Improving Fairness for Pedestrian Users of CDMA-HDR Networks

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***Abstract* – In this paper an approach to improve throughput and fairness for pedestrian users of CDMA-HDR networks is given. The advantages of using more accurate estimation of the SINR combined with H-ARQ in Cellular Data Networks, and some simulation results obtained with an available online simulator are given, too.**

***Keywords* – Cellular Data Networks, Fairness, SINR estimation, and Simulations.**

I. INTRODUCTION

Improving throughput and fairness in Cellular Data Networks is a problem of present interest. In these networks, time is divided into many time slots and each wireless terminal-WT is transmitting packets (to a base station). WTs use one or more time slots to transmit their payload, but each time slot can only accommodate one WT. Multiple WTs are accommodated using the time division multiple access-TDMA technique. As a result, each WT can use the maximum power of the entire base station-BS. In the wireless mobile environment, the RF condition changes significantly with time. When the RF condition is good, little coding protection is needed and modulation with high constellation can be used, making it possible to transmit at a high data rate in a given timeslot. The data from each timeslot are scrambled and spreaded using a computer generated pseudo-random - sequence (chip) unique to the sector of cell, i.e. Code-Division Multiple Access- CDMA. Cellular Data Networks- CDNs combine the advantages of both techniques- TDMA and CDMA. This combination is well suited to the bursty nature of packet data, as well as has the advantage of being able to have frequency reuse in every sector.

CDNs as CDMA systems are known to be interference limited, which means that their capacity can be increased by reducing the minimum required (for stable reception of data at the receiver) energy of signal with a given Signal to Interference and Noise Ratio-SINR. The SINR is a function of several factors such as path loss, shadowing, fading, noise, and intercell interference.

Such CDNs, as CDMA-HDR (High Data Rate), 1xEVDV (1x Evolution for High-Speed Integrated Data and Voice) , and other systems realize procedures for power control [1]: The WT measures the SINR of the received signal through the pilot channel and sends feedback to the BS; Based on the feedback from the WT, the BS adjusts its transmitted power level.

The Hybrid Automatic Repeat Request- H-ARQ (or more sophisticated Hybrid ARQ/FEC) is usually used to improve data throughput [4] and to allow for early packet termination. The general procedure of the H-ARQ is as follows: The packet is coded, interleaved, added CRC and formed into subpackets that are transmitted. The receiver decodes the packet and checks the CRC. If the CRC check passes/ does not pass, an acknowledgment /negative acknowledgment is sent back to the transmitter. Early packet termination refers to a successful reception of a packet before the nominal packet duration when the channel condition is good. In H-ARQ, the information bits are conveyed using several subpackets. If the packet can be decoded correctly before all the subpackets are transmitted, the packet transmission is terminated early and there is no need for additional transmissions. The repetition of the packet bits in the subpacket is accomplished by means of channel coding to obtain further coding gain. To allow time for the WT to process each subpacket and feed back the information to the base station, each subpacket is transmitted disjointly in time. In terms of energy, H-ARQ can be thought of as a scheme where additional energy for each subpacket is transmitted until the required SINR for the entire packet is reached [1- 4]. The effect of H-ARQ is quite similar to that of the fast power control technique since it minimizes the total interference to other WTs by controlling the power used to transmit packets. The H-ARQ is used to improve network performance in presence of inter-cell interference [5].

II. IMPROVING THROUGHPUT AND FAIRNESS

A. Background

The signal received by a WT over the forward link in a cellular data network contains interference from the neighboring base stations. In Fig. 1 is depicted WTs in some sectors of cell C receive inter-cell interference from corresponding sectors of cell C' and cell C''.

In [5], Mhatre et al. study the impact of network load in the neighboring sectors on the inter-cell interference in a cellular data network. The observation that signal received by a WT over the forward link contains interference from the neighboring base stations is used by the terminal to predict its SINR more accurately.

Also, It is shown that the SINR is function of signal amplitude-A, width of pulse- Tc (chip) , the channel gain from

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the base station of the interfering sector to the terminal- G_i, and the probability that a time slot on the forward link of i-th sector is busy- ρ_i.

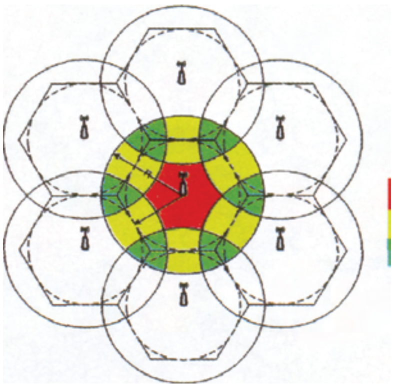

Fig. 1. Interference example.

