MULTI RELAY BEAMFORMING DESIGN FOR TWO-HOP SINGLE USER SYSTEM WITH PERFECT CSI

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ABSTRACT

The purpose of this research is to achieve maximum ergodic capacity of wireless MIMO relay assisted network by designing relay linear processing. A novel linear beamforming is developed for amplify-and-forward two-hop multi-relay wireless network. In this design matched-filter beamforming is applied as receive processing for multiple relays and leakage based beamforming is designed as the relay transmit beamforming. Each terminal of the network is fitted with multiple antennas for intra node array gain. The information of both links is exploited at the relay terminals. The link (direct) from the source to user terminal is avoided. The relay terminals operate in half duplex mode. Through Matlab® simulations, it is revealed that the proposed scheme out performs the existing conventional relay beamformings for multi-relay case in the two-hop network.

Keywords: Amplify-and-forward Relay, Capacity; Leakage; Multiple relays; Perfect CSI

I.INTRODUCTION

Wireless cooperative communication is getting high popularity due to cooperation in data transfer and is an emergent research area [1-3]. The incessant demand of high data rate for wireless multimedia services delivered by wireless technologies is increasing day-by-day due to the easy access and freedom of wireless system. The modern wireless communications technologies, are promising to meet high date rate demand on everywhere basis efficiently and cost effectively. The relaying transmission techniques have got much attraction over the solution of increasing the number of base stations due their implementation simplicity and low cost to extend the coverage and capacity of the existing macro cell based base station systems [4]. This is because, when the existing base station systems operating under high frequencies then the range of base stations is naturally limited and also suffers from the sever channel fading, multipath fading and high path loss which decrease the coverage, capacity and reliability of the system.

In terms of capacity and the endorsed transmit power, a limited amount of resources are assigned to a base station to serve a pre-defined quantity of customers in a cell. However with the growing number of customers the offered capacity becomes inadequate and consequences the substandard service and the systems becomes capacity limited. At the same time due to the limited transmit power of the base station, the users at the cell edge experience insufficient power level because of the weak signals from the base station [5].

The performance of the relaying networks can further be enriched by designing a suitable relay processing scheme that can control the relay transmission impairments and provide better quality of service with enhanced capacity. In existing literature several research works for AF relay beamforming design are presented that assume channel information at relay nodes for maximization of capacity [6-10] The capacity scaling of relay assisted network is designed in[6]. In [9] authors proposed linear processing for non-regenerative relays using matched filter (MF) at the receiver side for as the receive filter and design the multiple relay transmit precoding using regularized zero forcing a variant of zero forcing. The MF facilitated in increasing SNR at the relay terminals, whereas RZF scheme helped to mitigate interference among multiple antennas at the downlink of the relay network [9]. The MF-RZF technique presented in [9] using the non-zero percentage of parameter for RZF may not reduce the interference entirely. If it the parameter has very low value then the technique behaves like zero forcing technique and at high value an extra power would be consumed and more in interference [8]. Therefore the RZF technique permits definite quantity of interference [11]. This paper proposes a linear processing for relay terminals in MIMO network, the novelty design is reflected in MF and SLNR beamforming design using Fukunaga Koontz Transform (FKT) [12]. The idea of this design can provide the distributed array gain and intra-node array gain from the multiple antennas every node and distributed array gain from the multiple relay nodes.

The paper is outlined as: Section 2, describe the multi-relay assisted MIMO system model. In Section 3, the proposed relay processing is formulated. Section 4 presents and discusses the numerical results. The conclusion is given in section 5.

II.SYSTEM MODEL

Here a two-hop relaying network witha source, multiple relays in cluster making parallel relay branches and one destination with multiple antennas is considered and illustrated in Fig.1. It consist of N_s the number of transmit antennas at MIMO source $N_r$arerelay receiving antennas and $N_d$are destination antennas. Spatial multiplexing is to be done at the source.

