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Application of High Altitude Platforms to the Provision of 3G Mobile Services in Sparsely-Populated areas

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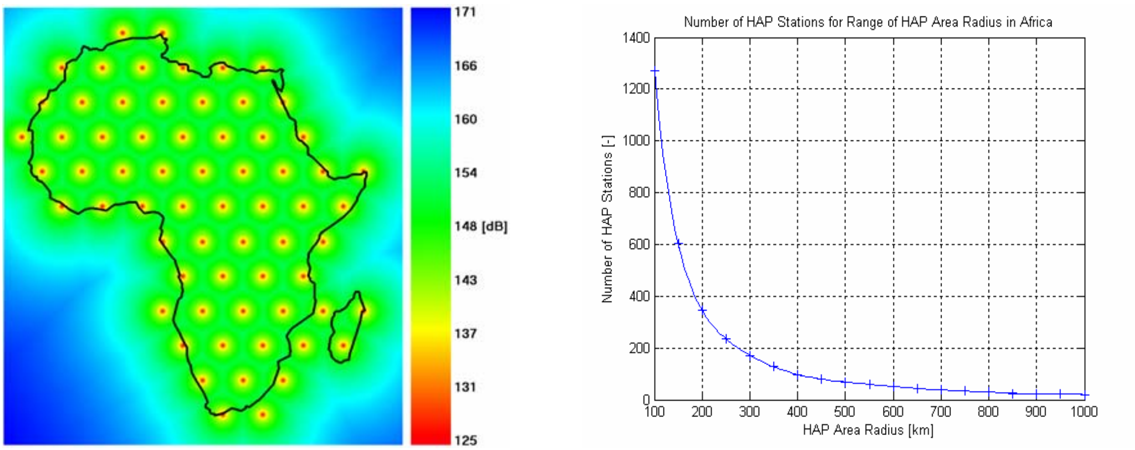
1. Introduction

This paper deals with the application of High Altitude Platform Stations (HAPS) to the provision of third generation mobile services in sparsely-populated areas. The coverage of extensive and sparsely populated areas by 3G mobile network signals is complicated and extremely expensive. A solution to this problem could be the use of HAPS, which appear to be very prospective, and not only for developing countries. High Altitude Platforms (HAPs), situated in the stratosphere at an altitude ranging from 17 to 22 km [1], offer many advantages when compared to terrestrial base stations, such as a large area of coverage and no shadowing for high elevation angles.

This paper focuses on the behaviour of large cells provided via a multiple HAP deployment and shows the possibilities of using small cells located inside these large cells to serve hot spot areas. The impact of the antenna power roll-off at the cell edge on cell capacity and the quality of coverage will be presented.

2. Basic Simulation Parameters

Fig. 1a illustrates the composite free space loss (FSL) for HAP stations located in a hexangular deployment above Africa (65 cells with a service area radius equal to 500 km above Africa). These HAPs were presumed to be at an altitude of 22 km. Fig. 1b shows the number of HAPs as a function of the service area radius of a single HAP. This service area could be formed by one cell or by more cells provided via a single HAP, particularly if elliptical antenna beams are used [2].



(a) (b)

Figure 1: a. Composite Free Space Loss for 65 HAPs with a service area radius of 500 km in Africa, b. Number of HAPS required to cover Africa as a function of the service area radius

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2. Parameters of the Simulation Scenarios

The studies were divided into two basic scenarios. The first scenario involved a study where a single HAP provided one large cell and the HAPs were situated in the hexangular deployment. An FSL model was used for the basic propagation prediction. An additional log-normal fade margin of 8 dB was applied to give a more accurate approach in order to simulate the slow fading. In the case of the second scenario, hot spot areas (for example villages) were modelled within the large cells. The modelling of these areas was based on an empirical propagation model for satellites. The propagation loss is then a function of the elevation angle [3].

The simulations were accomplished using computational methods based on iterative loops. A detailed description is given in [4]. Antenna radiation patterns were modeled based on [5]. Flat side lobes at a -40 dB level relative to the maximum gain were used. For the small cells, where the cell centre is sideways to HAPS position, elliptical beams were used [2], [5]. An example of antenna radiation patterns with power roll-off of 10 dB at the cell edge are depicted in Fig. 2. The HAP was assumed to be at an altitude of 22 km for results we have presented here.

