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MINIMUM ENERGY BROADCASTING PROBLEM IN WIRELESS SENSOR NETWORK: A REVIEW

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ABSTRACT

Construction of MEB tree is one of the emerging problem in WSN which have the tendency of keeping the lifetime of the network alive. This minimum energy broadcasting tree has been constructed previously with the use of exact algorithms and some heuristic algorithms for minimum energy consumption. Later after bio inspired algorithms comes into lime light for solving combinatorial optimization problems MEB grasps a number of researchers for solving it. This part of interest leads the researchers to produce many algorithms for solving MEB along with hybrid models for efficient local search procedure. In this paper a survey of MEB solved methods using generic solutions and bio-inspired algorithms are provided. Literature survey based on evolutionary algorithms provides, author, title of the paper, year of publication, issues described, constraints considered, mapping of MEB with the proposed method, algorithm used for solving MEB, modifications taken over original algorithm, need for the modification, performance measures, parameters used, algorithms compared with the proposed method are provided. Along with this some of the papers holds advantages and disadvantages of the proposed from this Thesis author's point of view.

Key words: Evolutionary Algorithms, Minimum Energy Broadcasting, Wireless Sensor Network.

1. INTRODUCTION

WSN is a special kind of ad-hoc network which is used to manipulate a wireless infrastructure (figure 1). This special kind of ad-hoc network is used to observe and respond to a phenomenon in natural environment. This infrastructure can communicate with itself for data transmission. This type of network is widely used in multidisciplinary stream for efficient monitoring and thus reduces the human resources. Some of the popular domains are described below Military applications: WSN in military serves as an artificial intelligent network. It monitors battlefield, for communication purposes, for controlling process, reconnaissance and for targeting the systems.

1)Transportation: many of the transportation are now of selfless drivers. In this stream, the sensors collect the

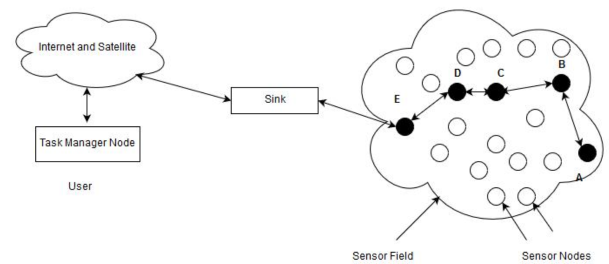

Figure 1: Overview of WSN

Information from all the sides of a vehicle and report it to the sink node for decision making.
2) Health applications: One another major stream which holds the contribution of WSN is in health applications. These applications include patient physical and conditional monitoring, medicine administration in drug manufacturing factories, an interface for disabled people [51-53].
3) Internet of Things (IoT): Yet another automated approach in the fast feed of computation. The sensors in this disciplinary monitors the environments and alert the user if there any precaution is mentioned in the system. Some of the examples includes water level monitoring in water tanks, automated washing machines and much more.
4) Environmental Sensing: For the contribution of earth science research WSN has been termed as Environmental Sensor Networks. This environmental sensor network monitors the changes in volcanoes, forests, seas, etc.
5) Agricultural sector: With the combined approach of data mining along WSN maintenance of field crops, enhancement of future crop cultivation has become an automated process with the help of WSN. Automation of irrigation in this field made a phenomenal change in minimal water consumption.
These significances made researchers to work in WSN domain where more utilization of computation increased with reduced man power on the other side.

1.1 Evolution of WSN

Evolution of WSN to this new era has been started in the year 1950 by US military which was named as Sound Surveillance System (SOSUS) for detecting submarines. This is the first ever wireless network based application of that decade. This network used hydrophones and acoustic sensors. This technology is still in use for monitoring the activities of volcanoes under oceans. In late 1960's and early 1970's based on the huge investment on developing wireless networks for monitor purposes in different aspects, DARPA initiated Distributed Sensor Network (DSN) in 1980 [1]. In late 1980's some other universities united together with DARPA to address all the issues arise while implementing WSN and finally WSN settled in the home of academia and civilian scientific research. In recent decades, the use of WSN by government increases in enormous amount which includes air population tracking, forest fire detection, prevention from natural calamities. From commercial point of view IBM and Bell labs initiated in building industrial based products such as power distribution, water waste management, etc. Evolution of WSN technology has been majorly contributed by academia and other industries. In 1993, Wireless Integrated Network Sensors has been contributed by academia. Later in the year 1999 PicoRadio has been developed. In the year 2001 and 2002 NASA Sensor Labs and ZigBee Alliance has been initiated. Later in 2002 Embedded Network Sensing centre has been developed. Apart from the basic components in a sensor, there are some other components also emerged in these many years. Micro electro mechanical systems (MEMS) a new sensor type has been emerged in the last decade. Components inside MEMS includes gyroscopes, accelerometers, magnetometers, pressure sensors, pyro electric effect sensors, acoustic sensors. Later CMOS-based sensors have been developed which includes some other new range of accessibilities. Those sensors sense the temperature, humidity, capacitive proximity, chemical composition by themselves without a third-party command. This sensor has been widely used in environmental situation where dew plays critical role on it. LED sensors are yet another new approach in sensor design which includes ambient light sensing, proximity sensing and chemical composition.

