ONEedge.io

A Software-defined Edge Computing Solution

D2.4. Solution Framework - d

Solution Framework Incremental Report

Version 1.0

3 November 2021

Abstract

ONEedge is a platform for extending private cloud orchestration capabilities to resources at the edge. It is built upon OpenNebula and applies a distributed cloud model to dynamically, and on-demand, build and manage private edge clouds to run edge applications. The aim of this third incremental version of the Solution Framework Report (D2.1)—which describes the framework's use cases, architecture, requirements and validation process—is to provide an updated report on the Agile methodology at the end of the Third Innovation Cycle (M17-M23). This document offers details about the fulfillment of the software requirements and the completed features for the main architectural components, and about the prioritization of features for the End Cycle (M24-M29) as part of our plans to meet the project's goal.

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Document History

Version	Issue Date	Status[1]	Content and changes
1.0	3/11/2021	Submitted	First final version of the D2.4 report

[1] A deliverable can be in one of these stages: Draft, Peer-Reviewed, Submitted and Approved.

Executive Summary

Document D2.4, released in M23 at the end of the Third Innovation Cycle, is the third incremental version of the Solution Framework Report (D2.1) in WP2 “User Success Management”. This report provides a description of the software requirements that have been addressed as part of the project’s Third Innovation Cycle (M17-M23), as well as a brief review of the priorities for the End Cycle (M24-M29).

During the Third Innovation Cycle (M17-M23), the project focused on those software requirements needed to achieve the third milestone in M23, which is the base functionality needed to meet networking & storage integration and its release as a standalone managed service (On-demand Edge Cloud Service).

The work carried out during this Third Innovation Cycle involved software requirements from components CPNT1, CPNT3, CPNT4 and CPNT5, with a special focus on the completion and integration of all components to release a first version of the On-demand Edge Cloud Platform service (CPNT1) and the deployment and provision of edge infrastructures (CPNT4). During the Third Innovation Cycle, we have developed campaigns that are specific to the ONEedge hosted service (standalone commercial solution) and not to be incorporated into OpenNebula. These are some of the main new features that have been implemented as part of this process:

- First version of the On-demand Edge Cloud Service (ONEedge “Edge as a Service” hosted instances) with definition of basic services and security requirements, key performance indicators, 24/7 health monitoring and alerts.
- Automatic customer environment deployment, configuration and bootstrapping, and complete life-cycle management of the ONEedge instances.
- ONEedge hosted framework implemented following a GitOps paradigm and leveraging Github WebUI portal and tools to simplify requests, monitoring and basic management, even for non-technical operators.
- Ability to dynamically load providers into OneProvision and extension of the OneProvision GUI, which features the Edge Provider Catalog Service, to scan and load new drivers without the need to update to a new release or modify any lines of code.
- Development of guides to create new providers that can be made dynamically available in the Edge Provider Catalog Service.
- Enhancements to provision and components to support transparent secure connection among geographically distributed edge locations.
- Development of new drivers for Google Compute Engine, Vultr (bare metal and virtual instances), and DigitalOcean.
- Development of new drivers for on-prem far-edge provisions.
- Support for ARM devices at edge locations.
- Addition of MetalLB load balancer to K8s appliance for better networking in Kubernetes clusters deployed at cloud and edge locations.
- New Sunstone GUI beta built using React/Redux and delivered by the FireEdge server.

These new features are described in report D3.6 “Software Source”, with the specifications and design of the new components being described in detail in document D3.3 “Software Report”. The testing process and certification infrastructure are described in D4.3 “Infrastructure

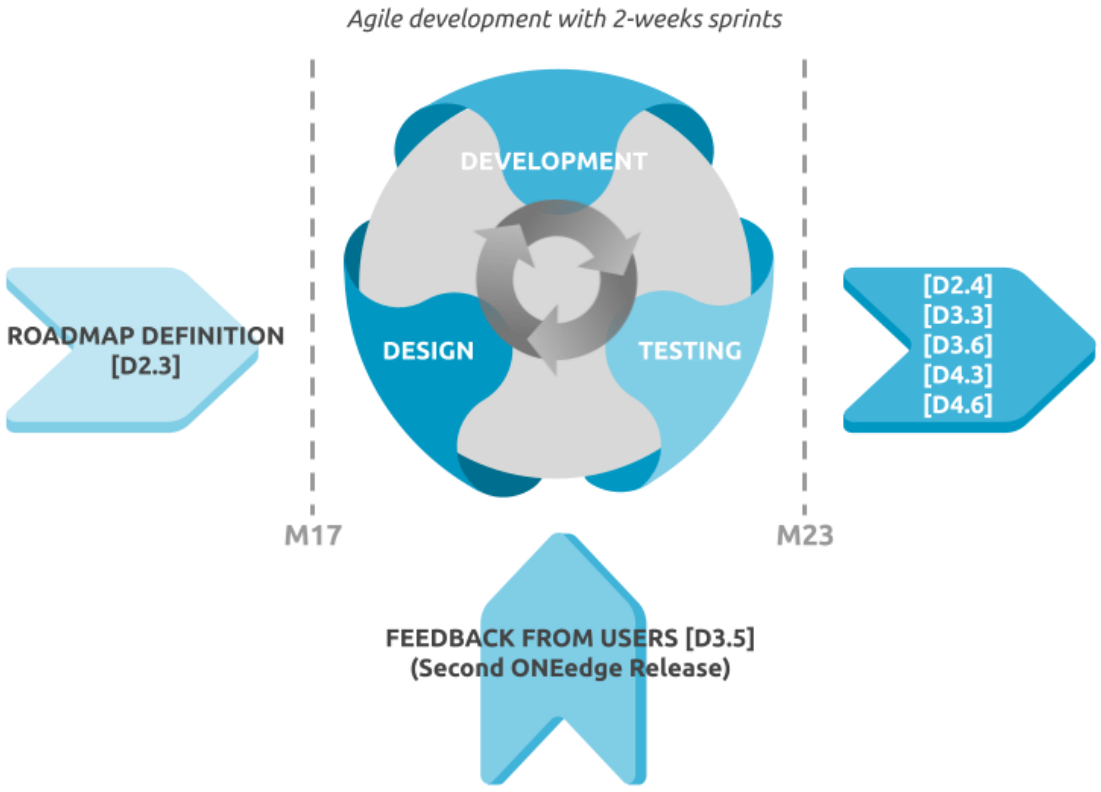
Report". The use cases demonstrating the new features developed in the Second Innovation Cycle are described in D4.6 "Deployment of Validation Cases and Demonstrations".

