Method of Dynamically Determining the Nodes that Hold Advertisements Suitable for the User's Preference and a Relay Routing Method Based on Area Division

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***Abstract*—Mobile communications carriers are providing GPS-based, location-dependent advertisement delivery services as supplementary services. As the number of mobile terminal types and the number of mobile users increase, the need is rising for a network that can handle location-dependent traffic within a locality efficiently. This paper presents an ad hoc network for location-oriented advertisement delivery, with an advertising node installed in each shop in a busy shopping area. Specifically, it describes a way to express the user's preference, such as their hobbies, based on a Bloom Filter, and a way to dynamically determine the nodes that hold advertisements suitable for the preference of the target user. In addition, the paper also presents a routing method based on area division, which can reduce the number of relay nodes. It has been confirmed, by using simulation, that the proposed method reduces the number of relay nodes by about 70% compared with a case where messages are unicast to collect suitable advertisements.**

Keywords-location-dependent advertisement delivery; ad hoc network; user's preference; bloom filter; routing.

I. INTRODUCTION

As mobile terminals and one-segment broadcasting become widely used, a system has been proposed that delivers advertisements of shops to nearby pedestrians using weak radio waves for one-segment broadcasting. However, a network that interconnects shops and a system that delivers advertisements of multiple shops close to the target pedestrian are yet to be implemented. A service is being provided, in a wide-area network, in which the advertisement delivery server receives GPS (Global Positioning System) data of mobile terminals and sends by email those advertisements of shops that are judged to be suitable based on the locations of the pedestrians and their pre-registered preference data [1]. However, despite of the fact that delivery of advertisements is confined to a certain locality, the delivery traffic is centrally handled by the possibly remote advertisement delivery server that covers a wide area. As such, the rapid growth in access traffic and the number of smartphones are increasing the traffic load on the core network. To simplify the traffic design of the network, service providers are increasingly using public Wi-Fi LANs (Local Area Networks) [2], which are provided by installing Wi-Fi access points at cafés and other types of shops. If an advertising node is installed at each access point and these nodes are interconnected in a network, regionally confined advertisement traffic can be handled locally. Since different shops have different business hours, this network must be configured dynamically so that it will interconnect the nodes of only those shops that are open. A wireless ad hoc network is suitable for this purpose. Routing protocols that have been defined by IETF as RFC for an ad hoc network include OLSR (Optimized Link State Routing), AODV (Ad hoc On-Demand Distance Vector) and DSR (Dynamic Source Routing) [3]-[6]. In addition, there are reports of protocols that extend these and incorporate the concept of link life [7]-[9]. However, it is necessary to study an application-level routing method suitable for providing an advertisement delivery service in an ad hoc network.

With a view to building an ad hoc advertisement delivery network, this paper proposes a way to dynamically determine nodes that hold advertisements suitable for the target pedestrian, and a routing method based on area division, which reduces the number of relay nodes. Section II discusses the conditions for providing an advertisement delivery service in an ad hoc network, and issues for implementing this service. Section III describes a way to express the user's preference based on a Bloom Filter, and a way to dynamically determine nodes that hold the suitable advertisements. Section IV presents a method of selecting efficiently routes to the nodes holding advertisements suitable for the pedestrian's preference in order to reduce ineffective traffic handled by advertising nodes. Section V describes a simulator developed to examine the proposed method, and how the proposed method reduces the number of relay nodes. Section VI describes the related works. Finally, Section VII gives conclusions and future issues.

II. AD HOC ADVERTISEMENT DELIVERY NETWORK

Busy shopping districts are often formed near train stations, with shops patronized by commuters and students. Districts with many specialty shops are also formed in other areas where people gather. In addition, when there is a special event, such as a festival at a shrine, many temporary shops open at the event site. The shops in such an area cooperate with each other, forming a shop owners' community. This paper assumes that each shop in an area has an advertising node, and that these nodes form an ad hoc network, as shown in Fig. 1. Each advertising node has information about the locations of all the advertising nodes in the area. It also holds the data on the advertisement types held by each node in the form of an Ad Filter (AF), which is generated using the Bloom Filter (BF) algorithm [10]. Data about advertisements are collected in this network in the following steps:

Step 1: The pedestrian registers his/her preference information in his/her mobile terminal in advance. The mobile terminal generates a Preference Filter (PF) from that information using the BF algorithm.

