Design of SDN based End-to-end Routing over Multiple Domains for Mobility Management

Misumi Hata
Graduate School of Information Sciences
Tohoku University
Sendai, Japan
m-hata@ci.cc.tohoku.ac.jp

Mustafa Soylu
Fuculty of Electrical and Electronic Engineering
Istanbul Technical University
Istanbul, Turkey
mohkargan@gmail.com

Satoru Izumi
Graduate School of Information Sciences
Tohoku University
Sendai, Japan
izumi@ci.cc.tohoku.ac.jp

Toru Abe
Cyberscience Center
Graduate School of Information Sciences
Tohoku University
Sendai, Japan
beto@tohoku.ac.jp

Takuo Suganuma
Cyberscience Center
Graduate School of Information Sciences
Tohoku University
Sendai, Japan
suganuma@tohoku.ac.jp

***Abstract*—IoT environment has spread and the use of Internet services during move has increased recently. The demand for mobility management, the technology to keep communication even when a communicating mobile node moves, is growing due to it. We proposed a SDN based mobility management scheme in our prior work to deal with inter-domain handovers, but its routing algorithm only considers the number of domains to go through and the number of flow entries to install. This prevents us from selecting suitable routes. In this paper, we show the design of a new routing mechanism that considers various parameters. This mechanism suppresses costs for changing route to carry out handover smoothly and avoids lengthy routes.**

***Index Terms*—Software Defined Networking, Mobility management, End-to-end Routing**

I. INTRODUCTION

These days, IoT environment has spread widely and it assists the use of Internet services in various places and scenes [1] [2]. Also, the standardization of IEEE802.11ai will urge more expansion of mobile networks and the use of Internet services while moving would increase [3]. Especially with session continuous Internet services, continuity of service during movement is a problem. When a mobile node (MN) moves across different domains, the IP address of the MN changes. The change of the IP address leads to a disconnection of communication and might affect the use of network services. If a MN's IP address changes during the use of a session continuous Internet service, problems that would affect the use of the service may occur such as lack of data and logging out from the service.

Mobility management is the technology to keep connection when the IP address of MN changes. Mobile IP is one popular mobility management technology standardized by Internet Engineering Task Force (IETF) [4] [5] [6]. Mobile IP enables a MN to continue communication while moving but has difficulty in route optimization. Also it requires MNs to be equipped with Mobile IP functions and it has not been deployed widely, it is difficult to say Mobile IP as a realistic way to maintain IP mobility.

SDN based mobility management has emerged recently to solve the problems of Mobile IP [7] [8]. They succeeded to optimize intra-domain routes when a MN moves. However, they mainly focus on intra-domain handover and routing so they have difficulty in inter-domain route optimization.

In this research, we propose end-to-end inter-domain routing mechanism for SDN based mobility management. This routing mechanism considers various parameters such as number of hops and bandwidth and selects a route that suites the objective of mobility management.

We have designed a basic algorithm of inter-domain routing and evaluate its effectiveness [9]. In this paper, we extended our existing algorithm by introducing new parameters such as network bandwidth and formulating the routing algorithm. Compared with our former work, the proposed algorithm enables us to keep communication delay low and realize comfortable use of Internet services. Also, it realizes fast route transition so that communication would not be disconnected.

II. RELATED WORK

A. SDN based mobility management

SDN is a technology to control network centrally and dynamically with software. Hence, applying SDN to mobility management enables us to control intra-domain routes easily.

Y. Wang et al. [7] uses Mobile IP by using SDN in case of inter-domain handovers. Though Mobile IPv6 has a route optimization function, MNs without IPv6 support or Mobile IPv6 support cannot have its route optimized and end up with lengthy route that cause big delay.

We introduced a SDN based mobility management scheme that can deal with inter-domain handover in our former work [9]. The overview of our scheme is shown in Figure 1. It realizes inter-domain route optimization after handover. To

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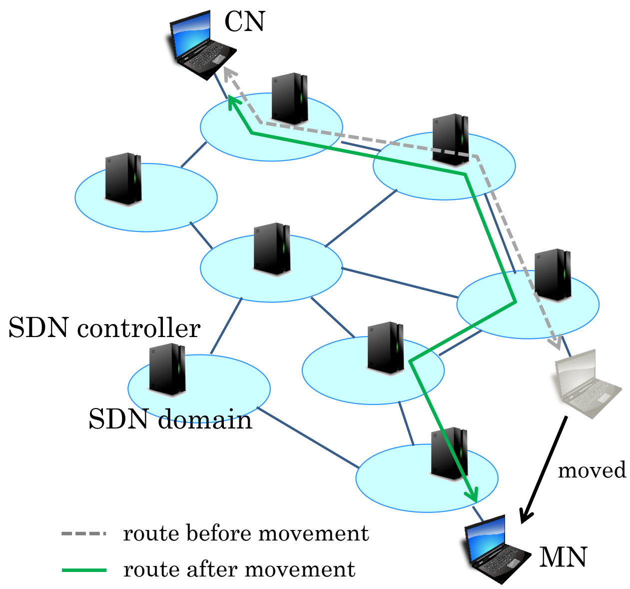

Fig. 1. Overview of out former work.

