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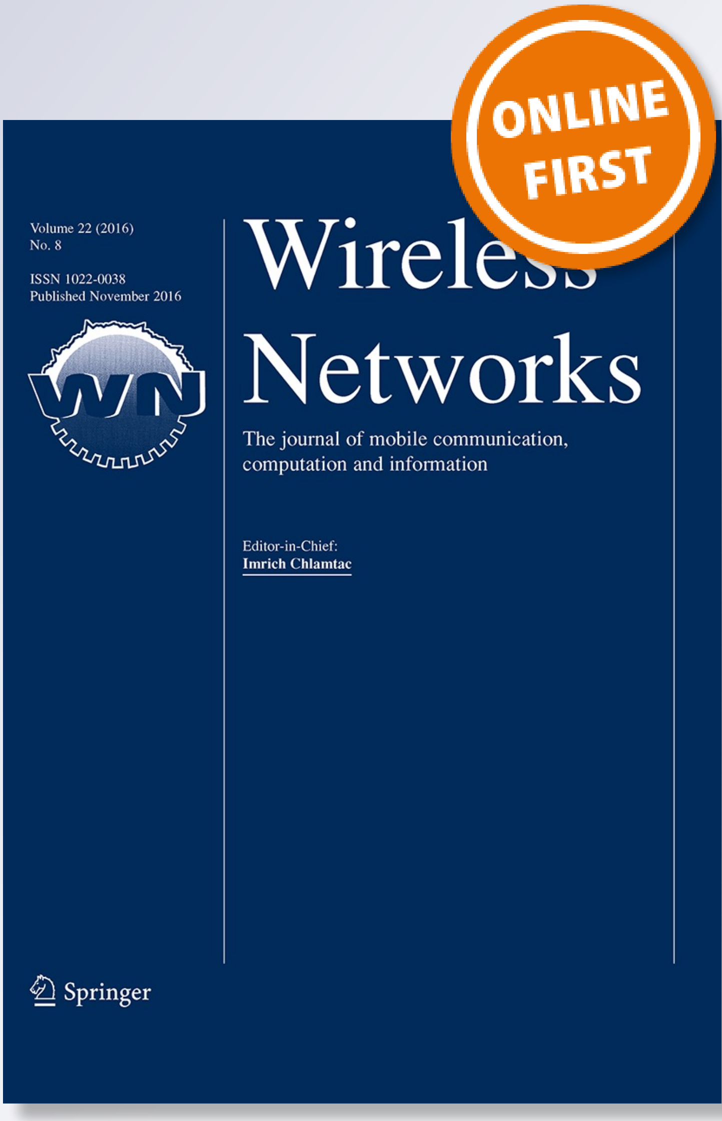

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SDN-based mobile packet core for multicast and broadcast services

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Abstract The current mobile packet core network is evolving to cope with the pressure of the mobile traffic explosion and the advent of new services. Software-defined networking (SDN) is currently being adopted as one of the promising drivers for redesigning the mobile packet core network toward a 5G network. SDN-based mobile packet core approaches are expected to deliver features, such as fast service deployment, flexibility, and capital expenditure and operational expenditure reduction within future 5G networks. However, current SDN-based mobile packet core approaches only focus on providing unicast services without considering multicast and broadcast services. In this article, we propose an efficient SDN-based mobile packet core network architecture for supporting multicast and broadcast services. The proposed architecture takes advantage of the SDN paradigm and enables multicast and broadcast service deployment. In addition, a new SDN-based multicast subscription procedure is introduced to reduce network bandwidth resources. By numerical analysis, our scheme improves the current multicast and broadcast solution in terms of signaling cost.

Keywords SDN · Mobile packet core · Multimedia broadcast multicast service · SDN-based mobile network

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1 Introduction

The current mobile packet core network architecture has some major design-inherent issues which make it difficult to cope with the explosion of mobile traffic and the advent of new service. In order to overcome these challenges and pay the way towards 5G mobile networks, the current mobile network architecture is required to change radically. Software-defined networking (SDN) [1–3] is considered as one of promising technologies to redesign current network architectures, including the mobile packet core network. SDN-based mobile packet core approaches [4–7, 13] which account on the clear separation of control and data planes provide some flexibility, fast service deployment, and programmability. In addition, these approaches also help reduce capital expenditure (CAPEX) when using network virtualization to share infrastructure for multiple network operators and operational expenditure (OPEX) by reducing the configuration and management complexity. Recently, some enhanced approaches [8, 9] have been proposed to take advantage of virtualization technologies by selecting which parts in SDN-based approaches could be virtualized in the cloud environment.

Multicast and broadcast modes can be enabled in the mobile network to support efficient multimedia content delivery to multiple users using minimum radio and network bandwidth resources. The multimedia broadcast multicast services (MBMS) standard defined by the Third Generation Partnership Project (3GPP) describes architectural solution and functionalities for the MBMS bearer service [10], user service [11], and radio access network [12]. The MBMS was first introduced in Release 6, and has evolved in the next releases. In Release 9, the MBMS has been updated to support the LTE network, also called evolved MBMS (eMBMS). After standardizing, eMBMS

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has been deployed by some mobile operators over the world. In the case of South Korea, some leading telecom companies such as Samsung, has a plan to provide nationwide PS-LTE (public safety) services in upcoming years [14]. The public safety services are based on the eMBMS technology to notify to thousands of people. Korea Telecom also provided mobile live streaming services in the sport complex based on the eMBMS [15].

Recent studies on SDN-based mobile packet core network concentrated on unicast services without considering multicast and broadcast services. The existing MBMS architecture can still operate with the current SDN-based mobile network proposals by using conventional interfaces. However, this results in a non-optimal architecture which lacks flexibility and complicates its management and configuration. Moreover, using IP multicast techniques in traditional MBMS architecture to deliver IP multicast packets in SDN-based approaches leads to additional protocol overhead. In this paper, we propose an efficient SDN-based mobile packet core network architecture for supporting multicast and broadcast services. We introduce new SDN modules, including a multicast broadcast handler (MB Handler), multicast broadcast routing (MBR), and multicast broadcast subscription database (MBSD), to enable multicast and broadcast services over a SDN-based core network. The protocol operations are also elaborated in detail within our proposed architecture. In addition, the multicast distribution tree is constructed using our new SDN-based mechanism instead of traditional multicast subscription procedures. By performance analysis, our proposed architecture is shown to display some improvement in terms of signaling cost.

The remainder of this paper is organized as follows. In Sect. 2, we describe some related works about current mobile core network architecture, the eMBMS system, and proposals for SDN-based mobile networks. Our proposal is presented in Sect. 3. Sections 4 and 5 present a detailed performance analysis and associated results. Last, we conclude the paper in Sect. 6.

