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Định tuyến động cho video streaming VBR thích nghi HTTP dựa trên mạng điều khiển bằng phần mềm

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TÓM TẮT

Gần đây, truyền tải thích ứng HTTP (HAS) được xem là một trong những kỹ thuật quan trọng nhất trong ngành công nghiệp truyền phát thông tin, nó cho phép truyền tải nội dung đa phương tiện một cách hiệu quả qua internet. Ngoài ra, mạng điều khiển bằng phần mềm (SDN) đã nhận được sự quan tâm đáng kể dựa trên những tác động của nó đối với sự phát triển của dịch vụ Internet qua các lớp mạng. Trong công trình này, chúng tôi đã giới thiệu một phương pháp thích nghi chất lượng mới của video có tốc độ bit biến đổi (VBR), kết hợp kỹ thuật HAS với sự phân bổ đường dẫn động trong mạng SDN. Việc đánh giá thí nghiệm được thực hiện dựa trên các kịch bản khác nhau, chứng minh rằng giải pháp đề xuất tốt hơn phương pháp best-effort truyền thống cả về tốc độ bit lẫn độ mượt mà của luồng video.

Từ khóa: *Truyền tải thích ứng, Định tuyến động, HTTP, SDN.*

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Dynamic routing for HTTP Adaptive VBR Video Streaming based on software defined networking

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ABSTRACT

Recently, HTTP Adaptive Streaming (HAS) has been considered as one of the most important technique in media streaming industry that allows multimedia content to be transmitted efficiently over the internet. In addition, Software-Defined Networking (SDN) has received significant attention based on its impacts on the development of Internet service across layers. In this work, we introduce a novel quality adaptation method of variable bitrate (VBR) that incoporates the HAS and dynamic path allocation in SDN networks. Experimental evaluation performed on different scenarios demonstrates that the proposed solution outperforms the traditional best-effort method on both overall bitrate and smothness of the stream.

Keywords: *Adaptive Streaming, Dynamic routing, HTTP, SDN.*

1. INTRODUCTION

In the recent years, video streaming over HTTP has occupied as a main video traffic source over the Internet, which account for roughly 82% of the total network traffic by 2022. Currently, adaptation methods on HTTP video streaming can be categorized into the buffer-based and throughput-based methods.[1-4] In our previous study,[5] we presented an adaptive video streaming approach over HTTP, but it only focuses on constant bitrate (CBR) videos in which segment bitrates are constant throughout the video. In this paper, in addition to the network bandwidth fluctuation, we need to take into account the bitrate fluctuation of variable bitrate (VBR) videos during playback time. In the state of the art, the methods have succeeded in bitrate adaptation for VBR videos,[3,4] which provides the best effort to acquire better Quality of Experience (QoE) in all contexts. However, the above HTTP-based adaptation methods only regard the client's behavior without concerning the transporting medium's characteristics such as the forwarding policy of the traditional switch network.

On the other hand, OpenFlow/Software Defined Networking (OF/SDN) has been quickly studied and implemented as one of the most important infrastructure for the future of network technology.[6] The authors of previous studies,[7,8] had pioneered in the area of Quality of Service (QoS) routing for scalable video coding video streaming over OF/SDN networks; nonetheless, they did not consider the adaptation problem at the client.

Furthermore, recent studies[9,10] have proposed SDN-based dynamic resource allocation and management architecture for HAS applications. However, only general adaptation

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mechanisms for CBR video streaming are considered in these studies.

In this paper, we present the HTTP-based bitrate adaptation combined with SDN-based dynamic routing mechanism to improve VBR video quality. Comparison of state-of-the-art studies with the proposed method is shown in Table 1.

Table 1. Comparison of related works with the proposed solution

Solution	Approach	Bitrate Adaptation	Adaptation Routing
[1 – 4]	HTTP	Yes	Conventional
[7 – 8]	SDN	No	QoS routing
[9 – 10]	Hybrid	Generally	Generally
Proposed	Hybrid	Specifically	Flexible rerouting

2. PROPOSED SOLUTIONS

2.1. SDN-assisted path selection optimization

As depicted in Figure 1, in our proposed controller architecture, we uniquely design a variety of functional modules as follows:

Topology Manager: Discovering the network topology.

Devices Manager: Supervising hosts connected to the forwarders.

Traffic Manager: Collecting statistical data from the forwarders.

Route Manager: Running routing algorithms to obtain desired network path, and installing flow rules onto the forwarders.

