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Optimization of Routing Protocol in Wireless Sensor Networks by Improved Ant Colony and Particle Swarm Algorithm

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Abstract

This paper mainly discusses the analysis and evaluation of routing protocols for Wireless Sensor Networks. Particle swarm algorithm has been proven to be very good solve many global optimization problems. Ant colony algorithm not only uses the positive feedback principle, the evolution process of speeding up to a certain extent, but also can be implemented in parallel in nature and different individuals through continuous information exchange and transmission. The paper presents optimization of routing protocol in wireless sensor networks based on improved ant colony and particle swarm algorithm. Finally, simulation results verify the effectiveness of the improved algorithm, and improve the search for optimal routing.

Keywords: *wireless sensor network, particle swarm algorithm, ant colony, routing protocol*

1. Introduction

Ant colony algorithm is a bionic intelligence algorithms, process it in real life from the ant foraging of inspiration, to use probability selection mechanism control path, also joined with the extension of time, pheromone volatilization factor. Many studies show that, ant colony algorithm has strong ability to find better solutions, this algorithm not only uses the positive feedback principle, the evolution process of speeding up to a certain extent, but also can be implemented in parallel in nature, different individuals through continuous information exchange and transmission, can work together, help to find a better solution. Ant colony algorithm can be understood as a kind of special reinforcement learning algorithm.

Particle swarm algorithm is easy to implement, low computational cost and uses less hardware resource. Particle swarm algorithm has been proven to be very good solve many global optimization problems [1]. Of course, PSO algorithm and other global optimization algorithm, is easy to fall into local optimum, convergence precision is not high, disadvantage of slow late convergence, in the theoretical study on algorithm. The PSO algorithm analysis did not mature theory, few researchers for the convergence of the algorithm is analyzed, and most of the research on the structure and performance of the improved algorithm are studied, including the analysis of parameters, topology structure, particle to maintain the diversity, fusion algorithm and performance comparisons.

Wireless sensor network routing protocol from the drive mechanism can be divided into proactive routing protocol, on-demand routing protocol and hybrid routing protocol: proactive routing protocol, all routing has been formed before use; on-demand routing protocol only when needed to form; hybrid routing protocol is a kind of the new routing protocol the two ideas together. Due to the resource constrained wireless sensor nodes, and the number of nodes in a sensor network, sensor nodes do not have enough space to store a large number of routing table, so in practical application, on-demand routing protocol and hybrid routing protocol is more popular. Wireless sensor network routing protocols from the network topology structure point of view can be divided into: flat and hierarchical routing protocols. The paper presents optimization of routing protocol in wireless sensor networks based on improved ant colony and particle swarm algorithm.

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2. Routing Protocol in Wireless Sensor Networks Based on Improved Particle Swarm Algorithm

Classification of routing protocols for wireless sensor networks on the continuation of the traditional classification method of Ad hoc network, according to the different angles can be classified differently. According to the routing strategy point of view, can be divided into active and passive routing routing two types, according to the logical structure of the network management and routing protocols can be divided into flat routing and hierarchical routing. Active routing: also called the table driven routing (Table Driven), an active routing path by found a similar strategy with traditional routing protocol, by periodically broadcast routing information packet nodes, routing information exchange, active discovery route, at the same time, nodes must maintain to all network nodes [2]. Its advantage is that when a node needs to send data packets to the destination node, as long as the route exists, the required delay is very small. Shortcomings need costly overhead, as far as possible the routing update followed changes in the current topology, waste of resources to build and rebuild those are not used routing.

Particle swarm algorithm is from this model in enlighten and used to solve the optimization problem. In PSO, each optimization problems of potential solutions is to search a bird in space, called the particle. All of the particles are determined by a function being optimized fitness (fitness value), each particle has a speed determine the direction and distance they fly. Then the particle will follow the optimal particle current search in the solution space.

