Design an Integration of Bee Hive into a Multi-Agent-based Resource Discovery Method in P2P Systems

Jun Yamasaki, Yoshikuni Harada, and Yasushi Kambayashi
Department of Computer and Information Engineering, Nippon Institute of Technology
4-1 Gakuendai, Miyashiro-cho, Minamisaitama-gun, Saitama 345-8501 Japan
{c1065434, c1015367}@cstu.nit.ac.jp and yasushi@nit.ac.jp

***Abstract*—One of the most important functions in P2P systems is the location of resources; it is generally hard to achieve due to the intrinsic nature of P2P, i.e., dynamic re-configuration of the network. We have proposed and implemented an efficient resource locating method in a pure P2P system based on a multiple agent system. All the resources as well as resource information are managed by cooperative multiple agents. In order to optimize the behaviors of cooperative multiple agents, we utilized the ant colony optimization (ACO) algorithm that assists mobile agents to migrate toward relatively resource-rich nodes. Even tough the ACO algorithm helped multiple search agents to find desired resources effectively while reducing communication traffic in the network, some research scientists have claimed that non-pheromone-based algorithm, such as honey bee algorithm, is significantly more efficient to find resources. Then efficient migration should be achieved through direct communication between bee agents in the dance floor instead of pheromone-based indirect communications. In this paper, we propose and discuss the possibility of integration of the bee-like agents into our resource discovery method to optimize the behaviors of the mobile multiple agents.**

Keywords-multi-agent system; mobile agents; resource discovery; swarm intelligence; honey bee algorithms

I. INTRODUCTION

As the Internet spreads throughout the world, it is used for a variety of human interactions. User interactions across various applications require software that exchanges resources and information within the network community. The traditional client-server model on computer networks barely accommodates the real-world situations such as the advent of video-streaming services. Intensive accesses on a server can easily create a bottleneck in a network. Peer-to-peer (P2P) systems can provide a solution to this problem. A P2P system consists of a number of decentralized distributed network nodes that are capable of sharing resources without central servers. Many applications such as IP-phone, contents delivery networks (CDN) and distributed computing adopt P2P technology into their base communication systems. A P2P system includes an overlay network where the nodes can interact and share resources with one another. Here, 'resources' means the variety of services that are provided by the network nodes.

One of the most important problems in P2P systems is the location of resources; it is one of the hardest mechanisms to implement. Napster avoids this problem by using a central server that provides indexing service [1]. Such a server, however, can be the most vulnerable point, where a failure can paralyzes the entire network. Therefore, P2P systems without any central server (pure P2P) are the area of active research in current P2P system developments. We have proposed and implemented an efficient resource location method based on a multi-agent system for a pure P2P system [2].

In this paper, we report our multi-agent system with an enhanced resource location mechanism. The efficiency is gained through a technique inspired by social insects like ants and honey bees. In order to optimize the behavior of cooperative multiple agents, we integrate the bee behaviors as well as DHT into mobile agents to migrate toward the desired nodes. In the previous paper, we discussed that the ant colony optimization algorithm provided quasi-optimally guidance for multiple search agents toward resource rich nodes and to assists them to find desired resources effectively while reducing communication traffic in the network. Efficient migration is achieved through an indirect communication that is typical of social insects, called *stigmergy*. When an agent finds a resource-rich node, it strengthens the path toward the node to gain efficiency. Strengthening of the route to a desirable node is achieved by pheromone applied by preceding agents that guides succeeding agents so that they can easily reach that node. This pheromone-based indirect guidance takes a certain amount of time to emerge the paths toward resource rich nodes, and even such paths are established, the guidance did not guarantee the suggested nodes have resources that the user really desired.

In order to ameliorate this problem, we are proposing and implementing a new type of resource discovery method that can be used in pure P2P systems. The method is based on yet another biologically inspired algorithm namely BeeHive [3]. BeeHive is a fault-tolerant routing algorithm and we have found it can be useful for P2P systems.

