Research of QoS routing protocol for underwater wireless sensor network

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Abstract

With the constant strengthen of detecting activity underwater in recent years, the research of underwater wireless sensor has been gradually paid more attention to. This paper mainly introduces the basic concept, main advantages and network structure of underwater wireless sensor network and stress on analyzing the relative characteristics of the QoS routing protocol of current underwater wireless sensor network under the application background of large scale of hydrometry monitoring. Besides, it also elaborates network topology architecture and data forwarding mechanism of the QoS protocol and attempts to put forward the improved QoS protocol on the base of colony. And this QoS (Quality of Service) routing protocol selects the routing mechanism of a route or a dynamic routing protocol covering all kinds of QoS parameters according to the available network resources and business flow requirements of QoS with a extremely essential realistic research significance.

Keywords: underwater wireless sensor networks, hydrometry monitoring, network topology architecture, data forwarding, routing protocol

1 Research of underwater wireless sensor network

1.1 INTRODUCTION AND BASIC CONCEPTION

Wireless sensor network is a newly-developing research field covering multidisciplinary knowledge and being highly integrated by technology [1]. It enables the logical information world connect and combine with the real physical world mutually so as to change the exchange ways between human and nature. That is why it has an extremely large potential application value and has been widely applied on some important areas, such as, environment monitoring and forecast, natural disaster warning, electricity system and so on. And with the wide application of Internet and the development of science in recent years, the research of detecting underwater environment for exploring the underwater source has been a new research emphasis. In order to detect the water regimen for the monitoring and protection of it, various scholars has done a lot of researches and figured out amounts of efficient methods among which underwater wireless network, whose routing protocol research even become the priority, has become a newly hot area of research in terms of its high enough science and strong enough real-time performance. Due to the shortcomings existed in wireless sensor network, such as, low wireless transmission broadband, poor security and easy to be disturbed, the reasonable choice of routing protocol has an important practical significance. In recent years, though scholars have put forwarded lots of routing protocol successively during the research, there are still a lot of unsolved problems temporarily on the aspect of practical application. Therefore, the choice of routing protocol has become a difficulty of the research and possesses important research significance.

Underwater wireless sensor network at random distributes the numerous cheap micro sensor nodes to the interested waters by using the submarine, aircraft or surface ships while these nodes corporate to perceive, collect and manage the information of perceived objects in the covered area through a multi-hop and self-organized network system formed by the underwater acoustic wireless communication mode and send these information to the receivers.

1.2 ADVANTAGE

Underwater wireless sensor network possesses the advantages which cannot be overtaken by the traditional sensor technology [2]:

1. Underwater sensor network mainly consists of some intensive, low-cost and distributed randomly nodes. And its particular self-organism and fault-tolerant ability guarantee that the whole network system will not break down after some nodes get damaged due to the hostile attack.

2. Distributing the nodes can realize the multi-angle and multi-dimensional information combination so as to improve the data collection efficiency and obtain the more accurate information.

3. Underwater sensor network uses the sensor node closed to the target to improve SNR (Signal to Noise

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Ratio) of receiving signal and the detecting performance of the system.

4. The combined application of various sensors in a node is beneficial to improve the location and tracking performance of the system and expand the ability of covering system's space and time. Some mobile nodes at the network can also be used to adjust the network topology architecture and eliminate the shadow and blind spots in the detecting area.

1.3 UNDERWATER SENSOR NETWORK STRUCTURE

According to some relative research, wireless sensor network has three kinds of basic primitives, that is, Target, Sensor Node and Observer Node. And the typical wireless sensor network structure is displayed as Figure 1: Target is the source of signal and in general the number is one or more than one; Sensor Node is the monitor of the signal and usually the nodes are connected by wireless multi-hop mode which have no center while the number of the nodes is one or more; Observer Node is the receiver and controller of the signal and in charge of monitoring and transmitting signals, sending request to network and so on. Though there are lots of observer nodes, the number of efficient nodes is limited. At the network, Sensor Node has a multi-hop transmission along the sensor backbone nodes (cluster head) after detecting the data. During the process of transmission, monitoring data might be managed by several nodes. After the multi-hop transmission, it goes from routing to sensor route and lastly to server by Internet or the satellites. And then the users dispose and manage the sensor network as well as announce the monitoring task and record the monitoring data through the server. In addition, this paper stresses that routing is a process which transmits the efficient nodes information to observer nodes.

