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Decode-And-Forward Full Duplex relaying in MIMO - OFDMA Systems

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Abstract: Co-operative communication with relay assistance helps in enhancing the capacity of point to point links. Next-generation wireless communication systems require higher spectral efficiency and macroscopic coverage to support the quality of service needed for a wide variety of multimedia applications. Much research has been devoted to enhancing the spectral efficiency of wireless communication systems. Among these, relay based communication systems have attracted a great deal of attention thanks to their potential to deliver extended cell coverage and reduced power consumption. We discuss resource efficiency in relay systems, particularly in two-way and full-duplex relay systems that utilize multiple antennas and improved duplexing to enhance system efficiency. Besides, a theoretically optimal hybrid relaying, which allows a dynamic selection between AF relaying and DF relaying protocols with full-duplex relays or half-duplex relays, is also considered in the problem formulation and serves as a performance benchmark. . Simulation results demonstrate that the proposed source and relay design algorithms perform much better than the existing techniques in terms of probability of error Vs transmit power.

Keywords: Amplify-and-forward relays, Decode-and-forward relays, full-duplex relaying, half-duplex relaying distributed resource allocation, multiuser diversity.

I. INTRODUCTION

One of the key expectations for the 4th Generation (4G) wireless system is to provide ubiquitous high data rate coverage. During these recent years, a large part of the research has focused on MIMO-OFDMA centralised transmission technology. Relay enhanced MULTIPLE-input multiple-output (MIMO) and orthogonal frequency division multiple accesses (OFDMA) are important techniques for high data rate wireless multiuser communication systems [1].

By deploying Relay Stations (RS) in a cellular system, it becomes possible to forward high data rates in remote areas of the cell while keeping a low cost of infrastructure. To exploit this potential gain in capacity and coverage, an adequate and practical radio resources allocation strategy should be design. Hence, the problem of resource allocation and scheduling for relay–aided cellular systems has been a flourishing topic for investigation and has produced a number of works such as [2] [3].

Relaying has also received much attention because of its capability to improve transmission coverage, network capacity, and system reliability [4]. In addition, relay nodes can be equipped with multiple antennas to take advantage of MIMO gains. Two kinds of relay schemes are commonly used in relay networks, namely amplify-and-forward (AF) and decode-and-forward (DF). Both schemes can be deploy to achieve cooperative diversity in wireless communication [5]. A large amount of work has been devoted to HD relaying as it enables a low-complexity relay design. Nevertheless, HD relaying systems require additional resources (time slots or frequencies) to transmit data in a multi-hop manner, which results in a loss of spectral efficiency [6]. Even though there exist several approaches for minimizing/recovering the spectral efficiency loss associated with HD relaying, such as non-orthogonal relaying and two-way relaying [7], these schemes do not solve the problem fundamentally since the associated protocols are still using HD relaying. On the contrary FD relaying suffers from inherent loop interference [8] which was considered impractical in the past.

In this paper, we consider the FD MIMO-OFDMA DF relay networks and derive the optimal structure of both source precoding matrix as well as the relay amplifying matrix such that the overall transmission power from source and relay is minimize subject to a given set of QoS constraints. However, efficient resource allocation and scheduling algorithms for MIMO-OFDMA FD relaying systems with interference cancellation error have not studied. A lot of work has been done on *Amplify-and-Forward* relaying in this paper we evaluate the performance of the *Decode-and-Forward* relaying protocol.

II. NETWORK MODEL

We consider a relay assisted MIMO-OFDMA downlink packet transmission network with nF subcarriers, one BS, M relays, and K mobile users which

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belong to one of two categories, namely, delay sensitive users and non-delay sensitive users. Delay sensitive users require a minimum constant data rate while non-delay sensitive users require only best-effort service. The BS, relays and users are assumed to be equipped with N antennas, respectively. A cell is modelled by two concentric ring-shaped discs as shown in Fig.1 . The cell coverage is dividing into M areas corresponding to the M relays and each user is assign to one relay. In this work, we focus on resource allocation and scheduling for heterogeneous users who need the help of relays, i.e., cell edge users in the shaded region of Fig.1 We assume that there is no direct transmission between the BS and the mobile users due to heavy blockage and long distance transmission.

