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SOBIGDATA.it
ITALIAN RESEARCH INFRASTRUCTURE

WP 1 EMPOWERING THE DIGITAL BACKBONE

D.1.2

PLAN FOR THE ACQUISITION AND INSTALLATION OF NEW COMPUTATIONAL RESOURCES

Finanziato dall'Unione europea NextGenerationEU | Ministero dell'Università e della Ricerca | Italiadomani Piano Nazionale di Ripresa e Resilienza | SOBIGDATA Italian Research Infrastructure | Consiglio Nazionale delle Ricerche

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EXECUTIVE SUMMARY

The SoBigData Research Infrastructure (RI) has the ambition to support the rising demand for cross-disciplinary research and innovation on the multiple aspects of social complexity from combined data and model-driven perspectives and the increasing importance of ethics and data scientists' responsibility as a pillar of trustworthy use of Big Data and analytical technology. Digital traces of human activities offer a considerable opportunity to scrutinise the ground truth of individual and collective behaviour at an unprecedented detail and on a global scale.

Work Package 1 (WP1) focuses on the creation of computational nodes within the SoBigData RI by connecting data centres to the RI network. This initiative aims to enhance the RI storage and computing capabilities, ensuring both short and long-term scalability, robustness, availability, and reliability of services. Furthermore, it integrates state-of-the-art nodes in the domains of pervasive computing and networking, as well as beyond 5G networks. These nodes are built using the latest-generation architectures and technologies, encompassing edge and far-edge devices, the Internet of Things (IoT), and next-generation networks. By adopting this comprehensive approach, SoBigData provides access to state-of-the-art data centres while embracing advanced solutions for decentralised data centres of the future. This decentralised infrastructure spans from the cloud to the network periphery, forming a continuum of distributed data processing and networking resources.

This Deliverable documents the plan for the acquisition and installation of new computational resources. The deliverable consists of 5 sections: Section 1 briefly introduces the role of this deliverable and highlights the composition of the infrastructure and its organisation in a multi-site, comprising central and peripheral sites. Sections 2, 3, and 4 provide detailed plans for the acquisition and installation of computational and hardware resources related to green data centres, pervasive computing, and beyond 5G networks. Specifically, Section 2 outlines the plan for green data centres. Section 3 focuses on the plan for pervasive computing and networking nodes. Section 4 details the plan for implementing the architectural framework of the infrastructure representing the beyond 5G node. Finally the report concludes with Section 5.

GLOSSARY

Acronym	Extended name
AI	Artificial Intelligence
API	Application Programming Interface
CPU	Central Processing Unit
GB	Giga Byte
GPU	Graphics Processing Unit
HTTP	HyperText Transfer Protocol
PNRR	Piano Nazionale di Ripresa e Resilienza
RAM	Random Access Memory
RI	Research Infrastructure
TB	Tera Byte
UPS	Uninterruptible Power Supply
VRE	Virtual Research Environment
WP	Work Package

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1 INTRODUCTION

Work Package 1 (WP1) is responsible for the empowering and creation of SoBigData computational nodes. These nodes will be created through the connection of data centres to the Research Infrastructure (RI) network. This initiative aims to increase the RI's capacity in terms of storage and computing power, ensuring the support of both short and long-term scalability, robustness, availability, and reliability of services. In Addition, the RI will integrate a series of cutting-edge nodes related to "pervasive computing & networking" and "beyond 5G network" domains. These nodes will be constructed using the latest-generation architectures and technologies, encompassing edge and far-edge computing, Internet of Things (IoT), and next-generation networks. By adopting this approach, SoBigData will offer access to state-of-the-art "data centres of today," while also incorporating advanced solutions for the "decentralised data centres of tomorrow." These decentralised centres will consist of a continuum of distributed data processing and networking resources, spanning from the cloud to the network periphery.Through these efforts, SoBigData aims to position itself at the forefront of experimentally-driven research, supporting its future scalability, and ensuring its alignment with the evolving landscape of research in data analytics, artificial intelligence (AI), distributed systems, and networking.

The SoBigData distributed computing infrastructure is organised as a multi-site digital infrastructure with a central hub and peripheral sites. The central hub is located in CNR-ISTI and will also be responsible for the Identity and Access Management (IAM) Service, the Information System, and the Resource Manager. The peripheral sites host most of the computing resources and the tailored storage devices that offer low-latency and efficient storage solutions for supporting large and complex data analytics processes. The pervasive computing & networking nodes and the beyond 5G network nodes will be integrated into this framework, and their resources will be provided via the common IAM and Resource Manager services. This approach (system of systems) will give: a good grade of autonomy at node level (independence and evolution), openness (join and leave; dynamic reconfiguration); distribution (interdependence and interoperability) which makes it easier to define policies for the addition of new nodes to the RI. All physical resources of the infrastructure will be manageable through a single platform for both hardware and software layers, which will simplify the RI management, enhance the scaling of the RI through a single platform for both hardware and software layers, enhance the scaling of the RI deployment, and reduce the total cost of ownership.

The remainder of the document is as follows: Section 2, Section 3, and Section 4 all describe in detail the plan for the acquisition and installation of the new computational and hardware resources related to the above described technologies. Specifically, Section 2 reports on the plan for the green data centres of the multi-site digital infrastructure both in the central hub and in the peripheral sites. Section 3 reports on the plan for the pervasive computing & networking nodes, devoted to creating one of the distributed nodes supporting edge computing and pervasive intelligence services focused on virtualised resource management in the edge-to-cloud continuum. Section 4 reports on the plan for the components to implement the architectural framework of the infrastructure representing the Beyond 5G node. Finally Section 5 concludes the report.

2 PLAN FOR THE GREEN DATA CENTRES

This section describes the plan for the acquisition and installation of new computational resources, aiming at empowering the existing computational nodes located at CNR-ISTI, where the central hub is located, and the peripheral sites at CNR-ICAR-SLSAS, CNR-ICAR-BMSA, UNIPI, UNIROMA1, including the new node at UNIVAQ.

The technological equipment deployed follows the concept of "Tier 4 ECO aisle." This concept entails the inclusion of a variable number of computational racks, each equipped with 8 servers boasting impressive specifications: 448 Cores and 896 Threads, 4096 GB RAM, 215 TB of SSD disks, and 4 GPUs. To ensure flexibility, each node will adjust the size of its Eco aisle according to the budget allocated for its specific activities.

2.1 CNR-ISTI Central Hub

The data centre in the central hub must be designed to comply with the recommended practices outlined in the document CEN-CENELEC CLC TR50600-99-1 "Data centre facilities and infrastructures - Part 99-1: Recommended practices for energy management." Additionally, it will adhere to the self-regulatory initiative called the "Climate Neutral Data Center Pact," which data operators and infrastructures have defined to contribute to the European Green Deal.

Therefore, the requested solution entails the following supplies:

- **Supply 1: Aisle Containment**

  Provision of an aisle containment for the proper management of thermodynamic flows in the server room, complete with the necessary conditioning system, continuity measures, and everything required for the E4M3 rating.

- **Supply 2: Computing Servers and GPUs**

  Provision of computing and storage resources organised in servers with GPUs suitable for typical usage in Cloud computing infrastructures for High-Throughput Computing (HTC) while being compatible with the existing infrastructure.

- **Supply 3: Networking**

  Provision of switches with optimal flexibility levels for cloud environments characterised by high storage and processing traffic, utilising a spine-leaf architecture. The switches should be equipped with cables for connectivity between switches and between switches and servers, in compliance with the existing D4Science infrastructure.

2.1.1 Detailed plan of the supplies

2.1.1.1 Aisle Containment Supply

The requested solution should include the following supplies:

- 8 racks with the following specifications:
- Width: 800mm, Depth: 1200mm, Height: 42U.
- 16 PDUs (Power Distribution Units).
- 3 air conditioning units ensuring N+1 redundancy.
- Provision for an additional air conditioning unit.
- 2 modular electric panels for the server room, remotely monitorable, both for input and output, with network analyzers and hot-swappable breakers.
- 1 containment aisle for thermodynamic flows.
- In terms of continuous power supply for the loads (servers), to comply with rating 3, the solution should consist of:
- 2 modular UPS (Uninterruptible Power Supply) with a 250 kW frame, each with:
- 3 power modules of at least 50 kW each to ensure N+1 redundancy.
- Battery cabinets provide a minimum autonomy of 5 minutes at 150 kW.
- The UPS units should be set up in adjacent rooms, together with the switchgear and control panels as per the rating 3 scheme.
- Any other components and services, even if not explicitly mentioned but necessary for the management, integration, and proper functioning of the supplied systems (e.g., connection cables, hardware/software configuration tools, management and monitoring tools, firmware, etc.), should also be included in the supply.

Synoptic Table of the Aisle Supply

Quantity	Description
1	Aisle
8	Racks
1	Predisposition for additional racks
16	PDUs
2	Electrical Panels

3	Air conditioners with support for indirect free-cooling
1	Arrangement for 4 air conditioners
1	UPS 250 KW
3	50 KW battery modules
1	UPS room air conditioner
2	Switching and command panels for the service rooms
1	Additional 250 KW UPS (optional)
3	additional 50 KW battery modules (optional)
1	additional UPS room air conditioner (optional)
1	Assembling the containment aisle
1	Transportation and placement
1	Activation of the conditioning system, continuity and electrical panels
1	Data center mechanical system for lengths up to 50 meters between indoor and outdoor units
1	Data center electrical system
1	Activation of additional system

Aisle Containment Topology

The provision of the aisle should involve the design of 3 rooms. The first room, called the server room, should be used for containing the aisle and the air conditioning systems. The second and third rooms, referred to as technical rooms, should be designated for housing the electrical panels, UPS units, battery packs, and dedicated air conditioning systems for the UPS room.

As an example, the following diagram illustrates a potential organisation of these areas.

The requested design should be modular, allowing for the possibility of adding racks and air conditioners in both the room hosting the containment aisle and the UPS rooms. Additionally, provision should be made for additional battery packs to increase autonomy under UPS power.

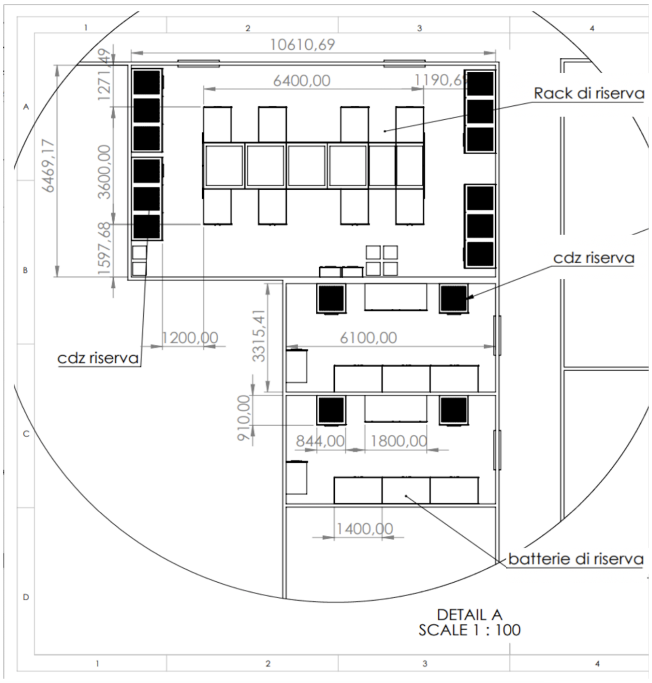


Figure 1: Potential Organisation of the 3 rooms for Aisle supply

2.1.1.2 Computing Servers and GPUs Supply

This supply consists of computing and storage resources organised in a modular and scalable server, suitable for typical usage in Cloud computing infrastructures for managing High-Throughput Computing (HTC).

The server models identified for this supply is as follows:

- 24 Dell PowerEdge R840 with 96 Cores/192 Threads CPU, 1512 GB memory, 23.04 TB disk, 1600W dual power each.