Particle swarm optimization algorithm is initialized to a group of random particle (stochastic). And then through the iteration to find the optimal solution. In each iteration, the particle is updated by following two "extreme": the first is the optimal particle itself to find the solution, the solution is called individual extremum point (personal best said its position). Another extreme is the optimal populations currently find solutions, this solution is a global extremum by global best, GB said its position). Also can only use one as a particle neighbor without the whole population, so extreme in all neighbors is a local extremum. Particle swarm optimization allows the intelligence algorithm is realized by constantly on the extreme point update.

Information dissemination protocol information consultation and has energy adaptive function based on. The basic idea of the protocol is: any two nodes are to be negotiated before the data transmission. Node will metadata (Meta2data) for a description of the original data, metadata includes some key information of the original data. The neighbor nodes according to the metadata information, decide whether you need to transport the raw data. When the information redundancy is very high, the amount of raw data is much higher than the metadata conditions, using this information negotiation protocol can greatly reduce the amount of data transmission based on it.

Compared to hierarchical routing protocol and single layer routing protocol, has better scalability, easier data fusion, thereby reducing power consumption. Single routing protocol, due to the expansion of the network size, gateway load will increase, leading to network delay. In order to improve the expansibility of the network, people put forward the concept of network stratification [3]. LEACH [5] is the first hierarchical routing protocol in sensor networks, routing protocol position need to know the location information of sensor nodes based on these information, can be used to calculate the distance between nodes, energy consumption and estimated construction more efficient routing protocol. As the sensor nodes are distributed in a region, and no IP address scheme similar to this, so we can build efficient routing protocol using location information, to prolong the network lifetime, as is shown by Equation (1).

$$Q_{x_i x_j} = 2\sum_{k=1}^{m} [\gamma_{x_i x_j}(k) - \gamma_{x_j x_i}(k)] D_k \sin(2\pi f k) \quad (1)$$

In the flat routing protocols, each node in the network status in the routing function the same, no hierarchical management mechanism. Advantages of planar structure routing is no special nodes in the network, the network traffic is uniformly distributed in the network, the routing algorithm is easy to implement. Disadvantage is scalability small, to a certain extent, limiting the size of the network, the network dynamic response speed.

In the hierarchical structure, cluster head node is not only responsible for the jurisdiction of the cluster information collection and fusion processing, forwarding is also responsible for the inter cluster data. The formation of each cluster hierarchical routing protocols are usually based on the retention of energy of sensor nodes and cluster heads close degree, at the same time in order to prolong the lifetime of the whole network, cluster head node selection need periodic updating. The advantages of hierarchical routing is suitable for wireless sensor network environment, large-scale, scalable. Disadvantage is that the cluster head nodes reliability and stability has great effect on the performance of the whole network, collecting and processing information will also be a lot of cluster head energy consumption.

In the theoretical study on algorithm. The PSO algorithm analysis did not mature theory, few researchers for the convergence of the algorithm is analyzed, and most of the research on the structure and performance of the improved algorithm are studied, including the analysis of parameters, topology structure, particle to maintain the diversity, algorithm and performance comparison [4]. PSO has simple, easy to implement, few parameters to set, without gradient information and other characteristics, in a continuous nonlinear optimization problems and combinatorial optimization problems have shown good results.

With the traditional PSO only to its historical best position and the neighborhood historical best position learning is different, each particle of CLPSO is random learning to their own or other particles, and each one can learn from different particle; the learning strategies so that each particle has more learning objects, can be in the latent space flight more, thus conducive to global search. CLPSO velocity updating formula.

$$v_{ij}(t) = wv_{ij}(t-1) + \varphi r(p_{f_i(j)}, j) - x_{ij}(t-1) \quad (2)$$

In the particle swarm algorithm, each optimization problems of potential solutions can be thought of as a point in the search space dimension, which we call "particle" (Particle). In flight particle to a certain speed in the search space, this to dynamically adjust the speed according to its own flight experience and companion flying experience. All particles have a adapt to the objective function to be determined value, and that his best position discovered so far.

