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Research Article

Cluster-Based Device Mobility Management in Named Data Networking for Vehicular Networks

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Named data networking (NDN) is an emerging technology. It was designed to eliminate the dependency of IP addresses in the hourglass model. Mobility is a key concern of the modern Internet architecture, even though the NDN architecture has solved the consumer mobility. That is, the consumer can rerequest the desired data contents, while the producer mobility remains as an issue in the NDN architecture. This paper focuses on the issue of producer mobility and proposes the cluster-based device mobility management scheme, which uses the cluster heads to solve the producer mobility issue in NDN. In the proposed scheme, a cluster head has all information of its attached devices. A cluster head updates the routes, when a device moves to the new access router by sending all the attachment information. The proposed scheme is evaluated and compared with the existing scheme by using the *ndnSIM* simulation. From the results, we see that the proposed scheme can decrease the numbers of interest packets in the network, compared with the existing scheme.

1. Introduction

NDN is a common networking model for all applications and network environment, and it is still under the developing phase. It has been designed as an alternative to the IP address-based network. IP was designed for conversation between endpoints, and it is used enormously for content distribution [1–3]. NDN uses data names instead of IP addresses. The NDN network removes the restriction of IP datagram which can only use both IP destination addresses and source addresses. NDN application removes middleware which causes inefficiency because middleware uses mapping application for interaction. In NDN, data looping is prevented via memory because every chunk of data has a unique name, while IP is used for single-path forwarding.

The NDN architecture uses the two types of packets [4], *interest packet* and *data packet*. A consumer uses the interest packet to request the desired contents, while a producer or NDN router uses the data packet to send the desired content to the consumer by using the reverse path. Each NDN router maintains the three tables for processing of interest packets and data packets [5]. These tables are content store (CS), pending interest table (PIT), and forwarding information base (FIB).

Initially, when an interest packet reaches the NDN router, the NDN router first checks the desired content in CS. If the content is found in the CS table, the NDN router will send the content back to the consumer. Otherwise, it is forwarded to PIT. When PIT waits for the same content from FIB, it only marks an entry in the PIT table. PIT forwards the desired content to the consumer upon reception. If PIT did not send the desired interest packet to FIB, it will forward it to FIB, and FIB will look for the desired content in the other NDN router. When the content is found, it will be delivered to the consumer by using the reverse path.

The producer mobility is a major issue in NDN. The consumer mobility is automatically solved by the NDN architecture since a consumer can rerequest the desired contents. If the consumer nodes are interested in a desired data content, the producer nodes will offer the content to the consumers. Problems may occur when a consumer requests the desired content and the producer moves to the new access router by handover. One of the problems may occur when the interest packets reach the previous access router, and thus the interest packets cannot be delivered to the producer. Based on this, in this paper, we introduce a cluster-based device mobility management (CB-DMM) so as to locate the devices in NDN that may possibly move from the previous access router to a new access router.

The remaining parts of this paper are organized as follows. Section 2 will briefly review the related work. In Section 3, we will explain the existing scheme. The proposed CB-DMM model will be described in Section 4. We will evaluate the performance of the CB-DMM models in Section 5. Finally, Section 6 will give conclusions and future works.

2. Related Work

NDN is a new emerging networking model that can be applied in various networking areas. Specially, NDN provides a lot of advantages such as network caching, security, and efficient response time in the vehicular ad hoc networks (VANETs) [2, 3, 6–8]. There are two types of mobility considered in NDN: consumer mobility and producer mobility. A lot of studies have been done on consumer mobility. However, there are not many studies on producer mobility.

The producer mobility issue is often addressed by using the mobile IP [9]. However, it suffers from the problems, such as a single-point failure, nonoptimal routingand so on. In [1], a distributed scalable mobility management (SMM) mechanism is introduced to solve the issues of MIP-based solution for NDN mobility without changing the original NDN paradigm. SMM protocol separates the content locator and the identifier. The hierarchical MIP [10] is used to support the intradomain and interdomain handover. However, the use of mapping systems on a global scale brings latency and complexity in the network.

