ALBUKHARY INTERNATIONAL UNIVERSITY

SCHOOL OF COMPUTING & INFORMATICS

Course Title : **OPERATING SYSTEMS**
Course Code : **CCC 2123**

ASSIGNMENT 2 (PAIR) (15%)

PERFORMANCE ANALYSIS OF OPERATING SYSTEMS

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1.0 Introduction

The objective of this report is to provide a comparative analysis of the performance of two distinct operating systems: Microsoft Windows and Kali Linux, based on collected data.

For the purposes of this assignment, a comparative analysis of two operating systems is conducted. Developed by Microsoft Corporation, Windows is a graphical operating system that facilitates file storage, software execution, gaming, video playback, and internet connectivity. The latest version of Windows is Windows 11. Conversely, Linux is a freely distributable open-source operating system created in the early 1990s by Finnish software engineer Linus Torvalds and the Free Software Foundation (FSF). Kali Linux, a specialized Linux distribution, is renowned for its robust security features and comprehensive suite of penetration testing tools, making it a preferred choice for cybersecurity professionals and enthusiasts (Microsoft Windows, n.d). Its latest version is Kali Linux 2024.1 .

The rationale behind choosing Windows stems from its dominant presence in the desktop computing market, catering to a diverse user base ranging from home users to enterprise environments. While Kali Linux was selected for its relevance in the cybersecurity domain and its distinct approach to operating system functionalities.

Through this analysis, we seek to inform decision-making processes for users and organizations considering the deployment of these operating systems in various environments, ranging from individual to organizational settings. Ultimately, our goal is to offer valuable insights into the performance capabilities of Microsoft Windows and Kali Linux, aiding in informed decision-making and potentially optimizing system performance.

Figure 1: Kali Linux vs Windows

2.0 Methodology

2.1 Data Collection

Ensure both systems are in a comparable idle state. Close unnecessary applications and services to ensure that the benchmark results are not affected by background processes.

2.2 Performance Metrics

We identified the following key performance metrics to evaluate:

- CPU Utilization
- Memory Usage
- Disk I/O Performance
- Network Throughput

2.2 Tools Used

2.2.1 Using Benchmarking Tool

To evaluate the performance of Kali Linux 2024.1 and Windows 11, we used Geekbench 6.

What is Geekbench?
Geekbench is a cross-platform benchmarking application that can attribute a score to both the single-core and multi-core computational capabilities of your device. Geekbench 6 provides a comprehensive set of benchmarks that measure the performance of the CPU and GPU under various real-world scenarios. This tool is particularly useful for comparing the computational capabilities of different operating systems (Conway, 2023).

Why use Geekbench?
Geekbench 6 is preferred for its simplicity and power, designed for cross-platform comparisons across devices, operating systems, and processor architectures. It uses practical, everyday scenarios and realistic data sets to measure performance, ensuring relevant and applicable results. With its comprehensive assessments of both CPU and GPU capabilities, user-friendly interface, and detailed reporting, Geekbench 6 provides a thorough, realistic, and convenient benchmarking experience. Its reputation and reliability in the industry further enhance its value for accurate performance evaluations (Loyola & Cross, 2023).

Linux

1. Using Sudo apt update: Retrieving the latest package information from the configured repositories.

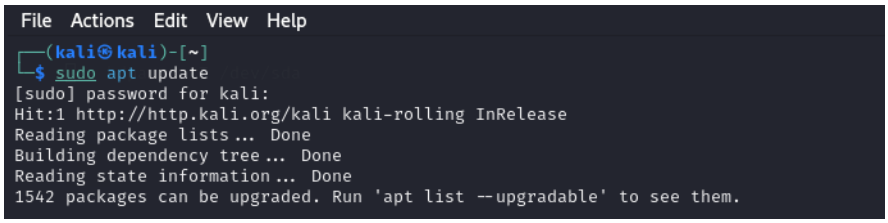

Figure 2: Update package

1. Download and install geekbench 6.3.0.
2. Install htop, iperf3, hdparm.
3. Begin performance evaluation.

Why use Htop?

Htop is a powerful, interactive system-monitoring tool that provides real-time insights into system performance. With a user-friendly interface, it allows for easy navigation, sorting, and management of processes while displaying CPU and memory usage, load averages, and detailed per-process resource consumption. This makes it an excellent choice for dynamically monitoring and identifying system resource bottlenecks.

Why use Hdparm?

Hdparm is a command-line utility designed for benchmarking and configuring hard disk drives (HDDs) and solid-state drives (SSDs). It offers capabilities to measure disk read speeds, retrieve detailed drive information, and tweak various disk parameters for performance optimization. By using hdparm, users can assess and enhance the performance of their storage devices effectively.

Why use iperf3?

Iperf3 is a widely-used tool for measuring network performance, particularly in terms of bandwidth and throughput. It operates on a client-server model, providing detailed metrics on TCP and UDP performance, including bandwidth, loss, and jitter. This makes iperf3 invaluable for diagnosing network issues and understanding the performance characteristics of network connections under various conditions.

Windows

1. Installation: Download and install Geekbench 6 from its official website.
2. Execution: Launch Geekbench 6 and run CPU benchmark.
3. Results: Record the single-core score and multi-core score.

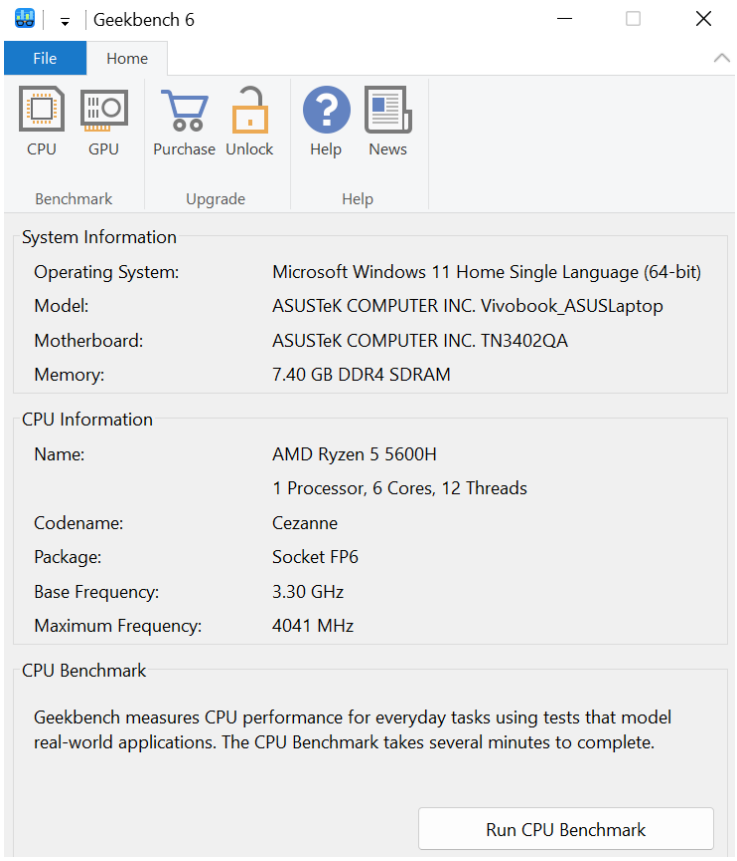

Figure 3: Geekbench 6 on Windows 11

Disk I/O Performance with Benchmarking tool CrystalDiskMark

- Download the CrystalDiskMark software from the official website.
- Install the software by following the on-screen instructions.
- Launch CrystalDiskMark after installation.

Why use CrystalDiskMark?

