Adaptive QoS for Mobile Multimedia Applications Using Power Control and Smart Antennas

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Abstract—**There has been an increase in demand for multimedia services in wireless communication networks. The increase in data transmission required for multimedia places considerable strain on the limited resources that have traditionally served users with only speech requirements. We address the problem of providing the individual quality of service (QoS) needs of each user, according to the different multimedia service type, be it voice, video, image or data. We propose a scheme to improve the signal to interference noise ratio (SINR) for those users with multimedia services by exploiting power control and smart antennas, while not affecting users with voice service. We also propose a scheme for fast activation of new users into such a network.**

I. Introduction

In this paper we consider integrated multimedia services in a wireless network, where the users request the service quality appropriate to their multimedia service needs. The kind of quality of service (QoS) we discuss here is the signal to interference and noise ratio (SINR) that each receiver is guaranteed, which translates to the ability of providing different data transmission rates. We focus on a network that uses power control to reduce the cochannel interference (CCI) received at base stations while ensuring a certain SINR for the desired link. Also, the system uses smart antennas to reduce the CCI level at each base station by manipulating the antenna gain pattern with signal processing techniques that place nulls in the directions of perceived interferers while maintaining a proper gain towards the desired link.

This paper presents two contributions to improve service to users in the described wireless network. The first is to increase the activation speed for new users. For this, we propose a fast and coarse method for finding the mobile powers and antenna weights. The second is to fine-tune the SINR for multimedia users by using an iterative incremental procedure that takes the SINR for all users closer to the desired SINR. This is done off-line, so there is no additional delay for any user.

Previous work on power control and smart antennas has focused on the minimization of overall power and improvement of all SINR, without regard to the individual needs of each user, [1], [2], [3], [4]. The additional issue of working towards satisfying the different channel rate needs has been seen in [4] from the perspective of providing several parallel lower rate data streams. Resource assignment for mobile cellular has been seen in [5] from the perspective of channel assignment, or more extensively in [6] with a broader set of resources. But they attempt to provide users with the QoS that is available, without changing mobile powers or antenna gains to create a better QoS for the users who need it. In our scheme, if current powers or antenna weights do not allow additional callers to have a certain SINR, we try to adjust these parameters to provide for the new users. In [7], they perform power allocation with consideration to different SINR levels, but they do not find the optimum power vector, nor do they consider smart antennas. Our method provides the optimum power vector for a given assignment of SINR levels.

Also, those works used methods that are computationally long [1], [2], [3], and they may extend the activation latency time of the system while it waits for these computations to be finished. The activation latency time refers, in this context, to the time that new users must wait for the system to calculate antenna weights and mobile powers before the system activates those new users' connections. Our method exploits norm one, which replaces the spectral radius, this allows us to quickly find a solution that allows new powers and antenna weights to be calculated. This, in turn, translates to a faster service for new users.

Our proposed scheme first applies a fast suboptimal technique to provide a high SINR to each new user. Then it proceeds to use an iterative algorithm to come up with the power for each mobile station as well as the weights for the antenna arrays. This fast method allows the new user to be activated quickly. After implementing this suboptimal solution, the algorithm incrementally improves the SINR for those users who would benefit from it. The algorithm uses results from matrix perturbation theory to adjust the SINR in such a way that we are guaranteed to obtain the power vectors.

The system model is described in Section II. The algorithms for quickly getting a new user activated, and then for fine-tuning the SINR for multimedia users are described in Section III. The formulas for choosing the best SINR to be adjusted are derived in Section IV. The complete algorithm is put together for the reader in section V. Finally Sections VI and VII have simulation results and conclusions, respectively.

II. General Model and Algorithm

Assume a wireless network with M cochannel bases, automatic power control and smart antennas. Minimum cochannel distances and formulas for the pathloss can be obtained from [8].