An anchor-based mobility support method was proposed in [5]. Mobility tracking node, called anchor, was used to redirect the consumer request to the producer from the old location to the new location. When the producer handover happens and the interest packet ends up with being undeliverable, the traveling interest packet is immediately redirected toward the anchor node instead of being dropped at the old point of attachment.

The content provider mobility is solved in [11] by providing the locator and the mapping system. The locator is used because we do not know where the information is located, and the mapping system is used to map an identifier to the locator. An identifier is used for matching in CS and PIT, and a locator is used for forwarding in FIB. The provider gets a locator when it joins the network. A locator represents the address of the provider in the access point. A mapping system, such as DNS, will resolve the query so as to map the name to the locator. These extra labels may cause more complexity and burden on the network.

In [12], the authors tested the named data network for mobility support in the wireless access network and provided the simulation-based results by using *ndnSIM*. This work focuses on delay-sensitive and delay-tolerant traffics by using different network topologies. These topologies are based on autonomous systems (ASs). The authors give the four scenarios. The first scenario is for a single mobile host and a single static host, which are assigned to the same AS. The second scenario is based on the first scenario with modification that allows both hosts to be mobile. The third scenario has a single mobile host and a single static host, and each host is assigned to different ASs. In the last scenario, the third scenario is modified, which allows both hosts to be mobile. In these scenarios, the application with delay-tolerant and delay-sensitive traffics may experience worse performance in the viewpoint of message overhead and throughput. NDN is not suitable for small size networks. The authors want to introduce the location-routing policies in NDN to satisfy the requirements of the different applications and to reduce the burden on network infrastructure.

In [13], the authors have divided the existing solutions for producer mobility in NDN into the three categories: routing, mapping, and tracking. A mobile node (MN) can keep its IP address while moving to another network, but MN must update the other routers in the routing-based approach. In mapping-based solution, whenever MN changes the network, it must update the current IP address at previous routers. The tracing-based approach is mainly used to reach the producer in the hop-by-hop manner by using the reverse path. The authors mainly concentrate on the producer mobility and give a detailed mechanism of the already available proposed solution. For producer mobility, the authors present the two chase mechanisms of the moving producer and also the two data-centric ways to find interest data.

In [14], a trace-based scheme is proposed for NDN mobility, called Kite. In Kite, a new forwarding mechanism is introduced for the producer mobility. A trade name field is used. Tracing flags are used to forward the tracking interest. The Kite is locator-free and based on application. The developer can make changes in its application to achieve better performance. But, the authors have not provided any simulation to validate the proposed approach. Trace-based solution also causes huge traffic in the network, and it is time-consuming.

In [15], the producer mobility problem is solved by data replication. The authors provided the two main strategies to handle the producer mobility. In the first strategy, they handle the producer mobility through data replication. Secondly, they evaluate when data replication improves the producer mobility in NDN. The producer mobility issue is divided into the two categories: unavailability period and reattachment to the network. In the unavailability period, they suggested replicating the content when the producer is unavailable. Through different parameters, they evaluate the performance for unavailability period and for reattachment to the network. But, the replication techniques can cause more storage and overhead in the network.

In [16], the authors minimize data loss in the real-time application which is caused by mobility in the NDN network. They used the three approaches to minimize the loss which is caused by mobility. In the first approach, the point of access (PoA) is used, where a mobile node (MN) registers itself with a nearby PoA. This PoA sends interest packets and data packets to the MN. In the second approach, the rendezvous points are used. Rendezvous points represent the strategically located routers. The authors used the rendezvous point for seamless mobility. In the last approach, multipath interest and multipoint content are used to solve the mobility issue in NDN.

In [17], the producer mobility is solved by using the cache techniques. Before the producer handover occurs, data can be cached to offer seamless operation in NDN.

In [18], the authors built a prototype of NDN in the ns-3 simulation. A forwarding hint is used for the producer mobility. The forwarding hint was used in the previous IP mobility solution. The authors argue that this new element can be used for content-centric data transmission.

