

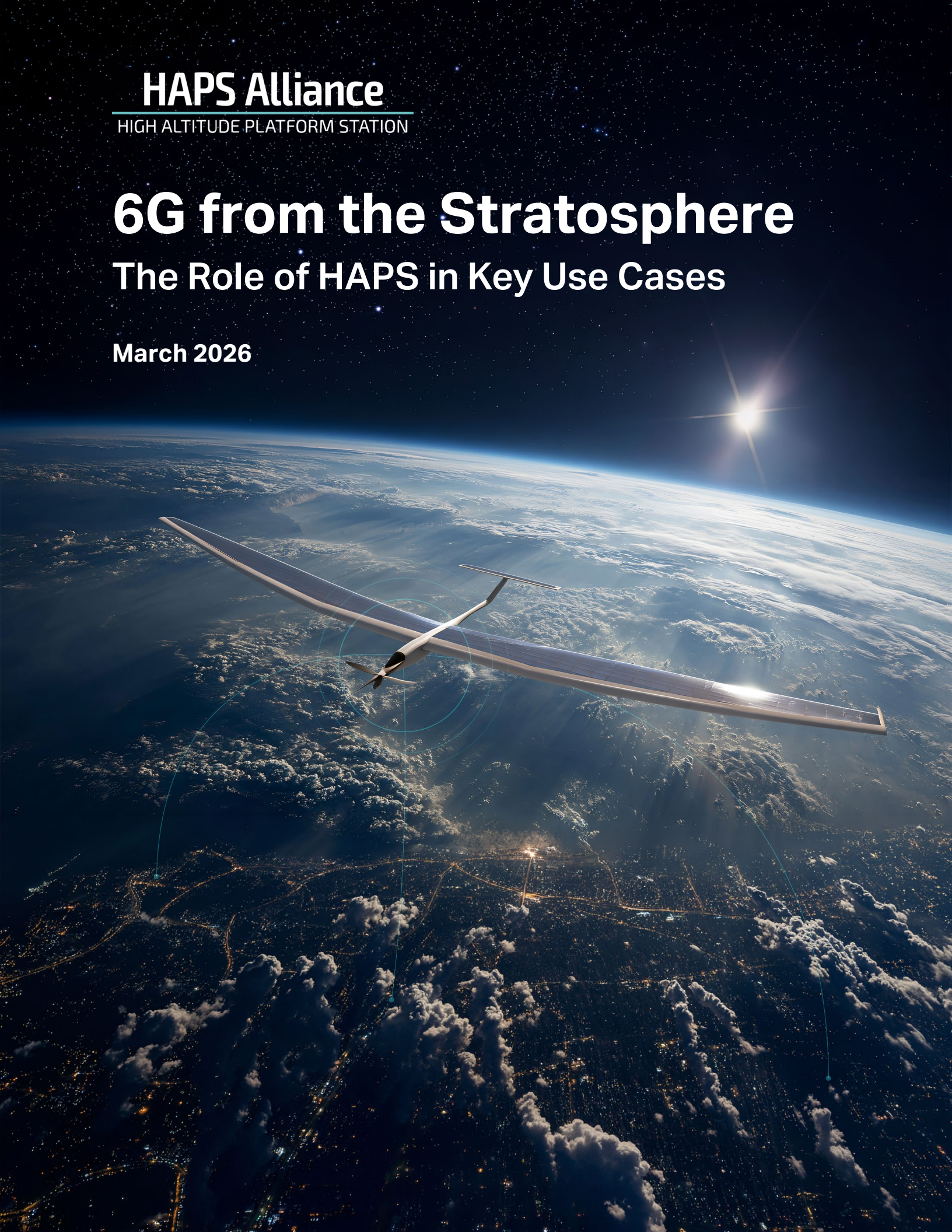
**HAPS Alliance**

HIGH ALTITUDE PLATFORM STATION

# 6G from the Stratosphere

## The Role of HAPS in Key Use Cases

March 2026



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## Executive Summary

This document outlines the transformative role of High Altitude Platform Stations (HAPS) and Non-Terrestrial Networks (NTNs) within the emerging 6G ecosystem. Positioned in the stratosphere (approx. 20 km altitude), HAPS serves as a critical bridge between terrestrial networks and satellites, creating a seamless, multi-layered architecture designed to achieve the “beyond-connectivity” goals of IMT-2030.

# 1. Introduction

The sixth-generation (6G) wireless networks aim to revolutionize connectivity by introducing a transformative beyond-connectivity paradigm that builds upon the foundations laid by previous generations. This vision goes beyond simply improving the broadband experience and supports novel use cases and applications that require stringent Key Performance Indicators (KPIs). The International Telecommunication Union (ITU) has outlined the capabilities of International Mobile Telecommunications for 2030 and beyond (IMT-2030), emphasizing key usage scenarios for future networks, as depicted in Figure. 1. Particularly, 6G aims to seamlessly merge the physical, digital, and biological worlds by creating a hyper-connected and intelligent global society through ultra-fast, low-latency, high-capacity wireless networks that support immersive applications, massive Internet of Things (IoT), and advanced Artificial Intelligence (AI). Achieving the ambitious objectives while ensuring an acceptable Quality of Experience (QoE) for consumers will necessitate the development and deployment of innovative technologies and network architectures.

