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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

D6.4 Report on Communication and Dissemination Activities and Exploitation Plans - Intermediate

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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 2 (Jan-Dec 2020) for what concerns the activities of communication, dissemination, standardization and exploitation activities executed by the Consortium.

Target Audience

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

Impressum

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Copyright notice	© 2020 Participants in project UNICORE

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Contents

List of Figures

List of Tables

1 Executive Summary

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 the 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.
During its Year 2, the UNICORE Consortium continued to work along the following main streams of actions to achieve its expected impacts:

- **Publications in top academic conferences**, which continued at at great pace despite the impact of lockdown measures due to pandemic;
- **Open-source development and community building**, which focused on consolidating the ongoing developments for UNIKRAFT, produced a stand-alone child site for the toolchain (https://unikraft.org) and to continue engaging with the FOSS community interested in unikernels;
- **Novel product development in selected markets**, which is mostly linked to UNICORE use cases and could not advance with great pace in 2020 due to reduced opportunities for showcase events.

The dissemination and communication strategy followed in Year 2 continued to focus on the presentation of the core UNICORE concepts and solutions for Linux kernels and security in top-tier scientific forums and international conferences. The communication campaign followed the scientific publication stream and generated awareness in the large network of industry and academia connected to the Consortium about the research progresses. The standardization and exploitation activities of Year 2 continued to be mostly driven by individual actions linked to the Unikraft open source project and its releases.
Key results achieved by the project in Year 2 can be summarized as in the following:

- **5** scientific papers published or accepted to relevant conferences and important events;
- **21** UNICORE/Unikraft presentations given in well-known international events;
- **1** public unikraft tutorials given (FOSDEM 2020);
- **1** virtual coding event among UNICORE partners in Sept 2020;
- The website registered an average of **33.5 users per week** with referral traffic increased from 9% to 36.61%
- The project video published in the project YouTube channel got **314 views since Nov 2019**;
- Continued a significant presence on socials: group active on LinkedIn, **117 followers on Twitter** with 51 published tweets with **19,905 impressions, 658 engagements**, 68 retweets, 137 likes, 42 user profile clicks and 114 media views in the period Jul-Dec 2020.

- **84 Unikraft repositories in GitHub** (https://github.com/unikraft) covering various libraries and ported applications as listed in http://unikraft.org/apps/
- Continued 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 despite the hard times due to COVID-19 lockdown measures (see Fig. 1.1).

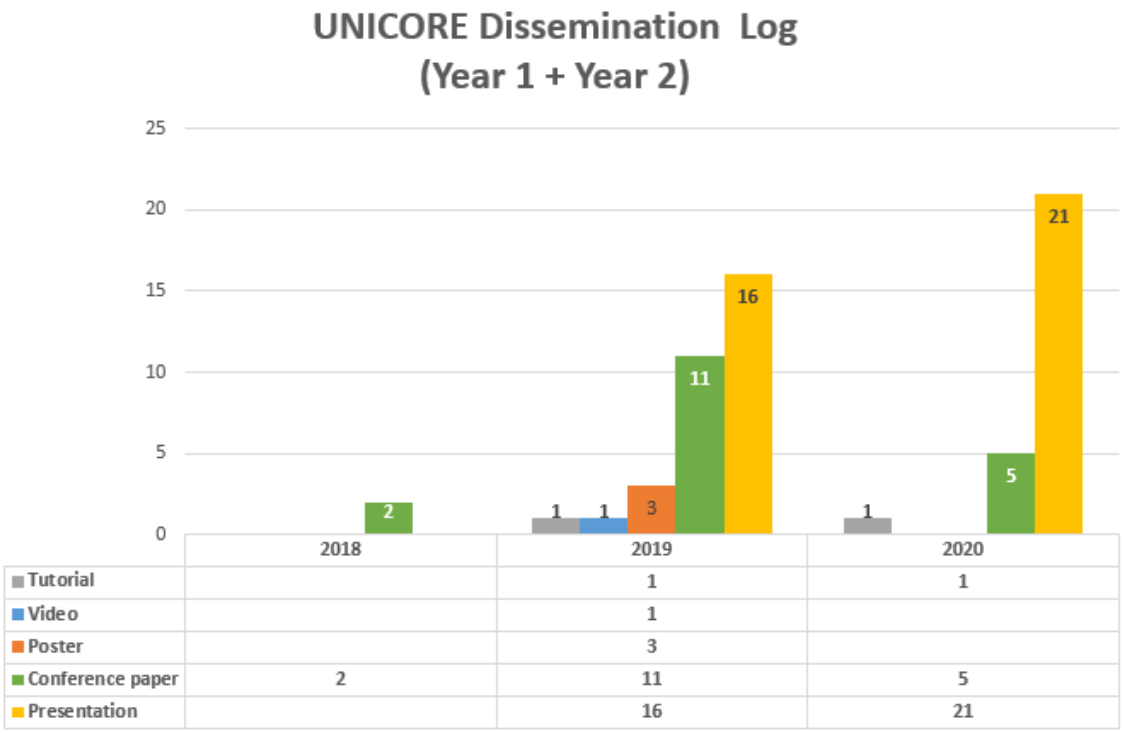

Figure 1.1: UNICORE Dissemination Log (Year 1 + Year 2).

Plans for Year 3 aim to continue impact achievement through demos, scientific papers, tutorials and engagement activities with various communities interested in unikernels.

2 Introduction

This document reports on the achievements of the UNICORE project in Year 2 (Jan-Dec 2020) for all the communication, dissemination, standardization and exploitation 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 2.
- 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 the UNICORE project.

For each chapter, a brief outline of the plans for Year 3 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

The following publications occurred during Year2.

