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On the Capacity of MIMO-MAC in Rician Channel

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A R T I C L E I N F O

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A B S T R A C T

The information theoretic limits for the single user MIMO ($N_t \times N_r$) communication channel are well established in literature for different scenarios of channel types and channel state information (CSI) availability. However, all obtained results in previous works are based on the linear system model in which the channel transfer function is defined as a single entity in which all environmental effects are captured. This paper proposes a modified scheme for MIMO-MAC in Rician channel to achieve better capacity gain with minimal interference. The capacity gain in MIMO over SISO systems is acquired by exploring the diversity in the channel transfer function. Our proposed scheme explores the geographical location of the MIMO system nodes independently that have a great influence on the overall system capacity. This is done by decomposing the channel transfer function into its equivalent transfer function in which the effect of the signal bearing information (Angle of Arrival (AoA)) is separated from the original channel. The comparison between conventional MIMO-MAC capacity in Rician channel and for the proposed partial zero-forcing scheme that depends on orthogonality condition are executed. Moreover, all previous work depends on studied the capacity of MIMO single user with Rician fading channel, but in our work, the multi-user (MAC) MIMO channel is used. The experimental results demonstrate that the proposed scheme gives better capacity of the single user MIMO channel scales linearly with min $\{N_r^2, N_t^2\}$ as opposed to min $\{N_r, N_t\}$ if the channel is considered as a single transfer function through exploring the geographical location of the system nodes. The results also show the effect of orthogonality between the users in decreasing the interference. Besides, the proposed scheme holds for both deterministic, Rayleigh and Rician fading channels. The effect of the (AoD) and (AoA) from all transmitting to all receiving antennas are considered to contribute in enhance the capacity of MIMO-MAC in Rician Channel.

1.INTRODUCTION

The information theoretic limits for the capacity of MIMO channel is well established in literature for all different scenarios of the channel matrix. The capacity of MIMO single user with Rician fading channel has been studied in [1]. Emre Telatar [2] has established the capacity of such system in case of deterministic random and random but fixed once chosen channel matrices. For the random case, the Rayleigh fading channel is considered. All capacity results obtained in [1] converge to those obtained in [2] as the Rician k factor goes to 0. That is because the Rayleigh fading channel can be considered as a limiting case to the Rician fading channel. For completeness, the main results therein are included in the next two sections.

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In [1], In case of the knowledge of the distribution under Rician fading process for Tx but the instantaneous CSI was not considered. While the specific channel capacity with this assumption is still not known up to date, the upper bound for the channel capacity is derived using Jensen's inequality. In fact, a significant gap in the capacity between the Rician MIMO channel with or without CSI at Tx. Thus, in case of where the Rician factor (k) only available at Tx was considered, a new signaling scheme was depended on Rician factor (k). As $k\rightarrow \infty$, the proposed signaling scheme tends to

contribution of other researchers to the beamforming that is optimal for AWGN channel. But, as $k \rightarrow 0$, the EPA tends to optimal solution for the Rayleigh fading case. Although, the signaling scheme in [1] was not derived as a solution to the capacity optimization problem given the Rician factor (k), the substantial capacity gain motivates the researchers to invest the knowledge of other parameters to establish the channel Rician-ness. Therefore, this algorithm concludes that the perfect CSI at the Tx is considered the best solution. Although the partial side of CSI may goal to substantial reduction in the gap to capacity.

In this paper, the proposed algorithm supposes that the only information available at the transmitter due to the MIMO channel with Rician fading is the Rician factor (k) and the (θt) and (θr) from all transmitting to all receiving antennas. These parameters are enough to build the gain of MIMO channel capacity with mean feedback [3]. The advantages of this fact are as follows: (1) the required feedback rate for these parameters with mean feedback is smaller than feedback rate for full mean channel matrix. (2) the rate change of these parameters is smaller than that of complete channel realizations. So, we conclude that this feedback model resolves both delay and rate requirement for the feedback link.

In this paper, the extension of the nature of the feedback model in [4] will be studied to extend to multi- user settings. In multiple access channel (MAC), the amount of CSI available about network users is determined by the optimizing signaling strategy. When the number of users increase, acquiring CSI of all users becomes more costly. Thus, the extension of this work to MIMO-MAC is our goal in this paper .

In [1,5,7,8,9], the Rician fading channels for point-to-point MIMO communication system are considered whether CSI is available at transmitter and receiver or CSI is not available at the transmitter. These techniques are used the very special case: an all matrix (1) happens for a perfectly aligned transmitter and receiver so that θt =θr=0.