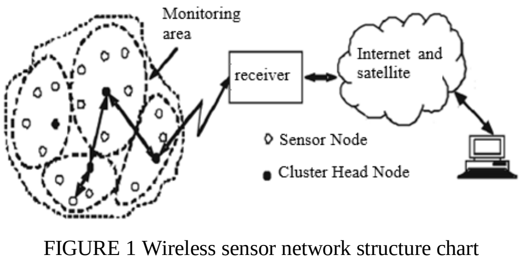

FIGURE 1 Wireless sensor network structure chart

Generally, underwater sensor node mainly consists of a master controller or CPU, which connects the sensor through the interface circuit and stores in memory after receiving the data of the sensor and then deals with these data and sends to the other network nodes by the MODEM. Its inner structure is displayed as Figure 2:

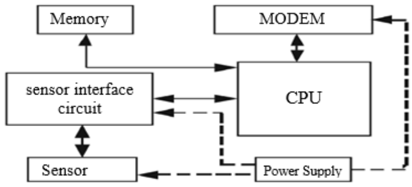

FIGURE 2 The inner structure of an underwater sensor node

There are two kinds of sensor nodes at the current network, Sink node and ordinary sensor (UW sensor node). Sink node's managing, storing and communication capabilities are all strong .The sink node, which is deployed on the water surface in general, is in charge of connecting sensor network and external network. Announcing the monitoring task and reflecting the situation to the external network while the ordinary sensor is deployed at the interested 3D area underwater with a weak managing and storing capability.

1.4 HYDROMETRY MONITORING NETWORK OF UNDERWATER WIRELESS SENSOR

There are mainly 3 kinds of underwater wireless sensor network on the current research: 2D, 3D static network and 3D network with AUVs. The sensor nodes of two structures of 2D and 3D static network are all deployed into the sea while the sensor node of the 3D network with AUVs is flowing. And the structure of 2D static network system is displayed as Figure 3:

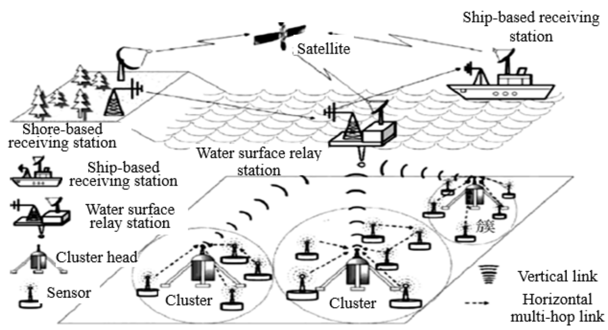

FIGURE 3 The structure chart of 2D static network system

The sensor network nodes of the 2D static network are fixed at the seabed and self-organized as cluster. The information collected are transmitted to cluster head through multi-hop and then transmitted to the water surface relay station or ship-based receiving station to realize the communication with shore-based receiving station and reach the data process center finally.

The structure of 3D static network system is displayed as Figure 4:

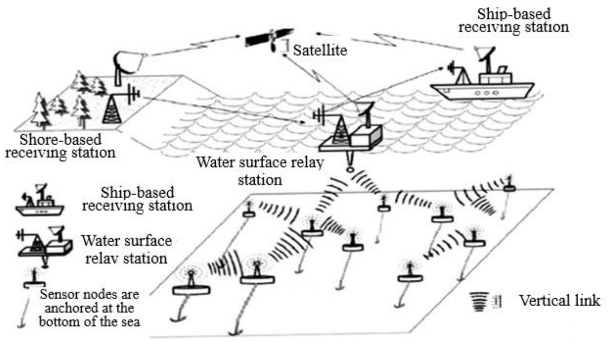

FIGURE 4 The structure chart of 3D static network system

The nodes of 3D static network are fixed at the seabed by the anchor chain. The 3D network distributed under the water is formed by adjusting the length of the anchor chain while each sensor node must be relaying the information to the aggregation node on the water surface which requires that there is at least one link existing between each node and water surface relay station. Therefore, 3D static network can obtain the underwater sample more easily than the 2D network.