2 Related works

2.1 Current mobile network architecture

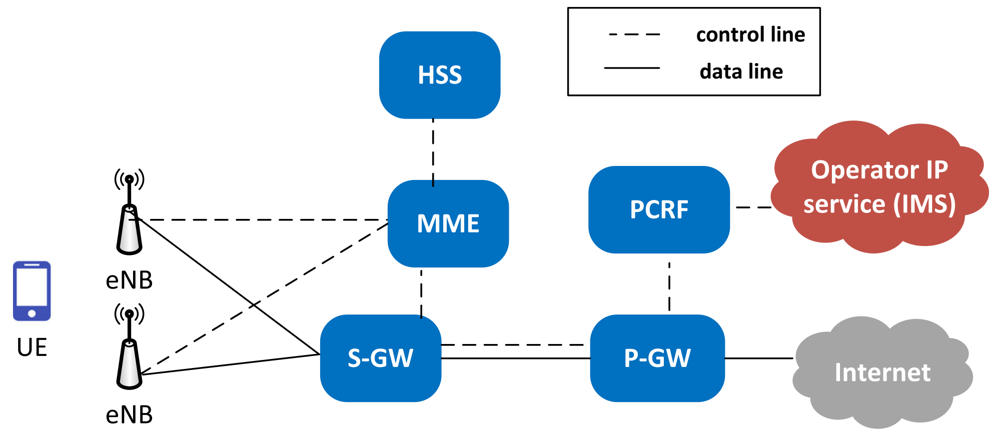
Mobile network architectures have evolved through many generations from 2G, 3G, and currently 4G (LTE). The LTE mobile network consists of two main parts: the radio access network (LTE) and evolved packet core network (EPC). Figure 1 shows the architecture of the current LTE mobile network. The radio access network is comprised of interconnected eNodeBs which provide wireless connections and radio-related functions, such as radio resource allocation and interference management. The eNodeBs are connected to the EPC core network through the serving gateway (SGW). The SGW serves as a mobility anchor for the inter-eNodeB handover. The mobility management entity (MME) is the control brain of the EPC, which maintains mobility management states and establishes the transport bearers for packet delivery through the LTE network. The LTE network is connected to the external network (e.g. Internet, IMS) via packet data network gateway (PGW), which is responsible for IP address allocation, packet filtering, policy and charging rule enforcement. The home subscriber server (HSS) is a central database, which stores subscription information and user profiles for authentication. The policy charging rule function (PCRF) is used to provide quality of service policy and charging rules to the PGW. User packets are delivered using GTP (GPRS Tunneling protocol) tunnels between eNodeB and PGW.

The current LTE core network architecture features hardware-based deployment and tight coupling between control plane and data plane functions. This lacks flexibility, slows down innovation, and results in costly CAPEX and OPEX. Thus, in next generation 5G networks, the SDN and virtualization technologies are used to overcome these issues.

2.2 Proposals for SDN-based mobile packet core

As addressed in [3], SDN has been considered as a key enabler for designing 5G network architecture with the benefits of flexible management, dynamic deployment and scaling of network functions. Up to now, many works have proposed to prove these benefits and their feasibility in different ways. However, these approaches [4] can be classified into two major categories: evolutionary approaches and revolutionary approaches. Revolutionary approaches radically changed the design of mobile packet core network architecture by replacing current entities with new ones [5] or decomposing them into smaller components [6] with respect to SDN's principle. SoftCell in [5] is simply composed of an SDN controller, local agents, OF switches, and middleboxes instead of conventional entities like SGW, PGW or MME, HSS. Control functions are now packaged as applications in an SDN controller, and responsible for managing subscriber's information, mobility, policy control, etc. This paper also proposed a new method to route user traffic by using the multi-dimensional tag to support scalable service routing and fine-grained service policies. Another SDN-based architecture [6] for 5G networks in which network functions are now decomposed into multiple modules running on virtual machines located in different data centers. For example, functions like connectivity management (CM), mobility management

Fig. 1 LTE mobile network architecture



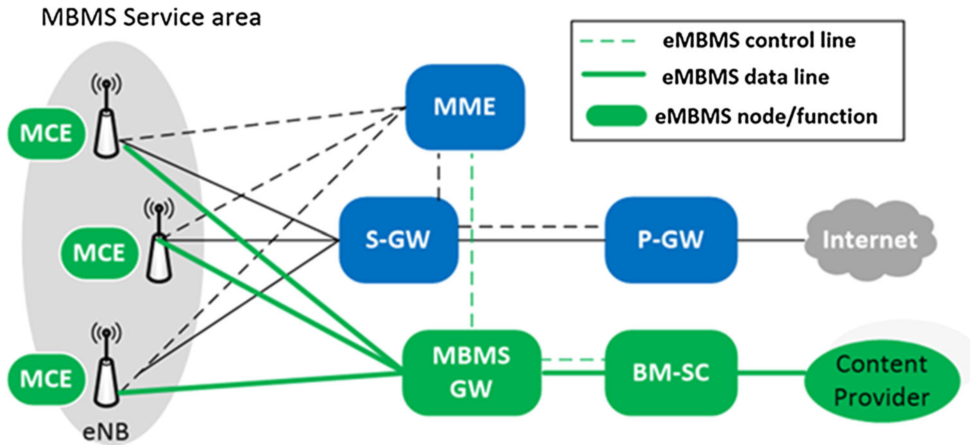
(MM) previously coupled inside MME are now becoming individual modules, namely the CM and MM module. The SDN controller sets path routing traffic between modules and between user devices and the Internet by interacting with a topology management (TM) module at each data center. Such a design could provide additional benefits as modules can be initiated at different locations according to service requirements (could be closer to the radio access network) in a flexible manner.

In contrast to revolutionary approaches, evolutionary approaches tend to keep some parts of the current mobile core network architecture (i.e. EPC) such as MME, HSS and split the control and data planes of gateways using the principle of SDN. In [7], the authors proposed a partial approach for adopting the SDN in the LTE/EPC architecture. In this architecture, the control and data plane are decoupled at SGW and still coupled at PGW. This architecture improves over the traditional architecture in terms of signaling load. However, the signaling load is still high. In [8], the authors presented a typical deployment of an SDN-based mobile packet core architecture named SDN-based MPC, which is being developed within Open Networking Foundation (ONF) standardization group. In SDN-based MPC, gateways (SGW, PGW) are now simplified as switches with capable of encapsulating and de-capsulating the GTP packets based on fine-grained rules installed by the SDN controller. OpenFlow is currently being extended to use as a southbound interface between the SDN controller and switches called OF-mpc [8]. The extensions include the modifications of match fields and action types so that OF switches can handle GTP user packets (GTP-U) in the data plane. In the control plane, control functions of gateways are consolidated as a unified module named combined GW handler. This handler is on the top of SDN controller and exposes the standard interfaces to other conventional entities (e.g. MME, HSS) and the northbound interface to the SDN controller. This paper also presented the migration of SDN-based MPC into the network function virtualization framework (NFV) where network entities (SDN controller, MME, HSS, switches) can be virtualized in NFV infrastructure in different domains. This could provide additional benefits in terms of dynamic resource provisioning and scalability. In [9], the authors presented a combination of the SDN and cloud environments by showing various implementation options of SDN-based mobile core networks on the cloud environment. In our previous work [13], we proposed OEPC (OpenFlow-Enabled mobile Packet Core) which fully adopts SDN and OpenFlow to redesign the entire EPC network. The OEPC detailed the protocol operations of key procedures showing how OEPC operates and illustrates the benefits of our design compared to traditional architecture and other schemes in terms of signaling cost reduction. However, our previous work considered only unicast services without multicast and broadcast services.

