

On-demand Anchor-based Mobility Support Method for Named Data Networking

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Abstract— Addressing producer mobility in a Named Data Networking (NDN) is one of the challenging issues in the wireless network, which causes content unreachability problem and may impede overall quality of service. To cope with this, intermediate NDN routers have to update the forwarding information of content request toward a new position of a producer as reactive as possible. Several researchers have contributed to resolving the problem, but there is still room for improvement in terms of reducing network overhead and content retrieval latency. In this paper, we propose *on-demand anchor-based mobility support method* which redirects consumer's requests from an old position to a new position of a producer via a mobility tracking node, which is named *Anchor*. When producer handover occurs, the proposed scheme supports on-the-fly route redirection procedure at the old position, so it can provide better content retrieval latency by reducing retransmission delay. Our preliminary simulation study verifies that the proposed algorithm mitigates network overhead and improves the time taken for content retrieval in a mobile environment.

Keywords—Named Data Networking (NDN), wireless, producer mobility, anchor-based;

I. INTRODUCTION

Named Data Networking (NDN) [1] has been investigated as an alternative for next-generation (5G) communication architecture both in wired Internet networks and wireless mobile networks [2]. NDN architecture separates content itself from any location information such as IP addresses and is redesigned based on the data-centric perspective. Two remarkable features of NDN are name-based content retrieval and in-network caching, which enables a consumer to fetch data of interest from either a remote content producer or adjacent NDN cache routers without referring IP addresses. The Interest packet, which is a content request message, is forwarded based on a NDN forwarding table that is much similar to a conventional routing table, and each entry consists of name prefixes and matched outbound face information. Due to in-network caching feature, the Interest packet is forwarded hop-by-hop until it arrives the producer without exact and optimized end-to-end routing information, and a Data packet, which is a response packet of an Interest packet, is sent back along the trace of Interest packets. Due to this connectionless packet forwarding mechanism, NDN makes the

communication more flexible and transparent to the topology and end-to-end connection, and it is suitable for supporting topology-agnostic communication. For this reason, NDN has been studied in various wireless communication domains such as mobile ad-hoc and IoT networks [3]-[5].

Yet, there are two kinds of mobility issues in NDN; consumer and producer mobility problems. Consumer mobility is a problem that is caused by the movement of the content requestor. In other words, when the consumer moves to somewhere after issuing an Interest packet, it fails to fetch the corresponding data successfully. However, it is natively resolved through NDN mechanism, which the consumer re-issues Interest packet when a retransmission timer expires. Contrast to this, the producer mobility is more complicated because it causes the content unreachability problem due to outdated FIB entries. To solve this problem, several management protocols have been developed such as flooding based fallback mechanism or partial FIB update methods. The main concerns of those mechanisms are mitigating network overhead for FIB reconstruction and reducing content retrieval time. However, the former scheme induces considerable network overhead according to the frequent movement and the latter one may generate non-optimal Interest forwarding path that causes larger path stretch. Moreover, loss detection on the consumer side using time expiration embeds retransmission delay and it affects content retrieval latency.

To resolve this problem, we designed on-demand anchor-based mobility support mechanism that aims to reduce retransmission delay during the content retrieval period as well as improving Interest forwarding efficiently. The rest of this paper is structured as follows. In Section II, we briefly explain the background of NDN and related works and provide some of its potential problems. Section III depicts the design of our proposed scheme consisting of mobility management and Interest forwarding. Section IV shows evaluation and we conclude the paper in Section V.

II. BACKGROUND AND RELATED WORK

A. Overview of Named Data Networking

NDN is one of the future-oriented substitutes for the current IP-based network in terms of resolving traffic explosion problems. Owing to the name-based communication

