THE ROLE OF HIGH ALTITUDE PLATFORMS IN BEYOND 3G NETWORKS

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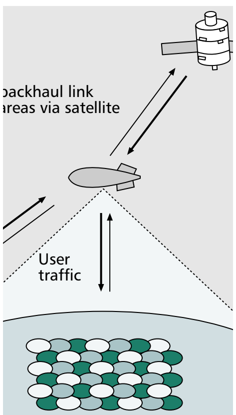

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ABSTRACT

High altitude platforms represent a new alternative to terrestrial and satellite communications systems, and have gained considerable interest in the past few years due to some of their outstanding features. Of the multitude of services HAPs can provide, in this article we focus on the potential role of HAPs in beyond 3G networks. First, a short introduction to HAPs is made. Then we discuss different hybrid system architectures with emphasis on the merits of HAPs and provide a potential mapping of services to the components of a terrestrial-HAP-satellite integrated system. We also examine critical issues that stem from the use of HAPs. Finally, the maximum uplink capacity is evaluated for a multiservice W-CDMA HAP network.

INTRODUCTION

Terrestrial and satellite systems represent two well established technologies that have been dominant in the telecommunications arena for years. However, in recent years a new alternative has emerged based on quasi-stationary aerial platforms located in the stratosphere, often dubbed high altitude platforms (HAPs). The platforms are positioned at an altitude between 17 and 22 km above the Earth's surface. HAPs seem to represent a dream come true for communication engineers since they preserve most of the advantages of both terrestrial and satellite systems.

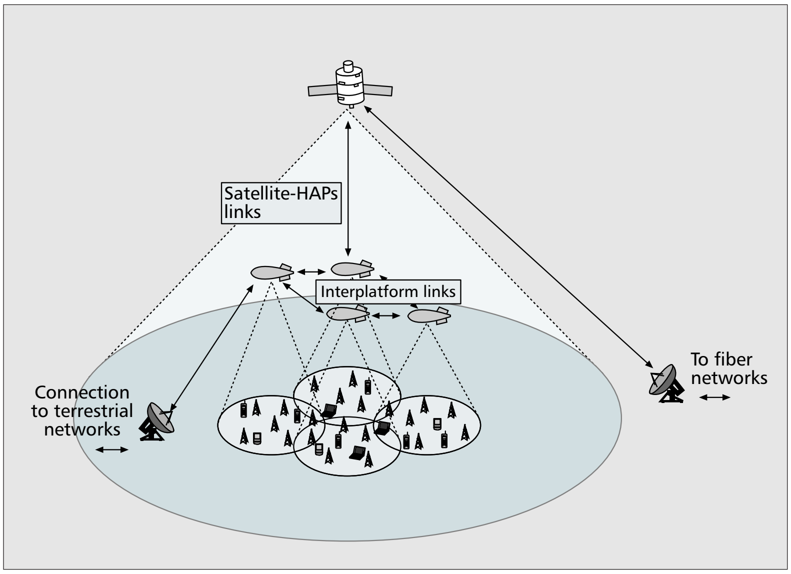
One of the appealing features of HAP networks is their easy and incremental deployment, which renders HAPs suitable not only for a host of communication applications but for services beyond telecommunications as well. Typical services that can take advantage of the flexibility of HAP systems are remote sensing and Earth monitoring, positioning and navigation, homeland security, meteorological measurements, and traffic monitoring and control. Moreover, as well as being able to provide permanent services, HAPs are also tailored for limited scope and emergency applications. However, the focus of this article is on the role of HAPs in beyond third generation (3G) networks. For more details on HAPs the reader is referred to [1], which provides a thorough survey on communications via HAPs.

The success of second-generation (2G) mobile systems, along with the growing exigencies for both mobility and ubiquitous access, prompted the development of new-generation wireless telecommunications systems. 3G networks offer multimedia services to mobile users at transmission rates ranging from some kilobits per second to 2 Mb/s. Notwithstanding, 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. The service discovery process can take advantage of some of the outstanding features of HAP systems. Multimedia broadcast and multicast services (MBMS) can be provided by the HAP component of 3G and beyond 3G networks to improve performance in terms of required system capacity and cost [2]. In addition, new applications are expected to thrive with the advent of fourth-generation (4G) networks. Although the term is still vague, it is safe to see 4G as a system that includes all existing and emerging fixed and mobile networks, including broadcast.

