A Novel Framework for Video Delivery to Handheld Devices using Cloud Environment

G. Rajasekaran, M. Lakshmanan, Venkata Naga Rani Bandaru

Abstract: Handheld devices are responsible for most of the internet traffic nowadays. Video streaming services plays a vital role in internet traffic because of its increasing size and high definition. Even though the mobile devices are capable to store and process huge data, the limitations of resources (Power, Memory, Processing, etc.), are creating bottleneck during video delivery process. Mobile devices are heterogeneous in nature in terms of service provider, geo location, hardware and software configuration and many other aspects. It is very difficult to provide the expected service to those devices without any compensation. To maintain the trade-off among the user expectation, device configuration and service provision a novel framework is proposed here. The framework covers various aspects of streaming services like user experience, delivery and storage of the contents, consumption of power resources, network conditions etc.,. The novel framework was tested with the cloud environment, within our parametric boundary it provide smooth streaming services to the handheld devices.

Keywords: Cloud Computing, Device Heterogeneity, Quality of Experience, Streaming Services, Subjective Analysis, User Experience, Video Transcoding.

I. INTRODUCTION

Cloud Computing, Streaming Services, User Experience, Video Transcoding Cloud Computing is a finite, scalable and resource rich environment that makes software, platform and infrastructure services available to the end users virtually using the Internet. The Cloud Computing environment consists of a huge set of resources like storage, processors, networking components, databases, platforms and the software both on application/system levels. Due to this capability of cloud environment, it can handle any type of service request that requires resources for any applications.

Multimedia Streaming Services (MSS), particularly video streaming is one of the services on the Internet that consumes huge amount of resources to produce the desired results. As these applications are delay sensitive, it accepts a certain level of compression for storage and transmission over the Internet. It requires massive amounts of storage space for video contents, huge number of processor cores with threads to transcode and compresses the video files, and a high bandwidth for transmission over the Internet.Video Streaming Services will normally produce expected results, under the controlled environments with stable network connectivity, but fails to deliver the exact results for the end users under uncontrolled environments with dynamic connectivity. The Quality of Experience (QoE) perceived by the user is also analyzed in a controlled environment with the person's expertise in the quality analysis. Now-a-days handheld devices, particularly smart mobile devices have come under the above category to deliver video streaming services.

Presently smartphones have become the mandatory gadgets of all peoples, despite age, profession and usage. According to the survey, more than 60 percentages of the people are using smartphones worldwide with different platforms which are responsible for most of the Internet traffic. A survey of CISCO states that the video application usage using smartphones is responsible for more than 66% of the total Internet traffic. Due to the easy and cost effective availability of smart devices, its ease of use, requests of people for various types of services through these mobile devices, huge amount of resources are demanded. Video Streaming is one of the services that incur heavy bandwidth, storage, process and a higher level of compatibility. But mobile devices are always limited in resources due to its compactness, power source (limited battery capacity), low processing speed, limited memory and network fluctuations due to the mobility of the user.

In order to compensate for the above limitations in mobile devices, researchers suggested the idea called computation offloading. In these, requests received from the users were submitted to the cloud environment and the processed results were given to the mobile devices of the end user. The actual computation, storage and other resources were all handled by the cloud environment and only the final results were given to the end user. This is one of the finest methods to preserve energy and other resources on user side.

Though the offloading method is efficient and the limitations of mobile devices were compensated by cloudlets, the Multimedia Service Providers (MSP) face challenges in delivering good Quality of Service (QoS) to the end users. If the QoS suffers, then the Quality of Experience felt by the end user will also deteriorate. Hence the service provider must consider multiple aspects like bit rate, throughput, transmission delay, availability, jitter, etc., as the parameters of performance to provide a good Quality of Service. QoE is the experience perceived by the end user who depends on the technical parameters of QoS and other non-technical parameters pertaining to the end user.

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Hence a framework to provide a video streaming service with good QoE on a smart phone using cloud computing becomes the need of the day. A novel framework using Cloud Computing Architecture has been designed to provide good QoE for mobile video streaming service on a smartphone.

