A Low-Complexity Subgroup Formation with QoS-Aware for Enhancing Multicast Services in LTE Networks

M Algharem¹, M H Omar¹, R F Rahmat² and R Budiarto³

¹InterNetWorks Research Group, School of Computing, College of Arts and Sciences, Universiti Utara Malaysia, Malaysia
²Dept. of Information Technology, Faculty of Computer Science and Information Technology, Universitas Sumatera Utara, Medan, Indonesia
³Dept. of Computer Information System, College of Computer Science and Information Technology, Albaha University, Albaha, Saudi Arabia

{algharem,mhomar}@internetworks.my, romi.fadillah@usu.ac.id, rahmat@bu.edu.sa

Abstract— The high demand of Multimedia services on in Long Term Evolution (LTE) and beyond networks forces the networks operators to find a solution that can handle the huge traffic. Along with this, subgroup formation techniques are introduced to overcome the limitations of the Conventional Multicast Scheme (CMS) by splitting the multicast users into several subgroups based on the users’ channels quality signal. However, finding the best subgroup configuration with low complexity is need more investigations. In this paper, an efficient and simple subgroup formation mechanisms are proposed. The proposed mechanisms take the transmitter MAC queue in account. The effectiveness of the proposed mechanisms is evaluated and compared with CMS in terms of throughput, fairness, delay, Block Error Rate (BLER).

1. Introduction

To handle the rapid growth of demand on multicast services such as Internet video streaming, video conferencing, news broadcast, and weather forecasts, Evolved Multimedia Broadcast Multicast Service (E-MBMS) as part of the Third-Generation Partnership Project (3GPP) LTE standard was proposed to deal with multicast services [1]. In E-MBMS, a multirate is used to server several users at the same time using same channel, which efficiently utilizes the network resources. Multicast services can be operated either in Conventional Multicast Scheme (CMS), Opportunistic Multicast Scheme (OMS), multirate (MR), or multilayers (ML). However, in CMS system, the network performance bounded by the user with the worst channel gain (WCG) in the multicast group. The fairness between users is increased on account of wasting network resources. In OMS, in each scheduling time, the best users are served. Then, in next transmission time, the best users among remain users are served. This process is repeated until all users get served. Even OMS utilizes the users diversity, it still waste the bandwidth by transmitting the same data several times. Moreover, it is difficult to use OMS in fast fading environment. To overcome the drawback of the CMS and OMS, the multirate system was used to improve the network resources utilization, as well as enhances the multicast throughput.

In contrary to CMS and OMS, multirate splits the users in each multicast group into several subgroups according to users channels gain. Each subgroup will receive the data at the worst user rate.
As result, different rates will be used to serve each multicast group. Frequently, users will join and leave the subgroup according to their instance channel gain.

In order to enhance the multicast performance, the number of subgroups and the number of users in each subgroup should be selected precisely. Finally, in multilayers, the video is splitted into several layers; base layer (BL) and one or more enhanced layers (ELs). The BL is transmit to all multicast group users, whereas the ELs layers are by the users with better channels gain. In fact, obtaining the best subgroup configuration or layer configuration, which results on maximizing the multicast performance is an NP-hard problem [2]. The complexity of finding the optimal subgroup configuration exponentially depends on the free network resources and on the number of the subgroups. The BL is sent to all subgroups whereas the ELs layers are sent to the subgroups which can decode the EL layers, which in turn, increase the network utilization. Authors in [3-6] proposed resources allocation approach by exploiting the frequency selectivity to schedule the EL to the subgroups that guarantees the best utilization of network resources. Consequently, determining the number of subgroups and the amount of radio resources that should be allocated to each subgroup is still an open issue and need to be properly selected.

In this paper, an innovative Radio Resource Management (RRM) mechanism is proposed to increase the E-GBMS performance by implementing the multirate scheme. The proposed RRM efficiently splits each multicast group into two or more subgroups according to the users channel quality, and allocated the resource to each subgroup in such a way that increases the network resources utilization. The proposed RRM uses two thresholds to split the multicast group into three subgroups (upper, lower, and medium subgroups). These thresholds are selected according to the Standard Division (StD), and the average of users channels quality.