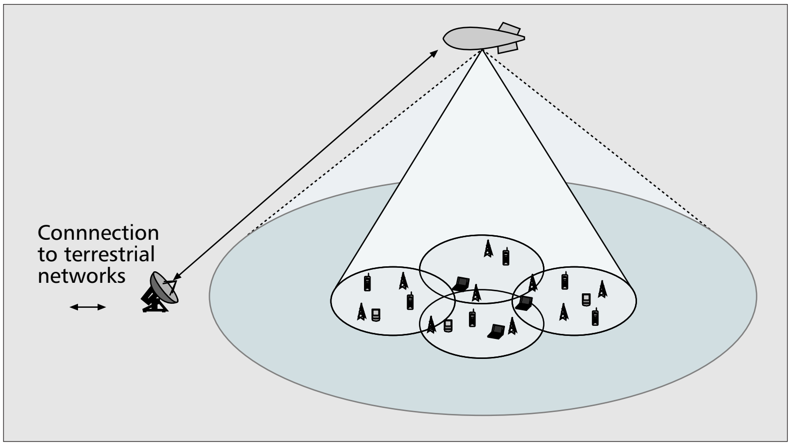
In the remainder of this article the following issues are addressed. Initially, hybrid architectural scenarios are discussed with an emphasis on the emerging role of HAPs and their unique features. Some critical issues within the scope of synergic interworking among terrestrial, HAP, and satellite networks are then examined. Finally, the uplink capacity of a cellular multiservice wideband code-division multiple access (W-CDMA) HAP network is evaluated, and conclusions are presented.

ARCHITECTURAL SCENARIOS

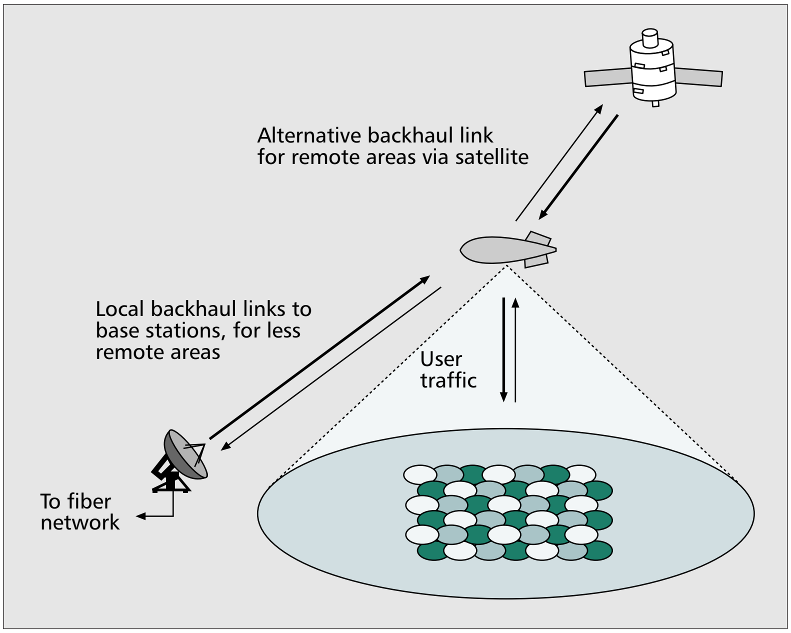
Although architectural solutions can be found in many studies in the literature, there are only a handful of studies that focus on the potential role of HAPs in 3G and beyond 3G networks [2–4]. Generally, the proposed architectures can be categorized as follows.



■ **Figure 1**. *An integrated terrestrial-HAP-satellite system.*



■ **Figure 2**. *An integrated terrestrial-HAP system.*



■ **Figure 3**. *A standalone HAP system.*

An Integrated Terrestrial-HAP-satellite System

A mixed infrastructure comprising HAPs and terrestrial and satellite systems can lead to a powerful integrated network infrastructure by making up for the weaknesses of each other [2, 5]. This hierarchical architectural solution (Fig. 1) can provide fault tolerance, and hence support quality of service (QoS) in failures. Satellite systems can be employed for the distribution of MBMS by virtue of their intrinsic capability of broadcasting and multicasting. In [2] the enhancement HAPs can offer to the delivery of MBMS was addressed in depth. The choice of multiple feeder links was considered to give great flexibility to content providers. Interplatform links could exist for unifying far-flung groups of people.

An Integrated Terrestrial-HAP System

A feasibility study for the integration of a HAP station within a terrestrial Universal Mobile Telecommunications System (UMTS) network was presented in [3]. One of the scenarios under consideration involved a rural macrocell served by an aerial platform and surrounded by cells served by terrestrial base stations. In the authors' opinion, the potential use of HAPs for covering suburban and rural areas holds considerable appeal, and is discussed at greater length in the following subsection. An integrated terrestrial-HAP system represents the most feasible network infrastructure for the near future. Such an architecture is illustrated in Fig. 2. The International Telecommunication Union (ITU) has proposed that footprints of a radius over 150 km can be served from a HAP. In this architectural scenario a HAP is considered to project several macrocells and serve high-mobility users characterized by low bit rates. Terrestrial base stations are also employed in order to provide access to users with high bit rates. It should be stressed that it is not deemed essential for terrestrial base stations to cover the whole area. Rather, they can be placed only at hot spots (e.g., shopping malls). The HAP network will be connected to terrestrial networks through a ground gateway.

