**HIGH-ALTITUDE AERONAUTICAL PLATFORM**

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**(ST/CS/ND/19/068)**

**A SEMINAR REPRESENTED TO THE DEPARTMENT OF COMPUTER SCIENCE, SCHOOL OF SCIENCE AND TECHNOLOGY, FEDERAL POLYTECHNIC MUBI, ADAMAWA STATE, NIGERIA**

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**Abstract**

*High Altitude Platform Stations (HAPs) are communication facilities situated at an altitude of 17 to 30 km and at a specified fixed-point relative to the Earth. They are mostly solar-powered, unmanned, and remotely operated. These platforms have the capability of carrying multipurpose communications relay payload, which could be in the form of full base station or, in some cases, a simple transponder as is being used in satellite communication systems. High altitude aeronautical platforms, when fully deployed will have the capability of providing services and applications ranging from broadband wireless access, navigation and positioning systems, remote sensing and weather observation/monitoring systems future generation mobile telephony, digital TV etc. High altitude aeronautical platforms are also known to be low cost when it comes to its implementation and are expected to be the next big provider of infrastructure for wireless communications. It is too hard to establish a Base station for particular small village for broadband communication or any wireless communication. High altitude aeronautical platforms have been proposed mobile services in stratosphere. It has advantages of both terrestrial as well as satellite. It also provides services like 3G, emergency services and Wi-MAX. HAP networks are providing different services like military application, earth monitoring, traffic monitoring and control. In terms of services, HAP offering low cost and high facility services.*

**Keywords**: Wireless communications, Base station, Propagation, High Altitude Platforms (HAPs).

**Introduction**

High Altitude Aeronautical Platform Stations (HAAPS) is a technology which facilitates wireless narrowband and broadband telecommunication services as well as broadcasting services with the help of different kind of platforms such as airships or aircrafts. High altitude aeronautical platform stations can cover a service area of approximately 1000 km diameter. This coverage of service area depends on minimum elevation angle accepted from the user's location. High altitude aeronautical platform stations consist of an airborne platform with a telecommunications payload, and associated ground station telecommunications equipment.   One of the most important features of high-altitude aeronautical platform stations is that it is not limited to a single service. Furthermore, this technology makes possible the linking and switching of traffic between multiple high-altitude platforms, satellite networks and terrestrial gateways (Tozer, 2017).

Wireless communication has stood out as one of the fastest and rapidly growing segment of the communications industry with the ability to provide high speed, quality and real-time information exchange between portable devices globally. It is defined basically as information transfer over a distance (without the use of known electrical conductors or cables. It is convenient and often less expensive to deploy relative to the fixed network. This technology has in no little way improved the level and standard of our living in this modern age. Research has shown that the worldwide cellular and personal communication subscriber base went beyond half a billion users in the late 2001 and it’s been projected to attain a 2 billion mark which is like 30% of the world population by the end 2008 (Theodore, 2016).

A very good example is the design of next generation cellular networks to facilitate high-speed data communications traffic in addition to voice calls. New technologies and standards are also being implemented to make wireless networks replace fiber optic and/or copper lines between fixed points that are several kilometers apart known as fixed wireless access. In many geographical areas, mobile telephones are the only economical way for providing phone service to subscribers. Base stations are erected quickly and with low cost compared to the cost involved when digging the ground to lay copper especially in some harsh terrain. Mobile telephones are only a small part of the cellular development; many new types of wireless devices are being introduced (Simon, 2008).

**Literature Review**

Presently, there can’t be said to be a single cellular network. Devices support one or two of a countless number of technologies and generally work within the boundaries of a single operator’s network. New standards for the next generation wireless devices are being developed, which will use higher frequencies to increase capacity and also help eradicate the problem of incompatibility issues, encountered presently (William *et al.,* 2014).

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 have 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 (Goran *et al.,* 2017).

