Emergency Group Call Over eMBMS

JunHyuk Song*, Rick Phung†
*Samsung Electronics, Suwon-si, Republic of Korea
†Anritsu Inc. Richardson, TX 75081, USA
junhyuk.song@samsung.com, rick.phung@anritsu.com

***Abstract*—In the event of an emergency, inter-agency collaboration is critical to prevent incidents that can further endanger the public. Our paper proposes the emergency group call over Long Term Evolution (LTE) Evolved Multimedia Broadcast Multicast Service (eMBMS). Current LTE eMBMS specification provides a mechanism for downlink video content delivery and file transmission only. We worked on a novel design for enhancing the current emergency group call network based on the eMBMS solution. Following features are technically further enhanced in our work to provide adequate emergency group services: Multimedia Broadcast Single Frequency Network (MBSFN) architecture, privacy, MBSFN area allocation, service continuity and reduced eMBMS call setup time.**

***Index Terms*—LTE, eMBMS, MBSFN, PTT, GCSE**

I. Introduction

In an emergency situation such as a natural disaster or terrorist attack, the public safety network will enable the collaboration among emergency services organizations (such as fire department, Emergency Medical Services, and police department) by providing a common wireless communications network. In such an event, the first responders as well as the emergency communication systems will be stressed to their limit. Currently, Terrestrial Trunked Radio (TETRA) emergency group call system based on the European Telecommunications Standards Institute (ETSI) standard, is used globally in more than 114 countries [1]. Project 25 (P-25) [2] is a U.S. Telecommunication Industry Association standard used by local public safety agencies in America. Both TETRA and P-25 were specifically designed for use by government agencies, although not inter-operable with each other.

In recent years, the need to support multimedia applications for public safety networks has been recognized. The ability to share multimedia information can make a great difference for the first responder and the ones for whom help is needed. This need is reflected in the increased public investment in broadband public safety communication systems. On June 11, 2012, "The National Public Safety Telecommunications Council (NPSTC) and the TETRA & Critical Communications Association (TCCA) announced they [had] signed a Memorandum of Agreement (MoA) to underscore their joint commitment towards the need to develop mission critical public safety communications standards for LTE-based technology. This agreement will enhance the development of wireless broadband communications which will improve public safety services for citizens around the world" [3]. In America, the Federal Communications Commission (FCC) announced they will reallocate 700 MHz D block spectrum and existing public safety broadband spectrum to FirstNet [4], and it will be built to public safety grade standards using LTE.

With this increasing interest to support a public safety network over on LTE system, the features and requirements of public safety networks have been identified in several previous works [5], [6], [7]. Largely, they identified requirements which come down to three main features: group communication, direct communication, and a resilient system. In 3GPP, the standards work is in progress to deliver the same or better services than using the existing public safety network. For group communication, Group Communication Service Enabler (GCSE) [8] and direct communication Proximity Services (ProSe) [9] have been set up and work is in progress. They are targeting the completion of the specification for Release 12 in 2014.

Our paper proposes an emergency group call over LTE eMBMS system. Current eMBMS specifications provide mechanisms for downlink video content delivery and file transmission. We worked on a novel design for enhancing the current emergency group call network based on the eMBMS solution. In this paper we analyze the current kown limitations and challenges for integrating multimedia caabilits into an emergency group call network based on an LTE eMBMS solutions. We then introduce several novel designs for enhancing the network to address these challenges

II. Group Communication System Enablers for LTE (GCSE_LTE)

The most widely available group communication service is "Push to talk" (PTT) in Land Mobile Radio (LMR). A group communication service depends on an efficient scheduling mechanism to deliver the same voice call to multiple users in a group. Thus, a group communication service based on LTE should provide PTT voice communications with performance comparable to TETRA or P-25. In 3GPP, TR 23.768 [10], technical report is in progress to evaluate the possible solutions for architectural enhancements to support GCSE for LTE. Several group communication solutions are being considered, all of which involve the eMBMS bearers. This is because eMBMS is the only solution that can deliver multimedia contents to large number of User Equipment (UE) in Radio Resource Control (RRC) idle mode. Outlined are some key issues that need to be resolved, such as group privacy, geographical scope, the type of media support, service continuity, roaming support, and priority and preemption. Fortunately, most of the issues previously noted are addressable in the current scope of eMBMS with little enhancement, which will be further elaborated on the following sections.

