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Performance Analysis of Cloud Server Selection Based on Fuzzy Logic

Anupama Mishra[1], Rakesh Kumar[2]

[1, 2] Department of Computer Science and Engineering, MMM University of Technology, Gorakhpur, India

Abstract: Cloud computing allows the use of Internet access to the centralized network of optimized computing resources, viz., application servers, network, hardware, software, and storage for clients. It provides cloud-based applications, including email, file storage and sharing, voice calling /video conferencing, and social media, to its clients. Network transmission quality is affected by bandwidth and propagation delay between client(s) and server(s), and between server(s) and client(s). The proposed protocol determines the impact of bandwidth and propagation delay of the cloud application server system using fuzzy logic decision-making techniques. The proposed protocol evaluates the quality of a cloud application server system for Email, FTP, and HTTP. The simulation is performed using OPNET. Four network scenarios, defined by combinations of bandwidth and propagation delay, are simulated and compared based on the overall transmission quality of the cloud application system. The simulation shows the performance of transmission quality rating as throughput as a function of bandwidth and propagation delay. Throughput is directly proportional to bandwidth and inversely proportional to propagation delay.

Keywords: *Cloud application server system, Bandwidth, Propagation delay, Fuzzy Logic.*

1. Introduction

Cloud computing is a model in which the term "cloud" refers to applications/resources hosted online. Cloud computing allows users to access the Internet as a centralized network to optimize computing resources such as networks, storage, servers, and different applications. They could be distributed with minimal management involvement of service providers. Cloud computing provides a distributed model for computing services and infrastructure, with users paying for use [1]—cloud computing infrastructure implemented by the integration of the NIST and IBM cloud computing reference architectures. The NIST defines cloud computing as a model that provides on-demand self-service, resource pooling, rapid provisioning, broad network access, and scalable services. IBM's research team provides specialized technology and management resources to help customers build and operate their cloud services [2, 3]. Infrastructure as a Service (IaaS) provides access to cloud-hosted infrastructure resources, such as virtual machines, storage, and servers. Platform as a Service (PaaS) offers cloud-based deployment tools and operating systems without requiring installation. Software as a Service for a software system implemented by the service provider and used as a service to cloud users over the cloud [4,5]. Multiple organizations can use public cloud services. Public cloud services, including applications, storage, and infrastructure, are accessible on a pay-per-use basis. Private cloud infrastructure is dedicated to a single company and cannot be shared with another company. Hybrid clouds comprise corporate organizations that use both private and public clouds [6, 7].

The performance of the cloud application system is primarily influenced by latency, bandwidth, jitter, and packet loss. Cloud application services include email, gaming applications, file storage, file sharing, and social media. The propagation, processing, and congestion delays are combined into a single network delay. The propagation delay is the time required for data packets to travel from the sender to the destination. The processing delay is the time needed to process data packets. When data does not reach its destination during transmission, it is called packet loss. The maximum transmission rate of a network is called its bandwidth. The variation in delay between packets in a cloud application is called network jitter. The cloud application system has low latency and high network bandwidth, offering a high-quality video stream [8]. OPNET is a discrete-event simulator (DES) used to model real-world environments. OPNET software enables the implementation and evaluation of transmission protocols and networks, as well as the modeling of network performance in wired and wireless cloud computing environments [9]. The paper proposes a transmission-quality analysis of a cloud application server system under varying bandwidth and propagation delay, using fuzzy logic techniques. The proposed protocol evaluates the quality of the cloud application server for Email, FTP, and HTTP. The simulation was conducted in OPNET and evaluated four network scenarios based on bandwidth and propagation delay to assess the overall transmission quality of the cloud application system. The contributions of this paper are as follows:

- We evaluated the user performance as packet /data quality rating, throughput, and performance of cloud servers for different cloud application systems.
- This proposes the effects of bandwidth and propagation delay on the cloud application server system using fuzzy logic decision-making techniques.
- We validate fuzzy logic decision-making rules by five cloud application systems with a set of bandwidth and delay through analysis, as well as using membership functions according to bandwidth and delay.
- This builds and evaluates the quality of cloud application server systems for Email, FTP, and HTTP using the OPNET simulator.
- The evaluation of the response time, traffic received, traffic sent, and throughput of the cloud application server system affects the overall transmission quality rating (User satisfaction).

The paper's organization is as follows. Section 1 provides the paper's introduction. Section 2 describes related works. Section 3 proposes model validation and analysis. Section 4 presents the proposed design scenarios, simulation results, and a discussion of these results; Section 5 concludes with future directions.

2. Related Work

They provide a cloud service measurement index model for evaluating quality-of-service attributes (functional and non-functional) from the cloud service measurement index consortium and for ranking services based on these attributes. The service measurement index approach consists of three layers. The first layer is where the cloud broker gathers the user's expectations and meets their needs. The second layer involves monitoring cloud services and their performance. The third layer is service schedules to store features that cloud providers finalize [10]. They propose a cloud service measurement index model based on the Analytic Hierarchy Process for decision-making across multiple parameters. The AHP technique assigns weights and conducts pairwise comparisons of cloud providers to select the best provider. This approach uses qualitative attribute standards across the procedure [11]. They provide a cloud computing framework for heterogeneous dynamic attributes. The stack holders act as cloud clients and cloud service providers in cloud computing. The client demands services, and the provider allocates resources to the client. Cloud computing provides a heterogeneous environment, including software services, infrastructure, protocols, and provider reliability. They define the ranking of cloud service providers to enable the client to assess the appropriate service provider [12]. They present a cloud service selection system that uses a fuzzy logic model to provide a specific quality of service to the client. The appropriate service setup and run-time Quality of service data are obtained across trustworthy sources, including monitoring systems, certified cloud providers, and customer feedback. The method for selecting the cloud service uses valid data as input to the selection process, employing fuzzy logic [13]. They provide a ranking framework based on random variable selection, with generalized constants representing cost reduction, service quality, efficiency, and the provider's response time. The cloud architecture automatically lists relevant cloud service providers for user tasks and selects the most suitable provider based on priority. To assess the quality-of-service-based SMI parameters, parameters derived from the cloud service provider pool [14] are measured.

