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A Hybrid SDN-Multipath transmission for a Reliable Video Surveillance System

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Abstract— Video surveillance is critical for different aspects of life. One of the most significant issues in the video surveillance system is how to reduce the packet loss rate (PLR) for the transmission path between source and destination. In this paper, two approaches are proposed to solve this problem. The first approach is to use bandwidth aggregation over multiple paths between the video source and the surveillance system to transmit the packets over multiple links with the aid of a software defined network (SDN) controller and openflow switches. The second approach is to use myEvalSVC environment to further enhance the transmission results. The myEvalSVC is an Integrated Simulation Framework for Evaluation of H.264/SVC Transmission. Based on emulation results, it is concluded that the two approaches that use multipath technique with myEvalSVC environment achieve an improved quality of service (QoS). In the first approach, the PLR for a single path is 5.3% while the PLR with multipath transmission is reduced to 3.1%. The second approach, which uses the myEvalSVC environment with multipath technique, enhances the PLR from 2.9% (single path transmission) to 0.67% (multipath transmission). Finally, the results of two approaches are compared in terms of end to end delay, packet loss rate and jitter.

Keywords—SDN, Video Surveillance, Multi-path Transmission.

1. Introduction

Software-defined Networking (SDN) has emerged as a new networking model for developing a self-controlled network management. The SDN architecture considers the isolation of the control from the data planes across the network devices, for example switches and routers. The control plane is logically centralized in SDN controllers which provide programmable APIs for physical layer administration. Furthermore, the SDN controllers produces instructions to the data plane to forward the packets accordingly. The SDN-controllers have a global view of the network status which makes the network more flexible in management and has a unified control via programmable interfaces and protocols[11]. Traditional network configuration is time-consuming and error prone, so many steps are required when an IT administrator needs to add, or remove, a single device within the traditional network. First, the administrator will have to configure multiple devices (switches, routers, firewalls) manually one by one. Then, the device-level management tools are used to update several configuration settings, such as advanced cardiovascular life support (ACLs), virtual LANs (VLANs), and Quality of Service (QoS). In Figure 1, it is shown that the configuration approach makes the traditional network much complex for an administrator to deploy a consistent set of policies. Accordingly, organizations are very likely to encounter security breaches, non-compliance with implications. The responding to changes in network status and structure has been made quick and easy with the aid of SDN. While the SDN seems not appropriate for a typical data center, software-defined technologies can be used effectively and efficiently in a harmonious relationship with More traditional networking. With the right plan, an IT team can create a single, unified infrastructure. The main differences can be described as follows Figure 1.

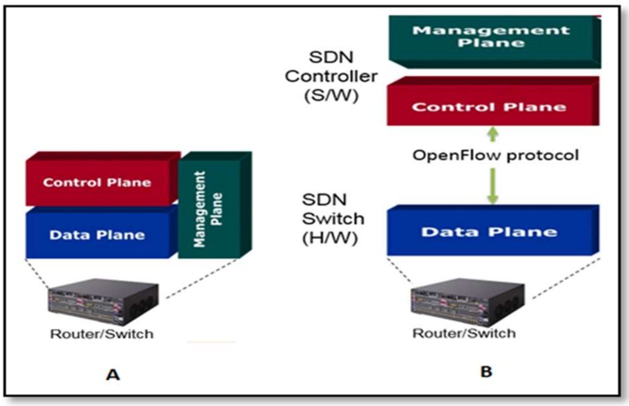


Figure1 :A-Traditional, B- SDN Switch

On the other hand, video-surveillance frameworks are very significant in our daily lives due to the number of applications they make them possible. The reasons for the usefulness of such frameworks are different, ranging from security requests and military applications to scientific purposes [6].

The high QoS, such as bandwidth, end-to-end delay and throughput, are highly requested to be achieved for real-time online applications, e.g. augmented-reality (AR), social networking high-definition video streaming. For example, AR applications require a minimum bandwidth of 10Mb/s to ensure that the video has sufficient information and rely on latencies under 20ms. However, most internet communications are established over a single path mechanism, which is subject to constraints on throughput, load balancing and delay, making it difficult to meet the expected communication performance [2]. Therefore, the communication traffic are spreading over multiple path to achieve a multipath-network mechanism. Compared to a single path mechanism, a multipath approach increases the available bandwidth, ensures high-quality network services, and guarantees quality of experience (QoE) [2, 15, 16].

