CHAPTER II

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HAP OVERVIEW AND LITERATURE SURVEY, PROBLEM DEFINITION

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The increased demand for wireless broadband communication has led to the rapid development of conventional terrestrial and satellite based wireless communication technologies. In recent years, an emerging competitive technology, called HAP, has attracted considerable attention for providing wireless broadband communications and other services. HAP has the capability to deliver performance as good as terrestrial and satellite systems and represents an alternative technology in 5G.

This chapter provides an overview of HAP in connection with the technical requirements of this thesis. HAP has been taken as our main concern for use in a heterogeneous environment. It covers its history of evolution, network architecture, coverage, spectrum allocation and applications. Then, an overview of selected research and industry oriented projects related to HAP has been summarized in a tabular form. Afterwards review of relevant research has been carried out from the recent past. Especially, hand-off technique, channel reservation technique, and CAC technique have been reviewed for delivery of enhanced QoS for mobile deployment using HAP.

In the concluding part of this chapter, problem definition and the objectives of this thesis of the write-up have been described.

2.1. High Altitude Platform Overview

HAP has been attracting much interest in the field of mobile communication. HAP also has the advantages both of satellite and terrestrial systems. In recent years, HAP system is among the novel technologies which has started to attract considerable attention the world over. The most important features of HAP are its high elevation angles, large coverage, low propagation delay, low cost operation, rapid deployment, broadband capability, large system capacity, line of sight, easy in incremental deployment, easy to maintain [65, 66], and its ability to move around in an emergency situation [67].

Therefore, HAP is expected to avoid some inherent limitations belonging to the satellite and the terrestrial systems such as stronger signal w.r.t. the satellite and too less number of BS w.r.t. the terrestrial system. These features make HAP capable of providing broadband services effectively and efficiently [68]. Thus, the International Telecommunication Union (ITU) has allocated the spectrum to this system at 2 GHz for 3 G mobile systems [69], 48/47 GHz for the usage worldwide [70], and 31/28 GHz band is allocated in certain Asian countries [71].

HAP may be manned or unmanned, with or without autonomous operation with remote control from the ground. The parameters that determine the characteristics of a flying machine are the flying principle and population mode [72]. Different types of platforms are shown in Figure 2.1. These platforms are Lighter Than Air (LTA), Heavier Than Air (HTA) and tethered balloon [73].

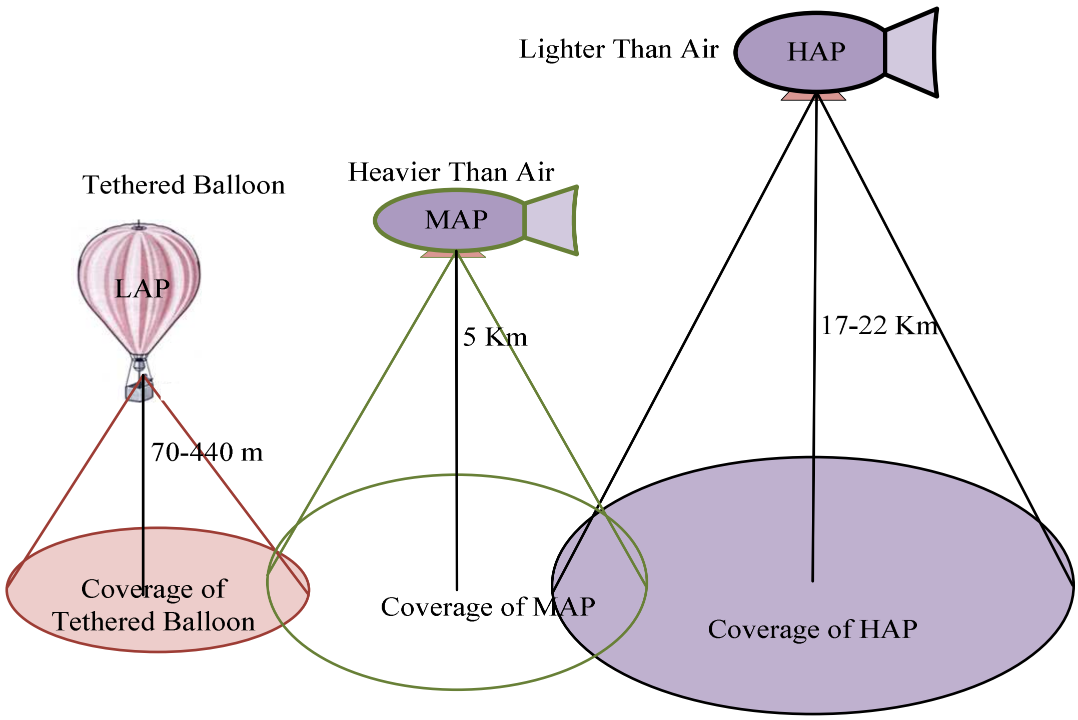

Figure 2.1 Categories of HAP

HAP is one type of aerial platform and there are two more types of similar platform called Medium Altitude Platform (MAP) and Low Altitude Platform (LAP). HAP provides an excellent option for emergency communications due to their survivability during a disaster. It is able to be continuously 'on station' and offers an ideal solution for an emergency communications capability [74].

In the recent years, many other types of aerial platforms have appeared which are either aerostats or aerodynes. Such platforms have been developed to operate at various altitudes in the troposphere as in the following Table 2.1.