They provide a dynamic cloud-service trustworthiness model for assessing trustworthiness across various cloud services. The cloud service can evolve due to factors such as users' perceptions, technological change, and emerging end-user needs [15]. They provide a financial attributes-based trustworthiness framework for selecting a cloud service. The model varies trustworthiness based on the user's perception. The framework estimates the trustworthiness of the entire cloud service by using a fuzzy integrated estimation model [16]. The OPNET software has specialist skills in how to perform network infrastructure, networking technologies, applications, and servers, offering network technology with an objective and reliable base level. Reduce time spent building the OPNET network, improve scientific results, and reduce the risk of investing in network design [17]. The OPNET tool includes a range of protocols and devices for the simulation development of various networks. The platform features are problem-solving, application modeling, traffic modeling, voice, video, printer database, FTP, email, and HTTP applications [18]. The OPNET network model simulates time-based performance and reduces network construction costs. They provide a cloud internet connection concept based on two OPNET simulation scenarios. Scenario 1 network contains 10 nodes and four servers, including a Database, Email, HTTP, and FTP. Scenario 2 network with fifteen nodes and four servers, the same as scenario 1. In the simulation results, traffic sent, traffic received, and throughput increased as the number of nodes increased in the scenario's network [19].

OPNET was used to analyze three scenarios and evaluate network efficiency across various link speeds in a SOHO LAN. The Internet Service Provider is responsible for determining network performance and server efficiency for video conferencing, Email, Database, FTP, and web browsing. It examined response time, performance, and network utilization across different connection links. The response time for downloading the application decreases very rapidly while the bandwidth increases [20]. Nodes in a MANET can only connect across a small range. The Web router that serves as a link between the traditional network and the MANET is used to extend the communication range of the MANET. The MANET is required to allow a long-distance connection. To select a less-congested, shorter channel, this study proposes a straightforward, effective adaptive gateway discovery and selection mechanism that uses fuzzy logic to integrate two metrics: Hop Count and Latency [21]. This research aims to build a new and efficient adaptive accessing finding technique with a focus on the best TTL value by utilizing the potential and power of fuzzy logic, which has a massive effect on routing overhead during gateway discovery. The proposed technique also incorporates effective load balancing to prevent any single gateway from becoming congested when multiple gateways are present. The proposed approach is logically confirmed and computationally examined [22]. They provide a model for analyzing the service efficiency of Voice Over Internet Protocol (VoIP) using Java Programming in the Session Initiation Protocol (SIP). They measured the performance parameters of VoIP as delay, packet loss, and jitter. They evaluated performance across six scenarios generated on a test bench, using delay, packet loss, and jitter [23].

They provide a model that monitors VoIP service and detects threats to the VoIP network. The proposed framework gathers the properties of VoIP traffic based on Netflow and enables statistical and behavioral tracking [24]. They provide a QoS performance analysis and evaluation model for Voice over Internet Protocol traffic performance across various voice codecs. The use of codecs to maximize QoS in VoIP implementations is critically analyzed [25]. They assess the impact of a cloud gaming application by identifying differences in frame rate across service conditions such as bandwidth, delay, and packet loss [26]. They provide a model for OnLive and Gaming applications, allowing users to play anywhere, at any time. We evaluate the effects of delay and packet loss on user experiences and the performance of cloud application services [27]. They provide a study model to show how delays appear in different geographical areas with different browsers providing different delays. An experiment is conducted to demonstrate the effect of bandwidth detected when trying to access google cloud documents in cybercafé [28]. The framework for the provider, with requirements for usability, flexibility, finance, security, and network performance, employs fuzzy logic to analyze cloud services—the performance of providers with respect to requirements for providing services to users [29]. The Cloud Armor framework offers a platform for assessing the quality of cloud providers' trust management. The framework relies on decentralized technology components, including financial reporting, reputation, validation, and recommendation, within a trust-based cloud service [30]. They provide a hierarchical trust relationship that analyzes the impact of different cloud vendors' trustworthiness levels, focusing on IaaS [31]. They propose a cloud ranking protocol based on fuzzy logic techniques for selecting cloud providers, using need-preference attributes for security, storage, and financial aspects [32]. The paper aims to examine how fuzzy logic is applied in the most challenging areas of cloud computing research. We also discussed the fuzzy approaches used to address cloud computing-related issues. The researchers concluded that fuzzy logic may be applied across research fields, particularly in cloud computing, to address problems and improve performance. Many cloud computing researchers also apply fuzzy logic in their studies to enhance system efficiency [34]. This study analyzes the QoS principles offered by the network to meet these objectives. This study compares six QoS control methods and selects the optimal technique for increased traffic. These techniques are referred to as first-in, first-out (FIFO), priority queuing (PQ), custom queuing (CQ), CQ with low-latency queuing (LLQ), weighted fair queuing (WFQ), and WFQ with low-latency queuing (LLQ). The outcomes of analyzing them using an OPNET simulation suggest that priority queuing is the most efficient, followed by CQ, CQ with LLQ, WFQ, WFQ with LLQ, and finally FIFO [35]. In this study, we use TCP Reno to examine system performance through in-depth simulation and modeling. The number of datagrams transferred and retransmitted, mean throughput, link-layer overhead, TCP window size, FTP download response time, packet dropping and retransmission, and the TCP congestion-avoidance mechanism are all considered in the analysis. By establishing a virtualized testbed with Linux hosts and a Linux router, we validate simulation results. The response time for FTP downloads is approximately 32 times that of a perfect channel (no packet loss). Researchers found that TCP Reno performs poorly in wireless environments with high bit error rates (BER). They conclude by offering advice to network researchers and engineers seeking to operate TCP over noisy channels [36]. Based on the above literature on service selection, the application was reviewed, and a comparative analysis is presented in Table I.

Table 1: Comparative analysis of different service selection applications

Related Research	Application areas	Issues
Limam & Boutaba (2010)	Automated quality and reputation-based framework for service rating and selection.	Risk management has been addressed in the context of project development involving external software service components.
Garg et al. (2013)	An Analytical Hierarchical Process (AHP) based ranking mechanism which can evaluate the Cloud services.	The different dimensional units of various QoS attributes.
Kiranbabu et al. (2019)	Cloud computing framework for heterogeneous dynamic attributes.	We may also use metaheuristic algorithms to rank service providers, but the results may not be approximations in all cases.
Masoumeh et al. (2014)	Cloud service selection system using a fuzzy logic model for a specific quality of service to the client.	The framework for converting linguistic terms of the customer's perception into precise numerical values.
Satheesh & Aramudhan (2019)	Random variable selection with generalized constant as cost reduction, service quality, efficiency, and response time of the provider.	Cloud service providers were unable to meet the needs of these multi-mode customers due to insufficient resources.
Pandey & Daniel (2017)	The financial attributes trustworthiness framework for selecting cloud services.	Only security and usability should be explicitly resolved to improve the trustworthiness of the cloud service.
Singh & Rai (2017)	The OPNET network model simulates time-based performance and reduces network construction costs.	The simulation model result is only based on the number of nodes.
Guo Hai & Jia Bo (2013)	The response time for downloading the application decreases very rapidly while the bandwidth increases.	The topology of the SOHO network in the paper maybe not be very appropriate for today's SOHO network.
Srivastava & Kumar (2016)	The technique also incorporates effective transfer to avoid having one gateway	Involve inaccurate estimation of optimal proactive area. which ultimately affects the network performance and throughput.