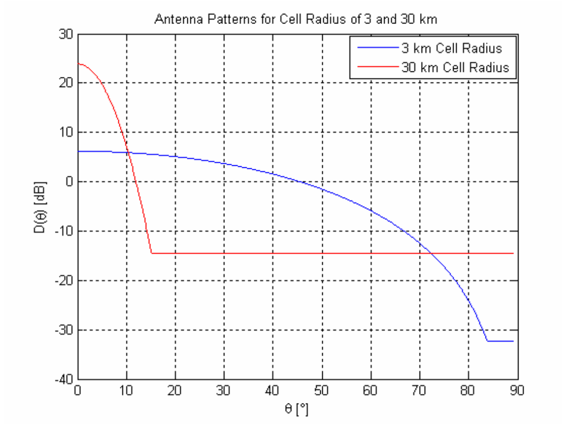


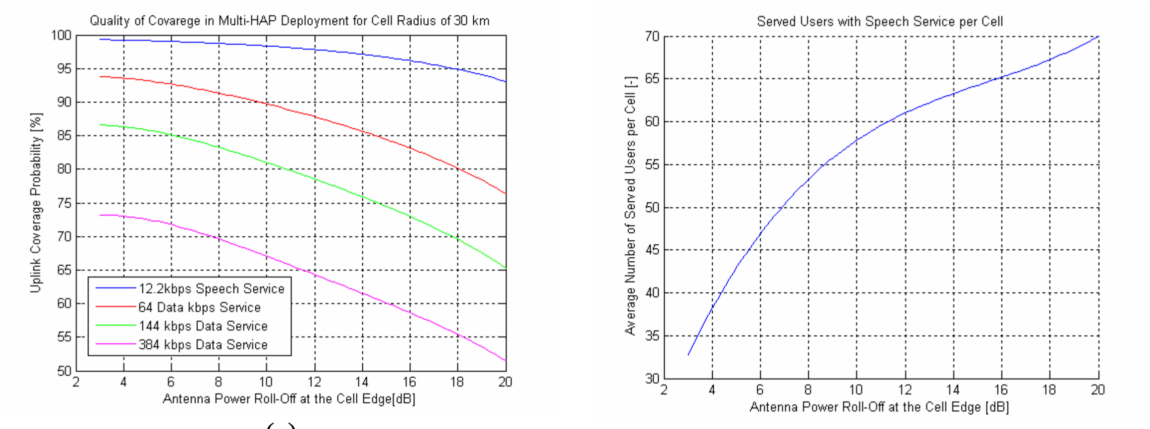
Figure 2: Antenna pattern as a function of the angle from boresight θ.

150 users per cell were randomly distributed in the target area. The Vehicular A channel model from the ITU-R recommendation was the pick up for the presented simulations in suburban and rural areas [6]. The results are shown as a function of system level parameters on the antenna power roll-off at the cell edge. An uplink loading of 60% was allowed for simulations of cells with a radius of 30 km and of 90% for cells with a radius of 3 km.

3. Multi HAP Deployment with a Single Large Cell

This scenario was modelled with 61 cells in a homogenous hexangular deployment with a radius of 30 km. This radius is typically used as the radius of a HAP service area in most works on the subject of HAPS. A 30 km cell radius seems to be a trade off between the cell capacity and quality of coverage. There are problems with ling budget for larger cells, because the HAP wide-beamwidth antennas do not offer sufficient gain (see Fig. 2). There is an insufficient power margin due to increasing FSL and shadowing effects for lower elevation angles, especially for high speed data services.

Fig. 3a illustrates the probability of coverage as a function of antenna power roll-off at the cell edge. Fig. 3b shows the average cell capacity (number of users having the speech service). From Fig. 3 it is obvious that the optimal antenna power roll-off at the cell edge must be a trade-off between the quality of coverage and the cell capacity. For higher roll-off the cells are more isolated at the expense of quality of coverage at the cell edge. A 10 dB antenna power roll-off for large cells was selected for the next scenarios.



(a) (b)

Figure 3: a. Uplink quality of coverage for range services, b. Number of users served per cell

3. Hot Spots

An additional 10 cells with radii of 3 km were situated within the large cells with a 30 km radius. These cells should simulate villages or other hot-spot areas with higher capacity requirements (see Fig. 4). Antennas with elliptical beams were focused on these cells. Their roll-off factor at the cell edge was changed in the 1 to 20 dB range. The study was divided into two cases. In the first case, the same carrier frequency was used for both the small and large cells. In the second, the small cells used a different carrier frequency (each UMTS operator should have 3 carriers).

