



A Review on the Challenges and Future of Energy Consumption in Edge Computing

¹Departement of Computer Science,
University of New Haven, USA

¹Rhoda Ajayi
^{2*}Kadir Ahmed Ibrahim
³Muhammed Muktar Tambuwal

^{1,2,3}Department of Computer Science,
Kaduna Polytechnic Kaduna Nigeria.

*kadry_ibrahim@yahoo.com

Abstract: Global warming has posed a serious threat to humanity's survival, the carbon dioxide (CO₂) concentrations in the atmosphere are widely acknowledged as its primary cause. As a result, global attention to energy conservation has increased dramatically in order to limit CO₂ emissions. Brown energy remains a big challenge; as such much need to be done to reduce the emission of carbon to the atmosphere. The traditional understanding of using the ground as a temperature moderator against harsh weather has great potential to become a strong remedy against the energy inefficiency of a building Heating, Ventilation and Air conditioning (HVAC). Attempt has been made to elaborate the thermal performance characteristics and conduct more research into the benefits and downsides of this passive cooling approach from many perspectives of long-term sustainability. Edge computing (EC), a novel computing paradigm innovation, has high potential to help with digitization. A lot of researchers have done review in cloud computing but few work on review of energy consumption, therefore, the purpose of this research is to review literature about challenges and future of energy consumption in edge computing, the paper present challenges in energy consumption and how other researchers applied different algorithms, simulators, performance metrics, type of energy used, and optimization problems to address the issue of sustainable energy.

Keywords: edge computing, energy consumption, sustainable energy management.

1 INTRODUCTION

During the last decade, cloud computing paradigm has revolutionized the horizon of computing. With the emergence of modern economy, cloud computing has thus allowed the establishment of new businesses in a very small amount of time, encouraged the development of initiative around the globe, it also enhanced the speed of scientific progress, and to the creation of various computing approaches for widespread and global application. Cloud computing paradigm provides on demand services to the end users such as software, storage and other computing services. Furthermore, it makes storage of data remotely possible by creating a data center that may be geographically distant from their users, thereby requiring the transfer of data from their source to infrastructure that can process it. The term Edge Computing refers to fixed and mobile network for processing, storage, and optimization at the edge. Edge computing was introduced as a bottle neck solution on cloud by placing computing resources close to sensors. IoT applications ultimately aim to provide seamless services without user intervention. Likewise, the inefficient use of Edge of things or Internet of Things (EOT/IoT) resources often triggers a significant increase in energy consumption, which definitely invokes the need to build techniques that are responsible for managing energy consumption IoT computing infrastructure. The Internet of Things (IoT) based



application interact on the demand of end users' side with the smart meter (SM) which track and regulates the appliances according to the information received from the utility for effective and efficient power usage).

Different techniques of data compression have also been studied and tools used within several key points to be explored in IoT devices and system development to decrease the protocols in Edge computing also helped to reduce energy usage. However, this review included among other things like taxonomy, graphical analysis and covered the most recent research issues. Benefits and challenges for Edge computing with different methods to be used in reducing wireless network energy consumption were also studied [1].

Inclusive review of existing edge computing technologies and techniques that have been used to reduce data processing, transmission and how to enhance efficiency and effectiveness of mobile data analytics. Integrated deep learning and edge computing technologies that would result in research based on Edge computing intelligence service were carried out [2]. This provides a list of open-source software according to their applicability. They introduced some optimization of edge computing technologies for energy efficiency and deep learning. Highlights open areas for edge computing design and analysis. Survey of edge data management in computing that explores the design, data flow, control and tenancy. The technology used in the management of resources, such as the use of software, hardware and middleware technologies. They also introduced several algorithms used in Edge computing services to help load balancing, placement, discovery and benchmark. All of the above highlights the Edge computing services ' data privacy and security, data compression, energy efficiency, and heterogeneity [3]. The breaking down of sustainable cloud computing into application design, energy management, capacity planning, virtualization, refrigeration, thermal conscious scheduling and waste heat use and compression of current technologies, based on their characteristics and common properties on scalable cloud computing of modern architecture and algorithms in data center management, reducing energy consumption through aggregation of virtual machines [4].

Survey on potential optimal network performance and information Centric Network (ICN) over Edge computing aimed at providing effective techniques that would shorten response time to address the Big Data Management, Latency, Availability, Security and Naming issues. The paper also looks at the definition of Edge computing, drivers, limitation and proposals. The highlight ICN overview in Edge computing and its inspiration with the various effort for the vendors ' software and hardware solution. They also research edge computing taxonomy approaches defined by different characteristics (e.g., aims, computing platform and attributes) and other computing. Edge computing requirement that provides connectivity for real time, local processing, high data rate and high availability [5].

The research on designing a novel edge computing reference architecture for future by accounting key attribute. The main objective is to achieve real time data analysis to minimize operational and management costs by reducing traffic and data transmission between Edge and the Cloud. Edge computing improves application performance that withstand lower latency network compared with cloud for security improvement by the use of block chain technologies embedded into the infrastructure at lower IoT layer to the upper layer of the cloud this help to attain real time data processing at the local device level [6]. Developing numerous computing models for global and



ubiquitous applications for the next decade is the significant requirement for heterogeneous IoT and sensor on a larger scale. The requirement will pose many new challenges in cloud computing and create new methods and research strategies. This gives room to revisit the existing model in order to address issues of resource provisioning, scalability and security [20]. Review on the current energy efficient resource management approaches and policies with primary focus on Virtual Machine (VM) consolidation to reduce server energy consumption to support sustainable cloud computing, a holistic management method is needed on some resources such as processor, storage, network, memory and cooling requirements [7]. Furthermore, due to the dynamic change in processor variable clock rates can applied. It was also proposed the renewable encourage cloud service providers to place their Cloud data Centers (CDC) closer to the green energy infrastructure that are spread in different geographical locations [8].

