QOE-AWARE RESOURCE ALLOCATION TECHNIQUES FOR FOG COMPUTING

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***Abstract*-Fog computing is a computing infrastructure where resources like data and applications are located in between data source and cloud. It allocates resources based on the need of the user. In our project we are allocating the resources based on Quality of Experience aware model. In Quality of Experience aware model, resources are dynamically allocating the resources for various tactile applications in Industrial Internet of Things. Quality of Experience aware resource allocation is a very important aspect in tactile internet. Tactile internet is an internet network which combines multiple technologies and applications to enable communication between human and machine in real time .The main use of tactile internet will be haptics communication. In various sectors we can apply the haptic communication use cases in tactile internet. The main aim of this project is to provide ultra-low latency, high reliability, security etc., by using tactile internet. This project gives an efficient algorithm and a model for resource allocation.**

***Key Terms*-Fog computing, Industrial Internet of Things (IIoT), quality of experience (QoE), quality of service (QoS).**

I. INTRODUCTION

Fog computing is the extension of cloud computing that consists of multiple edge nodes directly connected to physical devices. Such nodes are physically much closer to devices, which are able to provide instant connections. Both fog and cloud are inter connected. Cloud is a network of multiple devices connected to each other through the internet. In cloud, there are two layers they are frontend and backend. The frontend contains client devices and the backend contains storage and processing servers. Wireless connection is made between these two layers for communication. Cons of cloud are high latency, downtime, security and privacy. The difference between cloud and fog is that cloud remains as a centralized and fog is a decentralized system. Cons of fog are fog is more complicated when compare with cloud and it involves additional expenses. Data processing is close to the source of information in fog hence low latency.

In this project, we have used QOE aware model for resource allocation which is based on feedback given by the customers. In this QOE aware resource allocation method, we allocate resource according to customer's requirements. Resource allocation is a process of dividing and distributing the resources to the requested system. In this resources can be allocated according to the Net Promoter Score (NPS) value of a customer thus increasing the customer satisfaction. QOE can be obtained by different ways, one among them is NPS. This method improves the service quality, utilization of resources, customer reliability and also improves the profit for the service provider.

II. ROLE OF FOG COMPUTING IN IIOT

The role of fog computing in IIOT depends on the type of industry where IOT plays an important role. In this section, we present several use cases in the industrial sector.

A. Healthcare Sector

In health care sector, this can be applied in many areas for example remote surgery, Ambient Assisted Living, remote first aid. Using fog computing along with tactile internet, first aid can be provided in remote areas where less number of hospitals are available. This can also provide remote monitoring. In case remote surgery, Latency plays a vital role. Delayed imaging or poor can cause severe problems. Hence best fog node is selected to provide best service as there is no room for error.

B. Education Sector

In several educational tasks and training tasks hands-on experience is needed. To achieve this tactile internet along with fog computing can be

applied. This reduces the latency. Using this technology, trainer or trainee can feel the hand movement or the device. In education sector, low delay and some packet loss is acceptable when compared with health care.

C. Online Shopping Industry

Currently, in online shopping users cannot get the feel of the object for example cloth they are touching. This can be solved using tactile internet by transporting haptics. This enables the user to get the real feel of the object they are touching.

D. Intelligent Transportation

Transportation industry has kept few steps towards intelligent transportation, in last few years. In some parts of the world, delivery of goods using drones is already taking place. The drone operator remotely help the drones to deliver the goods where drones cannot find the place or in harsh regions. For this use case, packet loss, delay are acceptable

E. Food Industry

Food industry is an interesting area where tactile internet plays a vital role. The examples would be remotely smelling and tasting the food.

III. IMPLEMENTATION METHODOLOGY

A. QOE Basics

QOE is a measure of user's satisfaction and liking with the provided service. QOE can be obtained by different ways, one among them is NPS. NPS is feedback given by the customer. NPS is collected from the customer in several occasions. This NPS value ranges from 0-10. Every customer's feedback is gathered and NPS is calculated by using promoter and distractor NPS. Promoter lies between 9 and 10 .Distractor lies between 0 and 6. Passive lies between 7 and 8. Based on NPS ratio, resources are allocated according to default NPS, overall NPS, NPS given by the customers for k number of occasions.

