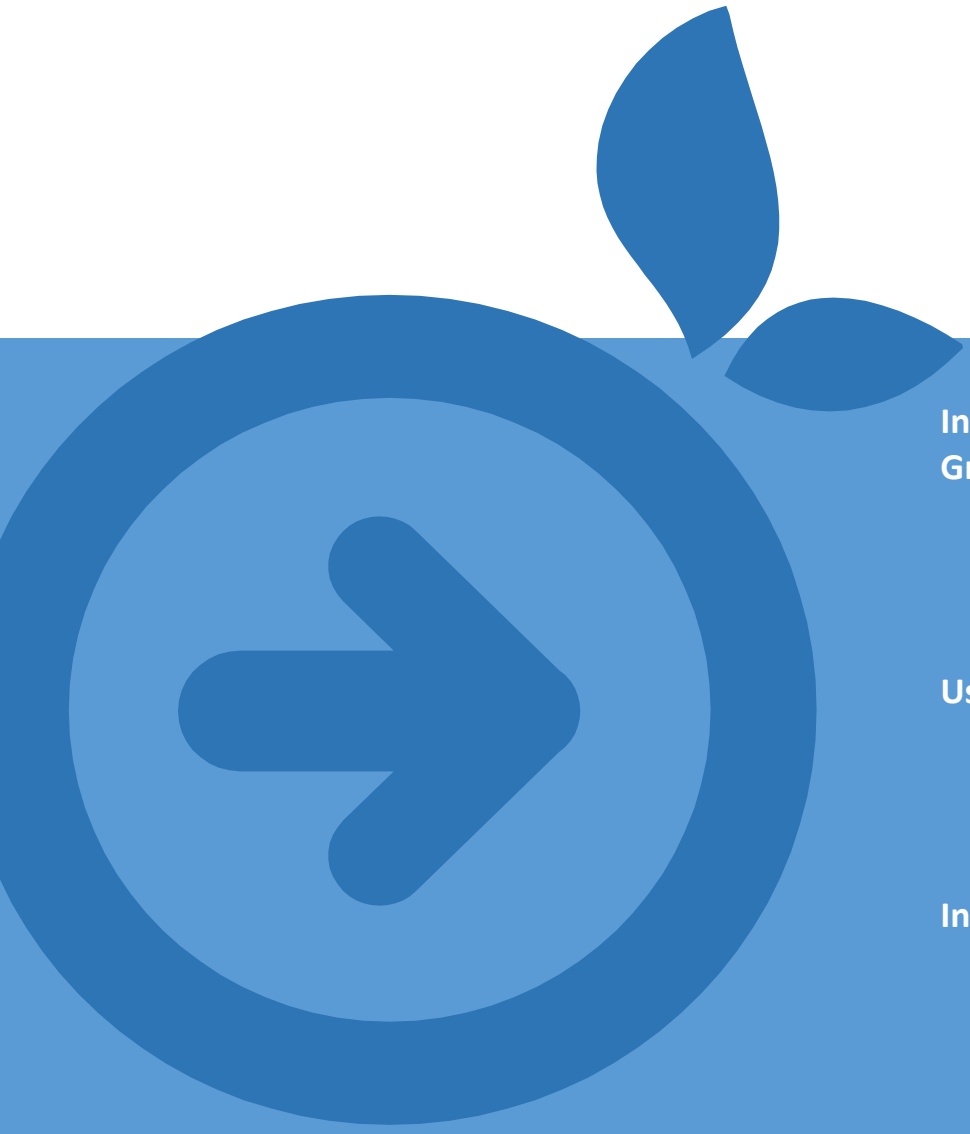
Green communications

Internet of Edges

An alternative to the cloud for
fast, secure, and resilient IoT applications
and data sovereignty



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INTRODUCTION

When you ask your mobile application for your heart health, sleep quality, stress level, etc. using your smart watch, and when the related IoT services are hosted on clouds based in California, it imposes that bits of information will travel to California and come back to you to provide you with an answer. This long travel raises concerns regarding privacy, energy consumption, security and sovereignty. Furthermore, this long travel introduces deadly latency to critical applications such as connected surgery and connected cars.