Step 2: The mobile terminal puts the PF in an advertisement acquisition message (AAM) and sends it to the advertising node closest to the terminal.

Step 3: The node that has received the AAM compares the PF in the AAM with the AFs of all the nodes in this area, and determines the nodes that hold the AFs that are suitable for the PF.

Step 4: This node determines the optimal route to pass the AAM to all the selected nodes, puts that routing information in the AAM, and sends the AAM to the next node.

Step 5: The advertising node that has received this AAM compares the PF in the AAM with its own AF to determine whether it holds an advertisement suitable for the pedestrian.

5-1: If it determines that it does not have such an advertisement, it passes the AAM to the next node designated in the routing information in the AAM.

5-2: If it determines that it does have such an advertisement, it sends that advertisement to the user, and passes the AAM to the next node designated in the routing information.

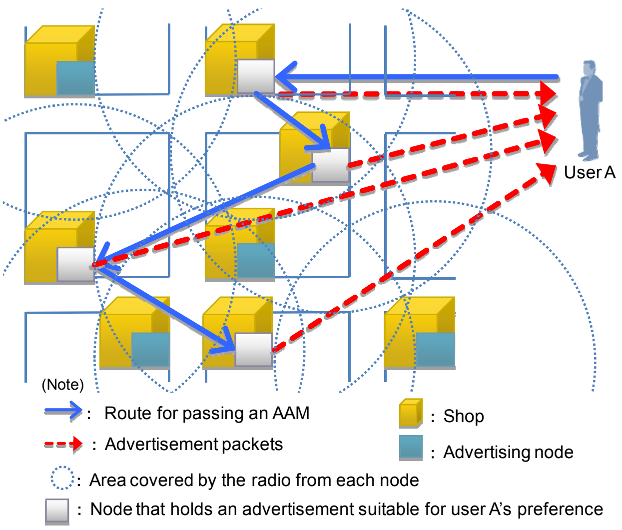

Figure 1. Example of an ad hoc advertisement delivery network.

To build an ad hoc advertisement delivery network, such as the one shown in Fig. 1, this paper address the following two issues:

Issue 1: How to generate a PF and an AF using the BF algorithm

A PF and an AF are generated using the BF algorithm, which can compare filters at high speed, and can express the elements of the user preference data and those of the advertisement data held by each node with small data. To generate these filters, it is necessary to specify the elements of the PF and to determine the bit array lengths of the PF and the AF taking the false positives of the BF algorithm into consideration.

Issue 2: How to determine the route that minimizes the number of relay nodes

To reduce the routing overhead in acquiring advertisement information in an ad hoc network, it is necessary to find a routing method that minimizes the number of advertising nodes that only relay advertisement information.

III. Elements of the PF and the AF and the Logic for Generating and Testing These Elements

A. Elements

To make it possible to check a match between an advertisement information and the user preference information, an element set, D, is defined as follows. The elements in D are the basic user data, such as the user's gender and job. An element, d, is defined as a combination of the element name, d_name, and its value, d_value. This definition allows two elements with the same element name but different values to be handled as different elements.

D={d_1, d_2, ・・・, d_n} , where d_i=(d_i_name: d_i_value).

To enable the user to express different aspects of his/her preference, and the advertisement provider to select potential receivers of their advertisements from different perspectives, the following element names have been defined: gender (gender), date of birth (year, month, day), body-mass index (bmi), job (job), annual income (income), whether married or not (partner), whether the user has a child or not (child), child's age (child_age), and hobby (hobby). Examples of element values are shown below. The number of elements, n, is 17. The element values for job have been defined in advance.