The structure of the balance of this paper is as follows. The second section describes the background. The third section describes the P2P system we are proposing. Static and mobile multiple agents work together to find network resources in the P2P system. We also discuss the honey bee behaviors for foraging that contribute the resource discovery. The fourth section describes the resource discovery algorithm that uses the multiple agents and a honey bee

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algorithm to find network resources in the P2P system. Finally, we sketch how the system is implemented using an overlay construction tool kit and a mobile agent construction framework and conclude our discussion in the fifth section.

II. BACKGROUND

The famous pure P2P system, Gnutella, employs message flooding for locating resources [1]. The advantage of such a system is its simplicity, but it is impractical for a large-scale network system, because flooding resource discovery messages alone can easily saturate entire networks. In order to solve this problem, the use of a distributed hash table (DHT) is proposed and used [4]. Even though DHT is one of the most promising methods and it certainly provides fast resource lookup (*O(log n)* computational complexity) for pure P2P systems, it is too rigid to process flexible and intelligent queries.

In order to ameliorate the problems in DHT-based systems, we have proposed a multiple-agent-based approach. One of the authors has engaged in a project where autonomous agents play major roles in an intelligent robot control system [5] [6]. The mobile agents in the project can bring the necessary functionalities and perform their tasks autonomously, and they have achieved reduction of communications as well as flexible behaviors. Thus, it is natural for us to employ not only static agents but also mobile agents in our P2P system in order to provide flexible search. The mobile agents are expected to reduce the quantity of query messages.

On the other hand, algorithms that are inspired by behaviors of social insects such as ants that communicate each other by an indirect communication called *stigmergy* are becoming popular [7]. Upon observing real ants' behaviors, Dorigo et al found that ants exchanged information by laying down a trail of a chemical substance (called *pheromone*) that is followed by other ants. They adopted this ant strategy, known as ant colony optimization (ACO), to solve various optimization problems such as the traveling salesman problem (TSP) [7].

Even tough ACO is effective; it is known that it takes some amount of time for the shortest path to emerge, and some doubts about its efficiency are posed [8]. It has been well known that honey bees have a remarkable sophistication of the communication capabilities those are comparative to ants. Von Frisch deciphered the enigma of bee's behaviors [9].

Honey bees' foraging behavior consists of two types that are recruitment and navigation. For navigation, bees use a strategy called path integration. They can compute their present location from their past trajectory continuously; hence they always know the direct route to their hive rather than retracing their outbound route, as ants do. For navigation, bees use a strategy called dance. Upon returning from a foraging trip, a bee communicates the distance, the direction and quality of flower site with its fellow foragers by performing waggle dances on the dance floor in its hive. The more zealously they dance, the more foraging bees are recruited to exploit the high quality flower site. Honey bees evaluate the quality of each discovered flower site and perform the waggle dance for the most promising flower site on the dance floor. As a result, high quality flower site are exploited quite intensively. Hence we abstract the dance floor into node management table by which the bee agent exchange resource information as BeeHive algorithm abstract the dance floor into routing tables [3].

BeeHive is a novel routing algorithm. For the algorithm, the network is organized into fixed parturitions called *foraging regions*, and two types of agents, *short distance bee agents* and *long distance bee agents* collect and disseminate routing information. Short distance bee agents only migrate in the foraging regions, thus they propagate routing information in the neighbors, while long distance bee agents can migrate to all the nodes in the network, thus they propagate routing information in the entire network [3]. In our approach, we model bee agents in resource discovery algorithm

III. THE P2P SYSTEM

The model of our system is a multi-agent system that consists of a set of cooperative static and mobile agents. All the resources as well as resource information are managed by cooperative multiple agents. They are: 1) information agents (IA), 2) two types of bee agents, namely long distance bee agents (LBA), and short distance bee agents (SBA), 3) node management agents (NA), and 4) DHT agents (DA). These five agents are the minimum configuration. LBAs and SBAs are the only mobile agents. IA's encapsulate all the interfaces between users and applications that utilize this P2P system so that all the other parts (agents) can be independent from any applications. We separate DA from NA, because only high performance nodes construct DHT. A Node with DA is called *super node*, and a super node dominates and administrates surrounding non-super nodes. We call this surrounding region a *foraging zone* and use it in our honey bee algorithm.

