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Modelling, Simulation of Multi-User Diversity with Channel State Information in MIMO Systems

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Abstract— In a Multiple Input and Multiple Output (MIMO) transmit antenna system, single antenna per receiver downlink channel with limited channel state information (CSI), we investigate the following: for given a constraint on the overall system-wide feedback load, is it desirable to get low rate channel feedback from a large number of receivers or high-rate/high-quality feedback from a smaller number of receivers. Achieving feedback from many receivers allows multiuser diversity to be exploited, while high-rate feedback concedes for very appropriate selection of beam forming directions. We show that there is a strong preference for obtaining high-quality feedback, and that obtaining near-perfect channel information from as many receivers as possible produces a significantly larger sum rate than collecting a few feedback bits from a large number of users. In terms of system design, this correlates to a preference for acquiring high-quality feedback from a few users on each time-frequency resource block, as opposed to coarse feedback from many users on each block. Simulation results presented by using MATLAB 2013a.

Keywords- MIMO, CSI , SNR &BER

I. INRODUCTION

Modern wireless networks are fastest growing in terms of technology innovations. The advancement in wireless networks requires high speed data rate and spectral efficiency. Current radio technology includes all information services such as data, voice, image and video applications. Multimedia networks like high speed internet and video on demand demands more bandwidth.

MULTI-USER (MUMIMO) communication is very dominant and has recently been the subject of most powerful research topic in the field of wireless communication. A transmitter implemented with *Nt* antennas can serve up to *Nt* users simultaneously over the same time-frequency resource and receiver is equipped with *Nr* antennas, even if each receiver has only a single antenna. Such a model is related to many applications, such as the cellular downlink from base station (BS) to mobiles (users). However, knowledge of the channel formation is required at the BS in order to fully exploit the gains produced by MU-MIMO. In systems design without channel reciprocity, the BS achieves Channel State information (CSI) via channel feedback from mobile users. . In these single antenna per mobile setting, feedback schemes involve each mobile quantizing its *Nt*-dimensional complex channel vector and feeding back the relevant bits approximately every channel coherence time.

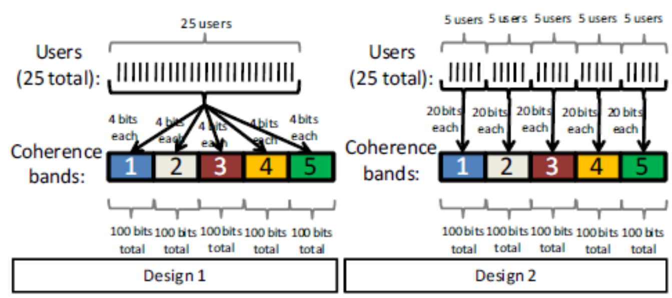


Figure1. Two possible schemes for MIMO Downlink system

From the last decade there has been considerable prior work on the MIMO downlink channel feedback [1]–[12], there is a disagreement between results on systems with a small number of users /receivers (on the order of *Nt*) and systems with many users. The capacity of systems with the number of users on the order of *Nt* has been presented to be extremely sensitive to the efficiency of the CSI, and thus many feedback bits are needed from each user in order to achieve a large sum rate shown in Figure.1. We considered 25 users and five coherence bands. This has been attractive improvement from a fundamental information theoretic perspective [5, 10]; additionally in terms of particular transmit methods. For example, Zero-Forcing (ZF) beam forming has been described to require CSI quality that scales proportional to the SNR in dB [2,16] [3,19]. At the other extreme, it has been shown that systems can require a very large sum rate even with very few feedback bits per user, in the asymptotic limit as the number of users is taken to infinity. For example, Random Beamforming (RBF) requires only log2 *Nt* bits and one real number per user [1].

While there already exists a large body of work focusing on ZF, RBF and Per unitary basis stream user and rate control (PU^2 RC) [12] [6] for the MIMO downlink, we believe that the questions considered in our work have not be addressed before, and are critical with respect to maximizing the sum rate. Prior work has compared ZF and PU2RC assuming a fixed number of per-user feedback bits and users [6], and it are shown that for certain combinations of bits and users, PU2RC outperforms ZF. As we shall see, our findings are quite different because we allow additional flexibility in terms of choosing the per-user feedback rate subject to a constraint on the aggregate feedback load. Comparisons with a fixed per-user feedback rate make sense for wireless standards that are currently being finalized and lack the flexibility to vary.

