Journal of Quantum Computing
DOI:10.32604/jqc.2020.016151
Article

Big Data of Home Energy Management in Cloud Computing

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Received: 08 November 2020; Accepted: 27 December 2020

Abstract: A smart grid is the evolved form of the power grid with the integration of sensing, communication, computing, monitoring, and control technologies. These technologies make the power grid reliable, efficient, and economical. However, the smartness boosts the volume of data in the smart grid. To obligate full benefits, big data has attractive techniques to process and analyze smart grid data. This paper presents and simulates a framework to make sure the use of big data computing technique in the smart grid. The offered framework comprises of the following four layers: (i) Data source layer, (ii) Data transmission layer, (iii) Data storage and computing layer, and (iv) Data analysis layer. As a proof of concept, the framework is simulated by taking the dataset of three cities of the Pakistan region and by considering two cloud-based data centers. The results are analyzed by taking into account the following parameters: (i) Heavy load data center, (ii) The impact of peak hour, (iii) High network delay, and (iv) The low network delay. The presented framework may help the power grid to achieve reliability, sustainability, and cost-efficiency for both the users and service providers.

Keywords: Cloud computing; virtual machine; data centers; internet of things; big data in smart grid

1 Introduction

A smart grid is the advanced version of a power grid with the incorporation of advanced sensing, communication, computing, monitoring, and control technologies. These technologies not only make the power grid intelligent but also make the power system sustainable, secure, and economical. To implement the smart grid in the proper sense, a large number of smart devices (i.e., sensors and smart meters) are installed with huge coverage that produces a large volume of heterogeneous data. The mined (useful) information from this data can be helpful to increase the quality of the smart grid from the perspective of a utility company. It also provides better services to the customer as compared to the traditional grid. Hence the use of big data in the smart grid offers a lot of benefits. The authors in [1] presented a model to find a suitable location for wind turbines. IBM has used four petabytes of historical data to form a module. The model helped to improve the efficiency and also improve the service life however, the transmission of big data in smart grid possess several challenges due to the massive data. In comparison to wired, wireless technologies have some unique benefits, i.e., easy deployment, easy expansion, and most importantly are economical. Moreover, due to the advancement in technology, wireless communication has a high data rate and is also considered as reliable. A lot of work is being done on wireless communication in the smart grid. For example, in [2], the authors studied the cognitive technology of spectrum resource management in the smart grid. Wireless communication offers capable support for big data transmission.

There are several applications of big data in the smart grid and those are classified as follows: Demand response, customer profiling, network planning, and pricing. Previously, a few research studies are published in this research field, i.e., in [3], the planning problem of energy storage. There is still a research gap in the planning of the consumer side and by keeping this in view we have presented a Renewable Energy Source (RES) for each home that consists of a solar or wind turbine with a battery storage system. The power consumption will be taken into account from the RES or from the local utility (when the RES cannot fulfill the demands of some appliances). The deployed smart meter will collect the consumption from the local utility and will communicate to the cloud. The load may vary based on the change in the day time. Power Generation Sources (PGSs) and Power Consumers (PCs) are connected by a common bus. PGSs (i.e., PV panels and wind generation) having similar DC-AC converter, may load a uniform usage of power. The Power Utilization Ratio (PUR) is calculated by Eq. (1) and Eq. (2) where POWtot is the total power received at the controller station and POWgen is the sum of power generated at host sources [4,5].

$$PUR_i = \frac{POW_i}{\sum_{i=1}^{n} POW_I} \tag{1}$$

$$POW^{t0t} = \sum_{i=1}^{n} POW^{gen} \tag{2}$$

The main contribution of this article is to propose and simulate a big data framework in the field of smart grids. The framework comprises the following layers: (i) Data source layer, (ii) Data transmission layer, (iii) Data storage and computing layer, and (iv) Data analysis layer. The data generated at the *data source layer* is deployed by devices, i.e., sensors and smart meters. The *data transmission layer* is responsible to take the data from the *data source layer* and pass it to the *data storage* and *data processing layers* respectively. The *data transmission layer* acts as a bridge among *the data source, the data storage,* and *the data processing* layers. The smart grid causes to produces a massive amount of data (big data) that cannot be processed by normal computers. Therefore, a *data storage and computing layer* is required to store and process data on the cloud. The *data analysis layer* is responsible for mining useful information from large data using different tools and techniques. The offered framework is simulated by the dataset of three cities of the Pakistan region.