Both of two kinds of static network mentioned above have obvious advantages. However, their shortcomings are also very clear, that is, a great difficulty of arrangement and maintenance which is hard to reach. Thus, the 3D static network based on AUVs(surface float)turns up at this situation [3]. Figure 5 below is the structure chart of 3D static network system based on surface float:

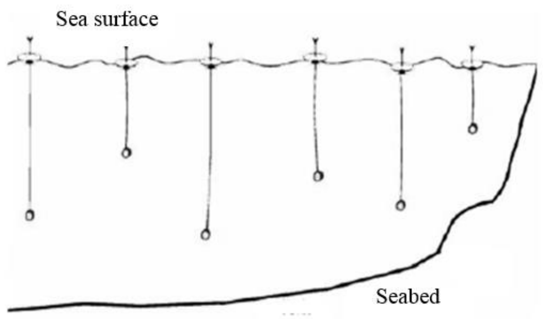

FIGURE 5 The structure chart of 3D static network system based on surface float

The sensor nodes locate in the float floated on the sea surface at the very start, but the sensor nodes are deployed under the water according to the calculated depth after distributing these floats so as to form the distribution space of 3D sensor nodes inside which each sensor nodes are all made up by a group of sensors and the sensors belonging to the same sensor node will be deployed at the same depth under the water. The sensors communicate with the floats through the cable while the sensor nodes communicate with each other and collect the floats to gather the data of sensor nodes by the wireless signal. This kind of network system structure is easy to arrange and maintain but easy to be found.

TABLE 1 A sketch of the logic of Hydrometry Monitoring based on wireless sensor

Data Processing: long-distance data server, data analysis and process software	**main function:** receive the monitoring data in the monitoring area, data process, offer the water quality information to the users; **key technology:** data storage, data analysis and processing;
Data transmission: wireless communication network, network routing algorithm;	**main function:** adopt the suitable WSN routing algorithm, transmit the data to data management center through the wireless communication network **key technology:** wireless communication mode, network routing strategy;
Data Collection: sensor hardware, sensor software;	**main function:** sensor nodes self-organize the monitoring network, perceive the monitoring data and pack it as data frame **key technology:** software and hardware structure of sensor node, network topology architecture

The system logic can be assigned to three parts, that is, data collection, data transmission and data processing (Table 1). The realization of the system function mainly depends on the cooperation of sensor node, wireless communication network and long-distance data server. The data collection of the monitoring area underwater mainly relies on the underwater sensor nodes to collect the hygrometry parameter data and then transmit the data to the Sink node on the water surface through multi-hop transmission. And the realization of part of functions of data transmission mainly depends on the wireless communication network and routing algorithm. After intercepting the data of Sink node, it should intermediately complete the data combination and transmit the data to the server through wireless communication mode (Internet or GPS). Besides, the data processing is operated by long-distance server which processes the data after receiving the monitoring data and then offers the data for the relative department of hygrometry monitoring (the users) [4].

1.5 ROUTING PROTOCOL SUITABLE FOR UNDERWATER SENSOR

According to the angle of discovering strategies by routing, wireless sensor routing can be divided into active routing and passive routing [5].Active routing can also be called as table driven routing whose nodes usually exchange routing information through periodically broadcasting routing information grouping to discover the routing on this basis actively [6]. Therefore, its advantage is the delay is short only if existing the routing destined for destination node as the nodes need to send the data grouping; its disadvantage is the high cost and the source waste caused by building or rebuilding some inefficient and unwanted routing as updating the current topology structure information [7]. Thus, for the moment, active routing is not suitable for wireless sensor routing protocol. Another kind of routing is based on the principle of labor-saving which means the routing discovery will be started only when the routing node without destining for destination one. Its advantage is that it can save a lot of sources and costs without building or rebuilding the inefficient routing. However, because passive routing will be started only when there is no destination node and keep waiting in the middle as sending the data grouping, the data will be delayed [8]. The passive routing protocol based on the usage of passive routing's advantage is a type of routing protocol owned particularly by the Ad-hoc network with the advantage of reducing routing consumption and improving network's handling capacity [9].