But, in this paper, the effect of orthogonality between the users is contributed to decrease the interference. The comparison between the conventional MIMO-MAC capacity in Rician channel and the proposed partial zero-forcing scheme depends on orthogonality condition will execute. The rest of the paper is organized as follows: Section 2 discusses the model of the general system and MIMO channel with Rician fading model. The MIMO-MAC field is covered in Section 3. Section 4 presents the capacity of MIMO-MAC Ricean channel. The proposed scheme for location aware MIMO-MAC Ricean channel is presented in Section 5. Section 6 discusses the simulation results. Section 7 concludes the paper.

2.SYSTEM AND CHANNEL MODEL

As depicted in figure (1), the single user MIMO scenario is considered for a transmitter equipped with uniform linear array antenna (ULA) of size N_t that is communicated to a receiver with ULA of size N_r .

Fig. 1. MIMO System Model

2.1. Model of the System

The received signal (Y) can be expressed as follows:

$$Y = HX + n \tag{1}$$

where, $X \in C^{Nt\times1}$ is the transmitted signal which follows a total power constraint

$$E[x^{\dagger}x] \leq P \tag{2}$$

or equivalently

$$tr\,(E[XX^{\dagger}]) \leq P \tag{3}$$

where tr(.) denotes the matrix trace operator and $(.)^{\dagger}$ denotes the Hermetian transpose. $n \in C^{Nr\ \times1}$, is an independent zero mean circular symmetric complex random vector, $n \sim CN(0,R_n)$ where $R_n = \sigma_n^2 I_{Nr}$. While, $H \in C^{Nr\times Nt}$, is the channel coefficients matrix.

2.2. MIMO Channel with Rician Fading Model

The channel coefficients are assumed to be Gaussian with independent real and imaginary parts, each distributed as N $(\mu/\sqrt{2}, \sigma^2)$in [3]. Therefore, the entries of the channel matrix $h_{ij} \sim CN(\frac{\mu}{\sqrt{2}}(1+j), 2\sigma^2)$. The magnitude $|h_{ij}|$ will have the following Rician distribution:

$$f|h_{ij}|\,(|h_{ij}|) = 2\,(1+k)\,|h_{ij}|\, e^{-(1+k)\,|hij|2 - k}$$

$$\times I_0(2\sqrt{k(1+k)}|h_{ij}|) \quad (4)$$

where k is the Rician factor that is defined as

$$k = \frac{|\mu|2}{2\sigma 2}$$

The normalization $|\mu^2| + 2\sigma^2 = 1$ is considered for more convenient notation. The phase ∠hij is uniformly distributed in the interval $[-\pi, \pi]$. With the entries of the channel matrix, H, distributed as described above, we have:

$H \sim CN(M, I_{Nt} \otimes \Sigma)$. Where $E[H]=\sqrt{\mu}/(1+j)\,\Psi_{Nr\times Nt}$ with $\Psi_{Nr\times Nt}$ is $N_r \times N_t$ all one matrix. And $\Sigma = 2\sigma\, I_{Nr}$ is the Hermitian covariance matrix of the columns.

3.RELATED WORK

The capacity results of the considered MIMO system have been well established in [1] with a proof of consistency with the results obtained in [2] for the Rayleigh fading case. For completeness, the major results therein are quoted for its relevance with our subsequent analysis.

In [2], it was shown that the capacity of the considered MIMO system for the limiting case k = 0 is achieved when the input, X, has a circularly symmetric complex Gaussian distribution with zero-mean and covariance $Q = E[XX^{\dagger}]\frac{P}{Nt} I_{Nt}$ and is given by:

$$\mathbf{C}_{N_t,N_r}^{k=0} = \mathbb{E}\left[\log_2 \det\left(I_{Nr} + \frac{\boldsymbol{P}}{N_t}\mathbf{H}\mathbf{H}^{\dagger}\right)\right] \quad (5)$$

However, in its general expression, the capacity for a general value of k is given by

$$\mathbf{C}_{N_t,N_r}^{k} = \max_{tr(\boldsymbol{Q})\le \mathbf{P}} \mathbb{E}_{\mathrm{H}}\left[\log_2 \det\left(I_{N_r} + \mathbf{HQH}^{\dagger}\right)\right]$$

$$= \max_{tr(\boldsymbol{Q})\le \mathbf{P}} \mathbb{E}_{\mathrm{H}}\left[\log_2 \det\left(\mathbf{QH}^{\dagger}\mathbf{H} + I_{N_t}\right)\right] \quad (6)$$

