# Broadband Communications and Applications from High Altitude Platforms

A. Mohammed and Z. Yang
Department of Signal Processing, Blekinge Institute of Technology, Ronneby, Sweden
Email: {amo, zya}@bth.se

***Abstract*—In this paper, we give an overview of using High Altitude Platforms (HAPs) for providing wireless telecommunication and broadband communication services. Comparisons of HAPs, satellite and terrestrial systems are shown to illustrate unique characteristics of the system. Three architectures for HAP systems are discussed in terms of cooperation with terrestrial and satellite systems. Telecommunication, broadband and disaster applications of HAPs are shown based on system scenarios.**

***Index Terms*— High Altitude Platforms (HAPs), broadband communications, wireless communications, 4G systems**

## I. Introduction

The last decade has experienced a development in wireless communications. New wireless technologies give people more convenience and freedom to connect to different communication networks. It is thought that the demand for the capacity increases significantly when the next generation of multimedia applications are combined with future wireless communication systems.

Wireless communication services are typically provided by terrestrial and satellite systems. The successful and rapid deployment of both wireless networks has illustrated the growing demand for broadband mobile communications. These networks are featured with high data rates, reconfigurable support, dynamic time and space coverage demand with considerable cost. Terrestrial links are widely used to provide services in areas with complex propagation conditions and in mobile applications. Satellite links are usually used to provide high speed connections where terrestrial links are not available. In parallel with these well established networks, a new alternative using aerial platforms at high altitudes has emerged and attracted international attentions.

Communications platforms situated at high altitudes can be dated to the last century. In 1960 a giant balloon was launched in USA. It reflected broadcasts from the Bell laboratories facility at Crawford Hill and bounced the signals to long distance telephone call users. This balloon can be regarded as an ancestor of High Altitude Platforms (HAPs). Traditional applications of airships have been restricted in entertainment purposes, meteorological usage, and environment surveillance due to safety reasons. However in the past few years, a technology advancement in communications from airships has given a promising future in this area [1].

HAPs as a new solution for delivering wireless broadband, have been recently proposed for the provision of fixed, mobile services in stratosphere at an altitude of 17 km to 22 km as shown in Figure 1 [2, 3, 4]. HAPs can act as base-stations or relay nodes, which may be effectively regarded as a very tall antenna mast or a very Low-Earth-Orbit (LEO) satellite [4]. This modern communication solution has advantages of both terrestrial and satellite communications [4, 5, 6]. It is a good technique for serving the increasing demand of broadband wireless access (BWA) by using higher frequency allocations especially in mm-wavelength and high-speed data capacity. HAPs are also proposed to provide other communication services, i.e. 3G services, WiMAX broadband services below 11 GHz. The International Telecommunication Union (ITU) allocated a frequency band around 2 GHz for IMT-2000 HAP service [7].

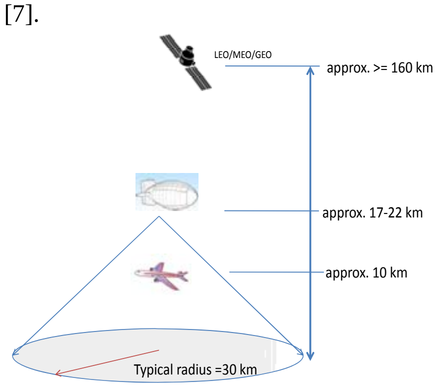


Figure 1. HAP system deployed at 17~22 km above the ground.

Many countries have made significant efforts in the research of HAPs system and its applications. Some well-known projects are: (1) HeliNet and CAPANINA of the European Union (EU) [8]; (2) SkyNet project in Japan [9]; (3) a HAP project managed by ETRI and KARI in Korea [10]; (4) In USA, Sanswire Technologies Inc. (Fort Lauderdale, USA) and Angel Technologies (St. Louis, USA) carried out a series of research and demonstrations for HAP practical applications [9]; (5) engineers from Japan have demonstrated that HAPs can be a new platform to provide High-definition television (HDTV) services and International Mobile Telecommunications (IMT-2000) Wideband Code Division Multiple Access (WCDMA) service successfully; (6) Since 2005 the EU Cost 297 Action has been established in order to increase knowledge and understanding of the use of HAPs for delivery of communications and other services [11]. It is now the largest gathering of research community with interest in HAPs and related technologies [4, 11]. Recently, the first author has led an international editorial team for a HAP special issue at EURASIP Journal of Communications and Networking [4] to promote this technology and the research activities of Cost 297 to a




DOI: 01.ijcom.01.01.08

wider audience. The authors are members of the Cost 297 Action and are closely involved in its research and activities [4, 11].