2. ENERGY MANAGEMENT IN EDGE COMPUTING

With high increase demand of cloud computing services through distributed cloud data center that significantly increase the power which in turn result in higher operating cost as well as carbon emissions. Cloud data centers are now powered by renewable energy resources which increase the efficiency of cloud computing by reducing the use of fossil fuel, brown energy or grid electricity. With efficient energy mechanism similarly allows cloud computing sustainable which significantly reduce CO₂ footprint and heat waste consumption from server power by using free server cooling mechanism to have sustainable CDC. Different approaches to energy efficiency have been developed where cloud computing devices are now using less energy while delivering the same or higher service to end user [9]. A critical aspect of network design is generally ignored, in order to minimize overall energy consumption. Eliminating any possible gaps in coverage to provide universal network services is usually a primary goal in cell planning. Nonetheless, because wireless service demands are not evenly distributed across all geographic regions, this ideal approach will potentially damage the overall energy consumption of mobile networks. In reality, network implementation of the strategic interests of operators will deal with different approaches for hot-spot and rural areas.

Many works show that less power is consumed in a distributed infrastructure than conventional cloud computing. Nevertheless, as distributed computing is being carried out on smaller devices, with a primary aim of creating computing applications which will maintain a limited battery life. Since edge mining reduces the number of packets sent to cloud which result to the reduced amount of energy consumption. Proper resource management can also lead to high energy efficiency, with the goal of using free computing slots in edge clusters on smartphones. The above figure 1 explain the taxonomy of energy management in edge computing with four main sub-heading that leads to better energy efficiency in edge computing [10]. The subheadings are energy consumption, energy efficiency, power usage effectiveness and average data center efficiency.

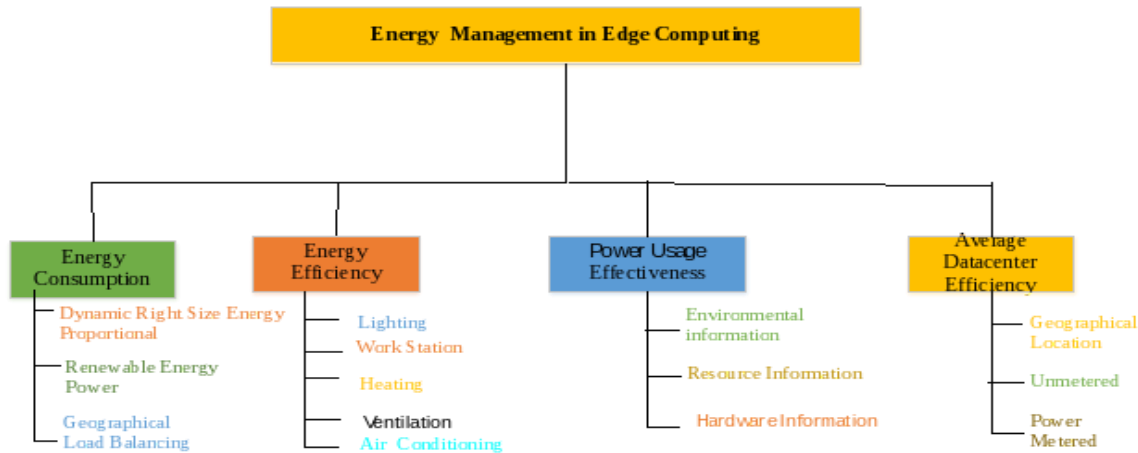


Figure 1: Taxonomy of Energy Management in Edge Computing (Source [9])

3. ENERGY CONSUMPTION

Due to the recent challenges in smart edge computing, there is a need to come up with an effective method that would minimize energy consumption of mobile edge device in wireless edge computing network. A non-dolomite sorting genetic algorithm II (NSGA II) is proposed with intention of reducing energy consumption and task offloading time. The algorithm was compared with local offloading and benchmark to prove its effectiveness in all the metrics and ensure devility of the population. But the algorithm is weak in user privacy protection and migration of tasks [11]. Proposal on energy efficiency dynamic offloading and resource scheduling algorithm for smart mobile edge device was proposed for better energy consumption [12]. The algorithm shows that offloading computation selection not only depends on the computing workload of task, but minimizes the completion time of clock frequency, predecessors and transmission of power to the mobile devices. The algorithm did well in reducing the energy consumption compared with tested algorithms. They also investigate mobile edge computing device with goal of minimizing device energy consumption, a modified non dominated sorting genetic algorithm II (MNSGA II) is proposed. The algorithm show that is very effective in computational latency and energy consumption. The simulation result revel that the algorithm has pare tor optimal compared with the greedy algorithm which gives its flexibility of choice. With all this work is needed to resolve issues of allocation and scheduling problems with the algorithm. This help in investigating the task of allocation of virtual machine (VM) and energy scheduling with aim to reduce brown energy consumption. Heuristic relaxation algorithm based is proposed with the intention of tackling random green energy and user demand challenges. The energy cost of joint consolidation of VMs, migration and green energy is minimized. Energy internet (EI) is used to compared with OPT, OTS, ATS and OWN to test the ability of the algorithm. Brown energy is also reduced to a minimum. The algorithm worst case is task processing energy consumption with local green energy. Modified non dominated sorting genetic algorithm III (MNDSGA III) was proposed in to reduces execution time and energy consumption in mobile edge devices through computation offloading approach. The algorithm effectiveness was proving by comparing with benchmark and other algorithm such as CCOM and CLCOM algorithms. The algorithm does not guarantee execution of large last to reducing energy consumption and execution time [13]. Proposal on algorithm reformed Schedule Method for Energy Consumption Constraints with the goal of reducing energy consumption and consumption time. The

