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Research Article

An Efficient Multi-criteria Routing Algorithm using Ant Colony with Colored Pheromones in Wireless Sensor Networks

[1]Fatemeh Rismanian, [2]Behrang Masoodifar, [3]Manaf Sharifzadeh and [4]Somayyeh Sheikhnia
[1]Department of Computer, Science and Research Branch, Islamic Azad University, Tabriz,
[2]Department of Computer, Damavand Branch, Islamic Azad University,
[3]Department of Computer, Firoozkooh Branch, Islamic Azad University,
[4]Department of Computer, Iran University of Science and Technology, Tehran, Iran

Abstract: Considering the features of non-uniformly distributed traffic load and possibly existing of the traffics requiring different performance in wireless sensor networks, this study proposes , a novel routing protocol based on an improved Ant colony optimization routing algorithm. The algorithm concentrates on the provision of Quality of Service in multi-criteria routing algorithm such as hop count, energy consumption, resident power, bandwidth and end to end delay. These metrics are used by means of colored pheromones of the ant colony system. There are different ants with colored pheromones, which each color is for a level of service. Simulation experiments show that the proposed algorithm has many advantages comparing with existing algorithm: proposing different service classes such as Real time and Best effort traffic; achieve slower delay and longer lifetime; besides, the proposed method behaves more scalable and robust.

Keywords: Ant Colony Optimization (ACO), Colored Pheromone, Quality of Service (QoS), Routing, Wireless sensor networks

INTRODUCTION

One of the most important applications of the Wireless Sensor Networks (WSNs) is to provide unmanned surveillance ofterrains where it is extremely difficult to bring up a traditional wireless infrastructure. These applications include forest fired detection, habitat monitoring, detecting radiation leakage, impurity level in sea discharge, intrusion detection for military purposes, etc. In such cases, reducing delay is more important than reliable transmission depending on the requirement of real-time applications. In the other word, transmission of such data requires not only energy but also QoS aware routing in order to ensure efficient usage of the sensors and early access to the gathered measurements.

We modified the traditional Ant Colony Optimization (ACO) algorithm according to the characteristics of WSNs and then used it to implement an energy-efficient, intelligent and robust QoS routing protocol EAQR, which can differentiate RT traffic and BE traffic so as to provide differentiated service for them and EAQR can also balance the energy consumption through the whole network.

Singh *et al*. (2004), the authors present an ant colony algorithm for Steiner Trees which can be ported to WSN routing. However, no changes are considered regarding the specific WSN requirements and also no considerations are made regarding the energy management essential to the WSN performance. Jeon *et al*. (2004) proposed an energy-efficient routing protocol that tries to manage both delay and energy concerns. Based on AntNetprotocol (Di Caro and Dorigo, 1998), this algorithm uses the concept of ant pheromone to produce two prioritized queues, which are used to send differentiated traffic. However, such approach can be infeasible in current sensor nodes due to the memory required to save both queues. This can be even more problematic if the sensor network is densely populated, since the routing table on each device depends on the number of neighbors. Zhang *et al*. (2004), study three distinct Ant-based algorithms for WSN. However, the authors only focus on the building of an initial pheromone distribution, good at system start-up. EEABR Camilo *et al*. (2006) introduced the energy level of node and transferred distance (the number of node passed by the ant) into the pheromone update equation of ACO algorithm, which made the ACO more applicable to the routing protocol of WSNs and aggregated the information carried by ants considering the features of WSNs such as limited memory and energy. Although EEABR is a representative of applying ACO in routing protocol of WSNs, it neglect some important point of balancing

Corresponding Author: Fatemeh Rismanian, Department of Computer, Science and Research Branch, Islamic Azad University, Tabriz, Iran

energy-consumption in the whole network, essential to prolonging the lifetime of WSNs.

Bagrodia *et al*. (1998), EAQR, the extended artificial ants emit different types of pheromone according to the quality of the path in their return journey, so that ants can choose their path meet their requirement according to corresponding pheromone. EAQR support two types of services RT and BE by ant colony with colored phermones. We use the main idea of EAQR and enhance it with considering more efficient parameters and a novel grading mechanism.