A few HAP trails have been carried out in the EU CAPANINA project to demonstrate its capabilities and applications.

- In 2004, the first trial was in Pershore, UK. The trial consisted of a set of several tests based on a 300 m altitude tethered aerostat. Though the aerostat was not situated at the expected altitude it have many tasks of demonstrations and assessments e.g. BFWA up to 120 Mbps to a fixed user using 28 GHz band, end-to-end network connectivity, high speed Internet, video on demand (VoD) service, using a similar platform-user architecture as that of a HAP [12].
- In October 2005, the second trial was conducted in Sweden. A 12,000 cubic meter balloon, flying at an altitude of around 24 km for nine hours, was launched. It conducted the RF and optical trials. Via Wi-Fi (IEEE802.11b) the radio equipment has supported date rates of 11 Mbps at distances ranging up to 60 km. This trial is a critical step to realize the ultimate term aim of CAPANINA to provide 120 Mpbs data rate [12].

The paper is organized as follows. In section 1, we give an introduction to the HAP concept and its applications in wireless communications. In section 2, comparisons of HAPs, satellite and terrestrial systems are shown to illustrate characteristics of the HAP system. In section 3, architectures for HAP systems are discussed. HAP system scenarios of different applications are also illustrated. In section 4 we propose a scenario of providing WiMAX from HAPs with multiple antenna payload and investigate the coexistence capability. Finally, conclusions are given in section 5.

## II. HAP Communication systems

HAPs are regarded to have several unique characteristics compared with terrestrial and satellite systems, and depending on the application are ideal complement or alternative solutions when deploying next generation communication system requiring high capacity [5]. Typical characteristics of these three systems are shown in Table 1.

The main advantages of HAPs can be summarized as following:

- *Large-area coverage*

HAPs are often considered to have a coverage radius of 30 km by virtue of their location [3]. The International Telecommunication Union (ITU) suggests that footprints larger than 150 km radius can be served from a HAP [13]. It would potentially allow a single HAP to replace several terrestrial base stations with a cost-effective deployment in suburban and rural regions.

- *Low cost*

Although there is no direct data of HAP operational cost, it is believed that the cost of HAP is going to be considerably cheaper than that of a satellite (LEO) because HAPs do not require expensive launch and maintenance and can be deployed for reconfiguration. The HAP network should be also cheaper than a terrestrial network with a large number of terrestrial base stations.

- *Broadband capability*

HAPs offers LOS propagation or better Non LOS propagation links owing to its unique position and gives a higher capacity for broadband applications.

- *Rapid deployment*

A HAP can be quickly deployed in the sky within a matter of hours. It has clear advantages when it is used in disaster or emergency scenarios.

Table 1 System characteristics of HAP, terrestrial and satellite systems. BS: Base Station, FSPL: Free Space Path Loss

| Subject | HAPs | Terrestrial | Satellite |
|---|---|---|---|
| Cell radius | 3~7 km | 0.1~2 km | 50 km for LEO |
| BS Coverage area radius | Typical 30 km | 5 km | A few hundred km for LEO |
| Elevation angles | High | Low | High |
| Propagation delay | Low | Low | Noticeable |
| Propagation Characteristic | Nearly FSPL | Well established, typically Non FSPL | FSPL with rain |
| BS power supply | Fuel (ideally solar) | Electricity | Solar |
| BS maintenance | Less complexity in terms of coverage area | Complex if multiple BSs needed to update | Impossible |
| BS cost | No specific number but supposed to be economical in terms of coverage area | Well established market, cost depending on the companies | 5 billion for Iridium, Very expensive |
| Operational Cost | Medium (mainly airship maintenance) | Medium ~ High in terms of the number of BSs | High |
| Deployment complexity | Low (especially in remote and high density population area) | Medium (more complex to deploy in the city area) | High |

## III. HAP system devloyment and applications

Generally, there are three proposed architectures for HAP communication systems [14]. The difference between them is mainly on the network infrastructure involved.