2.3 Multicast and broadcast support over current mobile network

In order to support multicast and broadcast services in the 3G networks, the MBMS architecture [10] was introduced in the 3GPP Release 6 and continued to evolve. Until the 3GPP Release 9, the eMBMS architecture was updated to support the LTE networks. Figure 2 shows the eMBMS architecture coexisting with the above LTE architecture. MBMS service area consists of a group of eNodeBs, which are synchronized to transmit in the same multicast channel. MBMS coordination entity (MCE) is a logical node, which can be deployed on every eNodeB or on an independent physical node. MCE is in charge of allocating time and frequency resources, performing admission control for MBMS service. MBMS gateway (MBMS-GW) is used to deliver MBMS packets to each eNodeB by IP multicast technique. The Broadcast Multicast Service Centre (BM-SC) takes care of authentication, content authorization,

Fig. 2 eMBMS architecture



billing, and configuration of multimedia data flow through the core network.

However, this eMBMS architecture also suffers the same issues as discussed above for the current LTE mobile network. Therefore, along with the evolution of LTE/EPC architecture for unicast services based on SDN, the current eMBMS architecture, obviously, needs to be evolved for supporting multicast and broadcast services in future mobile networks in a more efficient way. Therefore, in this paper, we introduce a resource-efficient SDN-based multicast and broadcast architecture to overcome these above issues. The initial idea for multicast and broadcast service over SDN-based mobile core was introduced in our previous work [16]. However, our previous work didn't show detailed network architecture, protocol operations, and performance analysis. To the best of our knowledge, this is the first work leveraging SDN concept into mobile network to support multicast and broadcast services with the detail of architecture design and protocol operations.

3 SDN-based mobile packet core for MBMS services

3.1 Architecture for multicast and broadcast service over SDN-based 5G mobile packet core

The overall architecture is shown in Fig. 3. In this architecture the mobile controller plays a role as the main control brain of the network. Since the mobile controller is in charge of handling all the signaling traffic in the core network, it possibly becomes a bottleneck point, thus resulting in the scalability problem. Traditionally, the scalability problem of having a single controller has been solved by some mechanisms such as using either horizontally distributed controllers or vertically distributed controllers as described in the literature [2]. However, currently, this problem can also be solved by leveraging the cloud technology with the capability of auto-scaling resources in a dynamic and elastic manner. In our architecture, the mobile controller will be hosted and implemented in a virtual machine running on a cloud platform (e.g. OpenStack [17]) as illustrated in Fig. 3. When the control traffic increases, the auto-scaling function of the cloud platform will help our mobile controller virtual machine to scale out. Therefore, the scalability issue of the mobile controller could be handled.

This mobile controller hosts main mobile network control plane functions, such as SGW-C, PGW-C, and MME. Those control plane functions are described in our previous work [13]. In order to support multicast and broadcast service, we introduce three new modules: (1) Multicast Broadcast Handler (MB Handler); (2) Multicast Broadcast Routing (MBR); (3) Multicast Broadcast Subscription Database (MBSD). In these modules, the MB Handler is the combination of control functions of traditional entities in the eMBMS network (MBGW and BMSC) and extended to communicate with the MBR modules to set-up forwarding rules in the forwarding devices of the data plane. The MBR is a new module used to create a distribution tree to deliver multicast traffic. The data plane consists of GW-Us, which are OpenFlow-enabled switches capable of processing GTP packets. The GW-U can be programmed and installed forwarding rules via an extension of OpenFlow protocol. The functionalities for each MBMS module are following:

MB Handler communicates with the MBMS subscriber information server (MBSD) for the purpose of authentication and content authorization. The MB handler is also responsible for session control information (start, update, stop, QoS parameters, and MBMS service area). It also allocates a transport IP multicast address and common TEID (Tunnel Endpoint Identifier) for multicast session delivery. MB Handler communicates with the MME to transfer session control information and QoS parameters. Then, the MME sends this information to the MCE

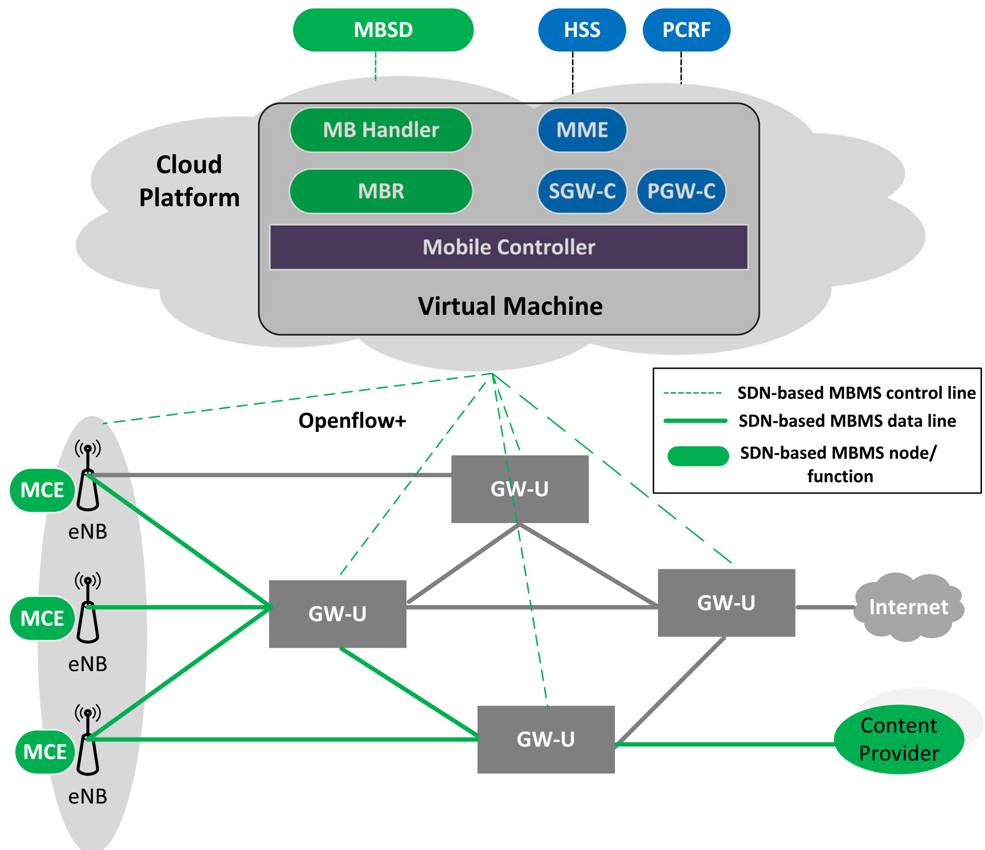


Fig. 3 SDN-based mobile packet core for multicast and broadcast services

functions of eNodeBs in the service area to prepare radio resources to transmit multicast data. MCE is responsible for the allocation of the same radio resources used by all eNodeBs in the service area.

MBR has the global view of data plane network topology and abilities to create forwarding rules for data plane switches. It receives the IP transport multicast address and the list of eNodeBs in the MBMS service area from the MB Handler. Then, MBR executes the multicast routing algorithm to create a multicast distribution tree for the delivery of multicast traffic to the list of the eNodeBs in the service area.

MBSD stores the MBMS subscriber information which is used for the authentication and authorization process.

3.2 Procedures

In order to enable a multicast service for one user equipment (UE), three procedures are required to execute, including MBMS multicast service activation, registration, and start session procedures. For broadcast service only start session procedure is required. Other procedures like update session, delete session are used to delete or modify some session related parameters for both multicast and broadcast sessions.