CrystalDiskMark is an excellent tool for testing the speed of any storage device or memory card, providing an accurate measure of performance through detailed read and write speed metrics.

It's easy to use: download, install, and run a benchmark test to get detailed performance data, including access times. This helps identify and resolve issues with storage devices, ensuring optimal performance and reliability (Connatser, 2023).

2.2.2 Using Monitoring Tool PerfMon (Windows 11)

Why Performance Monitor?

Performance Monitor is a tool that provides more extensive performance data than Task Manager and Resource Monitor. Performance Monitor allows for defining, saving, and

reviewing collections of various counters as easy-to-read reports. Its ability to save monitoring session results for later review or importing into other tools further enhances its utility for comprehensive performance analysis (Performance Monitor, 2023).

➢ **Performance Monitor (PerfMon)**
- Launch Performance Monitor by typing "perfmon" in the Windows search bar.

➢ **CPU Utilization with PerfMon**
- Launch PerfMon and create a new Data Collector Set named "CPU_Utilization".
- Counter Monitored:
  - \Processor(_Total)\% Processor Time
  - \Processor(_Total)\% Privileged Time
  - \Processor(_Total)\% User Time
- Sample Interval: 15 seconds.
- Duration:
  - 30 minutes
  - 1 Hour.

➢ **Memory Utilization with PerfMon**
- Launch PerfMon and create a new Data Collector Set named "Memory_Utilization".
- Counter Monitored:
  - Available Bytes: The amount of physical memory available for use.
  - Cache Bytes: The amount of physical memory used for system cache.
  - Committed Bytes: The total amount of virtual memory that has been committed.
  - Pages/sec: The rate at which pages are read from or written to disk to resolve hard page faults.
- Sample Interval: 15 seconds
- Duration: 1 hour

3.0 Results and Analysis

Kali Linux:
System monitor:

Kali Linux has a built-in system monitor that you can use to check CPU, memory, and disk usage. You can find it in the applications menu.

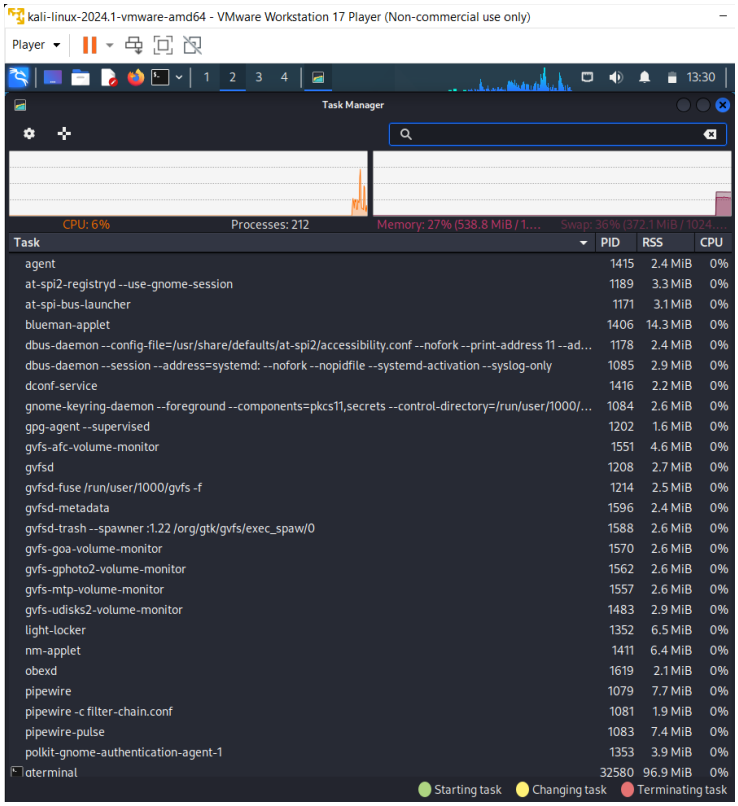

Figure 4: Kali System Monitor

Windows

Performance Monitor:

Windows has a built-in performance monitor that includes a complete system summary and other diagnostic details about your CPU, disk, network, and other system resources.

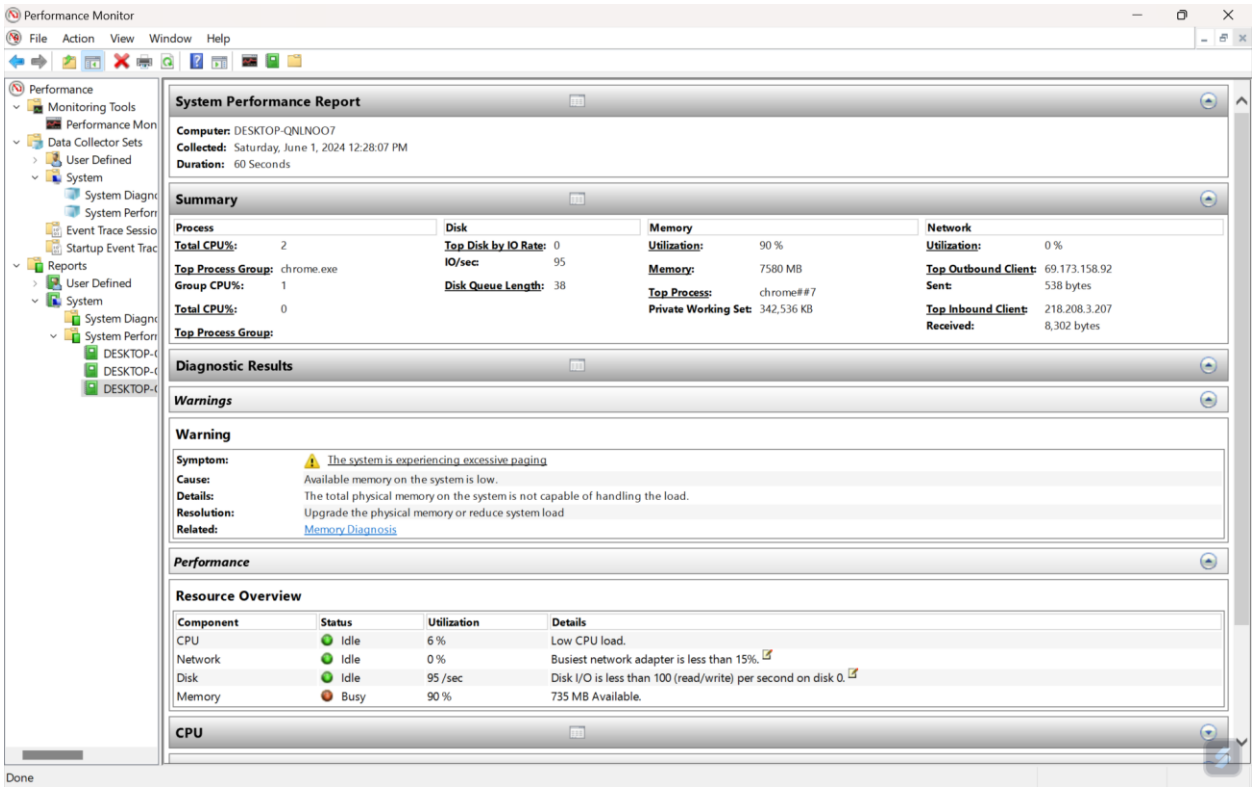

Figure 5: Windows Performance Monitor

3.1 CPU Utilization

Using Benchmarking tool

Kali Linux

[Geekbench Result]