II. RELATED WORK

Bandwidth and Device Monitoring, Transcoding of video contents, QoE Analysis, Caching mechanism, P2P technology and Tracking methodology were discussed by many researchers. Armbrust et al [1] discussed about the detailed view of cloud computing and the resources available on cloud environments. He also discussed the impact of the cloud computing on business, research, social and educational side. Viktor Mauch et al [2] analyzed the power of cloud resources and future technologies with the broad comparison of existing technologies and limitations. Y.K. Lai et al [3] had done the detailed analysis on mobile device power consumption by various hardware and software utilities and prediction methods for power usage statistics. J.M.Kang et al [4] analyzed the battery lifetime of the mobile devices with the usage pattern of the user, and analyzed how the hardware and software resources consume power resources for the particular usage pattern. Fangming Liu et al [5] all discussed how the limitations of the mobile devices are overcome by the cloud resources using job offloading and challenges during offloading methods. Also they analyze the performance improvement of the processes by using cloud computing resources.

B.Aggarwal et al [6] proposed the framework for energy in mobile communication by using cloud environment. Seungjun Yang et al [7] analyzed the transfer and cost minimization of the offloading methodology by using cloud and discussed and analyzed the application performances on computation, storage and energy based analysis by using cloud computing environment. W.Zhu et al [9] discussed the how cloud resources can be used for multimedia operations. S. Heiko et al [10] gave a detailed introduction about the Scalable and Adaptive video coding technologies and working principles. [11] proposed a model for cloud based video Transcoding services for mobile devices. L.Yao et al [12] measured a server side workload for mobile streaming service provision.

The survey covers the Transcoding of the video contents, audio video formats, device heterogeneity and hardware, software variations and practical limitations on service provision. W. Yu et al [13] proposed a model called CloudMOV a highly interactive mobile TV environment with social interactiveness. W.Xiaofei et al on [14] introduced a framework for video streaming works under the principle of caching and social interactiveness also called popularity based content caching mechanism. They proposed a burst transmission mechanism for the content injection with the user device by analysing the users network conditions. X.Jin et al [16] discussed the peer assisted streaming services using network and proxy caching method. S.Kalpana et al [17] discussed the subjective and objective video quality assessment models .The accuracy of those models and practical limitations are also discussed with the performance comparison. [19] discussed the impact of QoS on the user experience by QoS/QoE mapping model and QoE driven adaptive streaming services.

III. STREAMING FRAMEWORK USING CLOUD ENVIRONMENT

The video streaming is one of the multimedia delivery models to the user with various methodologies. The streaming contents can broadly differentiated into categories, live video streaming and stored video streaming. Both type of service delivery does not download the entire file contents to play the video files. The video file was separated into various chunks on the server side, these chunks are delivered to the end user based on their network quality. Before delivering the video contents the raw video and audio contents were compressed with various encoders. The compression was applied separately on audio and video files. Then these compressed files are packed with various containers mp4, flv, matroska(.mkv), etc,. The user module decode the received video/audio contents and play the subsequent file using video players, embedded players in the browser or the applications capable to play the video file.

A novel framework to stream the requested video contents to the user mobile device has been proposed in cloud computing environment has been proposed is shown in the Fig.1. It includes three main modules namely User Module (UM), Video Service Provider (VSP) module and Video Service Cloud (VSC) module.

