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Towards Energy Efficient Smart Grids Using Bio-Inspired Scheduling Techniques

ZUNAIRA AMJAD[1], MUNAM ALI SHAH[1], CARSTEN MAPLE[2], (Member, IEEE), HASAN ALI KHATTAK[1,3], (Senior Member, IEEE), ZOOBIA AMEER[4], MUHAMMAD NABEEL ASGHAR[5], AND SHAFAQ MUSSADIQ[6]

[1]Department of Computer Science, COMSATS University Islamabad, Islamabad 45000, Pakistan
[2]WMG Cyber Security Centre, University of Warwick, Coventry CV4 7AL, U.K.
[3]Department of Computing, School of Electrical Engineering and Computer Science (SEECS), National University of Sciences and Technology (NUST), Islamabad 44000, Pakistan
[4]Department of Physics, Shaheed Benazir Bhutto Women University, Peshawar 25000, Pakistan
[5]Department of Computer Science, Bahauddin Zakariya University, Multan 60000, Pakistan
[6]Institute of Information Technology, Kohat University of Science and Technology, Kohat 26000, Pakistan

Corresponding author: Hasan Ali Khattak (hasan.alikhattak@seecs.edu.pk)

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ABSTRACT Electric power grids are lagging in flexibility and time-response. A smart grid is an improved version of electrical grids that leverages Internet of Things (IoT) based devices to improve the overall infrastructure from the grid stations to intelligent appliances. It provides better understanding of supply and demand and overall flow of data depending based upon the requirements. Modern approach towards Smart grid envisions to provide electricity consumers with the opportunity to manage their respective power usage. Population increase has played a major role in the adoption of smart grid as a lot of electrical energy is consumed in the residential sector and a lot of architectures have been proposed for better flow of information from the smart meter to connectors and devices for improved customer participation. Customer needs have been very important in the smart grid. However, the customers have never been provided with the ease of choosing their own kind of benefits from the smart grid. In this work, we propose an enhanced architecture working effectively for multiple users based on their requirements. The users would be able to choose their type of scheduling techniques based on their requirements. These requirements may include cost reduction and increasing user comfort for better consumption of electricity and reliable systems. These requirements can be achieved using different Bio inspired computing based scheduling algorithms. Furthermore, in this work, we provide a comparison of these bio inspired scheduling techniques, i.e., Enhanced Differential Evolution, Bacterial Foraging Algorithm and Grey Wolf Optimization integrated in smart grid architecture for providing better consumption of electricity and achieving reliable systems. These algorithms mainly aim to schedule load, minimize electricity bills and maximize the user comfort depending on user demand.

INDEX TERMS Smart grids, smart cities, smart grid architecture, heuristic techniques, scheduling algorithms, energy efficiency.

I. INTRODUCTION

An increase in the demand for electrical energy by commercial, industrial and residential customers, power frameworks has been witnessed. The requirement for incorporating sustainable energy sources into the present grid has been observed. This has been impacted due to environmental conservation and preservation, difficulties of expanding energy tariffs and the requirement for a more satisfactory power framework. All of these combined are among the variables that have been required for expanded research in the academia and industry with respect to the change of traditional grids to smart grid. This smart grid is likewise called future grid, intelligent power frameworks or energy web [1].

In contrast, the conventional grid is a unified grid and is portrayed by one directional flow of information and mostly energy having basic architecture and irrelevant security risks The utility supplier is exclusively incharge of the overall Power Generation. Distribution and Transmission of the electrical energy process incorporates all operations, control and

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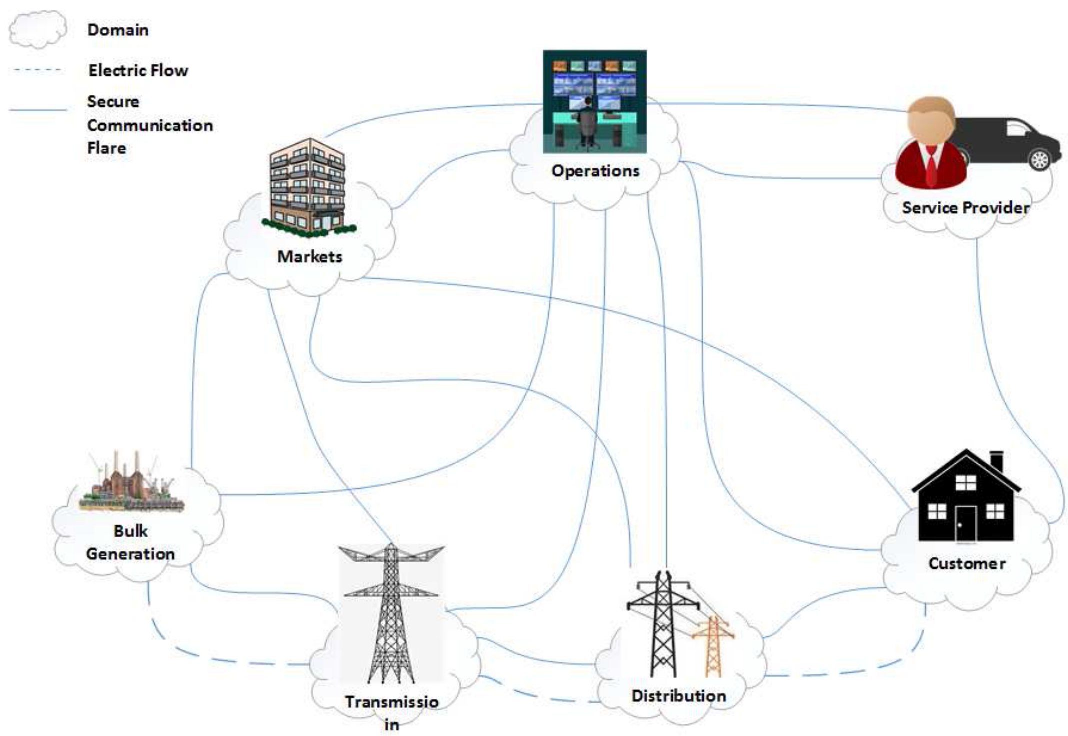

FIGURE 1. NIST Smart Grid Framework.

support elements of the grid. The monthly energy utilization by user is charged through manual meter reading process at customer's premises and the electric bills are conveyed in a comparable way, posted or e-mailed [2], [3]

In contrast to traditional grids, a smart grid is portrayed by bi-directional and even multi-directional flow of energy, combined with multi-directional communications among all partners in the electrical energy industry, as represented in smart grid architecture of the National Institute of Standards and Technology (NIST) [4], [5] in the United States of America as elaborated through a model architecture shown in Figure 1.

In contrast to smart grids, generation of electricity is centralized in traditional grids, information flow is only in one direction which is unsafe and unclean. Whereas smart grids provide secure and reliable systems.

Smart grids provide enhanced customer participation, inter-connectivity and interoperability among devices, bi-directional flow of information in generation and distribution. Moreover, information about energy consumption, pricing tariff and relation between user and utility can be described by bi-directional flow of information. Smart gird provides affordable cost for both utility and users. Due to optimized network assets low investment cost is being paid by utilities and low expenditure is paid by used due to consumption of energy and scheduling of appliances in order to reduce cost.

Smart grids provide increased intelligence due to the use of smart meters and smart devices. Furthermore, integration of renewable energy resources in smart grid provide energy mixes. Smart grids also provide secure reliable and flexible energy systems. Some key characteristics of smart grids are elaborated in Figure 2.