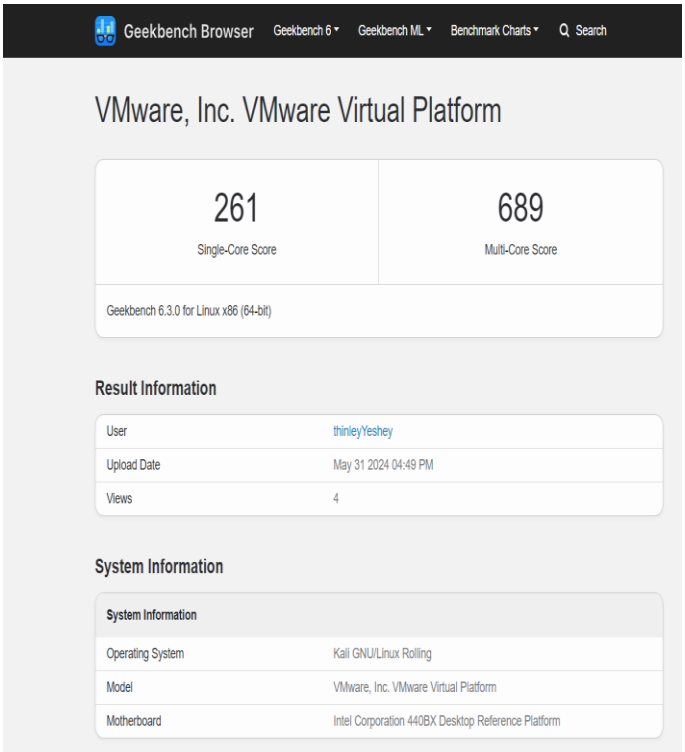

Figure 6*:* Geekbench 6 Single-Core and Multi-Core Performance on Kali Linux

- With a Single-Core Score of 261 and a Multi-Core Score of 689, Kali demonstrates moderate single-core performance and good multi-core performance, respectively.
- The system information reveals a hardware configuration featuring an Intel Core i7-1165G7 processor with multiple cores and a memory size of 1.92 GB, which influences the overall performance of Kali.

Windows

Geekbench Result

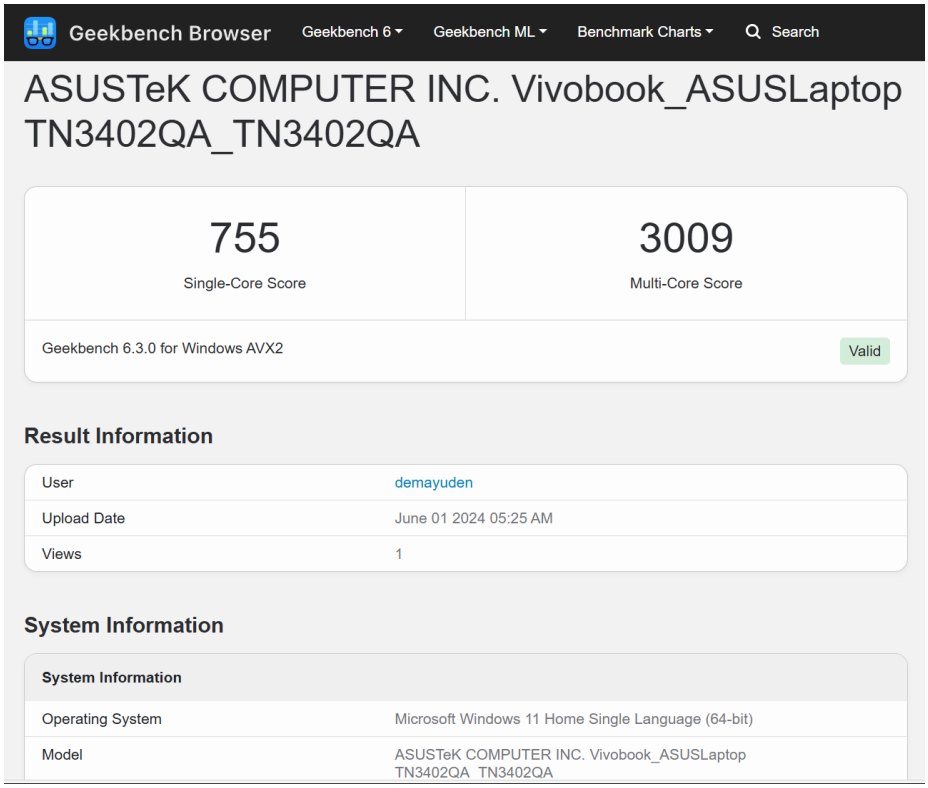

Figure 7: Geekbench 6 Single-Core and Multi-Core Performance on Windows 11

- The single-core score of 755 indicates strong performance in tasks that rely on a single CPU core, such as simple applications and certain gaming scenarios.
- The multi-core score of 3009 shows the capability of the CPU to handle multi-threaded applications, making it suitable for more demanding tasks like video editing and 3D rendering.

CPU Utilization using Monitoring Tool (Windows 11)

Results:
After 30 minutes

Metric	**Average (%)**	**Minimum (%)**	**Maximum (%)**	**Duration (min)**
% Processor Time	2.051	0.370	6.570	30:01
% Privileged Time	0.856	0.174	3.803	30:15
% User Time	1.195	0.286	4.692	30:15

Table 1: CPU usage after 30 minutes in Windows 11

After 1 hour

Metric	Average (%)	Minimum (%)	Maximum (%)	Duration (min)
% Processor Time	3.621	0.853	10.411	60:00
% Privileged Time	1.175	0.113	4.598	60:00
% User Time	2.446	0.573	8.277	60:00

