Novel Routing Method Using Slime Mold Algorithm Corresponding to Movement of Content Source in Content-Oriented Networks

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Abstract

Content-oriented networks are proposed as a novel network architecture in which routing is conducted using the content ID instead of an IP address. In content-oriented networks, there is a problem that users cannot discover contents when the mobile communication device that has the contents moves about. Therefore, many studies have been undertaken to solve this problem. In conventional research, by applying ant colony optimization (ACO), Manome and Asaka tracked the movement of contents by adding a pheromone to the route of the mobile device itself. This method improved the discovery rate after movement compared with the case without the pheromone, indicating the effectiveness of their method. However, since the path searching by ACO depends on the behavior of movement of the mobile device, there are problems such as detouring along the route to the contents and too many control packets. In addition, the discovery rate decreases when the time to live (TTL) is low.

To solve these problems, we use a slime mold algorithm instead of ACO for route searching. The slime mold algorithm is used to solve combinatorial optimization problems by employing ecological characteristics of slime molds. This algorithm has features such as if definitely finds the shortest route, the route search is quick, and adaptability to resetting the shortest route after the update of information is high. Therefore, in this research, we propose a routing control method to the mobile content source with a unique flow rate and conductivity on the basis of a CON. In the simula-

1. Introduction

In recent years, which has been called an era of information overload, many users send and receive information in the form of written material and moving images by using various services such as YouTube and SNS. Therefore, most of the traffic flow on the Internet is occupied by the content we use. Internet contents are received of IP addresses, including location information. Accordingly, the communication model is considered a location-oriented architecture or a client-server model. There are various problems in this communication model. For example, when too many users access a server, there is a risk of the server crashing. Content delivery networks (CDNs) [1] or peer-to-peer (P2P) [2] networks have been developed to avoid this. However, since these networks are composed of location-oriented networks, it is necessary to change the network architecture itself. A content-oriented network (CON), in which content IDs are used for routing, has been studied. In the CON, each communication terminal holding content transmits content information to all nodes by flooding them with its own content information. Each node creates a routing table based on this information. However, when the contents moves, since an inappropriate routing is executed until the rewriting of the previous routing table is completed, it becomes impossible to obtain the content.

Therefore, a routing control method using ACO to acquire the contents in a mobile device was proposed [3]. In ACO, the path to the content is determined by a layered pheromone. A pheromone is added to each route, and each agent (ant) diffused from the node that requests the content executes a route search to the next node that holds content by using the pheromone information. By adding a pheromone to the route along which the mobile terminal passed, it becomes possible to establish a route even if the terminal moves. This method improved the discovery rate after the movement compared with the case where no pheromone was left, indication the effectiveness of this method.

However, since route searching by ACO depends on the behavior of movement of the mobile device, there are problems such as detouring along the route to the contents and too many control packets. In addition, the discovery rate decreases when the time to live (TTL) is low.

To solve these problems, we use a slime mold algorithm instead of ACO for route searching. The slime mold algorithm is used to solve combinatorial optimization problems by employing ecological characteristics of slime molds. This algorithm has features such as if definitely finds the shortest route, the route search is quick, and adaptability to resetting the shortest route after the update of information is high. Therefore, in this research, we propose a routing control method to the mobile content source with a unique flow rate and conductivity on the basis of a CON. In the simula-
tion, this proposed method is compared with the conventional method [4], and we show a comparative evaluation of its performances.

2. Conventional Method

In conventional research [3], by applying ACO, Manome and Asaka tracked the movement of contents by adding a pheromone to the route of the mobile device itself. ACO is based on the ant system proposed by Dorigo et al. [5]. This method consists of the renewal of the pheromone information on the links and the behavior of I-ants and D-ants. Here, we describe the procedure of the conventional method. Figure 1 shows the concept of the conventional method.

\[ p_j = \frac{\tau_{ij}}{\sum_{l \in L} \tau_{lj}} \]  

(1)

Secondly, if the I-ants discover the desired content, as shown in Fig. 1 (Step 2), the quantity of the pheromone \( \Delta \tau_{ij} \) is given by Eq. (2), in which \( \lambda \) is the number of hops. The voluntary quantity of pheromone \( S \) is laid on a shorter path and a small quantity of pheromone is laid on a longer path.

\[ \Delta \tau_{ij} = \frac{S}{\lambda^2} \]  

(2)

Thirdly, when \( N \) I-ants reach the content source, the content source sends D-ants to the users, as shown in Fig. 1 (Step 3). The quantity of pheromones \( \tau_{ij} \) is laid on each trail where \( N \) I-ants have passed. The remaining quantity of pheromones from \( i \) to be renewed is given by

\[ \tau_{ij} := \tau_{ij} + \Delta \tau_{ij} \]  

(3)

Finally, the pheromones between all the nodes evaporate at rate \( \rho \) every fixed time frame, as shown in Fig. 1 (Step 4). \( \tau_{ij} \) is renewed by

\[ \tau_{ij} := \rho \tau_{ij} \]  

(5)

where \( \rho \) is the evaporation rate of the pheromones and is defined to be between 0 and 1. The paths become narrower because the pheromones on the paths along which the packets do not often pass evaporate.

