

Research Article

Machine Learning Based Distribution of Sports Video Stream Assisting Physical Training

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The rapid development of Olympic Games and the intensification of professional sports events make the competition between excellent athletes and teams become more and more fierce, so the demands on athletes' psychology, techniques, and physical strength are becoming higher and higher, especially that the demands on physical strength are more prominent. Therefore, physical training is an important part of sports training and the core link of competitive sports, which is widely valued by coaches and athletes all over the world. At the same time, with the influence and penetration of the rapid development of modern information technology and network big data on competitive sports, the scientific and digital process of athletes' physical training has also been accelerated, and many new ideas, scientific training methods, and advanced sports technology have emerged. During the pandemic, many aggregation activities have been disrupted, as well as physical training. Therefore, this paper improves the quality of physical training through video, so that athletes can do physical training at any time and any place. A cut vertices spanning tree algorithm based on machine learning is proposed to distribute layered multicast streaming and dynamically adjust the number of layers of sports video streaming. The cut vertices spanning tree algorithm is mainly applied to the situation when the network bandwidth resources are relatively scarce. The evaluation results indicate that the proposed method can improve the estimated quality of experience (QoE), packet loss rate, link utilization, and video delay on Mininet simulation platform. Furthermore, it can be seen from the experiments that the proposed method has a good performance on distribution of sports video stream assisting physical training.

1. Introduction

The theoretical research of physical training is developing gradually in China, which has a very important influence on the development of competitive sports and public health [1, 2]. Physical training is the size of cardiopulmonary function support caused by human movement, that is, the ability of cardiopulmonary system, which depends on the strength and scope of human movement system dynamics application [3]. The current physical training is strength training, speed training, aerobic, anaerobic endurance training, flexibility, and coordination training. As a result, physical training is difficult to connect with its supporting disciplines, and it is difficult to combine with biological science, nutrition, medicine, and other high-tech aspects, which also leads to

the emergence of many problems such as training difficult to control [4, 5].

The connotation of physical training should be the training of human body to improve the ability of walking, running, jumping, and throwing. Physical training has its systematic characteristics, that is, the integrity and comprehensiveness of training [6–8]. Physical training should combine the characteristics of sports and human body and cross disciplines through multidisciplinary support, and learn from and integrate the excellent achievements and advanced experience in other fields, so as to optimize the bone, joint, muscle, and sports auxiliary system of human body sports system and the large system of sports training in physical training [9, 10].

At present, there are some deficiencies in physical training. (i) In experiential physical training, physical training is a

TABLE 1: Symbol illustration.

Variable	Description
$G(V, E)$	Undirected connected graph
v	Chile node
u	Father node
n	Node
$ts[n]$	Timestamp of node n
$ets[n]$	Earliest timestamp of node n
CV	Cut vertex sets
CV'	Useful cut vertex sets
MT	Multicast tree
n_t	Terminal node
$Path_{n_i, u}$	Path with higher bandwidth
TN	Terminal node sets
S_N	Node sets
S_L	Link sets
$MT(S_N, S_L)$	State of MT

part of sports training, and its theoretical basis is inseparable from sports training, so its theoretical content is relatively more empirical. With the development of science and technology and the maturity of human anatomy, physiology, biomechanics, and other subjects, the scientific theory of physical training has become possible, but the deviation of understanding of physical training still leads to the existence of the problem of empirical theory. Especially in China, running is usually considered as the best way for physical training. (ii) For cognitive bias, core strength training, altitude training, and other training theories are being applied to specific sports training. But by definition, its essence is to train the core muscles of the body and its deep muscle capabilities, including strength, stability, balance, and other abilities. With the concept of core strength training, the connotation of this training theory is misinterpreted and its extension is narrowed. (iii) It can be seen from the essence of physical strength that the human body's athletic ability is determined by the structure of various organ systems with different physiological functions. System theory believes that the structure of the system determines the function, and only when the structure is reasonable, the function can be played better.

In the post epidemic era, physical training is usually realized in the form of video. Compared with the traditional mode, video can enable students to perform more effective physical training. However, how to bring good training effect for physical training through video becomes the focus of research. The main contribution of this study is that the spanning tree algorithm of machine learning is improved, and the cut vertices spanning tree algorithm is proposed to realize the distribution of sports video streaming and assist physical training.

The rest of the paper is organized as follows: Section 2 summarizes the related research; in Section 2, the cut vertices spanning tree algorithm is proposed; Section 4 discusses the results; and Section 5 concludes the paper.