D={gender:0, year:1988, month:5, day:21, bmi:1, job:14, income:0, partner:0, child:0, hobby:1, hobby:9, hobby:10, hobby:17, hobby:18, hobby:19, hobby:20, hobby:21}

Elements are classified into two categories: those in the main element set, D_m, and those in the sub-element, D_s. D_m includes gender, job and hobby, which do not vary greatly from user to user. On the other hand, D_s includes date of birth, annual income and child's age, which can vary greatly. Thus,

D={D_m, D_s}

D_m={gender:0, job:14, hobby:1, hobby:9, hobby:10, hobby:17, hobby:18, hobby:19, hobby:20, hobby:21}

D_s={year:1988, month:5, day:21, bmi:1, income:0, partner:0, child:0}

If elements for a filter are to include all the elements in D_m and D_s, the users at whom an advertisement is targeted

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will be extremely narrow, and the BF's advantage of high data efficiency will be reduced. Therefore, we have decided that the PF and AF, which are used to check a match between an advertisement information and the user information should contain only D_m. D_s is used by advertising nodes to determine whether it should store a specific advertisement or not. This paper does not consider this aspect.

B. Algorithm for Generating Filters and Filter Size

The BF algorithm passes one element through a hash function and generates multiple hash values. This computation is applied to all the elements. A filter is generated by replacing 0 with 1 at the bit positions specified by all the hash values in a bit array, initialized with 0, of an arbitrary size. The algorithm for generating a PF and an AF in a case where each filter is an *m*-bit array, the number of elements is *n*, and the number of hash values obtained is *k*, is as follows (see Fig. 2).

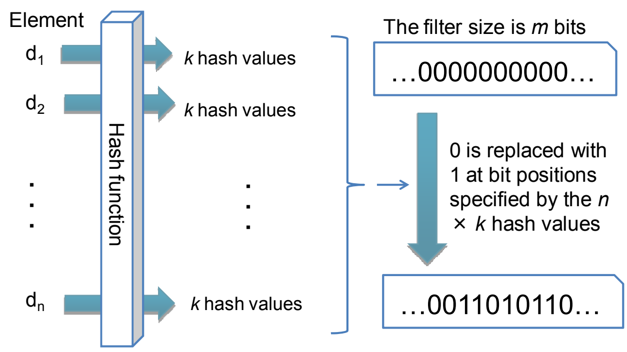

Figure 2. Example of generating a PF and an AF using the BF algorithm.

Step 1: The *m*-bit array is initialized with 0.

Step 2: The character string making up element, d_i, is multiplied with an arbitrary numerical value associated with each alphanumeric in the character string, and again multiplied with the character sequence information. The results for all the characters are added together, and this is converted into a numerical value, $X(d_i)$. For example, if d_i=[gender: 0], then the numerical value are associated with each character in advance, as g=16, e=14, n=23, d=13, r=17, :=36, 0=0. This is multiplied by the character sequence information: g=1, e=2, n=3, d=4, e=5, r=6, :=7, and 0=8. The result is as follows:

$X(d_i)=16\times1+14\times2+23\times3+13\times4+14\times5+17\times6+36\times7+0\times8 = 589.$

Step 3: To calculate *k* hash values from $X(d_i)$, $X(d_i)$ is multiplied by *k* different constants, α_1, ~, α_k, and *k* $X(d_i)_1= X(d_i)\times\alpha_1$, ~ , $X(d_i)_k= X(d_i)\times\alpha_k$ is obtained.

Step 4: $X(d_i)_1$, ~, $X(d_i)_k$ are input to the following hash function, H, to produce *k* hash values, $h(d_i)_1$, ~, $h(d_i)_k$.

$h(d_i)_k = H(X(d_i)_k) = (X(d_i)_k \; mod \; C) \; mod \; m$

where *mod* is an operator to obtain the remainder of the preceding value divided by constant, C, or constant, *m*. *m* is the filter's bit length. After the two *mod* operations, this bit length becomes smaller or equal to the bit array length of the defined filter.

Step5: Replace 0 with 1 of the *m*-bit array at bit positions specified by hash values $h(d_i)_1$, ~, $h(d_i)_k$ obtained in Step4.

Step6: Repeat Steps 2 to 5 for the number of elements, *n*.