Where the second equality follows from matrix determinant properties. We evaluate

$$\mathbb{E}[\mathbf{H}^{\dagger}\mathbf{H}] = N_r\mathbf{Y} \quad (7)$$

where Y is $N_t \times N_t$ matrix and is given by:

$$\mathbf{Y} = \frac{1}{1+k}\begin{bmatrix} 1+k & k & \cdots & k \\ k & 1+k & \cdots & k \\ \vdots & \vdots & \ddots & \vdots \\ k & k & \cdots & 1+k \end{bmatrix} \quad (8)$$

For any value of $0 \le k < \infty$, Y is non-singular, thus all it's eigenvalue are non-zero. The N eigenvalues of Y are given by [1] :

$$\lambda_i = \begin{cases} \frac{1+N_t k}{1+k} & \text{if } i = 1 \\ \frac{1}{1+k} & \text{if } 1 < i \le N_t \end{cases} \qquad 0 \le k < \infty \quad (9)$$

The eigenvalue decomposition is applied to get $Y = UGU^{\dagger}$ where $G \in C^{Nt\times Nt}$ is a diagonal matrix which has the eigen- values in (9) as its diagonal entries, and $U \in C^{Nt\times Nt}$ is a unitary matrix consisted of the eigenvectors of Y. Define $\tilde{Q} = U^{\dagger}QU$, we get the following alternative expression for (10)

$$\mathbf{C}_{N_t,N_r}^{k} = \max_{tr(\boldsymbol{Q})\le \mathbf{P}} \mathbb{E}_{\mathrm{H}}\left[\log_2 \det\left(N_r\tilde{\mathbf{Q}}\mathbf{G} + I_{N_t}\right)\right] \quad (10)$$

The above expression is maximized for the choice of $\tilde{Q}$ to be diagonal. The solution of the diagonal entries $\tilde{Q}$ was given in [1] by the water filling algorithm as follows:

$$\tilde{\boldsymbol{Q}}^{i,i} = \begin{cases} min\left\{\frac{\mathbf{P}}{N_t}, \frac{k(1+k)}{N_r(1+N_t k)}\right\}N_t + \left[\frac{\mathbf{P}}{N_t} - \frac{k(1+k)}{N_r(1+N_t k)}\right]^+ & \text{if} \\ \left[\frac{\mathbf{P}}{N_t} - \frac{k(1+k)}{N_r(1+N_t k)}\right]^+ & \text{if } .1 < i \le N_t \end{cases} \quad (11)$$

Where $0 \le k < \infty$ and $[x]^+ = \max\{0,x\}$. One could conclude that, the optimal transmit strategy for the Rician fading channel suggests that, for the large k values the transmitter will allocate all it's power to only the first antenna element while sending nothing on all other antenna element. This means that the channel matrix became degenerate (of rank 1) and has lost all its degrees of freedom. This yields a MIMO channel that can provide only a power gain rather than a diversity gain. It can be seen that this will happen for

$$\frac{k(1+k)}{N_r(1+N_t k)} \ge \frac{\mathbf{P}}{N_t} \quad (12)$$

By simple manipulation, the Ricean channel degeneracy condition in terms of its k factor is given by

$$k_d \geq \frac{(PN_r-1)+\sqrt{(PN_r-1)^2-(4PN_r/N_t)}}{2} \quad (13)$$

where K_d is the Ricean channel degeneracy threshold, i.e., for any $k \geq K$, the Ricean channel is degenerated.

In case of Ricean channel described above, the received signal consists of two components; First from the line of sight (LOS) and the second is from multipath reflections, or generally the non-line of sight component (NLOS). The LOS component is fixed while the (NLOS) component is the Rayleigh fading channel. Hence the channel matrix can be described as follows:

$$\mathbf{H} = \mathbf{H}_{los.} + \mathbf{H}_{nlos.} \quad (14)$$

Where

$$\mathbf{H}_{los.} = \sqrt{\frac{k}{1+k}}\left(\frac{1}{\sqrt{2}}+\frac{i}{\sqrt{2}}\right)\widehat{\mathbf{\Psi}}$$

