
CHAPTER 2

LITERATURE SURVEY

Several methods have been developed to address the issues in WSN. A detailed survey was conducted on the existing algorithms for clustering, routing, security, and the different sources for energizing WSN batteries; some of the techniques are described below.

2.1 CLUSTERING

Clustering is one of the important methods for extending the network lifetime in WSNs, which groups sensor nodes into clusters. Cluster Heads (CH) are selected for each cluster, and CH selection plays a crucial role in a WSN. CHs must be chosen to minimize intra- and inter-cluster distance with less energy consumption. Usually, CH nodes handle long-distance communication, data aggregation, and processing; hence, they use more energy than regular nodes. Therefore, compared to other cluster nodes, CH uses more energy. Additionally, careful CH selection will increase the network lifetime. Figure 2.1 represents the clustering in WSN.

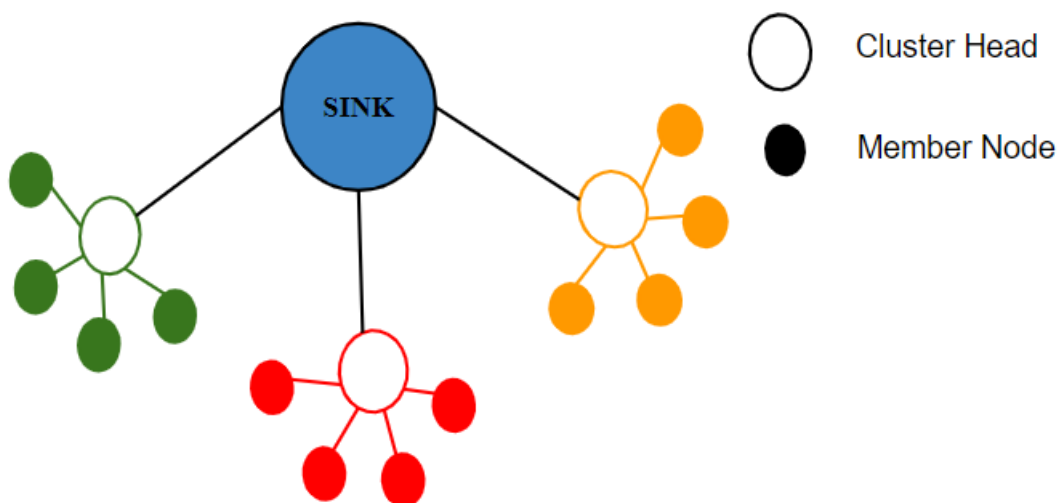


Figure 2.1 Clustering

Sudha. M and Sundararajan. J.,2017, surveyed different biologically inspired clustering algorithms in mobile WSN. Several optimization techniques are discussed

in this paper, in addition to the need for clustering. The paper also discusses various clustering attributes and the factors to consider while forming a cluster. Nigam, G.K., & Dabas, C. 2018., proposed a technique for energy efficiency in clustering based on LEACH and PSO. As a result of the deployment of sensor nodes, fitness is calculated for each node based on their average energy. Whenever the average energy of the cluster exceeds the energy of CH, the existing CH will be replaced with a new CH that is more efficient.

A Genetic Algorithm (GA) based method for minimizing energy consumption and increasing the network lifetime is introduced (Bayrakli, S., & Erdogan, S.Z. 2012). The algorithm is divided into two stages in which the starting stage is named as set up stage, where the numbers of clusters are formed and effective CHs are selected based on fitness value. The final stage is the steady state phase; here, the CH receives information from each node on a Time Division Multiple Access (TDMA) basis. Upon receiving the data from the CH, it is processed by the Base Station (BS) before being sent to the CH. After each iteration, the fitness of CH is evaluated and changed accordingly.

The use of Chicken Swarm Optimization (CSO) to reduce energy consumption and extend network lifetime is discussed by Osamy, W., et al. 2016. By designating a set of nodes as CH, the CSO-based clustering algorithm reduces the energy used in data transmission. Every node transmits the gathered data to the base station using TDMA. The authors also combine CSO and GA to lower energy usage and extend the network's life. Here, the energy consumption-based GA is used to choose the CH.

