Resource allocation for Multicast Services with Joint FGS Video Coding and UEP RS Coding Scheme in Single Frequency Networks

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***Abstract*—This paper propose an optimal resource allocation algorithm by exploiting layered coding combined with erasure correction coding for multicast services in the downlink of OFDMA-based single frequency networks (SFN). In this algorithm, we exploit unequal error protection (UEP) Reed-Solomon (RS) coding to compensate for possible data packet loss of base layer and enhancement layers which are obtained from fine-granularity-scalability (FGS) video coding. In order to reduce the feedback load, BSs only utilize the average channel state information (CSI) of the users. The proposed algorithm maximizes the enhancement layers throughput while guaranteeing the minimum data rate of the base layer in each multicast group. A two-phase suboptimal algorithm is proposed to reduce the computational complexity. Simulation results show that the performance of the algorithm with UEP RS coding is much better than the algorithm without. Moreover, the proposed algorithms significantly outperform conventional multicast scheme (CMS).**

***Keywords*—Multicast, Resource Allocation, FGS video coding, UEP RS coding, SFN**

I. INTRODUCTION

Multimedia broadcast/multicast service (MBMS) single frequency network (MBSFN) [1] has been exploited to support MBMS in SFN, in which the identical multicast/broadcast services (MBS) are transmitted to users from all the base stations (BSs) with the same time-frequency resources.

In CMS, the total throughput of multicast group was constrained by the user with the worst channel quality. In order to overcome this problem of limited throughput, layered coding techniques were proposed in multicast systems. In [2], an optimal subcarrier allocation algorithm for multicast services with QoS in one multicast group of single cell was proposed. The optimal algorithm exploited FGS video coding to improve throughput while satisfying the QoS requirements of all users. In [3], an optimal subcarrier/bit allocation algorithm for maximum throughput and proportional fairness in one multicast group of single cell was proposed. The algorithm utilized multiple description coding (MDC) which divided multicast data into multiple layers. But these algorithms with layered coding must require the instantaneous CSI of all the users. In [4], the FGS video coding which divided multicast data into base layer and enhancement layer was exploited. A power allocation algorithm maximized the data rate of the enhancement layer while guaranteeing the minimum data rate requirement of the base layer was proposed in SFN. Moreover, [4] also proposed a power allocation algorithm that minimized the probability of transmission failure while only exploiting the average CSI of the users. But it didn't consider how to compensate for possible data packet loss as no instantaneous CSI is available at the BSs.

Recently, OMS has been proposed to improve the limited throughput of CMS. OMS exploited both the multiuser diversity and the multicast gain simultaneously. In [5], an optimal user selection ratio to maximize the throughput of homogeneous networks was studied. Subsequently, in [6], the OMS scheme from homogeneous to heterogeneous networks with users subject to different channel statistics was developed. But, these algorithms must require instantaneous CSI of each user. In order to reduce the feedback load, in [7], an OMS scheme using erasure correction coding to maximize the total throughput of multicast group was proposed. This scheme sent only one copy to all users in the multicast group at a transmission rate based on a SNR threshold selected using only the knowledge of average SNR. The shortcoming of this scheme was that the average SNR was the same for all users, which might be tenderminded in practical multicast systems.

In order to overcome the shortcomings of [4, 7], in this paper, we propose an optimal resource allocation algorithm by exploiting joint coding scheme for different requirements of QoS among multiple multicast groups of SFN. The objection of optimal problem is to maximize the enhancement layers throughput while guaranteeing the minimum data rate of the base layer among multiple multicast groups. The optimal algorithm has high computational complexity. To reduce the complexity, suboptimal algorithm is proposed. Firstly, the original multicast data should be encoded into one base layer and multiple enhancement layers by FGS video coding. Secondly, in order to compensate for possible data packet loss due to average CSI, the data packets should be coded by UEP RS coding. Thirdly, we propose a subcarrier allocation algorithm with proportional fairness where subcarriers are distributed to different groups, proportional to their channel conditions and different requirements of QoS. At last, a modified iterative water-filling power allocation algorithm is proposed to further improve the performance.

II. SYSTEM MODEL AND PROBLEM FORMULATION

In this paper, we consider the downlink of OFDMA-based SFN multicast systems which support MBS. In SFN, all BSs can exploit the same time-frequency resource to transmit the identical multicast data to users with different propagation delays. The propagation delay can lead to inter-symbol interference (ISI). Thus, in order to mitigate this effect, a longer cyclic prefix is typically used to allow the user terminal to combine all the signals that are sufficiently strong. Fig. 1 illustrates the system model of SFN providing MBS to the users from different multicast groups.

