QoS Based Scheduling in Fog Computing Environment using AHP

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CERTIFICATE

This is to certify that project report entitled "**QoS based Scheduling in Fog Computing Environment using AHP**", submitted by Shefali Varshney in partial fulfillment for the award of degree of Master of Technology in Computer Science & Engineering to Jaypee University of Information Technology, Waknaghat, Solan has been made under my supervision.

This report has not been submitted partially or fully to any other University or Institute for the award of this or any other degree or diploma.

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ABBRIVATION

Abbreviations	Name
QoS	Quality of Service
QoE	Quality of Experience
ITU	International Telecommunication Union
QoD	Quality of Design
QoP	Quality of Performance
AHP	Analytical Hierarchy Process
SME	Small and Medium Enterprises
SVM	Support Vector Machine
CRITIC	Criteria Relevance Through Intercriteria Correlation
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
TOPSIS-CD	Technique for Order of Preference by Similarity to Ideal Solution- Connection Distance
QNS	QoE based Node Selection
MBDO	Measurement Based Delay Optimal
MeFoRE	Media Fog Resources Estimation
RR	Relinquish Rate
NPS	Net Promoter Score
FSP	Fog Service Placement
ANP	Analytical Hierarchical Process
SDRM	Software Defined Resource Management

ABSTRACT

With the rapid development in the technology Fog computing environment has appeared as a new paradigm reducing a lot of issues in Cloud computing. Earlier various users were dependent on Cloud for the execution of various applications such as health monitoring and emergency response which need low latency and delay. Fog computing environment has various layers that have their own computation and latency. Thus for a better quality of application such as video games various applications need to be placed on the appropriate Fog layer. Also, AHP is known for its multi-criteria decision making and can be used for the selection of best possible Fog layer among others. The current focus of our research is to perform QoS based scheduling in Fog environment using the Analytical Hierarchical Process (AHP). We have evaluated the performance on the basis of parameters such as storage, CPU cycle, network bandwidth, maximum latency, processing time.

CHAPTER 1

INTRODUCTION

Smart devices are becoming more and more popular day by day and are used in various felids such as for communication purposes, business, agriculture, banking, and transportation. Smart applications are those applications which include actionable and data-driven insights into the user experience. The insights are provided in such an environment where the features of the applications which allow users to more efficiently complete the desired work [1]. They commonly take the structure of estimates, recommendations and indicated the next actions.

1.1 Smart Applications

Smart applications could be employee facing or consumer-facing. In many cases, the end user may be a machine or system instead of a human. In such cases, the smart applications computerize the operational processes and business based on data-driven understanding [2]. For instance, healthcare smart applications provide possible patient diagnosis and treatment proposals to clinicians supported analyses of patient and research data. Also, retail smart applications create product references based on the study of consumer buying operation.

Smart applications have made their place among human beings in context to the smart home, smart cities, wearable's, smart grid, connected car, and smart farming are among the most famous smart applications [3]. Whereas data-driven understanding has no worth if operations cannot be performed and acted upon them. Smart applications percepts in context to systems and users hence they can take equivalent actions. Nowadays end user expects to be addressed as a particular by the organizations and companies. With the emerging customized knowledge, smart applications illustrate the user experience which leads to greater customer loyalty [4]. Some applications that deliver customized insights permit corporations to push users and customers to carry specific actions that lead to coveted outcomes in support of both strategic and tactical business goals.

Internet of things (IoT) is a system of devices that can accumulate, sense and transfer data through the internet excluding any human intrusion. IoT samples expand from smart connected associated homes to wearables to healthcare. However, IoT is playing a major role in our day to day lives [2]. IoT applications are improving the luxuries of our lives but it moreover gave control by easing everyday work life.

Widely known application of IoT is a smart home which is defined as the area under which all the devices are interacting with each other and also to their intangible surroundings. Whereas for efficient energy management and extended security smart home presents the owner an ability to control and customize the home environment [5]. For building and monitoring these smart homes there are abundant technologies present. Various people search for the term smart home every month. Also, various companies are active in the fields of smart home instead of other applications in IoT.

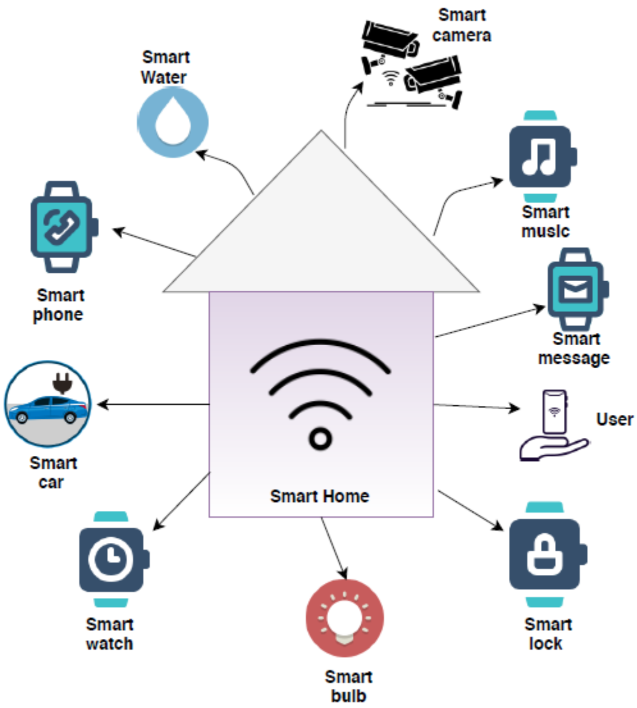


Fig. 1.1: Smart home illustration

For example, there are various companies which have started producing their own smart product based on new technologies. Many products such as smart bulbs, fire alarms, smart locks, smart security system, and a smart toothbrush [1]. IoT platform may be utilized to collect data associated with a particular geographic location with the help of performance analytics and monitoring tools in order to create awareness for a disaster.

For an instance what abilities a smart bulb can have than a regular bulb. As shown in Fig. 1.1 a smart bulb can change the color of the light and that too according to one individual choice. They can also be turned off and on from the smartphones. With the help of smart locks, a door can open automatically when the person gets closer to the door. Also, the door closes spontaneously when the person enters the house and closes the door. Whereas the grant access in the home can also be viewed with the help of smartphones [6]. Smart farming is one of the major concepts among other well-established categories such as mobility, health, or industrial. However, due to the distance among the farming operations and the great number of farm animals can be controlled which could change the way farmers work.

Regardless of this quality of the applications also play a very important role for consumers [7]. There are various kinda quality issues such as Quality of Service (QoS) and Quality of Experience (QoE). Fresh customers and network applications examine that service traders guarantee the services presented. Else the customers may be offended because of the service. This has imitated important execution and research efforts in QoS through the operating system, application, and network levels [8]. QoS is normally calculated through a combinatory leap of interdependent metrics that incorporates data loss rates, channel capacity, traffic load, delay jitter, and throughput. These parameters can be deliberated fairly with the help of networking equipment. To facilitate QoS provisioning in customary telecommunication networks several techniques have been developed such as admission control, congestion control, traffic shaping and engineering [9]. Since it is most of the importance to assure and monitor QoS for high-quality systems, the comprehensive knowledge and guarantee of the user received quality has emerged as a lively area of research.

1.2 Quality of Service (QoS)

The term QoS is commonly described as the operation of a network and error rates, bandwidth, and latency are major factors in the performance measurement of QoS. According to ITU QoS [10] is defined as the

"The whole amount of characteristics of a communication service that endures on its capability to meet the stated and implied needs of the end users of the service."