3. Existing SMM Scheme

Scalable mobility management (SMM) for content source in NDN is proposed in [1]. It solved the producer mobility issue in NDN. The authors used the mapping system on a global scale which may cause huge latency and bring more complexity to the network. The authors proposed the two handover models. In the first model shown in Figure 1, a producer is attached to a new access router, and it sends a special message to the mapping system by using a binding update (BU). The mapping system sends a binding acknowledgment (BA) to the producer. The mapping system also sends BU to the previous access router. The previous access router (PAR) sends data packets with BA, and the communication continues. In the second handover model, the producer sends the BU packet to both mapping system and PAR at the same time. The BA is sent from PAR to the producer. The second handover model introduced the mobility option (MO) packet which is a modification of NDN interest packets. The MO interest is sent from PAR to the new access router (NAR). We solve the mobility issue through the cluster-based device mobility in NDN. The device may be a producer or a consumer, which will further be discussed in Section 4.

4. Proposed CB-DMM Model

In this section, we will discuss the proposed CB-DMM model, including topology, handover procedure, selection of cluster heads, responsibilities of cluster heads, and NDN routers.

4.1. CB-DMM Topology Model. We have designed the cluster-based device mobility management (CB-DMM) to support the device mobility in NDN. In Figure 2, it is assumed that a consumer requests contents "contentsource/realtime/video1." The problem occurs when the interest packet reaches the previous access router and the producer moves to the new access router, and the interest packet cannot be delivered to the producer. To solve this problem, the cluster-based device mobility management scheme is used. Our model has the strength to solve other mobility issues such as consumer mobility. In CB-DMM, when the device moves from one access router to another, it will send its current location information to the cluster head, and the cluster head diverts the pending interest packets toward the intended device.

In Figure 2, a group of NDN routers selects cluster heads. There are different techniques available for selection of cluster heads based on the nature of network type. In a wireless network, we need more storage capacity, energy, and the location of the cluster head, while the situation is different for the wired network. Our topology is based on the mixed network. We use both wireless and wired networks in our model for simulation. The selection of cluster will be further discussed in Section 4.3.

4.2. CB-DMM Handover Procedure. A producer moves from PAR (previous access router) to NAR (new access router) in Figure 3. The moving device (producer) sends the attachment information to NAR. The NAR sends the attachment information to the cluster head and informs it about the producer. The cluster head updates its cached table and saves the current location of the producer. The cluster head sends the binding acknowledgment to NAR, and NAR sends BA to the content producer. The cluster heads exchange periodic updates with each other. When a request reaches the cluster head for producer, it simply checks its cache and sends a request to the current location of the producer. The producer sends the contents through the reverse path to the consumer.

4.3. Selection of Cluster Heads. Different approaches can be taken to select the cluster heads. The wired network is different from the wireless network. Selection of cluster heads in the wired network is easy, while selection in wireless is difficult. Our scenario is based on both wired and wireless networks. In our scenario, the consumer is connected to the wired network, and the producer is connected to the wireless network. The AP is connected to a cluster head via a wired link. Based on our approach, we select the cluster head on the following approaches. First, we use the existing algorithm [19] for the selection of cluster head, based on memory. Secondly, the cluster heads must provide easy connectivity to other cluster heads. Third, each cluster head knows the addresses of the other cluster head. Fourth, the cluster heads are connected with each other directly. In [19], the authors proposed an algorithm for selection of cluster heads. We will also use that algorithm for selection of cluster heads in a wireless network.

4.4. Operations of Cluster Head. In our scenario, different operations are possible for each cluster head. The different routers can be connected to the same cluster head. Now, User A is connected to router R1, and User B is connected to R2, and both (i.e., R1 and R2) are connected to the same cluster head R. User A requests the contents "contentsource/realtime/video1" and sends the interest packet for content toward R1. Then, R1 will forward the interest packet to the cluster head R.

