An Intelligent HAP for Broadband Wireless Communications: Developments, QoS and Applications

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***Abstract*—Aerial telecommunications have been investigated for three decades through the design and evaluation of stratospheric platforms able to offer multiple types of wireless services. HAP may be airplanes or airships and may be manned or unmanned with autonomous operation coupled with remote control from the ground. There is increasing interest in the development of airspace platforms in recent years, for example, HAP carrying equipment for telecommunications, remote sensing or digital broadcasting. The multiple types of platform are able to carry a communication payload at different altitudes. Regarding the altitude of aerial communication, there are three categories of balloons, High Altitude Platforms (HAP), Medium Altitude platform (MAP) and Low Altitude Platform (LAP). HAPs provide an excellent option for emergency communications, their survivability during a disaster and ability to be continuously on station offer an ideal solution for an emergency communications capability. This paper focused on the basic characteristics of communication systems based on HAP, it outlines alternative network architecture scenarios for provision of wireless access to broadband communication services. HAP can coexist with WiMAX in same coverage area. Therefore, these systems can work efficiently and effectively with share frequency to sustain high QoS.**

***Index Terms*—CINR, HAP, LAP, LTA, tethered balloon, WiMAX**

I. Introduction

The need and importance of new wireless communication infrastructure which can provide high-speed multimedia mobile communication service to users who are not satisfied with low-speed data and voice service provided by existing wireless network are rapidly increasing. Since the stratospheric communications system using an airship can provide observation/monitoring/surveying service as well as communication service, considerable demands can be expected in the near future.

Fig. 1 shows a future trend of mobile communications. It is very clear that they have to satisfy the demands of high data rate, high mobility, and seamless coverage. Data rate, coverage and mobility greatly depend on frequency band. Taking these technical problems into account, future systems will include several different systems. Some will have high performance in providing high data rates, others in service coverage or high mobility. Aerial platforms include the form of unmanned or manned aircraft, balloon or airship, which operate at different altitudes with various missions including remote monitoring, surveillance, positioning and navigation and provision of communications.

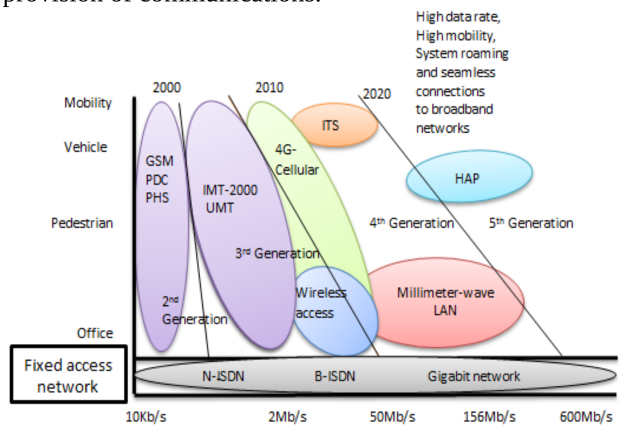

Figure 1. Generation of Mobile communication systems

Aerial platforms in a quasi-stationary position at the lower stratosphere have gained interests to deliver communication services. Aerial telecommunications have been investigated for three decades through the design and the evolution of stratospheric platforms able to offer multiple types of wireless services and have continually attracted significant interest in government and industry academia [1], [2]. Single aerial platform can replace a

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large number of terrestrial masts, along with their associated costs, environmental impact and backhaul constraints. Site acquisition problems are also eliminated, together with installation maintenance costs, which can represent a major overhead in many regions of the world. The platforms may be airplanes or airships and may be manned or unmanned with autonomous operation coupled with remote control from the ground. In that respect, all aerial platforms share common core properties, such as the potential modularity of the communication payloads they carrier, their relatively rapid deploy ability and due to their unique position, the ability to often support direct line of sight communication with terrestrial networks.

There is an increasing interest in the development of airspace platforms in the recent years, platforms carrying telecommunications, digital broadcasting, and remote sensing. Balloons can keep stationary in its altitude for long period 3-5 years and cover a wide range 500km^2. This makes them very attractive for the future broadband wireless access. This paper WILL focus on development and applications of aerial platforms as well as the coexistence of HAP system with terrestrial system for providing high QoS.

The paper is organized as follows; aerial platforms technology in section II is described. Types of aerial platform covered in section III and section IV, describes performance of coexistence. Then the result and discussion are taken up in section V. Finally, section VI brings in the conclusion of this work

II. Aerial Platforms Technology

Aerial platforms are classified to Higher Than Air (HTA) and Lighter Than Air (LTA) as shown in Fig. 2. According to anticipations, first commercial solutions will be based on those heavier than air platforms. However the target solutions will be lighter than air airships.