As per-user feedback, however, we argue that this results in a significant loss in sum rate, and that future standards should certainly consider feedback from an aggregate rather than per user perspective, with per-user feedback chosen optimally. A closely related work is [13], where the tradeoff between multi-user diversity and accurate CSI is studied in the context of two-stage feedback. In the first stage all users feedback coarse estimates of their channel, based on which the transmitter runs a selection algorithm to select *Nt* users who feedback more accurate channel quantization during the second feedback stage, and the split of the feedback budget between the two stages is optimized. Our work differs in that we consider only a *single stage* approach, and more importantly in that we optimize the number of users (randomly selected) who feed back accurate information rather than limiting this number to *Nt*. Indeed, this optimization is precisely why our approach shows such large gains over simple RBF or an optimized ZF.

There has also been related work on systems with *channel-dependent* feedback, in which each user determines whether ornot to feed back on the basis of its current channel condition (i.e., channel norm and quantization error) [6] [7] [14] [15] [16]. As a result, the BS does not *a priori* know who feeds back for each coherence block, and thus there is a random access component to the feedback. Channel-dependent feedback intuitively appears to provide an advantage because only users with good channels feedback. Although some of this prior work has considered aggregate feedback load c.f., [17]), that work has not considered optimization of *B*, the per-user feedback load, as we do here for channel independent feedback. We are currently investigating the pursuer optimization for channel-dependent feedback and our preliminary results actually reinforce the basic conclusions of the present work. However, this is beyond the scope of this paper and we consider only channel-independent feedback here (meaning the users who do feedback are arbitrary.

The paper is organized as follows .Section II gives proposed model of MIMO downlink system. An overview of the related work for multi user diversity with CSI in section III. Brief description of Zero forcing beamforming, Random beam forming and PU^{2}RC techniques in section IV optimization of Zero forcing beam forming section V employs optimization of PU^{2}RC , comparison of Simulation results of multi-user beam forming observed in section VI. Finally conclusion is in section VII.

II. SYSTEM MODEL & BACKGROUND

We consider a MIMO Gaussian downlink channel in which the Base Station (BS) has *Nt* antennas and each of the users or User Terminals (UT) has 1 antenna each (Figure 2). The MIMO channel output *yk* at user *k* is given by

$$Y_{k}=hk+N_{k}, \quad k=1,\ldots,K \qquad (1)$$

Where *Nk* □ *CN* (0*,* 1) models Additive White Gaussian Noise

(AWGN), **h***k* □ C*Nt* is the vector of channel coefficients from the *k*th user antenna to the transmitter antenna array and **x** is the input vector of channel input symbols transmitted by the BS.

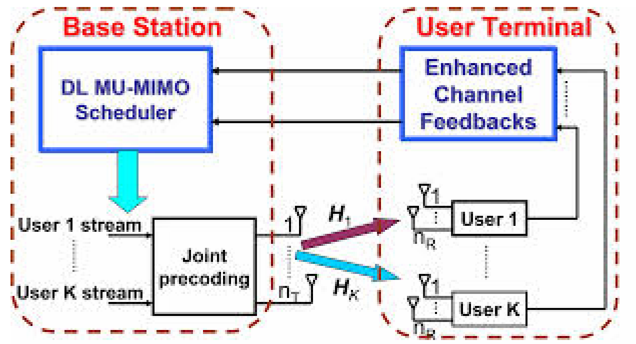


Figure2. Feedback of channel state information in MIMO downlink system

The channel input is subject to an average power constraint E ||x||2 ≤ SNR We assume that the channel state, given by the collection of all channel vectors, varies in time according to a Rayleigh-fading model, where the channels are Stationary within a block but vary independently from block to another block. The entries of each channel vector are i.i.d. Gaussian with elements □ *CN* (0*,* 1). Each user is analyzed to know its own channel perfectly. At the beginning of each block, each user quantizes its channel to *B* bits and feeds back the bits, in an error- and delay-free manner, to the BS shown in Fig.2. Vector quantization is performed using a codebook *C* that consists of 2*B Nt* dimensional complex unit norm vectors *C* = *{*w1. . . w2B*}*. Each user quantizes its channel vector to the quantization vector that produces the minimum angle to it. Thus, user *k* quantizes its channel to **h***k* and feeds the *B*-bit index back to the transmitter, where **h***k* is chosen according to:

$$\hat{h}_k = \arg\min_{w \in c} \sin^2\left(\angle\left(h_k, w\right)\right). \qquad (2)$$

