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Stratospheric wireless communication platforms

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Abstract

The 'final mile' of service delivery is becoming more difficult due to the need for high-capacity wireless services. While satellite systems have capacity restrictions, terrestrial systems are limited by the necessity for line-of-sight propagation channels unless a sufficient number of base-station masts are installed. High-altitude platforms (HAPs) are becoming more popular as a means to provide communication facilities that may take use of the finest aspects of both terrestrial and satellite systems. These platforms operate in the stratosphere at altitudes of up to 22 km. This article provides an overview of the functionality and characteristics of HAPs, as well as certain targeted development initiatives. The potential of HAPs to facilitate the distribution of high-speed wireless data connections is explored.

Introduction

1 The challenge for wireless communications

The importance of wireless solutions is rising as the need for communication services rises. In many cases, wireless may be the sole feasible delivery mode due to its ability to enable high-bandwidth service supply independent of fixed infrastructure and as a solution to the 'last mile' issue (delivering straight to a customer's premises). Cellular networks (such as 2G mobile) are now live all across the globe, and mobile services rely heavily on wireless technology. The usage of fixed wireless access (FWA) schemes to provide voice and data services to consumers and enterprises is also gaining traction.

Broadband data supply for multimedia is a growing industry because of the increasing popularity of bundled services like high-speed Internet (including e-mail), telephones, televisions, video-on-demand services, audio broadcasting, etc. The goal of broadband fixed wireless access (B-FWA) schemes is to provide customers with a variety of multimedia services at speeds of at least 2 Mbit/s. Services based on current wirelines, such as ISDN or xDSL, are not expected to be offered to all subscribers, although B-FWA should provide higher capacity to the user. The alternative would be cable or fiber distribution, but the high cost of installation might prevent new service providers from entering the market. It is expected that B-FWA would first appeal to commercial users like SMEs and SOHOs, but that the market will quickly expand to include consumers as well.

Nonetheless, wirelessly offering high-capacity services

This poses difficulties, as the radio spectrum is a finite resource that is under growing demand. A frequency reuse method, often centered on a static cellular architecture, is required to offer bandwidth to a high number of users. Each of the hexagons in Fig. 1a depicts a cell, complete with a base station in the middle, and operating on a distinct frequency or set of frequencies, as shown by the corresponding color. The distance at which these frequencies may be reused depends on a number of criteria, such as the local propagation environment and the allowable signal-to-interference-plus-noise ratio.

Cell sizes may be decreased to enhance capacity, as shown in Fig. 1b, and spectrum can be reused several times within the same region. Based on this theory, "microcells" might be set up in densely populated places, with a base station on every block. Indeed, one could imagine one cell for every user if the idea were taken to its logical conclusion; the obvious cost in either case would be the installation price and environmental impact of a vast number of base-station antennas, as well as the challenge of providing the backhaul links to serve them, via fiber or other wireless means.

There is a trend toward using higher frequency bands due to spectrum pressure since they are less crowded and can give more bandwidth. The 28 GHz band (26 GHz in certain countries) and the 38 GHz1 band are the primary allocations for broadband. Both LMDS (Local Multipoint Distribution Services) and MVDS (Multipoint Video Distribution Services) are used to define currently available broadband schemes2,3.

