SLICES

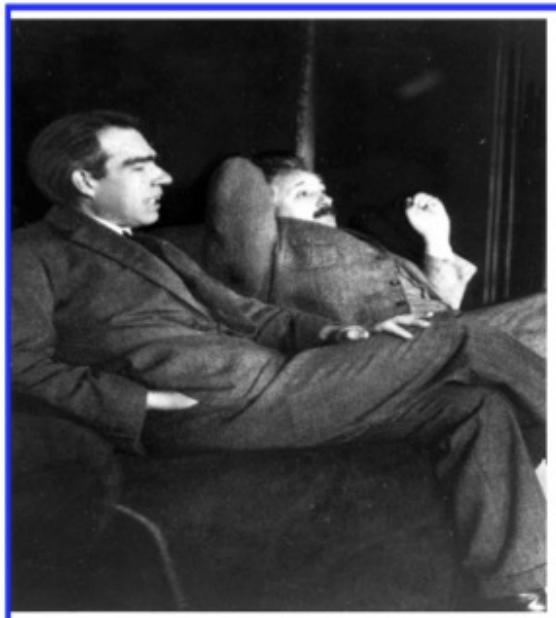
European Scientific Large-Scale Infrastructure for Computing/Communication Experimental Studies

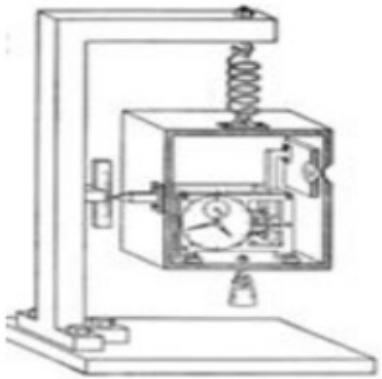
Serge Fdida
Sorbonne Université, France

IoTBDS 2023

Prague, April 21 2023

Thought experiments





Einstein, Bohr and their Photon Box…
a kind of experiment that
Schrödinger considered impossible
to realize….

THE NOBEL PRIZE

Nobel Price in Physics 2022

Entangled states – from theory to technology

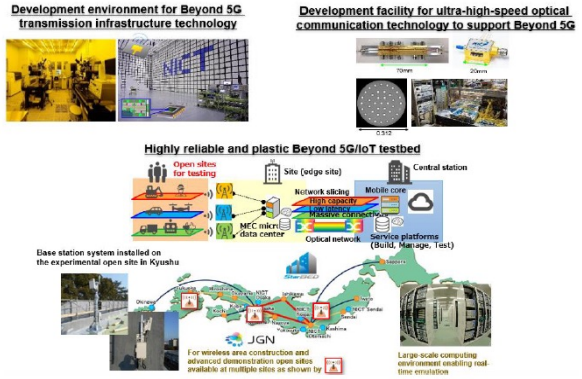
Alain Aspect, John Clauser and Anton Zeilinger have each conducted groundbreaking experiments using entangled quantum states, where two particles behave like a single unit even when they are separated. Their results have cleared the way for new technology based upon quantum information.

slicesRI

6G Research Infrastructures?

slicesRI

Third generation Mid-Scale Test Platforms



USA NSF PAWR (Platforms for Advanced Wireless Research): NSF + Industry, 100M€, 2017-2022

NSF Fabric: NSF, 20 M€, 2019-2023

Colosseum: NSF-DARPA, 20+7,5M$, 2017-2025.

BRIDGES: NSF, 2.5M€, 2020-2023

EU Horizon Europe
ICT 17-19-52, 2018-2022, 205 M€
SNS Stream C, first call, 2022-2025, 25M€

Japan NICT R&D
Shared Open Platform
200 M$

China CENI
Chinese Experimental National Infrastructure
2018-2022
190 M€

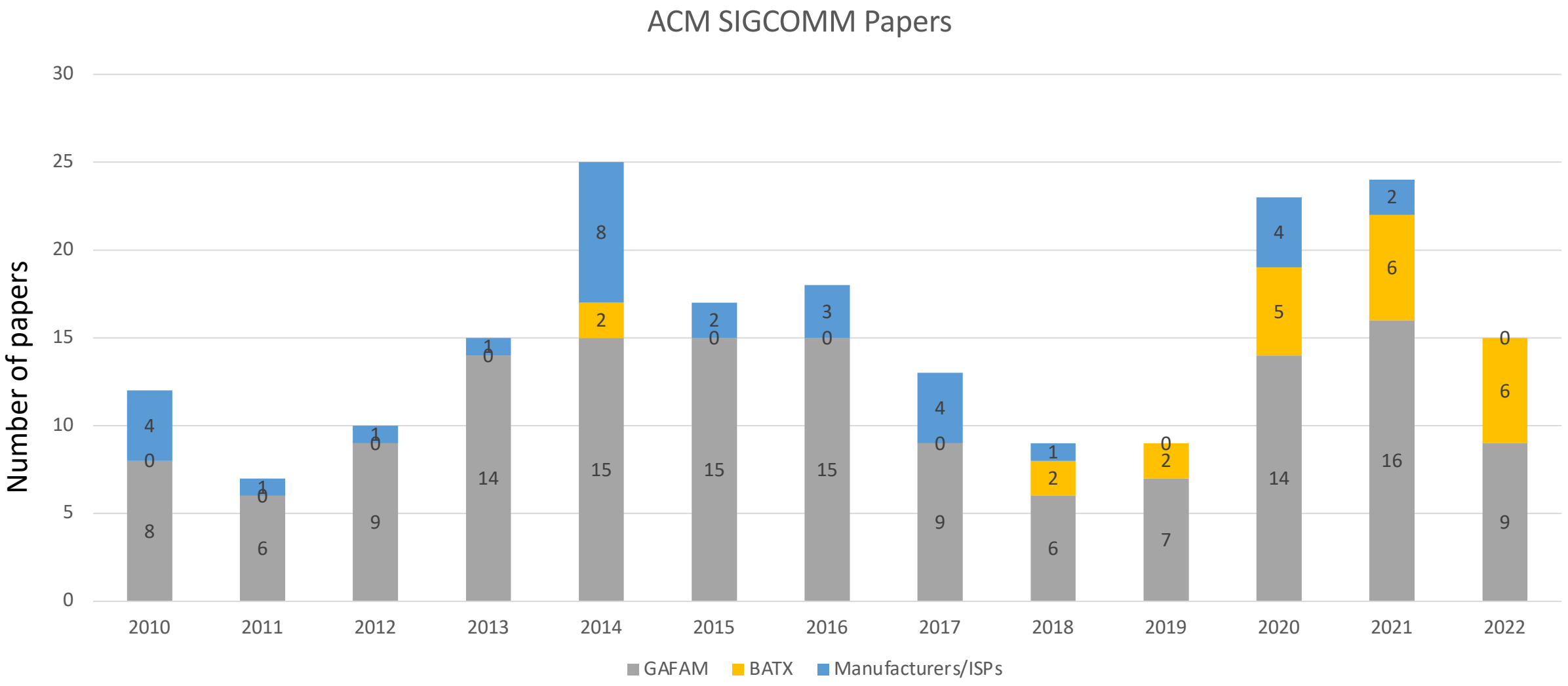
slicesRI

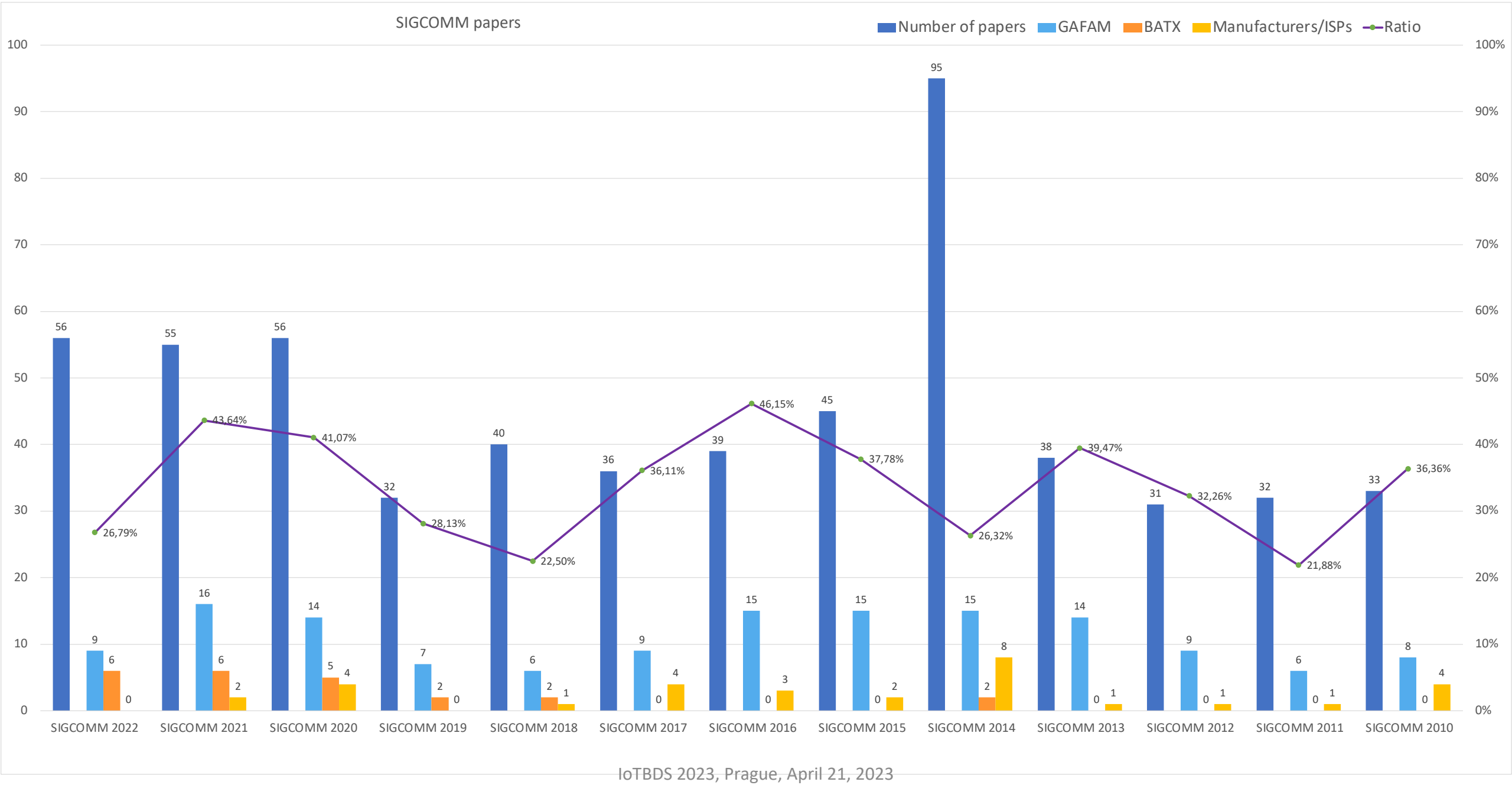
Important “competition”

Large Scale Infrastructures as a support to the design and validation of systems

- ACM SigComm scientific publications

slicesRI


ACM SIGCOMM Papers
Number of papers
30
25
20
15
10
5
0
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
4
0
8
1
0
6
1
0
9
1
0
14
8
2
15
2
0
15
3
0
15
4
0
9
1
2
6
0
2
7
4
5
14
2
6
16
0
6
9
GAFAM
BATX
Manufacturers/ISPs
ACM Sigcomm Edition (year)


SIGCOMM papers
Number of papers
GAFAM
BATX
Manufacturers/ISPs
Ratio
100
90
80
70
60
50
40
30
20
10
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
56
9
6
0
26,79%
55
16
6
2
43,64%
56
14
5
4
41,07%
32
7
2
0
28,13%
40
6
2
1
22,50%
36
9
0
4
36,11%
39
15
0
3
46,15%
45
15
0
2
37,78%
95
15
2
8
26,32%
38
14
0
1
39,47%
31
9
0
1
32,26%
32
6
0
1
21,88%
33
8
0
4
36,36%
SIGCOMM 2022
SIGCOMM 2021
SIGCOMM 2020
SIGCOMM 2019
SIGCOMM 2018
SIGCOMM 2017
SIGCOMM 2016
SIGCOMM 2015
SIGCOMM 2014
SIGCOMM 2013
SIGCOMM 2012
SIGCOMM 2011
SIGCOMM 2010

Why?

