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Effective Workload Allocation in Fog Device based on Power Consumption and Delay Tradeoff

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Abstract

Fog computing that emerges as an important paradigm, describes decentralized computing architecture between cloud and devices. It includes potential challenges, such as increase in traffic overhead, since all requests are sent to the main server that causes delay, which cannot be tolerated in delay sensitive applications and the usage of inappropriate scheduling causes high power consumption in fog device. These challenges must be overcome by employing effective workload. In this paper, in order to find effective workload allocation based on power and delay tradeoff various scheduling algorithms like SJF (Shortest Job First), FCFS (First Come First Served) and RR (Round Robin) are implemented in fog device and its power and delay trade off are analyzed in fog computing subsystem.

Keywords: Delay, Fog device, Power, Process, Trade-off, Workload

1. Introduction

Cisco in 2012 proposed the term fog computing which is also called fogging or fog networking gain lot of attentions due to its ability to meet the needs which are not able to meet by cloud computing and also for its decentralized computing architecture where computations, storage and communications are performed locally by using edge devices. Fog computing or fogging is an astonishment not a replacement for cloud computing. Fogging delivers service to user requests at edge of the network. Routers, gateways, and bridges are examples of fog layer devices that conduct networking functions. It decides the data dispatching to server and data be processed locally so it called as short-term analytic while cloud computing is a long term analytic. As a result, fog is an intelligent gateway that offloads clouds, allowing for more efficient data storage, processing, and analysis. SPAM

(Sensor Process Actuate Mode) is used in fog computing. Where sensors detect and collect data and communicated to a fog device for processing. The processed output is delivered to actuators for taking action. Because of rapid development in IoT (Internet of Things) leads to connect large number of devices, results in the generation of raw voluminous data in huge amount. The main idea behind fog computing is to do as much processing as possible in fog layer itself rather than forwarding all the data to cloud servers. Delivering the processed data rather than raw data to cloud can reduce bandwidth, latency and reaction time.

Fog nodes are a group of nodes or several nodes. It can be smart gateways, routers, switches, internal modems, and cellular base stations. Data protection, security, avoiding unnecessary communications by filtering data, quick response to delay sensitive applications, reduced latency, improved response time, and overall increase in speed and efficiency are all benefits provided by FOG. Intolerable transmission latency and deteriorate to end users were caused as a result of heavy burden on communication bandwidth when conveyance of massive data to cloud occurs.[1] On the other hand it leads to traffic became more dominant and mobility support critical. To address these challenges, cisco proposed fog concept. By introducing intermediate layers between cloud and user, fog locally process the workload & services in fog device. [9] Traffic overhead is increased because of all incoming requests are sent to the main server which causes delay not tolerated by delay sensitive applications as well as usage of inappropriate scheduling causes high power consumption of fog devices become dominant problem in fog computing.

2. Literature Survey

Arash et al[1] distinct on a partial offloading approach. Trade-off of energy consumption & task processing delay in fog network was taken into account in partial offloading approach. Authors focus at fog architecture challenges in communication and network. Goal of the approach is to provide optimal distribution by reducing delay and energy consumption along with increased lifetime of network. Performance of proposed approach was evaluated by considering delay, energy consumption and lifetime of network through simulation. Guo M et al[2] formulate workload allocation based on delay to inspect workload allocation problem energy efficient as well as delay. The problem is addressed by concerning delay-base workload allocation algorithm. Developed to determine optimal solutions and also for achieving the goal of diminishing system energy consumption and delay assurance to arriving jobs. Chen S et al[3] in fog computing for IOT evolves an energy

optimum dynamic computing offloading scheme. The motive of this paper is to lower energy utilization while computation tasks were realized inside desired energy aloft and delay. Firstly, authors formulate the problems by considering constraints in energy, delay and network. The scheme proposed by authors is patronize to local computing in addition to full as well as partial offloading with regard to energy consumption and time taken for completion.

Siasi N et al[4] introduce a scheme for hybrid architecture of fog – cloud of several resources namely SFC provisioning scheme. In order to accommodate the requirements of delay sensitive and delay tolerant of incoming requests proposed architecture consists of single fog as well as cloud layer hence it combines the asset of both technologies in same architecture at lower limitations. Proposed scheme gains trade off between cloud and fog solutions in terms of energy consumption, resource consumption, delay, number of satisfied request and realization cost.

