Journal of Data Acquisition and Processing
ISSN: 1004-9037
https://sjcjycl.cn/
DOI: 10.5281/zenodo.98549577

FOG BASED INTELLIGENT HEALTHCARE FRAMEWORK FOR MONITORING THE BODY MOVEMENTS OF COMA PATIENT

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Abstract
Coma is a prolonged state of unconsciousness for an extended period of time. Patients in coma are unable to move and communicate and therefore require continuous monitoring for their well-being and safety. Traditional monitoring techniques are labour-intensive, time-consuming, and require round-the-clock human observation. There is need for more automated and efficient approach for surveillance of coma patients. In this research manuscript, we propose a fog-based intelligent healthcare framework for monitoring the body movements of coma patient using smart cameras. The proposed system's effectiveness is evaluated using ifogsim toolkit. The results obtained demonstrate that fog computing exhibits a more efficient reduction in latency, network usage, and energy consumption compared to cloud computing, thereby establishing fog computing as a superior QoS framework.
Keywords - Fog Computing, coma patients, ifogsim

Introduction

In the era of this digital world, smart devices have become an imperative and daily requisite, and the growth of these devices is exponential in every sector whether it's for domestic use, healthcare, agriculture, etc. These smart devices, referred to as IOT devices are part of a network of interconnected devices that use their sensing capabilities to collect and transmit data over the internet [1]. IOT devices have upgraded the standards of human life by facilitating the connection between humans and devices. There are numerous smart applications serving society that use IOT as the backbone, such as smart cities, smart education, smart healthcare, smart agriculture, smart business, and many more [5]. It is anticipated that by 2025, there will be around 1 trillion IOT devices installed [15]. Consequently, data generation and data transmission are increasing. To handle this voluminous data for storing, accessing, and processing, cloud computing emerged as a powerful solution.

Cloud Computing is a computing paradigm that aims to deliver computing resources and services such as servers, storage, databases, networking, software, analytics, and intelligence over the internet on demand. Instead of building and maintaining the physical servers and data centres, cloud computing allows organizations to access and share these resources as per requirement and pay as per use. In context of IOT, cloud computing provides infrastructure that helps to process and store large amounts of data generated by these devices [8]. This has led to better performance, efficiency, and accuracy of IOT-based systems that would have not been possible with limited on-device processing and storage.

The centralised nature of the cloud, where practically all processing takes place, results in several drawbacks for IoT deployment, such as high network latency, high bandwidth consumption, and security concerns. Even though processing speed of data has risen but capacity of data to be transferred has not increased significantly which resulted in longer delay or high latency [16]. Various latency-sensitive applications such as smart healthcare, smart traffic system, emergency response require quick response and cannot afford delays. Additionally, sending sensitive IoT data to the cloud can raise security and privacy concerns, as the data is transmitted over public networks and stored on remote servers. Therefore, to address all the above issues as well as decision-making and processing requirements of these real-time projects, fog computing emerged as the complementary solution to cloud computing.

Fog Computing is decentralized computing paradigm that is deployed at the edge of network to carry out significant amount of computation resulting in reduction in latency and overcome cloud security challenges by extending the services and features of centralized cloud at the edge of network. It acts as intermediate layer between end-devices and cloud [18].

Integration of IOT and Fog computing have the potential to revolutionize the way in which healthcare is viewed and delivered. E-Healthcare have helped the humanity to accomplish the healthy lifestyle that they desire. Based around the idea of healthcare, wearable sensors can enable the real-time analysis of the health status of every human such as blood pressure, pulse rate, breathing rate, number of steps [5]. This data being huge and less sensitive can be processed and stored on the cloud. Whereas in case of emergency, where every second counts, fog computing is better option.

Critical care patients require constant monitoring over 24 hours and specially trained healthcare team. Coma patients are those individuals who are in state of unconsciousness for extended period of time and are unable to react to their surrounding environment. Coma may occur due to various complications which includes stroke, brain injury and underlying medical issues [17]. Smart monitoring through cameras can be helpful to monitor the coma patients that could be quite challenging through manual monitoring. Intelligent surveillance systems can be used to recognize the body movements of the patients like hand movements, blinking of eye, yawning, lower body movement and alert the healthcare providers and doctors when there are any anomalies detected. Cameras can also be utilised to keep an eye on the patient's surroundings. This can guarantee that the patient is receiving the right care and attention and help prevent mishaps like falls or other injuries. Therefore, proposed methodology ensures that patient is receiving best possible care.