Table 2.1 Difference Types of Aerial Platforms

Platform	**Height (Km)**	**Maximum Coverage**
HAP	17-21	$500\ Km^2$
MAP	Max. 5	$75\ Km^2$
LAPs	0.3-4	$72\ Km^2$
Tethered Balloon	0.07-0.440	$15.5\ Km^2$

In comparison with terrestrial wireless technologies, HAPs require considerably less communications infrastructure. HAPs also serve potentially large coverage areas from a single site and have little multipath fading. The cell planning of HAP is straighter forward because of its line of sight. Therefore, it is cheaper than a terrestrial network in terms of the cost to deploy w.r.t. the deployment of a large number of terrestrial BSs.

When compared with satellite communication system, HAP communication technology will also provide a quasi-stationary coverage area, easy maintenance, short propagation delay, wide bandwidth, and capability to provide broadband access. HAP operational cost is believed to be considerably cheaper than that of a Low Earth Orbit (LEO) or Geostationary Earth Orbit (GEO) satellites [75].

HAP can provide various services such as observation, monitoring, surveying and communication as well. Considerable demand of HAP can be expected in the nearest future. However, it is not intended to replace existing technologies, but instead work with these as a complementary system and in an integrated fashion. HAP could be outfitted to provide needed critical communications for search and rescue, command and control, and critical infrastructure repair. This unique service population and scenario of use requires a new mindset for understanding emergency network requirements and traffic loading. Emergency answering services such as 911 or 112 could be supported by HAP [74].

Typical, HAP offered services are: voice, video and data communications. The potential benefits of HAP technology (when compared with the conventional terrestrial or satellite systems), for providing wireless communication services are:

- Line of sight propagation paths to most users

- A single HAP platform can replace a large number of terrestrial towers, with savings in cost, site acquisition delay, and environmental impact.
- The HAP can carry additional payloads for surveillance and monitoring applications.
- Due to survivability, coverage, and capability, it is a ‘continuously on’ station.

2.1.1. Position and Altitude of HAP

The speed of wind increases at altitude higher than $25\ Km$. It is four times faster at altitude of $50\ Km$ than that of 20 Km as shown in Figure 2.2. HAP is operated at an altitude of 17-21 Kms with a position radius of $1\ Km$ for the airship, so as to make it stationary above an specific area [76].

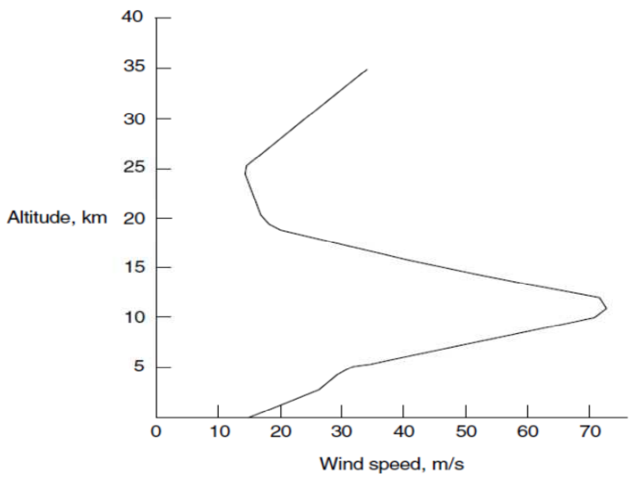

Figure 2.2 Wind Speed [77]

ITU has recommended that the HAP platform should be geostationary within a location sphere of $500\ m$ radius [70]. To keep the position of HAP at a nominal fixed point against the wind, much larger propulsion power is necessary and it requires heavier batteries for night operation. The three main reasons for selecting the HAP position [45] in the altitude range of 17 – 21 Km, are:

1. These altitudes are above aviation air lines.
2. The speed of wind is sufficiently low.

Lastly, the platform position allows the HAP based system to provide better channel conditions because the distance from HAP is much smaller than the satellites. Since a 'line of sight' condition is achievable over almost all the coverage area, HAPs generate much less shadow zones than the terrestrial systems. Also, since HAP's altitude is much smaller than satellites, the path loss is significantly decreased and the required transmit power is also quite low [62]. A diagrammatic presentation has also been shown in Figure 2.3.

Figure 2.3 HAP Altitude

HAP may need to compensate its movement in normal operating conditions and fly against the wind. These compensation are actuated by using suitable propulsion mechanisms, payload stabilisation and by using electronically steerable antennas [78]. Steerable antennas can also be used at Customer Premises

Equipment (CPE) as well as on the platform. The antenna steering mechanisms on the platform have several constraints associated with them [79-81].

2.2. HAP Network Architecture

HAP system has the capability of carrying a large variety of wireless communication payloads that can deliver high capacity broadband services to end users. There are two types of links between the payload and the ground equipment i.e gateway link and user link.

In case of user link, the communication is between the platform and user terminals on the ground. On the other hand, gateway link is defined as a radio link between HAP and HAP ground station. HAP ground station provides interconnection to other telecommunication networks.

Thus far, HAP based systems have mainly been conceived as an alternative to satellite for complementing the terrestrial systems. Therefore, integration of HAP with satellite and terrestrial systems can be used to provide more efficient fleet management and traffic control services. The proposed architectures of HAP can be categorized as: integrated terrestrial-HAP-Satellite systems, integrated terrestrial-HAP system and stand-alone HAP system [66, 82].

