An Agent Based Routing Algorithm for Ubiquitous Sensor Networks

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Abstract

An autonomic computing system has four basic characteristics, namely self-configuration, self-optimization, self-healing and self-protection. Autonomic computing can be viewed as a new computing paradigm and it is becoming a hot research topic in distributed and ubiquitous computing area. In this paper, we not only discuss the four basic aspects of autonomic computing comprehensively based on our own understanding but also proposed autonomic agent based power-aware routing approach for ubiquitous sensor networks which is a distributed and localized routing approach. Besides, we provide an application scenario to the sensor network among which the power consumption is one of the most critical issues. The amount of agent is carefully selected and network performance such as packet delivery rate and power consumption is also compared in the simulation part.

Keywords: *Autonomic Computing, Routing, Sensor Networks, Power Consumption*

1. Introduction

Autonomic computing [1] has recently attracted much attention as a novel computing paradigm. Basically, it is a concept of self-managed computing systems with minimum human consciousness or involvement, deriving from the human autonomic nervous system. In [2], the essence of autonomic computing, engineering and scientific challenges are thoroughly analyzed. Opportunities and possible research directions of autonomic computing in the system engineering field are well explained in [3].

Swarm Intelligence (SI) is an Artificial Intelligence technique involving the study of collective behaviour in decentralized systems. Such systems are made up by a population of simple agents interacting locally with one another and with their environment. Although there is typically no centralized control dictating the behaviour of these agents, local interactions among them often cause a global intelligent pattern to emerge. Swarm-like algorithms, such as Particle Swarm Optimization (PSO) [4] and Ant Colony Optimization (ACO) [5], have already been applied successfully to solve real-world optimization problems.

It is a good alternative to combine autonomic computing with swarm intelligence and to apply them to some distributed applications such as ubiquitous sensor networks and complex networks etc. Through localized collaboration among autonomic agents, better performance like power consumption, packet delivery rate and communication overhead can be achieved in a dynamic and distributed environment.

2. Overview of Autonomic Computing

Autonomic computing has attracted much attention recently as a novel computing paradigm. Autonomic computing itself is not a novel concept but a concept of self-managed computing system with minimum human consciousness or involvement, and with an ultimate goal to free administrators from details of system operation and maintenance. An autonomic computing system has at least four basic characteristics. In the following, we will briefly discuss them based on our understanding.

Self-Configuration: in a complex system, there are hundreds or thousands of tunable parameters which vary dynamically. When a new component is introduced, it will incorporate itself seamlessly and the rest of the system will adapt to its presence. If the current device is busy, the system should know an alternative device and reconfigure the request call to that device.

Self-Optimization: most people mainly concern about load-balancing and resource utility so as to improve system performance. Besides these, there are some other parameters which can be optimized. Some parameters which can be optimized include QoS, power consumption, latency and overhead, loss rate, bandwidth utility etc.

Self-Healing: Autonomic computing systems will detect, diagnose, restrict, mask, compensate and repair localized problems resulting from bugs or failures in software and hardware. Using fault detection, systems can determine whether a fault has occurred and the type of fault. Then, a diagnosis component can analyze from log files and find the cause of fault. Finally, the fault can be repaired either by modifying it or simply replacing it with another substitute.

Self-Protection: autonomic systems will be self-protecting in two aspects: (1) They will defend systems as a whole against large-scale, correlated problems from malicious attacks and cascading failures; (2) They will predict problems based on historical reports from sensors and then take actions to defend them.

3. Swarm Intelligence Mechanism

The principles of Swarm Intelligence (SI) were originally inspired by the observation of various natural phenomena, including the collective behaviour of social insects and flocking and shoaling in vertebrates. Under such circumstances, those insects may interact with each other in a very simple and localized way, but astonishing results can be achieved. Thus, the idea that subcomponents are extremely simple but the overall system manages itself adaptively is very promising from an engineering perspective.

The application of SI to distributed and real-time systems aims at developing robust task-solving methodologies by minimizing the complexity of the individual units and emphasizing parallelism and self-optimization.