At present, the wireless sensor routing protocols applied widely are mostly passive routing protocol. However, the active routing is more suitable considering about the characteristic of strong real-time performance and short routing delay required by underwater wireless transmission network for a large scale of hygrometry monitoring. And this research attempts to adopt multi-hop distributed network topology structure and chooses the QoS routing protocol of underwater transmission network in terms of the adaptability of the algorithm in consideration of the limited amount of energy of the underwater nodes and the large energy consumption of the communication of underwater nodes to study the low energy consumption routing protocol of underwater sensor network under the restrain of multi QoS parameters and verify its efficiency by simulation verification.

2 Network topology model of QoS routing

QoS (Quality of Service) routing selects the routing mechanism of a route or a dynamic routing protocol covering all kinds of QoS parameters according to the available network resources and business flow requirements of QoS [10]. QoS routing researched by this paper adopts multi Sink nodes and multi-hop underwater sensor network topology structure. As displayed as Figure 6, the network adopts 2 kinds of efficient sensor node, one of which is ordinary sensor (UW sensor node) deployed in the monitored 3D area under the water and equipped with underwater acoustic MODEM being used to monitor the hydrometry.

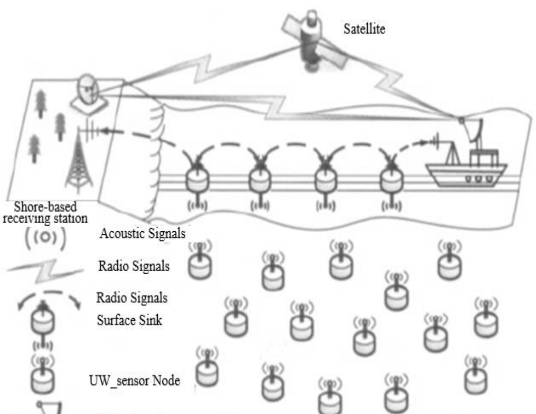

FIGURE 6 Network topology structure model of QoS

The other of which is Sink nodes distributed on the water surface and used for communication of Sink nodes which is in charge of transmitting data grouping and equipped with RF MODEM and underwater acoustic MODEM. When the underwater monitoring environment issue happens, imaging sensor will transmit the data of underwater environment, such as, figures, videos and etc., to Sink sensor through multi-hop transmission of the middle sensor and then to monitoring center by the servers such as, communication satellite or Internet. The monitoring center will make a hydrology judgment in terms of the backward data and take some efficient actions to handle and control the hydrology.

3 QoS routing algorithm of underwater sensor based on colony

3.1 BASIC CONCEPT

Typically QOS path optimization algorithm will be used in several common genetic algorithm can quickly and efficiently obtain good stability approximate optimal path [11]. Genetic factors as well as particle swarm algorithm based on improved particle swarm optimization algorithm to model solved, not only significantly improve the convergence rate, better path solving [12]. For underwater wireless network constructed for this paper, the use of ant colony optimization algorithm. This research is started for the purpose of applying the underwater sensor for hydrometry monitoring which is a task required of strong real-performance and great energy consumption. The colony algorithm adopted in this research is a swarm intelligence algorithm simulating the collective behavior of the real ants in nature. Its fundamental is to make use of the artificial ants to simulate the real ants' behavior of looking for the way forward by releasing pheromone. Then confirm the positive feedback system of the individual pathfinding according to the strength of the pheromone and finally find out the best routine in the system through all systems of individual pathfinding among the colony.

Because the principle of network construction is simulating the collective behavior of ants, swarm intelligence should be relied on and it can succeed through the individual pathfinding without the help of global information. This kind of algorithm is very suitable for the sensor due to its characteristics of strong dynamics, high reliability and strong expansion. This paper will start the research according to the application of QoS routing algorithm of underwater sensor with the colony algorithm.

In general, sensors are all aimed at data transmission. When a source node needs to transmit the data, there will be producing an ant which is in charge of data transmission by making use of pheromone in the area to look for another ant that is the other sensor node in the underwater monitoring area. This kind of ant starting off from the source node is called predecessor ant [13], which is mainly in charge of searching for the routine of data transmission and recording the information of the routine. The other ant is called successor ant which updates the pheromone with the global information [14]. After it reaches the Sink node, the Sink node will calculate the pheromone renewal of the whole path and produce the other ant which returns along the original way to update the sensor pheromone in the path. This kind of data transmission method based on the colony algorithm can reduce calculated amount of sensor nodes so as to reduce the energy consumption [15].

