Producer Mobility Support in 5G-ICN

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***Abstract*— Information centric networking (ICN) provides content efficiently by using name-based routing and content caching. Producers generate contents and consumers request contents by sending *Interest* messages. Then, either producers or content caching nodes return *Data* to consumers. In ICN, it is not easy to support producer mobility, since *Interest* packets are not successfully delivered to a producer, if the producer changes its point of attachment (PoA). Flooding, anchor, and pointer forwarding-based producer mobility support schemes have been proposed in ICN. Producer mobility support is an important issue in 5G, too, and procedures for flooding-based producer mobility support in ICN enabled 5G (5G-ICN) have been proposed recently. In this paper, we present procedures for anchor and pointer forwarding-based producer mobility support schemes in 5G-ICN. Finally, we compare flooding, anchor, and pointer forwarding-based producer mobility support schemes qualitatively in 5G-ICN.**

Keywords—5G, ICN, producer mobility

I. Introduction

Information-centric networking (ICN) provides content efficiently by using name based-routing and content caching. Pending interest table (PIT), forwarding information base (FIB) and content store (CS) are three main components of ICN [1],[2]. Producers generate contents *Data* and consumers request contents by sending *Interest* messages. Then, either producers or content caching nodes return *Data* to consumers. In ICN, consumer mobility is easily supported by retransmitting *Interest* packets additionally after changing its point of attachment (PoA). However, producer mobility still remains a problem because *Interest* packets are not successfully delivered to a producer, if the producer changes its PoA[2]. Several works have been proposed to support producer mobility in ICN[3]-[5], and they can be classified as flooding, anchor, and pointer forwarding-based producer mobility support schemes.

In flooding-based mobility support scheme[3], FIB update packets are broadcasted to all ICN routers, if producer changes its PoA. MapMe[3] can be classified as flooding-based mobility support scheme. In anchor-based mobility support scheme[4], there is an anchor router for a producer and a producer updates its PoA at the anchor router. Then, *Interest* packets are delivered to the anchor router firstly and are redirected to the current PoA of a producer for the requested content. KITE[4] can be classified as anchor-based mobility support scheme. In pointer forwarding-based mobility support scheme[5], there is an anchor router for a producer, similarly to anchor-based mobility support scheme, but a producer updates its PoA only to its previous PoA, not to anchor, differently from anchor-based mobility support scheme. Therefore, there is a chain of pointers between routers from an anchor router to the current PoA. PMC[5] can be classified as pointer forwarding-based mobility support scheme.

In flooding, anchor, and pointer forwarding-based mobility support schemes, there is a trade-off, depending on the ratio of *Interest* arrival rate to a producer and mobility of a producer, i.e., *Interest* to mobility ratio (IMR)[6]. Flooding-based mobility support scheme has smaller *Data* forwarding path overhead but higher FIB update overhead. Thus, if IMR is high, flooding-based mobility support scheme is better. On the other hand, if IMR is low, pointer forwarding-based mobility support scheme is better, since it has smaller FIB update overhead and higher *Data* forwarding path overhead.

Recently, works on 5G networks interworked with ICN are actively carried out. In ITU-T study group (SG) 13, network functions (NFs) for ICN are designed for edge network[7]. In Internet research task force (IRTF) ICN research group (ICNRG), a 5G architecture accommodating ICN is proposed by extending existing NFs and newly defining NFs in 5G core networks[8]. In [9], the authors proposed procedures of content name registration, ICN protocol data unit (PDU) session establishment, and *Interest*/*Data* packet forwarding in 5G core network architecture by adopting the architecture proposed in [8].

Recently, procedure for supporting producer mobility in ICN enable 5G (5G-ICN) has been proposed[10], where user plane functions (UPFs) in the user plane are deployed to establish ICN PDU session when a producer attaches at a radio access network (RAN). Then, new UPFs are deployed after producer mobility. This approach is similar to flooding-based producer mobility scheme, since new forwarding paths are replacing previous forwarding paths after producer mobility.