2.2.1. A stand-Alone HAP System

HAP is represented as an intermediate system between the terrestrial and satellite as shown in Figure 2.4. The cost and deployment of terrestrial system would be expensive and complex, such as for rural or remote areas. HAP has potential to be a stand-alone system in many applications such as weather monitoring, and disaster surveillance. Therefore, HAP system may be deployed economically and efficiently.

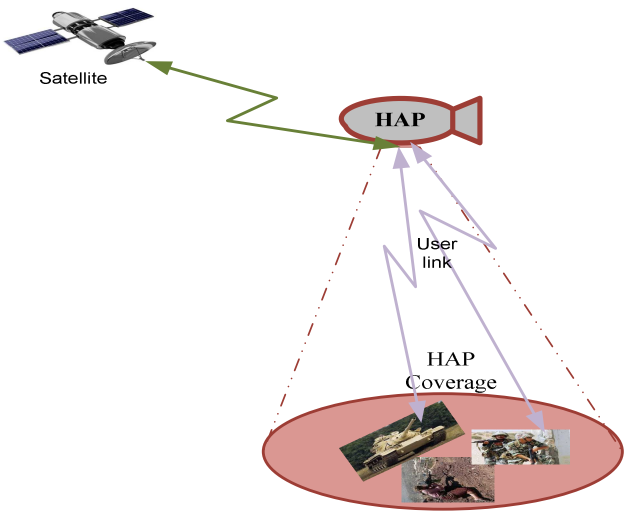

Figure 2.4 A Stand Alone HAP System

2.2.2. Integrated HAP-Terrestrial System

This network architecture is highly recommended. The HAP is directly connected to the fibre terrestrial networks through a ground gateway as shown in Figure 2.5.

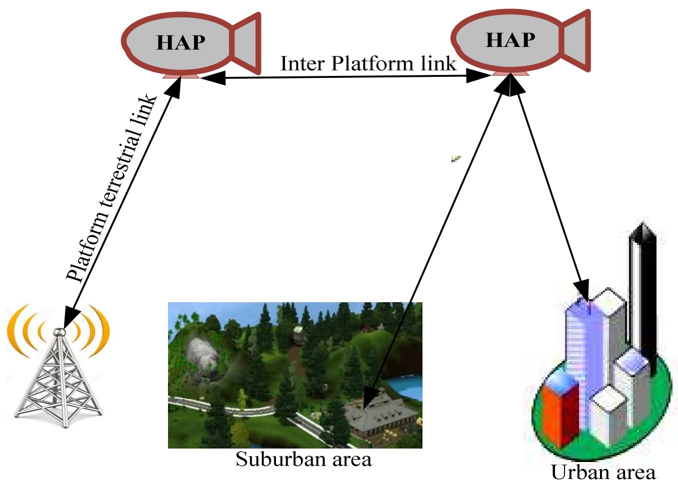

Figure 2.5 Integrated HAP-Terrestrial System

Gateway is used to obtain the contents and to deliver it to the final users. HAP is considered to be more of a macro cells and serves a large number of high mobility users with low data rate. Due to HAP wide coverage area and competitive cost of deployment, HAP could be employed to provide services for areas with high population density where it is expensive to deploy fibre or terrestrial networks.

2.2.3. Integrated Terrestrial-HAP-Satellite System

A terrestrial-HAP-Satellite system is an integrated infrastructure in which HAP is connected with the satellite as well as it is also connected to the terrestrial fibre networks. Such a network is shown in Figure 2.6. The network architecture is composed of links in order to take the contents and to deliver it to the final user.

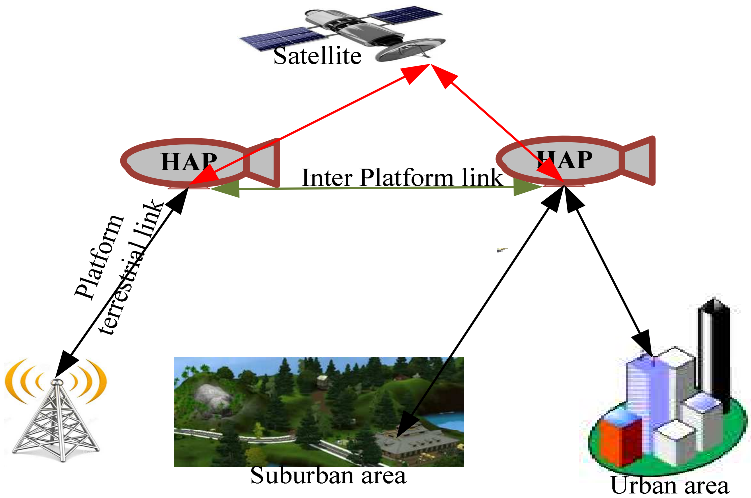

Figure 2.6 An Integrated Terrestrial – HAP - Satellite System

The most important feature of this network architecture is the capability of the satellite to broadcast and multicast are used to transmit information through HAP network to fibre network. HAP is used to improve the satellite performance over the earth, by providing a better delivering system to deliver the contents of broadcasting and broadband services can be delivered from the HAP. Inter-platform communications can be established for extending coverage area. The terrestrial layer is connected to the satellite layer through HAP. Thereby, HAP is achieving two significant advantages, firstly, satellite does not require to interact with a single terrestrial terminal user and secondly, the user terminals can be made without much financial and design efforts because now they don't have the requirement to interact directly with satellite layer [83].

