Available online at www.qu.edu.iq/journalcm
JOURNAL OF AL-QADISIYAH FOR COMPUTER SCIENCE AND MATHEMATICS
ISSN:2521-3504(online) ISSN:2074-0204(print)

OoE ROUTING OF VIDEO STREAMING OVER MANET BY USING NS3,VLC,LXC

Naseer Abdulhussein Jabbar[a], Aymen Dawood Salman[b]

[a] *Department of Computer Science , University of Al Qadisiyah, AL Dewania, Iraq..Email: naseer.alumrany@gmail.com*

[b] *Department of Computer Engineering, University of Technology ,Baghdad , Iraq.Email: : 120008@uotechnology.edu.iq*

ARTICLE INFO

Article history:
Received: 05 /08/2019
Rrevised form: 05 /09/2019
Accepted : 12 /09/2019
Available online: 22 /12/2019

Keywords:

MANET, video streaming, VLC, QoE, neural network

ABSTRACT

As technology is advancing the demand on video streaming which is one of the technologies increasing every day. From Through the last years, numerous researchers have presented various techniques and several algorithms for correct and dependable video streaming. In this paper, proposed system methods are introduced based on the described model of the network. The main flowchart is presented for the working procedure of the considered MANET to simulate video streaming between the nodes through VLC media player. In addition, it extraction the features of video and the original quality of experience (QoE) take it from an international dataset. Then describing and applying the neural network algorithm to training all videos in dataset. Finally test the video in this neural network and finding new QoE, the experiment begins with entering video and then streaming it by the VLC and sending it throw the MANET network, the video received by another VLC. The received videos are stored in the VLC and then the features extraction is applied for all the received videos. These features are used as an input in a neural network which gives result as new QoE videos scores. The results of new QoE score are compared with the original quality of experience score which is found in the dataset. The best qualified video is the one that is close to the original quality of experience video. two examples are applied in this paper that shows the aim of the system. The suggested system achieves 6 % average error and succeeded in transforming video with high average quality up to 94%.

MSC.

DOI: 10.29304/jqcm.2019.11.4.644

1. Introduction

Mobile ad-hoc networks obtained considerable attention in the academic and industrial fields. However, streaming video over MANET networks can be expensive and of poor quality due to lack of resources. Moving multimedia content through dedicated mobile networks becomes a promising alternative. There are many cases of using video streaming over ad-hoc networks. For example, video from a remote location in surveillance operations plays an important role in modern warfare. Another example is wireless communications scenarios after a disaster.

Corresponding author Naseer Abdulhussein Jabbara

Email addresses: naseer.alumrany@gmail.com

Communicated by Qusuay Hatim Egaar

Communications infrastructure can be damaged when a disaster occurs. To help people in dangerous areas, short hand clips can be sent to people's devices on request. However, ensuring the video quality in the receiver is complicated because data can be sent in ad hoc networks through many hops before reaching the destination. As a result, a routing algorithm is urgently needed for ad hoc networks that take into account video quality in receivers.In recent years, it has become increasingly recognized that QoE is a more important measure of assessing the quality of a multimedia context than QoS parameters in QoS service. In some cases, it is still possible to obtain an acceptable QoE, even if the network-oriented QoS metrics are insufficient. By adopting improved quality of experience as a goal to control data flow in networks, the operator can achieve better use of network resources while maintaining user satisfaction above the acceptable threshold. Measuring video quality can be done using objective or subjective approaches. In objective approaches, the explicit functions of measurable parameters can be exploited to assess user satisfaction. The main disadvantage of objective approaches is that they may not be associated with human perception. At the same time, subjective methods are based on assessments provided by human emotions under specific definitions and conditions. For subjective quality assessment methods, the average opinion score (MOS) recommended by the International Telecommunication Union (ITU) is the common measure of video quality. MOS is divided into five levels that correspond to users' perception as follows: 5 (excellent), 4 (good), 3 (regular), 2 (bad), 1 (bad). Plus a 5-point scale. [1],[2],[3][4]. Where the contribution of this paper : modify on **BRISQUE** algorithm to deal with video and connect VLC media player with mobile ad hoc network.
The other sections of the paper are organized as follows: section 2 explains the related works ,section 3 shows Quality of Experience, section 4 shows MANET and section 5 explains Proposal System Model.