This paper has been divided into following sections. Section 2 provides background of resource allocation in multicast. Section 3 introduces the proposed subgrouping mechanism. After that, simulation results are presented in Section 4. Finally, a conclusion is summarized in Section 5.

2. Long-Term Evolution (LTE) Network
Orthogonal Frequency Division Multiplexing (OFDM) is a promising technique for the future generation of wireless communication systems due to its tolerance to interference and fading. LTE networks use Orthogonal Frequency Division Multiplexing Access (OFDMA) which is based on OFDM [7]. However, in OFDMA, the full frequency bandwidth is divided into orthogonal subcarriers, where each subcarrier is allocated 15 kHz. The LTE frame consists of 12 consecutive subcarriers and 10ms duration. Each frame consists of 10 sub-frames; each sub-frame is 1ms, which is identical to the Transmission Time Interval (TTI); and then each sub-frame is equal to two-time slots, where each slot is 0.5 ms in the time domain and 12 subcarriers in the frequency domain. However, each slot is composed of a resource block (RB), which is the minimal radio resource allocation unit in the LTE. Each RB consists of seven symbols when the normal Cycle Prefix (CP) is used or six symbols when the extended CP is used. The extended CP is used in E-GBMS sub-frame [8]. Moreover, to take advantage of the frequency selectivity in the LTE network, each user periodically or non-periodically sends its Channel Quality Indicator (CQI) feedback to its base station which is called Evolved NodeB (eNodeB), as such the eNodeB dynamically selects the Modulation and Coding Scheme (MCS) level for that user which leads to high throughput while maintaining the block error rate (BLER) lower than 1% [9]. The high MCS means high transmission rate. Therefore, there are 15 levels of MCS supported by LTE network, as listed in Table 1.

Multicast data can be transmitted either in multirate or single rate mode. Each transmission mode has its own techniques, which are used to utilize the system resources and select the suitable transmission rate. Until recently, single rate transmission is more commonly used because of its low complexity and simplicity. On other hands, more attentions lately have been paid on multirate [10]. In the single rate mode, such as Conventional Multicast Scheme (CMS), a single data rate is selected to transmit the data to all users belong to the same multicast group. Usually, the data rate is selected according to the user with the worst channel gain (WCG) [11], [12], [13]. Moreover, the data rate can
be selected either by using predetermined fixed rate (PFR) [11], [14], by using average multicast group rate (AVG) [12], [15], [16], weighted average rate [11], or target Spectrum Efficiency [13], [12].

However, transmitting the data using the AVG or PFR may result in a high packet loss especially for cell edge users as they cannot decode the AVG rate. Furthermore, for a reliable multicast delivery, the transmission rate should be selected equal to the WCG rate. The WCG mechanism provides high fairness among users belong to the same multicast group on account of wasting the network resources by forcing the users with high channel gain to receive the data with low rate.

Multirate Multicast Scheme (MMS) was proposed to utilize the merit of single rate transmission and the multiuser diversity of OFDMA for reliable data decoded [7]. In MMS, the data are transmitted to all multicast group users using several streams with different data rates. In compare to the CMS, multirate transmission techniques are more computational complexity, challenging in grouping users with high mobility [10]. MMS can be operated using Information Decomposition Techniques (IDT) [17-22], which splits the transmitted data into several sub-streams or layers. Each sub-stream or layer is transmitted using different MCS levels to ensure that each user can receive the data with bit rate equivalent to its MCS level. The base sub-stream or layer is transmitted with a MCS level which can be decoded by all users. The other sub-stream or layer (so-called enhanced substream or layer) will be received by users with good channel condition. There are two types of IDT: Multiple Description Coding (MDC) [17-19 and Hierarchical Layering (HL) [20-22].