Ali B et al[5] target to explore the use of computational resources at edge the network. Volunteer supported fog computing aradigm was proposed by the authors which looks into interplay of two distributed computing domains for reducing intrinsic communication, energy utilization, delay also network usage. Performance of proposed scheme is evaluated using ifogsim with consideration of performance metrics such as energy consumption, delay and network usage.

 Li G et al[6] adopt a trade off strategy for acheiving delay as well as energy consumption balancing which can realize optimal energy consumption with delay threshold level. Directing tasks to cloud helps in saving energy but on the other hand in fog nodes it may results in increasing the delay. Therefore need to propose trade-off strategy allying delay and energy. This paper outlines delay & energy consumption of mobile terminal layer in addition to fog and cloud server by assisting queue theory. The experimental result of proposed scheme shows that energy consumption and delay reduced by 22% and 12.5% respectively than FCFS.

Qiang Fan et al[7] proposes scheme for minimizing latency in communication also in processing by introducing workload balance in fog network by correlating internet of thing devices. Authors besides convergence optimality were also proved for their proposed scheme. Performance and advantages of proposed scheme were related with other schemes and verified by usage of simulation.

3. Fog - Cloud Framework

The frame work of fog-cloud computing system has referred from Deng et al. [12] The architecture has been divided as four subsystems as LAN (Local Area Network) subsystem, fog subsystem, WAN (Wide Area Network) subsystem and cloud subsystem. LAN subsystem acting as an interface for user also called as front-end portals receives end user's requests. After receiving the incoming requests, they are separately given as input to a set of fog devices by LAN. Fog subsystem has an decentralized infrastructure for data computing and storing. It locates the applications between the data sources and process the requests which are mostly delay sensitive while forwards the other request to cloud.
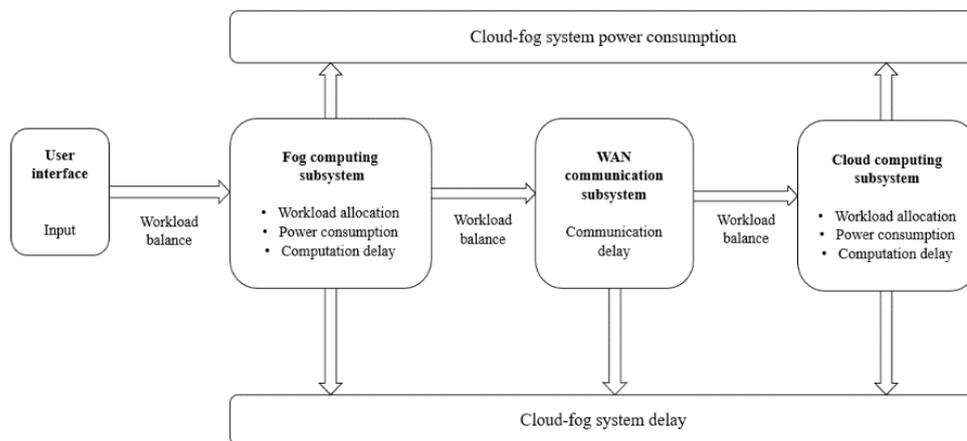
Figure 1. Fog-Cloud Framework (Source: Deng et al [12])

Fog drove by servers for performing its function remotely and to provide computing service on-demand over internet which leads to no need of organizations to own infrastructure for computing. In cloud it involves set of cloud servers, hosting numerous homogeneous machines for computing. Unprocessed request by fog devices in fog layer are directed to servers in the cloud through wide area network. Bandwidth, communication latency and throughput from edge to core should be taken into account. In this paper, power consumption and delay trade-off in the fog computing subsystem were primarily considered.

3.1 Power Analysis in Fog Device

Number of outlying devices were allied to the network due to the expeditious spread of internet of things which results in generation of huge amount of voluminous data from the number of devices. There is a need for effective scheduling for scheduling and processing these data. Usage of inappropriate scheduling makes less efficient in computation and

increases the forwarding of data to cloud which results increased power consumption. Therefore, a proper workload allocation can minimize power consumption of device in fog subsystem and overall network. [12] Consider fog device i, whose computation power is modelled by computation amount function x_i which is monotonically increase & strictly convex function.

$$p_i^{fog} = a_i \, x_i^2 + b_i \, x_i + c_i \tag{1}$$

where a_i should convex function while b_i, c_i be strictly convex and pre-determined parameters whereas x indicates workload allocation.

