



TD(05)054

**4th Management Committee Meeting
University of Wuerzburg, Germany, October 13-14 2005**

Telecommunications over High Altitude Platforms

Gorazd Kandus, Aleš Švigelj, Mihael Mohorčič
Department of Communication Systems, Jozef Stefan Institute,
Jamova 39, 1000 Ljubljana, Slovenia,
{gorazd.kandus,ales.svigelj,miha.mohorcic}@ijs.si

Abstract

Provision of broadband services is raising increasing challenges, particularly in operating environments requiring wireless access. In this context an emerging solution based on aerial platforms is attracting increasing amounts of research effort. This concept combines some of the best characteristics of terrestrial and satellite communication systems, and it provides alternative and complementary means of communications, particularly well suited for serving remote regions with low user density, short-term large-scale events and establishment of ad-hoc networks for disaster relief. This paper discusses some 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 research activities in this area.

Keywords

High Altitude Platforms, Network Architecture, Wireless Broadband Access, Stratospheric communications

Working Group 3

1. Introduction

The “last mile” problem represents the biggest challenge in the delivery of broadband services directly to customers’ terminals, whether in fixed or mobile operating environments. It is solved by various flavours of wired or wireless access technologies, depending on the population density, required services and coverage area, existing infrastructure (e.g. cables, fibres, ducts), configuration of the terrain, etc, but the network dimensioning is typically carried out based on long-term service requirements. To meet the demand for higher data rate communications a plethora of “last mile” technologies are used and under development, offering a range of performance and availability figures, and include:

- **Asymmetric Digital Subscriber Line (ADSL)** and its variants – based on the use of telephone wires at the very upper limit of their capacity, with availability limited by the customer's distance to a suitably equipped exchange.
- **Fibre optic cable** – offers high data rates but is not installed ubiquitously, and is uneconomic for installation in less densely populated areas.
- **Broadband Fixed Wireless Access (BFWA)** – offers high data rates over short distances at higher *mm*-wave frequencies. It requires a proliferation of base stations to obtain sufficient coverage. Availability is limited by requirement for line-of-sight.
- **Mobile telephony** – 2nd generation (ubiquitous in developed countries but offering limited data rates) and 3rd generation (promising moderate data rates but again requiring proliferation of base station infrastructure).
- **Wireless LAN (WLAN)** – based on IEEE 802.11 variants can offer typically 11 and up to 54 Mbit/s burst rates over short ranges. Higher rates are foreseen (IEEE 802.11n) but it will still be limited to localised hot-spot coverage.
- **Satellite** – offers moderate capacity at higher expense, mostly aimed at corporate users, but can give universal geographic coverage. Next generation services at Ka band and above have been slow to progress towards market. Low Earth Orbit (LEO) systems have been hampered by excessive cost and complexity.

As an alternative to terrestrial and satellite infrastructure, great interest has been recently shown in aerial platforms capable of providing broadband wireless access. These were first proposed back in 1992, typically operating in the lower stratosphere at altitudes around 20 km. They have the potential to deliver services over a wide coverage area, thus attracting significant interest for the provision of communications, as well as for surveillance and navigation. Two distinct types of aerial platforms have been proposed for the provision of communication services from the stratosphere:- unmanned airships; and manned/unmanned aircraft [1, 2]. Such a stratospheric aerial platform is usually described as a High Altitude Platform (HAP).

This paper describes basic characteristics of HAP based systems, which make them well suited for alternative infrastructure for short-term large-scale events and disaster relief missions. It discusses network architecture scenarios for provision of wireless access to broadband communication services, and briefly presents the IST project CAPANINA, which is concerned with the development of broadband communication networks based on the use of aerial platforms.

2. High Altitude Platforms

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, and the cell planning is more straightforward since they are able to provide line-of-sight links. When compared to satellite communication systems HAPs will provide a quasi-stationary coverage area, low propagation delays, broadband capability using small sized antennas and terrestrial terminal equipment, and easy maintenance and upgrading of the payload during the lifetime of the platform. All these characteristics make HAPs suitable also for the provision of broadcast and multicast services.