The present incremental report (Deliverable D2.4) includes a section with the priorities for the End Cycle (M24-M29).

Table of Contents

1. Introduction

The initial version of the Solution Framework Report (Deliverable D2.1), released in M3 after the initial framework definition phase, describes the use cases and user requirements that are guiding the innovative development of ONEedge, defines the main components of this Edge Computing platform, identifies the main software requirements derived from user requirements, and explains the test cases, methods, and demonstration scenarios that are being employed for the verification of the new Edge Computing features. An incremental version of this report has been released at the end of each development cycle at M9, M16, and M23 with a summary of the work done and priorities for the next cycle, as well as an incremental definition, if necessary, of use cases and requirements (T2.1), framework and architecture (T2.2), and verification suite (T2.3). However, as the ONEedge project deals with a software solution that is close to commercialization, and not a research prototype, no changes in the framework architecture are expected nor desirable at this late TRL stage, as that scenario would probably entail significant disruption to the implementation plans of the framework.



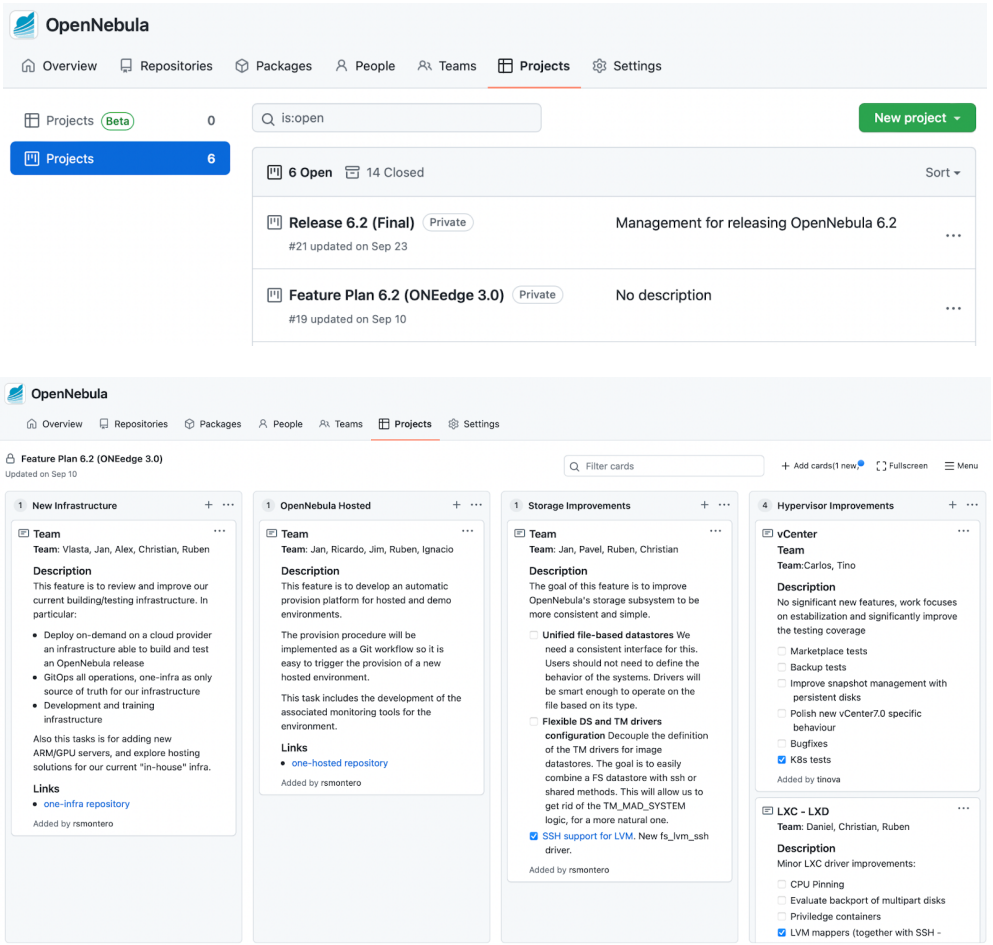
The aim of this incremental version (D2.4) of the Solution Framework Report is to provide an updated report of the Agile methodology in M23 at the end of the Third Innovation Cycle (M17-M23). It contains:

- A description of feedback (Section 2) collected during the Third Innovation Cycle (M17-M23) from early users of the second software version released in M16 after the end of the Second Innovation Cycle (M10-M16). This feedback has generated new requirements (Section 2.1) and extensions to existing requirements (Section 2.2) for the Third Innovation and the End Cycles.

