Journal of information and
communication convergence engineering
http://jicce.org

J. Inf. Commun. Converg. Eng. 18(1): 22-27, Mar. 2020 Regular paper

Route Optimization Scheme for Mobile Content Sources in Content Centric Networking

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Abstract

Content centric networking (CCN) is regarded as promising internet architecture because it can provide network efficiency in terms of bandwidth consumption by separating contents from a specific network location and decrease network congestion events. However, the application of a CCN does not widely consider the side effects of mobile devices, particularly mobile content sources. For content source mobility, a full routing update is required. Therefore, in this study, a route optimization scheme is proposed for mobile content sources in a CCN environment to provide low communication overhead, short download time, and low resource consumption. The proposed scheme establishes a direct path between content requesters and a mobile content source for the exchange of interest and data packets using interest-piggybacked data packets. Based on the inherent CCN naming characteristics, the content source does not know the name prefix of the content consumer, and thus the proposed optimized CCN scheme utilizes the content router in the home domain of the content source.

Index Terms: Content Centric Networking, Content Publisher, Mobility Management, Route Optimization

I. INTRODUCTION

Content centric networking (CCN) has appeared as new communication architecture in which content is identified by the content name itself, and not the IP address of the node with the content [1-3]. It is expected that CCN will enhance the network efficiency and reduce the occurrence of network congestion by disseminating traffic to the content source or nodes with the cached content. Moreover, CCN inherently provides content authentication and protection by providing a signature for the binding between the content itself and the name of the content.

However, CCN still has several aspects to be further studied for practical development, and in particular, movement of the device has been rarely considered. CCN inherently supports mobile consumers because data packets are reverted to the content consumer along with the path-of-interest packet in the reverse direction. That is, when moving away to a new network domain while recovering the requested content data, the mobile content consumer simply requests the content again at a new location. However, content source mobility cannot be easily solved without a full routing update.

Some studies have been conducted on mobility support in CCN. In [4], a proxy-based scheme is proposed for content consumer mobility. This reduces the content delivery latency by using in-network caching except through the original content source. However, it does not indicate a solution for content source mobility. In [5], it is assumed that the movement event of the content sources is infrequent and thus the content source mobility is not considered a significant problem. However, because a number of mobile devices act as both content consumers and content sources at the same time, the

Received 17 December 2019, **Revised** 14 January 2020, **Accepted** 20 January 2020
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Open Access **https://doi.org/10.6109/jicce.2020.18.1.22** print ISSN: 2234-8255 online ISSN: 2234-8883

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content sources may have common movements. Moreover, a path extension method for the mobile content sources (MCSs) is presented in [6-10]. This makes only one tunneled path between the original domain of the MCS and the new domain where the MCS is currently situated. However, it may create a false routing event owing to a long location update latency and degenerate the content transmission efficiency owing to a long indirect path through the original domain of the MCS. That is, all interest packets targeting the MCS are first forwarded to the original name prefix domain of the MCS and subsequently, the interest packets are then encapsulated and tunneled with the temporary name prefix indicating the current location of the MCS. Owing to the tunneled path from the home domain of the content source to the domain where the MCS is currently located, the content transmission latency is increased, which leads to a low network throughput. Therefore, a route optimization scheme for MCSs in a CCN environment is proposed to reduce the overall content retrieval latency and network resource consumption. As the main idea of the proposed optimized CCN (OpCCN) scheme, a direct path between the content consumer and the MCS is created to reduce the content retrieval latency.

The rest of this paper is structured as follows. In Section 2, the mobile CCN scenarios and their related side effects are described. Section 3 presents the proposed route optimization method in a mobile CCN, followed by the results of the performance evaluation. Finally, in section 5, we provide some concluding remarks regarding this research.

II. CONTENT SOURCE MOBILITY IN CONTENT CENTRIC NETWORKING

CCN protocol assumes two types of packets, namely, interest and data packets [2, 3]. An interest packet indicates a name for the requested data, and a data packet is utilized to deliver the real content. An interest packet includes a unique identifier for the content name, list of parameters such as the order preference, and random nonce value to prevent a looping of the packet. The content name is the most important among them. Each name prefix follows a hierarchical structure, and a '/' character indicates a delimiter between various components, which is represented as '/smu.ac.kr/jlee/ccn.txt'. Moreover, CCN applies name-based routing instead of the node location. That is, the CCN routers forward interest packets by looking up their routing table using the name carried in the packets.

