Low Power Processor Designs & Performance

Cassie Priddy, Devon Wilkening, Daria Casey, Kelcee Gabbard

Project Overview

This project aims to evaluate the performance of low-power processors versus high-power processors. We conducted five performance tests on both a Raspberry Pi 4B and a Linux desktop computer, compared the results, drew conclusions, and compared our findings to those in our sourced related works.

Low Power vs High Power Processor

Low Power

- Smaller chip sizes
- Multiple cores, but not as many
- Integrated graphics
- Small cache sizes
- Generates very little heat
- Good for portable devices

High Power

- Larger chip sizes
- Higher number of cores
- Larger cache sizes
- Generates more heat
- Found in larger desktops

Performance Tests

1

CPU Usage

Percentage of CPU capability used to complete a task

2

Memory

Percentage of memory used to complete a task

3

Disk I/O

Amount of time taken to read and write data to the disk during a given task

4

Response Time

Total amount of time taken for device to complete given task

5

Power*

Amount of power used by CPU specifically during a given test

Hardware Details

	Desktop	Raspberry Pi 4B
CPU	Intel Core i9 10900k	Quad Core Cortex-A72 (ARM v8)
RAM	16 Gigabytes	2 Gigabytes
Storage	Hard Drive	SD Card
Operating System	Linux Ubuntu 20.04	Linux Ubuntu Server 20.04

CPU Usage Test

Importance:

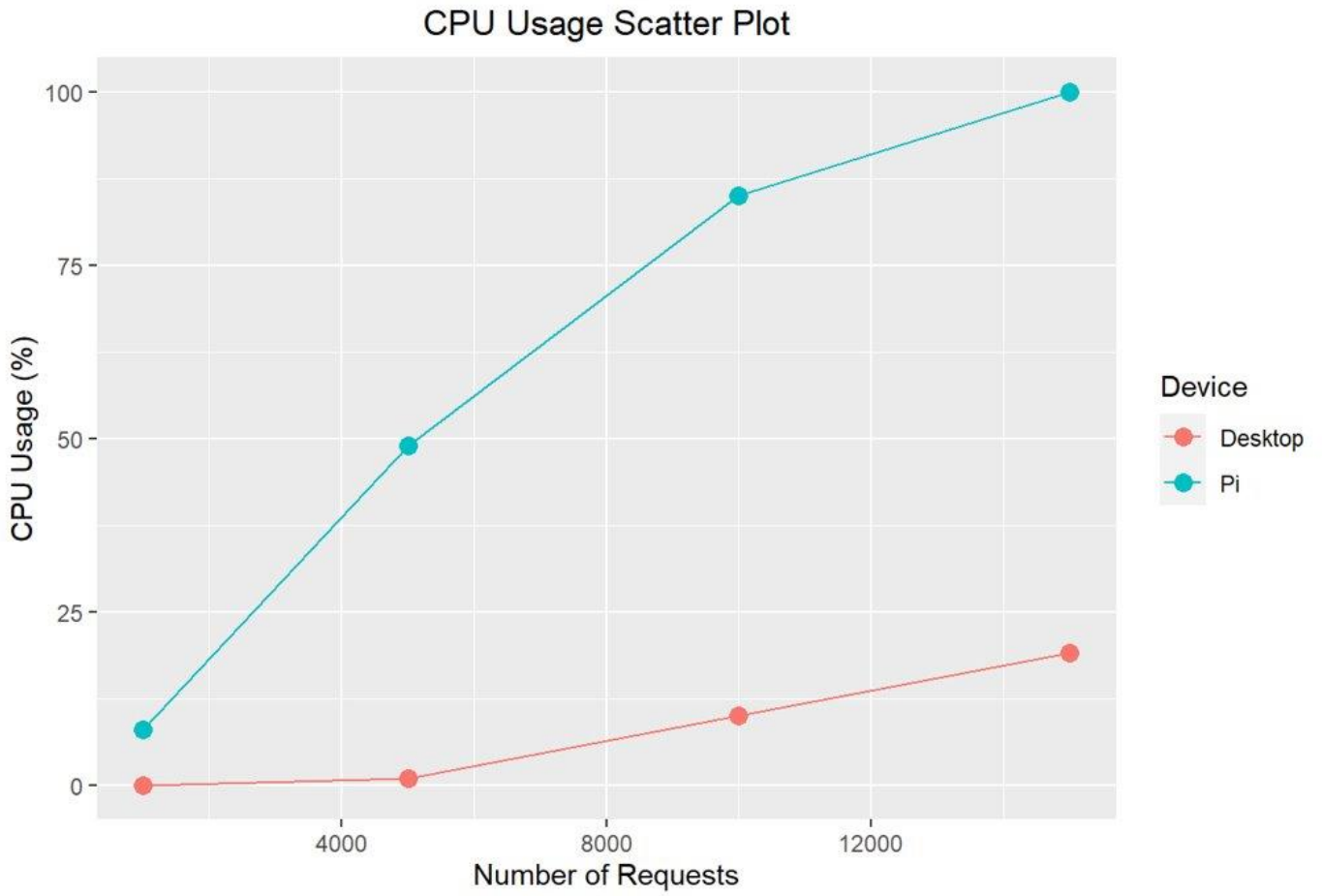
- Tests efficiency while completing tasks with varying workloads
- Tests how effectively the processor utilizes its power
- Helps identify bottlenecks in the system
- Helps gauge the responsiveness and smoothness of the system