In this paper, we present procedures for anchor and pointer forwarding-based mobility support schemes in 5G-ICN, by following a similar approach with the work in [10]. Then, we compare the flooding, anchor, and pointer forwarding-based producer mobility support schemes qualitatively in 5G-ICN.

In Section II, a considered 5G-ICN network architecture is described, and procedures for anchor and pointer forwarding-based producer mobility support schemes in 5G-ICN are presented. Then, these schemes are compared qualitatively with flooding-based producer mobility scheme. Summary and future works are presented in Section III.

II. Producers for Producer Mobility Support Schemes

In this section, we firstly show a considered 5G-ICN architecture. Then, we revisit the procedures of flooding-based producer mobility support scheme[10] in 5G-ICN for conveniently describing anchor and pointer forwarding-based producer mobility support schemes, where they have common procedures with flooding-based mobility support scheme. Then, we present procedures for anchor and pointer forwarding-based producer mobility support schemes in 5GC-ICN based on 3GPP architecture [11] and procedure [12].

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Figure 1 shows a considered 5G-ICN architecture, which is similar to the one in [10], where 5G is interworked with ICN data network (DN). An ICN enabled mobile producer is connected to 5G radio access network (RAN) and provides ICN content service through ICN PDU session. Access and mobility management function++ (AMF++) is an extension of AMF and manages the mobility of producers. Session management function++ (SMF++) is an extension of SMF and manages ICN PDU sessions and interacts with UPF to connect ICN PDU sessions to ICN DN. ICN SMF manages the UPF PDU session anchor (PSA) in the control plane of the 5G-ICN and manages information related with creating, modifying, and deleting ICN PDU sessions of the UPF (PSA). UPF uplink classifier (UL-CL) is connected both to the RAN and ICN gateway (GW) in the user plane and delivers traffic to an appropriate path. UPF (PSA) is co-located with the ICN gateway (GW) and it is the endpoint of the ICN PDU session.

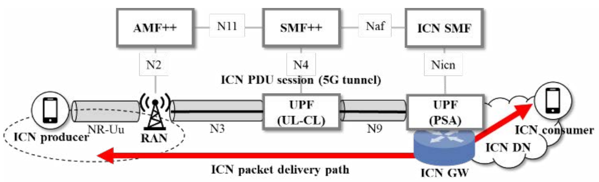

Fig. 1. A considered 5G-ICN architecture for supporting producer mobility.

A. *Flooding-based Producer Mobility Support Scheme*

Figure 2 shows the procedure of flooding-based producer mobility scheme in [10] and it is described here in detail to easily describe the procedures of anchor and pointer forwarding-based mobility support schemes and also show the difference between three producer mobility support schemes clearly for readers. In [10], it is assumed that there is no Xn interface between 5G RANs.