2.3. Coverage of HAP

The coverage is the geographical area in which a wireless network offers cellular services to the subscribers. A BS is a part of wireless network and lies at a fixed location. It allows the user of service to work within a local area. Furthermore, the cell is defined as a radio network distributed over the area. These cells can be joined together over network coverage to provide radio coverage. The overall coverage area is divided into sub-areas or cells. Basically, both cell and network coverage depend on natural factors like propagation conditions, human factors such as landscape (urban, suburban and rural) and subscriber behavior, etc.

HAP offers excellent coverage and availability as compared to terrestrial broadband FWA networks effectively [84]. The coverage area of HAP depends on the elevation angle and the altitude of HAP as shown in Figure 2.7. A multi-beam antenna is used to cover many subscriber ground stations by HAP with high frequency reuse efficiency [70]. There are three main zones under HAP footprint depending upon the elevation angle of HUTs (HAP User Terminal), UAC, SAC, and RAC [85].

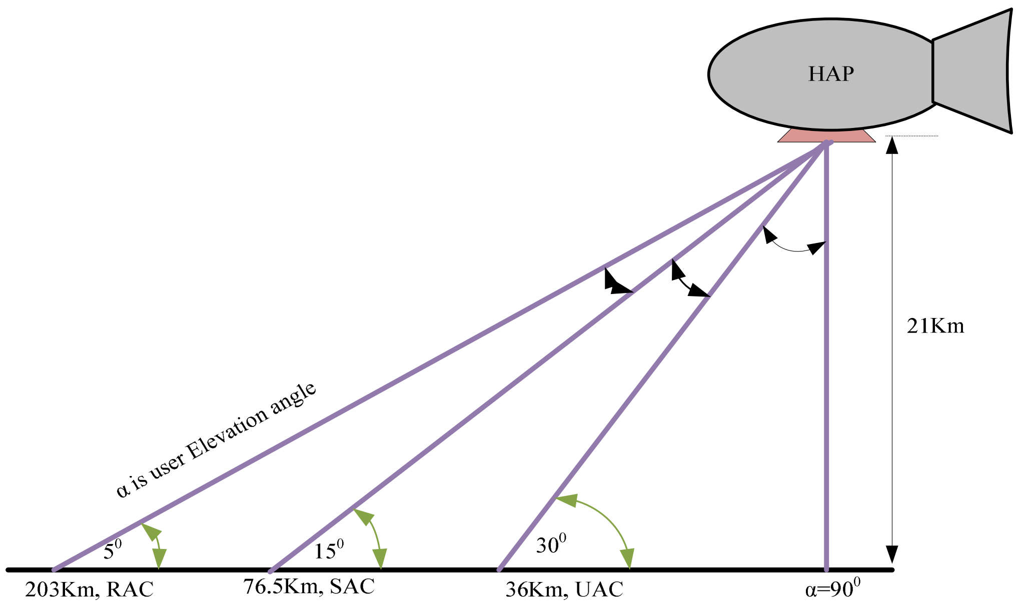

Figure 2.7 Coverage of HAP [85]

2.4. HAP Spectrum Allocation

In February (1997), ITU Radio Regulations Board (RRB) has recognized HAP as a separate category of radio stations. At that time, RRB made provisions for operation of HAP within the fixed service in the bands of 47.2-47.5 GHz and 47.9-48.2 GHz and the band for other regions as shown in Table 2.2 [86] [70]. Finally, in the WRC-2000, use of the 31 GHz and 28 GHz band was permitted for fixed services (FS) [71] as shown in Figure 2.8.

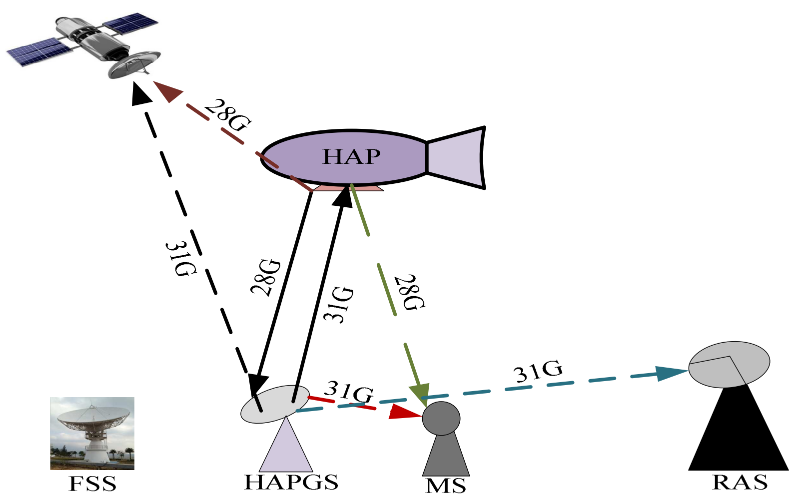

Figure 2.8 Frequency Allocation of HAP[87]

Table 2.2 Frequency Allocation of HAP Based Communications [86]

Frequency (GHz)	Regions
47.9–48.2	Global
47.2–47.5	North and South America and also some countries
31.0–31.3	North and South America and also some countries
27.5–28.35	Europe, Africa, Russia and Middle East, Asia and Pacific countries
2.160–2.170	Europe, Africa, Russia and Middle East, Asia and Pacific countries
2.110–2.160	Global
2.010–2.025	Europe, Africa, Russia and Middle East, Asia and Pacific countries
1.885–1.980	Global

2.5. Applications of HAP

HAP provides the flexibility to accommodate a wide spectrum of applications ranging from two-way telecommunications (e.g., interactive video and Internet access), to remote sensing, earth observation, navigation applications, pollution monitoring, meteorological measurements, real-time earth monitoring, traffic monitoring and control, land management and agriculture, etc. [88] as shown in Figure 2.9.

