Quality of Experience on Cellular Networks

Kartik Kumar[1], Mrs. Pratibha Kantanavar[2]
[1]Student, R.V College of Engineering
[2]Assistant Professor R.V College of Engineering

Abstract—**Quality of Experience (QoE or QoX) gives an estimate about the level of satisfaction a consumer feels with the services provided by the service providers. To some extent, quality of experience varies depending on the client since different consumers have different requirements. Depending on these requirements some consumers may be hard to please than others. A large number of subscribers should be tested or surveyed to obtain the best QoE assessments. Some of the factors that can affect quality of experience include bandwidth, efficiency, delay, jitter, reliability, frequency of use, security, sample rate and user confidence. In this paper the values of the parameters like uplink speed, downlink speed, jitter etc. which reflects the quality of experience are found. The values of these metrics are found by performing functions like ping, speed test, traceroute, IP service level agreement (IP SLA). Cisco router IR1101 is used, and python is used to obtain the values of all the aforementioned parameters. These parameters can then be sent to any network monitoring platform like Prometheus on a periodic basis say for every five minutes which could plot these parameters as a function of time and provide a real time estimate of the quality of experience. This provides a way for the service providers to have an idea about the quality of experience as experienced by the user.**

Index Terms—**Quality of Experience, Delay, Jitter, IR1101, Prometheus, IP Service Level Agreement(IP SLA).**

I. INTRODUCTION

Cisco Catalyst IR1101 Rugged Series Router or IR1101 is used. It is compact, FirstNet Ready industrial router. It is designed in a highly modular form factor which makes it an ideal solution for remote asset management across multiple industrial vertical markets. It provides features like

- Modularity and investment protection
- Dual active LTE-capable
- Cisco IOS XE Software
- Software defined WAN (SDWAN) capable
- GPS
- IoT enablement

Due to various advantages offered by IR1101 it is a great choice. The Figure 1 shows the cross sectional
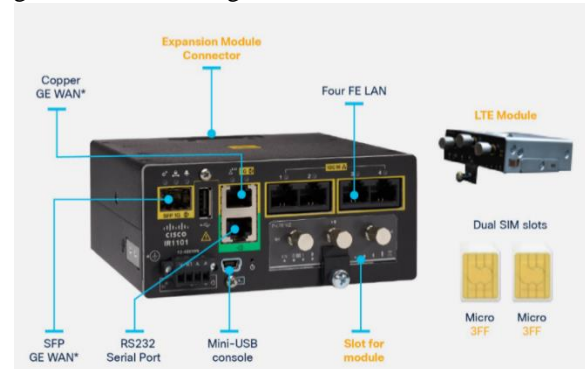

Figure 1: Cisco Router IR1101

view of Cisco router IR1101. To get the values of the parameters of interest different functions are created using python. For e.g., speed test can be used to get value of metrics like uplink speed, downlink speed, a script is created which extracts all the information associated with the server id. From all the values, the parameters of interest can be chosen. Similarly for ping, pingparsing is used to get the values of parameters like round trip time, packet loss, delay etc. These values then can be sent to a monitoring system like Prometheus, Dynatrace, AppDynamics, Datadog etc to plot the graph of the different metrics and any irregularity can be found.

II. LITERATURE REVIEW

[1] presents a way to estimate Quality of Experience using passive measurements which was implemented using Prometheus. The benefits this offers are cellular operators' specific challenges of lack of control, limited vantage points, and protocol complexity. It gave a detailed analysis how Prometheus can estimate QoE only with the help of passive network measurements and do not require any control on the target application which was not the case in the previous studies done in this regard. The advantage of using passive measurements is the scalability it offers that is it can cover all subscribers. The approach was easy to understand and did not require any deep

knowledge with respect to the relationship between network metrics and app specific QoE metrics.

[2] explains different techniques which can be used to measure Quality of Experience. To conduct the test various freely available tools were used. QoE of speech and audio was estimated using E-model which is a no reference model. QoE of Interactive gaming was estimated using First Person Shooter. G model was used for the prediction. Tests were performed on games like Counter Strike and Quake IV. QoE of video streaming was estimated. Factors influencing video quality includes resolution, brightness, sharpness, colorfulness etc. The three most important metrics to monitor are packet loss, delay, and jitter.

[3] provides an overview on the Quality of Experience of different services and applications. These applications have different network-level QoS requirements. In this paper specific case of smartphone devices was presented. The study presented the results of both lab as well as field. It shows that in the determination of QoE of highly interactive services downlink, bandwidth fluctuation plays an important role. It is seen that results obtained in the lab are comparable to the field ones. It was claimed that if end users are involved in the assessment more reliable results can be obtained.

