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OPERA

LOw Power Heterogeneous Architecture
for NExt Generation of SmaRt Infrastructure and Platforms
in Industrial and Societal Applications

Truck Use Case 1

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PARTICIPANTS		CONTACT
STMICROELECTRONICS SRL		Giulio Urlini Email: Giulio.urlini@st.com
IBM ISRAEL SCIENCE AND TECHNOLOGY LTD		Joel Nider Email: joeln@il.ibm.com
HEWLETT PACKARD CENTRE DE COMPETENCES (FRANCE)		Gallig Renaud Email: gallig.renaud@hp.com
NALLATECH LTD		Craig Petrie Email: c.petrie@nallatech.com
ISTITUTO SUPERIORE MARIO BOELLA		Olivier Terzo Email: terzo@ismb.it
TECHNION ISRAEL INSTITUTE OF TECHNOLOGY		Dan Tsafrir Email: dan@cs.technion.ac.il
CSI PIEMONTE		Vittorio Vallero Email: Vittorio.vallero@csi.it
NEAVIA TECHNOLOGIES		Stephane Gervais Email: s.gervais@lacroix-group.com
CERIOS GREEN BV		Frank Verhagen Email: frank.verhagen@certios.nl
TESEO SPA		Stefano Serra Email: s.serra@teseo.clemessy.com
DEPARTEMENT DE L'ISERE		Olivier Latouille Email: olivier.latouille@isere.fr

ACRONYMS LIST

Acronym	Description
KVM	Kernel-based Virtual Machine
IGN	Institut Géographique National
HA	High Availability
U	Rack Unit
SOTA	State of the Art

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EXECUTIVE SUMMARY

Position of the Deliverable within OPERA Project

To demonstrate that OPERA outcomes could be useful in real-life situations, the Consortium identified three different contexts where OPERA can intervene to improve the conditions, and for each one the Consortium will set up a use case:

- Task 7.1 - Traffic Monitoring
- Task 7.2 - Truck
- Task 7.3 - Virtual Desktop

The purposes of each use case, to demonstrate OPERA outcomes, are:

- the Integration of the hardware and the software developed and provided by OPERA
- the Validation of the set up solution

To achieve these goals properly, it's essential to define very well two aspects. The first one is the Scope of each use case, to determine unequivocally the boundaries of the Integration. The second one is the Baseline to describe the current situation and OPERA target for each use case.

These two elements are provided by D2.1 *Use Cases and Requirements* where we defined clearly the solutions that we want to realize and where each solution can intervene.

The strategy to provide Integration and Validation for these use cases consists of three cycles (M20, M28 and M36).. In order to improve the outcomes in the second and third cycles, at the end of the first and the second one we record the gap between the expected values and measured values. These values will be an input for deliverables D2.9 *Lesson Learned and Track Changes 1* and D2.10 *Lesson Learned and Track Changes 2*, to define where WP3, WP4, WP5, WP6 could intervene to enhance the results.

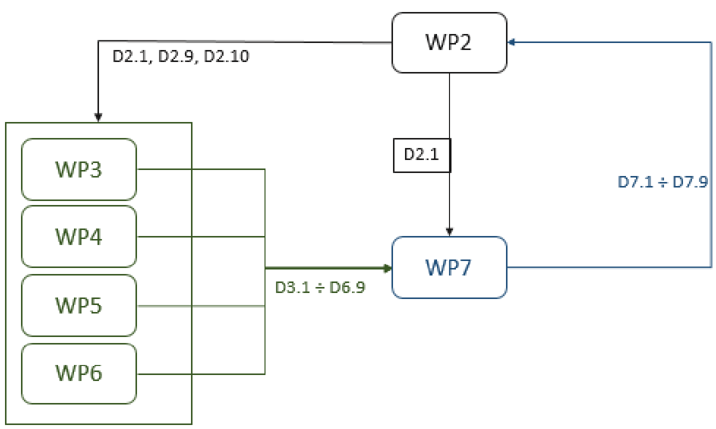

Figure 1 - Relationship between WP7 and OPERA Project

This specific deliverable (D7.4 Truck Use Case 1) is a Report about Truck use case for the first Cycle. In this document, we will describe the inputs received by D2.1 to start and to drive this use case and the evolution of solution during the three cycles with particular attention for the first step. In addition, we dedicated a section about the results to define the inputs for D2.9.

Description of the Deliverable

Aiming at guaranteeing coherence and consistency with the other Tasks and Deliverables strictly related to D7.4, we chose the following structure:

- Inputs – Starting Points, what can be used to launch the Deliverable
- Vision – Evolution of the use case during the Project
- Outcomes – Results of the use case during the first phase
- Output – Input of the use case for Lesson Learned

The main and important Inputs for D7.4 are contained in the chapter *3.2 Truck Use* of deliverable D2.1 "*Use cases and Requirements 1*" and they are:

- The General Architecture, to describe graphically the technologies involved and the guidelines about how to use them
- The Baseline, to define which parameters are important for Truck Use case and related measurements about the current situation and the target values that we want to achieve with OPERA Project

These Inputs take into account also the technological outcomes and results of WP4, WP5 and WP6.
To manage the Truck use case during the Project from M11 to M36, the Consortium chose to break down the period in three parts called Cycles. In this document, we describe the improvements from the technological point of view and the related target for each Cycle, to show the evolution of the use case during the Project to achieve the specified results.
About the first Cycle concerned to the current Deliverable, we provide details about the planning, the activities completed to setting up the current state, the current technological results and measurements about Truck use case.
About measurements, we took into account different condition to evaluate OPERA technological choices. Specifically, we measured the I° Cycle configuration and we compared also the current software (PhotoScanpro) and Micmac (the open source product selected for OPERA Project as described in D2.1) to elaborate orthophotos we want to assure that we don't take advantages by this change.
The measurements and the experience gained during the first cycle provide some inputs that are useful for Lesson Learned and they can improve use case quality over the Project.

List of Actions and Roles

Activities about D7.4 involve only some partners of OPERA Consortium, whose skills, knowledge and capabilities can support the aim of Truck use case.

ACTIVITIES LIST AND PARTNERS ROLES	CERTIOS	CSI	HPE	IBM	ISMB	Neavia	Technion
Description of the current state of Truck use case	I	P	P	I	I		
Description of the evolution of Truck use case	I	P	P	R	R		
Setting up of Truck use case – I° Cycle	I	P	P	I	I		
Measurements about Truck use case – I° Cycle	I	P	P	R	R		
Structure and writing of D7.4	I	P	P	R	R		
Deliverable Review	P					P	P

- P = Participating (includes I & R)
- I = Input delivery (Includes R)
- R = review

ISMB. Technical coordination; it contributes in the design of the architecture to set up OPERA Infrastructure, reviews the overall solution and the strategy about measurement.

CERTIOS. It leads the study about the definition of the baseline system according to the aim of the project and provides a substantial contribution about all aspects concerning power consumption.

HPE. It develops and provides the hardware to host virtualised systems, Micmac and FPGA Card. Contribution for setting up the hardware and for defining the tool for measurements. Contribution for taking measurement specifically the Orthophoto elaboration with FPGA Card.

IBM. It contributes in the design of the architecture and of the reviewing of the overall solution.

CSI. Task leader; it coordinates activity to set up OPERA Solution with the support of the others partners. Contribution for taking measurements.

Actions

In this section, we report a list of the meeting calls (with their short minutes) and F2F meetings, which is useful to describe the partners' activities:

Meeting Call 10-11-2016 – Hardware delivery and Micmac porting

Attendees (8): CSI: Luca Scanavino;HPE: Gallig Renaud; IBM: Joel Nider; IBM: Michael Rapoport; CERTIOS: Dirk Harryvan; ISMB: Olivier Terzo; ISMB: Pietro Ruiu; ISMB: Alberto Scionti;
Summary: discussion about the delivery of hardware and updates about Micmac porting on FPGA Card

Meeting Call 24-11-2016 – Hardware delivery

Attendees (8): CSI: Luca Scanavino; HPE: Gallig Renaud; IBM: Joel Nider; IBM: Michael Rapoport; CERTIOS: Dirk Harryvan; ISMB: Pietro Ruiu; ISMB: Alberto Scionti; STM: Giulio Urlini.
Summary: update about hardware delivery.