Implementation of search diversification in the previous velocity of particles under the action of (Diversification), and the realization of centralized search process in the cognitive part and social part of the traction under (intensification), so the balance and restrict each other between these three determines the main algorithm can. Particle swarm optimization search is formed by such a group of random initialization of the particles and a population composed, performed in an iterative manner, as is shown by Figure 1.

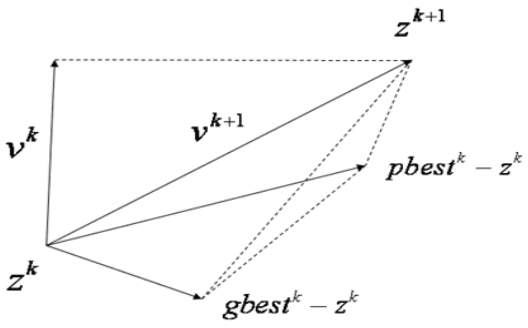

Figure 1. The Principle of Particle Swarm Move

Directed diffusion protocol is a routing mechanism based on the query. The whole process can be divided into interest diffusion, gradient is established and the path to strengthen the three stages. In the stage of interest spread, the sink node to the sensor node sends its want to obtain information types or content. A task type, the target area, the data transmission rate, time stamp message parameter of interest. Each sensor node after receiving the

information, save it in CACHE. When the information requirements throughout the sensor network, it would establish a gradient field between sensor node and sink node, a gradient field is based on the minimization of the cost and energy adaptive principle. Once the collection of sensor nodes to a sink node data of interest, can according to the gradient field for the fastest path for data transmission.

HREEMR is proposed based on the directed diffusion routing mechanism, the goal is to improve routing reliability by maintaining multiple available paths. The protocol in operation during the localization algorithm and DD the same source node and sink point optimal path P, at the same time in order to protocol can still the construction of more than one do not want with P redundancy path guarantee normal running of P failure (emergency measures in order to avoid the occurrence of the main path failure phenomenon and take). HREEMR protocol proposed disjoint multipath and winding path two different multipath mechanism.

$$\chi = \frac{2}{\left|2 - l - \sqrt{l^2 - 4l}\right|}, l = c_1 + c_2, l > 4 \tag{3}$$

Fundamentally speaking, most solutions are based on improved combined with other optimization algorithm, is to greatly improve the difficulty of understanding and implementation of algorithm complexity, which makes the particle swarm optimization algorithm lost some core advantages attractive, such as simplicity, understanding the implementation simplicity, this the algorithm of large area application is somewhat unfavorable. Therefore, the improved particle swarm algorithm as the starting point for improved particle swarm algorithm is simple and effective, it is necessary and meaningful.

The basic particle swarm optimization algorithm in the solution space search, every particle of flight time constant is 1, sometimes lead to particles in the optimal solution of the back and forth near "oscillation" phenomenon [5]. Adaptive adjustment of the time of flight method to dynamically adjust the time of flight, with the increase of the iterative algebras, flight time decreases linearly as is shown by Equation (4).

$$x(t) = \mathrm{Re}\left[\sum_{i=1}^{n} a_{C_i}(t) \exp\left(j \int \omega_{C_i}(t) dt\right)\right] \tag{4}$$

Routing strategy TEEN protocol is reactive wireless sensor network and design, it is real-time, can make a rapid response to emergencies. TEEN and implementation mechanism of LEACH is very similar, but the former is the response type, which belongs to the network active sensor. The advantages of TEEN protocol: protocol suitable for the application environment needs real-time perception; by setting the hard threshold and soft threshold of 2 parameters, TEEN can greatly reduce the number of data transmission, energy saving and other than LEACH. Disadvantages: not suitable for application in the system of periodic sampling, it is as if the nodes in the network have not received the relevant threshold, then the node cannot communicate with the base station, user also without any data network.

GEAR also can be considered as an improved method of Directed Diffusion. The protocol does not use the interest to the entire network to broadcast, but the use of location information, to a specific area of interest is then broadcast, using location information (as far as possible to choose the shortest path) and node residual energy situation, the packet is sent back to the sink node. The method can greatly save energy, prolong the sensor network lifetime.