3.2 Delay Analysis in Fog Device

Fog computing authorize localization while cloud furnish centralization at network edge. With bounteous data and enlarge service requests, power utilization on energizing cloud servers were mounting. Hence it is prime as well as desirable to consider delay in cloud-fog. Besides for service provider, it is equally decisive to assuring quality of service to end users. Due to latency which are intolerable leads users to subscribe other vendors resulted in revenue losses. [12] Formula for calculating delay in fog device as follows

$$D_i^{fog} = \frac{1}{vi - xi} \tag{2}$$

Assuming a queueing system having service rate v_i and workload x_i for fog device i.

3.3 Power-Delay Tradeoff Analysis in Fog Device

A trade-off occurs while choosing one course of action over another when introduce a weighting factor. Consider both power and delay having relative changes respect to the weighting factor and service requests. For an effective power-delay tradeoff there should be a minimum power and delay though increasing in the incoming request. It is accomplished through workload allocation by effective scheduling. In this paper, convex optimization technique is used for analyze. [12] Formulation of power consumption and computation delay trade-off in fog device as follows

$$\sum_{i \in N} \left(a_i x_i^2 + b_i x_i + c_i + \frac{n_i}{v_i - x_i} \right) \tag{3}$$

Where n_i is weighting factor and also adjustable parameter for trade-off allying power and delay in fog device.

4. Workload Allocation

Workload is defined as percentage of work required by the processor for executing the task. Also called quantity of task carry out by an entity in a stated time. Memory workload, CPU workload, I/O workload and database workload are types of workloads. In this paper, we considered the processor workload allocation for analysing power-delay trade off in fog computing subsystem. CPU workload means number of instructions being accomplished by the processor at a distinct instant of time indicates increment or decrement of processing power if CPU overloaded or falls below precise threshold. By employing effective scheduling refinement performance can be obtained. [13] Formula for calculating workload (x)

$$x = \frac{process\ time}{elapsed\ time} * 100 \qquad (4)$$

In above formula, process time includes burst time of CPU and I/O which refers to the amount of time taken by the process for its execution. Process time can be calculated from waiting time and turnaround time. Elapsed time refers to the amount of time from start of an algorithm to complete its execution. Waiting time defined as total time spend by process in ready state waiting for CPU while turnaround time means total amount of time spent over process from first time entering in ready state to its complete execution.

4.1 Scheduling

Fog applications has resource constrained and latency sensitive nature. Due to its nature, resource management becomes a difficult challenge in fog network. In resource management scheduling play's vital role and its aim is to find better solution for scheduling the set of tasks. [4] So appropriate scheduling is important in fog to overcome resource constrained challenges. Also, there is an another needs such algorithm should reduce the response time and overall network usages when it is employed in the applications mainly which are latency sensitive. Various algorithms like Round Robin, First Come First Served algorithm, Task scheduling algorithm with ant colony optimization, Job scheduling, non-preemptive algorithm, Static-cyclic algorithm and heuristic algorithms can be employed for finding optimal scheduling. In this paper, three scheduling algorithms namely SJF, FCFS and RR were examined for determining effective workload allocation to diminishing power consumption and delay in fog device at fog subsystem.

5. Results and Discussion

In this paper, workload allocation is evaluated by implementing three scheduling algorithm such as SJF scheduling, FCFS scheduling and RR scheduling in MATLAB for finding effective workload allocation to minimize fog devices power utilization as well as computation delay in fog subsystem. All results were obtained from MATLAB simulation.

5.1 Workload Allocation

In addition to power, also delay in fog device varies accordingly to workload allocation. Workload allocation is the amount of time allocated for the process to run and execute also called as amount of time processor utilized by the process. It is calculated in terms of percentage. In this paper three various scheduling algorithms were implemented in MATLAB for finding effective workload.