The nomenclature for the variables used in this paper are listed in Table 1:

Term	Definition
BS_i	used to describe base station i or cell site i.
MS_j	used to describe mobile station j.
P_j	transmitting power of MS_j. Without the subindex, $\mathbf{P}$ refers to the power vector for all M mobiles.
G_{ij}	pathloss between MS_j and BS_i. See Fig. 1.
$\hat{\gamma}_i$	desired SINR for the BS_i receiver.
$\mathbf{w}_i$	antenna weight vector for BS_i.
$\mathbf{a}_{ij}$	array response of BS_i array to the MS_j source.
N_i	thermal noise at the BS_i receiver.

Table 1. *Variable names and symbols.*

Our goal is to assign the γ_i according to each user's needs and test whether these SINR assignments allow us to achieve optimum power and antenna weight allocations.

The problem of joint power control and smart antennas has been addressed in [1], [2], [3], [4]. The performance measure that has been used for controlling the smart antennas is the minimum noise variance criterion [9], [2], [3].

Each antenna element of the antenna array of BS_i receives the signal from MS_i along with interfering signals which would all be arriving from different incident angles. Also, we can expect multipath effect due to reflecting surfaces from both our desired source, MS_i, as well as undesired sources, $MS_j, j \neq i$. Along with this, there would be

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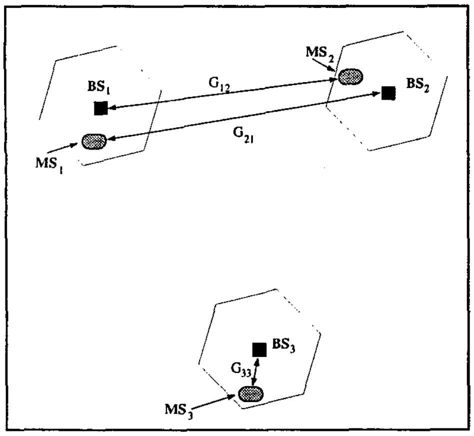

Fig. 1. These three cochannel cells each have a mobile unit. The gains between mobile stations and base stations are depicted in this figure.

thermal noise. Assuming a single signal from each mobile transmitter, the antenna output looks like:

$$\mathbf{x}_i = \sum_{j=1}^{M} \sqrt{P_j G_{ij}}\, s_j(t)\mathbf{a}_{ij} + \mathrm{N}_i(t) \tag{1}$$

where $\mathbf{w}^H$ is the Hermitian conjugate of the vector $\mathbf{w}$, and $\mathbf{a}_{ij}$ is the array response vector from BS_i towards MS_j, and $s_j(t)$ is the signal from MS_j. The minimum noise variance method for finding the optimal antenna weights, under the constrain $\mathbf{w}_i^H \cdot \mathbf{a}_{ii} = 1$, and setting $\Phi = E\{\mathbf{x}_i \mathbf{x}_i^T\}$, yields the optimal solution,[9]:

$$\hat{\mathbf{w}}_i = \frac{\Phi_i^{-1}\mathbf{a}_{ii}}{\mathbf{a}_{ii}^H \Phi_i^{-1}\mathbf{a}_{ii}}. \tag{2}$$

The results obtained from the smart antenna calculations are used to calculate the overall path gain between bases and mobiles in power control. The purpose of power control is to select the transmitting power of each mobile station so as to guarantee a certain SINR adequate for each user, while minimizing the overall power used by all mobile stations. If we define γ_i as the effective SINR for user i, then we can write

$$\gamma_i = \frac{G_{ii}P_i}{\sum_{j\neq i} G_{ij}|\mathbf{w}_i^H \mathbf{a}_{ij}|^2 P_j + n_i} \tag{3}$$

