A Review of Nature-Inspired Optimization Algorithms in Wireless Sensor Networks

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Abstract:

A Wireless sensor network (WSN) refers to a network of conceptually dispersed and customized sensors which are designed to monitor and record the physical state or conditions of the surrounding and progress the gathered data to a dedicated central location. WSNs are widely used in measuring environmental constrains such as air pressure, temperature, pollution levels, humidity, sound and wind.

Because of their inclusive and far-reaching applications, the Wireless Sensor Networks (WSNs) have evolved over the decades. In order to use these kind of networks for different applications the design of energy efficient routing method becomes an important issue because the sensor node's lifespan is very much limited by the battery fuelled devices. As an Upshot, in contemplation of maximise the lifetime of each sensor node, an extensive survey discussing the routing algorithms for energy efficient WSN inspired by natural phenomenon has been brought off in this paper. This paper scouts and inquires a detailed reviewed analysis of already existing energy efficient routing algorithms, with are based on natural science (meta-heuristics) as the basic parameters are connected to energy efficiency as the primary objective. The final section of the paper discusses the limitations of the various algorithms addressed in this paper, as well as suggestions for overcoming them.

Keywords— Wireless Sensor Network, Energy efficiency, Meta-Heuristic algorithm, Network lifetime.

1. INTRODUCTION

The methodically and efficiently designed deployment of wireless sensor networks has evolved over the decades and have become an interesting and hot area for researchers due to their extensive prospects to connect the real world with the virtual world. These large wireless networks are very promising and have potential applications in numerous fields such as medical monitoring, physical conditions monitoring, home safety and machinery monitoring, and also in military operations. Wireless networks are indeed regarded as one of the future lately developed computer technologies, with recent advancements in Micro electro-mechanical system technology, low-powered digital circuits, and RF architecture bringing them closer to wide-ranging and limitless feasibility[1].

Several useful and various WSN applications typically involve information collection in rough and unrestricted settings, such as weather and climate tracking, detection of chemical or biological hazards to agents, and safety tracking. Cheap and intelligent sensors linked via wireless Internet communication have remarkable applications in environmental control and tracking, houses, health care, military, and other fields. This includes the use of various tools such as cameras, acoustics, infrared, and seismic instruments, as well as sensors that calculate various physical parameters. A network of smart sensors can be deployed to detect various threats in a different situations, such as military environment[2].

Figure-1.1- Wireless Sensor Network Application Areas[18]

Sensors, in contrast to traditional appliances, usually have limited computational capacity, memory, and storage. Another significant limitation is that most sensors use non-rechargeable batteries, which limits the energy (lifetime) of such a network. Several research issues have arisen as a result of these constraints, which are defined as optimization problems aimed at discovering useful design strategies, such as the sensor deployment problem, efficient energy utilisation, and increasing network lifetime.

Many routing algorithms based on single path routing and multipath routing strategies were proposed in this context to enhance the performance requirements of various wireless sensor networks. The multi-path routing approach, also known as alternative path routing, was developed to address these performance issues and address the constraints of the single path routing approach. As the name implies, there will be various routes between the source from where data is being transmitted and the sink where the transmitted data is received through which the information can reach the destination. One such popular routing algorithm is Flat routing protocols based on hierarchy and location from the perspective of the network. Flat routing protocols for wireless sensor networks are designed for the networks with homogeneous nodes, which signifies that all nodes have the same power and capacity for transmission and processing. Another group of protocols is the Hierarchical routing protocol, which are proposed to boost network energy efficiency and scalability by clustering the nodes. In this type of protocol, all the sensing entities or the nodes are grouped making a cluster, and each cluster will have a Cluster Head which is responsible for collecting information from the sensing nodes of the clusters, processing data, and then forwarding information to the sink. Although this structure provides excellent network scalability, clustering operation but the replacement of the cluster head imposes significant overhead signalling on the network. Several routing algorithms are included in this category, including LEACH, HEED, TEEN, SEP, and others.