Nowdays, in the actual implementation of CDMA-HDR [5], the BSs are GPS-synchronized and all the BSs transmit their pilot signal at the same time. Hence, the SINR measured by the terminals contains the worst case inter-cell interference, since the interfering signals are transmited constantly during the measurement phase:

$$SINR' = \frac{G_0^2 A^2 T_C}{\frac{1}{3} A^2 T_C (G_1^2 + G_2^2) + 2N_0} \tag{1}$$

The SINR given by (1), is a function of G_i, and given by:

$$G_i^2 = cd_i^{-n} .10^{\xi_i/10} .W_i^2 \tag{2}$$

In (2), the first term in the product is deterministic (for a fixed WT location), and corresponds to path loss, while the second term is a random variable corresponding to lognormal shadowing loss. Here, ξi is a Gaussian random variable with mean 0, and variance σ_G. Shadowing is correlated over each time slot depending on the speed of the WT as per Gudmundson model [6]. Last term- Rayleigh fading is accounted through Wi.

However, If the terminal has the information about the network loads in all the sectors that are in its active set, it can calculate the actual SINR'':

$$SINR'' = \frac{G_0^2 A^2 T_C}{\frac{1}{3} A^2 T_C (G_1^2 \rho_1 + G_2^2 \rho_2) + 2N_0} \tag{3}$$

Thus, using more accurate estimation of the SINR, WTs will be able to improve data throughput.

Moreover, H-ARQ also improves throughput, even in spite of initial conservative SINR estimates [5], because as mentioned above, H-ARQ adjusts to network loading in the adjacent sectors.

B. Fairness

The classical index of fairness displays level of satisfaction of each user/WT, respectively fair sharing of the network resources, and is given by:

$$Fairness = \left(\sum X_i\right)^2 / n \sum X_i^2 \tag{4}$$

So, Fairness =1 speaks of quite fairness sharing of the network resources between users, then and Fairness =0 corresponds to absolutely opposite situations [7]. The performance metric is based on data throughput (X_i).

It is expected that more accurate initial estimation of the SINR and H-ARQ can improve throughput and fairness. In next section it will be verified through simulations whether these improve the fairness.

III. SIMULATION RESULTS

We present simulation results of fairness when three WTs are served over the forward link, as run two sets of simulations. In the first set, all WTs use (1) in order to estimate SINR, and H-ARQ for early packet termination (Primary Scheme), while in the second set, all WTs use (3) to estimate SINR, and also use H-ARQ (Secondary. scheme).

Simulation parameters are listed in Table I, and have been taken from [5]. Each simulation is run for 20,000 time slots, and 600 independent simulations are run to gather WT throughputs within 90% confidence interval. The WT location is selected so that the terminal is equidistant from the two interfering base stations. The locations from the serving base station of WTs are selected to be $0.4R_0$, $0.7R_0$ and R_0. The cell radius R is 1 Km. Simulations use ITU path loss models for pedestrian WTs with velocity- 3 kmph.

TABLE I
SIMULATION PARAMETERS

Carrier frequency, fo	2000 MHz
Log-normal Shadowing variance, σ_G	10 dB
Shadow correlation distance	20.0 m
Noise spectral density, No	-174 dBm/Hz
A, amplitude of transmit waveform (base station transmit power of 15W)	5.48
Chip duration, Tc (1.25 Mcps)	0.8 us
Radius of the sector, R	1 Km
R_0 for 90% cell coverage	0.95R = 0.95 Km
Miscellaneous gains: antenna gains, body loss, cable loss	15.2 dB
Building penetration loss, (only for pedestrian WTs)	12 dB
Pedestrian path loss in dB, (f_0 in MHz, d in Km)	$30\log_{10}(f_0) + 49 + 40\log_{10}(d)$

In all our simulations, although the time-varying shadowing and fading, it is assumed that the WT location remains unchanged during the course of the simulation. In all the simulations, for simplicity, it is assumed that the network loads in both the interfering sectors are the same, i.e., ρ1 = ρ2, and varied ρ to study the fairness of Primary (ρ1 = ρ2 =1) and Secondary Schemes (ρ1 = ρ2 = ρ) for different network loads in the interfering sectors.