Lessons learned from past and present platforms

Previous and current generations are successful but however,

- Mid-scale
- Federation is not transformative
- Not sustainable

Change the narrative

- Science driven (The full research life-cycle)

ESFRI

MAKING SCIENCE HAPPEN

A new ambition for Research Infrastructures in the European Research Area

http://www.esfri.eu/

Research Infrastructures as a Scientific Instrument

slicesRI

From mid-Scale (~100M€) to Large-Scale (~B€)

MAKING SCIENCE HAPPEN

A new ambition for Research Infrastructures in the European Research Area

The European ESFRI framework

European Strategy Forum on Research Infrastructures

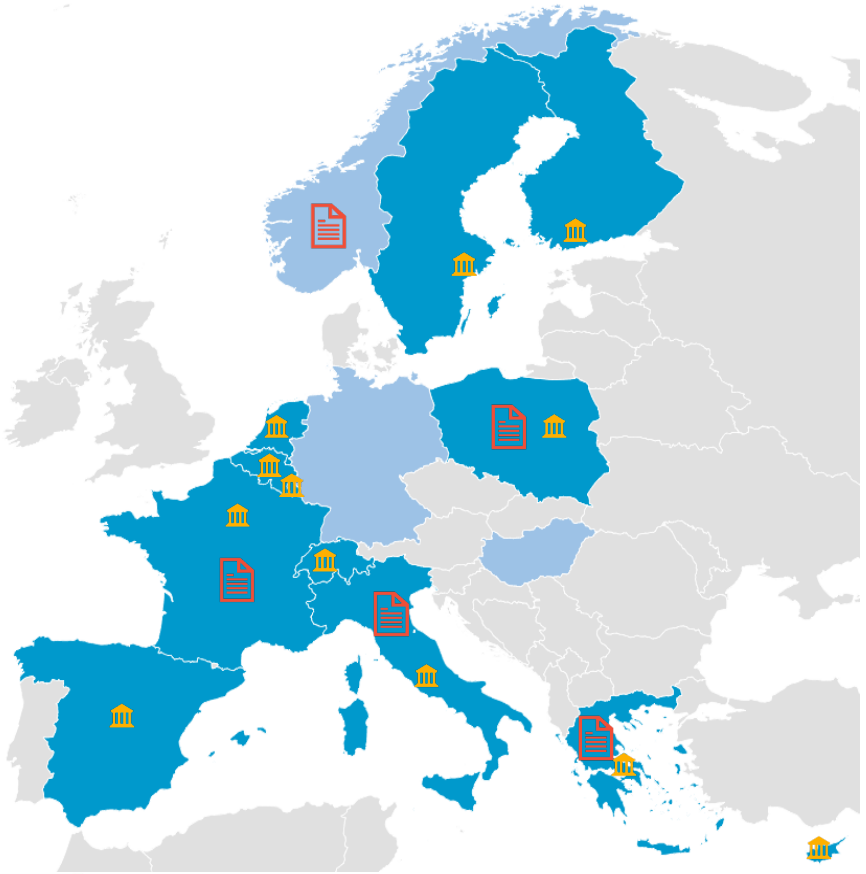
Supporting a scientific methodology

http://www.esfri.eu/

slicesRI

A vibrant community

SLICES for research on Digital Infrastructures



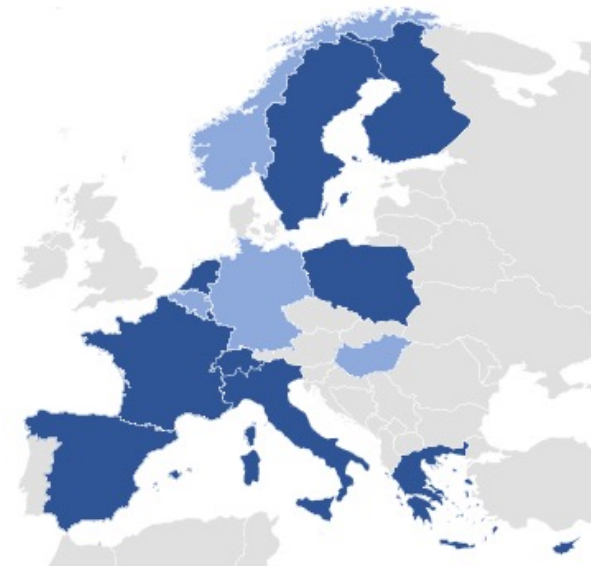
Initiated in 2017, **25 partners** from 15 countries:

- **12 political support** from National Ministries
- included in **5 national roadmaps**

SLICES will enable **scientific excellence and breakthrough** and will **foster innovation in the ICT domain**, strengthening the **impact of European research**, while contributing to European agenda to address **societal challenges**, and in particular, the twin transition to a sustainable and digital economy.

slicesRI

Current status of the partnership



SLICES
ESFRI successful application – 2020

slices RI

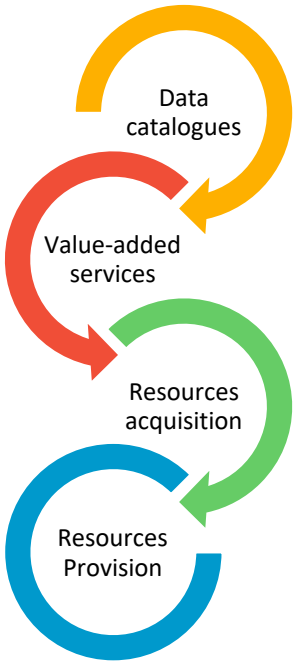
Countries	Government	Research and Academia		Industry	Clusters, networks and others	NRENs	Worldwide support
	National support	*Partners*	*Support*				
Core partners							
	Local support confirmed						

A strong identity

SLICES, first in digital sciences to entered the ESFRI Roadmap 2021

what we offer

- Launched in 2017, **SLICES** is an **RI** to support the **academic and industrial research community** that will design, develop and deploy the **Next Generation** of **Digital Infrastructures:**
  - **SLICES-RI** is a **distributed RI** providing several **specialized instruments** on challenging research areas of Digital Infrastructures, by **aggregating** networking, computing and storage **resources** across countries, nodes and sites.
  - ***Scientific domains***: networking protocols, radio technologies, services, data collection, parallel and distributed computing and in particular cloud and edge-based computing architectures and services.



www.slices-ri.eu

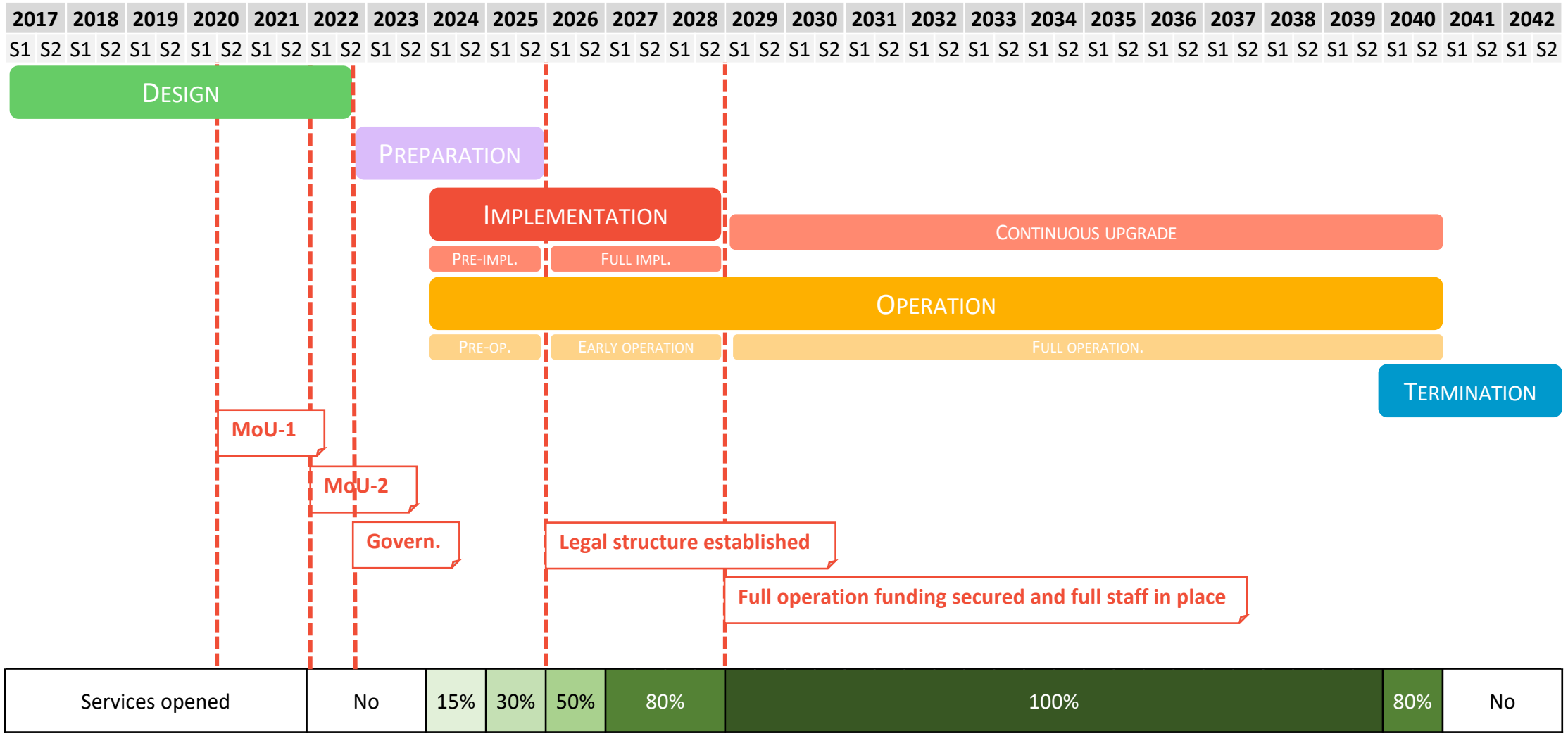
slicesRI

Fully Controllable, programmable Virtualized Digital Infrastructure Test Platform
Openness

