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Investigation of the Efficiency of an Internet of Healthcare Things for Healthcare Monitoring Using M/M/C/K Queuing Models

Dr.K.Sai Manoj [1]

[1] CEO, Innogeecks Technologies and Amrita Sai Institute of Science and Technology/Reviewer, Vijayawada, Andhra Pradesh, India.

Abstract

Modern computing facilities for medical surveillance, which appear to be the essential computing keystone that aided access and processing of health data of each patient at the very edge of the healthcare system to combat regional or global virus pestilence, appear to be the essential computing keystone. Many computing system architectures for medical surveillance have been given in past studies, but only a few researchers have focused on the pure effectiveness of healthcare data transport in depth. To test the efficacy of an Internet of Healthcare Things (IoHT) architecture, researchers used an M/M/c/K queuing network strategy in conjunction with a three-layer cloud computing continuum. Medical data from body-attached IoT devices at the network edge to local consumers in the fog layer and faraway customers in the fog layer is taken into account in the model. In addition, in two situations, researchers examine how changes in setup and computer layer processing capacity affect key performance indicators. The results of the analysis and modeling reveal that the proposed model can accurately forecast the system response time and the number of computing resources required for healthcare data services in a variety of workload scenarios to reach the goal of efficiency. As a consequence, the study's findings can be applied to better clinical administration in hospitals and medical centers, and also the development of computing structures that are suitable for medical monitoring in the case of a virus epidemic.

Keywords: fog computing, health care, monitoring, performance evaluation, queueing model,

I. INTRODUCTION

IoT is currently the most effective communication platform of the twenty-first century. Because of their communication and computational capabilities, most electronic gadgets in our daily lives will be connected to the internet in the IoT environment. IoT is the next essential step in the Internet's evolution from a communication platform that links computers to one that links and embraces daily items. Another key idea in this respect is the IoP. As per the IoP model, there is a complicated social and technical system in which humans and their devices serve as the network's main components.

In the cyber realm, user gadgets act as proxies for their owners. Devices must operate in the same way as their human customers would if they engaged in the material realm when communicating, exchanging, and managing data on their behalf. The Internet of Things (IoT) is a term that refers to the growing number of linked portable devices, detectors, and controllers. The enhanced connection protocols of IoT devices are making people's life easier. Sports, agriculture, and smart cities are just a few of the topics covered. The health sector has also benefited tremendously from IoT, even in crucial cases such as smart clinics.

By tracking their everyday activities, IoT improvements might considerably assist the most vulnerable populations. It is advised that older persons keep their independence; yet, they are more likely to be involved in accidents. It is critical to keep track of the elderly's health at all times. There have been a lot of studies done on surveillance devices for older people who live alone. The goal is to help before something unexpected happens. Small data capturing devices are insufficient for this. To process queries in live time, you'll require a strong computational architecture.

As a result, IoT enables the development of more accurate treatments. WSNs or BSNs capture the data. WSNs/BSNs are networks of independently geographically distributed sensors that work together to send data to remote processors. Sensors capture data from patients and send it to a separate piece of machinery (a gateway) that receives and retransmits it. A gateway can transport data to multiple distant servers, local data centers, or the cloud in a fraction of a second. BSNs are in charge of keeping an eye on the elderly and alerting family members and doctors in the event of an emergency.

To process a significant volume of generated information as quickly as feasible, strong computing resources are required. In this case, cloud and fog computational resources could be utilized. Furthermore, in terms of computation resources and memory space, the cloud outperforms the fog. The cloud, on the other hand, is extremely reliant on internet connectivity. Real-world trials are sometimes impractical for assessing the effectiveness of the hybrid fog-cloud-edge architecture. Prototyping in real-world settings is both expensive and often impractical. In this case, analytical models that make assumptions based on possibilities can be valuable.

The following is a brief description of a queuing system or system: Users come to receive a specific service and, because instant assistance is not possible. The terms "user" and "service" are used loosely here. Cars arriving at petrol station toll booths, machinery in need of repair, parts moving down a manufacturing line, and communications sent via communication lines are all examples. The goal of the queuing system is to improve a system's performance while lowering its running expenses. To do so, the system should meet a set of minimum performance requirements. The use of a queueing network structure to evaluate geriatric monitoring systems is proposed in this paper.