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 re-configurability. In this context typical applications of HAPs include short-term large-scale events and establishment of ad-hoc networks for disaster relief.

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, localisation and navigation, news and emergency message broadcasting, videoconferencing, remote sensing, etc.

3. HAP network architectures

From the system architecture perspective HAPs will provide broadband wireless access for single-user or group terminals in the coverage area, serviced from fixed or mobile / portable ground stations operating as backhaul nodes (hubs). The HAPs can operate as stand-alone platforms; alternatively, HAPs can be interconnected via the ground segment or by interplatform links (IPL) in the sky segment forming a network of platforms. Furthermore, such a telecommunication system can be deployed as a stand-alone network or it can be connected to external networks via gateways providing suitable internetworking functionality. User terminals communicate with platforms via user links in the *mm*-wavebands, while the hub ground stations, hosting gateways to external networks and different servers, are connected to platforms via backhaul links, together forming an up/down link segment.

System coverage and the services to be offered form the most important aspects of the architecture design phase. Typically, the coverage area of each platform will be composed of many smaller cells to increase the system capacity. The size of the service area has a direct impact on the number of required HAPs and on their configuration. Similarly, the choice of network topology has an impact on the wide range of services that can be offered. With respect to different possible interconnections of platforms, shown in Figure 1, four network architecture scenarios may be defined [3].

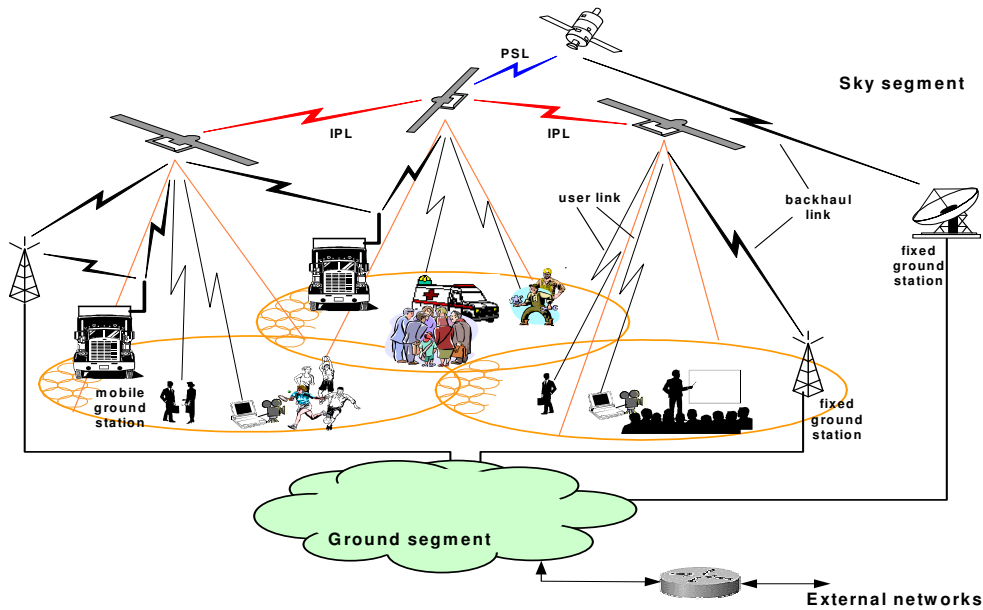


Figure 1: HAP communication network architecture.

A. Standalone platform scenario:

In a stand-alone platform scenario the system coverage is limited to the cellular coverage of a single platform, enabling only communication between terminals within the coverage area, or with terminals in other networks using a gateway located in the ground segment.

Taking into account the location of switching equipment we can distinguish between platforms without on-board switching (transparent platform) and those with on-board switching (switching platform). The choice between switching on the ground and on board depends on QoS requirements and on limitations with respect to the weight and power consumption of the platform payload. The stand-alone platform scenario is most suitable for temporary provision of basic or additional capacity for short-term events and for disaster relief missions; in the case of such temporary applications fixed ground stations may not be readily available in the platform coverage area. In such case the only alternative to a mobile / portable ground station with switching functionality (e.g. mounted on a truck) is the implementation of onboard switching.

