International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 8, August - 2014

A Comparative Study on Spectral Efficiency of Downlink Cellular Networks With Different Diversity Orders

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Abstract— **Demand for high data rate and quality of service is increasing now a days in the area of wireless communication. Cooperative relaying and network coding are promising candidates to improve the overall network throughput. So a method is proposed in this paper for downlink cellular networks, combining the above mentioned two techniques and a comparative study is done between the different non-relaying, relaying and proposed scheme when used in a downlink cellular CDMA network. SINR and spectral efficiency were analyzed which showed better performance results for the proposed scheme.**

Keywords— CDMA; cooperative communication; network coding; relay networks; wireless communication.

I. INTRODUCTION

Wireless communication is one of the fastest growing areas in communication industry. In the last few decades the growth of cellular communication is in an amazing extend. With the advent of smart phones, the need for higher data rate and global coverage is also increasing. The most common challenges faced by wireless systems include interference, noise, multipath fading, bandwidth limitations etc. Channel fading affects transmissions over wireless channels and it reduces the quality of signals. Diversity techniques are widely used to mitigate these effects, and the commonly used techniques include time, frequency, spatial diversity techniques or a hybrid of these. Recently cooperative diversity is gaining popularity and is considered as the promising method to reduce multipath fading. Here we are deploying relay stations between base stations and mobile stations. Through this way we will be able to send multiple signal copies to the destination.

Relay assisted cellular networks are attracting more attention recently. Even if this method increases diversity gain, there is still possibility to improve the gain much. Hence another novel and efficient method is incorporated into this paper, called the Network Coding. Both the techniques mentioned above are aimed to improve the network throughput and performance. Using multiple copies will improve the reliability of transmission also.

Cooperative diversity for the basic three terminal relay channels was introduced in 1968. In [13], the case of network coding for uplink transmission is considered where the outage performance of network coding on a link level was studied. In [10], a network coding based relaying protocol for handover in multi-cell networks is presented.

II. BRIEF IDEA ON RELAYING AND NON-RELAYING METHODS

In non-relaying schemes, there will be no relay station in between source and destination nodes. Hence communication is possible only via the direct link. Because of this, high quality service will not be available for destinations at a distance due to fading effects, noise, interferences etc.

In relaying methods, there will be source, relay and destination nodes [2]. Cooperative relaying can be classified into three different types on the basis of process taking place at relay node as

A. Amplify and Forward

In this method, at the relay station, the received signal will be amplified and then forwarded to the destination. Issue with this method is that the noise will also get amplified.

B. Decode and Forward

The relay will decode the received signal and after encoding it back, forwards it to the destination. During the decoding process, noise could be removed from the desired signal.

C. Compress and Forward

The relay compresses the received information and then forwards it to the final destination.

For traditional non-relaying schemes, there is only one path available (source-destination), and the diversity order is 1. Consider Fig.1.Conventional Type-1 Relaying (CTR-1) is shown in Fig.1(a),Here, between source and destination, only one path is available and the diversity order is 1.If there are two paths available (CTR-2) between source and destination (direct path and path through RS), diversity order will be 2 as in Fig.1(b).

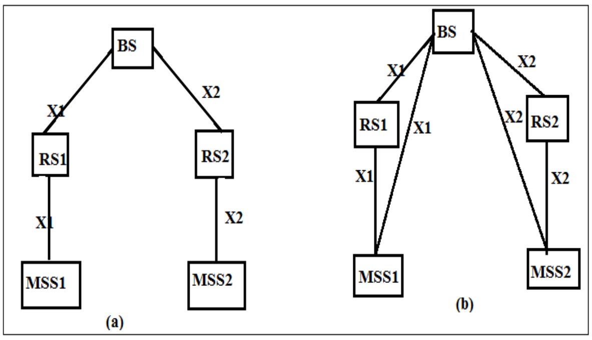

Fig.1 (a) CTR-1 (diversity =1) (b) CTR-2 (diversity =2)

III. OVERVIEW ON NETWORK CODING

Several benefits of using network coding (NC) in communication networks [3] have been proven in diverse subjects, such as throughput, end-to-end delay, security issues and robustness etc. Network coding can be considered as an effective alternative for routing. In routing methods, only one node uses the network resources at a time. This causes the overall delay to increase. In network coding, at the network layer, intermediate nodes can perform binary addition of independent bit streams and at the physical layer the intermediate nodes superimpose the incoming signals. The main attraction of network coding is that it utilizes cheap computational power to improve network throughput [12].