Citation: Rhoda Ajayi et.al., *A Review on the Challenges and Future of Energy Consumption in Edge Computing*, IJMSS, 2023. 1(3): p.17-32



algorithm is compared with HEFT, MSLECC, RMEC and MPEG A to prove it's significant. The method can be applied in both large- and small-scale mobile edge applications. Low or high heterogeneity result to poor performance of the method. The work is based on heterogeneous vehicles for large applications. The work is compared with dual control and device to device forging D2D. The proposed work used Chimera algorithm for energy efficient and deadline of crossing framework. The algorithm is only applied in vehicle applications. [14] proposed and investigate in multi objective problem that try to overcome the issues of energy consumption, throughput, fairness, queuing, priority level classes and user equality requirement in WLAN. A Hybrid Cooperative Consultative Radio Network HCCRN is proposed. The algorithm is compared with CCRN to prove its effectiveness. The algorithm is good in most of WLAN application of edge computing [15]. Where a connecting edge dominating set based on semi graph model. These are based on connecting dominating set algorithm. The algorithm is aimed at reducing energy consumption and average data transmission. The algorithm is compared with DSDV and AODV for its effectiveness. Thus, algorithms have issue with fault tolerance. [16] used clustering technique by dividing the node into clusters, each of the edge node have maximum distance that define by the energy transfer attenuation ratio. The research is aimed at reducing the total energy of the clustering nodes within and outside the system. The work rescheduling heuristic method algorithm. To test the effectiveness of the method it was compared with MTS, m-ETAR and NOMOV algorithms. The research can be expended to solve dynamic change of results by repeatedly applying all the edge nodes. There are many researchers that have conducted review/survey on sustainability energy management and algorithms for energy consumption in edge computing, where only twenty-six reviews are considered in the Table 1 and 2.

3.1 Energy Consumption Model

With complexity of energy management system, which involves distributed network, power and kinds of information needs to be exchanged in a real time. For example, customer need their energy profile that will be acceptable at user's level. Such criteria encourage the smart homes and cities to use developing information and communication methods such as IoT system to track and transmit data in utility control centers so that complex energy management policies in smart home and cities can be enforced. Some of the metrics for determining the level of energy usage in edge computing for a better environmental setting are as follows: dynamic correct sizing for electricity relative, regional load balancing and renewable energy [17]. Managing edge computing (MEC) servers' energy consumption extremely depends on the radio usage. An idles server can consume energy of about 70% of its full operational speed [18]. To have a perfect and effective decision dynamic right sizing, then the computation workload profile at each edge server should be accurately predicted. With MEC systems, pattern is influence by many factors such as location of the server, time, environment, nearby edge server and user mobility [19]. Key method for green distributed cloud network is that it leverages workload pattern, temperature and electricity on spatial diversity that make job routing choice between different data centers [20]. The strategy can also be extended to edge computing devices, where edge computing servers can now collaborate to support a mobile user, i.e., task to be redirected from hot spot edge server to a less workload nearby edge server.



Table 1: Summary of Literature Review on Energy Consumption

Author(s)	Edge Device	Proposed Algorithm	Compared Algorithms	Result	Limitation
{Li, 2018 #194}	Mobile device	Heuristic offloading Method (HOM)	Local offloading (LO) and Cloud offloading (CO)	The result evaluates the transmission delay between 2 points	The algorithm is good for the test-bed parameters
Hong & Varghese, (2018)	Base station	A Relaxation Heuristic based algorithm	The algorithm was capered with OPT, OTS, ATS and OWN	The result validated the algorithm is better in energy efficiency reduction.	The algorithm worst case in task processing energy at local green energy.
N. Hassan, Yau, & Wu, (2019)	Mobile edge device	Non dominated sorting genetic algorithm II (NSGA II)	The algorithm is compared with Local Offloading (LU) and Benchmark algorithms	The algorithm is effective in energy consumption in wireless edge computing network	The work is not active in privacy protection and migration
Maenhaut, Volckaert, Ongenaes, & De Turck, (2019)	Smart Mobile Edge devices	energy efficient Dynamic offloading and resource scheduling algorithm (eDors)	The proposed algorithm is compared with Zhang s algorithm and Chen’s algorithm	The proposed result of the algorithm revel that it outs perform the existing algorithms in reducing the energy consumption and offloading task completion time	The work did not consider security and privacy of the users.
Sittón-Candanedo, Alonso, Rodríguez-González, Coria, & De La Prieta, (2019)	Mobile edge device	Modified non dominated sorting genetic algorithm II (MNSGA II)	The algorithm was compared with greedy algorithm	The algorithm shows robotizes and operator optimality in terms of energy consumption reduction and task latency	The algorithm has look into allocation and scheduling of task
Toczé & Nadjm-Tehrani, (2018)	Mobile edge device	Reformed scheduling method for energy consumption constrains (RSMECC)	The algorithm is compared with HEFT, MSLECC, RMEC and MPEGA	Energy consumption and computational time	The algorithm is not good in tasks with low and high heterogeneity
Abbas et al., (2017)	Electric vehicle	Chimera	The algorithm is compared with D2D fogging and Dual control	Minimizing energy consumption of networked wide vehicle serving heterogenous crossing application	Only test in Internet of Vehicle