Where

$$\cos^2\left(\angle\left(h_k, w\right)\right) = \frac{\mathrm{I} h_k^H w \mathrm{I}^2}{\mathrm{II} h_k \mathrm{II}^2 \mathrm{II} w_k \mathrm{II}^2} = 1 - \sin^2\left(\angle\left(h_k, w\right)\right).$$

Each user also feeds back to a single real number, which can be the Channel Quality Indicator (CQI). or some other channel norm We presented that this CQI is known perfectly to the BS, i.e., it should not quantized, and thus CQI feedback is not included in the generalization of feedback budget.

For a total aggregate feedback load of *T*fb bits, we are mainly interested in the sum rate of (beamforming strategies) described. When *T*fb/*B* u"sers feedback *B* bits each. The *T*fb/*B* users who feed back are arbitrarily selected from a larger user set. Thus, we illustrated the block fading setting, only those users who feed back in a desired block/coherence time are considered for transmission in that block; in other words, we are limited to transmitting to a subset of only the *T*fb/*B* users.

There have been many schemes proposed for the MIMO downlink, and investigating all of these would be beyond the scope of this work. However, we describe that ZF and PU2RC represent and capture the two basic techniques associated with most MIMO downlink strategies: that of exploiting accurate per-user CSI, and that of forming multi-user diversity, respectively. Further, ZF and PU2RC have received a lot of attention in the MIMO research community, and thus we have chosen to analyze these.

III. PROPOSED ALGORITHM

A. Zero Forcing Beam forming

We consider Zero-Forcing (ZF) beamforming with the channel norm ||h*k*|| being fed back to BS perfectly as the CQI. The BS then uses the greedy user selection algorithm presented in [18], adapted to imperfect CSI by treating the vector ||h*k*|| ·h*k* as if it were user *k*'s true channel, and power allocated equally across the selected users. We denote the indices of selected users by Π (1)*,* Π (*n*), where $n \le N_t$ is the number of users selected. By the ZF criterion, the unit-norm beamforming vector vΠ(*k*) for userΠ(*k*) is selected in the direction of the projection of hΠ(*k*) on the null space of $\{\hat{h}_{\Pi(j)}\}_{j\neq k}$ Although ZF beamforming is used, there is residual interference because the beamformers are analyzed based on imperfect CSI. The post SINR for selected user Π (*k*) is given by:

$$\mathrm{SINR}_{\Pi(K)}= \frac{\frac{SNR}{n} \mathrm{II} h_{\Pi(k)} \mathrm{II}^2 \cos^2 \angle(h_{\Pi(k)}, \hat{v}_{\Pi(k)})}{1+\frac{SNR}{n} \mathrm{II} h_{\Pi(k)} \mathrm{II}^{2 \sum_{j\neq k} \cos^2} \angle(h_{\Pi(k),} \hat{v}_{\Pi(j)})} \quad (3)$$

And the corresponding sum rate is

$\sum_{k=1}^{n}$ log2 (1 + SINRΠ(*k*)).For the sake of ease of analysis and simulation, each user utilizes an independently and efficiently generated quantization codebook *C* consisting of unit-vectors independently selected from the isotropic distribution on the 2*Nt*-dimensional unit sphere [19] (Random Vector Quantization (RVQ). The sum rate is averaged and normalized over this ensemble of quantization codebooks. We show other quantization mathods. In [2] it is shown that this sum rate with *Nt* randomly selected users is very sensitive to the CSI accuracy. With *Nt* = 4 and SNR = 10 dB, for example, *B* = 10 corresponds to a sum rate loss of 4 bps/Hz (relative to perfect CSI) and 15 bits are required to reduce this loss to1 bps/Hz shown in Figure.3.

A. Random Beamforming

In this section ww presented Random beam forming (RBF) with random vector quantization (RVQ) was described in [1] [20], Where in each user feeds back log2 *Nt* bits along with one real Number.

