Peer-to-Peer Networking and Applications (2023) 16:1739–1760
https://doi.org/10.1007/s12083-023-01484-y

Quality of service aware routing in software defined video streaming: a survey

Suguna Paramasivam[1] · R Leela Velusamy[1]

Received: 2 August 2022 / Accepted: 1 April 2023 / Published online: 26 May 2023

Abstract
Software Defined Network (SDN) is a new emerging technology that has attracted enormous interest over the last few years as a result of existing networking designs' constraints. It allows a centralized programmable controller to interface with forwarding devices and is utilized in a variety of communication networking scenarios, including Service Provider networks, Campus networks, Hospitality networks, Video communication, etc. One of the promising applications is multimedia services to provide strict delay guarantees for the transferred flows. The video traffic demands a guaranteed Quality of Service (QoS) to provide a smooth consumer experience. Several QoS models have been proposed in the literature and individual studies are presented to measure the QoS metric. An overview of interesting research on QoS models for video streaming over SDN, issues in video streaming models, existing QoS models, QoS metrics used for emulation, and limitations of QoS models are presented in this paper.

Keywords Software defined network · OpenFlow network · Quality of service · Multimedia routing · Quality of metrics · Video Streaming services

1 Introduction

Due to the development of the Internet, more devices from various suppliers with varying needs are connected. It connects everyone and everything, including machines, objects, and devices, to provide a variety of services for the next networks [1]. When Fifth Generation (5G) is deployed, there will be more network traffic flow and needs to manage the exponential growth in bandwidth because of heterogeneous network devices. Due to advancements in technologies such as virtualization, cloud computing, and data analytics, the industry currently requires a network architecture that will allow several virtual networks for various use cases and will adhere to a service-based micro-structure. Network slices are virtual networks that, when appropriate, must support appropriate regulations and that must be dynamically modified to address changing network conditions and meet user-case needs. The primary components of network traffic are zero latency, quick processing, high dependability, and data security [2]. Additional issues with data security transmission over network traffic could arise [3]. Agility, programmability, automation, end-to-end service orchestration, and scalable control plane are requirements for future network design.

Traditional IP networks are complex and hard to manage when networking equipment's control plane and data plane are combined. Also, Network devices are vertically integrated. As a result, the network administrator must individually set up each network device. The following are challenges with traditional networks.

- Vendor lock-in
- Interoperability
- Long service bring up times
- Long development cycles
- Fixed function Application Specific Integrated Circuit (ASIC) switches/routers

Overcoming the aforementioned restrictions results in higher maintenance costs for a highly flexible and customized network. Small vendors or organizations can develop virtual network functions (VNFs), which can operate on general-purpose

✉ Suguna Paramasivam
psuguna2020@gmail.com

R Leela Velusamy
leela@nitt.edu

1 Department of Computer Science and Engineering, National Institute of Technology, Tiruchirappalli 620015, TamilNadu, India

or Whitebox hardware. It is the responsibility of operators to organize, configure, personalize, and optimize the various network slices connected to the same network infrastructure. SDN and Network Function Virtualization (NFV) integration makes it possible to deliver a wide range of unique end-to-end services over a single, common physical infrastructure. SDN is the answer to automating network administration in the future's dynamic networks. More diverse end-to-end services can be easily managed across a shared physical infrastructure. This is a benefit of network dynamism and programmability [4].

The main objective of the next-generation network [1] is to provide the QoS-guaranteed service for different applications in the digital world. Due to innovations and technological development, everyone has started using Internet connections for their personal needs, business operations, study purposes, etc. So, more wired or wireless devices with diversified configurations from different vendors are connected to the network. On the Internet, a lot of video data is distributed internationally. Peer-to-peer (P2P), Voice over the Internet Protocol (VoIP), distant learning, online interactive gaming, and online classrooms are just a few of the use cases for online streaming that have emerged, as the Internet has grown. In order to improve multimedia communications, Many research challenges are essential to improve the resource utilization, Quality of Service [5] and Quality of Experience (QoE) for the future expected behavior. The provision of a high-quality service to online users without any buffering is a significant problem. So, in order to manage various sorts of video streaming use cases like virtual reality, 3D video, and HTTP Adaptive streaming (HAS), QoS/QoE aware routing for multimedia transmission is required.

The Internet architecture is designed to support different protocols and provide reliable transmission over the QoS Model. For the past years, the popularity of multimedia real-time applications depend on the QoS service model with assurances of performance. The requirement for multimedia applications has increased and researchers are encouraged to study the IP Quality of Service to propose a solution for QoS. This is one of the historical issues to deliver quality to the end user. Today's Internet architecture delivers best-effort services that are unable to give meaningful quality-of-service guarantees. Therefore, the Internet Engineering Task Force (IETF) [6] has proposed several QoS architectures such as Integrated Services (IntServ)/Resource Reservation Protocol (RSVP), Differentiated Services (Diffserv), and Multi-Protocol Label Switching (MPLS) [7]. However, the limitations of the traditional internet architecture and the inflexibility of the underlying protocols, MPLS is difficult to configure, administer, and troubleshoot the network. None of the models has been successfully and globally deployed. Against this background, Software Defined Networks have been developed with the following list of features.

- Decoupling of control plane and data planes
- Network Programmability
- It can be offer of Centralized Management and Reduction of OpEX(operational expenditure cost)
- Deliver agility and Flexibility
- Openness for Innovation
- Vendor neutrality

Software Defined Network is changing the way we design and manage networks. It enables the networks to be independent, centralized, and more programmable. So, SDN is a new paradigm that separates the network's control logic from the data plane. For the purpose of creating and maintaining the IP routing table, the controller will have a broad perspective of the network [8]. The data plane packets are forwarded to the destination based on the controller flow table rules. The control plane and data plane are connected via the SDN OpenFlow protocols. The OpenFlow protocols support many features to solve problems such as the configuration of network policies, reconfiguration in response to faults, and load that enable the new path for the QoS-enabled frameworks. The rest of this survey paper is as follows and shows the same in the below Fig.1.

- Section 2 introduces an overview of the SDN Architecture and OpenFlow networks by defining the QoS supporting Features of OpenFlow networks and Traditional methods of QoS types.
- Discussed Video streaming concepts in Section 3.
- Discussed functions of the QoS framework and QoS-aware Multimedia routing algorithms for SDN in Sections 3.2 and 3.3 respectively.
- Discussed the application of SDN to modern video streaming to enhance QoE in Section 3.4.
- QoS parameters used for the estimation of QoS routing algorithms are summarized in Section 4.
- QoE metrics used for modern video streaming are explained in Section 4.10 and tabulated.
- Estimating the existing algorithms based on the following groups in Sections 4.7, 4.8 and 4.9 respectively.
    - QoS constraints, Video Service, results, and limitations
    - Performance metrics
    - Simulation Parameters
- Video Streaming issues and conclusion are discussed in Sections 5 and 6 respectively.

2 SDN architecture

The SDN architecture as shown in Fig. 2 can be represented as a set of simple programs and hardware switches, connected to a common controller (OpenFlow controller), implemented through its new concept separating the

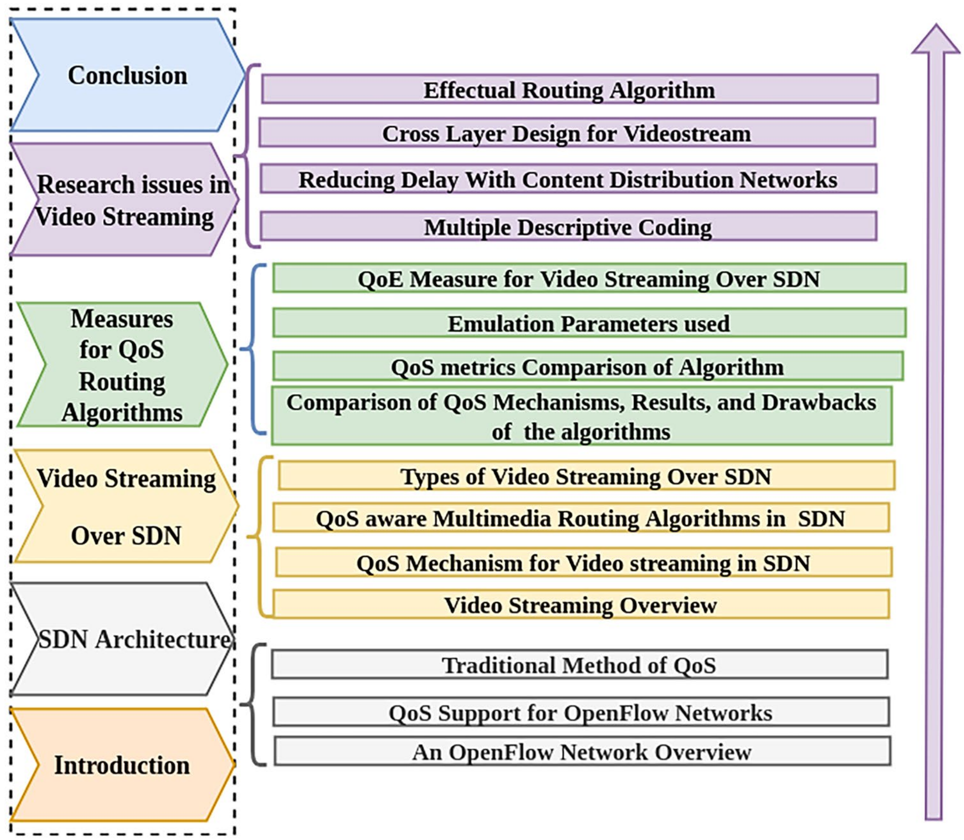


Fig. 1 Shows the brief summary of this QoS Routing survey.

control plane and data plane (Forwarding plane). The IP routing table is constructed and maintained by the control plane. The data plane is in charge of actually forwarding IP packets. It enables the networks to be more programmable with the ability to access the network via Application Programming Interface (APIs) and open interfaces. It has established a new method for creating and controlling networks. It allows for the control plane to have a global view of the network. Figure 2 shows the SDN architecture that the control logic is separated from the forwarding plane. The controller has a comprehensive perspective of the network. This is the main feature for differentiating the traditional network with SDN [9]. SDN is characterized by:

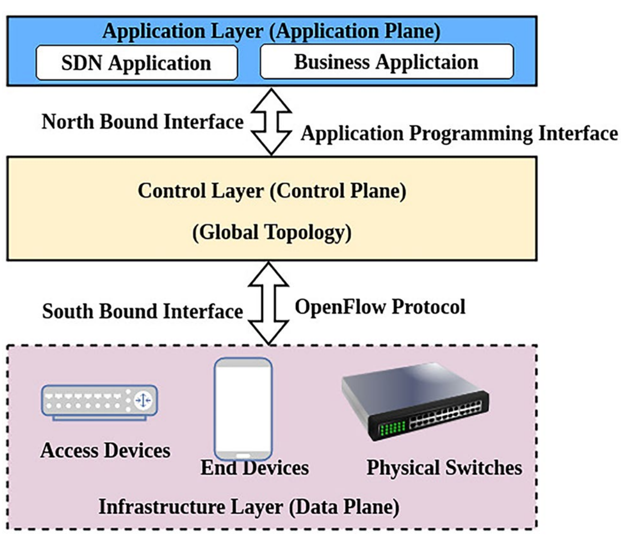


Fig. 2 SDN Architecture

1. Plane Separation: The network control logic is independent of the data plane
2. A simple device and centralized control: A Single software programs control multiple data plane elements
3. Network Automation and Virtualization: The controller is programmed to automate network control and provides the level of abstraction to virtualize the network through open interfaces.
4. Openness: It opens interfaces for both sides (North-South East-West) of the SDN architecture. (e.g open interfaces permit inter-operation of network devices from various vendors in the network world)

2.1 An OpenFlow networks overview

An Open Networking Foundation (ONF) is a non-profit Internet Organization. It was created in 2008 to develop and also to design the OpenFlow protocol. This is an innovative approach to controlling network flows. The stream of packets (also called Flow) is created between the source and destination. The standard OpenFlow protocols are used for the communication of the SDN control plane and SDN data plane. The OpenFlow controller and OpenFlow switches are called OpenFlow Components. The responsibility of the OpenFlow Controller is to program the packet matching rules and forwarding rules in the switch. An OpenFlow-enabled switch is called an OpenFlow Switch as shown in Fig. 3a. It consists of three components as a Flow table (Forwarding table), Secure channel, and OpenFlow protocols [10].