2. Related Research

Digital physical training is the inevitable trend of the development of physical training. Digital makes physical training more rational, and the quality of physical training will ultimately depend on scientific digital monitoring. At the same time, digital physical training is also the only way to intelligent physical training.

College students' physical health test is an important part of school physical education and school education evaluation system; in [11], the authors proposed a functional exercise test based on artificial intelligence (AI) to improve college students' physical exercise awareness. To improve the effect of physical training, in [12], the authors combined machine learning to identify physical training characteristics and action prediction, combined with the Internet of things technology to process physical training data, and constructed a machine learning and the Internet of things based on physical education and training system. To solve the problem of human motion recognition, in [13], the authors proposed a recognition system for human motion tracking in physical training. In [14], the authors presented a balanced shunt point field programmable gate array-based method of physical training planning to improve the effectiveness of physical training planning. In [15], the authors proposed a design method of computer multimedia simulation action training model based on fast detection and control of attitude change space, and the computer multimedia simulation method was used to construct human action training and mathematical model of human action.

The development of the Internet technology makes streaming media applications popularized rapidly. However, in the face of ever-expanding users and increasingly diversified content service requirements, the biggest challenge faced by service providers is the high deployment and maintenance cost of distribution system, poor scalability, and other problems, so how to effectively distribute massive video streaming has become a key problem that needs to be solved urgently. In [16], a platform compatible dynamic adaptive streaming over HTTP framework for wireless video sensor networks (WVSNP-DASH) was proposed to flexibly access video from sensors and other miniaturized source nodes. Previous studies had neither addressed appropriate data caching to support vehicle mobility nor provided appropriate seamless forwarding to ensure quality of service and QoE for real-time video streaming services. To solve this problem, in [17], a video packet distribution scheme called Clone was presented to integrate vehicle-to-vehicle communication for video streaming. In [18], a new emergency aware BitTorrent streams mechanism (UR-Aware) was proposed to improve the transmission efficiency of BitTorrent streams on peer-to-peer networks by balancing playback continuity and fragment scarcity distribution. In [19], the authors proposed a new scheme of content centric networking multisource video streaming based on quality of experience (QoE) perception. In [20], the theoretical framework proposed by the authors could analyze the performance of synchronous streaming media, video on demand streaming media, and video downloading. In [21], a new reinforcement learning-based viewport adaptive streaming

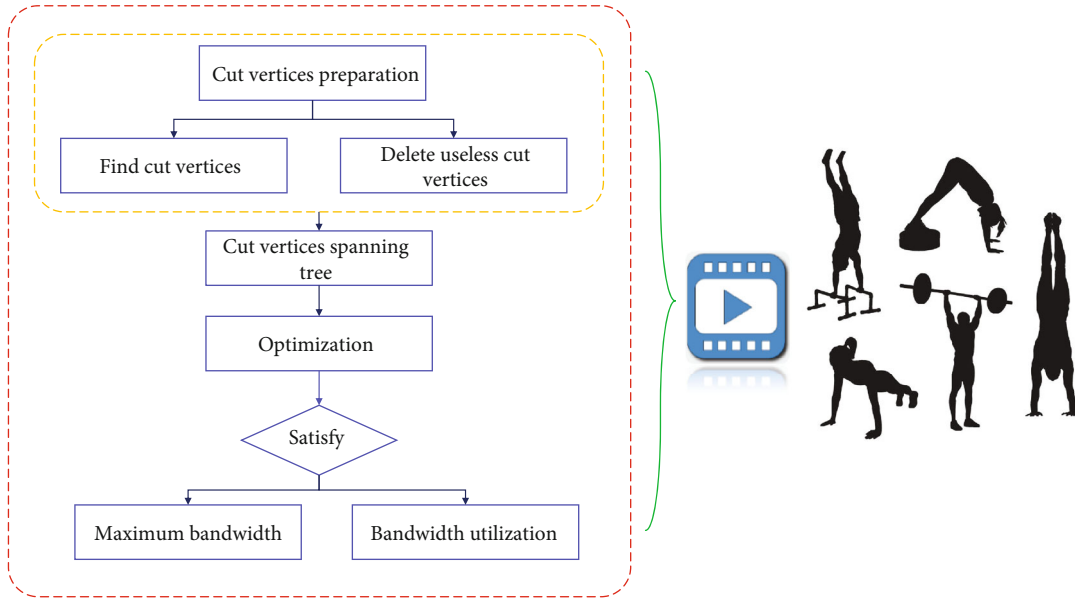


FIGURE 1: Overall scenario of sports video streaming for physical training.