The main different between MDC and HL is the sequence priority of received layers, in HL is required while in MDC is not. Another multirate technique is a cooperative multicast technique, in which a user with high gain channel can operate as a relay by forwarding the received packets to the rest users with bad channel condition who could not receive the packets. Cooperative multicast is a new technique, where the first was used in unicast network to improve the system performance. More details about cooperative multicast can be found in [23-26]. Furthermore, MMS can be operated using Multicast Subgroup Formation (MSF) techniques, or called as a group split, [16], [27], which overcome the limitation of CMS by separating users of a multicast group into two or more subgroups according to their channels gain. Thus, users with high channel gain can be formed as a subgroup and received a data with high bit rate, whereas, users with bad channel will receive the data with robust low bit rate. However, our proposed mechanisms are based on MSF techniques.
3. System Model and Problem Formulation

In LTE network, there are 15 levels of CQI, each level associated with an MCS level as listed in Table 1. Let \( L = 15 \) is the CQI levels, then \( CQI_l \), where \( l = \{1, 2, \ldots, L\} \). Thus, \( MCS_l \) is the MCS associated with the \( CQI_l \). Any user has sent a \( CQI_l \) feedback to its eNodeB, it can successfully receive and decode the transmitted data which is transmitted with the \( MCS_l \) level where \( i \leq l \).

| CQI Index | Modulation | Code rate x 1024 | SE [bit/s/Hz] |
|-----------|------------|-----------------|---------------|
| 1         | QPSK       | 78              | 0.1523        |
| 2         | QPSK       | 120             | 0.2344        |
| 3         | QPSK       | 193             | 0.3770        |
| 4         | QPSK       | 308             | 0.6016        |
| 5         | QPSK       | 449             | 0.8770        |
| 6         | QPSK       | 602             | 1.1758        |
| 7         | 16QAM      | 378             | 1.4766        |
| 8         | 16QAM      | 490             | 1.9141        |
| 9         | 16QAM      | 616             | 2.4063        |
| 10        | 64QAM      | 466             | 2.7305        |
| 11        | 64QAM      | 567             | 3.3223        |
| 12        | 64QAM      | 666             | 3.9023        |
| 13        | 64QAM      | 772             | 4.5234        |
| 14        | 64QAM      | 873             | 5.1152        |
| 15        | 64QAM      | 948             | 5.5547        |

Let consider \( K \) users belong to \( G \) groups that receiving the data using \( N \) subcarriers over a single eNodeB as illustrated in Figure 1. The set of users, groups, and subcarriers are represents by \( \mathcal{K}, \mathcal{G}, \mathcal{N} \) respectively. The system bandwidth \( W \) is equally shared between all subcarriers, so the bandwidth of subcarrier \( n \) is \( B_n = \frac{W}{N} \). In this research, for simplicity reason, we use one multicast group \( G = g = 1 \). Thus, all users belong to one multicast group. Furthermore, we assume each subcarrier \( n \) have equal power \( P_n \). Assume a perfect orthogonality preserved, and perfect synchronization, so there is no inter symbol interference and no inter-carrier interference. All users receive transmitted data over one or more subcarriers without any interference. It is assumed that the eNodeB using reliable feedback channels to received CQI report from each user without any delay. Let \( \mathcal{K}_g \) denotes the \( g \) users group set, and the cardinality \( \| \mathcal{K}_g \| \) denotes the number of users in group \( g \), where \( g = \{1, 2, \ldots, G\} \). Thus, for multicast \( \| \mathcal{K}_g \| \geq 2 \), and \( \| \mathcal{K}_g \| = 1 \) in unicast.

Moreover, \( \sum_{i=1}^{G} \| \mathcal{K}_g \| = K \), \( \mathcal{K} = \cup_{g=1}^{G} \mathcal{K}_g = \mathcal{K}_1 \cup \mathcal{K}_2 \cup \cdots \cup \mathcal{K}_G \). Let \( MCS_{g}^{v} \) represents the MCS vector of users in group \( g \), where \( MCS_{g}^{v} = \{MCS_{1}, MCS_{2}, \ldots, MCS_{M}\}, M = \| \mathcal{K}_g \| \).