- An up-to-date overview (Section 3) of the readiness and maturity level of each component of the ONEedge architecture in M23 at the end of the Third Innovation Cycle (M17-M23).
- A description of the software requirements (Section 4) that have been addressed as part of the project's Third Innovation Cycle (M17-M23) in order to achieve the third milestone of the project, including a description of the pending tasks for completion.
- A brief review (Section 5) of the external validation that will be performed from external use cases and collaboration with relevant initiative sin the EU.
- A brief review (Section 6) of the priorities for the End Cycle (M24-M29) in order to achieve the goal of the project.
- This report ends with a conclusion.

More details about the features developed are provided in report D3.6 "Software Source", with the specifications and design of the new components being described in detail in document D3.3 "Software Report". The testing process and certification infrastructure are described in D4.3 "Infrastructure Report". The use cases demonstrating the new features developed in the First Innovation Cycle are described in D4.6 "Deployment of Validation Cases and Demonstrations".

In order to implement an Agile approach, ONEedge uses GitHub Projects to track GitHub Issues, Pull Requests, and Notes. It provides a kanban-style board for managing work, and coordinating across separate code repositories. All the tasks for the internal development sprints are listed in one place by using an extension of what developers are already used to: GitHub Issues and Pull Requests that can be grouped in Milestones.



2. Overall Development Status

This section provides an overview of the readiness and maturity level of each component of the ONEedge architecture at the end of the Third Innovation Cycle. The table below shows the status of each software requirement following a simple color code: ✔ for completed activities and ↻ for activities in progress. Please note that:

- Section 8 “Software Requirements” of report D2.1 “Solution Framework” identifies the software requirements and lists the general tasks associated with each of the main components of the ONEedge architecture. Following an Agile approach, the specific tasks involved in the implementation of each of the software requirements are re-evaluated at the beginning of each Innovation Cycle.
- Section 4 of this document describes the tasks completed in the Third Innovation Cycle (M17-M23) and those in progress, including a description of the pending tasks for completion.
- The new software components corresponding to completed and in progress software requirements are described in report D3.6 “Software Source”, with the specifications and design of the new components being described in detail in document D3.3 “Software Report”. The testing process and certification infrastructure are described in D4.3 “Infrastructure Report”. The use cases demonstrating the new features developed in the Second Innovation Cycle are described in D4.6 “Deployment of Validation Cases and Demonstrations”.

Software Requirements	IC1	IC2	IC3	EC
Edge Instance Manager (CPNT1)				
SR1.1. Simple Product Deployment		↻	✔	
SR1.2. Automatic Product Upgrade	↻	↻		
SR1.3. Instance Management		↻	✔	
SR1.4. Subscription Management			↻	
SR1.5. Web Control Interface (GUI)			✔	
Edge Workload Orchestration and Management (CPNT2)				
SR2.1. Integration with Serverless Hypervisor	✔			
SR2.2. Specialized Cache Datastore		✔		
SR2.3. Secure and Scalable Distributed Monitoring	✔			
SR2.4. Virtual Machine Management Operations: Backups		↻		
SR2.5. Integration with Remote VMware vCenter Service	✔			
SR2.6. VNF Support	✔			
~~SR2.7. Support for Flows in Marketplace~~ [Redundant → SR5.1]				
SR2.8. Complete Service Flows	↻	✔		

SR2.9. Web UI extensions	↻	✔	
SR2.10. LXC virtualization drivers for OpenNebula [NEW]		✔	
Edge Provider Selection (CPNT3)			
SR3.1. Edge Provider Catalog Service		↻	✔
SR3.2. Edge Resource Latency Calculator Filter			
SR3.3. Edge Resource Cost Calculator Filter			
SR3.4. Driver Maintenance Process	↻	↻	✔
SR3.5. Edge Catalog Web Interface		✔	
Edge Infrastructure Provision and Deployment (CPNT4)			
SR4.1. Reliable Edge Resource Provision	↻	✔	
SR4.2. Usability, Functionality and Scalability of Provision	↻	↻	
SR4.3. Provision Template for Reference Architectures	↻	✔	
SR4.4. Inter-edge Networking Deployment Scenario			✔
SR4.5. Drivers for Host Provision		↻	↻
SR4.6. Drivers for IP Address Management		✔	
SR4.7. Drivers for Network Drivers and Helpers		✔	
SR4.8. GUI for Edge Resource Provision		✔	
SR4.9. Drivers for Far-edge Provision [NEW]			✔
SR4.10. Support ARM Deployments [NEW]			✔
Edge Apps Marketplace (CPNT5)			
SR5.1. Edge Applications and Services in Marketplace		✔	
SR5.2. Built-in Management of Application Containers Engine	↻	↻	↻
SR5.3. Integration with Application Containers Marketplace	↻	✔	
SR5.4. New Edge Applications Marketplace Entries	✔		
SR5.5. Edge Market GUI Developments		↻	↻

3. Feedback and Software Requirements Revision

As expected, the public release of the second version of software components produced during the Second Innovation Cycle, and its use in testing environments by some early OpenNebula users, has generated valuable feedback from the Community. This feedback has either been incorporated straightaway into the development of the Third Innovation Cycle, or is scheduled to be addressed during the End Cycle. This section summarizes the main contributions organized by Software Requirements:

