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An enhanced framework for providing multimedia broadcast/multicast service over heterogeneous networks*

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Abstract: Multimedia broadcast multicast service (MBMS) with inherently low requirement for network resources has been proposed as a candidate solution for using such resources in a more efficient manner. On the other hand, the Next Generation Mobile Network (NGMN) combines multiple radio access technologies (RATs) to optimize overall network performance. Handover performance is becoming a vital indicator of the quality experience of mobile user equipment (UE). In contrast to the conventional vertical handover issue, the problem we are facing is how to seamlessly transmit broadcast/multicast sessions among heterogeneous networks. In this paper, we propose a new network entity, media independent broadcast multicast service center (MIBM-SC), to provide seamless handover for broadcast/multicast sessions over heterogeneous networks, by extensions and enhancements of MBMS and media independent information service (MIIS) architectures. Additionally, a network selection scheme and a cell transmission mode selection scheme are proposed for selecting the best target network and best transmission mode. Both schemes are based on a load-aware network capacity estimation algorithm. Simulation results show that the proposed approach has the capability to provide MBMS over heterogeneous networks, with improved handover performance in terms of packet loss rate, throughput, handover delay, cell load, bandwidth usage, and the peak signal-to-noise ratio (PSNR).

Key words: IEEE 802.21, MIBM-SC, MBMS, MIIS, Heterogeneous networks, Network resource management
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1 Introduction

With improved multimedia availability and the rapid development of higher capacity user equipment (UE), the usage of multimedia applications has increased in the last few years, constantly challenging inherently limited network resources. Initially, multimedia applications were served by using point-to-point unicast connections. However, these are sufficient only for very low data traffic and performance degrades as the number of users increases. In response to this, a broadcast/multicast technology with the inherent feature of point-to-multipoint transmission mode has been developed, by which data can be simultaneously transmitted to a group of UEs who have subscribed to the same service. Compared to unicast, broadcast/multicast technology is more efficient in terms of bandwidth, power consumption, and complexity, when the number of UEs in the group is large. In a wireless mobile network, the provision of a multimedia application to mobile users is more complex than in a wired network. This is caused by rapid channel variations and limited radio resources at the air interface. In recent years, several wireless mobile broadcast/multicast solutions have been proposed. The European Telecommunications Standard Institute (ETSI) defined Digital Video Broadcasting for Handheld (DVB-H), using the digital terrestrial TV broadcast infrastructure to provide broadcast/multicast services to mobile users who are equipped with the specific interface (ETSI, 2010). The Third-

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Generation Partnership Project (3GPP) defined a multimedia broadcast multicast service (MBMS) standard, 3GPP TS 23.246 (3GPP, 2010), to cover all the terminal, access network, core network, and service provision aspects. It is worth noting that MBMS is based on 3GPP cellular networks. Thus, the existing network infrastructure does not require many changes to satisfy the provision of MBMS. In respect of radio resources, the radio spectrum that has already been purchased by the operator is still available to the MBMS service, so both operator and user can reduce their operation and service costs. In addition, a broadcast and multicast service (BCMCS) has been defined to provide broadcast/multicast services in 3GPP2 networks (3GPP, 2007d).

On the other hand, rapid growth and innovation of the various mobile communication technologies have caused a change in the paradigm of Internet access, resulting in a large number of wireless technologies, such as UMTS/LTE cellular networks, WiMAX (IEEE 802.16), and Wi-Fi (IEEE 802.11). The Next Generation Mobile Network (NGMN) will combine multiple radio access technologies (RATs) to provide ubiquitous services without interruption of the on-going session, especially in multimedia applications with rigid quality of service (QoS) requirements. Therefore, the existence of various RATs requires a means for seamless internetworking and vertical handover among heterogeneous networks. The 3GPP specifications 3GPP TS 23.234 (3GPP, 2009a) and 3GPP TS 23.402 (3GPP, 2011b) standardized the architecture enhancement for non-3GPP accesses. The IP multimedia subsystem has been extended in the 3GPP specification 3GPP TS 23.228 (3GPP, 2011a) to enable UMTS to support multimedia services over different RATs. In addition, to optimize vertical handover between various wireless networks, IEEE 802.21 has taken the lead in developing media independent handover (MIH) standardization since 2004 (IEEE, 2008).

Because of the development of broadcast/multicast services and the heterogeneity of wireless networks, the issues related to seamless handover for broadcast/multicast services over heterogeneous networks are becoming the subject of academic research. In this paper, we propose a novel approach for seamless handover for broadcast/multicast services with QoS provision in a heterogeneous network environment. The architecture of our proposed approach is based on the MBMS architecture specified in ETSI TS 102 832 (ETSI, 2010) and the 3GPP enhancements for non-3GPP accesses specified in 3GPP TS 23.234 (3GPP, 2009a) and 3GPP TS 23.402 (3GPP, 2011b). By extension and enhancement to a broadcast/multicast service center (BM-SC) and media independent information service (MIIS), seamless handover for the MBMS service is enabled over heterogeneous networks with QoS provision. The core idea behind the proposed approach is to create a new functional entity called the media independent broadcast multicast service center (MIBM-SC) combing the functions of both BM-SC and MIIS. Meanwhile, a novel network selection scheme and cell transmission mode selection scheme are proposed for selecting the best target network and best transmission mode. Finally, a network-assisted mobile-controlled handover scheme is proposed. The efficiency of the proposed approach is evaluated through extensive simulation, using network simulator ns-2, of a handover for an MBMS service between UMTS and WiMAX networks.

2 Literature review

2.1 Multimedia Broadcast Multicast Service

The MBMS standard first specified by 3GPP is an enhancement of the UMTS system to provide capability for broadcast and multicast services in a cellular network (3GPP, 2007c), and has been updated in 3GPP Rel-12 to enhance the mobility management of the MBMS service in Long Term Evolution-Advanced (LTE-A). The motivation behind the design of MBMS was to provide a point-to-multipoint service in which data is transmitted from a single source entity to multiple recipients, allowing network resources to be shared to increase the efficiency of network resource usage. The MBMS service can be divided into two parts: user services and bearer services. The user services are provided by the core network to the mobile user by means of bearer services. The bearer services are the procedures for the air interface between the access network and the mobile user, and provide capability to deliver IP multicast datagrams to multiple recipients with minimum network resources (3GPP, 2010). Fig. 1 shows the 3GPP reference model of MBMS for a UMTS network. An additional new entity, BM-SC, has been added to provide for MBMS user service provisioning and delivery.

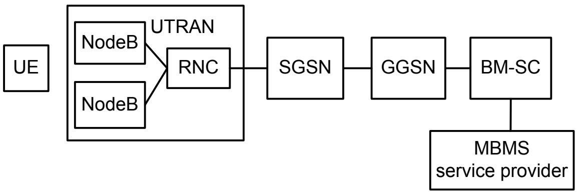

Fig. 1 The 3GPP reference model of MBMS for the UMTS network

MBMS was first extended in 3GPP Rel-9 to fit the common solution of Long Term Evolution (LTE). MBMS in LTE is also referred to evolved MBMS (eMBMS) (3GPP, 2009b). eMBMS has been further improved in performance by the flat LTE architecture, the operations of a single frequency network (SFN) as well as improvement in the area of service layer defined by 3GPP Rel-11. Fig. 2 gives the 3GPP reference model of eMBMS. For better radio efficiency, eMBMS supports two transmission schemes: (1) a single-cell point-to-multipoint transmission scheme with feedback mechanism and adaptive modulation and coding, but without coordination between neighbor cells; (2) the well-known SFN, which works on the coordination between neighbor cells. So, each cell uses the same frequency to transmit the same data at the same time, and the mobile user receives the signal from multiple base stations as a strength signal rather than with mutual interference.