A Standalone HAP System

Even though HAPs are usually considered as complementary systems to terrestrial and satellite networks, the potential of standalone HAP systems has been discussed in some studies [4]. HAPs constitute a real asset to wireless infrastructure operators to provide telecommunication services in rural, remote, and impervious areas since it is rather difficult and economically inefficient to cover these areas with cellular and fiber networks. Furthermore, the development cost of satellite systems is much greater, and it may be economically more efficient to cover a large area with many HAPs rather than with a satellite system or many terrestrial base stations. In addition, due to their long development period, satellite systems always run the risk of becoming obsolete by the time they are in orbit. A standalone HAP system is presented in Fig. 3. Backhaul links

Service class	Type of service	Applications	Bit rate	QoS requirements		
				End-to-end delay	Delay variation	Error tolerance
Conversational	Audio	Voice	4–25 kb/s	< 150 ms (preferred) Limit: 400 ms	< 1 ms	Yes
	Video	Video telephony	32–384 kb/s	< 150 ms (preferred) Limit: 400 ms	< 1 ms	Yes
	Data	Telemetry — two-way control	< 28.8 kb/s	< 250 ms	N/A	No
		Interactive games	< 1 kbyte	< 250 ms	N/A	No
		Telnet	< 1 kbyte	< 250 ms	N/A	No
Interactive	Audio	Voice messaging	4–13 kb/s	< 1 s (for playback) < 2 s (for record)	< 1 ms	Yes
	Data	Web browsing	—	< 4 s (per page)	N/A	No
		Transaction services–high priority (e.g., e-commerce)	—	< 4 s	N/A	No
		E-mail	—	< 4 s	N/A	No
Streaming	Audio	Speech, mixed speech and music, medium- and high-quality music	5–128 kb/s	< 10 s	< 2 s	Yes
	Video	Movie clips, surveillance, real-time video	20–384 kb/s	< 10 s	< 2 s	Yes
	Data	Bulk data transfer/retrieval, layout and synchronization information	< 384 kb/s	< 10 s	N/A	No
		Still image	—	< 10 s	N/A	No
Background	Data	Fax	—	> 10 s	N/A	Yes
		Email arrival notification	—	> 10 s	N/A	No

Table 1. *Service classes and their QoS requirements.*

can be provided via a satellite, while a ground gateway can be used to connect the platform to terrestrial networks.

Aircraft or Airships?

What is yet to be specified is which type of aerial vehicle is more suitable for HAP communications. Throughout the evolution of HAPs three types of aerial vehicles can be identified: airships, unmanned solar-powered aircraft, and manned aircraft. More information on these aerial vehicles can be found in [1]. Hereafter, we do not examine the case of manned aircraft since their short flight duration renders them unsuitable for a communications system. Concerning airships, they can stay aloft for some years and can afford high power levels. However, these advantages are negated by the fact that their takeoff and landing can only take place under good weather conditions. We consider that the most appealing type is unmanned solar-power aircraft. Although such aerial vehicles cannot stay aloft for more than a few months and their power levels are lower than those of airships, their manageable take-off and landing makes maintenance and upgrading of their communications payload fairly easy. Moreover, they are well suited to temporary applications.

Mapping of Services

Hereinafter, we consider an integrated terrestrial-HAP-satellite system, concentrating on the service classes 3GPP has defined in [6, 7]. These service classes are presented in Table 1. The main distinguishing factor among these classes is delay sensitivity. Conversational class represents the most delay-sensitive class, while background class is virtually delay-insensitive. Conversational and streaming classes correspond to real-time services, while interactive and background classes mainly indicate Internet applications.

The conversational class is the class with the most stringent QoS requirements. The most well-known type of service of this class is telephony. However, with the advent of the Internet a compelling range of new applications flourished, such as voice over IP and videoconferencing. The streaming class represents another class of real-time services. The proliferation of these types of service has raised a number of new

HAPs can serve medium or low bit rate users with either strict or loose QoS requirements, while satellites are employed for the delivery of low-bit-rate services with loose QoS requirements. However, it bears repeating that satellites and HAPs are also expected to play a role of paramount importance in the delivery of MBMS.

requirements in both telecommunications and data networks. Nevertheless, this class does not impose as strict QoS requirements as does the conversational class. Interactive class describes cases wherein an end user online requests data from remote equipment, so round-trip delay is of fundamental importance. Last but not least, background class accounts for all data files sent or delivered in the background. The main characteristic of this class is that the end user does not expect the delivery of data within a specific time interval; thus, in this respect this class is delay-insensitive.

The focus of this section is on the mapping of these kinds of services to the three components of the integrated system. HAPs do not have very limited capacity as satellite networks since extensive frequency reuse is possible. In addition, the propagation delay is comparable to the delay experienced in terrestrial networks, while HAPs enjoy more favorable path loss characteristics. In our effort to map services to the three components of the integrated system, we take into account the service bit rate and QoS requirements. Moreover, as a rule of thumb, we consider that the greater the bit rate, the lower the user mobility. Table 2 presents a potential mapping of services to an integrated terrestrial-HAP-satellite system. This mapping does not infer that each type of service can be served only by a specific component of the integrated network. Rather, it just indicates which component is well suited to each type of service.

