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MAXIMIZING EFFICIENCY: HARNESSING SECOND-HAND COMPUTER SYSTEMS FOR PARALLEL COMPUTING IN UNIVERSITY MICRO CLOUD

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Abstract: This article explores the utilization of second-hand computer systems in the context of parallel computing for physics simulations at New Bulgarian University. With the increasing demand for computational power in scientific research, particularly in the field of physics, the affordability and accessibility of high-performance computing (HPC) resources become crucial. However, acquiring brand-new HPC systems can be cost-prohibitive for many laboratories and institutions. In this paper, we investigate the feasibility and efficacy of repurposing second-hand computer hardware to construct parallel computing clusters tailored for physics simulations. We discuss strategies for selecting, refurbishing, and integrating these systems into a parallel computing environment, highlighting the potential benefits and challenges. Through case studies and performance evaluations, we demonstrate the practicality of this approach in achieving significant computational capabilities at a fraction of the cost of new systems. Our findings underscore the importance of resourcefulness and sustainability in advancing computational physics research, paving the way for cost-effective solutions to address complex scientific challenges.

Keywords: university micro cluster, technology reuse

1. INTRODUCTION

In the realm of scientific research, particularly within the domain of physics, the quest for computational power is relentless. At New Bulgarian University, the pursuit of groundbreaking physics simulations has led to an innovative approach: “The utilization of second-hand computer systems for parallel computing. This article delves into the transformative potential of repurposing pre-owned hardware, offering a cost-effective solution to the ever-growing demand for high-performance computing (HPC) resources”. With the escalating costs associated with acquiring brand-new HPC systems, especially for laboratories and institutions with limited budgets, the imperative for affordable alternatives has never been more pressing. This paper explores the feasibility and efficacy of harnessing second-hand computer hardware to construct parallel computing clusters tailored specifically for physics simulations. Through meticulous selection, refurbishment, and integration processes, these systems are optimized to deliver significant computational capabilities at a fraction of the cost of new counterparts. Our investigation encompasses strategies for assembling servers, configuring hypervisors, and evaluating performance metrics, providing insights into the practicality and sustainability of this approach. As we navigate through case studies and performance evaluations, a narrative emerges—one that underscores the importance of resourcefulness and sustainability in advancing computational physics research. By embracing technology reuse and repurposing, institutions can not only address complex scientific challenges but also contribute to a more sustainable and cost-effective research ecosystem. The proposed cluster was donated by unused computer systems [1, 2] from AlphaVPS a leading cloud VPS and server provider in Europe.

2. PROJECT DESCRIPTION

The construction of the micro-cluster for educational purposes is part of the project "Study of processes induced by radiation and chemical reactions occurring at various temporal and spatial scales. Technological applications," aimed at establishing a cost-effective platform for conducting experimental research in the field of lasers. The result is a 10-node cluster (Fig. 1) onto which research software can be freely loaded, thus expanding the development of software suitable for scientific computations on commercial clusters.