The main quality of a network which defines the system is the capacity of the network portion or network to offer the functionalities regarding communication between the end users. The quality can be measured in four distinct terms of ways such as customers QoS requirements, QoS offered by the provider, QoS obtained by the customer, and QoS observed by the customer. Though QoE is described as a whole perspective of a user, which is the level of gratification or pain of a person [11]. An information network forms the resolution of any effective organization. Such types of networks transport a large number of data and applications containing delay sensitive data and high-quality video like real-time voice. Whereas the bandwidth-intensive applications set up resources and network capabilities although complement, add value and increase every business process. The networks must also supply predictable, secure, measurable and at times guaranteed services. Attaining the needed QoS by organizing the jitter (delay variation), delay, packet loss and bandwidth on a network system is helpful in making the end to end business solution a success. Therefore, QoS is a group of techniques to handle the network resources.

1.2.1 QoS parameters

QoS is affected by several factors in the packet switched network that is further separated into two categories such as technical and human factors. Human factors comprise of availability of service, the stability of service quality, user information and waiting times. Whereas the technical factors include scalability, reliability, network congestion, and maintainability [12]. Various parameters which play a very efficient role in QoS are as follows:

- **Latency**: A packet might take much longer time to reach its target since it gets controlled up in extended queues, either it takes a lesser direct route to prevent congestion or in some other cases excessive latency can give an application such as online gaming or VoIP [11]. It can be said that the overall time duration for a signal to travel from one point to another point, normally from a transmitter via a network to a receiver. It is also disturbed by the time spent by the data packet in the queue much longer because of issues of network congestion.
- **Packet Loss**: The dumping of data packets while a device such as a router or a switch in a network is overstressed and thus cannot receive any incoming data at a given moment [14]. However, the higher level transport protocols such as

TCP/IP assures that the data which is sent during the transmission is obtained properly at the other end.

- **Bandwidth**: It is defined as the capability of a network contact link to transfer a higher amount of data from a single aim to another in a considered amount of time. QoS maximizes the network by managing bandwidth and putting priorities for the applications which require much more resources than others.
- **Jitter**: It is defined as the outcome of the route changes, timing drift, and network congestion.

1.2.2 QoS types

There are several aspects of quality which are related to its explanation is described below respectively:

- **Quality of Design (QoD)**: it is defined as the quality of design that is all about set conditions which the service must marginally have to fulfill the needs of the customer. Therefore the product must be planned such that it is fulfilling the needs of the customers [15]. Whereas the design should be easy and also least costly enough so as to address the end users desires. QoD is affected by several factors such as cost, product type, the demand for the product and profit policy.

- **Quality of Performance (QoP)**: it is known as quality of performance which is defined as how good the service performs or product functions when are set to use. It provisions the degree to which the service or product are fulfilling the customers need from the point of view of QoD. Gathering the customer's hopes is the focus of when QoP is generally talked about. A proper customer survey is conducted to find out the customer's viewpoint about a service delivered.

1.3 Cloud Computing

Cloud has been one of the major platforms at which most of the population is dependent upon and it facilitates its users to operate over the internet [2]. The term cloud computing is a simple process of accessing and storing the programs and data over the internet instead of a hard disk. The data cloud is anything like files, music, documents, images and much more [3]. The end user would be able to operate the data at any time anywhere just with the support of the net. Also, the speed of transfer depends upon distinct factors like the capacity of server and internet speed. The Cloud infrastructure consists of three layers which are SaaS, PaaS and IaaS which are described below as follows:

- **SaaS:** Software as a service (SaaS) is a platform which helps the end user by supplying them a software through internet. SaaS gives a benefit that system the applications can be uploaded by the system administrator to their individual servers. Thus the application can be accessed using SaaS without the software installation.
- **PaaS:** This platform as a service (PaaS) Cloud model permits the end users to run, develop and organize the applications by offering them the program and reducing the complexities of maintenance. User can send data from simple cloud-based applications to higher cloud-enabled applications. Also, the services can be purchased from the cloud service provider on a pay as you go basis and with the help of network connection these resources can be accessed.
- **IaaS:** this infrastructure as a cloud (IaaS) model provides the end users of the Cloud higher flexibility to lower level than other services. Generally, it offers even CPU clocks with OS levels control to the developers. For instance – S3 and Amazon EC2.

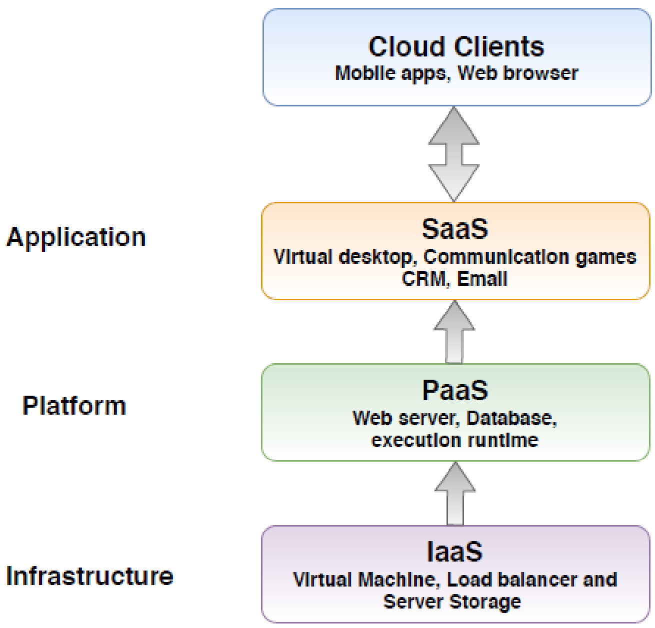


Fig. 1.2: Cloud Service Models

1.3.1 Cloud Deployment Models

There are three types of cloud deployment models which are namely Private Cloud, Public Cloud, and Hybrid Cloud and are discussed below as follows [3]:

- **Private Cloud**: This Cloud is retained by a constitution and is utilized only for their inside objective. This guides that the constitution can manage it with higher control and privacy. It comprises of a better understanding of the computing device that would supply the computing power as a service inside a virtualized environment.

- **Public Cloud**: This Cloud provides service that is open for experimenting and later they operate on a pay as you go basis. The main objective behind this is to provide benefits to the end user at the highest level possible. Basically, private individuals make use of their services that are in need of security and infrastructure that is provided by the private Cloud.

- **Hybrid Cloud**: This Cloud consists of a combination of private and public Cloud. Also, the workload can be divided among these two Clouds that makes it much more flexible. Besides, there are better data distribution alternatives in this Hybrid Cloud. If there is a little variation between the processing and computing demand, then the ability will be provided to portend their base structure which will be capable of handling the overflow.