We want γ_i as close as possible to $\hat{\gamma}_i$ for $i = 1, \dots M$. Given that pathgains and powers are non-negative, we can write the vector version of the constraining inequality as $\mathbf{P} - \Gamma F \mathbf{P} \geq (\gamma_1 \frac{n_1}{G_{11}}, \cdots, \gamma_M \frac{n_M}{G_{MM}})^T$. Denote the left side vector $\mathbf{u}$, and the matrix

$$F = \begin{pmatrix} 0 & \frac{G_{12}|\mathbf{w}_1^H \mathbf{a}_{12}|^2}{G_{11}} & \cdots & \frac{G_{1M}|\mathbf{w}_1^H \mathbf{a}_{1M}|^2}{G_{11}} \\ \frac{G_{21}|\mathbf{w}_2^H \mathbf{a}_{21}|^2}{G_{22}} & 0 & \cdots & \frac{G_{2M}|\mathbf{w}_2^H \mathbf{a}_{2M}|^2}{G_{22}} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{G_{M1}|\mathbf{w}_M^H \mathbf{a}_{M1}|^2}{G_{MM}} & \frac{G_{M2}|\mathbf{w}_M^H \mathbf{a}_{M2}|^2}{G_{MM}} & \cdots & 0 \end{pmatrix}.$$

The inequality is taken to be element by element. We may now write the problem statement for the power control problem as:

$$\text{minimize} \sum_{i=1}^{M} P_i \tag{4}$$

$$\text{subject to } (I - \Gamma F)\mathbf{P} \geq \mathbf{u} \tag{5}$$

If we leave the antenna weights constant and focus on calculating the power vector, it has been shown [10], [11] that, if the spectral radius of ΓF has norm less than one, $|\rho(\Gamma F)| < 1$, then the optimum solution to the constrained power control optimization problem is

$$\hat{\mathbf{P}} = (I - \Gamma F)^{-1}\mathbf{u} \tag{6}$$

The problem of jointly calculating the best power vector and the optimum set of antenna weights has been done efficiently in [2]. The requirement for the convergence in this case is more difficult to verify, since it involves an extensive search. The fact is that we must find any *feasible* set of weight vectors, $\{\mathbf{w}_i\}_{i=1,\dots M}$ in the complex plane such that $\rho(\Gamma F) < 1$, [2]. And for our purposes, we must find them for the most favorable Γ that is possible. We present a solution to this problem by reducing it to one of lower complexity for a suboptimal solution.

III. Method for Quick Activation and Fine Tuning

The need for speedy decisions in a mobile environment is clear; when a new user initiates a call, the system must choose the best base station for service, the frequency, a new power vector, antenna gains, and all this should be invisible to the user. In this section we provide the answers to two questions: How do we quickly guarantee convergence for a joint power control/smart antenna calculation? How do we improve the SINR for users who need it?

A. Fast Path to Convergence

We've already seen that the test for convergence for the joint power control/beamforming solution requires scanning over all the complex plane for M D-dimensional vectors that both comply with $\mathbf{w}_i^H \mathbf{a}_{ii} = 1$ and also have $\rho(\Gamma F) < 1$. We would want to perform this test for the best possible Γ.

One may be forced to make many attempts before finding the best Γ that is feasible. Also, it is not clear which γ_i should be lowered to yield faster results. We show how to use a fast test for convergence so that we have fast knowledge of the feasibility of a certain Γ.

We propose using norm one for the convergence test rather than the spectral radius of the matrix ΓF. Norm one will also yield an acceptable answer: if $(\Gamma F) \in \Re^{n\times n}$ and $||(\Gamma F)|| < 1$ then $(I - \Gamma F)$ is nonsingular with $(I - \Gamma F)^{-1} = \sum_{k=0}^{\infty}(\Gamma F)^k$, [11]. The non-negative elements of (ΓF) guarantee that the inverse has non-negative elements.

We must be cautioned that even though it is clear we can replace the spectral norm with this simpler norm one, the spectral radius should be used in the fine-tuning stage. This is because, though difficult to handle, the spectral radius is a more precise indicator of the convergence of the power control algorithms, since $\rho(A) \leq ||A||$ for all consistent norms, [12], such as norm one.

The above norm inequality means that there may be matrices such that $\rho(\Gamma F) < 1$, yet $||\Gamma F||_1 \geq 1$. In these cases the faster norm will push us to reduce the SINR for our new users, even though it is not necessary for convergence. This is the price we pay for using a low complexity norm.

