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RADIO RESOURCE OPTIMIZATION IN COOPERATIVE CELLULAR NETWORK WITH NETWORK CODING AT RELAY STATIONS

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ABSTRACT

Wireless cellular networks have to be designed and deployed with unavoidable constrains on the limited radio resources such as bandwidth and transmit power. The primary objective of this paper is to improve the capacity and utilization of the radio resources that are available by the service providers. This paper deals with the resource allocation problem relay-based Orthogonal Frequency Division Multiple Access (OFDMA) cellular network where relay stations (RS) perform network coding with downlink and uplink sessions of a mobile station (MS). The aim of the paper is to maximizing the weighted sum rate for both uplink and down link for all users while satisfying quality-of -services(QoS).To make the proposed system more realistic additive white Gaussian noise, and fading present in the communication channel for both uplink and down link.

Keywords: cooperative networks, sumrate, quality of service, power allocation, network coding.

INTRODUCTION

In a cooperative communication system, each wireless user is assumed to transmit data as well as act as a receiving agent for another user. In recent years the number of users in a cooperative system was increased. Due to this the resource utilization or sharing between users becomes a big problem. At the same time the frequency and high data rate requirement of each user is highly in demand.

Wireless link rate is mainly depend on the allocation power, frequency, path-loss, channel interference etc., The Scheduling and resource allocation are essential components of wireless data systems. Scheduling refers to the problem of determining which users will be active in a given timeslot and resource allocation refers to a problem of allocating power and subcarriers among these active users. In modern wireless data systems, frequent channel quality feedback is available enabling both the scheduled users and the allocation of resources to be dynamically adapted based on the users channel condition and QoS requirements. This has led to design an efficient and feasible algorithms for allocating OFDMA Uplink and Downlink resources for relay enhanced cellular networks. To increase network throughput, efficiency, scalability, to reduce delay network coding technique is performed at each relay section. The Relay station are the intermediate node which is located between Base Station and Mobile Station for long distance communications When Base Station and Mobile Station need to exchange the information via Relay Station, it maintains a buffer to store the receiver Uplink and Downlink data from Mobile Station and Base Station. The resource allocation problem in OFDMA consists of multiple independent problems:

1) Subcarrier assignment
2) Choice of modulation levels
3) Rate and fairness constraints

Paper [1] emphasis the resource allocation problem by using opportunistic resource scheduling algorithm for OFDMA based cellular network with network coding at fixed relay station. In [2] only sub channel is opportunistically scheduled for OFDMA based cellular network. To schedule available bandwidth equally for each user opportunistic sub channel scheduling algorithm was used. Paper [8] proposed a CADSA algorithm which is used to achieve higher downlink capacity by performing dynamic subcarrier assignment mechanism compared to static assignment. Opportunistic network coding is not performed at relay station; hence network throughput is reduced for higher uplink traffic. Paper [3] proposed an opportunistic resource scheduling algorithm to allocate the power and bandwidth dynamically. When the number of subchannels increases, the performance gain of opportunistic scheduling at relay station decreased. Network coding assisted cooperative diversity scheme [5] is proposed to increase the efficiency of relaying nodes. Polynomial time algorithms and subgradient based algorithms are used to solve the power allocation problem in dual domain. Paper [6] describes COPE architecture for wireless network. It defines a coding layer which detects the coding opportunities and exploits them to forward multiple packets in a single transmission. The major drawback is, if some senders transmit more data same direction through captured wireless channel, then it leads to reduce the coding opportunities and overall gain. Coding Aware Dynamic Subcarrier Assignment algorithm [7] is used to choose subcarrier with the highest channel gain for each link. Base station acts a relay station for multiple mobile users hence their coverage data rate is low. Major drawback is only limited number of subcarriers are used and no optimal solution for joint subchannel and power allocation. In paper [8] cross-layer approach is designed that includes network coding technique and dynamic

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subcarrier assignment mechanism in OFDMA wireless network. This paper proves that with network coding it becomes possible to assign the same set of subcarriers to different downlinks without introducing interference. In paper [9] COPE architecture describes the methods how to solve the problems like low throughput, dead spots and inadequate support for mobility. It needs high effort to design lower complexity encoding and decoding algorithms. Paper [10] describes how the network coding technique at relaying nodes improves the diversity gains for wireless network, especially when the number of mobile users increased in a network.