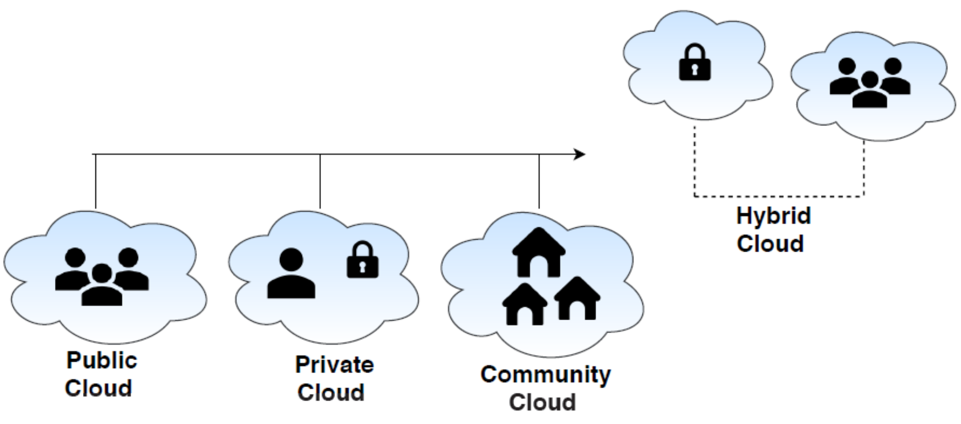


Fig. 1.3 : Cloud Deployment Models

1.3.2 Issues in Cloud Computing

There are several issues in the Cloud computing environment but one major issue which causes harm for various applications is latency. The amount of latency is much more in Cloud than in any other platform. Some issues are given as follows [2]:

- **Latency:** It is defined as the delay amidst a cloud service provider response and client request. It significantly affects anyhow enjoyable and usable devices and communication are working. These problems can be amplified for services of Cloud communications that could be specifically apt to latency for several reasons. Despite that latency in surroundings of Cloud is much more complex and slightly predictable for measurement [3]. There are several factors which affect latency like the ground to satellite communication hops or the standard amount of router hops in the route to target server. Latency may also increase in interchanging of data among Cloud services over the Internet. This obstruct can conclude in much greater costs to end users in favor of various Cloud services.

- **Security:** This is one of the important issues in Cloud computing which leads to various risks such as inadequate data backups and data loss, system vulnerabilities, shared Cloud computing services and social engineering attacks. Insufficient data backups have made to many businesses attackable which is a special type of security hazard. Especially in networks which have complex structures Cloud computing systems can still be vulnerable. Due to the openness of a Cloud computing system, attacks have especially become common. A malicious user can break into a structure so easily if it has acquired any confidential information or any login detail [3]. Also, various Cloud solutions does not offer proper security between the clients controlling the shared applications, resources, and systems.

- **Load Balancing:** This is performed with the help of load balancers where each entering request is diverted and is clear to clients who have created the request [3]. On the basis of several known factors like current load or availability, the load balancer uses several algorithms to establish the fact that which server should forward and handle the request on to the selected servers. Among the various applications, the most commonly used application of load balancing is to offer an internet service from various servers which are also known as a server farm.

- **Fault tolerance**: it is defined as designing a blueprint for maintaining the ongoing work whenever some parts are unavailable or down. This helps the corporations to measure their requirements, infrastructure needs and also offer them services when the connected devices are unavailable due to some reason. The major reasons behind fault tolerance in the Cloud are replication and redundancy [16]. The fault tolerant system operates on the idea of working various other duplicates for every single service. Whenever a system part moves towards a downstate or is crashed then it is of most importance to have alternate type systems. The server works with the contingency database which consists of several redundant services within.

- **Data issues:** There are several data issues in Cloud computing like data integrity, data loss, data theft, data availability, and data backups [17]. Anyone from any location can use the data which is on Cloud and it does not distinguish between a sensitive data thus making it a cause for data integrity. The data must be available accessible entire time for the clients besides having issues which affect the storage and head to the client data loses. The client is not aware of the actual place where data is centered or saved because it is distributed over many nodes. Thus it can direct to an actual data storage location.

1.4 Fog Computing

Fog computing is defined as the distributed computing paradigm as shown in Fig 1.4 that essentially expands the services offered by the Cloud to the network edge. It provides management and scheduling of networking, computes and storage services among the end devices and data centers [4]. Fog computing mainly includes elements of an application working both in the edge devices as well as in the Cloud between the Cloud and the sensors which are in the forms of routers, either sharp gateways, or allocated fog devices. Fog computing environment basically involves computing of resources, mobility, interface heterogeneity, protocols communication, distributed data analytics, and cloud integration to meet the demands of the utilization that oblige less latency with a large and compact spatial distribution.

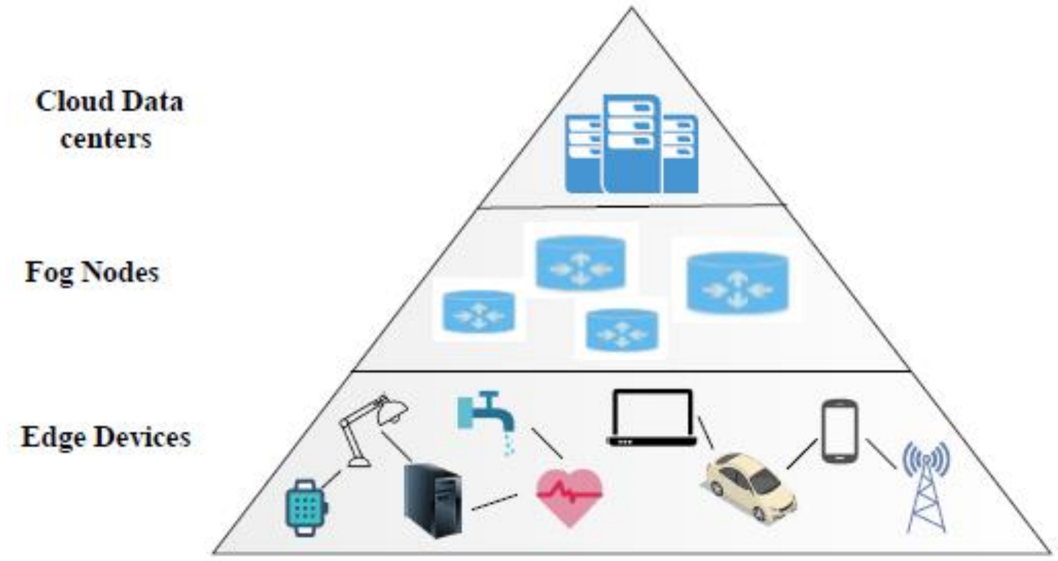


Fig. 1.4: Fog computing as a distributed paradigm

The Fog computing architecture has several layers and the concept of Fog computing is similarly defined as Edge computing also, which is a current involvement in the field of computing paradigms that focuses on providing Cloud like service at the edge of the network to help a large amount of IoT devices. However in Fog computing different devices like microdata center, Cisco IOx equipment, smartphone, Nano-server, Cloudlets, and personal computer normally are known as fog node. Therefore fog computing plays a very important role in reducing the latency of service delivery of various IoT enabled systems and resting the system from a very huge amount of data load. Fog nodes are not resource enriched as compared to Cloud datacenters. Thus more often Fog and Cloud computing paradigm work in a comprehensive manner to handle both QoS and resource needs of large immense IoT enabled systems [5].

1.4.1 Fog Computing Layered Architecture

The figure below represents the fog layer computing architecture. In the lowermost layer stands the sensors (side devices), along with gateways and boundary devices [5]. That layer further incorporates some applications which might be established in the side devices to improve the usefulness. Components on such types of layers uses the network, the adjacent layer, for disclosing amongst itself and also among opponents and the Cloud. The layer after this one consists of the services of Cloud and assets that sustains the processing of IoT and resource management that gets to the Cloud. Whereas resource management software resides above the Cloud layer that organizes the entire substructure and allows the QoS to applications of Fog computing [4]. And the top most layer consists of the applications that utilizes fog computing to convert intelligent and innovative requests to consumers. Within the SDRM layer, it accomplishes various middleware similar solutions to maximize the use of Fog and Cloud substances on the sake of the requests. The main objective of those service is to lower the expense of utilizing the Cloud at the just a similar time that execution of petitions achieve stages on latency that is acceptable by pressing task execution levels on nodes in Fog.

