Service Continuity for eMBMS in LTE/LTE-Advanced Network: Standard Analysis and Supplement

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***Abstract*—Evolved Multimedia Broadcast Multicast Service (eMBMS) has recently attracted a great attention from the telecommunication industry. All big companies in the field have invested and intended to deploy eMBMS as the broadcast solution in response to the immense demand in multimedia traffic. The eMBMS, also known as LTE broadcast, can provide high quality live video streaming services for a large number of users simultaneously in an open area such as a stadium or arena during an entertainment or sport event. Nowadays, in a high mobility environment, maintaining the service reception for moving users becomes a crucial task for mobile operators and service providers. Unfortunately, the support from LTE standard for eMBMS service continuity is very limited at the moment and in many cases, the users cannot continue to receive their desired services. To overcome the limitation in the standard, this paper will present a novel method to ensure the service continuity as well as to reduce the service interruption time during handover period for eMBMS users in the mobility context.**

***Index Terms*—eMBMS, service continuity, handover, LTE, LTE-Advanced.**

I. Introduction

The parallel evolution of mobile technologies and devices has allowed people to access high quality services with excellent experience. According to the recent Cisco's report [9], the global mobile data traffic grew 70 percent in 2012 (from 520 to 885 petabytes per month) and was nearly twelve times greater than the total global Internet traffic in 2000. The report pointed out video content is the biggest contribution to the mobile traffic volume and has exceeded 50 percent of the global mobile data traffic for the first time last year. A study from Ericsson [10] states that the mobile traffic is expected to continue increasing 12-fold by 2018. In the survey with US consumers also done by Ericsson, 68 percent respondents said they would watch more TV on their hand-held devices while on move and these interesting services include local news, weather information, movies, sitcoms and sports.

To meet the growing demand for mobile multimedia services, the Third Generation Partnership Project (3GPP) has defined the Multimedia Broadcast Multicast Service (MBMS) [1] as a solution for delivery multimedia content to a large number of users at the same time. Being built on top of 3GPP cellular network, MBMS was first introduced in Universal Mobile Telecommunications System (UMTS) standard and has been updated to evolved-MBMS (eMBMS) in Long Term Evolution (LTE) networks. With the improved performance thanks to OFDM and single frequency network (SFN) in LTE, eMBMS is now considered as the main competitor to the well-known Digital Video Broadcasting (DVB) technology.

The ability of reusing the LTE cellular infrastructure for broadcasting together with flexible and high data rates, has persuaded many telecommunication companies to invest and deploy eMBMS as an efficient and low-cost solution to deliver multimedia content. Ericsson and Qualcomm, two of the biggest telcos, demonstrated their evolved Multimedia Broadcast Multicast Services at Mobile World Congress (MWC) 2012 in Barcelona with the scenario of a live-football-match in a stadium area. Earlier this year, in the international Consumer Electronics Show (CES 2013), Qualcomm Labs in conjunction with Verizon Wireless and infrastructure provider Ericsson have showed their first commercial demonstration of LTE Broadcast eMBMS and announced plans to launch the services in 2014.

The Australian operator Telstra has also announced plans to expand its current LTE network coverage and deploy the Ericsson's LTE Broadcast solution which is based on three of the latest standards: HEVC (High Efficiency Video Coding), MPEG-DASH (Dynamic Adaptive Streaming over HTTP) and eMBMS. Alcatel-Lucent and 4G chipmaker Sequans Communications have announced that their eMBMS solution has been tested successfully. This robust eMBMS service which is based on Alcatel-Lucents LTE infrastructure equipment and Sequans eMBMS-capable LTE chipsets have worked well end-to-end and is commercially viable.

In the Asian side, the largest telecommunications equipment maker in the world, Huawei has launched its eMBMS innovation center to develop eMBMS and introduced their end-to-end solution to support broadcast video delivery in LTE networks. The Korean company Samsung has also participated in the video broadcasting market by cooperating with test-equipment manufacturer, Anritsu, to demonstrate LTE broadcast with intention to commercialize the service in the near future.