Citation: Rhoda Ajayi et.al., *A Review on the Challenges and Future of Energy Consumption in Edge Computing*, IJMCS, 2023. 1(3): p.17-32



Ai et al., (2017)	Mobile edge device	Hybrid Cooperation Cognitive Radio Network (HCCRN)	The algorithm is compared with Cooperative Cognitive Radio Network CCRN	The algorithm goal is on throughput computation delay and energy consumption	The algorithm is only used in WLAN
Boukerche et al., (2019)	Mobile edge device	Dynamic Mobility-Aware Partial Offloading Algorithm DMPO	The algorithm is compared with partial offloading with mobility management	The algorithm aims to reduce energy consumption and transmission delays	Does not consider black haul resource
Buyya & Gill, (2018)	Mobile edge computing	Multi-Pointer Network algorithm	Algorithm is compared with baseline heuristic algorithm	The algorithm goals reduce energy consumption on edge	The train method reinforcement neural network in heuristic algorithm learning
Gill & Buyya, (2018)	Mobile edge computing	Connected Edge Dominating based Semi graph Model S-CEDS	The algorithm is compared with DSDV and AODV algorithms	The algorithm generates size and power effectiveness network	The algorithm does not consider fault tolerance
Hartmann et al., (2019)	Mobile edge computing	Scheduling heuristic clustering algorithm	The method is compared with MTS, m-ETAR, NOMOV and random algorithms	The algorithm is to reduce total energy consumption within and outside system	The algorithm needs to be tested in dynamic environment

Table 2: Algorithms for energy consumption in Edge computing.

Author(s)	Algorithm	Role of the Algorithm	Remark
L. Gu et al., (2019)	Heuristic relaxation-based algorithm	Reduce brown energy consumption	The algorithm has low complexity
Xu, Li, Dai, et al., (2019)	Heuristic offloading algorithm	Reduce transmission delays	The algorithm finds the shortest path of transmission between two points
H. Sun, Zhou, & Hu, (2019)	Non-Dominated Sorting Genetic algorithm	Reduce energy consumption	The algorithm ensures diversity of population
Xu, Li, Huang, et al., (2019)	Energy-efficient Dynamic resource scheduling algorithm	Minimizing energy consumption	The algorithm has the advantage of CPU clock frequency and transmission power allocation.
Guo et al., (2019)	Modified Non-Dominated Sorting Genetic algorithm	Energy consumption minimization	More flexible choice racecourse operator optimality
Cui et al., (2019)	Modified Non-Dominated Sorting Genetic algorithm III	Energy consumption and execution time	Multi-objective optimization

Citation: Rhoda Ajayi et.al., A Review on the Challenges and Future of Energy Consumption in Edge Computing, IJMCS, 2023. 1(3): p.17-32



S. Mao, Leng, Maharjan, & Zhang, (2019)	Reformed Scheduling Method for Energy Consumption Constraint	Energy consumption and computation time	Can be applied in both small- and large-scale application
Ranji, Mansoor, & Sani, (2020)	Chimera Hybrid edge computing framework	Energy consumption saving	Scale for all large vehicle application
Chunlin Li, Sun, Chen, & Luo, (2019)	Hybrid Cooperative Cognitive Radio Network HCCRN	Energy consumption effectiveness	Can be applied in WLAN to reduce energy
Y. Mao, Zhang, & Letaief, (2016)	Dynamic Mobility-Aware Partial Offloading Algorithm	Energy consumption and constraint delay	Can be used in SDN controller to make decision sequentially in UEs
Tang, Lyu, Han, Wang, & Wang, (2019)	Multi-Pointer Network MPTR-Net	Energy consumption of mobile device while execution task	Have learn heuristic algorithms
X. Chen et al., (2019)	Connected Edge Dominating Set based semi graph S-CEDS	To reduce energy consumption and average of hub require for data trans	Increase throughput and network life time
Carrega, Portomauro, Repetto, & Robino, (2019)	Clustering scheduling heuristic algorithm	To reduce total energy consumption within and outside the system	Increases performance of the system.



4. ENERGY CONSUMPTION PARAMETER

An algorithm called dynamic mobility aware partial offloading aim at reducing the amount of energy consumption while delay constraint is maintained. To prove the effectiveness of the algorithm it was compared with dynamic partial offloading with mobility management and partial offloading with mobility management. The algorithm can save up to of energy with very tight delay constraint [21]. To improve on the proposed algorithm, a reformed Schedule Method for Energy Consumption Constraints was proposed [22]. The algorithm goal is to reduce energy consumption and consumption time. The algorithm is compared with HEFT, MSLECC, RMEC and MPEGA to prove it's significant. The method can be applied in both large- and small-scale mobile edge applications. Low or high heterogeneity result to poor performance of the method.

