ICI INNOLABS: A Platform for Exploring Emerging and Disruptive Technologies

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Abstract: In the digital era, developing and testing emerging and disruptive technologies are an absolute necessity to maintain competitiveness in an interconnected world. This paper presents ICI INNOLABS, a platform implemented with the objective to facilitate the development and testing of emerging and disruptive technologies. Having a software-focused infrastructure that integrates hardware resources, making it useful in hosting the development of IoT management platforms and tools for data analysis.
Keywords: Internet of Things (IoT), Hyper-convergent infrastructure (HCI), virtualization, containerization, data analysis, IoT management platforms, Artificial Intelligence, NUC, mini-pc.

INTRODUCTION

Emerging and disruptive technologies have become very important because they are reshaping current industries as well as the economies that are based on them. These technologies have great potential to transform the fields in which they are used. Since emerging technologies are always in their early stages and promise to significantly influence society in the future, it is essential to check and test them in the development stage. As these technologies promise to solve some problems that until now have no solution, it is very important to test them, so that the problem-solving is carried out in optimal and safe conditions.

In (Kricka, 2016) technologies that in 2016 were announced to be emerging are presented. Some of these have been confirmed so far and others are still considered emerging technologies such as robots, 3D printing, Blockchain, Internet of Things (IoT), Metaverse, Virtual Reality (VR), Artificial Intelligence (AI), Big Data, Nanotechnologies, Quantum Computing, Smart Cities and Machine Learning (ML).

There are a large number of research papers that address these emerging technologies and how they are used in several fields such as those presented in Table 1.

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Table 1. Domains that use emerging and disruptive technologies

Nr.	Domain	Emerging technologies that can be used	Sources
1.	Aquaculture	Robots, Drones, IoT, AI, VR, 3D Printing, Blockchain	(Yue and Shen, 2022), (Daigger, et al., 2019), (Harshadeep and Young, 2020)
2.	Transport	3D Printing, AI, Autonomous Vehicles, Big Data, Blockchain, Drones, IoT	(Dong, et al., 2021), (Gemici and Alpkan, 2015), (Herrera-Quintero, et al., 2019)
3.	Urban Farm	Artificial Intelligence, Robotics, Blockchain, Digital Twin, Nanotechnology, IoT	(Ng and Mahkeswarran, 2021), (Yadav, et al., 2022)
4.	Banking	FinTech, Blockchain, ML, Smart Contracts	(Rafay, 2019), (Omoge, et al., 2022), (King, et al., 2021)
5.	Education	AI, ML, Adaptive Learning, Blockchain	(Sosa, et al., 2022), (Ullah, et al., 2021)
6.	Governance	Smart cities, AI, Cryptocurrency, Blockchain, Big Data	(Brennan, et al., 2019), (Smith and Castonguay, 2020), (Taeihagh, 2021)

This study focuses on the ICI INNOLABS platform, an essential tool that offers users a flexible and scalable environment for developing and testing emerging and disruptive technologies. In this context, it details the levels of functionality of this platform, highlighting how it enables users to explore data storage applications through virtualized environments (containers, environments, and virtual machines). This platform facilitates the research and development of new innovative technologies, and each innovation laboratory has its pool of hardware and digital resources. Additionally, it discusses compact NUC (Next Unit of Computing) systems that integrate cutting-edge technologies and interfaces, enabling users to experience the best performance while minimizing energy consumption. The discussion section evaluates trade-offs, such as hardware limitations on consumer-grade computers and the learning curve associated with self-hosted solutions, providing a comprehensive overview of the platform's weaknesses. This article concludes by discussing the importance of emerging and disruptive technologies that are transforming modern life and efficient automation. Simultaneously, the ICI INNOLABS platform provides a secure and dedicated environment for exploring and testing digital technologies.

ICI INNOLABS PLATFORM OVERVIEW

ICI INNOLABS is a platform integrated into Heimdall Application Dashboard that improves user experience and productivity. It's an open-source dashboard app for managing web apps and services, accessible on personal servers or via a browser. It monitors and accesses information in a personalized way, facilitating efficient management of digital activities. It can be customized as the browser's home page and includes a search bar that can use Google, Bing, or DuckDuckGo.

