A SWARM INTELLIGENCE ALGORITHM FOR ROUTING RECOVERY STRATEGY IN WIRELESS SENSOR NETWORKS WITH MOBILE SINK

Seminar Report

Submitted in partial fulfillment of the requirements for the award of degree of

BACHELOR OF TECHNOLOGY

In

COMPUTER SCIENCE AND ENGINEERING

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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

Submitted By

TOM JOHN

Department of Computer Science & Engineering

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MAR ATHANASIUS COLLEGE OF ENGINEERING
KOTHAMANGALAM

CERTIFICATE

This is to certify that the report entitled **A Swarm Intelligence algorithm for Routing Recovery Strategy in Wireless Sensor Networks with Mobile Sink** *submitted by* **Mr. TOM JOHN, Reg. No.MAC15CS059** *towards partial fulfillment of the requirement for the award of Degree of Bachelor of Technology in Computer science and Engineering from APJ Abdul Kalam Technological University for December 2018 is a bonafide record of the seminar carried out by him under our supervision and guidance.*

....	....	....
Prof. Joby George	**Prof. Neethu Subash**	**Dr. Surekha Mariam Varghese**
Faculty Guide	***Faculty Guide***	***Head Of Department***

Date: Dept. Seal

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ABSTRACT

Considering the fault tolerance mechanism in the route optimization of the mobile wireless sensor network (MWSN), we analyze the routing fault tolerance between nodes and establish an intelligent fault-tolerant routing model for MWSN. We also propose a novel fault-tolerant routing algorithm for an MWSN based on an artificial bee colony (ABC) optimized particle swarm optimization algorithm (ABC-PSO), and this optimizes ABC-PSO algorithm is applied to study the optimal construction strategy of an alternate route. The proposed using of the path coding, the ABC algorithm optimization, the collaborative updating and the evolution of the principal and subordinate swarms, as well as particle selection, provides faster overall convergence performance and more accurate solutions for the network optimization. Analytical proofs and simulation experiments show that the route fault-tolerant strategy proposed in this paper can create a reliable transmission environment and an efficient route recovery mechanism for the MWSN. Moreover, it can lower the energy consumption of the network, and increase the network's lifetime and improve the robustness and the reliability of MWSN.

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List of Abbreviations

ABC	Artificial Bee Colony
PSO	Particle Swarm Optimization
WSN	Wireless Sensor Network
AODV	Ad Hoc on demand distance vector routing protocol
CH	Cluster Heads

Introduction

The environment of the wireless sensor networks (WSNs) is unpredictable because of various influence factors such as the vibrations, the electromagnetic interference, the system noise, the running down of the battery, the transmission loss of signal, the software errors, and other faults in the networks [1,2]. These faults cause the sensor nodes to fail and degrade the data transmission quality of the network, further influence of the reliability of the WSNs and the operational stability of WSNs. The reliability and stability of the network remain challenges to WSNs technology at present [3].The fault tolerance can improve the reliability and stability of WSNs, also it is a critical technical factor in network application [4]. In recent years, the fault-tolerant techniques have already become a major research topic in the field of mobile WSNs [5]. The fault-tolerant design focuses on various aspects of wireless sensor networks, including the fault tolerance of hardware, the coverage and topology control, the routing fault tolerance, and fault detection and the fault separation. The routing fault tolerance technology remains the basis and emphasis of research work on the routing algorithms of WSNs [6]. Currently, the fault-tolerant routing methods for WSNs that have been proposed by researchers have concentrated mainly on three aspects: the re transmission in the link circuit, the error correcting code mechanisms and multipath methods.

In recent years, designing highly efficient energy-saving fault tolerant methods, ensuring the robustness of data transmission and improving the performance of networks have become the key point of MWSN. Because of the changing the position of the mobile sink will change the topology of the network, it is feasible to solve the routing fault tolerance of a single mobile sink, and to maintain multiple non-intersect routings from the source node to the cluster head, by efficiently reconstructing an alternate route. In view of the routing fault tolerance in the MWSN, in this paper, we draw references from the characteristics of the swarm intelligence bionic algorithm. An intelligent routing fault-tolerant mechanism for MWSN based on the artificial bee colony particle swarm optimization algorithm is proposed. And we establish the corresponding fault-tolerant routing models to solve the complicated computations and application problems, such as routing fault tolerance optimization in the MWSN, so as to guarantee the stable operation of the network, enhance the network's performance, reduce the network's energy consumption, extend the network's lifetimes and improve the network's robustness and reliability.

The main contributions of our work in this paper can be summarized as follows:

1. Characterize the issues of a fault-tolerant routing protocol for the MWSN, and formulate the problem of the fault-tolerant routing algorithm.

2. Present a new fault-tolerant routing algorithm based on an artificial bee colony optimized PSO algorithm.

3. Provide extensive simulation results to demonstrate the use and efficiency of the proposed fault-tolerant routing algorithm.

4. Evaluate the performance of the proposed algorithms by comparing them with the fault-tolerant routing algorithms of AODV and AODV-PSO.

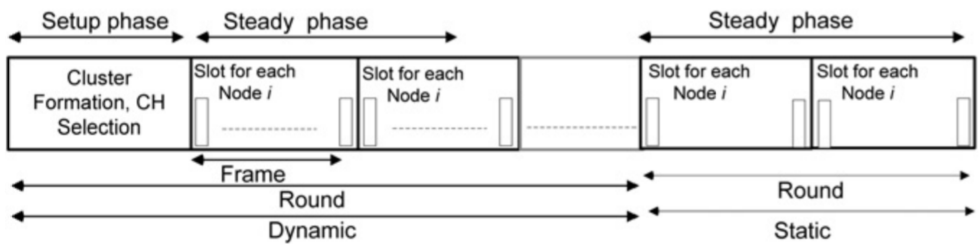
The rest of the paper is organized as follows: Section 2 discusses the related literature. Section 3 formulates the problem of the fault-tolerant routing algorithm for the MWSN. Section 4 describes the basic principles of the improved PSO algorithm and presents the applied mathematical models and optimization steps of a fault-tolerant routing mechanism for the MWSN. Section 5 provides the parameters and simulation results that validate the performance of our algorithm.

