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UMTS-HSDPA in High Altitude Platforms (HAPs) Communications

Bazil TAHA-AHMED[1], Miguel CALVO-RAMÓN[2], Leandro de HARO-ARIET[2]
[1] *Universidad Autónoma de Madrid, 28049 Madrid-SPAIN*
[2] *Universidad Politécnica de Madrid, 28003 Madrid-SPAIN*
e-mail: bazil@gr.ssr.upm.es

Abstract

In this paper, the performance of HAPs (High Altitudes Platforms) UMTS HSDPA (High Speed Downlink Packet Access) is studied for different HAPs height h, different cells radius R and two directions (0° and 30°) within the cell. The network under study is assumed to have 61 ground cells. It is noticed that, for urban zone users, the effective range is lower than the effective range for users in rural zones for a given modulation scheme. Also it is noticed that in rural zone, the HSDPA can support higher modulation schemes. It is noticed that, when 80% of the base station total power is assigned to the HSDPA service, then, for rural zones three HSDPA users can be supported with the highest modulation scheme (3/4 16QAM). Also it is noticed that, in urban zones, only one HSDPA user can be supported with the highest modulation scheme.

Key Words: *HAPs, W-CDMA, UMTS, HSDPA, Carrier-to-interference ratio.*

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 22km. A 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] and [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 high-altitude platform (HAP) communications networks operating in millimetre-wave band is presented.

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 (HSDPA) 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 5MHz 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.

To the author's best knowledge, nobody has studied the HSDPA performance for HAPs platforms. Thus, in this work, we will study the HAPs UMTS downlink performance when the mode HSDPA is used. The signal to noise ratio will be given assuming that users exists on the line of one of two directions within the cell under consideration ($0°$ or $30°$).

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

Let BS_j (j = 0, ... ,J) denote the base station serving the j-th cell, as shown in Figure 2. For a mobile located at (r, θ) in the reference cell served by BS_o, the carrier-to-interference ratio (C/I) is given by [3]:

$$\frac{C}{I} \approx \frac{P_u\, G(\psi_o)\, l_0^{-s}\, \varsigma_o}{(P_T - P_u)\, G(\psi_0)\, l_0^{-s}\, \varsigma_0\, \phi + \sum_{j=1}^{J} P_T\, G(\psi_j)\, l_j^{-s}\, \varsigma_j} \tag{1}$$

where

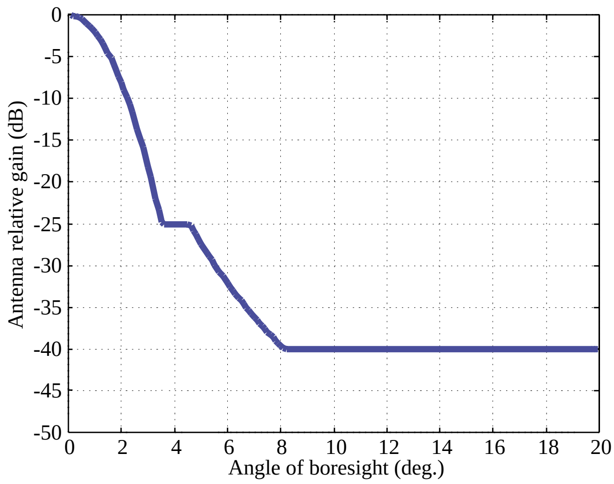

Figure 1. The antenna radiation mask.

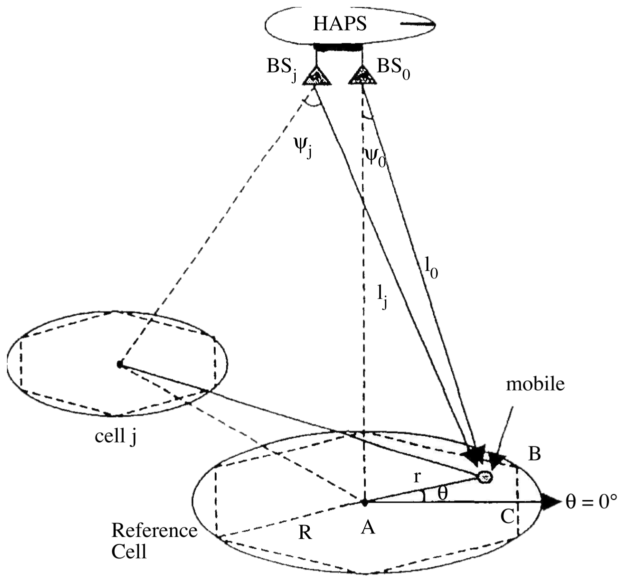

Figure 2. HAPs downlink interference geometry.