Let also consider \( r_{k,n} \) is the data rate of user \( k \) on subcarrier \( n \). The total multicast throughput depends on the number of groups, group rate, and the number of subcarrier allocated to each group. The RRM allocates the system subcarriers to all groups in a way that can maximize the system throughput while keep the fairness between users in acceptable level. According to [17], CMS throughput is bounded by the users with WCG, and will saturate when the users number increases in Rayleigh and Ricean fading environments. As aforementioned, the MMS techniques were emerged to overcome the limitations of the CMS. The MSF maximizes the multicast throughput by splitting the \( G \) groups into \( S \) subgroups with set \( S \), where \( S = \{1, 2, \ldots, S\} \) and \( G \leq S \leq K \). In details, each group \( g \) can be splitted into \( S_g \) subgroups, where \( S_{g} = S_{g}^{1} \cup S_{g}^{2} \cup \ldots \cup S_{g}^{I_g} \), and \( I \leq I \leq L \). Then it transmits the data to each subgroup using a WCG rate. To efficiently utilize the multiuser diversity, the MG users
are splitted according to their channel gains. Thus, each subgroup $S_g^l$ contains a set of users with same or close channel gains.

$$\max \sum_{s=1}^{S} \sum_{n=1}^{N} \sum_{k=1}^{K} r_{s,n} \alpha_{s,k} \omega_{s,n}$$

(1)

$$\omega_{s,n}, \alpha_{s,k} \in \{0, 1\}, \forall s \in S, \forall k \in K, \forall n \in N$$

(2)

$$\sum_{s=1}^{S} \omega_{s,n} = 1, \sum_{s=1}^{S} \alpha_{s,k} = 1, \forall s \in S, \forall n \in N, \forall g \in G$$

(3)

where $\omega_{s,n}, \alpha_{g,s,k}$ are binary indicators, which indicate either subcarrier $n$ and user $k$ belong to subgroup $s$ or not.

The RRM have to assign subcarriers and users to proper subgroups in order to maximize the total throughput. Thus, problem that is described in equations (1)-(3) is considered as NP-Hard (Non-deterministic Polynomial-time) Hard problem which does not have an optimal solution. Indeed, there is a solution for this problem by using exhaustive search algorithm, but it is usually a high complex and time-consuming computations [33]. Moreover, the complexity of NP-Hard increases exponentially with the number of subcarriers, subgroups, and groups which make it unrealistic to practical used. Furthermore, there are $S^N$ solutions for scheduling radio resources between all subgroups $S$ [2, 6]. Therefore, a lower complexity suboptimal mechanisms with an acceptable performance are usually preferable for practical systems. Nevertheless, this paper introduces simple but efficient suboptimal mechanisms which use the standard deviation (SD) of users channel gains to split each multicast group to three subgroups, worst, best, medium subgroups. The worst subgroup will contain all cell edge users whose MCSs are extremely low. The best subgroup will contain the cell center users whose MCSs are excessively high, whereas the medium subgroup will contain the remain users with medium MCSs levels. Another proposed mechanism split the multicast group users into two subgroups. First subgroup contains cell edge users, whereas the remain users will form the second subgroup.

4. The Multicast Packet Scheduling

To ensure that the proposed splitting mechanisms increase the multicast network, the eNodeB MAC queue status and utilized RBs increased as the number of subgroups increase. Moreover, the transmission delay increases as the number of subgroups increase. Therefore, the optimal subgroups number should be determined base on the MAC queue status and available RBs. In details, the Head of Line Delay (HOL), queue size, and available RBs are obtained to determine how many subgroups can be formed from a group $g$ and can be served with the free RBs before the packets delay meet the predefined maximum video delay.

$$T_{free} = HOL - \left(\frac{q_s}{r_g}\right)$$

(4)

Where $T_{free}$ is the free slot might remain after transmitting all packets which waiting in the MAC queue, $q_s$ represent the current size of all packets in the MAC queue, and $r_g$ is the selected transmission rate in multicast group $g$. Therefore, if $T_{free}>0$, then group $g$ can be splitted to $S_1$ and $S_2$ subgroups (or clusters). Thus, $S_2$ rate is selected to be able to transmit the data during the $(T_{free})$ slots. Then, it will contain users who can receive the data with $S_2$ rate. The remain users will join $S_1$. Moreover, if $T_{free}$ is more than enough to transmit the data to $S_1$ and $S_2$, then $S_1$ will be splitted to get $S_1$. These steps are repeated until $T_{free}=0$. In fact, the number of obtains subgroups is affected by the users channel gain, video rate, video type, available BW, and maximum video target rate. We used the $T_{free}$ in the account when implementing our subgrouping mechanisms.
5. The Proposed Subgrouping Mechanisms

