A max-max parametric demand response scheduling algorithm for optimizing smart home environment

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ABSTRACT

The majority of the power distribution problems are addressed in this study by outlining a scheduling and allocation system that is based on rules. The smart home environment incorporates the suggested model as the intermediate layer. In a smart home, managing overload and power failure is the primary goal of the suggested max-max-based demand response scheduling method. The proposed model is an extension of the demand response measure while considering the load and failure rate analysis. This model is applied in a real-time environment that processes the historical information of power usage in the environment. This model captures the information available by the resources, centralized database information, and the current request parameters. The control and configuration unit are defined to process the load, history, and demand of the users. In this model, effective resource allocation and scheduling are provided. The proposed model is compared against conventional first come-first serve (FCFS), shortest job first (SJF), longest job first (LJF), demand response, and fuzzy-based demand response methods. The comparative evaluation is done on average delay, failure rate, and task-switching parameters. The analysis results obtained against these parameters confirm that the presented max-max-based parametric demand response scheduling and resource allocation method enhanced the reliability and effectiveness of the smart home environment.

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1. INTRODUCTION

A smart house [1], [2] is a modern, high-tech dwelling that makes use of interconnected electronic systems, including appliances, sensors, actuators, and gadgets. Minimizing power consumption and costs is the primary goal of this smart home design. One of the primary goals of this network is to minimize the cost of power interruptions. The smart home area's energy use is monitored by employing energy-efficient equipment and smart meters. In order to track energy use and anticipate a customer's power needs, the network incorporates a number of sensor devices. Based on several criteria and characteristics, smart home systems imply a variety of smart house designs and models. Demand side management (DSM) [3], [4] and energy management systems (EMS) [5] are two examples of popular models. To keep an eye on how much power is being used, a predictive measure is applied to individual appliances or the whole house. By installing the various gadgets, one can keep tabs on how much electricity certain appliances, devices, and rooms in the house use.

Researchers are primarily focused on improving the capacity of next-generation smart grids to fulfill both environmental criteria and consumption demand. These state-of-the-art smart grids need to deal with several demand-side issues. By reducing energy usage and matching it with the available power source, these systems will work. Power usage at the client end is monitored via the capacity-driven setup and integration of smart meters. Whether the producer is in charge of energy transmission, consumption, or purchase, this is a conversation that goes both ways. Usage and energy cost are of utmost importance to the client. The manufacturer additionally takes advantage of the smart pricing mechanism to maintain a balance between consumption and load. This suggests that peak hours are when energy costs are highest [6], [7]. Figure 1 shows a power service provider and a billing and pricing model for a smart grid setting. This pricing model depends on energy load, use, and pricing for the consumers. These consumers can be from industry or home users. To keep costs down and energy use under control, you need a system that maps out all of your expenses and information consumption in real-time. Also influencing costs in a smart grid setting are power availability, peak hours, and customer power use. Consumers can reduce the cost of power use by setting an efficient usage schedule during off-peak hours. In real-world scenarios, electricity load may be reduced by a cooperative mapping of consumption and pricing schemes [8]. A person's power bill will go down as a result of the lower load. If there are a number of power providers to choose from, we may compare their rates, peak-hour loads, and frequency of power outages. All of these factors may be considered together to make a smart choice that will provide a reliable power supply at a lower price. One option is to choose a service provider that offers cheaper rates during peak hours or when the average load is lower. Depending on the needs of the buyer and the resources of the seller, there may be more than one deciding factor [1], [9].

