FUTURE 6G NETWORK SERVICES

Connecting transport hubs, serving society

Native 6G for widespread drone transport

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White paper

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Drone transport has the potential to transform society, but the challenge lies in leading its adoption while securing societal support. Achieving this requires collaboration across multiple sectors to harmonize policy, technology, and market frameworks. This is the goal of Future Networks Services in the Netherlands.

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Introduction

Drone transport has the potential to transform society, but the challenge lies in leading its adoption while securing societal support. Achieving this requires collaboration across multiple sectors to harmonize policy, technology, and market frameworks. This is the goal of Future Networks Services in the Netherlands.

Economically validating the capabilities of 5G and the proposed 6G nationwide networks is crucial. Demonstrating the economic viability on 5G and growth on 6G will help drive regulatory adoption and establish a solid ecosystem around this evolving technology, ultimately supporting the widespread use of drone transport in both urban and rural areas.

By enabling connected drone deliveries and integrating drones into rural areas, 6G will provide an affordable new approach to improving access to services, goods, and productivity. Additionally, it will facilitate service delivery in sectors such as logistics, emergency response, and urban mobility within cities and harbors.

Another aspect of this collaboration is spectrum harmonization to foster seamless (cross-border) aerial coverage in mobile networks and ecosystems, enabling efficient and reliable drone operations.

The Netherlands can capitalize on its strong digital infrastructure to lead the adoption of the European drone ecosystem, generating significant economic benefits.

> *6G will provide an affordable new approach to improving access to services, goods, and productivity*

Connected Drones in the Netherlands

Civil drone development has advanced rapidly since 2011, transitioning from a niche hobby market to a significant commercial sector. In the Netherlands, over 30,000 trained drone pilots are currently active, with many employed by one of the 200 professional drone companies.

Transport hubs in the Netherlands offer several promising use cases for connected drones. A transport hub is a central point where different modes of transport converge, enabling the efficient transfer of goods or people between various networks and transport systems. In the context of connected drone transport, a transport hub is a facility where connected drones land, take off, recharge, or transfer loads.

These use cases span industries such as logistics, emergency services, and infrastructure monitoring. Initial deployments are expected to occur in rural areas, particularly in the northern regions of the Netherlands, before scaling to urban and national operations.

Stakeholders

The Dutch connected drone transport ecosystem involves a range of stakeholders who contribute to its regulation, management, infrastructure development, and societal acceptance:

- Civil Aviation Authority (CAA-NL/ILT)
- Provinces;
- Municipalities;
- Ministry of Infrastructure and Water Management (I&W);
- Air Traffic Control (LVNL);
- The General Public.

The primary goal of FNS6G is to fully harness the 3GPP ecosystem by collaborating with mobile network operators (MNOs), vendors, and European regulatory bodies to ensure the safe operation of drones beyond visual line of sight (BVLOS) through advanced technologies and policies.

*The report **Programma Onbemande Luchtvaart 2023-2025** outlines the Dutch Ministry of Infrastructure and Water Management's (I&W) action plan for unmanned aviation (drones) between 2023 and 2025. The document highlights the goals, strategies, and measures the ministry plans to implement for the safe and efficient development of the drone sector in the Netherlands.*

Future Network Services

The Future Network Services consortium, comprising 60 companies, knowledge institutes, and governments, is spearheading the development of 6G mobile networks in the Netherlands. Known for its network innovation, semiconductors, and mobile applications, the country aims to establish a robust open 6G ecosystem by 2030. The program is divided into four program lines, with each contributing distinct activities and goals. Program line 3 focuses on pioneering applications, including a project on 6G drone applications in transport hubs.

> *Civil drone development has advanced rapidly transitioning from a niche hobby market to a significant commercial sector*

The value of connected drones

One of the use cases for drones in transport hubs is aerial delivery systems. In rural areas, where traditional delivery methods can be slow and costly due to the distance between locations, connected drones offer a faster, more efficient alternative for transporting goods, medical supplies, and essential services.