Related Research	Application areas	Issues
	become congested when there are several gateways present.	
Osman Eltaib et al. (2022)	The outcomes of analyzing them using an OPNET simulation suggest that the priority queuing method is the most efficient one, then by CQ, CQ with LLQ, WFQ, WFQ with LLQ, and eventually FIFO.	The contrast makes the movement of sound and video difficult.
Sarkar et al (2022)	We consider TCP Reno as a way to examine the system performance through in-depth simulation and modeling.	TCP Reno cannot properly work in wireless situations with a high bit error rate (BER).

3. Proposed Model

The Cloud application server is typically deployed at a distributed or remote location and managed by the cloud infrastructure provider. The primary applications of cloud computing include cloud gaming, email, file storage, file sharing, voice calling, video conferencing, and social media. The client application received an activity request from the user and sent it to the cloud server. The user's interaction is primarily with an interface via a mobile app or a web browser. The cloud server processes the client application's activity request, encodes and compresses the response, and returns it to the client application. During communication between the client and the server, network delay and bandwidth play an important role. Performance analysis of the cloud system under delay, packet loss, and bandwidth constraints using a fuzzy logic controller [33]. Various network operating conditions, such as bandwidth and propagation delay, affect the overall transmission quality of the cloud application system. Bandwidth is the maximum data transmission rate of a network. Bandwidth is measured in megabits/gigabits per second. The delay is defined as the ratio of the time required for packets/signals to travel from the sender to the destination to the connection length, divided by the propagation speed over the particular medium. The delay is measured in time units shown in Figure 1. The proposed protocol evaluates user performance in terms of packet/data quality rating, throughput, and cloud server performance across different cloud application systems. The proposed protocol determines the effects of bandwidth and propagation delay on the cloud application server system using fuzzy logic decision-making techniques. The proposed protocol evaluates the quality of the cloud application server system for Email, FTP, and HTTP.

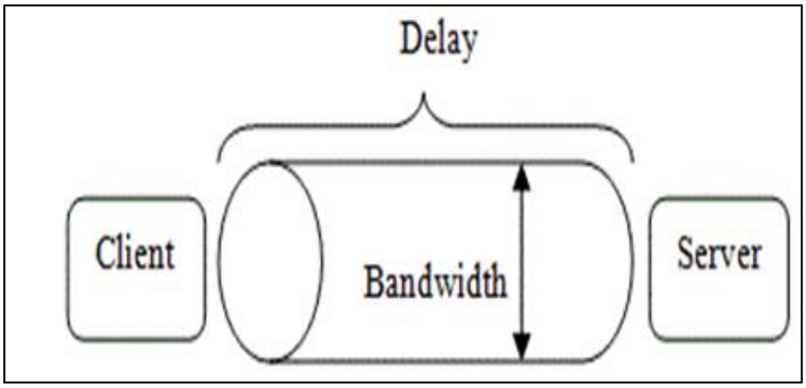

Figure 1. Bandwidth and delay

Fuzzy rule-based systems, equipped with fuzzification and defuzzification, were used for classification. A Fuzzy Logic System (FLS) is represented as a fuzzy logic input variable, such as bandwidth and delay, having three levels of membership values: Low, Average, and High. The fuzzy logic output is defined as the quality rating of the cloud application system based on the memberships of input variables.

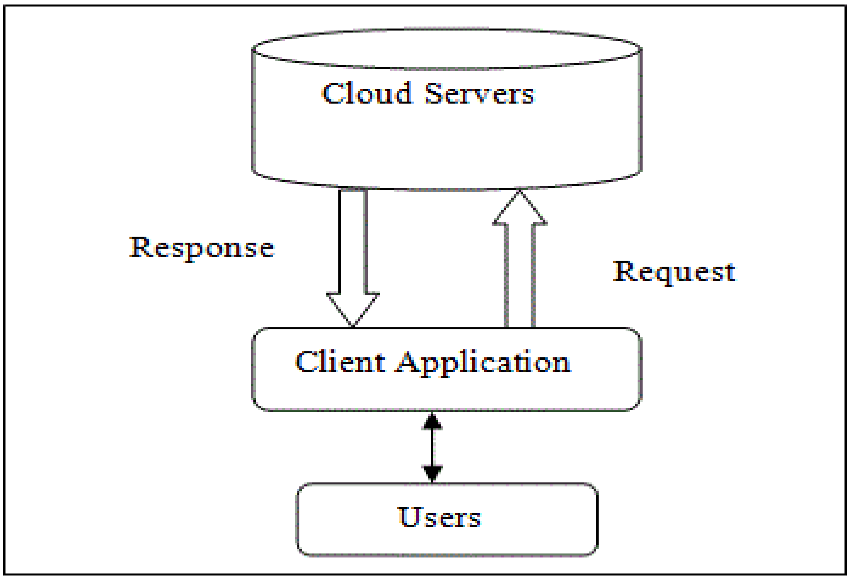

Figure 2. Cloud Application System

The proposed fuzzy-based decision-making protocol for determining the effects on the cloud application system is shown in Figure 2. The fuzzy logic inputs are transformed into fuzzy sets. Let two fuzzy sets A and B, belonging to bandwidth (BW) and delay (Del), be defined as follows.

$$A = \{(BW, \mu_A(BW))\}, BW \in \text{bandwidth}$$

$$B = \{(Del, \mu_B(Del))\}, Del \in \text{delay}$$

The membership functions μ_A and μ_B are used to determine the membership values in the fuzzy sets. The membership functions for the bandwidth parameter

$$\mu_A(BW) = \begin{cases} 0 & if BW \le TH_1 \\ (BW - TH_1)/(TH_2 - TH_1) & if TH_1 < BW < TH_2 \\ 1 & if BW \ge TH_2 \end{cases}$$

The membership functions for the delay parameter

$$\mu_B(Del) = \begin{cases} 0 & if Del \ge TH_2 \\ (TH_2 - Del)/(TH_2 - TH_1) & if TH_1 > Del > TH_2 \\ 1 & if Del \le TH_1 \end{cases}$$

TH_1= Min_Threshold with minimum input value

TH_2= Max_Threshold with maximum input value

Apply the MIN –MAX rule on the fuzzy BW and Del relationship.

$$\mu_A(BW) \wedge \mu_B(Del)$$

Let us consider the three-level membership values for delay and bandwidth, which are shown in Table II.