1.2 Issues in WSN

The recent technologies in WSN provides more precise results even in uneven situations or climates. But there exist some performance issues in WSN which degrades the design and robustness of WSN

1.2.1 Issues on Hardware and Operating System in WSN

WSN consists of thousands of sensor nodes in a single network for efficient tracking or monitoring of temporal changes in the given phenomena (figure 2). A sensor node consists of mote which holds all the components to process the sensed data by sensor. Motes are commonly called as Smart Dust.

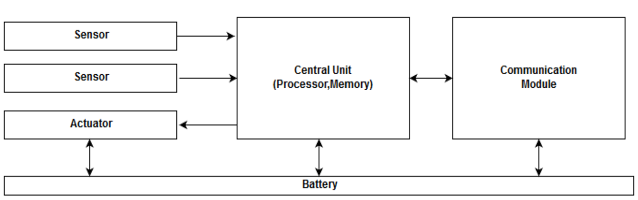

Figure 2: Architeture of Sensor Node

There are some constraints exist for using the sensor nodes in WSN. And those includes [2]

- The radio range is limited in sensor nodes. This range plays a major role to process the data to sink node. A strong and high radio range should be ensured in order to make a reliable network and for collecting the data from monitored environment.
- The use of memory chips in side sensor nodes are supposed to be non-volatile. For a particular instance if the node fails to communicate in a network, the monitored data are supposed to be stored in mote for further accessing. The memory chip should be inexpensive preferably.
- Power/ Energy consumption plays yet another critical role in hardware design. On using high energy consumption for data transfer or for monitoring let the battery power to drain sooner which lead failure of sensor node.
- CPU processing in mote is another issue in hardware issue. Since the sensor node is of power restricted the sensed data is supposed to be processed, manipulated, cleaned and given to the sink node of what it is needed from the monitored environment. If all monitored data are processed to sink node, the network might face bottleneck problem.
- The operating system in microcontroller are supposed to be application specific which processes only the needed data from raw collected data for efficient data transfer with reduced energy consumption.
- Since moto cannot be charged due to low cost budgeted sensor nodes, the OS in microcontroller should be designed in such a way to process all the data with respect to energy consumption.

Hardware and software issues are the one which are supposed to be handled at first since that plays a major role in WSN.

1.2.2 Issues in Medium Access Scheme

In WSN high energy is consumed by sensor nodes while transmitting the collected data to sink node either directly or via multi-hop manner. MAC protocols are used in WSN for controlling radio signal in sensor nodes. In designing the MAC protocol in order to utilize minimum energy consumption can highly increase the lifetime of network.

Some of the design issues [3-7] in MAC protocols are

- MAC layer gives a control strategy to the transceivers regarding on and Off of radio for efficient energy saving scheme in sensor nodes. In case of continuous on the energy will be consumed for continuous sensing of radio signals from all nodes which might reduce lifetime of network.
- The design of MAC protocol should consist of collision avoidant from other neighbor nodes, over emitting of radio signals, overhearing of other node signals and avoidance of idle listening.
- Design of MAC protocols should hold the property of Adaptability, scalability and decentralized in nature. Adaptability is property of enhancing the protocol to handle the communication if the network size gets increased.

- Low latency in WSN is achieved on tuning MAC protocols. This shows the consistency of a network. High throughput will be in need sometimes when the network cannot be stable in some environmental regions.
- On processing collected data towards sink nodes sometimes multi-hop communication is preferable. MAC protocols should be aware of the route it chooses for transmission of data. This process is called as Information Asymmetry.

These issues in MAC protocols of WSN can highly affect the performance of WSN over a practical situation. Addressing these issues many researchers worked on this theme for achieving betterment of WSN lifetime.

1.2.3 Issues in Network Layer

Routing is the process of sending data from one place to another. In WSN this routing plays a critical role in sending data from sensor nodes to sink node. Routing in WSN is a challenging issue since the transmission of data relies on other nodes in case of multi-hop communication. Before routing process, the respective node should be aware of the awaken nodes in the network. Challenges in network layer of WSN are listed below. Energy efficient paths are more preferable in WSN for data transfer to avoid the failure of network due to lifetime failure. A number of different methods are required to determine more efficient routes for transmission of data from sensor node to sink node.

- Designing more than one optimal path is another strategy that the network layer should handle in order to handle if the primary path fails to transmit the data.
- Fault tolerance in case of path collision or path damage while transmitting data is preferable in WSN. Routing protocols in network layer should have the tendency of choosing another route if the given route by the protocol gets collided or damage during runtime of data transmission.
- On handling routing and data management by sensor nodes, the burden of sink node can be reduced since WSN is a data centric network. All the data are collected by the sink node processed. In handling routing process by a reliable platform is needed for WSN.
- Handling heterogeneous nodes avoids the latency in WSN. When each node seems to be different either by its communication or computation, a predefined method handling is preferable by routing protocols to handle these scenarios.

