Telefónica Open Access and Edge Computing

White Paper

February 2019

CONTENT

ABSTRACT

This white paper is an introduction to Telefónica's access network and Multi-Access Edge Computing evolution.

INTRODUCTION

We are at the start of a new era in telecommunications that will redefine how humans interact with technology. Digitalization and ubiquitous connectivity with everything and everyone define this era. It is driven by:

- **A huge increase in data traffic**: Potentially up to 100x more capacity will be required. The number of mobile devices is already huge (5 billion unique mobile subscribers in 2017) and continues increasing. In addition, volume and variety of mobile traffic continues growing (around 60% CAGR) and it is expected to be multiplied eleven times in the next five years.
- **New services and users' demands**: Consumers demand new types of mobile services to enjoy anywhere: virtual or augmented Reality, video 360º, 4K or 8K , connected cars or smart cities.
- **IoT explosion:** A vast array of networked machines that will digitize our world. Where we had 8.4 billion connected things in use in 2017, up 31% from 2016, we could have up to 20 billion by 2020.
- **Digitalization**: Consumers are demanding services that they can provision in real-time to enjoy faster personalized services.

Nowadays, many cloud computing services (health-care, gaming, video… etc.) are directly accessible from mobile devices, solving some of the resource constraints that those kind of devices have versus the desktop experience (processing power, battery lifetime, and storage capacity), but these cloud services suffer from a number of deficiencies:

- **Latency**: is the key factor for quality of experience, delay of milliseconds are perceptible if an application requires instantaneous interaction.
- **Security and trust** regulations often require that critical applications and data be served from the same country of the user.
- **Network cost**: it is not economically viable to serve high volume content from a centralized location.

New applications and uses cases are emerging, and require high-performance real-time response: applications such as vehicular control, augmented reality, virtual reality gaming or new services for industries will have different network requirements.

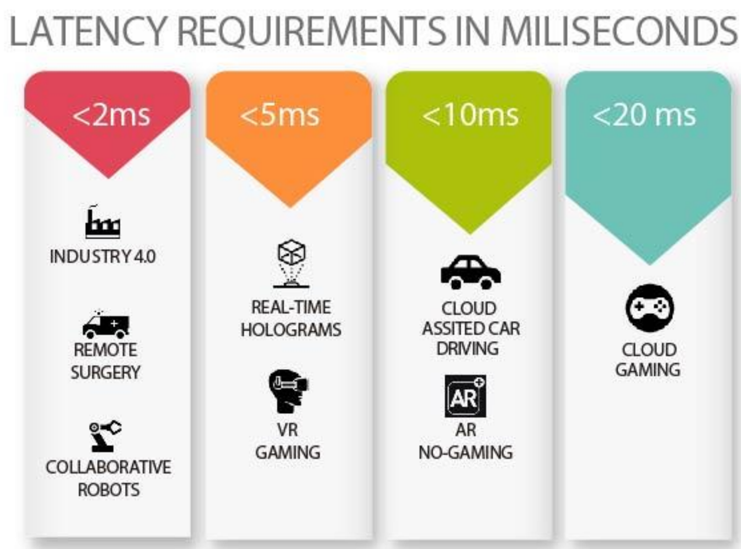


FIGURE 1: Estimation of requirements in milliseconds for each kind of applications

Telefónica's proposal to support this new paradigm is UNICA Edge (Telefónica's Multi Access Edge computing approach) over Open Access Architecture (OPA).

- **Open Access architecture:** This is a necessary evolution in order to deploy 5G, XGS-PON networks and CPEs in a sustainable way. Our access network will be transformed into an open and standard based access network. Natively built as a software-based solution with multivendor components integrated in a whitebox node.
- **UNICA Edge:** This is a scalable and orchestrated Multi-access Edge Computing infrastructure within the framework of our global network virtualization program UNICA. It will allow us the distribution of network loads or applications closer to the customers´ premises in order to improve network efficiency and reduce traffic processing delays. It will be made available to third-party developers as part of an "edge cloud" service offering.

Multi-Access Edge Computing (MEC or Edge Computing) is a telecommunications networks architecture that enables the placement of cloud and IT resources, methods and technologies in data centers within a telecoms operator network. These data centers can vary in size, location and capacity and can be deployed within mobile, fixed, TV and/or enterprise networks.
MEC is originally a standard from the European Telecommunications Standards Institute (ETSI) that was designed for mobile networks and was evolved to fixed and convergent networks. Deploying computing and storage resources closer to the customer, enables real time processing, guaranteed bandwidth and increased privacy and security while reducing latency, diminishing devices' computational needs, and lowering ineffective use of communication capacity vs. centralized Cloud. It plays an important part in delivering some of the promises of ultra-low-

latency and ultra-reliability in 5G standards. MEC promises to deliver the best of both worlds: cloud affordability and scalability, with on-premise performance and convenience.

WHY MULTI ACCESS EDGE COMPUTING?

Our digital lives know less and less boundaries. Between our phones, watches, tablets, computers, and TVs we produce and consume an extraordinary amount of data, in the form of videos, photos, files, calls, emails, etc. Increasingly, "machines" and "things" also use networks to communicate with us and with each other. Customers and services increasingly demand immediacy, which networks, clouds and devices struggle to provide, as demand and traffic increase. Cloud services have brought the internet to its next level, allowing content providers and developers to create global services that can be centrally managed and controlled while being distributed to nearly every region of the planet.
There has always existed, until now, a border between cloud and telecommunications networks, where cloud networks offered a set of IT tools and technologies to develop and locate services for international deployment, while telecommunications networks provided access to the services at the local level.

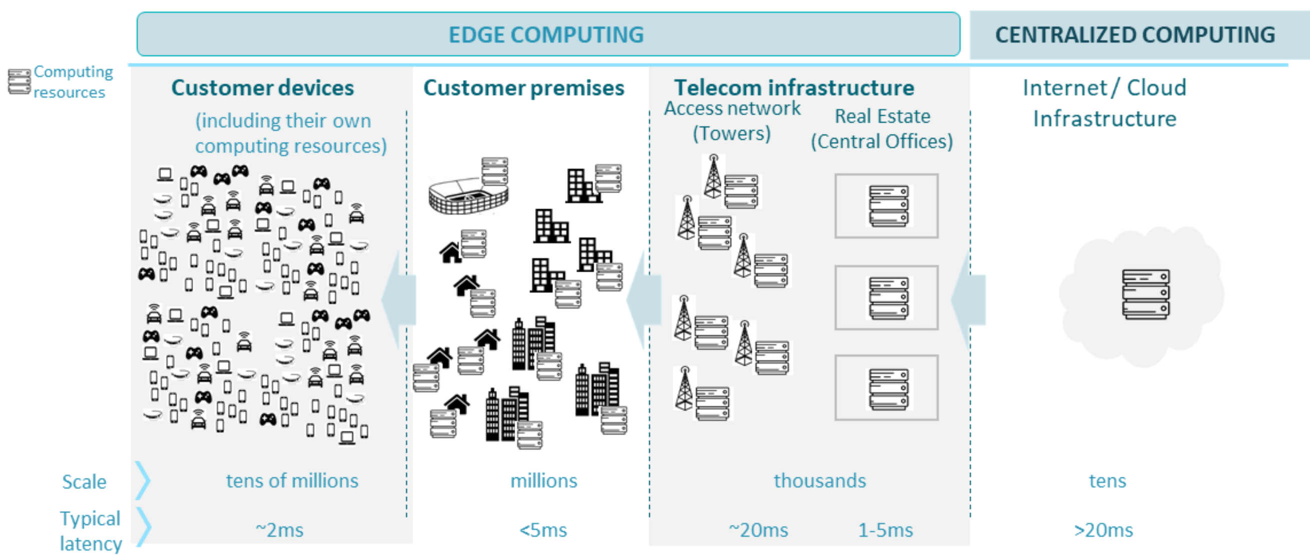


FIGURE 2: Edge computing, a solution with many possible locations

These boundaries are starting to blur, as customers demand better performance from the continuum between internet, public, private, hybrid clouds and telco networks. One aspect of providing better performance is to reduce latency, the round-trip time between a request and its response in a network. There are several ways to reduce latencies, but we will focus on the two following:

- **Computational latency:** Streamlining the computing processes to reduce the amount of request-response pairs, and the time necessary to process them in the computational framework

- **Transport latency**: Reducing the time it takes to move packets between the client and the server (the home and the cloud)

