A Mobile Agent-based Service Collection and Dissemination Scheme for Heterogeneous Mobile Ad Hoc Networks

Shuhei Ishizuka, Tomoyuki Ohta, and Yoshiaki Kakuda
Graduate School of Information Sciences, Hiroshima City University
3-4-1 Ozukahigashi, Asaminami-ku, Hiroshima 731-3194, Japan
Email: {ishizuka@nsw.info, ohta@, kakuda@}hiroshima-cu.ac.jp

***Abstract*—A mobile ad hoc network (shortly, MANET) that consists of mobile nodes (shortly, nodes) is one of autonomous decentralized networks. Since the network topology changes frequently due to the node movement, it is difficult for each node to grasp the application (service) in MANETs. In order to solve this problem, the service information discovery scheme using mobile agents has been proposed for MANETs. In this scheme, a mobile agent collects and disseminates service information while moving autonomously from a node to another node in the network. However, in heterogeneous MANETs, mobile agents cannot migrate between different MANETs. Therefore, in this paper, we propose the mechanism to efficiently collect and disseminate service information based on mobile agent, and then show the effectiveness of the proposed scheme through simulation experiments.**

Keywords-Ad hoc network; Service information; Mobile agent.

I. INTRODUCTION

A Mobile Ad Hoc NETwork (MANET) [1] is a wireless distributed network that consists of only mobile nodes without the aid of the access points and fixed infrastructure. When a node wants to communicate with another node outside the transmission range, both nodes can be communicated with each other through intermediate nodes between the two nodes. Since a MANET is easily configured by only mobile nodes, many types of MANETs are used for a variety of application. The number of nodes in a MANET, the frequency of the topology change or the total volume of data traffic is different among multiple MANETs. Therefore, a routing protocol that is appropriate for each MANET is different and each MANET uses a different routing protocol because the characteristics of each MANET is different. However, in this case, even if multiple MANETs coexist nearby in an area, MANETs cannot communicate with each other because routing protocols are different. As a result, each node cannot obtain many information that could obtain from nodes in different MANETs. One idea to solve this problem is that all MANETs use the identical routing protocol. However, in this case, it is expected that the performance may degrade in each MANET. The other idea is to deploy the network gateway between MANETs to connect with each other like the Internet. Therefore, we have proposed the mechanism to select the network gateways to provide the interoperability between different MANETs in [7]. The selected nodes serve as the network gateway, but the network gateways change with time because nodes are always moving in MANETs. In this paper, we define the network that multiple MANETs coexist in an area and each MANET can communicate with another MANET as a heterogeneous MANET environment. In addition, there is no network administrator to manage all services, it is difficult for nodes to discover the services in the network because the network topology changes. Therefore, many service discovery schemes [2], [3] have been proposed for the mobile ad hoc network environment.

In this paper, we propose a mobile agent-based service collection and dissemination scheme and a new node architecture for the proposed scheme, and then show the effectiveness of the proposed scheme through simulation experiments. In this scheme, mobile agents collect and disseminate service information that each node holds while migrating from a node to another node, and we have shown that mobile agents can efficiently work in MANETs [5]. In the heterogeneous MANET environment, as the number of network gateways in the network increases, much more links to connect between MANETs are configured, but the overhead becomes much higher. Therefore, in [7], the number of network gateways becomes as low number as possible in comparison with the tonal number of nodes in the network. A service information in a MANET must be forwarded to another MANET through the network gateways between these MANETs. Therefore, mobile agents have to migrate from a node to another node while considering the location of the network gateway nodes that are dynamically changed in heterogeneous MANET environment.

The rest of the paper is organized as follows. Section II presents the node architecture in the proposed scheme. Section III shows the proposed scheme in more detail. In Section IV, we evaluate the proposed scheme and show the simulation results. Finally, we conclude this paper in Section V.

