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Keeping Farms Continuously Connected

CASE STUDY | APRIL 2026

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Keeping Farms Continuously Connected

Trial demonstrates how a combination of terrestrial and satellite 5G networks and standardised network APIs can underpin smart agriculture

Executive Summary

— Farmers are looking to deploy digital solutions to optimise resource inputs (such as water, fertilisers, and pesticides) and improve operational efficiency and productivity.

— The combination of 5G networks and satellite communications (5G SatCom) and network APIs promises to boost the capabilities of those solutions, enabling real-time data processing and connectivity across vast and often remote agricultural and rural areas.

— Conducted in Tuscany in the summer of 2025, a smart agriculture trial led by the University of Pisa assessed how 5G SatCom can underpin an irrigation decision support system encompassing several soil-plant-atmosphere water content sensors.

— The project team used the CAMARA-based Quality on Demand network API to dynamically tailor satellite and 5G network slices to support an efficient transfer of the data collected in the field.

— The system delivered timely alerts and dynamic responses, which are essential for automated irrigation systems. The reliable connectivity enabled an intelligent decision support system to issue alerts in real-time, automatically triggering irrigation actuators, minimising water waste and optimising resource use.

— Widespread deployment of the smart irrigation system developed for this project could help farmers use water more efficiently, saving resources and improving crop productivity.

5G SatCom promises to drive greater digitisation

The integration of terrestrial 5G and satellite communications (known as 5G SatCom) is being standardised by the 3rd Generation Partnership Project (3GPP) with a focus on connecting the Internet of Things (IoT). To practically demonstrate the potential of these integrated systems in specific vertical sectors, the European Space Agency's 5G-HOSTS-SAT project is validating 5G SatCom through trials of two use cases:

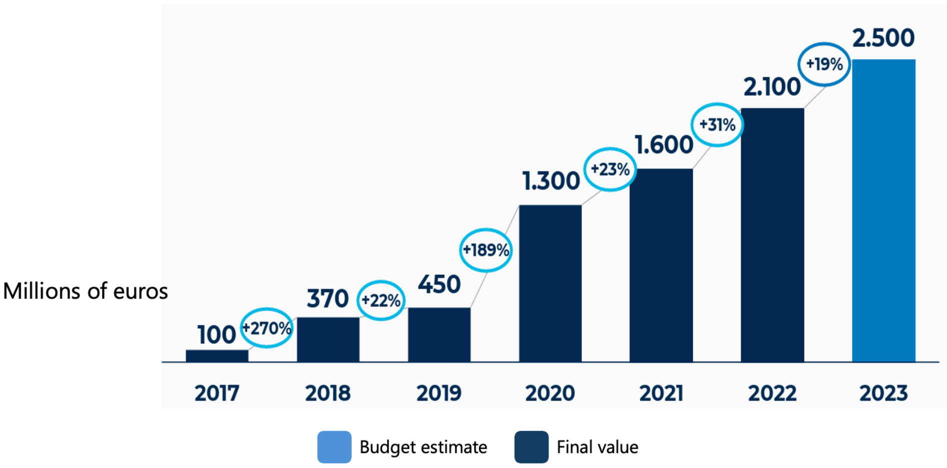
— developing a decision support system for precision irrigation in agriculture, led by the Department of Agriculture, Food and Environment (DiSAAA-a) of the University of Pisa, which is developing sensors and expert approaches for precision irrigation scheduling.

— expanding coverage, reliability and enhancing performance in supporting public protection and disaster relief (PPDR), led by a partnership between Hewlett Packard Enterprise (HPE) Italy and the "Protezione Civile del Friuli Venezia Giulia".

This case study focuses on the smart agriculture trial and its usage of a 5G SatCom platform with integrated IoT, edge computing, artificial intelligence (AI) techniques and open interfaces for advanced interactions between applications and the network.

The top priorities for agricultural businesses are to optimise resource inputs (such as water, fertilisers, and pesticides), thereby improving operational efficiency, enhancing farm awareness, and simplifying agronomic and management decision-making. Digital innovation can make the agricultural sector more efficient, sustainable, and competitive. The "Italian Agriculture 4.0" market grew 19% in 2023 to be worth €2.5 billion, according to Osservatorio Smart Agrifood and Laboratorio RISE.. Farm management software, machinery control systems, remote monitoring of crops and soil, and decision support systems are the most widely adopted Agriculture 4.0 solutions.