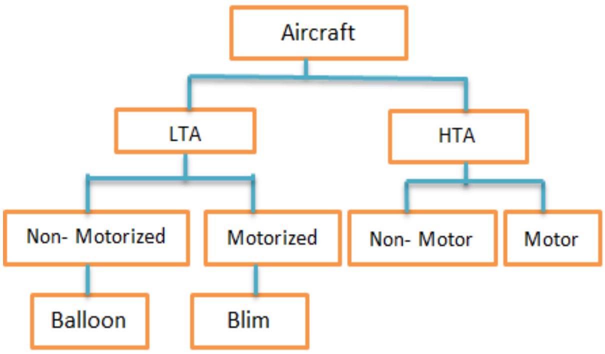

Figure 2. Classification of different kind of aircrafts

According to the altitude of HTA operate in 17-22km position [3]-[6] but LTA operate in maximum 5km. The parameters that determine the characteristics of a flying machine are the flying principle and population mode [7]. Persistence balloons can include both LTA and HTA unmanned crafts, flying at either medium or high altitudes as shown in Fig. 3. The most interested one is HAPs.

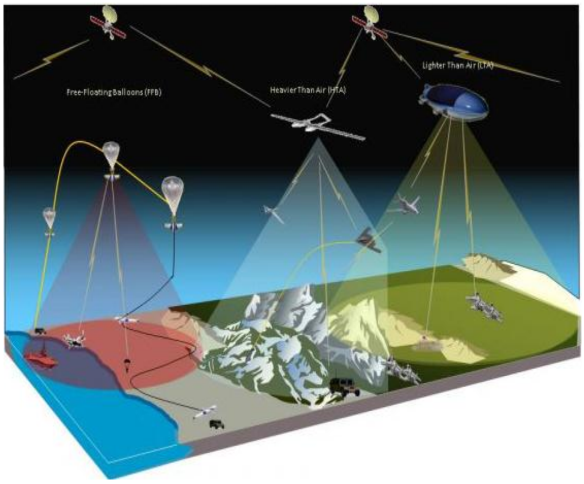

Figure 3. Categories of High altitude platform

HAPs communications system consists of sky and ground segments. The sky segment includes mainly the platform and the on board communications payload [8]. There are three types of aerial platform, HAP, MAP and LAP. HAPs provide an excellent option for emergency communications their survivability during a disaster and ability to be continuously on station offer an ideal solution for an emergency communications capability. However, in recent years, many other types of aerial platforms which either aerostats or aerodynes, have been developed to operate at various altitudes in the troposphere as the following Table I shows:

TABLE I. Comparative between Types of Aerial Platforms

	Height	payloads weighing	Coverage
HAPs	17-22Km	200 pounds	200Km^2
LMAPs	Max. 5km	2,400 pounds	
LAPs	0.3-4Km	5-10Kg	
Tethered Balloon	0.07-0.44Km	5-10Kg	2Km^2
EBAN Balloon	0.1-0.5Km	5-10Kg	2Km^2

III. Types of Aerial Platform

There are three types of balloons, HAP, MAP and LAP. These platforms are gathered under denomination of LAP or Low and Medium Altitude Platforms (LMAP). Two types of aircrafts can be distinguished, HAPs and LAPs. LAPs are designed for low to medium altitude operations between 0.3-4km altitudes. HAPs provide an excellent option for emergency communications their survivability during a disaster and ability to be continuously on station offer an ideal solution for an emergency communications capability.

A. Low Altitude Platform

Platforms, either aerostats or aerodynes, evolve at various altitudes and are named (LAPs) [9] or HAPs [10], [1], whether they fly in the lower troposphere or in the stratosphere. LAP combines one or more tethered balloons with WiFi technology could be implemented in actual disaster affected area. The tethered balloons lift a flying platform incorporating WiFi equipment to high dictated by the area to be covered, providing communications between the search and rescue teams, field hospital, and the forward and rear medical posts, and supporting mobile communication between relief staff in the most remote points of disaster- affected area. LAP systems are easy to deploy and take less than a day to prepare before the system is ready to turn on. Compared to a tower system, the temporary flying platform with tethered balloons costs less and provides reduce shadowing effects because of the higher elevation angle. LAPs in particular are not only seen as a fast and convenient way to experiment telecommunications payloads with relatively inexpensive aerial vehicles, but can also address actual scenario requirements where limited coverage, due to low altitude, is acceptable. The authors in [9] and [11] sought to evaluate several LAP vehicles for relief support in several regions of Indonesia particularly exposed to a large number of potential threats, including droughts, floods, landslides, earthquakes and volcanic eruptions.

The application of Tethered Balloon, Balloons as the earliest form of aerial platform technology is dated back to the time of the ancient Chinese. While in the west, aircraft, balloons and airships have been well developed in the last three hundred years. Aerostats and airships are more capable LTA platforms. Aerostats are aerodynamically shaped tethered balloons mounted with fins for stability. Airships are untethered. On board propulsion and control systems enable them to handle changes in ambient wind much better, and hence they can relocate and fly around. Both Aerostats and airships can act as high-altitude platforms for several scientific and commercial applications.

