PERFORMANCE OF CDMA POWER CONTROL FOR HAPS

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ABSTRACT

In parallel 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 project addresses downlink and uplink power control for high altitude platform station for a WCDMA under the assumption of power control imperfections. However in real systems power control imperfections degrade the system capacity. In this project, the performance of two distance based forward link power control schemes (nth-power-of distance and optimum power control schemes) are evaluated for high altitude platform station (HAPS) W-CDMA systems. For a HAPs system with 37 beams, the total capacity of the system would be in the order of 1776 voice users or 233 data users. The coverage of the platform with 37 beams each with a radius of 1.2 km can by approximated by a circle with a radius of 8 km.For uplink case the system capacity would be 2627 voice user and 370 data user. Thus, for the voice and data service, the uplink capacity is higher than the downlink capacity.

ABSTRAK

Seiringan dengan ragkaian terestrial dan satelit, satu alternatif rangkaian berdasarkan aplikasi pelantar terapung di lapisan stratosfera telah diperkenalkan. Ia dikenali sebagai High Altitude Platforms (HAPS). Teknologi HAPS menggunakan kapal terbang atau stesen udara yang diletakkan pada posisi 17km dan 22.5km daripada permukaan bumi. Teknologi ini berkemampuan untuk menghantar maklumat dalam julat spektrum frekuensi yang luas untuk aplikasi perhubungan pengguna-pengguna bergerak atau tetap. Posisi HAPS di udara membolehkan kawasan yang agak luas mendapat liputan darinya. Wideband code division multiple access (WCDMA) telah muncul sebagai kod penggunaan yang utama untuk solusi jaringan 3G yang menggunakan perantara udara. ITU telah mengkhususkan penggunaan beberapa julat frekuensi IMT-2000 (3G) untuk pengunaan teknologi HAPS.Projek ini merganalisa prestasi pautan bawah dan pautan atas kawalan kuasa untuk tanah tinggi stesen pelantar untuk WCDMA di bawah andaian ketidaksempurnaan kawalan kuasa.Namun, dalam kondisi sebenar, kondisi penalaan kuasa tidak sempurna merendahkan kapasiti sistem secara keseluruhan. Di dalam projek ini, prestasi dua skim penalaan jaringan kuasa arah-hadapan (skim kawalan kuasa-n-dengan jarak dan kuasa optimum) dilaksanakan ke atas sistem HAPS-WCDMA. Untuk sistem HAPS yang menggunakan 37 pancaran, jumlah kapasiti sistem berkenaan adalah 1776 suara pengguna atau 233 data pengguna. Kawasan yang mendapat liputan stesen HAPS yang mempunyai 37 pancaran dengan jejarian setiap pancaran 1.2km boleh dianggarkan dengan lingkaran yang berjejari 8km.Bagi kes pautan atas keupayaan sistem itu akan menjadi 2627 suara pengguna dan 370 pengguna data. Oleh itu, bagi perkhidmatan suara dan data, kapasiti pautan atas adalah lebih tinggi daripada kapasiti pautan bawah.

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LIST OF ABBREVIATIONS

BFWA	-	Broadband Fixed Wireless Access
BWA	-	Broadband Wireless Access
Cm	-	Centimeter
C/N0	-	Carrier to Noise Density Ratio
CDMA	-	Code Division Multiple Access
Db	-	Decibel unite
DBF	-	Digital Beam Forming
EHF	-	Extremely High Frequencies
4G	-	Fourth Generation
GEO	-	Geostationary Orbit
HAAP	-	High Altitude Aeronautical Platforms
HALE	-	High Altitude Long Endurance
HAPs	-	High Altitude Platform stations
ITU	-	International Telecommunication Union
Km	-	Kilometers
LEO	-	Low Earth Orbit
LMDS	-	Local Multipoint Distribution Systems
MEO	-	Medium Earth Orbit
MHz	-	Mega Hertz

mm/hr	-	Millimeter per Hour
MBMS	-	Multimedia Broadcast and Multicast Service
QOS	-	Quality Of Service
RAC	-	Rural area coverage
RF	-	Radio frequency
SAC	-	Suburban Area Coverage
SINR	-	Signal to Interference and Noise Ratio
SPFs	-	Stratospheric Platforms
3G	-	Third Generation
UAC	-	Urban Area Coverage
UAV	-	Unmanned Aerial Vehicles
UTMS	-	Universal Mobile Telecommunications System
WCDMA	-	Wideband Code Division Multiple Access

LIST OF SYMBOLS

Gm	-	Maximum main lobe Antenna gain
C/N0	-	Carrier to Noise ratio
r_i	-	Distance between center of cells and user
R	-	Radius of cell
θ	-	Direction of mobile user inside cell
d_{1j}	-	Distance between the home base station and tier-1
$d_2 j$	-	Distance between the home base station and tier-2
$d_3 j$	-	Distance between the home base station and tier-2
ψ_j	-	Angles under which the mobile is seen from the antenna boresights of *BSj – Bso*
$G(\psi_j)dBi$	-	Normalized antenna gains
$f(r)$	-	Power control
Ro	-	Distance at which the power control scheme changes the law of the power control.
P_{req}	-	Power required
P_t	-	Power transmitted
ρ	-	User density

