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Control and data plane separation architecture for supporting multicast listeners over distributed mobility management

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Abstract

Distributed mobility management (DMM) is currently being researched and standardized in academia and standardization development organizations for the purpose of overcoming the major issues of existing centralized mobility management. The most recent DMM protocols are being redesigned with regard to the control and data plane separation concept. However, at present, there is no solution for supporting IP multicast listeners in such new DMM environments. In this paper, we review ongoing academic research works, standardization activities and propose an IP multicast mobility design for the DMM environment using the control and data plane concept.

Keywords: Control and data plane separation; Distributed mobility management; IP multicast; PMIPv6; SDN

1. Introduction

Centralized mobility management (CMM) protocols exhibit certain major issues, such as a single point of failure, non-optimal routing, and scalability [1], which result from the nature of current hierarchical mobile network architecture. Therefore, distributed mobility management (DMM) is currently being studied and standardized in both academia and standardization development organizations (SDOs) in order to overcome these issues. In academia, the most commonly proposed DMM protocols are based on the traditional Proxy Mobile IPv6 (PMIPv6) [2,3] and the software-defined networking (SDN) concept [4,5].

IP multicast is used to provide efficient live streaming content distribution over IP-based networks. IP multicast mobility (MULMOB) management protocols offer subscribers seamless handover and the ability to keep receiving subscribed multicast traffic with low latency. Thus far, some base solutions have been standardized by the Internet Engineering Task Force (IETF) for the CMM environment [6,7] but not yet the DMM environment. In terms of DMM, several multicast mobility schemes [8–11] have been proposed in academia.

Currently, control and data plane separation is considered as a key factor in designing 5G networks. With this concept, control plane functions can be deployed as software on a cloud platform to facilitate the elastic scaling of control functions as signaling traffic increases. Furthermore, the data plane functions can be deployed on the high speed and simplified hardware networking devices, optimized for packet-forwarding tasks. Separation of the data and control planes also enables the efficient use of a common data plane and eases service provisioning by using the management and orchestration (MANO) framework of network function virtualization (NFV). This concept is not limited to SDN, with all functions placed on a centralized controller, but involves the separation of the control and data planes in both the horizontal and vertical axes. Control and data plane functions are designed as deployable and modular components. In the IETF DMM working group [12], this concept is being used to redesign the DMM protocols. Four major working items are currently being discussed, namely the

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mobility anchor function [13], forwarding policy configuration (FPC) [14], deployment models [15], and on-demand mobility [16].

However, to the best of our knowledge, the current IETF works are restricted to unicast traffic, and multicast mobility management is still lacking in such control and data plane separation environments. Apart from our previous work, an initial idea [17] was introduced; however, this study did not include detailed architecture of the integration and protocol operation. In this paper, we review state-of-the-art research works and current standardization activities in the DMM working group and present architecture to support DMM for multicast traffic. In addition, we provide a solution for integrating our newly defined multicast mobility architecture into the current unicast DMM, including detailed protocol operation.

The remainder of this paper is organized as follows. Section 2 presents state-of-the-art and ongoing standardization of DMM and multicast mobility. Our control-data plane separation architecture for multicast mobility and protocol operations are introduced in Section 3. Section 4 discusses our qualitative evaluation, and a discussion and conclusion are provided in Section 5.

2. Related works

2.1. Distributed mobility management

(1) State-of-the-art academic research

The existing proposals for DMM rely on two major approaches: one based on traditional CMM protocols, such as PMIPv6 or MIPv6; and the other based on the SDN concept. In the first approach [2,3], the mobility management functions of the traditional PMIPv6 protocol are reused and distributed into mobility access routers (MARs) close to access networks. The second approach [4,5] applies the advantages of the SDN concept to handle mobile node mobility. In this approach, the mobility management functions are deployed on top of the SDN controller and forwarding paths are established using the controller's routing module.