Data is generated by a sensor network linked to a person, and fog and the cloud are used as processing capabilities in the evaluated architecture. As a result, the following are the main contributions of the paper:

1. A efficiency queuing paradigm as a useful tool for users of fog/cloud-based healthcare monitoring to analyze efficiency even in the early stages of development. There are around 21 parameters that can be calibrated.
2. A load balancing study was carried out, taking into account the job dispersion between the fog and the cloud. Random probability, round-robin, least utilization, JSQ, and fastest reaction time were among the six options studied.

The memory and CPU utilization of each layer was measured through a performance study. presented a smart-healthcare system based on ECC. With differing arrival rates, the routing strategy possibilities were more efficient. provide an architectural and technological approach for doing real-time data dynamic analysis on wearable detectors built on Open Source big data technologies. The paper proposes a four-layer structure: a sensor layer, a preprocessing layer, a cluster computing layer, and a durability layer. The CPU and Memory utilization of each layer was measured through a performance study. presented a smart-healthcare system based on ECC.

It proposes a sensor-based patient surveillance architecture with cloud and fog computing. A sensitivity study is also presented in the paper, which reveals the elements that have the greatest effect on system reliability. [13] also, propose a cloud and fog-based monitoring system.

[14] presented a smart fog computing scheduling paradigm for IoT service provisioning that reduces latency. There's also a case study with significant healthcare usage (an ECG). The goal was to efficiently schedule

ECG sensor requests in a fog setting and manage their requirements on resources available for each fog layer.[15] In terms of the latency performance measure, the suggested model was assessed using the iFogSim toolbox.

II. PROPOSED SYSTEM

Figure 1 depicts a typical framework of the system for an IoHT network for medical surveillance in medical or hospital facilities. The IoHT architecture in question is made up of 3 major computing layers, which include

(i) a cloud computing layer at cloud data centers for remote connectivity by distant clients, such as familial members or healthcare experts from other countries,

(ii) a fog computing layer at fog data centers for local connectivity of internal clients such as medical physicians and doctors, and

(iii) an edge computing layer at local healthcare care rooms for consolidation and incorporation of healthcare sensor information. The edge computing layer, which sits at the very edge of the computer network, provides real-time healthcare information surveillance and gathering by using access points to gather and interpret raw data on patients' wellness in each room regularly.

The edge computing layer is made up of many edge nodes that gather and analyze healthcare data in every room on every floor of a building to provide health monitoring systems in a medical or hospital setting.

2.1. Message life-cycle

The design also depicts the data packets' life duration and the system's operational parameters for medical surveillance. IoT health sensors capture patients' medical data on time, which will then be automatically collected and bundled into medical signals by edge devices. Researchers expect bare physical equipment to be deployed as fog nodes in the fog layer for high processing efficiency at local medical centres. Customized medical systems and apps handle medical signals on fog nodes. These systems and applications are tailored to specific medical data types as well as local health authorities. The processed healthcare data from the fog layer is sent via a fog-cloud gateway to external cloud data centres for further storage and processing, as well as directly to internal clients' frontend interfaces. The cloud layer offers a lot of storage and processing power, as well as a variety of virtual machines (VMs) for sending processed data to remote consumers.

2.2. Assumptions and discussions

Many assumptions about the design and functioning of the IoHT network consideration are presented below to simplify modeling.

2.2.1 Edge layer

[e1]: In modeling, heterogeneous kinds of sensing devices are not taken into account. The creation of medical information by all sensors connected to a patient in a room is modeled as an information burst to a room's edge device.

[e2]: The modeling does not account for the various forms and delays of interaction between sensing devices and edge devices. Wireless communication is used to form the link in practice. However, we overlook the negative influence of near-distance transmission on total performance measures at the edge layer.