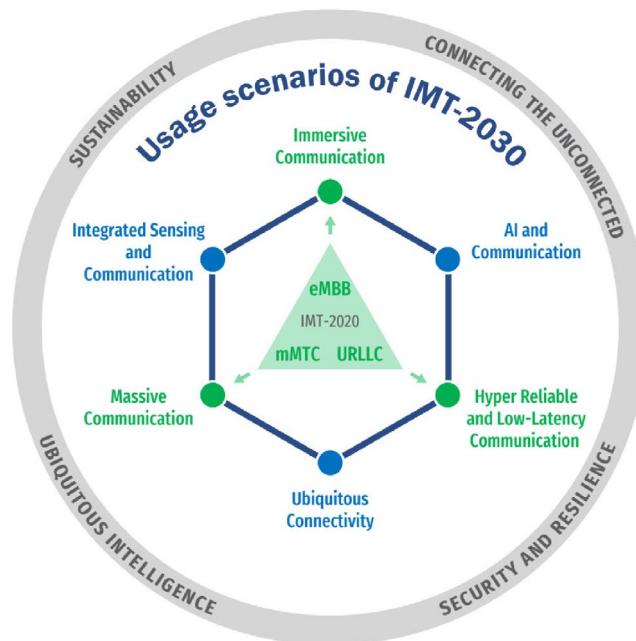


Figure. 1: IMT-2030 Capabilities [1]

The future 6G network will significantly improve performance and network operational efficiency by leveraging technological advancements in AI and advanced cloud computing infrastructure. In addition, unprecedented energy efficiency and sustainability across the entire spectrum of 6G operations will aim to achieve significant reductions in Total Cost of Ownership (TCO) and generate new revenue streams for network operators [2]. 6G in all considerations will be more than just a technical evolution from 5G/5G advanced, but will redefine connectivity in many profound ways. However, ensuring a smooth transition to and deployment of 6G necessitates careful consideration of interworking with 5G and 5G-Advanced, particularly to maintain backward compatibility and protect existing infrastructure investments.

A major enabler of ubiquitous connectivity in 6G will be the integration of Non-Terrestrial Networks (NTN), encompassing satellites, High Altitude Platform Stations (HAPS), and Uncrewed Aerial Vehicles (UAVs). Among these, HAPS is emerging as a critical component of the multi-layered 6G infrastructure, offering a flexible and rapidly deployable stratospheric layer that bridges terrestrial and satellite systems. HAPS is being positioned to contribute to the massive technical and operational shift in and implementation of 6G networks. By integrating HAPS with satellite and aerial systems as non-terrestrial infrastructure, this emerging hybrid or multi-layered network will ensure resilience and flexibility in the access layer. Moreover, AI-driven autonomy will enable the network to self-heal, adapt, and recover, significantly improving resilience and reliability. The technical and operational flexibility of HAPS will be essential in achieving the high reliability of the 6G access network infrastructure. The complementary role of HAPS in the NTN configuration, and by extension, the entire 6G connectivity fabric, is a dominant use case and a unique value proposition for the technology.

Ultimately, realizing the vision of a truly ubiquitous 6G society will depend on developing a multi-layered network architecture, in which the surface (terrestrial), stratospheric (HAPS), and space (satellite) layers operate in seamless coordination to deliver global, resilient, and intelligent connectivity.

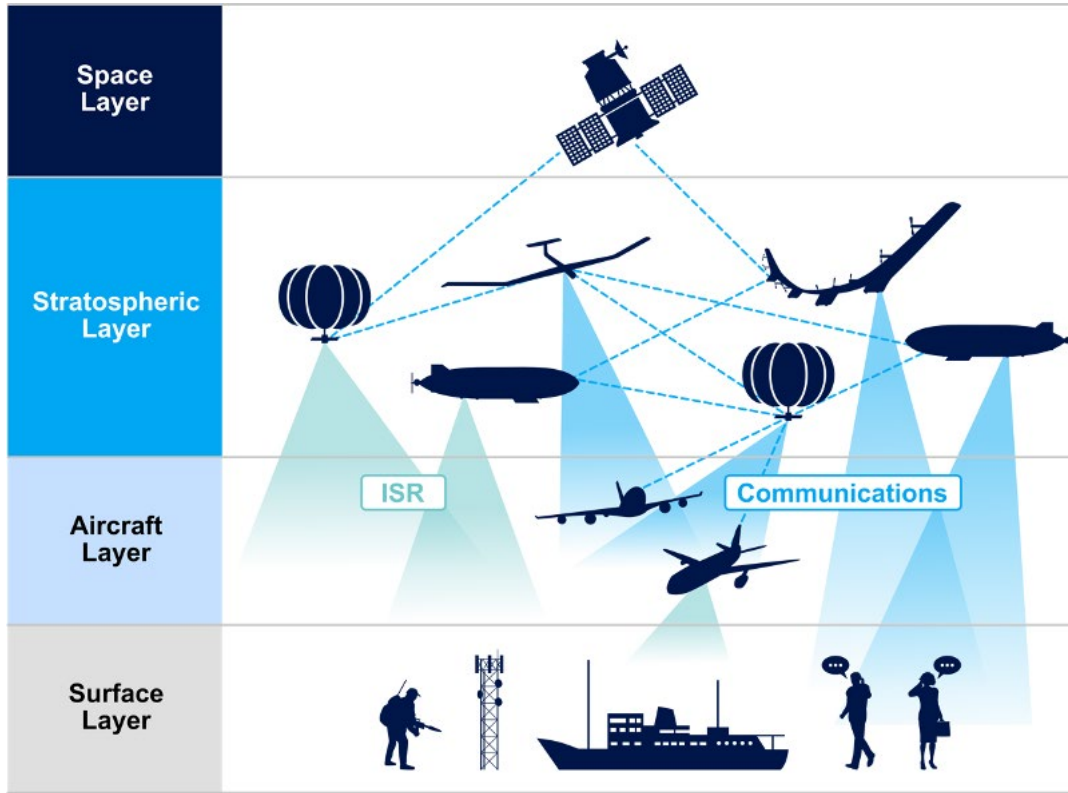


Figure. 2: Multi-layered network concept [3]

The multi-layered 6G architecture integrates three complementary domains, surface, stratospheric, and space, each offering distinct advantages and collectively enabling seamless global connectivity:

- The Surface Layer offers high-speed, high-capacity communication within the coverage regions of terrestrial networks.
- The Stratospheric Layer complements the terrestrial network by covering a wide area of 50-100 km per platform from the stratosphere. Positioned at a closer distance to the Earth compared to the satellites, the stratosphere can play a crucial role in rapidly restoring communication networks during natural disasters.
- The Space Layer ensures global connectivity by covering areas beyond the reach of HAPS and terrestrial networks, including oceans, deserts, and the sky.

