

# UPSTREAM INTERCELL INTERFERENCE STATISTICS IN BROADBAND FIXED WIRELESS ACCESS NETWORKS EMPLOYING OR NOT ADAPTIVE POWER CONTROL

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## ABSTRACT

Capacity has become of primary importance in broadband wireless access (BWA) networks due to the increasing demand for multimedia services and the possibility of providing wireless Internet, leading to their standardization by IEEE (802.16, WirelessMAN, WiMAX) and ETSI (HiperMAN). The major factor limiting capacity in such systems is interference originating from adjacent cells, namely, intercell interference. This paper presents a general analysis of intercell interference for a cellular configuration has been suggested in the Cellular Radio Access for Broadband Services (CRABS) Report with a dual frequency and polarization reuse scheme. In this paper, the statistical properties of the carrier-to-interference ratio (*CIR*) in upstream channels employing or not adaptive power control, are presented.

## INTRODUCTION

Broadband Fixed Wireless Access (BFWA) systems are a promising wireless solution to connect fixed users to the backbone network instead of broadband-wired networks. They are point-to-multipoint cellular networks operating at millimeter waves in the 20-50GHz [1,2]. In these frequencies, higher antenna directivities are exploited and greater communication capacities are achieved. At the same time, the radiowave propagation is strongly influenced by rain attenuation [3], which is a major factor limiting the performance of radio links and the cell coverage of BFWA systems. Intrasytem interference, among adjacent cells, in BFWA systems, limits the capacity in the BFWA cellular network for both the downstream (from base station to subscriber) and the upstream (from subscriber to base station). The configuration, which has been suggested in the Cellular Radio Access for Broadband Services (CRABS) Report with a dual frequency and polarization reuse scheme, will be considered here. As far as medium access is concerned, Time Division Multiplexing/Time Division Multiple Access (TDM/TDMA) is adopted, which is consistent with IEEE 802.16 standard [4].

To measure the performance of intercell interference, the carrier-to-interference ratio (*CIR*) must be calculated. In this paper, the upstream interference scenarios are analytically demonstrated taking into account an uplink power control scheme to combat rain attenuation, so every subscriber maintains the necessary Quality of Service within its own cell. The consequences of adopting this fade countermeasure on intercell interference will be thoroughly examined. The proposed analysis examines the statistical properties of the *CIR* focusing on the spatial inhomogeneity of rain attenuation. The lognormal distribution is adopted for the rain attenuation variables, and the convective raincell model is assumed to find the spatial correlation of the microwave paths [5]. The *CIR* is aggravated deteriorated due to differential rain attenuation of two converging links in the case of the employment of an adaptive power control scheme by all the users, while in the special case of not employment or not use of adaptive power control leads to the evaluation of the differential rain attenuation statistics on three converging paths.

Numerical results obtained from the proposed statistical upstream interference analysis for a 25GHz Broadband Fixed Wireless Access Network located in Athens are presented. Some useful conclusions are deduced.

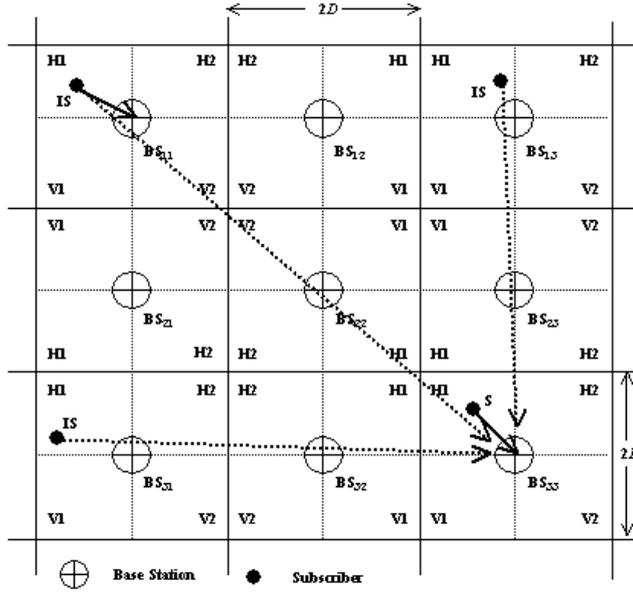


Fig. 1 Upstream intercell interference scenario: Reference base station  $BS_{33}$  receiving the desired signal from subscriber  $S$ , while users in  $BS_{13}$ ,  $BS_{11}$ , or  $BS_{31}$  are possible interferers.

### UPSTREAM INTERFERENCE ANALYSIS

Referring to Fig.1,  $S$ , located in sector H1 of this cell, is the subscriber transmitting the desired signal, while users in sectors H1 of  $BS_{31}$ ,  $BS_{11}$  and  $BS_{13}$  are possible interfering subscribers (IS). A two-level power control scheme is assumed for the upstream links, so that each subscriber maintains the necessary QoS within its own cell. The implications of using this fade mitigation technique on intercell interference will be examined. Therefore, the analysis is separated in two parts: First, it is assumed that rain attenuation  $A_D$  on the desired path is completely compensated for by the adaptive power control scheme, i.e.  $A_D$  takes values within the range of the power control margin  $M_p$ . Then in the second part, the analysis covers the special case when  $A_D > M_p$  which simulates the case of non-employment of adaptive power control.

