartphones and tablets that can connect to the Internet. This enables several applications and services, including medical care, medical analysis, radar traps, and intelligent ecosystems. The collected data is employed to meet the diverse needs and goals of users. After processing and analyzing the enormous quantity of data that was created, this information was obtained. In addition, the number and variety of applications and services are growing rapidly, requiring computer power that even the most powerful smartphones cannot provide. Because of virtualization, the cloud environment is seen as a likely place to handle the workload. It is a massive supplier of access and resources.

**Internet**: The use of Internet Protocols enables communication between objects, or "Things." The following section discusses IoT applications.
**Processing**: This component is responsible for processing data from sensors or "things" and producing usable results.

Power System Technology
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**Things**: Things that serve as sensors or instruments that pick up on their environment, like Radio-frequency identification (RFID) [9]. Things that serve as actuators or components that perform actions.
The following are some of the well-known use cases of IoT in the real world:
**Home Automation**: [10]. According to research, 60,000 individuals look for the term "smart home" on search engines each month.
**Wearables**: Another IoT use is wearables. These include the newest smartwatch from Apple and the Looksee bracelet [11]. The largest financing of any IoT start-up is held by Jawbone, a manufacturer of wearables, with more than 500 million dollars.
**Smart Grids**: The prominence of the idea is demonstrated by the over 41,000 Search terms every month [12], [13].
**Connected Car**: Since the automobile company's product innovations take close to 2-4 years, this is a slightly slower pace in research. Although connected vehicles are still relatively unpopular, major automakers and other companies have begun to develop them [14], [15].
**Connected Health**: IoT applications for the healthcare industry have potential and are valuable. Additionally, a hidden powerhouse among IoT-based Applications is connected health. These ideas, whether they relate to a networked public health system or intelligent medical equipment[16], have a lot of promising [17], [18].
**Smart supply chain**: Supply chains have received a fresh boost from IoT, making them smarter[19]. It aids in offering a method for transporting items on foot or aids the sources in communicating inventory data [20].
**Smart farming**: One of these IoT applications with significant potential but little research is smart farming[21]. As remote farming places can be monitored and livestock can be traced, this technology has the potential to revolutionize the way we think about farming [22]. It will grow to be one of the crucial applications in the nations where agriculture predominates [23].
IoT has consolidated important scientific fields including electrical engineering, electronics, and computer science[24]. Additionally, this enabled significant breakthroughs in modern technology. These gadgets, like all other equipment, need energy to work and run effectively, but there are times when they use more energy than they need[25]. Consequently, energy is wasted, and more heat is produced. For both financial and environmental reasons, it is important to decrease this energy loss and unneeded heat. The idea of the "Green Internet of Things" was born as a result. Green IoT is the IoT variant that uses less electricity[25].

The word "green" on the Internet of Things (IoT) affected how efficiently IoT devices used energy and network resources[26]. On the Internet of Things (IoT), the term "green" alludes to characteristics like energy efficiency and environmental friendliness[27], [28]. Energy-efficient practices and approaches must be applied at both the software and hardware levels to achieve these attributes. As a result, the already-used IoT devices, applications, and services

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use less energy and produce less greenhouse gas emissions[29]. IoT models are not yet designed to be energy efficient. As an outcome, it consumes unnecessary resources when it is on and transmits data continuously. In the Green IoT, it is made sure that the gadget is only active when it demands so and is inactive when there is no requirement. The Green IoT focuses more on energy-efficient device operation.

*Evolutionary Algorithms – Green IoT:*

The algorithms use the principles inspired by nature and solve complex problems with the main objective of solving optimization problems[30]. Evolutionary algorithms operate by replicating the process of natural selection[31]. Evolutionary algorithms work on a specific population in which everyone is associated with a fitness function[32]. The measure of how well it satisfies the optimization objective determines the fitness value of everyone. New progenies are generated by using genetic operators and choosing the fittest individuals repeatedly. This procedure is carried out until the best solution of all is found[33].

There is a wide range of problems in which EAs can be applied in the IoT domain. Some of them are as follows:

