High Altitude Platform Stations in Design Solutions for Emergency Services

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ABSTRACT

High Altitude Platform Stations (HAPS) are expected to conform a third major infrastructure for communications and broadcasting, after terrestrial and satellite systems. 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. Along with satellites, high altitude platforms (HAPs) will be completely isolated from the effects of disasters on the ground. A couple of stratospheric-based network scenarios are considered as examples for a HAPS-aided disaster deployment assessing communication viability and outlining issues in interoperability with existing networks.

1. INTRODUCTION

The big three options in the use of telecommunications are by means of the terrestrial wire systems (copper wire, coax and fibre optic cable), terrestrial wireless systems and satellite communication systems [5]. In the last few years, a new set of options have been added in the form of high altitude platform stations (HAPS) and unmanned aerial vehicles (UAVs) that operate as mobile telecom providers, mostly operating at stratospheric altitudes of ~20 km, or other low altitudes, above earth; in our days, it has been deeply studied that near-space platforms could be safely deployed at altitudes in the 17-25 km range. The origin of HAPS-based wireless systems comes principally from the military research, in such case are called UAVs, such as the Rover III that have assisted within the disaster recovery from Katrina, but these latter systems are being withdrawn from as commercial operation. Now, the issues of how HAPS-based systems, or solar-powered lighter-than-air (LTA) aircrafts, can be used to supplement communications and air surveillance during emergencies is examined under the point of view of specialised organisations and research groups, e.g., Department of Homeland Security [15], and CAPANINA [9].

The purpose of this paper is to describe how HAPS can be used to provide emergency telecommunication coverage in a disaster scenario. A general classification is defined identifying the main points that need to be considered for such application. An empirical GSM-TETRA-UMTS HAPS-based disaster layout is introduced and together with their suitability is discussed. Finally, the conclusion of the paper is given.

2. HAPS & EMERGENCY AID LIAISON

2.1. HAPS Survey

One major intention of this paper is to provide a contribution in the direction of describing the research activity performed (in particular at the European level) on HAPS-based communications [12], with particular attention to the two projects HeliNet and CAPANINA [9], both financed by the European Commission, in order to explore the use of HAPS for integrated communication services and broadband transmission.

In the broad multiform communications, HAPS possesses all the potentialities to be proposed as a novel stratospheric segment in the wireless communications market. They are able to overcome the main drawbacks of satellite technology due to its reduced distance from the ground with respect to satellites, and its quasi-stationary situation in the sky. Additionally, their costs for construction, deployment, launch, and maintenance can be kept in lower orders of magnitudes than those of satellites can, all these at an environmental sustainable effort because of their solar power supplies. On the other hand, it is evident that HAPS cannot replace satellites, nor terrestrial radio links, for reasons of coverage, reliability, safety, and cost. In fact, satellites, HAPS, and terrestrial broadband systems have different but complementary characteristics. While satellites are more suited for coverage of very large areas and broadcast applications, HAPS are able to cover remote or sparsely populated areas at reduced costs, and to offer broadband services to mobile users; meanwhile, terrestrial infrastructures are advantageous for interactive services in densely populated areas. For these reasons the final design goal must be a flexible and synergic integration between satellite, stratospheric, and terrestrial segments, which can lead to a truly evolutionary scenario.

As far as services integration is concerned, we can point out that the establishment of the stratospheric network is a challenging task, but whose positive benefits should be exploited in the best possible way. Since the weight constraints for HAPs are generally less critical than those for satellites, many different payloads may be carried by the same platform, thus exploiting the favourable transmitting position of HAPs for improving performance and coverage of a variety of services. Among those possible services that can benefit from a stratospheric segment, we can cite broadband communications, environmental surveillance, video surveillance, reconnaissance, meteorological and atmospheric measurements, localisation and positioning services, emergency cellular telephony services, broadcasting, and emergency communication services.

For now, in our emergency case, such emergencies can happen any time and any place and emergency communications in the damaged field requires a global infrastructure accessible 24 hours a day from any place [1]; HAPS-based constellations, and satellite-based networks, are proposed as the innovative aiding technologies. We can mention that all member countries in the International Telecommunication Union (ITU), who have allocated a wide frequency band of more than 500 MHz in total [1], have accepted such proposals.