All the attention from the industry clearly shows that eMBMS will become a key component in addressing the exponential growth in mobile multimedia traffic. Therefore, providing good eMBMS services would be the priority for the mobile network operators who want to stay ahead in this huge potential market.

One key feature of LTE network is supporting the seamless mobility of users across the network, hence, service continuity for user equipments (UE) that are using eMBMS while being mobile plays an important role in maintaining service quality. However, at this moment, the service continuity for LTE broadcast is still very limited in the standard. The motivation of this paper is to present the standard analysis and completed techniques that ensure service continuity in eMBMS.

The rest of this paper is organized as follow: Section II discusses the eMBMS services in a mobility environment, Section III will analyze the current broadcast service continuity in the 3GPP standard while our proposed methods to ensure the continuity for eMBMS will be mentioned in Section IV, finally the conclusion and discussion for future works are given in section V.

II. eMBMS in LTE and Mobility Issue

MBMS over a Single Frequency Network (MBSFN) transmission is a technique that allows multiple cells transmit the same content using an identical waveform at the same time. Cells participating in MBSFN transmission should be synchronized tightly in time. To support MBSFN transmission in a LTE system, the base stations are divided into different groups depending on their location and the eMBMS services that they are providing. In [1] and [4], new concepts listed below are introduced to help us understand how eNBs are organized for eMBMS transmission:

- **MBMS Service Area**: The area within which data of a specific MBMS session (or service) are sent. Each individual MBMS session of an MBMS Service may be sent to a different MBMS Service Area.
- **MBSFN Synchronization Area**: an area where all eNodeBs can be synchronized and perform MBSFN transmissions. The MBSFN Synchronization Areas are independent from the definition of MBMS Service Areas.
- **MBSFN Area**: an MBSFN Area consists of a group of cells within an MBSFN Synchronization Area of a network, which are co-ordinated to achieve an MBSFN Transmission. Except for the MBSFN Area Reserved Cells, all cells within an MBSFN Area contribute to the MBSFN Transmission and advertise its availability.
- **MBSFN Area Reserved Cell**: A cell within a MBSFN Area which does not contribute to the MBSFN Transmission.

It is worth noting that an MBSFN Synchronization Area is capable of supporting more than one MBSFN Areas or MBMS Service Area. Conversely, an MBMS Service Area may include one or more MBSFN Synchronization Area or MBSFN Area. The maximum size of a MBSFN Area can be equal to the size of a MBSFN Synchronization Area. From these definitions we can see that the ability of providing a specific eMBMS service of a base station is decided by its own type (normal or reserved cell) and by the group (MBSFN Area) it belongs to. For that reason, when a mobile terminal moves across base stations in the network, depending on the services transmitted by the current eNB and the new one, the user can either continue to receive the desired service or stop getting it.

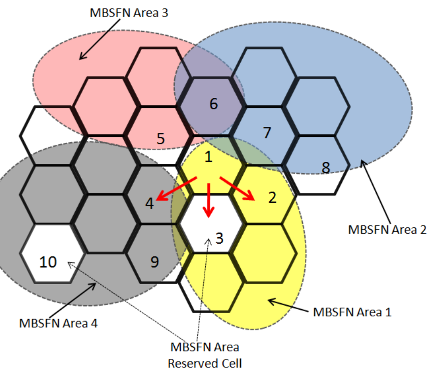


Fig. 1: MBSFN Area and eNB example

An example of eMBMS network configuration with several MBSFN Areas and many LTE base stations is depicted in Fig. 1. In the figure, each cell is represented by a hexagon area and the MBSFN Areas are eclipse areas in different colors. Cell 1 and 2 belong to MBSFN Area 1, cell 6, 7 and 8 are part of MBSFN Area 2 and so on; Cell 3 and 10 are two MBSFN Area reserved cells that do not participate in the eMBMS transmission. There is an overlap between MBSFN Area 2 and 3, i.e. cell 6 belongs to these both MBSFN Areas.