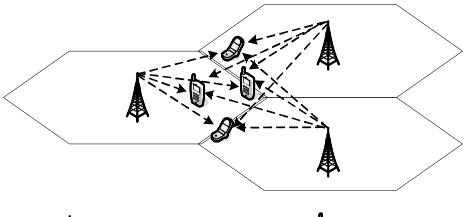

Fig. 1. model of SFN for providing MBS.

In this scenario, there are *M* BSs, *G* multicast groups with different requirements of QoS. *N* subcarriers with total bandwidth *B* are shared by each user. Each group is K_g users, $g \in G$. The power constraint of each BS is P_T. We assume a Rayleigh fading channel, the channel gains in different subcarriers are i.i.d. Then the channel gain between user *k* in multicast group g and BS *m* over subcarrier *n* is given by $h_{gk}^m(n) = \overline{h_{gk}^m}\left|g_{gk}^m(n)\right|^2$, where $\overline{h_{gk}^m}$ denotes the average channel gain and $g_{gk}^m(n) = r_{gk}^m(n) + j i_{gk}^m(n)$ for Gaussian random variables $r_{gk}^m(n)$ and $i_{gk}^m(n)$ have zero-mean and variance 1/2. The instantaneous SNR of the received signal of user *k* in group g over subcarrier *n* is given by

$$\gamma_{gk}(n) = \frac{\sum_{m=1}^{M} P_m(n)\overline{h_{gk}^m}\left|g_{gk}^m(n)\right|^2}{N_0 B/N} \quad (1)$$

where $P_m(n)$ denotes the transmitted power over subcarrier *n* from BS *m*. N_0 represents the single-sided power spectral density of the white noise. In order to reduce the computational complexity, we assume the transmitted power over each subcarrier is equal, $P_m(n) = {P_T}/{N}$. Since $\gamma_{gk}(n)$ is given by the weighted sum of the squares of the Gaussian random variables, we can get the probability density function of $\gamma_{gk}(n)$

$$f_{gk}(\gamma) = \sum_{m=1}^{M} \frac{\alpha_{gk}^m}{P_m(n)\overline{h_{gk}^m}} e^{-\frac{\gamma}{P_m(n)\overline{h_{gk}^m}}} \quad (2)$$

for

$$\alpha_{gk}^m = (\overline{h_{gk}^m})^{M-1} \prod_{i=1, i\neq m}^{M} (\overline{h_{gk}^m} - \overline{h_{gk}^i})^{-1} \quad (3)$$

Then the rate of user *k* over subcarrier *n* in group g can be written as

$$R_{gk}(n) = \frac{B}{N} \log_2(1 + \gamma_{gk}(n)) \quad (4)$$

The rate of subcarrier *n* in group g can be expressed as

$$R_g(n) = \min_{k\in K_g} R_{gk}(n) \quad (5)$$

We exploit FGS video coding to divide the original multicast data into one base layer and multiple enhancement layers [8]. Then, the enhancement layers throughput over subcarrier *n* in group g can be expressed by

$$T_g^{enh}(n) = \sum_{k=1}^{K_g} R_{gl}(n) 1(R_{gk}(n) \geq R_{gl}(n)) \quad (6)$$

where 1(A) is an indicator function that becomes 1 when the condition A is met and 0 otherwise. (6) can be explained that the optimal transmission rate of the enhancement layers over subcarrier n in group g, $R_{gl^*}(n)$ is determined such that $T_{gl}^{enh}(n)$ can be maximized, i.e., $l^* = arg\,max_{l\in K_g} T_{gl}^{enh}(n)$. In this case, $T_g^{enh}(n)$ can be $T_{gl^*}^{enh}(n)$.