Hence, HAPS bring the idea of a global emergency communications and information infrastructure defining the main objective in which integrates service operations in a cost-effective way. In a disaster scenario, HAPS can be deployed quickly over the emergency area carrying telecommunications payloads. What is more, from their operational stratospheric altitude they have a wide coverage area and can provide additional capacity to the existing network or replace the coverage holes left due to damaged masts and repeaters. And, besides to the superior flight endurance relative to airplanes and helicopters, HAPS have the potential for a variety of uses at the time of a natural disaster [3] –such as monitoring of the disaster area, traffic control and guidance for emergency vehicles, provision of search-related information, mobile communications, and emergency broadcasting. –

2.2. HAPS-Disaster Relief Assessment

Some brief terms of global emergencies are described in [6] that can be applied into HAPs emergency considerations. The global natural disaster assessment involves three types of data that human is exposed to: risk, hazards and vulnerability. For instance, the risk assessments (of mortality and economic losses) are based on two data sets characterizing elements at risk: population and Gross Domestic Product (GDP) per unit area. Global hazard data were compiled from multiple sources. Drought, flood and volcano hazards are characterized in terms of event frequency, storms by frequency and severity, earthquakes by frequency and probability of exceeding a set threshold of peak ground acceleration, and landslides by an index derived from probability of occurrence. For a given hazard, vulnerability will vary across a set of similar elements and from one element to the next.

After, the next items undertake a comprehensive review of all types of telecommunications systems in the context of upgrading emergency communications systems within appropriate technologies [5]. We consider the resilience, flexibility, upgrade-ability, modularity and interoperability for emergency communications standards inside the all possible relevant Information and Communications Technology (ICT): fibre optic networks, satellites (fixed, mobile, broadcasting and military), broadband wireless, WLANs, 802.11 & 802.16 systems, power line communications (PLC) systems, HAPS systems and UAVs, voice over IP-capable systems. We can have, additionally, every emergency communications systems working at 700 MHz, 800 MHz frequency bands and/or at newly designated 4.9 GHz bands.

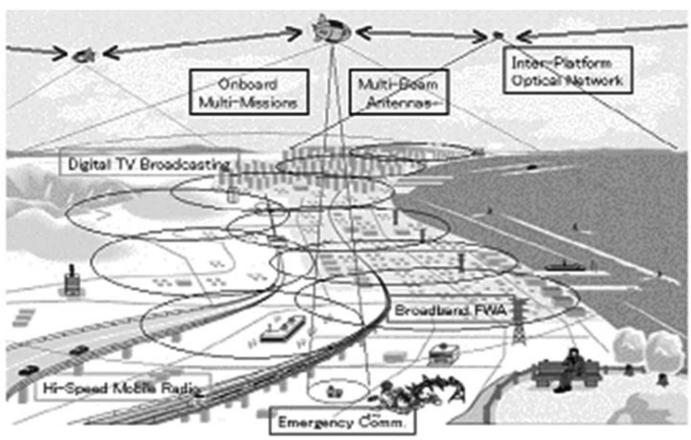

Figure 1. General HAPS-network (HAPN) architecture and the possible communications scenario [11].

Concerning the HAPS-based systems [2], essentially, HAPS-based wireless communications work even under the worst conditions, including natural disasters and emergencies. This potential, however, needs to be fully recognized and exploited. Current emergency communications within the 'active field' bases on an old narrowband technology created to transmit mainly voice messages over restricted areas only. Therefore, it is considered the use of HAPS that is found fully suitable for operational communications especially in the initial phase of an emergency, when real-time exchange of information is most essential.

Various potential resolution specifications and disaster-assistance functions are to be aimed from these stratospheric platforms [4, 5, 6]:

- HAPS will be maintained over the critical region for exchanging real-time information on operations within the disaster framework laws to facilitate decision-making.

- Interoperability, interconnection and credentials for all types of first responders (police, fire, utility repair and installation, dispatchers).

- Rapid information exchange with key partners and permanent monitoring of media resources (TV, radio); prompt notification and dissemination of emergency information in the event of an emergency.