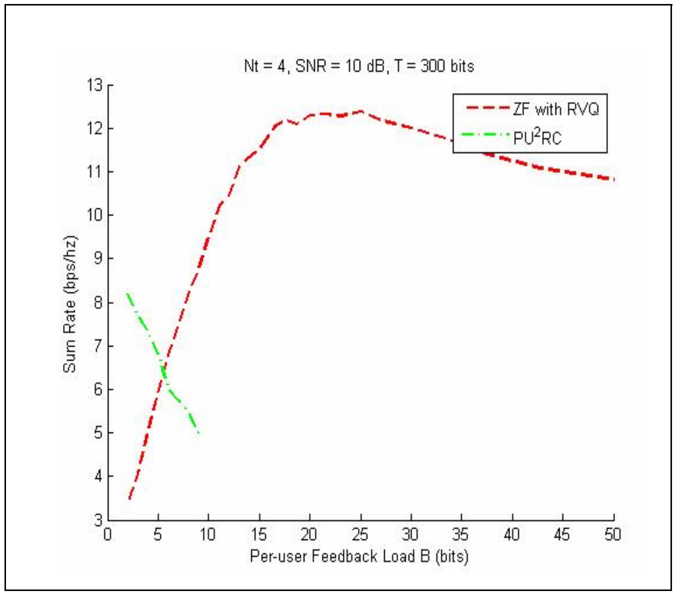


Figure.3. Behavior of B^{OPT} ZF (SNR*, Nt, T*fb) with *T*fb with SNR=10dB

In this case, there has been a common quantization codebook *C* consisting of *Nt* orthogonal unit vectors and quantization is produced according to (2). In addition to the quantization index, each user feeds back a real number representing its SINR. If **w***m* (1 ≤ *m* ≤ *Nt*) is the selected quantization vector for user *k*, then SINR*k* is given by:

$$\frac{\frac{SNR}{N_e} \mathrm{I} h_k^H w_m \mathrm{I}^2}{1+\frac{SNR}{N_e}\sum_{n\neq m} \mathrm{I} h_k^H Wn \mathrm{I}^2} = \frac{\mathrm{II} h_k \mathrm{II}^2 \cos^2 \angle h_{k,} w_m}{\frac{N_e}{SNR} + \mathrm{II} h_k \mathrm{II}^2 \sin^2 \angle h_{k,} w_m} \quad (4)$$

After receiving the feedback from the receiver, the BS selects the user with the largest SINR on each of the *Nt* beams (**w**1,**w***Nt*), and beamforming is performed along these same vectors. We analyzed that the ZF with RQ have produced more sum rate than the PU^2 RC.it is shown in Figure.4.

B. PU^2RC

We proposed Per unitary basis stream user and rate control (PU2RC), presented in [12] (a more widely available description can be found in [6]), is a generalization of RBF in which there is a common quantization codebook *C* consisting of 2 *B*−log2 *Nt* 'sets' of orthogonal codebooks, where in each orthogonal codebook consists of *Nt* orthogonal unit vectors, and thus a total of 2*B* vectors. Quantization is again obtained according to (2), and each user feeds back the same SINR statistic as in the RBF. User selection is produced as follows: for each of the orthogonal sets the BS repeats the RBF user selection procedure and computes the sum rate (where the single-user rate is log2(1+SINR)), after which it selects the orthogonal set with the highest sum rate. If *B* = log2 *Nt*, there reduces to ordinary RBF.

For each of the two schemes ZF and PU2RC, we determine an optimal B that maximizes the respective sum rate and compare the resulting rates. PU2RC and ZF differ in that the latter strategy involves a dedicated downlink training phase, while the former does not. Also, PU2RC is restricted to selecting users within one of the orthogonal sets and thus has very low complexity, whereas the described ZF technique has no such restriction. We describe, however, in Section VII-A, that our results hold even when ZF with selection strategies of comparable complexity is used With *Nt* = 4 and SNR = 10 dB, for example, *B* = 10 corresponds to a sum rate loss of 4 bps/Hz (relative to perfect CSI) and 15 bits are required to reduce this loss to1 bps/Hz shown in Figure.4

