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Fog computational-based deep learning model for optimization of micro grid connected WSN with load balancing

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Abstract

IoT applications for the smart environments have proliferated with the introduction of the Cloud Computing. However, delay-sensitive programmes can't use these resources because of how far apart they are. Fog computing has arisen to give such capabilities in close proximity to end devices via dispersed resources, and it plays a crucial role in optimizing the connection between load balancing, microgrids, and WSNs. Using the idea of the "stateless micro-Fog service replicas", these constrained resources may work together to support dispersed IoT application operations, ensuring service availability even in the face of failures. Through load balancing, workloads are distributed between Fog nodes in an equitable manner, maximizing the use of computation and network resources while reducing lag time for application execution.

Keyword: Cloud Computing; Fog Computing; Load Balancing; Smart Grid; WSNs.

1. INTRODUCTION

The past ten years have seen the rise of "cloud computing paradigm" as an efficient means of meeting the rising need of end users to have their requests processed by means of cloud data centers. The demand for gadgets, smartphones, Google Glass, and other IoT-based linked devices and apps has skyrocketed in recent years. As a result, there is a great deal of pressure on cloud computing server infrastructure to accommodate all these devices, and many new challenges have arisen in terms of optimizing vital Quality of Service (QoS) characteristics including bandwidth, latency, privacy, storage, reaction time, security, and processing. Thanks to the advent of fog computing paradigm, which supports the IoT idea, practically all nodes and devices are now capable of two-way communication and interaction. Proposing fog computing paradigm in academia and business as a viable solution to the aforementioned problems.

The Fog-based video surveillance system, where the total system performance is boosted by pipelined application processes, is just one example of many applications that benefit from Fog & Edge Computing to serve various IoT and mobile applications. The first component, located on the camera, uses basic subtraction operations to ensure that repeated still images are not sent. Edge and Fog modules recognize objects and identify faces, respectively, so that only images including people are sent and processed. Cloud-based facial recognition systems will be used to monitor restricted locations and identify potential threats by comparing photos of individuals against a private or public database. Frame rate and video Bitrate in the sensor may be dynamically adjusted based on real-time input from the application's various modules. If the face is found, for instance, the camera might be instructed to deliver more detailed images to improve facial recognition. But when no objects are in view, the camera is told to conserve energy by lowering its resolution and Bitrate.

Fog environments may be built to serve IoT frameworks and related applications, either from scratch or by expanding existing infrastructures. However, as the number of the IoT devices and associated applications continues to rise, it becomes more difficult to predict the total volume of the IoT workloads. Therefore, optimum resource management, including optimal resource supply and resource allocation strategies, is essential to meet these rising demands. Furthermore, without adding further hardware resources, effective utilization of current resources may be achieved by balancing IoT workload among Fog resources. When available hardware resources do not have the processing power to service all of the IoT workloads that have been produced at once, even excellent load balancing is not adequate.

Electric power providers employ smart grid (SG) technology to monitor and manage their customers' electricity use. Bidirectional communication between smart meters improves energy monitoring. SG's distributed energy management system includes load balancing to ensure the safety and dependability of all communications. By keeping tabs on their energy use, businesses may better control their power systems. Altering and keeping the SG energy load stable is possible. The load-balancing system relied on by SG for the communication is kept in excellent working order by control centers which monitor the power supply and the safety precautions.

As the number of intelligent gadgets in use grows, so does the need for safekeeping and protection. These issues may be addressed by using cloud computing. Cloud computing's popularity has skyrocketed in recent years. Since cloud computing is quick, flexible, and inexpensive, it paves the way for the usage of internet services. In modern times, most PMs are housed in cloud data centres. Because of virtualization, the cloud service providers may facilitate the sharing of resources and VMs. To minimize cost and the other QoS criteria, the latest emphasis has been placed on energy conservation, which may be achieved via task scheduling by obtaining the order of execution of jobs.

For more efficient resource distribution, smart buildings use both cloud and fog computing. The planned effort primarily aims to reduce energy use and associated expenses for consumers. More people utilising cloud services means more work for cloud data centres to handle as more people utilise the services. Energy infrastructure management and meeting consumer demands are, hence, of paramount importance. In this task, RHO is utilised to distribute the weight evenly. It's difficult to handle the needs of several users at once. Fog was therefore linked to clouds and virtual machines. The user's virtual machine sent an order into the mist. It's possible that certain fogs are underused while others continue to be overused. To save energy usage, idle fogs are put to sleep and their virtual machines are moved to more active ones.

