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Healthcare Model Implementation and Effectiveness Analysis

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Abstract

With ever-changing needs, interests, and preferences of healthcare system stakeholders, effective scaling of data processing is yet to be satisfactory, especially regarding the need to ensure that centralized cloud settings' requirements are fulfilled. Indeed, this problem has arisen from the existence of deadline oriented cloud attributes that include command control systems, flight control systems, and health monitoring, platforms that call for minimum response time and latency. Also, the problem arises from a situation in which large data amounts continue to be transmitted, translating into a big data component. Therefore, performance degradation tends to arise when there is an interaction between IoT applications and centralized databases that host the big data. To address latency or delay, one of the innovative solutions involves fog computing, which also responds to issues of network congestion and resource contention. Through fog computing, there is the tension of clouds to network edges. In this study, a fog-enabled information framework was proposed. The proposed framework was that which strived to offer healthcare in the form of a cloud service, with the process achieved via the utilization of IoT devices. From the results, the framework was able to manage heart patients' data efficiently. It is also notable that the proposed model's performance was evaluated by using iFogSim toolkit.

Introduction

The IoT concept continues to gain application in cloud computing environments. The application offers on-demand services to users in the cloud setting, forming the modern economy's key backbone. For cloud computing, some of the current technological developments that continue to play an additionally leading role in shaping the sector include smart cities, big data, IoT, fog computing, and edge computing [1-3]. In the healthcare sector, IoT-based systems link devices to achieve data processing, including the case of heart patients [4]. This procedure aids in making smarter decisions, coming at a time when the fashion is deadline-oriented [5]. From the literature, two healthcare data types exist, especially when heart patients are considered. They include big data, whose processing occurs at centralized cloud repositories, and little data, whose processing occurs at the fog servers [5-7]. As healthcare information is generated by IoT platforms, it exhibits velocity and huge volume; especially with the velocity standing at least 150 MB/min [8]. Indeed, it is important to use the two data types towards heart patients' current status prediction [9], translating into full smart city development [10, 11]. However, contemporary cloud computing systems have failed to fulfill IoT applications' dynamic requirements that come in the form of low latency and minimum response time. Hence, fog computing has been introduced for purposes of data processing and also fulfilling the aforementioned requirements. In particular, fog computing is seen to aid in offering roles such as networking, computing, and storage processes, occurring between IoT devices and centralized cloud services. Also, fog computing is seen to offer room for the creation of applications in the Internet of Everything (IoE), which call for minimum response time and latency. The main aim of this study was to develop a fog-enabled information framework that would aid in offering healthcare as a cloud service while also ensuring that heart patients' data is managed efficiently. The performance of the model was evaluated via the implementation of iFogSim toolkit. Also, the analysis of patient data sought to pave the way for health status diagnosis, while different IoT devices or fog nodes were used to collect data from the patients. These specific objectives sought to support the study's central goal of developing a fog computing-based framework for resource management in the healthcare sector.

Methods

As indicated in the earlier section, an IoT based fog-enabled cloud computing framework was proposed in relation to the usage in healthcare. The proposed model strived to aid in heart patient data's effective management, upon which the possibility of health status diagnosis would be realized; eventually allowing for the identification of heart disease.

From the figure above, the proposed model was designed in such a way that the body area sensor network aided in sensing heart patients' data before ensuring that it is transferred to the IoT devices attached. On the other hand, the role of the IoT devices, which included tablets, laptops, and mobile devices, lay in the ability to act as fog devices, responsible for the sensed data's detection from various sensors before ensuring that it is forwarded to the fog servers to be processed further. Regarding the fog server, it operated in such a way that the listener module received fog devices' requests prior to data transfer while the security module offered secure communication, protecting data from unauthorized use – and improve heart patients' health status accuracy.

Similarly, the messenger handler managed the data that was received relative to the details of patients, while the role of the service broker constituted the provision of patient information such as workloads, for the cloud server to process it further. Therefore, the fog server's main component was the service broker. For the case of the resource manager as part of the components of the proposed model, its workload manager played the role of handling patient information (such as the workload bulk). The resource scheduler was used to organize for provisioned cloud resources to ensure that cloud workloads are processed.

Lastly, the cloud data center played the critical role of patient data processing, whereby there was the pre-processing stage to convert big data into relevant formats. Also, there was data filtering to ensure that the selected data was specific to the users – via data analytics. Upon obtaining the filtered data, it would be compressed via the SPIHT (set partitioning in hierarchical trees) model, with the SVD (singular value decomposition) method aiding in the encryption process. The aim of these procedures involved the discovery of heart patients' health statuses, upon which there would be automatic decision-making and recommend medication, as well as relevant check-ups; eventually storing the results in databases – to be used or referred in the future.