SYSTEM MODEL

Consider a multi user network where M source nodes $S_i \in \{1,2.......M\}$ transmit messages to their corresponding destination nodes $D_i \in \{1,2.......M.\}$.There are N relay nodes R_k ,$k_i \in \{1,2.......N\}$ in the network. The set of relay assisting the transmission of S_i is denoted by $S(S_i)$The set of sources using the R_k relay is denoted by S (R_k).The one relay can forward the messages to several users. Consider the case of cellular networks shown in Figure-1, where some relays are deployed to assist the users located at the edges for both uplink and down link transmissions.

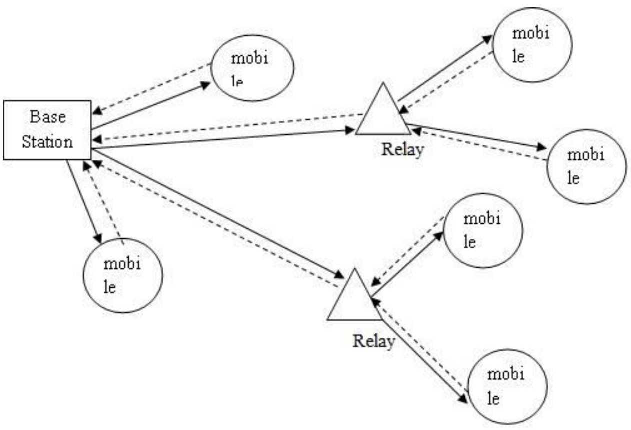

Figure-1. Relay based system model.

In a multiuser cooperative network each source S_i transmits message to its chosen relays in the set of S (R_k) in the first time slot the source broadcast the message X_i with unit energy P_{Si} to the relays R_k $\in R(S_i)$,the received message at the relay station can be written as

$$X_R = P_{S_i} h_R X_i + Z_{R_k} R_k \epsilon R(S_i) \quad (1)$$

In second time slot, the each relay R_k each amplifies and forwards its received messages to the destination D_i, the received message at the destination D_i can be written as

$$X_{D_i} = P_{R_k} h_{D_i} X_R + Z_{D_i} \quad (2)$$

In the third time slot, each mobile station multicast the required information to the corresponding relay station. In this same time slot the relay stations are perform network coding and transmit the messages to the destination. Whether or not to perform XOR network coding and which MS's session will be encoding is opportunistically determined for subcarriers in the third slot.

In OFDMA network the whole frequency band is divided into Northogonal sub channels each of which consists of a number of subsequent subcarriers. Each subcarriers are orthogonal to each other. Consider the channel state of a wireless link to be time-varying and frequency-selective. The channel state is flat within a sub channel and unchanged during a timeslot. The channel state of each wireless link on each sub channel acts as a stationary stochastic process. In addition, a system state can be defined as the combination of the current channel state of all wireless links on all sub channels in the system. Since our assumption is that the channel state is stationary, the system state also can be modelled as a stationary stochastic process, and thus in each time-slot, the system is in one of possible system states with the same probabilistic properties

PROBLEM FORMULATION

i) Optimal power scheduling

In this section, first we discuss the feasibility of the problem (P1) and then finding the solution of the sumrate maximization. In our objective, thesum rate of each link should be maximize the sumrate depends the power and gain of each link. We develop optimal scheduling algorithm.