Meeting Call 06-12-2016 – Micmac porting

Attendees (8): CSI: Luca Scanavino; HPE Gallig Renaud; IBM: Joel Nider; IBM: Michael Rapoport; CERTIOS: Dirk Harryvan; ISMB: Olivier Terzo; ISMB: Pietro Ruiu; ISMB: Alberto Scionti.
Summary: Discussion about Micmac porting, CSI will provide all information that could be useful.

Meeting Call 19-01-2017 – Hardware delivery

Attendees (5): CSI: Luca Scanavino; HPE Gallig Renaud; IBM: Joel Nider; CERTIOS: Frank Verhagen; ISMB: Alberto Scionti.
Summary: HPE and CSI agree about hardware delivery on January the 26th.

F2F 26-01-2017 – Hardware Delivery and Installation
Attendees (3): CSI: Luca Scanavino; CSI: Ignazio Cassano; HPE: Gallig Renaud
Summary: HPE delivers one Moonshot with one M510 cartridge. CSI and HPE installed the operating system.

Meeting Call 02-02-2017 – System Configuration

Attendees (5): CSI: Luca Scanavino; HPE Gallig Renaud; IBM: Joel Nider; CERTIOS: Dirk Harryvan; ISMB: Alberto Scionti.
Summary: CSI starts activities about the configuration of the system according the general architecture

Meeting Call 16-02-2017 – Configuration OPERA Infrastructure and measurements

Attendees (3): CSI: Luca Scanavino; HPE Gallig Renaud;; CERTIOS: Dirk Harryvan.
Summary: CSI completed the setting up of operating system for server RADIO and DOMINIO; CSI planned the activities about measurements with Micmac on MacBook; CSI asks HPE details about Moonshot chassis

F2F 02-03-2017 – Hardware Delivery and Installation. Measurements.
Attendees (3): CSI: Luca Scanavino; CSI: Ignazio Cassano; HPE: Gallig Renaud
Summary: HPE delivers two new cartridges M510. HPE describes how to take measurements for each cartridges.

F2F Meeting 16/17-03-2017 – Evolution of the Truck use case

Attendees (): all
Summary: description of the evolution throughout the three Cycles about technological outcomes and baseline.

Meeting Call 30/31-03-2017 – Open Points and OPERA Infrastructure

Attendees (5): CSI: Luca Scanavino; HPE: Gallig Renaud; IBM: Joel Nider; ISMB: Alberto Scionti; STM: Giulio Urlini.
Summary: CSI completes the setting up of Micmac on MacBook. Discussion about open points, specifically (1) Activities deadlines (2) how to manage the demonstrator (3) Script to take measurements. HPE provides the script about measurements. HPE will provide a new chassis that could be hosted on the Truck (RJ45 network connection).

Meeting Call 13-04-2017 – Update about activities
Attendees (3): CSI: Luca Scanavino; HPE: Gallig Renaud; CERTIOS: Dirk Harryvan.
Summary: ongoing the installation of Micmac on Macbook and Micmac Porting

Meeting Call 11-05-2017 – Update about activities
Attendees (6): CSI: Luca Scanavino; HPE: Gallig Renaud; CERTIOS: Dirk Harryvan, IBM: Michael Rapoport; ISMB: Pietro Ruiu; ISMB: Alberto Scionti.
Summary: completed the installation of Micmac on Macbook; ongoing the installation of Micmac on EL4000; ongoing Micmac porting.

Meeting Call 25-05-2017 – Update about activities
Attendees (3): Luca Scanavino; IBM: Joel Nider; ISMB: Alberto Scionti.
Summary: completed the measurements about Micmac on Macbook and EL4000 (model of cartridge M510). Ongoing Micmac porting.

F2F Meeting 29-05-2017 – New EL4000 chassis
Attendees (3): CSI: Luca Scanavino; CSI: Ignazio Cassano; CSI: Davide De Santis; HPE: Gallig Renaud
Summary: HPE provides a new EL4000 chassis with RJ45 connection.

F2F Meeting 14/15-06-2017
Attendees : all
Summary: CSI shows the results about the measurements of Micmac in different contexts.

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1 TRUCK USE CASE SCOPE

In this section, we describe the main elements that define the perimeter of this use case and reported in D2.1:

1. General Architecture, which graphically describes the involved technologies.
2. Baseline, which defines the parameters the starting values and desired ones.
3. Micmac, the open source software for Orthophoto elaboration.

Following these elements, we have the guidelines to lead, manage and realise the OPERA Solution for this type of context.

1.1 GENERAL ARCHITECTURE

The following figure reports the technological elements from the hardware and software point of view:

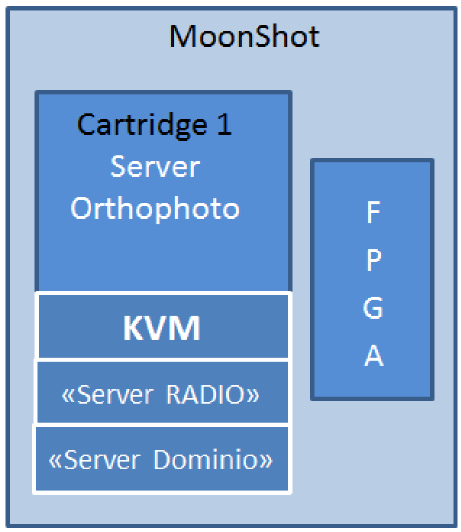

Figure 2 – General Architecture

In figure 2, we can find these elements:

1. One HPE Moonshot chassis equipped with one cartridge and an FPGA card.
2. The cartridge operating system runs the open source software (Micmac) to elaborate orthophotos.
3. The cartridge operating system hosts two virtual machine (Server RADIO and Server DOMINIO).

Each cartridge of the MoonShot can be considered as a physical server and each cartridge could host a different operating system and software.
For this use case, we dedicate the cartridge to install two types of software. The first one is a virtualization solution (for instance KVM), which hosts two virtual machines that run the current services of both Server RADIO and Server DOMINIO. The second one is Micmac, an open source software developed by IGN, a French Agency, that operates about geography information and one of its targets is the development of open source software and divulgation of it.
Consolidation of virtual machines and the Micmac software helps us to achieve the reduction not only of the power consumption, but also the elaboration time to produce the orthophoto, because with the State Of The Art infrastructure it takes roughly 15 hours to process 300 photos.
To achieve this aim, part of Micmac code will be moved on the FPGA card. It means that not only the cartridge is in charge of orthophoto elaboration, but also the FPGA card.

During the three Cycles, we will refine this General Architecture thanks to in-depth analysis with the aim to define the right number of cartridges and the right technologies that will allow us to fulfil the OPERA targets.

1.2 BASELINE AND MICMAC

The measurements are the way to validate the technological improvements achieved with OPERA Project. We consider two aspects to comply with the Proposal. The first one is which parameters are to be considered. The second one is a frame of reference to compare it with OPERA Infrastructure.

We defined these elements in the deliverable D2.1 “Use Case Requirements”; specifically we took into account the SOTA infrastructure for orthophoto elaboration and services hosted by Server RADIO and Server DOMINIO.