Literature Review: With the development of computer technology over the past few decades, numerous research projects have made major contributions to the healthcare sector.

Prabhdeep et al. in their work [9] propose fog and artificial intelligence-based healthcare system to predict and prevent covid-19. These technologies can help in minimizing the impact of this outbreak. Artificial intelligence algorithms help to predict the covid-19 by analysing the symptoms and by utilizing fog computing technology, the spread of virus can be monitored and controlled in time and cost-effective way. The framework proposed predict the infection in real-time and generates an alert to user, their guardians and doctors.

Ahmed and Mohamad in their work [2] developed a healthcare monitoring system for coma patients. By deploying the set of three sensors, including a temperature sensor, a pulse oximeter sensor, and a flex sensor, this system accurately measures key health parameters. Command processing is carried out via the Arduino IDE software, while the Internet of Things (IoT) is integrated via the Blynk application. Through this innovative setup, healthcare providers and cloud users can monitor vital signs such as oxygen level, heart rate, body temperature, and body movement in real-time, displayed through the Blynk application.

Ahmed et al. in their study [3] propose fog-based health monitoring system to observe patient's heart rate, body temperature, and blood pressure values obtained from the wearable sensors. Encryption processes and watermarking techniques are applied to the data recorded and stored on fog nodes. After analysis of this data if there is any deviation from the threshold value the notification is sent to doctor/expert and care taker of the patient via cloud.

ICU patients need 24-hour care. Due to manual monitoring of each patient, doctors and healthcare workers are overworked which results in monitoring mistakes. To solve this problem, in [4], the author proposes IOT-based smart monitoring system for ICU patients which will collect the data of various body parameters using sensors. To process and store this data, fog nodes are used. If any irregularities are spotted in these values, it will notify the doctors and ICU staff. The summary of the above is stored on the cloud for further analysis.

Vijayakumar V. in their work [11] proposes a fog based intelligent system for early detection and management of mosquito-borne infections. Wearable IOT sensors are used to collect the necessary information and fog nodes are used to evaluate, classify and communicate the necessary medical information among the healthcare workers and users. Fuzzy k-nearest neighbour algorithm is used to classify the infected and uninfected patients.

The purpose of work reported in [10] is to utilize the cloud and fog environment effectively to detect dengue virus outbreak at earlier stage and people are categorized on the basis of various symptoms and notified through their registered mobile number. The proposed framework is also useful for the doctors to analyse the current state and take any futuristic action.

Malathi Devarajan in their study [12] uses fog computing technology for detection of Parkinson disease which is a neurological disorder which causes harm to voice and motor skills. Case based reasoning classifier and fuzzy k-nearest neighbour are used to evaluate the performance of the proposed system on UCI-Parkinson dataset to classify the healthy and Parkinson patients.

The methodology proposed in [6] uses Internet of things technology to monitor the health status of coma patient. Sensors are used to collect various body parameters such as pulse rate, temperature and movement. Microcontroller board is used to analyse the data gathered by sensors and if there is any deviation in values, it causes monitoring system to give an alarm.

The study carried out in [13] is a vision-based monitoring of the patient in which meaningful information is derived from the visual inputs, such as digital images or videos, using techniques such as machine learning, artificial intelligence. A comprehensive review of various technologies and algorithms for seven applications is presented, namely: (a) sleep monitoring (b) fall detection (c) vital signs monitoring (d) activity and action monitoring (e) epilepsy monitoring (f) respiration monitoring (g) facial expression monitoring.

