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A New Method for Intelligent Message Network Management in Ubiquitous Sensor Networks

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ABSTRACT

Ubiquitous Sensor Network (USN) computing is a useful technology for autonomic integrating in different environments which can be available anywhere. Managing USN plays an important role on the availability of nodes and paths. In order to manage nodes there is a cyclic route starts from manager, passing nodes, and come back to manager as feedback. In this paper, a new, self-optimizing method presented for finding this cyclic path by combining epsilon greedy and genetic algorithm and then it is compared with other well-known methods in terms of cost of the route they find and the power consumption. The results show that the route that is found by our new method costs at least 53% less than other methods. However in some cases, it uses 32% more energy for finding the route which can be compensate in traversing the shorter route. The overall simulation results in prototype data show the effectiveness of the proposed method.

Keywords: Ubiquitous sensor network, management, autonomic computing, intelligence, routing.

1. INTRODUCTION

Ubiquitous computing is a new, economical and useful technology which can be available anywhere. It uses Wireless sensor networks technology consist of a large number of small, self-powered nodes with the ability to sense and gather information or detect special events, process them and transfer data to base station[1]. In USN, monitoring is used for understanding the availability of nodes and status of links. In this paper, for monitoring such networks some artificial intelligence algorithms for management message routing has been introduced and implemented and compared in the case of minimum cost and power consumption [2].

Finding the optimum path for monitoring nodes is the main problem in this paper. It is sufficient to monitor specific set of important nodes with a cyclic message to lower traffic and response time and omit the overhead of multiple point-to point transmissions. The genetic and ant colony are two algorithms that can find optimal solution (route) in a fair time. Then the message will start from the manager. Each node will get the message and pass it to the next node and retransmit it if fails. Passing all nodes in the order that is found by those algorithms, the message comes back to the manager. It will then contain information about nodes and links status and availability. Routing information will be collected from the neighbor table by the management application and it calculates the communication cost or delay [2].

In this paper, a new, self-optimizing method introduced for finding cyclic path by combining epsilon greedy and genetic algorithm. Three old versions and a new intelligent version have been declared. First the usual genetic algorithm with high cost invalid genes (valid genes have all nodes repeated just once). The second one is genetic with valid genes. The third one is ant colony. Finally the new method that is proposed is the combination of epsilon greedy with genetic algorithm that found the route with the minimum cost. The result of comparing the proposed method with other intelligent methods shows the effectiveness of the proposed method.

Remainder of the paper is organized as follows: in Section 2 Ubiquitous Sensor Networks are introduced and their components, challenges, and monitoring are discussed. Section 3 explains related works in the monitoring of USN. The proposed method is the subject of Section 4. In Section 5 the simulation results are compared and outlined. Finally in section 6 conclusion and remarks are expressed.

1. UBIQUITOUS SENSOR NETWORK (USN)

Ubiquitous computing is a new, economical and useful technology which can be available anywhere. Technology that use for building a ubiquitous system is sensor networks due to small dimensions of sensor nodes, interoperability with different technologies and easily integration into different environments. It interfaces the physical environment in different circumstances such as military, inter-vehicle communication, medical, building, agricultural, livestock and industry [2, 3].

The most important USN components are sensor nodes. Each node has sensors to collect and transmit environmental information, microprocessor, radio transceiver wireless communication and battery. It uses Zigbee for mac and IP-USN protocol for network layer to integrate IP network infrastructure with sensor network [4]. There is a sensor net protocol between network and link layers installs for updating neighbor table. By passing tables between each other they complete routing tables and calculate the cost (delay) between each two node [2, 3, 5, 6]. USN application platform contains tiny OS (an open source operation system) and tiny DB (little distributed data base) that keeps routing tables and sensor parameters, receives sensor readings, combines and filters data [2]. USN contains a gateway that collects information from sensors and transmits it between them, other networks and controller node. It enables users or system to control remotely and get feedback from manager to improve system [2]. There is also network infrastructure that integrates different networks and USN middleware that collects, process and filter big data [3].

USN challenges in various engineering fields are sensing, energy conservation, security issues, communication, etc. Sensor Network should be deployed randomly, self-managed and maintained with minimum human consciousness or involvement with four characteristics: self-configuration, self-optimization, self-healing and self-protection. It should be Infrastructure-less with distributed algorithms. Protocols, microcontroller, operating system, and applications should be designed to conserve power. Sensor nodes need to synchronize in a distributed way to detect temporal ordering of events, and omit redundant events/ messages. It should have dynamic topology and if nodes fail or join to the network, or if power supply changes, the topology should change intelligently. Communication should be real time and secure with cluster tree topologies in small-scale ad hoc networks implementations [5]. For intelligent and efficient management the central controller monitors the status of environment using sensors and passing cyclic message. For USN monitoring this information contains coverage bound, battery, topology, bandwidth and link state[2].