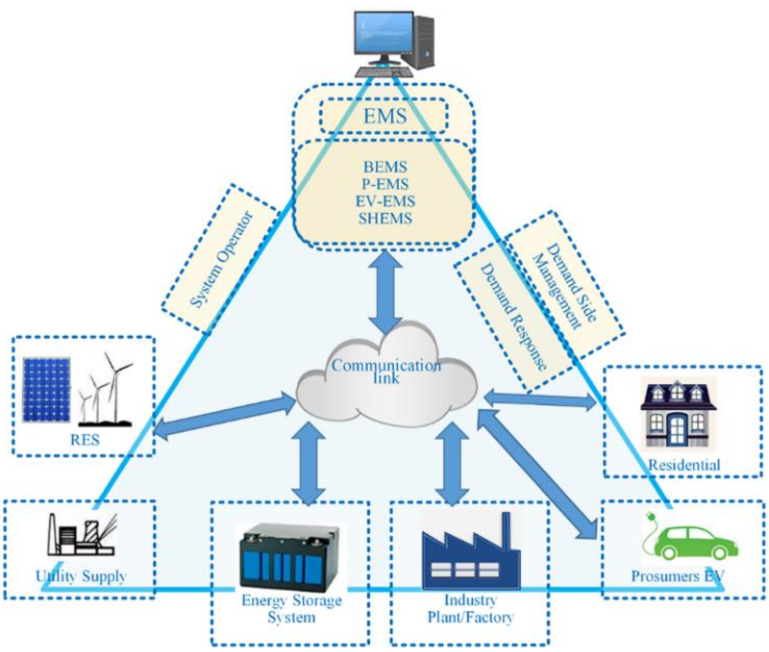

Figure 1. A standard power usage and distribution architecture

In this paper, an optimized model for smart home architecture is presented for effective resource allocation and scheduling. The proposed max-max model is the parametric mapping over the demand-response algorithm to optimize its behavior to improve user comfort and reduce the failure rate. In this section, the characteristics, behavior, and adaptations of smart homes and smart grids are defined. The requirement of power management in such a busy network with power utilization is explored using demand-response-based methods. The scheduling behavior and criticality of the power distribution environment are discussed in this section. In section 2, various scheduling and demand-side management-based methods investigated by earlier researchers are provided. The contribution and issues identified in the earlier research are discussed in this section. In section 3, the proposed algorithm is defined and provided. The characteristics and behavior of the proposed model with included work stages is defined. In section 4, the simulation and comparative results generated to validate the performance of the proposed model are provided. The conclusion and future scope of this work are provided in section 5.

2. RELATED WORK

Power usage optimization and management is a critical challenge in smart grid and smart home environments. Various resource allocation and scheduling methods were proposed and improved to obtain gain in the reliability and effectiveness of smart homes. In this section, the work provided by the earlier researchers is provided and discussed. The challenges and contributions of the work is discussed in this section. An internet of things (IoT) based power monitoring approach to smart grid optimization was suggested by Khan *et al.* [10]. The environment's power needs and load status were determined using this monitoring approach. In order to determine the load and peak load scenarios, the real-time limitations were set. Reducing power dues and energy usage is as easy as applying the decision-driven procedure when the parameters are set up. By combining cloud and fog computing, Rahman *et al.* [11] were able to design and set up a microgrid. The components were intended to be connected effectively with minimum energy consumption by the framework. In addition to ensuring connectivity through numerous sources, the developed framework can reduce energy consumption. The goal of defining the clustering-based strategy was to increase power utilization by classifying customers. In order to track energy use and determine individual users' power needs, a smart meter was installed in the surrounding area. For efficient distribution of resources, the optimized bubble sort was employed. Time to allocate resources, time to respond, and energy use were all cut down by the suggested technique. In their definition of fog computing-based smart grid architecture, Mehmood *et al.* [12] aimed to address real-world overload scenarios. They handled uneven load conditions by implementing the Odds, Throttled, and round-robin algorithms. The work's stated scheduling strategies enhanced resource utilization. The results of the investigation demonstrate that the suggested framework successfully decreased processing and response time. Even when faced with a heavy workload, the suggested solution managed to achieve effective response and processing times.

To address the issue of uneven load in a smart grid setting, Zafar *et al.* [13] employed a bat algorithm. With the goal of efficient resource allocation in mind, a policy for service brokers was formulated. An algorithm that has been suggested enhanced smart grid resource scheduling and allocation through the use of active virtual machine load balancing. By integrating with existing load-balancing algorithms, the suggested method produced the desired result. Ismail *et al.* [14] improve smart grid efficiency under extreme load conditions by including a bee colony optimization method in a load balancing system. Fog resource optimization was the goal of the method's definition. Particle swarm optimization throttled, and round-robin were the algorithms that the model was tested against. In comparison to prior techniques, the processing and reaction times for job execution were enhanced. A priority-driven approach to tracking and managing energy use in smart grid settings was introduced by Barman *et al.* [15]. It was the environment's smart meters that collected the data. In a heavy load scenario, the suggested solution enhanced performance while reducing energy usage.