The channel power is calculated in different phases. The constrain of power allocation is optimization of power consumption in each relay nodes ie) $P_R \leq p_{(i,j)} \leq P_0$.Here $P_{M(i,j)} \leq p_{(i,j)} \leq p_0$for first phase, ie) Link between BS to RS (down link).

$$\max_{\omega_r,\omega_b} P_{(i,j)} = \sum_{i\in M, j\in N} p_{M(i,j)} + \sum_{i\in M, j\in N} p_{R(i,j)} \quad (9)$$

subject to

$$\gamma \geq \gamma_{min} \quad (10)$$

$$P_B, P_R \leq p \leq P_0 \quad (11)$$

where,

$$\omega_b = \frac{1}{|Ha_{(i,j)}|} \Lambda \quad \text{and} \quad \omega_r = \frac{1}{|Ha_{(j,i)}|} \quad (12)$$

where Λ, Q,W are the parameters of Singular value Decomposition. The value must be chosen to satisfy

$$\Lambda\Lambda^H = dig\{\Lambda_1, \Lambda_2, \ldots\ldots\ldots.\Lambda_N\} \quad (13)$$

$$QQ^H = dig\{q_1, q_2, \ldots\ldots\ldots.q_N\} \quad (14)$$

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$$\gamma_{\min} = \{\gamma_{1min}, \gamma_{2min}, \ldots \gamma_{Mmin}\} \quad (15)$$

where Λ_N ,$q_N \geq 0$,P_M, P_R, $P_B$and $P_T$are power of Mobile station, Relay station ,Base station respectively and total power respectively..$\gamma_{Mmin}$is required minimum SNR to guarantee a QoS for user M.

It can be easily shown that the optimization problem is convex since the objective function is now concave increasing function of $P_{(i,j)}$and the constraints are linear. The Instantaneous power of each link can be calculated by three phases. For second phase, Link between BS to MS (down link).

$$P_{M(i,j)} = \sum_{i \in M, j \in N} p_{(i,j)} \leq P_0 \quad (16)$$

For first phase, Link between RS or MS to BS (Up link)

$$P_{R(i,j)} = \sum_{i \in M, j \in K} p_{(i,j)} \leq P_0 \quad (17)$$

Equation (9) can be achieved to assume equation (11-16) as the constrains.

ii) Sum-rate maximization

We now define the objective f ion of our problem that should be maximized. We then develop an optimal scheduling algorithm that solves that problem of P2.

$$\max_{p,q,t} \sum_{n \in N, i \in M, j \in K} \alpha_i C_{(i,j)} + \alpha_j C_{(j,i)} \quad (18)$$

$$f_u = \sum_{i \in M, j \in N} C_{(i,j)} - C_{(1,i)} \quad (19)$$

$$f_d = C_{0j} - \sum_{i \in M, j \in K} C_{(i,j)} = 0 \quad (20)$$

$$g_u = \sum_{i \in M, j \in K} C_{(i,j)} - \mu_i = 0 \quad (21)$$

$$g_d = \sum_{i \in M, j \in K} C_{(i,j)} - \mu_j = 0 \quad (22)$$

$$P_t = 0 \leq (P_m, P_r) \leq P_{max} \quad (23)$$

$$\Upsilon_{(i,j)} \geq \Upsilon_i \quad (24)$$

$$\Upsilon_{(j,i)} \geq \Upsilon_j \quad (25)$$

Where $\alpha_i$and α_j denote the weighting factors of MS j for its downlink and uplink sessions respectively. The average receiving and transmission rate of MS j,$j \in M$ are represented as,$\square_{(i,j)}$, $\square_{(j,i)}$.$\square_i$ and $\square_j$ are the minimum average data rate required for down link and uplink transmission. Hence, the equation (19-20) represents the constrains on two hop transmission, via RS, in order to relay all the data received at RS, its average achievable transmission rate must be higher than the receiving data rate.

The equation (21-22) represents the QoS requirements of each MS and RS. The equation (24-25) represents the channel state information of both mobile station and relay station. Here we are going to solve the problem P2 in distributed manner. The main idea is to separate the objective function in equation (18) is independent sub problems using the Lagrange decomposition method.

