# How High-Altitude Platforms Can Supplement Existing Wireless Networks

**Edwin Popaja** (A paper written under the guidance of Prof. Raj Jain) Download

---

## Abstract

The number of devices that require a mobile internet connection is on pace to exceed our current networking capabilities. As expanding our infrastructure to meet the needs of massive device growth can be very costly and time-consuming, high-altitude platform systems (HAPS) provide a supplement to existing infrastructure. These systems have the advantages of satellite and ground-based communication while managing to avoid a few of the consequences of them. As other technologies improve, they can be added to expand the use cases of diversified network needs.

---

## Keywords

High Altitide Platforms, HAPS, IoT

---

## Table of Contents

# 1 Introduction

Our world is becoming more connected at a rapid pace, and it is becoming difficult for networking infrastructure to keep up with the ever-growing demand. Recent advancements in 5G and Internet of Things (IoT) have allowed for large gains in data transfer speeds and reducing latency. These leaps in throughput, however, only apply to very close-range spaces. 5G frequency waves have difficulty penetrating through walls, rain, and even oxygen molecules. This requires several antennas to be placed near each other to cover a small region, which creates a large initial implementation cost.

IoT protocols operate at an even closer range with the intent of connecting several small devices to each other. The IoT industry has been growing at a rapid pace which leads to devices that had never been a part of the mobile network to join and increase strain on the network. While we are approaching a number of mobile devices that equals the earth's population, this one-to-one relationship will the overshadowed by the number of personal IoT devices. One person may have a mobile device accompanied by a smart watch, Bluetooth headphones, smart thermostat, etc. Ericsson and the Radicati Group have estimated that there a little over 7 billion smart phones in operation. According to iot-analytics, there are currently over 12 billion IoT devices connected, with a projection of 27 billion by 2025. This large influx of IoT devices has potential to revolutionize countless different applications, however, it would be severely restricted by the existing terrestrial base station networking system currently in place. Expanding these networking base stations to cover the expected demand is costly and therefore not financially viable in many situations and locations.

High-altitude platforms provide a viable solution to the problem above, as well as a variety of other use cases. The intensive demand placed on edge servers by IoT could be eased by integrating them into the HAP network. As supplements to terrestrial base stations, these high-altitude platforms provide additional throughput to regions in need in a more dynamic manner. As these systems can be quickly deployed, they can be used to respond to situations as needed, filling in for use cases that do not warrant the investment of ground based fixed lines.

Advancements in several other fields are increasing the appeal of HAPS as well. The networks can take the shape of stationary or self-propelled vehicles, both of which have made large strides in recent years. The developments in autonomous vehicles are allowing these mobile network stations to be more robust than ever before. Solar panel and battery technology have become more efficient and cheaper to produce, allowing them to create vehicles that can remain airborne for months at a time. The combination of these advancements allows for longer flight endurance, wider service coverage, and increases flexibility of deployment. High altitude networks will prove to be an important component in the dynamic needs of our connected future.

# 2 What is a HAP?

High altitude platforms are quasi stationary airborne platforms that act as a node in a greater networking infrastructure. They have unique advantages over other layers of the mobile network such as ground based stations, unmanned aerial vehicles (UAVs), and satellites. HAPs may come in two different vessels, self-propelled and buoyant. There are multiple different networking architectures that could be applied to each form of aircraft to cater to the unique demands of our world's dynamic networking needs.

## 2.1 How HAPs Work

HAPS are radio-based communication systems that utilize aircraft with onboard antennas to provide mobile communications to the ground area below. These aircraft are also referred to as stratospheric satellites as they are located 20 km in the atmosphere. Being at this altitude provides several strengths over other forms of networking infrastructure. It allows for a unique combination of quick deployment, large area coverage, and low latency. HAPs networks provide the benefits of each UAVs, satellites, and ground-based stations.

Firstly, the high operating altitude provides a much larger surface area of coverage compared to UAVs. The area covered can be reconfigured to suit the needs of the specific application but may cover up to a 200 km radius. A small number of HAPs could be grouped together provide supplemental connectivity to entire countries. For example, at only a 10° elevation angle, only 16 HAPs would be required to cover all of Japan and its 120 million inhabitants. UAVs also have disadvantage of operating in commercial airspace. Each regional government has a defined airspace that is strictly regulated. A UAV network would have to comply with not only telecommunication regulations, but also aviation requirements. HAPs networks operate well above commercial airspace and does not require the cooperation of local government bodies to operate.