A. Shortest Job First Scheduling

Simulation of workload allocation using SJF scheduling algorithm in MATLAB.
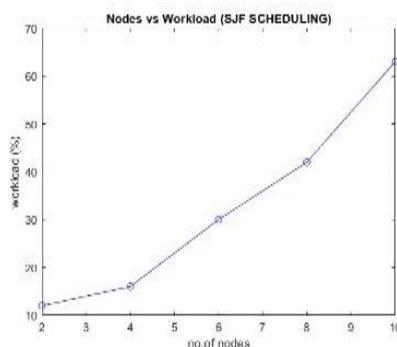
Figure 2. Simulation of workload allocation using SJF scheduling algorithm

Let x axis be number of nodes while y axis be workload. when SJF algorithm is used for workload allocation then six nodes with each node having one process results in the 30 % of processor workload (i.e., utilization).

B. First Come First Scheduling

Simulation of workload allocation using FCFS scheduling algorithm in MATLAB. Let x axis be number of nodes and y axis is workload. When FCFS algorithm is used for workload allocation then six nodes with each node having one process results in the 45 % of processor workload.
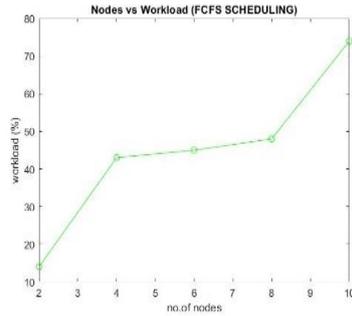
Figure 3. Simulation of workload allocation using FCFS scheduling algorithm

C. Round Robin Scheduling

Simulation of workload allocation using RR scheduling algorithm in MATLAB.
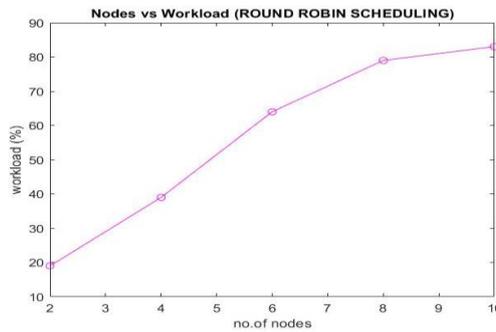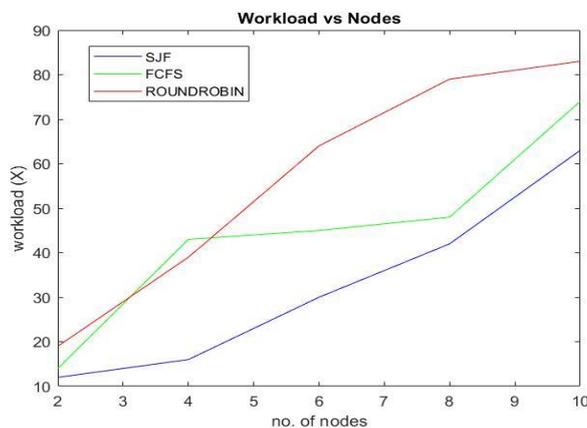

Figure 4. Simulation of workload allocation using RR scheduling algorithm

Let x axis is number of nodes and y axis is workload. When SJF algorithm is used for workload allocation then six nodes with each node having one process results in the 60 % of processor workload.

D. Comparison

Figure 5. Comparison of workload allocation using SJF, FCFS and RR algorithms

Comparison of workload obtained from implementing three different scheduling algorithms namely SJF, FCFS and RR.

5.2 Power Consumption in Fog Devices

Effective workload allocation can reduce fog device power utilization in fog subsystem. Fog device power consumption is calculated by using various workload obtained from different scheduling algorithms.

A. Shortest Job First Scheduling

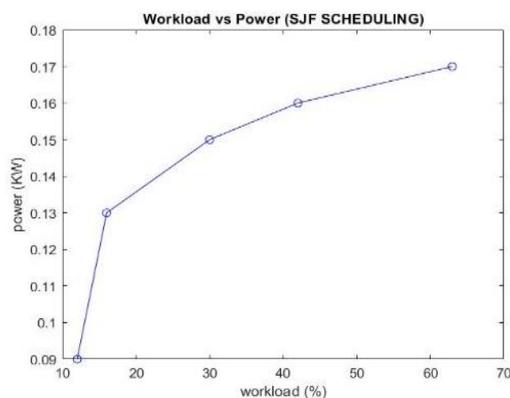Simulation of power consumption of fog device while using SJF algorithm.