Agriculture 4.0 market in Italy in 2023



5G SatCom promises to boost the capabilities of those solutions, enabling real-time data processing and connectivity across vast and often remote agricultural and rural areas. Specifically, the adoption of 5G networks would enable low latency and high-speed data transfer from the IoT devices installed across farms to edge and cloud systems for distributed analysis. Satellites, on the other hand, provide global coverage, ensuring that even in remote areas where terrestrial infrastructure is unavailable, agricultural monitoring tools can still operate effectively.

"By merging 5G and satellite communications, Agriculture 4.0 could benefit from universal connectivity, real-time automation, enhanced resilience, and improved sustainability," explains Nicola Ciulli, Nextworks[1], project coordinator of 5G-HOSTS-SAT. "This synergy could enable data-driven decision-making, precision resource management, and global accessibility, ultimately transforming agriculture into a more efficient, productive, and climate-resilient industry."

> By merging 5G and satellite communications, Agriculture 4.0 could benefit from universal connectivity, real-time automation, enhanced resilience, and improved sustainability

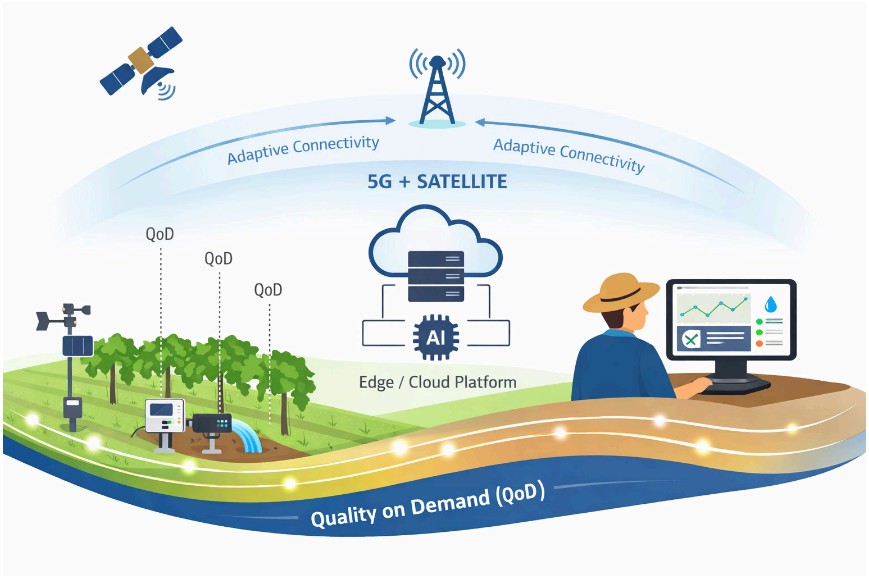
Nicola Ciulli - Project Coordinator of 5G-HOSTS-SAT

Trialling an irrigation decision support system

Conducted in the summer of 2025, the smart agriculture trial led by the Laboratory of AgroHydrological Sensing and Modelling (AgrHySMo Lab) of the University of Pisa assessed how 5G SatCom can underpin an irrigation decision support system exploiting several soil-plant-atmosphere water content sensors. The objective of this trial was to create a more rapid, intelligent and efficient approach to water management at several scales of the water use efficiency chain.

Set up in young vineyards of the Azienda Agricola Calafata in Lucca in Italy, the trial focused on enabling reliable irrigation scheduling and water accounting methodologies. It employed AI algorithms running on the edge and cloud continuum, analysing sensor data collected via satellite-enabled 5G networks, which were established using a temporary license.

The end-to-end communication and the placement of the AI engines were dynamically adjusted to jointly optimise IoT data communication and elaboration. The CAMARA-based Quality on Demand network API was used to dynamically tailor satellite and 5G network slices to the IoT data flows in the uplink. This mechanism allowed for the efficient transfer of the IoT data collected in the field towards the distributed elaboration points, while hiding the complexity of the underlying network fragmentation from the application perspective.



