COMPARATIVE STUDY OF CLOUD COMPUTING NETWORK SERVICES BASED ON QoS ANALYSIS USING TIPHON STANDARD

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Abstract

Currently, data plays a very important role for companies or agencies. The amount of data owned, processed, and exchanged is getting bigger, so companies need more and more resources to manage it. Cloud computing technology is an efficient and economical alternative that allows users to utilize Information Technology (IT) resources flexibly, in terms of infrastructure and applications. Its key advantages include cost efficiency, scalability, data security, disaster recovery, and fast global access. The rapid development of cloud technology has led to many Cloud Service Providers (CSPs). The performances of the CSPs vary widely, thus it is necessary to understand the network performance characteristic from the CSPs so that users can select a more suitable service. Network capabilities in cloud computing technology are crucial, considering that all company activities are carried out through the network. In this study, the main focus was to test the network capabilities of the two biggest cloud services The results of the Quality of Service (QoS) comparison will provide recommendations or input for companies or agencies in choosing the cloud service provider that best fits their needs. Thus, it was obtained that this research can provide useful guidance in optimizing the use of cloud computing technology to support business activities and innovation in various fields, including the field of education. Based on the results of the research, the network performance of the two CPS is very good in terms of the TIPHON standard. Based on QoS analysis, especially in terms of throughput, CPS "A" shows better upload activity results, while CPS B has better results for downloading activities.

Keywords: *cloud computing , cloud service provider, quality of service, throughput, TIPHON standard.*

1. INTRODUCTION

Cloud computing has been widely adopted by companies and agencies that require large Information Technology resources to process massive amounts of data. This technology is considered to provide an efficient, cost-effective, flexible, and quick solution beyond simple hardware and software services, including but not limited to artificial intelligence, big data, data stream, security, containers, data analytics, databases, and so on [1]-[3]. The service, which is typically maintained by a Cloud Service Provider (CSP), is connected to the internet, and follows a pay-as-you-use payment model [4],[5].

Aside from its analytical capabilities and increased flexibility, it offers overhead cost reduction by avoiding investments for purchasing, installing, administering, and maintaining software and hardware infrastructure [6],[7]. Simpler control, monitoring, security updates application, and other security-related tasks are supported. It continues to find ways to improve its ability to provide better

security [8], for example, by employing the blockchain technology [9]. The cloud computing also provides advanced storage and advanced internet experience [10]. Because of the advantages offered by the cloud computing, there is an increase in demand for this technology. Because of the many advantages offered, there is more demand for the provision of cloud computing. And it leads to the establishment of several Cloud Service Providers (CSPs). Amazon Web Services (AWS) and Microsoft Azure are selected for this study because both CSPs occupy the top two positions in the CSP market share [11].

There have been several studies that attempt to measure the quality provided by cloud computing services base, either based on analytical QoS parameters or comparisons between CSPs. For example, a study by Fandy et Al measured the network quality of a web server in AWS using the Apache Jmeter app, following the load balancing and HTTP packet request test [12]. The result of said study has shown that web servers that are built on top of the EC2 (Elastic Compute Cloud) service work

comparatively better than other servers built using different AWS services. In different research, cloud to user (C2U) latencies between AWS and Azure were analysed to provide an in-depth network performance characterization [13]. A method to improve load prediction system in the network by combining machine learning and QoS measurement is presented in [14], which is given the name Long Term Prediction System (LTPS). This system has been developed to assign connections between optimized system load and QoS parameter through a set of trials on the Azure cloud environment. The results of the trials has shown that a cost reduction of between 51% to 85% can be attained with this system. Xu et al has developed a model to monitor the availability of cloud computational resources based on QoS [15], Jing et al. conducted QoS-aware task scheduling for cloud computing [16], and other study published a survey on a variety of methods to increase the QoS of Cloud Computing services [17].

AWS is a cloud computing platform that is provided by Amazon.com that allows its user to use a variety of cloud services such as data storage, data processing, and programming for developing and running apps on the cloud. AWS has data centers on 31 countries, including Indonesia. For each particular region, there are a guaranteed minimum of 3 Availability Zones (AZ) that are accessible. AZ on AWS refers to the location of physical data centers, which are hidden and isolated geographically within an AWS region [18]. Each AZ in an AWS region consists of one or more data centers which are located on differing sites to ensure that applications and data can be served with high availability and redundancy. The use of multiple AZs within a single region is a common strategy to increase the availability, reliability, and scalability of applications running on the AWS platform. Even if anything happens to a single AZ point – natural disasters, electricity issues, and so on – downtime can still be avoided as there are redundancies within other AZ in the same region. Another cloud computing platform is Azure from Microsoft Corporation. Azure allows its users to rent cloud computing services such as virtual infrastructure, data storage, databases, application programmer, and development tools to create applications that run on the cloud [19].

