ABSTRACT

In similar with terrestrial and satellite wireless networks, a new alternative based on platforms located in the stratosphere has recently introduced, known as High Altitude Platforms (HAPS). HAPS are either airships or aircraft positioned between 17 and 22.5 km above the earth surface. It has capability to deliver a wide spectrum of applications to both mobile and fixed users over a broad coverage area. Wideband code division multiple access (WCDMA) has emerged as the mainstream air interface solution for 3G networks. Also the ITU has specifically authorized the use of some IMT-2000 (3G) frequency bands from HAPS. This paper addresses only forward link power control for high altitude platform station for a WCDMA under the assumption of power control imperfections. Power control improves the uplink and the downlink performance both by equalizing the powers of all users in a cell and by compensating for the channel fading. However in real systems power control imperfections disgrace the system capacity. The performance of two distance based forward link power control schemes (nth-power-of distance control schemes) are evaluated for high altitude platform station (HAPS) W-CDMA systems. For a HAPS system with 19 beams, the total capacity of the system would be in the order of 1206 voice users or 144 data users. The coverage of the platform with 19 beams each with a radius of 1.2 km can by approximated by a circle with a radius of 6 km. It has been shown that HAPS UMTS gives capacity and resource management improvements

KEYWORDS: HAPS, WCDMA, POWER CONTROL, INTERFERENCE.

1. Introduction

Terrestrial and satellite systems showed two well established technologies that have been leading in the telecommunications arena for years. However, in last year's a new alternative has emerged based on quasi-stationary aerial platforms located in the stratosphere, often named high altitude platforms (HAPS). The platforms are located at an altitude between 17 and 22 km above the Earth’s surface.[1] One of the interesting features of HAP networks is their easy and incremental deployment, which renders HAPS suitable not only for a host of communication applications but for services beyond telecommunications as well. Typical services that can take advantage of the flexibility of HAP systems are remote sensing and Earth monitoring, positioning and traffic monitoring and control, however, the focus of this paper is on the part of HAPs in beyond third generation (3G) networks. Communication service via review on HAPS was well reviewed by [2]. 3G networks offer multimedia services to mobile users at transmission rates ranging from some kilobits per second to 2 Mb/s. in spite of, new requirements for flexible network access have emerged within the telecommunications community, spurred by the vision of optimal connectivity anywhere, anytime. HAPs are expected to fulfill this vision, providing high bit rates at low cost.[1][2]

The service finding process can take advantage of some of the wonderful features of HAP systems. Multimedia broadcast and multicast services (MBMS) can be provided by the HAP component of 3G and beyond 3G networks to get better performance in terms of required system capacity and cost. In addition, new applications are expected to thrive with the advent of fourth-generation (4G) networks [2][3][4].

In this paper, we will show that in a HAPS CDMA system, interference is dependent on the antenna radiation pattern rather than the terrain features of the coverage area, i.e., shadowing. We will show that the unique HAPS geometry enables distance based power control schemes to perform positively [3][4]. Forward link power control is used in cellular W-CDMA systems to reduce the interference to the other neighboring cells and enhance system capacity. The performance of a distance based power control scheme based .We will also evaluate by analysis and simulation, the performance of these two distance based power control schemes (nth-power-of-distance power control) taking into consideration the unique characteristics of HAPS.

2. HAPS SYSTEM MODEL

We assume that a HAP shipping a W-CDMA communications payload and a multi-beam phased array
antenna with beam gain shaping capability is located at an altitude of 22.5 km in the stratosphere [5]. With the W-CDMA communications payload and phased array antenna onboard the HAPS, hundreds of spot beams can be projected on the ground within the service area in a pattern similar to that created by a traditional cellular system to provide mobile communications services [5]. The peak main lobe gain of the Phased array antenna is taken to be 36.7 dB. The mask of the phased array antenna radiation pattern with $G_m = 36.7$ dB is shown in Figure 1. Where (Gm) maximum gain in the main lobe (dBi) [3] [5] [6].

