Performance evaluation of TCP and UDP based video streaming in vehicular ad-hoc networks

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***Abstract*—Video streaming over vehicular ad-hoc network (VANET) is emerged as an important research area to increase communication intent for drivers. Many video streaming applications in VANET are used to improve safety issues and help to have a more comfortable ride. However, there are some important challenges including, high VANET dynamic topology, links disconnection and transmission video errors which decrease the video quality in such networks. The transport layer protocols serve as a link between the application layer protocols and the services provided by the network layer. The two most popular transport layer protocols are User Datagram Protocol (UDP) and Transmission Control Protocol (TCP). In this paper, we propose an adaptation of UDP and TCP protocols for video streaming in VANET. In addition, an evaluation and comparison between these protocols are performed in order to choose the better transmission protocol at transport layer level for video streaming in VANET. Some objective metrics are considered in this study namely throughput, packet delivery ratio, end-to-end delay and PSNR.**

***Keywords*—Vehicular ad-hoc network, video streaming, User Datagram Protocol, Transmission Control Protocol**

I. Introduction

The recent few years have witnessed the advancement of new exciting technology, which affect our lives in different ways to make it easier and more convenient. Wireless ad hoc networks have been of great interest motivated by a number of applications and by the continual advancement in wireless technology. Vehicular Ad Hoc Network (VANET) is a particularity of Mobile ad-hoc network (MANET) where mobile nodes are intelligent vehicles that move and communicate with each other to notify pre-collision, improve traffic management and comfort for road users [1]. Injury and deaths due to road traffic accidents (RTAs) is increasing day to day [2]. According to the World Health Organization (WHO) reports, the annual number of road fatalities is estimated approximately 1.3 million each year [3]. That is why the video streaming in VANET plays a very important role for reducing the accidents number in the road. In addition to traffic safety, there are some anti-social behaviors including crimes, robbery and terror acts which are in a continuous increasing, in such situations, the video dissemination over VANETs is very essential to avoid or reduce any risk. VANET provides three types of communication: vehicle to vehicle (V2V), vehicle to infrastructure (V2I) and vehicle to broadband cloud (V2B) [4]. Figure 1 shows the architecture of VANET. V2V and V2I communications are based on DSRC (Dedicated Short Range Communication), and V2B communication uses wireless broadband which is a technology that provides high-speed wireless access [4].

The transmission protocols at transport layer provide host-to-host communication services such as connection- oriented communication, reliability, flow control and multiplexing. User Datagram Protocol (UDP) and Transmission Control Protocol (TCP) are the most popular transport layer protocols used for data transmission in the networks. However, UDP dont have any error recovery mechanism [5], contrary to TCP which uses the retransmission technique to recover the missing data. The reliability mechanism of TCP can increase the transmission delay of the data [6][7].

In the literature of video streaming in VANET, many works use the UDP or TCP at the transport layer level. However, any comparison between these protocols in such networks was proposed. Our work evaluates and compares UDP and TCP to choose where is the most adequate for the video streaming in VANET. Many evaluation metrics were used in this work such as throughput, packet delivery ratio, end-to-end delay and Peak Signal to Noise Ratio (PSNR).

The rest of the paper is organized as follows. In section II, we present the related work about the video streaming in VANET. Section III presents an overview of UDP and TCP protocols. We describe in section IV our conceptual models of adapted UDP and TCP protocols for video streaming in VANET. Section V shows and investigates the simulation results. Finally, in section VI we conclude the paper.