This white paper outlines the critical role that HAPS plays within the integrated 6G network architecture in supporting the diverse use cases of the 6G era, along with specific technical requirements and advantages.

## 2. Non-Terrestrial Networks Role in 6G

The 6G mobile communication system aims to realize Ubiquitous Connectivity, extending beyond mere enhancements in communication speed to provide seamless connectivity in all environments, including the air, at sea, and in space. However, conventional Terrestrial Networks (TN) alone cannot fully cover areas where base station deployment is physically or economically challenging, such as mountainous regions, maritime areas, and airspace. The key to overcoming this coverage challenge and achieving a truly ubiquitous society with network resilience is the utilization of NTN, which leverages space satellites and HAPS. Integrated with TN, NTN will maintain communications during disasters and form the foundation for new industries such as autonomous driving, drones, and flying cars. This section clarifies the key technical requirements for NTN as an indispensable component of 6G networks, based on the 6G vision, IMT-2030, established by the ITU-R and ongoing discussions within the 3GPP Release 20 [4].

The following are the key roles of NTN, considering the overall goals of IMT-2030 alongside the unique physical constraints and use cases of non-terrestrial systems.

- **Latency:** In 6G, a multi-layered network is assumed. NTN leverages this three-dimensional portfolio of paths to extend coverage far beyond the reach of terrestrial infrastructure and to maintain connectivity even when disasters damage ground facilities. More importantly, the system can dynamically select the lowest-latency route that matches the service requirement. Consequently, latency-sensitive use cases—such as remote control, live video, or collaborative robotics—can be served via low-delay HAPS links. At the same time, traffic is flexibly offloaded to inter-satellite or terrestrial routes when appropriate.
- **Network Resilience:** Mission-critical applications such as public safety and disaster relief are one of the promised use cases of NTN. This is a critical requirement to ensure that NTN can function as a dependable alternative communication means to support life-saving and recovery efforts when terrestrial infrastructure is damaged or inoperable. Furthermore, service continuity—enabled by seamless handovers between TN and NTN, as well as between satellites, without user awareness—is an essential function to achieve network resilience. Multi-layered networks can contribute to service continuity.
- **Coverage Extension:** In contrast to terrestrial base stations, NTN offers the significant advantage of covering vast areas. In the 6G era, the seamless integration of NTN and TN is expected to achieve 99.9% area coverage, which was not possible until the introduction of 5G networks. This will make connectivity commonplace in previously hard-to-reach places like deserts, oceans, aerial pathways, and mountainous regions. The “Ubiquitous and Resilient Network” is truly realized through this integration.

- **Positioning:** IMT-2030 sets a high-precision target for positioning accuracy of 1 to 10 cm. NTN plays a crucial role, particularly in environments where Global Navigation Satellite Systems (GNSS) are unavailable or where higher reliability is required for aircraft and UAV operations. For example, use cases in 3GPP indicate that the 6G system provides positioning services independently of non-3GPP technologies, relying solely on its own capabilities.

## 3. HAPS and Satellite: Comparable Analysis and Synergies in Multi-Layered Network

A quantitative view of KPIs confirms that HAPS occupy a distinct middle ground between terrestrial and satellite networks. This position enables HAPS to deliver demanding 6G services in areas with sparse ground coverage or capacity constraints.

### 3.1 End-to-end Latency

End-to-end latency comprises propagation, transmission, and processing delays. HAPS altitude provides a fundamental advantage in propagation time.

- **Propagation delay:** At a nominal 20 km altitude, one-way propagation to a nadir user is  $\approx 0.067$  ms ( $20 \text{ km} / c$ ); round-trip is  $\approx 0.133$  ms. For a user at the edge of a 100 km radius cell, the slant range is  $\approx 102$  km, yielding  $\approx 0.68$  ms round-trip. These physical delays are an order of magnitude below Low-Earth Orbit (LEO) minimums; a 500 km LEO link is  $\approx 3.3$  ms round-trip, with Medium-Earth Orbit typically 60–200 ms and GEO  $> 480$  ms.
- **Processing delay:** Payload architecture is decisive. A transparent (“bent-pipe”) payload adds little onboard delay but forces all traffic through a ground gateway, creating a double hop even for local users. A regenerative payload—central to 6G-class HAPS—hosts gNB functions (baseband processing, decoding/switching, re-encoding) on the platform [5]. While this adds a few milliseconds of processing, it enables on-platform switching for users within the same footprint, materially reducing end-to-end delay for local communications.
- **Latency target:** Combining sub-millisecond round-trip propagation with efficient regenerative processing makes 1–10 ms end-to-end latency a realistic target. This range supports applications such as real-time video, cloud gaming, and many industrial control tasks, positioning HAPS between ultra-low-latency terrestrial 6G ( $< 1$  ms targets) and higher-latency LEO systems (typically  $> 20$  ms).