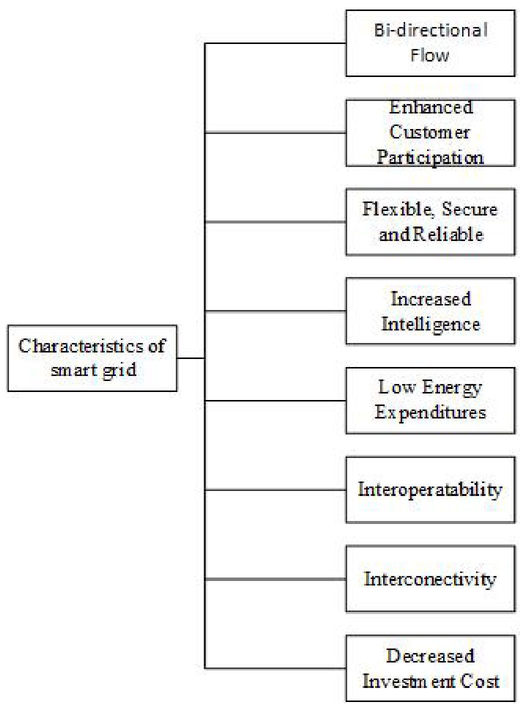

FIGURE 2. Smart Grid Characteristics.

As a necessity to smart grid, four major points have been pointed out and they are listed as below: [6]

- Advanced Distribution Operation (ADO)
- Advanced Transmission Operation (ATO)
- Advanced Asset Management (AAM)
- Advanced Metering Infrastructure (AMI)

The most important point of smart grid actualization is: AMI as it involves customer participation. [7], [8]. Moreover, the power frameworks in the smart grid will be distributive in nature as there will be many powers takes (generations and capacity) situated in users' premises and in provincial and urban micro grids [9]. A micro grid is communal energy framework territorial or residential energy framework involving distributed energy sources keeping in mind that the end goal is to enhance control quality. Efficiency, sustainability, and reliability with accompanying environmental and economic benefits. These micro grids have abilities for pitching to and purchasing energy from grids as wanted and could hence be either independent or framework associated for trade of energy associated to financial benefits [10].

Smart grids additionally upgrade request administration as users can deal with their energy consumption demands by moving their interest as desired, to time of low tariffs in view of pricing signals from utilities. Despite the fact that this self-mending digitized smart grid framework will offer advantages to the utility supplier, buyers and the environment it is, somehow, envisaged to have privacy issues, high initial investment cost and complex architectures. So smart grid network would utilize Demand Side Management (DSM) programs that can adequately manage request in customer premises and furthermore offer protection and security to purchasers in spite of the accessibility of their utilization information in the energy cloud [11].

In a smart grid environment, Smart Meters (SM), communication network devices substations, sensor nodes, home appliances and micro-grids are executed. Smart grid associated with the distributors, generate a lot of information to collaborate with clients and utilities. Keeping in mind the end goal to deal with such immense measure of information productively, smart grid more often depends upon advanced Information Technologies (IT) [1]. These advancements are incorporated as capacity, sensor, correspondence and cloud network areas. Moreover, information security and cyber security functionalities were additionally introduced. While, performance isn't well-thoroughly considered fundamental in this context [12].

The research in [13] centers around envisioning the smart grid as programming network to survey complex architectures. Concerning the fundamental stage, the prerequisites for smart grid design have been derived. The derived requirements for smart grid design have been verified by stakeholders for the project advancement. The software network comprises two noteworthy parts:

- Embedded Software Architectures: Implement highlights in smart grid including conventions.
- User Interface: Allows different clients to get to approvals in view of the engineering.

In any case, the developed multifaceted nature in smart grid is a fundamental factor in the game plan of new innovative frameworks, which are well equipped for dealing with various gadgets used as a piece of the framework diminishing the execution of smart grid [14]. Other than the tremendous volume of data in the smart grid connected network, effectively handling the storage, processing and analysis of the data in question is a difficult job [15].

In this work, our contributions are as follows:

- An enhanced framework for software architecture working effectively for multiple users based on the user requirements.
- A smart grid architecture which includes a choice of a scheduling algorithm in application layer at the user end.
- Facilitate the user to schedule their appliances to increase the user comfort, Peak Average Ratio (PAR) and reduce the cost according to their needs.
- Compare the results of various bio inspired scheduling techniques by carrying out simulations. Results will provide the best technique in terms of user comfort, consumption of energy cost and PAR.

The organization of the paper is as follow: Section II contains the related studies of different researcher along with the concrete problem statement. Section III contains our system model which depicts the overall system working. Then the proposed methodology is discussed along with different scheduling algorithms which have been used to enhance user reliability. To ensure that the provided research provide support to the claim, simulations are on the proposed scheme using MATLAB and results are being discussed in Section IV. Section V Discusses in detail the Evaluation and Results of the Scheduling Techniques we have adopted in for our proposed system. In the end, Section VI contains the conclusion along with possible future directions.

II. LITERATURE REVIEW

Smart Grid can be viewed as an arrangement of collaborations and interconnection of intensity frameworks, data and correspondence advances towards reliability, efficiency, maintainability, flexibility, security through effective bi-directional flow of data and energy among utilities and users. Smart grid has likewise been characterized by [4] as an automated, broadly distributed energy pattern described by two - path flow of electricity, equipped for observing and reacting to change in power plants, client's inclinations an individual appliance. Similarly, literature characterizes smart grid as a modernized network that empowers bi-directional flow of electricity and utilization through two-way communication and provides control abilities that will initiate a variety of new functionalities and applications.

A smart grid includes the utilization of appliances, switches and plugs even at users' premises. Customer energy utilization patterns can be modified on the basis of prior information used by energy tariffs [16]. The change of

TABLE 1. Smart Grid Architectures.

Architecture(s)	Purpose
Conceptual Architectures	The interactions and high-level demonstration of business domains and stakeholders
Information Architectures	Entities, their relationships, properties and operation to be performed are represented
Functional Architectures	Define the control and flow of data, and performance requirements
Communication Architectures	Connectivity of multiple devices can be handled.
Information Security Architectures	Describes the working of systems that how they are combined to fulfill the security requirements.

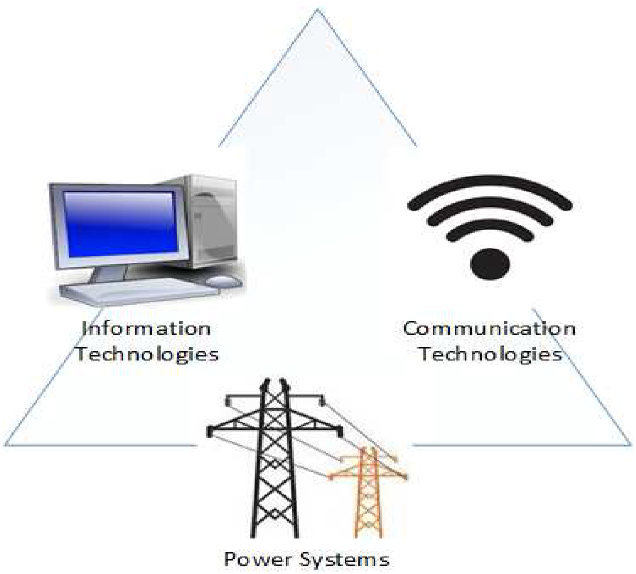

FIGURE 3. NIST Smart Grid Triangle.

present conventional grid to smart grid is proposed to be completed through the cooperation of intensity frameworks, data and correspondent technologies as appeared by Smart Grid Systems Triangle (SGST) 3. The intensity of framework will shape the base of SGST, while communication technologies and data would be its different sides to offer the required insight and connection among utilities and customers.

