QUESTION 9/2
Identify Study Group Questions in the ITU-T and ITU-R Sectors which are of particular interest to developing countries

ITU-D STUDY GROUP 2 2nd STUDY PERIOD (1998-2002)

Report on High Altitude Platform Stations: an opportunity to close the information gap

Telecommunication Development Bureau (BDT)
International Telecommunication Union

THE STUDY GROUPS OF ITU-D

The ITU-D Study Groups were set up in accordance with Resolution 2 of the World Telecommunication Development Conference (WTDC) held in Buenos Aires, Argentina, in 1994. For the period 1998-2002, Study Group 1 is entrusted with the study of eleven Questions in the field of telecommunication development strategies and policies. Study Group 2 is entrusted with the study of seven Questions in the field of development and management of telecommunication services and networks. For this period, in order to respond as quickly as possible to the concerns of developing countries, instead of being approved during the WTDC, the output of each Question is published as and when it is ready.

For further information

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1 Introduction

High Altitude Platform Stations, or HAPS, embody a new technology that can revolutionize the wireless industry. Thanks to the recent advances in power, material, propulsion, and telecommunication technologies, platforms can now be kept stationary in the upper atmosphere for a very long duration and serve as high-speed Internet gateways and relays for portable multimedia devices. Such stratospheric platforms may have technological advantages as compared with either space or ground-based networks.

2 Stratospheric infrastructure

Currently there are several major organizations that are devoted to the development and commercialization of high altitude platform-based systems for telecommunications as well as for environmental monitoring and remote sensing. Among them are Sky Station International, based in Washington, DC, USA, the Japanese MPT/STA (Ministry of Posts and Telecommunications/Science and Technology Agency) R&D Project, and ESTEC (European Space Agency Research and Technology Centre) HALE (High Altitude Long Endurance) Aerostatic Platform Project. Sky Station International projects that it may commence deployment in 2002. One concept of these organizations includes an extremely strong, lightweight, multi-layer skin containing buoyant helium, a station-keeping system consisting of GPS and an advanced propulsion system, a telecommunication payload, thin film amorphous silicon solar panels for daytime power, and regenerative fuel cells for night-time power. Baseline platform characteristics of an example system are provided in Table 1.

Although stratospheric platforms are an old idea, they only recently have become practical through the development of several enabling technologies. The enabling technologies are high efficiency solar cells and fuel cells that are both lightweight and durable, high strength ultrathin fibre and helium impermeable seal, thermal and pressure control/management techniques, as well as advanced phased antenna array and MMIC (microwave monolithic integrated circuit) technologies.

Table 1 – Stratospheric platform parametres (example system)

Operating altitude	20-22 kilometres
Lift at altitude	0.062 kg/m^3
Hull volume	371,000 m^3
Gross lift at altitude	23 metric tons
Hull area	30,000 m^2
Envelope weight	7,500 kg
Payload	1,200 kg
Dimensions	220 m × 50 m
Speed	200 km/hour
Possible operating frequencies	47.2-47.5 GHz /47.9-48.2 GHz 27.5-28.35 GHz/31.0-31.3 GHz 1885-1980 MHz/2110-2160 MHz

A global network of domestically operated stratospheric platforms may be deployed in a population-based heterogeneous manner instead of the orbital dynamics-based homogeneous spacing of low-earth orbital satellites. One solution includes gateway earth stations that connect each stratospheric platform to the public switched telephone network, high-speed frame relay and ATM (asynchronous transfer mode) network, as well as the Internet. In this solution, portable and fixed communication devices are used to send and receive digital information via the stratospheric platforms and gateway earth station. Channel speeds range up to 2 Mbit/s for a third-generation portable user terminal, 45 Mbit/s for a transportable 23 dBi antenna, and up to OC3 (155 Mbit/s) for a fixed steerable high gain antenna.

From the stratosphere, communication links of high-angles can be established across large land areas. For example, at 23 km altitude, links with 30° angles of elevation extend out to a radial distance of 40 km from the centre of coverage. Throughout any urban area centred on a stratospheric platform, the angles of elevation exceed 50°. The footprint of a stratospheric platform may be up to approximately 1000 km in diameter to the coverage horizon depending on the conditions of propagation.