$$\widehat{\mathbf{\Psi}} = \mathrm{a}(\theta_r)a^{\dagger}(\theta_t)$$

$$\mathbf{H}_{nlos} = \sqrt{\frac{1}{2(1+k)}}\,\widehat{\mathrm{H}} \quad (15)$$

where $a(\theta_r)$ and $a(\theta_t)$ are the antenna array steering vectors at receiver and transmitter respectively. θ_r and θt are the angle of arrival (AoA) and the angle of departure (AoD) of the transmitted signal. Without loss of generality,a uniform linear array (ULA) antenna configuration at both transmitter and receiver in [5] will be considered. However, our results can be generalized to any other array configuration. For the ULA, the inputs of the steering vectors are given by

$$\mathrm{a}(\theta_i) = \left[1 \;\; e^{-j2\pi\frac{d_r \sin(\theta_i)}{\lambda}} \;\; \ldots \;\; e^{-j2\pi(N-1)\frac{d_r \sin(\theta_i)}{\lambda}}\right]^T \quad (16)$$

where d_r, λ and N are the receiver array element spacing, the wavelength of the center frequency of the transmitted signal and the array size respectively. While $\hat{H} \sim CN(0, I_{Nt \times Nr})$ represents the coefficients matrix of the channel for the NLOS signal component. We have introduced $\sigma = \sqrt{1/2\,(1+k)}$, $\mu = \sqrt{k/1+k}$, and notice that the normalization $|\mu^2| + 2\sigma^2 = 1$ still holds.

The major difference between the channel described in [1] and the one described here is that in [1], the Riciean component is assumed to have the same value from all transmitting to all receiving antennas. It doesn't exploit the effect of the AoD and AoA. Hence, this model can be considered as the very special case when $\hat{\Psi}$ become an all1matrix which happens for a perfectly aligned transmitter and receiver so that $\theta t = \theta r = 0$.

4.CAPACITY OF MIMO-MAC RICEAN CHANNEL

As depicted in figure (2), the MIMO Multiple Access (MAC) scenario with N_r users is considered, each is equipped with N_t antennas with a total transmitting antennas of N_rN_t communicating to a receiver with N_r antennas. Each user channel is modeled as a Ricean channel as described in the previous section. The received signal from all users, Y, in such case can be expressed as follows:

$$\mathrm{Y} = \sum_{i=1}^{N_r} H_i X_i + n \quad (17)$$

where, H_i is the i^{th} user Ricean channel. The sum rate capacity expression of such channel is given by

$$\mathbf{C}_{sum} = \max_{\substack{tr(Q_i)\leq P_i \\ 1\leq i\leq N_r}} \mathbb{E}_{\mathrm{H}_1,\ldots,\mathrm{H}_{N_r}}\left[\log_2 \det\left(I_{N_r} + \sum_{i=1}^{N_r} \boldsymbol{H_i Q_i H_i}^{\dagger}\right)\right] \quad (18)$$

where $Q_i = \mathbb{E}\left[\boldsymbol{X_i X_i^{\dagger}}\right]$ is the covariance matrix of the i^{th} users. With no channel knowledge at the transmitter, the optimum transmit policy is the uniform one for which $Q_i = \frac{P_i}{N_t}\mathbf{I}_{N_t}$ in [6]. Without loss of generality, we assume equal power budget at all users, i.e., $P_i = P$, $\forall i \in \{1, 2, .., N_r\}$. In such case, the sum rate capacity upper bound can be given by:

$$\mathbf{C}_{sum} = \mathbb{E}_{\mathrm{H}_1,\ldots,\mathrm{H}_{N_r}}\left[\log_2 \det\left(I_{N_r} + \frac{P}{N_t}\sum_{i=1}^{N_r} \boldsymbol{H_i H_i}^{\dagger}\right)\right] \quad (19)$$

When all user channels have the same distribution that based on the discussion given in section II, one can evaluate the sum rate capacity upper bound as follows:

$$\mathbf{C}_{sum} = \log_2\left(1 + \frac{PN_r^2(1+N_t k)}{N_t(1+k)}\right) + (n-1)\log_2\left(1 + \frac{PN_r^2}{N_t(1+k)}\right) \quad (20)$$

where $n = \min\{N_t, N_r\}$.