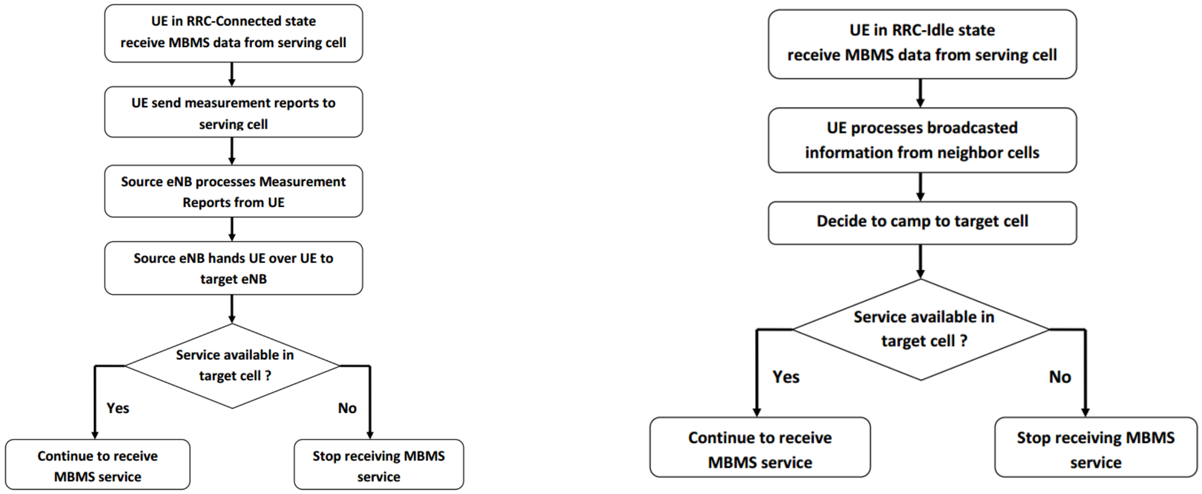
Fig. 1 also shows possible scenarios when a LTE terminal moves from one cell to a neighbor cell while receiving eMBMS service. These scenarios can basically be classified as follow:

Case 1: The UE is receiving an eMBMS service and moving to an MBSFN Area reserved cell. This is the case when a mobile device moves from cell 1 to cell 3.

Case 2: The UE moves to a target eNB which is in the same MBSFN Area with serving eNB. The scenario occurs when a UE is moving within MBSFN Area 1, from cell 1 moves to cell 2 or from cell 4 to cell 9 in MBSFN Area 4.

Case 3: The UE moves to a new eNB which does not belong to the same MBSFN Area with the serving eNB. The case happens when a terminal leaves MBSFN Area 1 to enter MBSFN Area 4 (cell 1 to cell 4).

Above are three basic mobility scenarios for an eMBMS capable LTE terminal. Among these scenarios, the LTE standard can only assure the service continuity for UE moving



(a) Handover procedure

(b) Reselection procedure

Fig. 2: Service continuity in 3GPP standard Rel-10

within an MBSFN Area (case 2). Our proposed method will address the solution for other cases. The scenario would be more interesting and complicated if we take into account the multi-frequency and/or Carrier Aggregation (CA) deployment in LTE network, which will be discussed later in this paper.

III. eMBMS Service Continuity in LTE Standard

In LTE network, a mobile entity is in either RRC-Connected state or RRC-Idle state and it can receive eMBMS services in both states. As a result, when studying the mobility of a user who is utilizing eMBMS services, we usually consider two situations: when that user is in the connected mode and when it is in the idle mode.

A. 3GPP Specification Release 10 and before

According to the 3GPP release 10 (Rel-10) and previous specifications, there is no specific mechanism supporting the mobility for UEs that are receiving an eMBMS service [1]. That means the UEs in RRC-Idle state will perform reselection procedure and in RRC-Connected state, they will follow the normal handover procedure in unicast transmission. Also, no new information is provided to help the UE in switching reception between MBSFN Areas neither.