High altitude aeronautical platforms are, generally, solar-powered, unmanned, remote-operated and electric motor-propelled aerial platforms held in stationary position, at altitudes between the 17 – 22 Km range above the earth’s surface (stratospheric layer of the atmosphere). They are somewhat new and are being proposed as means of providing wireless multimedia communications infrastructure for both metropolitan and remote areas. 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. Due to an interest in aerial platforms and due to advancement in technology, which have yielded better and stronger materials, which are UV resistant and leak-proof to helium, these airships are making their way back to our world. HAP´s can be considered as being hybrid architecture; they have some zones in common with terrestrial communications, particularly Fixed Wireless Access, but are similar to satellites in terms of power constraints and general network architecture. In a mobile communication context is the fact it could replace or support the terrestrial network, avoiding problems with environmental impact and electromagnetic pollution. Platform design has several constraints related to the applications to achieve: power available for the payload, stability, and maximum transmit power of the transmitters, link availability and so on (William *et al.,* 2014).

**Technology Advances on High Altitude Aeronautical platforms for Supporting Global Connectivity**

Extensive research has been going around exploring the potential benefits of High-altitude aeronautical platforms in order to provide the best quality of global services. In deciding the technologies to include in High altitude aeronautical platforms, one of the key concerns is the tradeoff between cost of implementation and practical advantage. The first two system architectures described in Section III consider relatively independent operation of HAP systems, merely providing a gateway to other networks, if needed. While this proves sufficient for some specific services such as disaster relief and short-term event servicing in remote areas, High altitude aeronautical platforms are expected to operate in the longer term also in developed countries with preexisting communication infrastructure (William *et al.,* 2014).

# Smart Antennas

Smart antennas in general are cooperative phased arrays capable of advanced signal processing to support spatial beamforming and spatial coding with the aim to avoid causing or to cancel interference in selected directions. Implementation of smart antennas in the millimeter-wave bands can prove difficult due to the small wavelength and the immature technology.

The antenna subsystem of High-altitude aeronautical platforms communication payload comprises phased array antennas or light weight reflector for communication with ground switching stations through gateways. The cellular patterns formed by High altitude aeronautical platforms, using separate spot beam antennas, make the ground communications susceptible to interference and require high gain directional antennas to support better coverage and high capacities. Efforts have been made to find suitable antenna design and techniques to ensure communications via High altitude aeronautical platforms with minimum interference with other infrastructures in coexistence scenarios. ITU has proposed a digital beamforming-based multibeam phased array antenna for High altitude aeronautical platforms WCDMA system. Extensive treatment of antennas for High altitude aeronautical platforms is available (Fabio, 2022).

# Cognitive Radio and Dynamic Spectrum Management

The dynamic spectrum management facilitated by the use of cognitive radio concept has the potential to ensure harmless coexistence and side-by-side operation of different wireless technologies in terrestrial, stratospheric, and satellite segments in potential future unlicensed or shared frequency bands. In fact, with their flexibility and inherent drawback of being a secondary system even in their designated frequency bands High altitude aeronautical platforms lend themselves as a perfect platform to make use of cognitive radio concepts and thus better adapt to the served area (William *et al.,* 2014).

As opposed to smart antennas the dynamic spectrum management tends to avoid causing and receiving interference by searching for a portion of the spectrum that is not being used, instead of shaping the radiation pattern. It assumes that user terminals and access networks comprehend computational intelligence about resources and services, are able to infer the user needs based on the context, and adapt transmission or reception parameters to meet those needs in most efficient way, taking into account also the environment in which it operates (Fabio, 2022).

# Diversity Techniques

Diversity in general is a technique that makes use of two or more statistically independent radio paths to improve the transmission reliability. The probability that all radio paths exhibit deep fade is very low, so if all received signals are properly combined, the system performance can be significantly improved. Clearly, in order to increase the transmission reliability diversity techniques, reduce the capacity of the communication system by sacrificing radio resources. In the case of diversity reception either the best received signal should be selected (selection diversity) or all received signals should be combined into one signal for data estimation (combining diversity) (William *et al.,* 2014).