Papers in Conference proceedings

1. Enes Gkta, Kaveh Razavi, Georgios Portokalidis, Herbert Bos, and Cristiano Giuffrida. 2020. Speculative Probing: Hacking Blind in the Spectre Era. In Proceedings of the 2020 ACM SIGSAC Conference on Computer and Communications Security (CCS 20), November 913, 2020, Virtual Event, USA. ACM, New York, NY, USA, 15 pages. DOI: https://doi.org/10.1145/3372297.3417289, LINK: https://download.vusec.net/papers/blindside_ccs20.pdf

2. Koschel, J.; Giuffrida, C.; Bos, H.; and Razavi, K. TagBleed: Breaking KASLR on the Isolated Kernel Address Space Using Tagged TLBs. In 2020 IEEE European Symposium on Security and Privacy (Euro SP), Genoa, Italy, 2020, pp. 309-321, doi: https://doi.org/10.1109/EuroSP48549.2020.00027, LINK: https://download.vusec.net/papers/tagbleed_eurosp20.pdf

3. Frigo, P.; Vannacci, E.; Hassan, H.; van der Veen, V.; Mutlu, O.; Giuffrida, C.; Bos, H.; and Razavi, K. TRRespass: Exploiting the Many Sides of Target Row Refresh. In 2020 IEEE Symposium on Security and Privacy (SP), San Francisco, CA, USA, 2020, pp. 747-762, doi: https://doi.org/10.1109/SP40000.2020.00090, Best Paper Award, Pwnie Award for Most Innovative Research. LINK: https://pwnies.com/winners/ and https://download.vusec.net/papers/trrespass_sp20.pdf

4. Kurth, M.; Gras, B.; Andriesse, D.; Giuffrida, C.; Bos, H.; and Razavi, K. NetCAT: Practical Cache Attacks from the Network. 2020 IEEE Symposium on Security and Privacy (SP), San Francisco, CA, USA, 2020, pp. 20-38, doi: https://doi.org/10.1109/SP40000.2020.00082, Intel Bounty Reward, Pwnie Award Nomination for Most Innovative Research. LINK: https://download.vusec.net/papers/netcat_sp20.pdf

5. Gras, B.; Giuffrida, C.; Kurth, M.; Bos, H.; and Razavi, K. ABSynthe: Automatic Blackbox Side-channel Synthesis on Commodity Microarchitectures. In NDSS, February 2020. LINK: https://download.vusec.net/papers/absynthe_ndss20.pdf

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

UNICORE members had the opportunity to participate in several conferences and workshops throughout 2020, most of them online, listed in chronological order as follows:

Industry events

1. Rapoport, M., Bottomley, J. Address Space Isolation in the Linux Kernel. FOSDEM 2020, Brussels, Belgium (BE), 1-2 Feb. 2020, LINK: https://archive.fosdem.org/2020/schedule/event/kernel_address_space_isolation/

2. Constantin, I. Cloud Cyber Security Course. Orange Education Program, Technical University of Iasi, Alexandru Ioan Cuza University of Iasi. Romania (RO), 8 April 2020, DOI: N/A, LINK: https://profs.info.uaic.ro/~springschool/Presentations/2020/Day1/OEP_CLOUD_CYBER_SECURITY.pdf

3. Constantin, I. Cloud Cyber Security Course. Orange Education Program, Ovidius University of Constanta. Romania (RO), 6 May 2020, DOI: N/A, LINK: N/A.

4. Constantin, I. Mobile Devices Security. Orange Education Program, Polytechnic University of Bucharest, ETTI. Romania (RO), 11 May 2020. DOI: N/A, LINK: N/A.

5. Huici, F., Kuenzer, S., Santhanam, S. Unikraft Weather Report. Xen Developer & Design Virtual Summit 2020, Bucharest, Romania (RO), 6 July 2020, DOI: N/A, LINK: https://xen2020.sched.com/event/baWR/keynote-session-unikraft-weather-report-felipe-huici-sharan-santhanam-nec-l

6. Constantin, I. Mobile Devices Security Course. Orange Education Program, Polytechnic University of Bucharest, ETTI. Romania (RO), 17 July 2020. DOI: N/A, LINK: N/A.

7. Constantin, I. Cloud Cyber Security Course. Orange Education Program, Polytechnic University of Bucharest, ETTI. Romania (RO), 20 July 2020. DOI: N/A, LINK: N/A.

8. Rapoport, M. Address Space Isolation in the Linux Kernel. Open Source Tech Conference 2020. Online, 10 August 2020, DOI: N/A, LINK: https://ostconf.com/en/materials/2835

9. Rapoport, M., Bottomley, J. Memfd Secret Memory Areas. Google Linux Kernel Exchange. 13 August 2020. DOI: N/A, LINK: N/A

10. Rapoport, M. Memory Management Bits in arch. Linux Plumbers Conference 2020. Online, 25 August 2020, DOI: N/A, LINK: https://linuxplumbersconf.org/event/7/contributions/666/

11. Rapoport, M. Restricted Kernel Address Spaces. Linux Plumbers Conference 2020. Online, 27 August 2020, DOI: N/A, LINK: https://linuxplumbersconf.org/event/7/contributions/660/

12. Constantin, I. Cybersecurity in the New Reality. CIO Council Romania Virtual Summit. Online, 16 Sept. 2020, DOI: N/A, LINK: https://www.cioconference.ro/

13. Huici, F. Towards Highly Specialized POSIX-compliant Software Stacks with Unikraft. International Conference on Embedded Software (EMSOFT). Online, 20 Sept. 2020, DOI: https://doi.org./10.1109/EMSOFT51651.2020.9244044, LINK: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9244044&isnumber=9244012

14. Huici, F. Towards Highly Specialized POSIX-compliant Software Stacks with Unikraft. Linaro Virtual Connect 2020. Online, 22 Sept. 2020, DOI: N/A, LINK: https://connect.linaro.org/resources/lvc20/lvc20-107/

15. Huici, F., Santhanam, S. Extremely Fast and Efficient NFV with Unikraft. Open Source Summit. Online, 29 Sept. 2020, DOI: N/A, LINK: https://static.sched.com/hosted_files/osseu2020/a7/dpdk.pdf

16. Constantin, I. 5G Toolbox: The Instrument of the Future. CERTCON10, The New Global Challenges in Cyber Security. 22 Oct. 2020. DOI: N/A, LINK: https://cert.ro/certcon10/agenda/#agenda

17. Constantin, I. Constientizarea si mitigarea amenintarilor actuale. Doing Business Webinar. 16 Nov. 2020.

18. Orange Business. Orange Business Internet Security Report, 3rd edition. 2020. LINK: https://www.orange.ro/images/business/solutii/files/raport_bis.pdf?v1

19. Kuenzer, S. Cut your Cloud Computing Costs by Half with Unikraft. Linux.com. 15 Dec. 2020. DOI: N/A, LINK: https://www.linux.com/news/cut-your-cloud-computing-costs-by-half-with-unikraft/

Academic events

1. Kuenzer, S. Unikraft A Unikernel Toolkit. 15th Workshop on Virtualization in High-Performance Cloud Computing. Online. 25 June 2020, DOI: N/A, LINK: https://vhpc.org/

2. Kuenzer, S. Specialized and Secure Unikernels with Unikraft. Herbstreffen 2020 in Aachen - GI Fachgruppentreffen Betriebssysteme. 24 Sept. 2020, DOI: N/A, LINK: https://www.betriebssysteme.org/aktivitaeten/treffen/2020-aachen/programm/

3.3 Demonstrations, Hackathons and Tutorials

UNICORE project partners held several technical presentations and an integration meeting virtually with the aim of making progress in the use cases on 24 September 2020.