There are a few energy enhancement strategies that depends on nature-enlivened techniques. Numerous issues in our regular routines are challenging to address because of the impediments of conventional strategies. Subsequently, numerous analysts have moved their concentrate away from conventional ways to deal with finding nature-motivated answers for these issues. Nature-motivated meta-heuristic calculations have their own critical thinking techniques and principles[4]. Meta-heuristic techniques gives proficient streamlining and have been applied to Wireless Sensor Networks to take care of some of the issues referenced above, especially power limitation of the sensors, energy effectiveness, and the network lifetime.

This paper talks about various types of meta-heuristic algorithms related to wireless sensor networks along with an account of the attributes of the Wireless Sensor Network.

Wireless Sensor Networks are comprised of many sensor nodes that are formed by embedded electronics and are capable of measuring environmental conditions such as air pressure, humidity, temperature, and many more. Designing appropriate routing algorithms for multiple applications while meeting various performance demands has been identified as a hypercritical issue in wireless sensor networks. Clustering of nodes is a technique for governing network energy consumption by minimizing the range of sensor transmission. The cluster head of a particular cluster manages the group's communication with the base station. Sensor nodes will no more transmit data straight to the base station; Instead, cluster heads get the messages from the entire group of nodes, aggregate them, and directly forward them to the base station[5].
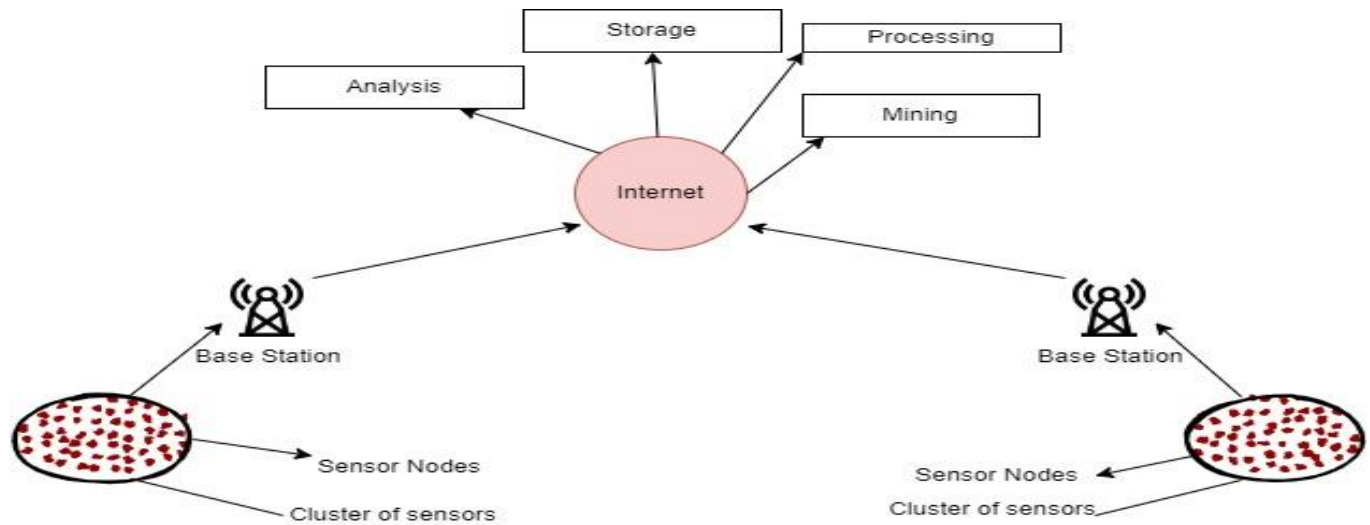