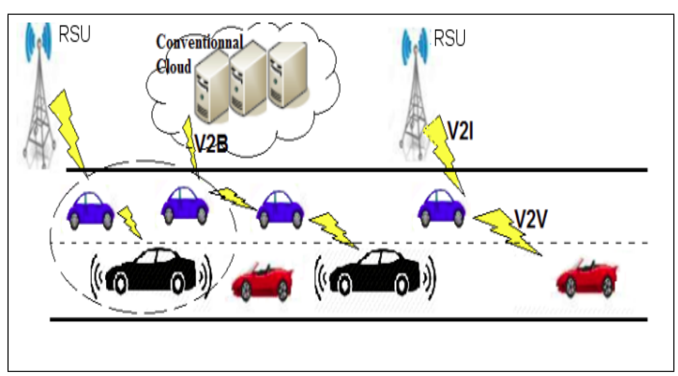

Fig. 1. VANET communication patterns

II. Related work

We present in this section some recent proposed video streaming solutions in VANET. Many research works have been achieved in order to resolve certain issues related to the dissemination of video information contents over vehicular networks (i.e. network disconnection, congestion, high transmission delay, video quality requirements).

Asefi et al. proposed in [8] an integrated scheme in VANET, which consists of two parts: geographic routing scheme of video packets and network mobility management scheme of vehicles IP address and handover prediction mechanism. The experiments proved that the proposed routing protocol improves the video quality in terms of start-up delay, frequency of the streaming freezes and frame distortion compared to greedy geographic routing protocol because the proposed protocol takes into account the distortion, delay and distance in the choice of relays vehicles contrary to greedy protocol, which considers only the distance factor.

Belyaev et al. in [9] proved that the use of Skype application [10] for the transmission of the video from the vehicles to infrastructure (V2I) suffers from the high rate of packet losses, which decreases the visual video quality. The main cause of this problem is the lack of the coordination between vehicular users for channel resource allocation at MAC layer when they upload the video data simultaneously, which produces a congestion in the network. This work concluded that the basis coordination between users is necessary to improve the bandwidth allocation.

Wang et al. in [11] proposed a Preference-aware Fast Interest Forwarding (PaFF) for video streaming in Information-Centric Networking (ICN) based VANETs. In PaFF, each vehicle selects a set of associate vehicles with similar mobility and video preference. At each vehicle, a High Preferred Content Table (HPCT) is created to save the status of associate vehicles. The vehicle uses its HPCT table to select the next hop for forwarding the interest packet. The simulations have been shown that the PaFF can achieve higher performances in terms of delay of finding data and cache hit ratio when comparing with the state-of-art solutions (i.e. social-tie based interest forwarding scheme (STCR) [12], Robust Forwarder Selection (RUFS) [13]). PaFF can be further enhanced by integrating new strategies of content centric mobile environment to further improve the performance of sharing video streaming.

Zaidi et al. proposed in [14] a new solution that aims to improve the quality of video and avoid network congestion called enhanced adaptive sub-packet forward error correction (EASP-FEC). This latter divides the packet into a set of sub-packets and creates the redundant sub-packets. The authors were concluded that EASP-FEC provides better error recovery rate than Sub-Packet Forward Error Correction (SPFEC) and Packet Forward Error Correction (PFEC) for video streaming in VANET. However, this solution didn't handle the problem of burst errors of the video. Zaidi et al. proposed in [15] an enhancement of UDP protocol that uses Sub-Packet Forward Error Correction (SPFEC). This solution improves the video quality in terms of PSNR and Mean Opinion Score (MOS) and reduces the overload of the network. However, the proposed adaptation of UDP suffers from the burst errors of the video. Zaidi et al. in [16] proposed a Hybrid Error Recovery Protocol (HERP) for video streaming over VANETs. HERP uses the Sub-Packet Forward Correction (SPFEC) mechanism to recover the uniform errors of the video, in addition HERP uses the retransmission technique to recover the burst errors. The simulation results have been showed that HERP achieves high video quality in real-time, comparing to UDP and UDP with SPFEC. HERP protocol needs more improvement by dynamic adapting of there parameters to improve further the video quality.