Results

For the basic event simulation operations, this experimental study utilized ClouSim, with the iFogSim structure on the focus. Through CloudSim layers, there would be the control of iFogSim's computing components. This arrangement would then suggest that the entire management of different functions in iFogSim's fog computing components would be attributed to the function of the main CloudSim layer. The following table highlights the experimental conditions that were set regarding the proposed model's system configuration. Specific attributes whose values for different parameters or variables are highlighted include power, RAM size, GHz, and CPU.

Device type	CPU GHz	RAM (GB)	Power (W)
ISP Gateway	4.0	6	117.445
Smartphone	2.6	2	88.64
WiFi Gateway	4.0	6	117.445
Cloud VM (Virtual Machine)	4.0	6	117.445

It is also imperative to highlight that in this study, a cloud simulation setting was utilized, whereby there was the extension of the datacenter class to achieve the desired fog devices. Also, the modeling of patient data was realized via VM. Furthermore, the realization of patient data was enabled by extending Cloudlets, upon which user requests would be executed accordingly. For fog applications, their execution demanded that only the respective fog nodes' hosts were scheduled to offer resources. It was also on fog nodes that there was the processing of data for heart patients in the fog-assisted cloud setting. To reduce the response time and decrease latency (as well as save the network bandwidth), the system closest to the IoT services was targeted.

From the specific results, one of the approaches involved the calculation of network usage time values for the respective requests made by different users, heart patients in this case; who had been linked to the fog-based environment and the cloud setting. From the findings or system behavior outcomes, the fog-based environment outperformed the cloud-based performance because it achieved a lower value of the network usage time. This superior performance was realized because the fog-based system was better placed to steer significant reductions in the user requests, which would approach the cloud. Particular observations held that for the average network usage time, the fog-based system yielded a reduction of between 22.61% and 26.78%, outperforming the cloud-based environment.

Additional analyses focused on the attribute of latency in relation to the implementation of Cloud and Fog. At this point, different numbers of user requests were used for a comparative analysis of the performance of these models, when implemented on heart patients. Indeed, it was also evident that Fog exhibited superior outcomes, have analyzed the aspect of latency. The next step involved analyzing the behavior of the systems relative to the variable of energy consumption. Similar to the earlier parameters, the aspect of energy consumption was evaluated relative to the performance of cloud versus cloud, especially in relation to the systems' capacity towards processing different user requests that heart patients would launch. In the results, fog was found to consume less energy than the case of cloud, having analyzed their performance on the same number of requests coming from users. For cloud, when the number of user requests was 33, the consumption of energy was 33.45% more than fog. When the number of requests coming from users was reduced to 20, cloud still consumed more energy at 8.25% more than fog. On the average when compared to the performance of cloud, fog was found to yield a reduction in energy consumption by 23.56%. At this stage, it became possible to provide a comparative analysis of the performance of Fog and Cloud computing relative to the three major parameters of latency, energy consumption, and network usage time. The following figures and table provide highlights of the key findings and insights that were gained from this experimental study.

Environment	Processing layer	Avg. network usage time (s)	Avg. energy consumption (J)	Avg. latency (s)
Cloud computing	IoT to Cloud	84.58	101.30	24.33
Fog computing	IoT to Fog	11.14	34.46	3.25
	Fog to Cloud	12.22	16.64	5.05
	Total	23.36	51.10	8.30

Conclusion

From scholarly observations, it can be seen that in the wake of big data, especially in the healthcare industry, the IoT concept has arrived timely. However, this promising trend comes at a time when effective scaling of data processing is yet to be satisfactory, especially regarding the need to ensure that centralized cloud settings' requirements are fulfilled. Indeed, this problem has arisen from the existence of deadline oriented cloud attributes that include command control systems, flight control systems, and health monitoring, platforms that call for minimum response time and latency. Also, the problem arises from a situation in which large data amounts continue to be transmitted, translating into a big data component. Therefore, performance degradation tends to arise when there is an interaction between IoT applications and centralized databases that host the big data. To address latency or delay, one of the innovative solutions involves fog computing, which also responds to issues of network congestion and resource contention. In this study, focus was on the broad area of big data application in the healthcare sector. The study's specific aim lay in the presentation of a fog-assisted data framework. The proposed model was that which would aid in the provision of healthcare as a cloud service. The objective of designing the model involved the criticality of fostering efficient data management, especially among patients diagnosed with or experiencing heart disease. Different IoT devices were incorporated into the simulated system and aided in offering heart patients' user requests. To evaluate the performance of the proposed system, this study relied on the role of iFogSim toolkit. From the findings, the superiority of fog computing, compared to cloud computing, was confirmed. This superior performance was observed when the two forms of frameworks were compared in relation to their performance in parameters such as latency, energy consumption, and network usage time. In the future, it is recommended that scholarly investigations apply the proposed model to real-world healthcare scenarios to determine if similar findings could be obtained, upon which informed decisions might be made on whether or not the framework could be put to practical use.

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