The internet industry has progressed rapidly in the former, with new protocols, architecture and software-defined networks that have pushed computational latency to its limits. The next gain opportunity in latency is in transport.
MEC is specifically designed to reduce transport latency by reducing the distance between the device and the compute and storage capabilities. This implies deploying compute and storage capabilities closer to where content and services are created or consumed.
Some of the possible locations for these data centres can be:

- **The telco cloud**: centralized data centres within the operator's network, serving a country or a region. Typically one per region. Latency 20 – 100ms
- **The telco core network**: centralized data centers serving mobile traffic. Typically 2-3 per country. Latency 20 – 50ms
- **Central offices, transport aggregation points**: decentralized traffic commutation centres, typically designed for copper or fibre aggregation, between the core network and the enterprise / home FTTH. Typically hundreds per country. Latency 5 – 20ms
- **Base stations, telco towers**: Compute and storage capabilities on telco towers. Typically 10's to 100's of thousand per country. Latency 1ms (5G) – 20ms (4G)
- **On-premise, on-device**: Computing solutions ranging from mini data centers in enterprise premises, to storage or compute appliances, to apps and software programs in devices. Typically, millions to 10's of millions per country. Latency >2ms

While, ideally, every customer and developer would like to benefit from the best possible latency, the cost of deploying and managing hardware and/or software in a handful or in millions of locations varies greatly and is a deciding factor in terms of the level of investment to enable edge computing.
Demand for latency-sensitive content is already starting to emerge, and as 5G is being defined in standards, a new generation of bandwidth hungry and latency-sensitive digital services and content services will continue to grow. The challenge of our industry is to find the minimum acceptable latency for each of them and the most economical way to enable it.

MULTI-ACCESS EDGE COMPUTING BENEFITS

ON PREMISE COMPUTING

On premise or on device benefits are clear. Pre-internet, it was the only model for development and execution of programs. It offers convenience and high performance, but is costly to acquire and manage over time, subject to obsolescence and not adapted for rapidly changing functional and performance needs. Nowadays, on premise solutions are chosen whenever an enterprise or user needs immediacy, complete control, and continuous use even without connectivity or for regulatory reasons (data sovereignty for example).

CLOUD COMPUTING

Cloud computing has brought infinite resources with the convenience of new business models (pay as you go, PaaS, IaaS,...) which allow developers and content providers to pay exactly for what they need / consume. The performance of cloud computing is variable in transport latency, depending on the location of the customer.

EDGE COMPUTING BENEFITS

With multi-access edge computing, telcos can make compute and storage capabilities available to customers at the edge of communications networks so workloads and applications are closer to customers, enhancing experiences and enabling new services and offers.

MEC implies improvement for existing applications such as content/application delivery or caching by bringing these closer to the user in a geographically distributed way. It is the key enabler for emerging scenarios such as Industry 4.0 (control and monitoring of industrial machinery), connected and autonomous vehicles, Augmented Reality (AR) and Virtual Reality (VR), federated artificial intelligence and consumer blockchain.

Multi-access edge computing brings:

- **Internal benefits for the operator (enabling savings and differentiation)** such as low latency, resiliency, network context awareness (analyse network information in real-time to optimise content/applications, etc.), backhaul cost savings, core congestion avoidance, etc. The first internal business rationale is to optimise network deployment and operation of its most distributed segments, in line with the transformation of Access and Central Offices. A driver is 5G deployment.
- **External benefits for end-customers and partners (enabling new services, new monetization opportunities)** such as cloud computing with low latency, resiliency, security, optimal allocation of resources (workload time shifting to optimise costs and performance), network context awareness, data sovereignty/localisation and lower end-device power consumption. The commercial opportunity is derived from potential integration with public and private clouds to provide a continuum of storage, computing and programmable connectivity. The business opportunity here is to explore whether low latency and local clouds have incremental value over transnational centralized clouds. If so, operators can capture additional revenues from 3rd parties hosting their functions, services and content in our infrastructure or consuming our networks resources as a service.

TELEFÓNICA OPEN ACCESS STRATEGY

Telefónica Open Access (OPA) is the evolution of Telefónica's access network based on hyper simplified network functions virtualization (NFV), software defined networking (SDN) and cloud computing technologies.
With that solution, Telefónica is progressing on "openness" by disaggregating the equipment components and opening standard reference designs for mobile and fixed access nodes, including customers´ premises equipment, hence further making headway in fixed-mobile access convergence.
Telefónica's OPA is increasing supply chain flexibility (access nodes are based on open reference designs and can be procured as whiteboxes), allowing development and introduction of network functionality and innovation from Telefónica and/or third parties in the access node. It provides opportunities for differentiation, facilitating fixed-mobile convergence (OPA-Fixed supports the backhauling of OPA-Mobile) and endowing the network with Multi-access Edge Computing (MEC) capabilities that facilitate the deployment of third-party applications at the edge.
The key principles of this architecture are:

- **Flexiblity –** It increases the flexibility in supply, as access nodes are based on open reference designs and be procured as whiteboxes.
    - OPEN books. Control the supply chain in HW and SW in order to have an end-to-end control of the costs.

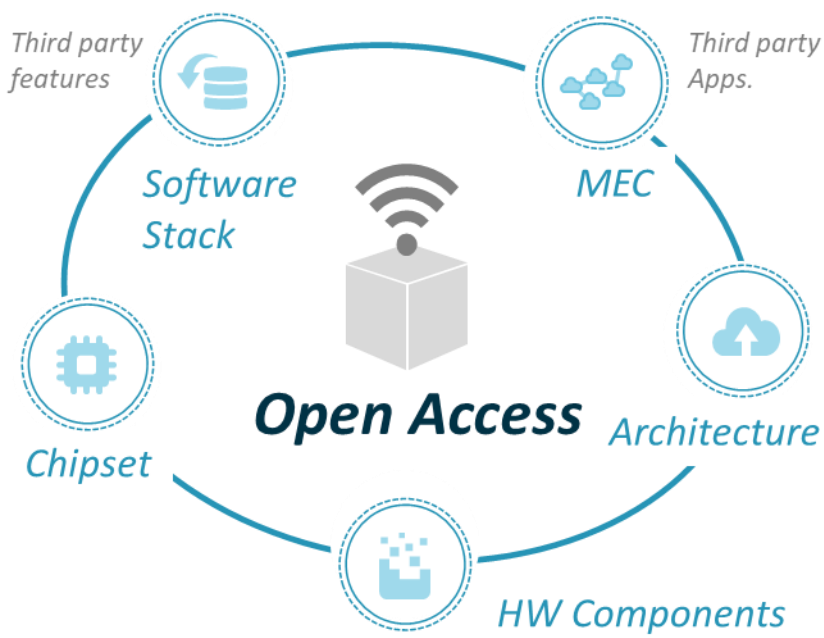


FIGURE 3: Open Access principles

- **Innovation** - It allows the development and introduction of network functionality and innovation from Telefónica and/or third parties in the access node enabling differentiation. This comes from the selection of components (focus on differentiation) and the use of open interfaces.

  - OPEN SW: SW stack with open APIs to facilitate deployment of new services and integration of components from different vendors
  - OPEN market. Decouple hardware and software, thus reducing the entry barriers for new entrants and fostering a healthier ecosystem

- **Efficiency by Convergence:** It facilitates fixed-mobile convergence: a) OPA-F, OPA-M and MEC shares computing infrastructure at the edge (Central Office and/or Access/Aggregation Node), b) OPA-F may support the backhauling of OPA-M
- **Efficiency by design control**: avoiding hardware vendor lock-in
  - It allows the operator to choose the right provider and technology for each component, being able to use wider-industry scale for some of them and opening competition at component level.
  - OPEN chipset. A node's architecture that can be easily transported to different chipset options to avoid HW lock-in.
  - OPEN RF (Mobile). Enable the aperture of the RF chain through open interfaces (e.g. CPRI) that foster interoperability and allow the long-term commoditization of the RF HW
  - OPEN OMCI (Fixed). Enable the interoperability between OLT and ONT through open interfaces
- **New Business:** it endows the network with Multi-access Edge Computing (MEC) capabilities that enables the deployment of own or third-party applications at the edge.
- **Intelligence —** Networks will become increasingly complex with the advent of 5G, that brings densification, new infrastructures and richer and more demanding applications. Our networks will become self-managed and will incorporate learning mechanisms to automate hardware and software life-cycle management and network function operation and maintenance, avoiding OPEX growth and operating risks.

