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Handoff Study of Ring Shaped Cellular Configuration Designed for High Altitude Platform Communications

Mahmoud A. Elghorab
Department of Electronics and Electrical Communications, Faculty of Electronic Engineering, Menoufia University,
Menouf, Egypt, 32952

Ahmed S. Elkorany
Department of Electronics and Electrical Communications, Faculty of Electronic Engineering, Menoufia University,
Menouf, Egypt, 32952

Moawad I. Dessouky
Department of Electronics and Electrical Communications, Faculty of Electronic Engineering, Menoufia University,
Menouf, Egypt, 32952

ABSTRACT
In this paper, the concentric ring shaped cellular configuration is designed for High Altitude Platforms (HAPs). An one dimensional (1D) vertical linear antenna array is used to generate this configuration. The effect of different types of HAP mobility models, e.g. drift, random walk, and reflection has been examined. The possibility of reducing the need for mechanical stabilization via handoff techniques is demonstrated through the study of handoff, dropping, and blocking probabilities.

General Terms
Handoff probability, blocking probability, and dropping probability.

Keywords
High Altitude Platforms (HAPs), concentric ring shaped cells, handoff probability, blocking probability, and dropping probability.

1. INTRODUCTION
HAPs are aircrafts or airships operating at an altitude in the range of 17-22 km in the stratosphere [1]. HAPs can find a place in the world of mobile communications. They have many advantages when compared to terrestrial systems or satellite systems [2]. HAPs do not need a large number of base stations as in terrestrial mobile communications. Also, they do not have problems like the limitations on the minimum cell size which appear in GEO satellite systems and handover problems provided by LEO satellites [1]. One of the major advantages of HAPs is the superior radio coverage in wireless communications because of the availability of line of sight communications as in satellite communications but with lower propagation losses due to the reduced altitude [1-5]. There are many other advantages of HAPs, e.g. easy deployment, low cost operation, flexibility, and broad coverage. HAPs can afford multiple broadband services, e.g. broadband internet access, video conferencing, voice telephony, voice over IP, entertainment services (radio and TV broadcasting and video on demand), distance learning, and telemedicine [1].

The instability of HAP position is the main disadvantage of HAPs. It requires frequent stabilization of the HAP antenna [6]. Another major problem is the rotation of the HAP around its central axis. This problem has a great effect on the outer cells in the hexagonal configuration [7]. It requires either redirecting all the beams forming the cells or performing high rate handoff techniques [6]. A solution of this problem is dividing the coverage area into concentric ring shaped cells [8]. This configuration affords many advantages, e.g. the reduction of the required motion monitoring and the needed corrections. Also, it reduces the power consumption.

In this paper, a 1D vertical linear antenna array is used to generate the concentric ring shaped cells to reduce both the antenna payload and the implementation complexity of the 2D array [6], [9-10].

Dividing the coverage area into concentric ring shaped cells solved the problem of HAP rotation around its central axis. For the other different types of HAP mobility models, handoff is expected to help users continue the calls with minimum dropping probability. Acceptable levels of blocking and dropping probabilities can reduce the need for mechanical stabilization.

The paper is arranged as follows, section 2 demonstrates High Altitude Platform mobility models. Section 3 illustrates the handoff simulation. Section 4 shows the Numerical results and, finally, conclusions are included in section 5.

2. MOBILITY MODELS FOR HIGH ALTITUDE PLATFORMS
HAPs may experience different types of movements, the drift movements with respect to x, y, and z-axis and the rotational movements with respect to x, y, and z-axis known as pitch, roll, and yaw respectively. Only the effect of x and z-axis drift and rotation was considered because the x and y-axis drift and x and y-axis rotation have the same effect on the performance of the system [6]. The drift and rotation movements can be combined into more complicated types of movements, e.g. reflection and random walk. The limitations on the boundaries of the HAP movement are specified according to ITU [11], where the HAP should be kept within a circle of radius 400 m and height limits of 700 m. The HeliNet project positioned the platform within a cylinder with a height of 3 Km and a radius of 4 Km for 99.9% of the time and within a cylinder with a height of 1 Km and a radius of 2.5 Km for 99% of the time [12].