The aim of this study is to compare the performance of cloud computational networks of AWS and Azure based on QoS network parameters, such as jitter, delay/latency, and throughput. This research aims to assist users in assessing network performance and evaluating reliability among various cloud computing providers. Additionally, by comparing Quality of Service (QoS) across providers, it strives to aid agencies and companies in making informed decisions aligned with their specific requirements.

2. METHODOLOGY

There are three types of service models that Cloud Computing operate under: SaaS (Software as a Service), PaaS (Platform as a Service), and IaaS (Infrastructure as a Service). In the SaaS model, the service provider is responsible for upkeep, maintenance, and upgrading of the provided application [20]. On the other hand, PaaS provides users with a platform for developing software which can be used to build, test, and deploy their applications through the internet. In this model, the service provider maintains and upgrades the provided platform. This model supports faster development of applications with greater flexibility and scalability [21]. Lastly, IaaS is a service model that provides a variety of hardware resources such as servers, networks, and memory storages that can be used by users to run applications or operating systems. The infrastructure's maintenance, upkeep, and upgrade are taken care of by the service provider [22]. Table 1 shows the comparison between the three models in closer detail. The blue cells denote the extent of which users have direct control of, while the red cells show aspects of the service that is managed by the cloud service provider.

Table 1. Comparison between SaaS, PaaS, and IaaS

SaaS	PaaS	IaaS	On-Premise
Application	Application	Application	Application
Data	Data	Data	Data
Runtime	Runtime	Runtime	Runtime
Middleware	Middleware	Middleware	Middleware
OS (Op.Syst.)	OS	OS	OS
Virtualizatio n	Virtualizatio n	Virtualizatio n	Virtualizatio n
Servers	Servers	Servers	Servers
Storage	Storage	Storage	Storage
Networking	Networking	Networking	Networking

There are several steps to test the performance of cloud computing networks of AWS Elastic Cloud Compute (EC2) and Azure Virtual Machine (VM) based on their respective QoS network parameters. Testing is conducted by sending data packets from the user to the network and vice versa. Measurement of QoS parameters is done using the Wireshark software. The methodology is described in figure 1.

In the first step, a cloud topology is planned and analyzed for hardware and software requirements for research. Next, the planned infrastructure is provisioned using AWS and Azure, starting from network infrastructure provisioning (VPC, subnet, route table, and IP address calculation) and creation of a static public IP to avoid address changes during instance restarts. Next, a server or instance is created in AWS EC2 and Azure VM respectively.

Figure 2 describes the topology of AWS and Azure in detail using the CSP's respective icon sets to improve readability for third parties such as cloud engineers or users to understand the infrastructure being built. AWS and Azure both utilize virtual machine (VM) technology. In AWS' case, VM is run