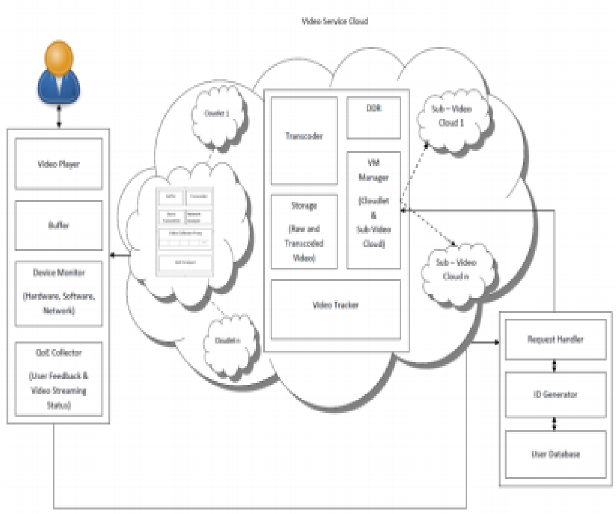

Fig. 1.Novel Video Streaming Framework

The video streaming service starts with the request from the user module which is given to the Video Service Provider (VSP). The VSP handovers the process to Video Service Cloud (VSC) to allocate a separate virtual machine module called cloudlet to perform the requested operation on behalf of the user module which takes the burden of the user module and it acts as a surrogate for user device. The requested video file was processed by the central cloud and cloudlet inside the VSC by using the parameters taken from the user module using HTTP request. Finally the video streaming was started from the cloudlet to user module.

A. User Module

The User Module (UM) is a handheld device of the user with the combination of software, hardware and network capabilities. It ranges from the low end mobile devices to high end laptops. The user module uses video player or video plug-in enabled web browser with HTML5 support or any application capable to play the video file. The buffer module is to store the incoming video packets during streaming process. The device status monitor collects the runtime information about the hardware, software and network status of the device. The information includes power consumption rate, power source (Battery or Direct power source), processor status (amount of processor consumed by the applications), sensor status, location, orientation etc, and status of the network used by device (2G, 3G, LTE, WIFI). During the user request process the required parametric values are invoked from the Device Monitor to build HTTP Request Message.

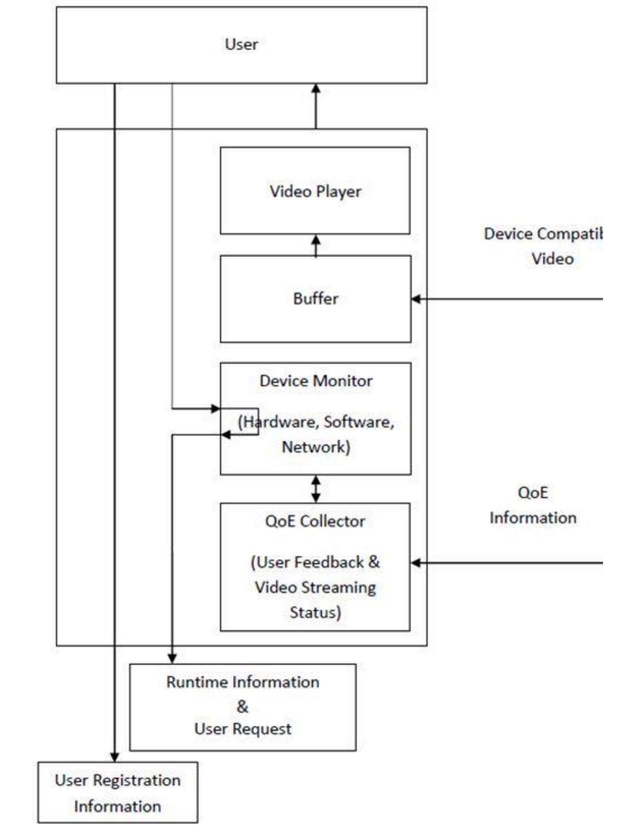

Fig.2. User Module

The QoE Collector module is an experience monitor which collects the experience perceived by the user upon receiving content and get feedback of the user. The QoE collector collects the information from the delivered video contents such as Initial Buffering Time (IBT), Post Buffering Time (PBT), and Video Discontinuity (VD). It also collects the information about the location and network conditions from Device Monitor and feedback from the user and submits it to the QoE Analyzer in Cloudlet.
The information about the user and their device is collected from the user module in two ways. First one is during the registration process and the second one is at the time of video request. The information collected during the registration is mostly static values given by the user.
The static information given by the user during registration process can be categorized into personal details, career details, personal interests, social connectivity, language, location, device model expected services and control, video player placement are collected during the registration process. The above detail comes under the category of static information related to the user and service.
The buffer module in the user collects the video chunks provided by the cloudlet and supplies it to the video playback software. The playback device may be a Video Player, the browser or any application with video playback capability which plays a given video file.