The communication between source to user is taken place through multiple relay terminals. Here the source sends signal $\boldsymbol{s}$to relay terminals that satisfy the source power constraint as $\mathbb{E}\{ss^H\} = \frac{P_s}{N_s}\boldsymbol{I}_{N_s}$. Where, P_s is the source transmission power and P_r is the relay transmission power. Therefore N_s is the number of source antennas and $\mathbf{I}_{N_s}$ is identity matrix of $N_s \times N_s$,$\boldsymbol{H}_k \in \mathbb{C}^{N_s \times N_r}$ is the channel from source to the relay terminals, k=1,2,…,K that is $\boldsymbol{H_1}, \dots, \boldsymbol{H}_k$. Where, $\boldsymbol{H}_{rd}$ is the channel between k^{th} relay nodes (k=1, 2,…,K) and destination.

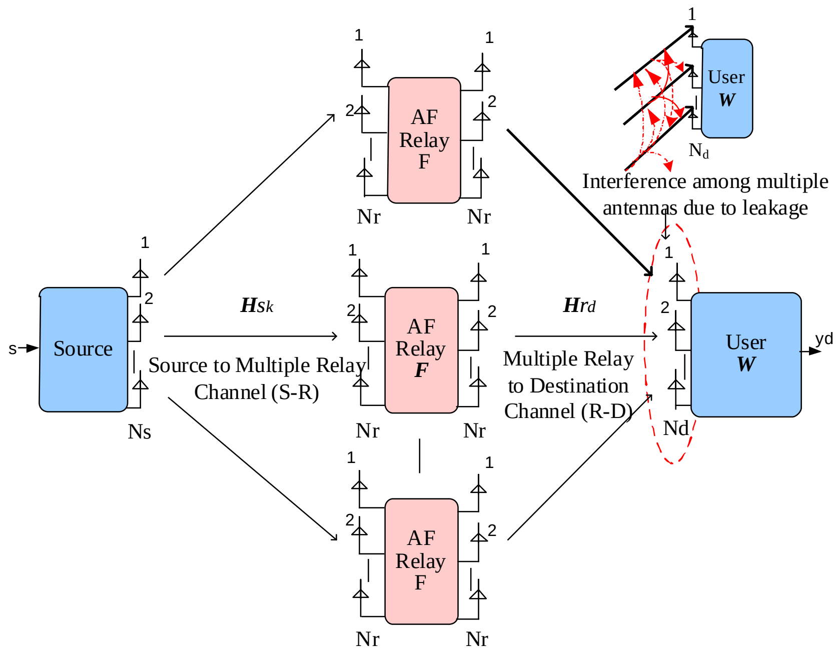

Fig.1. Atwo-hop multiple cascadedAF relay network

That is $\boldsymbol{H}_{rd} \in \mathbb{C}^{N_d \times N_r}$. Since $\boldsymbol{n}_d$ is $\boldsymbol{n}_d \in \mathbb{C}^{N_d}$ complex Gaussian noise with zero mean and covariance satisfying noise variance $\mathbb{E}\{\boldsymbol{n}_d\boldsymbol{n}_d{}^H\} = \sigma_d^2 I_{N_d}$ and σ_d^2 noise power at the destination. The corresponding received signals at thek^{th} relay terminals are given as;

$$\boldsymbol{s}_{rk} = \sum_{k=1}^{K} \boldsymbol{H}_k\, \boldsymbol{s} + \boldsymbol{n}_{rk} \quad (1)$$

Whereas,$\boldsymbol{n}_{rk}$ is zero mean additive Gaussian noise vector i-e $n_{rk} \sim CN(0, \sigma_r^2 \boldsymbol{I}_{M_r})$ independent across k^{th} relay terminals with noise covariance $\mathbb{E}\{\boldsymbol{n}_k\boldsymbol{n}_k{}^H\} = \sigma_r^2\boldsymbol{I}_{N_r}$. Where σ_r^2 symbolizes the power at each relay terminal. The relays retransmit the signal to the user after multiplying amplifying matrix $\boldsymbol{F}_k$ that is termed as beamforming matrix. Let the$\boldsymbol{F}_k$ be beamforming matrix i-e $\boldsymbol{F}_k \in C^{N_r \times N_r}$ at relay nodes.