High-bit-rate services are mapped to the terrestrial component. The reasoning behind this mapping is that the terrestrial component has fewer capacity limitations than the two other components due to the high degree of frequency reuse. In addition, due to low mobility, this kind of user will not experience a great number of handovers during a call. HAPs can serve medium- or low-bit-rate users with either strict or loose QoS requirements, while satellites are employed for the delivery of low-bit-rate services with loose QoS requirements. However, it bears repeating that satellites and HAPs are also expected to play a role of paramount importance in the delivery of MBMS.

Component	Type of service
Terrestrial	Conversational — audio/video/data
	Interactive — data
	Streaming — video/data
	Background — data
HAP	Conversational — audio/data
	Interactive — audio /data
	Streaming — audio
	Background — data
Satellite	Streaming — audio
	Background — data

Table 2. *A potential mapping of services in a hybrid system.*

CHALLENGES IN INTERWORKING

In this section several issues deemed critical to successful interworking among terrestrial, HAP, and satellite networks are addressed.

CELL PLANNING

Cell planning is a matter of the greatest importance to any wireless infrastructure provider. Efficient cell planning can reduce network cost and increase its capacity. In an integrated system the cell planning of the terrestrial component should be done in conjunction with the cell planning of the HAP system. In a HAP system cell planning is not determined by terrain as it is in terrestrial wireless systems, because all base stations are located onboard the HAP. In this respect, it may be considered simpler than in terrestrial cellular systems. Moreover, due to their ability to move around, HAPs are tailored to handle temporal and spatial traffic fluctuations, and provide initial commercial service in future hot spot areas.

An efficient cell planning for integrated systems should grapple with issues such as bandwidth allocation, QoS requirements, cell sectorization, cost, flexibility, and reliability, as well as frequency allocation to the cells of different networks. The frequency bands that are allocated to terrestrial cellular systems are well known. Table 3 presents the frequency bands available for communications via HAPs. Currently, a great deal of pressure is exerted on ITU in order to make the 31/28 GHz band available in Europe.

The frequency bands allocated for HAP services are nevertheless shared with some other services, complicating cell planning and making the coexistence of HAP, satellite, and terrestrial wireless systems a challenging task. In this respect, interference analysis is pivotal and should be included in the tasks of the cell planning process in order to attain optimum coverage and high signal quality. What is more, interference levels are dependent on antenna radiation patterns; consequently, designers should opt for onboard HAP antenna configurations that mitigate interference to other systems.

CALL ADMISSION CONTROL

Among the various aspects of resource management, call admission control (CAC) is of utmost importance since it directly controls the number of users, and thus is connected with users' QoS. CAC comprises the set of functions taken by the network during the phase of connection establishment to decide whether to accept or reject a user's request for a connection. There are several studies that addressed the issue of CAC for standalone systems (e.g., [8, 9]). However, CAC schemes for heterogeneous networks remain an issue to be addressed.

Frequency band	Direction of the link	Region	Services
1885–1980 MHz 2010–2025 MHz 2110–2170 MHz	Uplink and downlink	Regions 1 and 3	IMT-2000
1885-1980 MHz 2110–2160 MHz	Uplink and downlink	Region 2	IMT-2000
47.9–48.2 GHz 47.2–47.5 GHz	Uplink and downlink	Global	Fixed service
31.0–31.3 GHz	Uplink	40 countries worldwide (20 countries in Asia, Russia, Africa, etc. and in Region 2)	Fixed service
27.5–28.35 GHz	Downlink	40 countries worldwide (20 countries in Asia, Russia, Africa, etc. and in Region 2)	Fixed service

Table 3. *Frequency bands allocated for communications via HAPs.*

the need for intelligent handover schemes that will accomplish seamless handover in 4G networks is of vital importance. These schemes should take several factors into account such as user's mobility, QoS requirements and access rights, etc.

In future integrated telecommunications networks a key objective is to provide a multitude of services using their capabilities in an optimized way. Intelligent CAC schemes should be able to decide on the serving network according to several decision criteria. The most important ones are the QoS requirements of the application, the traffic load of each candidate serving network, user mobility, the available energy at the user terminal, and pricing. Nonetheless, the challenge in this case is to include all these criteria in a CAC algorithm without making its computational complexity intractable and without further complicating the design of multimode user terminals by requiring new functionalities to be added to them.

Seamless Handover

In heterogeneous systems two types of handovers can be identified: intrasystem handovers, also referred to as horizontal handovers, and intersystem handovers which are usually referred to as vertical handovers. A handover is usually initiated when the signal-to-interference ratio (SIR) is below a predefined threshold. Various studies have treated the issue of intrasystem handover, especially for terrestrial code-division multiple access (CDMA) cellular systems. In terrestrial cellular systems a user is connected to the base station toward which the radio path loss is minimum, which may not be the closest one. On the contrary, in a HAP system a user is connected to the base station that illuminates the cell in which the user is located. This fact alleviates the need for soft handover in HAP CDMA cellular systems. Even though we do not dwell on this issue in our work, we briefly describe the concept of soft handover.