## 3.2 User-Experienced Data Rates

HAPS can deliver high user data rates by leveraging favorable link budgets and advanced antennas.

- **Link budget advantage:** Free-space path loss scales with distance squared. Relative to a 500 km LEO link at the same frequency, a 20 km HAPS path reduces loss by  $\approx 28$  dB, strengthening the received signal for a given power and antenna gain. The improved SNR supports higher-order modulation and coding, increasing throughput to standard devices. This link-budget advantage also contributes to indoor coverage to some extent.
- **Advanced antenna systems:** The platform's stable, spacious form factor accommodates massive-MIMO arrays and 3D beamforming. Narrow, steerable pencil beams provide high gain to compensate residual loss and enable aggressive spatial reuse, lifting area capacity and per-user rates.
- **Throughput target:** Downlink user rates of around 500 Mbps and uplink rates of around 50 Mbps are feasible with sufficient bandwidth, including mmWave spectrum [6], when combined with dynamic beam management and scheduling. While direct-to-smartphone is a primary design goal, modest UE directional gain can further improve the power-limited uplink. These rates exceed today's mass-market satellite broadband for typical users and provide strong 4G/5G/5G-like experiences, bridging gaps outside terrestrial coverage.

## 3.3 Coverage Characteristics

A single HAPS can illuminate very large areas, typically with a radius of 50-100 km. Massive-MIMO beamforming enables dynamic capacity shaping, concentrating resources on "hotspots" such as shipping lanes, event venues, or disaster zones. This operational flexibility is difficult to match with fixed terrestrial sites or wide-beam satellite systems. The following table contrasts target HAPS KPIs—latency, user rates, and coverage—against terrestrial 6G and satellite networks to contextualize the performance envelope.

Table 1: Comparative KPI Analysis of NTN systems

KPI	HAPS (Direct-to- Unmodified-Smartphone)	Satellite (Broadband with propriety user terminals)		
		LEO	MEO	GEO
End-to-End Latency	<b>1-10 ms</b>	20-60 ms	60-200 ms	480-560 ms
User Exp. Data Rate (DL)	<b>~500 Mbps</b> [7]	50-200 Mbps	100-500 Mbps	10-100 Mbps
User Exp. Data Rate (UL)	<b>~50 Mbps</b> [7]	10-20 Mbps	10-50 Mbps	1-10 Mbps
Coverage Radius	<b>50-100 km</b>	~ 1000s km	~ 1000s km	Continental
Deployment Speed	<b>Rapid (Hours/Days)</b>	Slow (Launch)	Slow (Launch)	Slow (Launch)

While a direct comparison of KPIs helps clarify the advantages of HAPS, HAPS should not be viewed only as competitors to satellite networks but as complementary components of a multi-layer network architecture. This architecture uses the distinct strengths of terrestrial, stratospheric, and space layers to provide a resilient, wide-reaching network. In this model, HAPS occupy the middle layer between terrestrial networks and satellites, providing wide-area coverage, lower latency, and added capacity that complements the global reach of satellite constellations. The above table frames the roles of each platform in a multi-layer 6G system.

## 4. HAPS-Specific Use Cases in 6G and Beyond

### 4.1 Integrated Sensing and Communication

IMT-2030, the vision framework for 6G, promotes the seamless integration of terrestrial and NTN systems, including HAPS and LEO satellites, to enable reliable, continuous connectivity. Among its six key network scenarios, it highlights Integrated Sensing and Communication (ISAC) for its dual functionality that merges sensing and communication to improve spectrum efficiency and extend network capabilities.

ISAC enables advanced applications such as:

- High-precision environmental sensing and positioning using communication signals
- Intelligent traffic management
- Public safety and emergency response
- Industrial automation
- Panoramic environmental scanning
- Disaster early warning systems








HAPS operate at high altitudes but remain closer to the ground than LEO satellites, making them well-suited for integrating ISAC capabilities. This enables ultra-wide coverage, low-latency communication, and real-time environmental sensing, making it ideal for connecting remote or hard-to-access areas.

The deployment of ISAC applications on HAPS faces significant technological hurdles, particularly due to strict latency requirements and the need for precise positioning. Supporting these use cases requires specifically designed efficient waveforms for both communication and sensing, along with beamforming antennas operating in the Wave band.

The operation of HAPS can be envisioned as a vertically oriented 5G/6G network, that extends perpendicularly from the ground. Compared to terrestrial base stations, HAPS platforms are positioned significantly farther from end users, typically at an altitude of 20 km above ground, versus 1–5 km for ground-based stations.

Considering the constraints of HAPS deployment, the table below evaluates the suitability of each use case against technical requirements and 6G ISAC KPIs.

Table 2: Use cases, requirements, challenges, and applicability for HAPS.