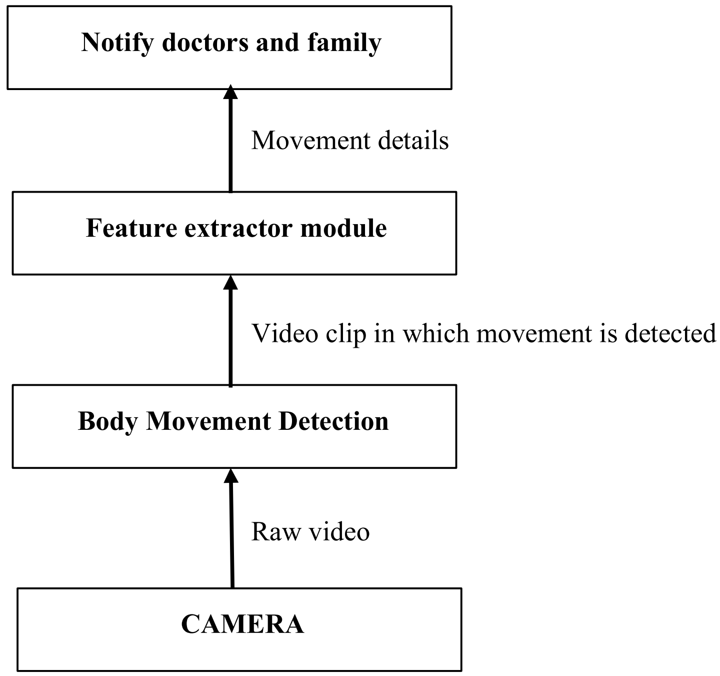
Janney et al. in their study [14] propose cloud-based healthcare monitoring system for coma patients. The goal of this work is to present a thorough analysis of the patient's EEG, hand movement, leg movement, number of eye blinks, heart rate, oxygen level, and body temperature. The Raspberry Pi integrated with camera configuration is used to distinguish eye motions and detect yawning. For easy access and long-term evaluation, patient records are stored in the cloud. It will continuously monitor the coma patient's vital signs, and once the patient moves, the device will recognize it, activate the message, and send it to the doctor.

[19, 20, 21] serve as a comprehensive review of fog computing in the context of healthcare, providing a comprehensive analysis and evaluation of its applications, challenges in the field and research issues.

The COVID-19 pandemic has spread globally, and drones are being used to handle the situation. The architecture proposed in [22] combines wearable sensors and drone-based systems to manage the pandemic in different scenarios, especially in remote or congested areas. It collects and stores data, enabling quick action when needed. Real-time implementation of drone-based healthcare systems has shown effective coverage for tasks like sanitization and patient identification. Additionally, IoT devices like the IoMT Smart-ID-Card [23] are being used to monitor and combat COVID-19 by tracking symptoms and ensuring social distancing.

Research Methodology: A latency sensitive healthcare framework for monitoring the body movement of coma patients is proposed. Smart cameras are used 24/7 for surveillance of coma patients. Multiple cameras can be deployed with different Field of View (FOVs) to surveil the patient closely. Fog computing infrastructure is used for processing the video streams in which movement of patient’s body part is detected to classify the kind of motion. This technology offers fast and efficient responses to IOT applications by bringing the computing resources closer to the end-user. To evaluate the effectiveness of proposed framework, a range of quality of service parameters have been computing namely: latency, execution time, energy consumption, cost of execution, and network usage.