framework was proposed to optimize 360-degree video streaming from the perspective of viewport prediction, pre-fetching scheduling, and rate adaptation. In [22], a design is effective in streaming, distribution, and caching multimedia content was proposed. In [23], a new energy efficiency method based on experience quality was proposed to distribute peer-to-peer video in mobile ad hoc networks. In [24], the authors used an online algorithm to jointly and dynamically select the right data center for broadcasters and viewers to save the operating cost of crowdsourced live streaming provider. In [25], the authors proposed a video control plane, which was used to monitor the QoE sent by any content delivery networks (CDN) in the CDN pool and to select the QoE with the best performance when a new video request is received.

3. Proposed Sports Video Streaming Algorithm

Definition 1. Cut vertex. In an undirected connected graph $G(V, E)$, if for a node $v \in V$, after deleting v and all edges connected to v from G , G will become multiple unconnected subgraphs, and then v is called a cut vertex of G .

The distribution of sports video streaming based on cut vertices spanning tree algorithm includes three stages, which are cut vertices preparation, spanning tree, and optimization.

3.1. Cut Vertices Preparation. In the cut vertices stage, two steps are mainly implemented. The first step is to find all the cut vertices in the network and form the cut vertex sets. The second step is to delete the useless cut vertices from the cut vertex sets and form the useful cut vertex sets.

By using the idea of depth first search (DFS) [26], the cut vertices in the network are solved. The idea of finding the cut vertices is roughly as follows. If the node u is reached during DFS, the nodes in the network are divided into two types: one has been DFS, and the other has not been DFS. Then, DFS is performed again on the child node v of node u . Here,

u is the father of v , and the visited node is called v 's ancestor. If v can return to its ancestors without passing through u , it means that u is not a cut vertex. On the contrary, if v cannot go back to its ancestors, it means that u is the cutting vertex.

$ts[n]$ is used to represent the timestamp of node n during DFS, and $ets[n]$ is used to represent the earliest timestamp that node n can trace back. The timestamp here refers to the number of accessed nodes during traversal. For node u , if there is a child node v , satisfying $ets[v] \geq ts[u]$, that is, it cannot be traced back to the ancestor. In this case, if u is not the root node, it can be directly judged that u is the cut vertex. If u is the root node and it has multiple child nodes, it can also be judged as a cut vertex.

After finding all the cut vertices in the network, the cut vertex sets, CV , are obtained. However, since the focus is to construct the spanning tree from the source node to each terminal node, some network nodes do not have to be connected [27]. Therefore, some useless cut vertices can be removed according to specific requirements, and finally a useful cut vertex sets CV' is obtained.

3.2. Spanning Tree. Prim spanning tree [28] is used for useful cut vertex sets, CV' . First, the link with the smallest bandwidth is accessed. Then, start with the cut vertices at both ends of the link, find the link with the smallest bandwidth connected to it, and add it to the multicast tree, MT, and iterate successively until no cut vertices can access MT. Since MT nodes are cut vertices at present, this is called a full-cut spanning tree. When links are added, cut vertices and terminal nodes that are not connected to the MT are grafted to the MT. The priority of grafts is determined by the sum of the bandwidths of the links that are connected to the paths in the spanning tree. The smaller the sum of bandwidths of the links, the higher the priority is. Since the spanning tree at this stage is dominated by cut vertices but contains common nodes, it is called the initial state cut vertices spanning tree.