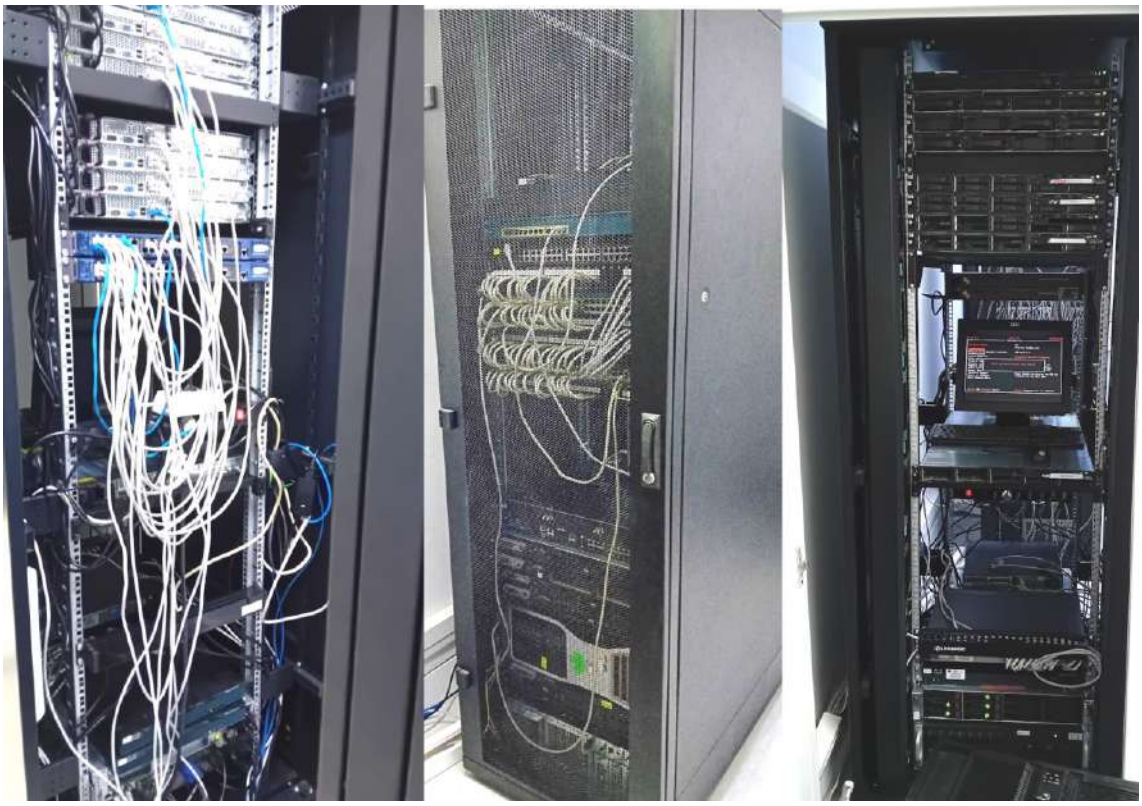

Figure 1. 10 node NBU micro cloud installed in laboratory 701

2.1 INFRASTRUCTURE AND VIRTUAL NETWORK SETUP

Hardware consists of 1 rack mounted two of 10 servers (Fig. 2 block diagram), Srv_09 and Srv_10, intended for high-performance tasks requiring disk space resilience, are equipped with 64 GB of RAM and a total disk space of 1.2 TB achieved through 3 2.5" SAS 3.0 drives with a capacity of 600 GB each, operating in RAID 5 configuration. The remaining eight servers - Srv_01 to Srv_08, have 32 GB of RAM and a total disk space of 600 GB achieved through two 3.5" SAS 3.0 drives, each with a capacity of 300 GB, operating in RAID 0 configuration. These server configurations will be used for applications and tasks with lower performance and disk space requirements.can be freely loaded, thus expanding the development of software suitable for scientific computations on commercial clusters.