B. Network of platforms connected via ground stations:

In a multiple platform system HAPs have to be interconnected via ground stations or via interplatform links. In a scenario with a network of platforms connected via ground stations the system coverage is no longer limited to that of single platform coverage, but it heavily depends on ground segment facilities. Similarly, as in a stand-alone platform scenario, switching can be performed in the ground station or on board. On-board switching provides some gain in terms of QoS parameters (mainly delay) to communicating parties within the same platform coverage area. In the case of switching at the ground station, however, the platform payload complexity, weight and power consumption can be significantly reduced, while backhaul requirements are more demanding and traffic from/to different cells needs to be efficiently aggregated/split on the platform.

C. Network of platforms connected via interplatform links:

The scenario with platform interconnection via interplatform links provides extended system coverage with significantly reduced terrestrial infrastructure. It is particularly attractive to bridge wider spans between ground stations and to offer the possibility to re-route part of the traffic to less loaded ground stations and gateways. To support communication between adjacent platforms without any ground network elements each HAP communication payload includes a switching device and one or more IPL terminals. We can choose between optical and radio frequency (RF) IPL terminals, depending on the technical requirements. In this scenario ground stations are used mainly as gateways to other public and/or private networks, while providing also a backup interconnection between platforms in the case of IPL failure.

Implementation of IPLs significantly reduces requirements for ground and up/down link segments, provides high flexibility of system coverage, and supports system operation independent of terrestrial network. On the other hand, IPL terminals represent additional weight and power consumption on the platform and require steerable IPL antennas to maintain permanent connection [4]. An IPL antenna must meet pointing, acquisition and tracking (PAT) requirements induced by the motion of platforms above their nominal location, and by the unpredictable flying conditions caused by stratospheric wind, unforeseen gusts, turbulence, etc. The effects of these phenomena change the IPL distance and antenna pointing angle. Thus, PAT requirements have an important influence on the choice between optical and RF interplatform links [4].

IPLs are not only suitable for the interconnection of adjacent platforms with partially overlapping coverage areas, but also for connecting remote platforms forming the same network. In such a backbone network the link budget analysis must take into account additional attenuation caused by water (rain, clouds, snow, ice) and gaseous components, as the signal travels through the troposphere. Due to the magnitude of attenuation in the higher *mm*-wavebands, this effect sets the maximum acceptable distance between platforms. To assure a minimum beam to ground distance higher than the maximum value of the upper boundary of troposphere (typically at altitudes from 10-13 km), the maximum distance between platforms connected by IPLs should not exceed 450-500 km.

D. Network of platforms connected with satellites:

A scenario with RF platform to satellite links (PSL) can be used to integrate a HAP system into other non-local terrestrial or satellite networks. Such an application is mainly targeted for the use in areas with deficient (rural and remote areas) or non-existing terrestrial infrastructure, hardly accessible even with mobile ground stations. In addition to providing connection of the platform to other public or private networks via satellite, PSLs could also be used as a backup solution in the case when the connection with the rest of the network via IPL or ground station is disabled due to a failure or extreme rain fading on up/down link segment. The main drawback of PSLs in comparison to IPLs is the use of heavier terminals with higher power consumption, due to the longer communication paths with correspondingly higher spreading loss.

4. HAP research activities

At present there are several national and international research activities underway worldwide, mainly concerned with the development of suitable aerial platforms and payloads for delivery of broadband and 3rd generation mobile communications to fixed and mobile users. The feasibility of 3rd generation mobile communications has recently been demonstrated by the Japanese project SkyNet in conjunction with Aerovironment/SkyTower using the NASA's Pathfinder solar-powered airplane [5]. In Europe ESA has recently set up a study to explore the grounds for the development and operation of a European stratospheric platform and to perform a conceptual design for the best suited platform concept answering the needs of future telecommunication markets focusing on broadband delivery, 3rd generation mobile communications and DAB/DVB-T broadcasting [6]. However, some other applications are also gaining an increasing interest, such as remote sensing and surveillance (e.g. environmental and traffic monitoring), localisation and navigation; but as with broadband communications they are still some years away from commercial implementation.