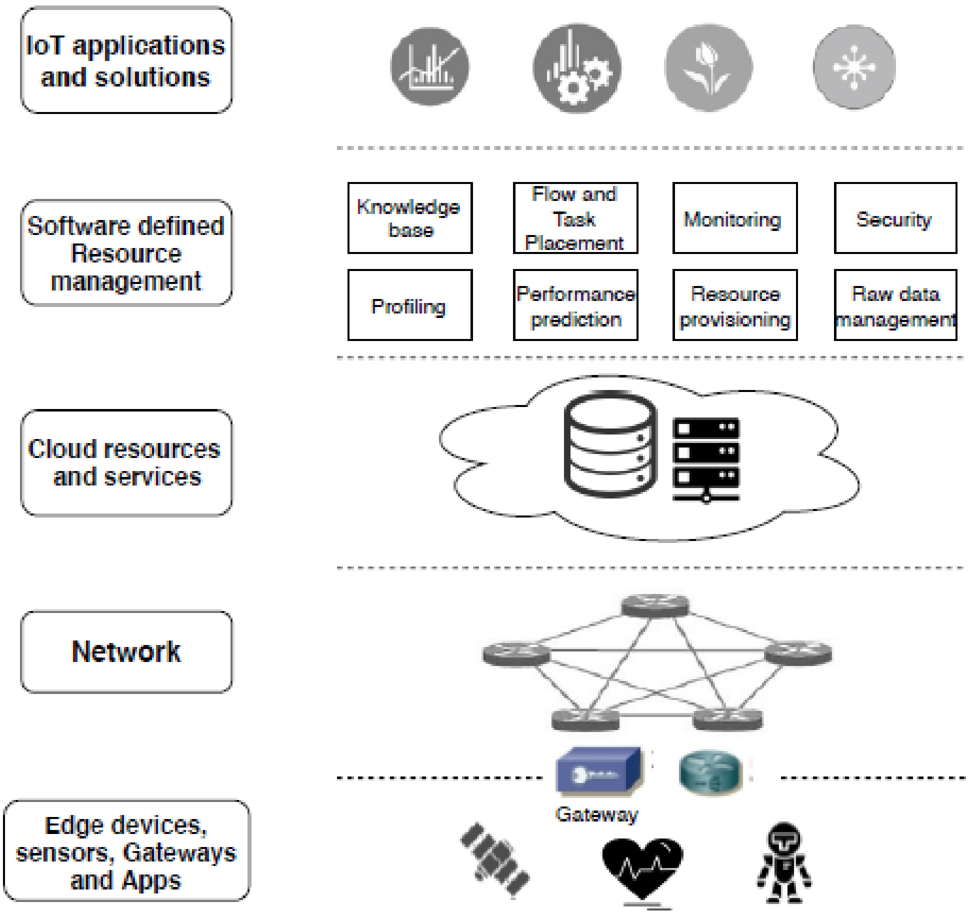


Fig. 1.5: Fog computing layer architecture

1.4.2 Fog Computing Characteristics

There are several characteristics of Fog computing in which it is helping the end users to settle its area:

- **Decrease in Network Traffic:** From an estimate done by Cisco there are presently 25 billion connected devices all over the world, an amount which could be around 50 billion in 2020. To generate receive and send data billion of devices such as tablets and mobile phones are being employed placing the computing capabilities nearer to the wherever the devices are situated [14]. Thus Fog computing profits right here by offering the stage for analysis and filtering of the data which is produced by these devices closer to the edge and for production of local data views. This also extremely decreases the traffic being sent to the Cloud.
- **Adequate for IoT queries and tasks:** The growing no. of intelligent devices, most of the demands concern to the surrounding of the device. Therefore similar demands can be provided in the absence of the global data submitted in the Cloud [15]. For an instance the foregoing sports pursuer's apps Endomondo permits an end user to track population playing a same sport around.
- **Low latency demands:** Real time data processing is required by mission critical applications. Number of great e.g. of such apps are managed, cloud robotics or anti-lock brakes on a vehicle [16]. Holding the command system working on Cloud may take the loop of sense process which actuate slowly. Now this is the area where Fog helps, by doing the evaluation which is needed for the management of systems much closer to the robots thus making the response in real time possible.
- **Scalability:** The Cloud may became the obstruction if once all the fresh data created by the end equipment's is constantly sent to it [17]. Whereas Fog targets at operating incoming data nearer to the data source itself, it reduces the burden of the processing which is to be performed on Cloud.

1.5 Analytical Hierarchical Process (AHP)

The Analytical Hierarchical Process (AHP) is a study of the relative importance of indefinite criteria. When the components to be measured are well known then with the help of this technique of relative computation a range of priorities is acquired from pairwise comparison assessments [18]. The capability to perform pairwise comparisons natural legacy and there is a need to manage with the world where everything is constant and relatively changing and therefore there is none firm on which the standards can be evaluated. Whereas in conventional measurements, there is a range that an individual shall apply to assess whatsoever component which arrives along and that contains the quality the range is for, the constituents are estimated one after the other, nor performing comparison among the elements with each other. In AHP the paired comparison is created on the basis of random decisions using geometric values which are adapted from the unqualified principal AHP scale from 1 to 9 is shown in Table 4.1. Further a range of relative values is acquired from all such paired comparisons and it also becomes a part of the real scale that is immutable according to the individuality change such as the real number systems. AHP process is helpful in making the decisions of multicriteria including opportunities, rewards, risks, and price. The thoughts are created under the stages and are expanded with the help of real-life choices.

Table 4.1: Saaty relative importance scale

Definition	Assigned Value
Equally important	1
Weak importance	3
Strong importance	5
Demonstrated importance	7
Absolute importance	9
Intermediate values	2,4,6,8

However, to fit the needs of the users AHP enables a platform to construct a hierarchy respectively. It also offers an efficient framework designed for bunch of decision making by magnificent control on the groups approaches. The need of allocating a numerical value to each and every unstable of the problem supports choice inventors to sustain coherent thought models by acquiring the relative weight of each and every component of the sequence alternatives and criteria's. Performing this entire process the user obtains the best alternative. The AHP process is implemented effectually to various types of issues in resources allocation [9], planning [9], prioritization [10], decision making, and conflict resolution [11] and forecasting or prediction [12] and in health care [6,7,8] also. AHP process is an exceptional case of the ANP, which utilizes a system framework that permits feedback and dependence in place of a sequence.

1.5.1 Applications of AHP

In health care environment various other applications of AHP are as follows:

i. Selecting the best optimal data provisioning ordering system of the hospital management. The primary standards in this petition were speed, simplicity, cost, quality, flexibility and safety.
ii. Selecting a corporate health plan among the five alternatives: Health Maintenance Organization (HMO), fee for services (FFS) that further has three choices: Individual Practice Association (IPA), Staff and Group, and Physician Provider Organization (PPO).
iii. Choosing the optimal method to offer health care for everyone.
iv. Doing a cost inquiry to choose whether or not on an infant formula policy to stop selling, sell to industrial countries, sold to third World countries.