- Creation of a basis for timely mobilization of international assistance to countries facing environmental emergencies to minimize the environmental impacts from brokerage of information and assistance.

- Establishment of an inventory of possible emergency information resources and tools, and facilitation of access to these during emergency incidents: better quality emergencies management, mitigation and response through rapid access for vital emergency tools and resources.

- Continuous assessment and implementation of best practices, improved use of HAPS-technology and more extensive reliance on automated system: improved response, more efficient and less time dissemination of information, and overall emergencies coordination and management.

- Efficient mobilisation and coordination for international assistance to requesting countries: delivery of specialised service to affected countries, and supplementing national efforts to respond to environmental emergencies.

- Development of post-incident measurements for the assessment of internal procedures following incidents: identification of lessons learned and areas for improvement, to increase efficiency and better coordinated emergency response management.

- Plan, organize and conduct periodical meetings of groups on environmental emergencies: further development and harmonisation of the international response to environmental emergencies, and better transparency of the joint environments Units.

3. GSM-TETRA-UMTS HAPS-BASED SCENARIO FOR EMERGENCY OPERATION, A CASE STUDY

The deployment of GSM, UMTS and TETRA services was examined in [13] with the help of an emergency scenario (Fig. 2). An island was assumed as an operational area of 16 km by 18 km. Due to a natural disaster all mobile communication nodes have failed. An emergency mobile network was deployed over the area to assist emergency services and served the public until the restoration of the terrestrial network was possible. As the HAPS flew over the area there were different important decisions that needed to be considered: service area needs, cell layout needs, backhaul needs, and operational current systems that could interfere with the HAPS network.

There were two different deployment scenarios: a single 25 km diameter cell covered the entire area during the early hours of an emergency to allow quick deployment, and within the allowed limits and no synchronisation problems were anticipated. Since capacity was limited in such deployment, only the emergency services have served; later on, extra smaller cells (2 km diameter) could be deployed over the residential areas, road links, airport, and other important facilities. When the smaller links were in place, the large coverage cell could be shut down leaving the next cellular deployment.

Small cells could provide the same data rates as the large cells use only a fraction of the power. This is due to the smaller antenna beamwidth required to create the footprint, which in turn resulted in a bigger antenna gain. Handovers, however, were needed as users moved between cells. These handovers increased the payload processing power and complexity. A cell larger than the coverage area could guarantee that there were no users at the edge of coverage and therefore they could be insensitive to small platform movements.

In the cases of GSM and TETRA protocols, they could face problems with long link lengths due to synchronisation problems inherited from their TDMA nature. The GSM stack included guard bands, which compensate for the propagation delays up to a theoretical maximum of 37.8 km. Having considered that HAPS operates from a 17 km altitude, HAPS-GSM cell was limited to 30.5 km radius. Taking into account the ITU-R recommendation and allowing 500 m of azimuth platform movements, the resulting GSM coverage was limited to a 60 km diameter cell assuming that HAPS-antennae were stabilised to ensure a fixed coverage area. Similarly, TETRA was also limited to a 60 km diameter cell. There was the option to use only 4 out of the 8 available time slots in each TDMA frame and hence doubled the guard band but also halved the capacity. In such case the maximum cell size could be doubled and a coverage area of 140 km diameter could be achieved. This scheme has been successfully running in Australian rural areas where traffic is limited. Successful trials increasing the theoretical maximum cell radius from 35 km to 121 km have carried out by Motorola's, Cellular Infrastructure Group (CIG), and Spanish GSM Operator Telefonica, at the expense of limited capacity.