We consider resource allocation problem can be modeled as an optimization problem with power constraint at each BS and the different requirements of QoS among multiple multicast groups. Therefore, the problem can be formulated as follows:

$$max \sum_{g=1}^{G} \sum_{n=1}^{N} w_g^{enh}(n) T_g^{enh}(n) \quad (7)$$

s.t.

$$\sum_{n=1}^{N} w_g^{bas}(n) R_g(n) \geq R_g^{req}, \ g \in G \quad (8)$$

$$\sum_{n=1}^{N} P_m(n) \leq P_T, \ m \in M \quad (9)$$

$$\sum_{g=1}^{G} w_g^{enh}(n) \leq 1, \sum_{g=1}^{G} w_g^{bas}(n) \leq 1,$$

$$w_g^{bas}(n) \cap w_g^{enh}(n) = \emptyset, w_g^{bas}(n) \cup w_g^{enh}(n) = N \quad (10)$$

where R_g^{req} is the required minimum data rate of the base layer in group g. $w_g^{enh}(n)$ is a binary value indicating whether subcarrier *n* is allocated to transmit the data of enhancement layers in group g or not. $w_g^{enh}(n)$ is equal to 1 if subcarrier *n* is allocated, otherwise, $w_g^{enh}(n)$ is equal to 0. This similarity as $w_g^{bas}(n)$.

III. SUBOPTIMAL RESOURCE ALLOCATION ALGORITHMS

In this section, we propose two suboptimal subcarrier allocation algorithms with proportional fairness and a modified iterative water-filling power allocation algorithm.

A. Subcarrier Allocation based on FGS Video Coding

We propose a subcarrier allocation algorithm with proportional fairness based on FGS video coding (PF-F), under the assumption that the transmit power allocated on each subcarrier is equal. In the PF-F algorithm, subcarriers are distributed to different multicast groups, proportional to their average CSI and the different requirements of QoS among multicast groups. We formulate the algorithm as follows.

$$\frac{R_1}{R_1^{req}} = \frac{R_2}{R_2^{req}} = \cdots = \frac{R_g}{R_g^{req}} = \cdots = \frac{R_G}{R_G^{req}} \quad (11)$$

where R_g is the actual achieved rate in group g. $PF_g = \frac{R_g}{R_g^{req}}$.

1. base layer algorithm

1) Initialization: $N_g^{bas} = \{\emptyset\}$ denotes the set of subcarriers of base layer in group g. $R_g = 0$, $g \in G$. *A={1, 2, …, N}* denotes the set of free subcarriers.

2) While ($R_g \leq R_g^{req}$). a) find a group g^* satisfying $g^* = arg\,max_{g\in G} PF_g$; b) for $n = 1{:}N$, calculate $R_{g^*k}(n)$, $R_{g^*}(n)$; c) find a n^* satisfying $n^* = arg\,max_{n\in A} R_{g^*}(n)$; d) $R_{g^*}^{bas}(n^*) = R_{g^*}(n^*)$, $R_{g^*} = R_{g^*} + R_{g^*}^{bas}(n^*)$, update $N_{g^*}^{bas} = N_{g^*}^{bas} + \{n^*\}$, $A = A - \{n^*\}$.

2. enhancement layers algorithm

1) Initialization: $N_g^{enh} = \{\emptyset\}$ denotes the set of subcarriers of enhancement layers in group g. *B=A={1, 2, …,* $\widehat{N}$*}* denotes the set of remaining free subcarriers from the base layer algorithm.

2) While $(B \neq \emptyset)$. a) find a group g^* satisfying $g^* = arg\, max_{g \in G}\, PF_g$; b) for $n = 1{:}\,\hat{N}$, calculate $R_{g^*k}(n)$ $R_{g^*}^{enh}(n)$ and $T_{g^*}^{enh}(n)$; c) find a n^* satisfying $n^* = arg\, max_{n \in B}\, T_{g^*}^{enh}(n)$; d) $R_{g^*} = R_{g^*} + R_{g^*}^{enh}(n^*)$, update $N_{g^*}^{enh} = N_{g^*}^{enh} + \{n^*\}$, $B = B - \{n^*\}$.

B. Resource Allocation based on FGS Video Coding Combined with UEP RS Coding

B.1 FGS video coding combined with UEP RS coding scheme

After the FGS video coding, each layer contains the same number of equal-length data packets. Each packet is composed of equal bits. Generally, the data of base layer must be correctly received by all the users. So, the data is always transmitted on poor channels. Therefore, base layer traffic should be coded with most redundancy data packets. Since the data of enhancement layers can be received by the users with better channel quality. Users with better channel quality can receive the more number of enhancement layers data. So, the data is always transmitted on better channels. Therefore, enhancement layers traffic can be coded with fewer and fewer redundancy packets as the number of layer increases. With the notations above, we exploit UEP RS coding to recode the data of base layer and enhancement layers. Fig. 2 shows an example that FGS video coding combined with UEP RS coding.