slicesRI

A sustainable facility

SLICES timeline



slicesRI

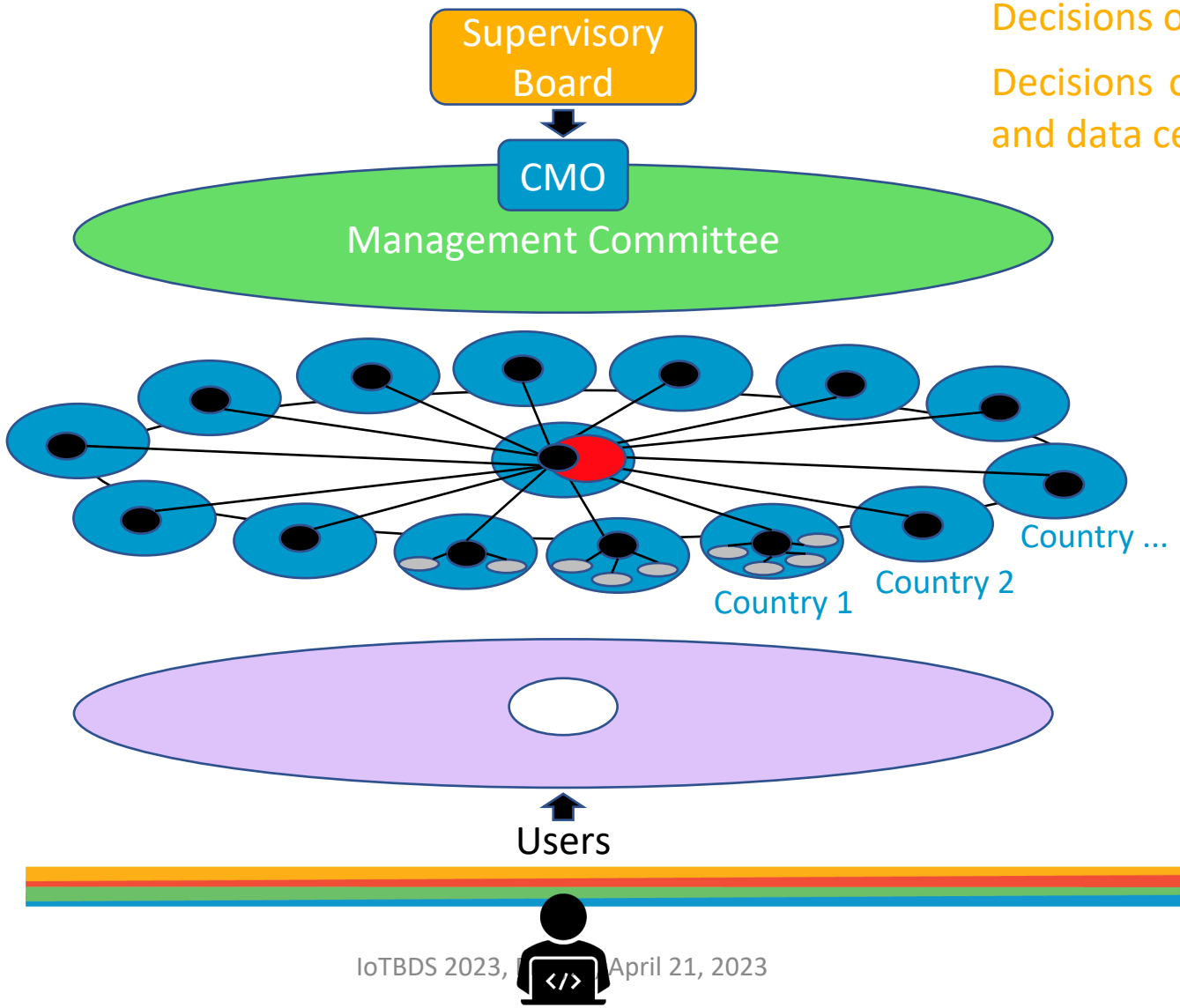
SLICES governance

SLICES is a distributed RI

Centralised governance

Distributed Infrastructure

Single entry point, single access policy



Joint investment strategy

Decisions on new nodes

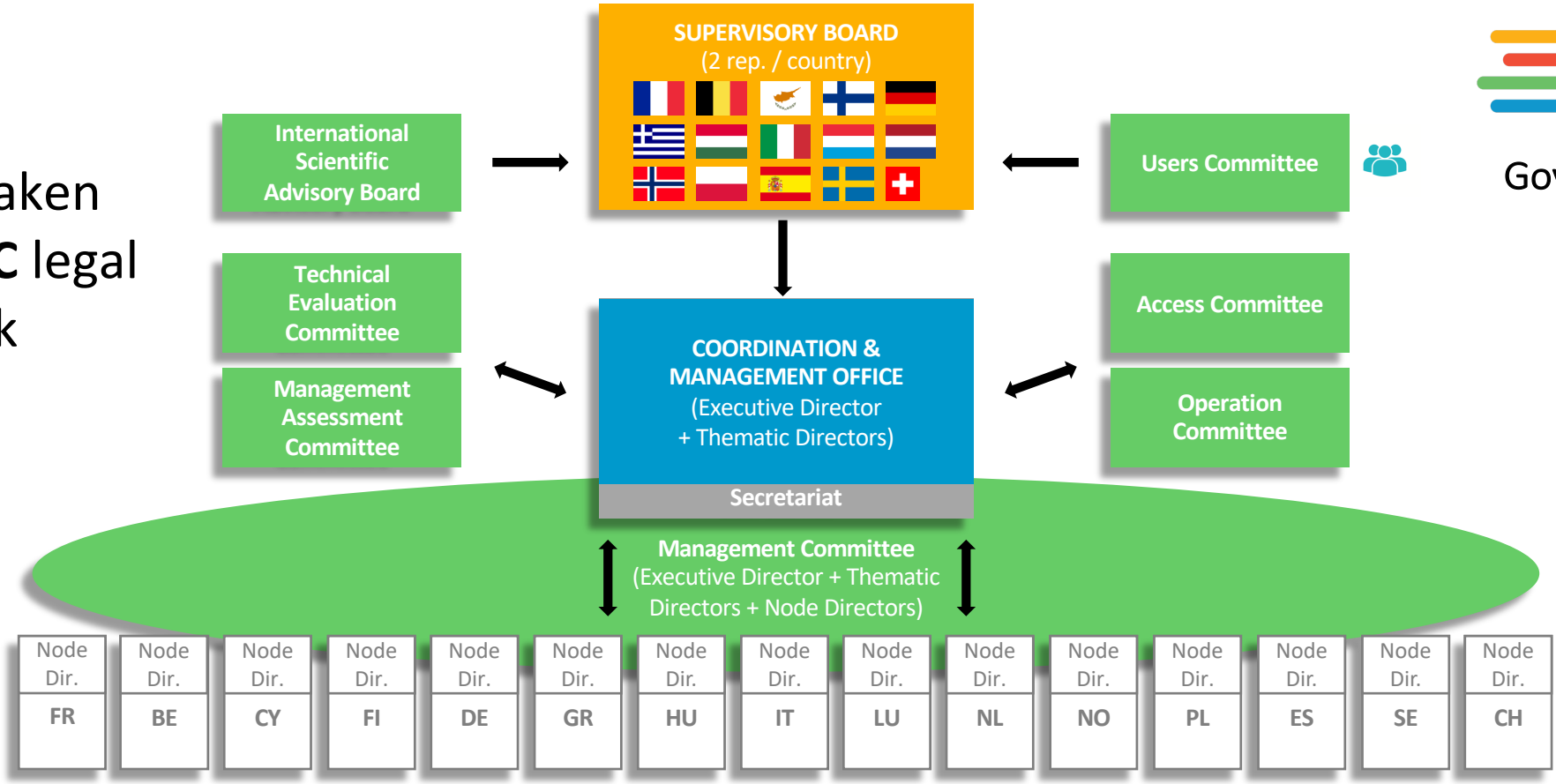
Decisions on core functions and data centre

Optimize the distribution of resources according to needs and competences: control plane, edge computing and slicing, terahertz, MIMO, ….

slicesRI

End Design & Preparation- Q1 2022

12/2022:
Decision taken for an **ERIC** legal framework



slices RI

Governance structure

slices RI

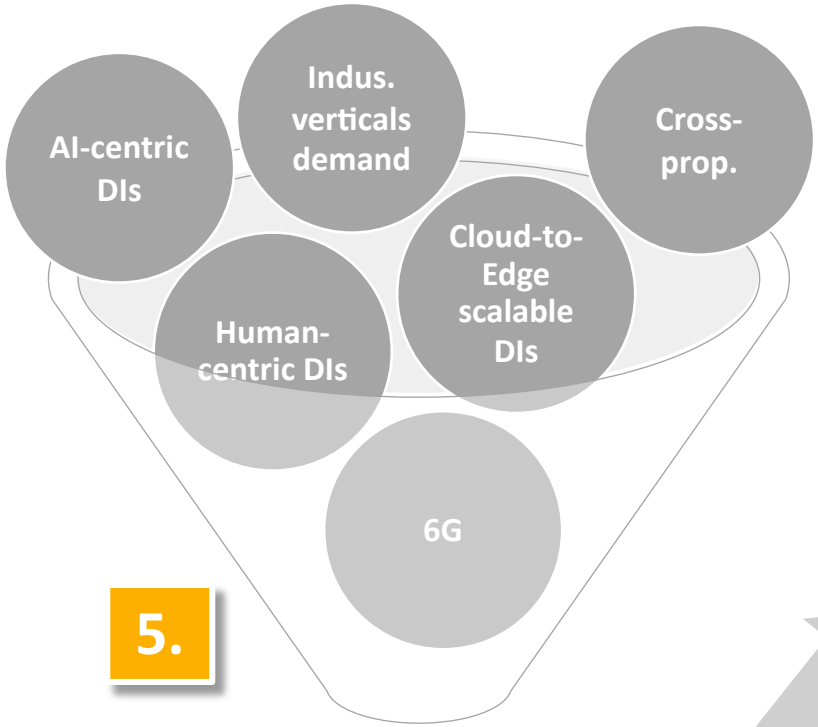
Impact assessment

A real challenge

slicesRI

Prioritisation of research topics

What's the methodology behind it?



5.

- New waveforms, higher frequencies up to THz.
- Spectrum and wireless management.
- Integrated sensing and communication.
- Heterogeneous radio management.

ADVANCED WIRELESS NETWORKING

- Advanced protocols and architectures (virtualization, softwarization, programmability).
- AI applied to infrastructure operation and optimization.
- Generation of data to train algorithms.
- Distribution of intelligence into (and beyond) the Edge of the network.

SMART INFRASTRUCTURE OPERATION AND MANAGEMENT

- Fog/Edge/cloud hyper converged infras
- Software component deployment.
- Distributed resource management & microservices.
- Geo-distributed data management.
- Federated deep learning.
- Datacentres infras for distributed systems, appli. and software stacks.

DESIGN & VALIDATION OF NEW DIS AND HYPER-CONVERGED INFRAS

- New challenges arising from the verticals and the ubiquitous networks.
- Interoperability, composable infrastructure services on-demand (RI as a Service).
- Seamless user experiences across technologies and domains.

ADVANCED FUNCTIONALITIES

ENERGY EFFICIENCY AND CARBON FOOTPRINT

SECURITY AND PRIVACY

Breaking down in priority research topics

Simultaneous but progressive exploration of research topics

slicesRI

“The Network is the Computer”

John Gage, Sun Microsystems, 1984

“We will think of a network as a programmable platform” …
“We will no longer think in terms of protocols. Instead, we will think in terms of software.

Nick McKeown, ONF Connect, 2020

“The network will be programmed by many and operated by a few ».

Nick McKeown, NetworkingChannel, March 2021

Open source software and network disaggregation

slicesRI

A SLICES BluePrint

Playground deployment

slicesRI

Post5G Experimentation in SLICES-RI

- Short/Medium term
- Evolve around 5G using ***open*** 5G technologies on large-scale end-to-end platform
  - Multi cell-site and multi-region, common infrastructure “blueprints” across sites
    - Reproducible experiments and reusable/collaborative tools (HW/SW)
  - Align with SNS Streams C/D in EU and related national initiatives
  - Align with international academic initiatives (US, Japan, Brazil)

- Focus on technologies targeting integration of ***disaggregated*** post5G RAN and Core with cloud-native deployment framework
  - Reuse and contribute to open-source initiatives (OAI, ONF, LF)
  - Experiment with fine-grain automatic control of network functions
  - Contribute to O-RAN architecture evolution : EU/USA collaboration on blueprints
  - Integration of new applications on experimental post5G infrastructure (SNS C/D)

The Blueprint – Bottom-Up POC

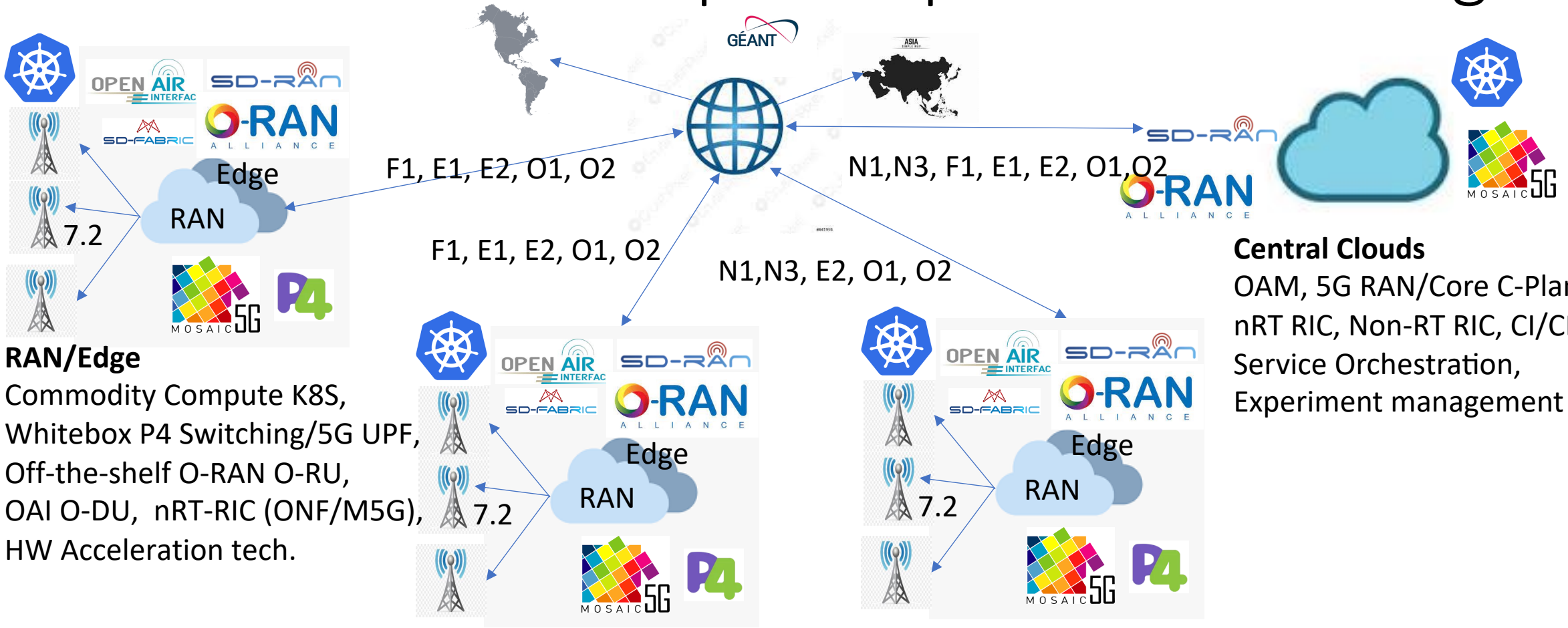
- **Recommendations and deployment scripts for RAN/Edge**
  - Servers/OS Configurations for RAN/Edge
  - Radio sub-system deployment
  - Switching (High-performance)
  - Ansible for BM -> single-node K8S/Docker, Helm for existing K8S clusters
- **Ansible scripts for deploying cloud services in support of post-5G networks**
  - 5G core network control plane (OAI 5GC now), VPN tunnel setup
  - Disaggregated RAN control plane (CU-CP), O-RAN controllers, orchestration and management
  - Measurement collection
- ***Generate requirements for SLICES-RI API***
  - Experiment management
  - Network management and orchestration

At a later stage

- *Cloud-based experiment development services (CI/CD)*
- *CD for Open-Source Communities (e.g. OAI, O-RAN OSC)*

slices RI

SLICES-RI PoC Blueprint – post5G Cloud-Edge



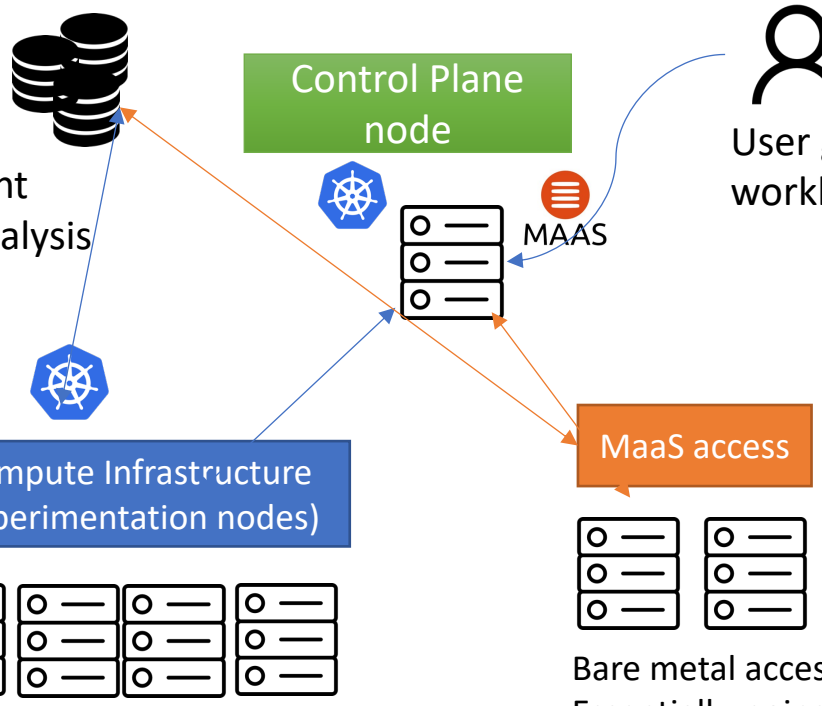
RAN/Edge
Commodity Compute K8S,
Whitebox P4 Switching/5G UPF,
Off-the-shelf O-RAN O-RU,
OAI O-DU, nRT-RIC (ONF/M5G),
HW Acceleration tech.

