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UNICORE

UNICORE: A Common Code Base and Toolkit for Deployment of Applications to Secure and Reliable Virtual Execution Environments

Horizon 2020 - Research and Innovation Framework Programme

D6.3 Report on Communication and Dissemination Activities and Exploitation Plans - Initial

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Abstract

The goal of the EU-funded UNICORE project is to develop a common code-base and toolchain that will enable software developers to rapidly create secure, portable, scalable, high-performance solutions starting from existing applications. The key to this is to compile an application into very light-weight virtual machines – known as unikernels – where there is no traditional operating system, only the specific bits of operating system functionality that the application needs. The resulting unikernels can then be deployed and run on standard high-volume servers or cloud computing infrastructure.

This deliverable reports on the achievements of the UNICORE project in Year 1 (Jan-Dec 2019) for all the communication, dissemination, standardization and exploitation activities executed by the Consortium.

Target Audience

The target audience for this document is **public**.

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1 Executive Summary

Dissemination, standardization and exploitation activities are essential for the success of any research project. The UNICORE Consortium has set three main streams of actions to achieve its expected impacts:

- **Publications in top academic conferences**, to increase visibility of the work and attract the attention of the research community on the toolstack;
- **Open-source development and community building**, in particular for what concerns the Unikraft unikernel buildtool and the UNICORE toolstack;
- **Novel product development in selected markets**, with the aim of developing exploitation plans for the foreground generated by the project activities and impact in the market sectors related to the UNICORE use cases.

The UNICORE project is developing tools to enable lightweight VM development to be as easy as compiling an app for an existing OS, thus unleashing the use of next generation of cloud computing services and technologies. With UNICORE toolchains for unikernels, software developers will be able to easily build and quickly deploy lightweight virtual machines starting from existing applications. The unikernel and toolchain technologies developed and enhanced within this project have several promising commercial opportunities, some of which under validation in four highly relevant industrial use cases: Serverless Computing, Network Function Virtualization, Home Automation and Internet of Things, Smart Contracts. The strategy we have applied to execute various dissemination and communication activities in Year 1 has primarily focused on the presentation in scientific forums and top international conferences of the projects core concepts related to unikernels and security. The communication campaign has followed this scientific stream and through the project website and its social channels has generated awareness in the large network of industry and academia connected to the Consortium about research progresses. The standardization and exploitation activities of this Year 1 have been mostly aimed at establishing individual plans and actions for selection and identification of foreground, with a major focus on the Unikraft open source project and the related developers community formation.

Key results achieved by the project in Year 1 can be summarized as in the following:

- **13 scientific papers** have been published or accepted to relevant conferences and important events, 2 of which before the formal project start;
- **11 UNICORE/Unikraft presentations** have been given in well-known international events;
- **1 public unikraft tutorial** has been given (FOSDEM 2019) and **3 internal Coding Day events** have been organized to ease the design and development of unikernel functions crafted via unikraft in the four project use cases;

- **The UNICORE website** has been launched at the end of Feb-2019 to convey information on project results to the general public;
- **1 project video** has been realized and published on Nov-19 on the project YouTube channel (59 visualizations in one month);
- A significant presence on social channels has been established: on Twitter **96 unique tweets** have been generated, we count **60 followers and over 22K impressions over Q4-2019**, which given the specific topic of the project is a great result for the first year);
- **40 Unikraft repositories at GitHub** (<https://github.com/unikraft>) which oversee other 27 maintained repositories at Xen project pages (http://xenbits.xen.org/gitweb/?a=project_list&s=unikraft);
- Executed preliminary individual exploitation actions related to the initial results and research topics of UNICORE

The achieved results confirm a good progress on all the KPIs set by the project in this area (see Fig. 1.1).

A significant number of activities is planned for Year 2 and many are just in progress to continue impact achievement for UNICORE through demos, scientific papers, tutorials and engagement activities with various communities interested in unikernels.

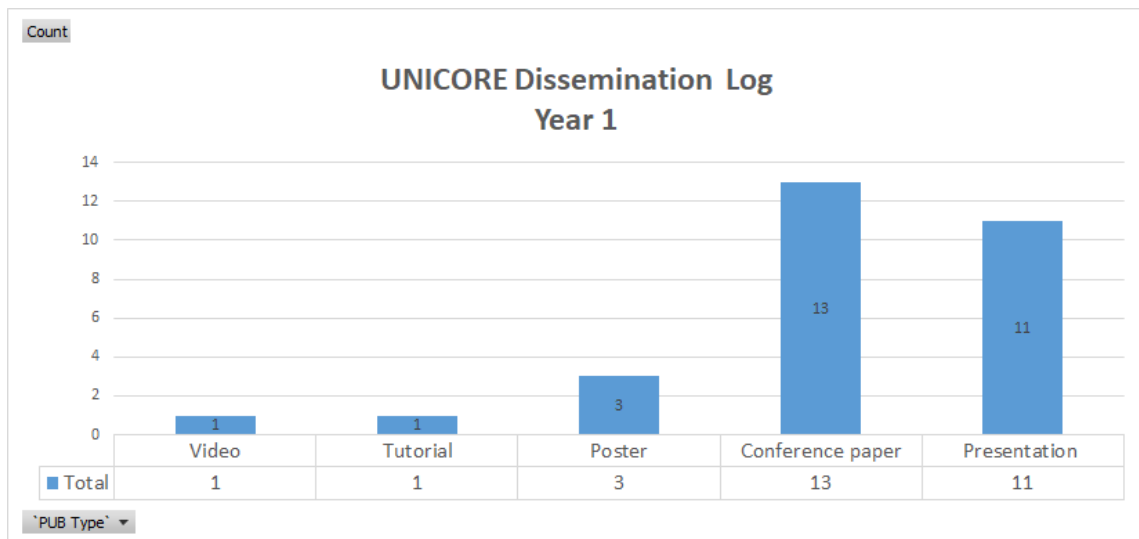


Figure 1.1: UNICORE Dissemination Log for Year 1

2 Introduction

This document reports on the achievements of the UNICORE project in Year 1 (Jan-Dec 2019) for all the communication, dissemination, standardization and exploitation activities executed by the Consortium.

The document is organized in three main chapters corresponding to different types of activities as follows:

- Chapter 3 reports on the dissemination and communication and public activities undertaken jointly by the consortium and individually by the partners in Year 1.
- Chapter 4 describes the standardization and open source activities pursued by the partners related to UNICORE research topics.
- Chapter 5 presents the initial exploitation plans defined by the partners both individually and jointly in relation to the knowledge and results to be generated within UNICORE project.

For each chapter, a brief outline of the plans for Year 2 is also provided.

The conclusions in Chapter 6 summarize the key relevant aspects and results of the Consortium in terms of impact achievement, and also provides an overview on the level of fulfilment of UNICORE KPIs which have been set in the Description of the Action.