Drone delivery has a significant social impact, as seen in the following examples:

Medical Supplies Delivery: Drones can rapidly deliver life-saving supplies like blood, vaccines, or medications to remote or hard-to-reach areas. In emergencies, drones can transport organs for transplantation, reducing the time required for delivery and improving the chances of successful transplants.

Disaster Relief: In disaster-affected areas, drones can deliver emergency food, water, and supplies where roads may be inaccessible due to floods, earthquakes, or other natural disasters. Additionally, drones can be used for aerial surveillance to assess damage, locate survivors, and coordinate rescue efforts.

Food and Essential Goods: In isolated regions with inconsistent supply chains, drones provide a reliable method for delivering fresh produce, groceries, or other essentials, thereby helping to reduce food insecurity. For elderly or disabled individuals in rural areas, drones can ensure timely delivery of medications, groceries, and other necessities.

Education: Drones can deliver textbooks, learning materials, or digital devices to remote schools or homes in rural areas, supporting access to education. In areas with limited internet connectivity, drones could potentially deliver internet hotspots or devices to help students participate in online learning.

Agricultural Support: In remote rural areas, drones can deliver agricultural inputs like seeds, fertilizers, or veterinary medicines, supporting farming and livestock care, which are often vital to rural economies.

Community and Social Connectivity: Drones can deliver communication devices, newspapers, or other media, helping rural communities stay connected with the outside world while also developing its safety track record and technologies.

Sustainability: Drones reduce reliance on traditional ground transport for logistics and deliveries, decreasing road congestion and lowering carbon emissions. Furthermore, in scenarios where helicopters are currently employed unnecessarily, drones can perform deliveries with comparable efficiency.

Drones reduce reliance on traditional ground transport for logistics and deliveries

Global use cases

United States
Companies like Amazon and UPS have initiated testing of aerial drone deliveries in rural areas, demonstrating the safety and feasibility of drone logistics. They have announced plans to expand into the EU and seek approval in the UK under their Prime Air initiative.

China
Since 2020, companies such as JD.com and SF Express have made significant progress in drone delivery routes and volumes. These drones transport goods to hard-to-reach rural areas and urban centers, significantly reducing delivery times and operational costs.

UAE
Dubai has heavily invested in aerial drone systems as part of its smart city initiative. These drones are primarily used for rapid logistics, goods delivery, and even passenger transport.

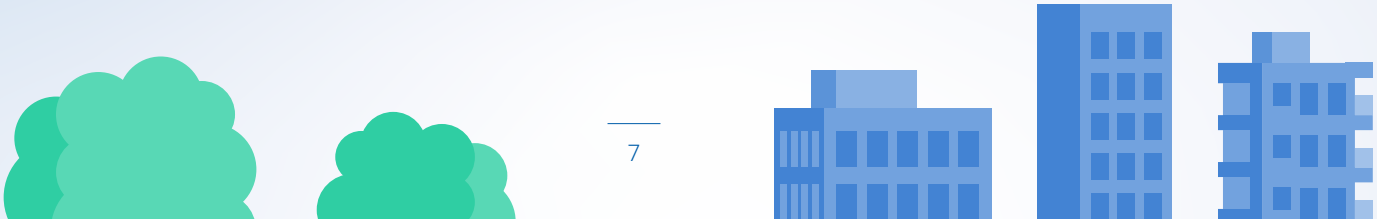
The Netherlands
Drone Delivery Services aims (in collaboration with the three northern provinces) to enhance impactful, social and health-care accessibility and availability to remote areas as well as to dense urban areas vice versa. As part of a longer-term Dutch regions vision to keep more remote areas inclusive and liveable. DDS existing roadmap scales up with routes stepping up in complexity. First regional, with reach to the Netherlands and beyond. Finally autonomous and uncrewed as well as crewed (air taxis). All in a lower layer, extensive safe airspace crossing borders.

The Netherlands
TenneT conducted a pilot project using drones to install bird wire markers on a 150 kV high-voltage line between Dodewaard and Ede. Traditionally, this task required helicopters, cranes, or climbers.