Next, satellites can provide connectivity to a large are as well but have several drawbacks. Satellites may be broken up into two different categories, low earth orbit and geostationary. LEOs operate at around 500-2,000 km in altitude which allows for the benefit of a reduced latency delay. However, these satellites travel at a very high-speed forcing the need to launch multiple satellites to cover one fixed area continuously. Moreover, this increases complexity as you need to have sophisticated hand over algorithms to pass the data along to the next node when the satellite is no longer in range. Geostationary satellites can resolve the handover issue by operating at an altitude of 35,000 km. This altitude can allow for the satellite to match the rotation of the earth remain in a fixed position relative to a viewer on the ground. Simplifying the continuous coverage comes at the cost of a sharp increase in latency time. GEO satellites can be 10 times slower than LEO, which limits the capabilities for bidirectional communication. Full latency comparisons between each application can be seen in Figure 1. HAPs can provide the latency gains of a LEO while maintaining the continuous coverage like a GEO. Working at a lower altitude than either satellite also allows for significantly lower transmission power requirements.

Lastly, ground based stations provide reliable communications to fixed regions but with a very long deployment time. Creating the infrastructure is an expensive and time-consuming process.

The adaptation of a new generation of cellular technology, such as 5G, takes several years to implement. Telecommunications companies must invest heavily in upgrading physical infrastructure around a large area to provide these upgrades. HAPs can provide much quicker initial deployment as well as generational upgrades. These high-altitude aircraft can be launched from any airfield and immediately begin operation.

| | | Satellite for global coverage | Timer per orbit (Hours) | Time in site per gateway | Latency: RTT (ms) | Mass (Kg) | Lifetime (years) |
|---|---|---|---|---|---|---|---|
| Global Coverage | GEO | 3 | 24 | Always | 600/700 | ~3500 | 15 |
| | MEO | 10-30 | 5-12 | 2-4 Hours | <150 | ~700 | 12 |
| | LEO | 100+ | 1.5 | 15 Minutes | <50 | 5-1000 | <5-7 |
| Spotted/ Regional Coverage | HAPS | 1 aircraft ~ 12 731 Km² (70 Km radius assumed in this paper) | | Always | <10 | < 320 (Balloon) <100 (Aircraft) | > 5 (Balloon) > 8 (Aircraft) |

Figure 1: Satellite Characteristicss Comparison[GSMA22].

## 2.2 HAP Vehicle Classifications

HAPs can be divided into aerodynamic and aerostatic classifications. These classifications are also referred to as being heavier than air (HLA) and lighter than air (LTA). The former is to describe aircraft that require their own form of onboard propulsion in order to remain operational. LTA vehicles take advantage of buoyancy to remain in flight. The harsh environment at this altitude creates several new variables that the aircraft need to account for such as air density, weather patterns, temperature, and specific lift. Maintaining flight at a 20 km altitude introduces a new set of challenges and opportunities that each classification handles differently.

First, fixed wing propulsion aircraft have the advantage of being at a targeted location with high precision. These vehicles are able to respond to changes quickly and relocate as necessary. However, doing so at such an altitude differs greatly from flying at sea level. The air density at 20 km can be around 7% of the air density at sea level. Generating lift with such a reduction in air density requires the plane to scale up its wings to account for the difference. The wings of a fixed wing HAPs can be up to 60 meters in width, limiting the number of airfields that can accommodate an aircraft of that size. Scaling up in size subsequently creates the demand for a more powerful propulsion system to handle the added weight of the larger wing size, increasing energy costs.

However, recent innovations have helped tackle this issue and turn it into an advantage. Being at this height means that the aircraft is above most weather formations, allowing for constant access to the sun's energy. The massive gains in solar panel technology are making it feasible to have lightweight solar powered aircraft. The increased wing size required to generate lift now allows for a greater surface area for solar panels to be placed. As battery technology also makes strides, the energy generated through the day can be stored and accessed at night. Fixed wing HAPs have the ability to provide mobile connections to regions dynamically for extended periods of time, all while generating zero emissions.