B. QOER Model

QOER model contains 3 steps. The first step is fog nodes are ranked and then they are selected based on their rank. In the second step NPS ratio is calculated and then QOE Ratio Estimation Algorithm is applied to find the resources need to be allocated. These three steps are explained briefly below.

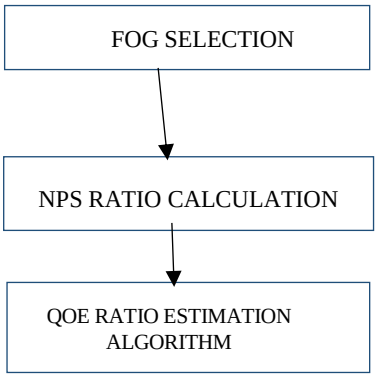

Fig 2 Flow chart for QOER Model

1. Fog Selection

The rank is calculated by using

$$f_{rank(j)} = \sum_{i=0}^{j}(f_i D_{min} + f_i j_{min} + f_i PL_{min} + f_i C_{min} + f_i P_{\beta_F min}) \quad (3.1)$$

$$0 \leq j \leq N$$

$$F_{sel:min(f_{rank}:0\rightarrow N)} \quad (3.2)$$

Equation 3.1 shows how the score for each fog node is calculated. While calculating the fog node score consider delay, jitter, packet loss, latency and blocking probability. The suitable fog node is selected based on the ranking. Equation 3.2 shows that fog nodes are ranked from minimum to maximum.

2. NPS Ratio Calculation

Equation 3.3 is for calculating NPS ratio. In first case, when no previous record exists and customer is new then apply default NPS. When overall NPS is greater than default NPS (7.5) then apply overall NPS. When overall NPS is greater than customer NPS given during k number of occasions then apply overall NPS else apply customer NPS. Equation 3.4 is for calculating all types of NPS, where NPS_{pr} represents promoters and NPS_{dt} represents distractors.

$$NPS_r = \begin{cases} \sum_{i=0}^{n} \frac{NPS_d}{\bar{x}NPS_{OI}}, \text{if } n = 0 \\ \sum_{i=0}^{n} \frac{\bar{x}NPS_{OI}}{NPS_d}, \text{if } \bar{x}NPS_{oi} > NPS_d \\ \sum_{i=0}^{n}\sum_{k=0}^{n} \frac{\bar{x}NPS_{OI}}{\bar{x}NPS_{ck}}, \text{if } \bar{x}NPS_{oi} \geq \bar{x}NPS_{ck} \\ \sum_{i=0}^{n}\sum_{k=0}^{n} \frac{\bar{x}NPS_{ck}}{\bar{x}NPS_{OI}}, \text{if } \bar{x}NPS_{ck} \geq \bar{x}NPS_{oi} \end{cases} \quad (3.3)$$

$$NPS = NPS_{pr} - NPS_{dt} \quad (3.4)$$

3. QOE Ratio Estimation Algorithm

Master node M is connected to fog node F which has highest rank and with workload w. After connecting Master node M with fog node and then QOE is determined according to the type of customer. When total workload production rate of master node connected to that fog node is less than the capacity of the current fog node and workload of the master node is less than the maximum workload, then resources will be allocated to the requested master node. When customer is new then check whether overall NPS is greater than default NPS, then allocate according to overall NPS else allocate resources according to default NPS. When customer is existing then allocate resources according to NPS given by customer for k number of occasions or overall NPS. When NPS given by customer for k number of occasions is greater than overall NPS, then allocate resources according to NPS given by customer for k number of occasions else allocate resources according to overall NPS. When a customer ask for more than half of the fog node size then we will allocate only 50% of the size required in one fog node and remaining requirement will be allocated in other fog nodes by considering the fog node size. This method reduces the idle time of the fog node and not all the resources will be dumped in the same fog node so that the workload of the fog node can be reduced to some extent.