In order to satisfy all users, each user should receive the data with its rate, hence; users with the same rate will form a subgroup. As consequently, the maximum number of subgroups is equal to the number of available rate offered by LTE network, which is equal to 15. In fact, the subgroups number will increase as well as the multicast group users increase, as shown in Figure 2a. The reason behind that is, when the number of user increases, the probability to use more different rate levels increased. Unfortunately, the benefit of multicast is reduced as the subgroups number increased (increasing the multiuser diversity on account of multicast gain), as illustrated in Figure 2b. As result, the multicast group throughput decreased as the subgroups number increased.

![Figure 2. Group-Based Evaluation Results (a) Subgroups Number. (b) Average User Throughput.](image)

Therefore, a trade off between multicast gain and users deversity selection should be applied. In this paper, two subgrouping mechanisms are proposed. First one uses two thresholds (upper and lower thresholds), thus, three subgroups are formed. The second mechanism uses the lower threshold to split users into two subgroups.

5.1. StD-based formation mechanism

This paper introduces a simple but efficient suboptimal mechanism referred as StD-Based, which uses the StD of users channel gains to split each multicast group to three subgroups, worst, best, and medium subgroups. The worst subgroup will contain all cell edge users whose MCSs are extremely low. The best subgroup will contain the cell center users whose MCSs are extremely high, whereas the medium subgroup will contain users with medium MCSs levels. As shown in Figure 3, the medium subgroup size is the biggest which means most users form it, whereas the smallest subgroup is the lower subgroup which contains only few users (usually cell edge users). The proposed subgrouping mechanism uses the StD to show how the users MCS levels are distributed and deviated from the average value of all users MCS level values. The StD with small value mean MCSs of all users are closed together, whereas, the big StD value mean that all users are far from each other. However, in case of the users MCSs standard deviation value is enough small; it means the MCS level of the worst user case will be suitable for all users. The StD and average of users MCSs will be used to divide the multicast users into several categories or subgroups by using upper and lower thresholds. These thresholds will be used to split each multicast group into three subgroups. The following equations are used to calculate the upper and lower MCS thresholds for each multicast group g.
Then, each group $g$ in $K$ set will be splitted into three subgroups ($S_g^b$, $S_g^m$, $S_g^w$), where

$$S_g^w = \{MCS_i \mid \forall MCS_i < T^g_{low}\},$$

$$S_g^b = \{MCS_i \mid \forall MCS_i > T^g_{up}\},$$

$$S_g^m = \{MCS_i \mid \forall MCS_i \leq T^g_{low}, MCS_i \leq T^g_{up}\}.$$

### 5.2. M-WCG-based formation mechanism

As mentioned by work in [29], the Modified WCG mechanism (M-WCG) sacrifices users with low channel rate, which deviate from remain users channel rates and degrades the multicast performance. The threshold which is used to determine users with low channel gain is obtained from equation 6. In fact, in urinate system, these users with low channel gain cannot receive the data until they improve their channel gain. To overcome the limitation of M-WCG, we will use multirate technique (MR) with our M-WCG (so-called MR-M-WCG) to split the users into two subgroups. The worst users will form a subgroup; whereas, other users will form the second subgroup. The algorithm to select the MCS level is as follows.