There are a number of phases involved in developing a deep learning model using fog computing for optimising the micro grid-connected "Wireless Sensor Network" (WSN) with load balancing. There are several subtasks inside this larger task:

- **Understanding Micro grids and WSNs**

Get started with energy management by learning everything you can about WSNs, microgrids, and load balancing. Microgrids are decentralised electricity networks that may function independently or in tandem with the larger utility grid. Networks of tiny, low-power sensors that collect and send data are known as WSNs. To achieve load balance, the energy demand is split between several generators and consumers.

- **Defining Objectives**

Define your optimisation model's goals precisely. In this context, load balancing, reducing energy expenditures, and increasing the use of the renewable energy sources are all possible goals.

- **Data Collection and Pre-processing**

Data on energy production, consumption habits, sensor readings, and load information should be collected from the microgrid and the WSN. You'll be using this information to train and test your deep learning model. For optimal model performance, preprocessing the data to account for missing values, remove outliers, and standardise the data is essential.

- **Fog Computing Architecture**

Integrate the WSN, microgrid, and deep learning model into the fog computing architecture. Fog computing is the practise of moving computation closer to the origin of data in order to speed up decision making in the real time and decrease the impact of latency.

- **Deep Learning Model Selection**

Pick a DL setup that works well with your optimisation challenge. Energy consumption and generation patterns are examples of time series data that may be analysed effectively using "Recurrent Neural Networks" (RNNs) or "Long Short-Term Memory" (LSTM) networks. If there is spatial information to be processed, “Convolutional Neural Networks” (CNNs) may be employed.

- **Feature Engineering**

Find important characteristics to feed into the deep learning algorithm. Energy use records, weather forecasts, sensor node statuses, and more might all fall under this category.

- **Training the Model**

Separate your information into the training set, the validation set, and the test set. The greatest results may be achieved by training a deep learning model on the training data and then fine-tuning the model's hyperparameters. To prevent overfitting, keep an eye on how well the model does on the validation set..

- **Load Balancing Algorithm**

Create an algorithm for load balancing that takes into account the deep learning model's predictions and evenly distributes the load between the microgrid and also WSN. This algorithm has to think about things like energy supply, the state of the sensor nodes, and the current energy load.

- **Real-time Decision-making**

To facilitate instantaneous decision making, use a fog computing architecture. You want your model & the load balancing algorithm to work together to make the best judgements possible when data flows in from the microgrid as well as WSN.

- **Evaluation and Testing**

Use either real-world data or simulated results to assess the efficacy of your deep learning model built using fog computing. Evaluate how well it serves the intended purposes, like load balancing and energy conservation.

- **Iterative Improvement**

Make adjustments to your model & algorithm based on the findings of your assessment. Changing hyperparameters, adding new functionality, or refining the load balancing algorithm might all fall under this category.

- **Deployment**

When your model's results satisfy you, go on to testing it in a live microgrid-connected WSN setting. Track its progress over time to see if any tweaks are needed. Keep in mind that this is only a summary, and that further in-depth study and development will be required at each stage. Your model's performance will also be affected by the depth of your neural network and the precision of your load balancing technique.

2. LITERATURE REVIEW

(Saif et al., 2023) IoT's disruptive powers and breadth of use have resulted in a deluge of data that has to be analysed. Tasks that can't wait, such as those containing delay-sensitive data, are sent to the nearest fog node, while more involved calculations and data storage are sent to the cloud data centre. Sending work out into the fog, however, reduces the lag time between transmit and receive. While moving jobs to the cloud may minimise end-user energy consumption, the trade-off is an increase in transmission latency owing to the long distance. Another challenge is matching tasks with resources that are up to the task's specifications. These are the most pressing issues that require fixing in cloud and fog computing. Since the fog broker is crucial to the job distribution process, this research presented a "Multi-Objectives Grey Wolf Optimizer" (MGWO) method to minimise the latency and energy consumption of the QoS goals. The simulation result confirms that the MGWO algorithm is beneficial in lowering latency and Energy consumption when compared to state-of-the-art methods.