SR	Description	Cycle
SR2.4	Support for snapshotting in back-up system	EC
SR4.5	Support Vultr for resource provisioning	3
SR4.5	Support Microsoft Azure for resource provisioning	EC
SR4.9	**[NEW]** Support on-premises far-edge for resource provisioning	3
SR4.10	**[NEW]** Support ARM for resource provisioning	3

3.1. New Requirements

SR4.9. Support On-Premises Far-Edge for Resource Provisioning
Feedback: We have seen a growing number of use cases in the mobility industry that require combining on-premises and edge resources. Customers want to deploy some parts of the application (usually state related components, like databases) in-house, while some other parts can be deployed in the *far-edge* or even in geo-localized cloud regions.
Description: Create new provision drivers that are able to deploy provisions in the datacenter resources in a similar way to edge or cloud locations. The drivers assume that resources are already available with a minimal configuration (base OS installation and SSH access). Based on these pre-existing resources, a new provision is created and pre-configured using a set of components similar to the edge provisions. Note that in this case, fully-functional components can be deployed as part of the provision like distributed storage systems.

SR4.10. Support ARM for Resource Provisioning
Feedback: One of the main demands from users deploying edge provisions is the ability to use instances that offer the best price. Usually the best price-to-performance value is offered by instances based on the ARM architecture; and so the ability to deploy edge provisions on this architecture has become crucial.
Description: Build ARM variants of ONEedge packages for the target operating systems.

3.2. Extensions to Existing Requirements

SR2.4. Virtual Machine Management Operations: Backups
Feedback: Being able to back up applications to different places, from private locations to the cloud, has been one of the most popular features of ONEedge. However, the initial implementation provides a limited range of functionality and flexibility to define a complete backup policy.
Description: Extend the VM and container management model to allow better backup functionality. ● Define a backup model for application disk images. ● Develop backup-specific drivers to accommodate different storage and backup solutions. ● Extended OpenNebula periodic actions to perform backups.
Extension: We plan to extend the backup interface to add additional functionality including: ● Retention time. How long or how many backups are kept. Automatically clean older backups. ● Adapt restore interface to manage multiple backups. ● Adapt one-shot backups to add a new entry in the backup list. ● Add a new quota to limit the number of backups or number of VMs with backups. ● Adapt Sunstone interface to previous modifications. ● Allow backups to be performed live if possible (e.g. configurable per VM or hypervisor).

SR4.5. Drivers for Host Provision
Feedback: A significant portion of the first users have declared their interest in using ONEedge with some providers not initially supported by the product. In particular, we have received requests to support Vultr and Microsoft Azure. Moreover, some use cases also benefit from running in virtualized nodes using a container technology. Users interested in these workloads are usually interested in DigitalOcean and Google Compute Engine.
Description: Improvements to host provision drivers and their interface. ● Improve logging and progress reporting from drivers. ● Extend types of operations with hosts (e.g. disk attach/detach).
Extension: Implement provision drivers and associated artifacts to run provisions on the following providers: ● Vultr ● Microsoft Azure ● DigitalOcean ● Google Compute Engine

4. Work Done in Third Innovation Cycle (M17-M23)

During the Third Innovation Cycle (M17-M23), the project focused on those software requirements needed to achieve the third milestone in M23, which is the base functionality needed to meet networking & storage integration, and its release as a standalone managed service (On-demand Edge Cloud Service).

Period	Summary	Main Results
M17-M23	Release as standalone distribution	• Solution meets networking & storage integration • Solution is distributed as a standalone distribution • Solution can be demonstrated in an operational environment • At least 20 users

The work carried out during this Third Innovation Cycle involved software requirements from components CPNT1, CPNT3, CPNT4 and CPNT5, with a special focus on the completion and integration of all components to release a first version of the On-demand Edge Cloud Platform service (CPNT1) and the deployment and provision of edge infrastructures (CPNT4). During the Third Innovation Cycle, we have developed campaigns that are specific to the ONEedge hosted service (standalone commercial solution) and not to be incorporated into OpenNebula. These are some of the main new features that have been implemented as part of this process:

- First version of the On-demand Edge Cloud Service (ONEedge “Edge as a Service” hosted instances) with definition of basic services and security requirements, key performance indicators, 24/7 health monitoring and alerts.
- Automatic customer environment deployment, configuration and bootstrapping, and complete life-cycle management of the ONEedge instances.
- ONEedge hosted framework implemented following a GitOps paradigm and leveraging Github WebUI portal and tools to simplify requests, monitoring and basic management even for non-technical operators.
- Ability to dynamically load providers into OneProvision and extension of the OneProvision GUI, which features the Edge Provider Catalog Service, to scan and load new drivers without the need to update to a new release or modify any lines of code.
- Development of guides to create new providers that can be made dynamically available in the Edge Provider Catalog Service.
- Enhancements to provision and components to support transparent secure connection among geographically distributed edge locations.
- Development of new drivers for Google Compute Engine, Vultr (bare metal and virtual instances), and DigitalOcean.
- Development of new drivers for on-prem far-edge provisions.
- Support for ARM devices at edge locations.
- Addition of MetalLB load balancer to K8s appliance for better networking in Kubernetes clusters deployed at cloud and edge locations.
- New Sunstone GUI beta built using React/Redux and delivered by the FireEdge server.