- *A stand-alone HAP system*

HAPs have the potential to be a stand-alone system in many applications, e.g. broadband for all, environment and disaster surveillance. The architecture is shown in Fig. 2. In rural or remote areas, it is rather expensive and inefficient to deploy terrestrial systems. Furthermore, a satellite system is costly to be launched if the traffic demand is small. HAPs system may be deployed economically and efficiently in this situation. A backbone link could be established by fibre network or satellites depending on applications.




DOI: 01.ijcom.01.01.08

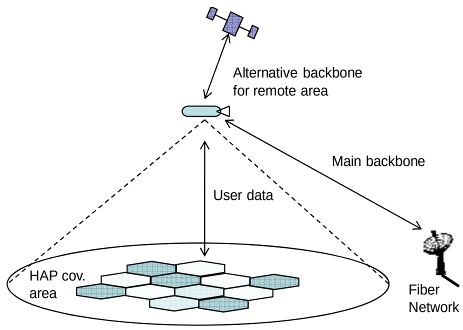


*Figure 2. A stand-alone HAP system.*

- *Integrated HAP-Terrestrial system*

HAPs have been suggested by ITU to provide the 3G telecommunication services. HAP system is considered to be competitive in the cost instead of deploying a number of terrestrial base stations. In the architecture shown in Fig. 3, HAPs are considered to project one or more macro cells and serve a large number of high-mobility users with low data rates. Terrestrial systems can provide service with high data rates or in areas where NLOS propagation is mostly prevailing. The HAP network can be connected to terrestrial network through a gateway. Due to its wide coverage area and competitive cost of deployment, HAPs could be employed to provide services for areas with low population density, where it could expensively deploy fibre or terrestrial networks.

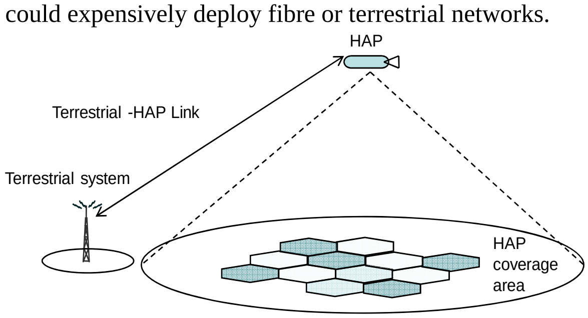


Figure 3. HAP-Terrestrial system.

The main telecommunications and broadband applications from HAPs are 3G WCDMA and WiMAX services [3, 15-22]. Generally these applications can be thought to equip base stations onboard, and based on well established terrestrial system design experience, but they are against new challenges, e.g. cell structures, handover controls and dynamic channel assignment. One of the cell structures with terrestrial cellular with frequency reuse factor of 3 in HAP-WiMAX broadband system is shown in Fig. 4 [20].

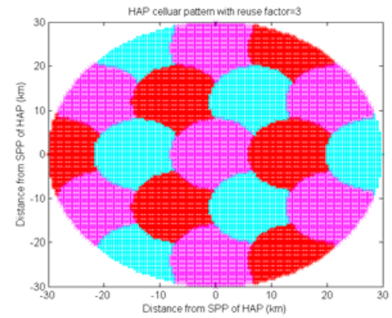


Figure 4. Cell structure with reuse factor of 3 in HAP-WiMAX Broadband System.

Wireless sensor network (WSN) applications are proposed for HAP system since the system has distinct advantages in environment surveillance and disaster scenarios, which usually require base stations to work in long duration and probable remote areas [21, 22]. One of the integrated WSN-HAP scenarios is shown in Fig. 5, where the HAP is used as a mobile gateway to remove multi-hop transmissions in the network and replace terrestrial gateways [22].