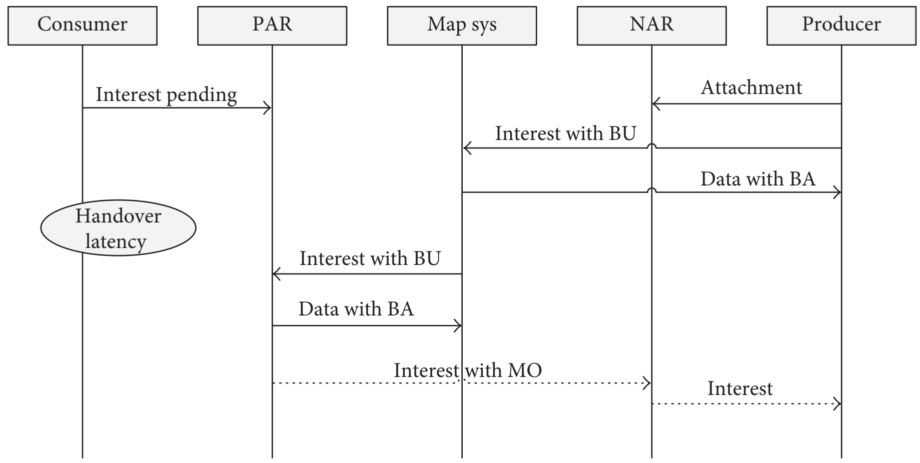

Figure 1: SMM handover model.

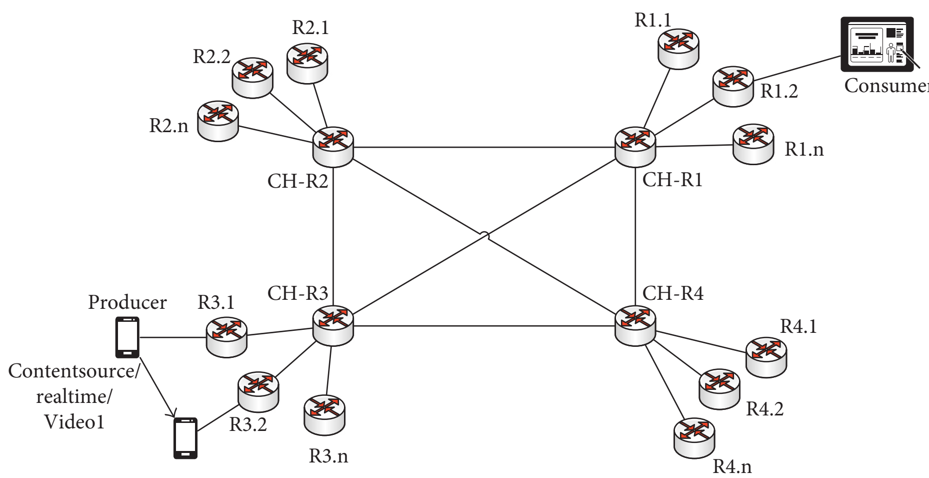

Figure 2: CB-DMM network topology model.

The "contentsource/realtime/video1" is sent through the data packet using the reverse path to User A. Now, User B sends interest packets for the same data through different router R2, when the interest reaches the cluster head. The cluster head simply sends data packets to User B from it CS table. Through this process, a lot of network resources can be saved, and overhead can be decreased from the network. Our model can also solve the consumer mobility because whenever a device moves to a new access router, it will send its current location information to cluster heads. Now, for both cases, the data packets will be sent to a new location. In case of a producer, the interest packets will be sent to the new location. The cluster heads in our scenario also send a periodic update about connected devices to each other. Through this process, the contents can be easily found in the network. The mobility problem can also be solved through periodic updates, which the cluster heads share with each other.

5. Performance Analysis

We simulate the CB-DMM model in *ndnSIM* [20] and compare our results with the SMM model. The SMM model is an existing scheme that is presented in Section 3. We used the two scenarios to simulate CB-DMM and SMM models in *ndnSIM*.

Figure 4 shows the basic network topology for CB-DMM and SMM models. For scenarios 1 and 2 in CB-DMM, the producer is initially connected to AP1. Both APs are connected to cluster heads, and the cluster heads are connected with each other through a direct link. The consumer is connected to an NDN router, and the NDN router is connected to a cluster head. For the SMM model, the mapping system is placed three hops away from the producer node for scenario 1. While for scenario 2, the mapping system is six hops away from the producer. In the SMM model, the mapping system is used to locate the desired contents in the NDN network. We placed the mapping system in a different position because according to [1], the mapping system can be placed globally in the NDN Network.

Table 1 shows the basic network parameters for both CB-DMM and SMM models. The SMM model uses the mapping system to locate the producer. The location of the mapping system in the network is a big challenge for the SMM model.