China
Drones are already employed for inspecting power lines and wind turbines in remote locations, reducing downtime and improving worker safety.

Germany
Drones have been adopted for large-scale infrastructure inspections, including bridges and railroads, improving the efficiency of maintaining transportation infrastructure.

> *Drone delivery has a significant social impact*



Role of mobile networks for drone operations

Lessons learned

The advent of 5G and 6G is highly relevant for drone connectivity. The primary requirement is a robust connectivity platform that ensures reliable connections for drones. A key lesson from past experiences with 4G, and now 5G, is that a genuine understanding of requirements emerges through direct collaboration with use case owners. Practical implementation, rather than theoretical planning, reveals true limitations.

The most viable business case for drone operations involves leveraging existing infrastructure. Building a completely new network just for drones is economically challenging. Nationwide mobile operator networks, which already have established infrastructure like masts, offer a scalable solution.

> *The advent of 5G and 6G is highly relevant for drone connectivity*

However, these networks were originally designed for static ground-level coverage, making it challenging to support drones operating at higher altitudes. For instance, tilting antennas upward can cause interference for UAVs and adjacent spectrum users who lack adequate protection (e.g., altimeters in airplanes). Additionally, maintaining small cell sizes to handle high mobile traffic in dense urban areas becomes increasingly complex.

Higher-altitude coverage with Air to Ground

The concept of mid- and high-altitude coverage is also an aspect of the 6G evolution. Air-to-Ground (A2G) technologies, including 3GPP based Terrestrial networks and satellites, aim to provide seamless connectivity above 200 meters in altitude without affecting telecom network UAV design. This would benefit seamless connectivity to UAV and mitigate the risk of ground network interference.

However, transmissions in IMT bands from drones flying above 400 feet (approximately 120 meters) can cause significant interference with existing terrestrial networks as drone traffic increases.

This approach aligns with the long-term evolution toward seamless and ubiquitous coverage in 6G for UAVs. Unlike previous generations, 6G is designed to deliver far more extensive and robust coverage, including aerial spaces. Native 3GPP based aerial coverage ensures that 6G networks are optimized for both terrestrial and aerial operations, enabling reliable connectivity for drones flying at higher altitudes.

Current challenges

As the development of 6G progresses, several key challenges from current drone services need to be addressed:

Ubiquitous Connectivity

A significant limitation today is achieving reliable, long-distance connectivity for drones, particularly in remote or non-urban areas. While 4G has limitations and 5G can support some drone operations, neither provides the scale required for seamless, widespread drone delivery. 6G could overcome these challenges by offering broader coverage, increased capacity, and access to new spectrum bands.

Quality of Service (QoS) and Network Slicing

Although network slicing and QoS are theoretically available with 5G, their practical implementation remains in the early stages. For drone services, especially high-stakes applications like medical deliveries or police surveillance, specific and guaranteed service levels are critical. 6G will need to provide dynamic network adjustments based on the drone's mission, altitude, and operational requirements.

Spectrum Interference Management

Efficient spectrum management will become increasingly critical as the number of drones operating at various altitudes grows. With the potential for hundreds of thousands of drones flying simultaneously for different purposes, spectrum allocation and usage must be optimized. 6G introduces advanced spectrum technologies, such as enhanced beamforming, to support large volumes of drones without interference or quality degradation. This capability will also enable more advanced mission-critical applications.

Altitude and Use Case Differentiation

Drones operate at various altitudes and for diverse purposes, such as commercial drones at lower altitudes and public safety drones at higher altitudes. Each type of operation will require tailored connectivity and regulatory approaches. 6G could facilitate these requirements by offering customized network slices, ensuring that drones operating at different altitudes avoid interference with each other or with ground-based networks.

> *6G is set to introduce AI-driven sensing and communication technologies that will improve drone tracking and security*

Resilience & safety concerns

GPS-based systems are vulnerable to spoofing and hacking, which is a growing concern for drone operations. While 5G offers some mitigation through improved location estimation, 6G is expected to further enhance resilience by incorporating advanced features.