Mezher et al. in [17] proposed a multimedia multimetric map-aware routing protocol (3MRP) to transmit the video reports to RSU in smart VANET cities. The proposed solution selects the forwarding nodes based on four metrics (i.e. distance, trajectory, density and available bandwidth). The change of VANET conditions makes the proposed routing protocol less adaptable.

Sun et al. in [18] proposed a channel allocation algorithm for video streaming in VANET by improving baseline algorithm. To achieve lower interruption ratio and higher visual quality, the RSUs allocate the channels for the most urgent vehicles to transmit data using the auction-based channel allocation mechanism. This algorithm needs to be optimized and makes it more practical, by taking into consideration more general channel and mobility models.

Many challenges of video streaming works in VANET can be extracted in different hands. On the one hand, most of video streaming works in VANET are based on the network and MAC layers level, and few of themes are based on the application and transport layers levels. The video streaming solutions at these latter layers can improve widely the video quality in VANET. On the other hand, many works use the most commonly used transport layer protocols UDP or TCP in VANET. In the VANET literature, it does not exist any work that evaluates and compares the two protocols UDP and TCP for video streaming in VANET.

III. UDP and TCP protocols

Many transport layer protocols are used for the real time applications (i.e. video and sound), we focus in our study on the two most used protocols, which are Transmission Control Protocol (TCP) and the User Datagram Protocol (UDP). Our main objective is to evaluate the performance and compare these two protocols for the video streaming in VANET. This section gives an overview of UDP and TCP protocols.

A. UDP

UDP is unreliable and connectionless protocol, which means that it cannot guarantee a protection of the transmitting packets and the reception of these packets in its original order. UDP mechanism is very simple and it achieves lower overhead data delivery due to its incapability to recover the lost packets. As shown in figure 2, the UDP packet format is composed of two fields UDP header and UDP Data. The UDP header consists of four (4) sub-fields: the first-one saves the address of the video source, the second-one contains the address of the destination, the third-one represents the length of the packets data and the last one uses to check the CRC of the packet. UDP can be used when the timeliness is more critical than the reliability, it's more suitable for some applications such as the streaming of audio or video.

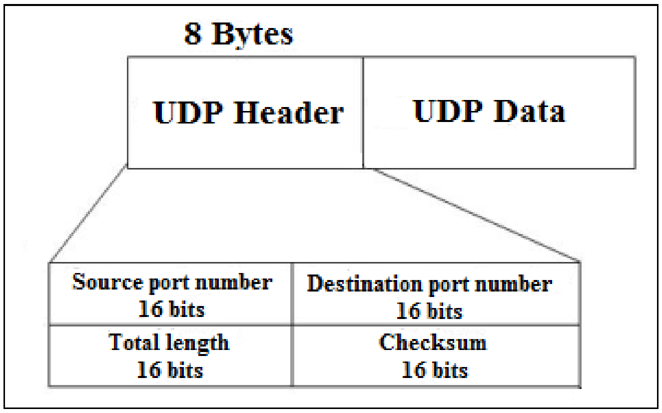

Fig. 2. Format of UDP packet

B. TCP

TCP is a connection-oriented transport layer protocol, in which data is not sent until the establishment of a connection. TCP is considered as a reliable protocol because it performs both error detection and error recovery and guarantees that packets will be delivered in the same order of their transmission. TCP is used with unicast communication only, the figure 3 shows a TCP header which is more complex than the UDP one, where TCP uses acknowledgment mechanism to ensure that the data is well received.

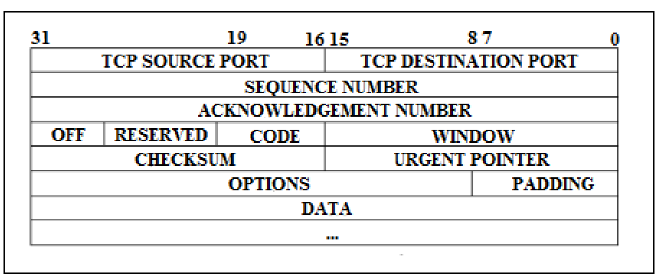

Fig. 3. Format of TCP packet

The table I summarizes the main differences between TCP and UDP.