FlowTable: In the OpenFlow Network, the switch has one or more flow tables. The flow table consists of flow entries. The flow entry contains header fields, counters, and actions related to that entry. The header fields are used for packet matching and counters are used to track the status of the flow. Based on the header fields and counter values, the corresponding actions like forwarding or of packets are executed in the data plane.

Secure channel: This is the transmission channel between the Controller and Data plane. To provide a secure channel between the planes, a protocol is implemented on top of the Secure Socket Layer.

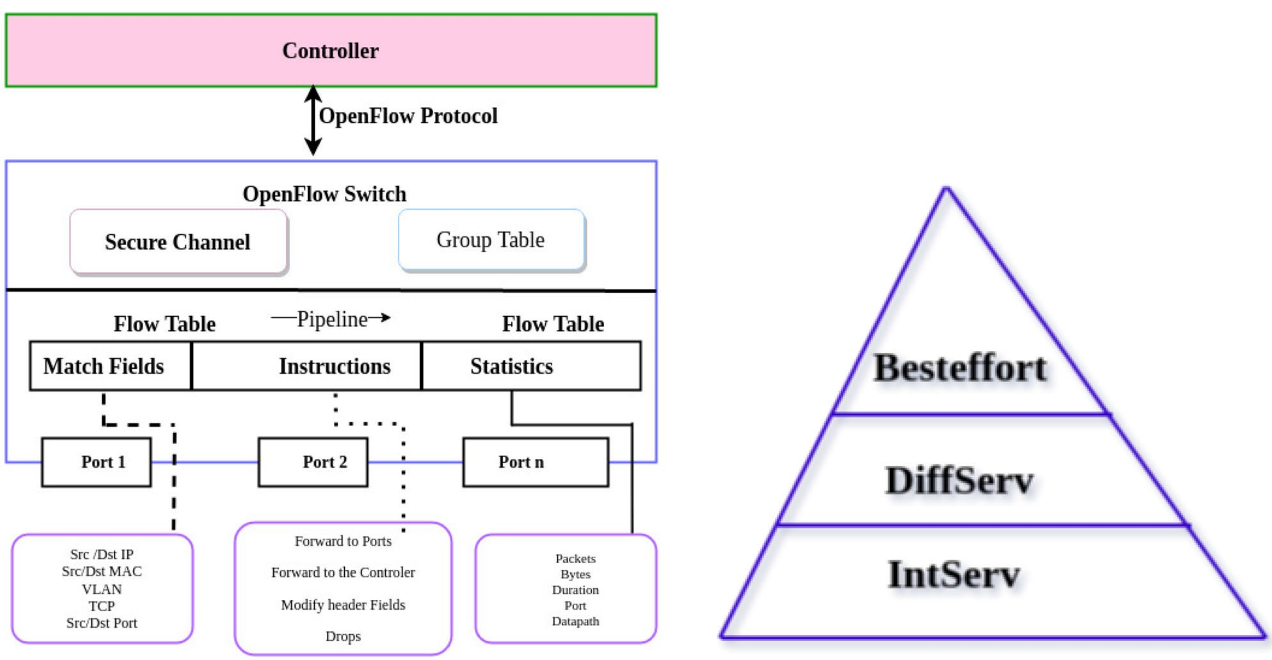
OpenFlow Protocol: It supports several messaging formats to be exchanged between SDN planes. The message types are symmetric, controller-switch, and asynchronous transmitted between the controller and data plane using this secure channel [10]. The forwarding device should respond to the controller command under various conditions of the Open Flow Messages.

2.2 QoS support for OpenFlow networks

Table 1 shows the OpenFlow-supported features for QoS service in SDN environments. The features of each version are explained in this Section. Figure 4 shows the timeline of OpenFlow versions. This Section presents the major changes in each version.

OpenFlow 1.0 [December 31, 2009]: This is the very first OpenFlow version [15]. It supports a single flow table with 12 matching fields like Ethernet source address, Ethernet destination address, IP Types of Service (ToS), etc. It performs only one operation to forward the packets due to less capability in matching fields and a single flow table. This is called a flow entry explosion and reduced the usage of OpenFlow version 1.0. The "enqueue" action's optional element is used to send QoS packets to the port.

OpenFlow 1.1 [February 28, 2011]: This version is supported with two features to overcome the previous version issues like flow table limitations. Multiple Tables and Group Table features are used to perform more operations to forward the packets [16]. The multiple levels of Virtual Local Area Network (VLAN) tagging, MPLS labels, and traffic classes are supported by this new version of VLAN tagging. i.e., to add, modify, and remove the VLAN tags.



(a) OpenFlowSwitch Components **(b)** Traditional Methods of QoS types

Fig. 3 OpenFlow Switch components and Traditional QoS methods

Table 1 QoS related features in different OpenFlow versions

OpenFlow Versions	OpenFlow Features for QoS
1.0	Enqueue action, minimum rate property for queues, and new header fields
1.1	More control over Virtual Local Area Network (VLAN) and Multi Protocol Label Switching (MPLS)
1.2	Maximum rate property for queues and controller query queues from switches
1.3	Introducing meter tables, rate limiting, and rate monitoring feature
1.4	Several monitoring features
1.5	Replacing meter action to meter instruction

OpenFlow 1.2 [December 5, 2011]: It supports two new structures of messages between the Openflow devices to improve communication in the network [17]. The TLV (Type-Length-Value) structure allows for the addition of a new match field in a modern way, which is called an OpenFlow Extensible Match (OXM). The controller plays different roles like the master, slave, and equal, which enables multiple controllers to support the availability of the controller in case of failover or load balancing in the networking environment. This is called role-changing by building more than one controller. The max-rate queue property is used to set the queue size to map the flows for the QoS improvement.

OpenFlow 1.3 [April 13, 2012]: Two new functions: rate limiting and meter tables are introduced. To implement QoS, meter tables contain meter entries. Meter Identifier, Meter Bands, and Counters are the three meter entry fields. A Meter identifier is used to identify metre entries [18]. The packets are dropped or remarked using the meter band. For the purpose of gathering network statistics, counters are used. Each queue, meter, and meter band, among other elements, are tracked by counters. The flow table's packets of unmatched entries are processed using the table-miss entry [19].

OpenFlow 1.4 [Oct 14, 2013]: It introduces two new features called Synchronized table and Bundle. A synchronized table is an extension of the flow tables that can be synchronized bidirectionally or unidirectionally [20]. This enhances the table scalability. Controllers can create a bundle (OpenFlow Modification requests) that is used to group the OpenFlow state changes of multiple switches. This enhances switch synchronization. This version supports the controller framework for flow monitoring. Thereby a controller can monitor the changes made by other controller and also the number of monitors are defined by selecting a subset of the flow tables in real-time. The flow tables are updated and pieces of information are sent to the controller by flow monitoring. This flow monitoring function improves QoS in the OpenFlow network.

Table 2 shows the QoS services supported SDN Controllers. The modules are inbuilt into Controllers applications. The Floodlight, Open Networking Operating System (ONOS), and ODL modules are implemented using Java. The RYU modules are implemented using python.

OpenFlow 1.5 [March 26, 2014]: This is the extended version of the OF 1.3 and 1.4 features. Here meter action is used instead of meter instruction. It allows a set of actions

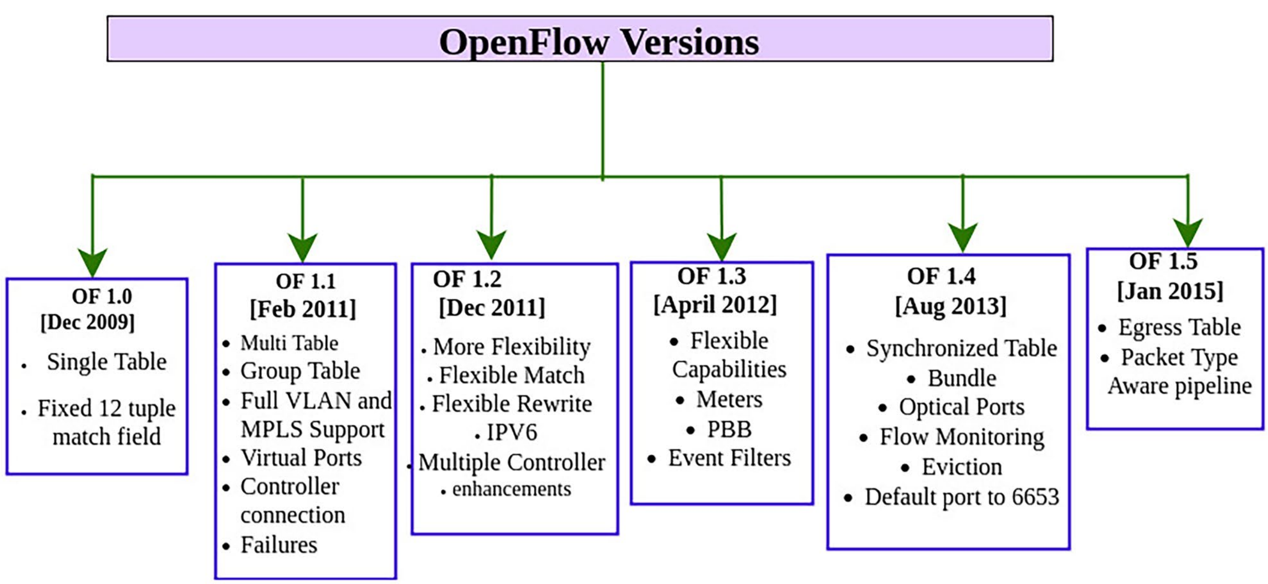


Fig. 4 OpenFlow version Timeline

Table 2 QoS related features in OpenFlow Controllers

Controller	Features and Modules
Flood Light [11]	QoS Module, Queue pusher module and CREATE, READ, UPDATE, DELETE (CRUD)API
RYU [12]	OpenvSwitch DataBase (OVSDB) API
OpenDay Light [13]	OVSDB API
ONOS [14]	OpenFlow Metering (limited QoS)

to be attached to a flow entry that is executed in group buckets [21]. It extends the scheduled bundle" by including an execution time property. When the switch receives the rules with this property, the packets are forwarded in time as much as possible. Also, it supports the egress table feature to match and process egress packets based on their output port.

2.3 Traditional method of QoS

The Internet Engineering Task Force (IETF) is a standard organization for developing Internet standard protocols and support various types of QoS architectures. There are three categories of QoS service models in a network. Figure 3b shows the three levels of QoS architecture in traditional methods.

Integrated Services (IntServ): Also called Hard QoS (Strict QoS), it gives guaranteed QoS service by using Resource Reservation Protocol (RVSP) for the explicit resource reservation for the flows [22]. This model depends on individual flows from source to destination and ports. It carries out admission control based on reservations for the resources that are available.

Differentiated Services (DiffServ): Also called Soft QoS (less Strict QoS). This is distributed service paradigm where resources are spread among the routers in the domain. It takes into account resources and enables hosts to categorize packets into different traffic classes [23, 24]. At each hop from the source to the destination, it receives a distinct Per-Hop-Behavior (PHB). Differentiated Service Code Point (DSCP) for traffic classification uses priority marking in each packet. It executes admission control based on traffic class statistics.

Best Effort Services: Also called as simplest and Default QoS (not strict) model for the Internet [25], it does not function for any real-time traffic classification and doesn't require any procedures for resource reservations. This is the Model which should not be used when the network resources are not enough to fulfill the end-user QoS application requirements.

