International Journal of Computer Networks and Applications (IJCNA)
DOI: 10.22247/ijcna/2021/209984 Volume 8, Issue 5, September – October (2021)

RESEARCH ARTICLE

Dynamic Path Selection Based Video Transmission in User Preference Assisted Adaptive Rate Control in 5G Multi-RAT Network

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Received: 23 July 2021 / Revised: 28 August 2021 / Accepted: 31 August 2021 / Published: 27 October 2021

Abstract – 5G mobile users consume a large amount of video content. Providing high-quality video to mobile users via a single path is a challenging task. It takes much time to transmit the video. In this paper, we proposed dynamic path selection-based video transmission is proposed for a 5G multi-RAT network. In our proposed system has four consecutive processes, which are discussed as follows: (1) Optimal access point selection which is done by Red Deer Algorithm (RDA) that selects optimal access point by considering data rate, Signal to Inference Noise Ratio (SINR) and Received Signal Strength Indicator(RSSI) to achieve better Quality of Experience (QoE). (2) Adaptive Video Encoding, for this purpose, we useH.265 encoding algorithm, which encodes the video packets in order to reduce transmission time and bandwidth consumption, here bit rate is adaptively controlled using the SARSA reinforcement algorithm, by considering the network environment factors (bit error rate, attenuation, bandwidth, throughput, and SNR) and user preference factors (high/low quality and processing speed). In this stage, the SWARA decision-making algorithm is used to select optimal QP parameters for each video packet, which considers three parameters: distortion, previous QP value, and CSI, which improves the quality of the video. (3). Dynamic path selection is made using the Deng-based Type 2 Fuzzy algorithm (Deng-T2F), which selects the optimal path between source and destination based on the following parameters: the number of hops, link stability, and buffer size increases high throughput and reduce transmission delay. (4). Adaptive Buffer Management is proposed for reducing latency during video transmission. The Adaptive Pre-order Deficit Round Robin (ADPDRR) algorithm is used to evaluate the parameters of layer information, deadline, packet size, and arrival time to reduce packet loss and packet waiting time during video transmission. The proposed APDRR algorithm maintains three queues based on the packet priority, and then the prioritized packets are transmitted adaptively to reduce the packet waiting time. Finally, simulation is conducted using an NS-3.26 network simulator that evaluates the performance based on the following metrics: PSNR, MoS, bandwidth utilization, jitter, Throughput, Delay, Packet drop rate, and Goodput.

Index Terms – Dynamic Path Selection, 5G-Multi-RAT, Red Deer Algorithm, SARSA, SWARA Decision Making, Adaptive Buffer Management.

1. INTRODUCTION

The fifth-generation (5G) wireless networks are intended to support numerous multimedia services such as real-time video monitoring, vision-based intelligent services, and more. Video transmission has attained greater importance among those services because of video application development and user Quality of Experience (QoE) requirements. Indeed, 5G wireless networks are aimed to support the multi-radio access technology (multi-RAT) to provide high capacity, better QoE, and low latency [1].

In a 5G multi-RAT network, the best access point selection process is a highly significant one. Since for best selection of the RAT provides the better connectivity of each user via the best serving RAT network. The author has introduced the RAT selection mechanism where the user selects the best RAT service based on the user and network-based parameters [2]. Video encoding is one of the significant processing the transmission of video in the 5G network. The video encoding is subjected to improve the video quality during the transmission [3].

Generally, the H.264 algorithm encodes the video packets before transmitting them to the destination. This paper also discussed the adjustment of the encoding parameters to get better video quality during the transmission. In recent years, many video industry developments have advanced video encoding used for video compression, recording, and distribution. It can support 8K UHD resolution. The authors adaptively controlled the bit rate of the encoding algorithm to enhance the quality of the video [4]-[7]. The best path between source and destination is essential to achieve the low packet loss rate during the video transmission in the cross-layer-based network. During video transmission, single path selection leads to poor reliability and high traffic in the network. That is why the multi-path section was introduced, which reduces network traffic and latency [8].

The authors [9-13] introduced a path selection mechanism where the data priority is estimated before transmitted data to the destination. A buffer management process has emerged and generally controlled the buffered by scheduling the data present in the buffer to reduce the latency and packet losses during the video transmission. Scheduling of the video packet in the buffer reduces the delay incurred during the video transmission. The authors in [14] have introduced the QoE aware scheduling in cross-layer-based wireless networks. Here, the scheduling process is achieved by the maximum buffer filling algorithm by considering the QoE constraints [15]. There have been many issues in video transmission in 5G multi-RAT-based wireless networks that are discussed as follows: The 5G wireless networks tempt multi-path fading issues, thus increasing the interference between the wireless nodes in the network. Besides, there exists time-varying nature in channel characteristics.

Further, reducing the latency during the video transmission is also a big issue in 5G network. In a 5G multi-RAT network, improving user service performance is challenging due to difficulties in optimal RAT selection. These issues reduce the video quality, increases the packet loss rate and delay during the video transmission.

1.1. Motivations and Contributions

Our main aim is to design the cross-layer with adaptive rate control in the video transmission in the 5G multi-RAT wireless networks. This paper scope is to reduce the packet loss rate, delay and improve the QoE performance during video transmission in the cross layer-based network. The objective of our proposed work is discussed as follows:

- To provide the best QoE performance during the video transmission via selecting the optimal access point in 5G multi-RAT networks.
- To enhance the video encoding performance by performing the adaptive rate control mechanism to increases the video quality.
- To manage the buffer of the 5G wireless device to reduce the latency during the video transmission.
- To schedule the packet adaptively using the effective scheduling algorithm in the 5G wireless networks.

A dynamic path selection-based video transmission is proposed in this paper. We used an adaptive rate control mechanism to enhance the performance of the video encoding. In our work, buffer management is proposed to reduce latency. The significant contribution of this research is discussed as follows:

- In this proposed system, we have selected the best RAT network using the Red Deer Algorithm, one of the significant heuristic algorithms. It establishes the best RAT network for video transmission. We used the RTP protocol for video transmission, which increases QoE results and PSNR performance and avoids packet loss.
- In this research, we have utilized the H.265 encoding algorithm where we adaptively change the bit rate and QP value parameters effectually using environmental factors such as attenuation, SNR, throughput, bandwidth, and bit error rate information. This increases the quality of the video and PSNR performance.
- We have selected the optimal QP value based on the decision-making algorithm by considering the significant features such as distortion, previous QP, and CSI. This increases the QoE performance.
- In our work, we have selected the optimal path between the source and destination with the aid of the Deng-T2F algorithm. Hence, our work has a high delay and packet loss rate, and we have prioritized the packets using the PDRR algorithm where it monitors the three different queues based on the video traffic.
- This study presents multiple links to transmit the encoded videos into the multi-path to the destination. Hence, our work doesn't face any packet overhead and delay during transmission.

The performance of the proposed system is measured in terms of PSNR, MoS, Throughput, Delay, Packet drop rate, and Goodput concerning the number of devices.

1.2. Paper Organization

The rest of this paper structure is discussed as follows; section 2 describes the related work and its limitations.

Section 3 explains the problem statements which are existed in previous works. In section 4 provides the proposed system methodology with algorithm and pseudocode. Section 5 presents the experimental validation of the proposed system, and it is compared to the existing system for different metrics. Finally, it proves that the proposed method achieves better performance than the current system. Section 6 concludes the research work.

2. RELATED WORK

In paper [16] proposed ultra HD-based video streaming in the 5G networks. In this paper, the path is investigated between the source and the destination to reduce packet loss. For this purpose, it estimates the congestion index between the source and destination along the available path. During congestion index estimation, it estimates both the measured congestion index between sender and receiver and also the expected congestion index between sender and receiver. Based on the estimated congestion index, it performs the video streaming process between source and destination. Limitation: During path selection, the congestion index alone considers thus tends to induce high packet losses and delay during the video transmission.