The question that remains is, how does this norm make the search simpler? We decompose F into three matrices, thus separating the weights from the other variables. Denote the collection of weights, pathgains, SINR, and antenna gains by $\mathcal{W} = \{\mathbf{w}_1, \mathbf{w}_2, \cdots \mathbf{w}_M\}$, $\mathcal{G} = \{G_{ij}\}_{i,j\in\{1,\dots M\}^2}$, $\mathcal{A} = \{\mathbf{a}_{ij}\}_{i,j\in\{1,\dots M\}^2}$, and $\Gamma = \{\gamma_1, \gamma_2, \cdots \gamma_M\}$, respectively. Then we can write $\Gamma F = L(\mathcal{W}) \cdot M(\Gamma, \mathcal{G}, \mathcal{A}) \cdot R(\mathcal{W})$, where the $M \times DM$ matrix L is:

$$L(\mathcal{W}) = \begin{pmatrix} \mathbf{w}_1^H & 0 & \cdots & 0 \\ 0 & \mathbf{w}_2^H & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \mathbf{w}_M^H \end{pmatrix}, \tag{7}$$

the $DM^2 \times M$ matrix R is $R(\mathcal{W}) = (\psi_1^*, \cdots, \psi_M^*)$, where each $DM \times M$ submatrix ψ_i is:

$$\psi_i = \begin{pmatrix} \mathbf{w}_i & 0 & \cdots & 0 \\ 0 & \mathbf{w}_i & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \mathbf{w}_i \end{pmatrix}, \tag{8}$$

and the asterisk indicates complex conjugate. And finally, the $DM \times DM^2$ central matrix M is:

$$M(\bar{\Gamma}, \mathcal{G}, \mathcal{A}) = \begin{pmatrix} \mathbf{f}_1 & 0 & \cdots & 0 \\ 0 & \mathbf{f}_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \mathbf{f}_M \end{pmatrix} \tag{9}$$

where each $1 \times M$ vector, $\mathbf{f}_i$ is:

$$\mathbf{f}_i^T = \begin{pmatrix} \frac{\gamma_i G_{i1} \mathbf{a}_{i1} \mathbf{a}_{i1}^T}{G_{ii}} \\ \vdots \\ \frac{\gamma_i G_{i\, i-1} \mathbf{a}_{i\, i-1} \mathbf{a}_{i\, i-1}^T}{G_{ii}} \\ 0 \\ \frac{\gamma_i G_{i\, i+1} \mathbf{a}_{i\, i+1} \mathbf{a}_{i\, i+1}^T}{G_{ii}} \\ \vdots \\ \frac{\gamma_i G_{iM} \mathbf{a}_{iM} \mathbf{a}_{iM}^T}{G_{ii}} \end{pmatrix}. \tag{10}$$

The prohibitively large dimensions of these matrices should not be a discouragement, since these matrices are dealt with during this derivation only. Working with these large matrices is not tedious either, since most elements are zero.

Now we use these matrices to answer our convergence question: $||\Gamma F||_1 < 1$. We can state that if $||L||_1 \cdot ||R||_1 < \frac{1}{||M||_1}$, then

$$\rho(\Gamma F) \leq ||\Gamma F||_1 \leq ||L||_1 \cdot ||M||_1 \cdot ||R||_1 < 1. \tag{11}$$

We can write $||M||_1$ and $||R||_1$ in terms of $\{\mathbf{w}_i\}_{i \in I}$. Therefore, the problem reduces to finding a set of vectors, $\{\mathbf{w}_i\}_{i \in I}$ such that $\mathbf{w}_i^H \mathbf{a}_{ii} = 1, i = 1, ...M$, and

$$\max_{j=1,\dots M} ||\mathbf{w}_j||_\infty \cdot \sum_{i=1}^{M} ||\mathbf{w}_i||_1 < \frac{1}{||M||_1} \tag{12}$$

Note that we have no control over $||M||_1$. Except for the γ_i, the right hand side must be estimated from the system. We wish to know if there is *any* set of vectors that complies with these constraints. If there are, we have convergence, and we can continue with our algorithms. We must, therefore, find a set of vectors that minimize the left hand side of the inequality.