One hop neighbor nodes and Sink is the root node of the multicast tree to realize the sensor nodes to the Sink multi hop path. It is characterized by the routing decision must take into consideration not only to each path of the energy, but also relates to the end to delay and data packet to be sent priority end [6]. The simulation results show that, with the minimum energy path energy consumption measurement protocols, SAR energy consume less. The disadvantage of the algorithm is not suitable for large and frequent changes in the network topology.

Particle swarm algorithm behavior is affected by its optimal pbest and optimal gbest, this version is called the global version of the PSO algorithm. Another is the local version of the

PSO algorithm, in this algorithm, the particle behavior is not affected by the global optimal gbest effect, but by the local optimal lbest adjacent particles in pbest and its optimal topology effect, the experimental results show that, w in between [0.8,1.2], PSO algorithm has faster convergence speed, and the when w>1.2, the algorithm is easy to fall into the local extremum.

A good routing protocol of wireless sensor network should have the following features: a dynamic choice of the sink node capacity. Obviously, the sink node directly affects the life cycle of the whole sensor network life cycle. In the process of information transmission, the sink node with the highest frequency, the maximum energy consumption. When a sink node energy consumption is too large, the sensor network according to the sink node energy consumption, energy consumption of nodes dynamically, convey information, the sink node balance the network energy consumption, can prolong the sensor network lifetime.

3. Using Improved Ant Colony to Optimization of Routing Protocol in WSN

The PEGASIS protocol is used to connect the sensor nodes in the chain structure. Running the PEGASIS protocol when each node using signal to measure the intensity of all its neighbor nodes, distance, when determining the nearest neighbor and adjust the sending signal strength to ensure that only the neighbors hear. Secondly, choose only one node chain as first of chain transmission to the sink node data [7]. The data collected by point-to-point transmission, fusion, and finally sent to the rendezvous point. Advantages of this protocol is: reduce the LEACH generated in the process of cluster reconfiguration overhead, and through the data fusion process to reduce the number of transceivers, which reduces energy consumption.

The wireless routing protocol and MFlood routing algorithm is a broadcast traditional routing protocols. It does not need to maintain the topology and routing networks, each node uses a data packet broadcast relay received, if the receipt of the duplicate packet is discarded. By setting the appropriate TTL value to avoid due to the diffusion of large area and occupy too much cyber source, the diffusion convergence, to ensure the data packet only after finite hop routing; in addition to repeat packet detection, each node needs to maintain a data packet sequence number SEQ and a routing table, the original node transmitting one packet SEQ is added by 1, and the SEQ is added to the data packet IP head, the remaining nodes by data packet will be the SEQ recorded in the routing table and repeated packet detection based on the SEQ, as is shown by equation5.

$$C\left(a(\ell) \mid \mathcal{R}_{\ell}\right) := \operatorname{cov}\left(a(\ell) \mid \mathcal{R}_{\ell}\right) = \sigma^{2}_{s.s_0}\, \beta\beta^{\mathrm{T}} + \Sigma_{\varepsilon} \tag{5}$$

For a route, ant it more choice, strength of ants in the path left by the pheromone is larger, and the intensity of pheromone attracts more ants, so as to form a positive feedback. Through this positive feedback, ants can find the shortest routing path eventually. In the ACO algorithm, the pheromone trail to be known as a parametric probability model of the pheromone model simulation. The pheromone model consists of a series of model parameters, the parameters of the model where the value is called the pheromone value.

On the road of wireless sensor networks by protocol and ant colony algorithm. Although many scholars have studied the routing protocol in wireless sensor networks of several classic, but in the routing protocol of the effective energy utilization research results are not many, the ant colony algorithm is introduced to the wireless sensor network routing algorithm to challenging. To find the optimal path in wireless sensor networks, but also consider the effective use of the sensor node energy [8]. A good wireless sensor network routing protocol can save energy effectively, but also can enhance the network scalability and reliability.