Relocating IoT services to the Edge, near the end device, so that local data remains local seems of common sense. The Edge provides significant benefits in terms of speed, control over personal or sensitive data, and reduction of the energy consumption of the Internet and datacenters. But the Edge is limited to a local coverage. Non-local, mobile, and large scale IoT projects, such as autonomous transports, smart cities, utilities, telemedicine, automation of the production, etc. must use Internet and Cloud resources still.

Green Communications innovates and creates the equivalent of a large cloud at the Edge by federating multiple and mobile Edges through secured tunnels with no central cloud. These collaborative Edge Clouds form an Internet of Edges (IoE) where IoT data is processed locally and travels among nearby Edges for greater data correlations. This way, the Internet of Edges of Green Communications brings large scale edge-based services to the Internet of moving things, massive IoT, and other IoT applications in constrained environments.

Green Communications is an innovative company specialized in energy efficient networks and distributed systems. The company is strongly engaged in the development of new networking solutions to answer challenges of Internet mobility, saturation, and sustainability. Therefore, we created Green PI, a new generation of autonomous network and cloud, after a technology transfer from top French universities (Sorbonne University and Paris Saclay) and the CNRS. Green PI products have gained the trust of leading companies in the Defense, Public Safety, IoT, Telecommunications and Public Internet sectors for providing resilient communications services in resource limited environments.

GREEN PI SOLUTION

Green PI brings together multiple connected objects, smartphones, and servers located at the edge of the network to create a cloud distributed near users, an edge cloud. The edge cloud provides these objects and users with low latency, high resiliency, and secure services, which can evolve independently from a centralized cloud as well as interact with it. Green PI also federates multiple edge clouds (Edges) located at different places to creates an Internet of Edges (IoE) with greater data correlation capacity.

The Edge Cloud

Figure 1 illustrates this edge cloud infrastructure. Sensors and objects connect to IoT platforms through various wireless network interfaces (Wi-Fi, Bluetooth, Ethernet, 4G, etc.). On this same platform are connected the various machines that process the information from the sensors. These machines contain intelligence that can be applied to the collected data in order to optimize the various processes of the IoT system. The owner of the edge cloud can visualize and administrate it through a local web page.

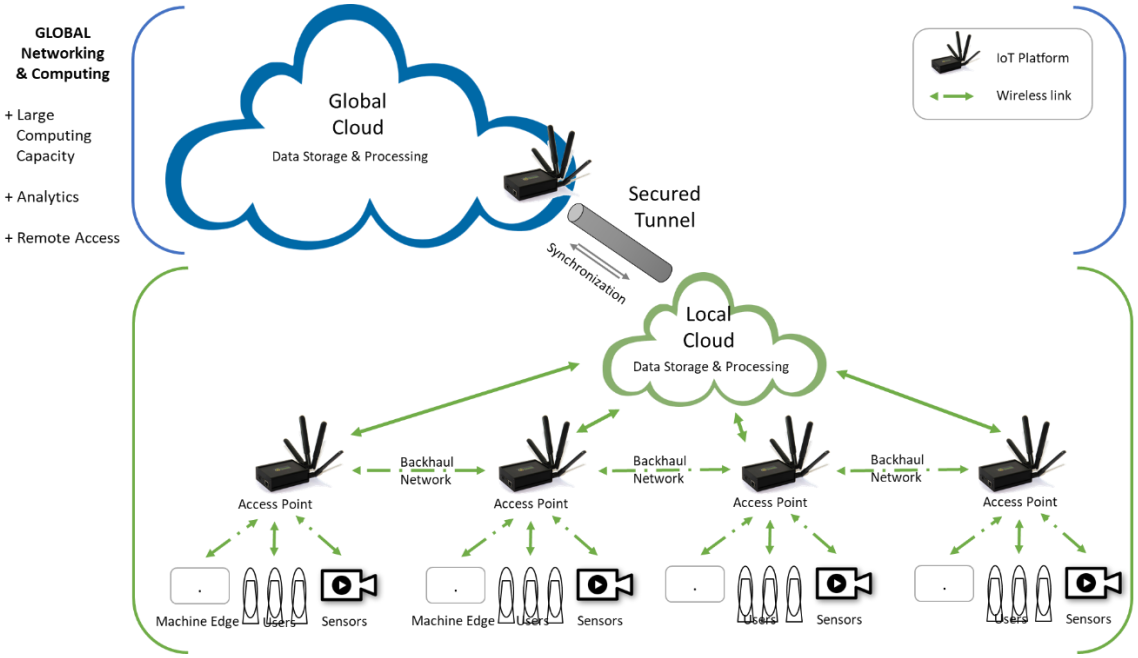


Figure 1 – IoT Platform of the Edge Cloud

The size of the edge cloud depends on the following parameters:

1. The communication infrastructure can be extended by deploying additional IoT platforms. Thus, to provide larger coverage and to connect a high number of smart devices. These platforms are mobile, plug&play, and connect together through robust device to device communications to form a local network.
2. The edge machines that contain the applications and the intelligence of the system depend on the computing power required for the various processing. You can use a single powerful machine or several smaller ones. Edge machines can be specific to each connected object for security or processing compatibility reasons. This distribution can also be done through the virtualization of several machines on a single physical edge server.
3. To ensure a smooth transition to the central cloud, the edge cloud allows the creation of VPN tunnels with machines located in the centralized cloud for backups or to synchronize with global intelligence in the cloud.

The Internet of Edges

Intelligence at the edge (edge cloud) makes sense when providing a solution to the constraint of isolation. Indeed, the major flaw of the edge is that it is isolated and confined to where it is installed. Our solution allows you to connect multiple edge clouds located in different locations to further extend their reach and thus create an Internet of Edges (IoE). Imagine two hospitals with two interconnected edge clouds. A doctor located in Hospital A could interact with machines and patients from Hospital B as if they were next door, directly, without any data being processed or stored by a centralized cloud. Thus, our Internet of Edges (IoE) solution proposes to connect two or *n* remote sites through secure tunnels (VPN) and then ensure that the machines of the two or *n* sites hear and see each other as if they were together in the same geographical location. IoE synchronizes its different Edges without the need to use a central machine in the cloud. Figure 2 shows three remote sites synchronized with each other through secure tunnels. As with a single site, we provide the ability to synchronize these sites with a cloud for a smooth transition from cloud to edge. Imagine an industrial company, divided into multiple sites, each one equipped with an edge cloud, and sensors that regularly send their reports to a digital journal to which company's personnel logs in to inquire the status of these objects. As soon as the synchronization between the edge clouds of this company occurs, the log automatically displays information from the sensors of all sites without any specific configuration.

