Evaluation of Traffic Mixing in the UTRA for Shadowed and Non-Shadowed Environments

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Abstract: This paper investigates the impact of shadow fading on the UTRA QoS performance when operating under mixed service conditions. Results are presented that characterise the behaviour of both circuit switched (i.e. 8kbps speech) and packet switched (144 kbps non-real time data) services. The fast dynamics of the shadow fading induce a large number of handovers and hence a large number of dropped calls due to blocked handover.

1. Introduction.

UTRA will provide a wide range of different bit-rate bearers to support from high data rate services to low data rate services, packet switched and circuit switched, and their combinations (multimedia services). Extensive specification work has been carried out at the standardisation bodies on the detailed description of these bearers and their performance through link level simulations. The system capacity for different bearers has been investigated through system simulations [1, 2]. However, few results are available on combining different bearers and traffic dynamics [1, 3], and its impact on the overall system performance. The radio resource management (RRM) algorithms employed will substantially affect these results. These algorithms are being left open in the specifications for proprietary solutions to allow for system differentiation and continuous system optimisation [4].

This investigation was carried out using a proprietary UTRA system simulator developed at the University of Leeds as part of the IST FP5 project SOQUET. The simulator allows experiments to be carried out at the system level for the characterisation of the UTRA under different configurations and operating conditions, and to determine the sensitivity of the system performance to certain important parameters.

Shadow fading has an important influence on the dynamics of the radio pathloss that is reflected by a considerable impact on the diversity and handover processes and, therefore, on the system's admission dynamics and outage control. Therefore, shadow fading has been implemented in the simulator and this implementation is described and evaluated in Section 2.

2. System Level Simulator.

The simulator models the uplink channel of the frequency division duplex (FDD) component of UTRA. The uplink simulation consists of dedicated channel data transmission and signalling being sent from the mobile station (MS) to the radio network subsystem (RNS), and signalling sent from the RNS to the MS. A multi-cell layout is simulated consisting of a cluster of cells in a wrap-around configuration which is adaptable to the test environments proposed in [5]. Base stations are located directly by a set of coordinates that can be placed in realistic arrangements. Multiple layers of cells can also be accommodated within this scheme. Simulation experiments are presented for the Vehicular A (low multipath delay spread) environment, as defined in [5], with one layer of omni-directional macro-cells. These are deployed on a regular cluster of 19 hexagonal cells, so that each cell has two tiers of independent interfering cells around it. This will ensure a low correlation level of inter-cell interference. Each cell has independent traffic generation set by a Poisson distributed call arrival process for each type of service, enabling unequal cell traffic load distributions to be simulated.

The users generating these calls are uniformly distributed in the cell, moving at a constant speed on a pseudo-random semi-directed trajectory. Realistic traffic movement patterns can be over-layed on the cell location map. The simulation sample period is 10 ms corresponding to a dedicated traffic channel (DTCH) frame. The mobility model for the vehicular environment case is defined by the following parameters: speed = 120 Km/h, probability to change direction at position update = 20%, maximum angle for direction update = 45 degrees (± 22.5 º) and period of position update (T_posUpdt) = 500 ms.

In principle, fast closed-loop, perfect power control has been assumed closely tracking the fast fading up to the simulated mobile station speeds. The shadow fading model uses a simple decreasing correlation function to model the correlation properties of the channel. Given a user velocity *v* (m/s) and signal strength (pathloss) measurement period *T* (s), the correlation of the pathloss between the samples is given by

$$R_{PL}(k) = \sigma^2 a^{|k|}$$

where $R_{PL}(k)$ is the correlation with sample *k*, σ is the variance of the shadow fading, and the correlation coefficient *a* is given by $a = \varepsilon_D^{vT/D}$. The term ε_D is the correlation between two points separated by a distance *D* and is provided in [6] calculated by curve fitting to a body of measurements.