3.2.1 MBMS multicast service activation

The MBMS multicast service activation procedure is used to register a UE to the network for the purpose of receiving data from a specific multicast MBMS bearer service. This procedure will establish MBMS UE contexts in UE, MME, MB handler, and eNodeB. The procedure for MBMS multicast service activation is shown in Fig. 4. The MBMS UE context [10] is used in multicast service and contained UE-specific information related to a particular MBMS bearer service that the UE has joined.

The UE sends IGMP (IPv4) or *MLD (IPv6) Join* message to receive data from a particular MBMS bearer service which is identified by an IP multicast address. The eNodeB encapsulates the *IGMP Join* message into *OFPT_PACKET_IN* message and sends it to the mobile controller. The mobile controller forwards the *IGMP Join* to the MB handler module. On receiving the IGMP Join message, the MB handler module will check in the MBMS subscription database (MBSD) to determine whether the UE can be activated to receive MBMS data.

After the authentication process, the mobile controller triggers the MME to send the *Request MBMS Context Activation* including the IP multicast address to the

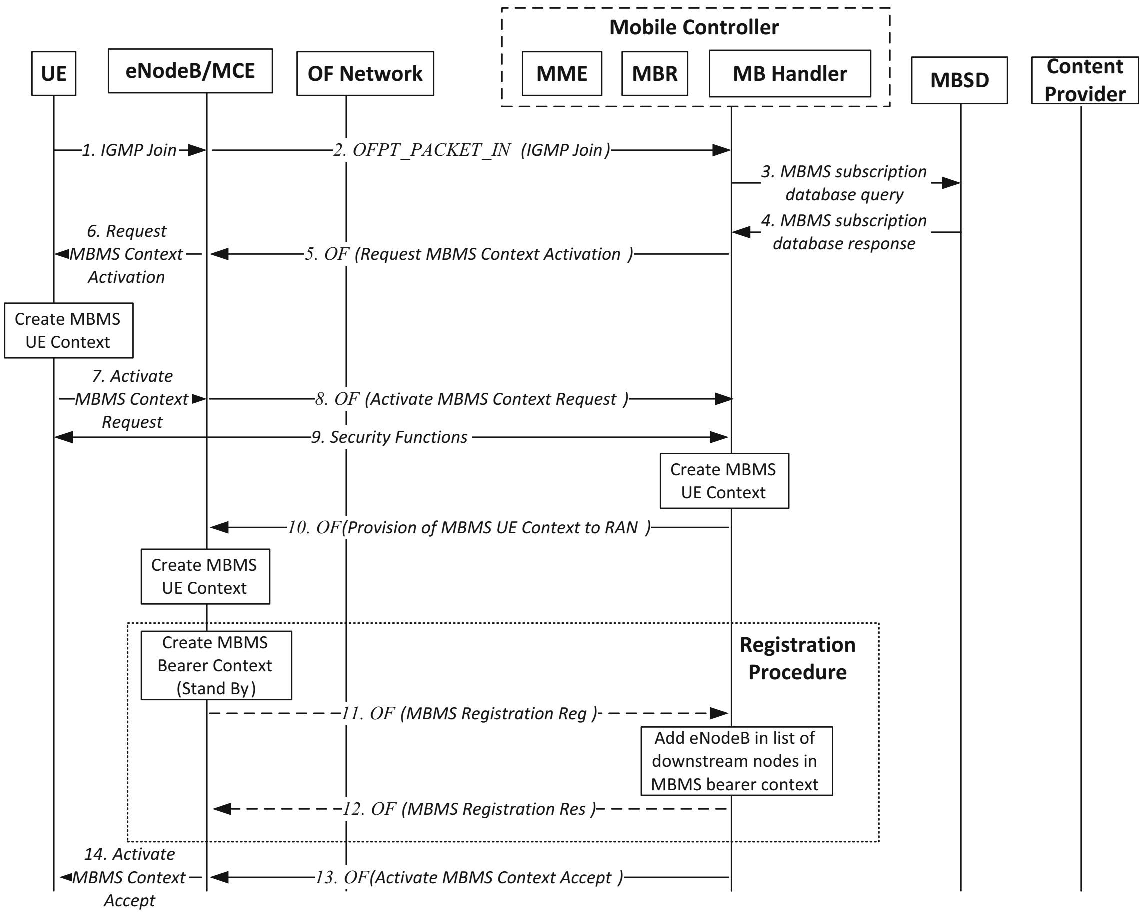


Fig. 4 MBMS multicast service activation procedure

eNodeBs via an OpenFlow message. OpenFlow message. In our design, the multicast-related messages are encapsulated in reserved OF message types beside defined ones. The fields in these OF encapsulated multicast messages are similar to multicast messages in traditional schemes and partially described in our text. From here, we denote the 3GPP messages which are encapsulated in the OpenFlow packets as OF (message). The UE creates an MBMS UE context and sends an *Activate MBMS Context Request* including IP multicast address, MBMS bearer ID, and MBMS bearer capabilities to the MME. The IP multicast is used to identify the MBMS multicast service. MBMS bearer ID is newly allocated for the MBMS service. The MBMS bearer capabilities indicate the maximum QoS which can be handled by the UE. If the MME has the MBMS bearer context [10] information for this MBMS bearer service, the MME should check the MBMS bearer capabilities of the UE. If the UE's bearer capabilities are less than the required MBMS bearer capabilities, the request will be rejected. Security functions can be required to authenticate the UE. The MME creates an MBMS UE context including IP multicast address, MBMS bearer ID, IMSI (International Mobile Subscriber Identity), TAI (Tracking Area Identifier) and RAT type (Radio Access Technology) and sends it to the MB handler. The MB handler also creates an MBMS UE context similar to the MME. Then, the MME provides the eNodeB with the MBMS UE context and sends the *Activate MBMS Context Accept* to the UE. If the eNodeBs in the radio access network don't have the MBMS bearer context for this MBMS service, the eNodeBs will trigger the registration procedure discussed later.

3.2.2 Registration procedure

This procedure is used by eNodeBs (downstream nodes) to notify the MB handler (upstream node) that it can receive session attributes and data for a particular MBMS bearer service. If the first MBMS UE context is created in the eNodeBs, the eNodeBs will set up MBMS bearer context in the Stand By mode and send *OF (MBMS Registration Request)* to the mobile controller. The mobile controller will forward this message to the MB handler module. Then, the MB handler will add the IDs of the eNodeBs to the list of downstream nodes in its MBMS bearer context. If the MBMS bearer context of the MB handler is active, the Session start will be initiated. The registration procedure is shown in the Fig. 4.

3.2.3 MBMS session start

For multicast service, the MB handler obtains the list of downstream nodes (the list of eNodeBs in the MBMS service area) through service activation and registration procedures. For broadcast service, the list of downstream nodes can be statically pre-configured in the MB handler by the network operators. The MBMS bearer context including all session attributes (QoS parameters, MBMS service Area, Session ID, session duration, transport IP multicast address, IP address of the content provider, common TEID) is also pre-configured in the MB handler. The start session procedure is shown in Fig. 5.