IV. PROPOSED METHOD

As in normal cellular network cases, we are considering a hexagonal model cell structure. Each cell will comprise of a base station and six relay stations. Base station will be located at the centre of each cell, and relays on the diagonals. Relay stations help in improving the throughput, reliability and quality of service provided [2]. According to the distance between user and base-station (BS), the users in a cell can be divided into cell-centre and cell-edge users. As the name indicates, cell-centre users are the ones nearer to the centre (BS) of cell and cell-edge users are the users to the edges of cell. Cell centre users are nearer to the base station than the Relay Stations (RSs) and hence they do not require RSs help to transmit signal to mobile station. If N_1 is the number of cell centre users and N_2 being number of cell edge users, total users in a cell can be written as $N=N_1+N_2$. Our proposed method, network coding aware cooperative relaying (NC^2R) is intended to help cell-edge users. Main rule for transmission is, if the distance between the MSS and BS is less than that of the sum of the distance between BS-RS and RS-MSS, then the base station can send signals directly to MSS, otherwise with the help of RSs.

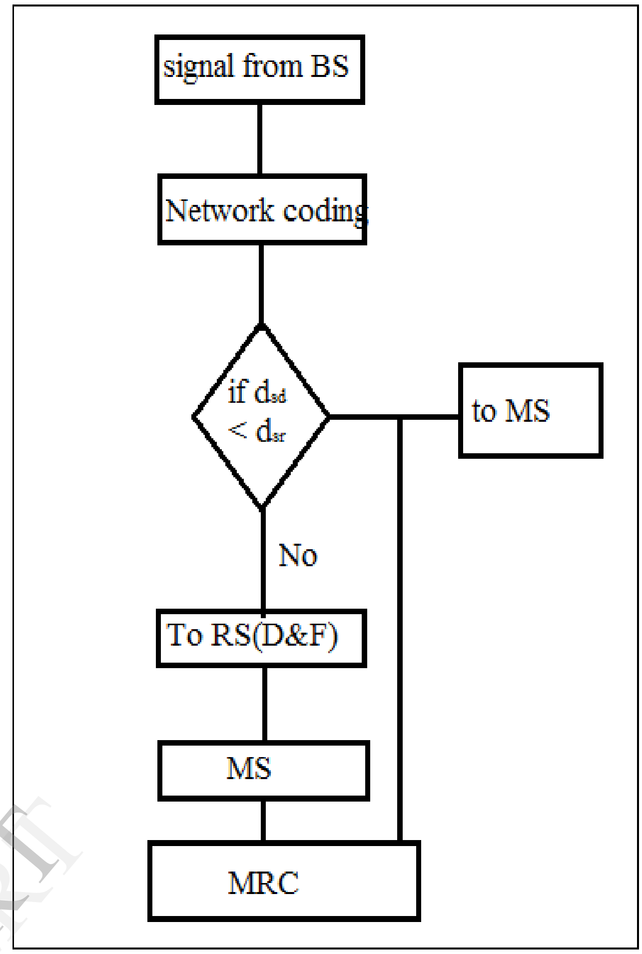

Fig.2 Flow chart of proposed method

There will be three phases for the proposed method. Consider that there are two MSS in need of receiving signals from a common base station, MSS1 and MSS2. In phase-1, the BS transmits a, b, a+b and a-b to MSS1, MSS2, R1 (RS) and R2 (RS) respectively through different channels. This occurs at the same time slot. In the second time slot, R1 and R2 decodes the received signals a+b and a-b, and forwards them to MSS1 and MSS2.Hence each MS will receive 3 copies of signal. Required signal can be extracted using MRC technique.

In Fig.2, d_{sd} represents the distance between source and destination and d_{sr} represents the distance between source and relay. MS is used to denote mobile station. Decode and forward relaying scheme is used in our proposed method. If the distance between MS and BS < distance between MS and RS, then there is no need for using network coding and relay stations for transmission.ie, transmission of signal will then occur directly between the BS and MS.

