OPERA

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

Exploitation plan - preliminary report 2

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ACRONYMS LIST

Acronym	Description
CPS	Cyber Physical Systems
IPR	Intellectual Property Rights
VDI	Virtual Desktop Interface
YOLO	You Only Look Once (CNN topology)
DCA	Data Center Alliance
PCIe	Peripheral Component Interconnect Express
HPC	High Performance Computing
ISA	Instruction Set Architecture

EXECUTIVE SUMMARY

The exploitation plan of the OPERA project is based on the individual plans and action of the partners toward the extension of the research conducted in the OPERA project and the usage and further implementation of the results, in terms of know-how and new devices.

The OPERA project is running in its third year, and some results are already available in the three main use cases. These results allow several partners to start the exploitation of these results, in their specific field of action.

A more complete and harmonized action, between the partners, in terms of common exploitation will be conducted after the end of the project, and it will be reported in the final Exploitation plan deliverable.

Position of the deliverable in the whole project context

This deliverable is the update of the Exploitation Plan presented in the deliverable D8.6 [4]. A final report on the exploitation plan will be presented at the end of the project with the deliverable D8.2 [5].

Description of the deliverable

This document is organized with the following structure:

- A global overall strategy for exploitation
- A list of individual exploitation plan for the partners of the project, with the focus on internal exploitation, between departments of the same company, and external, towards other entities. Joint activities are also described, where present.
- An overview of the overall actions for exploitation, derived from the goals of the partners.
- An evaluation of impact, that is partially shared by the business plan, presented in D8.11 [2].

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1 GLOBAL EXPLOITATION STRATEGY

The main goal of the exploitation of a research project is the use of the results during and after the project's implementation. It can be for commercial purposes, considered more in detail in the business plan deliverables, but also for improving policies, and for tackling economic and societal problems.[1]

The exploitation plan must consider the elements in the research that will impact specific topics and needs to drive the research and the development to increase such impact in interesting fields. For this purpose, in the OPERA project a deliverable is specifically focused on the impact of the project's results. As described in D2.5 [6], and refined in D2.6 [7], the impact of the OPERA project is strictly related to the objectives that has been stated for the project, related to parts of the entire OPERA system.

The exploitation activities conducted or planned by the OPERA partners are presented in chapter 2, and are summarized as a whole strategy in chapter 3.

The exploitation activity is strictly connected to the development of a business plan, presented in detail in deliverable D8.11 [2].

1.1 IPR MANAGEMENT

In order to prevent any issue in the exploitation of single or shared results coming from the project a specific action about the IPR management should be taken. This management is not taken explicitly by a partner of the project, but it is handled by the coordinator, supported by the partners TESEO and ISMB, with the support of the EU community.

The EU commission provides an IPR management service and help desk [3], that can be useful in this process. TESEO and STM have started to contact the EU IPR helpdesk for the definition of the options for the managements of IP rights for the exploitation of the results of the project.

Since several partners are defining also a business strategy for the commercialization of some outcomes of the project, it is critical to define the handling of the Intellectual Property rights, especially for shared results.

This process will be beneficial for the exploitation of the results, and fundamental for the business plan. A detailed section about IPR management is reported in the business plan description, D8.11 [2].

[1] https://ec.europa.eu/research/participants/portal/desktop/en/support/faqs/faq-933.html

2 INDIVIDUAL EXLPOITATION PLANS

In this chapter, a detailed description of the exploitation actions conducted by the partners individually is presented, as well as the plan for future activities.

2.1 STM

ST is a global semiconductor company. The products portfolio covers many different markets and applications, in sensors, IoT, automotive fields. The use of STMicroelectronics R&D technologies in the OPERA project is enabling the creation of new applications of the STRED processor family and is increasing the results obtained with this technology. In particular, the definition of an autonomous node for traffic monitoring applications is demonstrating the validity of the STMicroelectronics platform and it is enriched by the contribution of the OPERA partners' activities. The possibility to execute locally complex computations on acquired video data, and be supported when needed by the OPERA server infrastructure overcome the limitations of the autonomous device providing a full features solution.

This solution and the actual partial results already influence the internal development progress of the platform and it is beneficial for the demonstration of the solution to the STMicroelectronics customers and partners.