One of the most innovative projects concerned with the development of high altitude platforms equipped with communication payload was the IST project HeliNet [7] within the 5th Framework Programme of the European Union. The aim of the project was to design a telecommunication infrastructure based on high altitude very long endurance unmanned solar aerodynamic platforms, capable of providing various applications. The aeronautical part of the project dealt with the aerodynamic and structural design of the platform, including the design of the energy subsystem (using solar cells to generate and fuel cells to store electrical energy). The application part of the project was focused on three prototype applications in order to demonstrate application integration and interoperability. Vehicle localisation was intended to demonstrate the use of HeliNet as means to yield interoperable surveillance and positioning services for different transport modes [8]. Environmental surveillance aimed at designing an integrated surveillance system using innovative optical surveillance techniques with intelligent onboard data processing [9]. And broadband communications were concerned with preliminary design of critical elements and integration with pre-existing systems for provision of broadband telecommunication services via the HeliNet system. This required in-depth study of propagation and diversity aspects, specification of modulation and coding techniques, selection of the appropriate multiple access method, determination of the resource allocation techniques, handover procedures, and network protocols, as well as the design of antennas suitable for the provision of broadband services in the selected frequency bands [3, 9].

In the 6th Framework Programme the broadband capability from aerial platforms will be further developed in the EU funded project CAPANINA [10]; this builds upon the results of the HeliNet project that illustrated the enormous potential of broadband from HAPs and developed an outline system design. CAPANINA is focusing on development of cost-effective broadband technology from HAPs aimed at providing efficient ubiquitous coverage to users who may be marginalised by geography, distance from infrastructure, or those travelling inside high-speed public transport vehicles (e.g. trains). It is exploiting wireless access technology to deliver burst data rates of up to 120 Mbit/s anywhere within a HAP's 60 km diameter coverage area to fixed users and to vehicles travelling at up to 300 km/h, interfacing to on-board wireless LAN base stations. Both *mm*-waveband and free-space optical communications technologies are being considered. The latter have the potential to deliver very high data rates in clear air conditions, and are particularly suitable for interplatform links and to supplement *mm*-waveband communications for backhaul traffic.

The project is divided in four broad groups of research activity, concerned with:

- HAP broadband systems, applications, and services: here candidate applications and operating scenarios for delivery by broadband HAPs will be evaluated, marketing and business modelling information will be provided, and network requirements will be derived. The most suitable applications conforming to the CAPANINA scenario will be selected, and for each selected service a set of network architecture requirements will be derived including interworking / integration with other networks essential for providing the services. Suitable business models will also be derived and the commercial risks of the differing technologies will be evaluated.
- Broadband communications links and networking issues in HAP system: here various aspects related to communication links between HAPs, as a central point in the network, and ground nodes and satellites will be addressed. Much of the activity will concentrate on the high-speed vehicle application. This demanding application will require the development of an appropriate access standard, which will be based on the most suitable of the existing or developing standards with necessary adaptations as required. The development of an efficient radio interface for the high-speed vehicle application will be addressed, taking into account the specific propagation environment. Cutting edge technologies will be explored including the use of MIMO as a platform diversity technique and advanced signal processing algorithms that (i) minimise the processing power requirements, (ii) are computationally efficient, and (iii) cope with the high aggregate data rates and with the envisaged multipath / Doppler environment. Novel resource allocation strategies will be developed for both the user and backhaul links of a single HAP, to mitigate the effects of mobility and interference and provide both efficient spectrum utilisation and adequate QoS. Radio spectrum management will be explored in the 47/48 GHz and 28/31 GHz bands allocated for use with HAPs. Since these are shared with other services, interference and interference mitigation techniques will be studied.