[e3]: The edge-fog communication lag is essentially an information transmission delay from each edge node to the fog layer, that will be accounted for in the modelling.

[e4]: Because periodic health exams and the collection of healthcare data are unrelated, requests arrive at an exponentially distributed rate.

2.2.2 *Fog layer*

[f1]: Advanced load balancing is not considered in the fog layer. Jobs from the edge layer are distributed evenly throughout the fog layer's fog nodes via the edge-fog gateway. The issue of fog node load balancing isn't our key focus for modeling simplicity. This fog computing level challenge, which is based on the round-robin technique, could be expanded upon in future studies.

[f2]: These are unconcerned about the various fog node configurations. Fog networks, according to researchers, share the same processing resources and capacities, and data processing on each fog node is independent. For parallel computing, each fog node might have a multi-core CPU. We overlook the importance of data storage in the fog layer.

[f3]: A basic fog-cloud delay of data transmission from the fog layer to the cloud layer is considered the communication lag of the fog-cloud link.

2.2.3 Cloud layer

[c1]: Data is said to be processed on virtual machines (VMs) rather than actual devices at the cloud layer. As a result, we believe that bare physical machines and accompanying storage devices will be excluded from the modeling to reduce complexity, as we are primarily interested in the components (i.e. virtual machines) that analyze medical data in real-time scenarios.

[c2]: Virtual machines in the cloud layer can now have several cores for parallel processing thanks to newer CC platforms. The cloud layer can also elastically scale and manage the access demand of a certain number of remote customers at any given time on a multi-core virtual machine.