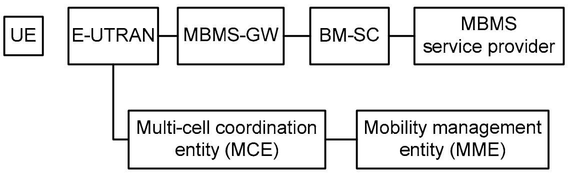

Fig. 2 The 3GPP reference model of eMBMS

Although SFN brings the benefit of efficient usage of network resources by improving the conditions for users who are located at the edge of a cell, research on SFN, such as the work in Alexiou *et al.* (2012), is out of the scope of this paper. The reason is as follows. While SFN is normally adopted in homogeneous networks, it is difficult to deploy the SFN concept to heterogeneous networks because of the different characteristics of the different network technologies. In this study, a single-cell point-to-multipoint transmission scheme is adopted in our simulation scenario.

2.2 IEEE 802.21 Media Independent Handover

In 2004, the IEEE 802.21 working group was formed to address issues related to the MIH protocol. The main goal was to develop a standard that would allow a mobile terminal to seamlessly roam across different types of IEEE network access technologies. It was then extended to allow the integration of 3GPP and 3GPP2 cellular networks. The design motivation of MIH was to facilitate the operations related to mobility by introducing a new standardized, technology-independent layer between the network layer and the link layer. This new layer is called the MIH layer and also known as layer 2.5. The operation and management of the network can be simplified through communication with the MIH layer, in which the upper layer (such as the network layer) does not require to know the differences between lower layers, and vice versa. Fig. 3 depicts the MIH architecture as proposed by IEEE 802.21. Usually, a mobile terminal can obtain information only from its neighbor networks. A smart handover requires the cooperation of the mobile terminal and a central server that contains information from all available networks. Therefore, the MIH layer is not only present in the mobile terminal, but is deployed in network entities that are involved in a handover procedure.

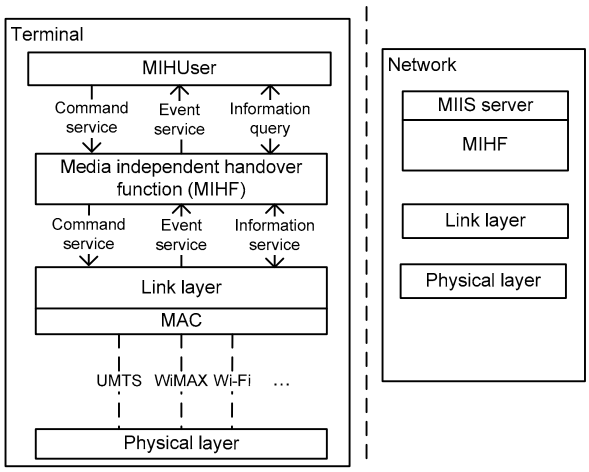

Fig. 3 General architecture of Media Independent Handover (MIH)

To help the upper layer manage the handover procedure, the media independent handover function (MIHF) uses a service access point (SAP) to associate with the link layer and the network layer to provide synchronous and non-synchronous services including event service, command service, and information service.

1. Media independent event service (MIES) defines the causes of handover due to the action of the users, the state of the environment, or some other network management functions defined as event. These events can be created by the MAC layer, the physical layer, or the MIHF on either the mobile device or the network sides.

2. Media independent command service (MICS) enables the upper layer to manage and control link-related handover behaviors. It is divided into two categories: MIH command and link command. The MIH command is created by the MIH user to MIHF and the link command is sent by the MIH layer to the MAC layer.

3. Media independent information service (MIIS) deals mainly with supplying handover-related information to the MIH user so that a successful handover can be carried out. Generally, it includes three categories: (1) general network information (GNI) that briefly describes the network, such as a list of network types, location of point of access (POA), name of network, network ID, and IP version; (2) link layer information (LLI) such as link parameters (channel, frequency), data rate, QoS, neighbor network information, and security information; (3) upper layer information (ULI) referring to the upper layer service and application, such as SMS/MMS, VoIP, mobile IP, network toll, and roaming.

In this study, IEEE 802.21 specified MIH has been extended to provide a seamless handover for an MBMS service in heterogeneous networks with a guaranteed QoS. This new framework is called MIH-MBMS architecture. In this new architecture, a new functional entity is added to MIHF in the mobile terminal to select the target satisfying network for the MBMS service and, in respect of the network, a partial function of BM-SC is added to the MIIS server to provide the functions of both BM-SC and MIIS.

2.3 Related work

In this subsection, we review previous research that has been done by other researchers on two topics: the capability of MBMS in both cellular networks and heterogeneous networks, and the performance of MIH in facilitating the vertical handover in heterogeneous networks. To our best knowledge, little research has been done on MIH-based handover for MBMS service in heterogeneous networks. That is our research motivation and contribution to the academic community.

In cellular networks, the issues related to optimal selection of the transmission scheme for an MBMS service are currently raising interest. In fact, selection between a single-cell transmission scheme and a multi-cell transmission scheme depends on the user density. While working on a single-cell transmission scheme, an increase in user density leads to an increase in the probable number of edge users who need to be served by a more source-consuming modulation and coding scheme. Therefore, when the user density achieves a certain threshold, a single-cell transmission scheme will no longer be the suitable transmission scheme compared with a multi-cell transmission scheme. Different values of the threshold have been given by the industry; for example, the simulation results from Nokia indicate that an average user density of less than one user per cell should be used as the threshold to justify a multi-cell transmission scheme 3GPP R1-070984 (3GPP, 2007a). Ericsson, by contrast, gives a threshold of three to four users per cell of Poisson distribution in an MBSFN with 120 cells (3GPP, 2007b). Although the results from the two companies are slightly different, the order of magnitude for the threshold is the same. Xylomenos *et al*. (2011) proposed an MBMS extension which allows multiple variants of the same content to be economically distributed to receivers. Meanwhile, both analysis and simulations were carried out to show that the proposed method would satisfy user requirements. However, they considered only the case in a single network environment, rather than a scenario of heterogeneous networks. Another important aspect in the MBMS framework is the forward error correction (FEC) technique in the application layer, which is an inherent feature of the MBMS service. Some related work was reported in Alexiou*et al*. (2011) and Bouras *et al*. (2012).

The deployment of an MBMS service in heterogeneous network environments is more complex, in respect of both the technique plane and the service one. Santos *et al*. (2008) proposed some methods of network convergence for multicast/broadcast services, such as IMS-MBMS based architecture and application. Kai *et al*. (2011) proposed a system model which treats selection of transmission mode and power consumption for an MBMS service in a heterogeneous network as an optimization problem. However, the authors did not describe the handover procedures in detail, and the simulation result offers only weak confirmation that the proposed method is effective and efficient. By contrast, this paper gives a detailed handover procedure for an MBMS service and proposes a novel network selection scheme and cell transmission mode selection scheme in a heterogeneous network.

IEEE working group 802.21 was formed in 2004 to standardize MIH. There has been much research on the subject. Chiu *et al*. (2011) proposed a session initiation protocol (SIP) based cross-layer method to support handover in heterogeneous networks, and gave a detailed description of the proposed method and infrastructure. Chiang and Chang (2010) proposed a mobile-initiated network-executed technique, also based on SIP, to provide simultaneous mobility in IP multimedia subsystems. In this method, the handover decision is made solely by the mobile host and executed by a mobility server. Thus, the mobile host faces challenges of complexity and battery life; however, the authors did not give any evaluation of these. Another enhancement on the IEEE 802.21 MIH protocol was proposed by Neves *et al*. (2009), in which the provisioning and activation of QoS resources in the target network is allowed during the preparation for handover. However, this model does not specify the link layer QoS parameter used or the QoS mapping mechanism; it focuses solely on the handover between Wi-Fi and WiMAX. Most of these researches rely on the IEEE 802.21 MIES and MICS services, and MIIS is seldom taken into consideration. Our work presents a detailed discussion on the architecture and functionalities of the extended MIIS server. Based on the extended MIIS server, we propose a novel network selection scheme and a cell transmission mode selection scheme.

