

# Connecting Rural and Remote Populations through High-Altitude Platform Stations (HAPS)

The internet connectivity gap between rural and urban regions is wide: the International Telecommunication Union (ITU), an agency of the United Nations (UN), reported that two billion people who are mostly living in rural and remote regions of low-income countries, remain unconnected to the internet as of late 2025 [1]. A 2021 report by the ITU makes clear that reliable, high-speed internet is a valuable resource for addressing inequality and poverty worldwide, as it attracts investment into rural communities, increases sales opportunities for local businesses, enables online education and telemedicine, and provides youth employment opportunities [2]. Rural areas, however, often have difficult terrain and limited power infrastructure, giving telecommunications operators little incentive to build the dense terrestrial network infrastructure needed to cover large, sparsely populated regions. Satellite constellations already provide coverage over the entire globe, but they are limited in capacity and expensive to scale, making them unsuitable to connect the large number of underserved people [3]. Saunders and Aragón-Zavala along with Arum et al. identify an emerging technology that could close this connectivity gap: high altitude platform stations (HAPS), which are solar-powered, long-endurance aircraft that fly around a single point in the Earth's stratosphere at altitudes around 20 km [3, 4]. This paper argues that HAPS are better suited to close the rural connectivity gap over satellites and terrestrial networks because they offer wide, targeted coverage, are more cost-effective and easier to deploy than conventional network infrastructure, and depend less on road and power infrastructure.

Spread-out populations, limited ground infrastructure, and difficult terrain are the biggest challenges facing operators in rural regions. For example, the ITU found that operators in Zimbabwe must clear vegetation from roads several times a year to service terrestrial networks that reach only small populations. Many African countries also face high transmission-line construction costs because of the

large distances between optimal cell tower sites and the nearest reliable power line [2]. Consequently, each rural cell tower serves fewer paying customers while requiring high installation and servicing costs. This lack of reliable service slows development in agriculture, healthcare, and education, reinforcing existing inequalities [2].

This persistent lack of service cannot be ignored. The ITU has long described HAPS as, “an opportunity to close the information gap”: at around 20 km above the ground, a HAPS’s wide line of sight provides coverage of up to 200 km depending on the equipment, far more than a single cell tower but with limited dependence on ground infrastructure [3, 5]. Arum et al. report a useful cost comparison, though the authors caution that these estimates are simplified: a 30 km-radius area with 1 km-radius cell towers could require around 900 cell towers and cost about 151 million euros, while a HAPS is estimated at roughly 5 million euros for a solar plane or 34 million euros for an airship [4]. This makes HAPS more attractive because they reduce the cost of reaching populations spread out over large regions by shifting from hundreds of ground sites to a smaller number of aerial platforms.

Because most internet in rural areas come from mobile devices, the best rural solution is one that can provide mobile-compatible coverage across a large region [6]. Satellite constellations orbit the globe providing coverage to almost every place on Earth; however, most communicate through user terminals on the ground rather than directly with devices. Stiri et al. describe how Starlink, the largest satellite operator, provides terminals which are simple to deploy, requiring only standard electrical power and connecting devices in its immediate vicinity [7]. While satellite-based direct-to-device is emerging through operators such as AST SpaceMobile, it is not independent of terrestrial infrastructure in the vicinity of users: the company’s own explanation states that after a phone’s signal reaches the satellite, it is relayed to a ground station then routed into partner operator’s network [8]. In addition, the quick, moving orbits of satellites provide only a few minutes of connection time with a device on the ground [3]. Therefore, a constellation of thousands of satellites is needed to maintain continuous coverage,

which is an unattainable investment for telecom operators in low-income countries [2, 7]. Moreover, near-global coverage does not mean that every rural community can connect, as capacity is shared across the entire world rather than concentrated over a specific region, so aggregate demand can exceed what a constellation can serve at the same time [3, 7]. For this reason, Stiri et al. treat satellites as a complement to terrestrial networks rather than a replacement for rural infrastructure [7].

When it comes to HAPS, the direct-to-device connectivity and wide area coverage have already been demonstrated. In March 2025, Japan's largest mobile carrier, NTT Docomo, collaborated with HAPS manufacturer AALTO to conduct a connection test between mobile devices and a HAPS at 20 km. As shown in Figure 1, the network consisted of a single ground-based station carrying the main equipment and a HAPS acting as a relay for that station. Over a coverage area roughly 200 km across, the test

