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UMTS-HSDPA in High Altitude Platforms (HAPs) communications with finite transmitted power and unequal cell's load

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ABSTRACT

In this paper, the performance of HAPs (High Altitude Platforms) UMTS HSDPA (High Speed Downlink Packet Access) is studied for different scenarios and two directions (0° and 30°) within the cell where the network under study is assumed to have 61 cells. It is concluded that, for urban zone users, the effective range is lower than the effective range for users in rural zones. It is shown that in rural zones, the HSDPA mode can support the modulation 16QAM with 7/8 code rate when cells are not fully loaded. For fully loaded rural cells, the 16QAM modulation scheme with code rate of 7/8 cannot be supported. Also, it is noticed that, in urban zones, HSDPA mode can support 16QAM with code rate of 1/2 and QPSK modulation schemes when cells are not fully loaded. For fully loaded urban cells, only QPSK with code rate of 1/2 can be supported.

1. Introduction

There is an insatiable demand for communications services throughout the world, driven largely by the need for Internet access. Wireless offers the only viable provision means in many scenarios, but both terrestrial and satellite systems suffer from fundamental limitations in cost and capacity. One potential delivery method is from High Altitude Platforms (HAPs), which are pilotless solar-powered airships or aircraft operating at an altitude of up to 22 km. HAP may be viewed as either a very low stationary satellite or a very tall radio mast, and can offer communications services with the best features of both.

Airship technology is developing steadily, with commercial applications becoming more of a reality. Wireless communication from HAPs offers considerable potential for new broadband services, for mobile phones and for niche markets such as disaster relief or military where rapid deployment is a key feature.

Wireless communications using HAPS have been proposed world wide due to the many advantages of HAPS system over terrestrial tower-based and satellite systems [1]. Recently, it has been accepted to use HAPS as an alternative means to deliver the third generation IMT-2000 wireless services.

In [2,3], the W-CDMA downlink capacity of HAPs systems is studied using two different power control schemes, where in [3], the capacity is higher than the capacity in [2] because of the modified power control scheme used in [3].

In [4], a method of significantly improving the capacity of HAP communications networks operating in millimetre-wave band is presented.

High Speed Downlink Packet Access (HSDPA) is based on WCDMA evolution, standardized as part of 3GPP Release 5 UMTS specifications. The new modulation method of HSDPA greatly improves the peak data rate and throughput, which enhances spectral efficiency. In addition to these benefits, users will perceive faster connections to services through shorter round trip times. As a result of these enhancements, operators using HSDPA will be able to support considerably higher numbers of high data rate users on a single radio carrier than is possible with any existing 3G technology.

High Speed Downlink Packet Access is a packet-based data service in W-CDMA downlink with data transmission up to 8–10 Mbps (and 20 Mbps for MIMO systems) over a 5 MHz bandwidth in UMTS downlink. HSDPA implementations includes Adaptive Modulation and Coding (AMC), Multiple-Input Multiple-Output (MIMO), Hybrid Automatic Request (HARQ), fast cell search, and advanced receiver design.

In [5], HSDPA concept, channel structure and peak data rates are given for the terrestrial cellular system. In [6], the performance of UMTS-HSDPA in HAPs communications has been studied assuming infinite transmitted power, equally loaded cells and outdoor users.

We have to mention that HAPs are cheaper than common terrestrial and satellite communications. This is due to the fact that

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each one of the HAPs substitutes many terrestrial base stations and dose not has the high cost of lunching and control of the satellite systems.

In this work, we will study the HAPs UMTS downlink performance when the mode HSDPA is used. The signal to noise and interference ratio will be calculated assuming that the indoor users exists on the line of one of two directions within the cell under consideration (0° or 30°) and the transmitted power is finite (which represents the practical case).

The rest of the paper is organized as follows. In Section 2, HAPs HSDPA downlink analysis is given. Numerical results for different HAPs scenarios are shown in Section 3. Finally, conclusions are presented in Section 4.

2. HAPs HSDPA downlink analysis

In Fig. 1, the antenna radiation mask of one of the beams is shown. It can be noticed that four zones can be distinguished, the mainlobe, sidelobes with decaying power and sidelobes with a relative power of −25 and −40 dBc. Let BS_j ($j = 0,\ldots,J$) denotes the base station serving the jth cell, as shown in Fig. 2. For a mobile located at (r,θ) in the reference cell served by BS_0, the carrier-to-noise and interference ratio (CNIR) is given by [7]:

$$CNIR = \frac{G_p P_{ru}}{P_{intra} + P_{inter} + P_N}, \tag{1}$$

where

- G_p is the HSDPA processing gain (Spreading Factor) = 16,
- P_{ru} is the received power of the desired signal of the HSDPA user under consideration,
- P_{intra} is the received intracellular interference,
- P_{inter} is the received intercellular interference,
- P_N is the receiver thermal noise.