Figure 6. Simulation of power consumption using SJF algorithm

Let x axis be workload in percentage (%) and y axis is power in kilowatts (KW). Usage of SJF scheduling results in 50% of workload consumes 0.16 KW.

B. First Come First Served Scheduling

Simulation of power consumption of fog device while using FCFS algorithm.
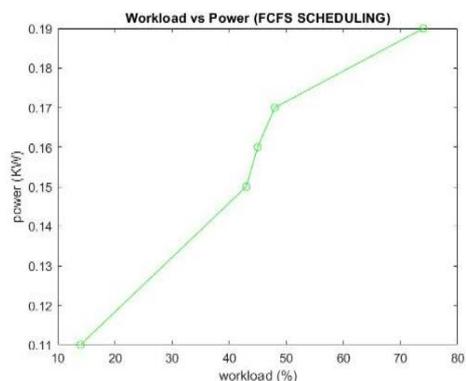
Figure 7. Simulation of power consumption using FCFS algorithm

Let x axis be the workload in percentage (%) and y axis is power in kilowatts (KW). Usage of FCFS scheduling results in 50% of workload consumes 0.17 KW.

C. Round Robin Scheduling

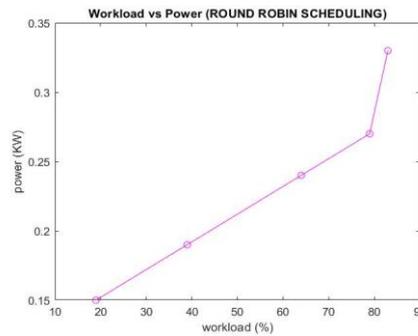Simulation of power consumption of fog device while using RR algorithm.

Figure 8. Simulation of power consumption using RR algorithm

Let x axis be the workload in percentage (%) and y axis is power in kilowatts (KW). Usage of RR scheduling results in 50% of workload consumes 0.21 KW.

D. Comparison

Power consumption of fog devices for workloads obtained from three different scheduling algorithms namely SJF, FCFS and RR were compared.
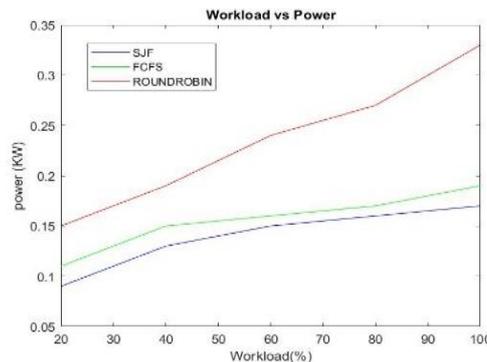
Figure 9. Comparison of power consumption using SJF, FCFS and RR algorithms

5.3 Delay in Fog Devices

Effective workload allocation can minimize the delay of fog devices in fog computing subsystem. Delay of fog device in fog computing subsystem is calculated by using various workload obtained from different scheduling algorithms.

A. Shortest Job First Scheduling

Simulation of delay of fog device against workload while using SJF algorithm.
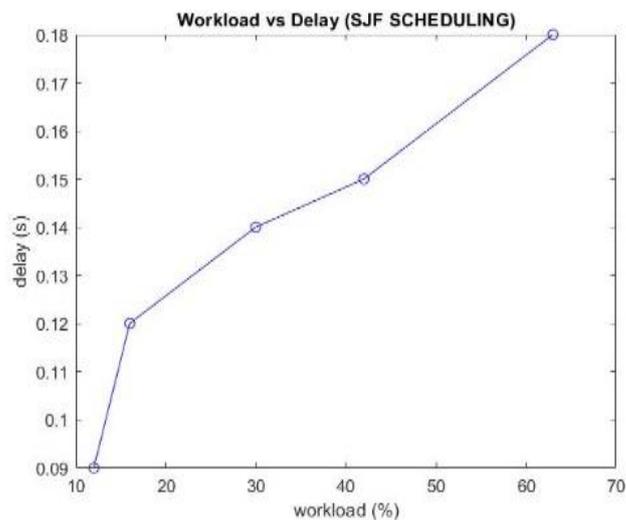

Figure 10. Simulation of delay using SJF algorithm

Let x axis be the workload in percentage (%) and y axis is seconds (s). Usage of SJF scheduling results in 0.18 s delay for 65% workload.