1.6 Motivation

Nowadays more amount of end users are storing their data on Cloud so that they can access it from anywhere and at any time. But besides that users are also facing latency issues due to the traffic which occurs on Cloud. So, to eliminate this cause Fog computing environment was introduced which basically improves the latency issues caused by the Cloud. Fog computing has various layers and each of its layer contains latency and computation. Whereas to achieve a better quality of the services applications need to be allocated on Fog layers.

CHAPTER 2
LITERATURE SURVEY

This chapter elaborates the work done under the fog service placement, and AHP decision making. After reading some papers we discovered the problem of placing the applications with better QoE on the Fog environment. Since in Fog architecture, there are various layers so the user will have to decide on which layer to place applications. Some of the papers which conveys this problem are discussed below:

2.1 Related Work

In 2018, Jatoth et al. [13] proposed a hybrid multi-criteria decision-making model including the option of cloud services between the possible alternatives. This technique also assigns several ranks to cloud services placed on the quantified QoS applying a novel extended Grey method for Order of priority by similarity to ideal solution incorporated with the AHP process. They also examined the proposed approach in terms of adequacy under changes in alternatives, sensitivity analysis, and adequacy to support group decision making and handling of uncertainty.

In 2018, Lavicevic et al. [14] described the method of identifying the much more multi-functional forest stand to utilize the multi-criteria methods of AHP and easy multi-attribute rating technique utilizing the ranks (SMARTER) about the loss function approach (LFA) like the aggregation method.

In 2018, Yang et al [15] considered a multiattribute decision-making technique on the basis of AHP and Rough set based on the architecture of maritime wideband communication system along with fog computing architecture and software-defined network (SDN). Based on the multi-attribute of various network this work focuses on selecting a workable network routing scheme.

In 2018, Guerrero et al [16] presented an optimization policy in Fog computing for the placement of services. This process is considered to place the services that are popular which is nearer to the end user. The iFogSim simulator is used for the experimental evaluation and has also compared the approach with the simulator policy. This algorithm puts the most important services closer to the end users enhancing the network usage and service latency. Whereas this algorithm is implemented in each and every fog device, by means of including only usage data and performance acquired in the apparatus itself. The outcome of this showed that the policy decreases the distance among the most requested services and the clients.

In 2018, Zhang and Chen [17] presented a fuzzy AHP method based on risk assessment focusing on the ambiguity and complexity of the substation operation. The experimental result shows that the evaluation method plus the suggested indexes can address the level of risk caused by the department accurately, and intuitively.

In 2017, Wu et al [18] proposed a new hybrid evaluation technique on the basis of AHP entropy weight and a Cloud model for the evaluation of community sustainability. The proposed method combines the entropy-based method and the AHP process to establish index weight. The outcomes show the overall sustainability of the community which lies between the good and middle level and much closer to the middle level. The level of social and economic sustainability is much greater than that of institutional, environmental and cultural sustainability.

In 2017, Laghari et al [19] presented the outcomes of the tests performed with the help of two mobile devices such as Samsung and HTC to examine the influence on the end users QoE during penetrating Cloud, when the internal storage of Samsung have10 GB free space and HTC mobile device is filled. With the help of experimental results, later changes in Cloud applications are proposed for the service worker to enhance end users QoE.

In 2017, Li et al [20] presented an integrated method of group decision making to resolve the services for cloud purveyor decision problem below the environment of Cloud computing emergence. The Service of Cloud purveyor index selection structure is developed from two standpoints i.e. management and technology. Whereas the classification model such as SVM is used for the initial covering to decrease the amount of candidate suppliers. Another method is planned to evaluate the index value of supplier by the proficient insights and experience. Further, the weight of the index is evaluated with the help of CRITIC. The purveyors are determined through improved TOPSIS substituting Euclidean distance through TOPSIS-CD.

In 2017, Cao and Chen [21] designed a QoE based node selection (QNS) scheme, with the help of which end users can choose a proper edge node from numbers of vehicles in obtaining a satisfying QoE overall. The authors have also illustrated the concept of edge computing enabled IoT (EC-IoT) that utilizes connected vehicles as the edge computing platform. The simulation results show the QoE improvement of QNS when matched with the baseline strategies.

In 2017, Taneja and Davy [22] presented a Module mapping algorithm for the efficient usage of the resources in the network infrastructure by effectively expanding the application modules in Fog-Cloud substructure for the IoT supported applications. Through Fog computing in the picture the computation is dynamically distributed across the Fog Cloud layer, and the modules over the Fog and Cloud layer, as well as the modules, can thus be positioned nearer to the source upon devices in Fog layer. The experimental results of this work can be served as a Micro-standard in research related to Fog computing and IoT and further might also be used for the Service level Objective benchmarking and QoS for IoT applications.

In 2017, Anand and Veciana [23] proposed a MBDO programmer that maximizes a price function based on the mean flow delays in system of multi class, such as file downloads, web interactive, etc. In such kind of environment, the price function declares coveted tradeoff amidst traffic classes considering diverse QoE awareness that is not linear in the flow delays or else in system loads. Their simulations results validate the capability at absorbing performance and pros and cons of the presented approach.

In 2017, Skarlat et al [24] examine the placement in Fog resources of IoT services considering their respective QoS requirements. The authors also show that the proposed model helps in preventing the QoS violations plus rises towards 35% lower cost of achievement against an approach based on Cloud. The authors also scheduled to enhance the suggested model by appending constraints around the existence of resources, the cost of resources and the reliability of services. One more issue is to find out most efficient colony of neighbor and to find the nearest neighbor colony fog extension. It is important to achieve realistic network data, for example, communication link delays.

In 2017, Gupta et al [25] proposed an iFogSim simulator to design Fog and IoT environment and evaluate the influence of resource management abilities in network congestion, latency, energy consumption, and cost. The authors have also discussed two case studies to illustrate a comparison among the resource management policies and the modeling of an IoT environment. Under different circumstances, scalability of the simulation toolkit of execution time and RAM consumption is verified.

In 2017, Mahmud et al [26] proposed a QoE aware application placement policy that prefers different applications positioning demands respective of each user expectations and calculates the abilities of Fog instances given the current status of the application. Whereas in Fog computing environment it also promotes the placement of applications to proper Fog instances so that user QoE is maximized in respect of resource consumption, utility access, and service delivery. Their experimental results show the policy is considerably increasing the network congestion, data processing time, and service quality and resource affordability.

In 2016, Aazam et al [27] designed a new methodology mentioned to as MeFoRE in order of supplying resource estimate on the ground of give up ratio of the services which is often known as RR and improve QoS with the source of aforementioned QoE and NPS records. This algorithm is designed using CloudSim as well as is used on real traces of IoT on the ground of resource pricing in Amazon EC2. Moreover emergency, healthcare, and multimedia service require a fast response with low latency. In context to IoT Cloud communications, it is becoming tougher to accomplish that.

In 2016, Wilson et al [28] suggested a framework to assist Cloud decisions for small and medium enterprises in Tamil Nadu (India) with the help of well-established morals of AHP. This research emphasizes on SMEs in Tamil Nadu, which is among the constituent states of Indian Union. This paper accounts on the outcomes of implementing AHP to real data which is collected out of decision makers and indicates its benefits as a decision support tool in favor of SMEs in Tamil Nadu. The experimental results presented in this paper shows that the AHP technique can also be used for obtaining the best alternative for a particular workload. The important limitation of this survey is the less amount of samples which are used to establish the significance of the criteria.