Partners involved in software development activities (NEC, Vrije Universiteit Amsterdam, University of Lige, University Politehnica of Bucharest and IBM) gave a presentation on kraft and how it works, memory deduplication and the current status of the toolchain, and Dafny scheduler, among other topics, with the participation

of 25 people (see Fig. 3.1). This way partners working to show UNICOREs applicability to a wide range of areas (cloud computing, telecom operators, home automation/IoT and smart contracts) received the latest update on technical progresses and could solve doubts related to the deployment of the use cases.

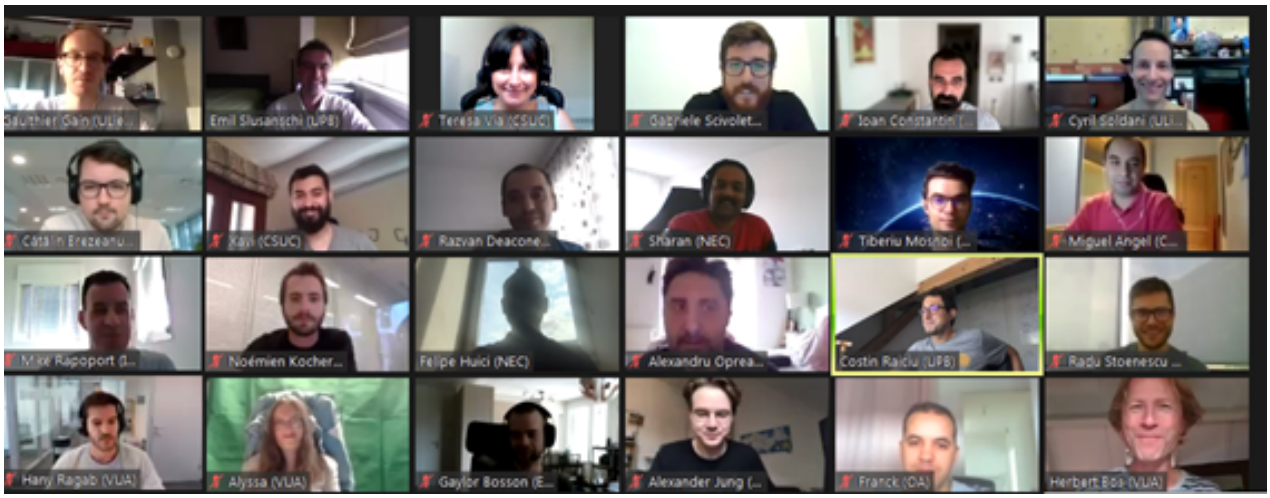

Figure 3.1: UNICORE team at the integration virtual meeting - Sept 2020

Moreover, UNICORE gave one public Unikraft tutorial (FOSDEM 2020) by Simon Kuenzer (NEC Labs) to update the Unikraft open source project to the audience, reviewing all the achievements and shedding light into recent project directions: binary compatibility (Linux ABI), support for a wide range of compiled and interpreted languages (e.g., web assembly, Go, Python, Ruby, etc.), enhanced safety features, and the ability to seamlessly produce images ready to run as extremely lean VMs, containers, or directly on bare metal. The goal under this tutorial was to make clear that Unikraft will represent a step forward towards wider adoption of unikernels beyond the research community (see Fig. 3.2).

Figure 3.2: Simon Kuenzer (NEC Labs) during his talk at FOSDEM2020

3.4 Collaborations with Other Projects

Durign the first semester of 2020, a few of the Unikraft components (e.g., support for the lwip stack) were tested in the H2020 5GCity project (www.5gcity.eu), which was in its final use case testing stage. 5GCity developed a cloud-like, multi-tenant neutral host infrastructure for smart cities/municipalities. Unikraft was used to provide strongly isolated, virtualized functionality at low cost.

Moreover, from Q1 2020 UNICORE started collaborating with the Horizon Cloud Coordination and Support Action project, H-CLOUD (https://www.h-cloud.eu/), which leads coordination and support activities for the consolidation and growth of the Cloud Computing research and innovation community in Europe (see Fig. 3.3). The H-CLOUD Forum aims to strengthen collaboration to address challenges and opportunities at research, technological, policy, standardisation and organisational level to unlock the potential of cloud computing for all European stakeholders. Within the H-CLOUD context in which UNICORE takes part, a number of activities at the support of the whole EU Cloud Computing community is done, especially focused on outreach as to increase visibility of cloud computing projects and their possible impact.

