ENHANCING MEDIA STREAMING IN WIRELESS NETWORKS USING IFW-CFH ALGORITHM

Satheesh Kumar NJ and Arun CH

(Received: 11-Mar.-2023, Revised: 13-Jun.-2023, Accepted: 11-Jul.-2023)

ABSTRACT

One of the major concerns for service providers and application developers is the Quality of Experience (QoE), where high traffic congestion on the Internet leads to the degradation of video quality. However, the effectiveness of video transmission is minimized due to the network based on packet loss, bandwidth and delay. Because of bandwidth limitations, the videos transmitted are obtained in low quality. Meanwhile, various outcomes, such as reduction in throughput, re-buffering or mosaic, are determined in packet loss which validated the video streaming obtained in reliable or unreliable modes. Therefore, this paper proposes an Improved Fuzzy Weighted queueing-based Crossover Fire Hawk (IFW-CFH) algorithm for effective real-time video transmission. The objective of the IFW-CFH approach is to reduce delay, packet loss and bandwidth to enhance the video quality via two key mechanisms; namely, congestion control mechanism as well as packet scheduling mechanism. During the generation of encoded video frames, the packaged packets to the local buffer are transmitted by the scheduler using our proposed IFW-CFH algorithm. Finally, experimentation is conducted and the results show that the proposed method minimized transmission delay, packet loss and bandwidth by 13.8% for effective real-time video transmission compared to the existing methods.

KEYWORDS

Video streaming, Fire hawk, Weighted queuing, Delay, Packet loss, Crossover, Transmission.

1. INTRODUCTION

Video streaming (VS) is defined as the transferring of video files continuously from a server to an applicant. VS authorizes users to watch online videos without downloading them. Video streaming over wireless networks is mandatory for several applications and a large number of systems are used in TV shows, movies and YouTube videos [1]. Video streaming is used to reduce memory storage and bandwidth requirements when storing and converting videos [2]. Video transmission in current networks is yet limited in terms of bandwidth and suffers from packet loss, depending on the streaming of videos, re-buffering and performance degradation, where such adverse factors are very detrimental to QoE [3].

Generally, two technologies are mainly used by video content providers, which are Moving Pictures Experts Group – Dynamic Adaptive Streaming over HTTP (MPEG-DASH) and WebRTC. MPEG-DASH is the latest streaming protocol established by the MPEG as a replacement for the HLS standard; the open-source standard of HLS is designed for video- and audio-like HLS. MPEG-DASH assists adaptive-bitrate streaming and allows users to obtain good-quality videos rather than handling their networks [4]. An open-source project is WebRTC, which provides streaming with real-time latency. Some of the most common consumer-facing applications of the day use WebRTC, such as Whatsapp, Google Meet and Messenger. What makes WebRTC unique is that it depends on peer-to-peer streaming, which is a preferable resolution when streaming needs low latency [5].

Nowadays, User Datagram Protocol (UDP) is the preferred option and considers latency to deliver video frames in an unreliable mode [6]. UDP is utilized to stream audio and video over Internet Protocol (IP). The Real-Time Protocol (RTP) has been expanded to real-time video streaming of broadcast transmission. The broadcast-transmission approaches contain two transport layer protocols which are Concurrent Multipath Transfer-Stream Control Transmission Protocol (CMT-SCTP) and Multipath Transmission Control Protocol (MPTCP). These protocols provide bandwidth, increase robustness, accelerate the process completion duration and reduce the usage of multipath context [7]-[8]. Due to the diverse routing paths, packets sent *via* several paths arrive at the receiver out of order, occupying buffer resources and causing Head of Line (HOL) blocking. HOL blocking improves the performance of

Satheesh Kumar NJ(Corresponding Author) and Arun CH are with Department of Computer Science, Nesamony Memorial Christian College (Affiliated to Manonmaniam Sundaranar University), Tamilnadu, India. Emails: njsdreams@gmail.com and dassarun@gmail.com

MPTCP, because rate rollback after packet-loss identification is not caused by network traffic, where the buffer allows the applicant to obtain data from multiple servers without affecting other streams [9]-[10]. The objective of the IFW-CFH approach is to minimize delay and packet loss and reduce the bandwidth in order to enhance the video quality *via* two diverse mechanisms; namely, congestion-control mechanism as well as packet-scheduling mechanism. The vital contribution is discussed in the following points:

- A novel IFW-CFH technique is proposed for effective real-time video transmission with high video quality, minimum transmission delay and minimum packet loss.
- The convergence accuracy and the convergence speed of Fire Hawk Optimizer (FHO) are enhanced by using both horizontal and vertical crossover strategies, thereby minimizing complexity.
- Congestion-control and packet-scheduling mechanisms are employed to attain a lower bandwidth and create an effective path diversity.
- Computing and investigating the efficiency of the IFW-CFH technique are based on bandwidth, transmission delay and packet loss.

The remainder of this article is organized as follows. Section 2 describes the related works of video streaming in wireless networks by various authors. Section 3 presents the system model. Section 4 explains the proposed methodology based on video streaming. The experimental analysis is discussed in Section 5. Finally, the conclusion of the article is illustrated in Section 6.