In 2016, Mushtaq et al [29] proposed a technique that reduces the whole network delay because of services in multimedia that are variable and constant bit rate traffic model. The authors also presented an approach for video streaming traffic that evaluates the users QoE utilizing the systems QoS parameters that are packet loss rate, and delay. The performance is compared to the proposed method with the QoV and QoE methods execute well by precisely handling the impact caused by the QoS parameters. The experimental results displays that the explained approach is effectively reducing the entire delays in the network that corresponds to maximize the users QoE.

In 2016, Nayak and Tripathy [30] proposed operation enhances the efficiency of the backfilling algorithm by planning an additional number of leases and reducing the lease rejection with the help of AHP. The main objective of this paper was to use AHP in backfilling algorithm as a decision maker to select the best possible lease so that to schedule the deadline sensitive lease. Also, AHP is used in different areas as a decision maker. The backfilling algorithm programs the leases on the ground of first come first serve. If there are more than two leases are similar than it can reduce the performance of the backfilling algorithm which is resolved by using AHP for evaluating ranks between the schedules and similar leases.

In 2016, Wang et al [31] proposed a scalable controlling system named QWatch that perceives and locates anomalies based on the users QoE in real time. The authors have evaluated QWatch in a systematic VoD system and production CDN and Microsoft Azure Cloud. This method efficiently locates and detects exceptions in their comprehensive experiments. They also discussed the insights acquired from running a VoD system. They also found numerous false positive and negatives in Cloud while system metric based deviations detection methods are applied.

In 2016, Laghari et al [32] analyzed the impact on end users QoE while videos from long distance and nearby location were accessed. In the First level of the analysis ping response of every Cloud from multiple sites were collected using 3G/4G and Broadband networks. The second level of the analysis based on observing videos from different codec, resolution, and bitrate. Further, the authors also conducted a questionnaire to the users to provide their knowledge about services for each cloud. The results show that the QoE level is high when perceiving videos from Cloud.

Table 2: Summarization of Related Work

Ref. No.	**Author**	**Proposed framework**	**Experimental Results**
[13]	Jatoth et al.	Hybrid multi-criteria decision-making model	Examined the proposed approach in terms of adequacy under changes in alternatives, sensitivity analysis
[14]	Lavicevic et al.	Identified the much more multi-functional forest	Process of combination of MC methods is displayed
[15]	Yang et al	Considered multiattribute decision-making technique on the basis of AHP	Focuses on selecting a workable network routing scheme.
[16]	Guerrero et al	Optimization policy in Fog computing	The iFogSim simulator is used for the experimental evaluation and has also compared the approach with the simulator policy.
[17]	Zhang and Chen	Fuzzy AHP method based on risk assessment	The evaluation method plus the suggested indexes can address the level of risk
[18]	Wu et al	New hybrid evaluation technique on the basis of AHP entropy weight	Overall sustainability of the community which lies between the good and middle level
[19]	Laghari et al	Presented the outcomes of the tests performed with the help of two mobile devices such as Samsung and HTC	Changes in Cloud applications are proposed for the service worker to enhance end users QoE.
[20]	Li et al	Integrated method of group decision making	The weight of the index is evaluated with the help of CRITIC
[21]	Cao and Chen	QoE based node selection (QNS) scheme	QoE improvement of QNS when matched with the baseline strategies.
[22]	Taneja and Davy	Module mapping algorithm for the efficient usage of the resources in the network	Results of this work can be served as a Micro-standard in research related to Fog computing

[23]	Anand and Veciana	MBDO programmer that maximizes a price function	Results validate the capability at absorbing performance and pros and cons of the presented approach.
[24]	Skarlat et al	placement in Fog resources of IoT services considering their respective QoS requirements	Scheduled to enhance the suggested model by appending constraints around the existence of resources, the cost of resources and the reliability of services.
[25]	Gupta et al	FogSim simulator to design Fog and IoT environment	Under different circumstances, scalability of the simulation toolkit of execution time and RAM consumption is verified.
[26]	Mahmud et al	QoE aware application placement policy that prefers different applications positioning	Results show the policy is considerably increasing the network congestion, data processing time, and service quality and resource affordability.

2.2 Research Gaps

i. In the earlier works AHP technique is applied in various fields but most of the researchers have not applied AHP technique in selection of best Fog layer.

ii. Also in the papers reviewed the Fog service placement operations has not been performed.

2.3 Conclusion

It has been concluded that for placing applications in Fog layers we have to decide the best possible layer in the Fog environment. Since in some papers it is clear that AHP is the best technique used for selection among various criteria's. So AHP will be used for the selection of best optimal application and best fog layer.

2.4 Problem Description

This chapter provides a detail explanation of the problems which are in Fog computing layered architecture such that the end user is perceiving a better quality. In general each and every fog layer in the hierarchy will provide more storage, processing and network capabilities in assistance of the vertical applications at their level of the hierarchy. For an instance, upper level layers offer additional processing to provide large storage capacities or data analytics. Since fog computing architecture has several layers and each of its layer has its own latency and computation. Therefor it is difficult for the user to select appropriate fog layer which can satisfy QoS requirements. Selected Fog layer should prevent over as well as underutilization of Fog resources.

3.2 Objective

To design a framework for allocating Fog resources to latency sensitive applications using AHP.

CHAPTER 3

PROPOSED SOLUTION AND METHEDOLOGY

A framework should be designed for the allocation of latency sensitive application on Fog layer with the help of AHP. Whereas the application parameters consist of storage, CPU cycle, network bandwidth, maximum latency and processing time and the Fog parameters consists of CPU cycle, storage, round trip time and processing time.

3.1 Proposed Framework

Figure 4.1 shows the proposed framework for application service placement in achieving better QoE for end users. It consists of three components: IoT devices, Fog environment, and Cloud infrastructure. The Fog environment consists of the Fog manager and Fog levels. Further, the application component, Fog level component and the decision making component are comprised under a repository known as Fog manager. The decision-making component helps in the selection of the best application suitable for the service placement at the Fog level with the help of a technique termed as AHP. The AHP technique is helpful in making the decision among the various other parameters. The IoT devices send their data to the fog manager and with the help of fog manager, the application parameter is selected with the help of AHP decision making approach and then the selected parameter is sent to the Fog level for the service placement. So with the help of this framework the end user can achieve a better quality of the application.