In smart grid, the flow of data is from sensors to smart meters and server frames require data and communication infrastructure [17] For an adaptable, flexible, secure, dependable and execution proficient framework; a streamlined frequency, information rate, latency and throughput detail is required for meeting the necessities for data and communication infrastructures [18], [19]. One of the basic step in smart grid is to assemble necessities for its architecture [13].

Diverse sort of smart grid architectures have been proposed to date that may incorporate correspondence, functionality and data architectures [6]. A short perspective of these architectures is given in Table 1

These proposed architectures give the services as per framework requirements. However, the greater part of these architectures needs in encouraging the user; as indicated by their necessities where scheduling is one of numerous approaches to facilitate them. In smart grid, the client cooperates with a utility utilizing technology and information framework [20]. Client interfaces with the framework so as to get encouraged as far as their expanding requests [21].

Differing algorithms have been proposed by authors to support the customer to the extent reducing cost, PAR and by reducing holding up time. Many authors have proposed distinctive algorithms to schedule appliances on pre-characterized demand graphs. However, authors have been unable to achieve all these described parameters simultaneously. Each algorithm is efficient in its own ways in terms of parameters. Trade off among user comfort and cost is essential in these parameters as user comfort is decreased in order to decrees cost. These parameters are proportional to each other. Moreover, energy consumption, PAR and integration of these in smart grid is also neglected by many authors. In [22], the author has focused on lowering the overall cost and providing user comfort by proposing a framework which handles residential load.

Reference [16] shows the review of a home energy management system which control energy for the residential areas. The main focus of the author is to identify peak load for both shift able and not shift able appliances. The pricing signals considered in this methodology are; Critical Peak Pricing (CPP), Time of Use (TOU), Increasing Block Rates (IBR), Real Time Pricing (RTP). Researchers have also contributed and proposed automated energy management systems (EMS) for residential and business areas is exhibited. They utilize the Q-learning algorithm for ideal demand response mechanism [23].

Adika and Wang [24], present another framework utilizes SM's to choose the scheduling plans of appliances in view of their power or load consumption. In the wake of scheduling, most of the information is traded to the aggregation module, where they control utilization of load of most of the appliances [23]. Along with that, Load clustering mechanism is also discussed in this research paper. For planning the group, three-time groups are defined which are from 1 a.m. to 7 a.m., 8 a.m. to 3 p.m., and 3 p.m. to midnight, respectively. Two battery scheduling situations are utilized as: (I) the First Come First Serve (FCFS) planning strategy and (ii) machine first planning strategy.

In [25] and [26], author has proposed different algorithms in order to schedule load, the main purpose of these techniques is to reduce cost and maintain user comfort by scheduling load. Authors in [27] and [28] have proposed quantum theory, demand modelling and integer linear programming for energy consumption. Cost and user comfort is also achieved by using these techniques. However, authors were unable to achieve optimized PAR. In [29] different scheduling approaches have been used by the authors for the integration of renewable energy resources in micro grids. The electricity cost is reduced along with maximum utilization of energy storage. Whereas the authors have ignored the consideration of clustered appliances.

Maintenance for large area population has been a problem in [16] and [30]. Energy consumption is the main focus of authors in these papers. the main advantage of [16] is reduction in PAR and attaining maximum user comfort. Moreover, [30] provides the optimal solution for solving envisaged problems in energy resource management. Genetic Algorithm (GA) along with different pricing signals, i.e., IBR and RTP is used to minimize cost and reduce peak formation [31]. The proposed model is designed for multiple users. However, a trade off between is noticed between user comfort and energy consumption.

Optimal DR mechanism has been used with high computational frequency has been used for cost reduction.Quantum theory used by author in [27] has also been used for residential area users. Efficient energy management has been the main concern of the paper.

A brief view of these techniques and their limitation is elaborated in Table 2

The smart grid architectures lack the ability to provide user reliability. The proposed architectures do not provide privilege to the users that they can select any of heuristic algorithm according to their needs, i.e., minimize the cost and increase in user comfort. So, there is no such architecture in smart grids that provide the mechanism of having the choice among their needs, i.e., minimize the cost and increase in user comfort.

In this article, we aim to propose an enhanced architecture working effectively for multiple users based on the user requirements. The user will be able to choose their type of scheduling techniques based on their requirements

III. SYSTEM MODEL

We consider a system model framework which demonstrate the highlights of SG with two-way correspondence. In this work, a smart home is integrated with different appliances as indicated by users needs is considered. Further, the arrangement of appliances is elaborated: Shift-able apparatuses and Non shift-able apparatuses.

Smart meter is introduced at every home to share value price signals and load request between the service organization and consumers. A micro-grid, which comprises of sun powered panel and wind turbine is additionally considered. Besides, Energy Management Controller (EMC) is additionally introduced for appliances' scheduling as indicated by evaluating power generation and pricing signals from micro-grid. The dynamic power signal CPP is received for electricity cost count. The whole time interval is accepted one day in this work. Furthermore, the proposed framework demonstrate is depicted in Figure 4.

A. HOME APPLIANCES

In this section, we elaborate the categorization of appliance. A set of appliances is considered in a smart home that work in a specific time interval. These appliance remain idle or work under some specific time interval in a 24 hour time slot. These appliance are further categorized as Shift-able and non shift-able appliance. Shift-able appliance are the ones which can be scheduled to be on in off peak hours such as vacuum cleaner, dishwasher, motor. Scheduled appliance on the other hand are one that can not be shifted in low load hours, i.e., light, fan etc. The working of these appliances is measured in term of four parameters, i.e., Cost, PAR, energy consumption and user comfort.

B. MICRO GRID

A micro grid is used for generation if electricity as Renewable Energy Source (RES) in integrated in it. A solar panel, wind turbine with Energy Storage System (ESS) are also a part of micro grid. Moreover, main source of electricity generation is RES integrated in micro grids. Furthermore, wind speed and weather can be predicted using historical data.

1) SOLAR PANEL

Solar panel generates electricity using sunlight. Solar panel gyrates electricity in for of direct current which is afterwards converted in alternating current.

2) WIND TURBINE

Electricity generated using wind turbines is based on the area cover by rooter blades and speed of wind. The amount of electricity generated from wind turbine is increased by the increase in wind speed and vice versa.

3) COAL/HYDRO POWER PLANTS

These coal/hydro power plants are domestic source of energy. Electricity can be generated from their own state.

IV. PROPOSED METHODOLOGY

In this article, we propose a smart grid architecture which incorporates a decision of scheduling algorithm in application layer at the client end. This design will give the benefit to the client, with the goal that they can utilize diverse scheduling algorithms as indicated by their necessities, i.e., decreasing cost, stack utilizing PAR and increment in client comfort. This architecture is considered as Master-Slave architecture. Master is the control unit, whereas transmission, generations,

TABLE 2. Scheduling Techniques and Their Limitations.