- P_u is the power assigned to the HSDPA user under consideration,
- P_T is the total power transmitted for a given cell,
- 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 power P_u assigned to the HSDPA user under consideration is given as:

$$P_u = \frac{P_T \, P_{HSDPA}}{N_u} \tag{2}$$

where

- N_u is the number of HSDPA users per cell and
- P_{HSDPA} is the power assignment for the HSDPA users.

Due to the unique HAPs geometry, the transmit antenna beams of all base stations essentially originate from the same point [2], so $l_j = l_o$ and $\zeta_j = \zeta_o$ (total correlation). Thus, the carrier to interference ratio (C/I) can be given as:

$$\frac{C}{I} \approx \frac{P_u \, G(\psi_o)}{(P_T - P_u)\, G(\psi_0)\, \phi + \sum_{j=1}^{J} P_T \, G(\psi_j)} \tag{3}$$

Now the ratio (E_b/N_o) is given by:

$$\frac{E_b}{N_o} = \left(\frac{C}{I}\right) G_p \tag{4}$$

where G_p is the HSDPA processing gain.

Numerical Results

To study the downlink performance we assume the following:

- $P_{HSDPA} = 0.2\ P_T$,
- $N_u = 1$,
- $G_p = 16$ and
- J = 60.
- For QPSK with 1/2 code rate and BER $< 10^{-5}$, the required $E_b/N_o = 6$ dB [6].
- For QPSK with 3/4 code rate and BER $< 10^{-5}$, the required $E_b/N_o = 9$ dB [6].
- For 16QAM with 1/2 code rate and BER $< 10^{-5}$, the required $E_b/N_o = 11$ dB [6].
- For 16QAM with 3/4 code rate and BER $< 10^{-5}$, the required $E_b/N_o = 16$ dB [6].

Let us study the case when users exist in urban zones where $\phi = 0.5$ [5] . In the first deployment we assume that h = 20 km and R = 1 km. Figure 3 shows E_b/N_o as a function of the distance from the centre of the cell for two different directions, i.e., for $\theta = 0^o$ and 30°. It can be noticed that for a distance lower than 760 m limited by the direction 0°, the relation E_b/N_o is higher than 6.0 dB necessary to support 1/2 code rate QPSK modulation. For a cell radius of 2 km, the coverage of the 1/2 code rate QPSK modulation will be 1050m. For a cell radius of 3 km, the coverage of the 1/2 code rate QPSK modulation is 1100m.

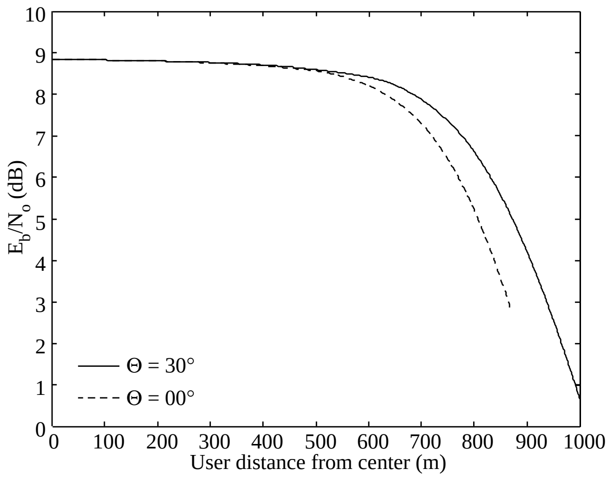

Figure 3. E_b/N_o as a function of the distance from the cell centre when $N_u = 1$, h = 20 km and R = 1 km.

Now we study the case when users exist in rural zones where $\phi = 0.1$ [5] assuming that h = 20 km and R = 1 km. Figure 4 shows E_b/N_o as a function of the distance from the centre of the cell for two different directions, i.e., for $\theta = 0^o$ and 30°. It can be noticed that for a distance lower than 700m limited by the direction 0°, the relation E_b/N_o is higher than 11 dB and thus $1/2$ code rate 16QAM modulation can be used. A modulation scheme of $3/4$ code rate QPSK can be used at a user distance of 700 to 750m from the cell centre while the $1/2$ code rate QPSK can be used at a user distance of 750 to 800m from the cell centre. From the results given by Figures 3 and 4, it can be concluded that, reducing the non-orthogonality factor gives arise to the possibility of higher modulation scheme or higher effective range. When R is 2km, the $1/2$ code rate 16QAM modulation will have an effective range of 950m. The $3/4$ code rate QPSK can be used for a user distance of 950 to 1020m from the cell centre while the $1/2$ code rate QPSK can be used for a user distance of 1020 to 1110m from the cell centre.