In this scenario, the most critical aspect is the elaboration time to produce an orthophoto. For this reason we paid serious attention to create a solution that integrate all the elements involved: Chassis, FPGA card and the software to do that. The first step is the software selection, because the current software, PhotoScan Pro, is a commercial product and it’s thus not possible to modify the code, then we involved Micmac, an open source product developed by IGN. Micmac can achieve the same outcome of the commercial product from the Protezione Civile point of view, that means an orthophoto with the same quality. This parameter is part of the baseline and it consists of the elements:

- Number of rejected photos during the elaboration
- Ground resolution of the orthophoto

We defined these aspects in Deliverable 2.1 and according to them we selected Micmac. Instead to define the Task baseline, we consider only these parameters:

- Power consumption
- Elaboration time

Thanks to the measurements about the SOTA infrastructure, we know the starting point that we can summarize in this Figure below, which graphically represents the average power consumption to complete the orthophoto elaboration and guarantee the services provided by Server RADIO and Server DOMINIO:

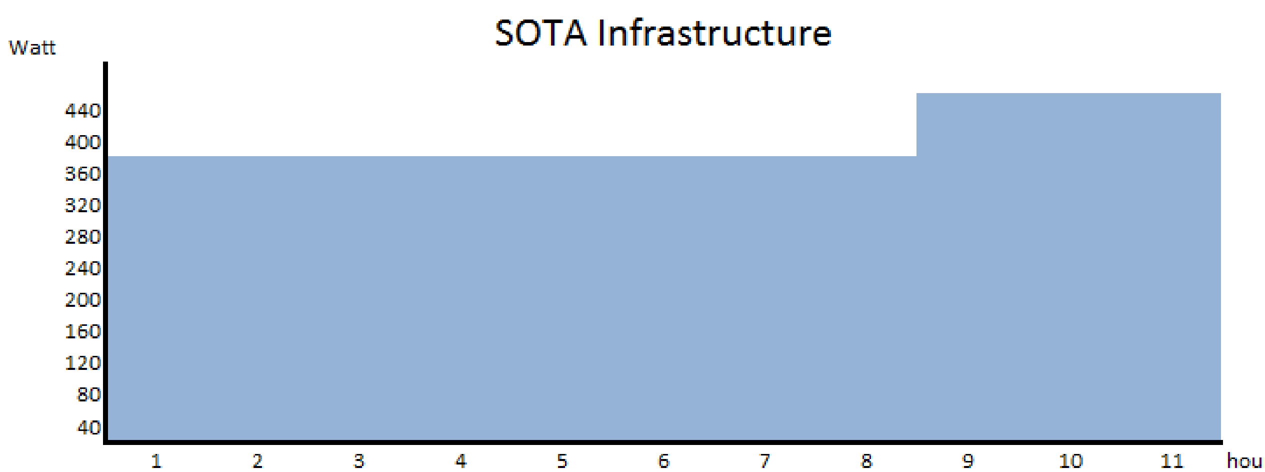

Figure 3 – Truck SOTA Baseline

We can see that the elaboration requires 11h, and we can break down this period in two phases. The first phase (8 hours) completes the pre-processing elaboration and guarantees the services (also called Other Services) of RADIO and DOMINIO servers. In the second phase (3 hours), MacBook completes orthophoto elaboration and RADIO and DOMINIO servers provide the Other Services. The baseline energy consumption is thus:

Current Infrastructure = 8h*360W + 3h*440W = (2880 + 1320) Wh = 4,200 kWh

Starting from this situation, thanks to OPERA Project we want to achieve the outcome represented in the Figure below.

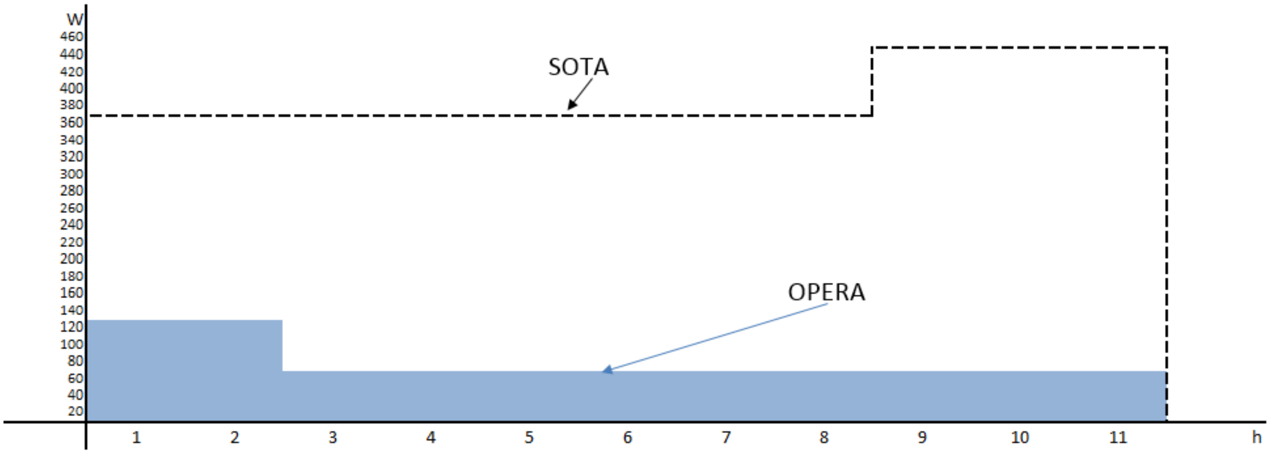

Figure 4 – Truck Target Baseline

Specifically, we wish to complete the orthophoto elaboration within two hours and at the same time we wish an average power consumption about 110 Wh. After the elaboration (between hour 3 and hour 11) we want to guarantee the services of Server DOMINIO and Server RADIO with an average power consumption about 50 W. In this way, we consider the same services and the same baseline period (11 hours). The energy consumption using the OPERA solution will be thus:

OPERA Infrastructure = 9h*50W + 2h*110W = 0,670 kWh

We established this target taking into account the current knowledge about every hardware (FPGA and HPE hardware) and software (Micmac) elements, over the project we'll gain experience not only about each one of them but also about their capability to cooperate. For this reason, it may be that in the future these target could be changed.

As discussed in deliverable D4.1 "*Report on energy efficiency metrics*", to quantify the efficiency differences, the following energy efficiency metric will be used:

$$EE_{Truck\ radio} = \frac{period\ full\ operational\ (AU)}{Energy\ used\ during\ period\ (kWh)}$$

$$EE_{Orthomap} = \frac{Reference\ ortho\ map\ (AU)}{Energy\ used\ creating\ the\ map\ (kWh)}$$

Application of this formula to baseline and target yields:

Baseline $EE_{\text{Truck Radio}}$ = 11h / (11h * 2*0,18 kW) = 2,77

Baseline EE_{Orthomap} = 1/(4,2 kWh) = 0,23

$$\text{Target } EE_{Truck\ Radio} = 11\ h / (11h * 0,05kWh) = 20$$

$$\text{Target } EE_{Orthomap} = 1/(2h*0,06kW) = 4,6$$

In addition, in D2.1 we also described the contexts where we took measurements:

- Micmac on the SOTA infrastructure
- Micmac on HPE Chassis – without FPGA card
- Micmac on HPE Chassis – with FPGA card

Over the Project we'll take measurement considering always the same cluster of photos to elaborate the orthophoto and the same quality as described in D2.1 and to use for the Baseline.

2 EVOLUTION DURING OPERA PROJECT

The OPERA Project consists of three cycles to achieve the expected outcomes described before. At the end of each cycle, we reach technological results that decrease the power consumption and/or the elaboration time. In this chapter, we want to focus the evolution of the technologies developed with OPERA (hardware and software) and how we want to integrate them. The technological pillars are the following:

- **Hardware Chassis.** We involve one HPE EL400 chassis with X86 technology to host the RADIO and DOMINIO services and part of Micmac code.
- **Hardware FPGA.** We involve one FPGA card in II° Cycle and two FPGA cards in the III° cycle to accelerate the remaining part of Micmac code, to distribute the orthophoto elaboration.
- **Micmac code.** We define which functionalities that could move to FPGA card to reduce elaboration time.