III. eMBMS Description

In this section, we briefly introduce eMBMS architecture and its related functions. eMBMS requires new network entities to enable MBSFN transmission: Broadcast Multicast Service Center (BM-SC), MBMS Gateway, and Multi-cell/multicast Coordination Entity (MCE). BM-SC acts as a proxy content server. It also manages the eMBMS subscriptions, service announcement, sessions control, SYNC protocol, MBMS security, point to point retransmission, and Application Level Forward Error Correction (AL-FEC). MBMS gateway is responsible for multicast IP address allocation and session management. The MBMS gateway receives MBMS content from BM-SC and then forwards MBMS service traffic to the eNodeB (eNB) over IP multicast network. The MCE, acting as an MBMS scheduler, allocates radio resources, performs session admission control, and manages the MBMS services. Therefore, the scheduling of MBSFN transmission is performed through an MCE. When the MCE receives a "Session Start" request from the MME, it runs the session admission control function to determine radio resource availability. Only if there are enough radio resources available will the MCE allocate the required radio frames.

Besides the function of the new entities, eNBs also need to support some eMBMS related MAC and PHY layer features, including 15 kHz sub-carrier spacing, extended Cyclic Prefix (CP), MBSFN reference signal, Physical Multicast Channel (PMCH) physical channel, Multicast Channel (MCH) transport channel, Multicast Traffic Channel (MTCH)/Multicast Control Channel (MCCH) logical channels, System Information Block 2 (SIB2) and System Information Block 13 (SIB13) system information, PDCCH with MBMS Radio Network Temporary Identifier (M-RNTI), RLC-UM mode, SYNC protocol, and M2 Application Part (M2AP) Interface. In an eMBMS system, a single eNB is served by one MCE at a time, although eNB can receive MBMS IP multicast packets from multiple MBMS gateways through an multicast routing tree.

A. MBSFN transmission

When the multiple paths of the signals with different delays are received by UE, the receiver may be able to combine them as a single signal with different path delay. This becomes possible when the signals are from sufficiently time synchronized cells, and are received within the CP at the beginning of the symbol. LTE eMBMS supports a broadcast transmission mode known as MBSFN. In LTE MBSFN operation, given the CP length of $16.7\mu s$ ensures the signals arrive within the CP, the UE receiver treats these different signals as multipath components of a single cell transmission. The use of the extended CP ensures that the signals remain within the CP at the UE, and thus reducing inter-cell interference by using additional symbols for extended CP. The gain from MBSFN operation is significant, especially at the cell edge where the signals from edge cells cause Inter-Symbol Interference (ISI) [11].

B. MBSFN related area

In eMBMS, all areas are formed either based on geographical area or logical area. MBSFN related areas and their mapping to the cells are depicted in Fig. 1. A logical area of the network, where the same MBMS service can be transmitted, is called an MBMS service area. On the other hand, a geographical area where all cells can have synchronized System Frame Number (SFN) is called MBMS synchronization area. Within an MBMS synchronization area where all cells can perform MBSFN transmissions for the same service area what is called an MBSFN area. An MBMS synchronization area may support several MBSFN areas, and its coverage in an eMBMS system is bounded by MCE capacity. Each eNB may have a different set of participating cells for MBMS service which belong to a certain MBSFN area. Thus each eNB and MCE have a table that maps each cells to the MBMS service and MBSFN areas. 3GPP standard defined cell can support up to 8 MBSFN areas, while one MCE can support up to 256 MBSFN areas. All MBSFN related areas and cells are semi-statically configured by Operations, administration and management (OAM).