architecture, NDN does not require any knowledge about where the content is and who the content has. A consumer who wants the data of interest pulls the corresponding contents from the adjacent NDN routers using a content name without effort to go to a content producer. Due to the symmetric-routing feature, the Interest packet leaves a forwarding entry (i.e., the content name and the incoming face) in Pending Interest Table (PIT) of each forwarding router, then the corresponding Data packet is transmitted back by consuming the PIT entries. Thus, it is possible to communicate with adjacent nodes as hop-by-hop manner, and suitable to support topology-agnostic communication. For this reason, it has been studied and discussed in mobile communication area actively. One of challenge issues in mobile NDN communication is how efficiently transmit Interest packets when communication nodes are not fixed over the network. In general, the wireless medium has limited resources such as bandwidth, relatively low data rate. Thus, simple Interest packet flooding for content retrieval causes severe network burden and impede reliable communication. For this reason, NDN constructs Forwarding Information Base (FIB), which matches name prefixes with outgoing faces to direct the received Interest packets toward its destination. Interest packets can be forwarded toward the content provider based on this information through the longest-prefix matching of the content name. However, when the content producer moves and changes its connected Point of Attachment (PoA), most FIB information in the network become invalidated and the consumer cannot retrieve dedicated contents successfully. To solve this problem, there are several types of research and it can be classified into three; 1) Rendezvous-based approach, 2) anchor-based approach, and 3) anchor-less approach.

B. Classification of Producer Mobility Support

1) Rendezvous Approach

Rendezvous server [6] is a fixed node that has the responsibility to track mobility information of all nodes in real-time. Generally, it resides in outside of a network, and mobile nodes that already have knowledge of the rendezvous server reporting their location information toward the server whenever they move. For instance, when a consumer cannot receive the Data packet from the dedicated producer after issuing the Interest packet (this procedure implies Interest retransmission), it queries to the rendezvous server to obtain the producer's new location information. Then, the rendezvous server responds to the consumer with fresh information, which is directly related to a new name prefix or an outgoing face in NDN. After receiving the response to the query, the consumer re-issues the Interest packet and results in successful content retrieval. This approach has good scalability and low overhead with less effort for FIB update because only the rendezvous server is required to update mobility information of the nodes. However, it is vulnerable to a single point failure problem and end-to-end delay increases according to the location of the server.

2) Anchor-based Approach

The anchor-based approach is similar to the rendezvous approach. In this mechanism, the anchor also keeps track of mobility information for all nodes but the difference is that one of the NDN routers is selected as an anchor node. In order to retrieve contents in mobile environments, the consumer sends Interest packet to the anchor first. After that, the anchor checks the name prefix information and forwards the received packet toward a new PoA. In this way, the consumer can receive target data from the content producer without querying to the third-party node such as a rendezvous server. For this reason, it achieves lower delay compared to the previous approach. In [7], the authors proposed scenario based mobility support method and they suggest the anchor-based method. They introduce '*Tracing*' and '*Traced*' Interest packets in order to update forwarding paths, and the Interest packet receivers keep track of the updated path information into PIT instead of FIB. However, some potential limitations of the anchor-based approach are that Interest packets, which are issued by a consumer, always travel via the anchor node and the length of the forwarding path can be much longer than the shortest path computed in NDN routing plane.

3) Anchor-less Approach

The anchor-less is another well-known approach to deal with producer mobility problem in a mobile NDN. It is similar to the conventional mobile IP solution. When a mobile producer handovers to another PoA, the node transmits prefix update message toward the old PoA. Then, the old PoA acts as a home-agent and redirects the incoming Interest packet toward the new PoA. The intermediated routers that received the messages update (or add) the backward path in their FIB temporarily thereby redirecting the matched Interest packets toward the new PoA. Many kinds of literature have taken this approach in NDN [8][9] because it is suitable to cope with the producer's mobility with less control overhead. However, in common with the anchor-based approach, it can lead low route efficiencies such as 'triangle-routing problem' due to a long distance between the old PoA and the new PoA.

III. ON-DEMAND ANCHOR-BASED MOBILITY SUPPORT

We proposed a new mobility support algorithm, "*on-demand anchor-based mobility support method*" that consists of the adaptive Interest packet forwarding and the mobility management methods. In brief, Interest packets are natively forwarded from a consumer to a producer based on the FIB built in the routing plane periodically. However, when the FIB entries become invalid due to the producer's handover and the Interest packet ends up being undeliverable, the traveling Interest packet is immediately redirected toward the anchor node instead of being dropped at the old PoA side. The anchor takes responsibility for handling the redirected Interest packet, which is named an "*on-demand anchor-based Interest forwarding*." The anchor checks the requested content name prefix contained in the received Interest packet and sends it toward the dedicated producer if it has knowledge of forwarding through the mobility management procedure. As a result, the proposed scheme reduces time delay caused by waiting for timer expiration on the consumer side.

