Computational Intelligence in WSN for Network Life Optimization

Rakesh Kumar Singh[1], Ajay Kumar Bharti[2]
[1,2]*Dept. of Computer Science, Maharishi University of Information Technology, Lucknow (UP),India*

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Abstract: Computational Intelligence (CI) have been increasingly used by researchers in pat years to Solve difficult problems. The sensor networks are controlled by battery and in this way they end up being dead after a specific period. Thus, improving the information exchange in power effective way still stays challenge for expanding the life expectancy of sensor gadgets. It has been demonstrated that the clustering technique could upgrade the life expectancy of WSNs. In the clustering approach, the choice of right cluster head in each cluster has been observed as the most appropriate technique for energy efficiency, which limits the transmission delay in WSN. Much exploration has been done in the recent past to decide an ideal path among source and goal sensor nodes, which will bring about improving the battery power dissipation of a system. The challenge is to design a scheduling algorithm that thinks about the significant issues of limiting power consumption and boosting system lifetime. Different ways of optimization are accessible to decide a proper routing method between a source and sink node. This paper investigates various optimization tools for effective routing in WSN. This article gives us a glimpse of the past investigations in WSN field during the period of 2010–2020. The outcomes listed in this article will guide to research community for bridging the gap in the WSN field and to discover new exploration in this area.

1 INTRODUCTION

WSN is playing a key job in remote or unattended kind of infrastructure less networks for the numerous applications, like checking the environment conditions, traffic tracking, observation in war zone, disaster event counteraction, health monitoring, clinical observations, weather and climate observing, Industrial monitoring and so on.(Akyildiz et al. 2002). Collecting the information from the sensor field, processing the data and communicating with other SNs are major activities performed by sensor nodes. WSN has constrained force with restricted limit with regards to processing. In some application, the energy can be renewed by external source, for example, solar based cells (Want et al.2005). However it is not able to make uninterrupted power supply due to weather and energy dissipation are prime issues to be addressed for the betterment of throughput in different application areas. Clustering plans, which partition the network with the aid of grouping the nodes, plays an important job in keeping up the network topology in successful way. It is inescapable to create clustering algorithm, which is proficient in preserving energy for hauling out the range of the system. Information is imparted from SN (for example it's starting point) to the base station (BS) or sink by single hop or multi hop communication. Trial results display that communication is relatively costly than computing which is less energy consuming. (Raghunathan et al., 2002). Transmitters and receivers consume much more power to communicate information than the processing counterpart. The energy dissipated by the sensors to sense information from surrounding is very small as compared to communication and computing activities. Power preservation techniques focuses on two parts: activity of sensor node and the communication protocol employed. Amalgam of various procedures can be applied for extensibility of the sensor system lifetime (Anastasi et al., 2009). Routing is probably the most difficult issue for which we can't utilize deterministic algorithms. Along this line, optimization calculations are utilized to introduce low cost routes among various possible routes. By actualizing Swarm Intelligence (SI) based calculations, different routing calculations have been created. SI can be thought of as a similarity between machine behaviour and nature driven conduct of the swarm. These swarm based intelligent calculations can possibly accomplish ideal solutions

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for real world tasks. Ant Colony Optimization (ACO), Particle swarm Optimization (PSO), Firefly algorithm (FA), Artificial Bee Colony (ABC), Fuzzy logic and Bacterial Foraging Optimization (BFO) are few examples of most famous routing methods. Here we have presented a review with respect to these strategies and look at them to figure out which procedures are progressively suitable as far as power utilization and system lifetime are concerned. In this survey, we additionally talk about different difficulties in routing methods of WSN and recognize approaches to address these difficulties utilizing optimization strategies. The primary goal is to examine the present status of-the-art enhancement methods utilized in routing information by means of WSN and identify proficient methodologies for routing in a WSN. The remainder of the article is sorted out as follows:

In Section II, a portion from the current related work with respect to taken subject is talked about. Section 3 explains various techniques to lead this review, while Sect. 4 describes a comparison of these optimization methods. Segment 5 is comprised of discussions and future directions and at last, Section 6 concludes this work.

2 LITERATURE REVIEW

Zengin et al. directed an overview where various routing strategies were examined to manage the issues of energy, expendability, intricacy, survivability and computational overhead. As indicated by this review, ant based methodology is viewed as a decent methodology and has pulled in numerous scientists than some other algorithm.