OPEN ACCESS MOBILE ARCHITECTURE

The Open Access Mobile architecture is the evolution of the traditional mobile radio composed by an open radio node where hardware, software and radio frequency components are decoupled. The **Baseband unit and the radio unit are interconnected by an open interface**, in such way that a single Baseband unit can connect with radio equipment from multiple providers hence covering many different frequencies and technologies.
Hardware components are disaggregated, and based on a standard reference design over commoditized general-purpose processors, so that hardware can be selected, and eventually procured, independently. The software can run on any general-purpose server and provides full interoperability with radio and core network equipment from multiple providers.

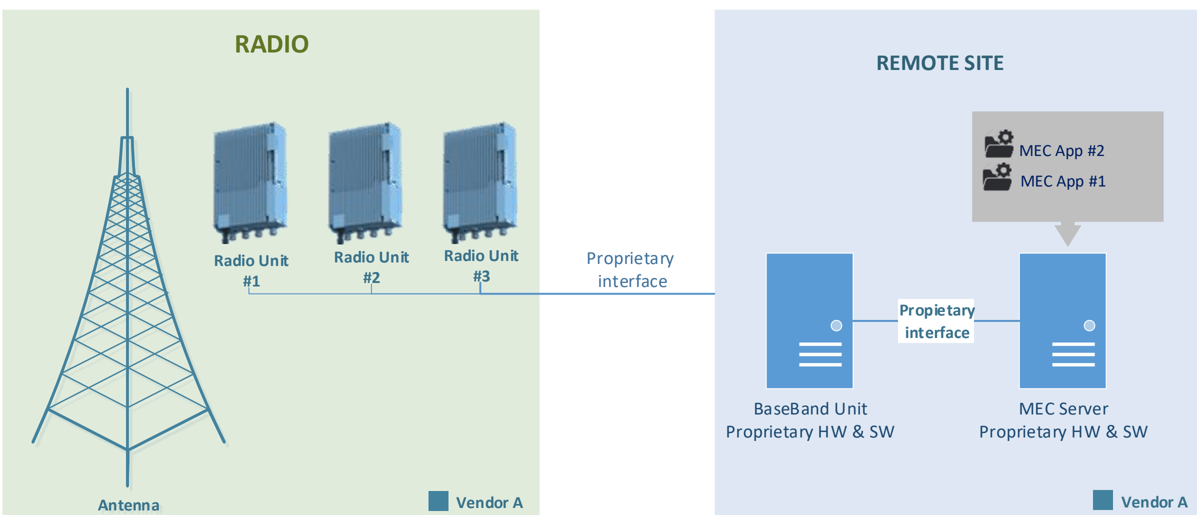
The pictures below shows the difference between traditional and Open architecture. In the traditional architecture,

- The **proprietary** nature of several interfaces (like CPRI) has stopped operators from using more than one vendor for radio and baseband equipment

- **Software** functionality is limited by what the **vendor** has developed and the licenses that are activated
- The **hardware is specific** so it could not be used with other software, as it could happen with general purpose processors (GPP)

With the open architecture,

- Telefónica will be able to execute functionalities and applications of a wide community of developers (including Telefónica's own)
- Telefónica could deploy a huge range of basebands and radios from different vendors, enabling **multivendor interoperability** as a way of increasing competition
- Telefónica will have a more **cost effective solution**, as it will be based on x86 platforms
- Telefónica will benefit from native RAN **virtualization** allowing **flexible RAN architectures**. 5G architecture need to evolve towards cloud design, leaving functions localization behind
- Telefónica will get open modularity and virtualization, that will be essential to deliver **agile and differentiated services** to our customers



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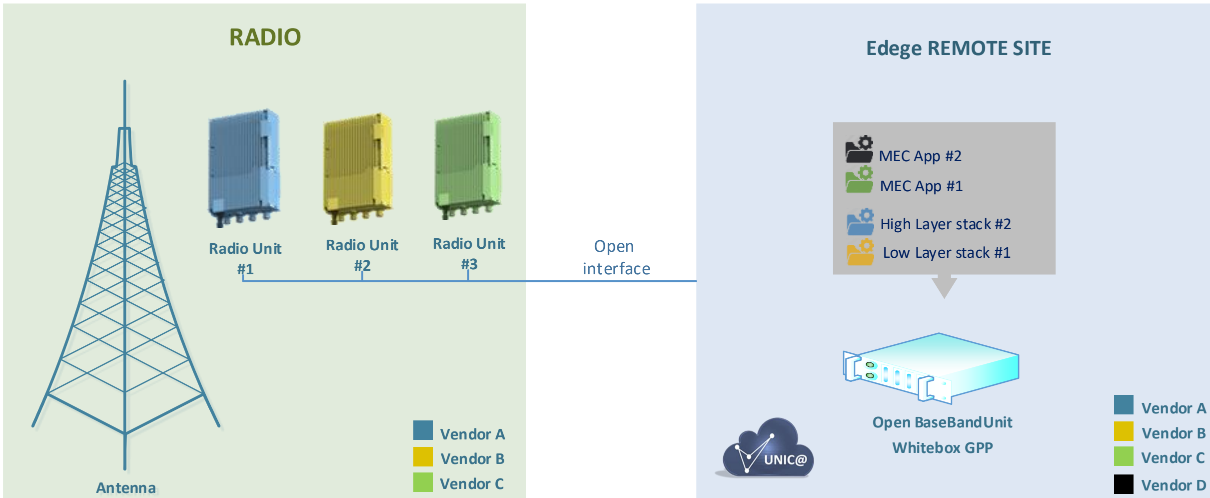
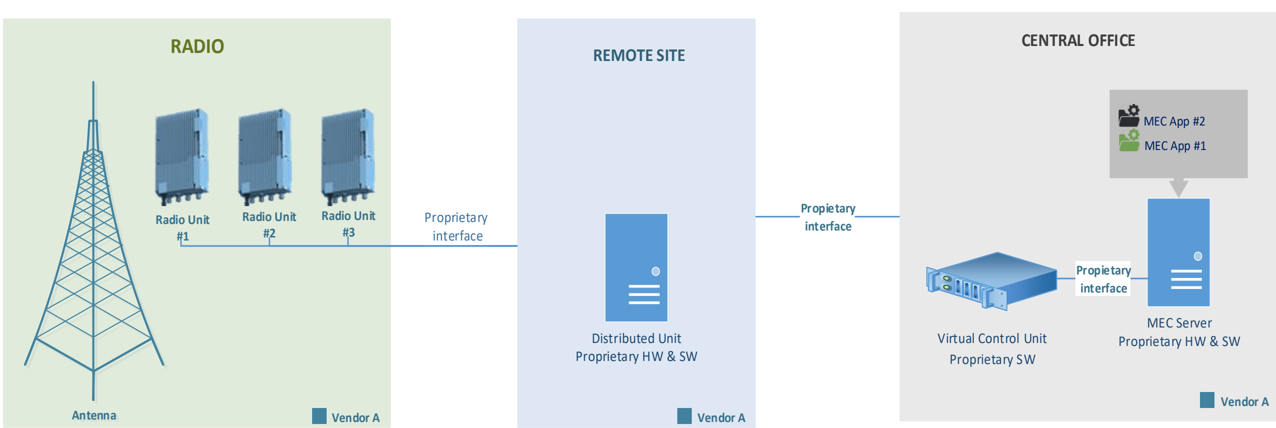


FIGURE 4: Distributed mobile Traditional vs. Open Access architecture

This open radio node can be used both in traditional and in Cloud RAN deployments with a simple configuration change, under exactly the same hardware. This confers a lot of flexibility for new 4G open access networks paving the way towards future efficient 5G deployments, opening new alternatives for supply and innovation.