These features have been developed in a coordinated way between WP3 and WP4. The new software components and extensions to meet the software requirements have been specified and developed within the work package WP3, and the new functionality has been tested, verified, and demonstrated within WP4. Some of the software requirements involved the development of appliances and the automation of infrastructure deployment and configuration are also performed as part of WP4.

A new software version (OpenNebula 6.2 "Red Square")[2] was released on November 3, 2021, with the components described in D3.6 "Software Source". The specifications and design of the new components are described in detail in document D3.6 "Software Report".

We have also worked heavily on the infrastructure and the development of use cases. The testing process and certification infrastructure are described in D4.3 "Infrastructure Report". The use cases demonstrating the new features developed in the First Innovation Cycle are described in D4.6 "Deployment of Validation Cases and Demonstrations".

The following section summarizes the work that has been done as part of the Third Innovation Cycle, including the completed tasks associated with each component and its software requirements, as well as the current status of those SRs.

4.1. Edge Instance Manager (CPNT1)

SR1.1. Simple Product Deployment
Status: DONE
Completed Tasks: Containerized deployment of ONEedge has been completed. In order to further ease the deployment of ONEedge and to explore additional business models we are providing ONEedge as hosted instances. In this task we have: • Defined the basic services and security requirements for ONEedge hosted instances • Created provision files for popular cloud providers • Created automatic configuration playbooks for the selected services • Defined key performance indicators to monitor ONEedge instances and establish alerts based on them

SR1.2. Automatic Product Upgrade
Status: IN PROGRESS
Completed Tasks: No activity during the cycle.
Pending Tasks: Define method to upgrade ONEedge hosted instances that includes: • Detection of out-of-date instances, including ONEedge and OS components • Automate the upgrade process • Integration of a roll back mechanism

SR1.3. Instance Management

[2] https://opennebula.io/opennebula-6-2-red-square-release-candidate-is-out/

Status: DONE

Completed Tasks: This software requirement has been focused on the life-cycle management of the ONEedge instances. In particular we have defined a detailed workflow for the instance life-cycle, from customer request of the environment to its decommission.

SR1.4. Subscription Management

Status: IN PROGRESS

Completed Tasks: The provision and configuration tools of ONEedge instances have been integrated with our customer portal and business logic:

- Automatic creation of users
- Customer tagging and instance association

Pending Tasks: Subscriptions should be charged in a *pay-per-use* mode. To implement this model a detailed accounting tool for the instances needs to be in place. As part of this requirement we will develop a fine-grain accounting mechanism for the instances.

SR1.5. Web Control Interface (GUI)

Status: DONE

Completed Tasks: The ONEedge hosted framework has been developed following a GitOps paradigm and leveraging Github portal and tools. In this way, non-technical people can easily request a new hosted environment, check its status and retrieve the relevant data associated with it. Github offers a simple and modern WebUI so all the previous steps can be done in a point-and-click fashion.

4.2. Edge Workload Orchestration and Management (CPNT2)

SR2.4. Virtual Machine Management Operations: Backups

Status: IN PROGRESS

Completed Tasks: No activity during the cycle.

Pending Tasks: The following features will be implemented to extend the backup interface:

- Retention time. How long or how many backups are kept. Automatically clean older backups
- Adapt restore interface to manage multiple backups
- Adapt one-shot backups to add a new entry in the backup list
- Add a new quota to limit the number of backups or number of VMs with backups
- Adapt Sunstone interface to previous modifications
- Allow backups to be performed live if possible (e.g. configurable per VM or hypervisor)

4.3. Edge Provider Selection (CPNT3)

SR3.1. Edge Provider Catalog Service
Status: DONE
Completed Tasks: Ability to dynamically load providers into OneProvision. The OneProvision GUI, which features the Edge Provider Catalog Service, has been extended to scan and load new drivers made available to a particular instance, without the need to update to a new release or modify any lines of code.

SR3.2. Edge Resource Latency Calculator Filter
Status: PENDING
Pending Tasks: Consider information about location latency available in the catalog data model.

SR3.3. Edge Resource Cost Calculator Filter
Status: PENDING
Pending Tasks: Consider information about price per hour and per instance type available in the catalog data model.

SR3.4 Driver Maintenance Process
Status: DONE
Completed Tasks: The final outcome of the work done to address this Software Requirement is a Development Guide that describes how to create new providers that can be made dynamically available in the Edge Provider Catalog Service. Tasks completed include: • Generalize the certification tests • Description of the certification process • Improvement of the driver integration guides

4.4. Edge Infrastructure Provision and Deployment (CPNT4)

SR4.2. Usability, Functionality and Scalability of Provision
Status: IN PROGRESS
Completed Tasks: No activity during the cycle.
Pending Tasks: Develop Edge location update and better bootstrap of provisions.

SR4.4. Inter-edge Networking Deployment Scenario

Status: DONE

Completed Tasks: Enhancements to provision and components to support transparent secure connection among geographically distributed edge locations. The initial approach will be to communicate applications through public IPs. In order to not exhaust the public IP pool of a provider or because of limitations in their provision model, we have implemented a port-forwarding driver. The new port-forwarding model includes:

- New lease type to assign free ports to a VM
- New driver set to automatically configure and remove DNAT and SNAT rules
- Integration with the Security Groups rules

SR4.5. Drivers for Host Provision

Status: IN PROGRESS

Completed Tasks: We have created a new driver set including: terraform templates, provision files, and runtime support for the following providers:

- Google Compute Engine
- Vultr (bare metal and virtual instances)
- Digital Ocean

SR4.9. Support On-Premises Far-Edge for Resource Provisioning

Status: DONE

Completed Tasks: We have extended the provision engine to support on-premises provisions, which consist of a set of pre-configured resources (minimal OS installation and SSH access). The on-premises provision includes configuration recipes for common storage and network solutions, as well as basic templates for the on-premises provision (i.e. cluster or datastores).