IV. Conceptual model: our contribution

In this section, we present our conceptual model of UDP and TCP for video streaming in VANET, at the level of sender and at receiver vehicles using a set of agents. As shown in figures 4 and 5, and in order to generate the video data, the sender

TABLE I
TCP vs UDP

No.	TCP	UDP
1	Connection-oriented	Connectionless
2	Reliable	Unreliable
3	Acknowledgment mechanism	No acknowledgment
4	Support unicast only	Support unicast and multicast
5	Basic header 20Bytes	Header 8Bytes

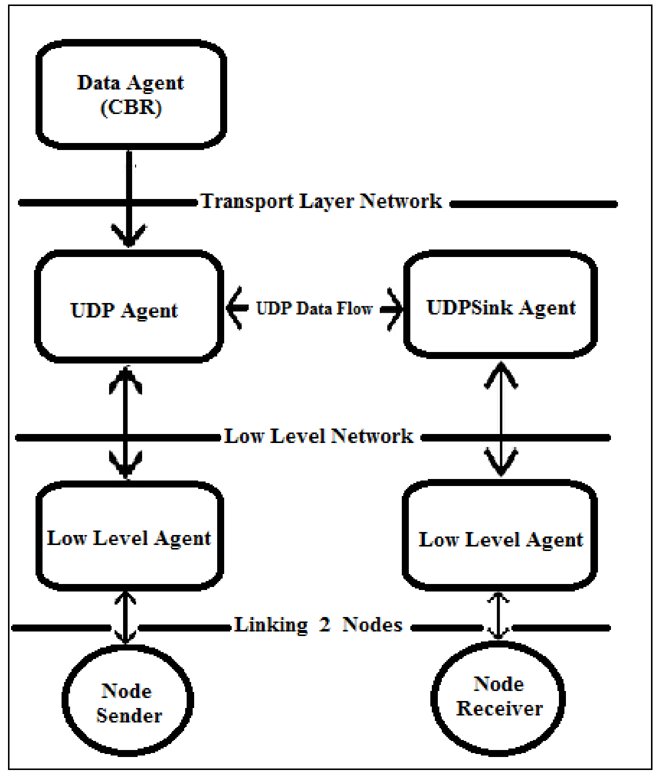

Fig. 4. Conceptual model of UDP

vehicle attaches Constant Bit Rate (CBR) and File Transport Protocol (FTP) agents at application layer level to UDP and TCP, respectively. TCP/FTP traffic scenario offers connection oriented transmission environment, where communication occurs in phases, connection establishment, data transmission, connection termination. UDP/CBR traffic offers transmission of data at constant bit rate and does not communicate in phases, and traffic moves in one direction from source to destination [19]. We note that myUDP is considered as an agent to send the video packets and myUDPSink is an agent to receive the video packets. At the transport layer level, the UDP sender vehicle uses myUDP agent to transmit the data at this level to myUDPSink agent of the receiver vehicle. Like UDP, TCP uses myTCP agent at the transport layer level of the sender vehicle and myTCPSink agent at the transport layer