In connected mode, the mobile terminal detects, measures the attributes of neighboring cells while moving and sends measurement results to the serving cell. Based on these reports, the serving cell will decide to make handover if necessary. The source eNB shall trigger the procedure by sending a Handover Request to the target eNB. If radio resources are allocated, UE can connect to a new cell and listen to eMBMS control information, which is conveyed in System Information Block Type 13 (SIB13), in order to know the MBSFN Area information. If the new cell is in the same MBSFN Area with the old cell, UE continue to receive the eMBMS service using the configuration in old cell. If they belong to different MBSFN Areas, the UE has to listen to the MCCH message which gives the detail information of a particular service (ID, position of radio resource allocated for that service) in the new cell. If the service that UE is receiving or interested in, is available, then it will continue receiving eMBMS data, otherwise, UE cannot receive MBMS data anymore. Fig. 2a describes the standard handover for the device receiving eMBMS service while on move.

In idle mode, UE performs cell reselection to support the mobility as given in Fig. 2b. During an eMBMS reception, UE obtains the broadcast information from neighbor cells and uses these information in evaluating process for cell reselection decision. After choosing one eNB with the highest priority, UE will camp to that eNB. Then, similar to the connected mode, the UE it will check SIB13 and MCCH message in new cell to receive the desired service if available.

We can realize that the service continuity can be surely maintained only in the case where the source and target cell are in the same MBSFN Area. With the other cases, there is a possibility that the eMBMS service could be dropped. The reason is the source eNB (or UE) decides to hand UE over (or to camp to) a target eNB without knowing which eMBMS services are available in that eNB. As a result, the chosen target cell (may be the one with maximum signal strength among neighbor cells) might not provide the eMBMS services that UE is interested in.

B. 3GPP Specification Release 11

With the multi-frequency deployment in LTE network, eMBMS services can be provided on more than one frequency. In the latest 3GPP specification (Rel-11), supplements were introduced to support the continuity of eMBMS by guiding UEs to find their interested services on other frequencies.

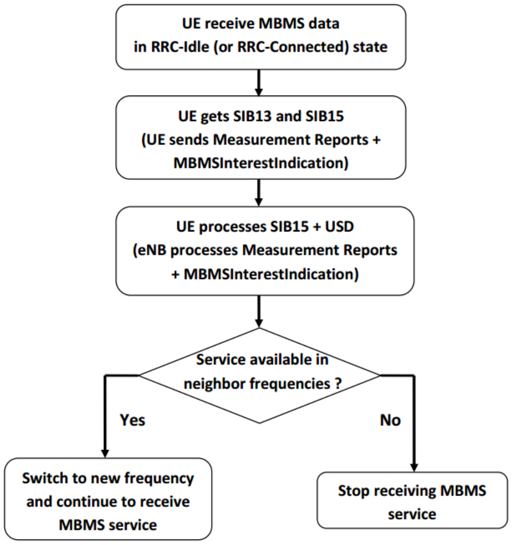


Fig. 3: Service continuity supported in Rel-11

To avoid the need for LTE mobile devices to read the eMBMS related information on neighboring frequencies in SIB13 and MCCH message, the network informs UEs which eMBMS services are provided on which frequency through a combination of User Service Description (USD) and System Information Block Type 15 (SIB15) [2]. In the USD, each service will be associated with its own Service Identity which is included in the Temporary Mobile Group Identity (TMGI), the frequencies and the MBMS Service Area Identities (SAIs) belong to the MBMS service area. The SIB15 has a list of neighboring frequencies together with the current frequency. Each frequency in the list contains a list of all SAIs supported by that frequency. Combining the information in USD and SIB15, the UE can determine which frequency provides the eMBMS services it is receiving or interested in.

The information obtained from USD and SIB15 is very important to the UE that is interested in receiving eMBMS services. In the idle state, when a user is moving out of one cell, it can prioritize to camp to the cells on the frequencies providing its desired eMBMS service. In such way, the continuity of eMBMS service will be maintained if at least one neighbor frequency provides the service required by the UE.