(2) Standardization activities in IETF

In the IETF DMM working group, the current focus is on four major working documents, namely those of the mobility anchor function [13], forwarding path configuration [14], deployment models [15], and on-demand mobility [16]. The mobility anchor document defines the functionalities and protocol solutions for a mobility anchor and anchor switching. The deployment model document covers several possible deployment options for control and data plane functions of both the mobility anchor and access nodes. The forwarding path configuration document describes southbound protocol used by a control node to configure one or more data plane nodes. The on-demand mobility document enables the mobile nodes' capabilities to select an appropriate IP address type for their desired mobility services.

2.2. IP multicast mobility from CMM to DMM

The solutions that support IP multicast listeners in centralized mobility management are presented in [6,7]. These solutions leverage the deployment of multicast listener discovery (MLD) proxies in mobile access gateways (MAGs). The MLD proxies are responsible for collecting mobile nodes' multicast subscription and reporting to the local mobility anchor (LMA). A base solution for multicast mobility in PMIPv6 is presented in [6], while [7] provides a routing optimization solution. Furthermore, solutions for IP multicast in the DMM environment are described in [8–11]. In [8], four use cases, which combine two DMM architectures (that is, partially DMM and fully DMM) and two approaches to multicast subscription notification (that is, proactive and reactive), are analyzed. In [9], the direct routing approach for multicast traffic without a tunnel is investigated. In [10], three mobility multicast modes are analyzed, and an algorithm proposed for selecting one of the three modes based on operator requirements and user profiles. In [11], certain contexts, such as the service's characteristics, node mobility, and network context, are considered in the selection of a mobility multicast solution.

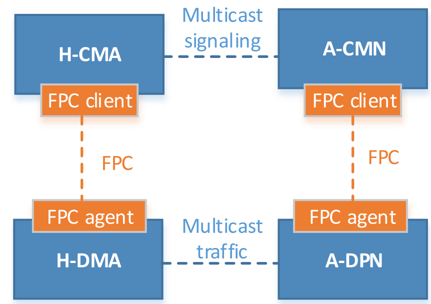

Fig. 1. Control and data plane separation architecture for IP multicast functions over DMM.

3. Proposed architecture

3.1. Control and data plane separation architecture for IP multicast listeners over DMM

In order to enable a mobile node to receive seamless multicast traffic during handover, we introduce three additional multicast functions: the home-control plane multicast anchor (H-CMA), home-data plane multicast anchor (H-DMA), and access-control plane multicast node (A-CMN). The proposed architecture is depicted in Fig. 1.

H-CMA: This function manages the life cycle of the mobile node's multicast sessions. A mobile node can participate in one or more multicast sessions, and these sessions can be anchored on the same H-DMA or different H-DMAs. The H-CMA interfaces with the H-DMA to manage the forwarding state.

H-DMA: This function is a topological anchor for multicast traffic moving towards the mobile node's subscribed multicast IP addresses or network prefixes. The H-DMA is responsible for receiving all multicast traffic heading towards the mobile node, and is selected by an H-CMA on a session basis. The H-DMA supports basic data plane functions, such as tunneling, routing, and quality of service (QoS) treatment.

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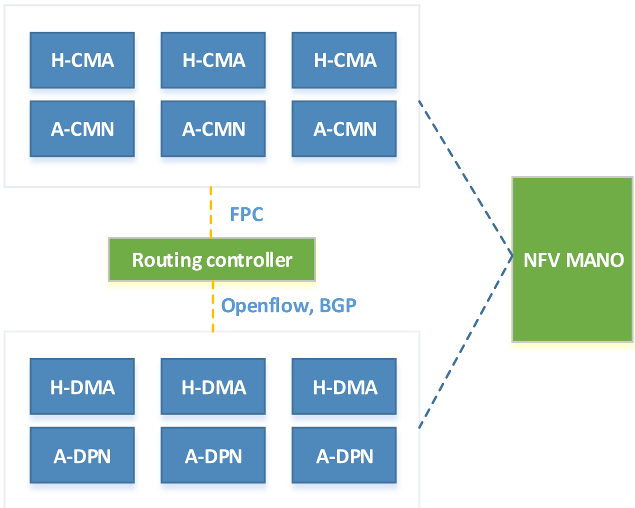

Fig. 2. Deployment model for distributed multicast mobility functions using SDN and NFV.