2.1.1 Internal Exploitation

In the research organization the results of the OPERA project with the detection executed on the SecSoC system with the traditional video processing applications suggested to improve the development of the new generation of R&D SoCs with an enhanced version of the HW accelerators used in the SecSoC platform, increasing the memory to support more use cases, that weren't considered at the beginning. The results of the OPERA implementation are disseminated within STMicroelectronics, in several product divisions. The demonstration of the actual possibility to implement several traffic monitoring use cases within the time duration requirements will allow the division marketing to propose to customers' new solution directly impacting traffic monitoring applications as well as other applications, regarding the monitoring of public and private areas. The development of the prototyped conducted in OPERA will allow also an accurate evaluation of the costs of the solutions, in terms of production and maintenance. The exploitation will conduct to a concrete business plan that will be detailed in the appropriate deliverable.

2.1.2 External exploitation

The team involved in the OPERA project is a research group, not directly interfaced to the customers. The exploitation of the results will be conducted by the marketing teams present in the product divisions involved in the internal exploitation activities.

2.2 IBM

As an industrial partner, IBM's contribution to the OPERA project is focused around obtaining relevant solutions related to enhancing efficiency through reducing power consumption in a cloud data center. We have 3 main avenues for exploitation of the results from the OPERA project. The first is the academic channel, in which we publish our latest research to advance the state-of-the-art. The second is the internal exploitation, in which we identify IBM Business Units that can adopt our technology to their benefit. The third channel is external exploitation, where we try to help other companies adopt our technology, directly or through Open Source.

2.2.1 Academic exploitation

For academic publications in the 3rd year, we aim to publish our work on container migration at SoCC (Symposium on Cloud Computing) whose deadline is not yet announced, but will likely be at the end of

April 2018 (the symposium takes place each year at the end of September or beginning of October). This is a highly rated conference with a high impact. We expect to publish an "experience" paper, detailing the implementation of post-copy container migration in CRIU, as well as the process of containerizing existing applications to package them as cloud services.

We also aim to publish a paper at OSDI (Symposium on Operating System Design and Implementation) related to our work on the low-latency interconnect used for fast remote page faults. The deadline is also around the same time, with the abstract due at the end of April, and the full paper due in May 2018. This is a highly rated conference, and a successful submission to this venue will require significant, positive results.

2.2.2 Internal Exploitation

For internal exploitation, we are in discussions with a couple of departments in the IBM Cloud Business Unit regarding the opportunities to exploit CRIU (checkpoint restore in user space) technology that we have contributed to and expanded as part of OPERA. Together with our business partners, we have identified several use cases where CRIU can be beneficial to IBM. In particular, we are aiming to reduce restoration time of containers used for IBM cloud services.

The remote page fault technology that we are developing also has some promise inside the company. We are in contact with a team responsible for development of POWER systems, and they have shown some interest in potentially including our remote page fault feature as a service offering.

2.2.3 External Exploitation

Our external exploitation plan revolves around contributions to established open source communities such as the Linux kernel and CRIU projects. These code bases are already in use by many other companies and are components in many products and services. By contributing our patches to these projects, we have direct impact on the many companies and products that rely on these communities. We have contributed the post-copy migration feature to the CRIU project, as well as several patches to the memory management subsystem in the Linux kernel. We are committed to delivering several more patches to these two projects by the end of the OPERA project. In addition to code contributions, we'll continue to publicize our work through community events, such as KVM forum, OSS summit, Linux Plumbers, and more. The first talk is planned to take place in FOSDEM'18 in February in Brussels.

2.3 HPE

The initial goal of Moonshot was to bring optimized servers for defined workloads to the market, taking into consideration the possibility to customize the Moonshot server with dedicated boards.

The VDI use case demonstrated that leveraging optimized servers can dramatically reduce the price, the used space and the power usage over generic systems.

This use case also demonstrated that SaaS applications require less energy than RDS ones.

The experience gained from this use case will be exploited in the solutions tailored for Service Providers.

Traffic Management and DataCenter in a Truck use cases demonstrated that packaging Moonshot servers with FPGAs will dramatically increase performance efficiency for a broad range of applications.

For internal exploitation, HPE researchers involved in the OPERA project are in discussions with a couple of departments in the HPE organization and with HPE Partners regarding the opportunities to exploit:

- Small form factor data center
- New generation of Moonshot servers with integrated FPGA hardware
- Metrics for energy efficiency

- Workload decomposition to dynamically execute tasks on the most suitable processing element

2.4 NALLATECH

One of the major contributions made by Nallatech during OPERA project was the creation of the 385-O FPGA accelerator. This FPGA board, after being slightly modified, has become a Nallatech commercial product. The 385A-SoC FPGA joined the standard 385A on Nallatech portfolio.

The 385A is one of the bestselling FPGA boards produced by Nallatech. Having alternate versions of this board to more closely fit customer requirements is a good opportunity for Nallatech.