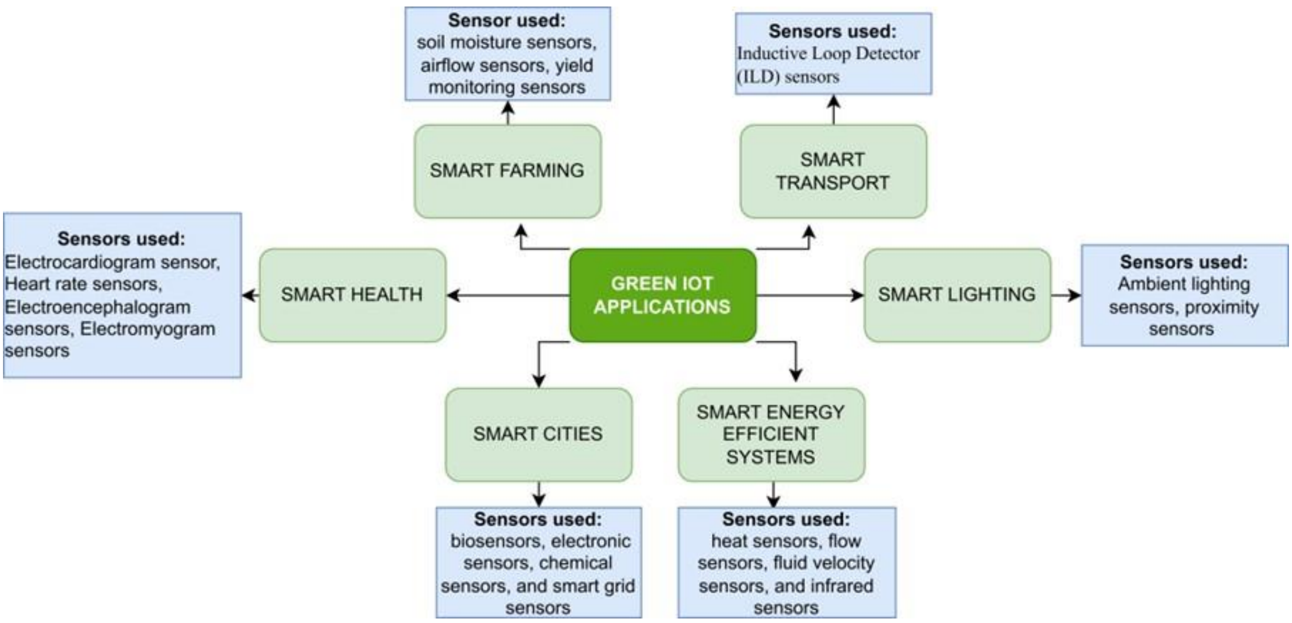


Fig. 1. Applications of IoT

*Machine learning model optimization for IoT*:

In machine learning, parameters are critical for a model to exist. To reduce the complexity of the ML model, it is very important to optimize the parameters of the ML model. Thus, the

Received: 15-10-2023 Revised: 12-11-2023 Accepted: 10-12-2023

implementation of evolutionary algorithms optimizes these parameters. Energy-Efficient routing: Utilization of energy in an optimized way is the most important factor in the context of Green IoT. The use of evolutionary algorithms on the Internet of Things conserves energy in many ways. For example, the pathways with less amount of energy required for data transmission are determined by using evolutionary algorithms. These algorithms are also used to extend the lifetime of battery-powered devices. Power Management: EAs are used to turn off those devices that are not in use to save energy. There are different power modes in IoT devices. The best time to switch between various power modes is calculated by applying evolutionary algorithms. Placement of sensors: Evolutionary algorithms are used to find the best position for sensor placement with maximum area coverage and less energy utilization[34].

## 2. Related Work

*Smart Energy Management*:
Monitoring and managing energy usage in businesses and homes can be done by various IoT devices to save energy. For example, Smart gardening systems are used to automate the process of water supply to the garden based on the analysis of weather conditions, and they also collect information about the upcoming conditions to implement the best strategies that improve overall productivity[35].

*Environmental Surveillance*:
Constantly changing weather patterns such as the quality of air and water, moisture of soil, and other factors can be tracked by IoT sensors. Thus, optimization of resource consumption and reducing the negative impacts on the environment can be achieved by utilizing the information collected by sensors.

*Smart Health*:
Remote monitoring of the health status of a patient is one of the major applications of IoT in the medical field. Various wearable devices continuously track different parameters such as fluctuations in heart rate, blood pressure, and glucose level in the human body. This data is sent to the patient's electronic health record. Thus, medical professionals can easily track the health issues that may occur and suggest the required precautions to be followed[36].

*Smart Cities*:
Researchers and new businesses are dealing with a variety of application cases, including water distribution systems, waste management, traffic control systems, urban security, and environmental monitoring, and encounter several challenges as a result of the growth of the smart city[37].

Power System Technology
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*Smart Transportation*:

Transportation is one of the major applications of IoT. IoT devices are used to gather real-time data on traffic which can be further analyzed to optimize the routes. This helps people to choose the path with minimum distance thereby reducing the consumption of fuel as well as carbon emissions. IoT devices that are embedded in automobiles ensure a safe driving experience with real-time navigation and safety alerts in case of overspending. IoT applications have immeasurable significance in a variety of fields, including medicine, manufacturing, mechanics, transportation, education, administration, mining, living space, and more. As more businesses and individuals implement IoT technology to promote environmentally friendly activities, the breadth of green IoT is anticipated to keep growing in the future[38]. Green IoT may expand in the following areas:

*Advancements in Technologies:*

New IoT-powered applications may evolve as technology develops further, helping to promote sustainability methods like the production and storage of renewable energy.

*Business Intelligence:*

It is a known fact that data is the fuel for many premium companies to generate revenue. The increased use of IoT sensors in business for gathering various types of data has increased the scope for analyzing the data and generating useful insights from the data. This leads to the requirement of high bandwisth which also needs to be allocated[39] efficiently. These insights are used for optimizing the needful and predicting future outcomes. So, data analytics is a promising area where the implementation of Green IoT may increase in the future.

*Agriculture:*

Green IoT is implemented in agriculture to increase the overall yield. Farming is made more efficient and productive with the help of IoT sensors and machinery which automates various agriculture processes such as irrigation and harvesting. Thus, in the future, the implementation of Green IoT in farming will reduce the need for farm labor.

*Mining:*

The mining sector is expected to benefit greatly from IoT, but there are significant obstacles to overcome. Cost reduction is one of the most significant needs of mining. The implementation of various sensors on the mining equipment optimizes the cost of mining and increases productivity. Real-time monitoring of the environmental conditions of underground mines ensures the safety of workers. In the future, it is anticipated that the methodologies of Green IoT will bring major advancements in mining.

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## 3. Methods

*Ant-Colony Optimization:*

To find the pathways in a way that ant colonies may utilize to choose the optimum path while searching for food, the Ant Colony Optimization method uses a straightforward mathematical technique. An ant that has found a quick and effective path to the food source will travel there and back more frequently than one that takes a longer route. The quicker emits a pheromone that alerts the colony to this, allowing it to find the fastest path without having to try each one individually.

