# D2D-Based Resource Saving and Throughput Enhancement for Massive Smart Devices in LTE eMBMS

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**Abstract.** With the development of Internet of Thing (IoT) technologies, more and more intelligent devices can detect many kinds of environmental conditions, and send collected data or alarm back to application system automatically. If those massive IoT devices are connected via LTE network and the system need to send instructions to those IoT devices, the amount of data transmission in LTE would be raised quickly. To reduce the transmission load, multicasting provided by LTE evolved Multimedia Broadcast Multicast Services (eMBMS) service is one of solutions. However, the eMBMS service is dominated by the device with lowest signaling quality resulting in poor efficiency. A Device-to-Device (D2D) based mechanism was proposed to improve transmission efficiency of eMBMS service in this paper. Simulation results have shown that the proposed D2D-based mechanism can reduce the number of allocated resource blocks.

**Keywords:** LTE · eMBMS · D2D

## 1 Introduction

Thanks to the development of wireless communicating technologies, mobile computing becomes more and more popular in recent years. People send messages or share information to each other through the Internet even if they are moving. With the development of Internet of Thing (IoT) technologies, many newly applications are developed and changing people's daily life. Traditional human-to-human (H2H) communications had been extended to a new era of machine-to-machine (M2M) style. In M2M, devices communicated with each other without human participated. The IoT devices such as smart meters, smart medical healthcare devices, earthquake monitoring systems, etc., are also M2M applications.

Long Term Evolution (LTE) is developed by the 3rd Generation Partnership Project (3GPP), it has been designed to support all IP packet-switching services and is competing access network technologies in the fourth generation of mobile phone mobile communication technology standards (4G) wireless networks with IEEE 802.16 Worldwide Interoperability for Microwave Access (WiMAX) [1, 2]. LTE not only can


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offer traditional voice telephony service, but also can provide cost effective broadband communication services. 3GPP formally approves the LTE to be the standard technology for the wireless communication. Since LTE is defined and developed by telecom vendors and is backward compatible with previous cellular systems such as GSM/UMTS, this makes LTE deployment much easier than WiMAX.

The Service & Systems Aspects (SA) working group of 3GPP also develops a new M2M technology, called Machine Type Communications (MTC), which is operated without interactive with human and can transmit data directly to servers located in LTE core network [3]. LTE-enabled IoT devices is similar to MTC devices. They need access network service in order to send their collected data to management servers located in LTE core network. Thus, the communications between massive deployed IoT devices and server may cause the system load of LTE increased largely.

To reduce the transmission load, the LTE evolved Multimedia Broadcast Multicast Services (eMBMS) is developed to provide broadcast and multicast services [4]. However, there are two problems found in current LTE eMBMS mechanism. The first one is about resource allocation issue. Since LTE will allocate the whole resources to eMBMS, it may cause a waste of radio resource when lower traffic transmission. The other one is about coding efficiency issue. Since eMBMS service is dominated by the device with lowest Modulation and Coding Scheme (MCS). In the paper, a Device-to-Device (D2D) based mechanism was proposed to improve the resource allocation and coding efficiency. The eMBMS service area is reduced in order to provide better radio link quality and higher channel coding rate. Devices outside the reduced eMBMS service area still can receive data by using D2D relay-connection from devices inside the eMBMS service area. Simulation results have shown that the proposed D2D-based mechanism can reduce the number of allocated resource blocks.

The remainder of the paper is organized as follows. In Sect. 2, a survey of the eMBMS and D2D communications in LTE is presented. Proposed D2D-based mechanism for LTE eMBMS is presented in Sect. 3. Results of performance evaluation are presented in Sect. 4. Finally, Sect. 5 concludes this paper.

## 2 Literature Review

### 2.1 LTE and LTE-Advanced

LTE was proposed by 3GPP which can use OFDM, OFDMA or SC-FDMA access technologies. It also can use $2 \times 2$ or $4 \times 4$ Multi-Input Multi-Output (MIMO) antenna systems and provide either frequency division duplex (FDD) or time division duplex (TDD) mode. Moreover, LTE not only offers traditional voice telephone service, but also can also provide cost effective broadband communication services. Since LTE is defined and developed by telecom vendors and is backward compatible with GSM/UMTS cellular systems. This makes LTE deployment much easier than WiMAX. Furthermore, LTE can combine OFMDA, MIMO and HARQ technologies. This means LTE can dynamically configure its bandwidth according to available frequencies and can support a high mobility environment. This is a desirable solution for high speed rail which moves at speeds up to 350 km/h.