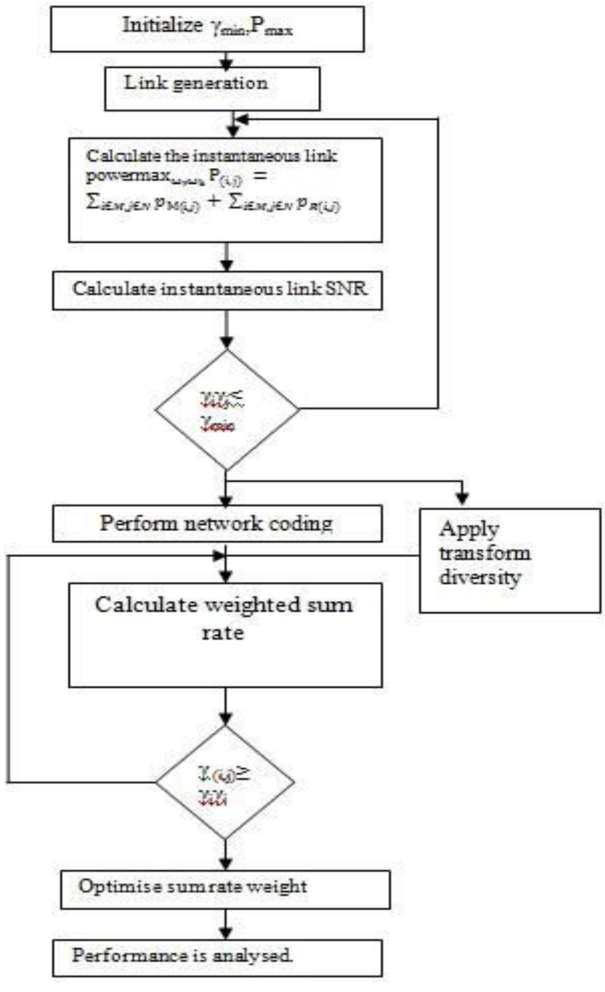

Figure-2. Flow chart of proposed algorithm.

The Lagrangian of problem (18) is

$$L(\bar{p}, \bar{r}, \bar{t}, \bar{s}, \bar{\phi}) = \sum_{n \in N, i \in M, j \in N} \alpha_i C_{(i,j)} + \alpha_j + \lambda_1 f(f_u, f_d) + \lambda_2 f(g_u, g_d) + \lambda_3 f(\Upsilon) \quad (26)$$

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$$L(\bar{p},\bar{r},\bar{t},\bar{s},\bar{\phi}) = \sum_{n\in N, i\in M, j\in N} \alpha_i C_{(i,j)} + +\lambda_1 \sum_{i\in M, j\in N} C_{(i,j)} - C_{(1,i)} + \lambda_2 \sum_{i\in M, j\in K} C_{(i,j)} + \lambda_3 \sum_{i\in K, j\in M, n\in N} \gamma_i \quad (27)$$

where,

$\bar{\phi} = [\lambda_1, \lambda_2, \lambda_3]$ is the vector of Lagrangian multipliers. $\lambda_1 = [\lambda_{1UL}, \lambda_{1DL}], \lambda_2 = [\lambda_{2UL}, \lambda_{2DL}], \lambda_3 = [\lambda_{3UL}, \lambda_{3DL}]$.
Then the dual problem for the given problem can be written as,

$$\min_{\lambda_1, \lambda_2, \lambda_3} F(\bar{\phi}) \quad (28)$$

To solve the equation 3.22 we use water-filling gradient method is used. This method is used to find the step size of gradient approach.$F(\bar{\phi})$at t[th] time slot is denoted as

a^t, b^t, c^t

where
$\delta = \frac{1}{t}$, $\delta > 0$.

$$a^t = f_s((\gamma_s, \bar{\phi}^{(t)}), (p_s, \bar{\phi}^{(t)}) \quad (29)$$

$$b^t = g_s((\gamma_s, \bar{\phi}^{(t)}), (p_s, \bar{\phi}^{(t)}) \quad (30)$$

$$c^t = \square_s((\gamma_s, \bar{\phi}^{(t)}), (p_s, \bar{\phi}^{(t)}) \quad (31)$$

Then the water-filling gradient is carried out by their iterative updating using the above equations. Using Equation (29-31) in equation (18) is afford a QoS based resource allocation in all nodes. Our proposed method is outlined as a flow chart in Figure-2.