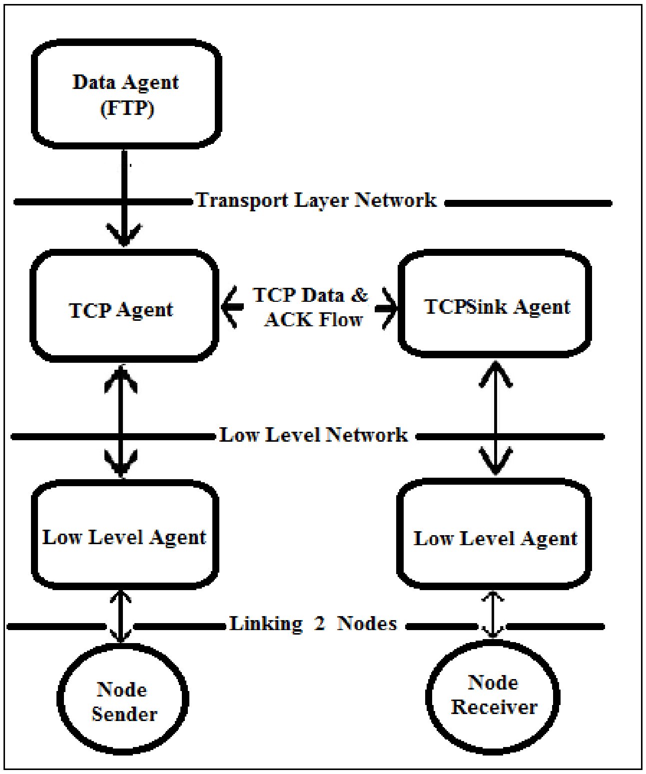

Fig. 5. Conceptual model of TCP

level of the receiver vehicle to guarantee the transmission of the video data and the acknowledgement. The other agents serve to achieve the services at the lower layers (network, MAC, etc.).

Figures 6 and 7 depict the main functions of myUDP and myUDPSink agents in the case of UDP (myTCP and myTCPSink agents in the case of TCP, respectively) for the transmission of video data. myUDP agent uses the function sendmsg() to send the video data to the receiver vehicle. On the other hand, myUDPSink agent uses recv() function to receive the video data from the sender vehicle. In the case of TCP, myTCP agent contains three main functions namely sendmsg() to send the video data, recv() to receive the acknowledgement from the receiver vehicle and output() to retransmit the lost data. On the other hand, myTCPSink uses three functions such as recv() to receive the video data, ack() to send the acknowledgement, and other function recv() to receive the retransmitted video data.

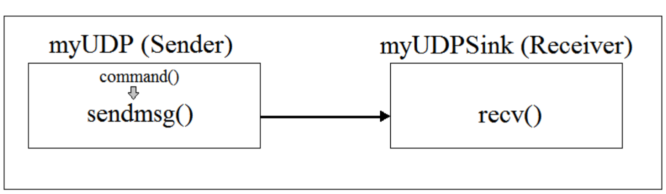

Fig. 6. Main functions of myUDP and myUDPSink agents

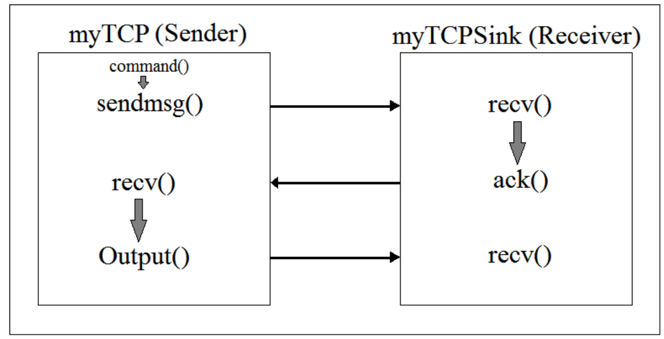

Fig. 7. Main functions of myTCP and myTCPSink agents

V. Simulation and Results

A. Simulation setup

To evaluate and compare the two transport layer protocols UDP and TCP for video streaming in VANET, we have performed many series of simulation using network simulator 2 (ns-2) [20]. The network topology is extracted from Souk-Ahras city (Algeria) using OpenStreetMap [21]. The traffic mobility is generated using SUMO [22]. Table II summarizes the general simulation parameters of our simulation in urban scenario such as propagation model, routing protocol, video file, packet size, simulation time, etc.