Next, LTA aircraft provide a different set of advantages that can complement the use cases of HTA aircraft. Having an aircraft that does not require a propulsion system greatly reduces weight and simplifies the device. LTAs can therefore carry much larger cargo capacities than their more mobile counterparts. Having a stationary aircraft also greatly reduces energy consumption. The lack of air density creates the same problems for buoyant aircraft as they do for fixed wing. The hull size of an airship must be over twice the size of a traditional airship to compensate for the increased altitude. Increasing the hull size by this factor makes them more difficult to operate when launching and recovering the large aircraft. LTAs must be light enough to remain buoyant while having enough structural rigidity to remain intact during its ascent through potentially difficult wind conditions before it reaches its calmer destination at altitude. These airships must also consider the different atmospheric conditions that exist between different latitudes. The stratosphere begins at around 18 km at the equator but at 7 km when near the earth's poles. As the LTAs are less maneuverable, they are more prone to the different flying dynamics that exist at different latitudes

## 2.3 Different Implementations of HAPs

HAPs currently have several different allocated frequency bands for use. In 2019, the world radio congress allocated three bands for HAPs, 21.4-22 GHz, 24.25-27.5 GHz, and 38-39.5 GHz. The first two frequencies were allocated for use in the Americas and several Pacific islands. The last frequency band was allocated worldwide to facilitate 5G implementation. However, the technology is still in its infancy and optimal global standards are still being investigated. The Taif University in Saudi Arabia has done extensive research on the most effective frequencies for each use case. Their research shows that the 28 and 39 GHz frequencies, with BPSK and QPSK modulation, are most effective for HAPs communicating with other airborne nodes. The millimeter wave of these bands has a large attenuation rate when traveling through clouds and is most useful when communicating to airplanes or other HAPs nodes. These frequencies allow for a 3 Gbps data transmission rate at a 400 MHz bandwidth with an error rate of 10^(-13). When communicating with ground-based stations, they have discovered that 3.5 GHz can be used at a 100 MHz channel to deliver 773 Mbps reliably.

HAPs can have wide variety of techniques and architectures. Beamforming is a signal processing technique that is most frequently used for HAP systems. This technique focus signal in a specific direction rather than having it spread in all directions. The result is a direct connection that is faster and more reliable than traditional antennas. Modern smart beamforming technology can be used to allow for spatial beamforming that can reduce interference in a particular direction. An array of transmitting or receiving transducers can control the sensitivity or directionality of a frequency pattern. For example, when receiving a signal, beamforming can amplify the sensitivity from that direction to reduce noise and interference from the other directions. Conversely, it may do the same when transmitting and increase the power in the direction that the signal will be sent in.

Now that the frequencies and techniques have been specified, there are a couple architectures that can be used. An architecture is the logical layout between different nodes in the network. First, there is the ring-shaped cell clustering. This architecture resembles the ground based cellular approach. Land areas are divided into circular rings called cells. This architecture simplifies hand off procedures as each cell has a small number of neighbors. Cell scanning is another architecture in which a beam will scan each cell at an interval of time. When data needs to be sent, it will be added to a buffer and transmitted when the beam reaches the correct destination cell. More than one beam can be used in this architecture to speed up data transmission. Next, there is the stratospheric radio relay. In this architecture, HAPs would be placed over maritime routes to provide better connections while at sea. The HAPs would be used as another node to relay messages to existing infrastructure.

The last segment in organizing a HAP network is choosing a topology. Topologies define the physical arrangement of nodes in a network. A clustered topology allows for a grouping of cells on the ground to communicate to a local cluster head. This cluster head will then communicate to a HAP. The alternative is to have each end node communicate to the HAP directly in what is called a non-clustered topology.