B. First Come First Served Scheduling

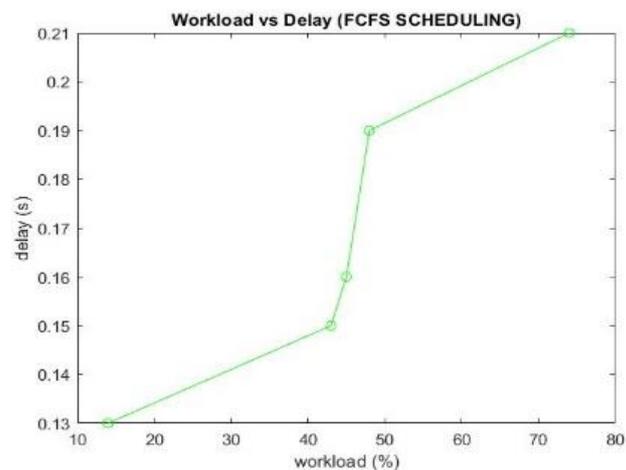Simulation of delay of fog device against workload while using FCFS algorithm.

Figure 11. Simulation of delay using FCFS algorithm

Let x axis be the workload in percentage (%) and y axis is seconds (s). Usage of SJF scheduling results in 0.20 s delay for 65% of workload.
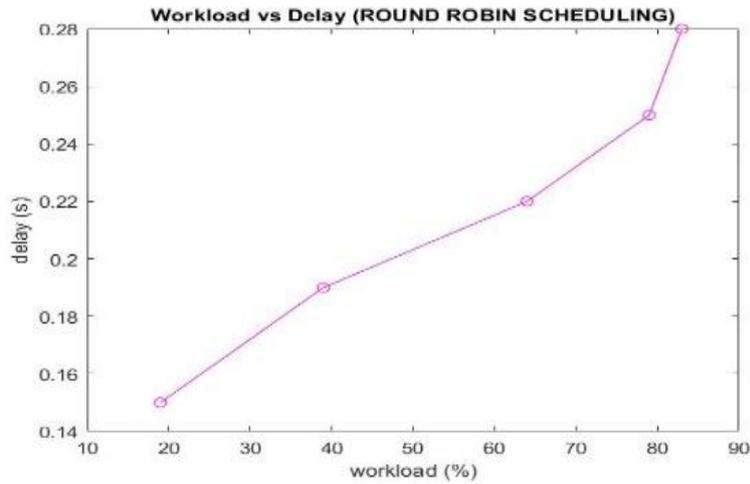
C. Round Robin Scheduling

Figure 12. Simulation of delay using RR algorithm

Simulation of delay of fog device against workload while using RR algorithm. Let x axis be the workload in percentage (%) and y axis is seconds (s). Usage of SJF scheduling results in 0.22 s delay for 65% workload.

D. Comparison

Delay of fog devices for workloads obtained from three different scheduling algorithms namely SJF, FCFS and RR were compared.
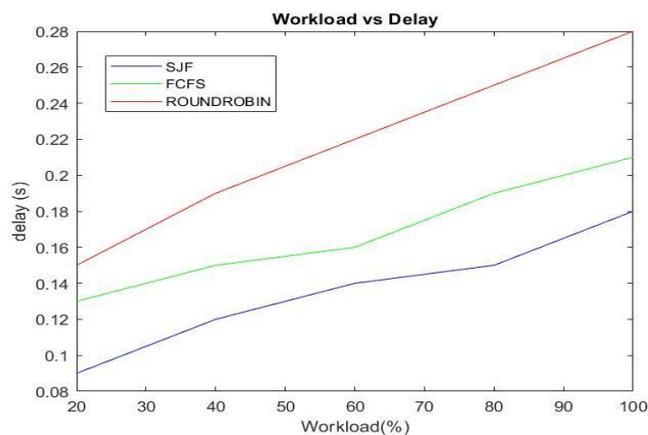

Figure 13. Comparison of delay using SJF, FCFS and RR algorithms

5.4 Power-Delay Tradeoff

Power-Delay trade of fog device for respective changes in request with considering the weighting factor while implementing three different scheduling algorithms were obtained.