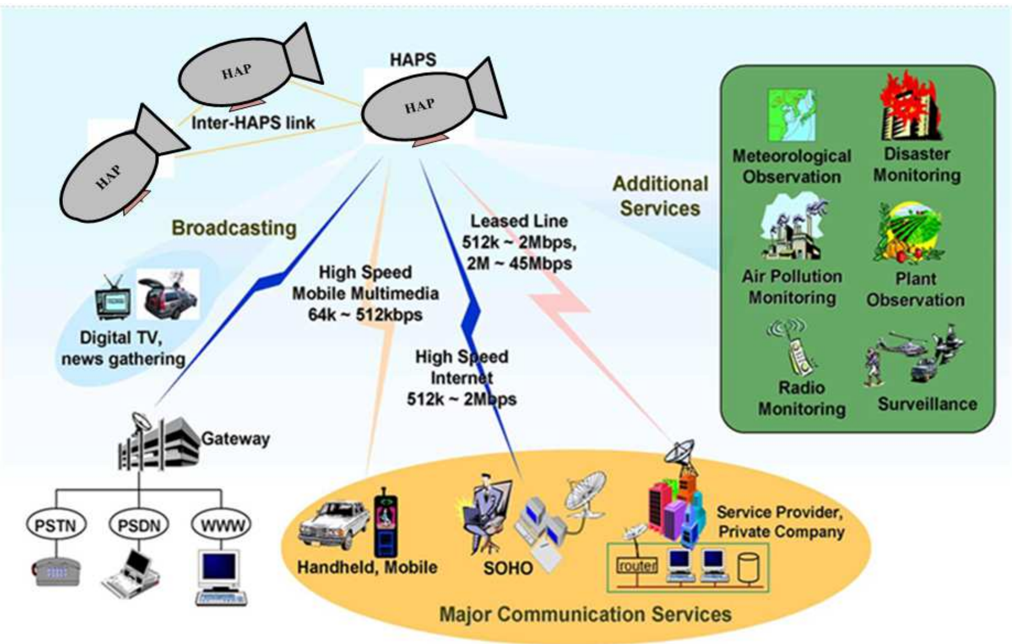

Figure 2.9 HAP Applications [89]

2.5.1. HAP for Emergency Communication

HAP is able to have a significant advantage when rapid deployed in emergency situations such as those stemming from natural (e.g, floods, volcanic eruptions, earthquakes, tsunamis) or human-induced (e.g, London's Killer Fog, The Nuclear Power Plant Explosion in Chernobyl, Russia, The Kuwait Oil Fires) disasters (e.g, rapid deployment to cover a large coverage area, immunity to disasters such as floods, earthquakes, hurricanes etc.), or in cases where terrestrial network outage or overload is expected (e.g., due to a large concentration of users at a major event).

2.5.2. HAP Application for Wireless Communication Technologies

Due to easy deployment of HAP, HAP networks are oriented to provide not only broadband services and provision of communications [90]. HAP can also be applied for telecommunication technologies such as: Broadband wireless Access (BWA), 3G and 4G mobile technologies, and multicast and broadcast services such as digital video broadcasting-handheld (DVB-H) [91]. More specifically:

- BWA provides potentially very high data rates in terms of Megabits per second (Mbps). The spectrum allocation for HAP worldwide for the provision of BWA services consists of a pair of 300 MHz bands in the 47/48 GHz band. Although the 28/31 GHz is also specified in much of Asia. The typical bit rate of the access link is a few Mbps for most fixed and portable terminals. A several hundred Mbps link is available for limited fixed terminals with antennas larger than typical ones [91].
- 3G/4G, HAP and Universal Mobile Telecommunications System (UMTS) systems will use the same Round Trip Times (RTTs) to provide the same

functionality and service. The HAP can be designed to replace the tower BS network with a BS in the sky or can be integrated into a system that employs traditional terrestrial BS towers, satellites and HAP [91].

- Multicasting and Broadcasting, number of towers are required to reduce the percentage of outage areas. HAP located at high altitude could potentially be used as an alternative solution for digital video broadcasting/ Digital Audio Broadcasting (DVB/DAB) repeater/transmitter [91].

2.6. History of HAP

The history of HAP development is shown below in Table 2.3.

Table 2.3 Development of HAP History [22]

Date	Description
1783	Mongolfier brothers launched the first hot air balloon.
1900	First airship had an internal framework of steel or aluminum girders which support.
1910	Zeppelin built the world's first commercial airship.
1928	Graf Zeppelin airship launched by the Germans made many successful trips.
1936	The Hindenburg lunched and made successful trips between Germany and U.S.
1960	People start to use of airborne craft capable of providing a semi-permanent presence to deliver communications.
1964	The U.S Navy stopped using airship because of a quiet period of development.
997/ 1998	International SkyStation who put forward the concept of a 200 m long solar powered airship HAP capable of flying at 20 km altitude for a period of years.
1997	World Radio Communication conference (WRC) successfully managed to get 47/48 GHz band for HAP. Angel technologies aircraft technology was more conventional, but the communications technology and capability claims were overambitious.
1998	Japan Aerospace Exploration Agency (JAXA) coordinated the aeronautics aspects, with the telecommunications activities and earth observation.
1999	Professor Bernd Kroplin of the university of Stuttgart and of Lind strand technologies shared Prize for innovation for putting forward the outline aeronautical designs for an unmanned solar powered airship.
1999/ 2000	HeliNet project in Italy was to develop a scale-sized prototype solar powered plane and three pilot applications: broadband communications; remote sensing; and traffic localization.
2002 / 2003	CAPANINA project, coordinated by the university of York and UK. This aimed to capitalize on HeliNet, but now in the more focused area of HAP delivery of broadband communications for fixed and high speed users.
2000-2003	In the USA, NASA's ERAST programme had already successfully developed the Pathfinder. Pathfinder Plus and Helios unmanned stratospheric planes, each capable of flying modest payloads.