2.1 Drift Movement
The HAP will start moving from the center of the coverage area (0, 0, 20) Km to one end of the position cylinder and then back to the other end. The current position for a drifting HAP is given by the following equation [6]:

$$u_t = u_{t-\Delta t} + v.\Delta t.\hat{a} \tag{1}$$

The current position is u_t. The previous position is $u_{t-\Delta t}$. The HAP velocity is v.

2.2 Random Walk Movement

Random walk is a combination of two different types of movements, drift and yaw. The current position for a random walk movement is given by the following equation [6]

$$u_t = u_{t-\Delta t} + \Delta t[v_h \cos(\theta)\,\hat{x} + v_h \sin(\theta)\hat{y} + v_v\hat{z}] \qquad (2)$$

The horizontal velocity component (v_h) defines the horizontal HAP position. The vertical velocity component (v_v) defines the rate of decent and ascent. Figure 1 illustrates an example of random walk movement [6]. HAP should be kept within cylindrical boundaries defined in HeliNet [12].

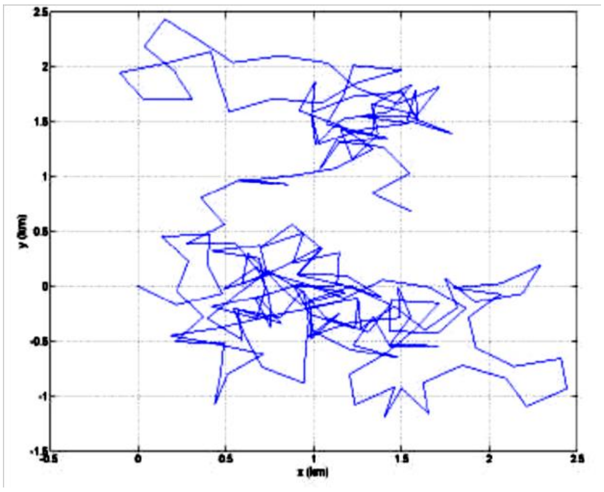

Fig 1: Random walk movement [6].

2.3 Reflection Movement

HAP moves to a point that is randomly located within the position cylinder. The current position of the HAP is given by the following equation [6]

$$u_t = u_{t-\Delta t} + v.\Delta t.\hat{a} \qquad (3)$$

The reflection and drift type movements have the same equation but the direction of the new location differs. For the reflection movement, the direction is randomly selected. For the drift movement, the direction is kept on a specific axis.

Figure 2 gives an example of reflection movement [6]. The HAP is kept within cylindrical boundaries defined in HeliNet [12].

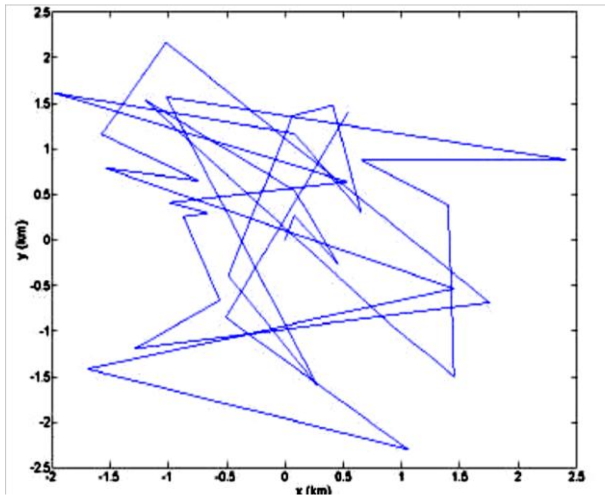

Fig 2: Reflection movement [6].