Table 2: Input Values

Input	Membership Function		
Delay	L	A	H
Bandwidth	L	A	H

Let us consider the membership values for the output, which are shown in Table III.

Table 3: Output Values

Output	Membership Function
Quality Rating	VS, S, HG, MH, M, ML, MN, VM, LW
where L=Low, A=Average, H=High, VS=Very Strong, S=Strong, HG=Highest, MH=Medium Highest, M=Medium, ML=Medium Low, MN=Minimal, VM=Very Minimal, LW=Lowest.	

The order of precedence of membership values for output is as follows.

VS>S>HG>MH>M>ML>MN>VM>LW

The relationships of fuzzy logic are described in Table IV.

Table 4: Logical Rule Sets

Bandwidth	Delay	Quality Rating
L	L	MN
L	A	M
L	H	LW
A	L	S
A	A	HG
A	H	VM
H	L	VS
H	A	MH
H	H	ML

The following rule sets are used to determine the quality rating of the cloud application system. The rule sets of cloud application systems for quality rating are specified, and groupings of specific fuzzy rules are structured to generate the output shown in Table V.

Table 5: Rule Sets

Number	Rule
Rule 1:	If BW is L ∧ Del is L THEN the quality rating MN
Rule 2:	If BW is L ∧ Del is A THEN the quality rating M
Rule 3:	If BW is L ∧ Del is H THEN the quality rating LW
Rule 4:	If BW is A ∧ Del is L THEN the quality rating S
Rule 5:	If BW is A ∧ Del is A THEN the quality rating HG
Rule 6:	If BW is A ∧ Del is H THEN the quality rating VM
Rule 7:	If BW is H ∧ Del is L THEN the quality rating VS
Rule 8:	If BW is H ∧ Del is A THEN the quality rating MH
Rule 9:	If BW is H ∧ Del is H THEN the quality rating ML

3.1 Validation and Analysis

Let us consider five cloud application systems. Suppose a set of bandwidth and delay for a cloud application system be, Bandwidth = {28Kbps, 2Mbps, 20Mbps, 40Mbps, 45Mbps}, Delay = {0.002ms, 0.003ms, 0.005ms, 1.000ms, 1.035ms}. A membership function according to bandwidth is given as follows:

$$\mu_{bandwidth}(BW) = \begin{cases} 0 & if BW \leq 10Mbps(TH_1) \\ (BW-10)/(20) & if\ 10\ Mbps < BW < 30Mbps \\ 1 & if BW \geq 30Mbps(TH_2) \end{cases}$$

A membership function according to delay is given as follows:

$$\mu_{delay}(Del) = \begin{cases} 0 & if Del \geq 0.008\ ms(TH_2) \\ (0.008-Del)/(0.004) & if\ 0.004\ ms < Del < 0.008 \\ 1 & if Del \leq 0.004\ ms(TH_1) \end{cases}$$

Let us compute the degree of membership of bandwidth and delay using the membership function result that shows in Table VI.

Table 6: Membership Value of Input Variable

Bandwidth	Membership	Delay	Membership
28 Kbps	0	0.002 ms	1
2 Mbps	0	0.003 ms	1
20 Mbps	0.5	0.005 ms	0.75
40 Mbps	1	1.000 ms	0
45 Mbps	1	1.035 ms	0

As per the degree of membership shown in Table V, the fuzzy representation of bandwidth is {28Kbps|L, 2Mbps|L, 20Mbps|A, 40|H, 45|H} and delay is {0.002|L, 0.003|L, 0.005|A, 1.000|H, 1.035|H}. The Fuzzy relationship of membership value with bandwidth and delay is shown in Table VII.

Table 7: Fuzzy Relationship

BW / Del	28Kbps	2Mbps	20Mbps	40Mbps	45Mbps
0.002	1∧0	1∧0	1∧0.5	1∧1	1∧1
0.003	1∧0	1∧0	1∧0.5	1∧1	1∧1
0.005	0.75∧0	0.75∧0	0.75∧0.5	0.75∧1	0.75∧1
1.000	0∧0	0∧0	0∧0.5	0∧1	0∧1
1.035	0∧0	0∧0	0∧0.5	0∧1	0∧1

The Fuzzy MIN–MAX rule is applied to the above fuzzy set membership value of bandwidth, and the delay is shown in Table VIII.

Table 8: The output of Min -MAX on Bandwidth and Delay

BW / Del	28Kbps	2Mbps	20Mbps	40Mbps	45Mbps
0.002	0	0	0.5	1	1
0.003	0	0	0.5	1	1

BW / Del	28Kbps	2Mbps	20Mbps	40Mbps	45Mbps
0.005	0	0	0.5	0.75	0.75
1.000	0	0	0	0	0
1.035	0	0	0	0	0

The possible bandwidth-delay combinations with the higher membership value are shown in Table IX.

Table 9: The output of Bandwidth and Delay with Higher Membership Value

Bandwidth	Degree	Delay	Degree
40Mbps	H	0.002	L
45Mbps	H	0.003	L

Therefore, the possible combinations of bandwidth and delay according to the de-fuzzification system are as follows.

Bandwidth =40Mbps and Delay=0.002 ms

Bandwidth =40Mbps and Delay=0.003 ms

Bandwidth =45Mbps and Delay=0.002 ms

Bandwidth =45Mbps and Delay=0.003 ms

The above combinations of bandwidth and delay achieve the highest quality rating for the cloud application system. When bandwidth is 45 Mbps (High), and delay is 0.002 ms (Low) for data packet transmission in cloud computing environments. Therefore, according to rule 7 of the rule sets provide the best quality rating is "Very strong".