(Singhal et al., 2023) As the cloud-based smart grids gradually replace conventional grids, data centres' output of data has increased dramatically. The fast proliferation of automated systems has stimulated the development of cloud storage and processing. Cloud computing allows businesses to provide their services more effectively and at a lower cost. More and more individuals are turning to cloud computing, despite the difficulties associated with it, such as increased energy use, slower responses, and longer processing times. Extension of cloud computing, "fog computing" It incorporates cloud services that reduce congestion, tighten data security, and quicken operations. By centralising and decentralising request processing, cloud and fog computing aid smart grids in reducing energy use. In this study, we look at how Rock Hyrax Optimisation (RHO) might be used as part of the Smart Grid load-balancing strategy to improve both reaction time and energy efficiency. The suggested approach uses virtual machines more efficiently by allocating tasks to them and powering them down when they are not in use. After being run via the CloudAnalyst simulator, the suggested model's implementation reveals that, in comparison to both static & dynamic algorithms, its reaction time is faster while its energy consumption is lower. Time spent processing data is cut by 26%, time spent responding by 15%, energy used by 29%, cost by 6%, and time spent waiting by 14% thanks to the proposed algorithm

(Ali et al., 2023) Monitoring smart grids in the real time requires the effective management of large volumes of data. Strategically placed fog cloud nodes inside the smart grid may collect data from smart metres, perform local processing and control, and relay that data to the smart grid's control centre in real time or with as little delay as possible. In contrast to previous research, we suggest a Fog node allocation mechanism that is intrinsically linked to the power grid architecture and therefore takes into consideration the power grid's geographical distribution of the data traffic sources (such as smart metres). The allocation method also takes into account the discrepancy between the latency needs of the fixed scheduling and those of the event-driven data services in power grid. In order to establish the initial number and placement of Fog nodes able to service the data traffic with minimal overall latency, the suggested allocation mechanism employs the "unsupervised machine learning approach". Finally, a reinforcement-based technique is used to map Fog nodes and smart metres efficiently, reducing the number of the Fog nodes needed while still meeting latency requirements and cutting down on upfront costs. Our simulation experiments show that the suggested allocation technique reduces the necessary number of Fog nodes by 50% while also reducing latency.

(Malik et al., 2022) The delivery and operation of healthcare services in the modern day rely heavily on Internet-of-Things (IoT) devices. After COVID-19, healthcare's future will be determined by how well it incorporates AI mechanisms into its day-to-day operations, and this will be realised through the widespread adoption of sensor-enabled smart as well as the intelligent IoT devices for providing comprehensive care to patients in accordance with the symmetric concept. These AI-enabled services provide solutions for the massive amounts of data collected and detected by the smart medical sensors without sacrificing other important performance factors. As a consequence, there is a pressing need to ensure that the smart operating devices are not overworked. In this research, we present a fog-based architecture that can evenly distribute the processing and the communication demands of intelligent real-time applications over a distributed network of the fog nodes.

(Kashani, 2022) One of the biggest benefits of the cloud computing in the healthcare is that it allows services to be brought closer to the patient's home, which in turn lowers healthcare costs for everyone. In addition to these benefits, patients benefit from a clean, safe space and quick access to necessary medical supplies during medical emergencies. Using cloud services for disease detection and early diagnosis has great potential. When dealing with time-sensitive tasks, cloud computing might falter at times. It becomes more challenging for the cloud computing to handle all requests with minimal latency as the number of requests and calculation requirements rises.

(Sheikh et al., 2022) In addition to the cloud computing, the fog computing is seen as a powerful next-generation option. Several issues have been presented in modern cloud architectures due to the exponential increase in number of Internet of Things (IoT) devices. The processing and storage capacity of cloud computing may be increased by adding fog computing as an intermediary layer between consumer devices and the cloud. To get an optimum user experience in terms of application quality and system performance, offloading may be used as a technique that moves computations, data, and energy consumption from the resource-limited user devices to the resource-rich fog or cloud layers. This article gives a thorough analysis of recent and present fog offloading strategies. In order to clearly describe and effectively handle the current possibilities and concerns of offloading mechanisms in a fog environment, we investigate and analyse the merits and downsides of each of the chosen papers. We divide offloading mechanisms in the fog system into four categories: those that rely on compute, those that rely on energy, those that rely on storage, and those that use a combination of the two. Additionally, this article delves into offloading measures, application algorithms, and assessment techniques as they pertain to the selected offloading mechanisms in the fog systems. The unanswered questions and emerging tendencies identified by the evaluated research are also highlighted.