2. Related Work

It is important to go throughout the related research works considering the QoE routing of multimedia communication over MANET. Different researchers considered routing discovery and finding based on numerous methods and procedures. This is to solve the rising issues from data transmission .

In 2014, Bustos-Jiménez, J., et al.[5] Provide a standard agenda for studying the relationship concerning QoE and QoS metrics aimed at multimedia transmission is named Boxing Experience. Grounded in the split-up of interests , for instance, the Internet protocols set, Boxing Experience depend on Linux containers plus exposed source software: NS3 for network simulation and VLC (inside Linux containers) for streaming / viewing multimedia contented .

In 2015, Ammar, D. and M. Varela [6] Introducing a new QoE- aware routing policy aimed at video streams. This method observer's real-time network circumstances besides animatedly creates adaptive routing choices founded on end-user perceptions of video quality. MOS is used in order to evaluate the quality of the video. The experimental results demonstrated the proposed system leads to trade-off concerning the QoE predicted via the end-user plus the resource operation.

In 2015, Abdul Manap, R. and L. Shao [7] introduced a recent review of recent developments in NDS research is presented by NR-IQA. In general, this type of algorithm attempts to identify IQA tasks as a classifying or else regression task by which the classifier/ regression are trained by some of the extracted features. These characteristics may be extracted founded on dual main methods: through machine learning (learning-based techniques) otherwise determined through the use of Natural Scene Statistics (NSS-based techniques). The methods are based on the assumption that landscapes show guaranteed statistical properties that are changed through alteration. So, via gaining the suitable characteristics that might show the deviation quantity of these facts in the inaccurate image, estimation the image quality is possible. These algorithms explore and use the different statistical characteristics of the natural image to determine the appropriate features to be extracted, in addition to the altered schemes to create quality metrics.

In 2015, Dobrijevic, O., M. Santl, and M. Matijasevic [8] Design and presented an evaluation of the focus on quality of experience (QoE) for flow routing in SDN, that is founded on the optimization of ant colonies. The evaluation outcomes specify hopeful QoE developments above the routing of the shortest route, in addition to a little runtime. For scalability aims, they are presently evolving a prototype using changed SDN controllers in charge for arranging routes for the respective categories of multimedia services.

In 2015, Mirzamany, E. and V. Friderikos [9] Proposed scheme for local mobility management that focuses on QoE for future mobile networks. The planner tries to take advantage of centralized and distributed mobility management techniques to allow improved performance for sensitive delays flows. To reduce congestion and scalability imposed on the mobility anchor implemented within the network, ideal algorithms are provided and help find ways to discover the logical topology of the network, which provides greater routing flexibility. The proposed schema allows flexibility in configuring the network configuration on how to handle mobility, and a wide range of numerical evaluations show that the proposed schema achieves significant improvement in performance with respect to link usage and user experience quality.

In 2016, Quang, P.T.A., et al.[10] Discuss a QoE-aware routing approach over SVC multi-hope wireless networks. They used the multi- commodity network flow model to define flows in networks. The difficulty with optimization lies in increasing the total MOS within time constraints. The difficulty is developed as a linear programming trouble of mixed integers plus as well appears as NP-hard. So, they planned an indicative algorithm to hurry the search for explanations. The results from the simulation approve that the planned algorithm may discover decent explanations within suitable calculation periods.

In 2017, Siahaan, E., A. Hanjalic, and J. Redi [11] presented that an image's semantic category information might be operated in order develop the quality estimation to align superior with human insight. Across particular experimentations, primary detected that an image's scene besides entity class's effect consumers' decision of visual quality for JPEG compressed plus blurry images. Later achieved experimentations happened on changed kinds of No-Reference Image Quality Metrics (NR-IQMs), and then presented that blind/no-reference image quality (BNRIQ) estimates may be enhanced via joining semantic class features within estimate model.