User Scenario	Potential Requirements (KPIs)	Technical Challenges	Applicability for HAPS
 <p><b>Drone Control</b> Drone navigation, collision avoidance, low-altitude economy.</p>	<ul style="list-style-type: none"> <li>Scalability lowers reliability to 99.99%.</li> <li>Power limits latency to &lt;5 ms, accuracy to &lt;20 cm.</li> <li>Data transmit throughput to 50-500 Mbps</li> </ul>	<ol style="list-style-type: none"> <li>Data Processing: Large-scale data requires edge computing.</li> <li>Spectrum Challenges: mmWave/THz bands face atmospheric absorption.</li> <li>System Integration: Sensing, communication, and computing coordination.</li> </ol>	<p><b>High:</b> Ideal for low-altitude drone control.</p>
 <p><b>Disaster Early Warning</b> Monitors disaster precursors, provides alerts, communication.</p>	<ul style="list-style-type: none"> <li>Weather lowers reliability to 99.99%.</li> <li>Deployment delays raise latency to &lt;10 ms.</li> <li>Doppler limits throughput to 50-500 Mbps, coverage to 95%.</li> </ul>	<ol style="list-style-type: none"> <li>Sensing Range: Wide-area sensing requires high sensitivity.</li> <li>Channel Dynamics: Doppler effects need compensation.</li> <li>Reliable Transmission: Stable communication in disaster environments.</li> </ol>	<p><b>High:</b> Wide coverage ensures effective disaster response.</p>
 <p><b>Public Safety</b> Crowd monitoring, crime detection, emergency communication.</p>	<ul style="list-style-type: none"> <li>Encryption raises latency to &lt;10 ms.</li> <li>Sparse HAPS lowers reliability to 99.99%, coverage to 95%.</li> <li>Regulations limit throughput to 50-500 Mbps.</li> </ul>	<ol style="list-style-type: none"> <li>Sensing Range: Wide-area sensing requires high sensitivity.</li> <li>Channel Dynamics: Doppler effects need compensation.</li> <li>Reliable Transmission: Stable communication in disaster environments.</li> </ol>	<p><b>High:</b> Broad coverage for safety, emergency response.</p>
 <p><b>Panoramic Scanning</b> 3D maps digitization, geospatial data acquisition for civil and military usage</p>	<ul style="list-style-type: none"> <li>Data volume &amp; Payload limits throughput to 500 Mbps.</li> <li>mmWave/THz attenuation impacts &lt;20 cm accuracy.</li> <li>Latency rises to &lt;5 ms.</li> </ul>	<ol style="list-style-type: none"> <li>Near-Field Sensing: Complex environments require accurate modeling.</li> <li>Hardware Integration: HAPS needs lightweight ISAC modules.</li> <li>Resource Competition: Dynamic allocation of sensing/communication resources.</li> </ol>	<p><b>Moderate:</b> Supports high-resolution mapping.</p>
 <p><b>High-Precision Sensing &amp; Positioning</b> Cm-level sensing for climate monitoring, target tracking.</p>	<ul style="list-style-type: none"> <li>Power limits raise latency to &lt;5 ms.</li> <li>Weather impacts &lt;20 cm accuracy.</li> <li>Payload limits throughput to 50-500 Mbps</li> </ul>	<ol style="list-style-type: none"> <li>Spectrum Efficiency: mmWave/THz bands require efficient waveforms (e.g., OFDM, OTFS...).</li> <li>Channel Modeling: High-altitude near-field sensing needs precise modeling.</li> <li>Power Constraints: HAPS requires low-power sensing hardware.</li> </ol>	<p><b>Moderate:</b> Wide coverage (100 km) enables large-scale sensing.</p>
 <p><b>Intelligent Traffic Management</b> Traffic flow monitoring, autonomous driving, UAV navigation.</p>	<ul style="list-style-type: none"> <li>Indoor penetration limits relax accuracy to &lt;10 cm, latency to &lt;3-10 ms.</li> <li>Payload restricts efficiency to 50-500 Mbps</li> <li>Multipath lowers reliability to 99.999%.</li> </ul>	<ol style="list-style-type: none"> <li>Dynamic Positioning: High mobility requires real-time positioning.</li> <li>Interference Suppression: Multi-drone environments need beamforming.</li> <li>Power Optimization: HAPS requires low-power operation.</li> </ol>	<p><b>Limited:</b> Supports wide-area traffic, UAV control.</p>
 <p><b>Industrial Automation</b> Positioning for AGVs, robotic arms in factories.</p>	<ul style="list-style-type: none"> <li>Indoor penetration limits &lt;5 cm accuracy, &lt;0.5 ms latency.</li> <li>Payload restricts 50-500 Mbps</li> <li>Multipath affects 99.99999% reliability.</li> </ul>	<ol style="list-style-type: none"> <li>Coverage Range: HAPS needs wide Line-Of-Sight coverage.</li> <li>Data Security: Sensing and communication data require encryption.</li> <li>Synchronization: Multi-node sensing needs high-precision timing.</li> </ol>	<p><b>Limited:</b> Viable for outdoor sites, not indoor.</p>

The integration of HAPS with ISAC forms a foundational building block for future air-to-ground intelligent networks. This convergence addresses the smart society and defense tactics demand for ubiquitous sensing and communication. To fully realize its potential, the most critical tasks ahead lie in optimizing spectrum utilization, hardware efficiency, and low-SWaP array antenna across a diverse range of application scenarios.

## 4.2 Direct-to-Unmodified-Smartphone (D2US)

### 4.2.1 D2US Communication via HAPS

As a key component in realizing ubiquitous connectivity, HAPS can provide direct communication services to smartphones without requiring specific modifications or dedicated antennas—an approach defined as Direct-to-Unmodified-Smartphone (D2US). Compared to satellites, HAPS operate at lower altitudes (typically 20-50 km), resulting in significantly reduced propagation loss and, consequently enabling direct communication with unmodified smartphones as well as TN. Instead of constructing terrestrial base stations that are unprofitable or infeasible to deploy due to geographic constraints, HAPS can be operated to complement coverage gaps in TN, enabling the construction of ubiquitous connectivity in a more flexible and cost-effective manner.

### 4.2.2 Deployment Scenarios

D2US communication via HAPS is valuable in the following situations, many of which fall within coverage gaps where stable TN connectivity is not guaranteed and improvements are expected through NTN. Although users in these areas may not experience services with the highest performance levels (e.g., such as no Ultra-Reliable Low-Latency Communication (URLLC) or the most immersive experiences), they will be able to access a wide range of services with dependable connectivity, including high-quality voice and video streaming, without connecting to the TN.