The rest of the paper is organized as follows. Section 2, presented the related work. Section 3 providing the motivation to conduct this research. Section 4 formulated the problem and also described the system model. The experiments are analyzed and discussed in Section 5. Finally, the conclusion is presented in Section 6.

2 Related Work

Cloud computing-based big data in smart grid is described in [5], the main focus is to deploy energy storage system in consumer's end and optimally schedule the consumption of the energy in the storage and utility company context. Cloud-based big data architecture is presented to process the data generated by the smart meters and the sensors that are installed in the electric power system. Moreover, a Genetic Algorithm (GA) based scheduling mechanism is also offered. The main emphasis of this research is on wireless transmission but the computing and analytics effects are missing. In [6], Dynamic Demand Response (DDR), cloud-based software built for data-driven analytics in smart grid is presented. By way of the demands of consumption change with time may cause a mismatch in demand and response, the proposed solution detects and preemptively adjusts the demand response mismatch accordingly. The presented work is implemented by use of the machine learning approaches on big data to sense the dynamic load of different appliances and handle the dynamic load. According to the authors, the system is contributed by personnel of multiple disciplines such as data analysts, engineers, behavioral psychologists, and micro-grid managers. The idea published in this research is implemented in the real environment but the interaction of smart meters and sensors with the cloud is not shown.

Daki et al. discussed the analytics of Big Data for dynamic energy management in smart grid in [7]. This paper is a met-analytical review on the efficient processing of dynamic energy management. The insight into the analytics of Big Data and dynamic energy management in smart grids is elaborated precisely. The importance of data mining and predictive analytics is also specified by solid justifications. Diamantoulak et al. in [8] described a *smart electric power grid* using cloud computing. This paper discusses the use of different tools and techniques to improve energy efficiency and reliability. Firstly, the authors illuminated the pros and cons of the traditional energy sources i.e., limited fossil fuels and its threat to human life, and global warming. Secondly, the authors deliberated the monitoring and controlling of electrical energy to reduce the energy consumption or shift the peak hours load to the off-peak hours and termed it a virtual power generation. According to the research published in [9], the electrical power system is one of the largest artificial systems and is also considered as the weakest system in the context of lengthening different areas. A little catastrophe can cause the power to be unavailable for a long time in the whole or the larger part of the system. Cloud computing is projected for optimal dispatch, simulation of power, and to increase the computation power. Cloud computing can also make the system reliable, secure, efficient, and help to recover the early faults. Intelligent decision automatically helps to make the fault limited to a small region. These research works are further needed to be strengthened through experiments.

Fang et al. [10] published their research about the optimal resource allocation in the smart grid. Authors presented that the resources, provided by cloud computing, i.e., memory and processing, are categorized as reserved instances (RSIs) and on-demand instances (ODIs). RSIs are chosen as first reserved with an upfront payment and then can be availed at any time. ODIs are not needed to choose as reserved and sometimes it is not available for use. The RSIs are more economical if resources are to be used for a long time, but the ODIs are economical when the instances are needed for short periods of time. To achieve a better allocation of resources, two states of the art algorithms (Simulated Annealing and modified priority list (MPL)) are implemented and compared where the MPL is considered as more efficient. Although the idea is implemented on real devices, the processing and delay caused by the network are not considered.

Al-Faruque et al. introduced Energy Managements as a service Over Fog Computing Platform in [2,11] and described a case study to show the importance of energy management. Although most of the energy is consumed by the residential buildings therefore the main focus of the published work is on home energy management (HEM). Different hardware, software, and communication technologies related to the HEM are discussed in detail. By focusing on Fog Computing, two prototypes on the home, and micro-grid level for HEM were implemented. The system has a small scope and is implemented on an abstract level. According to the work published in [12], the smart grid is considered as an electrical distribution network for future generations. With the production of energy from green energy sources, the control and monitoring of energy are discussed in the context of the smart grid. A fog computing based simple but realistic reference model (with its advantages) for smart grid is enumerated because the smart grid generates a huge amount of data. The fog computing environment is planned to store and process the data. The published model (and the hypothesis) needs to be supported by solid experiments and justifications.