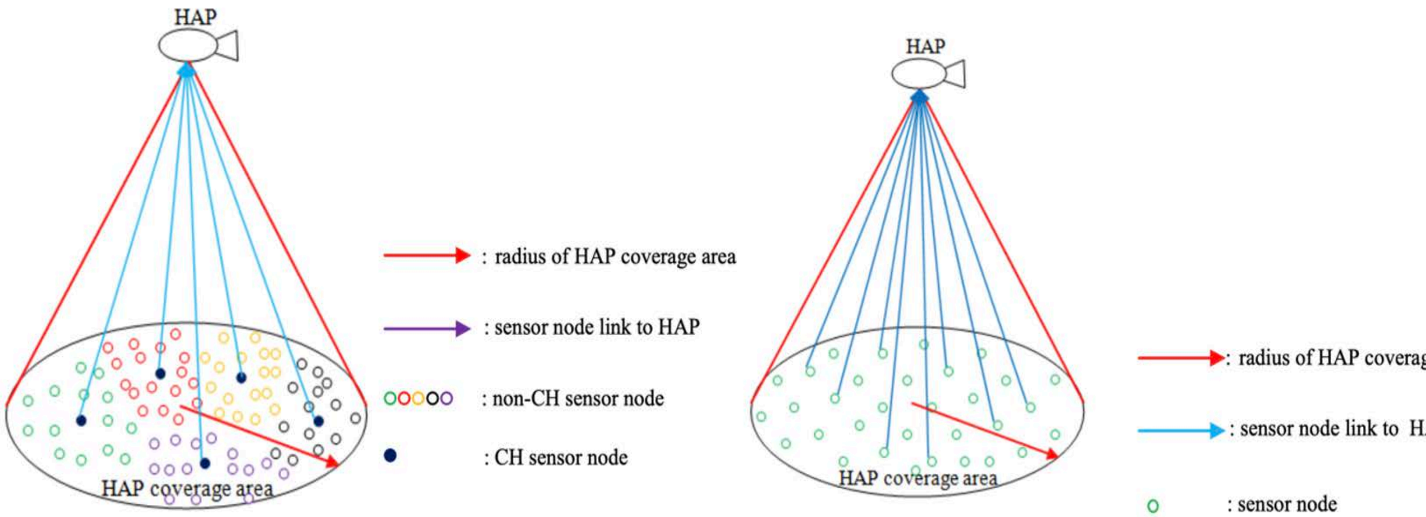


Figure 2: Clustered vs Non-Clustered Topologies[GSMA22].

HAPs can come in many different types of aircraft, frequencies, architectures, and topologies. Any combination of these configurations can be used to create a custom solution and allow for versatile responses to our networking needs. These networks have unique benefits over other infrastructures and allow them to fill several different gaps in our existing networking system.

# 3 Benefits of Using HAPs

HAPs are mobile and versatile which allows them to fill certain networking roles easier than traditional systems. Its mobility allows them to be implemented in situations that require a temporary boost in data transmission capacity. HAPs could also be used as a cost-effective method of connecting remote regions that do not have the financial viability of developing long term fixed terrestrial infrastructure. These agile networks provide a case for easing the networking load that will be created by massive adoption of IoT devices in the coming future as well.

## 3.1 Temporary Broadband Applications

HAPs provide the advantage of being mobile and able to respond to our ever-changing world. They provide a viable solution for situations that require short term or emergency networking needs, for example, after a natural disaster. Natural events such as wildfires or floods can devastate networking infrastructure and bring down communications when they are needed the most. HAPs can be quickly deployed in these times of need to help facilitate recovery after a disaster. A reliable communication can be crucial when emergency teams are coordinating efforts for search and rescue missions after a disaster. This reliable connection could also be used to help restore other critical system such as water or energy supply.

In addition to supporting networking infrastructure when ground stations are damaged, they can also support existing infrastructure when demand surges past existing capacity. For example, large tourist attractions or events can bring hundreds of thousands of people together in proximity for a short period of time. This large influx of people can easily overwhelm the network and reduce capabilities for each user. Again, HAPs could be quickly deployed to alleviate the demand temporarily. HAPs have the potential to complement existing satellite networks by cooperating with them in what is called backhauling. Backhauling allows HAPs nodes to become an intermediate between a ground and satellite receiver. This two-step system introduces another hop in the communication in which there is a connection between a satellite and HAP, and then gets carried down to the end node on the ground. This would allow for a very high-speed communication between the satellite and HAP node as there is less signal attenuation in the step. It can then repeat this step down to the ground node using a higher frequency than what would be traditionally capable from a direct connection between a satellite and a ground receiver.