Messages Observer: Handling messages from application services.

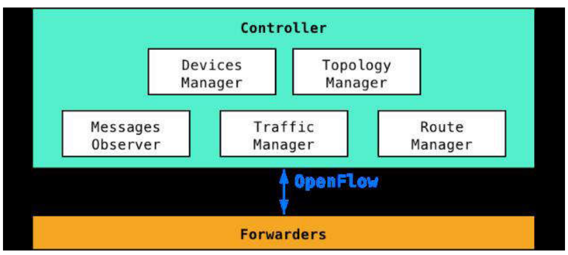

Figure 1. Proposed controller and interface

The controller communicates with the forwarders through an OpenFlow channel. The controller is implemented with two distinct mechanisms for reallocating the path in the SDN controller plane: Periodical Routing and Adaptive Routing. The idea of our routing mechanisms is to find out some paths with the least congestion or the sufficient bandwidth to accommodate requirements in increasing of bitrate adaptation. Definitely, a path with greater flow capacity is capable of delivering video segments of higher bitrate.

In Periodical Routing, the finest path is cyclically selected at a fixed interval as shown in the *Switching Stage* block and the *Steady Stage* block of Figure 2. After obtaining all paths' bandwidth, the controller keeps the least congested path for a short period until the procedure repeats. The total time for a procedure T is determined as:

$$T = (n + \alpha)t \tag{1}$$

with n being the number of paths, α is the steady parameter and t is the switching period.

In contrast, Adaptive Routing is only activated when there is a demand from the streaming service to SDN controller (Figure 2). There could be a monitoring process, which continuously inspect the currently installed path. Whenever the path's throughput do not meet the minimum requirement level BW^{th}, the controller intermediately find a new path to the controller without waiting for a routing request. After detecting a path with improved delivering capability, the controller installs new flow rules so that the video packet can travel along that path. All of the rerouting procedures are appeared transparent to the client.

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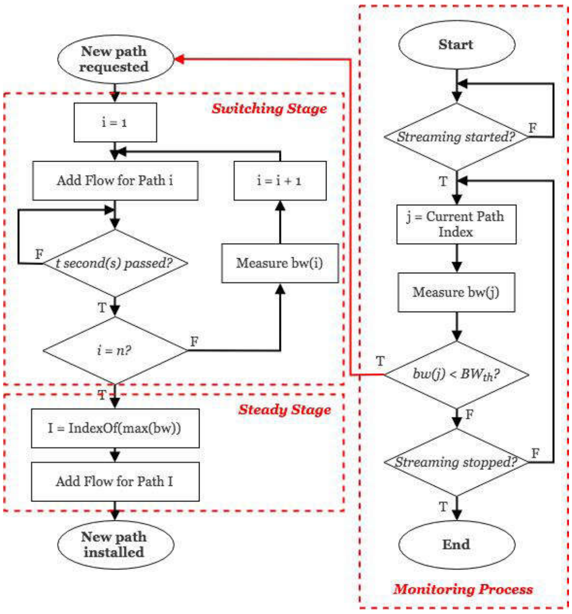

Figure 2. The Flowchart of optimum path selection

2.2. Variations of throughput and VBR bitrate

VBR video bitrate usually fluctuates significantly at some scene changes. An example of the bitrates a VBR video at different quality levels is shown in Figure 3. This property of VBR video makes the delivering the high video quality to clients a real challenge.

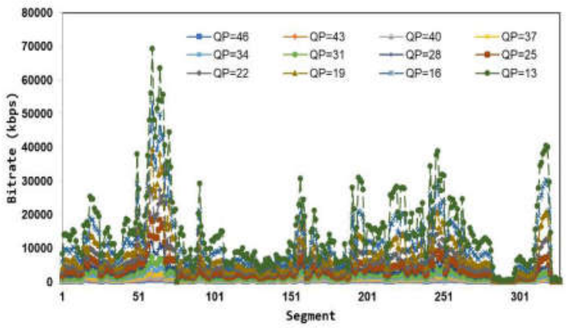

Figure 3. Bitrates of the video

To deal with the above issue, we introduce a *deviation* parameter δ, which was defined as in existing research:[11]

$$\delta = \frac{T_i}{R_i} - 1 \tag{2}$$

where T_i is the throughput and R_i is the segment bitrate.

Specifically, we adopt the simple method presented in [2] to measure the estimated throughput.

$$T_i^e = (1-\mu)T_{i-1} \tag{3}$$

where μ is the safety margin in the range of [0, 1].