The relay precoded signal vector retransmitted by the k^{th} relays to the destination/user is written as;

$$\boldsymbol{r}_k = \boldsymbol{F}_k \sum_{k=1}^{K} \boldsymbol{F}_k \boldsymbol{H}_{s,k}\, \boldsymbol{s} + \boldsymbol{n}_k \quad (2)$$

Constraintof power at the relay satisfies as,

$$\mathbb{E}\{\boldsymbol{r}_k{}^H \boldsymbol{r}_k\} \le P_r \quad (3)$$

The relay power constraint can be derived as;

$$P(\boldsymbol{r}_k) = tr\left\{\boldsymbol{F}_k\left(\frac{P_s}{N_s}\boldsymbol{H}_{sk}\boldsymbol{H}_{sk}^H + \sigma_r^2\boldsymbol{I}_{N_r}\right)\boldsymbol{F}_k^H\right\} \le P_r \quad (4)$$

The relay precoded and forwarded signal at destination is written as;

$$\boldsymbol{y} = H_{rd}\boldsymbol{r}_k + n_d$$

$$\therefore \quad \boldsymbol{r}_k = \boldsymbol{F}_k \boldsymbol{s}_{rk}$$

$$\boldsymbol{y} = \sum_{k=1}^{K} \boldsymbol{H}_{sk}\, \boldsymbol{F}_k \boldsymbol{H}_{rd}\boldsymbol{s} + \sum_{k=1}^{K} \boldsymbol{H}_{rd}\, \boldsymbol{F}_k \boldsymbol{n}_k + \boldsymbol{n}_d \quad (5)$$

III.RELAY PRECODING

The ergodic capacity of the AF relay assisted MIMO relay network is analyzed at the destination by applying QR decomposition and successive interference cancellation (SIC) detections [9]. Here QRD is exploited as detection scheme for destination node. Let in (5) the terms $\sum_{k=1}^{K} \boldsymbol{H}_{rd}\, \boldsymbol{F}_k \boldsymbol{H}_{sk} = \boldsymbol{H}_{sd}$is an effective channel and $\sum_{k=1}^{K} \boldsymbol{H}_{krd}\, \boldsymbol{F}_k \boldsymbol{n}_{rd} + \boldsymbol{n}_d = \boldsymbol{n}$ is effective noise. The equation (5) can be regenerated as $\boldsymbol{H}_{sk} = \lfloor \boldsymbol{H}_1, \dots, \boldsymbol{H}_k \rfloor$.

$$\boldsymbol{y} = \boldsymbol{H}_{sd}\boldsymbol{s} + \boldsymbol{n} \tag{6}$$

Where, $\boldsymbol{H}_{sd}$ is effective channel from source to user and $\boldsymbol{n}$is the effective noise vector.

The QRD implementation at the effective channel $\boldsymbol{H}_{sd}$ is given as;

$$\boldsymbol{H}_{sd} = \boldsymbol{Q}_{sd}\boldsymbol{R}_{sd} \tag{7}$$

Whereas, $\boldsymbol{Q}_{sd}$ is an$N_s \times N_d$ unitary matrix and $\boldsymbol{R}_{sd}$ is $N_s \times N_d$ right upper triangular matrix.