A distributed algorithm is deriving for resource allocation and scheduling purposes. Based on the CSI of the users, the algorithm selects between transmission strategies on a per Subcarrier basis for hybrid relaying.

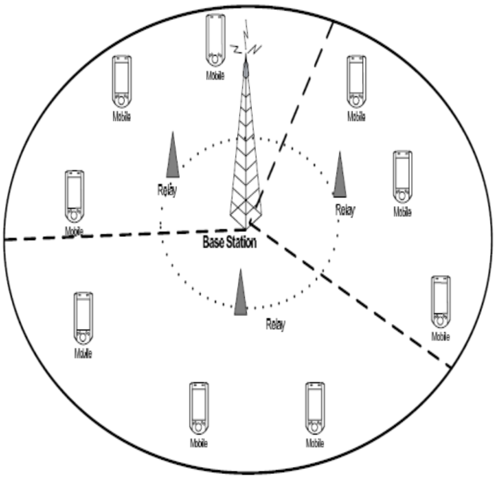

Fig.1. Relay assisted packet transmission system model with $K = 9$ users, and $M = 3$ relays.

III.NOTATION

For a square-matrix **S**: det[**S**], diag(**S**), eig(**S**), tr(**S**), (**S**)−1, and (**S**)1/2 denote the determinant, diagonal element vector, eigenvalue vector, trace, inverse, and square root of matrix **S**, respectively; **S** _ 0 means that **S** is a positive semi-definite matrix. (**S**)H and rank(**S**) denote the conjugate transpose and the rank of matrix **S**, respectively. Matrix **I**N denotes the N × N identity matrix. E{·} denotes statistical expectation. CN×M and (R+0)N×M represent the space of N × M matrices with complex and non-negative real entries, respectively. The distribution of a circularly symmetric complex Gaussian (CSCG) vector with mean vector **x** and covariance matrix **Σ** is denoted by CN(**x**,**Σ**), and ∼ means "distributed as". (x)+ = max{0, x}. Operator μi(·) returns the i-th largest eigenvalue of an input matrix. O(g(x)) represents an asymptotic upper bound, i.e., f(x) = O(g(x)) if lim x→∞ | f(x) g(x) | ≤ N for 0 < N < ∞.

IV.DECODE-AND-FORWARD FULL-DUPLEX RELAYING CHANNEL MODEL

The channel impulse response is assumed time invariant within a scheduling slot. The data symbol vector $s_k^{[i]} \in C^{N\times1}$ on subcarrier i ∈ {1, . . . , nF } using transmission strategy t ∈ {1,2} for user k ∈ {1, . . . , K} is linearly precoded at the BS as

$$x_{m,k}^{[t,i]} = B_{m,k}^{[t,i]} s_k^{[i]} \qquad (1)$$

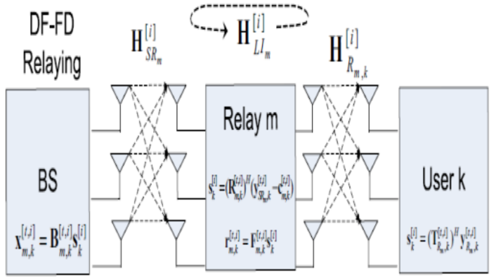

Fig 2 Block diagrams for DF full-duplex relaying with loop interference cancellation

where $B_{m,k}^{[t,i]} \in$ CN×N is the transmit precoding matrix on subcarrier i. In the first time slot, if the DF-FD relaying protocol is used for transmission, i.e., t = 1, the (frequency domain) received vector symbol on subcarrier i at relay m ∈ {1, . . . , M} for user k is given by

$$y_{S\,Rm,k}^{[i]} = H_{SRm}^{[i]} x_{m,k}^{[t,i]} + \Delta H_{LIm}^{[i]} r_{m,k}^{[t,i]} + z_m^{[i]} \qquad (2)$$