IV. OPTIMIZATION OF ZERO-FORCING BEAMFORMING

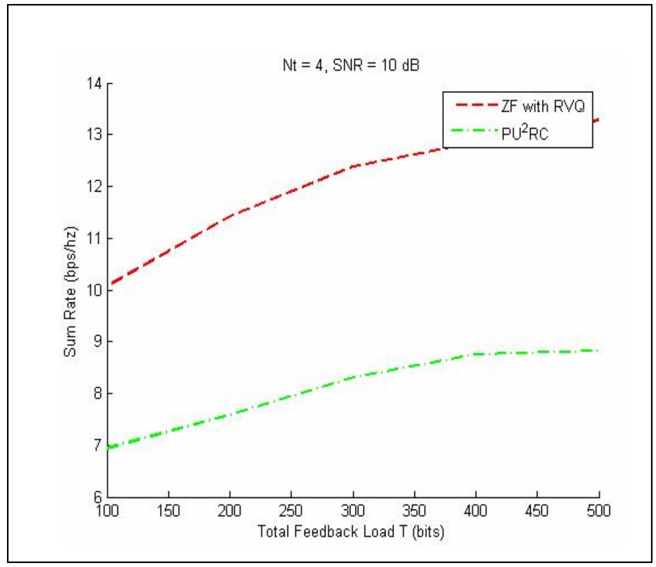
Equation 5 in section III, where the expectation is carried out over channels, as well as random codebooks. No closed form for this expression is known to exist

In this section we presented optimization scheme for zero forcing beamforming.we assume $\overline{R}_{ZF}\left(SNR, N_t, \frac{T_{fb}}{B}, B\right)$ be the sum rate for a system using ZF with *Nt* antennas at the

Figure.4 .sum rate vs feedback load for zero-forcing with SNR=10dB

Transmitter, signal-to-noise ratio SNR, and *T*fb*B* users each feeding back *B* bits for MIMO downlink system.

Even in the case of perfect CSI, but this quantity can be



easily computed via Monte Carlo simulation. We described in the number of feedback bits per user *B*OPT ZF (SNR,*Nt, T*fb) that maximizes SNR and also sum rate for a total feedback budget of *T*fb.The optimized solution for total feedback bits per user is given by:

$$B_{ZF}^{OPT}(SNR, N_t, T_{fb}) \triangleq \arg\max_{\log_2 N_t \leq B \leq \frac{T_{fb}}{N_t}} \widetilde{R}_{ZF}\left(SNR, N_t, \frac{T_{fb}}{B}, B\right) \quad (5)$$

Thus, this optimization is not analytically tractable; it is well illustrated and can be meaningfully analyzed. *B* for 2 and 4 antenna systems for various values of SNR and *T*fb. Based on this analysis we observed that the plot immediately evident sum rate increases very progressively with *B*, and that the optimizing and maximizing-rate BZF^{OPT} is extensively very large, e.g., in the range 15−20 and 20− 25 for *Nt* = 4 at 5 and 10 dB, respectively. Both of these observations show a strong significance for accurate CSI over multi-user diversity.

Consider figure.3 $\overline{R}_{ZF}\left(SNR, N_t, \frac{T_{fb}}{B}, B\right)$ is simulated. We observed the sum rate versus total feedback load is presented in figure.5

The next part is to achieve sum rate with ZF and desired user selection is described in [4], while the behavior of the sum rate is determined by identifying three regimes: the *large user regime*, the *interference limited regime*, and the *high resolution regime*.