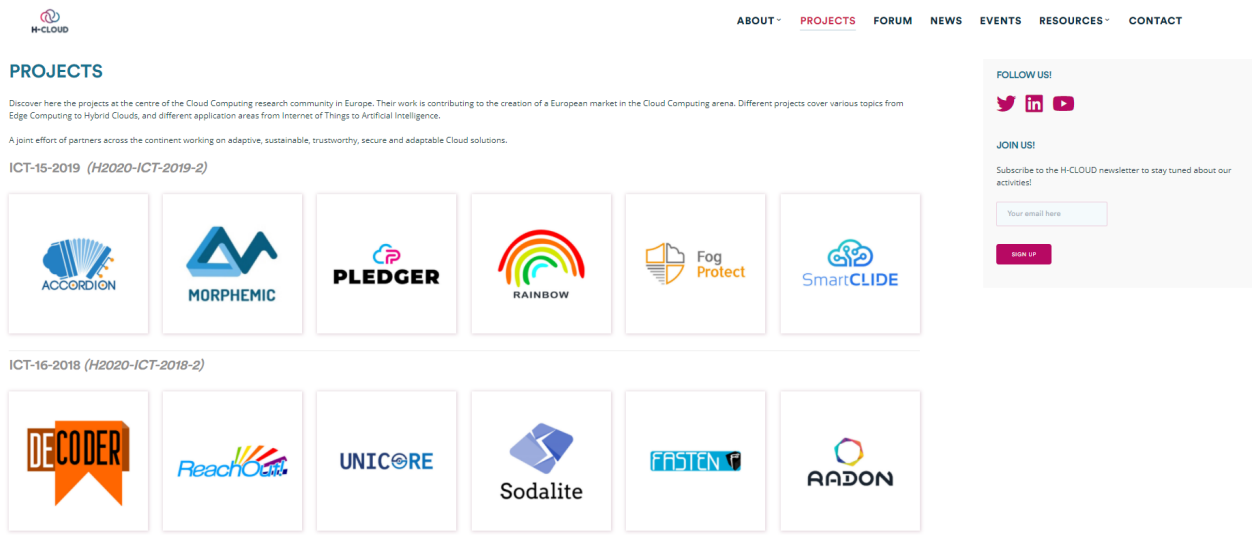

Figure 3.3: Projects across Europe working on H-CLOUD for adaptive, sustainable, trustworthy, secure and adaptable Cloud solutions, being UNICORE one of them.

3.5 Communications via public Web Site

The UNICORE website (www.unicore-project.eu, [1]) is online from the end of February 2019. Standard web traffic analysis tools (provided by Google) were used to track the number of visitors and relative metrics during website lifetime.

The UNICOREs website traffic within July-December 2020 increased by 24.11% compared to the previous semester period (January-June 2020), with 839 unique visitors in total that represent an average of 33.5 users per week, as shown in the Fig 3.4. These users have viewed 2,601 pages and have loaded an average of 2.48 pages within one visit to UNICORE. Time spent per session on UNICORE lengths 02.39 minutes.

The following Fig. 3.5) shows the most visited pages within the specified range date, being the UNICOREs

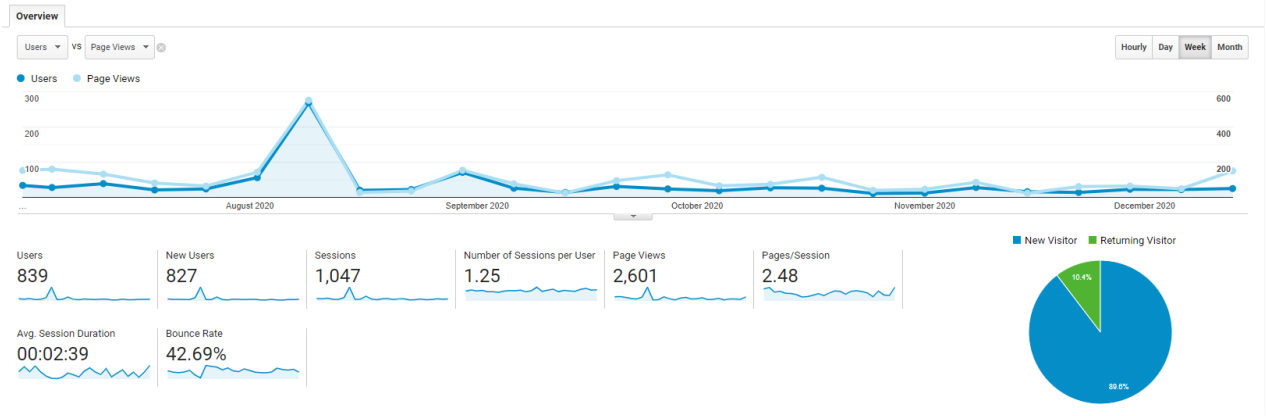

Figure 3.4: UNICOREs website overview from July-December 2020.

homepage website the one registering more views.

Page Title	Page Views	Unique Page Views	Avg. Time on Page
	2,038 % of Total: 78.35% (2,601)	1,517 % of Total: 84.32% (1,799)	00:02:09 Avg for View: 00:01:47 (21.04%)
1. UNICORE	**559** (27.43%)	411 (27.09%)	00:01:29
2. Deliverables – UNICORE	**218** (10.70%)	112 (7.38%)	00:02:09
3. What's UNICORE about? – UNICORE	**144** (7.07%)	119 (7.84%)	00:01:35
4. News – UNICORE	**127** (6.23%)	75 (4.94%)	00:01:07
5. Events – UNICORE	**100** (4.91%)	56 (3.69%)	00:03:33
6. Consortium – UNICORE	**84** (4.12%)	72 (4.75%)	00:01:57
7. Unikernels and toolchains – UNICORE	**70** (3.43%)	58 (3.82%)	00:01:01
8. Use Cases – UNICORE	**63** (3.09%)	45 (2.97%)	00:04:26
9. Use cases – UNICORE	**59** (2.89%)	48 (3.16%)	00:01:16
10. Try the Unikraft Tutorial, it's available online! – UNICORE	**53** (2.60%)	51 (3.36%)	00:03:56

Figure 3.5: Top ten most visited pages on UNICOREs website.

Referral traffic has increased from 9% to 36.61% and represents a significant leap forward in bringing UNICORE to new users, as chances of new visits to the website and engagement have considerably grown over the last period. Organic search holds the second place (31.11%), followed by direct traffic (28.77%) and social (3.51%).

In regards to social traffic, it is important to note that 95.74% of it comes via Twitter, becoming the most influential social network nowadays in UNICORE.

3.6 Communications via Social Networks

UNICORE has presence in five major social platforms: LinkedIn, Twitter, Slideshare, Youtube and Zenodo.

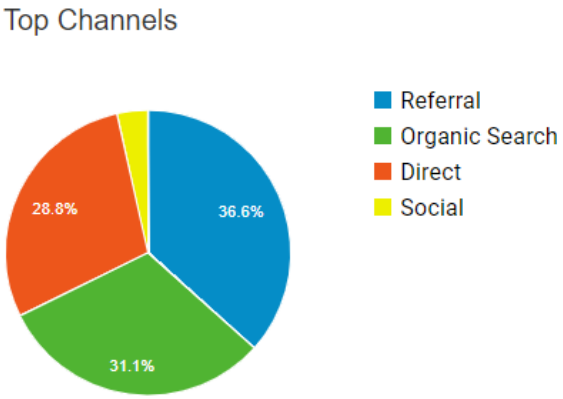

Figure 3.6: Top channels for traffic on UNICOREs website.