Some of the routing protocols in WSN are LEECH, TEAN, GEAR, SAR, SPIN, etc.

1.2.4 Security Issues in WSN

A secure network should possess the capability of protecting message from a hacker or attacker. Confidentiality is the process of avoiding an attacker from being intruded into the network for stealing a message. Integrity is the process of making a secure way to transmit the data without any damage to the message. Freshness of data refers that the user or network receives an information which is recently sent with low latency. In order to fulfill all these capabilities WSN provides layer based approach for improving robustness of WSN.

1) Application Layer: in application layer the reliability of data is being handled. In [8] author proposed a scheme for cluster based network to ensure the reliability of network with the help of resilient aggregation. Since this is applicable for cluster based networks there exist a practical constraint in it. This actually acts as a aggregation node in which where all the data from other sensor nodes gets cumulated here and further process will be made. So apparently, this node should be in a range of where it should be reached by all other nodes. The cumulated data validity can be proved by using cryptographic techniques by cluster heads.

2) Network Layer: Property of Network layer in WSN is to ensure the message transmission from node to node, messages from cluster head to nodes, message transfer between cluster heads, cluster heads to sink nodes and vice versa.

3) Data link Layer: data link layer possesses the potentiality of error detection, error correction, encoding and decoding of data. Jamming and DoS attacks are more frequent in data link layer. Researcher worked on this level encryption technique for secure processing of data.In [9] author proposed LMAC which holds anti-jamming properties which seems to be a better proposal when this layer is concerned.

4) Physical Layer: Use of physical properties for transmitting data from one node to other is encountered at this layer. This layer holds the media to propagate the messages to the concern node or cluster head or to sink node. Data rate at which the data getting transmitted, strength of the signal that the node possesses, and the type of frequency that the node holds can be retrieved at this level.

Security issues in WSN are concerned with the attacks of the above listed layer. On attacking these layers, attackers or hackers can breach into the network

1.2.5 Issues in Node Deployment

Deployment of sensors refers to the actual location of placement of sensors in real world scenarios. Deployment of sensors can be done either by planting it one after the other or it can be randomly plotted by dropping it from plane. Issues on deploying sensor nodes are as follows:

- In case of node death either by energy depletion caused by frequent transmission or monitoring of data or due to short circuit which results in improper observation results.
- Random deployment of sensor nodes leads to network congestion or collision of data between nodes. Sometimes repeated observations of same location can be made due to neighborhood conflict of sensors.
- Due to environmental challenges, sometimes neighbor sensor nodes also cannot be able to communicate with each other. This may be due to bad weather conditions, formation of mist, etc. These issues are in need to be addressed before deploying sensors in real world scenarios.

There are two different radio range will be available in each and every node in the network. One will be called as sensing range and the other one as coverage range. This coverage range will be used to monitor real world locations and sensing range is used to transmit the data from one node to another. Some of the nodes due to bad weather conditions the gathered information will not be completely delivered to sink nodes.

Self-regulation of sensor nodes is one possible method for random deployment of sensor nodes in WSN.

1.2.6 Energy Consumption in WSN

In WSN, one of the most important factor is energy consumption since the lifetime of the whole network depends on the restricted battery power. Since power plays a major role in WSN due to its limited power for sensor nodes, the design of network in terms of routing of data transmission are supposed to be optimized. Optimizing energy consumption become a tedious task in WSN since optimizing routing not only depends on the energy of the sensor node but also on the lifetime of the network. The basics of energy requirements by sensor nodes in WSN are categorized into four subsystems.

1) Computing Subsystem: Microprocessors in mote uses power from battery for controlling the sensors and protocols used in sensors. For the purpose of power management these microprocessors in motes operated in different modes. When this processor operates at different modes, energy consumption by these processors varies and this should be considered when solving energy consumption issue.

2) Communication subsystem: a short-range radio is usually used for the communication purpose between nodes in WSN. This also consumes a considerable amount of battery power for communication purpose. It's advisable to shut down the antenna instead of making it to be in idle mode since idle mode also consumes power.

3) Sensing subsystem: a sensing system consists of considerable number of sensors and actuators which are used to communicate with outside environment. In this subsystem by using low power consumption components can be used to reduce energy consumption.

Power supply subsystem: This is the actual power supply system which supplies the power to all other components in sensor node. For efficient handling of power supply subsystem, it should be turned off when there is no use of it. This can be done by automating the scenario.

2. RELATED WORKS

2.1 Generic Solutions

In the year 2000 and 2002 [10, 11] author Jeffrey E. Wieselthier, et al proposed a method for efficient handling multicast/ broadcasting routing using Broadcast Incremental Power (BIP) algorithm. The design process of proposed BIP algorithm includes efficient handling of data transmission by choosing which nodes should be used for data transmission and the power level that they use for transmission of data.