The main difference between these accelerator cards is the selection of the FPGA chip, the heart of the device, as described in D6.1. The 385A-SoC, which is based on the 385-O, is leveraging an Intel Arria 10 SX660 which enables new use cases thanks to the embedded ARM cores.

Having ARM cores inside the FPGA facilitates smaller and cheaper solution designs, by bypassing the requirement to install the FPGA in a host server.

Domains, such as IoT and real-time network analytics are seeking devices which would respond to the following requirements:

- smaller footprint (need to be installed on the edge)
- ruggedized system (potentially no air conditioning but dust)
- contained price (large deployment)
- energy efficiency
- remote monitoring and management

Following the work done on the 385A-SoC, Nallatech decided to tackle these requirements and designed a housing which transforms the FPGA PCIe board into a stand-alone device.

The FPGA MicroNode has been specifically engineered to answer new challenges demanded by computing on the edge.

- The IoT market is in a period of constant expansion with around 300B$ spending planned in this domain in 2020. Intelligent gateways, used as geographically distributed aggregators for the “things” will play a huge role in data security and network optimization on top of edge analytics.
- With all the security threats we are facing today, Network Intelligence has a 25% CAGR. This market was around 750M$ in 2015 is targeted to reach 2.3B$ in 2020.

The hardware part of the solution being mostly solved, Nallatech is now working with partners to build a software and services ecosystem which is required in any IoT projects.

The work being delivered with Neavia and ISMB on Artificial Intelligent for the Traffic Monitoring use-case is also a field which can be adapted to be integrated in commercial products.

Today, CNN’s are used in many domains, from medical (genome sequencing) to video broadcasting (content based encoding) and Nallatech is planning to reuse part of the research conducted in OPERA to add “intelligence” to some of our existing customers’ workloads. It will also enable Nallatech to expand and to differentiate on a highly competitive market.

http://www.nallatech.com/store/fpga-accelerated-computing/pcie-accelerator-cards/nallatech-385a-soc/

http://www.nallatech.com/store/fpga-accelerated-computing/nallatech-fpga-micronode/

2.5 ISMB

Istituto Superiore Mario Boella (ISMB) is a research and innovation centre operating in the Information and Communication Technologies (ICT) domain. Founded in 2000 by Compagnia di San Paolo and Politecnico di Torino, today ISMB relies on the technological and process competences of around 150 researchers working in close cooperation with companies, academia and public administration. ISMB

operates according to the knowledge management model: this means that it plays an active role not only in devising innovative solutions, but also in their implementation and consequent developments. This approach represents a step forward with respect to technology transfer, and in this sense the evolutionary lines of European research are taken into account.

ISMB is organised in Research Areas focused on some core sectors of ICT: computing infrastructure based on technologies of cloud computing solutions and electromagnetic simulation (Advanced Computing & Electromagnetics).

ISMB intend to focus exploitation on three aspects:

- Workload management and resources allocation in Cloud computing environment for heterogeneous architecture
- Reconfigurable antennas
- CNN development on FPGA architecture

2.5.1 Internal Exploitation

The ISMB team involved in the OPERA project is in discussion with other research Areas for reusing and exploit its activities on workload management and resources allocation in heterogeneous architectures, specifically for the convergence between IoT and Cloud.

Another point of discussion is the results coming from the Low Power reconfigurable antennas to be placed on CPS for covering better communications between smart object in energy efficiency constraint.

As ISMB focus is also on targeting Big Data and HPC, discussions are also on exploiting the knowledge regarding the CNN development on FPGA with OpenCL. The major exploitation will be on targeting activities for using FPGA for Datamining algorithms.

2.5.2 External Exploitation

Concerning Workload management and resources allocation in heterogeneous environment a specific action will be on targeting new H2020 calls, mainly Innovation Actions. One example of these calls is the ICT11-2018, related to HPC, Cloud and big data convergence.

Results and applied research coming from the Software define radio and reconfigurable antennas (Traffic monitoring use case) will be part of a specific action for APRR, a road services provider. This action will be joined with TESEO.

For the CNN development on FPGA in collaboration with Nallatech, the intention is to increase the collaboration for software development in the field of artificial intelligence on machine learning.