3 Video streaming over SDN

3.1 Video streaming overview

Due to the development of wireless technology, the data transfer rate has increased. For example, the maximum download speed of the model 4G+LTE advanced cat 16 is 979Mbit/s and 5G model is 1000-10,000 Mbit/s. The data may be audio, video, and image. Video data are very large files nowadays [26]. There are 3 types of video delivery: File Download, Video delivery via Streaming, and Video delivery streaming as a sequence of Constraints. Today everyone is watching Videos on their smartphones due to the development of technology and being in an Internet world. They can stream high-definition movies or make a video call over the Internet. The popularity of video communication continues to grow rapidly with 80 percent of people watching at least one video online every day. This technology is called streaming. To satisfy the end user, the QoS models are needed and encouraged by new types of applications in the IP World. Examples like Video streaming services, Video Conferencing, Voice Over Internet Protocol (VOIP), and Legacy system network architecture/Datalink switching. Video delivery services use both types of protocols such as streaming protocols and HTTP-based protocols [27]. The following are the example of Video streaming protocols:

- Streaming Protocols
  - **Real-Time Messaging Protocol (RTMP)**: TCP-based open source protocol used to stream audio or video with low latency [28].
  - **Real-Time Streaming Protocol (RTSP)**: Network control protocol used to stream the video from a remote source using RTSP request services [29].
  - **Real-Time Transport Protocol (RTP)**: The Protocol used to transfer real-time sensitive, real-time audio-video data over IP networks [30].
- HTTP based Protocols
  - **HTTP Adaptive Streaming (HAS)**: HTTP Adaptive Streaming is used by video (streaming) services. The term is adaptable. A video player can use HAS to choose the best multimedia quality from the several back-ends renderings [31].
  - **Apple HTTP Live Streaming (HLS)**: Adaptive streaming communication protocol used to stream servers from different vendors like Akamai, Adobe, and Microsoft [32].
  - **Low-Latency HLS**: It is used to distribute the media at the live edge of the media through the parallel channel (provides low latency of 2 to 5 seconds) [33].
  - **Moving Picture Expert Group Dynamic Adaptive Streaming over HTTP (MPEG-DASH)**: Stream videos at different quality levels by breaking videos into smaller chunks and encoding them in different quality levels [34].

Table 3 QoS Enabled Frameworks in SDN

S.NO	QoS Mechanisms	SDN Plane	Functions
1	Multimedia flows routing [35]	Control Plane	Selects the optimal route between nodes
2	Inter-domain QoS routing mechanism [36]	Control Plane	Find an optimal route between Autonomous systems
3	Resource Reservation mechanisms [37]	Control Plane	Reserve the resources for the requested flow
4	Network Monitoring and Admission Control mechanisms [38]	Control Plane	Based on capacity to accept or reject a request
5	Traffic Classification and Congestion avoidance [39]	Data Plane	Assignment of a packet to a traffic network load will be balanced in an acceptable level
6	Queue Management and Scheduling mechanisms [40]	Data Plane	To manage the length of packets queue and arrange the packets in order
7	Framework for Traffic shaping and Policy enforcement [41]	Data Plane	Controls the rate and volume of traffic
8	Traffic Metering and recording [42]	Management Plane	Collect and stores the traffic information for analysis, and Metering can do shaping or drop for the stream packets based on traffic information
9	Service Level Agreements [43]	Management Plane	Describes the important aspects of the service and quantitative thresholds

3.2 QoS mechanisms for video streaming in SDN

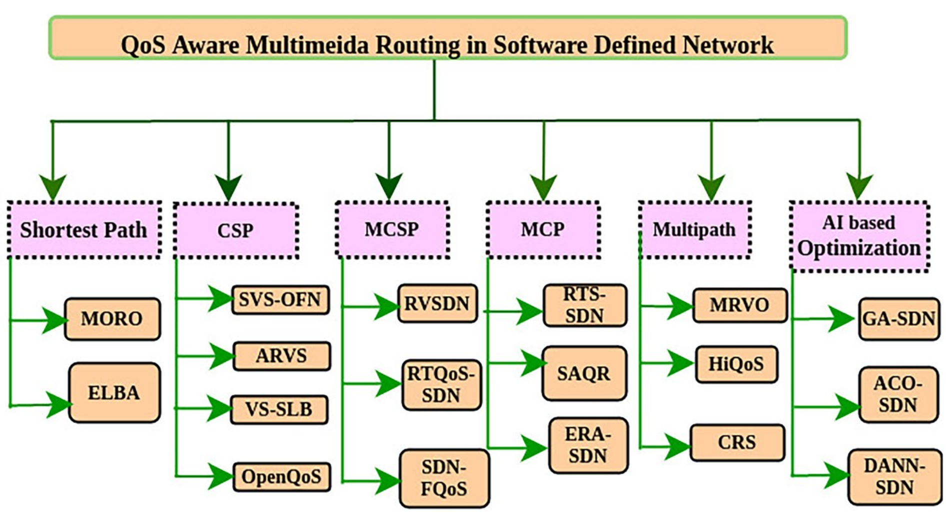
Table 3 shows the common network QoS mechanisms for controlling the service request and service responses for traffic across SDN.

3.3 QoS aware multimedia routing algorithms in SDN

This section reviews some of the existing QoS routing algorithms for multimedia traffic in SDN. In this review, the QoS mechanisms are classified based on many distinct routing methods. They are Shortest Path (SP), Constraint Shortest Path (CSP), Multi Constraint Path (MCP), Multi Constraint Shortest Path (MCSP), Multi path, and Artificial Intelligence (AI) based optimization algorithms. Figure 5 shows the different categories of QoS mechanisms used for QoS video streaming. The core aim of QoS routing is determining the optimum paths for the different types of traffic produced by diverse applications while maximizing network resources efficiently.

- **Shortest Path routing (SP):** The SP uses the conventional routing algorithm like the Dijkstra algorithm and Bellman-Ford algorithm. It uses any one single criteria as a routing metric to find the optimal path. The used criteria in this survey [44, 45] are the number of hops and bandwidth.
- **Constraint Shortest Path (CSP):** The CSP goal is finding the shortest route (least cost path) among the available paths using single criteria shortest path algorithm with any one constraint. The constraints such as minimized delay variation and packet loss rate are satisfied to find the minimum

Fig. 5 QoS Aware Multimedia Classification



cost function [35, 46-48]. It is well known that the CSP problem is NP-complete. As a result, the shortest path was discovered by applying the LARAC (Lagrange Relaxation-based Aggregated Cost) technique to solve this issue. [49].

- **The Multi Constraint Shortest Path (MCSP):** The MCSP finds the multiple shortest path with two or more constraints. This MCSP is needed for real-time applications where synchronization and timeliness are important to fulfill their task. The multiple constraints used are Bandwidth, Delay, Delay variation, and Reliability [50-52].
- **The Multi Constraint Path (MCP):** The objective of MCP is to find a path that satisfies the set of QoS metrics (bandwidth, delay, reliability, jitter, and cost) for QoS service multi-constrained path selection, with or without optimization. This path selection is an NP-complete problem. To find an optimal path, it uses a heuristic algorithm and simulated annealing [35, 53].
- **Multipath**: The goal is to find multiple paths that satisfy the set of constraints between source and destination. This is an NP-complete problem. This is solved using heuristic and subgradient algorithms [54, 55].
- **AI-based Optimization**: The heuristic method uses various approaches such as Genetic Algorithms (GA), Ant Colony, or Bee Colony Optimizations. To achieve their objective function, these approaches use several parameters in their fitness function. Also, these AI-based algorithms instantly compare various potential solutions to find the optimal one [56, 57].

Following are some of the QoS-based routing algorithms that handle QoS for video application services in SDN.

3.3.1 MORO

Karl et al. [44] suggested an optimal multimedia routing scheme by analyzing the network state information and intercepting RTSP (Realtime Session Protocol) / RTP (Real-time Transport Protocol) streaming packets in OpenFlow SDN Networks. The RTSP and RTP protocols are used for video transmission. The OpenFlow nodes are configured to forward the RTSP messages to the controller to parse the RTSP messages like SETUP handshake, SESSION, and Transport fields. Thereby, the controller is creating session memory with all network statistics information. The QoS routing for the video flows can be adjusted with the help of the network state information. The controller is designed with two special features called periodical polling and book keeping to handle the high data rate stream. The Dijkstra algorithm with different metrics is applied to determine the edge weights to find the optimal path.

3.3.2 ELBA

An Efficient Layer Based routing Algorithm called ELBA was proposed by Gangwal et al. [45], where it adapts streaming dynamically and improves the video quality by monitoring the device status and network conditions. ELBA helps to stream different layers of Scalable Video Coding (SVC) into different paths by updating the SDN flow tables dynamically to improve the video quality without affecting other traffic and enhance the network resource utilization. The SVC video layers are interdependent with different QoS requirements. This algorithm classifies the traffic stream into 3 classes; The first stream consists entirely of lossless QoS traffic for base layer packets. The second stream is the lossy QoS of the enhancement layers with packet loss. The remaining traffic is treated as background traffic and is provided with best-effort service. The proposed algorithm route the svc packets using a modified Dijkstra algorithm with a weighted metric and the rest of the traffic is routed using hop based shortest path. Video layers are identified using Types of Service (ToS) mapping which is sent by the controller to the server. When the streaming starts, the server sets this ToS mapping which contains the id for the layer and IP ToS for the video layer. Then the controller identifies video layer packets using these ToS values. This mapping is additionally done along with PACKET IN and PACKET OUT OpenFlow messages. In terms of Peak Signal-to-Noise Ratio (PSNR), frame loss rate, and throughput, the ELBA algorithm surpasses the present shortest path approach for both video and background traffic.

3.3.3 SVS-OFN

The proposed framework by authors Egilmez et al. [47] is used to solve the two optimization problems for QoS traffic: rerouting of baselayer as a lossless QoS traffic and rerouting of both lossless and lossy traffic. This architecture performs dynamic QoS routing using the non-shortest path for lossy (with packet loss) or lossless (without packet loss) QoS flows and the shortest path for best-effort traffic in OpenFlow Networks. The optimized problem is rerouting the base layer of Scalable video streaming as lossless QoS traffic and the rest of the traffic (lossy traffic) is routed in the shortest path. The controller creates two flow tables to address the issue: one for the QoS flows and the other for the remaining traffic. The second problem is rerouting both lossless traffic (base layer) and lossy traffic (enhancement layer) of SVC as QoS traffic and the remaining traffic is routed in the shortest path. There are three flow tables namely lossless QoS, lossy QoS, and best-effort used to solve the second problem. The proposed optimization problem is the minimum cost value function in the networks theory that implements the LARAC algorithm to find the optimal route by calculating the packet loss rate to route the video packets. The video quality indicator of PSNR values is calculated from the received video with the original video. By rerouting the base layer, the suggested framework assures that the received video quality is increased. Rerouting the base layer and enhancement layers improves the quality even further.

3.3.4 ARVS

Feng Yu et al. have designed an adaptive routing approach to improve the quality of video streaming with various levels of QoS in SDN. The objective of ARVS (Adaptive Routing for Video Streaming) [35] is to identify the first road as the shortest one that satisfies the criterion for delay variation and the second path is a realistic path based on the available bandwidth to lower the packet loss rate. This design supports two levels of QoS flow: QoS level-I (shortest path) for the base layer packets without any packet loss and QoS level-II (feasible path) or best effort for the enhancement layer packets with little packet loss. The LARAC algorithm is used to find the first route for the base layer packets in the shortest path with satisfied delay constraints. Base layer packets are diverted to the determined feasible path if the delay requirements are not met. Therefore, the base layer packets are the priority packets based on available bandwidth. Enhancement layer packets choose the quickest route possible. Alternatively, if the intended bandwidth is not supported, the enhancement layer packets are diverted to the most possible path. In this way, video quality is improved by mitigating the shortest path congestion problem. By alternately routing base layer packets and enhancement layer packets, the proposed ARVS reduces the higher packet loss rate. The ARVS is compared with OpenQoS [46] and supported by the service providers to improve the video quality at a reasonable cost.