The authors in this paper [17] proposed the two-sided matching algorithm in the 5G multi-RAT network. Here, the user selects the best RAT network for their association with the 5G multi-RAT network. For this purpose, this paper proposed the matching theory algorithm, which is the stable matching algorithm. It estimates the utility function for the candidate access points. And, then it selects one RAT network based on the estimated utility function. The utility function is evaluated based on the SINR and RSSI factors. By considering these factors, each user in the network selects the optimal access point. In paper [18] proposed radio access technology-based communication in 5G network. In this, paper the user selects the best radio access network to gather better communication performance in the 5G network. For this paper, this paper considered the two different criteria that are network and user-based parameters. Here, the user criteria are jitter delay and packet loss rate. And then, network parameters are considered as the data rate and received signal strength information.

The authors in this paper [19] introduced the video encoding procedures in the 5G cellular networks. The main objective of this paper is to provide high QoE to the user requesting the video service. Here, the encoding is performed using the H.264 encoding algorithm. Here, the user request is processed with the aid of the 5G base station, which transmits the request to the service provider to provide the requested video service to the user. During video encoding, this paper adjusted the encoding parameters such as QP and frame rate. In paper [20], the novel rate control mechanism is applied to the multi-view-based video encoding model. Here, the high efficiency-based video coding model is utilized where the bit rate is adaptively controlled. It is achieved through the multi-objective-based optimization algorithm. The bit rate control also controls the layer rate during the video encoding process, such as frame and view parameters. Here, the similarities between the different frames are considered for the adaptive rate control process. Limitation: The highly significant network environment factors (SNR, throughput) are not considered during the video encoding process, thus affects the video quality during the transmission processes.

In paper [21] proposes the priorities aware data scheduling to provide multimedia services. Here, the Multi Path-based TCP protocol is utilized to transmit the prioritized packet to the destination without any loss. Here, the priority is allocated for each data to be processed. Based on the preference of the data, this paper performs routing in wireless networks. In this, the multi-attribute-based multi-path is selected to transmit the multimedia data to the end-user.

In paper [22], video delivery is optimized in the wireless networks in the cross-layer-based mechanism. This paper performs the video delivery based on the two different techniques that are scheduling the transmission and future capacity variations. This paper mainly aims to avoid the re-buffering during the video delivery in the wireless networks. Here, the receiver buffer capacity is considered afore to the video transmission. It schedules the video packets by considering the status of the buffer.

In paper [23] proposed the QoE-based scheduling process is based on the video delivery-based wireless networks. For the scheduling purpose, this paper utilized the maximum buffer filling algorithm. Here, the buffer scheduling process is performed based on the channel quality index. In this, the channel quality index is measured from the wireless networks. This constraint also considers the current buffer capacity to schedule the packets in each device that exists in the wireless network. Limitation: The video transmitted over HTTP doesn't provide optimal results on the receiver end. Hence, this paper has fewer QoE results and video quality.

In paper [24] proposed adaptive bitrate-based video transmission using the cross-layer network. Video transmission path selected based on QoS awareness, end-to-end delay, and so on. The proposed multi-hop cognitive radio network environment does not have an administrator to control the network communication. The proposed system used an on-demand routing protocol for video transmission. The proposed system network has multiple channels with different service rates; hence it has much traffic. This research has two parameters, queuing delay and service delay, to measure one-hop delay. Finally, end-to-end delay calculates between the path of source and destination. The best approach is selected based on the threshold value. In paper [25] proposed video retrieval using cache d2d communication network. The proposed system has two phases such as cache placement phase and the content retrieval phase. In the cache placement phase, the probability of caching requested is adopted for every D2D user. First, check the self-caching stage in the content retrieval system and then check near the D2D cache. The proposed method used two content retrieval schemes: select the nearest D2D pair and selected the closest D2D pair with content caching. These schemes are used to improve the probability success rate.

In paper [26] performs video transmission for DASH. The proposed system used two-hybrid analog and digital video transmission methods for DASH, and three ways are used to enhance the user's QoS performance. Energy-aware recombination algorithm is used for given importance for video quality, and h.264 algorithms are used for video encoding. The adaptive bitrate allocation method is used for changing the bitrate adaptively, which improves the video quality and bandwidth consumption. And last retransmission method is used to find the problem of decoding and receiving due to channel errors in paper [27] proposed cross-layer optimization-based video transmission in a wireless mesh network using MDC. The first process has split the videos into several sequences, which improves video quality. The second process is selecting multiple paths by using the AOMDV protocol. The following process is congestion monitoring which is monitored by using hello packets and stored in the routing table. Based on congestion monitoring, two hops are selected for transmitting video. Finally, the video packets are decoded by the MDC stream merger. The performance of the proposed system is evaluated in terms of QoS, PSNR, and frame delay.

3. PROBLEM STATEMENT

Transmitting video over the wireless network is a challenging task. Because the wireless network has multi-path fading and interference issues that tend to reduce video quality, packet losses, and delay during video transmission. Most of the works have utilized H.264 to encode the video packets. However, these methods consume more bandwidth and require high processing power. This introduces difficulties during video transmission. In the wireless network, video packet is transmitted through the air medium, which is highly affected by the network environment factors such as bit error rate, SINR, and more. These network environment factors affect video transmission significantly, such as quality reduction and packet losses. However, most of the works don't utilize network environmental and user preference factors for video transmission. This reduces the QoE performance and also video quality. This paper [28] proposes video data transmission in cross-layer-based wireless networks. This paper concentrates on the bit rate adaptation and error control mechanisms. The major problem of this research is discussed as follows:

- Here, the lower and upper limit values of QP is adaptively changed between 23 and 51. However, the lower the QP value (<23) provides high-quality video during transmission. Since the QP value starts from 0 to 51, the lower QP value offers better video quality during transmission. This degrades the high QoE performance in video transmission in cross-layer-based wireless networks.
- The video packets have different priorities; however, this paper doesn't schedule the video packets with an effective mechanism as it delivers packets one by another without considering their importance. Thus tends to increase in the delay during the video transmission.
- The bit rate is adaptively controlled without considering the strong network environment characteristics. Since the network environment parameters (attenuation, bandwidth) significantly affect the video transmission, thus results in a high packet loss rate.

In this paper [29], proposed partially reliable transfer-based high definition video is streamed in wireless networks. The main problem of this paper is listed below,

- This paper follows the partial reliability-based video transfer to satisfy the high retransmission behavior of the sender node. However, partial reliability-based video transfer leads to ineffective results in better QoE performance, i.e., low video quality score, high Mean of Score (MoS), and low Peak Signal Noise Ratio (PSNR).
- This paper controls the buffer by dropping the common priority packets via executing the high proactive substitution methods. Thus tends to increase the packet loss rate for the low-priority video packets.
- This paper uses the UDP protocol for video transfer; however, it is highly suitable for the best effort packets. Hence, it is not apt for the video transmission that tends to increase the packet loss rate.

The authors of this paper [30] proposed multipath-based concurrent video streaming over 5G networks. The main problem of this paper is listed as follows,

- This paper doesn't select the optimal RAT network to provide better QoE performance in the video transmission. Since it frequently uses cellular and wifi network during video transmission for two different paths, respectively. However, high QoE requires users may use the wifi network, thus resulting in poor QoE results.
- Here, H.264 encoding scheme is used where the QP and bit rate are not adaptively changed based on the essential

factors. This affects the quality of the video and results in low PSNR.

- Even though this paper reduces the delay during the multi-path selection, it doesn't provide an optimal path for video transmission. Hence, this paper doesn't consider the link stability, number of hops, and buffer size. This results in more packet losses during the video transmission in the 5G multi-RAT network.

The authors of this paper [31] introduced the preference-aware multi-path video streaming over the MPTCP. The problems of this paper are discussed as follows:

- Here, the two links are utilized to perform multi-path video streaming in wireless networks. However, the second link is used less and doesn't able to transmit the high-quality level videos. This results in high packet overhead and also increases the delay during the video transmission. Since all video chunks are most of the time transmit through link 1.
- This paper utilized the available path to send the video packet, thus increasing the packet loss rate. Since the path with higher delay and worst channel conditions affects the video transmission.
- The proposed H.264 encoder doesn't provide better performance under the high-resolution video. Thus reduces the QoE during the video transmission over wireless networks.