2.6 TECHNION

Technion would exploit the virtual memory research under OPERA, focused on hashed page tables in future projects aiming at CPU design. Like other computer-architecture works, our preliminary research results are based on simulation and will thus not manifest in actual systems developed in the OPERA project. Still, the Technion's research has many practical implications because hashed page tables are implemented in IBM Power and Intel Itanium platforms. Specifically, Technion studied the Intel Itanium virtual memory design, proposed several ways to optimize it, and showed that our carefully optimized hashed page tables outperform virtual memory implementation with radix, hierarchical page tables in existing x86-64 processors. In future work, Technion hopes to also examine the IBM Power architecture for similar improvements and to exploit these insights in developing new computer systems (CPUs and operating systems support).

The most important insight from our work is that the current, widely-available x86-64 platforms are inherently less scalable than hashed designs because they use more and more levels of translation as the Memory size increases. In fact, Intel announced its plans to extend the virtual memory address spaces supported in x86-64 CPUs [1] a few months ago. The new Intel design will lengthen the page walk length from 4 to 5 memory references, further amplifying the overhead of virtual memory on modern, memory-intensive applications. Our proposed hashed page tables, in contrast, require only 1 memory reference for address translation regardless of the address space size. We believe that our work may guide future computer architects in their designing of new computer processors.

To further exploit the Technion research results, the Technion has initiated two exploitation activities, with Intel and Mellanox. The Intel Haifa site is the home of the computer architecture group, which, among other things, is responsible for designing the next generations of Intel x86-64 processors. The Technion presented the virtual memory work to this group of engineers, which expressed interest in implementing it. The main concern of Intel was that the Technion proposal requires architectural changes, and Intel has strong legacy constraints of course. The Intel engineers therefore suggested to examine a virtual memory design that combines hashed page tables in tandem with the Intel radix page tables. The Technion didn't have the chance to carry out this research, but two other works have explored this approach and built on the Technion “Hash, Don’t Cache” paper (and cited it, of course). These two works were published in ISCA 2017, the premier forum for computer architecture research [8][9].

A few months ago, The Technion also presented their work in Mellanox, which, after the acquisition of EZchip in 2016, is building high-performance network processors and multi-core processors. The Mellanox architects were therefore interested in the research results and the lessons we learned, and we hope to collaborate with them on future projects.

2.7 CSI

CSI provides services for Italian Public Bodies and it is leading two of the three Use Cases (Truck and VDI) to integrate OPERA technological outcomes and to demonstrate its results and feasibility in real-life conditions. For this reason, in this section we have a provider perspective and, starting from the current state of the two Use Cases, we can focus for each one of them the achieved results thanks to OPERA Project, the Stakeholders involved by these outcomes and what OPERA wants to realize in the future. Finally, we highlight a general point of view in terms of exploitation.

Truck Use Case

- Recognized exploitable results: Currently the Truck operator is using the hardware provided by OPERA Project in real-life situation, that means two important improvements. The first one is the substitution of two servers of 2U each one with one server of 1U and the second one is a reduction of the power consumption (about 40%).
- Stakeholders: At the moment only the CSI takes advantage of the project results in economic (power consumption reduction) and management (less servers) terms.
- In the future: In the next cycles of the project, we want to reduce the orthophoto elaboration time (thanks to FPGA cards), that is the main target for this use case. Thanks to that also Protezione Civile and population will take advantage of OPERA Project, because we could reduce the intervention time.

VDI

- Recognized exploitable results: During this period, we demonstrated that SaaS applications require less energy than RDS ones. In additions, CSI gained experience about SaaS applications and containers technologies, thanks to direct use of them and to the knowledge exchange with the other partners.
- Stakeholders: In this moment the CSI takes advantage of the project from the knowledge point of view. But potentially, also other Service Providers could know

OPERA outcomes and choose to invest in SaaS applications and not in RDS ones to reduce power consumption.

- In the future: In the next cycles of the project, we want to move micro services among different hardware architecture with a NIC with ROCE, thanks to that it will be possible to reduce further the power consumption and then to increase the odds drawing attention of other providers.

The experience about the Track and VDI Use Cases can lead to some general considerations that can be valid also in other contexts. First of all, two elements are highlighted by Opera Project at this moment:

- Space reduction
- Power consumption reduction

These two improvements are due to Low Power Servers that can guarantee them not only for these two services but also in other situations for other Service Providers.

2.8 NEAVIA

Lacroix Neavia is a key player in smart road infrastructure. In the road surveillance business, Lacroix Neavia portfolio targets devices under high-constrained conditions, making cameras suited from freeways to isolated mountains roads. Those specific conditions require having both network accessibility and high energy efficiency. Cameras can then run autonomously using a solar panel and embedded smart software utilities for road condition evaluations. Thus, cameras can be deployed with more flexibility providing there is enough communication access and sunlight.