The main contribution of this work is to use the hybrid approach of multiple disjoint active paths and SDN to improve the video surveillance QoS. Furthermore, the video compression and encoding is used along with the SDN-multipath approach to enhance transmission reliability. Specifically, the following two approaches have been used as follows:

- **First approach**: is to make use of SDN capabilities in allocating bandwidth resources efficiently across two independent paths from the source and destination. Those paths both are active to transmit two video streams from the surveillance source to the destination. Sending the data over multiple paths minimizes the risk of losing the whole link in case of link failure. Without the link failure, the whole performance metrics have been improved significantly.
- **Second approach**: is to use the myEvalSVC framework that contains the methods of compression and encoding of the packets before transmission over the SDN-multipath network.

2. Related works

The multipath transmission for traditional and SDN-controllers are discussed in this section. The discussion reviewed the studies for video surveillance, single and multipath transmission using the traditional network with the aid of SDN. The study includes a comparison of these studies in terms of the type of the network, programming languages, protocols, and types of SDN-controllers.

The literature on [9] has highlighted the converses about multipath network in several different approaches with traditional networks. In [7], the authors reviewed many multipath protocols, from application layer to physical layers, operating at different parts of the Internet. In addition, this research had discussed the mathematical foundation of multipath networks.

In a study conducted by the authors of [12], an adaptive multipath routing construction in physical layer networks is proposed. This construction adapts the links and path failures to calculate multipath.

Another study, which was conducted by the authors of [13], has discussed the Transmission Control Protocol (TCP) in multipath network by using Android smartphones. In addition, this research has analyzed how many smartphone applications cooperate with multipath TCP with both Wi-Fi and cellular networks.

Moreover, The authors of [16] have presented a multipath network virtualization scheme that implements SDN and network function virtualization (NFV). They showed that the multipath networks can be implemented in the virtualized environment with the aid of Mininet emulator.

A seminal study in this area is the work presented by the authors of [1]. The authors proposed a multipath SDN-architecture to select other paths in parallel to provide higher throughput and aggregate capacity by allowing the network to use multiple paths in a physical or network layer.

Other than previously mentioned works, a preliminary work in multipath networks is presented by the authors of [3]. They have explained the advantages of using Multipath TCP (MPTCP) for load balancing in SDN-technologies, and offer a platform for using VLANs, SDN, and MPTCP for traffic management. This research has discussed how the MPTCP can improve the network utilization by coupling it with IP Aliasing. Therefore, more than one IP-address can be connected with a network interface.

Together, these studies provide important insights into the multipath transmission in traditional networks rather the

SDN. Overall, it seems to be some evidence to indicate that the multipath can improve the performance that we need to improve the video surveillance systems. Therefore, this paper discusses five cases in different networks scenarios which are as follows.

- Multipath routing at source node with multiple interfaces.
- Multipath routing at gateway node with multiple interfaces.
- Multipath at source node with multiple wireless interfaces.
- Inverse multiplexing over multiple parallel point to-point narrowband links.
- Multipath routing over wireless mesh network or mobile ad hoc.

3. System model

SDN is one of the most promising paradigms for improving network behavior and performances. The network administrator can dynamically program the network and manipulate the behavior of the network by using a separate control plane from the forwarding plane with the aid of SDN. The control plane globally controls the network-by-network management in a centralized manner. The forwarding plane is accountable for packet forwarding features and follows the rules of the control plane[7].

Devices and controller in SDN architecture. OpenFlow is a Southbound API, which communicates the controller with switches, therefore it allows both the controller and all the switches to understand each other. The protocol is used to control over the forwarding tables that found in the switches, within this control the controller can become the centralized brain in the network [14].