2.7. Research Oriented Projects

During the last decade, communication via HAP were attempted and evaluated. First, balloon was launched in the USA in 1960 [92]. A few milestones in the history of balloons are presented in [93]. The most important research oriented projects worldwide have detailed description in Table 2.4.

Table 2.4 Research Oriented Projects Worldwide [22]

Project	**Stands for**	**Place/ year Height**	**Applications**
SHARP	Stationary High Altitude Relay Platform	Canada 1980 21 Km	Platforms for telecommunications services Capable to distribute Ultra High Frequency (UHF), direct broadcast TV channels to rural regions. It provides reliable radio telephone service to user sets and permit frequency reuse [94].
HALE	High-Altitude Long Endurance Platform	Canada /1999 15 Km [95]	Emergency preparedness and disaster management.
HeliNet	Health Science Library and Information Network	Europe-an Union (EU) /2000/17Km	Broadband communications, remote sensing and traffic localization, environmental data processing.
CAPANINA	Communications from Aerial Platform Networks Delivering Broadband Comuni-cations for All	University of York/ 2002 17-22 Km	It has to manage disaster, monitoring, broadband, 3G and communications for developing countries and backbone for rural areas Military applications.
SkyNet		Japan/ 1998 20 Km	Delivering broadband and 3G communications.
ESA	European Space Agency	Paris, France /1975 $20 - 80\ km$	Performed for stratospheric platforms driven by complementing space systems with stratospheric platforms in the area of telecommunication applications.
ETRI	Electronics and Telecommunications Research Institute	Korea $20\ km$	The main interest in aeronautics parts, research and development on communications from HAP [96].
COST Action 297	Co-operation in Scientific and Tech-nical research fun-ded the 297 Action	European /2005 $17\text{–}22\ km$	It supports radio communications, optical communications and aerial platforms.
COST Action ES0802		European/ 2008	It provided an initiative on an atmospheric research by the use of Unmanned Aerial Systems (UAS). Application of UAS as a cost-efficient, trans-boundary method for the monitoring of the atmospheric boundary layer and the underlying surface of the Earth [97].

Other projects were subsequently proposed worldwide, including HALO (U. S. A) [98], Helinet (Europe) [25], and SkyNet (Japan) [5]. With today's space technology, HAP will become one of the safest methods of transportation. The ITU has described HAP which is one the most important form of aerial platforms as: "representing a new and long anticipated technology that can revolutionize the telecommunication industry" [85].

2.8. Motivation and Previous Work

Mobile phones with their modern day applications have ushered a communication revolution worldwide. The impact of communication revolution has been manifold and more effective in a developing and high populated nation. Recently, the ITU has accepted HAP as an alternative technology and a new wireless infrastructure for realizing the next generation of mobile communication technologies. An investigation of the QoS for deployment of wireless communication via HAP is essential for providing high QoS and to choose a proper technology to be used in HAP. Thus, HAP offers an avenue for providing telecommunications services in both rural regions, isolated regions, disaster areas, and the best solution for relief disaster [99, 100].

In the early days of mobile wireless communications, the systems suffered from poor coverage and poor performance in terms of blocking probability and dropping probability. Here, the CAC is required to manage the bandwidth required to satisfy the QoS requirements for different applications. Also, a lot of investigations on diverse parameter of QoS in conventional terrestrial and satellite systems have been already reviewed in the first chapter. However, to our best knowledge, QoS for HAP are not much investigated. A particular attention is paid to fairness of QoS. Dropping a call in progress is more annoying than blocking new. Therefore, performance of any communication system judges and measures in terms of Probability of call blocking (Pcb) and Probability of call dropping (Pcd) against traffic load [101].

Therefore, to achieve the goal of QoS, provisioning newer techniques are required to be efficient and practical. For this reason, this thesis is focused primarily on techniques which are used for enhanced QoS such as: intelligent hand-off technique, reservation channels technique, and efficient CAC technique for HAP deployment based on wireless communication networks.

Kalyanasundaram et al. (2001) proposed that HAP hand-off scenario has some similarities to commercial Low Earth Orbit (LEO) satellites. The only difference is that, movements in satellite are highly predictable and hand-off strategies are intended to deal with users with wide-beam width antennas [102]. One year later, Foo et al.(2002), have proposed and analyzed two centralized CAC schemes, based on total received power, for HAP UMTS [103, 104]. The unique characteristics of integrated HAP terrestrial system are that all BS are collocated. Furthermore, centralized CAC schemes can achieve better Grades of Service (GoS) than the distributed global CAC schemes. CAC is managed independently at an individual BS. In the same year, Katzis et al. (2002) proposed a Fixed Channel Allocation (FCA) scheme for HAP system and Uniform FCA Scheme (UFCA) [105]. It is shown that total call blocking in case of UFCA has been significantly reduced compared to FCA scheme. Similarly, Katzis et al. (2002) have shown that the areas served by more than one cell (i.e. overlapping areas) get benefitted from the multiplexing of gain resulting into lower call blocking in those areas in comparison to the areas served by one cell [105]. On the other hand, platform motion on IMT-2000 soft handover have also been addressed [97]. Moreover, conventional 3G hand-off for mobile users, assuming stationary HAP modeled [106].