The optimal bitrate for segment *i+1* can be defined as:

$$R_{i+1}^{opt} = max\{R_i^{avg} | R_i^{avg} < T_i^e\} \tag{4}$$

2.3. VBR adaptation algorithm

Using the flexible threshold, the segment buffer is splitted into four ranges ($B_{max} > B_{high} > B_{th} > B_{low} > 0$). Each range is corresponding to one of the cases: *switch-up, stable, switch-down* and *assisted switch-down*. Specifically, our method are shown in Algorithm 1.

Algorithm 1: VBR Adaptation Algorithm
Input: R_i^{avg}, R_i^{opt}, T_i, R_i, B_i, δ
Output: I_{i+1}

```
//Switch-up case
if B_i ≥ B_high then
    if δ > δ_0 and R_i^avg < R_{i+1}^opt then
        I_{i+1} = I_i + 1;
    end if
end if
//Stable case
else if B_i ∈ [B_th, B_high) then
    I_{i+1} = I_i;
end if
//Switch-down case
else if B_i ∈ [B_low, B_th) then
    if δ < −δ_0 and (R_i^avg > R_{i+1}^opt or R_i > R_i^avg)
        I_{i+1} = I_i − 1;
    else
        I_{i+1} = I_i;
    end if
end if
//Assisted switch-down case
else if B_i < B_low then
    Request for a new path;
    for every representation v
        if R_v^avg == max{R_v^avg | R_v^avg < R_{i+1}^opt}
            I_{i+1} = v;
        end if
    end for
end if
```

The first case is the switch-up case in which the decision engine sends a signal to increase the video quality. However, the client only request a higher bitrate when a secure deviation value ($\delta > \delta_0$) is confirmed, and the average bitrate of the current representation still is not exceed the optimal bitrate ($R_i^{avg} < R_{i+1}^{opt}$).

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For the *switch-down* case ($B_{low} \le B_i < B_{th}$), the buffer threshold B_{th} is determined as follows:

$$B_{th} = B_{high} - \frac{1}{1+e^{-\delta}}(B_{high} - B_{low}) \quad (5)$$

Similar to the switch-up case, when a severely negative deviation value is detected ($\delta < -\delta_0$), and the current version is still higher than the optimal value ($R_i^{avg} > R_{i+1}^{opt}$); or the current scene is intensive i.e. consumes significant network resource ($R_i > R_i^{avg}$); the client reduce the quality level in the next segment.

We activate the *stable* case when the current buffer level is in [B_{th}, B_{high}). The range is considered to be safe, thus the client do not change the segment representation in the next request.

The last case, *assisted switch-down*, is indicated by the condition $B_i < B_{low}$. The decision engine will downgrade the video quality to an adequate bitrate while the controller proposes a new path with improved delivering capability as discussed in Section 2.1.

3. PERFORMANCE EVALUATION

3.1. Experiment setup

The test-bed setup in this paper is illustrated as Figure 4. The test video is a short animation movie named Elephants Dream, which is VBR-encoded at 12 versions with different quantization parameters (QPs). In the experiments, we set the QP values to be (13, 16, 19, 22, 25, 28, 31, 34, 37, 40, 43, 46). Each version is divided into two-second segments.

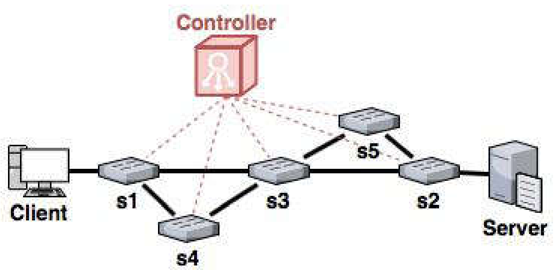


Figure 4. Experimental network topology.

For our proposed solution, the adaptation logic is adopted with the following parameters: $B_{low} = 15s$, $B_{high} = 25s$, $B_{max} = 100s$ and $\delta_0 = 0.5$. For simulation, we use real captured bandwidth when streaming online videos are sent through a Wi-Fi network as in Figure 5. The average latency is around 100ms, while the packet loss rate varies from 0 to 5%. The parameters in the equation (1) are fixed: n = 4, $\alpha = 1$, t = [2*s*, 4*s*, 6*s*]. The threshold bandwidth of the monitoring process BW^{th} = 1.000kbps. In a Non-SDN network [2-5], data packets travel along the path such that minimizes the number of hops, i.e. through switch s2-s3-s1, as illustrated in Figure 4.