Considerable effort has gone into ensuring the safety of stratospheric platforms. They are deployed from cleared airspace like the hundreds of high altitude science research and weather balloons that are launched worldwide each day, and they reach their stratospheric altitude within only a few hours. They then move under their own power through the stratosphere to fixed locations above metropolitan areas at altitudes high above all commercial and most military aircraft. Redundant safety systems prevent deflation and system failures and provide advance warning so that the platforms can be manoeuvered to service centres or unpopulated areas for recovery and repair. Each platform will be subject to inspection, approval and regulation by aviation authorities such as the Federal Aviation Administration, the International Civil Aviation Organization (ICAO), and national regulators in each Administration.

3 Stratospheric telecommunication applications

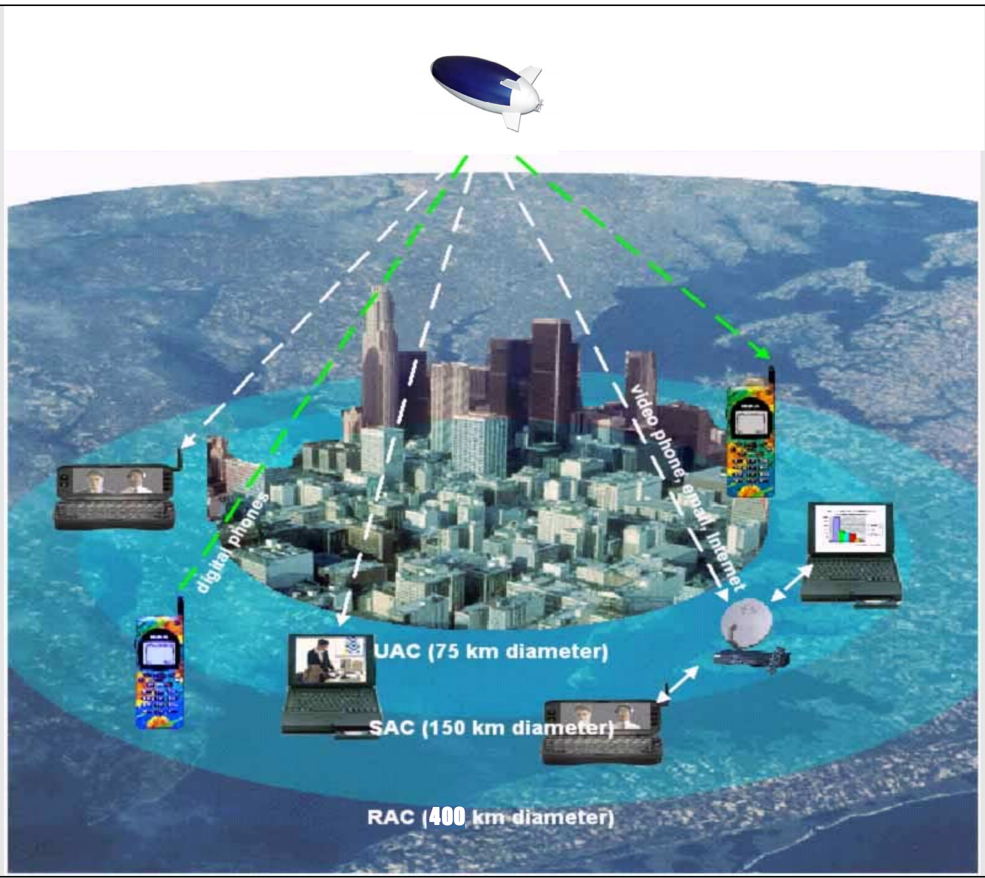
Stratospheric platforms are designed with telecommunication technology capable of providing full duplex digital channels of from 14.4 kbit/s to 155 Mbit/s. At these speeds, compressed voice and web TV applications can be supported at the low-end, and high-speed OC-3 LAN, MAN and WAN channels can be implemented at the high end. Generally, stratospheric platforms will enable a complete blending of digital telephony, computer and video information to be delivered to hand-held multimedia terminals, wireless local loop terminals, and fixed wireless networks. A list of stratospheric services is provided in Table 2.

