# Resource Allocation using Fog-2-Cloud based Environment for Smart Buildings



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# Resource Allocation using Fog-2-Cloud based Environment for Smart Buildings

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***Abstract*—In this paper, a new orchestration of Fog-2-Cloud based framework is presented for efficiently managing the resources in the residential buildings. It is a three layered framework having: cloud layer, fog layer and consumer layer. Cloud layer is responsible for the on-demand delivery of the resources. Effective resource management is done through the fog layer because it minimizes the latency and enhances the reliability of cloud facilities. Consumer layer is based on the residential users who fulfill their daily electricity demands through fog and cloud layers. Six regions are considered in the study, where, each region has a cluster of buildings varying between 80 to 150 and each building has 80 to 100 homes. Load requests of the consumers are considered fixed during every hour in the complete day. Two control parameters are considered: clusters of buildings and load requests, whereas, three performance parameters: request per hour, response time and processing time are also included. These parameters are optimized by the round robin algorithm, equally spread current execution algorithm and our proposed algorithm shortest job first. The simulation results show that our proposed technique has outperformed the previous techniques in terms of the aforementioned parameters. Tradeoff occurs in the processing time of the algorithms as compared to response time and request per hour.**

***Index Terms*—Cloud computing, Fog, Demand requests time, Demand response time, Demand processing time, Resource allocation, Energy management, Smart grid, Microgrid**

## I. INTRODUCTION

Demand Side Management (DSM) with the integration of Information and Communication Technologies (ICTs) is a paramount trait of the Smart Grid (SG). Lot of electric gadgets and control services are designed and integrated with DSM: charging and discharging of the Electric Vehicles (EVs), smart devices (i.e., Smart Meters (SMs), Distributed Generators (DGs)), shiftable loads and etc. With the development of massive electricity market, multiple entities are involved in the DSM side: NASDAQ trading organizations of OPower, $C_3$Energy and etc. [1]-[3]. For optimizing the energy management on demand side, these organizations employ existing techniques for the bidirectional interactions and online processing facilities. Many small businesses and standalone buildings or homes are also participating in electricity market on DSM in order to engage themselves in development of the SG applications [4].

Two major aspects are required to be considered in future DSM based on the above scenarios. One is technical aspect and the other is economical aspect. Technical aspect considers the large size data of the appliances which needs to be processed within the specific time constraints and by maintaining its computational complexity. Whereas, economical aspect includes that most of the newly developed businesses and buildings are not participating in ICT framework in early stages and it becomes difficult to maintain its reliability without their participation. Especially, computational needs suffers from the fluctuations due to consumers demands for DSM services. Hence, allocating the ICT services: processing power, storage capacity and resource availability are the critical problems [5], [6]. Fog computing is the specialized model of the cloud computing which deals with the resource management on the edge for efficient management of the consumers' resources. It improves the locality, reliability, security and latency of the consumers' demands [7]-[9].

### A. *Motivation and Contributions*

Previous studies ([10]-[12]) have incorporated the cloud services in SG environment. Authors have considered the charging and discharging schedules of the EVs in decentralized manner to procure the load shuffling facility [10], [11] and the scheduling problem is formulated with the help of mixed discrete programming technique. Another decentralized algorithm for optimally scheduling the EV charging has been presented by Gan *et al.* [12] and this algorithm has led to the exploitations in terms of EV loads for filling the valleys in their load profiles. Fog computing [13] is incorporated as the middle layer between the consumers and cloud environment. All of aforementioned studies are either based on the cloud or fog based environment, no one considers the fog and cloud environment together for resource optimization. Although, cloud provides the on-demand availability of the resources, however, it increases the latency and violates the efficient response time for the consumers which creates frustrations. In this work, we have proposed and implemented the Fog-2-Cloud framework for the efficient management of the consumers' demands using the six fogs and twelve Microgrids (MGs) in the residential buildings. Fog servers helps in storage of the consumers' private data (SM information) and MGs usage facilitates in cost minimization. Response time, requests per hour and processing time are optimized using the Shortest Job First (SJF) algorithm. It is compared with the previous two algorithms: Round Robin

(RR) and Equally Spread Current Execution (ESCE) and it has outperformed the previous two algorithms.