Therefore the QR detection at destination is selected as;

$$\boldsymbol{W} = \boldsymbol{Q}_{sd}^{H} \tag{8}$$

Then after detection the received signal vector becomes;

$$\widehat{\boldsymbol{y}} = \boldsymbol{R}_{sd}\boldsymbol{s} + \boldsymbol{Q}_{sd}^{H} \tag{9}$$

The optimal relay precoder design is formulated as;

$$\widehat{\boldsymbol{F}}_{\boldsymbol{k}} = \underset{F_k}{\operatorname{argmax}}\, SLNR_k(\boldsymbol{F}_{\boldsymbol{k}})$$

$$\text{s.t } P(r_k) \le PQ_k \tag{10}$$

It is assumed that a power coefficient ρ_k is used with k^{th} relay precoder $\boldsymbol{F}_{\boldsymbol{k}}$ in (2) to confirm that transmit power of each relay equal to Q_k the total power of k^{th} relay terminals. After applying precoding and power coefficient the relay forward signal is written as;

$$\hat{r}_k = \rho_k \boldsymbol{F}_k r_k \tag{11}$$

From (3) the factor P_k that controls power is written as;

$$P_k = \left(\frac{Q_k}{tr\left\{ F_k\left(\frac{P_s}{N_s} H_{sk} H_{sk}^{H} + \sigma_r^2 I_{N_r}\right) F_k^{H} \right\}} \right)^{\frac{1}{2}} \tag{12}$$

IV.MATCHED FILTER-PER ANTENNA SLNR BASED MULTI-RELAY PROCESSING (MF-PASLNR)

In this relay transceiver design for amplify-and-forward multiple relay aided network, MFis used as multiple relay receive beamforming while leakage based relay transmit beamforming. In this scheme the matched filter remove the noise effect [13] at the relay reception for the multi-relay network, whereas the leakage based relay transmit beamforming tries to control the interference due to leakage signal at the user end. Here each relay beamforming is segregated into two components a relay receive beamforming based matched filter and transmit precoder based on SLNR maximization.

The matched filter beamforming matrix for the k^{th}relay for first hop of the network is set to,

$$\boldsymbol{F}_{sk}^{MF} = \boldsymbol{H}_{sk}^{H} \tag{13}$$

Here receive precoder is $\boldsymbol{H}_{sk}^{H}$ is optimal weighting matrix that maximize SNR received at relays.

The interference caused by the leakage signal cannot be cancelled by using conventional techniques like regularized zero-forcing and zero forcing. Though, leakage based downlink precoding can show robustness against interference among multiple antennas at the destination. In this design, interference due to leakage at the destination side is taken into account for multi-relay downlink precoder design as [14]. The proposed technique reduces interference (leakage) among multiple antennas. In Fig 1 the channel from multiple relay terminals to the destination is represented by notation$\boldsymbol{H}_{rdc}$.

$$\boldsymbol{H}_{rdc} = \lfloor \boldsymbol{H}_1^{H} \boldsymbol{H}_2^{H}, \dots, \boldsymbol{H}_K^{H} \rfloor^{H} \tag{14}$$

The matrix for k relay terminals to the destination for j^{th} antennas is given as;

$$\boldsymbol{H}_{rdc}^{j} = \lfloor \boldsymbol{H}_{k-1}^{H} \boldsymbol{H}_{k+1}^{H}, \dots, \boldsymbol{H}_K^{H} \rfloor^{H} \tag{15}$$

Under the relay power constraints the transmit precoding is designed as;

$$\widehat{\boldsymbol{F}}_k^{j} = \arg \max_{F_k^j \in C^{N_r \times 1}} SLNR_k^{j}\left(\boldsymbol{F}_k^{j}\right)$$

$$\text{s.t } P(r_k) \le PQ_k \tag{16}$$

where, $\boldsymbol{F}_k^{j}$ is the k^{th} relay transmit precoding for j^{th} destination antennas. For multiple relay network the signal to leakage and noise ratio is given as;

$$PASLNR_k^{j} = \frac{\left\| h_{rd}^{j} f_k^{j} \right\|_F^2}{\sum_{\substack{i=1 \\ j \neq k}}^{L} \left\| H_{rd} f_k^{j} \right\|_F^2 + \sum_{\substack{i=1 \\ j \neq k}}^{N_d} \left\| \mathrm{h}_{rd} f_k^{j} \right\|_F^2 + \sigma_d^{j^2}} \tag{17}$$