In year 2001,J.E. Wieselthier, et al [15] proposed a new set of algorithms for handling multicast routing in ad-hoc network. The proposed algorithms were evaluated under several modes by selecting appropriate relay nodes based on their transmission level for message transfer. Egecioglu, et al [17] proposed an approximation algorithm for solving multicast energy consumption by assuming that each node in the network is possible to communicate with all other nodes.

In year 2003, author I.Kang, et al [14] proposed an algorithm namely Greedy Perimeter Broadcast Efficiency for efficient allocation of power based on the density of nodes distributed. It enables the choice of choosing multiple nodes for data transmission at same time which on which each node uses minimum amount of power. This leads the nodes to utilize less power on each transmission and use residual power for further processes. This paper addressed to enhance the lifetime of sensor nodes.

In year 2004, D. Li, et al [23] proposed three different broadcast routing algorithms for solving asymmetric wireless ad-hoc network with the assumption that each node in the network holds a fixed amount of power. Among these three-proposed approximation algorithms one has solving ratio of $1+2\ln(n-1)$.

In year 2006, W. Liang [20] proposed another algorithm for solving multicast tree problem in WSN which is based on approximation. This algorithm is proposed for solving symmetric wireless ad-hoc network where the transmission power for and to the node will be same irrespective of the environmental conditions. Performance of this algorithm solves MEB with minimal time complexity from the algorithms given above with $4\ln_k$.

In year 2007, D. Li, et al [24] proposed three different multicast routing algorithms for solving asymmetric wireless ad-hoc network with the assumption that each node in the network holds a fixed amount of power.

In 2010, P. Kamboj, et al [22] proposed an energy efficient routing protocol for Mobile Ad-hoc Networks with minimum control overhead during data transfer. In 2011, D. Li, et al [21] proposed approximation algorithms for solving multicast energy routing problem in WSN.

2.2 Evolutionary Algorithm Based Solution Models

The exact methods for solving MEB problem seems to be a time-consuming process in which all the possible solutions are supposed to be calculated and finding best solution among them. After the emergence of Bio-Inspired Algorithms for solving NP-hard problems MEB instances grasped many researchers interest for solving MEB using Bio-Inspired Algorithms. Some of the algorithms which are used for solving MEB are stated below.

2.2.1 Solution Models Using Genetic Algorithm

In the year 2008, Steffen Wolf, et al [26] proposed an Evolutionary Local Search for the MEB Problem which holds the objective of finding a broadcast scheme for MEB instance for efficient data transfer in wireless ad-hoc network. Evolutionary algorithm used in this paper is Genetic Algorithm. The proposed algorithm is mapped into the problem as follows: Each gene is represented as a node in WSN. Each solution represents a complete solution for message transfer form sensor node to sink node or vice versa.

The modifications handled in this proposed local search mechanisms are: two different kind of solution representation combined together and used with this GA namely tree representation and range assignment representation for each node. Tree representation is used for retrieving receive range of node and assignment range representation is used to calculate the maximum possible range it can communicate with another node. r-shrink is another procedure used in this algorithm. The need for this modification: r-shrink is used for efficient local search in GA. This proposed algorithm is compared with the existing algorithm for efficient data transmission like Nested Partitioning, Iterated local optimization, broadcast incremental power-r shrink. Performance factors that are used to compare the proposed algorithm with existing algorithms are excess rate, number of times minimal solutions found, time taken for achieving the minimum value. In the year 2011, Singh,et al, [46] proposed a paper titled “Hybrid GA for the MEB problem in wireless ad hoc networks”. The objective of proposed algorithm is to minimize energy consumption by WSN. The proposed method comprises of one evolutionary algorithm named GA and 2 other local search heuristic algorithms namely 1 shrink and 2-shrink local search. The proposed algorithm is mapped with the given problem as follows: Permutation encoding is used for solution initialization. The solution is represented in an array format which comprises of the sensor nodes of WSN. During permutation encoding not all solutions starts with source node since it’s of random in nature. Cyclic crossover is used for efficient adaptation of GA towards MEB problem. A decoder of arborescence is used for fixing the first node as source node. Proposed algorithm performance has been compared with Evolutionary local search, iterative local search and Nested partitioning. Performance measures includes excess rate, number of times minimal solutions found, time taken for achieving the minimum value.

2.2.2 Solution Models Using Multi-Objective Evolutionary Algorithm

In the year 2010, Konstantinidis, Andreas, et al [43] presented a paper titled a multi-objective evolutionary algorithm for the deployment and power assignment problem in wireless sensor networks. Deployment and power assignment problem (DPAP) for minimizing energy consumption is the objective presented in this paper. A multi objective evolutionary algorithm based on decomposition is proposed in this paper which solve more deployment and power consumption issues in WSN. The problem is represented and solved using proposed algorithm as follows: The DPAP is decomposed into a set of sub problems where each sub problem is considered as an individual to solve using evolutionary algorithm. A new M-tournament selection operator is used for choosing the parents to participate in crossover. It comprises of mutation restriction over a normal selection tournament operator. Window crossover is designed for efficient handling over sub problems of DPAP. An adaptive mutation operator also proposed for mutation purpose which induce global search capability in evolutionary algorithm. The modification over existing selection operators and crossover operators are due to adaptability of evolutionary algorithm on DPAP and for efficient convergence towards global optimal solution. Proposed multi objective based evolutionary algorithm is solved and the results are compared against NSGA-II. Performance metrics taken into account are as follows: Δ metric, computational time and non-dominated solutions.

