Journal of Theoretical and Applied Information Technology
30th September 2018. Vol.96. No 18

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

RATE ADAPTIVE MULTICAST VIDEO STREAMING OVER SOFTWARE DEFINED NETWORK

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ABSTRACT

Multicasting has always been a topic of importance when it comes to multiple receiving users. The participants are heterogeneous in terms of their capacity to process the video data and network technology. This capability difference affects the QoS and QoE of multicast video communication. In this work, we have developed a rate adaptive streaming mechanism to stream the video to meet the device and network constraints. The method uses SIP and SDP protocols to learn device constraints and link statistics to estimate the network resources. Later, this information is made available to the adaptation module to decide the video rate for streaming. We have implemented the method in the floodlight controller and streamed multiple rates of video over an SDN enabled network. The objective quality of the video is used for analysing the performance of the proposed adaptation technique.
Keywords— Video Adaptation, Multi-rate Video, Scalable Video Communication**.**

1. INTRODUCTION

Video communication is real-time communication, which is increasing on the internet by attracting the users. The applications such as video conferencing, video chat, video-on-demand, IPTV and social media exchange media contents over the Internet. The resource constraint of the Internet leads to quality degradation and poor user satisfaction. Hence, many researchers are working on improving the QoS and QoE of media data in the above-said applications. Here, the video content is generated by a user and shared with multiple users over the internet. The receiving end users form a group and participate in the multicast communication.

Multicast communication [1] benefits in bandwidth utilization by reducing the resource consumption. Currently, the internet streams the same content to multiple end users using unicast communication, which consumes enormous amounts of bandwidth. In multicast communication, the routers duplicate the packets and forward it to the routers connected to the end users. The multicast implementation has many challenges such as managing and creating groups, managing the participants, media adaptation to meet the end user capabilities, and security. IGMP [2] and RGMP [3] are the group management protocols used for creating the multicast group and later helping a user join or leave a group. These management protocols create network traffic due to the messages generated for intimating the group membership and making this information available to the routers that are routing the multicast data. The media adaptation techniques reduce the number of streams to meet the heterogeneous end users, where the media contents are adapted based on the end user capacity and network resource availability. Hence, adaptation increase the efficiency and resource utilization of the multicast communication.

Adaptation is a process of adapting contents to the requirements of a user and a network [4]–[6]. It is implemented in two ways, which are layered video adaptation and rate adaptation. The layered video coding method such as Scalable Video Coding (SVC) [7] is an extension to H.264/AVC where video is encoded into multiple layers. In a layered video, the base layer provides low-quality video in terms of frame rate, resolution, and SNR levels. The enhancement layers are used with the base layer to achieve higher quality. The layered video adaptation is a process of removing the unwanted layers to meet the capabilities of a user but requires intelligent intermediate devices to gather user capability, network capacity, and dynamics of the network. Therefore, multirate video streaming is an alternate solution to improve the resource utilization in a multicast communication using the available routers and switches. Here, the video is coded into multiple rates and maintained at the media server. The media server multicasts all the video data and users join a session based on their capability to process the data. In multi-rate multicast communication, the bandwidth consumption is less compared to a unicast communication.

The IP based network uses distributed routing to stream multicast video data [8]. Hence, adapting the video contents at intermediate devices is difficult. The technologies such as Software Defined Network (SDN) provides global topology information to route the data from a source to multiple destinations. The global view obtained from SDN helps in effective implementation of the in-network adaptation process. SDN decouples the data plane and control plane. The SDN controller which implement the control plane is the central entity that decides the route for each flow and updates the decision to the switching devices that are forwarding the packets accordingly.

This paper aims to develop a rate- adaptive streaming mechanism to improve the QoS and QoE of the multicast video communication. The proposed method uses a static mechanism to adapt the video rate to meet the requirements of the end users. The end user joins the multicast session using SIP and SDP protocol, where SDP is used for describing the video requirements, device capabilities, and network connectivity details. The SDN controller collects details of the video session, media server, and participants to identify the multicast path. The controller monitors the network resource availabilities and adapts the video stream accordingly. We implemented and tested the method developed and analyzed the impact of rate-adaptation on video quality received by the end users.