In 2017, Quang, P.T.A., et al.[12] Discuss the routing solution based on the QoE over multi-hop wireless networks. they assessed the quality of the experiment (QoE) under the method of standardized Mean Opinion Score (MOS) using the tool (PSQA). The primary suggested a linear model for the non-linear implicit PSQA purpose. A multi-product network flow model was used in order to define the flows in ad hoc wireless networks. The QoE-based routing issue is defined as an improvement issue to increase entire MOS under link besides period constraints. The difficulty of QoE-based routing this one is framed as a linear dilemma of a mixed-integer. They suggested a heuristic algorithm to discover a possible explanation. The simulation outcomes established that the suggested method could be resolved well within an acceptable period.

In 2018, Taha, M., et al.[13] Suggest a default testbed design for real-time adaptive video transfer experimentations in dissimilar network surroundings. Their system introduced a multipart virtual network situation in addition to several virtual nodes using diverse functions. The testbed system was implemented to assess the quality of the adaptive multimedia transmission experience. The assessment method is founded on the relationship between the subjective plus the objective measures. Towards determine the procedure of evaluating the QoE assessment, several purpose metrics plus a subjective metric are provided in order to show the exact choice on the perceptual. For QoE assessment, adaptive video streaming contented was set in changed segment dimensions besides two network levels performance were formed.

In 2018, Zeng, Z., et al.[14] Introduced report a new global BIQA model, the greatest of the current BIQA procedures convert the image to about converted fields plus later extract several sub-band parameters towards estimation the image quality. Though, rare BIQA approaches pay courtesy towards physical deterioration. Within this work, they complete the primary effort to utilization the histogram sequence of high-order LDPs for extraordinary- execution BIQA execution. BIQA difficult may be addressed in several stages through our technique. First, the (distorted) image is divided into four scales using the LoG filter. Second, the statistical graph of the LDP map is calculated for every scale. Finally, trained SVR is consumed to evaluate the quality of a particular image. They have experimented with the monotony of estimation, accuracy of estimation, computational complexity, etc**.**

3. QoE (Quality of Experience)

QoE is frequently operated intended for standing for the user assessment. To evaluate the network facility, an individual must measure, observe, count and analyse the quality of the experiment to identify, evaluate and manage the characteristics of the services provided through this network. Total quality is the key aspects to be accomplished. Quality of service reflects the user experience more clearly, which tries to measure the service provided objectively, and the quality of the experience takes into account the requirements and needs of subscribers while consuming the services of the network. Moreover, the main challenge is in what way to take into account dynamic alterations in network resources to deliver the overall quality of service for individual flows. Development of quality mechanism, effective and accurate is the effort of numerous challenges; above all is difficulty besides constancy. Equally technologies and wishes remain evolving, so difficulty plus charge come to determine the future network development. In order to resolve portion of this difficulty, a single of them has integrated the quality of the experience into the network structures to adjust the decision controller in real-time or on-demand. In actual fact, QoE doesn't substitute QoS, but then again it does. A significant factor for end-to-end user visualization, QoE is the main metric for designing schemes plus manufacturing procedures. Furthermore, through the QoE model [15].

4. A Mobile Ad hoc Network (MANET)

A mobile ad hoc network (MANET), too recognized as wireless ad hoc network or else ad hoc wireless network is a network of continuously configured mobile devices without a connected infrastructure. Each MANET device can shift freely of any address, and will, thus, alteration its connections to new machines regularly. Both of them necessity redirect traffic that is not related to their usage besides then, must be a router. The key task is to create MANET in processing every device constantly to preserve the statistics needed to correctly route traffic. These networks can work on their own or can be linked to the superior Internet. It can encompass a single or several future transmitters among nodes. This leads to an extremely dynamic and independent (autonomous) topology. Wireless technologies, such as the IEEE 802.11 standards, allow mobile devices to create a custom mobile network (MANET) through dynamic communication over the wireless medium without any central structure. Wireless ad-hoc networks have established considerable attention in theoretical besides manufacturing regions appreciations to their gains. An ad hoc network is a self- organizing capability that allows deployment on a large area without any infrastructure. In addition, custom networks depend on the standard IEEE 802: 11 families as a class to medium access control (MAC) layer that permits their ubiquitous placement. In the middle of services over wireless networks, the volume of multimedia traffic through wireless networks has increased intensely. Though, the transfer of multimedia over cellular networks may cost highly plus of poor quality caused by resources absence. Streaming multimedia content over cellular wireless networks is therefore, one of the most promising alternatives. The mobile ad-hoc network (MANET) is an autonomous, spread network merely consuming ad hoc Communication among mobile terminals. A rising curiosity in applying MANET as an additional for current networks which have been mess up via a tragedy. Though, MANET's communication quality is more minor than the present networks since it is disturbed via nonstop alterations in its topology besides non-uniformity in its functioning plus lasting battery levels of individual mobile terminals. The MANET allows a mobile terminal to interconnect by a remote terminal over many hops on further mobile terminals. If nodes in a are mobile and can move around, we denote it as a mobile ad hoc network (MANET)[16],[17].