6G is set to introduce AI-driven sensing and communication technologies that will improve drone tracking and security, providing a more robust and scalable solution compared to GPS and centralized air traffic control systems alone.

These advancements enable drones to communicate and sense their environment simultaneously, improving their ability to avoid collisions, adapt to weather conditions, and navigate through complex urban areas. Centralized sensor fusion for air traffic awareness will provide full contextual understanding by integrating sensor inputs from UAVs, networks, and application-level systems.

Scalability & open ecosystem

The advancements enabled by 6G are open and scalable across different regions, starting in the Netherlands and expanding globally. Transport hubs and corridors in the Netherlands serve as pilot projects for testing and validating these new technologies and policies.

The global adoption of 6G will facilitate the development of standardized systems, ensuring that drone technology, communication networks, and transport hubs are interoperable across borders and operators.

By fostering an open ecosystem for drone transport with 6G, the Netherlands can establish itself as a leader in innovation and technology, standing apart from proprietary or closed ecosystems. The foundation of Future Network Services allows any drone or mobile operator and its suppliers to innovate and operate within this space. This approach not only attracts global investment and talent but also stimulates the creation of new business models in logistics, e-commerce, healthcare, and urban mobility.

The advancements enabled by 6G are open and scalable across different regions, starting in the Netherlands and expanding globally

How 6G enables widespread BVLOS drone operations

6G technology, featuring advanced beamforming and Massive MIMO (mMIMO) capabilities, enables more efficient use of spectrum and infrastructure resources for both aerial and terrestrial coverage. It is expected to significantly enhance Beyond Visual Line of Sight (BVLOS) drone operations, expanding their applications in industries such as logistics, agriculture, and surveillance.

Although mMIMO and beamforming capabilities already exist in 5G, they were primarily designed to address the increasing demand for connectivity in urban areas. Their application in aerial operations is an advantageous byproduct. In 6G, beamforming technology will feature narrower beams, broader frequency ranges, and faster adaptability to target aerial devices, ensuring more efficient and reliable connectivity. The native design of 6G for both aerial and terrestrial coverage supports widespread BVLOS operations.

Beamforming is a technology that improves the efficiency and range of wireless communication. Traditional antennas broadcast signals in all directions, but beamforming enables antennas to focus signals toward specific communication devices, creating targeted pathways. For BVLOS drones, this means signals can be directed precisely to the drone, reducing interference and minimizing signal loss.

Satellites play a critical role in the development and resilience of 6G networks. They are immune to most ground-based physical threats, such as earthquakes and floods, providing a robust layer of connectivity for critical communications and supporting recovery efforts during disasters.

Increased Quality

6G networks are expected to deliver ultra-low latency and faster data transmission rates compared to 5G. This enables real-time control and communication between drones, transport hubs, and centralized systems, which is crucial for tasks like Beyond Visual Line of Sight (BVLOS) flights, air traffic management, and drone fleet coordination.

The integration of Joint Communication and Sensing (JCAS) will enable drones to simultaneously communicate and sense their environment, enhancing their ability to avoid collisions, adapt to weather conditions, and navigate through complex urban areas.