3 Dissemination and Communication Activities

3.1 Scientific Publications

A couple of articles published by the end of 2018, before the beginning of the project, are listed below as part of the preparatory research work executed before the formal start of UNICORE

Papers in Conference proceedings:

1. Tatar A., Giuffrida C., Bos H., Razavi K., 'Defeating Software Mitigations Against Rowhammer: A Surgical Precision Hammer - BEST PAPER AWARD', International Symposium on Research in Attacks, Intrusions, and Defenses RAID 2018, Heraklion, Crete, Greece, September 10-12, 2018, DOI: https://doi.org/10.1007/978-3-030-00470-5_3, LINK: N/A
2. Radhesh Krishnan Konoth and Marco Oliverio and Andrei Tatar and Dennis Andriess and Herbert Bos and Cristiano Giuffrida and Kaveh Razavi, 'ZebRAM: Comprehensive and Compatible Software Protection Against Rowhammer Attacks', 12th USENIX conference on Operating Systems Design and Implementation USENIX-ACM OSDI 2018, 8-10 October 2018, Carlsbad, USA, DOI: N/A, LINK: <https://www.usenix.org/conference/osdi18/presentation/konoth>, Proceeding OSDI'18 Proceedings of the 12th USENIX conference on Operating Systems Design and Implementation Pages 697-710 ISBN: 978-1-931971-47-8

The list of publications from the beginning of the project is as follows:

Papers in Conference proceedings:

1. Osterlund, S., Koning, K., Olivier, P., Barbalace, A., Bos, H. and Giuffrida, C., 'kMVX: Detecting Kernel Information Leaks with Multi-variant Execution', 24th ACM International Conference on Architectural Support for Programming Languages and Operating Systems, April 13th April 17th, Providence, RI, USA, DOI: <https://doi.org/10.1145/3297858.3304054>, LINK: N/A
2. Cojocar, L., Razavi, K., Giuffrida, C. and Bos, H., 'Exploiting correcting codes: On the effectiveness of ECC memory against rowhammer attacks. BEST PAPER AWARD', 2019 IEEE Symposium on Security and Privacy (SP), May 20-22 2019, San Francisco, CA, US, DOI: <https://doi.org/10.1109/SP.2019.00089>, LINK: N/A
3. van Schaik, S., Milburn, A., sterlund, S., Frigo, P., Maisuradze, G., Razavi, K., Bos, H. and Giuffrida, C., 'RIDL: Rogue In-Flight Data Load. INTEL BOUNTY REWARD', 2019 IEEE Symposium on Security and Privacy (SP), May 20-22 2019, San Francisco, CA, US, DOI: <https://doi.ieeecomputersociety.org/10.1109/SP.2019.00087>, LINK: N/A
4. Kuenzer, S., Santhanam, S., Volchkov, Y., Schmidt, F., Huici, F., Nider, J., Rapoport, M. and Lupu, C., 'Unleashing the power of unikernels with unikraft', 12th ACM International Conference on Systems

- and Storage - SYSTOR'19, Haifa, Israel June 03 - 05, 2019, DOI: <https://doi.org/10.1145/3319647.3325856>, LINK: N/A
5. Nider, J., Rapoport, M. and Bottomley, J., 'Address space isolation in the linux kernel', 12th ACM International Conference on Systems and Storage - SYSTOR'19, Haifa, Israel June 03 - 05, 2019, DOI: <https://doi.org/10.1145/3319647.3325855>, LINK: N/A
 6. van der Kouwe, E., Heiser, G., Andriess, D., Bos, H. and Giuffrida, C., 'SoK: Benchmarking flaws in systems security.', 4th IEEE European Symposium on Security and Privacy, June 17-19, 2019 in Stockholm, Sweden, DOI: <https://doi.org/10.1109/EuroSP.2019.00031>, LINK: N/A
 7. S.Kuenzer, 'Unikernels Made Easy with Unikraft', 14th Workshop on Virtualization in High-Performance Cloud Computing (VHPC'19), Frankfurt Germany, DOI: N/A, LINK: <https://vhpc.org/>
 8. Ioan Constantin, Cristian Patachia, Carmen Patrascu, Andrei Avadanei, Lucian Nitescu, 'Threat Classification in Current Communication Infrastructures', IEEE ECAI, 27-29 June 2019, Pitesti, Romania, DOI: N/A, LINK: N/A
 9. Hong, S., Frigo, P., Kaya, Y., Giuffrida, C. and Dumitra, T., 'Terminal Brain Damage: Exposing the Graceless Degradation in Deep Neural Networks Under Hardware Fault Attacks. arXiv preprint arXiv:1906.01017.', 28th USENIX Security Symposium, Aug 14-16, 2019 SANTA CLARA, CA, USA, DOI: <https://arxiv.org/abs/1906.01017v1>, LINK: N/A
 10. Gauthier, G., Soldani, C. and Mathy, L., 'UNICORE: A toolkit to automatically build unikernels', Grascomp Doctoral Day, 22 November 2019, Namur, Belgium, DOI: N/A, LINK: N/A
 11. Pawlowski, A., van der Veen, V., Andriess, D., van der Kouwe, E., Holz, T., Giuffrida, C. and Bos, H., 'VPS: excavating high-level C++ constructs from low-level binaries to protect dynamic dispatching', 35th Annual Computer Security Applications Conference, ACSAC 2019, Dec 9-13 2019, San Juan, Puerto Rico., DOI: <https://doi.org/10.5281/zenodo.3523939>, LINK: N/A

3.2 Participation to Talks/Posters/Panels/Webinars/Workshops

Apart from publishing on scientific journals, partners have participated in other activities listed below:

Tutorial:

1. Simon Kuenzer, 'Unikraft: Unikernels Made Easy', FOSDEM 2019, Brussels (BE), 2-3 Feb 2019, DOI: N/A , LINK: https://archive.fosdem.org/2019/schedule/event/unikraft_made_easy/

Poster session:

1. C. Lupu , 'Is the Hypervisor the New Kernel?', EuroSys, Doctoral Workshop, 25-28 March 2019, Dresden, Germany , DOI: N/A , LINK: N/A
2. Kuenzer, S., Santhanam, S., Volchkov, Y., Schmidt, F., Huici, F., Nider, J., Rapoport, M. and Lupu, C., 'Unleashing the power of unikernels with unikraft', 12th ACM International Conference on Systems and Storage - SYSTOR'19 , Haifa, Israel June 03 - 05, 2019, DOI: <https://doi.org/10.1145/3319647.3325856>, LINK: N/A
3. Nider, J., Rapoport, M. and Bottomley, J., 'Address space isolation in the linux kernel', 12th ACM International Conference on Systems and Storage - SYSTOR'19 , Haifa, Israel June 03 - 05, 2019, DOI: <https://doi.org/10.1145/3319647.3325855>, LINK: N/A

Presentations/Talks:

1. J. Guijarro , 'UNICORE Project: Unikernel Power', OpenNebula Techday, 8 May 2019, Barcelona, Spain , DOI: N/A , LINK: https://www.slideshare.net/CSUC_info/unicore-project-unikernel-power
2. L. Mathy (speaker), F. Huici , 'Unikraft: Unikernels for NFV', The 3rd Future Network Development Conference, Nanjing, China , DOI: N/A , LINK: N/A
3. X. Peralta , 'Another Step Beyond Containers', Jornadas Tcnicas RedIRIS, 28/30 May 2019, Sevilla, Spain , DOI: N/A , LINK: <https://tv.rediris.es/es/jjtt2019/video/5ce6bb06cc464677048b45b7>
4. Cristian Patachia & Orange CEO , 'UNICORE Presentation by Orange', Digital Assembly, 13-14 June 2019, Bucharest Romania , DOI: N/A , LINK: <https://ec.europa.eu/digital-single-market/events/cf/digital-assembly-2019/programme.cfm?id=465>
5. S. Santhanam, S.Kuenzer, F. Huici , 'Building DPDK Unikernel with Unikraft', DPDK Summit 2019, Shanghai, China , DOI: N/A , LINK: <https://www.youtube.com/watch?v=1fjCz0wV7hs&list=PLo97Rhb4ceIpqgEWAc6nWfaIuldgDH5h&index=8&t=0s>
6. Alexandre Chartre, Mike Rapoport, James Bottomley, Joel Nider , 'Kernel Address Space Isolation', Linux Plumbers, 9-11 September 2019, Lisbon, Portugal , DOI: N/A , LINK: <https://www.linuxplumbersconf.org/event/4/contributions/277/>
7. Mike Rapoport , 'Memory management bits in arch/*', Kernel Summit, 9-11 September 2019, Lisbon, Portugal , DOI: N/A , LINK: <https://linuxplumbersconf.org/event/4/contributions/550/>

