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Time correlation of intercell to intracell interference ratio in W-CDMA network

F. Adelantado, O. Sallent, J. Pérez-Romero, and R. Agustí

***Abstract*—W-CDMA performance is tightly coupled to the amount of interference in the air interface and eventually depends on many strongly interrelated system parameters that need to be suitably managed through radio resource management (RRM) strategies in order to achieve a high efficiency. Interference characterisation in terms of average and standard deviation, which are suitable for radio network planning, may not suffice for a proper RRM design because of its inherently dynamic nature. The time correlation of the interference and the main system level parameters affecting its dynamics are raised: shadow fading, mobile speed, traffic characteristics and cell load.**

I. INTRODUCTION

W-CDMA access networks provide an inherent flexibility to handle the provision of future 3G mobile multimedia services with different QoS guarantees. In W-CDMA-based systems interference becomes one of the most important aspects to take into account when planning a network and has a key impact on the network performance. Interference can be divided into intracell ($I_{intracell}$, generated by users within the serving cell) and intercell interference ($I_{intercell}$, generated by users from the rest of cells). Focusing in the uplink direction, in many studies the intercell to intracell interference factor, $f = (I_{intercell}/I_{intracell})$, has been characterised by means of the average and standard deviation [1–3]. Nevertheless, it is noted that first-order statistics are valuable when analysing static situations, as in the case of radio network planning, but they may not suffice for dynamic network evaluation as in the case of radio resource management (RRM) strategies.

For a given network deployment, RRM strategies define the way radio resources are dynamically managed to meet the instantaneous demand of the users moving around the network. RRM functions have to guarantee a certain target QoS, to maintain the planned coverage area and to offer a high capacity while using radio resources efficiently. RRM includes (i) power control, that maintains the radio link level quality by adjusting the downlink and uplink powers. (ii) Handover control, that maintains the radio link quality and minimises the radio network interference by optimum cell selection. (iii) Admission control, that decides whether a request to establish a radio access bearer (RAB) is admitted in the RAN or not. It is used to maintain stability and to achieve high traffic capacity. (iv) Packet scheduler, that schedules radio resources for non-real-time radio access bearers. The traffic load of the cell determines the scheduled transmission capacity. (v) Load control, in overload situations, performs recovery actions by using the functionalities of power control, admission control, packet scheduler and handover control.

All these RRM strategies implemented in the form of practical RRM algorithms use interference measurements. Since these algorithms are executed continuously, it is important to consider in the algorithms' definition the time correlation of the interference patterns arising in the network to decide suitable measurement periods.

As a particular example, admission control principles use the load factor, η, and the estimate of the load increase that the establishment of the new bearer request would cause in the radio network. The load factor is a measurement of the theoretical spectral efficiency of a WCDMA cell [4]:

$$
\begin{aligned}
\eta &= \left(\frac{1 + I_{intercell}}{I_{intracell}}\right)\sum_{i=1}^{n}\frac{1}{\frac{SF_i}{(E_b/N_0)_i}+1} \\
&= (1+f)\sum_{i=1}^{n}\frac{1}{\frac{SF_i}{(E_b/N_0)_i}+1} < 1 \qquad (1)
\end{aligned}
$$

where SF_i is the ith user spreading factor, $I_{intercell}$ is the intercell interference, $I_{intracell}$ is the total received own-cell power at the base station, $(E_b = N_0)_i$ is the target quality level for the ith user and n is the number of transmitting users.

For implementation, RRM policies can be divided into modelling based and measurement-based policies [5]. In any case, a RRM algorithm implies a control of the load factor which is influenced by f. The better the estimation of f the better the estimation of η. Since interference in a W-CDMA network varies with time, the purpose of this Letter is to study the time correlation of the interference patterns arising in the network dynamics and to point out the main system level parameters affecting this variability. The results presented may be useful for different dynamic RRM strategies, as for example admission control as stated above, which are expected to be very important for final optimisation of 3G networks [6]. In particular, to acquire a better knowledge of f variations, the main parameters to be analysed are standard deviation for shadowing fading, mobile speed, service characteristics (i.e. traffic generation pattern) and cell load level (number of active users).