Diversity of proposed method can be calculated using

$$\rho_e \approx SNR^{-\alpha} \qquad (1)$$

The diversity order of proposed scheme can be calculated using (1) and hence the diversity order is obtained as 3.

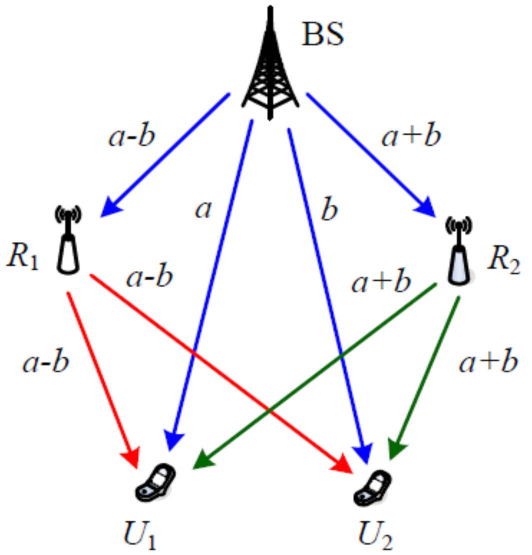

Fig.3 Proposed method using network coding and relay stations

V. INTERFERENCE AND SINR ANALYSIS

Here we will discuss about the downlink performance of four different schemes, traditional non-relaying, CTR-1, CTR-2 and the proposed scheme considering the received SINR. We will be considering a CDMA network with propagation model consisting of log-normal shadowing, distance attenuation and Rayleigh fading. If P_r denotes received power and P_t denotes transmitted power, then,

$$\frac{P_r}{P_t} = \frac{g_r g_t X_\sigma Y}{L_p} \qquad (2)$$

Where g_r and g_t represents the antenna gains of receiver and transmitter respectively, X_σ is the log normally distributed random variable and Y is a unity mean exponential random variable, capturing the effects of multipath fading. L_p is the path loss factor defined as

$$L_p = \left(\frac{4\prod d_0 f}{c}\right)^2 \left(\frac{d}{d_0}\right)^\alpha \qquad (3)$$

Where c is the velocity of light, f is the carrier frequency, d is the distance between transmitter and receiver and d_0 is the reference distance. Let

$$\beta = \frac{X_\sigma Y c^2 d_0^2}{(4\prod f)^2} \qquad (4)$$

Then it can be expressed as $P_r = \beta P_t d^{-\alpha}$

We will be using CDMA as platform in our analysis, and hence the frequency reuse factor will be 1.However due to influence of channel fading and noise, one receiver may not be able to cancel out MAI completely resulted from the signals transmitted to other receivers. Also the signals transmitted over downlink CDMA channels are influenced by the transmitted power from neighboring BSs and RSs (ICI). Hence we will be taking into account, both MAI and ICI. We assume that only six neighboring BSs and forty two RSs including six local RSs and thirty six neighboring RSs.

SINR of a signal sample of a MS can be determined using

$$SINR(i) = \frac{GP_{MS}(i)}{\eta I_{total}(i) + N_0} \qquad (5)$$

Where G is the CDMA system gain (G=W/R).W be the CDMA bandwidth and R signal transmission rate. N_0 be the power of AWGN. η shows the scaling degree of orthogonality of CDMA codes. Total received SINR of MS can be expressed as :

$$SINR_{total} = \sum_{i=1}^{m} SINR(i) \qquad (6)$$

The downlink spectral efficiency of MS can be calculated using equation $\log_2(1+SINR_{total})/K$ where k is 2 for cell-edge users in three relaying schemes and 1 for non-relaying schemes. SINR values for non-relaying, CTR-1, CTR-2 and NC^2R methods can be obtained from [1].

VI. SIMULATION RESULTS

Simulation is done in MATLAB and N is assumed to vary from 10 to 200. For each N 10,000 simulations were performed. We will be setting some values for simulation. Cell radius is set to be 1km. The channel bandwidth W is set to 5MHz and f is 2 GHz [10]. η= 0.5, this shows that orthogonally condition is not kept well so interference occurrence will be more. α= 4 and σ =8.The signal transmission rate R=100 kbps. P_B =25 W, P_R=2 W.