Related Works

Low energy adaptive clustering Protocol (LEACH) works well for homogeneous networks, where every node has the same initial energy. This protocol works in rounds and each round is divided into cluster formation and steady phases. In the cluster formation phase, a cluster is formed and p.n sensor nodes are selected as cluster heads (CH) for the proper utilisation of energy, where n is the number of sensor nodes and p is the desired percentage of CH. Otherwise, if only one node is selected as CH it will fail because of the shortage of energy. If a random number (between 0 and 1) chosen by a node A is less than a threshold value, A is selected as a CH in the current round. The steady state is divided into many frames where CH assigns time slots to each non-CH node using TDMA scheme. At the end of each round, the CH collects and aggregates data and sends to the BS. In LEACH, a new cluster formation is initiated in every round, which is not energy efficient. Moreover, occasionally all CHs exist in a close area (since CH rotates in a cluster) and require more energy for non-CH nodes to communicate CHs. LEACH also does not support mobility of sensors.

Bajaber and Awan propose dynamic static clustering protocol (DSC) for (WSN) and find the DSC has better performance than LEACH in terms of energy efficiency, network lifetime and communication overhead. DSC protocol has dynamic and static cases. Dynamic case is divided into two phases: setup and steady phase. In the setup phase, the base station (BS) forms clusters and selects CH for each cluster based on the energy levels and positions of the sensor nodes. Then, the BS broadcasts CH ID to all nodes. A sensor node will be a CH if its ID matches with the CH ID. In the steady phase, CH uses TDMA scheme by dividing each frame into x number of timeslots, where x is the total number of non-CH nodes in that cluster. A non-CH node transmits data to the CH only in the allocated timeslots and saves energy by turning its radio off (sleep mode) in all other timeslots. When a round is completed, data transmitted by all non-CH nodes are aggregated and sent by the CHs to the BS. In the next round, the current CH of a cluster selects a node as a new CH, which has the most remaining energy.

Static case has only the steady phase, which is similar to that of dynamic case except for after a certain number of rounds (i.e. 10) a new cluster formation/setup phase is initiated. However, the static case has less number of cluster formation phases as compared to the dynamic case and so, has less transmission overhead. However, DSC also does not provide mobility of sensor nodes and cannot be used in applications that require mobile sensor nodes such as habitat monitoring, target tracking. Figure illustrates the working principle of DSC protocol.



To provide mobility of sensor nodes, Kim and Chung propose LEACH-Mobile (LEACH-M) routing protocol where cluster formation and CH selection mechanism is same as LEACH. LEACH-M ensures the communication of a node with a CH even if node is in motion by transmitting data request packet from CH to the sensor node in its allocated timeslot using TDMA scheme. For this purpose, a member node A of a cluster with CH B waits two timeslots of two consecutive frames to decide whether A has moved. The node A does not send any data at its allocated timeslot to B until it receives data-request from B and if the node A does not receive any Data Request at the beginning of a timeslot (when it is awake) from B then A goes to the sleeping mode and waits for the Data-Request from B until the next frame. If A does not any receive the Data Request in the next frame as well it requests for a JOIN-ACK message to join in a new cluster. Then A joins to a new CH which is in the vicinity of A and from which A receives the advertisement message for the first time by sending a registration message. The CH then sends A a TDMA schedule, which contains timeslots that are assigned to all members including new mobile node A. Similarly if a CH does not receive data from

A in two consecutive rounds (after sending the DataRequest packet) CH discards A from its membership and removes A from its TDMA slot considering that A has moved.

However, LEACH-M handles node mobility by assuming that the CHs are stationary. Hence, LEACH-M is not considered efficient in terms of energy consumptions and data delivery rate because a large number of packets are lost if the CH keeps moving before selecting a new CH for the next round. To alleviate this problem of LEACH-M, Kumar et al. propose LEACH-Mobile-Enhanced (LEACH-ME), where a node with the minimal mobility factor is selected as a CH, if the residual energy of the node is not below a threshold value. They calculate mobility factor based on the number of times a node moves from a cluster to another cluster. Since mobility factor (or remoteness) is a function of distance among nodes it is calculated by multiplying node's velocity with the time required to move a node from a position to another. For this purpose, an extra timeslot known as ACTIVE slot is assigned during TDMA scheduling, where all member nodes wake up simultaneously, broadcast their IDs with timestamp information and receive their neighbouring nodes IDs by setting a time out. For example, node i can make use of IDs of all other nodes it hears and calculate dij(t) as dij(t) ¼ RadioVelocity |t2 - t1|, where at time t1 node i broadcast its ID and at time t2 it receives the ID of node j. This modified CHs election process of LEACH-ME provides a minimal data loss in case of node's mobility. In steady phase, a non-CH node A might not receive Data Request that is sent by the CH because of mobility and since the new location of node A is out of the range of CH. In this case if CH does not receive any acknowledgement from A in two timeslots in consecutive frames, then A is declared as mobile and its allocated timeslot will be deleted and A joins in a new cluster. The performance of LEACHME is better than LEACH-M in successful data transmissions in different mobility factors. However, LEACH-M is not energy efficient since it consumes energy for determining mobility factor in active slots. Awwad et al. propose cluster based routing