## 3.2 Fixed Broadband Applications

Although most of the population has mobile coverage, the remaining uncovered regions are the most difficult to connect. Many remote and rural regions do not have the population density to justify the financial cost of laying down ground-based infrastructure to deliver fixed wireless access. As HAPs become more cost effective, they would deliver the stable connection speeds to replace ground-based stations. HAPs could help bridge the digital divide between those with access and those without. Not only could it help bring underdeveloped regions up to speed in mobile connectivity, but they could also fill in white spots in developed regions as well. HAPs could be deployed to fill in smaller gaps that are left without signal, usually caused by terrain blockages. Rural regions being connected can open other niche use cases as well, such as environmental monitoring. Environmental agencies can use sensors in extremely remote areas to track pollution, temperature, humidity, and more to monitor climate change. Farmers could have several small devices that monitor water levels, soil nutrition levels, and track other long terms patterns constantly with a live feed of information over a large area. These small, connected devices come together to create what is called the internet of things.

## 3.3 Iot

The internet of things promises to revolutionize countless industries by adding connection capabilities to small devices. The interconnection of these devices can optimize processes, lower costs, and generate new data streams. These data streams can be processed to extract new information, but crucially, they are not processed locally. These small devices need to transfer their data to clouds for computing. A large influx of network traffic could overload terrestrial capabilities and severely degrade the network connection. In this application, HAPs could be used to complement existing infrastructure and offload some of the workload. It has the potential to be more efficient and reliable as well. Cellular networks operate in smaller areas that require many handoffs between nodes. As HAPs operate over much larger regions, this could significantly reduce the number of hand offs which would increase reliability. Moreover, when many devices are making data requests at the same time, this introduces in increase in contention for access to the limited resources. As a result, the latency will increase significantly. HAPs would alleviate this demand and keep IoT devices operating at the low latency they require. This combination of benefits also proves useful mobile applications such as autonomous vehicles, UAV communications, and even drones. To achieve these ideal implementations, edge computing servers would need to be migrated into HAP networks.

HAP networks are versatile, quick to deploy, and cost effective. Temporary networking capacity can be increased through HAPs, as demand for data transmission capacity changes. Rural regions can benefit greatly from a quick and cheap deployment to help bring fixed broadband connection to underserviced regions. HAPs can also be used in a predictive manner to help ease the network intensive adoption of IoT devices in the future as well.

---

# 4 Limitations

Although HAPs networks promise great functionality and support, there are still some potential issues that need to be worked out before widespread adoption is possible.

## 4.1 Interference

Although a few governing bodies have allocated certain frequency bands for HAP devices, there is still not a global standard. Many governments have different allocated spaces for existing technologies. For example, the 60 GHz bands differ between countries. The United States allows for public use of the 57-71 GHz band while Japan allows a narrower 57-66 GHz. Devices manufactured for the US market may not be allowed to operate in Japan. HAPs may operate over several different country borders which requires the cooperation of each. It may be difficult for countries to come together and create a common frequency as there is limited space available.

Interference between frequencies already in use is the next potential issue. Although there are many different forms of modulation and beamforming to mitigate interference, it is still a limitation to widespread adoption. Several of the frequencies that HAPs could use would be shared with other existing infrastructures. Many of the simulations and trials of HAP implementation have been very isolated to prove its initial concept of communicating from an aircraft at the 20 km altitude range. These initial tests have shown successful communication but has yet to test implementations that are integrated with other networking systems. It is important to make sure the next step is to test HAP capability when in a dense urban environment that may introduce more interference or building penetration challenges.

Millimeter frequency bands have poor indoor penetration as they have a high attenuation rate. As HAPs operate high up in the atmosphere, they create an angle when beaming down to the edges of its conical coverage. This angle is more likely to interfere with buildings and reduce its effectiveness at the edges of its range. There is still no good solution for HAPs networks to penetrate to indoor locations. Further research needs to be done to mitigate the fading that occurs at millimeter wavelengths. To help overcome the fading and interfering issues, advancements in modulation and coding channels could be investigated to further improve communication efficiency.