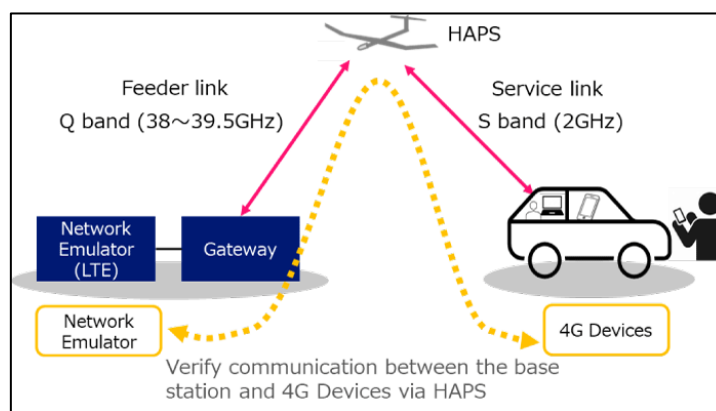


*Figure 1. Network configuration for the HAPS connectivity test with AALTO and NTT Docomo [9].*

achieved a throughput of 4.66 Mbps—enough for a high-definition video call—while replacing what would otherwise require a network of several dispersed cell towers with far smaller coverage [9]. NTT Docomo plans to begin commercial operations in 2026, covering remote, mountainous regions and improving the resilience of terrestrial networks during severe natural disasters in Japan. Arum et al. describe additional network configurations for next-generation HAPS that use solar-powered platforms without a ground station, reducing dependence on ground infrastructure [4].

Saunders and Aragón-Zavala explain how rain, snow, and atmospheric gases degrade connection quality by absorbing signals and scattering them in different directions. As a result, the reliability and coverage of all wireless networks are reduced during severe weather in the troposphere—the lowest layer of the atmosphere where we live—and the effect worsens the farther a signal propagates. As shown in Figure 2, this strongly affects satellite signals, which travel hundreds of kilometers through the atmosphere. Over these distances, the signal also diverges and is more easily blocked by local obstructions such as mountains and trees that often surround rural areas. However, the shorter propagation distance of

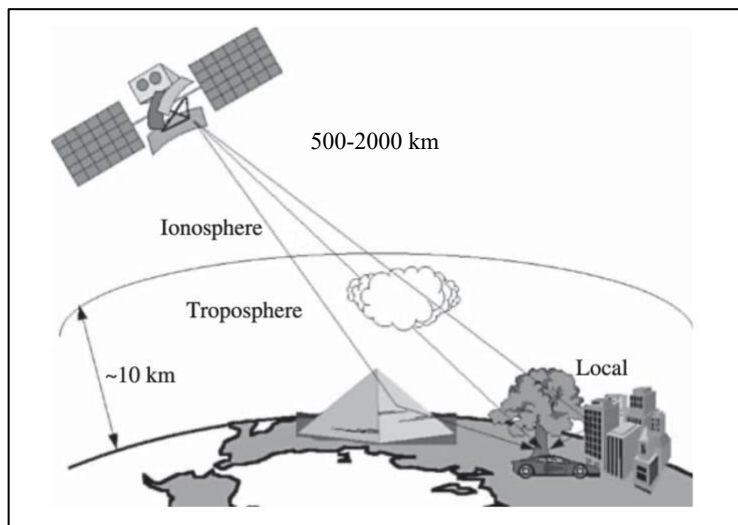


*Figure 2. Satellite signal propagation from the atmosphere to ground [3].*

HAPS, which station-keep at around 20 km, substantially reduces both effects [3]. Cell towers are affected by atmospheric absorption to a far lesser degree, but a severe storm or earthquake can cut power lines and topple cell towers, leaving both urban and rural areas without connectivity when residents need it the most: receiving regional alerts, calling for help, and navigating to safety [3, 4]. By contrast, HAPS are stationed far above tropospheric weather and have little dependence on ground infrastructure. Additionally, in the event of a disaster that disables terrestrial networks, a HAPS's ease of deployment over affected regions could restore temporary coverage and improve the resilience of existing networks [4].

Critics are correct that limited battery capacity constrains the equipment a HAPS can carry; however, they overstate things when they claim that this undermines HAPS coverage or endurance. Dörfler et al. explain that HAPS developers are turning to more energy-dense battery chemistries such as lithium-sulfur (Li-S) in place of the conventional lithium-ion (Li-ion) batteries. Higher energy density allows a platform to store more power using the same weight, extending both the reach of signals through higher power and the long periods of flight needed for long-lasting, wide-area coverage [10].

Out of all the available options for closing the rural connectivity gap, HAPS are best suited to reach the world's sparsely populated regions: they can be targeted to specific areas, are more cost-effective and simpler to deploy than conventional infrastructure, and depend far less on ground infrastructure that rural areas often lack. Terrestrial networks such as cell towers and cable networks are most effective where there are dense populations and reliable power such as in urban areas, but they face challenges with terrain and tropospheric weather, and are more costly to deploy, which is what HAPS are designed to overcome. On the other hand, satellites are a strong complement to terrestrial networks, but their shared global capacity and reliance on user terminals and ground stations limit their ability to provide targeted coverage to the large number of underserved, rural populations. Atmospheric effects reduce the reliability and coverage of all wireless systems during severe weather; however, HAPS station-keep far above severe weather, and are close enough to provide reliable connections while having little dependence on ground infrastructure that can be cut off during a disaster. Battery capacity is being actively improved through advances in lithium-sulfur battery chemistry, supporting the long endurance and wide coverage of platforms. As HAPS nears their first commercial deployments in 2026, the technology is positioned to fill the missing middle layer between cell towers and satellites and to connect the last two billion people.

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