Moreover, ICI INNOLABS is a platform developed by the IoT Innovation Laboratory within the National Institute for Research and Development in Informatics – ICI Bucharest. It is designed for teams of professionals from various fields, such as engineers, data scientists,

researchers and cybersecurity experts. The platform offers a variety of applications for users to utilize, including:

- *Gogs* – is a self-hosted Git web service developed in Go, also known as „Go Git Service". It is a lightweight, open-source alternative to popular git-hosting platforms such as GitHub, GitLab and Bitbucket. With Gogs, users have the ability to host their own Git repository on their own servers, which allows them to maintain control over their code and promote collaboration among developers.
- *JupyterLab* – is a web interface developed by the Jupyter project, providing a modular structure and an experience that is similar to working in an integrated development environment (IDE). This platform is useful for developing, testing, and documenting Python code, especially used in the fields of data science, machine learning, and data analysis. Users can use the JupyterLab interface to create and edit interactive notebooks that integrate Python code with text, images, graphs and multimedia elements. This allows the creation of comprehensive and reproducible documentation that can be easily shared.
- *Etherpad* – is a collaborative editor that allows multiple users to work on a document together in real-time. It provides a web-based interface where users can simultaneously create, edit and collaborate on plain text documents. This tool facilitates seamless teamwork and communication, enabling individuals to collaborate on projects, brainstorm ideas and make changes to documents without the need for constant file sharing and version control.
- *Kimai* – is open-source time-tracking software that allows individuals and teams to manage their work hours and projects using a web-based interface. It also provides features such as task management and report generation for analysis and invoicing.
- *Ticket Zammad* – is open-source software that efficiently manages customer support and communication across different channels like email and social media. It automates tasks, enables teams to collaborate on tickets and provides reports to improve customer service. It's also highly flexible and customizable to fit the unique needs of different businesses.
- *HomeAssistant* – is a platform for home automation that is open-source and allows for the integration of IoT (Internet of Things) devices. This platform provides a central system for managing all IoT devices in a user's home, including home appliances, motion sensors, surveillance cameras and smart thermostats. With this platform, users can easily control their devices from a single location.
- *ThingsBoard* – is an open-source IoT platform that simplifies the development, management, and scaling of IoT projects. It provides an out-of-the-box solution for IoT applications, either on-premises or in the cloud. The platform features include provisioning devices, assets and customers, collecting and visualizing data, analyzing telemetry, controlling devices, building workflows, designing dynamic dashboards, enabling use-case-specific features and pushing device data to other systems.
- *Leantime* – is an open-source project management tool that helps individuals and teams streamline their project planning, execution and collaboration. It offers a range of features to support agile project management methodologies and enhance productivity.
- *Vikunja* – is a project management tool that simplifies sharing with individuals or teams. It enhances collaboration through clear assignments, indicating who is responsible for specific tasks. Users can choose their preferred task view: classic list layout, Gantt Chart, Table view, or Kanban Board.