A monitoring and controlling system was suggested by Priyadharshini *et al.* [16] to address the issue of excessive energy usage in the smart grid. In order to manage energy consumption, the framework was built for designing IoT-based environments. This research defined appliance-based load monitoring and tracking. Overload problems were effectively handled by the proposed strategy. To predict and forecast loads, Raju and Laxmi [17] developed a method that relies on machine learning. In this setting, the author used a number of machine-learning methods. Among these methods are the following: ensemble boosted regression, fine tree regression, gaussian process regression, support vector machine, and ensemble bagged regression. The results of the investigation showed that the proposed method improved prediction accuracy while decreasing the error rate. The three-tier design was enhanced by Rabie *et al.* [18] by the incorporation of a load forecasting approach into the environment. During the pre-processing step, the approach was used to detect the load condition early on. After the load had been detected, preventative measures were taken to modify the load condition and enhance the smart grid network's performance. Large amounts of data are present in the system, and the model was created on top of a fog architecture. The cloud data center was the source of the data collection. This model used the filtration approach in the pre-processing stage to prevent outliers. Afterward, the load condition was determined by applying a prediction algorithm to the identified effective data processing characteristics. To determine which features were most important, we used a feature selection and ranking algorithm. As a last step, we used the optimization technique to make the system more reliable and efficient. The suggested model increased the prediction rate and enhanced the accuracy of load prediction, according to the comparison study.

An additional adaptive approach to enhancing smart grid infrastructure service was put out by Yu *et al.* [19]. Functional behavior, device consumption, and object utilization in the environment may all be managed with the technique that was developed. This work successfully utilized resources. In those efforts, the management layer was implemented to study the actions of various devices and resources. Modifying the grid's power distribution required the inclusion of session-specific analysis. During busy times, the suggested approach produced the desired outcomes. The author failed to specify the previous load condition. As an alternative, the environment's service allocation and processing were optimized through the use of demand-driven mapping. To automate functional control in a smart grid setting, Parashar and Parashar [20] offered an artificial intelligent (AI) based approach. Through the usage of smart meters, the user's activity might be monitored and recorded in the IoT system. Over several time intervals, we were able to determine whether the electricity use was reasonable. Environmental accountability and dependability were both enhanced by the strategy. In order to improve energy management and source appropriation, Pawar and Vittal [21] introduced an improved IoT based architecture for smart grid environments. Finding the customer's preferred method of dealing with the load issue led to the definition of the effective controller. In order to improve energy management, the environment specified the constraint particular limit. Improving the structure's authenticity and performance was the goal of the cost optimization strategy.

Banat and Al-Qudah [22] proposed an edge-enabled smart city architecture to support the transportation and healthcare domains. A priority adaptive scheduling algorithm was used to optimize the maximum and mean waiting time. Premalatha and Prakasam [23] presented an optimal energy-efficient resource allocation model to identify the fault and to perform minimum cost resource allocation in IoT-Fog computing networks. This model improved the response time with a high fault detection rate. Sharif *et al.* [24] proposed a resource requirement-based priority adaptive model for optimizing resource utilization in mobile edge computing. The priority-based resource allocation method improved the effectiveness under latency, resource usage, energy consumption, and response time parameters.

3. RESEARCH METHOD

The smart home adaptation is about to optimize power usage and consumption in residential scenarios. The smart grid is responsible for fulfilling the power demands and its distribution over society. The smart home is the consumer end that generates the power requests respective to all its appliances. The pricing scheme for power usage in smart homes is flexible and dynamic. It means in the peak time; the cost can be higher. Because of this, the smart usage of power is required to reduce the electricity bill and to avoid power failures. The suggested algorithm's goal is to optimize power consumption while also reducing power outages. The goal of the work is to improve the user experience and finish user requests on time.