In the OPERA project, Lacroix Neavia provides its know-how in embedded software domain so that specific road use cases can be addressed, taking care of using efficient but limited hardware resources.

Through the OPERA project, Lacroix Neavia intends to push further the bounding of state-of-the-art products in road management. In those respects, the use of neural network architecture like YOLO could be a technological breakthrough for smart road surveillance. Lacroix Neavia intends to integrate such advanced computing into whether local and / or remote processes for more robust solutions, mainly regarding recurrent artefacts resulting from various light and weather conditions, and occlusions. A hybrid system including local detections from classical video processing approach on a smart camera and a remote expert system based on YOLO is currently under investigation. This heterogeneous architecture (from both hardware and software points of view) could allow higher performances in road incident detections.

Taking advantage of new and efficient network and hardware architecture, and developing specifically designed software allows new solutions to road use cases such as congestion, wrong way or specific condition detections to be brought to the road managers. Thus, road surveillance can be taken to another step which opens new insights into the future of road management appliances for a safer and smarter road usage.

2.9 CERTIOS

The core business of Certios is:

- IT Research projects
- Infrastructure consultancy (emphasis on data centres and energy efficiency aspects)
- Teaching at universities and
- Assisting organizations to become compliant to the General Data Protection Regulation (GDPR).

Thanks to OPERA, Certios has the improved opportunity to teach the OPERA findings at the different institutions where Certios has teaching contracts (HvA, Amsterdam, HU, Utrecht). For the infrastructure assignments of Certios, the increased knowledge of infrastructural aspects and the applied energy efficiency metrics in the uses cases of the OERA projects, will improve the value of our infrastructure

consultancy significantly. Enriched with the experiences of what did work out and what didn't - the core of every research project – the commercially exploitable knowledge has been improved.

Short term and concrete: we expect to insert the outcomes of the VDI use case in an advice that we are currently producing to a public-sector customer. For the longer term Certios will exploit the OPERA innovations and disseminate these via the Data Centre Alliance (www.datacentrealliance.org) members. Certios representatives are in the Board of Commissioners, and the expectations of the DCA members will be addressed. There is a high interest in energy efficiency with the members of the DCA. OPERA Products and services will be highlighted in the DCA's Newsletters, conferences, and several strategic Interest groups. Certios will expand its clients base by rendering consultancy and implementation, measuring and proving the advantages of the OPERA products and services within the DCA members.

2.10 TESEO

TESEO, thanks to the "Traffic Monitoring" use case, has started to exploit and propose OPERA's solution into Eiffage Group and in several sectorial events like ITS European Congress (Intelligent Transport Systems) and the "European night of researchers". The return of experience for TESEO from OPERA is an incredible growth of the market because the technologies involved in the project are tailored for IoT and Industry 4.0 applications. The can be proposed to various players of the market, also due to the presence in the consortium of the Departement de l'Isere. For this reason, TESEO intends to commercialise the hardware platforms that will come out from the use case.

2.11 ISERE

ISERE manages a 4700 km interurban road network and it is leading one of the three Use Cases (Road traffic management) to integrate OPERA technological outcomes and to demonstrate its results and feasibility under real-life conditions. For this reason, in this section we have an end-user perspective and, starting from the current state of the traffic monitoring Use Case, we consider action plan for two topics:

- Real time detection of road event by embedded video platform
- and further use of off-loading process to analyse big and/or sophisticated video data

For the moment, around 50 video surveillance cameras monitor the ISERE road network. These cameras have been installed only in areas where electrical grid and wired network are available. The cameras are delivering a video stream, which is analysed by a human operator able to visualize 16 images on an image wall. The OPERA technologies are expected to enable traffic monitoring at any location (access to electrical grid and communication wired network to transmit continuous video stream is no more required) and to enable faster and more systematic traffic event detection (thanks to the automation of the video data treatment).

2.11.1 Real time detection of road event by embedded video platform

OPERA showed that an embedded platform could detect road event by consuming less than 1W. More precisely the OPERA ULP technologies are able to detect and analyse the start and the end of traffic congestion (as shown on the test 1) under real conditions.

These results encourage Département de l'Isère to investigate solutions based on ULP energy autonomous system video sensor to detect road events and to send alarms to the road management centre, from the collection and the local treatment of video information. The identification of road events by local embedded smartness maximizes the capacity to alert the road manager while moderating data communication flow. Consequently, it will maximize the capacity to operate roads and to inform road users. Events as the storm Eleanor that strikes Isere on the 3rd and the 4th of January 2018 remind all the interest of this type of real time detection solutions including in isolated areas (up to 75 closed roads at the peak crisis, in particular in Gresivaudan and Oisans mountain areas).