Awwad et al. propose cluster based routing protocol for mobile nodes in WSN (CBR Mobile-WSN) to reduce energy consumption and the number of packets loss of LEACH-M. CBR-M is an adaptive protocol that avoids wastage of timeslots and hence, ensures efficient bandwidth utilisation. Each CH keeps some free timeslots to enable other incoming mobile nodes from other clusters to join its cluster. A CH sends data request message to the non-CH nodes and if the CH does not receive data from a member, the packet is considered to be lost and the CH discards the nodes membership, at the end of the frame. Consequently, if a sensor node A does not receive data request message from its CH then A tries to join in a new cluster to avoid loss of packets. If the sensor node A receives Data Request message from CH but A has no data to send, A will not hold any time slot and this timeslot can be assigned to another member node that has data to send. In another scenario, if a sensor node A moves and hence, does not receive data request message from its CH at its allocated timeslot A sends its data to the free CH to avoid the loss of data. Then A sends a registration message to join the cluster of a nearby CH. When a CH finishes receiving data messages from all sensor nodes in a round, the CH checks whether it receives data messages from all members, and then removes the sensor nodes from which the CH did not receive any data. Each sensor node A wakes up one timeslot before its scheduled timeslot to check whether it has really been assigned that timeslot. If A has not been assigned any timeslot it goes back to sleep mode and its timeslot might be used by a mobile sensor node that enters the cluster. This phenomenon reduces energy consumptions. However, CBR-mobile has more average delay as compared to LEACH-M since the moved sensor nodes send data to the free CH whenever that sensor node did not receive any data request from its CH which adds delay to the network whereas in LEACH-mobile assume packets are lost when sensor nodes do not receive any data request from CH.

There are many other clustering protocols, which considering both stationary and mobile sensor nodes, such as LESCS, ECR, SP, CBR-MWSN, GBEER, are not discussed here. Although they are considered as energy efficient most of them are not fault tolerant. This signifies our proposed routing protocol that is presented in the next section.

There is some literature about optimization-based multipath fault-tolerant routing algorithms for large-scale mobile wireless sensor networks. In this literature, the authors proposed a distributed multipath fault tolerance routing scheme for wireless sensor network (DFTR).The multipath fault tolerance routing provides better resilience to various faults in wireless sensor network. The authors proposed a comprehensive survey of both best effort data and real-time multipath routing protocols for WMSNs, and Results of a preliminary investigation into design issues affecting the development of strategic multipath routing protocols that support multimedia data in WMSNs were also presented and discussed from the network application perspective. Hasan M. et al. proposed a bio-inspired particle multi-swarm optimization (PMSO) routing algorithm to construct, recover, and select k-disjoint paths that tolerates the failure while satisfying the quality of service parameters. Azharuddin M. et al. proposed distributed clustering and routing algorithms jointly referred as DFCR. The DFCR used a distributed run time recovery of the sensor nodes due to sudden failure of the cluster heads In literature, the authors gave an overview of WSN mechanisms that provide or improve the fault tolerance property of wireless sensor networks, and proposed a new classification based on the network size, since the performance of the majority mechanisms depends on the size in terms of geographical area and number of nodes. The authors proposed a high fault-tolerant and energy-efficient multipath routing protocol based on the idea of hybrid, energy-efficient distributed (HEED) clustering protocol, called HEED fault tolerant (HEED-FT) is proposed, and improved the routing reliability and energy balance between cluster heads

Bohacek, S. et al. proposed game theoretic stochastic routing for fault tolerance and security in computer networks. Hu Y. F. et al. proposed an immune cooperative particle swarm optimization algorithm in the model to provide rapid routing recovery and reconstruct the network topology to correct for path failure in heterogeneous wireless sensor networks. Multipath fault-tolerant routing protocols are the primary method used to improve the reliability of data transmission for WSNs, as compared to single-path routing mechanisms, which have obvious advantages in terms of transmission reliability, load balancing, and fault tolerance restoration.

We claim that the routing recovery strategy problem studied in this paper is essentially different from conventional wireless sensor network. In previous works, the general method is to reduce data packet dropout rate and improve the network lifetime. However, in this study we explore the pervasive usage of mobile wireless sensor networks to meet different industrial application environments.

The motivation of this paper is that, we aim to develop an efficient routing recovery scheme such that the optimal transmission path can be carefully maintained and updated as the movement of the mobile Sink. We establish corresponding fault-tolerant routing models to guarantee the stable operation of the network, enhance network performance, reduce network energy consumption, extend network lifetimes and improve network robustness and reliability.

Focus on optimizing the network's performance of multipath fault-tolerant routing protocols, and different from earlier research in the following aspects:

1) In contrast to the common methods used in most existing work, we propose the mechanism of an improved PSO-based fault-tolerant routing algorithm for mobile wireless sensor networks, and improve the efficiency and the reliability of the network.

2) Different from the optimal fault-tolerant routing with a static sink, Our simulation environment use the Sink mobility for more efficient energy utilization, greater the network's traffic capacity, reduce the packet loss rate, and prolong the network's lifetime.

3) In addition to the energy constraints inherent with the network's lifetime, we also impose the reliability and latency constraints on the Sink mobility as related to the fault-tolerant routing problems.

Proposed System

3.1 System Model And Problem Statement

In this section, we formulate the problem of the fault tolerant routing algorithms for wireless sensor network with mobile Sink. Table I illustrates the notations used in the rest of this paper.

TABLE I
LIST OF NOTATIONS USED IN PROBLEM FORMULATIONS

Symbol	Quantity
G	Graph with sensor node set N and link set E: G=(N,E)
n	Sensor node
n_b	Neighbor node
Q_j	The path from the source node n_j to mobile Sink
$N(Q_j)$	Node set of the source node to the Sink transmission path Q_i
$N(n_{sink})$	Neighbor routing table stored in the sensor node of Sink
$N(node)$	Sensor node set
h_j	The hop on the transmission path of Q_j
e^m_j	The link of m adjacent nodes on the path of Q_j
m	The hop of neighbors routing nodes to Sink

In this paper, the mobility in mobile wireless sensor networks is a mobile Sink node for data collection. At the same time, it is also based on the classic LEACH clustering model and the proactive routing environment to build a mobile sensor network environment. Multi-path routing fault tolerance technology is used to establish a multiple transmission path between the source node and Sink to improve the reliability of the data transmission. Although this method increases the power consumption and complexity of the route setup, it improves the network's load balancing and the transmission bandwidth. Moreover it improves the stability and reliability of the data transmission. It is a quite common method of implementing fault tolerance at the network layer.