The efficient measurement factors of sensor routing mainly are Bandwidth, Delay and Lost ratio. These three measurements collectively reflect the influence of each parameter on the network performance and make up a function as a new single measurement together as the bellowed expression:

$$f(p)=\frac{Bandwidth(p)}{Delay(p)\times Lostratio(p)}. \quad (1)$$

But when *Bandwidth* cannot satisfy the requirement of QoS and the answer of *Delay*(*p*)×*Lostratio*(*p*) is less than a certain value, *f*(p) can get a larger value. However, as a matter of fact, this routine cannot satisfy the requirement of QoS due to the Bandwidth. Therefore, we also need to discuss about the influence of each factor on the network performance among them three.

Suppose *p*(*s*,*d*) is a path from *sender*(*s*) to *receiver* (*d*), and the calculation equation of *Bandwidth*(e), *Delay*(*e*), *packet-loss*(n) and *energy*(*n*) is as follows:

$$bandwidth(p(s,d)) = \min\{bandwidth(e) \mid e\in p(s,d)\}, \quad (2)$$

$$delay(p(s,d))=\sum_{e\in p(s,d)} delay(e), \quad (3)$$

$$packet\_loss(p(s,d)) = 1-\Pi(1-packet\_loss(n)), \quad (4)$$

$$energy(p(s,d))=\min\{energy(n)\mid n\in p(s,d)\}, \quad (5)$$

QoS path should satisfy the bellowing conditions: Bandwidth restraint: $bandwidth(p(s,d))\geq B$. Delay restraint: $delay(p(s,d)\leq D$; packet-loss restraint: packet-*loss*(*p*(*s*,*d*))<=*PL*; energy restraint: *energy*(*p*(*s*,*d*))>=*E*.

According to the colony algorithm in this paper, the probability function of the kth ant choosing the next node *j* from node *i* is:

$$P_{ij}(k)=\begin{cases}\dfrac{\tau_{ij}(t)^{\alpha}\, n_{ij}(t)^{\beta}}{\sum_{h\in tabu_k}\tau_{ij}(t)^{\alpha}\, n_{ij}(t)^{\alpha}\, n_{ij}(t)^{\beta}}, & j\in tabu_k\\ 0, & j\notin tabu_k\end{cases}, \quad (6)$$

where n_{ij} is the heuristic information from node *i* to node *j*; τ_{ij} is the amount of pheromone with a initial value of τ_0, α is the regulatory factor that pheromones choose the next node; β is the regulatory factor that the distance of two nodes chooses the next node; $tabu_k$ is the gather of optional nodes chosen by the ants in the next step and if it is 0, the ant is assumed to be dead.

In general, the service type of underwater sensor network in this research can be divided into three different types with different calculation equation of startup information and generative rule of candidate nodes in Equation (6).

The classified calculations in terms of specific circumstance are as follows:

1) If *service*=1, it means the audio and video streaming service required of high bandwidth, low delay and energy saving but low reliability. Suppose at present, the predecessor ant is at node *i*, which is most close to node *u*, then the generative rule of candidate node:

$$tabu_k=\{u\mid ant^k.p\_d+delay(i,u)\leq D\wedge bandwidth(i,u)\geq B\wedge dist(i,\sin k)>dist(u,\sin k)\wedge u.en\geq E\}, \quad (7)$$

where $ant^k.p\_d$ means the delay from the source node to the current node while the calculation of heuristic information:

$$n_{iu}=\frac{1}{E_c delay(i,u)^{v}} \quad (8)$$

$$E_c=\frac{dist(i,u)}{dist(i,\sin k)-dist(u,\sin k)}, \quad (9)$$

$$v=\begin{cases}2; & \dfrac{dist(i,\sin k)}{D-ant^k.p\_d}\geq ant^k\dfrac{dist(s,\sin k)}{D}\\ 1; & otherwise\end{cases}, \quad (10)$$

where E_c means the energy consumed when the mark carries forward at a unit distance. $\frac{dist(i,\sin k)}{D-ant^k.p\_d}$ means the forward speed required when the ant moves from the current node to aggregation node. If it is larger than the nominal speed, it means the speed of the ants moving from source node *s* to *i* is slow so that the delay factor should be attached more attention to and *v*=2.