5. Proposal System Model

The proposed system methods are introduced based on the described model of the network. The main flowchart is presented for the working procedure of the considered MANET to simulate video streaming between the nodes through a VLC media player. In addition, it extraction the features of video and the original QoE take it from dataset. Then describing and applying the neural network algorithm to training all videos in dataset . Finally test the video in this neural network and finding new QoE

5.1proposal System Algorithm

General Implementation Of The Proposal System
Input: video
Output: images that are approximate with the entered sketch.
Begin **Step 1:** Using NS3 to simulate MANET with the default environment**.** **Step 2**: Using two Linux containers to run VLC media player and implement video streaming in both sides. **Step 3**: Send video over MANET and saved the received video. **Step 4**: Change the network simulation parameters (number of node ,area, mobility of node). **Step 5**: Return to step 3 until exceeding maximum iteration. **Step 6**: Extract features from videos to test it. **Step 7**: compare original QoE with new score QoE of video which get from 3 after Predict by neural network. **End**

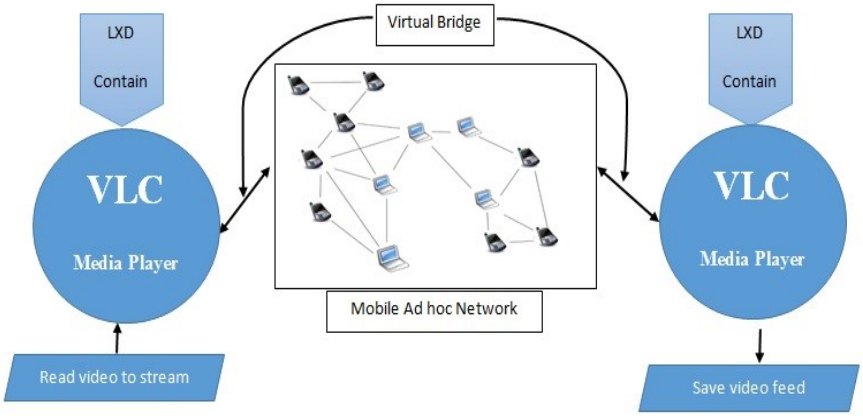

Figure 1: The Proposal System Implementation

Presenting the main components of the proposed system for video streaming plus illustrate in what way it's connected with NS3.

NS3.29 is an open-source discrete-event network simulator aimed at Internet systems. It ensures a modular architecture and it depends on a group of libraries which are spread from [NS3. [Online]. [Available: http://www.nsnam.org]. An API is likewise accessible. Public library go towards several sets:

- CORE: generic functionality, for example call-backs, correcting objects, etc.
- SIMULATOR: agendas, events and other.
- COMMON: autonomous objects like packets;
- INTERNET: models besides protocols connected to the Internet for instance, TCP/UDP;
- NODE: contain abstract classes.

NS3 delivers accurate network models by simulated physical/link layers that mimic the behaviour of real equipment appropriate strictly, that's the reasons it is implemented commonly in educational study. Moreover, it natively aids dissimilar emulation interfaces, tap devices plus real-time simulations which data are handled via the emulator by the identical timing they would have when traversing a true network.

LXC. Linux container is a user space interface for the Linux kernel containment features. It permits to track several remote Linux systems on a solo mechanism. LXD (the new LXC experience) is a succeeding generation system container manager. In which proposes a user skill comparable to computer-generated machines nonetheless operating Linux containers in its place. Its image grounded by pre-made images accessible for an extensive amount of Linux distributions plus is constructed about an incredibly strong, however quite easy.