using the hypervisor AWS Nitro, while Azure uses the hypervisor Microsoft Hyper-V to run its VMs. Virtual machines in AWS use the AWS EC2 service running an Ubuntu 20.04 LTS instance, while Azure uses the Azure VM with the name of Azure-instance. AWS cloud uses the Tokyo region, which denotes that the server is physically located in Japan. This is the same for Azure. In this research, the public IP address of AWS is 3.114.122.161 and the public IP address of Azure is 20.222.79.224.
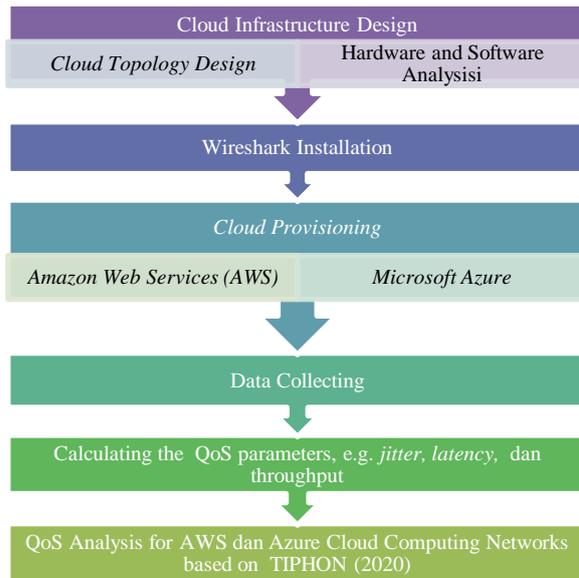
Figure 1. Methodology
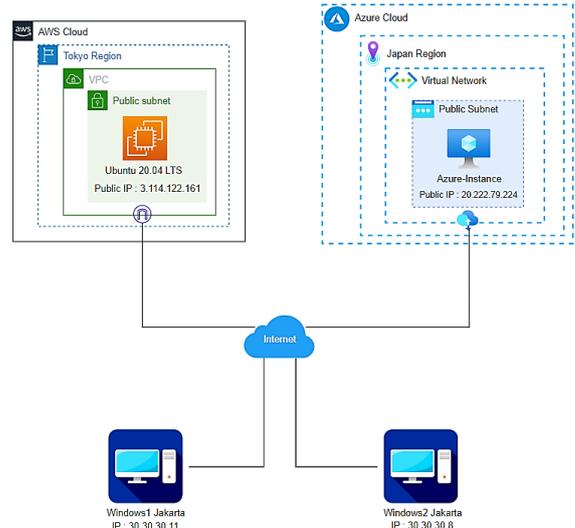
Figure 2. Infrastructure Topology of *Cloud* AWS and Azure

Experiments and data collections are all performed in devices with identical specifications, both for AWS and Azure, and Windows1 and Windows2, as detailed in Table 2. Windows1 and Windows2 use the same internet connection from the same provider with the same speed and bandwidth. The bandwidth of networks connected by respective CSPs to both AWS and Azure is also identical.

Table 2. Cloud Infrastructure Specifications

Nodes	CPU	RAM	Disk	OS	Network	SSh Version
AWS EC2	Intel Xeon (t2.micro,1 vcpu)	1 GB	GP3 Standard SSD (30GB)	Ubuntu 20.04 LTS	Up to 300 Mbps	SSHv2
Azure	Intel Xeon (Standard_B1s, 1 vcpu)	1 GB	GP3 Standard SSD (30GB)	Ubuntu 20.04 LTS	Up to 300 Mbps	SSHv2
Windows 1	Intel Xeon (2 cpu)	4 GB	50 GB (SSD)	Windows Server 22	Up to 5 Gbps	SSHv2
Windows 2	Intel Xeon (2 cpu)	4 GB	50 GB (SSD)	Windows Server 22	Up to 5 Gbps	SSHv2

After determining the requisite hardware and software for research, the next step is to provision those resources in the cloud, which is a process in which a cloud infrastructure is built, and cloud resources are prepared and maintained. As shown in Figure 3, cloud provisioning consists of multiple steps. The first step is to create an AWS account by setting up payment on the AWS website and paying an initial fee. If a user has multiple AWS accounts, users can utilize the service of AWS organization, which helps users manage access through features such as single sign on (SSO) and user policies.
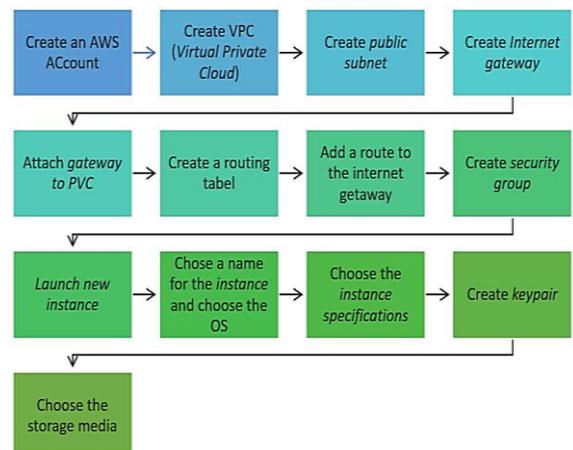
Figure 3. AWS Provisioning Steps

Next, a network infrastructure in the AWS cloud is created. The process begins with the creation of a VPC with the name of AWS-VPC, assigned to a

CIDR IP address of 10.10.10.0/24. The next step is to create a public subnet for the cloud. The name of the subnet is the public-subnet-AWS with a CIDR IP address of 10.10.10.0/27. As this research utilizes public networks using the public subnet, an internet gateway is used to provide a route towards the public internet. This gateway is then connected to the VPC.