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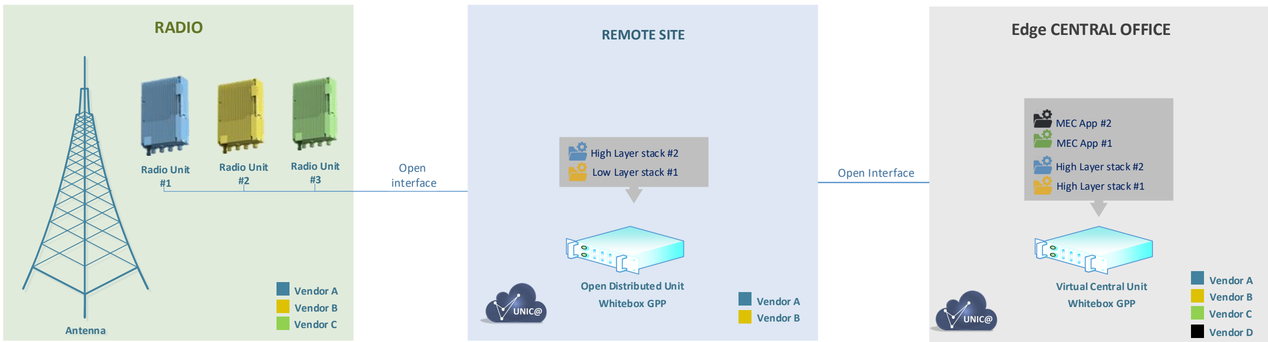

FIGURE 5: Centralized mobile Traditional vs. Open Access architecture

OPEN ACCESS FIXED ARCHITECTURE

The fixed architecture includes an **open XGS-PON optical access node (open OLT)** that uses open software and general-purpose hardware, **increasing interoperability** and flexibility. The new solution **brings full control of the OLT, enabling differentiation by adding new functionalities** to fixed access nodes; for instance, self-provisioning of FTTH connections or self-configuration of broadband in a dynamic way.

The picture bellow shows the difference between the traditional model and the Open Access Architecture. While **traditional** model:

- Uses proprietary chassis and hardware
- Uses a proprietary backplane
- Uses proprietary interfaces for control & management; it is not possible to connect to third party apps.

The fixed **open access** architecture:

- Uses a whitebox OLT as HW, and we can use different SW stacks on top.
- Uses open interfaces to connect with 3rd party apps for a richer control and management, allowing Telefónica to execute functionalities and applications of a wide community of developers (including Telefónica's own)

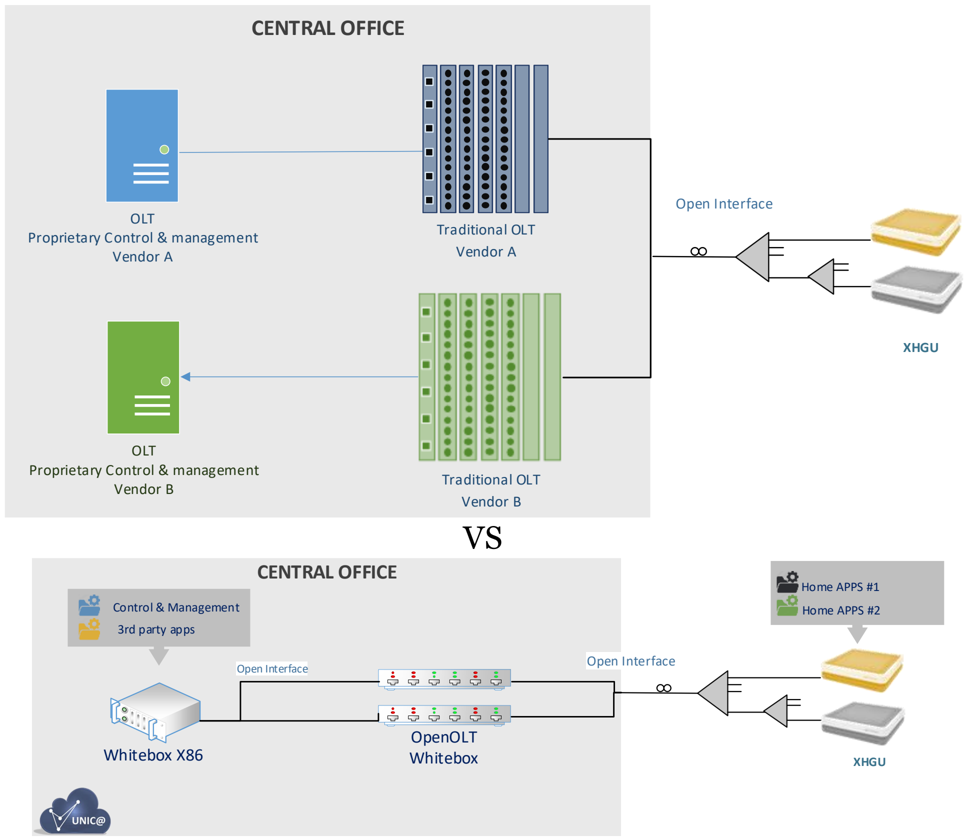

FIGURE 6: Distributed Fixed Traditional VS Open Access architecture

OPEN ACCESS HOME ARCHITECTURE

Telefónica, developing its CPE strategy, has evolved the concept from a Connectivity Center to a Service Center. For this step, Telefónica has adopted an architecture with two main elements; a service logic hosted in the cloud and a software agent integrated in the CPE.

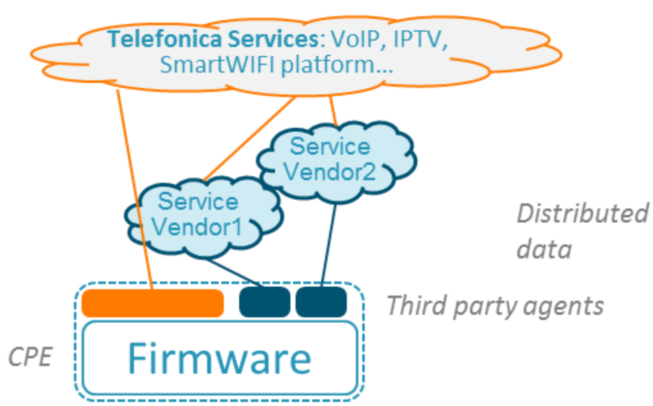

FIGURE 7: CPE current approach

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However, this model implies a long Time to Market apart of other aspects with a long improvement path. Telefónica, by means of **Open Access – Home devices (OPA-H)**, is going a step further, and is introducing an open and flexible model to expose and control the CPE capabilities through the Telefónica cloud.

OPA-H adds some additional benefits such as

- **Agility**, with faster developments and field deployments , reducing Time to Market,
- **Stability**, with CPE firewalls that do not require to be updated to support these new services,
- **Control**, with a complete solution based on the Telefónica cloud.

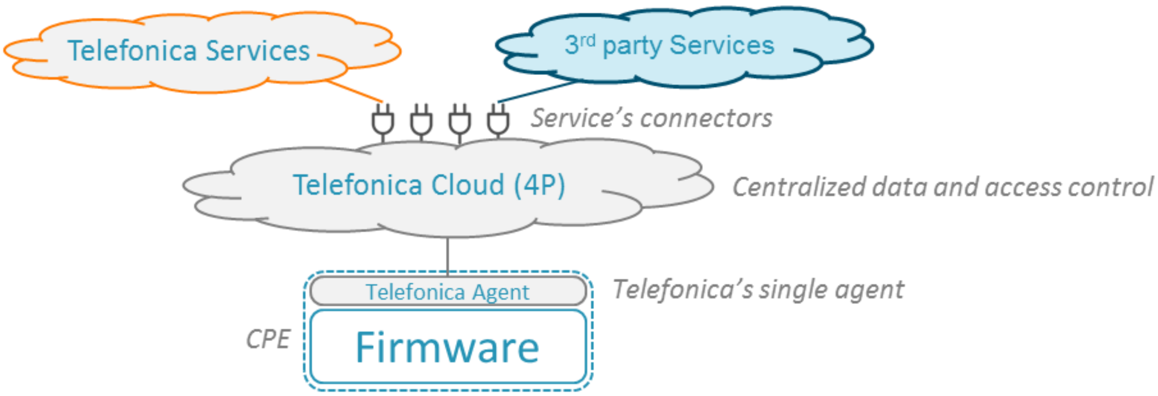

FIGURE 8 : Open Access Home approach

Furthermore, Telefónica is going to open this model to third parties by publishing public APIs to make the services integration easier and to promote an ecosystem of service developers.

TELEFÓNICA MEC STRATEGY

Network Virtualization, open architectures underpinned by open interfaces and multi-access edge computing are essential components for Telefónica's network evolution. For many years, we have already been progressing in all these areas, transforming our networks, models and organizations to tackle the challenges of the future.

We believe that many connectivity services will benefit from multi-access edge computing in the future and that the borders between internet, commercial clouds, hybrid, private clouds, core network and edge computing (fixed and mobile) will blur over time. Internet and content service providers will design their services with specific performance needs in mind (computation, storage, bandwidth, latency, location, volume…) and their deployment will depend on networks and cloud availability, specific service level agreements, and commercial and regulatory provisions.