The MB handler starts an MBMS data session by triggering the MBR to build up a transport network and the MME to send control information to the list of eNodeBs. Here, instead of using the normal multicast mechanism, such as IGMP (Internet group management protocol) and MLD (multicast listener discovery) protocols, the new SDN-based multicast subscription mechanism is proposed to replace the current one. First, the MB handler sends the MBR module the list of downstream nodes. The MBR module, which has the topology of the Openflow-based transport network, runs the multicast routing algorithm to create a multicast distribution tree from content provider to a list of eNodeBs (downstream nodes). The *OFPT_FLOW_MOD* message is used to set up forwarding rules in the GW-Us to deliver the MBMS packets. The matching fields of the flow entry in the GW-Us includes the transport IP multicast address and common TEID. The action field of the flow entry includes the ports connected to the next GW-Us along the multicast distribution tree. At the same time, the MB handler triggers the MME to create the MBMS bearer context and send an *OF Session Start Request* including the session attributes to the downstream nodes in the service area. The downstream node stores all session attributes and sets the state attribute of its MBMS bearer context to "active" and responds to the MME. Then, the enodeBs establish all required radio resources for MBMS data delivery to the subscribed UEs. From now on, the MB handler can start the packet transfer from the content provider to the subscribed UEs. Figure 6 shows an example of extended OpenFlow entry for forwarding the multicast traffic. Beside the fields defined the OpenFlow protocol 1.4 [19], new match fields were introduced. *Content provider IP address field* includes the IP address of multicast content provider. *Transport multicast IP address field* includes the IP address of the multicast group address used by content providers to deliver multicast traffic. Other GTP-related fields are described in our previous work [13].

3.2.4 MBMS session stop

Similarly, the Stop session procedure is used to stop a MBMS data session. The MB handler triggers the MBR to remove the multicast distribution tree from the OpenFlow transport network and the MME to send the OF Session

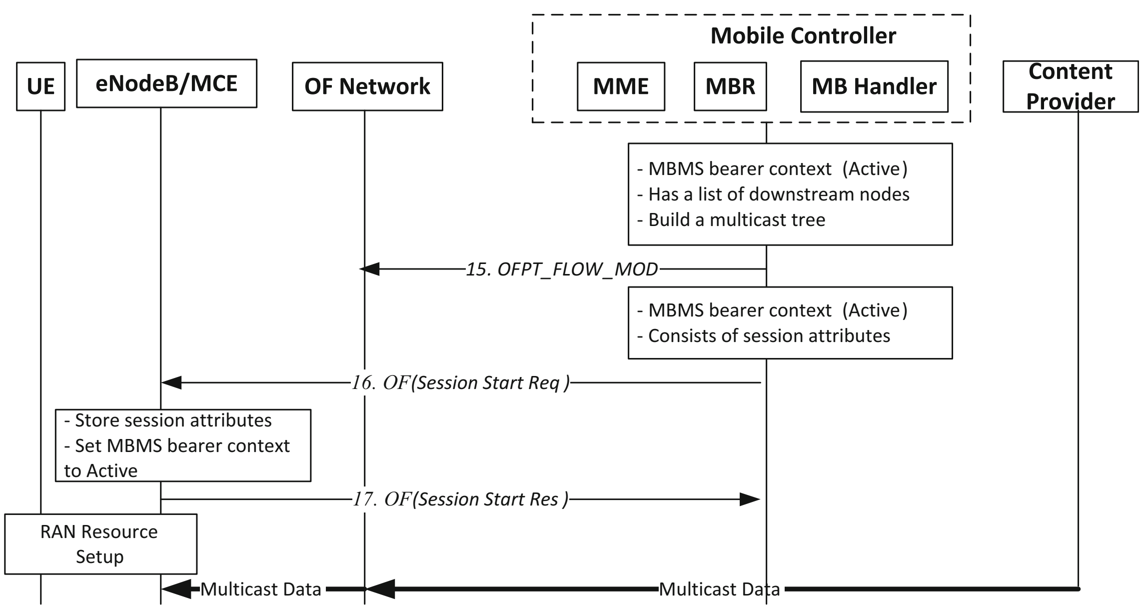


Fig. 5 Start session procedure

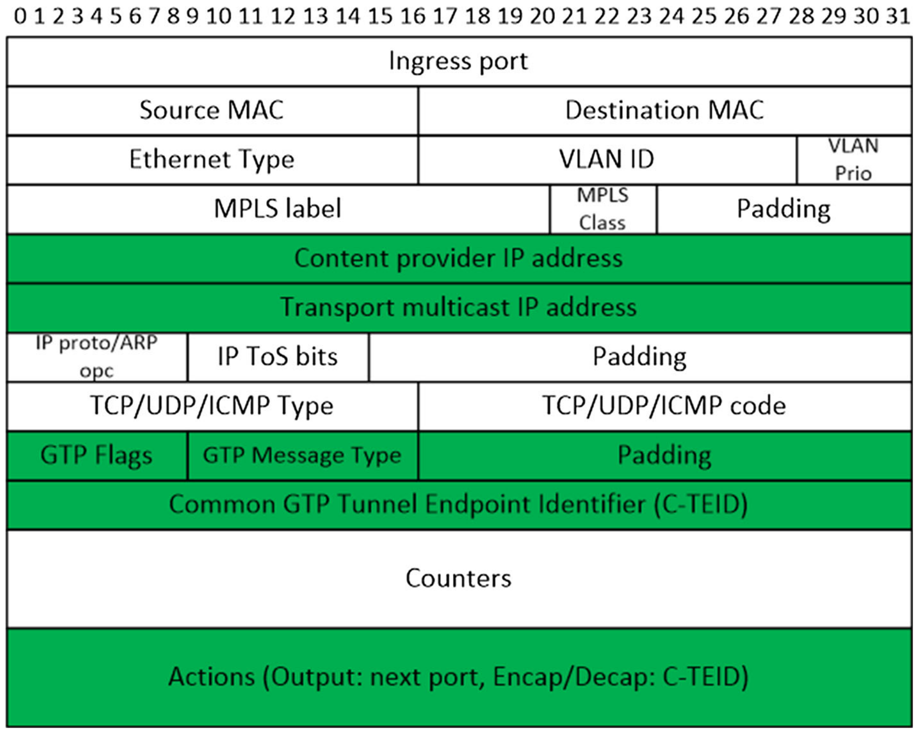


Fig. 6 An example of multicast OpenFlow entry

Stop Request to the radio access network. The MBMS bearer context on the MME, the eNodeBs will be set to “Stand By”. All affected radio resources will be released. The session stop procedure is shown in Fig. 7.

3.2.5 MBMS session update

Similarly, the Update Session Procedure is used when the service attributes (e.g. service area) for ongoing MBMS broadcast service session are changed. The MB handler trigger the MME to send out the OF Session Update Request messages including updated session attributes. The session ID and QoS attributes are kept identically as the start session procedures. On receiving the update message, the enodeBs re-establish the MBMS bearer contexts and releases or setups radio resources in order to refuse or accept the MBMS data. At the same time, the multicast distribution tree is also modified to deliver MBMS data to a new service area. The session stop procedure is shown in Fig. 8.