“By leveraging the Quality on Demand API, the project moved beyond best-effort connectivity and introduced application-aware network behaviour, aligned with the real operational requirements of precision agriculture,” explains Giada Landi, Nextworks, Technical Manager of the 5G-HOSTS-SAT project.

Specifically, the system was deployed across two vineyards, covering approximately 1.2 hectares, and in the irrigation district’s water channel. The trial was designed to monitor water use at field, farm and irrigation district scale.

The sensors in the fields were connected to a 5G-SatCom gateway using a LoRa wireless network. The image below shows the wireless sensor network display for the Calafata farm, with the different segments and their location:

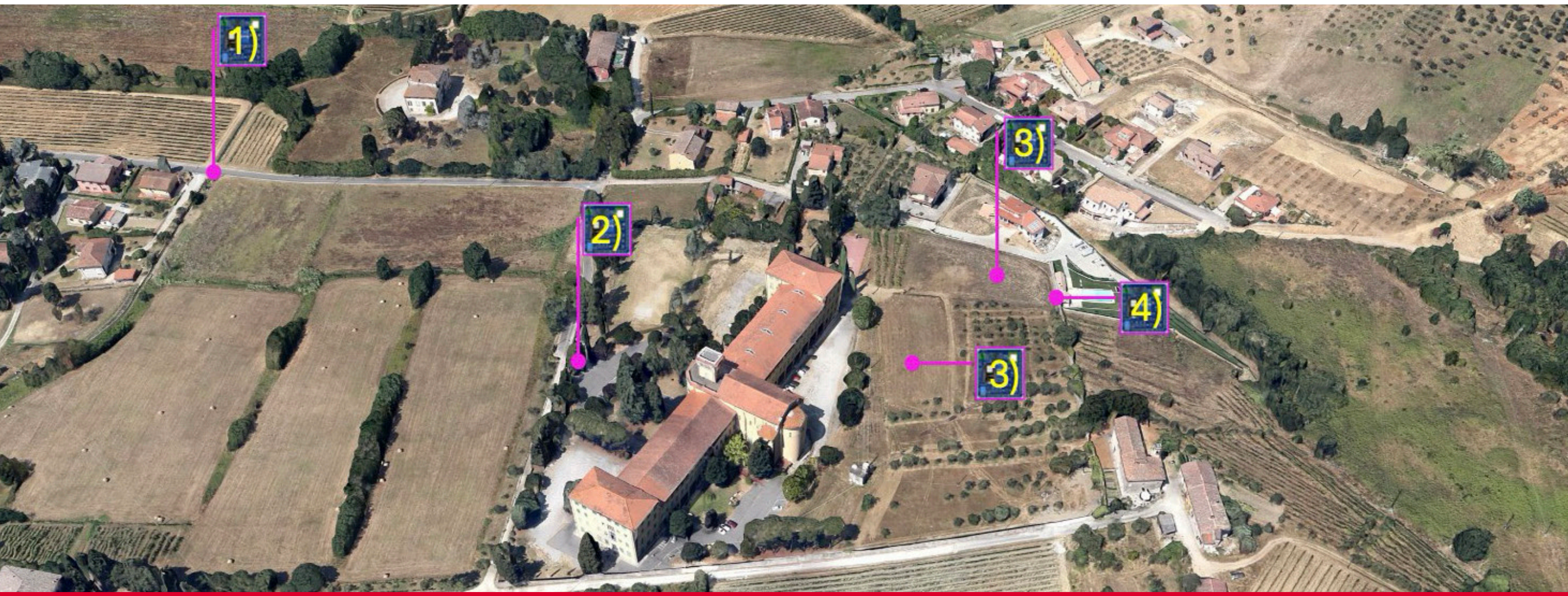
1. system to monitor water channel level
2. LoRa and 5G-SatCom receive and transmit
3. system to monitor the soil plant atmosphere continuum
4. node to control the hydraulic electric valves.

The trial utilised Arduino microcontrollers, Raspberry Pi single-board computers, and an array of hydrological sensors and actuators. These sensors are categorised into three specialised segments to monitor the water status of the soil-plant-atmosphere continuum:

- Atmospheric monitoring (atmometric segment): measures meteorological variables
- Soil monitoring (reflectometric segment): tracks volumetric soil water content
- Plant monitoring (thermometric segment): Assesses crop water stress through the Crop Water Stress Index.

