

WEB SERVICES PERFORMANCE EVALUATION ON SINGLE BOARD COMPUTERS FOR MOBILE APPLICATIONS AND IoT DEVICES

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Abstract

Single Board Computers is an adequate device that can be applied in the smart home, smart farm, and industry to sustain the performance of various data services. However, the number of connected devices and sensors which request to access the web service affects the performance. In this article, we would like to present the evaluation of operating web services on Single Board Computers. In the experiment, four Single Board Computers were used to examine are Raspberry Pi Zero, Raspberry Pi 3, Raspberry Pi 4, and ASUS Tinker Board. Throughput that can support web API services at 3,913.45, 7,485.72, 24,773.4, and 56,769.84 messages/sec, respectively. When measuring overall performance against the value in various inputs-oriented with the DEA model, the Raspberry Pi 4 and the ASUS Tinker Board were approached the optimum with the rating of Scale Efficiencies is 1.000. The Raspberry Pi 3 and Raspberry Pi Zero present the overall performance rating of 0.595 and 0.574, respectively which means inadequate to be a server.

Keywords: Performance, Single Board Computer, Data Envelopment Analysis, API, Web Service, IoT

Introduction

The Internet of Things (IoT) communication or Machine to Machine (M2M) communication has been applied in various communication technologies such as the agriculture industry, tourism, medical and mobile technology. The web services with REST API are often used to exchange data between them since the communication channels over HTTP/HTTPS protocol are manageable to employ for IoT, mobile devices, and the server which is provided services through the

website. Moreover, the REST API consumes a smaller overhead and data size than other communications. In addition, the goal of API web services technology is to enable distributed applications that can be dynamically assembled, adapt to changing business needs, and customized based on device and user access (Papazoglou, 2008). There is an unofficial specified requirement by the standard agency RFC 2616 to limit the number of request messages on the service

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(Fielding *et al.*, 1999). In practice, an error on REST API may appear during communication between users and their applications, the IoT devices, and the service providers because of the period of data transmission, limited memory sizes, and resources for the service request. These factors are affecting expected services (Manik *et al.*, 2019).

The development of different intelligent application systems requires a various number of peripherals and sensors. Moreover, the web service control device, which is operated by the server in the network, is also needed in the processing. In addition, current technology can reduce the size of the network service including energy consumption, heat dissipation, and hardware platform's price. However, the small size of network service is still efficient for providing service, especially control IoT devices. In general, a Single Board Computer (SBC) can be used as a server for providing the data and controlling the operation of various devices simultaneously (Madoš *et al.*, 2017). There are several types of Single Board Computers available now which hold several manufacturing methods, memory sizes, connections, processing speeds, and including prices. Most Single Board Computers are selected based on their platform, production structure features, processing speed, and network connection patterns (Galkin *et al.*, 2018). These mentioned above are all influences when considering a gateway or a server on IoT and IIoT applications. (Morabito and Research., 2016). However, when considering Single Board Computers based on their features, CPU size, RAM, thermal, maximum power consumption, and sleep mode, they reveal that the high ability of board leading cause of high value. Therefore, comparing the cost against the required capacity should be considered, which there are no other sources of information, decide which Single Board Computers should be applied in IoT and Smart Application developers.

This article aims to evaluate the performance of the web API, which provides data service for IoT and smart application, and run a database on the server. Then explores the popular Single Board Computers products, including determining the optimum efficiency and cost-effectiveness for IoT and data services on the smart application.

Materials and Methods

Materials

In this article, the speed of services between the network and clients is one of the parameters, was measured to evaluate the performance of web services REST API or API for mobile applications

and IoT devices. The client can be in terms of computers, programs, sensors, applications, and electronic devices, and connected the API to communicate with web services through the network (Masse, 2011). Figure 1, data services were built in Single Board Computers within a LAN network by a conceptual form of centralized communication called Request/Response Cycle to control external factors that affect the operation of the system. In this process, the clients sent an HTTP Request to the server. After that, the server replies HTTP Response back to the client's requests (Cooksey, 2014).

Computer Network Design

The computer network in this article applies computers as clients' networks to examine the performance of request functions through REST API. Furthermore, the router devices were used to control internet services, and assign IP addresses to all devices on the network. A gigabit switch was used to distribute the signals and then provide connectivity. In addition, the access point was used to join with the Raspberry Pi Zero Single Board Computer through a wireless interface, as shown in Figure 2.

