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Distributed Minimum Outage Removal Algorithm for Multi-Rate CDMA Wireless Communication Systems

Mohammed Elmusrati[1], Naser Tarhuni[2], Riku Jäntti[1] and Heikki Koivo[1]

[1] Control Engineering Laboratory
Helsinki University of Technology
PL5500 – 02015TKK – Finland

[2] Communications Laboratory
Helsinki University of Technology
PL3000 – 02015TKK - Finland

ABSTRACT

In this paper we propose heuristic and efficient algorithm to minimize the dropped connections in real time congested communication networks. This problem can be classified as combinatorial optimization problem. It is well known that there is no general closed form solution for this type of problems. Furthermore finding the optimal solutions in medium and large size cases of these problems is usually very expensive. Our proposed heuristic algorithm is very simple to implement and gives a close solution to the optimum in many different cases.

1. INTRODUCTION

The modern cellular communication systems can support different types of services such as voice, video, and data communications. These different services need different QoS levels. One of the QoS items is the transmitted data rate. The radio resource scheduler (RRS) aim is to divide the available radio resources between users in optimum way to achieve some target objectives such as maximizing the system capacity. If the system capacity is near to congestion then the connection admission control (CAC) in the radio resource manager (RRM) will refuse any new connection (which may congested the system). Even without acceptation of new calls the communication system may fall in the congestion state. The main reason for that is the random time varying nature of the mobile channels. The congestion in cellular communication system means that some users in the cell can not obtain their target QoS. In this situation, which user (or users) must be dropped from the suffered cell to relax the congestion? The optimum removal algorithm depends on the targeted criteria whether is maximizing the total throughput or minimizing the outage. The optimal dropping algorithm which minimizes the outage is that one which keeps the number of dropped users at minimum. This criterion is considered in this paper. The work on centralized removal algorithms was initiated by Zander's work in [2], where a stepwise removal algorithm (SRA) was proposed. Later, the stepwise maximum interference removal algorithm (SMIRA) was shown to outperform the SRA [5]. Generalized algorithm for distributed constrained power control is proposed in [3]. All previous algorithms are mainly for fixed rate communication systems. In this paper we introduce a simpler algorithm than the existing algorithms and it is for multi rate communication systems.

The concepts of the optimal removal algorithm are presented in next Section. The proposed heuristic algorithm is given in Section 3. Section 4 shows simulation results. Finally the conclusion is presented in Section 5.

2. THE CONCEPTS OF OPTIMAL MINIMUM OUTAGE REMOVAL ALGORITHM

In multi-rate cellular communication system each user should achieve at least his target QoS. The target QoS can be expressed by target Carrier to Interference Ratio (*CIR*). The *CIR* of user *i* is given as

$$\frac{p_i(t)\, g_{ij}(t)}{\sum_{\substack{k=1\\k\neq i}}^{Q} p_k(t)\, g_{kj}(t) + n} = \Gamma_i^T(t) \qquad (1)$$

where $p_i(t)$ is the transmitted power of user *i* at time slot *t*, g_{ij} is the channel gain between user *i* and base station *j*, *n* is the additive white noise power at receiver *j*, *Q* is the number of users, and Γ_i^T is the target *CIR* of user *i.*

For CDMA systems the target *CIR* is given by

$$\Gamma_i^T = \frac{R_d}{R_s}\delta_i^T \quad (2)$$

where R_d is the transmitted data rate, R_s is the ship rate ($\frac{R_s}{R_d}$ is called the processing gain), and δ_i^T is the target bit energy to noise power spectral density ratio. The δ_i^T value determines the allowed bit error rate. Equation (1) can be expressed in matrix form such as

$$\mathbf{p} = \mathbf{\Gamma}\left[\mathbf{Gp} + \mathbf{u}\right] \quad (3)$$

where $\mathbf{\Gamma} = diag\left(\Gamma_1^T, ..., \Gamma_Q^T\right)$, $\left(\mathbf{G}\right)_{ik} = \begin{cases} 0 & \text{k=i} \\ \frac{g_{kj}}{g_{ij}} & \text{k} \neq \text{i} \end{cases}$, $\mathbf{p} = \left[p_1, ..., p_Q\right]'$, and $\left(\mathbf{u}\right)_i = \frac{n}{g_{ij}}$.