Central Clouds
OAM, 5G RAN/Core C-Plane,
nRT RIC, Non-RT RIC, CI/CD,
Service Orchestration,
Experiment management

slicesRI

SLICES Node preliminary blueprint – User Plane

The master/control plane node of each testbed, handling all
the workloads deployed at the different geographical sites of the node



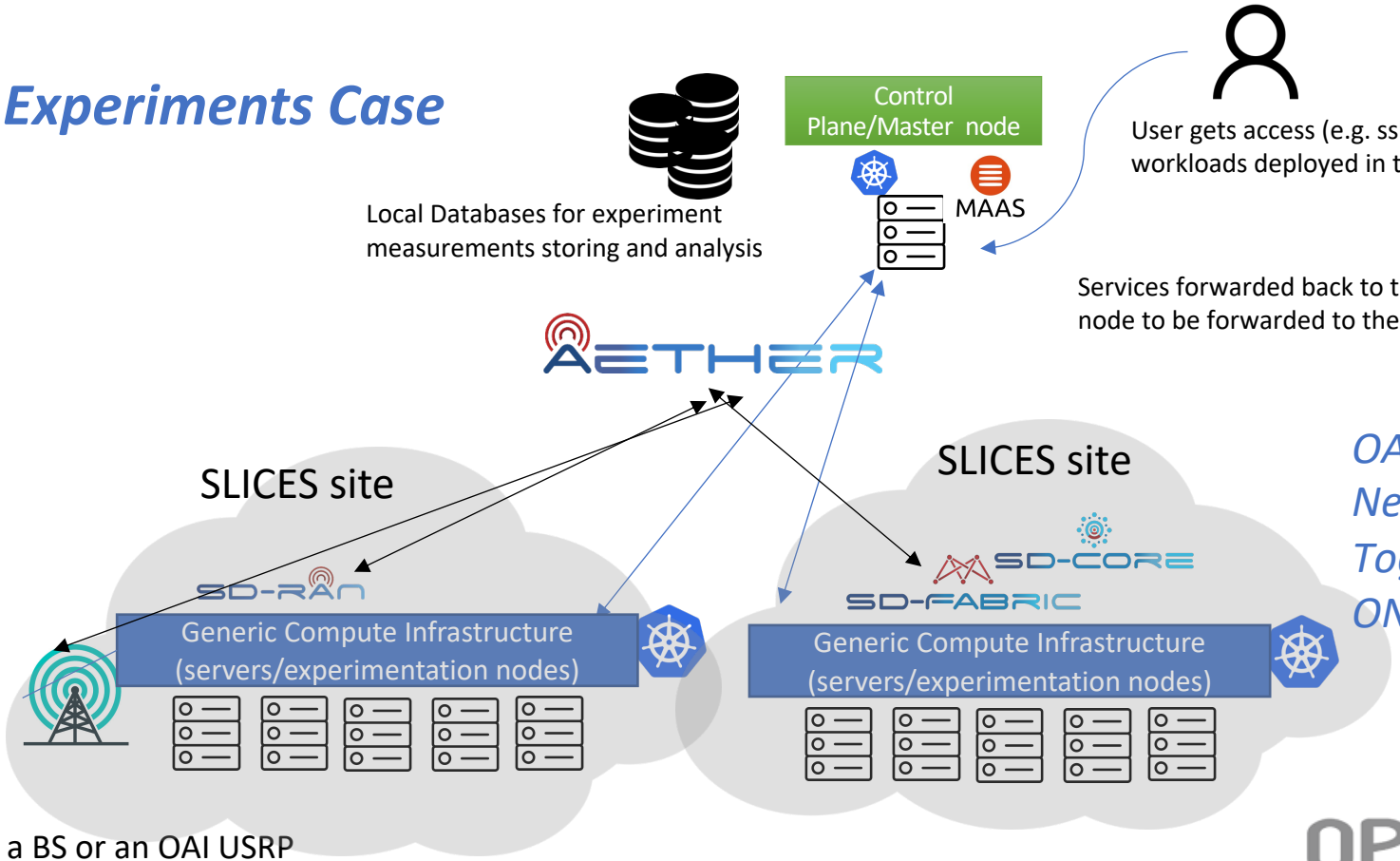
Local Databases for experiment measurements storing and analysis

User gets access (e.g. ssh) here, and can access the workloads deployed in the compute space

Bare metal access to be clarified, Canonical MaaS is only an example
Essentially, going with an option allowing PXE booting of images on the Bare Metal nodes would suffice for such experiments.

SLICES Node preliminary blueprint – User Plane

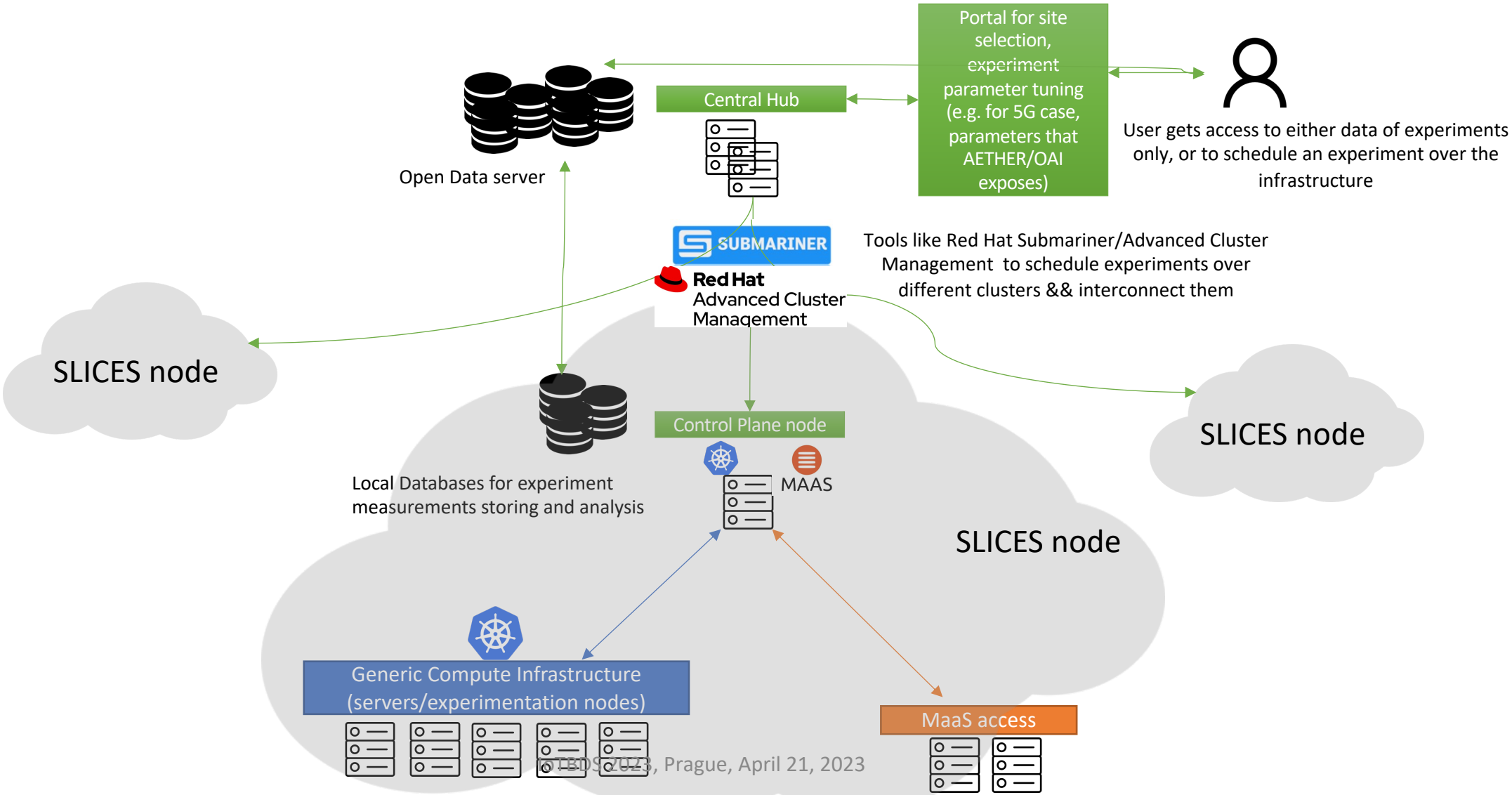
5G Experiments Case



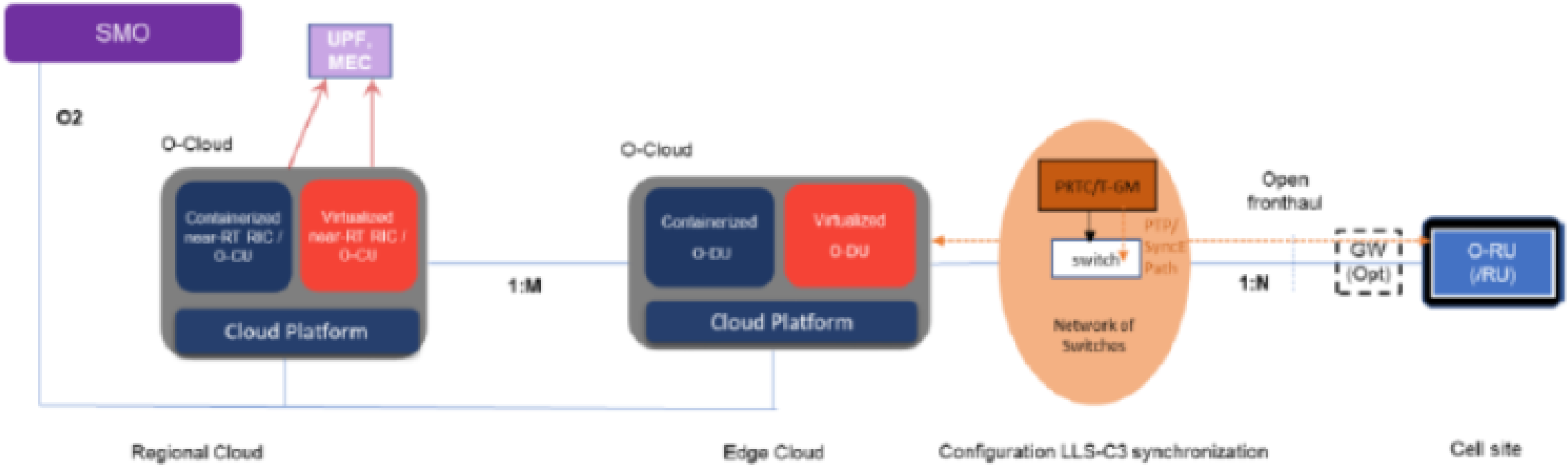
OAI Core
Network (AMF, SMF, UDM, UDR, NRF, NSSF)
Together with
ONF UPF combined with P4 Switches

Can be a BS or an OAI USRP reachable from the respective BS-function (e.g. DU/RU) on the compute infrastructure

SLICES-Central Hub preliminary blueprint – User Plane



Relation to O-RAN



User Perspective - Experiments

Vertical service integration and testing

- Users embed software a) in the network infrastructure user-plane, either in the a1) cloud center or a2) at the RAN/Edge (low-latency services)

- User's can also embed software in b) terminals (e.g. drones, robots, fixed stations). We will also allow users to add HW ("bring your own device") to the terminal end for special experiments (e.g. multimedia or connected robotics).