Afterwards, a route table is created as shown in Figure 4. The route table is then connected to the subnet, and additional routes towards the internet are added to the route. Adding routes toward the public internet can be done by adding a destination that points to *anywhere*, which is the IP address of 0.0.0.0, which targets the created internet gateway. In this research, the security group allows all incoming and outgoing traffic to pass through, but in practice it is better to impose restrictions to provide protection to data stored in the server.
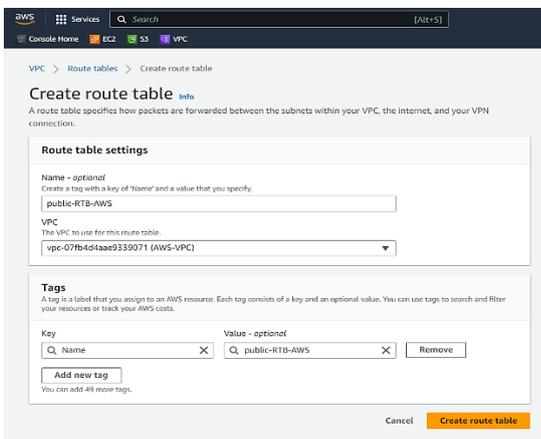
Figure 4. Creation of Route Table in AWS *Web Console*

After the network infrastructure is created, the third step is to create a server in AWS through the provisioning of an AWS EC2 instance. An instance in cloud computing is a virtual machine server [23]. In the EC2 menu, one can set up a server by clicking on the launch new instance button and setting up the name of the instance and selecting an operating system. In this research, the operating system Ubuntu 20.04 LTS is used, and the instance being used is of the t2.micro type with 1 VCPU and 1 GB RAM. Next, a keypair is created as a means of accessing server, and an SSD with 30gb capacity is chosen for storage.
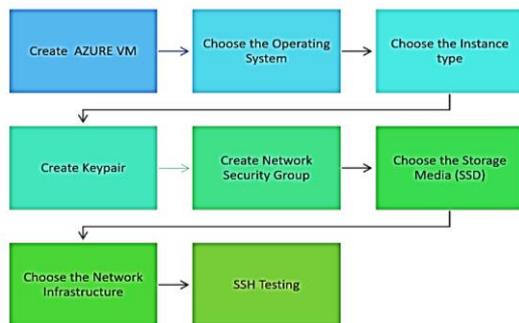
Figure 5. Azure Provisioning Steps

On the other hand, cloud provisioning in Microsoft Azure follows an almost identical process to the AWS, albeit in a different order. The first step is to create an account and process a subscription in Azure. Next, a Virtual Network (VNET) and a public subnet is created. The name of the VNET to be used is referred to as Azure-VN with the assigned IP address of CIDR 10.10.10.10/24. The process can be seen in detail through Figure 5.
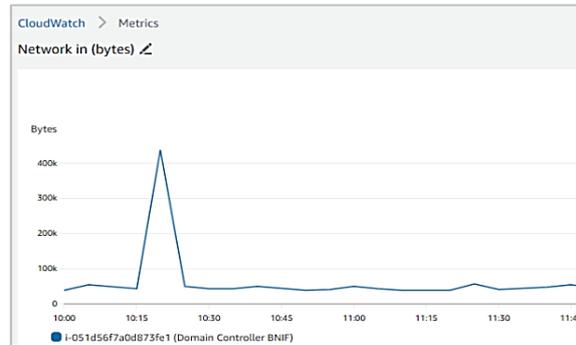
Figure 6. CloudWatch Graph Showing Morning Network Traffic of a Company

After the provisioning process for AWS and Azure is complete, the next stage is measuring QoS on both machines. Performance of network is measured twice a day, once at around 10:00 and again after 22:00. The morning time for measurement (10:00) is chosen because internet traffic is typically highest around this time as it is part of the typical worker's core hours. The selection of peak time is based on a company's CloudWatch data on network traffic. As shown in Figure 6, significant jumps in internet traffic can be observed between 10.15 ~ 10.30, reaching a peak of around 480 KB.

3. RESULTS

The QoS of AWS and Azure networks when a 680 MB-sized video or a 1 GB-sized binary file is sent has been measured by Wireshark. The results are then analyzed to compare the network performance of AWS and Azure.