Table 2: CPU usage after 1 hour in Windows 11

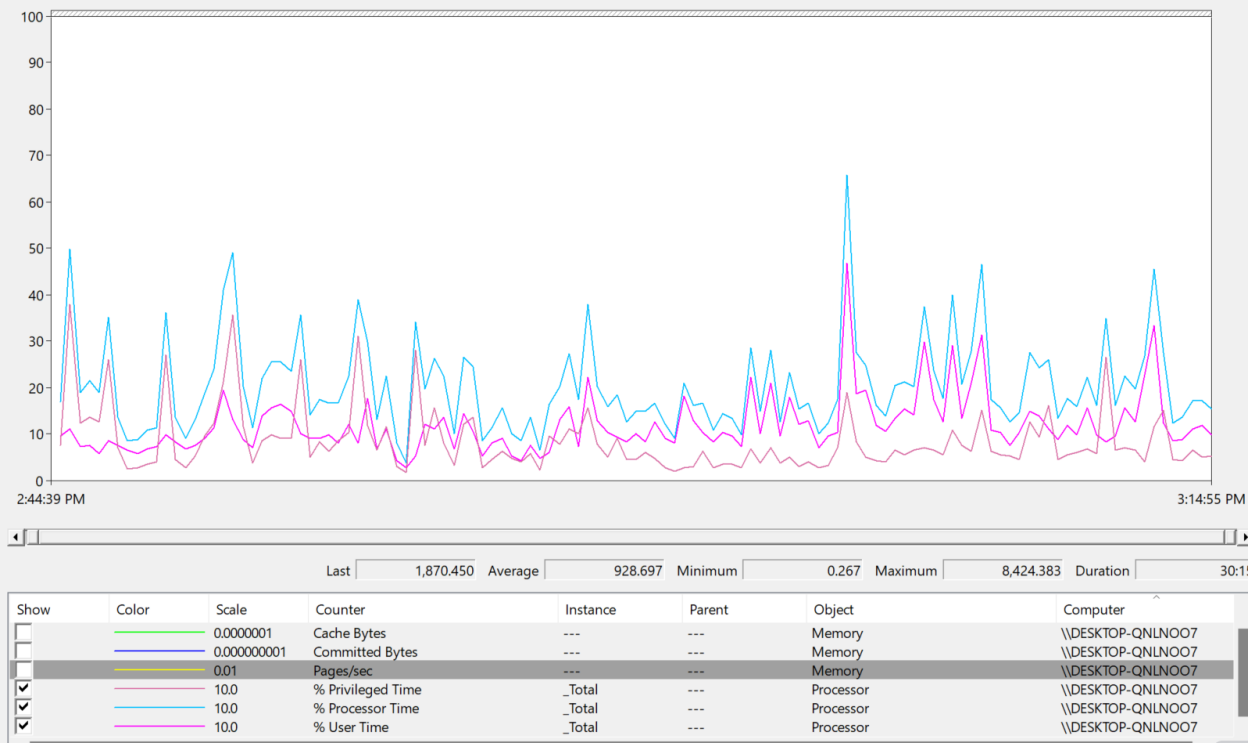

Figure 8: CPU Utilization in 30 minutes on Windows 11

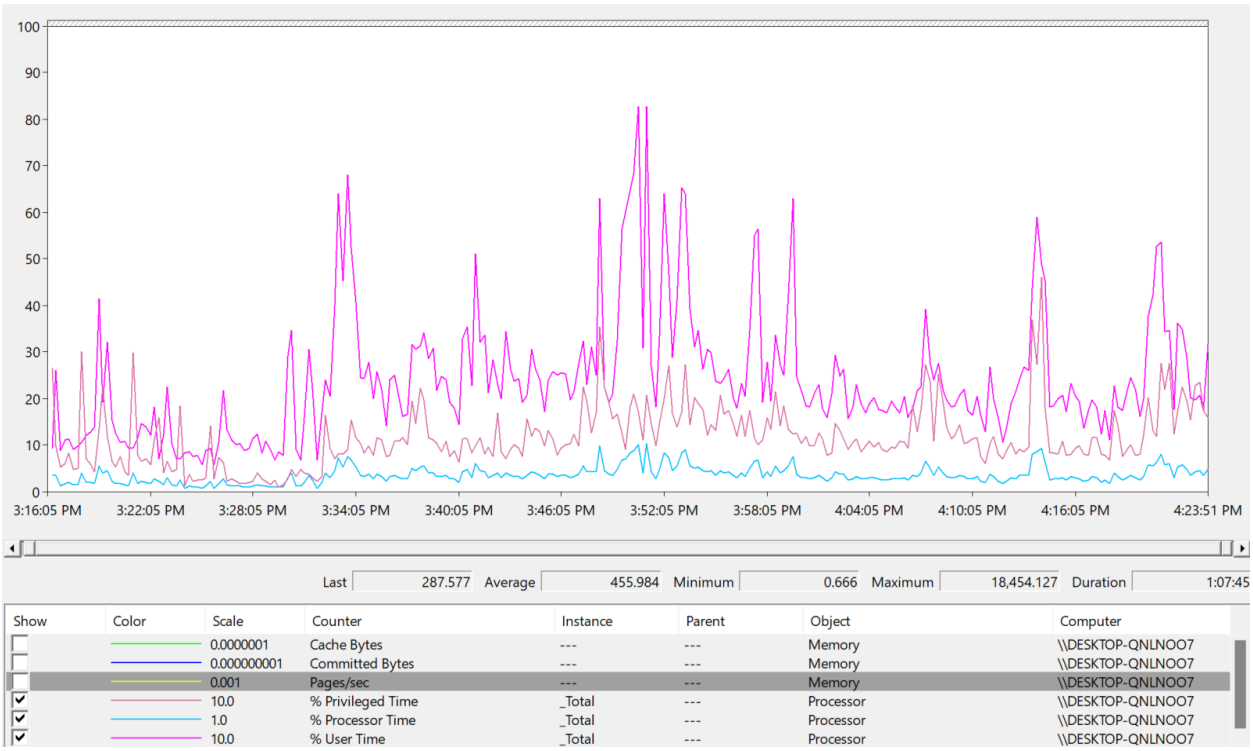

Figure 9: CPU Utilization in 1 hour on Windows 11

- The CPU utilization on Windows 11 demonstrates efficient handling of resources, with occasional peaks indicating periods of high activity. This data suggests that Windows 11 can handle typical workloads effectively with minimal performance issues.

3.2 Memory Usage

All computers come with random access memory (RAM). RAM is utilized by a computer and a percentage of the RAM is in use at all times.

Kali Linux

Using Benchmarking Tool

Htop:

Htop is an interactive process viewer for monitoring CPU and memory usage.

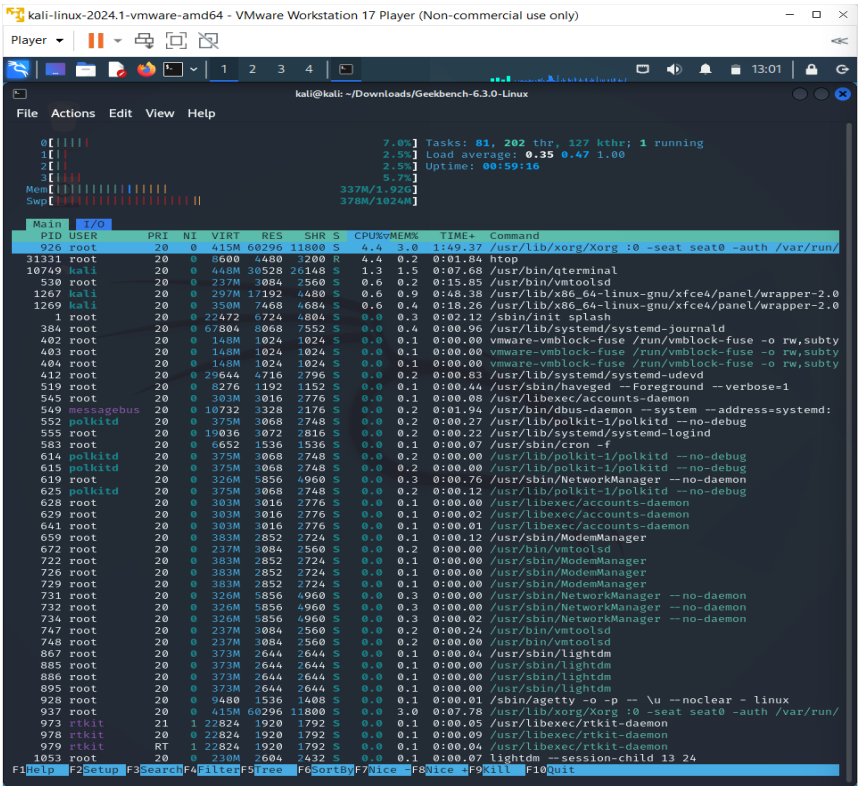

Figure 10: Kali htop result

- Across the four CPU cores, varying levels of usage are observed, with core 0 at 7%, core 1 at 2.5%, core 2 at 2.5%, and core 3 at 5.7%.
- Memory usage is reported as 337 MB out of 1.92 GB, indicating moderate memory utilization, while swap usage is at 378 MB out of 1024 MB, suggesting some activity in virtual memory management.
- The system is currently running 81 tasks and 202 threads, with one task in a running state.
- The load average over the last 1, 5, and 15 minutes is reported as 0.35, 0.47, and 1.00, respectively, indicating a relatively low to moderate system load. The system uptime is approximately 59 minutes.