Every node n in the MWSN has a neighbor table that is used to store the ID number of the neighboring node and other information (residual energy, energy consumption, the neighbor table of the mobile Sink stores the nodes near it. N(nsink) is the neighbor table that is stored in the Sink. The information is used for later path recovery. The recovery process of the routing fault-tolerance of the mobile Sink is shown in Figure 1.

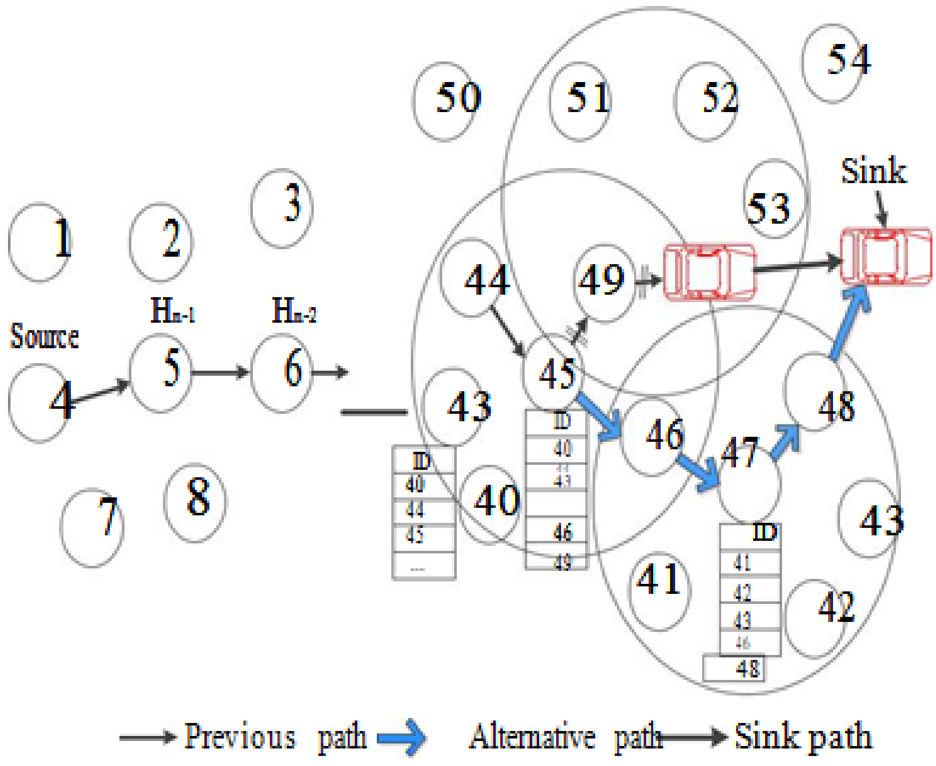


Figure 3.1: Fault tolerance recovery

Since the mobile Sink rapidly changes in the WSN's topology, we set only one valid path from the source node to the Sink, so as to reduce the communication control overhead required to restore routing after the path fails. According to the definition in the literature [19], the node in the direction from the source node to the Sink is called the downstream node, while the node in the direction from the source node to the Sink is called the upstream node. Each node of N(Qj) will build one task list to store current transfer tasks in the routing protocol. Each node transfers data packages to the downstream node according to the task list. The task list includes the originating node, the ID of the Sink, the data type and the ID number of the upstream node of Qj in the transfer path. In Figure, the transfer path from the source node to the Sink is 4-5-6. . . 44-45-49-Sink.

The node search package GNm (Get Node) will be broadcast after the mobile Sink finds that it does not connect with the node and the attached task list, and it then searches the neighbor node. The parameter m represents the number of hops between nodes transferred to the Sink. The hop will reach from m to m+1 after receiving the node of GNm, and it will then broadcast it repeatedly to the neighbor node. If the node received the data package of GNm that belongs to the original path N(Qj), then the response package GNRm will be sent with the neighbor list and task list. Therefore, the node involved in reconstructing the replacing path in the original path N(Qj) to restore routing can be implemented in the local area, so that energy may be saved. The set of nodes N(node) shall be extracted after the node including the neighbor list and task list is received by the Sink to construct and take the place of path Qj. The ABC-PSO algorithm proposed in this paper is a new path of the optimal fitness value fitness (Qj) formed by selecting suitable nodes.The new transfer path Qj from the source node to the Sink is 4-5-6. . . 44-45-46-47-48-Sink.

The effect factors of Qj include the following:the residual energy Rene(n_j^k) of the single node and the path length Dist(ej) of the efficient link between the neighboring node on a path; the single node and Ene(n_j^k) and the Ene(n_j^k) of energy consumption between adjacent nodes and the single node; and the transfer delay like Delay(n^k) and Delay(e^k) between adjacent nodes and the single node and network reliability between two adjacent nodes like Rel(n_j^k) and Rel(e^k) and the single node and the balance of the load including that between two neighbor nodes LBF(n_j^k)and LBF(e_j^k) The fitness degree fitness(Qj) of Qj is as shown:

$$fitness(Q_j) = \frac{\sum_{n_j^k \in Q_j} Rene(n_j^k)}{w_1 f_1 + w_2 f_2 + w_3 f_3 + w_4 f_4 + w_5 f_5} \qquad \text{(Equ: 3.1)}$$