The rest of the paper is organized as follows: some of the related literature are discussed in section 2. The background technologies scalable video coding and software defined networks are discussed in section 3 and 4 respectively. In section 5, we provide details of the proposed adaptation mechanism. The experimental setup and results obtained are discussed in section 6. Finally, section 6 concludes and lists the planned work for the future.

2. LITERATURE SURVEY

There are many research works on rate adaptive multicast streaming, and we have listed some of them in this section. In [9] proposed a method, where a leader is identified from a group of multicast participants, and he is responsible for sending the feedback to the server. In [10], a leader based feedback mechanism is used for sending ACK and NACK to the sender on behalf of the multicast participants. The Auto Rate Fallback mechanism performs adaptation.

In [11], a leader based approach is used to enhance the multicast transmission in WiFi devices. They use physical layer data rate of multicast flow to adapt the stream. The physical layer parameters such as signal strength, Bit Error Rate, and SNR are used for deciding the adaptation. In [12], the leader is dynamically selected based on the link conditions. The model proposed here adapts the transmission rate and coding rate based on the feedback received.

In [13], each receiver estimates the channel and rate selection which is then communicated to the sender. Upon receiving the feedback from the receiver about the channel and video status, the sender reacts accordingly by adapting the video stream.

The DYNSDM [14] proposes a multi-tree mechanism to distribute the multicast data in an SDN enabled network. In [15], the algorithm was developed to reduce the tree size, and recovery cost, where the tree size is measured in terms of the number of links used and the recovery cost describes the cost involved in a tree recover. In [16], the algorithm aims to reduce the total cost of links and nodes in a multicast tree.

From the literature, we studied that the rate-adaptive multicast streaming performs better compared to single rate multicasting. In the above-

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

said approaches, the leader is used for sending the feedback to the sender to enable rate-adaptive streaming. SDN is a technology, which needs to be explored to avoid the leader selection and feedback transmission delays.

This paper uses an SDN controller to monitor the link status centrally and adapts the stream to meet the resource constraints. The research works listed in the literatures use distributed approach to monitor the network and user conditions. This leads to delay in the adaptive decision module.

The goal of the research to improve the quality of the communication and user satisfaction in video based communications. The rate adaptive using central decision module improve the adaptive decisions to deliver suitable video quality for a given condition. The module is the novel approach detailed in this paper.

3. SCALABLE VIDEO CODING

Scalable Video Coding (SVC) [7] is a standardized extension to H.264/MPEG-4 Advanced Video Coding (AVC) [17] standard. SVC implements layered video coding, where removal of partial bitstream forms a valid bitstream. It allows multiple formats of a single video stream in terms of frame rate, resolution, and SNR. This single bitstream simplifies the video streaming over a heterogeneous environment having a variety of receiver device capabilities, network technologies, user preferences, and transmission paths of varying bandwidth.