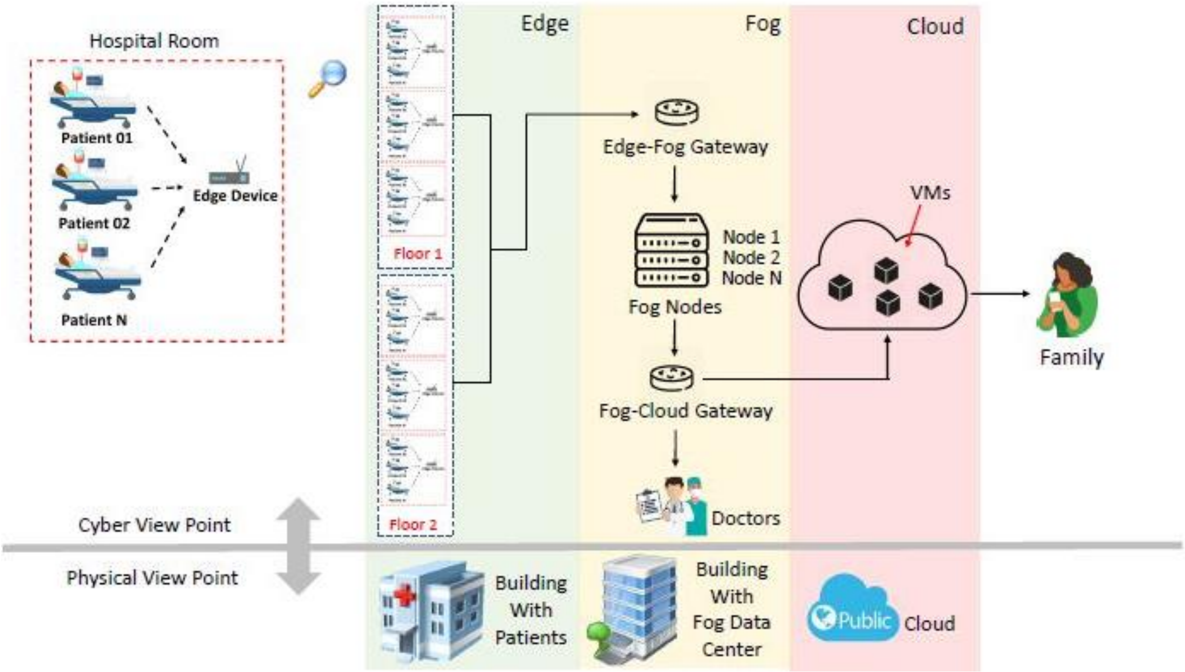


Fig. 1: *IoHT structure for Medical Surveillance Conceptual Architecture*

2.3. Model of queueing

Figure 2 depicts a model for the provided architecture depending on queuing theory. The names of all of the model components are consistent with the architectural standard. All of the above factors were factored into the model. Patients arrive at varying rates, therefore each room generates continuous data. The fog layer is separated from each floor by a certain amount of distance. Delay elements do not provide a specific service; in other words, they are simply components that produce a delay in the transfer of a request, imitating a network delay. There are two doorways in the fog layer, one for entry and one for escape. When these messages arrive at each gateway, they can be dispersed according to a load balancing scheme. In this paper, we look at the equally distributed distribution approach. It's worth noting that while the fog is nearer to the detectors, the cloud was usually more powerful. The M/M/c/K queue paradigm is used to model the delays from the cloud and fog. The queue length, service duration, and the number of inner servers are the major criteria of such stations. The c service stations are represented by the M/M/c/K model. The capacity of every service station is limited to K nodes.

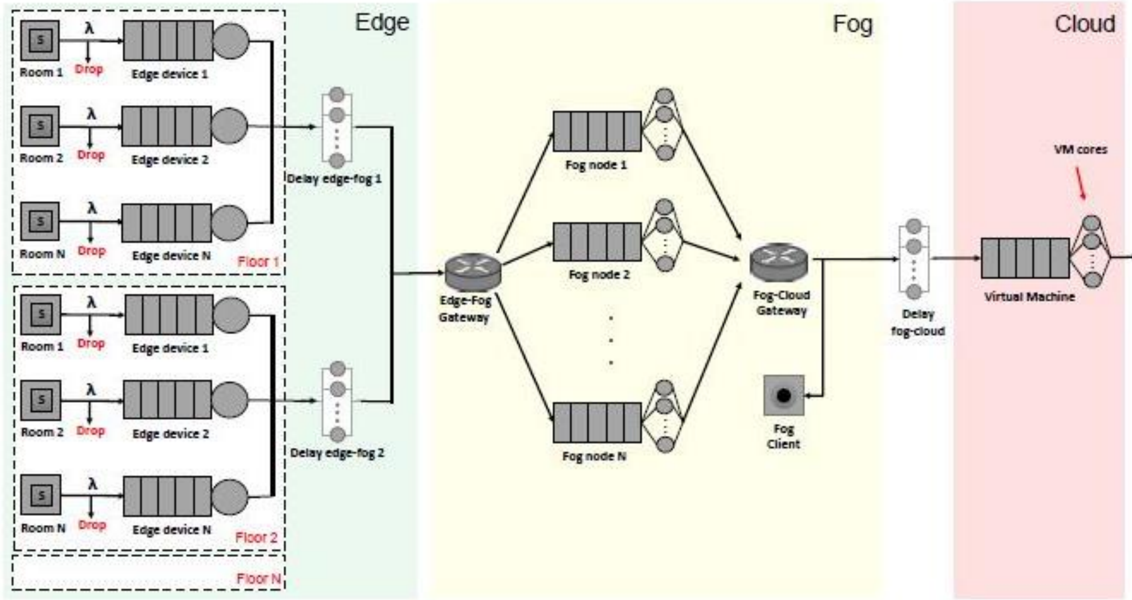


__Fig. 2:__ Performance of an IoHT architecture for healthcare surveillance using a queuing network model.

III. SIMULATION RESULTS

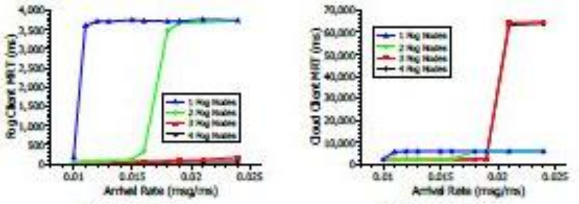
The input data for each modeling framework are listed in Table 1. The X tag signifies that the queue has no capacity defined for the component. The maintenance schedule for the queue elements is represented by the time column. Communication time is represented by the time between the delay elements.