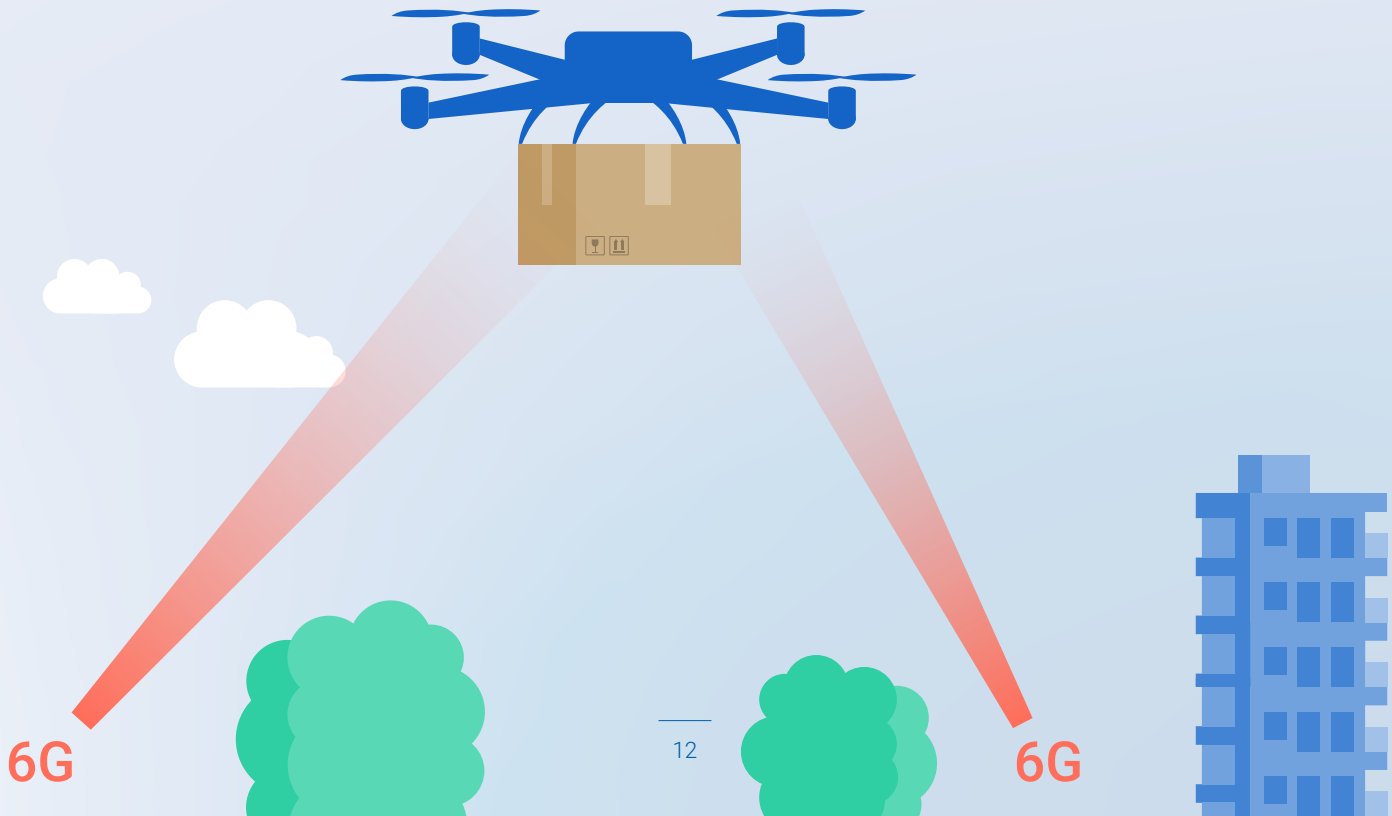
The cell-less architecture of 6G prevents quality degradation at cell edges and during handovers. UAV connectivity will benefit from this, as airborne drones often encounter multiple cell sites in their line of sight, which can cause interference and quality issues. The cell-less design maintains consistent connectivity.

With AI-driven communication and decision-making features, 6G networks can predict optimal flight paths and manage drone fleets more intelligently. This not only increases overall operational efficiency but also reduces the risk of communication breakdowns, ensuring that drone fleets operate continuously and safely.

Security

As the number of connected drones increases, so does the risk of cyberattacks. 6G will involve complex interconnections between drones, transport hubs, and networks, and each node must be protected from hacking, spoofing, and data interception.

Many stakeholders, including regulatory authorities, are hesitant because they are unsure if the connectivity is stable and secure enough for widespread drone use. It is therefore important to prove that current mobile networks can handle this safely and provide a blueprint for how such technologies could be implemented across Europe.



Challenges to be addressed for BVLOS drone operations

Market Demand

Market demand is evolving with new use cases emerging daily. However, to achieve large-scale commercialization, the industry must collaborate on areas like BVLOS regulations and ecosystem development. The Dutch government also needs to play a role by supporting test sites, such as the corridor between Drachten and Groningen. These use cases not only test technical limits but also help identify market demand and areas where further collaboration and standardization are required for UAV operations.