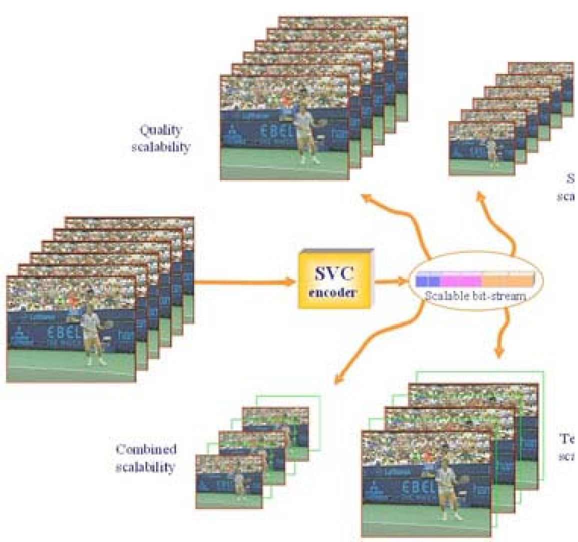

Figure 1: Scalable bitstream generation

The SVC stream includes AVC backward compatible base layer and one or more enhancement layer(s). The AVC decoder can decode the base layer to obtain the video with minimal quality, frame rate, and resolution as shown in Figure 1. The gradual increment of quality, frame rate, and resolution is attained by adding enhancement layers to the base layer. Hence, a single scalable video stream provides high quality, frame rate, and resolution to the end user with the capability to receive it and lower the quality for the user having constraints. This feature can also be extended to video streaming applications, where video quality can be improved with the increased bandwidth availability and vice versa. Encoding multiple video formats into a single scalable stream minimizes the resources required to store the data at archival sites and stream it over the bandwidth constrained network.

In this work, we have used an SVC encoder to obtain a multi-rate video sequence. The combination of a base layer and enhancement layer is used for deriving the video rates which are further used for streaming over the SDN enabled network.

4. SOFTWARE DEFINED NETWORKS

Software Defined Networking [18], [19] technology improves the flexibility in processing the packets. It defines a new network architecture which is dynamic, adaptable, and manageable. In SDN, the network's control and forwarding planes are separated to optimize the building and management of the network. The control takes part in decision making, collects the network details such as traffic, node information, transmissions occurring and so on, and decides the optimal path for each flow in the network. Hence, SDN is more suitable for implementing video adaptation in the network. The video adaptation in the network requires the devices to be more intelligent than the traditional networking devices.

SDN architecture [20] consists of 3 layers, which are the application layer, the control layer, and the infrastructure layer as depicted in Figure 2. The application layer provides services to the users through different SDN applications. Control layer is the logically centralized entity. The main tasks of control include translating the application layer requirements to SDN data paths and providing the abstract view of the network to the application layer. Finally, the infrastructure layer exposes

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

visibility and many control over the advertised forwarding and data processing capabilities. An important feature of SDN is the control layer because it is decoupled from the data plane and provides logical centralization. Hence, it can summarize the status of the network and translate application level requirements to infrastructure level rules. The control layer installed devices are called controllers, which can be physically distributed to serve the purposes of the control layer functionality. An SDN controller implements the software components that reside in some network devices identified in the infrastructure layer. Thus, details of the physical port, status, network traffic, and so on are replicated at the controller for deciding the forwarding directions. The directions and decisions taken by the controller are updated into the flow table and then fed into the network devices. The network devices forward the packets according to the flow tables shared.

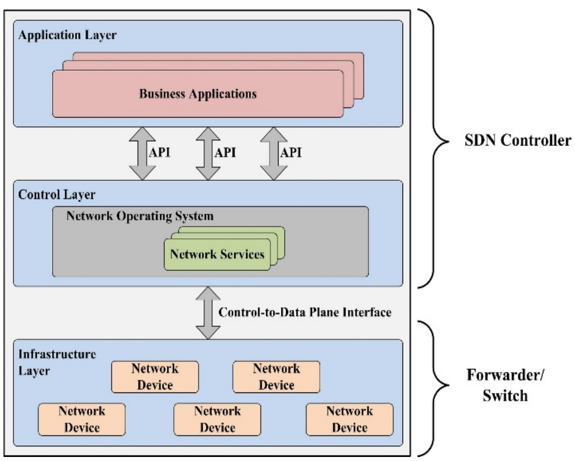

Figure 2: SDN architecture

OpenFlow [21] is the only stable implementation of SDN technology. It is a kind of protocol used for the communication between an SDN controller and its forwarders. The flow decisions taken at the SDN controller are fed into the forwarder using OpenFlow. Similarly, the controller uses this protocol to learn the network topology and traffic and hence manages the network [22]. We use the features of SDN controller to in this work for implementing rate adaptive streaming.

5. PROPOSED METHOD

In this section, we discuss the proposed method in detail. This work aims at identifying a video stream which suits the network resource availability and user device constraints. Here, the method consists of two modules: adaptation decision module and flow updater module.