Average spectral efficiency achieved by different relaying and traditional non-relaying schemes are shown in Fig.4 for cell edge users. From the result we could see that the NC^2R method with diversity order 3 has got higher spectral efficiency. It can be thus concluded that NC^2R enhances downlink data rate and improves the total throughput on relay assisted networks. The proposed NC^2R method is taking into consideration cell-edge users much, since they are dealing with interferences, noise, poor quality etc than cell centre users. NC^2R widens the service capacity of relay assisted cellular networks.

Fig.5 shows the average spectral efficiency achieved by different relaying and traditional non-relaying schemes for cell-centre users. Spectral efficiency of cell-centre users is smaller when compared with that of cell-edge users. Since d_{RB}=0.5, cell centre users will only be 25%, and cell edge users will be 75%. Hence 75% users in cell can obtain improved downlink performance. Thus we could say that the overall cellular system is enhanced by NC^2R

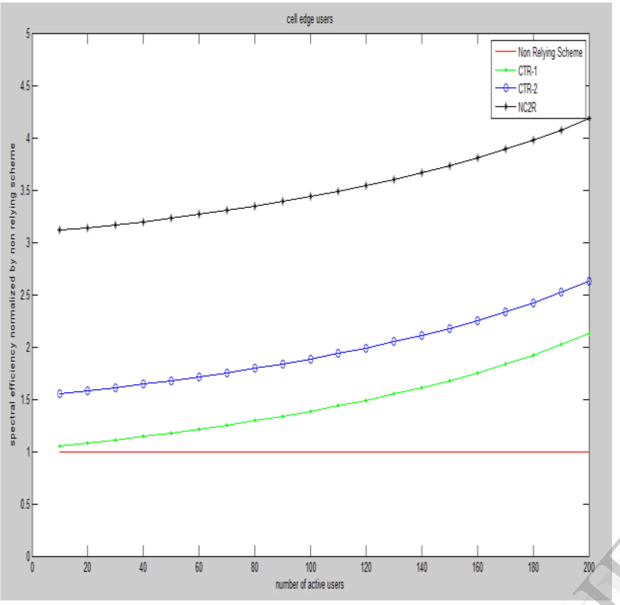

Fig.4 Avg spectral efficiency for cell edge users

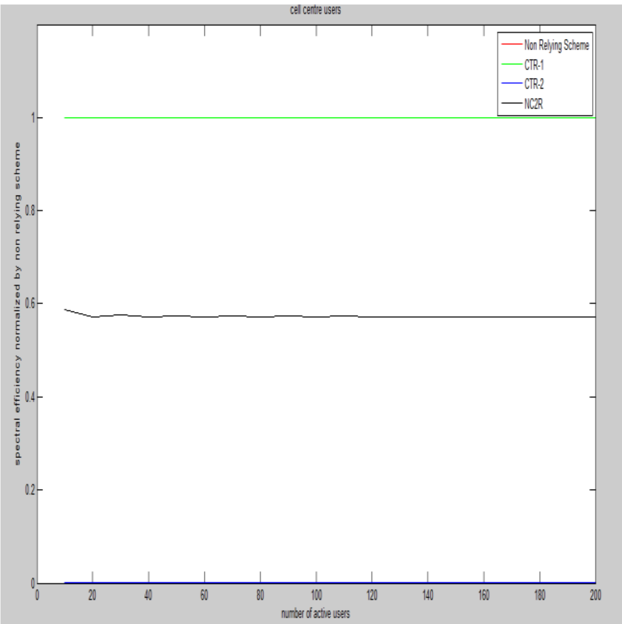

Fig.5 Avg spectral efficiency for cell centre users

VII. CONCLUSION

Different relaying and traditional non-relaying schemes were studied and a network coding aware cooperative relaying scheme was introduced. Diversity order of each was calculated and came to know that NC^2R has got much diversity order than other schemes. SINR analysis and spectral efficiency of each method were calculated. From the results it could be concluded that the overall cellular system is enhanced by NC^2R.

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