The rest of the paper is organized as follows. In Section II, the literature review is discussed along with the existing limitations. Section III describes the proposed system model and simulation results are discussed in Section VI. Finally, the conclusion and future work is described in Section V.

## II. Literature Review

Multiple methodologies have been proposed in the literature which are categorized according to their architectures: 1) methodologies for cloud based architecture and 2) methodologies for fog based architecture.

### A. Methodologies Regarding Cloud based Architecture

A novel architecture for EVs charging and discharging is presented using public supply stations [14]. In order to schedule the EV charging and discharging, two priority assignment algorithms: random priority attribution and calender priority attribution are designed and implemented in the cloud computing environment. Waiting time of EVs is monitored by considering these algorithms even maintaining grid stability during the high demand hours using the demand supply graph as a constraint. The presented study is based on the public supply stations instead of the home supply stations and study supply stations. Smart phone has been considered as a part of the cyberphysical system for dynamic voltage scaling by reducing the frequency of smart phone which led to energy minimization [15]. Authors also develop energy aware dynamic task scheduling algorithm in order to reduce the aggregated energy consumption of the running applications by considering the time and probability constraints. This study has been restricted to the energy minimization in smart phone system. It also lacks its applicability in smart grid energy management domain.

The concept of nanogrids is added in sustainable smart buildings for multi-tenant cloud environment in [16]. In addition, a game theory technique using the coalition for energy management in SG cyberphysical system is discussed in [17]. A payoff function is formulated by examining every player's data (i.e., transmission and service delay data) using conditional entropy.Furthermore, a dynamic workflow management is developed to run the jobs in virtual cloud environment. In this case, multiple VMs are used in a coalition to execute the tasks in an efficient manner. In [18], the energy hubs are manoeuvre for storage of the consumers' data in the cloud computing environment for effective DSM. Stochastic dynamic programming is also applied to organize the DSM in real time environment for minimizing the cost by integrating the DR.

### B. Methodologies Regarding Fog based Architecture

In [19], authors propose a cloud based demand side management system which manages energy for the consumers in multiple regions and micro-grids in order to minimize the utility and consumers' cost. It also reduces the time and efforts by incorporating the modularity feature in developing smart cities. They develop and apply bi-level optimization algorithm using linear cost function. Authors in [20], proposed energy management technique for electricity and natural gas network using integrated demand side management. This scheme differentiates the electricity consumption mechanisms because they consider the consumption regarding each user and this scheme considers multiple user interactions. Nash Equilibrium (NE) is used in this scheme for measuring the interactions of the players. Electricity cost, peak load demand and energy demand is reduced using NE.

Afterwards, a new approach regarding electricity cost reduction problem presents the internet payload requests and SG dynamic electricity pricing mechanism [21]. They also discuss predictive cost control for the smart charging on both sides: 1) electricity from the power grid and 2) battery energy for the servers. Batteries are charged during the low price rate hours and they are discharged during the high price rate hours in order to mitigate the overall cost of the system.

The aforementioned techniques are discussed for the energy management of the specific set of buildings or appliances. None of these techniques can tackle the energy management using optimized resource allocation in the specific region of world. This paper presents the energy management in the residential buildings around the world using fog and cloud environment.

## III. Proposed System

In the proposed system, resource allocation using the Fog-2-Cloud framework is discussed. The system is comprised of six fogs within the regions and set of buildings and their load requests. There are six regions considered for the residential energy consumption and its management. When clusters of the buildings send requests to the fog for the load demands, this framework uses MGs on first priority to fulfill the demands of the consumers, otherwise, it will communicate to the cloud for communicating to the utilities. Two MGs are deployed in each region as shown in the Figure 1. MGs include distributed generation, loads and storage devices etc..

There are three layers in the proposed system: cloud layer, fog layer and the consumers' layer. Cloud and fog layers are used for orchestrating and monitoring the cloud's resources and consumers' requests. Consumers utilize cloud and fog services for fulfilling their daily load requirements. When any home in the buildings makes the requests, it is first recorded at the fog server, then the availability of resource is checked and it is processed (allocated to a resource). Each fog is responsible for its own region's services. Region can be any continent which is in the communication range of that fog. The communication medium is used as the wi-fi for communicating to the system's components.