The low level of energy consumption enables to consider an energy autonomous solution supplied by very small solar panels and batteries, which does not require civil engineering infrastructure. It makes possible a high scale deployment of video platform across the road network

Département de l'Isère could consider the deployment of several tens of video platforms across the road network, after the validation of the technology, but practical issues have not yet been validated. The R&D results of OPERA still require to be integrated in a commercial and operational product that is fully adapted to all the practical issues of a road manager system:

- The energy autonomous system has to be optimized: lighter and more compact, easier to install, and reliable.
- The system has to be validated under any climatic and environmental conditions, and more completed evaluated: as an example, operation could not be tested under snowfall (example of 4th December)
- Achieved packaging is required to provide the easiness of installation on light support, the easiness of mechanical and optical adjustments, the protection from vandalism and raspberry.

So the exploitation plan of Isere will be the research of operational solutions based on OPERA technologies, and a closer contact with technology suppliers as NEAVIA who showed its capacity to develop these technologies. ULP technologies enable to deploy the system in any place, at a large scale, and embedded smartness enables to send already treated information to the operators of the road management centre, as an alarm about identified road event. So the objective is to research solutions using OPERA results but based on more achieved commercial and operational product with more systematic tests under all types of road environmental conditions. Innovation steps are still required to achieve a product that can be daily and reliably used by the road managers under all real conditions.

2.11.2 Use of off-loading process to analyse big and/or sophisticated video data

OPERA encourages Isere to investigate solution based on off-loading process coupling embedded ULP video platform and high efficiency data centre. Off-loading process will bring Isere to use treatment of big data, about the maintenance of road infrastructure, about the knowledge of road traffic, about the preparation and the evaluation of different types of public policies (tourism, economy, house, etc…)

OPERA enables Département de l'Isère to become aware of all the opportunities that could be provided by off-loading solutions, and to begin considering deep evolution of road management strategies.

Département de l'Isere will be interested in participating to innovation action to better investigate the opportunity provided by off-loading process, in particular in terms of processing of sophisticated data and/or big data: aggregation of big data collected from several geographical sizes, aggregation of big data collected from long periods, sophisticated treatment of video data, etc. Use cases need to be investigated, elaborated and tested during further innovation actions.

3 GLOBAL EXPLOITATION ACTIVIES

3.1 EVALUATION OF THE COMPATIBILITY OF EXPLOITATION POLICIES OF THE CONSORTIUM PARTNERS

The organization of the collaboration in the OPERA project allow the partner to be complementary in the various components developed in the project. This organization will make easier the exploitation of the different results, avoid conflicts of interests. In particular, on the Small form factor data center, the main industrial partners involved (IBM, Nallatech, HPE) are providing to the system a crucial different element, that will allow a shared exploitation of the results, as well as individual exploitation of the single elements (Moonshot, FPGA, optimizations in the execution). The CSI partner can identify the areas (industrial and academic) where the exploitation of these results can be more beneficial, especially in the public sector.

The implementation of the ULP device also integrates different and complementary expertise, like the SoC, the hardware integration, the software and the use case requirements and deployment. In this case a common exploitation is also strengthen by the demonstration of the device on the field, that can be evaluated directly by the end user (Département de l'Isère). The company that has a long history of devices used in the traffic monitoring applications (Neavia-Lacroix) can identify the correct ways to exploit the research, and STM and TESEO will contribute to the elements needed to integrate the new devices (prototypes and products) that can be considered after the end of the OPERA project.

Finally, the partners that are horizontal to this approach (ISMB, CERTIOS and TECHNION) can provide support to the entire OPERA system, for the harmonization of the different parts, and for the evaluation and optimization of the power needs.

3.2 INTERACTION WITH STANDARDIZATION BODIES

In the OPERA project, differently from what stated in the original proposal, there were no chances to provide a feedback to the standardization bodies considered. In particular, the standard OpenCL and OpenVX have been analysed for their relation to the project elements. The OpenCL standard has been adopted for the implementation of the FGPA accelerators. The support of the API and the OpenCL compiler has been provided by Nallatech.