IoTs employ ACOs to solve additional optimization issues. In WSNs, ACO-based Clustering is an adaptive clustering approach for energy efficiency. As a part of this process, several cost functions are employed at the central station. These cost functions are employed in the development of a novel energy-aware clustering technique. With the help of this technique, the cost of data transmission over long distances and data aggregation among all the available sensors is reduced and distributed equally. The routing issue can be treated as a clustering issue, to choose X out of N nodes as cluster heads. This was accomplished using software ants as agents[40].

The ant Chain approach is used for data gathering and communication. Energy efficiency and data integrity are the main objectives of this algorithm. An optimal chain is obtained by using the ACO method, which is implemented at the base station, in various other routing protocols in which the sensor nodes need to be connected to establish a transmission path. However, the sensor nodes in this protocol only get meaningful information via base station broadcasts Furthermore, pre-existing network knowledge need not be known to the sensor nodes in the chain. As a result, the sensor network's reduction of the routing process results in significant energy savings.

*PSO:*

The PSO algorithm uses the principle of animal society to determine the optimal solution. It is inspired by the social behavior of birds in a group that does not have a leader. Birds in the group that are in a better position or possess the potential to discover a better solution alert the other birds to follow them in that direction. This in turn is iterated several times until the flock finds the best possible solution. Particle indicates each bird that can find a solution in the given problem space and offers a potential resolution based on a strategy for optimization. Position and velocity serve as a representation of each particle. Every Particle maintains a record of its optimal location using Pbest. The Global best position is determined by finding out the best of all the Pbest available[41].

For a quite long time now, Virtual Machine (VM) has been providing computational support for IoT-based applications. For efficient and better utilization of resources, an energy-efficient container-based (EECS) is deployed in a well-managed cloud service using optimum

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scheduling strategies. These processes are lightweight and start-up in just 1 second, whereas the same task on a VM instance requires comparatively higher energy and takes a considerable amount of time to kick-start. Accelerated Particle Swarm Optimization (APSO)is used to determine an appropriate container for every individual task within a short time. This becomes a multi-objective optimization problem when we consider the management of optimum resources on the cloud. After several comparisons, this method was proven to outperform the existing ones in terms of consumption of energy, time taken to compute, utilization of resources, and CO2 emissions[42].

*Genetic Algorithm:*

The genetic algorithm is a widely used strategy based on Darwin's Theory of natural selection. A wide range of problems can be used for the implementation because of its flexibility. The key factor in GA is the determination of fitness function, which has to increase in the evolution process. Using a genetic algorithm with an essence of complex continuous parameter optimization problems to optimize the neural network structure and connection weights is the current path of research. A three-tier approach is used. The second layer is where the number of hidden layers is controlled. The neurons that are activated in each layer are determined by the first layer. The regulating gene's active and inactive states are denoted by "1" and "0," respectively. Real number coding is used to represent the weight of the connections and the threshold of each neuron. The complexity is determined by dividing the number of active weights by all weights in the topology [43][44].