- 1 Dell PowerEdge R750XA GPU with 64 Cores/128 Threads CPU, 1024 GB memory, 15.36 TB disk, 4X Nvidia A100 80GB GPU, 2400W dual power.

The specific type of server and its components are chosen to extend the existing D4Science computational infrastructure, which is composed of multiple servers. In particular, all GPUs managed by the infrastructure are compatible with the Dell PowerEdge R750XA GPU. Therefore, there is a requirement for close compatibility in terms of components and characteristics.

The capacity and features of the D4Science infrastructure serving SoBigData and the planned extensions of the Pisa site are outlined in the table.

Type	Servers	Power (KW)	CPU cores	RAM (GB)	Storage (TB)
D4Science	86	94	6,840	43,704	1132.68
Dell PowerEdge R840	24	38.4	4,608	36,288	552.96
Dell PowerEdge R750XA GPU	1	2.4	128	1,024	15.36

2.1.1.3 Networking Supply

The object of this supply includes:

- SPINE Switch: 2 devices
- LEAF Switch: 6 devices
- AOC cables for LEAF and SPINE interconnection
- DAC cables for interconnection
- Any other components and services, even if not explicitly mentioned but necessary for the management, integration, and proper functioning of the supplied systems (e.g. connection cables, HW/SW tools for configuration, management, and monitoring, firmware, etc.) must also be included in the supply.

In order to guarantee a high level of integration between the components and effectiveness of support as a whole, the equipment subject to supply must all be manufactured/marketed by the same producer. All hardware and software parts of the supply must be officially marketed, appear in the manufacturer's catalogue, be in regular production without any announced end of maintenance or specialised support.

LEAF and SPINE devices within the manufacturer's portfolio must belong to the same product line/series.

The proposed architecture must allow multiple devices to act as a single logical device with separate and independent Data Plane, Control Plane, and Configuration Files. The proposed technological solution must be implemented by a data centre architecture based on a single topological level and, therefore, on a single logical device, capable of optimising traffic forwarding between different affiliated users. This architecture must also allow the exclusion of protocols that inhibit the utilisation of the entire available bandwidth, such as Spanning Tree, for example. The aforementioned architecture will be referred to as MLAG. MLAG and MC-LAG are equivalent terms representing the same system according to the defined standard. LAG systems that use proprietary and non-standard protocols will not be accepted.

Performing packet forwarding tasks within a line-rate device implies that this operation is implemented with network processors optimised for such functions and equipped with dedicated hardware (internal equipment in terms of hardware components for specific tasks ASIC, CAM, TCAM...) for table lookup, pattern matching, and header rewriting operations. The latency introduced by the packet processing chain must be negligible, within the limits of the current state of the art for data centre packet forwarding systems, compared to the theoretical latency of the device at the OSI layer on which it operates.

Packet classification, filtering, and policing activities in a mixed IPv4 and IPv6 environment, configured in addition to standard protocol forwarding operations, must not introduce latencies that impact the declared throughput of the device and its network interfaces.

Hardware redundancy mechanisms based on Layer 3 redundancy, which ensure the availability of packet forwarding capabilities within the entire LAG using standard protocols in active/passive mode or proprietary protocols in active/active mode, are not accepted. Connection to other switches and servers must be possible through static LAGs or IEEE 802.3ax Link Aggregation Control Protocol (LACP) without the use of proprietary protocols.

Synoptic Table of the Networking Supply

Quantity	Description
2	SPINE
2	Perpetual software license
2	60 months or more support for SPINE switches

6	LEAF switches
6	Perpetual software license
6	60 months or more support for LEAF switches
12	15-meter AOC 100G QSFP28 to QSFP28 cables
14	0.5-meter DAC 100G QSFP28 to QSFP28 cables
576	5-meter DAC 25G QSFP+ to QSFP+ cables.

2.1.2 Energy efficiency index

The data centre must achieve an average Power Usage Effectiveness (PUE) of less than 1.3. This will enable the CNR-ISTI in Pisa data centre to comply with the "Climate Neutral Data Centre Pact." According to this initiative, by January 1st, 2025, new data centres operating at full capacity in cold climates should achieve an annual PUE target of 1.3, while new data centres operating at full capacity in warm climates should achieve a PUE target of 1.4.

The calculation of PUE to be included in the technical report should consider the following conditions:

- Pisa's climatic profile according to ASHRAE.
- Total thermal load of the server room: 140 kWf based on 8 racks with an average individual thermal power of 17.5 kWf.
- Server room air conditioners: 2 units operational at a power of 70 kWf.
- UPS (Uninterruptible Power Supply): 2 units operational at a power of 70 kWe, providing a total power of 140 kWe distributed across the 2 branches.
- UPS room air conditioners: 2 units operational [additional information is missing].

2.2 CNR-ICAR-SLSAS Computational Node

The data centre room of the CNR-ICAR-SLSAS in Naples will host the computing infrastructures from three different PNRR projects: SoBigData.it, FOSSR and H2IOSC. Therefore, the room and cooling facilities have been redesigned, taking into account the needs of all the projects, optimising in this way the use of the available spaces, the cooling systems and the power consumption. The supply provisions include the cooling and the room modifications (referred to the global and joint solution adopted for all three PNRR infrastructures that will be installed in the data centre of Naples), a set of computing servers and GPUs, and the networking systems. Moreover, the supply also includes an edge computing environment, which will be installed in the CNR-ICAR/Università di Messina joint laboratory, located in Messina, which will act as a further node of the SoBigData.it infrastructure.

In summary, the supply of the designed solutions includes:

- **Supply 1: Cooling and construction works**

  As explained above, the provision of the cooling system has been designed in conjunction with the other PNRR projects that will be hosted in the data centre room in the Naples branch of ICAR-CNR. Therefore, the details of the provision of the cooling system, including the construction works for the required modifications of the room and the UPS, reported below in Section 2.2.1.1, as well as the energy efficiency index, calculated in Section 2.2.1.4, refer to the whole solution.

- **Supply 2: Computing Servers and GPUs**

  Provision of computing and storage resources organised in servers with GPUs suitable for typical usage in Cloud computing infrastructures for High-Throughput Computing (HTC) while being compatible with the existing infrastructure (Section 2.2.1.2).

- **Supply 3: Networking**

  Provision of switches with optimal flexibility levels for cloud environments characterised by high storage and processing traffic, utilising a spine-leaf architecture. The switches should be equipped with cables for connectivity between switches and between switches and servers (Section 2.2.1.3).

- **Supply 4: Edge Computing Environment**

  Provision of a shared IoT-Cloud infrastructure, consisting of IoT devices, edge gateways and datacenter-class servers. This environment has the purpose of supporting the deviceless server paradigm (Section 2.2.2).

The details of supplies are reported below.

2.2.1 Detailed plan of the supplies

2.2.1.1 Cooling system and data centre room modifications

The air conditioning system solution is based on a 'Direct Expansion system' architecture with the possibility of indirect free cooling by means of pumped refrigerant technology. They will be connected to an electrical panel, intended to power both the air conditioning units and the UPS with rack PDUs. To improve efficiency, the thermodynamic flows (Hot-Cold) will be separated by containment, as shown in Figure 2. The solution considers compartmentalization of the cold aisle, which allows for better control of temperatures at the mouth of the servers and greater efficiency, as less cold air volume is produced.

As underlined in the previous Section 2.2, the cooling system

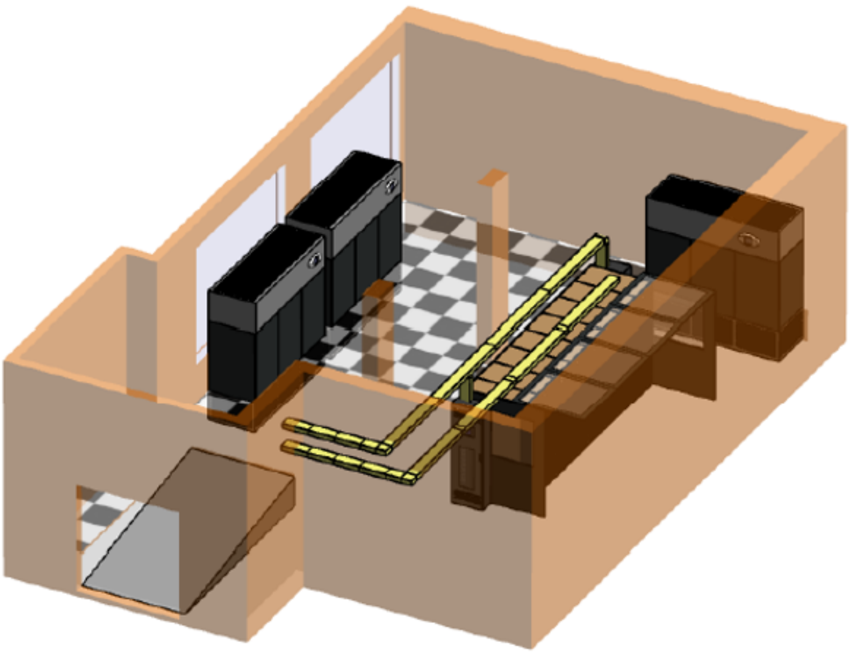


Figure 2: 3D rendering of the cooling containment aisle of Naples data centre

The solution is characterised by:

- Racks that will contain the infrastructure compute nodes, GPUs, management nodes, storage, and network equipment.
- 14 PDUS.
- Air conditioning units inside the data centre room with N+1 redundancy (3 air conditioning units).
- Electrical panels, modular and remotely monitored.
- Network analyzer and hot-swappable switches on switchboards.
- Thermodynamic flow containment aisle.

- 2 modular UPSs with 150kW frames (consisting of several modules to provide N+1 redundancy).
- Battery cabinets for 13-minute runtime at 120 kW.

Moreover, the realisation of this solution requires a series of construction works, with the purpose of modifying the room (floor, entrances, electrical systems, fire protection system, etc.). The final supply assigned to the SoBigData.it project, according to the foressen budget, will depend on the definitive project and the detailed list of interventions/supplies required.

2.2.1.2 Computing Servers and GPUs Supply

This supply consists of computing and storage resources organised in a modular and scalable server, suitable for typical usage in Cloud computing infrastructures for managing High-Throughput Computing (HTC). The server models identified for this supply are:

- 20 Dell PowerEdge R7525 with 48 Cores/96 Threads CPUs, 768 GB memory, 11.2 TB disk, 1400W dual power each.
- 2 Dell PowerEdge R7525 (used as a shared storage system) with 48 Cores/96 Threads CPU, 2048 GB memory, 74.24 TB disk, 1400W dual power each.
- 5 Dell PowerEdge R7525 GPU with 32 Cores/64 Threads CPU, 1536 GB memory, 55.68 TB disk, 2X Nvidia H100 80GB GPU, 2400W dual power.

All GPUs managed by the infrastructure are compatible with the Dell PowerEdge R7525 GPU servers, which requires close compatibility in terms of components and characteristics.

The capacity and features of the planned infrastructure of the Naples node of SoBigData are summarised in the next table.

Type	Servers	Power (KW)	CPU cores	RAM (GB)	Storage (TB)
Dell PowerEdge R7525	20	28	960	15,36	256
Dell PowerEdge R7525 (storage)	2	2.8	4,608	3,072	148.48
Dell PowerEdge R7525 GPU	5	12	160	10,240	278.40

2.2.1.3 Networking Supply

The object of the network supply includes:

- SPINE Switch: 2 devices (48 ports switches).
- LEAF layer: 27 (one x server) high speed HPC switchless network devices.
- Optical and copper cables (in the corresponding required physical standard technologies) for any required interconnection.
- Any other components and services, even if not explicitly mentioned but necessary for the management, integration, and proper functioning of the supplied systems (e.g. connection cables, HW/SW tools for configuration, management, and monitoring, firmware, etc.) must also be included in the supply.

In order to guarantee a high level of integration between the components and effectiveness of support as a whole, the equipment of the LEAF layer devices subject to supply must all be manufactured/marketed by the same producer of the computing servers. All hardware and software parts of the supply must be officially marketed, appear in the manufacturer's catalogue, be in regular production without any announced end of maintenance or specialised support. LEAF (and, if required, also SPINE) devices within the manufacturer's portfolio must belong to the same product line/series.