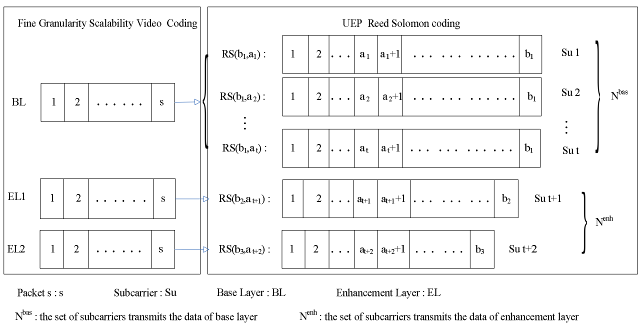

Fig. 2. FGS video coding combined with UEP RS coding

At first, the original multicast data is coded by FGS Video coding, each layer can contain *s* equal-length packets. Each packet is *q* bits. Secondly, the data packets of base layer and enhancement layers can be recoded to b_j *{j=1, 2, …}*, *(b_1>b_2>…)* equal-length packets by using UEP RS (b_j, a_i) *{i, j=1, 2, …}* coding. In other words, the UEP RS (b_j, a_i) coding generates a_i information packets and $b_j - a_i$ redundant packets which protect a_i information packets [9]. The encode rate of base layer is ${a_i}/{b_1}$ *{i=1, 2, …, t}*, *t* is the number of subcarriers which transmit the data of base layer. The encode rate of enhancement layers is ${a_i}/{b_j}$, *{i=t+1, t+2, …}*, *{j=2, 3,…}*. Thirdly, after the UEP RS (b_j, a_i) coding, we allocate N^{bas} and N^{enh} subcarriers to transmit the data packets of base layer and enhancement layers, respectively. Each packet can be sent to users in one time-slot. If one user can correctly receive any more than a_i packets in b_j time-slots, then the original a_i information packets can be reconstructed.

B.2 Throughput analysis

If the rate of subcarrier *n* happen to be the rate of user k^*, $R_{gk^*}(n)$, $k^* \in K_g$, we can calculate the probability of user *k*, $k \in K_g$, who correctly receives data over subcarrier *n* with this rate.

$$p_{gk}(n) = \int_{2^{\frac{R_{gk^*}(n)N}{B}}-1}^{\infty} f_{gk}(\gamma)d\gamma = \sum_{m=1}^{M} \alpha_{gk}^{m} e^{-\frac{(2^{\frac{R_{gk^*}(n)N}{B}}-1)}{P_m(n)h_{gk}^{m}}} \tag{12}$$

Under the assumption of a quasi-static i.i.d. fading environment, $p_{gk}(n)$ is the same during one time-slot, and the probability that each user can correctly receive at least a_i data packets over subcarrier *n* at a transmission rate of $({\alpha_i}/{b_j})R_{gk^*}(n)$ is

$$p_{gk}^{RS}(n)\{x \geq \alpha_i\} = \sum_{y=\alpha_i}^{b_j} \binom{b_j}{\alpha_i} p_{gk}(n)^y (1 - p_{gk}(n))^{b_j - y} \tag{13}$$

where *x* is the total number of correctly received data packets within b_j transmitted packets. Therefore, the probability that all users in multicast group g can successfully receive at least a_i packets of the base layer is

$$p_g^{bas}(n) = \prod_{k=1}^{K} p_{gk}^{RS}(n) \tag{14}$$

Then the throughput in group g over subcarrier *n* is

$$T_g^{bas}(n) = K_g p_g^{bas}(n) \left({\alpha_i}/{b_1}\right) R_{gk^*}(n) \tag{15}$$

Then the effective transmission rate of base layer over subcarrier *n* is

$$R_g^{bas-e}(n) = p_g^{bas}(n) \left({\alpha_i}/{b_1}\right) R_{gk^*}(n) \tag{16}$$

The probability that certain users who have better channel quality can correctly receive at least a_i data packets of the enhancement layers is

$$p_g^{enh}(n) = \sum_{k=1}^{K_g} p_{gk}^{RS}(n) \tag{17}$$

Then the throughput in group g over subcarrier *n* is

$$T_g^{enh}(n) = p_g^{enh}(n) \left({\alpha_i}/{b_j}\right) R_{gk^*}(n) \tag{18}$$

Then the effective transmission rate of enhancement layer over subcarrier *n* is

$$R_g^{enh-e}(n) = \left({\alpha_i}/{b_j}\right) R_{gk^*}(n) \tag{19}$$

B.3 Subcarrier allocation algorithm

Under the assumption that the transmit power allocated for each subcarrier is equal, we propose a subcarrier allocation algorithm with proportional fairness based on FGS video coding combined with UEP RS coding (PF-FR). In PF-FR algorithm, subcarriers are distributed to different multicast groups, proportional to their average CSI and the different requirements of QoS among multiple multicast groups. Therefore, we can formulate the PF-FR algorithm as follow. In order to keep the proportional fairness among multiple multicast groups, we exploit the same of Eq. (11).