II. NODE ARCHITECTURE FOR HETEROGENEOUS MANETS

In order to implement the proposed node architecture, the mechanisms of autonomous clustering [4] and ATR(Ad hoc Traversal Routing) [6] in each node are required as a common platform. Each node has the routing protocol specified by the network on the common platform. In the heterogeneous mobile ad hoc network environment where some networks exist, each network is divided into multiple clusters and the nodes in the cluster is managed by the autonomous clustering. In the proposed scheme, each cluster in the networks autonomously

 ISBN: 978-1-61208-318-6

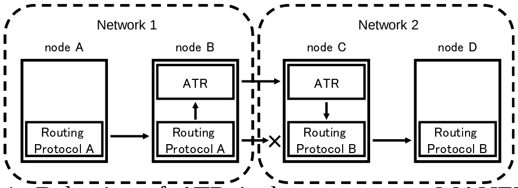

Figure 1: Behavior of ATR in heterogeneous MANET environment.

and dynamically selects one or more network gateway nodes from the nodes in the cluster. The nodes which become network gateway nodes can forward any packets to nodes of the different network by using the mechanism of ATR so that the interoperability between different networks can be provided.

A. ATR(Ad hoc Traversal Routing)

We have proposed ATR that provides the communication between different networks in heterogeneous MANETs. We define a node that both any routing protocol and ATR work as a NwGW (Network GateWay) node. A NwGW node converts from control packets of a routing protocol into control packets of ATR and vice versa. As a result, a node in a network can communicate with another node in a different network through NwGW nodes.

We explain ATR using an example as shown in Figure 1. Given that there are two networks, which are Network 1 and Network 2, and nodes A and B belong to Network 1 and nodes C and D belong to Network 2. When node A wants to communicate with node D, the route between nodes B and C cannot be created because the routing protocols are different. However, in this example, ATR works on nodes B and C so that nodes between Network 1 and Network 2 can communicate with each other through nodes B and C. Node B that receives a control packet of routing protocol A from node A converts from the control packet to a control packet of ATR, and then forwards it to node C. Node C that receives the control packet of ATR converts from the control packet to the corresponding control packet of routing protocol B, and then forwards it to node D. As a result, the route between nodes A and D can be created through nodes B and C.

B. Network Gateway Selection Scheme Based on Autonomous Clustering

In each network, the NwGW nodes must be selected to forward any packets from a network to another network in heterogeneous MANET environment. In MANETs, since all nodes are always moving, NwGW nodes must be dynamically selected from nodes in each network according to the topology change. Therefore, in order to select NwGW nodes dynamically in each MANET, we proposed an autonomous clustering-based dynamic network gateway selection for heterogeneous MANETs [7]. Autonomous clustering is the scheme to divide the network into multiple clusters. Each cluster consists of one cluster head, some gateways, and cluster members.

Figure 2 shows the outline of the heterogeneous MANET environment based on the network gateway selection scheme. In Figure 2, there are two networks, which are Networks 1 and 2. In each network, NwGW nodes are selected based

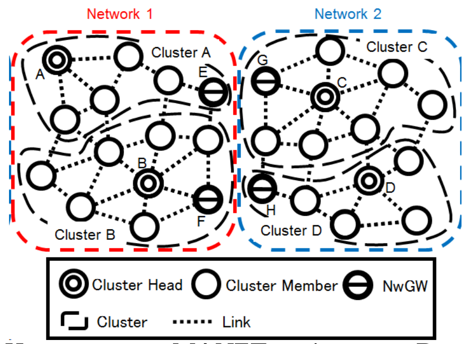

Figure 2: Heterogeneous MANET environment Based on Network Gateway Selection Scheme.

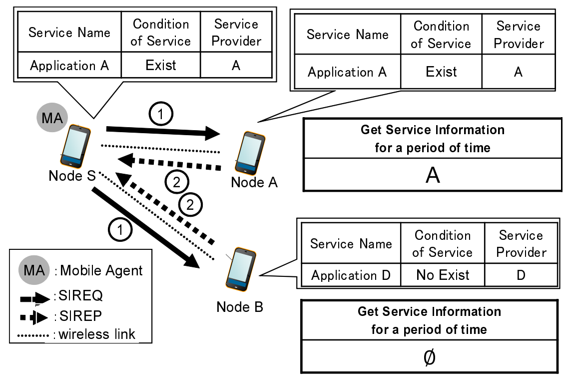

Figure 3: Mobile agent migration mechanism.

on the dynamic network gateway selection scheme. In this environment, any packets are forwarded from Network 1 to Network 2 through the link between two NwGW nodes in different networks, which are nodes F and H.