- We will provide an environment to build such services using the infrastructure itself (from source, binaries or pre-built container images)

User Perspective - Experiments

Software Defined Networking

- The user has access to well-defined interfaces to the network functions (e.g. O-RAN xAPP/E2 interface, O1 interface, 3GPP NEF interfaces) and writes applications which stimulate the interface to alter the network behavior or collect KPI
- This typically involves writing software in the framework of a controller
- Eventually it could even be in a DPU or programmable switches (P4) for low-level real-time behaviour

User Perspective - Experiments

Radio/Network Development Software

- Users without specific radio/processing HW can use a site for development and testing purposes (ssh access) with the objective of pushing software improvements to companion OSS projects

- A user develops improved network function implementations using one of the CI/CD frameworks of companion projects (e.g. OAI,ORAN O-SC) used by SLICES-RI sites for CD. These go through the normal CI procedures (testing) and get deployed on SLICES-RI for larger-scale testing
  - Physical layer procedures
  - MAC-layer scheduling
  - Crypto functions

User Perspective - Experiments

Low-level access to radio ressources

- Experiment with candidate 6G technologies. This will typically involve insertion of hardware elements into sites such as
  - Novel RF devices such as antennas, RIS, optical wireless devices, THz radios…
  - Hardware accelerators for key functions like channel decoders, cryptographic functions, user-plane packet-processing
  - Real-time edge devices (TSN, real-time multimedia, industrial IoT, etc.)
- Once inserted (or provided by sites) users can reserve time to develop and test scenarios using these devices

User Perspective - Experiments

Joint use of Post5G infrastructure services and SLICES-RI HPC resources

- **Example 1: Real-time Digital twin of radio network**
  - GPU farms can be used as real-time 3D radio emulators. When interconnected with radio and core network infrastructure can make a digital twin of a deployed network
  - This requires tight interconnection between radio processing infrastructure and the GPU farm but can be used to perform experiments not possible on the real network (large number of terminals).
  - Novel aspect, joint radio and digital twin. This requires proximity of HPC and real radio infrastructure

- **Example 2: Code analysis and bug fixing**
  - Protocol implementations are bug-ridden. In the CI/CD Type 3 experiment, developers of OSS networking software can make use of SLICES-RI GPU farms for code analysis and bug fixing.
  - Today in projects like OAI, CI makes use of “simple” tools like `cppcheck` to analyze community contributions. Use of AI/ML tools will take this to another level.

Roadmap

- ***July 2023 - Initial PoC***
  - IEEE HPSR Tutorial (USA)
  - EUCNC demo
  - SLICES-SC Summer School tutorial
- ***June 2023 - December 23 lessons / Deployment . Consolidation . Lessons learned***
  - Buildup of initial SLICES-RI post-5G sites (Targeting 6 countries – 10 physical sites)
  - Blueprint will provide input for planning new sites
  - Alignment with O-RAN NGRG platform activities and SNS Streams C/D
  - Alignment with other International activities (OpenRANGym, Japan, Brazil, 6G hubs in Germany)
- ***January+ 2024 – SLICES-RI Pre-operation***
  - Development of required interfaces for SLICES-RI (portal, central cloud services, contribution to API development)
  - CD activities

slices RI

SLICES and EOSC Interoperability and Integration

EOSC: European Open Science Cloud

https://eosc-portal.eu/

Lessons learned

What is your scientific question?

No Reproducibility – No Science!

Essay

Why Most Published Research Findings Are False

John P. A. Ioannidis

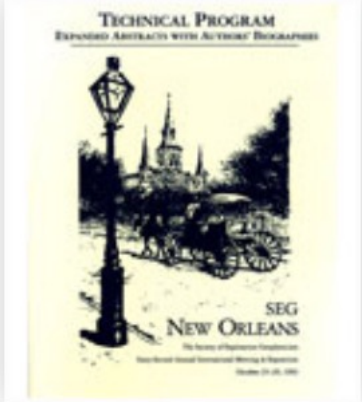
PLoS Medicine | www.plosmedicine.org 0696 August 2005 | Volume 2 | Issue 8 | e124

Summary

There is increasing concern that most current published research findings are false. The probability that a research claim is true may depend on study power and bias, the number of other studies on the same question, and, importantly, the ratio of true to no relationships among the relationships probed in each scientific field. In this framework, a research finding

slicesRI

SEG Technical Program Expanded Abstracts 1992



Electronic Documents Give Reproducible Research a New Meaning

RE1.3

Jon F. Claerbout and Martin Karrenbach, Stanford Univ.

SUMMARY

A revolution in education and technology transfer follows from the marriage of word processing and software command scripts. In this marriage an author attaches to every figure caption a pushbutton or a name tag usable to recalculate the figure from all its data, parameters, and programs. This provides a concrete definition of reproducibility in computationally oriented research. Experience at the Stanford Exploration Project shows that preparing such electronic documents is little effort beyond our customary report writing; mainly, we need to file everything in a systematic way.

In 1990 we began experimenting with electronic documents that merge our scientific software with our word-processing software. A year later we manufactured a CD-ROM containing a new textbook, Joe Dellinger's doctoral dissertation, and two progress reports of the Stanford Exploration Project. We distributed these CD-ROMs[1] to sponsors and many friends at the 1991 SEG meeting.

In 1990, we set this sequence of goals:

- Learn how to merge a publication with its underlying computational analysis.
- Teach researchers how to prepare a document in a form where they themselves can reproduce their own research results a year or more later by "pressing a single button".
- Learn how to leave finished work in a condition where coworkers can reproduce the calculation including the final illustration by pressing a button in its caption.
- Prepare a complete copy of our local software environment so that graduating students can take their work away with them to other sites, press a button, and reproduce their Stanford work.
- Merge electronic documents written by multiple authors (SEP reports).
- Export electronic documents to numerous other sites (sponsors) so they can readily reproduce a substantial portion of our Stanford research.

We met all these goals and set new ones:

- produce all new documents in this form, including lab reports in formal classes and "lab notebooks" of research progress.
- make incremental improvements in electronic-document software
- seek partners for broadening standards (and making incremental improvements).

Our basic goal is reproducible research. The electronic document is our means to this end. In principle, reproducibility in research can be achieved without electronic documents and that is how we started. Our first nonelectronic reproducible document was a textbook in which the paper document contained the name of a program script in every figure caption. The program scripts were organized by book chapter and section so they could be correlated to an accompanying magnetic tape dump of the file system. The magnetic tape also contained all the necessary data to feed the program script.

Now that we have begun using CD-ROM publication, we can go much further. Every figure caption contains a pushbutton that jumps to the appropriate science directory (folder) and initiates a figure rebuild command and then displays the figure, possibly as a movie or interactive program. We normally display seismic images of the earth's interior, but to reach wider audiences, Figure 1 shows a satellite weather picture which the pushbutton will animate as seen on commerical television. We include all our plot software as well as freely available software from many sources, including compilers and the LaTeX word processing system. Naturally we cannot include licensed software, but with the exception of Fortran and C compilers and the UNIX system itself, our publication includes source code for everything needed. The CD-ROM, at 680 megabytes, is so large we have had room for many executable programs on popular brands of workstations. The presence of these executables gives our readers a fast start.

Nearly everyone would rather read a paper book than the bitmapped page images on a screen that you see with an electronic document. But the illustrations in the electronic book are mostly in color, many are movies, and some are interactive. So the electronic book gives the reader a better understanding of the results. We typically use an interactive movie program to compare seismic sections where successive frames include processing with various parameters. The movie medium is much more informative than comparing seismic sections side by side. 3-D volumes are much better exhibited by movies than static paper illustrations. We are delivering a volume of software that is accessed like a book.

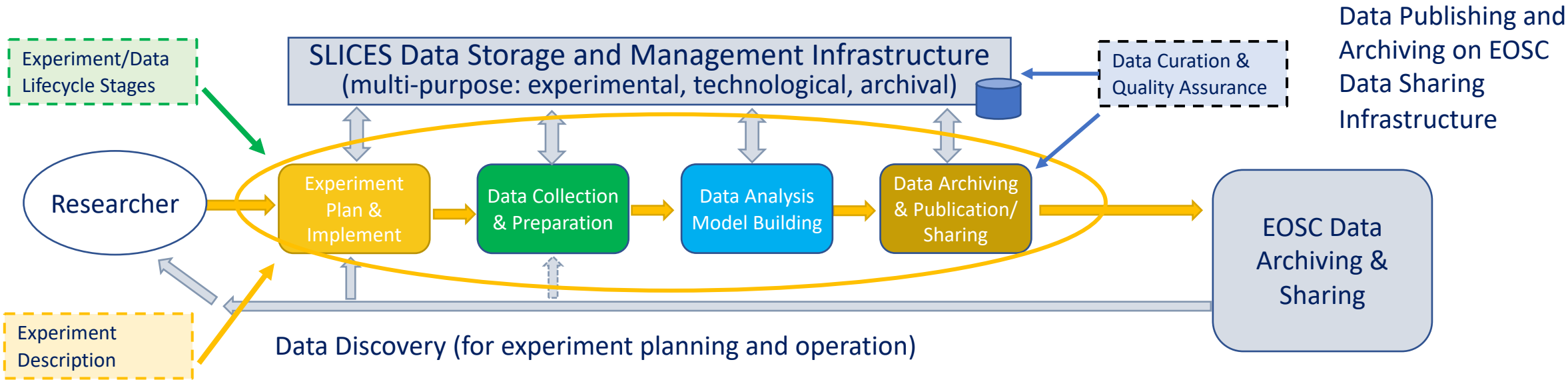
[1]SEP-CD-1 is available from Stanford University Press, $15 plus shipping, tel 415-723-1593

slicesRI

SLICES Full research lifecycle
Open data & Reproducibility

slicesRI

SLICES Experimental Data Lifecycle Model and Dataflow



- **Each Data Lifecycle stage** – experiment, data collection, data analysis, and finally data archiving, works with own **data set,** which must be **linked**.
  - All data sets need to be stored and possibly re-used in later processes.
- Many experiments and research require already existing datasets that will be available in SLICES data repositories or can be obtained/discovered in EOSC data repositories

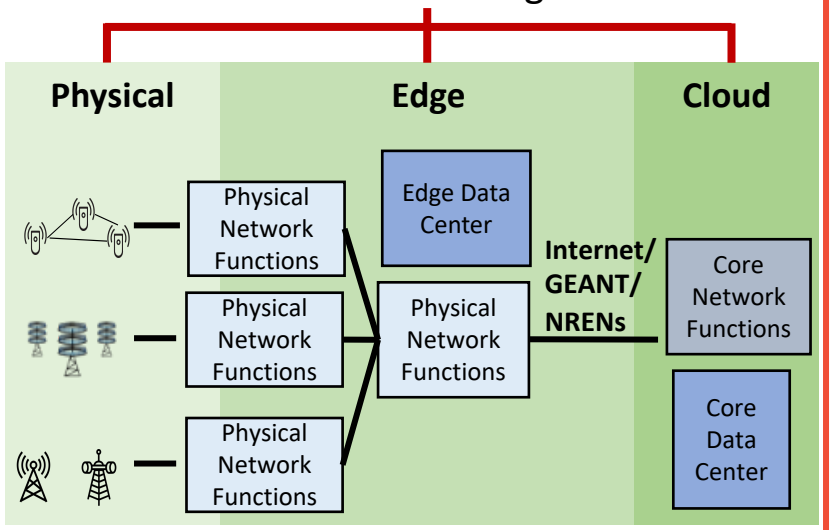
slicesRI

SLICES contribution to the development of the EOSC

slices RI ⟷ EUROPEAN OPEN SCIENCE CLOUD

Objectives: **federate existing research data infrastructures in Europe** and **realise a web of FAIR data** and **related services for science.**

#1 Enable experimentation at multiple network levels through **SLICES RI**



Allow experimentation with future/emerging digital, IT and network technologies (e.g., 6G, IoT, Edge, AI, hyper-converged infrastructure).

#2 EU-wide availability of **unique Software and App Repositories**

- ICT research-related services (e.g., testing new infrastructure and network solutions);
- Applications deployed within SLICES;
- Simulation tools;
- Data analysis tools.

Published in the EOSC Catalog and Marketplace and accessible with different access options.

open access

Orderable via provider channel

Orderable via EOSC hub

#3 Interoperability with **Open and FAIR data**

- Producers of unique data;
- Maximize data reuse by adopting of FAIR data principles in Data Management and Governance;
- Processing of sensitive and personal information.