TABLE II
Simulation parameters and its values

No.	Parameter	Value
1	Simulator	NS-2.35
2	Protocols studied	TCP/FTP, UDP/CBR
3	Simulation Area	Souk-Ahras city(1631mX1329m)
4	Routing protocol used	AODV
5	Video file	Akiyo_cif
6	Packet size	1024Bytes
7	Radio propagation	TwoRayGround
8	Number of vehicles	65
9	Simulation Time	150s
10	Communication type	Unicast

B. Simulation results

1) Throughput: it represents the number of successful delivered packets per unit of time, which is measured in bit per second (bps), the throughput formula is given as follows:

$$Throughput[kbps] = \frac{Received\_data[kbytes]}{Simulation\_time[second]} \quad (1)$$

Figure 8 depicts the achieved throughput in the case of UDP and TCP protocols after the transmission of all video packets.

As shown in this figure, the UDP throughput value (396.75 kbps) is higher than TCP throughput value (243.76 kbps). The main reason of this result is when a TCP sender detects a packet loss, it will trigger a congestion control and reduce the transmission rate in order to mitigate network load to avoid the congestion. Consequently, this behavior will lead to low bandwidth utilization rate and cause lower throughput. It is contrary to UDP sender which uses perfectly the bandwidth.

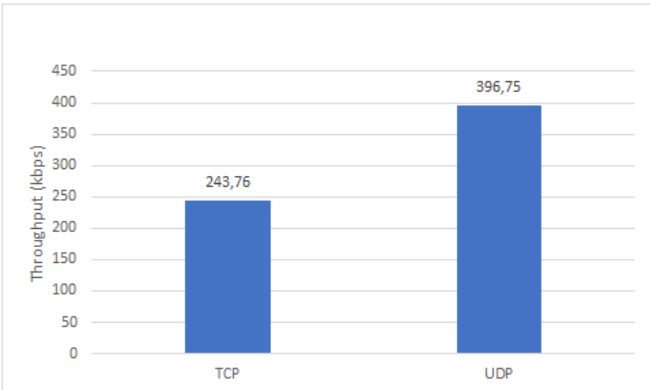

Fig. 8. Reached Throughput of TCP vs UDP

2) Packet Delivery Ratio (PDR) and Packet Lost Ratio (PLR): PDR is the ratio of packets successfully received comparing to the total number of sent packets; its formula is given as following.

$$PDR[percentage] = \frac{Received\_Packets}{Sent\_Packets} \quad (2)$$

Contrariwise, PLR is a ratio of lost packets comparing to the total number of sent packets. It is calculated by the following equation.

$$PLR[percentage] = \frac{Lost\_Packets}{Sent\_Packets} = 1 - PDR \quad (3)$$

Figure 9 shows the PDR and PLR of UDP and TCP. As depicted in this figure, the PLR of TCP (31.45%) is lower than the PLR of UDP (43.35%). This result is due to the reliability mechanism of TCP which retransmit the lost packets, contrary to UDP which cannot recover the lost packets. Figure 9 shows also that the PDR of TCP (68.55%) is higher than PDR of UDP (56.65%), because the PLR of TCP is lower than PLR of UDP.

3) Average End-to-End delay (E2E delay): it represents the sum of end-to-end delay of all transmitted packets over the total number of these packets. While the end-to-end delay of a packet is the interval time between the send time and received time of this packet. The average end-to-end delay is calculated as following.

$$Average\_E2E = \frac{\sum_{j \in received\_packets} (Received[j] - Send[j])}{Received\_Packets} \quad (4)$$

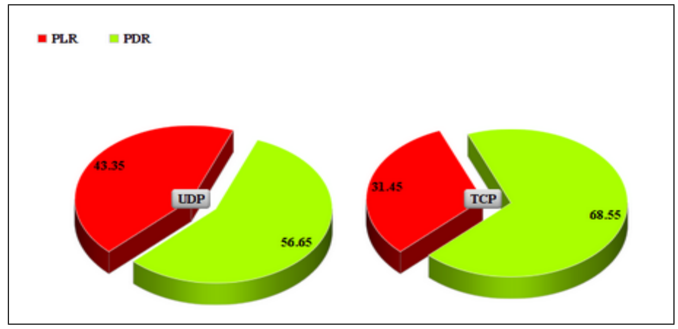

Fig. 9. PDR and PLR of TCP vs UDP

Figure 10 shows the average end-to-end delay of all transmitted video packets in the case of UDP and TCP protocols.