A-CMN: This function has a protocol interface with the A-DPN [8] and H-CMA. The A-CMN is responsible for selecting the H-CMA, based on the mobile nodes' attachment preferences or the access and subscription policy.

A-DPN: This data plane function, introduced in [8], supports the basic service primitives of a data plane node, such as tunneling, routing, and QoS treatment. This data plane node is selected and configured by the A-CPN to receive multicast traffic from the H-DMA. The mapping of the above multicast functions to the basic service primitives is displayed in Table 1.

We assume that the control plane functions (H-CMA and A-CMN) can interact with and configure the data plane functions (H-DMA and A-DPN) for establishing forwarding states, using the forwarding policy configuration (FPC) protocol [7]. In order to enable data plane configuration, the control plane functions are required to support the FPC client, while the data plane functions are required to support the FPC agent. The FPC agent receives the semantic commands from the FPC client, and the data plane node is configured using local configuration commands specific to data plane technologies.

Our proposed functional architecture can be deployed using several models, similarly to the five DMM function deployment models in [8]. We simply present the most general and flexible deployment model using the SDN and NFV framework, as illustrated in Fig. 2. The control and data plane functions described previously can be instantiated and managed by the NFV MANO framework. The routing controller abstracts the data plane to the control plane; therefore, the control plane functions can configure multiple data plane nodes with different technologies.

3.2. Architecture for integrating IP multicast into DMM

In order to integrate the proposed multicast architecture into the current DMM, we introduce a new control plane entity, known as the control selection function (CSF). The CSF enables the selection of control plane functions based on mobile nodes preferences, subscription policies, or operator policies. When a mobile node attaches to a new access network, this attachment is detected by the CSF. The CSF then contacts the home subscriber servers (HSSs) to retrieve the mobile node subscription information (or user profile), and determines which control plane functions will process the attachment request. The CSF enables the mobility and multicast services to be provided on demand, based on the subscription information and various mobile operator use cases. The integration architecture is depicted in Fig. 3, in which it can be seen that if both multicast and unicast mobility services are enabled, the CSF forwards the attachment request to both the A-CMN and A-CPN.

3.3. Handover protocol operation for IP multicast over control-data plane separation DMM architecture

Fig. 4 shows a protocol operation for enabling the mobile node to receive the multicast stream seamlessly during handover between two edge nodes. Firstly, when the mobile node attaches to node 1, the attachment request is routed to CSF1. Then, CSF1 communicates with the HSS for authentication and authorization (for the sake of simplicity, we do not show this step in Fig. 4). CSF1 relies on the HSS user profile to determine which services should be provided to the mobile node. If the mobile node's multicast mobility service is enabled, the attachment request is forwarded to the appropriate control plane functions. In this case, the attachment request is forwarded to A-CMN1, which is responsible for processing multicast mobility signaling. There are several means by which control function A-CMN1 can collect the multicast subscription information list from the mobile node. The A-CMN1 can obtain this list by querying the multicast subscription from the mobile node, or from the previous control function A-CMN. After receiving the multicast subscription list, the A-CMN1 reports it to the control function H-CMA. The H-CMA then selects an appropriate data plane node (H-DMA), which serves as an anchor for the mobile node's multicast traffic. The H-CMA uses the FPC protocol to configure the H-DMA. The H-CMA creates a new context and adds the following properties: tunnel type, tunnel endpoint in each direction, QoS values for the mobile node's multicast traffic, and multicast IP addresses subscribed to by the mobile node. The H-CMA sends this new context to the H-DMA by means of the CONFIG (CREATE) command. In this case, after receiving the command, the FPC agent on the H-DMA configures the H-DMA using local configuration commands to enable a tunnel to forward all multicast traffic destined for the mobile node. When the mobile node conducts a handover, a similar attachment process occurs. The CSF2 selects the A-CMN2 to process the attachment request. The A-CMN2 sends the mobile node's multicast subscription list to the H-CMA. Because the context for the mobile node already exists in this case, the H-CMA configures the new endpoint for the multicast traffic tunnel on the H-DMA by means of CONFIG (MODIFY). The new endpoint value is set to the currently attached edge node, A-DPN2. From this point onwards, the multicast traffic is tunneled to the new data plane edge node A-DPN2, which is the attachment point of the mobile node.