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Input:  $G(V, E), TN$ 
Output:  $MT(S_N, S_L)$ 
use finding cut vertex sets method to get cut vertex sets  $CV$ ;
for  $cv \in CV$ 
  if the subnet connected to  $cv$  does not have terminal nodes
    delete  $cv$  from  $CV$ 
end for;
use Prim algorithm for all  $CV$  to get a basic  $MT$ 
while (all  $v \in TN$  are not all in  $S_N$ ) do
  for all  $v \in TN - n_t$ 
    find  $v$  with the smallest bandwidth value used to connect to the current  $MT$ 
    add the terminal node and path to  $MT$ 
  end for;
end while;
for all terminal nodes
  if maximum bandwidth requirements are not met
    find other paths that can increase bandwidth reversely
    if find a path with higher bandwidth
      replace the original path
    end if;
  end if;
end for;
for all links
  if find links that can improve link utilization without reducing the bandwidth requirements of the end nodes
    replace the original path
  end if;
end for;
return  $MT$ ;

```

ALGORITHM 1: Cut vertices spanning tree algorithm

3.3. *Optimization.* This stage mainly optimizes the initial state cut vertices spanning tree obtained in the spanning tree stage. The optimization stage is divided into two metrics. The first metric is to check whether the maximum bandwidth of the terminal node is satisfied or to the best of its ability. This metric is also first priority if no alternative path is available. The second metric is to check whether the bandwidth utilization of the link can be improved again without reducing the first metric. In this stage, the method of reverse path check is also adopted [29]. All terminal nodes are traversed, checking whether it can be the highest bandwidth requirement in the current MT satisfied; if meeting the check, whether the link utilization can be improved, that is, after another link is connected to the MT, the link utilization is improved compared with that of the original MT. If cannot be improved, to continue, check the next terminal node. If the highest bandwidth demand of the terminal node cannot be met in the current MT, start from the terminal node, n_t , and reverse search to see if there