5.LOCATION AWARE MIMO-MAC RICEAN CHANNEL (PROPOSED SCHEME)

In this section, the notion of geographic location aware MIMO-MAC channel is proposed in which the geographic location of transmitting entities is explored. Our proposed scheme considers the same system settings provided in section III with the sole difference that the user channels, $H_i : \forall i \in \{1,2,..,N_r\}$, are decomposed into a deterministic line of sight component plus a scattering component so that the transmitter's location effect is explored according to (14) and (15) as follows:

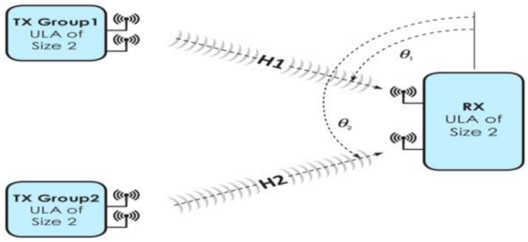

Fig. 2. MIMO System Equivalent.

$$\mathrm{H}_i = \sqrt{\frac{k}{1+k}}\left(\frac{1}{\sqrt{2}}+\frac{i}{\sqrt{2}}\right)\mathrm{a}(\theta_{r_i})a^{\dagger}(\theta_{t_i})+\sqrt{\frac{1}{2(1+k)}}\widehat{\mathbf{H}}_i \quad (21)$$

$a(\theta_{ri})$ and $a(\theta_{ti})$ are the steering vectors corresponds to the (AoA) and (AoD) of the signal of the ith user antenna array which are defined as in (16). Without loss of generality, we will assume ULA antenna configuration at all communication nodes. For any other array configuration, our results still apply with a straightforward manipulation. Each transmitter is located in a different geographic location such that their respective transmission departs the i^{th} transmitter at an AoD θ_{ti} and appears at the receiver at a different AoA which are assumed to be known by the receiver, θ_{ri} , $1 \leq i \leq N_r$.

It is noted that all possible antenna steering vectors are unit vectors which lies in the unit ball in CN_r. Each steering vector of dimension N_r partitions the unit ball into groups of N_r orthogonal vectors. Hence, the geographic location of the users can be chosen such that the corresponding steering vectors at the receiver are orthogonal. The choice of the transmitter location seems to be irrelevant assumption for a mobile network. However, in the design of MIMO microwave links, there is a flexibility in choosing transmitter locations to some extent. Also, in a mobile network with large number of users, by estimating AoA of user's transmission, the receiver will be able to partition the users into groups of N_r clusters where users belongs to each group satisfies the above orthogonality condition.

By the knowledge of θ, $1 \leq i \leq N_r$, the receiver can easily separate the LOS component of each individual user signal. When decoding each individual user signal, the LOS component of all other $N_r - 1$ users can be completely suppressed, while the scatters of each user still a significant source of inter-user interference. However, for a large value of the Rician k factor, most of the signal energy is contained in the LOS component which leaves the scattering component as a weak source of interference. In such case, spatial multiplexing of the N_r users is possible and the channel is said to provide an additional Nr degrees of freedom. However, as seen in the previous section, as k exceeds K_d in (13), each user channel turned into a degenerate one which provides only one degree of freedom. Hence, the overall degrees of freedom provided is again N_r. One important question is, the k value that induces a weak inter-user interference is the same as the one which will cause individual user channel degeneracy. Hence, a trade-off arise between obtaining a higher signal to interference and noise ratio (SINR) and acquiring more degrees of freedom. It is noted that the overall system capacity increases linearly with the degrees of freedom while logarithmically with the SINR. With the proposed location aware MIMO-MAC scheme, the i^{th} user component of the received signal is given by

$$Y_i = \mathbf{A}(\theta_{r_i})\mathbf{Y}$$

$$= \mathrm{H}_i\mathbf{X}_i + \sum_{\substack{j=1\\ j\neq i}}^{N_r}\boldsymbol{A}(\theta_{r_i})\boldsymbol{H}_{Rayl.(j)}X_j + \boldsymbol{n}_i \quad (22)$$

Where A(θ) is the θ direction subspace defined as follows:

$$\mathrm{A}(\theta_{r_i}) = \mathrm{a}(\theta_{r_i})\left(\mathrm{a}^{\dagger}(\theta_{r_i})\mathrm{a}(\theta_{r_i})\right)^{-1}\mathrm{a}^{\dagger}(\theta_{r_i}) \quad (23)$$

with the orthogonality condition, A(θ) satisfies:

$$\mathrm{A}(\theta_{r_i})\mathrm{a}(\theta_{r_j}) = \begin{cases} \mathrm{a}(\theta_{r_j}) & \text{if } i=j \\ 0_{N_r \mathrm{x} N_r} & \text{if } 1 < i \leq N_t \end{cases} \quad (24)$$

$\boldsymbol{H}_{nlos.(j)}$ is the Rayleigh scattering part of the jth user channel as given in (15) and $n_i = A(\theta_{ri})$ is the noise component along the θri direction subspace.