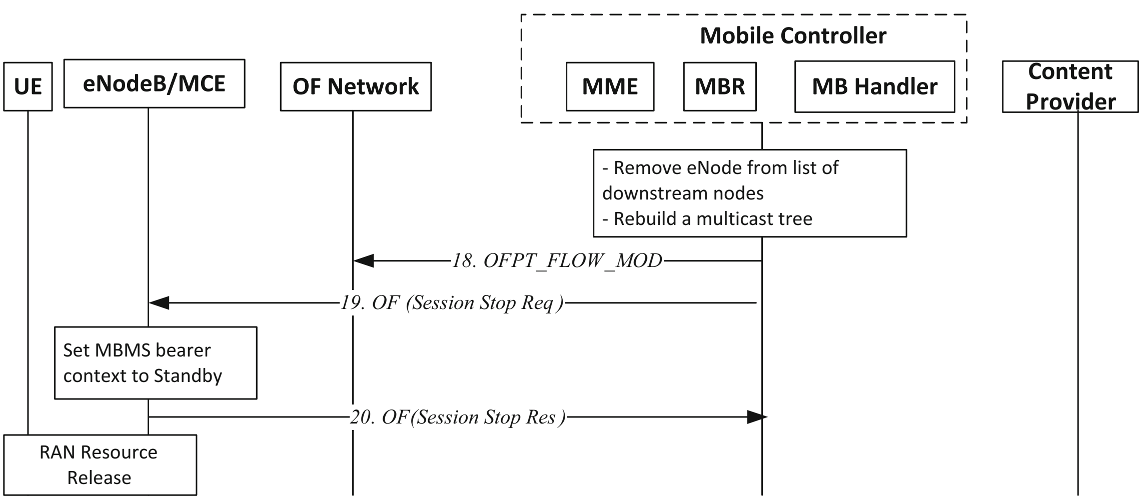


Fig. 7 Stop session procedure

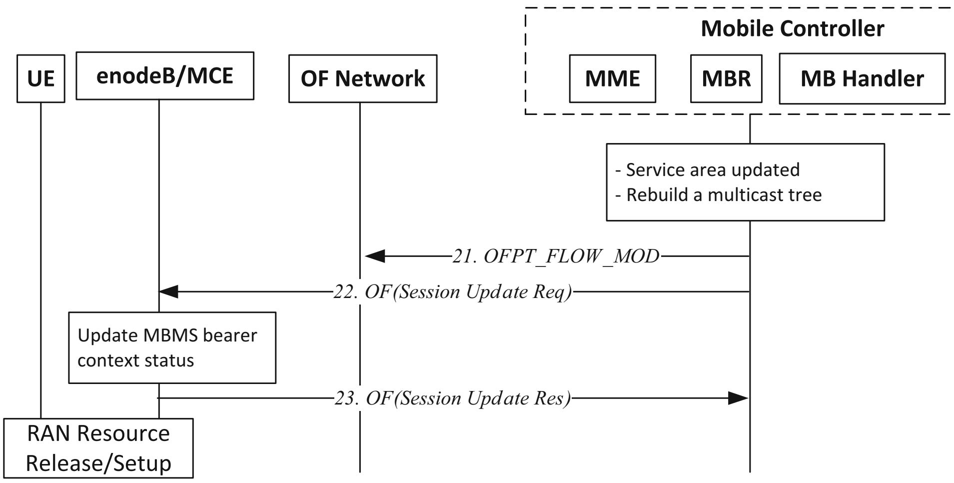
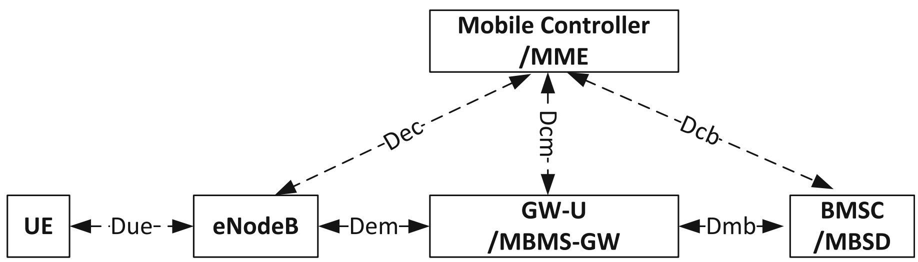


Fig. 8 Update session procedure

Fig. 9 Network reference model



4 Performance analysis

In this section, we evaluate the proposed architecture with the current MBMS architecture in terms of signaling cost. The analysis model and parameter values are partially employed in the literature [7, 18–20]. We assume that the number of UE is n and each UE has the MBMS session request rate r. The broadcast service area (a) is the number of eNodeBs involved one broadcast session. The D_{ec}, D_{cm}, D_{cb}, D_{em}, D_{mb}, D_{ue} denote the hop distances, i.e. the number of hops between network components. In our evaluation, we do not consider the security and RAN resource setup messages as these procedures are the same in both architectures. Figure 9 shows the network reference model for evaluation.

4.1 Signaling cost for 3GPP MBMS architecture

We assume that these procedures occur successfully and there is no failure. The signaling cost is calculated by the product of the message size and the hop distance. The procedures for enable multicast and broadcast services in traditional MBMS architecture are presented in the 3GPP technical specification [10].

4.1.1 Multicast service

Activation procedure:

$$\begin{aligned} C_{Tradition\_activation} = {} & n * r * \big(D_{ue} * \big(S_{join} + S_{qmca} + S_{amcq} \\ & + S_{amca}\big) + D_{ec} * \big(S_{qmca} + S_{amcq} \\ & + S_{pucr} + S_{amca}\big) + D_{mb} * \big(2 * S_{maq} \\ & + 2 * S_{mas}\big) + D_{em} * S_{join} + D_{cm} \\ & * \big(S_{mnq} + S_{mns} + S_{mnrq} + S_{mnrs} \\ & + S_{cmcq} + S_{cmcs}\big)\big) \end{aligned} \tag{1}$$

Registration procedure:

$$\begin{aligned} C_{Tradition\_registration} = {} & n * r \\ & * \big((D_{ec} + D_{cm} + D_{mb}) * \big(S_{mrq} + S_{mrs}\big)\big) \end{aligned} \tag{2}$$

Start Session procedure:

$$\begin{aligned} C_{Tradition\_start} = {} & n * r * \big((D_{ec} + D_{cm} + D_{mb}) * \big(S_{mssq} + S_{msss}\big) \\ & + D_{em} * S_{mumr}\big) \end{aligned} \tag{3}$$

Signaling cost for enabling multicast service in traditional MBMS architecture:

$$C_{Tradition\_multicast} = C_{Tradition\_activation} + C_{Tradition\_registration} + C_{Tradition\_start} \quad (4)$$

4.1.2 Broadcast service

Signaling cost for enabling broadcast service in traditional MBMS architecture:

$$C_{Tradition\_broadcast} = a * D_{ec} * (S_{mssq} + S_{msss}) + (D_{cm} + D_{mb}) * (S_{mssq} + S_{msss}) + a * D_{em} * S_{mumr} \quad (5)$$

4.2 Signaling cost for proposed SDN-based MBMS achitecture

4.2.1 Multicast service

Activation procedure:

$$C_{sdn\_based\_activation} = n * r * (D_{ue} * (S_{join} + S_{qmca} + S_{amcq} + S_{amca}) + D_{ec} * (S_{of\_join} + S_{of\_qmca} + S_{of\_amcq} + S_{of\_pucr} + S_{of\_amca}) + D_{cb} * (S_{msdq+}S_{msds})) \quad (6)$$

Registration procedure:

$$C_{sdn\_based\_registration} = n * r * (D_{ec} * (S_{of\_mrq} + S_{of\_mrs})) \quad (7)$$

Start session procedure:

$$C_{sdn\_based\_start} = n * r * (D_{cm} * (S_{of\_cmt}) + D_{ec} * (S_{mssq} + S_{msss})) \quad (8)$$