8. Mike Rapoport, James Bottomley , 'Address Space Isolation for Container Security', Linux Plumbers, 9-11 September 2019, Lisbon, Portugal , DOI: N/A , LINK: <https://www.linuxplumbersconf.org/event/4/contributions/431/>
9. Mike Rapoport, James Bottomley , 'Address Space Isolation inside Linux Kernel', Open Source Summit Europe, 28-30 October 2019, Lyon, France , DOI: N/A , LINK: <https://sched.co/TPGq>
10. Mike Rapoport , 'Boot Time Memory Management', Embedded Linux Conference Europe, 28-30 October 2019, Lyon, France , DOI: N/A , LINK: <https://sched.co/TLEU>
11. Mike Rapoport, James Bottomley , 'Address Spaces for Namespaces', Linux Security Summit Europe, 31 October - 1 November 2019, Lyon, France , DOI: N/A , LINK: <https://sched.co/TynJ>

3.3 Demonstrations, Hackathons and Tutorials

During the KOM in Haifa, NEC organized a demo on Unikraft for the rest of technical partners as a part of the technical introduction to the project (see Fig. 3.1).

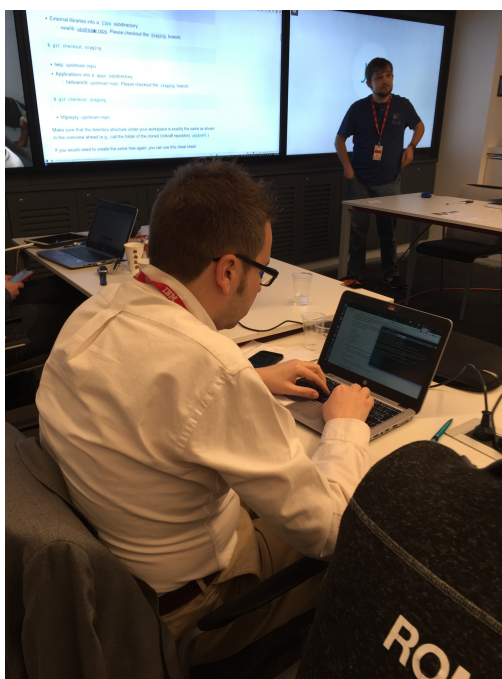


Figure 3.1: Unikraft demo at Kick-off Meeting in IBM Haifa (IL)

Moreover, with the occasion of the face to face plenary meetings, a couple of Coding Days have been organized. The first one took place in Bucharest (RO), at the UPB facilities on 26 June 2019, jointly with the first F2F general meeting.

The second coding day was organized before the technical and admin meetings also, on 12 November 2019 in Barcelona (ES), and it was a starting point for porting the use-cases to Unikraft (see Fig. 3.2).

A Unikraft tutorial to help users to build a unikernel is available on the UNICORE website (see Fig. 3.3).



Figure 3.2: Unikraft Coding Day before Plenary Meeting in Barcelona (ES)

Figure 3.3: Online Unikraft tutorial to help building unikernels

3.4 Collaborations with Other Projects

A few of the Unikraft components (e.g., support for the lwip stack) are or were developed under the auspices of the H2020 5GCity project, which has as main goal to create a cloud-like, multi-tenant neutral host infrastructure provided by smart cities/municipalities so that third-parties can deploy smart city verticals without having to incur major investment costs up-front. Unikraft is used to provide strongly isolated, virtualized functionality at low cost.

3.5 Communications via public Web Site

The UNICORE website [1] is online from the end of February 2019. Standard web traffic analysis tools (provided by Google) are used to track the number of visitors and relative metrics during website lifetime. It gives detailed information such as number of users, page views, number of sessions per user, average session duration and bounce rate, and it is shown in the next Fig. 3.4.

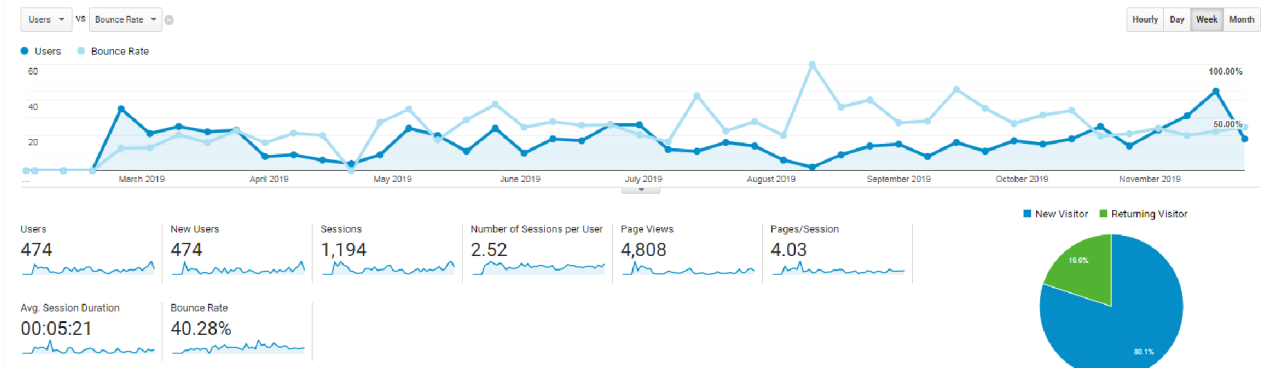


Figure 3.4: Web analytics - audience overview

Since the webpage was available on February 28th, in general, the number of users has increased apart from summer (see Fig. 3.5). Is specially remarkable the bounce rate, which is quite low (40%). An entry page with a low bounce rate means that the page effectively causes visitors to view more pages and continue deeper into the web site. High bounce rates typically indicate that the website is not doing a good job of attracting the continued interest of visitors. In the same way, the average session duration is quite good (05:21 mins), which confirms the users interest in the content.

The following two figures show the traffic source:

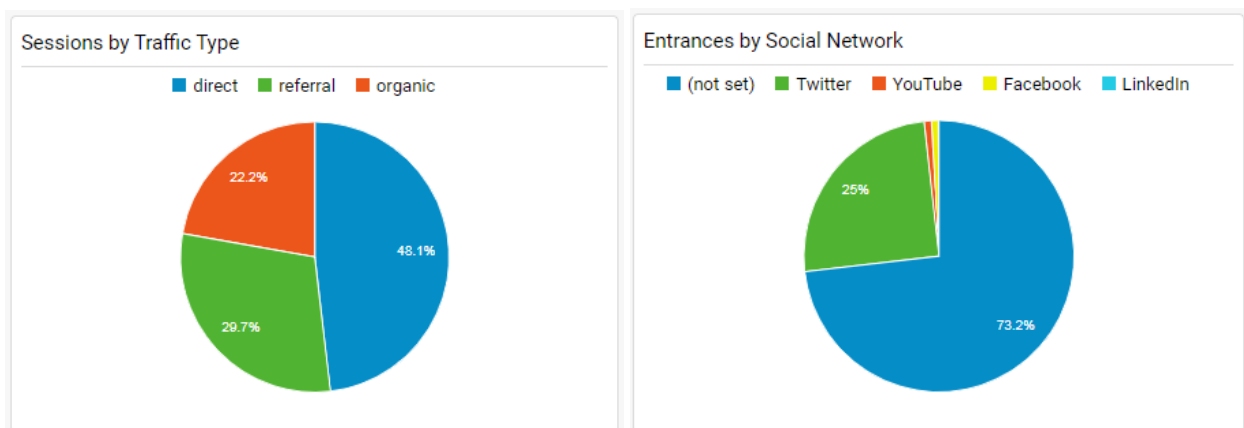


Figure 3.5: Web analytics - traffic acquisition

Fig. 3.5 on the left shows the percentage of traffic depending on its source: direct (visits that arrived on the website either by typing the URL into a browser or through browser bookmarks), referral (when someone clicks on a hyperlink to go to our webpage, i.e. UNICORE link on Nextworks website or on CSUCs newsletter), and organic (visitors used a known search engine and clicked a link to reach UNICORE website).