3.1 *OpenFlow switch*

The flow Table located inside switches. The Tables contains a set of match fields, counters and instructions. The header information of every packet is compared with the flow Table entries. If this flow matches, the switch executes the specified actions for this packet. If the flow doesn't match, the controller needs to solve the issue. The switch sends a request (flow request message) to the controller, which has the new packet header. The controller takes a decision for this packet and sends the instructions to the switch (add a new entry in flow Table). The new rule specifies the suitable actions that will be taken for this packet [5].

3.2 *The Network Topology and Video File*

In this subsection, the network topology for video surveillance system will be created. The network topology uses SDN-controller and OVS-switches between source (IP-cameras) and destination (monitoring system). The type of SDN-controller is the default controller used by MININET emulator. The OVS-switches support OpenFlow 2.11.0 version. This version supported Multiprotocol Label Switch (MPLS) ,whichallows the packets or data to be forwarded from layer two rather than forwarded from layer three. More specifically, forwarded from switching level rather than routing level.

In particular, the following steps are applied.

A. **First approach**: the time of video file, which is sent from the camera to the monitoring center, is 10 sec that is spilt

into 300 frame and 895 packets. The resolution of this video is (352 x 288). This approach uses the Video LAN Client (VLC) to transfer the video. The methods that will applied on this approach are:

- Single path transmission.
- Multipath transmission.

B. **Second approach:** the time of video file, which is sent from the camera to the monitoring center is 60 sec that spilt to 1800 frame and 5365 packets. The resolution for this video is (352 x 288). This approach uses the myEvalSVC environment to transmit the video. The myEvalSVC environment is based on the H.264 Scalable Video coding streaming Evaluation Framework (SVEF), which encodes and compress the packets before the transmission over the network. The methods that will be applied on this approach are:

- Single path transmission.
- Multipath transmission.

First approach - VLC: Single Path Transmission

In this approach the network that will be used is shown in Figure 2. The network contains one OVS-switch between source and destination. The packet loss rate (PLR) is the main performance metric that concern the video QoS. Therefore, this paper will propose the approaches that can reduce the PLR. Consequently, we made the initial loss rate for the source link is 5% to test the rate of losses on the video file and how can enhance this rate. In Figure 2, the video file is divided into number of packets. All packets sent on one link to reach the destination. This approach uses the VLC to transmit the video between the camera and monitoring center. The PLR calculated on the file that received on the destination.

First Approach- VLC: Multipath transmission

In this approach, the network that will be used is shown in Figure 3. The network contains three OVS-switches between source and destination. The loss rate for the source link is also made 5% to test the rate of losses on the video file and how could this approach enhance this rate. In Figure 3, the video file is divided into number of packets. In this method the source has two links. One of them experiences 5% loss rate and the other has 1% loss rate. Consequently, all the packets are transmitted on two links to reach the destination. The destination switch (switch 5) should collect the packets and deliver them to destination host. This process completed by feature on OpenFlow protocol which is called match groups. This feature allowed to collect *the packets from two links and delivered to* one link (destination link). This approach uses the VLC to transmit the video between the source and destination.