Figure 1 Proposed Methodology



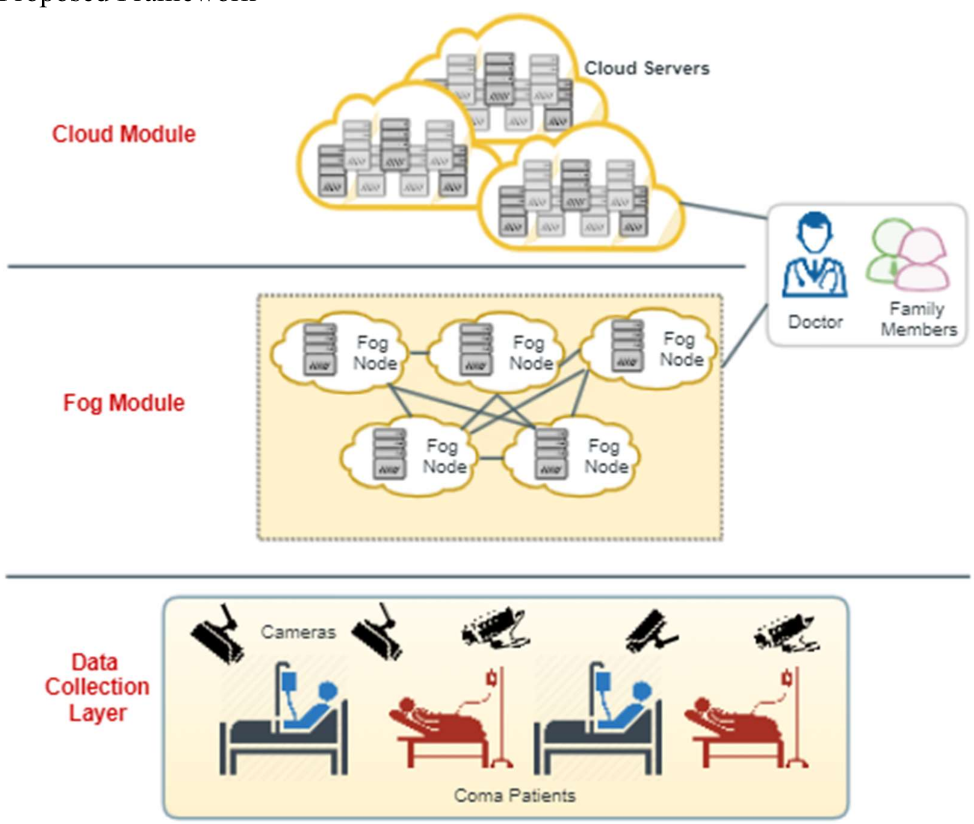
Objectives: The aim of this research work is to develop fog-based intelligent healthcare framework for monitoring the body movement of comatose patient with the following objectives:

i To develop a framework for monitoring the health status of coma patients using fog computing.
ii To implement proposed system on the basis of various parameters such as latency, energy consumption, network usage.
iii To compare the performance of proposed system with existing techniques.

Proposed Framework: In this section, Fog-based intelligent healthcare framework for monitoring body movements of coma patients is proposed. In this framework, surveillance cameras are deployed in the room of the coma patient to capture live video footage of any body movement of the patient. The cameras are connected to fog computing system which processes the video feed instantaneously. To determine the patient's condition and level of consciousness, fog computing system can utilise machine learning algorithms to detect the motion and classify the type of body movement such as yawning, hand movement, leg movement, and many more. The data from the cameras after processing is securely transmitted to the cloud for permanent storage and further analysis, sending an alert to the concerned doctors/experts and family members. This allows healthcare professionals to monitor the patients remotely and intervene if necessary. The fog- based intelligent healthcare framework helps in potential improvement in the quality of care for coma patients by offering real-time monitoring and early detection of changes in patient's conditions.

I. ***SMART CAMERAS:*** Coma patients requires continuous monitoring to ensure their safety and well-being. Manual monitoring of patients by healthcare experts is challenging and time-consuming as it requires specially trained medical team to take care of patient. This has increased workload of staff and ultimately is super stressful. Therefore, CCTV cameras are the essential tool in providing around the clock monitoring of coma patients. CCTV cameras allows the medical practitioners to maintain a close check on patient's status all the time. But, manual monitoring of CCTV footage is impractical. Thus, we need automated tools to analyse data coming from the camera and provide useful summaries to the user. CCTV camera is responsible for collecting real- time video of coma patient and forward it to Body Movement Detection

Figure 2 Proposed Framework



Application. Multiple smart cameras are installed in the patient's room to monitor the patient from different angles. The cameras need to be positioned in such a way that every activity in the room could be captured. The camera should be of high quality to record the clear and detailed movements.

As depicted in figure 1, Body movement detection of coma patient's application consists of three modules namely, Body movement detection, Motion classification module, and user interface. Among these modules, Body movement detector and Motion classification module are placed on fog nodes because they require real time processing of data whereas user interface module is placed on the cloud.