3 The proposed method

3.1 The proposed network architecture model

To provide an MBMS service in a cellular network, a new component, BM-SC, is introduced to serve as an entry point for a service provider to schedule and deliver MBMS user services. It can also be used to authorize and initiate MBMS bearer services (3GPP, 2010). On the other hand, as the basic structure of MIIS is not completely standardized in the IEEE 802.21 standard, our proposed MIBM-SC also accommodates the diversity of MIIS servers. In this study, the core idea is to introduce a framework with a new entity, MIBM-SC, which acts with the function of both BM-SC and MIIS to support an MBMS server in heterogeneous networks. Due to the significant role of BM-SC in the MBMS service, our proposed MIBM-SC is chosen as the anchor of MBMS provision and management. Fig. 4 presents our network model including MIBM-SC. The general architecture is based mainly on the architecture specified in 3GPP enhancements for untrusted non-3GPP access. A WiMAX's Access Service Network (ASN) is connected to the 3GPP core network through ePDG, which has been enhanced to support functions corresponding to GGSN. The function of the enhanced ePDG is to receive MBMS data and to interact with MIBM-SC and map MBMS data to the WiMAX access.

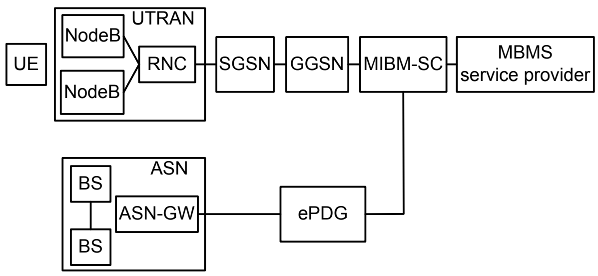

Fig. 4 The proposed network model including MIBM-SC

3.2 Architecture of the functionalities of MIBM-SC

The proposed MIBM-SC can be divided into two parts: a broadcast/multicast service center (BM-SC) and MIIS. It is built by the extension and enhancement of BM-SC and MIIS to provide the partial function of both BM-SC and MIIS. There are five sub-functions in the original BM-SC: membership function, session and transmission function, proxy and transport function, service announcement function, and security function. However, the functions for membership and security are not included in our proposed MIBM-SC. This is because we assume that all the users are authorized and have already subscribed to the MBMS services and an MBMS agreement has been set among the different operators. Also, there is no security issue involved in our scenario. In respect of MIIS, by reviewing the literature, we summarize that the MIIS server should have the following features:

1. The MIIS server should communicate with other MIH-enabled network entities via an MIH network service assess point.

2. The MIIS server should have the capability to manage network information required to collect, maintain, update, and clean the database.

3. If the handover scheme is network-controlled, then the MIIS server additionally should have the capability to select the network. In contrast, our proposed handover scheme is mobile-controlled, so the network selection mechanism is shifted to the mobile terminal side.

Another important feature of MIIS is that the information provided by the MIIS server relates not only to the technology in use, but the surrounding available technologies that can also be accessed from any technology. For instance, a mobile node (MN) connected to a WiMAX network will be able to obtain information about a UMTS network within its geographical area without the need of an active UMTS interface.

To describe the structure of the MIIS part in our proposed MIBM-SC, several assumptions are made. First, an MN can measure its location timely and report it to the MIIS server. Second, an MIIS server records a map of points of attachment (PoAs) in a certain geographical area, and updates when a new network is deployed. Third, we assume that the number of always available PoAs is limited. These assumptions are rational and can easily be extended. The overall handover procedure can be divided into three stages: neighbor network discovery, network selection, and handover execution. In this work, the MIIS server is responsible mainly for network discovery, and network selection is carried out by MN. Fig. 5 gives the overall internal architecture of our proposed MIBM-SC. It is composed of six subcomponents. The session and transmission function module (STFM), service announcement function module (SAFM), and proxy and transport function module (PTFM) are responsible for the function of MBMS services; the local database (LD), neighbor network discovery agent (NNDA), and information collector (IC) are implemented to control the function of MIIS.

STFM is an entry point for the service providers. It should be able to authenticate and authorize external sources and accept a service from them. Meanwhile, it should be able to provide transport related parameters to GGSN such as the required QoS and MBMS service area. STFM is used to initiate and terminate MBMS bearer resources when scheduled MBMS session transmission and an MBMS session identifier have been assigned to each MBMS session.

SAFM is a user service level function that provides service announcements for multicast and broadcast MBMS services. It delivers not only

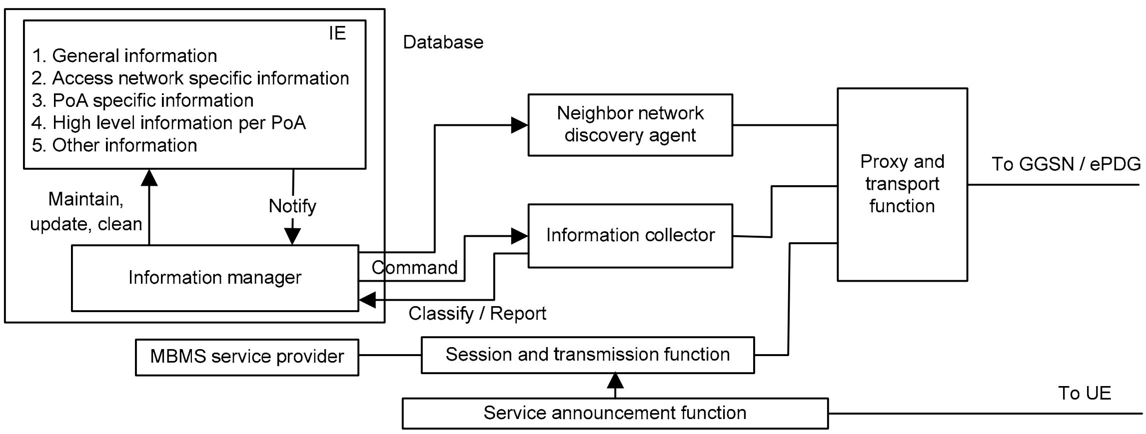

Fig. 5 The overall internal architecture of our proposed MIBM-SC

session media to MN, but also the session description. Service announcements can be triggered by various events; in our framework they are triggered by the handover event.

PTFM is an MBMS bearer service function and serves as a proxy agent between GGSNs and other models. It forwards the MBMS data sent from STFM to GGSN. In our proposed MIBM-SC, PTFM is enhanced with MIH functions as an interface to communicate with other MIH-enabled entities through MIH_NET_SAP.

The local database (LD) contains an information manager and stores various local information elements (IEs). It can be extended easily to exchange database information with remote MIIS servers or MIBM-SC. The IEs can be divided into five groups: (1) general information (GI) such as network type, operator identifier, or service provider identifier, (2) access network specific information (ANSI) which is related to QoS information and roaming partners, (3) point-of-attachment specific information (PSI) which comprises aspects such as the media access control (MAC) address of the PoA, geographical location, data rate, and channel range, (4) high level information (HLI) which includes information about the available services for each PoA such as the IP configuration methods, the number of subnets supported by the PoA, a list of all supported services on the PoA, and (5) other information (OI) such as vendor specific information or services that can be added to our proposed MIIS server. An information manager is located within the database to manage various activities of the IEs; it serves as an interface to interact with other components of the MIIS server.

NNDA leverages the results of the comparison and calculation of the location of PoA and the dynamic information that has been measured among the available candidate neighboring networks. Therefore, the number of PoAs that should be spectrum scanned and channel synchronous is reduced.

IC is used to take orders from the information manager to collect measurements by MN from RNC or BS, and report them to the information manager.

Fig. 6 gives the procedure of our proposed approach to facilitate the handover for an MBMS service in heterogeneous networks. As mentioned earlier, an MN always monitors the received signal strength (RSS) from the connected networks to determine if a handover is needed. Meanwhile, MN periodically sends messages to the MIIS server asking for probable neighbor networks and the parameters of the related networks. When this MN moves toward the boundary of the coverage area, a drop in the RSS is observed. The following four thresholds are used in the proposed algorithms:

1. $\text{Threshold}_{\text{\_lgd(UMTS)}}$, which is used to trigger the link_going_down event in the UMTS network;

2. $\text{Threshold}_{\text{\_ho(UMTS)}}$, which is the handover threshold in the UMTS network;

3. $\text{Threshold}_{\text{\_lgd(WiMAX)}}$, which is the threshold used to trigger the link_going_down event in the WiMAX network; and

4. $\text{Threshold}_{\text{\_ho(WiMAX)}}$, which is the handover threshold in the WiMAX network.