LXD uses LXC below the shelters for several container organization tasks. Nevertheless, it saves its individual container formation information besides requires its specific conventions; therefore it is finest not to use typical LXC guidelines through indicator by LXD containers.

There are several features of LXD, the following several of the largest types of LXD are

- Secure via design (poor containers, resource restrictions besides far further)
- Scalable (from containers on your laptop to thousands of compute nodes)
- Intuitive (simple, clear API and crisp command line experience)
- Image-based (with an extensive diversity of Linux distributions available every day)
- Support for Cross-host container and image transfer (as well as live migration with CRIU).
- Advanced resource control (CPU, memory, network I/O, block I/O, disk usage and kernel resources).
- Device pass-through (GPU, USB, UNIX character plus block devices, NICs, disks plus paths).
- Storage management (support for multiple storage backends, storage pools and storage volumes).
- Network management (bridge formation and configuration, cross-host tunnels).

5.1 Video Streaming

The archetypal organization applied to join NS3 with a group of Linux containers is through NS3 native support of tap machines connected with container's virtual Ethernet interface, as depicted in Figure 2

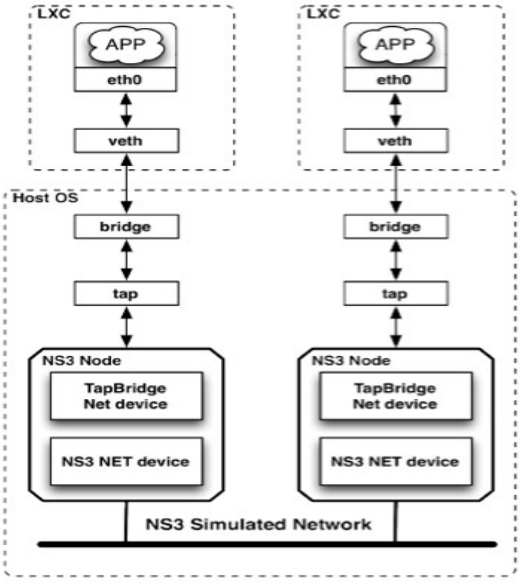

Figure 2: joining NS3 with LXC by virtual Ethernet and top machines

Every LXC will execute the VLC media player. The VLC media player is permitted and open-source software which may be applied as a server (VLS) plus as a client (VLC) in order to stream and receive/show multimedia streams.

Video streaming in wireless environments is a critical problem that requires high encryption performance and a network-compatible system. Video conferencing is a future multimedia application that allows people in different geographic regions to work together with interactive video and computer technologies. Video streaming allows the customer to start the video without downloading the entire bitstreams. To support playback without interference, even if the network bandwidth variants, a client first buffers the information it receives and starts playing once a delay of up to several seconds occurs. In addition to achieving constant playback, each image (frame) has a deadline once all the packets that match the image are submitted to the customer for viewing. When some coded bitstreams are lost at the deadline, they will be measured as missing and the hidden error will be used in the decoded video frame. According to the number of customers, video streaming can be classified as follows:

- **Point-to-point**: There are one server and one client where the video is streaming in a unicast manner, and video conferencing is a clear example of a point-to-point video streaming that needs simple latency.
- **Broadcast video streaming**: video broadcasting includes a single server and multiple clients (one per connection). Feedback between server and client are often undesirable, restricting the server's ability to adapt to different channel conditions.

An important feature of broadcast communications is that the system must be configured to provide each receiver with the essential signal. This is a significant problem, as different receivers may experience different channel features and as a result, the system is mostly configured for the worst channel condition.

- **3. Multicast video streaming:** It contains a server and more customers, but it does not mean any for anyone like video broadcasting. The IP multicast video transmission over the network is an example of (multicast) video streaming. It saves the channel bandwidth where one copy is delivered to the number of clients in the multicast group. Some of the requests that take benefit of multicast involve corporate communications, distance learning and video conferencing.