SR4.10. Support ARM for Resource Provisioning

Status: DONE

Completed Tasks: We have added ARM (aarch64) packages to the ONEedge release. Apart from updating the package templates we have extended the building infrastructure to support the new architecture.

4.5. Edge Apps Marketplace (CPNT5)

SR5.2. Built-in Management of Application Containers Engine

Status: IN PROGRESS

Completed Tasks: Improvements in K3s appliance (lightweight Kubernetes distribution for the edge) to run on KVM and addition of MetalLB (load balancer) to our Kubernetes appliance for better networking at cloud and edge.

Pending Tasks: The following tasks to be developed in the last cycle:

- User should define only the main attributes like number of nodes, CPUs or RAM of each node to fully deploy a K8s cluster
- Tighter integration of K8s/K3s deployment
- Network improvement through integration with Calico CNI

SR5.5. Edge Market GUI Developments

Status: IN PROGRESS

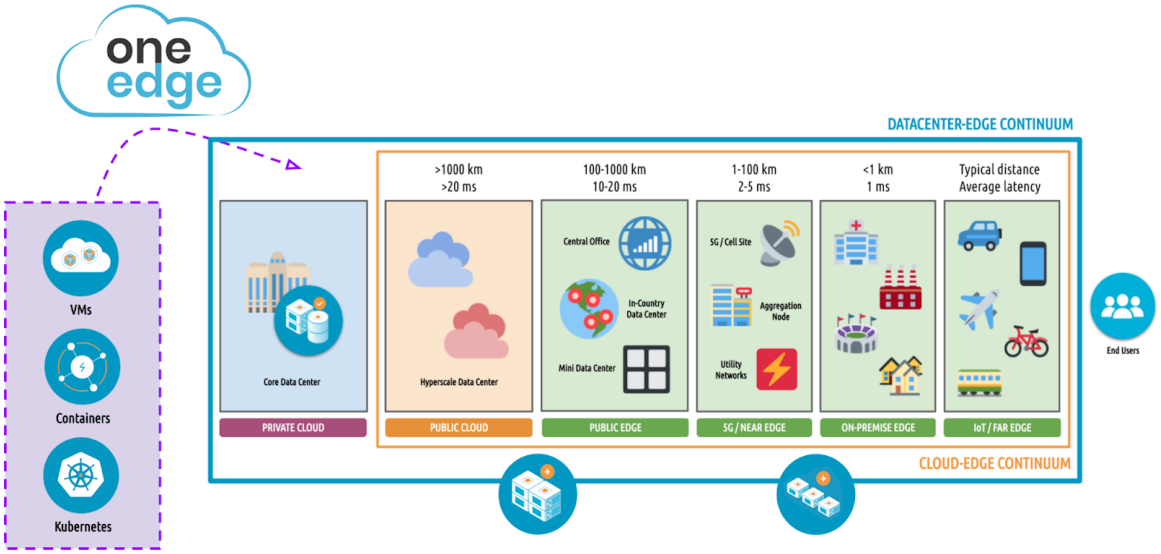
Completed Tasks: New Sunstone GUI beta present in OpenNebula 6.2, built using React/Redux and delivered by the FireEdge server, which has been extended to deliver several applications, including the OneProvisionGUI and this new Sunstone interface.

Pending Tasks: Complete development of Sunstone GUI to cover all OpenNebula resources, enabling the deployment of workloads over different OpenNebula clusters and edge clusters.

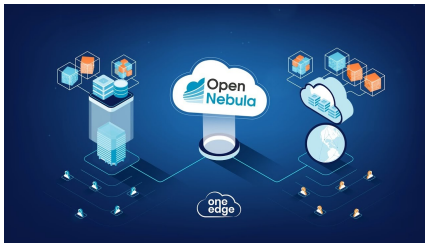
5. External Validation Cases

OpenNebula 6.0 "Mutara" was released in M18[3] (April 2021), at the end of the Second Innovation Cycle, with all the innovative Edge Computing enhancements developed in ONEedge during the first two innovation cycles. This software version was the **first integrated solution that brought simplicity and automation to build true hybrid and edge cloud environments**. The software provides unified management of IT infrastructure and applications that avoids vendor lock-in, reduces complexity, resource consumption and operational costs, while providing a simple solutions for users to manage:

- **Any Application:** Combine containerized applications from Kubernetes and Docker Hub ecosystems with virtual machine workloads in a common shared environment to offer the best of both worlds: mature virtualization technology and orchestration of application containers.
- **Any Infrastructure:** Unlock the power of a true hybrid, edge and multi-cloud platform by combining private cloud with infrastructure resources from third-party virtual and bare-metal cloud providers such as AWS, Microsoft Azure and Packet (Equinix Metal).
- **Any Time:** Automatically add and remove new clusters in order to meet peaks in demand, or to implement fault tolerant strategies or latency requirements.