We define

$$\boldsymbol{R}_{n_i n_i} = I_{N_r} + \mathrm{A}(\theta_{r_i})\sum_{\substack{j=1\\ j\neq i}}^{N_r}\mathbf{H}_{nlos.(j)}\mathbf{Q}_j\mathbf{H}_{nlos.(j)}^{\dagger} \quad (25)$$

to be the covariance matrix of the interference plus noise for the ith user where it is used the fact that

$$\mathrm{A}(\theta_{r_i})\mathrm{A}^{\dagger}(\theta_{r_i}) = \mathrm{A}(\theta_{r_i}) \qquad (26)$$

While the orthogonality condition governs the zero forcing for the LOS components of other users, it is seen that the scattering component of other users remains as a source of inter-user interference. The inter-user interference term will cause degradation in the SINR per user for small values of the Ricean k factor. However, for a large values of the k factor, the effect of interference is insignificant as the big portion of each user power is contained in the LOS component which have been already zero forced. So, the interference is decreased in this case.

5.1. Evaluation of the Interference Term

For the sake of the evaluation of maximum achievable rate by each user under the proposed scheme, evaluating the interfer- ence term (25) is crucial. It is noted that, we assume neither channel nor interference knowledge at each transmitter. With that assumption in mind, one can evaluate the interference term as follows

$$\mathbf{R}_{n_i n_i} = \mathbb{E}_{\substack{\mathbf{H}_{Rayl.(j)} \\ j\neq i}}\left[I_{N_r} + \mathbf{A}(\theta_{r_i}) \sum_{\substack{j=1 \\ j\neq i}}^{N_r} \mathbf{H}_{Rayl.(j)} \mathbf{Q}_j \mathbf{H}^{\dagger}_{Rayl.(j)} \right] \qquad (27)$$

Using the same convention used in the previous section, the above expectation can be evaluated as

$$\mathbf{R}_{n_i n_i} = \mathbb{E}_{\substack{\mathbf{H}_{nlos.(j)} \\ j\neq i}}\left[I_{N_r} + \mathbf{A}(\theta_{r_i}) \sum_{\substack{j=1 \\ j\neq i}}^{N_r} \frac{\mathbf{P}_j}{N_t} \mathbf{H}_{nlos.(j)} \mathbf{H}^{\dagger}_{nlos.(j)} \right]$$

$$= \mathbf{I}_{N_r} + \mathbf{A}(\theta_{r_i}) \frac{\mathbf{P}(N_r-1)^n}{N_t(1+k)} \mathbf{I}_{N_r} \qquad (28)$$

5.2. Capacity Evaluation

Based on the signal model for the ith user component of the received signal, one can evaluate the maximum achievable rate of the i_{th} user as follows:

$$\mathbf{C}_i = \max_{\substack{tr(Q_i)\leq \mathrm{P}_i \\ 1\leq i \leq N_r}} \mathbb{E}_{\mathrm{H}_1,\dots,\mathrm{H}_{N_r}}\left[\log_2 \det\left(I_{N_r} + \mathbf{H}_i \mathbf{Q}_i \mathbf{H}_i{}^{\dagger} \mathbf{R}^{-1}_{n_i n_i}\right)\right] \qquad (29)$$

With no channel knowledge at the transmitter, the optimum transmit policy is the uniform one for which

$$Q_i = \frac{\mathrm{P}_i}{N_t} \mathrm{I}_{N_r}$$

Hence, the capacity expression of the i[th] user can be given by

$$\mathbf{C}_i = \mathbb{E}_{\mathrm{H}_1,\dots,\mathrm{H}_{N_r}}\left[\log_2 \det\left(I_{N_r} + \frac{\mathbf{P}_i}{N_t} \mathbf{H}_i \mathbf{H}_i^{\dagger} \mathbf{R}^{-1}_{n_i n_i}\right)\right] \qquad (30)$$