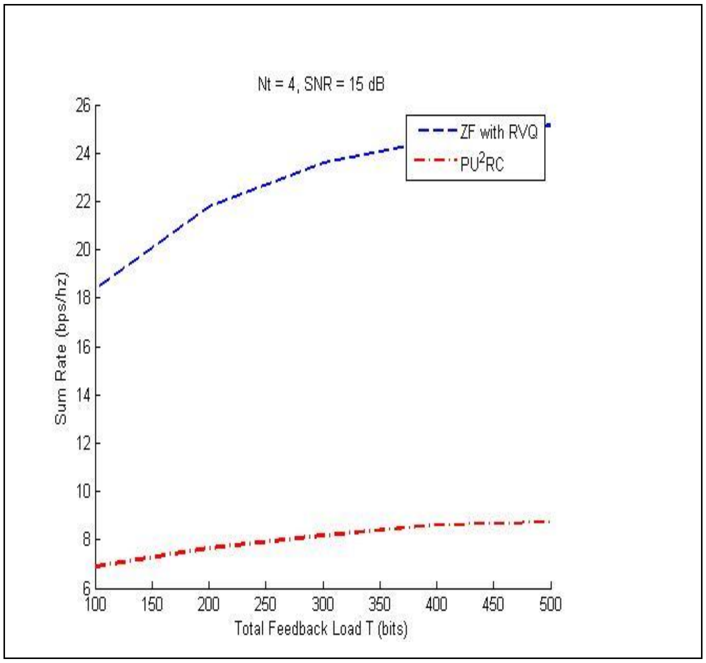


Figure.5 .sum rate vs. feedback load for zero-forcing with SNR15dB

While the number of users feeding back is very large, i.e., Tfb$/B$ is large, the system operates in the mode of large user regime, and the achievable rate with SINR feedback is demonstrated in [4]. In that regime, the achievable rate effectively increases with the quantity 2B (Tfb$/B$), and when increasing the per-user feedback by one bit is equivalent to monitoring the per-user feedback, but doubling the total number of users. This effect is shown in Figure 4, while increasing the user group from 10 to 100 results in a large increase in sum rate, but the rate progress very slowly with the number of users thereafter. Hence, the sum rate with 2000 users feeding back 15 bits each is the same as with 4000 users feeding back 14 bits each. Because 2B(Tfb$/B$) is effectively increasing in B (for B > 2), the sum rate is increasing in B within the large user regime when there is constraint on total feedback, i.e. feedback load is fixed, and thus it is sub-optimal to operate in the range of large user regime. As B increases, Tfb$/B$ drastically decreases, thus eventually driving the system away from the range of large user regime and into the high resolution regime. Unconditionally, the characterization of the sum rate for the range of high resolution regime illustrated in [4] is not accurate and also restricted to capture the behavior for the strategies of our optimization. Thus, in order to understand more efficiently and precisely this behavior, we introduced the following sum rate approximation, denoted by $\overline{R}_{ZF}\left(SNR, N_t, \frac{T_{fb}}{B}, B\right)$ given by;

$$N_t \log_2\left[1+\frac{\left(\frac{SNR}{N_t}\right)\log\left(\frac{T_{fb}N_t}{B}\right)}{1+\left(\frac{SNR}{N_t}\right)2^{-\frac{n}{N_t-1}}\log\left(\frac{T_{fb}N_t}{B}\right)}\right], \quad (6)$$

Where RZF ≈ _RZF. This approximation is considered from the expression for RZF in eq(5) by (a) assuming that the maximum number of users are selected (i.e., n = Nt), (b) replacing each cos2□(**h**Π(k),_**v**Π(j)) in the SINR denominator with its expected value 2 .the term in the SINR numerator with unity. Further, ||**h**Π(k)||2 is described as the largest channel norm among Tfb B users, which stochastically predominates the maximum of TfbNt/B random variables with Γ(1, 1) distribution, the latter having an expected value which behaves as log(TfbNt/B). Thus, for the large$T$fb approximation of eq(6) is not meant to accurately obtain the sum rate, but rather to capture the effect of B, we have presented that this captured with reasonable accuracy. Further, when the number of users feeding back is large, behaves like the logarithm of the number of users available for selection [4].

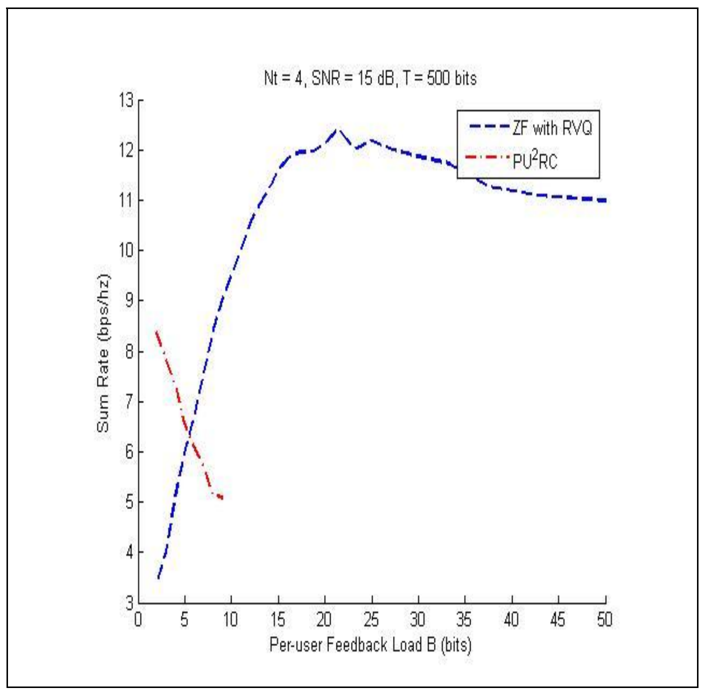


Figure.6. Behavior of B^{OPT} ZF (SNR,Nt, Tfb) with Tfb with SNR=15dB

The value of n is difficult to determine, but when the number of users feeding back is very large, we generally expect to select Nt users (except, when the SNR is very small). Hence, eq. (6) becomes a lower bound to the sum rate when the number of users is large, and SNR is large enough to produce selection of Nt users.