3.3.5 VS-SLB

Yilmaz et al. suggested a framework [48] to improve the QoS for video streaming applications with server load balancing in the OpenFlow network. Two of the main functions of the proposed controller program are server load monitoring and server selection/flow update. The dynamic server load monitoring function monitors each server's load continually and detects congestion when the link's bandwidth usage rises over a set threshold. The threshold value is set by the ratio of total bandwidth usage of links divided by byte count at a particular time interval. Once the congestion is detected, counters are used to count both congested and non-congested events to avoid taking a few wrong decisions in the congested link status. Two main factors are playing important role in selecting the server for video service from the cloud. They are Packet loss rate and Delay/Delay variation. Delay and packet loss rates for each link were calculated to find cost metrics for all routes. The least cost server was determined by finding the new route from client to server using LARAC. Now the flow tables are updated and flow rules are forwarded to all switches with the new route. The implementation of this work performs better delay reduction for video streaming when server overload is detected.

3.3.6 OpenQoS

Egilmez et al. [46] proposed a framework for multimedia traffic to achieve end-user QoS. The design of the OpenFlow controller architecture is to classify the traffic into two categories- Multimedia traffic and Data traffic. This architecture places the traffic using the prioritization-based dynamic QoS routing. So the multimedia traffics are grouped based on their header fields like ToS in IPv4, traffic class fields in IPv6, and placed in the QoS-guaranteed routes, and normal traffic is placed in the shortest path as the traditional route. The proposed OpenQoS supports per-flow routing and different flow classifications. The OpenQoS is designed with many interfaces like controller-controller, controller-service, and controller-forwarder. Also, supports many key functions such as route management, route calculation, topology management, Call admission, and routing policy. But the OpenQoS controller is implemented with two main modules like Route Management and Route calculation for dynamic QoS routing. The route management function collects the total network state information and finds the congested and non-congested routes based on delay and cost metrics. The route calculation function finds the optimal route by executing the LARAC algorithm. The controller will be having the global network state information collected from the forwarders to process the packet and calculate the optimal route. The flow tables and flow rules are stored in the forwarding devices. Based on the flow table information, the multimedia traffic is placed dynamically in the optimal route. It gives guaranteed end-to-end QoS service without affecting constraints like packet loss and latency of the other types of traffic.

3.3.7 RVSDN

Owens et al. [50] argued and illustrated their interest in end-to-end quality of service for reliable video applications (such as Telesurgery) over SDN. The network must find a feasible path for quality of service metrics including bandwidth, delay, and jitter, according to the VSDN. [62]. The proposed work RVSDN is the enhancement of the VSDN. The RVSDN ensures the quality of service through the number of requests serviced by network architecture. Here Reliability is added as a QoS parameter with high priority for the path selection. This reliability constraint is not built with the architectural design. To provide reliability, many path failover links are constructed in the network. But those links do not provide the required reliability for specific applications like Standard Definition (SD) and High Definition (HD). The network reliability problem is solved using the A* prune algorithm [63]. The results show that RVSDN processed more requests with high reliability when compared to VSDN.

3.3.8 RTQoS-SDN

This is the extension model of the work by Guck and Kellerer [51]. The goal of the model is to establish an abstraction layer between the SDN data plane and real-time applications so that the best path for real-time video applications may be determined. The abstraction layer makes use of the logically centralized view of the network. This model contains three functions; use of multiple queues, ease to calculate the admission control and ease to assign priorities for a queue. It uses the deterministic network model of the network calculus to calculate the delay bound per hop. The token bucket is used as a traffic model that is characterized by the average data rate and burstiness. A Mixed-Integer Program is used to solve the problem, which is depicted as a Multi-Constrained Shortest Path (MIP).

3.3.9 SDN-FQoS

The authors Tomovic et al. [52] suggested an SDN-based QoS provisioning control system and aim that the network resources should be utilized efficiently in a fine-grained manner. Resource Monitoring (RM), Route Calculation (RC), Call Admission Control (CAC), and Resource Reservation are the four function blocks (RR). The output of the RM is the input for the route calculation module. The RM uses OpenFlow messages to gather statistics like flow bandwidth and link load. The RC function calculates different routes for different types of traffic by the Dijkstra algorithm using this current state of network information. The Dijkstra algorithm is used to calculate the optimal route and weights of the edges (weight(i,j)) are calculated by using Eq. (1).

$$weight(i,j) = \frac{C(i,j)}{C(i,j) - max(res(i,j), est(i,j))} \tag{1}$$

where C(i,j) indicates the capacity of the link, res(i,j) denotes the reserved bandwidth, and est(i,j) represents the output of RM. The link weight calculation function finds the path for the QoS flow. The controller fixes the threshold at 80% value and examines the amount of link use along the way. It calculates the available bandwidth and releases the bandwidth based on the threshold value. This value is used for the Controller rerouting program. The Resource reservation modules reserve the resources for the priority flows by configuring the maximum and minimum rates of output queues in the network devices. Once the controller receives the flow, the modules create a buffer for all the interfaces in the calculated route. This module allows to achieving the guaranteed end-to-end bandwidth by Hierarchical Token Bucket [64] scheduling algorithm.

The Call Admission Control Module accepts or rejects calls for QoS flows based on the requirement of the conditions. If the condition is not satisfied, it sends a feedback message to the client. The proposed algorithm outperforms the best-effort and Intserv by the throughput of flows of each model.

3.3.10 RTS-SDN

A framework for real-time network flows has been presented by Kumar et al. [53] that guarantees the bandwidth and end-to-end timing requirements using SDN. The critical real-time flows of routing management and integration overheads are reduced by the global view of the SDN using "Delay Monotonic-Flows Prioritization". i.e., The importance of critical flows is determined by their sensitivity to delay requirements. This problem is solved by two levels: Finding the path layout and Mapping the path layout. The path layout is determined utilizing each flow that satisfies the latency and bandwidth restrictions using (Multi Constraint Path) MCP. The suggested algorithm finds a solution by relaxing one of the requirements and finding a path using another constraint, and vice versa. As a result, find a way by allocating each flow to a distinct queue, or use an algorithm that multiplexes flow into a group of queues and prioritizes packet delivery. After finding the path the flow rules are installed at the OpenFlow switches using CLI (Command Line Interface) or API (Application Programming Interface) based on the flow requirements. Using COTS (commercial-off-the-shelf) SDN switches, this suggested mechanism ensures end-to-end delays for essential traffic in real-time systems while being more cost-effective.

3.3.11 SAQR

Chienhung Lin et al. proposed SAQR, a simulated annealing-based QoS-aware routing method [58] which dynamically adjusts the QoS parameters such as delay, loss rate, and bandwidth to find the best-fit path. The QoS routing algorithm is divided into three sections: topology detection, network status collection, and flow scheduling. The first module receives the packets from all forwarding elements and the SDN Controller creates a virtual topology. The second module starts collecting the network status of all switches and forwards this information to the third module. The flow scheduling module allocates the network resources and uses topology discovery and network status collecting module information to find the best-fit path based on the pre-defined SLA (Service Level Agreement). To find the best path, it has to satisfy multiple constraints like delay and packet loss rate. This will be considered a Multi Constraint Problem. Therefore Simulated annealing heuristic approach is used in the flow scheduling phase to find the optimal solution. The suggested SAQR surpasses the related work MINA [65] in terms of meeting delay, loss rate, and bandwidth requirements, according to the simulation findings.

3.3.12 ERA-SDN

Based on the SDN's Efficient Resource Allocation assumption, Al-Harbi et al. [59] created a ground-breaking intelligent model and a flexible QoS management paradigm. It is split into two sections. 1. The Sharing Control module of the Control Plan makes use of resource sharing. 2. The Control Plans Release Control module uses resource release. The first step collects unused bandwidth before reallocating the whole amount of available bandwidth according to queue priority. In the second step, the queue status is monitored, information about available bandwidth is collected, and bandwidth is finally released depending on the Admission Manager's decision. The model's objective is to release and dynamically reallocate bandwidth while taking the rate of use into consideration. The suggested model was contrasted with FIFO (the standard model), MAM (an example of the IntServ model), and CBWFQ on a variety of traffic (VoIP, HTTP, FTP, TFTP, and Video Streaming) (an example of the DiffServ model). The suggested approach might offer the best VoIP and video streaming quality while enabling HTTP transactions, TCP connections, File Transfer Protocol (FTP), and Trivial File Transfer Protocol (TFTP) load delays.

3.3.13 MRVO

A novel routing mechanism based on a multipath heuristic subgradient algorithm called Multipath Routing for video streaming in OpenFlow Network (MRVO) in SDN was proposed by Thi et al. [55]. The video stream is divided into multiple substreams and used video distortion as a QoS routing metric to enhance the quality of the Multiple Description (MD) video streaming. There are two phases: Controller processing and Heuristic subgradient optimization routing. A new flow is added to the list for the controller to watch during the first step. Whenever the flow is terminated, the controller removes the flow from the list and saves the remaining routing information before calling the heuristic subgradient algorithm. The controller used the heuristic subgradient approach to discover the loopless path after the communication between the controller-forwarder was complete. The controller updates routing path information based on the network state changes. In second phase using the Dijkstra algorithm, the best path can be found. The modified Dijkstra algorithm follows the same process as the conventional Dijkstra algorithm but it selects the pair nodes when it starts at the source node. Estimate the cost for the candidate node and also the previous node. This algorithm traverses the graph link by link and finds two optimal paths as the routing solution that satisfies the video distortion constraint. The proposed work simulated three topology sizes: 24 nodes, 300 nodes, and 400 nodes. It shows that the MRVO mechanism outperforms the existing work Dijkstra Shortest Path (DSP) [66], Maximally Link Disjoint algorithm (MLD) [67] in terms of loss rate, delay, and PSNR.

3.3.14 HiQoS

Yan et al. [54] proposed the HiQoS application that differentiates multiple traffic and guarantees the bandwidth for different types of traffic using the queuing mechanism. The HiQoS consists of two components namely the differentiated service components and multipath routing. In the differentiated service components, the traffic is differentiated like multimedia traffic and normal data traffic by the source IP address of the application. The Controller periodically queries for the IP address of the application and set up queues in the Open Flow Switches (forwarders). It enables one to set one or more queues per port to avoid delay. Then the normal data traffic is forwarded based on the available bandwidth from the network state information. The second component is multipath routing. The Dijkstra algorithm is used to find multiple paths between the source and destination that should satisfy the QoS constraints and store the paths in a hashmap. The controller periodically checks the status of these paths by querying the switches about the queue length and available bandwidth to select the optimal route. Flow entries are saved in the OpenFlow switches and forwarded through the best route based on the network's current state. The HiQoS is compared with the LiQoS (single-path solution without differentiated services), and MiQoS (single-path solution with differentiated services). The HiQoS performances are analyzed in terms of server response time (delay of transmission from server to client), system throughput, and resilience to a path failure. It increases system throughput and resiliences performance through multipath data transmission.

3.3.15 CRS

In an SDN network, Henni et al. [60] suggested a consistent QoS routing approach that provides QoS stability and prevents any quality degradation of prioritized traffic while maximizing resource efficiency. Abstract Vision (consistent network view(s)), Decision-Making (acting consistently on a view), and Network Control are the three types of consistency (consistent rules). The abstract vision involves discovering and diagnosing the sources of network problems, as well as monitoring the effectiveness of network strategies, and correcting measurement inaccuracies using filtering techniques or predictive technology. It is feasible to operate efficiently on the resources (i.e. resource allocation) with a consistent view of the network, ensuring the QoS of prioritized traffic in the decision-making consistency. The network consistency is ensured by the rule enforcement mechanism. To ensure distributed controller consensus, integrate the CRS Algorithm (consistent Rotating Strategy) mechanisms at all levels. The CRS work is compared to three benchmarks: Standard Single Shortest Path-based Routing (SSPR), LFB-based Multipath Routing (LFBMR), and OpenQoS in order to assess and validate performance. The results are consistent in the Mininet context and beat earlier frameworks in terms of average throughput, average video bitrate, and video quality of experience (QoE).