3. HANDOFF SIMULATION

The effect of HAP movement on station keeping represents a problem for HAP communications. A study of handoff as a potential solution for this problem is considered here.

Users are randomly distributed in a coverage area of radius 32.7 Km divided into 23 concentric ring shaped cells generated by a vertical linear array antenna on the platform [6]. Line of sight communications have been proposed. The simulation parameters were introduced in the following table [6]. The radius of the coverage area, the noise level, the selected frequency, the platform altitude, the transmitted power, mean call holding time, and HAP speed parameters are identical to the reference values. The other parameters, e.g. the number of cells, the number of channels per cell, the cluster size, and the offered traffic are changed according to the proposed communication scenario of the concentric ring shaped cells.

Table 1. Handoff simulation parameters

parameters	values
Noise received level	-133.9 dBm
Frequency	30 GHz
Platform altitude	20 Km
Transmitter power	-26.6 dBm
Number of cells	23
Channels per cell	400
Total offered traffic	641.67
Cluster size	2
HAP initial position	(0,0,20) Km
Mean arrival rate for each user	10 calls/hour
Mean call holding time	300 sec
HAP speed	0-200 Km/h

The Poisson process governs call generation. The holding time of each call changes according to the exponential distribution. The traffic is uniformly randomly distributed [6].

4. NUMERICAL RESULTS

Results of handoff, blocking, and dropping probabilities for the previous three different movement models of HAP movement are introduced as follows:

For the x-axis drift movement, figure 3 illustrates the increase of handoff probability with the increase of HAP velocity. The rate of increase for speeds below 100 Km/h is larger than for higher speeds. The handoff probability is approximately constant for speeds between 100 and 120 Km/h. It increases again to reach a maximum handoff probability of 82.1% at 160 Km/h then it decreases at speeds from 160-180 Km/h. It is approximately constant again at speeds from 180-200 Km/h .The dropping probability due to the lack of channel availability is considered here, the simulation results show that the uniform random distributed users in a coverage area divided into concentric ring shaped cells experience no dropping probability for all the speeds of the HAP. Increasing the traffic raises the blocking probability above 2% and increases the dropping probability.

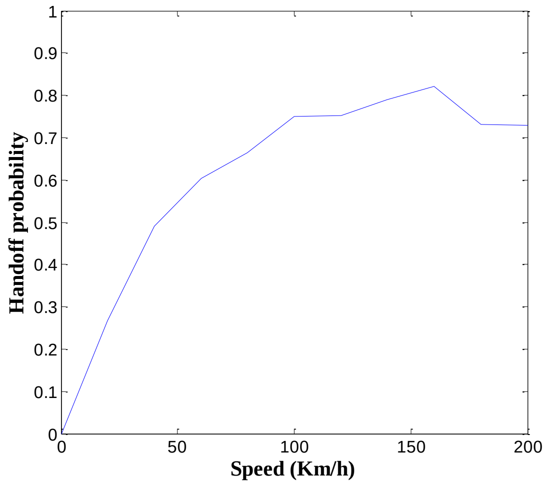

Fig 3: Handoff probability for drift movement

Figure 4 illustrates the change of blocking probability with HAP speed. The blocking probability decreases as the speed decreases with a maximum blocking probability of about 2% at 0 Km/h. The chance for new calls to find free channels increases with the increase of HAP speed. The maximum rate of decrease is for a range of HAP speeds (0 - 20 Km/h). The rate of decrease of blocking probability decreases at speeds from 20-60 Km/h then it increases to reach the minimum blocking probability of 0.17% at 80 Km/h. The blocking probability increases again at HAP speeds 80-140 Km/h. It decreases for HAP speeds 140-180 Km/h then it increases again to reach 0.35% at 200 Km/h.