(Manna, 2022) Cisco's innovative concept of fog computing brings cloud-like functionality closer to things in order to boost performance in ways like reduced latency and faster response times. Several factors, such as insufficient bandwidth & server queue capacity, may lead to packet failure across the large number of messages from IoT sensors on a single fog server. To address the issue of packet loss in the fog and the servers, this study proposes a "fog-to-server architecture" based on the Internet of Things that employs hybrid load balancing and the distributed setting. The suggested solution takes into account the load and the time and allocates requests to active servers using the "hybrid load balancing" relying on least connection as well as weighted round robin algorithms mixed together in fog nodes. The results show proposed system enhanced network evaluation parameters like total response time (131.48 ms), total packet loss rate (15.670%), average total channel idle (99.55%), total channel utilisation (77.44%), average file transfer protocol (FTP) "file transfer speed" (256 KB to 15 MB files) of 260.77 KB/sec, and the average time (256 KB to 15 MB files) of 19.27 seconds.

(Varmaghani et al., 2021) With the development of wireless technologies and miniaturisation of computer equipment, wireless sensor networks have the potential to become the best solution for many problems. The optimum use of node energy has long been one of the greatest difficulties in wireless sensor networks due to the importance of energy supply restrictions in limiting the functioning of the sensor network. And since nodes in WSN have a finite lifetime, managing energy consumption is one of the biggest obstacles to expanding the network's longevity. This study presents two computational distributions for the dynamic wireless sensor network, one using an optimistic approach and the other using a blind approach to dividing the computing burden across several fog networks. The name "Distribution-Map-Transfer-Combination" (DMTC) describes the four basic stages of the described approach. In addition to the described distribution techniques, "Fuzzy Multiple Attribute Decision-Making" (Fuzzy MADM) is utilised for clustering and routing networks. Especially in large-scale networks, the optimistic approach was more effective and used less energy than the blind one; yet, the blind plan produced the most energy-efficient network in tiny WSNs. Furthermore, optimistic WSN saves more energy than blinded ones due to network expansion. Complexity study shows that both the optimum and blind approaches provided here may be made better by 28% and 48%.

(Singh et al., 2021) The proliferation of Internet of Things (IoT) nodes & devices has increased rapidly in recent years. Fog computing is already a well-established paradigm for optimising important QoS needs such latency, bandwidth constraint, reaction time, privacy, scalability, and security as the number of connected devices continues to grow. In this study, we provide a comprehensive analysis of the literature on fog computing. The purpose of this review is to summarizes recently released research and look at where we are now with fog computing. We have discovered many problems with fog computing frameworks and analysed their implications for the architecture, quality of service measures, implementation details, applications, and forms of communication. Based on the available literature, we have created a taxonomy for the "fog computing frameworks" as well as compared the various works of study using this taxonomy. Finally, a number of research questions remain unanswered and potential future avenues for fog computing study are mentioned.

(Masri & Al-jabi, 2021) Keeping the lights on is a major problem everywhere, but particularly in third world nations where infrastructure and supplies are few. However, as our dependence on electronic devices grows, so do the difficulties operators have in finding and resolving faults quickly and efficiently. Despite a plethora of studies, not many have focused on finding ways to shorten the time a flaw lasts—especially in low-income nations. Decisions can only be made with sufficient knowledge in a short period of time if information technology is integrated with the current electrical networks. In this study, we provide robust estimating methods for redistributing loads. "Multiple linear regression", "nonlinear regression", and "classifier neural network models" are all examples of machine learning models that form the basis of the modelling approaches suggested in this study. This is a new contribution since it presents a fault-tolerant strategy that makes use of the machine learning and SCADA. The goal of this strategy is to reduce the time that a power outage lasts for consumers and the businesses that provide them with energy. The study relied on actual data from smart grids that had been partitioned into zones of about 20 transformers. When the models are fed information from the electrical grid's distributed sensors, the grid gains the capability to redistribute loads using adequate procedures. The models were tested and validated using MATLAB & Anaconda-Python, two very effective modelling tools. An approximate precision of 97% was found, with a standard variation of 2.3%. Specifics on the rebalancing of the loads were also provided. These promising outcomes validate our model's efficacy in shortening the period a defect lasts by facilitating the system's taking of appropriate measures at the opportune moment.