[4] presents a mechanism to estimate web Quality of Experience metrics from the network with the help of machine learning. The dataset was n for a month, collected from a major service provider. The data collected was anonymized. The impact of network characteristics on web QoE was studied. From the service provider point of view parameters like session length, abandonment rate and partial download ratio was presented. Text-classification-based mechanisms were used to extract mobile web browsing session. The results obtained were 20% better than the previous similar studies conducted.

[5] provides a way to associate various network characteristics on an operator's network and how user experiences it with the help of an experimental platform. It is very crucial to understand how network performance impacts user. Relation between QoE which was expressed in opinion scores and different QoS parameters such as loss ratio, throughput and download times were studied. It provides a way for service providers to make use of correlation between QoE and traffic characteristics for assessment of applications. It can also be used on operational networks to track the changes in the application's traffic characteristics.

III. METHODOLOGY

Paramiko is a library in python and is used to connect to remote devices with the help of SSH. Paramiko uses SSH2 in the place of secure socket layer.SSH2 is used to make a connection between two devices secure. Paramiko also supports the Secure File Transfer Protocol (SFTP) client and server model. The Figure 2 shows the methodology used.
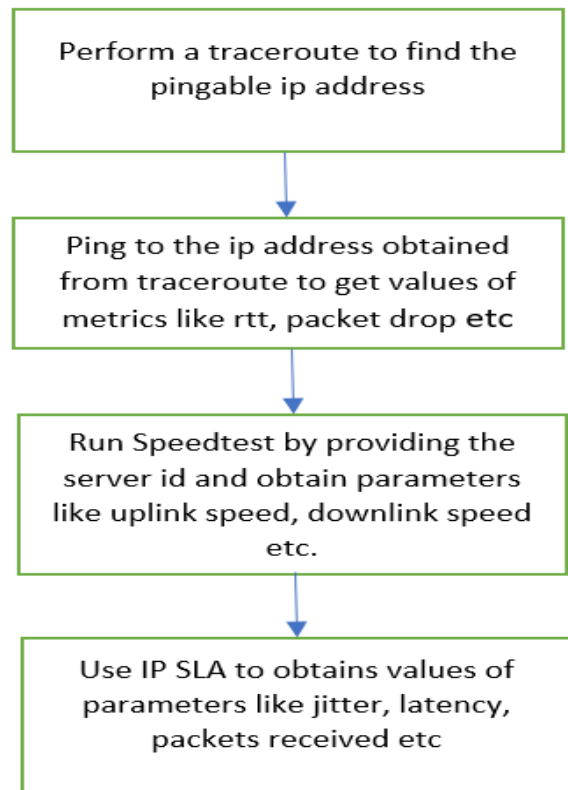

Figure 2: Methodology

A. Traceroute

When a user interacts with a server or a website the data from the source to the destination passes through many network devices before reaching its destination. Traceroute helps in tracing the path the data took to reach its intended destination. It is very helpful in debugging as it can be used to identify the part of the network where the communication has failed. Traceroute is implemented by making use of time to

live of a packet. Time to live (TTL) is a measure of how many hops a packet is allowed before being discarded. When a packet passes through a router 1 is subtracted from the ttl. Traceroute makes use of this and sends packet with increasing ttl to the destination. This means the ttl of first packet would be one. The first router will send an Internet Control Message Protocol (ICMP) back and will also drop the packet. The ICMP message will contain the ip address of the router, So the ip address of the first router is learnt. Similarly, a packet with ttl 2 and so on will be send and the ip address of each successive router will be learnt thus knowing the whole route of the packet. Traceroute can be implemented either with ICMP or UDP. Ping is sent if traceroute is being implemented through ICMP. To implement this socket library of python is imported. It contains functions like gethostbyname(), getprotobyname() ,setsocket() and bind() are present which helps in implementing traceroute. The first hop as provided by the results of the traceroute is used as the pingable ip address. This is the ip address that will be used to run ping and obtain the metrics associated with it.

B. Ping

Packet Internet Groper or Ping is a technique for deciding communication latency between two networks. Basically, ping is a technique for deciding latency or how much time it takes for information to go between two devices or across a network. As communication latency diminishes, communication effectiveness gets to the next level. A low ping time is basic in circumstances where the ideal conveyance of information is a higher priority than the amount and nature of the desired data. Pingparsing is a CLI command and is available in python which performs function like ping and it can also parse the results. Destination has to be provided; it is the ip address which is to be pinged. The hop 1 extracted from traceroute is chosen as the transmitter destination. Count is chosen as 10, count here means it stops after sending the count.