Cobo *et al*. (2010) proposed a QoS routing algorithm for wireless multimedia sensor networks based on an improved ant colony algorithm. The AntSensNet protocol introduces routing modeling with four QoS metrics associated with nodes or links. The algorithm can find a route in a WMSN that satisfies the QoS requirements of an application, while simultaneously reducing the consumption of constrained resources as much as possible. Moreover, by using clustering, it can avoid congestion after quickly judging the average queue length and solve convergence problems, which are typical in ACO. Simulation results show that the proposed algorithm improves the performance of other typical protocols such as Ad hoc On Demand Distance Vector Routing (AODV). The clustering element uses special agents (ants) to guide the selection of CHs in a totally distributed manner. In comparison with T-ANT, another ant-based clustering algorithm, this novel clustering process achieves a permanent CH connection with lower energy costs. Routing comprises both reactive and proactive components. In a reactive path setup aimed at the classes of traffic in the multimedia sensor networks, the algorithm can select paths to meet the application QoS requirements, thus improving network performance. Multimedia data are sent over the found paths. Over the course of the session, paths are continuously monitored and improved in a proactive way. Simulation results show that the performance of AntSensNet outperforms the standard AODV in terms of delivery ratio, end-to-end delay and routing overhead.

In this study, a novel method based on ACO is proposed to provide differentiated services for different classes. the proposed method considers multiple efficient issues to find the best paths to destinations.

THE PROPOSED ALGORITHM

In traditional ant colony system, the amount of pheromone to be deposited depends on the length of path, i.e., the shorter the path is, the more the pheromone will be. In real world, there are two different priority-giving situations as follows: some gerontic or ailing ants would like to choose the patheasy to walk or laborsaving one, giving priority to the comfort of path like the smoothness, bramble, slope of the path over the length of the path on one hand; the hungry ants in direneed of food always give predominance to the length of the path followed by the comfort of the path in case they will behungrier or hungry to death on the other hand. Artificial ants can be extended to make decision onpriority-giving at will through enduing them with the ability to emit and identify different types of pheromone. The extended ants are more suitable for QoS routing of WSNs. Delay-sensitive RT traffic need to be transferred to destination as soon as possible so when we forward such data packets, we choose path mainly in terms of the pheromone identifying the length of the path, i.e., RT pheromone. Whereas, for non-delay-sensitive BE traffic, we focus on improving energy efficiency firstly and reducing delay secondary. So when we choose the next hop for BE traffic, we would follow the pheromone trail identifying the comfort of path, i.e., BE pheromone.

Table 1: Different supported classes in the proposed method

Class type	Color of ant	Description (critical)
Real Time	Red	Delay and bandwidth
Streaming	Blue	Bandwidth
Interactive	Green	Delay
Best effort	Black	

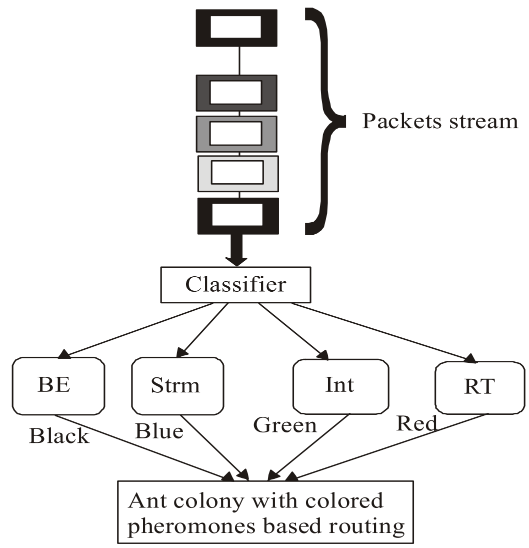

Fig. 1: Implementing the proposed method in a typical wireless sensor networks

The proposed method discovers all possible paths by forwarding ants and marks them with different backward ants, which have different colored pheromones. We use four colors to support four different classes: Real Time, Streaming, Interactive and Best Effort (Table 1). Each class has different needs; in Table 1, critical parameters have been determined.

