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HIGH ALTITUDE PLATFORM FOR WIRELESS COMMUNICATIONS AND OTHER SERVICES

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ABSTRACT

High Altitude Platform Stations (HAPs) is a new and promising technology which can serve a large number of users at low-cost and quick access to modern wireless communication services.

This paper reviews on the system structure, the advantages of HAPs over terrestrial and satellite architectures and possible communications applications of HAPs. It also present an overview about some underway HAPs projects worldwide. Finally, it focuses on the technical challenges and critical issues of energy source, platform station keeping, modulation, coding, antennas design, propagation, diversity, interference and handoff issues.

1. INTRODUCTION

ITU publish a report on early 1998, which outlines HAPs technology and chose a title of "High Altitude Platform Stations: An Opportunity to Close the Information Gap"[1], and define HAPs as a term referring to balloons or high altitude aircraft that can be used to provide communication services [2].

The HAPs are proposed to operate at altitudes between (3 to 22 km) to cover a service area up to 1,000 km diameter and 800,000 square kilometers depending on the minimum elevation angle accepted from the user's location. Platforms to be considered are explained in the following sections.

1.1 Unmanned airships

These can range from micro-vehicles to substantive craft, and may be powered by fuel or solar energy. Most have limited mission duration with propulsion systems, which are semi-rigid or non-rigid, huge and mainly solar-powered balloons, over 100 m long with a payload of about 800 kg or more. The achievable mission duration is hoped to be about 5 years (Figure 1).

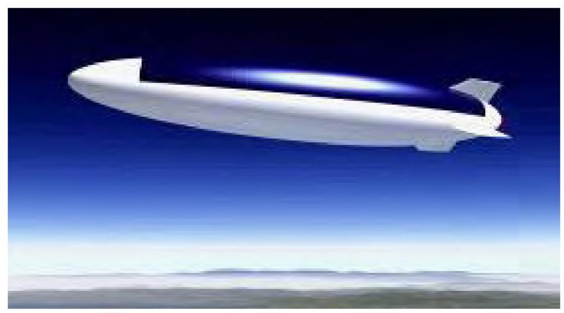

Fig. 1 Unmanned airships.

1.2 Unmanned aircraft

Use electric motors and propellers as propulsion, while solar cells mounted on the wings and stabilizers provide power during the day and charge the on-board fuel cells. Some proposals make claims of continuous flight up to six months or more as shown in Fig. 2.

Fig. 2 Unmanned aircraft.

1.3 Manned aircraft

The aircraft will circle above commercial airline traffic to serve as the hub of communication network. It has average flight duration of several hours due to fuel constraints and human factors (Figure 3).

Fig. 3 Manned aircraft.

2. HAPS APPLICATIONS

The flexibility of the system allows for utilization of HAPs not only for carrying telecommunication payloads but also for remote sensing, earth observation, navigation applications, pollution monitoring, meteorological measurements, real-time monitoring of coastal regions and terrestrial structures, traffic monitoring and control, agriculture support [3].

The ability to move around give HAPs a great advantage in emergency situation, for examples in natural disasters, military mission[4], restoration where a terrestrial network failure or overload due to a large concentration of users at a major event for examples. Temporary large gatherings of people requiring communications service can result in an overload of the normal communications infrastructure. HAPs could provide a solution to this exceptional peak traffic. HAPs are likely to offer very useful communication services in areas of no pre-existing wired/ cabled telecommunications. It is rather difficult and economically inefficient to cover remote and impervious areas with cellular networks or fiber networks.

Fiber may be less widely available for regions with dispersed geography and low population, and cost per subscriber in terrestrial wireless systems is quite high for low traffic densities. HAPs constitute a real asset to wireless infrastructure operators to provide telecommunication services in these areas. HAPs are significantly cheaper than satellites, so developing countries may be able to afford HAPs whereas satellite control is beyond their reach.

3. HAPS TOPOLOGY

A proposed HAPs design planed to offer high reliability, low power consumption and light payload. HAPs can acts as a relay station, transferring information from an uplink to a downlink channel. Figure 4 illustrates the transparent transponder, single beam case, which is the simplest implementation of HAP.

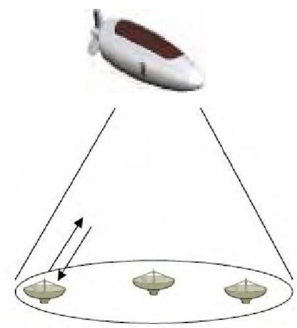

Fig. 4 Single HAP, transparent transponder.

However, it can be a processing device incorporating a level of functionality itself (a multi channel transponder, user and feeder-beam antennas, antenna interfaces, DSP system, etc), often referred to as an On-Board Processing system [3]. Inter-platform links could exist for backhaul communication and provide redundancy link, which can be useful in case of a link failure. Additionally, HAP could have direct connectivity to a satellite to enable a connection to a core network [5]. Figure 5 illustrates an integrated HAP- Satellite-Terrestrial system.