2. LITERATURE REVIEW

To stream high-quality video through various wireless access networks, Afzal et al. [11] developed a multipath MMT-based technique. MPEG, a media-transport protocol, was used in this method to stream the video in several paths and to assist this task, a Content-Aware and Path-Aware (CAPA) technique was employed. The ns-3 DCE with various multipath networks was utilized to experiment with the functioning of the suggested CAPA and the working of CAPA was examined over wireless lossy network conditions. This technique obtained video-quality improvement in comparison with a simple scheduling strategy of Evenly Splitting and Path-Aware strategy.

Taha et al. [12] established a Quality of Experience (QoE) adaptive management system to stream video *via* wireless networks in high definition. To manage the QoE of customers and optimize assessing, a smart algorithm for the service of video streaming was suggested in this paper. The suggested algorithm contains two methodologies; namely, predicting the QoE with the machine learning technique and outperforming the previously suggested methods by enhancing the quality of the video and obtaining significant bandwidth savings.

Guo et al. [13] employed Deep Reinforcement Learning (DRL) with transcoding at the network edge for Adaptive Bit-rate Streaming (ABS) in wireless networks. In this method, communication and joint computation were suggested for Adaptive Bitrate (ABR) streaming utilizing Mobile Edge Computing (MEC) in wireless channels with time variation. To assist the ABR streaming, a combined video-quality adaptation and framework transcoding was provided using a Radio Access Network (RAN) with computing ability. An automatic DRL algorithm was created to execute the video-quality adaptation and computational-resource assignment. The suggested DRL algorithm exhibited its superiority over other current methods and it was not an omnipotent one.

To attain secured energy-efficient video streaming, Zhang et al. [14] introduced the safe Deep Qlearning Network (DQN) technique in Unmanned Aerial Vehicles (UAV)-activated wireless networks. A secured and energy-saving video streaming-activated wireless network was studied in this article, where the safe-DQN was created with the Lyapunov function to solve the issue designed as a Constrained Markov Decision Process (CMDP), which proved superiority over other current techniques.

Jiao et al. [15] developed a Dynamic Cache and Resource Allocation (DCRA) to stream the video in Orthogonal-frequency-division Multiple Access (OFDMA) by cross-tier interference to overcome problems, such as wireless resource allocation, cache placement and video-layer selection. DCRA scheme was used to overcome stochastic-optimization issues by applying the Lyapunov optimization theory. The suggested DCRA scheme proved to be more effective for streaming scalable videos and better for maintaining cross-tier interference.

Duraimurugan and Jeyarin [16] joined together and employed distributed multimedia streaming in a heterogeneous wireless network (DMSHN) to expand the QoS. QoS played a major role in distributed multimedia streaming for transferring videos from the server to the applicant. Superior quality of service was needed to produce higher-resolution videos to attain superior quality video, packet loss and reduced latency. As a result, this suggested scheme provided a superior quality of service in DMSHN by permitting the applicant to obtain data from multiple servers without affecting other streams. Meanwhile, the proposed method has not yet been exploited in direct video/audio applications of heterogeneous wireless networks.

Taha and Ali [22] adapted a smart algorithm for video streaming in wireless networks, which can be utilized in the healthcare system. This model can find out the relation between the quantization parameter (QP) and the QoS. In the rural areas as well as on the highway, a vehicular *ad-hoc* network (VANET) is utilized. So, a smart real-time multimedia traffic shaping system is illustrated by Ahmed et al. [23], which is based on distributed reinforcement learning (RMDRL). Liu and Kong [24] utilized a combination of video-streaming services and wireless networks for evaluating the performance of the video-streaming application. For this reason, an NS-3-based simulation platform is involved for the effectiveness of the system. Table 1 represents a summary of the literature review.

Author (s)	Technique	Uses	Pros	Cons
Afzal et al. [11]	САРА	Streaming the video in multipath systems	High video quality	Low Performance
Taha et al. [12]	QoE	Streaming video on a wireless network	Enhanced Video Quality	High Latency
Guo et al. [13]	DRL	Wireless networks in ABS	Low Latency	Not Omnipotent
Zhang et al. [14]	Safe DQN	Activating wireless networks in UAV	Better Performance	High Costs
Jiao et al. [15]	DCRA	Overcoming the stochastic optimization	Maximizing the Time	Low Quality
Duraimurugan and Jeyarin [16]	DMSHN	Obtaining data from multiple streams	Superior-quality Video	High Packet Loss &Latency
Taha and Ali [22]	Smart algorithm	Healthcare system	Low and High Video Motions	Low Video Quality
Ahmed et al. [23]	RMDRL	Real-time multimedia traffic shaping systems	Short Frame Latency	ReducingVideo with Low Quality
Liu and Kong [24]	NS-3-based simulation platform	Performance of video- streaming application	Saving the High Costs of Real Equipment	Not to Implement in a More Realistic System

Table 1. Summary of literature review.

3. System Design

The significant factor for real-time video transmission is traffic control, which assures better transmission of bandwidth as well as conflicts with the other types of video flow. The congestion controller is applicable in various paths of video streaming [17]. The packets transmitted from the local buffer to the network are evaluated by congestion control. The congestion-control algorithm transmits the packets in the burst mode and these packets are queued at the median routers for generating the additional delay. The originator is responsible to send the packets in several paths to the local buffer. The bitrate of the video is adjusted by the controller to obtain an effective output [18]. The utilization function F_u is employed for equipping better service satisfaction. Generally, it is assumed to be an increasing and concave function. Here, finding of an acceptable bandwidth allocation scheme is the main goal to gain fully utilized resources. The following equation expresses the optimization problem.

$$Maximum \sum_{r \in R} T(z_r) \quad s.t \sum_{r \in R} y_r, k \le dk$$
(1)

In the above equation, the user r can use the multiple routing paths for building the concurrent connections, dk indicating the bottleneck capacity, y_r , k representing the packet sending rate of path k and R signifying the number of network users.