According to the above discussion, according to the characteristics of the wireless sensor networks need to design new routing approach, ant colony algorithm is one of them. Ant colony algorithm is derived from the observations of the natural world ant swarm behavior and abstract. Ant colony foraging can find the shortest path between the nest and food, which depends on the chemical substances in a pheromone, ant and in between, they release a pheromone, provide the path for the later ants wizard. Such behavior is very good for the reality reaction, this idea is also suitable for wireless sensor networks, as is shown by Equation (6).

$$\mu_i(k) = P\{m_i(k) \mid Z(k)\} = \frac{f_i(k)\sum_{j=1}^{n} \pi_{ji}\mu_j(k-1)}{\sum_{i=1}^{n} f_i(k)\sum_{j=1}^{n} \pi_{ji}\mu_j(k-1)} \quad (6)$$

The agreement calls for network operation by the end user Sink of the sensor nodes are partitioned into clusters, the location information of the nodes are assigned and notify each cluster head node ID logo and clusters [9]. The sensor node can run with low energy consumption and the standby in two ways, and can be in existence in the one of four states, namely perception, forwarding, sensing and forwarding dormancy.

The cluster head as the network management center, energy change can monitor nodes, four state decision and maintain the sensor. Based on the two node energy consumption, delay optimization performance index to calculate the path cost function. The cluster head nodes using the cost function as the link cost.

Routing strategy TEEN protocol is reactive wireless sensor network and design, it is real-time, can respond rapidly to emergencies. TEEN and LEACH using the structure and operation of multi cluster in the same way, is different in the course of establishing cluster, with the selected cluster nodes, cluster head in addition to realize data scheduling by TDMA way, also hard close to cluster member broadcasting data about the value and soft close values of two parameters. Hard close value is monitored data can not be crossed with value, soft close value is specified by range monitoring data. In the stable stage cluster, node through the sensor constantly aware of its surroundings. When a node first monitoring data to hard closing value, then open the transceiver for data transmission, and the detection value stored in the node internal variables in the SV, as is shown by Equation (7).

$$q_{j_l}(x) = \sin^L(\frac{x}{2})(l_j(\frac{x}{2}))^l \cos^{2l}(\frac{2^{j-1}x}{2})h_j(\frac{x}{2}) \quad (7)$$

This paper introduces the concept and characteristics of wireless sensor networks, the analysis and design of network routing protocol challenge, given by the algorithm of wireless sensor network based on ant colony optimization algorithm. The routing algorithm considering the characteristics of the network, with self-organization, dynamic. Pheromone method consider the energy, round trip time, hops and other factors. Therefore more suitable for wireless sensor network routing.

The first ACO algorithm ant system practical principle and algorithm model and describe, ant system is best explained as the basic idea that ACO meta heuristic algorithm. The basic principle of ant system to pave the way for the characteristics, meta heuristic algorithm, can the meta heuristic framework proposed by ACO, the algorithm of association definition of combinatorial optimization problems, ACO meta heuristic is indeed a component and the operation mode of the basic [10]. In this framework, the ant system is as an example of algorithm, and can be derived from the other algorithms, although other derivative algorithm is presented alone, but the ACO meta heuristic framework is the best summary of their. Then describes several variants of typical ACO algorithm, these are better than the performance of the original ant colony system has greatly increased.

In the static network, also can not guarantee the integrity of the network topology. After the formation of the network topology, may encounter many unexpected situations, such as network node position, network nodes have no energy, or is subject to certain obstacles blocked and so on, will have an impact on the network topology, and network application effect. In the design of routing protocol should be fully taken into account the characteristics of the network topology dynamics, in order to reduce the influence brought by the network node failure.

4. Optimization of Routing Protocol in Wireless Sensor Networks Based on Improved Ant Colony and Particle Swarm Algorithm

Performance evaluation of WSN routing protocol can be measured from multiple aspects. The analysis of the routing protocol, here from whether the topology of routing

protocols, protocol performance, the network life time, need to maintain multiple paths, robust, scalable routing protocol in the network Festival, whether to provide QoS support for mobility support, or whether to provide security mechanism etc. the summary.