Experimental Equipment

In this section, there are two parts of representation; hardware for the computer network and software for the server. Further, the software was employed to measure and examine the service performance on the server.

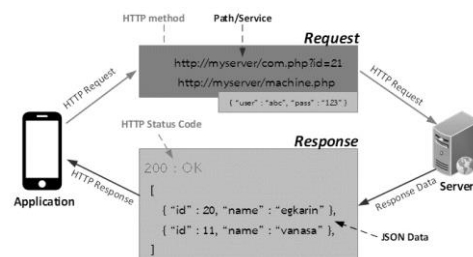


Figure 1. API calling by using HTTP protocol (Watanyulertsakul, 2020).

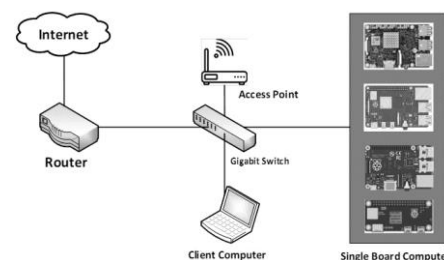


Figure 2. Network diagram.

1. Hardware

1.1 There are four Single Board Computers; Raspberry Pi 3, Raspberry Pi 4, Raspberry Pi Zero, and ASUS Tinker Board were used to evaluate the performance of the web services.

1.2 16 GB Mini SD Card for Single Board Computers

1.3 Personal computer was used to measure and examine the performance.

1.4 Standard network interface devices such as Gigabit Switch, Router, UTP Cable, Access Point, etc.

2. Software

2.1 The Raspberry Pi OS which was previously called Raspbian, is an open-source operating system for the Raspberry Pi. In addition, the TinkerOs developed from Debian operating system is applied for the ASUS Tinker Board. Both of them were used for operating system programs on Single Board Computers.

2.2 The development language program was used as a performance testing equipment, for example, Python was used to measure the hardware performance of Single Board Computers, CPU, RAM, and processing of the web service requests.

2.3 Web server software including Apache, PHP, MySQL, and phpMyAdmin.

Experiment and Evaluation

The performance of web service requests was evaluated on four Single Board Computers namely Raspberry Pi 3, Raspberry Pi 4, Raspberry Pi Zero, and ASUS Tinker Board, respectively. In addition, for each Single Board Computer, HTTP Request was sent in the form of POST to the server to examine the web performance. After that, the server was responded after receiving the HTTP Response by query data from the MySQL database. There are 1-100,000 returning messages that have been collected to represent the performance of the server. Furthermore, the database connection times, query execution times, data preparation times, and response times have been also collected and recorded in the database when the client started the request. Moreover, the Python program which is used in part of a web service is applied to monitor the amount of CPU and memory usage.

Figure 3 represents an analysis of the web service performance on each Single Board Computer for mobile applications and IoT devices. Moreover, this article would like to present the advantage of Single Board Computers for web services on IoT devices and smart applications. Then, multiple inputs and outputs have been used

to analyze and evaluate the performance of web services, and also indicate the efficiency of server performance. Furthermore, input-oriented factors such as RAM, cost, time, and resource consumption of the server have been used based on Data Envelopment Analysis (DEA) technique that is a nonparametric method. The nonparametric method is a performance measurement technique that is appropriate to decision-makers with little or no background in economics and operational research (Huguenin, 2012). Furthermore, the technical efficiency of a production unit can be calculated as shown in Equation (1).

$$\text{Technical efficiency} = \frac{\sum \text{weighted outputs}}{\sum \text{weighted inputs}} \quad (1)$$

The DEA model was used to measure the performance of web services and consider the inputs orient under the variable return to scale (VRS) assumption. This measurement performs in the event of an incomplete race. Therefore, the server cannot operate at the optimal level of performance. In addition, the technical performance measurement under the Constant Return to Scale (CRS) assumption has a limitation that every production unit has to be operated at an optimal scale to test the group of Single Board Computers for comparing the performance of the complete competition. Table 1 represents variable values which used in the paper as follows.

1. Input-oriented Measure
 - 1) CPU usage unit percentage
 - 2) Memory usage unit percentage
 - 3) Transmission time unit millisecond
 - 4) Memory size unit MB
 - 5) Cost of equipment unit Dollar
2. Output-oriented Measure
 - 1) Throughput unit messages/sec

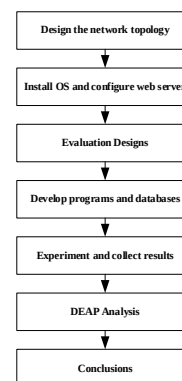


Figure 3. Experimental method.