According to the work published by Markovic et al. in [13], each building has a sufficient number of smart gadgets, i.e., smartphones, digital cameras, personal digital assistants, and many more that operate on DC power. To supply DC power to these appliances, there can be a local DC nano grid in the house as an alternative to supplying AC from a local utility having some line and rectification losses. The extra power can be saved in battery storages to make the building self-sustainable. The energy sources (i.e., solar and wind) are considered intermittent sources that need intelligent decisions for integration. While handling intermittent energy sources on the micro-grid level, a huge amount of data can be handled efficiently by cloud computing.

From the above discussion, it can be concluded that (i) the smart grid is an emerging field to fulfill the increasing demands of energy, and (ii) cloud computing is an important component of the smart grid. Although a few research studies have been published on cloud computing in the smart grid, it is still an emerging field and a lot of work needs to be done.

3 Methodology

Smart grid is a new era equipped with advanced sensing, communication, computing, and monitoring technologies in order to bring sustainability and security to the power grid. The main purpose is to make the grid system economical for power suppliers as well as for the consumers [14]. To implement smart grid sensing in the real environment, several sensors and smart meters are installed that cause to produce a large volume of data (big data). Big data cannot be handled by a traditional computing environment. It is handled by cloud computing that provides resources (IaaS, PaaS, and SaaS) on demand and is reliable, scalable, and secure [15]. The useful information can be extracted or mined from this dataset which is helpful to improve the quality of utility companies but also provide better services to the customer [2,11]. Cloud Computing is one of the most promising and exciting features of the recent development in ICT [4] and it is also helpful for better energy management [16].

Motivated from studies published by Cao et al. in [5] and [17] where authors elaborated the importance, features, opportunities & challenges to the smart grid and also presented an architecture for wireless big data analysis. Inspired by this generic architecture, we have improved this architecture further and simulated it on the dataset of three cities of the Pakistan region.

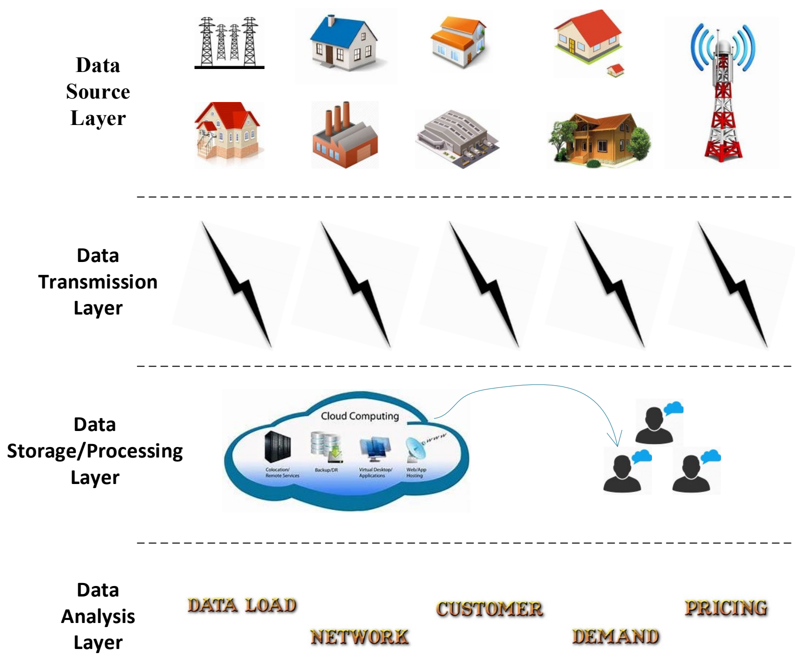

Figure 1: Architecture of the cloud-based smart grid system

In this research study, we have assumed that each city comprises a set of homes *N* and each home *n* has a smart meter and a RES. A utility company is responsible to provide power to homes of the cities. The data sources and transmission lines are equipped with sensors to monitor and control power consumption. A centralized data center is considered because a separate data center is not feasible for each city. The power consumption in a home may be recorded either from the local utility or RES. The smart meters will record the consumption from the local utility and will communicate to the cloud.

3.1 System Architecture

According to the work published in [18], the smart meters generate a huge amount of data that can be analyzed through different machine learning (big data) approaches. By considering generated data, firstly, customer's profiles are maintained by forming different clusters of similar customers to manage easily. Secondly, the analysis may help in the load forecasting process to achieve sustainability and reliability. Thirdly, on one hand, a network is planned and on the other hand, the demand response is managed (easily and efficiently). The generated big data needs to be processed on capable machines by cloud computing techniques.