Figure 1 presents how one packet streams arriving and classifying to different classes. The proposed method discovers different paths to services to different classes. In servicing to all classes, the proposed method

Source Node:

If *it is the time* **then** *send FA*
If *receive a BANT* **then** *save rout and update tables*

Intermediate Node:

If *receive a FANT* **then**
    Begin
    Compute and update *CTP, MRP and MB for FANT*
    Forward *Ant Base on neighbor's pheromone*
    End
If *receive a BANT* **then**
    Begin
    Update *pheromone table*
    Backward *Ant Base on its path list*
    End

Destination Node:

If *receive a FANT* **then**
    Begin
    Compute and update *CTP, MRP and MB for FANT*
    Save *this FANT in temp list*
    If *number of FANT in temp list is greater than N* **THEN**
        Begin
        Compute *parameter of G for all FANT in temp lists by formula (6) with different value of a*
        Produce *BANTs for N number of FANTs with highest value of GOP in each temp list*
        End
    End

Fig. 2: Pseduo code of the proposed method

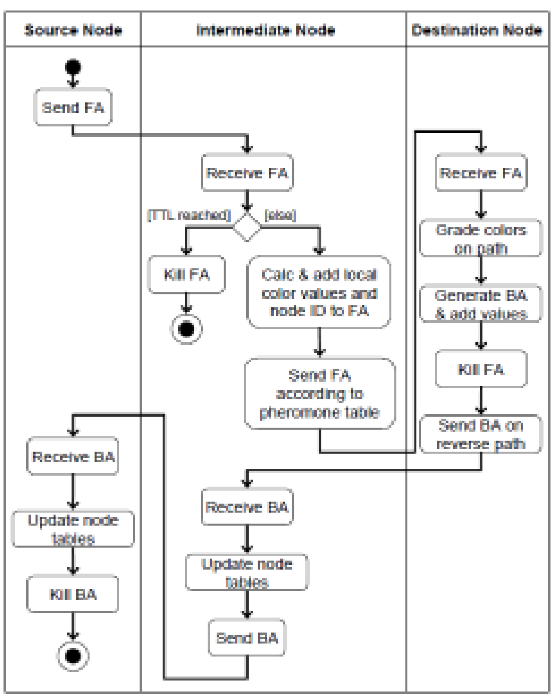

Fig. 3: Flowchart of the proposed method

tries to providence network resources such as bandwidth, energy and memory.

Destination node
Next node
Update time
Value of Red Pheromone
Value of Blue Pheromone
Update time
Value of Green Pheromone
Update time
Update time
Value of Black Pheromone

Fig. 4: Different fields of routing table

In the proposed method, there are two general phases: discovering all possible paths and coloring them with considering their qualities. FAnt (Forward Ant) used to discover paths and backward ant used to mark different paths. indeed, we have BAnt (Backward Ant) with different colors: Red BAnt, Blue BAnt, Green BAnt and Black BAnt.

Source sends a Fant gathering various parameters to discover paths to destination. In other hand, destination send various BAnt with different color for different classes. Figure 2 presents pseduo code of the proposed method. To clarify the proposed method' steps, Fig. 3 present actions from sending a Fant to receiving and killing a BAnt.

The structure of routing table is given in Fig. 4. In routing table of each node, different values of pheromones are saved. When an ant is sent via a neighbor node, it update pne color type phermone. Each pheromone type has an individual update time.

FORWARD ANTS PHASE IN THE PROPOSED METHOD

In original ACO based approach, each ant tries to find a path in the network, providing minimum cost. Ants are launched from a source node and move towards destination node d, hopping from one node to the next. The minimum cost is computed according to MRP (Minimum Resident Power) minimum bandwidth, consumed enery to deliver packet to dest and end to end delay.

Figure 5 presents different fields of ant's database. Each ant computes and carry different information to destination node.