N	-	Number of user
P_T	-	Total power transmitted
(C/I)	-	carrier-to-interference ratio
BSj	-	Base station (j=0 – J)
Pch	-	Power assignment for the users
Lj	-	distances from the mobile to BSj
Lo	-	distances from the mobile to BSo
S	-	path loss exponent
A	-	Source activity factor
ϕ	-	Orthogonality factor
$\frac{E_b}{N_\circ}$	-	Energy pit to noise ratio
G_p	-	W-CDMA processing gain

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CHAPTER 1

INTRODUCTION

1.1 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.

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 project is on the part of HAPs in beyond third generation (3G) networks. 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. 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 [9].

1.2 Problem statement

There are several important factors that makes our current mobile communication system work properly. Major research areas include coding and optimizing power control schemes. The issue of power control is very important in maximizing the capacity of a CDMA system and ensure a good quality of reception. There will always be limitations in how many users BS will be able to handle simultaneously. It has been stated that when having all MS's power arriving at equal power levels to the BS the system capacity is maximised. Without a proper power control scheme the communication system would not be able to handle as many users as it does today.

Wireless communications systems using high altitude platform stations (HAPS) have been proposed worldwide due to the many advantages of HAPS systems over terrestrial tower-based and satellite systems. Recently, the International Telecommunication Union (ITU) has accepted HAPS as an alternative means of delivering the next generation's IMT-2000 wireless services. It is also suggested that HAPS may use CDMA based IMT-2000 radio transmission techniques derived from standards such as IS-95 (and its extensions) and other emerging W-CDMA standards. In cellular CDMA systems, forward link power control is used to reduce the interference to other neighbouring cells and increase system capacity. For terrestrial tower-based systems, it is in [11] suggested that with knowledge of mobile positions, distance based power control schemes can be used to minimize the total power transmitted by the base station. For such schemes, the base station allocates a higher power level to users located near the cell boundary and a lower power level to users close to the cell center. The performance of a distance based power control scheme based on an nth exponent of a mobile's distance from the center of its serving cell was analyzed in [11], [8] and [16] in the absence of shadowing. In [8], an optimum power control scheme based on a function of the mobile's distance from the center of its serving cell and its distances to the centers of adjacent cells was also proposed to ensure that a uniform level of service is provided to users in all locations in a cell. This scheme was further developed to include a mobile's direction from the center of its serving cell in [16]. While distance based power control schemes perform well in non-shadowed environments, they may not be appropriate in shadowed environments because the received power depends not only on distance but also on the shadowing spread [12].

1.3 Objective

1. To study the performance of forward link power control schemes (n-th-power of distance and optimum power control schemes) for HAPS WCDMA.
2. To estimate the downlink capacity for WCDMA HAPS under the power control imperfection.
3. To estimate the uplink capacity for WCDMA HAPS and compare it with downlink.

1.4 Scope of work

1. At preliminary stage, the network architecture, end user radio link performance of HAPS was understood. For end user radio link research was performed for an UMTS terminal in the allocated 3G frequency.

2. Capacity estimation for a WCDMA HAP station under the assumption of power control imperfections.
3. Improvement of the downlink performance by equalizing the powers of all users in a cell and by compensating for the channel fading.
4. Evaluation downlink capacity considering imperfect power control, letting the number of users in each cell followed uniform distributed will be conducted.

1.5 Organization of the Thesis

This thesis is organized into five chapters to completely cover the whole research work that has been conducted for WCDMA HAPS platform positional instability project.

After introduction the literature review was presented in the second chapter. Third chapter discuss and describes the methodology that has been followed. Forth chapter presents the obtained results and detailed discussion of obtained findings. Lastly, fifth chapter presents conclusion and future works.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The need to improve on the existing bandwidth available for mobile communication devices and application has made researchers and telecommunication experts delve into more technologies that can provides the needed bandwidth. There has been several works on improving the bandwidth provision from satellite and terrestrial communication. While these are unfolding, there has been several other technologies been looked into that could possibly provide a better bandwidth as required by users of these mobile services. The advantages and disadvantages of terrestrial and satellite systems are well known and have been extensively documented in several works over the years. The drawbacks, in particular, have made engineers continuously search for alternative means of making broadband fixed wireless access available to the ever-growing population of users worldwide [3].

2.2 Related work

Some of distance based power control schemes in case of downlink for HAPS CDMA system have been discussed in [1] and [7], which are n-th power of distance scheme and optimum power control scheme. However, analysis and system capacity obtained in the simulation are performed under the assumption of platform positional stability in the air.