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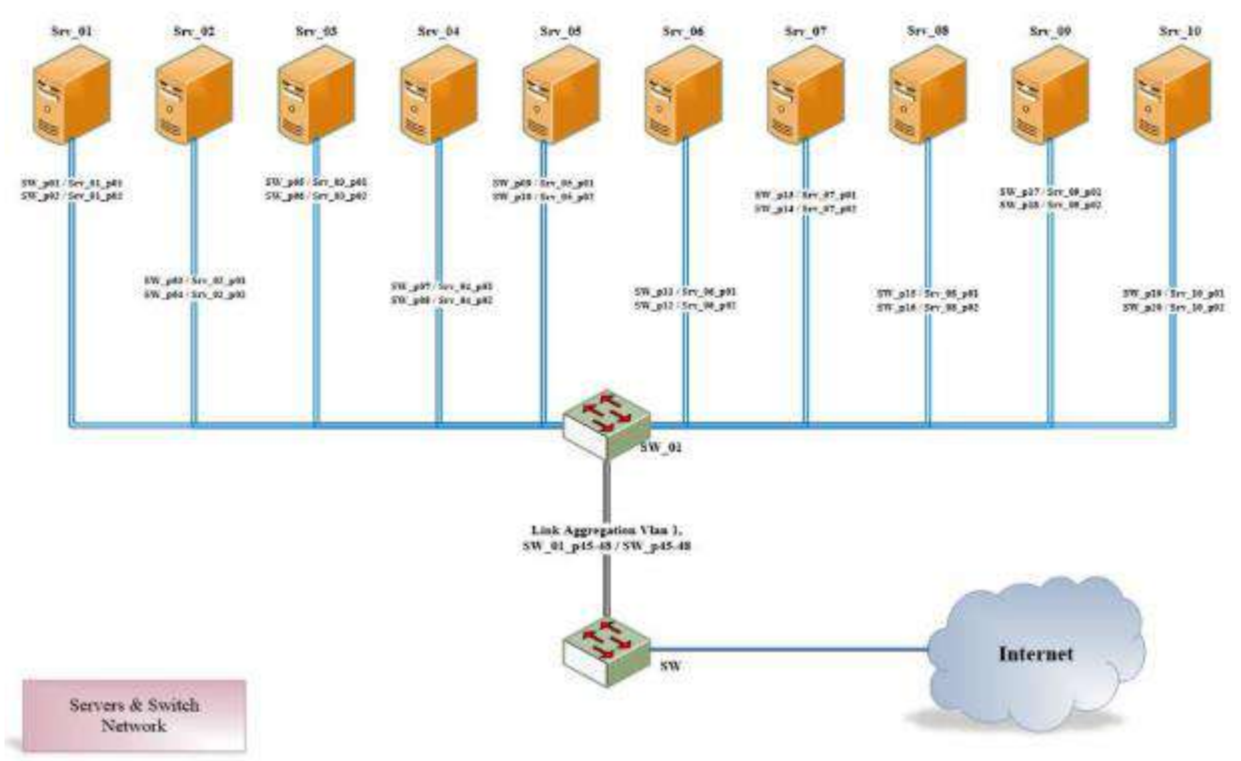

Figure 2 . Block diagram of Servers & Switch Network

2.2 IMPLEMENTING VLANS AND FIREWALLS WITH OPNSENSE IN A 10-NODE XEN SERVER ENVIRONMENTOBJECTIVE

Implementing VLANs and Firewalls with OPNsense [4, 5] in a 10-Node Xen Server EnvironmentObjective: Deploy a secure network infrastructure using OPNsense for VLAN segmentation and firewall protection within a 10-node Xen Server setup to enhance security and optimize resource utilization.

Key Steps:

- Network Planning: Define VLANs and IP addressing schemes for logical segmentation, considering network requirements and connectivity.
- Configuration: Set up VLAN interfaces on Xen Server nodes and integrate OPNsense as the firewall solution to enforce security policies.
- OPNsense Deployment: Install and configure OPNsense to create firewall rules for traffic control between VLANs, ensuring secure communication and access.
- Testing and Optimization: Validate firewall functionality, optimize configurations for performance, and monitor network traffic for security threats and performance issues.

Benefits:

- Enhanced Security: OPNsense firewall provides robust protection against unauthorized access and threats, ensuring network integrity.
- Efficient Resource Utilization: VLAN segmentation optimizes bandwidth and resource usage, enhancing network performance.
- Scalability: Easily scale the network infrastructure by adding or modifying VLANs and firewall rules to accommodate growth.

- Compliance: Align with industry standards and regulatory requirements, ensuring data security and privacy compliance.

Conclusion: Utilizing OPNsense for VLAN segmentation and firewall protection in a 10-node Xen Server environment establishes a secure network infrastructure, meeting security, performance, and compliance needs. Regular monitoring and updates are essential for maintaining network integrity and effectiveness. In our cluster students can use and setup different types of firewalls in comparison to other alternatives see Table 1.