A. Shortest Job First Scheduling

Simulation of power-delay tradeoff of fog device w.r.t request using SJF algorithm.
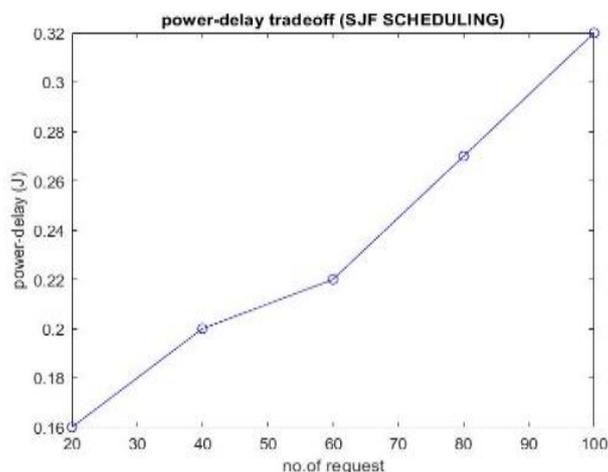

Figure 14. Simulation of power-delay tradeoff using SJF algorithm

Let x axis be number of request and y axis is power-delay (J). Usage of SJF scheduling results in 0.22 J of power-delay for 60 incoming requests.

B. First Come First Served Scheduling

Simulation of power-delay tradeoff of fog device w.r.t request using FCFS algorithm.
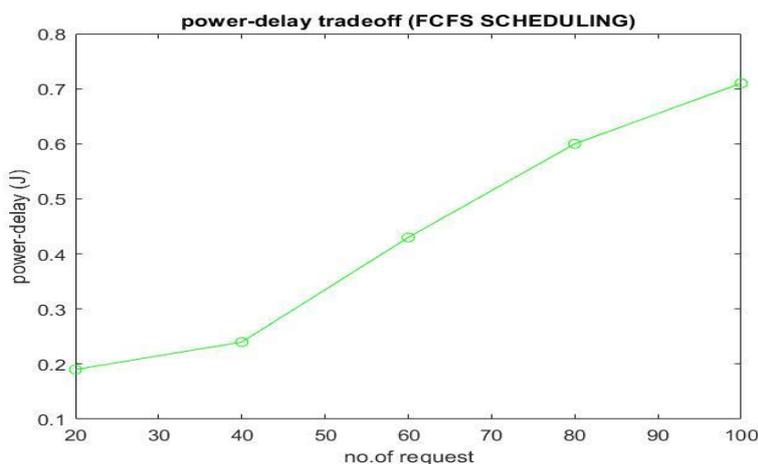

Figure 15. Simulation of power-delay tradeoff using FCFS algorithm

Let x axis be number of request and y axis is power-delay (J). Usage of SJF scheduling results in 0.39 J of power-delay for 60 incoming requests.

C. Round Robin Scheduling

Simulation of power-delay tradeoff of fog device w.r.t request using RR algorithm.
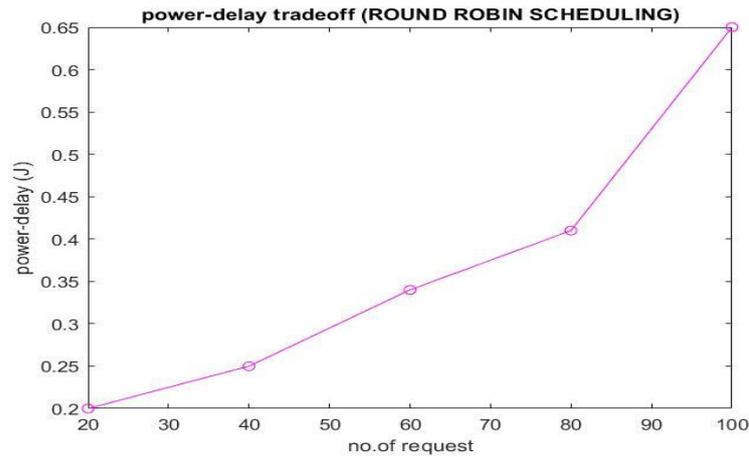
Figure 16. Simulation of power-delay tradeoff using using RR algorithm