Investigation of internet of vehicle with aim of reducing the energy consumption in done to improve the consumption of energy by the cloud [23]. The proposed work is on heterogeneous vehicles for large applications. The work is compared with dual control and device to device forging D2D. The proposed work used Chimera algorithm for energy efficient and deadline of crossing framework. The algorithm is only applied in vehicle applications. Due to the recent challenges in smart edge computing, the is a need to come up with an effective method that would minimize energy consumption of mobile edge device in wireless edge computing network. A non-dolomite sorting genetic algorithm II (NSGA II) is proposed with intention of reduce energy consumption and task offloading time. The algorithm was compared with local offloading and benchmark to prove its effectiveness in all the metrics and ensure deviltry of the population. But the algorithm is weak in user privacy protection and migration of tasks [24]. [25] also investigate mobile edge computing device with goal of minimizing device energy consumption, a modified non dominated sorting genetic algorithm II (MNSGA II) is proposed. The algorithm show that is very effective in computational latency and energy consumption. The simulation result revel that the algorithm has pare tor optimal compared with the greedy algorithm which gives its flexibility of choice. With all this work is needed to resolve issues of allocation and scheduling problems with the algorithm. A modified version of non-dominated sorting genetic algorithm III (NDSGA III) was developed [26]. The algorithm reduces execution time and energy consumption in mobile edge devices through computation offloading approach. The algorithm effectiveness was proving by comparing with benchmark and other algorithm such as CCOM and CLCOM algorithms. The algorithm does not guarantee execution of large last to reducing energy consumption and execution time.

Investigation on the task allocation, virtual machine (VM) and energy scheduling with aim to reduce brown energy consumption. Heuristic relaxation algorithm based is proposed with the intention of tackling random green energy and user demand challenges. The energy cost of joint consolidation of VMs, migration and green energy is minimized. Energy internet (EI) is used to compared with OPT, OTS, ATS and OWN to test the ability of the algorithm. Brown energy is also reduced to a minimum. The algorithm worst case is task processing energy consumption with local green energy. [27] proposed and investigate multi objective problem that try to overcome the issues of energy consumption, throughput, fairness, queuing, priority level classes and user equality requirement in WLAN. A Hybrid Cooperative Consultative Radio Network HCCRN is



proposed. The algorithm is compared with CCRN to prove its effectiveness. The algorithm is good in most of WLAN application of edge computing.

An algorithm Multi-Pointer-Network Matr-Net was proposed by [29]. The algorithm is applied to solve the issue of mobile edge computation offloading problem where a multidimensional multiple knapsacks with constraint is a problem. The algorithm reduces energy consumption of mobile device during task execution. The algorithm is compared with heuristics algorithm to measure its effectiveness. Neural network needs long time for training which is one of the limitations of the algorithm. Investigation on power node, topology-based power control as an essential in energy consumption reduction is done in order to have a bases of comparison by [30]. Where a connecting edge dominating set based on semi graph model. These are based on connecting dominating set algorithm. The algorithm is aimed at reducing energy consumption and average data transmission. The algorithm is compared with DSDV and AODV for its effectiveness and it was discovered that the algorithms have issue with fault tolerance.

Clustering technique by dividing the node into clusters, each of the edge node have maximum distance that define by the energy transfer attenuation ratio. The research is aimed at reducing the total energy of the clustering nodes within and outside the system. The work rescheduling heuristic method algorithm. To test the effectiveness of the method it was compared with MTS, m-ETAR and NOMOV algorithms. The research can be expended to solve dynamic change of results by repeatedly applying all the edge nodes.

Table 3: Parameters used in Edge computing articles.

Author(s)	Parameters
Bharathi & Jeyanthi, (2018)	System bandwidth, chip computing efficiency, block length, static power circuit and total number of users.
Yu et al., (2018)	Task performance scaling, load balancing, energy consumption and total offloading time.
Yan et al., (2019)	Clock Frequency, computational offloading and transmission of allocation power
H. Liu et al., (2019)	Praetor optimal, energy consumption and latency of task offloading.
Jiang et al., (2020)	Time division multiple access (TDMA), frequency division multiple access (FDMA), energy efficiency delay trade-off and NOMA.
Al-Turjman, (2020)	Energy efficiency, task offloading, deadline and request constraint of edge device.
Zhou, Wang, Dong, & Ota, (2019)	Transmission cost, bandwidth, migration time and number of data block.
Lin, Chen, & Wang, (2019)	Average execution cost, time distance, ratio of dropped task, deadline, battery energy level and average completion time,
Ali et al., (2019)	Local computing time, data transmission time, energy consumption, data size, maximum delay, server computing frequency, Minimum computing frequency, maximum transmission power and overhead.
Al-Turjman, Deebak, & Mostarda, (2019)	Energy consumption, response time and location.
Peng et al., (2019)	Taks, VM allocation, energy consumption, time, bandwidth and live migration
Suriya Praba et al., (2019)	Bitrate and YUV Peak signal to noise ratios
Wan, Li, Xue, Lin, & Xu,	Number of clustering, original data points, clustering result using my K-mean, response



(2019)	time and number of service request
Hao et al., (2021)	Throughput, delay with mirror, parked size, scalability and monitoring response time
Y. Sun et al., (2021)	Accuracy and normalized energy efficiency,
Gu et al., (2019)	Power, utilization, time, energy consumption and cumulative CPU load
Xu, Li, Dai, et al., (2019)	Input data size, energy consumption, energy efficient cost and latency deadline
H. Sun et al., (2019)	SU energy efficiency, peak interface power, average and peak transmission power and probability outage of SU
Xu, Li, Huang, et al., (2019)	Energy consumption, bytes and period
Guo et al., (2019)	Packet transfer, transmission delay, energy consume per parked, queue size, queue length, normalized overhead and bitt error rate
Cui et al., (2019)	Average delay, average data size, execution delay, time step and energy consumption