**ALGORITHM:** MCS Selection Using Multirate Technique

1: Start
2: **Input:** $T^i_{up}, T^i_{low}, MCS^v_i$ ($i = 1, 2, \ldots, g$)
3: **Output:** $MCS^v_i, S^i_b, S^i_m, S^i_w$ ($i = 1, 2, \ldots, g$)
4: **Method:**
5: **Foreach** $g$ in $K$
6: Calculate($MCS^v_g$);
7: Calculate($\sigma_g$);
8: $T^g_{up} = MCS^v_g + \sigma_g$;
9: $T^g_{low} = MCS^v_g - \sigma_g$;
10: **Foreach** $MCS_i$ in $MCS^v_g$;
11: $S^w_g = \{MCS_i \mid \forall MCS_i < T^g_{low}\}$;
12: \[ S^b_g = \{MC_S_i| \forall MC_S_i > T^b_{up}\}; \]
13: \[ S^m_g = \{MC_S_i| \forall MC_S_i \geq T^m_{low}, MC_S_i \leq T^m_{up}\}; \]
14: EndForeach
15: Foreach \( S \) in \( g \)
16: \[ MCS^g_S = \text{argmin}\{S\}; //select the smallest MCS in each subgroup \]
17: Return MCSpw;
18: EndForeach
19: EndForeach
20: End

6. Simulation of the model and results

In this section, the proposed mechanisms performance are evaluated and compared with M_WCG, WCG (or known as CMS), and MCS-Based mechanisms.

6.1. Simulation Scenario

Since we use multirate mode, each multicast group may be split to one or more subgroups, several rates of Foreman video sequences (traced files) are used, which can be obtained from a Video Trace Library [30]. The trace file is coded by H.264/AVC coders at 30 fps. At first, we used the Foreman traced file with 242 kb/s rate as a based stream to serve the worst subgroup. Then, we generate several copies of the based stream with different rates by following the steps which recommended by Seeling et al. [31]. First, we scale the frame size to get a new trace file with higher rate than base traced file rate. Then, we wrap around the base trace file, if its end is reached. Therefore, the simulation continues transmits the data from the beginning of the traced file again once it reaches the end. By these steps, we generate a set of video traced files with different bit rates.

The proposed RRM mechanisms have been compared with the CMS in terms of average users throughput, fairness, delay, Block Error Rate, and resources utilization. For simplicity seek, only E-MBMS has been activated in the simulation. Thus, the whole bandwidth was assigned to the E-MBMS. For more accurate, each scenario was performed with a different number of users who uniformly distributed. Each scenario was repeated until obtain 95% confidence interval, then the average results were calculated and plotted. A realistic video trace files with 440 Kbit/s was used, which is available in [30]. The main simulation parameters are selected as defined in [32]. More details about simulation parameters are listed in Table 2.

| Parameter                  | Value                                      |
|----------------------------|--------------------------------------------|
| Carrier Frequency          | 2GHz                                       |
| Path loss                  | \(100.54 + 34.1\log_{10}(d), d \text{ in km}\) |
| Thermal noise              | \(-174 \text{ dBm/Hz}\)                   |
| Downlink Bandwidth         | 3 MHz                                      |
| Symbols for TTI            | 12                                         |
| Sub-Frame Length           | 1 ms                                       |
| Frame Type                 | FDD                                        |
| eNodeB radius              | 1 km                                       |
| eNodeB Power transmission  | 43 dBm                                     |
| Modulation Schemes         | QPSK, 16QAM, 64QAM (dynamic)               |
| No. of users               | 20-100 users                               |
| No. of E-MBMS group        | 1                                          |
| User transmission power    | 23 dBm                                     |
| User distribution          | Randomly and uniformly distributed         |
| User speed                 | 30 km/h                                    |
| User mobility model        | Random direction model                      |
CQI scheme Full Bandwidth
Application flows Video
Video rate 440 kbps
Simulation time 20 Second
Shadow fading Log normal, $\mu=0$, $\sigma=8$ (dB)
Scheduling correlation 50 m [32]
Fast fading ITU-R Pd6B (extended for OFDM [32])
TTI $i$ ms
MIMO conclusions 1 Tx, 2 Rx
Penetration loss 20 dB

6.2. Performance metrics
The proposed mechanisms are compared by using the following performance metrics.

- Resource Utilization Rate indicates the rate of utilized resources that consumed to support the multicast group to deliver its video stream. Thus, It is computed as the number of assigned RBs, during the session, divided by the total number of available RBs. Therefore, the Resource Utilization Rate for group $g$, referred as $U_g$ can be obtained as follows:

$$U_g = \frac{1}{T \cdot N} \sum_{i=1}^{T} RB_g^i$$

(7)

where $RB_g^i$ is the number of RBs which is assigned to group $g$ in $i$ scheduled time (TTI), and $N$ is the number of RBs that associated with the selected bandwidth (for example, 15 RBs within 1.4 MHz system bandwidth).