Table 1. Raw data for processes in DEP techniques.

Throughput	CPU Usage	Memory Usage	Response times (ms)	RAM (MB)	Price (Dollar)
62.50	1.06	29.69	16.00	1024.00	41.46
561.79	9.70	9.40	1.78	4096.00	65.06
3.79	10.00	55.30	264.00	512.00	24.38
143.78	2.51	17.40	19.95	2048.00	60.50
8064.52	5.69	30.32	620.00	1024.00	41.46
24022.17	10.00	9.70	208.14	4096.00	65.06
3891.05	100.00	58.00	1285.00	512.00	24.38
27115.97	7.72	17.71	184.39	2048.00	60.50
7824.73	8.49	33.16	1278.00	1024.00	41.46
23069.60	12.35	10.40	433.47	4096.00	65.06
3546.10	100.00	62.00	2820.00	512.00	24.38
41364.19	10.27	18.14	241.76	2048.00	60.50
7684.43	9.96	34.27	1952.00	1024.00	41.46
25983.98	15.30	11.00	577.28	4096.00	65.06
4335.26	100.00	64.00	3460.00	512.00	24.38
47401.44	13.07	18.62	316.45	2048.00	60.50
7773.03	10.39	34.95	2573.00	1024.00	41.46
26392.05	19.53	11.40	757.80	4096.00	65.06
3787.88	100.00	67.00	5280.00	512.00	24.38
50806.79	13.28	19.08	393.65	2048.00	60.50
7886.44	11.44	39.19	3170.00	1024.00	41.46
25325.15	20.90	11.80	987.16	4096.00	65.06
4332.76	100.00	71.00	5770.00	512.00	24.38
54558.83	12.96	19.44	458.22	2048.00	60.50
7886.44	12.21	40.63	3804.00	1024.00	41.46
26942.90	25.79	12.50	1113.47	4096.00	65.06
4291.85	100.00	75.00	6990.00	512.00	24.38
57000.19	15.99	19.33	526.31	2048.00	60.50
7943.71	11.68	42.73	4406.00	1024.00	41.46
24011.38	26.59	13.10	1457.64	4096.00	65.06
4447.27	100.00	77.00	7870.00	512.00	24.38
59662.11	16.98	19.91	586.64	2048.00	60.50
7984.03	11.37	47.01	5010.00	1024.00	41.46
26505.48	27.83	13.38	1509.12	4096.00	65.06
4545.45	100.00	79.00	8800.00	512.00	24.38
61966.51	15.90	20.38	645.51	2048.00	60.50
7849.29	12.55	51.08	5733.00	1024.00	41.46
26759.69	28.27	13.50	1681.63	4096.00	65.06
4257.33	100.00	83.70	10570.00	512.00	24.38
64010.37	18.25	20.94	703.01	2048.00	60.50
7808.84	15.28	53.42	6403.00	1024.00	41.46
26952.75	28.15	14.70	1855.10	4096.00	65.06
4476.28	100.00	88.40	11170.00	512.00	24.38
64158.00	17.48	21.39	779.33	2048.00	60.50
7801.44	13.11	59.27	7049.98	1024.00	41.46
25297.71	27.99	15.47	2174.11	4096.00	65.06
4428.34	100.00	90.00	12420.00	512.00	24.38
65171.67	17.96	21.82	843.92	2048.00	60.50
7774.17	15.51	62.95	7717.87	1024.00	41.46
27368.75	27.09	15.67	2192.28	4096.00	65.06
4405.29	100.00	91.60	13620.00	512.00	24.38
64458.04	17.74	22.34	930.84	2048.00	60.50
7777.97	16.34	66.25	8356.94	1024.00	41.46
25442.06	28.97	16.00	2554.82	4096.00	65.06
2912.19	100.00	95.60	22320.00	512.00	24.38
65067.27	19.54	23.14	998.97	2048.00	60.50
7851.62	16.38	70.26	8915.36	1024.00	41.46
26881.65	29.46	16.62	2604.01	4096.00	65.06
4257.91	100.00	94.00	16440.00	512.00	24.38
65994.28	16.59	23.26	1060.70	2048.00	60.50
7817.95	17.14	71.85	9593.31	1024.00	41.46
26312.22	30.00	17.15	2850.39	4096.00	65.06
4076.09	100.00	94.00	18400.00	512.00	24.38
65668.61	16.09	23.76	1142.10	2048.00	60.50
7896.30	18.16	75.64	10131.32	1024.00	41.46
26281.12	29.53	18.00	3044.01	4096.00	65.06
3929.27	100.00	95.20	20360.00	512.00	24.38
66354.69	20.54	24.40	1205.64	2048.00	60.50
7895.72	19.16	75.64	10765.33	1024.00	41.46
26397.52	29.68	18.60	3220.00	4096.00	65.06
3808.24	100.00	95.60	22320.00	512.00	24.38
66793.24	17.91	24.80	1272.58	2048.00	60.50