# Multiple-Input–Multiple-Output

The MIMO systems, based on multiple antennas on transmit and receive side, offer the promise of link reliability, increased capacity, high spectral efficiency, and high gains by exploiting space-time processing techniques without any additional bandwidth or power requirements under different propagation environments. One of the key concerns of MIMO technology is to find suitable geometrically small size antennas ensuring low mutual coupling between individual antenna elements. In this respect compact antennas with polarization and in particular 3-D feature of electromagnetic waves are expected to play a significant role in MIMO technology. Particularly, the application of MIMO compact antennas to the High-altitude aeronautical platforms communication systems is of foremost interest in order to achieve diversity and spatial multiplexing gains (William *et al.,* 2014).

# Free-Space Optics

FSO technologies can provide large bandwidths and have the ability to support high throughput links. In case of FSO communications attenuation due to different weather effects is negligible above the tropospheric region. Due to their immunity to propagation conditions and high spectral efficiency as compared to microwave links, optical communication technology can be used to establish high data rate IPLs and High-altitude aeronautical platforms -satellite links to serve as broadband backhaul communication channels, which will play important role to globally distribute and receive data in integrated scenarios. By using optical links, data can be downloaded from Low Earth Orbit (LEO) satellites to High altitude aeronautical platforms at rate of 10 Gb/s. There are some challenges to establish such communication links. In order to reduce misalignment errors caused by motion and vibration instabilities of satellite and High-altitude aeronautical platforms, precise pointing, tracking, and acquisition algorithms need to be applied. Other factors are Doppler shift in the received signal caused by the relative high speed of LEO satellite and optical carrier choice for transmitter design (William *et al.,* 2014).

# Cross-Layer Design and Optimization

HAP-based communications require efficient utilization of resources because the available resources of bandwidth, transmit power, and battery-storage energy are limited. The existing layered architecture or internet protocol stack does not exploit efficiently the available resources and is a suboptimal solution to the system performance improvement. To meet the demands of future communication systems, the broadband networks need to be optimized by taking into account the quality-of service (QoS) demands from the applications and the challenges from physical medium. In this view, cross-layer approaches provide better resource utilization and tradeoffs using the knowledge and parameters of other protocol layers and propagate this information among different protocol layers. This results in efficient system design but at the expense of increased system complexity. The cross-layer design concept is expected to address the issues of variability in data rates, total transmission delays and jitter, end-to-end latency, packet reordering, and QoS control in 4G and B4G networks. In addition to optimizing network radio resources, this concept avoids the need of deploying extensive backbone infrastructure for global connectivity to different technologies. The recently proposed cooperative cross-layer joint source and channel coding scheme to mitigate propagation impairments in IP multimedia applications are required to exploit in integrated scenarios for global connectivity. Taking into account the similarity of HAP-based communication systems and terrestrial wireless systems in most parameters but propagation conditions, the same cross-layer approaches can be applied as in terrestrial systems, just optimized to HAP specifics (Andrea, 2005).

# Applications high-altitude aeronautical platforms

#### **Telecommunications**

One of the latest uses of HAPS has been for [radiocommunication service](https://en.wikipedia.org/wiki/Radiocommunication_service). Research on HAPS is being actively carried largely in Europe, where scientists are considering them as a platform to deliver high-speed connectivity to users, over areas of up to 400 km. It has gained significant interest because HAPS will be able to deliver bandwidth and capacity similar to a [broadband](https://en.wikipedia.org/wiki/Broadband) wireless access network (such as [WiMAX](https://en.wikipedia.org/wiki/WiMAX)) while providing a coverage area similar to that of a satellite. High-altitude airships can improve the military's ability to communicate in remote areas such as those in Afghanistan, where mountainous terrain frequently interferes with communications signals (Iskandar, 2015).