Theorem 1: The collection of vectors, $\{\mathbf{w}_i\}_{i \in I}$, that minimizes the left hand expression of (12), with $\mathbf{w}_i^H \mathbf{a}_{ii} = 1, i = 1, ...M$ is

$$\tilde{w}_i(k) = \begin{cases} \frac{1}{a_{i,max}^*} & , k = \underset{j=1,\dots D}{argmax} |\mathbf{a}_{ii}(j)| \\ 0 & ,\text{otherwise} \end{cases} \tag{13}$$

where $a_{i,max} = \mathbf{a}_{ii}(k)$ for the k that maximizes the argument. $\diamond$

Therefore, problem (4) has an element by element positive solution, as in (6), if

$$\frac{1}{\underset{k=1,\dots M}{min} ||\mathbf{a}_{kk}||_\infty} \sum_{i=1}^{M} \frac{1}{||\mathbf{a}_{ii}||_\infty} < \frac{1}{||M||_1} \tag{14}$$

It should be repeated that if the inequality does not hold, we may or may not have convergence, it is not possible to know simply from that inequality.

Equation (14) tells us the fast way to determine if the system with the new users will yield a positive power vector.

B. SINR Fine-tuning

The previous section describes a fast method to get a reasonable Γ that lets us obtain the power vector and the antenna weights; once we have those, we can activate the new users. With the users now functioning, and we may devote our computing resources to improving and fine-tuning the SINR of those new users, and other existing users.

Now, we do not have time constraints, and we can use more computationally expensive methods to get better results. We wish to *increase* as many γ_i's as we can, and by as much as we can, but *we must not drive* $\rho(\Gamma F)$ *to 1.* The tool that we use to make this choice is the rate of change of $\rho(\Gamma F)$ as we change each γ_i. Let's first assume that these derivatives exist, and we have sorted them from the smallest to the largest.

If we have convergence with the present Γ for our algorithm, and we wish to increase some γ_i while imposing the smallest possible effect on $\rho(\Gamma F)$, we use the sorted derivatives to choose the *smallest* one. Specifically, we seek

$$i_{des} = \arg \min_{i=1,\dots M} \frac{\partial \rho}{\partial \gamma_i} \tag{15}$$

We should only consider those i corresponding to users who have multimedia services. It is of little use to increase the channel quality for a user who is simply using voice quality service, while ignoring another user who is transmitting video.

Once the i_{des} is selected, we increase $\gamma_{i_{des}}$ and test for convergence. Now, we assume that in the small span of time in which this takes place, the positions of the mobiles do not change significantly. This is important because we assume that the antenna weights need not be recalculated. We only wish to find a new power vector that is more favorable to user i_{des}, while not chastising the other users. To do this, we can use existing techniques [13], [14] that quickly give us a new power vector, and this time, we can use the more exact test, $\rho(\Gamma_{new} F) < 1$.

If the test still passes, we can find a new power vector, and implement it. If the test fails, we reduce the SINR for a different user:

$$i_{red} = \arg \max_{i=1,\dots M} \frac{\partial \rho}{\partial \gamma_i} \tag{16}$$

And we test for convergence. The sequence of increasing the γ_i that least affects $\rho(\Gamma F)$ and decreasing the γ_j that most affects it is repeated until the system perceives new users to have been added to the group, or until a certain amount of time has passed. After some time, it is no longer possible to assume that the mobile units have not moved significantly, so the system must recalculate the weight vectors as well as the power vector. The algorithm will be summarized in Section V.

This suboptimal approach may not yield a unique answer. Consider we have not made any statements regarding the convexity of the spectral radius of our matrix. Even further, we can count on the spectral radius to have expressions with high powers of the matrix elements. This will imply a number of local minima. We implement a steepest descent algorithm that may lead ultimately to a local minimum. Furthermore, it does not give a unique answer, since our selection of the size of increments and reductions may lead us through different paths.