II. SIMULATION MODEL AND RESULTS

A multi-user, multi-cell and multiservice system level simulator using the Opnet tool platform has been developed for performance evaluation [7]. This simulator is fed with statistics obtained from an off-line link level simulator for block error rate (BLER) characterisation, including the effects of a 1/3 rate turbo code. The scenario used to obtain the results is composed of seven cells with radii 500 m. Mobile users are uniformly distributed and move at constant speed. The propagation model is defined in [8]. Two possible services have been considered: videophone (as a representative conversational service) and web browsing (as an example of a bursty interactive service). Traffic models and RAB for supporting each service are taken from [9]. Results are shown in terms of the autocovariance function, which is no more than subtracting the autocorrelation function the square of the average value [10]. This is done because average values may be different for different cases and the main interest is to study the time-varying nature of the interference, which is also retained with the autocovariance.

III. IMPACT OF PROPAGATION ENVIRONMENT (SHADOW FADING)

Fast power control is performed in W-CDMA systems to control interference. E_b/N_0 is theoretically maintained at the base station during the whole connection. Any increase or decrease in transmitted power from own cell users has no effect on the serving base station (intracell interference) but it has an impact on adjacent base stations (intercell interference). To analyse the behaviour of f, different values of standard deviation s for shadowing fading have been considered. Fig. 1 shows that the higher the deviation, the faster the correlation function decreases. Therefore, a high deviation value is translated into faster variations of the intercellular interference and, of course, f variations. Additionally, correlation function reaches an asymptotic level, and this level is lower for σ=10 dB than for σ=4 dB.

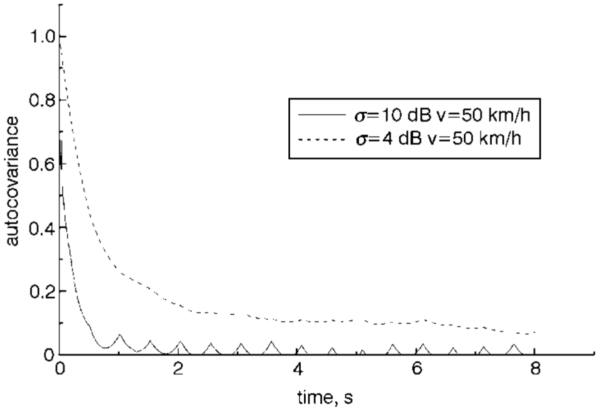

Fig. 1. f autocovariance function for different shadow fading levels.

IV. IMPACT OF MOBILE SPEED

The higher the mobile speed, the more variant the radio channel. Similar to the shadowing study, variations in the environment translate into variations in the interference. This is shown in Fig. 2. The highest f correlation values are associated with the situation where existing users are pedestrian (3 km/h). In this case, the scenario suffers few changes because of the low speed, while in the case where users are vehicular (50 km/h) correlation decreases very fast. It can be observed that for vehicular users correlation decreases to 50 in only 60 ms.

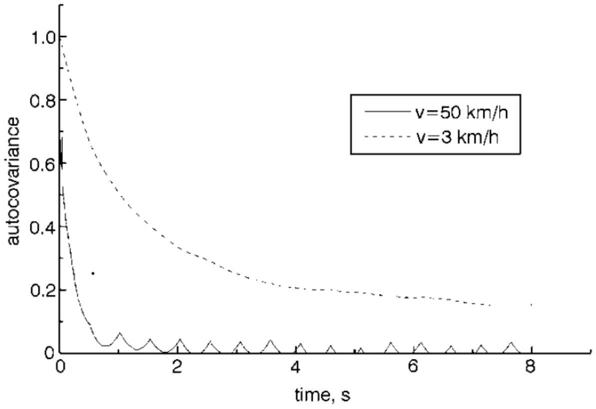

Fig. 2. f autocovariance function for different mobile speeds.

V. IMPACT OF TRAFFIC CHARACTERISTICS

Interference is related to the number of simultaneous users in the network (i.e. users transmitting at a given frame). This number eventually depends on the radio network access mechanism but is also strongly dependent on the traffic generation process. For W-CDMA-based networks, the burstiness of the traffic sources has a direct impact on the network performance, even for circuit switched transmissions. This influence will also be reflected in the variability observed in f since this is related to the amount of interference instantaneously received.

Since conversational users have a constant bit rate (videophone), their contribution to global interference is expected to be much more constant than that of variable rate users (web browsing). To compare the system loaded with different services in fair conditions, the average system throughput of web users is the same as videophone users. Fig. 3 shows results for pedestrian users (3 km/h) and a shadowing deviation equal to 10 dB. Differences are clearly noticeable. Web users cause faster f variations than conversational users.

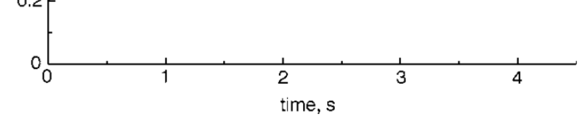

Fig. 3. f autocovariance function for different services (at throughput of 1.28 Mbits/s).