3.3.16 GA-SDN

An effective routing mechanism based on a genetic algorithm called Genetic Algorithm in SDN networks (GA-SDN) was proposed by Yu et al. [56]. In this method, the video flows are periodically checked together with the level of network link utilization. The GA-SDN contains two phases: Routing and Evaluation. The GA-SDN routing algorithm finds the best feasible path for the video flows based on the fitness function to avoid congestion. The fitness function is equal to the path cost function. The fitness function takes two values: zero means not feasible and one means path cost decreases the fitness value. The evaluation phase gives the user a friendly framework to evaluate the transmitted SVC video quality content based on the calculated PSNR value. The proposed GA-SDN shows better results in terms of bandwidth utilization, packet loss rate, and PSNR.

3.3.17 ACO-SDN

Dobrijevic et al. [57] proposed the Quality of Experience (QoE) Centric routing algorithm for the different types of traffic. The Quality of Experience mainly depends on the QoS factors such as delay, jitter, and packet loss. Packet loss is an important factor to satisfy an end-user with different types of service requests based on the video types features (e.g., video resolution) and user device features (screen resolution, codec type). Based on the end-to-end path's flow type, delay variation, and packet loss rate, QoE for a client request is computed. Due to the flow demand of the end-user, this problem is designed as a multi-constraint problem, and finding the solution uses Ant Colony Optimization (ACO). This ACO-based algorithm is compared with Shortest Path Routing (SPR) and the results show that it maximizes the QoE values of the flow and satisfies the flow constraints.

3.3.18 DANN-SDN

Begovic et al. [61] have proposed a QoS model (DANN-SDN)for traffic-differentiated routing in SDN-IoT networks. It is divided into two parts. The first phase focuses on employing a Multi-Criterion-based Deep Packet Inspection approach to classify network traffic, while the second phase uses the ISOMAP algorithm to connect network topology for effective rule placement and routing. In the face of massive requests from IoT device users, deliver QoS in IoT using SDN. To fix the load imbalance between controllers and switches, the Deep Alternative Neural Network (DANN) and Hassanat Distance-based K-nearest neighbors (HDK-NN) algorithms were employed to find the best route. To overcome the imbalanced load problems among the controllers and switches, the ranking-based Entropy function (R-Ef) was applied. The suggested work reduces end-to-end delay and increases throughput by reducing packet loss rate. Improve the proposed method to provide higher data throughput and lower latency in a 5G context.

3.4 Types of video streaming over SDN

Software-Defined Networks (SDN) was developed to address issues with network administration and control. It provides a global network perspective and decouples the control plane and data plane to give controllers access to comprehensive topology data and flow statistics and the availability of network resources even more in-depth forwarding/routing data that helps in effective way to solve QoS awareness for routing applications. These features enhance the QoS framework by:

- The ability of the administrator to quickly apply Service Level Agreements (SLAs) and Quality of Service (QoS) management policies that can be dynamically altered at a higher abstraction level, without having to set them at each forwarding device.
- The logically centralized controller monitors the network state continuously and keep track of the flow path's states, could make it simpler to develop algorithms for quality-based routing and to offer end-to-end QoS for each flow.

Since QoS routing decisions are based on traffic characteristics, OpenFlow networks are an appropriate option because their forwarding device tables are constructed on a per-flow basis. Since the controller can reroute the video traffic along an alternative path to prevent congestion and improve stream quality at the end receivers' side, SDN can be highly helpful for state-dependent routing. Fig. 6. shows the different types of SDN enabled video streaming. The core aim of QoS routing is to determine the optimum paths for the different types of traffic produced by diverse applications, while maximizing network resource efficiently. The QoS mechanism, video threshold metric, video QoS/QoE measure, video applications, and implementations tools of the papers under consideration are tabulated.

3.4.1 QFR-VR

Liu et al. developed an adaptive routing [68] approach employing SDN to better meet the quality of experience (QoE) needs of Virtual Reality (VR) video users with constrained resources. Fine-grained routing (QFR) compute resources have been driven by the projected QoE under service needs based on the fifth-generation mobile networks. The QFR procedure has two steps. The Dijkstra algorithm finds the k pathways with the shortest delay in the first stage. In the second stage, the k pathways are ranked based on their expected quality of experience. The route allocation approach also distributes the sorted k pathways with the least amount of latency by the remaining bandwidth. The suggested routing design can successfully increase the average download bitrate and the quality of VR video (SDN) by employing SDN, which allows for more precise management of network resources and decouples the control plane and the forwarding plane.

3.4.2 MR-VR

The authors Zou et al. framework [69] is utilized to address the growing demand for virtual reality (VR) video applications to adopt appropriate techniques to address the difficulties of the future network based on SDN controller architecture. The suggested approach is known as the MCTS-based VR video multipath transmission technique (MVRMPT) using the Monte Carlo tree search (MCTS). With the least amount of time between node pairs, the Monte Carlo tree search (MCTS) algorithm is modified to locate numerous disjoint pathways. The pathways are then ranked based on the estimated QoE. The VR video is then spatially separated into various zones and assigned to these paths in accordance with their priorities. Zones with higher priorities are those that have a bigger impact on the user's QoE.

3.4.3 EQ-HAS

Thinh and colleagues suggested a unique architecture [70] that includes bitrate adaption and dynamic route allocation. The MPEG-DASH standard serves as the foundation for the adaption logic of VBR video streaming on the client side. On the network side, the OpenFlow protocol is built upon by an SDN controller that employs a number of routing methods. i.e. More creative approaches are required to enhance both user and quality of service (QoS) provider for future Internet infrastructure to enhance services of various Internet layers based on software-defined networking due to the growth in traffic for video streaming over the Internet (SDN).

3.4.4 AP-HAS

The authors proposed a design for a video streaming system where the SDN controller is knowledgeable about the

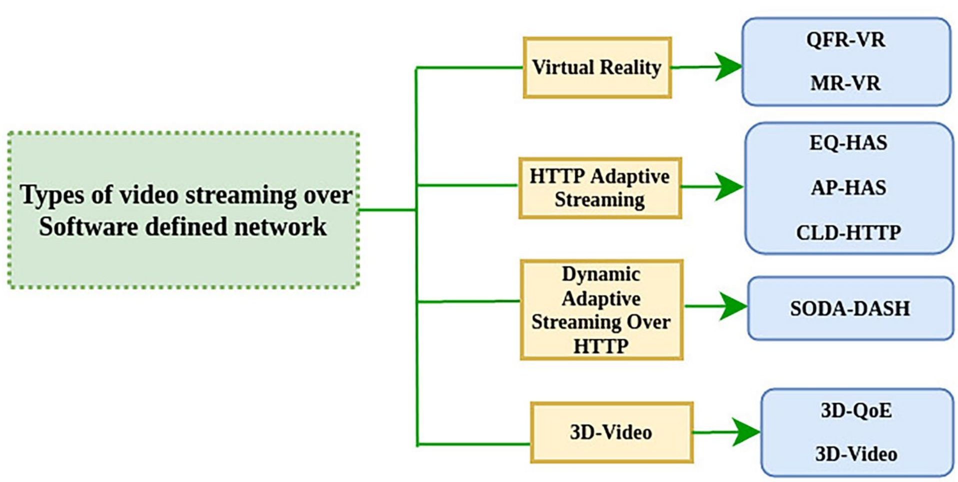


Fig. 6 Types of video streaming over SDN

various video codec types and HAS characteristics [71]. While taking into account layer dependency constraints of both codecs, projected packet loss ratios, and current network conditions, the controller selects the appropriate codec type for the clients and dynamically assigns streaming paths for each layer of the movies streamed to all clients. i.e.The HAS aware controller can anticipate the available bandwidth with greater accuracy even though both use the identical data regarding the volume of traffic and the current bandwidth.

3.4.5 CLD-HTTP

An approach to forecasting user experience quality over a software-defined network based on cognitive computing [72] was proposed by Parameshachari et al. with the aid of a linear discriminant regression technique that forecasts the anticipated mean opinion score using the mean opinion score under varied network conditions. The simulation results showed that the linear discriminant regression technique produced better video quality than the linear regression technique in terms of peak signal-to-noise ratio, structural similarity index, and video quality metric by adjusting the video resolutions, bit rates, and frame rates.

3.4.6 SODA-DASH

An SDN-based optimization method for boosting QoE in DASH streaming [SODA] has been developed by Majdabadi et al. that maximises both quantity and quality of service [73]. It has two competing goals for maximizes both number and quality. i.e. The first goal is to increase the number of concurrent streaming sessions, and the second goal is to allocate the least amount of bandwidth possible across a network. The number of accepted flows and the amount of bandwidth allotted to each flow is maximized. The optimizer, flow manager, and topology manager are the three modules of SODA-Stream that the SDN controller implements. Using the OpenFlow SDN protocol, the topology and flow managers continuously track the state of the network and the total demand for the DASH streaming service. The network graph G is created by the topology manager, and the list of active flows (DASH sessions) F is sent to the optimizer by the flow manager. Link Accepted (LS), Flow Accepted (FS), and Required Rate (RR) are the outputs of the optimizer module once it has solved the optimization issue for all sessions. The topology manager creates forwarding rules using the LS, and FS values, whereas the flow manager creates queues for bandwidth reservation using the RR and FS values. Both manager modules utilize the southbound of the OpenFlow protocol to remotely configure the flow tables on switches.

3.4.7 3D-QoE

Liu et al. developed 3DQoE-optimized 3D video flow path routing for the effective distribution of 3D video across centrally regulated networks in terms of quality and energy cost [74]. When choosing the best routing paths for numerous 3D video streams, the video characteristic and depth of the 3D video are effectively included. The described problem is NP-hard, and a heuristic technique based on the branch-and-bound method is used to solve it after drastically condensing the solution search space. By balancing operator cost and visual experience, the suggested optimization framework can deliver improved streaming performance for 3D Video streaming applications.

3.4.8 3D-video

By combining Mobile Edge Computing (MEC) with Software-defined Networking, Pan Zhou et al. proposed a unique resource allocation model (RAM) [75] to allocate resources and reduce latency. This networking and computational architecture promises the Quality of Experience (QoE) Model (QoEM), which employs data obtained during 3D video playback to adaptively assign the pace of future tiles. By combining the historical data for the blocks into the Actor- Critic network for observations, the LSTM network is used for various transmissions to anticipate the bandwidth and viewport during playback. The network can adaptively decide the proper transmission speed for subsequent tiles based on observations to improve QoE.

4 Measures for QoS multimedia routing algorithms

QoS routing is a process of determining the path which satisfies QoS demand for a selected data flow. QoS routing is different from the shortest path route. Any network feature, such as bandwidth, delay, or jitter, is taken into account while determining the shortest path routing. But QoS routing takes the combination of these network characteristics like bandwidth and delay, delay, and packet loss rate. These will be considered as a QoS metric. The QoS-aware multimedia routing considers both parameters such as network parameters and encoding parameters such as resolution, number of frames, codec type, etc. Two basic types of QoS metrics depend on the network and end-user device features. 1. **Performance parameters**: Bandwidth, Transmission delay, and Jitter 2. **Reliability parameters**: Quality of the transmitted data or accuracy, amount of Packet loss rate. The following QoS metric is widely used in SDN.

4.1 Bandwidth utilization

Also called as data transfer rate. The amount of time it will take to transfer the data from source to destination. Bandwidth utilization is calculated using Eq. (2).

$$Bandwidth\_Utilization = \frac{Bandwidth\,utilized\_Flow\,transmission}{Total\,available\,Bandwidth} \tag{2}$$

All QoS routing algorithms must try to maximize bandwidth utilization of the link.

4.2 Delay

It refers to the transfer delay that occurs during the delivery time of packets. This is measured in milliseconds. It is calculated between the source and destination time of successfully transferred packets. It is mentioned using Eq. (3).

$$Delay\_metric = Delay \tag{3}$$

4.3 Delay variation or jitter

It refers to the out-of-order packets (irregular speed of packets) that appear in the audio or video due to deviations in signal pulses. Example: cross talk in other signals. QoS routing should minimize the occurrence of Jitter.