IV. Criteria for SINR Adjustment

This section deals with the question of choosing which SINR to adjust to best fit our purpose, be it to quickly find a feasible Γ as seen in Section III-A, or to meticulously increase as many γ_i by as much as we can as seen in Section III-B. For the first goal, we wish to choose the γ_i to be altered so that a *small* decrease in γ_i will have a *large* impact on the reduction of $\rho(\Gamma F)$. For the second goal we would like to increase some SINR without driving $\rho(\Gamma F)$ above one. For this case, we wish to choose a γ_j to be altered so that a *large* increase in γ_j will have a *small* impact on the increase of $\rho(\Gamma F)$.

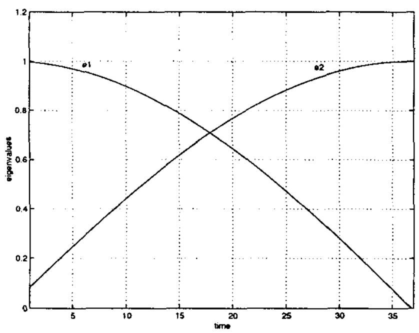

Fig. 2. Both eigenvalues change continuously as the elements of the matrix change. But $e1$ starts as the spectral radius, and then at point $(17.8, 0.7)$ $e2$ becomes the spectral radius. Thus, the spectral radius is not smooth at that point.

For both of these, we wish to calculate the derivative of $\rho(\Gamma F)$ with respect to each γ_i. The question of the existence of the derivative of the spectral radius of such a matrix is addressed in [12], in conjunction with Frobenius' Theorem,[11]. We can now derive an expression for the derivative.

Theorem 2: Let ρ be a simple eigenvalue of ΓF, with right and left eigenvectors, $\mathbf{x}$ and $\mathbf{y}$, respectively. Let $\tilde{F} = \Gamma F + E$. Then there exists a unique $\tilde{\rho}$, eigenvalue of $\tilde{F}$ such that

$$\tilde{\rho} = \rho + \frac{\mathbf{y}^H E \mathbf{x}}{\mathbf{y}^H \mathbf{x}} + \mathcal{O}\left(||E||^2\right) \tag{17}$$

Proof: [12] ◇

In our case, $E = \Delta\gamma_i \cdot F_i$, where F_i is a matrix whose ith row is the same as F, and all other elements are zero. Then, using 17, we conclude that

$$\frac{\partial \rho}{\partial \gamma_i} = \frac{\mathbf{y}^H F_i \mathbf{x}}{\mathbf{y}^H \mathbf{x}} \tag{18}$$

Note that the denominator is constant for all $i = 1, ...M$. We can sort these derivatives to suit our needs for the Quick Activation and Fine Tuning schemes.

We may choose to reduce several SINR, but our decision of *which* and *by how much* should be influenced by the sorted indexes. The criteria for choosing the γ_i may still have some subjective contribution. For example, even if a certain user, j has the higher derivative, we may not wish to reduce this users SINR, since he has been functioning with a high quality, and would be displeased with a reduction. It would perhaps make more sense to take the subset of new users and only work with their SINR. Another consideration is that we may have reduced a certain user's SINR several times during the iterations. We may wish to tag users so that they do not suffer repeated quality deprivation. These considerations have been included in the simulations, though not in Table 2. They are provided as an indicator of what the designer may do to improve customer satisfaction, but they are subjective, and thus, tangential to the material we present.

It should be noted that the derivative is a measure of infinitesimal change, therefore, we must remind ourselves to choose small perturbations of the γ_i, so that these results may have some value. Another reason to keep the perturbations small is that the spectral radius may change from one eigenvalue index to another, as was seen in Fig. 2.

V. Integrated Multimedia QoS Scheme

In this section, we put together the tools described in the previous sections and we formulate a working algorithm, which is detailed in Table 2.