In those papers, HAPS movement assumed to be compensated by appropriate station keeping mechanism by steering the beams electronically. This assumption refers to an ideal condition of HAPS which is impossible situation in practical. HAPS supposed to be move or drift due to some factors such as wind and earth gravitation. The movement scenarios of high altitude platform have been analyzed in [4]. This paper describes that HAPS has three possible movement scenarios which are vertical movement, horizontal movement, and inclination movement/HAPS's tilt. The effect from each of the movement has also been derived. Moreover, system capacity in term of the number of user per cell has been shown for each of the movement scenarios. However, the CDMA capacity obtained in [4] is evaluated under the employing of the power control whose the scheme is not clearly explained. In cellular HAPS CDMA, scheme of the power control significantly determines the capacity of the system.

In [10], the effect of HAPS instability/movement on the effect to the capacity of CDMA system using two schemes of distance-based power control was evaluated and quantified. ITU has specified that such platforms should be kept within a circle radius sphere of 400 m with height variations of ±700 m [17]. The author did a computer simulation for the evaluation of instability HAPS within the scope of ITU specification for the horizontal and vertical movement. The inclination movement scenario has not been specified by ITU or other telecommunication standard body therefore the computer simulation obtained with respect to the proposed model. The simulation result concluded how much the platform may incline regarding the system capacity. In [2] did just the effect of HAPS movement on the effect to the capacity of CDMA system using same schemes.

Forward link power control is used in cellular W-CDMA systems to reduce the interference to the other neighboring cells and increase system capacity. The performance of a distance based power control scheme based on an n-th exponent of mobile's distance from the center of its serving cell was studied in [8] and used to analyze the forward link capacity of high altitude platform W-CDMA system in [7] (for voice service only). The drawback of the above mentioned n-th power of distance power control scheme is that it is suitable only for environments with low orthogonality factor between the users ($\varphi \approx 0.0$) that is not the real case for the HAPs W-CDMA system in which φ ranges from 0.4

to 0.6 in practice. For that reason, in [14] the n-th power of distance power control scheme was improved to calculate the HAPS downlink capacity of a W-CDMA using the methodology given in [7] and then compared it with the uplink capacity. It has been found that, the downlink is the link that limits the HAPs capacity.

Also in [15] did the same thing, in addition to study the power requirement and the deployment of the system over Madrid as an example.

2.3 Why HAPS

Is it possible to have a system which combines most of the advantages of satellite and terrestrial systems while avoiding many of the pitfalls identifiable in either of them? In searching for an answer to this question, the attention of wireless communications engineers has shifted to a system known under different names as High Altitude Platforms (HAPs), Stratospheric Platforms (SPFs), High Altitude Aeronautical Platforms (HAAPs) and High Altitude Long Endurance (HALE) [3].

These are, generally, solar-powered, unmanned, remote-operated and electric motorpropelled aerial platforms held in a quasi – stationary position, at altitudes between the 17– 22 Km range above the earth's surface (stratospheric layer of the atmosphere).

Table 2.1: The different atmospheric layers [3]

Atmospheric layer	Altitude/Height	Existing objects in layer
Troposphere	Up to 18 km	Mountains , buildings ,commercial airplanes,etc
Stratosphere	Between 18 km and 50 km	Weather balloons , HAPs
Mesosphere	Between 50 km and 80 km	Meteors
Thermosphere	Between 80 km and 690 km	Aurora , shuttles
Exosphere	Between 690 km and 800 km	

These platforms carry multipurpose communications relay payload, which can range from a complete base station to just a simple transponder, like we have on most satellites. The idea of floating a ‘big balloon’ in space is not an altogether new one. As far back as the 18th century, the Montgolfier brothers invented a lighter-than-air craft using hot air and they demonstrated its use in a manned flight in 1783. The main goal in the current efforts is more business-oriented and it focuses on developing an economically viable and highly reliable HAP that can serve communication applications.

2.4 Aerial Platforms

The history of HAPS has brought about three distinguishable types of proposed aerial vehicles. These types of platforms can be balloons, aircrafts or airships. They are categorized depending on the way they are managed and maintained.

2.4.1 Unmanned Airships

These are mainly balloons and are semi-rigid or non-rigid huge and mainly solar powers balloons which can be well over 100m in length and could carry a payload of about 800kg or more. This typed of aerial vehicle is aimed at staying up for a period of 5 years or more.

Figure 2.1: Solar-powered unmanned airships

2.4.2 Solar-powered Unmanned Aircraft

These types of aerial vehicles are also known as High Altitude Long Endurance platforms (HALE Platforms) and they make use of Electric motors and propellers as propulsion while during the day, they get power supply from solar cells mounted on their wings and stabilizers which also charge the on-board fuel cells. There has not been an agreed span of flight duration for this category of vehicles but proposals declare that they can stay aloft for six months or more.

Figure 2.2: Solar-powered unmanned aircraft [5]

2.4.3 Manned Aircraft

This category of vehicles has an average flight duration of some hours which is mainly due to the fuel constraints and human factors.

Collectively, Solar powered unmanned aircraft and manned aircraft are referred to as High Altitude Aeronautical Platforms (HAAPs) [3].

