Pricing Based Resource Allocation Scheme for Video Multicast Service in LTE Networks

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***Abstract*— How to efficiently use the limited wireless bandwidth is of paramount important in the radio wireless network area. To use the wireless bandwidth in an efficiently way, one can consider a pricing model to improve users received video layers. In this paper, the users are divided into three classes. For different class users, they pay different price and enjoy different QoS. In a pricing model, more video layers are allocated to those users who pay a higher price. We propose a Pricing Class based Resource Allocation Scheme (PCRAS) that considers the price of multicast group and uses channel quality indicator to compute resource allocation priority to dispatch resource blocks efficiently. Experimental results shows that the proposed scheme can increase users' received video layers and users between different classes will receive different level of services. In comparison to other existing scheduling schemes, the proposed scheme can improve users' video experience.**

I. INTRODUCTION

In 4G, mobile TV and Video on Demand (VoD) streaming services are two of the most important services [1]. LTE provides a service which can allow users to form a group and play the same video in broadcast or multicast. This service is named Evolved Multimedia Broadcast/Multicast Service (eMBMS) [2]. With this service, the same group of users can receive the same video information in a specific cells coverage. Based on the protocol of eMBMS, all of the cells need to use the same frequency to broadcast or multicast the same groups at the same time. In the future, service providers might develop a business model to multicast users streaming videos in LTE cell range based on the price to use resources more efficient. Based on the price users pay, give different class users different number of resource blocks is one of directions to utilize resource blocks more efficiently. As a result, one can improve the whole LTE networks system's performance. In this paper, we proposed a resource allocation scheme called Pricing Class based Resource Allocation Scheme (PCRAS) in an eMBMS scenario. PCRAS is to decide the transmission order of the multicast groups using a user class, channel condition and price factors. With the multicast transmission order, users can receive video layers depending on how much they pay. Related Works

In the LTE system, eNodeB transmits to UEs with a downlink reference signal to help UE to calculate the users' Signal to Interference and Noise Ratio (SINR) [3]. Equation (1) is used to calculate sub-channel k's SINR value. $P_{RX,i,k}$ is the receiver power of the i-th UE for the k-th sub-channel. F, N_0, B, and I are the noise figure, the noise spectral density, the bandwidth of the resource block, and the interference, respectively. The noise figure F default value is 2.5. The noise spectral density's value N_0 default is -174 dBm. The bandwidth of the resource block B is defined in the LTE specification and the default value is 180 kHz. $P_{RX,i,k}$ is expressed as (2). $P_{TX,k}$, $M_{i,k}$, L_i, T_i, and $S_{i,k}$ are the eNodeB transmission power, the loss, path loss, penetration, and shadowing. The value for variables are expressed in dB. After knowing the sub-channel's SINR, one could obtain an estimation of a UE's SINR. Equation (3) shows the exponential effective SINR mapping [4], with this equation, one can obtain the modulation method.

$$SINR_{i,k} = \frac{P_{RX,i,k}}{(FN_0B) + I} \tag{1}$$

$$P_{RX,i,k}|_{dB} = \left(P_{TX,k} - M_{i,k} - L_i - T_i - S_{i,k}\right)|_{dB} \tag{2}$$

$$eff_{sinr_i} = -\beta \ln\left(\frac{1}{N}\sum_{k=1}^{N} e^{-\frac{SINR_k}{\beta}}\right) \tag{3}$$

RRM is a management unit that is responsible for allocating wireless resources. Efficient resource management aims to satisfy the QoS requirements, provides a fair services, and maximizes the system performance [5]. In the previous researches, many scheduling schemes were proposed as follows:

a. Maximum Throughput (MT): The scheme is to choose a better channel quality group and give him a priority to use resource. r_{G_i} is channel condition.

$$\arg\max_{G_i}(r_{G_i})$$

b. Round Robin (RR) : The scheme performs fair sharing of resources among users.

$$G_i, from\ i = 1\ to\ N$$

Mir et al. [6] highlighted several aspects related to pricing in modern day wireless multimedia 4G networks. The adaptation of different existing pricing strategies within LTE networks is presented. Maiti and Belghith et al. [7] [8] introduce some pricing strategies.