Facilitation innovation through APIs

The emergence of specialized global and regional platforms offering certified services, authorized by relevant regulatory bodies, is expected in this sector. APIs are critical for managing Quality of Service (QoS), sharing data, and keeping integration costs low, making scalability achievable. With advancements from 4G to 5G, networks now provide significantly more functionality, creating substantial growth potential for APIs. For network providers, APIs present a future growth area, enabling them to offer services to various industries while acting as brokers that simplify access to telecom services.

> *A critical requirement for networks is the ability to operate across multiple frequency bands*

For example, drone operators may prefer a broker model to access networks, avoiding the complexity of negotiating individual agreements with multiple operators. Technologies must provide APIs for QoS control and location data, linking the application development community with telecom networks. This approach allows businesses to focus on innovation without being burdened by connectivity challenges.

Flexibility to improve resilience

Managing latency is critical to prevent loss of control. Network stability and uninterrupted connections are essential, particularly in densely populated areas where drones must maintain constant communication.

One of the experimental areas being explored is the use of antennas for both communication and object detection, such as detecting drones or vehicles. This dual-purpose technology, still in its early stages, could allow for greater efficiency in using radio signals.

Another critical requirement for networks is the ability to operate across multiple frequency bands. For example, new frequency bands like the 700 MHz band, allocated for 5G, provide excellent terrestrial coverage, although limitations exist for aerial coverage.

The 3.5 GHz band, previously reserved for satellite communications, has recently been made available for 5G in the Netherlands. This band offers high capacity but has a smaller coverage range. The Netherlands should take guidance from ECC decisions on spectrum bands for aerial coverage, but it is critical that development aligns with 3GPP-supported bands.

This allows nationwide and cross-border BVLOS flights based on (future investments) in its national digital infrastructure. Creating a separate ecosystem in non-3GPP bands would delay this progress.

This enables networks to dynamically switch between different frequency bands depending on the device's needs and location. This flexibility ensures that users can still access reliable connections even if one band is not optimal for their location.

Electronic Conspicuity

Electronic conspicuity is a critical aspect of drone operations, referring to the ability of drones to be electronically visible to other drones, air traffic management systems (UTMs), and vehicles in the airspace. This visibility is essential to prevent collisions as drone traffic increases.

Current technologies like ADS-B (Automatic Dependent Surveillance-Broadcast) and V2X (Vehicle-to-Everything) help with visibility for aircraft and vehicles, but there is no widely adopted solution for drones to avoid collisions, especially as their numbers grow. A key challenge is developing systems for real-time awareness of a drone's surroundings to ensure safety within a 50–100-meter radius which is currently under investigation in 3GPP.

Another evolving area is Advanced Air Mobility (AAM), which includes air taxis—larger drones capable of transporting people. This market is expected to become a commercial reality within the next few years. Regulatory bodies like the United Nations (ICAO), EASA, and FAA are already developing frameworks to guide this market. While air taxis are classified as manned drones, they share many challenges with unmanned drones regarding airspace management, safety, and connectivity.

Variety in regulations

Regulatory approaches vary by country. In the UK and Japan, mobile operators are allowed to use their terrestrial networks for aerial services, including drones. However, in countries like the United States and Canada, the regulatory stance remains unclear, with no explicit approval from authorities like the FAA or FCC.

Countries like Finland and Switzerland, known for their innovation in drone technology, have taken a more restrictive approach. They have raised concerns about potential long-term interference issues if large numbers of drones begin to operate, potentially disrupting existing traditional networks. As a result, they have been hesitant to allow the current spectrum to be used for aerial applications.

Addressing this regulatory ambiguity is critical for establishing leadership. Mapping the global regulatory landscape, including permitted 5G/6G spectrum bands for aerial use and their restrictions, is a prerequisite for enabling this market in each IMT region.