Figure 2.3: Manned aircraft [5]

2.4.4 Unmanned Fueled Aircraft

They are also known as unmanned aerial vehicles (UAVs). These are used only for military short time surveillance (up to 40 hour) and they fly generally at modest altitudes [13].

Figure 2.4: Unmanned fueled aircraft [5]

The table 2.2 shows a breakdown of general comparison of Airships, Solar powered unmanned and manned aircrafts.

Table 2.2: General comparison of Airships, Solar powered unmanned and manned Aircrafts [3]

	Airships (unmanned)	**Solar-powered Unmanned Aircraft**	**Manned Aircraft**
Size	Length 150 ~ 200 m	Wingspan 35 ~ 70 m	Length ~ 30 m
Total weight	~ 30 ton	~ 1 ton	~ 2.5 ton
Power source	Solar cells (+ fuel cells)	Solar cells (+ fuel cells)	Fossil fuel
Environmentally Friendly	Yes	Yes	No
Response in emergency situations	No	Yes	Yes

Flight duration	Up to 5 years	Unspecified (6 months)	4 – 8 hours
Position keeping (radius)	Within 1km cube	1 – 3 km	4 km
Mission payload	1000 – 2000 kg	50 – 200 kg	Up to 2000 kg
Power for mission	~ 10 kW	~ 3 kW	~ 40 kW
Example	Japan, Korea, chine , ATG, Lockheed martin , Skystation etc	Helios , Pathfinder Plus (AeroVironment), Helipat (European project)	HALO (Angel Technologies)M-55(Geosem Network)

2.5 HAPS Compared With Other Systems

From the outset, HAPs have not been modeled as the successor to either the terrestrial or satellite systems but as a complementary system. However, the potential of stand-alone HAPs systems still remains an attractive one in communications research. In providing cellular network coverage for impervious or remote areas, deploying xDSL or fiber is not economical but HAPs constitute a real asset to operators to reach users in such areas.

The most important similarities and differences of stratospheric platforms terrestrial and satellite systems are summarized in the table 2.3.

Table 2.3: Basic characteristics of Terrestrial Wireless, Satellite and HAPS systems [3]

Issue	Terrestrial wireless	Satellite	High altitude platform
Availability and cost of mobile terminals	Huge cellular /PCS market drives high volumes resulting in small low-cost , low-power units	Specialized, more stringent requirements lead to expensive bulky terminals with short battery life	Terrestrial terminals applicable
Propagation delay	low	Causes noticeable impairment in voice communication in GEO (and MEO some extent)	Low
Communications technology risk	Mature technology and well-established industry	Considerably new technology for LEOs and MEOs; GEOs still lag behind cellular	Terrestrial wireless technology supplemented with spot-beam antennas ; if widely deployed

		/PCS in volume , cost and performance	,opportunities for specialized equipment (scanning beams to follow traffic)
Deployment timing	Deployment can be staged ,substantial initial build-out to provide sufficient coverage for commercial service	Service cannot start before the entire system is deployed	One platform and ground support typically enough for initial commercial service
System growth	Cell-splitting to add capacity ,requiring system reengineering : easy equipment upgrade/repair	System capacity increased only by adding satellites; hardware upgrade only with replacement of satellite	Capacity increase through spot-beam resizing ,and additional platforms; equipment upgrade relatively easy
System complexity due to motion of components	Only user terminal are mobile	Motion of LEOs and MEO s is a major source of complexity ,especially when intersatellite links are used	Motion low to moderate (stability characteristics to be proven)
Radio channel "quality"	Rayleigh fading limits distance and data rate, path loss up to 50 dB/decade; good signal quality through proper antenna placement	Free-space-like channel with Ricean fading; path loss roughly 20 dB/decade;GEO distance limits spectrum efficiency	Free-space-like channel at distances comparable to terrestrial
Indoor coverage	Substantial coverage achieved	Generally not available (high-power signals in Iridium to trigger ringing only for incoming calls)	Substantial coverage possible
Breadth of geographical coverage	A few kilometers per Base station	Large regions in GEO (up to the 34% of the earth surface); global for LEO and MEO	Hundreds of kilometers per platform (up to 200km)
Cell diameter	0.1 – 1 km	50km in the case of LEOs. More than 400km for GEOs	1 – 10 km
Shadowing from terrain	Causes gaps in coverage; requires additional equipment	Problem only at low elevation angles	Similar to satellite
Communications and power infrastructure; real estate	Numerous base stations to be sited, powered, and linked by cables or microwaves	Single gateway collects traffic from a large area	Comparable to satellite

Public safety concern about flying objects	Not an issue	Occasional concern about space junk falling to Earth	Large craft floating or flying overhead can raise significant objections
Cost	Varies	More then $200 Million for a GEO system. Some billion for a LEO system (e.g. $5 billion for Iridium, $9 billion for Teledesic)	Unspecified (probably more than $50 million), but less than the cost required to deploy a terrestrial network with many base stations

As the need for mobile and ubiquitous access to multimedia services grows, there is a need for the development of new generation wireless systems. As a result, 4G networks have been billed to provide the always-on, globally available optimal connectivity with higher bit rates at low cost and this is where HAPs can play an important role in the post-3G evolution. Multicast services are one of the most interesting in the wide spectrum of services that 4G networks are called to support.