- *TeamMapper* – is an open-source web application designed for collaborative mind mapping. It allows multiple users to contribute to the same mind map, fostering efficient brainstorming and idea development.
- *Bitwarden* – is a password manager that securely stores and manages passwords and sensitive information across different platforms. Its encryption and helpful features aim to simplify password management while enhancing online security.
- *Gist* – is a web-based platform provided by OpenGist for sharing and collaborating on code snippets, notes and other short texts. It is popular among developers and programmers due to its simplicity and convenience.
- *Nginx Proxy Manager* – is a web-based tool that simplifies the process of configuring and managing Nginx as a reverse proxy. It makes routing incoming web traffic to different backend servers or services easier.
- *phpMyAdmin* – is a web-based GUI (Graphical User Interface) tool for managing and administering MySQL and MariaDB databases. With its intuitive interface, users can perform a wide range of tasks, from managing databases and tables to manipulating data with ease. Additionally, it provides the ability to create and delete users, as well as define different levels of access for them. phpMyAdmin simplifies database management and aids in the process of securing and accessing options through authentication and authorization mechanisms.
- *pgAdmin* – is an open-source administration and management tool for PostgreSQL, being a powerful and feature-rich relational database management system (RDBMS). In contrast to MySQL and MariaDB, which are managed using phpMyAdmin, pgAdmin provides an intuitive graphical user interface (GUI) that facilitates interaction with PostgreSQL databases and streamlines administrative tasks.
- *Uptime Kuma* – is an open-source tool that enables monitoring services on HTTP/S, TCP, DNS and other protocols. It tracks and monitors the uptime and performance of websites, servers and other network resources. Also, it offers real-time monitoring and alerting features to keep users updated on the availability and performance of their online services.
- *Grafana* – is an open-source software that enables users to query, visualize, explore and gain insights from their metrics, logs, and other data from various sources. It allows the creation of informative graphs and dashboards from time-series database (TSDB) data, enabling better decision-making, system optimization, and troubleshooting. Grafana is a flexible tool that can integrate with various data sources, including databases, ticketing systems and CI/CD (Continuous Integration/Continuous Delivery) tools.
- *Cockpit* – is a web-based graphical interface for server administration, suitable for users of all levels. It simplifies server management for Linux beginners and experienced users alike, while also providing an overview of individual systems for advanced administrators.
- *Ansible UI* – is a graphical interface that simplifies IT automation by allowing users to create, manage, and execute complex tasks and workflows using Ansible's automation engine.
- *Portainer* – is an open-source container management platform that provides a user-friendly graphical interface for managing Docker environments. It allows users to manage Docker containers and orchestration within Swarm. Additionally, Portainer streamlines container deployment, platform management, IoT device security, troubleshooting, compliance and lifecycle management for accelerated adoption.
- *Proxmox VE* – is an open-source server virtualization platform to manage KVM

(Kernel-based Virtual Machine) for virtual machines and LXC (Linux Container) for containers through a web-based interface. It allows easy management of VMs and containers, high availability for clusters and seamless disaster recovery.

Figure 1 illustrates all applications available on the ICI INNOLABS platform. These applications can be categorized into several distinct groups:

- Collaboration Facilitation Apps: Leantime, Etherpad, Gogs, Vikunja, Gist, Ticket Zammad, Kimai, TeamMapper;
- IoT Platforms: HomeAssistant, ThingsBoard;
- Utility: Bitwarden;
- Monitoring Tools: Grafana, Uptime Kuma;
- SQL GUI: phpMyAdmin, pgAdmin for PostgreSQL;
- Server Administration: Portainer, Proxmox VE, Cockpit, Ansible UI, Nginx Proxy Manager;
- Integrated Development Environment (IDE): JupyterLab.

These categories succinctly delineate the diverse functionalities offered by the ICI INNOLABS platform, catering to a wide spectrum of professional needs and facilitating collaborative innovation across an array of disciplines and industries.