2) If *service*=2. It means the common information service required of high energy-saving but low Bandwidth, Delay and liability. Therefore, the generative rule of candidate node is:

$$tabu_k=\{u\mid dist(i,\sin k)>dist(u,\sin k)\wedge u.en\geq E\}. \quad (11)$$

The calculation of heuristic information is:

$$n_{iu}=\frac{1}{E_c}=\frac{dist(i,\sin k)-dist(u,\sin k)}{dist(i,u)^2}. \quad (12)$$

3) If service=3, it means the abnormal warning situation. Thus, the generative rule of candidate node is:

$$tabu_k = \{u \mid ant^k.p\_d + delay(i,u) \le D \wedge dist(i,\sin k) > dist(u,\sin k)\}. \quad (13)$$

The calculation of heuristic information is:

$$n_{iu} = \frac{dist(i,\sin k) - dist(u,\sin k)}{delay(i,u) \times packed - loss(u)}, \quad (14)$$

where the calculation of selection probability of predecessor ant is as mentioned above and it can calculate the routine of predecessor ant. Besides, the successor ant is in charge of the end-to-end delay. Therefore, we also need to calculate the path of the successor ant and the pheromone renewal calculation of the successor ant should be accomplished according to the following expression:

$$\tau_{ij}(t+n) = (1-\rho)\tau_{ij}(t) + \rho\Delta\tau_{ij}. \quad (15)$$

The equation mode of $\Delta\tau_{if}$ is:

$$\Delta\tau_{ij}^k = \begin{cases} Q; delay > D_{\max} \vee e_{ij} \in t \\ Q + \dfrac{1}{E_{park}(t)}; delay(r_k) \le D_{\max} \vee e_{ij} \in t \end{cases}. \quad (16)$$

We can see that successor ants usually update the pheromone by a constant *Q* as its delay requirement cannot be satisfied on the path from node *i* to node *j* from the Equations (15) and (16). On contrary, when the delay needs are satisfied, successor ants update the pheromone by the global heuristic information. The combination of these two ways can avoid of the loss of local message.

3.2 DESCRIPTION OF QOS ROUTING PROTOCOL

The routing algorithm studied in this research is based on the QoS routing algorithm of colony and start to make each node of the sensor network obtain n pieces of path which take n neighbor nodes as next hops. And the purpose of the QoS routing algorithm studied in the research is to evaluate comprehensively each path among these n pieces of path and select the transmission path which satisfies the delay needs with the most efficient energy.

The specific algorithm flow chart is as follows Figure 7. The basic steps of QoS algorithm of ant colony optimization at underwater wireless sensor network are as follows:

Step 1: at the beginning, *NC*=O, that is to say, the searching time is 0 at the very start and the pheromone concentration of all paths are set as the initial value while the individual in the ant colony starts to look for paths.

Step 2: during the process of pathfinding of any ant *k* (*k*= 1, 2,…, *m*) in the colony, we should calculate the probability of choosing the next hop node j from node *i* according to the Equation (6) and add node *j* to $tabu_k$ so as to avoid repeating this node and save energy.

Step 3: When the ant find the Sink node, it calculate the pheromone of different paths in terms of Equation (15) to search for the optimal solution and then realize the pheromone renewal.

Step 4: Record the optimal solution obtained from the calculation of successor ants, *NC*=*NC*+1.

Step 5: If coming out the optimal solution, the progress should be ended and output the optimal value; but if the optimal solution till cannot be calculated, we should be back to the step 2 and repeat the cycle till work out and output the optimal value.