Ref.	Technique(s)	Problem (s) addressed	Achievement(s)	Limitation(s)
[25]	GA	Management of unscheduled load	Cost reduction	User comfort and PAR are ignored
[32]	Scheduling algorithm for optimal energy consumption	Customers does not use energy optimally which results in increase of cost	Cost reduction	User comfort along with Res is ignored.
[33]	Load Management	Optimal energy Consumption results in user frustration	Increase in user comfort, cost and PAR reduction	Degraded performance due to explicit values pressure.
[16]	Energy Management	User comfort is ignored in order to minimize cost.	Maximizes waiting time and PAR	Effective maintenance is difficult
[23]	Optimal DR Mechanisms	Computational complexity is high.	Negotiation on DR mechanism	Energy Management is ignored
[33]	Scheduling using home energy management systems	Lack of effective home automation systems	Increasing user comfort and Cost reduction	Initial cost in ignored.
[11]	Scheduling Approaches	Energy cost and PAR, are not catered	Reduction in cost and maximum storage utilization	Inconsideration of Super clustering
[30]	Simulated annealing approaches	Execution time for management of large distributed resources is increased.	Energy resource management in view point of virtual power layer. Optimal for solving envisaged problem.	Not suitable of large area population
[34]	Game theoretical Scheduling system	Each user shares their own energy pattern.	PAR reduction and privacy control.	Tactlessness of cost
[35]	Communication Infrastructures.	Energy efficiency reduction	Energy consumption	user comfort in neglected
[27]	Demand Modelling and security for smart homes	Robust regression in process is on exploration of cross-categorical static and linear models.	Efficient consumption of energy	Inconsideration of electrical Demand along with trade-off between electrical Demand and user comfort
[36]	Load management.	Customer contribution is nil	Efficient consumption of energy.	Inconsideration of cost
[21]	Quantum theory.	In residential areas, efficient energy management is main area of concern.	Minimization of cost and delay in operation time is controlled.	Tuning of parameter has been avoided
[26]	Load Scheduling .	Power consumption follow their own patterns	Energy Efficiency is main focus	Cost Reduction is neglected
[37]	Integer linear programming	Dealing with Unscheduled load and changing power rates	Lessen the peak load to schedule the load	Lack of non-adaptability with DPM and RES integration
[38]	Dynamic Programming + game theoretic approach+ liner programming	Load scheduling and power exchange with RERs	Energy expenses are reduced.	User comfort is not determined and market clearing price will rise due to insufficient demands
[39]	GA RTP+IBR	Reduction of electric bill and peak formation	PAR and Cost Reduction	Ignores User comfort and RES integration
[40]	Hybrid GWD RTP Signal	Scheduling and removing burden from on-top to off-top hours	Exchange off amongst cost and client comfort	60 percent user comfort is less
[41]	Optimal power Scheduling	Power scheduling	Exchange off amongst cost and client comfort	PAR is ignored
[42]	GA+BPSO+ ACO+IBR+ TOU	Multiple knapsack problem	User comfort is maximized and PAR is minimized	Increase in Cost
[43]	BPSO	Eliminating power demand, intensifies user comfort and reducing cost.	To achieve a level in cost and appliance utility up to user demand.	RESs integration is ignored.
[44]	GA+ PCT+ IPCT	Reduction of Peak formation and cost	Reduce cost, waiting time, energy usage, user frustration, fuel cost.	user comfort and energy usage trade-off
[31]	GA IBR+RTP	To minimize the cost and peak formation	One or multiple user are able to use this model	integration of RESs and user comfort levels are neglected
[28]	Integer non-linear programming	To limit energy utilization and cost.	Flexible and low computational complexity	Can't manage an expansive number of appliances
[45]	BPSO	Minimize Cost	Reduction of cost	user comfort is ignored

distributions, and operations work as slaves. It turns up into a hierarchical structure with multiple interfaces and layers. The features and functionalities of smart grid consist of three main layers:

- Base layer
- Abstraction Layer
- Application Layer

Base layer involves basic modules through which direct permission is granted to micro controllers and peripherals along with the implementation of all the device drivers.

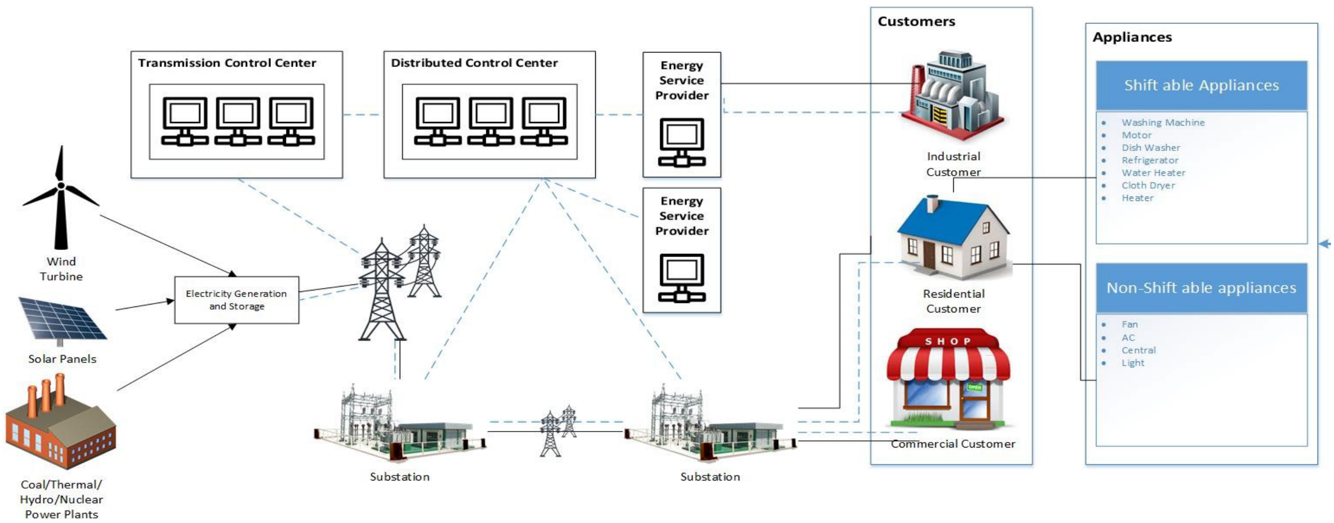

FIGURE 4. System Model.

The functionality of abstraction layer is to obtain information from modules that are arranged on the lower layer architecturally. Key modules to abstraction layer can be named as: OS interface, communication protocol, and independent device services. The smart grid specific modules are placed in Application layer including scheduling algorithm as referred in Figure 5.

The user is allowed to choose the genetic algorithm according to their needs based on their requirements. Application layer consists of smart grid module including heuristic techniques which is extension to our own work [46]. Different heuristic techniques: Bacterial Foraging algorithm (BFA), Grey Wolf Optimization (GWO) and Enhanced Differential Evolution (EDE) algorithm can be used to fulfil user requirements.

A. SCHEDULING TECHNIQUES

In this section, four scheduling techniques: Bacterial Foraging algorithm (BFA), Enhanced Differential Evolution (EDE), Grey Wolf Optimization (GWO) and Elephant Herding Optimization (EHO) are discussed from the view point of both home consumer and power grid in order to evaluate performance of our proposed architecture.

