Performance and Cost Analysis of Web Application Deployment on Raspberry Pi versus Enterprise PaaS Provider

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1 Introduction

This project aims to analyze the performance, resource utilization, and cost aspects of deploying a web application on a Raspberry Pi device compared to an enterprise-level hosting environment. We evaluate the response time, resource usage, and associated costs involved in running the web application on both platforms as well as identify the bottlenecks. We hope that this analysis will aid new budget oriented web developers determine the optimal hosting platform for their next web application.

2 Experimental Setup

2.1 Application

For this project, we will use a Monitor Recommendation web application designed by one of the co-authors. This application accepts two types of request:

- Get-Course
- Find-Monitor

The application is structured as follows:

```
/
/recommender
/crash-course
/api/monitor-recommendations
```

The Get-Course request simply a returns a "Monitors 101 Course Page" that is designed to help users unfamiliar with basic monitor terminology. In this project we are mainly interested in the Find-Monitor request.

The Find-Monitor request from /recommender calls the API endpoint at /api/monitor-recommendations and displays up-to 8 monitors. The request sends a JSON object with 25 fields.

/ corresponds to the Landing page of the website.

The UI of the application was designed using React@18 and the recommender API was made using Flask@2.2.3, a python backend framework. The application runs in a Gunicorn Web Server Gateway Interface (WSGI) server. The application does not have any dedicated database server and uses a csv file to store the monitor information.

On average, this website gets 50 users per day.

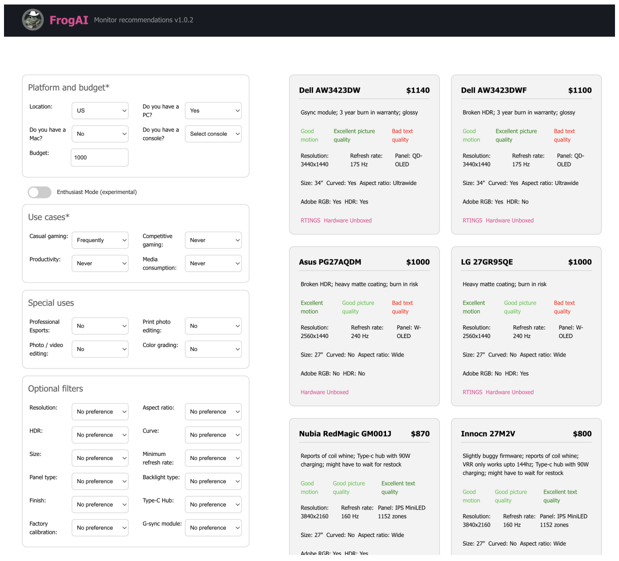
2.2 Test Environment

In this project, we are comparing the same application hosted on two different platforms:

- Raspberry Pi 3B+ with a 4-core CPU and 1GB memory running a clean installation of Raspbian Linux 11, a flavor of Debian. No other user level applications except gunicorn are allowed to run.

- Render.com enterprise hosting on starter tier with 0.5 vCPU and 512MB Memory running on Debian Linux 10. Only one instance is enabled and autoscaling is turned off.

The load is generated using `wrk`, a modern HTTP benchmarking tool, from a local computer connected to a 500 Mbps internet connection. `wrk` reports the distribution of the total response time and throughput. To measure the CPU and memory utilization, we use a script that calls the Linux `top` command at fixed intervals and then calculates the mean, on both the render.com server and the RPi.


FrogAI Monitor recommendations v1.0.2

Platform and budget*

Location:	US	Do you have a PC?	Yes
Do you have a Mac?	No	Do you have a console?	Select console
Budget:	1000		

Enthusiast Mode (experimental)

Use cases*

Casual gaming:	Frequently	Competitive gaming:	Never
Productivity:	Never	Media consumption:	Never

Special uses

Professional Esports:	No	Print photo editing:	No
Photo / video editing:	No	Color grading:	No

Optional filters

Resolution:	No preference	Aspect ratio:	No preference
HDR:	No preference	Curve:	No preference
Size:	No preference	Minimum refresh rate:	No preference
Panel type:	No preference	Backlight type:	No preference
Finish:	No preference	Type-C Hub:	No preference
Factory calibration:	No preference	G-sync module:	No preference

Dell AW3423DW **$1140**
Gsync module; 3 year burn in warranty; glossy
Good motion Excellent picture quality Bad text quality
Resolution: 3440x1440 Refresh rate: 175 Hz Panel: QD-OLED
Size: 34" Curved: Yes Aspect ratio: Ultrawide
Adobe RGB: Yes HDR: Yes
RTINGS Hardware Unboxed

Dell AW3423DWF **$1100**
Broken HDR; 3 year burn in warranty; glossy
Good motion Excellent picture quality Bad text quality
Resolution: 3440x1440 Refresh rate: 175 Hz Panel: QD-OLED
Size: 34" Curved: Yes Aspect ratio: Ultrawide
Adobe RGB: Yes HDR: No
RTINGS Hardware Unboxed