is a path with higher bandwidth $Path_{n_t, u}$ to replace the original path. In this process, the change can only be made under the condition that the transmission quality of other terminal nodes is not reduced. If the reverse path reaches the source node, a path with higher bandwidth $Path_{n_t, u}$ is found, and the original path can be replaced. Otherwise, keep the original state and perform the preceding steps to check the link bandwidth utilization.

Let TN be the terminal node sets. $MT(S_N, S_L)$ is used to represent the state of MT in the process of building a

TABLE 2: Parameter settings.

Parameter	Number
Server	1
Proxy server	2
User	100
User requests	1-5000

branching node spanning tree, where S_N represents the node sets in MT and S_L represents the link sets in MT.

The variables used in this study are shown in Table 1 (according to the order in the paper).

The overall scenario can be shown as Figure 1.

Pseudocode for the cut vertices spanning tree algorithm is shown as follows.

4. Evaluation

4.1. *Setups.* The simulation is driven on Mininet, which is a very useful network simulation tool. It can run a virtual network composed of multiple terminals, multiple switches, and multiple links. The port can be customized for the terminal, and the parameters such as bandwidth and packet transmission latency can be designed for the link. The number of experimental parameters is shown in Table 2.

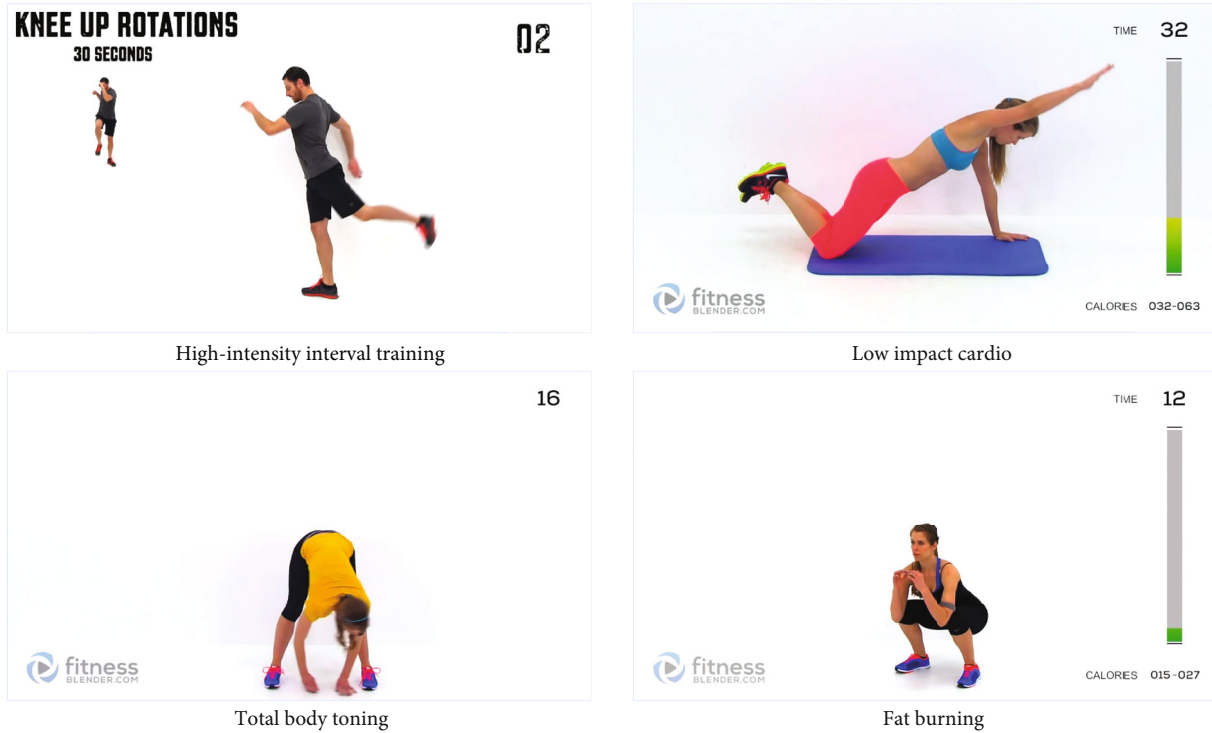


FIGURE 2: Snapshots of physical training videos.

4.2. Metrics

(1) Estimated quality of experience (QoE)

In physical training video transmission, QoE is the most important metric to evaluate the performance of the algorithm. However, questionnaire survey is the most direct way to obtain QoE. Therefore, the validity of the sports video streaming distribution based on cut vertices spanning tree algorithm proposed in this paper is tested through the obtained estimated QoE.

(2) Packet loss rate

It refers to the amount of data lost in the transmission of a packet as a percentage of the amount of input data. Packet loss rate is a critical metric for video transmission quality. A small packet loss rate indicates that link congestion is rare, while a large packet loss rate indicates that link congestion is frequent.