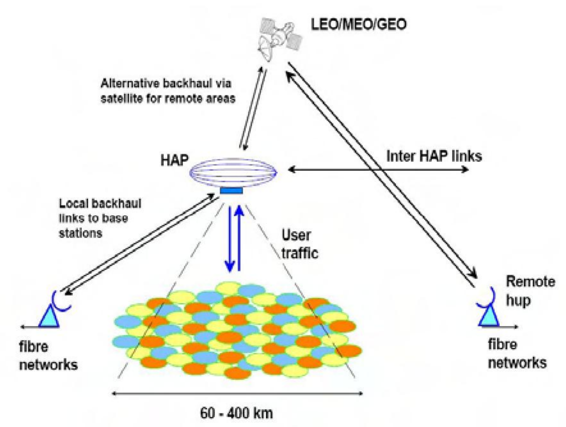

Fig. 5 Integrated HAP- Satellite-Terrestrial system

4. FREQUENCY ALLOCATION

Until 1997, no international telecommunication regulations were addressing the HAP specifically. In February 1997, ITU Radio Regulations Board (RRB) has recognized HAPs as a separate category of radio stations [6]. In 2000, ITU licensed several frequency bands for communications from HAPs.
One bands at around 2GHz (1885 -1980 MHz, 2010 -2025 MHz). Others in the *mm*-wave bands 27.5 - 28.35 GHz, 31.0 - 31.3 GHz (ka band) in Asia and 47.2 - 47.5 GHz, 47.9 - 48.2 GHz (V band) worldwide [7].

5. ADVANTAGES OF HAPS

The HAPs aim to exploit potential benefits of intermediate altitudes between those used by the terrestrial and satellite technologies. HAPs have the following potential advantages over terrestrial and/or satellite architectures [8, 9]:

- Relatively low cost operation and upgrading of the platform.
- Can be brought down to Earth for upgrading or repairing, and be re-deployed again.
- Broadband capability using the mm-wave LMDS bands.
- Ideally suited to multimedia services, broadcast, and multi-cast.
- Flexibility to respond to traffic demands through extensive and adaptable frequency re-uses.
- They can use most of conventional base station technology and terminal equipment.
- Large area coverage compared with terrestrial.
- Less ground-based infrastructure required than with terrestrial.
- Large system capacity; smaller cells than satellite, with link budgets more favorable.
- Low propagation delay compared with satellites.
- Lower launch costs than satellites; no launch vehicles require.

6. HAPS MAJOR PROJECTS WORLDWIDE

HAPs technology has been recognized as a critical future technology and several governments decided to invest capital and intellect in its development. International Telecommunication Union (ITU) has been involved in this area since the late 1990s. Here are a few examples as far as known, none of them is in commercial operation, and all projects are under development or in experimental stage.

6.1 ARC

The Airborne Relay Communications (ARC) System is the name of an airship platform planned by the US Company, Platforms Wireless International [10]. The ARC system is designed to operate at lower altitudes, 3 to 10.5 km. The system developed to provide fixed wireless broadband as well as mobile services to areas of 55 to 225 km diameter per system and servicing up to 1,500,000 subscribers (depending on system configuration and antenna projection power).An ARC airship is a 46 m long helium-filled balloon, which can carry almost 700 kg of payload. Power is supplied to the payload via a 2.5 cm thick cable. It also incorporates a fiber-optic cable link that connects the airborne base stations to the rest of the network.

6.2 HALO Network

The American project, HALO Network will offer access to subscribers within a "super metropolitan area" from an aircraft operating at high altitude.

The pilots will assure a continuous service in three eight hours shifts using two or more aircrafts. The transmission capacity of a single platform, initially of 10 Gbps, can grow up to 100 Gbps and beyond, serving the coverage area of 100 km diameter by more than 100 separate antenna beams. Consumers will be offered access to video, data and Internet at rates of 1...5 Mbps. The architecture of the system presented in Figure 6 [11].

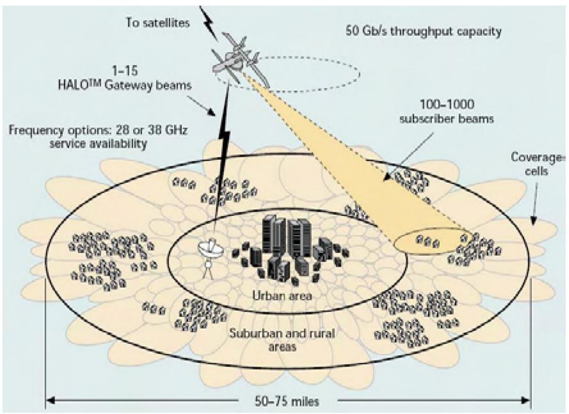

Fig. 6 HALO Project

6.3 HeliPlat

HeliPlat is the name of an unmanned solar-powered stratospheric platform developed in the framework of a European project [14]. Its applications cover localization, environmental monitoring and broadband communications. A number of interconnected HeliPlat's will create a HeliNet, offering broadband fixed wireless access (BFWA) or local multipoint distribution services.