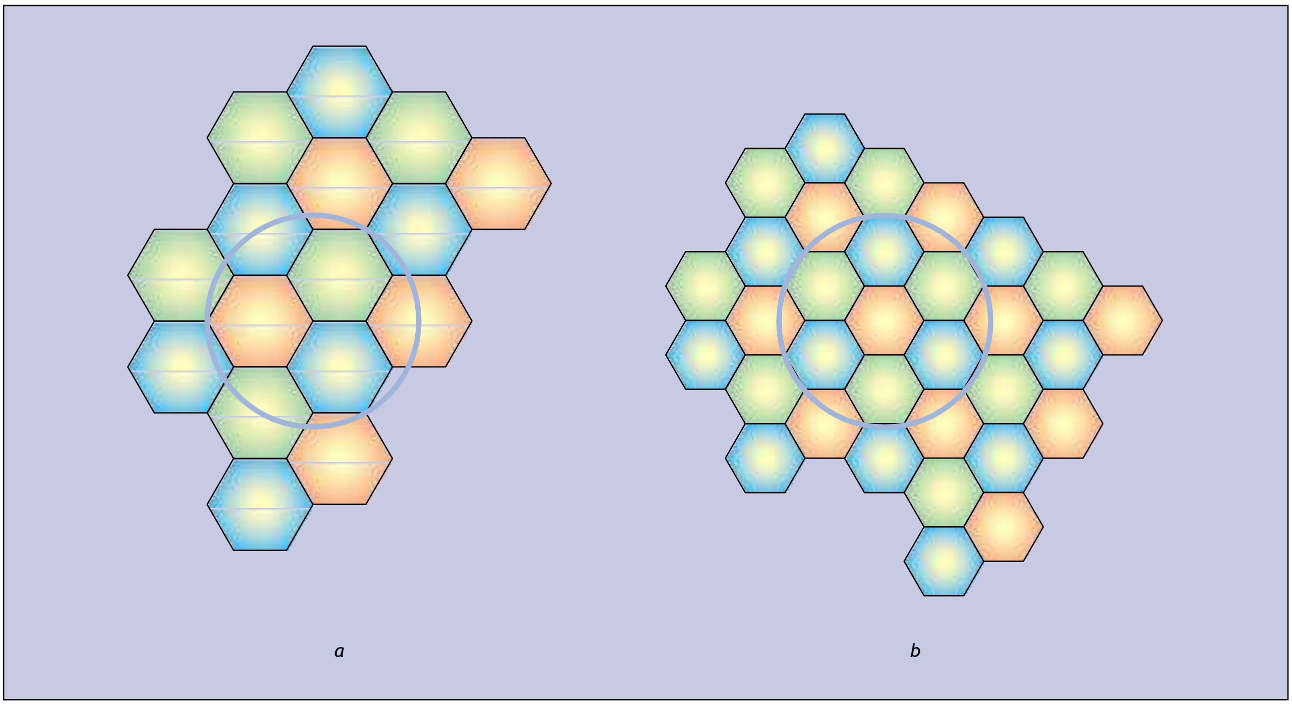


Fig. 1 Cellular frequency reuse concept. In *b* the smaller cells provide greater overall capacity as frequencies are reused a greater number of times within a given geographical area.

Various ideas for providing broadband services, which may be included under the umbrella term B-FWA or just BWA.
Millimeter-wavelength communications need line-of-sight propagation, which is more difficult than lower frequencies. Consequently, a microcellular structure is required for propagation purposes, since local obstructions would create issues and each client terminal has to'see' a base-station. Once again, this need a massive infrastructure of base stations.
Very tall base-station masts with direct line-of-sight to consumers might solve these issues. However, they would be very wasteful as well as harmful to the ecosystem. Satellite transmission is another option since it enables widespread line-of-sight communication. In fact, it is expected that the market for broadband services provided by geostationary (GEO) satellites would grow substantially during the next several years4. The free-space path loss (FSPL) on the order of 200 dB at a range of c. 40 000 km, and the physical limits of on-board antenna size, both put a cap on performance. As a result, the frequency reuse density and, by extension, the total capacity, are constrained by these minimum dimensions for the spot-beam (i.e. cell) diameter on the ground. Furthermore, in order to attain broadband data rates, the high FSPL necessitates the use of large antennas at ground terminals. Another drawback is the geostationary satellite link's long propagation latency of 0•25 s, which may be problematic for both voice and certain data protocols.

Some of these restrictions may be avoided using low Earth orbit (LEO) satellites, although this approach is complicated by the need for frequent handoffs between cells and platforms. There must be a lot of

The cost of maintaining a fleet of LEO satellites to provide constant service is high, and no such business model has yet been proven viable.

2 Aerial platforms: a solution?

Aerial platforms holding communications relay payloads and operating in a quasi-stationary position at altitudes up to about 22 km may provide a solution to the wireless delivery dilemma. Like the vast majority of satellites, a payload may be as complex as a full base station or as simple as a transparent transponder. With a low FSPL, services that combine the advantages of terrestrial and satellite communications may be made available to the vast majority of consumers.
A huge number of terrestrial masts, together with their costs, environmental effect, and backhaul limits, may be replaced by a single aerial platform. Maintenance fees for installations, which can be a significant outlay in certain parts of the globe, and difficulties in securing a suitable site are also avoided.
The vehicles may be airplanes or airships (basically balloons, called "aerostats"), and they could be operated either autonomously or remotely from the ground. High-altitude platforms (HAPs)2,3,5 -7, which are intended to operate in the stratosphere at a height of between 17 and 22 km, are of particular interest. While the precise meaning of HAP is unclear, we understand it to refer to a solar-powered, unmanned aircraft or airship with the ability to remain in one location for an extended period of time (say, many months). High Altitude Long Endurance (HALE) platform is another common word, referring to spacecraft designed for extended periods of time spent on station (up to many years).

Recent increased interest in developing HAPs is a result of both the profitable demand for wireless services and advancements in platform technology, such as materials, solar cells, and energy storage.
Balloons
Balloons, the first kind of airborne platform, date all the way back to ancient China. In 1783, the Montgolfier brothers of France

made history by piloting the first human lighter-than-air device, a hot air balloon. Balloons were mostly used for military objectives throughout subsequent evolution, but they have found some use in the field of communication.

Fig. 2 The Zeppelin NT airship, launched in June 2000 (Courtesy of ZeppelinLuftschifftechnik GmbH)[10]

fairly restricted in scope. The Zeppelin firm in Germany built rigid, powered airships for passenger transport in the early 20th century, and they proved to be a spectacular technical accomplishment, allowing people to fly from Europe to South America. The tragic Hindenburg crash in Lakehurst, New Jersey, USA, in 1937 put a stop to this period abruptly. The use of extremely flammable hydrogen to fill the airship was deemed unacceptable after that tragedy, and with the advent of commercial air travel following World War II, huge airships looked doomed to oblivion.

After then, people mostly flew hot-air balloons for fun, tiny weather balloons, and tethered aerostats (sometimes known as "balloons on strings"). The latter can fly to heights of up to 5,000 meters8, but their usage is severely limited because of concerns about air traffic safety. Typically, they fly at considerably lower altitudes. (Surveillance is a common use case for tethered aerostats.

They are used in large numbers to monitor the border between the United States and Mexico for illegal entry9.