The emergence of dedicated 3GPP Aeriel Broadband networks serving communication needs of drones, aviation at large is gaining momentum due to its affordability. For example, Swedish telecom operator Teracom can provision 3GPP connectivity till 3000 meters plus from ground thus enabling multiple use cases and no interference with the ground terrestrial networks.

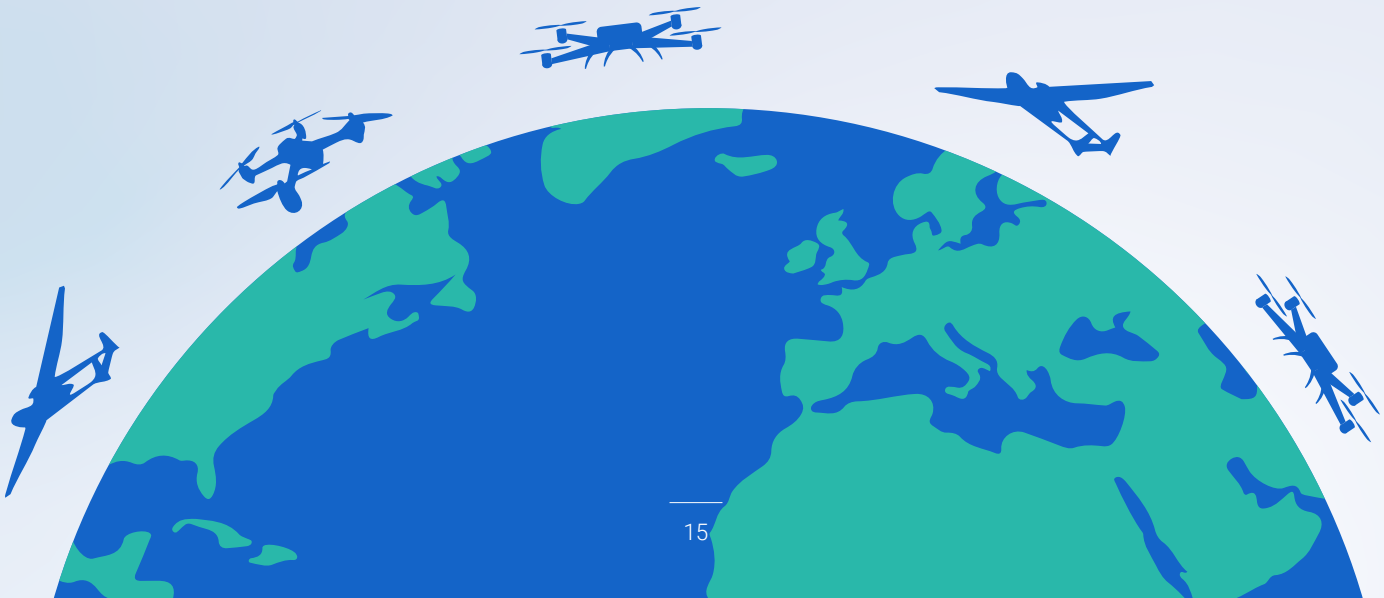
Conclusion

Drone transport has the potential to transform accessibility by delivering essential goods to remote areas and improving delivery efficiency in urban centers. Although current 5G networks can support drone operations, they rely heavily on GPS for navigation and may cause undesired interference when the number of Unmanned Aerial Vehicle (UAV) increases. As UAV deployments expand, the limitations of 5G—specifically in coverage, interference management, and GPS reliability—could create challenges for standardizing drone safety systems. Nevertheless, 5G is expected to support the evolving market through 2030 by providing certified connectivity, telemetry, and reduced interference.

Next-generation 6G technology must be natively designed to deliver certified aerial connectivity and reliable navigation for large-scale drone flights at varying altitudes and across borders without interfering with terrestrial communications. With more advanced beamforming compared to 5G and utilization of multiple frequency bands, 6G enables efficient coverage up to 300 meters in altitude, supporting the UAV market beyond 2030.