4. Proposed Design Scenarios

The proposed simulation network is a private network of different cloud locations/office locations. The network consists of three subnets representing different cloud locations/office locations as office 1, office 2, and office 3. Office 1, Office 2, and Office 3 subnets model contains various workstations, switches, routers, firewalls, and five servers. The IP_cloud represents the internet connections between the subnets, as shown in Figure 3. Office 1, Office 2, and Office 3 networks shown in Figure 4, Figure 5, and Figure 6 have cloud application servers such as Database servers, Email servers, File servers, HTTP servers, and Video servers. Each server executes in a cloud computing environment.

The proposed model is simulated using OPNET. The OPNET tool includes models, protocols, and devices for the development of simulation models across various networks. The platform supports problem-solving, application modeling, traffic modeling, voice, video, printer database, FTP, email, and HTTP applications. The OPNET tool is used to simulate network performance.

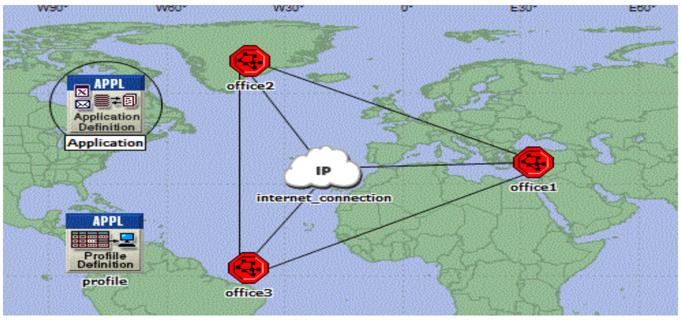

Figure 3. Network with three subnets

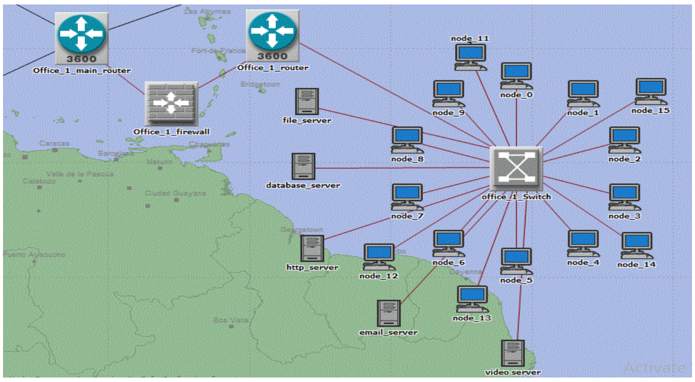

Figure 4. Office 1 Network Model

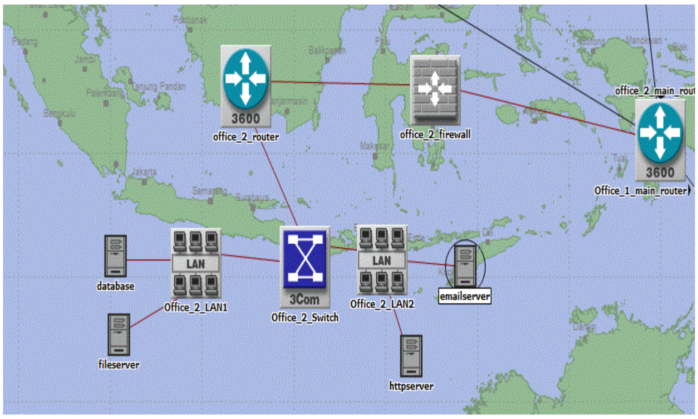

Figure 5. Office 2 Network Model

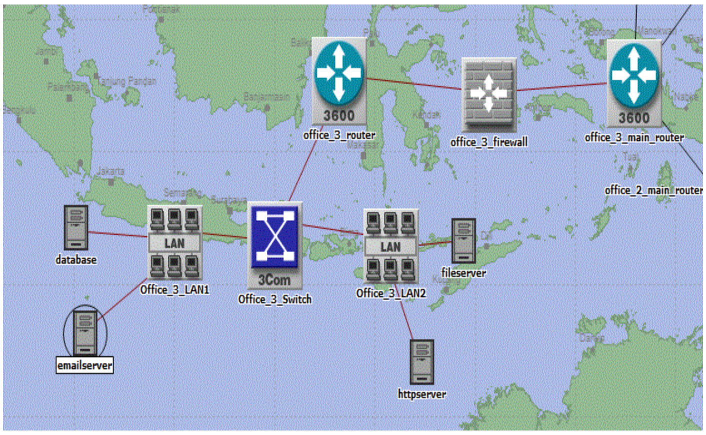

Figure 6. Office 3 Network Model

The proposed simulation scenarios model is based on network parameters such as bandwidth and propagation delay. The data transfer rate (in links) of a scenario is called the bandwidth. The time required to move data/packets between two nodes in the cloud is called the propagation delay. The simulation scenarios for the design under bandwidth and delay are shown in Table X.

Table 10: Simulation Scenarios with parameter values

Scenario	Bandwidth	Delay	Quality rating
Scenario 1	H	H	Medium Low
Scenario 2	H	L	Very Strong

Scenario	Bandwidth	Delay	Quality rating
Scenario 3	L	H	Lowest
Scenario 4	L	L	Low

Scenario 1: High Bandwidth and High Delay

Subnets are connected via a PPP DS3 (45 Mbps) link to the IP cloud. Subnets are interconnected via a PPP DS3 (45 Mbps) link. Each node in the cloud/office network is connected via a 100 Gbps Ethernet link. The propagation delay on the connection link between the two nodes is 1.035 ms in Scenario 1.

Scenario 2: High Bandwidth and Low Delay

Subnets are connected via a PPP DS3 (45 Mbps) link to the IP cloud. Subnets are interconnected via a PPP DS3 (45 Mbps) link. Each node in the cloud/office network is connected via a 100 Gbps Ethernet link. The propagation delay between the connection links of two nodes is 0.002 ms for Scenario 2.

Scenario 3: Low Bandwidth and High Delay

Subnets are connected via the PPP_28K (28 kbps) link to the IP cloud. Subnets are interconnected via a PPP_28K (28 kbps) link. Each node in the Cloud/office network is connected via a 100BaseT (100 Mbps) Ethernet link. The propagation delay on the connection link between the two nodes is 1.035 ms in Scenario 3.