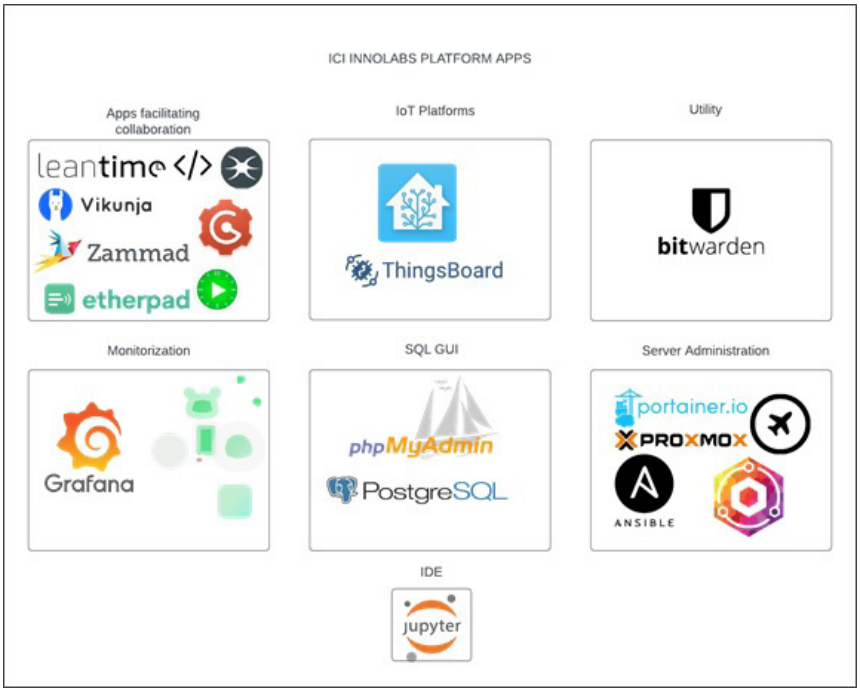

Figure 1. *Presentation of Applications on the ICI INNOLABS Platform*

VIRTUALIZATION LEVELS OF THE ICI INNOLABS PLATFORM

The virtualization level allows separation between the operating system, running applications and the underlying hardware. Each VM has the capacity to host an independent operating system, presenting users with an impression of exclusive access to tangible computing resources. This setup guarantees both performance and protection against failures because each VM operates in isolation from others that share the same physical server (Pearce et al., 2013). Positioning between the hardware and the operating system, a virtualization layer oversees the allocation of resources. This part is taken on by a virtual machine monitor (VMM), which manages resource allocation and plays a role in the power management functions of the system.

To deploy all the required virtual machines, the ICI INNOLABS platform has a hyper-convergent infrastructure that manages the hardware workloads through a unified interface. A hyper-convergent infrastructure offers an „all-in-one solution" (Azeem and Sharma, 2017), forming a cluster out of all the hardware resources made available (servers, storage devices, etc.). Therefore, the chosen „hardware virtualization software" is Proxmox, which has proven to be reliable and robust in deploying and managing workloads of various VM's. Over the „hardware virtualization" layer, Proxmox makes it easy to further develop a pipeline using its hypervisor. Different VM's are created, hosting applications and containers and defining the „second layer" of virtualization. Moreover, a container orchestration tool was used to run the Docker containers. Docker swarm manages different containers deployed across the servers.