The potential of multiple HAP constellations combined with highly directional user antennas to enhance capacity by means of overlapped or co-located regions of coverage will be investigated, and suitable network and application layer protocols will be determined, capable of supporting selected broadband services with diverse quality of service requirements in a scalable and manageable IP based network. Networking aspects of applying optical wavelength routing techniques in an all-optical backhaul network will also be examined.
- Broadband communications node technology for HAP systems: here the effort 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. Thus, this task will be concerned with the integration of existing equipment for the need of trials, and with the investigation of smart antennas, the associated signal processing for advanced beam forming, and with the design and realisation of the necessary hardware to demonstrate a high-speed optical backhaul downlink from HAP to a ground station and a free space-optical interplatform link.
- Aerial platform system testbed for trials and measurements: an aerial platform system testbed will be developed to support testing of selected broadband services, e.g. high-speed Internet, corporate communications and video on demand. These services along with different components developed in the project will be validated and evaluated on different aerial platform technologies: a low-altitude tethered

aerostat (at approximately 300 m); a stratospheric balloon; and (potentially) a high altitude solar powered unmanned aircraft. Additionally, during the trial missions the testbed will also be used for propagation channel measurement in fixed and mobile operating environments.

5. Interworking Requirements

Interworking with other networks is one of the main properties of each communication system as the appropriate interworking with other networks exploits the full capabilities of the system. In general there are two main fundamentally different ways of solving the interworking issues (i) loose interworking and (ii) tight interworking [12].

Loose interworking is defined as the utilization of HAP network as an access network complementary to current access networks. There are no common network elements with other networks (i.e. avoiding the common SGSN, GGSN nodes, etc.). In the case of loose interworking the HAP network is more independent and flexible. In order to provide IP compatibility at the level of HAP, security, mobility, and QoS need to be addressed using IETF schemes.

In the tight interworking HAP network is connected to some other network as the sub part. For example HAP network can be connected to the rest UMTS network (the core network) (HeliNET scenario) in the same manner as other UMTS radio access technologies (UTRAN, GERAN). In this way, especially the mechanisms for mobility, QoS and security of the UMTS core network can be reused. In addition the GGSN is the interface between the UMTS core network and the Internet.

In this paper we are focusing on loose interworking with a particular consideration of interworking with an IP networks. Different services demands different network architecture requirement. Thus we divide the candidate services in two main categories: (i) *Native IP based services*: High-rate unrestricted information Tx. service, FTP, High resolution image communication service, Mixed document communications service, Data retrieval service, Multimedia retrieval service; (ii) *Not native IP base*: Video telephony, ISDN videoconference, Video surveillance, Video/audio information transmission service (DVB), MPEG-2 or 4, Voice.

For the first group of services general network requirements apply, which are suited for the provision of IP based services and encompass the mobility and handover issues, described in the next paragraph.

The second group has higher QoS requirements and also in some cases (e.g. DVB, MPEG-2 or 4) the IP is not the most appropriate for providing such services, thus some adaptations and additional architecture requirements are necessary. As an example we are describing VoIP requirements.

The requirements for mobility and handover differ depending upon the type of the networks involved. Several different mobility options can be considered Mobility shall be supported between HAP networks belonging to different administrative domains. Handover shall be provided within a HAP network belonging to the same administrative domain. Different types of handover might be performed. It can be based on the MAC layer, or network handover procedure with the possible addition of higher layer mobility protocols. In All-IP concept the Mobile IP and all its flavours is recommended. In addition, handover should be supported within a HAP network belonging to different administrative domains. Terminals shall support mobility between different HAP and other networks.

6. Requirements for Provision of VoIP Services over HAP Network

Although the voice over IP (VoIP) has been in existence for many years, nowadays it becomes more and more popular and a viable alternative to traditional public switched telephone networks (PSTN). In addition, VoIP promises to deliver many nice features such as advanced call routing, computer integration, unified messaging, integrated information services, long-distance toll bypass, and encryption [13]. Because of the common network infrastructure, it is also possible to integrate other real time and non-real time media services, which are particularly well suited for broadband access networks (e.g. HAPS). In order to identify the requirements for VoIP services in HAP networks we will first describe the VoIP features.