Let x axis be number of request and y axis is power-delay (J). Usage of SJF scheduling results in 0.35 J of power-delay for 60 incoming requests.
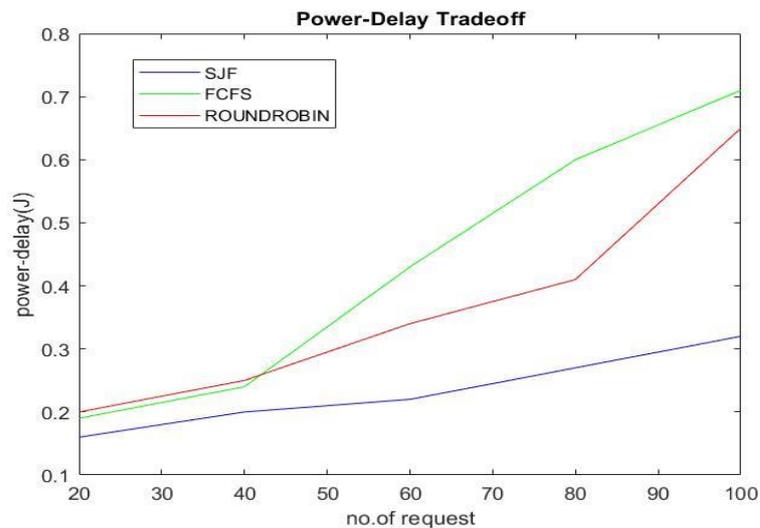
D. Comparison

Figure 17. Comparison of power-delay tradeoff using SJF, FCFS and RR algorithms

Power-Delay tradeoff of fog devices for incoming request obtained from three different scheduling algorithms namely SJF, FCFS and RR were compared.

5.5 Result

The following table summarized the obtained values of workload, power consumption and delay of fog device as well as power-delay tradeoff when using three different scheduling algorithms such as SJF, FCFS and RR while considering same number of process and requests.

Table 1. Comparison of Scheduling Algorithms

Algorithms	SJF	FCFS	RR
No. of process	5	5	5
Processing Time (s)	2.2	2.2	2.2
Elapsed Time (ms)	0.20	0.013	0.046
Workload, x (%)	23	41	45
Power (KW)	0.13	0.15	0.2
Delay (s)	0.12	0.16	0.19
No. of request	60	60	60
Power-Delay (J)	0.22	0.35	0.39

Consider five number of process and it have same processing time of 2.2 s in implementing three algorithms. For five process SJF scheduling has elapsed time of 0.20 ms with 23% workload and has power consumption and delay of 0.13 KW and 0.12 s respectively also results in power-delay of 0.22 joules for 60 requests. Whereas FCFS scheduling has elapsed time of 0.013 ms with 41% workload and has power consumption and delay of 0.15 KW and 0.16 s respectively also results in power-delay of 0.35 joules for 60 requests. While RR scheduling has power-delay of 0.39 J for same number of request and has elapsed time of 0.20 ms for five processes with 45% workload and has power consumption and delay of 0.2 KW and 0.19 s respectively.

6. Conclusion

In this paper, power consumption and delay of fog devices as well as power delay trade-off in fog computing subsystem is analysed based on the workload allocation which involves scheduling. Hence in order to find the effective workload allocation for minimizing power and delay in fog devices addition to power-delay tradeoff, three scheduling algorithms such as SJF scheduling, FCFS scheduling and RR scheduling was implemented. Also, comparison was made among the implemented algorithms in order to find effective scheduling to implement in fog computing subsystem by considering the performance metrics such as workload, power consumption, delay and power-delay trade off. Among these scheduling algorithms for same number of nodes while implementing SJF scheduling results in 18% and 23% lesser workload, 0.02 % and 0.07 % low power, 0.04 % and 0.07 % lower

delay and 0.13% and 0.17% low power-delay trade off in comparison with FCFS and RR algorithms respectively. Hence SJF provide effective workload allocation in fog device because it results in low power and delay as well as power-delay trade off.

Acknowledgement

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