New plastic envelope materials that are sturdy, UV resistant, and leak-proof to helium, which is now almost widely used instead of the much cheaper hydrogen, have contributed to the recent rebirth of interest in balloons and airships. Such high-tech airships (like the Breitling Orbiter10) have been used in well-publicized efforts to circle the world. In addition, the Zeppelin firm released a new low-altitude airship, the Zeppelin NT, in the year 2000.

perspective on the landscape tourist industry (Fig.11. Cargolifter12 (Fig. 3), another massive project despite its low height, is designed to serve as a "flying crane" for the carrying of big items across rough terrain.

However, creating a HAP in the stratosphere that can reliably and cheaply support communication applications is still an important commercial objective. The capacity of the HAP to sustain station-keeping in the face of winds is a significant difficulty for any airborne vehicle, whether it an airship or aircraft. Because this height corresponds to a layer of relatively calm wind and turbulence in most parts of the globe, it is considered as the optimal operating altitude. Although the wind profile may vary greatly with latitude and with season, one with a shape similar to that depicted in Fig. 4 will often acquire. At this altitude (> 55 000 ft), commercial air-traffic heights no longer apply, removing a possible barrier.

Fig. 3 Artist's impression of Cargolifter (Courtesy of Cargolifter GmbH)[11]

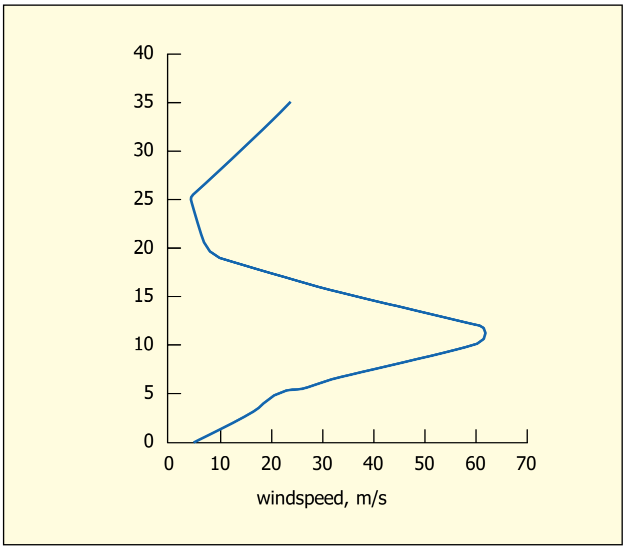


Fig. 4 Windspeed profile with height. Values vary with season and location, but generally follow this rough distribution. (Source: NASA)

Airship HAPs

Proposed implementations of airships for high-altitude deployment use very large semi-rigid or non-rigid helium- filled containers, of the order of 100 m or more in length. Fig. 5 shows an artist's impression of a HAP from Lindstrand Balloons. Electric motors and propellers are used for station-keeping, and the airship flies against the prevailing wind. Prime power is required for propulsion and station-keeping as well as for the payload and applications; it is provided from lightweight solar cells in the form of large flexible sheets, which may weigh typically well under 400 g/m^2 and cover the upper surfaces of the airship. Additionally, during the day, power is stored in regenerative fuel cells, which then provide allthe power requirements at night.

The overall long-term power balance of a HAP is likely tobe a critical factor, and it will be the performance and ageing of the fuel cells that are likely to determine the achievable mission duration. However, this is mitigated by

satellites, HAPs may be brought down to Earth rather easily to have their fuel cells serviced or replaced and to undergo any other necessary maintenance or upgrades.

The Japanese SkyNet13 is a significant HAP airship project. This project, spearheaded by Yokosuka Communications Research Laboratory and funded mostly by the Japanese government, proposes to build an integrated network of around 15 airships to provide broadband communication services running in the 28 GHz band and broadcasting to most of Japan.

Advanced Technologies Group, of Bedford, UK14, is developing a series of airships, and they've previously worked with SkyStation International, of the USA15, who suggested an airship 150 m in length capable of sustaining a communications payload of up to 800 kg. Lindstrand Balloons16 is also advocating for HAP airships to be used. To solve some of the structural and aerodynamic issues that come with very large airships, researchers at the University of Stuttgart17,18 are working on a novel design of HAP that consists of a series of smaller airships joined together in a 'Airworm' configuration.

HAPS in Aircraft

The unmanned solar-powered aircraft is another kind of HAP, and it too must fly against the wind, or in a somewhat tight, circular pattern. Again, the power balance is the greatest difficulty, since the ship must be able to store enough energy to remain at its station throughout the night. American company AeroVironment has the most advanced ship of this kind, with a projected wing span of 75 meters for its Helios aircraft (Fig. 6). its Pathfinder and Centurion programmes19 (Fig. 6) have already shown flying endurance experiments at an altitude of 25 kilometers (80 thousand feet). These programs, which were originally funded by NASA, aim to achieve long-term operation for commercial communications and other purposes.

The European Commission's Framework V program is supporting the development of the solar-powered HeliPlat20 aircraft at the Politecnico di Torino in Italy as part of the HeliNet Project21,22. Broadband telecom- munication services, environmental monitoring, and vehicle localization are just three of the numerous topics HeliNet is investigating. A full-scale prototype aircraft is also in the works. Broadband communications are being spearheaded by York University23; a related piece in this issue24 provides further detail.

However, the HAP concept closest to market for communications at the moment is a manned aircraft with pilots working in shifts of 8 hours. The Proteus plane was built specifically for Angel Technologies' HALO project25.