Scenario 4: Low Bandwidth and Low Delay

Subnets are connected via the PPP_28K (28 kbps) link to the IP cloud. Subnets are interconnected via a PPP_28K (28 kbps) link. Each node in the cloud/office network is connected via a 100BaseT (100 Mbps) Ethernet link. The propagation delay between the connection links of two nodes is 0.002 ms for Scenario 4.

4.1 Simulation and Analysis of Performance Parameters for Network Scenarios

The analysis of performance for network scenarios in this research paper has been performed on four performance metrics, which are mentioned below:

Response Time: The average time required to submit a service request and receive a response during network data transmission.

Traffic Received: The total number of data packets per second delivered to the network by the transport layer.

Traffic Sent: The total number of data packets per second transmitted over the network to the transport layer.

Throughput: Network performance is measured using throughput. Throughput is the number of messages transmitted per unit time. It can also be defined as the effective transmission of a message through a communication channel.

4.2 Simulation and Results

Case 1. Performance Analysis of Response Time

All scenarios run simultaneously by using global statistics and object Statistics discrete event simulator (DES) from the OPNET tools on Scenario1, Scenario 2, Scenario 3, and Scenario 4 for download response time (sec) under Email, FTP, and HTTP objects shown in Figure 7, Figure 8, and Figure 9.

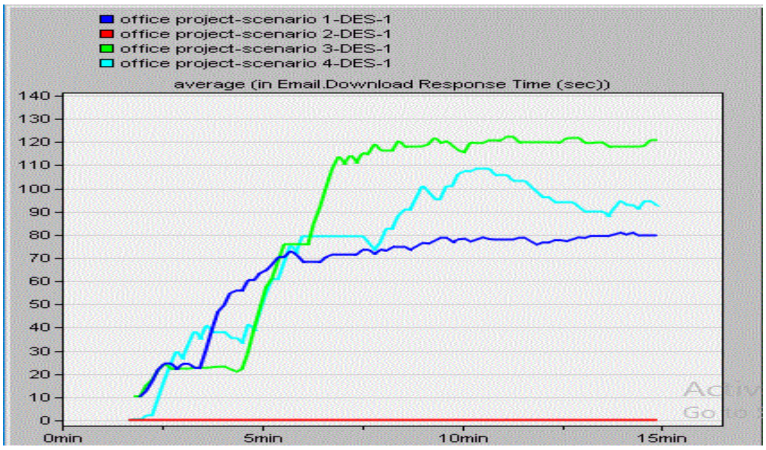

Figure 7. Downloading Response TimeUnder Email

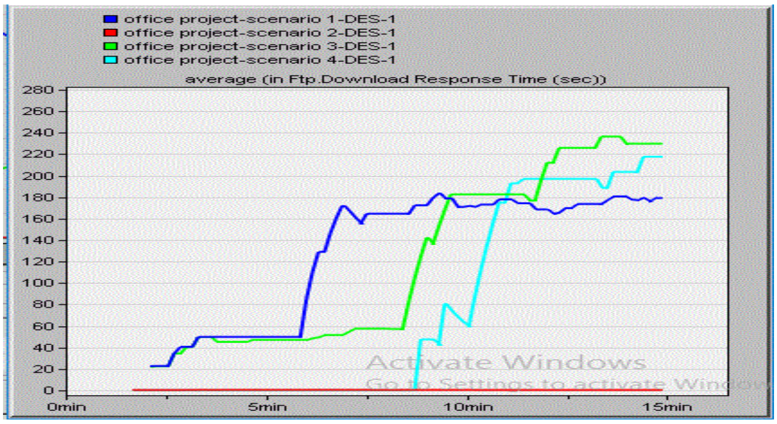

Figure 8. Downloading Response Time Under FTP

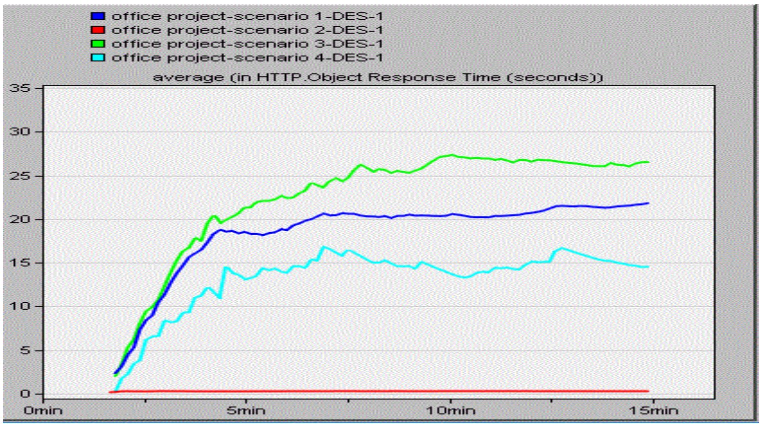

Figure 9. Object response time under HTTP

As shown in Figures 7, 8, and 9, the download response time for the Email, FTP, and HTTP objects is higher for Scenario 3 than for the other scenarios (1, 2, and 4).

Scenario 3>Scenario 4 >Scenario 1>Scenario 2

Case 2. Performance Analysis of Traffic Received/Traffic Sent

All scenarios are run simultaneously using global statistics and the Object Statistics discrete-event simulator (DES) from the OPNET tools, on Scenarios 1, 2, 3, and 4 for Traffic Received/Traffic Sent Email, FTP, and HTTP. The traffic is shown in Figures 10, 11, and 12. The traffic is shown in Figures 13, 14, and 15.