2.2.2 Energy efficiency index

The PUE calculated for this solution (Figure 3), considers the CDZ IT room of two machines running at the power of 59.5 kWf and two UPS machines sharing the electrical load on 2 BUS, at the power of 60kWw each. In the calculation, it was assumed the losses in the Electricity Distribution cables and switchboards is 58.52 kWh/year, an average UPS efficiency (Dynamic OnLine algorithm) η=0.986, also remembering that PUE, Power Usage Effectiveness, is an index that measures how efficient a data centre is, in using the electricity that feeds it, we go on to calculate the PUE, which is equal to 1.18.

We underline that the PUE calculation refers to all the infrastructures related to three different PNRR projects, which will be installed in the same data centre room in Naples and that will share the cooling system described in previous Section 2.2.1.1.

PUE	1,18
Annual cooling power consuption	172.608 kWh
Total losses	58,52 kWh
Total IT load	119 kW
Total facility annual energy consuption	1.238.791 kWh

Figure 3: PUE calculation (considering the all the infrastructures served by the cooling and power systems in the same data centre)

2.2.3 Edge Computing Environment in Messina

The Virtual Lab on Pervasive intelligence in Cyber Physical Systems (CPS) for future society will be responsible for defining and implementing a development strategy to better face the challenge of the digital transformation of our cities and businesses as an aware country, systematically involving administrations, citizens, businesses and research centres in the development of innovative solutions and services.

The objectives and the strategy to be adopted for the practical operation of this Laboratory are summarised below.

- Create a model for the development and dissemination of services and solutions for Cyber Physical Systems, with specific applications in the smart cities and Industry 5.0 fields based on the use of AI and the enhancement of "best practices" on the national territory. Open mechanisms, protocols, supports and middleware/software modules will be considered, which are highly inclusive of the excellences (universities, companies, professionals) present in the country.
- Reuse the successful experiences present in the area, sharing them with reuse mechanisms, so as to reduce costs and promote uniform approaches, to simplify citizens' access to the value-added services offered, even when moving between cities, and allow companies to

adopt new solutions tested in an environment with great potential for computing, storage and networking resources, made up of federated resources on national and European territory.

The specific activities include to:

- Create an integrated environment made available to the various municipal administrations and companies interested in developing and promoting services for citizens, innovating industrial products and processes and improving the quality of life in our urban realities.
- Create the conditions to interact with the physical world (Internet of things), collect and manage the data (Big Data) generated in order to develop and offer new services. Such a system must adopt "open" solutions for hardware, software and data, in order to favor their adoption, stimulating the demand and supply of new services and skills.
- Disseminate this system at the Italian level, covering the territory in a pervasive way. Italy could thus assume a leading role in the use of new technologies, enabling and attracting experimentation initiatives from all over the world. The benefits are more than evident: investing consistently in this area means creating a driving force capable of attracting financing, creating the conditions so that our best minds do not abandon our land, and improving the quality of life in numerous sectors (e-health , e-agriculture, environmental monitoring, energy, transport, construction, etc.).
- Strengthen and consolidate an Italian IR of reference for Smart Cities and Industry 5.0
- Starting from the operational nodes of the project (CNR-Pisa, CNR-ICAR, Univ. Bologna, CINI to then extend the IR in the various metropolitan areas of the country and connect it at European level with similar initiatives
- Install permanent demos, in which to show services and solutions developed by Italian companies and integrated within the system.

2.2.3.1 Computing servers and GPU supply

- 1 Dell PowerEdge R7525 GPU with 32 Cores/64 Threads CPU, 768 GB memory, 960 GB disk, 2X Nvidia A100 80GB GPU, 2400W dual power.
- 1 Gigabyte ARM SERVER: G242-P33 | 2U Ampere Altra ARM HPC Server with M128-30; 512 GB Memory, 3.8 TB disk, NVIDIA RTX A4500 20GB GPU

2.2.3.2 Devices to realise Edge/IoT-based computation

Device by category:

- IoT:
  - 50 Raspberry PI4
  - 5(+) Nicla senso ME Arduino
  - 5(+) MKR Vidor 4000 Arduino
  - 2 JETSON TX2 NVIDIA Jetson TX2, 1,33 TeraFLOPS, 8 GB di RAM, PCIe

  - 5(+) Jetson Nano Developer Kit 16G eMMC
  - 5(+) Google Coral Dev Board Mini
  - 2(+) Jetson AGX Xavier
  - 5(+) ESP32-EVB-EA (RISCV)
  - 2(+) Sipeed RV Dock Pro Allwinner D1 Development Board RISC-V Linux Single Board Computer Starter Kit con 16 bit 1 GB DDR3 RAM Onboard WiFi Bluetooth Modulo Supporto Tina Linux Debian YoC (RTOS)
  - 5(+) Sipeed Maixduino Kit per RISC-V AI + IoT K210 Dev. Scheda ESP32 Compatibile con Arduino (Maixduino)
  - 5(+) youyeetoo Sipeed Nezha 64bit RISC-V Linux SBC Board Allwinner D1@1.0GHz con 1GByte DDR3 256MByte Nand Flash Support Sistema Tina/Debian (kit standard)
  - 10 Centralina IoT smartme® edge
  - 20 Periferica IoT smartme® mignon
- FPGA:
  - 5(+) Xilinx Spartan-7 (open source)
  - 5(+) Digilent Basys 3 (open source based on Artix 7)
  - 5(+) Icebreaker FPGA (open source)
  - 2 FPGA Spartan-6 (open source)
  - 5(+) TinyFPGA BX (ICE40LP8K)
  - 2 ECP5 Evaluation Board
  - 5(+) QuickLogic Thing Plus - EOS S3
  - 5(+) CLEAR - the Open Source FPGA ASIC - by chipIgnite
- BOT:
  - 5(+) ROS-Bot on Wheels
  - TurtleBot 4 Pro
  - ROSbot 2R
  - LEGO Mindstorm Robot Inventor
  - 1 ROV: BlueROV2 (underwater)
  - 2 Yahboom DOFBOT AI Vision Robotic Arm
- DRONE:
  - 1 HOLYBRO PX4 DEVELOPMENT KIT X500 V2
  - 5(+) bitcraze STEM ranging bundle (CrazyFlie 2.1)
  - 1 bitcraze Loco explorer bundle (CrazyFlie 2.1)
  - 1 coex Clover drone kit
  - 2 Kopis X8 Cinelifter 5" (caged) full kit (PX4)
  - 1 mRo Quad Zero Kit
- Mobile Dev:
  - 2 Fairphone 4
  - 2 PinePhone Pro

    - 2 Puri.sm Librem 5
    - 3 iPad mini
- Wereable:
    - 5(+) Warpx - IoT and wearable development platform
    - 5(+) PineTime SmartWatch Dev Kit
    - 5(+) PineTime SmartWatch (Sealed)
    - 2 Google Pixel Watch
- IPA:
    - 5(+) Alexa
    - 5(+) MyCroft Mark II
- Telecamere:
    - 3 smartme® Crowd Master
- Air monitoring system:
    - 3 smartme® ARIA

2.3 CNR-ICAR-BMSA Computational Node

Within the SoBigData.it digital infrastructure CNR-ICAR-BMSA, we worked on the creation of a new pervasive & networking center. The group of devices we want to acquire is classified as small with a negligible impact overall; for this reason, we can consider the self-assessment verification checklist (ref. **31.2-Brief analysis related to the DNSH principle of Annex B - Part 2**). We expect to acquire Extended Reality services offered by different devices, including Drones; Thermo, Multi-spectral cameras; Outdoor/Indoor Environmental Sensors; and, Virtual/Augmented Reality tools, AI Accelerated Servers and Containers, and Data Storage Servers for local/edge computation. We defined the plan necessary to acquire all the required HW/SW to realize the project: The tenders for the HW/SW acquisition of the project materials are currently being published.

We comply with the DNSH directives for acquiring devices and for the systems dedicated to servers' cooling. In particular, the goal is to maintain the level of the PUE below the threshold of 1.4, which is required for the climatic zone of operation.

Therefore, the requested solution entails the following supplies:

- **Supply 1: Rack-based cooling aisle**

Rack-based cooling on two IT racks. Continuous cooling output adjustment due to using an output-controlled compressor in the LCP (Liquid Cooling Package) Rack DX (evaporator). An external condenser is required to operate the unit.

- **Supply 2: Computing Servers and GPUs**

Provision of computing and storage resources organised in servers with GPUs suitable for typical usage in Cloud computing infrastructures for High-Throughput Computing (HTC), Artificial Intelligence (AI), and Data Analytics while being compatible with the SoBigData.it infrastructures.

- **Supply 3: Networking**

Provision of switches with optimal flexibility levels for cloud environments characterised by high storage and processing traffic. The switches should be equipped with cables to connect between switches and between switches and servers.

- **Supply 4: Devices**

Provision of different devices, including Drones; Thermo and Multispectral Cameras; Outdoor/Indoor Environmental Sensors; and, Virtual/Augmented Reality tools.

- **Supply 5: Software and Services**

Provision of a software stack for cluster orchestration and services authentication, with five years of SW/HW assistance.

2.3.1 Detailed plan of the supplies

2.3.1.1 Rack-based cooling aisle

The requested solution should include the following supplies:

- 2 server racks with the following specifications:
  - Width: 800mm, Depth: 1200mm, Height: 42U.
  - 4 PDUs (Power Distribution Units).
- 2 cooling racks with speed-regulated compressor, the cooling output is ideally adapted to actual requirements. With 40Kw total cooling output to DIN EN 14511
- 1 modular UPS (Uninterruptible Power Supply) with minimum 27kW (currently in planning stage) frame, each with battery cabinets providing a minimum autonomy of 10 minutes.

- Any other components and services, even if not explicitly mentioned but necessary for the management, integration, and proper functioning of the supplied systems (e.g., connection cables, hardware/software configuration tools, management and monitoring tools, firmware, etc.), should also be included in the supply.

Synoptic Table of the Rack-based cooling aisle Supply

Quantity	**Description**
2	Server Racks
2	Cooling Racks
4	PDUs
2	Electrical Panels
1	UPS
1	Transportation and placement
1	Activation of the conditioning system
1	Gas system for fire extinguishing system

2.3.1.2 Computing Servers and GPUs Supply

This supply consists of computing and storage resources organised in a modular and scalable server, suitable for typical usage in Cloud computing infrastructures for managing High-Throughput Computing (HTC), Artificial Intelligence (AI), and Data Analytics.

The server models identified for this supply is as follows:

- 3 Nvidia DGX A100 640GB System 640G. 8 x GPU Memory: 80GB. Performance: 5 petaFLOPS AI & 10 petaOPS INT8. N. 6 NVIDIA NVSwitches. System Power Usage: 6.5 kW max. CPU:

Dual AMD Rome 7742, 128 cores total, 2.25 GHz (base), 3.4 GHz (max boost). System Memory: 2TB. Networking: n. 10x.

- 1 Master Server 1U Single Socket with 16-Core CPU, 256 GB memory, 55 TB disk, 750W dual power each.
- 1 NFS Server 1U Single Socket with 16-Core CPU, 128 GB memory, 1920 GB disk, 750W dual power each.
- 1 x 4U SAS 12Gb/s JBOD with 220TB SAS III.

These components have been selected so that they can be compatible with other similar nodes installed by other "SoBigData.it" partners. Specifically, the node is scheduled to offer a computing environment organised in containers and services such as Jupiter Notebooks, commonly used by the scientific community for their projects. Furthermore, containers provide an independent environment to install libraries and Extended Reality applications.