TELEFÓNICA'S UNIQUE DIFFERENTIATORS

Telefónica has started its network virtualization years ago through the UNICA program. As the program progresses from the core, it is natural to extend virtualization to the edge and access functions. This network evolution is already part of our current CAPEX envelope, including Telefónica's traditional products and services. As we are readying our infrastructures, we are also exploring the opportunity to deploy innovative cloud services and content at the edge.
Customer demand and advanced uses cases that emerge could trigger additional investment, proportional to the expected revenues.

Telefónica's MEC is an evolution of UNICA and FUSION programs, enabling a programmable, software-defined, virtualized, orchestrated multi-tenant environment relying on a disaggregated, virtualized and programmable fixed and mobile access.

The key differentiators of Telefónica's MEC are:

- **UNICA** based: benefits from Telefónica's private cloud in elasticity, automation and centralized control
- **FUSION** based: virtualization, simplification and collapsing of the transport layer allow fixed and mobile access convergence
- **Open Access**: open APIs and interfaces allow easy integration of new vendors and open solutions
- **Programmable**: enable easy implementation of third party services and cloud workloads
- **UNICA EDGE**: UNICA EDGE is Telefónica's first implementation of edge computing, selecting the central office as the natural first edge location for the deployment of its multi access services.

This implementation enables elastic and automated function and service placement, based on real-time resource availability and cost considerations.
This programmable environment is not only suitable for telco functions and services, but also enables cloud service providers and developers to enjoy the same benefits.

A MULTI PRONGED APPROACH

The transformation towards a MEC-enabled network takes place at the same time as we renew different network elements and involves several lines of work:

- **Infrastructure and Architecture:** Telefónica is preparing its network architectures for edge computing while it transforms its network edge and access through
  - FUSION (simplification and collapse layers in transport network),
  - UNICO program (UNICA in the Central Office) and
  - Open Access Architecture for Fixed and Mobile access nodes.
- **Functional and commercial trials:** advance trialing and testing of uses cases with industry and verticals to find attractive business cases and refine business models.
- **Scale Up:** Telefónica is advancing in deployments, collaborating with other operators (need for API standards) and building common open industry platforms to get hyperscale.

EDGE USE CASES

Use cases are still being investigated in the industry. Telefónica's strategy is to trial many use cases, ranging from internal services (access virtualization, programmable connectivity…), commercial Telefónica services (TV, internet, enterprise cloud storage…) and third party services (cloud gaming, content catching, file storage and synchronization, SDWAN…) to measure customer's appetite, as well as understand new business models necessary for successful commercial roll out.
Edge computing will gradually approach access and will enable the precise distributed infrastructure to develop Edge use cases. We see that evolution in the medium term, advancing with virtual RAN, vBBU, vOLT, vBNG, vCDN…
In any case, our network virtualization strategy and integrated view of network, IT and edge infrastructure will allow us to make all our infrastructure multi-access edge-compliant. This will allow deployment based on use cases

Telefónica's Edge Computing approach, by combining access virtualization, programmable connectivity and multi access edge computing unlocks a number of attractive scenarios.

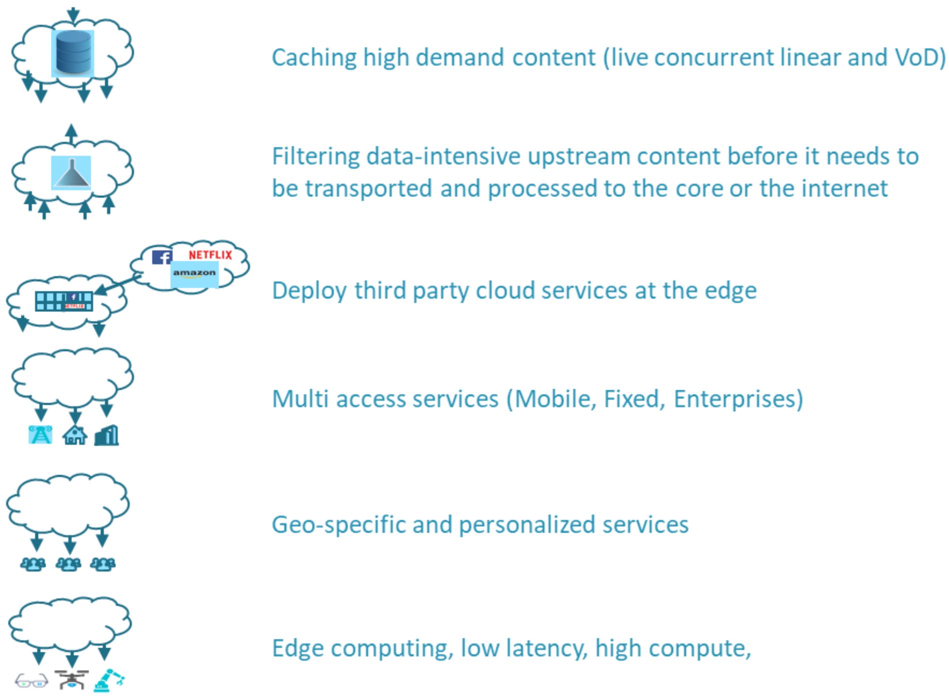

FIGURE 9: Edge computing services categories

- **Content caching:** Content virality means that most popular content is viewed many times, by many people. Storing this content closer to the screen or device it is played means a better user experience, with faster connection, download or stream and, most importantly, lower cost of transport.
- **Content processing:** As an increasing number of connected cameras try to upload their content for video surveillance, anomaly detection, etc., it becomes clear that in many cases, only a small proportion of this content needs to be processed and transmitted in real time. Storing, preprocessing and filtering this content at the edge allow for immediate reaction, as well as cost saving in transport.
- **Edge computing:** many computing intensive tasks such as Artificial Intelligence / machine learning are expensive or inefficient to run on premise and can be federalized and shared at the edge for better performance than the cloud at a cost benefit compared to on-premise / on device.
- **Cloud services:** virtually any cloud computing or storage service can be translated at the edge with performance improvement
- **Multi access services:** With the capacity to deploy services in an undifferentiated fixed, mobile and enterprise transport infrastructure, comes the ability to define new services that work seamlessly and simultaneously in fixed and mobile networks.
- **Geospecific services:** MEC allows to deploy services granularly and adapt them to the location / segment / vertical served by the host data center.

There are some services categories that will specifically benefit from edge computing such as those using intensively personal, biometric and geolocalized data (facial, object, location, situation recognition, etc.), so securing their treatment will be a highly appreciated added value.

The use of the edge will allow data treatment to be carried out locally, avoiding the transfer of data to the core or the cloud. Additionally, we envision that services that require a low response time / low latency such as in Industry 4.0 and massive IoT will benefit significantly from edge capabilities.

These categories, when crossed with our customers segment results in a number of innovative edge computing services opportunities and use cases:

- **Enhanced cloud services**: remote desktop, High performance cloud storage
- **Massive IoT:** Edge computing reduces the need for on device storage and computing, moving these functions to the edge and drastically reducing cost and enhancing battery life.
- **Gaming streaming:** replacing consoles by cloud game streaming.
- **Low latency services for Autonomous devices**: drones, cars, trucks, robotics.
- **Vehicle infotainment**: Streaming UHD content to fast moving vehicles.
- **Augmented, virtual, mixed reality, 8K** require edge computing because of the enormous amount of data that need to be transported and the necessity to create immersive environments without lag / delays that induce movement sickness.
- **Tactile internet** is a further evolution of AR/VR, where haptics (voice control, motion control, eye control) allow to manipulate / remote control vehicles, tools, devices… (Popular use cases: Remote surgery, Mining / dangerous environment tools, vehicles, remote-control robots).
- **Bandwidth / compute-hungry data services:** video surveillance, facial recognition, remote video production…
- **Federated Artificial Intelligence:** allowing prediction and learning in the edge, with only selected knowledge travelling up to the cloud. This reduces response times and protects data anonymity while preserving learning at scale.
- **Consumer blockchain:** running blockchain nodes in the edge which allow users to interact safely and with confidentiality with the blockchain from their devices.

REACHING HYPERSCALE

At Telefónica we see deploying MEC in our own network as the first step of the journey. If we take the examples of what happened with cloud players we can expect three stages of evolution to MEC:

- **Stage 1. Internal transformation**. First, we will start by using MEC for our own internal needs, much like Amazon deployed AWS to serve the needs of its online commerce business. This is already happening at Telefónica. The case for MEC makes sense just by considering our own internal virtualization and softwarization initiatives. The liquid network that will emerge from our UNICA, FUSION, UNICO, Open RAN and other initiatives will use compute and storage capabilities in the edge for its functioning. This makes it extremely cost effective to add extra capacity that can be used beyond Telefónica.
- **Stage 2. Early adopters.** Second, we will open up our surplus MEC capacity in the liquid network to early adopters. Companies in which the pain of latency is so high that it is worth it to work with a new emerging technology. For AWS it was Netflix and

SaaS companies which kickstarted product development and growth. It was extremely technical users that knew what they needed and were willing to work to get it. We need to find those early users for MEC and evolve the technology for them.