This was an essential milestone to deliver the ONEedge service and its commercialization because it has allowed us to receive **more valuable feedback from corporate users and providers.**



OpenNebula 6.0 "Mutara", released in April 2021, provides a **powerful, open, multi-cloud platform** that prevents vendor lock-in, enabling private clouds to extend to the edge and also make use of infrastructure provided by hyperscalers and telcos, with technology that can also be used by new edge providers to offer their own infrastructure to customers.

[3] https://opennebula.io/opennebula-6-0-mutara-expanding-your-multi-cloud-to-the-edge/

5.1. External Use Cases

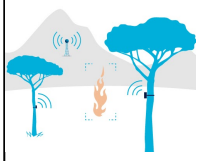
As part of the Third Innovation Cycle, as outlined in D2.3 “Solution Framework”, we have continued working with the members of our **Edge Computing User Group**. The objective of this group is to share new developments and ideas and to get feedback from those OpenNebula corporate users interested in contributing to building robust Edge Computing capabilities into the new versions of OpenNebula.

The members of the Edge Computing User Group are providing us with informal feedback and helping us identify new requirements and possible synergies and collaborations with other industry actors and projects. This is the list of external use cases that we are considering:

Use Case	Company	Country	Main Challenge	Infrastructure
Smart Tourism	Play&Go	Spain	AR/VR, AI/ML analytics	5G / Near Edge
Wildfire Management	CMCC	Italy	Data transfers	5G / Near Edge, IoT / Far Edge
Smart Cities	ACISA (Grupo Aldesa)	Spain	Deployment of multi-tenant edge environments	5G / Near Edge, On-Prem Edge
Farming	Solidaridad Network	Netherlands	Low bandwidth and occasional loss of connectivity and/or power	Public Edge / On-Prem Edge

Smart Tourism Use Case

In the last decade, digital technologies have brought significant transformation to the EU tourism industry by disrupting tourist destinations and businesses with innovative products and experiences, fuelling the competitiveness of a wider range of destinations. In the post-COVID era, Smart Tourism is expected to make the sector more resilient and sustainable in the medium and long term, and to contribute to re-launching the European economy. Smart Tourism destinations demand the deployment of a new generation of applications capable of leveraging the benefits of 5G to offer a better user experience to their visitors and to improve the local AI-based processing of relevant data as close as possible to the end-user, thus minimizing latency, security risks, and energy consumption derived from data transfers. Apart from the experience we have got from long-term engagements with corporate users with large OpenNebula deployments, such as Booking.com, we are already collaborating with a number of highly-innovative SMEs in the tourism sector, including the Spanish company Play&Go Experience. Together we are looking at ways in which a combination of Edge Computing and 5G technologies can help overcome a number of limitations derived from the use of centralized cloud when deploying applications of augmented reality, spatial intelligence, geomarketing, Big Data, and AI/ML.



Smart Wildfire Management

The year 2021 has witnessed a significant increase in the number and ferocity of the so-called 'mega-fires', a phenomenon linked with climate change that has had dramatic consequences in several European countries. IoT/Edge technologies, coupled with AI/ML and 5G technologies, can play an important role in preventing and fighting wildfires. Information gathered from thermal/HD video cameras and environmental sensors deployed in the forest not only offers better monitoring but also helps to predict, detect, and manage wildfires while still in their early stages. By using a traditional cloud-centric model, latency and near-real-time analytics on the behavior and spread of wildfires cannot be achieved effectively due to the large amount of information to be transmitted. Bringing data processing capabilities at the edge, close to the IoT devices and response teams deployed on the ground, can provide a powerful tool for real-time assessment of wildfires. We are working with scientific institutions, like the Euro-Mediterranean Center on Climate Change (CMCC) and several European SMEs to analyze how to provide edge capabilities and deliver the real-time responses required to model the dynamic behavior and spread of wildfires. These solutions would support the development of low-latency edge applications capable of extracting knowledge from the continuous stream of information coming from heterogeneous IoT devices, providing real-time information for assessing and fighting wildfires more effectively.

Smart Cities

Edge Computing makes it possible for local governments to deliver public services that are responsive to the real needs of their citizens, something that has a direct impact on our quality of life. In Smart Cities, distributed intelligence and data processing can inform smart devices, like traffic lights and parking meters, and also improve the response to traffic incidents and emergency situations. Combined with 5G, new edge applications are being developed to improve cities in terms of traffic congestion, pollution, public safety, energy consumption, and urban waste management. We are working with companies like ACISA (Aldesa Group) to design urban deployments of new edge infrastructure for Smart Cities. Using OpenNebula's orchestration and automation features, these next-generation solutions would be able to provide a multi-tenant environment for the on-demand deployment of edge applications, which optimizes the use of physical resources and offers immediate integration with new 5G technologies.

Farming

As part of its new “Fair Data Program”, the Dutch NGO Solidaridad is interested in using our edge technology (in combination with the P2P cloud edge infrastructure provided by the ThreeFold Grid) to accelerate digital transformation across their network of local producers by deploying a decentralized, hyperscaler-independent platform that incentivizes local communities to directly deliver intelligence and relevant data (e.g. soil conditions, temperatures, rainfall, expected/real crop production, revenues, local trading info, etc.) to companies, analysts, and investors who are committed to the production of sustainable commodities and to the consolidation of fair supply chains. This new sovereign data marketplace would establish a stable, secondary income stream by consolidating an inclusive data economy for smallholder producers around the globe.