5.2 DATASET

A dataset called Waterloo Streaming QoE Dataset III (SQoE-III). Dissimilar present Dataset created using manual test sequences, the SQoE-III Dataset, the major besides furthermost accurate of its types to date, contains overall of 450 streaming videos formed from different source contents besides different distortion patterns, through six algorithms Adaptation of different features beneath 13 characteristic network conditions. The Waterloo Streaming Experience Quality Dataset contains 20 RAW HD reference videos also 450 built-in simulations, with a regular period of 13 instants. So as to create expressive plus illustrative test videos, we performed a group of DASH video streaming experiments, recorded relevant transmission actions, then prepared the transmission period consuming the video processing instruments. The streaming sessions generated by 6 adaptive streaming algorithms including rate-based, BBA, AIMD, Elastic, QDASH, and FESTIVE under 13 wide-ranging bandwidth conditions are recorded and evaluated by 34 subjects. Subjects notch the quality for every video sequence corresponding to the 0-100 numerical quality scale. In the following Snapshots of video sequences [18].

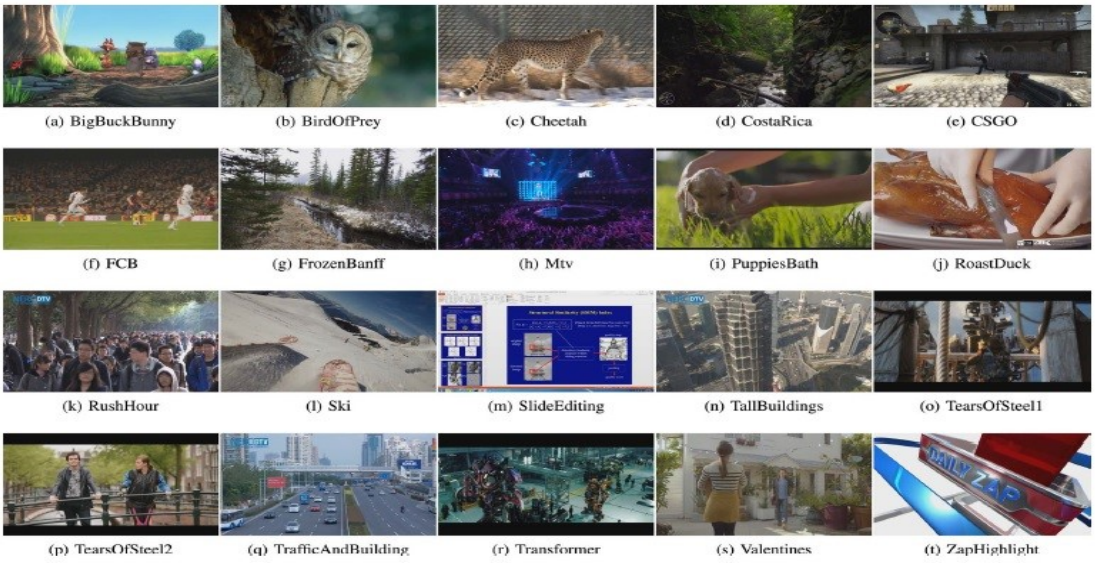

Figure 3: Snapshots of video sequences

Table 1: Sample that describes the videos details information's of the DATASET

Index	Name	FPS	SI	TI	Description
1	BigBuckBunny	30	96	97	Animation, high motion
2	BirdOfPrey	30	44	68	Natural scene, smooth motion
3	Cheetah	25	64	37	Animal, camera motion
4	CostaRica	25	45	52	Natural scene, smooth motion
5	CSGO	60	70	52	Game, average motion
6	FCB	30	80	46	Sports, average motion
7	FrozenBanff	24	100	88	Natural scene, smooth motion
8	Mtv	25	112	114	Human, average motion

9	PuppiesBath	24	35	45	Animal, smooth motion
10	RoastDuck	30	60	84	Food, smooth motion

5.3 Features Extractions

The features of the video are extracted by using an algorithm named Blind/Reference less Image Spatial Quality Evaluator (**BRISQUE**) note that this algorithm deals with images and has been modified to deal with the video, The steps of the algorithm as shown in Figure 4.

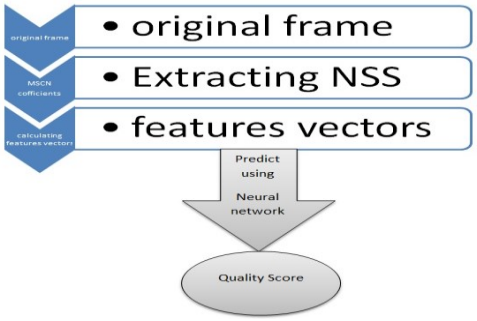

Figure 4: Blind/Reference less Image Spatial Quality Evaluator (**BRISQUE**)

Calculating the Feature Vector Algorithm

Input: Original Image

Output: QS: Quality Score

Begin:

Step1: Start

Step2: Read the original image I.