II. PROPOSED METHOD

In this section, the novel resource allocation scheme called Pricing Class based Resource Allocation Scheme (PCRAS) for multicasting videos is proposed. In the literature, the price of different users can be split into three class of users : Golden, Silver and Bronze. Golden class users pay the most expensive price, Silver class users pay the medium price, and Bronze class users pay the lowest price. Here, we also split the users into three classes based on the level of the price: called class1, class2, class3, from higher price to lower price. In Fig. 1, the eNodeB is placed in the center, and the grey circle represents the transmission range of the eNodeB. The users with user equipment (UE) in the grey circle range is colored differently based on their class.

In the following, the eNodeB has to multicast videos to the users in the transmission range. We merge users into one multicast group if they are receiving the same video and in the same class. In the proposed scheme, the transmission priority of a user is based on the price they are willing to pay. The higher price the better video layers a user can receive. But in the regular resource allocation scheme, this will cause some problems. The lower class users will not receive any video layer, if higher class users use all resource blocks. This kind of problem has to be solved. LTE service provider will collect users' information to allocate resources to proper users. The proposed scheme, PCRAS, is mainly operating on an eNodeB. The entire PCRAS flowchart is illustrated in Fig. 2.

Fig. 1 Illustration of multicast groups

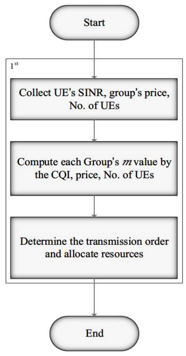

Fig. 2 The flowchart of the PCRAS

The proposed scheme, PCRAS, will provide the basic video service for all users. It collects users' information to compute multicast groups' transmission orders and allocates resources. In PCRAS, we will formulate the different levels of service to each class user first as shown in Fig. 3. Fig. 3 shows the basic requirement video layers for each class's users. The video multicast is based on scalable video coding scheme. We let Class three users receive the base layer at least. Class two users can receive base layer and one enhancement layer. Class one users can receive a base layer and two enhancement layers. In equation (4), P_1, P_2, P_3 are the price model. $C(G_i)$ is the class of multicast group i. We formulate the revenue as follows. Table I lists the parameters that will be used for the PCRAS.

$$C(G_i) = \begin{cases} 1, \; if \; P(G_i) = P_1 \\ 2, \; if \; P(G_i) = P_2 \\ 3, \; if \; P(G_i) = P_3 \end{cases} \quad (4)$$

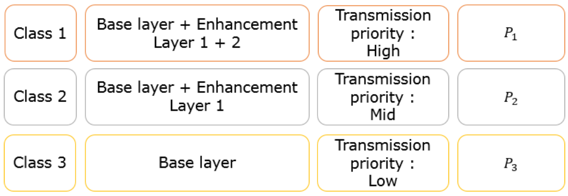

Fig. 3 The video layers are available for each class's users

First, the scheme have to estimate all the multicast group's resource using efficiency. One has to collect all the UE's SINR to measure the channel quality indicator (CQI). And eNodeB will select the proper modulation and coding scheme to the multicast group according to the CQI feedback. In the LTE specifications, there is a SINR spacing can be referred. With exponential effective SINR mapping [4], one can obtain the modulation method. Equation (5) shows the multicast group i required resources for the layer l. $d(G_i, l)$ is requested data rate of the multicast group i for layer l. $\theta(G_i)$ is the minimum transmission efficiency of a user in the multicast group i.

$$\varepsilon(G_i, l) = \left\lceil \frac{d(G_i, l)}{\theta(G_i)} \right\rceil \quad (5)$$