In this research work, a system is described to process the big data on the cloud computers generated by the smart grid. The system is further divided into four layers (also shown in Fig. 1). The four layers are (i) The data source layer, (ii) The data transmission layer, (iii) The data storage and processing layer, and (iv) The data analysis layer and are described as follows.

3.1.1 The Data Source Layer

In the data source layer, the data is recorded by using the installed smart meters and sensors. There are three types of components in the data source layer: smart home, intelligent generating source, and intelligent transmission. The data generated by different sources can be monitored and controlled, sets according to the needs and requirements. As monitoring and controlling of the data is considered as a real-time activity and the data generated sources need to be processed dynamically. The transmission system needs to be prepared as intelligent by installing diverse sensors that may help to identify faults. Faults can be identified on a short term basis and may limit the scope to a small area. The main purpose is to manage faults from their escalation in the system and may result to avoid system malfunction. Every home is equipped with a smart meter and a RES, and mostly by a solar (installed with a battery). All homes use RES energy and if some appliances cannot fulfill the needs then will consume power locally. The data related to the local utility for each home is recorded by its smart meter and sent to the cloud for storage and further processing.

3.1.2 The Transmission Layer

The transmission layer is responsible for propagating data from the data source layer to the data storage and processing layer. The data transmission can be controlled by both of the mediums (wired or wireless) but due to the strong and wider cellular signal availability, the wireless mode of transmission is more suitable than the wired for Neighbor Area Network (NAN) [19].

3.1.3 The Data Storage and Processing Layer

The data storage and processing layer are responsible to store data in the cloud and process it through high-speed processing units in the cloud computing environment. On a cloud, different machine learning (data mining) and other data extraction tools can be applied to extract useful information from the data.

3.1.4 The Data Analysis Layer

In the data analysis layer, useful information can be extracted by applying different machine learning approaches. In this layer (a) the customers' profiles are maintained that may help design different decisions according to provided services, (b) the power load is forecasted, (c) the network is planned by receiving information i.e., where and how to extend, and (d) the prices are calculated and can be accessed from anywhere by the users.

When data sources of homes interact with the cloud server, it may cause congestion on the network. Therefore, a home called a focal home is assigned the responsibility to collect data from nearby homes and transmit data to the cloud. The collection and transmission of the data through a focal home is periodic and has a limited time-interval to communicate its demand timely to the server. In Eq. (3), where P_n is the packet data created by focal home and is the sum of the collection of data of each home P_i.

$$PP_n = \sum_{i=1}^{n} P_i \tag{3}$$

Power obtained by each house per hour from the utility can be calculated by Eq. (4) and is useful for billing purposes and also for power management.

$$T_{PU} = UH_1 + UH_2 + \cdots UH_n \tag{4}$$

where, T_{PU} is the total power and UH is the power recorded from the utility company per hour. It is obvious that UH_1 and UH_2 show hours from 1 to 24. Similarly, the total power consumed by each home from the renewable energy sources per hour can be calculated by Eq. (5). Where T_{Pr} is the total power recorded from the renewable energy sources and *RH* is the power recorded from renewable energy sources per hour.

$$T_{Pr} = RH_1 + RH_2 + \cdots RH_n \tag{5}$$

4 Experiments and Results

Processing of big data in the smart grid is implemented for three cities of the Pakistan region. While on average, a power supply company supplies power to three cities whereas it can be extended to more than three. A city comprises of houses (between 800 and 30,000), a utility company having distribution system provide power and transmission. All the residential, commercial, and hospital buildings along with utility companies and transmission systems are connected to the cloud system. In a simulation, data centers are not considered in cities because it is not feasible to have a data center practically. The houses of one city can process their data in a data center located in a different city with a little delay due to the following reasons: network delay, load on the data center, and the processing speed of the systems. These are considered as key factors and are analyzed by experiments (in this research study). The basic configurations of experiments are shown in Tab. 1, Tab. 2, and Tab. 3.