Fig. 5 Lindstrand HAP concept (Courtesy of Milk Design and LindstrandBalloons Ltd.[15])

(Fig. 7) operating at altitudes of 16–18km (51000–60000ft) to deliver

Providing high-speed Internet access to a radius of 40 kilometers or more. The plane will stay relatively still when flying in a circle with a diameter of less than 13 kilometers. An under-fuselage pod with as many as 125 microwave antennae is used for the communications payload. The aircraft has a long track record of success, thus this option might be seen as low risk; nonetheless, the aircraft's eventual commercial success will rely on the economics of operating.

Other airplanes in the sky

UAVs, or unmanned aerial vehicles, are another kind of airborne platform. Fueled unmanned aircraft of this size often have limited mission times and fly at relatively low altitudes. UAVs are mostly used for

Fig. 6 Helios. AeroVironment's craft has a wing span of 75 m and aims to operate up at 100 000 ft under solar power (Photo: NASA Dryden/Tom Tschida)

monitoring by the military, with some smaller aircraft being seen essentially as expendable. Because of their limited flight time, unmanned aerial vehicles (UAVs) have found limited use as communication relay nodes. Larger military UAVs like the Global Hawk26 and Predator27 (Fig. 8) can carry heavy cargo and travel great distances, but they have not been widely adopted as a cost-effective means of providing routine communications.

The tethered aerostat is the most accessible and simplest sort of aerial platform. A cable as long as five kilometers might support this airship. While tethering helps with the larger issue of station-keeping, a movable platform is still a challenge. The cable might also serve as a power source and a communications backhaul link. The obvious difficulty is the threat posed to air traffic; yet, certain aerostats are already being used in airplane exclusion zones, suggesting that their widespread use may be better suited to less developed locations. A significant flow

Platforms Wireless International is working on a scheme to create a tethered aerostat that may be used in Brazil at an altitude of 4•6 km (15000ft)28 to provide wireless internet access to the country. More than 125,000 customers are expected to benefit from the company's efforts to provide cellular communication services through its ARC (Airborne Relay Communications) technology.

3 Communication applications

A typical communication setup inside a HAP is shown in Fig. 9. With uplinks and downlinks to user terminals and backhaul lines into the fiber backbone as needed, services may be delivered from a single HAP. Connecting a group of HAPs29 is possible by inter-HAP connections, and if necessary, a link may be built from the HAP itself using satellite technology.

At higher frequencies, line-of-sight propagation and minimum elevation have a larger role in determining a HAP's coverage area than any other factors.

Fig. 7 HALO Proteus aircraft. Note the pod for the payload underneath. (Courtesy of Angel Technologies Corp.)

Fig. 8 Predator, a military UAV (Courtesy of General Atomics Aeronautical Systems Inc.)

ground terminal angle of departure. While 15 degrees is often thought of as the minimum acceptable elevation for BWA services, a lower restriction of 5 degrees would be more realistic. However, for many service applications, for example to a city or suburban region, such vast coverage may not be necessary or desirable, since 5° indicates an area of c. 200 km radius or 120 000 km2 from 20 km height above smooth terrain.

This broad region may be partitioned into several smaller coverage zones, or cells, allowing for the optimization of total capacity using frequency reuse strategies. The antennas on the HAP may now be designed to decide the size, quantity, and form of these

cells, allowing for easier reconfiguration and adaptation to changing traffic needs. Adaptive resource allocation methods, which allow for effective use of bandwidth and maximum capacity, are especially well-suited to the HAP design.
Since the minimum spot-beam size from a satellite is limited by the available bandwidth, the cells may be much smaller than they would be with geostationary satellite services.

dimensions for an antenna board. Since the HAP is very near, the connection budget is considerably more favorable than with satellites, allowing for more capacity. This implies a power advantage of up to around 34 dB compared to a LEO satellite, or 66 dB compared to a GEO satellite. In addition, the connection design ensures that most impediments will be avoided, making a single HAP provide capacity similar to that offered by a large number of individual base-stations.

Uses for BWA
As was said above, B-FWA is considered to be the primary use case for HAPs because to the very high data rates it may be able to provide its users. HAPs have access to 2 300 MHz of bandwidth at 47/48 GHz, which might be split evenly between user and backhaul lines, and then again between up- and down-links. (An exception might be made if Internet traffic makes up a disproportionate share of the link's use.) Researchers have come up with a plan for global coverage based on the HeliNet scenario.