III. Mobile Agent Management Mechanism

A. Outline

The purpose of the mobile agent-based service collection and dissemination scheme is to collect and disseminate service information for a shorter time in heterogeneous MANETs. In heterogeneous MANETs, the proposed scheme creates a mobile agent when a NwGW node holds service information and the other mobile agents do not come to the NwGW node for a certain period.

B. Mobile Agent Migration Mechanism

In Moving Average-based (MA-based) migration mechanism, mobile agents recognize the service information that each of neighboring nodes newly obtained for a specified period and migrate to the neighboring node that the number of the services is the lowest. Here, we define the specified period as the service collection time.

We explain the mobile agent migration mechanism using Figure 3. Given that there are three nodes: nodes S, A, and B, and a mobile agents is staying at node S in Figure 3. Each table denotes the list of service information that each node manages. First, as shown in Figure 3①, node S that a mobile agent is staying broadcasts a Service Information REQuest (SIREQ) including Service ID of node S to obtain the service

 ISBN: 978-1-61208-318-6

information from neighboring nodes like SN-based migration mechanism. Then, as shown in Figure 3②, nodes A and B that received the SIREQ from node S sends a Service Information REPly (SIREP) back to node S. Here, the SIREP includes the service information that the mobile agent does not have and each node (that is, nodes A and B) has, and a set of services (SPT_i) that each node i newly obtained for a specified period. In this time, if the neighboring nodes do not have the service information contained in the SIREQ, they can obtain a new service information from the SIREQ. Finally, the mobile agent that received the SIREPs from the neighboring nodes migrates to the node that the number of new obtained services for the specified period is the lowest.

For example, given that node S receives SIREPs from nodes A and B as shown in Figure 3. In this case, $SPT_A = \{A\}$ and $SPT_B = \emptyset$. Therefore, the mobile agent migrates to node B such that $|SPT_B| < |SPT_A|$.

C. Mobile Agent Creation-Termination Mechanism

The mobile agent creation-termination mechanism creates or terminates mobile agents to control the number of mobile agents in the network.

1) Mobile Agent Creation Conditions: A mobile agent is created on a node when one of three conditions is satisfied.

Condition 1: A node with a service generates or updates a service.

Condition 2: A node does not receive a SIREQ for a specified period.

Condition 3: A node is selected as a NwGW node and it has collected service information for a specified period, which is defined as a service collection time, in the past.

By Condition 1, the generated service or updated service is disseminated by mobile agents. By Condition 2, the node creates a mobile agent when each node judges that the number of mobile agents in the network is low. By Condition 3, a NwGW node creates the mobile agent in order to easily migrate the mobile agent between different networks.

2) Mobile Agent Termination Conditions: A mobile agent is terminated when one of following two conditions is satisfied.

Condition 1: A mobile agent receives a SIREQ from the other mobile agents.

Condition 2: A node with a mobile agent does not have neighboring nodes.

By Condition 1, the node terminates a mobile agent when the number of mobile agents in the network is high. By Condition 2, the node terminates a mobile agent when a mobile agent cannot disseminate service information.

D. Types of Mobile Agents

The proposed scheme uses two types of mobile agents in heterogeneous MANETs.

IMA (Internal MA): A mobile agent disseminates service information in a network.

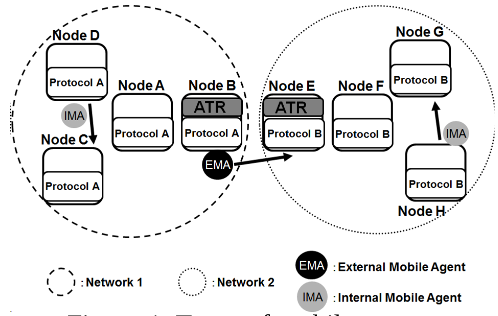

Figure 4: Types of mobile agents.

TABLE I: Simulation environment in Simulation I.

Network Simulator	QualNet ver. 5.0
Field size [m^2]	1570×1570
Number of nodes	200
Number of networks	2
Number of nodes in each network	100
Transmission range [m]	250
MAC protocol	IEEE802.11b
Node moving speed [m/s]	1∼4
Node mobility model	Random Way Point
Size of MAs [byte]	4096

EMA (External MA): A mobile agent disseminates service information between different networks.