4. PROPOSED METHODOLOGY

Our work has overwhelmed the problems encountered in the existing video transmission in the 5G multi-RAT wireless network. Our cross-layer-based 5G multi-RAT network comprises a 5G base station, LTE access point, WiMAX access point, wifi access points, and 5G wireless devices shown in figure 2. We have utilized the RTP protocol for our video transmission in cross-layer-based 5G multi-RAT wireless networks. In our work, we have concentrated on four different processes such as

1. Optimal access point selection,
2. Adaptive video encoding,
3. Dynamic path selection
4. Adaptive buffer management.

4.1. Optimal Access Point Selection

In our work, each user in the network selects the optimal access point to attain the better QoE performance in the 5G multi-RAT wireless network. For this purpose, we have employed Red Deer Algorithm (RDA). One optimization algorithm selects the optimal access point through three significant parameters the data rate, Signal to Interference Noise Ratio (SINR), and Received Signal Strength Indicator (RSSI). With the aid of these parameters, RDA selects the optimal access point for each user in the network. SINR is an important metric for evaluating the quality of the connection, which improves transmission data rate. If the AP provides the highest SINR for a user, then the user is present in the AP coverage area.

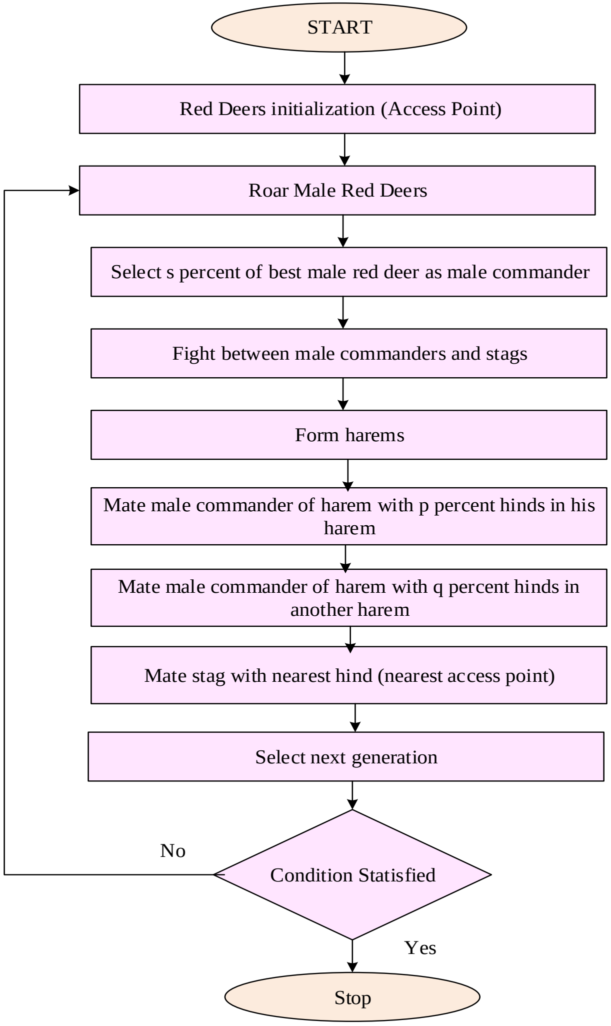

Figure 1 Red Deer Algorithm

For each user selection of the optimal access point in the network, that we used Red Deer Algorithm. In first, we initialize the random population of the access points. Several best RDs among the people are selected and which is called male RD (Access Point). After initializing the searching process in this stage, the algorithm performs a local search to choose optimal access points that consider data rate parameters, Signal to Interference Noise Ratio (SINR), and Received Signal Strength Indicator (RSSI). Based on these parameters, the optimal access point is selected. If selected optimal access point, the process will stop; otherwise, go to step2. These selection processes are shown in Figure 1.

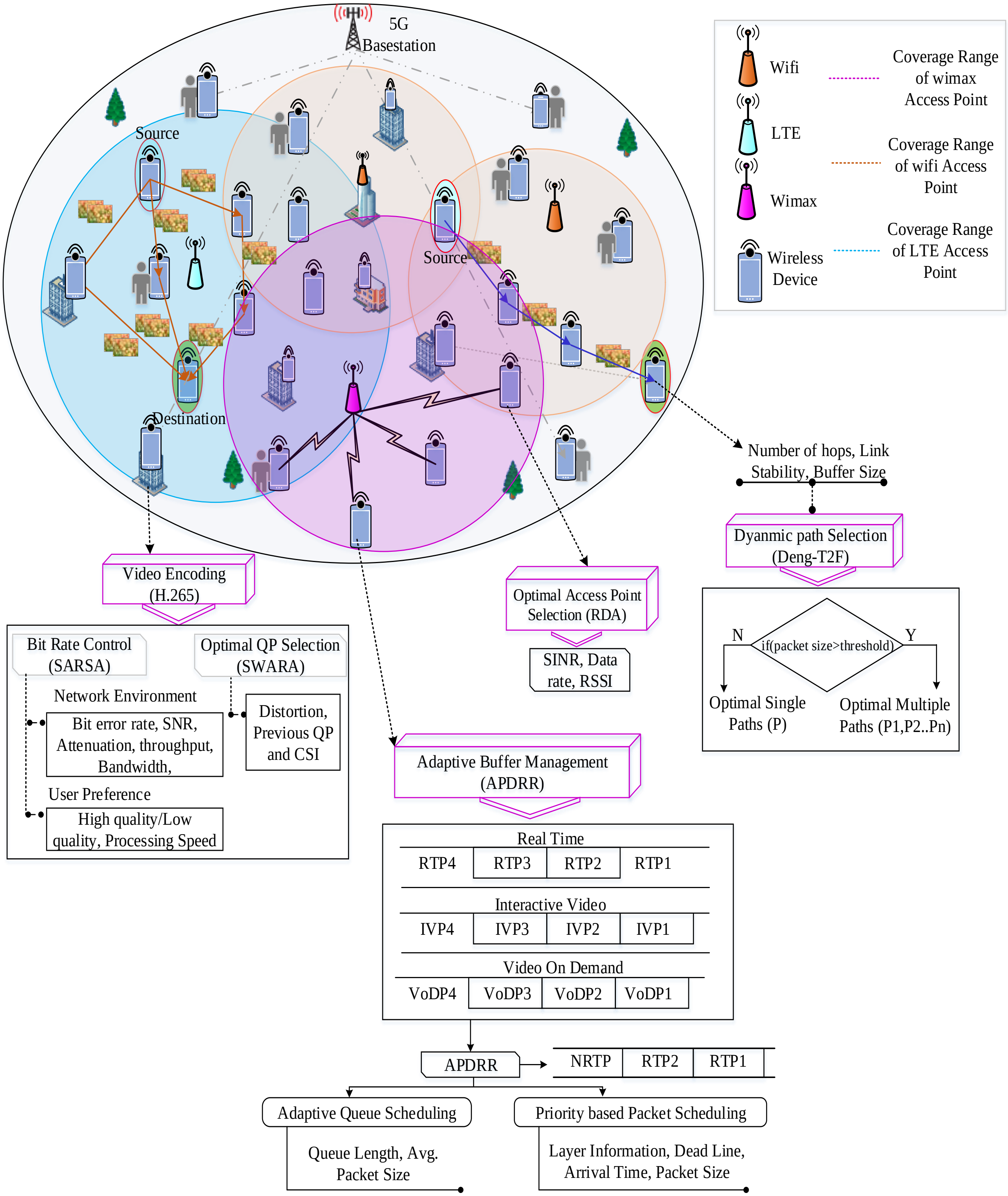

Figure 2 Proposed System Architecture

4.1.1. Definition (SINR)

It represents the power of particular signal interest is divided by the total amount of inference power and noise, which is used to measure the quality of the channel

$$SINR = \frac{Power}{Inferecne + noise} \quad (1)$$

4.1.2. Definition (RSSI)

An RSSI stands for Received Signal Strength Indicator, which is used to measure the power level of the user device received from the access point, including noise and interference.

$$RSSI\ = \text{Ŋ} + \bar{\text{I}} + \text{Ś} \quad (2)$$

Where Ŋ represents noise and Ī represents interference power, and Ś represents serving cell power.