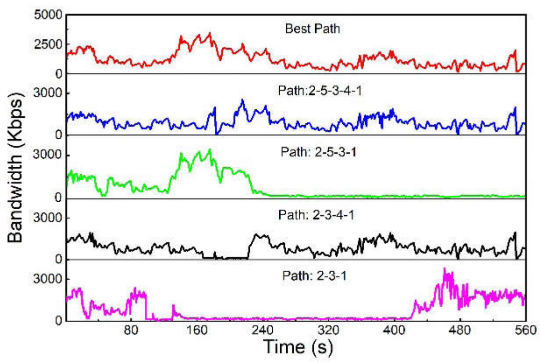
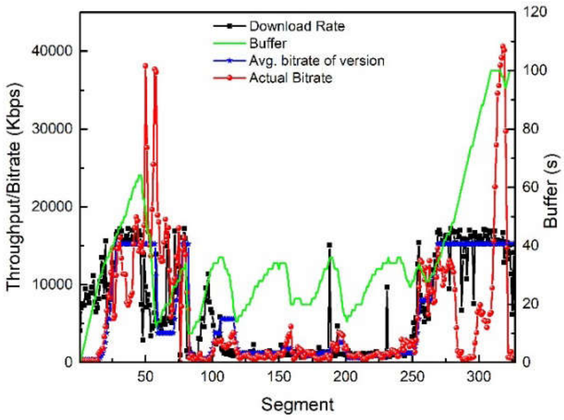


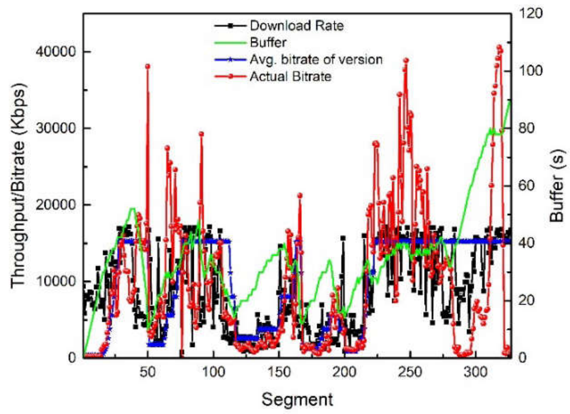
Figure 5. Experimental bandwidths

3.2. Experimental results and discussion

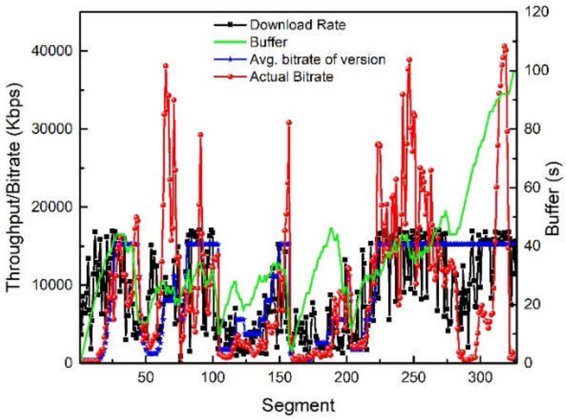
Results of all scenarios are shown in Figure 6, Figure 7 and Figure 8. Results for VBR adaptive video streaming over HTTP protocol without SDN are shown in Figure 6a. And the same results in different cases periodical routing with SDN which are given in Figure 6b, 6c, 6d. Resulting of the adaptive routing with and without monitoring process are shown in Figure 7a, 7b. Finally, comparative results of the quality assessment parameters are shown in Figure 8a, 8b. In order to evaluate more accurately for the above solutions, we can look at Table 2.