Step3 : compute the Statistic features of the original image by MSCN

Step4 : From MSCN coefficient capture pair-wise products of MSCN

$$H(i,j) = \hat{I}(i,j)\,\hat{I}(i,j+1)$$

$$V(i,j) = \hat{I}(i,j)\,\hat{I}(i+1,j)$$

$$D1(i,j) = \hat{I}(i,j)\,\hat{I}(i+1,j+1)$$

$$D2(i,j) = \hat{I}(i,j)\,\hat{I}(i+1,j-1)$$

Step5 : Extract feature vectors from pair-wise products of MSCN shown in table(3.1)

Step6 : fetch the feature vectors from pair-wise products of MSCN as Neural Network input

Step7 : predict the QS of the input image

End

6. RESULTS

The experiment begins with entering the video and then streaming it by the VLC and sending it throw the MANET network, the video received by another VLC in the experimentation in the system the source can send the packet with many ways with different nodes. The received videos are stored in the VLC and then the features extraction is applied for all the received videos. These features are used as an input in the neural network which gives , as a result , the new quality of experience videos scores. The results of neural network are compared with the original quality of experience score which is found in the dataset. The best-qualified video is the one that is close to the original quality of experience video. two examples are applied in this paper that shows the aim of the system. The transformed video is being through the feature extraction steps in order to get the QoE-New-Score and matching it with the QoE-Score of the original video, the closed one to the original is the best high-quality video.

As showing in the following table (1) and table

Table 2: the result of sending the Cheetah video

Index	FileName	QoE_Score	QoE_New_Score	error
117	Cheetah01.mp4	26.728	45.37308948	18.64509
118	Cheetah02.mp4	53.757	53.73761892	0.019381
119	Cheetah03.mp4	45.528	45.89748881	0.369489
120	Cheetah04.mp4	52.224	45.37308948	6.850911
121	Cheetah05.mp4	60.15	56.97973644	3.170264
122	Cheetah06.mp4	67.57	66.86729951	0.7027
123	Cheetah07.mp4	72.658	68.02846252	4.629537
124	Cheetah08.mp4	68.715	68.74374946	0.028749
125	Cheetah09.mp4	70.583	63.60549634	6.977504
126	Cheetah10.mp4	62.916	60.94235837	1.973642

As it appears the Cheetah video have been sent many times in each time there are different original video and after applying the feature extraction using neural network and getting the QoE, the video of index 118 is the best and qualified video witch have the smallest an error number 0.019381

Table3: the result of sending the CostaRica video

Index	FileName	QoE_Score	QoE_New_Score	error
126	Cheetah10.mp4	62.916	60.94236	1.973642
127	CostaRica01.mp4	39.182	47.94434	8.762339
128	CostaRica02.mp4	64.72	67.30167	2.581671
129	CostaRica03.mp4	61.014	57.78316	3.230838
130	CostaRica04.mp4	26.733	45.37309	18.64009
131	CostaRica05.mp4	65.658	63.6444	2.0136
132	CostaRica06.mp4	74.81	64.37161	10.43839
133	CostaRica07.mp4	82.03	71.97225	10.05775
134	CostaRica08.mp4	84.884	74.88891	9.995094
135	CostaRica09.mp4	71.988	70.88418	1.103821

As it appears the CostaRica video have been sent many times in each time there are different original video and after applying the feature extraction using neural network and getting the QoE, the video of index 135 is the best and qualified video witch have the smallest an error number 1.103821

7. CONCLUSIONS

From the practical experience of the proposed system and the previous executed systems and different algorithms some conclusions can be drawn as follows:

There is no system which can recognize an image with 100% of accuracy and this means that such systems allow a little percentage of errors. The practical implementation of the proposed system has shown that error percentage could reach 6% or little more and the results are good, the transforming of videos should pass through the path that keeps the quality of video according to the QoE measure. Using the neural network in feature extraction steps gives very good results in getting the QoE according to the MOS in the dataset. VLC media player are used in video streaming witch used as captioning for video h264. It's hard to keep the quality in MANET network spatially when mobility is found.