$$f_1 = \frac{\sum_{n_j^k \in Q_j} Ene(n_j^k) + \sum_{e_j^k \in Q_j} Ene(e_j^k)}{\sum_{n \in V} Ene(n) + \sum_{e \in V} Ene(e)} \qquad \text{(Equ: 3.2)}$$

$$f_2 = \frac{\sum_{n_j^k \in Q_j} Delay(n_j^k) + \sum_{e_j^k \in Q_j} Delay(e_j^k)}{\sum_{n} Delay(n) + \sum_{e \in V} Delay(e)} \qquad \text{(Equ: 3.3)}$$

$$f_3 = \frac{\sum_{n_j^k \in Q_j} L_{BF}(n_j^k) + \sum_{e_j^k \in Q_j} L_{BF}(e_j^k)}{\sum_{n \in V} L_{BF}(n) + \sum_{e \in V} L_{BF}(e)} \qquad \text{(Equ: 3.4)}$$

$$f_4 = \frac{\sum_{e_j^k \in Q_j} Dist(e_j^k)}{\sum_{e \in E} Dist(e)} \qquad \text{(Equ: 3.5)}$$

$$f_5 = \frac{\sum_{n_j^k \in Q_j} Rel(n_j^k)}{\sum_{n \in Vs} Rel(n)} \qquad \text{(Equ: 3.6)}$$

$$\sum_{n_j^k \in Q_j} Dist(e_j^k) > L \qquad \text{(Equ: 3.7)}$$

$$\sum_{n_j^k \in Q_j} Rel(n_j^k) \geq R_{el} \qquad \text{(Equ: 3.8)}$$

$$\sum_{v_j^k \in Q_j} Delay(v_j^k) + \sum_{e_j^k \in Q_j} Delay(e_j^k) \leq D \qquad \text{(Equ: 3.9)}$$

$$\sum_{v_j^k \in Q_j} Ene(v_j^k) + \sum_{e_j^k \in Q_j} Ene(e_j^k) \leq Ene \qquad \text{(Equ: 3.10)}$$

We adopted the normalization method for the given fitness function. The parameter f1 of the normalization function represents the proportion of total energies consumed in this path Qj and the total energies of all links in the network that may be consumed. f2 means the ratio of the total delay of the nodes concluded in path and the total delay of all nodes in the WSNs.f3 refers to the proportion of the total load of the nodes concluded in path Qj and the total loads of all the nodes in WSNs. f4 means that the ratio of the total distance of all links in the links concluded in path Qj. f5 is the total reliability of all links concluded in path Qj and the total reliability of the total distance of all links in the WSNS.Therefore, w1, w2, w3, w4 and w5 are respectively the weight numbers of f1 f2,f3,f4 and f5, w1+w2+w3+w4+w5=1.According to the different emphasis on the route recovery transmission path, we set w1=0.25, w2=0.15, w3=0.15, w4=0.2and w5=0.25[26]. In the formula for path constraint, L is the constraint of the path distance, Rel is the constraint of network reliability, D means the constraint of link transfer delay, Ene is the constraint of link energy consumption and LBF is the constraint of link load balancing.

3.2 Artificial Bee Colony-Particle Swarm Optimisation Algorithm and application in routing protocol of Mobile Wireless Sensor Network

Fault-tolerant technology for routing intelligent data transfer in the MWSN is analyzed in this paper. We propose to solve problems using operations such as path coding, an improved PSO algorithm based on artificial bee colony swarm optimization, and collaborative evolutions of master-slave groups and particle selections, so that the operational efficiency and reaction ability of our calculation methods will be improved, and the comprehensive fault tolerance of the MWSN and the reliability of network will be enhanced.

3.2.1 PSO Algorithm

Particle swarm optimization algorithms simulate the foraging action of a group of birds on the basis of the experience and cognition produced by foraging for food and sharing information. The first best solution will be found by way of individual collaborations and has wide applications [20]. In a D-dimensional vector space set, one group consists of M particles and one of the positions of particle i-th is x_i =[x_{i1} , x_{i2} , x_{i3} ......, x_{iD} $]^T$ The speed is v^i = [v_{i1}, v_{i2},......., v_{iD} $]^T$, and i=1,2,. . . , M. The i-th particle indicates that the previous best position is pi, and the optimal position searched by all particles is pg .Putting xi into the target function allows the application value to be calculated. Each particle needs to update its speed and position basing on the following formula for the (k+1)th iteration [21]. Where d=1, 2,. . . , D, w is the inertia weight, c1 and c2 are recognition parameters, and social parameters r1 and r2 are random numbers between 0 and 1.

$$V_{i,d}^{k+1} = V_{i,d}^{k} + c_1 r_1 (p_{i,d} - X_{i,d}^{k}) + c_2 r_2 (p_{g,d} - X_{i,d}^{k}) \qquad \text{(Equ: 3.11)}$$

$$X_{i,d}^{k+1} = X_{i,d}^{k} + V_{i,d}^{k+1} \qquad \text{(Equ: 3.12)}$$

3.2.2 Artificial Bee Colony Optimised PSO Algorithm

In the PSO algorithm, the search trajectory of guide particle pi (i=1,2, . . . ,M). When complicated multimodal functions are optimized, they will guide particle i to the best area, if it falls into an optimal local area and cannot jump out. Many particles will become mature earlier when they are led to the best local area and may weaken the particle's search ability. A new method of developing particle swarm optimization is proposed in this paper to overcome the problem of certain particles in the swarm maturing earlier and to promote a convergence rate and precision of optimization. The method of the proposed ABC algorithm is introduced into the PSO algorithm to search for operators, and the particle searches shall be directed to search in order to make the particles jump out of the local advantages as soon as possible.

$$Z_{i,j} = X_{i,j} + \emptyset_{i,j}(X_{i,j} - X_{k,j}) \qquad \text{(Equ: 3.13)}$$