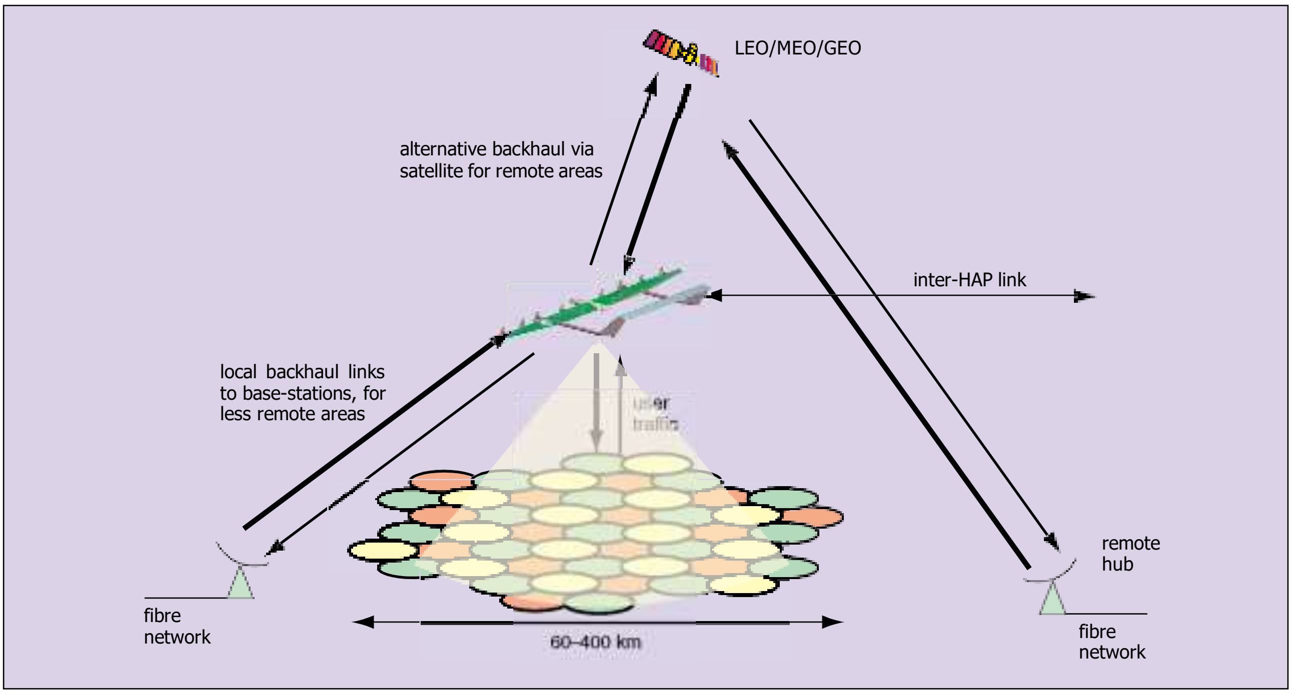


Fig. 9 HAP communications scenario

There are 121 cells in this HAP, and their nominal ground diameters range from 5 km24 to 60 km. Data speeds of up to 60 Mbit/s may be supported by the 1 W of downlink HAP power per cell, which is well within the per-cell bandwidth requirement of 25 MHz when using 16-QAM or higher order modulation methods. Although the HALO method boasts 100 Gbit/s25, the total payload throughput in this cautious demonstration sample is above 7 Gbit/s.
Since in theory what goes up must come down, it is clear that the backhaul criteria are just as demanding as the user connections themselves. Backhaul capacity must also be managed through a cellular system since no single wireless connection can deliver the required amount. Since the backhaul lines will be higher specification and handle larger capacity, with higher-order modulation methods, a number of dispersed backhaul ground-stations will be required, however this number may be far lower than the number of user cells serviced. Thankfully, these ground-stations may still be small and inconspicuous, and their position within the coverage area is non-critical; they will likely be installed on the tops of buildings.

Uses for 3G/2G Networks
The ITU has authorized the use of the IMT-2000 (3G) bands from HAPs, which might allow for the deployment of next-generation (3G) mobile cellular services or even current (2G) services30. With the right antenna, a single HAP base station may cover a large area, which may be preferable in less densely populated areas. Alternatively, directional antennas might be used to set up a cluster of smaller cells. Rapid deployment over a wide area, less interference on propagation channels, and a reduced need for ground stations would all be positive outcomes.

HAP systems
It is possible to cover a large area with a network of HAPs. Several HAPs are shown in Fig. 10 that are active in the UK. High-frequency electromagnetic-field (EMF) communications or optical links between HAPs are feasible options; these technologies are well-tested for use with satellites and should not cause significant issues.

Use in emerging economies
HAPs provide several possibilities for service provision in underdeveloped regions. Telephony, media, and data services are all examples of these. Where ground infrastructure is insufficient or is difficult to access, such services may be invaluable.

Useful in Cases of Emergencies or Disasters
In the case of a catastrophe (such as an earthquake or flood), HAPs may be quickly deployed to restore services and complement current infrastructure.

Rapid deployment is one of the most appealing features of HAPs for use in military communications.

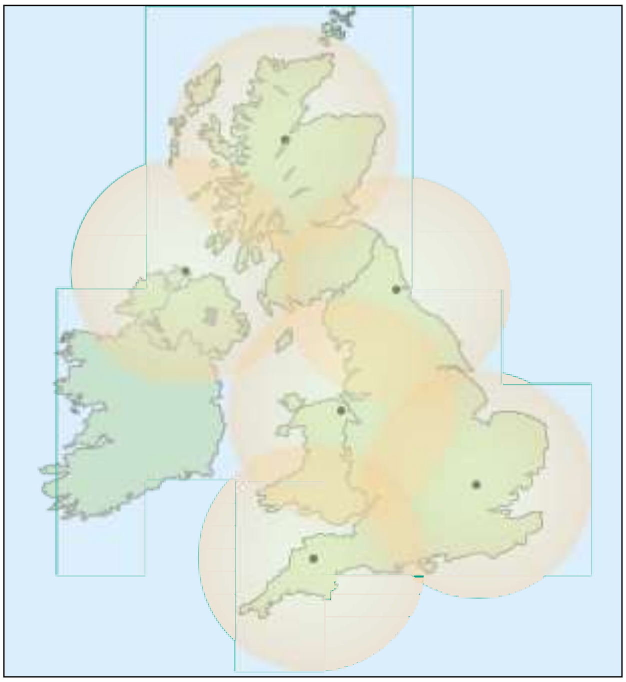


Fig. 10 Coverage of the UK with a network of HAPs(approxiately line-of-sight propagation)