The values of $\text{Threshold}_{\text{\_lgd(UMTS)}}$ and $\text{Threshold}_{\text{\_lgd(WiMAX)}}$ are set based on the coefficient of received power before sending and the minimum signal strength that can be received by MN in each network, and the values of $\text{Threshold}_{\text{\_ho(UMTS)}}$ and $\text{Threshold}_{\text{\_ho(WiMAX)}}$ are set based on the link handover imminent in each network.

To conveniently describe the procedure of our proposed handover scheme facilitated by MIBM-SC for MBMS in heterogeneous networks, Table 1 gives the definition of the messages and events used in the proposed method.

We take an example in which MN is connected to a UMTS network and will be handed over to a WiMAX network. Initially, the MBMS session is transmitted to MN via the UMTS network while MN periodically sends the neighbor_network_list_query message to the MIBM-SC. The MIBM-SC then provides the probable neighbor networks and network-related information of them to MN through the PoA-specific IEs in the neighbor_network_list_response message. When the RSS value drops below $\text{Threshold}_{\text{\_lgd(UMTS)}}$, the MN will be triggered to scan each candidate network to obtain the link-related information. After that, when the RSS value further drops below $\text{Threshold}_{\text{\_ho(UMTS)}}$, the MN activates the network selection algorithm to evaluate the suitability of each network depending upon our proposed network selection scheme, which will be described in Section 3.3. After completing the evaluation, the MN sends the MIH_N2N_MBMS_HO_Commit message to the selected network to reserve network resources to the MBMS session, and then the selected network responds with a message via MIH_N2N_MBMS_

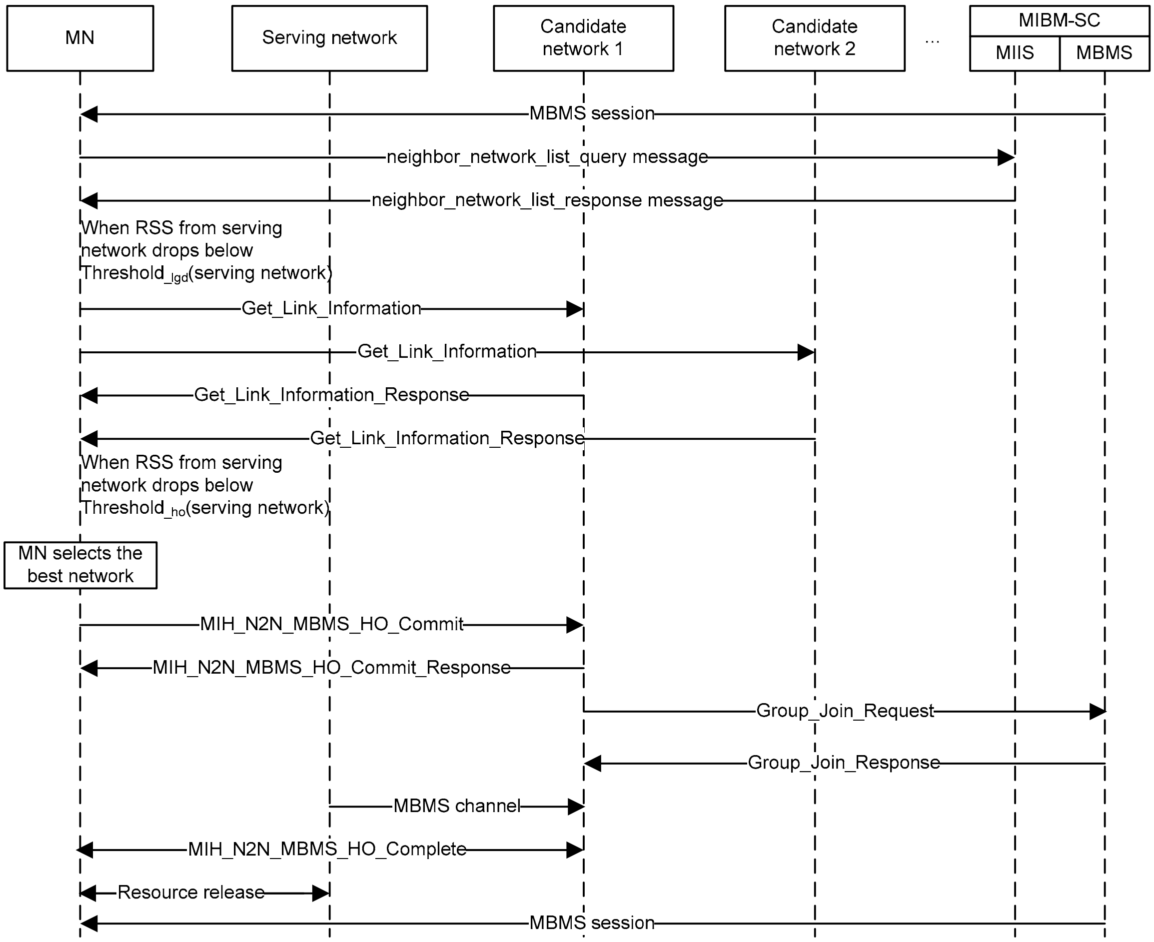

Fig. 6 The proposed handover procedure for MBMS service in heterogeneous networks

Table 1 Definition of the messages and events used in the processing of network discovery

Name	Description
neighbor_network_list_query	This message is sent by MN to MIBM-SC to request the neighboring network list; it includes the location of the MN
neighbor_network_list_response	This message is used by MIBM-SC to respond to MN's query; it contains the neighboring network information
Get_Link_Information	This message will be triggered when RSS drops below a certain threshold; it is used to obtain the link-related information from each neighboring network
Get_Link_Information_Response	This event represents the link-related information obtained by MN from each neighboring network
MIH_N2N_MBMS_HO_Commit	This message is extended from the original MIH message with MBMS features, and it is sent by MN to the selected network to reserve network resource for an MBMS session
MIH_N2N_MBMS_HO_Commit_Response	This message is used by the selected network to respond to the request from MN for resource reservation
Group_Join_Request	This message is sent by the selected network to MIBM-SC to request joining the broadcast/multicast group at the network level
Group_Join_Response	This message is used by MIBM-SC to respond to the request from the selected network at the network level
MIH_N2N_MBMS_HO_Complete	This event is used between MN and the selected network to complete the handover process

HO_Commit_Response with the decision. If network resources have been successfully reserved, a group joining procedure will be executed between the selected network and MIBM-SC. After that, an MBMS channel will be established between the selected network and MIBM-SC in advance before MN leaves the range in which a specific QoS can be guaranteed by the original serving network. After the MBMS channel is established, MN sends MIH_N2N_MBMS_HO_Complete to the selected network and releases the network resource from the serving network to complete the handover process. At last, the MBMS session will be transmitted to MN via the selected network.

There are two points worth highlighting: first, there is an additional logic entity, the handover decision agent for MBMS service (HDA-MBMS), added on top of the MIHF in MN to select the network; second, the new messages used in the execution of the handover are all command services and are extended from the original MIH messages by introducing new parameters such as MN_MBMS_Group and Network_MBMS_Group. Table 2 gives a summary of the IEs implemented in our proposed MIIS part in MIBM-SC.