B. Video Service Provider (VSP)

The Video Streaming Server (VSP) collects the request given by the User via the registration process and runtime HTTP request URL. After getting the information it generates identification String (ID) to every user. The ID was stored in the server database and the replica was given to the Video Service Cloud (VSC) to store it in a tracker DB.

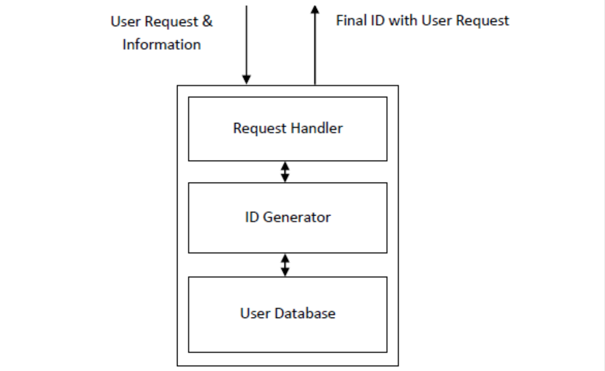

Fig.3. User Module

The static Id was permanently stored in a server Data Base (DB) with the unique username as a key. During submission of user request to the cloud environment the runtime ID was append with the static ID along with the video request. After initiating the static ID for the user it was retrieved from the DB with the unique user name as the key value pair.

C. Video Service Cloud (VSC)

Video Service Cloud (VSC) is created to handle the video streaming operations on behalf of the Video Service Provider (VSP) and User Device (UD). In order to escape from the real-time service provisioning problems like dynamic request scaling, single point failure, power and resource (Processing, Storage and Networking) constraints Service Provider handover the request to cloud environment. Due to the limitations in the mobile devices it also requests assistance from the cloud computing environment particularly here for decoding the video contents. VSC handles the storage operations like storing Raw and Transcoded video contents on central cloud, Sub-Video Clouds (SVCs) and cloudlets. It Transcodes the Video files depending upon the users device model and network conditions. The Virtual Machine Manager (VMM) in VSC is to allocate the new Virtual Machines, depending upon the user request given by the Tracker module.

The capacity of the new VM is based on the configuration of the User Device. It allocates two flavours of Virtual Machines (VMs) one is cloudlet and another one is Sub-Video Cloud (SVC). It performs routing operations using tracker module inside the cloud environment to collect the distributed video files in SVC and Cloudlets on various locations.

The VSC contains Central Cloud with large amount of storage and computation capacity. This module includes the sub-modules Transcoder, DDR, Central Storage, Virtual Machine Manager (VM Manager) and Video Tracker.

D. The Transcoder

The Transcoder performs an operation like audio/video compression and conversion using high end processor cores. The Transcoding here is carried over by invoking the values from the DDR with the user's device model as a key. Before Transcoding, it first collects the required parameters from the user request for the accurate conversion. The collected parameters categorized into two based on device model and current network type (2G,3G,LTE,WIFI). The device considerations include supporting Audio/Video Bit Rate (BR) and Compression Factor (CF). It requires the hardware parameters like width in pixels (wp), height in pixels (hp), diagonal resolution in pixels (dp) and Pixel Per Inch (PPI). The BR is calculated from the values of height, width, Colour Depth (CD) and Frames per Second (FPS). The supported Compression Factor (CF) was applied on the Colour Depth of each video frames to minimize the size of the video file. On the network side the Transcoder considers the type of network for conversion because the data transfer rate was limited within the boundary of each network type. Due to this the bandwidth fluctuation of each type of network is also comes under this limit.