Table 2 – Possible stratospheric services

Digital telephony, fax and e-mail	14.4 kbit/s
Full motion videophone service	64 – 384 kbit/s
High-speed web surfing, web TV and file transfers	128 kbit/s – 45 Mbit/s
OC 3 LANs, MANs and WANs	155 Mbit/s

Stratospheric transmissions can connect mobile or pocket telephones to desktop phones via millimetre wave, submillimetre wave transmission, or conventional microwave bands. Similarly, laptop or notebook computers can transmit or receive information directly via a stratospheric platform (Figure 1), or indirectly through Radio Local Area Networks (RLAN) transcoding relay station. It could also connect through to a gateway ground station and the public switched telephone network (PSTN) to either cellular or desktop phones or databases such as the World Wide Web anywhere in the world.

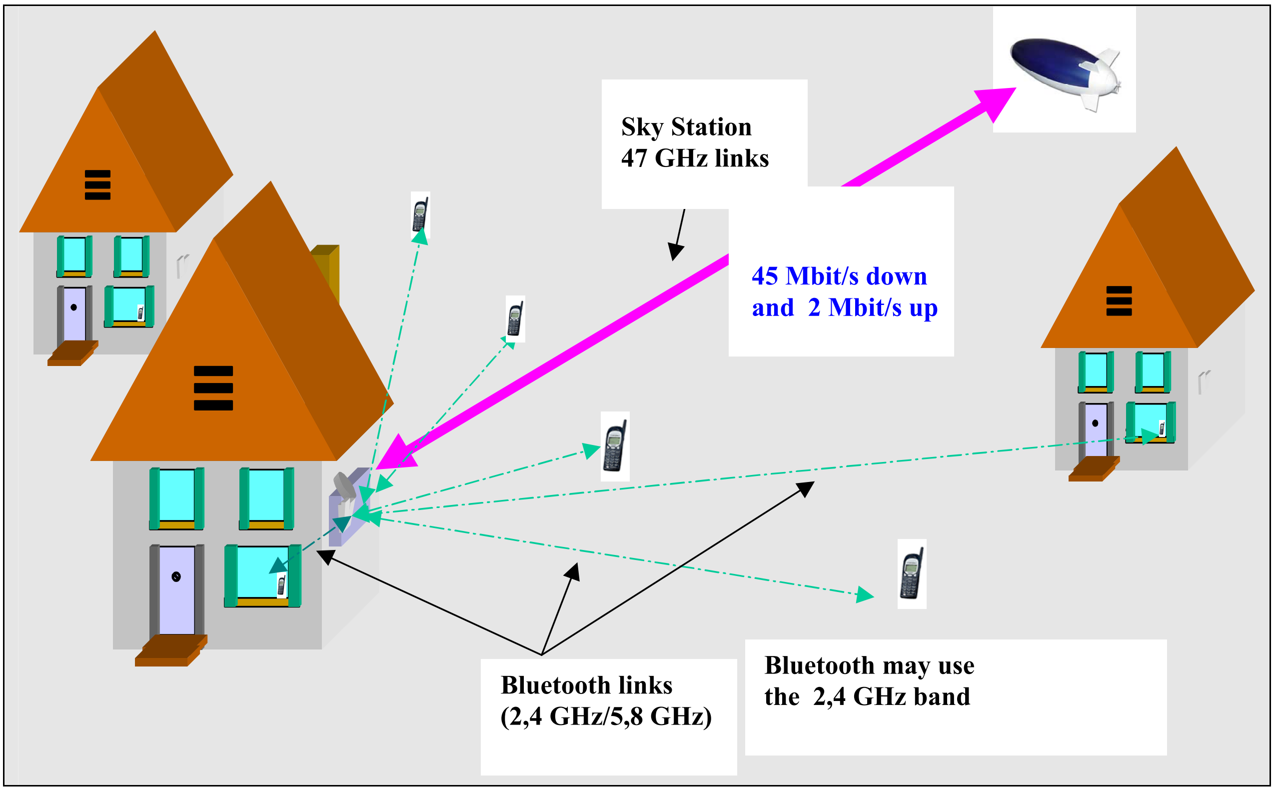
Figure 1 – HAPS-based direct addressing high-speed wireless data and Internet access



The stratospheric platform system could be used to provide backhaul links to thousands of RLAN-based nano-basestations, which serve as the hubs for inexpensive cordless phones over a short range of about 100 metres. The Stratospheric Telecommunication System (STS) may become a developing nation's lowest-cost high-speed digital backbone.