Feature	OPNsense	pfSense	Sophos XG Firewall	Untangle NG Firewall
Open Source	Yes	Yes	No	Yes
Community Support	Strong	Strong	Limited	Limited
Feature Set	Firewall, VPN, IDS/IPS, Traffic Shaping, Intrusion Detection	Firewall, VPN, IDS/IPS, Traffic Shaping	Firewall, VPN, Web Protection, Application Control	Firewall, VPN, Web Filtering, Intrusion Prevention
Web Interface	Intuitive	Some users find it less intuitive	User-friendly, Easy setup	Simple, Intuitive
Stability	Generally stable, Regular updates	Known for stability, Regular updates	Stable	Stable
Support Options	Limited official support, Community-driven	Comprehensive documentation, Commercial support options	Sophos Central management for devices	Limited support for free version
Deployment Options	Software appliance, Virtual appliance, Hardware appliance	Software appliance, Virtual appliance, Hardware appliance	Software appliance, Virtual appliance	Software appliance, Virtual appliance, Cloud appliance
Security Features	Robust security features including firewall, VPN, IDS/IPS	Similar to OPNsense	Advanced security features including application control, sandboxing	Comprehensive suite of security features
Licensing	Open-source, Free	Open-source, Free	Free home edition, Commercial options available	Free version with limitations, Commercial options available
Ease of Use	Intuitive interface, Requires some technical expertise	Some users find it less intuitive	User-friendly interface, Easy setup	Simple interface, Intuitive

Table 1. Comparison of OPNsense, pfSense, Sophos XG Firewall, Untangle NG Firewall

3. COMPUTATIONAL SOFTWARE INSTALLATION

3.1. VIRTUALIZATION

XCP-ng is an open-source virtualization platform that serves as a hypervisor, allowing users to create and manage virtual machines (VMs) on their hardware infrastructure. XCP-ng (pronounced as "Xen Project for Cloud-Next Generation") is based on the Xen Project, an open-source hypervisor developed by the Linux Foundation. It was created to provide a fully open-source alternative to Citrix XenServer, which is a commercial virtualization platform built on top of the Xen Project on small HPC [3]. XCP-ng offers features similar to other virtualization platforms, including:

- Virtual machine management: Create, configure, start, stop, and migrate Vms.

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- Hypervisor management: Monitor and manage the hypervisor itself, including host maintenance, updates, and configuration.
- Storage management: Manage storage repositories (SRs) for VM disks and ISO images.
- Networking: Configure virtual networks and connect VMs to different networks.
- High availability: Implement failover and redundancy mechanisms to ensure continuous operation of Vms.

It also supports advanced features such as live migration, snapshots, and resource pooling. Architecture:

- XCP-ng follows a client-server architecture, where the XCP-ng hypervisor runs on physical hosts (servers) and provides virtualization capabilities.
- Users can manage XCP-ng hosts and VMs using a web-based management interface called XCP-ng Center or through the XCP-ng command-line interface (CLI).
- XCP-ng supports various storage types, including local storage, network-attached storage (NAS), and storage area networks (SANs), allowing flexibility in storage configuration.
- XCP-ng is supported by a vibrant community of users and contributors who provide assistance, documentation, and development contributions.
- The project offers community forums, documentation, and tutorials to help users get started with XCP-ng and troubleshoot issues.

XCP-ng is suitable for various use cases, including:

- Server virtualization: Consolidate multiple physical servers into virtual machines running on a single host.
- Desktop virtualization: Provide virtual desktop infrastructure (VDI) solutions for remote access to desktop environments.
- Cloud computing: Build private or hybrid cloud environments for deploying and managing applications and services.