In the following, we use multicast transmission order score

TABLE I
OVERVIEW OF LIST OF NOTATIONS

Symbol	Explanation
$d(G_i, l)$	Request data rate of the multicast group i for layer l
$\theta(G_i)$	Minimum transmission efficiency of a user in the multicast group i
$P(G_i)$	Price of the multicast group i, $P(G_i) = P_1 \; or \; P_2 \; or \; P_3$
$C(G_i)$	Class of the multicast group i
$\varepsilon(G_i, l)$	Required resources of the multicast group i for layer l
m_{G_i}	Multicast transmission order score of the multicast group i
r_{G_i}	CQI index for the multicast group i
T_{G_i}	Average throughput achieved by the multicast group i
w_{G_i}	Weighted of the multicast group i, $0 \le w_{G_i} \le 1$
U_{G_i}	Number of all UEs in the multicast group i
$\lvert V \rvert$	Number of layers in a video is encoded in. i.e. $\lvert V \rvert$ = 6 layers
ω	Total resources
n_{UE}	Number of all users
N	Number of all multicast groups

to decide which multicast group will be served fisrt. Equations (6)(7) indicate the resources are allocated to the multicast group whose multicast transmission order score is the biggest from layer 1 to layer 3. Class one users will be served three video layers, class two users will be served two video layers , class three users will be served one video layer. Multicast transmission order score is a score considering the efficiency of resource usage and the past throughput achieved in the multicast group. Moreover, the price of each class user is also in consideration.

$$\arg\max_{G_i}(m_{G_i}) \quad (6)$$

$$subject \; to:$$

$$from\ layer\ l = 1\ to\ 3\ in\ sequence$$

$$m_{G_i} = \begin{cases} \frac{r_{G_i}}{T_{G_i}} \cdot w_{G_i}, & if\ (l = 1)\ or\ (l = 2\ and\ C(G_i) < 3)\ or\ (l = 3\ and\ C(G_i) < 2) \\ 0, & otherwise \end{cases} \quad (7)$$

$$w_{G_i} = \frac{U_{G_i} \cdot P(G_i)}{\sum_{i=1}^{N} U_{G_i} \cdot P(G_i)} \quad (8)$$

Equation (7) calculates the multicast transmission order score for the group i. r_{G_i} is channel quality indicator. r_{G_i} indicates how many bits a PRB can load. Transmission efficiency can be obtained by CQI refering to MCS. r_{G_i} will help obtaining the transmission efficiency for the multicast group i. And r_{G_i} will be decided by the worst channel condition user of his CQI in multicast group i. Because we would like to let every user in the multicast group receive the video layer. T_{G_i} is the throughput achieved by the group i so far. w_{G_i} is the arrangement for transmission order based on the different multicast group's price. Equation (8) shows the weights of multicast group i and the weights value considers the number of users in the multicast group and the price of the class. U_{G_i} is the number of users in the multicast group i. $P(G_i)$ is the price of multicast group i. We assume there are N multicast groups in the network. The equation will calculate a value w_{G_i} between 0 and 1. The more users in the multicast group or the price of the class is higher, both can obtain a higher transmission order score in the network. In other words, the less users in the multicast group or the price of the class is lower, will obtain lower transmission order score in the network.

III. SIMULATION

In this simulation environment, LTE specifications and scenarios are used to conduct the performance evaluation. The goal is to evaluate the performance of the proposed scheme. In the simulation, we adjust multicast group numbers. The simulation parameters are listed in Table II. High Profit First (HPF) scheme is a variation of PCRAS. HPF based on the provider's revenue can choose a multicast group with more users and higher price and give it higher priority to use resources. It considers the pricing model and is tend to let provider receive more revenue without considering channel condition and throughput. HPF will assign resource block to the group i with considering n_{G_i}, number of users in the multicast group and P_i, the price of the multicast group. Its objective formulation is as follows.

$$\arg\max_{G_i}\left(\frac{n_{G_i} \cdot P(G_i)}{\sum_{i=1}^{N} n_{G_i} \cdot P(G_i)}\right) \quad (9)$$

Considering the proposed scheme, we built an LTE network environment with an eNodeB. There are several users within this eNodeB coverage. After the simulation starts, users are in the Random Direction pattern. The base layer's bit rates is 32 Kbps and the five of enhancement layers are 32, 64, 128, 256, 512 Kbps. Each multicast group has 1 to 20 users and on average the users in multicast group is 10. In the following, the performance evaluation targets are average layers and number of served UEs. Average layers are evaluated by the accumulation of all the number of layers multicast group users that can receive multiply the number of users in the multicast group and then is divided by the total users in the network. Served UEs are evaluated by the number of users can at least receive one video layer. The proposed scheme is compared to three scheduling schemes : Maximum throughput (MT), High Profit First (HPF) and Round Robin (RR). MT produces the most throughput compared with the proportional fiar scheme. RR is the most fair scheme. HPF considers revenue.