Throughput	CPU Usage	Memory Usage	Response times (ms)	RAM (MB)	Price (Dollar)
7847.82	19.69	78.09	11468.15	1024.00	41.46
26663.68	29.73	19.47	3375.38	4096.00	65.06
3706.75	100.00	95.78	24280.00	512.00	24.38
68182.13	17.49	25.28	1319.99	2048.00	60.50
7900.09	20.22	79.91	12025.18	1024.00	41.46
26685.39	29.78	20.27	3560.00	4096.00	65.06
3620.43	100.00	96.20	26240.00	512.00	24.38
68762.84	18.14	25.71	1381.56	2048.00	60.50
7869.01	18.67	82.11	12708.08	1024.00	41.46
26385.22	28.81	20.95	3790.00	4096.00	65.06
3546.10	100.00	96.00	28200.00	512.00	24.38
67525.72	18.54	26.28	1480.92	2048.00	60.50

Results and Discussion

This work is interested in the performance of web services that work on four different types of Single Board Computers namely Raspberry Pi 3, Raspberry Pi 4, Raspberry Pi Zero, and ASUS Tinker Board. According to Figure 4, the result shows an average CPU usage that Raspberry Pi 3 exhibited the lowest average CPU usage 13.94%, followed by ASUS Tinker Board 15.47%, Raspberry Pi 4 24.54%, and Raspberry Pi Zero 95.71%. In parts of memory usage, the Raspberry Pi 4 exhibited the lowest average RAM usage with 14.72%, followed by ASUS Tinker Board 21.58%, Raspberry Pi 3 55.16%, and Raspberry Pi Zero 82.04%. According to Figure 5(a), the capacity of package transmission depends on each type of Single Board Computers which is measured by the numbers of service requests until it converges. Figure 5(b), ASUS Tinker Board provided the highest number of package transmissions 56,769.84 messages/sec, followed by Raspberry Pi 4, Raspberry Pi 3, and Raspberry Pi Zero were 24,773.44, 7,485.72, and 3,913.45 messages/sec, respectively. Figure 6 represents the result from server responding in terms of JSON encoding format which can be appropriately applied on IoT devices and smart applications.

Although the efficiency of a Single Board Computer is less than an expensive high-performance server system, it can be provided web services and manage limited system resources as well as the high-performance server system. Considering the cost of maintenance, a Single Board Computer is more affordable than a high-performance server system which is enough to apply on web services, mobile applications, and IoT devices. It is related to Baun's research which claims Single Board Computers are an option for providing resources to student projects and researchers (Baun, 2016). The results of CPU usage during package transmission on different versions of Raspberry Pi Boards are related to Caldas's work which shows

Quality of Service (QoS) of Virtual Private Network (VPN) on Raspberry Pi via wireless networks (Caldas-Calle *et al.*, 2017).

The results previously mentioned revealed that measurements based on multiple inputs or input-oriented, cannot recognize the performance of these Single Board Computers. Hence, the DEA method which is calculated by equation 2, has been

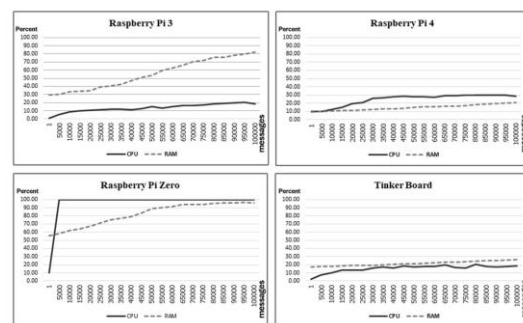


Figure 4. CPU and RAM usage.