3.6.1 LinkedIn

A LinkedIn group (www.linkedin.com/groups/8752067) is available to maintain discussions and build meaningful interactions around UNICORE. The UNICORE LinkedIN group with 18 members by the end of 2020. No specific group discussion originated yet, as the main target for this social channel was decided to cover unikraft lessons learnt with UNICORE use cases which have not been completed yet.

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.

During July-December 2020 this social network has registered the following data: 51 published tweets with 19,905 impressions in total, 658 engagements, 68 retweets, 137 likes, 42 user profile clicks and 114 media views.

Compromised with the dissemination of UNICORE, the use of this social network made visits to UNICOREs Twitter increase by 205% during this period. The most popular tweets usually refer to conferences in which members of UNICORE have participated with a talk or paper, but also to highlight aspects of the project such as use cases. Some examples are reported in Fig. 3.7.

3.6.3 Slideshare

Two presentations are uploaded on SlideShare (UNICORE Project Technical Overview and CSUC UNICORE Project UNIKernel Power) which registered 207 views since their publication in 2019. The SlideShare account is available at https://www.slideshare.net/UNICORE_project.

3.6.4 YouTube

The YouTube channel (https://www.youtube.com/channel/UCcYdu2ikMYlKoV9LRJBiOhQ) in which the video of the UNICORE project is available has registered 314 views since its publication in November 2019.

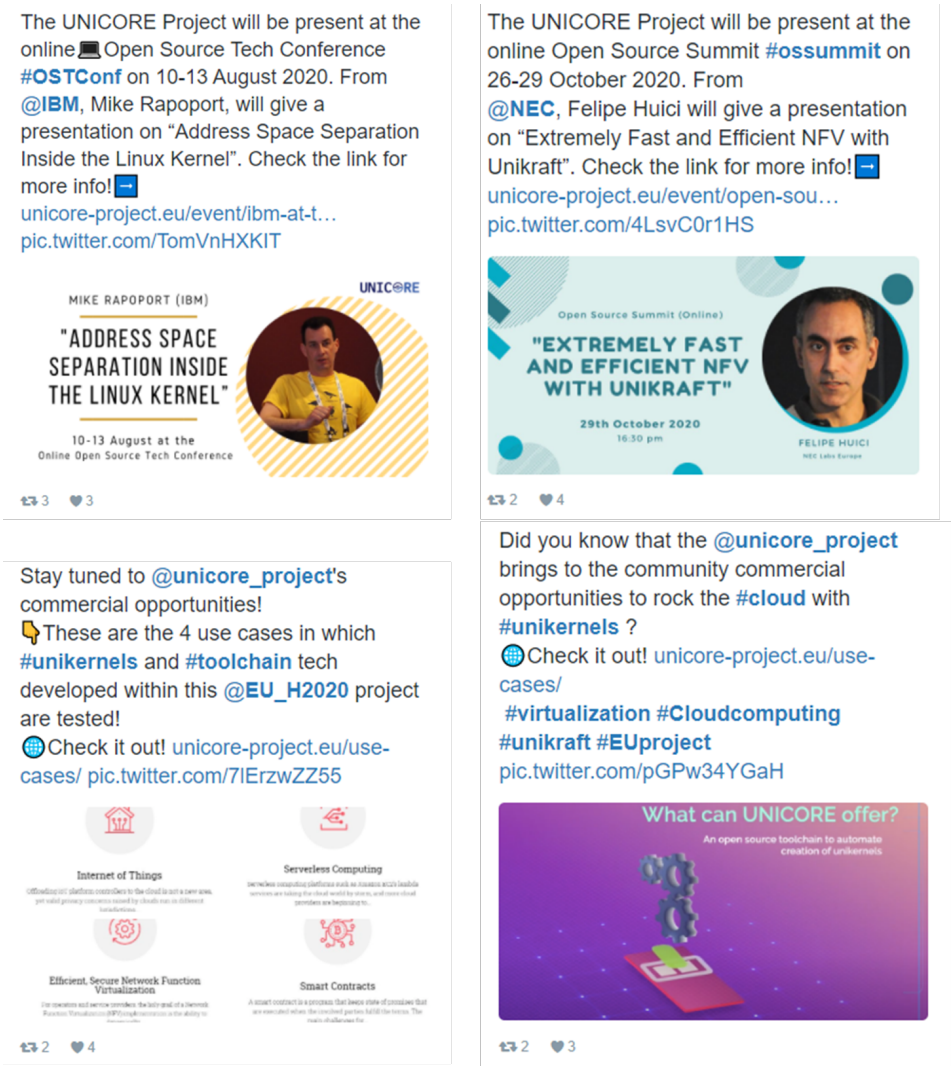

Figure 3.7: UNICORE Twitter profile

3.6.5 UNICORE community in Zenodo

The Zenodo account closes this period with 15 publications in open access (1 added during the period from July to December 2020), 595 views and 691 downloads, distributed in chronological order as shown in Fig. 3.8.

№	Publication	Views	Downloads
1	UNICORE Project - Technical presentation	10	7
2	D6.1 Website Social Accounts and Advertising Material	63	56
3	D2.1. Requirements - Initial	100	88
4	D6.2. Data Management Plan	56	46
5	D2.2. API Design	34	43
6	D4.1. Design & Implementation of Tools for Unikernel Deployment	61	71
7	D3.2. Security, Safety and Validation Support Definition	28	28
8	D2.3. Platform Requirements - Final	54	128
9	UNICORE: A Common Code Basse and Toolkit for Deployment of Applications to Secure and Reliable Virtual Execution Environments	32	28
10	D6.3. Report on Communication and Dissemination Activities and Exploitation Plans - Initial	26	38
11	D2.4. API Design - Intermediate	26	54
12	D5.1. Deploymentt Plan, Requirements and Business Cases	30	38
13	D3.3. API, Library and Security Primitives Implementation - Initial	24	25
14	D4.2. Design & Implementation of Tools for Unikernnel Deployment - Intermediate	24	19
15	D5.2 Initial Deployment	27	22
TOTAL		595	691

Figure 3.8: Deliverables and other materials are available on Zenodo

3.7 Dissemination plan for next period

The dissemination plan for Year 3 at the time of writing this report consists of the following potential target opportunities:

- UNICORE will participate at the ASPLOS 2021 Virtual Conference, to be held in April 19-23, 2021 with the paper: *PIBE: Practical Kernel Control-flow Hardening with Profile-guided Indirect Branch Elimination* by Duta, V.; van der Kouwe, E.; Bos, H.; and Giuffrida, C. In ASPLOS, April, 2021.