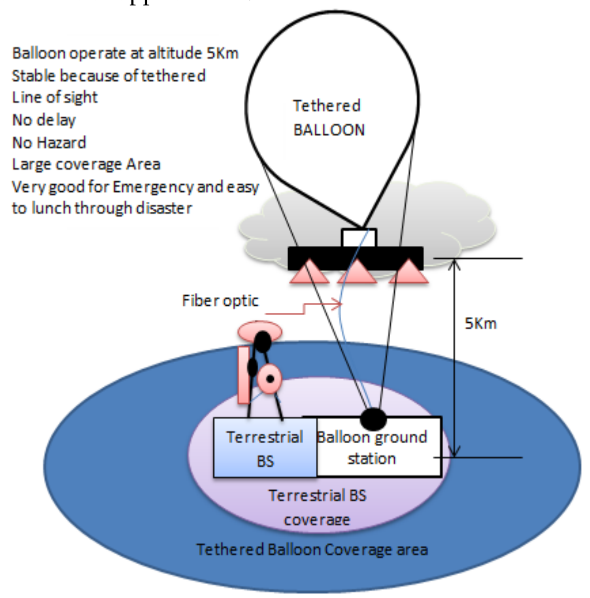

Figure 4. Tethered balloon

The U.S. Air Force has made extensive use of tethered aerostats as surveillance systems, and there are available on the market aerostats, which can fly up and beyond 5km altitude tethered with a cable that supplies the aerostat onboard systems with electric power. These aerostats are designed for long-duration missions and they are designed to be able to withstand lightning strikes and strong winds.

Aerostats have been actively applied to various problems as shown in Fig. 4. These include aerial imaging [12], remote sensing [13], radar [14] visual and infrared monitoring of international borders [15], relaying electromagnetic signals [16], and collection of solar power from above the cloud layer. Williams [17] proposes power generation from aerodynamic kites, but many of the application lessons may be applied and scaled up to use aerostats which can guarantee lift off from the ground and endurance regardless of ground-level or upper-level winds.

The aerostat has three tethers. The tethers minimize the need for propulsion for station keeping in high winds, convey or remove fill gas, send communication signals and video feed, and most of all, in our case, provide low-pressure waveguides to convey millimeter wave power. Highly efficient corrugated waveguides have been developed as commercial products for millimeter wave power. One known option is a 63 millimeter diameter metallic corrugated waveguide [18], that offers extremely low power loss, making it nearly as efficient as Space transmission. Tethered mass always varies with altitude.

B. Low-Medium Altitude Platform

Captive balloons, which have been widely used in many areas, are good tool for LMAPs. However, compared with HAPs, it is very difficult for LMAPs to provide globe mobile communications. So LMAPs are considered only as a temporary platform, and there have been only a few studies and test beds concerning the telecommunication payload systems based on LMAPs [19]. There has been an increase in the development of Airspace platforms in recent years. Balloons, Airships or Aircrafts are carrying equipment for communication, remote sensing or digital broadcasting.

LMAPs are being actively researched and developed as a key solution to improve the performance and services of emergency communications. It can also provide higher capacity, throughput and quality of service guarantee to terrestrial users in emergency scenarios. Balloons can keep stationary at low medium altitude of about 2km or high altitude of about 21km and cover a wide range. This makes them very attractive for the future broadband wireless access. The telecommunication payload systems on LMAPs can be implemented with various wireless technologies including 3G, LTE, WiMAX and WiFi or combination of more than one type.

C. High Altitude Platforms

High altitude platform is airplane or airship which operate at 17Km to 21Km altitude as shown in Fig. 5. The important of HAP position are, above of aviation airline, speed windy is sufficiently low. Being much closer to ground, HAPs deliver better channel conditions than satellites, a line of sight condition is achievable in almost all the coverage area, so it generates much less showing areas than terrestrial systems. HAP combines the most important characteristics of satellite system and terrestrial systems which made it the third layer of communication systems. HAPs combine some of the best characteristics of terrestrial and satellite communication systems while avoiding many of their drawbacks. Thus they provide alternative and complementary means of communications. In comparison to terrestrial wireless technologies, HAPs require considerably less communications infrastructure, they can serve potentially large coverage areas from a single site, little multipath fading and the cell planning is more straightforward since they are able to provide a line of sight and a free-space-like channel path. When compared to satellite communication systems, HAP communications system will provide a quasi-stationary coverage area, easy maintenance, short propagation delay, wide bandwidth, broadband capability using small size antennas and terrestrial terminal equipment, upgrading of the payload during the lifetime of the platform and the cost for fabrication and operation of airship is competitive compared with satellite system and it is a great advantage that airship can be recovered and repaired when system failure occurs.

