SELECTED PAPER AT NCSP'18

Information-Centric Architecture Using Mobile Agent for MANET

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Abstract

Information-centric networking (ICN) is an emerging research area. Moreover, nowadays ICN is also applied to mobile ad hoc networks (MANETs). In a MANET, each node has limited resources. However, in many protocols, a node sends the interest packet by flooding. This increases traffic in the entire network. Furthermore, it causes duplicate content transmissions. To solve these problems, we propose an information-centric architecture using a mobile agent (MA). In this method, the MA manages location information and a content list of all nodes and constructs a route. The use of an MA can realize information acquisition without any flooding of interest packets. The performance evaluation results show the effectiveness of the proposed method in terms of power consumption, packet delivery rate, and content acquisition delay.

1. Introduction

Recently, a considerable number of studies have been devoted to ICN [1], a new paradigm for the future Internet. The basic idea of ICN is to change the Internet communication model by replacing host addresses with named content. NDN [2] and CCN [3] are two of the well-known current research projects in this area.

In typical ICN, when a node requests a content, it simply broadcasts a request packet, called an interest, which includes the content name. A node that receives the request and has cached the requested content may send corresponding content packets in response, otherwise it forwards the interest packet.

Although most of the works on ICN focus on wired environments, nowadays ICN is also applied to wireless environments such as MANETs. A MANET is a self-organized network and can construct a network without any fixed infrastructure. In a MANET, every node can be connected directly or indirectly with other nodes by multihop communication. Owing to these features, each node has limited resources.

However, in many protocols, a node sends an interest packet by flooding. This increases traffic in the entire network. Moreover, it causes duplicate content transmissions. To solve these problems, some schemes have been proposed.

Figure 1: MA existence area and forwarding to MA

For example, TOP-CCN [4] reduces the number of control packets by multipoint relay (MPR) based packet flooding. E-CHANET [5] uses a counter-based suppression mechanism before packet transmissions. REMIF [6] reduces the power consumption by restricting duplicate interest packet transmissions. Moreover, in an IP-based MANET, routing protocols using an MA have been proposed [7][8]. These protocols aim to decrease the number of control packets.

In this paper, we apply an MA to an information-centric architecture. The use of an MA can realize information acquisition without any flooding of interest packets and can markedly reduce the power consumption. We also improve the packet delivery ratio by using greedy forwarding.

2. Proposed Method

In this section, we describe our proposed method. In this method, the MA manages location information and a content list of all nodes and constructs a route from a provider to a requester. The requester is a node that requests a content, and the provider is a node that sends the content to the requester. The protocol consists of three sub-protocols: information update, content request, and content transmissions.

2.1 Mobile agent

The MA is a distributed processing technology. While moving the nodes connected to the network, it executes various processes. Originally it was developed as a distributed system in a wired network [9]. In recent years, its application to ad hoc networks [10] has been also studied.

The proposed method is based on the routing protocol using an MA [7][8]. In this method, it is assumed that the MA is executed by one of the nodes in a particular circular area called the MA existence area, defined by its center location and radius, as shown in Fig. 1. It is also assumed that all

Figure 2: Forwarding by GEDIR

nodes in the network know the location of this center in advance. Thus, without knowing the ID or the location of the MA, it is possible to deliver a packet to the MA by forwarding toward the center location. In this case, the information packet is sent by GEDIR [11], which is a greedy forwarding method. In GEDIR, the closest node to the destination is chosen as the next relay node as shown in Fig. 2. If the MA moves outside of the MA existence area, the MA migrates to the node nearest to the center of the area. At that time, it sends location information and a content list of all nodes and program code to execute MA by TCP transmissions.

2.2 Information update

When a node moves more than a threshold of distance, it sends its location information and the content list to the MA. This packet is forwarded by GEDIR.

2.3 Content request

By the mechanism described in sects. 2.1 and 2.2, the MA can retain the location information and the content list of all nodes. Therefore, the MA can construct a complete route between any two nodes.

When a node (requester) requests a content, it sends an interest packet to the MA by GEDIR. When the MA receives the interest packet, it constructs two kinds of routes by holding information as shown in Fig. 3. These routes are constructed by Dijkstra's method. The first one is between the MA and the provider node. The second one is between the provider and the requester. At that time, if multiple nodes have requested content, the closest one to the requester node is selected as the provider. Then, the MA sends a content transmission request packet. This packet includes the latter route, location information of the requester and provider, and the requested content name.

2.4 Content transmissions and caching

When the provider node receives the content transmissions request packet, it sends a content message to the requester node by the acquired route. At that time, the relay nodes cache the sent content message and add it to the content list. If a relay node cannot find any next hop node from the route information, it switches the sending method to the forwarding by GEDIR using the location information of the requester. In this case, when another relay node can find a next hop node from the route information, it again switches to the routing with the route information.

Figure 3: Two routes constructed by MA

3. Computer Simulation

We evaluate the performance of the proposed method by computer simulation to verify its effectiveness. We compare the proposed method with REMIF. Table 1 shows the simulation parameters. The power consumption of the node is based on that of a general wireless LAN module. In the simulation, all nodes move with a random waypoint model. As the radio wave propagation model, we use the two-ray ground model.