The CNIR given by (1) can be rewritten as [2]

$$CNIR = \frac{G_p \kappa P_u G(\psi_0) l_0^{-s} \varsigma_0}{\kappa (P_{T0} - P_u) G(\psi_0) l_0^{-s} \varsigma_0 \phi + \kappa \sum_{j=1}^{J} P_{Tj} G(\psi_j) l_j^{-s} \varsigma_j + P_N}, \tag{2}$$

where

- κ is the propagation loss factor,
- P_u is the power assigned to the HSDPA user under consideration,
- P_{Tj} is the total power transmitted by the cell j,

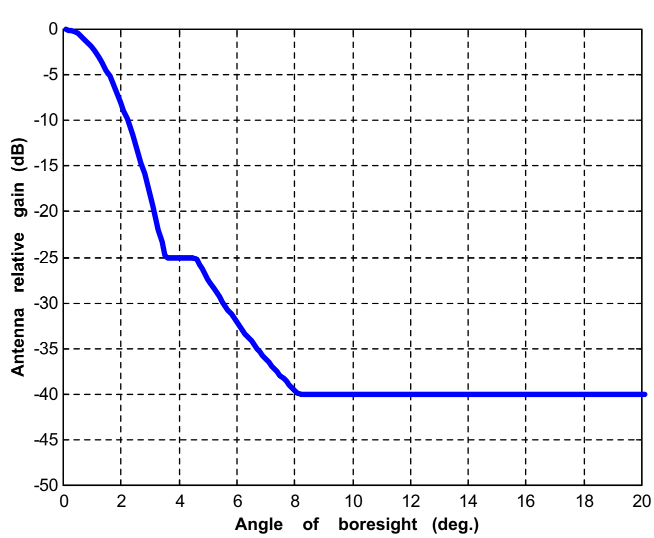

Fig. 1. The antenna radiation mask.

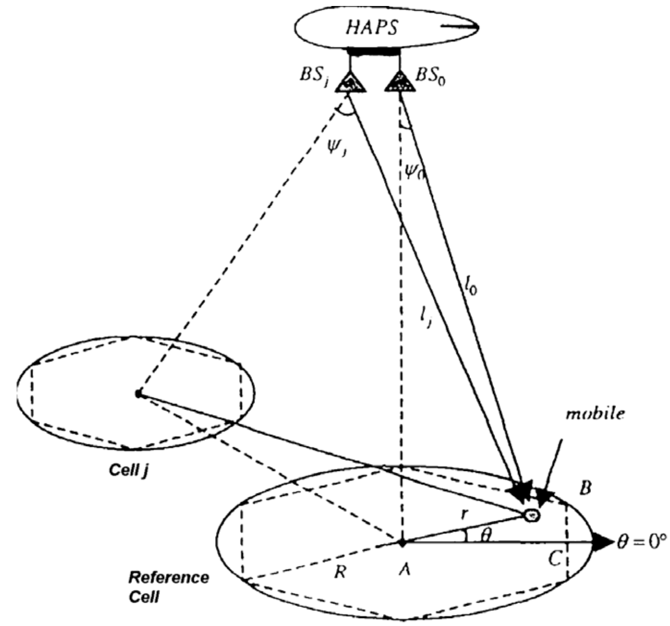

Fig. 2. HAPs downlink interference geometry.

- l_j and l_0 are the distances from the mobile to BS_j and BS_0, respectively,
- ζ_j and ζ_0 denote the shadowing corresponding to these two paths measured in dB,
- s is the path loss exponent = 2,
- $G(\psi_j)$ and $G(\psi_0)$ are the normalized antenna gains measured in dB evaluated at the angles under which the mobile is seen from the antenna boresights of BS_j and BS_0, respectively,
- ϕ is the non-orthogonality factor,
- J is the number of cells in the HAP constellation that contribute in the intercellular interference.

The first term in the denominator of (2) represents the intracellular interference whilst the second term represents the intercellular interference.

The effective path loss L between the HAP and the HSDPA user under consideration is given by

$$L\,(\mathrm{dB}) = 20\log_{10}\left(\frac{4\pi d}{\lambda}\right) + L_{BPL} + L_{shd} - G_{ant\text{-}HAP}\,(\mathrm{dB}), \tag{3}$$

where

- d is the distance in m between the HAP and the user under consideration,
- λ is the operating wave length in m,
- L_{BPL} is the additional building penetration loss assumed to be 12 dB,
- L_{shd} is the shadowing margin assumed to be 10 dB in urban zones and 5 dB in rural zones, and
- $G_{ant\text{-}HAP}$ is the HAP antenna gain at the boresight given in dB.

The factor κ is given by

$$\kappa = \frac{1}{10^{L(\mathrm{dB})/10}}. \tag{4}$$

The power P_u assigned to the HSDPA user under consideration is given as

$$P_u = \frac{P_{HSDPA}}{N_u}, \tag{5}$$