By having a quick look at Fig. 3.5 on the right, it can be stated that even though the number of followers on Twitter is still quite low, a good percentage of traffic comes from this social network.

3.6 Communications via Social Networks

UNICORE has presence in four major social platforms: LinkedIn, Twitter, Slideshare and Youtube. Apart from Youtube account, that was created in mid-November when the UNICORE video was finalized, the rest of social media were available when the website was launched by the end of February 2019.

3.6.1 LinkedIn

A LinkedIn group (www.linkedin.com/groups/8752067) is available to maintain discussions and build meaningful interactions around UNICORE (see Fig. 3.6).

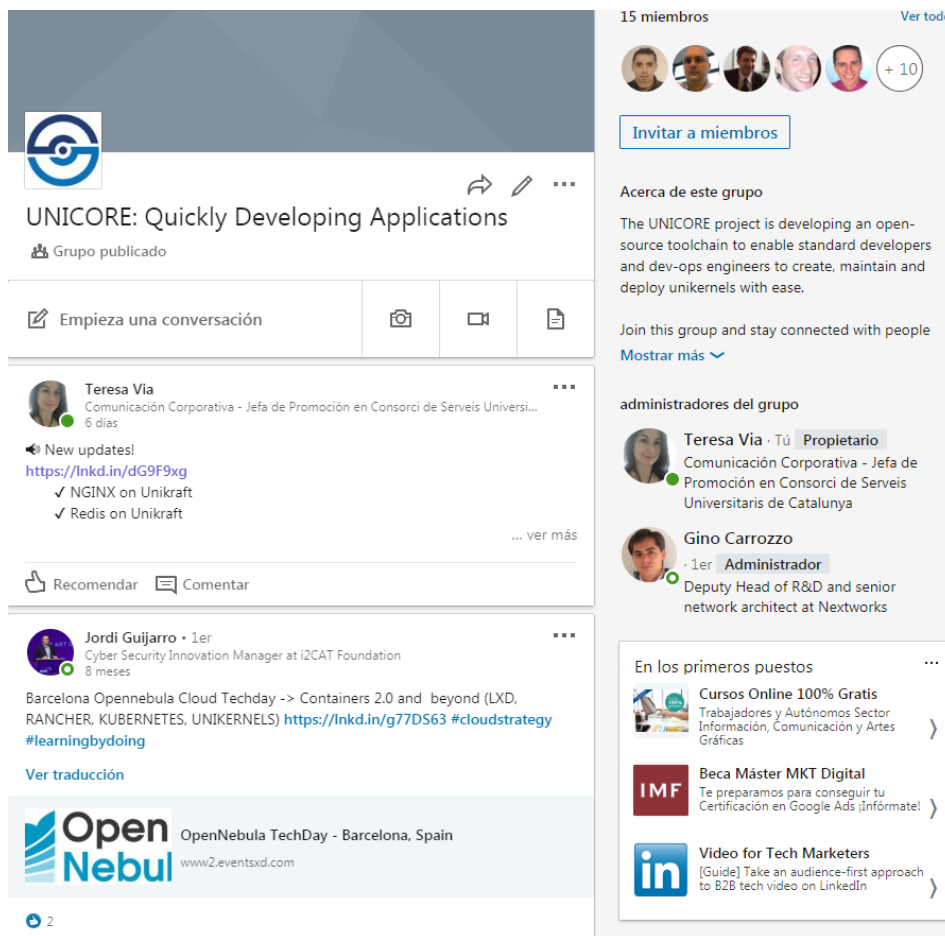


Figure 3.6: UNICORE LinkedIn group

No specific group discussion has been originated yet, given the maturity of UNICORE research in Year 1. During Year 2, discussions will be stimulated on unikraft lessons learnt, its applicability and preliminary feedbacks from UNICORE use cases.

3.6.2 Twitter

A Twitter account (https://twitter.com/unicore_project) is used to give visibility to the project activity and to interact with other users and stakeholders (see Fig. 3.7).

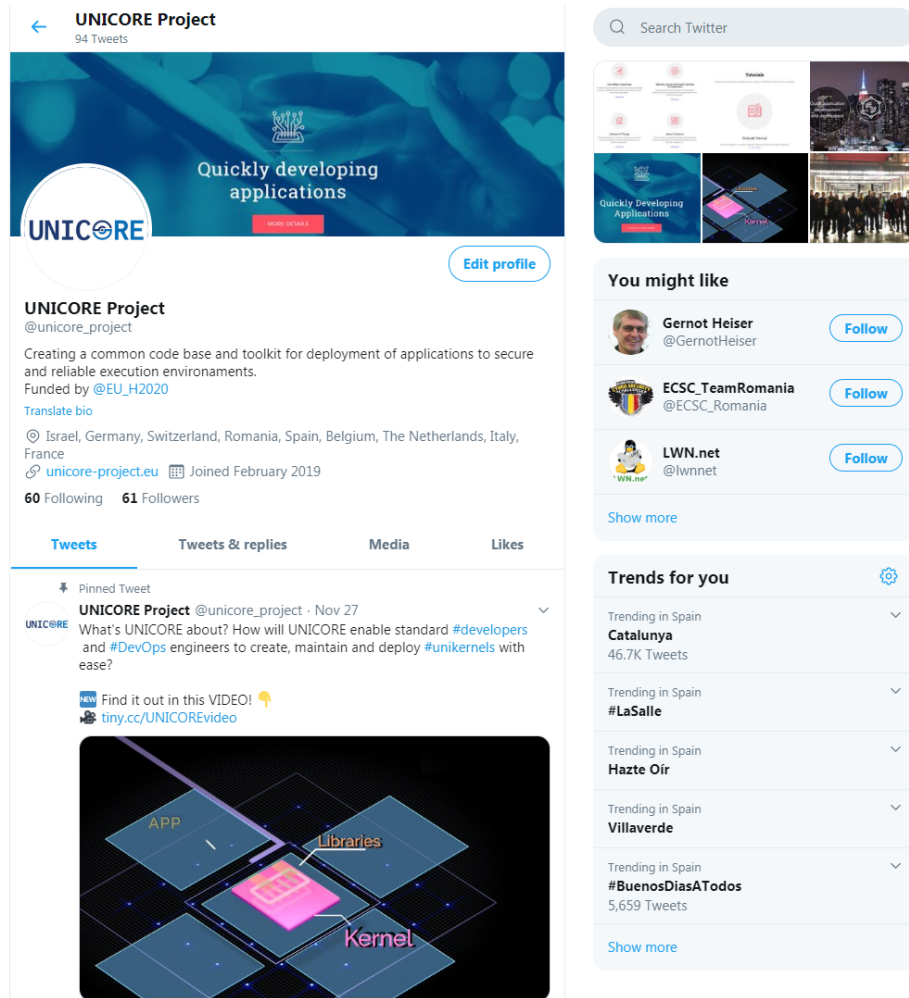


Figure 3.7: UNICORE Twitter profile

At the moment that partners have started to participate in conferences also the activity on Twitter has started to increase (see Fig. 3.8).