B. BACTERIAL FORAGING ALGORITHM (BFA)

The key idea of this algorithm is application of social gathering of a swarm of E. coli bacteria in multi-perfect streamlining capacity. Microorganisms search for enhancements is an approach to extend energy gotten per unit time. With the help of signals, Particular bacterium moreover talks with another bacterium. A bacterium takes rummaging decisions in the wake of thinking about two past components. The strategy, in which a bacterium moves by bringing little advances while chasing down supplements, is called chemotaxis. The key idea of BFOA is replicating the chemotactic advancement of virtual bacteria in the issue look for space [47]. The cell to cell signaling is elaborated by the following Equation 1.

$$J_{cc}[(\Theta, (P(j,k,l,))$$

$$= \sum_{(i=1)}^{s} J_{cc}(\Theta, \Theta^{i}(j,k,l))] \tag{1}$$

$$= \sum_{(i=1)}^{s} [d_{attractant} exp - w_{attractant} \sum_{(m=1)}^{p} (\Theta_i - \Theta_m^i)^2)] \tag{2}$$

$$+ \sum_{(i=1)}^{s} [h_{repellent} exp(-w_{repellent} \sum_{(m=1)}^{p} (\Theta_i - \Theta_m^i)^2)] \tag{3}$$

where J (theta, P(j, k, l)) is the value of actual objective function at the time of varying objective, number of bacteria is represented by S, p is considered as the number of optimized variables in each bacterium and is a point in the dimensions of p. Attractant repellent of d, w, h are different coefficients that are chosen such that:

The least healthy bacteria at the end dies whereas the healthier bacteria are asexually divided into multiple bacteria, located at the same location and this process is carried out under reproduction. However, elimination takes place due to sudden and abrupt changes in environments [47]

C. ENHANCED DIFFERENTIAL EVOLUTION (EDE)

Differential Evolution (DE) is one of the productive evolutionary procedures that appear to be successful to deal with improvement issues in many practical applications. On the other hand, the execution of DE isn't constantly flawless to ensure quick union to the global optimum. It can surely get inaction bringing about low precision of gained results. An upgraded differential development (EDE) calculation by incorporating energized self-assertive limited hunt (EACS) to enlarge the execution of a fundamental DE algorithm [48].

The EDE has two main objective functions:

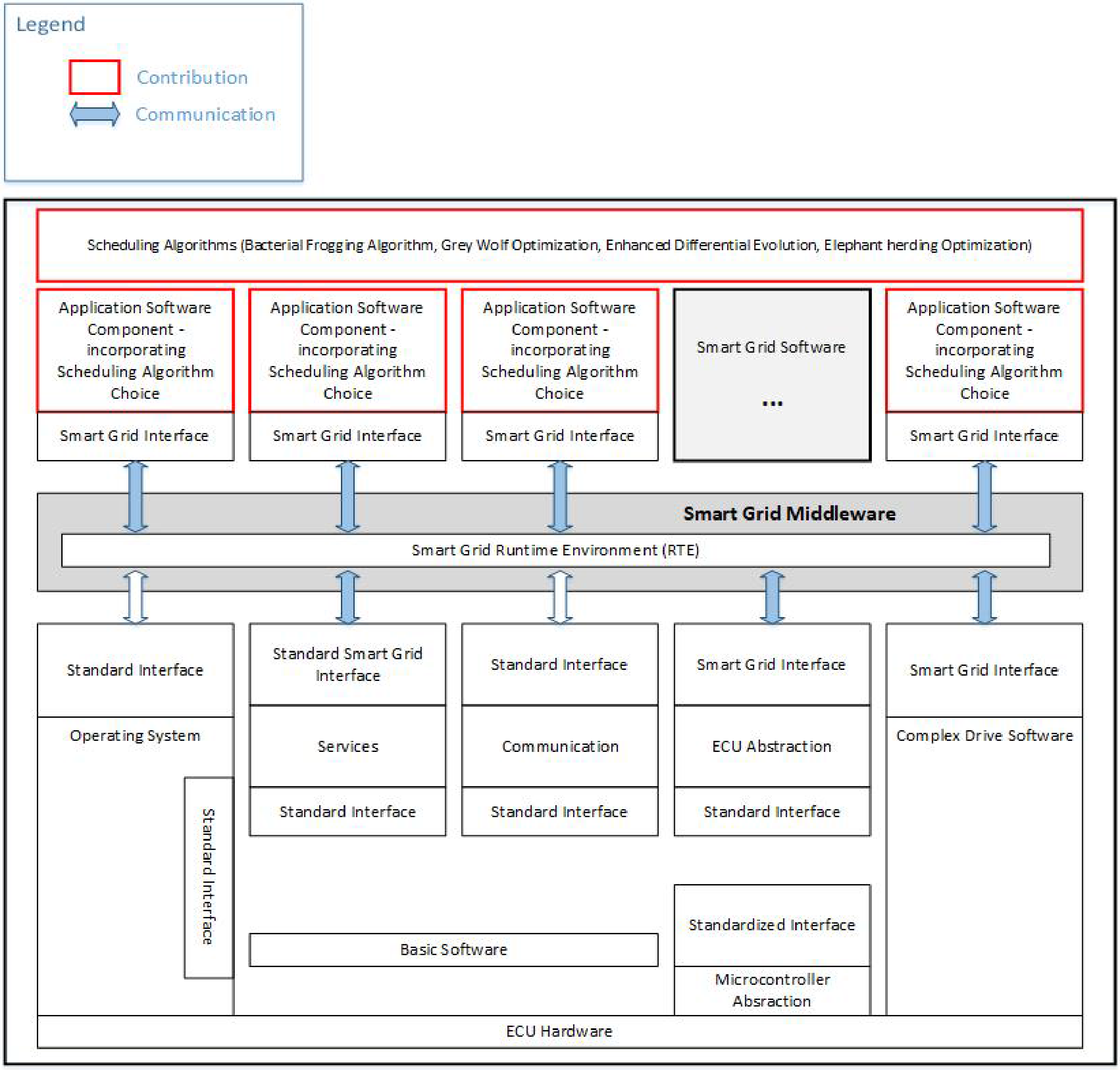

FIGURE 5. Proposed Smart Grid Architecture with Bio Inspired Scheduling Algorithms.

1) ACTIVE POWER LOSS

The goal of the responsive power dispatch issue is to limit the dynamic power lessened can be characterized in Equation 4 as described:

$$F = P_L = \sum_{k \varepsilon Nbr} g_k(V_i^2 + V_j^2 - 2V_iV_j cos\Theta_{ij}) \quad (4)$$

where F is the function, PL is a loss of power, gk is branch conductance, Vi and Vj buses voltages i and j, Nbr are the total transmission lines in power systems.

2) VOLTAGE POWER IMPROVEMENT

To limit the voltage deviation in PQ transports as shown in Equation 5, the goal work (F) can be composed as:

$$F = P_l + W_v + VD \quad (5)$$

where VD is the voltage deviation, is a weighting factor of voltage deviation.

D. GREY WOLF OPTIMIZATION (GWO)

The GWO impersonates the chasing conduct and the social chain of command of dark wolves. Notwithstanding the social chain of command of dark wolves, pack chasing is another engaging societal activity of dark wolves. The fundamental portions of GWO are circling, chasing and assaulting the prey. The chasing strategies and the social order of wolves are numerically demonstrated with the end goal to create GWO and perform advancement. The GWO algorithms adopted with the standard test works that demonstrate that it has predominant investigation and exploitation qualities than other swarm intelligence techniques. Further, the GWO has been effectively connected for taking care of different engineering optimization issues [49]. This technique is further elaborated in Algorithm 1.