where $H_{SRm}^{[i]}$ is the N × N MIMO channel matrix between the BS and relay m on subcarrier i and captures the effect of both multi-path fading and path loss, $H_{LIm}^{[i]}$ is the N ×N loop interference channel matrix, and $F_{m,k}^{[t,i]} \in C^{N\times N}$ is a post-processing matrix used at relay m. $r_{m,k}^{[t,i]}$ is is the concurrent transmitted signal vector from relay *m* to user *k* when DF-FD relaying is selected. $z_m^{[i]} \in C^{N\times1}$ is the additive white Gaussian noise (AWGN) vector with distribution CN(0,**Σm**) on subcarrier i at relay m, where Σm ∈ $(R_0^+)^{N\times N}$ is a diagonal covariance matrix with each main diagonal element equal to N0. The relay subtracts vector $c_{m,k}^{[t,i]} = \widehat{H}_{LIm}^{[i]} F_{m,k}^{[t,i]} r_{m,k}^{[t,i]}$ from $y_{S\,Rm,k}^{[i]}$ for loop interference cancellation which yields

$$\tilde{y}_{S\,Rm,k}^{[i]} = y_{S\,Rm,k}^{[i]} - c_{m,k}^{[t,i]} \quad (3)$$

In order to simplify the subsequent mathematical expressions and without loss of generality, we assume in the following a normalized noise variance of *N*0 = 1 at all receive antennas of the relays and the users. Assuming a linear receiver is employed at user *k*, the estimated data vector symbol $s_k^{[i]} \in C^{Nx1}$ on subcarrier *i* is given by

$$\hat{s}_k^{[i]} = (R_{m,k}^{[t,i]})^H \, y_{S\,Rm,k}^{[t,i]} \qquad (4)$$

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Thus, the optimal MMSE post-processing matrix and the corresponding MMSE matrix at relay *m* can be written as

$$R^{*[t,i]}_{Rm,k} = (\Phi^{[t,i]}_{m,k}(\Phi^{[t,i]}_{m,k})^{H}+\Upsilon^{[t,i]}_{m,k})^{-1}\Phi^{[t,i]}_{m,k} \quad \text{and}$$

$$\Delta^{*[t,i]}_{m,k} = [I_{N}+(\Phi^{[t,i]}_{m,k})^{-1}(\Upsilon^{[t,i]}_{m,k})^{-1}((\Phi^{[t,i]}_{m,k})]^{-1} \quad (5)$$

Respectively, $\Phi^{[t,i]}_{m,k}$ and $\Upsilon^{[t,i]}_{m,k}$ are the equivalent MIMO channel matrix of the BS-relay links for DF relaying on subcarrier *i* and the noise covariance matrix at relay *m* on subcarrier *i* given by

$$\Phi^{[t,i]}_{m,k} = H^{[i]}_{Rm,k}B^{[t,i]}_{m,k} \quad \text{and}$$

$$(\Upsilon^{[t,i]}_{m,k}) = \varepsilon(\Delta H^{[i]}_{L,Im}r^{[t,i]}_{m,k})\,(\Delta H^{[i]}_{L\,Im}r^{[t,i]}_{m,k})^{H} + I_N (6)$$

Where $\widehat{H}^{[i]}_{LIm} \sim CN(0,\Xi^{[i]}_{m})$ denote, respectively, the corresponding estimation error, which are mutually uncorrelated, $\Xi^{[i]}_{m}$) is a diagonal covariance matrix with each main diagonal element equal to σ_e^2 .

Assuming error-free decoding at relay *m*, in the second time slot, the decoded signal vector at relay *m* on subcarrier *i* is encoded again with a new precoding matrix $F^{[t,i]}_{m,k}$ and forwarded to user *k*. The re-encoded signal vector is given by

$$r^{[t,i]}_{m,k} = F^{[t,i]}_{m,k}\,\hat{s}^{[i]}_{k} \quad (7)$$

In addition, the received signal vector at user *k* from the BS via relay *m* on subcarrier *i* is given by

$$y^{[i]}_{Rm,k} = H^{[i]}_{Rm\,k}\,r^{[t,i]}_{m,k} + z^{[i]}_{k} \quad (8)$$

User *k* multiplies the received signal vector with a post-processing matrix to extract the original signal vector. The estimated symbol vector $\hat{s}^{[i]}_{k}$ at user *k* on subcarrier *i* can be expressed as

$$\hat{s}^{[i]}_{k} = y^{[i]}_{Rm\,k}\,T^{[t,i]}_{m,k} \quad (9)$$

Where, $T^{[t,i]}_{m,k}$ is linear receiver post-processing matrix is given by

$$T^{[t,i]}_{m,k} = (H^{[i]}_{Rm\,k}F^{[t,i]}_{m,k}\,(H^{[i]}_{Rm\,k}F^{[t,i]}_{m,k})^{H} + I_N)^{-1}\,H^{[i]}_{Rm\,k}F^{[t,i]}_{m,k} \quad (10)$$