In the year 2011, Enan A. Khalil, et al [32]proposed a paper named Energy-aware evolutionary routing protocol for dynamic clustering of wireless sensor networks for achieving network stability, Optimal energy consumption with long lasting lifetime of the network. Energy aware Evolutionary routing protocol is the protocol defined in this proposed methodology to carry out minimum energy consumption process. The proposed protocol is mapped with the existing problem as follows: Each node in EA will be considered as a node in sensor network. 0 and 1 are used to represent the cluster head node. If 1 then that particular node has been elected as cluster head and if 0 it is not.EA is used to choose the cluster head from the available nodes using centralized evolutionary algorithm and this process is carried out in Sink node. For identifying the stability period of network, it runs the algorithm until the first node dies in the network. And to check long lasting (longevity) the proposed algorithm runs until last node dies. The modification is carried out is for enhancing the stability of the network if one node fails by acting as a cluster head. Proposed protocol is compared with the results of existing protocols such as LEACH, stable election protocol, hierarchical clustering-algorithm-based genetic algorithm. Performance measures used for evaluation purpose are stability period, network lifetime, energy consumption, throughput and computational time. Soumyadip Sengupta, et al [34] in the year 2012 proposed a paper on Energy-Efficient Differentiated Coverage of Dynamic Objects using an Improved Evolutionary Multi-objective optimization Algorithm with Fuzzy-Dominance. The proposal composed of the objectives such as tracking of sensor nodes which are dynamic in nature with static coverage range. The given algorithm is imposed with the constraint, minimum energy consumption of data transfer for dynamic nodes. Evolutionary algorithm used in this proposed algorithm is Multi objective evolutionary algorithm. The algorithm has been mapped with the problem is as follows: Each gene in a chromosome is represented as a node and a complete chromosome is considered as a complete path for routing. The phases carried out in the proposed algorithm are, an efficient energy optimization technique namely energy efficient senor manager. A new concept for tracking all kind of information with a single ping. A dynamic differentiated coverage procedure is incorporated for efficient tracking of dynamic nodes. The phases are proposed for tracking dynamic nodes sensor manager is proposed. Tracking location of a node equals the same energy of retrieving other information from that node. Parameters used in the proposed algorithm for efficient computation of MEB are Radius of sensing, confidence, range of communication, node maintenance energy, node transmission energy, node reception energy, node activation energy and non-connectivity penalty parameter. Performance measures includes rate of energy

consumption, total number of non-dominated solutions, and distribution of non-dominant solutions in the populations.
In the year 2013, S Sengupta, et al [38] proposed algorithm are 1. Minimum number of sensor nodes used for deployment in order to reduce the deployment cost 2. Minimum power consumption by deployed nodes for improving the lifetime of the node 3. Enhance the lifetime of WSN 4. Maximum coverage by deployed nodes for reducing number of nodes. Constraint followed in the proposed methodology is that there should be at least one path for communication between sink node and sensor node. The algorithm is mapped with the problem as follows: Each node is represented as a parameter in a solution and a whole solution is represented as a complete individual. Proposed algorithm is compared with existing algorithms like Particle swarm optimization, Comprehensive learning PSO, Differential evolution, NSGA-II, JADE. Parameters taken for consideration includes radius of sensing, confidence, range of communication, node maintenance energy, node transmission energy, node reception energy, node activation energy and non-connectivity penalty parameter. Performance measures used to evaluate and compare the proposed algorithm are coverage, spacing metric, minimum energy, minimum lifetime, maximum lifetime.
In the year 2014, J. Lu, et al [39] proposed a new optimization algorithm is proposed in this paper namely fuzzy random and multi objective optimization (FRMOO) algorithm for efficient routing in WSN. Proposed algorithm is mapped with the problem in WSN as follows: The random variables of fuzzy algorithm uses the randomness for initializing the link delay, reliability and node residual energy. The proposed algorithm uses fuzzy random expected value for building a routing model. For obtaining optimal solution from the available feasible solutions the fuzzy random simulation has been made. Proposed algorithm performance has been compared with the existing technique called RMOO (random multi objective optimization). Performance metrics that are used for evaluation of proposed algorithm includes average delay, average reliability, average jitter, average interference, average energy, average residual energy. This paper holds a number of objectives it fails in one perspective. A multipath solution is given but the optimal path used for the simulation to generate the results is not mentioned.