IMAs are created by Conditions 1 and 2 of the mobile agent creation mechanism in order to disseminate service information in a network. EMAs are created by Condition 3 of the mobile agent creation mechanism in order to disseminate service information between NwGW nodes in each network. A mobile agent transits from the EMA to the IMA in order to disseminate service information in the network after the EMA has migrated between different networks.

In Figure 4, there are two networks, which are Networks 1 and 2 in heterogeneous MANET environment, and nodes B and E are NwGW nodes in Networks 1 and 2, respectively. In the proposed scheme, the IMA migrates from a node to another node while collecting and disseminating service information only in each network. On the contrary, the EMA is generated at node B in Network 1, and then it migrates from node B to node E to disseminate service information in Network 2. After that, the EMA becomes the IMA of Network 2 and disseminates service information only in Network 2.

IV. Simulation Evaluation

We conducted simulation experiments to evaluate the proposed scheme through network simulator QualNet [8]. We show the effectiveness of the proposed scheme in comparison with Random scheme.

Random scheme is a scheme to randomly migrate mobile agents from a node to another node without considering the efficient service collection and dissemination. Here, mobile agents in Random scheme are generated only by Conditions 1 and 2 of mobile agent creation conditions.

A. Simulation I

In Simulation I, we investigate the property of the service collection time of the proposed scheme.

TABLE II: Service dissemination time versus service collection time in Simulation I.

Dissemination Rate[%]	Service collection time [s]							
	Case 1				Case 2			
	10	50	100	200	10	50	100	200
60	115	96	86	87	102	89	84	84
70	138	113	102	102	121	105	99	99
80	165	133	121	121	147	125	118	118
90	207	163	148	148	187	154	146	146

TABLE III: Total number of EMAs in Simulation I.

Service collection time [sec]	10	50	100	200
Case 1	7	35	63	88
Case 2	14	48	73	91

1) Simulation Plan: We conducted simulation experiments in the environment where there are two types of MANETs in the field. Table I shows simulation environment. In the simulation experiment, the service collection time of the mobile agent creation condition is set at 10, 50, 100, and 200 seconds. Evaluation criteria are the service dissemination time versus the service dissemination ratio and the number of EMAs. Here, the service dissemination ratio is the ratio of the number of service disseminated nodes to the number of nodes. In addition, one node in Network 1 generates a new service at fixed intervals from the simulation start to the end. First, we investigate the influence on the service generation interval in two cases as follows. In Case 1, the number of services and the service generation interval are set at 10 and 50 seconds, while in Case 2, the number of services and the service generation interval are set at 100 and 5 seconds, respectively. Next, we show the effectiveness of the proposed scheme in comparison with Random scheme.

2) Results for the effect on the service collection time: Table II shows the service dissemination time versus the service collection time in Cases 1 and 2, and Table III shows the number of generated EMAs. The service dissemination times in both Cases 1 and 2 become shorter as the service collection time increases from 10 to 100, while there is no difference between 100 and 200 of service collection time. As shown in Table III, the number of EMAs increase as the service collection time becomes more. When the service collection time is 200, the number of EMAs becomes more than the service collection time 100. However, the dissemination time of the service collection time 200 does not become shorter than that of the service collection time 100. As a result, even if the service collection time becomes more and more EMAs are generated, the service dissemination time does not become shorter. Therefore, we can confirm that the service collection time 100 is appropriate for the proposed scheme in this experiments.

3) Results for the effectiveness of the proposed scheme: In the simulation experiments, the service collection time of the proposed scheme is set at 100 [sec]. Table IV shows the service dissemination time in Cases 1 and 2. The proposed scheme becomes shorter than Random scheme in both cases because of the mobile agent migration mechanism as well as the mobile agent creation condition 3.

Next, we focus on the service dissemination time in Network 1 where there is the service generation node. Table V shows the service dissemination time in Network 1. As shown in Table V, the dissemination time of the proposed scheme becomes shorter than that of Random scheme. In the proposed scheme, mobile agents migrate to a node in which the number of service information obtained for the service collection time is the lowest, while in Random scheme, mobile agents randomly select the node to which they migrate.

TABLE IV: Service dissemination time [sec] in Simulation I.