TABLE II
LIST OF SIMULATION PARAMETERS

Parameter	Value
eNB transmission radius	1 km
Transmits power	43 dBm
Distance dependent pathloss (R in km)	$128.1 + 37.6 \times \log_{10}(R)$ dB (Urban and Subburban Areas)
Bandwidth	20 MHz
Resource block width	180 kHz
Number of PRBs	100 (12 subcarrier/PRB)
Modulation and coding schemes	QPSK, 16QAM, and 64 QAM
Traffic	Video
Number of UEs in group	Random, 1 to 20
Ratio for three classes(class1:class2 :class3)	(1:1:1)
PCRAS	$P_1 = 2.5, P_2 = 2, P_3 = 1.5$

As shown in Fig. 4, one can see the proposed scheme, PCRAS, can receive more video layers than other schemes. PCRAS considers the channel quality and number of UEs in the multicast group. PCRAS uses the RB more efficiency than HPF and RR because of the two do not consider the channel quality condition. PCRAS serves all the users from the base layer. Compared to MT, MT concentrates on serving the users with the best channel quality condition and doesn't consider the number of UEs in the multicast group, as a result, part of the multicast group can't receive video layers. Fig. 5 shows that each class receives average video layers in MT. MT only considers channel quality and attains maximum throughput. For each class UEs receive almost the same average number of video layers. It is not fair for those UEs who pay more fees, but receive almost the same video layers with the lower fee UEs. Fig. 6 shows that each class receives average video layers in HPF. HPF only considers the price of UEs and number of UEs in the multicast group. The result shows the RB usage efficiency is low. Three class users receive less video layers than the proposed scheme, PCRAS. Fig. 7 shows that each class receives average video layers in RR. RR transmits the video layer in a very fair way. But the result shows the distribution of video layer is the same average number to each class. It is also not fair to the UEs who pay more fee, but receive almost the same video layers with the lower fees UEs. Fig. 8 shows each class receives average video layers in the proposed scheme.

PCRAS considers the channel quality, the price of each class and the number of UEs in the multicast group. The result shows the distribution of each class is in a certain order. The higher class UEs receive more video layers. PCRAS also satisfies the basic requirement video layers for all UEs.