3.Nth-POWER-OF-DISTANCEOF POWER CONTROL

We consider a power control format based on the nth power of a mobile’s distance away from the center of its serving cell. The cellular layout consists of two tiers of neighboring cells centrally located base stations. The power control law $f(r)$ of such a power control scheme can be given as:

$$f(r) = \begin{cases} \alpha + \beta \left( \frac{r}{R} \right)^{n_1} & \text{For } r \leq r_o \\ \gamma \left( \frac{r}{R} \right)^{n_2} + d \left( \frac{r}{R} \right)^{n_3} & \text{For } r > r_o \end{cases}$$  

(1)

where $a$, $b$, $c$, $d$, $n1$, $n2$, $n3$ and $ro/R$ are the power control scheme parameters such that $ro$ is the distance at which the power control scheme changes the law of the power control.[5]

4.HAPS INTERFERENCME MODEL

Interference is an important issue in any communication system. In a HAPS-based system interference is caused by antennas serving cells on the same channels and arises from overlapping main lobes or side lobes. There are two kinds of interference: interference originating from users of the HAP-based network and interference from/to terrestrial and satellite systems sharing the same or adjacent frequency band [2]. A user in the HAPS service area will experience intracell interference from its serving beam users and intercellular interference from the adjacent beams users. In CDMA systems the forward link capacity is limited by interference by users in the same cell or other cells.

The HAPS downlink interference geometry showed in Fig 2. $(r, \theta)$ be the coordinates of a mobile with respect to the center of the cell projected by its serving beam. The power transmitted by a base station onboard the HAPS to its serving mobile located at $(r, \theta)$ is given by

$$P_i(r, \theta) = P_{req} f(r, \theta)$$  

(2)

Where $f(r, \theta)$ is the power control law and $P_{req}$ is the power required to reach a user at the cell corner $(R, 30^\circ)$.[1]

In this paper we focus on the service area near the nadir and assume that the beams project approximately circular cells, each serving a uniform distribution of $N$ mobiles per cell (user density $\rho = N / \pi R^2$).[16][18]. We consider 2
tiers of neighboring cells and assume that the interference from tiers further away is negligible. We further assume that the total power \( P_T \) transmitted by the HAPS in each beam is the same.

\[
P_T = \int_0^\infty \int_0^\pi P_r(r, \theta) r dr d\theta 
\]

\[
= \frac{N}{\pi R^2} \int_0^\infty \int_0^\pi P_r(r, \theta) r dr d\theta 
\]

\[
= \frac{2N \pi \rho_{req}}{R^2} \int f(r) rdr = 2NP_{req} f_P \tag{5} 
\]

Where \( 2 f_P \) can be exposed as [5] [6] [8].

\[
2 f_P = a \left( \frac{r}{R} \right)^2 + b \left( \frac{r}{R} \right)^{n+2} + c \left( \frac{r}{R} \right)^{n+2} + d \frac{r}{n+2} \frac{n+2}{n+3} \tag{6} 
\]

As shown in Figure. 2, Let \( BS_j \) denote the base station serving the \( j \)th cell. The carrier-to-interference ratio (C/I) of a mobile located at \((q, r)\) in the reference cell served by \( BS \) is given by

\[
C = \frac{P_{ch} G(\psi_j) I^{n+2} \xi_j / \alpha}{P_T G(\psi_j) I^{n+2} \xi_j (1-\phi) + \sum_{j=1}^{18} P_T G(\psi_j) I^{n+2} \xi_j} \tag{7} 
\]

Where
- \( P_{ch} \) is the power assignment for the users channels \( \approx 0.8 \),
- \( l_j \) and \( l_o \) are the distances from the mobile to \( BS_j \) and \( BS_o \) respectively,
- \( \zeta_j \) and \( \zeta_o \) denote the shadowing corresponding to these two paths measured in dB,
- \( s \) is the path loss exponent = 2,
- \( G(\psi_j) \) and \( G(\psi_o) \) 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 \( BS_o \) respectively,
- \( \alpha \) is the source activity factor and
- \( \phi \) is the orthogonality factor.