### Employment of Adaptive Power Control

Positions which cause strong interference are the ones in the corners of the interfering sectors, where the BSs of the ISs are aligned with  $BS_{33}$ . Since it is common in TDMA/BWA networks to separate upstream transmissions not only in time but also in frequency, it is quite rare to have all three ISs in the strong interference positions transmitting simultaneously in the same time slot and frequency sub-channel. Hence, upstream CIR is calculated by considering a single IS at distances  $d_I$  and  $d_W$  from  $BS_{33}$  and from its own BS, respectively. The corresponding rain attenuation random variables are denoted by  $A_I$  and  $A_W$ . The upstream CIR when rain attenuation is within the range of power control is given by

$$CIR = \frac{P_{T,S}(d_D, A_D) G_{T,S}(\max) G_{R,BS} FSL(d_D)}{10^{A_D/10} \frac{P_{T,IS}(d_W, A_W) G_{T,IS}(\theta) G_{R,BS} FSL(d_I)}{10^{A_I/10}}} \quad (1)$$

where  $G_{R,BS}$  is the receiving antenna gain of  $BS_{33}$ , assumed constant over the  $90^\circ$  beamwidth, and  $\theta$  is the angle formed by  $d_I$  (IS- $BS_{33}$ ) and  $d_W$  (IS- $BS_{11}$ ). The dependence of  $P_{T,IS}$  on  $d_W$  and  $A_W$  is due to the upstream power control also assumed for the IS own cell. Writing (1) in a simpler form using the decibel scale, one obtains

$$(CIR) = (CIR)_{cs} - A_w + A_I \quad (2)$$

where the clear sky  $CIR$  term is given by

$$(CIR)_{cs} = [G_{T,S}(\max) - G_{T,IS}(\theta)] - 20 \log \left( \frac{d_w}{d_I} \right) \quad (3)$$

Under the assumptions made,  $CIR$  becomes independent of the position of its own subscribers, depending only on the parameters of the IS. Therefore, the *Acceptable Interference Probability* ( $AIP$ ) is defined:

$$AIP = \Pr \left\{ (C/I) \leq \gamma_{th}, 0.5 \leq A_w \leq M_f \right\} \quad (4)$$

Following a straightforward statistical analysis, the final expression for the  $AIP$  is as follows

$$AIP = \int_{u_{a_s}}^{u_{M_f}} du p_U(u) \left[ 1 - \frac{1}{2} \operatorname{erfc} \left( \frac{u_s - \rho_{nWI} u}{\sqrt{2(1 - \rho_{nWI}^2)}} \right) \right] \quad (5)$$

The limits  $u_{M_f}$ ,  $u_{a_s}$ ,  $u_s$  are determined in [5]. The function  $p_U(u)$  is the pdf of the normal distribution and  $\rho_{nWI}$  is the correlation coefficient between  $\ln A_I$  and  $\ln A_w$ .

In the following Figures 2 and 3 the above methodology is applied for the BWA network located in Athens, Greece. Fig.8 shows the sector distribution of  $CIR$  that  $BS_{33}$  experiences due to interference from an IS in position  $(x,y)$  of the sector  $BS_{11}$ . It must be pointed out that the losses of the  $BS_{33}$ -S link are fully compensated for by the power control scheme adopted. Fig.2 deals with the same problem but for a parallel IS located in sector  $BS_{13}$  interfering with  $BS_{33}$ . From these figures, the main conclusion is that due to the two-level power control scheme assumed, the largest part of interference originates from ISs at the furthest position in their own BS. This is contrary to what would be intuitively expected, that is, nearby interferers would cause stronger interference.