The size and diversity of the current network system are very difficult issues in the global bandwidth allocation. The Lagrangian rate-control algorithms are to solve these issues, defined as follows:

$$L_{\arg}(Z_r, \delta) = \sum_{r \in R} T(Z_r) + \sum_k \delta_k (d_k - \sum_{r \in R} y_r, k)$$

$$= \sum_{r \in R} T(Z_r) - \sum_k \delta_k (\sum_{r \in R} y_r, k) + \sum_k \delta_k . d_k$$

$$= \sum_{r \in R} T(Z_r) - \sum_{r \in R} \sum_k y_r, k \delta_k + \sum_k \delta_k d_k$$
(2)

The Kelly's shadow-price parameter is δ_k for path k. The function of the shadow-price original problem is;

$$\underset{\delta}{Minimum} C(\delta) \tag{3}$$

The function $C(\delta)$ is defined as:

$$C(\delta) = Maximum \ L_{arg}(Z_r, \delta) + \sum_k \delta_k d_k$$
(4)

where,

$$L_{\arg}(\delta) = MaximumY(Z_r) - \sum_{k} y_r, \delta_k$$
(5)

The aggregate surplus is shown in Equation (7). To attain the maximum aggregate surplus while maintaining the minimum link cost, packets must be sent at a high rate. Congestion-control algorithm maintains the stability of the network system to enhance the rate of high bandwidth and bridge congestion through rate reduction. Regarding the congestion-control algorithm, an improved IFW-CFH for real-time video transmission is implemented. The main focus of the analysis is to minimize the transmission-cost liability of the packet-scheduling mode.

To discover less bandwidth, the congestion-control algorithm maximizes the rate. Then, the reduction of rate leads to link congestion and the network system's constancy is maintained. For multipath packet scheduling, the utilization theory is well employed. It is expressed in the equation below.

$$Maximum \ T(y) - \sum_{q} \delta_{q} y_{q} \tag{6}$$

In the above equation, δ_q denotes path price, q signifies path index and y_q represents packet-scheduling rate. Generating the rate of packets is y, $y_q = \beta_q y$. β_q is a splitting ratio rate, where the multipath session aggregate cost is represented by p. The expected cost of a single packet is calculated through the multipath as shown in Equation (8).

$$y_p = \sum_q y_q \delta_q \tag{7}$$

$$q = \sum_{q} \delta_{q} \beta_{q} \tag{8}$$

At the local buffer, the additional sent packets are queued and this happens when the packet-scheduling rate $y_q(u)$ exceeds the path-sending rate d_q .

$$\delta_{q}(u) = p_{q}(u) + p_{p}(u) + \int \frac{(y_{q}(u) - d_{q}(u))\mathbf{1}(y_{q}(u) - d_{q}(u))}{d_{q}(u)}$$
(9)

The minimization of the second term is the major goal of the packet-scheduling algorithm.

$$p_u = \delta_{q,u} \gamma_{q,u} \tag{10}$$

In the above equation, $\gamma_{a,u}$ helps in scheduling the incoming packets to a particular path. The total cost

of the packets scheduled with the minimum path cost at the current time should be minimized. The frame rate is considered as the sum of available bandwidth for all sub-paths $y = \sum_{a} d_{a}(u)$; *i.e.*, a single path

must not send incoming packets with the video frame rendering deadline. Additional packets that cannot be sent immediately are buffered and the path cost is increased to the least cost path shown in Equation (9). At a certain time point, the packets should be routed such that a system can achieve a balanced path cost in all terms.

4. PROPOSED METHODOLOGY

Video streaming is significant for transmitting video effectively; for effective real-time video, IFW-CFH method is proposed to enhance the performance of video-streaming quality. Two diverse mechanisms; namely, the congestion-control mechanism and the packet-scheduling mechanism, are used to transmit the video effectively as presented in the following sub-sections. Figure 1 presents the schematic flow diagram of the proposed real-time video-transmission system.

4.1 Congestion-control Mechanism

The QoE for services, such as cloud gaming, video conferencing and video streaming, is greatly impacted by congestion control, where sending packets faster can submerge the network, which leads to loss or delay in data, while sending too slow can affect the video quality. In general, the state is employed for removing the extra queues gathered at the startup stage. The state is converted to ProbeBW if the in-flight packets are below the Bandwidth Delay Product (BDP). 8 RTTs control the transferring rate by various gains [1.25, 0.75, 1, 1, 1, 1, 1] at this stage and the sender could increase the transferring rate to capture the excess available bandwidth. The stage is set as ProbeRTT if the minimal RTT is not sampled in ten seconds. The RTT allows only four packets to transfer outside. For real-time video transferring, during the initial phase, the rate in the underload path rises gradually and yields a sub-optimal throughput.



Figure 1. Real-time video-transmission system.