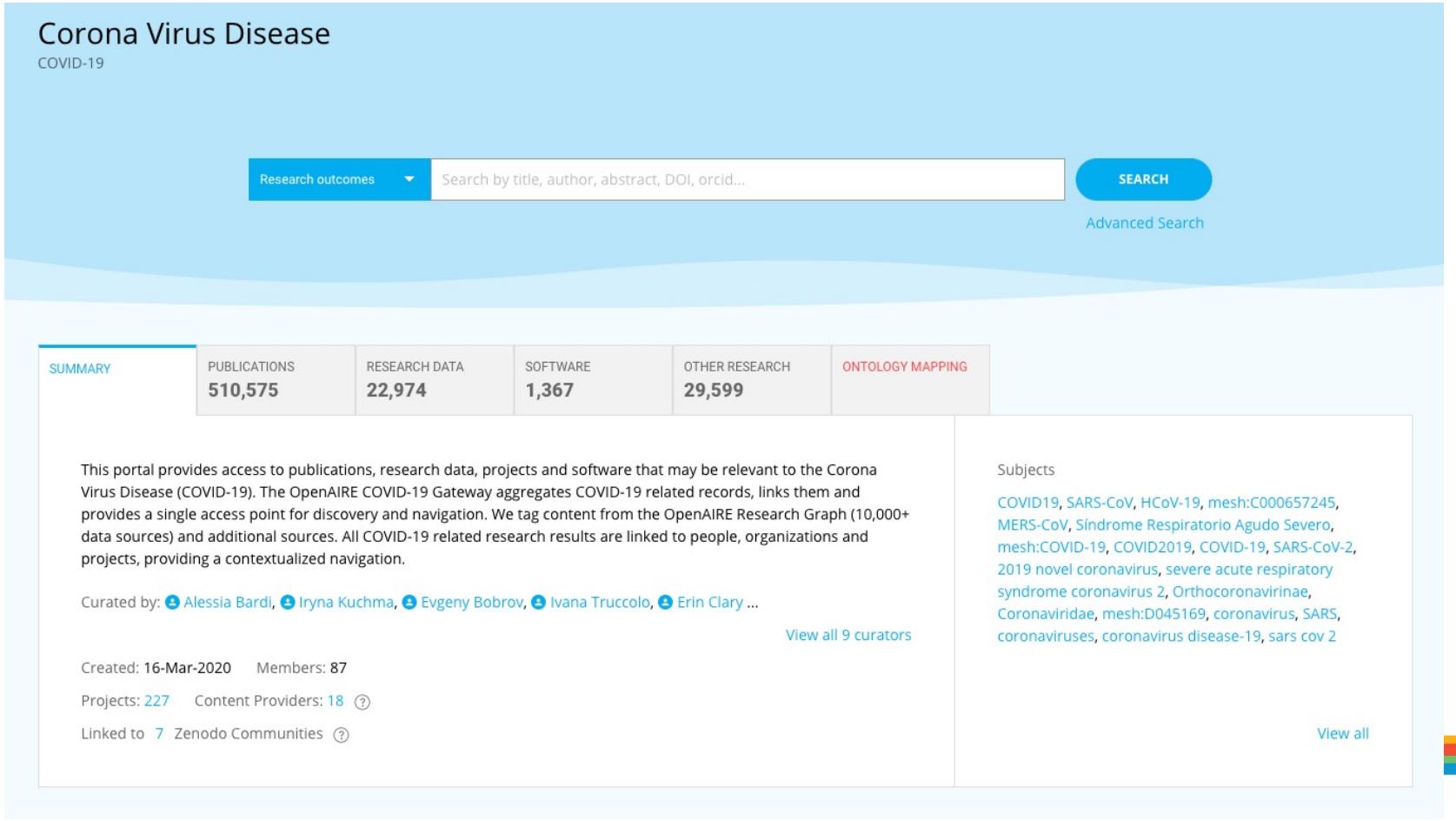
#4 Integration of the **SLICES communities to EOSC**

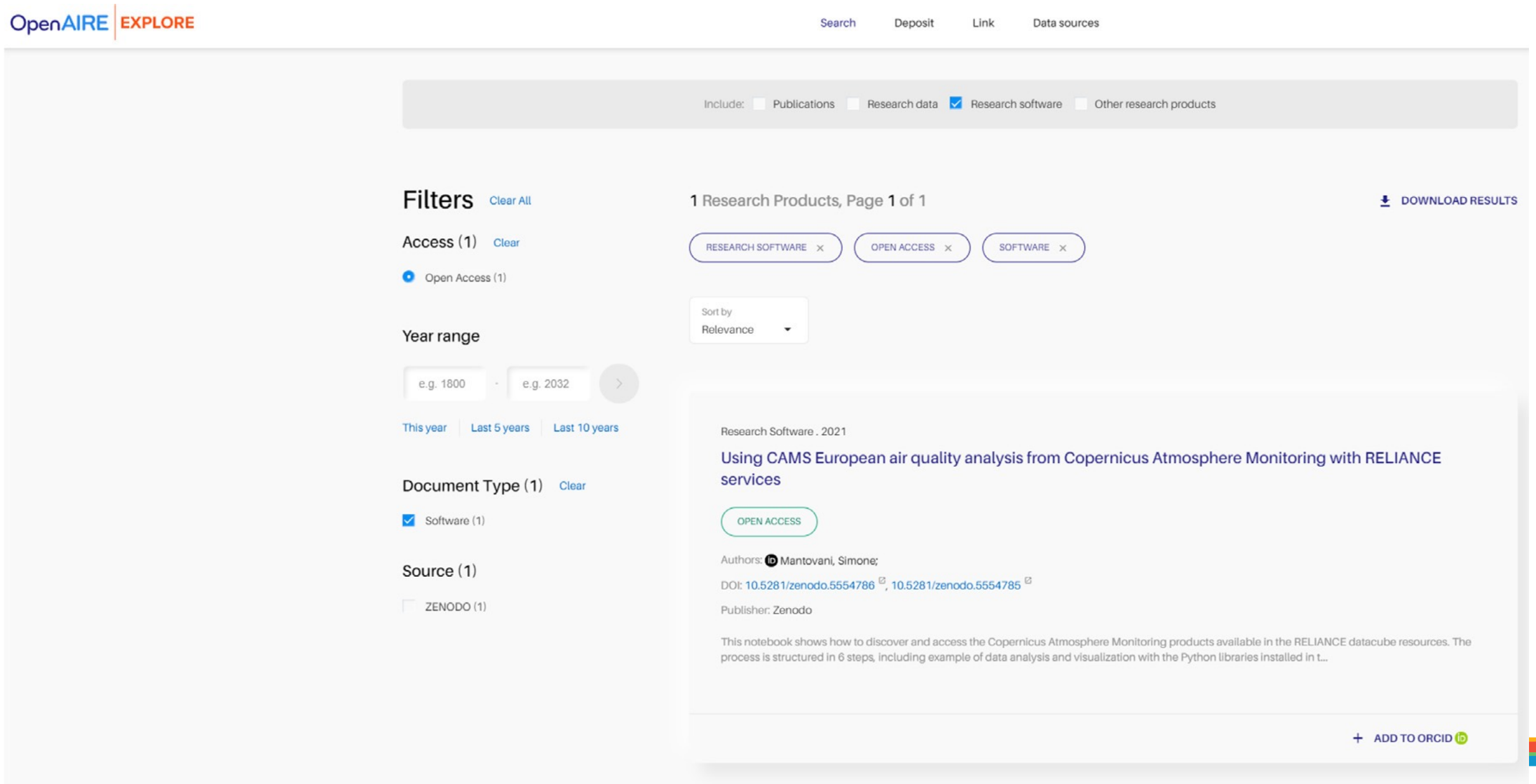
- SLICES community building
  - More than 120 participants to the 1st SLICES workshop;
  - Thousands of users of existing infrastructures.
- Training services

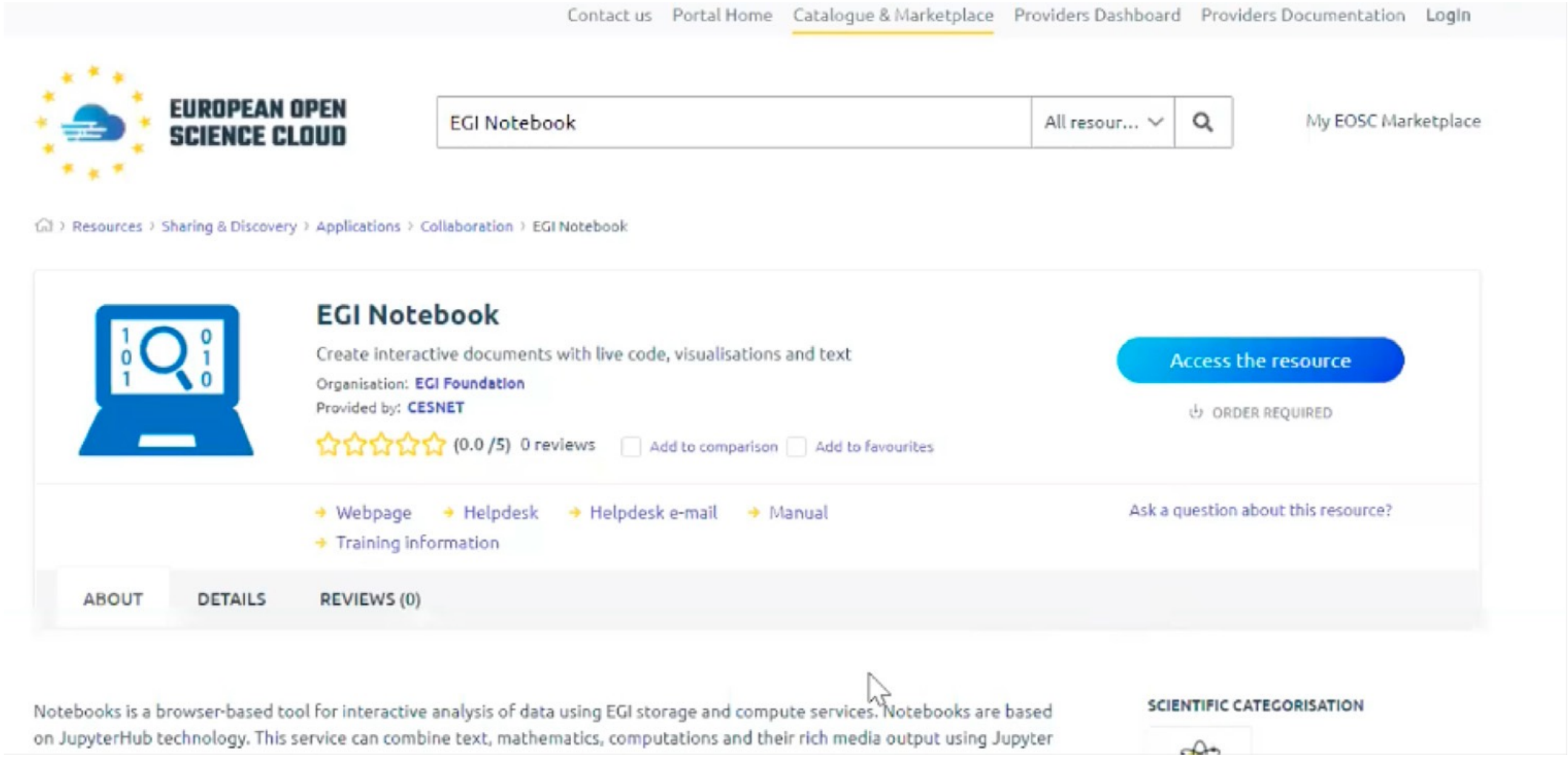
slices RI

Empowering Communities

OpenAIRE explorer: https://beta.openaire.eu/




OpenAIRE EXPLORE
Search
Deposit
Link
Data sources
Include:
Publications
Research data
Research software
Other research products
Filters
Clear All
Access (1)
Clear
Open Access (1)
Year range
e.g. 1800
e.g. 2032
This year
Last 5 years
Last 10 years
Document Type (1)
Clear
Software (1)
Source (1)
ZENODO (1)
1 Research Products, Page 1 of 1
DOWNLOAD RESULTS
RESEARCH SOFTWARE
OPEN ACCESS
SOFTWARE
Sort by
Relevance
Research Software . 2021
Using CAMS European air quality analysis from Copernicus Atmosphere Monitoring with RELIANCE services
OPEN ACCESS
Authors: Mantovani, Simone;
DOI: 10.5281/zenodo.5554786, 10.5281/zenodo.5554785
Publisher: Zenodo
This notebook shows how to discover and access the Copernicus Atmosphere Monitoring products available in the RELIANCE datacube resources. The process is structured in 6 steps, including example of data analysis and visualization with the Python libraries installed in t...
ADD TO ORCID


Contact us
Portal Home
Catalogue & Marketplace
Providers Dashboard
Providers Documentation
Login
EUROPEAN OPEN SCIENCE CLOUD
EGI Notebook
All resour...
My EOSC Marketplace
Resources › Sharing & Discovery › Applications › Collaboration › EGI Notebook
EGI Notebook
Create interactive documents with live code, visualisations and text
Organisation: EGI Foundation
Provided by: CESNET
(0.0 /5) 0 reviews
Add to comparison
Add to favourites
Access the resource
ORDER REQUIRED
Webpage
Helpdesk
Helpdesk e-mail
Manual
Training information
Ask a question about this resource?
ABOUT
DETAILS
REVIEWS (0)
Notebooks is a browser-based tool for interactive analysis of data using EGI storage and compute services. Notebooks are based on JupyterHub technology. This service can combine text, mathematics, computations and their rich media output using Jupyter
SCIENTIFIC CATEGORISATION

slicesRI

LIVE MANUAL EXECUTABLE RESEARCH OBJECT PUBLIC

EARTH SCIENCES

Uploaded 23 January 2022 (22:30)

PM10 in France Jupyter notebook demonstrating the usage of CAMS European air quality analysis from Copernicus Atmosphere Monitoring with RELIANCE services

Resources 10

Anne Fouilloux, Jean Iaquinta

This Research Object demonstrates how to use CAMS European air quality analysis from Copernicus Atmosphere Monitoring with RELIANCE services and compute monthly map of PM10over a given geographical area, here France

Focus on SLICES-EOSC Interop & Integration

Requirement: Compatibility and compliance with the EOSC Interoperability Framework