- **Stage 3. Global scale and mass market**. Finally, we will reach the point of deploying at scale. While for AWS this has involved opening up availability zones, for us it will probably entail bringing in other telcos to deploy with a standard format in their footprints. MEC requires the capillarity of footprint that only one of the leading telcos in a country can have. It might be in the guise of a standard like 5G, a common interoperable protocol like TCP-IP, a de-facto standard like Linux, a unifying layer like VISA in financial payments or Akamai in Content Delivery or maybe a federated model like networks themselves. Only time will tell and at this point Telefónica is exploring all the options to be able to provide what clients need as quickly and with the best experience possible.

We are working hard in the early stages of the journey that are totally under our control and have a clear business cases, even with no external demand. We are working on the **UNICA Edge project:** The virtual network infrastructure that Telefónica is building at the edge of its networks, to host access and user plane core virtual network functions in a first step and edge computing applications will come immediately after.
UNICA Edge is an extension of the current UNICA infrastructure, built at Data Center and Core locations to host mainly Core control plane VNFs and network service platforms. It uses UNICA's management and orchestration mechanisms, benefiting from its automatic VNF life-cycle management and operation. UNICA and UNICA Edge are a complete network virtualization environment that provides the basis for end-to-end network slicing, Network-as-a-Service and MEC functionality.

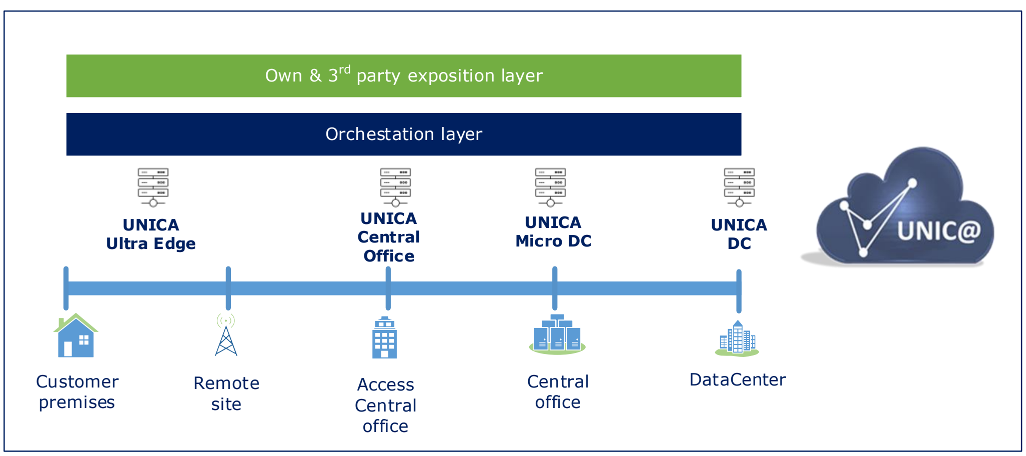

FIGURE 10: Telefónica's Edge Computing approach is based on UNICA Infrastructure

At the same time, we are looking for the early adopters to help us define and adapt our MEC products to meet customer needs. We are talking with our peers and other influential actors to find the right path to global scale in an ecosystem which is fragmented by default

TELEFONICA´S EDGE USE CASES OVER OPA´S DEMOS AT MWC19

Telefónica "Edge uses cases over an Open Access" is Telefónica's demo of Open Access architecture and Unica Edge: It shows an **Open Access prototype** in which hardware and software components are decoupled. It is built on general-purpose processors and based on an open and standard design.

The architecture is providing a platform that host fixed and mobile access network functions and edge applications (**UNICA edge**), demonstrating that this solution is able to serve several edge use cases, provided by either the operator or by its edge computing partner ecosystem.

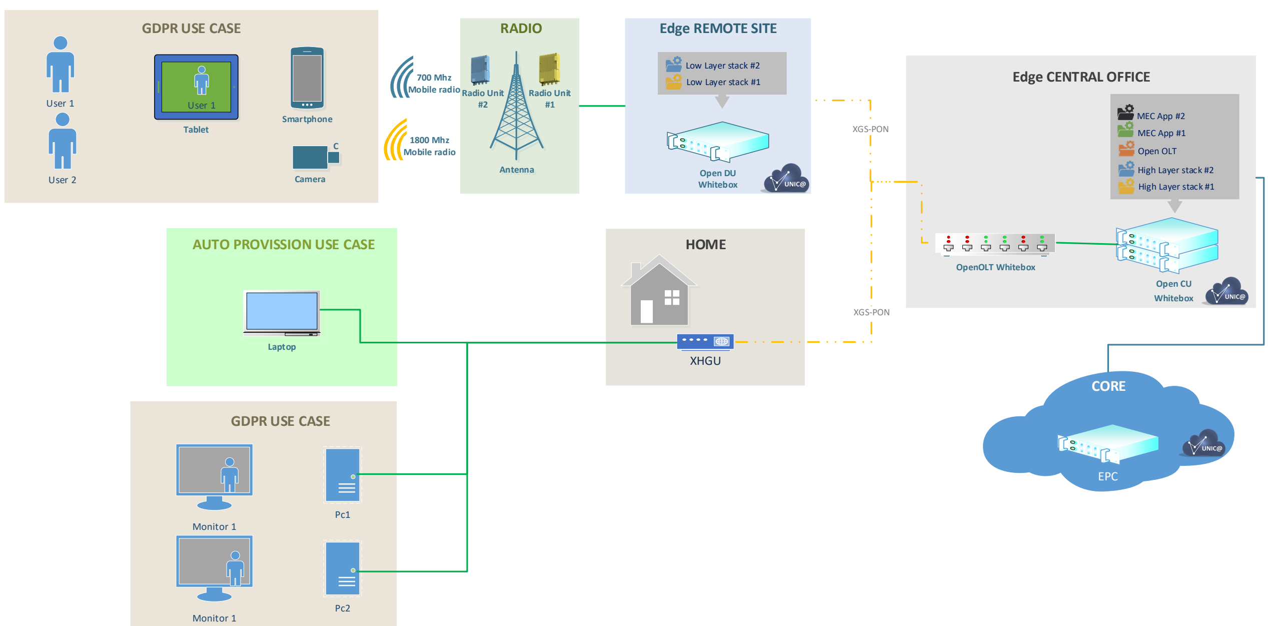

FIGURE 11: Telefónica's MWC19 Demos network diagram

The **Open Access architecture (OPA)** is composed of two radio access nodes connected to a fixed network disaggregated node and a home device. The backhaul connectivity is provided by the XGS-PON Open OLT demonstrating how fixed-mobile convergence is met. Telefónica's OPA initiative covers three areas:

- **Open Mobile Access (OPA-M)** an Open & virtualized RAN, with distributed solution (RRH, vBBU and vCU):
  - Chipset based on Intel x86 CPU
  - Ability to work with software from different suppliers (Altiostar, Mavenir) and with different hardware boards (Kontron, Dell)
  - Open and interoperable network interfaces
  - Open and interoperable antenna interface, capable of operating with multiple radio heads (MTI, Fujitsu,) in 4G and 5G
  - Able to support Cloud Radio Access Network (RAN) architectures and distributed RAN through software configuration

- **Open Fixed Access (OPA-F)** an Open & virtualized fixed optical access with a disaggregated Open OLT (XGS-PON)
    - Programmable 10-Gigabit Symmetrical Passive Optical Network (PON) interfaces based on FPGAs (Adtran)
    - Management & Control plane based on (x86 CPU) and Open SW
    - Open and interoperable software interfaces
    - Capable of interoperate with different Customer Premise Equipment (CPEs) and XGS-PON ONT - Small form-factor pluggable (ONT-SFPs from Cortina)

- **Open Access for Home (OPA-H)** introduces an open and flexible model to expose and control the CPE capabilities. Telefónica builds its own services and publishes public APIs allowing the creation of a developer ecosystem. The new Telefonica X-HGU (Mitrastar & Askey):
    - Main Chipset based on CA8279 (Cortina)
    - XGS-PON (ITU-T G.987.2) 10 Gbps symmetric
    - Wi-Fi 6 Dual Band 5GHz 8x8 & 2.4GHz 4x4 up to 9.7 Gbps (Quantenna)

- **Open Multi Access Edge Computing** for fixed, mobile, residential and enterprise
    - Commercial off the shelf hardware based on (x86 CPU) and Open Compute architecture
    - Open Source Software (VOLTHA and ONOS)
    - Telefónica's in-house development CLOSfwd 4.0
    - Open source VIM Open Nebula
    - Open source SDN Control ONOS

The demo shows two edge use cases, for mobile and fixed, deployed at the central office over the **UNICA Edge** platform:

1. An artificial intelligence Facial recognition based on GDPR regulations use case, executed at the mobile access
2. An auto-Provisioning use case applicable to the fixed access.