4.1.3. Definition (Data Rate)

It represents the speed of data transmitted between the user equipment and access points at a particular time. The data rate is measured for video files in terms of bits per second.

$$DR = 2 \times BW \times log_2 L \quad (3)$$

Where DR represents data rate, and BW means bandwidth.

4.2. Adaptive Video Encoding

We have performed an adaptive rate control mechanism in the video encoding process. In this process, we adaptively controlled the bit rate and QP parameter of the video encoder. In our work, we have utilized the H.265 encoding algorithm for encoding the video packets. The proposed encoding algorithm has high error resilience and consumes less bandwidth during the encoding process. It provides high-quality video transmission at a different resolution. H.265 utilizes half of the bandwidth of H.264 with the same quality of the video. It offers high-resolution video (8K UHD). The benefits of H.265 is defined as follows,

- It has superior compression performance and low bandwidth consumption.
- To maintain the same quality, H.265 saves 50% of the bit rate when compared to H.264.

The first process of H.265 video encoding is to split the pictures into the number of block regions that are used for predicting intra picture. It is used to show the information of the picture. After completing this process, the picture will go for loop filter, and the final picture is stored in decoded picture buffer. These encoding processes are shown in Figure 3.

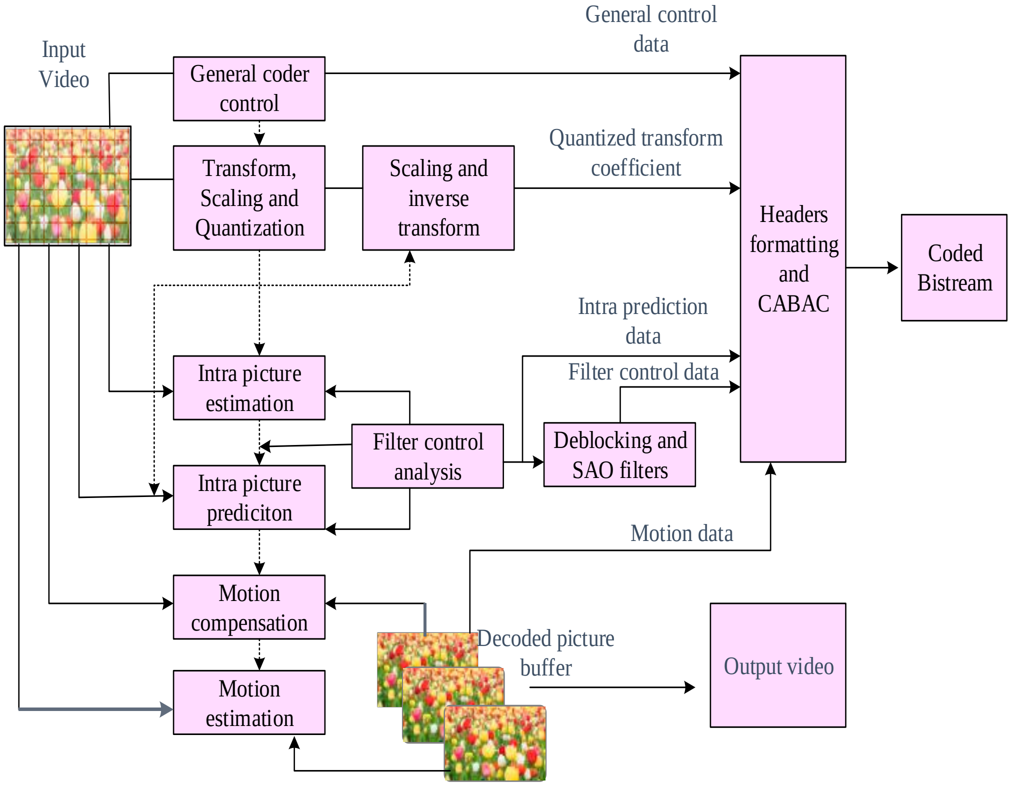

Figure 3 Block Diagram of H.265 Video Encoding Algorithm

In our proposed system the bit rate is adaptively controlled using the SARSA reinforcement algorithm. Here, the bit rate is controlled by considering the network environmental factors and the user preference factors. The network environment factors are bit error rate, attenuation, bandwidth, throughput, and Signal to Noise Ratio (SNR). And, the user preference factors are high quality/low quality and processing speed of the user device.

```
$E - episode, st - State, ac - Action\ re - Reward$
$Initialize\ Q(st, ac), \forall st \in St, ac \in Ac(st) arbitarily$
Repeat for each E:
Initialize St
Select Ac from St using policy derived from Q
Repeat for each E:
Take action Ac, observe re, $St'$
Select $Ac'\ from\ St'\ using\ policy\ drived\ from$ Q
$Q(St, Ac) \leftarrow Q(St, Ac) + \alpha[re + \gamma Q(St', Ac') - Q(St, Ac)]$ (4)
$St \leftarrow St'; Ac \leftarrow Ac'$ (5)
Until St is terminal
```

Pseudocode 1 SARSA Algorithm

Description of pseudocode 1 SARSA reinforcement learning learns the environment automatically and updates the state and reward based on that action; for that purpose, we use this algorithm for adaptive bitrate control. The bit rate is adaptively changed based on that current action. It simplifies the overall workload and gives better results. In SARSA $Q(St, Ac)$ represents updates Q value, and $Q(St, Ac)$ describe as current Q value and $\alpha[re + \gamma Q(St', Ac')$Denotes target Q value and $Q(St, Ac)]$ represents the current Q value α represents the learning rate.

The optimal QP parameter for each video packet is selected using the SWARA decision-making algorithm. Here, the SWARA algorithm considers the three different parameters that are *distortion (d), previous QP value, and CSI.* SWARA algorithm used to select optimal QP parameter for each video packet based on the weight values. It computes the weight values for each parameter. The step of SWARA is defined as follows:

Step 1: All the parameters are sorted in a descending order based on their importance. (i.e.) the essential parameter listed as the first, second important parameter listed as second, and so on

Step 2: Begin from the second parameter, it expresses the relative parameter importance j compared to the previous parameter j-1, and this process for performing for every parameter which is known as average importanceA_j.

Step 3: Next process is to find the coefficient of the parameter, which is defined as follows,

$$C_j = \begin{cases} 1 & j = 1 \\ A_j + 1 & j > 1 \end{cases} \tag{6}$$

Step 4: Next process is to calculate the recalculated weighting of the parameter, which is defined as follows,

$$Rw_j = \begin{cases} 1 & j = 1 \\ \frac{y_j - 1}{c_j} & j > 1 \end{cases} \tag{7}$$

Step 5: Finally, weight is calculated for every parameter, which is defined as follows,

$$W_j = \frac{RW_j}{\sum RW_j} \tag{8}$$

These computations are shown in Table 1. This process will continuously run for each video packet. Hence our process will provide high-quality video.

Parameter	Average value importanc e	coefficient	Recalculated weight	Weight
D	0.15	1.15	0.130	0.310
QP	0.20	1.20	0.833	0.284
CSI	0.25	1.25	0.728	0.152

Table 1 Weight Calculation of SWARA Algorithm

Based on these above processes, our work encodes the packet effectually by considering both user preference and network environment factors. By performing a video encoding process based on these procedures enhance the video quality during the video transmission.