- User Fairness Index (FI): this metric is used to measure the how the RBs assigned between the users within a multicast group [17]. The FI is defined as:

$$FI = \left( \sum_{k=1}^{K} \frac{r_k}{\sum_{k=1}^{K} r_k} \right)^2$$

(8)

where $r_k$ denotes the throughput of the $k$-th user, and FI value varies between $1/K \leq FI \leq 1$. The maximum $FI=1$ can be obtained when all users are served with the same rate.

- Average User Throughput is the cumulative throughput of multicast group $g$ divided by the number of users in that group.

- Delay is calculated as the time taken from transmit the packet until it is received at the target node.

6.3. Simulation Results
The number of subgroups formed in each mechanism is shown in Figure 4. The proposed MR-M-WCG produced a lower BLER compared to other mechanism as shown in Figure 5.

The first evaluation is in term of average user throughput as shown in Figure 6. The proposed MR-M-WCG and StD-based subgrouping mechanisms outperform the CMS and MCS-Based in term of throughput. The StD-based mechanism provides the best throughput among other mechanisms especially, when the users are more than 20. The MCS-Based throughput degrades rapidly as the number of users increased. The rational is because the subgroups number increase as the users of multicast group increasedThus, the resource blocks are distributed between all subgroups, which increases the multiuser diversity in account of reducing the multicast gain.
As it clearly appears in Figure 7, the lowest delay is achieved by M-WCG since it does not include the abnormal users who suffer very bad channel gain. The highest delay is performed by MCS-Based mechanism. The reasons behind this is because MCS-Based has more subgroups than other mechanisms, which take several TTIs until all its subgroups get served. The of the proposed subgrouping mechanism provide moderate delay.

As shown in Figure 8, the maximum fairness is achieved by CMS. The FI of the proposed subgrouping mechanism is less than FI of CMS. Therefore, the FI of the proposed subgrouping mechanism decreased as the number of users increased, because the subgroups size increases as the users increase. However, the FI of proposed mechanism is near the optimal value because each multicast group was splitted to only three subgroups, which mean three different rates available for all users in the multicast group.

In Figure 9 we can observe that the network resources utilized increases as the subgroup number increased. Therefore, the MCS-Based utilizes all available resources.
7. Conclusion
In this paper, an efficient and low complex subgrouping mechanism was proposed to improve the performance of the EMBMS. The SINR of a multicast group users have been used to split the users into several subgroups. The Std and average of the users SINR were used as criteria to classify the users according to their SINR. The simulation results showed that the proposed subgrouping mechanism improves the throughput of the E-MBMS compared to the Conventional Multicast Scheme, while keeping the fairness between all users in acceptable level.