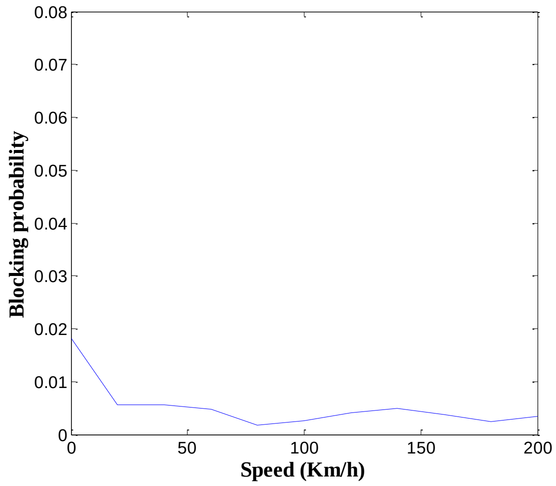

Fig 4: Blocking probability for drift movement

For the reflection type of movement, figure 5 illustrates the increase of handoff probability with the increase of HAP speed. The maximum rate of increase is at speeds from 40-60 Km/h. The maximum handoff probability is 91.2% at speed of 200 Km/h. Also, the simulation results show no dropping probability for the reflection movement.

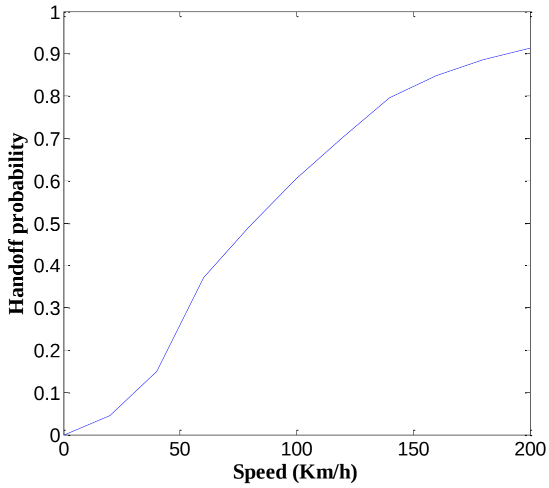

Fig 5: Handoff probability for reflection type of movement

Figure 6 illustrates the change of blocking probability with HAP speed. The blocking probability decreases as the speed decreases which means that the new incoming users experienced a better channel availability at higher speeds. A maximum blocking probability of approximately 2% is at 0 Km/h then it decreases to reach 0.48% at 40 Km/h. It decreases in a lower rate to reach 0.27% at 80 Km/h then it experiences a small increase to reach 0.37% at 100 Km/h. The minimum blocking probability is 0.07% at 180 Km/h.

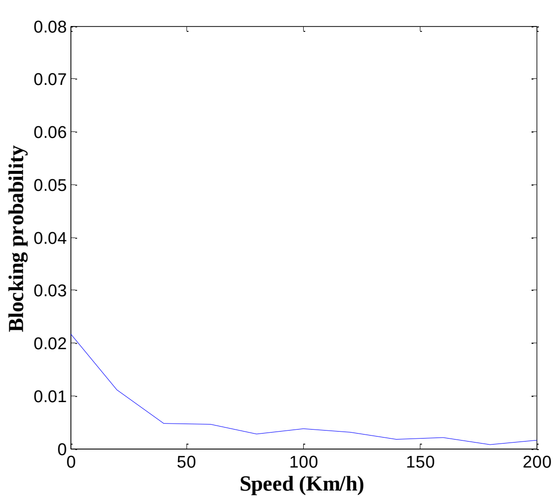

Fig 6: Blocking probability for reflection type of movement

For the random walk type movement, figure 7 illustrates the increase of handoff probability with the increase of HAP velocity. The handoff probability increases to reach 81.2% at 160 Km/h then it decreases to reach 79.3% at 180 Km/h. It increases again to reach a maximum handoff probability of 86.7% at 200 Km/h.