We'll decrease the power consumption and the elaboration time gradually during the project thanks to the technological progress. Specifically, we wish to guarantee the following trend during the three cycles:

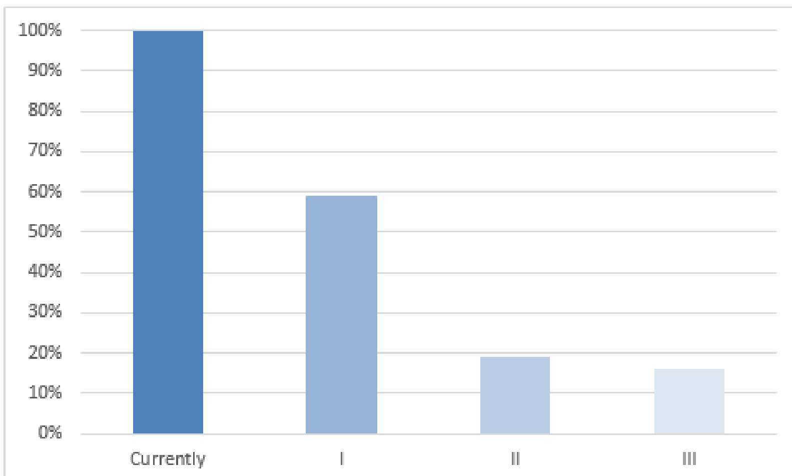

Figure 5 – Power Draw over the Project

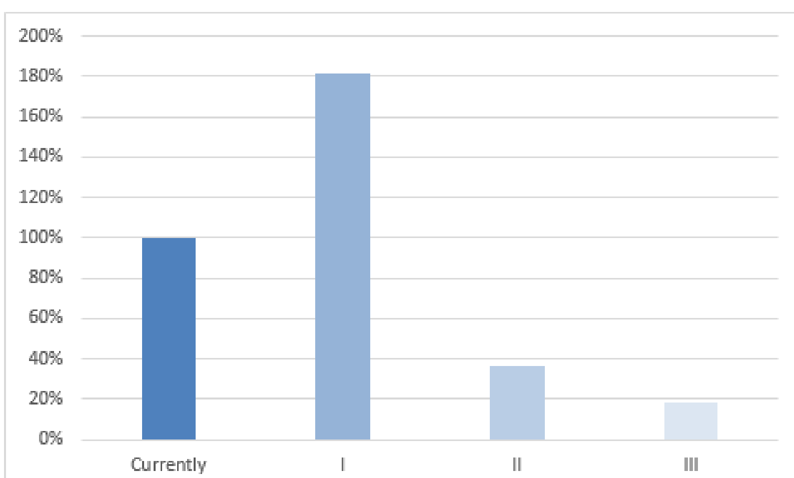

Figure 6 – Orthophoto Elaboration over the Project

It means to guarantee, at the end of OPERA Project, an orthophoto with the same current quality, but consuming about 16% of SOTA energy and about 20% of the SOTA time. In the first cycle, we improve only the energy consumption, because it's necessary to find out the right configuration of the FPGA card (I° Cycle) and only after (from II° Cycle) it's possible to utilize it for reducing the orthophoto elaboration time.

This aspect and the other technological improvements are described in the following paragraphs, where we described the hardware/software evolution over the project and how the energy consumption and the elaboration time change.

2.1 I° CYCLES – TECHNICAL OUTCOMES AND BASELINE

During the first cycle, the pillars of the Truck use Case have a low level of integration, that will increase in the other cycles. In particular, at the end of the first step we have this situation:

- **Hardware Chassis.** We involve one HPE EL4000 chassis with one M510 cartridge to host not only two virtual machines (which replicate the original server RADIO and server DOMINIO) but also to run the Micmac application.
- **Hardware FPGA.** During this phase WP6 works to verify if Micmac is compatible with HPE cartridges and FPGA card.
- **Micmac code.** WP6 tests some simple Micmac function on FPGA Card.

The following figure shows the Macro Architecture, that describe the design at the end of the I° Cycle. There is only one cartridge M510 that host two virtual machines and the Micmac software. I° Cycle configuration doesn't involve FPGA card.

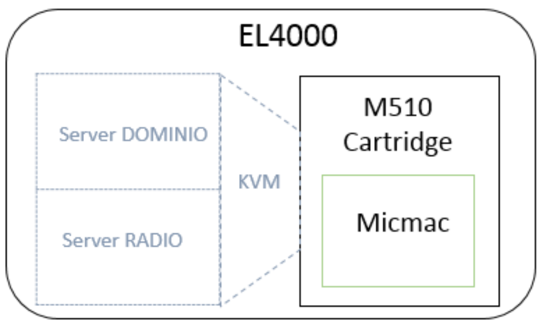

Figure 7 – Truck I° Cycle – Macro Architecture

With this configuration, we think, taking into account the current knowledge about every hardware (FPGA and HPE hardware) and software (Micmac) elements, that it's possible to achieve these targets about power consumption and elaboration time:

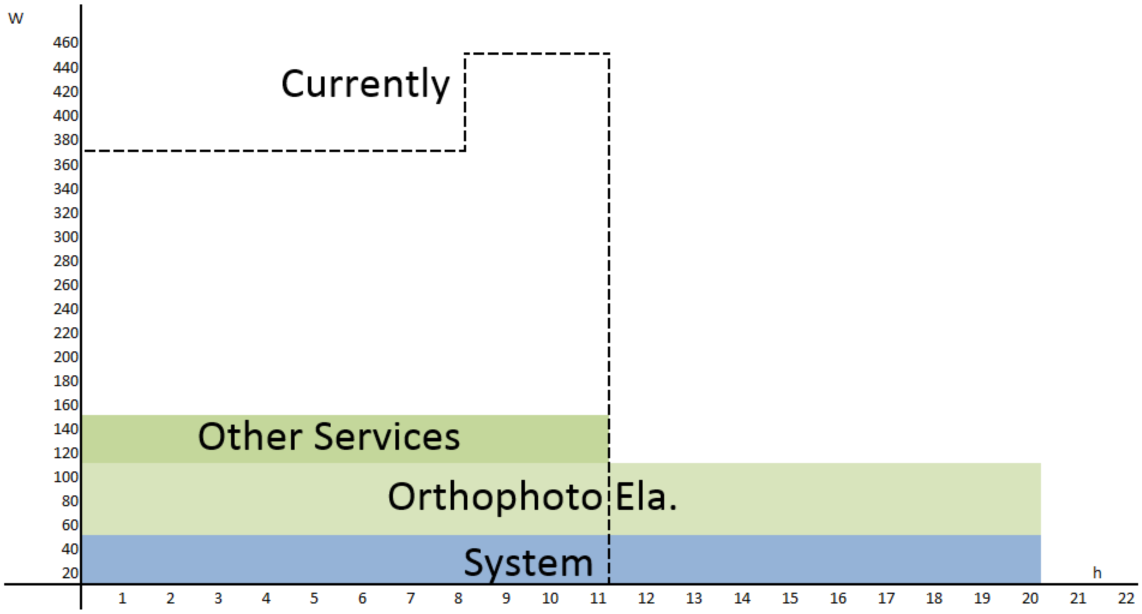

Figure 8 – Truck I° Cycle Target

With this configuration, the elaboration requires more time than the baseline solution. In fact, during the software selection to find out an open source product for orthophoto elaboration, we noticed that PhotoScanPro process is faster than Micmac. Specifically, we think, taking into account the current knowledge about every hardware (HPE hardware) and software (Micmac) elements that it's possible to complete the activity in 20 hours. In first 11 hours, the energy consumption is due not only to the orthophoto elaboration, but also to the System, and to the Other Services. This first period consists of 11 hours that is the same duration of the SOTA Truck service to generate the orthophoto. After this period (from hour 12 to hour 20) we consider only the power consumption due to the System and the orthophoto elaboration.

Taking into account that, for the I° Cycle the targets are:

I° Cycle Elaboration Time: 20 hours

I° Cycle Energy Consumption: 11h*135W + 9h*110W = 2,475 kWh

As discussed in D4.1, two energy efficiency metrics will be used. One for the Radio services, this will mostly reflect the hardware improvement from the Moonshot cartridges

$$EE_{truck\ radio} = \frac{period\ full\ operational\ (AU)}{Energy\ used\ during\ period\ (KWh)}$$

$$EE_{Orthomap} = \frac{Reference\ ortho\ map\ (AU)}{Energy\ used\ creating\ the\ map\ (KWh)}$$

An important note of the measurement of the "Energy used to create the map" is that this energy is calculated from the difference in energy used by the total configuration when only the radio functionality is being delivered and the total energy use of the platform when running both the radio functionality and the orthomap creation. The energy thus calculated only covers the additional energy of the orthographic map creation and $EE_{Orthomap}$ can then be compared between the reference value calculated for the currently active baseline configuration and the value obtained from the OPERA replacement.

Applying this to the numbers above, 55 W for Radio services and system

$$EE_{truck\ radio} = 18{,}2$$

Orthophoto: 80 Watt, 20 hours.

$$EE_{Orthomap} = 0{,}625$$

2.2 II° CYCLE – TECHNICAL OUTCOMES AND BASELINE

During the second cycle we will increase the integration of OPERA Solution, in fact the focus will be on FPGA Card, where we want to move a part of Micmac to distribute the orthophoto elaboration.