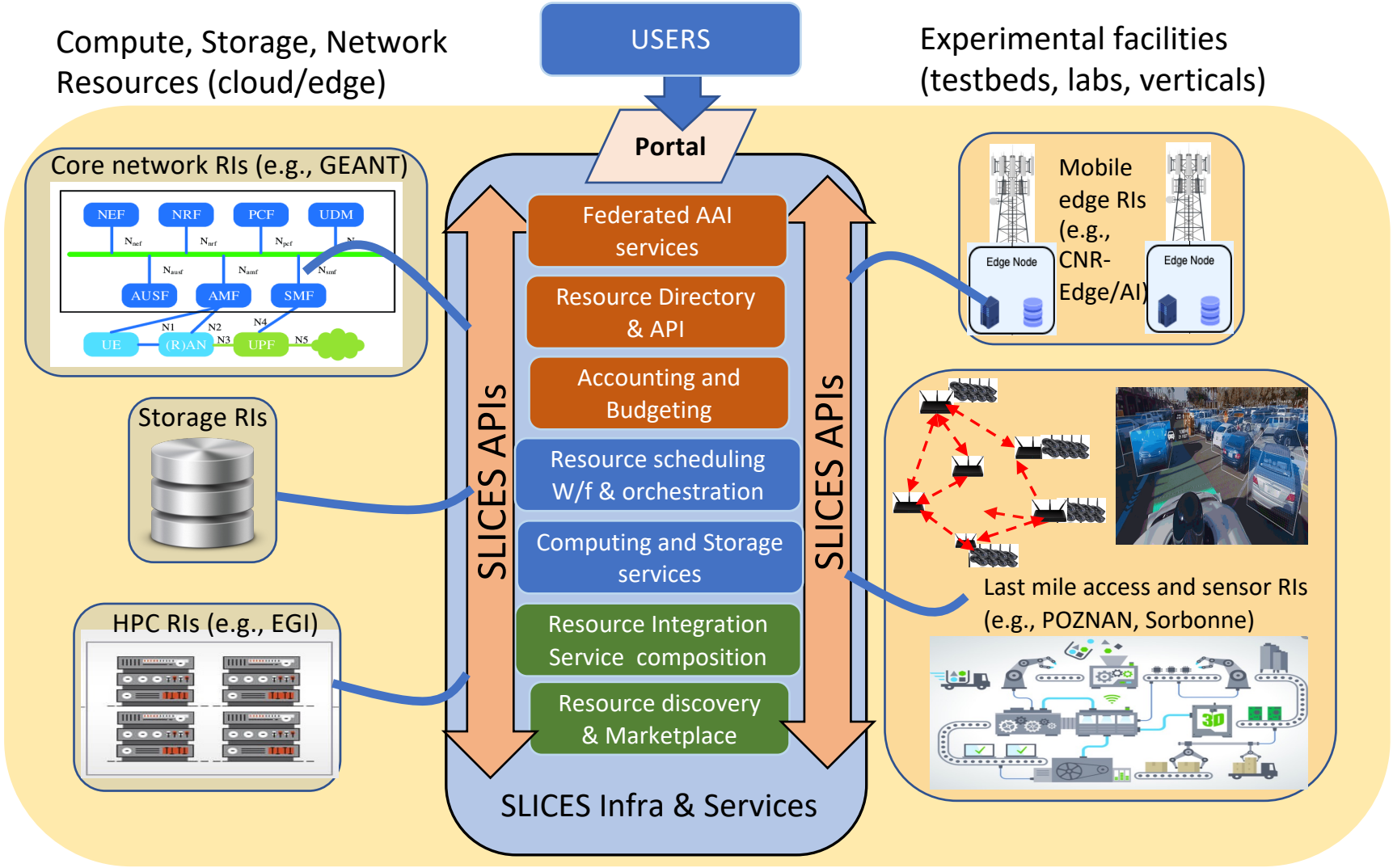
1. ***Minimum viable infrastructure***/service model for SLICES regional nodes
2. ***Integration with the EOSC***, external and domain specific RIs, and public clouds
3. API design approach to effectively ***manage and publish SLICES-RI resources and services***
   - Differentiating accessibility zones/profiles: site local, SLICES internal, and external access modes
   - Federated access control and zero-trust security model (explicit identity and access session mgnt)
4. Data Management & Governance: Define ***metadata*** to be used for the resource and experimental facilities description. Define metadata for sharing and publication of data produced by SLICES.
   - Well defined metadata for research publications/data but limited metadata profiles for infrastructure resources and experimental data

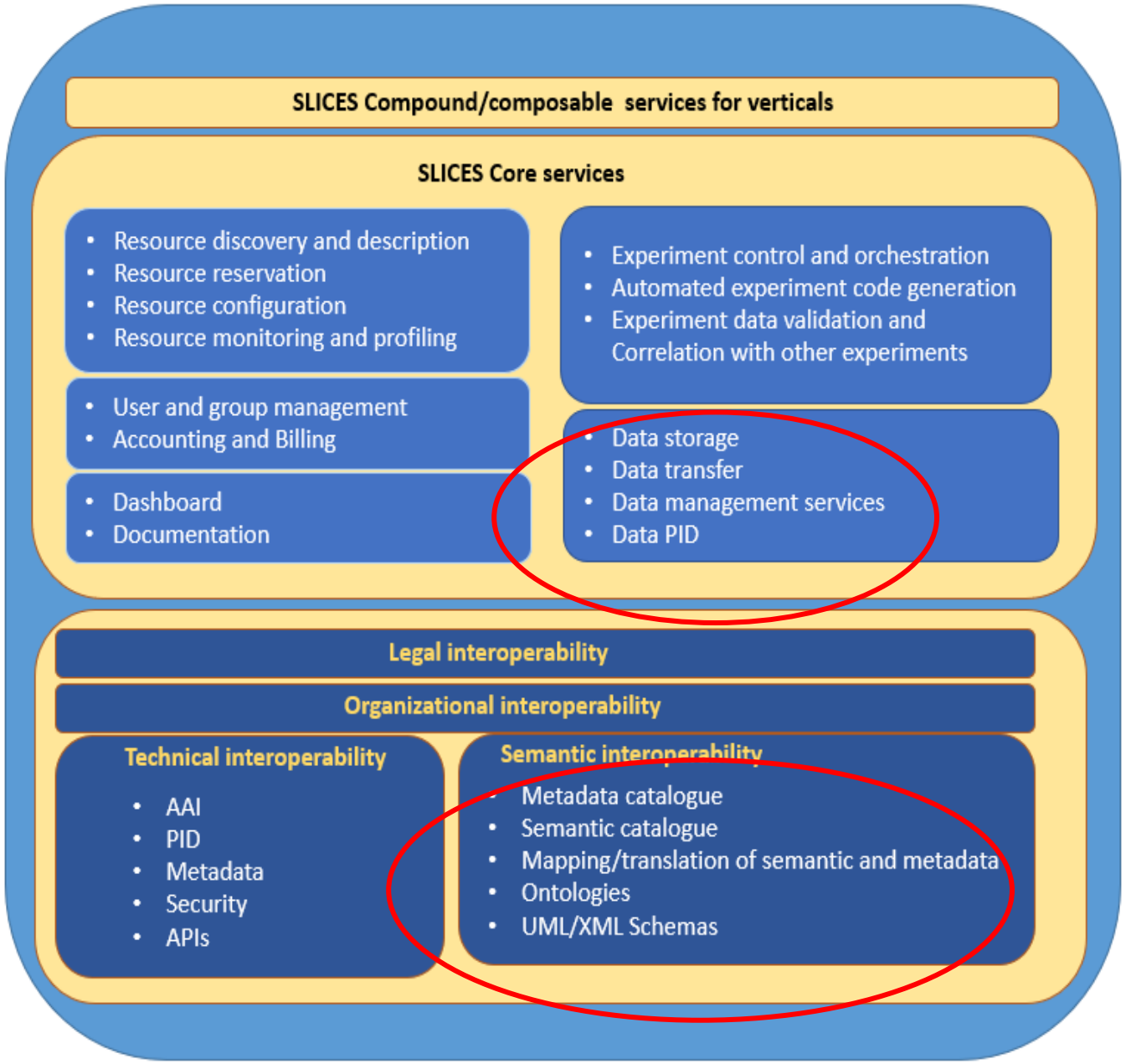
SLICES Interoperability and Integration Architecture Model

- Common model for connecting to internal and external resources and services
  - Cloud native and IoT – Edge – Cloud continuum
- SLICES Common Infrastructure and Services
  - Platform for experimental research automation and SLICES Core services interoperable with EOSC
- SLICES Portal and Catalogue
  - To be federated with EOSC Catalog and Portal
  - API to SLICES services and data to be published
- SLICES Data Management and Governance: Infrastructure, Services, Policy
  - FAIR data principles and PDI infrastructure

slicesRI

SLICES Interoperability and Integration Architecture





Conceptual view of the SLICES Interoperability Architecture

- Provides vision and roadmap to achieving interoperability with EOSC
  - Interoperability layers: Technical, Semantic, Organisational, Legal
- Some services can be used from EOSC, some services will require API with EOSC services of metadata mapping
- Data Interoperability and sharing is an important component of SLICES-RI
  - Compliance with the Open Science and FAIR data principles
  - Semantic interoperability
  - Supported by robust data infrastructure
  - Data Management and Governance

SLICES Reproducible Experiment Workflow

NSF 23-018

Dear Colleague Letter: Reproducibility and Replicability in Science

October 25, 2022

Dear Colleagues:

A 2019 consensus study report published by the National Academies of Sciences, Engineering, and Medicine (NASEM) discussed the meaning of the terms replicability and reproducibility and identified approaches for researchers, academic institutions, journals, and funders to improve reproducibility and replicability in science [1]. In July 2021, at NSF's request, NASEM convened an expert meeting focused on National Science Foundation (NSF) policies and investments to make reproducible and replicable science easier for scientific communities to understand and execute and to embed reproducibility and replicability within the fundamental scientific method.

Through this Dear Colleague Letter (DCL), NSF reaffirms its commitment to advancing reproducibility and replicability in science. NSF is particularly interested in proposals addressing one or more of the following topics:

1. **Advancing the science of reproducibility and replicability.** Understanding current practices around reproducibility and replicability, including ways to measure reproducibility and replicability, what reproduction and replication means in practice, the right degree of replicability to target, quantitative measures of progress to understand the effectiveness of interventions to improve reproducibility and replicability, and exploration of reasons why studies may fail to replicate.
2. **Research infrastructure for reproducibility and replicability.** Developing and facilitating adoption of cyberinfrastructure tools and/or research methods that enable use

No incentive, Regulation is needed

IEEE, ACM … should make the publication of data mandatory (in most venues)

slicesRI

Motivation for Reproducibility

Problems with reproducibility

- Two workshops at SIGCOMM conference dedicated to reproducible research:
  - SIGCOMM'03: MoMeTools workshop
  - SIGCOMM'17: Reproducibility workshop
  - Problems remained the same over 14 years

Best solution so far…

- Artifact Evaluation Committees & Reproducibility Badges
- Problems:
  - High effort
  - Potentially low robustness (CCR Apr. '2021 [1])

ACM's badges awarded by the Artifact Evaluation Committee

[1] N. Zilberman, "An Artifact Evaluation of NDP", Comput. Commun. Rev., vol. 50, no. 2, pp. 32–36, 2020

slicesRI

What is Reproducibility?

3-stage process according to ACM [2]:

1. **Repeatability:** *Same* team executes experiment using *same* setup
2. **Reproducibility:** *Different* team executes experiment using *same* setup
3. **Replicability:** *Different* team executes experiment using *different* setup

A testbed-driven approach targets the experimental setup:

- Focus on **repeatability** and **reproducibility**
- **Replicability** requires additional effort by others

[2] https://www.acm.org/publications/policies/artifact-review-and-badging-current

Reproducibility-as-a-Service

How can we limit the effort spent on reproducibility?

- Reduce amount of work for experimenters to create reproducible experiments
- Reduce amount of work for other researchers to recreate experiments
- Make reproducibility an integral part of experiment design

➢ Automate entire experiment (setup, execution, evaluation)

How can we create robust, reproducible experiments?