TABLE II
FAIRNESS OF PRIMARY SCHEME

ρ	X_1	X_2	X_3	Fairness
1.0	991	423	149	0.687252
0.9	999	428	151	0.689400
0.8	1007	432	153	0.690167
0.7	1012	436	155	0.691723
0.6	1018	439	158	0.693303
0.5	1023	442	160	0.694448
0.4	1027	445	162	0.695846
0.3	1034	450	165	0.697832

TABLE III
FAIRNESS OF SECONDARY SCHEME

ρ	X_1	X_2	X_3	Fairness
1.0	991	423	149	0.687252
0.9	992	432	156	0.696332
0.8	990	443	163	0.705844
0.7	987	453	172	0.716467
0.6	985	468	182	0.728971
0.5	980	480	193	0.741667
0.4	973	496	208	0.758444
0.3	963	517	228	0.780033

The tables 2and 3 present the throughput (kbps) received by each WT as a function of the interfering network load under the both schemes for pedestrian model. Table 2 gives the indexes of throughput and fairness for standard CDMA-HDR networks (Primary Scheme). In columns titled as X1, X2, and X3 are presented end to end throughput for WTs 1, 2, and 3. In the last column is calculated the indexes of fairness using (4). Simulation results for Secondary Scheme are given in table 3. Note that as the interfering network load decreases, both the schemes result in higher throughput for WTs 2 and 3. This is because both the schemes are designed to improve the throughput of a WT when the inter-cell interference is lower. However this benefit is especially more pronounced for WTs located near the cell boundary (WTs 2 and 3).

Figure 2 shows the fairness as a function of the interfering network load under Primary and Secondary Schemes for pedestrian users (See respectively table 2, and table 3).

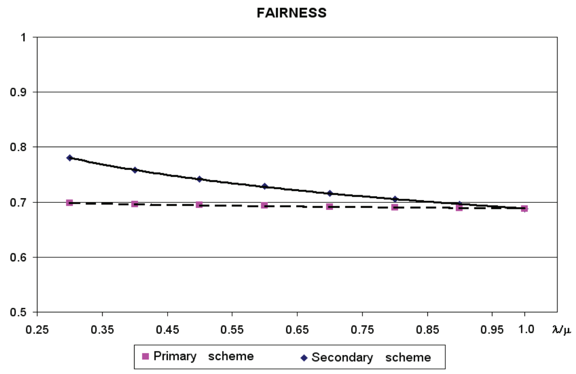

Fig. 2. Fairness of Primary and Secondary Schemes

Fairness of Primary Scheme is worse then Secondary Scheme. This can explain with fact, that the Secondary Scheme benefits the WTs located far from the serving base station, as well as penalizes near located WTs. One can compare throughput received by WS1 in tables 2 and 3, and see that unlike Primary Scheme, where the throughput of WT 1 increases with decreasing network load, in Secondary Scheme, the throughput of WT 1 decreases with decreasing network load. As it has been shown above proposed mechanism (Secondary Scheme) is better than standard CDMA-HDR, taking on account throughput and fairness.

IV. CONCLUSION

In this paper the advantages of using more accurate estimation of the SINR combined with H-ARQ in Cellular Data Networks, as well as some simulation results obtained with an available online simulator [5] are given.

REFERENCES

[1] Dimitrov, D. Communication systems in medicine, hand book, TU-Sofia, Bulgaria, 2005.
[2] Dimitrov D.,Georgieva V.,A media system for telemedicne, Proceedings pp.83-84, 46 IWK 2001, TU-Ilmenau, Germany
[3] Dimitrov D., Velchev Y., Communication Protocol for Medical Mobile Network, Proceedings of 48. Internationales Wissenschaftliches Kolloquium, September 22-25 2003, Ilmenau, Germany
[4] Lee K. and Samuel C., Analysis of a Delay-Constrained Hybrid ARQ Wireless System, IEEE Transactions on Communications, Vol. 54, No. 11, November 2006, pp.2014- 2023
[5] Mhatre V. et al., Impact of Network Load on Forward Link Inter-Cell Interference in Cellular Data Networks, IEEE Transactions on Wireless Communications, Vol. 5, No. 12, December 2006, pp. 3651-3661
[6] ITU-MTR M.1225, Guidelines for Evaluation of Radio Transmission Technologies for IMT-2000, 2000.
[7] Осипов Е.А., Проблемы реализации надежной передачи данных в самоорганизующихся и сенсорных сетях, ISSN 0013-5771. сп. "Электросвязь", № 6, 2006, с.29- 32.
[8] Valentin Hristov, Dimiter Dimitrov, Distance learning system of low frequency magnetic field and beatdown problem, p.77-84, Proceedings of the Technical University –Sofia, v.52/2003
[9] D.Dimitrov D., Georgieva V. ,Information system for telemedicine pp.343-347 Proceedings of 12th European EAEEIE conference May ,14-15, 2001,Nancy, France