4.2 Packet-scheduling Mechanism

During the packet-scheduling process, the scheduler forwards the packets to the local buffer path for generating the encoded video frame with the least cost and the path price is formulated in Equation (11).

$$H = \arg\min_{a} \lambda_g \tag{11}$$

$$\lambda_g = \frac{RTT_g(s)}{2} + \frac{O_g(s)}{f_g(s)} \tag{12}$$

 $RTT_g(s)$ signifies the round-trip time. In network connection, the term $\frac{RTT_g(s)}{2}$ is defined as the

utilization queuing delay and propagation delay. $f_g(s)$ denotes the pacer's packet-sending cost, $O_g(s)$ and indicates the engaged buffer length at the sender.

Due to several unknown components in the routing path, the scheduling algorithm cannot guarantee sending all packets to the receiver. For example, the buffer length is occupied by routers that change paths to achieve the least arriving delay by selecting the lowest cost. After the received packets are reconstructed into video frames, they are pre-delivered to the uppermost layer.

Considering that these packets use the same frame and maybe dispatched to various paths, it is not possible for the receiver to determine whether an unfinished frame originated from late arrival or packet loss. Sent packets are cached by the sender for approximately 500 milliseconds. If a missed one is detected, it is immediately rerouted with minimal delay in transmission. The receiver chooses a maximum duration to wait for retransmitted packets. The receiver must wait to retry the miss and a complete frame is successfully carried in the keyframe. If the waiting time exceeds the maximum limit, an incomplete frame is dropped at any keyframe.

4.2.1 Fuzzy Weighted Queuing Algorithm (FWQA)

The fuzzy weighted queuing algorithm approximates packet-based Generalized Processor Sharing (GPS) regulation [19]. The backlogged flow of GPS's m^{th} flow and n^{th} flow is represented in Equation (13).

$$\frac{A_{S_m}(\gamma, d)}{A_{S_m}(\gamma, d)} \ge \frac{\omega_m}{\omega_n}$$
(13)

In equationabove, $A_{S_m}(\gamma, d)$ represents the number of sessions in m^{th} flow served within the range (γ, d) . The number of sessions in the nth flow served within the range (γ, d) is denoted by $A_{S_n}(\gamma, d)$. In the router, each entrance of the packet is computed by using a virtual finishing time. The fuzzy weighted queuing algorithm contains different variants, such as worst-case fair weighted fair queuing (WFFQ) and self-clocked fair queuing (SCFQ). The WFFQ is corresponding to GPS and it chooses the packet for streaming without delay. However, computational complexity is a major issue at a higher speed of streaming. SCFQ is utilized to validate the beginning time of the packets, which minimizes the computational complexity. The weights of numerous classes are described in Equation (14).

$$\sum_{m=1}^{n} \omega_m = 1, \ 0.01 \le \omega_m \le 1$$
(14)

In equation above, ω_m represents the weight of service in the m'' class. The total number of service classes is denoted by m. The fuzzy weighted queuing algorithm is established to stream the video efficiently and fairly. The FWQA router contains two service classes Transport Control Protocol (TCP) and UDP for video streaming. After receiving every fifty packets, the new weight queue is computed. The delay-sensitive UDP service class is assumed as an RTP carrier which is constrained to guarantee high reliability for UDP video streaming. Packet priority is achieved by computing new queue weights for the FWQA algorithm. This scenario is mathematically represented as follows.

$$S_{QL} = \frac{QL_{udp}}{QL_{tcp} + QL_{udp}}$$
(15)

In the equation above, S_{QL} indicates the share of queue length. QL_{tcp} is the queue length share of TCP video streaming. QL_{udp} represents the queue length of UDP video streaming.

Fuzzy Reasoning

Fuzzy reasoning is utilized to establish the fuzzy logic from the theory of fuzzy set. Reasoning should be completed by utilizing individual-based inference or combination-based inference. In this part, we deployed individual-based inference, because it is easy to implement. Fuzzy reasoning allows multiple possible truth values to be processed by a single variable. It solves the issue of pocket loss, which makes it possible to obtain consistently accurate results.

Fuzzy Control Model

The fuzzy control model is utilized to accelerate the modeling approaches for the fuzzy weighted queuing algorithm. The main goal is to minimize fall and rise times and improve and succession in UDP and TCP video streaming.

213

Jordanian Journal of Computers and Information Technology (JJCIT), Vol. 09, No. 03, September 2023.

Tuning in Queue Weight Control

To identify membership functions and appropriate rules for both input and output variables to respond to the variation of video streaming, latency, re-buffering, packet loss and degradation are controlled weight values in routers. Tuning and testing are capable of maximizing the length of the rule-base operation and minimizing the computational complexity. Dividing the control variables and dynamic range of state into fuzzy membership functions are performed offline.

4.2.2 Crossover-based FireHawk Optimization

The Fire Hawk Optimization (FHO) [20] metaheuristic method imitates the fire hawk's foraging action by scattering fires as well as prey. The process of random initiation is employed to recognize the beginning position as mentioned in the following equation.

$$p_{a}^{b}(0) = p_{a,\min}^{b} + rand(p_{a,\max}^{b} - p_{a,\min}^{b}), \begin{cases} a=1,2,..,P.\\ b=1,2,..,M. \end{cases}$$
(16)

where P_a describes the a^{th} candidate solution from the search space area, M signifies the dimension, P denotes the total number of candidate solutions, p_a^b and $p_a^b(0)$ are the b^{th} decision variable as well as the initial position of a candidate solution, $p_{a,\max}^b$ signifies the minimum and maximum limits and *rand* represents the random number that is uniformly distributed within the range [0,1]. T_c^d is calculated by using the following equation:

$$\mathbf{T}_{c}^{d} = \sqrt{\left(m_{2} - m_{1}\right)^{2} + \left(n_{2} - n_{1}\right)^{2}}, \begin{cases} d = 1, 2, \dots, y.\\ c = 1, 2, \dots, x. \end{cases},$$
(17)

The distance between the d^{th} fire hawk and the c^{th} prey is T_c^d , where x and yindicate the total prey as well as fire hawks in the search space area. (m_1, n_1) and (m_2, n_2) describe the fire hawk and prey coordinates.