The I-ants, D-ants, and “Interest” are deleted when their number of hops is greater than the TTL, which is the number of hops taken from start to finish. After deletion, the next node cannot be selected when all the neighbor nodes have already been passed. A large quantity of pheromones is laid on a shorter path and a small quantity of pheromones is laid on a longer path. Then, the pheromones on the longer paths evaporate and gradually disappear because of the repetition of Steps 1 to 4. Moreover, since the contents are detected after they move in Step 3, “Interest” can follow along the trajectory from their prior location to the present location. Therefore, users can acquire the objective content sources using the shorter paths and detect them even after the content moves.

This method led to an improved discovery rate after movement compared with the case of not leaving the pheromone, indicating the effectiveness of the method. However, since path searching by ACO depends on the behavior of movement of the mobile device, there is a problem of detouring along the route to the contents in some cases. In addition, this method has the problem that too many control packets are generated. Moreover, the discovery rate decreases when the TTL is low.
3. Proposed Method

To solve the above problems, we use a true slime mold algorithm [4] instead of ACO. Tero et al. reported that this algorithm can quickly find the shortest path, and is highly adaptable to the reconstruction of the shortest path from the update of movement information. In this paper, we propose a route control method in a CON using the slime mold algorithm. The content lay flow rate and conductivity on the moving trail (Fig. 2). This shortest path search algorithm is called the Physarum solver. The conductivity and flow rate of each path can be found by solving

$$\sum_{i} D_{ij} \frac{p_i - p_j}{L_{ij}} = \begin{cases} -I_0 & j = 1 \\ I_0 & j = 2 \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

$$\frac{d}{dt} D_{ij} = \delta t (\alpha |Q_{ij}| - \gamma D_{ij}) \quad (7)$$

$$Q_{ij} = \frac{D_{ij}}{L_{ij}^2} (p_i^0 - p_j^0) \quad (8)$$

The largest flow rate $Q$ among connected nodes is used in next route selection. When the content moves, the conductivity is conventionally initialized to 0 and the shortest path search is performed again. On the other hand, in our method, the previous conductivity is set on each path as the initial value. Therefore, it is considered that the shortest route can be found faster.

In addition, when the content moves, both the flow rate $Q_{ij}$ and conductivity $D_{ij}$ are updated as

$$Q_{ij} = Q_{ij} + \Delta q \quad (9)$$

$$D_{ij} = D_{ij} + \Delta d \quad (10)$$

The initial value of conductivity $D_{ij}^0$ is 1. Then, $D_{ij}^n$ is updated by Eq. (7). “Interest” is deleted when the number of hops exceeds the TTL. A large flow is given on a short path, and a small flow is given on a long path. By repeating this, the flow rate on the long path gradually decays. Since “Interest” selects a route based on the flow rate, the content source is detected using Eq. (9) when content moves. Therefore, users can acquire content sources using the shortest path and detect the sources even after the mobile device with content moves.

4. Simulation Results

We describe the simulation model and the results of evaluating the proposed method in this section. Table 1 shows the parameter values used in this simulation. The network model is shown in Fig. 3. Node 0 is the user node that sends out the flow and “Interest”. First, we set Node 99 as having the desired content. When 1000 units of time elapse, the content moves to Node 9. We compared the proposed method with the conventional method using ACO.

The results of a comparison of the discovery rate is shown in Fig. 4. The green line shows the time that the content moves. In our proposed method, the discovery rate was 100%. On the other hand, in the conventional method, the discovery rate was not always 100% even when the correct route was learned, and the discovery rate after movement was markedly low. This is because many ants could not find the content in the TTL.

Figure 5 shows the number of hops for the two methods. In the proposed method, when content moves, it is acquired in a moment by detouring. After that, the shortest path is learned very quickly. This is because route searching is unaffected by the previous flow rate. In the conventional method, it took...
Table 1: Parameter values in simulation

| Heading                                      | Values |
|----------------------------------------------|--------|
| Number of contents                           | 1      |
| Number of users                              | 1      |
| Simulation time [unit time]                  | 10000  |
| Point of movement [unit time]                | 1000   |
| Sending rate of “Interest” [unit time]       | 2      |
| $I_0$: Amount flowing from the starting node | 1.0    |
| Number of repeats of Physarum solver         | 2      |
| $\delta, \alpha, \gamma$: Constants          | $0.1, 1.0, 1.0$ |
| $\tau$: Time constant                        | 1.0    |
| $\Delta q$: Quantity of flow rate contents laid | 10.0  |
| $\Delta d$: Quantity of conductivity contents laid | $10^{-25}$ |
| TTL                                          | 25     |

5. Conclusion

In this paper, we proposed a routing information management method using the slime mold algorithm to track the movements of mobile content sources. In the simulation, we showed that the proposed method enables efficient retrieval even if the mobile content moves in a network. However, since only the movement of the mobile device with content is verified in this simulation, it is necessary to verify its validity in an environment where both the content request device and all other nodes move. In addition, it is necessary to perform simulations with various parameter values and network models as a future work.

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