A white Gaussian process filtered through a first-order filter with a pole at *a* will produce a shadow fading component with a normal distribution in dB as required. Such a filter, represented in Figure 2, can be described by the following difference equation.

$$y_n = x_n + a \cdot y_{n-1}$$

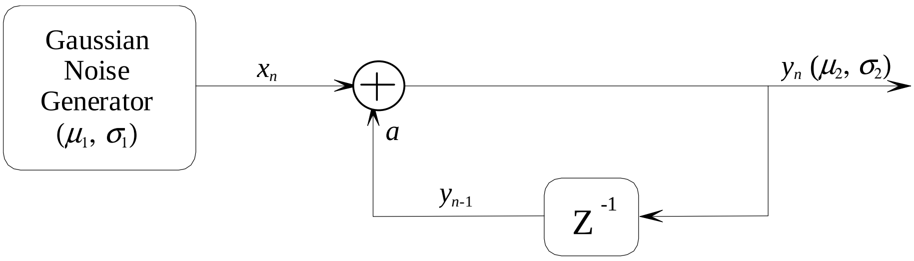

Fig. 1: Block diagram for the shadow fading component generator.

Given that the Gaussian sequence x_n has a mean μ_1 and a standard deviation σ_1, the filter output will have a mean value μ_2,

$$\mu_2 = \frac{\mu_1}{1-a},$$

and a standard deviation,

$$\sigma_2 = \sqrt{\frac{\sigma_1^2}{1-a^2}}.$$

The desired shadow fading component has mean 0, therefore, the Gaussian noise generated, x_n, will have mean $\mu_1 = 0$ and also the mean of the filter output μ_2 will be 0.

The shadow fading will be updated in the UTRA Simulator with user position updating, with a period *T* = 0.5 s. The vehicular user velocity, *v*, is constant at 120 km/h (i.e. 33.3 m/s) and this implies a correlation distance between consecutive samples, *D* = 16.6 m. Looking at the graph provided [6], a distance *D* = 16.6 m corresponds to $\varepsilon_D = 0.97$. The shadow fading standard deviation used, σ_2, as recommended in [5], is 10 dB.

3. System Simulation Results.

The impact of the shadow fading on 8 Kbps Speech and UDD144 services has been evaluated for a cell radius of 2000m with perfect power control determined for mixed traffic conditions. Figures 2 & 3 compare the effect on the performance of the speech service of considering shadow fading. It can be seen how calls start to be blocked at a lower offered load when including shadow fading (around 600kbps of offered load versus 720 kbps without shadow fading) due to the larger average intercell interference introduced by the shadowed calls. The average intracell and intercell interference levels can be seen in Figure 3. They show the intercell interference being consistently larger for the shadowed case and the intracell interference being the same for both cases (as commanded by the power control) though the interference for shadow fading saturates at a lower load. This has the effect of reducing the system throughput.