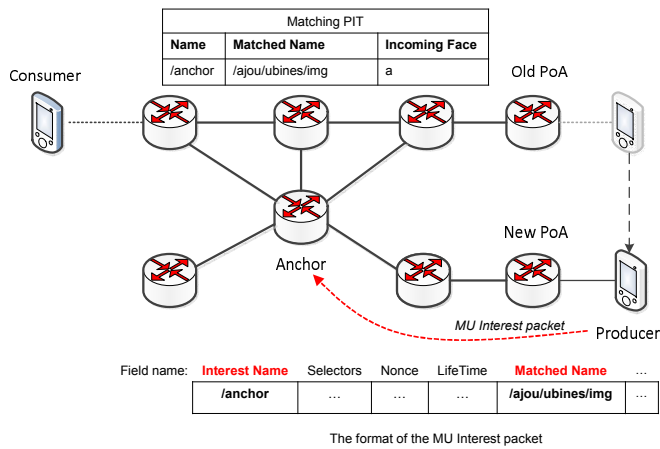


Figure 1. An example of Mobility Update Interest packet transmission.

A. Mobility Management

This section describes the detailed procedure of mobility management for the anchor and the content producer. Since this is a work in progress, we place less focus on the issue of the anchor selection problem and instead concentrate on how to efficiently utilize the anchor depends on the situation. (We will discuss the anchor selection issue briefly in section V). To support mobility management, we propose *Mobility Update (MU)* Interest packet to track mobility information. Upon occurring handover of the producer, it generates MU Interest packet and transmits it to the anchor node as similar to the anchor-less approach. The packet is forwarded by intermediate NDN routers along the FIB entries. We assume that NDN routers are static (i.e., infrastructure nodes) and have knowledge of the FIB information toward the anchor. As an outcome of periodic computation of protocol in the routing plane, it maintains shortest path routes. One significant difference with the anchor-less approach is that our proposed scheme only allows MU Interest packet to be forwarded to the anchor node, not to the old PoA. This is because all nodes are already aware of the forwarding path from the old PoA to the anchor, the MU Interest packet is not necessary to be propagated to the end-point (i.e., the old PoA). Note that the native NDN protocol keeps information of received Interest packets in the PIT with the requested content name and the incoming face. This is consumed by the response Data packet later by leading it to the actual consumers. In the same manner, MU Interest packet is also registered in the PIT and the entries lead the redirected Interest packets to the new PoA.

In Figure 1, let us assume that the mobile producer moves from the old PoA to the new PoA. Whenever the producer detects its handover, it expresses MU Interest packet with the anchor's prefix (e.g., /anchor) and the name prefix of the producer (e.g., /ajou/ubines/img) at 'Interest name' and 'matched name' fields, respectively. Then the routers record the received packet information into the *matching PIT* that leads the redirected Interest packets from the old PoA to the new PoA. As a result, a new forwarding path is constructed to guide the corresponding native Interest packets from the

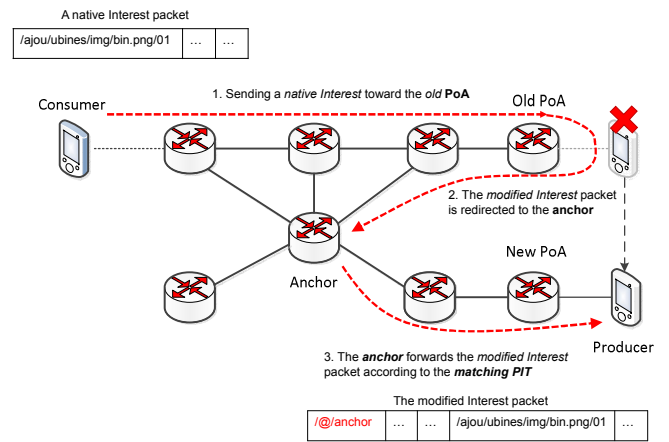


Figure 2. An example of Interest redirection during packet travelling.

anchor to the new PoA, and intermediate NDN routers are ready to forward them.