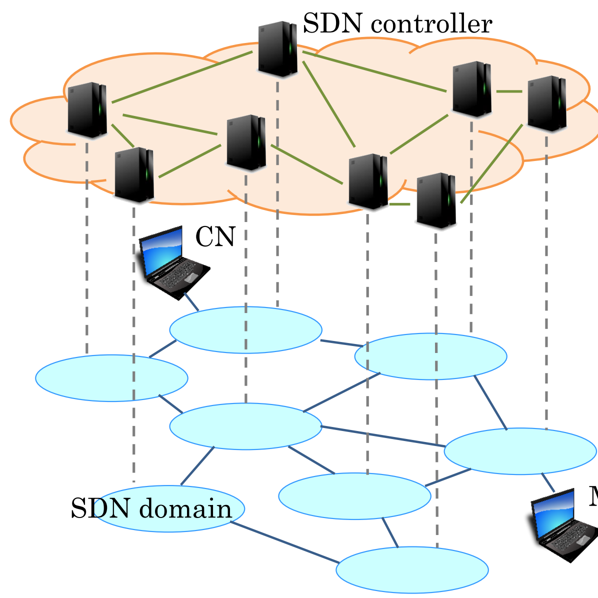

Fig. 2. Expected network environment.

select an optimized route, this scheme takes the number of domains a route goes through and the number of flow entries we have to install in SDN switches when calculating the end-to end route between a MN and its corresponding node (CN).

However, there are some problems in routing algorithm in this scheme. First, it does not consider costs and time for switching route. It is essential to finish a whole handover procedure including route changing before a session gets disconnected. Therefore, we cannot disregard the number of flow operations. From now on in this paper, we call operation such as adding and changing flow entry as flow operation. Second, it mainly focuses on one single communication it is dealing with and does not take other communication in same network into consideration. Generally, many MNs communicate with each other in a network, thus we have to consider other communication in order to avoid links with little bandwidth available.

B. Routing approach in SDN networks

There are some researches about routing across domains by using SDN. S. A. Astaneh et al. proposed a routing algorithm considering the path cost and the number of flow operations [10]. However, since this algorithm is for the case of link failure, it is not suitable for mobility management.

M. Idri introduced master controller that controls SDN controllers of domains under management [11]. Though introducing master controller makes it easy to control multiple domain network, a problem arises that who would manage the master controller of the network which is a collection of domains with different administrators.

III. Mobility Management Aware Routing

A. Overview

To deal with the problems we mentioned in section II, we propose an SDN based route optimization mechanism specified for mobility management.

Our basic concept of routing is to choose a route that takes balance between communication delay and number of flow operations. First of all, we must assure that TCP connection will not be broken during the handover procedure. With this on mind, we optimize the end-to-end communication route after a handover. If we choose a route with shortest path but with many flow operations, it might end up not being able to change route before session is disconnected. To the contrary, if we choose a route with minimum flow operations, the route might be lengthy and it will lead to a communication delay. As you can see, we cannot focus on just one side. We must choose the best trade off relationship between the communication delay and the number of flow operations. Furthermore, it is likely to avoid paths used by other communication to reduce communication delay.

Regarding the master controller administrator problem, controllers communicate with each other and share information in need so our scheme does not require master controller. Thus, we do not have to worry about administrator of a master controller.

The difference from our former work [9] is that we take 1) the number of domains each route candidate goes through, 2) the number of flow operations for each route candidate and 3) real-time available bandwidth information into consideration. Each information is normalized and calculated using weighting coefficient.

In our mechanism, each SDN controller has inter-domain topology information and can communicate with each other in controller network. Inter-domain topology information includes the connection relationships between domains. This information is stored in each domains' controllers at the time the network was constructed and the change of topology should be reflected manually whenever any changes have been made. Figure 2 shows the expected network environment. The network consists of SDN domains with different administrators. Each domain has a SDN controller that controls SDN switches inside it. This has two types of networks; one is controller network, the other is data network. The SDN controllers communicate with each other via the controller network. The data network consists of SDN switches and MN communicates via the data network.