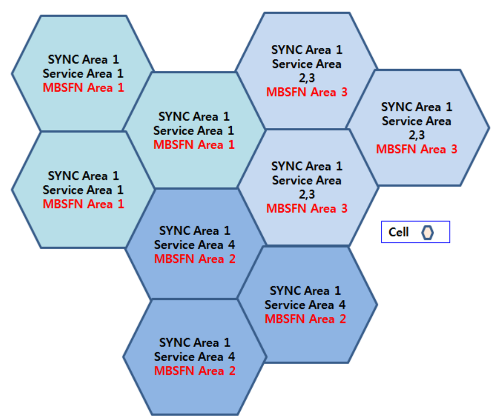

Fig. 1. MBSFN Cells configuration example

C. MBMS channel description

LTE eMBMS requires the implementation of two new logical channels, MTCH and MCCH. Both the MCCH and the MTCH logical channels are multiplexed to the MCH transport channel. The eNB performs MAC-level multiplexing for different MTCHs to be transmitted on a single MCH. Multiple eMBMS services can therefore be transmitted using a single MCH (29 MTCHs can be multiplexed on one MCH instance), provided that they use the same MBSFN area. At the physical layer up to 15 MCH channels per MBSFN area can be time multiplexed to one physical subframe within a Common Scheduling Allocation Period (CSAP) interval.

IV. PROPOSED eMBMS EMERGENCY GROUP CALL ARCHITECTURE

In this section, we describe the architecture and its related functional enhancement of eMBMS to support emergency group call for a public safety network.

A. Centralized MCE architecture

In a public safety network, a broad range of coverage is a crucial requirement. In the case of a natural disaster such as an earthquake or hurricane that can have a large impact zone, the disaster response and planning need to be over a wide area. This broad area coverage requirement puts MCE in a centralized location with high availability support. Figure 2 provides a view of the centralized MCE architecture of eMBMS. The centralized MCE can support up to 65536 eNBs, and they can be grouped into the same MBSFN area.

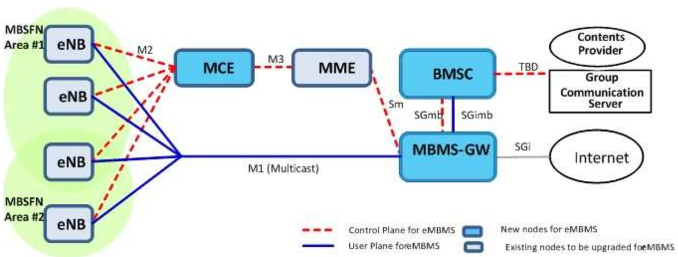

Fig. 2. Centralized eMBMS architecture

By locating MCE outside of eNB, a single point of failure can be avoided. The malfunction of one eNB has no impact on group call users camping in other cells. Even in the case of MCE failure, each eNB can continue to support the ongoing group call. This is possible because the traffic can continue to multicast from MBMS-GW as described in Fig. 3.