If the system is feasible (all users can obtain their target *CIR*), then the optimum power vector is given by

$$\mathbf{p} = \left[\mathbf{I} - \mathbf{H}\right]^{-1}\mathbf{\Gamma u} \quad (4)$$

where $\mathbf{H} = \mathbf{\Gamma G}$. It is well known that in order to obtain feasible system the spectral radius of matrix **H** must be less than one [2], i.e.

$$\rho\left(\mathbf{H}\right) < 1 \quad (5)$$

Define $\mathbf{H}^{(k)}$ as a square sub-matrix of **H** with removed kth row and kth column. To minimize the number of dropped connections, the ith removed user should satisfy the following criteria

$$i = \arg\max_{k=1,...,Q} G_a\left(\mathbf{H}^{(k)}\right) \quad (6)$$

where $G_a\left(\mathbf{H}^{(k)}\right)$ is the achieved gain by removing the kth user and it is given by

$$G_a\left(\mathbf{H}^{(k)}\right) = \left(\frac{1}{\rho\left(\mathbf{H}^{(k)}\right)} - \frac{1}{\rho\left(\mathbf{H}\right)}\right) \quad (7)$$

From (6) and (7) all connections need to be examined to select the optimum removed user. If the new reduced system is feasible then stop otherwise repeat (6) with the reduced new matrix. It is clear that the optimum removal algorithm has mainly two disadvantages which are the computational complexity and all information (channel gains) are needed to compute the spectral radius.

3. HEURISTIC DISTRIBUTED MULTI RATE REMOVAL (DMRR) ALGORITHM

Our heuristic algorithm is based on removing the user which has *the highest power and data rate multiplication value*. It is assumed that the base station can estimate the transmitted power of each mobile phone. This assumption is tractable because the transmitted power of mobile phones is controlled by the base station. The DMRR algorithm can be described by the following pseudo-code

1) ***If*** *the network is congested then start step 2*
2) ***Sort*** *all users according to their value of transmitted power and data rate multiplication*
3) ***Remove*** *the first user (has highest multiplication value) and* ***re-sort*** *the list.*
4) ***If*** *the congestion is relaxed then* ***stop*** *otherwise* ***go*** *to step 3*

Note that in the proposed procedure, the spectral radius and the total gain information are not needed. The performance of the proposed algorithm is demonstrated by simulations in next Section.

4. **Simulations**

To test the proposed method, we assumed cellular CDMA system with 9 cells. The number of users changes from 3 up to 100. Each user has been assigned a data rate from the set {15,30,60,120,240,480,960}Kb/s. The chance to assign one data rate from the rate set is equally likely. The assigned data rates are assumed to be the minimum required data rates for users, i.e. it is not allowed to be decreased. In each case we compute the best removed user using the optimum procedure (6)-(7) and also using the proposed heuristic method in Section (3). In many cases both methods give same results. Even in cases where the removed user number is different, we found that the achieved gain difference (7) is very close in both methods. Figures 1 shows that the **DMRR** algorithm removes the same user as the optimal procedure in about 70% of cases. Figure 2 shows that the achieved gain (7) for both the optimal procedure and the heuristic algorithm. It is clear that both methods are almost identical. This means that even if the removed user is not the optimum one but his impact on the network is very close to the optimum.

In second simulation 100 users have been assumed in an area contains 9 base stations. The same set of data rates as pervious has been assumed. The target SNR (target bit energy to noise power spectral density ratio) for all users is changed from 0.5 dB up to 18 dB. The number of removed connections is computed using the optimal procedure and the proposed **DMRR** algorithm. The results show that the **DMRR** method is close in terms of the number of removed connections to the optimal but at about 1 % of computation time as shown in Figures 3 and 4. The computation time is in minutes (the simulations have been done using Matlab on a PC with 2.2GHz Celeron processor).

5. CONCLUSION

In case of congestion the RRM tries first to reduce the data rates of users. If each user is working at his minimum required data rate and the system is still in congestion then one or more users should be removed from the congested network. New simple and efficient heuristic removal algorithm has been proposed in this paper. Our proposed algorithm is heuristic and it is based on removing the user(s) with largest value of transmitted power and data rate multiplications. The simulations show that this very simple and distributed procedure gives a very close performance to the very expensive optimal removal procedure.