- The project has another accepted paper at the 42nd IEEE Symposium on Security and Privacy, to be held in May 23-27, 2021, with title *CrossTalk: Speculative Data Leaks Across Cores Are Real* by

Ragab, H.; Milburn, A.; Razavi, K.; Bos, H.; and Giuffrida, C. In S&P, 2021. Intel Bounty Reward

Moreover, the website will be extended with great emphasis on use cases during 2021 as a part of the activities planned to create awareness about the results on commercial opportunities prototyped and demonstrated through four highly relevant industrial innovation directions (Serverless Computing; Efficient, Secure Network Function Virtualization; Internet of Things, and Smart Contracts).

Opportunities for organizing UNICORE/Unikraft tutorials and webinars and/or hackathons in public conferences and other events organized by ourselves will be discussed in Q1-2021. In that sense, we expect to organize an OpenNebula TechDay focused on An introduction to Unikernels and Unikernels in practice: Serverless Computing.

All consortium partners plan to publish a press release to publicize the outcomes of UNICOREs use cases, adjusted to meet the local and global demands. We will use our social networks to maximize the impact and value of this press release, as well as the website itself.

4 Standardization and Open Source Activities

The UNICORE Consortium continues to keep the main commitment to open source as a tool to directly influence the scientific community, industry and standardization bodies. Also in the hard times of 2020, several UNICORE partners have continued to work with open source communities at Linux Foundation and in standardization bodies.

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 2

SDO/Working Group	Involved partners	Activities in Y2	Future Plans
ETSI ZSM ISG	NXW	Continued investigation of applicability of Unikernels to ZSM scenarios. Potential for reuse of MQTT unikernel-based service into ZSM Communication Fabric instantiated in some Nextworks prototypes of ZSM architecture.	Potential contribution to ZSM ISG with a PoC in 2021
ETSI MEC ISG	XLRN, NXW	None specific to UNICORE	Cloud-native approaches are gaining more momentum in edge computing. The Consortium is in Wait & see mode before defining any 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 2

Software Community	Involved partners	Activities in Y2	Future Plans
OpenStack, Kubernetes, Docker	CNW	Continued 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	UPB was to be host of the yearly Xen Summit (cancelled due to COVID).	Upstreaming of Xen support for Unikraft.
DPDK	NEC	Contributed multiple talks to DPDK summit on DPDK/NFV unikernels	Upstreaming of DPDK support to Unikraft project
Unikraft Linux Foundation Project	NEC, UPB, ULG, CSUC, OA, CNW, VU	ARM support, expanded KVM support, optimization of Xen networking, multiple security features	Unikraft as a framework for exploring security and performance trade-offs, and for providing extremely secure software stacks.
OpenNebula	CSUC	Developing and Testing different features to fully support unikernels in OpenNebula Platform	Check and validate the new features and upstream to OpenNebula Project.
Kubernetes	CSUC	Testing some KubeVirt plugin features to support unikernels on Kubernetes	Validate the new features.
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

The work on security enhancements for the Linux kernel using memory management techniques targets inclusion to the mainline Linux kernel. The preparatory work that included improvements to boot time memory management, page table manipulation and cross-architecture abstraction for physical memory representation are already merged into various releases of the Linux kernel during 2020.

The implementation of secret memory areas intended for applications to store secret information that would be invisible even from the privileged code has undergone several reviews by the kernel community and it is merged into the memory management tree. We anticipate that it will be included in Linux v5.11.

There was interest in the secret memory areas expressed by Amazon, Google, Intel, Oracle and other companies to utilize such areas for storing application secret information, e.g. private keys, or even the entire memory of the VM guests.

5.1.2 NEC LABORATORIES EUROPE

NEC plans to exploit the Unikraft technology to be able to enhance its wide portfolio of cloud solutions. In addition, NEC is making a major push to migrate many of its services, including internal ones, to the cloud; using efficient, Unikraft-built unikernels is seen as a clear path to using infrastructure resources efficiently. In addition, NEC is running a business incubation activity around Unikraft, to see if the technology could be turned into a start-up.

5.1.3 EPFL

The 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 consensus among the validators.

One of the ongoing projects at DEDIS is building a new architecture that can support general-purpose decentralized applications and address the shortcomings of the existing decentralized-application platforms (i.e., smart contracts). We have already published a high-level position paper on this topic in HotOS 2019. We are now working on the actual systems paper that will be based on the design, implementation and evaluation of the system.

The key idea behind our architecture is separating consensus from code execution, which are tightly-coupled in smart contract systems such as Ethereum. One of the benefits of this separation is that our system can support different code execution engines (VMs), unlike Ethereum that currently only supports Ethereum VM (EVM) and therefore has limitations in terms of performance and the computations that it can support.
Our plan is to have a UNICORE-based execution engine in our system to enable execution of smart contracts that are written in generic high-level languages (e.g., Go). In this way, we can evaluate the success of our system in addressing the shortcomings of Ethereum and its code execution engine. More specifically, we can show that a UNICORE-based code execution engine can support a wider range of cryptographic operations and cryptographic curves. Second, we can compare the performance of a UNICORE-based execution engine with EVM and other potential alternatives to EVM, such as Ethereum-flavored WebAssembly (eWASM).

5.1.4 UPB

UPB has a strong systems group and a large base of enthusiastic students. Unikraft has helped further boost this strength, and galvanise students around this easy-to- understand and customize OS. As a result, we have observed a significant boost in the number of students interested in doing their undergraduate projects on Unikraft, of which 10-20 work on Unikraft every year. This interest translates also in Masters level projects (with 3-5 joining each year), as well as people wanting to join Correct Networks, UPBs spinoff, to work on Unikraft at a company.

5.1.5 CSUC

CSUCs plan for UNICORE is to profit off the advantages that it can offer and apply them into the cloud services for any of our institutional repositories. These advantages will allow CSUC to replace the always running virtual machines, which are in charge of converting the files before uploading them to the repositories, by a serverless functions environment which only will use the resources when they are really needed. The use case will allow CSUC to also test new storage technologies and work in a more automatic way.
Furthermore, CSUC is planning to integrate unikernels in the kubernetes and OpenNebula platforms, always using KVM as a hypervisor. This has to permit unikernel technology to be easier to adopt by the community. This Year 2 CSUC developed a first draft of the use case creating a unikernel capable of transforming images. Also during this year CSUC has been working on the integration of unikernels with Kubernetes by testing different alternatives, like using KubeVirt plugin to launch the unikernel as if it were a virtual machine. Along the Y3 the focus will be on developing and testing a functional serverless computing function which will integrate all the tools needed to run in a unikernel.