Overall, XCP-ng is a robust and feature-rich virtualization platform that provides an open-source alternative for organizations looking to leverage the benefits of virtualization in their infrastructure. There are several reasons why someone might choose XCP-ng (Xen Project Community Edition) over other hypervisors:

- Open Source: XCP-ng is fully open-source, which means it's free to use and offers transparency in its development and operation. This can be appealing for organizations looking to avoid vendor lock-in and have full control over their virtualization infrastructure.
- Feature-Rich: XCP-ng offers a wide range of features comparable to other hypervisors, including high availability, live migration, snapshots, and resource pooling. It provides comprehensive virtualization capabilities suitable for various use cases.
- Stability and Reliability: Xen Project, the underlying hypervisor technology of XCP-ng, has been around for many years and is known for its stability and reliability. XCP-ng inheris these qualities, making it a dependable choice for production environments.
- Community Support: XCP-ng has a vibrant community of users and contributors who provide support, documentation, and development contributions. The community-driven nature of XCP-ng ensures that users have access to resources and assistance when needed.

- Compatibility: XCP-ng supports a wide range of guest operating systems, including various versions of Windows, Linux distributions, and BSD systems. This compatibility makes it suitable for hosting diverse workloads and applications.
- Enterprise-Grade: Despite being open-source, XCP-ng offers enterprise-grade features and support options. It can meet the needs of businesses of all sizes, from small startups to large enterprises, without compromising on performance or reliability.
- Migration Path: For organizations currently using other hypervisors, XCP-ng provides migration tools and guides to facilitate the transition. This makes it easier for users to adopt XCP-ng without significant disruption to their existing infrastructure.

Let's compare XCP-ng with three other popular free hypervisors: VMware vSphere Hypervisor (formerly ESXi), Proxmox VE, and KVM (Kernel-based Virtual Machine):

XCP-ng:

Pros:

- Fully open-source, providing transparency and freedom from vendor lock-in.
- Feature-rich with capabilities like high availability, live migration, and snapshots.
- Stable and reliable, built on the Xen Project hypervisor known for its performance.
- Vibrant community support and enterprise-grade features.
- Compatibility with various guest operating systems.

Cons:

- May have a steeper learning curve compared to some other options.
- Limited official support compared to commercial solutions.

VMware vSphere Hypervisor:

Pros:

- Widely used in enterprise environments, with robust features and performance.
- High level of maturity and extensive documentation available.
- Simple installation and setup process.
- Integration with other VMware products for comprehensive virtualization solutions.

Cons:

- Proprietary software with limited features in the free version.
- Requires additional licensing for advanced features like vMotion and High Availability.
- Less flexible in terms of hardware compatibility compared to open-source solutions.

Proxmox VE:

Pros:

- Open-source platform with a user-friendly web interface.
- Supports both virtualization (KVM) and containerization (LXC).
- Integrated backup and restore features.
- Cluster management capabilities for scalability.

Cons:

- Less mature compared to some other solutions, with occasional stability issues in past versions.
- Limited support for commercial features compared to paid versions.
- Requires dedicated hardware or virtualization extensions for optimal performance.

KVM (Kernel-based Virtual Machine):

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Pros:

- Part of the Linux kernel, offering strong performance and stability.
- Flexible and customizable, with support for various guest operating systems.
- Widely adopted by cloud providers and enterprises for virtualization.
- Integrated with popular management tools like libvirt.

Cons:

- Requires manual configuration and management compared to some other hypervisors.
- Limited GUI-based management tools compared to solutions like VMware and Proxmox VE.
- May have higher resource overhead compared to bare-metal hypervisors like VMware vSphere Hypervisor.

3.2. HARDWARE DEPENDENT SOFTWARE KITS

CUDA (Compute Unified Device Architecture):

- A parallel computing platform and programming model developed by NVIDIA.
- Enables developers to harness the computational power of NVIDIA GPUs for parallel computing tasks using CUDA C/C++ or CUDA Fortran.

OpenCL (Open Computing Language):

- An open standard parallel programming framework developed by the Khronos Group.
- Enables developers to write code that can be executed across various compute devices, including CPUs, GPUs, and other accelerators.
- Provides a standard interface and runtime for parallel programming, enabling developers to write code in a C-like language and execute it on heterogeneous platforms.