The P2P system is loosely partitioned into a number of foraging zones. Each foraging zone is constructed around one super node. Therefore the number of foraging zone is the same as the number of super nodes. Each node also has its specific foraging zone that consists of all nodes to which its short distance bee agents can reach. The union of these specific foraging zones is the foraging zone constructed around the super node. Each non-super node periodically dispatches a short distance bee agent in order to disseminate the resource information in its node management table. In order to prevent communication congestion, short distance bee agents only move in its specific foraging zone and have short lives. Therefore the foraging zone that partitions the P2P system (super-node's foraging zone) is not homogeneous; it is just an aggregate of many non-super nodes' foraging zones.

Only the super nodes can dispatch the long distance bee agents that can migrate to other super nodes, and propagate the node management table information as short distance bee agents do as well as collect node information in other

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foraging zones. The followings are the descriptions of each agent.

1) *Information Agent (IA):* Each node has a static information agent (IA) that manages resource information. IA periodically launches a short distance bee agent in order to collect and carries resource information in its specific foraging zone. IA also interacts with users. Each non-super node has resource information in the specific foraging zone. If the requested resource is in its foraging zone, IA can reply to the user immediately by consultation with the fellow node management agent (NA).
2) *Short Distance Bee Agent (SBA):* A Short distance bee agent circulates in its specific foraging zone to disseminate resource information. Each non-super node dispatches one short distance bee agent and it restricts its scout area in its specific forager zone so that it does not cause communication congestion. They are trying to uniform the node management tables in its specific foraging zone. Since the foraging zones for non-super nodes are overlapping each other, ultimately the resource information in the super node's foraging zone becomes relatively homogeneous.
3) *Long Distance Bee Agent (LBA):* If the user's requesting resource is not in the specific foraging zone of the non-super node that accepts the query, the non-super node's IA delegates the request to the super node, and then the super node creates a long distance bee agent to search the entire P2P system. There is small possibility that the requested resource is in a specific foraging zone of another non-super node in the same super node's foraging zone due to non-homogeneity. We are trying to measure empirically the rate of such anomaly. LBA also plays the role of messenger to convey DHT query messages.
4) *Node Management Agent (NA):* Each node has a static node management agent (NA) that has neighbor information collected dispatched short distance bee agent. NA has a table that contains the IP addresses of neighbors and resources that are hold by the neighbors.
5) *DHT agent (DA):* DHT agents (DA) construct DHT through cooperation with other DA's that reside on other super nodes. Only high-performance nodes have DA's so that we can construct pure P2P systems in a heterogeneous environment. Nodes with DA are called super nodes, and they construct a kind of super highway for the long distance bee agents (LBA). Though current implementation integrates the Chord [10] as the DHT algorithm, we can replace it with other algorithms just through replacing DA's. Due to the high churn property of pure P2P network, we can not expect DHT is ever complete. Therefore arriving LBA has incomplete information for the hash value, and DA can only provide incomplete information. Still the super node has nearly complete information about the non-super node under its dominance; it is therefore straightforward for LBA to find the requested resource in the foraging zone in which it arrives.

The majority of foragers exploit the food source in the closer vicinity of their hive while minority visit flower sites faraway from their hive [3] [9]. This observation inspires us to transform the search agents in the previous system into two groups namely short distance bee agents, and long distance bee agents. Short distance bee agents are not search agent in the current system. They collect and disseminate resource information in the neighborhood of source node, while long distance bee agents actually search for entire network to find the requested resource.