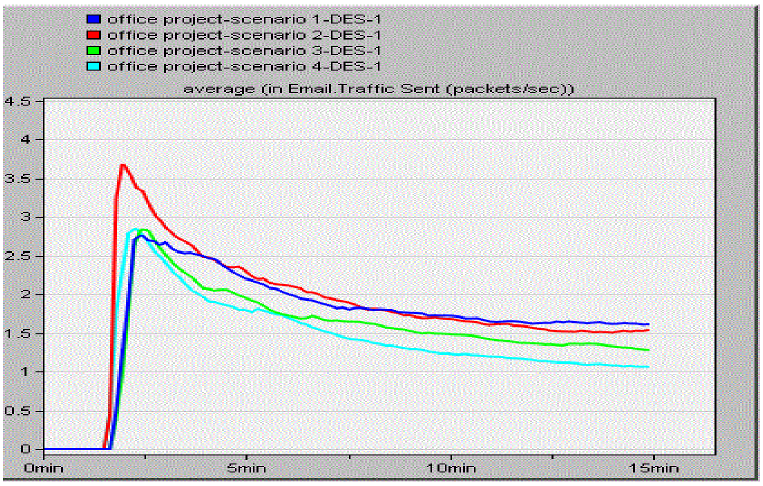

Figure 10. Sent Traffic Under Email

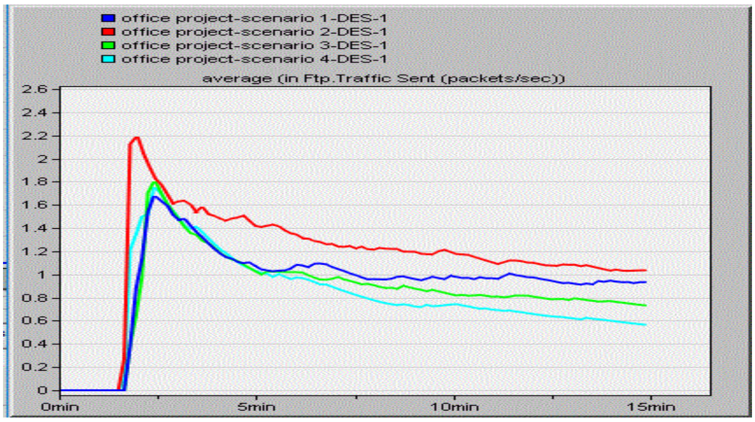

Figure 11. Sent Traffic Under FTP

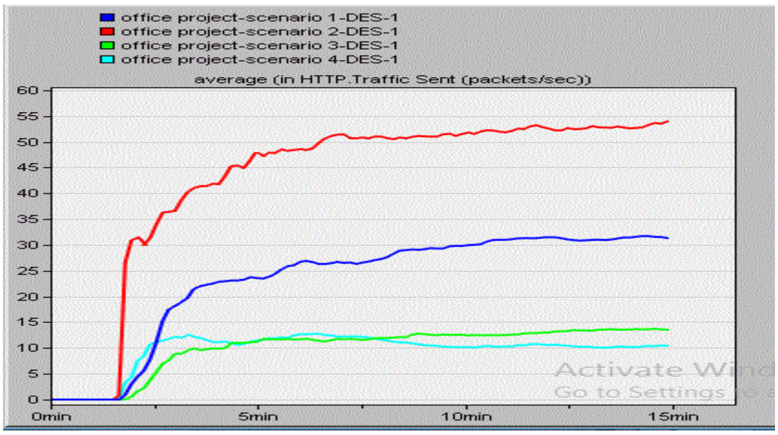

Figure 12. Sent Traffic Under HTTP

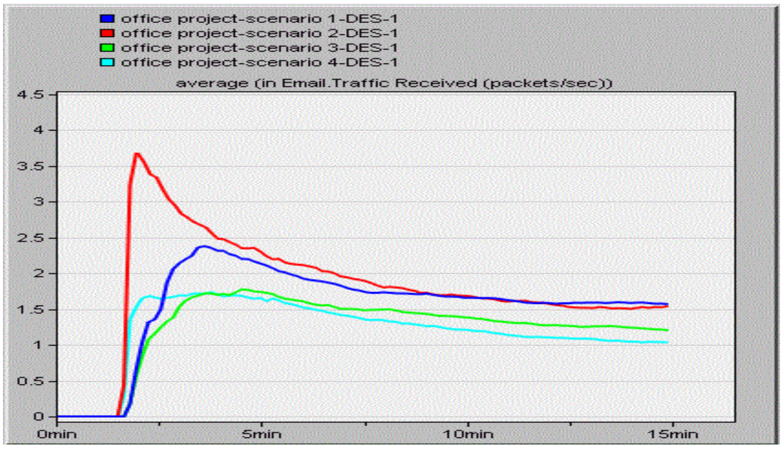

Figure 13. Received Traffic Under Email

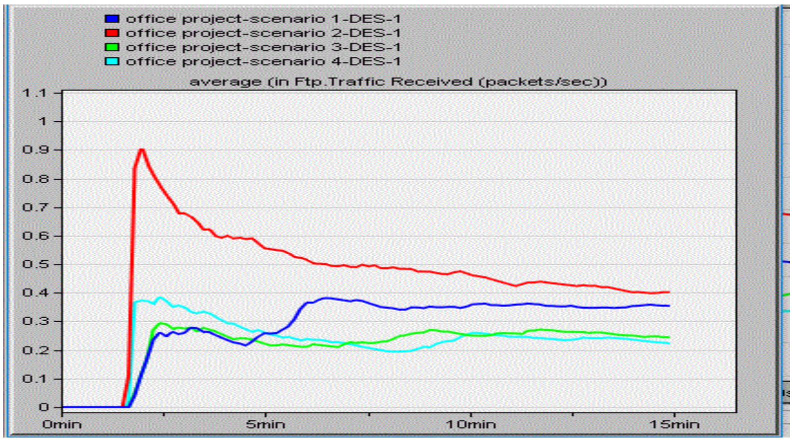

Figure 14. Received Traffic Under FTP

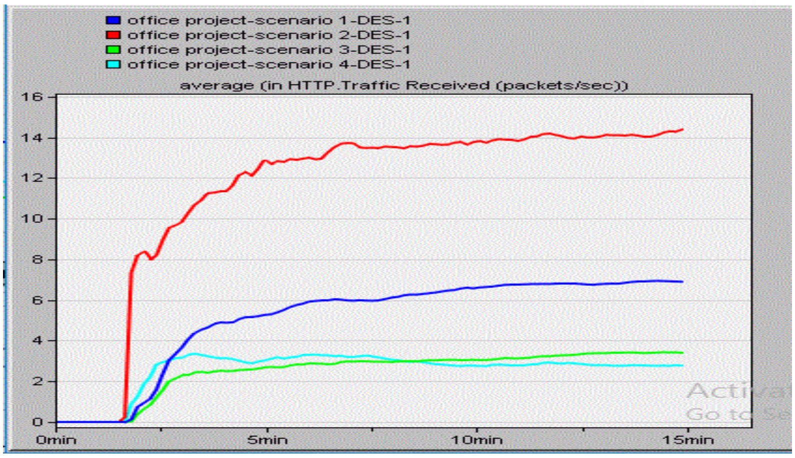

Figure 15. Received Traffic under HTTP

Figures 10-15 show that traffic sent / traffic received under Email, FTP, and HTTP are higher for Scenario 2 than for the other scenarios (Scenario 1, Scenario 3, and Scenario 4).