Assuming identical user power budget and channel distribution and using the result obtained in (28),the above expression can be evaluated as

$$\mathbf{C}_i = \log_2\left(1 + \frac{\mathrm{P}N_r(1+N_t k)}{N_t(1+k)+\mathbf{P}_n(N_r-1)}\right) + (n-1)\log_2\left(1 + \frac{\mathrm{P}N_r}{N_t(1+k)+\mathbf{P}_n(N_r-1)}\right) \qquad (31)$$

$$\mathbf{C}_{sum} = \sum_{i=1}^{N_r} \mathbf{C}_i$$

$$= N_r \log_2\left(1 + \frac{\mathrm{P}N_r(1+N_t k)}{N_t(1+k)+\mathbf{P}_n(N_r-1)}\right) + N_r\,(n-1)\log_2\left(1 + \frac{\mathrm{P}N_r}{N_t(1+k)+\mathbf{P}n(N_r-1)}\right) \qquad (32)$$

6.SIMULATION RESULTS AND DISCUSSION

In this section, the computer simulation is used to compare between the sum rate capacity expression found for the conventional MIMO-MAC in Rician channel obtained in (20) and that for the proposed partial zero-forcing scheme obtained in (32). It is noticed that the loss in power gain with a factor:

$$\frac{N_t(1+k)}{N_t(1+k) + \mathbf{P}n(N_r-1)} \qquad (33)$$

Due to the admitted inter-user interference. However, a linear gain of a factor of N_r is introduced by the proposed partial zero-forcing due to spatial multiplexing of users having ($N_t N_r$) antennas. But the major question here is, what is the minimum value of the Rician k factor is required to insure an overall capacity gain. In fact, a direct comparison between the sum rate capacity expressions given in (20) and (32) does not yield an answer to this question in a closed form. However, for a given values for N_t and N_r, it is easy to come up with an answer to this question. In fig. (3), fig (4), and fig (5), the capacity as a function of signal to noise ratio is plotted for k = 0, k = 1, k = 5, k=10, and k=20 values of Rician factor for the constant receive and transmit antennas. It is noticed that the capacity is enhanced as the Rician factor increased. When the receive and transmit antennas are increased, the capacity as a function of SNR is increased for various values of Rician factor k as shown in fig (6), fig (7), and fig (8). It is concluded that the capacity is enhanced when the parameters (k, N_r, N_t) are increased.