- Rugged mountains and forests where terrestrial base stations cannot be installed (including temporary sites such as construction zones)
- Remote islands without submarine cable infrastructure
- Ocean (including on ships)
- Suburban areas without nearby terrestrial base stations
- Airspace (including aircrafts)

## 4.2.3 Expected Services

For satellite communications, achieving uplink speeds at the Mbps level typically requires dedicated terminals. With unmodified smartphones, the range of available services is limited by insufficient uplink power. However, HAPS can provide services comparable to TN without dedicated terminals, including voice, video, and broadband.

## 4.2.4 Key Requirements for 6G Systems

To fully realize D2US communication via HAPS, 6G systems should evolve to meet several key requirements:

- Support schemes to avoid interference between existing TN and HAPS networks.
- Enable coordinated operations between TN and HAPS (e.g., handovers and carrier aggregation between TN and NTN).

## 4.3 Disaster Recovery

### 4.3.1 HAPS for Rapid Disaster Recovery

HAPS offer distinct advantages for quickly establishing or restoring communication services in areas affected by natural disasters—such as earthquakes, floods, hurricanes, and wildfires—or other emergencies where terrestrial infrastructure is compromised. With their aerial mobility, HAPS platforms can be pre-positioned or swiftly deployed to disaster zones, providing immediate wide-area coverage (typically a 50–100 km radius per platform). They support first responders and affected populations through direct-to-device connectivity and can also serve as temporary backhaul for surviving or newly deployed terrestrial cells. Operating in the stratosphere, HAPS are largely immune to ground-level disruptions, allowing resilience and reliability in critical situations. Multiple HAPS platforms can be deployed in tandem for expanded coverage and redundancy.

### 4.3.2 Integration with Satellite Communications

Satellite communications also play an important role in disaster recovery, if sufficient satellites and ground antennas are available. However, HAPS offer an additional benefit: high-speed, direct connectivity to user devices with fewer platforms. Future disaster recovery strategies will increasingly rely on the integrated deployment of HAPS and satellite technologies, balancing speed, capacity, and coverage to meet scenario requirements.

### 4.3.3 Typical Operational Flow

When a disaster or emergency disrupts terrestrial communications, HAPS platforms can be rapidly deployed or activated near the affected area. Provided that emergency-use spectrum and compatible devices are available, and backhaul connectivity is secured (via satellite, ground gateway, or other HAPS), essential communication services can be quickly restored. Upon deployment, HAPS establishes service links and connects to the core network using available backhaul options. Emergency responders and authorized users can access the network via standard smartphones or dedicated terminals, and HAPS prioritize emergency traffic, deliver voice, data, and location services, and enable direct device-to-device communications if needed. HAPS may also link temporary or surviving terrestrial base stations to the core network, with remote monitoring ensuring network reliability. As terrestrial infrastructure recovers, communication traffic gradually transitions back to ground systems, guaranteeing continuity and resilience.

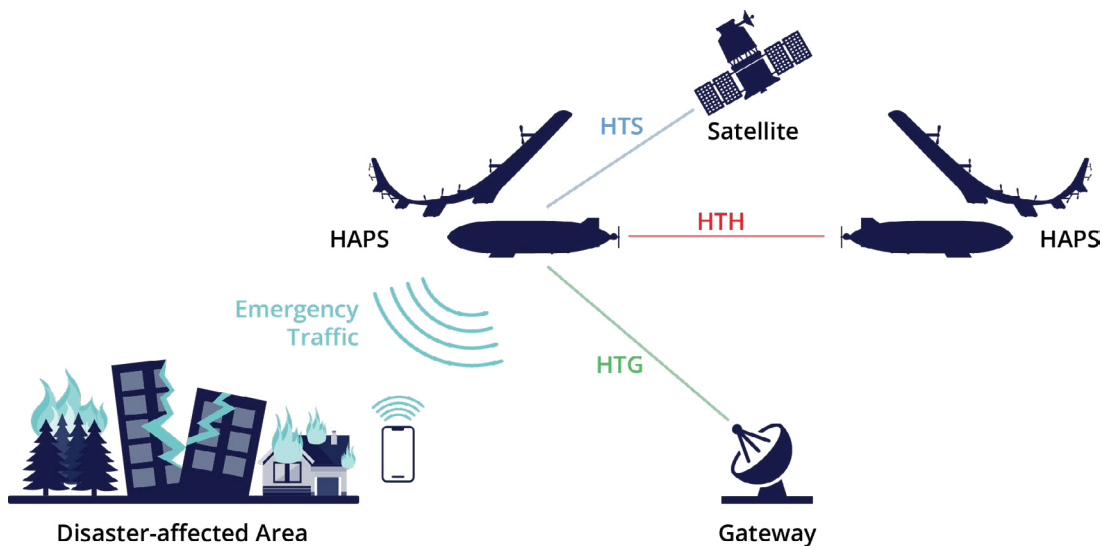


Figure 3: HAPS-based rapid deployable network.

### 4.2.4 Key Requirements for 6G Systems

To fully realize effective HAPS-based disaster recovery as described, 6G systems should evolve to meet several key requirements:

- Enable ultra-rapid deployment, configuration, service activation, and adaptive management for HAPS platforms in emergencies.