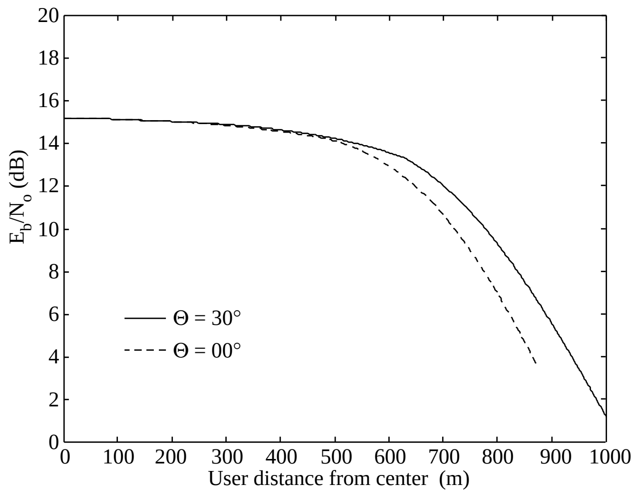

Figure 4. E_b/N_o as a function of the distance from the cell centre when $N_u = 1$, h = 20 km and R = 1 km when users are in rural zones ($\phi = 0.1$).

Figure 5 shows E_b/N_o at the cell centre as a function of the non-orthogonality factor when h = 20 km for two different cell radius. It can be concluded that the $3/4$ code rate 16QAM modulation can not be used when the non-orthogonality factor is higher than 0.1 whatever is the cell radius. When the cell radius is higher than 2.5km and the non-orthogonality factor is little bit lower than 0.09, only users in vicinity with the cell base station will support the $3/4$ code rate 16QAM modulation.

Figure 6 shows E_b/N_o as a function of the distance from the centre for $N_u = 2$, R = 1km, $\phi = 0.5$ and the power assigned to the HSDPA is 50% of the base station total power. It can be concluded that for a distance lower than 660m limited by the direction 0°, the relation E_b/N_o is higher than 9 dB and thus $3/4$ code rate QPSK modulation can be used. A modulation scheme of $1/2$ code rate QPSK can be used at a user distance of 660 to 810m from the cell centre. Here it can be noticed that, increasing the power assigned to the HSDPA service will increase the number of the supported user for a given modulation scheme. Only one HSDPA can be supported with the lower modulation scheme when the power assigned to the HSDPA is 20%.

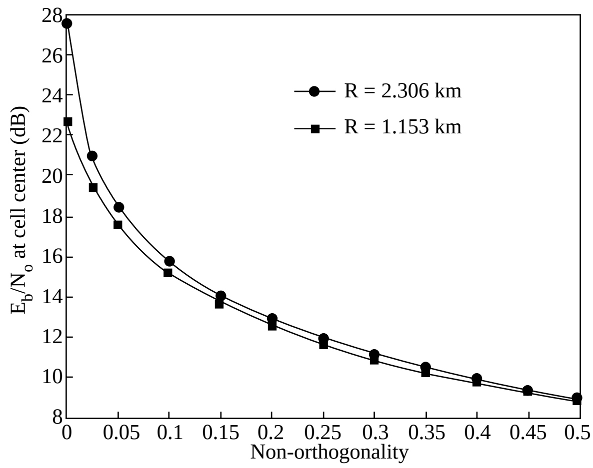

Figure 5. E_b/N_o at cell centre as a function of the non-orthogonality factor ϕ when $N_u = 1$ and h = 20 km.

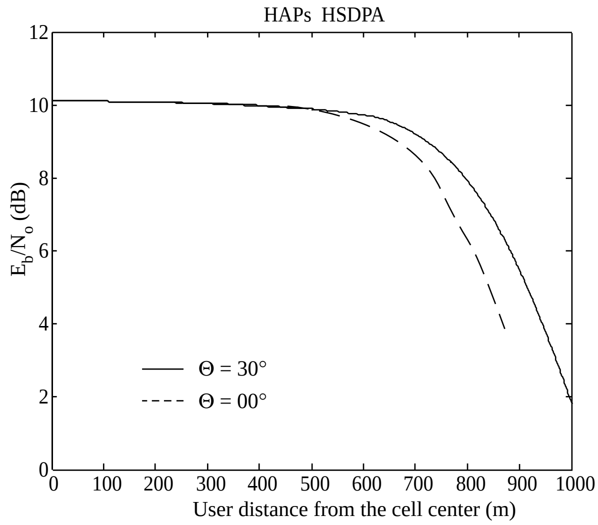

Figure 6. E_b/N_o as a function of the distance from the cell centre when $N_u = 2$, $P_{HSDPA} = 50\%$ of the base station total transmitted power, h = 20 km and R = 1 km when users are in urban zones ($\phi = 0.5$).