B. Routing Process

We show the flowchart of route calculating process in Figure 3. Source domain is the domain a MN attaches to before movement and destination domain is the domain a MN attaches to after movement. In this scheme, the controller of destination domain does the calculations in the routing process. Other controllers are just directed by the controller of destination domain to obtain information of their managing domains and respond to requests from it.

When searching for flow entries as shown in Figure 3, we use flow entries for communication of MN and CN for clue. Thus, we would end up tracing the route MN and CN were using before movement like shown in Figure 4. Figure 5 shows how to gain available bandwidth information. The controller of the destination domain collects all the information from controllers of every domain in the network and record available bandwidth of every link. SDN controllers reply bandwidth usage information of the links they are connected to.

$$W_k = W_{F_k} + W_{D_k} + W_{B_k} \qquad (k = 1, 2, \ldots, K) \quad (1)$$

Equation 1 is used to calculate the total weight of each route we listed up. W_k denotes the total weight of route k. W_{F_k} is the total weight for flow operation, W_{D_k} is the total weight for the number of domains to go through, and W_{B_k} is the weight for the bandwidth of each route.

$$W_{D_k} = \frac{D_k}{D_{max}}\alpha \quad (2)$$

$$W_{F_k} = \frac{F_k}{F_{max}}\beta \quad (3)$$

$$W_{B_k} = (1 - \frac{B_k}{B_{max}})\gamma \quad (4)$$

Equation (2) calculates the weight for the number of domains to go through, Equation (3) calculates the weight for the flow operation, Equation (4) calculates the weight for bandwidth of each route. D_k denotes the number of domains route k goes through, F_k denotes the number of flow operation for route k, and B_k denotes the minimum bandwidth of route k. D_{max} is the number of domains in the network and B_{max} is the largest bandwidth in the network. F_{max} is $2(K-1)$ when we set the number of domains in a network as K. This is because we need to set flow entries for both ways, from MN to CN and from CN to MN, to establish communication between MN and CN. α, β, and γ are fixed numbers to attach importance to each parameter. We have not fixed these numbers yet, so we need to carry out experiments to adjust them.

Based on this process, we choose effective route for mobility management to keep seamless communication with low delay.

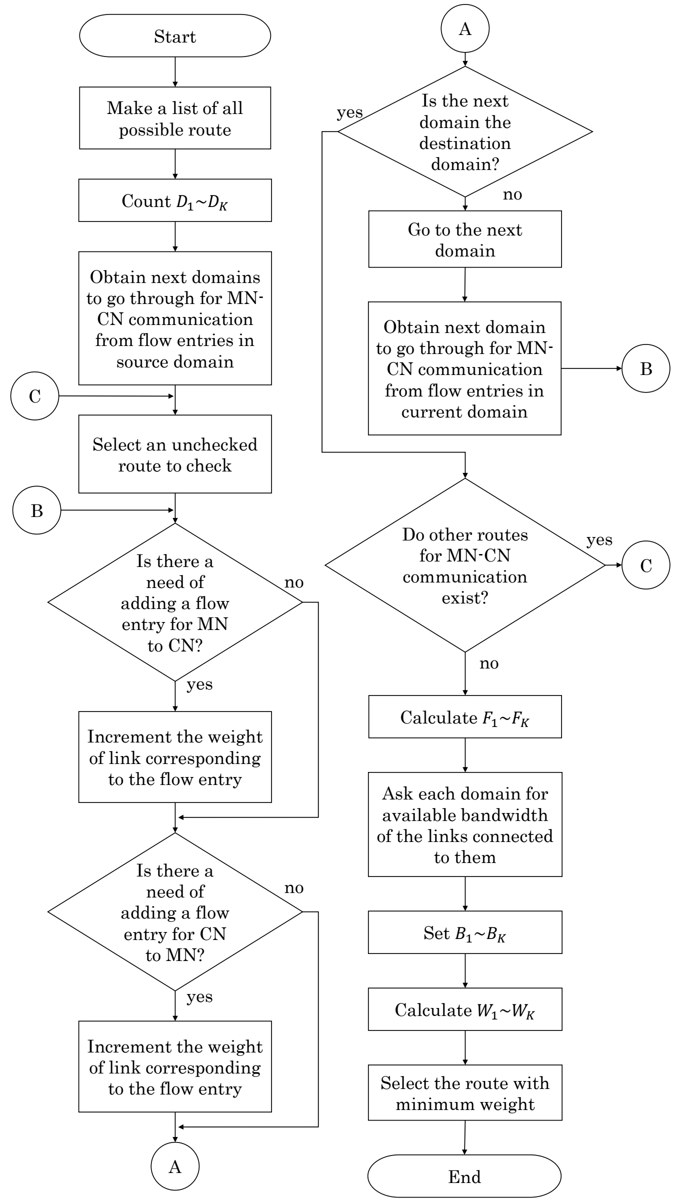

Fig. 3. Flowchart of route calculating process.