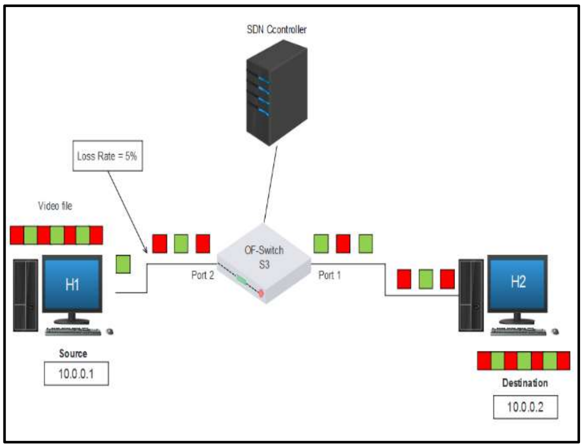


Figure2 :First approach single path transmission

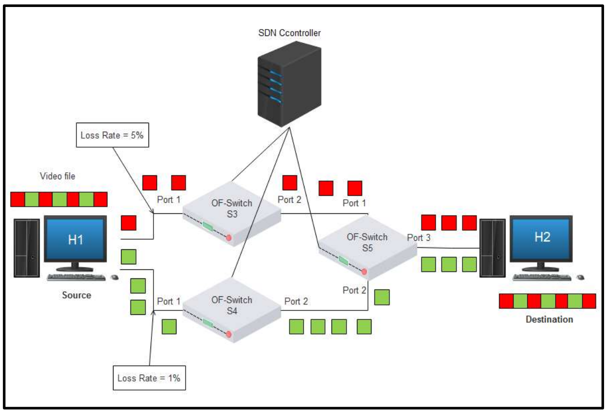


Figure3 : First approach multipath transmission

Second approach - myEvalSVC: single path transmission

The network that will be created in this approach is similar to the network created in the first approach but different on the video file and the method that used to transmit the video to the destination. In Figure 4, the video file is 60 sec to be divided into 5364 packets and 1800 frame to reach to the destination. In this approach, the myEvalSVC environment is used for video file before transmitting it over the network. Therefore, the packets have been encoded and compressed on the source. Conversely, the destination should decode and decompress the packets.

Second approach - myEvalSVC: multipath transmission

The network topology for this method is shown in Figure 5. The source host has two links for transmitting the video packets. Those links are combined into one bond that has same IP address, which is connected to one host (source). Switch 5 will collect the packets from the two links and delivered to one link (host link) as shown in Figure 5. This process supported from OpenFlow protocol specifically OF version 2.11.0 while the first version does not support this feature. This method also used myEvalSVC environment before sent the packets.

On the source side, all the streams are divided into packets. These packets are combined in to small groups. These groups are transmitting on two paths. The first path will be occupied by the packets belong

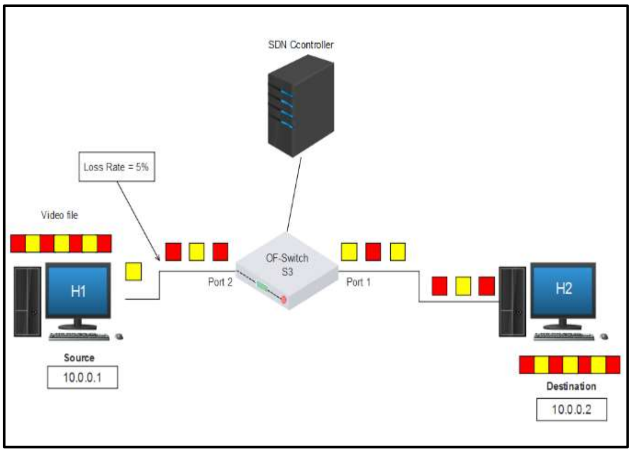


Figure 4: second approaches single path transmission

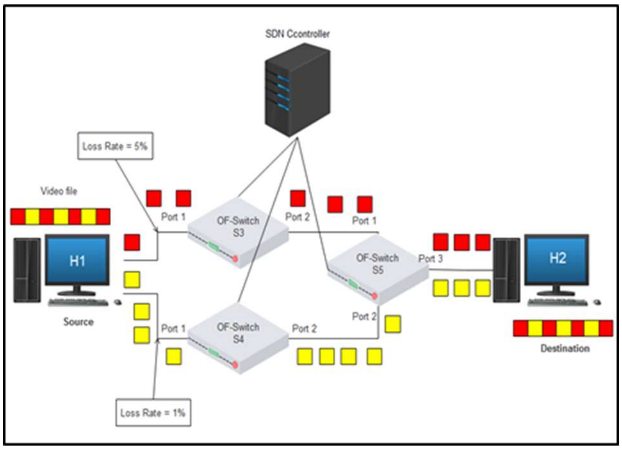


Figure 5: second approach multipath transmission

To the first group of video file while the other path will be occupied by last groups of video file to speed up the transmission. When one link has the high loss rate, most packets are sent on another link.

4. Benchmarking Methodology for SDN Multipath Transmission

In this section, the multipath techniques are applied on the same network that have been used by [16]. The network used one SDN controller (pyretic controller), Five OVS-switches, and Four hosts H6, H7, H8, H9. Host H6 sends the video file to H8 while H7 sends background traffic to H9 as shown in Figure 6.