Synoptic Table of the Networking Supply

Type	Servers	Total Power (KW)	Total CPU cores	Total RAM (GB)	Total Storage (TB)
Nvidia DGX A100	3	19.5	384	1920	96
Master Server	1	0.75	16	256	55
NFS Server	1	0.75	16	128	2
JBOD Archives	1	0.4	-	-	220

2.3.1.3 Networking Supply

The object of this supply includes:

- Switch InfiniBand 40 HDR (200Gb/s) Port Managed: 1 device
- Switch Management 48Port 2x1GbE RJ45+ 4x10GbE SFP+: 1 device

- Any other components and services must also be included in the supply, even if not explicitly mentioned but necessary for the management, integration, and proper functioning of the supplied systems (connection cables, HW/SW tools for configuration, management, monitoring, firmware, etc.)

The equipment subject to supply must be manufactured/marketed by the same producer to guarantee a high level of integration between the components and effectiveness of support. All hardware and software parts of the pool must be officially sold, appear in the manufacturer's catalogue, and be in regular production without any announced end of maintenance or specialised support.

The proposed architecture must allow multiple devices to act as a single logical device with separate and independent "Data plane", "Control plane", and Configuration Files. The proposed technological solution must be implemented by a data centre architecture based on a single topological level and, therefore, on a single logical device capable of optimising traffic forwarding between different affiliated users. This architecture must also allow the exclusion of protocols that inhibit the utilisation of the entire available bandwidth, such as Spanning Tree.

Synoptic Table of the Networking Supply

Quantity	Description
1	Switch InfiniBand
1	Switch Management

2.3.1.4 Devices Supply

The object of this supply includes:

- Magic Leap 2, augmented reality device that maintains its user's view of their environment while integrating digital content within it.
- Moverio BT-45CS, binocular smart glasses with Intelligent Controller of usability in industrial applications.
- TESLASUIT Dev Kit, Human-to-digital interface designed to monitor human behaviour and improve performance, comprising up to three major systems.

- TESLAGLOVE Dev Kit. The ability to touch and feel virtual objects opens up endless possibilities.
- Hexoskin Pro Kit Sportsman Health Monitoring Set for Men with Shirt & Meter.
- PRIME X Haptic VR Glove with Core Pro licence, The new generation of data gloves with haptic feedback for virtual reality.
- Unitree B1, quadrupedal terrestrial drone with characteristics of all-weather operation, strong load and expansion space, multi-dimensional perception, full scene coverage, strong computing power and accurate insights. Facing the complex environments and high-level needs of industrial applications, this industrial protection level quadruped robot will provide a more efficient and intelligent solution.
- Unitree Z1 Manipulator is an arm designed for the B1, with the possibility of using it on other mobile robots to perform complex tasks and explore different application scenarios.
- Gripper for the Unitree Robotics Z1 robot arm.
- RoboSense RS-Helios-16P LiDAR.
- Libelium One complete with solar power system. Device for continuous monitoring of a huge range of parameters covering the most relevant IoT applications.
- Waspmote Plug & Sense. Device includes top market performance sensors for the most exigent field applications. This integration enables the measuring of different parameters related to weather conditions, light and radiation levels, soil morphology, fertilizers presence, frost prevention, daily growth of plants and fruits and other environmental parameters to improve crop quality production and to prevent harvest losses.
- Mobile network data connectivity services, Cloud Services and software applications.
- Gill MaxiMet GMX551 Compact Weather Station.
- Sensor kits Libelium compatible.
- SFM1 Sap Flow Meter. Measures Tree and Plant Water Use with IoT Connectivity
- SNiP-SPT is a 'Sensor Node Integrated Package' for LoRaWAN or CAT-M1 communication of real-time water levels and temperature measurements for continuous environmental water level monitoring.
- Sensor kits SNiP-SPT compatible.

- Quadcopter aerial drone equipped with thermal imaging camera and multispectral camera.

Synoptic Table of the Devices Supply

Quantity	Description
1	Magic Leap 2
1	Moverio BT-45CS
1	TESLASUIT Dev Kit
1	TESLAGLOVE Dev Kit
1	Hexoskin Pro Kit
1	PRIME X Haptic VR Glove
1	Unitree B1
1	Unitree Z1 Manipulator
1	Gripper for the Unitree Robotics Z1
1	LiDAR
3	Libelium One complete with solar power system
2	Libelium Waspmote Plug & Sense
5	Mobile network data connectivity services, Cloud Services and software applications
2	Compact Weather Station

2	Temperature sensor and water potentials in the soil
2	Contactless infrared surface temperature sensor
2	Sensor for measuring soil oxygen levels
2	Vapor pressure sensor, air pressure, temperature and humidity
2	Solar radiation sensor
2	Sensor volumetric content of water in the ground, temperature, electrical conductivity
2	SFM1 Sap Flow Meter with solar power system
1	Installation kits
1	SNiP-SPT with solar power system
3	Mobile network data connectivity services, Cloud Services and software applications
1	Software license for a HRM (Heat Ratio Method) and HFD (Heat Field Deformation) measurement tool
1	Dendrometer Increment Sensor DBL60
1	Soil moisture probes SMT-100
1	Drill & Drop probe for measuring soil humidity and temperature
1	ICT-LWS Leaf Wetness Sensor
1	SQ-310 Series Sun Calibrated Linear PAR Sensors

1	SDI-12 Leaf and Bud Temperature Sensor
1	Quadcopter aerial drone
1	Thermal imaging camera
1	Multispectral camera

Advanced equipment in Extended Reality, including drones, specialised cameras, environmental sensors, and VR/AR tools, enhances XR environments' immersive and interactive nature. These technologies enable realistic visualisations, precise spatial mapping, accurate object tracking, and responsive sensory feedback. As XR continues to advance, further integration of these equipment types will shape the future of immersive experiences across various industries, including gaming, entertainment, education, training, and scientific research.

2.3.1.5 Software and Services

The software suite will offer a “ready-to-use” Kubernetes cluster designed to guarantee high performance and integrate GPU and network RDMA support, the persistence of container data, and manage workloads of Kubernetes cluster with a DevOps methodology. The winning company will provide installation, access to repositories for updates, and support for five years.

Synoptic Table of the Software and Services

Quantity	Description
1	Software
1	Services

▪

2.3.2 Energy efficiency index

Following the project objectives, the pervasive & networking centre must achieve an average Power Usage Effectiveness (PUE) of less than 1.4. Cosenza is a city in southern Italy, specifically in the region of Calabria. It experiences a Mediterranean climate characterised by hot, dry summers and mild, wet winters. The centres operating at total capacity in warm temperatures should achieve a PUE target of 1.4. For this purpose, since we do not have our installation rooms, we have opted for a self-contained architecture with low impact on the building.

The calculation of PUE to be included in the technical report should consider the following conditions:

- Cosenza's climatic profile according to ASHRAE.
- Total thermal load of the server room: 21.87 kW based on 2 racks with an average individual thermal power of 11 kW.
- Cooling racks: 2 units operational at a power of 14.6 kW.
- UPS (Uninterruptible Power Supply): 1 units operational at a power of 27 kW.

2.4 UNIPI Computational Node

UNIPI Computational node is hosted inside Green Data Center infrastructure. Green Data Center hosts 66 Racks (max 15 KW/Rack dual PDU), 4 redundant UPS and FreeCooling/ Adiabatic Cooling system .It reaches a 1.2 PUE medium/year. Internal Networking is based on Arista Networks 25 to 400 Gb/s Ethernet switches and 100 to 400 Nvidia Infiniband switches.

2.4.1 Detailed plan of the supplies

Unipi Computational Node is based on “Nvidia/Vast Mini Pod” based on Nvidia DGX-H100 node and Vast Data All-NVme storage system.

The node is connected to the 400 Gb/s IB Network of the Green DataCenter and 100 Gb/s Ethernet Backbone

Nvidia DGX-H100 is a fully integrated hardware and software solution based on the following configuration.

- 8x NVIDIA H100 GPUs With 640 Gigabytes of Total GPU Memory   18x NVIDIA® NVLink® connections per GPU, 900 gigabytes per second of bidirectional GPU-to-GPU bandwidth
- 4x NVIDIA NVSwitches™   7.2 terabytes per second of bidirectional GPU-to-GPU bandwidth, 1.5X more than previous generation
- 10x NVIDIA ConnectX®-7 400 Gigabits-Per-Second Network Interface   1 terabyte per second of peak bidirectional network bandwidth

- Dual Intel Xeon Platinum 8480C processors, 112 cores total, and 2 TB System Memory
  Powerful CPUs for the most intensive AI jobs
- 30 Terabytes NVMe SSD   High speed storage for maximum performance

Software Environment is DGX-OS 6.0 (based on Ubuntu 22.04) completed by Nvidia AI Enterprise software solution.

VAST Data offers a all-flash scale-out file and data storage solution.

Based on a disaggregated and shared everything (DASE) architecture VAST solution offers one of the best price/performance storage solution at exabyte scale.

Figure XX : Vast Data Storage Control Panel

2.5 UNIROMA1 Computational Node

The activity is finalising the procedures for acquiring, deploying, and managing the physical infrastructure composed of a tier 4 ECO aisle. The infrastructure will be incorporated in the data center of the OU and to make it a SoBigData.it computational node. The objective is to empower the storage and computing capabilities needed to support short and long-term scalability, robustness, availability, and reliability of services.

In particular , uniroma1 is proceeding with the acquisition of two computational nodes, NVIDIA A100 HGX to be integrated in the HPC computational infrastructure of Sapienza, that will be composed of

7 Server di classe enterprise specializzati Server NVIDIA DGX-A100,

2 Server di classe enterprise generici Server E4 RF128

2 Nodi Storage di classe HPC Storage E4 RF228

1 Switch di rete per network dati Infiniband Switch Nvidia QM8700

1 Switch di rete per network di management Switch Edge-core AS5835-54T

and all software modules needed for the management of the infrastructure.

2.6 UNIVAQ New Computational Node

Univaq is designing the data centre considering as the requirements the recommended practices outlined in the document CEN-CENELEC CLC TR50600-99-1 "Data centre facilities and infrastructures - Part 99-1: Recommended practices for energy management." Additionally, it will consider to the self-regulatory initiative called the "Climate Neutral Data Center Pact," which data operators and infrastructures have defined to contribute to the European Green Deal.

Univaq is considering establishing the data centre leveraging two sites. In the main one, there will be the core of the Univaq R.I.'s node, and in the second one, there will be the backup unit and a lightweight replication of main R.I. This solution will improve the robustness of the Univaq Node by extending the resilience to natural disasters. To reach this objective, the shelter depicted in the following photo will be adapted to comply with the cooling and energy requirements. Since the sites are not completely finalised, the cooling and power requirements reported in the following are susceptible to future changes.

Figure YY: Univaq's shelter infrastructure

Therefore, the requested solution entails the following supplies:

- **Supply 1: Containment Aisle**

  Provision of an aisle for the proper management of thermodynamic flows in the server room, complete with the necessary conditioning system, continuity measures, and everything required for the E4M3 rating.

- **Supply 2: Computing Servers, GPUs, and Backup**

  Provision of computing and storage resources organised in servers with GPUs suitable for typical usage in Cloud computing infrastructures for High-Throughput Computing (HTC) while being compatible with the existing infrastructure. Additionally, an external backup unit is planned.

- **Supply 3: Networking**

  Provision of switches with optimal flexibility levels for cloud environments characterised by high storage and processing traffic, utilising a spine-leaf architecture. The switches should be equipped with cables for connectivity between switches and between switches and servers, in compliance with the existing D4Science infrastructure.

2.6.1 Detailed plan of the supplies

2.6.1.1 Containment Aisle Supply

Univaq is working on the following solution, which should include the following supplies. As mentioned before, the cooling and power requirements reported in the following are susceptible to future changes due to the final choice of the sites:

- 4 racks with the following specifications:
- Width: 800mm, Depth: 1200mm, Height: 42U.
- 8 PDUs (Power Distribution Units).
- 3 air conditioning units ensuring N+1 redundancy.
- Provision for an additional air conditioning unit.
- 2 modular electric panels for the server room, remotely monitorable, both for input and output, with network analyzers and hot-swappable breakers.
- 1 containment aisle for thermodynamic flows.
- In terms of continuous power supply for the loads (servers), to comply with rating 3, the solution should consist of:
- 2 modular UPS (Uninterruptible Power Supply) with a 250 kW frame, each with:
- 3 power modules of at least 50 kW each to ensure N+1 redundancy.
- Battery cabinets provide a minimum autonomy of 5 minutes at 150 kW.
- The UPS units should be set up in adjacent rooms, together with the switchgear and control panels as per the rating 3 scheme.
- Any other components and services, even if not explicitly mentioned but necessary for the management, integration, and proper functioning of the supplied systems (e.g., connection cables, hardware/software configuration tools, management and monitoring tools, firmware, etc.), should also be included in the supply.