Location information of many routing protocols for wireless sensor networks require sensor nodes. Because the WSN does not have access to a mechanism similar to IP address, and is distributed in a particular area, they can make the transmission of data in some energy saving methods using the address information. Therefore, if known induction area, using the sensor location, query information will be issued only to the perceived area, reduce the number of data transmission.

Because the traditional PSO is often the search in the middle of the global and local best position, searching capability and convergence performance is heavily dependent on constant acceleration and inertia weight settings, in order to overcome the shortcomings, the Gauss function was introduced to the PSO algorithm, is used to guide the movement of the particles; GPSO does not require the inertia weight, and constant acceleration generated by random the number of Gauss distribution. Tension will be called the PSO:SPSO stretching technique and deflection and rejection technology applied to the PSO, to transform the target function, limit the particle to have found a local minimum solution of motion, which helps to have more of a chance to find the global optimal solution, as is shown by Equation (8).

$$v_{ij}^{t+1} = \omega_t v_{ij}^t + c_1 r_1 (pbest_{ij}^t - x_{ij}^t) \quad (8)$$

Change the particle inertia weight swarm algorithm a kind of dynamic. In the algorithm, the algorithm change inertia weight operation effect, by the evolution speed of particle swarm optimization and particle swarm aggregation degree comprehensive decision. Compared with the LDW algorithm, the average number of iterations at least an average reduction of 25%, convergence speed and accuracy are improved obviously. Chen Guimin, on the basis of LDW, and gives three kinds of nonlinear decreasing inertia weight strategy, found that for most continuous optimization problems, the strategy of decreasing concave function is better than that of linear strategy, while the linear strategy is better than the convex function strategy.

Elitist ant system, rank based ant system, ant colony system and the maximum min ant algorithm, ant colony optimization algorithm according to the basic ant colony algorithm for its shortcomings, improve the performance of the algorithm. Regardless of is the basic ant colony algorithm and improved ant colony algorithm, is the single species, single algorithm based on pheromone, not made full use of parallel and distributed computing and other excellent characteristics of ant colony algorithm, can not fully reflect the complexity of real ant society.

Overweight may lead to serious network congestion and even congestion collapse load nodes closer to the base station in wireless sensor network, sensor nodes near the base station is selected from one of the molecular aggregation node, other nodes only through the sub assembly communicates with the sink node can, as the sensor nodes in common use many different ant in ant colony algorithm between pheromone interaction and dynamic update to quickly find the optimal path from the source node to the sink node cost small son.

By using the object oriented OMNeT++ as the simulation platform of multi ant colony algorithm and efficient access load aware cross layer routing protocol based on Design of experiment. Perceived as (0,0) to (18451,66521) square planar monitoring area, sensor nodes are randomly deployed 260, simulation time is 1200s. Considering the reality of sensor network node, the node is the maximum transmission distance is set to 90m, the fixed sink nodes location is (451254). Transmission of the data packet size is 1024B, buffer queue length is set of sensor nodes into 100 data packets, the source node generates data at a rate of 10packet/s. The IEEE802.11 protocol uses MAC layer. Operation of improved particle swarm optimization algorithm and ant colony algorithm to optimize the program of wireless sensor network routing, averaging the results of 20 experiments to compare, in Figure 2.

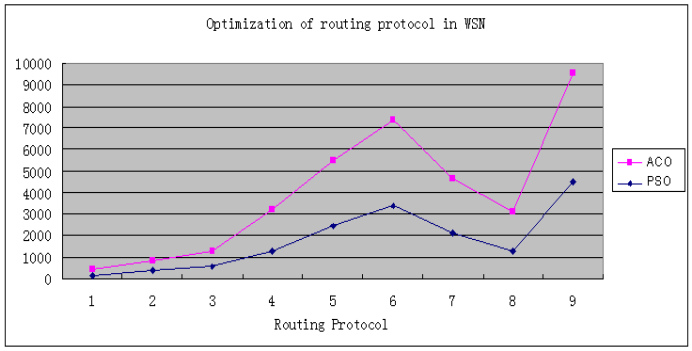

Figure 2. Comparison of Routing Protocol in Wireless Sensor Networks Based on Improved Ant Colony with Particle Swarm Algorithm