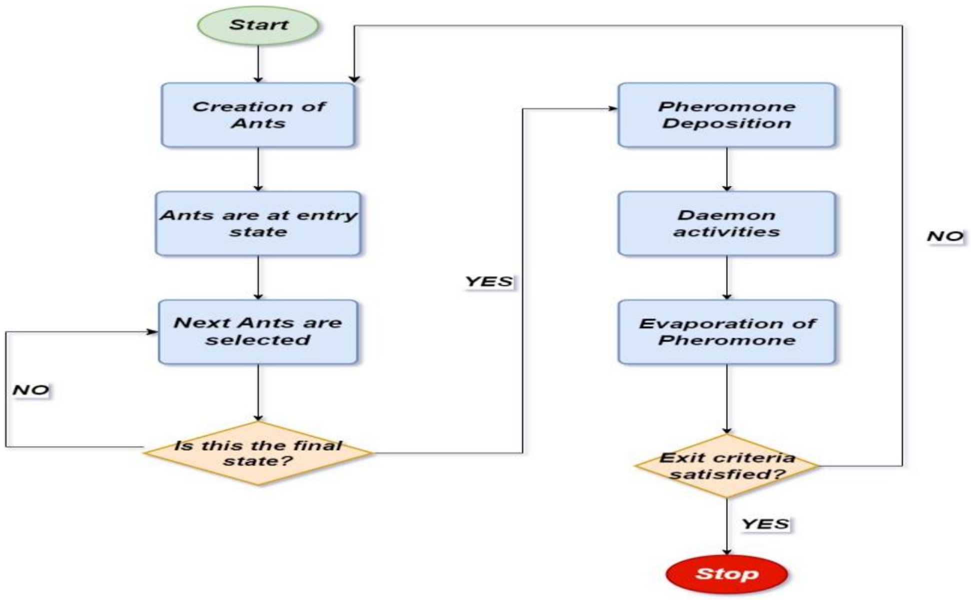


Fig 2. Flow chart of Ant-Colony Optimization

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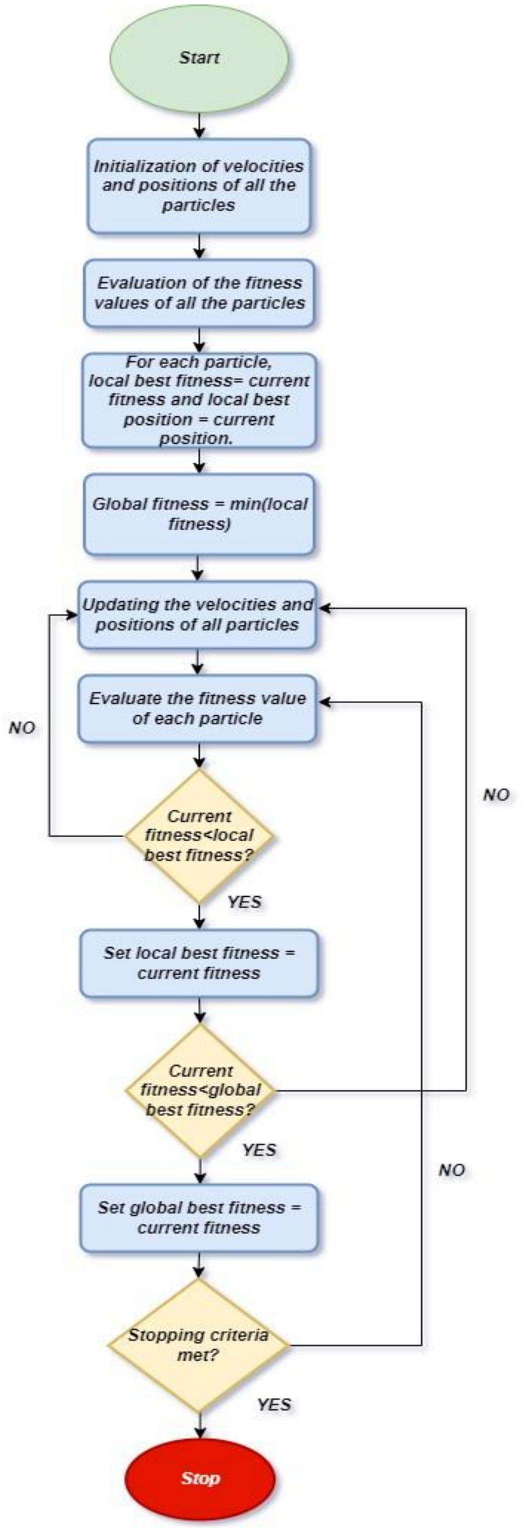


Fig 3. Flow chart of Particle Swarm Optimization

Power System Technology
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*NSGA:*

To handle non-convex and non-smooth multi-objective optimization issues, it uses a genetic sorting algorithm. Efficiency is higher with the NSGA-II. When a specific non-dominated zone is located, this method tends to spread rapidly and properly. To solve benchmarks, we use the NSGA-II evolutionary algorithm. We then conduct statistical analysis to assess and validate the findings. The outcomes demonstrate the algorithm's success and the explicit grant of interest to the emission minimization target. The key benefit is that no predefined parameters are needed for the diversity preservation technique utilized in NSGA-II[45].

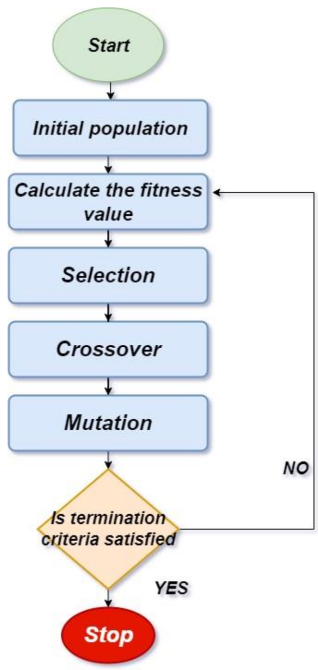


Fig. 4. Flow chart of Genetic Algorithm

*Optimization using HHO:*

A cutting-edge, swarm-based meta-heuristic optimization technique that takes cues from nature is the Harris Hawks Optimization algorithm. The HHO algorithm was built based on Harris Hawks' harmonic behavior and "seven kills" pursuit strategy. Depending on the rabbit's fleeing behavior and the plot's structure, the directions of assault or pursuit tactics may change. The HHO algorithm suggests exploration and exploitation characteristics considering the distinctive assault tactics, seven kill strategies of Harris Hawks, and the fleeing skills of prey. Because of its simplicity and ease of implementation, it might be used to solve a variety of challenges, including finding routes, routing based on clusters, and optimization of paths. between vehicles.[46]

Power System Technology
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*Whale Optimization Algorithm – WOA:*
WOA involves prey seeking, prey encirclement, and bubble-net feeding. Humpback whales can locate and cover their prey. The target prey is believed to be the current best search agent in the WOA algorithm, and humpback whales iteratively adjust their location to the best search agent. The bubble-net assault technique of humpback whales is concurrently modeled using the spiral updating location method and the shrinking encircling mechanism. By putting the coefficient vector, A within the range (1, 1) and linearly decreasing the value of a throughout repetitions, the shrinking encircling process is realized. By doing this, the new job will be situated halfway between the agent's existing position and the best search agent's position. The penalty method was introduced as the constraint-handling technique. The primary components of total energy consumption are transmission power consumption and circuit power consumption. It is possible to achieve the trade-off between energy efficiency and spectrum efficiency by optimizing global energy efficiency, having a constraint on a minimum requirement of energy and minimum expenditure of energy for transmission. To deal with this constraint the use of the penalty method has been introduced. Here, the devices are to be treated as search agents or humpback whales. P is considered as the power of transmission for each search agent X. At iterations, either the search for prey, the surrounding of prey, or the bubble-net feeding approach can be used to update the transmit power of each search agent[47].