Some of the other advantages stratospheric platforms hold over their terrestrial and satellite counterparts are discussed below.

• They provide large-area coverage compared with terrestrial systems because their deployment geometry provides relatively little rain attenuation on long-range links due to shorter slant path through the atmosphere. This can yield significant link budget advantages within large cells at shorter mm-wave bands.

• HAPs are well suited for the provision of centralized adaptable resource allocation, i.e. flexible and responsive frequency reuse patterns and cell sizes which are not constrained by the location of base stations.

• Going by projections, HAPs will be cheaper to procure and launch than a GEO satellite or a constellation of LEO satellites. It will also be cheaper to deploy a HAP network than a terrestrial network of several base stations.

• HAPs can be incrementally deployed to provide coverage for an area based on the expansion of the network or capacity requirements. A LEO satellite network, in contrast, requires a large number of satellites to achieve seamless coverage while a terrestrial system will also require several base stations to become fully functional.

• Designing, implementing and deploying a HAP-based system is easier and quicker compared to satellites which may take several years from procurement to launch or terrestrial systems which require a lot of time-consuming procedures. This makes HAPs systems well-suited for providing emergency services e.g. natural disasters, restoration of service in case of a terrestrial system failure or at large events which will only last for a while like sporting events.

• Due to the low propagation delay and high capacity provided by HAPs, they are well-suited for broadband and broadcast/multicast service provision.

• HAPs can be brought down relatively readily for maintenance or upgrading of the payload.

• Power supply for HAPs is largely from solar cells and thus emissions from burning of fuel are eliminated. This and the elimination of terrestrial masts also make HAPs rather environmental friendly [3].

2.6 HAPS Architecture

The figure depicts a general HAP Architecture and communication scenario. A single HAP with up- and down-links to user terminals can be used to provide services along with a backhaul link if required. HAPs may also be interconnected in a network of HAPs and a satellite link may also provide direct connections from the HAP.

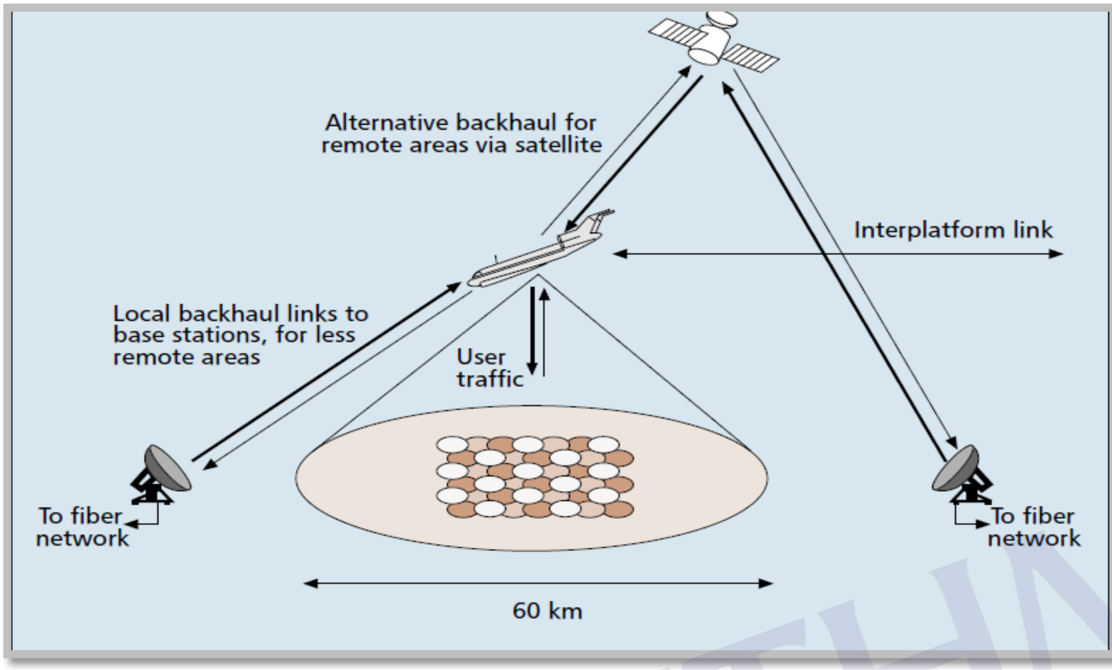

Figure 2.5: HAPS Structural model

The ITU has a proposal that footprints of a radius more than 150Km can be served from a HAP. Some researchers and authors have found out that HAPs could cover a whole country giving specific examples of 16 HAPs covering the whole of Japan with a minimum elevation angle of 10° and that 18 HAPs would cover the whole of Greece including all the Islands.