The basic VoIP functions are [13]:

- Signaling; Different signaling protocols are used in VoIP (e.g. SIP, H.323)
- Database services; Database services are used to locate an endpoint and translate the addressing that two (usually heterogeneous) networks use. A call control database contains these mappings and translations. Another important feature is the generation of transaction reports for billing purposes.)
- Call connect and disconnect (bearer control); In a VoIP implementation, the connection is a multimedia stream (audio, video, or both) transported in real time. This connection is the bearer channel and represents the voice or video content being delivered. When a communication is complete, the IP sessions are released and optionally network resources are freed.
- CODEC operations Signaling; The process of converting analog waveforms to digital information is done with a coder-decoder. There are many ways an analog voice signal can be transformed, all of which are governed by various standards. Each encoding scheme has its particular bandwidth needs. The output from the CODECs is a data stream that is put into IP packets and transported across the network to an endpoint. These endpoints must use the standards, as well as a common set of CODEC parameters.

These functions must be able to perform the same functions as the PSTN network. The major components of a VoIP network, while different in approach, deliver very similar functionality to that of a PSTN and enable VoIP networks to perform all of the same tasks that the PSTN does. The one additional requirement is that VoIP networks must contain a gateway component that enables VoIP calls to be sent to a PSTN, and visa versa.

There are four major components of a VoIP network [13]: Call Processing Server/IP PBX (Soft Switch); User End-Devices; Media/VOIP Gateways, and IP network

Call Processing Server / IP PBX (Soft Switch) is the main part of a VoIP phone system as it manages all VoIP control connections. Call processing servers are usually software-based and can be deployed as a single server, cluster of servers, or a server farm with distributed functionality. It is worth noting that call processing servers do not handle VoIP payload (which is the RTP stream carrying voice itself) traffic, but only manages the VoIP control traffic follows. VoIP payload flows in a peer-to-peer fashion – from every VoIP terminal to every other VoIP terminal. In this case, the VoIP terminals determine traffic flows and the call processing servers negotiate those flows within the control messages.

The user end-devices consist of VoIP phones and desktop-based devices. VoIP phones maybe software based (“softphones”) or hardware based (“hard phones” or “handsets”, like traditional phones) [13]. VoIP phones use the TCP/IP stack to communicate with the IP network, as such, they are allocated an IP address for the

subnet on which they are installed. Softphones are software application running on notebook computers, usually targeted towards mobile users, which are particular interesting in the case of HAP network scenario, where users are traveling with high-speed trains. They have the same base features as VoIP phones.

The major function of *media / VoIP gateways* is analog-to-digital conversion of voice and creation of voice IP packets (CODEC functions) [13]. In addition, media gateways have optional features, such as voice (analog and/or digital) compression, echo cancellation, silence suppression, and statistics gathering. The media gateway forms the interface that the voice content uses so it can be transported over the IP network. Media gateways are the sources of bearer traffic. Typically, each conversation (call) is a single IP session transported by a Real-time Transport Protocol (RTP) that runs over UDP or TCP.

The *IP network* must ensure smooth delivery of the voice and signaling packets to the VoIP elements. Due to their dissimilarities, the IP network must treat voice and data traffic differently. If an IP network is to carry both voice and data traffic, it must be able to prioritize the different traffic types, as VoIP traffic is extremely sensitive to latency. An example of VoIP architecture for HAP scenario is depicted in Fig. 2. In general the VoIP users within the HAP network can communicate with VoIP users connected to the IP network or to users, which are connected to PSTN network (ISDN or analog) via Media and Signaling gateways. As the HAP network fully supports IP there is no additional network elements required within the HAP network for support of VoIP. However, as there are more stringent requirements for the delay in VoIP networks the HAP network should provide differentiation of classes in order to fulfill the delay requirements.