Dissemination Rate [%]	Case 1		Case 2	
	Proposed	Random	Proposed	Random
60	86	137	84	127
70	102	164	99	154
80	121	199	118	189
90	148	252	146	242

TABLE V: Service dissemination time [sec] in Network 1 in Simulation I.

Dissemination Rate [%]	Case 1		Case 2	
	Proposed	Random	Proposed	Random
60	62	73	59	68
70	76	90	74	86
80	94	109	92	107
90	121	139	118	137

Next, we focus on the time when the service information is forward from Network 1 to Network 2 in order to show the effectiveness of the mobile agent creation condition 3. Table VI shows the service dissemination start time in Network 2. As shown in Table VI, the proposed scheme can disseminate the service information to the neighboring network (Network 2) in a shorter time. In the proposed scheme, in case that NwGW nodes have obtained a new service information for the service collection time in the past, they create EMAs to disseminate the service information to the neighboring network. On the contrary, in Random scheme, only when mobile agents arrive at NwGW nodes, the service information is disseminated to the neighboring network. Therefore, the proposed scheme can provide the efficient service information dissemination among networks.

Finally, we focus on the overhead. Figure 5 and Table VII show the number of MAs versus simulation time and the number of MAs per second. The proposed scheme creates EMAs by the mobile agent creation condition 3 to disseminate the service information to the neighboring network. However, as shown in Table VII, there is no difference between the proposed scheme and Random scheme because the number of MAs is adjusted by the mobile agent creation-termination mechanism.

Table VIII shows the total volume of control packets from the simulation start to 1000 seconds. As shown in Table VIII, the proposed scheme becomes 10 percents more than Random scheme because SIREQ packets are generated by the mobile agent termination mechanism due to EMAs.

B. Simulation II

In Simulation II, we confirm that the proposed scheme can be applicable for service collection and dissemination in heterogeneous MANET environment where the number of networks is three. From the results of Simulation I, the service collection time is set at 100 seconds in Simulation II.

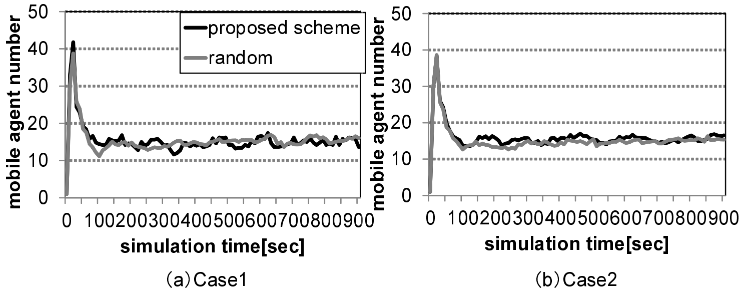

Figure 5: Number of MAs versus simulation time in Simulation I.

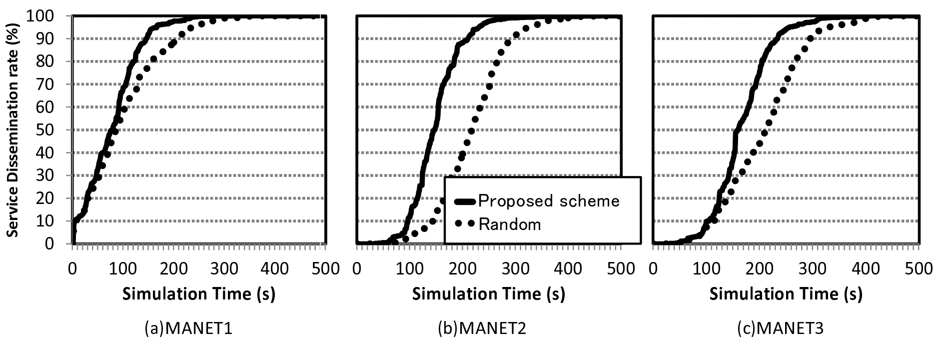

Figure 7: Service dissemination rate versus simulation time in each MANET in Simulation II.

TABLE VI: Service dissemination start time [sec] in different network in Simulation I.

Case 1		Case 2	
Proposed	Random	Proposed	Random
32	102	32	84

TABLE VII: Average number of MAs per second in Simulation I.