Algorithm 1 Grey Wolf Optimization (GWO) Algorithm

procedure GWO($Y_i = 1, 2, 3 \ldots, n$)
  Initialize the choatic map Y_o
  Initialize A, B and C
  Calculate the fitness wolf
  Y_a = First Best wolf
  Y_b = Second Best wolf
  Y_c = Third Best wolf
  while $s \leq MaxNumberofIterations$ **do**
    SORT wolf on basis of fitness criteria
    while *foreachwolf* **do**
      UPDATE position of wolf by chaotic map equation
    UPDATE A, B and C
    CALCULATE fitness wolf
    UPDATE Y_a, Y_b and Y_c
    $s = s + 1$

E. ELEPHANT HERDING OPTIMIZATION (EHO)

An elephant is one of largest group of mammals on earth. Asian and African elements are two mainly recognized species. In general, elephants are social and their female calves have complex social structures. Elephant work under the leadership of a matriarch, as they are grouped in the form of clan.

A clan consist of a female elephant with other related female elephants or their calves. Male elephants abandoned themselves from other elephants as they like to live in isolation as they grow up, whereas female elephants live in groups.It can easily be said that exploration is represented by behaviour of clans. However, elephants who live in isolation are used of exploration. Even though male elephants live in isolation, they are connected to other elephants in their clan through low frequency vibrations [50].

In this work, EHO is used to carry out the problem faced in global optimization for scheduling appliances. For scheduling the appliances EHO uses two operators, i.e., "Update" and "Separate". Prior one is used to update the schedule of the appliances while the latter one is used to separate the devices with high consumption in terms of cost and load from the rest [29]. Optimization problem can be solved by using EHO if basic rules are to be followed:

- Electrical devices (elephants) are divided on the basis of their class, i.e., shift-able and non-shift-able. The number of devices (elephants) are fixed in each class(clan)
- In each population (each iteration of device scheduling), devices with worst fitness value are deleted while the rest of appliances are scheduled to minimize load for specific time interval.
- Matriarch is considered as solution as it is avoids peak creation and defines the less consumption of electricity.

The optimization operators for EHO are described as follows:

1) UPDATE OPERATOR

In order to update the devices, a new generation is created and placement of each electrical device (elephant) is based on each iteration. aggregated no of devices (elephant clan) is here represented as En, where number of devices is represented by p in each clan. Electrical devices is updated based on its fitness value [50].

$$x_{new,En,p} = x_{En,p} + \alpha \times (x_{best,En} \times x_{En,p}) \times r \quad (6)$$

where, $x_{new,En,p}$ and $x_{En,p}$ are updated positions and for electrical devices old position is En. α at the scale 1-10 defines the best solution. $x_{best,En}$ is considered the best solution in clan En. and r is the random number from scale 1-10.

$$x_{new,En,p} = \beta \times x_{center,En} \quad (7)$$

where, β determines the $x_{center,En}$ on $x_{new,En,p}$. $x_{center,En}$ in Equation 7 is generated in the basis of information obtained from each electrical device in clan. Here, center solution of En is $x_{center,En}$

2) SEPARATE OPERATOR

Devices (elephants) with worst fitness functions are excludes from the clan is known as separator operator. Devices with worst value leave the class after each iteration as depicted in Equation 8.

$$x_{worst,cp} = x_{min} + (x_{max} \times x_{min} + 1) \times rand. \quad (8)$$

Here,x_{max} and x_{min} defines upper and lower limit, respectively. And $x_{worst,cp}$ describes the worst electrical device (elephant) in the clan cp. where as, r defines the range of distribution of devices on scale 1-10.

F. USER INTERFACE

To make the proposed solution accessible, we have developed a user interface for the users. This tool allow developers to create an interactive and responsive applications or web pages. We have developed a responsive website for users that help them to interact with utility and obtain the required information.

Dashboard represent the overview of all the evaluation parameters.Side navigation bar represents "User Profile", "techniques" and "notifications". Moreover, this represents the details of three mostly used techniques in last month. These techniques are selected on the basis of chosen techniques by the user.

User profile is used to update the information about the user. User can change his personal information, details, picture at the required time. User can also check his total cost spent, total files (techniques) used till.

Each time a new activity is performed by the user the system notifies them about their recent activity. As after updating their profile the user receives a notification from the user that informs them about the recent activity on their account.

V. EVALUATION AND RESULTS

In order to evaluate already proposed work, and to carry out comparison between various algorithms, simulations are directed in MATLAB utilizing the CPP pricing signal. The real time behavior of proposed framework in 24-h day and generations which are partitioned into peak hours and off peak hours is evaluated. The simulation scenario that is examined here is single home.A home with 12 appliances is considered, and appliances are divided into two categories: (I) Shift-able appliances (II) Non-shift-able appliances. The CPP dynamic pricing signal is used to calculate the cost for every hour according to consumption of load in each day. A brief view of evaluation is described in Table 3

TABLE 3. Evaluation Criteria.

Parameters	Values
Tool	MATLAB
Appliances	12
Pricing Signal	CPP
Time Slot	24hr
Simulation Area	Residential Area, Single Home
Input	Unscheduled Load
Total Time for Simulation	29 sec
Parameters for Evaluation	Cost
	User Comfort
	Energy Consumption
	PAR

To assess execution of BFA, GWO, EHO and EDE algorithms, the accompanying execution parameters are described as:

- Cost: It is computed as the number of aggregate units used. Electricity bill is calculated as per unit time in rupees.
- User comfort: It is figured as far as least cost and least appliance delay.
- Energy Consumption: The total amount of energy used in kilowatts in terms of time each day.
- PAR: It is characterized as the distribution of aggregate peak load and normal load in a 24 hour time slot.

A. ENERGY CONSUMPTION

The use of energy in regards to BFA, GWO, EHO and EHE in unscheduled and scheduled cases is appeared in Figure 6. This figure exhibits that the most extreme energy usage esteems are 12.3 kWh, 11.8 kWh, 11.7 kWh, 9.5 kWh and 8kWh for the unscheduled case, GWO, BFA EHO and EDE algorithms, respectively. The energy consumption of these scheduled load using defined algorithms is less than that of unscheduled load. The energy utilization in BFA, GWO and EHO and EDE is acquired by separating the scheduled and

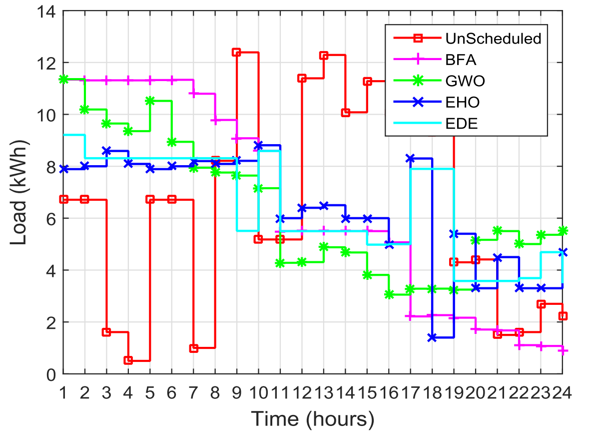

FIGURE 6. Energy Consumption.

unscheduled expense alongside their cost. While, the EDE algorithm performed better to the BFA, GWO and EDE in regard to load or energy utilization.