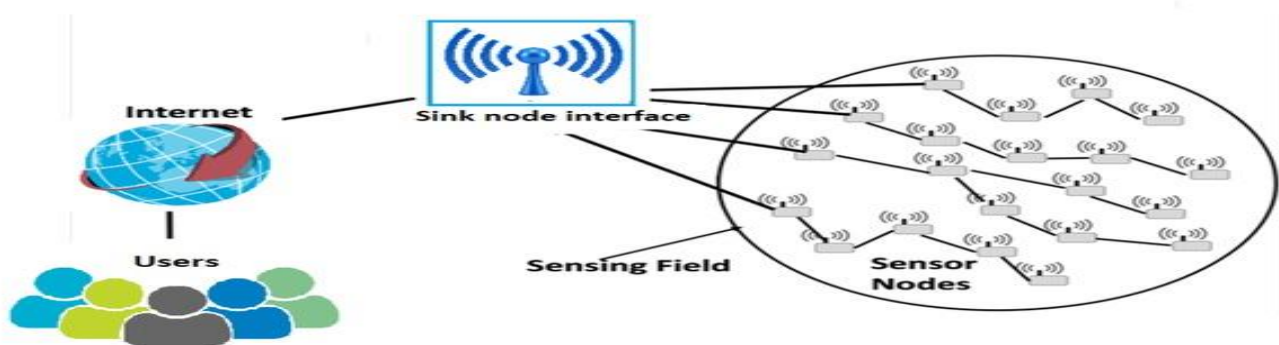**Figure 1.2- A Wireless Sensor Network**

Figure 1.3- WSN Architecture[19]

According to the dissipation model for radio energy depicted in the figure shown below, the energy augmented by the radio to achieve a tolerable Signal-to-Noise Ratio (SNR) in transmitting a "L-bit message" over a distance "d" is specified as:

$$Etx_{(L,d)} = \begin{cases} LE_{elec} + LE_{fsd2} & \text{if } d < do \\ LE_{elec} + LE_{mpd4} & \text{if } d > do \end{cases}$$

Where, "E_{elec}" is the measure of energy expended per bit to power the transmitter (E_{TX}) or receiver circuit (E_{RX}). There are many factors which influences the "E_{elec}," including digital coding, modulation of the signal, filtering out the unwanted noise, and signal spreading. The values of "E_{fs}" and "E_{mp}" are decided by the transmitter amplifier model, and 'd' is the distance between the source and the destination. Depending upon the distance between the source and the destination, the free space (d^2 power loss) and multi path fading (d^4 power loss) channel models were used in the experiments described here. The free space (f_s)

model is used   if the distance is less than a certain threshold else, the multi path (mp) model is accountable. We've set the value of "d^0".
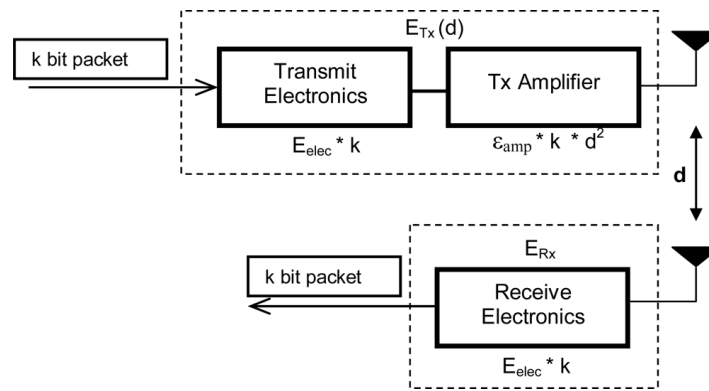

Figure 1.4- Network Model

The various equations for estimated analysis of the average energy of a network, as well as the cluster head selection algorithm depending on residual energy are given by:

The following is the average energy of the r_{th} round:

$$E(t) = 1/(N)\, E_{total}(1-r/R) \qquad (1)$$

where R denote the total rounds of the network lifetime and is defined as:

$$R = E_{total}/E_{round} \qquad (2)$$

E_{round} is the total energy dissipated in the network during a round, is equal to:

$$E_{round} = L(2NE_{elec} + NE_{DA} + kE_{mp}\, d^4{}_{toBS} + NEfs\, d^2{}_{toCH}) \quad (3)$$

where "k" is the number of clusters, E_{DA} denotes the cost of data aggregation in the cluster heads, d_{toBS} denotes the average distance between the base station and the cluster head, and d_{toCH} denotes the average distance between the cluster head and the cluster members in a particular cluster.