2.6.1.2 Computing Servers and GPUs Supply

The servers, GPUs, and backup comprise computing and storage resources organised in modular and scalable servers, suitable for typical usage in Cloud computing infrastructures for managing High-Throughput Computing (HTC).

The server models, GPUs and backup are identified as follows:

- 24 Dell PowerEdge R840 with 96 Cores/192 Threads CPU, 1024 GB memory, 24,96 TB disk, 1600W dual power each.
- 3 Dell PowerEdge R750XA GPU with 64 Cores/128 Threads CPU, 1024 GB memory, 15,36 TB disk, 4X Nvidia A100 80GB GPU, 2400W dual power.

- 1 Lenovo Thinksystem SR650 V2 with 24 Cores/48 Threads CPU, 256 GB memory, 600 TB disk, and 4 external DAS - Lenovo D1212.

The specific type of server and its components are chosen to be coherent wih the existing D4Science computational infrastructure, which is composed of multiple servers. In particular, all GPUs managed by the infrastructure are compatible with the Dell PowerEdge R750XA GPU. Therefore, there is a requirement for close compatibility in terms of components and characteristics.

The capacity and features of the Univaq infrastructure devoted to SoBigData are outlined in the following table.

Type	Servers	Power (KW)	CPU cores / threads	RAM (GB)	Storage (TB)
Dell PowerEdge R840	24	38,4	2.304 4,608	24,576	599,04
Dell PowerEdge R750XA GPU	3	7,2	192 384	3,072	46,08
Lenovo Thinksystem SR650 V2	1	0,75	24 48	256	600,00

2.6.1.3 Networking Supply

We plan to acquire the following main networks devices:

- SPINE Switch: 2 devices
- LEAF Switch: 6 devices
- AOC cables for LEAF and SPINE interconnection
- DAC cables for interconnection
- Any other components and services, even if not explicitly mentioned but necessary for the management, integration, and proper functioning of the supplied systems (e.g. connection cables, HW/SW tools for configuration, management, and monitoring, firmware, etc.) must also be included in the supply.

In order to guarantee a high level of integration between the components and effectiveness of support as a whole, the equipment subject to supply must all be manufactured/marketed by the same producer. All hardware and software parts of the supply must be officially marketed, appear in the manufacturer's catalogue, be in regular production without any announced end of maintenance or specialised support.

LEAF and SPINE devices within the manufacturer's portfolio must belong to the same product line/series.

The proposed architecture must allow multiple devices to act as a single logical device with separate and independent Data Plane, Control Plane, and Configuration Files. The proposed technological solution must be implemented by a data centre architecture based on a single topological level and, therefore, on a single logical device, capable of optimising traffic forwarding between different affiliated users. This architecture must also allow the exclusion of protocols that inhibit the utilisation of the entire available bandwidth, such as Spanning Tree, for example. The aforementioned architecture will be referred to as MLAG. MLAG and MC-LAG are equivalent terms representing the same system according to the defined standard. LAG systems that use proprietary and non-standard protocols will not be accepted.

Performing packet forwarding tasks within a line-rate device implies that this operation is implemented with network processors optimised for such functions and equipped with dedicated hardware (internal equipment in terms of hardware components for specific tasks ASIC, CAM, TCAM...) for table lookup, pattern matching, and header rewriting operations. The latency introduced by the packet processing chain must be negligible, within the limits of the current state of the art for data centre packet forwarding systems, compared to the theoretical latency of the device at the OSI layer on which it operates.

Packet classification, filtering, and policing activities in a mixed IPv4 and IPv6 environment, configured in addition to standard protocol forwarding operations, must not introduce latencies that impact the declared throughput of the device and its network interfaces.

Hardware redundancy mechanisms based on Layer 3 redundancy, which ensure the availability of packet forwarding capabilities within the entire LAG using standard protocols in active/passive mode or proprietary protocols in active/active mode, are not accepted. Connection to other switches and servers must be possible through static LAGs or IEEE 802.3ax Link Aggregation Control Protocol (LACP) without the use of proprietary protocols.

Synoptic Table of the Networking Supply

Quantity	Description
2	SPINE
2	Perpetual software license
2	60 months or more support for SPINE switches

6	LEAF switches
6	Perpetual software license
6	60 months or more support for LEAF switches

2.6.2 Energy efficiency index

The Univaq data centre aims to achieve an average Power Usage Effectiveness (PUE) of less than 1.3. This will enable the Univaq data centre to comply with the "Climate Neutral Data Centre Pact." According to this initiative, by January 1st, 2025, new data centres operating at full capacity in cold climates should achieve an annual PUE target of 1.3, while new data centres operating at full capacity in warm climates should achieve a PUE target of 1.4.

The calculation of PUE should consider the following conditions:

- L'Aquila's climatic profile according to ASHRAE.
- Total thermal load of the server room: 4 racks with an average individual thermal power of 17.5 kWf;
- Server room air conditioners: 2 units operational (for each site);
- UPS (Uninterruptible Power Supply): 2 units operational (for each site);
- UPS rooms air conditioner: 2 units operational (for each site).

3 PLAN FOR THE PERVASIVE COMPUTING AND NETWORKING NODES

This section reports on the plan for the acquisition and installation of the pervasive computing & networking nodes. These nodes are devoted to creating one of the distributed nodes supporting edge computing and pervasive intelligence services focused on virtualised resource management in the edge-to-cloud continuum.

3.1 CNR-IIT pervasive computing & networking node

The CNR-IIT pervasive computing and networking node is built following the SLICES Blueprint for post-5G networks. SLICES is an ESFRI DIGIT Research Infrastructure (Roadmap 2021) addressing the need of the worldwide research community working on Future Internet, encompassing technologies from post-5G networks to the continuum between edge and cloud. SoBigData.it is partnering with SLICES at the European level, and some of the SoBigData.it national nodes are developed also to support synergies between the two complementary RIs.

Specifically, the CNR-IIT is equipped to implement the following architecture, which realises the testbed for post-5G network solutions based on open standards and components.

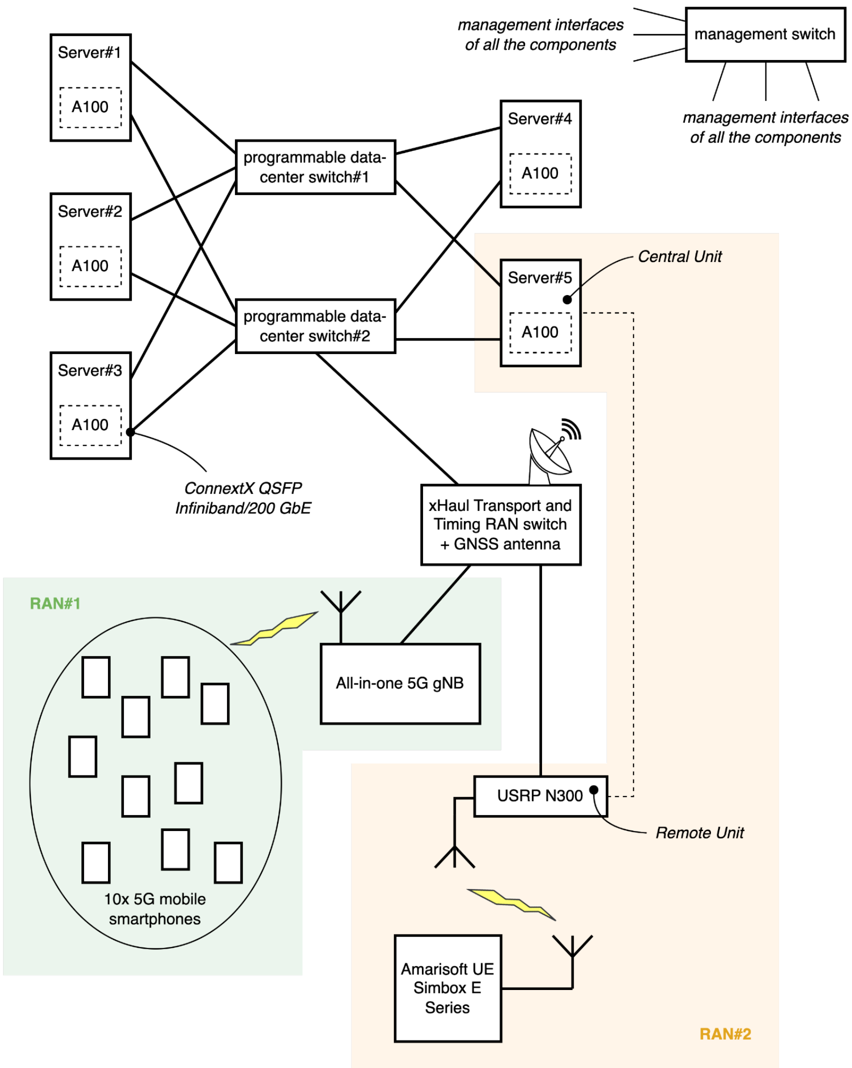


Figure XX: Architecture of the testbed for post-5G network solutions based on open standards and components.

The architecture represented in the diagram above consists of three areas:

- The *core* area includes five servers, each equipped with 200 Gb/s NICs and interconnected to one another in a full mesh through two programmable switches via fiber optic transceivers/cables. The servers are also equipped with NVIDIA A100 GPUs, which support Multi-Instance GPU (MIG) mode that allows one GPU to be made available to user processes in virtual slices with smaller computational capabilities. MIG is intended for use with Docker containers, which makes it a good fit for the concurrent and dynamic realisation of network functions on the servers.
- The *legacy RAN* area includes 10x 5G smartphones, which are unlocked and can be controlled remotely from a central station (not shown in the picture), which are provided with wireless access by an all-in-one 5G equipment.
- The *advanced RAN* area includes a programmable radio front-end, i.e., an Ettus USRP N300 with 100 MHz bandwidth, which acts as the Remote Unit (RU) for a variable number of emulated UEs that are managed by an Amarisoft UE Simbox equipment. The Central Unit (CU) of the RAN resides in one (or more) of the servers in the core area. We plan the purchase of a second USRP N300 radio front-end, both as a backup and to enable more advanced configurations (e.g., separation of development/production networks, canary deployments).

An xHaul RAN switch interconnects the all-in-one equipment as well as the RU/CU, providing both transport and timing services. This switch acquires precise timing information from a GNSS antenna. Finally, a GbE switch interconnects all the components shown in the diagram (except the mobile phones) through a dedicated management interface for easier configuration and control of the experiments. Ancillary components (racks, PDUs, KVMs, etc.) are not shown in the diagram but will be part of the on-site deployment.