A place is considered as safe when most animals are assembled to remain sound and safe during danger. The corresponding mathematical equations re illustrated below.

$$SP_{d} = \frac{\sum_{e=1}^{z} PR_{e}}{z}, \begin{cases} e=1,2,\dots,y.\\ d=1,2,\dots,z. \end{cases}$$
(18)

$$SP = \frac{\sum_{c=1}^{x} PR_c}{x}, c = 1, 2, \dots, x.$$
 (19)

where, PR_e is the e^{th} prey surrounded by the d^{th} fire hawk (FH_d) and PR_c is the c^{th} prey in the search space.

CrossoverStrategy

This technique enhances the functioning of the firehawk, the convergence accuracy and convergence speed, which leads to the development of problems, like image multi-threshold segmentation accompanied by computational power and high complexity. Hence, this article suggested a superior firehawk algorithm with vertical as well as horizontal and crossover strategies [21].

Merging vertical, horizontal and crossover techniques with the firehawk, these techniques execute vertical, horizontal and crossover functions in every generation. After each crossover, junior individuals collide with senior individuals and junior individuals are placed higher than senior individuals for reiteration, which avoids firehawk collapse in the local optimum.

At first, the individual firehawks in the population are collected in the two-by-two non-repeating groups Qi and Qj to create the descendants by executing the horizontal crossover function in the pair of Equations (20) and (21).

$$F_{l,f}^{ke} = s_1 \cdot w_{l,f} + (1 - s_1) \cdot w_{m,f} + t_1 \cdot (w_{l,f} - w_{m,f})$$
(20)

$$F_{m,f}^{ke} = s_2 \cdot w_{m,f} + (1 - s_2) \cdot w_{l,f} + t_2 \cdot (w_{m,f} - w_{l,f})$$
(21)



Figure 2. Flow diagram of the IFW-CFH algorithm.

where, s_1 and s_2 represent the memory coefficients. For effective packet scheduling, this paper proposes an IFW-CFH algorithm for effective real-time video transmission, which is shown in Figure 2. The diffusion coefficients denoted by t_1 and t_2 are randomly selected within the range [-1,1]. $w_{l,f}$ and $w_{m,f}$ are the dimensional vectors, where $F_{l,f}^{ke}$ and $F_{m,f}^{ke}$ are the offspring. The firehawk has an insufficiency of a robust mutation mechanism. Hence, after the completion of the horizontal crossover function performed by the algorithm, an individual population falls into the local optima to create the spatial-edge region. Due to this, there is a necessity for vertical crossover operation.

$$w_{l,f_1}^{le} = x \cdot w_{e,f_1} + (1-x) \cdot w_{e,f_2}$$
(22)

From the equation above, we notice a longitudinal crossover of the f_1 and f_2 dimensions of fire hawk *Qi*. The vertical *x* is an arbitrary number within the range [0, 1] and w_{l,f_1}^{te} is the individual offspring. Table 2 and Table 3 represent the Nomenclature list of all symbols and abbreviations.

Abbreviation	Description
QoE	Quality of Experience
IFW-CFH	Improved Fuzzy Weighted queueing-based Crossover Fire Hawk
VS	Video Streaming
MPEG	Moving Pictures Experts Group
DASH	Dynamic Adaptive Streaming over HTTP
UDP	User Datagram Protocol
IP	Internet Protocol
RTP	Real-time Protocol
HOL	Head of Line Blocking
FHO	Fire Hawk Optimizer
CAPA	Content-Aware and Path-Aware
DRL	Deep Reinforcement Learning
ABS	Adaptive Bit-rate Streaming

Table 2. Nomenclature list of abbreviations.

MEC	Mobile Edge Computing	
DQN	Deep Q-learning Network	
UAV	Unmanned Aerial Vehicles	
CMDP	Constrained Markov Decision Process	
DCRA	Dynamic Cache and Resource Allocation	
OFDMA	Orthogonal-Frequency-Division Multiple Access	
DMSHN	Distributed Multimedia Streaming in the Heterogeneous Wireless NetworkS	
BDP	Bandwidth Delay Product	
GPS	Generalized Processor Sharing	
WFFQ	Worst-Case Fair Weighted Fair Queuing	
SCFQ	Self-Clocked Fair Queuing	
TCP	Transport-Control Protocol	
FWQA	Fuzzy Weighted Queuing Algorithm	
CMT-SCTP	Concurrent Multi-path Transfer-stream Control Transmission Protocol	
MPTCP	Multipath Transmission Control Protocol	
DCE	Direct Code Execution	
ABR	Adaptive Bitrate	
RAN	Radio Access Network	

Table 3. Nomenclature list of symbols.