In the succeeding year, Grace et al. (2003) have shown that carrier to interference threshold checks at the HAP end of the link only are sufficient to maintain adequate QoS for connections in progress, even at high traffic loads with larger cluster sizes [107]. Then again, Grace et al. (2003) have developed several radio resource management strategies for a broadband multi-beam HAP architecture [107]. These are based on FCA at the HAP and distributed dynamic channel assignment at the user end of the link. Therefore, the optimum shape of beams for each cell should create the regular hexagonal layout. Furthermore, D. Grace (2003), Katzis et al. (2002) and Thornton et al. (2003) have assigned group of channels to each cell [105, 107, 108]. The natural of HAP network is able to achieve overlap between cells. Therefore, the capacity of system maximized whilst ensuring uniform and fair QoS to all subscribers. On the other hand, Liu et al. (2003) proposed soft hand-off algorithm for motion of a platform and UMTS [109]. The system performance includes call dropping probability, outage probability and blocking probability.

In 2004, Yu Chiann et al. (2004) used the unique characteristic of HAP and proposed two centralized power reservation CAC for HAP and terrestrial tower-based hierarchical UMTS with HAP providing the contiguous macro cell coverage in hotspot areas [110]. In same year, Thornton et al. (2004) have suggested the structure of the side lobe region is rather less important than its mean level [111]. Also they described how a system of many co-channel antenna beams may be modeled by deriving for each beam. The theoretical radiation pattern is based on the aperture electrical size and field distribution. Therefore, the importance of minimizing the average side lobe level form HAP was identified. Also in the same year, Katzis et al. (2004) have developed a new channel assignment strategy for a broadband multi-beam HAP architecture that exploited cell overlap [112].

One year later, Suleesathira et al. (2005) obtained a significantly improved performance in comparison to the hysteresis rule. The evaluations are done in measurements of hand-off rate, blocking rate, dropping rate versus the traffic intensities and mean arrival times [113]. Similarly, Suleesathira et al. (2005) have proposed a hand-off algorithm based on the neural network in a joint system of terrestrial and HAP cellular systems [114]. Therefore, HAP is considered as a complementary to the terrestrial systems. Radial-Basis function (RBF) network is used for making a hand-off decision to the chosen neighbor BS. In same year, Katzis et al. (2005) have identified ways to improve the system performance by exploiting cell overlap and by dedicating channels for hand-off users [115]. Exploiting cell overlap improved the overall levels of blocking and dropping calls. One year later, steerable antennas have proposed to be employed to practically compensate for HAP movement [116]. These antennas can be used in CPE and on the platform itself. By employing the combination of hand-off techniques and steering mechanism, the effects of HAP movements can be eliminated resulting into avoidance of interruptions between Ms and platforms [116].

In the succeeding year, Karapantazis et al. (2007) proposed CAC for multiservice HAP wideband-CDMA (W-CDMA) cellular systems that caters for multimedia services [117]. Also in same year, Pace et al. (2007) have proposed a novel strategy for the admission procedure, based on dynamic power sharing. In order to guarantee a high fairness level to all users of the implemented cellular system is considered [118].

One years later, Chowdhury et al. (2010) have focused on the integration of CAC and Uplink Packet Scheduling (UPS) mechanism to identify quantitative measurement of some QoS parameters [119]. It lies within the scope of analyzing the flow services using Markov chain model in an integrated way for BWA systems. In the same way, Jindal et al. (2010) proposed two concepts in WCDMA network i.e. CAC by considering the distance of the cell as a deciding factor in order to minimize the bandwidth reservation scheme and the bandwidth degradation scheme [120].

Shufeng et al. (2011) have presented hand-off requirements of a group of mechanically steered and aperture type antennas that serve cellular network from an HAP [121]. The combined effects of the pointing strategy and hand-off mean that the negative effects of HAP lateral displacement can be largely mitigated. Then again, Haque et al. (2011) have proposed two channel allocation schemes in WiMAX cells to reduce the probabilities of blocking (Pb), handover failure (Ph), forced termination (Pft) and of not completed calls (Pnc) and channel allocation [122]. These schemes are Non Priority scheme (NPs) and reserved channel. But then, Rouzbehani (2011) has presented a fuzzy channel allocation scheme in HAP for emergency mobile communications [123]. The suggested scheme is based on guard channel policy. It dynamically adjusts optimum number of reserved channels according to important QoS parameters to make an efficient use of channels, while prioritizing on-going calls over new calls.