Scenario 2>Scenario 1>Scenario 4>Scenario 3

As bandwidth increased and propagation delay decreased, traffic sent / traffic received increased. When bandwidth decreases and propagation delay increases, the traffic sent/received decreases.

Case 3. Performance Analysis of Throughput

All scenarios are run simultaneously using global statistics and the Object Statistics discrete-event simulator (DES) from the OPNET tools, on Scenario 1, Scenario 2, Scenario 3, and Scenario 4, to compute throughput. The download throughput between the office 1 main router and the office 2 main router, and between the office 1 email server and the office 2 email server, is shown in Figures 16 and 17.

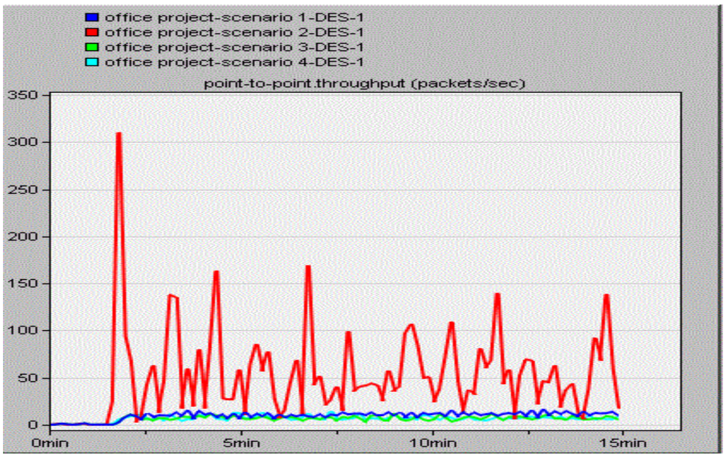

Figure 16. Download Throughput between office 1 main_router to office 2 main_router

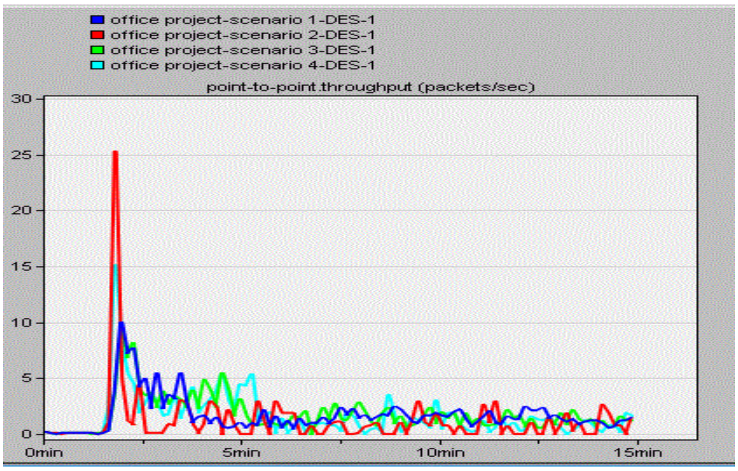

Figure 17. Download Throughput between office 1 Email Server to office 2 Email Server

Figures 16 and 17 show that the download throughput between office 1 and office 2 is higher for Scenario 2 than for the other scenarios (Scenario 1, Scenario 3, and Scenario 4).

Scenario 2>Scenario 1>Scenario 4>Scenario 3

As bandwidth increases and propagation delay decreases, download throughput increases. When bandwidth decreased and propagation delay increased, download throughput decreased.

The quality of the cloud application server system is "Very Strong" when the bandwidth is 100Gbps between ethernet workstation to switch, switch to router, LAN to switch, and router to firewall and 45Mbps between the main router to IP cloud, subnet to subnet, and IP cloud to subnets, and the propagation delay is 0.002ms. The quality of the cloud application server system is "Lowest", when the bandwidth is 100Mbps between ethernet workstation to switch, switch to router, LAN to switch, and router to firewall and 28Kbps between the main router to the IP cloud, subnet to subnet, and IP cloud to subnets and the propagation delay is 1.035ms. The quality ratings of the cloud application server system across four scenarios are computed using the OPNET simulator. The simulation Scenarios show that as bandwidth increases and propagation delay decreases, the overall transmission quality rating of the cloud application server system improves. As bandwidth decreased and propagation delay increased, the overall transmission quality rating of the cloud application server system decreased, as shown in Figure 18. Therefore, the system response in terms of throughput is a function of bandwidth and propagation delay. Throughput is directly proportional to bandwidth and inversely proportional to propagation delay.

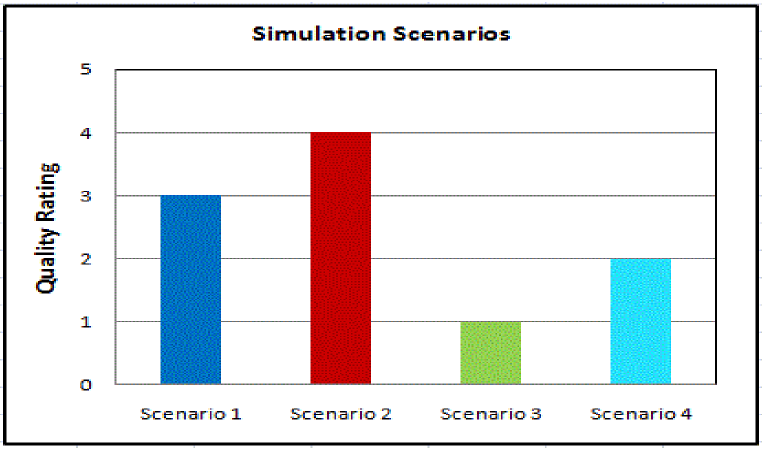

Figure 18. quality rating between four different scenarios

5. Conclusion and Future Directions

The proposed protocol evaluates the effects of bandwidth and propagation delay on the cloud application server system using fuzzy logic decision-making. The proposed protocol evaluates the quality of the cloud application server system for Email, FTP, and HTTP. The simulation results show that as bandwidth increased and propagation delay decreased, the overall transmission quality rating of the cloud application server system increased; conversely, as bandwidth decreased and propagation delay increased, the overall transmission quality rating decreased. Throughput is directly proportional to bandwidth and inversely proportional to propagation delay.

Our future work will focus on multi-criteria decision-making approaches for cloud service selection based on user need-preference attributes.

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