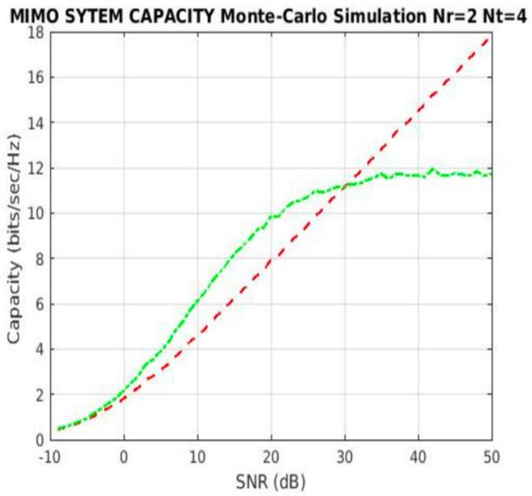

Fig. 3. Capacity Vs. SNR for N_t =4, Nr =2, k=0

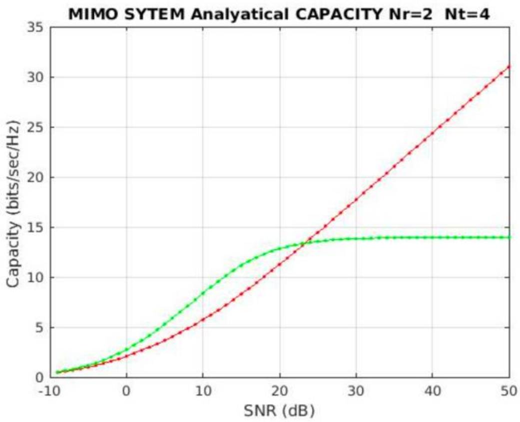

Fig. 4. Capacity Vs. SNR for N_t =4, Nr =2, k=1

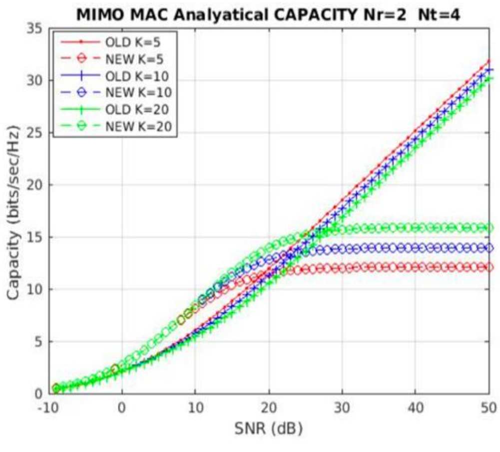

Fig. 5. Capacity Vs. SNR for N_t =4, Nr =2, k=5&10&20

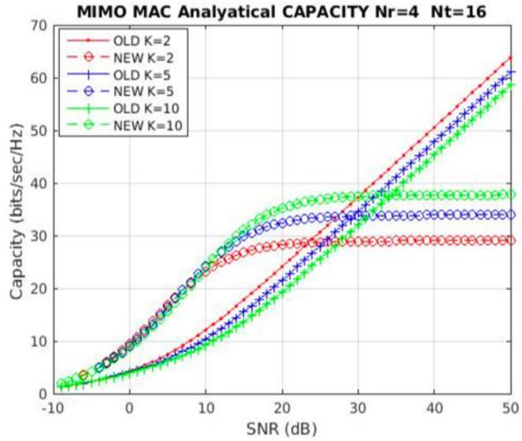

Fig. 6. Capacity Vs. SNR for N_t =16, Nr =4, k=2&5&10

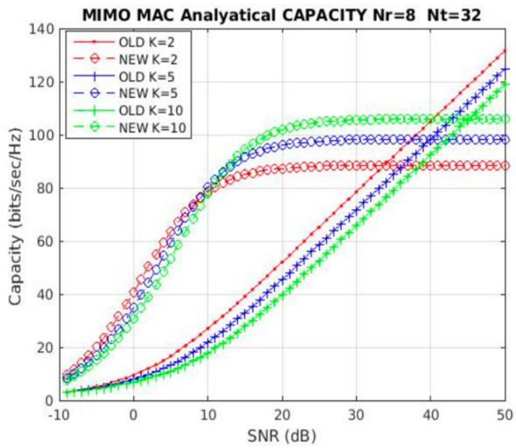

Fig.7. Capacity Vs. SNR for N_t =32, Nr =8, k=2&5&10

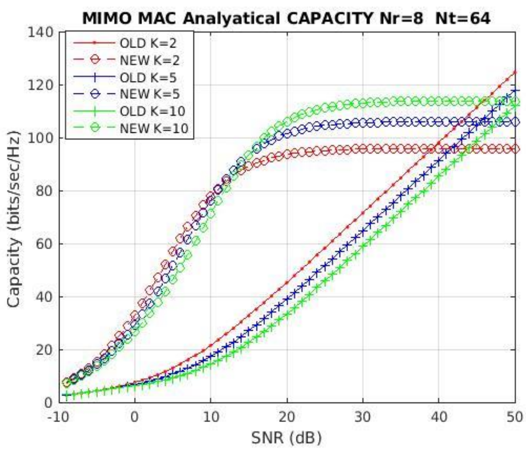

Fig. 8. Capacity Vs. SNR for N_t =64, Nr =8, k=2&5&10

7. CONCLUSION

In this paper, the capacity of Rician fading channel is discussed when the receiver has full CSI and the transmitter has only the Rician factor (k), angle of departure (θt), and angle of arrival (θr). The proposed scheme is showed that (k, θt, θr) are enough to have the advantage of full mean feedback model. Our solution has two advantages. First, it provides result close to optimal over a wide range of parameters (k, SNR, P, ...). Second, it can be used as an initial point for any numerical optimization tools. Therefore, this form of feedback reduces both delay and rate requirement of the feedback link.

The compressed nature of the feedback model is studied in this paper. In multiple access channel (MAC) optimizing signaling strategy is highly dependent on the amount of CSI available about network users. However as the number of users increase, acquiring CSI of all users becomes more costly. Therefore, the extension of this work to MAC an appealing topic from CSI feedback. The effect of orthogonality between the users is contributed to decrease the interference. The comparison between conventional MIMO-MAC capacity in Rician channel and that for the proposed partial zero-forcing scheme depend on orthogonality condition are done.

This work is aimed to enhance the capacity in case of MIMO-MAC in Rician channel due to decrease the latency and data rate of feedback model . Simulation results show that the capacity is enhanced over a wide range of parameters (k , SNR , N_t , N_r). It can be used as initial point for any numerical optimization tool. The required feedback rate for these parameters with mean feedback is smaller than feedback rate for full mean channel matrix. The rate change of these parameters is smaller than that of complete channel realizations. So, this feedback model resolves both delay and rate requirement for the feedback link.

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