EXPERIMENTAL SETUP

In this section we provide the numerical results of our proposed algorithm. To get the required output we consider a single base station based relay network. The OFDMA method is used for data transmission. The distance between each mobile station is 500m.We used 12 mobile station, and 6 relay stations for this simulation. The frequency is set as 10 MHZ and 15 sub channels are used with equal bandwidth. The path loss coefficient for base station to relay station is taken as 4, all others are taken as 5.8.The weightage fairness index is taken as equal for QoS constraints. The below table consolidate the various simulation parameters used for simulation. Here the parameters considered are the total bandwidth, total transmit power, noise power density, Standard deviation ratio, path loss component for both the base station as well as the receiver station and finally the total number of base station and mobile stations.

Table-1. Simulation parameters.

S. No.	Parameters	Values
1	Cell Radius	500m
2	Number of Relay Station	6
3	Number of Mobile Station	12
4	Number of Relay Station	1
5	Path loss exponent for BS-RS links	3-5
6	Path loss exponent forRS-BS links	5-6
7	Standard Deviation Ratio	8
8	Noise Power Density	174 dB/Hz
9	Total transmit power	25W
10	Total Bandwidth	10 MHz

RESULT AND DISCUSSIONS

In this session we discussed the numerical result for our proposed algorithm. In Figure-3 we simulate the system with one base station and 15 mobile station and 6 relaystation. The distance between each mobile and relay stations is considered as 500m. In Figure-4 and Figure-5 we compare the performance of our algorithm with considering the following scenarios.

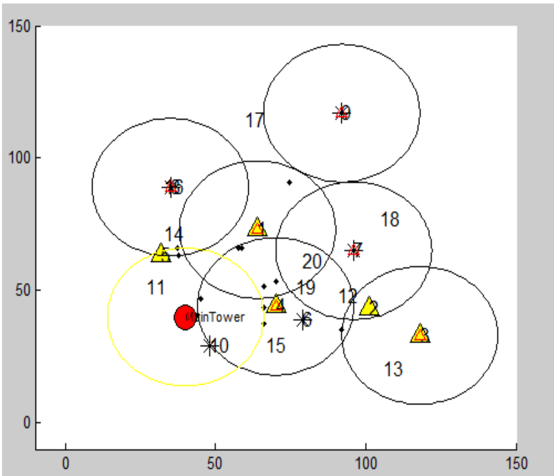

Figure-3. Node creation.

In Figure-4, the performance of with and without network coding is analyzed. In the graph first graph shows opportunistic scheduling with Dynamic Network Coding, the second one shows the system allows opportunistic

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scheduling with Diversity Coding finally the system transmits data without network coding.

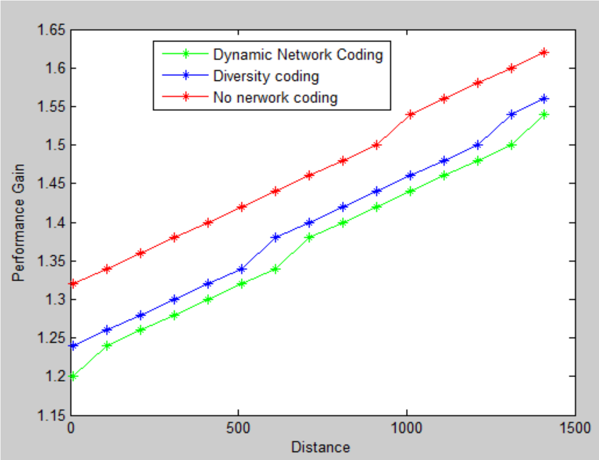

Figure-4. Performance gains with and without Network Coding.