The actuation segment used electro valves controlled by integrating two irrigation scheduling logics: feedback and feedforward protocols.

To enable farmers to easily view the real-time information collected by the system, the trial employed a user dashboard.



The dashboard supported simultaneous visualisation and management of multiple monitored areas, allowing users to compare different geographic zones side by side. The project team says this capability is particularly useful for optimising irrigation strategies, monitoring microclimatic differences across a vineyard or any agricultural field, and identifying environmental variations on a regional scale (see image below).

The system also allows users to group data by time and see average values, helping them better understand trends in soil and weather conditions.

Using this information, the system calculates how much water the crops need and tells farmers the best time to irrigate. "It can even turn irrigation valves on and off automatically, based on how dry or wet the soil is," adds Angela Puig Sirera from the Department of Agriculture, Food and Environment (DAFE), University of Pisa, AgrHySMo Lab. "This makes irrigation more precise and reduces water waste."

The system deployed for the trial is designed to be scalable and adaptable, allowing the integration of new sensors or additional monitoring locations without significant reconfiguration. Alerts and notifications can be configured based on predefined thresholds, providing real-time insights and early warnings for critical conditions, such as excessive soil dryness or sudden temperature drops.

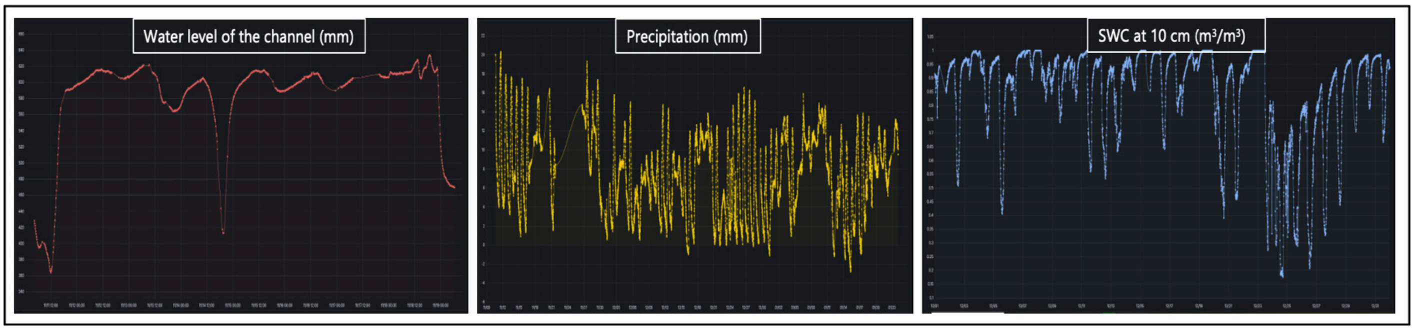
Trial system achieves near-continuous uptime

In the trial, the nodes were able to transmit data to the gateway at regular intervals, approximately every 10-30 seconds. The gateway forwarded this data to the rest of the transmission infrastructure only when the message was received correctly by the nodes and was error-free from transmission issues. In this way, the system maintained near-continuous uptime throughout the trial period, according to the project team.

Via the Quality on Demand API, the application was able to request specific network performance characteristics on demand, such as enhanced uplink reliability and reduced latency during critical operational phases (e.g., irrigation activation, threshold-based alerts, or rapid changes in soil moisture conditions). These QoD requests were translated by the 5G-SatCom orchestration layer into dynamically tailored 5G and satellite network slices, ensuring that the required quality levels were met end-to-end, independently of the underlying access technology. "From the application perspective, this abstraction removed the complexity of managing hybrid terrestrial and satellite connectivity, enabling a simple, service-driven interaction model," explains Attilio Vaccaro of MBI, which provided the satellite communications for the project.

However, minor service interruptions were observed during episodes of extreme weather, which impacted the performance of the solar panels, temporarily preventing the sensor stations' batteries from charging adequately.

"Given the low data payload (approximately 255 bytes per message), typically generated by agrohydrological sensors of the nodes, the LoRa network easily handled the data traffic between



the nodes and the gateway," says Cesare Roseti of RomARS, the systems integrator for the project. "These connectivity characteristics enabled the delivery of timely alerts and dynamic responses, which are essential for automated irrigation systems. The consistent link allowed uninterrupted data flow, which is critical for real-time monitoring and control in precision agriculture applications."