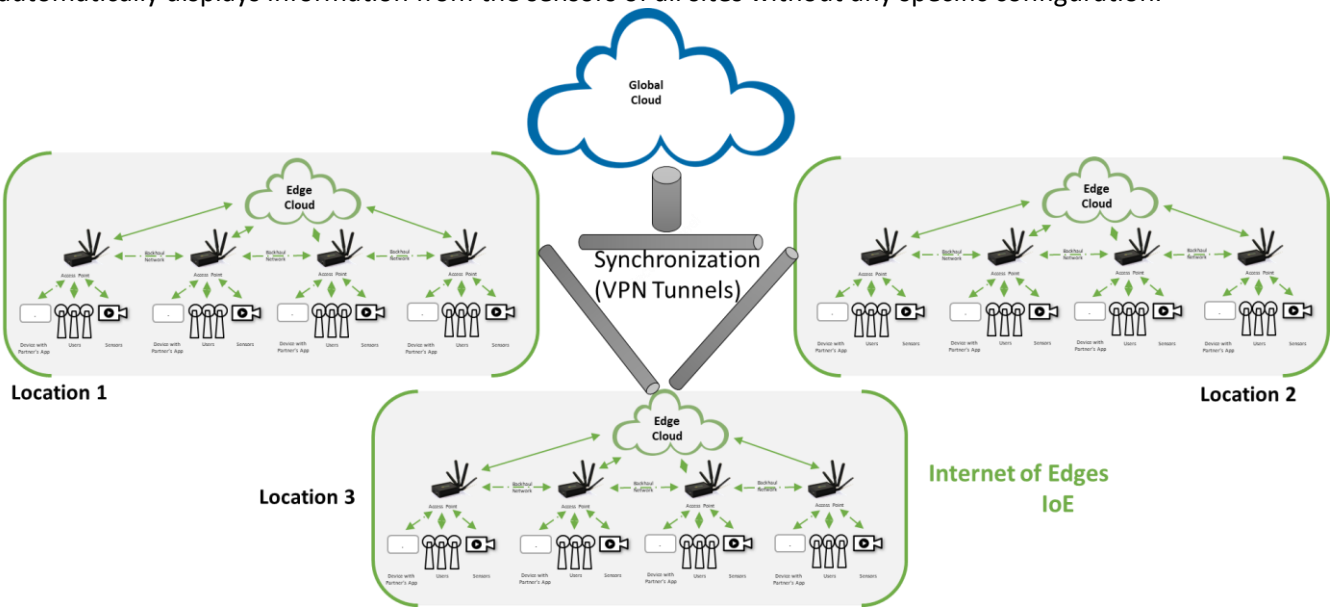


Figure 2 – Internet of Edges platform

This infrastructure has many advantages for the processing of connected objects:

1. Mobility: all the components of the Internet of the Edges can move. The IoT platforms that create the infrastructure are in embedded format, equipped with Wi-Fi and Bluetooth technologies and are preconfigured to form a mesh network of platforms that reconfigures itself automatically and instantly in the event of mobility of the platforms. Connected objects and edge machines can also move in the infrastructure without being disconnected or their services being interrupted, as IoT platforms support handovers (passage of a connected object from one platform to another).
2. Low carbon footprint "by design": The Internet of Edge reduces the circuit between objects and their intelligence. The data only travels a few paths to reach their servers in the edge cloud. Current centralized clouds represent an impressive ecological cost with information travelling thousands of kms. De-centralizing the Internet by bringing servers closer to their objects is becoming essential and especially with the exponential growth of the IoT. The energy consumption of Green PI's IoT platform is also optimized. The platform is low power and can run on clean and renewable energy resources.

3. Security: A successful attack on the cloud has dramatic consequences because once inside, the hacker has access to a lot of information. If an attack on the edge cloud is successful, it remains confined to a very small site compared to the global cloud.
4. Resilience: The central cloud is a point of failure in the system. If a problem occurs in the cloud it can stop millions or even billions of connected objects. On the other end, edge clouds operate independently, each in its area. A failure of an edge cloud would only have a local impact.
5. Data protection and privacy: In the Internet of Edges, data go directly from the object to its edge machine. There is no intermediary that sees this information passing through, and that would use it for purposes unrelated to the function of the connected object. Data protection is very difficult to achieve with a model where information is processed in a central server located far in the cloud.
6. Latency: IoT is moving more and more towards the automation of industrial tasks that require extremely low latency, such as, factory automation or connected driving. This extra-low latency regardless of the performance of the technology used can only be guaranteed over short distances. Even if you are going at the speed of light (physically the fastest), a latency of one millisecond can only be achieved over a distance of less than 300 km (150 km if you consider a round trip). No cloud today can guarantee that it is less than 150 km away from the connected objects. The millisecond is a requirement for critical applications such as robotically assisted surgery, autonomous vehicle, and automated production line. On the edge cloud, this latency is possible.
7. Simplicity and openness: The decomposition of a centralized global architecture into smaller elements ease the customization the configuration of the Internet of Edges using specific edge machine.

In summary, the short circuit remains a major advantage that should dominate the communication of the future in the objective of the scaling up the Internet of Things and its market applications.

The IoE Platform

Green Communications provides an open platform for the management of connected objects (IoT) with an emphasis on:

- processing data at the edge of the network (Edge);
- flexibility and openness of the solution, which will allow all types of objects and edge machines to be connected and will offer the possibility of working independently or in interaction with a centralized cloud;
- security with the use of a blockchain system to certify communications on this distributed system;
- scale up by offering connection and synchronization with other platforms at multiple geographic locations.

Figure 3 shows the software stack of the IoE platform of Green PI. This stack comprises several horizontal and transverse layers. The green layers are provided by Green PI. The blue ones are left to the free choice of the platform user who can install the software that best suits their applications.