When a Fant arrives in a node, it uses formulas 1,2 and 4 to compute different quality parameters. In formula 1 and 2, FAnt determines minimum level of botteleneck bandwidth and resident power. Formula (3) computes end to end delay by difference time of send time and receive time:

$$MB = Min(BW_i) \quad \forall BW_i \; in \; P \tag{1}$$

$$MRP = Min(RP_i) \quad \forall RP_i \; in \; P \tag{2}$$

$$ETE = ReceieveTime - SendTime \tag{3}$$

Destinatoin Address	Source Address	Consumed Energy to Deliver	Minimim Bandwidth
Minimum Resident Power	List of Nodes in path	TTL (Time to Live)	Ant Type

Fig. 5: Structure of different ants in the proposed method

Table 2: Different values of α

Service Type	α_1	α_2	α_3	α_4
Real Time	0.45	0.05	0.05	0.45
Streaming	0.2	0.1	0.1	0.6
Interactive	0.65	0.1	0.1	0.15
Best effort	0.05	0.4	0.5	0.05

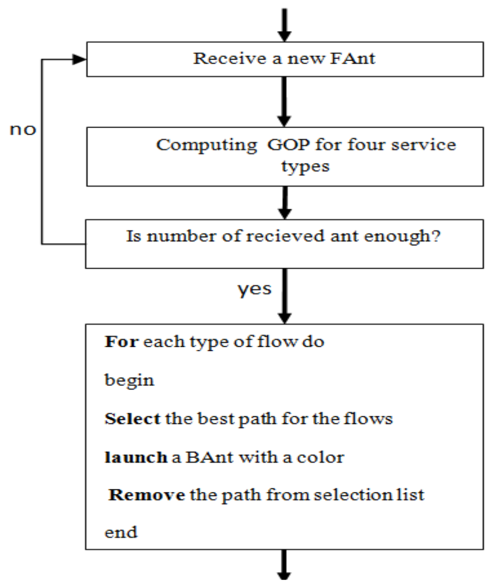

Fig. 6: Flow chard of grading of discovered path

We define an efficient parameter called CTP (formula 4 and 5), to compute how much energy is needed to deliver one packet to destination. Formula 5 shows relation between transmits power, CTP and receiving power:

$$CTP = \sum_{i=1}^{n} CTP_i \quad (4)$$

$$CTP_i = TP_{i-1} - RP_i \quad (5)$$

Grading different discovered paths: In formula 6, GOP (Grade of Path) is used to determine grade of each pach. For example, for RealTime flows, coefficient of end to end delay(α1) is the greatest value and after that α2 is the greatest value. Relation between different values of α is shown in formula 7. Different type of flows need different values for α1,α2,α3 and α4.

$$GOP_i = \alpha_1 \left| \frac{ETE_i}{MAX\_ETE} \right| + \alpha_2 \left| \frac{MRP_i}{MAX\_MRP} \right| + \alpha_3 \left| \frac{CTP_i}{MAX\_CTP} \right| + \alpha_4 \left| \frac{MB_i}{MAX\_MB} \right| \quad (6)$$

$$\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 = 1 \quad (7)$$

In Table 2, we use different values for αn which are computed based on simulation experiences. Four types of flows consider their needs in computing GOP.

Figure 6 presents handling of Fant in destination node. It shows how different color of BAnt is lauched and grading is done. Process of best path selection is done for Real time with Red BAnt, Streaming with Blue BAnt, Interactive with Green BAnt and Best Effort with Black BAnt, respectively.

ROUTING TABLE UPDATE

Each BAnt updates routing table of intermediate node in according GOP of the selected path. It means better paths have stronger pheromones; so they would be selected with more probability to forward packets. Formula 8 presents how a type of pheromone is updated by a BAnt:

$$P_n^d = P_n^d + \Delta * GOP \quad (8)$$

Each node periodiccally updates route table with neighbour nodes. It sends value of different type of pheromones and updates route table by formula 9. In formula 9, CW is Color Weight, which can be Blue Weight, Green Weight, Black Weight and MCW is Maximum CW. Indeed, GON (Grade Of Node) determines how much node is good based on value of different pheromones. GON is computed for different colors:

$$GON_i = CW_i / MCW \quad (9)$$

To compute probality of selection one neighbour node , formula 10 is used. It is determined for each flow, probability of selection. In formula 10, n is number of neighbors:

$$\Pr ob_i = GON_i \Big/ \sum_{j=1}^{n} GON_j \quad (10)$$

Performance evaluation: The simulation code and scenario of this research was implemented within Global Mobile Simulation (GloMoSim) library (Bagrodia *et al*., 1998). The GloMoSim is a scalable simulation environment for wireless network systems by using parallel discrete-event simulation capability provided by PARSEC (UCLA. (n.d.), Year). This simulation study modeled a network of mobile nodes (100 nodes to 500 nodes) placed randomly within an