Pitchaimanickam et al. 2019, discussed optimal CH selection using Bacterial Foraging Optimization (BFO) and the Cuckoo Search Algorithm (CSA). Here, the levy flight feature of CSA modifies step size in the tumbling process of BFO for selecting optimal CH. Ant Colony Optimization (ACO) is utilized in WSN with a mobile sink (Wang, J., et al. 2016). Initially, the cluster is formed, and the node located at the centre is selected as CH. After each iteration, the distance between the node and the centre of the cluster is computed based on residual energy. Nodes

common to two clusters receive CH information, facilitating inter-cluster communication. New CH is selected only when the current CH residual energy falls below the threshold value.

Clustering using GA minimises energy consumption in WSN(Deshmukh, G., et al. 2016). Here, CH is located at the centre of the cluster and the centre of the network area over which the base station is located. After every iteration, the location of CH and the base station is changed. As a result, it reduces the communication costs.Dattatraya, K.N., & Rao, K.R. 2019, proposed a hybrid technique for increasing network lifetime and energy efficiency by selecting proper CH utilizing a hybrid method combining Glowworm Swarm Optimization and Fruit fly Algorithm. Fitness is calculated based on delay and distance. The fitness is arranged, and the five best fitness indices are selected. If the index is more significant than five, select the best CH using the fruit fly algorithm. Otherwise, glow worm swarm optimization is used to find CH.

A Cuckoo Search Algorithm is employed for clustering (Movahedi, Z., et al., 2019). This method is based on the reproductive strategy of cuckoos, where they lay eggs randomly in nests, and the nest with the most eggs is more likely to be passed on to the next generation. The algorithm is divided into two parts. The initial stage is the validation stage when the fitness of all nodes is determined by considering energy and distance. The nodes are organized in descending order according to their fitness rating, and 20% are chosen. The node with the highest fitness is selected as the CH. During the repetition step, if a new node with higher energy than the preceding node is discovered, it is substituted, and the process persists until the stopping requirements are satisfied.

Kalla, N., & Parwekar, P. 2018., presented clustering in WSN using the Social Group Optimization technique, which depicts the group of individual concepts. It comprises two phases: an improving phase and an acquiring phase. During the improvement phase, individuals gain knowledge from experts. During the acquisition phase, individuals engage randomly and develop problem-solving skills. The sensor

nodes communicate with other nodes and choose the node that uses less energy and is closest to the CH.

Karthick, P.T et al. 2019, used the Krill Herd Algorithm to select CH. Initially, the node's fitness is calculated based on energy, number of CH, intra-cluster distance and inter-cluster distance. Roulette wheel, Rank, and Tournament are some techniques that implement selection and cross-over operation, and finally, based on the mutation rate, CH is selected. During the KH algorithm, nodes are set up, and the cost of each node is computed. The node with the most advantageous position is chosen as the CH, and a cluster is then established with the optimal combination of nodes and the CH.

Famila, S., & Jawahar, A. 2019., enhanced the characteristics of Artificial Bee Colony (ABC) Optimization by using the Cauchy operator and Grenade explosion to choose the best CH, extending network life and lowering energy consumption in WSN. Madhusudhanan Baskaran et al. 2015, modifies Fire Fly (FF) Algorithm by allowing fireflies with high brightness to attract fireflies with less brightness for selecting proper CH to increase energy efficiency and reduce packet loss rate.

Sharawi, M., et al. 2015, utilize Grey Wolf Optimization (GWO) for effective cluster formation and CH selection. The cluster is initially established by considering the distance between two nodes and the energy needed for communication with neighbouring nodes. Clustering using the GWO method chooses Cluster Heads based on the remaining energy of each cluster. CH gets data from individual nodes and transmits it straight to the base station without involving any intermediary nodes.