Table 1: Basic configurations of buildings

CB	Stations	R/H	DS/R	PHS	PHE	APU 2000	AOPU 900
Building1	1	60	100	3	9	2000	900
Building2	2	60	100	3	9	3000	800
Building3	3	60	100	3	9	2500	1100
Building4	1	60	100	3	9	3000	1200
Building5	2	60	100	3	9	2500	900

Table 2: Basic configurations of data centers. C/Vm for Cost

Name	Region	Arch	OS	VMM	C/V	MMC	SC	DTC	PHW
DC1	3	x86	Linux	Xen	0.1	0.05	0.1	0.1	1
DC2	4	x86	Linux	Xen	0.1	0.05	0.1	0.1	1

Table 3: Basic configurations of virtual machines

	No. of Virtual Machines	Image size (KB)	Memory (MB)	BW (MB)
DC1	5	1000	512	1000
DC2	5	10000	512	1000

4.1 Response Time

The response time is considered an important criterion to measure the efficiency of the system. It is the time taken by a system to react to a specific event. Systems often preferred to reduce the response time as much as possible but there is a trade-off with the cost factor. To keep the system cost-effective, by reducing the response time, two data centers are placed in such a way that one is employed in home city while the other one is sited at a different city (other than a home city). The data center placed in the home city responds immediately to the data processing and storage requests. Although, in reality, it is not possible to place different data centers in all cities however in this study we have considered both of the scenarios.

The response time of the data centers is shown in Fig. 2. The response from cloud to the buildings is as:

- B1 is a building located in a different city (other than the home city) and the data center is heavily loaded therefore the response time is very high. The response time is recorded as high in peak hours.
- B2 is a building located in a different city however the data center is not heavily loaded. Here the response is delayed by the network latency only.
- B3 is the building located in the data center of the same city. In this case, the data center is heavily loaded but devises lower network latency. The curve in Fig. 2 shows that the response time is recorded as very low.

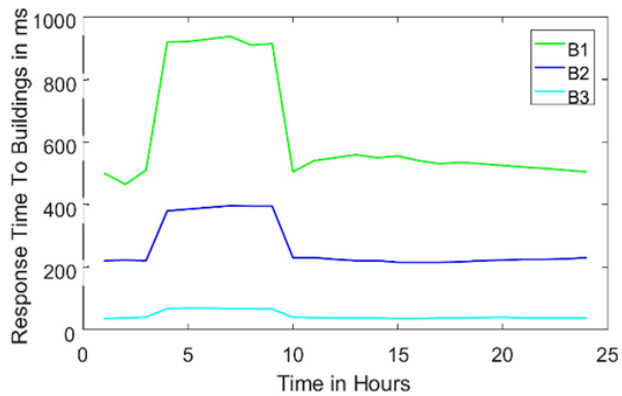

Figure 2: Response Time to Buildings. B1 means Building 1, B2 means Building 2 and B3 means Building 3

4.2 Processing Time

The processing time is a time interval, a system takes to execute. To calculate the processing time, we have considered two data centers. The first one is located in the same city that receives the data of two contagious cities, and the second one is located in a different city and receives the data of one city only. The processing time of the cloud-based data centers is shown in Fig. 3 and illustrates that the processing is affected by the increase of data in the peak hours.

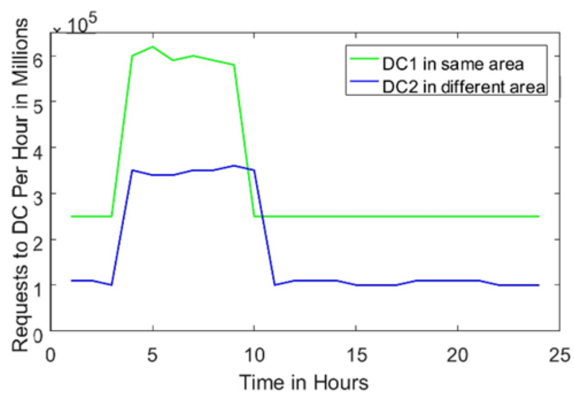

Figure 3: Processing Time, DC1 means Data center1 and DC2 mean Data center2

The data center 1 (DC1) is placed in the same city where buildings/homes are located and can receive requests from nearby cities. The processing time of DC1 is recorded as high due to the overload of the data put away by both cities. The overload is recorded in peak hours because most of the smart meters are sending requests to cloud computers. DC2 is placed in a different city (other than the city where buildings are located) but processes the data of only one city. In this case, the processing time is recorded as low. Although there is a data load but not overloaded. Hence the processing time is important for those data centers which are placed and processed on cloud computing.