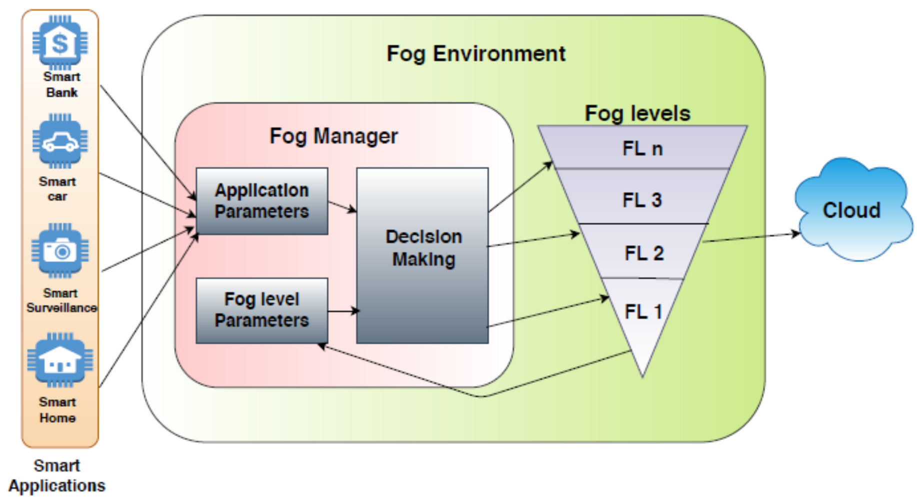


Fig. 3.1 Proposed Framework

3.1.1 Decision maker Component

AHP is used for the decision making and also for selection of various parameters detailed working of the AHP is provided here and the steps are listed as follows:

Step 1: We have selected the range for various parameters as follows:

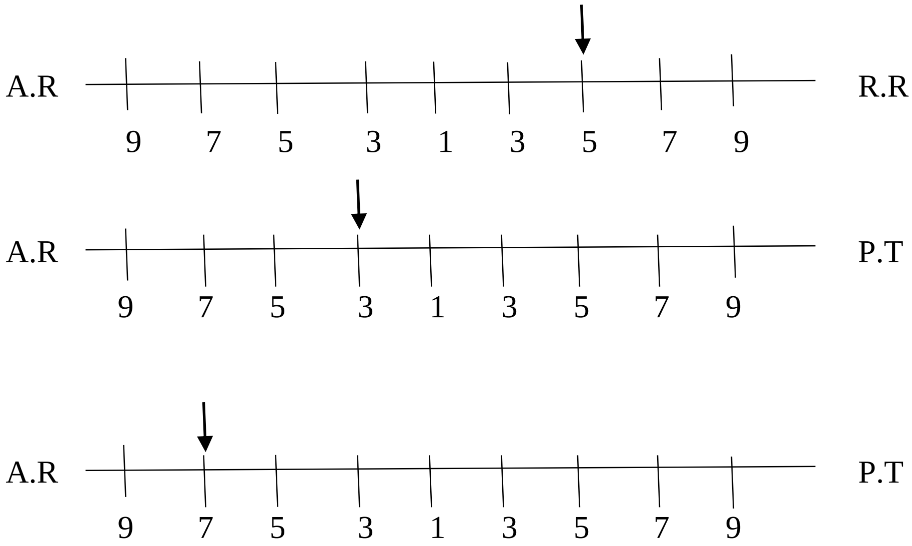
1 - Equally important

3 - Moderately important

5 – Strongly important

7 – Thought to be much more important

9 – Much more important



Step 2: In this step, a pair wise comparison matrix has been created and considered the above defined values for evaluation purpose

$$A = \begin{bmatrix} 1 & 1/5 & 3 \\ 5 & 1 & 7 \\ 1/3 & 1/7 & 1 \end{bmatrix}$$

Now the sum of each column will be evaluated

Sum of A=19/3   47/35   11

Step 3: Dividing each element of matrix by their column sum

$$A = \begin{bmatrix} 3/19 & 7/47 & 3/11 \\ 15/19 & 35/47 & 7/11 \\ 1/19 & 5/47 & 1/11 \end{bmatrix}$$

Step 4: Calculating sum of each column which is supposed to be equals to 1. This is called priority or Eigen value vector

$$A = \begin{bmatrix} 0.15 & 0.14 & 0.27 \\ 0.78 & 0.74 & 0.63 \\ 0.05 & 0.10 & 0.09 \end{bmatrix}$$

Sum = 1 1 1

Step 5: Normalizing principal Eigen vector:

$$A = 1/3 \begin{bmatrix} 0.15 + 0.14 + 0.27 \\ 0.78 + 0.74 + 0.63 \\ 0.05 + 0.10 + 0.09 \end{bmatrix}$$

$$A = \begin{bmatrix} 0.1866 \\ 0.7166 \\ 0.08 \end{bmatrix}$$

Normalizing value obtained in the above matrix are given as access rate is 18.66%, required resources is 71.66 %, and processing time is 8.0 %. Since the percentage value of required resources is 71.66% which is more among the other two. So, we will consider required resources as the best parameter for the evaluation.

Step 6: Calculating threshold value λ_{max}:

λ_{max} = [19/3(0.1866) + 47/35(0.7166) + 11(0.08)]

= 3.024

Step 7: Calculating consistency Index:

CI = (λ_{max} –n) / (n-1)

CI = (3.024 – 3) / 3-1

CI = 0.012

Now we calculate the consistency ratio. The formula is given by:

CR= CI/RI

CR=2.0% which is less than 10%

If $0 < CR < 10 \Rightarrow$ inconsistency is acceptable

If $10 < CR < 100 \Rightarrow$ repeat the process

3.1.2 Smart applications

The data mainly required for processing is arriving from the smart applications which reside under the internet of things (IoT). These applications send their data to the fog manager which is in the fog environment. Smart applications consist of a smart home, smart car, smart surveillance and smart bank. These applications are the most popular among the end users, especially the smart home and smart car. Whereas some associations are much more effective in smart home applications as compared to any other application. Whereas now people prefer smart work instead of something which takes more time for processing. Therefore the smart applications have been into consideration for a good reason. The products related to smart home are helpful in saving energy, time and money. Even some companies are also planning on providing the city with a new experience which has never seen before. Also, a large number of heterogeneous and different end systems are incorporated transparently and seamlessly with the help of IoT. The large variety of link layer technologies, devices, and services are also involved in this system. Whereas millions of devices with ultra-dense interworking within the IoT scenario are characterized. Generally, IoT contains physical objects and inter network of the devices, the data can be collected at remote locations by the number of objects which further communicate to units organizing and managing the data in the services.

3.1.3 Application Parameters

The first parameter is storage that is defined as the amount of space required so that various operations are performed. Whereas number of CPU cycle required are also important for the fog applications which is measured in gigahertz (GHz). The next parameter is network bandwidth that is also very important to estimate and is measured in MB\sec. Next comes the maximum latency which is deliberated in seconds. The parameter after this is processing time which here tells about the duration in which a user request is processed and quality is also maintained.

3.1.4 Fog level Parameters

In the proposed technique some parameters are same as the Fog level parameters such as storage, CPU cycle, and network bandwidth. Whereas here round trip time is also considered which is described as the actually the time that involves the processing of a network request in some little amount of time from starting to end and then back to the starting step. The last parameter defined here is processing time which is same as the applications parameters.

3.1.5 Fog levels

The fog computing environment consists of multiple layers in which each layer is responsible for a particular task which further simplifies operations of other higher layers. The lowest level of the fog level architecture consists of the IoT devices which are the source of the data and communicate with the real world. Likewise, the bottommost layer of the architecture is operated by the IoT sensors for managing a system. Basically, actuators are the patterns which acknowledge the changes in the environment that are imposed by the applications on the basis of the data occupied by the sensors. In IoT, each and every device is the origin or drop of the data, therefore, can be represented by an actuator and sensor. Hosting of application modules is done with the help of Fog device which is an element in the network. The connection among sensors to the network through Fog devices is known as gateways. From edge device to the cloud the Fog device layer surrounds the whole resource. The Fog devices also produce data streams that are operated by the monitoring layer for a better understanding of the state of devices. This layer also manages the usage of power consumption, resource and the availability of actuators, sensors and Fog devices. This information is further supplied to the resource management layer by the monitoring elements and can also share this to others in need as well. The core element of the architecture is the resource management and contains elements that organize resources of the Fog device layer such that the application level QoS constraint is fulfilled and the wastage of resources is minimized. Also, the scheduler and placement elements contribute towards the management of the available resources so that the best participant is selected for hosting an application and thus allocating the resources of the device to the module itself.