B. PEAK AVERAGE RATIO

In order to reduce electricity bills and the peak created b using maximum amount of load, numerous utilities are presenting algorithms that urge their clients to utilize electricity during off peak-hours. The algorithms pass on the investment funds to the client, through refunds or lessened electricity rates. The PAR execution of all algorithms (BFA, GWO, EDE and EHO) is appeared in Figure 7. This figure demonstrates that PAR is essentially lessened in EDE contrasted with the GWO, BFA, EHO and unscheduled scenario. Simulation results demonstrate that the presented algorithms successfully handle the peak reduction issue. However, EDE demonstrates the best outcomes because of hybrid and mutation process.

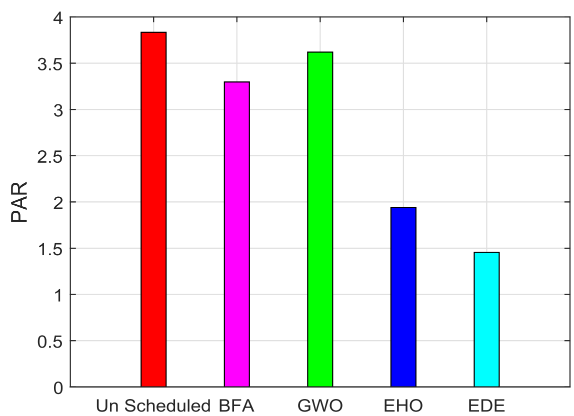

FIGURE 7. Peak Average Ratio.

C. COST

Base charges calculated for the expended loads given by the utilities to the clients refers to the reduction in Cost.The total amount of expenses charged to the user in order to consume load per unit time is used by these algorithms is described in Figures 10,9 and 8 which is obtained by scheduling appliances and their process.The maximum measure of the electric cost for the unscheduled scenario is 2900 cents, as appeared in Figure 8. It is decreased to 1800 cents on account of EDE and EHO, while it is lessened from 2900 cents to an amount of 700 cents in regard of BFA and up to 2300 cents using GWO.

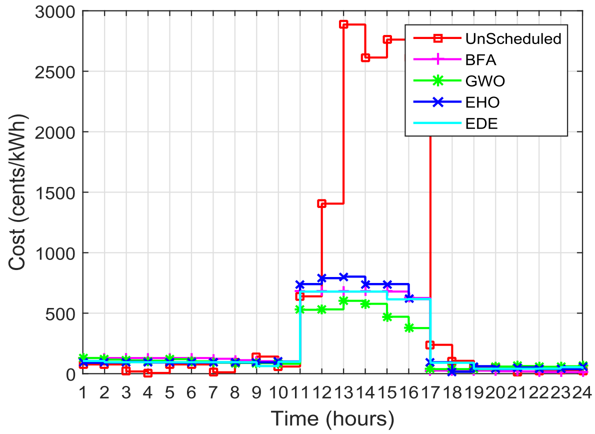

FIGURE 8. Hourly Cost.

During peak hours, adequate electricity cost reduction is accomplished for every single composed algorithm (BFA, GWO, EDE and EHO). GWO performs better to alternate algorithm in terms of electric cost reduction. The EDE cost is most noteworthy in contrast with different calculations as appeared in Figure 9.

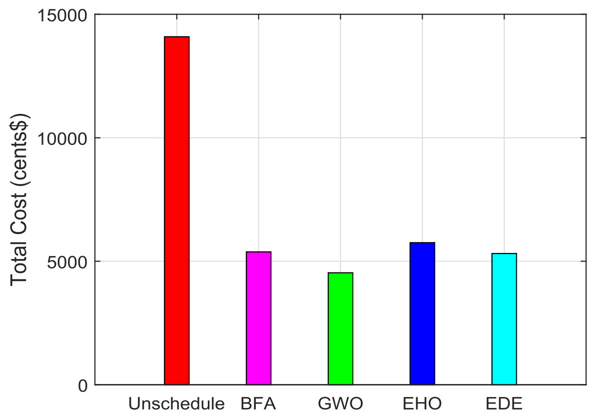

FIGURE 9. Total cost.

1) COST WITH CPP

The PAR diagram for BFA, GWO, EHO and EDE shows that the energy utilization of appliances is ideally distributed without making peaks amid the off peak hours and peak hours of the day. Formation of peak due to utilization of unscheduled load is a noteworthy disadvantage in the conventional electric power framework,due to which clients have to pay high electricity bills, and the utility additionally experiences increase in demand for electricity, which prompts load shedding, power outages and blackouts. The execution of these heuristic algorithms in this condition is enhanced because of load distribution, which makes utilities satisfy the requests of clients and allows clients to decrease their power bills in regard to CPP pricing technique as shown Figure 10.

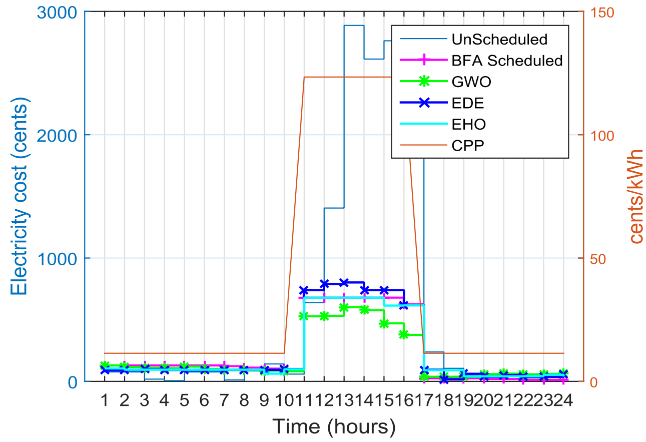

FIGURE 10. Cost in CPP.

D. WAITING TIME

Client comfort is exhibited as the extent of the base delay of appliances and perfect cost for the electricity bills. Along these lines, consumers reliably expect utilities with slightest delay and uniform cost. Furthermore, in a similar manner utility helps in restricting the customers' disappointment when the energy usage is high in peak hours. In these circumstances, a particular priority is assigned, and high need appliances are arranged in the most available time intervals amid the off-peak hours. The undertakings of the low need appliances are dropped or put off in the peak hours, as they have to be On in that particular shift. Along these lines, appliances' waiting time is diminished, and maximum user comfort is accomplished.

In our research, we have accomplished the desired user comfort as shown in Figure 11. It demonstrates that user comfort is altogether achieved for EHO, EDE, BFA and GWO, respectively. By applying scheduling, this work upgraded the execution as far as user comfort is concerned.

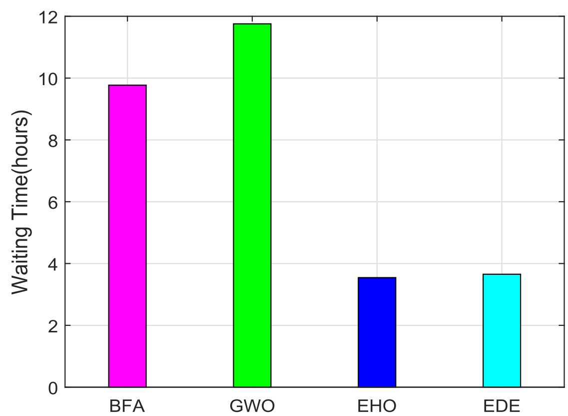

FIGURE 11. Waiting Time.