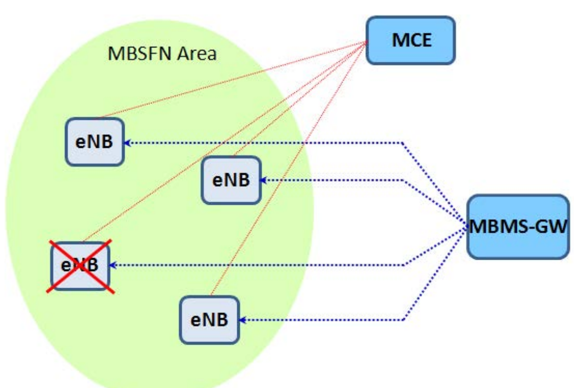

Fig. 3. High Availability System

B. Group privacy requirement

The use of eMBMS as a broadcast downlink channel requires broadcasting eMBMS channel information over MCCH in each cells. The control information carried in an MCCH for each MBSFN area contains the session specific information such as Temporarily Mobile Group ID (TMGI), session ID and PMCH configuration information, just to name a few (see Fig. 4). It is sent in plain text within the same geographic area to let anyone interested in eMBMS service in that MBSFN area to chime in anytime. The problem is the emergency

```
MBMS-SessionInfo-r9 ::=        SEQUENCE {
 tmgi-r9          TMGI-r9,
 sessionId-r9     OCTET STRING (SIZE (1))OPTIONAL
 logicalChannelIdentity-r9    INTEGER (0..28),
 ...
}

TMGI-r9 ::=       SEQUENCE {
 plmn-Id-r9       CHOICE {
  plmn-Index-r9        INTEGER (1..maxPLMN-r11),
  explicitValue-r9      PLMN-Identity
 },
```

Fig. 4. MCCH information

group call activities, such as adding or removing a TMGI, can be easily monitored through MCCH. It can reveal there is a dispatching of first responders in certain areas. The 3GPP MBMS security specification [12] can only provide group call encryption between the BM-SC and the UE. No protection for MCCH is defined in the specification. It is therefore recommended for eNB to encrypt a MCCH for each public safety MBSFN areas with a new control channel encryption key. Each public safety MBSFN area must have a unique MCCH encryption key. The MCCH encryption key can be delivered to UE through either a service announcement or Multimedia Internet KEYing (MIKEY) [13] from BM-SC. The eNB in public safety network can obtain the encryption key through an M3 setup message from BM-SC through MME.

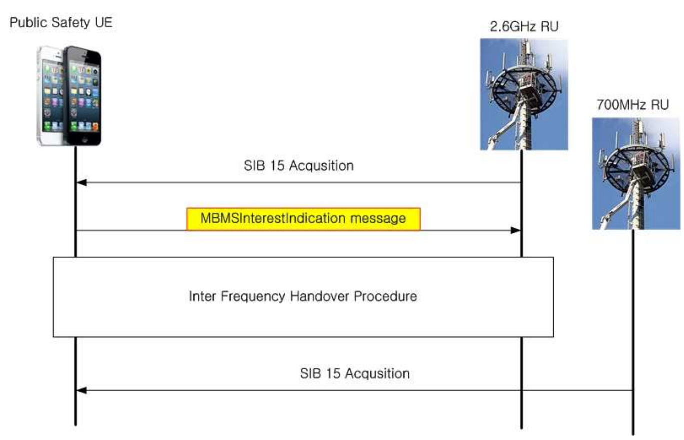

Fig. 5. SIB 15 Acquisition

LTE Rel.11 specification has recently introduced an SIB 15 system information message that pairs with *MBMSInterestIndication* RRC message. These two messages basically enable Inter-Frequency handover between two carriers in the interest of the eMBMS service continuity. In Fig. 5, the public safety UE is connected to the 2.6 GHz commercial LTE cell, and receives an SIB 15 message that indicates there is an emergency group call service area in 700 MHz neighbor cells. If the public safety UE indicates its MBMS interest of 700 MHz frequency by sending a RRC *MBMSInterestIndication* message, eNB in 2.6 GHz can command the UE to perform Inter-Frequency handover to the 700 MHz LTE cell. However, it could open another threat, since a rogue UE that wants to monitor the emergency group call activity can masquerade as a public safety user. That UE can easily scan the neighbor cells, and then send *MBMSInterestIndication* message for inter-frequency handover to the public safety system. Therefore, the eNB should allow only public safety UE to Inter-Frequency handover to public safety network cells. This requires an additional protection for the *MBMSInterestIndication* RRC message. The *MBMSInterestIndication* message must be authenticated by a specific group message authentication key, derived for each service area. The source eNB shall be able to verify the *MBMSInterestIndication* message is indeed the message from the public safety UE. This key must be unique for each MBMS service area, and shared between public safety personnel and the concerned eNB.