In the connected mode, besides sending the measurement reports like in unicast transmission, the UE who is receiving or interested in eMBMS service will send one RRC message to the serving cell as a response to the SIB15. This message is named MBMS Interest Indicator and it consists of a list of frequencies on which the UE is receiving or interested to receive eMBMS services. In addition, this message also contains one bit in order to indicate to the serving cell whether the UE prefers eMBMS reception to normal unicast reception. The current eNB will use this information in choosing the cell to hand the UE over. The candidate cell on the frequency providing the appropriate eMBMS services will be in first priority and when the UE switch to this frequency, it can continue to receive its interested service in the target cell.

The procedure to support the MBMS service continuity in Rel-11 is depicted in Fig. 3. With this additional enhancement, the service continuity support for eMBMS has been improved. The UE can now camp or be handed over to the cell on the frequency that transmits the service it wants. However, the continuity of eMBMS service is still not assured completely. For example, in the network where only one frequency is deployed or in the case non of neighbor frequencies provide the desired eMBMS service (but it is available in another MBSFN Area), we will turn back to the situations previously presented in Fig. 2. Our methods mentioned in next section will complete the solution in the standard to ensure the continuity for eMBMS in LTE networks.

IV. Proposed Solution for Service Continuity in eMBMS

The idea of our method is taking the information of services provided in the neighbor cells into account when choosing candidates for handover or reselection procedure. Knowing where the desired services are available will help the serving eNB chooses the right target eNB to hand UE over or help the terminal camp to a suitable cell. Although the idea is in general similar to the LTE standard Rel-11, our method does have the difference: we focus on the neighbor cells and their supporting eMBMS services instead of the services transmitted on other frequencies. Moreover, the proposed method will help the UE to find the neighbor cells that have its interested services in the same frequency with the current cell before searching on the other frequencies.

In idle mode, the LTE terminal decides itself which cell it should camp to when entering the overlap region among base stations. From the SIB15, UE knows on which frequency its desired services are available. But in the case there is only one frequency deployed in the network or no frequency provides the required services except the current one, the UE does not know which cell it should choose. It then select the cell with the highest signal strength and the eMBMS service continuity is not guaranteed. We can see that the lack of information about services supported by neighboring cells (on the same

Current Cell	MBSFN Area 1	Service 1 (TMGI #1)
		Service 2 (TMGI #2)
	MBSFN Area 2	Service 3 (TMGI #3)
		Service 4 (TMGI #4)
Neighbor Cell 1	MBSFN Area 2	Service 3 (TMGI #3)
		Service 4 (TMGI #4)
Neighbor Cell 2	MBSFN Area 3	Service 5 (TMGI #5)
Neighbor Cell 3	MBSFN Area 1	Service 1 (TMGI #1)
		Service 2 (TMGI #2)
	MBSFN Area 4	Service 6 (TMGI #6)

Fig. 4: eMBMS Service Support Information

frequency with serving cell) in other MBSFN Areas may cause the discontinuity. Therefore, the UE needs to obtain the supported eMBMS service information of the neighbor cells. To remind, the SIB13 broadcasted by one cell contains all information about MBSFN Areas (MBSFN Area ID, location of the corresponding MCCH message) that cell belongs to. However, the list of eMBMS services in each MBSFN Area and their actual position together with other information are given in MCCH message. In our method, we propose that in the SIB13, the base station should broadcast the list of all eMBMS services (only the service ID or TMGI value [3]) supported by its MBSFN Areas as well as by its neighbor cell on the same frequency layer.

The current cell can collect the eMBMS services supported by its neighbor cells either from a network entity or directly from the neighbors through X2 interface. The network entity mentioned above can be the Multicell/Multicast Coordination Entity (MCE) which is responsible for the admission control and the allocation of the radio resources used by all eNBs in the MBSFN Area. It also can be the Mobility Management Entity (MME) in the core network.

After receiving this information from SIB13, the UE should have a mapping among Cell identities, MBSFN Areas and eMBMS services as shown in Fig. 4. Note that all services listed are supported by neighbor cells on the same frequency with the serving cell. This mapping will help UE choose the appropriate cell to camp to. In case the UE cannot find its interested service in all neighbor cells on current frequency, it will search on neighboring frequencies using the SIB15 receive from the primary cell similar to the standard method.