Equation (17) is the relationship between wanted signal to the leakage and noise power, here,$\boldsymbol{h}_k^{j}$ shows row vector of the j^{th}receive antennas $j = 1, \dots, N_d$, $\sigma_d^{j^2}$ is the destination noise variance, i.e $\sigma_d^{j^2} = \sigma_1^{j^2}, \ldots, \sigma_d^{j^2}$ and $f_k^j = f_1, \ldots, f_{N_d}$ is vector wise k^{th} relay transmit precoding for j^{th} antenna elements is generated as;

$$\boldsymbol{f}_k^j = \arg \max_{\boldsymbol{F}_k^j \in \mathbb{C}^{N_r \times 1}} \frac{\boldsymbol{f}_k^{j^H} (\boldsymbol{h}_k^{j^H} \boldsymbol{h}_{rd}^j) \boldsymbol{f}_k^j}{\boldsymbol{f}_k^{j^H} (\boldsymbol{H}_{rd}^{j^H} \boldsymbol{H}_{rd}^j + \sigma_{rk}^{j^2} \boldsymbol{I}_{N_r}) \boldsymbol{f}_k^j} \quad (18)$$

$$\boldsymbol{F}_k^j = [\boldsymbol{f}^1, \ldots, \boldsymbol{f}^{N_d}].$$

Here, $\boldsymbol{F}_k^j$ is the k^{th} relay transmit precoding matrix for j^{th} receive antennas at the destination that helps to maximize the SLNR. After multiplying relay receive beamforming matrix (13) with (18) we get;

$$\boldsymbol{F} = \boldsymbol{F}_k^j \times \boldsymbol{H}_{sk}^H \quad (19)$$

The optimization problem in (18) for k relays transmit beamforming mapped to Fukunaga Koontz Transform as follows;

$$\hat{T}_1 = h_k^{l^H} h_k^l \quad (20)$$

$$\hat{T}_2 = \boldsymbol{H}_{rdc}^H H_{rdc} + \sigma_d^2 I_{N_d} \quad (21)$$

Now,

$$T = \hat{T}_1 + \hat{T}_2 = \boldsymbol{H}_{rdc}^H \boldsymbol{H}_{rdc} + \sigma_d^2 I_{N_d} \quad (22)$$

Then signal received at destination is given by;

$$\boldsymbol{y}_d = \sum_{\substack{j=1 \\ k \neq j}}^{N_d} \rho \boldsymbol{H}_{rd} \boldsymbol{F} \boldsymbol{H}_{sk} \boldsymbol{s} + \sum_{\substack{j=1 \\ k \neq j}}^{N_d} \boldsymbol{H}_{rd} \boldsymbol{F} \boldsymbol{s}_i + \boldsymbol{H}_{rd} \boldsymbol{F} \boldsymbol{n}_k + \boldsymbol{n}_d \quad (23)$$

In (23) $\boldsymbol{G}_{sd} = \rho \boldsymbol{H}_{rd} \boldsymbol{F} \boldsymbol{H}_{sk}$ is an equivalent channel, whereas $\boldsymbol{I} = \boldsymbol{G} \boldsymbol{F} \boldsymbol{s}_i$ is the interference of the leakage signal and $\boldsymbol{n} = \boldsymbol{H}_{rd} \boldsymbol{F} \boldsymbol{n}_k + \boldsymbol{n}_d$ is the destination equivalent noise. The notation $\boldsymbol{s}_i$ symbolizes the interference signal. The QR decomposition operation of channel $\boldsymbol{G}_{sd}$ gives $\boldsymbol{Q}$ and $\boldsymbol{R}$the unitary and upper right triangular matrix. The receiver filter using QRD [9]is given as;

$$\boldsymbol{W} = (\boldsymbol{Q}_{sd})^H \quad (24)$$

The effective SINR in terms of power of relay beamforming is given by;

$$SINR = \frac{\left(\frac{P_s}{N_d}\right) r_{j,j}^2}{\left\| (\rho (\boldsymbol{Q}_{sd})^H \boldsymbol{H}_{rd} \boldsymbol{F})_j \right\|^2 \sigma_k^{l^2} + \sigma_d^{j^2}} \quad (25)$$