II. **FOG MODULE/ LAYER:** The fog module consists of fog nodes, data processing unit and data repository. The fog unit has the capacity to gather the data from different sources like IOT sensors, cameras, etc. and process the data, store it temporarily. Fog nodes are the smart devices with computational capabilities (memory, CPU, and storage). Fog nodes helps the data to process in real time with reduced delays, quick response time which is important aspect in healthcare applications. The data processing unit decides that whether the body movement occurred or not. If there is any motion of body, it analyses the features and patterns of the body movement and classify it accordingly and stores it in the data repository. The data repository on the fog node is in continuous sync with cloud storage.

a. **Body Movement Detection Module*:*** This module is integrated inside the smart cameras used for surveillance. It continuously analyses the camera's raw video streams to determine if any bodily movement took place or not. This module utilises computer vision [7] to detect the body movements of the coma patients from the continuous footage from the camera. Computer vision algorithms filters out the regions of interest and irrelevant part in the footage and transmits the relevant video stream to the Motion Classification module.

b. **Motion Classification Module:** This module receives the video stream from the Body Movement detection module. This module extracts all the specifics of the body movement occurred. It categorizes the body movements such as blinking of eye, yawning, hand movement, etc. Finally, it generates a detailed report of kind of body movement detected which may include time stamp, duration, type of body movement, its intensity, whether immediate action is required or not and suggestions.

III. **CLOUD MODULE/ LAYER**: The patient's personal data is stored on the cloud with proper authentication and authorization. The data is encrypted before storage and decrypted while accessing. The cloud repository is designed to store static as well as dynamic data of the patient and is synchronized with the fog data repository located on fog unit. To maximize energy efficiency and server utilization, cloud provides virtual machines for computation which can be scaled as per demand or current load. Scalability, reliability and availability are objectives of cloud architecture.

a. **User Interface Module:** The user interface module is placed on the cloud. This interface can a website or mobile application. This interface helps in improvement of patient and doctor communication. A notification or alert message along with the portion of video stream containing body movement and its detailed report is sent to the concerned doctor and family members of coma patient under surveillance to investigate further and take necessary care. User interface module provides doctors a platform to take care of critical patients virtually and intervene if necessary.

Experimental Setup and Performance Evaluation: The proposed framework is simulated to analyze its performance and efficiency based on different factors such as delay, energy consumption, and network usage. For the evaluation of the performance of proposed framework, iFogSim has been selected as a testbed. iFogSim is Java-based open-source simulation tool, which enables simulation of cloud and fog environments. iFogSim uses CloudSim libraries to utilize event-simulation capabilities to facilitate the simulation of fog-based architectures and applications. It allows researchers to perform the simulation based on various metrics such as energy consumption, latency, network consumption, execution time, cost of execution, and many more. The comparison between the proposed fog-based framework and the traditional cloud framework is conducted in two cases discussed below:

Case 1: Cloud-only placement

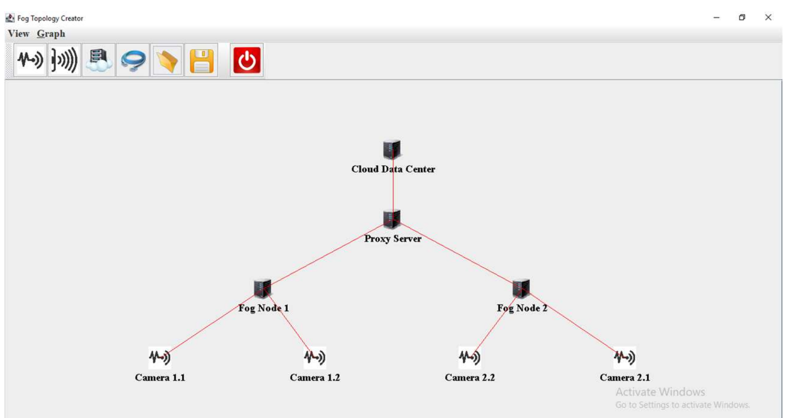
In this case, all the modules of application are placed on the cloud. Data generated by smart cameras is transmitted to the cloud module only.

Case 2: Edgeward placement

In this method of placement, application modules are placed closer to the devices i.e., at the edge of network. Data generated by smart cameras is transmitted to the fog module for processing and then sent to the cloud module. Here, the fog module acts as an intermediate fog layer between cloud and IoT devices.