The project team says the trial found noticeable fluctuations in the temporal dynamics of soil water content (SWC) at different sensor positions corresponding to rainfall events. For instance, rain led to a sharp increase in SWC in the top soil layers. A sharp drop in SWC after each peak indicated rapid water uptake or drainage, reinforcing the need for precise timing in irrigation to avoid inefficiencies or stress conditions.

"These measurements exemplify the role of real-time, multi-depth soil moisture sensing integrated into a 5G-SatCom infrastructure," says Professor Giovanni Rallo, from DAFE, University of Pisa, AgrHySMo Lab. "The variability in SWC across depths and time highlights the complexity of vineyard water dynamics and the necessity for fine-scale monitoring. By connecting sensors through 5G and satellite networks, the system ensures continuous, remote access to data even in poorly connected rural environments."

The connectivity enabled the intelligent decision support system to issue real-time alerts and automatically trigger irrigation actuators, minimising water waste and optimising resource use. The project team says SWC measurements confirmed a fast and consistent response to irrigation events, showing that water was reaching the root zone effectively without being lost to deep drainage. "This indicates that the system can help farmers apply the right amount of water, precisely when and where it's needed," says Dr. Daniele Tuccori, Agronomist of the Calafata farm. "In this way, by combining remote actuation with real-time soil monitoring, the solution supports a more efficient, data-driven approach to irrigation, reducing water waste, improving crop health, and lowering operational costs."

Beyond individual fields, the project also addressed water use at the irrigation district level. The image below shows how the flow rate of a nearby public canal was estimated using water level sensors and portable flow meters. These measurements can help optimise the timing and volume of water deliveries to farms. "The ability to continuously monitor canal flow adds an important layer of precision to irrigation planning, ensuring public water is used efficiently and sustainably, particularly during periods of high demand or limited supply," adds Professor Giovanni Rallo.

Better water conversation, greater productivity

The combination of smart irrigation control, soil moisture monitoring, and canal flow measurement used in the trial points to how digital technologies, supported by 5G and satellite connectivity, can play a vital role in improving water conservation and farm productivity in modern agriculture.

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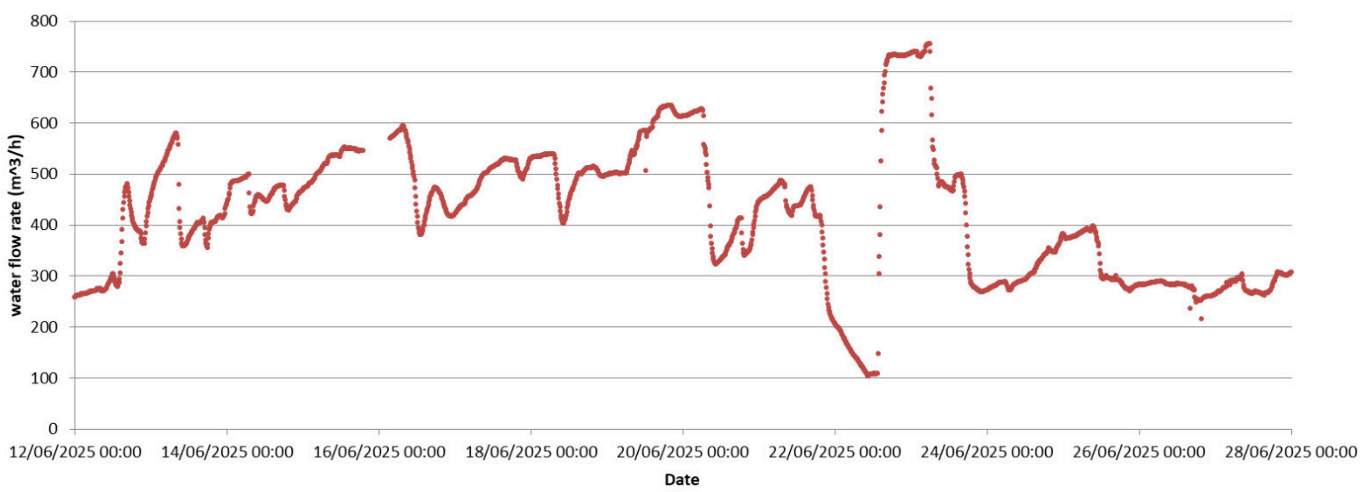

"The use of the Quality on Demand API meant that the system requested enhanced network quality only when needed, optimising the use of both 5G and satellite resources and reducing operational costs," notes Daniele Munaretto of Hewlett Packard Enterprise (HPE) Italy. The API also enabled a smooth extension of 5G services over satellite links, preserving service continuity and performance when terrestrial connectivity was unavailable or degraded, without requiring changes at the application level.