***Table 1:** Simulation parameters*

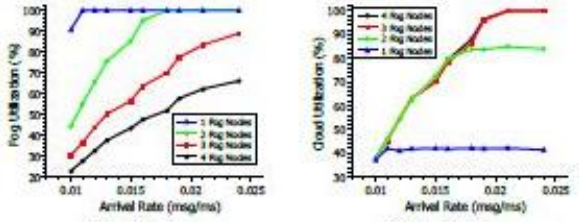
Component type	Component	Time (ms)	Queue Size
Queue	Edge Devices	5	50
	fog nodes	30	250
	Cloud VMs	50	5000
Delay	Edge-fog 1	6	X
	Edge-fog 2	12	X
	Fog-cloud	2000	X

3.1. Scenario A: Variation in fog capacity

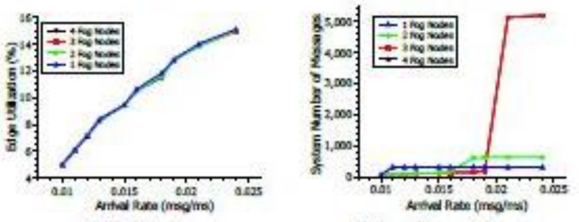
Modifying the no. of resources in the fog layer to replicate a healthcare monitoring system is demonstrated in this section. In this situation, the configuration was Table 3 depicts one experiment. The number of fog nodes was changed from one to four, while the other elements stayed the same. The findings are shown in Figure 3 for varying numbers of fog nodes.



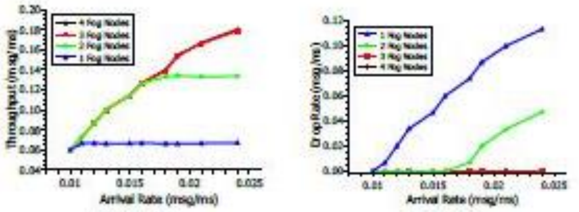
(a) Fog Client MRT (b) Cloud Client MRT



(c) Fog Utilization (d) Cloud Utilization



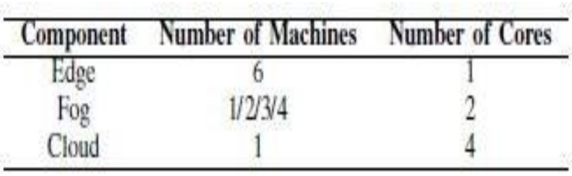
(e) Edge Utilization (f) System Number of Messages



(g) Throughput (h) Drop Rate

__Fig. 3:__ Outcomes of simulations with various numbers of fog nodes.

Table 2: *Scenario A component parameters*



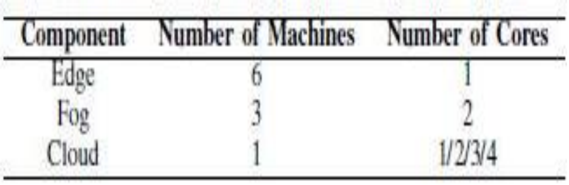
Component	Number of Machines	Number of Cores
Edge	6	1
Fog	1/2/3/4	2
Cloud	1	4

Figure 3 shows the outcomes of simulations with various numbers of fog nodes. In general, the faster the reaction time, the more resources necessary to maintain processing capacity. The MRT for the systems with three and four fog nodes ranged from 46 to 174 milliseconds. Configurations with one or two fog nodes clocked in at over 3500 milliseconds. AR of 0.011msg/ms for one fog node and 0.015msg/ms for two fog nodes causes saturation. Messages begin to vanish when MRT expansion reaches saturation and stabilization.