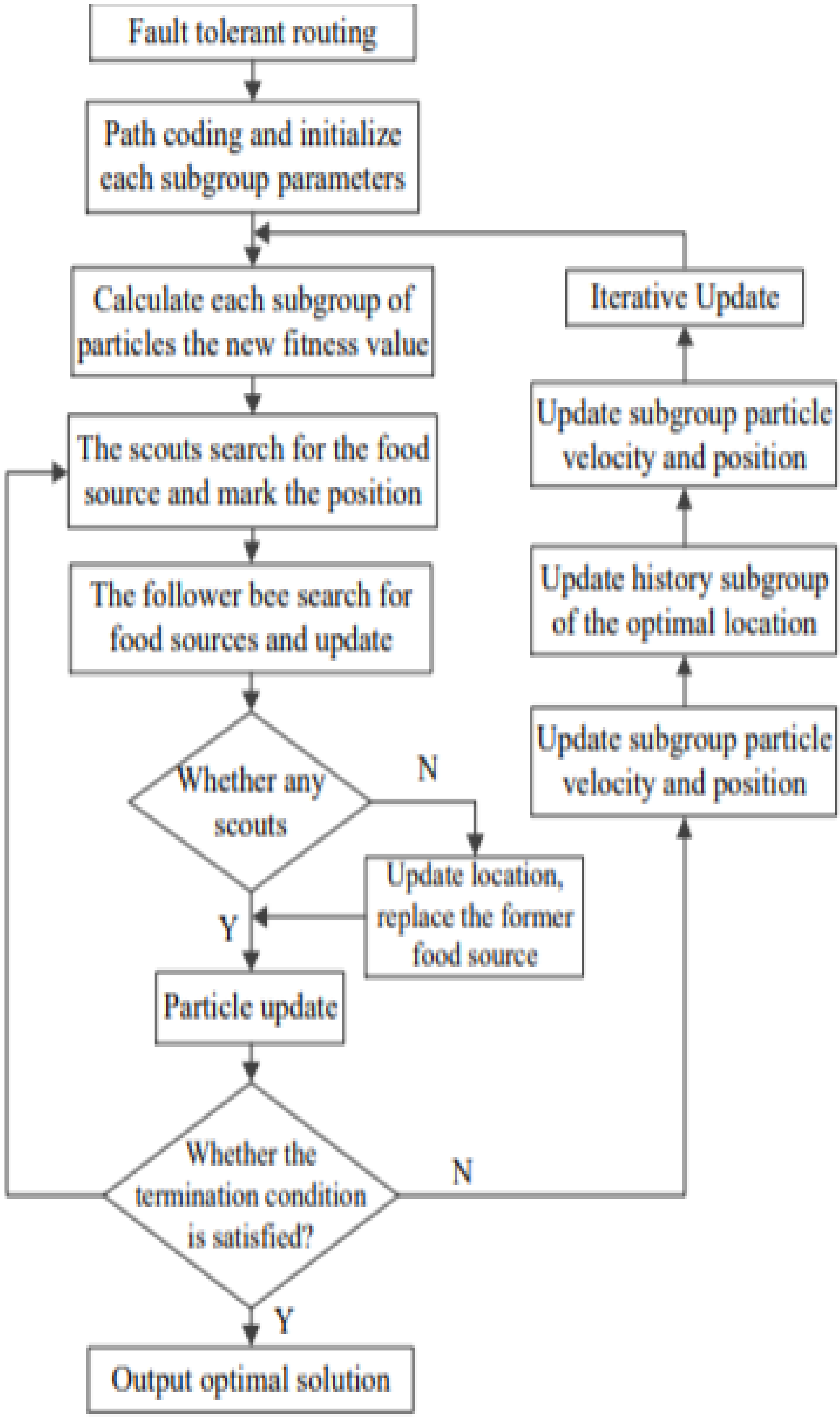


Figure 3.2: Flow chart of optimized PSO based on ABC algorithm .

TABLE II
SPECIFIC STEPS OF ABC OPTIMIZED PSO ALGORITHM

1)	Initialization, set the influence factor c_1 and c_2, the inertia weight of w, Generate M particles to form a population x_i, the initial speed of v_i, i=1,2,…,M.
2)	Calculate the fitness function value of each particle, update p_i and p_g of each particle.
3)	While the algorithm stop condition is not satisfied
4)	for i=1 to M
5)	for d=1 to D
6)	According to formula (12) to update the particle velocity
7)	According to equation (13) Update particle position
8)	end for
9)	if $f(v_i) < f(p_i)$
10)	$p_i = v_i$
11)	end if
12)	for k=1 to K
13)	According to equation (14) search for a candidate solution z_i around p_i
14)	if $f(z_i) < f(p_i)$
15)	$p_i = z_i$, $x_i = z_i$
16)	end if
17)	end for
18)	if $f(p_i) < f(p_g)$
19)	$p_g = p_i$
20)	end if
21)	end for
22)	end while
23)	Output of the optimal solution and the optimal value

Figure 3.3: SPECIFIC STEPS OF ABC OPTIMIZED PSO ALGORITHM

In 2006, a new intelligent bionic artificial bee colony algorithm with metaheuristics was proposed by the doctor Karaboga on the basis of the model of the bee swarm. Optimization performance in optimizing complicated unequal multimodal functions, mainly because the artificial bee colony algorithm has a very strong search ability. where k belongs to 1,2,. . . ,M, j belongs to 1,2,. . . ,D, are the indexes chosen randomly, and k not equal to i, phi i,j is the random number between -1 and 1. The strong search ability of the artificial bee colony algorithm is used in this paper and guides the pi(i=1,2,. . . ,M) to jump rapidly out of local best option to avoid prematurity in the algorithm. A flow chart of optimized PSO based on an artificial bee colony algorithm (ABC-PSO) is shown in Figure.Specific steps of the ABC-PSO algorithm are shown in Table.