Table 4: Edge computing environment setup

Author(s)	Edge Computing Setup
Xu, Liu, et al., (2019)	Network based topology of Abilene US continental network comparing 11 nodes connected with 14 links.
Hu et al., (2019)	MEC server and UE channels are model as a joint effect for large and small scale fading with unitary Gaussian random variable.
Pu et al., (2018)	In accordance with ECN and ECNs network topology relationship.
Bharathi & Jeyanthi, (2018)	Computing task N parkers need to be offloaded to M socket of ECN via Aps.
Yu et al., (2018)	5 of smartphone where randomly scattered an over 50m x 10m region while the base station is located at center.
Yan et al., (2019)	The mobile edge device network is located at the center with 100m radius of the network. While the MeNB is at the center of the entire network, MSeNBs are also deployed and SMDs were randomly deployed within the network.
Liu et al., (2019))	Mean value of $h_{U,i}$ and $h_{D,i}$ is give as $0.1 \cdot I$ and $0.2 \cdot I$ respectively where the noise power satisfied $\delta^2 = 2 \cdot 10W/Hz$, bandwidth B-5KHZ, power beacon $P_{Omax}=4$ and transmission power $T=10ms$.
Jiang et al., (2020)	Tasks are assigned randomly in accordance 100 iterations parameter to have an average energy saving and running time parameters. The maximum distance is considered to be 100m between each base station device.
Li et al., (2020)	The Edge cloud environment and central cloud consists of six heterogeneous virtual machines and Hadoop cluster are built on the edge cloud.
Al-Turjman et al., (2019)	Used an open stack node with three compute node and used an intel system with following configuration NUC6i7KYK, i7-6770HG 2.60GHz 4 core with 4GB RAM for 1 network and 1 controller node, open flow network with 4 open switch instance running on a heterogeneous set of low commercial desktops with configuration of 2-4 core around 1.1Ghz and link capacity of 100 Mbps/1Gbps in 1 control node running.

Table 4 describe parameters and experiment setup been used by some selected literatures. Different algorithms explain as the by different researchers as state in the above tables 2 for all sub-heading where type of algorithm where stated, its role on the algorithm and if the goal were achieved or not on the said role of the algorithm were examine in tables 3.



5 CHALLENGES AND FUTURE RESEARCH DIRECTION

Edge computing is still at its infant stage with many challenges, such of these challenges are still open for more research. Some the sustainable edge computing problems are computational uploading, device to device communication, data transmission with the network and computational time just mention a few. Thus, improving or reducing any of the above can increase the overall energy effectiveness of the system.

Many authors have done several reviews and surveys but this area needs more hand to do more in the energy efficiency of sustainability edge computing with the intention of reduce and improve energy costs used by the edge, smart, mobile and electric vehicles to have greener environment. Some of the outline challenges where hardware technologies, application driven processing, heterogeneity and dynamism, cross layer explore, energy and sustainability, human activity awareness and security, privacy and resilience.

Other great challenges of this Edge computing with respect to the 5G network are security and privacy, heterogeneity, standardization of protocol and service enhancement. Since Edge is new and there is a wide area of research which still needs to be explored such as several computing, validation of resource management strategies, management of hybrid edge, management of bare-metal containers and dynamic resource allocation centralization application.

While other issues at hand are energy and smart farming. Moreover, data storage, energy resource, mobility while the supply of multi-level. One of the big issues of Edge computing is resource optimization, web interface, transport migration application and pricing, this includes service requirement support, mobility strategy management and network slicing capability.

A model that consider several technical important points where users are considered to have even distribution while in real environment is unevenly distributed were proposed [31]. The future would consider other technologies architecture such us VNF, containers, mobile networks and heterogeneous telecommunication network. Investigation on the power production mechanism of flopping investor energy in full detail, where the challenge and future work would be on more kinematic motion effectiveness based on LEV energy have sting system.

Future research work on VNF characterization which includes bit rate output with transcoded function, heterogeneous SCs combination with different resource consumption and configuration and the used of technological to analyses the relationship between service pricing and aggregated user traffic cost requirement of infrastructure [32], using NSGA-II to study the computational offloading based on Pareto optimal under different parameters to get an optimal solution which can be executed to scheduling and allocating channel of communication for decision making process. [33] used optimal offloading policy and transmission power allocation on dynamic computation offloading. Since users can change position during the period, where users' migration per tern is greatly needed in the problem formulation. Markov approximation-based algorithm is been to solve single and static mobile device problem which show a convergent in a near optimal solution. This can be extended to multi-dynamic mobile devices in order to evaluate the real test bed of mobile edge computing. [34] proposed the use of NSAG-III in multi objective optimization where the method can be extended to solve real world issues of IoT. The method if improve can



handle workflow execution and offloading strategies to maximized energy consumption saving in a mobile edge device.