1. Diverse Connectivity: This is an abstraction level of connectivity to be able to integrate any type of communication interface in order to connect diverse objects. The platform offers Wi-Fi, Bluetooth, Ethernet and 4G connections.
2. Device management: This is the management layer for connected things and edge computing machines. This layer offers the necessary tools to control the objects, create them a profile, display their characteristics, to access their contents, to allow their updates ...
3. Edge Management: This is the heart of the IoE system where we can establish a set of Edges to form a kind of virtual cloud made up of its different Edges. This layer makes it possible to create these tunnels and to apply the routing and configuration protocols necessary to merge the different physical Edges to form a single logic.

4. Local and native applications: this layer offers applications that IoE provides by default to facilitate the work of teams and communication with objects. Several applications are already integrated into IoE such as a chat, distributed storage, video streaming, audio conferencing, etc. with a distributed mode to manage arrival or the disappearance of Edges in the system. The audio and video system will offer a local alternative to applications such as Zoom, Teams ... With the IoE, you can even connect to it from several sites. The Covid-19 lockdown has shown the power that this type of application can have in terms of data protection.
5. The other layers correspond to (i) openings of the platform towards the processing of data by the applications of the use cases of the IoT system which uses our IoE (ii) the integration of additional tools to the needs of the user of IoE, (iii) SDKs and APIs in order to connect our IoE to external platforms. We already offer the necessary tools for these integrations and interconnections.
6. Database: This is a database that the IoT user can install to store their data in edge machines. This database is outside the purview of Green PI and is left to the free choice of the platform user who can install the database that best suits their applications. The database is accessible from all other levels, hence its vertical position.
7. Blockchain: This is a distributed ledger of transactions that can be recorded on edge machines or in the distributed IoE infrastructure. The Blockchain serves as a tamper-proof ledger to record all the transactions that take place on the IoE. It is distributed and uses a PBFT-based consensus algorithm to elect from among infrastructure nodes a leader to record conflict-free transactions. The Blockchain is positioned vertically on the architecture so that any level can access it to record possible transactions.

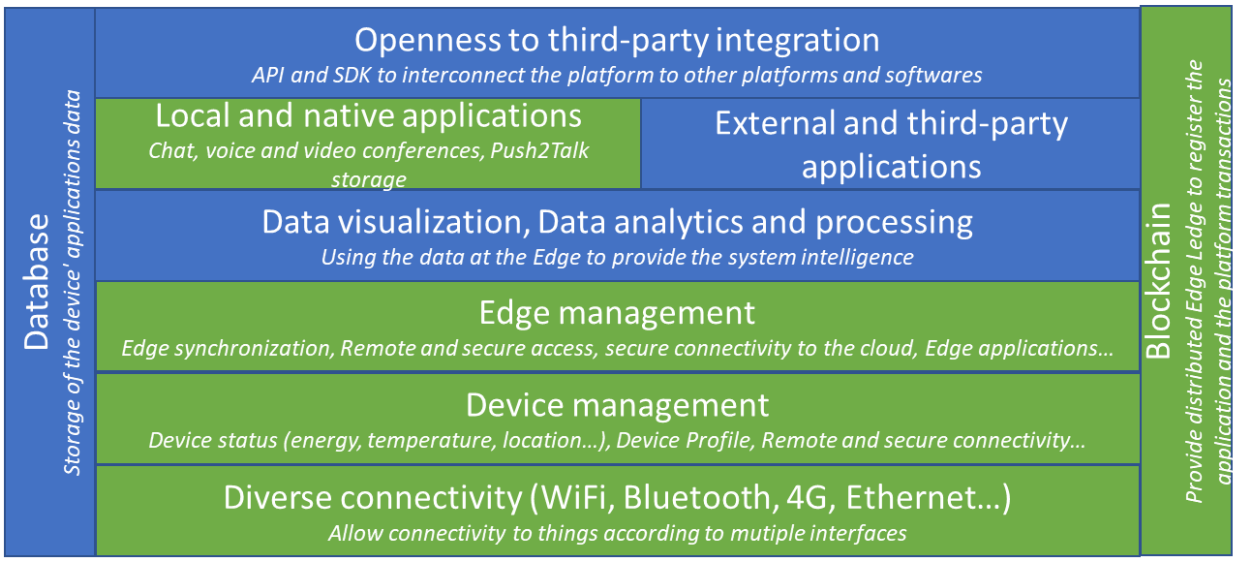


Figure 3. Green PI IoT Platform Stack (green color for what we provide and blue color for third party tools)