2.6.1 Minimum Elevation Angle

The lower the minimum elevation angle of HAPs, the larger the coverage area enjoyed but this gives rise to a higher propagation or blocking loss at the edge of the servicing area. Practically for Broadband Wireless Access, a minimum elevation angle of 5° is expected but it is more commonly acceptable to have a minimum elevation angle of 15° to avoid or guard against excessive ground clutter problems. This implies that for example, a platform placed at an altitude of 20Km (HAPs altitude) will have a coverage of 200km approximately. However, ground stations that connect HAPs network with other terrestrial networks can be placed on roofs of buildings. Satellite usage can be employed as backhaul in rural and remote areas where there is not sufficient terrestrial infrastructure.

Figure 2.6 depicts the radius of the maximum coverage area with respect to HAP altitude.

The coverage region served by a high altitude platform is essentially determined by line-of- sight propagation (particularly at higher frequency bands) and the minimum angle of elevation at the ground terminal. In general, user terminals in a HAPs system are classified along the broad line of elevation angles as follows:

• Urban area coverage (UAC)

The relative elevation angle is from 30° to 90° and there are line-of-sight (due to the short distance of the user terminal from the HAP) and diffuse multi-path components (consisting of many reflections from obstacles in the area each of them being independent and randomly phased) of the transmitted signal.

• Suburban area coverage (SAC)

The relative angle of elevation is from 15° to 30° and the obstacles near the receiver cause signal shadowing and attenuation of direct signals. Attenuation of direct signals varies due to moving obstacles e.g. vehicles and undergoes log-normal distribution.

• Rural area coverage (RAC)

The relative angle of elevation is between 5° and 15°. The practical lower elevation limit for broadband wireless access (BWA) is 5° and to avoid excessive ground clutter problems, the elevation angle should be 15° at the minimum.