The purpose of sending the background traffic is to create the network congestion so that the behavior of the network will be examined. It is obvious from the Table 1 the PLR that was obtained by [10] is 13%. Taking this into consideration, this paper will apply the multipath techniques on this network to improve the PLR, which in turn will improve the QoS of video surveillance systems. The modifications that have been applied on this network to achieve the multipath approach is made by creating another path from H6 to switch 4. As a result host H6 has two paths that transmit the video file as shown in Figure 7.

Considering the video transmitted over the network, according to [10], the PLR reaches to 13% while after using multipath transmission the packet loss rate can be reduced to 2.6 %. Therefore, the multipath technique is better than single path transmission for transmitting the video files from the camera to monitoring center. In this section, the results for all previous approaches are discussed. The metrics that are used for comparison between these approaches are as the following,

1. End-to-end delay.
2. Packet Loss Rate.
3. Jitter.

Table 1 : PLR calculation

Method	Total packets	Received packets	Loss packets	PLR
Work of [10]	5364	4666	698	13%
Proposed system	5364	5221	143	2.6%

A. End-to-End Delay

The End-to-End packets delay can be calculated by:

$$\boldsymbol{Delay[P.N] = Receiving\ Time - Sending\ Time} \qquad (\boldsymbol{Eq.1})$$

P.N is packet number. The Receiving Time can be found in the file received by destination host. For example, the received file that found in the destination contain receiving time column. In addition, the Sending Time can be found in the sent file in source side. The proposed system uses file written in C-language for subtracting the sending time from receiving time. In Figure 8 part (A) approach 1 represents the delay when using single path transmission. When the video transmission started, the delay is about 0.002 sec. The highest delay obtained when using this approach is 0.011 sec while back to steady threshold, 0.002 sec, at the end of transmission. However, Figure 8 approach 1 part (B) represents the delay when the multipath in the second approach is applied. It is obvious from the figure that the multipath transmission keeps the delay below 0.01 sec.

On the other hand, part (A) approach 2 represents the delay when single path transmission is applied to approach 2. When the video transmission started, the delay ranges from 0 to 0.008 sec.

Part (B) approach 2 represents the delay when using multipath transmission in approach 2. At the beginning of the transmission, the delay is around 0.001sec. Then, it will increase up to 0.006 sec. Therefore, it is obvious that using multipath transmission with aid of SDN controllers improves the network performance as shown in Table 2.

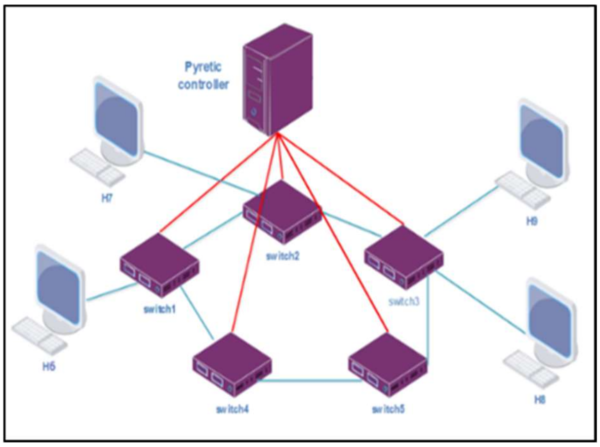


Figure 6: Network topology used by [10]

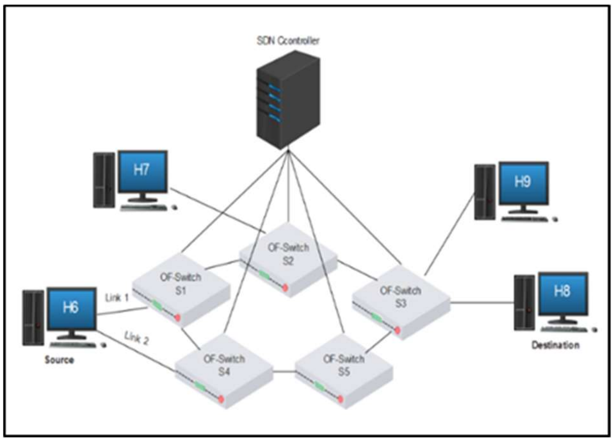


Figure 7: The modified network topology used by [10] after applying multipath transmission