4.4 Packet loss rate (PLR)

This is called the failure of packets. Due to the congestion or some delay in the network (exceeded transferred rate) in the network device, the packets are unable to reach the destination. The router or switch simply discards the packets. It is calculated between the total number of transferred packets and generated packets as per Eq. (4).

$$Packet\_Loss\_Rate = \frac{No.\ of\ Packets\ Reached\ Destination}{Total\ No.\ of\ Packets\ Generated} \tag{4}$$

4.5 Peak signal-noise ratio (PSNR) & Mean square error (MSE)

This image quality metrics such as PSNR and mean square error (MSE) were used to measure the quality of the reconstructed compressed image. While PSNR denotes the peak error value, MSE denotes the total square error between the original and received video sequences. If the value of PSNR is high. It means the reconstructed video is of higher quality and vice versa. These metric values may vary based on the codec and content. This objective metric value should be calculated very carefully when comparing results. Equations 5 and 6 provide the general formulae to determine MSE [72] and PSNR [76].

$$MSE = \frac{1}{mn}\sum_{x=0}^{m-1}\sum_{y=0}^{n-1}\|S(x,y) - D(x,y)\|^2 \tag{5}$$

Thus, D(x,y) stands for the received video sequence, S(x,y) for the original video sequence, and m and n stand for the video dimensions.

$$PSNR = 20log_{10}\left(\frac{max(S(x,y))}{\sqrt{MSE}}\right) \tag{6}$$

4.6 LARAC cost metric

Lagrange Relaxation-based aggregated cost is a proposed statistic for QoS routing (LARAC). It employs two types of QoS metrics: transfer delay and packet loss rate. It gives them a polynomial heuristic of a modified cost function. LARAC cost metric is calculated using Eq. (7).

$$LARAC\_Cost\_Metric = (1-\delta)\cdot Delay + \delta\cdot PLR \tag{7}$$

where, δ is operating coefficient.

4.7 Comparison of QoS mechanism, results, and drawbacks of the algorithms

Table 4 defines the QoS mechanism, QoS routing method, and limitations of the reviewed papers. This review shows that QoS parameters play a primary role in the QoS process as well as selecting the QoS parameter is a crucial task in QoS routing.

4.8 QoS metrics comparison of algorithms

This section provides a perspective view on the quality measures used for estimating the performance of the algorithms discussed in Section 3.3. QoS metrics considered for the existing works are given in Table 5.

4.9 Emulation parameters used

The emulation parameters used for routing algorithms are presented in Table 6. The OpenFlow Controller is used in all the routing methods for finding the path. The emulation of each QoS mechanism was done in various virtual network topologies. The type of guarantee and type of traffic varies for each routing method.

Table 4 Comparison of algorithms with advantages and limitations

Title/Ref	Description	QoS Mechanism	Results	Drawbacks
MORO [44]	A Dijkstra routing for resource utilization by intercepting RTSP/RTP protocols	Shortest path routing	Increased resource utilization	Uses a single QoS criteria
ELBA [45]	Design of efficient layer-based routing for SVC video streaming in SDN	Shortest path routing-Dijkstra algorithm	Reduced the frame loss rate, Increased throughput, Improved video quality (bit rate)	No jitter and congestion calculation, no multi-domain
SVS-OFN [47]	An optimized framework to provide the QoS for Scalable video coding	Dynamic QoS routing (CSP) with LARAC	Reduced packet loss rate, Improved PSNR value	Computational overhead as no of nodes and links increases
ARVS [35]	A dynamic routing for scalable video streaming with QoS support	Adaptive routing with LARAC (CSP)	Reduced packet loss rate	No guarantee for the performance of enhancement layer packets
VS-SLB[48]	Design of OpenFlow controller to improve the QoS for video stream through server load balancing	Dynamic rerouting (CSP) with LARAC	Reduced the playback delay	Introducing slight delay when server overload occurs
OpenQoS [46]	Design of controller to achieve End-to-End Quality of Service for multimedia traffic	Dynamic QoS routing (CSP) with LARAC	Reduced PLR, Latency of other traffic	Route calculation and Route management considered for QoS. Flow management is not implemented in detail
RVSDN [50]	An A*prune algorithm based on Constraint shortest path finds most reliable path for video applications	MCSP (QoS constraints and reliability constraints)	Increased no of requests serviced, Reduced the request processing time	No PSNR and PLR calculation
RTQoS-SDN [51]	A deterministic model finds the best path to optimize the resource allocation based on the network state information to achieve the real-time QoS	MCSP (resource reservation) using MIP	Improved the high utilization in buffer rate, Link rate, Delay deviation	Use of MIP is more resource consuming in case of online routing algorithm
SDN-FQoS [52]	Design of SDN control framework that performs the smart traffic management	Resource reservation (MCSP)	Guaranteed bandwidth for priority flows	No Delay guaranteed solutions
RTS-SDN [53]	Critical flows routing to guarantee the end-to-end delay in real-time system	MCP with heuristic algorithm	Guaranteed the end-to-end delay, Reduces the integration overhead with real-time flows	Hardware switch limitation for Queue size (Queuing delay increased), No admission control policy
SAQR [58]	Finding the best path using simulated annealing to satisfy the flows QoS demand.	MCP with simulated Annealing	Reduced delay, loss, Bandwidth utilization	Uniform traffic used
ERA-SDN [59]	Development of a novel intelligent and flexible QoS management strategy based on the SDN's Efficient Resource Allocation (ERA).	MCP with Resource release algorithm	Reduced delay, loss rate, improved Streaming quality for VoIP, Video	No Bandwidth guaranteed solutions in case of link failure no offload and no aggregation of link
MRVO [55]	Design of Multipath routing to enhance video quality of Multiple descriptive coded video	Multipath routing	Increased PSNR, Reduced delay	Loss rate increases as traffic load increases and PSNR degrades
HiQoS [54]	Design of Multipath routing and queuing mechanism to guarantee QoS for different types of traffic	Multipath routing	Reduced transmission delay, Increased throughput	No experimental video data considered

Table 4 (continued)

Title/Ref	Description	QoS Mechanism	Results	Drawbacks
CRS[60]	Design of a software-defined architecture for video streaming QoS routing services that are consistent and resource-efficient.	Multipath routing	Improves video quality (bit rate), Average throughput, and video quality of experience (QoE) (MOS)	No jitter and congestion calculation, no multi-domain
GA-SDN [56]	Finding the best path for video flows using genetic algorithm	AI Based Optimization	Reduced the end-to-end delay, Increased PSNR	No jitter and congestion calculation, No multiple flow support
ACO-SDN [57]	An ant colony optimization based on heuristic algorithm finds the best path for QoE centric flows	AI Based Optimization	Improves the QoE for end user, Low running time	Additional overhead as the network size increases
DANN-SDN [61]	Design traffic differentiated QoS model for routing and dynamic flow offloading, and fulfill QoS in IoT with SDN in the face of massive requests from IoT devices owned by consumers.	Deep Alternative Neural Network	Improves the QoE for the end user, Low running time	Additional overhead as the network size increases

4.10 QoE measures for video streaming over SDN

The term "quality of experience" (QoE) refers to a set of measures [77] that are focused on the needs of people and measure whether a service or application is generally regarded favorably or negatively by its customers. QoE is the extension of the traditional QoS. i.e. user's opinion, user perception, and user expectation. The video must be evaluated using both subjective and objective quality measures. For the purpose of assessing the quality of experience (QoE) models, the Mean Opinion Score (MOS), Peak-to-Signal-Noise Ratio (PSNR), Structural Similarity Index (SSIM), Video Quality Metrics (VQM), and Mean Absolute Difference (MAD) metrics are utilized [76, 78]. There are three types of references in the objective model: Full-Reference (FR), No-Reference (NR), and Reduce-Reference (RR). The original and received videos are compared for quality with the goal of supporting the full-reference metrics. The only requirement for evaluating the No-reference (NR) metrics is the outcome video. To support Reduce-Reference (RR) metrics, extract a few features from the reference and the outcome and compare them. The video applications, implementations tools, video QoS/QoE measure, video threshold metric, and QoS method are specified in Table 7. For different video streaming, the QoE measures and mapping functions are reported in Table 8.

Methods for QoS/QoE Correlation. There are commonly two approaches top-down and bottom-down for mapping QoE/QoS. Whereas the top-down method starts from the user side (QoE), the bottom-up technique starts from the network side (QoS). The literature review for a multimedia service in this review effort is directed to the development of the QoS/QoE correlation modeling approaches that are listed below.

- A mapping model based on VQM
- QoE models use network QoS and application QoS
- Machine learning-based QoE models
- Quantitative and qualitative assessment-based QoE models

5 Research issues in video streaming

This section introduces the following future issues in Video streaming [44-46, 52, 56, 57].

5.1 Multiple descriptive coding

MDC is a technique that minimizes the packet loss between descriptions and the video stream was played continuously by receiving only one description. At the same time, It improves the video quality by receiving multiple descriptions. To overcome the issues related to video streaming in a heterogeneous network, Multiple descriptive coding can

Table 5 QoS Performance metrics considered for existing works

Sl.No.	Title	Delay	Bandwidth	Jitter	Packet loss	LARAC Cost metric	PSNR
1	**MORO**	NO	YES	NO	NO	NO	NO
2	**ELBA**	NO	YES	NO	YES	NO	YES
3	**SVS-OFN**	YES	YES	NO	YES	YES	YES
4	**ARVS**	NO	NO	YES	YES	YES	NO
5	**VS-SLB**	NO	NO	YES	YES	YES	NO
6	**OpenQoS**	YES	YES	NO	YES	YES	NO
7	**RVSDN**	YES	YES	YES	NO	NO	NO
8	**RTQoS-SDN**	YES	YES	NO	NO	NO	NO
9	**SDN-FQoS**	YES	NO	NO	NO	NO	NO
10	**RTS-SDN**	YES	YES	NO	NO	NO	NO
11	**SAQR**	YES	YES	NO	YES	NO	NO
12	**ERA-SDN**	YES	YES	NO	YES	NO	NO
13	**MRVO**	NO	YES	NO	NO	NO	YES
14	**HiQoS**	YES	YES	NO	NO	NO	NO
15	**CRS**	NO	YES	NO	NO	NO	NO
16	**GA-SDN**	YES	NO	NO	YES	NO	YES
17	**ACO-SDN**	NO	YES	NO	YES	NO	NO
18	**DANN-SDN**	YES	YES	NO	YES	NO	NO

Table 6 Parameters used for simulation

Title	QoS constraint	QoS traffic	Tool used	Controller(C/D)	Type of Guarantee	Domain/Flow support
MORO	Data Rate	Video stream	OpenFlow nodes	NOX-C	Hard & Hop-by-Hop	Single/Multiple flows
ELBA	Bandwidth	SVC based video stream	Mininet	POX-C	Hard & Hop-by-Hop	Single/Multiple flows
SVS-OFN	Bandwidth, Delay, PLR	SVC base layer and enhancement layer	LEMON C++	SDN-C	Hard & Hop-by-Hop	Single/Multiple flows
ARVS	Delay variation, PLR	Base layer and Enhancement layer	Mininet	Floodlight-C	Soft & End-to-End	Single/Multiple flows
VS-SLB	Delay variation, PLR	Video stream	Flowvisior	OpenDaylight-C	Hard & End-to-End	Multi/Multiple flows
OpenQoS	Bandwidth, Delay, PLR	Video traffic	OpenFlow Switches	Floodlight-C	Soft & End-to-End	Single/Multiple flows
RVSDN	Bandwidth, Delay, Jitter	Video application	NS3	RVSDN-C	Hard & End-to-End	Single/Multiple flows
RTQoS-SDN	Delay, Bandwidth	Different types of classes	Mininet	SDN-C	Hard & End-to-End	Single/Multiple flows
SDN-FQoS	Bandwidth	Video stream	Open Vswitch	POX-C	Hard & End-to-End	Single/Multiple flows
RTS-SDN	Delay, Bandwidth	Video stream	Mininet	RYU-C	Soft & End-to-End	Single/Multiple flows
SAQR	Bandwidth, PLR, Delay	Hotspot traffic	Mininet	Floodlight-C	Soft & End-to-End	Single/Multiple flows
ERA-SDN	Bandwidth,Latency	Video, VOIP,FTP traffic	GNS3	Controller ERA Server-C	Soft & Hop-to-Hop	Multiple/Multiple flows
MRVO	Bandwidth, PLR, Delay, PSNR	Multiple descriptive coded video	Opnet	OpenFlow Controller-C	Soft & End-to-End	Single/Multiple flows
HiQoS	Bandwidth, Delay	Video stream	Mininet	Floodlight-C	Soft & End-to-End	Single/Multiple flows
CRS	Bandwidth, Delay	Video stream	Mininet	RYU-D	Soft & Hop-to-Hop	Single/Multiple flows
GA-SDN	Bandwidth, Delay	Video stream	Mininet	POX-C	Soft & End-to-End	Single/Multiple flows
ACO-SDN	Delay, PLR	Audio, Video, Data	Mininet	OpenDay light-C	Soft & End-to-End	Multi/Multiple flows
DANN-SDN	Delay, PLR	Audio, Video, Data	NS3	OpenDay light-D	Hard & End-to-End	Multi/Multiple flows