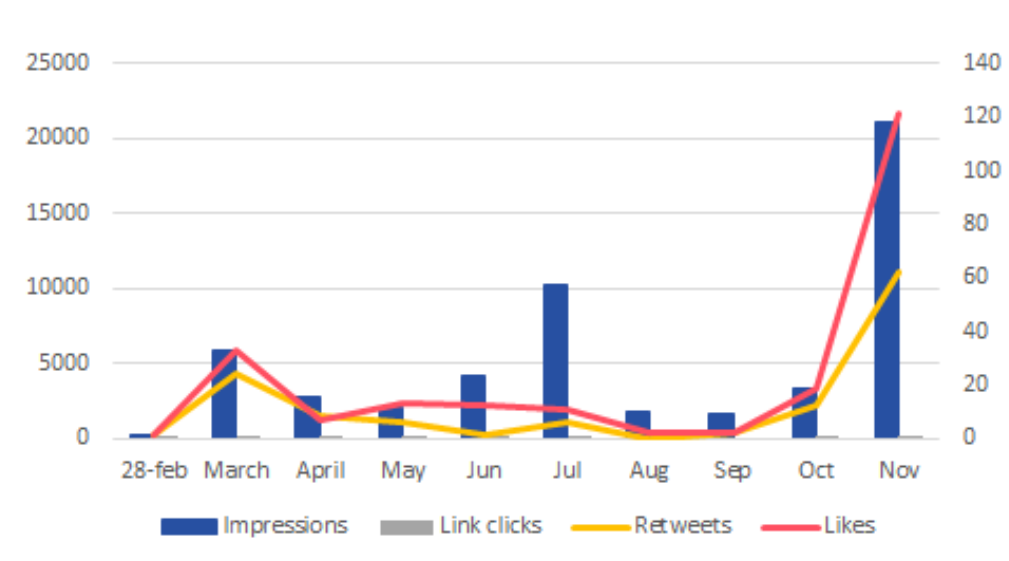


Figure 3.8: Twitter activity in Year 1 (2019)

3.6.3 Slideshare

Even though Zenodo is the main platform to give open access to UNICORE materials, a UNICORE profile is also available on Slideshare (https://www.slideshare.net/UNICORE_project) just to give additional visibility to the project presentation and others (see Fig. 3.9).

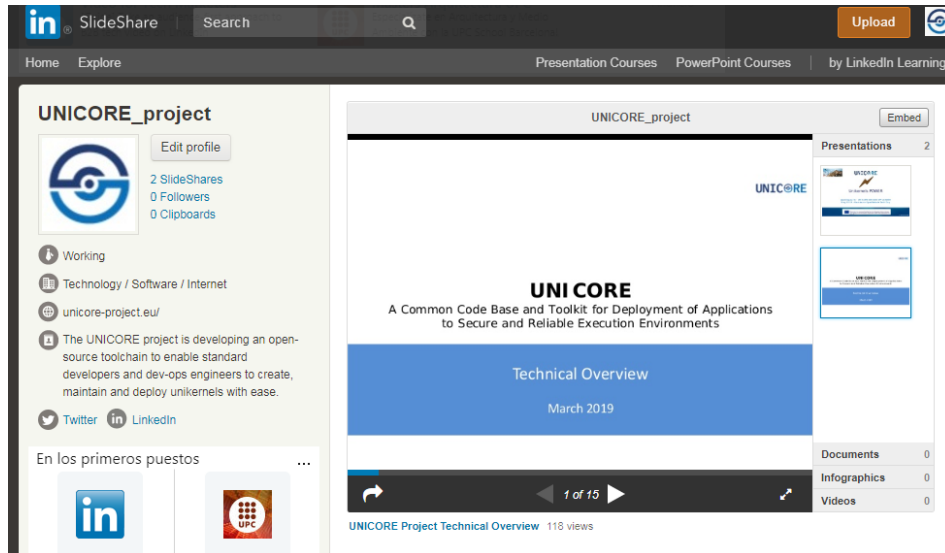


Figure 3.9: UNICORE Slideshare profile

3.6.4 YouTube

A short promotional video (<https://www.youtube.com/watch?v=EQKwA23wEdY&t=75s>, 02:27 mins long) has been produced to give a general overview about UNICORE. This video is available on the YouTube channel that has been created to give visibility not only to this intro video, but also to other audio-visual materials (webinars, etc.) that may be created during the project lifetime (see Fig. 3.10).

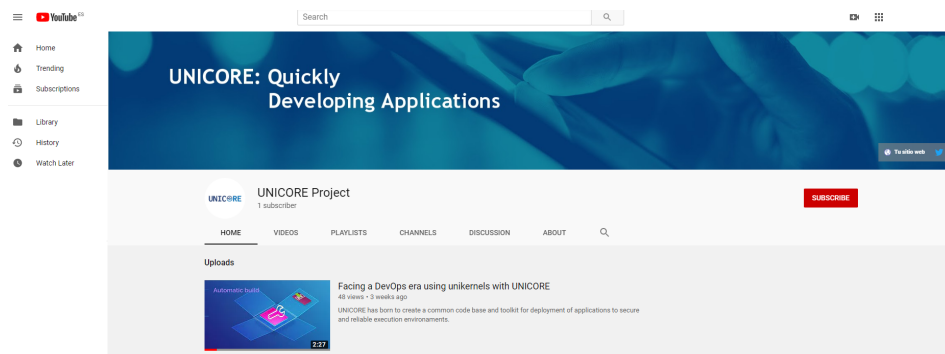


Figure 3.10: UNICORE intro video available at the UNICORE channel on YouTube

3.6.5 UNICORE community in Zenodo

All the public reports written within the UNICORE project, as well as other communication materials, are available on Zenodo under the community that has been created for UNICORE.

The screenshot shows the Zenodo website interface. At the top, there is a search bar with the text 'Search H2020 UNICORE' and a search icon. To the right of the search bar are buttons for 'Upload', 'Communities', 'Log in', and 'Sign up'. Below the search bar, the page title is 'H2020 UNICORE project'. The main content area shows search results for 'All versions' of the project. There are 8 results found. The first result is 'UNICORE: A Common Code Base and Toolkit for Deployment of Applications to Secure and Reliable Virtual Execution Environments', dated November 27, 2019. The second result is 'D4.1 Design & Implementation of Tools for Unikernel Deployment', dated September 30, 2019. The third result is 'D3.2 Security, Safety and Validation Support Definition', dated September 30, 2019. The left sidebar contains filters for 'Access Right' (Open (8)), 'File Type' (Pdf (8)), and 'Keywords' (H2020 (7), IoT (7), NFV (7), Serverless Computing (7), Smart Contracts (7), Applications (7), Toolchain (7), Unikernels (7), Vm (7), Toolkit (6)).

Figure 3.11: Deliverables and other materials are available on Zenodo

3.7 Dissemination plan for next period

The dissemination plan for Year2 at the time of writing this report consists of the following potential target opportunities:

- Feb.2020
 - FOSDEM 2020 Open Source Conference
 - * Contribution on Unikraft updates by Sharan Santhanam, Felipe Huici, Simon Kuenzer [ACCEPTED]
 - * Contribution on Address Space Isolation inside Linux Kernel by Mike Rapoport and James Bottomley [UNDER SUBMISSION]
 - WASM 2020 - WebAssembly Summit 2020
 - * Conference paper on Unikraft by Sharan Santhanam, Felipe Huici, Simon Kuenzer [UNDER SUBMISSION]
- Jun. 2020
 - IEEE DSN 2020
 - * Conference paper on Practical Software Crash Recovery by Cristiano Giuffrida [IN PREPARATION]

Opportunities for organizing UNICORE/Unikraft tutorials and/or hackathons in public conferences will be discussed in Q1-2020.