The Transcoder performs these conversions when the given request is first time for the particular video content or the request is anonymous. Also if the requested file having very low QoE value and vary rarely requested then it was placed in the central storage. These kinds of files are said to be the rare video contents it is handled by the central cloud components.

E. The Device Description Repository (DDR)

The DDR is the Device Description Repository that contains the specifications of the devices. The VUClip server based survey [25] states that there is more than 3465 mobile models with 109 resolutions. The well known DDR's are WURFL, AMD etc. It can be invoked by using specified API's like Apache Device Map which offers API's for several languages [31]. By using the device model, the static parameters like screen size, supporting codecs, available sensors, players, power source and capability, etc, stored in the DDR was invoked from the video conversions and operations.

F. The Sub Video Cloud (SVC)

The Sub-Video Cloud is also a virtual machine but it is an enhanced version of the cloudlets, its computation and storage capability is higher than the cloudlets. It was used to store the video contents based on the location, QoE Score and Quality of the video file. The sub video cloud purely contains Transcoded video files. The highly requested video file with user acceptable quality was placed on SVC and distributed among the SVCs and Cloudlets on various locations. It contains the metadata of the stored files and it will be shared with the tracker module in the Central Cloud Manager. The metadata inside the SVC is dynamic in nature because for every video transaction the log was updated frequently.

G. The Cloudlet

The cloudlet is the virtual machine assigned by the Virtual Machine Manager (VM Manager) based on the user request, ID and device model. The capacity of the cloudlet will vary depends upon the user device. It performs storage and computation operations on behalf of the user device. When the user login to the service, separate cloudlet was allocated for the user based on the user device model. The cloudlet communicates with the video tracker for video file locations, based on the information given by the video tracker it collects the video files from sub video cloud distributed on various locations. The collected video chunks are arranged on the cloudlet by using the proxy module and placed on its buffer. The Transcoder in the cloudlet analyze the current network and device condition of the user and transcode the video content on the fly with adaptive streaming support. Then the content was placed again in buffer storage. The network analyzer requests the user module about the network condition at the time of instance. Based on the network condition the burst transmitter creates the video chunks and delivers it to the user. During the chunk separation the burst transmitter considers the network condition of the user, quality of the video file and duration of the video file content. Based on the above three parameters, the size of the chunk or the number of chunks were scaled.

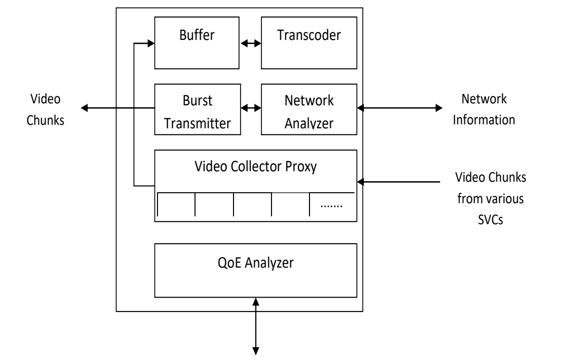

Fig.4. Cloudlet

r about the quality and experience of the delivered video content from QoE collector on user module. Then it provides the QoE rank to the video file based on the location, network condition, user satisfaction and video quality. The QoE ranking was given to the tracker module as a reference for the future usage.

H. The Tracker Module

The tracker module in the central cloud is the heart of the Video Service Cloud (VSC). It maintains the location of the sub video clouds and its metadata, cloudlet information, user details, quality of the video files and QoE rank of the videos in its database. It collects the user request from the service provider and maps it to the database it maintains. After analyzing the database it informs the VM Manager to allocate the separate cloudlet for the user and update the information about the cloudlet in its database.

Then it collects the video file information from all nearby Sub-Video Clouds and handover it to the cloudlet proxy. It uses Distributed Hash Table [22] to perform video metadata collection from SVC's.