Signaling cost for enabling multicast service in the proposed SDN-based MBMS architecture:

$$C_{sdn\_based\_multicast} = C_{sdn\_based\_activation} + C_{sdn\_based\_registration} + C_{sdn\_based\_start} \quad (9)$$

4.2.2 Broadcast service

Signaling cost for enabling broadcast service in the proposed SDN-based MBMS architecture:

$$C_{sdn\_based\_broadcast} = a * D_{cm} * (S_{of\_cmt}) + a * D_{ec} * (S_{mssq} + S_{msss}) \quad (10)$$

5 Evaluation results and discussion

5.1 Numerical results on signaling cost

In this section, we present and discuss numerical results showing the impact of using software-defined networking in the MBMS architectures. The default values of the evaluation parameters are as follows: $D_{ec} = D_{em} = 4$, $D_{cm} = D_{cb} = D_{mb} = D_{ue} = 1$ [7] as shown in Table 1. Table 2 provides the MBMS message sizes which are

Table 2 The 3GPP MBMS messages and sizes

Message	Notation	Size (bytes)
IGMP join	S_{join}	128
MBMS notification request	S_{mnq}	188
MBMS notification response	S_{mns}	60
MBMS authorization request	S_{maq}	61
MBMS authorization response	S_{mas}	56
Request MBMS context activation	S_{qmca}	171
Activate MBMS context request	S_{amcq}	176
MBMS notification reject request	S_{mnrq}	171
MBMS notification reject response	S_{mnrs}	60
Create MBMS context request	S_{cmcq}	201
Create MBMS context response	S_{cmcs}	82
MBMS registration request	S_{mrq}	172
MBMS registration response	S_{mrs}	86
Provision of MBMS UE context to RAN	S_{pucr}	171
Activate MBMS context accept	S_{amca}	60
MBMS session start request	S_{mssq}	203
MBMS session start response	S_{msss}	81
IP multicast membership report	S_{mumr}	128

Table 1 Hop distance values

Notation	Hop distance (number of hops)	Value
D_{ue}	Between UE and eNodeB	1
D_{mb}	Between GW-U/MBMS-GW and BMSC/MBSD	1
D_{cb}	Between mobile controller and BMSC/MBSD	1
D_{cm}	Between mobile controller and GW-U/MBMS-GW	1
D_{em}	Between eNodeB and GW-U/MBMS-GW	4
D_{ec}	Between eNodeB and the mobile controller	4

Table 3 The Openflow MBMS messages and sizes

Message	Notation	Size (bytes)
OFPT_FLOW_IN	S_{of_join}	140
OF request MBMS context activation	S_{of_qmca}	183
OF activate MBMS context request	S_{of_amcq}	188
OF MBMS registration request	S_{of_mrq}	184
OF MBMS registration response	S_{of_mrs}	98
OF provision of MBMS UE context to RAN	S_{of_pucr}	183
OF Activate MBMS context accept	S_{of_amca}	72
OF MBMS session start request	S_{of_mssq}	215
OF MBMS session start response	S_{of_msss}	93
OFPT_FLOW_MOD	S_{of_cmt}	178
MBMS subscription database query	S_{msdq}	61
MBMS subscription database response	S_{msds}	56

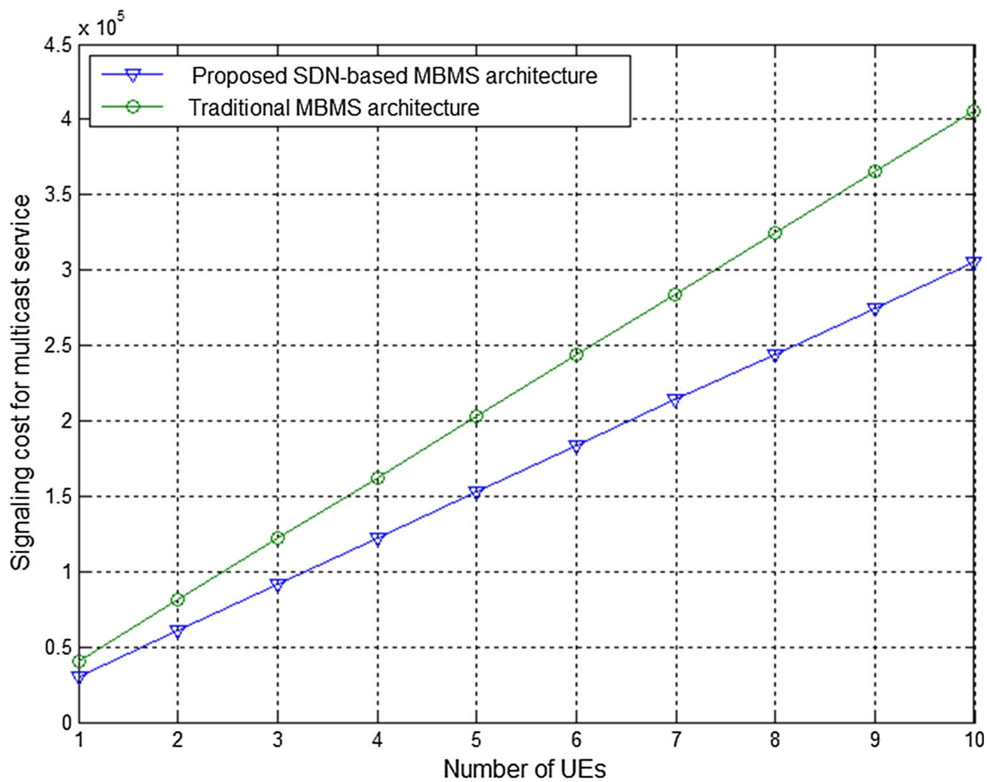


Fig. 10 The impact of UE number on signaling cost

determined from 3GPP specifications [18, 19]. Table 3 provides the OpenFlow MBMS message sizes.

Figure 10 shows the variation of signaling cost with the number of UEs. We can see that the signaling cost for enabling the multicast service in our proposed architecture is lower than the traditional architecture as the number of UEs increases. This results from the reduction of exchange messages among network entities such as MME, MBMS GW, and BM-SC. In addition, in the Start Session procedure of our proposed architecture, instead of sending the IP multicast Membership Report messages in a long way from the eNodeBs to the core network, the messages are just needed to exchange in the core network to create a multicast tree for multicast traffic distribution. Therefore, the signaling cost for this procedure is reduced, so the total signaling cost for activating the multicast service is also reduced accordingly.