Deepa, S., & Rekha, D. 2020., explained Bacterial Foraging Optimization (BFO) for efficient clustering. In this paper, BFO is used to eliminate nodes that consume high energy during transmission. The selection of CH is determined by its proximity to the base station and the amount of remaining energy. Clusters are created by assigning nodes to their corresponding Cluster Heads (CHs).

Table 2.1 Shows various algorithms implemented to form proper clusters for energy optimization in WSN

Table 2.1 Different algorithms for the formation of Clustering in WSN

| S. No | Author & Year | Optimization technique used | Parameter considered | Inference |
|-------|---------------------------------------------------------------------------------------|------------------------------------------------------|--------------------------------------------------------------------------|-----------------------------------------------------|
| 1. | Mechta, D., &Harous, S. (2017). | Fish Swarm Optimization | Network lifetime, energy usage, number of active nodes, and throughput. | Improves network lifetime by proper selection of CH |
| 2. | K.Thenmozhi, S.Udhaya, NVinothini, V.Nagaraju, 2019 | Lion Optimization | Residual energy, throughput | Proper cluster formation and CH selection |
| 3. | Rao, P.C., Banka, H., & Jana, P.K. (2015). | Gravitational Search Algorithm | Energy consumption, network lifetime, quantity of living nodes , latency | Forming cluster and CH selection |
| 4. | Chandirasekaran, D., &Jayabarathi, T. (2018). | Cat Swarm Optimization | Number of alive nodes, fitness | CH Selection |
| 5. | Mittal, N., Singh, U., Salgotra, R., & Sohi, B.S. (2017). | Boolean Spider Monkey Optimization | Energy consumption, number of alive nodes | Cluster formation |
| 6. | Osamy, W., El-sawy, A.A., & Salim, A. (2020). | Chicken Swarm Optimization and Genetic Algorithm | First node and half node death | Proper cluster formation and proper CH selection |
| 7. | Poonguzhali, P.K., Ananthamoorthy, N.P., Elhoseny, M., Yuan, X., & Kumari, S. (2019). | Ant Colony Optimization and Harmony Search Algorithm | delivery delay, network life time, energy consumption, throughput | CH selection |

| S. No | Author & Year | Optimization technique used | Parameter considered | Inference |
|-------|-----------------------------------------------|--------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|---------------------------------|
| 8. | Dattatraya, K.N., & Rao, K.R. (2019). | <i>Glowworm Optimization technique & Fruitfly optimization</i> | QoS, energy, delay | CH selection |
| 9. | B.Pitchaimanickam, G.Murugaboopathi, 2019 | Bacteria Foraging Optimization & Cuckoo Search Algorithm | Number of alive nodes, energy consumption, network life | CH selection |
| 10. | Lavanya, N., & Shankar, T. (2019). | Squirrel search algorithm & Harmony search algorithm | First node and last node death, residual energy, throughput | CH selection |
| 11. | Yue, Y., Li, J., Fan, H., & Qin, Q. (2016). | Artificial Bee Colony Optimization | Latency depends on number of rounds and number of sensors, network connectivity and reliability | Cluster formation |
| 12. | Kumar, S. (2016). | Ant Colony Optimization | Residual energy, active node count, and transmitted packet count | CH Selection |
| 13. | Nguyen, T., Pan, J., & Dao, T. (2019). | Bat Algorithm | Number of alive nodes, energy consumption | Cluster formation |
| 14. | Kavitha, G.R., & Wahidabanu, D.R. (2014). | Bacterial Foraging Optimization | Throughput, data dropped, delay | CH Selection |
| 15. | Aparna S. Shinde, Rajankumar S. Bichkar, 2020 | Particle Swarm Optimization | Network life, energy consumption, packets sent | Cluster formation, CH selection |

2.2 ROUTING

Routing is another important technique which involves finding the shortest path from nodes present in the cluster to CH and from CH to the base station. Network lifetime and energy efficiency can be increased by choosing the shortest path.