After the service gets finished, it analyzes the QoE ranking from the cloudlet. If the QoE ranking for the video content and the pattern of video collection or the service pattern was stored in the tracker database. If the QoE ranking and the video request frequency was very low then it was stored in the central DB to improve the availability. It also informs the VM Manager to migrate the contents of the SVC to other SVC improve the service quality. When the similar request was received again the same pattern will be suggested to the cloudlets.

I. VM Manager

VM Manager is the Virtual Machine Manager is responsible for allocation, maintenance and de-allocation of Virtual Machines on cloud environment. It receives the instructions from the tracker module scripts and allocates the new Cloudlet and Sub-Video Cloud (SVC). It assigns a new cloudlet with computation, storage and networking capability when users get signed in, based on the device model the cloudlet is allocated for each user. The cloudlet will be deleted by the VM Manager as soon as the user gets signed out from the service. The capacity of the cloudlet VM's is purely based on the device specifications invoked from the Device Description Repository (DDR) on central cloud. But the size of the SVC's are scaled depending upon the rate of request and storage.

IV. PROCESS FLOW

Initially the user request the video content to the video streaming server along with the runtime parameters taken from the status monitor in user module. Before the process the individual user was requested to register for the service. During the registration static information was collected from the user and separate ID was assigned on server side. The tracker module provide the request to the VM Manager, the VM Manager invoke the Device parameters from DDR and assigns the new cloudlet for the user. The tracker module analyzes the metadata of the Sub-Video Cloud about the video contents and it will give it to the cloudlet proxy collector. Using the metadata proxy collector collects the video from corresponding Sub-Video Clouds in a parallel manner.

The Transcoder module in the cloudlet took the video file from the proxy and adds the subsequent data to the video and placed it in a buffer. The Burst transmitter in cloudlet separates the video files into chunks depending upon the network condition of the user by using the values collected by network analyzer from the user module. Then the final video chunks are all given to the buffer in user module and to the player respectively. During the video streaming the QoE collector collects the data like buffering time, video discontinuity etc from the player and other dynamic contents from the status monitor and inform it to the QoE analyzer in cloudlet. Finally the user rating given by the viewer is also given to the QoE analyzer. The QoE analyzer analyzes the values and provide ranking to the service. Then this value was given to the Tracker module. Tracker module analyze the QoE database , if the new QoE value was better than the existing one then it will save the service pattern on a database. The analysis pattern includes video distribution and collection from Sub-VC's, network condition, location of the user and user personal details. This pattern was used for the future service provision.

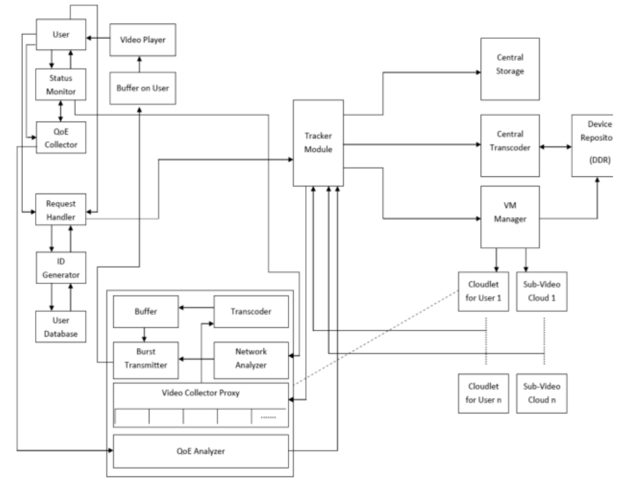

Fig.5. Process Flow

V. IMPLEMENTATION

For the prototype implementation of our novel framework we create OpenNebula cloud management platform, fully open-source software released under Apache license. We install Ubuntu 14.04 OS on all OpenNebula nodes and VMs. We select the bare metal configuration with core i7 processor of 4 cores and 8 threads each with 2.44 GHz processing capability and RAM memory of 16 GB. We allocate 100 GB storage memory for each VM and 4 cores for processing the video files. As a mobile client we use ASUS ZenFone Max (ZC550KL) with android system 6.0 version. The raw video content was Big Buck Benny in y4m file format of 24 fps, 1920x1080 resolution and 597197 kb/s with 00.09:56 minutes duration. Apache2 server was installed on the node and cloud VMs with MySQL to handle the client requests. In Transcoder VM ffmpeg and ffserver was used for encoding and streaming respectively. The streaming was performed on desktop PCs and mobile devices with VLC media player and Chrome, Firefox and Edge browsers.