- **Hardware Chassis.** We will involve one HPE Edgeline chassis with one M510 cartridge to host not only two virtual machines to replicate server RADIO and server DOMINIO but also part of Micmac code.
- **Hardware FPGA.** We will complete the Micmac profiling, that means to identify the portion of Micmac code that can be moved on the FPGA card and its best hardware architecture to reduce energy consumption.
- **Micmac code.** We will move the portion of Micmac code identified to the FPGA card.

The Macro Architecture is similar to the first cycle. The only one difference is the FPGA card, because the aim is to distribute the code between it and M510 cartridge, as described in the following figure:

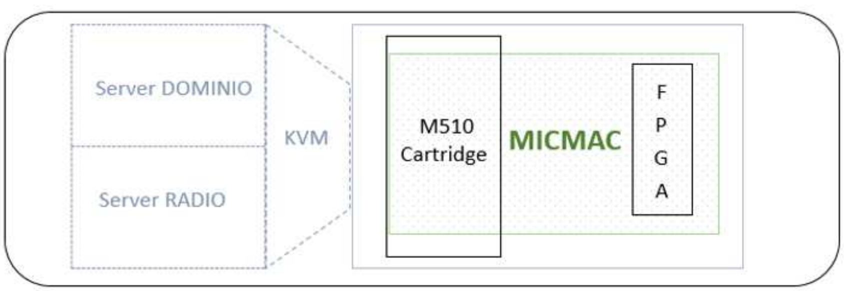

Figure 9 – Truck II° Cycle – Macro Architecture

Thanks to the activity about the code and the FPGA card, we think that it’s possible to reduce both power consumption and elaboration time, in the following figure the target for the second cycle:

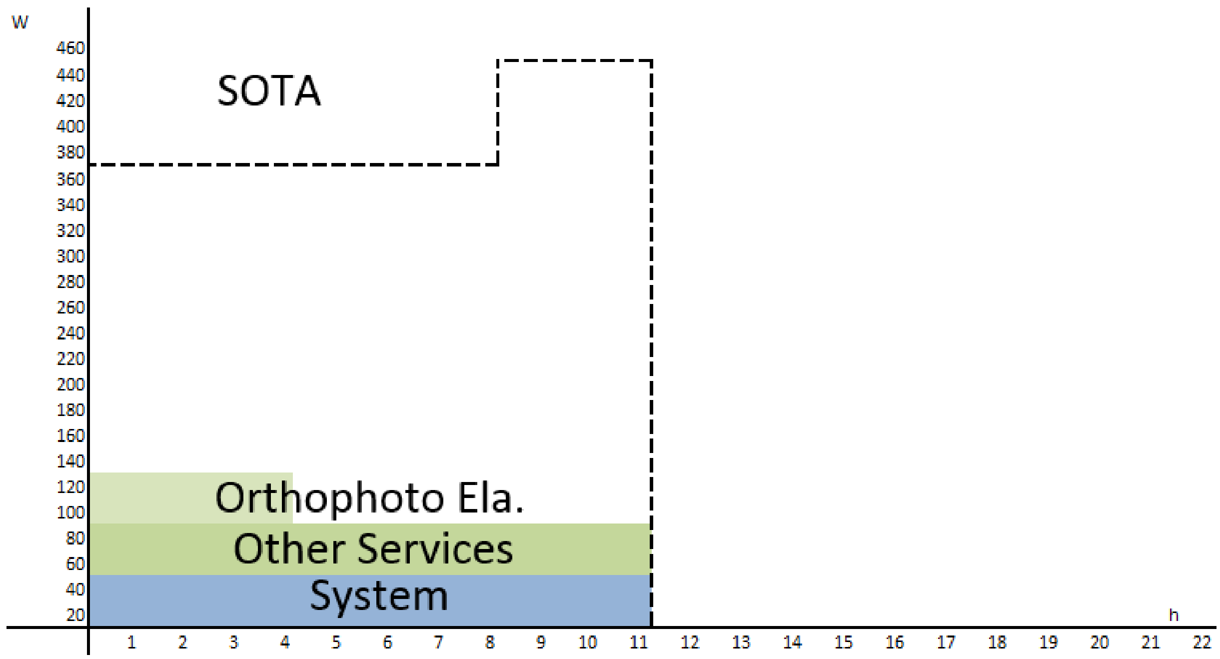

Figure 10 - Truck II° Cycle Target

The first phase to complete the Orthoptoho requires four hours (from hour 1 to hour 4) and guarantees the same SOTA quality (as described in D2.1). During the first phase, we consider also the power consumption of Other Services and System. The average power consumption in the first phase is 110W. After the completion of the Orthophoto, in the second phase, between hour 5 and hour 11, the power consumption is due to the Other Services and the System, and its average value is 50W. It means that we have these targets:

II° Cycle Elaboration Time: 4 hours

II° Cycle Energy Consumption: 4h*110W + 7h*50W = 0,790 kWh

$$EE_{truck\ radio} = 20$$

Orthophoto: 110 Watt, 4 hours.

$$EE_{Orthomap} = 2{,}3$$

2.3 III° CYCLE – TECHNICAL OUTCOMES AND BASELINE

During the third cycle, we will concentrate our attention also on the infrastructure and not only on Micmac porting. We want to increase the computational power with two FPGA cards and to introduce high availability (HA) for RADIO and DOMINIO servers:

- **Hardware Chassis.** We will involve one HPE EL4000 chassis with two M510 cartridge. Each cartridge hosts two virtual machines to replicate server RADIO and server DOMINIO, with an ACTIVE-PASSIVE configuration. In addition, we have also two FPGA cards to distribute Micmac code among one M510 cartridge and the FGPA cards.
- **Hardware FPGA.** We will involve two FPGA cards to distribute Micmac code among them and one M510 cartridge.

- **Micmac code.** We will refine the porting activity on FPGA card to reduce further the elaboration time.

The Macro Architecture changes again in this cycle and the following figure describes the last evolution for Truck use case:

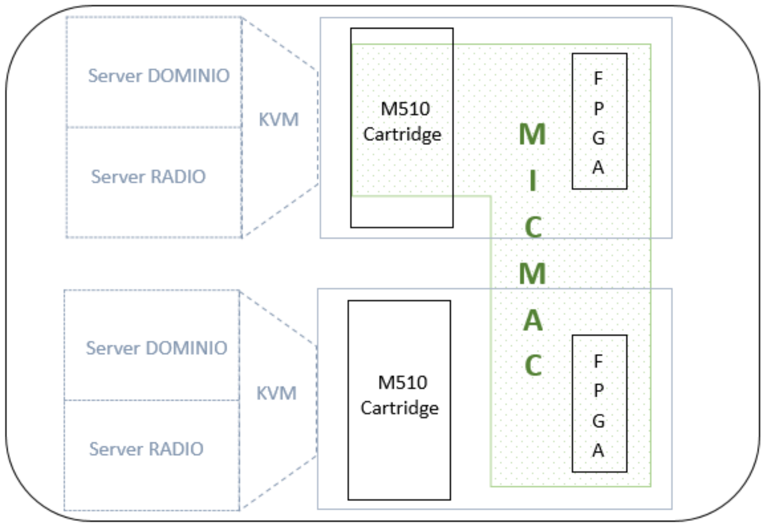

Figure 11 – Truck III° Cycle – Macro Architecture

These further improvements both about hardware (one additional cartridge and one additional FPGA card) and about the new distribution of Micmac, we can further improve the situation reducing both the orthophoto elaboration and the power consumption, as described in the following figure:

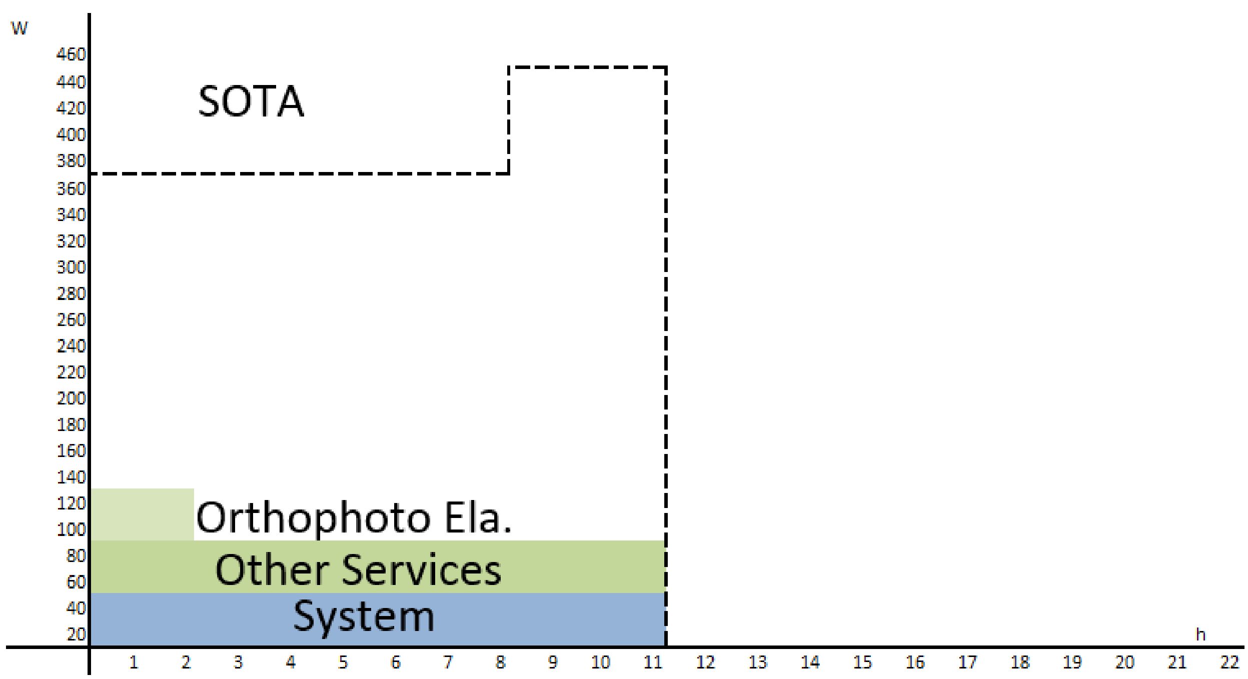

Figure 12 - Truck III° Cycle Baseline

We want to complete the Orthophoto Elaboration in the first phase within two hours (from hour 1 to hour 2) and guarantee the same quality (as described in D2.1). During the first phase, as described in the previous paragraphs, the power consumption is due to not only to Orthophoto Elaboration, but also to Other Services and the System and its average value is 110W. At the end of the Elaboration, the second phase starts (from hour 3 to hour 11), the power consumption is produced by Other Services and by the System and it has an average value of 50W. It means that the targets are:

III° Cycle Elaboration Time: 2 hours

III° Cycle Energy Consumption: 2h*110W + 9h*50W = 0,670 kWh

$$EE_{truck\ radio} = 20$$

Orthophoto: 110 Watt, 2 hours.

$$EE_{Orthomap} = 4{,}6$$

3 I° CYCLE DETAILS

In this chapter, we describe what we did during the first cycle, specifically the setting up of the different conditions, as described in D2.1, and for each one we took measurements:

- Micmac on the SOTA infrastructure
- Micmac on HPE Chassis – without FPGA card

The reasons of these different contexts are, first, to verify that OPERA can improve the current situation, but also to guarantee that Micmac is not better than the current software (PhotoScanPro) in terms of elaboration time and energy consumption.

For each condition, we considered, as described in D2.1, the same cluster of photos involved to establish the baseline and we took measurements both about the time to elaborate the orthophoto and the power consumption over the considered period (11 hours).

In addition, we replicated the current services provided by Server RADIO and DOMINIO on two virtual machines hosted in the same cartridge where there is Micmac. The aim is to evaluate the average power consumption generated by these applications.

3.1 MICMAC ON THE SOTA INFRASTRUCTURE

This measurement requires the installation of Micmac using the SOTA hardware. The aim is to verify that with Micmac we don't take advantage in terms of energy consumption or in terms of elaboration time.

The SOTA hardware consists of three servers because Server RADIO and DOMINIO pre-process the photos before the elaboration with ProtoScanPro on the MacBook. With Micmac, it's not possible to implement the pre-processing phase, it means that we can't involve the Server RADIO and DOMINIO for this measurement. For this reason, we chose to elaborate the orthophoto only involving the MacBook. In this way we can guarantee the same conditions: the same hardware and the same cluster of photos. The only difference is the software for the orthophoto elaboration.

The MacBook Pro (2012) has this configuration:

MacBook Pro (2012)	
CPU	**RAM**
Intel Core i7 quad-core 2,3 GHz	8 GB

Table 1 – MacBook Pro configuration

We took the measurements with the same Wall Plug Meter that we used to define the baseline (RCE PM600):

Figure 13 - Wall Plug Meter

3.1.1 Micmac on Macbook

We installed the Micmac version for Mac OS X (v_5368) on the Macbook Pro (2012) and we started the elaboration.

To complete this activity, we used a sequence of three commands to process the cluster of photos:

- Tapioca
- Tapas
- C3DC

For each step, we recorded the time to complete the step and the average power consumption, as show in the table:

Command	Time (h)	Average Power consumption (w)
Tapioca	99,5	58,7
Tapas	86,5	44,5
C3DC	12	45,6

Table 2 – Micmac on MacBook - Time&Power

As shown in the following figure, we aggregated the data, it means the average power consumption over the elaboration period (broken down for each step/command):

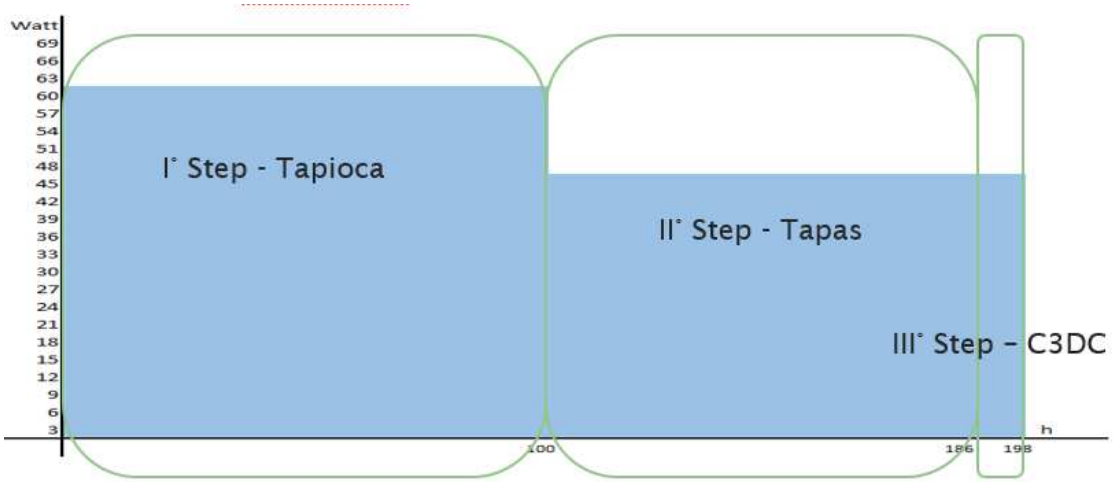

Figure 14 – Elaboration of Micmac on Macbook Pro

We can see that the activity requires this time:

Elaboration time: 99,5h + 86,5h + 12h = 198h

Moreover, we can calculate the energy consumed:

Energy consumed = 99,5h*58,7W + 86,5h*44,5W +12h*45,6 = 10,237 kWh

3.1.2 PhotoScanPro on MacBook

We repeated the same elaboration with PhotoScanPro (without the pre-processing) and we recorded the time to complete the task and the average power consumption:

PhotoScanPro on MacBook	
Time	74,5 h
Average Power Consumptio	66,7 W

Table 3 – PhotoScanPro on MacBook Pro

In the following figure, we have the graphical representation:

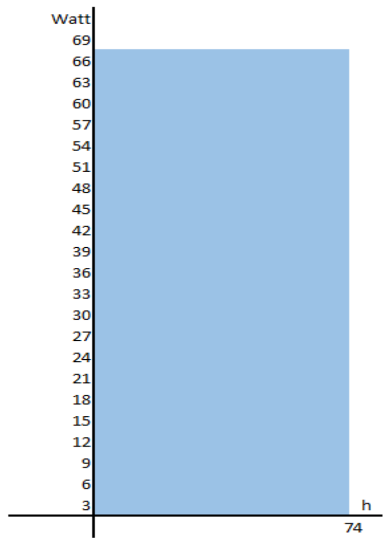

Figure 15 - Elaboration of Micmac on Macbook Pro

We can calculate the energy consumed:

Energy consumed = 74,5h*66,7h= 4,969 KWh

3.2 OTHER SERVICES ON HPE CHASSIS

The previous measurements don’t consider the energy consumption due to the Other Services. For this reason, we set up two virtual machines to replicate RADIO and DOMINIO servers and their services described in D2.1. These two Virtual Machines are on the same M510 cartridge involved for the measure of Micmac on HPE Chassis without FPGA, as described in the following figure:

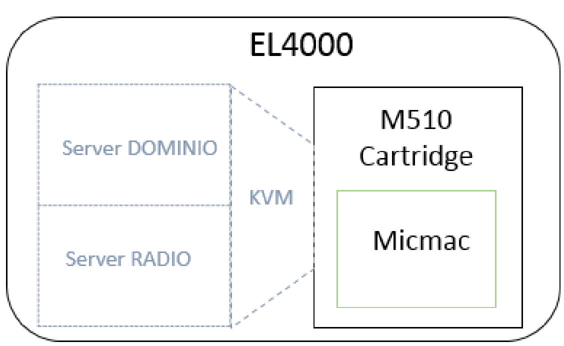

Figure 16 – Micmac and Other Services on HPE Chassis – without FPGA

After the setup of the environment, we started the Other Services (software to manage the radios and the network appliances on the truck as described in D2.1). Thanks to the ILO, it's possible to see the difference in terms of power consumption when the Other Services are active or not:

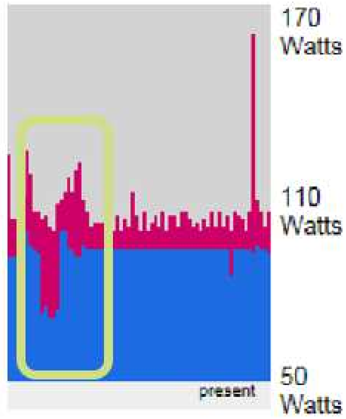

Figure 17 – Details about Other Services power consumption

From the previous figure, we can see that when the Other Services are not active the average power consumption is about 70W and when they are active the average value is 95W. It means that the Other Services require an average power consumption of 25W

3.3 MICMAC ON HPE CHASSIS – WITHOUT FPGA CARD

To evaluate this measurement, we set up one M510 cartridge on HPE EL4000 chassis and we installed the Micmac version for Ubuntu (v_5348). The configuration of the cartridge is described in the table below:

Model	CPU	RAM
M510	2 Intel Xeon D-1587, 1.7 GHz (16) x86 cores	64 GB

Table 4 – M510 Cartridge description

In the following figure, there is the Macro Architecture of this environment:

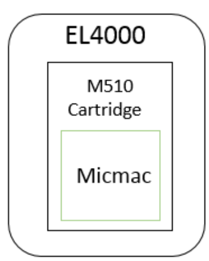

Figure 18 – Micmac on HPE Chassis without FPGA card

We repeated the same elaboration, using both the same group of photos and the same commands (Tapioca, Tapas and C3DC). We followed the same pattern described in paragraph 3.1.1. We recorded for each command its elaboration time and the average power consumption. We did that thanks to the report provided by the ILO (Integrated Lights-Out), which is an HPE proprietary server management tool. Using this management console, it's possible to visually monitor the status of the server and one of the parameter is the Power Consumption, thanks to a graphical report it's possible to see this aspect over the time. In ANNEX 5.1 there is the original graphs.

From the original graph, it's possible to evaluate time and average power. In the following table, we reported these values:

Command	Time (h)	Average Power consumption (w)
Tapioca	11,8	132
Tapas	6,2	102
C3DC	0,3	107

Table 5 - Micmac on HPE Chassis - Time&Power

It's also possible to aggregate this values graphically as showed in the figure below:

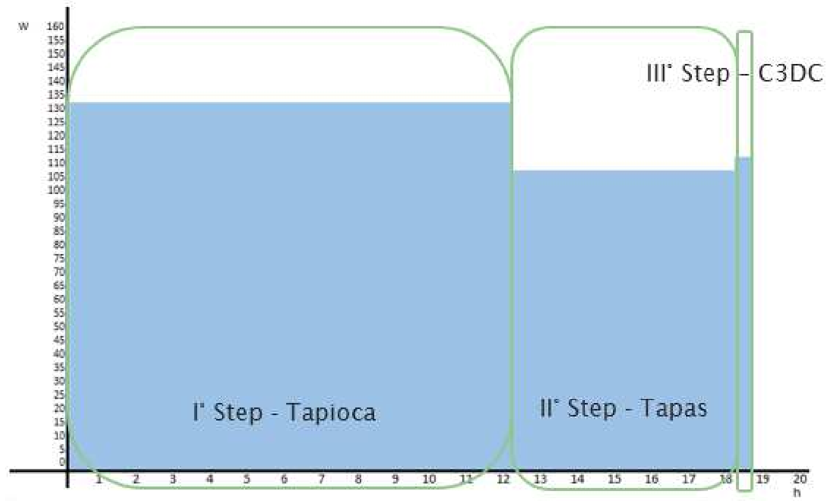

Figure 19 – Elaboration of Micmac on HPE Chassis – without FPGA Card

Thanks to the graphical representation, it's possible to appreciate the differences with the other elaborations and we can evaluate the energy consumed:

Energy consumed Orthophoto elaboration = 11,8h*132W + 6,2h*102W + 0,3h*107W = 2,222 kWh

To define the Total Energy Consumed, we have to consider also the energy consumed by the Other Services to guarantee the same condition of the Baseline:

Energy consumed Other Services = 11h * 25W = 0, 275 kWh

Total Energy Consumed = 2222,1 Wh + 275 Wh= 2,497 kWh

$$EE_{truck\ radio} = 20$$

$$EE_{Orthomap} = 0{,}45$$

4 OUTPUTS

At the end of the first cycle, we gained experience and knowledge from the activities described in chapter 3 *I° Cycle details*. In this section, we want to highlight the main elements that can influence the future activities for Truck use case.

Measurements are definitely the fundamental aspects to involve in this analysis, because with the correct interpretation, they provide an objective point of view, such as the elaboration time and the energy consumption to determine the best configuration. Nevertheless, also the personal experience could be a component of interest to better define the outputs, for instance the management of HPE Chassis and the consolidation of the services on RADIO and DOMINIO servers are topic to take into account.

4.1 INPUT FOR LESSON LEARNED

4.1.1 Micmac code and FPGA card

During the orthophoto elaboration with Micmac on HPE Chassis, we noticed (with Linux's "top" command) that all the available CPU are utilized for this activity. It means that the code is good not only for the results that it can provide (orthophoto quality as described in D2.1) but also from the technical point of view.

In fact, the capability to distribute the computational effort among all the available CPUs is a great advantage due to the presence of the FPGA card, where we can move part of Micmac code, that means part of the orthophoto elaboration and then it is reflected on the reduction of the elaboration time.

This aspect will be clearer from the II° Cycle and in the last one, when we'll involve two FPGA Cards.

During this cycle, we couldn't involve the FPGA card, but we laid the foundation to introduce it from the second cycle. In fact, WP6 completed the validation activity about Micmac code that consists in two tasks:

- to verify that it is compatible with HPE Cartridge
- to verify that simple Micmac functions can be elaborate by FPGA Card

During the II° Cycle, as described in chapter 2 *Evolution During OPERA Project*, we'll profile Micmac code to define:

- which parts of Micmac code can be elaborate by FPGA Card
- which parts of Micmac require more energy
- which is the best FPGA hardware architecture

And, finally, we'll distribute Micmac between HPE cartridge and FPGA card.

4.1.2 Micmac Vs. PhotoScanPro

The aim of this activity is the demonstration that the change of software doesn't provide any advantages to OPERA Project in terms of elaboration time and/or energy consumption.