5.1.6 ULIEGE

ULIEGE will use UNICORE in order to develop high performance software virtual routers, high performance packet processing systems (FastClick), high performance NFV platforms (MiddleClick), as well as security appliances (parallel high-volume IDS and cloud-based, anonymous, and secure firewalls).
We are also currently working on memory alignment in order to get better performance and memory sharing

when running several unikernels instances (doctoral work). Finally, we are also exploiting UNICORE outputs in future students work, as well as incorporate UNICORE outputs in the curriculum of the specialisation in system security of both the MSc in Computer Science and the MSc in Computer Science and Engineering taught at the University of Liege, both as part of class content and Master theses.

5.1.7 ACCELLERAN

Accelleran commercializes dRAX, a cloud native microservice based vRAN solution consisting of near-RT RIC, CU and xApp framework components running on COTS platforms. These cloud native dRAX microservices are normally delivered to customers as docker containers orchestrated in Kubernetes, but can also be delivered in other Type 1 or Type 2 VM platforms. Delivering microservices as unikernels, right between the performance and security trade offs of VMs and containerised environments, opens the door for Accelleran to deliver to the market a dRAX solution that can dramatically reduce the TCO for our customers thanks to the reduction in the computing/memory requirements needed in the underlying COTS NFVi platform without compromising security. Having lower computing/memory requirements not only reduces TCO, but also makes it easier to enable the deployment of microservices in edge COTS platforms that do not benefit from the computing/memory footprint that can be found in regional sites or data centre cloud NFVi environments. A dRAX solution based on unikernels is a key value add to deliver to our customers.

5.1.8 VU

VU is working on security and safety primitives for unikernels as part of the UNICORE project. There is growing interest in industry for such primitives in cloud settings. VU has a framework with Philips to patent research results that are amenable to further exploitation. We have already patented our ZebRAM security solution, which offers software-only Rowhammer protection to cloud platforms, in collaboration with Philips. We plan to take a similar route for other successful UNICORE research results.

The work on Rowhammer vulnerabilities has led to a research grant of $100,000 a year from industry to one of the VU researchers to continue investigations into the security of modern memory chips.

5.1.9 NEXTWORKS

Nextworks interest towards unikernel-based prototypes of Symphony functionalities (www.nextworks.it/en/products/brands/symphony) remained confirmed during Year 2. In fact, the UNICORE toolbox matches the strategy undertaken by the company towards the transformation and improvement of automation and flexibility of the proprietary Symphony IoT middleware, which is migration to a microservices and containerised platform. The testing activities within UNICORE with selected Symphony functions carried out in Year 2 did not allow yet to mature specific exploitation paths for the unikernel prototypes of Symphony functions, due to a number of open issues found in the execution environment of the krafted functions. The plan for Y3 is to continue troubleshooting with Unikraft developers and follow up on technical performance evaluations, in order to be capable of testing UNICORE products in a real case scenario of a Smart Home at Nextworks premises. The ultimate goal remains to derive useful insights on the possibly im-

proved computation resource footprint and applicability to a commercial/production environment. Currently, the Smart Home use case activities follow the staged approach defined in Deliverable D5.2 [2] and remain at functional verification (stage 1) due to the execution issues mentioned above. After a complete performance evaluation can be executed (stage 2), a business impact evaluation can follow up which will quantify unikernel/UNICORE benefits in terms of costs for the production of Symphony releases and costs for maintenance operation.

Nextworks expects to derive from this analysis insights on a potential marketability of the UNICORE-flavoured Symphony products in 2/2.5 years from the project completion, being this highly dependent on the stability of the UNICORE toolbox and its derived unikernel functions.

5.1.10 EKINOPS

Ekinops plans to use the Unikraft technology to enhance the performance of its solutions, especially the vCPEs and SD-WAN. Today, Ekinops supports Mobile (Virtual) Network Operators (M(V)NOs) and Service Providers (SPs) to deploy virtualized solutions across their network by designing and developing a Virtual Infrastructure Manager (VIM) and a large asset of Virtual Network Functions (VNFs).

To be competitive with well-known companies such as Cisco, Ekinops has to address efficiently several challenges and satisfy crucial Performance Key Indicators (KPIs) including, the performance in terms of resource footprint, execution time, network bandwidth and latency, high availability and reliability, and security. Unikernels is a promising technology to address such issues and KPIs.

According to this, Ekinops have built the first Unikernel for the key server functionality included in the SD-WAN solution. This Unikernel is under testing/debugging as some functionalities are not yet available for Unikraft. In meanwhile, Ekinops is also working on its second Unikernel, a lightweight vCPE, which consists of building a Unikernel for the vCPE data plane. Demonstrations and experimentations with different customers and prospects, with various services and configurations, will be performed to validate prototypes before going to market. 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 reduced specification equipment. With these Unikernels, Ekinops expects to bring more flexibility and support more services/VNFs. Therefore, get 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

Correct Networks is developing a lightweight virtualization platform called PacketCloud that aims to boot instances when traffic arrives for them, rather than keeping them running all the time. PacketCloud is aimed at resource-constrained, client facing edge clouds where the number of customers (instances) is very large

but only a subset of them are actively sending traffic. PacketCloud relies on lightweight virtual machines to do its job, both based on Unikraft (preferred) and minimalistic Linux distributions like Alpine when dealing with legacy VMs.

As part of growth strategy, CNW has taken part in two accelerator programs for startups - Innovation Labs and HowToWeb - where it presented PacketCloud to a wide audience and received feedback for the proposed development plan.

As a result, a commercial partnership was formed with Orange Romania where CNW will deploy a prototype of PacketCloud and develop one use-case in 2021 for another security company that aims to run a per-client security solution in the Orange edge cloud. Another use-case is likely to be developed for at-edge machine learning inference.

5.1.12 ORANGE ROMANIA

ORO is interested, in principle, to exploit this projects outcome in the direction of prototyping new B2B and B2C products and services based on the technologies and knowledge gained from UNICORE. ORO is interested in building sustainable products, services and applications aligned with the objectives of UNICORE and furthermore refined by the relevant input gathered by OROs Product Management teams from Business Verticals.