(3) Link utilization

Link utilization refers to the percentage of throughput in a specific time interval in the link access rate. The higher the efficiency of congestion control algorithm, the better the bandwidth allocation algorithm, and the higher the link utilization.

(4) Video delay

When the layered video arrives at the terminal node, it will be cached and waited and then reordered according to the rule number. If the delay is too large, the layered video will not be sorted in time, and the playback quality of the played video will be very poor.

4.3. Physical Training Video Traces. In this study, four videos were selected from Fitness Blender with over 600 free home workout videos for evaluation. All these video traces were 1920 × 1080 resolution, and one-minute segments of each video were extracted for the experiment. The video clips of the four videos are shown in Figure 2, which are high-intensity interval training, low impact cardio, total body toning, and fat burning.

4.4. Performance Comparison. To verify the effectiveness of the proposed algorithm, some popular video streaming distribution algorithms were selected for comparison in this study which are WVSNP-DASH [16], Clone [17], and UR-Aware [18].

As can be seen from Figure 3, the estimated QoE of the algorithm proposed in this paper always remains above 9. The QoE of the four algorithms on fat burning video is not very good. Only the QoE of the algorithm proposed in this paper exceeds 9, and the QoE of the other three baselines is below 9, while the QoE of the Clone algorithm does not even exceed 8; this is because the frames per second of fat burning videos is 60. Throughout the QoE of the four algorithms on the four videos, except for the satisfactory QoE of the algorithm proposed in this paper, the QoE of the other three baselines were more or less unsatisfactory with different video contents. Among them, the better is the QoE of WVSNP-DASH algorithm. QoE is a very important indicator in the scenario of improving physical training effects through videos constructed in this paper, and the level of QoE determines users' recognition of this form.