ROCm (Radeon Open Compute Platform):

- An open-source HPC platform developed by AMD, designed to provide developers with tools and libraries for GPU computing on AMD GPUs.
- Includes libraries like ROCm Math for mathematical computations optimized for GPU execution and ROCm-OpenCL for AMD GPU support.

3.3. HARDWARE INDEPENDENT SOFTWARE KITS

Google Cloud Vertex AI:

- Offers good integration and transparency.
- Provides managed services for building and running machine learning models in production.

Microsoft Azure Machine Learning:

- Well-integrated and transparent.
- Offers a browser-based, visual drag-and-drop authoring environment for building predictive analytics solutions.

Databricks Data Intelligence Platform:

- Strong integration and transparency.
- Built on a lakehouse for unified data and governance, with a Data Intelligence Engine for understanding unique data characteristics.

AWS Machine Learning:

- Less caring and inspiring, harder to customize.
- Offers predictive analytics solutions based on discovering patterns in end-user data through algorithms.

Dataiku:

- Transparent, easier to use, and better at support.
- Democratizes access to data and enables enterprises to build their path to AI in a human-centric way.

Eclipse Deeplearning4j:

- Transparent, easier to use and implement, better at support and integrating.
- Commercial-grade, open-source distributed deep learning library written for Java and Scala.

Alteryx:

- Better at integrating, less innovative, and less caring.
- Provides a single workflow for data blending, analytics, and reporting.

DataRobot AI Platform:

- Less caring, inspiring, efficient, and transparent.
- Includes machine learning model building products deployable in various ways.

KNIME Analytics Platform:

- Less transparent and worse at support.
- Offers a complete platform for end-to-end data science with a free and open-source analytics platform.

Altair RapidMiner:

- Less caring, innovative, efficient, transparent, and reliable.
- Helps organizations overcome obstacles in their data journey without requiring radical changes.

H2O AI Cloud:

- Less caring, reliable, and efficient.
- A fully open-source, distributed in-memory machine learning platform with linear scalability.

Each platform has its strengths and weaknesses, so it's essential to evaluate them based on your specific business requirements, such as transparency, integration, efficiency, and customization capabilities. Here's the comparison table 2:

Platform	Transparency	Integration	Efficiency	Innovation	Inspiration	Care	Customization	Support
MathWorks MATLAB	High	High	No issues	No issues	Low	High	No issues	High
Google Cloud Vertex AI	High	High	Low	Low	Low	High	Low	Issues
Microsoft Azure Machine Learning	High	High	No issues	Low	Low	Low	No issues	Issues
Databricks Data Intelligence Platform	High	High	Low	No issues	Low	High	No issues	High
AWS Machine Learning	Issues	Low	Low	Low	Low	Low	No issues	Issues

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Platform	Transparency	Integration	Efficiency	Innovation	Inspiration	Care	Customization	Support
Dataiku	High	High	No issues	No issues	Low	High	Issues	High
Eclipse Deeplearning 4j	High	High	No issues	No issues	No issues	No issues	Issues	High
Alteryx	High	High	Low	Low	Low	Low	Issues	No issues
DataRobot AI Platform	Issues	Low	Low	Low	Low	Low	Issues	Issues
KNIME Analytics Platform	Low	Issues	Low	Issues	Issues	Low	Issues	Issues
Altair RapidMiner	Issues	Low	Low	Issues	Issues	Low	Issues	Issues
H2O AI Cloud	Issues	Low	Low	Low	Low	Low	Issues	Issues

Table 2. Comparison of software tool-kits for parallel computing.

In the table:

- "High" indicates a positive attribute.
- "Low" indicates a negative attribute.
- "No issues" indicates no specific issues mentioned.
- "Issues" indicates issues mentioned.

4. OPTIMIZATION AND CONCLUSION

Importance of Optimization in Second-Hand Computer Systems: Optimizing second-hand computer systems is crucial for unlocking their full potential in parallel computing for physics simulations [6]. By fine-tuning hardware configurations, optimizing software settings, and implementing efficient resource management techniques, organizations can maximize computational power while minimizing operational costs.