There are three types of the consumers: traditional consumers, consumers with the Home Energy Management System (HEMS) and consumers with the local generation and HEMS. We have included a scenario with the 50 VMs and two DCs for the optimization of the resources in the residential buildings which is validated through the simulations.

### A. Scenario Description: Fifty VMs with Two DCs

In this scenario, fifty VMs are considered with two DCs in order to fulfill the demands of the consumers from each region of the world. Load demands are assigned to the VMs

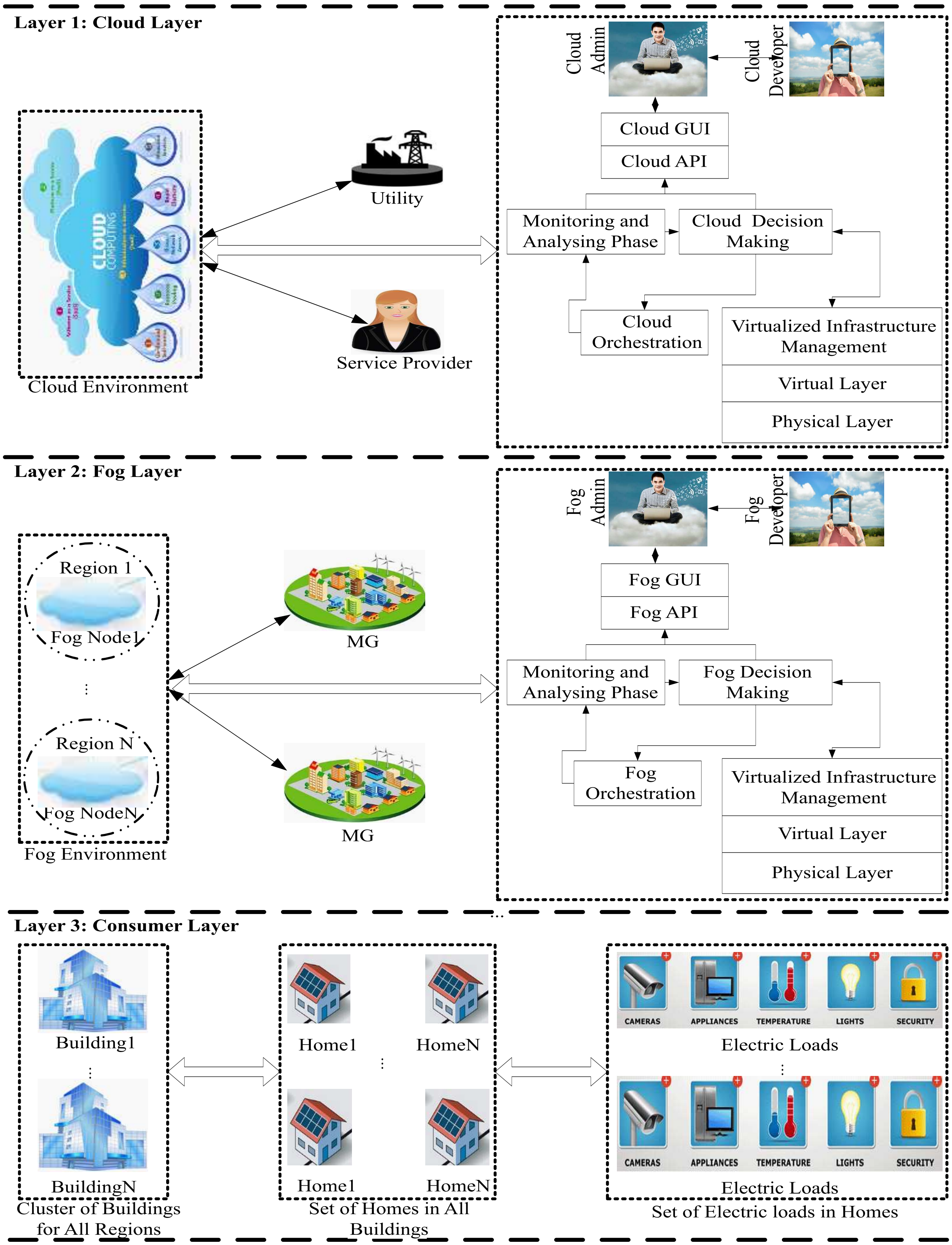


Fig. 1: Fog-2-Cloud based framework, Components and their Communication and Resource Allocation