The functional contribution of this work is divided into two main stages called resource allocation and request scheduling. In the first stage, the resource allocation is done based on pricing, criticality, and demand-driven considerations. This approach determines the user's present power consumption in relation to the available resources. The allotment of resources is decided upon based on that. The load is another issue that has been found in this work with regard to the power allocation and demand-based system. A time slot's load is its greatest demand for power. In a high-load situation, demand is more than expected demand. To manage situations with severe loads and prevent resource allocation failures, this study defines a load-adaptable technique. This research defines a larger model, as seen in Figure 2. In order to optimize scheduling and resource allocation, the model specifies the model's functional phases.

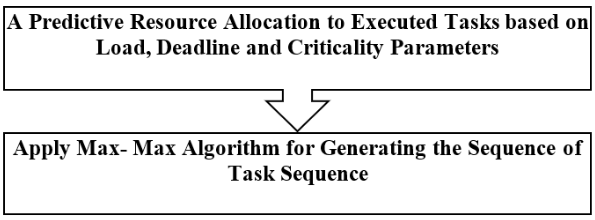

Figure 2. Proposed max-max algorithm for deadline and criticality optimized demand response scheduling

The two primary steps of this rule-based approach are the allocation of resources and the prediction of demand. A data analysis approach developed under certain criteria and parameters is load prediction. In a smart grid setting, predicting the load is the goal of this phase. In this step of parameter-driven analysis, the three primary parameters are taken into account in order to forecast the load. These factors include the customer's power consumption pattern, the present demand for electricity, and the peak hours of use. Using these criteria, you may pinpoint when things are about to break down. The mapping is executed using the characteristics provided by the provider once the power need has been anticipated. During off-peak and peak hours, these characteristics determine the cost and availability of power. In order to detect a peak load condition, the smart meter keeps track of all of these analytical parameters and uses controller-based processing. This approach detects the load status and avoids power faults and delays by performing a rule-based mapping. In the event of a grid failure, the anticipated load-based load shift is executed. In a smart grid setting, the regulations are sufficient to optimize power consumption and distribution. Efficient resource allocation in a smart grid setting is now possible because of the new system's ability to detect network failures and excessive loads. When deciding whether or not to transfer loads, delay and other relevant circumstances are taken into account. Algorithm 1 shows the process of resource allocation and job scheduling in the smart home environment.