High bit efficiency of the BF algorithm is achieved by tolerating *false positives* [10]. A *false positive* means incorrectly identifying the presence of an element not in the relevant filter, when a match between the PF and the AF is checked. For example, some of the *k* hash values obtained from element, d_i, and those obtained from element, d_j, in Step 4 can be the same sometimes. In such a case, the bit positions specified by the hash value obtained from element, d_j, have already been specified by the hash value obtained from element, d_i, and have been replaced with 1. In other words, these bits are discrimination information encompassing both elements, d_i and d_j. Therefore, in checking a match between the filters, d_i and d_j are not accurately distinguishable. Let *m* be the size of the BF, *n* the number of elements, and *k* the number of hash values obtained by applying the hash function, then the probability at which a *false positive* occurs can be calculated by

$$P = \left(1-\left(1-\frac{1}{m}\right)^{kn}\right)^{k} \approx \left(1-e^{-kn/m}\right)^{k} \qquad (1)$$

Eq. (1) indicates that, if *m* and *n* are fixed, there is a *k* that minimizes this probability. If *false positives* occur in the proposed ad hoc advertisement delivery network, the number of relay nodes increases. Therefore, we have set *m*=150, *n* = 15, and *k* = 7 to keep the *false positive* occurrence probability to 1% or lower. The number of elements, *n*, has been determined based on a questionnaire survey conducted with multiple subjects.

C. Advertisement Suitability Test

The advertising node that was the first to receive an advertisement acquisition message (AAM) from the user must check a match between the user preference information in the AAM and the advertisement information held by each node, and determine the nodes that hold advertisements suitable for the user. A node that has received an AAM from another node must determine whether it should send an advertisement to the user or simply relay the AAM to the next node. With the BF, information is contained at bit positions of a bit array. Therefore, whether information is present or not can be determined by checking whether the value at the relevant bit position is 0 or 1. In other words, if the value is 1 at all bit positions specified by the *k* hash values computed from a given element, that element is valid. On the other hand, if the value at any specified bit position is 0, that element is invalid. The steps for this advertisement suitability test are as follows:

Step 1: A bit *AND* operation is performed on the PF and the AF to produce a Result Filter (RF).

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Step 2: If the RF and the AF are identical, the element concerned is determined to be valid. If not, invalid.

IV. ROUTING BASED ON AREA DIVISION

Since advertising nodes are assumed to be installed in shops, they will be at fixed places for a relatively long time. In such a case, a proactive protocol, for which the routing table is predetermined, is an efficient protocol for use as the basic routing protocol. However, if the source node is to search for nodes holding advertisements suitable for the specific user based on a routing table designed for point-to-point connections, it must send many unicast packets to all the target nodes. For example, in a simple node configuration in which the radio from a node can reach only its adjacent nodes as shown in Fig. 3, the routes from node 1 to advertisement holding nodes 3, 6, 8, 9, 10 and 15 are as shown in Table I. Nodes 2, 5 and 7 only relay an AAM, twice, twice and once, respectively. Since the relayed AAM has nothing to do with the delivery of their own advertisements, the AAM traffic is invalid traffic for these nodes. It is desirable that such an AAM do not come to these nodes. Nodes 6 and 10 deliver their own advertisements and also relay an AAM separately. It is desirable that they can handle these in one access attempt. For example, if the routing is such that the AAM is passed in the sequence of nodes $1 \to 2 \to 3 \to 8 \to 7 \to 6 \to 9 \to 10 \to 15$, the nodes that only relay an AAM are reduced to only nodes 2 and 7, thus reducing the overall traffic load on nodes and the network.

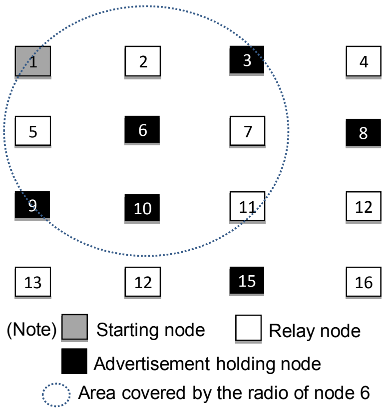

Figure 3. Node configuration example.