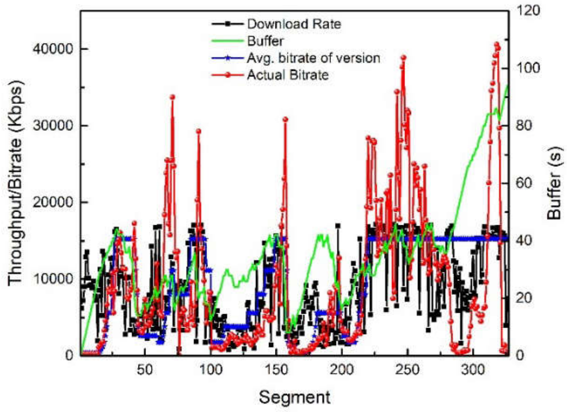
(a) Non-SDN



(b) t = 2s

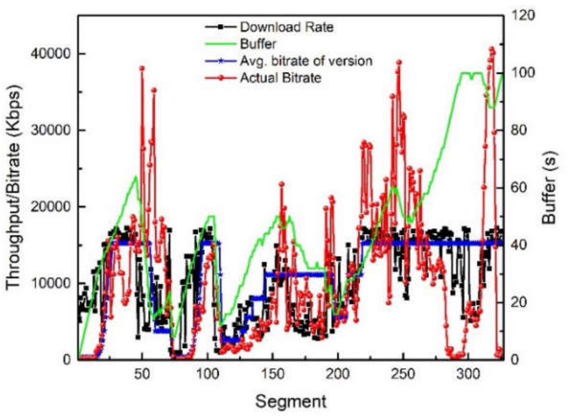


(c) t = 4s

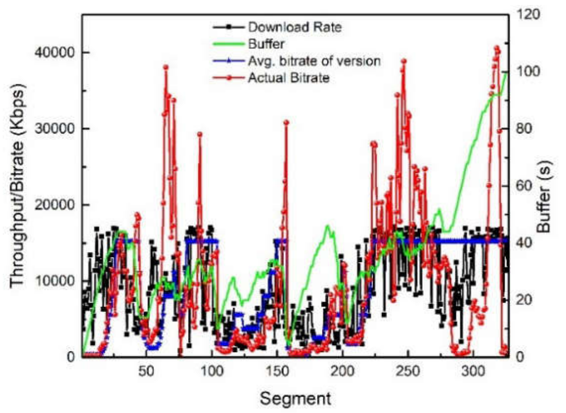


(d) t = 6s

Figure 6. Result of Non-SDN case (a) and Results of Periodical Routing with SDN case (b, c, d).

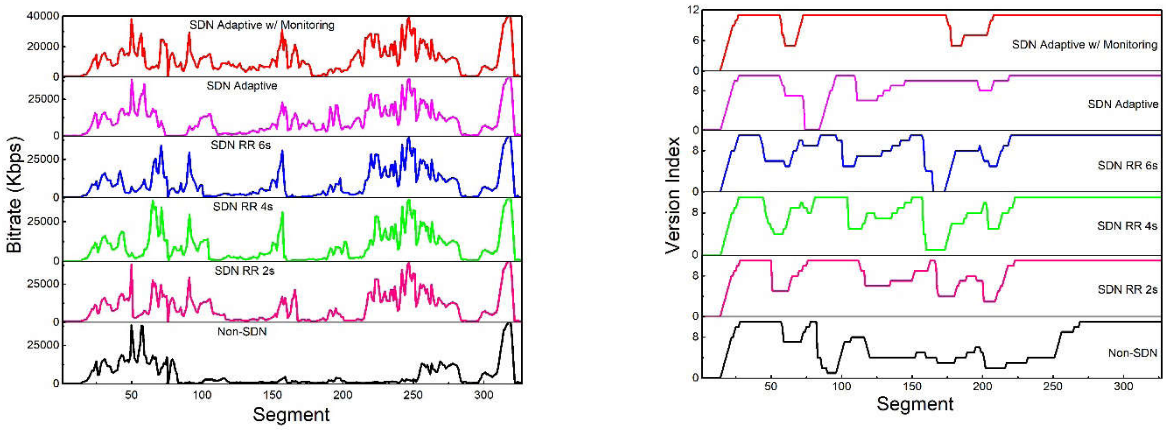


(a)



(b)

Figure 7. Results of Adaptive Routing without (a) and with (b) monitoring.



(a) (b)

Figure 8. Comparison of actual (a) and average (b) bitrate results.

Table 2. Statistics of different methods.

Statistics	**Non-SDN**	**SDN-based Periodical Routing**			**SDN-based Adaptive Routing**	
		t = 2s	**t = 4s**	**t = 6s**	**Without Monitoring**	**With Monitoring**
Average bitrate (kbps)	5767	9535	9250	8975	10425	11445
Proportion of version ≥ 8.000kbps (%)	35,8	61,5	58,4	57,8	72,8	81,0
Average buffer (s)	37	35	36	35	45	53
Proportion of buffer < 15s (%)	7,3	5,8	9,2	7,3	5,8	3,4
Number of version switch-downs	14	9	14	16	9	6
Controller Workload (%)	N/A	74,47	72,06	67,46	62,95	66,96

As shown in Table 2, the proposed methods can improve some QoE parameters for users. For the Periodical Routing case, the overall video quality is improved by exploiting the data transport capability of all the paths rather than of a single path as in Non-SDN networks.