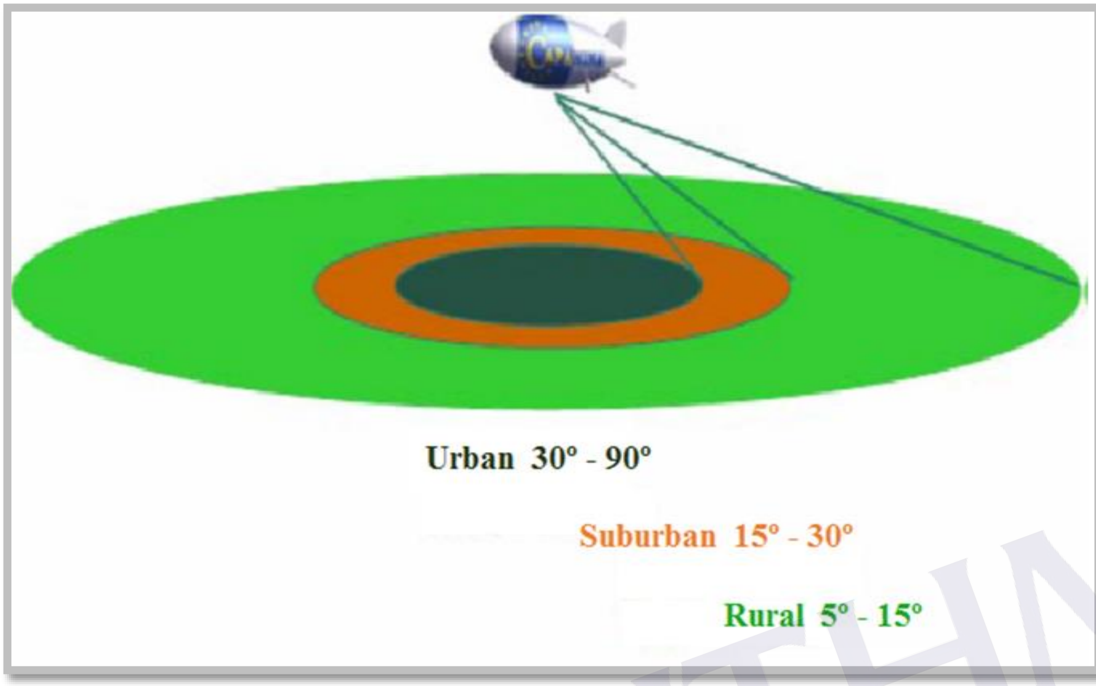

Figure 2.6: HAPS coverage analysis for different areas

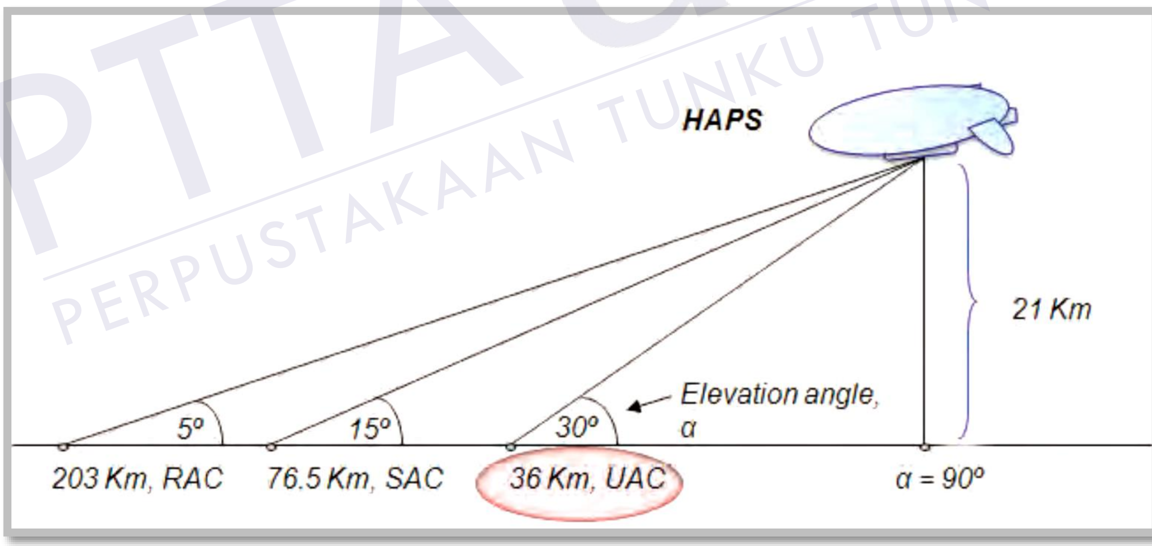

Figure 2.7: the influence of the elevation angle and radio coverage

2.7 Services and Applications

HAPs have an advantage over terrestrial networks in the area of multicasting where the many of the benefits of GEO satellites are provided in addition to uplink channels for interactive video and internet access. HAPs also serve well in areas with low population e.g. islands, oceans, developing towns, etc where the cost per subscriber in terrestrial systems will be too high for the low traffic densities because of the access points needed to cover these areas. Communication services provided by HAPs are broadly divided into low data rate services for mobile terminals and high data rate services for fixed terminals. Some of them are listed below;

1. The main application for HAPs is the Broadband Fixed Wireless Access (B-FWA) which is capable of providing very high data rates to the user to the tune of 2 X 300MHz bandwidth provided that the links are not used for internet traffic basically.
2. The use of the IMT-2000, i.e. 3G bands, from HAPs has been authorized by the ITU. Even the 2G services can be comfortably deployed via HAPs. One HAPs base-station fitted with a wide-beamwidth antenna or a number of directional antenna covering smaller cells can serve a very wide area.
3. HAPs are very useful for such 'developing world' applications like rural telephony, broadcasting and data services where existing ground infrastructure is lacking or difficult.
4. HAPs can be quickly deployed to provide extra service coverage in the event of a disaster such as earthquake, flood, etc or as a restoration following failure in a core network.
5. A number of HAPs may be deployed in a network to cover an entire region. It is also possible to achieve inter-HAP links at high Extremely High Frequencies (EHF) or through the use of optical links.
6. Military communications is also another major that has enjoyed the deployment of HAPS.

2.8 HAPS Spectrum Allocation.

The Local Multipoint Distribution Systems (LMDS) types of services (which include services such as high-speed internet and other data services) have frequency band of over 24GHz allocated to them. HAPs services operate at 600MHz at 48/47 GHz frequency worldwide allocation from the ITU except in Asia where it operates at 31/28 GHz, though it can be deployed in some 3G services which is around the 2GHz range. There is also the possibility of using the band range of 18 – 32 GHz for fixed services. This range is allocated in Region 3 for broadband wireless applications [3].

Table 2.4: Services and frequency allocations [3]

Frequency Band	**Areas**	**Direction of the Link**	**Services**	**Services to be shared with**
47.9-48.2 GHz **47.2-47.5 GHz**	Global	Up and downlinks	Fixed service	Fixed and mobile services Fixed satellite service (uplink) Radio astronomy band neighboring
31.0-31.3 GHz	40 countries Worldwide (20 countries in Asia, Russia, Africa, etc and in Region 2)	Uplink	Fixed service	Fixed and mobile services Space science service in some areas Space science service band (passive) neighboring
27.5-28.35 GHz	40 countries Worldwide (20 countries in Asia, Russia, Africa, etc and in Region 2)	Downlink	Fixed service	Fixed and mobile services Fixed satellite service (uplink)
1885-1980 MHz **2010-2025 MHz** **2110-2170 MHz**	Regions 1 and 3	Up and downlinks	IMT-2000	Fixed and mobile services(in particular, terrestrial IMT-2000 and PCS)
1885-1980 MHz **2110-2160 MHz**	Region 2	Up and downlinks	IMT-2000	Fixed and mobile Services (in particular, terrestrial IMT-2000 and PCS)
Region 1: Europe, Africa, Russia, the Middle East, and Mongolia **Region 2: North and South America** **Region 3: Asia, except for the Middle East, Pacific countries, and Iran**				

2.9 Capacity Analysis of HAPS

When discussing HAPs, one of the most important design consideration is the available bandwidth. An important bandwidth calculation tool is the Shannon equation which deals with the relationship of the Carrier Signal to Noise.

$$\frac{R}{B_W} = \log_2[1 + \frac{C}{N_0}] \qquad (2.1)$$

In this equation:

R = Maximum Data rate (Symbol rate)

B_W = Nyquist Bandwidth = samples/Sec

C = Carrier Power

N = Noise power

HAPS have been found never to be as spectral efficient as terrestrial broadband systems due to the fact that the minimum size of their cell is limited by the maximum size of the antenna that can be accommodated on the platform. To mitigate this, the user antenna can be highly directive, giving rise to a good spatial discrimination between HAPs in a HAP constellation.

