Integrated Satellite-HAP-Terrestrial system

{xtypo_sticky} Integrated Satellite-HAP-Terrestrial system architecture: resources allocation and traffic management issues {/xtypo_sticky}
Next generation satellite systems will provide personal communications to mobile and fixed users. As the demand grows for communication services, wireless solutions are becoming increasingly important. Wireless solutions may solve the ‘last mile’ problem, i.e. the direct services delivery to customer’s premises, offering high-bandwidth services without reliance on a fixed infrastructure. Furthermore, in many scenarios wireless represents the only viable delivery mechanism. A potential solution to the wireless delivery problem lies with aerial platforms, capable of carrying communications relay payloads and operating in a quasi-stationary position at altitudes up to 22km.
The platforms may be airplanes or airships (essentially balloons, termed ‘aerostats’) and may be manned or unmanned with autonomous operation coupled with remote control from the ground. Great interest lies with crafts designed to operate in the stratosphere at an altitude typically between 17 and 22km, which are referred to as high-altitude platforms (HAPs) [1][2][3][4]. This particular range of altitude is due to the wind speed that is slower in the region of 20km. HAPs can offer a wide range of services. Such services may particularly valuable where existing ground infrastructure is missing or difficult.

Moreover, HAPs are ideally suited to the provision of centralized adaptable resources allocation, i.e. flexible and responsive frequency reuse patterns and cell sizes, unconstrained by the physical location of base-stations, the smaller cells provide greater overall capacity as frequencies are reused a greater number of times within a given geographical area.
Such almost real-time adaptation should provide greatly increased overall capacity compared with current fixed terrestrial schemes or satellite systems [5][6]. In particular, such platforms could effectively integrate or substitute terrestrial satellite systems in different ways: as an example, they can be rapidly deployed to provide immediate coverage in disaster areas, or relocated, expanded, and upgraded with new payloads, reducing the obsolescence risk typical of traditional satellites. System flexibility is not only in the payload reconfigurability but also in the possibility of changing platform demands, configuring the system according to needs.

Satellite-HAP-Terrestrial System
Due to their low altitude, HAPs provide a better link budget with respect to satellites; however, their coverage area is limited to a diameter in the order of 200 km; hence, they are conceived mainly to offer services on a regional basis. Therefore it is mandatory to clearly understand the potentialities resulting from a synergic integration of earth, space and stratospheric segments.
The system architecture proposed is shown in figure 1. User terminals cannot communicate with each other without the necessary use of HAPs forward and return links. An HAP-Gateway (HGTW) terrestrial terminal must exists for each HAP coverage area.

Fig. 1 Satellite and HAPs scenario
The HGTW guarantees communications among users belonging to different HAP coverage areas. In the proposed scenario, HGTW links together HAP and satellite layers; the latter is used to interconnect areas managed by different HAP stations.
HAP usage mitigates multipath effects, typical of terrestrial cellular systems, and decrease geostationary satellite propagation delays. Stratospheric platforms work as simple transponders and all functionalities of control and management are forwarded to the HAP Master Control Station (HMCS) that performs resources allocation and traffic management inside a single stratospheric platform coverage area.
Terminals can be equipped with miniaturized antennas and designed for low energy consumption because they interact mostly with the HAP layer.
In this scenario, HAPs are strongly new and there is an increasing interest about them: more and more research projects are performed [7]-[10]. This system scenario consists of tree layers: Terrestrial Layer, HAP Layer and GEO Layer.
Terrestrial Layer
Terrestrial layer is composed of all user terminals, control and management stations. Terminals can be classified according to their mobility, sizes, functions and transmission rates. For example a classification based on mobility is: Fixed Terminal (FT) and Mobile Terminal (MT).
Consumer (home users, small office users) and corporate (enterprise users, service providers, gateway stations) terminals would belong to the first category; individual (lap top, mobile phones, PDA) and collective (small gateway for trains, ships…) terminals would belong to the second one.
HAP Layer

The stratospheric platform layer hosts the set of HAPs. Since HAPs do not have OBP, they act like simple hubs. Inter HAP links utilization is not foreseen.
GEO Layer
Satellite layer uses GEO regenerative satellites that are provided with On-Board Processing (OBP). It can use forward channel both towards terrestrial layer and HAP layer.

Advantage of the proposed scenario
The very first advantage is the simple design and implementation. HAP and GEO layers are independent so that it is possible to develop the segments in a separate way and without any integration trouble.
An HAP layer can be seen as a terrestrial system extension. The terrestrial is connected to the satellite layer only by the HGTW, achieving two significant advantages: firstly, the satellite does not have to manage traffic of a single terrestrial terminal user because it receives aggregate traffic from HGTW; secondly, terminals can be made without great financial and design efforts because they do not have the task of interacting directly with the satellite segment. This architecture allows communications protocols between HAP and satellite to be chosen in a distinct way and without restraints.
This innovative system architecture shows more benefits for the mobile and fixed communications but also introduce a set of potential problems and several open issues; first of all a channel assignment and resource allocation schemes will need to be developed for the HAP scenario, which is essentially different from either a terrestrial or a satellite cellular scenario. The most appropriate medium access control (MAC) and network protocols will be selected as a starting point Integration with terrestrial and/or satellite architectures will also require careful planning. However, delay and jitter limitations for future multimedia services (especially video) may impose much more stringent constraints on the handoff process than with conventional 2G or 3G services, and this is a topic of current research.
Others studied issues regard:

- Choice of an HAP and GEO layers protocol platform (MPEG, DVB, ATM, IP).

- Design of an efficient resources allocation and traffic management algorithms. These functions have to be implemented inside the HMCS in the ground segment.

- Design of traffic aggregation (integrated and differentiated) techniques in the HGTW based on different traffic sources and satellite segment constraints.

- Design of a centralized Call Admission Control (CAC) algorithm in order to guarantee an efficient bandwidth usage avoiding unconditioned access of multimedia traffic sources.

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Further papers

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2. P. Pace, G.Aloi, “Multilayered architecture supporting efficient inter HAP-Satellite routing”, Proceedings of IEEE Vehicular Technology Conference (VTC Spring), Dublin – Ireland, April 22-25, 2007.

3. P. Pace, G. Aloi, “Effective Routing Algorithm for Multilayered Terrestrial-HAP-Satellite Networks” IEEE COMMUNICATIONS LETTERS, Vol. 11, No. 6, June 2007, Page(s):510-512.