In in above equation $r_{j,j}^2$ are j^{th} entries of $\boldsymbol{R}$. The ergodic capacity for multi-relay network is given as;

$$C_{erg} = E_{\{H_{sk}, H_{rd}\}} \left\{ \frac{1}{2} \sum_{\substack{j=1 \\ k \neq j}}^{N_d} \log_2 (1 + SINR) \right\} \quad (26)$$

V.RESULTS AND DISCUSSION

The simulation is conceded out for corroborating the performance supremacy of the proposed relay precoding approaches. The ergodic capacities of proposed relay processing scheme MF-PASLNR-Max with the scheme MF-RZF proposed in [9], MF-ZF and ZF-ZF. The mode of transmission is supposed as half duplex for AF relay protocol in dual-hop MIMO multi relay network system. The capacity upper bound set in [6] is taken as baseline. All relay processing designs are assessed under the condition of many factors. The equal power P_s is assumed from source to the all relay nodes. The entries of all links are flat fading and H_{sk} and H_{rd} are i.i.d with complex Gaussian. The same power constraint is considered for all the cascaded relay terminals. The both channel knowledge is assumed as perfect. The outcome of the projectedarrangement is compared with the available traditional relay processing schemes.

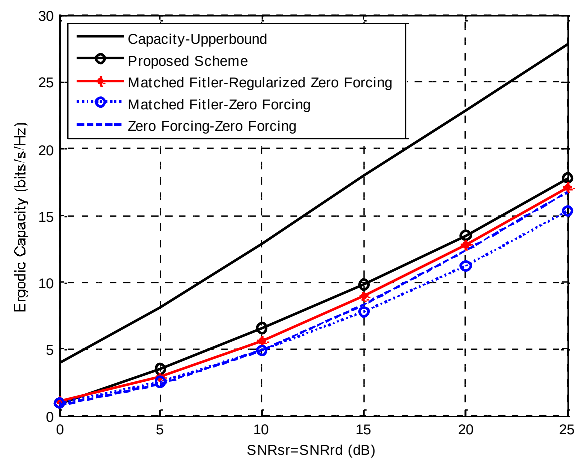

Fig. 2: Performance of the beamforming schemes in b/s/Hz versus SNR ranges (0-25 dB)

The graphs in Figure 2 represent performance comparisons of the proposed technique with other conventional scheme for AF relay in multi-relay network scenario. The performance is obtained at under system configuration $N_s = N_r = N_d = 3$antennas and the number of relay terminals=3.

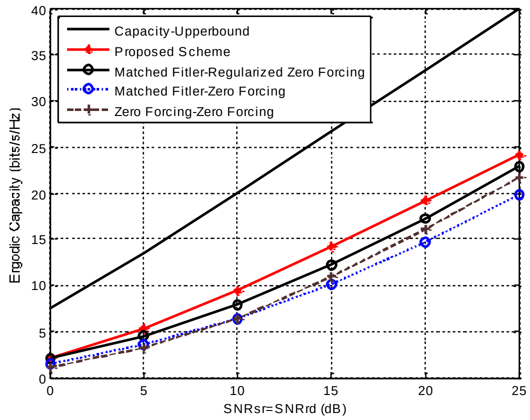

Fig. 3.Performance of the beamforming schemes in b/s/Hz versus SNR ranges (0-25 dB).