The OpenVX standard has been considered for the ULP device. The adaptation of the current software stack to the OpenVX standard has been considered too complex for the SecSoC platform, on which the overhead of the standard implementation would have decreased the efficiency of the system. For the Orlando platform, the adoption of this standard, and in particular related to the CNN extension, is under evaluations. Some more details about the standards considered can be found here:

https://www.khronos.org/news/press/khronos-launches-dual-neural-network-standard-initiatives

The only standardization body where OPERA still has a role to play is when it comes to the monitoring of heterogeneous hardware. Redfish is still a very new standard which is getting a lot of attraction from large cloud companies but still lacks features. The work conducted for FPGA monitoring under Redfish (new schema for PCIe Accelerators) is being pushed to the standard organization.

https://www.dmtf.org/standards/redfish

3.3 IPR MANAGEMENT (IMPLEMENTATION)

The IPR management support provided by the European community provides a list of steps to be followed. The intention of the OPERA consortium is to follow the procedure. For the moment TESEO and STM have started to contact the help desk to start the procedure.

4 EVALUATION OF IMPACT

For this section, a reference will be made to project deliverables D2.5 “Innovation Potential of OPERA platform 1” (OPERA Consortium, 2017)and D2.6 “Innovation Potential of OPERA platform 2” (OPERA consortium, 2017). To avoid too much duplication, only the headers and a minimum of contextual texts from the referenced documents will be repeated. A similar analysis is presented in the deliverable D8.11 [2]. Here a wider picture is considered, while an analysis more focused on the business areas is conducted in D8.11.

4.1 MARKETS

The evaluation of where the OPERA innovative results will have the most impact by being applied most successfully, led to the following markets:

- Oil and Gas industry (HPC in the OPERA fit out)
- Maintenance industry, drones (checking planes, as a part of maintenance of air planes)
- Other Industries; in need of mobile platform, high computations. Edge.
- Customers without a datacenter (ship, car, plane, submarines)
- Cyclomedia (a la Google, but measured).
- IT service providers

4.2 MARKET AREAS

What the OPERA project will contribute mostly to is:

4.2.1 Internet of things

4.2.1.1 IoT Analytics

One of the markets that will benefit from Opera’s “datacenter in a box” containing different ISA processors and an energy aware application management layer is the “Internet of things (IoT) analytics”.

IoT analytics will be one of the industries that will benefit from the different instruction set architectures (ISA’s) that are part of the OPERA solution. The expected increase in dataflow from sensors, including video, and the need to contain costs underline the targets set for OPERA, doing things faster and more efficient then can currently be done.

4.2.1.2 EDGE analytics

Gartner in its document “Internet of Things Primer for 2016” (Gartner, 2016), predicts that we are quickly approaching the era where tens of billions of networks enabled devices are in use.

- To sustain that many, mostly wireless, devices, both communication and the device itself must operate with extreme energy efficiency and Ultra low power (ULP).
- One of the many types of IoT devices is a camera, specifically OPERA will work on a traffic management camera usable in area’s that lack both electrical as well as wired communication grids.
- Reconfigurable directional antenna for wireless communication and an ULP image processing addition to the camera that will limit the amount of energy needed to send data by the camera and support autonomous operation of the device for traffic safety purposes.

It is to be expected that this technology will have a broad range of applications. Many of the billions of IoT devices will operate without either a wired network or wired energy connection and must function for most time without human intervention. Demonstrating a highly functional element such as a traffic management camera will open the way for many other applications.

4.2.2 Environmental management

Environmental management itself is creating an enormous amount of data collected by sensors that need to be analysed for decision support. The results obtained from the smart camera proves not only the potential

for low power sensors, but the need for, and resulting efficiency from, embedded intelligence. The embedding of local processing power and autonomous decision making greatly diminishes the amount of data that is sent and stored. As such the sensor intelligence contributes to energy/equipment and cost savings in both the connecting networks as well as the end point datacenters. The smart camera created within the OPERA project can be used for demonstrating that this intelligence can be added to a sensor, even in a very tight energy envelope.

4.2.3 Hyper converged Infrastructure

Hyper converged infrastructure has, according to Gartner's "Cool Vendors for Compute Platforms" (Gartner, 2016), a growing enterprise adoption. The datacenter in a box that Opera is creating could be at the heart of such a differentiating Hyper Converged Infrastructure Solution, offering better energy efficiency and greater capacity for application hosting then current solutions in the market.

4.2.4 Cloud

Cloud is a booming industry where, according to Gartner's "Cool Vendors in Cloud Infrastructure" (Gartner, 2016) OPERA will have 3 opportunities to exploit results:

4.2.4.1 Energy aware resource management

Containers are an emerging technology for delivering cloud services. Dedicated software platform for running container technology has entered the market which has added other operational features: packaging and installation services, resource management, scheduling, provisioning, and orchestration, all bundled within a unified software stack. Through the VDI use case, OPERA adds energy aware resource management to the mix. OPERA partners could get in touch with Cloud Service providers and discuss high level infrastructure architectural improvements, options to save money and to increase energy efficiency. OPERA partners can approach datacenter owners directly. In addition, the OPERA resource manager will monitor microservices for signs of inefficiency and performance. This last point is expected to help adoption of this OPERA resource manager in a performance sensitive market.