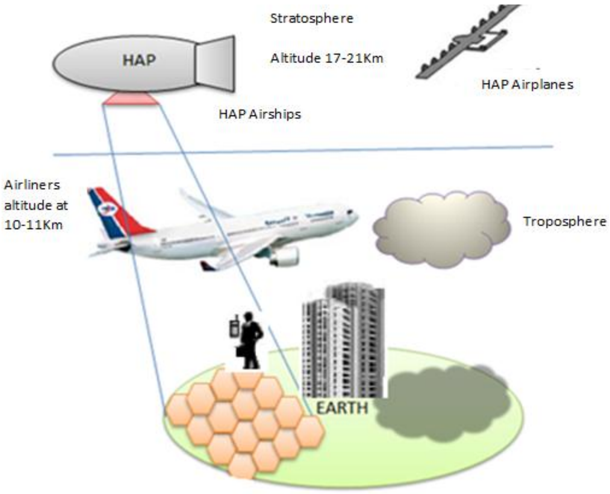

Figure 5. High Altitude Platform System

Due to their easy deployment, HAP networks are oriented to provide not only broadband services but also services like remote sensing, earth observation, positioning, military communication, 4G/3G, navigation, meteorological measurement, traffic monitoring, surveillance, control and emergency communication.

HAP has the advantages of both satellite communication system featuring flexibility of network planning and construction, wide bandwidth, wide coverage and so on, and terrestrial communication system featuring timely supply meeting the demands, easy maintenance and so on. On account of the active development of the HAPS in some countries and its potential interference to other countries, the matters including technical and regulatory issues are treated as the international common issues. All these featuring flexibility of HAP network planning and construction; make HAPs suitable also for the provision of broadcast and multicast services. Since HAP communications system using an airship can provide observation/monitoring/surveying service as well as communication service, considerable demands can be expected in the near future as shown in Fig. 6. HAPs are also easy to move. The fact means they can be deployed at any place as required. This characteristic enables HAP Communication System (HAPCS) to be applied to many scenarios, such as environment monitoring, rapid deployment for disaster relief and so on.

HAPs have the potential to deliver broadband services cost effectively, offering a step-change in performance and availability. However, they are not intended to replace existing technologies, but instead work with these in a complementary and integrated fashion. While representing a perfectly suitable alternative infrastructure for long-term provision of broadband access to fixed or mobile users, HAPs are particularly well-suited for temporary provision of basic or additional capacity requirements, due to the possibility of rapid deployment and controlling the flight path in compliance with changing communication demands, providing network flexibility and configurability. Typical services to be offered from aerial platforms include basic voice, video and data communications, as well as more advanced services such as telemedicine, news gathering, localization and navigation, news and emergency message broadcasting, videoconferencing, remote sensing. The potential benefits of HAPS technology, compared to the use of conventional terrestrial or satellite networks, for providing wireless communication services are:

- Line-of-sight propagation paths to most fixed user.
- A single HAPS platform can replace a large number of terrestrial towers, with savings in cost, site acquisition delay, and environmental impact. The platform can carry additional payloads for surveillance and monitoring applications.
- Due to survivability, coverage, and capability of being continuously on station.

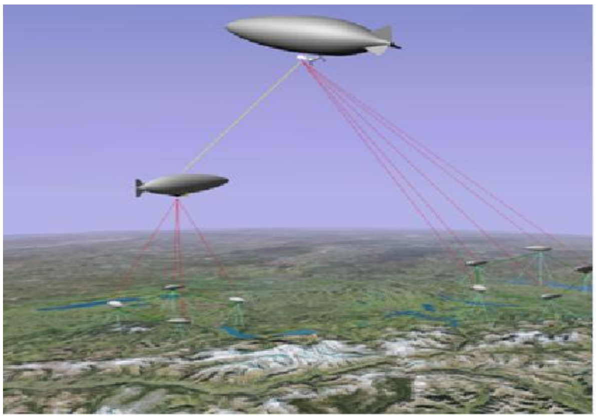

Figure 6. Different altitude of HAP

HAPs offer an excellent alternative for providing emergency telecommunications after the occurrence catastrophic incident. This unique capability provides significant advantages over terrestrial based deployable systems and even other airborne systems. HAPs 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 require a new mindset for understanding emergency network requirements and traffic loading.

In the late 1990s, a larger series of projects from various parts of the world further addressed key issues related to stratospheric telecommunications, including the design of efficient wireless communication systems, the study of radio propagation and potential interference with terrestrial and satellite systems and the development of modular communication payloads. The author of [20] investigated how first-responder and emergency answering services such as 911 or 112 could be supported by HAPs. As shown in Fig. 6 the multiple types of aircrafts are able to carry a communication payload at different altitudes.

A. HAPs for Emergency and Medical Communication

HAPs provide an excellent option for emergency communications. Their survivability during a disaster and ability to be continuously on-station offer an ideal solution for an emergency communications capability.

The proposal, which is maintained by many authors, is the use of HAPS as alternative wireless network provider that can partially replace or add capacity to damaged or overloaded wireless networks during a man-made or large- and small scale natural disaster. During these critical phenomena, the telecommunications infrastructure and the required coverage for the emergency service operations might be unavailable due to the destroyed area or overloading by the excessive communications demand.