TABLE I. ROUTING EXAMPLE USED WHEN THE STARTING NODE, NODE 1, PASSES AN AAM TO ADVERTISEMENT HOLDING NODES 3, 6, 8, 9, 10 AND 15

Node number / UC number	1	2	3	5	6	7	8	9	10	15
UC1	S	R	H							
UC2	S	R				R	H			
UC3	S				H					
UC4	S			R				H		
UC5	S			R					H	
UC6	S				R				R	H

(Note)UC: Unicast, S: Starting node, H: Advertisement holding node, R: Relay node

The control of the relay routing to divided areas is based on an existing proactive protocol but is overlaid on it as shown in Fig. 4. In the upper layer, the area with shops is divided either vertically or horizontally to make up multiple long, thin sub-areas. A set of advertisement holding nodes belonging to the same sub-area are selected, and an AAM is passed from one end of a sub-area if the sub-area number is odd, and from the other end of a sub-area if the sub-area number is even. For example, if the area is divided horizontally, an AAM is passed from the leftmost node in a sub-area whose sub-area number is odd, and from the rightmost node in a sub-area whose sub-area number is even. In the lower layer, an AAM is passed in the sequence determined in the upper layer. If the current node cannot reach the next node in one hop, an alternate route is searched for and used to pass the AAM. By determining the routing this way, an AAM can be passed to nodes in the area in a unicursal line. This is an efficient routing because it reduces the number of nodes that only relay the AAM. Figure 5 shows this routing method for a case where an area is divided into q areas vertically.

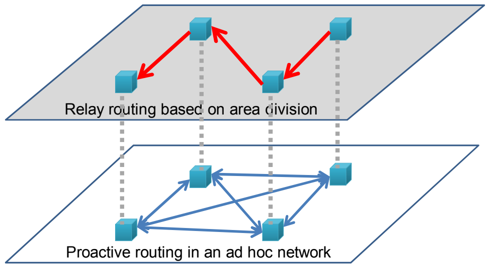

Figure 4. Two-layered routing control.

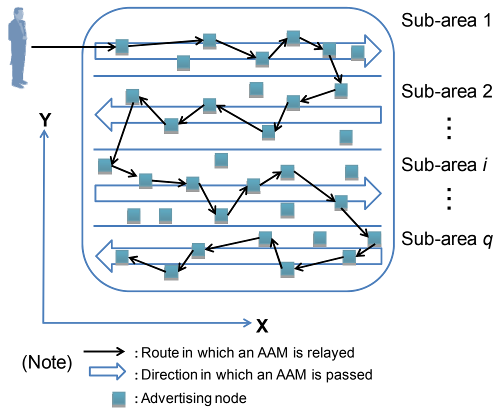

Figure 5. Example of the relay routing based on area division.

The detail routing control is performed as follows. A given area can be divided vertically, horizontally or in other division patterns depending on the layout of shops and users' locations. In the following, we assume that the area is divided vertically into q sub-areas as shown in Fig. 5, and that the starting point is at the top left. Additionally, we assume that each node has the following control data, RD:

RD={node identifier (node_id), IP address (ip_address), location coordinates (location_xy), AF, division pattern identifier (div_id), sub-area number (subarea_no)}

Sub-area number is determined as follows:

$X_s+(q\text{-}1)\times w < \text{subarea\_no}(q) < X_s+q\times w$, where $(W/w) > q \geqq 1$ and W is the width of the area, X_s is the X-axis coordinate of the starting point, and w is the width of a sub-area.

Step 1: The node that has received an AAM, node N_A, checks a match between the AF in its RD and the PF in the AAM in accordance with the test criteria described in Section III.*C*, and generate a list of nodes that hold suitable advertisements, nodelist NL_A. Note that NL_A and RD share the same attributes.

Step 2: Node, N_A, determines the user location based on its own position, and determines the division pattern identifier. It searches the NL_A for nodes that have this identifier. The nodes found are sorted in the sequence of the sub-area number.