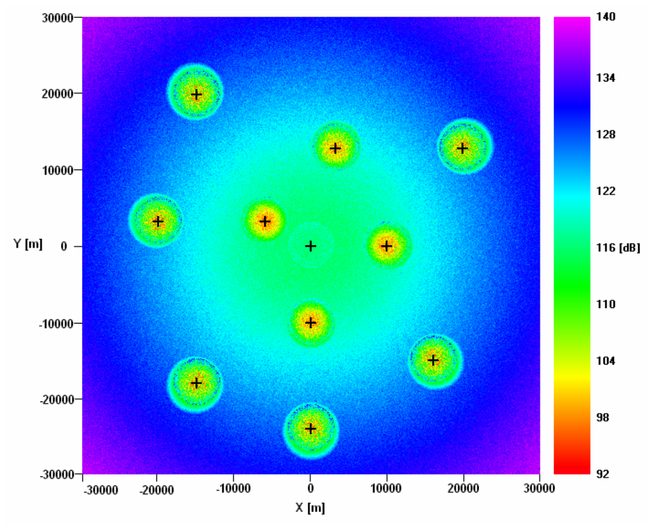
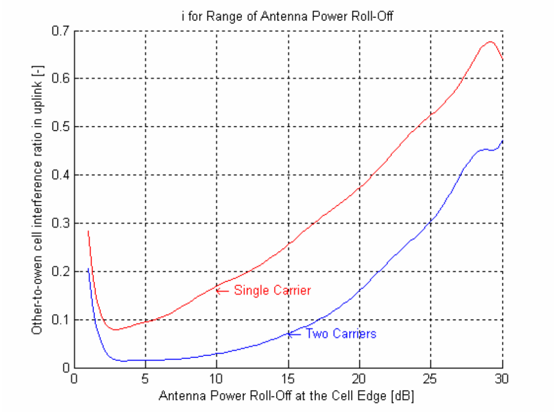
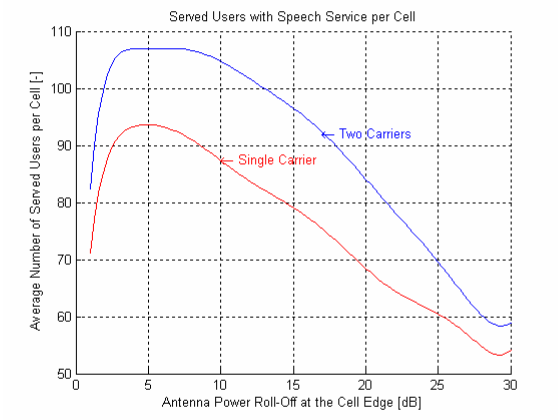


Figure 4: Path loss including Antenna gain of 10 hot-spot cells inside a large cell

The impact of the antenna power roll-off of small cells on their capacity is shown in Fig. 5. From this figures an optimal roll-off at the cell edge in the range between 3 - 7 dB can be distinguished. The lower value in comparison with the multiple HAP study is caused by the fact that the hot-spot cells are not in a homogenous hexangular deployment and so the interference is not such a crucial parameter as in the case of multi-HAP hexangular deployment. The different carriers of small and large cells particularly impact large cells. There is an average cell capacity of about 33 users for a large cell (almost 50% less – see Fig. 3) in the case of single carrier frequency. In the case of 2 carriers the cell capacity of large cell is almost the same as in the scenario without small cells.



(a)



(b)

Figure 5: a. Other-to-own cell interference ratio in the uplink, b. number of served users per cell

Conclusion

The impact of the antenna power roll-off at the cell edge when providing 3G mobile services in sparsely populated areas was presented. It was shown that for large cells with a radius of 30 km in a homogenous hexangular deployment, the value of antenna power roll-off is a trade off between the cell capacity and the quality of coverage. A steep roll-off can guarantee great cell isolations, but at the expense of high quality coverage. Small cells were also distributed within the large cells to simulate hot-spot areas with additional path loss as a function of the elevation angle. For these not directly adjacent small cells the optimal antenna power roll-off is about 5 dB. The application of different carriers for large cells and hot-spot cells can increase cell capacity, especially for the large cells.

Acknowledgments

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