The TIPHON standard is used to determine the QoS of the network, which is a standard that was developed by ETSI (European Telecommunications Standards Institute) to harmonize telecommunication networks and internet networks [24], [25]. The TIPHON standard consists of four parameters: throughput, latency, jitter, and packet loss. First throughput is the original speed of a network, the difference between bandwidth and throughput is, bandwidth   is the maximum speed of a network. While throughput is the real speed of the network we are using. The second parameter is latency or total delay, which is the time it takes for data packets sent from the sender to arrive at their destination. The average result of latency or delay in ms (milliseconds) can determine the quality of stability of a network. The third parameter is jitter, which is the variation of

time delay that occurs in sending data packets through a computer network. Packet loss indicates the number of packets lost during the transmission process. Table 3 shows TIPHON standard for throughput.

Table 3. TIPHON Standard for Throughput

THROUGHPUT Category	THROUGHPUT (Mbps)	INDEX
Excellent	> 2,1 Mbps	4
Good	1200 Kbps - 2,1 Mbps	3
Fair	700 - 1200 Kbps	2
Poor	338 - 700 Kbps	1
Bad	0 - 338 Kbps	0

The measurement results are compiled into 4 tables, 2 of which are measurement results when video is uploaded using AWS and Azure, while the other 2 are the results when the 1 GB binary file is downloaded. Wireshark provides the result in these following parameters: packets, time span, average pps, average packet size, and bytes, as shown in Figure 7.

```
Hardware:        Intel(R) Xeon(R) Platinum 8259CL CPU @ 2.50GHz (with SSE4.2)
OS:              64-bit Windows Server 2022 (21H2), build 20348
Application:     Dumpcap (Wireshark) 4.0.5 (v4.0.5-0-ge556162d8da3)

Interfaces

Interface        Dropped packets              Capture filter
Ethernet 3       0 (0.0%)                     none

Statistics

Measurement                   Captured                    Displayed
Packets                       88915                       35851 (40.3%)
Time span, s                  98.414                      38.160
Average pps                   903.5                       939.5
Average packet size, B        8108                        19968
Bytes                         720891957                   715857843 (99.3%)
Average bytes/s               7325 k                      18 M
Average bits/s                58 M                        150 M
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Figure 7. Capture Of Wireshark Screen During Video Upload Process To AWS.

Packets denote the number of packets sent in each time span (in seconds). Average pps (packet per second) is the rate of packets sent per second. Packet size is the size of a single packet in Byte units (B). Table 4 and 5 display several measurement results taken from the Wireshark.

The measured data will be used to calculate the latency, jitter, and throughput of the network. Latency is the time necessary to send a packet of data in a network from its source to its destination, typically measured in milliseconds (ms) or microseconds (μs). Lower latencies mean that networks and applications will have a faster response time [26]. Jitter, typically measured in milliseconds (ms) or microseconds (μs), is a measure of variance of latency between subsequent packets. Jitter can also be calculated by averaging latency sample differences. Throughput is a measure that reflects the amount of data being set through the network per second. Each of the parameters can be calculated as follows :

$$Latency = time\ span/packets \tag{1}$$

$$Throughput = \frac{packets.average\ packet\ size}{time\ span} \tag{2}$$

$$Jitter = \frac{total\ latency\ differences}{Number\ of\ data-} \tag{3}$$

Table 4. Wireshark Measurements for Video File Upload in AWS (Morning)

Day-	Time	Time Span (seconds)	Packet Loss	Packets	Average Packet Size (Bytes)	Average pps