Based on this architecture, the CNR-IIT node will be equipped with the following devices:

Equipment category	***Description***	***Quantity***
data centre switch	100G Top-of-Rack or Spine Data Center Switch supporting 40 GbE, 50 GbE, or 100 GbE ToR and spine interconnects with 32x100G QSFP28 ports, 2 x 10G SFP+ ports with Trident3-X7, pre-loaded with ONIE, compatible with SONiC open source network software, Intel Xeon D-1518 2xAC, front-to-back airflowr	3
LTE/5G xHaul Transport and Timing RAN switch	Timing Aware xHaul Switch, 12x10G (SFP+), 8x25G (SFP28) ports, Advanced Timing spec w/ GNSS Rx, 1 removable AC power supply (FPS10012/A), compatible with O-RAN architecture	1

management switch	Smart L3 switch with 48-Port 10/100/1000 + 4 x 1GE SFP	1
radio frontend	USRP N300 (NON-TPM, ZYNQ-7035, 2 CHANNELS, 10 MHZ - 6 GHZ, 10 GIGE)	2
5G gNB	FlexFi All-in-one small cell	1
5G terminals	SAMSUNG Galaxy S20+ 5G (128 GB)	10
5G terminal emulator	AMARI UE Simbox E Series 064 FIX (5G SA NR 100MHz 4x4)	1
Server	Data centre server with following features: - 2U Rackmount form factor - 2xCPU with Cores: 16 Clock>= 3.00 GHz Max. turbo clock>= 3.70 GHz L3 Cache>=64 MB TDP: 200 W - 3xbus PCIe 5.0 x 16 FH; 2xbus PCIe x 8 FH; 12x 3.5" hot-swap NVMe drive bays - 24 x 16GB DDR5-4800 1RX8 (16Gb) RDIMM slot - 1x SSD 6.4TB NVMe PCIe 4.0 3D TLC 7mm, 3DWPD - 1 x AIOM 2-port 1GbE RJ45, Intel i350-AM2 with 0.5U Bracket - 1x NVIDIA A100 80GB HBM2 PCIe	5
Network card	Network adapter with following features: - dual QSFP112 InfiniBand (NDR200 200Gb/s) and Ethernet 200GbE (Default Speed) ports - Gen 5.0/4.0 PCI Express Interface, Half Height, Half Length 2.71 in. x 6.6 in. - secure boot enabled, crypto disabled.	5
Antenna	GNSS antenna, active (3-5VDC), standard gain (33dB), Bullet type, Multi constellation, TNC connector + GNSS cable, RG6, Quad Shield, TNC to TNC connector, PVC jacket	1

Table 1: List of the main hardware components of the CNR-IIT pervasive computing & networking node

These components have been selected based on the SLICES Blueprint Bill of Materials (BoM), so that it can be compatible with other similar nodes installed by other SoBigData.it parnters, as well as other SLICES partners at the European level. Specifically, the node is scheduled to participate in the initial set of experiments to interconnect multiple EU sites implementing the same Blueprint, thus providing connectivity and exposure of SoBigData.it to the EU community of researchers working on this topic.

3.2 CNR-ICAR-SLSAS pervasive computing & networking node

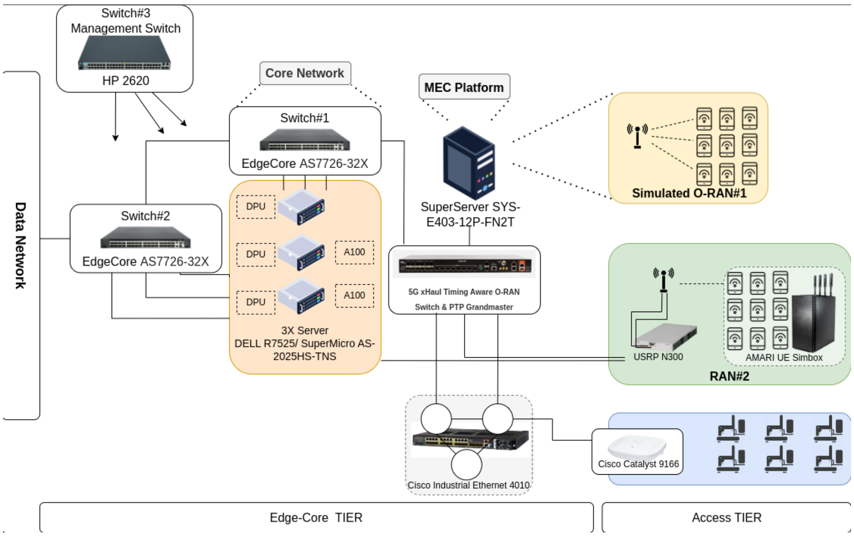
See section 2.2.3.

3.3 CNR-ICAR-BSMA pervasive computing & networking node

See section 2.3.1.4.

3.4 UNIBO-DISI pervasive computing & networking node

The UNIBO-DISI node architecture adheres to the SLICES blueprint (footnote) for an end-to-end 5G network deployment. In addition, the testbed has the ambition to enable and serve heterogeneous verticals, accessed and readily made available to the community also via non-3GPP access technology (untrusted). The hardware components and network topology depicted in Figure XY, have been carefully selected to purposefully build these envisioned capabilities.



While there is a certain degree of over provisioning, this is reasonable considering the planned systematic evolution the infrastructure will be subject to. The components of the testbed can be logically organized into three main layers: the Radio Access Network (RAN), the Edge and Core Network (APP) layer. The access layer comprises 5G RAN components, either emulated or simulated via state-of-the-art simulation environments. The Edge layer comprises multiple tiers, which can be leveraged as-a-whole or siloed to serve a specific vertical, e.g., via non-3GPP access. Lastly, the Core Network hosts the 5G SBA control plane along with application functions (AF), servicing UEs, while also enabling remote access to the testbed facilities. Some additional details:

- The RAN layer consists of both a simulated and an emulated RAN. The emulated RAN involves the use of real hardware, with only the behaviors of UEs being emulated. Specifically, in this RAN (referred to as RAN#2 in the figure) an Ettus USRP N300 is employed as a remote unit for a variable number of emulated UEs allocated by an Amarisoft UE Simbox. The current plan also envisions the possibility of deploying yet another O-RAN compliant access network (fully disaggregated) and UEs, which in the near term will be simulated to assess r/x-APPs for network resource optimization purposes.
- The Edge layer encompasses several compute layers hosting the ETSI-MEC platform servicing time-sensitive 5G verticals. The telco edge leverages on a pool of commodity and resource-capable server devices, I.e., SuperServer SYS-E403. In addition to the telco edge, the testbed will be evolved to encompass non-3GPP access, e.g.., wired industrial time-sensitive networks (i.e. Cisco Industrial Ethernet 4010) and time-sensitive WiFI servicing other IIoT verticals, expanding the possibilities of assessing smart management mechanisms at the distributed edge in mobile scenarios etc.
- The Core Network layer hosts the 5G SBA and application functions, providing also access to external (Internet) services. It comprises three datacentre-like servers connected via fiber optic cable to an in-rack network switch (EdgeCore ASS7726). The switch serves as the link between the rack and another switch (I.e., PTP Grandmaster) that connects the 5G Core/telco Edge and the RAN alternatives.

Commented [2]: https://github.com/open-sdr/openwifi

Below is reported a non-exhaustive, yet representative list, of the hardware components.

Equipment Category	Description	Quantity
Data center switch	[illegible]	2
Management switch	Product: HP J9627A 2620-48-PoE+ • [illegible]	1
[illegible]	[illegible]	1
WiFI Access Point	[illegible]: Cisco Catalvst 9166	1
Switch TSN	Product: Cisco Industrial Ethernet 4010 • [illegible]	2

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Radio frontend	Product: USRP N300 (NON-TPM, ZYNQ-7035, 2 CHANNELS, 10 MHz - 6 GHz, 10 GIGE)	1
5G terminal emulator	Product: AMARI UE Simbox Series. It acts as a 3GPP compliant LTE and 5G SA/NSA UE. it [illegible] different types of traffic within [illegible] multiple cells.	1
Server	Product: Hyper A+ Server AS -2025HS-TNR Features: • 2x AMD EPYC™ 9254 Processor [illegible] core • [illegible] DDR5 • [illegible] NVMe Solid State Drive [illegible] Series M.2 PCIe 4.0	ieiit3
Network card	Product: • Mellanox ConnectX®-6 100-Gigabit HDR100 [illegible] • DPU NVIDIA BlueField-2	3
Edge Server	Product: SuperServer SYS-E403-12P-FN2T Features: • Intel® Xeon® Gold 6312U Processor 24-Core • [illegible] SATA 6.0Gb/s 7200RPM • [illegible] M.2	1

4 PLAN FOR THE BEYOND 5G NETWORK NODES

This section reports on the plan for the acquisition and installation of the beyond 5G network nodes. In line with the vision for 6G technology, this infrastructure is anticipated to exert control over the electromagnetic propagation conditions.

4.1 CNR-IEIIT-SRE BEYOND 5G NETWORK NODE

This section reports on the plan for the acquisition and installation of infrastructure for the realization of the Smart Radio Environment (SRE) Laboratory (SRE) whose main components are described in the following subsections. .

- Intelligent surfaces for Smart Radio Environments

6G wireless systems will foster the advent of new technological solutions capable of boosting wireless communications capabilities while achieving an extremely accurate localization of users even in non-visibility conditions. Indeed, this would be hardly attainable with current 5G as it would require the massive deployment of base-stations and access points and, thus, it would be environmentally unfriendly, extremely expensive, and complex from both hardware and software point of view. In this context, one possibility is to unveil the potentialities of smart radio environments, in which a network of intelligent surfaces, coating walls and objects (see Fig. IEIIT 1), is used to guarantee precise mobile user localization and extremely high data-rates communications.

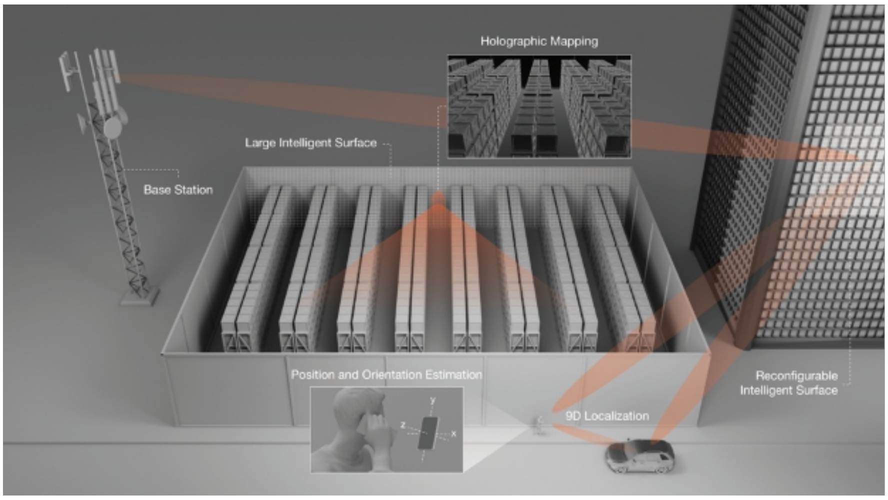
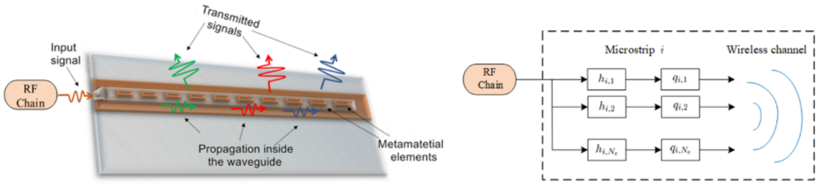


Figure IEIIT-xx. A pictorial vision of future smart radio environments.

A promising solution for the realization of a smart radio environments is provided by intelligent surfaces, usually made of metamaterials.
When intelligent surfaces are employed as Active Antennas (LIS), they can be used as transmitters, receivers or for both purposes. In this scenario, they can be interpreted as compact and low-cost antenna arrays that might be exploitable at the BS. Such antennas can be fabricated with either tiny antennas or metamaterial radiating elements capable of actively communicating over a wireless link. When a LISs is used actively and with the adoption of many tiny antennas, it represents a natural evolution of massive MIMO technology. Recently, it has been investigated the possibility to adopt dynamic metasurfaces, reported in Fig. IEIIT 2, as active antennas to control the transmit/receive beam patterns with advanced hybrid A/D signal processing capabilities. Compared with conventional antennas implemented by patch antennas and phase shifters, dynamic metasurface antennas operate at low power consumption and cost, while naturally implementing RF chain reduction without requiring dedicated analog circuitry but by exploiting metamaterials located within waveguides. Another possibility is to place a reconfigurable EM lens in front of a single transmitter/receiver antenna, such that part of the signal processing is performed in the analog domain through large surfaces. In this way, there is the advantage that the digital signal processing is dramatically reduced, as it is delegated to the lens that operates in the analog domain. On the other side, the cost to be paid is reduced flexibility, as only one RF chain is connected to the antenna that collects the resulting signal after the lens processing.