The figure below (Figure 2) illustrates the Sky Station International concept. Note that the stratospheric platform can provide more than 700 beams, each of which in turn, can support more than 100 Bluetooth basestations. Since each basestation can support up to 200 DECT subscribers, potentially each platform can provide basic semi-mobile telephony service to 14 million subscribers. In addition, each stratospheric network can also provide high-speed Internet service either through the inherent packet-data capabilities of the Bluetooth protocol, or through a stratospheric access device directly. The phase 1 Bluetooth protocol can provide up to 1 Mbit/s packet data access. Later-generation Bluetooth will achieve 11 Mbit/s packet data capabilities. Through a direct stratospheric access device, the maximum throughput can reach 45 Mbit/s, equivalent to that of a T-3.

Figure 2 – HAPS-based Wireless Local Loop using Bluetooth nano-basestations to provide DECT telephony and high-speed Internet access



One of the most common multimedia applications of HAPS technology will be the provision of video telephony between two service subscribers in the same coverage areas. This can be accomplished through either a stratospheric access device, a third-generation phone service, or an RLAN enabled PC or PDA (personal digital assistant). Here the HAPS overcomes the bandwidth limitations of traditional infrastructure that have impeded videophone to date. Alternatively, two HAPS users can communicate with each other in different coverage areas via gateway ground stations and the PSTN or directly through a high-speed DWDM (dense wavelength division multiplexing) link between two stratospheric platforms.

It is also possible for communications to be maintained between a HAPS user and a HAPS non-user. Here the multi-protocol gateway ground station and PSTN/Internet serve to provide protocol compatibility. If the PSTN lacks adequate bandwidth or ATM switching capability, gateway ground stations or direct DWDM laser links can be used with different antennas interconnecting multiple stratospheric platforms. This will enable stratospheric communicators in one coverage area to enjoy direct communications with stratospheric communicators in adjacent coverage areas, although a 'last-leg' of PSTN must be used to connect the non-HAPS subscriber. For example, if agreed between neighbouring Administrations, adjacent coverage areas in several countries can be interconnected by stratospheric platforms alone for long-distance links, including transoceanic platforms interconnected by satellite or inter-platform laser transmission.

4 Stratospheric requirements

It has been projected that by 2005 there will be 300 million people using the Internet worldwide as a ubiquitous secure multimedia communications medium connecting businesses and homes for business, entertainment and educational applications[1]. A large majority of these users can be expected to prefer high-speed wireless connections over low-speed wired connections.

It is widely recognized that more than half the people in the world have never placed a phone call. This stunning demonstration of the information gap between developed and developing countries requires a cost-effective solution that brings the developing countries high-speed channels (to close the gap) at affordable prices. Simply providing phone circuits to developing countries, while developed countries go broadband, will not close the gap. And the information gap cannot be closed at dollar-per-minute tariffs or with thousand-dollar terminals. What is needed are flexible broadband channels, accessible via a low-cost cordless telephone or an RLAN enabled intelligent device such as a low-cost PC, and delivered to developing country markets at low cost.

5 The stratosphere's natural advantages

Stratospheric platforms have intrinsic advantages that enable HAPS to provide communication capacity to metropolitan areas at a low infrastructure cost per subscriber. A single platform may be able to provide a metropolitan area with full duplex broadband service to more than one million subscribers. If the frequencies are divided into narrowband channels, a platform could provide basic telephone service to a substantially larger number of subscribers.

For example, a HAPS platform at 21 kilometres altitude, using just 100 MHz of bandwidth in each direction in the 47.2-47.5 and 47.9-48.2 GHz, can generate 700 spot beams over an 80 kilometre diameter coverage area with a minimum elevation angle of 15°. Assuming a frequency reuse factor of 7, the total metropolitan capacity of the system is 7.68 Gbit/s which can be directed to provide high-speed services to high-density populations at a low cost, ideal for the developed and the developing countries.