Parwekar et al. gives investigation of enhancement strategies to WSN. They recognized few difficult issues as routing, node localization and clustering. These issues can't be solved using deterministic methodology. Hence optimization algorithms are increasingly reasonable for them. They give basic investigation of all optimization strategies and utilize this for future research.

Ali et al. led a study on MANETs and WSNs dependent on swarm knowledge. They recognized that in loop free, power efficient and multi hop routing the “Ant Colony Optimization (ACO)” and “Particle Swarm Optimization (PSO)” give all the more encouraging outcomes. This article incorporates detailed examination of all methods for wired and wireless network and states that PSO and ACO beat the other routing protocols.

An overview on routing with a point of upgrading energy utilization was introduced by Saleh et al. This gives a complete overview of residual power centric convention in WSN. It gives an outline of significant sensor nodes’ attributes that are utilized in various routing methods. Diverse routing conventions that fall under ACO algorithm are discussed with their pros and cons.

A review on Swarm intelligence based scheduling convention in WSNs was led by Saleem et al., in which design and implementation plans are talked about. The point is to recognize viable optimization methods to discuss the issues of scalability, fault tolerant property and adaptability. They additionally give a few insights about swarm intelligence and its conceivable execution for communication in a WSN. A rundown of basic highlights is recognized to bring up the difficulties in evaluation procedure and consider this for actualizing real-world implementation.

SGui et al. led an overview on swarm based routing convention. They first introduced the properties of swarm intelligent methods, then after they investigated routing protocols to have new optimization method. They talk about the properties of “ant colony and spider monkey optimization”. They additionally discuss about the issues present in this approach and show future bearings.

Zungeru et al. presented a survey by looking at “Swarm based routing” conventions with traditional routing protocols. Routing protocols are ordered as information driven, level based, geographic location based and Quality of service (QOS). Distinctive routing protocols are re-evaluated utilizing MATLAB based test system to see the outcomes and give a benchmark to future work.

Guo et al. directed an overview of intelligent routing conventions in a WSN with a point of upgrading system lifetime. They talked about intelligent algorithms, for example, “Fuzzy Logic (FL), Reinforcement learning (RL), Neural Networks (NNs), and Genetic Algorithm (GA)”, to examine their behaviour regarding the system lifetime.

3 ROUTING IN WSN USING DIFFERENT OPTIMIZATION TECHNIQUES

3.1 Fuzzy Logic based Routing Protocols

“Fuzzy Logic is a decision making control framework approach that fits usage in frameworks extending from straightforward, little, inserted smaller scale

controllers to huge, organized, multi-channel PC or workstation-based information securing and control frameworks". It may be actuated in hardware, software, or hybrid model. FL gives a straightforward method to arrive to a distinct end result dependent on dubious, questionable, uncertain, noisy, or missing information. FL's way to deal with control issues emulates how an individual would settle on choices a lot quicker. FL joins a straightforward, rule-based IF A AND B THEN C way to deal with a taking care of control issue instead of setting a framework mathematically. The FL model is observation based, depending on user's experience as opposed to their specialized technical knowledge of the framework. For instance, as opposed to managing temperature control in terms, for example, "BT =100F", "T <500F", or "20C <TEMP <200C", terms like "IF (process is too hot) AND (process is getting hotter) THEN (add coolant to the process)" or "IF (process is too cold) AND (process is cooling rapidly) THEN (add heat to the process quickly)" are used. These terms are loose but extremely descriptive of what should really occur. Consider what you do in the shower if the temperature is excessively cool, you will make the water agreeable rapidly with little difficulty. FL is fit for mirroring this kind of behaviour at exceptionally high rate. FL is comprised of two steps. A fuzzy membership- function is designed to generate the membership for an input of a linguistic variable. The membership-function can be formulated in a precise manner to represent the needed output pattern of an objective-function. FL also offers a "fuzzy aggregation operator, Ordered Weighted Averaging (OWA)", to design a multi-objective cost function as an alternative. Normally, the "And-like" and "Or-like" OWA operators are used in FL. Control systems such as automobile systems, energy systems, image processing, pattern matching, home appliances, and elevators etc. are some applications where FL is very effective. FL is also suitable for optimized clustering and routing to find different objectives. Sometimes non-optimal solutions are generated. This issue can be resolved by re-learning of fuzzy rule base.