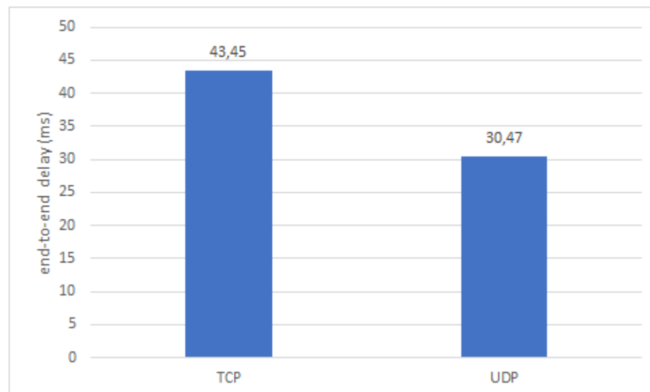

Fig. 10. Average E2E delay of TCP vs UDP

As illustrated, TCP provides higher average end-to-end delay (43.45 ms) than UDP (30.47 ms). This result is because the retransmission technique and the congestion control mechanism of TCP protocol which add additional transmission delay that increase the average end-to-end delay. Notice that this is contrary to UDP which does not retransmit the lost packet nor control the congestion problem.

4) Peak Signal-to-Noise Ratio (PSNR): it is an objective measure widely used as a method of comparing the quality of compressed images and measured to the original ones. PSNR is based on the mean square error (MSE), and it calculated as following.

$$PSNR[dB] = 20log_{10}\frac{V_{peak}}{MSE} \quad (5)$$

Where $V_{peak} = 2^k - 1$, and k is the number of bits per pixel.

Figure 11 presents the video quality in terms of PSNR in the case of UDP (b) and TCP (c) compared with the original video (a). As shown in this figure, UDP (22.96 db) provides lower PSNR than TCP (26.09 db). This outperformance of TCP is due to its lower PLR compared to UDP which influence greatly on the quality of transmitted video.

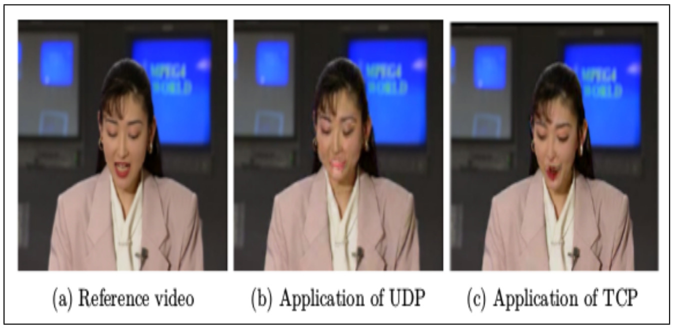

Fig. 11. Example of video frame

VI. Conclusion

The main purpose of this study is to evaluate and compare the performance of the two traditionally transport layer protocols, UDP and TCP for video streaming in VANET under urban scenario. These evaluation and comparison were performed according to some metrics such as throughput, PDR, PLR, average E2E delay, PSNR.

The obtained results have showed that UDP provides a faster transmission of video data than TCP. While TCP provides higher video quality than UDP because TCP is more reliable than UDP.

We have considered in this paper that the number of the hops between the source vehicle of the video and the destination vehicle is only 2. For future work, we intend to evaluate and compare UDP and TCP for video streaming in VANET in the case that the number of hops between the first sender and the last receiver is higher than 2.

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