The processing time is considered as extremely important for the applications having critical tasks, i.e., hospitals, electricity generation monitoring centers, heat control centers, and the applications that are analyzing the streaming data (coming from different sources).

4.3 Cost

There can be multiple costs in a smart grid, i.e., power consumption billings, local Internet billings, etc. but in this experiment, we will consider the *usage of the cloud computers cost*. We have undertaken two data centers and each of them has the following specification:

System architecture:	x86,
Operating system:	Linux,
Virtual Machine Manager:	Xen,
Cost per VM:	0.1 $/hour,
Memory Cost:	0.5 $/s,
Storage Cost:	0.1 $/s,
Data Transfer Cost:	0.1 $/Gb and
Physical Hardware:	1 unit with 5 VMs on each.

The simulation is executed for 24 hours and the system will process the data of all the affiliated instances by considering the peak and off-peak hours. Tab. 4 shows the total cost of each data center.

Table 4: Cost of using data centers for 24 hours

	VM Cost	Data Transfer Cost	Total
DC1	12.001	42.464	55.06

4.4 Scheduling to Reduce the Cost

To reduce the consumers' cost, the authors proposed a scheme in [16] and suggested that use RES when an average or below average load is needed. Based on this scheme customers *N* (having a smart meter), are requesting some energy from a local company and are producing some energy from RES at the residential host station. The overall load of each customer for 24 hours can be shown by Eq. (6).

$$l_n = \{l^1_{n,}\, l^2_{n,}\, l^4_{n,} \dots l^{24}_{n,}\} \tag{6}$$

where *N* represents the number of users getting power from the grid, customer *n* defines a vector l_n that shows the used power load and his an hour from the set of hours *H= {1, 2, 3….24}*.

Similarly, the overall power load of the grid can be calculated by Eq. (7).

$$L_b = \sum_{n=1}^{N} l_n^h \tag{7}$$

The peak and average load in a local grid can be calculated by Eq. (8) and Eq. (9) respectively.

$$L_{peak} = max_{heH}\, L_h \tag{8}$$

$$L_{avg} = \frac{1}{24} \sum_{heH} L_h \tag{9}$$

Another important factor in the power system is the peak-to-average ratio (PAR) that can be calculated by the virtual machine migration task and also shown by Eq. (10).

$$PAR = \frac{L_{peak}}{L_{avg}} = \frac{24 max_{h\epsilon H}\, L_h}{\sum_{h\epsilon H} L_h} \tag{10}$$

Virtual Machine (VM) can be placed at different data centers by different number and size of resources *VMi*. When a VM located at specific station is not working (running up) with its full potential, it is essential to switch it off and its load can be transferred to the other VM located at the other data center. VM migrations require a unified policy to calculate the migration cost. The network cost is computed by considering the number of incoming requests *I*, number of channels *C*, and the available bandwidth *B*. Based on these parameters, the current migration cost on the network can be computed by Eq. (11):

$$Cost = IX \frac{B}{C} \tag{11}$$

The experiments have shown that the framework is supportive to achieve reliability, sustainability, and cost efficiency for the users as well as for the services providers. Besides wherewithal publicized by offered framework, it also has some shortcomings that must be revealed in future. The framework can further be improved by integrating the effective machine learning methods.

5 Conclusions

A cloud computing based framework for the smart grid by integrating a big data approach has been described in this article. The framework has been designated by considering the following four layers: data source, data transmission, data storage/processing, and data analysis. A case study has simulated by taking the dataset of three cities of Pakistan region and by considering two cloud-based data centers. Results show that the heavy load (on data centers) and network latency can decrease the overall efficiency by creating a delay in response time. This study suggests that it can be useful to have a local data center to reduce the data load and network latency. The presented framework may helpful for the power grid to achieve reliability, sustainability, and cost efficiency for both the users and services providers. In the future, the framework can be improved further by incorporating efficient machine learning approaches in the proposed framework. The data analysis in the smart grid can be explored further by using advanced approaches.

Acknowledgements: This work was supported by the National Natural Science Foundation of China (61871058).

Funding Statement: The author(s) received no specific funding for this study.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

References

[1] A. Khan, "Cloud security analysis for health care systems," *International Journal of Computers Communications & Control*, vol. 3, no. 1, pp. 23–31, 2016.