Soft handover is the technique whereby mobile users in transition between one cell and its neighbor transmit to and receive from two or more base stations simultaneously. This technique improves system performance of terrestrial CDMA cellular networks at the expense of increased backhaul connections [10]. Moreover, it ameliorates the undesirable "ping-pong" effect where the user is handed back and forth several times from one base station to another as he/she hovers around the cell boundary. Nevertheless, in a practical HAP cellular system this can be avoided by handing over the user only when the base station power is sufficiently below its value at the theoretical cell boundary. Moreover, the very sharp antenna radiation pattern of a HAP base station makes soft handover easier said than done since the soft handover zone would be rather small. In this study, for the sake of brevity we do not accentuate the performance disparity between hard and soft handover.

As noted previously, in 4G networks a handover between different networks is also required. Intersystem handovers require the frequency to be changed at the time of handover. What is more, Mobile IP uses a hard handover, which is unsuitable for multimedia services due to the large number of packets that can be lost during the handover procedure. Therefore, the need for intelligent handover schemes that will accomplish seamless handover in 4G networks is of vital importance [11]. These schemes should take several factors into account such as user mobility, QoS requirements and access rights, the capacity of each candidate serving network, and pricing.

Multimode User Terminals

Although the amalgamation of heterogeneous access networks has been proposed to fulfill the "anywhere, anytime," concept, a main research challenge is to develop terminals that can adapt to different wireless networks by reconfiguring themselves. The benefits of multimode user terminals are that users will be able to select a network depending on service requirements and cost; worldwide roaming will come true as well. The software radio approach is reckoned as the most promising way to implement multimode terminals [12]. Notwithstanding the great benefits that stem from the use of software radio technology, there are some technological problems that need to be tackled such as the need to support a wide range of frequency bands, the real-time execution of frequency conversion, digital filtering, spreading and despreading, and power consumption.

Service type	Bit rate (kb/s)	$(E_b/N_0)_{min}$ (dB)	Power factor (dB)
Conversational — audio	12.2	5	0
Interactive — data	64	2	4.2
Interactive — data	144	1.5	7.22

Table 4. *Services under consideration.*

Content Scheduling Techniques

A compelling approach to 4G networks involves the use of both HAPs and satellites for the provision of broadcast and multicast services. In both push and pull multistage content delivery systems, the optimization of content scheduling techniques and radio planning is deemed necessary for achieving better content access times and increased coverage with efficient capacity utilization.

Capacity of a W-CDMA HAP Network

Terrestrial and satellite networks have been the subject of extensive research since the early 1970s; there are a plethora of studies in the literature that address capacity issues. However, capacity issues have scarcely been addressed for HAP networks. In [3] both the uplink and downlink capacity were estimated for a CDMA HAP macrocell. However, the assumptions of a fixed number of users in a cell and perfect uplink power control render the results rather optimistic and inaccurate. Moreover, an oversimplified channel model was used to derive the downlink capacity. In [4] the downlink capacity of a CDMA HAP cellular network was evaluated; however, as in [3], an oversimplified channel model was considered, and the number of users per cell was fixed. In [13] the uplink capacity of a CDMA HAP cellular system was evaluated. Notwithstanding, the results of this work are limited due to the following two reasons:

- The number of users per cell was fixed.
- The results were obtained under the assumption of perfect power control.

Furthermore, in the aforementioned studies, each time the capacity was estimated the system was considered to support only one service class.

Wideband CDMA (W-CDMA) has emerged as the mainstream radio access technology for next-generation wireless cellular systems, and this section is devoted to estimation of the uplink capacity of a multiservice W-CDMA HAP network. In CDMA cellular systems the capacity is limited by the uplink since the transmission onto this is asynchronous while the transmission onto the downlink is synchronous and part of the intracell interference can be cancelled through the use of orthogonal codes. Thus, in this work we restrict ourselves to estimation of only the uplink capacity. What is more, we consider imperfect power control, letting the number of users in each cell be Poisson distributed as well. This model is more realistic than a model that assumes a fixed number of users per cell since it accounts for instantaneous unequal cell loading, while the average load per cell is the same in every cell. Besides, perfect power control is beyond the realms of possibility in any real system.

We consider three types of services, presented in Table 4. Our analysis is based on the well-known energy per bit to noise spectral power density ratio E_b/N_0. The link is considered to be in outage when E_b/N_0 is smaller than the minimum required $(E_b/N_0)_{min}$. The $(E_b/N_0)_{min}$ values have been taken from [3].