2. RELATED WORKS

In this section we review some intelligent algorithms found during experiments. In paper "An intelligent policing-routing mechanism based on fuzzy logic and genetic algorithms and its performance evaluation" [7] intelligence, policing and routing combined to formed an intelligent, flexible and adaptive network management based on fuzzy logic and genetic algorithm to control traffic in rapidly changing network and improve quality and utilization. Simulation results for comparing TARG (tree base routing using genetic) and FPM (fuzzy policing mechanism) shows that FPM has a good packet rate monitoring, responsiveness, ideal selectivity and better performance than leaky bucket mechanism. TARG has simpler and faster evolution than genetic load balancing routing, save time by avoiding routing loops.

"Review of routing protocols based on ant-like mobile agents" [8] discussed routing algorithms in mobile ad hoc temporary infrastructure networks (MANET). AODV is reactive ant like agent that has delay for establish communication from source to destination but transmit without delay. Proactive ant like agent is not good enough due to dynamic characteristic of MANET routes and nodes. Its' overhead can be reduced by using only forward ants (come from source) to update intermediate nodes routing table. USN required more efficient routing protocols. High connectivity and minimum overhead can be gained by Ant-AODV for processing ant-like agents. Nishimura said that finding a generic method is almost not possible to select a best route in multi agent dynamic systems and too many factors are effective, like nodes relational positions, packet sending rate, topology changes, etc. Evaluation function is different base on environment.

In "energy-efficient multi-speed routing protocol for wireless sensor networks" [10], a new localized routing protocol with different QoS requirements in WSN is proposed by considering different speed layers and reliability and dynamically adjusting the transmission power level. Choose next hop based on consumed energy at sender and remaining energy at receiver. Considering latency, reliability and energy consumption shows that this protocol performs better than MMSPEED.

In other paper [11] ant colony algorithm, local search and fuzzy inference system combined to find optimal route in WSN. Simulation results showed the effectiveness for optimization problems and increase energy efficiency. Combining ant colony, bee, pro and other local search algorithm can be used in finding optimum route in WSN and result in achieving greater quality and optimum energy consumption.

3. GENETIC ALGORITHM & EPSILON GREEDY (The New Proposed Method)

The genetic algorithm is based on natural selection. In each step it reduces genes with low quality so the better ones can be the majority of a population and lead to the optimal solution. It contains a method for initial population that produce random genes and evaluates them, then there is an iteration of making new genes, cross over and mutation [2]. The route (gene) will be represented by an array of nodes. The cost is represented as sum of distances between nodes that the message passes, in meter. In this paper we combined epsilon greedy algorithm with genetic. In this algorithm the flowchart in Figure.1 repeated about 1000 times making 1000 genes for each thread. The blue line shows the loop and iteration.

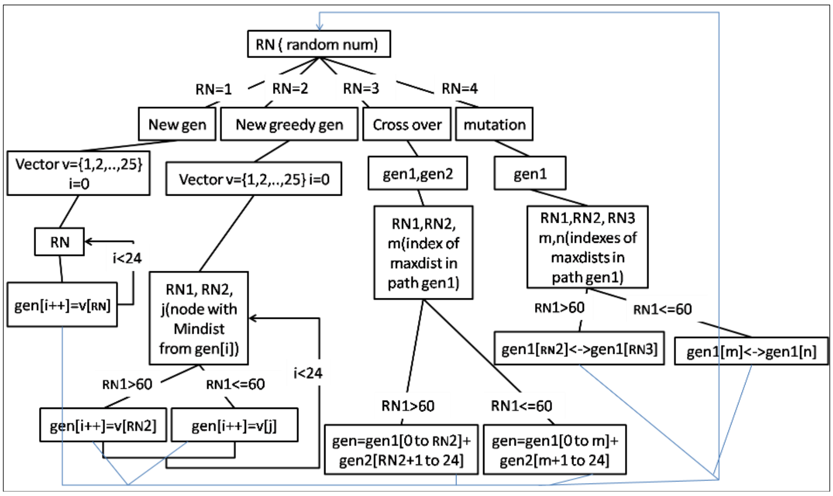

FIGURE 1 Genetic greedy flowchart , the new proposed method

As you can see in flowchart Figure.1 for creating new genes there are some ways including making normal genes, making greedy genes, cross over, and mutation. There were some genes that were invalid, means having duplicate node or not including some of them. In our proposed method just valid genes are used. In creating normal genes, generating paths performed by using a vector that has all nodes in it. Each time add one of them randomly to the gene and omit it from this vector. In creating greedy genes, for adding new node to genes, the minimum cost with the possibility of 60% will be chosen from mentioned vector. In other words the node with minimum distance from the last node will be added to the path with the possibility of 60%. For cross over in this version with the possibility of 60% it crossover from the place that it burden the max cost to the route. In mutation, with the possibility of 60% it will change the place of two nodes that have burden the max cost to the route. Mutation will prevent from being trapped in local minimum.