(a) Physical model (b) Mathematical model

Figure IEIIT 2. Example of dynamic metasurface antenna.

When instead intelligent surfaces are employed as reflectors, they are often referred to as reconfigurable intelligent surfaces (RIS). RISs can be also employed to ease and enable the wireless localization between the BS and multiple users by acting as a method to control the multipath, and they are also referred to digitally controllable scatterers (DCSs), since each element of the surface is treated as a local scatterer. Indeed, this is in principle different from relays that are usually active, or they require more energy and sophisticated processing operations. This emerging technology exploits the possibility to adjust the physical properties dynamically and artificially, such as permittivity and permeability, of the EM waveforms to obtain some desired electrical or magnetic characteristics that in principle are not available in nature. Operating like this, radio waves can be shaped in a way that the reflected signals might not obey Snell's law, but rather a generalized Snell's law. As an example, such an effect can be realized with unit cells made of metallic or dielectric patches that can be modeled as a passive scattering element. To preserve energy and cost efficiency, each unit cell can be equipped with some low-power tunable electronic circuits, e.g., PIN diodes or varactors, and sensors. An alternative is represented by metaprism, which refers to a passive and non-reconfigurable metasurface that acts as a metamirror. Its reflecting properties are frequency-dependent within the signal bandwidth and they can be optimized at the BS by proper frequency resource allocation to increase the communication and localization coverage even in situations where the line-of-sight (LOS) is obstructed.

- ### Channel sounder at millimetre wave and subTHZ

There is a lack of accurate channel models in the millimetre-wave/subTHz regime (30 - 300 GHz and above) with particular reference to both indoor and outdoor propagation. Channel sounders are the first step towards the characterization of such radio channels. In this work, we will use a Vector

Network Analyzer with suitable extender modules (up/down converter) to reach the frequency range of interest. This instrument will exhibit two measurement ports i.e. tx and rx to measure both magnitude and phase of the transmission coefficient. We will not only consider the direct link between a transmitter and a receiver (see Figure IEIIT1, dashed arrow). The extenders and the corresponding antennas will be placed on two-dimensional positioning systems (scanners) to mimic (virtualize) the behavior of a phased array (or MIMO system), see Figure IEIIT1. The presence of Intelligent Reflecting Surfaces (IRS, or metasurfaces) will be also virtualized by considering multiple positions of the scan systems in the radio environment and multiple links between them.

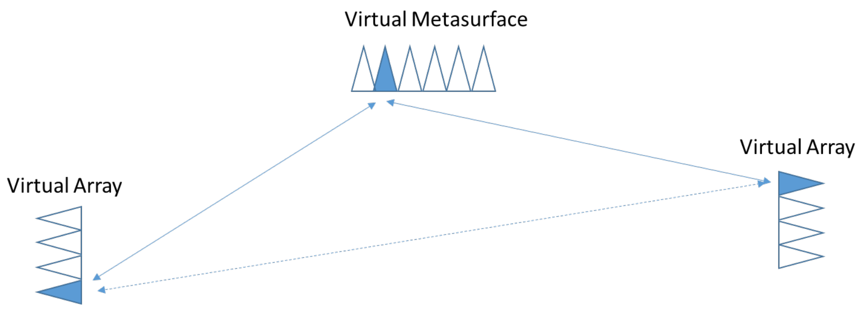


Figure IEIIT1: Channel sounder capabilities for virtualization of Phase Arrays, MIMO access and Reflecting Surfaces

The millimetre-wave extenders mentioned above are shown in Figure IEIIT2. Both the extenders and the Vector Network Analyzer will be available thanks to the CNR Infrastructure TERAM "TEraheRtz Advanced Manufacturing"

Figure IEIIT2: Millimetre wave/subTHz extenders operating at W-band (65-115 GHz), G-band (170-260 GHz) and 500-750 GHz.

Additional cables and positioning systems will be procured for this project. Figure IEIIT3 shows two linear stages with a travel range of 300 mm and an accuracy of 2 μm. The millimetre-wave extender with its waveguides sections is visible on the right. This solution can mimic both a phased array and a reconfigurable metasurface with size 300 x 300 mm. The element spacing can be selected at will thanks to the submicrometer resolution of the encoders. Two identical scanners will be built to allow a fully automated two-port characterization.

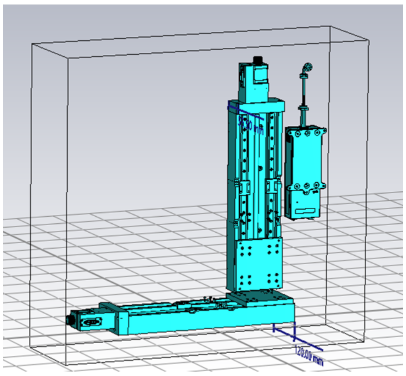


Figure IEIIT3: Sketch of the designed 2D scanner for mmwave/subTHz channel sounder with two linear stages with a travel range of 300 mm and an accuracy of 2 μm. The millimetre wave extender with its waveguides sections is visible on the right. Connecting flanges are not depicted.

- USRP and software radio access networks

Prototypes of 5G and beyond network nodes can be built by using open fully software architectures such as those provided by Openair Interface [1] or by the srsRAN project [2].

These typically require a set of PCs running the software, one for each network node, and a set of software-defined radio (SDR) platforms, one for each network node transmitting or receiving radio signals (RAN nodes).

The PCs, especially those associated with RAN nodes, have stringent requirements on computational power, type of processor, number of cores, and clock frequency. The SDR platforms should support a sufficiently large signal bandwidth to accommodate one or more users, and a large enough output frequency range.

To support the radio base station in 5G networks (gNB) Openair Interface recommends PCs, with CPU Intel Core i9 CPU or better with clock speed of minimum 4.0 GHz, with minimum

10 physical cores. Also they recommend equipping the PCs with 10 Gbps ethernet network cards such as the Intel X710-DA2. Fast network cards are required to support the transfer of baseband signal samples from the PC to the SDR platform.

As for the SDR devices, many models are supported by Openair Interface. Among them, we mention the National Instruments (NI) Ettus USRP X310 and X410.

In particular the NI Ettus USRP X410 is a high-performance, multi-channel SDR designed for output frequencies from 1 MHz to 7.2 GHz, with 4 independent TX and RX channels and capable of 400 MHz of instantaneous bandwidth each. Digital interfaces for data offload and control include two QSFP28 interfaces capable of 100 GbE, a PCIe Gen3 x8 [1] interface, as well standard command, control, and debug interfaces: USB-C JTAG, USB-C console, Ethernet 10/100/1000. The NI Ettus USRP X410 is an all-in-one device built on the Xilinx Zynq Ultrascale+ ZU28DR RF System on Chip (RFSoC) with built-in digital up and down conversion and onboard Soft-Decision Forward Error Correction (SD-FEC) IP.

To meet the Openair Interface and srsRAN requirements we decided to buy the Ettus X410 USRP and two workstations with processor intel Core i9-13900k (24 cores/32 threads) equipped with 64GB of RAM DDR5, and 10Gb/s network card.

In addition, an extremely high-performance workstation is required to permit the post-analysis of the data collected by the testbed previously defined. When experiments based on wireless technology, and 5G/6G specifically, are carried out in practice, the amount of data collected is of a really huge dimension. Firstly, a significant amount of RAM is essential to handle big data analysis, especially when algorithms require loading all the data into memory. For what concern this project, a dimension of 1024 GB is considered essential, and the type of memory should be DDR5 with an access speed of 4800 MHz or higher. The processor needs high processing power distributed on many cores to enable a true parallelization of the algorithms and to handle complex computational tasks efficiently. A suitable solution could be a dual CPU of type Intel® Xeon® Platinum 8468, where each CPU is composed of 48 cores running at a maximum speed of 3.80 GHz. A graphic card, for instance, the NVIDIA RTX A5500, would be indispensable for the execution of those tasks requiring a very high level of parallelism. Finally, fast storage (e.g., 4TB of type SSD) and fast connection (e.g., two 10GbE Ethernet network adapters) are needed to guarantee sufficient bandwidth for data access.

4.2 UNIBO-DEI BEYOND 5G NETWORK NODE

This section reports on the plan for the acquisition and installation of the beyond 5G network nodes.

The plan is to implement a 5G radio access network (RAN) by acquiring a dedicated hardware and software platform that aligns with the open-RAN paradigm. This strategic approach ensures that the RAN platform remains open and accessible, granting access to the RAN controller and, consequently, enabling the implementation and testing of algorithms specifically developed to achieve the project's objectives. Specifically, researchers and specialist software suppliers will have the opportunity to develop "xApps" and "rApps" tailored to specific tasks (e.g., handover and scheduling), also addressing their interactions and conflicts. The final purpose is to contribute to the development of future mobile networks by developing effective solutions as well as by fostering collaboration in the field of 5G technology.

The platform will include all physical devices and software licenses required to make it fully functional and interface with Core Network (CN) implementations available within the project or provided by third parties.

The initial phase of this activity was dedicated to market research for solutions that aligned with the required characteristics. After thorough evaluation, a platform inspired by the ARENA solution, developed by Northeastern University in Boston (USA), emerged as the ultimate choice. The configuration we have determined to be suitable for the needs of the SoBigData project allows for installation of a RAN consisting of three gNodeBs, enabling connectivity for commercial off-the-shelf (COTS) user equipment (UE). Specifically, the platform will include the following components:

- Three USRP software-defined radio devices, either x410 or X310, functioning as gNodeBs.
- Approximately ten commercial User Equipment (UE) devices.
- Five servers equipped with dual socket motherboards, supporting 16 cores CPUs. The servers also include routers/switches.
- Software licenses for the OpenShift platform to be installed on the five servers, enabling the development and deployment of container-based applications.
- O-RAN package consisting of near-real-time RIC, xApp templates, interfaces, and 4G and 5G stacks.

The procurement of the platform, including both hardware and software components, will strictly adhere to the regulations set forth by the public administration and will align with the timelines specified by the Administrative Staff of the University of Bologna.

4.3 UNIGE BEYOND 5G NETWORK NODE

No information is available. A delay is envisaged for the acquisition of the resources.

4.4 UNICT BEYOND 5G NETWORK NODE

The objective is to deploy a 5G&B and IoT cloud-native access radio network (RAN) with edge-computing capabilities to provide mobile nodes with both offloading facilities, for heavy computation jobs, and network softwarization facilities, for deploying virtual network functions in virtual machines and containers at the network edge.

The platform will be realised according to the Open-Ran (O-RAN) paradigm in order to achieve the principles of disaggregation, openness, virtualization, and programmability, also allowing to expose data and analytics and enabling data-driven optimization, closed-loop control, and automation. The UniCT RAN platform will also implement algorithmic control thanks to the presence of the RAN Intelligent Controller (RIC), considered in the O-RAN architecture as an extension of the classical Radio Resource Management (RRM) with data-driven approaches based on live telemetry from the RAN processed by Machine Learning (ML) and Artificial Intelligence (AI) pipelines.

The UniCT RAN will be compliant with the 5GC standard in order to allow not only support for 5G&B vertical services developed by third parties, but also future integration with external Core Network implementations and, specifically, with the European SLICES network whose implementation is ongoing.

The UniCT RAN platform will be constituted by two main parts: the radio portion and the edge-computing infrastructure. The radio interface has been planned as constituted by three gNodeBs. Nine heterogeneous user equipment (UE) devices will be also included. The edge-computing infrastructure will be realised with five servers and the hardware for interconnection of the above network devices. Finally, the platform will also support IoT communications with a certain degree of flexibility, thanks to the inclusion of portable SDRs for the simulation of additional UEs, IoT devices, and both. These SDRs will be controlled and configured through proper notebook PCs, for the sake of maximum flexibility.