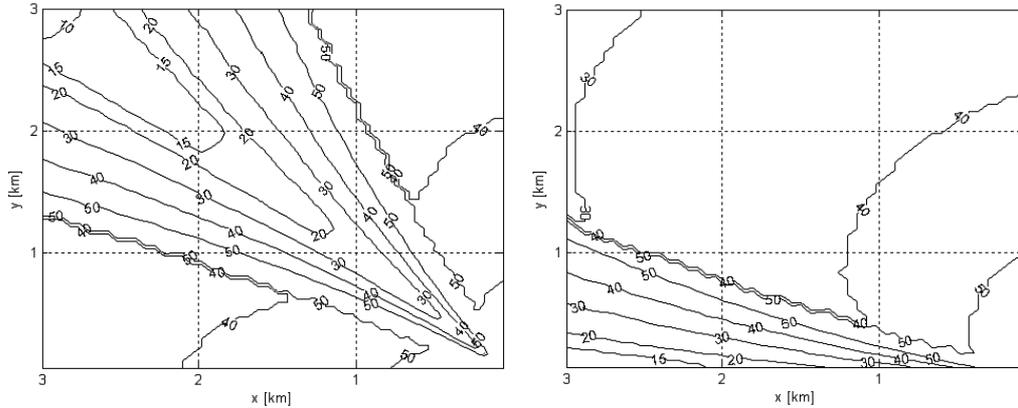


Fig. 2 Diagonal Upstream  $CIR$   $(x,y)$  sector distribution for the LMDS system in Athens for  $AIP=0.001\%$  at a distance  $5\sqrt{2}D$  from  $BS_{33}$  while in Fig. 3 is from parallel interference at a distance  $5D$ .

### Not Employment of Adaptive Power Control

In this section we investigate the case when the rain fading occurring exclusively on the desired path is stronger than the power control capability or there is no power control. This aggravates to an even greater extent the performance of the desired subscriber S. So, it is necessary to take into account the excess attenuation  $(A_D - M_p)$  in the evaluation of  $CIR$ . Then,  $CIR$  becomes a function of three random variables instead of only two  $AIP$  is now defined as

$$AIP = \Pr \left\{ (CIR) \leq \gamma_{th}, M_p \leq A_D \leq M_f + M_p \right\} \quad (6)$$

ensuring that  $A_D$  lies within the range of interest. After a similar straightforward probabilistic analysis, its final expression is

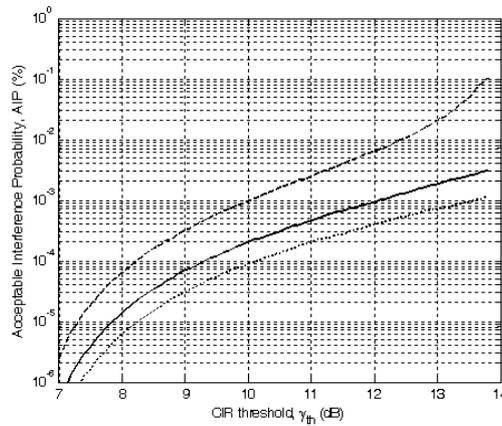
$$AIP = \int_{u_{a_s}}^{u_M} du_D \int_{u_w^{th}}^{+\infty} du_w P_{U_D U_w}(u_D, u_w) \left[ 1 - \frac{1}{2} \operatorname{erfc} \left( \frac{u_I^{th} - \mu}{\sqrt{2}\sigma} \right) \right] \quad (7)$$

where the limit  $u_{a_s}$  is determined from

$$a_s = \begin{cases} M_p, & a_D^{th} < M_p \\ a_D^{th}, & M_p \leq a_D^{th} < M_f + M_p \\ M_f + M_p, & a_D^{th} \geq M_f + M_p \end{cases} \quad (8)$$

As for the calculation of  $u_w^{th}$ ,  $u_I^{th}$ ,  $\mu$  and  $\sigma$ , they are determined employing equations presented in [6].

Fig.4 presents  $AIP$  vs.  $\gamma_{th}$  for this special case for various levels of the power control margin,  $M_p = 0, 3, \text{ and } 5\text{dB}$ . The  $M_p = 0\text{dB}$  curve illustrates as the performance of a subscriber not employing adaptive power control (due perhaps to cheaper or outdated RF equipment) participating in a network where the rest of the users have this option.



**Fig. 10.** Investigating the effect of the power control margin  $M_p$  through  $AIP$  curves.  
..... :  $M_p=5\text{dB}$       ————— :  $M_p=3\text{dB}$       - - - - - :  $M_p=0\text{dB}$

## CONCLUSIONS

Upstream  $CIR$  distributions within a cell sector of Broadband Fixed Wireless Networks have been presented through an analytical propagation model. A general upstream prediction model for intercell interference statistics has incorporated the effect of a finite power control margin. It is quite flexible and can be employed in any location of the world.

## REFERENCES

- [1] H. Sari, "Broadband radio access to homes and businesses: MMDS and LMDS," *Computer Networks*, vol. 31, pp. 379-393, 1999.
- [2] ITU-R Recommendation P. 1410-2, "Propagation data and prediction methods required for the design of terrestrial broadband millimetric radio access systems operating in a frequency range of about 20-50 GHz", 2003.
- [4] <http://www.ieee802.org>
- [5] A.D. Panagopoulos, J.D. Kanellopoulos, "Statistics on differential rain attenuation on converging terrestrial propagation paths," *IEEE Trans. Antennas Propag.*, vol. 51, no. 9, pp. 2514-2517, September 2003.
- [6] A. D. Panagopoulos and J. D. Kanellopoulos "Optimum Utilization of the channel capacity of a dual polarized satellite link suffering from interference due to atmospheric precipitation", 27th Triennial General Assembly of the International Union of Radio Science, p.2175, Maastricht, Netherlands, August 2002.