Pseudocode 1 details the working of the Adaptation Decision Module. This module is supported by submodules such as a network analyzer, video metadata, session information, topology manager and a multicast tree formation module. These modules share the information collected with the adaptation module to estimate the video stream efficiently.

Pseudocode 1: Adaptation Decision Module

```
networkStats =
        NetworkAnalyzer()
videoMetadata =
        VideoMetatData()
sessionInfo =
        SessionInformation()
networkTopology =
        TopologyManager()
multicastTree =
       MulticastTreeFormation()
if change in networkStats
   then
 admFlag = 1
end if
if admFlag == 1 then
 Read current networkStats
   for resource availability
 Calculate the
        end_to_end_path
 resource availability using
 networkTopolog and
 multicastTree
 Read user requirements from
 sessionInfo
 Collect current flowDetails
 from the switches
 Read video bitrate from
 videoMetadata
if end_to_end path resource
is matching with video bitrate
    then
   Identify the scalable
    video level
    Set extractionPoint
 end if
```

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```
19: end if
20: adaptationParamter for a
    receiver is
    extractionParameter
```

Initially, the media server announces the multicast session, and multicast participants join the session using SIP and SDP. The session information module captures the session's details and participant's capabilities. The participant details consist of display resolution, frame rate, processing capacity, memory space available, and power capacity. From the session announcement, the controller learns about video types and video rates available at the media server. The controller then constructs the multicast tree to stream the video to the session participants.

The topology manager module maintains link details and network node information. The controller periodically sends probe messages to all the SDN switches and collects switch status information. This information is shared with the multicast tree construction module, where the tree is constructed to reach all the multicast participants from the media server. Here, the shortest path spanning tree method is used for forming the tree.

The SDN controller calculates link statistics dynamically to perform adaptation. The network analyzer module collects the number of packets sent and received by the switches and derives the link bandwidth and resource availability. The bandwidth information is later used in deciding the video rate for streaming.

The adaptation module checks for the change in the network resources such as bandwidth. The controller periodically collects the switch statistics from SDN switches and maintains it through the network analyzer module. The adaptation module compares current resource details with the previously recorded one. If the difference is more than the threshold value, it triggers the estimation procedure.

The module identifies suitable a scalable video based on the availability of the resources. It uses video bitrate, which is available in the video metadata to compare with the available bandwidth. As a result, a scalable level is selected for streaming to have uninterrupted video communication. The selected scalable level is made an extraction point or adaptation parameter.

The adaptation parameter is used for updating the flow in the SDN network. Pseudocode 2 shows the steps involved in the process. The user requirements are signaled to a media server and the SDN controller through SDP packets which describe the quality requirements. This information is used for deciding the hard or soft QoS requirements. If the user is flexible, then the video stream is adapted and delivered. If the QoS requirement is hard, the controller needs to perform a multicast tree alteration to meet the user requirements.

In case of hard QoS requirements, an alternate path needs to be identified to meet the requirements. Hence, the proposed module triggers the multicast tree formation module for identifying the alternate route to reach the receiver having sufficient resource to meet the user's QoS metrics. After forming a new tree, the SDN switches are updated accordingly. If the user is flexible to receive any video quality, then the video is only adapted and streamed over the same path. Here, an SDP packet needs to be generated in such a case. The adapted video will have a different scalable level, address, resolution, frame rate and quality level, which need to be shared with the decoder to process and display. An SDP packet shares these details with the receiving device.

Pseudocode 2: Flow Updater

```
1: adaptationParameter =
     AdaptationDecision()
2: if change in
     adaptationParameter then
3:  if hard quality requirement
     of the receiver then
4:        Change the routing path
5:        Update the multicast
          tree
6:        Update flow tables
          entries
7:        Send the flow tables to
            corresponding switches
8:   else
9:        Adapt the video stream
10:       Generate SDP update
           packet
11:       Send SDP update to
           receiving devices
12:       Update flow tables
           entries
13:       Send the flow tables to
            corresponding switches
```

Journal of Theoretical and Applied Information Technology
30th September 2018. Vol.96. No 18

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