Day 1	10:16:00	40.996	0%	57558	12458	1404
Day 2	10:02:00	42.234	0%	37740	18971	893.6
Day 3	10:07:00	43.761	0%	39149	18290	894.6
Day 4	10:10:00	39.103	0%	41868	17106	1070.7
Day 5	10:09:00	39.103	0%	41868	17106	1070.7
Day 6	10:07:00	40.775	0%	33232	21539	815
Day 7	10:11:00	44.484	0%	34088	20998	766.3

Table 5. Wireshark Measurements for 1GB File Downloads using Azure (Night)

Day-	Time	Time Span (seconds)	Packet Loss	Packets	Average Packet Size (Bytes)	Average pps
Day 1	21:37:00	48.016	0%	750466	1454	15629.5
Day 2	21:29:00	49.197	0%	742821	1469	15098.9
Day 3	21:33:00	49.553	0%	745728	1463	15049.1
Day 4	21:26:00	49.014	0%	749895	1455	15299.6
Day 5	21:32:00	47.889	0%	749851	1455	15658.1
Day 6	21:32:00	49.207	0%	750215	1455	15246.1
Day 7	21:24:00	49.758	0%	746211	1462	14996.8

As an example, to calculate the latency from the first row measurement in table 4, time span is divided by the number of packets sent. Doing this, a latency of 0,7122 ms can be calculated.

40.996 / 57,558 = 0.7122 ms.

Following the same method, all the latencies can be obtained. Tabel 6 shows some of the latencies obtained from uploading 680 MB video file in the morning (around 10 am) using AWS cloud network.

Table 6. *AWS Video Upload Latency (Morning)*

No.	Time Span (sec)	Packets	Latency (msec)
1	40,996	57558	0,712
2	42,234	37740	1,119
3	43,761	39149	1,118
4	39,103	41868	0,934
5	39,103	41868	0,934
6	40,775	33232	1,227
7	44,484	34088	1,305

Throughput can be computed by multiplying the total amount of the packets with average packet size (in bytes) and then divided by the time span (in seconds). Still using the previous table 4 data, the following throughput value can be determined.

(57,558 x 12,458) /40.996
= 17,490.95 byte per second
= 139.93 Mbps.

Jitter can be assessed by quantifying the variance of latency values from the measured data, which can be obtained by calculating the difference between latency in samples 1 with 2 (in table 6), samples 2 and 3, and so on until 6 latency differences are enumerated, which are 0.407 ms, 0.001 ms, 0.184 ms, 0 ms, 0.293 ms, and 0.078 ms. The difference adds up to 0.923 ms. Therefore, the jitter is the total latency difference divided with the number of samples, which is (0.407+0.01+ 0.184+0+ 0,293+ 0,078)/6= 0.963 / 6 = 0.16 ms.

Latency and throughput can be calculated using formula (1) and (2). One example of such calculations is shown in table 7, where the latency and throughput of one of the possible scenarios is thoroughly measured. The values are then averaged to obtain an accurate reflection of the general performance of the network. In the scenario where a 680 MB video is uploaded on the Azure cloud network, an average throughput of 166.24 Mbps and latency of 0.795 ms is measured. While for the uploading video using AWS network, the obtained average throughput and latency are 136.8 Mbps and 1.144 ms. For downloading 1 GB binary file, the average throughput when using AWS is 180.86 Mbps and using Azure is 178.44 Mbps. And the average latency to download binary file for AWS and Azure are 0.0632 ms and 0.0654 ms, respectively.

Table 7. Latency and Throughput of 680MB Video Upload in Azure

No.	Time Span (s)	Packet Numbers	Latency (ms)	Throughput (Mbps)
1	34.383	43443	0.79145231	166.660704
2	38.281	43392	0.8822232	149.685476
3	32.615	43446	0.75069439	175.688005
4	32.827	43447	0.75557235	174.564356
5	32.32	43487	0.74321813	177.304608
6	32.423	43401	0.74704916	176.738035
7	35.563	43426	0.81893375	161.126587
8	33.597	43380	0.77447336	170.552026
9	35.222	43478	0.81011017	162.693920
10	32.991	43476	0.75884049	173.686040
11	33.415	43510	0.76799017	171.481362
12	32.597	43491	0.74951282	175.794192
13	34.092	43443	0.78474457	168.075073
14	32.984	43390	0.76016724	173.730192
15	35.291	43373	0.81366965	162.365648
16	37.11	43745	0.84832033	154.413370
17	35.286	43649	0.80840744	162.393360
18	36.311	43635	0.83215445	157.807244
19	34.201	43534	0.78560767	167.534006
20	36.176	43661	0.82856906	158.393556
21	35.691	43604	0.81853155	160.541154