Proposed QOE Ratio Estimation Algorithm

Input**:** Rank for each fog nodes, NPS ratio

Output**:** Resource to be allocated

Step 1: Initialization: Master node connects to fog node F_j with workload, initialize flag = 1 and resourceoccupiedlist as empty list

Step 2**:** Determining Quality of Experience according to the type of the customer

1. While $\sum_{i=0}^{n} \lambda_\omega i < \omega_c$ && $\omega_i < \omega_{max}$ && flag =1 && resourceoccupiedlist != currentfogid do
2. allocate resources to Master node M_i
3. If M_{new} then
4. if $NPS_o > NPS_d$ then
5. $\theta \leftarrow NPS_o$
6. else $\theta \leftarrow NPS_d$
7. end if
8. if M_{exist} then
9. if $NPS_{ck} > NPS_o$ then
10. $\theta \leftarrow NPS_{ck}$
11. else $\theta \leftarrow NPS_o$
12. end if
13. end if
14. If θ > 50% of respective fog node size then
15. Allocate resource half of θ
16. Store the fog id in the resourceoccupiedlist
17. else
18. Allocate resource of size θ
19. flag=0
20. end if
21. end while

IV. EVALUATION

We evaluated our proposed model, which we have implemented using java, by using iFogsim. The software requirements for this setup are eclipse IDE along with iFogsim. The hardware requirements for this setup requires a Intel core i5 processor, At least 1 GB hard disk, 8GB RAM and windows operating system. We implemented this model using 5 fog servers.

Performance Analysis

Figure 2, 3 and 4 shows the comparison of the results obtained from the proposed QOER algorithm and the enhanced QOER algorithm. The first graph (fog server instance versus resource utilization level) shows that there is an increase in resource utilization level while using the enhanced QOER algorithm. The second graph (fog server instance versus workload) shows that there is a decrease in workload as the resource allocation is fairly distributed while using the enhanced QOER algorithm. The third graph (fog server instance versus idle time (in minutes)) graph shows that the idle time of the fog servers is reduced considerably when the enhanced algorithm is used thus indicating improved performance.

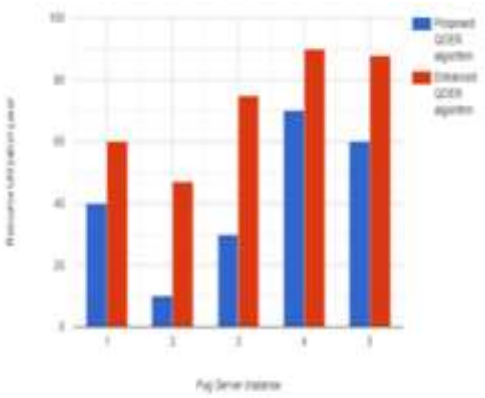

Fig 2 Fog server instance Vs Resource utilization level

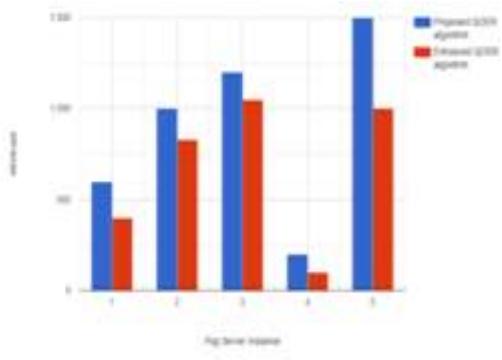

Fig 3 Fog server instance Vs Workload

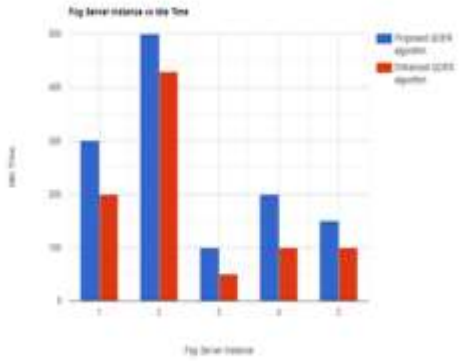

Fig 4 Fog server instance Vs Idle time

V. CONCLUSION

In this project, we have used QOE ratio estimation algorithm for resource allocation. In this the resources are dynamically allocated using QOE aware model. Resource allocation can be achieved through the middleware such as fog. By using QOE ratio estimation algorithm, resources can be allocated based on the user's experience. In this we showed that how tactile internet can be applied to solve the problems in distant communication. This method reduces the workload of the fog nodes and reduces the idle time of the fog nodes and also utilizes the resource in a better way.

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