C. Group handling requirement

3GPP TS 22.468 has specified the requirements for group handling, such as geographic restriction and dynamic group creation, modification, and deletion. It requires the system to provide a mechanism to restrict its reception of the service in the specific geographic area. Since the MBSFN area is defined by physical cells boundary, it is unnecessary for eMBMS to restrict its service area by physical location. However, an eMBMS's broadcast characteristics only allows a static configuration of MBSFN area by OAM, and 3GPP TS 36.300 clearly states that no dynamic change of area is allowed. Semi-statically assigning an MBSFN area for emergency group call would be a waste of radio resources since no one can predict when a disaster will strike. Thus, we need a little enhancement on eMBMS to flexibly support this group handling requirement.

The dynamic MBSFN area allocation can be supported in an eMBMS. In an eMBMS, physical radio resources for each MBSFN area can be separately allocated without causing any interference. With a given Radio Frame Allocation Period (RFAP) and an offset, it is possible to allocate 10*ms* physical radio frame in interleaved fashion for each cell of an MBSFN area. As it is shown in Fig. 6, it is possible to dynamically allocate an MBSFN area. In the given example, when an M2 interface was set up between eNB and MCE, MCE allocated MBSFN areas 1,2,3 with offset 0,1,2. In the event of emergency, MCE can add or remove MBSFN areas by sending an *MCE configuration update* message. This procedures will not cause service interruption for the existing MBSFN areas, since radio frames will be automatically interleaved by using different offsets.

D. Service continuity and roaming support

Service continuity means uninterrupted service while UE is moving around the cells. UE located in the MBSFN area can

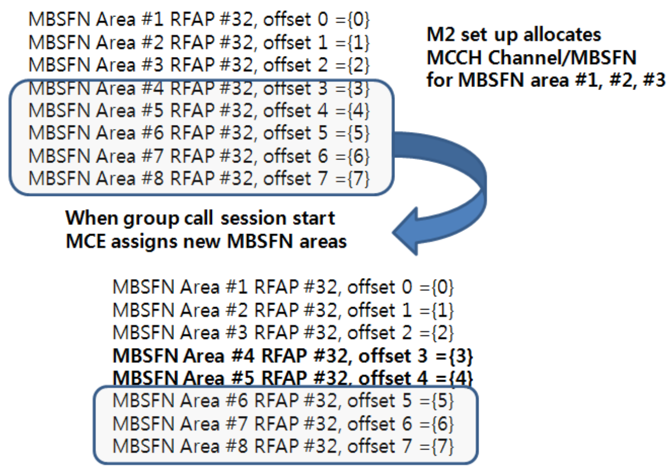

Fig. 6. Dynamic MBSFN Area procedures

start or continue to receive eMBMS service when changing cells. However, there is a special case when this is not possible, such as when the frequencies used to provide MBMS services may be different within a Public Land Mobile Network (PLMN). The aforementioned SIB 15 defined in Release 11 of TS 36.331 [14] can provide the service continuity over inter-frequency within the same MBSFN area.

In the 2011 Tohoku earthquake, 116 countries and 28 international organizations offered assistance that included first responder teams from Australia, New Zealand, South Korea, and the United States [15]. The roaming support for a public safety network is an imperative requirement. In LTE, roaming is an essential service that is widely used every day. However roaming for eMBMS is currently not supported. The MBMS service area is only unique within a PLMN. As depicted in Fig.7 each TMGI is made of service area and PLMN (MCC, MNC), therefore when inter-PLMN handover occurs, the service is interrupted. To avoid this interruption, special public safety TMGI should be newly defined. In case of a nation wide emergency, eMBMS should be able to broadcast to any MBSFN area regardless of the PLMN.