IV. Resource Discovery Algorithm

Our resource discovery method is based on mobile multiple agents based on BeeHive [3]. The network is loosely partitioned into several foraging zone. The reason why it is *loosely* partitioned is that the nature of P2P system is high frequency of joining and leaving of participating nodes (churning). Therefore rigid partitioning is impossible and unnecessary. On the other hand this property of loose provides robustness in the network. The foraging zone has one super node with DHT agent and surrounding non-super nodes that are reachable in some limited number hops. Each participating node launches one short distance bee agent (SBA) to collect and to carry resource information in the foraging zone. Upon arriving neighboring nodes, a SBA communicate with the residing node management agent (NA) to check the node management table, and if there are some missing information, the agent gives it to NA, and if it lacks some information, it receives it from NA. Therefore the NA's in one foraging zone share relatively uniform information of the resources the participating nodes in that foraging zone. Figure 1 shows the activity of SBA.

When a user requests that the information agent (IA) in the current node locate a resource, the user has to specify the lookup keywords and search terminating conditions such as the number of hops, duration time, and the number of found nodes. The user is also required to specify how IA should

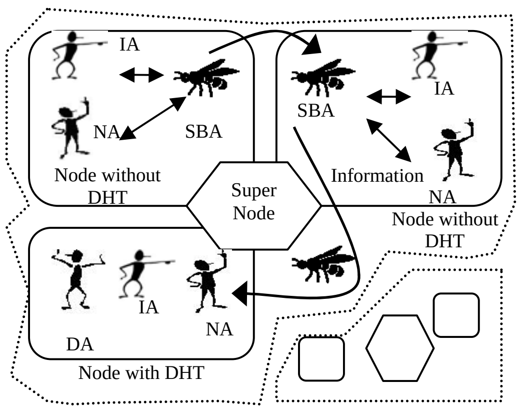

Figure 1. The activities of short distance bee agents to disseminate the resource information among the participating nodes.

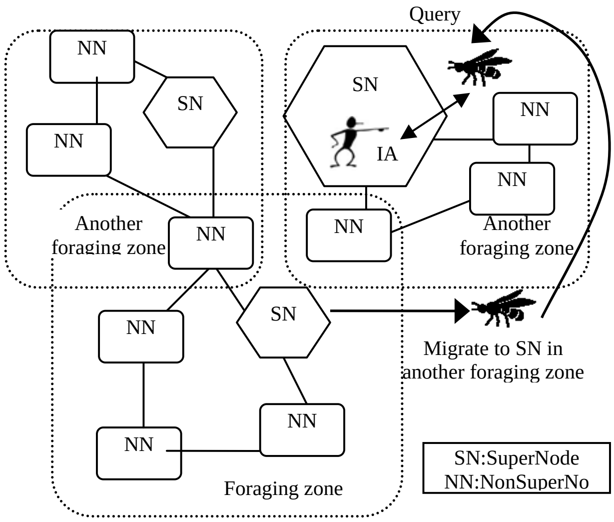

Figure 2. The activities of long distance bee agents to locvate a resorce. They communicate with super nodes.

behave when the dispatched LBA does not return due to some accidents. Figure 2 shows the activities of LBA that interact with other cooperative agents to locate desired resources. The resource discovery algorithm that the coordinated multiple agents perform is as follows:

1. IA consults NA whether the requested resource is in the local foraging zone. If it exists, IA reply so with the IP address stored in the node management table.
2. If the requested resource is not in the local foraging zone, IA delegates the request to the super node in the foraging zone.
3. The super node creates a long distance bee agent (LBA) for specific search.
4. The LBA requests the DHT agent (DA) to receive the IP address to which it migrates. The given address by DA may be inaccurate due to ambiguity of given information by the user. LBA's flexibility covers such incompleteness.
5. The LBA migrates to the selected super node in a different foraging zone.
6. The LBA then interacts with the IA in the arriving super node to find whether it has the requested resource. Then IA consults its NA.
7. If the foraging zone has the resource, the IA gives the IP address of the node to LBA, then goes to step 8, otherwise repeats at step 4.
8. The LBA checks the terminating condition, and if it is satisfied, migrates back to the original node where the user query was created.