Future Perspectives and Concluding Remarks on Technology Reuse and Sustainability: In terms of technology reuse, extending the lifespan of second-hand computer systems promotes sustainability by reducing electronic waste. Repurposing and refurbishing older hardware provide cost-effective computing resources for parallel computing tasks in physics simulations. Integrating sustainable practices, such as minimizing energy consumption and adopting eco-friendly hardware components, further mitigates environmental impact and contributes to a greener computing ecosystem.

Potential of Computational Software in Second-Hand Systems: Computational software like CUDA, OpenCL, and OpenMPI holds significant potential for maximizing the performance of second-hand computer systems in physics simulations. These parallel computing frameworks efficiently utilize available resources, leveraging parallel processing capabilities to accelerate simulations and data analyses. Such software solutions offer cost-effective alternatives to new equipment, achieving comparable performance at a fraction of the cost.

In conclusion, optimizing second-hand computer systems for parallel computing in physics simulations requires a multifaceted approach integrating optimization techniques, sustainable practices, and advanced computational software. By harnessing refurbished hardware, embracing sustainable computing, and leveraging cost-effective software, organizations can achieve efficient solutions for challenging simulations, significantly reducing upfront capital expenditures compared to purchasing new equipment.

Containerization and Orchestration: In educational settings focused on high-performance computing (HPC) and related fields, containerization tools like Docker and orchestration platforms such as Kubernetes play a significant role. These technologies accelerate application development, deployment, and management, providing students with hands-on experience in modern software deployment practices. By incorporating containerization and orchestration into the curriculum, students learn to create portable, scalable applications while gaining insights into managing complex software ecosystems.

Serverless Computing: Educational programs in HPC benefit from exploring serverless computing models, allowing students to focus on writing application logic without managing infrastructure. This fosters deeper understanding of cloud computing and dynamic resource allocation, preparing students for cloud-native application development and deployment careers.

AI and Machine Learning in Server Environments: Integrating AI and machine learning into server environments offers exciting opportunities for HPC education. Students explore optimization algorithms and resource management techniques, gaining practical insights into leveraging AI for system performance enhancement. Incorporating AI and ML concepts into coursework empowers students to tackle complex computational challenges and innovate in scientific computing and data analysis.

Scalability Strategies in Educational Settings: Scalability concepts like horizontal and vertical scaling are essential for HPC education. Educators guide students in experimenting with cloud services to dynamically scale resources, fostering understanding of cloud computing principles and distributed systems architecture. Exposure to software-defined networking and hardware equips students with skills for designing and managing scalable infrastructure in educational and research environments.

Automation and Resource Management: Automation's role in HPC education streamlines resource management tasks, improving operational efficiency. Incorporating automation tools prepares students for real-world scenarios where automated deployment and scaling are crucial. Hands-on projects enable students to design, deploy, and manage scalable HPC environments, paving the way for successful careers in scientific research and data analysis.

The present micro-server was created with the kind participation of professors and students from the Telecommunications Department at NBU and minimal funding from the Scientific Research Fund "Studying processes induced by irradiation and chemical reactions occurring at various temporal and spatial scales. Technological applications," funded by the Scientific Research Fund under the Procedure for Providing National Co-Funding for

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Participation of Bulgarian Teams in Established Actions under the European Cooperation Programme in the Field of Scientific Research and Technology COST.

AlphaVPS, established in 2013, is a Bulgarian-based hosting provider that offers affordable yet reliable server infrastructure and VPS hosting, coupled with an outstanding customer experience. It is a core value of the company that their customers' success is synonymous with the company's success, and they are fully dedicated to helping them achieve it! The company and its core values are centered around the principle that web hosting and server rental should be simple, frustration-free, and at the same time, affordable and accessible to everyone. In alignment with their community-driven ethos, AlphaVPS recently donated old machines to New Bulgarian University (NBU) for educational purposes, reinforcing their support for the community and open-source projects. This gesture not only aids in the practical education of students but also reflects the company's dedication to fostering technological growth and innovation.

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