# Open Challenges for a Production-ready Cloud Environment on top of RISC-V hardware

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## Abstract

As part of the Vitamin-V *Vitamin-V* n.d. European project, we have built a prototype of a RISC-V cluster managed by OpenStack, with the goal of realizing a functional RISC-V cloud ecosystem. In this poster we explain the hardware and software challenges encountered while porting some elements of OpenStack. We also discuss the current performance gaps that challenge a production-ready cloud environment over such new ISA, an essential element to fulfill in order to achieve European technological sovereignty

## Introduction

Large-scale supercomputers and datacenters have become essential in many scientific applications requiring big- data processing. However, most current computing architectures are proprietary and closed-source technologies such as x86 and ARM, which creates concerns about the reliability of privacy and security.
The Vitamin-V project emerged as an effort to build European data centers based on the EPI ( Kovač 2019) processor as a reliable alternative to traditional proprietary systems like x86 and ARM. As a part of the Vitamin-V project, we have devoted the last year to developing a functional OpenStack cluster utilizing real hardware instead of emulators. To this end, we are using a hardware platform based on RISC-V development boards ( SiPeed n.d.).
In this poster, we explain some open challenges in RISC-V that need to be addressed to compete with clouds built on top of commodity hardware, as well as the challenges that we have had to overcome in order to build a functional cloud stack on top of RISC-V, and particularly a cloud stack based on the OpenStack framework.

## Ecosystem Maturity

### Hardware

Transitioning from QEMU emulation to physical RISC-V hardware highlights the limited availability of commercial boards, which are either expensive or under-performing. Only one HPC board Milk-V n.d. supports RVV1.0 vector extensions, but its release was delayed by six months and it sold out in three months at 600 €. These boards are intended for development, not business use, creating a performance gap even with powerful chips. This is due to the RISC-V ISA still evolving, with many extensions not yet implemented in hardware. For example, RVV1.0 was ratified in 2024, with only one commercial implementation, and hypervisor extensions remain unimplemented.

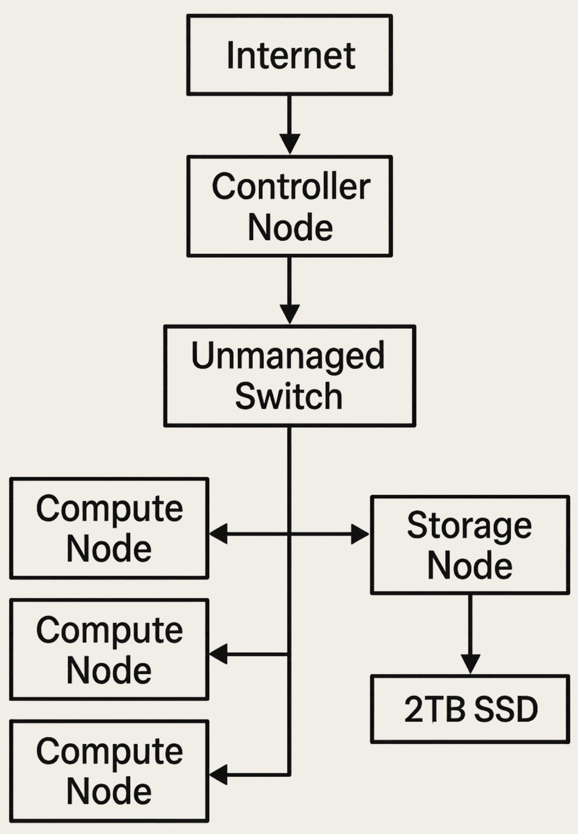


Figure 1. OpenStack cluster using LicheePi4a boards.

In our setup, we use the Sipeed Lichee Pi 4A RISC-V board, featuring a TH1520 CPU (4 threads), 16GB RAM, 128GB storage, and dual Gigabit Ethernet, ideal for building an OpenStack cluster. Our setup includes a controller, four compute nodes, and a storage node with a 2TB USB SSD, as shown in Figure 1.
In contrast, we tested a cluster of 8 Intel Xeon Silver 4114 nodes with 126GB DDR5 RAM and 10Gbps Ethernet, plus a 10TB storage node. The performance comparison in Table 2 shows RISC-V is up to 10 times slower, making it unsuitable for production-ready cloud environments like OpenStack, where performance and scalability are critical.

| Test | RISC-V | x86 |
|---|---|---|
| Coremark (iter./sec) | 8500 | 22730 |
| Disk I/O SeqW. (MB/s) | 204 | 1451 |
| Disk I/O RandW.(MB/s) | 28.8 | 1316 |
| Network Throughput (MB/s) | 118 | 1200 |
| Power Consumption (W) | 11 | 270-350 |

Table 1. Performance Comparison between LicheePi 4A (RISC-V) and Intel Xeon Silver 4112 @ 2GHz (x86) machine.

### Software

The software presents several challenges. OpenStack depends on hundreds of Python libraries with strict version requirements, needing frequent updates for stability. The LicheePi 4A's Debian-based OS initially lacked essential packages, especially development tools. As Debian's RISC-V package coverage grew to 95%, we switched to its official repositories for better availability.
During OpenStack deployment, we faced issues with unported libraries and abandoned dependencies, such as bcrypt and passlib, causing compatibility problems. We had to choose between locking package versions or applying custom patches to resolve conflicts. These challenges highlighted the difficulties of deploying complex software on emerging architectures.
Additionally, the LicheePi 4A shipped with kernel 5.10.113, and obtaining an updated kernel image (6.6.48) took over a month of discussions with the vendor, emphasizing long-term maintenance challenges.
Recently, Ubuntu upgraded its repositories with stable OpenStack packages. We are currently testing OpenStack deployment on an Ubuntu image on top of the LicheePi4a boards, and while some patches are still required, there are no version mismatches or deprecated packages.

### Instance performance

We launch multiple instances on our OpenStack cluster. Below we show a performance comparison between bare metal and the instance.

| Metric | RISC-V TH1520 (ms) | OpenStack VM (ms) | QEMU VM (ms) |
|---|---|---|---|
| real | 5.81 | 408.00 | 382.00 |
| user | 1.78 | 218.70 | 227.80 |
| sys | 4.13 | 121.70 | 138.00 |

Table 2. Execution time for the `cat /proc/cpuinfo` command repeated 100 times across different platforms. Measurements compare performance on bare metal TH1520, OpenStack VM, and QEMU VM environments.

This simple test on different virtualization areas on top of RISC-V reveals a significant gap in readiness to production-grade cloud environments, highlighting a general lack of maturity, both software and hardware-wise. It is important to contextualize the results on each tested environment. We can see an expected small overhead between an instance running inside the OpenStack system and one running on top of QEMU, having very similar user and system times. When comparing RISC-V bare metal runtimes with virtualized runtimes, performance degrades dramatically ( 100x slower), underscoring the current limitations of RISC-V virtualization.

### Future work

RISC-V is a rapidly maturing open ISA, increasingly adopted as Europe and China seek silicon sovereignty. Major ecosystems such as Debian and Ubuntu now offer stable RISC-V packages, while Fedora runs on SiFive P550, Milk-V and QEMU thanks to the community-driven efforts. Despite this momentum, significant work remains to achieve ecosystem maturity and HPC performance parity with the counterpart x86, particularly to enable production-ready cloud environments.

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