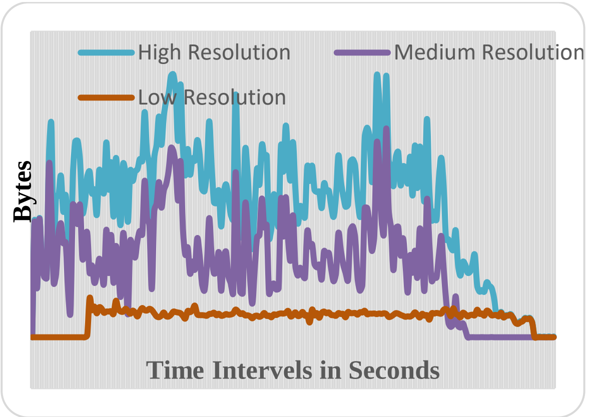

Fig.6. Streaming Bit Rates for 3 Videos with Different Resolutions

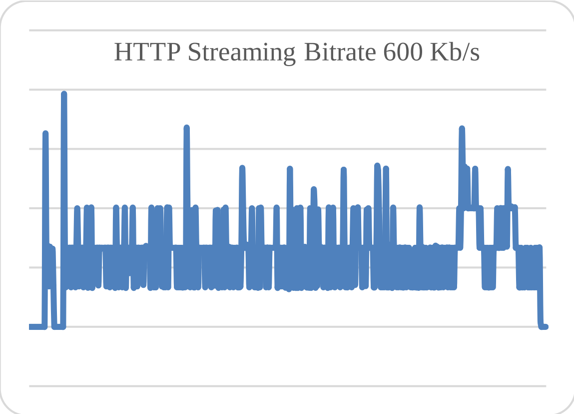

Fig. 7.Streaming Transcoded Videos using HTTP

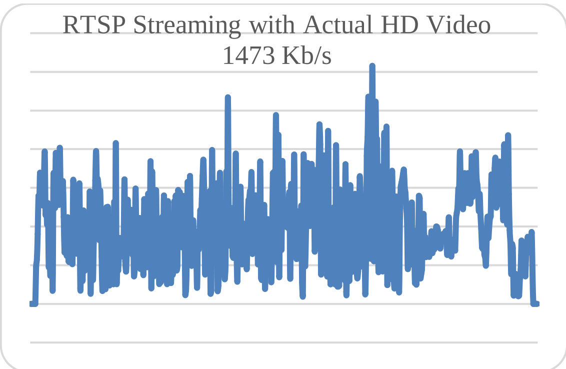

Fig.8. Raw Video Streaming using RTSP

wireless (WIFI) environment, the bandwidth capability of the network interfaces was limited for test requirement with WonderShaper [34]. The video files are encoded with different bit rates and resolutions and streamed it using HTTP and RTSP protocols. The processor and network performance during the streaming process was tested with nbox [35] and WireShark [36] respectively.

VI. CONCLUSION

In this paper the investigation was carried out for streaming process using various types of network conditions and video resolutions. The video processing was mainly dependent on network conditions and device capability. In order to provide effective streaming with acceptable QoE the QoS metrics are mandate. Instead of requesting the user feedback for each and every video file and subjective video analysis in controlled environment is not suitable for experience enhancement. Because the actual video streaming was always in uncontrolled environment most of the times. So there is a need for automation in parameter collection and higher number of parametric inclusion without security violation is the need of the day. Also the requirement of the cloud environment also unavoidable for the streaming services because of its unmatched capability. The current work can be extended by including the higher number of parameters from network and devices and effective resource allocation in computation environments will improve the QoE of the user.

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