```
14:   end if
15: end if
```

In the proposed module, an SDN controller performs video adaptation and streams it over the network having heterogeneous terminals and network constraints. The static video adaptation is a type of case under dynamic video adaptation. The proposed method implements static adaptation video.

6. EXPERIMENTAL SETUP AND DISCUSSION

To study the performance of an SVC video over SDN, we have used the following tools: JSVM [23], Mininet[24], VLC Player [25] and Floodlight Controller [26]. The proposed modules are implemented in a Floodlight Controller. A Floodlight Controller is an open-source controller module, which implements OpenFlow [21] protocol for communicating with the SDN switches. The SDN switches use OpenVswitch open-source SDN switch in a Linux environment.

Table 1. Bitstream Statistics of Forman Video Sequence

Layer	Resolution (WxH)	Framerate (fps)	Bitrate (Kbps)	DTQ
L0	176x144	7.5	65.50	(0,0,0)
L1	176x144	15	79.80	(0,1,0)
L2	176x144	7.5	154.50	(0,0,1)
L3	176x144	15	183.70	(0,1,1)
L4	352x288	7.5	297.00	(1,0,0)
L5	352x288	15	354.70	(1,1,0)
L6	352x288	30	395.40	(1,2,0)
L7	352x288	7.5	561.30	(1,0,1)
L8	352x288	15	649.00	(1,1,1)
L9	352x288	30	710.00	(1,2,1)

Table 2. Bitstream statistics of BUS video sequence

Layer	Resolution (WxH)	Framerate (fps)	Bitrate (Kbps)	DTQ
L0	176x144	7.5	120.00	(0,0,0)
L1	176x144	15	147.20	(0,1,0)
L2	176x144	7.5	275.00	(0,0,1)
L3	176x144	15	339.00	(0,1,1)
L4	352x288	7.5	636.20	(1,0,0)
L5	352x288	15	790.70	(1,1,0)
L6	352x288	30	904.80	(1,2,0)
L7	352x288	7.5	1078.90	(1,0,1)
L8	352x288	15	1339.50	(1,1,1)
L9	352x288	30	1558.40	(1,2,1)

Joint Scalable Video Model (JSVM) is used to encode videos to generate a scalable bitstream and for adapting the video sequence. Table 1, 2 and 3 show the bitstream statistics, where DTQ depicts the Spatial (D), Temporal (T) and Quality (Q) levels of the various adapted video sequences. Here, CIF and QCIF in the spatial domain, 7.5, 15 and 30 fps in temporal level, and two levels of quality have been considered. We have encoded FORMAN, BUS and NEWS video sequences for streaming [27]. The videos that are considered in this experiment represent different levels of motion complexity. FORMAN and BUS have a high motion from one frame to another. The motion in the frames creates more residual data while coding. The bitrate increases with the increase in the residual data. Hence, the video with high motion requires more bandwidth. The NEWS video has very low motion between the frames. As a result, the video has very low bitrate. In the video sequences that are considered, bitrate varies from low to high.

For streaming the video from source to receiver, we have used the VLC media player. At the receiver, the video is received and displayed locally using VLC. The Mininet emulation tool is used for creating a virtual network. It allows us to create of the hosts, controllers, switches, and links for the topology. The SDN controller modules are implemented using floodlight controller. It also supports OpenFlow protocol to communicate between controller and SDN switches. Using Mininet and Floodlight, we simulate the SDN network. Also, we have created different topologies such as bus, mesh, ring, and tree .

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Table 3. Bitstream statistics of NEWS video sequence

Layer	Resolution (WxH)	Framerate (fps)	Bitrate (Kbps)	DTQ
L0	176x144	7.5	31.80	(0,0,0)
L1	176x144	15	34.50	(0,1,0)
L2	176x144	7.5	71.50	(0,0,1)
L3	176x144	15	77.30	(0,1,1)
L4	352x288	7.5	122.60	(1,0,0)
L5	352x288	15	133.20	(1,1,0)
L6	352x288	30	139.80	(1,2,0)
L7	352x288	7.5	209.00	(1,0,1)
L8	352x288	15	224.40	(1,1,1)
L9	352x288	30	236.40	(1,2,1)