1. base layer with UEP RS coding algorithm

1) Initialization: $N_g^{bas} = \{\emptyset\}$, $R_g = 0$, $g \in G$. *A={1, 2, …, N}*.

2) While ($R_g \leq R_g^{req}$). a) find a group g^* satisfying $g^* = arg\, max_{g \in G}\, PF_g$; b) for $n = 1{:}\,N$, calculate $R_{g^*k^*}(n)$, $p_{g^*k}(n)$; c) for x=1: b_1, calculate $p_{g^*k}^{RS}(n)$ with

the encode rate x/b_1, and $p_{g^*}^{bas}(n)$, $R_{g^*}^{bas-e}(n)$; d) $\hat{R}_{g^*}^{bas-e}(n) = max_{k^* \in K_g} R_{g^*}^{bas-e}(n)$; e) find a n^* satisfying $n^* = arg\,max_{n \in A} \hat{R}_{g^*}^{bas-e}(n)$; f) $R_{g^*} = R_{g^*} + \hat{R}_{g^*}^{bas-e}(n)$, update $N_{g^*}^{bas} = N_{g^*}^{bas} + \{n^*\}$, $A = A - \{n^*\}$

2. enhancement layers with UEP RS coding algorithm

1) Initialization: $N_g^{enh} = \{\emptyset\}$, $B=A=\{1, 2, \ldots, \hat{N}\}$.

2) While $(B \neq \emptyset)$. a) find a group g^* satisfying $g^* = arg\,max_{g \in G} PF_g$; b) for $n = 1{:}\hat{N}$, calculate $R_{g^*k^*}(n)$ and $p_{g^*k}(n)$; c) for $x=1{:}b_j$, $j=\{2, 3, \ldots, \hat{N}\}$ calculate $p_{g^*k}^{RS}(n)$ with the encode rate x/b_j, $p_{g^*}^{enh}(n)$, $R_{g^*}^{enh-e}(n)$, $T_{g^*}^{enh}(n^*)$; d) $\hat{T}_{g^*}^{enh}(n) = arg\,max_{k^* \in K_g} T_{g^*}^{enh}(n)$; e) find a n^* satisfying $n^* = arg\,max_{n \in B} \hat{T}_{g^*}^{enh}(n)$; f) $R_{g^*} = R_{g^*} + R_{g^*}^{enh-e}(n)$, update $N_{g^*}^{enh} = N_{g^*}^{enh} + \{n^*\}$, $B = B - \{n^*\}$.

B.4 Power allocation algorithm

In order to reasonably allocate the limited power at each BS, a modified iterative water-filling algorithm with the different requirements of QoS is exploited. In [4], OPA-HE algorithm was proposed. This algorithm adopted iterative water-filling to allocate power, but it didn't consider the different QoS requirements among multiple multicast groups. Therefore, we propose a modified OPA-HE algorithm (MOPA-Q) which can allocate power to multiple multicast groups with different requirements of QoS. It can be expressed as: at each iteration, the objective is maximized with respect to each of transmission power vectors $P_m^t = (P_m^t(1), P_m^t(2), \ldots P_m^t(N))$. It denotes the transmission power of each subcarrier from BS m at the t-th iteration. We allocate power to BS m assuming the other BSs' power is fixed. Suppose that the power allocation $(P_1^t, P_2^t, \ldots P_M^t)$ is given at the t-th iteration. Then P_m^{t+1} is determined as the solution of the following problem

$$P_m^*(n) = max\left\{\lambda_m - \frac{1+\sum_{l=1,l\neq m}^{M} P_{gl}^t(n) h_{gk^*}^l(n)}{h_{gk^*}^m(n)}, 0\right\} \quad (20)$$

$$k^* = max_{k \in K_g} R_g^{bas-e}(n), n \in N_g^{bas} \quad (21)$$

$$k^* = arg\,max_{k \in K_g} T_g^{enh}(n), n \in N_g^{enh} \quad (22)$$

where the constant λ_m is the water level. $P_{gl}^t(n)$ denotes the transmission power from BS l over subcarrier n of group g at the t-th iteration. The amount of the allocated power is determined by both the channel gain of the user from Eq. (21) or (22) and the aggregated signal strength from other BSs. MOPA-Q algorithm can be stated as follows.