Figure 4 shows that even with the increasing number of user requests, the packet loss rate of the algorithm proposed

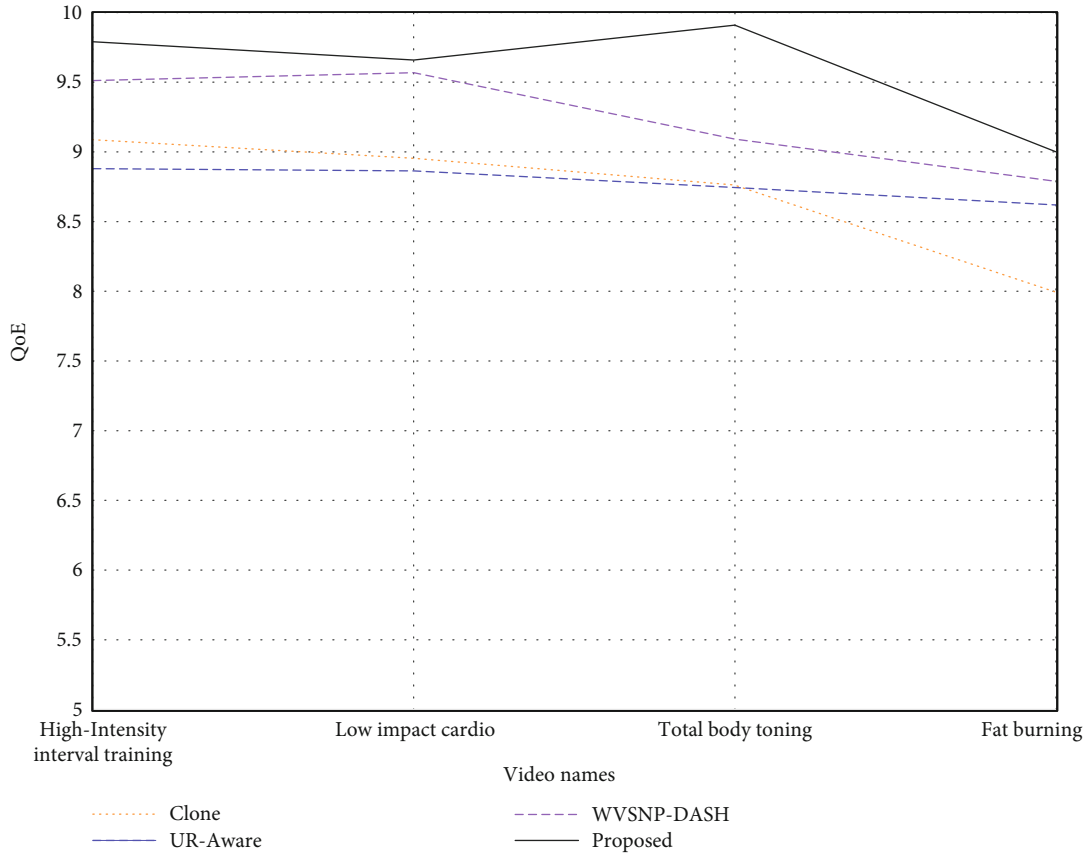


FIGURE 3: QoE for different videos under four algorithms.

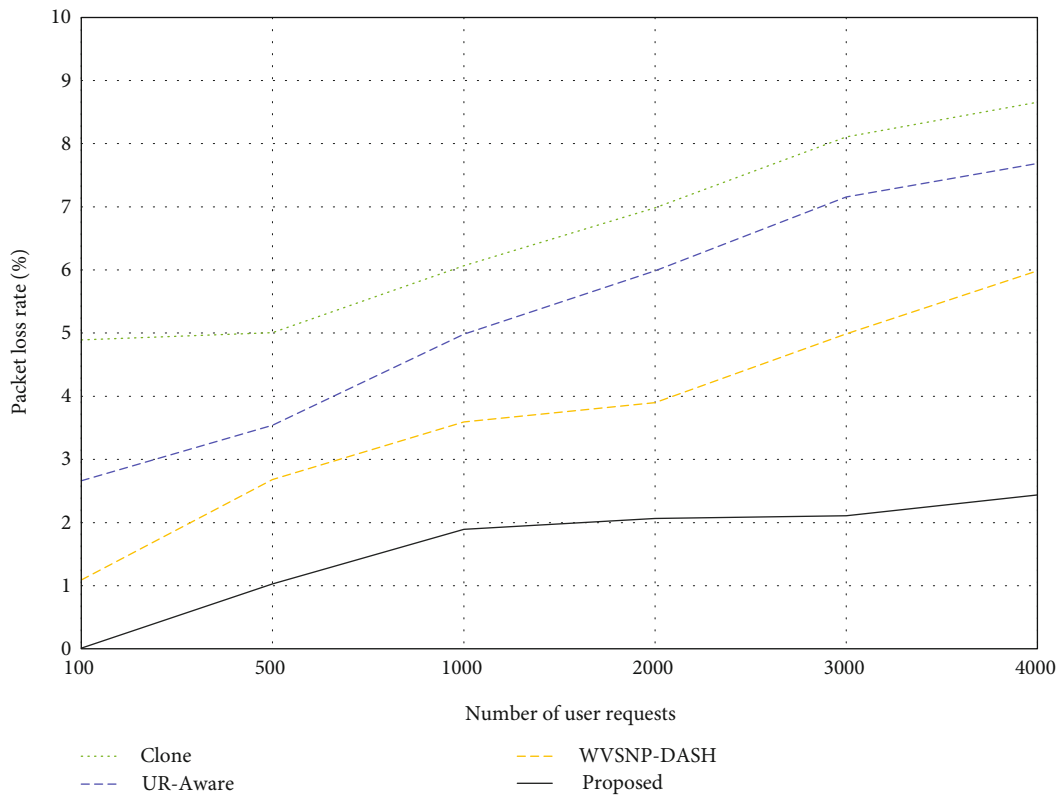


FIGURE 4: Packet loss rate for different videos under four algorithms.

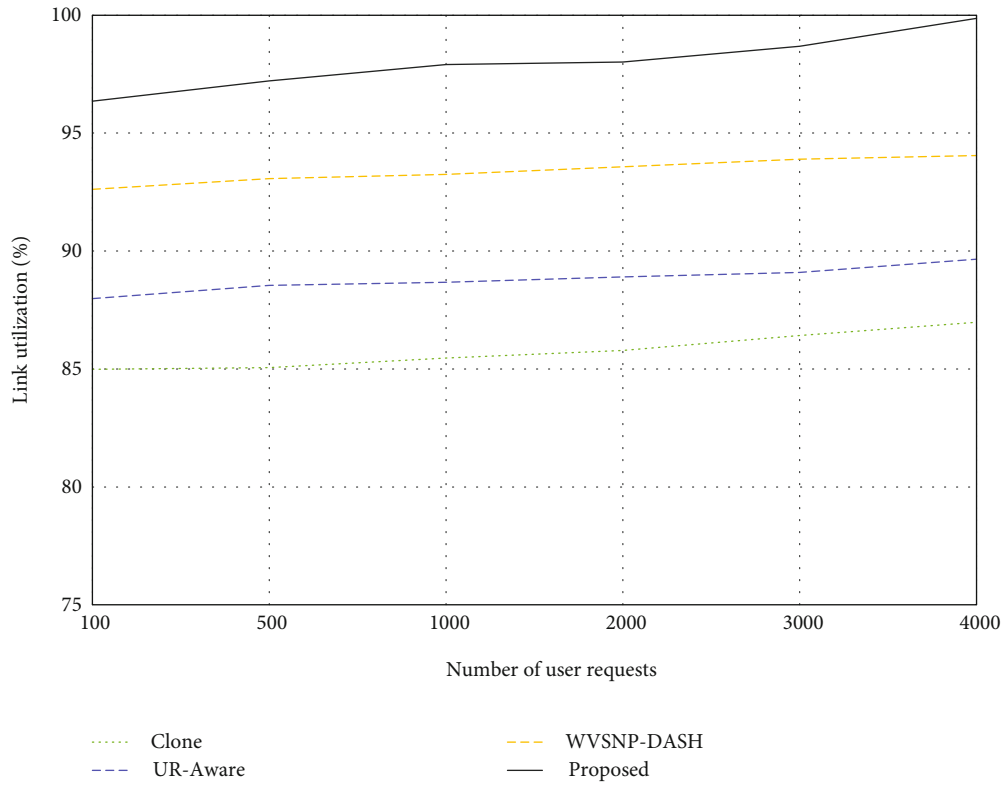


FIGURE 5: Link utilization of different algorithms under number of user requests.

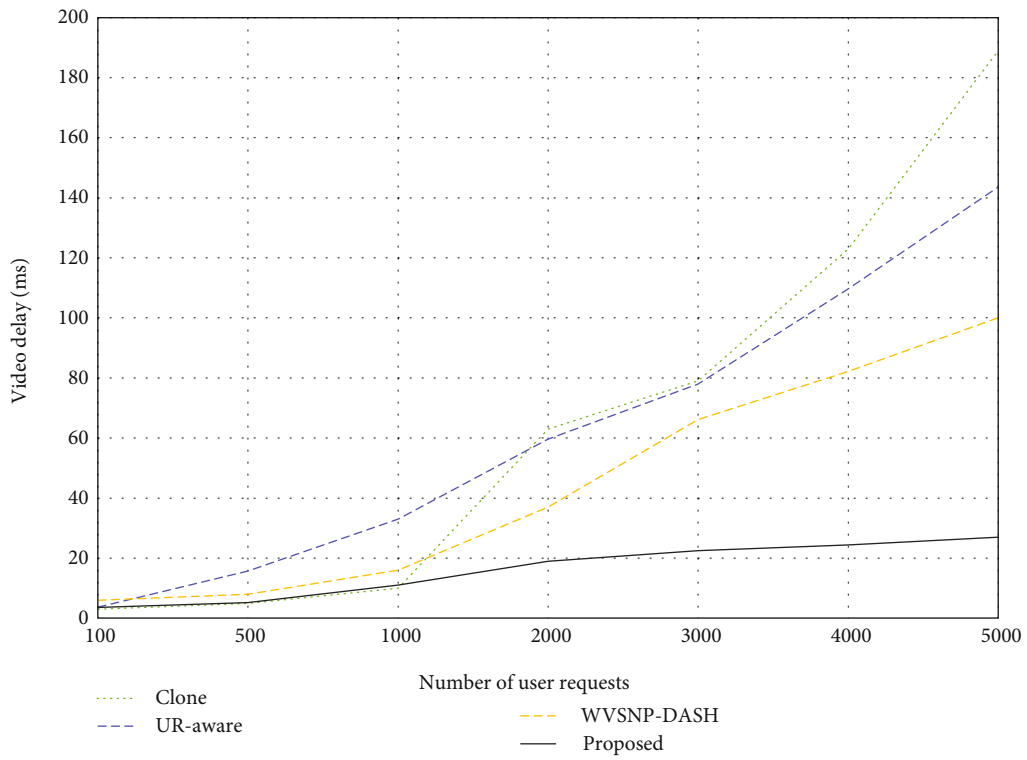


FIGURE 6: Video delay of different algorithms under number of user requests.

in this paper remains below 3% and tends to be stable. Packet loss rate for the other three baselines have been increasing. However, the packet loss rate of WVSNP-DASH algorithm is acceptable because the WVSNP-DASH framework is based on independent playable video clips, which causes specific naming syntax and can transfer basic metadata, so as to promote flexible search, transmission, distribution, and playback. In the physical training through videos, if the packet loss rate is too high, the video pull stream will be incomplete and the video quality will be reduced to a certain extent, which is not a good experience for users.

As indicated in Figure 5, even with the increasing number of user requests, the link utilization of the algorithm proposed in this paper always remains above 95%, which is a good phenomenon. However, the link utilization of UR-Aware and Clone algorithms is always below 90%. Although the link utilization of WVSNP-DASH algorithm does not perform well, it is always at a very stable level. This is because that WVSNP-DASH framework has low client load and provides significant power saving potential on the source node serving video streams.