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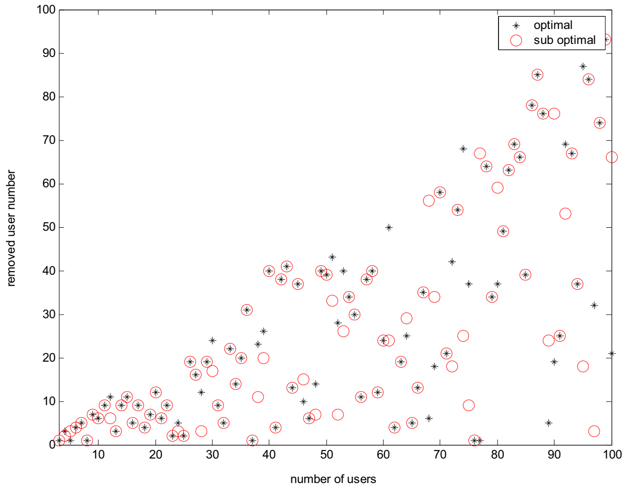

Figure 1. The removed user number with number of users

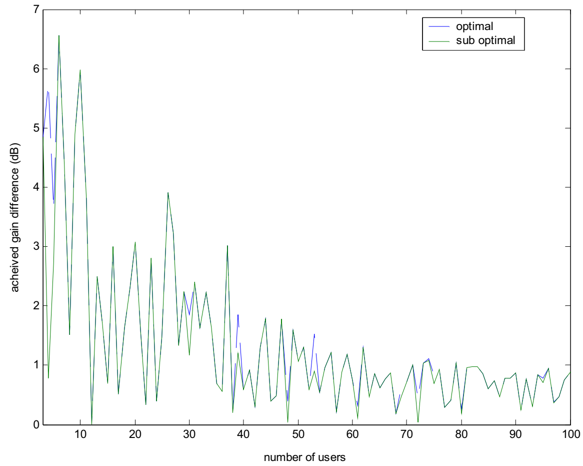

Figure 2. The achieved gain with number of users

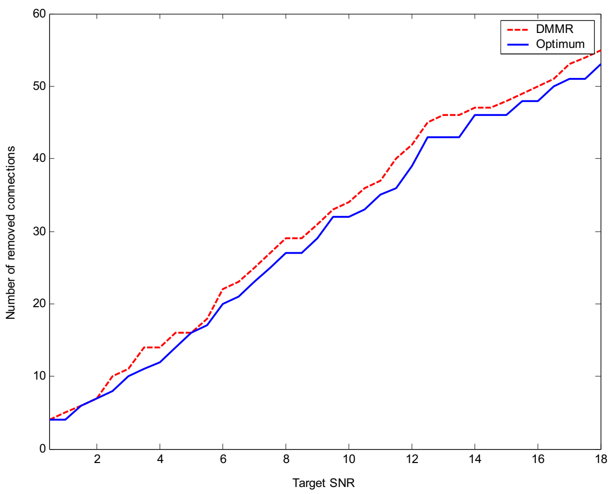

Figure 3. The number of removed users with target SNR.

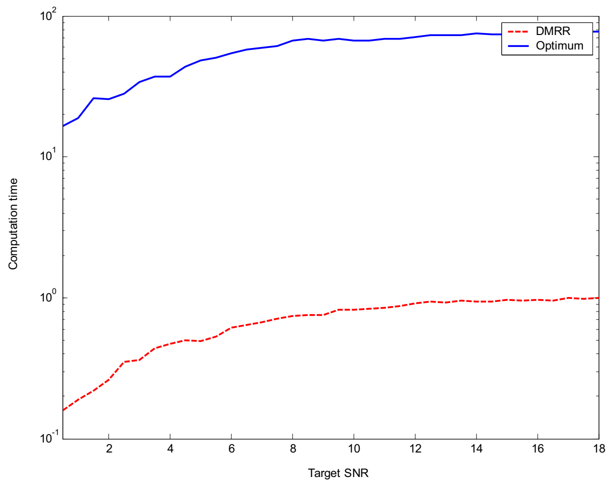

Figure 4. The computation time with target SNR.