Symbol	Description	
F_u	Utilization function	
r	User can use the multiple routing paths	
dk	Bottleneck capacity	
y _r , k	Packet sending rate of k th path	
R	Number of network users	
δ_q	Path price	
q	Path index	
y_q	Packet-scheduling rate	
$RTT_g(s)$	Round-trip time	
$RTT_g(s)/2$	Utilization queuing delay and propagation delay	
$f_g(s)$	Pacer's packet-sending cost	
$O_g(s)$	Engaged buffer length at the sender	
$A_{Sm}(\gamma,d)$	The number of sessions in m^{th} flow served within the range (γ, d)	
ω_m	Weight of service in m^{th} class	
m	Total number of service classes	
S_{QL}	Share of queue length	
QL_{tcp}	Queue length share of TCP video streaming	
QL_{udp}	Queue length of UDP video streaming	
P_a	a^{th} candidate solution from the search space area	
M and P	Dimension and total number of candidate solutions	
p_a^b and $p_a^b(0)$	b^{th} decision variable as well as the initial position of a candidate solution	
$p^b_{a,max}$	Signifies the minimum and maximum limits	
T_c^d	Distance between the d^{th} fire hawk and the c^{th} prey	
S_1 and S_2	Memory coefficients	
t_1 and t_2	Diffusion coefficients	
$w_{l,f}$ and $w_{m,f}$	Dimensional vectors	
$F_{l,f}^{ke}$ and $F_{m,f}^{ke}$	Offspring	
W_{l,f_1}^{te}	Individual offspring	
x	Arbitrary number within the range [0, 1]	
f_1 and f_2	Longitudinal crossover	
δ_k	Shadow price of the parameter	
$C(\delta)$	Dual function of the original problem	

5. RESULTSAND DISCUSSION

Video streaming is performed in real-time video transmission by the IFW-CFH algorithm. For effective video transmission, the parameters link capacity, one-way propagation delay and buffer strength are used. The entire results of this paper are discussed in the following sub-sections.

5.1 Experimental Setup

The experiments of the proposed IFW-CFH algorithm are simulated on the ns-3.26 tool, which is used to validate the effectiveness of real-time video transmission. Network simulators are used to provide an accurate understanding of system behavior in communication networks that are too complex for traditional analysis methods. Practical feedback is provided to users when designing real-world systems and designers are allowed to study a system of abstraction at multiple levels. Also, a highly modular platform for wired and wireless simulations supporting various network components, protocols, traffic and routing types is presented.

5.2 Parameter Description

The parameter tuning process is conducted to effectively achieve video streaming by using the proposed IFW-CFH approach as delineated in Table 4. To define the parameters of the system parameter setting is utilized. Here, the size of the population is 30 with 100 iterations. To formulate the search space of the prey, the space is allocated by 1, 2,... etc. Also, the random interval of the horizontal crossover and the vertical crossover is defined as [-1,1] and [0,1], respectively.

Parameter	Value
Population size	30
Maximum number of iterations	100
Prey in search space	1,2,etc
Random interval of horizontal crossover	[-1,1]
Random interval of vertical crossover	[0,1]

Table 4. Parameter description.

5.3 Performance Analysis

In this sub-section, the performance of one-way propagation delay, capacity estimation, packet loss, transmission delay and bandwidth are validated to attain a better achievement of the IFW-CFH method. Figure 3 illustrates the average packet transmission delay for the proposed IFW-CFH method and the existing CAPA, DRL, safe DQN and DCRA methods. It is defined as the ratio between the link length and the propagation speed over a specific medium. Here, the proposed IFW-CFH approach can obtain a lower level of transmission delay than those of the other methods. The delay is stable at 10 milliseconds.

$$PD = \frac{l}{f} \tag{23}$$

It is determined by the propagation delay and the queuing delay that demonstrate the dynamics of the employed buffer in routers. The proposed method minimized the transmission delay related to the existing methods for better efficiency and video streaming is performed accurately.

Figure 4 depicts the average rate of packet loss. The different algorithms are initiated at varied points and the packet loss rate is evaluated for CAPA, DRL, safe DQN and DCRA methods, as well as for the proposed IFW-CFH algorithm. The rate of transmission is calculated by the sender and the packet loss is stored by the receiver. By increasing the buffer, the packet loss rate is reduced and the delay in transmission is maximized in the existing methods. But, the proposed method reduced the packet loss rate compared to the state-of-the-art methods.

Figure 5 shows the average frame transmission delay. The packet-scheduling algorithms are validated in the existing methods, such as CAPA, DRL, safe DQN and DCRA, as well as the proposed IFW-CFH method. The average frame transmission delay is utilized to measure the delay packets across the Internet Protocol (IP). While simulating huge frames is created by the encoder, the proposed method attained the minimum average frame delay when compared with the existing methods.



Figure 3. Comparative analysis of one-way transmission delay.



Figure 4. Comparative analysis of packet loss rate.

Table 5 delineates the comparative analysis of the proposed method with various parameters. The parameters transmission delay, packet loss rate and frame delay transmission comparison of the proposed method are performed with nine index values. Each parameter value for the proposed IFW-CFH method is minimized when compared with the existing CAPA, DRL, safe DQN and DCRA methods. The minimization of various parameter values enhances the video quality.