In the enhanced LTE version, LTE-Advanced, the transmission bandwidth is further increased. The downlink transmission rate can go up to 1 Gbps if UEs are in low mobility status. Even when UEs are in high mobility status, the transmission rate can still reach 100 Mbps. Therefore, ITU has been certified that LTE-Advanced conforms to the requirements of IMT-Advanced for 4G. The major difference between 3GPP Rel. 10 LTE-Advanced and original LTE is a new entity called Relay Node (RN) introduced in LTE-Advanced. Each base station, namely evolved Node B (eNB), has a limited serving area. It is more difficult to deploy a new eNB since residents have expressed much concern about the electromagnetic waves impact on health. Thus, the idea of signal relaying by RN has been proposed and becomes an LTE-Advanced specification. A Donor eNB (DeNB) can expand its serving area by using RN to relay signal.

## 2.2 Device-to-Device Communications

When two nearby user equipments (UEs) served by the same eNB and exchanging data, the packets issued by sender UE have to route through LTE core network and back to receiver UE via same eNB. Even if those communicating UEs are close enough, the transmission still need to go through core network due to standard specification. If two nearby UEs can communicate directly without passing through the core network, it can significantly reduce the burden on the core network. This type of directly transmission was called Device-to-Device (D2D) communications [5]. Thanks to the largely development of hand-held devices and IoT technologies, the D2D scenario becomes more and more important.

When a UE (Sender UE) wants to send packet to another UE (Receiver UE) served by same eNB, they have to find each other by using D2D discovery mechanism. After confirming that the UE pair can use the D2D transmission mode, the eNB will allocates resources used for the D2D link. Then, those two UEs can use the D2D link for direct transmission.

## 2.3 LTE eMBMS

The eMBMS is used to provide broadcast and multicast service for LTE networks [6, 7]. The system architecture of eMBMS is illustrated in Fig. 1. An additional control entity called Multi-cell/Multicast Coordination Entity (MCE) is embedded within eNB. Also, two additional entities, namely e-MBMS-GW and e-BM-SC, are added in the EPC core network.

In LTE system, the resource scheduling interval is 1 ms namely TTI (Transmission Time Interval) which further divided into two resource blocks (RBs) and each RB contains 84 resource elements (REs). Each RE may use different channel coding mechanism allocated to single UE for transmitting or receiving. However, the allocation unit is TTI but not RE in eMBMS service. When the broadcast/multicast traffic is small, the unused REs are wasted. Even in highly broadcast/multicast traffic scenario, the unused REs may still happen resulting in poor transmission efficiency. Furthermore, the broadcast/multicast is one-to-all or one-to-many style of transmission. In order to achieve the broadcast/multicast service, the channel code scheme need to fit the farthest UE with lowest channel quality. Thus, the channel coding efficiency is quite poor.

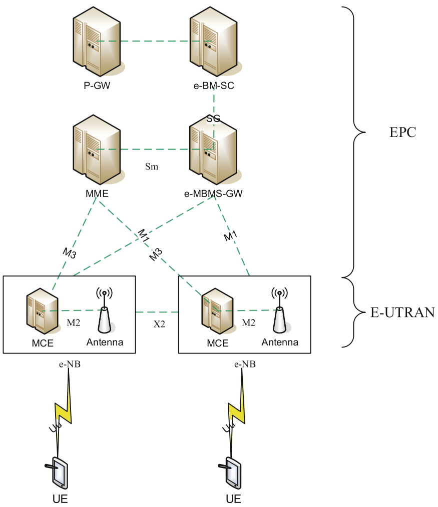


**Fig. 1.** LTE eMBMS Network Architecture.

# 3 Proposed D2D-Based eMBMS Service

As mentioned, the eNB can only transmit broadcast/multicast messages with worst channel coding technique in order to guarantee packet reception for all serving UEs. The transmission efficiency is quite poor. An interesting idea raised. If the UEs located in signal edge can be temporarily ignored and only UEs with well channel quality will receive the broadcast/multicast messages then the coding efficiency can be improved. The UEs that already receive broadcast/multicast messages can further forward to those temporarily ignored UEs via D2D communications with higher signal quality. The overall system throughput may be also improved. Based on this idea, the D2D-Based eMBMS service was proposed in this paper.