[2] H. Farhangi, "The path of the smart grid," *IEEE Power & Energy Magazine.*, vol. 8, no. 1, pp. 18–28, 2010.

[3] J. Lee, "A view of cloud computing," in *International Journal of Computers Communications & Control*, vol. 1, no. 1, pp. 2–8, 2013.

[4] K. Arshid, I. Hussain, M. K. Bashir, S. Naseem and I. A. Khan, "Primary user traffic pattern based opportunistic spectrum handoff in cognitive radio networks," *Applied Sciences-Basel*, vol. 10, no. 5, pp. 1–19, 2020.

[5] Z. Cao, J. Lin, C. Wan, Y. Song, Y. Zhang *et al.,* "Optimal Cloud Computing Resource Allocation for Demand Side Management in Smart Grid," *IEEE Transactions on Smart Grid*, vol. 8, no. 4, pp. 1943–1955, 2017.

[6] G. Carpinelli, G. Celli, S. Mocci, F. Mottola, F. Pilo *et al.,* "Optimal integration of distributed energy storage devices in smart grids," *IEEE Transactions on Smart Grid*, vol. 4, no. 2, pp. 985–995, 2013.

[7] H. Daki, A. El Hannani, A. Aqqal, A. Haidine and A. Dahbi, "Big data management in smart grid: Concepts, requirements and implementation," *Big Data*, vol. 4, no. 1, pp. 1–19, 2017.

[8] P. D. Diamantoulakis, V. M. Kapinas and G. K. Karagiannidis, "Big data analytics for dynamic energy management in smart grids," *Big Data Research.*, vol. 2, no. 3, pp. 94–101, 2015.

[9] B. Fang, X. Yin, Y. Tan, C. Li, Y. Gao *et al.,* "The contributions of cloud technologies to smart grid," *Renewable & Sustainable Energy Reviews.*, vol. 59, no. 1, pp. 1326–1331, 2016.

[10] X. Fang, S. Misra, G. Xue and D. Yang, "Smart grid–The new and improved power grid: A survey," *IEEE Communications Surveys and Tutorials*, vol. 14, no. 4, pp. 944–980, 2012.

[11] M. A. Al Faruque and K. Vatanparvar, "Energy management-as-a-service over fog computing platform," *IEEE Internet of Things Journal.*, vol. 3, no. 2, pp. 161–169, 2016.

[12] N. Kumar, A. V. Vasilakos and J. J. P. C. Rodrigues, "A multi-tenant cloud-based DC nano grid for self-sustained smart buildings in smart cities," *IEEE Communications Magazine*, vol. 55, no. 1, pp. 14–21, 2017.

[13] D. S. Markovic, D. Zivkovic, I. Branovic, R. Popovic and D. Cvetkovic, "Smart power grid and cloud computing," *Renewable & Sustainable Energy Reviews.*, vol. 24, no. 1, pp. 566–577, 2013.

[14] S. Rusitschka, K. Eger and C. Gerdes, "Smart grid data cloud: A model for utilizing cloud computing in the smart grid domain," in *First IEEE International Conference on Smart Grid Communications*, pp. 483–488, 2010.

[15] Y. Simmhan, S. Aman, A. Kumbhare and R. Liu, "Cloud-based software platform for big data analytics in smart grids," *Computing in Science & Engineering.*, vol. 15, no. 4, pp. 38–47, 2013.

[16] R. Yu, C. Zhang, X. Zhang, L. Zhou and K. Yang, "Hybrid spectrum access in cognitive-radio-based smart-grid communications systems," *IEEE System Journal*, vol. 8, no. 2, pp. 577–587, 2014.

[17] F. Y. Okay and S. Ozdemir, "A fog computing based smart grid model," in *2016 Int. Symp. Networks, Comput. Commun, ISNCC 2016*, pp. 1–6, IEEE, 2016.

[18] P. Purohit, "A study on use of big data in cloud computing environment," *International Journal of Computers Communications & Control*, vol. 3, no. 1, pp. 1312–1318, 2015.

[19] E. Vayena and A. Blasimme, "Biomedical big data: New models of control over access, use and governance," *Journal of Bioethical Inquiry*, vol. 14, no.4, pp. 501–513, 2017.