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Table 1
Mapping of multicast mobility functions.

Service primitives	H-CMA	H-DMA	A-CMN	A-DPN
Multicast IP anchoring		X		
Multicast subscription management	X			
Multicast subscription report	X		X	
Multicast subscription query			X	
MN detection			X	
Routing		X		X
Tunneling		X		X
QoS enforcement		X		X
FPC client	X		X	
FPC agent		X		X

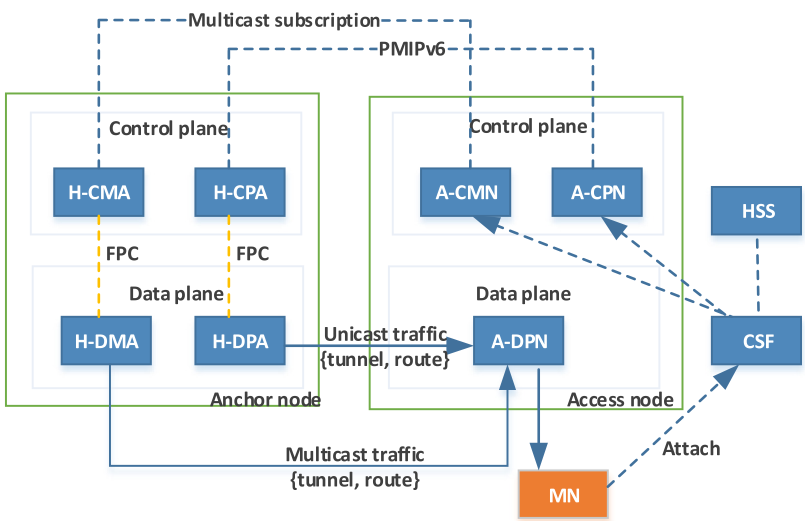

Fig. 3. Architecture for integrating mobility and multicast.

4. Qualitative evaluation

Table 2 displays a qualitative evaluation of different approaches to multicast mobility. We compare five methods: multicast mobility support over PMIPv6-based DMM (MUL_PMIP_DMM), multicast support over SDN-based DMM (MUL_SDN_DMM), our approach (MUL_CPDP_DMM), multicast support over centralized mobility management (MUL_CMM), and no multicast mobility support (NOMUL_DMM). We observe that the NOMUL_DMM handover latency is the highest, due to the long duration of rejoining the multicast tree whenever the mobile node attaches to a new point. The MUL_PMIP_DMM exhibits the lowest handover latency, due to signaling messages only being exchanged in access networks. The MUL_SDN_DMM and MUL_CMM both exhibit high latency, due to signaling messages occurring between the core and access networks. Our approach displays a fair amount of handover latency, because signaling occurs between the control and data plane functions and only within access networks. In terms of the routing path, the MUL_CMM exhibits a triangle routing problem, because the packets must traverse through a central mobility anchor. However, the NOMUL_DMM displays optimal routing, because the packets move directly to the current mobile node attachment point. The other methods achieve near-optimal routing, due to the old multicast sessions being routed in a triangle; however, the new multicast sessions have an optimal routing path. The MUL_SDN_DMM and MUL_CMM approaches have the same single point of failure issue, due to the single point for processing control signaling or data packets. In MUL_CMM, only one anchor exists for signaling and data traffic. In MUL_SDN_DMM, multiple anchors exist for data traffic, but signaling must still need to go to SDN controller. Our approach and two others (MUL_PMIP_DMM and NOMUL_DMM) include multiple anchors for both signaling and data traffic. The Our method, which is based on the separation of the control and data planes in both axes, is more scalable than other approaches that combine data and control or simply decouple control and data in one axis. Our approach makes use of a mobility-specific configuration protocol (FPC) and can be deployed with a routing controller to support different data plane technologies, as illustrated in Fig. 2.