Gupta et al. proposed a FL based FCH protocol to addresses cluster-head election for WSNs. In this approach, cluster-heads are selected by the sink node in each round. For each node, residual power, node density and nodes' intra cluster distance are considered as inputs to evaluate the criteria to be the cluster head. Node density is calculated as number of nodes by which the concerned node is surrounded, and intra cluster distance is treated as nodes' centrality with respect to the cluster. The node energy and node density linguistic variables have three levels: low, medium and high. Intra cluster distance has the levels: close, moderate and far. The output for presentation of the node's chance to become cluster head was levelled into seven stages: "very small, small, rather small, medium, rather large, large, and very large". The fuzzy rule base look like: if the residual energy and node density is high and intra cluster distance is close then there is very large chance for the node to become cluster head. In this manner there are 3^3=27 rule base permutations. To demonstrate medium and adequate fuzzy sets, triangle membership functions are used. Trapezoid membership functions are used to demonstrate low, high, close and far fuzzy sets. As far as performance is concerned, FCH has a substantial edge over network lifetime in comparison to LEACH routing protocol. Gupta et al. claims that round in which first node is dead, is about 1.8 times better than LEACH. However, this protocol is not scalable due to a non-distributed approach.

"Cluster head election using fuzzy logic (CHEF)", presents a clustering method in distributed manner via fuzzy logic approach. Initially CHEF selects CHs on the basis of probability approach. Operational CHs are chosen from initially selected CH list using remaining power, and intra cluster separation of nodes. Fuzzy inference computes the input parameters. The result parameter chance is indicator to choose a node as CH. Nodes having higher chance value are the candidate for CH. It has a major disadvantage that input variable intra cluster distance does not suit for network sizes apart from 200m×200m.

"Energy aware distributed dynamic clustering protocol using fuzzy logic (ECPF)" performs all the operations in setup and steady state phases. Cluster Head election and formation of cluster are done in set-up phase. TDMA schedule formation and data communication happens in steady state phase. Degree and centrality of node are the input parameters and fuzzy output cost is treated as the decision making value. Every node will wait for a delay time (1/ residual energy). If no tentative CH is received by node within its delay time, it declares itself as tentative CH and broadcasts a message which includes its id, fuzzy cost, and its status. Now it checks in the cluster whether there is any other node with lower fuzzy cost value. If it does not find any, concerned node declares itself as the CH, and informs every member node with final CH message within its cluster range.

3.2 Particle Swarm Optimization (PSO)

Nature inspired the invention of "Particle Swarm optimization technique by Eberhart and Kennedy". This strategy adopts the social behaviour of flying birds in a flock where all the birds have equal status and decision making capacity. They haphazardly discover their food by that bird, which is closest to the food position. All the animals have property to move in the group, especially birds and fishes. They never crash into one another because of the fact that each individual from the flock follows their head bird and alters its position and speed accordingly. This phenomenon also reduces the effort time for searching the food. position and area of food are broadcasted by all the birds in the flock. In PSO, 'bird' represents a solitary solution. In some cases it is also called as particle. All the particles have its wellness value to access the nature of the solution. "Two-tier Particle Swarm Optimization (PSO)" routing convention has been created by numerous specialists to solve the clustering and routing issues. With the aid of PSO, it is now possible to choose optimal cluster head to improve network lifetime, throughput, scalability, and delay etc. in wireless sensor network. Routing protocol adopts "particle encoding scheme" and wellness output to access the optimal route from source to destination. Authors, discusses about two issues: routing and clustering. PSO with multi-objective wellness function has been executed to mimic the routing method. LP and NLP formulations are used to improve the behaviour. "Optimized energy efficient routing protocol (OEERP)" is mentioned. This methodology increases network lifetime by consistently depleting nodes' power. Proposed methodology has no reference point based transmission to arrive at the passage. One disadvantage of "OEERP" methodology is that remaining sensor nodes are considered in set-up stage, which reduces framework lifetime as contrast with different methodologies. During formation of clusters, few nodes do not get included in any cluster. This phenomenon gives birth to residual node formation. Such remaining nodes transmit the detected information either legitimately to the BS or by getting suitable gateway node through control messages. Excessive increase in control messages results in reduced network lifetime. Authors, proposed Enhanced optimized energy efficient routing protocol (E-OEERP). This protocol minimizes the chance of residual nodes creation to improve the energy efficiency. Clustering and routing are performed with the assistance of "Particle swarm optimization (PSO) and Gravitational search algorithm (GSA)" in route construction phase. Saranraj et al. combined ACO with PSO to create Particles with "Ant Swarm optimization" for finding CH in a wireless sensor network. Authors applied pheromone path to the PSO for the particles' position synchronization. This method attains the best objective value to find the optimal path from source to sink node. Authors combined PSO and neural networks characteristics to make a scalable and secure system. They figured out that fixed base station frequently experiences hotspot issue as they have more traffic density close to the sink hub. To improve the hot spot problem, the authors presented algorithm for mobile sink nodes with control parameters to improve delay and network life. Particle Swarm Optimization Routing (PSOR) protocol has been proposed to create best path for less energy consumption in data communication. Though there are many routes between source and destination, this protocol uses leftover node power as a fitness function to discover the optimized route. We come to conclusion that PSO is good for single-hop communication, however it is not efficient for multi-hop communication.