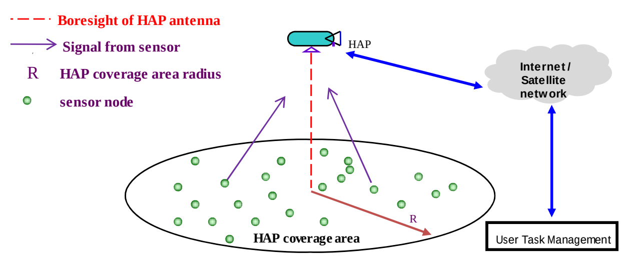


Figure 5. WSN-HAP system.

- *Terrestrial-HAP-Satellite system*

The network architecture is shown in Fig. 6. It is composed of links between HAPs, satellite and terrestrial systems. It can provide fault to tolerance, and thus support a high quality of service (QoS). Broadcasting and broadband services can be delivered from the platform. Inter-platform communications can be established for extending coverage area.

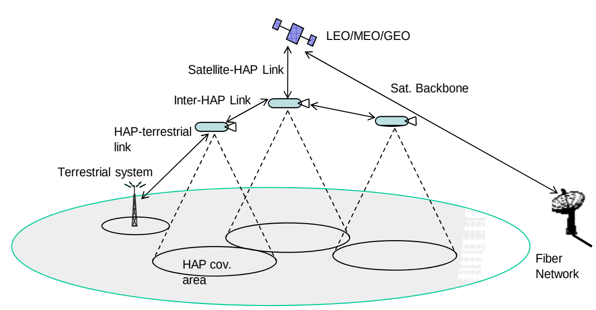


Figure 6. Integrated Terrestrial-HAP-Satellite system.




DOI: 01.ijcom.01.01.08

## IV. Performance of Delevering WiMAX IEEE802.16 from HAPs

The performance of providing IEEE 802.16 is shown inside the HAP coverage area of Fig. 7. This evaluation scenario consists of a single HAP with a multi-beam antenna payload at an altitude of 17 km to serve multiple cells [15, 20]. The radius of HAP coverage area and a single HAP cell is typically about 30 km and 8 km, respectively. We assume that cells are hexagonally arranged and clustered in different frequency reuse patterns to cover the HAP service area.

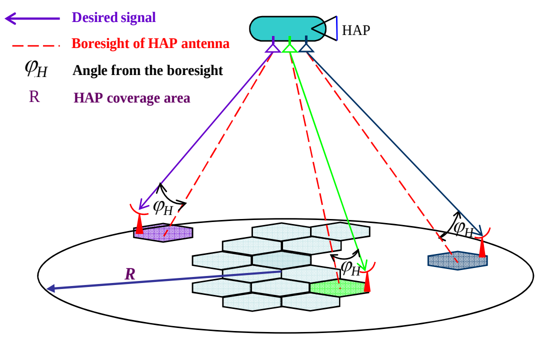


Figure 7. HAP system with multi-beam antenna serving multiple cells on the ground.

Considering a user in location *(x,y)*, it communicates with its serving HAP antenna and receives interference from other antennas serving other cells with the same bandwidth allocation. Performance can be evaluated by carrier-to-interference ratio *(CIR)* and carrier-to-interference plus noise ratio *(CINR)*, respectively:

$$CIR_H(x,y) = \frac{P_H A_H A_U PL_{HU}}{\sum_{i=1}^{N_H} P_{H_i} A_{H_i} A_{U_i} PL_{H_iU}} \quad (1)$$

$$CINR_H(x,y) = \frac{P_H A_H A_U PL_{HU}}{N_F + \sum_{i=1}^{N_H} P_{H_i} A_{H_i} A_{U_i} PL_{H_iU}} \quad (2)$$

where,

- $P_H$ is transmission power of HAP to user in the target cell at 40 dBm.
- $P_{Hi}$ is transmission power of interfering HAP antennas to the target cell.
- $A_H$ and $A_U$ are antenna gains of HAP and user depending on the angle away from the boresight respectively.
- $PL_{HU}$ is pathloss from HAP to user.
- $N_H$ is total number of cochannel cells in HAP system.
- $N_F$ is noise power at -100 dBm.