In regions that are susceptible to heavy rainfall, the provisional Ka-band designation of 850 MHz for downlink and up to 300 MHz for uplink will provide a much higher availability figure for critical telecommunication functions. Using a direct radiating large aperture phased array antenna onboard HAPS, up to 700 spot beams can be generated to cover a radius of 50 km and beyond, with a minimum elevation angle of approximately 23°. Lower availability coverage is also possible beyond the 50-km radius, as long as there is line-of-sight, for up to 500 km. The 850 MHz downlink bandwidth and 300 MHz uplink bandwidth can be partitioned into 7 bands each to produce a 7-cell frequency reuse pattern. This gives rise to a downlink band of 110 MHz per spot beam, with a capacity of 110 Mbit/s per beam.

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1 "Trends and Technologies in Personal Wireless Local Loop Communications", *Montgomery Securities*, Volume 27, 23 September 1996, Montgomery Securities.

The uplink bands are further subdivided into 35 frequency sub-bands with 1 MHz bandwidth each. Using 16-QAM (quadrature amplitude modulation) for the uplink with 2.5 bit/s/Hz spectral efficiency (with FEC, or forward error correction), and QPSK with 1 bit/s/Hz spectral efficiency, each HAPS broadband access device can support a maximum downlink speed of 110 Mbit/s and a maximum uplink speed of 2.5 Mbit/s. Higher uplink speed is possible with channel aggregation for up to 87.5 Mbit/s maximum uplink speed.

Since the Ka-band WAD (wireless access device) for HAPS initially will be expensive, the aforementioned RLAN nano-basestations can be integrated into HAPS WAD to provide ultra-low-cost broadband access. In one system design 100 mW RLAN basestation can support up to 200 phone subscribers for circuit-switched voice, using inexpensive cordless phones. Each spot beam can link to about 100 such basestations. Hence, for each HAPS, approximately 14 million subscribers can be supported. Cordless phones provide limited mobility within its 100-metre radius (outdoors). The slow reconnection time when the mobile station crosses from one RLAN coverage cell to another one essentially prevents its use within a fast-moving vehicle. So the RLAN network does not challenge second-generation (2G) or third-generation (3G) cellular systems.

The additional benefit of the RLAN based access network is that any RLAN enabled device, such as a PC, a cell phone, or a PDA device, can be linked to an RLAN basestation to provide high-speed packet data at a maximum speed of several Mbit/s depending on the system.

The benefit of using HAPS to deploy 3G cellular network is also readily apparent. Due to its physical dimension, HAPS can house a 15 m × 15 m phased array antenna with tens of thousands of direct radiating elements to provide spot beams as small as 300 metres within a radius of 20 km from the centre of coverage.

Instead of the conventional waveguide structure that is too bulky and heavy for this kind of array application, a DM (directly modulated) RF/fibre feed structure is used to feed and steer multiple beams simultaneously. DM RF/fibre uses the RF signal to directly modulate the output of a laser diode to convert the RF signal into an (analogue) optical signal to be transmitted over a single-mode fiber. Furthermore, multiple RF signals can be transmitted over a single fibre using the DWDM technique to further reduce the weight and cost of such feed structure. The extremely low loss characteristics of the optical fibre, as well as the ready availability of the low-cost optical delay lines and MEMS (micro-electric-mechanical system)-based all optical switches makes it possible to provide coarse-steering of hundreds of spot beams simultaneously within a millisecond using the optical delay-line matrix switching technique.

Additional fine beam shaping and forming can be accomplished using digital beamformers that rely on the fast DSP (digital signal processing) technique to sculpt the beams. The main benefit of such a multi-beam payload for the 3G system is that a single HAPS can provide the equivalent of from 700 to 1000 cellular. In addition, the steered beams can be used to reallocate radio resources dynamically to release radio traffic congestion and prevent traffic hotspots.

Since HAPS is like the tallest tower, it also has a much better look angle for most users, which translates into higher average link quality.

In a TDMA-based 3G system, such a strategy will produce better link quality but will not substantially increase the capacity of the existing network, unless the frequency plan is revised to increase the network capacity. This is possible since HAPS can help to reduce substantially the inter-cellular interference. It can also extend the coverage to regions previously not covered by the terrestrial network. With a CDMA-based 3G system, the link quality can be further improved through a soft-handover procedure between HAPS and one or more terrestrial basestation(s). The big reduction of the same-cell and adjacent cell interference afforded by HAPS also translates immediately into a direct increase in net capacity since the capacity of the CDMA network is largely a function of the interference level.