When the producer handovers from RAN-1 to RAN-2, the procedures of the flooding-based producer mobility support scheme are as follow: (1) The ICN producer transmits a *handover request message* containing RAN-2 information and ICN PDU session information of the target of handover to RAN-2. (2) RAN-1 transmits a *handover request message* containing ICN PDU session information and RAN-2 information to AMF++. (3) AMF+++ transmits a *handover request message* containing producer information and RAN-2 information to SMF++. SMF++ identifies the UPF (UL-CL-2) and UPF (PSA-2) connected to the RAN-2 as user plane candidates for the ICN PDU session. (4) SMF++ transmits a *control message* containing PDU session information to UPF (UL-CL-2) for forwarding the uplink (UL) traffic of the ICN PDU session from UPF (UL-CL-2) to UPF (PSA-2) and the downlink (DL) flow from UPF (UL-CL-2) to RAN-2. (5) SMF++ transmits a *control message* containing UPF (UL-CL-2) information to the ICN SMF for the provisioning of ICN PDU session tunnel between UPF (UL-CL-2) and UPF (PSA-2). (6) ICN SMF transmits a *control message* containing UPF (UL-CL-2) information to UPF (PSA-2) for switching ICN traffic. (7) ICN SMF transmits a *control message* containing UPF (PSA-2) information to UPF (PSA-1) so that *Interest* packets can be delivered to UPF (PSA-2). (8) ICN SMF acknowledges SMF++ for the mobility update success. Then SMF++ acknowledges AMF++ for the mobility update success and information for connecting between RAN-2 and UPF (UL-CL-2). (9) AMF++ transmits a *control message* containing ICN PDU session information and UPF (UL-CL-2) information to RAN-2 for the producer's ICN PDU session tunnel from RAN-2 to UPF (UL-CL-2). (10) AMF++ transmits a *handover response message* to the producer and authorizes the handover to RAN-2. (11) The producer transmits a *handover confirmation message* to RAN-2, and at this time, ICN PDU session consisting of RAN-2, UPF (UL-CL-2) and UPF (PSA-2) is established as a new path handling UL-DL traffic between the producer and ICN DN. (12) RAN-2 acknowledges AMF++ for the connection success with the producer, and then AMF++ transmits a *control message* to RAN-1 to remove the allocated resources of the previous ICN PDU session. RAN-1 removes the tunnel state about UPF (UL-CL-1). (13) AMF++ acknowledges SMF++ for handover success, and then SMF++ transmits a *control message* to UPF (UL-CL-1) to remove the allocated resources of the previous ICN PDU session. UPF (UL-CL-1) removes the tunnel state. (14) SMF++ transmits a *control message* to remove the allocated resources of the previous ICN PDU session to UPF (PSA-1) through ICN SMF. UPF (PSA-1) removes the ICN PDU session state. Finally, *Interest* can be delivered to UPF (PSA-2) after updating name resolution server (NRS) through ICN SMF.

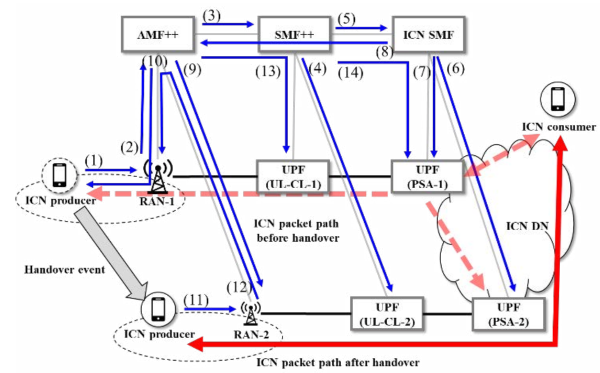

Fig. 2. Flooding-based producer mobility support scheme in 5G-ICN.

B. *Anchor-Based Producer Mobility Support Scheme*

Figure 3 shows the procedure of anchor-based producer mobility support scheme, where UPF (PSA-anchor) is used as the endpoint of the ICN PDU session instead of new UPF (PSA), as shown in Fig. 2. The UPF (PSA-anchor) can be deployed when the initial ICN PDU session is established. We used the concept of re-allocation of intermediate UPF method, as described in [12], where it is defined in Xn-based handoff procedure.

When the producer handovers from RAN-1 to RAN-2, the procedures of the anchor-based producer mobility scheme are as follow: (1), (2) Handover request procedures are the same with the procedures (1), (2) of Fig. 2. (3) SMF++, which receives the *handover request message* containing producer and RAN-2 information, identifies UPF (UL-CL-2) and UPF (PSA-anchor) as user plane candidates for the ICN PDU session. (4) SMF++ transmits a *control message* containing PDU session information to UPF (UL-CL-2) for forwarding the UL traffic of the ICN PDU session from UPF (UL-CL-2) to UPF (PSA-anchor) and the DL flow from UPF (UL-CL-2) to RAN-2. (5) SMF++ transmits a *control message* containing UPF (UL-CL-2) information to the ICN SMF for the provisioning of ICN PDU session tunnel between UPF (UL-CL-2) and UPF (PSA-anchor). (6) ICN SMF transmits a *control message* containing UPF (UL-CL-2) information to UPF (PSA-anchor) so that *Interest* packets can be delivered to UPF (UL-CL-2) through UPF (PSA-anchor) by adding ICN traffic tunnel. (7)~(13) The procedures (7)~(13) are the same with the procedures (8)~(14) of Fig. 2, except that ICN PDU session consisting of RAN-2, UPF (UL-CL-2), and UPF (PSA-anchor) is established as a new path for handling UL-DL traffic between the producer and ICN DN in (10) and UPF (PSA-anchor) removes the previous ICN PDU session state in (13).