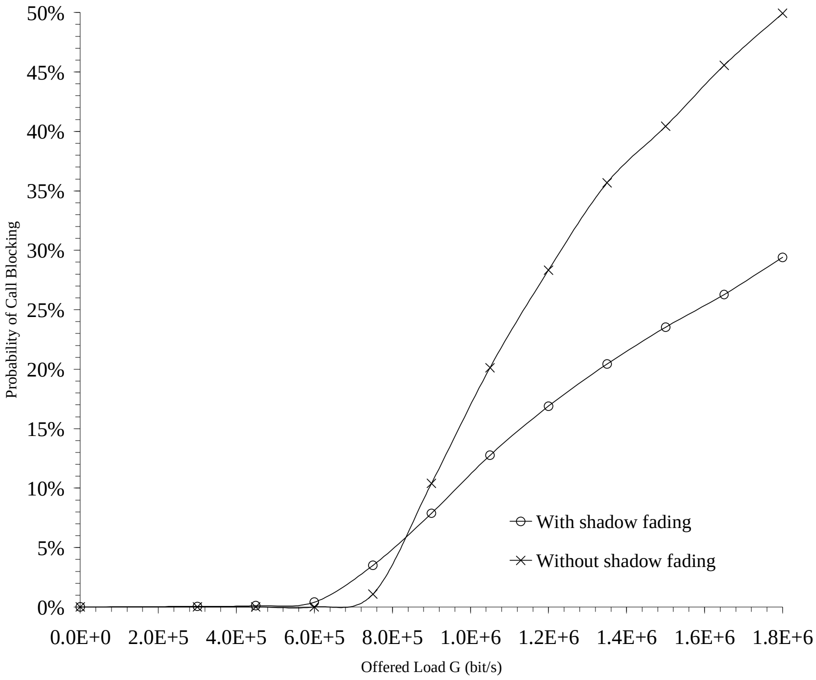

Fig. 2: Impact of shadow fading on Speech service: call blocking vs. offered load

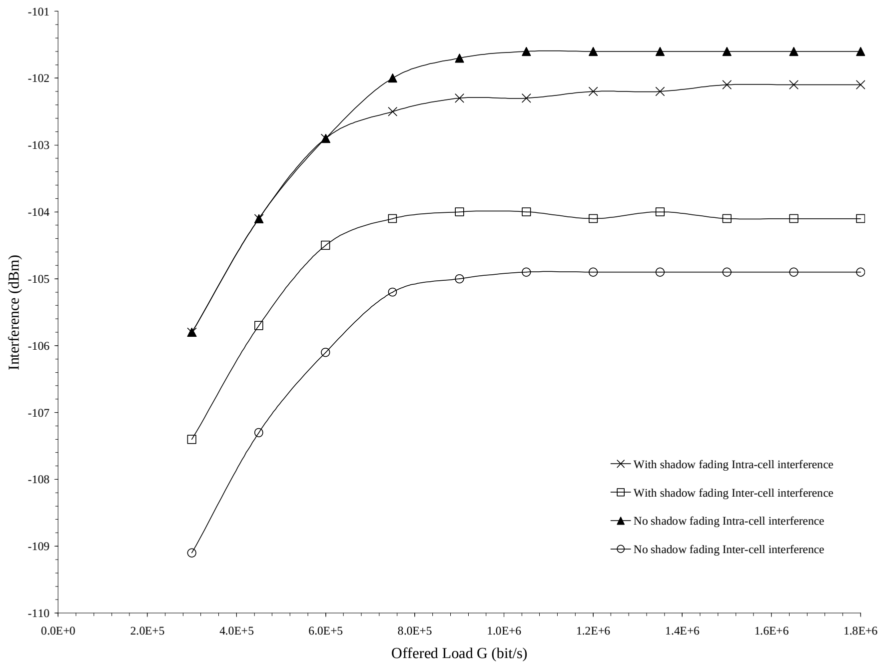

Fig. 3: Impact of shadow fading on 8 Kbps Speech service:
intra-cell and inter-cell interference levels vs. offered load.

In the case of the UDD 144 service, the handover blocking probability for non-shadowing remains low over the offered load range investigated. This is attributable to the fact that the packet call durations are short compared to the cell dwell time thus reducing the natural handover frequency of packet calls. However, when shadow fading is included the number of handovers increases dramatically as shown in Fig. 4. This is attributable to the more frequent degradation of the link quality caused by shadow fading taking place during the call hold time. In other words, the shadowing effect is more dominant that the normal cell pathloss effect. With shadow fading the probability of being handed over is increased even though the mobile may not be close to the cell perimeter.