(Alhasnawi et al., 2021) In this work, we provide a new scheduling method for IoE-based "home energy management systems" that can operate in real time. The strategy is a multi-agent approach that balances user happiness and the cost of energy usage. The concept was developed in a microgrid setting. In terms of system effectiveness, the user impact in terms of reduced energy expenditures is usually considerable. This is why homeowners play an important role in the administration of home electronics. Both rainfall algorithm and salp swarm algorithm have been refined to create the optimisation algorithms. The "Time of Use (ToU) model" is introduced in this study as a means to determine off-peak and peak rates. The MATLAB-based microgrid infrastructure is linked to the cloud via a two-tiered communication method. IP/TCP and MQTT are utilised for the local communication, which in turn serves as a protocol for worldwide communication. This research's suggested scheduling controller achieved a 25.3% reduction in energy consumption when using the salp swarm algorithm and a 31.335% reduction when employing the raining method.

(Khan et al., 2017) An emerging concept, fog computing places processing power at the network's periphery rather than in a central data centre. It's comparable to the cloud in that it provides access to data, processing, storage, and applications, but it's not really the cloud. Fog systems provide several advantages over traditional data processing methods, including the ability to process massive volumes of data locally, running on-premise, portability, and the ability to be deployed on a wide variety of hardware. Fog's strengths in these areas make it an excellent choice for time- and location-sensitive software. For instance, IoT gadgets are essential for the rapid processing of massive amounts of data. Data, virtualization, isolation, malware, network, and monitoring are just some of the areas where this diversity of the functionality-driven applications presents significant challenges. In order to identify common security flaws, this research conducts a literature review of Fog computing applications. We've added related technologies such as Cloudlets, Edge computing, and micro data centres to make sure we've covered everything. Functionality and user needs drive the bulk of the Fog applications, whereas security is generally overlooked or treated as an afterthought. This article also evaluates the consequences of these security concerns and potential remedies, pointing the way forward for those responsible for the design, development, and maintenance of Fog systems in terms of security.

(Moura & Hutchison, n.d.) Fog Computing Systems (FCS), along with IoT assets, will power many cutting-edge computing services in the future. The new services that are being developed via the convergence of many technologies must perform time-sensitive tasks, provide varying degrees of integration with their surroundings, and include data storage, computing, sensing, communications, and control. However, there are major issues that need to be addressed before such systems are able to be called functional. Integral resilience management solutions are required because of the increased obstacles to robust and dependable operation posed by the "resource-constrained systems” complexity, high heterogeneity,and dynamics. This article provides a comprehensive overview of the relevant topics, as well as a discussion of the developing research concerns and trends. We predict that FCSs will play a crucial role in enabling future applications with strict criteria, such as high-precision latency and synchronisation across a broad collection of flows. Since Internet of Things (IoT) gadgets, edge computing server nodes, and the wireless sensor networks are able to be modelled using Game Theory and are easily programmable with cutting-edge software and virtualization platforms, we believe that our study may shed fresh light on the design and administration of robust FCSs.

3. CONCLUSION

The amount of data stored in the cloud continues to grow daily. To get power, clients submit requests to servers. Traditional networks are being converted into smart grids, creating a connection between energy consumers and generators. Given the growing number of users and requests, it's time to figure out how to allocate resources more efficiently. For the purposes of microgrid load balancing, the fog computing serves as the link between the real-time data acquired by WSNs and the intelligent decision-making that is necessary. It allows microgrids to more effectively manage energy supplies, respond to fluctuating circumstances, and maintain a reliable energy distribution network. In this research, we take a look at the literature on resilience features for contemporary Cyber-Physical Systems enabled by deep learning and apply it to the supply of the "future Fog Computing Systems" (FCSs).

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