Figure 8 shows the downlink carrier to interference ratio (CIR) performance in the HAP coverage area by considering the cochannel interference. It can be seen that HAP cellular performance is not susceptible to cochannel interference and is stable inside its coverage area.

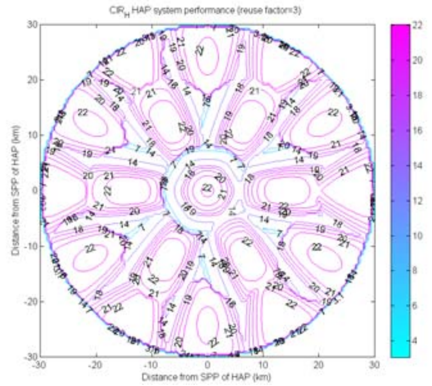


Figure 8. CIR$_H$ HAP WiMAX system performance (reuse factor=3).

Figure 9 shows the cumulative distribution function (CDF) of $CIR_H$ and $CINR_H$ of HAP WiMAX system. It can be seen that WiMAX services can be provided averagely around 21 dB in both scenarios. Interference from cochannel is dominant compared to noise in the system since the curves in Fig. 9 are overlapping. Hence system performance improvement can mainly focus on reducing excess power radiated from cochannel HAP antenna to the target cell. A potential solution is to adopt smart antennas to provide an optimized beam pattern.

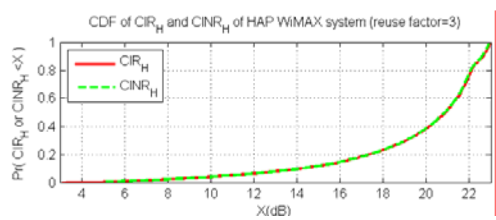


Figure 9. CDF of CIR$_H$ and CINR$_H$ in HAP WiMAX system.

## V. Conclusions

In this paper, we have proposed to use HAP systems, an airship located in 17 km above ground, to provide communication services for suburban and urban areas. An overview of the HAP concept development and HAP trails have been introduced to show the worldwide interest in this emerging novel technology. A comparison of the HAP system has given based on basic characterises of HAP, terrestrial and satellite systems. The major advantages of HAP for wireless communication applications in rural areas were wide coverage area, high capacity and cost-effective deployment. Three architectures for HAP communication systems have been discussed in terms of different applications in conjunction with terrestrial and satellite systems. Finally, we have shown a scenario of providing WiMAX IEEE 802.16 from HAPs with multiple antenna payload and investigated the coexistence capability. The simulation results show that it is effective to deliver WiMAX via HAPs and share the spectrum with terrestrial systems.




DOI: 01.ijcom.01.01.08

## REFERENCES


[1] S. Karapantazis and F. N. Pavlidou, "The role of high altitude platforms in beyond 3G networks," *Wireless Communications, IEEE [see also IEEE Personal Communications]*, vol. 12, pp. 33-41, 2005.

[2] T. C. Tozer and D. Grace, "High-altitude platforms for wireless communications," *IEE Electronics and Communications Engineering Journal*, vol. 13, pp. 127-137, 2001.

[3] D. Grace, J. Thornton, T. Konefal, C. Spillard, and T. C. Tozer, "Broadband communications from high altitude platforms - The HeliNet solution," *Wireless Personal Mobile Conference*, Aalborg, Denmark, 2001.

[4] A. Mohammed, S. Arnon, D. Grace, M. Mondin, and R. Miura, "Advanced communications techniques and applications for high-altitude platforms," *Editorial for a special issue in EURASIP Journal on Wireless Communications and Networking*, vol. 2008, 2008. http://www.hindawi.com/journals/wcn/volume-2008/si.7.html

[5] G. M. Djuknic, J. Freidenfelds, and Y. Okunev, "Establishing wireless communications services via high-altitude aeronautical platforms: A concept whose time has come?," *IEEE Communications Magazine*, vol. 35, pp. 128-135, 1997.