5. Discussion and conclusion

Following the standardization of DMM protocols for unicast traffic, it is expected that solutions for IP multicast mobility will be standardized. Therefore, in this paper, we have presented a

Table 2
Qualitative evaluation.

Approach	MUL_ PMIP_ DMM	MUL_ SDN_ DMM	MUL_ CPDP_ DMM	MUL_ CMM	NO MUL_ DMM
Handover latency	Low	High	Fair	High	Very high
Routing path	Nearly optimal routing	Nearly optimal routing	Nearly optimal routing	Triangle routing	Optimal routing
Single point of failure	No	Yes	No	Yes	No
Signaling traffic anchor	One or multiple	One	Multiple	One	Multiple
Data traffic anchor	Multiple	Multiple	Multiple	One	Multiple
Scalability	Low	Fair	High	Low	Low
Different data plane technology	Not support	Not support	Support	Not support	Not support

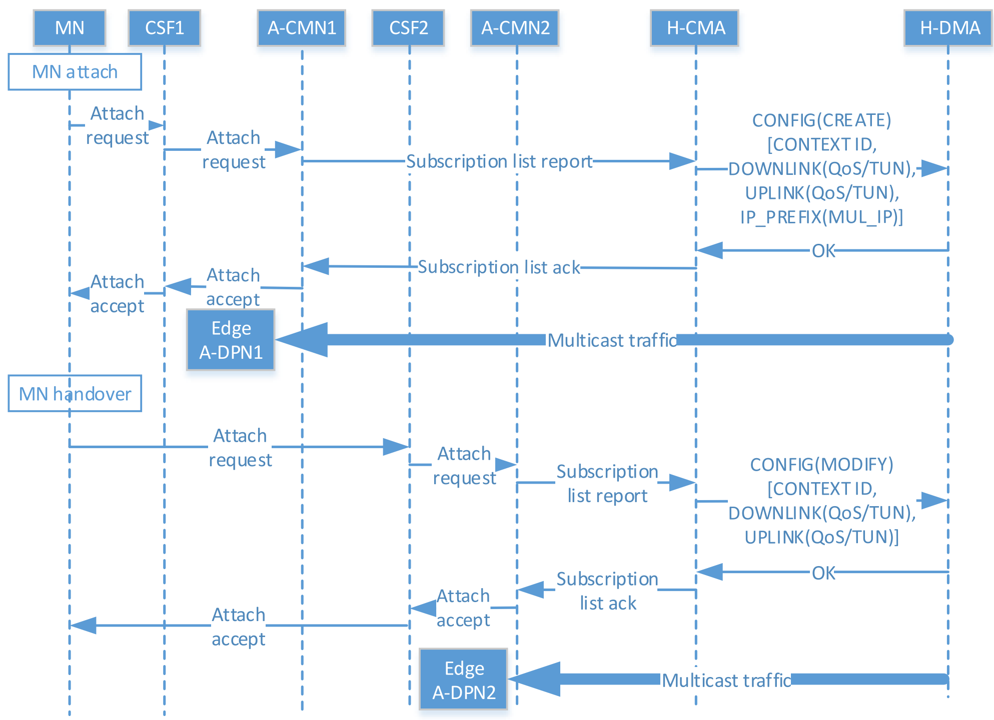

Fig. 4. Handover protocol operation.

novel architecture for distributed multicast mobility management, which considers the concept of control and data plane separation. This work is expected to contribute to incorporating multicast mobility into the current standardization of DMM.

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Conflict of Interest

The authors declare that there is no conflict of interest in this paper.

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