6 Stratospheric implementation schedule

Sky Station International predicts that it will begin deployment starting in 2002. At a deployment rate of one platform per week, 90 per cent of the world's population could be covered by 2008. Most major cities would be covered by 2004. It is hard to imagine a more efficient means of achieving universal broadband service and thus closing the information gap.

Global rollout of HAPS multimedia services may proceed quickly by focusing on new urban markets. For developing countries, the STS at 47 GHz and at 27-31 GHz may offer an opportunity to leapfrog into broadband multimedia parity with the most economically developed nations. For those developing countries wishing for an early deployment of IMT-2000 (third-generation mobile), a single HAPS platform may be able to support the same number of users as 700 to 1000 sectored radio towers. And since the HAPS system uses the same IMT-2000 handsets without modification, the economy of scale is at work here on the terminal side as well.

With the stratospheric telecommunication service, access to full multimedia information could be accessible to people everywhere, from Africa to the Americas and from Asia to Europe.

7 Stratospheric regulatory issues

From a regulatory perspective, ITU and the domestic telecommunication authorities that have considered the matter have concluded that stratospheric services are best defined as a high density fixed service using stations located in the stratosphere. The service is high density because of the extraordinarily high number of communication circuits it can provide in a fairly small, urban area. The technology creates a fixed service because most user terminals will be accessed through a fixed antenna. Another reason that HAPS has been considered a fixed service is because the platforms do not meet the definition of a space service and consequently must be a terrestrial service.

Each stratospheric system will operate within national airspace, not transnational outer space and, therefore, will be regulated as a domestic service by the country it serves. This will enable domestic authorities to regulate the frequency use and the system technology. However, in order for HAPS to be economically feasible in global application, stratospheric systems also require an international designation to enable worldwide compatibility of components and systems as well as investor confidence necessary to rapidly build out the service.

WRC-2000 granted the extension of Resolution 122, as well as the approval of two new resolutions. Resolution 122 was originally approved at the WRC-97 conference to designate the radio-frequency bands 47.2-47.5 GHz and 47.9-48.2 GHz for use by high altitude platform stations (HAPS), thus establishing regulatory procedures to enable the filing by countries wishing to deploy HAPS-based systems such as Sky Station's. The extension of Resolution 122 includes the provisional approval of the use of the two Ka-bands 27.5-28.35 GHz and 31.0-31.3 GHz for countries in the Asia-Pacific region where heavy rain can sometimes cause service outages for links using the original HAPS bands in the 47/48 GHz range.

Resolution 221 (WRC-2000) concerns the use of HAPS as an optional platform for the deployment of terrestrial IMT-2000 (third-generation cellular) services. The resolution allocated the IMT-2000 bands in the 1885-1980 MHz (in Regions 1 and 3, 2010-2025 MHz is also included), and 2110–2160 MHz (2110-2170 MHz in Regions 1 and 3) ranges non-exclusively for use by HAPS. Resolution 734 (WRC-2000) calls for the study of the feasibility of use of HAPS in terrestrial frequency bands above 3 GHz. This opens up the way for the International Telecommunication Union (ITU) to study the issues of sharing and interference to existing services from HAPS as well as possible future allocations of other frequency bands for HAPS on a co-primary basis.

Resolution 800 (WRC-2000) contains three agenda items for the next World Radiocommunication Conference (WRC-03) to examine additional services and frequencies for use by HAPS.

Because the 47/48 GHz bands are strongly susceptible to heavy rain attenuation, they may not be suitable for regions or countries with heavy rainfall. Thus it would be desirable to seek other bands in the Fixed Service that are less affected by rain. The provisional permission granted by WRC-2000 for HAPS to use the two Ka-bands 27.5-28.35 GHz and 31.0-31.3 GHz can potentially alleviate much of the rain attenuation problem in the wetter regions. WRC-03 will consider this provisional use.

8 Conclusion

A global stratospheric telecommunication system employing fixed platforms in the stratosphere could help to meet the world's demand for affordable high-speed wireless communications.