The services can include Internet, Intranet, e-mail, telephony, data, LAN, videoconferencing, video-on-demand, TV broadcast, etc. Burst data rates can be as high as 155 Mbps. The present design foresees up to about 120 cells, each served by a single horn antenna. System design was presented in Figure 8 [14].

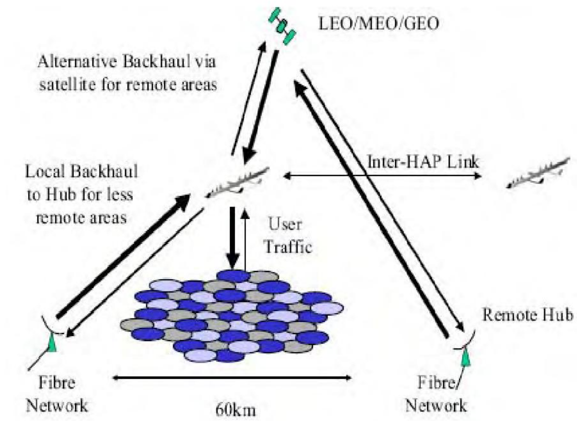

Fig. 8 HeliPlat Project

6.4 Japanese HAPs

A Japanese national project led by the Science and Technology Agency (STA) and the Ministry of Posts and Telecommunications (MPT) for the development of a balloon-based SPF capable of operating at an altitude of 20 km and carrying onboard mission payloads for communications,

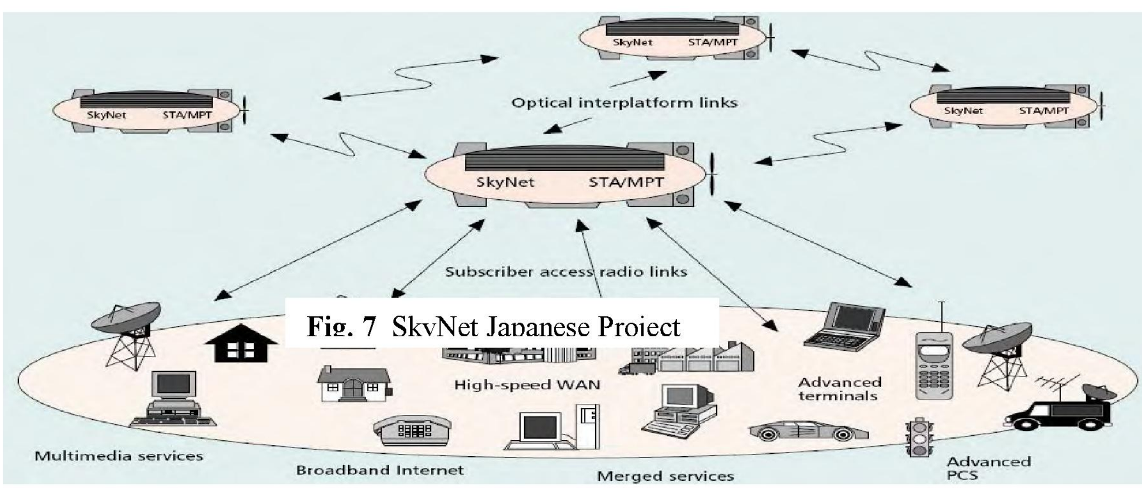

Fig. 7 SkyNet Japanese Project

broadcasting, and environment observations started in 1998 [12].
The project will offer classic mobile, fixed, broadcasting services, emergency access, business access, car access, train access, air access and maritime access. A network of five HAPS will cover almost the total Japanese territory with signal of arrival elevation angle above 5 degrees. The architecture of the system presented in Figure 7 [13].