C-Centralized Controller

D-Distributed Controller

Table 7 Types of SDN-enabled video streaming, video metrics, and implementation tools comparison

Approach	QoS Mechanisms/ML techniques	Video threshold Metrics	Applications	Network Category	Implementation Tools
QFR-VR [68]	Shortest path routing/ Regression Decision Tree	Delay and Bandwidth	Virtual reality video stream	Wireless (5G)	Mininet, RYU controller, DASH apache video server, VR video player.
MR-VR [69]	Multipath Routing/ Monte Carlo tree search (MCTS) algorithm	Bandwidth and Delay	Virtual reality video stream	Wireless (5G)	Mininet, RYU controller, VR video "Google Spotlight-HELP".
EQ-HAS [70]	Adaptive Routing(on Demand Routing)/ Reinforcement routing policies	Throughput, Buffer level	HTTP Adaptive Streaming	NIL	Floodlight controller, Mininet, DASH client, SDN network and Video server
AP-HAS [71]	Dynamic Routing/Not used ML	Packet loss and Available Bandwidth	HTTP Adaptive Streaming	NIL	Mininet, Flood light controller, DASH Client, server, SVC and MDC Codec.
CLD-HTTP [72]	Linear discriminant regression technique	Bandwidth,Delay, jitter, buffering, and RTT	HTTP video streaming	NIL	Floodlight Controller, Mininet, Motion videos, Steady video
SODA-DASH [73]	Dynamic Routing/Not used ML	Bandwidth,number of Flows,Number of Links	DASH streaming	NIL	Mininet, Gurobi, Internet Zoo Tolopogy, FFmpeg, NGINX HTTP server.
3D-QoE [74]	Dynamic Routing/Not used ML	Bandwidth,Packet loss,Delay	H.264/SVC-based 3D video streaming	3D VoD	Mininet, SDN controller, medium motion video Balloons and the low motion video Newspaper
3D-video [75]	Resource Reservation/ Not used ML	Bandwidth(MAE), Delay	3D Video	Mobile Edge Computing	MEC server, Not in detail.

be done. The issues related to encoder /decoder complexity, content type, and error concealment techniques are considered before using MDC in video streaming. Also, need to find the optimized route to transmit the packets of descriptions over an error-prone channels [79].

5.2 Reducing the delay with content distribution networks (CDNs)

Multimedia streaming applications such as Video on Demand, Real-time video, and Internet live broadcasts should have high availability of resources and high performance without delay [80]. These applications are still facing many challenges to the effective delivery of media streams. To overcome this deficiency, the content delivery networks are used to balance the networking load using OpenFlow and distribute the content to end-users. The load balancer selects a server by considering many factors like server location (propagation delay), content type, and the amount of traffic assigned to a server. In this way, CDN is used for reducing the delay in media communication.

5.3 Cross layer design for video stream

The Cross-Layer design approach plays a vital role in the performance improvement of the QoS video stream. In this design, all the layers are performed independently and coordinate themselves to have better control over the data, so that it improves the overall network efficiency. This cross-layer design helps to improve PSNR value by optimizing the

Table 8 Comparision of types QoE metrics and QoS mapping Functions

Approach	Video QoE metrics	Typical mapping techniques	Mapping Function	Video Reference
QFR-VR [68]	Video download bitrate	Bottom-down approach	NQoS	No Reference
MR-VR [69]	Video download bitrate	Bottom-down approach	NQoS	No Reference
EQ-HAS [70]	Bitrate distribution, Stalling event, and duration	Top-down approach	MoS	Full reference
AP-HAS [71]	Codec type, rebuffering duration, number of video layers, and video bitrate	Top-down approach	AQoS	No Reference
CLD-HTTP [72]	PSNR, SSIM, VQM video resolutions, bit rates, and frame rates	Top-down approach	MoS	Full-Reference
SODA-DASH [73]	Bitrate level and Buffer level	Bottom-down approach	NQoS	Full Reference.
3D-QoE [74]	Bitrate, Video/depth rate, and PSNR	Top-Down approach	MAD	Full Reference
3D-video [75]	CLS(Cross user Learning) and Tile-Rate	Top-down approach	AQoS	Full Reference

decodable video frame number. We can enable the cross-layer design in the Internet and OpenFlow wireless network for effective network resource utilization.

5.4 Effectual routing algorithm

All the surveyed routing works use the video streaming application for their experimental results but still in future need-based experimental and other types of streaming multimedia applications, such as video surveillance systems and video-on-demand should be evaluated using alternative QoS/QoE and encoding parameters. With this idea, we need different routing algorithms for distinct layers of scalable video streaming. As a result, sophisticated QoS models are designed to meet the QoS/QoE requirements for various types of traffic applications and satisfy the end user.

6 Conclusion

From our review, it is realized that classifying the traffic into different QoS levels give the solution for scalability issue using SVC video streams. But dynamic adaptive routing and frequent flow table updates are most needed in real-time applications. The Existing QoS models and re-routing create complex situations. Some QoS models are used to enhance the reliability metrics (PSNR) by reducing the Packet loss rate and end-to-end delay. All the routing algorithms described in this paper use a QoS mechanism by considering only the network-level parameters to utilize the network resources effectively. But this is not suitable for heterogeneous device networks. This will degrade the video quality for the end user. The video quality is improved by the design of combining QoS/QoE models. The video quality is improved by the design of combining QoS/QoE models. So developing a QoS mechanism for video streaming in SDN is based on user requirements and application types. There is a need to develop the following:

- A powerful QoS-enabled framework to guarantee QoS in an OpenFlow Network.
- Use some meta-heuristic approaches to find the optimal path for Video streaming in SDN.
- To deal with various and constantly changing situations across the Internet, an efficient fault-tolerant mechanism and congestion control algorithm are required.
- Using more than one controller to handle different devices in the heterogeneous IP network.

Acknowledgements The authors thank the anonymous reviewers for their valuable comments, which helped us to considerably improve the content, quality, and presentation of this paper.

Author contributions Each author who participated in the literature review and work revision made a contribution.

Funding This research received no external funding.

Availability of supporting data Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

Declarations

Human and animal ethics The review does not include any ethically approved human or animal experiments.

Consent for publication The authors have given the journal their informed consent to publish their review article.

Competing interests The authors declare no conflict of interest.

References

1. Foukas X, Patounas G, Elmokashfi A et al (2017) Network slicing in 5g: Survey and challenges. IEEE Commun Mag 55(5):94–100
2. Popovski P, Trillingsgaard KF, Simeone O et al (2018) 5g wireless network slicing for embb, urllc, and mmtc: A communication-theoretic view. IEEE Access 6:55765–55779
3. Kobbaey T, Hamzaoui R, Ahmad S et al (2021) Enhanced collision resolution and throughput analysis for the 802.11 distributed coordination function. Int J Commun Syst 34(16):e4953
4. Nunes BAA, Mendonca M, Nguyen XN et al (2014) A survey of software-defined networking: Past, present, and future of programmable networks. IEEE Communications surveys & tutorials 16(3):1617–1634
5. Karakus M, Durresi A (2017) Quality of service (qos) in software defined networking (sdn): A survey. J Netw Comput Appl 80:200–218
6. Behringer M, Pritikin M (2005) Internet engineering task force. https://ietf.org/topics/netmgmt/
7. Rosen E, Viswanathan A (2001) Multiprotocol label switching. https://en.wikipedia.org/wiki/Multiprotocol_Label_Switching
8. Kreutz D, Ramos FM (2014) Software-defined networking: A comprehensive survey. Proc IEEE 103(1):14–76. https://doi.org/10.1109/JPROC.2014.2371999
9. SDNArchitecture ONF (June,2014) https://www.opennetworking.org/wp-content/uploads/2013/02/TR_SDN_ARCH_1.0_06062014.pdf
10. Lütkebohle I (2013) openflow. https://www.sdxcentral.com/networking/sdn/definitions/what-is-openflow/
11. Izard R (2016) Floodlight sdn controller. https://floodlight.atlassian.net/wiki/spaces/floodlightcontroller/overview
12. RYU Project Team (2011) Ryu sdn controller. https://ryu.readthedocs.io/en/latest/getting_started.html
13. RYU Project Team (5 February, 2014) Opendaylight sdn controller. https://www.opendaylight.org/what-we-do/odl-platform-overview
14. Apache 2 0 license (December 5, 2014) Onos sdn controller. https://www.opennetworking.org/onos/
15. OpenFlow SwitchSpecification VWPx (December 31,2009) https://www.opennetworking.org/wp-content/uploads/2013/04/openflow-spec-v1.0.0.pdf
16. OpenFlow VWPx (February 28,2011) https://www.opennetworking.org/wp-content/uploads/2014/10/openflow-spec-v1.1.0.pdf
17. OpenFlow VWPx (December 5, 2011) https://www.opennetworking.org/wp-content/uploads/2014/10/openflow-spec-v1.2.pdf
18. OpenFlow SwitchSpecification VWPx (June 25, 2012) https://www.opennetworking.org/wp-content/uploads/2014/10/openflow-spec-v1.3.0.pdf