Windows

Using Monitoring Tool

Performance Monitor (PerfMon)

Results:

Metric	Average (bytes)	Minimum (bytes)	Maximum (bytes)	Duration (min)
Available Bytes	1,459,374,984	508,837,888 bytes	2,055,364,608	60:00

	bytes (1.46 GB)	(0.51 GB)	bytes (2.05 GB)	
Cache Bytes	75,142,686 bytes (75 MB)	47,734,784 bytes (47 MB)	158,605,312 bytes (159 MB)	60:00
Committed Bytes	16,537,000,000 bytes (16.54 GB)	12,313,000,000 bytes (12.31 GB)	18,597,000,000 bytes (18.60 GB)	60:00
Pages/sec	0.666 pages/sec	455.984 pages/sec	18,454.127 pages/sec	60:00

Table 3: CPU utilization using PerfMon in Windows 11

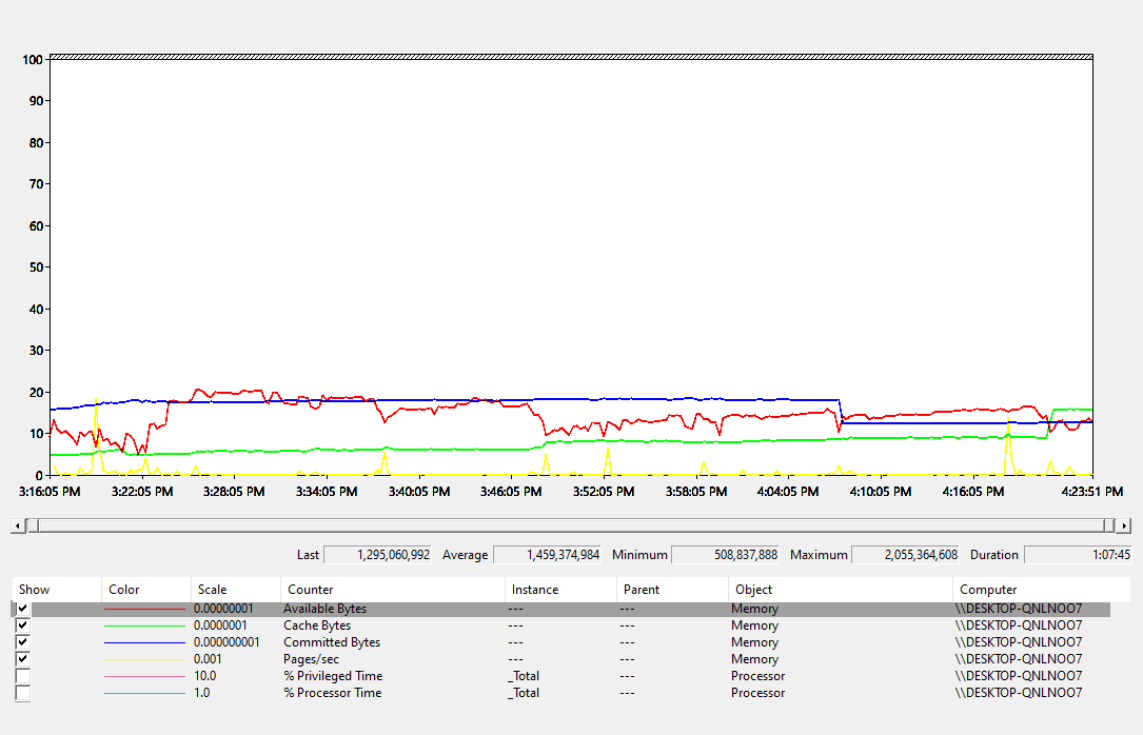

Figure 11: Memory Utilization in 1 hour in on Windows 11

- The memory utilization analysis of Windows 11 over a one-hour period revealed moderate usage of system resources with occasional spikes in page rates. By optimizing memory usage and considering hardware upgrades, overall system performance can be improved.

3.3 Disk I/O Performance

In general terms, I/O refers to the input/output functions of the physical disk in your computer. The process of I/O includes every characteristic that involves in the read-and-write process of the hard drive. During maintenance time or while running heavy programs, the rate of I/O may run high and put a heavy load on the disk's performance.

Kali Linux
Using Benchmarking Tool
Hdparm:
For measuring disk I/O performance.

Figure 12: Kali hdparm result

- Cached reads achieved a throughput of approximately 8458 MB/sec for 20826 MB of data in 1.99 seconds, showcasing significantly faster access times due to data stored in memory.
- Buffered disk reads, on the other hand, yielded a throughput of approximately 422 MB/sec for 294 MB of data in 3.01 seconds, indicating the disk's lower throughput when accessing data directly from the storage medium.

Windows
Using Benchmarking Tool
CrystalDiskMark

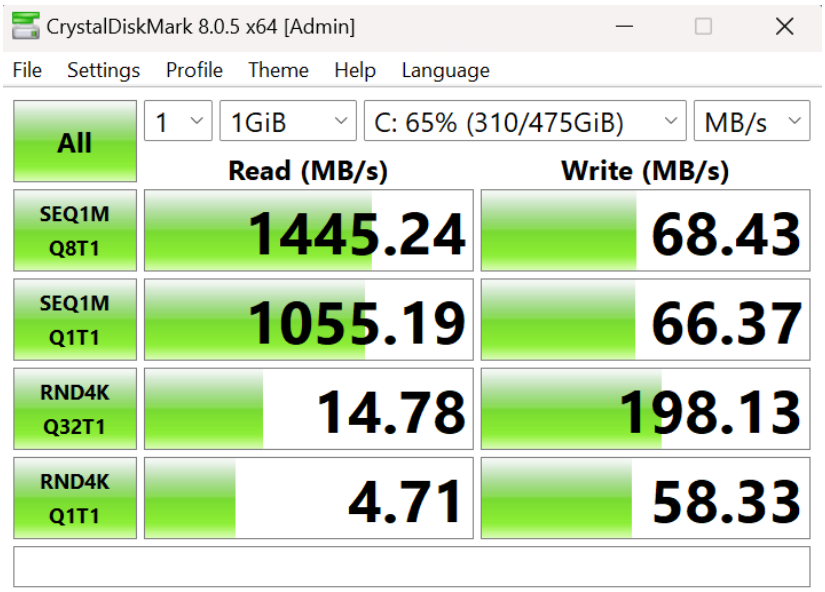

Figure 13: Windows CrustalDiskMark result

- The sequential read speeds (1445.24 MB/s and 1055.19 MB/s) are significantly higher than the sequential write speeds (68.43 MB/s and 66.37 MB/s). High read speeds are excellent for tasks like loading large files or media playback. Lower write speeds suggest inefficiency in writing large files.

- The random read speeds (14.78 MB/s and 4.71 MB/s) are relatively low compared to the random write speeds (198.13 MB/s and 58.33 MB/s). High write speeds benefit applications with frequent small writes, like logging or database updates. Lower read speeds may slow down operations involving small, scattered files.