3.3 Network selection algorithm for MBMS service

3.3.1 Motivation of the proposed network selection algorithms

As mentioned in Section 3.2, when the value of RSS from the connected network drops below the handover threshold ($Threshold_{ho(UMTS)}$ or $Threshold_{ho(WiMAX)}$), MN will determine the target network. In this study, a new functional entity called the network selection agent (NSA) is added on the top of MIHF in MN to carry out the network selection process. The selection scheme is based on our proposed load-aware network capacity estimation algorithm. Fig. 7 presents the internal architecture of the NSA. The interface manager (IM) is used as the interface between the NSA and MIHF to maintain and manage the communication. The policy manager (PM) decides the policy for executing the handover. It can be easily extended or modified by other policies. The network manager (NM) serves to monitor the changes in status of channels and networks, and reports to the PM. The handover director (HD) selects the best target network to satisfy the requirements of the on-going MBMS session and efficiently balance the network loads. There are two transmission schemes for MBMS services. Therefore, the MN that is on the move and receives an MBMS service may have to deal with four types of handover when crossing the coverage: handover from dedicated channel (DCH) to DCH, from common channel (CCH) to CCH, from CCH to DCH, and from DCH to CCH. The first type of handover (from DCH to DCH) can be efficiently executed using any soft vertical handover approach while the second type of handover (from CCH to CCH) can be executed using the selective or soft combining approaches. The last two types of handover (from CCH to DCH, and vice versa), however, have to accommodate dynamic changes of channel and network resources. From the perspective of conventional mobility management of

Table 2 Summary of the IEs implemented in the MIIS part of the proposed MIBM-SC

General information	Access network specific information	PoA specific information	High level information per PoA	Other information
TYPE_IE_LIST_OF_NETWORKS	TYPE_IE_NUMBER_POA	TYPE_IE_POA_ADDRESS	TYPE_IE_POA_SUBNET_INFORMATION	Vendor specific
TYPE_IE_NUMBER_OF_OPERATORS	TYPE_IE_OPERATOR_IDENTIFIER	TYPE_IE_POA_LOCATION	TYPE_IE_POA_CAPABILITIES	N/A
TYPE_IE_LIST_OF_OPERATORS	TYPE_IE_ROAMING_PARTNERS	TYPE_IE_POA_DATA_RATE	N/A	N/A
N/A	TYPE_IE_COST	TYPE_IE_POA_PHY_TYPE	N/A	N/A
N/A	TYPE_IE_NETWORK_SECURITY	TYPE_IE_POA_MAC_TYPE	N/A	N/A
N/A	TYPE_IE_QOS	TYPE_IE_POA_CHANNEL_RANGE	N/A	N/A

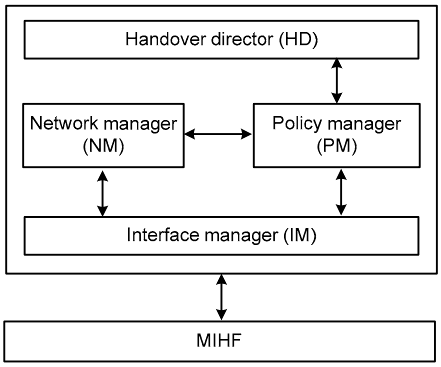

Fig. 7 Internal architecture of the proposed network selection agent (NSA)

the MBMS service in cellular networks, an important handover criterion is to minimize the power consumption for the downlink of the overall network. This is due to the conflict between the advanced technologies of the broadcast/multicast transmission scheme and the unicast transmission scheme in cellular networks. For the broadcast/multicast transmission scheme, the power for downlink is fixed and strong enough to serve the cell-edge MNs with guaranteed QoS, and the service can be shared by a group of MNs. For the unicast transmission scheme, due to the use of self-adaptive modulation and coding technology, transmission power for downlink is dynamically controlled, and an MN that is further from the BS needs more transmission power to be served. Therefore, conventional handover schemes for MBMS service focus mainly on geographical solutions related to find a balance point at which the MN can still be served by the broadcast/multicast transmission scheme in the serving network, while being closer to the target BS to reduce the downlink power consumption. These kinds of scheme consider only power consumption as the network resource and do not consider network capacity as a factor. In such a case, the network with the minimum power consumption may lack the capacity to provide satisfied MBMS service and will lead to the disconnection of the ongoing MBMS session. The power consumption cannot be compared directly due to the heterogeneity of the networks in a heterogeneous environment. Thus, we propose a load-aware network capacity estimation algorithm to evaluate the capacity of networks in different access technologies separately. In this study, we consider a scenario with two types of network, UMTS and WiMAX networks, but the proposed scheme can be easily extended to other types of network. Although the performance of the proposed scheme was evaluated only in our designed scenario, we believe that good results can be obtained in other topologies because the complexity of the designed scenario and the parameters are close to those in a real world implementation.

3.3.2 Capacity estimation algorithm for the UMTS system

The most common form of UMTS uses Wideband Code Division Multiple Access (WCDMA), which is an interference limitation system when a frequency division multiplexing factor of 1 is used. It is necessary to estimate the capacity provided by each NodeB. The capacity of a WCDMA cell can be estimated as follows.

The energy per bit to noise power spectral density ratio (E_b/N_0) is defined as the bit strength of a user divided by the interference spectral density:

$$\left(\frac{E_\mathrm{b}}{N_0}\right)_j=\frac{W}{v_jR_j}\frac{\mathrm{RSS}_j}{\mathrm{TX}_\mathrm{total}-\mathrm{RSS}_j}, \tag{1}$$

where W is the chip rate, RSS_j is the received signal strength of user j, v_j is the activity factor of user j (usually set to 0.58 for voice traffic and 1 for data traffic), R_j is the bit rate of user j, and $\mathrm{TX}_\mathrm{total}$ is the total transmitted signal strength of the NodeB. The first term on the right side of Eq. (1) indicates the processing gain of user j, and the second term indicates the signal to interference ratio. From Eq. (1), we can derive an equation for the received signal strength of user j:

$$\mathrm{RSS}_j=\left(\frac{W}{v_jR_j(E_\mathrm{b}/N_0)_j}+1\right)^{-1}\mathrm{TX}_\mathrm{total}. \tag{2}$$

Usually, we define $\mathrm{RSS}_j=L_j\cdot\mathrm{TX}_\mathrm{total}$, where L_j is the load factor of user j connecting in the cell and can be denoted as

$$\Delta\eta=L_j=\left(\frac{W}{v_jR_j(E_\mathrm{b}/N_0)_j}+1\right)^{-1}. \tag{3}$$

The total load factor for all users connecting to a nodeB is given by

$$\eta = [(1-\alpha)+i]\sum_{j=1}^{N} L_j, \quad (4)$$

where α is the orthogonal factor of the cell, which usually takes a value of 0.5, i is the interference rate from neighbor cells, which is set to 0.55 due to the use of an omnidirectional antenna in the cells. A value of η close to 1 indicates the capacity of a nodeB reaching saturation.

3.3.3 Capacity estimation algorithm for the WiMAX system

Different from the UMTS system, the capacity of a WiMAX base station is estimated according to its throughput:

$$\text{Throughput} = n \cdot \text{BW} \cdot b_m c_r N_{\text{utilFFT}} \left(N_{\text{FFT}} + \frac{N_{\text{FFT}}}{T_{\text{g}}} \right)^{-1}, \quad (5)$$

where n is the sample rate, BW is the channel spacing, b_{m} and c_{r} are the order of modulation and coding respectively, N_{utilFFT} is the number of data subcarriers which is equal to 384 when part of subchannels uses 5 MHz bandwidth, N_{FFT} is the number of fast Fourier transform (FFT) samples, and T_{g} is the cyclic prefix for the OFDMA system, T_{g}=1/8.

For handover from WiMAX to UMTS, our proposed scheme considers the total load factor of the network, and the network with a smaller value of η (which means a higher priority) is chosen. On the other hand, while performing handover from UMTS and WiMAX, throughput of each WiMAX network is the dominating factor and the one with the maximum throughput is chosen.