Nonetheless, a higher switching period *t* results in a slight drop in the average bitrate. This method demands intensive computing capacity from the controller.

The method of Adaptive Routing with Monitoring delivers the paramount average bitrate of 11.445kbps, nearly twice the Non-SDN case (5.767kbps). In addition, the average buffer, the percentage of average bitrate is higher than 8.000kbps (sufficient for encoding Full HD videos) and the percentage of low buffer status are all exceptional. Its six version switch-downs also record the undermost number among all, providing a smoother video quality. To achieve such a performance, the controller has to operate more laboriously than that without path monitoring (66,96% compared to 62,95%).

In other words, the Adaptive Routing with Monitoring method is the most efficient method; the controller utilization is taken into account, the Adaptive Routing without Monitoring still provides acceptable performance in the video perceiving experience.

4. CONCLUSION

In this paper, we have presented a novel adaptive streaming method of VBR videos over HTTP incoporating with the dynamic network path allocation over SDN. An extensive experiments has been conducted to study the performance of our algorithm with and without the aid of SDN. The experiments have showed that the proposed solution outperforms existing Non-SDN methods with up to 200% video bitrate improvement.

To develop this architecture in the future, we could broaden the network topology and add heterogeneous types of clients which share the same network resources. The optimized model should consider the client properties to provide traffic balance, stability and fairness among all devices.

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REFERENCES

1. T. C. Truong, D. Q. Ho, J. W. Kang, A. T. Pham. Adaptive streaming of audiovisual content using MPEG DASH, *IEEE Transactions Consumer Electronics*, **2012**, *58*(1), 78–85.
2. T. C. Truong, H. T. Le, H. X. Nguyen, A. T. Pham, J. W. Kang, and Y. M. Ro. Adaptive video streaming over HTTP with dynamic resource estimation, *Journal of Communication and Networks*, **2013**, *15*(6), 635–644.
3. T. C. Truong, H. T. Le, A. T. Pham, and Y. M. Ro. An evaluation of bitrate adaptation methods for HTTP live streaming, *IEEE Journal on Selected Areas in Communications*, **2014**, *32*(4), 693–705.
4. T. Vu, H. T. Le, D. V. Nguyen, N. N. Pham, and T. C. Truong. Future buffer based adaptation for VBR video streaming over HTTP, *2015 IEEE 17th International Workshop on Multimedia Signal Processing (MMSP)*, **2015**, 1-5.
5. T. H. Pham, A. D. Nguyen, T. Nguyen, H. T. Truong, and N. N. Pham. Adaptation method for streaming of CBR video over HTTP based on software defined networking, *2017 International Conference on Advanced Technologies for Communications*, **2017**, *1*, 16–20,
6. N. McKeown et al., OpenFlow: Enabling innovation in campus networks, *ACM SIGCOMM Computer Communnication Review*, **2008,** *38*(2), 69-74.
7. H. E. Egilmez, S. Civanlar, and A. M. Tekalp. An optimization framework for QoS-enabled adaptive video streaming over openflow networks, *IEEE Transactions on Multimedia.*, **2013**, *15*(3), 710–715.
8. H. E. Egilmez and A. M. Tekalp. Distributed QoS architectures for multimedia streaming over software defined networks, *IEEE Transactions on Multimedia*, **2014**, *16*(6), 1597–1609.
9. A. Bentaleb, A. C. Begen, R. Zimmermann, and S. Harous. SDNHAS: An SDN-enabled architecture to optimize QoE in HTTP adaptive streaming, *IEEE Transactions on Multimedia*, **2017**, *19*(10), 2136–2151.
10. LIOTOU, Eirini, et al. QoE-SDN APP: A rate-guided QoE-aware SDN-APP for HTTP adaptive video streaming, *IEEE Journal on Selected Areas in Communications*, **2018**, *36*(3), 598-615.
11. H. N. Nguyen, T. Vu, H. T. Le, N. N. Pham, and T. C. Truong. Smooth quality adaptation method for VBR video streaming over HTTP, *2015 International Conference on Computing, Management and Telecommunications ComManTel 2015*, **2016**, 184–188.