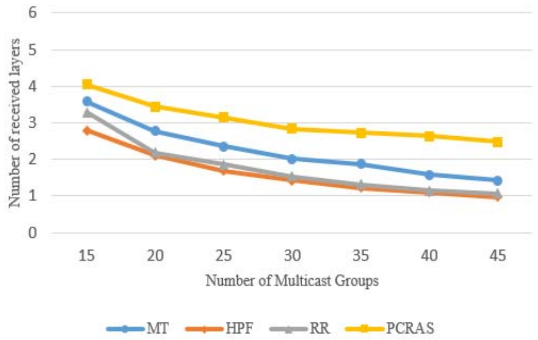

Fig. 4 Average layers

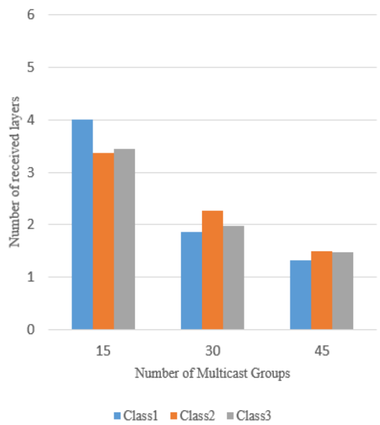

Fig. 5 Average layers - MT

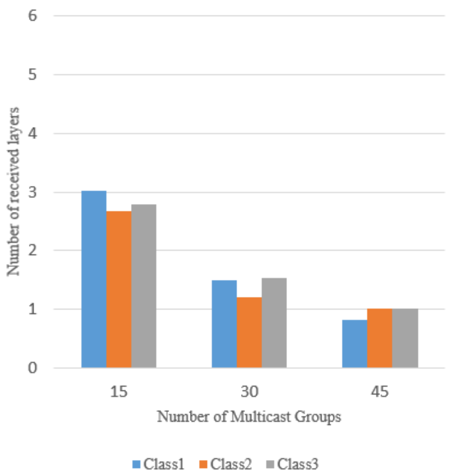

Fig. 6 Average layers - HPF

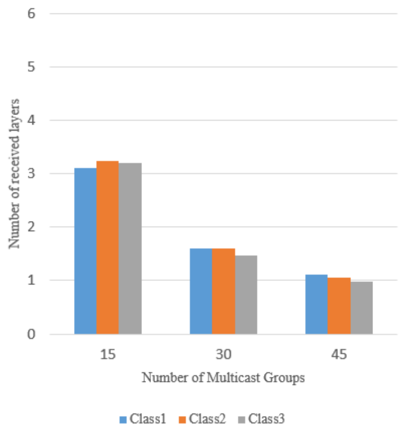

Fig. 7 Average layers - RR

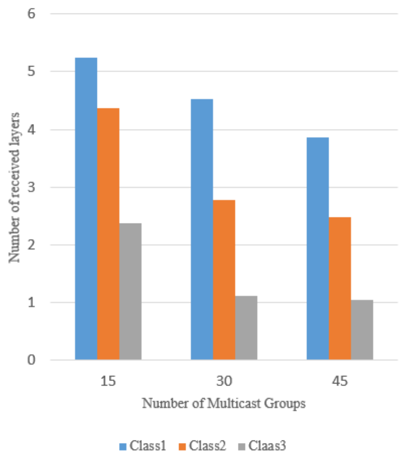

Fig. 8 Average layers - PCRAS

IV. CONCLUSION

In this paper, we have proposed the PCRAS algorithm. In PCRAS, users are split into three classes. A higher class user pays higher price. PCRAS considers the price of multicast group, resource efficiency, the number of users in the multicast group and revenue. The performance evaluation indicates that a user can receive more video layers by using the proposed scheme compared to other existing scheduling schemes. In 15 multicast groups network. In comparison to MT, HPF and RR, the proposed scheme can improve users' video layers 12%, 22% and 44%, respectively. As a result, the proposed scheme, PCRAS, can enhance users' experience.

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REFERENCES

[1] R. Radhakrishnan, B. Tirouvengadam and A. Nayak, Channel Quality-Based AMC and Smart Scheduling Scheme for SVC Video Transmission in LTE MBSFN Networks, IEEE

International Conference on Communications (ICC), pp. 6514-6518, 2012.
[2] E. Dahlman, S. Parkvall and J. Sköld, Chapter 17 – Multimedia Broadcast/Multicast Services in 4G: LTE/LTE-Advanced for Mobile Broadband (Second Edition), ed Oxford: Academic Press, pp. 403-411, 2014.
[3] G. Piro, L. A. Grieco, G. Boggia, F. Capozzi and P. Camarda, Simulating LTE Cellular Systems: An Open-Source Framework, IEEE Transactions on Vehicular Technology, vol. 60, no. 2, pp. 498-513, 2011.
[4] J. Olmos, A. Serra, S. Ruiz, M. García-Lozano and D. Gonzalez, Link Level Simulator for Lte Downlink, Technical report, COST 2100, Braunschweig, Germany, 2009.
[5] Y. Xu, J. Bigham and L. Cuthbert, Resource Management for Service Providers in Heterogeneous Wireless Networks, IEEE Wireless Communications and Networking Conference, vol. 3, pp. 1305-1310, 2005.
[6] U. Mir and L. Nuaymi, LTE Pricing Strategies, Vehicular Technology Conference (VTC Spring), pp. 1-6, 2013.
[7] R. Maiti, A Simplified Pricing Model for the 3G/4G Mobile Networks, Global Trends in Computing and Communication Systems, pp. 535-544, 2012.
[8] A. Belghith, S. Trabelsi and B. Cousin, Realistic Per-Category Pricing Schemes for LTE Users, IEEE International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt), pp. 429-435, 2014.