3.1.6 Cloud

Cloud in itself is a warehouse which stores data in huge amount and perform processing and computation. It can be accessed from anywhere at whatever time the user want to access their personal information. Cloud has various uses which are such as it consumes less cost, it also provides security when any sensitive data is lost. Cloud computing refers together to the application that are transferred as services via internet and the hardware and software systems which offer those services in the datacenters. Some applications requires a model of storage, a model of communication and a model of computation. Also mobile interactive applications may also be captivated because these services depend on the huge amount of data instead of that they must be extremely available. Batch parallel processing can also be performed on the Cloud.

3.2 Proposed Algorithm

The following algorithm is proposed for the problem definition which is given below:

Algorithm: Scheduling Algorithm based on AHP

Step 1: Set Buffer size for time‘t’.

Step 2: FSP advertise their services with respective parameter to Decision making Block.

Step 3: All applications parameters are stored in Buff1 [ ].

Step 4: Apply AHP on all application parameter and calculate their respective score.

Step 5: Rank application according to their respective score and store them in Buff2 [ ].

Step 6: Calculate score of the available FSP network close to the application deployment.

Step 7: Rank the FSP and calculate their score using AHP and store them in Buff3 [ ].

Step 8: Find all the FSP whose score is greater than Application score from Buff2 [] and Buff3 [ ] and store these FSP in Buff4 [ ].

Step 9: **IF** Buff4 [ ] is empty store the application parameter to Buff5 [ ].

ELSE IF Buff4 [ ] has one element then allocate the FSP to application remove the FSP from Buff4 [ ].

ELSE Buff4 [ ] has more than one element allocate it to the minimum FSP.

Step 10: **IF** Buff5 [ ] has elements pick the topmost element from the buffer and the element from the remaining FSP.

IF their variation is less than 0.5 than allocate FSP to the current application.

ELSE print there is no FSP available and send it to the Cloud.

The current scenario of our research is to place application on Fog instances by deciding which fog layer is best for placing the applications with the help of AHP. In this process first the application arrives and then the parameters for the application are analyzed. In the next step the parameters on each and every fog layer are analyzed for the selection process of the best possible fog layer. Further analytical hierarchy process (AHP) is used for the selection of fog layer best suitable for the applications. In this process we make the pair wise comparison matrices and then calculate the consistency of that matrix by comparing it with the threshold value which should be less than 10 %. Whereas if the matrix is consistent than the application with those parameters are send to the fog layer otherwise the process is repeated again. The parameters are analyzed again for the further process. The pair wise comparison matrix is formed as follows: numerical expression of pair wise comparisons (Table 1) are placed in the upper triangle matrix; values of 1 are placed on the main diagonal, while the lower triangle contains reciprocals of the values in the upper triangle and these numbers are placed symmetrically to the main diagonal. After this Eigen vectors are calculated and then the consistency index of the matrix is calculated as follows:

$$CI = (\lambda_{max} - n) / (n-1)$$

Where n is number of elements in the comparison matrix and λ_{max} is the maximum Eigen value of the matrix. Accordingly the consistency ratio is defined as:

$$CR = CI / RI$$

Where the random index (RI) is the mean of the CIs computed over hundreds of randomly generated matrices of the same size. According to Saaty (1980), if $CR<0.1$ the evaluation is considered acceptable. The later research has discussed the acceptable the acceptable threshold value, and according to Wedley (1993), if $0.1< CR < 0.2$ the evaluation is considered moderately.

CHAPTER 4

IMPLEMENTATION AND EXPERIMENT

Proposed Algorithm is applied on the application and Fog parameters. Implementation part is performed on Matlab (R2013a). The detailed explanation s of the result is listed in the following section.

4.1 Implementation and Result from Proposed Algorithm.

Firstly some parameter are considered for an application and also for Fog layers. Five parameters are taken into consideration such as storage, CPU cycle, network bandwidth, maximum latency and processing time. Now AHP selection technique is applied on these parameters to choose the best according to its AHP score. Straightaway five Fog layer standards are also considered which are storage, CPU cycle, network bandwidth, round trip time and processing speed. Then again AHP technique is applied on the Fog layer parameters to select the superior one among them. After the selection is done now the better application will be allocated on the superior Fog layer with the help of the proposed algorithm. The implementation steps are as follows:

i. The screenshot of the values of application and Fog parameters is as follows:

	A	B	C	D
1		Layer1	Layer 2	Layer 3
2	**Storage (GB)**	80	70	74
3	**CPU cycle (GHz)**	10	8	7
4	**Network Bandwidth(NB) (mb\sec)**	10	11.5	9.5
5	**Maximum Latency(ML) (sec)**	2	3	5
6	**Deadline (min)**	15	10	11
7				
8				

Fig. 4.1: Application and Fog parameters values

ii. After applying AHP technique a pair wise comparison matric is formed is listed as follows:

	A	B	C	D	E	F
1		**Storage**	**CPU cycle**	**NB**	**ML**	**Deadline**
2	Storage	1.00	5.00	1.00	7.00	5.00
3	CPU cycle	0.20	1.00	0.20	2.00	1.00
4	NB	1.00	5.00	1.00	7.00	5.00
5	ML	0.14	0.50	0.14	1.00	0.50
6	Deadline	**0.20**	1.00	**0.20**	2.00	1.00
7						
8						

Fig.4.2: Pair wise Comparison matrix

iii. Now the resultant AHP score is shown as follows:

AHP score for the application parameters:

No. of attributes: 2

No. of alternatives: 3

	A	B	C	D	E	F
1						
2	weights(w	0.833333	0.166667	0.454545	0.048508	0.084117
3	Sr.No.	Alternativ	Score	Rank		
4		Layer1	1	1		
5		Layer 2	0.8625	3		
6		Layer 3	0.8875	2		
7						

Fig. 4.3: AHP score of application parameters

iv. AHP score for the fog layer parameters:

No. of attribute: 3

No. of alternative: 3

	A	B	C	D	E	F
1						
2	weights(w	0.454545	0.090909	0.454545	0.048508	0.084117
3	Sr.No.	Alternativ	Score	Rank		
4		Layer1	0.940711	1		
5		Layer 2	0.925	2		
6		Layer 3	0.859585	3		
7						

Fig. 4.4: AHP scores of Fog parameters

CHAPTER 5

CONCLUSION AND FUTURE WORK

In this report we discovered the best layer to place an application which has better QoS in Fog computing environment using AHP. AHP is basically used for Multi Criteria decision making. The performance evaluated is on the basis of these parameters such as storage, CPU cycle, network bandwidth, maximum latency and processing time. QoS is the most important factor in any field which itself states that QoS is a measure of acceptance or rejection of a service. In this AHP is used to select the best layer to place the application which has better QoS.

5.1 FUTURE DIRECTIONS

There are various future direction that can enhance the capabilities of Fog computing and resource management strategies in the area of IoT applications. It could be included in deep neural network in context of Healthcare. Data can be stored and managed with the help of this application in Fog computing environment. Whereas TOPSIS is also a multi criteria decision making technique that could also be integrated with AHP and fuzzy alternatively. Further ANEKA platform can also be used for generating distributed application on Cloud.

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