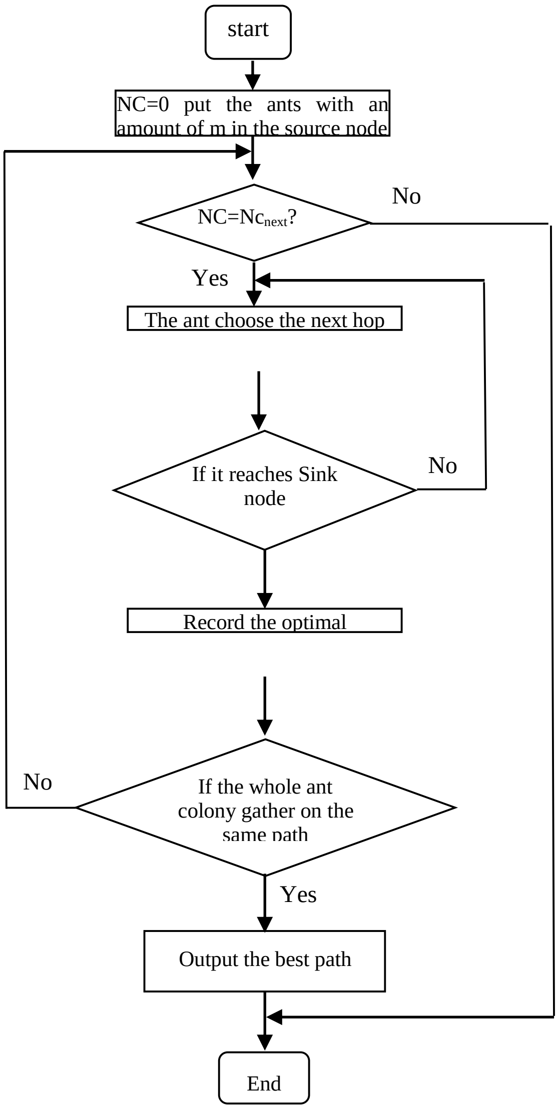

FIGURE 7 The algorithm flow chart of QoS routing of ant colony optimization for underwater wireless sensor network

The realization process of pseudo code of QoS algorithm of ant colony optimization at underwater wireless sensor is described as follows:

1) Set the initialization:

```
NC=0; //set cycle counter
τij = C; //set the amount of initial pheromone on each edge C
Δτij = 0;//the amount of initial pheromone increment on each edge 0
S=1; //S is taboo index, the initial tabuk in tabu List is 0
for k=1 to m do //put each ant randomly at each node
End for
```

2) process of pathfinding:

for k=1 to m do;
For j =l to n-l do; //node j
S=S+1;
If(have real-time packet) //produce real-time monitoring data
{ for(k=0;k<i.NeighborList;k++){
//examine neighbor node
If （QoS>=i.NeighborList[K]);

$$P_{ij}=\frac{\tau_{ij}\left(t\right)^{\alpha}n_{ij}\left(t\right)^{\beta}}{\sum_{h\in tabu_k}\tau_{ij}\left(t\right)^{\alpha}n_{ij}\left(t\right)^{\alpha}n_{ij}\left(t\right)^{\beta}}$$

//calculate the probability
Then{addInTempleList1(node,templeList);
//add the node to TempleList1
NC=NC+l;}
Node=Random(i.TempleList;count);
//select any node from TenpleList1
Send(QoSpacket,node);
//send information packet to node}
（3）update the pheromone
For k = 1 to m do;
For S =l to n-1;
For each routingnode j from Sender do;
//transmit the data from Sender to the node
Begin;
dim node;
If(received real-time packet);
//receive real-time data
Then{set PacketPRI(Packet:BIG);
//set packet's dispatching priority big
$\tau_{ij}(t+n)=(1-\rho)\,\tau_{ij}(t)+\rho\Delta\tau_{ij}$
//pheromone
Else{//delayed data
Set PacketPRI(Packet:SMALL) }
//packet's dispatching priority is small
for(k=0;k<i.NeighborList.count;k++){
//examine neighbor node
if(i.NeighborList[k].MHC=Sender.MHC-1)
//if the neighbor node MHC is Sender's node MHC-1
Then{addInTempleList1(node,templeList)}
//Add the node to TempleList1}
node=BiggestPRE(i.TempleList1:count);
//select the node with the biggest PRE in TempleList1
Send(QoSpacket,node);
//Send the information packet to the node
NC=NC+1;
end

The adoption of QoS routing protocol based on ant colony can not only have the real-time hydrometry monitoring but also reduce the energy consumption of the network and lengthen the network life cycle.