There is a tradeoff in user comfort of every single executed algorithm with cost. As EHO gives the greatest client comfort with increment in power bills. Additionally, GWO gives most extreme user comfort with least reduction in electricity bills. In any case, the execution of these algorithms is enhanced by considering the need bits and slightest least delay during scheduling.

As these algorithms are intended to fulfill the client needs. Our clients get encouraged by lessening their power bills and increasing their comfort. Whereas, the utilities get the advantage by holding the power limit of grids.

VI. CONCLUSION

In this work, we have proposed a smart grid architecture along with implementation of heuristic algorithms (BFA, GWO, EDE and EHO) in comparison to unscheduled load. Electric cost can be decreased by decreasing the consumption of energy as well as by scheduling appliances and diminishing waiting time.In this work, a smart grid architecture is proposed for users flexibility. Multiple techniques have been applied in this work, for electricity cost, energy consumption and PAR reduction based on CPP signals in the residential area. To give a parity among cost-viability and machine utility clients have been given the straightforwardness to pick among them as indicated by their necessities.

GWO have reduced the electricity consumption 15% to BFA and EDE, where as 22% of electricity is decreased by GWO in comparison to EHO. It further offered to reduce peak, by utilizing electricity during off-peak-hours. EDE here outperforms in controlling PAR as compared to other scheduling techniques. EDE reduces PAR 30% as of EHO, 56% to BFA and 62% of EHO. On the other hand, waiting time of appliances is increased on the basis of the priorities assigned to the appliances, in order to enhance user comfort. EHO performs 5% better than the EDE where as waiting time of GWO AND bfa IS increased by 60% and 72%, respectively.

The proposed algorithms have given the optimal solution as indicated by client ease, by giving the decision among scheduling algorithms. Moreover, these heuristic algorithms can be upgraded by improving these parameters and upgrading the execution. We have considered the load scheduling and power trading issue at the same time in a smart home. Moreover, to explore the adequacy of our proposed work, a comparison of different techniques has been carried out. Reduction in electricity cost, PAR and increase in user comfort is obtained due to outflanks performance of our proposed framework. However, as user is given the choice for selecting the desired optimal scheduling technique, one can get offended by choosing these techniques on daily basis or each time. So, for this purpose a machine learning algorithm will be proposed for providing further ease to the user.

In future, we will evaluate the performance of our proposed technique for other electric consuming sectors, i.e., commercial and industrial as well. Our main focus will be integration of energy renewable resources for further cost reduction and energy consumption. In addition to that, our main priority is to provide comfort to the users. As choosing scheduling technique each time a day can be hectic or may irritate user. So, to increase user comfort and reliability we will provide new mechanism. In this regard, we will-in cooperate machine learning algorithm for smart grids for providing user the ease for not choosing the techniques each time. It will be trained to learn the pattern on which the user is choosing their techniques and then perform according to those patterns. This will provide more ease to the user and make their life easier.

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ZUNAIRA AMJAD received the M.S. degree in computer science from COMSATS University Islamabad, Pakistan. Her current research interests include resource allocation and management in smart grid and integration of state of the art technologies in 5G enabled vehicular networks.

MUNAM ALI SHAH received the B.Sc. and M.Sc. degrees in computer science from the University of Peshawar, Pakistan, in 2001 and 2003, respectively, the M.S. degree in security technologies and applications from the University of Surrey, U.K., in 2010, and the Ph.D. degree from the University of Bedfordshire, U.K., in 2013. Since July 2004, he has been an Assistant Professor with the Department of Computer Science, COMSATS University Islamabad, Pakistan. He is the author of more than 190 research papers published in international conferences and journals. His research interests include MAC protocol design, QoS, and security issues in IoT-based systems. He received the Best Paper Award from the International Conference on Automation and Computing, in 2012.

CARSTEN MAPLE (Member, IEEE) is currently the Director of research in cyber security and a Professor of cyber systems engineering with the Cyber Security Centre, University of Warwick, where he leads the GCHQ-EPSRC Academic Centre of Excellence in Cyber Security Research. He is the Privacy and Trust Stream Lead and has led the project constellation in transport and mobility with PETRAS, the U.K. research hub for cyber security of the Internet of Things. He is also a Principal or a Co-Investigator for a number of projects in cyber security. He is currently, or has recently been, funded by a range of sponsors, including EPSRC, EU, DSTL, the South Korean Research Agency, Innovate U.K., and private companies. He has published over 200 peer-reviewed articles and has provided evidence and advice to governments and organizations across the world, including being a high-level scientific advisor for cyber security to the European Commission. He is a member of various boards and expert groups. He is also a Fellow of The Alan Turing Institute. He is the Immediate Past Chair of the Council of Professors and Heads of Computing, U.K.

HASAN ALI KHATTAK (Senior Member, IEEE) received the B.C.S. degree in computer science from the University of Peshawar, Peshawar, Pakistan, in 2006, the master's degree in information engineering from the Politecnico di Torino, Turin, Italy, in 2011, and the Ph.D. degree in electrical and computer engineering from the Politecnico di Bari, Bari, Italy, in 2015. He is currently serving as an Associate Professor with the School of Electrical Engineering and Computer Science, National University of Sciences and Technology, Islamabad, Pakistan. His research interests include the application of machine learning and data sciences for improving and enhancing quality of life in smart urban spaces through predictive analysis and visualizations. He is an Active Member of the IEEE ComSoc, the IEEE VTS, and the Internet Society.

ZOOBIA AMEER received the master's degree in solid state physics from the Center for Solid State Physics, University of the Punjab, Lahore, and the Ph.D. degree in bio-molecular magnetic materials from the University of Salento, Lecce, in 2016. She is currently working as an Assistant Professor with the Department of Physics, Shaheed Benazir Bhutto Women University, Peshawar, Pakistan. Her recent work has been published in several reputed journals. She has been actively involved in various funded projects related to synthesis of DNA-based sensors for cancer detection and drug delivery. Her research interest includes characterization and fabrication of DNA-based sensors that can be used for invasive diagnosis as well as drug delivery.

MUHAMMAD NABEEL ASGHAR received the Ph.D. degree from the University of Bedfordshire, U.K., with a focus on modeling for machine vision, specifically digital imagery, and its wide spread application in all vistas of life. He is currently an Assistant Professor with the Department of Computer Science, Bahauddin Zakariya University, Pakistan. He has been investigating machine learning approaches for analyzing video content ranging from broadcast news, sports, surveillance, personal videos, entertainment movies, and similar domains, which is increasing exponentially in quantity and it is becoming a challenge to retrieve content of interest from the corpora, and also on their applications, such as information extraction and retrieval. His recent work is concerned with multimedia, incorporating text, audio, and visual processing into one dynamic novel frame work. His research interests include information retrieval, computer graphics, computer vision, image processing and visualization, graphics modeling and simulation, CR MAC protocol design, the Internet of Things, and security issues in wireless communication systems.

SHAFAQ MUSSADIQ received the Ph.D. degree from the National University of Sciences and Technology (NUST), Pakistan. She is currently an Assistant Professor with the Institute of Information Technology, Kohat University of Science and Technology, Pakistan. Her research interests include machine learning, deep neural networks, and big data in education.