The future work of this paper : Applying the proposed methods with more than metrics of QoE, such as PSNR,SSIM, improve on QoS (delay , jitter, … etc.) and Implementing the proposed methods in real MANET and evaluating the real-time performance in terms of providing the best service to the user, saving energy consumption, extend network life.

REFERENCES

[1] D. Saladino, A. Paganelli, and M. Casoni., "A Tool for Multimedia Quality Assessment in NS3: QoE Monitor", Elsevier Simulation Modelling Practice and Theory journal for possible publication, 2012.

[2] Pham Tran Anh Quang, Kandaraj Piamrat, and César Viho, "QoE-aware Routing for Video Streaming over Ad-hoc Networks", Globecom 2014 - Ad Hoc and Sensor Networking Symposium.

[3] Zhang, Y. and D. Chandler, An Algorithm for No-Reference Image Quality Assessment Based on Log-Derivative Statistics of Natural Scenes. Vol. 22. 2013.

[4] Bustos-Jiménez, J., et al. Boxing experience: Measuring QoS and QoE of multimedia streaming using NS3, LXC and VLC. in 39th Annual IEEE Conference on Local Computer Networks Workshops. 2014.

[5] Kadhim, Ahmed & Hosseini Seno, Seyed Amin & Shihab, R.A.. (2018). Routing protocol for SDN-cluster based manet. Journal of Theoretical and Applied Information Technology. 96. 5398-5412.

[6] Ammar, D. and M. Varela, QoE-aware routing for video streaming over wired networks. IEEE 23rd International Symposium on Quality of Service (IWQoS), 2015.

[7] Abdul Manap, R. and L. Shao, Non-distortion-specific no-reference image quality assessment: A survey. Vol. 301. 2015.

[8] Dobrijevic, O., M. Santl, and M. Matijasevic. Ant colony optimization for QoE-centric flow routing in software-defined networks. in 2015 11th International Conference on Network and Service Management (CNSM). 2015.

[9] Mirzamany, E. and V. Friderikos, QoE-Centric Localized Mobility Management for Future Mobile Networks. 2014.

[10] Quang, P.T.A., et al. Q-SWiM: QoE-based routing algorithm for SVC video streaming over wireless mesh networks. in 2016 IEEE 27th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC). 2016.

[11] Siahaan, E., A. Hanjalic, and J. Redi, Semantic-aware blind image quality assessment. Vol. 60. 2017.

[12] Quang, P.T.A., et al., Video Streaming Over Ad Hoc Networks: A QoE-Based Optimal Routing Solution. IEEE Transactions on Vehicular Technology, 2017. 66(2): p. 1533-1546.

[13] , M., et al., Adaptive video streaming testbed design for performance study and assessment of QoE. International Journal of Communication Systems, 2018. 31(9): p. e3551.

[14] Zeng, Z., et al., No-reference Image Quality Assessment for Photographic Images Based on Robust Statistics. Vol. 313. 2018.

[15] Tobias Hoßfeld, Poul E. Heegaard, Martın Varela and Sebastian Moller, "Formal Definition of QoE Metrics".

[16] Pham Tran Anh Quang, Kandaraj Piamrat, Kamal Deep Singh and César Viho, "Q-RoSA: QoE-aware Routing for SVC Video Streaming over Ad-hoc Networks", 2016 13th IEEE Annual Consumer Communications & Networking Conference (CCNC).

[17] A. Al-Ani and J. Seitz, "QoS-aware routing for video streaming in multi-rate Ad hoc Networks," 2016 9th IFIP Wireless and Mobile Networking Conference (WMNC), Colmar, 2016, pp. 193-198. doi: 10.1109/WMNC.2016.7543989

[18] Zhengfang Duanmu , Student Member, IEEE, Abdul Rehman, and Zhou Wang, "A Quality-of-Experience Database for Adaptive Video Streaming", This article has been accepted for inclusion in a future issue of this journal. Content is final as presented, with the exception of pagination. IEEE TRANSACTIONS ON BROADCASTING, 2018.