Fault tolerant routing protocol based on ABC-PSO

The ABC-PSO algorithm is used to conduct fast rerouting when path failure is caused by the Sink moving to a new position. Some of the fittest nodes collections shall be adapted to assemble the path with the optimal fitness value using sensor nodes near the original path. The steps of rapid rerouting are as follows: Step 1: The data package GNm including any task lists will be broadcast when the mobile Sink loses connection with $n^j k$ Step 2: What belongs to the node of the original path N(Qj) should be checked after the node of GNm. is received.The data GNRm will be sent with the neighbor and task lists if it is, or the m will increase to m+1 and broadcast to the adjacent node. Therefore, only part of the node is updated in the original path N(Qj) and the other nodes of the original path are retained in the alternative pathway. As a result,only the path restoration protocol is implemented in the local area of the network for the purpose of balancing energy consumption and saving energy. Step 3: The information associated with the nodes of data package GNRm sent by the Sink and the node collection Nn constructing path shall be raised and the collection N(vSink) of the neighbor list shall be updated. Then, the alternative path Qj shall be calculated and constructed by the method of ABC-PSO (the path as shown in Figure 3 is 4-5-6. . . 44-45-46–47-48-Sink) and the task list shall be updated at the same time. Step 4: The broadcast of the Sink includes current data package GNRm_ACK. Once the node receives this package and finds that its ID belongs to the node of path Qj in the task list, then the connections will be built with those of the same upstream and downstream nodes of path Qj . The GNR_ACK will be sent to the neighbor node until this data package is received by the source node. At this point, the construction of the new alternative path from the source node to the Sink has been completed and the protocol is finished.

3.3 Simulation Comparison And Perfomance Analysis

3.3.1 Simulation Environment

In order to test the fault tolerance and efficiency of the algorithm in this paper, we use MATLAB to analyze the performance of the proposed algorithm. In the simulation environment set in this paper, Es is the sensing energy consumption of the sensor node, E_{N-R} is the energy consumption of the received data, received data energy consumption, E_{N-T} is the energy consumption of the transmitted data, Fa is the average transmission delay, and Rgad is the average delivery rate of the group are calculated as follows:

$$E_S = l * \varepsilon_s \tag{15}$$

$$E_{N-R} = l * \varepsilon_r \tag{16}$$

$$E_{N-T} = \begin{cases} l * E_{elect} + l * \xi_{fs} d^2, d < d_0 \\ l * E_{elect} + l * \xi_{mp} d^4, d \geq d_0 \end{cases} \tag{17}$$

$$F_a = \frac{\sum (F_r + F_p - F_n)}{N} \tag{18}$$

Where in formula (15), s=60×10-9J/bitin formula (15), $_r$=135×10-9J/bit in formula (17), mp is a multipath transmission parameter, mp=0.0013×10-12J/bit/m4, fs is the ordinary space transmission parameter, fs=10×10-12J/bit/m2.Eelect=45×10-9J/bit Parameter l is the length of the transmitted packet data. l=4000bit, d0=87mInitial energy of the sensing node E0=1J. The simulation of the round frequency is set to 300, and sensor nodes for each simulation have 10 data packets transmitting from the source node to the Sink with a 4kb capacity for each packet.The initial energy of the mobile Sink is 1000J, and the Sink would move uniformly in a straight line at a speed of 1 m/s.Artificial bee colony algorithm parameters are set as follows: population number is 50, limit value is 200, and the number of iterations is 50. Particle Swarm Optimization algorithm parameters are as follows: population number is 20, inertia weight w=0.96, c1=0.5, c2=0.7, and the maximum number of iterations is 200. Simulation environment parameters are set as shown in Table III.

TABLE III
SIMULATION ENVIRONMENT

Parameter	Value
Network size	500×500 m^2
Node number	100, 200
Radius	140 m
V_{Sink}	1 m/s
Initial energy	2 J
E_{elec}	50 nJ/bit
E_{fs}	10 pJ/bit/m^2
E_{mp}	0.0013 pJ/bit/m^4
Data size	4000 bits
d_0	$\sqrt{E_{fs} / E_{mp}}$=87 m

Figure 3.4: Simulation Environment

In this paper, AODV-SMS , AODV-SMS (PSO) ,AODV-SMS (ABC-PSO)—three kinds of routing recovery protocols are compared. We study the performance of average energy consumption, network lifetime, network latency, network connectivity, and reliability in this section. AODV-SMSAODV routing recovery strategy for a single mobile Sink. Ad Hoc on demand distance vector routing protocol (AODV), when the source node detects the mobile Sink, the failure path will be replaced by the new path. AODV-SMS(PSO) Routing intelligent recovery strategy based on particle swarm optimization algorithm for wireless sensor networks with mobile Sink. AODV-SMS(ABC-PSO)Our proposed algorithm.

3.3.2 Comparison of Simulation Results

Network Energy Consumption

We can see that with the increase of network polling, whether for 100 nodes or 200 nodes, the network's total energy consumption increases, and the energy consumption of the AODV routing recovery protocol increases quite significantly, followed by that of the AODV-SMS(PSO) algorithm, while energy consumption increase for the AODV-SMS(ABC-PSO) algorithm is minimal. After the nodes increase, node density also increases. At this moment, the first died nodes of the AODV are generally located at the place where the path most commonly used by multiple nodes is closest to the Sink. Due to increased node density, more nodes tend to use the same path, and the energy consumption of the nodes in ”hot spots” begins to increase dramatically, resulting in a significant decline over the lifetime of the network. The routing recovery mechanisms of multiple paths based on the AODV-SMS (ABC-PSO) bring the path structure closer to the net, select a path using residual energy to reduce the chances of overheating the individual path, and alleviate energy loss at ”hot spots” so as to control the energy consumption of these nodes to some extent.