#### **Surveillance and intelligence**

One of the best examples of a high-altitude platform used for surveillance and security is [Northrop Grumman RQ-4 Global Hawk](https://en.wikipedia.org/wiki/Northrop_Grumman_RQ-4_Global_Hawk) UAV used by the [US Air Force](https://en.wikipedia.org/wiki/US_Air_Force). It has a service ceiling of 20 km and can stay in the air for continuous 36 hours. It carries a highly sophisticated sensor system including radar, optical, and infrared imagers. It is powered by a [turbofan](https://en.wikipedia.org/wiki/Turbofan) engine and is able to deliver digital sensor data in realtime to a ground station (Fabio, 2022).

#### **Real-time monitoring of a region**

Another future use that is currently being investigated is monitoring of a particular area or region for activities such as flood detection, [seismic](https://en.wikipedia.org/wiki/Seismic) monitoring, [remote sensing](https://en.wikipedia.org/wiki/Remote_sensing) and disaster management (Fabio, 2022).

#### **Weather and environmental monitoring**

Perhaps the most common use of high-altitude platforms is for environment/weather monitoring. Numerous experiments are conducted through high-altitude balloons mounted with scientific equipment, which is used to measure environmental changes or to keep track of weather. Recently, [NASA](https://en.wikipedia.org/wiki/NASA) in partnership with The National Oceanic and Atmospheric Administration ([NOAA](https://en.wikipedia.org/wiki/NOAA)), has started using Global Hawk UAV to study Earth's atmosphere (Iskandar, 2015).

#### **As a rocket launch platform**

Due to the height, more than 90% of atmospheric matter is below the high-altitude platform. This reduces atmospheric drag for starting rockets. "As a rough estimate, a rocket that reaches an altitude of 20 km when launched from the ground will reach 100 km if launched at an altitude of 20 km from a balloon." Such a platform has been proposed to allow the usage of (long) [mass drivers](https://en.wikipedia.org/wiki/Mass_driver) for launching goods or humans into orbit (Fabio, 2022).

# Advantages of high-altitude aeronautical platforms

1. Replace extensive ground-based infrastructure
2. High altitude aeronautical platforms can provide multi-cellular services over large areas
3. We do not need a local terrestrial backbone
4. Backhaul can be provided to a place where fiber optics are available
5. Better Propagation in Many Scenarios (Altitude ~22 Km)
6. Line of sight paths
7. Rain may affect the hap systems less than terrestrial systems
8. Large system capacity
9. Use of mm bands (47/48 GHz, 2x300 MHz Bands)
10. Frequency Re-Use
11. Flexible and adaptive resource allocation.

**Conclusion**

HAPS, which is a rather developing, low-cost and efficient communication technology has been considered in this thesis work as to how it could be used as substitution to or complement satellite and terrestrial communication. HAP combines the benefits of satellite and terrestrial systems. There are still obstacles in it’s development such as the one dealt in this thesis i.e. attenuation caused by rainfall. The simulation results show us that altering modulation techniques with the surrounding attenuation can solve this problem. HAP is still on the drawing board and the problems that are arising are being solved one by one. It can be safely assumed that HAP will be the future of telecommunication industry.

**Recommendations**

Since they collect traffic into a single point on the ground, HAAPs would reduce the amount and geographic extent of ground-based equipment against their terrestrial counterparts.

HAAP-based systems would generally be more accessible for repairs and upgrades than satellites that have been launched, and, while the airborne portions may be less accessible than terrestrially based systems, the HAAPs’ terrestrial components would be more accessible since they would be more centralized.

The minimum system size for a single HAAP corresponds well to a metropolitan marketing region, facilitating rapid initial deployment for coverage so that commercial service can be started. The vantage point of HAAPs and the centralization of their beamforming apparatus would open new possibilities for smart antenna technology such as beam scanning.

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