2. META-HEURISTIC TECHNIQUES

Meta-Heuristic techniques are widely spread for a variety of problem domains and several meta-heuristic algorithms which are inspired by various natural classes have been presented. Meta-heuristic algorithms are esteemed by their use of so-called transition, evaluation and determination operators to "Guess"applicable solutions in the solution space.

Ant Colony Optimization (ACO)- Marco Dorigo developed Ant Colony Optimization (ACO), which is laid upon the foraging behavior of social ants. Plenty of insects, including ants, leaves a chemical messenger known as pheromone for the following ants next in order. Ants are a class of social insects whose population ranges from 2 to 25 million individuals. Each ant releases a scented chemicals or pheromones to establish the communication with other ants in the queue. Individual ant can also follow the path which is pheromone-scented by the preceding ants. When an ant discovers a food source, it will release a pheromone trail that leads to and from the food source.

Though, the pheromone concentration ϕ vanishes or evaporates at a fixed rate γ . That is,

$$\phi(t) = \phi_0 \exp[-\gamma t] \qquad (5)$$

where, "ϕ_0" is the initial concentration at time (t)= 0. Evaporation is worth noticing in this study because it grants convergence and self-organization.

Cuckoo searching (CS)- It is an algorithm invented by Xin-she Yang and Suash Deb. It was originated by the manipulated brood parasitism of few cuckoo species, which means laying eggs in the nests of either of the same species or different species and raising the eggs. Cuckoos Invading in other's nests may cause direct dispute with host birds. If a host bird comes to discover that the eggs are actually not their own, it will either throw away the foreign eggs or abandon its own nest and will build a new one at different place.

Because CS search accounts for such breeding behavior, it can be pertained to an extensive range of optimization issues. It seems to outperform the other meta-heuristic algorithms in various applications.

Artificial Bee Colony Optimization (ABCO)- **ABCO** is a swarm optimization technique that is based upon the intelligence possessed by the bees. Bees are highly intelligent creatures on the planet that can construct complex structures and use intelligent pathfinding techniques. Bees are classified into three different types according to ABC: the first ones are Employed bees, the second ones are Observing or Onlookers, and the last ones are Scouts. The number of bees operating is proportional to the number of food sources accessible. The diligent bees travel to their chosen food source, then return to its colony and dance in this area. When an operating bee cannot find food, it then becomes a scout for others. Observing or the Onlooker bees choose a food origin based on the bees' dance and fly to that place. Ensuing that, a nearest neighbor in the locality of the nectar source is picked up, and the nectar sum is calculated. So far, the best food discovered is the most affordable.

Firefly Algorithm- Yang discovered the Firefly algorithm based on the nature of fireflies and it is meta-heuristic swarm algorithm. This algorithm accounts for how fireflies flashes its light in swarm, and mimics how they interact. The algorithm presumes that all fireflies are unisex, which ultimately depicts that any firefly can get attracted by any other firefly, the captivation or attractiveness of a firefly is directly proportional to the intensity of light it is emitting, as determined by the intended function. A firefly is captivated by brighter firefly. Based upon its performance in the intended function, the algorithm allocates a light intensity to a randomly generated feasible solution known as a firefly. This intensity of the light will be used to calculate the firefly's brightness, which is proportional to the intensity of its light. When resolving minimization problems, the solution with the lowest functional value receives the most light intensity. When the solution's intensity or brightness is assigned, each firefly will follow fireflies with higher light intensities. The brightest firefly will perform a local hunt by moving around in random motion.