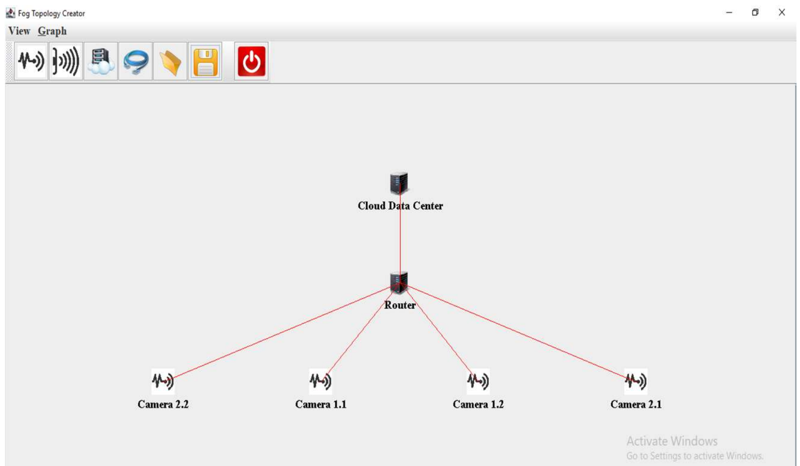
To ensure the validity of proposed framework, we designed a three-tiered structure as shown in FIGURE 3. This involves deploying cloud data centers at level 0, proxy server at level 1 which connects fog nodes to cloud data centers and fog nodes at level 2 in case of edgeward placement.

Figure 3 Topology when edgeward placement



In case of Cloud-only placement, cameras are connected to cloud data centers through router as shown in FIGURE 4.

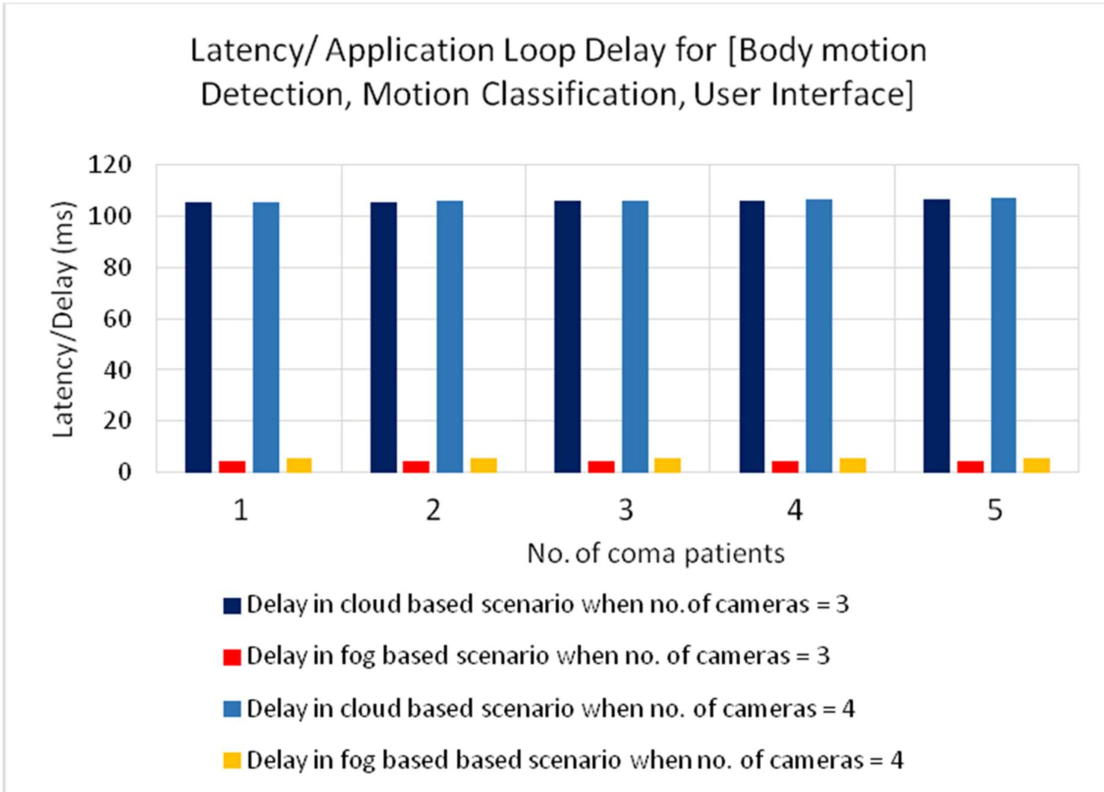
Figure 4 Topology when cloud-only placement