3.4 Transmission mode selection

Various related issues have been investigated by the academic and industrial bodies. However, most of these issues are related to 3GPP cellular networks and a new functional entity was proposed to count the number of MNs in each cell to determine which transmission mode should be used. However, using the number of MNs as the only metric to make a decision on transformation is obviously not precise. This is because a single cell-edge MN may consume more network resource compared with many MNs located closer to the BS. Thus, some mixture methods (Soares *et al*., 2006; Alexiou *et al*., 2010) and grouping problems (Xylomenos, 2005; Sanigepalli *et al*., 2006; Chaudhry and Khan, 2008) were studied to optimize the transformation decision. To our best knowledge, there has been little research related to the heterogeneous network environment. Thus, in this study, we propose a novel approach to deciding when the transformation should be carried out in a heterogeneous network environment. The proposed approach is based on the network capacity estimation algorithm described above. There are two thresholds, Threshold$_{\text{_nc(UMTS)}}$ and Threshold$_{\text{_nc(WiMAX)}}$, defined as percentages of the total network capacity, and used as the transfer threshold in UMTS and WiMAX networks, respectively. When the network capacity consumed by unicast transmission achieves average Threshold$_{\text{_nc(UMTS)}}$ or Threshold$_{\text{_nc(WiMAX)}}$, the transformation process will be prepared for transfer to the broadcast/multicast transmission mode. The values of Threshold$_{\text{_nc(UMTS)}}$ and Threshold$_{\text{_nc(WiMAX)}}$ are determined by the mapping between power consumption and network capacity consumption. The settings of Threshold$_{\text{_nc(UMTS)}}$ and Threshold$_{\text{_nc(WiMAX)}}$ are based on the percentage of network capacity when the power consumption of the unicast transmission mode is equal to the power consumption of the broadcast/multicast transmission mode. In order to avoid unnecessary transformation from unicast transmission mode to broadcast/multicast mode and vice versa, a timer is adopted as well. The thresholds must be achieved for a certain time, and then the transformation will be executed.

Algorithms 1 and 2 describe the overall procedures of the handover, including the network selection process and transmission mode selection process from UMTS to WiMAX and vice versa. For handover from UMTS to WiMAX, when the MN moves toward the edge of the coverage area, two stages are involved. First, when the value of RSS from the connected UMTS network drops below Threshold$_{\text{_lgd(UMTS)}}$, MN scans the selected neighbor networks to obtain the link information. Second, a handover is initiated when the value of RSS drops below Threshold$_{\text{_ho(UMTS)}}$. At this stage, the MN calculates the network capacity of the current network and nearby UMTS and WiMAX networks based on

Eqs. (4) and (5). These values are compared. In general, the proposed scheme prioritizes horizontal handover over vertical handover because horizontal handover is less complicated, and introduces lower delay. Meanwhile, the network working on broadcast/multicast transmission mode has a higher priority than the network working on unicast transmission mode. With these factors in mind, a neighbor UMTS network with RSS higher than $\text{Threshold\_}_{\text{lgd(UMTS)}}$ works on broadcast/multicast transmission mode, and the best network capacity is chosen. Otherwise, the UMTS network with RSS higher than $\text{Threshold\_}_{\text{lgd(UMTS)}}$ works on unicast transmission mode and the best network capacity is chosen. Alternatively, a vertical handover is performed by choosing a WiMAX network with the greatest value of network capacity, working on broadcast/multicast transmission mode and with RSS greater than $\text{Threshold\_}_{\text{lgd(WiMAX)}}$. The session will be dropped only under the worst case scenario, in which both UMTS and WiMAX networks fail to fulfill the above requirements.

The handover process for an MN in a WiMAX network travelling to another network is similar to the previous case. The MN scans the neighbor networks to obtain the link information when its RSS value drops below $\text{Threshold\_}_{\text{lgd(WiMAX)}}$. Subsequently, if its RSS value drops below $\text{Threshold\_}_{\text{ho(WiMAX)}}$, a handover process is initiated by first calculating its current network capacity and the capacity values for neighbor networks. Again, horizontal handover has higher priority than vertical handover for the reason explained above.

Algorithm 1 Procedure of handover from UMTS to WiMAX

```
IF the value of RSS from the current network ≤ the threshold of link going down in UMTS
    MN scans each candidate network to obtain link information
ELSE MN continues connecting to the current network
ENDIF

IF the value of RSS from the current network ≤ the threshold of handover in UMTS
    MN calculates the network capacity of the current UMTS and each neighbor network
ELSE MN continues connecting to the current network
ENDIF

IF any RSS from neighbor UMTS networks ≥ the threshold of link going down in UMTS AND there exists a neighbor UMTS network working on the broadcast/multicast mode AND any network capacity of UMTS networks ≥ network capacity of the current network

    select the network working on broadcast/multicast mode and with the lower network load
      // Horizontal handover will be executed

ELSEIF any RSS from any UMTS ≥ the threshold of link going down in UMTS AND there does not exist a neighbor UMTS network working on the broadcast/multicast mode AND any network capacity of UMTS ≥ network capacity of the current network

    select the network with the lower network load
      // Horizontal handover will be executed

ELSEIF any RSS from the neighbor WiMAX network ≥ the threshold of link going down in WiMAX AND there exists a neighbor WiMAX network working on the broadcast/multicast mode AND any network capacity of the WiMAX network ≥ network capacity of the current network

    select the network working on broadcast/multicast mode and with the maximum throughput
      // Vertical handover will be executed

ELSEIF any RSS from any WiMAX ≥ the threshold of link going down in WiMAX AND there does not exist a neighbor WiMAX network working on the broadcast/multicast mode AND any network capacity of the WiMAX network ≥ network capacity of the current network

    select the network with the maximum throughput
      // Vertical handover will be executed
ELSE
    MBMS session will be dropped
ENDIF
```

Algorithm 2 Procedure of handover from WiMAX to UMTS

```
IF the value of RSS from the current network ≤ the threshold of link going down in WiMAX
    MN scans each candidate network to obtain link information
ELSE MN continues connecting to the current network
ENDIF

IF the value of RSS from the current network ≤ the threshold of handover in WiMAX
    MN calculates network capacity of the current WiMAX and each neighbor network
ELSE MN continues connecting to the current network
```

```
ENDIF

IF any RSS from neighbor WiMAX networks ≥ the
  threshold of link going down in WiMAX AND there ex-
  ists a neighbor WiMAX network working on the broad-
  cast/multicast mode AND any network capacity of Wi-
  MAX networks ≥ network capacity of the current
  network

  select the network working on broadcast/multicast
    mode and with the maximum throughput
    // Horizontal handover will be executed

ELSEIF any RSS from any WiMAX ≥ the threshold of
  link going down in WiMAX AND there does not exist a
  neighbor WiMAX network working on the broadcast/
  multicast mode AND any network capacity of WiMAX
  ≥ network capacity of the current network

  select the network with the maximum throughput
    // Horizontal handover will be executed

ELSEIF any RSS from the neighbor UMTS network ≥
  the threshold of link going down in UMTS AND there
  exists a neighbor UMTS network working on broadcast/
  multicast mode AND any network capacity of the UMTS
  network ≥ network capacity of the current network

  select the network working on broadcast/multicast
    mode and with lower network load
    // Vertical handover will be executed

ELSEIF any RSS from any UMTS ≥ the threshold of
  link going down in UMTS AND there does not exist a
  neighbor UMTS network working on the broad-
  cast/multicast mode AND any network capacity of the
  UMTS network ≥ network capacity of the current net-
  work

  select the network with lower network load
    // Vertical handover will be executed
ELSE
  MBMS session will be dropped
ENDIF
```

4 Simulation and results

4.1 Simulation model

In this study, a system level simulation study was carried out using ns-2 (version 2.31) with the MIH module developed by NIST and EvalVid (Klaue *et al*., 2003). For performance evaluation, we measured the packet loss rate, throughput, handover delay, cell load, bandwidth usage, and PSNR. Table 3 gives the overall mapping of QoS classes between UMTS and WiMAX. Class 2 service with a simulation value of 64 kb/s video streaming was used to simulate an MBMS user service and traffic was sent from the correspondent node (CN) to the mobile node (MN). The topology used consisted of 20 UMTS cells overlaid with 20 WiMAX cells to simulate a heterogeneous network (Fig. 8). The MN moved within a rectangle area of 16 km×12 km, located at the center of the topology. Table 4 gives the network parameters set for each network. We assume that the radius of a WiMAX cell is smaller than that of a UMTS one, and each UMTS cell overlaps with a WiMAX cell. All NodeBs were connected to an access router and all the BSs were connected to another access router with a data transmission rate of 100 Mb/s and a link delay of 30 ms. Both access routers communicate to MIBM-SC via a link with a data transmission rate of 100 Mb/s and 30 ms delay. CN was connected to MIBM-SC through a link with a data transmission rate of 100 Mb/s and 15 ms delay. Fig. 9 presents the network simulation scenario. In this scenario, the proposed MIBM-SC acts as the entry point for the CN to initiate MBMS bearer