ORO aims at prototyping and validating the technology allowing for the future development of the outcomes of UNICORE, specifically the lightweight BNG Use-Case. Given the TRL of UNICORE, ORO intends to further develop on the working instances of the vBNGs to better scale in terms of efficiency and cost the rollout of new products.

One key component of the exploitation of UNICOREs outcomes for the Projects final year is to better understand the interactions between our vBNG Use-Case and the work done by the other partners in the consortium on developing vCPEs.

5.2 Joint Exploitation Plans

COVID-19 lockdown measures impacted the advancement of joint exploitation activities, due to the reduced opportunities for community/stakeholder meetings from which to gather further stimulus for exploitation outside and beyond the project.

Therefore, the core activities of 2020 related to joint exploitation remained focused on community software strategy setup and oriented towards the Unikraft community of developers. Focus of the year was on the consolidation of the toolchain features and on the activation of outreach tools for engaging with the community. In fact, a dedicated website for UNIKRAFT (http://unikraft.org/) was published online to serve as one stop information container for the FOSS community interested in UNIKRAFT and the main UNICORE outputs.

This joint exploitation stream related to the UNICORE toolchain is for the moment mainly led by the core developers in the Consortium, and it aims to establish a strong lead of the Unikraft community in FOSS. In

addition, we are currently undergoing an effort to integrate all Unikraft tools developed in UNICORE under the Unikraft kraft tool and related github repository. This will not only ensure better visibility, but it will also assure that the code will live beyond the projects end.

The following Table 5.1 summarises the major streams of these joint technical activities with potentials for joint exploitations.

Table 5.1: Joint technical activities with potentials for exploitation

Implementation Area	**Topic**	**Collaborating partners**	**What's new in Year 2**
UNIKRAFT / UNICORE Core	API and library implementation	NEC with UPB	APIs have been designed, implemented, and upstreamed
	Security and isolation primitives	VUA with UPB and NEC	Many primitives are implemented already (e.g., stack protection, page protection), several are still under development (HW capabilities)
	Deterministic execution support	UPB with EPFL	Control of randomness (APIs, memory layout), support for multiple compilers (gcc, clang) and compiler options for determinism, support for multiple languages (D language support added)
UNICORE Toolstack	Compile Toolchain	ULG with NEC	Most of the tools are implemented and are in the process of being integrated into the Unikraft kraft tool
	Multi-Target Support	NEC with UPB	Most of the tools are implemented and are in the process of being integrated into the Unikraft kraft tool
	Symbolic Verification Support	CNW with UPB and NEC	Currently in the process of developing Unikraft components (schedulers and memory allocators) with the Daphne language.
	Performance Optimization Tools	NEC with ULG	The focus is currently on a tool for efficient memory deduplication for unikernels
	Orchestration Tools Integration	CSUC with NEC	First prototype able to launch a Unikraft instance via Kubernetes is now ready.

An evaluation on the sustainability of the FOSS community efforts related to UNIKRAFT will be carried out in 2021, once effects of potential ingress of external developers might be evaluated.

As the UNICORE project will advance in Year 3 and new outputs will mature linked to the activities of UNICORE use case teams, also other opportunities for joint exploitations might emerge by the other UNICORE partners. These opportunities could be related to UNICORE use case elements in other R&D projects or in commercial demos.

6 Conclusions

This deliverable reported results of dissemination, communication, standardization and exploitation activities carried out during the Year 2 of the UNICORE project.

Impacted by the COVID-19 lockdown measures, the Consortium has continued to build a relevant impact based on the available project results, mostly leveraging on the UNIKRAFT tools and its related FOSS initiative as stand-alone public software projecte and in GitHub.

Apart from continuing dissemination of UNICORE scientific results in top level international conferences and journals, as well as in top events like FOSDEM and Linux Plumbers, the plan for Year 3 includes also seeking opportunities for showcases of UNICORE use cases at relevant events related to 5G networks and IoT, in order to demonstrate the achieved maturity of UNICORE toolchain assets in specific application scenarios.

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 2

Activity	KPIs	Cumulative Results
Industrial events (exhibitions and congresses)	• number of events attended • size of audience • number of impacts (real interest in UNICORE)	• Y1 – 9 industry-driven events – 500+ attendees – <15 interested in unikernels • Y2 – 19 all virtual industry-driven events – 500+ attendees – <15 interested in unikernels
Academic events (workshops and conferences)	• number of events attended • number of events organized	• Y1 – 13 scientific events/conferences – 300+ attendees on avg – >15 interested in unikernels • Y2 – 9 all virtual scientific events/conferences – 300+ attendees on avg – >15 interested in unikernels
Scientific publications	• number of accepted (peer-reviewed) papers in journals vs. impact factors of respective journals • number of accepted (peer-reviewed) papers at conferences and workshops	• Y1 – 13 conference papers • Y2 – 5 conference papers
Website	• positive trend in visitor numbers/month • adequate length and depth of visit	• Y1 – 474 users for 1194 sessions in year 1 – > 5 mins session duration on website • Y2 – average of 33.5 users per week – referral traffic increased from 9% to 36.61%

Activity	KPIs	Cumulative Results
Social media	increasing number of followers and impact	• Y1 – 60 followers and 28.8K impressions over Q4-2019 • Y2 – 17 followers on Twitter with 51 published tweets with 19,905 impressions, 658 engagements, 68 retweets, 137 likes, 42 user profile clicks and 114 media views in the period Jul-Dec 2020.
Press Releases	• 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	*Press releases have beed postponed to Year 3 due to their poor penetration into the target UNICORE stakeholder communities. Socials and news on website, as well as Blogs on UNIKRAFT website achieve a better impact*
Advertising Materials	• 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 with 314 views since its publication in November 2019.

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
vBNG	Virtual Border Network Gateway
vCPE	Virtual Customer Premise Equipment
VNF	Virtual Network Function
WG	Working group
WP	Work Package

7.2 Definitions

No definition is introduced by this document

References

[1] Unicore website. [Online]. Available: http://unicore-project.eu/

[2] I. Constantin, M. Iordache, C. Patachia, F. Messaoudi, T. Masson, S. Parker, E. Martnez, X. Peralta, G. Scivoletto, C. Basescu, G. Bosson, F. Huici, R. Stoenescu, R. Deaconescu, E. Slusanschi, and M. Rapoport, "D5.2 initial deployment," Aug. 2020. [Online]. Available: https://doi.org/10.5281/zenodo.4010280