Asus PG27AQDM **$1000**
Broken HDR; heavy matte coating; burn in risk
Excellent motion Good picture quality Bad text quality
Resolution: 2560x1440 Refresh rate: 240 Hz Panel: W-OLED
Size: 27" Curved: No Aspect ratio: Wide
Adobe RGB: No HDR: No
Hardware Unboxed

LG 27GR95QE **$1000**
Heavy matte coating; burn in risk
Excellent motion Good picture quality Bad text quality
Resolution: 2560x1440 Refresh rate: 240 Hz Panel: W-OLED
Size: 27" Curved: No Aspect ratio: Wide
Adobe RGB: No HDR: Yes
RTINGS Hardware Unboxed

Nubia RedMagic GM001J **$870**
Reports of coil whine; Type-c hub with 90W charging; might have to wait for restock
Good motion Good picture quality Excellent text quality
Resolution: 3840x2160 Refresh rate: 160 Hz Panel: IPS MiniLED 1152 zones
Size: 27" Curved: No Aspect ratio: Wide
Adobe RGB: Yes HDR: Yes

Innocn 27M2V **$800**
Slightly buggy firmware; reports of coil whine; VRR only works upto 144hz; Type-c hub with 90W charging; might have to wait for restock
Good motion Good picture quality Excellent text quality
Resolution: 3840x2160 Refresh rate: 160 Hz Panel: IPS MiniLED 1152 zones
Size: 27" Curved: No Aspect ratio: Wide

Figure 1: *FrogAI recommendation website*

2.3 Test Configuration

To load test this applicaiton on the two different platforms we are sending a custom JSON object to the API directly. The static UI is simple and we assume that it does not contribute significantly to the total latency. We created a simple Lua script that defines the request parameters:

```
wrk.method = "POST"
wrk.body = [[ "country": "US",
"pcGpu": "yes", "consoles": "no",
"mac": "no", "budget": 1000, "mode":
"basic", "casual": "imp", "comp":
"imp", "text": "imp", "media": "imp",
"persistence": "not", "response":
"not", "contrast": "not", "brightness":
"not", "volume": "not", "sharp":
"not", "subpixel": "not", "esports":
"not", "edit": "no", "print": "no",
"grade": "no", "aspect": "nopref",
"curve": "nopref", "size": "nopref",
"res": "nopref", "minRR": "nopref",
"panel": "nopref", "backlight":
"nopref", "hdr": "nopref", "finish":
"nopref", "calibrated": "nopref",
"hub": "nopref", "module": "nopref"
]]
wrk.headers["Content-Type"] =
"application/json"
```

For the initial test, the load generator is configured to use two threads with 5 concurrent connections at a time each to send requests for 1 minute to the two platforms. This amounts to 10 connections open at a time which is a reasonable expected load for this application. We are also using a timeout duration of 5s as anything above that is considered unacceptable for this application. Each test is run 5 times.

System	Stats	Mean
RPi 3B+	R	2.18s
	X (req/s)	4.25
	U_{CPU}	0.265
Starter	R	1.11s
	X (req/s)	8.78
	U_{CPU}	0.452

Figure 2: Initial results

System	Conns.	R	X (req/s)	U_{CPU}
RPi 3B+	2	0.47s	4.26	0.248
	10	2.20s	4.46	0.266
	20	4.32s	4.46	0.263
	50	10.27s	4.38	0.266
	250	30.21s	4.31	0.265
Starter	2	0.25s	8.14	0.450
	10	1.10s	8.99	0.486
	20	2.20s	8.86	0.459
	50	5.35s	8.89	0.500
	250	21.54s	8.82	0.500

Figure 3: Variable load results

Then, we run a series of tests with varying loads to determine the primary bottleneck in this system. We set the timeout to 100s in this case. Each test is run 3 times.

3 Results

We summarize the results of the initial experiments in 2. Memory utilization remains constant around 100MB on both systems during idle periods as well as stress tests. There were no timeouts and all responses were received within 5s on both platforms.

We summarize the results of the variable load tests in 3.

3.1 Performance Analysis

Python has a Global Interpreter Lock (GIL) that prevents applications from using more than 1 core using multiple threads. Further the Raspberry Pi has 4 CPU's and `top` reports all 4 cores busy as 1.0. Based on these two facts, we suspect that the utilization being consistently around 0.25 on the RPi indicates that only core was loaded 100% the entire time. For the Starter instance the utilization does not go above 0.5 usually as the current plan only allows that much.

It performs worse than the starter instance while having no ability to scale up and being senstive to power outages. However, we still see some use cases where it might be the choice, especially for hobbyist applications.

3.2 Cost Analysis

The Render.com starter instance costs $7.00 per month as long as we do not go over the free build minutes and bandwidth usage which is not a concern for this application. The Raspberry Pi 3B+ has initial hardware cost of $35 and a power usage cost of approximately $0.67 per month in California. Over a long period of time, it is clearly cheaper than the enterprise hardware.

4 Future Work

5 Conclusion