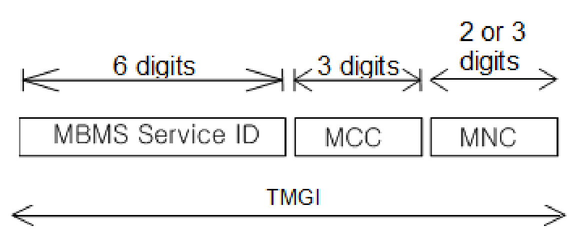

Fig. 7. Temporary Mobile Group Identity

E. Multimedia support

One of the limitation of the conventional PTT service is a lack of high speed packet data transmission capability. eMBMS can support up to 29 logical channels which can be multiplexed into one MCH. It allows the first responder to receive multimedia data such as video clips of the affected area as well as satellite maps, while listening to group communication on another channel. The shortest MCH scheduling period defined for eMBMS is 80*ms*. In an 80*ms* MCH scheduling period, eNB can schedule group communication and some multimedia rich logical channels together.

F. Priority and preemption

LTE is known for excellent QoS scheduling that comes with standard and operator QoS Class Identifier (QCI), Guaranteed Bit Rate (GBR), Maximum Bit Rate (MBR), and Allocation and Retention Priority (ARP). eMBMS inherited the same QoS parameters from unicast QoS. In the previous section of Group handling requirement we described how an MBSFN area can be dynamically assigned upon request. Based on ARP and the availability of resources, eMBMS can prioritize and preempt the physical resources. In case of an emergency, MCE can redistribute the radio resources by resetting RFAP and offset for the MBSFN areas.

G. Call set up time enhancement

TS 22.468 states that the end-to-end setup time of group communication should be less than or equal to 300*ms*. However, in our previous work on "Relative Time Based on MBSFN content synchronization" [16], we found that the existing eMBMS MCCH modification period is not adequate for real time streaming data transmission. This is due to the time delay caused by the MCCH modification period. 3GPP TS 36.331 defines two MCCH modification periods, and we found that both 512 RF and 1024 RF are not adequate for live streaming. In case of 512 RF, it causes a minimum 5.12 second delay, since UE has to obtain the updated MCCH information in advance to decode eMBMS session. As depicted in Fig. 8, when the new session is started, the updated MCCH information is transmitted in the next available MCCH modification period (n+1). During the current MCCH modification period (n), eNB sends the MCCH change notification over PDCCH.

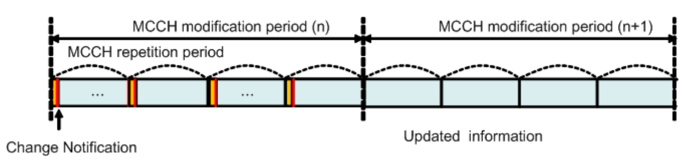

Fig. 8. MCCH Modification Period

To show how the MCCH modification period causes the RLC transmission delay, we ran tests on our eMBMS system with the Table 1 test configuration. As our experiment results show in Fig. 9, RLC is buffering in packets beginning from SFN 329, until the next available MCCH modification period, SFN 1024 without transmitting any packets. SFN 329 is the system time when RLC begins to receive packets from SYNC frame handler. The SYNC frame handler is the function of eNB that receives eMBMS traffic from BM-SC and reorders them before sending it to RLC. In the beginning the next

TABLE I
LAB TEST SETTINGS

Parameter	Value
3GPP spec.	Release 9
Access Technology	TDD
Carrier Frequency	2.6 GHz
Cellular Layout	6 cell sites
System Bandwidth	20 MHz
Extended Cyclic Prefix Duration	$16.7\mu s$
PDCCH Symbol Length	2
Data MCS	13
Signaling MCS	7
GBR	1.5 Mbps
MCCH Modification Period	512 RF
Common SF Alloc Period	64 RF
MCH Scheduling Period	640 ms
Allocated Subframe Number	3, 4, 8, 9
Video Encoding	H.264 AVC
Transport Coding	DASH/FLUTE
Video Title	Big Buck Bunny