2.2.3 Solutions Models Using Memetic Algorithm

In the year 2013, Arivudainambi, D, et al [47] proposed a methodology uses MA and r-shrink procedure. The proposed algorithm is mapped with the MEB problem as follows: Permutation encoding is used for solution initialization. The solution is represented in an array format which comprises of the sensor nodes of WSN. During permutation encoding not all solutions starts with source node since it's of random in nature. Cycle crossover and swap mutation is used for solution generation for participating in next iteration. The proposed algorithm is compared with Evolutionary local search, iterative local search and Nested partitioning. Performance measures includes excess rate, number of times minimal solutions found, and time taken for achieving the minimum value. In the year 2009, Jiang, Joe-Air, et al. [49] proposed a paper entitled "CoCMA: Energy-Efficient coverage control in cluster-based WSN using a MA". The objective of proposed algorithm is to design an energy efficient coverage control with evolutionary memetic algorithm. The algorithm has been mapped with MEB problem as follows: Binary representation of solutions is used in the proposed algorithm. When 0 is used that particular sensor, node is inactivated and it is not among one of the transmission node for data transfer and vice versa for 1.Tournament selection strategy is used in for choosing the parents to participate in crossover process. For wake-up procedure TDMA is used. Proposed algorithm is compared against LEACH, LEACH-Coverage-U, PEGASIS and EGDG in terms of Convergence time, network lifetime prolongation and coverage preservation.