E_b/N_0 is given by

$$\frac{E_b}{N_0} = \frac{W}{R_{b,i}} \frac{P_{c,i} e^{a\theta_k}}{(1-\beta) I_{intra} + I_{inter} + n_0}, \quad (1)$$

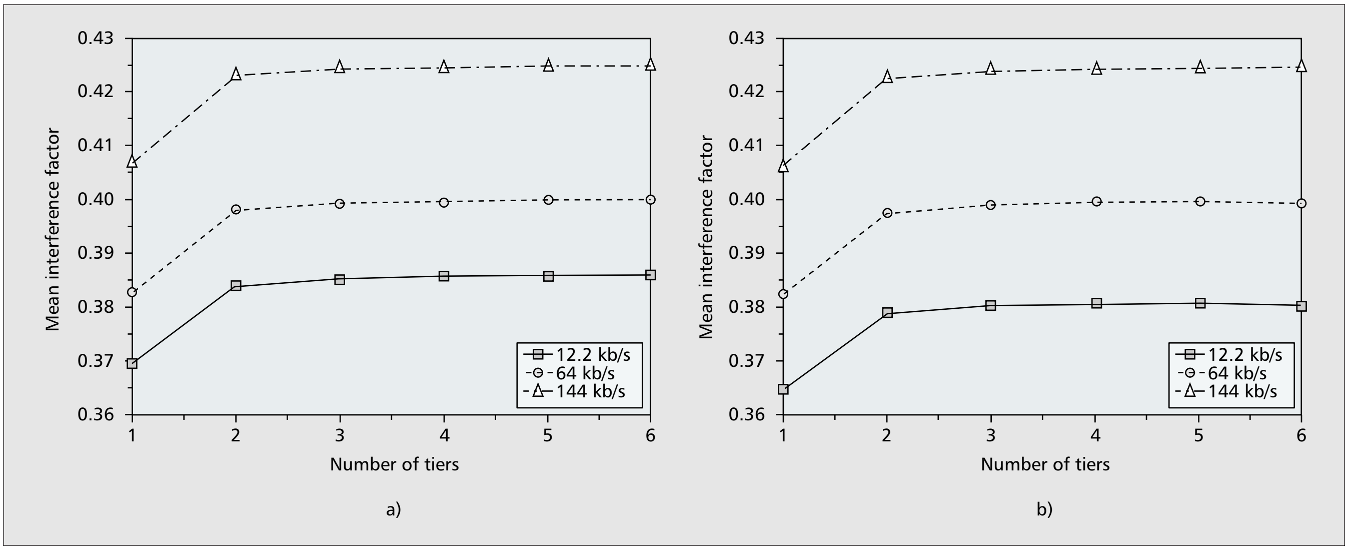
where W denotes the transmission bandwidth, $R_{b,i}$ is the bit rate, I_{intra} is the interfering power that stems from users in the same cell (intracell interference), I_{inter} is the interfering power that stems from neighboring cells (intercell interference), and n_0 is the thermal noise power. β denotes the percentage of I_{intra} that can be cancelled with the employment of base station multiuser detection (MUD). The nominator of the righthand fraction expresses the power from a user that is received by a base station when power control impairments are taken into account. In essence, $P_{c,i}$ is the nominal received power with ideal power control, α is equal to $\ln(10)/10$, and θ_k is a random variable that accounts for power control imperfections in dB. Power control imperfections are considered to be log-normally distributed, and since θ_k represents the signal power variations in dB, it is therefore a zero mean Gaussian random variable with standard deviation σ_i. It must be stressed that all interfering signals are affected by power control impairments with the same statistics as the desired signal.

Regarding $P_{c,i}$, this was obtained similar to the way proposed in [8], according to which the power factor, that is, the ratio of the received power of a type of service to the received power of the lowest bit rate type (the conversational-audio in our case), is equal to

$$Power\ Factor = \frac{E_{b,i} R_{b,i}}{E_{b,c-a} R_{b,c-a}}, \quad (2)$$

where $E_{b,i}$ and $R_{b,i}$ are the energy per bit and bit rate of each service type, while $E_{b,c-a}$ and $R_{b,c-a}$ are the energy per bit and bit rate of the conversational-audio type of service.