We first analyzed rapid sum rate increase with B. From eq. (6) we see that increasing B by $Nt-1$ bits reduces the interference power by a factor of 2. As long as the interference power is should significantly larger than the noise power level, this leads to a 3 dB SINR effectively increase and thus a Nt bps/Hz sum rate increase. When the system is restricted to operate interference limited, the two instances of 1 in eq(6) can be dropped, which leads $\overline{R}_{ZF}\left(SNR, N_t, \frac{T_{fb}}{B}, B\right) \approx$ $BNt/(Nt-1)$,

i.e., sum rate increases almost linearly with B for the smaller values of B, and the BS should take advantage of the maximum possible CSI accuracy that it can generate.

We observed that the accurate CSI is strongly preferred to multiuser diversity in the range of B for which sum rate increases linearly with B. However, we analyze from Figure 3 that progressively increasing B beyond a point actually decreases total sum rate. To demonstrate the desired combination of CSI and multi-user diversity are plotted versus B for a system with $Nt = 4$, Tfb = 300 bits and SNR = 10 dB. Motivated by [2], we approximate the sum rate by the perfect CSI sum rate minus a multi-user interference penalty given by:

$$R_{ZF}\left(SNR, N, \frac{T_{fb}}{B}, B\right) \approx R_{ZF}\left(SNR, N_t, \frac{T_{fb}}{B}, \infty\right) - N_t \log_2\left(1 + \frac{SNR}{N_t} 2^{-\frac{n}{N_T-1}} \log\frac{T_{fb}N_t}{B}\right) \quad (7)$$

This penalty term reasonably gives the loss due to imperfect CSI which is presented in Figure 5. In the figure we have shown that for $B \geq 25$ the sum rate curves for perfect and imperfect CSI essentially match and thus the penalty term in (7) is nearly approximate to zero. As a result, it reduces the number of users but does not provide a reasonable CSI benefit. This motivates, the most interesting observation gleaned from Figure 5 is that B^{OPT} corresponds to a point where the loss due to imperfect CSI is very small. Although BOPT ZF is quite very large for many parameter choices, it considers to not being particularly dependent on the total feedback budget Tfb, but is very sensitive to SNR and Nt. We demonstrate this by computing the optimal B corresponding to eq. (6), i.e., is given by:

B^{OPT} (SNR,Nt, Tfb) ≈ B^{OPT} ZF (SNR,Nt, Tfb),

Where the approximation is consider in B, and thus the following fixed point characterization of _ B^{OPT} ZF is obtained by setting the derivative of RZF$\left(SNR, N_t, \frac{T_{fb}}{B}, B\right)$ should equal to zero:

$$\frac{SNR}{N_t} 2^{-\frac{\overline{B}_{ZF}^{OPT}}{N_t-1}} \frac{\overline{B}_{ZF}^{OPT} \log 2}{N_t - 1}\left(\log\frac{T_{fb}N_t}{\overline{B}_{ZF}^{OPT}}\right)^2 = 1. \quad (8)$$

This quantity is easily computed numerically, but a more analytically convenient form is found by approximating (8) as:

$$\overline{B}_{ZF}^{OPT}\left(SNR, N_t, T_{fb}\right) = -\frac{N_t - 1}{\log 2} W_{-1}\left(-\frac{N_t}{SNR}\frac{1}{L}\right) \quad (9)$$

ZF (SNR,Nt, Tfb) are simulated and plotted versus Tfb and SNRdB, respectively sum rate with Nt randomly selected users is very sensitive to the CSI accuracy. With $Nt = 4$ and SNR = 15 dB, for example, $B = 10$ corresponds to a sum rate loss of 4 bps/Hz (relative to perfect CSI) and 12 bits are required to reduce this loss to1 bps/Hz shown in Figure.5and Figure.6

V. OPTIMIZATION OF PU^2 RC

We presented per unitary basis stream user and rate control (PU2RC) demonstrates RBF to more than log2 Nt feedback bits per user. A general quantization codebook, consisting of 2B/Nt 'sets' of Nt orthogonal vectors each is effectively utilized by each user. A user finds the best of the 2B quantization vectors, according to (2), and feeds back the index of the set ($B-$log2 Nt bits) and the index of the vector/beam in that set (log2 Nt bits). The key difference is in user selection. While ZF provides for selection of *any* subset of (up to) Nt users, the low-complexity PU2RC procedure detailed in Section III constrains the BS to select a set of up to Nt users from one of the 2B/Nt sets.