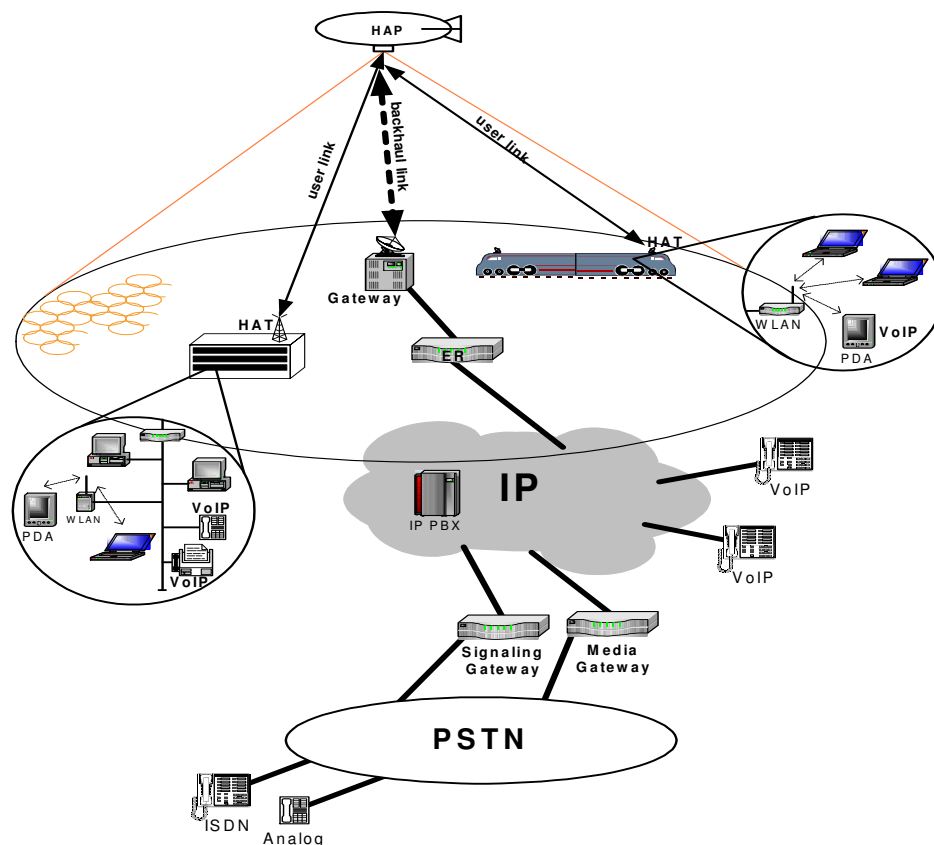


Fig. 2. VoIP System Architecture for HAP Network

In addition, the HAP network should support signaling protocols (e.g. SIP, H.323, H.248/MEGACO, MGCP), which are used for call connect / disconnect and management procedures.

The HAP network should also allow common architecture for all real-time services and it should envisage also the future services [14]. The quality, reliability and availability of VoIP services should be comparable to that of PSTN network.

8. Conclusions

In this paper we have presented aerial platforms as a very attractive means to establish broadband communication networks, particularly well suited for serving remote regions with low user density, short-term large-scale events or disaster relief missions. Such networks could efficiently provide various services in such areas or during events that do not economically justify the deployment of alternative required terrestrial telecommunication infrastructure. During disaster and emergency situations it could significantly improve communications between rescue teams and headquarters, thus limiting human, environmental and economic consequences of the disaster.

We have described alternative network architecture scenarios, focusing on the impact of each scenario on the system coverage and on the interconnection of the platforms. The four identified scenarios are a stand-alone platform scenario, scenario with platforms connected via ground stations, scenario with platforms connected via interplatform links, and scenario with platform to satellite links. These scenarios are all suitable for normal operation of HAP communication networks as well as for short-term large-scale events and disaster relief mission.