*Sailfish Optimization – SFO:*
SFO employs Multi-Objective Based Clustering and Sailfish Optimizer (SFO)-guided routing to keep WSNs' energy efficiency high. SFO is a metaheuristic algorithm that is based on the population. The population-based metaheuristic algorithm SFO has a search area, where the location of a sailfish is noted as a variable in the original problem, and a candidate's solutions are seen as sailfish. The sailfish adjust their location based on where other hunters are close to the prey school. The SFO algorithm verifies the sailfish attack alternation tactic when it conducts group attacks. Within a constricting circle, these sailfish have the potential to strike from every angle. At the beginning of the hunting operation, the energy of the sailfish is high, and the sardines are likewise unharmed and unfatigued. Sardines can therefore move fast and are free to flee. Additionally, the sardine adjusts its position and power in response to the sailfish's movement. In the SFO algorithm, sardines and sailfish positions are randomly generated. The update for every sailfish is carried out using elite sailfish and wounded sardines. The goal function is used to determine each sardine and sailfish's position once their positions have been updated[48].
In SFO, the Cluster Head (CH) is chosen using a reliable fitness function that takes into account several factors. It decreases the number of inactive sensor nodes and helps to reduce the usage of energy. Post CH selection, SFO is used to choose the best route to the sink node for data transmission. In terms of energy usage, throughput, delivery ratio, and network lifespan, the

Power System Technology
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suggested technique was analytically studied, and the findings were compared with those of similar current systems. According to the simulation findings, the proposed method improved GWO by 21.9 percent in terms of energy consumption and 24.4 percent in the number of active sensor nodes. Additionally, it displays noticeably superior outcomes than other optimization-based strategies. The ability of SFO to avoid local optima and reach quick convergence is facilitated by a variety of applications in software and hardware.

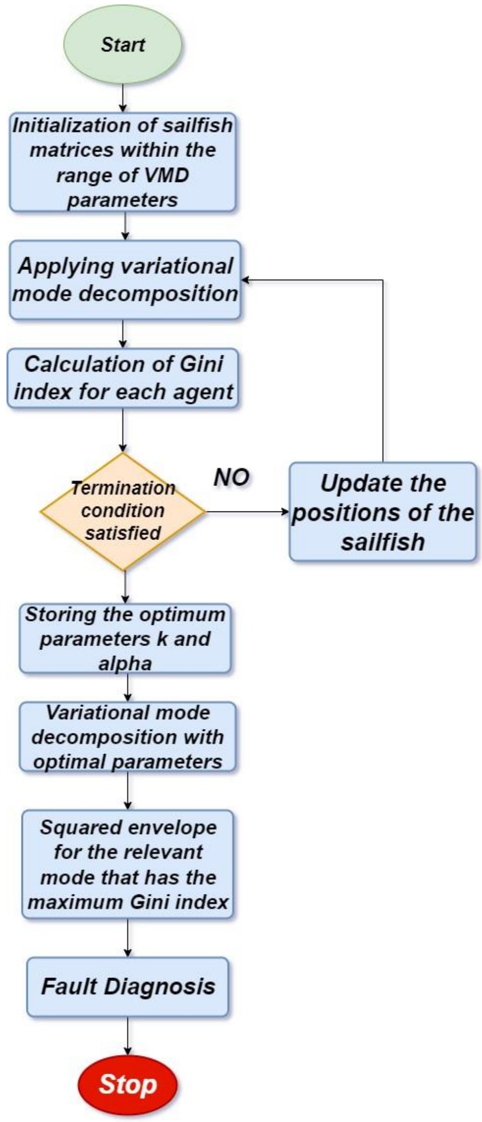


Fig. 5. Flow chart of Sailfish Optimization

Power System Technology
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*Grey Wolf Optimization – GWO:*

Mirjalili created the Grey Wolf Optimizer (GWO) algorithm in is based on the grouping mechanism and hunting tactics of grey wolves[49]. According to legend, grey wolves are pack animals and are top predators. In GWO, a population of randomly generated wolves (solutions) serves as the starting point for the hunt. Alpha, beta, and delta are the top three effective answers respectively. These three best methods utilize a repeating strategy to forecast the position of the prey while hunting (optimization). Alpha, beta, and delta are the top three wolves in terms of hunting ability; omega wolves trail them. There are three stages to the hunting strategy: (1) Surrounding the prey; (2) stalking the prey; and (3) striking the victim. It is suggested to use GWO-based clustering to distribute load among gateways to eliminate energy hole issues and to use GWO-based clustering to save network energy. The activation of wolves, the computation of each wolf's fitness value, and the updating of the wolves' velocity and position are the first three stages of GWO-based routing. The representation of each solution is a mapping from one gateway to another, also known as a BS. The total number of gates equals the size of the solution. The method provides a route from each gateway through the network's subsequent gateways to the BS. To approach the prey (the best solution), each wolf(solution) must update its location in line with the locations of the alpha, beta, and delta wolves. In the GWO-based method, the best solution in its initial stage is the beta wolf whereas the optimal solution from the current iteration is the delta wolf. In the collection of solutions, the alpha wolf is the best choice. The locations of the omega wolves are updated using the average of the updated locations of alpha, beta, and delta wolves[49].

*Reinforcement learning with Differential Equation:*

Reinforcement learning in IoT devices is used when there is no requirement to feed large quantities of data as input. Based on the hidden Markov chain, this model benefits from having filtered storage. This kind of control on the traffic can be brought into action, as it suffices for spot decisions while having a comparatively lower demand. The formula for this can be derived after determining the status of node S, the action A that follows while being evaluated by a parameter Q which considers the rate of transmission per head and switching between states. The final solution to maximize the optimization thereby saving more energy will be derived from the policy "pie", which has all the values state S mapped to it. To decrease the spike of impact on the recent events, a mini batch of the training sample is considered to have a proportion of immethodically picked samples from the past. This is done several times to increase stability. The optimum mutation method and performance traits for the DE algorithm were determined by the author using reinforcement learning (RL) in a novel manner. To address issues with multi-energy flow optimization inside an industrialized integrative power system a framework for industrial multi-energy scheduling is offered. The framework simultaneously considers multiple power storage, sources of energy, energy conversion, and

Power System Technology
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energy trade. Each member of the population iteratively adopts its mutation method and parameters in the RLDE algorithm to maximize rewards from the present state, defining its ideal evolutionary behavior as an agent. The RLDE algorithm's primary objective is to employ a positive feedback loop to either advance each entity's hierarchical stage or keep them in their current position. This suggests that choosing the best mutation approach and parameters is advantageous.