3.3 Firefly Algorithm (FA)

Firefly calculation (FA) is another enhancement method initially proposed by Dr. Xin She. This strategy copies the manner in which genuine flies get pulled in to one another dependent on flash light. Fireflies produce unique pattern by their flash dependent on the species. Fireflies attract each other with two fundamental patterns: mating and preys. Female fireflies answer with some remarkable flash light pattern to the male in mating case. The separation between fireflies is contrarily relative to the light emitted by fireflies. This implies fascination between fireflies is dependent on the intensity of Light emitted by them. As the separation increases, received light brightness will diminish. This behavior is inherited in firefly algorithm where fireflies are represented as generated solutions and fitness function is linked with the light intensity. WSN can be implemented with the help of firefly algorithm. It uses various parameters like remaining power, intra and inter cluster node distance, node density etc.to optimize path between Cluster Head and base station.

In firefly algorithm was implemented by decreasing fitness value as hop count of any route increases. This is worth in WSN to conserve the energy of nodes, and add residual energy in its fitness value. Authors, proposed a power saving algorithm

using ACO and firefly algorithms. They claim that FA outperforms the ACO for less distant routes while ACO is good in the case of longer routes. Mobile sink node has been introduced in a paper proposed by authors, named as mobile data transporter (MDT). It gathers data from every sensor node to send the collected stuff to the BS. In this FA approach, average path length decreases in comparison to Ant Colony Optimization. Firefly algorithm (EDFA) is presented to solve vehicular routing problem with time windows (VRPTW). This algorithm aims to optimize (min) the number of possible paths in a network. Algorithm is suitable for multi-objective optimization problems. This technique faces the problem of delay in path search.

3.4 Genetic algorithm (GA)

Genetic algorithm (GA) is one of the techniques proposed by Holland et al., which solve search and optimization problems. This technique is based on the Darwin theory of biological evolution, reproduction and "survival of the fittest". It copies the behaviour of genes transfer from parents to children through crossover, mutation and selection operators. In selection phase, few genes are chosen for crossover and mutation; genes get swapped in crossover for children production, whereas new attributes are added in mutation phase. The same characteristic is mimicked in Genetic Algorithm. In this algorithm, population is constituted as chromosomes and each string of chromosome is written as binary or real numbers. First of all, the random generation of population is performed, then process of selection, crossover and mutation generate next generation of population. Strength of produced chromosome in a population is examined by the objective function. In, GA has been taken to optimize the inter node distance for energy conservation. The objective function incorporates the transmission distance between nodes and CH within a cluster and from the cluster head to the BS. Node with maximum residual battery power and minimum intra cluster distance is selected as CH, to minimize the communication cost and increase the life of network. Authors presented an algorithm which reduces the chance of weak node consideration in any route selection. Authors, considered clustering and routing issues using Genetic Algorithm (GA) ,which gives better result. According to paper presented, authors have used the advantages of genetic algorithm and simulated annealing together for efficient energy utilization via efficient route selection. Author applied GA on hierarchical based clustering protocol to make network properties better. To maximize the network lifetime and to minimize the average intra cluster distance, paper applied GA based algorithm. This algorithm is not suitable in the paradigm of mobile sensor nodes.