Figure 6 depicts the bandwidth evaluation for the existing CAPA, DRL, safe DQN and DCRA methods, as well as for the proposed IFW-CFH algorithm. The bandwidth analysis attained better efficiency in real-time video transmission. The existing methods CAPA, DRL, safe DQN and DCRA achieved 19.2%, 20.5%, 15.8% and 17.9%, while the proposed IFW-CFH algorithm achieved 13.8%, respectively. Compared to other methods, the proposed method has a lower bandwidth capability for video streaming.

Number of	Parameters		
indices	Transmission delay	Packet-loss rate	Frame-transmission delay
1	223	0.032	201
2	230	0.041	180
3	218	0.064	153
4	216	0.052	148
5	217	0.040	104
6	256	0.081	176
7	239	0.078	185
8	262	0.076	182
9	213	0.075	146

Table 5. Comparative table of the proposed method with different parameters.





Figure 5. Comparative analysis of frame transmission delay.

Figure 6. Comparative analysis of bandwidth with the proposed method.

Table 6 depicts the comparative analysis of the various existing methods along with the proposed method for validating the range of bandwidth values to obtain better performance of video quality. CAPA, DRL, Safe DQN and DCRA are the existing methods that obtained bandwidth value ranges of

19.2%, 20.5%, 15.8% and 17.9%, respectively, whereas the proposed IFW-CFH method attained 13.8%. This reduction of bandwidth in the proposed method will improve the quality of video when compared with the existing methods.

Existing Methods	Bandwidth (%)
CAPA	19.2
DRL	20.5
Safe DQN	15.8
DCRA	17.9
Proposed IFW-CFH	13.8

Table 6. Comparative analysis of bandwidth for the proposed method and the existing methods.

6. CONCLUSION

In this article, an IFW-CFH algorithm is proposed to enhance video quality. Different parameters are used to estimate the efficiency of video transmission. The QoE is necessary for generators and service providers for performing video streaming. The reduction in throughput, re-buffering or mosaic is determined in packet loss to validate whether video streaming is employed in a reliable or unreliable mode. The proposed approach is validated by various measures, such as propagation delay, bandwidth and packet loss. Congestion control and packet scheduling are the two crucial objectives that are used to handle the lower bandwidth as well as to generate effective path diversity. In a comparative analysis, the proposed IFW-CFH algorithm is compared with CAPA, DRL, safe DQN and DCRA methods to validate the performance of video quality. The IFW-CFH method attained effective real-time video transmission by reducing the bandwidth by 13.8%, as well as transmission delay and packet loss when compared to the existing methods CAPA, DRL, safe DQN and DCRA of 7.8%, 11.9%, 9.7% and 5.2%, respectively. In the future, the proposed approach will be used to increase the efficiency of video transmission by implementing a new paradigm based on the privacy criterion and cost of providing the desired video quality of tele-training videos. IFW-CFH algorithm should be implemented in a real system, like WebRTC and SignalR and optimal settings should be found by the adjusting parameters to change video quality against bandwidth.

REFERENCES

- [1] T. A. Q. Pham, K. D. Singh, J. A. Rodríguez-Aguilar et al., "AD3-GLaM: A Cooperative Distributed QoEbased Approach for SVC Video Streaming over Wireless Mesh Networks," Ad Hoc Networks, vol. 80, no. 2018, pp. 1-15, 2018.
- [2] Y. Yu and S. Lee, "Remote Driving Control with Real-time Video Streaming over Wireless Networks: Design and Evaluation," IEEE Access, vol. 10, pp. 64920-64932, 2022.
- [3] J. Du, F. R. Yu, G. Lu, J. Wang, J. Jiang and X. Chu, "MEC-assisted Immersive VR Video Streaming over Terahertz Wireless Networks: A Deep Reinforcement Learning Approach," IEEE Internet of Things Journal, vol. 7, no. 10, pp. 9517-9529, 2020.
- [4] J. S. Leu and C. W. Tsai, "Practical Design of a Proxy Agent to Facilitate Adaptive Video Streaming Service Across Wired/wireless Networks," Journal of Systems and Software, vol. 82, no. 11, pp. 1916-1925, 2019.
- [5] G. Bijur, R. Mundugar, V. Mantooret al., "Estimation of Adaptation Parameters for Dynamic Video Adaptation in Wireless Network Using Experimental Method," Computers, vol. 10, no. 4, p. 39, 2021.
- [6] Y. S. Baguda, "Energy-efficient Biocooperative Video-aware QoS-based Multiobjective Cross-layer Optimization for Wireless Networks," IEEE Access, vol. 8, pp. 127034-127047, 2020.
- [7] R. Murugadoss and M. M. V. M. Kumar, "The Quality of Experience Framework for HTTP Adaptive Streaming Algorithm in Video Streaming over Wireless Networks," Int. J. Fut. Gener. Commun. Netw., vol. 13, pp. 1491-1502, 2020.
- [8] M. Morshedi and J. Noll, "Estimating PQoS of Video Streaming on Wi-Fi Networks Using Machine Learning," Sensors, vol. 21, no. 2, p. 621, 2021.
- [9] S. Kumarganesh, S. Anthoniraj, T. S. Kumar et al., "A Novel Analytical Framework is Developed for Wireless Heterogeneous Networks for Video Streaming Applications," Journal of Mathematics, vol. 2022, Article ID: 2100883, 2022.
- [10] S. Felici-Castell, M. García-Pineda, J. Segura-Garcia, R. Fayos-Jordan and J. Lopez-Ballester, "Adaptive Live Video Streaming on Low-cost Wireless Multihop Networks for Road Traffic Surveillance in Smart Cities," Future Generation Computer Systems, vol. 115, pp. 741-755, 2021.