B. Basic and On-demand Anchor-based Interest Forwarding

Basically, Interest packet transmission follows the native protocol of NDN so they are forwarded based on the FIB that is periodically computed in the routing plane. Until the forwarding information is valid, the native Interest packet is directly forwarded to the producer to achieve short path stretch and low latency. However, if the FIB information is no longer valid due to the producer's handover, then the consumer fails to retrieve contents at the end. This situation can be resolved through the Interest fallback algorithm (e.g., blind flooding [12]) or FIB reconstruction in the next routing period but these are time-consuming and increase network overhead. To resolve this problem, we propose "*on-demand anchor-based Interest forwarding*" method that does not require any fallback algorithms to overcome contents unreachability problem. Figure 2 depicts our proposed scheme easier to understand.

Initially, the consumer and intermediate routers do not know about whether the target producer moves to the other PoA and existing FIB entries are invalid or not. Thus, a native Interest packet is simply forwarded based on the FIB. In the meantime, if the target producer moves to a difference PoA, it fails to reach to the corresponding producer. In this case, the old PoA that recognized the absence of the producer modifies the field information of the received Interest packet. In this paper, we do not specify how a PoA is able to detect the existence of the target producer but we can utilize a simple method for this by applying traditional link-layer solutions in wireless communication such as probing.

Prior to redirect the Interest packet, the old PoA changes the original name field of the Interest to the anchor's prefix with special character (e.g., '@/anchor' as shown in Figure 2) and copies the actual content name (e.g., '/ajou/ubines/img/bin.png/01') to the matched name field. After that, the Interest packet is redirected to the anchor node. Receivers check the included Interest name and if the name begins with a '@' then they look up outgoing face from the

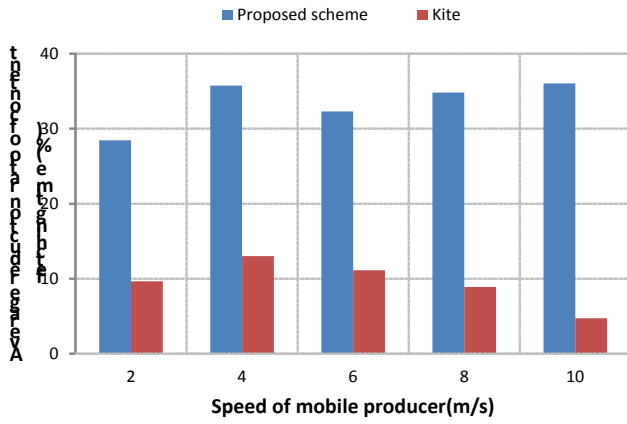


Figure 3. Comparison of average reduction ratio of content fetching time.

matching PIT through longest prefix matching producer. Otherwise, it is forwarded based on the original FIB. Therefore, the Interest packets are headed to the new position of the producer without Interest packet retransmission or fallback mechanism that implies longer delay.

IV. PERFORMANCE EVALUATION

Simulation experiments are performed to estimate the efficiency of content retrieval in mobile producer environments. We use ndnSIM 2.0 [10] that is an extension of ns-3 simulator [11]. Experimental parameters are summarized in Table 1. The 16 NDN routers form an infrastructure for NDN communication and those are deployed with grid topology in a network. Also, the mobile producer moves around in a network with constant velocity until the end of the simulation. No intermediate NDN router caches received data to identify the impact of the proposed algorithm itself. That is, a consumer always fetches data only from a content producer. We compare the proposed scheme with Kite in file uploading scenario.