In order to achieve objectives of the proposed mechanism, there are three issues should be solved. First of all, which UEs can be temporarily ignored? A suitable evaluation mechanism should be developed. For a temporarily ignored UE, which relay UE can forward its received message via D2D? A suitable D2D selection mechanism should also be developed. If there is no any suitable relay UE found, how can the temporarily ignored UE receive its message? Therefore, a correction procedure should also be defined. Since no suitable UE can forward traffic, unicast delivery is used for the correction procedure. The eNB will send the missing data to edge UEs directly by unicast transmission. The remaining two issues are explained in the following sections. Figure 2 illustrated the basic idea of D2D-Based eMBMS service.

## 3.1 eMBMS Zone

Since only UEs with LTE Channel Quality Indicator (CQI) values lower than six may benefit on D2D transmission [8]. Therefore, the broadcast/multicast coverage area, namely eMBMS zone, can be bounded among CQI values smaller than six. The LTE

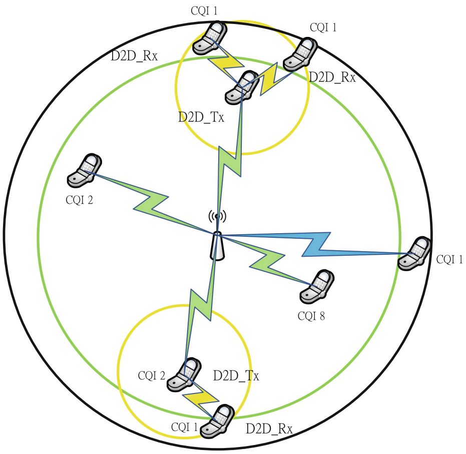


**Fig. 2.** Proposed D2D-Based eMBMS service.

serving area outside the eMBMS zone is called D2D zone. However, only benefit on the throughput enhancement and used RB reduction, the shirking down of eMBMS zone can be triggered. Therefore, RB usage calculation should be perform before making eMBMS zone decision. The RB usage can be calculated by Eq. 1:

$$\#RB = \left\lceil \frac{data\_eMBMS}{TBS(CQI_k)} \right\rceil \tag{1}$$

where *data_eMBMS* is the traffic would like to be sent by eMBMS, $TBS(CQI_k)$ is the payload in a single RB with CQI value $k$. Thus, the RB needed for traditional eMBMS mechanism can be calculated by Eq. 2:

$$RB_{ori\_eMBMS} = \left\lceil \left( \left\lceil \frac{data\_eMBMS}{TBS(CQI\_lowest)} \right\rceil \right) / N_{TTI}^{RB} \right\rceil \times N_{TTI}^{RB} \tag{2}$$

where *CQI_lowest* is the lowest CQI value among all serving UEs. $N_{TTI}^{RB}$ is the number of RB in a single TTI interval.

The goal of proposed mechanism is try to minimize the RB used:

$$\mathrm{Min}(RB_T = RB_{adj\_eMBMS} + RB_{D2D} + RB_U) \tag{3}$$

$RB_T$ is the number of RB used in the proposed mechanism. $RB_{D2D}$ is the number of RB used in the D2D transmission portion while $RB_U$ is the number of RB used in the correction procedure.