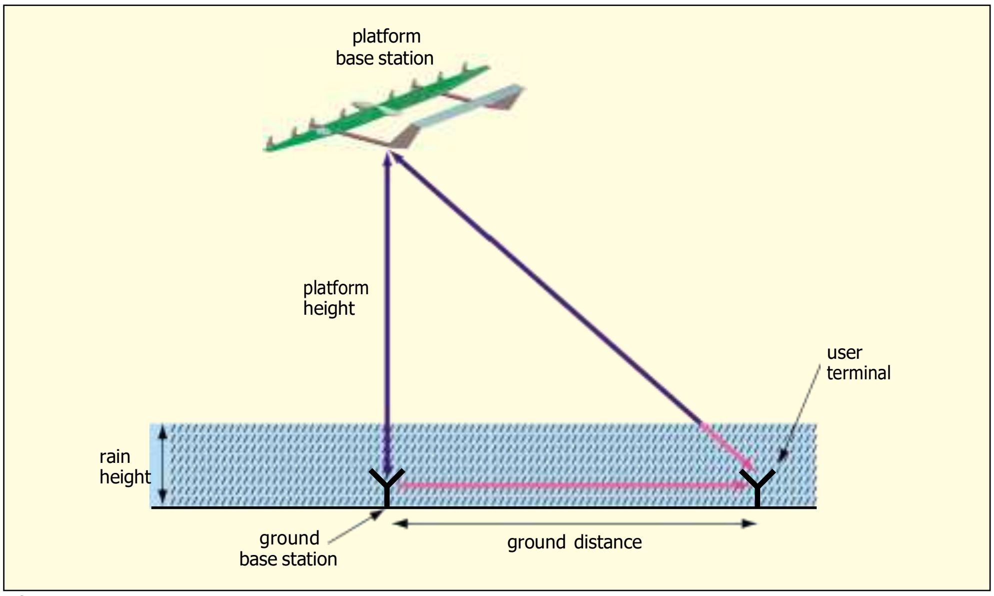
They may either function as nodes inside preexisting military wireless networks or as'surrogate' satellites, in which case they would contain a satellite payload and be used in conjunction with traditional satcom terminals. In addition to facilitating communication where none previously existed, the low transmit power requirements of such networks' ground terminals contribute to their increased LPI (Low Probability of Interception) benefits.
The full potential of airships as a communications tool within military situations has not yet been realized, and they are now mostly limited to usage at relatively low altitudes for mine clearing operations. Airship HAPs may seem susceptible to enemy assault, but they really have an advantage because to the fact that their envelope is mainly transparent to microwaves and they

display an exceptionally low radar cross-section, despite their massive size.

The Four Benefits of HAP Communications

The following is a brief summary of the possible advantages of HAP communications.
Widespread protection (in comparison to Earth-based alternatives). Due to the slanted route through the atmosphere, long-range connections incur less rain attenuation than terrestrial links over the same distance when HAPs are deployed. In large cells, this may improve the connection budget in the shorter millimeter-wave frequencies (Fig. 11).
Ability to adapt to changing traffic conditions. HAPs excel at providing centralized adjustable resource allocation, which allows for unrestricted cell sizes and frequency reuse patterns regardless of the location of base-stations. In this almost real-time

Fig. 11 Slant path in rain. The attenuated portion may be shorter from a HAP than from a terrestrial base-station.



When compared to conventional fixed terrestrial schemes or satellite systems, the total capacity should be considerably boosted by adaptation.
To a little extent. The operational costs of a small constellation of HAPs are unknown at this time, although they are expected to be far lower than those of a geostationary satellite or a constellation of LEO satellites. In addition, the cost of deploying a HAP network should be lower than that of deploying a terrestrial network with several base stations.
Rollout in stages. It is possible to start providing service with a single platform and then progressively extend the network when the need for more coverage and/or capacity arises. Instead of relying on a few number of LEO satellites to provide coverage, as is the case with a LEO satellite network, a terrestrial network will likely need a sizable number of base-stations before it can be considered completely functioning.

Instant action. With the right infrastructure in place, a new HAP-based service may be developed, tested, and launched rapidly. However, satellites often take many years from acquisition to launch to on-station operation, during which time the payload is frequently outdated.

launched. In a similar vein, deploying a terrestrial network may need lengthy civil works and planning processes. Providers that want to gain a head start on the competition might take use of HAPs to rapidly roll out their services.
There's also not much standing in the way of ready HAPs being launched and installed on-station in a matter of days or even hours. This makes them more accessible in times of need. When a terrestrial network fails, as in the case of a natural catastrophe or a military operation, or when there is a significant concentration of users, as in the case of a big event, the network might become overloaded.
Improving the platform and the payload. Some advocates have even suggested that HAPs may remain in place for as long as five years15. A favorable aspect that allows for a high degree of "future-proofing" is that they may be hauled down reasonably easily for maintenance or upgrading of the payload.
Safe for the planet. Solar energy is used to power HAPs, therefore there is no need for costly launch vehicles. They are an example of eco-friendly, reusable vessels that stand out from the