With the corresponding MMSE matrix

$$E^{*[t,i]}_{m,k} = [H^{[i]}_{Rm\,k}F^{[t,i]}_{m,k}\,(H^{[i]}_{Rm\,k}F^{[t,i]}_{m,k})^{H} + I_N]^{-1} \quad (11)$$

The signal model for DF-HD relaying is obtained.

V. SIMULATION RESULTS

In this section, we evaluate the system performance using simulations. Each cell is modelled as two concentric ring shaped discs as shown in Fig. 1. The outer boundary and the inner boundary have radii of 1 km and 500 m, respectively. There are M = 3 relays equally distributed on the inner cell boundary for assisting the transmission and K active users are uniformly distributed between the inner and the outer boundaries. Unless specified otherwise, there are 3 delay sensitive users. in the system, while the remaining users are non-delay sensitive. The number of subcarriers is nF = 128 with carrier centre frequency 2.5 GHz, system bandwidth B = 5 MHz, and wk = 1. Each subcarrier has a bandwidth of 39 kHz and a noise variance N0 = −128 dBm. The 3GPP path loss model is used. The small scale fading coefficients of the relay-to-user links are modelled as independent and identically distributed (i.i.d.) Rayleigh random variables. On the other hand, a strong line of sight communication channel between the BS and the relays is expected since they are placed in relatively high positions in practice and the number of blockages between them is limited. Hence, the small scale fading coefficients of the BS-to-relay links are modelled as i.i.d. Rician random variables with Rician factor κ = 6 dB. The weighted average system throughput is obtained by counting the number of packets which are successfully decoded by the users averaged over both macroscopic and microscopic fading.

A. *Probability or error versus signal to noise ratio at different modulation technique*

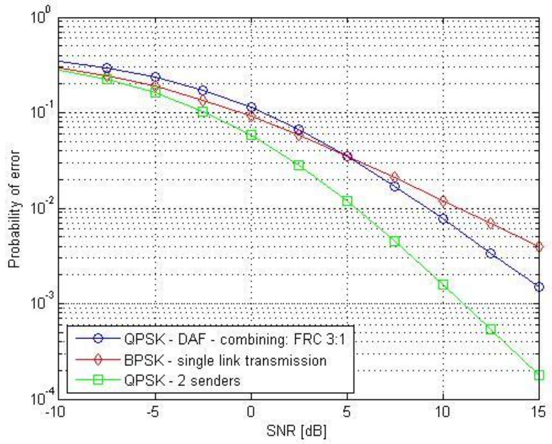

Fig. 3 probability of error Vs signal to noise ratio with different modulation technique and different number of transmitters

Fig 3 shows the performance of the received signal at different modulation technique. It can be observed that as number of transmitter and receiver antennas increased the probability of error decreased.

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B. *Comparition between AF and DF*

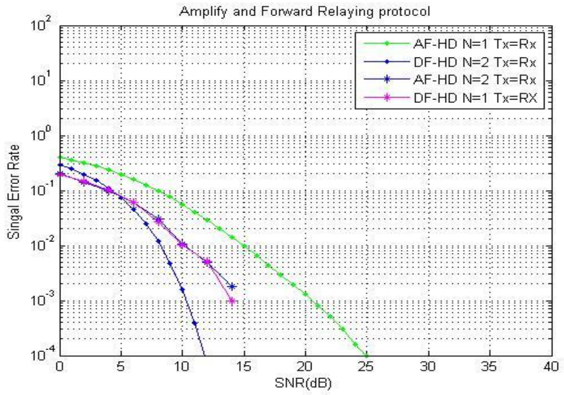

Fig 4 Performance of AF and DF at Half Duplex relay with no. of Antennas.