- Support dynamic coverage shaping, including beamforming, to focus capacity on critical areas within the disaster zone.
- Ensure interoperability between HAPS and existing public safety systems, including trunked radio services without a core network, and standard direct-to-device communication.
- Provide secure and prioritized channels for emergency services.
- Permit HAPS platforms to carry supplementary payloads (e.g., optical/infrared sensors) integrated with communication services to enhance situational awareness

## 4.4 Vehicular Connectivity

Vehicular connectivity is one of the most promising use cases for 6G NTN, in general and for HAPS in particular. This is especially important for providing low-latency, high-reliability connectivity to vehicles as they reach higher levels of autonomy (levels 4 and 5 according to SAE J3016 [8]) and as coordinated groups of autonomous vehicles (e.g., platoons and convoys) become increasingly common. In parallel to these specific scenarios, and taking in consideration the broad spectrum of Vehicle-to-Everything (V2X) applications (V2V, V2P, V2I, V2N [9], etc.), it is clear that HAPS can significantly facilitate cellular vehicular communications (C-V2X), and enable Advanced Driver Assistance Systems (ADAS). HAPS can provide vital support in unserved and underserved areas, while also serving as an effective tool to augment and distribute capacity in high coverage regions.

### 4.4.1 6G for autonomous cars and HAPS

The service requirements for C-V2X services have been defined in detail by organizations such as 3GPP (e.g., TS 22.185 and TS 22.186) and 5GAA [10]. This process started with 4G and progressed to 5G, although the implementation of more complex use cases, such as high-density platooning, is still far from being achieved. 6G will facilitate additional use cases and also a more massive and ubiquitous implementation of current ones.

Specifically, 6G-empowered HAPS will leverage ultra-reliable, low-latency, and high-bandwidth connections for advanced V2X communications, enabling fast data exchange for improved safety, immersive in-car experiences, efficient AI-driven autonomous driving, and the facilitation of advanced intelligent transportation systems. Key 6G capabilities in this context include THz communication, advanced machine learning, and sophisticated network architectures to support the massive data requirements of future CAVs (Connected Autonomous Vehicles).

Additionally, the implementation of ISAC as a native capability in 6G will enable HAPS to fulfill multiple CAV-related use cases, such as Sensing for Hazard Information and Road Event Collection for AVs, Sensing for Vulnerable Road Users (VRUs), real-time wide-area traffic flow optimization, aerial-assisted autonomous driving, and more. Organizations such as ETSI [11] and 5GAA [12] have defined sets of ISAC use cases for C-V2X.

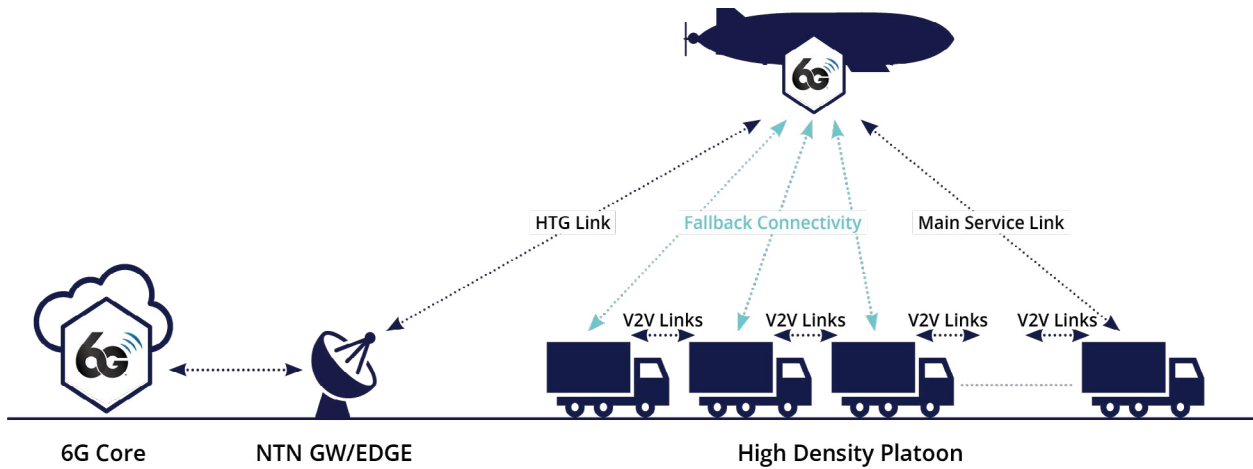


Figure 4: 6G-enabled HAPS facilitating high-density platoons.

#### 4.4.2 Facilitating Low-Latency C-V2X via HAPS

One of the distinct advantages of HAPS over satellite is its ability to provide significantly lower latencies, which can enable many of the lower-latency C-V2X use cases. This is clearly shown in the table below, which showcases some of the most important C-V2X use cases from the sources mentioned above. Use cases highlighted in green \* but not by satellites, regardless of their orbit. Use cases highlighted in red cannot be fulfilled by either HAPS or satellites, and both HAPS and LEO can fulfil those highlighted in light blue.

Table 3: Sample list of C-V2X use cases and their latency requirements.

C-V2X Use Case	Latency Requirement	Description
Exchange of normal CAM messages	≤ 100 ms	Automated vehicles exchange normal CAM (cooperative awareness) messages. No information about future trajectories is exchanged.
Exchange of CAM messages, high automation	≤ 10 ms	Autonomous cars exchange planned, future trajectories with each other. Based on those, more accurate estimations regarding possible collisions are possible.
Cooperative collision avoidance	≤ 10 ms	Cooperative collision avoidance between UEs supporting V2X applications.
Cooperative lane change	≤ 10-25 ms*	Cooperative lane change between UEs supporting V2X applications (high and low automation).
Emergency trajectory alignment	≤ 3 ms	Emergency trajectory alignment between UEs supporting V2X application.
Normal Density Platooning	≤ 25 ms*	Coordination between vehicles in a platoon for safe and efficient movement *
High-Density Platooning	≤ 10 ms	Tight coordination in high-density platooning scenarios.
Video Sharing – near real time VaD sharing	≤ 50 ms	Video data sharing for assisted and improved automated driving (VaD) for a human visual system
Video Sharing – machine-centric video data analysis	≤ 10 ms	Video data sharing for ultra-accurate position estimation
Infrastructure-based TeleOperated Driving (ToD)	≤ 100 ms	Enables the remote driver to support the vehicle remotely in the absence of sensor data from the vehicle itself, by relying on sensors at the infrastructure.
Remote Driving	≤ 5 ms*	Low-latency communication for remote control of vehicles.
Vulnerable Road User (VRU) Safety	≤ 100 ms	Alerts to protect pedestrians, cyclists, and other vulnerable road users.
Traffic Signal Priority	≤ 100 ms	Communication between vehicles and traffic signals for priority management