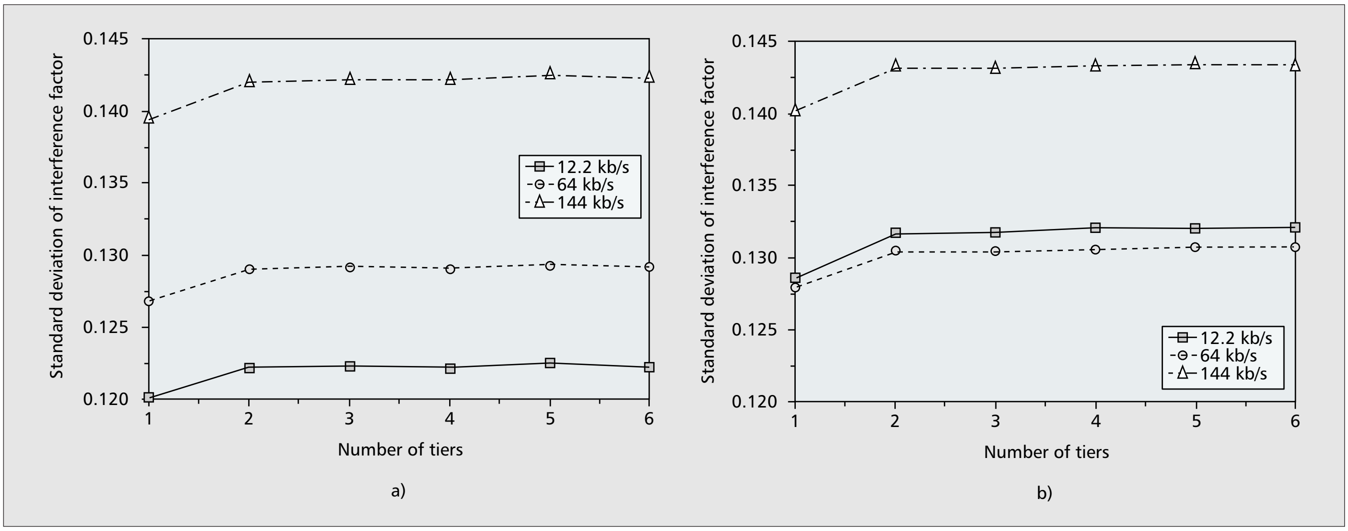
The objective of this section is to estimate the admissible combinations of users with respect to the maximum outage probability. We consider a HAP located at an altitude of 20 km above the Earth's surface, using a multibeam phased array antenna. The antenna radiation pattern conforms to ITU specifications [14], and we assume that the gain at the cell boundary is 10 dB below the maximum gain. A hexagonal cellular layout is assumed, and a reference cell is considered directly below the HAP, surrounded by N_T tiers of interfering cells. The displacement of the HAP is assumed to be compensated for by means of either beam control or an antenna steering mechanism.



■ **Figure 4**. *Mean interference factor vs number of tiers* N_T *for a) perfect power control; b) imperfect power control (average number of 12.2 kb/s users per cell = 25, average number of 64 kb/s users per cell = 6 and average number of 144 kb/s users per cell = 2).*

For the rest of the simulations we set $W = 5$ MHz, $\beta = 0$, and $n_0/P_{c,c-a} = 1$ dB, where $P_{c,c-a}$ is the nominal received power of conversational-audio users with perfect power control. Users are randomly distributed in every cell while the number of users of each service in each cell is Poisson distributed. However, before conducting the main set of simulations we also had to decide on the number of tiers surrounding the reference cell that we were going to simulate.

Figure 4 presents the mean interference factor, which is defined as the mean of the ratio of I_{intra} to I_{inter} as a function of the number of neighboring tiers N_T for both perfect and imperfect power control. The values of σ_i were 1 and 0.5 dB for conversational-audio (12.2 kb/s) and interactive-data (both 64 and 144 kb/s), respectively. The reason we set a smaller value to σ_i of interactive-data users can be ascribed to the lower mobility of this kind of user. It must be stressed that the value of the interference factor is not the same for every combination of users; however, due to space limitations we provide figures for one combination. It is interesting to notice that the mean interference factor is greater in terrestrial CDMA systems where it is around 0.5. Figure 5 depicts the standard deviation of the interference factor. As can be seen, power control imperfections result in an increase in standard deviation, which is more evident in the conversation-audio type of service. It is evident from Figs. 4 and 5 that I_{inter} stems mainly from the first three tiers, and for the rest of the simulations we set $N_T = 3$. We should also stress that in terrestrial CDMA cellular systems the standard deviation of the interference factor is somewhat greater. This performance disparity can be partly attributed to the fact that in a HAP system all base stations are located onboard the HAP; hence, there are no significant variations in the power level of interfering signals over time.



■ **Figure 5**. *Standard deviation of interference factor vs number of tiers* N_T *for a) perfect power control; b) imperfect power control (average number of 12.2 kb/s users per cell = 25, average number of 64 kb/s users per cell = 6 and average number of 144 kb/s users per cell = 2).*