It can be seen from Figure 6 that with the increasing number of user requests, the video delay of the three baselines presents an exponential growth trend, while the video delay of the algorithm proposed in this paper is always within 40 ms. But on the whole, the delay of the four algorithms is acceptable. Surprisingly, the video delay of Clone algorithm is lower than that of the proposed algorithm when the number of user requests is less than 1000. Video delay is very important in physical training through videos, and lower video delay ensures the quality of video, thus providing users with a high quality reference for physical training.

5. Conclusions

In this paper, video is used to improve the quality of physical training, and a cut vertices spanning tree algorithm is proposed to distribute layered multicast streaming and dynamically adjust the number of layers of sports video streaming. At first, all the cut vertices in the network are found, and the cut vertex sets are formed, and the useless cut vertices are deleted from the cut vertex sets, and the useful cut vertex sets are formed. Then, Prim algorithm is used to generate the initial state spanning tree of useful cut vertices. Finally, the initial cut point spanning tree that obtained in the spanning tree stage is optimized. The simulation is driven on Mininet, compared with baselines; the proposed algorithm has good performance in terms of estimated QoE, packet loss rate, link utilization, and video delay on physical video streaming distribution.

With the mobile possibilities of fitness training, we will investigate video distribution in mobile edge networks. (i) In mobile edge network, edge nodes have computing capability, which can encode, decode and transcode video content, and this features can be taken into account in video distribution. (ii) The operating environment of edge nodes in video distribution is complex and changeable. If edge nodes need to be trained from every time they receive a

new task, the learning speed of edge nodes may not keep pace with the speed of environmental changes or task changes. (iii) Users can take advantage of the computation, storage, and communication capabilities of terminals to participate in video distribution.

Data Availability

All data used to support the findings of the study is included within this paper.

Conflicts of Interest

The authors declare no conflicts of interest in this paper.

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