A survey is conducted on nature inspired optimization technique for routing in WSN (Al Aghbari, Z., et al. 2019). They discussed PSO, ACO, GA, FFO and BFO to determine their performance in optimizing the network's lifetime by decreasing the energy consumption.

K. Raj Kumar et al. 2019, have reviewed some nature-inspired optimization algorithms to solve routing issues in WSN. This paper concentrated mainly on routing issues and the optimization techniques utilized to solve those issues.

Grasshopper optimization technique for improving QoS parameters and energy efficiency of WSN (Amrinder Singh, D., & Sharma, A. 2019). This technique's swarm size varies based on the nymph and adult stages. The CH is chosen at random, and the nodes are heterogeneous. CH is selected according to fitness, defined based on distance, energy, and interaction with the other nodes. Stability parameters are calculated only when the cluster size is optimized according to sink location. If the energy is not optimized, the sink position is randomly selected.

Yogarajan, G., & Revathi, T. (2016)., described discrete Ant Lion Optimization (ALO) to solve tour problem. Ant Lion performs hunting in the larval stage and reproduction in the adult stage. Here, it searches for food randomly, and builds a pit in a place where a huge quantity of food is available. It sends sand toward the outside edge if it discovers food close to its trap to catch its prey, modifies the pit, and gets ready for the next hunt. Similarly, mobile CH is selected based on the roulette wheel method and moves randomly. It collects information from the nodes present in the network and is then transmitted to the base station.

Gheraibia, Y., & Moussaoui, A. 2013., presented a Penguin Search Optimization algorithm (PeSOA) to solve energy issues in WSN. Nodes that form cluster is based on the quality of data. The amount of data and energy used determines

which CH will be used. CH consists of details of all members in the cluster. If the node energy is less, it communicates with another node in the cluster and then migrates to another cluster.

The Binary Particle Swarm Optimization (BPSO) technique is used to optimize energy by selecting an alternate route if the current route fails (Santosh Kumar Verma., & Neetesh Kumar Gupta. 2020). Mehta, D., & Harous, S. 2017., describe the Fish Swarm Algorithm (FSA) for improving the network's life. Fishes travel in groups in search of food, and the group with the greatest amount of food finds the best food source. CH is chosen in this paper based on the node's degree and residual energy. If the number of nodes belonging to one CH is more than the total number of clusters, then the sink finds the optimal position near that particular CH.

Hedayatzadeh, Ret al. 2010, present Termite Colony Optimization (TCO) for solving optimization issues in WSN. TCO is like ACO except the fact that it decides its movement based on pheromone deposits by adjusting its trajectory. Using local information, nodes move to their new location based on pheromone deposits and the distance between two nodes.

The Harmony Search Algorithm (HSA) application in clustering and routing applications is described (Lavanya, N., & Shankar, T. 2019). The foundation of HAS is harmony memory, Modified pitch and Randomization. The harmony memory can be considered by selecting CH based on node_id or by pitch-adjusting and updating the memory. The CH coordinates are updated during pitch adjustment. Any site close to a node that is present there is chosen as the CH. Fewer member nodes make up the cluster, and there should be less space between them and the CH and higher CH energy. Based on optimal fitness, the shortest path can be chosen in routing. The remaining energy, intra-cluster and inter-cluster distances, and nodal degree are used to calculate fitness.

Baranidharan V et al. 2018, modified the Clustered Chain Routing Protocol using a mobile agent. A mobile agent is used to monitor the mobility of nodes and data

aggregation, achieve energy efficiency, and avoid node and transmission failure. Annushakumar, G.R., & K. Devarajan 2019., proposed GA for increasing energy efficiency and network life in routing. In this paper, the cluster is formed initially with all nodes. After each iteration, the cluster is formed with a number of alive nodes. The base station constructs a new cluster on receiving information provided by population generation using GA, and the sensor nodes are re-configured according to the new cluster.