More in details, the UniCT RAN platform will include the following components:

- 3x NI Ettus USRP X410, equipped with power cables, QSFP28 to 4xSFP28 Breakout Cable and 4 Antennas working at the 5G bands n77 (TDD C-Band [3300-4200] MHz) and n78 (TDD C-Band [3300-3800] MHz)
- 3x NI Ettus USRP X310, equipped with power cables, QSFP28 to 4xSFP28 Breakout Cable and 4 Antennas working at the 5G bands n77 (TDD C-Band [3300-4200] MHz) and n78 (TDD C-Band [3300-3800] MHz) and 5G-ANT-SV02 antennas
- 10x portable USRP B205MINI-I (1X1, 70 MHZ - 6 GHZ), equipped with 5G-ANT-SV02 antennas
- 5x UE Sierra Wireless EM9191 5G NR Sub-6 GHz Module in format M.2 with adapter for laptop/pc
- 4x UE smartphones 5G 12GB+256GB Dual Sim International Version
- 9x programmable nano-SIM cards
- 1x Clock Distribution Device with GPSDO (OctoClock-G) CDA-2990
- 1x gateway node realized with an Intel NUC 11 with 16 CPU cores, 64 GB RAM
- 1x router 10 Gbps with 8 Ethernet ports
- 1x switch 1 Gbps with 24 Ethernet ports
- 1x PDU with 16 sockets
- 1x UPS
- 1x rack
- 5x Servers Dell PowerEdge R740xd with 16 CPU cores, 192 GB RAM, Mellanox ConnectX-6 NIC with QSFP28 ports, RTX 4070 12GB, Ram 32Gb DDR5 5600MHz, SSD Nvme 1000GB, 240mm AiO Cooler
- 2x Dell XPS15 Intel® Core™ i9-12900HK notebooks (24 MB di cache memory, 14 core, 20 thread, 5,00 GHz Turbo), NVIDIA® GeForce RTX™ 3050 Ti, 4 GB di GDDR6, 40 W, 64 GB memory DDR5, 4.800 MHz, SSD PCIe NVMe M.2 1 TB, to

- 5x OpenShift licenses
- 1x O-RAN software environment with Near-real-time RAN Intelligent Controller (RIC) compliant with the O-RAN Alliance specifications, O-RAN E2 interface, and with the software needed for automatic collection and monitoring KPI data, specifically throughput, latency and bit-error-rate.

4.5 UNIPA BEYOND 5G NETWORK NODE

The Telecommunications laboratory at UNIPA focuses on architectures for reprogrammable 5G network nodes, coexistence problems and strategies for cooperation between heterogeneous technologies coexisting in unlicensed bands (WiFi, LTE, ZigBee), development of intelligence solutions for dynamic and automatic reconfigurations of networks based on contexts, long-range low-power technologies (such as LoRa) for IoT applications, development of modulators for underwater transmissions. Currently, the lab is equipped with 4 WARP Software-Defined-Radio (SDR) platforms with integrated FPGAs and 5 USRP SDRs of the N200 family from National Instruments, for prototyping wireless nodes based on innovative (non-standard) physical and medium access layers. It also has a spectrum analyzer and several computers with commercial wireless network cards.

In the context of the project, UNIPA is developing and testing Beyond-5G network solutions at radio and core levels, exploiting the capabilities of softwarized access/core network technology. This will enable researchers to deploy and experiment with end-to-end networks where the classical operational and control boundaries between networks, computing and devices are becoming less distinct. In particular, UNIPA is planning to acquire and install the following equipment:

- *Computing equipment:*

Equipment	Quantity	Description
Server	1	DELL Smart Selection PowerEdge R640 Server 2.5 Chassis with up to 8 Hard Drives and 3PCIe slots PERC11 Trusted Platform Module 2.0 V3 Processore Intel® Xeon® Silver 4210R 2.4G, 10C/20T, 9.6GT/s, 13.75M Cache, Turbo, HT (100W) DDR4-2400 2x16GB RDIMM, 3200MT/s, Dual Rank Dischi rigidi 480GB SSD SATA Read Intensive 6Gbps 512 2.5in Hot-plug AG Drive, 1 DWPD Broadcom 57416 Dual Port 10GbE Base-T + 5720 Dual Port 1GbE Base-T Adapter, rNDC, V2

Workstation PC	4	WORKSTATION INTEL Core i9 12900K con Processore 16 Core 5.2 GHz di dodicesima generazione (30 MB di memoria cache, 16 core, 24 thread, da 3,20 a 5,20 GHz Turbo, 125 W, Estensioni set di istruzioni Intel® AVX2) - CPU Intel Core i9-12900KF 3,2 GHz (Cache 30Mb) Turbo Frequency 5.2 GHz - Memorie DDR5 32GB 4800 Kingston Fury Beast Black (2X16) - SSD M.2 Gigabyte Aorus 1TB High Performance NVMe PCIe 4.0 - Scheda di rete NVIDIA Mellanox MCX4121A-ACAT ConnectX®-4 Lx EN Network Interface Card, 25GbE Dual-Port SFP28, PCIe3.0 x 8, Tall&Short Bracket
Notebook	2	Dell XPS15 Processore Intel® Core™ i9-12900HK di dodicesima generazione (24 MB di memoria cache, 14 core, 20 thread, fino a 5,00 GHz Turbo) Scheda video NVIDIA® GeForce RTX™ 3050 Ti, 4 GB di GDDR6, 40 W Memoria 64 GB, 2 da 32 GB, DDR5, 4.800 MHz, doppio canale Disco rigido Unità SSD PCIe NVMe M.2 da 1 TB

- *Network and radio equipment:*

Equipment	Quantity	Description
SDR	4	USRP N310 10 MHz to 6 GHz extended frequency range Up to 100 MHz of instantaneous bandwidth per channel 4 RX, 4TX in half-wide RU form factor RX, TX filter bank 16 bit ADC, 14 bit DAC Xilinx Zynq-7100 SoC (Dual-core ARM Cortex-A9 800 MHz CPU)
Antennas	32	5G-ANT-SV02B-SMA SR PASSIVES Antenna; 5G,LTE; 5dBi; angular,twist-on; 50Ω; 600÷6000MHz; 194mm
SMA cables	20	SMA-SMF/50/10 BQ CABLE

External Clock	1	OctoClock-G CDA-2990 Fully Integrated Timing Source with 8-Way Distribution (10 MHz and 1 PPS) Convenient Solution for Multi-Channel Synchronization Use with MIMO-Capable USRP Devices for Coherent System User Selection between Internal GPSDO Or External 10 MHz & 1 PPS Source Source detection with automatic switch-over in case of failure or disconnect 19" 1U rack mountable
SFP+ Cables	8	ETTUS 10 Gigabit Ethernet Cable w/ SFP+ Terminations (1 Meter)
Router	1	MikroTik CCR2004-1G-12S+2XS 10/100/1000 Ethernet ports 1 SFP+ ports 12 Number of 25G SFP28 ports 2 Serial console port RJ45 Architecture ARM 64bit CPU AL32400 CPU core count 4 CPU nominal frequency 1700 MHz Size of RAM 4 GB Storage size 128 MB

- *Other equipment and IoT devices:*

Equipment	Quantity	Description
Smartphone 5G	1	OnePlus 9 5G NSA：N1, 3, 5, 7, 8, 20, 28, 38, 40, 41, 66, 78 5G SA：N1, 3, 7, 28, 41, 78 MIMO：LTE: B1, 3, 7, 38, 40, 41 ; NR: N1, 3, 7, 38, 40, 41, 78 2×2 MIMO, supporto 2,4G/5G, supporto WiFi 802.11 a/b/g/n/ac/ax Bluetooth 5.2, support aptX & aptX HD & LDAC & AAC
Smartphone 5G	1	Google Pixel 6a - 5G Android smartphone - Unlocked 12 Megapixel Camera Memory Storage Capacity 128 GB

<table>
<tr><td></td><td></td><td colspan="3">Connectivity Technology Bluetooth, Wi-Fi, NFC
Screen Size 6.13 Inches</td></tr>
<tr><td>Customized cleaning robot (for localization experiments)</td><td>1</td><td colspan="3">Roomba i5+ (I5652)</td></tr>
<tr><td rowspan="19">NB-IoT & GNSS Kit</td><td rowspan="19">1</td><td colspan="3">Kit Hardware Content:</td></tr>
<tr><td>Item</td><td>Name</td><td>Quantity</td></tr>
<tr><td>1</td><td>5G NB-IoT Hardware Board</td><td>1</td></tr>
<tr><td>2</td><td>LTE & GPS Antenna</td><td>1</td></tr>
<tr><td>3</td><td>4*4 Matrix Keypad</td><td>1</td></tr>
<tr><td>4</td><td>5V Relay</td><td>1</td></tr>
<tr><td>5</td><td>Step Motor</td><td>1</td></tr>
<tr><td>6</td><td>Temperature Sensor LM35</td><td>1</td></tr>
<tr><td>7</td><td>Motor</td><td>1</td></tr>
<tr><td>8</td><td>IR Receiver</td><td>1</td></tr>
<tr><td>9</td><td>Vibration Sensor SW-520D</td><td>2</td></tr>
<tr><td>10</td><td>Jumper Cap</td><td>4</td></tr>
<tr><td>11</td><td>Key Switch(yellow)</td><td>5</td></tr>
<tr><td>12</td><td>DHT11 Module</td><td>1</td></tr>
<tr><td>13</td><td>Clock Module</td><td>1</td></tr>
<tr><td>14</td><td>Big Sound Module</td><td>1</td></tr>
<tr><td>15</td><td>Water Module</td><td>1</td></tr>
<tr><td>16</td><td>Photocell</td><td>3</td></tr>
<tr><td>17</td><td>Active Buzzer</td><td>1</td></tr>
</table>

		18	SN74HC595	1
		19	3-color LED	1
		20	7 Segment	1
		21	4-7 Segment	1
		22	Passive Buzzer	1
		23	B10K Variable	1
		24	Flame	1
		25	SG90 Servo	1
		26	1602 Display	1
		27	8*8 Matrix	1
		28	830 Breadboard	1
		29	Joystick	1
		30	RFID Module	1
		31	Remote Control	1
		32	Blue LED	10
		33	Red LED	10
		34	Green LED	10
		35	330R Resistance	10
		36	220R Resistance	10
		37	10K Resistance	10
		38	1K Resistance	10
		39	Jumper Wire	1
		40	F-M Dupont Wire	1
		41	2.54mm 40Pin	1

5 CONCLUSIONS

This Deliverable has detailed a plan for the acquisition and installation of new computational resources, providing schemes and strategies for deploying green data centres, pervasive computing and networking nodes, and beyond 5G network components. The plan emphasises the importance of energy efficiency, low-latency storage solutions, and virtualized resource management in the edge-to-cloud continuum.

The system-of-systems approach adopted by SoBigData facilitates autonomy, openness, and distribution at the node level. This allows for the seamless addition and evolution of new nodes, ensuring flexibility and adaptability to changing research needs. The multi-site digital infrastructure, with its central hub and peripheral sites, provides a scalable and robust foundation for storing and processing large and complex datasets. The integration of pervasive computing and networking nodes, along with 5G and 6G network nodes, ensures the availability of state-of-the-art resources and capabilities. In particular, 6G wireless systems will foster the advent of new technological solutions capable of boosting wireless communications capabilities while achieving an extremely accurate localization of users even in non-visibility conditions. These nodes utilise advanced architectures and technologies such as edge computing, Internet of Things (IoT), and next-generation networks, enabling SoBigData to offer access to both current and future data centre solutions.

By centralising management through a single platform for hardware and software layers, the infrastructure simplifies operations, enhances scalability, and reduces the total cost of ownership. It not only offers a substantial return on investment for providers joining the SoBigData ecosystem, rather it also positions the project to support future advancements in data analytics and distributed computing.

All in all, by leveraging green data centres, pervasive computing, and beyond 5G networks, SoBigData aims at positioning itself at the forefront of data-driven research and at being well-equipped to address the evolving needs of the scientific community so as to contribute to the progress of Data Science and Data Intensive Research.