The classes of natural disasters considered in our system architecture include earthquakes in rural and urban areas, landslide and avalanche, flood, cyclonic storm and tidal waves, tsunami, tornadoes, and ice storms. Natural disasters and terrorist acts have significant potential to disrupt emergency communication systems. During disaster and emergency situations, the aerial platform could significantly improve communications between rescue teams and headquarters, but is limited in human resources, as an environmental obstacle, and by budget constraints [21]. HAPs designed for emergency situations has been presented [20]. This technology used to propose emergency communications systems requirements and traffic patterns for catastrophic event.

The other most important advantage of HAPS is that all type of content voice, data, video streaming can be served by the existing client terminals which are used daily to communicate. Another emergency medical communication solution proposed by [22] considers the scenario where the only available system for transmitting important vital patient data is VHF/HF radio link and costly satellite communication. All communication capabilities on the HAP should be interoperable using gateways and an IP core to allow communications between all networks.

B. Development of HAPs

The basic two types of airborne vehicles used for HAPs are aerostatic and aerodynamic platforms. They are based on the underlying physical principle to provide the lifting force, and can be either manned and unmanned aircrafts or airships with hybrid power of fuel and solar.

- Aerostatic platforms make use of buoyancy to float in the air. They appear in the shape of balloons and airship, and make the use of a lighter-than-air (LTA) gas such as helium to generate buoyancy. In order to move horizontally and run on board equipment, the aerial platform uses gasoline engines or solar power to propel forward or backward. For example aerostatic platform is the type of high altitude balloon shown in Fig. 7 which has been widely used in meteorological and scientific research. Balloons are usually unmanned platforms, which need to tether.
- Aerodynamic platforms use dynamic forces generated by the movement through the air. By exploiting the aerodynamic lift in the air, they need to circle above coverage area and maintain a quasi-stationary altitude.

Figure 7. High altitude balloon

Figure 8. Manned HAP

Figure 9. Unmanned HAP

An example of these high altitude platforms is a manned high altitude research aircraft developed by (NASA) as in Fig. 8. Another example, is unmanned shown in Fig. 9 which is developed by High-Altitude, Long-Endurance Unmanned Aerial Vehicle (HAE UAV) program to demonstrate sustained data support from anywhere within the target area during day or night.

TABLE II. HAP DEVELOPMENT

	Airship unmanned	Solar plane unmanned	Jet unmanned
Total length	200m	70m	30m
Energy	Solar cell	Solar cell	Fossil fuel
Radius	1km	1.5km	10km
System example	Jaban, Korea, china sky station	Hellos, pathfinder plus In U.S	HALO In U.S

C. *Advantages of HAPs*

HAPs are regarded to have several unique characteristics compared with terrestrial and satellite systems. The novel HAP has features of both terrestrial and satellite communications and has the advantages of both systems [23]. Main advantages can be summarized as follows:

- Large coverage area, HAPs are often considered to have a coverage radius of 30km by virtue of their unique location. Thus, the coverage area is much larger than terrestrial systems. HAPs can yield significant link budget advantages with large cells at the mm-wave bands where line of sight (LOS) links are required.
- Rapid deployment, HAPs can be quickly deployed in the sky within a matter of hours. They have clear advantages when it is used in disaster or emergency scenarios.
- Broadband capability, HAP offers LOS propagation or better non line-of-sight (NLOS) propagation links owing to its unique position. Users can get a high quality communication with a low propagation delay and blocking from the HAP.
- Low cost, HAP operational cost is believed to be considerably cheaper than that of a low earth orbit (LEO) or geostationary earth orbit (GEO) satellites because HAPs do not require expensive cost of launch and maintenance [24]. Due to the large coverage area from HAP, this network should be also cheaper than a terrestrial network in terms of the cost to deploy a large number of terrestrial BSs.

Generally, the proposed architectures can be categorized in the following way as shown in Fig. 10:

- An integrated terrestrial/HAP/Sat system.
- An integrated terrestrial/HAP system.
- A standalone HAP system.

While HAPs provide substantial advantages over terrestrial and satellite systems, the successful deployment of HAPs communications systems would require integration of available and emerging platform technologies to make long term operation feasible and profitable.

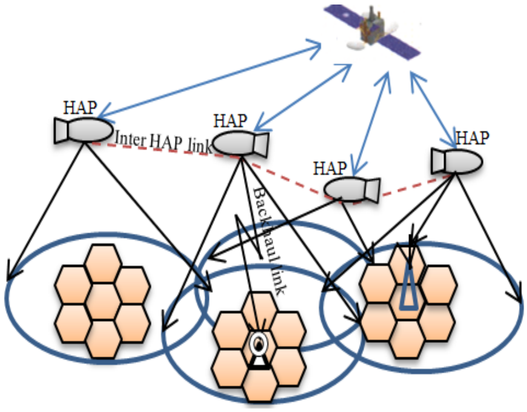

Figure 10. An integrated terrestrial/HAP/Satellite system

D. *APPLICATIONs OF HAPs*

HAPs provide 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. [25] as shown in Fig. 11. The platform position allows the HAPS based system to provide better channel conditions than satellite.