A survey is conducted to analyze the routing performance in WSN (Selvaraj, Rathipriya, 2017). They discussed a few optimization techniques and concluded that PSO and GA are often used for issues related to energy consumption in WSN. Yadav, S., et al. 2019, explained the usage of water cycle algorithm in routing. Here, CH is selected based on intra cluster distance, centrality, and communication speed in the network. Routing finds the best path for data transfer based on the quality of data and energy required for transferring and receiving that data. Following optimization, data is communicated to more nodes, and at the end, the number of dead nodes and the time delay are computed.

Handa, P., et al. 2019, explained dividing networks into uneven ring structures to balance the energy usage in each sensor node. Rings near the base station are small, and ring size increases as it moves farther. Nayak, P., & Vathasavai, B. (2017), proposed a GA based clustering to optimize routing in WSN. Area is regarded in this study as a graph $G(E, V)$, where V is the link between two nodes and E is the number of nodes. A direct link between two nodes is denoted by "1" or "0" otherwise. The shortest path between a source and a destination is found, and fitness is assessed based on residual energy and the distance between two nodes.

Bat Algorithm (BA) for selecting the shortest path is discussed (Sharma, S., et al. 2016). BA is inspired by the echolocation behaviour of bats. Bats select the best food sources among the food sources based on the quality of food, the energy they require after consuming that food and the distance between the bat and the food.

Assigning the same path for multiple source destination pairs can be avoided by this method.

Table 2.2 shows various algorithms for routing to select the shortest path in WSN

Table 2.2 Various Algorithms for Routing in WSN

| S.No | Author & Year | Optimization technique used | Parameter considered | Inference |
|------|---------------------------------------------------------------------------|----------------------------------|--------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|
| 1. | Benaddy, M., Habil, B.E., Ouali, M.E., Meslouhi, O.E., & Krit, S. (2017). | Multi-path routing algorithm | Energy, distance | Ensures dependable data transfer while addressing issues related to distance and energy efficiency. |
| 2. | Swapna, S., & Santhosh, R. (2020). | Ant lion optimization | Throughput, energy consumption, delay | Achieves connection, coverage, network longevity and minimum energy consumption. |
| 3. | Liu, Y., Luo, Z., Xu, K., & Xu, C. (2013). | Shortest Path Tree | Power consumption | Optimizes the energy usage of individual nodes to prolong the lifespan of Wireless Sensor Networks (WSN). |
| 4. | Khan, G., Bathla, G., and Ali, W. (2011). | Minimum Spanning Trees | Time of node death based on the location of the base station | Expands network life time. |
| 5. | Onur Yilmaz, Sercan Demirci, Yagiz Kaymak, Serkan Ergun, | Shortest hop multipath algorithm | Energy, time, hop count, path length | Balances the load and finds the optimal path. |

| S.No | Author & Year | Optimization technique used | Parameter considered | Inference |
|------|---------------------------------------------------------------------------|-----------------------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| | Ahmet Yildirim, (2012). | | | |
| 6. | Saravanan, M., & Madheswaran, M. (2014). | Minimum Spanning Tree | Energy, average delay, number of live nodes, packet delivery ratio | Balances energy consumption during the route selection. |
| 7. | Al Aghbari, Z., Khedr, A.M., Osamy, W., Arif, I., & Agrawal, D.P. (2019). | Clustered tree routing | Residual energy, number of alive nodes, first node death, last node death | Improves the network lifetime and finds an optimal path in a stable period. |
| 8. | Tang, L., Lu, Z., & Fan, B. (2020). | DS evidence theory | Average packet loss, energy, number of hops | It extends the network's lifespan and equalizes energy distribution among nodes. |
| 9. | Liu, W., Cui, Y., & Zhao, Z. (2015). | Ant Colony Optimization and Genetic Algorithm | Network Lifetime | Improves the network lifetime and accelerates the coverage speed. |
| 10. | Kong, L., Chen, C., Shih, H., Lin, C., He, B., & Pan, J. (2013). | Cat Swarm Optimization | Energy | Finds the shortest path in optimal time. |
| 11. | Masoodi, I.S., Dar, M.A., & Banday, M.T. (2018). | Dynamic Cuckoo Search Algorithm | Energy | Reduces the energy consumption. |
| 12. | Lalwani, P., Ganguli, I., & Banka, H. (2016). | Firefly Algorithm | The remaining energy, quantity of active nodes, received data packets | Optimizes the remaining energy. |
| 13. | MeeraG, S., Gupta, V.K., Sekhar, P., Sreejith, & | Dynamic Steiner Tree | Energy, number of packets, number of hops | Enhances the network lifetime. |