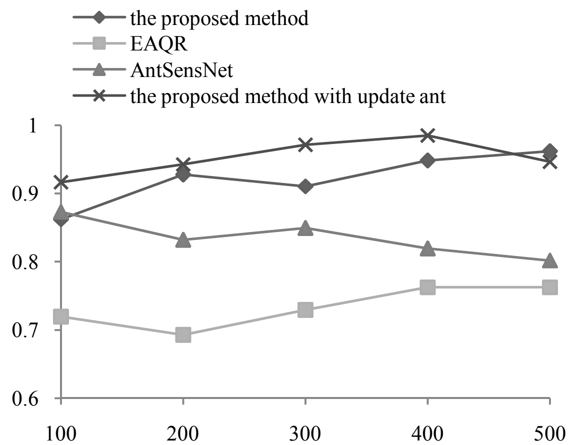

Fig. 7: Packaet delivery ratio as function of number nodes

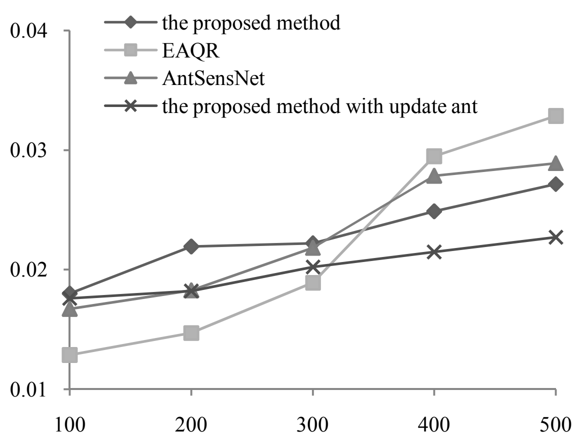

Fig. 8: End to end delay as function of number nodes

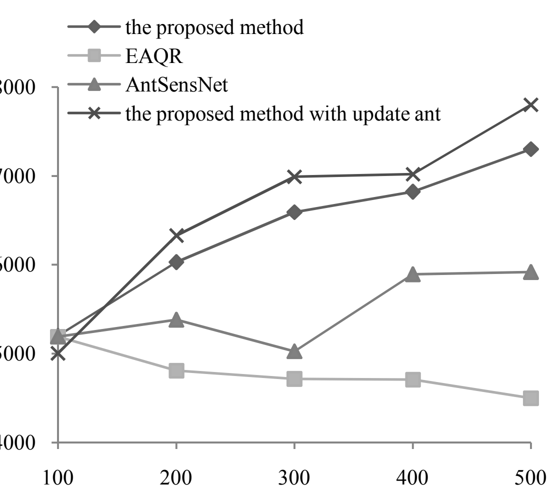

Fig. 9: Throughput as function of number nodes

area of 1000×1000m2. Radio propagation of each node was set to about 250 meters and channel capacity was 2