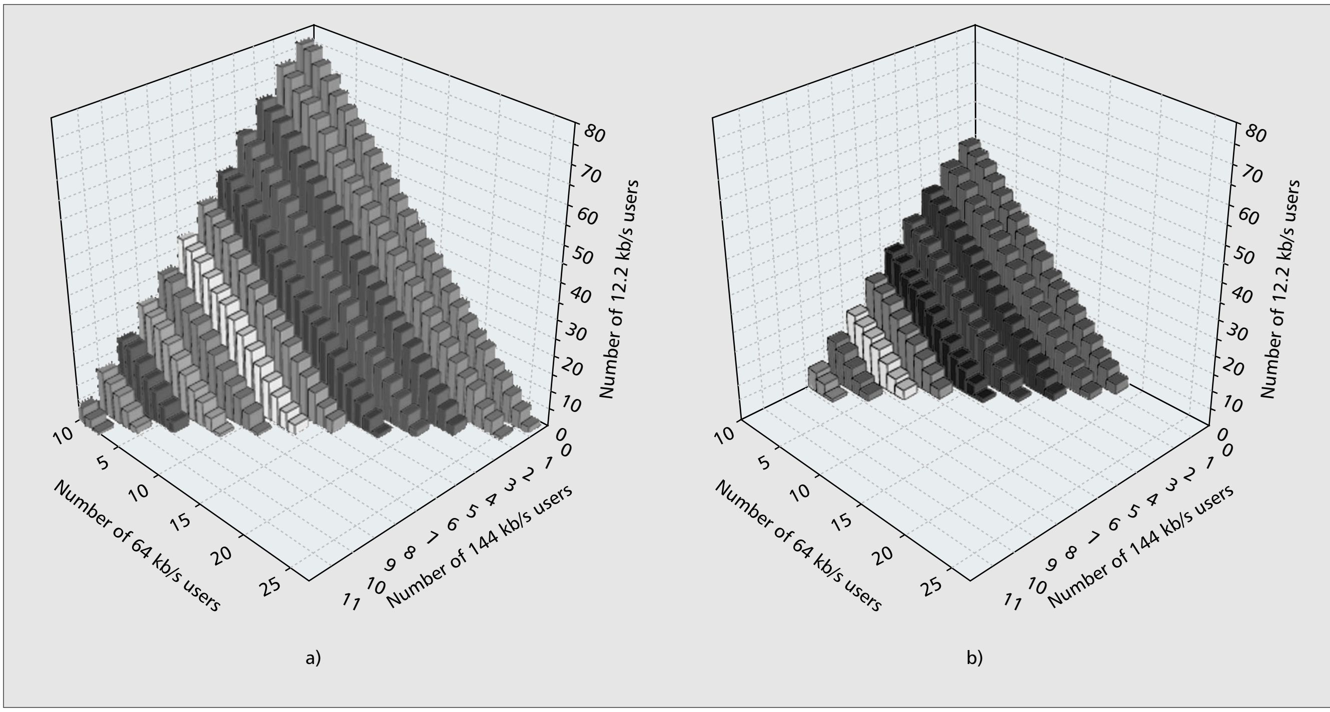


Figure 6. *Maximum average number of users per cell for a) perfect power control; b) imperfect power control ($\sigma_{12.2}$ = 1 dB, σ_{64} = 0.5 dB, and σ_{144}= 0.5 dB). In both cases $P_{out} \le 10^{-2}$ for any type of service.*

Figure 6 illustrates the admissible combinations of users for both perfect and imperfect power control. Due to space limitations, we provide the results for only one possible combination of σ_i. We should note that the axes represent the maximum average number of users per cell so that the outage probability for every service would be less than or equal to 10^{-2}. Apparently, there are specific limits on the maximum average number of users per service that can coexist at the same time. In our effort to map services to the components of an integrated terrestrial-HAP-satellite system we mapped high-bit-rate services to the terrestrial component. The results in Fig. 6 reinforce this policy, especially if we take into consideration that the radius of HAP cells will be 1 km or even more. Furthermore, as can be seen in Fig. 6b, the capacity is severely exacerbated in imperfect power control.

From Fig. 6 it is apparent that the capacity of HAP systems is comparable to that of terrestrial CDMA cellular systems [8] and definitely higher than that of geostationary or low Earth orbit satellite systems. As far as power control imperfections are concerned, they have more or less the same detrimental impact on the uplink capacity as in terrestrial systems. Therefore, while HAPs do offer an avenue for providing telecommunications services in rural and isolated regions, HAPs can also be integrated with terrestrial wireless networks, leading to a powerful mixed network infrastructure capable of providing high-quality beyond 3G services. Furthermore, we should point out that, as in all wireless systems, system performance is affected by the antenna configuration employed. Additional advantages can accrue through the use of more directive antennas; however, the more directive an antenna is, the larger its dimensions. In this context HAPs face limitations on the minimum cell size projected on the Earth's surface, which cannot be smaller than 1 km in radius. System capacity can also be increased if base station MUD is employed. MUD with efficiency β of around 0.2 can make up for the decrease in system capacity due to power control imperfections with σ_i = 1 dB.

Conclusions

High altitude platforms constitute a new alternative to terrestrial and satellite systems. With some of their outstanding features, as well as their capability to provide a wide spectrum of compelling services, it is envisaged that HAPs will play an important role in next-generation networks. In this article we discuss the role of HAPs in beyond 3G networks. Different architectural scenarios are spelled out, and a potential mapping of services to the components of an integrated terrestrial-HAP-satellite system is proposed. Moreover, we address several critical issues for synergic interworking including cell planning, call admission control and seamless handover, multimode user terminals, and content scheduling techniques. Finally, we evaluate the uplink capacity of a multiservice W-CDMA HAP cellular system. It is shown that power control imperfections reduce system capacity. However, base station MUD can ameliorate the detrimental effects of power control impairments.

Acknowledgment

Mr. Stylianos Karapantazis thanks the Bodossaki Foundation for supporting his PhD studies.

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While HAPs offer an avenue for providing telecommunications services in rural and isolated regions, HAPs can also be integrated with terrestrial wireless networks leading to a powerful mixed network infrastructure capable of providing high quality beyond 3G services.