We have concluded the paper with a brief overview of research activities concerned with delivering broadband communications from aerial platforms, focusing on the 6th Framework Programme IST project CAPANINA. The project only started at the end of 2003 and will validate delivery of broadband services to fixed users using a system test-bed with different aerial platform technologies, and further develop the system to offer access to broadband services also from high-speed moving public transport vehicles, particularly addressing trains equipped with an on board wireless LAN.

Acknowledgements

This work has been produced as part of the FP5 HeliNet (IST-1999-11214) "Network of Stratospheric Platforms for Traffic Monitoring, Environmental Surveillance and Broadband Services", FP6 Capanina (FP6-IST-2003-506745) "Communications from Aerial Platform Networks delivering Broadband Communications for All", and FP6 SatNEx (IST-2003-506745) "Satellite Communications Network of Excellence" projects. Thanks also to all members of the HeliNet, Capanina and SatNEx teams.

References

- [1] G.M. Djuknic, J. Freidenfelds, Y. Okunev, "Establishing Wireless Communications Services via High-Altitude Aeronautical Platforms: A Concept Whose Time Has Come?", IEEE Communications Magazine, September 1997, pp. 128-135.
- [2] D. Grace, N.E. Daly, T.C. Tozer, A.G. Burr, D.A.J. Pearce, "Providing multimedia communications services from high altitude platforms", International Journal of Satellite Communications, Vol. 19, 2001, pp. 559-580.
- [3] M. Mohorcic, G. Kandus, D. Grace, "Provision of Fixed Broadband Wireless Access Over Stratospheric Platforms", Electrotechnical Review, 2004, Vol. 71, No. 3, pp. 89-95.
- [4] M. Mohorcic, D. Grace, G. Kandus, T. Tozer, Broadband communications from aerial platform networks. 13th IST Mobile & Wireless Communications Summit 2004, Lyon, France, 27-30 June, Proceedings, pp. 257-261.
- [5] AeroVironment Inc., SkyTower Telecommunications, <http://www.skytowerglobal.com/>.
- [6] ESA Telecommunications: Stratospheric Platforms - a definition study for an ESA system, <http://telecom.esa.int/telecom/www/object/index.cfm?fobjectid=8188>.
- [7] FP5 IST Project HeliNet: Network of stratospheric platforms for traffic monitoring, environmental surveillance and broadband services, <http://helinet.polito.it/>.
- [8] I. Ozimek, T. Javornik, F. Dovic, "Navigation-related services over Stratospheric Platforms", Electrotechnical Review, 2004, Vol. 71, No. 3, pp. 96-102.
- [9] D. Grace, J. Thornton, G.P. White, C.L. Spillard, D.A.J. Pearce, M. Mohorcic, T. Javornik, E. Falletti, J.A. Delgado-Penin, E. Bertran, "The European HeliNet Broadband Communications Application - An Update on Progress", in Proceedings of 4th Japanese Stratospheric Platform Systems Workshop SPSW'03, Tokyo, Japan, 26-27 February, 2003, Proceedings, pp. 90-98.
- [10] FP6 IST Project CAPANINA: Communications from Aerial Platform Networks delivering Broadband Communications for All, <http://www.capanina.org/>.
- [11] <http://www.satnexus.org/>
- [12] ETSI TR 101 957, Broadband Radio Access Networks (BRAN); HIPERLAN Type 2; Requirements and Architectures for Interworking between HIPERLAN/2 and 3rd Generation Cellular systems.
- [13] S. Brunner, A. A. Ali Voice Over IP 101 Understanding VoIP Networks (White Paper) Juniper Networks, www.Juniper.net, Part Number: 200087-001, Aug 2004.
- [14] G. Kandus, A. Svirgelj, M. Mohorcic, Telecommunication Network over High Altitude Platforms. 7th International Conference on Telecommunications in Modern Satellite, Cable and Broadband Services, TELSIKS 2005, Nis, Serbia nad Montenegro, 28-30 Sept. 2005, Proceedings, Vol. 2, pp. 344-347.