The graphs represent performance comparisons of the proposed technique with other conventional scheme for AF relay terminals. The performance is obtained under system configuration of $N_s = N_r = N_d =$ 4antennasand the relay terminals=5.

The result of MF-PASLNR-Max using FKT is shown in Fig.2 and Fig.3. The capacity of the newly designed relaying strategy approximately grows linearly with SNR values and outperforms other schemes. The Fig.3 shows the outcome of the proposed design with the increased quantity of antennas at each node of the network that is 4 antennas at each node of the network including each relay.

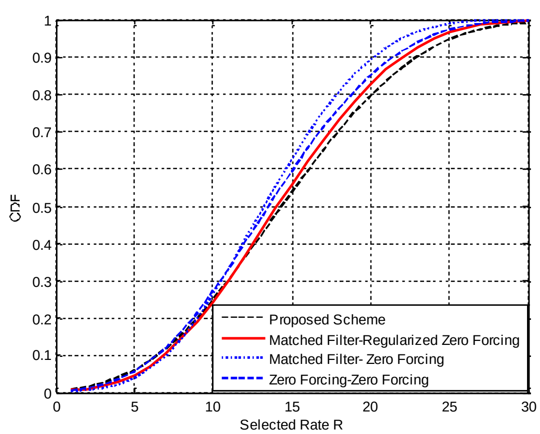

Fig.4. Outage capacity comparison of the proposed relay processing technique other available techniques, the system is configured with 3 antennas at each terminal and 5 relay are connected in parallel in dual-hop MIMO system

Figure 4, compares the outage capacity enactment of the proposed relay linear processing for multi-relay MIMO system. The outage performance of the proposed MF-PASLNR-FKT technique is compared with the MF-RZF, MF-ZF and ZF-ZF. The proposed technique out performs the other available conventional relay processing techniques

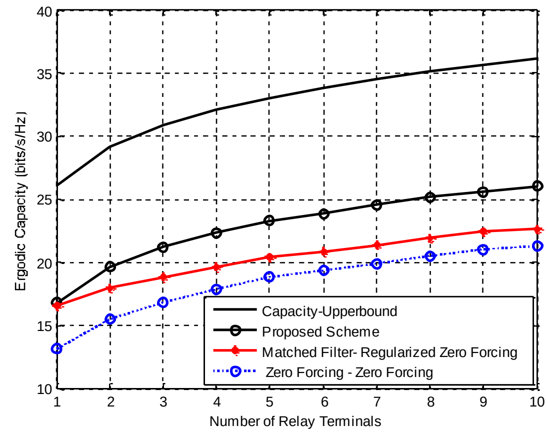

Fig.5. Maximum ergodic capacity versus number of AF relay terminal with configuration of 3 antennas at each terminal and SNR= 40 dB.

The ergodic capacity is to be examined with various relay precoding schemes and presented in Fig.5 that shows that, an apparent variation in the capacity with the increasing number of relay terminals in the two-hop network, with 3 antennas at each terminal, SNR=40 dB and K=1-10 relay terminals. Note that, the proposed relay processing scheme out performs the other conventional schemes for AF relay terminals at every number of the relay terminal from 1 to 10.

The simulation reveals that, by considering the criterion for amplify-and-forward relay processing using matched filter and SLNR criterion at the multiple relay terminals, the SNR is maximized at the relay terminals by controlling the noise, whereas due to leakage control at the relays downlink SLNR is maximized. Increasing relay terminal in parallel the system performance is improved that results and multiple antennas at each node increase the capacity.

CONCLUSION

A new beamforming scheme based on MF and SLNR techniques is developed for multiple MIMO AF relay terminals in two-hop MIMO network. The network design delivers both the intra node and distributed array gains contributed by the multiple antennas and multiple relay terminals. Simulation results obtained under various network parameters validate that the projectedsystem outperforms the conventional relay beamforming techniques in terms of ergodic capacity. The above mentioned results and discussion concludes that the proposed technique is more efficient technique.

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