3. RELATED WORK

Hoang et al.[6] presented an algorithm based on music which is known as Harmony Search Algorithm (HSA) to lessen intra-cluster distance and enhance the energy efficiency of the system. This protocol is a meta-heuristic optimization method based on music that is like the way in which performers clean their pitch until the best harmony is achieved. HSA was contrasted with LEACH, which is a notable cluster-based algorithm grown for WSNs, in addition to heuristic advancement algorithms like Particle Swarm Optimization and Genetic Algorithm. HSA was likewise contrasted with customary K-means and also with Fuzzy C-Means (FCM) clustering protocols. The investigation yields positive outcomes, showing that this music-based search algorithm is fit for advancing network power adequacy and also increases the network life expectancy.

Khalil along with Bara'a[7] suggested designing the main component of Evolutionary Algorithms (EAs) (i.e., the intended goal) to acquire a suitable routing algorithm that is capable to deliver more vigorous outcomes than contemporary heuristic and metaheuristic algorithms concerned to the network stability expectancy, life time of the network and power utilization. It was intended to utilize a transformative based routing algorithm. It guarantees a superior compromise between network life time and steadiness period with effective power utilization. To show the previously mentioned point, ninety homogeneous and heterogeneous WSN models were assessed and contrasted with Low-Energy Adaptive Clustering Hierarchy (LEACH), Stable Election Protocol (SEP) and a developmental based routing algorithm, Hierarchical Clustering-Protocol (HCR)- based Genetic Algorithm.

Abu-Mouti and El-Hawary[8] introduced the Artificial Bee Colony (ABC) algorithm momentarily. It was a recently introduced meta-heuristic method for optimization based on population that was enlivened by the swarm of honey bee wise foraging conduct. The algorithm's essential characteristics and execution measurements are explored.

Kuila et al.[9] introduced a new GA for WSN in view of a load adjusted clustering protocol. When tried for something different or same loads of sensor nodes, this algorithm yields a good performance. The author produced the proposed algorithm widely and contrasted the outcomes with other developmental based techniques and related clustering algorithms. The experiments show that the protocol beats its

contemporary algorithm with regard to few exhibition measurements, for example, load balancing, execution time, power utilization, the quantity of dynamic sensor nodes, the quantity of dynamic CHs, and the rate of intermingling.

Nanda and Panda[10] re-examined all significant nature-inspired meta-heuristic algorithms utilized for partitional clustering to-date. Moreover, central questions engaged with the plan of different meta-heuristics, like the clustering issue, as well as other significant application regions, are examined.

Hoang et al.[11] a research scholar proposed a design to help with the improvement of a practical strategy for incorporated cluster-based techniques for optimization upheld by optimization methods for sensor networks. In view of this model, an algorithm for WSNs was made and executed in real time utilizing HAS, a music-based meta-heuristic optimization method. This algorithm is relied upon the idea to decrease intra-cluster distances between the part nodes and their CHs, moreover it will upgrade WSN energy dissemination. This strategy was contrasted with well-known cluster-based calculations intended for WSNs like LEACH-Centralized (LEACH-C) and an algorithm based on clustering of nodes with respect to the FCM clustering protocol. The stimulation outcome tells that the HAS-based calculation can be utilized in centralized cluster-based WSNs for surveillance or security practices in an environment.

Alam et al.[12] examined the advancement of research on a lately popular technique known as Swarm Intelligence (SI) and its protocols, explicitly Particle Swarm Optimization. The algorithm's two significant commitments are: To start, it gives a careful overview of the literature writing, concentrated on the absolute most often referred to schemes utilized in PSO-based clustering of data. Furthermore, the author cited the stimulated outcomes to feature the significance of different techniques in contrast with current clustering strategies. The author summed up the PSO-based Hierarchical clustering technique (HPSO-clustering) and contrasted the outcomes with conventional Hierarchical Agglomerative Clustering (HAC), PSO clustering, and K-means.