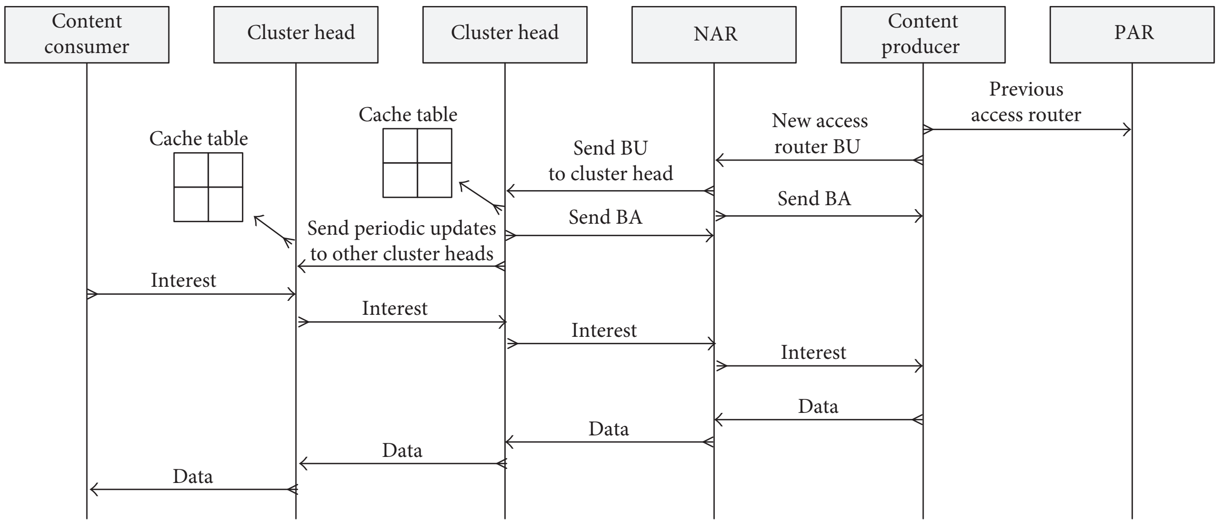

Figure 3: CB-SMM handover procedure.

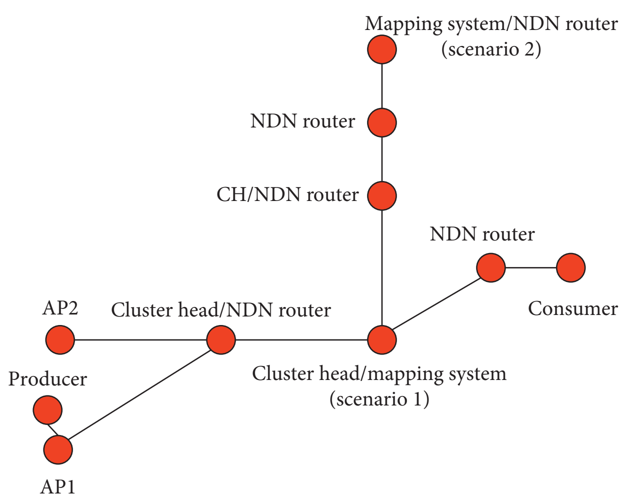

Figure 4: Models for CB-DMM and SMM network simulation: scenarios 1 and 2.

We use the two scenarios for the SMM model, where the mapping system is located 3 and 6 hops away from the producer. According to the SMM model, the mapping system is placed on a global scale in the network. The topology of Figure 4 is used for simulation of CB-DMM and SMM models. The difference occurs in the node functionality. That is, when we simulate the SMM model, the node has the functionality of the mapping system; whereas for the CB-DMM model, some nodes have the functionality of cluster heads. The number of nodes in the networks is 11. The capacity of the link is set to 100, 50, and 10 Mbps, and the link delay is set to 1, 10, and 20 ms, respectively. The *RandomWalk2Mobility* model is used as a mobility model. The Wi-Fi bandwidth is set to 24 Mbps, and the simulation time is 15 seconds.