## 4.2 Hardware Challenges

Although many of these concepts work in simulated environments, more real-world tests are still needed to work out the fine details. Google's HAP balloon project in 2019, named Loon, identified several key aspects that require more technological advancements. The test was concluded after 312 days in operation, a massive leap over Airbus's Zephyr HAP that only lasted 26 days. This tenfold increase in operation time is impressive, but only a fraction of time that researchers have expected. Many have theorized that with renewable energy, these aircraft could remain airborne for several years at a time. The main limitations from this becoming a reality is the material sciences in the solar panel technology, battery, and hull design. High strength and lightweight materials that are required to make these aircraft possible are not currently at a price point that would be financially viable. Moreover, battery technology does not contain the energy density or come in a package that is light enough to meet the requirements of long term sustained HAP operation. Google shut down the Loon project in 2021 without achieving commercial success. It is important that Loon proved technical success and that many of the theories that were researched were able to be applied in the real world. As material sciences and battery technology improve, there is a use case for HAPs and that they will become more commercially viable over time. Beginning with urban applications to ease surges in demand could be the first commercial success as the population density would make it the first feasible application. As more progress is made in the industry, the price point of manufacturing and operating HAPs will decrease enough to cover extremely remote and rural regions of the world.

Solara 50 is another Google project that was launched in 2015. In this project, they used an unmanned fixed wing propeller aircraft to test HAP internet drones. As stated previously, these aircraft must have large wingspans to generate enough lift to maintain flight. These aircraft are designed to be as light and thin as possible to increase efficiency in its ideal operating environment. While the atmosphere at the operating ceiling is calm, ascending to that altitude may include flying through difficult patches of unpredictable weather. It is difficult to design an aircraft that can balance the needs of being rigid enough to maintain rigidity during launch and recovery, while also being light and efficient enough to carry out its networking tasks. Solara 50 experienced these challenges firsthand. During a test flight, Solara 50 was hit by a sudden burst of wind that hit the wing vertically. The result was the left wing experiencing a failure which deemed the aircraft uncontrollable. The aircraft had an erratic flight path and eventually crashed after only being in the air for 4 minutes.

## 4.3 Outlooks and Future Developments

Despite its current signal and physical design limitations, HAPs are a still a promising technology that may solve many networking issues. HAPs are still in its infancy in terms of research and applications but still contain many interesting ideas for future implementations. Unmanned aerial vehicles have been a popular area of research recently, although, it has mostly been funded by defense applications. Soon these technologies will trickle down to the commercial sector and open new use cases for HAPs. A limiting factor in this application is the various safety issues posed by autonomous civil aircraft. These technologies will need to be deeply vetted by aviation regulation bodies but is in the works.

---

# 5 Summary

HAPs provide unique benefits over other forms of networking infrastructure. It allows them to fulfill certain gaps in connectivity coverage that are left behind by traditional ground stations and satellites. They manage to provide the large geographic coverage of satellites while maintaining the low latency of ground-based stations. It manages to combine these benefits while also being quicker to deploy and modular. This allows HAP networks to be dynamic and respond to changes in demand which may prove crucial in emergency situations. Although still in its infancy, HAPs have shown quick developmental progress and are on a trajectory of widescale adoption in the future. HAPs may be the solution to the bottlenecks that would come with a large influx of connected devices as IoT becomes increasingly adopted.

---

# 6 References


- [Arum20] Steve Arum, “A review of wireless communication using high-altitude platforms for extended coverage and capacity” 2020. 1 May 2020 https://eprints.whiterose.ac.uk/159534/