Algorithm 1. A max-max based demand response optimized task scheduling

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1. Initialize the Internal and external Resources to perform Power management and
   distribution
2. Capture the available power, power rate and the actual demand of power
3. Initialize the Datacenter with smart home adaptation to the device-specific power
   requirement and power usage history of an individual
3. Define the number of requests generated by the user and number of available power
   sources.
4. ForEach request in N_Requests
   Begin
5. Capture request parameters request.getTimeStamp(), request.Criticality(), request.Usage
6. ForEach resource in M_Resources
   Begin
7. Capture power resource constraints resource.Load(), resource.Price(),
   resource.Availability()
8. Map the generated requests over the available resources under Max-Max Rule
9. According to this, Allocate the highly critical request with minimum load resources and
   MAX available resources to ensure a low failure rate
10. Allocate the less critical and high usage tasks to Medium Load and average price
    resources
11. Keep the task in a queue with least criticality and lesser usage and wait for the time
    with lesser power cost for allocation
12. If wait_time>threshold
    Allocate the process to the resource with the least cost
    End If
    End
```

Algorithm 1 provides the detailed process of max-max algorithm to perform effective resource allocation and scheduling to optimize the demand response scheduling. This algorithm is parametric and requires the analysis of resource constraints and parameters. All the internal and external resources that are involved in the power distribution and scheduling are analyzed and initialized in this work. The power availability details are collected in terms of available power, power rate, peak load, and peak load rate parameters. The actual power demand for a particular instance is also computed. All these details are also processed under the data center present in the smart home environment. This data center contains the usage history of equipment and power. The power requirement for specific appliances is also available in this data center. After collecting the details of power usage behavior, power requirement, and resource capabilities, the proposed algorithm is performed over it. This algorithm processed each of the requests under the max-max approach. It captures the request constraints including the type of request, power requirement, and power usage. It also acquires the resource features including price, load, and availability. A max-max mapping is applied for allocating the requests to different resources. A highly critical request is allocated to a resource with minimum load and maximum availability. This max-max mapping reduced the failure rate for critical requests.

4. RESULTS AND DISCUSSION

In this section, a comparative analysis of the work is provided against some conventional scheduling and resource allocation methods. These methods include shortest job first, first come first serve [25], longest job first, demand response model and fuzzy based demand response model. The proposed and the conventional models are simulated in a real-time grid environment with a specification of the number of users. The number of resources is fixed over the smart home and smart grid environment. The proposed algorithm is implemented in the smart home environment as an intermediate layer. The centralized database, and smart meter data are available to it to make decisions about effective resource allocation and scheduling in the environment. The evaluation of the performance of the algorithms is done under user comfort, power failure count, and average task switch count parameters. The first parameter considered for evaluating the effectiveness of max-max based demand scheduling and resource allocation algorithm. Average delay is also defined as user comfort. If the user request gets an instant response, then it is considered with higher user comfort. If the response is delayed, it shows that the average delay is increasing. Figure 3 provides the average delay-based comparative evaluation. In this figure, the number of user requests is provided as the x-axis and the y-axis represents the average