Although a CCN is effective for content dissemination, cases may occur in which such benefits are attenuated if there are MCSs. Because a CCN adopts content name-based routing, false routing information may invoke interest packets to be misrouted. Therefore, whenever the content sources may move away to a different name prefix domain, all con-

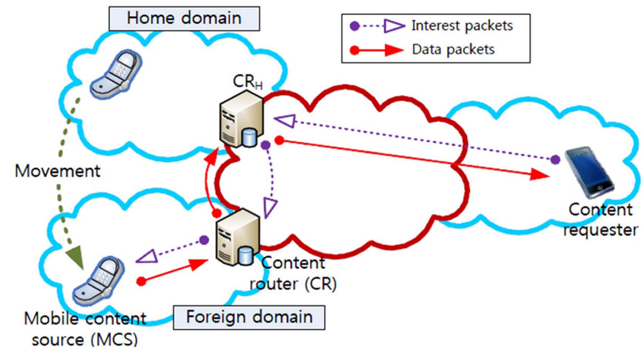

Fig. 1. Triangular routing problem in a mobile CCN.

tent routers should update their routing information to accurately deliver future/on-going interest packets toward the MCS. However, it takes a long time to update all routing tables in all CCN networks. Thus, interest packets may be not delivered if the route to the MCS has not made changes to the new location; thus, a temporary service disruption may occur.

Moreover, an interest packet does not include any information for the content requester. Thus, to support the content source mobility, data packets must follow the extended path through the encapsulated name prefix in the reverse direction. Such an extended path may incur a long content delivery latency, which may be worsened owing to an increasing number of domain changes. As shown in Fig. 1, interest packets are forwarded through the original domain of the MCS through the long-extended path even when a content consumer is nearly located at the MCS. Such a non-optimized path may incur a high consumption of network resources and a longer transmission latency, which is directly related to the degradation of the network throughput. Thus, this paper describes a dynamic route optimization scheme for MCSs in a mobile CCN environment.

III. OPTIMIZED CCN SCHEME

The proposed optimized CCN (OpCCN) scheme is targeted to reduce the routing control overhead and content delivery latency for MCSs in a CCN environment through a direct path establishment between the content requester and content source.

The proposed scheme begins when MCS movement occurs. When an MCS moves away to a different network domain, it delivers a 'Prefix update (PU)' message to the content router (CR_H) in its home domain. Through the exchange of prefix update and 'prefix update acknowledgement (PUack)' messages, a long tunneled path is established from the original domain network to the domain network of the new MCS. Moreover, another local extended path is configured between the previous CR (pCR) and the new CR (nCR) to prevent packet losses during a handoff. For route optimization, the MCS instructs its location to a content consumer through a data packet piggybacking its current location information and current tentative name prefix. The operation of the proposed OpCCN scheme is made up of four phases, the detailed operations of which are as follows.

A. Phase 1. Location update

An MCS checks whether to start the mobility management functions by means of the underlying initialization information from a wireless content router. When recognizing a change in the network domain based on a comparison of the domain name prefix with its name prefix and the name prefix from a wireless router, an MCS first constructs a tentative prefix, which shows the name prefix of the moved domain, for the path tunneling between CR_H and the moved domain. Next, MCS sends a PU message representing the new current location to its CR_H. The PU message contains both the tentative name prefix and signature of the MCS. The signature information is utilized to check whether the PU originator is valid. In Fig. 2, the *pu* component indicates that this interest packet is of a prefix update type and *hp* indicates the home prefix information of the MCS. When receiving the PU message, CR_H processes a validity check to determine whether the original initiator of the PU message has been registered. If the signature is valid, the CR_H sends back a PUack message. The routing entry for the MCS at CR_H is then altered to reflect the current location of the MCS. That is, the outgoing face field is changed to the face through which the PU message is entered, and the tentative name prefix in the PU message is also recorded for future path tunneling.

B. Phase 2. Interest Tunneling

When interest packets from a content consumer are forwarded toward the original domain of the MCS, CR_H can forward the interest packets by looking up its pre-configured routing information toward the current foreign domain of the MCS. In other words, the CR_H tunnels all interest packets toward the MCS to its current location.

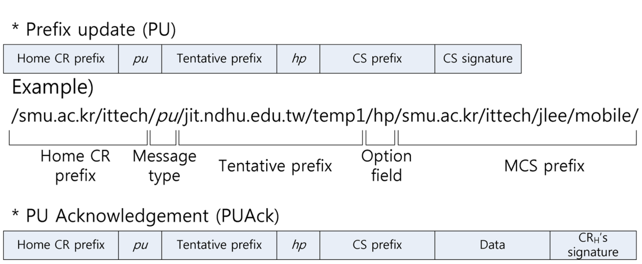

Fig. 2. Prefix update and acknowledgement message format.

C. Phase 3. Route optimization

To directly send interest packets toward the MCS, the consumer must acquire the current location information of the MCS specifying its temporary domain prefix. The route optimization process is initiated along with the reception of the tunneled interest packets. That is, when receiving the tunneled interest packets from CR_H, the MCS can be notified that the content requester (i.e., the original requester of the tunneled interest packet) does not know its current location. At this time, the MCS piggybacks the temporary domain name on each outgoing data packet.