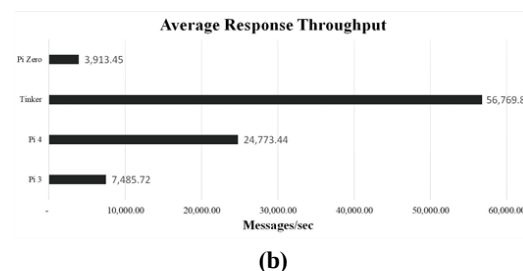
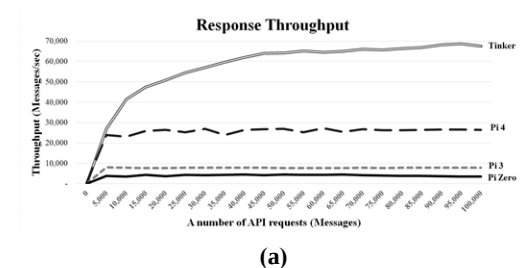


Figure 5. Throughput result.

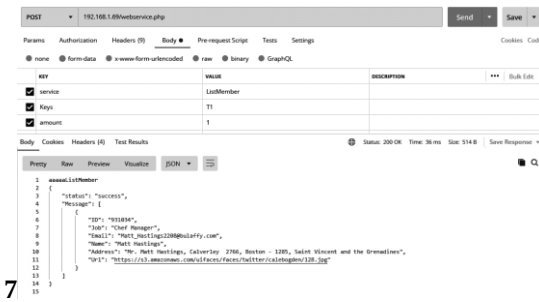


Figure 6. Example response data.

Table 2. Efficiency summary of Single Board Computer

SBC	CRS	VRS	Scale Efficiencies
Raspberry Pi 3	0.595	1.000	0.595
Raspberry Pi 4	1.000	1.000	1.000
Raspberry Pi Zero	0.574	1.000	0.574
ASUS			
Tinkerboard	1.000	1.000	1.000

employed to evaluate the overall performance of four Single Board Computers. The result shows that the Raspberry Pi 4 and the ASUS Tinker Board contain Scale Efficiencies (SE) at 1.000 when optimized web services. Furthermore, the SE of Raspberry Pi 3 and Raspberry Pi Zero were 0.595 and 0.574, respectively.

$$SE = \frac{CRS}{VRS} \quad (2)$$

From Table 2, when considering the VRS values, the four Single Board Computers are reasonable to work as a server. However, the CRS values show that the Raspberry Pi 4 and ASUS Tinker Board are suitable for IoT and smart applications when compared to the amount of CPU usage, RAM, responding time, memory size, and value for money selection of Single Board Computers.

Considering efficiency services of Raspberry Pi 3 and Raspberry Pi Zero reveal that Ethernet Network Interface Card contains 10/100 Mb/s are less than Raspberry Pi 4 (Raspberrypi, 2021) and ASUS Tinkerboard 10 times which both of them contain 1000 Mb/s (ASUS, 2021). In addition, the different architecture of CPU and the price of Raspberry Pi 4 and ASUS Tinkerboard are cheaper than the rest 3 times, so they are a reasonable choice to apply these boards as a server.

Conclusions

This article studied the design and compared the performance of various Single Board Computers servers. The server performance was evaluated by receiving several requests from many clients. The number of requests was range from 1-100,000 sets. When analyzing the effectiveness of selecting a Single Board Computer based on pricing and managing of board resources which should contain large numbers of requests for web services. The experimental results were analyzed by using the DEA method to show that the Raspberry Pi 4 and ASUS Tinker Board represent a high level of input-orient utilization and performance which the CRS reached 1.000. The Raspberry Pi 3 and Raspberry Pi Zero are inappropriate to be a server because the overall performance rating is 0.595 and 0.574, respectively.

The results of the DEA method analysis show that the Raspberry Pi Zero was selected by the web service when the requirement does not exceed 5000 message/sec because it contains few links of information and reasonable prices. The Raspberry Pi 3 can be applied to support a higher quality of web services since its Ethernet network interface card is 10/100 Mbps. Therefore, it contained more stability than the Raspberry Pi Zero connection via USB connection or Wireless LAN. Although the Raspberry Pi 4 and ASUS Tinker Board have the same level of cost-effective input orient. However, considering the throughput, the average of the ASUS Tinker Board is 2.29 times higher than the Raspberry Pi 4. Moreover, the ASUS Tinker Board slightly cheaper than the Raspberry Pi 4.

Acknowledgments

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