3.2. Scenario B: Variation in cloud capacity

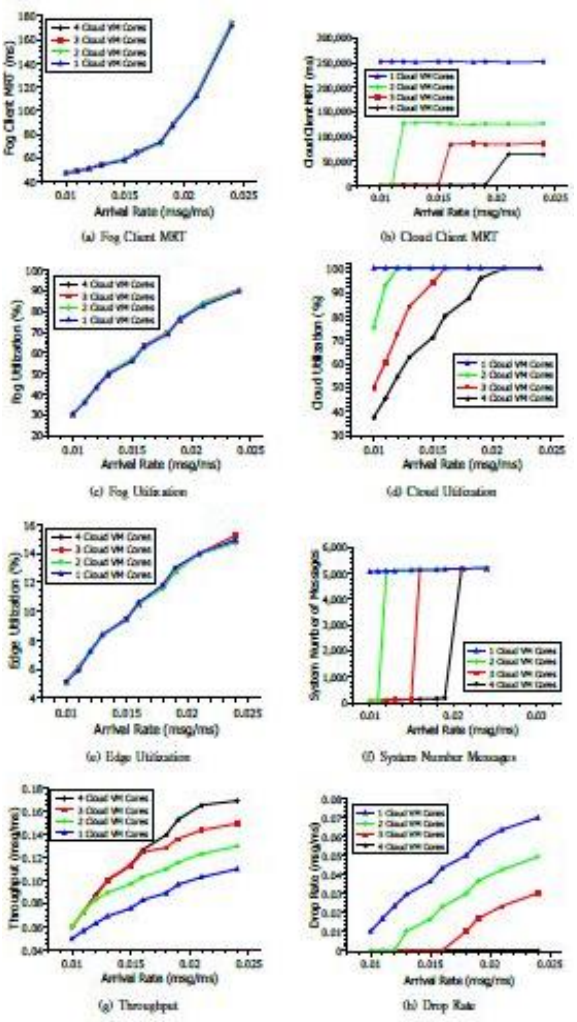
This scenario shows the results of the simulation model when the processing capacity of the cloud is changed in terms of virtual machines. The configuration utilized in the scenario B trials is shown in Table 4. One, two, three, and four virtual machine parts were used in the experiment. The comparable findings are shown in Figure 4.

Table 3: *Scenario B component parameters*



Component	Number of Machines	Number of Cores
Edge	6	1
Fog	3	2
Cloud	1	1/2/3/4

Figure 4 depicts the MRT when the Fog Client output is taken into account. Because the capacity modification was done in the cloud, MRT's performance for these various cloud capabilities was the same. Nonetheless, the Fog Client MRT was significantly lower than the majority of Cloud Client MRTs.

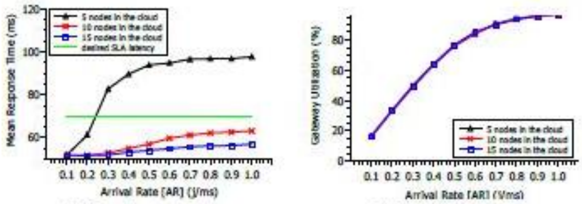


(a) Fog Client MRT (b) Cloud Client MRT (c) Fog Utilization (d) Cloud Utilization (e) Edge Utilization (f) System Number Messages (g) Throughput (h) Drop Rate

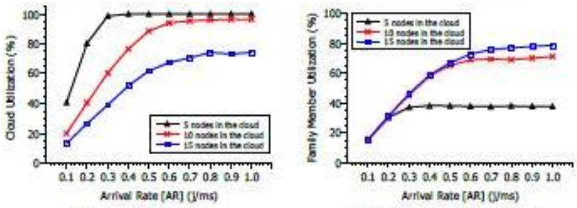
Fig. 4: *Outcomes of model simulations with various numbers of cloud virtual machine cores.*

3.3. Variation in Cloud Resources Analysis

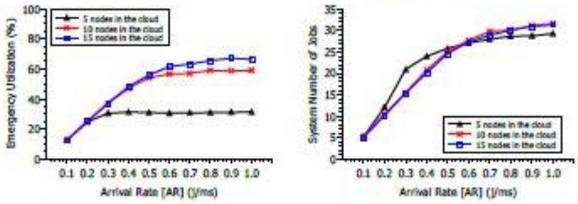
Figure 4 shows the results of identifying cloud resource capability variation. It's vital to notice that the fog was limited in this case. The MRT indicates how responsive the system is. As resources rise, the MRT tends to become smaller; however, this tendency is not always obvious. Figure 5 depicts the results for MRT. In circumstances where there were fewer supplies, smaller MRTs were obtained. The results for 10 and 15 nodes, on the other hand, were very similar. Only when supplies are decreased to five nodes does the MRT increase significantly due to AR.