## 4. IOT Dataset

*Camera Traffic Counts:*
This is the data on traffic counts received by the City of Austin's GRIDSMART optical traffic detectors. The 'ATD Device ID' parameter links the Travel Detectors dataset to this one. Additional information on the status of the device and its location is available in the Travel Detectors dataset. Vehicular ad-hoc networks (VANETs) were proposed[50].

*Travel Sensors*:
This dataset comprises statistics about travel sensors in Austin, Texas. The City of Austin Transportation Department owns and operates travel sensors, which are used to monitor traffic conditions around the city. The features are Sensor ID, Sensor Type, Location Name, Location Type, Landmark, and Sensor Status. Class label: Sensor Type[51].

*Beach Water Quality*:
Automated Sensors: Weather sensors are maintained by the Chicago Park District along the shoreline of Lake Michigan. While the sensors are active throughout the summer, they typically take the mentioned readings on an hourly basis. The features are the Name of the Beach, Temperature of water, Turbidity, Transducer Depth, Height of wave, and Wave Period[52].

*Smart Green Infrastructure Monitoring Sensors-Historical*:
This dataset represents the outcomes of a project in which sensors are installed across the city to monitor the water runoff from roadways. These statistics can be used to assess the influence of green infrastructure on floods. Weather data was also collected by these sensors. The features are Measurement Type, Measurement Title, Measurement Value, Measurement Period Time, Latitude, Longitude, and Location. Class label: Measurement Type[53].

*IoT normal fridge*:
This dataset has information about the temperature of a refrigerator and classifies that information into two different temperature conditions, the first one is "high", and the latter is "low". Temperature Sensors are used to record the data. The features are Time, Fridge Temperature, and Temperature Condition. Class label: Temperature Condition.

*Chapel Hill Public Foot Library*:
Three locations at Chapel Hill Public Library's hourly occupancy rates are included in the statistics. People counter sensors gather information, which is then computed to show building

Power System Technology
ISSN:1000-3673
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occupancy on an hourly basis. To facilitate data analysis, an "Adult" is defined as someone who is at least 4’9" tall, while a "Child" is defined as someone who is at least 4’9".

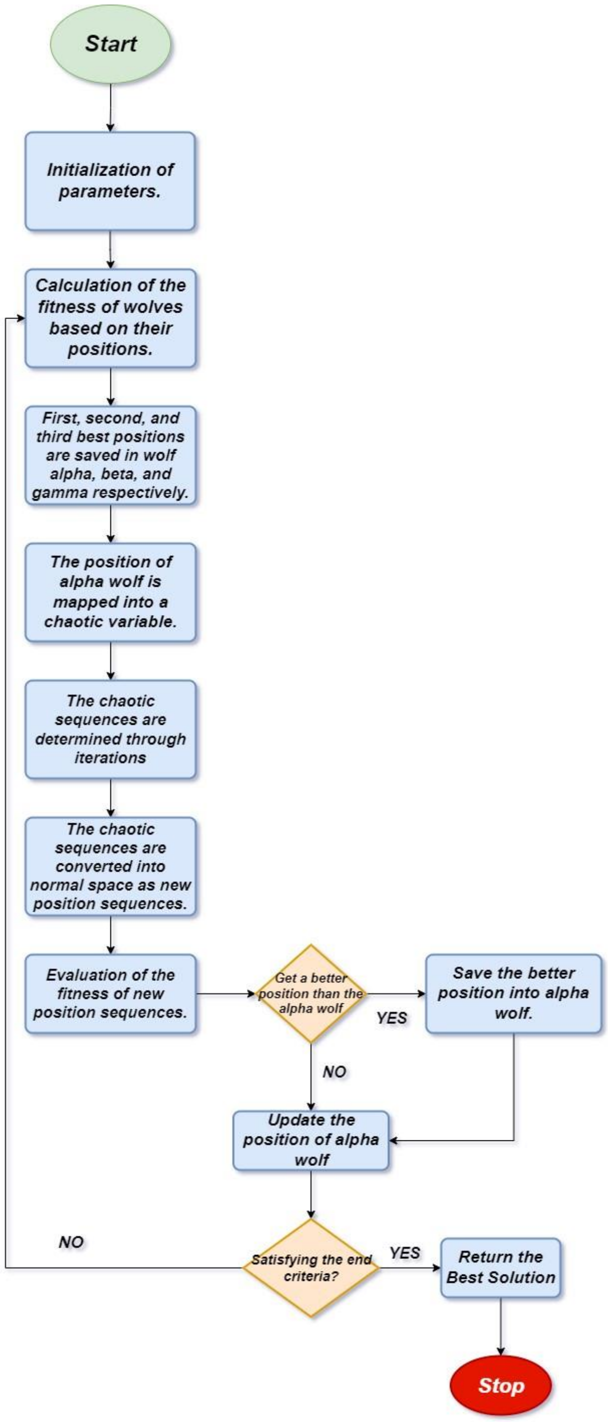


Fig. 6. Flow chart of Grey Wolf Optimization

Power System Technology
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## 5. Medical-IOT

Healthcare devices are among the IoT industry's fastest-growing subsectors. It is expected that this industry, commonly referred to as IoMT - Internet of Medical Things will be worth nearly 179 billion dollars by 2027. The most prominent example of IoT in the healthcare sector is physiological monitoring. IoT devices designed exclusively for monitoring patients gather information about them, including their normal temperature, pulse, and respiratory rate. Following are some ways that IoT is transforming healthcare, as well as some effects that it is having on IoT security.