using the DCs which is responsible for the management of the requests and services. Each VM is further monitored by the hypervisor which decides either it has finished its task or it is in idle state. Each region's load demands are evaluated using this scenario. Three types of the communications are used in this scenario, consumer to fog, fog to cloud and appliances to appliances. Cloud and fog interact with each other in order to manage the resources of consumers. Consumers sends requests to each fog in their region from the buildings. Buildings in each cluster vary between 80 to 150. The input parameters and their values for this scenario are taken from [22]. We have used three algorithms for resource allocation in the Fog-2-Cloud environment. In this paper, ESCE, RR and SJF algorithms are applied in order to schedule the resources in the fog and cloud environment.

### *B. The RR Algorithm*

RR is used as load balancing algorithm in cloud computing. It has been adapted on the basis of defining the time schedules [22]. Scheduler develops the details of the VMs in assignment table. In addition, it allocates the jobs which are received for the DCs to a set of the VMs. First, VM is initialized with the ID of the current VM variable and requested job is mapped with the current VM variable. In some cases, if the ID of the last VM is similar to ID of the first VM then it redefines the current VM ID.

### *C. The ESCE Algorithm*

ESCE algorithm applies spread spectrum approach and works with the large number of active tasks on the VMs at any time interval [22]. Using this algorithm, scheduler records the VMs' assignment table and maintains lists of VM IDs and active jobs on any VM. At every time interval, when the jobs are executed, VM table is modified. At start, active job count is zero, however, on the occurrence of every job, scheduler determines the VM having the minimum job count. If jobs are allocated to the multiple VMs with the minimum job count then first one will be selected. Multiple job queues are orchestrated according to the VMs.

### *D. The SJF Algorithm*

It executes the jobs by considering the short size task as the priority and that priority is controlled by determining consumers' requests' sizes [23]. It assigns the tasks to the VMs based on their distance and size priorities. The processes having the minimum lengths or sizes are served first and VMs are allocated to them respectively because it takes minimum time. Scheduler distributes the jobs on various VMs using the same spread spectrum approach as followed in the ESCE algorithm. SJF schedules the jobs by providing the minimum completion time, provides the higher efficiency and minimum turnaround time. In this way, it improves the system's functionality.

## IV. Simulation Results

In order to conduct the simulations of the proposed system, six regions are considered for the simulation purposes. Each region comprises of cluster of the buildings varying between 50 to 150 and every building have 80 to 100 homes in it. Simulations are performed for the 24 hours in a complete day by considering the performance parameters: demands request time, demands processing time and request per hour. The information about regions is taken from [22].

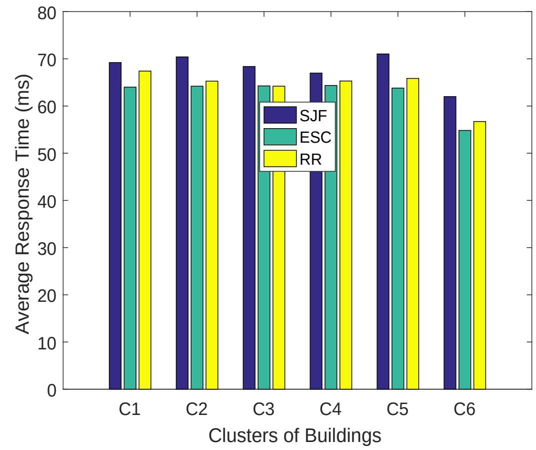


Fig. 2: Response Time of All the Fogs

For performing the simulations, resource allocation policy is used as the optimized response time, whereas, the load balancing algorithms are used as RR, ESCE and the SJF algorithm. As, there exists randomness in taking each iteration of these algorithms, so, we have taken the average of ten times during the results computation process. We have considered one scenario for the simulations: Fifty VMS with two DCs.