22	39.027	43574	0.89565607	146.833148
23	34.341	43459	0.7902015	166.863768
24	34.216	43454	0.78740157	167.467280
25	33.834	43443	0.7788162	169.354464
26	33.275	43387	0.76692998	172.198250
27	35.673	43386	0.82223319	160.635696
28	33.688	43360	0.77694041	170.092839

Figure 7 shows how download throughput in an AWS and an Azure instance look like when downloading a 1 GB-binary file, while Figure 8 shows differences in latency.
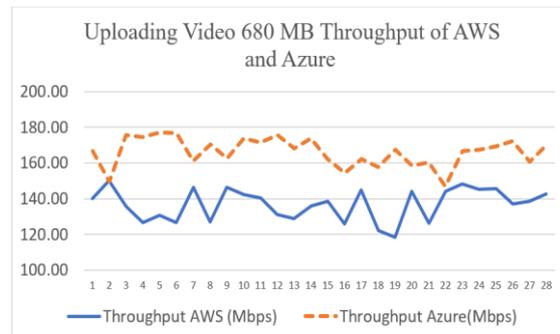
Figure 7. Comparison of Binary File Download Throughput
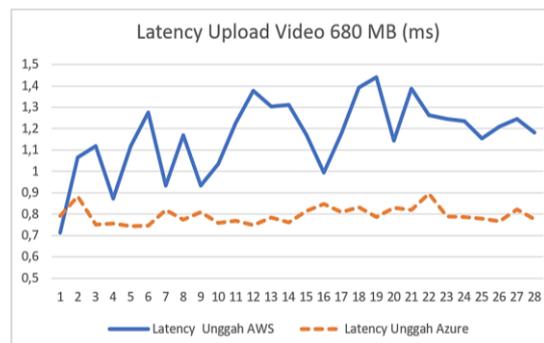
Figure 8. Comparison of Video Upload Latency

QoS between AWS and Azure network are also compared by analyzing the differences in several QoS parameters when given upload and download tasks during both daytime and night-time. The average jitter value in upload operations using AWS showed

a higher value of 0.16 ms, while Azure had an average jitter of 0.033 ms. For both CPSs, the average jitter around 10 am is lower than the average jitter value at night. For example, the jitter for uploading video file 680 MB using AWS network 0.134 ms in the morning and 0.186 ms after 10 pm While for Azure, the obtained values are 0.028 ms during the day and 0.038 ms at night.

4. DISCUSSION

QoS between AWS and Azure network are compared by analyzing the differences in several QoS parameters when given certain tasks of uploading and downloading big files. The obtained values of throughput, latency, and jitter are analysed based on TIPHON standard. Throughput is measured in megabit per second (Mbp), while latency and jitter are measured in millsecond (ms).

Table 8. QoS Comparison between AWS and Azure for Upload Operation

Parameter QoS	Cloud provider	Avg.	TIPHON	Category
Throughput (Mbps)	Azure	166	>2,1 Mbps	Excellent
Throughput (Mbps)	AWS	136	>2,1 Mbps	Excellent
Latency (ms)	Azure	0.795	<150 ms	Excellent
Latency (ms)	AWS	1.144	<150 ms	Excellent

When looking at the parameters (latency and throughput,), each parameter falls under the category of excellent based on the TIPHON standards. Each of the values can be seen in tables 8 and 9. From the tables 8 and 9, it can be understood that the network quality during uploads and downloads on both AWS and Azure are excellent. However, Azure upload network is comparatively faster and stabler than AWS, both during daytime and nighttime. Still, in general, comparisons of the entirety of QoS parameters (latency, jitter, and throughput) always reflect highly excellent network quality under the TIPHON standard.

Table 9. QOS Comparison between AWS and Azure for Download Operation

Parameter QoS	Cloud provider	Avg.	TIPHON	Category
Throughput (Mbps)	Azure	178.44	>2,1 Mbps	Excellent
Throughput (Mbps)	AWS	188.73	>2,1 Mbps	Excellent
Latency (ms)	Azure	0.065	<150 ms	Excellent
Latency (ms)	AWS	0.063	<150 ms	Excellent

Since both CSPs offer high quality network, virtually no packet loss was observed during the experiment. Therefore, packet loss is irrelevant when comparing the two CSPs network performance.

Network stability of both networks are also considered excellent, as the latency of AWS and Azure are both less than 150 ms.

5. CONCLUSION

1. QoS parameters of latency, throughput, packet loss, and jitter on AWS and Azure have been measured using Wireshark and evaluated in accordance with TIPHON standards.
2. The network speed of AWS and Azure cloud are classified as excellent under TIPHON standards as the throughput of AWS and Azure both exceed 2.1 Mbps.
3. When uploading files, Azure network maintains a better quality than AWS as they are faster, with a throughput difference of up to 29 Mbps. Network quality in Azure is also more stable as they have less latency by 0.38 ms. However, when downloading, AWS maintains a slight advantage in network quality relative to Azure, as they have a higher throughput by 3 Mbps. AWS is also slightly more stable when downloading, as they have less latency by 0.01 ms.

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