7. CHALLENGES AND CRITICAL ISSUES

The HAPs plan to operate at unusually high altitudes. Such altitudes have not been used until now by communication systems and a number of potential problems and technical challenges arise. Several research initiatives were carried out at various research institutions to study following issues;

7.1 Platform Station-Keeping and stabilit
7.2 Energy Source

HAPs station usually need to take off, fly, landing, correct the position and all these movement beside

For airships as well as for aircraft, the movement is a problem to be faced. Aircraft usually fly on a tight circle (about 2 km radius or more), while airships can theoretically stay still and they only need to compensate for the winds [3]. The ITU has specified that HAP should be kept within a circle of 400 m radius, with height variations of ±700 m [15], so that services are available almost all the time. GPS can play an important role in the precise positioning of High Altitude Platform Stations.
The ability of HAPs to maintain position reliably in the face of variable winds is a major challenge

7.3 Antennas

The antenna system is one of the most critical performance factors in a HAPs configuration. In [8, 12] the required functions for a successful broadband HAPs antenna were summarized below:

the payload equipment consumed power. So the choice of energy source is a fundamental issue.
One approach concerns sending energy from the earth in the form of microwave beams [16].
However, the transmission efficiency is low, the cost of the ground station is quite high, and the radiation to other flying objects can be considerable.

Another alternative is to carrying fuel reserves on the board [11]. In this case the platform becomes heavy and expensive beside the bad environmental impact due to the gases exhausted by engines. Capturing solar energy is one of the solutions used by numbers of proposed projects [14, 17]. At higher latitudes both the variation in the angle of the sun relative to the solar panels between summer and winter, and the short winter days will limits the power. Large and heavy stored batters which used to store the power during days and used at nigh have an additional significant effect payload with electric power . At very low altitudes around 5 km, we can use a cable-tether to supply onboard systems and the Communication backhaul may also be provided through the tether via fiber optic link.

- A large number of spot beams will be required; these may be produced either by a multi beam antenna or some form of phased array.
- Use of high radio frequency in order to secure a sufficient bandwidth.
- Directional antenna with a high gain to cope with attenuation in high frequencies.
- Reduced weight, size, and power consumption of the mission payload.

7.4 Diversity

Propagation from HAPs is not fully characterized at high frequency which allocated by the ITU for HAPs at 47/48 GHz worldwide and 28GHz in Asia. Rain fading, could cause serious degradations to some services [9]. Real time services, such as TV and video streaming, would be most affected. So one of the main required is to develop rainfall attenuation, sandstone attenuation and scattering statistic. An important objective is to determine the most appropriate diversity techniques. Different diversity methods can be assigned to different traffic and user categories.

7.5 Handoff

In mobile cellular schemes, handoff occur due to motion of the user, this is in contrast to HAPs schemes where handoff may occur due to platform motion which move the antenna beams. Delay for multimedia service may impose much more stringent constraints on the handoff process.

7.6 Interference

Interference represents an issue of paramount importance for any communication system. The interference levels always affect the supported number of system users. In HAPs we can distinguish the following cases of interference paths:

- Between HAPs ground stations and other terrestrial stations or satellite earth stations.
- Between HAPs ground stations and satellites space stations.
- Between HAPs on-board stations and other terrestrial stations.
- Between HAPs on-board stations and space stations.

7.7 Modulation and Coding

To offer telecommunication service with specified QoS, suitable modulation and coding schemes will be required to optimize network capacity and to be applicable under different attenuation conditions. These should range from low-rate schemes involving powerful Forward Error Correction (FEC) coding when attenuation is severe, up to high rate multilevel modulation schemes when conditions are good, allowing an optimum adaptive modulation and coding scheme to be developed [18].

An interesting approach is the use of adaptive coding and modulation based on channel conditions [3]. Due to the centralized nature of the HAP, the base station on board the HAP is aware of the channel losses to the subscribers, and can select the most appropriate modulation and coding scheme.

The modulation parameters can be controlled either dynamically and can be changed during the connection, or they can be assigned at the call setup and remain invariable during the call duration.

8. CONCLUSION

This paper has presented an overview of the wireless communications from High Altitude Platforms. The High Altitude Platform Stations are expected to provide, in a cost effective way, a multitude of telecommunication and other services over large areas.

We have outlined a few possible applications of communications from HAPs, such as telecommunication services, remote sensing, monitoring and navigation applications

The HAPs aim to exploit potential benefits of intermediate altitudes between those used by the terrestrial and satellite technologies. Compared to terrestrial telecommunication systems, the HAPs offer high signal arrival angle and large coverage area. Compared to satellites, they do not require any launch vehicles and offer much shorter signal path.

HAPs can operate individually or be interconnected with other HAPs or terrestrial and satellite network. HAPs do not intend to replace existing technologies, but rather complement them.

We have presented an overview of some HAPs proposed project worldwide. Hopefully, in the next few years some of these projects will come to operation stage, confirming the usefulness of HAPs technology.

The requirements imposed are new and difficult to satisfy. The critical elements include materials, platform stability and its effects on handoff, antenna design, availability of payload power, interference problem, propagation and rain fading in V-band, modulation and coding.

But we believe it is only a question of time and all these technological problems will be solved and HAPs will be implemented widely depends not only on the successful technologies and standards, but also on policy decisions, international cooperation, regulations and market forces.

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