Steps:

1. Start Nginx web server on desktop and Raspberry Pi
2. Install Apache Bench tool. Use it to send varying number of generated HTTP requests to each server individually
3. Use command line utility "htop" to display live CPU usage percentage on desktop and Raspberry Pi
4. Monitor CPU usage percentage while requests are being sent to the servers. Record number of requests and peak CPU percentage while requests are being processed on both individual machines

CPU Usage Test Results

As seen in the graph, the desktop CPU usage is significantly lower than that of the Raspberry Pi's CPU usage across the varying tests. The Raspberry Pi's CPU maxes out while processing 15,000 requests compared to the desktop's 19% CPU usage.



Memory Usage Test

Importance:

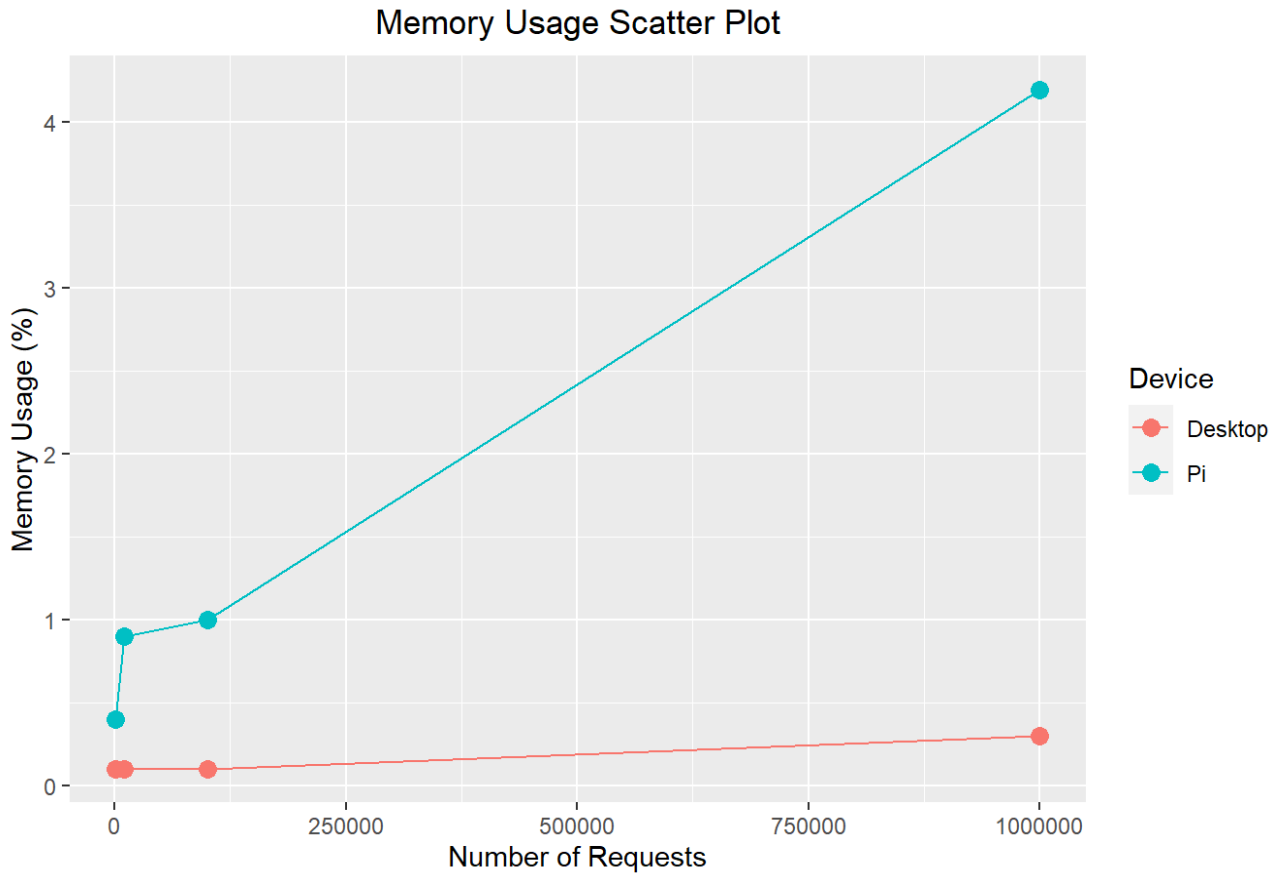
- Helps evaluate how each processor handles multiple simultaneous tasks
- Handling memory intensive tasks poorly causes freezes and instability in the system
- Can help assess scalability