- [11] S. Afzal, C. E. Rothenberg, V. Testoni, P. Kolan and I. Bouazizi, "Multipath MMT-based Approach for Streaming High Quality Video over Multiple Wireless Access Networks," Computer Networks, vol. 185, p. 107638, 2021.
- [12] M. Taha, A. Canovas, J. Lloret and A. Ali, "A QoE Adaptive Management System for High Definition Video Streaming over Wireless Networks," Telecommunication Systems, vol. 77, pp. 63-81, 2021.
- [13] Y. Guo, F. R. Yu, J. An, K. Yang, C. Yu and V. C. Leung, "Adaptive Bitrate Streaming in Wireless Networks with Transcoding at Network Edge Using Deep Reinforcement Learning," IEEE Transactions on Vehicular Technology, vol. 69, no. 4, pp. 3879-3892, 2020.
- [14] Z. Zhang, Q. Zhang, J. Miao, F. R. Yu, F. Fu, J. Du and T. Wu, "Energy-efficient Secure Video Streaming in UAV-enabled Wireless Networks: A Safe-DQN Approach," IEEE Transactions on Green Communications and Networking, vol. 5, no. 4, pp. 1892-1905, 2021.
- [15] L. Jiao, H. Yin and Y. Wu, "Dynamic Resource Allocation for Scalable Video Streaming in OFDMA Wireless Networks," IEEE Access, vol. 8, pp. 33489-33499, 2020.
- [16] S. Duraimurugan and P. J. Jayarin, "Maximizing the Quality of Service in Distributed Multimedia Streaming in Heterogeneous Wireless Network," Multimedia Tools and Applications, vol. 79, no. 5-6, pp. 4185-4198, 2020.
- [17] W. Liu, H. Zhang, H. Ding and D. Yuan, "Delay and Energy Minimization for Adaptive Video Streaming: A Joint Edge Caching, Computing and Power Allocation Approach," IEEE Transactions on Vehicular Technology, vol. 71, no. 9, pp. 9602-9612, 2022.
- [18] S. Zhang, W. Lei, W. Zhang, Y. Guan and H. Li, "Congestion Control and Packet Scheduling for Multipath Real Time Video Streaming," IEEE Access, vol. 7, pp. 59758-59770, 2019.
- [19] S. Nandhini, "Low Latency Weighted Fair Queuing for Real time Flows with Differential Packet Dropping," Indian Journal of Science and Technology, vol. 8, no. 22, pp. 1-8, 2015.
- [20] M. Azizi, S. Talatahari and A. H. Gandomi, "Fire Hawk Optimizer: A Novel Metaheuristic Algorithm," Artificial Intelligence Review, vol. 56, pp. 287–363, 2022
- [21] G. Ma and X. Yue, "An Improved Whale Optimization Algorithm Based on Multilevel Threshold Image Segmentation Using the Otsu Method," Engineering Applications of Artificial Intelligence, vol. 113, p. 104960, 2022.
- [22] M. Taha and A. Ali, "Smart Algorithm in Wireless Networks for Video StreamingBased on Adaptive Quantization," Concurrency and Computation: Practice and Experience, vol. 35, no. 9, p. e7633, 2023.
- [23] A. A. Ahmed, S. J. Malebary, W. Ali and O. M. Barukab, "Smart Traffic Shaping Based on Distributed Reinforcement Learning for Multimedia Streaming over 5G-VANET Communication Technology," Mathematics, vol. 11, no. 3, p. 700, 2023.
- [24] G. Liu and L. Kong, "Simulation of Video Streaming over Wireless Networks with NS-3," arXiv preprint, arXiv:2302.14196, 2023.

ملخص البحث:

إنّ إحدى المشكلات التي تواجه مقدِّمي الخدمة ومطوّري التّطبيقات تتمثَّل في "جودة الخبرة" (QoE)، حيث يودي "الازدحام المروري" على الإنترنت الي تدهور جودة صور الفيديو. وتقلّ فعالية نقَّل صور الفيديو في الشبكات لأسباب تتعلّق بفقَّد الحُزَم وعرض النّطاق والتّاخير. وبسبب محدِّدات عرض النّطاق، فإنّ صور الفيديو المنقولة تكون ذات جودة منخفضة.

لــذا فــانّ هــذه الورقــة البحثيــة تقتــرح خوارزميــة مــن نــوع (IFW-CFH) لنقْـل صــور الفيـديو بفعاليــة فــي الــزّمن الحقيقــي. وتهـدف الخوارزميــة المقترّحــة الــي تقليـل التّــأخير وفقْـد الحُـزَم وعـرض النّطـاق مـن أجْـل تحسـين جـودة صـور الفيـديو المنقولــة مـن خـلال آليّتين هما: آليّة التّحكم بالازدحام، وآليّة جدولة الحُزَم.

وقد أشارت نتائج التجريب الى أنَّ الطَّريقة المقترحة قلَّلت من تأخير النَّقل وفقَّد الحُرزَم وعرض النَّطاق بنسبة 13.8%، وهي تفوَّقت بذلك على تقنيات أخرى مستخدَمة في در اسات سابقة للحصول على نقُّلٍ فعّال لصور الفيديو في الزّمن الحقيقي.



This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license http://creativecommons.org/licenses/by/4.0/).