Case 1		Case 2	
Proposed	Random	Proposed	Random
15.3	15.4	15.9	15.1

1) Simulation plan: Table IX shows the simulation environment in Simulation II. Three types of networks, which are MANETs 1, 2, and 3, coexist in the field and we conduct simulation experiments in the heterogeneous MANET environment. The total number of nodes in the network is 300 and the number of nodes in each MANET is 100. The node moving speed is between 1 and 4 m/s. In this environment, the number of network gateway nodes (NwGW nodes) became 5.5 on average. In addition, a node generates a mobile agent at 100

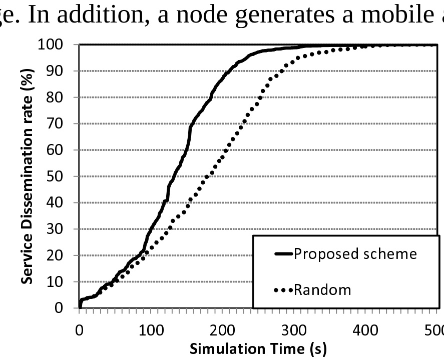

Figure 6: Service dissemination rate versus simulation time.

TABLE VIII: Total control overhead [Mbyte] in Simulation I.

Case 1		Case 2	
Proposed	Random	Proposed	Random
5.5	5.1	22.6	19.7

TABLE IX: Simulation environment in Simulation II.

Simulator	Qualnet ver. 5.0
Field size [m^2]	1570 $\times$ 1570
Number of nodes	300
Number of networks	3
Number of nodes in each network	100
Node moving speed [m/s]	1∼4
Node mobility model	Random Way Point
Number of generated services	10
Transmission range [m]	250
MAC protocol	IEEE802.11b
Size of MAs [byte]	4096

second interval by Mobile agent creation condition 2, and when NwGW node that holds any service information does not hold a mobile agent for 30 seconds, it generates a mobile agent by Mobile agent creation condition 3. In the simulation, nodes in MANET 1 generates ten services at 10 second interval from the simulation start.

2) Simulation results: Figure 6 shows the service dissemination rates of the proposed scheme and Random.

From Figure 6 , we can confirm that the proposed scheme can disseminate service information in a shorter time than Random. This is because mobile agents can appropriately decide the next node that they should move according to the mobile agent migration mechanism. On the other hand, in Random scheme mobile agents move to the node that does not require the service dissemination and collection because mobile agents randomly move around the network. In addition, the proposed scheme generates EMAs (External Mobile Agents) to forward service information between different MANETs. Therefore, in

 ISBN: 978-1-61208-318-6

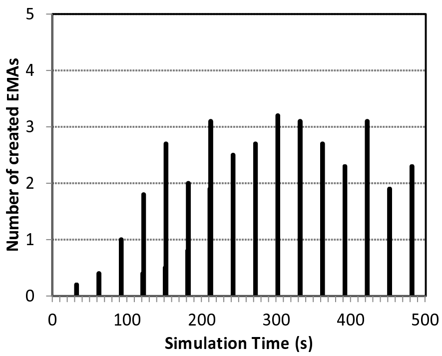

Figure 8: Number of generated EMAs versus simulation time in Simulation II.

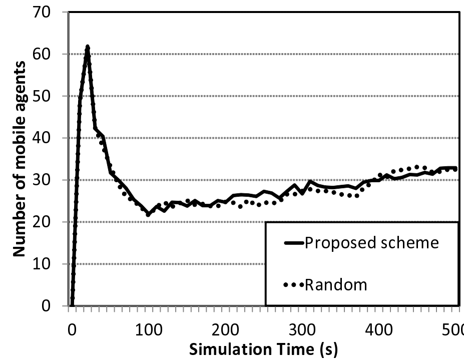

Figure 9: Number of mobile agents versus simulation time in Simulation II.

the heterogeneous MANET environment, the proposed scheme could disseminate service information from MANET 1 to MANETs 2 and 3 in a shorter time.

