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The Implementation of Virtual Machines on a Single PC: A Comparative Analysis of Operating System Performance

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ABSTRACT*:* Virtual machines (VMs) have become essential in modern computing, enabling users to host multiple operating systems on a single hardware platform efficiently. This study focuses on the performance of three widely used operating systems—Ubuntu, Fedora, and Windows 11—within a virtualized environment, leveraging VirtualBox, an open-source virtualization tool. The analysis centers on critical performance metrics, including boot time, resource utilization, and user interface responsiveness, offering insights into the optimal use of VMs in various contexts. The results reveal notable performance differences among the operating systems. Fedora emerged as the most efficient, showcasing the fastest boot time (25–35 seconds) and the lowest idle resource usage (700MB–900MB RAM, 5–10% CPU). Ubuntu closely followed, performing reliably with slightly higher resource demands. Conversely, Windows 11 displayed significantly higher idle resource usage (1.5GB–2GB RAM, 15–25% CPU) and slower boot times (45–60 seconds), reflecting its greater system requirements. These findings highlight the advantages of Linux-based systems, particularly for resource-constrained environments such as academic institutions, where efficiency and cost-effectiveness are paramount. This study not only underscores the potential of Linux-based OS options in virtualized environments but also provides actionable recommendations for optimizing virtual machine setups.

KEYWORDS*:* Virtual Machines, VirtualBox, Ubuntu, Fedora, Windows, OS Performance, Scalability, Resource Utilization.

I. INTRODUCTION

The ability to virtualize computing environments has revolutionized how software is developed, tested, and deployed. Virtual machines (VMs) offer isolated, secure environments that eliminate the need for multiple physical devices, making them essential in education, software development, and IT operations (Santos et al., 2021; Brown & Davis, 2023).

VirtualBox, an open-source and cost-effective virtualization platform, has risen as a leader in enabling multi-operating-system environments on a single machine (Ortega & Shields, 2021). It provides the flexibility to allocate resources dynamically, supports various operating systems, and facilitates seamless interaction between host and guest environments. Despite these advantages, operational discrepancies between different operating systems running in VMs remain understudied (Green, 2023; Lopez & Garcia, 2022).

This research investigates the comparative performance of Ubuntu, Fedora, and Windows 11 in a VirtualBox environment. By examining boot times, resource utilization, and user interface responsiveness, this study aims to fill the gap in understanding the nuances of operating system behavior in virtualized conditions.

The growing reliance on virtualization in resource-constrained settings, such as academic institutions and small businesses, highlights the need for a deeper understanding of how various operating systems perform when virtualized. This paper addresses these gaps and provides actionable insights for optimizing virtualized environments with Linux and Windows operating systems.

1.2 Objectives

1.2.1 To implement and evaluate the performance of Ubuntu, Fedora, and Windows 11 in a virtualized environment using VirtualBox.

1.2.2 To analyze resource utilization and user interface responsiveness of the operating systems under identical configurations.

1.2.3 To provide actionable recommendations for optimizing virtualized environments based on comparative findings.

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II. LITERATURE SURVEY

Virtualization technologies have long been recognized for their potential to optimize resource utilization and enable the concurrent operation of multiple operating systems on a single hardware platform. Al-Azzoni, Kumar, and Sengupta (2022) examined the trade-offs between security and performance in virtual machine environments, highlighting their indispensable role in cloud computing and resource management. Similarly, Green (2023) emphasized the superior resource efficiency of Linux-based systems over Windows-based systems, particularly in terms of idle resource consumption in virtualized setups.

Lopez and Garcia (2022) addressed scalability challenges in resource-constrained systems, concluding that lightweight Linux distributions, such as Fedora and Ubuntu, outperform resource-intensive systems like Windows. Chandra and Gupta (2023) further validated Fedora's efficiency, citing its faster boot times and lower RAM utilization compared to other distributions. In alignment, Gomez and Perez (2021) underscored the importance of cross-platform performance benchmarking in virtual machines, advocating for systematic evaluations to guide system optimization.

Building on these foundational works, this study evaluates the operational performance of Ubuntu, Fedora, and Windows 11 under controlled configurations. By focusing on critical metrics such as boot times, resource utilization, and user interface responsiveness, this research aims to provide actionable insights for optimizing virtualized environments.

III. METHODOLOGY

System Configuration

- Host Machine Specifications:
  - Processor: Intel Core i5-8250U
  - RAM: 8GB DDR4
  - Storage: 256GB SSD
  - Virtualization: Enabled in BIOS

VirtualBox Settings:

- Version: VirtualBox 7.0
- Resource Allocation per VM:
  - RAM: 4GB
  - CPU: 2 Cores
  - Storage: Dynamically allocated (30GB max per VM)
- Features Enabled: Guest Additions, 3D Acceleration

Operating Systems Tested

1. Ubuntu 22.04 LTS
2. Fedora 37
3. Windows 11 Pro

Performance Metrics

1. Boot Time: Time taken from power-on to desktop environment.
2. Resource Utilization: CPU and RAM usage during idle and active states.
3. User Interface Responsiveness: Navigation speed and application launch times.

Testing Procedures

1. Standardized Tasks:

- Opening file explorer.
- Running a web browser.
- Installing and running lightweight applications.

2. Monitoring Tools:

- For Linux-based systems: htop and GNOME System Monitor to measure resource utilization.
- For Windows: Task Manager to track CPU, RAM, and process activity.