Energy Utilization Rate

The algorithm proposed in this paper has a higher efficiency than AODV routing protocol. The main reason is that AODVSMS(ABC-PSO)algorithm only repairs failure paths within the local area near the Sink, thus as Sink mobile network energy consumption gets more balanced, AODVSMS(ABC-PSO) energy consumption is lower than other protocols. So this algorithm adopted high efficiently saves energy of nodes and extends the network life time. Similarly,although swarm intelligence optimization algorithm AODV-SMS(ABC-PSO) consumes parts of energies tooptimize search, this algorithm can offer faster global convergence and higher-quality fitness solutions. It allows those nodes with superior QoS parameters to build alternative paths, so as to get a more stable transmission condition to save energy and extend network lifetime. It can also be seen that, with the expansion of the network scale, the energy loss of protocol also gradually increases. This suggests that a larger network scale will extend the path distance, which in turn will cause unstable routing and increased power consumption.

Packet Loss Rate

In terms of packet loss rate that the AODV-SMS(ABC-PSO) algorithm has a lower rate than the AODV-SMS and AODV-SMS(PSO), and it can transfer 20percent and 5 percent more data packets respectively, than the AODV-SMS and AODV-SMS (PSO)to the Sink in most cases. The reason for this is that when the AODV-SMS (ABC-PSO) detects a broken routing path,it provides a rapid and efficient routing recovery mechanism to find the best alternative path, so as to enhance the success rate of the data transfer. When the network scale expands, the packet loss rate will also go up.Apparently, the expansion of the network scale results in longer paths from the source node to the Sink, increasing the packet loss rate. Overall, the packet loss rate of the algorithm presented in this paper is still the lowest.

Data Transmission Latency

The time-delay of end-to-end data transmission refers to the average time the data groupings require to go from the routing layer of the source nodes to the routing layer of the destination nodes, including the route discovery time-delay, queue delay on the interface of the data packets,and transmission delay and re-transmission delay in the MAC layer, reflecting the overall routing efficiency. This is mainly because with fewer nodes, the congestion of the network is not serious. However, the multiple path mechanism of the AODV-SMS(PSO) and AODV-SMS(ABC-PSO) means that the chances of using the non-shortest paths increases, and thus the end-to-end delay performance is higher than that of the AODV. The AODV-SMS(ABC-PSO) routing recovery protocol shows the trend of having a larger difference in packet transmission delay than the other protocols, which suggests that a greater network scale may bring about a greater path of distance and delay. Therefore, the proposed algorithm may have advantages in that it can choose more suitable nodes to build better alternative paths and make the distribution of network power consumption more balanced

Network Connectivity

For mobile networks, generally, the continuous motion discretization method is used to calculate the rate of network connectivity. That is, over a relatively short time period, it is believed that the network topology does not change. For the network at a moment, the method of node traversal is used to calculate network connectivity. The node traversal method is set up to select an initial node and directly connected nodes, and then binary-hop connected nodes and three jump connected nodes are searched in sequence, until the node number connected to the initial nodes does not further increase The network connectivity of the AODV-SMS(PSO) algorithm is high and more stable, ranging between 0.70 and 0.82. The network connectivity of the proposed algorithm has the highest overall stability, ranging between 0.70 and 0.82, but there are large fluctuations in some points, ranging from 0.75 to 0.88. On the whole, the network connectivity of the proposed algorithm has the highest performance

Network Reliability

The connectivity reliability of the sensor node I1 refers to the interconnected reliability of the end-to-end nodes, and the reliability matrix is calculated in line with the distance between nodes in particular, according to the reliability matrix and the random edge reliability matrix sample, and then on the basis of a Monte Carlo analysis in which the average node connectivity reliability value is obtained after 50 times. The capacity of the network I3 is the survival probability of the network, and the survival probability of the network is usually obtained by dividing the surviving node of the network nodes by the number of all network nodes. The integrated network reliability of the AODV-SMS(PSO) algorithm is relatively stable and slightly fluctuant, in the range of 0.81 to 0.89, with an average of 0.84. The integrated reliability volatility of the AODV-SMS(ABC-PSO) algorithm is high, ranging from 0.87 to 0.94, with an average value of 0.9. It is thus clear that the reliability of the artificial bee colony algorithm is the highest, which is consistent with the expectations of the simulation. In the data collection process for the WSNs, the artificial bee colony algorithm has the highest collection efficiency, the lowest energy consumption, the least latency and the best reliability of the network.

Path Recovery

We can find the shortest path as quickly as possible, and with the best performance. Regardless of whether the simulated sensor network is placed in 100 or 200 nodes, compared with the other two methods, the proposed algorithm has better network connectivity and reliability, longer network lifetime, and shorter delay. The main reason for this success is that after the routing recovery strategy replaces the path by using the proposed algorithm, it will redesign the shortest path will rarely overlap the paths before. The proposed algorithm is not confined to the original shortest path, but searches for the shortest path again according to the surviving nodes to find the global optimal path.

Conclusion

Given the routing fault tolerance in mobile WSNs, and giving consideration to the energy balance mechanism in the optimization process, in this paper we analyze the fault tolerant routing between nodes in the MWSN and establish an intelligent fault-tolerant routing model within the clusters. We adopt an artificial bee colony particle swarm optimization algorithm to study the optimal recovery strategy of an alternate route. We then further enhance the exploration and optimization capacity of the algorithm to prevent convergence to a local optimum, and we improve the optimization efficiency and optimal performance, as well as the operational efficiency and response capabilities, of the sensor network, which ultimately enhances the overall fault tolerance and reliability of the MWSN. In this paper, we consider only the mobility of a single Sink node. In future research, we will explore the routing fault tolerance problems of multiple mobile Sink nodes and heterogeneous WSNs; further improve the efficiency of fault tolerance, network reliability and energy utilization rates; enlarge the message capacity of the network; and extend the network lifetime. These further research directions will be important topics for studies on the fault tolerance of the MWSN.

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