In the succeeding year, Kolate et al. (2012) described several CAC schemes and provided a survey of admission control schemes and Hand-off prioritization for cellular networks [101]. Furthermore, Wang et al. (2012) have proposed CAC algorithm to determine the admission criteria according to network loads and to adopt an adaptive QoS strategy to improve the utilization efficiency of network channels [124]. Bandwidth reservation mechanism is also important for the provisioning of QoS and given hand-off user more prioritized. A comparison of the performance of CAC algorithm and bandwidth reservation scheme has also shown. On the other hand, Alsamhi et al. (2012) have proposed etiquettes for reducing interference. Reducing interference is dependent on the separation distance between HAP ground station and FWA station [45]. In addition, Alsamhi et al. (2012) have presented methods of reducing the interference from HAP ground station to terrestrial station in both conditions i.e. clear sky and rainy [47].

One year later, Bijwe et al. (2013) discussed the hand-off algorithms by Artificial Neural Networks (ANN) and considered ANN as one of the tool which is explored to achieve vertical hand-off [125]. On the other hand, Balaji et al. (2013) have compared as well as discussed various bandwidth reservation schemes with their unique features [126]. Bandwidth reservation scheme played a major role in improving the bandwidth utilization.

Lately, Nguyen et al. (2014) have proposed a QoS-aware Dynamic Resource Allocation (QDRA) scheme which dynamically adjusts the DL/UL ratio to allocate bandwidth for guarantee QoS [127]. It is found that QDRA provides a better performance for real time Polling Service (rtPS), non-real time Polling Service (nrtPS), and Best Effort (BE) by comparing to the pre-reported priority scheme while satisfying QoS requirements for all classes of service.

2.9. Objectives

Our objective in the present research is to exploit the unique characteristics of HAP to provide high QoS. A very important and challenging problem in any wireless communication system is providing guarantee QoS for heterogeneous class services having different QoS requirements. The QoS requirements are given in terms of bandwidth, delay, power control and etc. In order to fulfill the service differentiation and QoS provisioning defined in HAP, the following techniques and technologies will be employed in this research work:

- To study and compare various technologies and parameters for QoS enhancement in advance wireless communication technology which could also be used to enhance QoS in HAP based heterogeneous communication networks.
- Provision of an adaptive intelligent hand-off technique for QoS using HAP.
- Improvement on an efficient and practical reservation channel technique for QoS in HAP cellular based communication systems.
- Implementation of an efficient CAC technique satisfying the guaranteed QoS.

2.10. Definition of the Problem

Nowadays, HAPs have gained interest due to their characteristics that make them one of the most potential options in network deployment for future broadband services. A number of techniques with different criteria and enhancements have already been proposed for terrestrial systems. Most of the existing techniques and their enhancements are expected to work efficiently in the

HAP environment also because of sharing of the same radio transmission technology between the HAP and terrestrial systems.

Our contribution will establish an approach to explicit guarantee QoS by using important techniques such as: hand-off, reservation channels, and CAC. We propose to use the standard simulation platform of MATLAB and neural network for the evaluation of possible performance.

Considering the literature and advancements in HAP techniques developments as reviewed in section 2.8, the following themes have been identified for future explanation and assessment.

Theme #1

Efficient hand-off algorithm enhances the capacity and QoS of cellular systems. Hand-off algorithm is used in wireless cellular systems to decide when and to which BS will receive the handoff call, without any service interruption. HAP is considered as a complementary BS to mobiles in an obstacle position. HAPs can supply services to uncovered areas of terrestrial systems, thus with the goodness of HAPs total capacity in a service-limited area will be improved.

Recently, artificial neural network (ANN) has been utilized to improve hand-off algorithms due to its ability to handle large data. As a revolutionary wireless system, ANN helps in taking the hand-off decision based on receive signal strength, distance, direction, and traffic intensity with available. Radial based function network is used for making a hand-off decision to the chosen neighbor BS.

Accordingly, novel ANN based hand-off approach for efficient hand-off between HAPs and terrestrial system in a particular coverage area has been proposed.

Over all, the performance of proposed technique of hand-off using ANN, unnecessary hand-off expected to be reduced and hand-off rate expected to be improved.

Theme #2

In order to provide committed QoS to the users, telecommunication service providers use different resource allocation schemes. One of such schemes is the adaptive bandwidth allocation scheme. QoS is improved by minimizing the probability of dropping and blocking calls and by allocating channels, optimally.

Therefore, for delivery of enhanced QoS, a reserved channel scheme has been proposed for HAPs based communication services deployment. Such implementation is especially feasible in HAPs as, on a single HAP, multiple mobile cells are created and optimal channel allocation could be done, centrally.

Hence, by varying the value of permanent channels and reserved channels for handoff, the Pcb and Pcd of a new call and successful handoff of an ongoing call expected to be enhanced.

Theme #3

Exponential growth in the number of subscribers of mobile communication services has prompted service providers to maintain high level of QoS. The performance of QoS is usually measured in terms of the probability of call blocking (Pcb) and probability of call dropping (Pcd) parameters. Recently, HAPs are being explored to deploy mobile communication services due to various advantages.

In this problem area, a modified CAC technique has been proposed. We have proposed a novel CAC technique which uses two schemes viz. “Bandwidth reservation” and “Degradation scheme” to deliver the desired QoS.

Under the ‘bandwidth reservation scheme’, we allocated dedicated bandwidth to each category of service. Further, ‘Degradation scheme’ has been used to create additional channels. Consequently, when a new call request arrives and when there are no more channels available, in that particular class; we use the ‘adaptive degradation scheme’ under which the allocated bandwidth of each channel is reduced slightly and additional channels are created and hence allocated to the new call request.

Using these schemes in conjunction with call admission control, better bandwidth utilization and user services are expected with reduced call blocking and call dropping probability.