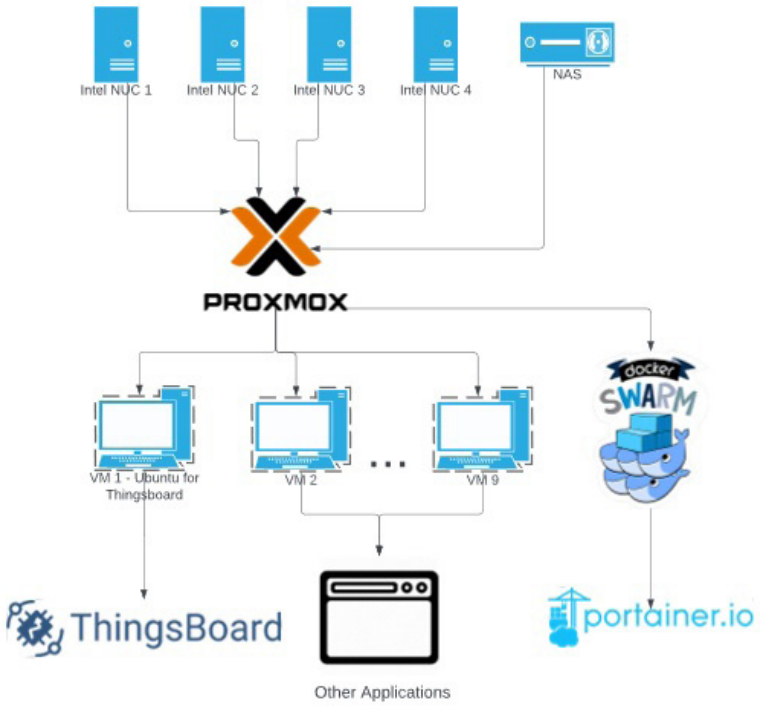

Figure 2. *General arhitecure of the ICI INNOLABS Platform*

Figure 2 illustrates the general architecture of the ICI INNOLABS platform, with Proxmox managing the Intel NUCs and NAS (Network Attached Storage), using the QEMU emulator combined with the KVM virtualization module to create the needed virtual machines. Ten virtual machines host all the applications that make up the Heimdall Application Dashboard.

HARDWARE LAYER

By using an array of Intel NUCs (Next Unit of Computing), compact devices that enable a full desktop PC or edge device experience, the hardware infrastructure of the platform can be defined as cheap to upkeep and a robust cluster of servers. A NUC includes all the components of a standard PC, such as a processor, memory, SSD, LAN, or Wi-Fi, and also offers integrated and discrete graphics options. Initially associated with mini PCs, the NUC has evolved into a solution that defines the future of computing and, consequently, its name. NUC packs the same power and capabilities of a standard PC into a small size. In the past, NUC models had motherboards measuring four by four inches squared. Today, NUCs are available in a variety of shapes, sizes

and materials to suit different needs. There are NUCs available for almost any purpose, whether for gaming, content creation, productivity-focused workstations, or even modular devices specifically designed for business, with built-in Intel Pro platform support. In the case of the ICI INNOLABS, the platform is hosted on six Intel NUC 12 PRO mini-computers used to host core services. Moreover, three other NUC 12 Extreme, which are powered by dedicated graphics cards, facilitate the processing and training of machine learning models.

DISCUSSION

Like any other platform, ICI INNOLABS has trade-offs compared to other solutions in the field. For example, although a cloud-based infrastructure is a popular alternative to a self-hosted HPC infrastructure, ICI INNOLABS is primarily designed for experimental applications and testing, such as retrieving sensor data using the Thingsboard IoT management platform. Therefore, the platform may have some limitations when it comes to supporting more complex solutions that are in production. When evaluating the functionality of ICI INNOLABS, it is important to consider the following potential weaknesses:

- *Hardware limitations* are a critical aspect of ICI INNOLABS' hosting infrastructure. Consumer-grade computers are used to host the platform, as it is a more cost-effective solution compared to professional-rated hardware. While this choice comes with its benefits, it also has its weaknesses. One such shortcoming is its inability to support zero-downtime deployment. Furthermore, the Intel NUC computers used in this infrastructure lack enterprise features such as memory hot swapping and Error Correction Code (ECC) memory. However, it is important to note that these limitations do not present significant difficulties for an IoT laboratory. The platform caters to a small number of users who access it at specific times. Therefore, the associated hardware limitations do not affect the laboratory's operations. Despite these limitations, ICI INNOLABS remains a robust and reliable platform for users to carry out their IoT projects.
- *Ease of use:* A self-hosted solution presents certain challenges that must be addressed by an experienced member who can oversee its maintenance and supervision. Additionally, users must possess a basic understanding of the hardware infrastructure, which may result in a steeper learning curve when utilizing the features that comprise the ICI INNOLABS platform. For example, when working with the JupyterHub coding environment, users need to be aware of the available resources at any given time and choose hardware with less workload.

CONCLUSIONS

In conclusion, platforms such as ICI INNOLABS play a pivotal role in driving innovation and addressing the need for testing and development of emerging and disruptive technologies posed by the ever-changing field of computer science. ICI INNOLABS provides a controlled, contained and collaborative environment in which developers can experiment with different technologies, mitigating issues in the deployment of innovative services. These platforms play a part in diminishing risk, serving as a sandbox to identify and rectify potential flaws and vulnerabilities before deployment. Furthermore, the general infrastructure of the platform is an easy-to-implement solution, using off-the-shelf hardware, with a low upkeep cost, emphasizing resource and energy optimization.

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