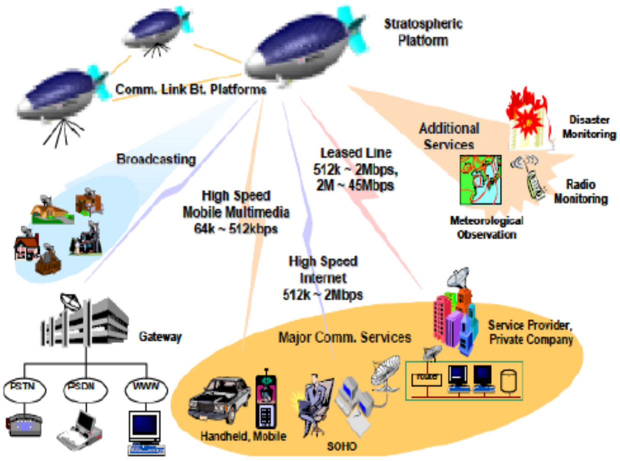

Figure 11. HAPs Applications and Services

A Line Of Sight (LOS) condition is achievable in almost all the coverage area, thus less shadowing areas than terrestrial systems. Therefore, HAPs require much less transmission power for a given Quality of Services (QOS) [26].

A. *Emergency Response*

HAPs can have a significant advantage when deployed in emergency situations such as those stemming from natural or human-induced 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). The rapid deployment of HAPs, operating as airborne base stations capable of establishing "on-the-fly" cellular links (i.e., rapid restoration capability), while allowing users to operate their existing mobile handsets in disaster regions.

B. Intelligent Transportation Systems

Intelligent transportation systems (ITS) include a broad range of wireless and wire-line communications-based technologies. These technologies may be incorporated in vehicles and in the transportation infrastructure and their objective is to improve safety, security and to introduce new services to vehicle passengers via co-operative communication schemes. Communication cooperation on the road includes car-to-car or car-to-infrastructure links. These links may be used for the following applications such as: collision avoidance, traffic warnings, fleet management, electronic toll collection, emergency vehicle notification system, congestion pricing, automatic road enforcement schemes, navigation, location-based information download.

C. Earth Observation

HAPs can play a key role in earth observation applications, especially in the case of new partnerships, such as the Global Earth Observation System of Systems (GEOSS) and the European GMES (Global Monitoring of Environment and Security) as shown in Fig. 12.

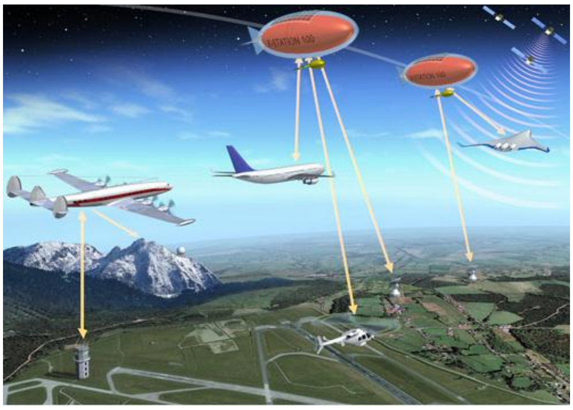

Figure 12. HAP for earth observation

These initiatives encompass in-situ, airborne and space borne sensors' deployment, interconnected ground infrastructures for, data sharing, processing and analysis, value added information production up to systems for decision making. Additional applications in disaster monitoring are numerous with earthquakes, volcanic eruptions, industrial accidents, landslides, avalanches, and oil spills give only a few examples.

D. HAPs in Telecommunication Applications

HAPs can also be applied for telecommunication applications such as fixed, broadband wireless applications (BWA), for integration with 3G/4G mobile systems and also for providing multicast/broadcast services (DVB-H) [8]. More specifically:

- *Broadband Wireless Access:* BWA provides potentially very high data rates in terms of megabits per second. The spectrum allocation for HAPs worldwide for the provision of BWA services consists of a pair of 300MHz bands in the 47/48GHz band, although the 28/31GHz is also specified in much of Asia. The backhaul requirements are severe as the user links themselves based on the principle that goes up must come down. As no wireless link can provide the full backhaul capacity so it is required to handle it via a cellular scheme that further requires a number of distributed backhaul ground stations that would handle a greater capacity with higher order modulation schemes. However these ground stations are low profile and their location within coverage region is non-critical hence they will be probably situated on roofs of buildings. The typical bit rate of the access link is a few Mbps for most fixed and portable terminals, while a several hundred Mbps link is available for limited fixed terminals with antennas larger than typical ones [8].