Multiple Input and Multiple Output is emerging technique today for user demand and their special feature Diversity technique. In the system as the number of antennas, increase the performance of the system increased. Fig 4 showing the performance of the Amplify-and-Forward and Decode-and-Forward relaying protocol with different antennas. DAF is batter protocol for relay enhanced network but it require more time for decode and re-encode the message.

C. *Probability of error Versus Transmit Power*

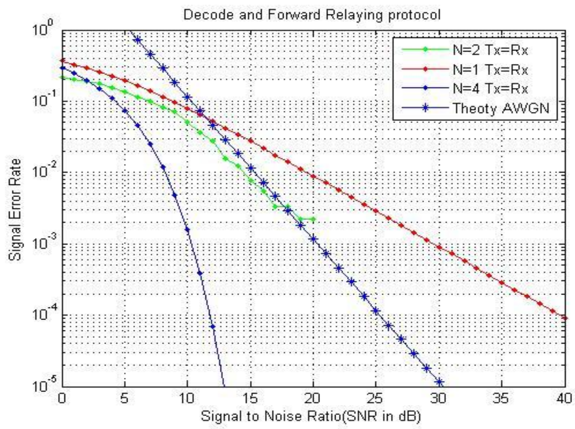

Fig. 5. Signal Error Rate versus SNR(db) for an average residual loop interference power with different numbers of antennas N

fig. 5 shows the signal error rate versus total transmit power and illustrate that as the number of antennas increase in the system with loop interference power 29 db the performance of system increase and fig 4 shows that number users increase system performance also improve.

VI. CONCLUSION

Simulation result showing the grate advantages of Decode and forward relaying protocol for relay enhanced network. Here we add some more feature to relays are multiple antennas, and so that the system performance are dramatically increased and have given batter performance then single link communication.

DF and AF are emerging technique for higher data transmission for long distance user. In this paper, we evolutes the performance of Decode and forward relaying protocol in MIMO-OFDMA system with full duplex as a non-convex and combinatorial optimization problem, simulation result showing the advantage of the MIMO technique as the number of antennas increases the system performances also increased. Simulation results not only showed that the performance of the proposed iterative algorithm approaches the optimal performance within a small number of iterations, but also demonstrated the possible performance gains obtained by FD MIMO-relaying system as number of antennas increases.

REFERENCE

[1] H. Viswanathan and S. Mukherjee, “Performance of Cellular Networks with Relays and Centralized Scheduling,” IEEE Trans. Wireless Comm., vol. 4, no. 5, pp. 2318–2328, September 2005.
[2] H. Hu and H. Liu, “Range Extension without Capacity Penalty in Cellular Networks with Digital Fixed Relays,” in IEEE GLOBECOM, Dallas, Texas, December 2004.
[3] J. Z. D. Zheng and J. Sadowsky, “Hierarchical Multiuser Diversity (HMD) Transmission Scheme,” in IEEE GLOBECOM, San Francisco, CA, December 2003.
[4] M. K. Awad and S. Xuemin, “OFDMA based two-hop cooperative relay network resources allocation,” in Proc. 2008 IEEE Int. Conf. Commun., pp. 4414–4418.
[5] .BeckandY.C.Eldar, Cooperative diversity in wireless networks, IEEE Trans. Inf. Theory, vol.52 ,no.9 ,pp. 3062 {3080, 2004.
[6] P. Li and et al., Spectrum partitioning and relay positioning for cellular system enhanced with two-hop fixed relay nodes, IEICE Trans. Comm., E90-B (Nov. 2007), pp. 3181–3188.
[7] I. Krikidis, J. Thompson, and S. Mclaughlin, “On the diversity order of non-orthogonal amplify-and-forward over block-fading channels,” IEEE Trans. Wireless Commun., vol. 8, pp. 1890–1900, June 2010.
[8] H. Ju, E. Oh, and D. Hong, “Catching resource-devouring worms in next-generation wireless relay systems: two-way relay and full-duplex relay,” IEEE Commun. Mag., vol. 47, pp. 58–65, Sep. 2009.