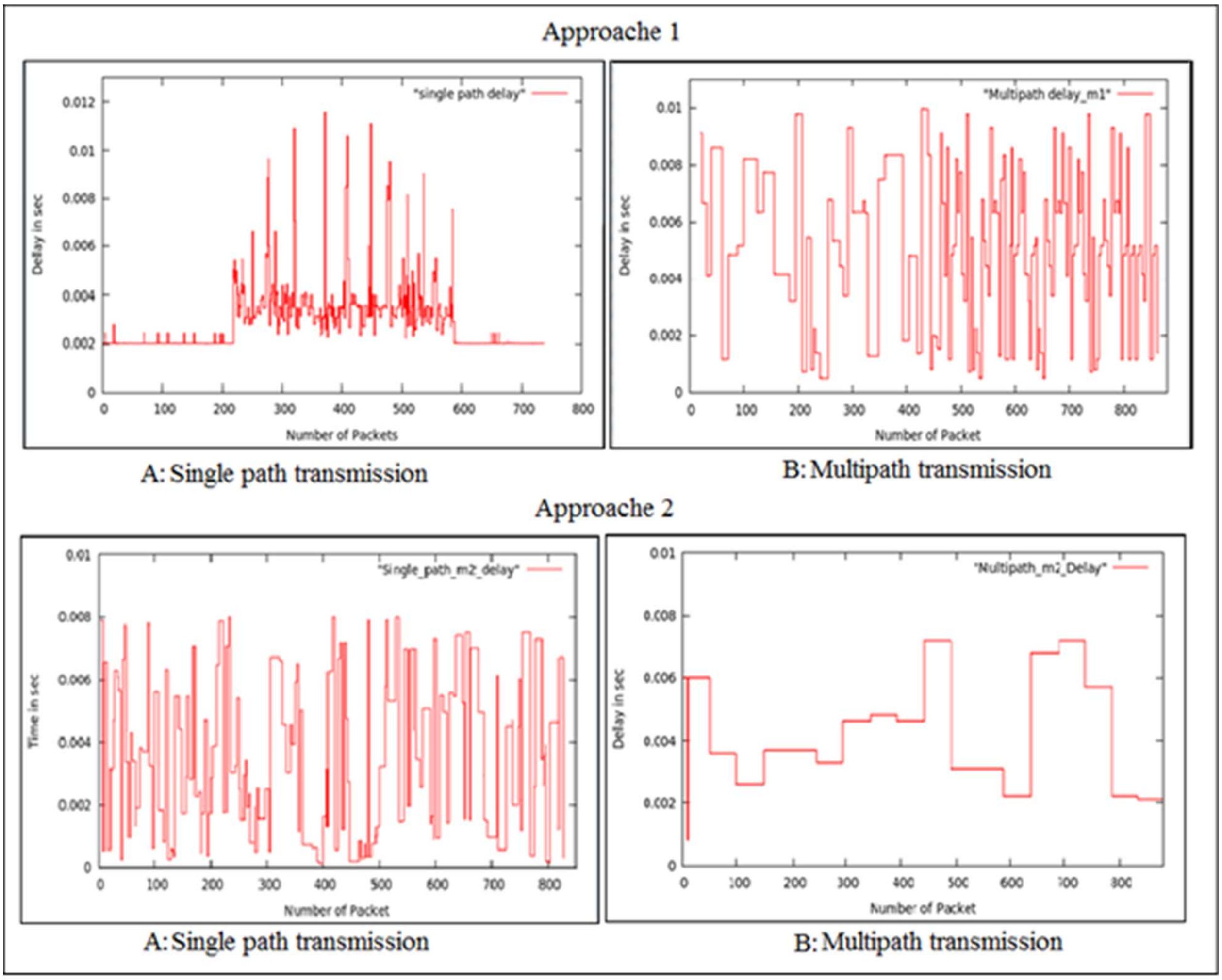


Figure 8: Single and multipath delay for approach 1 and approach 2

Table 2: Delay comparison

Approach		Starting time	High point	Ending time
Approach 1	S	0.002	0.011	0.002
	M	0.009	0.010	Around 0.01
Approach 2	S	0.008	0.008	Around 0.007
	M	0.001	0.006	Around 0.005