For the UE in connected mode, the mobility is supported by network-controlled handover procedure, i.e. the serving eNB will decide when and where to hand over the mobile terminal. To ensure the eMBMS continuity, the serving cell needs to know two things: *i)* the services supported by other cells (referred as MBMS Service Support Information), *ii)* the services UE is receiving or interested to receive (MBMS Service Interest). For the first element, the current cell already has according to the method we proposed earlier. The latter one is still missing (the MBMS Interest Indication in the standard [2] only gives the list of frequencies not services), therefore, the UE should give it to the serving cell by means of a RRC message. This message simply contains a list of services that UE is receiving or interested in receiving and could be send to the serving eNB together with the measurement reports when an trigger event occurs or when the UE change its interest.

Using the MBMS Service Support Information together with the MBMS Service Interest and the measurement reports from UE, the source eNB can choose the eNB (on the same frequency) providing the required service for UE. In the case target eNB is in different MBSFN Area with the source, to avoid the need to read the MCCH message in new eNB, the MCCH message can be sent from target eNB to UE via source eNB. This can be archived during the Handover preparation phase when source eNB sends Handover Request to target eNB and gets the Handover Request Acknowledgment. If the source eNB informs the target eNB (e.g. by a flag bit), target eNB could enclose the MCCH message in the response together with necessary info for UE to connect to new cell. The MCCH message will then be transferred to the UE by source eNB before the handover procedure ends. By this way, right after connecting to the target eNB, the UE can receive the MBMS data, hence the interruption time can be reduced, giving a better quality of experience for the user. If there is no neighbor cell on the same frequency layer provide the desired service, the serving cell will search on other frequencies as illustrated in Fig. 6.