19. Guru, Parulkar (2011) opennetworking. https://www.opennetworking.org/sdn-definition/
20. OpenFlow SwitchSpecification VWPx (2013) https://www.opennetworking.org/wp-content/uploads/2014/10/openflow-spec-v1.4.0.pdf
21. OpenFlow SwitchSpecification VWPx (December 19, 2014) https://www.opennetworking.org/wp-content/uploads/2014/10/openflow-spec-v1.5.0.pdf
22. Ford YB (2000) Integrated services. https://tools.ietf.org/html/rfc2998
23. Black DP (2015) Differentiated services. https://tools.ietf.org/html/rfc7657
24. Mirchev A (2015) Survey of concepts for qos improvements via sdn. Future internet (FI) and innovative internet technologies and mobile communications (IITM) 33(1)
25. S.Floyd M (2008) Besteffort. https://tools.ietf.org/html/rfc5290
26. (2005) Videostreaming. https://en.wikipedia.org/wiki/Streaming_media
27. (2000) Videostreaming protocols. https://www.vocal.com/video/video-streaming-protocols-rtp-rtcp-and-rtsp/
28. (2022) Real-time messaging protocol. https://www.wowza.com/blog/rtmp-streaming-real-time-messaging-protocol
29. (2022) Real-time streaming protocol. https://antmedia.io/rtsp-explained-what-is-rtsp-how-it-works/
30. (2022) Real-time transport protocol. https://datatracker.ietf.org/doc/html/rfc3550
31. (2022) Http adaptive streaming. https://www.dacast.com/blog/hls-streaming-protocol
32. (2017) Apple http live streaming(hls). https://datatracker.ietf.org/doc/html/rfc8216
33. (2009) Low-latency hls. https://cloudinary.com/guides/live-streaming-video/low-latency-hls-ll-hls-cmaf-and-webrtc-which-is-best
34. (2012) Low-latency hls. https://mpeg.chiariglione.org/standards/mpeg-dash
35. Yu TF, Wang K, Hsu YH (2015) Adaptive routing for video streaming with qos support over sdn networks. In: 2015 International Conference on Information Networking (ICOIN), IEEE, pp 318–323. https://doi.org/10.1109/ICOIN.2015.7057904
36. Karakus M, Durresi A (2015) A scalable inter-as qos routing architecture in software defined network (sdn). In: 2015 IEEE 29th International Conference on Advanced Information Networking and Applications, IEEE, pp 148–154. https://doi.org/10.1109/AINA.2015.179
37. Afaq M, Rehman SU, Song WC (2015) A framework for classification and visualization of elephant flows in sdn-based networks. Procedia Computer Science 65:672–681. https://doi.org/10.1016/j.procs.2015.09.011
38. Isolani PH, Wickboldt JA, Both CB et al (2015) Interactive monitoring, visualization, and configuration of openflow-based sdn. In: 2015 IFIP/IEEE International Symposium on Integrated Network Management (IM), IEEE, pp 207–215. https://doi.org/10.1109/INM.2015.7140294
39. Jeong S, Lee D, Choi J et al (2016) Application-aware traffic management for openflow networks. In: 2016 18th Asia-Pacific Network Operations and Management Symposium (APNOMS), IEEE, pp 1–5. https://doi.org/10.1109/APNOMS.2016.7737212
40. Wang JM, Wang Y, Dai X et al (2015) Sdn-based multi-class qos guarantee in inter-data center communications. IEEE Transactions on Cloud Computing 7(1):116–128. https://doi.org/10.1109/JPROC.2014.2371999
41. Ahmad A, Floris A, Atzori L (2018) Timber: An sdn based emulation platform for qoe management experimental research. In: 2018 Tenth International Conference on Quality of Multimedia Experience (QoMEX), IEEE, pp 1–6. https://doi.org/10.1109/QoMEX.2018.8463387
42. Fawcett L, Mu M, Hareng B et al (2017) Ref: enabling rapid experimentation of contextual network traffic management using software defined networking. IEEE Commun Mag 55(7):144–150. https://doi.org/10.1109/MCOM.2017.1600507
43. Yang H, Wang X, Nguyen CT et al (2018) Optimizing user experience through implicit content-aware network service in the home environment. In: Proceedings of the 2018 ACM Conference on Supporting Groupwork, pp 51–60. https://doi.org/10.1145/3148330.3148339
44. Karl M, Gruen J, Herfet T (2013) Multimedia optimized routing in openflow networks. In: 2013 19th IEEE International Conference on Networks (ICON), IEEE, pp 1–6. https://doi.org/10.1109/ICON.2013.6781969
45. Gangwal A, Gupta M, Gaur MS et al (2016) Elba: Efficient layer based routing algorithm in sdn. In: 2016 25th International Conference on Computer Communication and Networks (ICCCN), IEEE, pp 1–7. https://doi.org/10.1109/ICCCN.2016.7568515
46. Egilmez HE, Dane ST, Bagci KT et al (2012) Openqos: An openflow controller design for multimedia delivery with end-to-end quality of service over software-defined networks. In: Proceedings of the 2012 Asia Pacific signal and information processing association annual summit and conference, IEEE, pp 1–8
47. Egilmez HE, Gorkemli B, Tekalp AM et al (2011) Scalable video streaming over openflow networks: An optimization framework for qos routing. In: 2011 18th IEEE International Conference on Image Processing, IEEE, pp 2241–2244. https://doi.org/10.1109/ICIP.2011.6116083
48. Yilmaz S, Tekalp AM, Unluturk BD (2015) Video streaming over software defined networks with server load balancing. In: 2015 International Conference on Computing, Networking and Communications (ICNC), IEEE, pp 722–726. https://doi.org/10.1109/ICCNC.2015.7069435
49. Juttner A, Szviatovski B, Mécs I et al (2001) Lagrange relaxation based method for the qos routing problem. In: Proceedings IEEE INFOCOM 2001. Conference on Computer Communications. Twentieth Annual Joint Conference of the IEEE Computer and Communications Society (Cat. No. 01CH37213), IEEE, pp 859–868. https://doi.org/10.1109/INFCOM.2001.916277
50. Owens H, Durresi A, Jain R (2014) Reliable video over software-defined networking (rvsdn). In: 2014 IEEE Global Communications Conference, IEEE, pp 1974–1979. https://doi.org/10.1109/GLOCOM.2014.7037097
51. Guck JW, Kellerer W (2014) Achieving end-to-end real-time quality of service with software defined networking. In: 2014 IEEE 3rd International Conference on Cloud Networking (CloudNet), IEEE, pp 70–76. https://doi.org/10.1109/CloudNet.2014.6968971
52. Tomovic S, Prasad N, Radusinovic I (2014) Sdn control framework for qos provisioning. In: 2014 22nd Telecommunications Forum Telfor (TELFOR), IEEE, pp 111–114. https://doi.org/10.1109/TELFOR.2014.7034369
53. Kumar R, Hasan M, Padhy S et al (2017) End-to-end network delay guarantees for real-time systems using sdn. In: 2017 IEEE Real-Time Systems Symposium (RTSS), IEEE, pp 231–242. https://doi.org/10.1109/RTSS.2017.00029
54. Yan J, Zhang H, Shuai Q et al (2015) Hiqos: An sdn-based multipath qos solution. China Communications 12(5):123–133. https://doi.org/10.1109/CC.2015.7112035
55. Thi TM, Huynh T, Hwang WJ (2015) Qos-enabled streaming of multiple description coded video over openflow-based networks. Nonlinear Theory and Its Applications, IEICE 6(2):144–159. https://doi.org/10.1587/nolta.6.144
56. Yu YS, Ke CH (2018) Genetic algorithm-based routing method for enhanced video delivery over software defined networks. Int J Commun Syst 31(1). https://doi.org/10.1002/dac.3391
57. Dobrijevic O, Santl M, Matijasevic M (2015) Ant colony optimization for qoe-centric flow routing in software-defined networks. In: 2015 11th International Conference on Network and Service

Management (CNSM), IEEE, pp 274–278. https://doi.org/10.1109/CNSM.2015.7367371
58. Lin C, Wang K, Deng G (2017) A qos-aware routing in sdn hybrid networks. Procedia Computer Science 110:242–249. https://doi.org/10.1016/j.procs.2017.06.091
59. Al-Harbi A, Bahnasse A, Louhab FE et al (2021) Towards an efficient resource allocation based on software-defined networking approach. Comput Electr Eng 92(107):066. https://doi.org/10.1016/j.compeleceng.2021.107066
60. Henni DE, Ghomari A, Hadjadj-Aoul Y (2020) A consistent qos routing strategy for video streaming services in sdn networks. Int J Commun Syst 33(10). https://doi.org/10.1002/dac.4177
61. Begovic M, Causevic S, Memic B et al (2020) Ai-aided traffic differentiated qos routing and dynamic offloading in distributed fragmentation optimized sdn-iot. Int J Eng Res Technol 13(8):1880–1895. https://doi.org/10.37624/IJERT/13.8.2020.1880-1895
62. Owens H II, Durresi A (2015) Video over software-defined networking (vsdn). Comput Netw 92:341–356. https://doi.org/10.1109/NBiS.2013.10
63. Liu G, Ramakrishnan K (2001) A* prune: an algorithm for finding k shortest paths subject to multiple constraints. In: Proceedings IEEE INFOCOM 2001. Conference on Computer Communications. Twentieth Annual Joint Conference of the IEEE Computer and Communications Society (Cat. No. 01CH37213), IEEE, pp 743–749. https://doi.org/10.1109/INFCOM.2001.916263
64. (1995) Token bucket algorithm for network. https://en.wikipedia.org/wiki/Token_bucket
65. Jararweh Y, Al-Ayyoub M, Benkhelifa E et al (2015) Sdiot: a software defined based internet of things framework. J Ambient Intell Humaniz Comput 6(4):453–461. https://doi.org/10.1007/s12652-015-0290-y
66. Begen AC, Altunbasak Y, Ergun O et al (2005) Multi-path selection for multiple description video streaming over overlay networks. Signal Processing: Image Communication 20(1):39–60. https://doi.org/10.1016/j.image.2004.09.002
67. Sidhu D, Nair R, Abdallah S (1991) Finding disjoint paths in networks. In: Proceedings of the conference on Communications architecture & protocols, pp 43–51. https://doi.org/10.1145/115994.115998
68. Liu X, Wang Y, Liu Y (2020) Qfr: A qoe-driven fine-grained routing scheme for virtual reality video streaming over sdn. In: 2020 IEEE Wireless Communications and Networking Conference (WCNC), IEEE, pp 1–6
69. Zou F, Wang Y, Liu Y (2021) A multipath routing approach for tile-based virtual reality video streaming based on sdn. In: 2021 IEEE 45th Annual Computers, Software, and Applications Conference (COMPSAC), IEEE, pp 560–565
70. Thinh PH, Dat NT, Nam PN et al (2020) An efficient qoe-aware http adaptive streaming over software defined networking. Mobile Networks and Applications 25(5):2024–2036
71. Kalan RS, Sayit M (2021) Sdn assisted codec, path and quality selection for http adaptive streaming. IEEE Access 9:129917–129932
72. Parameshachari B, Gurumoorthy S, Frnda J et al (2022) Cognitive linear discriminant regression computing technique for http video services in sdn networks. Soft Comput 26(2):621–633
73. Majdabadi RH, Wang M, Rakai L (2022) Soda-stream: Sdn optimization for enhancing qoe in dash streaming. In: NOMS 2022-2022 IEEE/IFIP Network Operations and Management Symposium, IEEE, pp 1–5
74. Liu Y, Liu J, Argyriou A et al (2018) 3dqoe-oriented and energy-efficient 2d plus depth based 3d video streaming over centrally controlled networks. IEEE Trans Multimedia 20(9):2439–2453
75. Zhou P, Xie Y, Niu B et al (2020) Qoe-aware 3d video streaming via deep reinforcement learning in software defined networking enabled mobile edge computing. IEEE Transactions on Network Science and Engineering 8(1):419–433
76. Taha M, Canovas A, Lloret J et al (2021) A qoe adaptive management system for high definition video streaming over wireless networks. Telecommun Syst 77:63–81
77. Skorin-Kapov L, Varela M, Hoßfeld T et al (2018) A survey of emerging concepts and challenges for qoe management of multimedia services. ACM Transactions on Multimedia Computing, Communications, and Applications (TOMM) 14(2s):1–29
78. Taha M, Ali A, Lloret J et al (2021) An automated model for the assessment of qoe of adaptive video streaming over wireless networks. Multimed Tools Appl 80(17):26833–26854
79. Multiple-Description Coding(MDC) AV (2005) Network working group, july 2005. https://www.opennetworking.org/wp-content/uploads/2013/02/TR_SDN_ARCH_1.0_06062014.pdf
80. (1990) Content delivery network. https://en.wikipedia.org/wiki/Content_delivery_network

P. Suguna is a Research Scholar in the Department of Computer Science and Engineering at NIT, Tiruchirappalli. She completed her degree in Computer Science and Engineering from Jayam College Of Engineering and Technology, Periyar University, Tamilnadu in 2003 and M.E. in Computer Science & Engineering from Annamalai University, Chidambaram, Tamilnadu in 2005. She has 6 years of teaching experience. Her teaching and research interest includes Graphics and Multimedia, Computer Networks, Software Defined Networks, etc.

R. Leela Velusamy obtained her degree in Electronics and Communication Engineering in 1986 from REC Tiruchirappalli, and a Postgraduate degree in Computer science and engineering in 1989 from REC Tiruchirappalli. She was awarded Ph.D. degree from the NIT Tiruchirappalli, in 2010. Since 1989, she has been in the teaching profession and currently, she is a Professor in the Department of CSE, NIT Tiruchirappalli, Tamil Nadu, India. Her research interests include QoS routing, Ad hoc and Wireless Sensor Networks, Internet of Things, Social Networks, and Digital forensics.