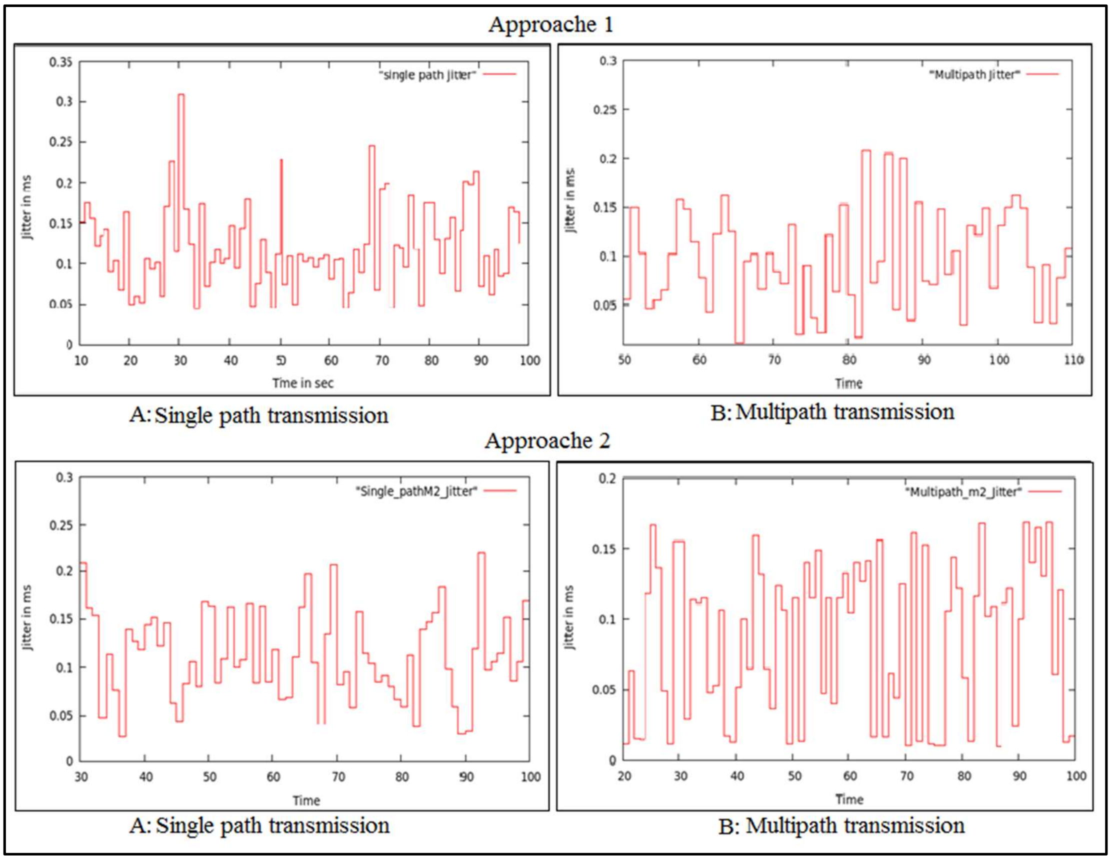
B. Packet Loss Rate

The packet Loss Rate is the second performance metric, which is calculated by:

$$PLR = \left(\frac{Total\ Packets - Received\ Packets}{TotalPackets}\right) \quad (Eq.2)$$

The total packets for first approach is 895 packets while it is 5364 for second approach. The packet number column found in the file received by the destination. Consequently, the PLR can be calculated by subtracting the number of packets that arrived via network from the total packets to get the missed packets, then divide it by the total packets.

Table 3 explains the comparison between the two approaches and two methods (single and multipath transmission). Consequently, It proves the importance of using multipath techniques for enhance the PLR from 5% down to 0.67 %. Therefore, the multipath techniques with myEvalSVC is better than all previous methods.