IV. Architecture

In this section, we show the basic architecture of our scheme. Figure 6 shows the basic architecture. In order to realize SDN based mobility management considering inter-

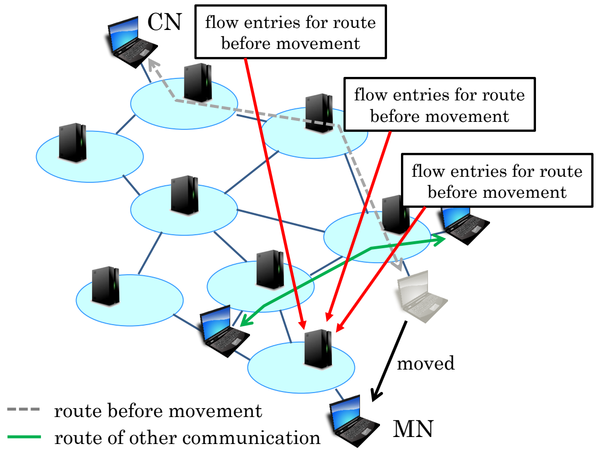

Fig. 4. Obtaining flow entry information.

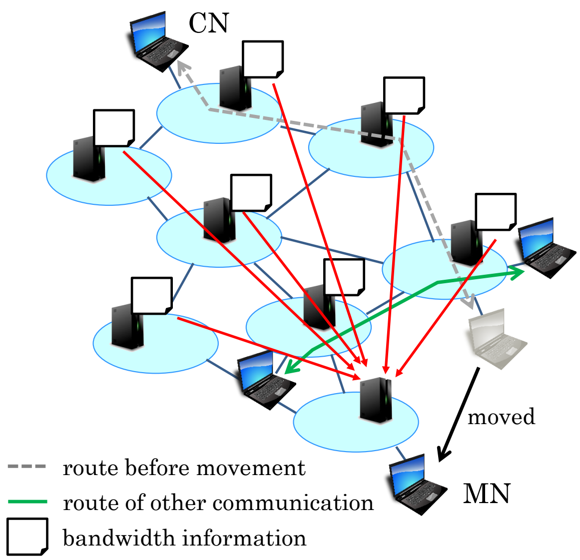

Fig. 5. Obtaining bandwidth information.

domain handovers, each domain in a network need to exchange information such as information of a MN, node connection information, and route information. Controllers exchange these information through controller network. The scheme consists of the Management Information Sharing Function (MISF) and the Inter-domain Routing Function (IDRF). The routing process we showed above is used for IDRF. These functions communicate with the corresponding functions in each domain and exchange information we mentioned above.

In our SDN architecture, we use OpenDaylight [12] as SDN controllers and Open vSwitch [13] as SDN switches. OpenFlow [14] is used for communication protocol between SDN controllers and SDN switches. For interface between our scheme and SDN architecture, which we use to obtain flow entries and network information from SDN switches, we use REST API.

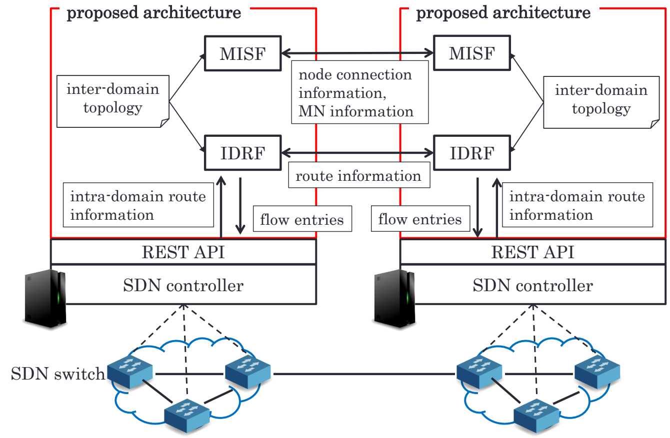

Fig. 6. Basic architecture of our scheme.

V. Conclusion

In this paper, we proposed a routing mechanism suitable for mobility management and showed the detailed design. This mechanism allows us to communicate with low-delay route after inter-domain handovers and avoid disconnection that might occur when switching the route.

For future work, we will verify weight of each information and design the detailed routing algorithm. Also we will carry out experiments to evaluate the proposed routing algorithm.

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