  Basic characteristics of communication systems based on aerial platforms, it outlines alternative network architecture scenarios for provision of wireless access to broadband communication services, and it provides a short overview of the IST project CAPANINA, which is developing broadband communication networks based on the use of aerial platforms. Broadband communications node technology for HAP systems will be distributed between the development of communications equipment configurations for the aerial platform and ground stations (including customer premises terminals) on one side, and the development of advanced techniques critical to HAPs broadband communications on the other
- *3G/4G:* HAPs and UMTS systems will use the same RTTs (Round Trip Times) and provide the same functionality and meet the same service and operational requirements as traditional terrestrial tower-based UMTS systems. The HAPs systems can be designed to, replace the tower base station network with a "base station network in the sky") or can be integrated into a system that employs traditional terrestrial base station towers, satellites and HAPs [8].
- *Multicasting/Broadcasting:* To reduce the percentage of outage areas (blank spots), higher communication link margin and/or higher tower and/or larger number of towers are required. HAPs located at high altitude could potentially be used as an alternative solution for DVB/DAB repeater/transmitter [8].
- *Military Communications:* It can benefit military communications as these can be rapidly deployed. They can act as nodes within existing military wireless networks or as surrogate satellites. But HAPs are vulnerable to enemy attack. Despite large size, their envelope is largely transparent to microwaves and they present an extremely low radar cross section as shown in Fig. 13. HAPs can

also be deployed in military applications, where they can function as surrogate satellites coupled with shorter transmission distances for relaying ground-based communications and shorter ranges for sensor surveillance of a battleship and acquisition of ground targets [27].

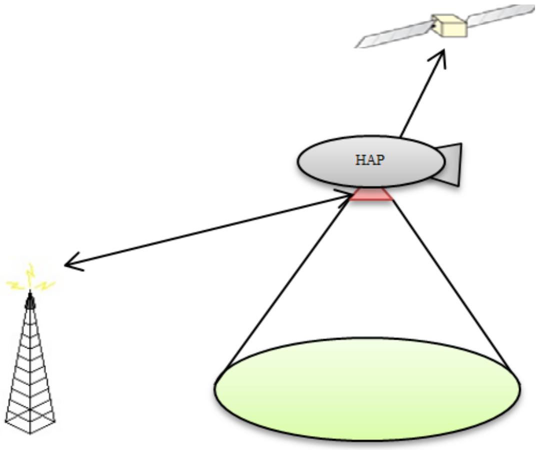

Figure 13. HAP for military communication

IV. Performance of Coexistance

The acceptable level of INR is the main parameter utilized in this paper to evaluate the performance of the system. Accordingly, it is the reference to apply the proper adjusted power to reduce the interference level from HAPS to TS. HAPS transmit power must be adjusted in accordance with principles in which the interference is acceptable between the HAPS and the TS. The HAPS is the new technology that will occupy a frequency that is adjacent to the TS, and will cause interferences. The first step in the compatibility calculation is to activate the TS and assume there are no HAPS services to cause interfere. After a while, the HAPs are activated and starts to transmit with its highest transmit power. The HAPS activation will cause degradation of performance to the TS; hence the INR is calculated based on three steps [28]. First to calculate the interference from HAPS into TS, second to compute the noise level of the TS receiver and third we find the INR level of the receiver in order to extract the required adapted to transmit power from HAPS.

The HAP located at altitude of 17km above the ground with coverage radius area equal to 30km as in Fig. 14. The separation distance between sub-platform point (SSP) on the HAP ground and the terrestrial base station equal to 40km [29].

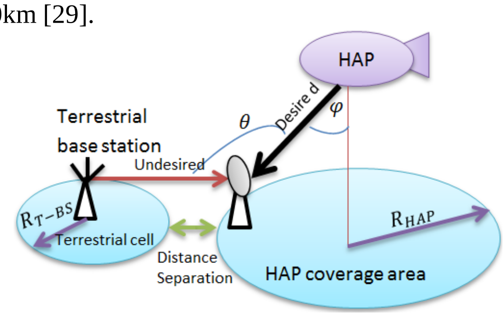

Figure 14. Coexistence model providing WiMAX from HAP

Directional antenna with either elliptical beam can offer better optimized power at cell edges than circular beams. Therefore, a directional antenna is considered for HAP system to radiate power across the desired coverage area at a minimum guaranteed level. The directional antenna is considered to be suitable for the users in order to gain the benefit of the high radiating power efficiency.

There are two variable power control schemes called CINR and INR based scheme which getting to improve coexistence performance between HAPS system and terrestrial WiMAX system. The CINR scheme takes the carrier to interference plus noise ratio level as reference. On the other hand, INR, takes interference to noise ratio level as reference, and use to control new activated system transmit power.

V. Result and Discussion

This study focused on providing QoS in HAP system. One of the parameter of QoS is to mitigate interference from HAPGS to TS and also interference from HAPS to TS. So that the separation distance that required providing QoS between HAP and others is the only solution for the coexistence of Terrestrial subscriber stations and the HAPS. QoS is impossible without interference mitigation. Separation distance has been considered in the clear sky condition only as well as in case of coexistence of HAP and WiMAX. In clear sky condition loss only consist of atmospheric absorption loss, free space loss and feeder loss. As well as we consider WiMAX as example for broad band communication and its coexistence with HAPS. Calculations are done by using MATLAB software following the ITU recommendations.