To ensure the accuracy of experimental results, different topologies with different placement strategies are simulated in iFogSim. The performance metrices are evaluated by varying number of coma patients and number of cameras per patient and collecting the corresponding results.

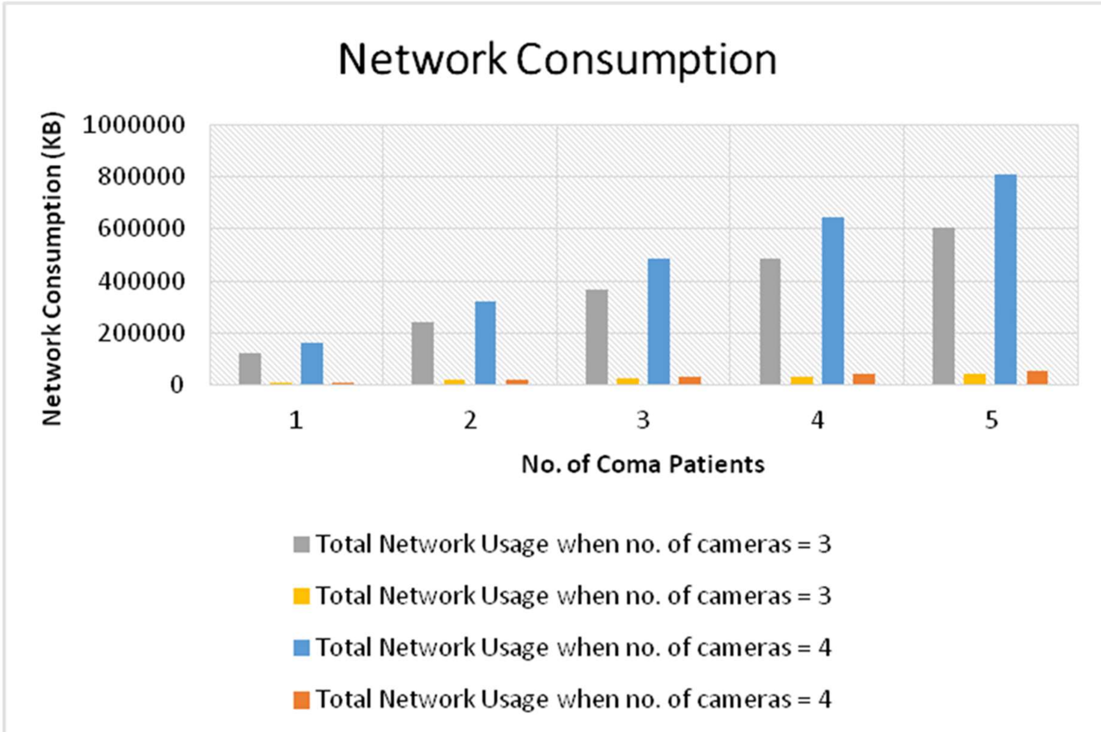
i. **Latency/Delay:** Latency refers to delays in communication over network or time taken by data packet to travel from its source to its destination. We evaluate the values of application loop delay for data transfer between the smart cameras and cloud module with and without fog module. The experimental results for case 1 and case 2 are presented in FIGURE 5.