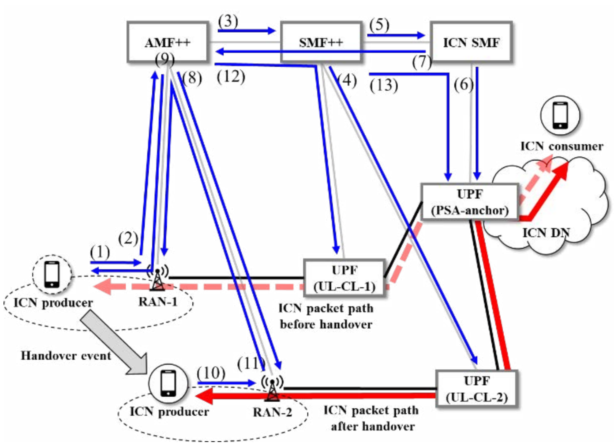

Fig. 3. Anchor-based producer mobility suppot scheme in 5G-ICN.

C. *Pointer Forwarding-Based Producer Mobility Support Scheme*

Figure 4 shows the procedure of pointer forwarding-based producer mobility support scheme, where UPF (PSA-anchor) is used as the endpoint of the ICN PDU session instead of new UPF (PSA), similar to Fig. 3. Different from Fig. 3, however, UPF (UL-CL-anchor) is used as the intermediate UPF in the ICN PDU session. The UPF (PSA-anchor) and the UPF (UL-CL-anchor) can be a UPF (PSA) and a UPF (UL-CL) deployed when the initial ICN PDU session is established. We used the concept of insertion of intermediate UPF method, as described in [12], where it is defined in Xn-based handoff procedure.

When the producer handovers from RAN-1 to RAN-2, the procedures of the pointer forwarding-based producer mobility scheme are as follow: (1), (2) When the producer requests handover, handover request procedures are the same with the procedures (1)~(2) of Fig. 2. (3) SMF++, which receives the *handover request message* containing producer and RAN-2 information, identifies UPF (UL-CL-2), UPF (UL-CL1), and UPF (PSA-anchor) as user plane candidates for the ICN PDU session. (4) SMF++ transmits a *control message* containing PDU session information to UPF (UL-CL-2) for the purpose of switching the UL traffic of the ICN PDU session from UPF (UL-CL-2) to UPF (UL-CL-1) and the DL flow from UPF (UL-CL-2) to RAN-2. (5) SMF++ transmits a *control message* containing UPF (UL-CL-2) information to UPF (UL-CL-1) for switching the DL flow from UPF (UL-CL-1) to UPF (UL-CL-2). (6) SMF++ acknowledges AMF++ for the mobility update success and information for connecting between RAN-2 and UPF (UL-CL-2). (7)~(11) The procedures of (7)~(11) are the same with the procedures (9)~(13) of Fig. 2, except that ICN PDU session consisting of RAN-2, UPF (UL-CL-2), UPF (UL-CL-1), UPF (UL-CL-anchor), and UPF (PSA-anchor) is established as a new path for handling UL-DL traffic between the producer and ICN DN in (9), and UPF (UL-CL-1) removes the previous ICN PDU session state in (11).