4.3. Dynamic Path Selection

If users in the 5G multi-RAT network require video packets, then it broadcast the video packet request along with its preference that needs to be in the transmitted video packet. 5G wireless device that receives the video request transmits the response to the destination device. After receiving the response from the multiple source devices, the destination device selects one response based on the Round Trip Time (RTT). Then, it transmits the acknowledgment to the selected source device. The source device selects the best path between the source and destination devices. For this purpose, we adopt the Deng-based Type 2 Fuzzy (Deng-T2F) algorithm. The parameters considered for the path selection are the number of hops, link stability, and buffer size. The type 2 fuzzy algorithm has four steps which are shown in Figure 4.

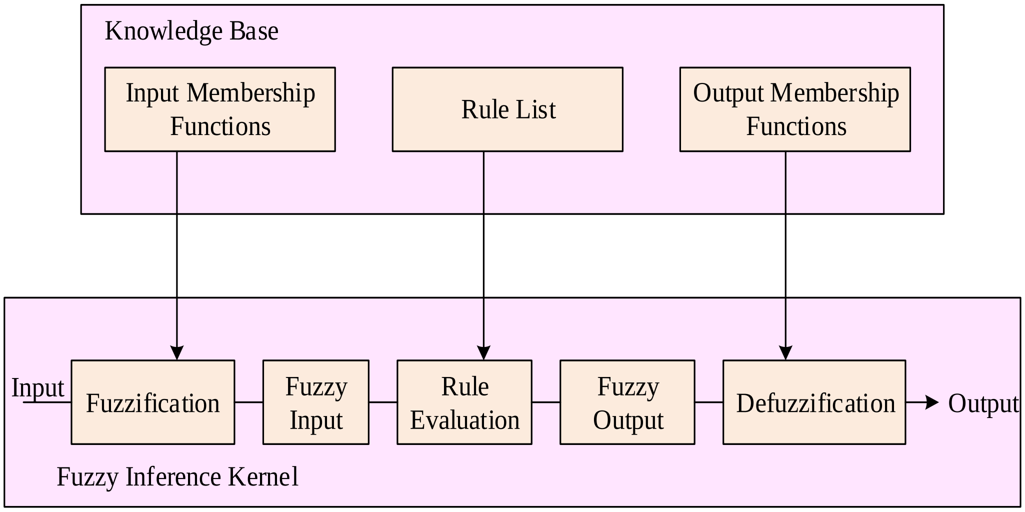

Figure 4 Process of T2F Algorithm

Figure 4 shows the process of type-2 fuzzy algorithm, which has two blocks as knowledge-based and fuzzy inference kernel block. Knowledge base inference has input member function, rule list, and output membership function. Input membership function represents the process of fuzzification, rule list represents the process of rule evaluation, and output membership function represents Defuzzification. The process id fuzzy is discussed as follows,

1. *Fuzzification:* It is the process of converting input value or fuzzy value into fuzzy sets.
2. *Inference:* This process is also called rule evaluation. The result of the fuzzification process is considered as input of the rule evaluation process. The fuzzy input sets are mapped into fuzzy output set by using the rule evaluation block.
3. *Aggregation:* In this process, the fuzzy sets representing every rule's output are combined into a single fuzzy set.
4. *Defuzzification*: It is the process of converting the fuzzy sets into input values. In the Deng-T2F algorithm, Deng entropy is utilized in the de-fuzzifier part of the T2F algorithm. It selects the best path after checking the threshold conditions. For packets with a size greater than the threshold, Deng sets the multiple paths between the source and destination. And for the packets which have a size less than the threshold, Deng selects the single path between source and destination.

$$E(M) = -\sum_{A\subseteq X} M(a)\log_2 \frac{M(a)}{2^{|a|}-1} \qquad (9)$$

DE (M) represents Deng entropy, and M(a) represents a mass function that is found based on the number of nodes and packet rate. If the hop number is high, then Deng can select multiple paths; otherwise, it specifies a single path between source and destination. In our proposed system, we used three fuzzy inputs (no. of hops, link stability, and buffer size) and the two outputs (single path, multiple paths), and if-then rules are computed for selecting an optimal path which is shown in Table 2.

No. of Hops	Link Stability	Buffer Size	Path Selection
High	high	Low	Multiple
Low	medium	Low	Single
Medium	medium	Medium	single
Low	high	High	single
High	medium	Low	multiple
Medium	high	Low	multiple
High	low	Low	multiple
Low	low	High	single
Medium	low	High	single

Table 2 Rules of Deng Based T2F Algorithm

4.3.1. Definition (No. of Hops)

Hops represent the intermediate node between the source and destination, which transmit the data from source to destination. If the hop count is low, then the Deng entropy selects a single path. Otherwise, it selects multiple paths to transmit the video.

4.3.2. Definition (Buffer Size)

Buffer size determined how many packets are under waiting for the process. If the buffer size is small, then Deng entropy considers as best for transmitting video.

4.3.3. Definition (Link Stability)

Link stability is used to measure the link stability between the hops which is used to select the optimal path to transmit the video. It is defined as follows,

$$L_s = \frac{R}{Dis(hm,hn)} \tag{10}$$

Where h represents, the hops between source to destination and R represents the range of communication.

4.4. Adaptive Buffer Management

We have proposed adaptive buffer management in the cross-layer-based 5G multi-RAT network to reduce the latency during video transmission. In each device buffer, we have to maintain three different queues that are real-time, interactive, and video on demand. Here, the Adaptive Pre-order Deficit Round Robin (APDRR) algorithm is utilized to maintain these three different queues which are entered into the preorder queuing block to determine the order of the packets around. The classifier is used to classify the packets into the high priority or low priority. Each queue prioritizes the received packet based on four different parameters: *layer information, deadline, packet size, and arrival time.* Packet timeslot value is also considered a forgiven priority; if the packet has less time, it will be executed first. It is calculated as follows,

$$T_i^n = T_i^{n-1} + \frac{S_i^n}{R_i} \tag{11}$$

Where, T_i^n Represent the timeslot of nth packet flows i after time t. S_i^n Represent the size of the nth packet flows i after time t. By substitute A_i^n for $T_i^n \times R_i$, which is defined as follows,

$$\frac{A_i^n}{Q_i} = \frac{A_i^n + S_i^n}{Q_i} \tag{12}$$

Where, A_i^n Denotes the increased amount of data; consider that total n packets can be transmitted in the jth round. Replace A_i^n with $D_i^0 - D_i^n$ which is defined as below,

$$\frac{D_i^n}{Q_i} = \frac{D_i^{n-1} - S_i^n}{Q_i} \tag{13}$$

Where D_i^n Represent the remaining flow of i in this round after sending the nth packet into the preorder queue block.

Our proposed APDRR algorithm performs the following three phases: packet pass, packet arrival, and packet departure. The packet pass is responsible for updating the deficit counter for every packet flow, and it also classifies the packets into the priority queue module from the inputs. Packet arrival time performs placement of arrival packets into corresponding input. Packet departure represents the starting of the new round. Once the packets are entered into the priority queue block, it picks them. It arranges them into a high priority to lower priority based on layer information, deadline, packet size, and arrival time. After prioritizing the packets in each queue, during the transmission, it transmits the packet adaptively to reduce the waiting time of the packet in queues. For this purpose, it considers the queue length and average packet size. These parameters monitor the queue and schedule the packet adaptively, reducing the packet waiting time and packet drops. Figure 5 represents the process of adaptive preorder deficit round robin. It has three inputs: real-time, interactive, video on demands, and video on demands given to the preorder queue. The classifier is used to classify the given packets into the high priority or low priority. After prioritizing, the packets are transmitted adaptively to reduce waiting time.

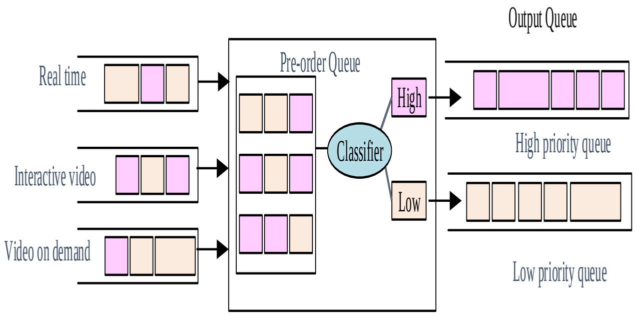

Figure 5 Adaptive -Preorder Deficit Round-Robin

5. EXPERIMENTAL STUDY

This section explains the simulation results with a detailed description of the simulation results. These include simulation setup, comparison study, and research summary for the proposed system than the existing system.