Figur4 : The jitter for two approaches with two methods

C. Jitter

The jitter is simply the difference in packet delay. In other words, jitter is measuring time difference in packet inter-arrival time. To calculate the Jitter in SDN topology, the IPerf (Network Performance Measurement) is used. Open the client side in the source and server side in the destination. In Figure 9, part (A) while single path transmission is applied with the aid of SDN, the jitter at the starting point reaches at 0.15 sec when the video packets starts to be transmitted. The highest jitter value is ms. However, when multipath transmission is 0.3 considered, the jitter starts at 0.006, and never exceeds 0.2 ms during the transmission. Thus, a noticeable improvement is observed.

On the other hand, when it comes to the second approach that uses the myEvalSVC environment, further improvement is achieved. Specifically, when singlepath transmission is applied, the jitter ranges from 0.05 up to 0.21 ms. While with multipath transmission, the jitter never exceeds 0.16 ms which is the lowest jitter that have been achieved compared to previous approaches. Table 4, in addition to Figure 9, are summarizing the jitter performances in all methods and approaches

Table 3: PLR Comparison

Approach		Sending packets	Received Packets	Loss packets	Loss rate
Approach 1	S	895	847	48	5.3%
	M	895	867	28	3.1%
Approach 2	S	895	869	26	2.9%
	M	895	889	6	0.67%

Table 4: Jitter comparison

Approach		Starting Jitter	High point	At 70 Sec
Approach 1	S	0.15	0.3	0.25
	M	0.06	0.2	0.1
Approach 2	S	0.21	0.2	0.2
	M	0.01	0.16	0.15

5. Conclusion

A video surveillance framework over SDN comprises multi IP cameras, OpenFlow switches, a monitoring center and a controller. The objective of creating such a framework is to monitor a predefined region. Such video surveillance system requires high QoS to transmit the video over the network. Therefore, a multipath transmission based on a software defined network is proposed. This approach proved an enhancement in network performance. Furthermore, using such hybrid approach with myEvalSVC environment is further enhanceds the performance. Specifically, this approach is used to reduce the PLR rate. In addition, the delay and jitter are also enhanced.

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عملية ارسال البيانات باستخدام الشبكة المعرفة برمجيا والمتعددة المسارات لمنظومة مراقبة فديوة موثوقة

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الخلاصة: المراقبة بالفيديو أمر بالغ الأهمية لجوانب مختلفة من الحياة. تتمثل إحدى أهم المشكلات في نظام المراقبة بالفيديو في كيفية تقليل معدل فقد الحزمة (PLR) لمسار الإرسال بين المصدر والوجهة. في هذه الورقة ، تم اقتراح طريقتين لحل هذه المشكلة. تتمثل الطريقة الأولى في استخدام مسارات متعددة بين الكاميرا ونظام المراقبة لإرسال الحزم عبر رابطين بمساعدة وحدة تحكم شبكة محددة بالبرمجيات (SDN) ومفاتيح تدفق مفتوح. الطريقة الثانية هي استخدام بيئة myEvalSVC لتحسين نتائج الإرسال. يعد myEvalSVC إطار محاكاة متكامل لتقييم نقل SVC / H.264. بناءً على نتائج المحاكاة ، تم التوصل إلى أن الطريقتين اللتين تستخدمان تقنية تعدد المسارات مع بيئة myEvalSVC تحقق جودة خدمة محسنة (QoS). في النهج الأول ، تبلغ نسبة PLR لمسار واحد٪ 5.3 بينما تنخفض نسبة PLR مع الإرسال متعدد المسارات إلى٪ 3.1. الأسلوب الثاني ، الذي يستخدم بيئة myEvalSVC بتقنية متعددة المسارات ، يعزز معدل PLR من 2.9٪ (انتقال بمسار واحد) إلى 0.67٪ (إرسال متعدد المسارات). أخيرًا ، تتم مقارنة نتائج الطريقة المستحدثة من حيث التأخير من طرف إلى طرف ، ومعدل فقد الحزمة.

الكلمات الرئيسية: الشبكات المعرفة برمجيا، المسارات المتعددة ، مراقبة الفديو