Table 3 The mapping of the QoS classes between UMTS and WiMAX

Class No.	UMTS	WiMAX
1	Conversational	UGS
2	Streaming	rtPS
3	Interactive	nrtPS
4	Background	BE

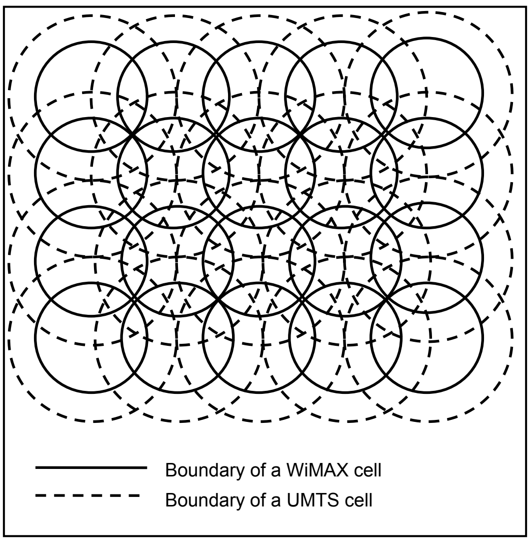

Fig. 8 Simulation topology for providing MBMS service

services to schedule and transmit the MBMS user service to MN. Again, all the procedures illustrated in 3GPP TS 23.246 (3GPP, 2010) to provide MBMS service have been followed. In this study, we consider only the case in which broadcast/multicast is used in the access network; broadcast/multicast in the core network and between the corresponding node (CN) and MIBM-SC is not considered. However, the simulated network scenario can be easily extended to simulate broadcast/multicast services at different levels. Table 5 gives the simulation parameters. In this simulation, we compared the proposed scheme with the basic MIH scheme, i.e., the fast Mobile IPv6 handover scheme. We also compared it with other related work such as Mehdi *et al*. (2011).

Table 4 Network parameters set for UMTS and WiMAX in the simulation

Parameter	Value/Description
UMTS	
Radius	3 km
Downlink BW	384 kb/s
Uplink BW	384 kb/s
Downlink TTI	10 ms
Data rate of Iub	622 Mb/s
Delay of Iub	15 ms
Type of antenna	OmniAntenna
Chip rate	3.84 MChip/s
WiMAX	
Radius	2 km
Modulation BW	5 MHz
Number of subcarriers	384
Number of fast Fourier transform samples	512
Number of subcarriers per subchannel	48
Number of subchannels	8
Type of antenna	OmniAntenna
Modulation	OFDM/16QAM
Propagation model	Two ray ground

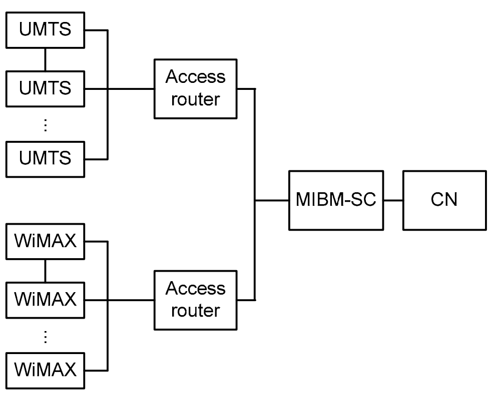

Fig. 9 Network simulation scenario

Table 5 Parameters used in simulation

Parameter	Value/Description
Area size	20 km×20 km
Simulation time	1000 s
Speed	3–30 m/s
Mobility model	Random way point
Number of MNs	1000

4.2 Results and discussion

The parameters used in the performance evaluation are the packet loss rate, throughput, handover delay, cell load, bandwidth usage, and PSNR. Fig. 10 shows the simulation results of the average packet loss rate of an MN in the simulation versus different numbers of MN deployed. As the number of MNs deployed increases, the packet loss rate increases in all handover schemes. The proposed scheme gives the best performance with an average packet loss rate of 1.56% as compared to 3.32% using the fast mobile IPv6 handover scheme and 4.02% using the MIH-based handover scheme. The superior performance of the proposed scheme is due to its ability to balance the network load. As system load increases, the load at each cell becomes unbalanced; thus, when an MN moves from one location to another, the fast mobile IPv6 handover scheme and MIH-based handover scheme that make the handover decision solely based on RSS but not the QoS may make a handover to a network that is lacking resources, thus causing more packet loss. Note that in the proposed scheme the packet loss rate is only about 4.96% at the maximum number of MNs deployed. According to IEEE 802.20 ITU-T Recommendation Y.1541 (IEEE, 2002), packet loss should be less than 1% for video over mobile networks. We can conclude that the proposed scheme satisfies that requirement of video over mobile networks if the number of MNs deployed in the topology is smaller than 600.

Fig. 11 illustrates the average throughput of an MN in the simulation versus the number of MNs deployed. A drop in throughput can be observed as the number of MNs increases because the load at each cell is unbalanced when network load increases. The proposed scheme gives the best performance with an average throughput of 93.15% as compared to the fast mobile IPv6 handover scheme with average 90.33% and the MIH-based handover scheme with average 85.27%. There are two reasons contributing to this superior performance. First, the proposed method gives higher priority to horizontal handover, which is faster and less complex, over vertical handover. That action can save network resources. Second, network capacity is also considered in choosing the most suitable network to which to handover the connection. This consideration not only reduces the probability of handover failure, but also distributes the workload more evenly among the networks. The fast mobile IPv6 handover scheme and the MIH-based handover scheme, which make handover decisions without considering network capacity, may make a handover to a network short of resources, leading to a drop in throughput. It is obvious that the proposed scheme gives a more stable performance regardless of the number of MNs.

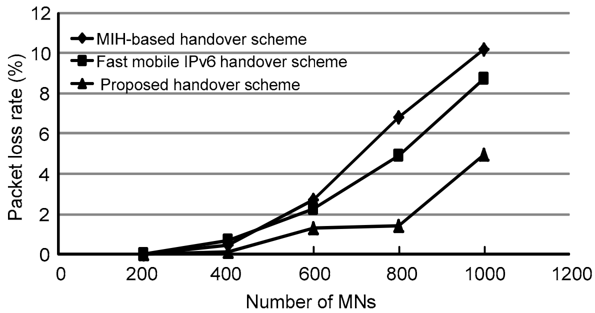

Fig. 10 Average packet loss rate of a mobile node (MN) versus the different numbers of MNs

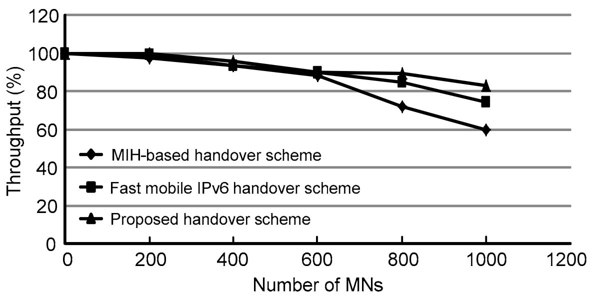

Fig. 11 Average throughput of a mobile node (MN) versus the different numbers of MNs

Fig. 12 presents the handover delay of the MN monitored in simulation versus the number of MNs deployed, with the MN moving at 3 and 25 m/s, respectively, to simulate walking and driving. Due to the delay-sensitive feature of MBMS session, handover delay becomes an important indicator for the performance of the proposed scheme. In this work we define handover delay as the time between the last packet received from the previous PoA and the first packet received from the new PoA. Fig. 12a shows that as the number of MNs deployed increases, the handover delay increases in all handover schemes. The fast mobile IPv6 handover scheme gives the best performance with an average of 148.8 ms, and the proposed scheme gives the worst performance with an average of 193.4 ms. This is because in the proposed scheme, as the number of MNs increases, the network load increases and leads to the load at each cell being unbalanced, so it takes more time to calculate the target network. From IEEE 802.20 ITU-T Recommendation Y.1541, handover delay should be less than 280 ms for non-interactive video. For interactive video, a handover delay of 100 ms is acceptable for class 0 and up to 400 ms for class 1 ITU-T Recommendation Y.1541 (IEEE, 2011). From the results, we can see that although the proposed scheme gives the worst performance in handover delay, it still satisfies the requirements from IEEE 802.20 ITU-T Recommendation Y.1541. There is a tradeoff between handover delay and other performances. Fig. 12b shows the same results but for movement at 25 m/s. Again, the proposed scheme gives the worst performance with an average of 254.2 ms.