Figure 5 shows the performance of CB-DMM and SMM models. We used two scenarios for the SMM model and compared the results with the CB-DMM model. The performance measurement is based on the interest satisfied ratio. At the start of simulation for the CB-DMM model, the interest satisfied ratio was 30 percent at 0.2 seconds, and the interest satisfied ratio reached 100 percent at 1 second. For the SMM model (scenario 1), the communication started at 1 second, and the interest satisfied ratio was 20 percent; whereas for scenario 2, the communication started at 2 seconds, and the interest satisfied ratio was 20 percent. The SMM scenario 1 reached 100 percent approximately in 2.2 seconds, and the SMM scenario 2 reached 100 percent in 4 seconds.

Table 1: Network parameters.

Parameters	Values
Number of nodes	11
Link capacity	100, 50, 10 Mbps
Link delay	1,10, 20 ms
Mobility model	*RandomWalk2Mobility*
Wi-Fi AP bandwidth	24 Mbps
Simulation time	15 seconds

At 7 seconds, in the CB-DMM and SMM model, the producer moves to another network. Both models use their handover procedures to locate the producer node. The CB-DMM model locates the producer in 0.2 seconds, whereas the SMM model scenario 1 takes 1 second, and the SMM scenario 2 takes 2 seconds.

In Figure 6, we reduce the link speed to 50 Mbps and increase the link delay to 10 ms, and then compare the CB-DMM model with the SMM scenarios. The CB-DMM model starts communication at 0.2 seconds, and the interest satisfied ratio is 20 percent. Compared to Figure 5, the interest satisfied ratio was less at 0.2 seconds. For SMM scenario 1, the communication started at 1 second, and the interest satisfied ratio was around 8 percent; whereas for scenario 2, the interest satisfied ratio was the same but the communication started at 2 seconds. The CB-DMM model reached 100 percent of the interest satisfied ratio at 0.8 seconds, while the SMM model reached 100 percent at 2 seconds and 3.6 seconds, respectively. When a handover happened again at 7 seconds,

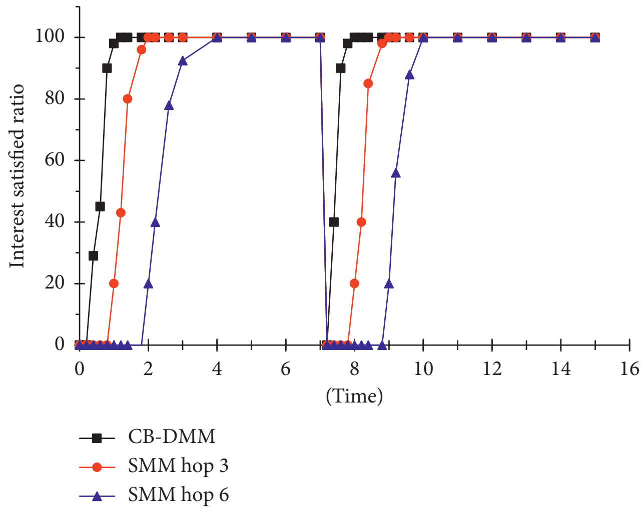

Figure 5: Comparison of CB-DMM and SMM (3 and 6 hops) with 100 Mbps and 1 ms.

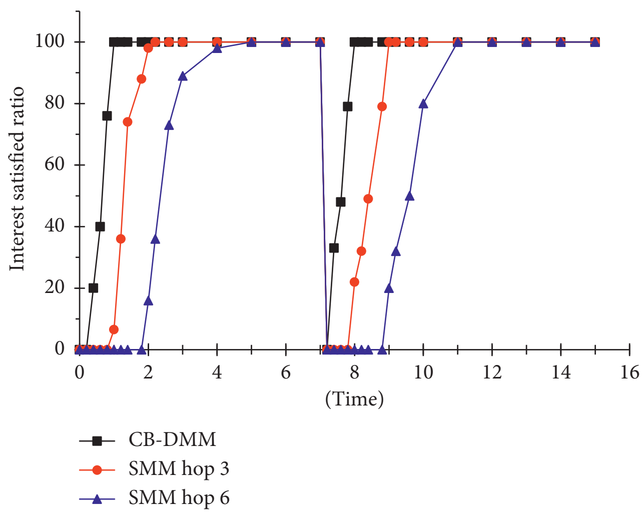

Figure 6: Comparison of CB-DMM and SMM (3 and 6 hops) with 50 Mbps and 10 ms.

both models went down to 0 percent. The CB-DMM model started communication again at around 7.2 seconds, while the SMM model started the communication at 8 seconds and 9 seconds, respectively.