Figures 7 and 8 show the service dissemination rate in each MANET and the number of generated EMAs, respectively. From Figure 7, in each MANET, the proposed scheme can disseminate service information in a shorter time than Random. Figure 7(a) shows the service dissemination rate in MANET 1. In MANET 1, the services are generated and disseminated by mobile agents, and then the proposed scheme can disseminate service information in a shorter time than Random. In the proposed scheme, mobile agents migrate from a node to another node by the mobile agent migration mechanism, while in Random scheme, they migrate randomly. On the contrary, because MANETs 2 and 3 does not generate service information, MANETs 2 and 3 can disseminate service information after nodes in MANETs 2 and 3 receive service information from mobile agents that are migrated from MANET 1. Figures 7(b) and 7(c) show the service dissemination rate in MANETs 2 and 3. As shown in Figure 8, the proposed scheme can disseminate service information between different MANETs by EMAs. Therefore, especially in MANETs 2 and 3, the proposed scheme can disseminate service information in a shorter time than Random in comparison with MANET 1. Consequently, we can say that the proposed scheme can disseminate service information in a shorter time in the heterogeneous MANET environment.

Next, we focus on the overhead. It is expected that the proposed scheme becomes higher overhead than Random because the proposed scheme generates EMA for service dissemination and collection. Figure 9 shows the number of mobile agents in the proposed scheme and Random. We can confirm that there are no big difference between the proposed scheme and Random from Figure 9. In addition, Table X shows the average number of mobile agents per 1 second in the proposed scheme and Random. Here, in the proposed scheme, the ratio of EMAs to MAs is only 0.003 %. As shown in Table X, the difference between the proposed scheme and Random is very small. This is because the total number of mobile agents is controlled by the mobile agent creation-termination mechanism. As a result, we can say that that the proposed scheme is appropriate for the service dissemination and collection in heterogeneous MANET environment.

TABLE X: Average number of mobile agents in Simulation II.

	Proposed scheme	Random
Average number of MAs [/1 sec]	28.8	28.3

V. Conclusion

We have proposed a mobile agent-based service information collection and dissemination in heterogeneous MANETs, and its node architecture, and shown the effectiveness of the scheme based on the new node architecture in terms of the service dissemination time through simulation experiments. In the future work, we are planning to implement the proposed node architecture on the mobile terminals like android smart phones and verify the behavior in heterogeneous MANET environment through field experiments.

Acknowledgments

This work was supported in part by JSPS KAKENHI (Grant Number 24700073 and 24300028), the Hiroshima City University under Grant for Special Academic Research, and MIC SCOPE (No.131408006).

References

[1] C. K. Toh, “Ad Hoc Mobile Wireless Networks Protocols and Systems,” Prentice Hall Inc., 2002.

[2] C.N. Ververidis and G. C. Polyzos, “Service discovery for mobile ad hoc networks: A survey of issues and techniques,” Communications Surveys and Tutorials, IEEE Computer Society, pp.30–45, 2008.

[3] C. Cho and Duckki Lee, “Survey of Service Discovery Architectures for Mobile Ad hoc Networks,” Department of Computer and information sciences and Engineering, pp.30-45, 2005.

[4] T. Ohta, S. Inoue, and Y. Kakuda, ”An adaptive multihop clustering scheme for highly mobile ad hoc networks,” Proc. 6th IEEE Int’l Symp. on Autonomous Decentralized Systems (ISADS2003), pp.293-300, April 2003.

[5] T. Hashimoto, T. Ohta, and Y. Kakuda, “Evaluation of mobile agent-based service dissemination schemes in MANETs,” Proc. 2nd Int’l Conf. on Networking and Computing (ICNC’11), pp.257–260, Nov. 2011.

[6] S. Fujiwara, T. Ohta, and Y. Kakuda, “An inter-domain routing for heterogeneous mobile ad hoc networks using packet conversion and address sharing,” Proc. 32th IEEE Int’l Conf. on Distributed Computing Systems Workshops (ADSN 2012), pp.349–355. June 2012.

[7] K.Okano, T.Ohta, and Y.Kakuda, ”A dynamic network gateway selection scheme based on autonomous clustering for heterogeneous mobile ad hoc network environment”, Proc. 7th IEEE International Workshop on Heterogeneous, Multi-Hop, Wireless and Mobile Networks (GC’12 Workshop - HeterWMN 2012), pp.513-517, Dec. 2012.

[8] Scalable Network Technologies, Inc., ”QualNet network simulator”. http://www.scalable-networks.com/, (accessed 2013-12-29).