### *A. Fifty VMs with Two DCs*

Using the fifty VMs and two DCs, the response time of all fogs deployed throughout the regions is more efficient to the previous schemes, especially during the peak hours. Because, during these hours, consumers requests are more as compared to off-peak hours as shown in the Fig. 7. Overall response time of the SJF in this scenario is higher than the RR and ESCE because SJF facilitates the more requests with the minimum jobs time first and then entertains the other requests. It puts all the requests with the largest job sizes in the queue and entertains them on the their turn. Fig. 9 displays the number of requests received from the buildings in each region. After the requests' receiving is done, fog loading phase is initiated, computation of the tasks is started and requirements of each building's requests are fulfilled. For fulfilling the requests, number of VMs, MGs and other relevant services are available on the cloud. SJF's fog loading time is optimized because it efficiently receives the requests from cloudlets and schedules them efficiently. The processing time of each fog is displayed in Fig. 8 for the whole day, however, there is a tradeoff in the processing time to the other parameters: request per hour and response time. SJF processing time is large as compared to the other two algorithms because it takes large number of requests which ultimately compromises the time.

## V. Conclusion and Future Work

In this paper, an orchestration of the Fog-2-Cloud based framework has been presented for intelligently managing

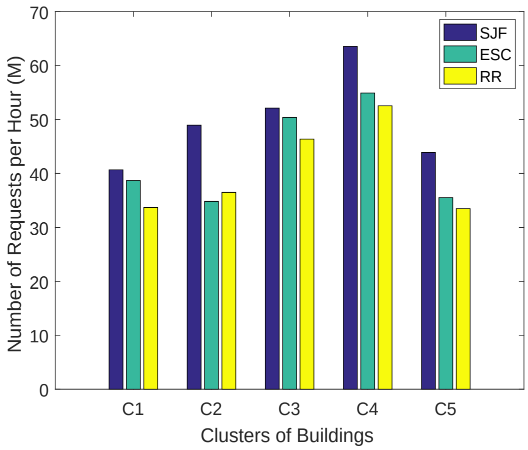


Fig. 3: Request per Hour of All the Consumers

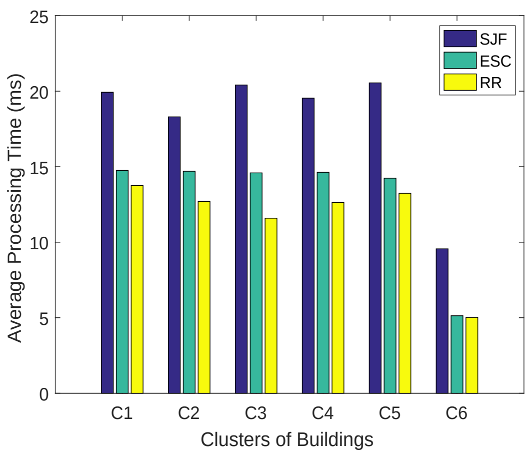


Fig. 4: Processing Time of All the Fogs

the resources in the residential buildings. Assignment of the resources has been done through the fog layer. The fog layer has reduced the latency and enhanced the reliability of the cloud computing services. Six regions have been considered in the proposed work, where each region has cluster of buildings varying between 80 to 150 and each building comprises of 80 to 100 homes. Consumers' requests have been considered fixed during every hour in a day. The control parameters are clusters of buildings and load requests in the residential buildings and the performance parameters are request per hour, response time and processing time. These parameters have been optimized by the SJF, ESCE and RR algorithms using one scenario which is considered for simulations: two DCs with 50 VMs. Simulation results showed that our technique has outperformed the previous techniques in terms of the aforementioned parameters.Tradeoff occurs in the processing time as our system receives more requests and it takes maximum time to process the consumers' demands. For substantiating the implications of this study, it will be extended for enhancing the smartness in the individual residential appliances.

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