During a simulation period, we randomly select a requester node and a request content name, and a node sends a content by a UDP packet. In this simulation, all nodes generate one content. Therefore, the number of kinds of content is equal to the number of nodes. Additionally, we assume that all nodes have copies of other two contents that are selected randomly at the beginning of the simulation. The size of each content is 1 Mbyte. Each node can cache 10 contents. Leave copy everywhere (LCE) and least recently used (LRU) are considered as the caching and replacement policies, respectively. In LCE, all relay nodes cache a copy of the content. In LRU, when the cache is full, it discards the least recently used content first. The measuring factors are the packet delivery ratio (PDR), total power consumption, and average content acquisition delay. PDR is defined as the ratio of the number of arrival packets at the requester node to the number of transmitted packets. Total power consumption is defined as the average power consumed by a node per second. Average content acquisition delay is defined as the average sending delay of each UDP. UDP sending delay is time from sending, UDP packet by the provider node to its arrival at the requester node. In addition, the threshold of the information update is set to 20 m in the proposed method.

4. Simulation Results

Figures 4 to 7 show the results versus content request rate which is defined as the number of content requests generated per second. The number of nodes is 500 units and the movement speed is set to 1-3 m/s and 1-9 m/s. Figure 4 shows the PDR. It can be seen that the PDR of the proposed method is higher than that of REMIF and it does

Table 1: Simulation parameters

Parameter	Value
MAC layer protocol	IEEE802.11g
Channel rate	54 [Mbps]
Communication range	100 [m]
Simulation time	1000 [s]
Simulation area	1000×1000 [m]
Movement model	Random way point
Movement speed	1-3, 1-9 [m/s]
Number of nodes	400, 500, 600, 700 [units]
Content request rate	0.05, 0.1, 0.15, 0.2 [/s]
Number of kinds of content	400, 500, 600, 700
Content data size	1 [Mbyte]
Packet size	1024 [byte]
Caching policy	LCE
Replacement policy	LRU

not fall even if the content request rate becomes larger. This is because if the route is unavailable, the proposed method can use GEDIR. On the other hand, REMIF fails to transmit and the PDR decreases. From the result for a node speed of 1-9 m/s, the proposed method maintains high performance even if the nodes move faster due to the use of GEDIR. In contrast, REMIF is affected by the increase in the speed and its PDR decreases. This is because it is difficult for REMIF to maintain the route under a high-speed environment.

Figure 5 shows the total power consumption. This figure also shows the superiority of the proposed method to REMIF. This is because the proposed method sends the interest packet without flooding and it markedly reduces the number of packet transmissions. In contrast, the REMIF sends the interest packet by flooding. Therefore, when some nodes have the same request content, it causes duplicate transmissions of the same content. This increases the power consumption for packet sending. On the other hand, in the proposed method, the provider is selected by the MA. Therefore, duplicate transmissions do not occur. In a high-speed environment, the power consumption of REMIF is lower than that in a low-speed environment. This is because, as shown in Fig. 4, many packet losses are caused. In the proposed method, the power consumption is almost the same regardless of the speed.

Figure 6 shows the total duplicate transmit data size. This figure shows that duplicate transmissions only occur in REMIF. Figure 7 shows the average content acquisition delay. It can be seen that the delay of the proposed method is shorter than that of REMIF. This is because stability of the route is better than that in REMIF. Moreover, the proposed method does not use any flooding of control packets, and the duplicate sending of content does not occur as shown in Fig. 6. For this reason, the proposed method does not cause collision between the UDP packets. As a result, the number of packet retransmissions is small and the delay becomes short. The delay of REMIF in a high-speed environment is shorter than that in a low speed environment. This is because only

Figure 4: Packet delivery ratio versus content request rate

Figure 5: Power consumption versus content request rate

Figure 6: Total duplicate transmit data size versus content request rate

packets using stable routes arrive at the requester node. In contrast, the delay of the proposed method is almost the same. This is because the proposed method uses GEDIR and it is not affected by the movement speed.

Figures 8 to 10 show the results versus the number of nodes. The content request rate is fixed to 0.1 /s and the movement speed is set to 1-3 m/s and 1-9 m/s. These figures show that the performance of the proposed method is better than that of REMIF under all conditions. Also it can be seen that the

Figure 7: Content acquisition delay versus content request rate

Figure 8: Packet delivery ratio versus number of nodes

Figure 9: Power consumption versus number of nodes

number of nodes does not strongly affect the performance. Moreover, in term of the effect of the movement speed, the same tendency as that in Figs. 4, 5, and 7 is shown.

5. Conclusions

In this paper, we proposed an information-centric architecture using an MA for MANET. In this method, the MA manages location information and a content list of all nodes

Figure 10: Content acquisition delay versus number of nodes

and constructs a route. The use of an MA can realize information acquisition without flooding interest packets. From the results obtained by computer simulation, we showed the validity of the proposed protocol in terms of the PDR, the total power consumption, and the average content acquisition delay.

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