Due to the unique HAPS geometry, the transmit antenna beams of all base stations fundamentally originate from the same point [5], so \( l_j = l_o \) and \( \zeta_j = \zeta_o \) (quasi total correlation). Now the carrier to interference ratio (C/I) can be given as:

\[
\frac{C}{I} = \frac{P_{ch} P_T(r) / \alpha}{P_T^2 \gamma(r, \theta)} \tag{8} 
\]

Where \( \gamma(r, \theta) \) is the HAPS forward link interference factor. Note that the interference factor is dependent on the antenna radiation pattern rather than path loss and shadowing and given by

\[
\gamma(r, \theta) = \frac{(1-\phi)G(\psi_j) + \sum_{j=1}^{18} G(\psi_j)}{G(\psi_j)} \tag{9} 
\]

The downlink capacity profile \( N(r) \) for each cell at distance \( r \) is given as:

\[
N(r) = \frac{E_b}{N_o} \frac{P_{ch} f_P(r) / \alpha}{(2 f_P) \gamma(r, \theta)} \tag{10} 
\]

The minimum value of \( N(r) \) is taken to be the system capacity. As highlighted in [6], because of the symmetry of the cellular layout, we only need to evaluate \( C/I \) at locations within the triangle ABC (see Fig. 2).

5. Numerical Results

We assume a platform altitude of \( h = 22.5 \) km, cells radius of \( R = 1.2 \) km (typical in HAP systems over cities) and a continuous power control. \( a, b, c, d, n1, n2, n3 \) and \( ro/R \) are varied and the corresponding system capacities to the power control scheme parameters. A computer program has been used to evaluate the optimum values of \( a, b, c, d, n1, n2, n3 \) and \( ro/R \). These values are well accepted for voice and data services [6]. Figure.3 shows \( Eb/No \) as a function of the distance from the centre of the cell for two different directions, i.e., for \( \theta = 0^\circ \) and \( \theta = 30^\circ \). It can be noticed that for a distance lower than 840m limited by both direction,

![Figure 3: Eb/No as a function of the distance from the centre when h = 20 km and R = 1 km.](image)
We first study the voice only users assuming that:

Prossing gain \( G_p = 256 \), Energy bit to noise ratio \( (Eb/No)_{req} = 7 \text{ dB} \) and the source activity factor \( \alpha = 0.5 \).

We begin with the case of orthogonality factor \( \phi = 0 \). Fig. 4 shows \( N(r) \) for the following obtained near optimum values: \( a = 0.195, b = 0.125, c = 0.5, d = 0.6, n1 = 1.75, n2 = 2.5, n3 = 3 \) and \( r_0/R = 0.7 \). As can be seen the capacity per beam is of 33 voice users. The power control reduction coefficient \( (2 \, f_p) \) in this case is 0.490.

Next case of orthogonality factor \( \phi = 0.5 \) which is the practical case. Fig. 5.5 shows \( N(r) \) for the following obtained near optimum values: \( a = 0.18, b = 0.12, c = 0.5, d = 0.5, n1 = 2.4, n2 = 3.5, n3 = 3.0 \) and \( r_0/R = 0.70 \). As can be seen, the capacity per beam is about 67 voice users. The power control reduction coefficient \( (2 \, f_p) \) in this case is 0.422. If an optimum power control scheme is used in the capacity calculation, the capacity can reach a value of 70 users/cell.

Data user

For the voice only users, with the assumptions of:

• \( G_p = 26.6 \),
• \( (Eb/No)_{req} = 3 \text{ dB} \),
• \( \alpha = 1 \)

We begin with the case of \( \phi = 0 \). Fig. 5.6 shows \( N(r) \) for the following obtained near optimum values: \( a = 0.195, b = 0.125, c = 0.5, d = 0.6, n1 = 1.75, n2 = 2.5, n3 = 3 \) and \( r_0/R = 0.70 \). We can notice that the downlink capacity is 4.2 data users per beam.

Next we study the case of \( \phi = 0.5 \) which is the practical case. Fig. 5.7 shows \( N(r) \) for the following obtained near optimum values: \( a = 0.18, b = 0.12, c = 0.5, d = 0.5, n1 = 2.4, n2 = 3.5, n3 = 3.0 \) and \( r_0/R = 0.70 \). As can be seen, the capacity per beam is about 9 voice users.
6. Conclusion

In this work, the performance of a modified n-th power distance based downlink power control model has been evaluated for high altitude platform stations (HAPs) W-CDMA systems. The practical capacity of the HAP system considered here, for an orthogonality factor of 0.5, would be of around 55 voice users, or 7 data users, per cell (beam). HAPS system with 19 beams the total practical capacity of the system would be in the order of 1045 voice users or 133 data users.

7. Reference


Figure 7 HAPs down link capacity profile against normalized distance from cell Centre for data users orthogonality factor ( $\phi = 0.5$ ).