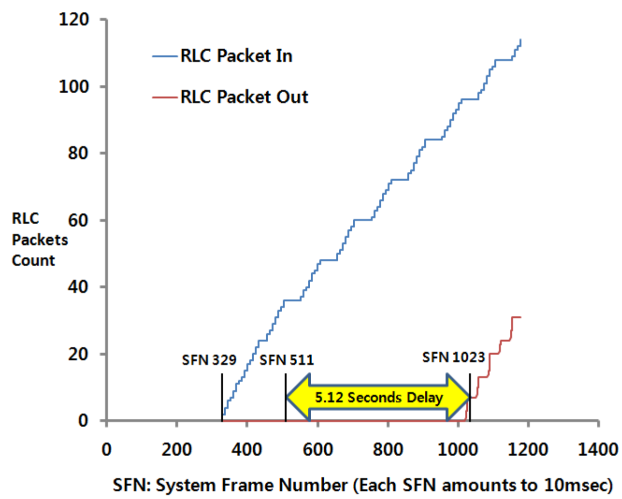

Fig. 9. RLC packet transmission delay

modification period (SFN 1024) RLC begins to flush its buffer to MAC scheduler.

In order to meet the requirements for real time audio and video delivery a much shorter MCCH modification period (such as 160*ms*) should be specified in the 3GPP specifications. With that 160*ms* MCCH modification period and reasonable backhaul and processing delay, eMBMS can meet the 300*ms* delay requirement. That 300*ms* time delay only counts for eMBMS session setup time. Since eMBMS bearer only covers downlink, it isn't necessary to be established for each member of the group communication. In the event of emergency, it is a job for a dispatcher to enable or disable a group communication service in an MBSFN area. Each group member can setup their uplink connection to a PTT application server whenever they establish an RRC connection to the eNB.

V. eMBMS Group call procedures

In this section, we describe the end-to-end procedures for emergency group call over eMBMS. It is assumed there is a group call client application available in UE and the application server on the core network side. There are several commercial Voice-over IP (VoIP) based half-duplex dispatch services available on the market [17], [18], [19]. Some are more optimized to LTE than others. A detailed description of interaction between UE and group call application is beyond the scope of this paper, since it does not directly involve eMBMS. 3GPP will provide the reference architecture with group communication server and callflows in TS 22.468.

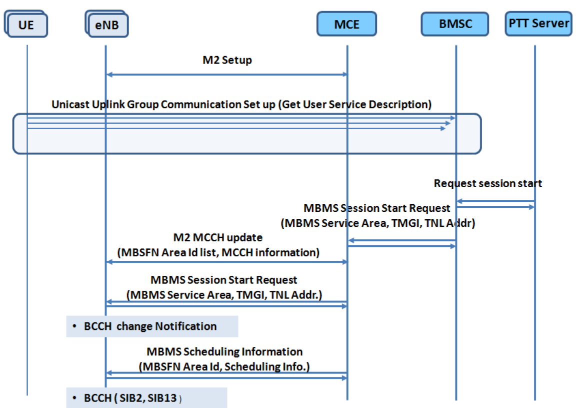

Fig. 10. eMBMS Group Talk Call flows

In Fig. 10, before the originator places a PTT call, eNB performs M2 setup to MCE. This procedure registers each cell to a specific MBSFN area that is managed by MCE. MCE is supposed to bind the service area and physical cells, while allocating physical radio resources for all cells in the MBSFN area. Once M2 setup is complete, each cell's resources are reserved for MBSFN areas. UE can get its bootstrapping information anytime during this procedure. The bootstrapping information contains the necessary information to join the PTT groups within the service area. When this event happens, the PTT server can initiate the session start to BM-SC, and it will trigger BM-SC to send MBMS session start that will be delivered to MCE. MCE will then allocate MBSFN area for emergency group call, and update cell configuration information by sending an M2 MCCH update message to eNB, followed by an MBMS session start request message. The MBMS session start message will establish MBMS-ERAB and begin broadcast traffic from BM-SC.