3.4 Network Throughput

Kali Linux
Using Benchmarking Tool
Iperf3:

Test configuration:

- Server: localhost, port 5201
- Client: port 56892
- Test Duration: 0.00 - 10.00 seconds

To measure network performance, you need two machines.
On the server, run:

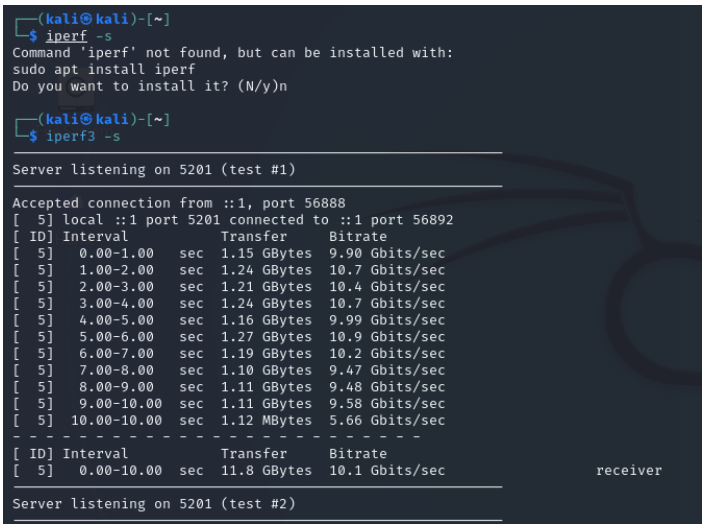

Figure 14: Kali iperf on server terminal

- The server achieved an impressive average throughput of approximately 10.1 Gbits/sec during the test, with fluctuations observed between 9.46 Gbits/sec and 10.9 Gbits/sec across individual intervals. These variations indicate dynamic network performance throughout the test.

On the client, run:

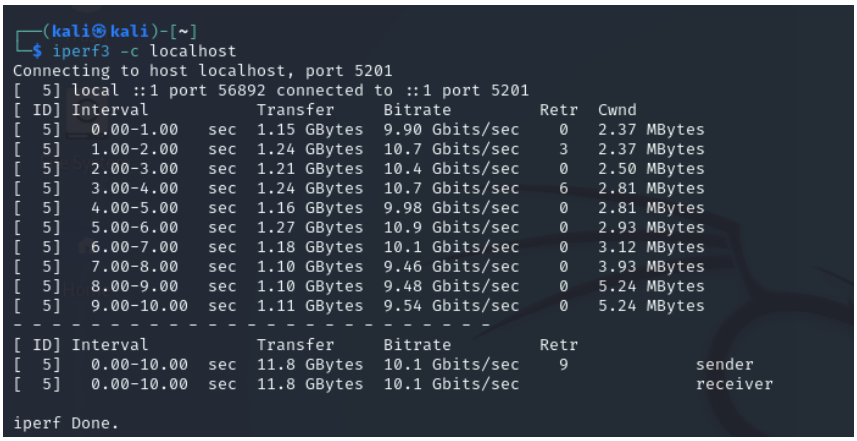

Figure 15: Kali iperf on client terminal

- Similarly, the client achieved comparable throughput, averaging approximately 10.1 Gbits/sec over the entire test duration. Despite minor fluctuations and occasional retractions, the client maintained a consistently high throughput, demonstrating the reliability and stability of the network connection.

Windows
Using Benchmarking Tool
Iperf3

Test Configuration:

- Server IP Address: 172.16.225.159
- Client IP Address: 172.16.226.170
- Test Duration: 0.00 - 10.11 seconds

To measure network performance, you need two machines.
On the client, run:

```
C:\Users\User>cd../../iperf

C:\iperf>iperf3 -c 172.16.225.159
Connecting to host 172.16.225.159, port 5201
[  5] local 172.16.226.170 port 52027 connected to 172.16.225.159 port 5201
[ ID] Interval           Transfer     Bitrate
[  5]   0.00-1.00   sec  3.00 MBytes  25.1 Mbits/sec
[  5]   1.00-2.01   sec  3.12 MBytes  26.1 Mbits/sec
[  5]   2.01-3.01   sec  4.62 MBytes  38.5 Mbits/sec
[  5]   3.01-4.00   sec  4.25 MBytes  36.2 Mbits/sec
[  5]   4.00-5.00   sec  4.25 MBytes  35.6 Mbits/sec
[  5]   5.00-6.00   sec  4.38 MBytes  36.6 Mbits/sec
[  5]   6.00-7.01   sec  4.50 MBytes  37.6 Mbits/sec
[  5]   7.01-8.00   sec  4.12 MBytes  34.8 Mbits/sec
[  5]   8.00-9.00   sec  4.12 MBytes  34.6 Mbits/sec
[  5]   9.00-10.00  sec  4.62 MBytes  38.7 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate
[  5]   0.00-10.00  sec  41.0 MBytes  34.4 Mbits/sec                  sender
[  5]   0.00-10.11  sec  41.0 MBytes  34.0 Mbits/sec                  receiver

iperf Done.
```

Figure 16: Windows iperf on client computer

- The network throughput test from the client computer, identified by IP address 172.16.226.170, to the server recorded a duration of 0.00 - 10.00 seconds. During this period, a data transfer of 41.0 MBytes was conducted, achieving a bandwidth of 34.4 Mbits/sec. These results indicate a stable and consistent network performance during the test duration.

On the server, run:

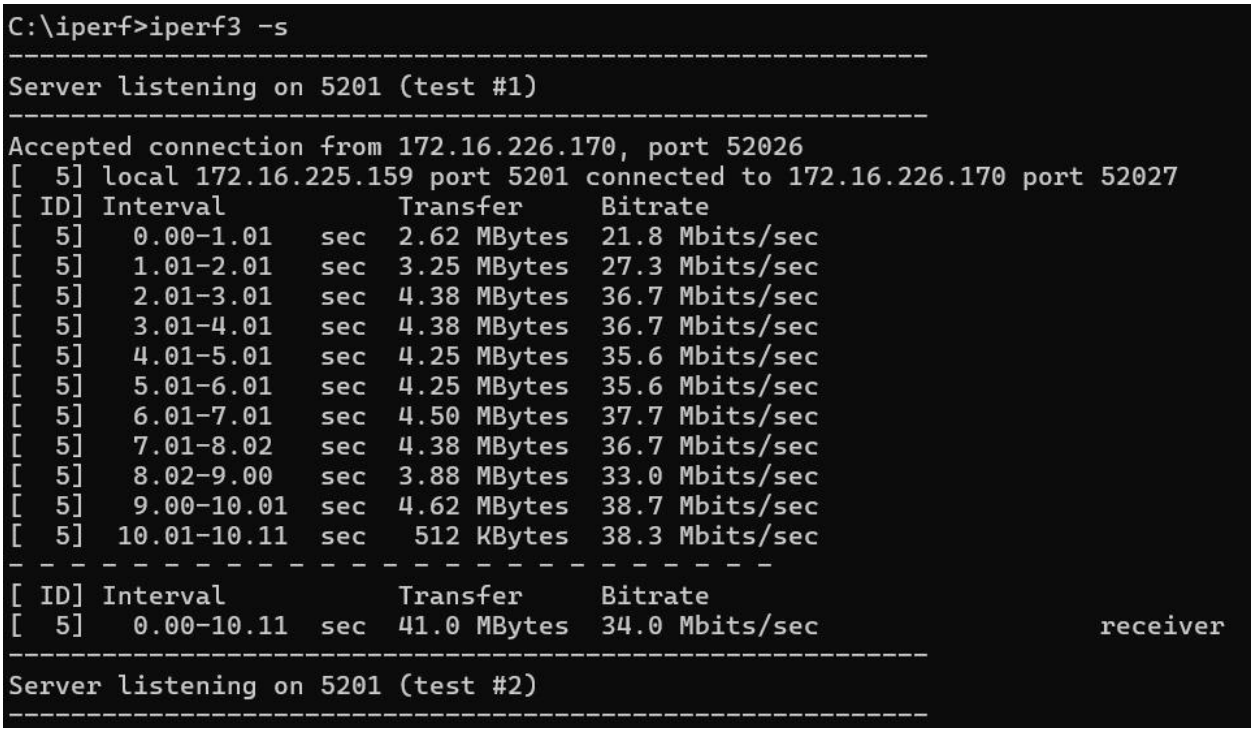

Figure 17: Windows iperf on server computer

- Conducted from the server computer, identified by IP address 172.16.225.159, to the client, the test spanned from 0.00 to 10.11 seconds. Similar to the client run, a data transfer of 41.0 MBytes occurred, resulting in a bandwidth of 34.0 Mbits/sec. The test demonstrated reliable network performance between the server and client endpoints throughout the duration of the test.