2.2.4 Solutions Models Using Ant Colony Optimization

In year 2002, Das, Arindam K., et al[45] proposed a paper titled "The MPB problem in wireless networks: an ACO system approach" Minimizing power consumption in WSN. The proposed method uses Ant colony system for solving MEB problem in WSN. Using ant colony system, the broadcast tree is built in such a way by considering each node as a vertex in ACS. Now when the ant moves across the graph through the edges to the food source that path is considered as broadcasting path and the vertices that it chosen for travelling is considered as the node by which the data can be transferred. Proposed algorithm has been evaluated and compared with the existing algorithms like BIP and BIP sweep. The performance measure used to evaluate the proposed algorithm is mean tree power. In the year 2012, Hugo Hernandez, et al [33] proposed a paper on Distributed ACO for MEB in WSN with realistic antennas. The objective of this paper is to minimize the energy consumption in distributed environment. The constraint imposed with the objective is to minimize the energy consumption with respect to number of newly added nodes (i.e. the number of newly added nodes should not expand the usage of energy consumption by which we can achieve improved lifetime network). The proposed algorithm is a hybrid of two algorithms namely Ant colony optimization and BIP. The algorithm is mapped with the problem as follows: each node in ACO is considered a sensor node in WSN. Modifications in the proposed methodology: Instead considering only increment of transmission power level in the proposed work newly added node power consumption power level were considered in BIP greedy function. This modification has been carried out for adapting the algorithm in distributed environment. The proposed algorithm is compared with existing BIP+ and Centralized ACO. The performance measures which are considered while computing and comparing simulation result are best, Average, Deviation rate, Number of iterations. In the year 2011, Hugo Hernández, et al [31] Minimum energy broadcasting in wireless sensor networks: Ant colony optimization approach for antenna mode. Objective of this paper includes adapting realistic antenna for MEB problem in wireless ad-hoc network. The constraint followed in this proposed methodology is to minimize energy consumption with respect to defined antenna range. Ant colony optimization is the metaheuristic evolutionary algorithm used in this proposed methodology. A complete solution from source to destination is defined as a foraging path from nest to food source in ACO. Modifications done with the existing ACO includes: A realistic antenna model which has fined set of transmission range is applied for depicting real world scenario. The need for the proposed procedures are as follows: SWEEP procedure and variable neighbourhood descent algorithm are used for local search. SWEEP procedure is used to identify the nodes which reduce transmission power level of network and resolve it. Variable Neighbourhood Descent algorithm is further used to improve the quality of solution. This comprises of r-shrink procedure in it. The proposed methodology has been compared with the existing algorithms like Broadcast Incremental Power (BIP) and BIP-Variable Neighbourhood Descent algorithm (BIP-VND). The parameters carried out in the whole process is rmax (defines the rate of shrink used in r-shrink procedure. Performance measures used to carry out comparison process includes deviation rate, Best energy consumption, average energy consumption and computational time. In the year 2006, T. Camilo, et al [27] proposed a metaheuristic bio inspired algorithm used in this proposed work is Ant colony optimization. The problem has been mapped with the proposed algorithm as follows: Each sensor node is represented as a node in ACO. The source and sink nodes are fixed. The problem is to find out the intermediate nodes that are used to transmit data. The proposed algorithm alters conventional ACO algorithm as follows: Changes are made while updating pheromone trail. 2 types of ants are used in this algorithm. The forward ant chooses which node to participate in the solution. The backward ant is used to update the pheromone trail. In this algorithm both the path length and energy consumed to transmit data are considered while updating pheromone trial. The change made in order to achieve both energy efficiency by the network and lifetime for the network. For performance comparison, this proposed algorithm has been compared with the existing algorithms like Basic ABR, Improved ABR, Energy-efficient ABR. Performance of the proposed algorithm has been qualitied with the performance measures such as average energy consumed by network, minimum energy, standard deviation and energy efficiency by the network In the year 2010, J. Yang, et al [29] proposed a MPR Based on Clustering and ACO for WSN. The objective is to provide a multipath routing scheme between sources and sink with MEC and improved network lifetime. Multipath is one such scenario where there will be more than one path available in all the nodes to reach the sink node. This multipath scheme will be effective when the highly preferable path has been collided or some interruption occurs which cannot further be available for remission usage. There are three different phases has been proposed for secure and effective data transmission in this proposed work. The three phases are 1. Dynamic clustering 2. Multipath construction 3. Data transmission. The metaheuristic algorithm used in this proposed work is Ant colony optimization for multipath construction. Proposed algorithm has been mapped with the problem as follows: Each vertex in ACO is considered as a cluster head in sensor node. A complete path driven by ACO is considered as a path from sink to source or vice versa. The modification over existing ACO algorithm has been done in probability calculation for choosing next node in order to participate in the data dissemination process. Modification over existing ACO was made for balancing the load in the path and for maximized network lifetime. The proposed algorithm has been compared with existing algorithms such as Energy-Efficient Multipath Routing, Multipath Routing Based on Ant Colony System, TEEN: A Routing Protocol. Parameters used for simulation are packet size, broadcasting packet size, location coordinates of sink node, event radius for communication, for evaluation purpose performance metrics used for comparison are average energy consumed by network, minimum energy, standard deviation and energy efficiency by the network. In the year 2009, S. Okdem, et al [28] proposed a paper as “Routing in wireless sensor networks using an ant colony optimization (ACO) router chip”. This paper holds the real-time implementation of ACO in a router chip in order to implement the use of ACO in real world applications. The objective is to achieve reliable communication which handles only the length of the path. Ant colony optimization algorithm which is one of the major discrete cum probabilistic algorithm in Evolutionary computing is used here as base algorithm. The problem has been mapped with the proposed algorithm as follows: Each node in the path of transmission is considered as a vertex in ACO. The choice of next node to be transmitted is based on the newly designed probabilistic decision rule. The modifications in the proposed algorithm comprises of change in probability calculation in ACO. Performance measure used in this algorithm for evaluation purpose is response time. Advantages of this algorithm over other evolutionary algorithm is that the packets that are to be forwarded to the sink nodes are not needed to be retained by the transmission nodes which further reduces the packet head and thus saving energy. Cons: While pheromone trail update only the distance between the nodes are considered and energy levels of nodes are suppressed which reduces the lifetime of WSN. M. Sousa, et al [35] in 2012, proposed a Cognitive LF-ant: a new protocol for healthcare WSN in order to provide an inter cluster based routing protocol between sink and sensor node. ACO algorithm is altered with the help of Saharan Desert ant behaviour which mimics a safety based inter cluster routing mechanism. The modifications in calculating the change in pheromone rate and probability calculation. This modification helps to form cluster when cognitive LF-Ant scheme is combined with ACO. For scheduling based on the priority of emergence a intra cluster emergency reporting protocol has been designed. An inter cluster cooperative modulation has been decided for reducing the packet loss rate, etc. performance measures that are used to compare the existing algorithm with the proposed are as follows: Average delay time, Average SNR, packet loss rate. E. Amiri, et al [40] in the year 2014 proposed a paper titled EER in WSN based on Fuzzy ACO. The objective is to minimize the energy consumption by WSN and thus enhance the lifetime of network. ACO algorithm is used in this paper for solving energy based routing along with FL. Proposed algorithm works as follows: Forward ants build the solution for data transmission based on the pheromone table. Backward ants are used to update the pheromone table based on the path that are chosen on that iteration. This updated level of pheromone will be used in next generation for choosing the best nodes. Modifications of proposed algorithm over conventional ACO are made in updating the change in pheromone trail. Fuzzy rule is incorporated for efficient choice of next node participation in data transmission. Proposed algorithm is compared with the existing Ad-hoc On demand Distance Vector (AODV).