References
[1] 3GPP, Multimedia Broadcast/Multicast Service (MBMS); Architecture and functional description, TS 23.246, 3rd Generation Partnership Project (3GPP) (2009). URL http://www.3gpp.org/ftp/Specs/html-info/23246.htm.
[2] Afolabi R, Dadlani A and Kim K 2013 Multicast scheduling and resource allocation algorithms for ofdma-based systems: A survey, IEEE Commun. Surveys Tutorials 15(1) 240–54.
[3] Eusebio P and Correia A 2005 2nd Int. Symp. Wireless Commun. Syst. pp 777-81.
[4] Araniti G, Scordamaglia V, Molinaro A, Iera A, Interdonato G and Spano F 2011 IEEE Int. Symp. BMSB pp 1-5.
[5] Militano L, Condoluci M, Araniti G and Iera A 2012 IEEE VTC Fall pp 1-5.
[6] Condoluci M, Araniti G, Molinaro A and Iera A 2016 Multicast resource allocation enhanced by channel state feedbacks for multiple scalable video coding streams LTE networks 65(5), pp 2907–21.
[7] Tan C K, Chuah T C and Tan SW 2014 Comput. Networks 64 pp 180–194.
[8] Rimne M and Tirkkonen O 2010 Comput. Commun. 33(16) pp 1894–1906.
[9] Mehlführer C, Wulich M, Ikuno J C, Bosanska D and Rupp M 2009 Simulating the long term evolution physical layer 7th Eur. IEEE Signal Process. Conf. pp 1471–78.
[10] Afolabi R O and Kim K 2012 4th ICUFN pp 255-60.
[11] Kim J and Cho DH 2005 62nd IEEE VTC-2005-Fall pp 725-9.
[12] Bochrini S, Bouras C and Kokkinos V 2013 6th Joint IFIP WMNC pp 1-8.
[13] Alexiou A, Bouras C, Kokkinos V, Papazois A and Tschritzis G 2010 Spectral efficiency performance of mbsfn-enabled lte networks IEEE 6th Int. Conf. WiMob pp. 361–7.
[14] Agashe P, Rezaifar R and Bender P 2004 IEEE Communications Magazine 42 2 pp 83-89.
[15] Won H, Cai H, Eun D Y, Guo K, Netravali A, Rhee I and Sabnani K 2009 Wireless Commun. 8 9 pp 4540-49.

Figure 8. FI between Proposed subgrouping Mechanisms and CMS
Figure 9. Network Resources Utilization Rate between Proposed subgrouping Mechanisms and CMS
[16] Koh C H and Kim YY 2006 64th IEEE VTC-2006 Fall pp 1-5.
[17] Suh C and Mo J 2006 25th IEEE INFOCOM pp 1-12.
[18] Yoon J, Zhang H, Banerjee S and Rangarajan S 2012 MuVi: a multicast video delivery scheme for 4G cellular networks ACM Proc. 18th Annu. Int. Conf. Mobile Comput. Network. pp 209–210.
[19] Shao M, Dumitrescu S and Wu X 2011 IEEE Trans. Multimedia 13 2 pp 353-65.
[20] Deb S, Jaiswal S and Nagaraj K 2008 27th IEEE Communications Society Conference on Computer Communications INFOCOM pp 2252–60.
[21] Suh C and Hwang CS 2004 15th IEEE Int. Symp. PIMRC 3 pp 2102-6.
[22] Han T and Ansari N 2011 IEEE Communications Letters 15 6 pp 620-2.
[23] Elrabiei S M and Habaebi MH 2010 21st IEEE Int. Symp. PIMRC pp 1719-24.
[24] Elrabiei S M and Habaebi MH, 2010 5th IEEE Int. Symp. Wireless Pervasive Comput. pp 600-5.
[25] Hou F, Cai I-L X, Ho P-H, Shen X and Zhang J 2009 IEEE Trans. Wireless Commun. 8 3 pp 1508-19.
[26] Shrestha N, Saengudomlert P and Ji Y 2010 Int. Conf. ECTICON pp 410-414.
[27] 3GPP, 2013 Evolved Universal Terrestrial Radio Access (E-UTRA); physical layer procedures, TS, 36.213, 3rd Generation Partnership Project (3GPP).
[28] Video trace library. [Online]. Available: http://trace.eas.asu.edu/.
3GPP, 2006 Physical layer aspect for evolved Universal Terrestrial Radio Access (UTRA),” TR, 25.814 3rd Generation Partnership Project (3GPP), 2006.
[29] Algharem M, Omar M H, Alghamdi I, and Budiarto R 2015 An efficient modulation and coding scheme selection mechanism for single-cell mode e-MBMS 2nd Int. Conf. Electrical Eng. Comput. Sci. Inf. 2(1).
[30] Seeling P and Reisslein M 2005 Evaluating multimedia networking mechanisms using video traces IEEE potentials 24 (4) pp 21–5.
[31] 3GPP 2006 Physical layer aspect for evolved Universal Terrestrial Radio Access (UTRA), TR 25.814, 3rd Generation Partnership Project (3GPP) (Oct. 2006).
[32] Sharangi S, Krishnamurti R and Hefeeda M 2011 IEEE Trans. on Multimedia 13 1 102-15.