Figure 7 shows E_b/N_o as a function of the distance from the centre for $N_u = 1$, R = 1km, $\phi = 0.1$ and the power assigned to the HSDPA is 30% of the base station total power. It can be concluded that for a distance lower than 375m limited by the direction $0°$, the relation E_b/N_o is higher than 16 dB and thus $^3/_4$ code rate 16QAM modulation can be used. Thus, for only one HSDPA user, the higher modulation scheme is supported only when the power assigned to the HSDPA service is equal to or higher than 25% of the base station total power. For two HSDPA users in rural zone, the power assigned to the HSDPA service should be equal to or higher than 50% of the base station total power. No more than three HSDPA users in rural zone can be supported with the higher modulation scheme whatever is the power assigned to the HSDPA users (80% of the base station total power as a maximum). In urban zones ($\phi = 0.5$), only one HSDPA can be supported with the higher modulation scheme whatever is the power assigned to the HSDPA users.

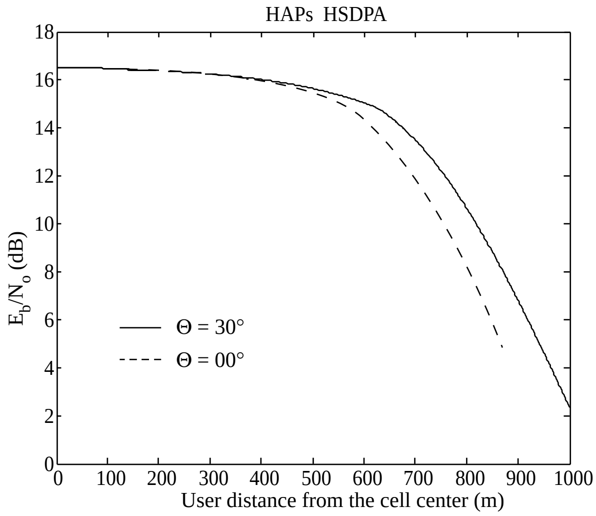

Figure 7. E_b/N_o as a function of the distance from the cell centre when $N_u = 1$, $P_{HSDPA} = 25\%$ of the base station total transmitted power, h = 20 km and R = 1 km when users are in rural zones ($\phi = 0.1$).

It has been noticed that increasing the HAP height h will reduce the effective ranges little bit (lower than 2%) for h = 22km.

Table shows the effective range for different modulation schemes in different scenarios.

Table. Effective range for different modulation schemes in different scenarios.

h = 20 km and $\phi = 0.5$, $P_{HSDPA} = 0.2\ P_T$.

Modulation scheme	Range (m) for R = 1km	Range (m) for R = 2km	Range (m) for R = 3km
¾ 16 QAM	——	——	——
½ 16 QAM	——	——	——
¾ QPSK	——	——	——
½ QPSK	0-760	0-1050	0-1100

h = 20 km and $\phi = 0.1$, $P_{HSDPA} = 0.2\ P_T$.

Modulation scheme	Range (m) for R = 1km	Range (m) for R = 2km	Range (m) for R = 3km
¾ 16 QAM	——	——	——
½ 16 QAM	0-700	0-950	0-1075
¾ QPSK	700-750	950-1020	1075-1150
½ QPSK	750-800	1020-1110	1150-1610

3. Conclusions

The performance of HAPs (High Altitudes Platforms) HSDPA (High Speed Downlink Packet Access) has been studied for different HAPs height h, different cells radius R and two directions (0° and 30°) within the cell. It has been noticed that, for urban zone users, the effective range is lower than the effective range for users in rural zones for a given modulation scheme. Also it has been noticed that in rural zone, the HSDPA service can support higher modulation schemes. It has been noticed that, when 80% of the base station total power is assigned to the HSDPA service, then, for rural zones three HSDPA users can be supported with the highest modulation scheme (3/4 16QAM). Also it has been noticed that, in urban zones, only one HSDPA user can be supported with the highest modulation scheme.

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