| S.No | Author & Year | Optimization technique used | Parameter considered | Inference |
|------|--------------------------------------------------------------------|-----------------------------|----------------------|-------------------------------------|
| | Anupama, K.R. (2016). | | | |
| 14. | Anzola, J.P., Espada, J.P., Bermúdez, G.M., & Crespo, R.G. (2018). | k-d tree algorithm | Energy, delay | Provides better quality of service. |

2.3 SECURITY

One of the primary obstacles in WSNs is ensuring stringent security measures with limited resources. WSN security requirements include node authentication, data confidentiality, anti-compromise measures, and robustness against traffic analysis. To distinguish between dependable and untrustworthy nodes, sensors need to undergo node authentication by their respective CH. Unauthorized nodes can be excluded from the WSN during this authentication process. All packets sent between a sensor and the CH must remain confidential to prevent interception by eavesdroppers who may alter, analyze, and extract meaningful information from WSNs.

Zhou. J., 2010, elucidated the BEARP protected routing protocol, which relies on encryption and authentication. The protocol encrypts data packets, authenticates nodes and base stations, and ensures security features such as confidentiality of routing information, authentication, integrity, freshness, and load distribution among nodes by transferring routing tasks to the base station. This results in energy efficiency, extended network lifetime, and enhanced security.

Patil, D.S., & Patil, S.C. (2017)., detected node clone attacks using Node Location Speed Time based Detection (NLSTD), which in turn reduces communication cost, routing overhead and throughput. Here, the source node moves at diverse speeds in the network. Based on this moving nature of the source node, the node delivers the message regarding its current location at different intervals of time. Its neighbours are also updated frequently, and the destination assumes it as a claim node. To prevent false claims, the authentic message from the source node is transmitted to the destination through intermediate nodes using optimal path detection.

The Euclidean distance determines the difference between the two locations if another message is received at the destination. When the distance surpasses the maximum limit, the clone is identified. Upon detection of the clone node, the algorithm is stopped, and the clone node's identity in the network is revoked.

A cutting-edge security technique is suggested to shield a network from threats while maintaining data secrecy (Rani, A., & Kumar, S. (2017)). The detected data is encrypted and decrypted based on the unique number assigned to each node, ranging from 1 to N. However, this process requires more memory and energy. The cryptographic algorithm is adjusted accordingly to ensure that the detected data is encrypted and decrypted between 1 and N/2 and 1 and N/4.

The encrypted data is compared instead of the original data to improve security since it makes it possible for apps to order queries over encrypted data effectively (Khoury, E.E., et al. 2018). One of the key areas for maintaining encryption is WSN, which has a significant influence and can be combined with safe data aggregation protocols that use comparison operations (max, min, etc.) to aggregate data. As a result, less power is used because the sensor node does not handle the decryption.

An innovative method is suggested for balancing the trade-off between energy use and security (Kommuru, K. et al. 2018). The complexity of the security algorithm rises with an increase in energy usage. The hybrid LEACH-PSO method and low complexity XOR technique balance the trade-off. In the XOR approach, data is first encrypted with a static key and then with a dynamic key again. In the LEACH-PSO protocol, PSO is used to choose the routing path, while LEACH is used to pick the CH. A routing algorithm is used to connect the chosen algorithm to the base station. As a result, the CH uses other CHs as hops rather than sending the data straight to the base station.