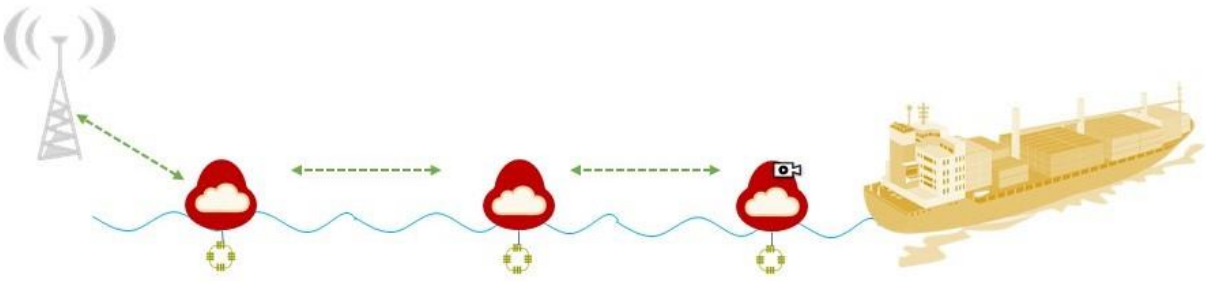
USE CASES

IoT in Constrained Environments

Green PI brings your IoT applications deep indoor, into tunnels, vessels, at sea and other isolated areas to perform video surveillance, fire or intrusion detections, maritime pollution monitoring, etc. The main market applications are: Defense, Public Safety, Security, Governments, Etc.

Green PI's IoT platform can be battery powered and set as a transportable/wearable case. Or it can be integrated into a buoy and powered by solar panels. Thus, to be deployed in a minute and with no need for external resources into tunnels, buildings, vessels, and at sea for temporary or permanent IoT applications. The system lifetime can be further increased using Green PI's Start&Stop (SaS®) functionality that turns off and on a platform when needed.

Smart things (cameras, sensors, devices, etc.) connects to the IoT platform using various interfaces (Wi-Fi, Bluetooth, Ethernet, 4G). The related IoT services and applications can be hosted locally on the edge cloud of the IoT platform. The edge cloud enables data correlation at source offering quick response time, high bandwidth, and resilience to Internet breakdown. High level data generated at the edge can be sent to a remote decision center *via* the IoT platform's gateway or *via* the gateway of a nearby platform though robust device to device communication channel among Edges. Greater correlation capacity can be provided by federating multiple Edges deployed at different locations thanks to the scalable Internet of Edges (IoE) functionality of Green PI.

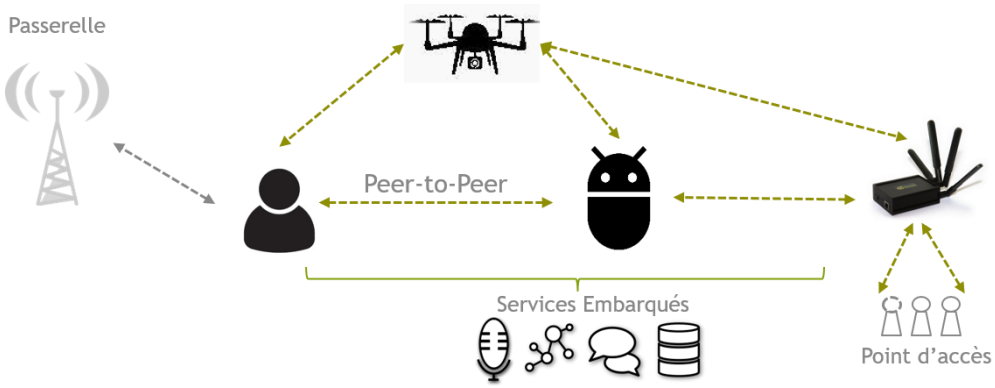


Use case example: Maritime pollution monitoring

Internet of Moving Things

Green PI connect fleets of moving things and provide them with shared intelligence for swarming, collaboration, and autonomous vehicles. The main market applications are: Transports & Logistics, Automotive, Defense, Public Safety, etc.