Table 4. Experimental Setup Parameters

Videos	Bus, FORMAN, NEWS
SDN Switches	25
Number of Hosts	6
Noise Traffic	1, 2, 5 kbps
Link Capacity	6 kbps

The network topologies have SDN forwarders/switches and hosts. Table 4 shows the experimental parameters considered for video streaming. For realizing the real-time network communications, we have created few UDP communications between hosts, which generates network traffic. The network consists of 4 receivers having a heterogeneous environment. The heterogeneity in the device capabilities is depicted in Table 5. They have capabilities in different display resolution, frame-rate supported, RAM capacity, memory size, and processor. These are signaled to a media server and SDN controller for enabling video adaptation. In the case of display resolution, viewable video resolution is always lesser than the values given in the table.

For experimentation, we created a network topology having 25 nodes. The results obtained from this experimentation is shown in Table 6. The scalable level identified demonstrates the maximum level that can be extracted from a fully scalable video to meet the constraints such as network topology, network traffic, and video type.

Table 5. Heterogeneity in Receiving Devices

Devices / Capabilities	Resolution WxH	Framerate (fps)	RAM (MB)	Memory Size (GB)	CPUs (Number of cores)
Receiver – 1	320x240	18	512	16	1
Receiver – 2	640x480	25	1024	80	2
Receiver - 3	1024x768	40	2048	256	4
Receiver - 4	1280x1024	60	4096	1024	8

Figure 3 depicts the qualitative analysis of video adaptation. Here, the video received before and after performing video adaptation is used for comparing the qualities. Videos are adapted as decided by the adaptation engine. It is observed that the PSNR value has been increased after video adaptation with the reduced resolution and framerate. The video of lower scalable layer meets the available resources. Hence, viewable video quality is received by the devices.

The results obtained demonstrate the quality of the video for different network conditions. The network dynamics are monitored and used at adaptation modules to decide the suitable scalable video level. The scalable level identified for a network conditions maintains the video quality with the cost reduced resolution and frame rate. The aim of the research work was to maintain the video quality throughout the communication and same is achieved using adaptation.

Table 6. Heterogeneity in Receiving Devices

Parameters and Video type	1 kbps	2 kbps	5 kbps
Slow (NEWS)	L9	L9	L9
Medium (FORMAN)	L4	L3	L3
Fast (BUS)	L3	L0	L0

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

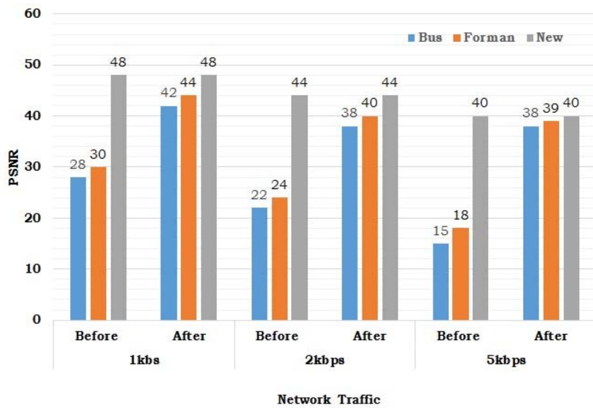

Figure 3. PSNR observed before and after adaptation

7. CONCLUSION

Video communication is increasing exponentially and internet service providers are interested in improving the QoE and QoS of the communication by reducing the network resource consumption. The adaptation process helps in improving the quality of the communication in a dynamic network scenario. In this paper, we proposed an adaptation method for SDN based networks. The proposed method uses user device and network capability information to estimate the suitable scalable level. Then, the identified scalable level is used for streaming. The rate adaptive using SDN controller improve the video quality and simplify the decision-making process. The scalable video levels are identified based on the dynamic condition of the network and user requirements. The experimental results show the improvement in the objective quality metrics. Hence, the QoE of the communication is also improved.

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