USES CASES DESCRIPTION

Telefónica MWC 19 demos show several uses cases to demonstrate how the new OPA architecture can be used to deploy innovative cloud services and content at a Datacenter infrastructure at the Edge of the Network (at Telefónica Central offices).

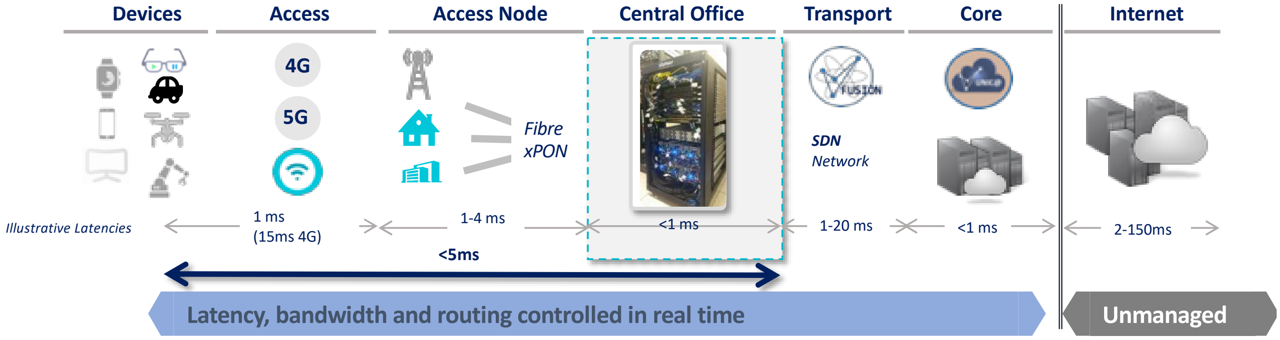

FIGURE 12: illustrative latencies based on location.

USE CASE 1: EDGE COMPUTING BASED AI-ASSISTED COMPUTER VISION - GDPR COMPLIANT

In this demo, we see a simple IP Camera, with no video processing capability. It is a simple and cheap equipment, that any customer can afford. This camera is connected to our Edge Computing node through a Mobile network (over 4G or 5G), and we are sending the video signal to the Central Office to which the base station is connected to, the one that provides radio coverage to the camera.

FIGURE 13: IP Camera

Using the Edge Computing infrastructure available in the Central Office, we can deploy an application that, using Artificial Intelligence, is able to perform facial recognition, but only shows the faces of people who have given their explicit consent for the use of their biometric data (as part of this demo) following the new GDPR regulations.
The visitors can register to the demo using a simple App in a tablet that takes a picture of the face of the visitor and registers biometric data. The app displays a blurred image of the set up at Telefónica booth, and only when user grants permission to use his bio data, the app shows the face of the visitor in a clear display.

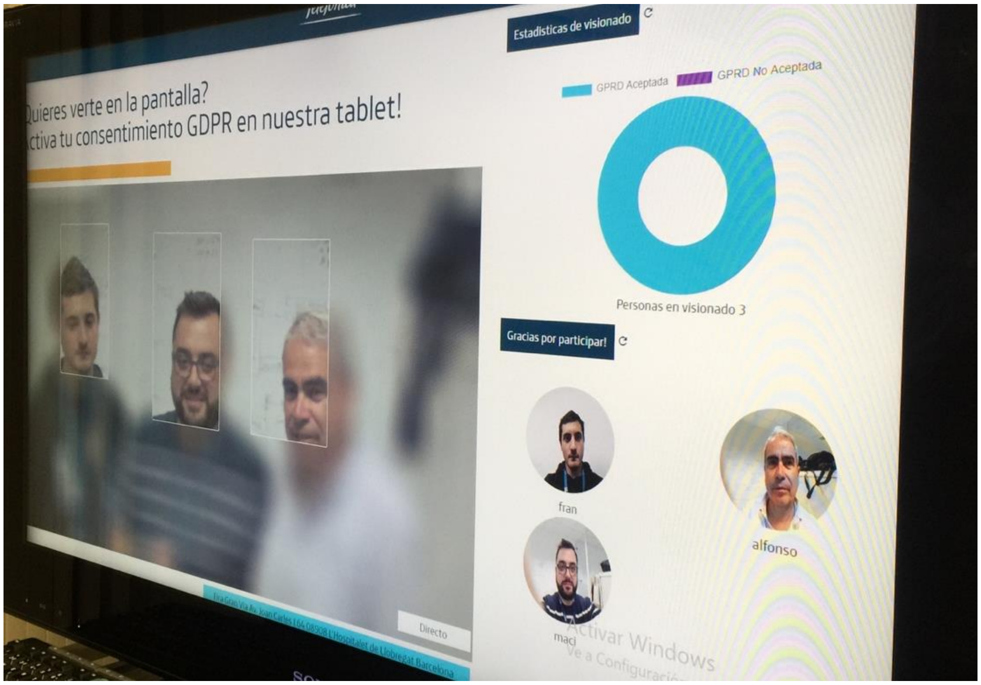

FIGURE 13: Telefonica GDR demo

If user revokes the permission to use his data, the application blurs the face again.

USE CASE 2: EDGE COMPUTING – TELCO SERVICES AUTO PROVISIONING

Telefónica is the leading operator in fiber deployment to the home (FTTH), but even so .... for each new fiber customer, we have to send a technician to install the service.
In the 21st century, users demand 100% digital experiences, also in their connectivity services.
What we are going to see in the auto-provisioning demo is a 100% digital experience for Fiber Fusion services self-provisioning. We have softwarized the fiber access by disaggregating the optical equipment using open hardware on one side and open software on the other side that we can integrate and control ourselves, with no need to contract any vendor
Imagine that a customer buys or rents a house, or simply decides to buy FUSION service and that the real estate unit is connected to our network. This customer can buy a CPE at any shop and connect it to their home with no assistance from any technician.
All the provisioning process logic runs in the edge computing infrastructure that controls access network, and is capable of provisioning in real time the capacity that user has selected for the Fusion package to buy.

#RECONECTA

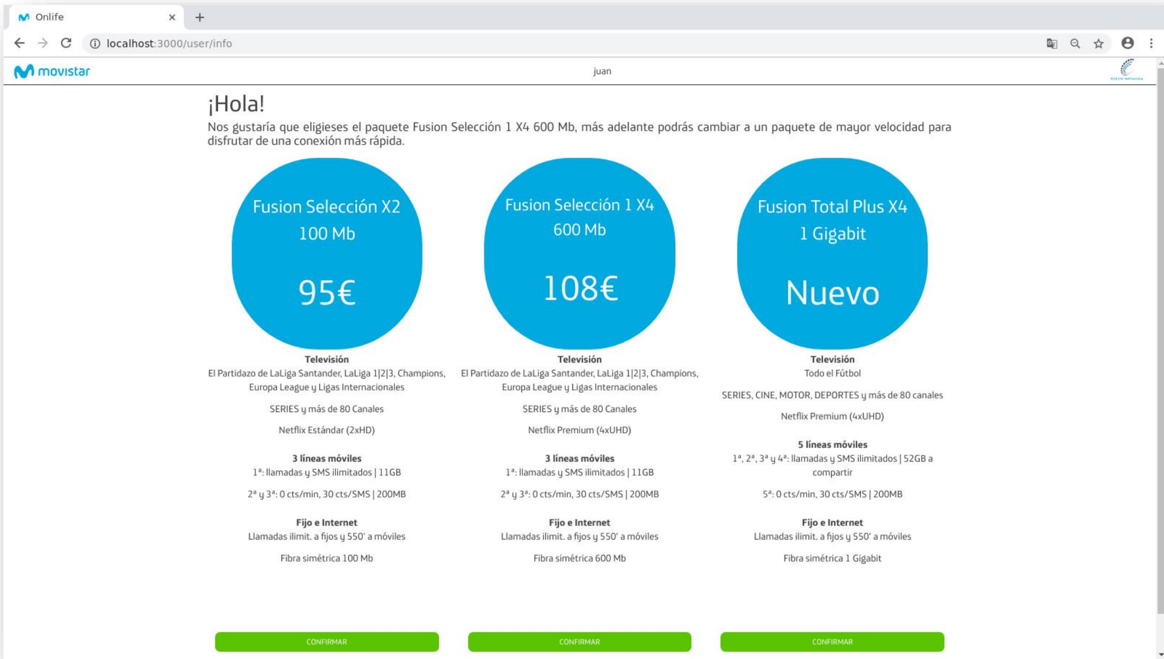

FIGURE 14: Telefonica auto provisioning demo

VENDOR ECOSYSTEM

The Ecosystem for OPA is wide and growing for both mobile and fixed networks:

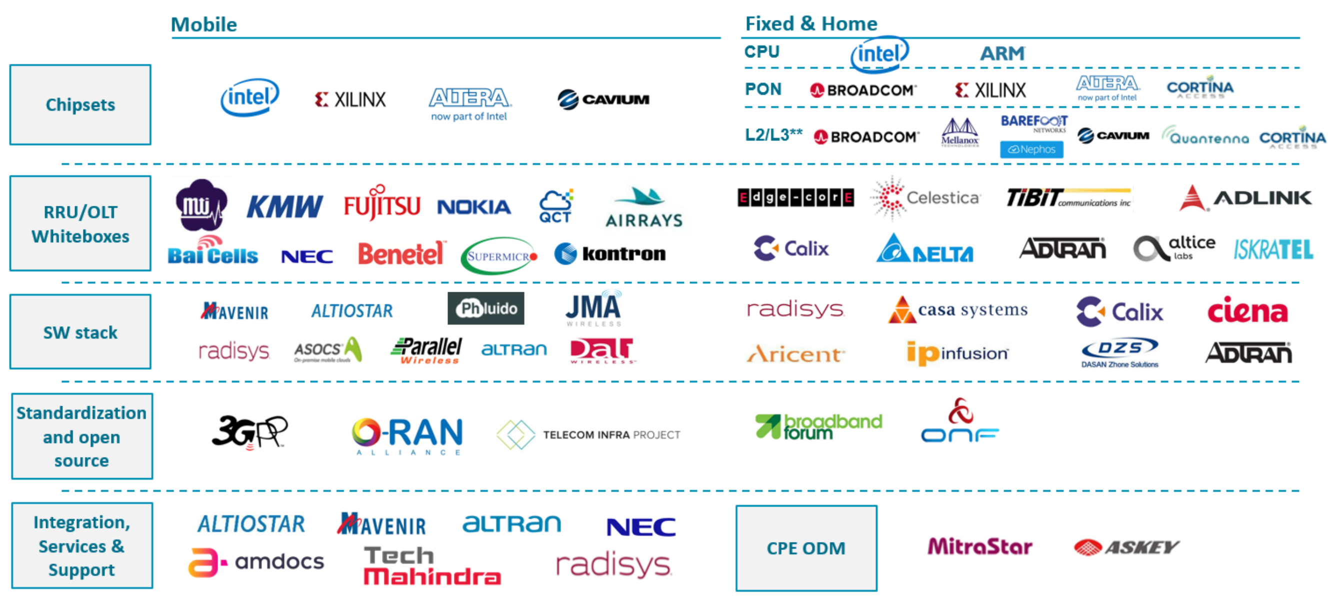

FIGURE 15: Telefonica OPA ecosystem

Following vendors have been take part on the Telefónica demo:

Vendor	Product	Function
Open Networking Foundation	ONOS	SDN Controller
Open Networking Foundation	VOLTHA	OLT – HGU Controller
Telefónica I+D	CLOSfwd	CLOS Fabric Controller
OpenNebula Systems	ONE	VIM
Celestica	Switches	Open OpenFlow Switches
Intel	Servers/Chipsets	a.Intel® Xeon™ Scalable and Xeon™ D processors b.Intel® FPGA and Programmable Devices c.FlexRAN: Intel® vRAN Reference Architecture
Altran	Facial recognition App	Facial recognition app implementation based on OpenVino
Adtran	OLT XGS-PON	OPA-F access node XGS-PON
Adtran	Switch	Switch top of rack

Cortina	ONT-SFP+ XGS-PON	ONT XGS-PON for mobile backhaul
Adtran	Open OLT XGS-PON	OPA-F access node XGS-PON
Mavenir	RAN SW stack	OPA-M SW components
Altiostar	RAN SW stack	OPA-M SW components

Some of the main vendors taking part in this demo have commented:

Robert Conger (Adtran - CTO America):
"As an ONF partner, ADTRAN provides access solutions for the open networking ecosystem so that service providers around the world can streamline the creation and deployment of revenue-generating servicesTelefónica is leveraging ADTRAN's SD-Access portfolio with flexible 10 PON to support existing FTTH subscribers while seamlessly providing a path to higher-bandwidth services."

John Baker (Mavenir - SVP Business Development):
"Mavenir Open RAN solution follows the O-RAN initiative having open interfaces between DU (Distributed Unit) and CU (Centralized Unit). Mavenir´s software solution allows to MNOs to use any Intel x86 COTS hardware (i.e. Kontron and Dell, HP, etc.), any hypervisor layer (i.e. RH, WindRiver NFV), as well as any RRU (i.e. MTI, Tecore Networks, Baicells, NEC, AceAxis, KMW, Benetel, CommScope, Blue Danube Systems, Airrays, etc.)."

Shabbir Bagasrawala (Altiostar - Head of Product Go-To-Market team*):*
"Open access solutions is the means by which that operators will be able scale to support the diverse services, features and applications that the next generation of users are going to demand from their service providers. By espousing the principles of an open architecture, Telefonica is laying the foundation for an elastic, scalable and software-centric network that has the innovation velocity to meet this growth. Altiostar supports Telefonica with this initiative by providing open virtualized RAN software solutions that help drive growth and innovation while enabling new business models for the industry."

Zino Chair (Cortina Access - CEO*):*
"As a partner in the Open Home Device (OPA-H) with Telefonica, Cortina Access provides an integrated 10G XGS PON Gateway Network Processor which delivers high performance wire-speed 10Gb/s WAN to LAN routing and provides the fully programmable offload engines for customized applications including Wi-Fi Offload (WFO) and security applications. This unique and future-proof architecture enables Telefonica to deliver virtualized home services and cloud-based applications."

Allen Lin (MitraStar Technology -Vice President)
"OPA-H offers us substantial benefits. It reduces the time and effort we spend on software integration when developing different applications and accelerates our ability to bring new

services to our customers in the market. MitraStar is fully committed to supporting this new deployment architecture. In this age of ever-increasing application demand, a streamlined network is vital to delivering next-generation services. Driven by our design and manufacturing initiative, we at MitraStar are excited to partner with Telefonica to deliver reliable networking products."

Joe Chow (Quantenna - Vice President of Product & Program Management)
"Quantenna provides high performance Wi-Fi 5 and 6 technologies along with Cloud based Wi-Fi monitoring solutions to enable Telefonica's CPEs and network services for their global residential subscribers. We are pleased to collaborate with Telefonica's Open Access-Home initiatives for reducing time-to-market of products and services while providing technology to improve performance, stability, management, and control of residential subscriber networks."

Robert Lin (Askey Computer Corporation - CEO)
"Askey continues to create connectivity solutions for Telefonica. Our latest 5G, xGPON, WiFi 6 (802.11ax) Router, Small Cell technologies and more, are all packed with customizable flexibility. We are confident to provide Telefonica with the most competitive and efficient customer-centric networking solutions and devices."

CONCLUSIONS

Telefónica is progressing in the execution of its strategy to digitalize and virtualize its networks.

As an extension of its UNICA program, it is pioneering access network equipment's disaggregation and virtualization, both mobile (open radio node) and fixed (open OLT) for residential and enterprise. The customer premises equipment, on whitebox design has its service logic integrated in the cloud and the edge.

The application of its governing principles – openness, disaggregation and programmability – allows Telefónica to create innovative services, with rapid time to market in a cost effective and sustainable manner.

Open Access heralds an era where networks can be assembled from interchangeable modular components, under Telefónica's control. Edge computing, as a natural evolution of the network allows the flexibilization of Telefónica's internal IT and telecom services placement and opens the door to collaboration with traditional cloud providers to create true hybrid cloud solutions and services.