5.1. Simulation Setup

Network simulator NS3.26 is used to measure the performance of the proposed system. Hardware and software requirements are shown in table 3, Network parameters are shown in table 4, and simulation parameters are shown in table 5. NS3 has better functionalities of network and support all the specification of 5G network. The proposed dynamic path selection-based video transmission method is considered a 500m ×600m simulation environment for testing video transmission.

Software Specifications	Network Simulator	NS3.26
	OS	Ubuntu 14.04 LTS
Hardware specifications	Processor	Pentium Dual Core and Above
	RAM	4GB
	Hard Disk	60GB

Table 3 Software and Hardware Requirements

	Data Rate(mbps)	Delay(ms)	Jitter
LTE	2 to 100	50-300	3-12
Wi-Fi	2 to 90	50-250	2 to 12
Wi-Max	2 to 80	50-240	3 to 10

Table 4 Network Parameters of Access Points

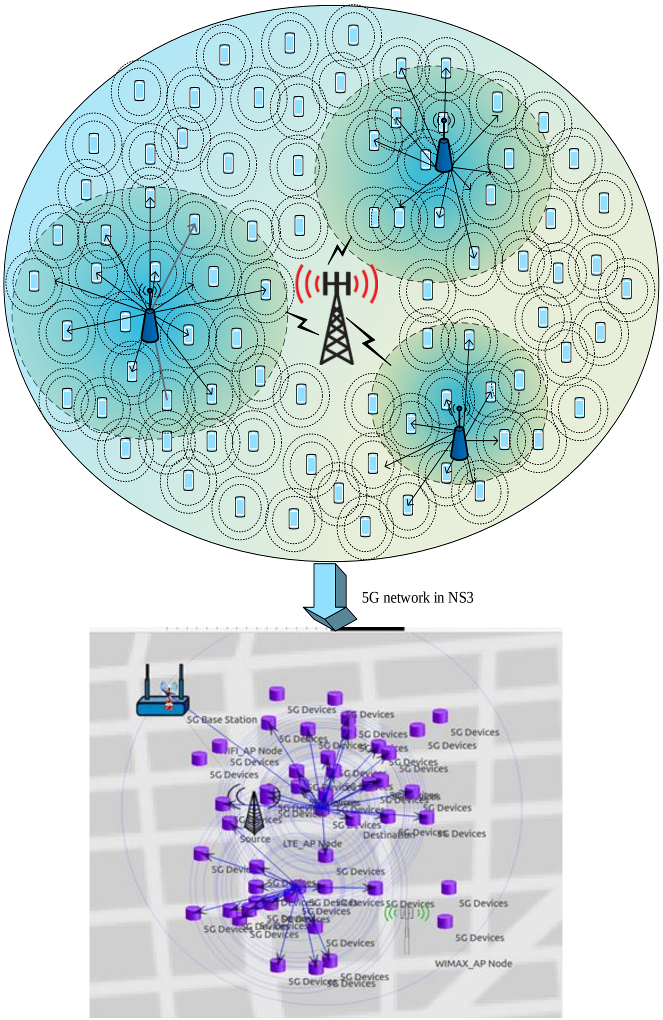

Figure 6 Simulation Environment

Figure 6 represent the testbed of the proposed dynamic path selection-based video transmission method, which has 50 5G devices, one base station, one wifi, one Wi-max, and one LTE access point. Our proposed system used an NS3.26 network simulator to evaluate video transmission performance in a 5G multi-RAT network. The simulation environment has two protocols, TCP and UDP, for video transmission in the 5G network.

Parameters	Description
Simulation area	500m*600m
Node speed (Max)	5m/s
Packet transmission rate	1024 bytes/packet
Number of nodes	50
No. of gateway and LTE	1
No. of wifi and Wi-max	1
Video format	H.265/HEVC
Round duration	20000ms
Simulation time	100000ms
Transmission range	250m
Number of flows	50
Node buffer size	64 packet (fixed)
No. of frames for each video	350
Traffic type	TCP, UDP
Duration for packets carrying	500 to 1000 ms
Neighbor nodes waiting time	300ms
Forwarding capacity	2Mbps
Propagation delay mode	Constant
Node mobility model	Random
Queue type	Priority-based queue
Nodes distribution	Random manner
Interface type	Physical wireless

Table 5 Parameters of Simulation and Description

5.2. Comparison Study

This section explains the evaluation of the proposed dynamic path selection-based video transmission method in different metrics. The proposed system is compared with the existing system. In particular, we consider the following metrics: bandwidth utilization vs. No of devices, delay vs. No. of devices, Goodput vs. No of devices, jitter vs. No of delay, MoS vs. No. of devices, Packet drop rate vs. No of devices, PSNR vs. No of devices, Throughput vs. No. of devices. Table 6 explains the comparison of technique topic and drawback of the existing systems.

5.2.1. Impact of Bandwidth Utilization

Bandwidth utilization represents that the percentage of bandwidth utilized from the total amount of bandwidth.

$$BU = Total\ bandwidth - Residual\ bandwidth \qquad (14)$$

Where BU denotes bandwidth utilization, the residual bandwidth subtracted from the total amount of bandwidth known as bandwidth utilization.

Figure 7 represents the comparison of proposed and existing system bandwidth utilization concerning the number of devices. The comparison result shows that the proposed system utilizes low bandwidth compared to existing systems. In our proposed approach, we used H.265 encoding algorithm for video encoding, which consumes less bandwidth during the encoding process. And we perform adaptive buffer management in which the packets are transmitted adaptively to reduce waiting time and reduce bandwidth utilization. The existing system does not perform buffer management. Hence many packets are waiting for transmission; it utilizes high bandwidth, which reduces the performance of the process.

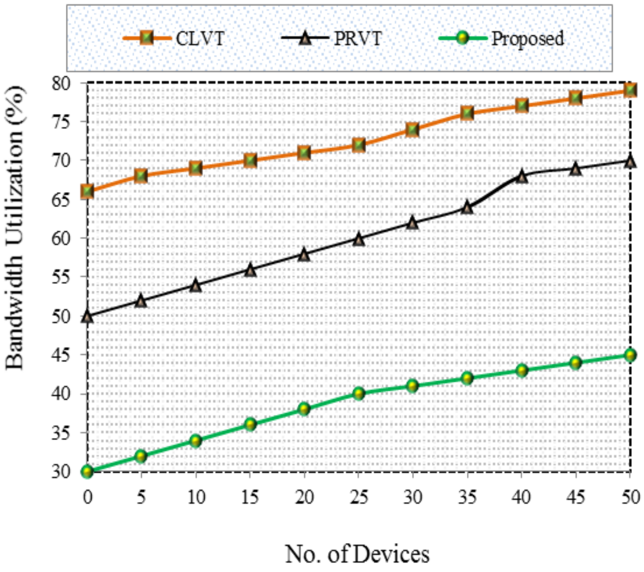

Figure 7 Bandwidth Utilization vs. No. of Devices

5.2.2. Impact of Delay

Delay represents how long time it takes to transmit the video from source to destination. In other words, the delay is representing as the system takes additional time to transmit the video than the expected time.