6 CONCLUSIONS

It has already demonstrated that IoT platforms show some of its use in tackling the looming sustainability concerns brought on by the exponential proliferation of Internet-connected gadgets. Although the first wave of IoT platforms were all cloud-based, the demand has led to a demand for decentralized solutions as well. Edge computing is a computer paradigm that pushes a piece of logic from the cloud closer to the network and devices for faster communication. The study reviews some details of extensive literature on sustainable energy efficient management in Edge computing. The study also showed the effectiveness of various edge computing paradigm, algorithms used and type of energy in contention that will enhance sustainable energy efficiency. The study discovers some significant point issues to stimulate and create more cost-effective and energy-efficient Edge computing by collaboration with designers of edge devices. Furthermore, solar energy, wind energy and other green renewable energy sources should be encouraged and supported all regards to edge cloud computing.

REFERENCES

- [1] Ai, Y, Peng, M, & Zhang, K. (2017). Edge cloud computing technologies for internet of things A primer. Digit. Commun. Netw.
- [2] Al-Turjman, Fadi, Deebak, BD, & Mostarda, Leonardo. (2019). Energy Aware Resource Allocation in Multi-Hop Multimedia Routing via the Smart Edge Device. IEEE Access, 7, 151203-151214.
- [3] Ali, Zaiwar, Jiao, Lei, Baker, Thar, Abbas, Ghulam, Abbas, Ziaul Haq, & Khaf, Sadia. (2019). A Deep Learning Approach for Energy Efficient Computational Offloading in Mobile Edge Computing. IEEE Access, 7, 149623-149633.
- [4] Bharathi, GP, & Jeyanthi, K Meena Alias. (2018). An optimization algorithm-based resource allocation for cooperative cognitive radio networks. The Journal of Supercomputing, 1-21.
- [5] Boukerche, Azzedine, Guan, Shichao, & Grande, Robson E De. (2019). Sustainable offloading in mobile cloud computing: Algorithmic design and implementation. ACM Computing Surveys (CSUR), 52(1), 1-37.
- [6] Buyya, Rajkumar, Netto, Marco A. S., Toosi, Adel Nadjaran, Rodriguez, Maria Alejandra, Llorente, Ignacio M., Vimercati, Sabrina De Capitani Di, . . . Vaquero, Luis Miguel. (2018). A Manifesto for Future Generation Cloud Computing. ACM Computing Surveys, 51(5), 1-38. doi: 10.1145/3241737



- [7] Carrega, Alessandro, Portomauro, Giancarlo, Repetto, Matteo, & Robino, Giorgio. (2019). Energy efficiency for edge multimedia elastic applications. *Multimedia Tools and Applications*, 78(17), 24739-24764.
- [8] Cui, Laizhong, Xu, Chong, Yang, Shu, Huang, Joshua Zhexue, Li, Jianqiang, Wang, Xizhao, . . . Lu, Nan. (2019). Joint Optimization of Energy Consumption and Latency in Mobile Edge Computing for Internet of Things. *IEEE Internet of Things Journal*, 6(3), 4791-4803. doi: 10.1109/jiot.2018.2869226
- [9] Gill, Sukhpal Singh, & Buyya, Rajkumar. (2018). A taxonomy and future directions for sustainable cloud computing: 360 degree view. *ACM Computing Surveys (CSUR)*, 51(5), 1-33.
- [10] Gu, Xiaohui, Jin, Li, Zhao, Nan, & Zhang, Guoan. (2019). Energy-Efficient Computation Offloading and Transmit Power Allocation Scheme for Mobile Edge Computing. *Mobile Information Systems*, 2019.
- [11] Guo, Songtao, Liu, Jiadi, Yang, Yuanyuan, Xiao, Bin, & Li, Zhetao. (2019). Energy-Efficient Dynamic Computation Offloading and Cooperative Task Scheduling in Mobile Cloud Computing. *IEEE Transactions on Mobile Computing*, 18(2), 319-333. doi: 10.1109/tmc.2018.2831230
- [12] Hao, Yongsheng, Cao, Jie, Wang, Qi, & Du, Jinglin. (2021). Energy-aware scheduling in edge computing with a clustering method. *Future Generation Computer Systems*, 117, 259-272.
- [13] Hartmann, Morghan, Hashmi, Umair Sajid, & Imran, Ali. (2019). Edge computing in smart health care systems: Review, challenges, and research directions. *Transactions on Emerging Telecommunications Technologies*, e3710.
- [14] Hassan, Muneeb Ul, Rehmani, Mubashir Husain, & Chen, Jinjun. (2019). Privacy preservation in blockchain based IoT systems: Integration issues, prospects, challenges, and future research directions. *Future Generation Computer Systems*, 97, 512-529.
- [15] Jiang, Qingmiao, Zhang, Yuan, & Yan, Jinyao. (2020). Neural Combinatorial Optimization for Energy-Efficient Offloading in Mobile Edge Computing. *IEEE Access*, 8, 35077-35089.
- [16] Li, Chao, Xue, Yushu, Wang, Jing, Zhang, Weigong, & Li, Tao. (2018). Edge-oriented computing paradigms: A survey on architecture design and system management. *ACM Computing Surveys (CSUR)*, 51(2), 1-34.
- [17] Li, Chunlin, Sun, Hezhi, Chen, Yi, & Luo, Youlong. (2019). Edge cloud resource expansion and shrinkage based on workload for minimizing the cost. *Future Generation Computer Systems*, 101, 327-340.
- [18] Lin, Hai, Chen, Zhihong, & Wang, Lusheng. (2019). Offloading for Edge Computing in Low Power Wide Area Networks With Energy Harvesting. *IEEE Access*, 7, 78919-78929.
- [19] Liu, Fang, Tang, Guoming, Li, Youhuizi, Cai, Zhiping, Zhang, Xingzhou, & Zhou, Tongqing. (2019). A survey on edge computing systems and tools. *Proceedings of the IEEE*, 107(8), 1537-1562.
- [20] Liu, Haolin, Cao, Le, Pei, Tingrui, Deng, Qingyong, & Zhu, Jiang. (2019). A Fast Algorithm for Energy-Saving Offloading With Reliability and Latency Requirements in Multi-Access Edge Computing. *IEEE Access*, 8, 151-161.