2.4 BATTERY

WSNs have been used for various purposes, including health care and environmental monitoring. Battery sources are used to power the sensor nodes. Recharging or replacement of batteries is often needed, which is expensive. To ensure uninterrupted service, it is necessary to plan battery replacement before the battery gets depleted. Lithium-ion batteries are subjected to continuous cycling in mobile applications and operate under constant voltage conditions. Users experience intense heating of batteries because of high temperatures that result in electrolyte degradation. Based on the type of material and its quantity, capacity of battery and maximum energy delivered by the battery can be determined. The battery's energy output depends on its weight and size.

Rohner C et al. (2013) evaluated the energy efficiency of three battery models for WSN. The parameters taken for analysis are capacity effect with a rate of change and power recovery, indicating battery discharge behaviour. The result is the load's peak current plays a vital role in saving energy compared to its timing.

Threenovel power management techniques are suggested for increasing energy solutions for the battery energy of WSN (Agnelo Silva et al. (2012). The work is implemented outdoors with high temperatures underground by placing it beneath the ground and in structures such as buildings, bridges, and roads. The allocation of the developed techniques extended the battery lifetime of communication devices.

Park. C., et al. 2005 analyzed the performance characteristics of the battery to improve the operating life of battery powered systems through the battery discharge in WSNs. The impact of environmental parameters in sensor networks and how these parameters interact with the electrochemistry of battery parameters such as efficiency, capacity recovery rate and effects due to temperature is studied.

2.5 COMPARISON OF OPTIMIZATION TECHNIQUES USED IN WSN

Table 2.3 discusses commonly used nature-inspired optimization techniques like Ant Colony Optimization, Particle Swarm Optimization, Artificial Bee Colony Optimization, Bacterial Foraging Optimization, Fire Fly Optimization and Genetic Algorithm with their behavioural patterns and operators used in those algorithms. It also briefly explains the role of each algorithm in WSN and its merits and demerits.

Table 2.3. Different Optimization Techniques and its merits and demerits

| Optimization technique used | ACO | PSO | ABC | BFO | FFO | GA |
|------------------------------------|-------------------------------------------------------------------|------------------------------------------------------------|--------------------------------------------------|-------------------------------------------------------------------|---------------------------------------------------------|----------------------------------------------------------|
| Behavioural pattern | Foraging behaviour of ants | Behaviour of flock of animals | Foraging behaviour of bees | Foraging behaviour of bacteria in search of nutrients | Based on the attraction of the flashlight | Genetic process in biological organisms |
| Search parameter | Ants find the shortest path in search of food | Birds find optimal paths in searching for food | Honeybees find best path in search of their food | Bacteria find the shortest path by moving in search of their food | Fireflies are attracted based on the intensity of light | Search parents and form good offspring |
| Operators | Pheromone deposit | Velocity and position of particle | Nectar quantity | Chemotaxis quantity | Fireflies are attracted on the basis of distance | Chromosome "0" & "1" |
| Clustering & Routing | Find the shortest optimal path between the source and destination | The optimal path is found by selecting CH with high energy | CH selection is based on intra cluster distance | Optimal routing based on grid-based clustering | Selects node for optimal routing in a cluster | reduces distance based on pre defined number of clusters |
| Merits | Solves travelling salesman | Reduces energy consumption | Used in slow converge | Good energy consumption | Solves multi-objective | Used for selecting the number of |

| Optimization technique used | ACO | PSO | ABC | BFO | FFO | GA |
|-----------------------------|-------------------------|------------------------------|----------------------------------------------------------------------|-------------------------------------|------------------------------------------------------------------------|--------------------------------------|
| | problem | tion and fast convergence | nce problem | on and solves optimization problems | optimization problem | required nodes |
| Demerits | High energy consumption | Increase in network overhead | In terms of energy consumption and network life, average performance | Reduces network life | High computational cost. Valid only for randomly deployed sensor nodes | Challenging to manage mobile sensors |