4 Standardization and Open Source Activities

The UNICORE Consortium is putting strong commitment to open source as a tool to directly influence the scientific community, industry and standardization bodies. We claim that open source software and working prototypes can serve as powerful facilitators in building de-facto standards, e.g. for unikernels. Several UNICORE partners are well positioned in open source communities at Linux Foundation and in standardization bodies. Towards SDOs and Open source communities we plan to work to:

- produce feedbacks to SDOs and to the open source communities of interest on the applicability of the latest standards and software releases. These contributions will be in the form of reports, presentations or filing of bugs;
- contribute to new work items e.g. on orchestration of lightweight virtualized functions based UNICORE innovations.

In the following tables a brief report of activities done and future plans is provided to show how the Consortium intends to work in the two areas of Open source communities (see Table 4.2) and SDOs (see Table 4.1).

Table 4.1: Work with SDOs in Year 1

SDO/Working Group	Involved partners	Activities in Y1	Future Plans
ETSI ZSM ISG	NXW	Investigation of applicability of Unikernels to ZSM scenarios	Unikernel experience is not mature yet for a PoC in these ISGs. Potential contribution to ZSM ISG with a PoC in 2021
ETSI MEC ISG	XLRN, NXW	None specific to UNICORE	3GPP are defining EDGEAPP (3GPP TR 23.758; r17 study item) which is not fully compatible with ETSI MEC. Cloud-native, Fog & Mist providers have also gained momentum in pushing their ETSI incompatible solutions to the edge. We are not convinced ETSI MEC will win the edge battle. Accelleran is currently in Wait & see mode for commitment to ETSI MEC.
Oasis Virtio	IBM	None specific to UNICORE	Investigate if modifications or extensions can make the virtual I/O interface more efficient when hosting unikernels

Table 4.2: Work with Open Source communities in Year 1

Software Community	Involved partners	Activities in Y1	Future Plans
OpenStack, Kubernetes, Docker	CNW	Initial exploration phase to understand how to integrate PacketCloud in existing orchestration frameworks.	CNW is currently developing PacketCloud as a single machine platform; to scale it beyond multiple machines, and to orchestrate it, we will integrate it with an orchestration framework such as Kubernetes in the next year.
XEN Projects Linux Foundation	UPB, NEC	minios-devel and IRC channel used for Unikraft development hosted under Xen Projects.	Maintain links with XEN community XEN support in Unikraft
DPDK	NEC	Port of DPDK to Unikraft, presentation at Intel DPDK Summit North America 2019	Maintain DPDK support in Unikraft
Unikraft Linux Foundation Project	NEC, UPB, ULG, CSUC, OA, CNW, VU	Large set of contributions and functionality to the Unikraft project has been released, which forms the core of UNICORE. See https://github.com/unikraft	Upcoming Unikraft release in Q1 2020. Add more Open Source libraries to support use cases.
OpenNebula	CSUC	Initial exploration on how to bring unikernels to OpenNebula (check compatibility of unikernels and OpenNebula), presentation at the OpenNebula Techday	Consolidate porting of relevant functions by 2020
Kubernetes	CSUC	Initial exploration on how to integrate unikernels on Kubernetes. Allow kubernetes to launch unikernels as if they were containers.	Consolidate porting of relevant functions by 2020
Linux Kernel	IBM	Enhancements and improvements for the Linux kernel in the area of memory management with a focus on security and isolation of guest workloads and particularly unikernels and containers	Maintain links with Linux Kernel community and continue work on memory management

5 Initial Exploitation Plans

5.1 Partners Individual Exploitation plans

5.1.1 IBM ISRAEL

IBM is one of the largest cloud companies in the world, positioning itself as a ubiquitous cloud platform for enterprises and highly regulated industries. For such a platform, considerations of integrity, security, and reliability are of utmost importance, in addition to considerations of business efficiency and cost that all cloud providers have. IBM research division is tasked with building a cloud virtualization platform that will address the requirements for lightweight virtualization and dense consolidation on the one hand, and for the secure and reliable execution on the other hand.

With this goal in mind, we are investigating new operating systems architectures to be used in cloud data centers, serving a base for cloud workloads and services packaged as Virtual Machines, Bare Metal hosts, containers, kubernetes clusters, and unikernels. Our ultimate vision is achieving a secure and efficient execution environment for fully containerized workloads, while also supporting other kinds of popular and viable ways of delivering software to the cloud. In particular, we are researching ways to fully isolate kernel space memories of guests colocated on the same host OS. UNICORE project gives us a unique opportunity to validate our platform OS innovation in the context of one of the most advanced and versatile unikernels platforms, Unikraft.

In addition to validating our research ideas are adequate for unikernel type of workloads, our participation in UNICORE supports us in contributing the results, if successful, to upstream Linux kernel codebase. Being part of base Linux and its distributions, these results will eventually become part of the IBM cloud platform deployed worldwide, as well as part of other platforms based off the Linux kernel. This future cloud OS will be suitable to securely run unikernel workloads thanks to work done as part of UNICORE project.

5.1.2 NEC LABORATORIES EUROPE

NEC targets the exploitation of the projects results mainly towards its line of IoT services (<https://www.nec.com/en/global/solutions/iot/concept/index.html>) and into the NEC the Wise IoT Platform (<https://www.nec.com/en/global/solutions/iot/iotplatform/index.html>), to run both as efficiently as possible on resource-constrained IoT devices and on data centers in support of IoT solutions. The use of UNICORE results means that existing solutions can be deployed at a fraction of the cost: many of the NEC solutions are increasingly deployed as cloud services, but so far standard VMs are used for deployment; the use of UNICORE/Unikraft-built VMs is being explored in order to decrease the deployment cost severely (e.g., using 10-100MBs of RAM for deployed instance instead of 1+GB). In addition, we are exploring the use of UNICORE/Unikraft technology in NECs next generation IoT devices, where the golden standard is Linux, but at the cost of it consuming a significant amount of the devices constrained resources. The work carried out in UNICORE, and especially that targeting secure,

efficient ARM64 deployments, should prove beneficial to this product line.

5.1.3 EPFL

DEDIS lab at EPFL makes research available to a wide range of users by working together with industry partners. A very important principle in software design is the modularity of the tools so that they can be improved from multiple sources. Currently, the smart contracts developed at the DEDIS lab are deeply coupled to the base code written in Go and this does not allow an open participation from the partners.

The UNICORE project can help in that regard by enabling smart contracts to be written out of the box and using generic high level languages like C, C++, Go or any supported one. The unikernel can provide an environment that will ensure a deterministic execution independently from the platform/architecture and thus a final output consistent among the network of participants, which is essential to reach a consensus among the validators.

5.1.4 UPB

The Netsys group from the UPB is one of the most active research groups in Europe in areas ranging from networking to operating systems and security. Within UNICORE, the Netsys team continues its strong involvement in open-source software development in virtualization, as well as its involvement in standardization bodies. Collaborations with industry partners like NEC, ORO and CNW are stronger, and future plans involve other operators and partners both national and international.

To ensure student engagement, a number of Hackathons were organized with graduate and undergraduate participants, thus expanding the foundation of the UNICOREs UPB open-source community around UNICORE. Unikraft (as part of UNICORE) will be referenced in the Security of Information Systems graduate lecture (<http://elf.cs.pub.ro/sis/>) in the Advanced Cybersecurity master program, as well as the Datacenter Computing graduate lecture in the Advanced Computer Architecture master program.