- [21] Mao, Sun, Leng, Supeng, Maharjan, Sabita, & Zhang, Yan. (2019). Energy Efficiency and Delay Tradeoff for Wireless Powered Mobile-Edge Computing Systems with Multi-Access Schemes. *IEEE Transactions on Wireless Communications*, 1-1. doi: 10.1109/twc.2019.2959300
- [22] Mao, Yuyi, You, Changsheng, Zhang, Jun, Huang, Kaibin, & Letaief, Khaled B. (2017). A survey on mobile edge computing: The communication perspective. *IEEE Communications Surveys & Tutorials*, 19(4), 2322-2358.
- [23] Peng, Kai, Zhu, Maosheng, Zhang, Yiwen, Liu, Lingxia, Zhang, Jie, Leung, Victor CM, & Zheng, Lixin. (2019). An energy-and cost-aware computation offloading method for workflow applications in mobile edge computing. *EURASIP Journal on Wireless Communications and Networking*, 2019(1), 207.
- [24] Pu, Lingjun, Chen, Xu, Mao, Guoqiang, Xie, Qinyi, & Xu, Jingdong. (2018). Chimera: An energy-efficient and deadline-aware hybrid edge computing framework for vehicular crowdsensing applications. *IEEE Internet of Things Journal*, 6(1), 84-99.
- [25] Ranji, Ramtin, Mansoor, Ali Mohammed, & Sani, Asmiza Abdul. (2020). EEDOS: An energy-efficient and delay-aware offloading scheme based on device-to-device collaboration in mobile edge computing. *Telecommunication Systems*, 73(2), 171-182.
- [26] Sittón-Candanedo, Inés, Alonso, Ricardo S, Rodríguez-González, Sara, Coria, José Alberto García, & De La Prieta, Fernando. (2019). Edge Computing Architectures in Industry 4.0: A General Survey and Comparison. Paper presented at the International Workshop on Soft Computing Models in Industrial and Environmental Applications.
- [27] Sun, Haijian, Zhou, Fuhui, & Hu, Rose Qingyang. (2019). Joint offloading and computation energy efficiency maximization in a mobile edge computing system. *IEEE Transactions on Vehicular Technology*, 68(3), 3052-3056.
- [28] Sun, Yingying, Song, Chunhe, Yu, Shimao, Liu, Yiyang, Pan, Hao, & Zeng, Peng. (2021). Energy-Efficient Task Offloading Based on Differential Evolution in Edge Computing System With Energy Harvesting. *IEEE Access*, 9, 16383-16391.
- [29] Suriya Praba, T, Sethukarasi, T, & Saravanan, S. (2019). Energy Measure Semigraph-Based Connected Edge Domination Routing Algorithm in Wireless Sensor Networks. *Mobile Information Systems*, 2019.
- [30] Tang, Qiang, Lyu, Haimei, Han, Guangjie, Wang, Jin, & Wang, Kezhi. (2019). Partial offloading strategy for mobile edge computing considering mixed overhead of time and energy. *Neural Computing and Applications*, 1-15.
- [31] Wan, Shaohua, Li, Xiang, Xue, Yuan, Lin, Wenmin, & Xu, Xiaolong. (2019). Efficient computation offloading for Internet of Vehicles in edge computing-assisted 5G networks. *The Journal of Supercomputing*, 1-30.
- [32] Xu, Xiaolong, Li, Daoming, Dai, Zhonghui, Li, Shancang, & Chen, Xuening. (2019). A heuristic offloading method for deep learning edge services in 5G networks. *IEEE Access*, 7, 67734-67744.
- [33] (Xu, Li, Huang, et al (2019). An energy-aware computation offloading method for smart edge computing in wireless metropolitan area networks. *Journal of Network and Computer Applications*, 133, 75-85. doi: 10.1016/j.jnca.2019.02.008



- [34] Yan, Hui, Li, Ya, Zhu, Xiaomin, Zhang, Dayu, Wang, Ji, Chen, Huangke, & Bao, Weidong. (2019). EASE: Energy-efficient task scheduling for edge computing under uncertain runtime and unstable communication conditions. *Concurrency and Computation: Practice and Experience*, e5465.
- [35] You, Changsheng, Huang, Kaibin, Chae, Hyukjin, & Kim, Byoung-Hoon. (2016). Energy-efficient resource allocation for mobile-edge computation offloading. *IEEE Transactions on Wireless Communications*, 16(3), 1397-1411.
- [36] Yu, Fangxiaoqi, Chen, Haopeng, & Xu, Jinqing. (2018). DMPO: Dynamic mobility-aware partial offloading in mobile edge computing. *Future Generation Computer Systems*, 89, 722-735. .
- [37] Zhou, Zhenyu, Wang, Bingchen, Dong, Mianxiong, & Ota, Kaoru. Secure and efficient vehicle-to-grid energy trading in cyber physical systems: Integration of blockchain and edge computing. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, 50(1), 43-57. and *Cybernetics: Systems*, 50(1), 43-57.