1. base layer with UEP RS coding algorithm

1) Initialization: The remaining power of each BS is $P_m^r = P_T$, $P_m(n) = 0$, $m=\{1, 2, \ldots, M\}$, $n \in N_g^{bas}$;

2) While $(N_g^{bas} \notin \emptyset)$, $\forall g \in G$ a) find a group g^* satisfying $g^* = arg\,max_{g \in G} R_g^{req}$; b) at each iterative, find a user k^* satisfying Eq. (21), distribute power to the subcarriers in group g^* according to Eq. (20). If $P_m^*(n)$ is less than P_m^r , then λ_m is chosen such that $\sum_{n=1}^{N_{g^*}^{bas}} R_{g^*}^{bas-e}(n) = R_{g^*}^{req}$. Otherwise, λ_m is chosen such that $\sum_{n=1}^{N_{g^*}^{bas}} P_m^*(n) = P_T$; c) $P_m^r = P_m^r - P_m^*(n)$ if $P_m^r \leq 0$, $m=\{1, 2, \ldots, M\}$, then algorithm end. Otherwise, go to 2.

2. enhancement layers with UEP RS coding algorithm

1) Initialization: set the remaining power of each BS is $\hat{P}_m^r = P_m^r$, and $P_m(n) = 0$, $m=\{1, 2, \ldots, M\}$, $n \in N_g^{enh}$;

2) While $(N_g^{enh} \notin \emptyset)$, $\forall g \in G$ a) find a group g^* satisfying $g^* = arg\,max_{g \in G} R_g^{req}$; b) find a user k^* satisfying Eq. (22), according to (20) distribute power to the subcarriers of g^*. λ_m is chosen such that $\sum_{n=1}^{N_{g^*}^{enh}} P_m^*(n) = P_T$; c) $\hat{P}_m^r = \hat{P}_m^r - P_m^*(n)$ if $\hat{P}_m^r \leq 0$, $m=\{1, 2, \ldots, M\}$, then algorithm end.

IV. NUMERICAL RESULTS

In this section, we present some simulate results to compare the performance of different subcarrier and power allocation algorithms. The graph labels, PF-FR+MOPA-Q, PF-FR+EP (equal power), PF-F+MOPA-Q, PF-F+EP, and CMS, denote different subcarrier allocation algorithms combined with different power allocation algorithms and conventional multicast scheme, respectively. We employ the system model proposed in Fig. 1. There are two multicast groups which have different requirements of QoS in SFN, R_1^{req} =5*Mbps*, R_2^{req} =3*Mbps*. We set the bandwidth, B=10*MHz* and the number of subcarriers equals to N. The number of users in each multicast group is the same and equals to K. The users are randomly placed in a 1*km*× 1*km* field and four BSs are putted at the points (0.5, 0.5), (1.5, 0.5), (0.5, 1.5), (1.5, 1.5), respectively. The channels between the BS and the users are modeled as frequency selective Rayleigh fading channels corrupted by AWGN. N_0 is 10^{-9} *W/Hz*. The pathloss exponent is 3. All the numerical results presented in this section are averaged over 10000 independent trials.

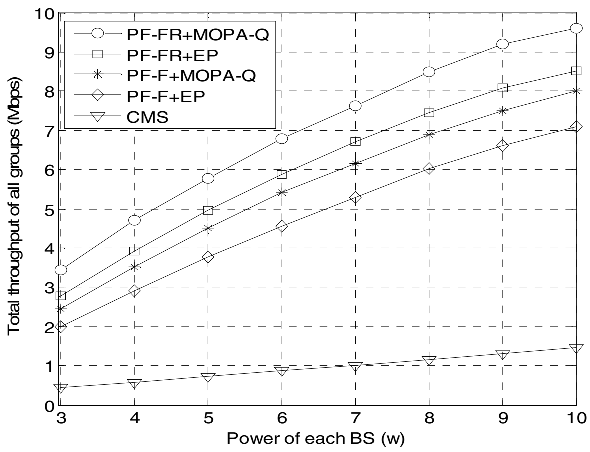

Fig. 3 Total throughput vs. Power, K=8, N=16.