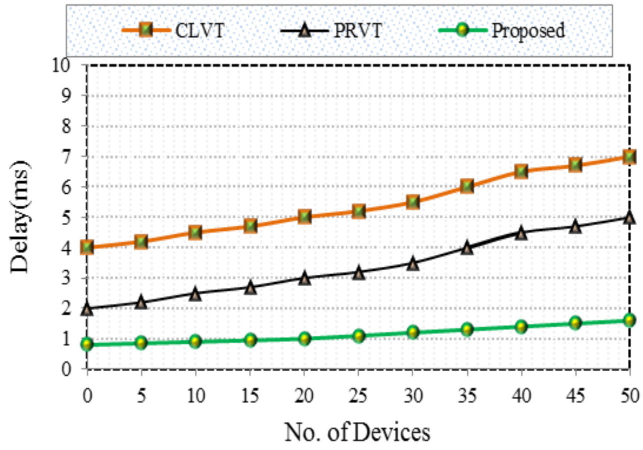

Figure 8 Delay vs. No. of Devices

Figure 8 represents the comparison of proposed and existing system delay concerning the number of devices, in which the uncertainty increases with the increases in the number of devices. Our proposed system selects multiple paths to transmit the video from source to destination, reducing the waiting time. And we perform adaptive buffer management for sending the packets adaptively, which reduces waiting time and delay. The comparison result shows that the proposed system achieves minor delay compared to existing systems.

5.2.3. Impact of Goodput

Goodput is defined as the application-based metric, the number of bits (relevant)delivered from source to destination in a particular time over the network. However, it suffers from three factors such as protocol overhead, high congestion, and retransmission of packets due to bit error (packet loss rate). Ex. If we transmit the video file to the user, the video size is divided by the transmission time.

$$Goodput = \frac{Video\ size}{Transmission\ time} \qquad (15)$$

Figure 9 represents the comparison of proposed and existing system Goodput for the number of devices. In which the Goodput is increasing with the increases in the number of devices. The graph shows that the proposed system achieves a high Goodput value compared to an existing design. In our proposed approach, we maintain buffer management that monitors congestion, and the packets are adaptively transmitted to the network, reducing the packet loss rate. Hence, our proposed system has a high Goodput value compared to existing systems like CLVT and PRVT.

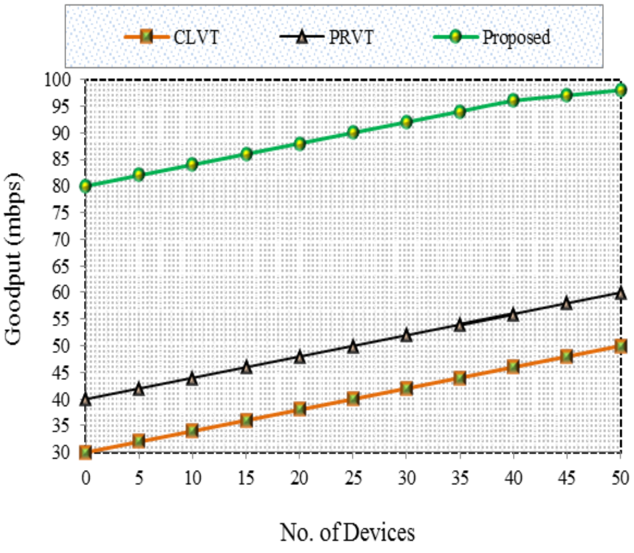

Figure 9 Goodput vs. No. of Devices

5.2.4. Impact of Jitter

Jitter is varied from a delay. It is used to measure the time difference between packet transmission and reception from source to destination.

$$Jitter = \tilde{\iota} - \dot{\rho} \qquad (16)$$

Where ĩ represents transmission time and ρ̇represents receiving time.

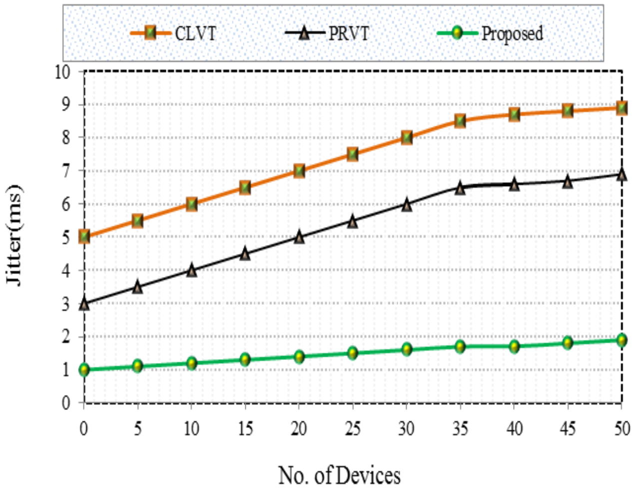

Figure 10 Jitter vs. No. of Devices

Figure 10 represents the comparison of proposed and existing system jitter concerning the number of devices. The comparison result shows that the proposed system achieves low jitter than the current systems because our proposed system selects multiple paths to transmit the video from source to destination; it reduces the transmission delay rather than choosing the single path. And we send the packets adaptively, which reduces waiting time and jitter.

5.2.5. Impact of MoS

It is used to measure the quality of the video packets. It is one of the essential QoE metrics which is calculated based on the user experience.

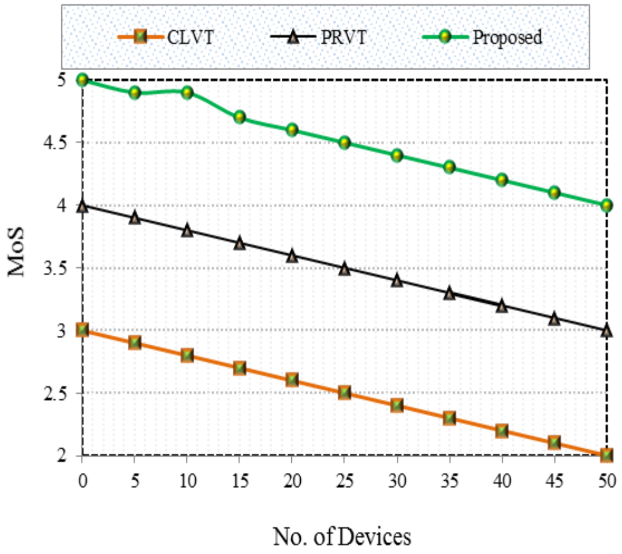

Figure 11 MoS vs. No. of Devices

Figure 11 represents the comparison of proposed and existing system MoS concerning the number of devices. In which the MoS is used to evaluate the efficiency of the proposed system. Here, we have used the H.265 encoding algorithm, which provides high-quality video even with many devices; hence we achieve high MoS compared to an existing system. The quality of the video is evaluated at the destination is given an acknowledgment to the source device to enhance the quality of video for the subsequent packet transmission.

5.2.6. Impact of Packet Drop Rate

It is used to measure the packet loss rate between source and destination during packet transmission. Packet drop rate is occurring due to congestion and inefficient path selection.

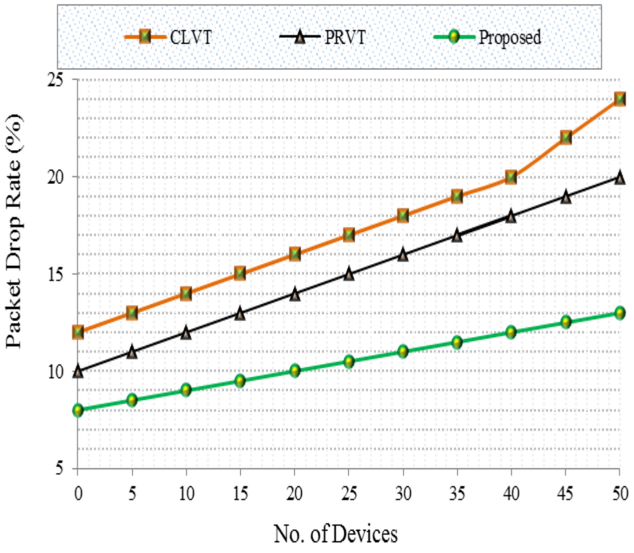

Figure 12 Packet Drop Rate vs. no. of Devices

Figure 12 represents the comparison of three methods, including the proposed method. It shows the comparison of packet drop rates concerning the number of devices. The main reason of packet drop is network congestion and buffer. Our system selects multiple paths to reduce waiting for time and congestion, which reduces packet drop rate. The packets are transmitted adaptively for reducing waiting ties, which also reduces the packet drop rate. The comparison result shows that the proposed system achieves less packet drop rate than existing systems like CLVT and PRVT.