Research actually showed that the level of bandwidth saving is dependent on the transmitter power. An increase in the transmitted power gives rise to an increase in bandwidth saving. The minimum received $\frac{C}{N_0}$ (on the edge of the coverage area) is deteriorated by the displacement of the platform but does not affect the peak minimum bandwidth requirements. The maximum $\frac{C}{N_0}$ (with a rain rate of 28mm/h) is the same in all cases and achieved in the cell at the sub-platform point.

2.10 Analysis of Interference in HAPS

Another important issue when discussing communication system is interference. Considering our present study, HAPS, interference is caused by antennas serving cells on the same channel and arises from overlapping main lobes or side loves. Two main kinds of interference can be said to happen in HAPS. The first is the interference originating from the users of the HAP-based network and the other one is the one from and to terrestrial or satellite systems sharing the same adjacent frequency bands.

When discussing the first case of interference, we need to take into consideration the differences between the interference that occurs in HAPs network and what happens in the satellite and terrestrial network. It's been discovered that terrestrial systems are generally interference limited but not easy to say what the interference level will be in different places as they greatly depend on terrain and building patterns. In disparity, propagation in HAPS systems is achieved mainly through free space (free space loss and so on) thus the interference levels can be predicted and assumed easily and successfully.

2.11 Antennas for HAPS

A very good performance factor for HAPS lies in the antenna system. Researchers in HAPS systems have stated some required functions for a successful broadband HAP antenna and they are listed below:

a) Use of high radio frequency in order to secure a sufficient bandwidth.

b) Directional antenna with a high gain to cope with attenuation in high frequencies. It's been found out that co-channel cells are interference limited by antenna beam overlap. Minimization of interference can be attained by side lobe minimization. Beam-forming can use either phased-array antennas or lightweight, possible inflatable parabolic dishes with mechanical steering.

c) Multibeam antenna that accommodates 100 beams or more, both for transmission and reception, to cover views as wide as 120º or more from the stratosphere with a high gain and to achieve effective use of the frequencies involved..

d) Cancellation of the influences of altitude/position variations of the HAP on the footprint on the ground by means of beam control.

e) Reduced weight, size, and power consumption of the mission payload.

f) Must operate reliably in the stratospheric environment.

Considering the movement of HAPs, it is necessary to compensate this movement by mechanical or electronic steering. A serious limitation is the available payload aperture. As the size of cells decreases, the number of cells increases and also the required payload aperture increases. The size of the antenna array is also determined by the altitude of the platform for a specified radius of the central cell. As the altitude of the platform increases, the size of the array also increases. However, the higher the operating frequency, the smaller the array.

For ground terminals, highly directive antennas are required for high data rate application. When the terminal is on a moving vehicle, it is compulsory it has should have a steering capability. Theoretically, the easiest and simplest solution is the mechanically steered antennas, which gives good performance at low cost.

However, high-speed steering may become challenging due to the large mass of such an antenna. Digital beam-forming (DBF) antennas can achieve rapid scanning, but this advantage is made of no effect by the cost associated with the very large number of antenna active elements which is required to achieve a high gain aperture [3].

2.12 HAPS UMTS (Universal Mobile Telecommunications System)

Universal Mobile Telecommunications System (UMTS), network belongs to the 3rd Generation (3G) of mobile networks. It denotes the radio interface of 3G services. The main idea behind 3G is to prepare a universal infrastructure able to carry both existing and future wireless services. This is a very challenging task. In general, the UMTS network is designed to include ambitious service features, the ability to communicate in movement, anytime and anywhere, through an enormous variety of applications and universally usable terminals. UMTS provides a variety of services and data rates up to 2Mb/s in indoor or small-cell outdoor environments and up to 384kbps in larger-cells (wide area coverage). In the packet switched mode UMTS allows mobile users to have seamless access to the Internet. It has a channel bandwidth of 5 MHz.

The UMTS architecture is comprised of the access, transport and service (connection control) technologies. Therefore, the entire architecture can be broken down into subsystems based on different parameters such as the nature of traffic, protocol structures or physical elements.

In CDMA2000 system specifications, the downlink is called the *forward link*, and the uplink is called the *reverse link*. The same naming convention is used in this section. The carrier composition of CDMA2000 can be different in the forward and reverse links [13].

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