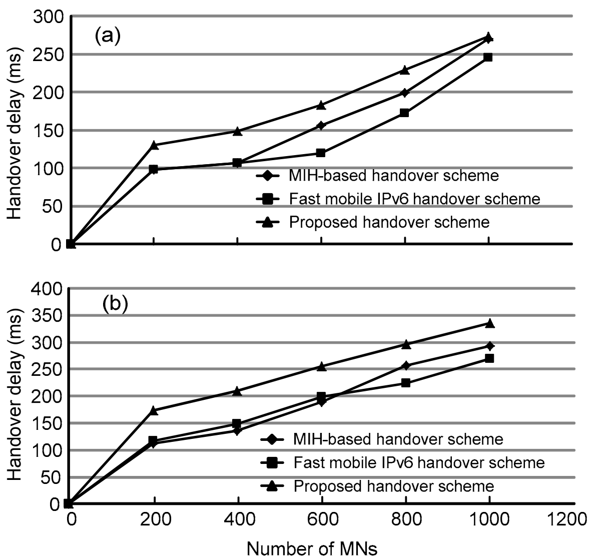

Fig. 12 Average handover delay of a mobile node (MN) versus the different numbers of MNs

(a) The MN moves at 3 m/s; (b) The MN moves at 25 m/s

Fig. 13 gives the handover delay of the MN monitored in simulation versus the movement speed of MN, when 600 MNs were deployed in the scenario. There is an increase in handover delay as the movement speed of the MN increases. Compared to the fast mobile IPv6 handover scheme and MIH-based handover scheme, the proposed scheme presents the worst performance in handover delay with an average of 254.2 ms and a maximum handover delay at 336 ms. However, we did a comparison on handover delay with Mehdi *et al*. (2011), in which the best handover delay reported was between 400 and 500 ms. The proposed scheme still gives a better performance at all speeds.

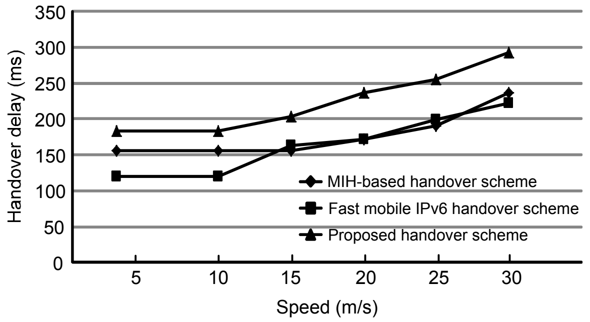

Fig. 13 Average handover delay of a mobile node (MN) versus the different speeds of movement

Fig. 14 presents the standard deviation of cell load versus the different numbers of MNs deployed. The proposed scheme gives the best performance with an average standard deviation of 17.73 as compared to 67.32 using the fast mobile IPv6 handover scheme and 60.2 using the MIH-based handover scheme. This is due to the fact that the proposed scheme is a load-aware scheme that distributes the workload to cells with lower load. It can also be observed that at the beginning, there is an increase in the standard deviation of cell load as the number of MNs increases; this is because, at the initial time, the number of MNs is small and the load at each cell is unbalanced. After a further increase in the number of MNs, the standard deviation of cell load tends to decrease. Another important finding is that the proposed scheme has smoother changes of the standard deviation of cell load with change in the number of MNs compared to the other two schemes. This is because the proposed scheme is load-aware based, whereas the other two schemes do not consider cell load.

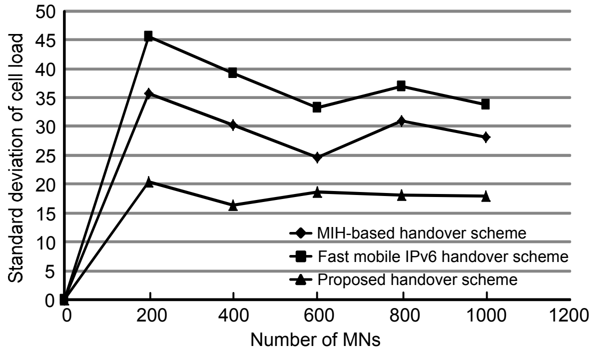

Fig. 14 Standard deviation of cell load versus the different numbers of mobile nodes (MNs)

Fig. 15 shows the average bandwidth usage versus the different numbers of MNs deployed. As the number of MNs increases, bandwidth usage in all three schemes increases as more traffic is transmitted. The proposed scheme gives the minimum bandwidth usage with an average of 32.44% as compared to 51.32% and 59.42% by using the MIH-based handover scheme and fast mobile IPv6 handover scheme, respectively. The less bandwidth usage in the proposed scheme is due to the fact that broadcast/multicast transmission mode has a higher priority than unicast transmission mode during network selection. Hence, the number of MNs that connect to the broadcast/multicast transmission channel is increasing and thus the total bandwidth usage decreases.

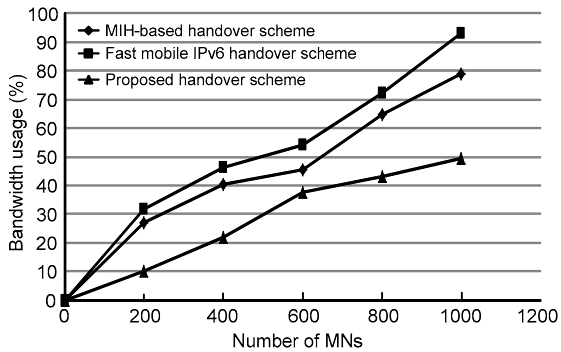

Fig. 15 Average bandwidth usage versus the different numbers of mobile nodes (MNs)

As described in Fig. 10, the packet loss during handover is related to the number of MNs deployed in the scenario. Packet loss affects the received video quality. Fig. 16 gives the MBMS user service's average PSNR of the MN monitored in simulation versus the different numbers of MNs deployed when handover occurred. As the number of MNs increases, there is a drop of the PSNR in all handover schemes. The proposed scheme shows the best performance with an average of 28.41 dB as compared to 21.28 dB and 17.97 dB by using the MIH-based handover scheme and fast mobile IPv6 handover scheme, respectively. From these results, we believe that the proposed scheme has the capability to guarantee the quality of an MBMS user service.

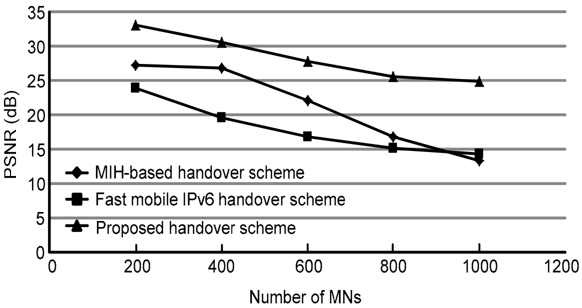

Fig. 16 Average PSNR for a certain mobile node (MN) versus the different numbers of MNs

5 Conclusions

The main motivation of this paper is to propose an approach for providing seamless MBMS in a heterogeneous network environment. Our approach is based on a newly proposed functional entity, MIBM-SC. A protocol extended from the MIH standard is proposed to effectively collect information from networks and broadcast/multicast groups. The architecture of this approach is based on the MIH standard, the MBMS architecture, and 3GPP specified enhancements to non-3GPP accesses, to minimize any modification of current network architecture.

We also propose a novel handover scheme for enhancing MN mobility experience in the provision of MBMS in heterogeneous networks, which is a network-assisted mobile-controlled handover scheme. Additionally, a network selection scheme and a cell transmission mode selection scheme are proposed for selecting the best target network and best transmission mode for the cell. Both schemes are based on a load-aware network capacity estimation algorithm. Through extensive simulations, it is shown that the proposed scheme enhances the MN mobility experience in the provision of MBMS in terms of packet loss rate, throughput, handover time, cell load, bandwidth usage, and PSNR.

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