Figure 11 shows how the MBMS session request rate affects the signaling cost for enabling the multicast service. As expected, the signaling cost increases in a linear manner with the session request rate in both cases. The signaling cost in our proposed architecture is still lower than that in

Fig. 11 The impact of session request rate on signaling cost

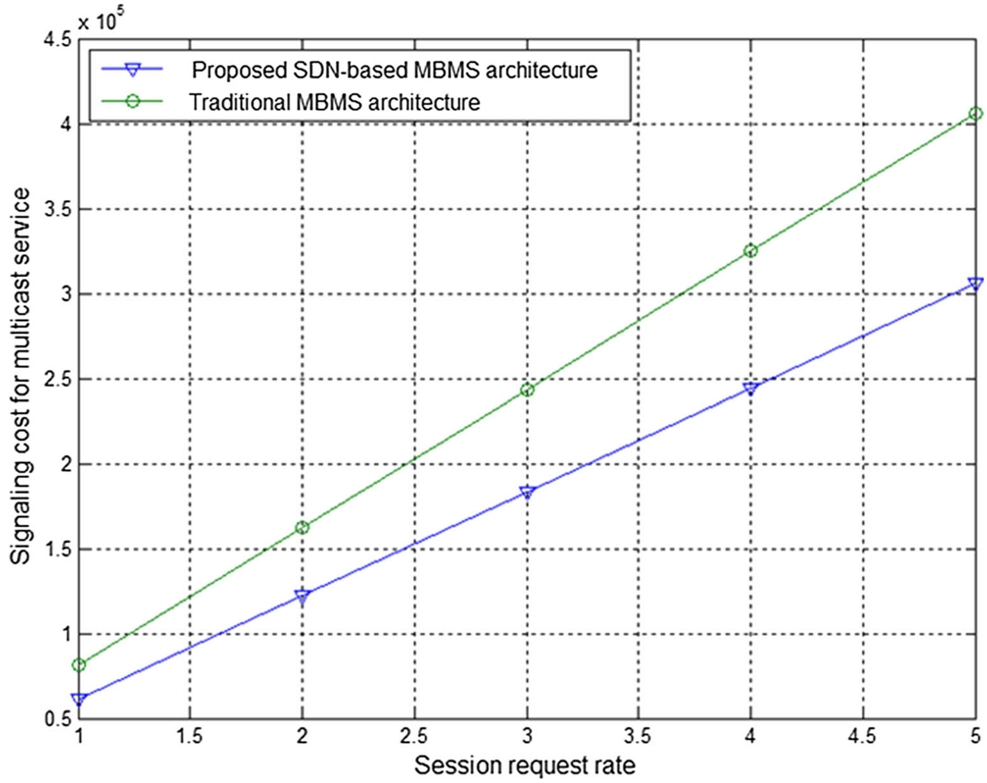
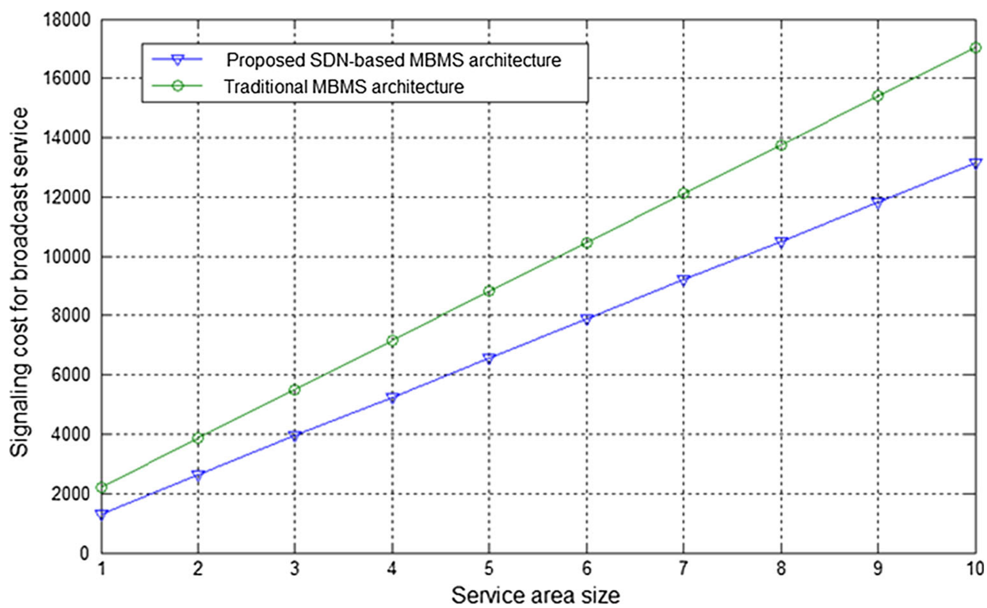


Fig. 12 The impact of service area on signaling cost



the traditional architecture as the session request rate increases. This occurs due to the same two reasons discussed above.

Figure 12 shows the variation of signaling cost for activating the broadcast service with the size of service area (number of eNodeBs). As shown in the figure, the signaling cost for enabling broadcast service in our proposed architecture increases proportionally with the size of service area and always lower than the traditional MBMS architecture. This is also due to the reduced number of exchange messages and efficient SDN-based multicast traffic distribution which is used in the proposed scheme.

5.2 Discussion on CAPEX and OPEX cost

This section will discuss about how CAPEX and OPEX can be reduced by using SDN.

For CAPEX cost, the cost for traditional eMBMS system includes the cost for purchasing and installing the hardware devices such as MBMS-GW, BMSC. For the transport services, the switches and routers are also needed to set up. For SDN-based scenarios, the cost for setting up the transport network is reduced by using the centralized SDN controller and programmable switches. The SDN-based approach introduces the cost for software development, but actually this cost is included in both cases at the initial phase. Another advantage of SDN-based approach that can help to reduce the cost of setting up the network is to enable network sharing or network slicing [21].

For OPEX cost, this cost includes the continuous cost of infrastructure, maintenance, and service provisioning cost. The continuous cost of infrastructure is calculated from floor space and energy consumption. We can see that in the SDN-based approach, the continuous cost of infrastructure is lower than traditional approach. This is due to the savings of the energy consumption in the network switches when the control software moves to the centralized controller. However, the cost for floor space increases slightly due to the controllers. The maintenance cost in traditional approach involves the cost for maintenance and repair of hardware devices and upgrade software on them. In the SDN-based approach, this maintenance cost is also lower due to the reduction of maintenance cost for a bunch of hardware devices. The software upgrade in one controller is much easier than the upgrade every hardware device and its control software. Service provisioning cost includes cost for providing services to customer. In SDN-based approach, the configuration and provisioning is highly automated and then reduce the total operational cost and time.

In order to clarify actual benefits that service providers and operators would achieve, some studies have been done [21, 22]. According to these work, CAPEX and OPEX are basically estimated by using a cost model or a techno-economic model which covers most of aspects discussed above such as number of devices, cost of first time instantiation, cost of software development, cost of configuration and maintenance, etc. For instance, as pointed out in [22], the saving for the SDN scenario compared to current deployment of mobile network in Germany is 12% in which CAPEX and OPEX savings are, respectively, 65% and 35% of the total savings. These numbers implied that SDN can obviously help network operators and providers reduce their expenses or total cost of ownership in terms of CAPEX and OPEX.

6 Conclusion

In this paper, we proposed architecture to enable multicast and broadcast service in the SDN-based mobile packet core. The detailed protocol operations are also presented and analyzed. Our architecture not only takes advantage of software-defined network paradigms, such as programmability, flexibility, CAPEX and OPEX reduction, but also is more efficient than traditional approaches in terms of signaling cost.

In the next few years, the trend for 5G core network driven by two technologies: software-defined network and network function virtualization. Telco will have the major changes in their mobile core network based on SDN and NFV. The mobile core network will soon be deployed using SDN and NFV. Therefore, our solution for multicast and broadcast scenarios will give the operators the initial solutions related to architecture and protocol operations for their implementation and deployment of multicast solution in the future. Our future work will consider the combination of mobility management and multicast in the SDN-based mobile packet core to achieve seamless handover for multicast service.

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