Step 3: Sub-areas are classified into two groups depending on whether the sub-area number is odd or even: $i_o=\{2r-1\}$ and $i_e=\{2r\}$ $(q/2>r\geqq 1)$. It is assumed that r=1 for node, N_A, and the node belongs to i_o.

Step 4: A routing node list RNL is generated by sorting nodes in the sub-area in i_o with r=1 in the order of closeness to node N_A. Note that RNL is an ordered array of node identifiers.

Step 5: Conversely, nodes in the sub-area in i_e with r=1 are sorted in the order of distance to node N_A, and added to the RNL.

Step 6: Make r=r+1. Steps 3 through 5 are repeated for the number of sub-areas belonging to the same division pattern.

Step 7: The completed RNL is put in an AAM, and sent to the next node via the lower layer.

V. Development Of A Simulator And The Evaluation Results

A. Development of a Simulator

To evaluate the methods proposed in Sections III and IV, we specified the size of the target area, developed 5 different node layout lists showing different layouts of randomly placed advertising nodes, and also developed a simulator shown in Fig. 6, which takes the above data as inputs, and outputs suggested routes. We considered 16 types of occupation and 24 types of hobby for the main elements in the AF, which specify advertisement information held in nodes. By combining these with gender, we created 20 AFs and allocated each of them to a node randomly. We also created a PF, which contains one set of elements that indicate the user preference. Only one division pattern shown in Fig. 5 was used. We also developed a unicast simulation program so that we can compare the routing results of the relay routing based on area division with those obtained by using unicast for acquiring advertisement information. A relay node counting program was developed to collect data on the number of relay nodes in the results of both the proposed method and the unicast method. We also developed a relay routing drawing program in order to make it possible to understand different routings visually.

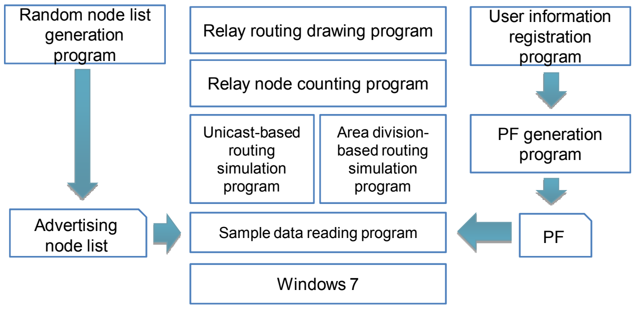

Figure 6. Simulator software configuration.

Figure 7 shows the relay routing in a case where the area with shops measures 800 m × 800 m, the number of advertising nodes is 200, the distance that can be reached by the ratio from each node is 200 m and the area is divided in 5 sub-areas. The number of valid advertising nodes is 66. The number of nodes that relayed AAMs is 67, of which 2 are relay nodes. Nodes are represented by either squares or circles in the figure. Squares indicate nodes that hold advertisements suitable for the user. The selected routes are shown in solid lines. The distance between N:163 and N:80 and that between N:146 and N:53 are longer that the distance that can be reached by the radio waves of these nodes. Therefore, N:194 and N:63 serve as relaying nodes for these pairs of nodes respectively. The new alternate routes are N:163-N:194-N:80 and N:146-N:63-N:53 respectively.

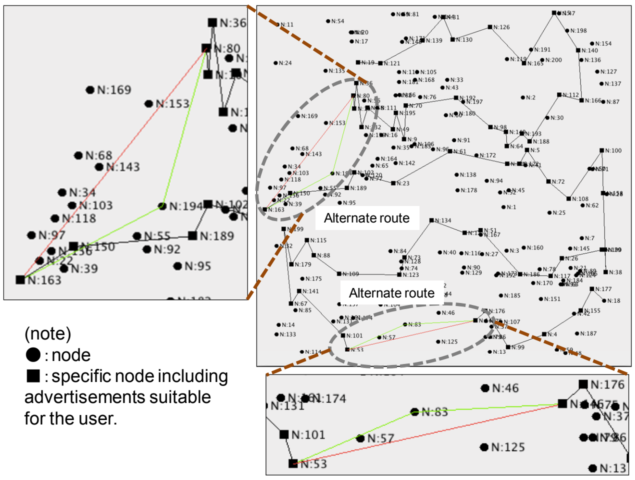

Figure 7. Routes selected for the relay routing based on area division. (Number of sub-areas: 5; number of advertisement holding nodes: 66; total number of nodes that relayed AAMs: 67, number of pure relay nodes: 2, and number of node layout lists: 1)