Both client-to-server and server-to-client transfers had similar transfer sizes of 41.0 MBytes. The client-to-server transfer achieved a slightly higher bandwidth of 34.4 Mbits/sec compared to the server-to-client transfer, which had a bandwidth of 34.0 Mbits/sec. These results indicate relatively stable network performance between the client and server, with consistent bandwidth close to 34 Mbits/sec in both directions.

4.0 Comparison table for Windows and Kali Linux

Metric	**Tools Used**	**Windows 11**	**Kali Linux 2024.1**	**Observations**
CPU Utilization	**Benchmarking tool -** Geekbench 6 (for both Linux and Windows)	Average CPU Utilization: 3.621%	Varying CPU Core Usage: 7%, 2.5%, 2.5%, 5.7%	Windows shows slightly higher average utilization; Kali

	Monitoring Tool - Performance Monitor (for Windows)			displays usage per core, reflecting multi-core tasks.
Memory Utilization	**Benchmarking tool -** Htop (for Linux) **Monitoring tool -** Performance Monitor (PerfMon for Windows)	Moderate usage with occasional spikes. Average available bytes: 1.46 GB. Cache: 75 MB. Committed bytes: 16.54 GB	Memory Usage: 337 MB out of 1.92 GB. Swap Usage: 378 MB out of 1024 MB.	Both show moderate usage; Windows has higher memory capacity and utilization.
Disk I/O Performance	**Benchmarking tool** - Hdparm (for Linux) **Benchmarking tool** - CrystalDiskMark (for Windows)	Sequential Read: 1445.24 MB/s, 1055.19 MB/s. Sequential Write: 68.43 MB/s, 66.37 MB/s. Random Read: 14.78 MB/s, 4.71 MB/s. Random Write: 198.13 MB/s, 58.33 MB/s.	Cached Reads: 8458 MB/sec. Buffered Reads: 422 MB/sec.	Windows excels in sequential reads; Kali has significantly faster cached reads.
Network Throughput	**Benchmarking tool** - iperf3 (for both Linux and Windows)	Client-to-server: 34.4 Mbits/sec. Server-to-client: 34.0 Mbits/sec.	Server-to-client: 10.1 Gbits/sec. Client-to-server: 10.1 Gbits/sec.	Kali Linux shows much higher throughput, indicating better network performance.

Table 4: Comparison between Windows 11 and Kali Linux 2024.1

5.0 Comparison and Discussion

Comparing the performance metrics obtained from the evaluations of both operating systems, it's evident that Kali Linux exhibits commendable efficiency in resource management, with low CPU usage and moderate memory and swap utilization.

Its Geekbench scores reveal a balanced performance profile, reflecting moderate single-core performance and robust multi-core capabilities.

Additionally, cached reads exhibit significantly faster access times compared to buffered disk reads, highlighting efficient data retrieval mechanisms. However, Kali's hardware limitations, such as the limited memory size (1.92 GB), may impose constraints on performance scalability.

Windows 11 demonstrated strong CPU performance with Geekbench 6 scores of 755 (single-core) and 3009 (multi-core), highlighting its capability for both single-threaded and multithreaded tasks. PerfMon showed efficient resource handling with occasional activity peaks. Memory utilization over a one-hour period was moderate, with average available bytes at 1.46 GB, cache bytes at 75 MB, and committed bytes at 16.54 GB, indicating reasonable memory availability and usage. CrystalDiskMark results revealed high sequential read speeds (1445.24 MB/s and 1055.19 MB/s) but lower write speeds (68.43 MB/s and 66.37 MB/s). Random read speeds were relatively low (14.78 MB/s and 4.71 MB/s), while random write speeds were higher (198.13 MB/s and 58.33 MB/s). Network throughput tests using Iperf3 showed stable performance with client-to-server bandwidth at 34.4 Mbits/sec and server-to-client bandwidth at 34.0 Mbits/sec, indicating consistent and reliable network performance.

6.0 Recommendations

To improve Kali's performance, several suggestions can be considered:

1. **Optimize Resource Usage:** Implement optimizations to reduce memory and swap usage further, such as identifying and terminating unnecessary processes or services running in the background.
2. **Upgrade Hardware:** Consider upgrading hardware components, such as increasing the memory size or utilizing faster storage devices, to enhance system performance and scalability, particularly in memory-intensive tasks or when handling larger datasets.
3. **Tune System Configurations:** Adjust system configurations and parameters to optimize performance for specific workloads or tasks. This may involve fine-tuning kernel parameters, adjusting file system settings, or optimizing network configurations.
4. **Utilize Caching Mechanisms:** Leverage caching mechanisms more effectively to improve disk I/O performance further. Implementing caching strategies at the application or system level can help reduce disk access times and enhance overall system responsiveness.
5. **Monitor and Analyze Performance:** Continuously monitor and analyze system performance metrics using tools like htop, hdparm, and iperf3 to identify performance bottlenecks and areas for improvement. Regular performance tuning and optimization efforts can help maintain optimal system performance over time.

To improve Windows performance, several suggestions can be considered:

1. **Upgrade Hardware Components:** Upgrading to higher-capacity RAM can improve overall system responsiveness and handle more applications simultaneously. Switching to a faster SSD with higher write speeds can enhance disk I/O performance, particularly for write-intensive tasks.
2. **Disable Unnecessary Startup Programs:** Reducing the number of programs that start automatically can free up CPU and memory resources.
3. **Maintain Regular System Updates:** Ensure that Windows is always updated to the latest version for performance improvements and security patches. Keep all device drivers updated, particularly for the GPU, storage devices, and network adapters.
4. **Regular Monitoring:** Use tools like PerfMon to regularly monitor system performance and identify potential bottlenecks. Periodically run benchmarking tools like Geekbench and CrystalDiskMark to measure performance improvements and identify areas for further optimization.
5. **Manage Background Processes:** Regularly check Task Manager for high-resource-consuming processes and terminate unnecessary tasks.

7.0 Conclusion

This project aimed to provide a comparative analysis of the performance between Windows 11 and Kali Linux 2024.1 based on CPU utilization, memory utilization, disk I/O performance, and network throughput.

CPU utilization for both operating systems was measured with Geekbench 6 and PerfMon providing insights into single-core and multi-core performance, as well as real-time CPU activity. Memory utilization was assessed using PerfMon on Windows and Htop on Kali Linux, offering detailed statistics and real-time data on memory and swap usage. Disk I/O performance was evaluated using CrystalDiskMark on Windows and Hdparm on Kali Linux. Network throughput was measured using Iperf3 on both operating systems, providing detailed reports on data transfer rates and network stability. These tools allowed for a comprehensive analysis of both operating systems, highlighting their strengths and areas for improvement. The results from these evaluations provide valuable insights into how each system manages resources and handles various tasks, guiding potential optimizations and hardware enhancements for improved performance.

Kali Linux is primarily aimed at cybersecurity professionals and offers specialized tools for penetration testing, while Windows 11 is a general-purpose operating system catering to a wide

range of users. Both operating systems have their strengths and areas for improvement. Windows 11 offers strong performance and user-friendly features for a broad audience, while Kali Linux excels in specific domains like security and network performance. The choice between these two systems should be guided by the specific needs and use cases of the user, with considerations for potential optimizations and hardware enhancements to achieve the best performance outcomes.