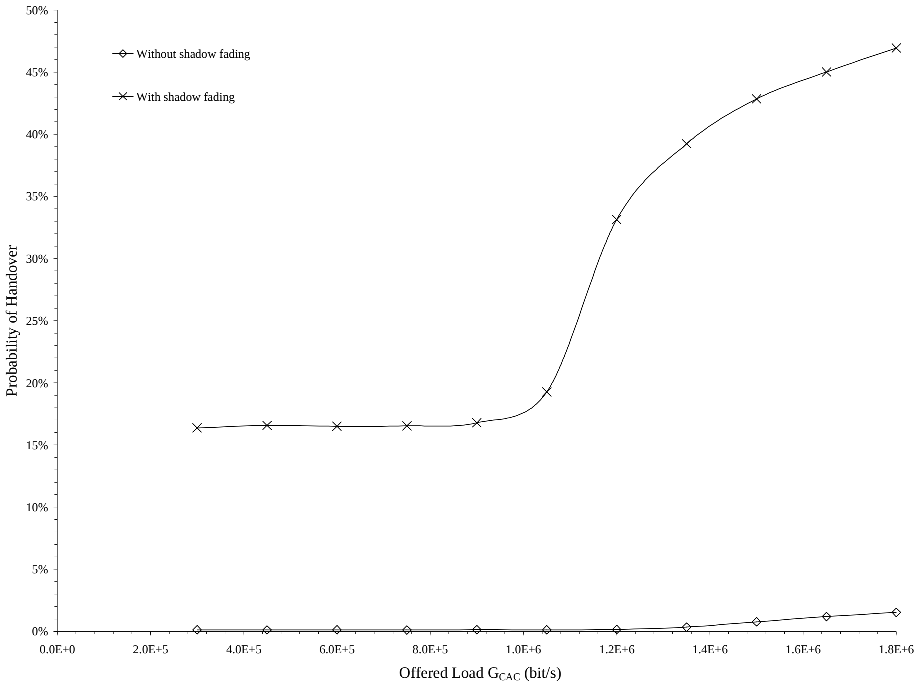

Fig. 4: Impact of shadow fading on UDD 144 service: call handover vs. offered load

4. Conclusions.

A simulation investigation into the impact of shadow fading on UTRA performance under mixed-traffic conditions has been presented in this paper. The pathloss calculated including shadow fading for each user to each neighbour cell generates a much more dynamic intercell interference pattern in the system's interference map. This generates a large number of handovers and with it a two-fold effect on the QoS. On the one hand, since the shadow fading will add positively or negatively to the pathloss, the UE will attempt to handover to that cell with less destructive shadow fading in an attempt to improve quality. On the other hand, by increasing the number of admission control events due to shadowing, the system has more opportunities to block calls in order to control outage dips within a cell. This leads to substantially more dropped calls within the system.

5. References.

[1] ETSI SMG2, "Concept Group Alpha – Wideband Direct-Sequence CDMA (WCDMA). Evaluation Document (3.0)," ETSI SMG #24, Madrid, Spain, 15-19 December 1997.

[2] ETSI SMG2 UMTS-L1 EG, "RTT Revision-Performance Results," *Tdoc SMG2 351/98*, ETSI SMG2 #27, Marseille, France, 21-25 Sept. 1998.

[3] L. Ortigoza-Guerrero and A. H. Aghvami, "A Distributed Dynamic Resource Allocation for Hybrid TDMA/CDMA System," *IEEE Trans. Veh. Technol*., vol. 47, pp. 1162-1178, Nov. 1998.

[4] ETSI SMG2 UMTS-L23 EG, "UMTS YY-21 V0.1.0 • Description of the MAC Protocol," *Tdoc SMG2 094/99*, ETSI STC SMG2 #29, Sophia Antipolis, France, 25-29 Jan. 1999.

[5] ETSI SMG5, "Universal Mobile Telecommunications System (UMTS). Selection Procedures for the choice of radio transmission technologies of the UMTS" (UMTS 30.03, v. 3.0.0).

[6] Gudmundson, M., "Correlation Model for Shadow Fading in Mobile Radio Systems", *Electronics Letters*, Vol. 27, No. 23, November 1991.