It should be noted that steps should be taken if there is no convergence even after SINR reduction. Clearly, if all users have been demoted to a the lowest allowable SINR, and we still can't get a positive power vector from the algorithm, then the system should have some user handoff to another frequency. This may be a frequency within the same base station, or it may have to handoff to another base station whose service area overlaps with the current base station's service area. As a last resort, the system may have to drop a call.

1	Check system for new cochannel users, assign the desired γ to new users according to their service type
2	Get $\|\|M\|\|_1$ with initial Γ.
3	Test if there are $\{\mathbf{w}_i\}_{i\in I}$ s. t. $\|\|L\|\|_1 \|\|R\|\|_1 < \frac{1}{\|\|M\|\|_1}$.
3.a	If success, then this Γ works. Go to Step 4.
3.b	If failure, reduce the γ_i for $i = \arg\max_j \frac{\partial\rho(\Gamma F)}{\partial\gamma_j}$. Return to Step 3.
4	Obtain $\{\mathbf{w}_i\}_{i\in I}$ and $\mathbf{P}$.
5	Assign antennas weights in bases and transmit power settings to mobile units.
6	Check to see if new mobiles have been added or if the clock has timed out.
7	Increase the γ_i for $i = \arg\min_j \frac{\partial\rho(\Gamma F)}{\partial\gamma_j}$. Call this new set which we are testing Γ_{new}.
8	Check if $\rho(\Gamma_{new} F) < 1$.
8.a	If success, Γ_{new}, go to Step 9.
8.b	If failure, reduce the γ_i for $i = \arg\min_j \frac{\partial\rho(\Gamma_{new} F)}{\partial\gamma_j}$. Got to Step 6.
9	Obtain power vector, $\mathbf{P}$. Go to Step 5.

Table 2. *Algorithm description.*

VI. Simulation Results

We assumed a wireless network with $M = 40$ cochannel bases using FDMA, and a (2,1) reuse pattern. $D = 4$ for all base stations. We assumed only two user types, voice quality and multimedia quality. The algorithm can be readily extended to several quality types. We assumed that voice users would get a constant $\hat{\gamma}_v$ SINR, and the other users would try to have $\hat{\gamma}_m$ SINR, which was considerably higher than $\hat{\gamma}_v$.

The simulations presented run along a time axis. M is the maximum number of cochannel calls that may be working at any given time. We assume that about eighty percent of those M links would be on at any given time, and of the ones that are on, p fraction of them desire a multimedia quality channel. Call lengths are exponentially distributed with an average of six minutes. The time-out for exiting Steps 7, 8, and 9 of the algorithm was set to be 16 time units times the number of active users.

The values that are plotted are: the desired SINR for the multimedia users, $\hat{\gamma}_m$ which is labeled "desired", the effective SINR for those high quality users using the entire algorithm, γ_m, which can be seen in Fig. 3 to be close to the desired level, the SINR for the high quality users if they do not use the fine-tuning method, which can be seen to be lower, and the SINR for voice users, $\hat{\gamma}_v$. For Fig. 3, $\hat{\gamma}_m = 30dB$ and $\hat{\gamma}_v = 16dB$. Another example with larger difference between $\hat{\gamma}_m$ and $\hat{\gamma}_v$ can be seen in Fig. 4.

Fig. 5 compares the results of our method with the possibility of giving a constant SINR to all users, and implementing the algorithm without the benefit of calculating the derivative of the spectral radius with respect to the γ_i.

Fig. 6 compares the time that our scheme takes to calculate the mobile powers and antenna weights when new users are being added to the system, to a trial and error scheme. In the trial and error scheme, the desired $\hat{\gamma}$s are assigned to the new users. The system then engages in an iterative algorithm to get the powers and antenna weights. If the algorithm did not converge in $4 * M$ iterations, it would reduce the SINR