Elhoseny et al.[13] suggested a Genetic Algorithm-based CH Selection (GA-CHS) method for balancing energy and network lifespan in WSNs. The GA-CHS method utilized the advantages of hybrid and transformation to keep up with energy and node solidity all through the network. It incorporated a responsive technique for maintaining energy utilization for request to altogether increment network lifetime by permitting the energy of sensor nodes to exhaust uniformly. It was designed to altogether increment network lifetime as far as first-node-die on and last-node-die by 31.21 percent and 13.26 percent, respectively, when contrasted with the baseline approaches utilized for comparison. It was a contemplation to work on computational effectiveness and total interim by 0.62 seconds with a standard deviation of 0.06.

Ray and De[14] proposed an algorithm called Energy Efficient MultiParameter Reverse Glowworm Swarm Optimization (EEMRGSO) for operating sensors in an energy-productive way. By moving the sensor nodes, the presented algorithm lessens redundant coverage region. The proposed motion-based algorithm diminished the quantity of covering sensors and accomplished coverage of roughly 80-89 percent.

Sengottuvelan and Prasath[15] introduced an Improved Fish Swarm Algorithm-based CH Selection (IFSA-CHS) technique for ideal clustering process in WSNs with far better energy balance of the network. When contrasted with conventional LEACH and GA-based CH selection techniques, the consequences of this IFSA-CHS enhanced lifetime anticipation of the network by 16.21 percent, energy stability increased by 14.96 percent and the rate at which a packet is delivered increased by 19.42 percent.

An upgraded Harmony Search Cuckoo Search-based Clustering Protocol (HSCSCP) was given by Gupta and Jha[16] for stability of energy and network life expansion. This HSCSCP was planned with a narrative that supports the uniform dispersal of cluster heads over the network. Harmony search, specifically, is improved and fused into the routing scheme to work with solid distribution of data packets between sinks and cluster heads. It coped with the problem of uneven energy utilization of sensor nodes in the network, as nodes nearer to the sink might be over-burdened with an excessive traffic load. It considered the routing issue between cluster heads and sinks utilizing energy adjusted node clustering.

Rambabu et al.[17] defined a Monarch Butterfly and Artificial Bee Colony Optimization Algorithm (MBABCOA) for clustering sensor nodes fully intent on energy balancing and bringing down the latency of network. The advantages of mutated butterfly adjusting component for supplanting and further developing the ability of employee honey bee state were examined in this MBABCOACP. It was proposed

with the capacity to forbid delayed convergence and also the arrangement from bringing about the local optimality spot. The MBABCOACP stimulation outcomes affirmed their importance in encouraging energy efficiency when contrasted with the other benchmark approaches.

4. CONCLUSION

A Wireless Sensor Network is made out of countless low-cost sensors that have restricted battery life and computational abilities. The deployed sensors are capable of conveying messages to each other, gathering information, and remotely sending it to the base unit. The meaning of energy adequacy in Wireless Sensor Networks is that it extends the network's lifetime. An algorithm based on Clustering of the sensor nodes is intended to increase the life expectancy of a network while lowering costs and economizing energy. Inspired by nature, meta-heuristic strategies have been proposed to take care of various issues connected with optimization of WSN. In this paper, various well known meta-heuristic approaches have been examined alongside the work done by scientists in the course of the last ten years in applying meta-heuristic techniques for further developing energy effectiveness in Wireless Sensor networks. The utilization of nature-motivated algorithm has encouraged a new revolution in cutting-edge computing. These algorithms are appropriate for tackling multi-objective issues related to optimization in WSN. Different highlights of nature-propelled algorithm, for instance, rational computational time, view as worldwide ideal and appropriateness make them suitable for optimization issues. Conversely, obsolete algorithms fall through to deliver good outcome principally as a result of the computational intricacy and size of the complication structure. In this paper we have introduced a brief review of some existing algorithms regarding different issues connected with the WSNs. We have assessed the capability of some meta-heuristic nature-motivated strategies that compute adaptive routing and clustering in WSNs. Sometimes it happens that an individual optimization algorithm can't be capable of delivering optimal outcome. So, using different blends of meta-heuristic nature-roused approaches can be more efficient in such situations. Likewise, we can map out smart routing and clustering schemes based on IoT empowered approaches.

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