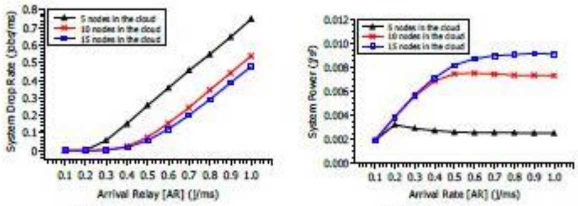
(a) Mean Response Time (b) Gateway Utilization



(c) Cloud Utilization (d) Family Member Utilization



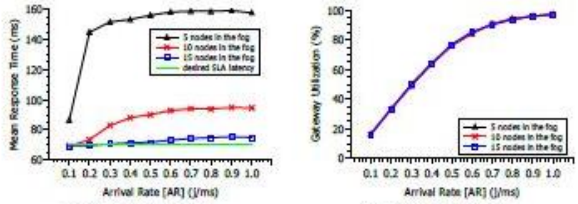
(e) Emergency Utilization (f) System Number of Jobs



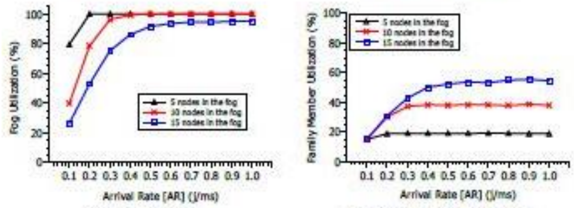
(g) System Drop Rate (h) System Power

Fig. 5. *The arrival rate of new requests was varied in the analysis.*

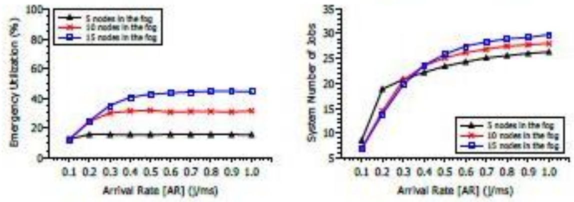
Figure 6 shows how output elements, family members, and emergencies are used. Because of their commonalities, both findings are given together. The main variation between the charts is that the outcomes for family members are slightly greater than the results for emergencies. The service times may account for this disparity. The family member is set to have a longer service time (Table 2).



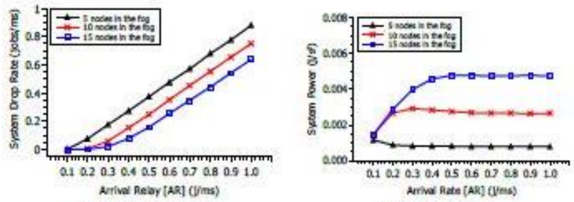
(a) Mean Response Time (b) Gateway Utilization



(c) Fog Utilization (d) Family Member Utilization



(e) Emergency Utilization (f) System Number of Jobs



(g) System Drop Rate (h) System Power

Fig. 6. *The investigation of the variation in fog resources yielded the following results.*

IV. CONCLUSION

In the context of IoHT, this research developed a type M/M/c/K queuing model to define and evaluate the effectiveness of a medical surveillance scenario similar to a medical or hospital facility. Many other metrics, like mean reaction times, utilisation level, and drop rate, can be calculated using this method. The model shines out when compared to other similar projects. The model comprises four levels, which is more than what is suggested by the literature. You can configure different arrival rates for each group of sensors because the sensors are organized by location. The model's capability is reflected not only by the number of machines but also by the number of processing units inside each machine. Finally, the model enables us to determine a variety of mean response times, both in the cloud and in the fog.

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