The performance gain is analyzed by considering different type of network coding .It clearly shows that the opportunistic network coding is better than the other coding methods. In diversity coding method is performed by considering 64 QAM as the modulation technique To obtain the QoS we consider the fairness index as α_i = 0.5 and α_j = (1-α_i).

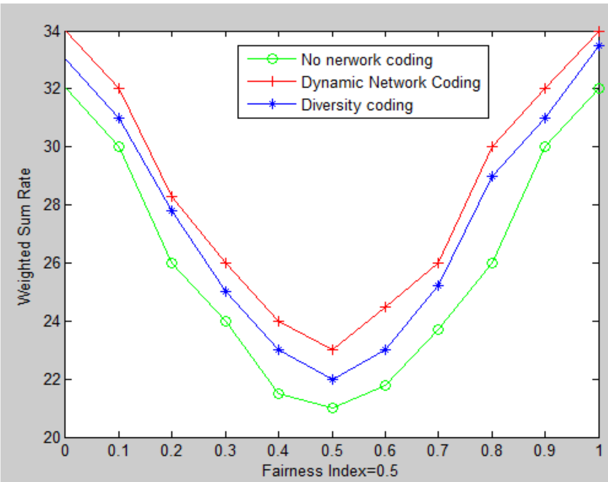

Figure-5. Performance comparison varying with weighting factor α_i = 0.5.

In Figure-5 we analyzed the system performance for a constant (α_i =α_j = 0.5) fairness index with various network coding method. It gives the result that the dynamic network coding is gives the better result than the other method. Comparing with the Diversity coding method, the dynamic network coding.

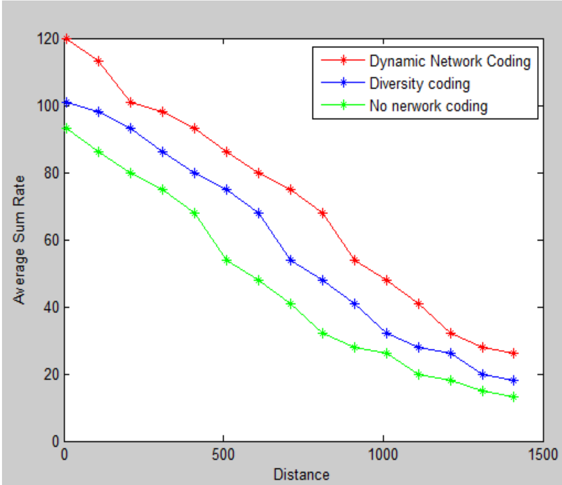

Figure-6. Average weighted Sumrate.

In Figure-6 we compare the performance of our algorithm with considering the following scenarios. (1) If the system allows opportunistic scheduling with Dynamic Network Coding. (2). If the system allows opportunistic scheduling with Diversity Coding. (3) If the system transmits data without network coding,

The Joint sub optimal power allocation is used for allocating power between relay station and mobile station is adopted from [2]. Here we considered the Base station allocate power to the relay and mobile station. The Base station power is 8W, Mobile Station power is 4W and relay station power is 2W.From the above figure the average sum rate is higher for the nearest mobile stations. If the mobiles are moving away from the base station the diversity is achieved by relay station. For achieving the QoS we used both diversity and network coding in this algorithm. The result of this algorithm shows that the average sumrate is high for dynamic network coding method.

CONCLUSIONS

In this paper, resource scheduling problem is solved for mobile relay enhanced cellular network with network coding at relay nodes. The simulation results shows that, the effective utilization of available bandwidth and transmission power and with network coding at relay nodes improve the spectral efficiency and overall network throughput.

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