Green PI's IoT platform can be integrated as a software or embedded as a module onto smart robots, drones, vehicles, and wearables. A group of smart things enabled by Green PI gets broadband device to device capabilities for fast and autonomous communications among the fleet. The fleet also share an edge cloud with edge-based applications with quick data synchronization for swarming, collaboration, etc. Greater synchronization capabilities can be provided through the Internet of Edges of Green PI that federates multiple fleets located at different places.



Use-case example: Heterogeneous swarm of drones, robots, vehicles, and users

Massive IoT

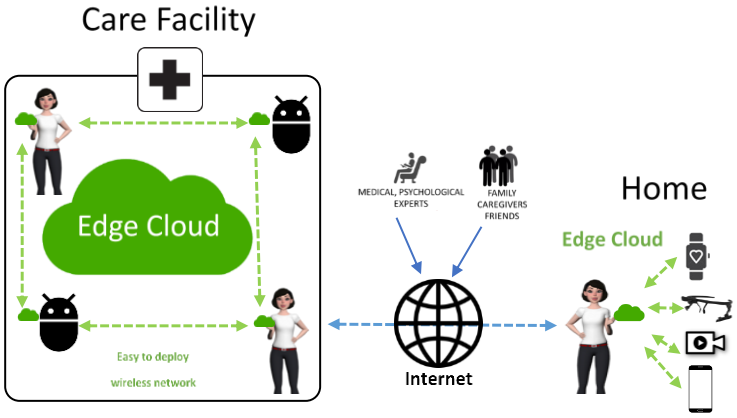
Green PI provides a scalable edge-based solution for massive IoT applications. Thus, over multiple locations. The main market applications are: Healthcare & Telemedicine, Manufacturing, Utilities, Smart Cities, Etc.

Green PI connects various types of smart devices with its open IoT platform. If the amount of smart device is high and requires more coverage, one can deploy additional IoT platforms. These platforms will synchronize with each other and act as a single hotspot. IoT devices will be able to move from one platform to another seamlessly.

Smart devices connected to Green PI's IoT platforms share a common edge cloud. The edge cloud hosts critical applications and services near the data source to guarantee access, sufficient speed, quick response, resilience to Internet breakdown, and data privacy.

Green PI offers the possibility to synchronize the edge clouds deployed at multiple locations to create an Internet of Edges. The Internet of Edges enables one to interact with any user, thing, and program of the Internet of Edges like if they were located nearby.

Thus, a doctor located at his office can interact with patients and their sensors locates at home and a surgeon in hospital A can interact with robots from Hospital B with a dedicated infrastructure and no data going to an external clouds.



Use case example: Smart hospital and telemedicine

INNOVATION

	Existing Edge platforms	Green PI IoE Platform
Architecture	Hierarchical towards a node in the cloud.	Horizontal from edge to edge
Services	Centralized in a distant cloud, a regional cloud (MEC) or in a fog node.	Distributed in the edges.
Scalability	Localized or extended using hierarchical architecture.	Scaled by tunnels from edge to edge.
Mobility	Moderate: mobility of objects only thanks to a fixed network of antennas including in the 5G infrastructure.	Full: mobility of objects and infrastructure. Thanks to an embedded platform and a synchronization system that supports the split and merge of resources in the edge.
Autonomy	NO. The platforms are dependent on a node: a central cloud, a MEC or a fog.	YES. The services are distributed in the edges without a central node.
Sovereignty	NO. The platforms are based on regional, national or international data centers owned by operators or large companies.	YES, IoE allows you to deploy IoT applications without leaving the edge and without going through a central node.
Openness	Owner with partial openness (open source OS, SDK, development environment)	Agnostic, it is possible to add interfaces, services, connect any type of object and edge.
Blockchain	Based on a fixed infrastructure with resources known in advance	Supports mobility, the split and merge of edge resources.
Carbon footprint	Will contribute to 30% of the global carbon footprint by 2027	Will allow an energy gain of up to 25%

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