Figure 5 Comparison of Latency/ Delay



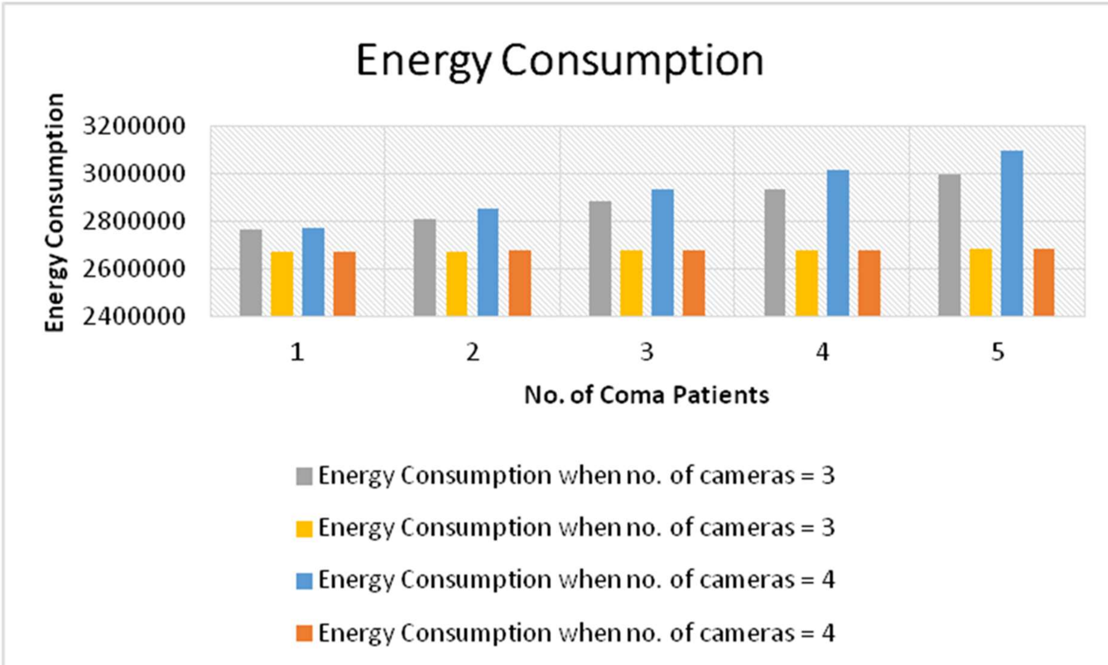
ii. **Network Consumption:** Network consumption refers to amount of data transmitted between the cloud module and smart cameras. This includes both upstream and downstream traffic which is quite high in case of cloud-only placement as compared to edgeward placement as depicted in FIGURE 6.

Figure 6 Comparison of Network Consumption



iii. **Energy Consumption:** Energy consumption refers to amount of energy consumed by various components such as IoT devices, fog nodes, cameras, cloud, servers etc during the execution of tasks and data transfer operations. FIGURE 7. shows that is significant reduction in energy consumption when the proposed framework is used.

Figure 7 Comparison of Energy Consumption



Discussion: This research manuscript compares the proposed framework with the traditional cloud-based methodology. The study analyzed the performance of the system by varying the number of patients from 1 to 5, while keeping the number of cameras per patient constant at 3 and 4. The proposed framework exhibits shorter average latency/delay than the conventional methodology and uses less network and energy consumption compared to rival framework, making it more efficient.

Conclusion and Future Scope: Combination of IOT and Fog Computing technologies have potential to transform healthcare industry and improve the quality of care. The proposed framework for body movement detection of coma patients using smart cameras and fog computing technology is a potential approach that can provide real-time monitoring and early identification in state of coma patient. This research demonstrates the effectiveness of proposed framework by evaluating various performance parameters, including latency/delay, energy consumption, network usage. It has been observed from the proposed work that when number of coma patient is 1 and number of cameras per patient is 3, values of latency (fog-based = 4.6 & cloud-based = 105.1), energy consumption (fog-based = 2668792.8 & cloud-based = 2765927.6) and network usage (fog-based = 9275.7 & cloud-based = 121164.2) are reported to be very less as compared to cloud computing. The findings from the research justifies the proposed methodology. The framework helps the healthcare professionals to diagnose the patient with more accuracy and have reduced the manual monitoring burden of the healthcare experts. The proposed framework can be enhanced by adding sensors at the body of coma patient along with the camera surveillance. This framework can be re-designed for surveillance of ICU patients, bedridden patients, etc. as a general fog-based framework.

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