4. SIMULATION RESULTS

Here implementation of management routing simulation scheme in USN is explained. There are 25 nodes randomly placed. It has been done with java (jdk7), running on Windows Seven operating system on the platform with Intel Corei5-560M processor 2.66 GHz CPU, and 4.0 GB memory. In our implementation, the number of genes in each population and also the first population for ants is set to 25. For the random generating “Math.Random()” is used. The experiment measures the minimum and average cost change according to the progress of iteration steps. The power each algorithm consumes for finding route is also measured. Each thread runs its own initial generation begins from the high cost solutions, but converges to a lower constant value soon and then it is hardly possible to achieve more reduction but average value will continue to lower the cost.

4.1. GENETIC ALGORITHM VERSION1

There were some genes that were invalid means having duplicate node or not including some of them. In version1, a very high cost is given to the invalid genes so that it will be removed by time. The crossover also will be like initial population and will get high cost if it is not valid. In the mutation the place of two nodes will be changed with each other in the route randomly. The result is shown in Figure.2. The minimum cost for this method was the highest of all methods.

4.2. GENETIC ALGORITHM VERSION2

In version 2 just valid genes are used by using a vector that has all nodes in it. Each time add one of them randomly to the gene and omit it from this vector. The cross over will make the gene by two parents then validate it by replacing doubles with not repeated nodes in the gene. In the mutation, the place of two random nodes will be changed with each other in the route. The result is shown in Figure.3.

4.3. ANT COLONY ROUTING

Ant colony algorithm applied successfully to solve optimization problems, inspired by the observation of social insects that achieve astonishing results and global intelligent pattern by interacting with each other in a simple local way. It emphasizes parallelism, self-optimization and minimizing the complexity of the individual units. It uses pheromone based solution with evaporation to reduce effect of past experience. When an ant passes a route it puts some pheromone on it and updates the pheromone table. The amount has an upper bound to prevent bottleneck effect and has opposite relation with cost. Next ant chooses city S calculated as (1):

$$S = \begin{cases} s_1 = \arg(\max\left\{[Ph_{ij}(t)]^{\alpha}.\left[\eta_{ij}\right]^{\beta}\right\}) \\ \quad s_2 \end{cases} \qquad (1)[9]$$

That Ph is pheromone table and η is 1 over distance. Ants will choose S with the possibility of P_{ij} as (2) [9].

$$P_{ij}{}^{k} = \begin{cases} \frac{[ph_{ij}(t)]^{\alpha}.\eta_{ij}{}^{\beta}}{\sum_{j\epsilon NotVisited(k)}[ph_{ij}]^{\alpha}.[\eta_{ij}]^{\beta}} & j\epsilon NotVisited(k) \\ 0 & otherwise \end{cases} \qquad (2)[9]$$

The result is shown in Figure.4.

4.4. GENETIC & EPSILON GREEDY (THE NEW PROPOSED METHOD)

As explained in section 4 in this proposed algorithm the genetic algorithm and epsilon greedy has been combined and just valid genes are used. Creating new genes will be done by making normal genes, making greedy genes, cross over, and mutation. In creating normal genes, generating paths performed by using a vector that has all nodes in it. Each time the algorithm removes one of them from vector and adds it to the gene. Creating greedy genes performed by choosing the minimum cost with the possibility of 60% from mentioned vector and adding it to the path. Cross over with the possibility of 60% from the place that it burden the max cost to the route, and mutation change the place of two nodes that have burden the max cost to the route with the possibility of 60%. The result is shown in Figure.5. As you see in this method the cost is the least of all methods implemented in this article.

In Figures 2,3,4,5 vertical bars show cost (0-1000) and the horizontal is number of iteration (0-1000). Ants routes cost /Genes are shown with black points. The min cost of each generation showed with red points and the average is green. These algorithms can be decentralized. In ant colony the pheromone /delta matrix could be passed between nodes. In the genetic algorithm nodes will pass their best genes to each other. They are also making USN self-optimized [5].

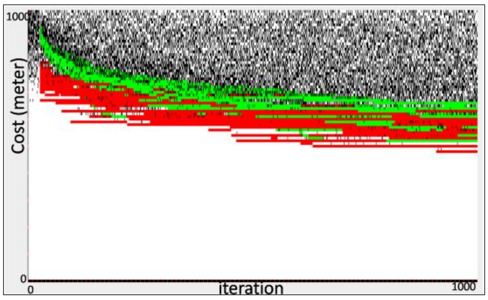

FIGURE 2 Genetic1: min cost =866m.