B. Number of Sub-areas and Number of Relay Nodes

In the proposed routing, the number of sub-areas greatly affects how many node become relay nodes. The relationship between the two as examined with the 5 created node layout lists (nodelists 1 to 5) is shown in Fig. 8. The assumptions used in this examination are the same as those used in Section V.*A*. Figure 8 shows that the number of relay nodes

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is minimal when the number of sub-areas is 5. The reason is that, when the number of sub-areas is smaller or larger than this figure, the distances between advertisement holding nodes are beyond the distance that can be reached by the radio waves from nodes, thus increasing the number of cases where alternate routes with relay nodes must be used to pass AAMs from one advertisement holding node to another.

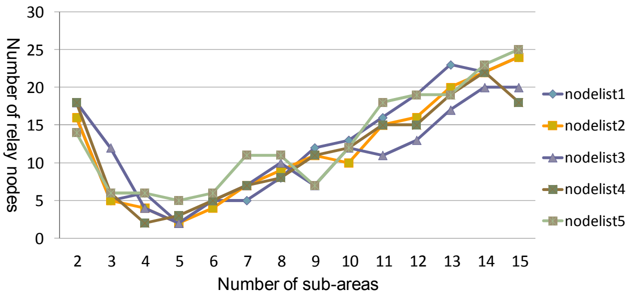

Figure 8. Relationship between the number of sub-areas and the number of relay nodes.

C. *Comparison with a Unicast-Based Advertisement Information Acquisition in Terms of the Number of Relay Nodes*

The proposed method (method *p*) was compared with the method of unicasting AAMs (method *u*) in terms of the number of relay nodes. The size of the area, the number of advertising nodes, the distance reached by the radio waves from nodes, and the number of valid advertising nodes were the same for the both methods. The computation result for method *u* is shown in Fig. 9. In this method, the advertising node closest to the user sends AAMs to all the nodes that hold advertisements that are considered to be suitable for the user. Therefore, even though the number of advertisement holding nodes was 66 as in the case of method *p*, the number of relay nodes jumped up to 258.

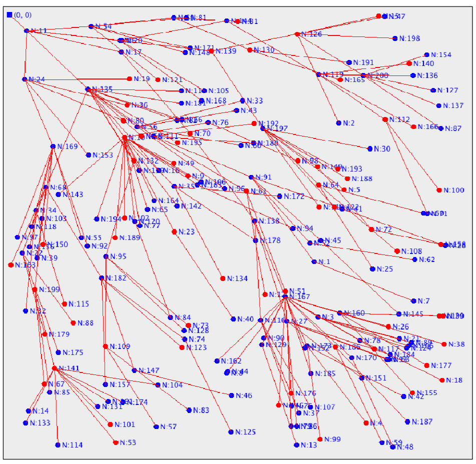

Figure 9. Relay routing based on unicast-type advertisement information acquisition.
(Number of advertisement holding nodes: 66; total number of relay nodes: 258; and the number of node layout lists: 1)

Figure 10 shows comparison of methods *p* and *u* in terms of the number of relay nodes. For method *u*, all the advertising nodes that have relayed an AAM sent by the advertising node closest to the user before the AAM reaches a node holding an advertisement suitable for the user are counted as relay nodes. Such nodes were added together for all the advertisement holding nodes. For method *p*, the number of sub-areas was 5, and 5 advertising node lists were used. A total of 10 simulations were performed for methods *u* and *p*. The route through which an advertisement message is sent from an advertisement holding node to the user is assumed to be the same for methods *u* and *p*. In Fig. 10, the results for method *u* are designated by *u* while those for method *p* are designated by *p*, followed by the list number of the advertising node list used. Figure 10 shows that the number of relay nodes for method *p* is much smaller than for method *u*. The percentage of this reduction ranged from 68.2% to 74.5% with the average being 71.9%.