V. CONCLUSION AND DISCUSSION

We are proposing and implementing a new type of resource discovery method that can be used in pure P2P systems. The method is based on yet another biologically inspired algorithm namely BeeHive that is a fault-tolerant routing algorithm. We have found it can be useful for P2P systems.

We are implementing our resource discovery methods by using Overlay Weaver [11] and Agent Space [12]. Overlay Weaver is an overlay construction tool kit for the Java language, and provides common API's for high-level services such as DHT and Multicast. This emulator can handle several thousand (virtual) nodes and records the number of produced messages and their duration time. Agent Space is a framework for constructing mobile agents. By using its library, the user can implement a mobile agent environment with the Java language. Since the integration of ACO into P2P system had provided a significant reduction of messages, we are expecting a similar or better effect on the system by the integration of honey bee behaviors.

REFERENCES

[1] S. Saroiu, K. P. Gummadi, and S. D.Gribble, "Measuring and analyzing the characteristics of Napster and Gnutella hosts," Multimedia Systems, vol. 9, 2003, pp. 170-184.

[2] Y. Kambayashi and Y. Harada, "A resource discovery method based on multi-agents in P2P systems," in Intelligent Agents in the Evolution of Web and Applications', N. T. Nguyen and L. C. Jain Eds. Studies in Computational Intelligence 167, Springer-Verlag, 2009, pp.113-135.

[3] H. F. Wedde, M. Farooq, and Y. Zhang, "BeeHive: an efficient fault-tolerant routing algorithm inspired by honey bee behavior," Proc. International Workshop, ANTS, Ant Colony, Optimization and Swarm Intelligence, Lecture Notes in Computer Science 3172, 2004 pp. 83–94.

[4] A. S. Tanenbaum, Computer Networks, 4th ed., Prentice Hall, Upper Saddle River, 2002.

[5] Y. Kambayashi and M. Takimoto, "Higher-order mobile agents for controlling intelligent robots," International Journal of Intelligent Information Technologies, Vol. 1, No. 2, 2005, pp.28-42.

[6] M. Takimoto, M. Mizuno, M. Kurio, and Y. Kambayashi, "Saving Energy Consumption of Multi-Robots Using Higher-Order Mobile Agents," Proc. KES International Symp. on Agent and Multi-Agent Systems: Technologies and Applications, Lecture Notes in Artificial Intelligence 4496, Springer-Verlag, 2007, pp. 549-558.

[7] M. Dorigo and L.M.Gambardella, "Ant colony system: a cooperative learning approach to the traveling salesman," IEEE Transaction on Evolutionary Computation, vol. 1, no.1, 1996, pp. 53-66

[8] N. Lemmens, S. de Jong, K. Tuyls, and A. Nowé, "Bee behaviour in multi-agent systems: a bee foraging algorithm," in Adaptive Agents and Multi-Agent Systems III. Adaptation and Multi-Agent Learning, Lecture Notes in Computer Science 4865, Springer, 2008, pp. 145-156.

[9] K. von Frisch, The Dance Language and Orientation of Bees," Harvard University Press, Cambridge, Massachusetts, 1967.

[10] I. Stoica, R. Morris, and D. Karger, "Chord: a scalable peer-to-peer lookup service for Internet applications," Proc. ACM SIGCOMM Conference, 2001, pp. 149-160.

[11] K. Shudo, Y. Tanaka, and S. Sekiguchi, "Overlay weaver: an overlay construction toolkit," Proc. Symposium on Advanced Computing Systems and Infrastructures, 2006, 183-191, In Japanese.

[12] I. Satoh, "A mobile agent-based framework for active networks," Proc. IEEE System, Man and Cybernetics Conference, 1999, pp. 71-76