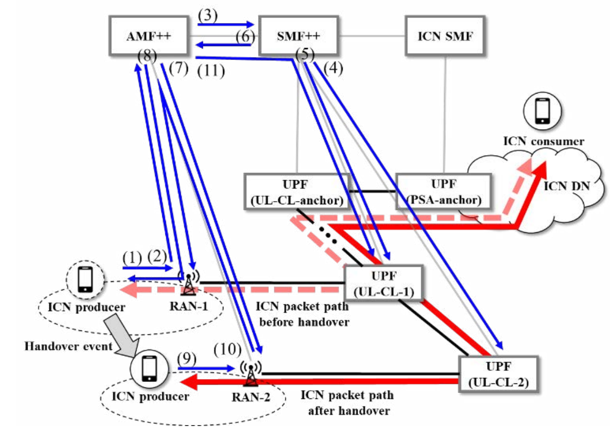

Fig. 4. Pointer forwarding-based producer mobility support scheme in 5G-ICN.

D. *Comparison of Producer Mobility Support Schemes*

Table 1 shows comparison of producer mobility support schemes. In this paper, we compare these schemes, from the aspect of NF usage (CP), NF usage (UP), deployment cost, convergence time, update cost, and delivery cost. NF usage (CP) and NF usage (UP) are defined as the overhead of control plane NFs and user plane NFs, respectively. Deployment cost is defined as the overhead of creation/removal of UPFs due to the producer mobility. Convergence time is defined as the delay until new connection between new RAN and ICN DN is created and thus, Interests can be successfully delivered via new path after producer handover. Update cost is defined as the overhead of control procedures to support producer mobility. Delivery cost is defined as the overhead of ICN packet delivery from ICN consumer to ICN producer.

The flooding-based scheme and the anchor-based scheme use AMF++, SMF++, and ICN SMF. However, pointer forwarding-based scheme does not use ICN SMF and thus, is the most efficient, from the aspect of NF usage in control plane. The flooding-based scheme and anchor scheme are more efficient than the pointer forwarding-based scheme, from the aspect of NF usage in user plane. When a producer handovers, the flooding-based scheme removes two UPFs and deploys two new UPFs. Anchor-based scheme removes one UPF and deploys one new UPF. Pointer forwarding-based scheme deploys one UPF additionally, without removing any UPF. So pointer forwarding-based scheme is the most efficient and the flooding-based scheme is the most inefficient, from the aspect of deployment cost. Anchor-based scheme has simpler procedure than the flooding-based scheme, so the anchor-based scheme is more efficient than the flooding-based scheme, from the aspect of convergence time and update cost. The pointer forwarding-based scheme uses AMF++ and SMF++ on the control plane and the procedure of the scheme is simpler than the other two schemes, so it is the most efficient, from the aspect convergence time and update cost. The flooding-based scheme uses UPF (UL-CL) and UPF (PSA) on the user plane to deliver ICN packets via appropriate path. The pointer forwarding scheme uses UPF (UL-CL) and UPF (PSA) in the user plane, and UPF (UL-CL) is added depending on the mobility of the producer. Therefore, flooding-based scheme has the lowest delivery cost and pointer forwarding scheme has the highest delivery cost.

Table. 1. Comparison of producer mobility support schemes

	Flooding-based scheme	Anchor -based scheme	Pointer forwarding-based scheme
NF usage (CP)	High	High	Low
NF usage (UP)	Low	Low	High
Deployment cost	High	Medium	Low
Convergence time	High	Medium	Low
Update cost	High	Medium	Low
Delivery cost	Low	Medium	High

III. SUMMURY AND FUTURE WORKS

Producer mobility support is an important issue in 5G-ICN. In this paper, we presented procedures for anchor and pointer forwarding-based producer mobility support schemes in 5G-ICN. Then, we compare flooding, anchor, and pointer forwarding-based producer mobility support schemes qualitatively in 5G-ICN. This work can be used as a guideline for selecting appropriate producer mobility support scheme in 5G-ICN. In our future work, we plan to implement and verify the presented procedures in a 5G-ICN open source testbed and also propose an adaptive producer mobility support scheme by selecting appropriate producer mobility support scheme, depending on the IMR.

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