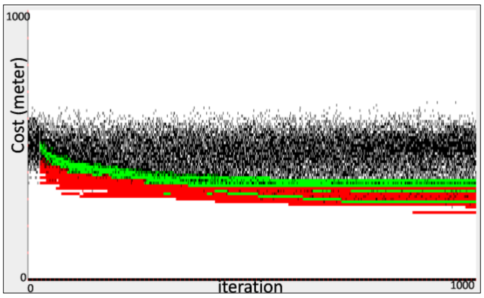

FIGURE 3 Genetic2: min cost=483m.

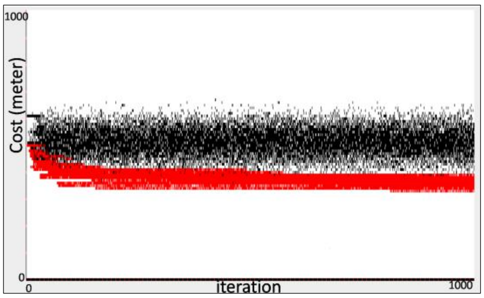

FIGURE 4 Ant colony: min cost=596m.

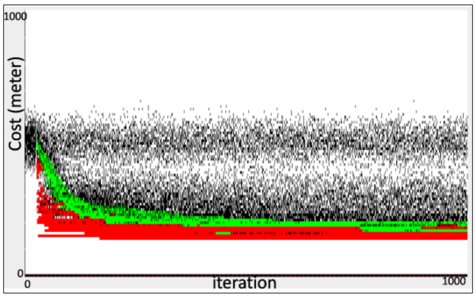

FIGURE 5 Proposed method:min cost=227m

4.5. COMPARING GENETIC1, GENETIC2, ANT COLONY AND GENETIC GREEDY (THE PROPOSED METHOD)

The result of running each algorithm with 30 threads is shown in the Figures 2,3,4,5. As you can see the first version of Genetic algorithm found a way with high cost. The genetic 2 algorithm with valid genes has found much better way that is comparable with ant colony and even does better than that. Among these algorithms genetic greedy (proposed method) search a wider area and find the best answer of all. After energy that is the most important factor in WSN is measured by Joel meter [12]. The average and confidence interval of 10 times repetition with Alfa=0.1, for energy that use for finding path, the power it needs, and the time that the algorithm used are shown in table 1:

TABLE 1.
Measuring the energy, power, time and cost.

	Genetic 1			Genetic 2			Genetic-Greedy (proposed method)			Ant colony		
	E(Joel)	*P*	*T(ms)*	*E(Joel)*	*P*	*T(ms)*	*E(Joel)*	*P*	*T(ms)*	*E(Joel)*	*P*	*T(ms)*
Avg	2.7	1.12	2.5	3	0.88	2.5	4.4	1.82	2.5	72.8	6.065	12
Conf	0	0.37	0.82	0.16	0.25	0.82	0.16	0.53	0.82	0.658	0.057	0

In Table.1 measuring the energy, power, time and cost used for finding optimal route, shows that ant colony use much more time and power and energy than any other one. It was predictable since ant colony needs more power for calculating possibility, choosing next city and updating pheromone table but it reaches the knee with less repetitions that others. The energy unit is Joel and the time is millisecond. The genetic1 was the best of all in case of energy and power but was equal to genetic2 and genetic3 in time and it had the highest cost of all. Genetic2 used almost of 10% more energy than genetic1 but finds better results with lower minimum route cost about half in compare with genetic1. Genetic-Greedy is the proposed method that had combined epsilon greedy with genetic. It used about 32% more energy than genetic2 but found route with much less cost that can compensate the energy it use in routing, the found path was about 53% shorter than genetic2. Because the energy it use for finding route is more but the energy for passing the message between nodes and come back to manager will be less cause the path it finds is the shortest of all algorithms in this article. So by considering all aspects we can suggest that genetic-greedy is an effective algorithm that can find the route with lowest cost.

5. CONCLUSION

Ubiquitous sensor network has been widely used. In this paper 4 intelligent algorithms implemented and compared in the case of cost and energy for finding the best cyclic route to monitor nodes. Three of them were genetic algorithm. In the first one, high cost is given to invalid genes. The second one changes the invalid genes to valid one. Then ant colony was implemented, and in the last one we combine epsilon greedy with possibility of 60 with genetic algorithm. Among them ant colony used the most energy and genetic1 has the worst optimum path with highest cost. So it is not suggested to use them. Then genetic2 and Genetic-Greedy (the proposed method), found a fair path with fair energy. Genetic-Greedy found the best path that cost 53% less that genetic2, but use 32% more energy than that. This extra energy can be compensated by traversing the shorter path, so genetic greedy (the proposed method) will be suggested. Genetic-Greedy is an effective algorithm that can find the route with lowest cost and can be used in USN networks for finding shortest path for management messages and reduces the energy needed for traversing route.

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