UPB will present Unikraft as part of Xen Summit 2020, which will be hosted in June 2020 by the University POLITEHNICA of Bucharest. The results obtained within UNICORE will be published at top systems venues such as OSDI and SOSP.

5.1.5 CSUC

CSUC creates and maintains different data repositories from universities or Catalan public institutions. In order to simplify the visualization of the data in a website, some of these repositories need to convert or resize files before storing them in the repository. Currently, CSUC has dedicated virtual machines for each of the repositories that launches a cron job every night checking if there is some file to be managed. The virtual machines are always on, so they are always consuming resources. UNICORE is an opportunity for CSUC to evolve the way repository files are managed by reducing and consolidating resources. CSUCs plan is to replace these always-on virtual machines by a function as a service platform based on unikernels. This FaaS platform has to allow CSUC to execute a function per file to be handled by reducing the time of use of resources with fast instantiation and low footprint. Only if a file needs to be handled, resources will be

allocated to run the function.

5.1.6 ULIEGE

The Research Unit in Networking (RUN) at ULiege exploits UNICORE outputs in doctoral work. Indeed, we are currently investigating two research axes: inter-unikernels memory sharing and automated optimization of unikernels. Content-based page sharing is a technique often used in virtualized environments to reduce server memory requirements. With UNICORE, we are currently researching if it is possible to limit the number of physical frames required by improving pages-sharing between several instances of unikernels. Concerning the automated optimization of unikernels, we are currently porting Fastclick (an extension to the Click modular router, which is faster and simpler to use, thanks to semi-automatic resource allocation) that has been developed by RUN. This one consists of finding the best suitable parameters for Virtual Machines thanks to active learning. We will maintain our tradition of releasing research output as open-source software, as well as publishing in specialized top systems venues, such as ACM/IEEE ANCS, SOSP, OSDI, NSDI, SIGCOMM, and top-level journals such as Trans. on Network and Service Management, Trans. on Networking, etc. Finally, consulting towards the exploitation of UNICORE output by European industry will be provided. In addition to research, we are also working on the UNICORE toolchain and have developed several tools which are available on Github. For now, we are currently working on the verification tool which basically ensures the correctness and security of unikernels.

5.1.7 ACCELLERAN

Accelleran is fully committed to extend dRAXTM (which was developed within H2020 5GCity project & used as Unikernel test case in this project) towards full O-RAN Alliance aligned 5G NSA (r15) & SA (r 16/17) vRANs (including developments in H2020 5G-CLARITY & 5G-COMPLETE projects). In 5G-COMPLETE, vRAN VNFs will extend SoA towards secure & trusted NFV orchestration with Unikernels.

In additional R&I activities, truly disaggregated NFV/SDN 5G vRANs focussed on commercial lower-cost deployments, running on commodity white boxes and embeddable devices, are ongoing to advance to commercial-grade TRL 8 system readiness (including Unikernel VNFs from Unicore).

In light of the current Cloud-Native (ONF, Kubernetes, etc) SoA and market demand, the current Accelleran dRAXTM capability of container-based VNF deployment is already generating considerable market interest. The market does not yet seem ready for commercial Unikernel VNF deployments. At trade-show demos & thought leadership marketing level, Unikernel demos of Unicore results (currently scheduled for MWC2020 in Barcelona) will further position Accelleran as market innovators.

Accelleran is satisfied with the Unicore results, which we believe we will be able to exploit, when market demand evolves, with TRL 8 commercial 5G vRAN VNFs.

5.1.8 VU

VUA Security group pursues the mission to push security solutions to industry through top-level contribution to the scientific community and the hackers & industrial security communities. As preliminarily described

in DoA, VU has set the scientific and training (MSc, PhD) goals at the core of their exploitation strategy. Possibilities for raising startup ventures on secure unikernel-based solutions is at the moment left for further evaluation in Year 2 and Year 3.

5.1.9 NEXTWORKS

Nextworks' participation in UNICORE has the exact aim to evaluate potentials of unikernels in the implementation of efficient microservices within the core Smart Home and Smart Building Management platform product of the company, i.e. Symphony (<http://www.nextworks.it/en/products/brands/symphony>).

Symphony is currently a system commercialized by Nextworks and by a network of partner system integrators in Italy and few other countries in the world (TRL 9). The strategy of the company is to evolve Symphony into a modern IoT platform capable to be highly decomposed and distributed, to overcome the limitations of the current mostly monolithic system offered to the market, and get ready to be applicable to a variety of distributed IoT environment like Smart factories, Smart Buildings (containing a number of Smart Homes) and Smart Cities.

In agreement with this strategy, the technical activities of the Nextworks R&D team in UNICORE are oriented to evolve part of Symphony to prototype with unikernel demonstrated in relevant environment (TRL 7) in order to plan a subsequent product consolidation and commercialization. During the Year 1 of the project, the focus has been mostly on technical activities, and specifically we have worked to select application contexts and to prepare functions of the Symphony platform to be migrated into unikernels, in order to allow a subsequent evaluation in Year 2. In parallel to this technical performance evaluation, the company expects to derive useful insights on the new computation resource footprint and the service manageability achievable with unikernels in Symphony, in order to compile a complete set of information for the product roadmap consisting of technology evaluations and business aspects like CAPEX (as related to potential decrease of computing requirements to obtain similar performances) and OPEX (as related to flexibility and easiness of the platform maintenance and operations).

The technical plan is to use a staged approach to perform the unikernel technology evaluation for Symphony, as described in Deliverable D2.3 [2]. It will consist of a functional verification (stage 1), then performance evaluation (stage 2), and eventually the addition of new service functionalities like automatic deployment and unikernel functions build (stage 3). In parallel to the technical activities, and precisely from the end of stage 2, a business impact evaluation will be executed to quantify unikernel benefits in terms of costs for the production of Symphony and costs for maintenance operation. Methodologies like SWOT analysis might be used for this work.

The expected marketability of the UNICORE-flavoured Symphony product is set in the next 2/2.5 years, in alignment with the current targets for consolidated market opportunities for Symphony in large Smart Resorts and Smart Cities.

5.1.10 EKinOPS

Ekinops supports Service Providers to deploy virtualized solutions across their network by designing and developing a network-oriented NFVI middleware and networking VNFs for qualified hardware. Virtualization is a critical trend to deliver innovative services in a more flexible model. A challenge is the upfront hardware cost: while adding services meant yesterday increasing step by step the hardware cost by adding appliances, virtualization means the consolidated equipment cost is due upfront because it must support the required resources (CPU, RAM, storage, interfaces) for the most complete configuration - potentially with Routing, Firewall, SD-WAN, third-party services and more. Another challenge to address is service availability with the capacity to (re)start services faster, in the case of new service ordered by customer as well as in the case of service crash. Vulnerability exposure is also a critical Service Provider concern, especially when combining multiple VNFs.

In this context, Ekinops plans, starting during this project, to validate unikernel technology and add unikernel support to its middleware platform as well as selected VNFs, such as lightweight vCPEs and other services. Demonstrations and experimentations with different customers and prospects, with various services and configurations, will be performed to validate prototypes before releasing products. Starting and running performance as well as attack surface will be assessed on actual customer infrastructures. Those products will be marketed to Service Providers to reduce their initial investment and required protection and therefore be profitable faster by lessening services deployment and energy costs with lower specification equipment. For example, an EPC made of an entry Intel C3000-based equipment with reduced CPU, RAM and energy may replace a more powerful Intel Xeon-based server. Or, on a given platform, unikernels will bring more flexibility and/or may support more services/VNFs. Ekinops works already with NEC on Open Source libraries migration for a Key Server service for its SD-WAN product line. Ekinops expects therefore to benefit from increased competitiveness and be among the market migration leaders providing a unikernel integrated lower footprint/same performance system as well as increasing the supported load of high-end servers, all specifically designed for Service Providers to deliver lower priced services.