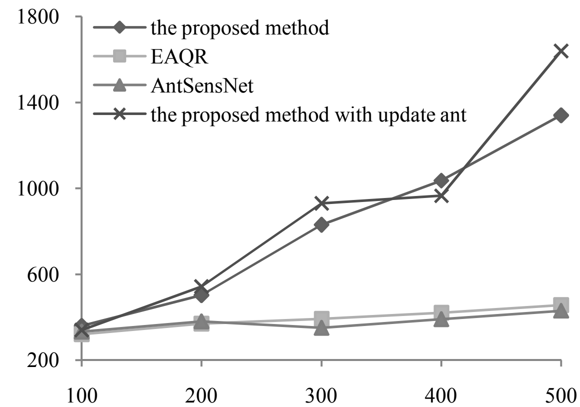

Fig. 10: Life time as function of number nodes

Mbit/sec. Each simulation is executed for 300 sec of simulation time. The IEEE 802.11 Distributed Coordination function was used as the medium access control. The mobility model is Random-Way point where nodes randomly selected the moving direction and when they reached the simulation terrain boundary, they bounced back and continued to move. The Constant Bit Rate (CBR) was selected as the traffic since the GloMoSim does not support Variable Bit Rate (VBR) traffic. The size of data payload was 512 bytes. To evaluate the proposed method, it is compared with two novel methods which recently proposed: EAQR (Jietai *et al*., 2009) and AntSensNet (Cobo *et al*., 2010).

In the first scenario, results have been shown with increase of number node from 100 to 500. Results for different flows are presented in one chart. They present that overall performance of our proposed method completely come over EAQR and AntSensNet. AntSensNet consider four different issues in routing process. Thus it has higher delay than EAQR. In other hand, the proposed method considers efficients parameters e.g.. Bandwidth in routing process. This efficiency leads to higher rate of packet delivery.

Figure 7 presents number of delivered packets in the proposed method is very higher than EAQR. Figure 8 shows end to end delay for two simulated method. The proposed method uses high efficient hueristic mechanism to decrease overall ETE delay.

Through put is number of received bits in a period of time (Fig. 9). When our proposed method try to find paths with high available bandwidth and minimum dela, obviously it would have higher throughput. Figure 10 clarifies another aspect of the proposed method. It presents that the proposed method uses minimum number of overhead packets to handle packets to destionation nodes.

In the second scenario, we present details of performance evaluation for four type of service. In Table 3, normilized control is computed from dividing total control packets by number of received data

Table 3: Detail of results for four type of services

	Proposed method				Proposed method with update ant				Ant sens net				EAQR	
	Service 1	Service 2	Service 3	Service 4	Service 1	Service 2	Service 3	Service 4	Servic 1	Service 2	Service 3	Service 4	Service 1, 2, 3	Service 4
Average ETE Delay (ms)	13	189	46	452	15	112	41	329	23	217	128	319	75	371
Packet delivery ratio (%)	95%	79%	86%	81%	97%	85%	86%	89%	84%	66%	67%	88%	81%	52%
Throughput(bit/sec)	3014	2978	1986	2417	3005	3140	2239	2891	2134	1786	1502	2871	2809	2067
Lifetime (sec)	417				401				386				319	
Total control packets	17802				18994				18892				19273	
Normalized control packets	0.034				0.031				0.066				0.087	

packets. Another important indicator in Table 3 is life time that describe time to the first sensor node turns off. The proposed method tray to balance power consumption in thoughout of network with considering power level of intermediate node as a main issue in routing process.

CONCLUSION

The promising pace of technological growth has led to the design of sensors capable of sensing and producing multimedia data. However, as multimedia data contain images, video, audio and scalar data, each deserves its own metrics. These characteristics of multimedia sensor networks depend on efficient methods in order to satisfy QoS requirements. Given such motivation, this study proposes a QoS routing algorithm for wireless multimedia sensor networks based on an Ant Colony optimization framework and a biologically inspired clustering process. The routing algorithm also offers different classes of traffic, adapted to the needs of applications. In this study, a new routing scheme based on ant colony system was proposed for different applications like as multimedia applications, games, chat and email. Simulation results shows that the proposed method has very high performance in comparison to other multicriteria routing algorithms due to considering efficient parameters in routing process.

In future researches, we are going to examine our work over real traffic sessions and evaluate its performance with different scenarios. we plan to investigate is to extend the proposed architecture to a t cross-layer architecture proposed in this study to include a better interaction with a transport entity and the MAC sublayer. Similarly, Instead of the 802.11 MAC layer, we will investigate the use of Sensor MAC (SMAC) which is a MAC protocol designed for wireless sensor networks. SMAC has the potential to make the cross-layer architecture more energy efficient.

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