- [Ke21] Malong Ke, "An Edge Computing Paradigm for Massive IoT Connectivity over High-Altitude Platform Networks" 2021. October 2021 https://ieeexplore-ieee-org.libproxy.wustl.edu/stamp/stamp.jsp?tp=&arnumber=9615110
- [Lin21] Zhi Lin, "Robust Multi-Objective Beamforming for Integrated Satellite and High-Altitude Platform Network With Imperfect Channel State Information" 2019. 15 December 2019 https://ieeexplore-ieee-org.libproxy.wustl.edu/stamp/stamp.jsp?tp=&arnumber=8892508&tag=1
- [Mahyastuty17] Veronica Windha Mahyastuty, "Wireless Sensor Network Exploiting High Altitude Platform in 5G Network" 2017. https://online.bpostel.com/index.php/bpostel/article/view/150105
- [Albagory21] Yasser Albagory, "An Adaptive Bidirectional Multibeam High-Altitude Platforms Aeronautical Telecommunication Network Using Dual Concentric Conical Arrays" 2021. 15 March 2021 https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9378524
- [Qiu19] Junfei Qiu, "Air-Ground Heterogeneous Networks For 5G and Beyond via Integrating High and Low Altitude Platforms" 2019. December 2019 https://ieeexplore-ieee-org.libproxy.wustl.edu/stamp/stamp.jsp?tp=&arnumber=8869712
- [Ahmadinejad22] Hosein Ahmadinejad, "Forming a Two-Tier Heterogeneous Air-Network via Combination of High and Low Altitude Platforms" 2022. February 2022 https://ieeexplore-ieee-org.libproxy.wustl.edu/stamp/stamp.jsp?tp=&arnumber=9645207
- [Guan21] Mingxiang Guan, "Research on anti-interference based on particle swarm optimization algorithm in high altitude platform stations" 2021. 8 November 2021 https://link-springer-com.libproxy.wustl.edu/content/pdf/10.1007/s11276-021-02851-4.pdf
- [GSMA21] "High Altitude Platform System – A point of view from the mobile operators" 2022. 27 February 2022 https://www.gsma.com/futurenetworks/latest-news/high-altitude-platform-system-a-point-of-view-from-the-mobile-operators/
- [Hasan22] Mohammad Hasan, "State of IoT 2022: Number of connected IoT devices growing 18% to 14.4 billion globally" 2022. 18 May 2022 https://iot-analytics.com/number-connected-iot-devices/
- [Turner22] Ash Turner, "November 2022 Mobile User Statistics: Discover the Number of Phones in the World & Smartphone Penetration by Country or Region" 2022, November 2022 https://www.bankmycell.com/blog/how-many-phones-are-in-the-world
- [Roston16] Brittany Roston, "Google's Solara 50 drone crash caused by wing failure" 2016, 29 Jan 2016 https://www.slashgear.com/googles-solara-50-drone-crash-caused-by-wing-failure-29424946?utm_campaign=clip
- [ITU22] "HAPS – High-altitude platform systems" 2022, April 2022 https://www.itu.int/en/mediacentre/backgrounders/Pages/High-altitude-platform-systems.aspx
- [Uppal21] Rajesh Uppal, "High Altitude Platforms (HAPs) for communications and persistent, wide area, real time Intelligence, Surveillance, and Reconnaissance (ISR)" 2022, 20 March 2022

https://idstch.com/space/high-altitude-platforms-haps-for-communications-and-persistent-wide-area-real-time-intelligence-surveillance-and-reconnaissance-isr/

- [Lee22] Ju-Hyung Lee, "Spectral-Efficient Network Design for High-Altitude Platform Station Networks with Mixed RF/FSO System" 2022, 9 September 2022 https://ieeexplore.ieee.org/document/9729099
- [GSMA22] "High Altitude Platform Systems Towers in the Skies" 2022, February 2022 https://www.gsma.com/futurenetworks/wp-content/uploads/2022/02/HAPS-Towers-in-the-skies-draft-v-2.1-clean.pdf

---

# 7 Acronyms

| | |
|---|---|
| HAP | High-Altitude Platform |
| HTA | Heavier Than Air |
| LTA | Lighter Than Air |
| IoT | Internet of Things |
| UAV | Unmanned Aerial Vehicle |
| GEO | Geostatic Earth Orbit |
| MEO | Middle Earth Orbit |
| LEO | Low Earth Orbital |
| BS | Base Station |

---

Last modified on December 7, 2022
This and other papers on recent advances in Wireless and Mobile Networking are available online at http://www.cse.wustl.edu/~jain/cse574-22/index.html
Back to Raj Jain's Home Page