

NARRATIVE REPORT

As edge computing continues to reshape modern technological ecosystems, the question of whether traditional virtualization or the emerging approach of containerization offers the most effective foundation has become increasingly significant. This debate is at the heart of a 2024 investigation published in Future Internet by researchers from the University of the West of Scotland, Télécom SudParis/Orange, and the Universitat de València. Positioned within a special issue dedicated to next-generation IoT applications, the work reflects the broader shift in computing infrastructure, from the comfort of centralized cloud systems to the demanding, heterogeneous, and resource-restricted environments found at the network edge.

This critical investigation lands right in the middle of a massive shift in how we build software. The rise of containerization over the last decade shook things up, offering a snappy, portable alternative to the bulkier virtual machines, immediately sparking a debate over which one truly shines in the real world. Now that computing is stretching far out to the edge, think fog nodes and tiny IoT sensors, it's absolutely essential to figure out which technology can handle the pressure: the varied power supply, the tight energy budget, and the unpredictable swings in workload. The study, therefore, positions its findings as a vital guide for navigating the evolving cloud continuum and the ever-growing sophistication of the Internet of Things.

At the heart of the authors' deep dive is the simple, fundamental difference in how these two technologies are built. Containers are lightweight speedsters because they cleverly share the host system's central brain (the kernel), avoiding the hassle of simulating hardware. This design makes them inherently flexible and efficient. Virtual machines, on the other hand, are self-contained ecosystems; they wrap up a complete operating system, giving them total system independence, military-grade isolation, and crystal-clear control over hardware. This distinction creates a classic trade-off: containers win on speed and portability, while virtual machines offer the isolation and control that are non-negotiable for certain critical tasks.

To figure out where the trade-offs matter most, the study created a smart, three-dimensional scorecard: Compatibility and User Experience, Scalability and Elasticity, and Energy Efficiency. The first criterion, Compatibility and User Experience, asks how easy it is to actually get the system running and maintain it—a huge consideration at the edge where you might not have a full IT crew. Scalability and Elasticity looks at how fast and well the technology can handle huge, sudden spikes in data from all those IoT sensors. And finally, Energy Efficiency zeros in on minimizing power usage, which is often the main operational constraint where energy is scarce or every penny counts.

When the authors looked specifically at containerization, they logically chose Kubernetes—the industry standard for orchestration. Yet, they quickly hit a roadblock with the standard Kubernetes scheduler, especially when managing the mixed bag of devices typical of the computing continuum. The default scheduler's one-pod-at-a-time strategy hobbles the ability to optimize resources globally across diverse hardware. To smash through this limitation, the researchers designed a custom scheduler. This new tool is far more flexible, introducing a batch-based allocation method that can look at and decide on multiple placement choices simultaneously, making it far more effective than the sequential, "next-in-line" nature of the default tool.

The research team didn't stop at theory; they put their ideas to the test with real-world experiments using virtual machines. They ran demanding stress tests to push performance to the limit and compare the effectiveness of different scheduling strategies. The results were crystal clear: the batch-based scheduling delivered a noticeable performance boost, confirming that simply using Kubernetes' built-in extension tools isn't enough to fully meet the complex demands of continuum computing environments.

After all the analysis, the study delivers a crucial takeaway: there is no single winner. You can't just declare virtualization or containerization superior for everything. Instead, the best choice is a highly customized decision based entirely on where you are deploying, what your workload looks like, and what your top priorities are. For example, containers are the clear choice when you need quick scaling, portability, and low resource use, perfect for dynamic edge scenarios. But if your project demands total system control, bulletproof security, or direct access to specific hardware, virtual machines remain the stronger option. This conclusion, along with the proposed Kubernetes fix, underscores the constant need to fine-tune container orchestration.

Beyond just comparing the two technologies, this study gives a huge gift to the world of edge and distributed computing. By combining rigorous testing with systematic analysis, it fills a major hole in the existing literature, which has traditionally ignored the messy, heterogeneous world of the edge in favor of clean cloud datacenters. The custom scheduler is a real-world tool, a practical framework that companies can implement today to noticeably boost system performance, proving that smart software optimization can yield massive gains without ever touching the underlying hardware.

The study also provides a fantastic launchpad for future investigations. The authors lay out several exciting research directions, including exploring hybrid models that smartly combine both virtualization and containerization, designing next-level scheduling algorithms that use predictive analytics to anticipate needs, digging deeper into the security trade-offs at the edge, and calculating energy consumption that accurately accounts for both processing and data transmission costs.

Overall, the research by Sturley et al. is an essential guide to the rapidly changing world of edge computing. By giving us a clear, balanced comparison of virtualization and containerization, and by

offering concrete strategies to make orchestration better, the study strengthens both our theoretical understanding and our practical ability to deploy systems. As the computing continuum expands and IoT devices flood the landscape, this kind of systematic analysis will be absolutely vital for making smart architectural decisions and optimizing our distributed infrastructure for everything the future demands.