2.2.5 Solutions Models Using PSO

M. Liu, et al [36] in the year 2012 proposed an agent-assisted QoS-based routing algorithm for WSN. The objective of proposed algorithm is to improve the performance of network by improving the QoS based services such as delay, bandwidth and packet loss. A wide spread evolutionary algorithm is used for efficient routing called as Particle swarm optimization. This PSO mimics the foraging behaviour of birds. This algorithm works with personal best and global best concept. Two different parameters are used in this particle swarm optimization namely cognitive and social parameter. New intelligent software agent is imposed to monitor the topology of network and nodes transition state. The proposed particle swarm optimization based routing is mapped with the existing problem as follows: two different types of agents are used namely Forward and backward agent. Forward agent is used to give options to find next node to be transmitted. Backward agent actually travels route which is chosen by the forward agent. Particle swarm optimization has been carried out with some modifications for maintaining network routing and maintenance. In the year 2011, Molina, et al [42] proposed a paper titled Location discovery in WSN using metaheuristics. The objective is to provide an efficient procedure to mitigate distance estimation errors, which result in node positioning errors during location discovery. The proposed methodology uses three algorithms and simulates the problem to find which performs better and the algorithm includes SA, GA and PSO. Given problem is mapped with the algorithms are as follows: solution representation is in the form of location coordinates. Each solution consists of twice the length of number of sensor nodes. Each sensor nodes represented in the form of x and y coordinates. For GA ranking method is followed for choosing the parents and rephrasing the selection phase with elastic replacement. Sbx crossover is used in this proposed methodology. A set of 10 configurations are simulated and performance are measured. Performance measures includes minimum error obtained and average error obtained while locating the sensors for evaluation and comparison purposes with existing algorithm.

2.2.6 Other Evolutionary Algorithm based Solution Models

T. Hu, et al [30] proposed a new novel based algorithm is proposed in this paper named QELAR which is inspired from machine learning technique. WSN is mapped into machine learning process as follows: The current state of is defined as ‘s’ and the action to be taken for transmission to next state is defined as ‘a’ and the policy for transition is defined as π. For adaptation of machine learning technique to WSN, QELAR introduced Q-learning technique for balancing loads in the nodes in order to extend the lifetime of the network. A new learning based technology is imposed for achieving the adaptation capability of proposed protocol for dynamic network environment. The proposed algorithm is compared with Vector based Forwarding Protocol (VFP). The performance measures taken into account for comparison of existing with the proposed are delivery rate, latency, energy consumption, residual energy. M. Saleem, et al [37] in the year 2012 proposed a paper titled as “BeeSensor: an energy-efficient and scalable routing protocol for wireless sensor networks“ The objective is to provide an efficient routing protocol for path maintenance and multiple route discovery between sink and source node. the proposed methodology is inspired from the behavior of honey bees. The proposed algorithm consists of 4 important phases of bees. 1. Packer bees: it allocates the forager bees to packets which are received from upper layer. 2. Scout bees: scout bees are further divided into forward and backward scouts. The forward scout builds the path between sink and the source node. backward scout reports the fitness of given path. 3. Forager bees: it transmits the packets from source to destination in the defined path by scout bees. 4. Swarm: collection of foragers is called swarm. This swarm helps to get return back to its own source nodes with the help of embedded route in the payload. The proposed algorithm is compared with the existing algorithms like EEABR, FP-Ant, FF-Ant and SC-Ant and AODV. Performance measures taken into account for comparison and evaluation purpose includes loss ratio, control overhead, Packet delivery ratio, latency and energy efficiency and lifetime of network. In the year 2013, Hsiao, Ping-Che, Tsung-Che Chiang, and Li-Chen Fu [48] author proposed algorithm comprises of PSO and Intensified r-shrink procedure for efficient local search. The algorithm has been mapped with the problem as follows: Power degree encoding is used for solution reorientation. At the stage of acceleration (i.e. updating velocity of each particle in PSO). After acceleration process the solution comes to landing phase. During this phase the particles are divided into three different modules. No change in power degree, increase in power degree and decrease in power degree. For solution feasibility, intensified r-shrink procedure is carried out. For conversion of static to dynamic MEB the author proposed a new repairing scheme to avoid instability over the network. And a simple conditional incremental power heuristic function is imposed. The proposed algorithm is compared with Evolutionary local search, BIP, ACO and hybrid GA in terms of excess rate, number of times minimal solutions found, time taken for achieving the minimum value, average energy consumed by the population of a single cycle and standard deviation of an entire population. In the year 2016, Zeng, et al [41] proposed an improved harmony search based EER algorithm for WSN. The objective of proposed algorithm is to maximize the lifetime of network. Constraint followed in the proposed algorithm is to follow a restricted length of path. Conventional Harmony Search algorithm is used in this proposed methodology. The algorithm is mapped into the proposed algorithm as follows: A set of nodes are placed in an individual in harmony search and that set of node which connects from source to destination is called as a complete path for data transmission. Modifications taken place for adaptation of proposed method with existing problem included as follows: Initialization process of the random permuted solution has been replaced with harmony memory based initialization. An adaptive parameter is introduced for adapting the protocol with current scenario. Modifications carried out for faster convergence towards optimal solution.

3. CONCLUSION

In this paper a detailed literature survey on MEB problem and its solution methods are given. The section 2.1 describes the generic solutions represented for solving MEB instances in overall wireless domains are described in detail. Some of the solutions from exact methods produce better results but with high computational time. Then in section 2.2 evolutionary based solution instances for solving MEB are described in a detailed manner. The details emphasized includes mapping of MEB with Evolutionary algorithms, its modifications, need for modifications, performance measures that are encompassed with it for comparison purpose, etc.

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