Steps:

1. Start Nginx server on Pi & desktop
2. Send varying number of requests with set number of connections(1,000) to server with Apache Bench Tool on both machines
3. View metrics on machine using the command line utility "`htop`" on both machines
4. Monitor percentage of memory used during the processing of the requests. Record peak percentage while processing each set of requests for each machine individually

Memory Usage Test Results

On average, the Pi's memory usage for the same number of requests is 9.25 times higher than the memory usage of the desktop device. When calculating the amount of memory used (by multiplying percentage used and amount available), we still found that the pi used significantly more memory than the desktop. This contrast makes the Pi slower and more unstable in comparison to the desktop when handling multiple tasks.



Response Time Test

Importance:

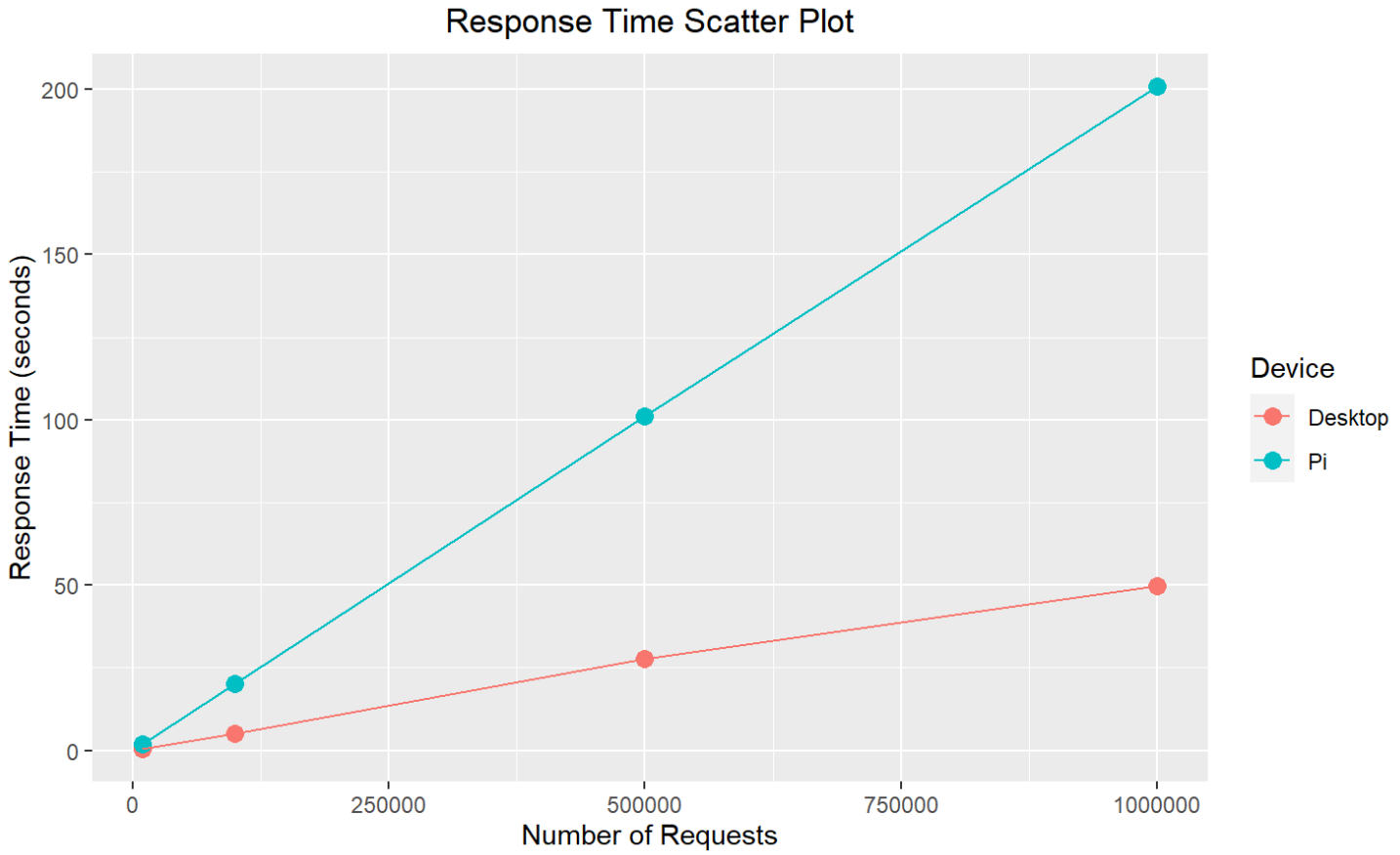
- Faster response times result in a quicker system and seamless user experience
- Tests how quickly the processor can execute a given task
- Tests how quickly the processor can respond to requests

Steps:

1. Start Nginx server on Pi & desktop
2. Use Apache Bench tool to send varying number of requests and set number of connections to server on both machines
3. In the output from running the Apache Bench tool, monitor the listed response time for each set of requests
4. Record the number of requests and listed response time for each machine

Response Time Test Results

The desktop response times are significantly lower than the Raspberry Pi's. Overall, the Pi's response times are 3.92 times higher than the desktop's. The desktop provides a much faster and smoother experience for the user, while it is likely the user will experience delays running the same tasks on the Pi.



Power Test

Importance:

- Power consumption should justify the rest of the Raspberry Pi's data underperforming
- It is designed to balance power consumption with performance capability. This is metric is what makes sacrificing performance worth it.

Complications:

- Could not accurately record wattage consumption on the desktop without a power meter.
- We tried software tools like PowerStat. They output wildly inaccurate results
- We were able to output voltage on the Pi and convert it to watts

Power Tests Results

Results:

- The most power that the Pi consumed while we ran heavy task loads was 7.6 watts.
- The average desktop idles at 50-100 watts.
- The Pi consumes at least 6.6 times less power than the Pi

Conclusion:

The Raspberry Pi excels at what it is designed for, which is low power consumption. Low power consumptions results in the following advantages:

1. Longer battery life in portable devices
2. Generates much less heat, so there is no need for a cooling solution
3. More environmentally friendly

Disk I/O Test

Importance:

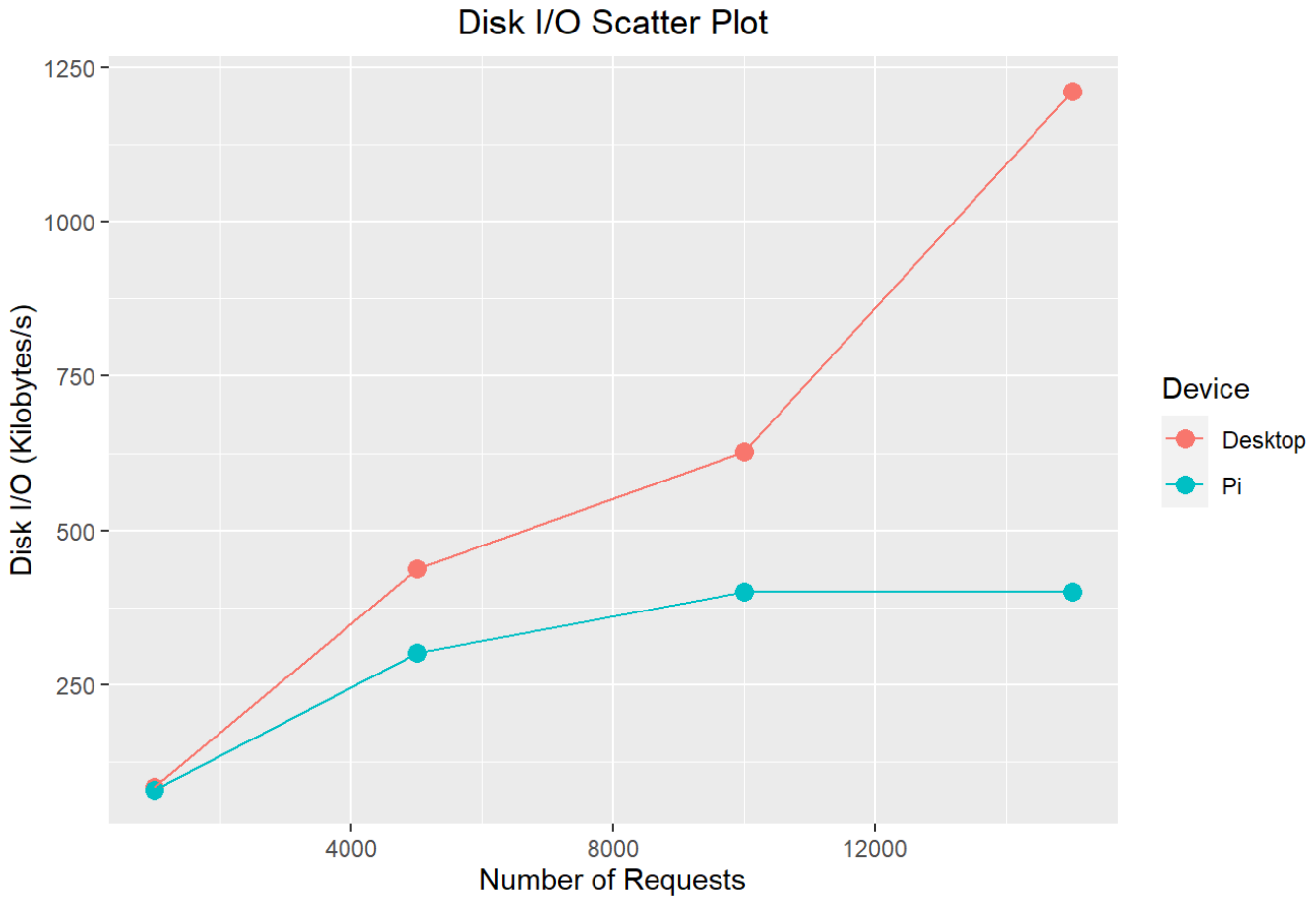
- Another way to measure the responsiveness of a system
- Helps access how quickly the processor can retrieve and write data to/from storage
- Influences the times it takes to load applications
- Tests how effectively the processor uses its available storage technology

Steps:

1. Start the Nginx server on both the Pi & desktop
2. Install and utilize the command line tool "`iotop`" to view live disk I/O rates on both machines
3. Use Apache Bench tool to send varying number of requests to both servers
4. Monitor disk read rate. Record highest number output while processing each set of requests on both machines