Mobile 3GPP standardization has fostered a highly innovative and competitive environment. Ensuring an open ecosystem for drone operations is essential to avoid the limitations of proprietary systems and to maximize economic and societal benefits.

6G is designed to deliver enhanced certified connectivity and robust navigation, essential for large-scale drone operations, while minimizing interference with terrestrial communications. Furthermore, 6G's cell-less and cloud-centric mobile network architecture is expected to improve stability and resilience, enabling global support for Beyond Visual Line of Sight (BVLOS) operations.



Consortium partners

Ericsson is one of the leading providers of Information and Communication Technology (ICT) to service providers. We enable the full value of connectivity by creating game-changing technology and services that are easy to use, adopt, and scale, making our customers successful in a fully connected world.
Digital airspace exemplifies a promising new cellular ecosystem and a compelling 5G use case. By leveraging existing infrastructure with strategic enhancements, Ericsson strives to empower mobile operators to deliver efficient and predictable three-dimensional broadband coverage in the sky, enabling advanced services across sectors.

Paul van de Wiel is Business Development Director at Ericsson, where he combines his passion for technology with the ability to translate it into tangible business value. He brings extensive experience in mobile networks, spanning from the first generation to the emerging 6G technologies. Throughout his career, Paul has held a variety of roles in sales, delivery, and support, showcasing his diverse skill set and adaptability in the telecommunications industry.

Drone Delivery Services BV (DDS) drives innovation in autonomous aerial delivery. As a drone operator, DDS focuses on advancing projects and providing solutions for smart, safe, and efficient transportation of essential goods through the air.
While global developments in drone technology—especially in medical applications—sparked the company's inception, the road to full-scale drone delivery still faces regulatory and technical hurdles. DDS envisions a future where drones transport goods weighing up to 200 kilograms over distances of up to 30 kilometers and more, enabling intercity, island deliveries and offshore support.
For now, DDS prioritizes projects with significant societal impact, such as delivering urgent medical supplies and maintaining connectivity in rural areas. These initiatives aim to address challenges such as declining access to healthcare and public services.

Together with three partners **Egbert Swierts** started the company Drone Delivery Services. He has been a leading expert in the unmanned aviation sector for over 12 years and has played an important role in training drone professionals and promoting innovative technologies. Egbert advises organizations and governments on the societal and organizational impact of drones. With his expertise and passion for drone innovation, he is a driving force behind the sustainable future of unmanned aviation.

Consortium partners

As one of the Netherlands' largest telecom providers, we are committed to making technology more human. We believe technology should be meaningful, sustainable and inclusive for people and for society. Next to being the ISP with the largest FTTH footprint, Odido has a largest and most extensive 5G network of the Netherlands. About 98% of the Dutch population lives in a Odido 5G coverage area where both 5G coverage band (700MHz) and both 5G capacity band (3.5GHz) are been deployed. 80% of these 5G capacity antenna's even use advanced Massive-MIMO technology.

Our mobile network has been named "Best tested mobile network in the Netherlands" 5 times by the testing authority Umlaut. According to Ookla speedtest.net we deliver the highest speeds on both our mobile and fixed services. So, whether you want mobile telephony, television service, and a fixed and/or mobile Internet service, Odido has the ideal solution for you. For both business or pleasure.

Richard Marijs is a Mobile Technology Strategist at Odido. In this role he is responsible for Odido's mobile network strategy. His focus is on improving and innovating mobile services in the Dutch market.

TNO is an independent public research organisation. With over 4,000 specialists, we work together with entrepreneurs, scientists, policymakers, individuals, and society as a whole to create a safe, healthy, sustainable, and digitally connected society. Technological innovation can bring health and happiness to people and the planet. That is what drives us every day.

Jos Berière has 16 years of mobile operator experience at KPN, TNO and as Independent consultant. He has been overall responsible for the 5G launch in the business market. Led operations for customer & vendors tenders, customer trials, standardization and multi-billion spectrum auctions & leases. Recently he started supporting the NGO SmartParks. He is also father of 2 sons and striving for a sustainable world through reducing footprint and mastering judo.