In Figure 7, we reduce the link speed to 10 Mbps and increase the link delay to 20 ms, and then compare the CB-DMM model with both the SMM scenarios. Initially, the interest satisfied ratio for the CB-DMM model was around 10 percent; whereas for the SMM model scenario 1, the interest satisfied ratio was approximately 7 percent, and for scenario 2, the ratio was around 5 percent. In the CB-DMM model, the interest satisfied ratio was good, and after around 1 second, the ratio reached 100 percent; whereas for the SMM model, the interest satisfied ratio for scenario 1 reached 100 percent in 1.8 seconds, and for scenario 2, the ratio reached 100 percent in 4 seconds. When the producer changed the network, both models started searching for the producer node to get data contents. After around 7 seconds,

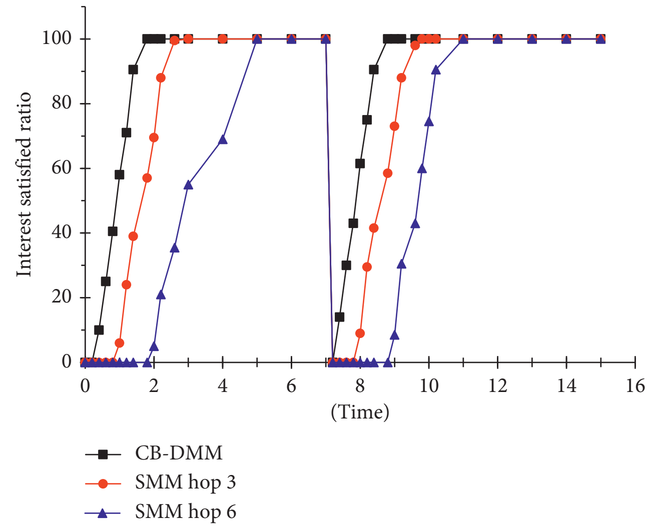

Figure 7: Comparison of CB-DMM and SMM (3 and 6 hops) with 10 Mbps and 20 ms.

the producer moved to another network. The CB-DMM model started communication again after 7.2 seconds, and the interest satisfied ratio was 12 percent. In the SMM model, for scenario 1, the communication started again in around 8 seconds, and for scenario 2 the producer started communication approximately in 9 seconds. After around 8 seconds, the CB-DMM model reached 100 percent, and in the SMM model, the first scenario reached 100 percent in approximately 8.4 seconds, while scenario 2 reached 100 percent after around 10.2 seconds. We can see that the CB-DMM model is better than the SMM Model in terms of the interest satisfied ratio and time.

6. Conclusions and Future Work

This paper proposes the solutions to locate the producer in the NDN network. In the proposed CB-DMM model, devices send their information to a cluster head after handover. The cluster head keeps that information for future use. We have compared our results with the existing SMM model. In the SMM model, the producer sends the new location information to the mapping system. Then, the mapping system sends the information to the previous access router to divert the interest packets toward the new access router. In our solution, we send the device information to the cluster head, and the cluster head is responsible for diverting the interest packets toward the new access router. There is no need to tell the previous access router to divert the interest packets.

The proposed scheme provides better performance than the existing SMM model in terms of diversion of interest packets toward producer and the interest satisfied ratio. The diversion of interest packets toward producer is quicker in our proposed model, compared with the existing scheme. The interest packet satisfied ratio is also good in our proposed scheme.

The future work will be made to reduce the overhead of the cluster head in the network and to use the cluster head for other purposes, which can solve the network query very quickly. We also plan to move the producer into different cluster heads in the network.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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References

[1] S. Gao and H. Zhang, "Scalable mobility management for content sources in Named Data Networking," in *Proceedings of IEEE Annual Consumer Communications and Networking Conference (CCNC)*, Las Vegas, NV, USA, January 2016.