VI. IMPACT OF CELL LOAD

Interference variability depending on the cell load level is also considered. For this purpose, two different numbers of videophone users are considered in Fig. 4. No relevant differences are found in this case.

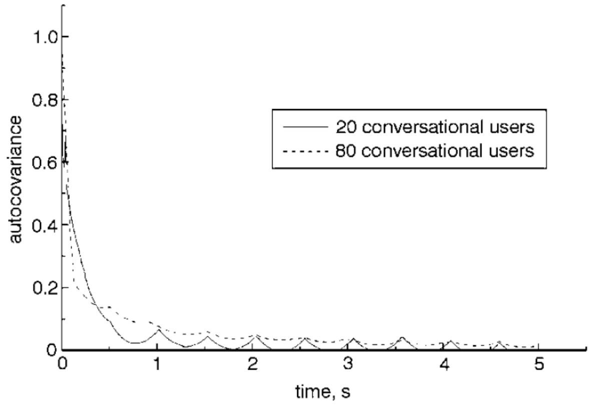

Fig. 4. f autocovariance function for different load levels.

Table 1 shows the time required for the autocovariance function to half (half the normalised value at the origin) as a reference criterion to consider how much time is required to face significantly different interference conditions and as a summary of some of the above results. Note that this criterion provides some parallelisms between how the time varying nature of the propagation radio channel is quantified (the concept of time coherence of the channel [11]) and how the time varying nature of the interference in a W-CDMA network is quantified. It can be observed that for a quite static scenario (slow mobiles, 3 km/h, moderate shadow fading, σ=4 dB, and continuous traffic, conversational users) interference remains the same for large periods of time. For scenarios with more obstacles (σ=10 dB shadowing) the reference period is $\sim$1 s. The strong impact of the traffic pattern becomes clear when web traffic is considered, as the period reduces to values as low as 20 ms. Also, if mobiles move faster (50 km/h) interference varies quite rapidly, of the order of 60 ms.

Scenario	**Time (ms)**
v=3 km/h	3200
σ=4 dB	
20 conversational users	
v=3 km/h	1020
σ=10 dB	
20 conversational users	
v=3 km/h	20
σ=10 dB	
160 web users (same throughput as 20 conversational users)	
v=50 km/h	60
σ=10 dB	
20 conversational users	

VII. CONCLUSIONS

RRM strategies have to guarantee a certain target QoS to maintain the planned coverage area and to offer a high capacity while using radio resources efficiently. Thus, unlike 2G systems, where such a dynamic network control is not envisaged, it is important to characterise the time-varying nature of interference. We have studied the major issues affecting the time correlation of interference: shadow fading, mobile speed, traffic characteristics and cell load level. Results obtained allow quantifying of interference dynamics under different scenarios.

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REFERENCES

[1] T. Luo, S. Pasupathy and E. S. Sousa, *Interference control and chip waveform design in multirate DS-CDMA communication systems*, IEEE Trans. Wirel. Commun., 2002, 1, pp. 56–66.

[2] R.G. Akl, *et al.*, *Multicell CDMA network design*, IEEE Trans. Veh. Technol., 2001, 50, pp. 711–722.

[3] A.J. Viterbi, *et al.*, *Other-cell interference in cellular power controlled CDMA*, IEEE Trans. Commun., 1994, 42, (2/3/4).

[4] H. Holma and A. Toskala (Eds.), *W-CDMA for UMTS*, John Wiley and Sons, 2000.

[5] V. Phan-Van and S. Glisic, *Radio resource management in CDMA cellular segments of multimedia wireless IP networks*, WPMC'01 Conf. Procs., Aalborg, Denmark, 2001.

[6] O. Sallent *et al.*, *An emulator framework for a new radio resource management for QoS guaranteed services in W-CDMA systems.',* IEEE J. Sel. Areas Commun., 2001, 19, pp. 1893–1904.

[7] J. Pérez-Romero, O. Sallent and R. Agustí, *Impact of user location in W-CDMA downlink resource allocation.*, ISSSTA'02 Conf. Proc., Prague, Czech Republic, September 2002.

[8] 3GPP, *TR 25.942 v.2.1.3, 'RF system scenarios'.*

[9] 3GPP, *TS 34.108 V.3.2.0, 'Common test environment for user equipment. Conformance testing'.*

[10] A. Papoulis, *Probability, random variables, and stochastic processes*, McGraw-Hill, 1991.

[11] J. G. Proakis, *Digital communications*, McGraw-Hill, 1995.