VI. Conclusion

Today there is increasing interest in multimedia-enabled public safety communication. Unlike the commercial cellular network, a government operated public safety network cannot afford the luxury of high tech smart phones, and rich multimedia content. Unfortunately, there's *not* an "app for that." The main requirement of traditional public safety network was focused on the robustness and the resiliency of the system. Now there is on going standard development in 3GPP for on LTE-based public safety network, and one of the candidates for emergency group communication that can replace P-25 and TETRA is eMBMS. In this paper, we outlined the 3GPP requirements for group communication, and shared our insights on how eMBMS can meet the group communication requirements with minimal enhancement. The next to this work could be eMBMS operation on demand which is currently a Rel.12 work item [20]. This feature anticipates the user interest for the specific content, and allows switching back and forth between unicast and broadcast modes of transmission. This feature can be applied to group communication application, since it would not be an efficient use of radio resources if there are only a handful of users in the cell and allocate the broadcast resources. In addition, privacy concerns of eMBMS on a public safety network need to be further discussed in a 3GPP SA3 work group.

Acknowledgment

The author would like to thank Ishwinder Singh of Qualcomm and Richard Barrett of Purdue University for their hawk-eyed review.

References

[1] http://en.wikipedia.org/wiki/Terrestrial_Trunked_Radio
[2] http://project25.org/modules.php?name=Content&file=viewarticle&id=2.
[3] TCCA and NPSTC: http://www.tandcca.com/about/article/17582.
[4] FirstNet: http://www.ntia.doc.gov/category/firstnet
[5] Doumi, T. ; Dolan, M.F. ; Tatesh, S. ; Casati, A. ; Tsirtsis, G. ; Anchan, K. ; Flore, D. "LTE for public safety networks", Communications Magazine, IEEE Volume: 51 , Issue: 2 Digital Object Identifier: 10.1109/MCOM.2013.6461193 Publication Year: 2013 , Page(s): 106 - 112
[6] Ferrus, R. ; Sallent, O. ; Baldini, G. ; Goratti, L."LTE: the technology driver for future public safety communications ", Communications Magazine, IEEE Volume: 51 , Issue: 10 Digital Object Identifier: 10.1109/MCOM.2013.6619579 Publication Year: 2013 , Page(s): 154 - 161 IEEE Journals & Magazines
[7] Yaacoub, E. ; Kubbar, O. "Energy-efficient Device-to-Device communications in LTE public safety networks" Globecom Workshops (GC Wkshps), 2012 IEEE Digital Object Identifier: 10.1109/GLOCOMW.2012.6477603 Publication Year: 2012 , Page(s): 391 - 395
[8] 3GPP TS 22.468; Technical Specification Group Services and System Aspects; Group Communication System Enablers for LTE (GCSE_LTE) (Release 12)
[9] 3GPP TS 22.803; Technical Specification Group Services and System Aspects; Feasibility study for Proximity Services (ProSe) (Release 12).
[10] 3GPP TR 23.768; Technical Specification Group Services and System Aspects; Study on architecture enhancements to support Group Communication System Enablers for LTE (GCSE_LTE)(Release 12).
[11] 3GPP R1-071049, "Spectral efficiency comparison of possible MBMS transmission schemes: Additional Results", 2007
[12] 3GPP TS 33.246 V10.0.0 Technical Specification Group Services and System Aspects; 3G Security; Security of Multimedia Broadcast/Multicast Service (MBMS) Dec 2011
[13] IETF RFC 3830 "MIKEY: Multimedia Internet KEYING"
[14] 3GPP TS TS 36.331 V10.0.0 Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification.
[15] http://en.wikipedia.org/wiki/2011_T%C5%8Dhoku_earthquake_and_tsunami
[16] Jun Hyuk Song, Ishwinder Singh, Rick Phung, Daejoong Kim, "Relative Time Based MBSFN Content Synchronization", IEEE Preceeding of WiMoB 2013
[17] http://www.qualcomm.com/solutions/multimedia/voice/qchat
[18] http://www.voxer.com
[19] http://pspc.harris.com/Solution/BeOn/Overview.aspx
[20] 3GPP MBMS operation on demand work item description http://www.3gpp.org/ftp/Specs/html-info../WID-history–590243.htm