[2] M. F. Majeed, S. Ahmed, S. Muhammad, H. Song, and D. B. Rawat, "Multimedia streaming in information-centric networking: a survey and future perspectives," *Computer Networks*, vol. 125, pp. 103–121, 2017.

[3] S. Isa and P. Kadam, "Named data networking in VANET: a survey," *International Journal of Scientific Engineering and Science*, vol. 1, no. 11, pp. 45–49, 2017.

[4] X. Jiang, J. Bi, and Y. Wang, "What benefits does NDN have in supporting mobility," in *Proceedings of IEEE Symposium on Computers and Communication (ISCC)*, Messina, Italy, June 2014.

[5] X. Jiang, J. Bi, Y. Wang, P. Lin, and Z. Li, "A content provider mobility solution of named data networking," in *Proceedings of IEEE International Conference on Network Protocols (ICNP)*, Austin, TX, USA, October 2012.

[6] S. Ahmed, D. Mu, and D. Kim, "Improving bivious relay selection in vehicular delay tolerant networks," *IEEE Transactions on Intelligent Transportation Systems*, vol. 19, no. 3, pp. 987–995, 2018.

[7] S. H. Bouk, S. Ahmed, D. Kim, K. J. Park, Y. Eun, and J. Lloret, "LAPEL: hop limit based adaptive PIT entry lifetime for vehicular named data networks," *IEEE Transactions on Vehicular Technology*, vol. 67, no. 7, pp. 5546–5557, 2018.

[8] S. Ahmed, S. Hussain Bouk, M. A. Yaqub, D. Kim, and H. Song, "DIFS: distributed interest forwarder selection in vehicular named data networks," *IEEE Transactions on Intelligent Transportation Systems*, 2018.

[9] IETF RFC 6275, *Mobile IPv6*, IETF, Fremont, CA, USA, 2011.

[10] IETF RFC 5380, *Hierarchal Mobile IPv6*, IETF, Fremont, CA, USA, 2008.

[11] J. Su, X. Tan, Z. Zhao, and P. Yan, "MDP-based forwarding in named data networking," in *Proceedings of Chinese Control Conference (CCC)*, Chengdu, China, July 2016.

[12] Y. Zhang, H. Zhang, and L. Zhang, "Kite: a mobility support scheme for ndn," in *Proceedings of International Conference on Information-Centric Networking*, Paris, France, September 2014.

[13] D. Kim and Y. Ko, "On-demand anchor-based mobility support method for named data networking," in *Proceedings of International Conference on Advanced Communication Technology (ICACT)*, Pyeongchang, Republic of Korea, 2017.

[14] A. Aytac, R. Ravindran, and G. Wang, "Mobility study for named data networking in wireless access networks," in *Proceedings of IEEE International Conference on Communications (ICC)*, Sydney, Australia, June 2014.

[15] M. Lehmann, M. Barcellos, and A. U. Mauthe, "Providing producer mobility support in NDN through proactive data replication," in *Proceedings of Conference on Network Operations and Management Symposium (NOMS)*, Istanbul, Turkey, April 2016.

[16] R. Ravishankar, S. Lo, X. Zhang, and G. Wang, "Supporting seamless mobility in named data networking," in *Proceedings of IEEE International Conference on Communications (ICC)*, Ottawa, ON, Canada, June 2012.

[17] F. Hesham and H. Hassanein, "Optimal caching for producer mobility support in named data networks," in *Proceedings of IEEE International Conference on Communications (ICC)*, Kuala Lumpur, Malaysia, May 2016.

[18] Z. Liu, Y. Wu, E. Yuepeng, J. Ge, and T. Li, "Experimental evaluation of consumer mobility on named data networking," in *Proceedings of International Conference on Ubiquitous and Future Networks (ICUFN)*, Shanghai, China, July 2014.

[19] S. Muhammad, "Cluster-based mobility support in content-centric networking," *Research Notes in Information Science (RNIS)*, vol. 14, pp. 441–444, 2013.

[20] A. Alexander, I. Moiseenko, and L. Zhang, "ndnSIM: NDN simulator for NS-3," Technical Report, University of California, San Francisco, CA, USA, 2012.