Table 1: Comparison of broadband terrestrial, HAP and satellite services: typical parameters

	Terrestrial (e.g. B-FWA)	HAP	LEO satellite (e.g. Teledesic[31])	GEO satellite
Station coverage (typical diameter)	<1km	up to 200km	>500km	up to global
Cell size (diameter)	0·1–1km	1–10km	c. 50km	400km minimum
Total service area	spot service	national/regional	global	quasi-global
Maximum transmission rate per user	155Mbit/s	25–155Mbit/s	<2Mbit/s up 64Mbit/s down	155Mbit/s
System deployment	several base stations before use	flexible	many satellites before use	flexible, but long lead time
Estimated cost of infrastructure	varies	$50million upwards?	c. $9billion	>$200million
In-service date	2000	2003–2008?	2005	1998

potential benefits of removing the need for large numbersof terrestrial masts and their associated infrastructure.
Table 1 summarises a comparison between terrestrial, HAP and satellite delivery for broadband services.

4 Some issues and challenges

Since HAP communications are so novel, they need certain untested ideas for service delivery (like B-FWA), which poses serious problems for progress. The platforms also have their own set of difficulties and issues that might arise.
Prerequisites at the system level. Developing HAP networks for broadband communication service delivery will center on the frequency planning of various spot beam layouts, which are subject to wide angular variations and changes in link length, as well as frequency reuse patterns for both user and backhaul links. To ensure connection, the network design must take use of inter-terminal switching that may take place on the HAP rather than on the ground and make use of inter-HAP links.
Distribution and variation. The ITU has designated the 47/48 GHz millimeter-wave channels (and the 28 GHz spectrum in ITU Region 3, which is mostly Asia) for use by HAP services. Because of the importance of rain attenuation in these higher frequency bands, developing statistics for rain attenuation and scattering is one of the major criteria for characterizing HAP propagation at these higher frequencies. Incorporating suitable margins and identifying issues with system-level frequency reuse plans will be made possible with this method. One crucial goal is to identify the place, time, and frequency diversification strategies that work well for various traffic profiles.

Coding and modulation. Broadband communications services need appropriate modulation and coding techniques to meet QoS (Quality of Service) and BER (Bit Error Rate) standards, applicable across a variety of connection circumstances, and hence maximize network capacity. When attenuation is strong, adaptive approaches will switch to low-rate schemes with robust forward error correction (FEC) coding, and when circumstances improve, they will switch to high-rate multilevel modulation schemes.
Protocols in networks and the distribution of resources. Since the HAP situation is fundamentally distinct from either a terrestrial or a satellite cellular scenario, new channel assignment and resource allocation techniques will need to be devised. The schemes need to consider the system architecture and the chosen modulation/coding scheme in addition to the multimedia traffic. To get things rolling, we'll choose a MAC and network protocols that perform best in the given situation. Broadband wireless access (BWA) services may employ a variant of the IEEE 802.16/ETSI BRAN standards. Careful preparation is also needed for integration with terrestrial and/or satellite architectures.
Antennas. BWA will rely heavily on antenna technology.

cause by HAPs. There will be a need for a high number of spot beams, which might be generated by a phased array or a collection of horn antennas. Intercell interference and, by extension, system capacity, are impacted by sidelobe performance. Both the HAP-based antenna and the ground terminals will need to be robust to support the technology at the desired frequency of 48 GHz.
Maintaining a steady position and a fixed platform. The success of communication services relies on a HAP's capacity to stably maintain position in the face of fluctuating winds, hence solving this problem is of paramount importance. HAP placement is probably best expressed as a likelihood of staying inside some bounded volume, like a location cylinder. There is an apparent incompatibility between the provision of communication services with conventional 'four nines' availability such as 99.99% and the HeliNet programme's example numbers of 99% and 99.9% platform uptime within defined geographical boundaries. Some fresh ideas are needed, maybe based on the use of a number of HAPs and diversity strategies.
The question of stability is also crucial. The platform will roll, pitch, and yaw owing to atmospheric turbulence; bigger ships will likely be more stable in this aspect. Mechanically stabilizing a sub-platform, which might add unnecessary weight to the HAP, or using electrical steering of an array antenna are both viable options for keeping the antenna pointed in the right direction. While the latter approach is promising, it is also technologically challenging, particularly in the millimeter-wave frequencies that are anticipated to be employed for broadband services.
Handoff. Multiple spot beams throughout the coverage area are proposed by most HAP designs, which may increase capacity by reusing frequencies. Handoffs may occur when the antenna beams shift due to platform motion in a BWA network design, although this will rely on the HAP stabilization procedures used. In contrast to more traditional mobile cellular methods, where user mobility is the only cause of handoff, this one doesn't rely on it. The frequency of these will be determined by the size of the

cells on the ground and the physical stability of the HAP antenna pointing. It's feasible that the HAP may employ stationary antennas and instead account for movement using speedy handoff operations. Future multimedia services (particularly video) may place more rigorous limits on the handoff process than do present 2G or 3G services, and this is an area of active investigation.
Do we need stationary or movable antennas on the ground? The horizontal and vertical positions of HAPs will fluctuate, with the latter perhaps being done on purpose to achieve optimal height for reducing prevailing winds. The need for either stationary or directional ground-based antennas may be gauged by measuring the look angle from the ground terminal as the vehicle moves. If the angular deviation is more than the antenna's beamwidth, which depends on the antenna's gain in order to