The trial demonstrated the potential of a 5G SatCom system to provide real-time, bidirectional communication even in rural or signal-challenged environments and scale to manage multiple sensor nodes, while requiring minimal on-site infrastructure for satellite uplinks.

However, the project team says the deployment also revealed some limitations, including occasional signal degradation caused by environmental obstructions and the relatively high cost and complexity of the initial setup, which may pose a barrier to adoption for smallholder farmers without external support or subsidies. "These insights underscore the transformative potential of 5G-satellite connectivity for digital agriculture in remote regions, while also emphasising the need for continued technological refinement and supportive policy frameworks to enable broader, equitable implementation," concludes Nicola Ciulli of Nextworks.

The successful trial also highlights the value of the GSMA Open Gateway concept, which harnesses standardised CAMARA APIs to bridge vertical applications and programmable networks, especially in hybrid 5G-satellite environments. The integration of open APIs for QoD transformed connectivity into an active component of the smart irrigation service, rather than a passive transport layer. In real field conditions, QoD contributed to higher service robustness, more responsive irrigation control, and greater confidence for end users in relying on automated, data-driven decisions, according to the project team.

Robust connectivity in rural areas can deliver significant socio-economic benefits. Widespread deployment of the smart irrigation system developed for the trial in Tuscany could help farmers use water more efficiently, saving resources and improving crop productivity.

Beyond helping individual farms, the system could also support better water management at the community level. By collecting data from multiple farms, local authorities or cooperatives can get a clearer picture of overall water use and availability. This can support fairer and more sustainable water policies for entire regions.

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Daniele Munaretto - Hewlett Packard Enterprise (HPE) Italy

About the GSMA

The GSMA is a global organisation unifying the mobile ecosystem to discover, develop and deliver innovation foundational to positive business environments and societal change. Our vision is to unlock the full power of connectivity so that people, industry, and society thrive. Representing mobile operators and organisations across the mobile ecosystem and adjacent industries, the GSMA delivers for its members across three broad pillars: Connectivity for Good, Industry Services and Solutions, and Outreach. This activity includes advancing policy, tackling today's biggest societal challenges, underpinning the technology and interoperability that make mobile work, and providing the world's largest platform to convene the mobile ecosystem at the MWC and M360 series of events.

For more information, please visit the GSMA corporate website at gsma.com

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About Nextworks

Founded in 2002, Nextworks is an innovation-driven SME at the forefront of European research in 5G/6G, AI, edge computing, and cybersecurity. The company provides specialised consulting and system integration services to design and implement advanced private mobile networks. Driven by a cutting-edge R&D department with a portfolio of over 80 successfully executed EC and ESA-funded projects, Nextworks operates at the forefront of international technological innovation. Its unique know-how delivers end-to-end control, orchestration, and automation solutions that bridge the gap between advanced research and real-world deployments across diverse vertical sectors, including industry, agriculture, transport, logistics, automotive, defense, energy, and environmental monitoring. Nextworks also develops products for IoT and smart building platforms, applied to yachting and high-end residential sectors, completing its offering with design, deployment, and lifecycle support services.

For more information, visit: www.nextworks.it/it/

About the GSMA Foundry

The GSMA Foundry is the go-to place for cross-industry collaboration and making positive change happen, supported by leading technology organisations and companies. By bringing together members and key industry players, engaging, and unifying the end-to-end connectivity ecosystem, the GSMA is solving real-world industry challenges.

Our vision is to unlock the full power of connectivity so that people, industry, and society thrive. This enables the mobile industry's mission: to connect everyone and everything to a better future.

Find out more, or submit a new project idea, at www.gsma.com/get-involved/gsma-foundry/

About this case study