8.0 Video Link

VIDEO ON PERFORMANCE ANALYSIS OF OPERATING SYSTEMS

9.0 References

1. Connatser, M. (2023, April 25). *CrystalDiskMark: How it actually works*. XDA Developers. Retrieved June 6, 2024, from https://www.xda-developers.com/crystaldiskmark/

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Link to Geekbench : https://www.geekbench.com/
Link to Htop: https://htop.dev/downloads.html
Link to iperf3: https://iperf.fr/iperf-download.php
Link to Hdparm: https://sourceforge.net/projects/hdparm/
Link to CrystalDiskMark: https://sourceforge.net/projects/crystaldiskmark/
Link to Performance Monitor: https://performance-monitor.en.softonic.com/

10.0 Appendix

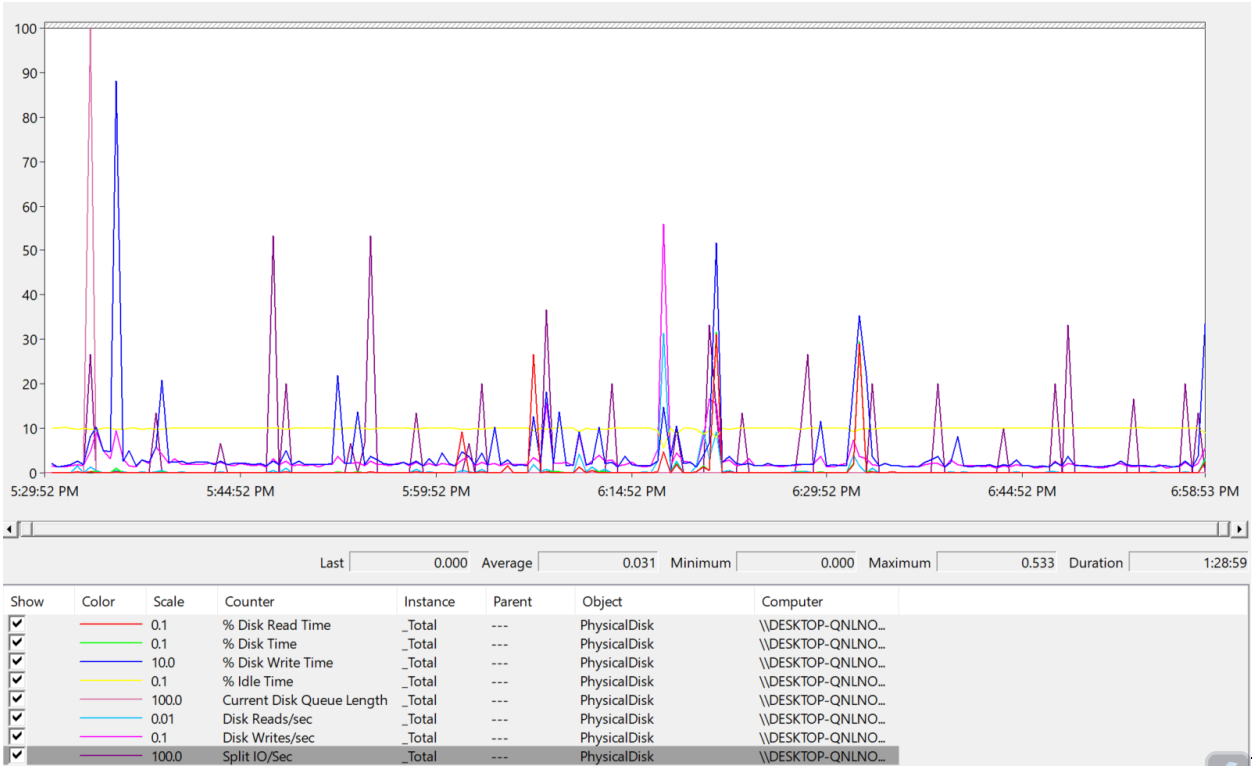

Figure 18: Disk I/O Performance in 1 hour in Windows 11 using PerfMon

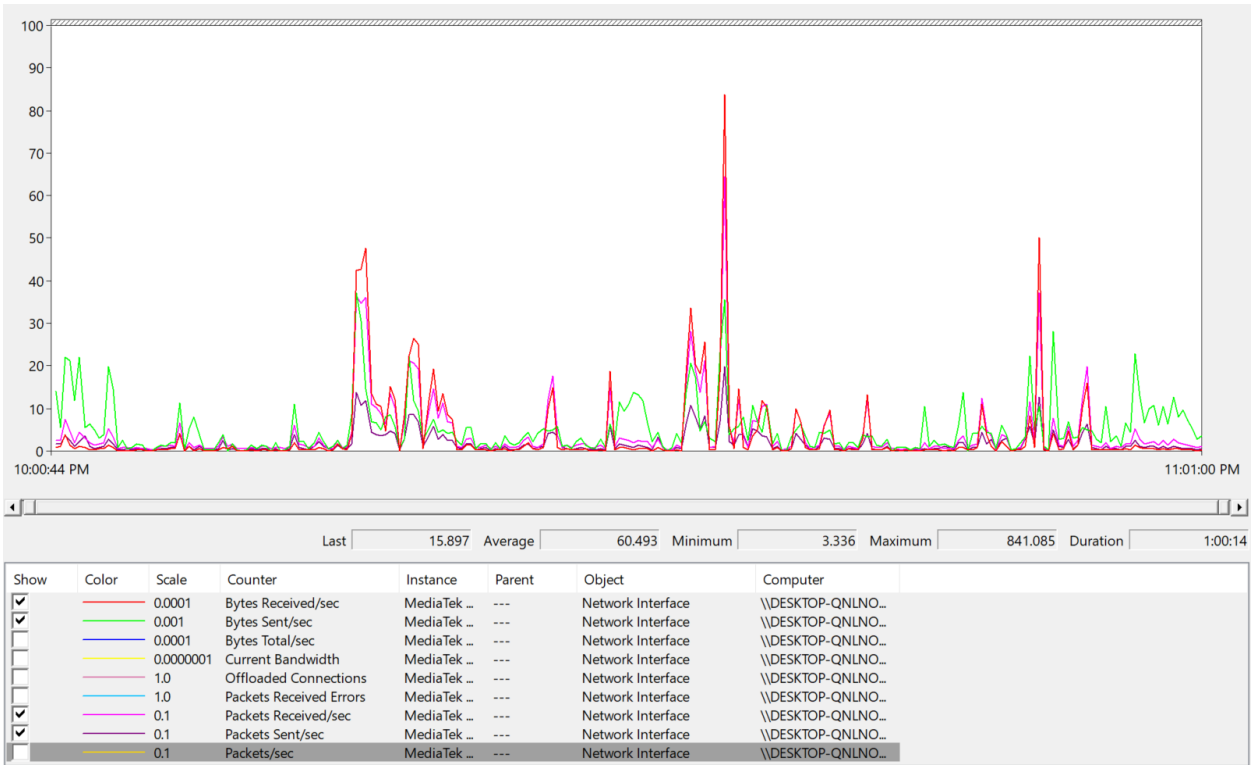

Figure 19: Network Throughput over 1 hour duration in Windows 11 using PerfMon

Metric	Average	Minimum	Maximum
Bytes Received/sec	37839.434	184.176	837520.102
Bytes Sent/sec	5143.751	48.504	37236.722
Packets Received/sec	42.210	2.269	643.810
Packets Sent/sec	18.283	0.667	197.275

Table 5: Network Throughput in 1 hour in Windows 11