4.2.4.2 Heterogeneity

Several large vendors (Google, Baidu, Microsoft, Apple, AWS, possibly Facebook) are experimenting with alternative chip architectures (ARM, POWER) to prevent vendor lock-in (Intel). If the trend continues/proves itself, it could drastically change the makeup of large data centers. Following the example set by these very large companies, it may be expected that other large data centers will implement heterogeneity within their configurations. The work done by OPERA, characterizing applications in terms of processor affinity under varying load and the experience using heterogeneity in a single virtual system has the potential to accelerate such a shift resulting in a better resource usage and higher energy efficiency for the data centers.

4.2.4.3 Cloud solution providers

Thanks to the OPERA innovations, solution providers (like CSI), who offer their software solutions in the form of micro services (Open Source), will be able to dramatically increase the number of potential users while reducing the hardware and energy cost of operation. The OPERA resource manager will not only detect and try to remedy inefficient operations but also detect situations in which microservices require more resources. In this way, the resource manager helps to ensure the service levels that customers require.

4.2.5 Video Vision

Video vision, machine recognition or cognitive computing (Villa, 2016), all refer to the ability of video sensors to analyse video data autonomously and base decisions on this data. The market is growing quickly as identified in the Gartner analysis "Internet of Things Primer for 2016" (Gartner, 2016). A use case

addressing exactly this trend is part of the OPERA project and will result in a demonstrable product for use in industry workshops.

4.2.6 ADAS

Advanced driver assistance systems (ADAS) are systems developed to automate/adapt/enhance vehicle systems for safety and better driving. Driving cars means producing data; who is where and when. Interesting for governments and insurance companies. The ADAS will likely include more than one video sensor, this sensor will need the capability of cognitive computing, selecting data for logging and making decisions such as braking, steering or alarming a driver when the situations warrants such actions.

4.2.7 Deep Neural Nets

Deep learning is a variant of machine learning that involves neural nets with more than two processing layers. Neural networks are algorithms, modelled loosely after the human brain, designed to recognize patterns and do predictions. The Deep Learning market is moving very quickly with different benchmarks being undertaken. Intel and NVidia have already started a war of words arguing which processor technology delivers the best results, and which datasets/test benches should be used (NVIDEA, 2016).

4.2.8 CPU design (Intel/IBM)

The work executed by partners of the consortium (Technion) with regard to the memory management will potentially have effect on the way CPU hardware is designed.

4.2.9 Sensor industry and monitoring of public infrastructure

The investigations about use cases as road traffic management, reinforced the potential interest of OPERA technology for the sensor providers: OPERA could provide new opportunities to develop the capability of the sensors, to locally treat in real time and to collect data for further investigation by very high power centralized smartness.

5 REVIEW OF THE RECCOMENDATIONS

The recommendations related to the previous version of the exploitation plan were:

"The consortium is requested for the next version of this report to describe explicitly the exploitation activities after the end of the project" and to discuss key issues such as IPR handling, compatibility of exploitation policies of the consortium partners and any interaction with standardisation bodies., which was explicitly planned in the DoA. The deliverable should be put in context of D2.5. The current deliverable focused too much on issues that should have been handled in other work packages and documents (dissemination, communication, research planning)."

The main actions considered in this document, based on the recommendation of the review of the preceding version of the exploitation plan have been:

- Consider the impact and innovation, as described in D2.5 and D2.6, in the individual exploitation actions and plans. The results of the projects in terms of innovation are already available, and the actions can be more concrete. This plan is strictly related to the business plan development, regarding the Following these considerations a more detailed plan of exploitation for any partner is presented. In the document has been considered the impact of OPERA project, as desc4ribed in deliverables D2.5 and D2.6.
- Implement an IPR management mechanism, started with the analysis of the helpdesk service provided by the EU community
- Review of the interaction with the standardization bodies, described in a devoted paragraph
- A description of the exploitation actions already started is also provided, mainly in the partners' specific activities (chapter 2)

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[5] OPERA deliverable D8.2 “Exploitation plan”
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[7] OPERA deliverable D2.6 “Innovation Potential of OPERA platform 2”
[8] "Do-It-Yourself Virtual Memory Translation", http://dl.acm.org/citation.cfm?id=3080209
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