[6] R. Steele, "Guest Editorial: An update on personal communications," *IEEE Communications Magazine*, pp. 30-31, 1992.

[7] D. Grace, N. E. Daly, T. C. Tozer, A. G. Burr, and D. A. J. Pearce, "Providing multimedia communications from high altitude platforms," *International Journal of Satellite Communications*, pp. 559-580, 2001.

[8] D. Grace, M. Mohorcic, M. Oodo, M. H. Capstick, M. B. Pallavicini, and M. Lalovic, "CAPANINA - communications from aerial platform networks delivering broadband information for all," *IST Mobile Communications Summit*. Dresden, Germany, 2005.

[9] T. C. Hong, B. J. Ku, J. M. Park, D.-S. Ahn, and Y.-S. Jang, "Capacity of the WCDMA system using high altitude platform stations," *International Journal of Wireless Information Networks*, vol. 13, 2005.

[10] J.-M. Park, B.-J. Ku, Y.-S. Kim, and D.-S. Ahn, "Technology development for wireless communications system using stratospheric platform in Korea," *IEEE PIMRC 2002*, vol. 4, pp. 1577-1581, 2002.

[11] The European Community Cost 297 Action, "Cost 297 overview," http://www.hapcos.org/overview.php, 2008.

[12] "CAPANINA project", http://www.capanina.org/, 2004.

[13] ITU-R, "Minimum performance characteristics and operational conditions for high altitude platform stations providing IMT-2000 in the bands 1885-1980 MHz, 2010-2025 MHz and 2110-2170 MHz in the Regions 1 and 3 and 1885-1980 MHz and 2110-2160 MHz in Region 2," *Recommendation ITU-R M.1456*, 2000.

[14] S. Karapantazis and F. Pavlidou, "Broadband communications via high-altitude platforms: a survey," *IEEE Communications Surveys & Tutorials*, vol. 7, pp. 2-31, 2005.

[15] Z. Yang and A. Mohammed, "Evaluation of WiMAX uplink performance in high altitude platforms cellular system," in *4th IEEE International Symposium on Wireless Communication Systems (ISWCS'07)*. Trondheim, Norway, 2007.

[16] Y. C. Foo, W. L. Lim, and R. Tafazolli, "Centralized downlink call admission control for high altitude platform station UMTS with onboard power resource sharing," IEEE Vehicular Technology Conference, VTC 2002-Fall, 2002.

[17] D. Avagnina, F. Dovis, A. Ghiglione, and P. Mulassano, "Wireless networks based on high-altitude platforms for the provision of integrated navigation/communication services," *IEEE Communications Magazine*, vol. 40(2), pp. 119-25, 2002.

[18] F. Dovis, R. Fantini, M. Mondin, and P. Savi, "4G communications based on high altitude stratospheric platforms: channel modeling and performance evaluation," *Global Telecommunications Conference, GLOBECOM '01 IEEE*, vol. 1, pp. 557-561, 2001.

[19] T. Hult, A. Mohammed, and D. Grace, "WCDMA uplink interference assessment from multiple high altitude platform configurations," *EURASIP Journal on Wireless Communications and Networking*, vol. 2008, 2008.

[20] Z. Yang, A. Mohammed, T. Hult, and D. Grace, "Assessment of coexistence performance for WiMAX broadband in high altitude platform cellular system and multiple-operator terrestrial deployments," in *4th IEEE International Symposium on Wireless Communication Systems (ISWCS'07)*. Trondheim, Norway, 2007.

[21] J. D. Deaton, "High altitude platforms for disaster recovery: capabilities, strategies, and techniques for emergency telecommunications " *EURASIP Journal on Wireless Communications and Networking*, vol. 2008, 2008.

[22] Z. Yang and A. Mohammed, "High altitude platforms for wireless sensor network applications," *5th IEEE International Symposium on Wireless Communication Systems (ISWCS'08)*. Reykjavik, Iceland 2008.





DOI: 01.ijcom.01.01.08