In Fig. 3, we can obtain some conclusions. Firstly, the performance of algorithm with FGS video coding or UEP RS coding is more than the CMS. It implies the two coding schemes can effectively improve the performance of multicast systems. Since FGS video coding can provide enhancement layers data to the users with better channel quality. UEP RS coding can compensate for data packets loss which happen in poor channel quality. Secondly, the performance of FGS video coding combined with UEP RS coding outperforms that only with FGS video coding. Since the joint coding scheme can obtain the advantage of both FGS video coding and UEP RS coding. Thirdly, under the same coding scheme, the scheme with MOPA-Q has more throughput than that with EP. Since MOPA-Q can allocate power to each subcarrier, according to individual quality of channel.

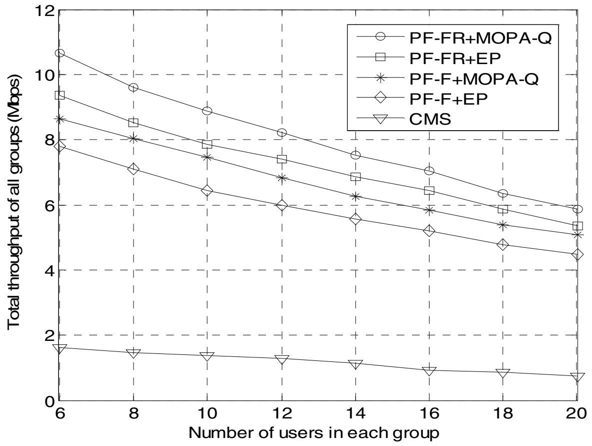

Fig. 4. Total throughput of all groups vs. Number of users in each group, N=16, P_T=10 W.

In Fig. 4, we can obtain some conclusions. Firstly, the throughput decreases when the number of users in each group increases. Since the increased number of users with poor channel quality, when the number of users increases. So, more subcarriers are allocated to guarantee the rate of base layer for all users. Only a few subcarriers can be allocated to enhancement layers. Secondly, the throughput of scheme with UEP RS coding is more than that without. It implies that the UEP RS coding can improve the throughput of systems.

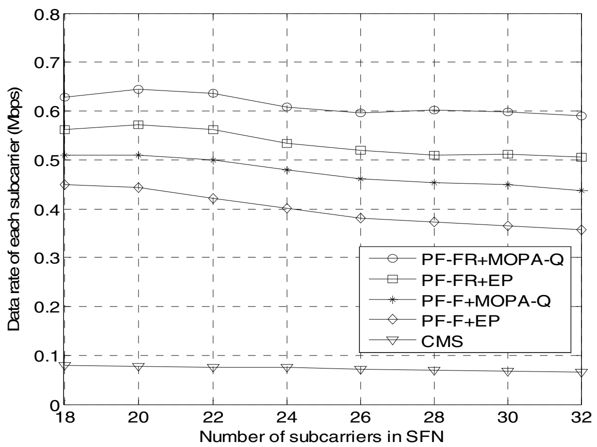

Fig. 5. Data rate of each subcarrier vs. Number of subcarriers in SFN, K=8, P_T=10 W.

In Fig. 5, the bandwidth of each subcarrier is fixed. We can see that the each subcarrier data rate decreases as the number of subcarriers increases for all algorithms. Since the number of subcarriers increases, while the total power of each BS is fixed, the allocated power of each subcarrier decreases.

V.CONCLUSION

In this paper, we discussed a novel resource allocation algorithm by exploiting a joint coding scheme in the downlink of OFDMA-based SFN. In order to reduce feedback load, we only required the average CSI. Since the optimal algorithm had very high computational complexity, we proposed a suboptimal algorithm composed of subcarrier allocation phase and power allocation phase. In subcarrier allocation phase, we proposed two subcarrier allocation algorithms that PF-F algorithm and PF-FR algorithm. In power allocation phase, a modified iterative water-filling power allocation algorithm that MOPA-Q algorithm was exploited. Simulation results showed that FGS video coding combined with UEP RS coding can improve the performance of multicast systems and the performance of the proposed algorithms significant outperform CMS. Moreover, the performance of the algorithm with UEP RS coding was better than that without.

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