TABLE 1. PARAMETER SETTING FOR EXPERIMENT

Parameter	Value
Network size (m ²)	400×400
# NDN routers	4×4 (16 nodes over 300×300m ²)
#Mobile Producer	1
Mobility speed (m/s)	{2, 4, 6, 8, 10}
Interest interval (ms)	300
Segment size (Bytes)	1024
Mobility model	RandomWalk2dMobility Model
Comparison	Kite, Proposed scheme

Figure 3 depicts the average reduction ratio of content fetching time. The content fetching time indicates the time taken between sending an Interest packet for content fetching and receiving the corresponding data from the producer. To measure the performance, we benchmark the proposed scheme and Kite against a native blind flooding method propagating the Interest packet over the network until arriving content producer or caching routers. Mobility supporting mechanism is inherent in it. Comparing to the blind flooding methods, the

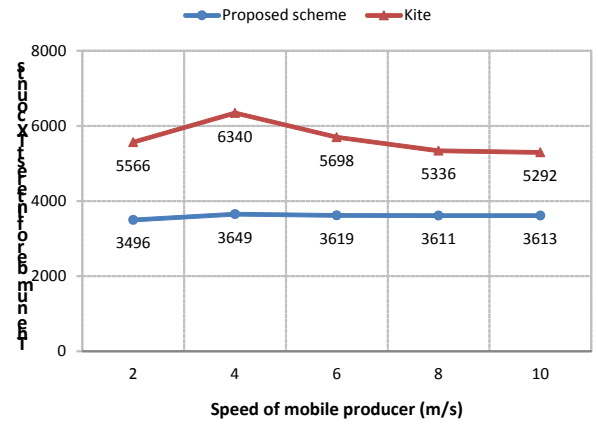


Figure 4. Comparison of the number of Interest transmission counts.

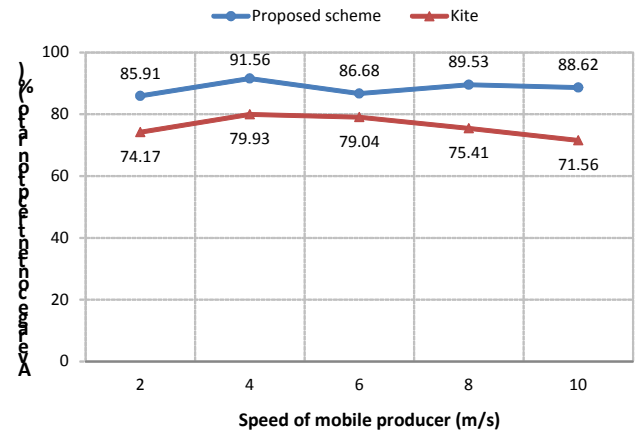


Figure 5. Comparison of average data reception ration.

proposed scheme improves more than 28%-36% time reduction, and Kite shows about 5%-13% higher performance, respectively. By redirecting Interest packet immediately to the new PoA, the proposed scheme achieves lower delay compared to the Kite. Figure 4 presents the number of Interest packet transmission counts for data fetching, which means the total amount of forwarding Interest packets in the network. In case of the proposed scheme, it shows stable performance compared to the Kite when the node velocity increases. The main reason is that our proposed scheme redirects the traveling Interest packets when an old PoA detects the mobile producer's leave. Therefore, it does not require additional Interest packet retransmission on the consumer side so the proposed scheme reduces more than 30%-40% of Interest packet transmissions compared to the Kite. Finally, Figure 5 shows the average content reception ratio of the consumer, which is the ratio of received content to the total request excepting the number of retransmitted Interest packets. In the figure, the proposed scheme outperforms the comparison for about 10%-24%.

V. CONCLUSIONS AND DISCUSSION

Producer mobility issue in NDN is essential for reliable content retrieval. In this paper, we propose on-demand

anchor-based mobility support, which redirects traveling Interest packets toward an anchor node only if when a mobile producer moves, and the existing FIB information becomes invalid. Since this is work in progress, some issues to be resolved are remained. First, we do not indicate specific anchor selection method but it is indispensable to reduce path stretch efficiently. Simply, we can pre-determine a fixed node that has the highest network centrality (e.g., betweenness or degree centralities) as an anchor in the network. However, in this case, the detoured path length may be larger than anchor-less approach. Thus, the anchor should be selected dynamically with careful considerations of relationship among a consumer, a new PoA, and old PoA. Even though the proposed scheme mitigates the total amount of Interest packet transmission counts compared to the previous study, there still remains inefficient Data packet forwarding path problem caused by Interest packet redirection. Thus, we have studied about technical solution to resolve those issues we mentioned.

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