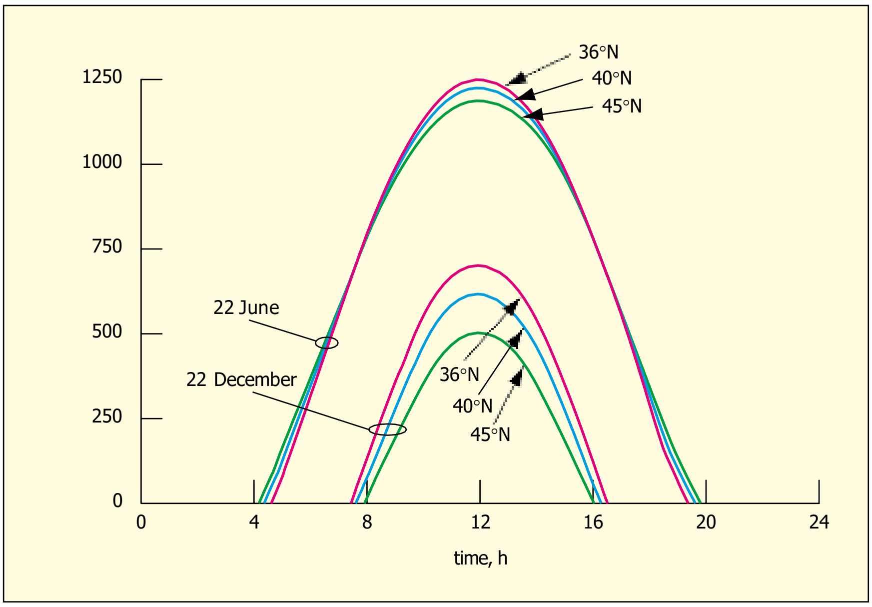


Fig. 12 Solar power flux on a HAP at a height of 17 km as a function ofseasonal extreme, time and latitude

square meter as a function of climatic extreme, solar zenith angle, and geographical location.

The Advanced Technologies Group has proposed using solar-powered airships in conjunction with diesel engines during times when station-keeping is difficult. Solar-powered aircraft technology, however, has a particularly severe power budget constraint; the amount of power available to the payload is limited by the size of the solar panels and the maximum allowable mass of the fuel cells.

5 The way forward

While it's true that some HAPs' ultimate aims are still a while off,

a ground terminal antenna that can be steered is required in order to run the connection. While the largest angular fluctuation occurs just below the HAP, bigger antenna beamwidths may be possible at this close range owing to favorable link budgets. Antennas towards the edge of coverage may be more sensitive to changes in altitude if they have a greater gain and, thus, a smaller beamwidth. Steerable antennas are more expensive to implement at the terminal, but they may be required for high link capacity.

Strength for the payload. The amount of accessible power to the payload is a key differentiator between the various HAP kinds. Due to the airship's vast surface area, solar cells may generate more than 20 kW of power, which can be used to power the cargo. Conventional fuel-powered aircraft (like Angel Technologies' HALO system) will also have access to substantial power. This constraint is comparable to that faced by satellites and will likely limit the maximum attainable downlink RF power and, by extension, the total capacity of solar-powered aircraft such as HeliPlat. Power output from solar panels, payload mass, and usable volume on the platform are all ways in which solar-powered aircraft are similar to communication satellites. Careful design of spot beams and antenna arrays, as well as implementation of power-efficient modulation and coding algorithms, will be essential.

Due to having to operate through lengthy periods of darkness each night, a HAP will need a larger percentage of the electricity to charge the batteries (fuel cells), especially on the shortest day (22nd December in the northern hemisphere). The shorter winter days and greater seasonal change in sun angle relative to solar panels will have a greater impact at higher latitudes. The fluctuation in incident solar power each day is seen in Fig.

that in the future, providing wireless services would rely more and more on aerial platforms. It's not so much a matter of 'if,' but 'when,' thanks to 'technology push' from platform providers and 'applications pull' from the unstoppable need for communications.

The HALO program and the PWI tethered aerostat project in Brazil are two examples of existing commercial aerial platform programs. Technology for airships and aircraft driven by solar energy is advancing quickly. The main problem is determining whether HAPs can offer the necessary grade-of-service, particularly in the face of variable winds at their operating height. Another concern is durability over time; whereas existing aerial devices have short lifespans, manufacturers predict on-station lives of five years or more.

However, these considerations must be weighed against the monetary value of the service and the ongoing operational expenses. In many deployments, a single HAP may not need to guarantee high link availability if diversity approaches are used or if '99•99%' service is not needed. The problem of HAPs living for a long period may be less pressing now that they may be brought back to Earth for upkeep.

The performance of energy storage like fuel cells seems to be one of the technological obstacles for makers of HAPs, whether solar-powered aircraft or airship, and there is substantial ongoing development in this field. Full-size HAP prototypes will need to be created and tested to persuade consumers and investors of their commercial feasibility; this is because not all aerodynamic, structural, and energy challenges scale linearly.

We should expect to see major advancements in HAPs for communication service delivery over the next several years in light of the clear prospects for improved communication services presented in this study.

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