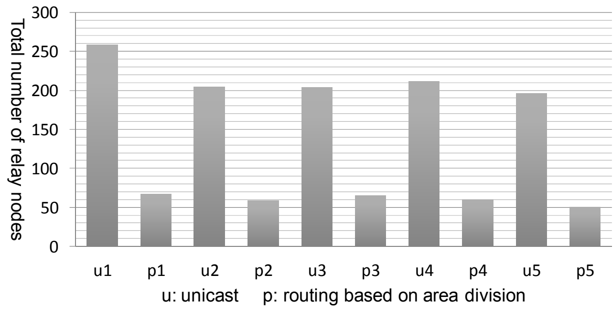

Figure 10. Comparison with a unicast-type advertisement information acquisition in terms of the number of relay nodes.

VI. RELATED WORKS

Typical overlay-based multicasting protocols that use the proactive routing of ad hoc networks include AMRoute (Ad hoc Multicast Routing protocol) [11], PAST-DM (Progressively Adaptive Subtree in Dynamic Mesh) [12] and ALMA (Application Layer Multicast Algorithm) [13]. In these protocols, each member node forms a mesh-based virtual topology. Information delivery is achieved using a multicast tree in the case of AMRoute, and a source-based tree in the cases of PAST-DM and ALMA. ALMA takes a receiver-driven approach to improve the performance of PAST-DM.

Our proposed method also relies on a source-based tree. It differs from PAST-DM in the following aspects. Since PAST-DM's meshed-based virtual topology assumes node mobility, the link states are updated periodically. The source-based tree used for information delivery is dynamically generated by the source-based steiner tree algorithm from this virtual mesh. Therefore, control packets for obtaining the latest routing information are periodically flooded, which results in an increase in network traffic. The parent node, which is the branching point of the tree, manages the participation and withdrawal of child nodes, copies the packets as many times as there are child nodes, and sends the copied packets.

In contrast, in our proposed relay routing method based on area division, the nodes that make up the ad hoc network are shops at fixed locations. Therefore, in setting up the network, it is possible to build a virtual topology as an unbranched source-based tree in which nodes are connected in the sequence of physical distances between nodes for each area division pattern. This also reduces the number of control packets. In addition, the source-based relay routing tree for the transmission of advertisement information acquisition messages over the network is reconfigured as an unbranched relay routing tree by selecting, from this virtual topology at the time when the advertisement information acquisition messages is received from the user, only those nodes that hold advertisements suitable for the preferences of the user. The participation or withdrawal of a delivery member is updated as part of the operations and maintenance system data when the relevant node is physically included in or disconnected from the advertising delivery ad hoc network. The routing at the time of node failures is left to the lower layers as is the case with other methods.

VII. Conclusions And Future Issues

This paper has proposed a locality-oriented ad hoc advertisement delivery network. It has described the filter structure and the algorithm used to determine whether an advertisement is suitable for a specific user based on the Bloom Filter algorithm. In addition, it has proposed a relay routing method based on area division. This method can reduce the number of nodes that purely relay advertisement information acquisition messages in an ad hoc network. This method has been compared with a unicast-type advertisement information acquisition using simulation, and it was found that the proposed method uses 70% fewer relay nodes than the unicast-type method.

In the future, it will be necessary to examine cases that take into consideration node layouts that reflect actual cases, different area division patterns, the impacts of users' movements and those of buildings on reachability of radio waves. In addition, it is necessary to study in detail the protocol that enables the proposed relay routing algorithm based on area division, and to use general-purpose network simulators, such as Opnet [14] and NS-2 [15], to evaluate the delay up to the final node when the network's background traffic is taken into consideration, and the effects of node failures. It is also necessary to investigate the standard used for the optimization of the relay routing tree based on area division. The quantitative difference in performance between the proposed method and the existing ALM (Application Layer Multicast) needs to be found out through these studies.

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