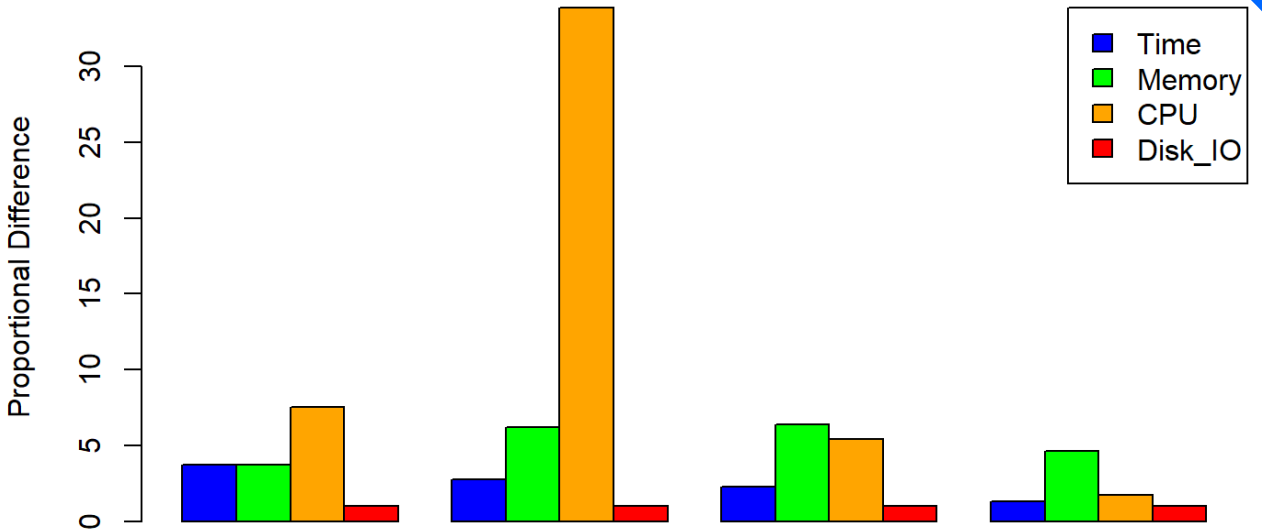
Disk I/O Test Results

While the task load increases, both machines have higher rates. It is important to note that the Raspberry Pi capped at the last data point, 400.93 Kilobytes per second. The desktop tripled the Pi's fastest rate with the rate of 1,212 Kilobytes per seconds and was able to perform faster. The desktop retrieves data 1.775 times faster than the Pi overall. This results in the Pi having longer boot times and an overall sluggish system in comparison to the desktop.



General Comparison

A value of 1 in the table to the right would indicate that the Pi and the Desktop measured the same performance in a test, the higher the value in all columns except Disk I/O the worse the Pi performed in comparison to the Desktop. As is demonstrated by the table and graph, the pi routinely tested poorly compared to the desktop many times over, with the most significant difference in performance being measured during the CPU tests. However, while not graphed due to technical constraints, the Raspberry Pi is drastically more efficient with regards to power consumption at the expense of overall performance parameters.



Proportional Difference in Test Results (Pi/Desktop Result)

	Time	Memory	CPU	*Disk I/O
test 1	3.978431	4	8	0.942618
test 2	4.039671	9	49	0.691076
test 3	3.633268	10	8.5	0.637959
test 4	4.029078	14	5.263158	0.3308
Overall Diff.	**3.920112**	**9.25**	**17.69079**	**0.650613**

***In the case of Disk I/O a worse performance is indicated by a lower value**

Overall Findings

Overall, our findings correspond to those of other studies comparing the low-power processor design of Raspberry Pi's and other low-power devices to traditional desktops. The low-power processor design of the Raspberry Pi's CPU has a significant impact on CPU usage and other associated components. However, while the Raspberry Pi has much less to offer in terms of general performance, it also consumes significantly less power than a traditional desktop PC while completing the same task.

Sources & Related Works

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Questions?