*Glucose Check*:
Diabetes is very common among people these days. So, a check on glucose levels in the body is of utmost importance to stay safe from various side effects of diabetes. Monitoring and recording these levels in the body manually is not significant because of the time constraint. In these situations, IoT devices provide automated glucose level monitoring to get around these difficulties. Additionally, it's not necessary to manually keep records. Alert alarms are triggered when the glucose levels in the body exceed the minimum threshold level.

*Heart-rate Monitoring*:
Like glucose checks, heart rate monitoring is also important, especially for people who crossed the age of 50. Monitoring the heartbeat is now possible using several inexpensive Internet of Things devices. Patients can move around as they choose while still having their pulses monitored constantly.

*Depression Monitoring*:
Information about depressive symptoms is another type of data that has been difficult to regularly collect. Even though the data on depression levels of patients are periodically tracked, sudden mood changes are difficult to expect. These problems can be solved by IoT devices. By collecting and analyzing information like heart rate and blood pressure, devices can analyze the specifics of a patient's mental state. For mood monitoring, powerful IoT sensors may even track the patient's eye movements.

*Ingestible sensors*:
These sensors are placed in the digestive tract to collect information about PH levels and other systems. As it is uncomfortable to have sensors in their body, these devices must be tiny and capable of neatly moving out from the body. Many companies are diligently developing ingestible sensors that meet these specifications.

Power System Technology
ISSN:1000-3673
Received: 15-10-2023 Revised: 12-11-2023 Accepted: 10-12-2023

*Connected inhalers*:
Patients who are suffering from diseases like asthma face sudden attacks. These devices help to better inform patients about the management of their asthma by tracking the frequency of attacks and environmental variables surrounding asthma attacks. These devices are also smart enough to alert patients in case of improper use of inhalers.

*Robotic surgery*:
IoT devices play a key role in performing surgeries that are complex to perform. These devices can minimize the number of openings needed, making the procedure less painful and promoting quicker patient recovery. The size of these devices matters the most as they must be very small to carry out the process with ease and minimum disturbance.

## 6. Framework

It is a four-layered framework in which the topmost layer consists of various types of sensors that reflect various applications of IoT in everyday life. This layer incorporates major applications including health care, agriculture, smart cities, and intelligent traffic monitoring. This layer serves as a data collection unit in which real-time data is captured by various sensors that are positioned at their appropriate locations in this layer. The second layer is the data preprocessing layer. In this layer, data is converted into a format that can be handled more quickly and efficiently in machine learning operations which are carried out in the bottom layer of the framework. The third tier of the architecture stores the processed data, in the cloud storage layer. Cloud storage enables us to store the data in an off-site location that can be accessible via public internet or a private network connection. The fourth layer or the bottom layer is the core part of the framework where the various AI techniques are implemented. Evolutionary algorithms like ACO, PSO, etc. are implemented at this level.

## 7. Issues and Challenges

*IoT and Security in Healthcare*: Considering the uses of IoT in the medical industry, numerous security challenges need to be addressed. The design of IoT devices must be robust to securely store and process the recorded data according to the requirement. If there are no proper mechanisms specifically designed for securing the data collected by IoT devices, then it can be easily manipulated.

*Lack of Standardization*: IoT devices connect and form a well-defined hierarchy. Generally, devices like heart rate monitoring systems, blood pressure monitoring systems, Glucose level trackers, and some other devices are connected to a central channel to form a robust architecture. The ownership and control of data are unclear since there are no common rules that are widely acknowledged. So, standardization is important to design universally accepted protocols to make communication among IoT devices efficient and significant.

Power System Technology
ISSN:1000-3673
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*Information Exchange*: IoT devices are of no use if they are incapable of communicating with each other and sharing information among themselves. The design patterns of various IoT devices vary depending upon their use and those patterns are very complex. Moreover, the development of communication standards and protocols of various IoT devices which are meant for various purposes is not similar. Manufacturers develop their products independently of one another and inside their own IoT ecosystem. So, integrating these devices and enabling them to communicate with each other is difficult.