In Fig. 3, the *pb* component indicates that the current tentative prefix information of the MCS is piggybacked and *tunnel* indicates that this packet is tunneled. When receiving the data packet piggybacking the temporary domain name from the MCS through CR_H, the content consumer acquires the current location and the temporary domain name to directly route the interest packets. Next, the content consumer sets the location name for all subsequent interest packets to the temporary domain name delivered from the MCS. Thus, the interest packets are directly routed to the MCS without taking a bypass path through CR_H. The data packets are delivered through the direct path between the content consumer and the MCS, and the content routers then cache them under their original content name. That is, the optimal path is established between the content consumer and the MCS, whereas the tunneled path between CR_H and MCS is utilized, which means that the optimal path configuration does not need an additional reconfiguration latency.

D. Phase 4. Local path extension and route re-optimization

When MCS detects another domain prefix through the initialization data, the path toward the MCS must be updated. To reduce the prefix update latency, the proposed scheme

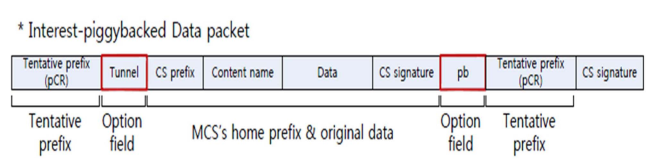

Fig. 3. Prefix update and acknowledgement message format.

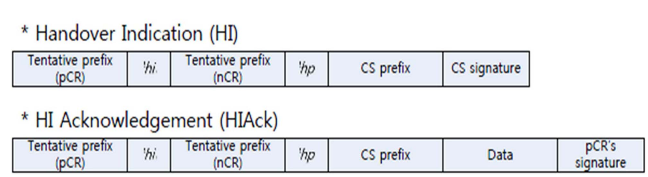

Fig. 4. Handover indication and acknowledgement message format.

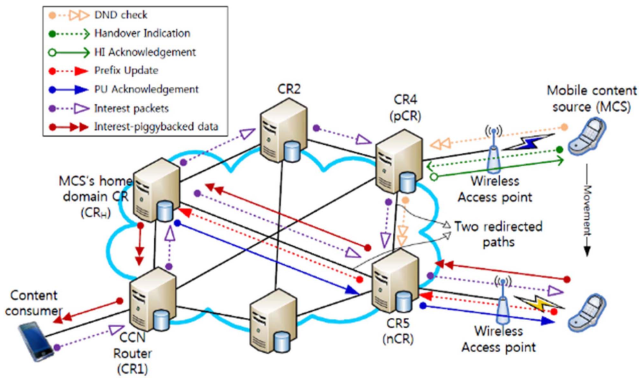

Fig. 5. Procedure for path extension and route optimization.

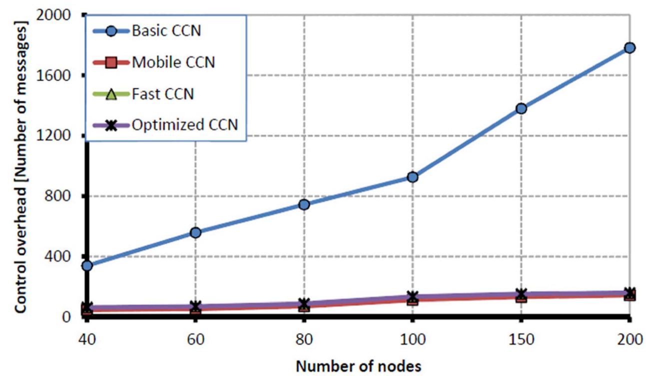

Fig. 6. Control overhead.

specifies a localized binding between the previous CR (pCR) and the new CR (nCR). To do so, MCS sends a 'handover indication (HI)' message to its previous CR (pCR) to establish a localized tunnel. As shown in Fig. 4, the HI message contains its new tentative prefix information and signature information to ensure the validity of a localized binding. The *hi* component indicates that this interest packet is for a handover. Upon receiving the HI message, pCR applies a validity check for an HI message. If valid, the pCR sends a 'handover indication acknowledgment (HIack)' message in the data packet type. Next, pCR is re-forwarded to the nCR interest packets tunneled from CR_H. After moving into nCR, MCS conducts a path update operation with CR_H. Establishing a new redirection path is identical to the path redirection in Phase 2. That is, the MCS temporarily maintains two paths: a local extended path between the pCR and nCR, and a redirected path between CR_H and nCR. Moreover, when receiving the interest packets using the local extended path from pCR, the MCS can detect that the content consumer does not know its new location. Thus, the MCS sends data packets piggybacking its new location information through the route optimization phase during phase 4. Next, the content consumer can exchange interest and data packets using the direct path with the MCS within the nCR.