5.2. Collaboration with Relevant International Initiatives

In late November 2020, OpenNebula Systems joined the GAIA-X project as a Day-1 Member of the **Gaia-X Association**,[4] the international non-profit organization that is going to provide a formal structure to this initiative, coordinating the efforts of the GAIA-X Community, promoting international cooperation, and developing the necessary regulatory frameworks and rules to ensure the interoperability and reliability of the providers, services, and data sources made available through GAIA-X.

In 2021 we have been playing a key role in establishing the **Spanish Hub of GAIA-X**, in coordination with other Spain-based members of the Gaia-X Association and in conversations with the Secretary of State for Digitalization and Artificial Intelligence (SEDIA), under the Ministry of Economic Affairs and Digital Transformation. We are now participating in the process of creating the local Statutes of the new Spanish association that will coordinate the GAIA-X community in the country.

This year we have also participated in a number of events and panels about GAIA-X, using these occasions to present the ONEedge project and emphasize how our pioneering work is going to contribute to strengthening the European edge and cloud industry by offering a new open source edge computing platform.

Panel organized by i2CAT (May 2021)

Panel at OpenExpo Europe (June 2021)

[4] https://opennebula.io/opennebula-joins-gaia-x/

Interview by Maldita.es (July 2021)

Panel at Madrid Tech Show (October 2021)

With its focus on open source and Edge Computing, GAIA-X is the perfect platform for us to both promote ONEedge and obtain valuable feedback from relevant vendors and end-users, especially from those based in Europe. That is why we are planning to sponsor the upcoming **Gaia-X Summit 2021** (November 18-19, 2021) as a way to promote ONEedge and create opportunities to review the application of our technology to real business cases, while gathering relevant feedback from industry adopters.

In 2020, OpenNebula Systems also joined the **Linux Foundation**, the **Cloud Native Computing Foundation** (CNCF)[5] and the **LF Edge** initiative.[6] It is in the context of LF Edge that we are working on the promotion of ONEedge via the "Member Spotlight" series, to be published as a monographic post on the project's website in early 2022, which we expect will encourage other members of the community to adopt the software and send us their feedback. That is the principle that we follow with other relevant initiatives in which we participate, such as the EOSC Association, the H-CLOUD initiative, the **Eclipse Foundation**'s Edge Native Working Group, PLANETIC, and HUB4CLOUD.

[5] https://opennebula.io/opennebula-joins-cncf/
[6] https://opennebula.io/opennebula-joins-the-linux-foundation-edge-initiative/

6. Priorities for End Cycle (M24-M29)

During the End Cycle, the project will focus on those software requirements needed to achieve the final aim of the project in M29:

AIM OF THE PROJECT
To bring a disruptive software product—**ONEedge**—to industrial readiness and maturity for market introduction (TRL8)

- ONEedge will provide companies with an automated software-defined platform to build their own private, light and nimble Edge Computing environments based on highly-dispersed edge nodes in close proximity to the users, machines, and sources of data.
- Not only will companies be able to easily create their own edge environments, and to manage them with utmost simplicity, but they will be able to create these environments without needing to provide or own those underlying resources at all.

The main ONEedge product will not be the open source software extension but an **on-demand Edge Cloud Platform service**, built on top of the ONEedge extensions to OpenNebula and fully managed by OpenNebula Systems, through which companies will be able to easily build their distributed edge environments, using resources from existing edge, telco and cloud providers.

From a technical perspective, reaching this goal requires the development of:

(1) Innovative OpenNebula functionality to meet the needs of edge cloud orchestration, and

(2) The tools and methods to deploy and maintain an On-demand Edge Cloud Platform service, built with the ONEedge software and fully managed by OpenNebula Systems.

The **first technology preview** of the On-demand Edge Cloud Platform service (standalone distribution) will be released and ready for evaluation in M25 (November 2021), and the plan is to release the **first version, industry-ready and mature for market introduction (TRL8)**, in M29. Consequently during the End Cycle, we will concentrate mainly on the component for the completion and integration of all components for the On-demand Edge Cloud Platform service (CPNT1), and on the pending features for edge provider selection (CPNT3), deployment and provision of edge infrastructures (CPNT4), and the integration of the marketplaces of application containers and GUI (CPNT5). Some of these campaigns will be exclusive to the ONEedge commercial solution and will not be incorporated into OpenNebula.

During Business Acceleration, after Project termination, the aim will be to bring our game-changing edge platform to **full commercial application and market deployment (TRL9)**, and to scale up its user base and provider community.

7. Conclusions and Next Steps

The initial version of the Solution Framework Report (Deliverable D2.1), released in M3 after the initial framework definition phase, described the use cases that are guiding the development of the project, identified the main user requirements derived from these use cases, and defined the architecture of the ONEedge management platform. From the user requirements, we extracted the list of software requirements and functional gaps that are being implemented as part of the development of the various components of the ONEedge management platform, and the methods and scenarios that are being used to verify their fulfillment.

This third incremental version of the Solution Framework Report (Deliverable D2.4) provides a description of the software requirements that have been addressed as part of the Third Innovation Cycle (M17-M23), as well as a brief review of the priorities for the End Cycle (M24-M29). The new software components and extensions that are being implemented in order to meet the software requirements are specified and developed within the work package WP3, with the new functionality being tested, verified, and demonstrated within WP4. Some of the software requirements involve the development of appliances and the automation of infrastructure deployment and configuration that will also be performed as part of WP4.