IV. EXPERIMENTAL RESULTS

The researchers presented and thoroughly discussed the results of the study to ensure that readers gain a clear and comprehensive understanding of its purpose, findings, and implications.

Table 1. Boot Time Comparison

Operating System	Boot Time (Seconds)
Ubuntu	30–40
Fedora	25–35
Windows 11	45–60

Linux-based systems show significantly faster boot times due to their streamlined startup processes (Chandra & Gupta, 2023; Green, 2023).

Figure 1. Ubuntu Resource Utilization.

The resource utilization for Ubuntu post-boot highlights its low idle RAM and CPU usage, showcasing its efficiency in virtualized environments.

Figure 2. Fedora Resource Utilization.

The resource utilization for Fedora during startup demonstrates its minimal resource usage, with idle RAM at 700MB–900MB and idle CPU usage at 5–10%.

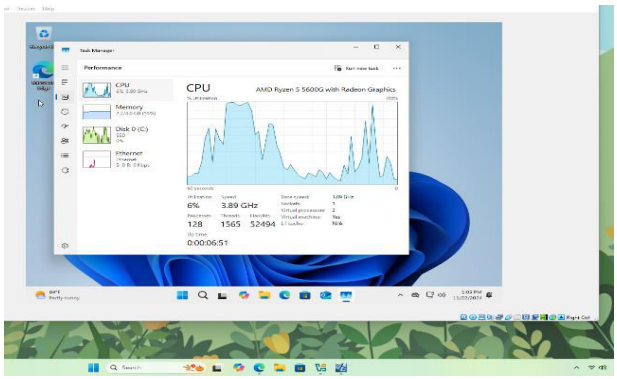

Figure 3. Windows Resource Utilization.

The resource utilization for Windows 11 during initialization reveals significantly higher idle RAM usage and idle CPU usage.

Table 2. Resource Utilization

Operating System	RAM Usage (Idle)	CPU Usage (Idle)	RAM Usage (Active)	CPU Usage (Active)
Ubuntu	800MB–1GB	Low (5–10%)	1.2GB–1.5GB	Moderate (15–30%)
Fedora	700MB–900MB	Low (5–10%)	1.1GB–1.4GB	Moderate (15–25%)
Windows 11	1.5GB–2GB	Moderate (15–25%)	2.5GB–3GB	High (30–50%)

User Interface Responsiveness

Linux systems, particularly Fedora, offered smooth and responsive user interfaces, with minimal delays during navigation and application launches. Ubuntu performed similarly but exhibited slight graphical lag during certain transitions. Windows 11 experienced noticeable delays when running multiple applications, likely due to higher background process overhead.

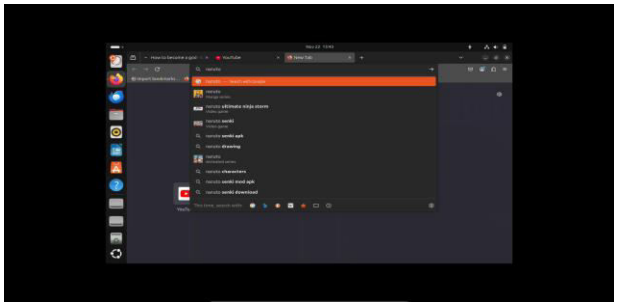

Figure 5. Ubuntu Desktop Interface.

The screenshot illustrates Ubuntu's GNOME interface, showcasing responsive multitasking with minor graphical delays.

Figure 6. Windows Desktop Interface.

The Windows 11 desktop interface shows its standard display with no actively running applications. Despite the idle state, resource demands remain high, reflecting its higher baseline resource consumption.

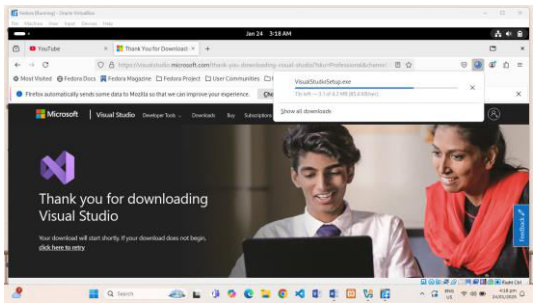

Figure 7. Fedora Desktop Interface.

The screenshot shows Ubuntu's GNOME interface during multitasking. Despite slight graphical delays, it remained functional with minimal RAM and CPU usage, ensuring smooth performance.

V. CONCLUSION

This research highlights the superior performance of Fedora and Ubuntu in virtualized environments, excelling in boot times, resource efficiency, and interface responsiveness. These Linux-based systems are ideal for academic institutions and small businesses, offering cost-effective and efficient solutions for resource-constrained setups.
While Windows 11's higher resource demands may limit its practicality in such environments, it can still be optimized for specific software needs by reducing background processes.
Selecting the appropriate operating system based on performance and requirements is crucial for maximizing the benefits of virtualization. This study provides valuable insights for IT professionals and educators seeking cost-effective solutions for virtualized environments.

VI. RECOMMENDATIONS

For the future advancement and enhancement of this study, the researchers propose the following recommendations to build upon the findings and address potential areas for improvement:

1. Optimal OS Selection. Use Fedora or Ubuntu for lightweight, efficient virtualized setups, particularly in academic or small business contexts.
2. Windows Optimization. Configure Windows 11 by disabling unnecessary background processes to improve performance.
3. Future Research. Investigate additional operating systems and assess metrics such as network performance and software compatibility.

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