Figure 1 shows the generalized procedure of pheromone based solution. To reduce effect of past experience, an approach called pheromone evaporation (Pher-evap) is used to prevent pheromone concentration in optimal paths from being overused. In each iteration, pheromone values are decreased by a factor so that more routing candidates can be chosen. Pheromone reinforcement (Pher_reinf) is used to reinforce certain routes which are frequently visited. Pheromone aging (Pher_aging) is used to reduce historical influence and a pheromone upper bound is adopted to avoid bottleneck effect.

```
Procedure Pheromone-based Solution ( )
    While (not stopping criterion)
     Activities_scheduling
        Pher_evap ( );
        Pher_reinf ( );
        Pher_aging( );
        Pher_........ ( );
     End Activities_scheduling
    End While
Return optimal solution
```

Figure 1. Generalized Procedure of Pheromone based Solution

4. Our Agent Based Routing Algorithm

Inspired by [6], we present an autonomic agent (AA) based routing approach in Figure 2 by combining some autonomic functions with routing mechanism.

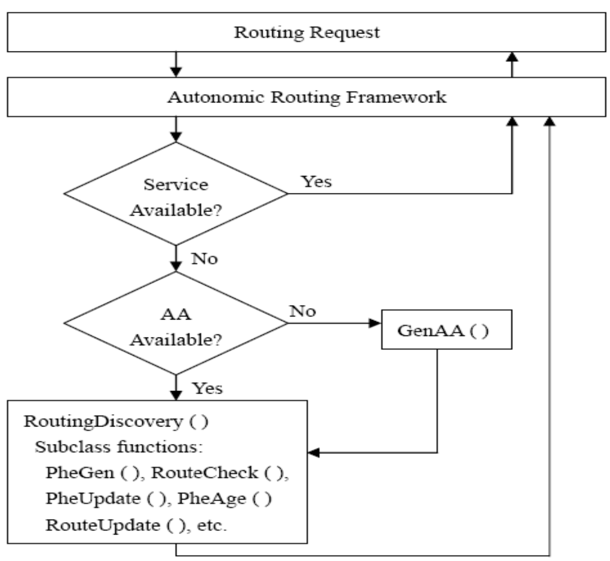

Figure 2. An Autonomic Agent based Routing Approach

Usually, each AA is piggybacked into a hello packet and periodically broadcasted to collect information like available services, remaining energy, distance, hop number etc. SI mechanism is adopted with pheromone evaporation, reinforcement and aging.

Once source node has routing request, it will follow the routing approach in Fig. 3 which is consisted of many closed loops. It will first check the availability of service and send its data to the next candidate neighbor if service is available. If not, it will check availability of AA and perform routing discovery process and use subclass functions like pheromone generation, update and aging etc. Self-healing mechanism and security policies are adopted here and best services are provided finally.

Thus, each node will find its next hop candidate and forward the traffic packet based on the routing table and pheromone table during route setup phase. During route maintenance phase, routes are maintained either through periodical hello packets or AA exchange. In the meantime, pheromone value is reinforced or evaporated to represent real network situation. Once there is a link failure, local repair can be adopted. In this way, the autonomic computing functionalities are achieved.

5. Performance Evaluation

We set our simulation environment as follows. There are [40,150] nodes randomly placed within a 200*200 m^2 area with transmission range [30, 80]m. Taking N=50 as an example, we can see the random deployment of sensor nodes in Figure 3.

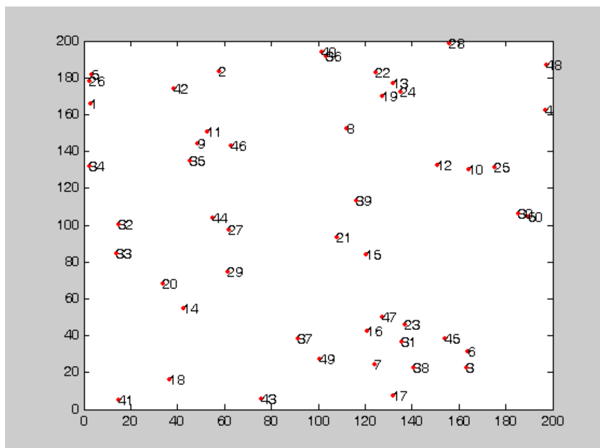

Figure 3. Random Node Deployment in WSN

In Figure 4, we make a comparison between different numbers of agent approaches in the aspect of successful routing set-up rate. From this figure, we can see that there is no reliability guarantee if the agent number is too small. As node number increases, the successful packet delivery rate will also increase.