From the simulation results it is not difficult to see that, the number of ants the size of M ant colony algorithm cycles (convergence) influence increases linearly change, when the number of ants is too large (such as close to the scale of the problem), while the stability and global search is improved, but the algorithm convergence rate slow. A number of ants in ant colony algorithm m choice, should also consider the global search ability and convergence speed of two indicators.

Through theoretical analysis and simulation show that, the particle swarm optimization algorithm for wireless sensor network business dynamic scheduling, a MTCH at the end of the subframe is starting a MTCH frame of a great probability. According to this conclusion, only indicates the MTCH occupied by the sub frame in DSI in the starting end sub frame or subframe, gain scheduling information corresponding to the user can be accurately. Compared with the method of indicating end sub frame, indicating method starting sub frame's presence in MTCH the end of sub frame is not good positioning problem. Based on the combination of advantages of indication method end sub frame at the same time, through further analysis found, an ant colony algorithm occupied sub frame number not much, the absolute position of the sub frames end sub frame indicates the index method still has some redundancy, this paper proposes a end sub frame difference index scheme points, to further reduce the overhead of DSI information.

5. Conclusion

The paper presents optimization of routing protocol in wireless sensor networks based on improved ant colony and particle swarm algorithm. This paper uses the ant colony algorithm and improved particle swarm algorithm to optimize the routing in wireless sensor network, according to the special requirements of network, the nodes in a single hop delay and statistics obtained MAC layer node access efficiency, load parameters of queue length information as routing path selection. Experiments show that, the algorithm to solve the optimal transmission path that can meet the needs of wireless sensor networks, real-time, reliability and load balancing and other requirements, to ensure the event driven wireless sensor network quality of service.

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References

[1] J Ibriq, I Mahgoub. Cluster-Based routing in wireless sensor networks: Issues and challenges. *Performance Evaluation of Computer Telecommunication System*. 2004; Jan: 759-766.
[2] Long Chengzhi, Luo Jianping, Xiang Mantian, Yu Guicai. Research on the Ant Colony Optimization Algorithm for Load Balance in WSN. *JCIT*. 2012; 7(18): 425- 433.

[3] Yunliang Pan, Jun Du, Weitao Hu. An ant colony optimization-support vector machine for ground target optimal tracking. *IJACT*. 2013; 5(9): 696- 703.
[4] D Ganesan, R Govindan, S Shenker, D Estrin, Highly Resilient. Energy Efficient Multipath Routing in Wireless Sensor Networks. *Mobile Computing and Communication Review (MC2R)*. 2002; 1(2).
[5] Andi Muhammad Ilyas, M Natsir Rahman. Economic Dispatch Thermal Generator Using Modified Improved Particle Swarm Optimization. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2012; 10(3): 459-470.
[6] D Braginsky, D Estrin. *Rumor Routing Algorithm for Sensor Networks*. in the Proceedings of the First Workshop on Sensor Networks and Applications (WSNA), Atlanta, GA. 2002.
[7] N Higashi, H Iba. Particle swarm optimization with Gaussian mutation.*Institute of Electrical and Electronics Engineers*. 2003; (4): 72-79.
[8] Xiong Jian-qiang, Huang Ju-hua, Liao Qun. Simulation Analysis of Controlling Buffeting Noise Based on Hybrid Particle Swarm Algorithm. *JCIT*. 2012; 7(23): 753- 761.
[9] Haijiang Wang, Shanlin Yang. Electricity Consumption Prediction Based on SVR with Ant Colony Optimization. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2013; 11(11): 6928-6934.
[10] Banks A, Vincent J, Anyakoha C. A review of particle swarm optimization. *Part I: background and development Natural Computing*. 2007; 45(6): 467-484.