The separation distance required for providing QoS in clear sky with varying azimuth angle 30°, 60°, 90°, and 120° is shown in Fig. 15, when separation distance increases for various azimuth angles. For azimuth of 30°, or any azimuth less than 60°, the minimum separation distance required to obtain optimum I/N is 182km. For azimuth of 60°, 118km is needed, 51km is necessary for azimuth of 90°, and for azimuth angle equal to 120°, the minimum separation distance required to obtain optimum interference is 22km.

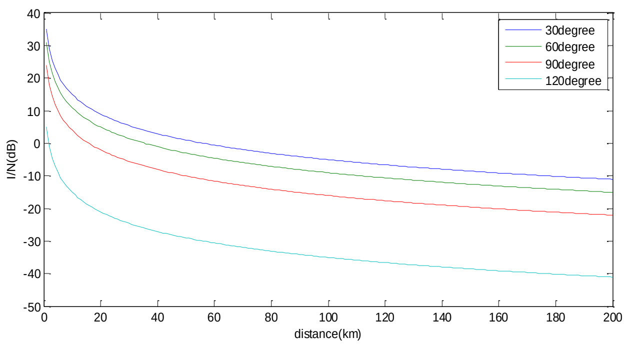

Figure 15. Separation distance required in clear sky

In this study, the enough separation distance needed for providing QoS of HAP and TS in clear sky condition is shown in Fig. 16 which has a nonlinear relationship. I\N increase constantly until about 40km from the HAPS nadir, then reached up to the peak point about 54km and decreases down as the distance increases. We assumed the distance between terrestrial WiMAX system and HAP is 10km. The terrestrial WiMAX system used Rayleigh channel to transmit power to the user.

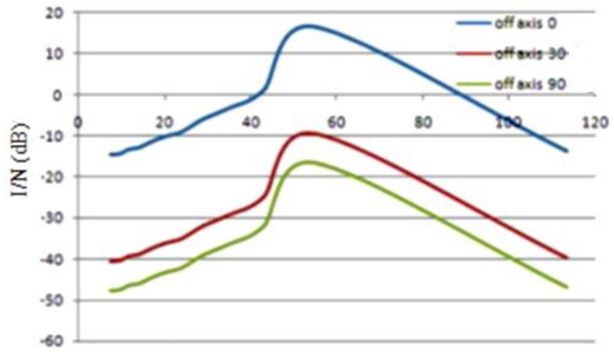

Figure 16. The distance required to coexistence TS and HAP

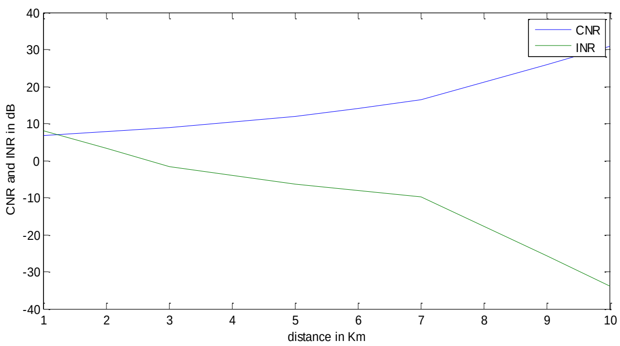

Figure 17. 64QAM CNR and INR versus distance

Fig. 17 shows the relationship between carrier to noise ratio of HAP with various distance when the modulation scheme is 64QAM. The carrier to noise ratio increases when the distance between HAP and user increases. When the user's distance from HAP is 7km, the interference decrease drastically because the user starts to go out of the HAP coverage and transmission of power of terrestrial system is getting higher there for QoS to improve the chances of coexistence.

VI. Conclusion

In this paper, we surveyed the civilian aerial communication network, with an overview of the multiple types of aircrafts able to carry a communication payload at different altitudes. Then, we outlined a series of issues mostly related to the performance of aerial networks.

Afterwards, we further detailed our analysis of the current and specific challenges related to three typical use cases that offer promising perspectives. This investigation led us to conclude that, beyond the structural issues that still prevent long endurance aircrafts to be readily available for commercial development, EBAN system can provide a wide area hotspot for emergency relief. Furthermore, significant efforts are also required in terms of safety and security regulations to help characterize aerial communication platform operations for effective airspace integration of the LAP/HAP systems and applications. In case of separation distance required to provide QoS of HAP and HAPGS to TS, for various azimuths the separation distance increases as well as optimum I/N decreases in clear sky condition.

For Coexistence performance of HAP with WiMAX become good as the separation distance increase between two systems as well as the interference from HAP system to terrestrial WiMAX decrease and both system can work effectively because the transmission of power from terrestrial WiMAX can be adjusted to provide high power.

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