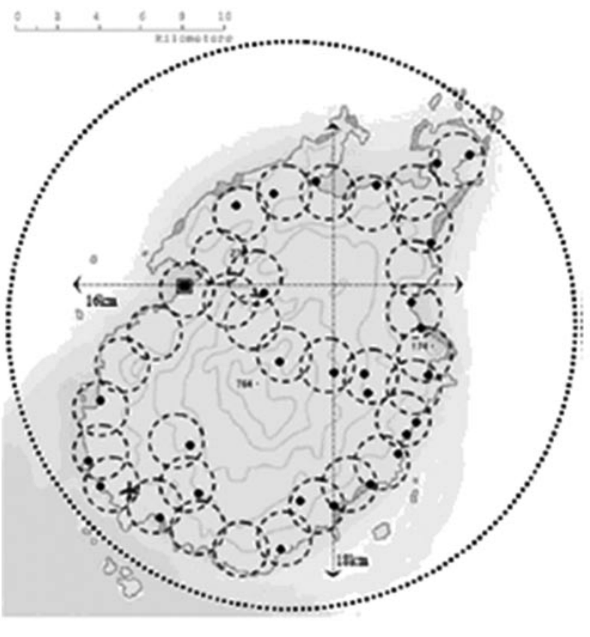

Figure 2. GSM-TETRA-UMTS scenario [13].

Studies and simulations in [13] showed that HAPS-antenna roll-off rate is a trade-off between having sufficient gain at edge of coverage and reducing unwanted interference. To meet the required specification, a roll-off factor n=15 has been chosen for the 25 km diameter cell while n=2000 has been chosen for the 2 km diameter cell; aperture efficiency of 70% has been decided for link budget calculi.

So far, the empirical scenario in [13] assumed that no other mobile network was active at the emergency area. This can rarely be realistic since most of Europe enjoys some kind of wireless telephony service.

To ensure the operability of the provided services, a satisfactory link budget needs to be achieved for both the uplink and downlink for GSM/TETRA (~900 MHz) and UMTS (~2 GHz) correspondingly. It is noted that similar link budgets can be produced for TETRA services, which shares the same principles as GSM due to their common TDMA nature. UMTS can re-use an already used frequency due to the CDMA nature of the multiple access method. The limiting factor is that with the addition of every new user the noise level of the cell rises. UMTS can support different types of services, each with different Eb/N0 requirements. In [13] already presents a scenario with the speech service (up to speeds of 120 km/h) and the 384 kbps real-time data service (up to 5 km/h).

The link budget for the HAPS-downlink has also been considered in [12, 14]. Due to the system and regulatory constraints, some extra parameters must have been stated. The use of a high-gain multi-beam on-board antenna was discussed. The HAPS-altitude and the broadband service provision over a region of about 35 km radius on the ground were thought about; the region covered by the HAPS was divided into cells and frequency reuse was adopted in order to avoid inter-cell interference. A uniform cellular structure was obtained by illuminating the covered area with multiple antenna elliptic beams so a circular footprints on the ground were shown.

Towards the end, regarding to enable co-existence with the existing GSM/TETRA network, in [13] a second layer of GSM cells could be laid by the HAPS overlapping the terrestrial cells. The overlapping cells used different frequencies from the terrestrial ones to avoid interference. Alternatively, HAPS could project cells over the coverage gaps produced by the non-operational base stations. The problem in the latter deployment was how to determine, in a short time, which base-stations were not operational and which frequencies were not used. Getting up-to-date information from mobile providers during a major disaster could be impossible, so an alternative way of determining which base stations were not in service should have been devised. Finding available frequencies for operation is mainly a GSM specific problem. TETRA is not used widely and it was highly unlikely that all the frequencies in [13] the area would be occupied. In this unlikely event, authors in [13] proposed the techniques of area scan using a selective frequency scanner for locating an unused frequency can apply.

Finally, [13] addressed the implications arising from the coexistence between the terrestrial UMTS network (2km diameter cell) and the HAPS-based UMTS network (25km diameter cell). The effects on the HAPN from the interference caused by the terrestrial network showed that the operational threshold (10dB below the noise floor, as specified by the ITU-R) was reached when the HAPS-cell completely overlaps the terrestrial 2km cell. As the terrestrial cell moved towards the centre of the HAPS-cell, the interference level raised and system was saturated.

4. CONCLUSIONS

This paper has briefly presented the idea of the use of HAPS as base stations to provide and face emergency services. Advantages of such an application include rapid deployment, large coverage area and certain immunity to most catastrophes. A case study of an emergency scenario for GSM, TETRA, and UMTS, and coexistence with the HAPS network, have been implicated to show the evaluations to be followed for a viable disaster planning and crisis-services.

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