C. Speedtest

Speed test is used to measure the speed between a device and a test server, by making use of user's device's internet connection. There could be several reasons in deciding the speed recorded by a test device. For e.g., different devices can have different Wi-Fi and distinct radio capabilities. Usually, Speed test servers

tend to perform differently. Faster speeds are noted if the server is closer to the user. To get accurate results it is generally advised testing different test servers. In the beginning of the test Speed test uses the server which is closer and gives a fast-ping result. This is done to obtain the best results internet can offer. Instead of using the default server, the testing server can be changed. Rather it is advised to use different servers to get a better idea and results can be compared. Speed test module provide different functions like get_servers(), get_best_server() , download(), upload() etc. To get the server information associated with a specific server get_servers() method is used and server id is provided as the parameter. Various values like downlink speed, uplink speed, latency, server information etc are obtained using this.

D. IP Service Level Agreement(IP SLA)

IP SLA is used to monitor and report the performance of the network. IP SLA generates and monitors traffic actively and continuously across the network. An IP SLA Router as IR1101 in our case is capable of generating traffic. It can also report the traffic in real time. IP SLA can be configured in such a way that it can report on statistics such as: Jitter, Response time, Packet loss, Voice Quality Scoring (MOS), connectivity, server or website responses and downtime, delay. IP SLA can be configured in two parts. The first being IP SLA router. It is used to generate traffic. The second being IP SLA responder. It is not necessary for the responder to be a cisco router it can be any device. It is important to note that the IP SLA Responder is not mandatory for IP SLA to function. The advantage of using IP SLA responder is that the information which is collected and reported is more detailed.

To achieve this, a ssh client is created and all the required fields like username, password, port, destination ip address are passed as arguments. Invoke_shell() method is used to pass the "**show ip sla statistics detail**" command. It gives an insight to various parameters like jitter, packet loss, rtt, packet skipped, latency, packets unprocessed etc.

IV. RESULT

The functions created will provide the metrics, values can be found by parsing through the results and only

extracting the values of the parameters of interest. The values can then be sent to any network monitoring platform in a format like json.

Figure 3 shows the result of the traceroute to google (8.8.8.8). The count here is 20 but it could be

Figure 3: Traceroute Result

increased to number of one's choice. Usually, it is chosen as 30. The first hop that is the first ip address in the list is chosen as the pingable ip address.

The figure 4 shows the result of ping to the google and reflects values like the destination, packets transmitted, packets received, packets lost, rtt minimum, rtt average and rtt maximum etc. These values give an idea about the quality of experience as experienced by the user. Any ip address can be pinged by providing the ip address as the destination.

```
$ pingparsing google.com
{
    "google.com": {
        "destination": "google.com",
        "packet_transmit": 10,
        "packet_receive": 10,
        "packet_loss_rate": 0.0,
        "packet_loss_count": 0,
        "rtt_min": 34.189,
        "rtt_avg": 46.054,
        "rtt_max": 63.246,
        "rtt_mdev": 9.122,
        "packet_duplicate_rate": 0.0,
        "packet_duplicate_count": 0
    }
}
```

Figure 4: Ping Result

The figure 5 shows the result of the speedtest and it gives values of parameters like latency, download speed, upload speed and the server information. To test the server of own choice, service id has to be provided and the results will be similar to this.

Figure 5: Speedtest Result

The figure 6 shows the results obtained from IP SLA. The results of IP SLA give information about the metrics directly correlated to the quality of experience. The most important ones being Number of RTT, RTT minimum, average, maximum value, latency, jitter both source to destination and destination to source. These metrics can be used to estimate the quality of experience.

Figure 6: IP SLA Results

V. CONCLUSION

Quality of Experience refers to the satisfaction a user gets from the services provided by the service providers. Maintaining a good Quality of experience is essential not only for end users but for service providers as well. Good Quality of Experience for end users ensures that they not only get the services but

also are satisfied with the services they are paying for. For service providers Quality of Experience becomes crucial as there is a huge competition in the market, if a consumer is not satisfied with the services offered by the service provider, he might switch to the competitor. So, to monitor Quality of Experience, parameters reflecting the Quality of Experience should be monitored. This paper presented how to obtain values of the parameters which can be used to estimate the quality of experience a user is experiencing. Cisco router IR1101 was used which provides many useful functionalities needed to execute the project like its support for IP SLA. Network automation with python was used to obtain these metrics. The most useful library used was Paramiko which provides basic functionalities like being able to ssh to a device. Other libraries like speed test, socket, os were used to obtain the values of interest.

VI. FUTURE SCOPE

The obtained values of different metrics can be sent to any monitoring platform on a periodic basis and the values can be plotted as a function of time. This would help the service providers to get a better insight about the quality of experience and issues faced by the consumers. The IR1101 is also capable of reporting the location which can help in identifying the areas facing regular issues. The work done in the project only talks about the reporting of Quality of Experience but does not provide any qualitative analysis. On the server-side alerting system could be created which will alert if the values of any of these parameters falls below the critical or threshold level. Apart from the metrics discussed here in the project many more metrics can be reported.

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