delay. The figure shows that the average delay obtained for 10 users is 0.543 sec for functional status scale (FSS), 0.539 for shortest job first (SJF), 0.558 for longest job first (LJF), 0.503 for Demand Response Method, and 0.489 sec for fuzzy-based demand response method. The results show that this approach achieved an effective request processing with 0.1135 sec average delay. For an experiment with 50 requests, the average wait-time obtained is 1.18 sec for first come-first serve (FCFS), 0.84 sec for SJF, 1.14 sec for LJF, .826 sec for demand response method, and 0.716 sec for fuzzy based demand response method. The proposed max-max based demand response analysis method reduced the average delay and claimed 0.467 sec.

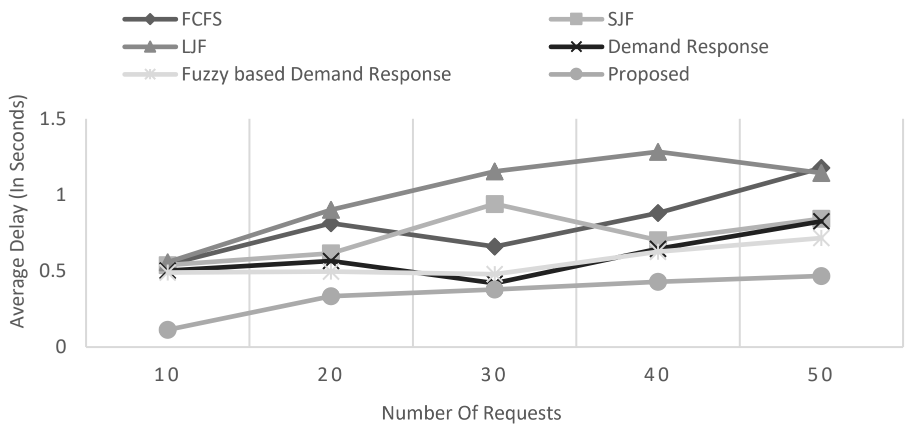

Figure 3. Average delay analysis

Another parameter considered in this work is the average task switch parameter. Task switching is performed between resources if a new resource with lesser cost or with higher performance is available. The task switching affects the reliability of the work. Figure 4 shows the average task switching-based comparative evaluation. The x-axis in this chart depicts the number of user requests, while the y-axis reflects the average task switching. The figure reveals that the average task switching achieved for ten users is 2.46% for FCFS, 1.96% for SJF, 2.2% for LJF, 1.9% for demand response method, and 1.12% for fuzzy-based demand response method. The findings reveal that the suggested model lowered the average switching and claimed to process requests with an average switching of 1.12%. For 50 requests, the result achieved is 11.2% for FCFS, 9.8% for SJF, 11.46% for LJF, 9.0% for the demand response technique, and 7.8% for the fuzzy-based demand response method. The suggested max-max based demand response analysis approach decreased the average switching to 6%.

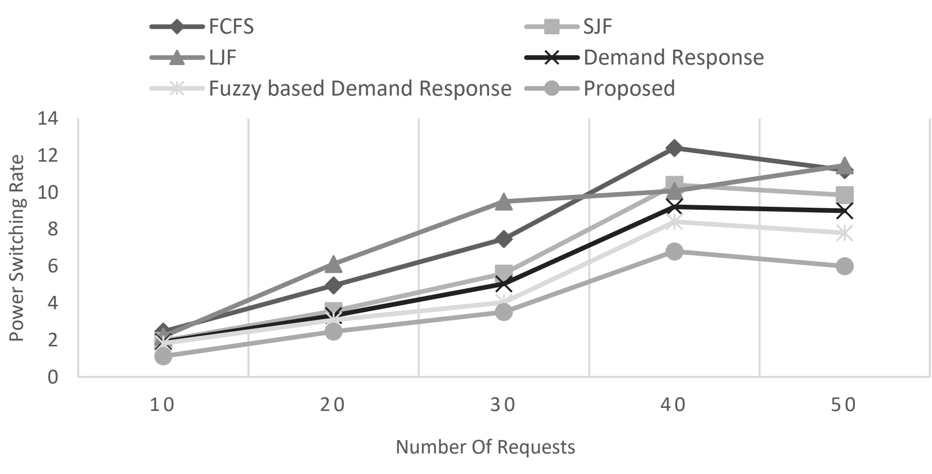

Figure 4. Average task switch analysis

Another metric studied in this study is the average failure parameter. Task failure occurs if the task is not handled by the resource within the threshold period. Task failure has an impact on job dependability. Figure 5 depicts the average task failure-based comparative evaluation. The y-axis represents the average task failures. The figure shows that for ten users, the average task failure rate is 1.23% for FCFS, 0.98% for SJF, 1.1% for LJF, 0.95% for demand response method, and 0.91% for fuzzy-based demand response method. The results show that the recommended approach reduced the average failure rate and claimed to handle requests with an average failure rate of 0.56%. For 50 requests, the failure rate obtained is 9.11% for FCFS, 8.01% for SJF, 9.32% for LJF, 7.32% for demand response methodology, and 6.34% for fuzzy-based demand response method. The proposed max-max-based demand response analysis technique reduced average switching to 4.88%.

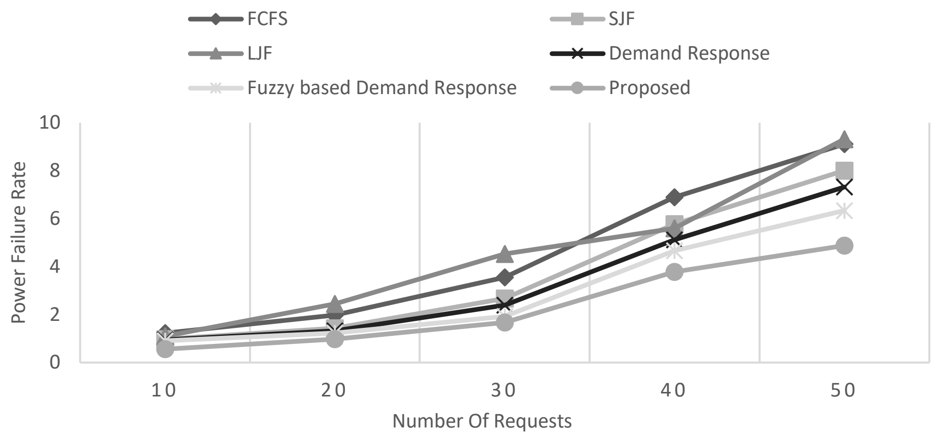

Figure 5. Average power failure analysis

5. CONCLUSION

This paper addresses the bulk of power distribution difficulties by proposing a rule-based scheduling and allocation system. The recommended model serves as an intermediary layer in the smart home environment. The recommended max-max-based demand response scheduling strategy is primarily intended to manage overload and power failure in a smart home. The suggested model extends the demand response measure to include load and failure rate analysis. This model is used in a real-time context to process historical information about power use in the environment. This model captures the information accessible from the resources, centralized database information, and current request parameters. The control and configuration unit are defined to process the users' load, history, and demand. This model demonstrates good resource allocation and scheduling. The suggested model is compared to traditional FCFS, SJF, LJF, demand response, and fuzzy-based demand response approaches. The average latency, failure rate, and task-switching factors are all evaluated in comparison. The study findings obtained against these parameters demonstrate that the suggested model lowered the average delay while improving performance in a smart home context.

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