### 4.4.3 Analysis and Discussion

Based on the qualitative requirement assessment of the sample C-V2X use cases, the following observations can be made:

1. As shown in the table above, among the thirteen C-V2X use cases considered, five can be clearly supported by both HAPS and LEO systems, while two more are conditionally supported. Furthermore, four use cases can be supported exclusively by HAPS (with one additional conditional case), and one is likely beyond HAPS' capabilities, and would require terrestrial infrastructure.
2. From this qualitative assessment, it can be inferred that HAPS serves as an important complementary bridge between terrestrial and LEO systems, enabling most C-V2X use cases except those with the most stringent latency requirements.
3. To further support low-latency applications and content distribution in connected vehicle scenarios, the deployment of Multi-Access Edge Computing (MEC) on HAPS platforms could be explored, taking into account the SWaP (Size, Weight, and Power) constraints of these systems.

## 4.5 Shared Networks and Neutral Hosts

HAPS can play a crucial role in enabling 6G shared networks and neutral hosts across specific areas, providing advanced, resilient, low-latency services for multiple tenants. This can be very beneficial for private networks (stand-alone, hybrid, or virtual), for C-V2X use cases in unserved or underserved areas, for multi-RAT connectivity, and for slicing scenarios.

### 4.5.1 Shared Networks and HAPS

Shared network architectures, such as MOCN (Multi-Operator Core Network) or MORAN (Multi-Operator Radio Access Network), can enable one or several HAPS to hover over a particular region of interest, and provide services to multiple tenants subscribed to different operators.

One use case that illustrates the value of shared networks via HAPS is shown in Figure 4, where a high-density platoon is connected to a HAPS that provides it with 6G connectivity services. In many cases, the lead truck in the platoon will be equipped with a UE that subscribes to a different operator than the others, driving the need for the HAPS to support shared networks. This will require multi-core connectivity, usually by network functions such as MOCN gateways, which can

reside on the HAPS or as part of the ground equipment. Other interesting use cases requiring support of shared networks are listed below:

1. When HAPS are required to provide connectivity services to large events to complement terrestrial coverage, or to provide the primary coverage in events that take place in more remote areas.
2. When HAPS provides connectivity services to private networks.

In both cases, the HAPS will connect to UEs (human subscribers or machines) that might belong to private networks as well as other service providers, physical or virtual. Additionally, areas covered by HAPS might require multi-RAT (Radio Access Technology) support, such as LTE, LTE-M, NB-IoT, or 5G NR. Several network configurations could be implemented to provide shared services to multiple subscriber types and sensor networks, such as MOCN, MORAN, or INS (Indirect Network Sharing), a 5G-Advanced feature that enables sharing of 5G cores beyond RAN assets.

## 4.5.2 Neutral Hosts

In TN, Neutral Hosts are third-party service providers that own and operate infrastructure (small cells, DAS, RAN, backhaul, towers, fiber) and offer vendor- operator-agnostic access to multiple mobile/network operators and service providers under commercial agreements. This multi-tenant access model enables Neutral Hosts to provide NaaS (Network-as-a Service) offerings.

In NTN, Neutral Hosts can also provide Network as a Service offerings by operating parts of, or the entire, SAN (Satellite Access Network, including the satellites (or HAPS), their payloads, the feeder link,, and the ground stations. This model can work very well for disaster recovery use cases, for example. In such an area there will be different UEs compatible with other radio access technologies, HAPS payloads will likely be required to support multi-RAT access schemes like MRSS (Multi-Radio Spectrum Sharing).

## 4.5.3 Summary

Regardless of the specific model implemented, network sharing and neutral host capabilities are crucial to 6G and will enable and improve advanced HAPS-related use cases.

## 5. Conclusion

6G will emerge as a multi-layer fabric integrating terrestrial, stratospheric, and space assets. In this architecture, HAPS forms the middle layer, complementing ground and satellite systems to extend coverage, improve continuity, and add resilience. The paper's analysis shows that HAPS can offer low-latency, wide-area service with coverage on the order of tens of kilometers per platform and user rates sufficient for voice, video, and broadband. With regenerative payloads, beamformed radio, and on-platform compute, HAPS behaves as programmable network nodes, enabling local breakout and dynamic capacity shaping. These properties align with priority 6G scenarios: direct-to-unmodified smartphones that close coverage gaps across remote and mobile environments; rapid disaster restoration that combines terminal direct access with temporary backhaul; vehicular connectivity that benefits from a stratospheric anchor for cooperative perception; and integrated sensing-and-communication that couples wide-area awareness with communications for public safety and infrastructure. The paper also highlights neutral-host operation, allowing multiple operators and radio technologies to share a single footprint. Taken together, the evidence indicates that HAPS is a pivotal pillar of 6G, delivering ubiquitous reach and dependable performance while operating in concert with terrestrial and satellite networks.

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