3.5 Ant Colony Optimization (ACO)

Darigo and Gambardella in 1997 proposed Ant Colony Optimization technique. It mimics ants' behaviour. It tackles the issue of ideal path discovery between source and goal, based on genuine ants' characteristic. In beginning, ants move in any direction to search food. Upon the successful discovery of food source, ants turn towards colony. Ants release pheromones while going back to home which in turn guides way for food source. Different ants follow a similar way to reach on food source. When these ants copy the same path, fair amount of Pheromones are deposited to indicate a stronger path. The quantity of deposited pheromones is directly proportion to quality and magnitude of food source. At a point of time when food sources diminish, quantity of deposited pheromones also decreases to inform the ants about less or no availability of food. Authors in applied ACO to find optimal path for data communication in WSN. ACO is applicable in the case of predefined source and destination. It works well only for symmetric paths. According to authors, Pheromone quantity is computed in terms of hop count between source and destination. Nodes receive data values as Destination Address (DA), Next hop (NH), Pheromone value (PH) and stores in routing table. An algorithm named "optimal-distance based transmission strategy (ODTS)" based on ACO optimization is mentioned. This strategy searches for the optimal distance among the sensor nodes for cluster head selection, which ultimately improve energy efficiency and life of the network. To minimize the earlier death of sensor nodes, ACO based load balancing in WSN is presented in article.

4 COMPARISON AND RESEARCH GAP

Summary of various surveys for different class of problems and applications are summarized in Table I. We derive the conclusion as mentioned below:

- Residual energy is the basic criteria for most routing protocols to improve the network life time.
- Most routing protocols have complete knowledge of the network.

- Node coverage issue were not discussed in depth.
- Fault tolerant and scalability are less explored.
- Cross-layer methods, mobility, non-uniform deployment, etc. are not discussed much.
- Most routing protocols assumed BS as stationary. Use of multiple BS is also not taken into consideration.
- Novel approaches should be addressed for mobility.
- The relation between heterogeneity and routing is not addressed.
- Most researchers have considered performance metrics such as intra cluster distance, power consumption,
- Network life, packet delivery ratio and delay. The metrics such as reliability, load balancing, computational
- Conversion of simulated experiments into real-world applications is a big challenge for future.

5 CONCLUSION

Various Optimization techniques like Fuzzy Logic, ACO, FA, PSO, GA were used for optimization in WSN. The parameters mentioned in Table-I have been considered for the comparison of these optimization techniques. In this study, we have surveyed some challenges of routing in WSN. Few optimization methods are discussed here to suggest the best technique for a particular application. Though many optimization techniques are available, still there are plenty of open issues and challenges for pursuance of optimal solution in a Wireless Sensor Network. Most of these algorithms are still being improved by the researchers. The tabulated results given in this article may help researchers working in this field. This paper gives insight about some challenges also, which are not explored yet. This article will probably guide new researchers to fill the gap in the area of Wireless Sensor Network.

Table 1.

Parameters	ACO	PSO	FA	GA	Fuzzy Logic
Representation	Undirected Graph	Dimensions for vector position and speed	Distance based attraction	Random binary number	Multidimensional vector values between 0 and 1
Operators	Pheromone updates and trial evaporation	Evaluation and update Current state	Attraction, intensity of light	Selection, crossover, mutation	Fuzzy aggregation operator, Ordered Weighted Averaging
Control Parameters	Magnitude of ants, iteration, pheromone decay rate	Position, magnitude of pheromone, Range, weight, iterations	Force of attraction, light intensity	Population size, selection procedure, crossover and mutation probability, magnitude of chromosomes	Fuzzy Membership Function
Node Deployment	Placed in distributed manner, used in dynamic applications	Random, Centralized nodes deployment	Random manner	Both	Distributed and random both
Clustering and routing	Explore closest route between source and destination for better transmission	Find optimal path by choosing high energy nodes as CH in every round	Choose cluster head on distance basis	Number of predefined clusters are chosen to reduce communication distance	Selects CH on basis of energy, concentration and centrality etc.
Advantages	1.Can be used in dynamic applications like travelling salesman problem	1. It finds best positioned nodes for CH. 2. Inherently continuous, 3. no overlapping and mutation calculation	Used in optimization with multi objective functions	1. Solve complex problems where parallel operations are required 2. Discrete in nature	1. Ideal for problems with imprecise and vague data 2. Can Model nonlinear problems of arbitrary complexity
Disadvantages	1. Only local search 2. More energy Consumption for more number of paths	1. Not suitable for distributed paradigm 2. Suitable for coordinate system only	Suitable for nodes which are deployed randomly.	Suited for arbitrarily placed sensor nodes.	1.The results are perceived based on assumption, 2. not accurate always

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