5.2.7. Impact of PSNR

This metric is used to evaluate the quality of video compression. It is calculated the value of MSE between sending and receiving video packets. Figure 13 represents the comparison of proposed and existing PSNR for the number of devices. It means the proposed system achieved high PSNR compared to existing systems. We used the H.265 video encoding algorithm in our system, which provides high-quality video even to many devices. And multiple paths are selected for transmitting video that scheduled the packets based on their priority, thus increasing the quality of video and reducing packet loss rate, increasing the PSNR values compared to existing systems.

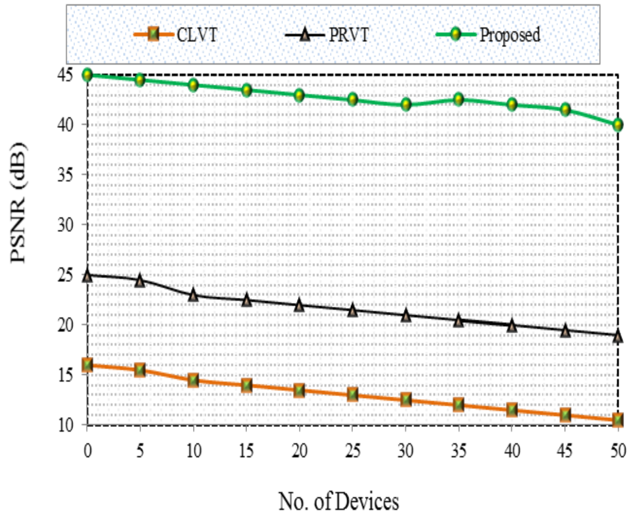

Figure 13 PSNR vs. No. of Devices

5.2.8. Impact of Throughput

It defined as the amount of successful video is transmitted from source to destination at a particular time over the network.

$$Throughput = \frac{ŋ̀}{Ţ} \qquad (17)$$

Where ŋ̀ represents the number of video packets is transmitted from source to destination. Ţ represents the time taken for transmitting the video over the network.

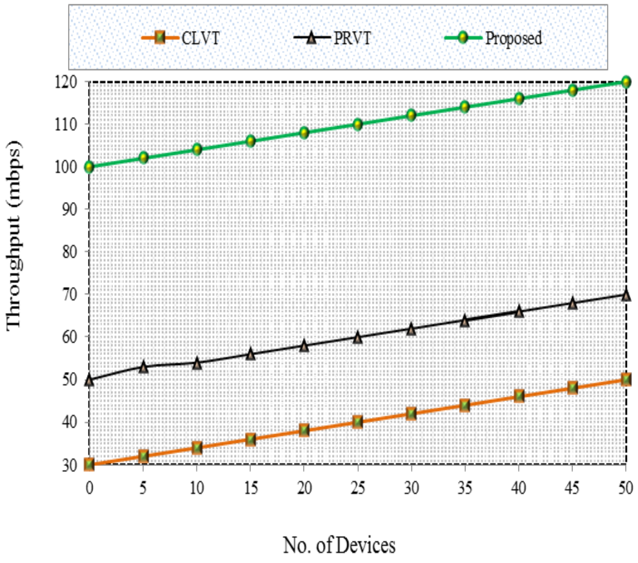

Figure 14 Throughput vs. No. of Devices

Figure 14 represents the comparison of proposed and existing system throughput to the number of devices. The comparison result shows that the proposed system achieves high throughput compared to a current system. Our proposed dynamic path scheduling-based video transmission method used the H.265 encoding algorithm to enhance video quality then transmitted via multi-path by using the Adaptive Pre-order Deficit Round Robin (APDRR) algorithm that sends the packets adaptively to reduce waiting time. Thus, our proposed system achieves high throughput than the existing system.

Technique	**Topic**	**Drawback**
CLVT[28]	Perform video transmission in the cross-layer-based wireless network. And it also concentrates adaptive bitrate control and error mechanisms	• It decreases the QoE performance in video transmission • High latency • High packet loss
PRVT[29]	Proposed partially reliable transfer based high definition video is streamed in wireless network	• Low video quality and PSNR • High packet loss • High (Mean of Score) MoS
MVS[30]	This paper proposed multi-path based video streaming in a 5G network	• Poor QoE performance • Low-quality video and low PSNR • High packet loss
PAMVS[31]	This paper introduced the preference aware multi-path video streaming over the MPTCP	• High packet overhead • High latency • Poor video quality and QoE results

Table 6 Drawbacks of Existing Systems

5.2.9. Research Summary

In this section, we summarize how the proposed system has improved superior performance compared to previous systems. Figure 7-14 describes the performance of the proposed system in terms of bandwidth utilization, delay, jitter, Goodput, PSNR, MoS, Packet drop rate, and throughput. Table 7 represents the comparison of the above performance metrics for both proposed and existing systems. Dynamic path selection and dynamic bitrate adaptation methods are used to transmit the video over a 5G network. The research highlights are discussed as follows,

- We have utilized the H.265 encoding algorithm in our work, which provides better video quality and consumes low bandwidth.
- In our work, we have adaptively changed the encoding parameters such as bit rate and QP. Here, the bit rate is adaptively changed by considering the network environmental factors such as attenuation, bit error rate, SNR, throughput, bandwidth. The adaptive bitrate control is performed with the aid of the SARSA algorithm, which provides better results in the video transmission with higher quality.
- We optimally select the QP parameter using the SWARA algorithm, which considers the three parameters that are distortion, CSI, and previous QP.
- We perform a dynamic path selection process with the aid of the Deng-T2F algorithm, which selects the single or multiple paths dynamically by considering the packet size threshold condition.
- We enhance the QoE performance through the optimal selection of the access point through the effective optimization algorithm RDA.

Metrics	CLVT	PRVT	Proposed
Bandwidth utilization (%)	72	60	40
Delay (ms)	5.5	4.3	1.14
Goodput(mbps)	40	50	89
Jitter(ms)	7.3	5.2	1.4
MoS	2.5	3.5	4.5
Packet drop rate (%)	17.2	15	10.5
PSNR(dB)	13	21	42
Throughput(mbps)	40	60	110

Table 7 Comparison of Proposed vs. Existing Systems

6. CONCLUSION

In this paper, dynamic path selection-based video transmission is proposed in a 5G multi-RAT environment. Firstly select an optimal access point; for that, we employ the Red Deer algorithm, which determines the access point based on data rate, SINR, and RSSI, and it also improves the performance of the QoE results. Secondly, video packets are encoded by using H.265 encoding algorithm, which consumes less bandwidth and produces high-quality video. During encoding, bit rates are adaptively changed using the SARSA reinforcement algorithm. The optimal QP parameter for each video packet is selected using the SWARA decision-making algorithm; performing video encoding based on this procedure enhances the video quality during video transmission. The third process is dynamic path selection which is done by using Deng-based type 2 fuzzy algorithm. The path is selected based on the threshold, if the packet size is less than the threshold, then Deng specifies a single path for video transmission, and the packet size is greater than the threshold. Deng selects multiple paths for video transmission. Finally, we perform adaptive buffer management for reducing the waiting time during transmission. We employ an adaptive preorder deficit round-robin algorithm that schedules the packets based on the priority and transmits the packets adaptively. This process is also used to reduce the packet drop rate. Simulation is conducted to evaluate the performance of the proposed system in terms of PSNR, MoS, throughput, delay, jitter, Goodput, packet drop rate, bandwidth utilization. We planned to include device-to-device communication to enhance video transmission quality over a 5G network in future work.

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RESEARCH ARTICLE

How to cite this article:

M. Muni Babu, R. Praveen Sam, P. Chenna Reddy, "Dynamic Path Selection Based Video Transmission in User Preference Assisted Adaptive Rate Control in 5G Multi-RAT Network", International Journal of Computer Networks and Applications (IJCNA), 8(5), PP: 507-523, 2021, DOI: 10.22247/ijcna/2021/209984.