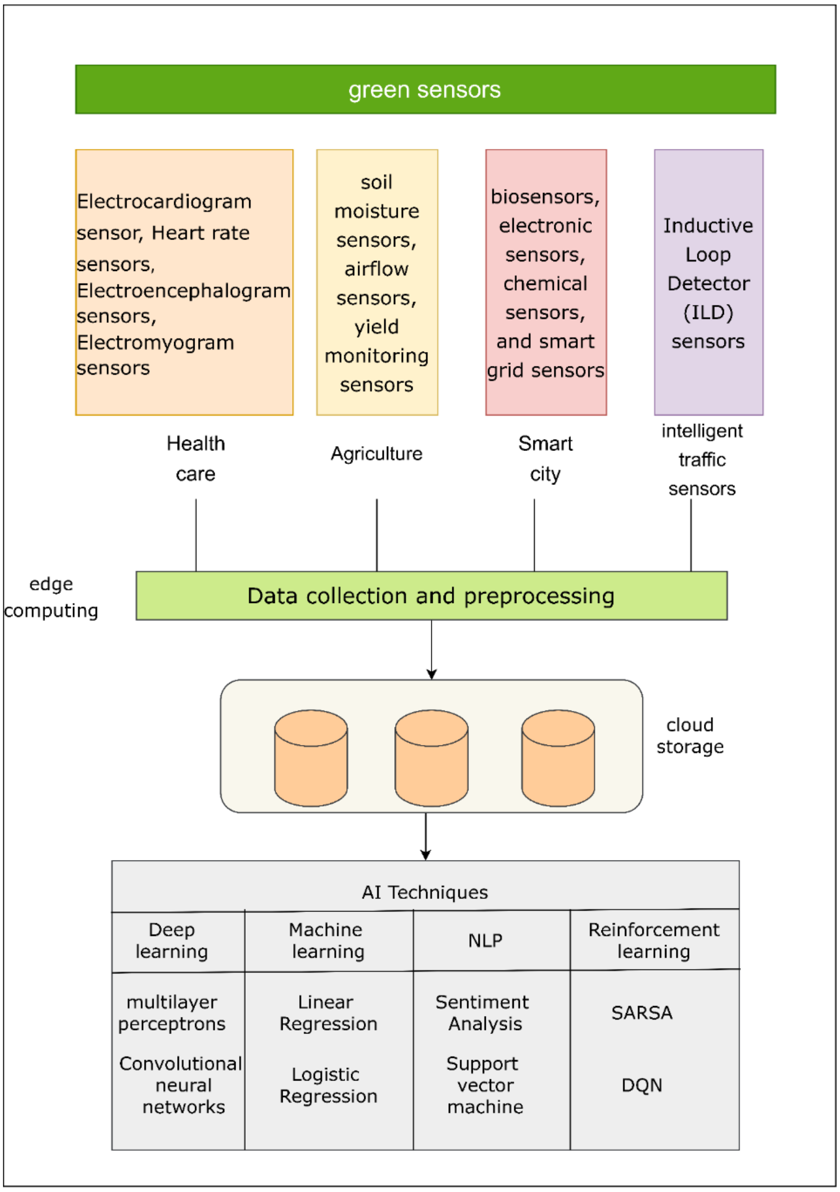


Fig. 7. Proposed Framework

Power System Technology
ISSN:1000-3673
Received: 15-10-2023 Revised: 12-11-2023 Accepted: 10-12-2023

*High Implementation Costs*:

Costs usually seem to be one of the bigger obstacles anytime technology implementation is being considered. It is highly expensive for healthcare businesses to adopt IoT[54]. As a result, there will be a huge rise in the costs of their medical treatments. This results in medical travel where people with critical health conditions start searching for less expensive healthcare services.

## 8. Conclusion

Green IoT will make significant improvements in the future to lead to a green environment. Every day, we will witness sensors, machines, drones, and other devices connecting to perform intelligent work for a green and sustainable environment. The integrated architecture of sensors, IoT devices with proper access to 5G networks, and the efficient assistance of AI will address various issues in an optimized way. The contribution of AI to IoT makes IoT devices context aware. Thus, they become capable enough to address various contextual challenges. This optimizes communication between IoT devices. As they become context-aware, they automatically turn off When not in use to reduce energy use. Green IoT leads to sustainability and influences the IoT industry on a larger scale. The energy sector may benefit from the Internet of Things in several ways. The capability of Green IoT will expand in the future if some advancements are made. Those advancements specifically include the optimization of energy consumption of devices by employing alternative resources, minimizing the emissions of carbon dioxide gas, and identifying the best technological solutions for improving QoS parameters (bandwidth, throughput, and delay**).**

Table 1. Optimization Feasibilities under IoT in different areas

| Application | Sensors Required | Types of Data | Objective | Recommended Algorithms |
|---|---|---|---|---|
| IoT Retail Shops | Drone based Sensors | Sales Information, Product Information, Product Information | Customer Oriented Service with smart shopping carts that are enabled with sensors. | GA based NN |
| Water/ Waste Management | pH Sensors, Level Sensors, Turbidity Sensors, Ultrasonic sensors Temperature sensors | Acidity of a solution, Liquid level, Temperature of the solution, | Regulation of water flow, Recycling of various sources of water, and | Naive Bayes, Support Vector Machine, and KNN, GA-based ANN |

Power System Technology
ISSN:1000-3673
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| | | | | |
|---|---|---|---|---|
| | | Redox measurement information | Enhancing water quality. | |
| Smart Grids | Relay-Based Smart Sensors, PMU-Based Smart Sensors, Temperature/ Voltage Smart Grid Sensors | Power Shortage information, Data on Power Consumption, and Power Transmission. | Continuous monitoring of all sorts of operations of the smart grid and protection of the grid. | Ant-Colony, Genetic Algorithm |
| Traffic Management | Inductive Loop Detector (ILD) sensors | spot speed or time-mean speed (TMS), flow, and occupancy. | To detect the vehicles in motion and the vehicles which are in a stationary position. | Differential Evolution (DE) algorithm. |
| Smart Healthcare | Electrocardiogram sensors, Heart rate sensors, Electroencephalogram sensors, Electromyogram sensors | Rate of Heartbeat, Electrical Activity of Brain, Disfunction of nerve-to-nerve Signal Transmission | Transformation of diverse stimuli into an electrical signal for examination. | Genetic Algorithm, Bird Swarm Algorithm, Fuzzy Logic |
| Industrial Plant | Pressure Sensors, Humidity Sensors, Proximity Sensors, Force Sensors, Flow Sensors, Light Sensors | Temperature of the Environment, Tension Force, Movement of objects, and Presence of Light | Ensure Factory Automation which leads to intelligent production | Ant-Colony, PSO, Multistage Optimization, Bird Swarm Algorithm. |
| Smart Supply Chain Management | Acoustic Sensors, Electrical Sensors | Audio Vibrations, Changes in Electrical or Magnetic Signals | System Automation, Monitoring, and Process Control. | Genetic Algorithm, Ant Colony, PSO |

Received: 15-10-2023 Revised: 12-11-2023 Accepted: 10-12-2023

| | | | | |
|---|---|---|---|---|
| Self-driven Cars | Camera Sensors, Radar Sensors, Lidar Sensors | Images, Radar Frequencies, Presence of Light | Safe Navigation | Ant-Colony, PSO, Bayesian regression, decision forest regression, neural network regression |

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