An example of the proposed OpCCN scheme is shown in Fig. 5. From Fig. 5, contents are shared through two types of path, an indirect path through CR_H and a direct path from the content consumer to the MCS. To establish a direct path, the MCS delivers a data packet that includes the current location information. After that, the content requester can directly send interest packets by using a temporary domain prefix that MCS is allocated within the current foreign domain.

IV. PERFORMANCE EVALUATIONS

To evaluate the proposed optimized path control scheme, we created a chain of simulations where the velocity of the MCS was varied. First, we constructed a flat network topology with a range of 40-200 CRs, where each CR is linked to a wireless router. The wired link bandwidth is set to 100 Mbps. It is assumed that the route refresh is triggered by new name prefix advertisement periodically sent from a wireless content router. The name prefix advertisement message interval is set to 1 s. A high-volume multimedia video is chosen to assess the enhancement of the proposed OpCCN scheme while supporting the movement of the MCS. Content consumers and an MCS are initially configured at a random position. As the simulation runs, an MCS starts to move according to the smooth random waypoint mobility model because it is considered to make the user mobility smoother and more practical than other mobility models [11].

The control overhead is assessed based on the numbers of normal and retransmitted interest packets including additional location update messages. The control overhead is described in Fig. 6 as a function of the varying number of content routers. As the network size increases, the control overhead of basic CCN rapidly increases when compared to other schemes including the proposed optimized CCN (OpCCN). In other words, basic CCN needs a full routing update to support the MCSs, which generates more control packets for such an update. Even if the proposed OpCCN scheme reduces the number of retransmitted interest packets through a route optimization, additional control packets are required for the direct path established between the content consumer and moving MCS. That is, it additionally invokes more processing loads through a route optimization than fast and mobile CCN schemes. Meanwhile, the mobile and fast CCN schemes need one redirected path between CR_H and a new CR, or two paths for the redirected and local extended paths, respectively, bringing about more interest packets than the proposed OpCCN owing to the indirect and extended paths.

The results obtained when measuring the average route length to exchange interest and data packets are shown in Fig. 7. The path length of the mobile and fast CCN schemes

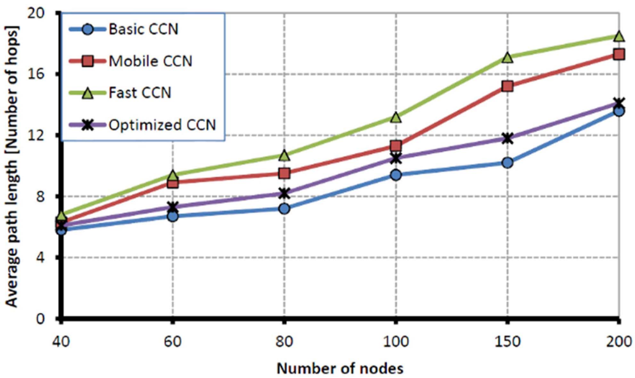

Fig. 7. Routing efficiency.

is sharply increased owing to a longer indirect path through the original domain of the MCS. In other words, in mobile and fast CCN schemes, all packets including interest and data packets are exchanged through CR_H. Moreover, the route length of the basic CCN scheme depends on the distance between the content consumer and MCS. After full routing updates, the basic CCN always takes the optimal path between the content consumer and the MCS. However, the basic CCN scheme requires full routing updates for the successful interest delivery after a node movement, incurring a lengthy update of all routing tables. Meanwhile, the proposed OpCCN scheme temporarily utilizes an indirect path through CR_H similar to the mobile and fast CCN schemes and largely utilizes a shorter direct path between a content consumer and the MCS.

V. CONCLUSIONS

In this paper, the following two points were made: First, the dynamic movement of mobile sources leads to a performance degradation of content sharing in a CCN environment. This may result in a long download completion time and high control overhead. Second, the optimized path configuration scheme is presented to complement the side effects of movement of the content sources. The MCS instructs its movement event to the content routers on the path between the previous and new domains. Moreover, it delivers its new domain information to the content consumers. In this way, it can establish a direct path with the content consumer and reduce the consumption of resources by the content routers and decrease the content retrieval latency by establishing a direct path between the content consumers and MCS as compared to existing schemes such as a basic CCN, mobile CCN, and Fast CCN approaches. Such characteristics are important in CCN environments because MCs lead to a high network resource consumption, low routing efficiency, and dynamic routing changes.

ACKNOWLEDGEMENTS

This research was supported by a 2019 research grant from Sangmyung University.

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