- Document all relevant parameters for experiments
- Automate the documentation of experiments

➢ Well-structured experiment workflow serving as documentation

slicesRI

Testbed-driven Experiments

The plain orchestrating service (pos) [3], a framework for reproducible experiments:

1. A testbed management system
2. A well-defined experiment workflow

Achieving Repeatability

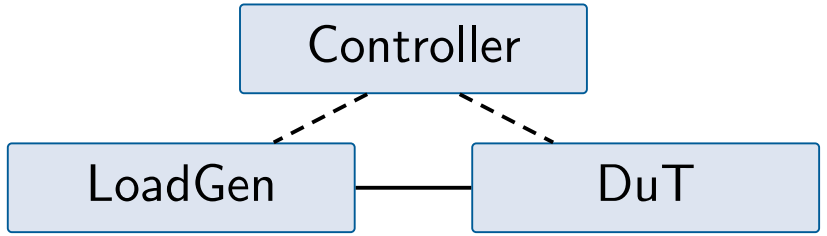
- Automation & Linux Live Images
  - Researchers **must** automate configuration
  - No residual state between reboots

➢ Experiments become **repeatable**

Achieving Reproducibility

- Providing access to experiment infrastructure
- Other researchers can easily (re-)run experiment

➢ Experiments become **reproducible**



Minimal Experiment Topology

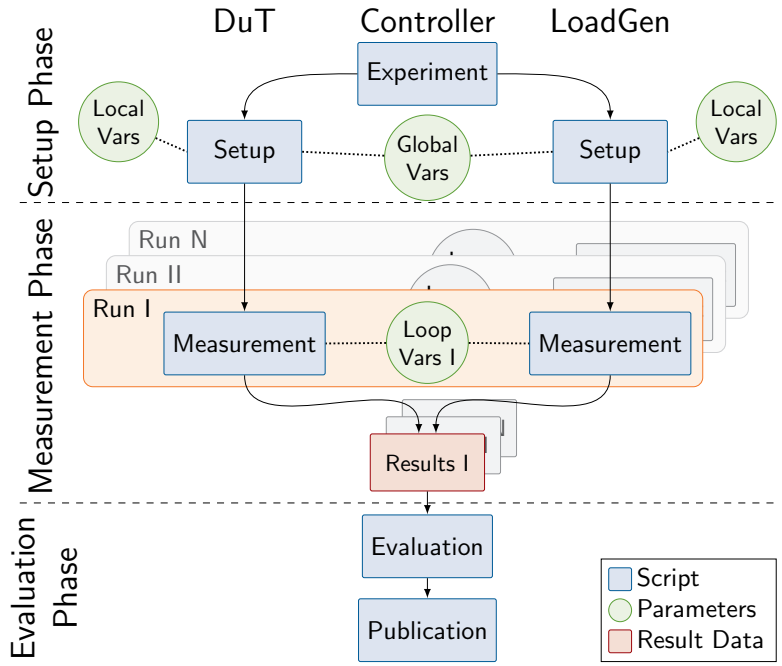
[3] S. Gallenmüller, D. Scholz, H. Stubbe and G. Carle, “The pos Framework: a Methodology and Toolchain for Reproducible Network Experiments,” in ACM CoNEXT‘21, https://dl.acm.org/doi/10.1145/3485983.3494841

Experiment Workflow

Setup phase
- Controller manages experiment
- Controller configures experiment nodes (DuT, LoadGen)
- Global/local variables (vars) parametrize setup

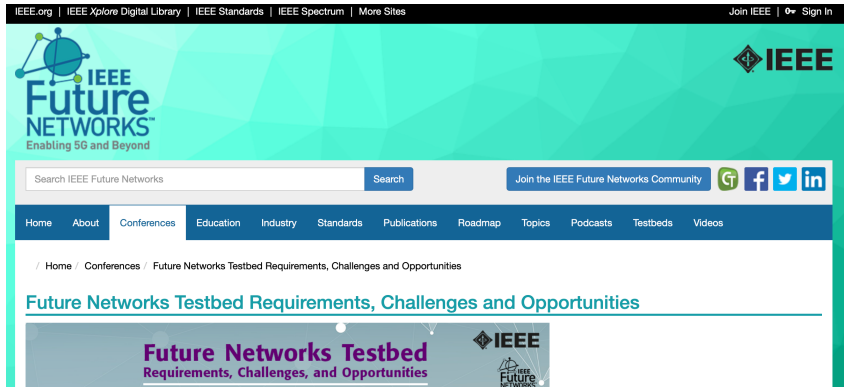
Measurement phase
- Repeated execution of measurement script
- Loop variables parameterize each measurement run
  - e.g., different packet rates
  - data of each run is connected to a specific set of loop vars

Evaluation phase
- Collected results/loop vars used for experiment evaluation
- Automated experiment release (git repository, website)



Structured Experiment Workflow with pos

Establishing SLICES as a transformative initiative



OPEN AIR INTERFACE

NETWORLD EUROPE

General Assembly

CET	13th December	
09:30	Welcome, opening of the meeting	Rui Aguiar
09:40	Elections process - last call for voting + overview of membership	Uwe Herzog
09:50	NetworldEurope Brief overview of 2022	Rui Aguiar
10:05	The SLICES ESFRI infrastructure	Serge Fdida
10:25	The German 6G Initative	Hans Schotten
10:45	Coffee Break (virtual)	
11:05	HE programme and SNS call 1 results	Peter Stuckman
11:35	6G IA - SNS upcoming workprogram	Colin Willcock
12:05	The Hexa-X view on 6G networks	Mikko Uusitalo
12:25	Lunch break (also virtual)	
13:25	Overview of the different WGs	Jacques Magen, Ari Pouttu, Tomaso de Cola, Maziar Nekovee
14:05	The SRIA 2022 presentation	Ari Pouttu
14:25	Steering board election announcements	Uwe Herzog

B5GPC

Beyond 5G Japan

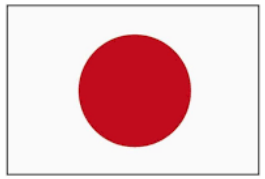
10:20~ (60min: 15min *4)	Subcommittee① -R&D session-	Palazzo, Tsuru (West)	Open RAN	Beyond 5G advanced technology
			Mr, Alex Botting, ORPC(Open RAN Policy Coalition)	Mr. Hideyuki IWATA, TTC
			Mr. Nozomu Watanabe, NEC	Ms. Yuko HANADO, NICT
			Mr. Larry Peterson, Open Networking Foundation	Dr. Andreas Müller, Bosch
			Prof. Serge Fdida, University of Sorbonne of France	Mr. Kazunori Sakumoto, Fujitsu

SLICES International value

SLICES able to engage a large community
SLICES Academy
SLICES Blueprint

- Baseline software components that will form the backbone of SLICES



Stimulate cooperation with important stakeholders

- ***EU:*** SNS program (Stream C)
- ***USA:*** NSF PAWR, ONF/Aether/OAI
- **Brazil:** RNP
- ***Japan***: NICT BY5G/6G?

Thanks for your attention

Questions?

For more information, please contact:
Serge Fdida
serge.fdida@sorbonne-universite.fr

Follow the *NetworkingChannel*,
brought to you by
ESFRI SLICES, NSF PAWR and ACM Sigcomm

Experience with Aether deployment

Options for deploying Aether:

- Aether-in-a-Box on Hardware Radios
  - AiaB: SD-Core / UPF/ ROC
  - Sercomm Cell
  - SIM Cards and End Devices needed
- Aether-in-a-Box for Developers
  - AiaB: SD-Core / UPF/ ROC
  - OAISIM needed

slicesRI

Our Setup

- Cloud Native Tools:
  - Openstack
  - Kubernetes

} **SD-Core Network Functions**

- Cells:
  - 2 CBRS LTE Sercomm → **Aether-in-a-Box on Hardware Radios**
  - OAI SIM → **Aether-in-a-Box for Developers**

- UEs:
  - iPhone 11

slicesRI

CONNECTING WITH OTHER TESTBEDS

AETHER

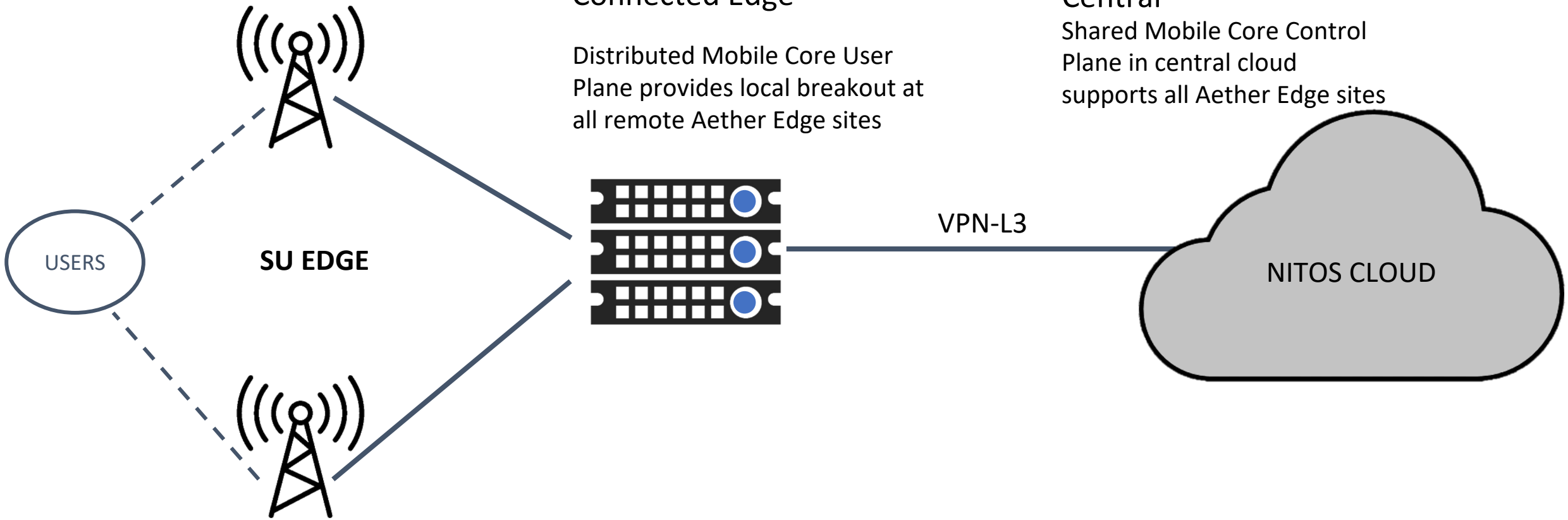
Connected Edge

Distributed Mobile Core User Plane provides local breakout at all remote Aether Edge sites

Shared Mobile Core Control

Central

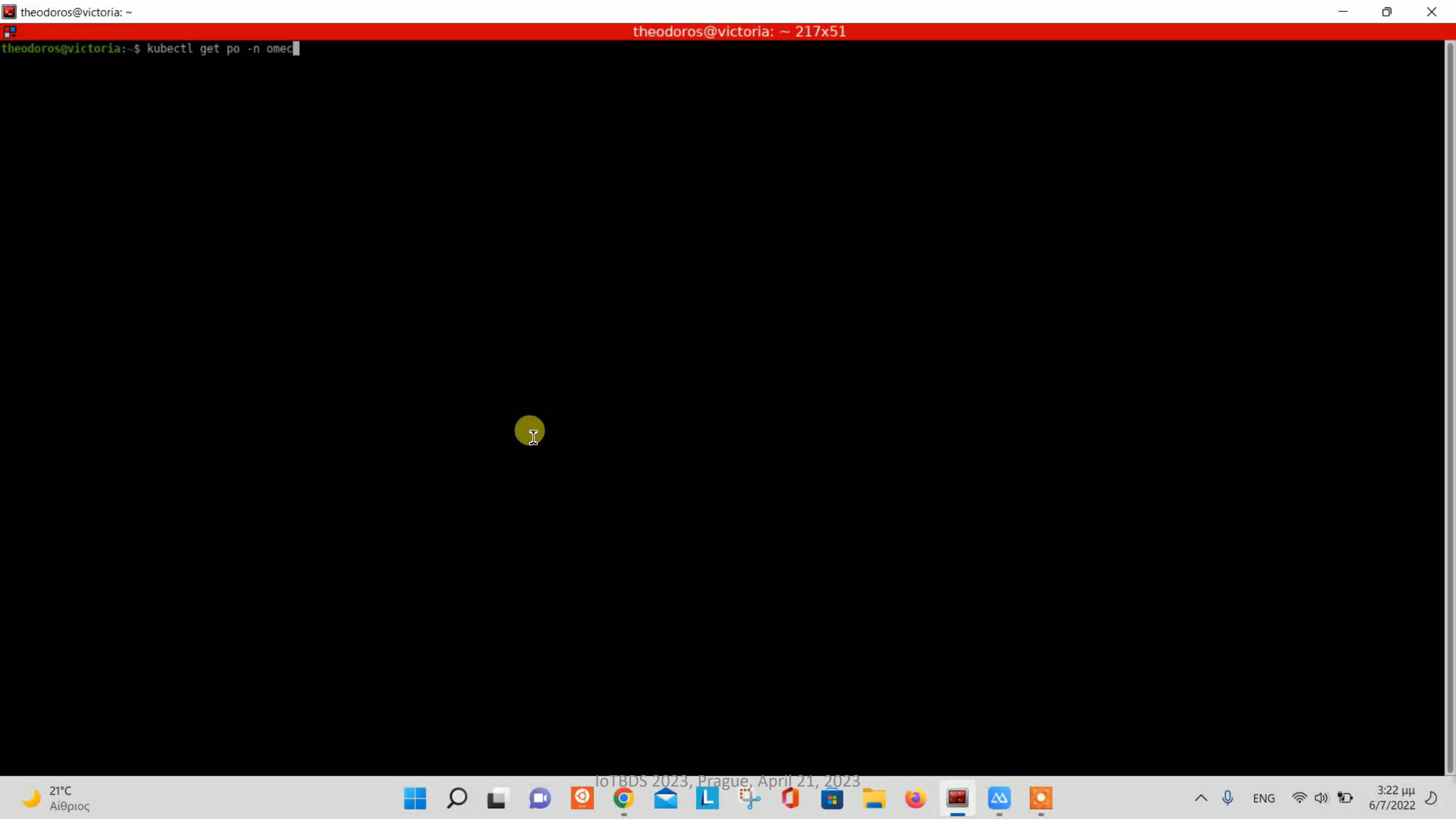
Shared Mobile Core Control Plane in central cloud supports all Aether Edge sites



slicesRI

Aether in a Box - démo

https://www.youtube.com/watch?v=bq4wu5w2_8c


theodoros@victoria: ~
theodoros@victoria: ~ 217x51
theodoros@victoria:~$ kubectl get po -n omec