$$RB_{adj\_eMBMS} = \left\lceil \left( \left\lceil \frac{data\_eMBMD}{TBS(CQI\_eMBMS)} \right\rceil \right) / N_{TTI}^{RB} \right\rceil \times N_{TTI}^{RB} \tag{4}$$

$$RB_{D2D} = \sum_{i=1}^{K} \left\lceil \frac{data\_eMBMS}{TBS(d_i)} \right\rceil \quad (5)$$

$$RB_U = U \times \left\lceil \frac{data\_eMBMS}{TBS(CQI\_lowest)} \right\rceil \quad (6)$$

$$RB_{adj\_eMBMS} < 6 \times N_{TTI}^{RB} \quad (7)$$

$$RB_T < RB_{ori\_eMBMS} \quad (8)$$

*CQI_eMBMS* is the new CQI value that the eMBMS used to limit the new broadcast/multicast zone. Since the proposed D2D transmission adopt the spatial reuse techniques, there are *K* group of D2D pairs and each pair in a same group can send their traffic simultaneously [9]. The Eq. 7 shows that no more than six TTIs can be used by eMBMS as defined in LTE standard. If those equations are true, D2D-based eMBMS service is triggered. Otherwise, the standard eMBMS service is used.

### 3.2 Relay Selection

The proposed mechanism use smaller eMBMS serving zone in order to improve transmission efficiency. D2D is used to serve UEs outside the eMBMS zone. Moreover, the D2D transmission adopt the spatial reuse techniques to reduce totally RB used. Therefore, the selection of relay UE and D2D transmission scheduling should be carefully arranged.

Assume eNB has location information of all serving UEs. eNB firstly sort the UEs inside D2D zone by location information. Begin with the nearest UE, find an appropriate UE located in eMBMS zone and inside its signal coverage with highest signal quality (CQI value). This UE is chosen to act as relay. The next UE in the sorted list follows the procedure until all UEs are finished the relay selection. Beside, when a UE already act as relay, it will serve UEs as many as possible. The priority of the relay UE is much higher than other candidates. This can further reduce the number of D2D transmission pairs.

## 4 Performance Evaluation

Table 1 shows the simulation parameters used in the simulation program. In addition, the signal quality is measured by Signal-to-Interference-plus-Noise Ratio (SINR). Each UE will periodically report a Channel Quality Indicator (CQI) value to the eNB based on the signal quality. The SINR can be retrieved from the Eq. 9.

$$\frac{P_{eNB} - Path\_Loss}{Interference + Noise} \quad (9)$$

**Table 1.** Simulation parameters

| Parameter | Value |
|---|---|
| LTE bandwidth | 100 MHz |
| eNB signal diameter | 3400 m |
| Path loss between UE and eNB | 128.1 + 37.6log10(R) dB, R in km |
| Path loss between D2D UEs | 140.7 + 36.7log10(R) dB, R in km |
| e-NB power | 46 dBm |
| UE power | 19 dBm |
| PRB size | 12 sub-carrier per PRB |
| Data rate | 1100 kbps |
| UE number | 50–500 |
| UEs distribution | Uniform |

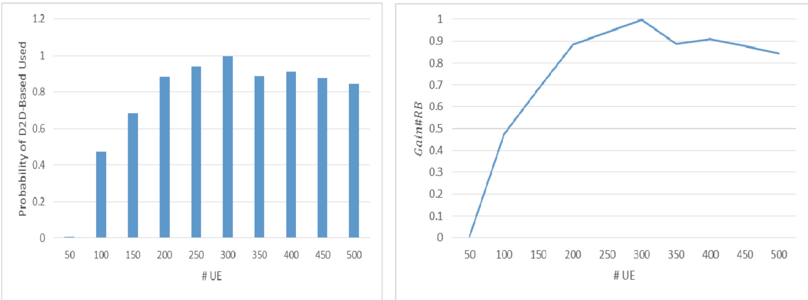


**Fig. 3.** Simulation results. (a) Shows the probability of adopting proposed mechanism while (b) shows the RB reduction as number of UE increased.

Figure 3 shows the simulation results. The probability of adopting D2D-Based eMBMS service increased as number of UE increase. More opportunity to trigger the D2D-based mechanism, resulting in more RB saving. When the number of UE larger than 300, the probability of adopting D2D-Based eMBMS service decreased due to the D2D spatial reuse difficulty.

## 5 Conclusion

A Device-to-Device based mechanism was proposed to improve transmission efficiency of eMBMS service in this paper. An idea of smaller eMBMS zone is used to improve transmission efficiency while D2D and unicast transmission are used to serve UEs located in D2D zone. A suitable zone size decision mechanism and a D2D relay UE selection algorithms are also proposed. Simulation results have shown that the proposed D2D-based mechanism can reduce the number of allocated resource blocks.

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