4 Simulation verification

In order to verify the efficiency of QoS routing protocol based on ant colony at underwater sensor and make the effect obvious, this research will have a simulation test which takes energy consumption and end-to-end delay as the measurement under the same experiment environment with SAR,SPEED and QoS algorithm based on ant colony [16].

SAR algorithm is the first routing protocol which possesses QoS awareness [17]; it has built pieces of paths from source nodes to Sink nodes with the advantage of less energy consumption comparing with the Least Energy Consumption Measurement Protocol which only considers about the energy consumed on the path. Besides, SPEED protocol is a real-time routing protocol supporting soft real-time communication service on the basis of Stateless Non-deterministic Geographical Forwarding (SNGF) Mechanism with the advantage of reducing the delay and routing void [18].

Currently, there are a lot of simulation environments of wireless sensor network, and this research choose NS-2 simulation tool to evaluate the performance of simulation routing protocol of wireless sensor [19]. In this experiment, we assume that there are 50 nodes being distributed randomly in the 500×500 monitoring area and at random pick out the source node and the target node. The communication scale of nodes is 60m and the initial energy is 10J while the speed of periodic data packet produced by each node is 10packet/s. The energy consumed during the nodes send data packet is set 0.009(J/packet) while the energy consumed during the nodes receive data packet is set 0.013(J/packet). In the experiment, the parameters are: α = l, β = 2, ρ = 0.5, $\tau_{ij}(0)$ = 10, Q = 100. The Bandwidth is a random number between [1,10], the delay is limited around 10-30s, the iteration times are 20 and we will do 20 experiments and choose the average value to compare the results.

As displayed in Figure 8, we can see that there is a big difference between ACA, SAD and SPEED algorithm from Figure 9. as ACA algorithm has a lot of extra work at the beginning and the process of searching for the optimal path of ant colony is longer compared with the other two algorithms, it cannot be accomplished at short time. Thus, the energy consumption of ACA algorithm is very high for such a long period and it is also the shortcomings of ACA algorithm. However, we believe that it will be overcome in the future

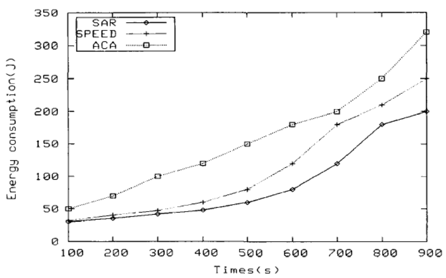

FIGURE 8 energy consumption of QoS algorithm

The experiment result on delay is displayed as Figure 9:

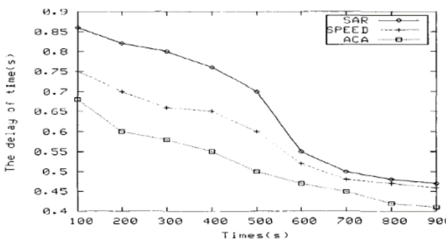

FIGURE 9 delay comparison of QoS routing algorithm

ACA algorithm always keeps low delay and occupies a much greater delay advantage than SAR and SPEED algorithm in 500s of residence time. But after 500s, these three are getting closer and closer and even once coincide with each other while ACA algorithm still shows its constantly reducing advantage. It is because that the network topology structure of ACA algorithm tends to be stable and the average delay becomes less with the constant increase of residence time.

5 Conclusion

The research of underwater sensor network is developing. This article firstly states the basic concept of underwater wireless sensor network and analyzes the advantages and different service types of different network system further. And then the author combines the underwater environment characteristics with the current sensor level to put forward the QoS routing protocol based on the ant colony which is suitable for the underwater sensor network application. In addition, this paper describes the formula and model of the QoS routing protocol based on the ant colony in detail and then do the simulation experiment by comparing the ACA, SAR and SPEED algorithm in terms of two measurements, that is energy consumption and delay. And the experiment proofed that the real-time performance of ACA protocol is stronger than the other two while its energy consumption is larger. Finally, the paper expects the research direction in the future to offer some thinking for the further study of underwater wireless sensor. We believe that there is an extremely wide prospect for the QoS routing protocol based on the ant colony.

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