As a result of this difference, we optimize the per-user feedback load B for PU2RC: we observed that B = log2 Nt (i.e., RBF) is near-optimal and thus the optimization illustrates little advantage. Sum rate is simulated and plotted versus B (for PU2RC) in Figure 8. Very different from ZF, the sum rate does not increase rapidly with B for small B, and it begins to decrease for even moderate values of B.

If B is selected too large, the number of orthogonal sets 2B/Nt becomes comparable to the number of users Tfb/B and thus it is likely that there are fewer than Nt users on every set (there are on average TfbNt B2B users per set). For example, if Tfb = 500 and B = 8, there are 26 orthogonal sets and 40 users and thus less than a user per set on average. Hence, the BS likely schedules much fewer than Nt users, thereby leading to a reduced sum rate. For moderate values of B > log2 Nt, As B increases the quantization quality increases, but because there are only TfbNt B2B users per set (on average) the multi-user diversity (in each set) decreases sharply, so much so that the rate per set in fact decreases with B. The BS does choose the best set (amongst the 2B/Nt sets), but this is not enough to compensate for the decreasing per-set rate. Hence, we find that PU2RC strongly prefers multiuser diversity

VI. COMPARISON OF MULTI-USER BEAMFORMING SCHEMES

In this section we presented comparison of multi user-beamforming In Figure 9, the sum rates of ZF and PU2RC are compared for various values of SNR, *T*fb and *Nt*; for each scheme. It is seen that ZF maintains a significant advantage over PU^2RC for transmitting antenna's *Nt* = 4. At small *Nt*, both strategies perform similarly, but ZF maintains an advantage. Also exploited, is the performance of RBF/PU2RC with the following enhancements: (a) the BS may select to schedule fewer than *Nt* beams (as detailed in [9]), (b) power is near-optimally (rather than uniformly) allocated across users using the iterative procedure proposed in [9], and (c) an optimal DFT-based codebook is designed, as suggested in [19,20].. In spite of these enhancements, we observed that the performance of ZF is superior, and the advantage of ZF increases extremely rapidly with *Nt* and SNR. We presented that the SINR of the *k*th user By basic results in order statistics, the average of the maximum amongst *K* i.i.d. random variables is accurately approximated by the point which the CDF equals $(K - 1)/K$ [20]. Hence, in order to achieve a target SINR which approximately explains the ZF SINR with a total feedback budget of *T*ZF .

Thus analyze this, we consider the *smallest* quantization error amongst the *T*fb/ log2 *Nt* users, which, due to independence of the channels, is efficiently and effectively the same as the error of a single codebook of size *B* = log2 (*T*fb*Nt*/log2*Nt*). For example, with *Nt* = 4 and *T*fb = 300 bits, the *best* quantization error produce only as good as an 8-bit quantization. The sum rate is very sensitive to quantization error and multi-user diversity cannot compensate for the efficient system design. Hence, the "large-user" advantage of RBF is never realized, even as *T*fb grows progressively.

VII. Conclusion

In this paper, we have considered the basic of whether low-rate feedback/many user systems and high-rate feedback/limited user systems produce a larger sum rate in MIMO downlink channels. We have compared simulations between multi-user diversity (many users) and accurate channel information (high-rate feedback), and the surprising conclusion is that there is a very prominent preference for accurate CSI. Multi-user diversity describes a throughput gain that is only double-logarithmic in the number of independent users who feed back, while the marginal benefit of increased per-user feedback is very large up to the point where the CSI is essentially perfect. In terms of channel correlation across time and frequency, we presented that a recent research work has illustrated a closely related tradeoff in the context of a frequency-selective channel should each user quantize its entire frequency response or only a small portion of the frequency response The first option corresponds to coarse CSI (even though frequency-domain correlation is exploited) but a large user density, where as the second corresponds to desired CSI but fewer users per resource block. We observed that the simulation results are consistent in terms of accuracy; the second option has to provide a considerably larger sum rate than the first. We present the same holds true in the context of temporal correlation, across a user quantizing its channel across.

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