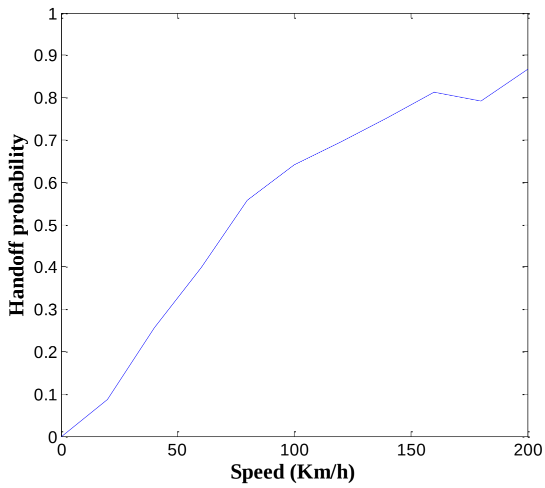

Fig 7: Handoff probability for the random walk type of movement

Figure 8 shows the change of the dropping probability with HAP speed. Users experience no dropping probability at speeds lower than 80 Km/h. At higher speeds, the dropping probability starts to change to reach a maximum of 0.025 % at 200 Km/h.

Figure 9 represents the blocking probability. The maximum blocking probability of approximately 2% (1.67 %) is measured at a HAP speed of 0 Km/h. It decreases as the HAP speed increases to reach 1.12 % at 20 Km/h. For higher speeds, the blocking probability changes within a limited range. It increases again to reach 1.17% at 40 Km/h then it decreases to reach a minimum blocking probability of 0.76% at 100 Km/h.

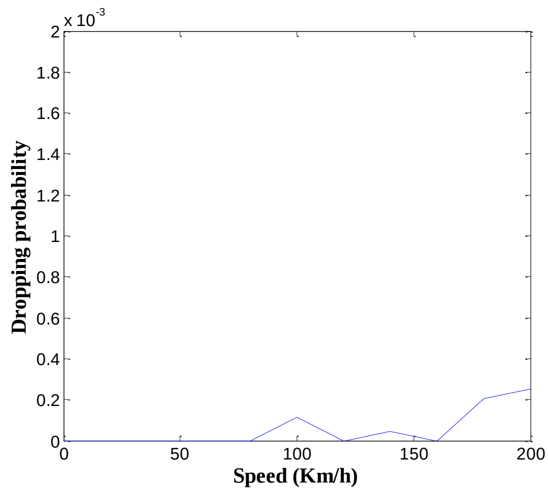

Fig 8: Dropping probability for random walk type of movement

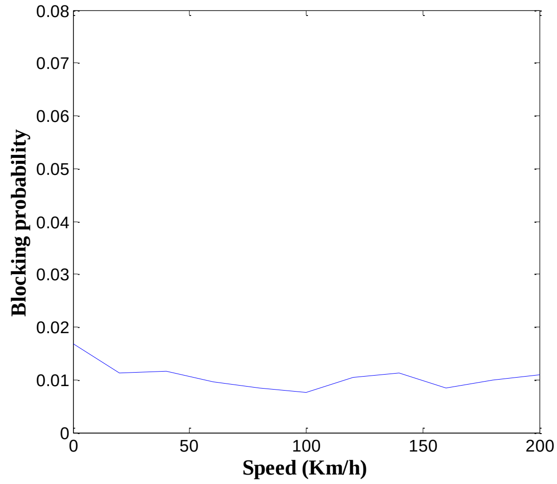

Fig 9: Blocking probability for random walk type of movement

5. CONCLUSIONS

The study of the effect of HAP movement in the concentric ring shaped cellular configuration shows the need for mechanical stabilization to overcome the problem of HAP movement. This stabilization can be reduced through the use of handoff techniques. For an acceptable blocking probability, approximately 2%, the dropping probability is improved due to the proposed concentric ring shaped cellular configuration. Three types of HAP motions were studied. The random walk has the worse effect because of the increase of the dropping probability.

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