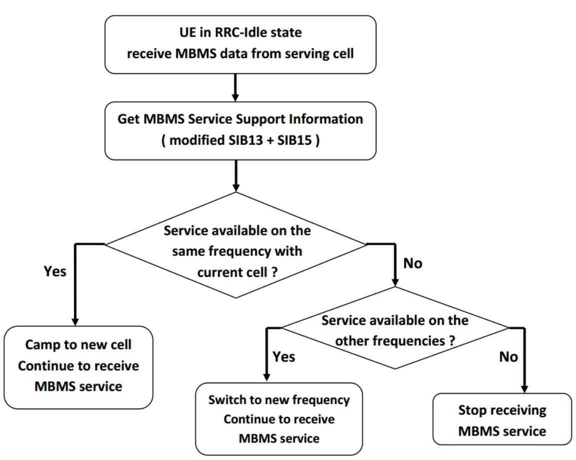


Fig. 5: Cell reselection procedure in proposed method

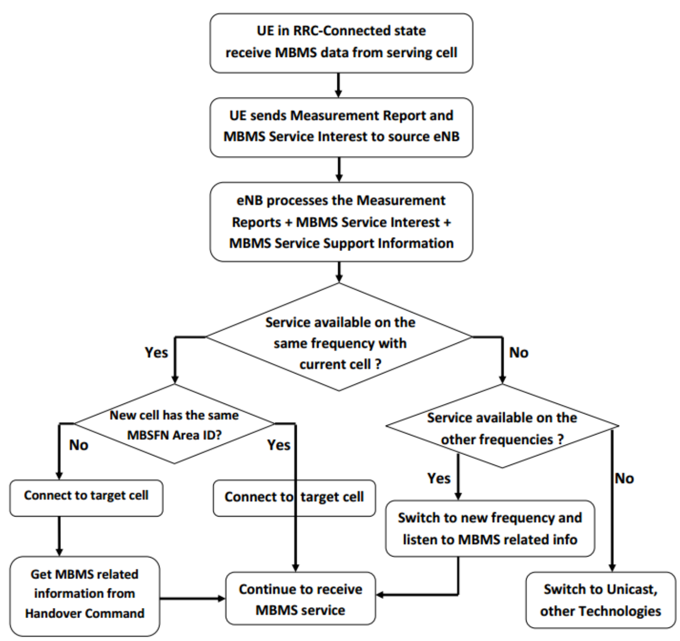


Fig. 6: Handover procedure in proposed method

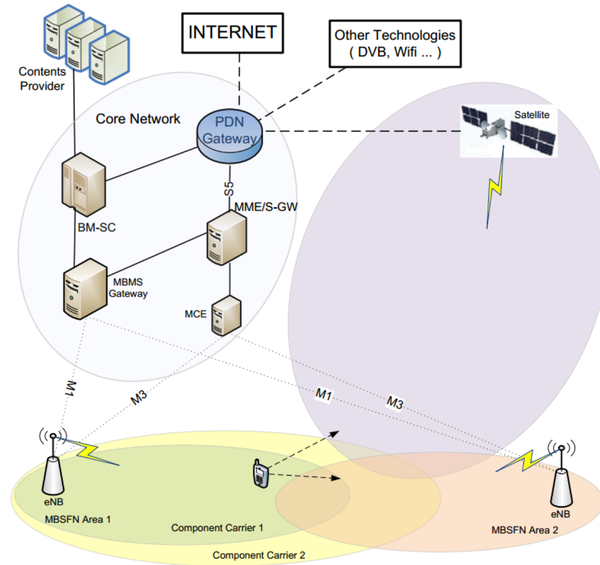


Fig. 7: Scenario for future study

To summarize, our method presented here is a supplement to the standard for supporting the eMBMS service continuity in LTE/LTE-Advanced network. All MBSFN Areas and frequencies in the neighbor cells will be checked to find the candidates providing the service UE is interested in. In case the user gets in the non-MBMS area or reserved cell, the continuity can be only maintained by changing to unicast transmission or to another broadcast technologies. The detail mechanism to buffering, transferring the data from broadcast to unicast or other transmission is out of scope of this paper.

V. Conclusion and Discussion

In this paper, we have presented and analyzed the service continuity for eMBMS in the current LTE standard. Based on the imperfection in the 3GPP specification Rel-11, we introduce some improvement to supplement the existing eMBMS service continuity mechanism. Our method together with the standard helps to ensure the eMBMS reception for mobile users while moving across different cells, through different MBSFN Areas and on different frequencies. Furthermore, with the UEs in RRC-Connected state, we suggest to transfer the eMBMS-related information from source eNB to UE via Handover Command message. If the UEs can get these information during handover period, they do not need to collect them after connecting to the new cell, thus the service interruption time can be reduced and the service quality will be improved.

For the future research in this topic, we are now focusing on two main directions. The first one is optimizing the procedure of choosing the best candidate for the UE to connect to while on move. In LTE-Advanced network where multi-frequency and carrier aggregation can be deployed, a particular eMBMS service can be diffused in many carrier components and/or MBSFN Areas, therefore, the mobile terminal could have many options to connect to when moving out of the current cell. In our proposed method, cells working on the same frequency with the serving cell have higher priority than those on different frequencies. However, the candidate with highest priority order might not give the best quality of service for the eMBMS users. The quality perceived by the users during the mobility can only be evaluated by using a simulation tool or better with a real test-bed.

We have already implemented eMBMS in the OpenAirInterface (OAI) platform [6] which can be used as a real-time emulator or deployed in real RF test-bed for testing in real environment. The performance of eMBMS system in OAI platform with a basic scenario (one eNB and several UEs) has met the requirement indicated by the 3GPP standard in term of BLER and user throughput [5].

The other research direction is the ability of handover with other broadcast technologies such as satellite or DVB in the region where there is no cellular network available. From user point of view, it can get the MBMS Service Support Information of other technologies from current eNB similar to the way presented in section IV with a small addition: in the mapping show in Fig. 4, other broadcast technologies should be represented by special predefined values instead of normal cell ID. From the network point of view, more research need to be done in order to connect different technologies together.

An interesting example for future research is described in Fig. 7. In this scenario, the LTE cellular network which has two component carriers (different coverages) cooperates with the satellite system to provide the same eMBMS services. The Quality of Experience (QoE) metric can be used to decide whether the mobile user should change to another MBSFN Area, switch to neighbor component carrier or connect to satellite system in order to maintain its eMBMS service with the best performance.

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