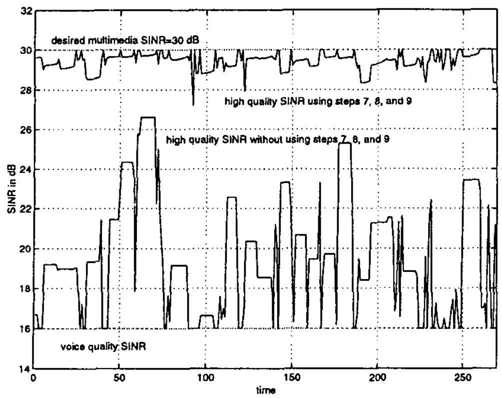

Fig. 3. $p = .3; \hat{\gamma}_v = 16dB; \hat{\gamma}_m = 30dB$. The average difference between the method without steps 7 through 9 and that with those steps was $10.2dB$.

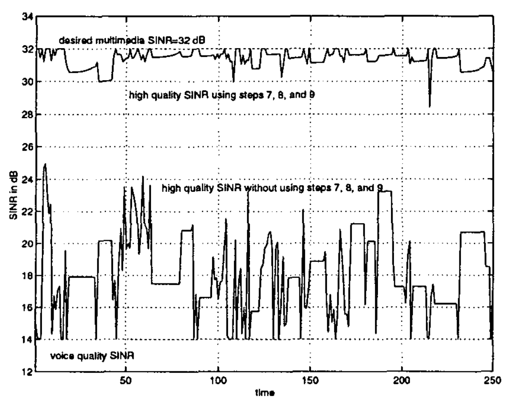

Fig. 4. $p = .3; \hat{\gamma}_v = 14dB; \hat{\gamma}_m = 32dB$. The average difference between the method without steps 7 through 9 and that with those steps was $13.4dB$.

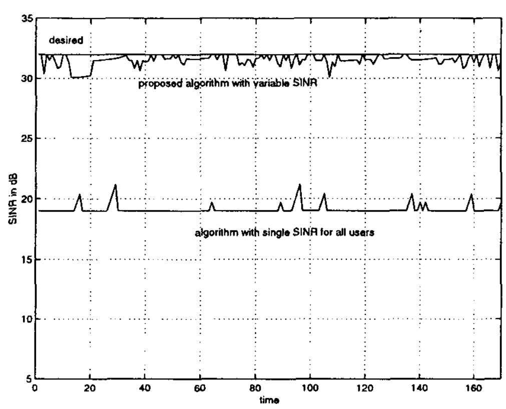

Fig. 5. $\hat{\gamma}_m = 32dB$. The average SINR for our method using variable SINR was $31.5dB$. The average SINR using the same algorithm, but using a constant SINR for all users and raising and lowering them at the same time was $19.2dB$.

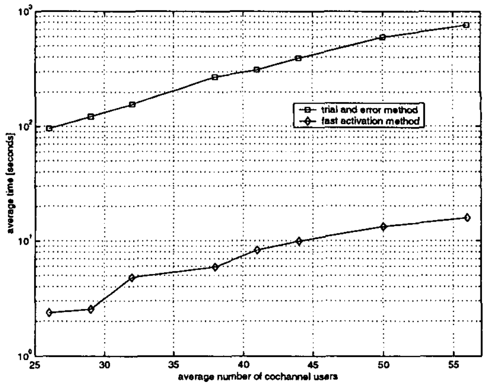

Fig. 6. Comparison of the processing time for the fast activation method proposed in this paper to a trial and error method.

for a randomly chosen multimedia user and try again.

VII. Conclusions

We can gain a significant increase in the SINR for certain users by estimating the spectral properties of the system matrix and using those properties to adjust the power for the mobile units. Our simulations show over 10dB of improvement of the SINR by using the proposed SINR fine-tuning scheme.

It should be mentioned that one advantage to our iterative method for improving the SINR for multimedia users is that the system is seeking a better quality off-line, so there is no latency associated to it. It guarantees no detriment to voice quality users, and it seeks to drive the SINR closer to the desired levels.

We've also managed to reduce the activation latency time for new users significantly by using a coarser and faster method for finding feasible SINR. Our simulations have shown an improvement of about two orders of magnitude in the time required to find a feasible solution.

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