In the following table, we can see the values about time and energy consumption:

Software	Elaboration time (h)	Energy consumption (kWh)
PhotoScanPro	74,5	4,969
Micmac	198	10,237

Table 6 – PhotoScanpro Vs Micmac

According to this context, PhotoScanPro requires less time and less energy to elaborate the same orthophoto, it means that we don't take advantage of Micmac.

4.1.3 HPE Cartridges and Chassis

In this phase of the project, we have had the opportunity to use and to appreciate the hardware provided by HPE (chassis and cartridges).

For a provider of services such as CSI Piemonte, there are some features described below that are very important:

1. the ability to concentrate in a very restricted space a great computational power, a Moonshot can host 45 cartridges in 4,3 U;
2. the possibility to move cartridges from a chassis to another (also different models) without loss of information;
3. the low energy consumption of cartridges both in idle and operative conditions

The last one is the most important for OPERA Project, in the following table we can appreciate the difference between the SOTA services and the solution realized in the first cycle, in terms of energy consumption:

Configurations	Energy consumption
SOTA infrastructure (PhotoScanPro)	4,200 kWh
HPE Chassis without FPGA card (Micmac)	2,497 kWh

Table 7 – SOTA infrastructure Vs. I° OPERA Cycle

The first measurement is the baseline, it means the SOTA infrastructure + PhotoScanPro to elaborate the selected cluster of photos. The second measurement is the I° Cycle Configuration, that means HPE hardware + Micmac. From the point of view of the energy consumption, the second configuration is better. We achieve this target thanks to HPE hardware, in fact in the previous paragraph we see that Micmac requires more energy that PhotoScanPro when we use the same hardware.

4.1.4 Replica consolidation of Other Services

At the end of the first cycle we replicated the services of RADIO and DOMINIO servers (also called Other Services) in two virtual machines, as described in Chapter 3 *I° Cycle details*. However, we have to consider that in real-life situation the Truck operator faces different situations and in different conditions that are not possible to recreate.

In the coming months, the Truck operator will use this environment with the aim to find out possible improvement or changes. For this reason, it could be that in the next cycles the current configuration will be changed for the Other Services.

4.2 RESULTS

The first cycle provided good outcomes that help us to understand that we have a good chance to achieve the target described in the Chapter 1 *Starting points* and we have to continue in this direction.

In fact, the I° Cycle configuration can't reduce the elaboration time, but we demonstrated that HPE hardware can reduce the energy consumption to process the same cluster of photos involved in baseline (as showed in the previous paragraph). A further element to consider is the validation of Micmac code, specifically, WP6 demonstrated its compatibility with both FPGA card and HPE Cartridge. These two aspects combined together realize a strong cooperation that, in the next two cycles, will reduce the orthophoto elaboration time. In fact, we can see from measurements (Micmac on Macbook and Micmac on HPE Chassis) when we have more computational power it's possible to reduce the procedure duration.

In addition, we demonstrated also that we don't take advantage by the use of Micmac code, because in the same condition (same hardware and same cluster of photos) it requires more time and more energy than PhotoScanPro. It means that all the improvements will be introduced by Opera Project.

With regard to these aspects, we can say that we are on the right track, because we demonstrate the feasibility of the OPERA Project, all the elements can cooperate properly together, and because the first measurements provide good results. We have the capability to achieve OPERA target and to do that we have to pay attention about the crucial activity for the Truck Use Case: Micmac porting, because only this improvement can enhance the current values.

5 ANNEX

5.1 MEASUREMENTS: MICMAC ON HPE CHASSIS – WITHOUT FPGA CARD

In the figures below, we highlighted the power consumption over the period of elaboration for each one of the three command to complete the elaboration.

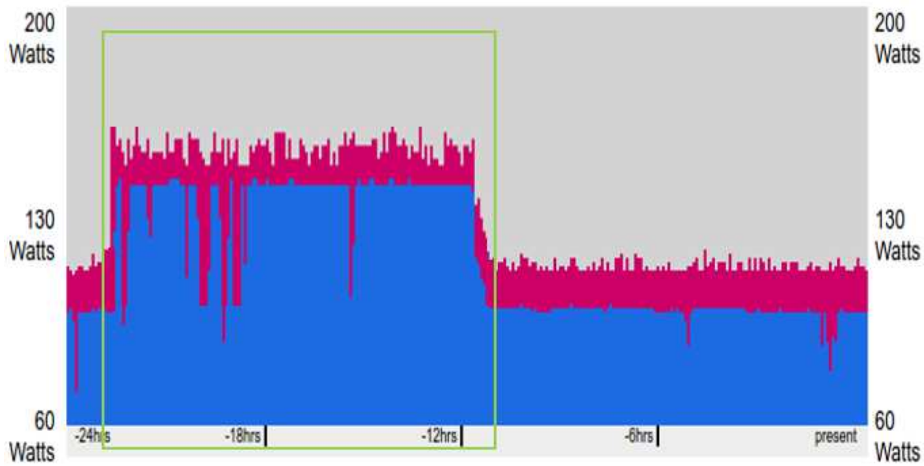

Figure 20 – Tapioca command - Power Consumption

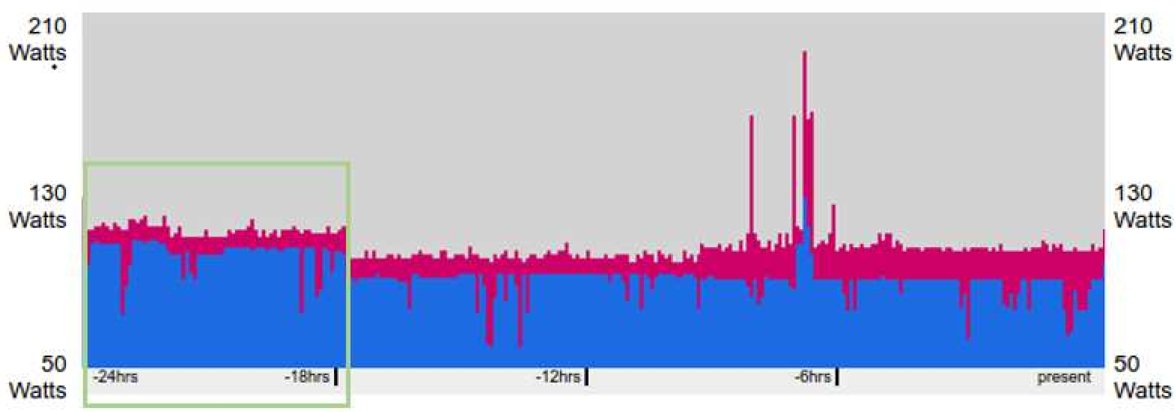

Figure 21 – Tapas command – Power Consumption

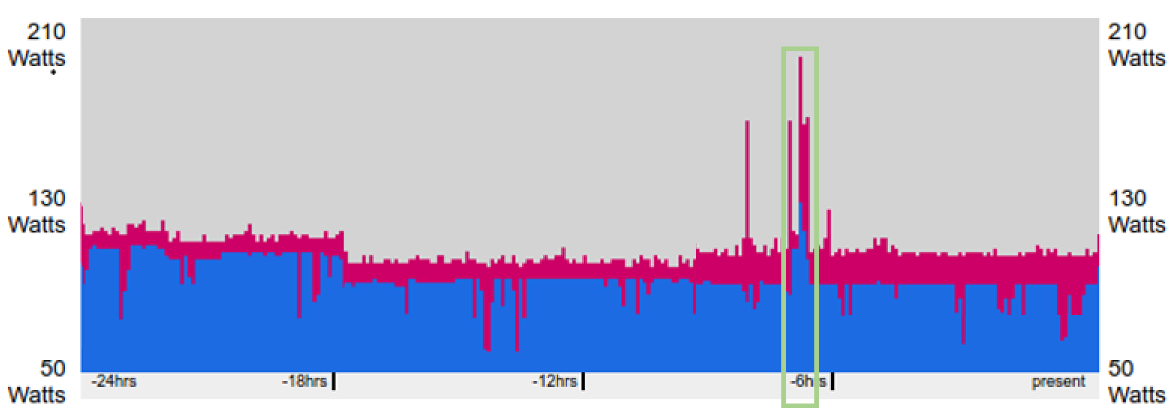

Figure 22 – C3DC command – Power Consumption