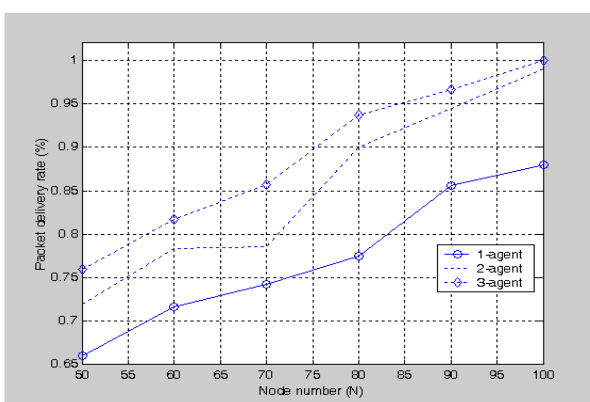

Figure 4. Comparision of Successful Rate of Packet Delivery

In Figure 5, we compare power consumption between broadcasting mechanism and our agent based routing algorithm. We can see that our algorithm is always better than and the packet delivery rate is guaranteed. The larger N is, more energy will be saved.

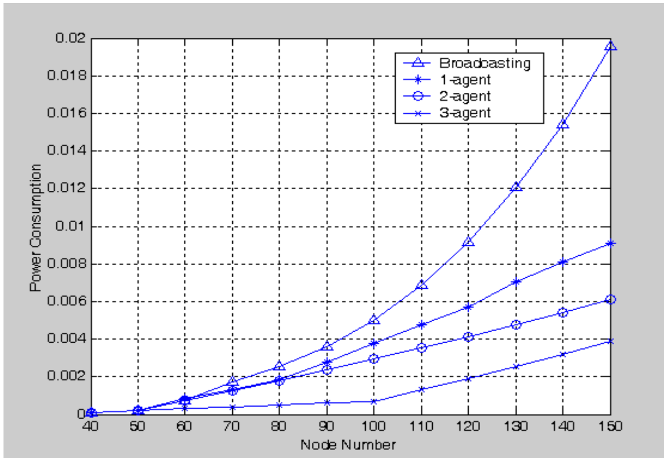

Figure 5. Power Consumption between Different Approaches

6. Conclusion

By combing the mechanism of autonomic computing and swarm intelligence, an autonomic agent based novel routing approach is proposed in this paper. The detailed autonomic routing approach is discussed and simulation results also validate the effectiveness of our proposed approach.

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References

[1] R. Murch. "Autonomic Computing", Upper Saddle River, Prentice Hall, New Jersey, **(2004)**.

[2] J. Kephart and D. Chess, "The Vision of Autonomic Computing", IEEE Computer, 1, 36 **(2003)**.

[3] H. Schmeck, "Autonomic computing - vision and challenge for system design", Proceedings of the International Conference on Parallel Computing in Electrical Engineering, **(2004)** September 7-10; Dresden, Germany.

[4] Y. Valle, G. K. Venayagamoorthy, S. Mohagheghi, J. C. Hernandez and R.G. Harley, "Particle Swarm Optimization: Basic Concepts, Variants and Applications in Power Systems", IEEE Transactions on Evolutionary Computation, 2, 12 **(2008)**.

[5] L. Xing, P. Rohlfshagen, Y. W. Chen and X. Yao, "A Hybrid Ant Colony Optimization Algorithm for the Extended Capacitated Arc Routing Problem", IEEE Trans. on Systems, Man, and Cybernetics, Part B, 4, 41 **(2011)**.

[6] J. Suzuki and T. Suda, "A Middleware Platform for a Biologically Inspired Network Architecture Supporting Autonomous and Adaptive Applications", IEEE Joul. on Selected Area in Communications, 2, 23 **(2005)**.

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