5.1.11 CORRECT NETWORKS

In the first year of Unicare, Correct Networks has built a prototype of PacketCloud, a function-as-a-service platform for packet processing. PacketCloud manages a database of network functions and boots them on demand, as traffic arrives. The initial prototype supports the Firecracker VMM running Alpine Linux images (eBPF network functions) or the QEMU VMM for Unikraft virtual machines running the Click modular router.

To promote PacketCloud, CNW is now running experiments to determine the performance and scalability of PacketCloud-based network processing and contrast it to DPDK-based processing; the goal is to have similar performance while offering much better power consumption at low traffic loads and better isolation. The results will be captured in a white-paper targeting network operators, which will then be shared and

promoted actively.

CNW is also collaborating with ORANGE Romania and plans to install a trial deployment of PacketCloud at Orange; the aim is to test the virtualized BNG running on top of PacketCloud. This will provide useful feedback with regards to deployment constraints and operator requirements, which we will use to refine the product.

After PacketCloud matures, CNW will showcase PacketCloud at operator fora such as Open Networking Forum or RIPE NCC meetings.

5.1.12 ORANGE ROMANIA

Orange Romanias participation to UNICORE aims to test the deployment of Unikernels in the implementation of a Decomposed Border Network Gateway, to be prototyped in a laboratory environment. This deployment will validate UNICORE features and security and will measure performance results in a laboratory environment by comparison with the existing technological deployments of Hardware BNG and virtualized BNG. In Orange Romanias use-case and test environment, UNICORE will be used to replace the current monolithic approach for BNG with unikernel Virtual entities with each PPPoE session running in a separate, secured unikernel Virtual Machine.

Orange Romanias testbed for UNICORE is to be configured to enable the transition from legacy infrastructure, in the form of the single physical BNG a Nokia SR-C 7750, as a single network function for CPEs to an interim virtualized BNG and finally to an Unikernel-based, lightweight VM with network functionality for each unique CPE. The testing and prototyping will be accommodated on dedicated x86 Xeon Platinum W-Series CPU powered HP Servers.

The testing scenarios will focus on measuring performance related to efficiency in power consumption, number of virtual clients served, traffic volumes averages and instantiation times. Orange Romanias expects improvements over the security of current deployment, with each session being instantiated in dedicated Virtual Machines, faster service instantiation, resources optimization and performance increase with scalability to serve thousands of customers.

Orange Romania will exploit the developed Unikernel BNG during a number of sessions and workshops(technical hackathons, B2B Workshops) and the achievements will be presented and highlighted during Orange Romania actions.

5.2 Joint Exploitation Plans

The availability of the UNICORE/Unikraft toolstack in open source, combined with Unikernels in action commercial reference cases deriving from the four UNICORE use cases (i.e. Serverless Computing, Network Function Virtualization, Home Automation and Internet of Things, Smart Contracts) are the key asset and enabling foreground the Consortium is planning to build though this Innovation Action.

The formation of a Unikraft community around the open source software is perceived as the most viable way to ensure that the UNICORE results can obtain wide impact and long-lasting adoption. The aim of the

Table 5.1: Joint technical activities with potentials for exploitation

Implementation Area	Topic	Collaborating partners
UNIKRAFT / UNICORE Core	API and library implementation	NEC with UPB
	Security and isolation primitives	VUA with UPB and NEC
	Deterministic execution support	UPB with EPFL
UNICORE Toolstack	Compilation Toolchain	ULG with NEC
	Multi-Target Support	NEC with UPB
	Symbolic Verification Support	CNW with UPB and NEC
	Performance Optimization Tools	NEC with ULG
	Orchestration Tools Integration	CSUC with NEC

Consortium is to make UNICORE/Unikraft known to the community in order to stimulate it the same way that common software compilers and linkers are used in everyday software builds and deployment toolchains, by hobbyists and in commercial products.

The strategy for joint activities from the Consortium is to establish and lead/steer the Unikraft community in FOSS, maintaining control of the roadmap for the evolution and completion of the core Unikraft parts and the main toolstack elements.

Following this strategy, many operative threads have been started in year 1 as part of the technical work to be carried out in the project.

Teams have been formed as per table 5.1 which captures the current technical interests from the involved partners.

As the UNICORE project will advance and Unikraft software will mature in future releases during 2020, there could be an evaluation on the sustainability of the community efforts and of potential further exploitation opportunities of the know-how and object code/toolkit generated.

6 Conclusions

This deliverable has reported on the results of dissemination, communication, standardization and exploitation activities carried out during the Year 1 of the UNICORE project. Overall, the consortium has regularly and successfully worked during the period to build a consistent and relevant impact through the preliminary project results. In particular, our action during the Year 1 has tried to maximise the interaction with the scientific community interested in unikernels, establish the roots for visibility of the project activity in the network of contacts of the respective partners, consolidate the Unikraft FOSS initiative and code availability in GitHub. For the future period, the consortium has identified a set of target international conferences and events where to publish the project results and continue the engagement with the scientific and industrial community.

6.1 Progress on UNICORE KPIs

Based on the KPIs identified in the UNICORE Description of Action, the progress achieved by the consortium during Year 1 is summarized in the following Table [6.1](#).

Table 6.1: Progress on Dissemination KPIs - Year 1

Activity	KPIs	Year 1 results
Industrial events (exhibitions and congresses)	<ul style="list-style-type: none"> ● number of events attended ● size of audience ● number of impacts (real interest in UNICORE) 	<ul style="list-style-type: none"> ● 9 industry-driven events ● 500+ attendees ● <15 interested in unikernels
Academic events (workshops and conferences)	<ul style="list-style-type: none"> ● number of events attended ● number of events organized 	<ul style="list-style-type: none"> ● 13 scientific events/conferences ● 300+ attendees on avg ● >15 interested in unikernels
Scientific publications	<ul style="list-style-type: none"> ● number of accepted (peer-reviewed) papers in journals vs. impact factors of respective journals ● number of accepted (peer-reviewed) papers at conferences and workshops 	13 conference papers
Website	<ul style="list-style-type: none"> ● positive trend in visitor numbers/month ● adequate length and depth of visit 	<ul style="list-style-type: none"> ● 474 users for 1194 sessions in year 1 ● > 5 mins session duration on website
Social media	increasing number of followers and impact	60 followers and 28.8K impressions over Q4-2019
Press Releases	<ul style="list-style-type: none"> ● at least 3 press releases (at the beginning, when major project results are available and at the end of the project) ● published by all consortium partners in their countries 	<i>Press releases postponed to Year 2</i>
Advertising Materials	<ul style="list-style-type: none"> ● 1 short video explaining benefits of UNICORE ● number of events where the project has been presented by print media ● number of downloads from the website ● number of video visualizations 	1 video online

7 Abbreviations and Definitions

7.1 Abbreviations

DoA	Description of Action
EC	European Commission
FOSS	Free Open Source Software
IPR	Intellectual Property Rights
MANO	Management and Orchestration
NFV	Networks Function Virtualization
SDO	Standard Developing Organization
VNF	Virtual Network Function
WG	Working group
WP	Work Package

7.2 Definitions

No definition is introduced by this document

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