Identification of Most Influential Parameters for Interactive Communication using DOE Technique

Syed Jawad Hussain[a], Ayesha Shahid[b], NZ Jhanjhi[c], Shakeel Ahmed[d], Khalid Hussain[e], and G.Suseendran[f]

[a] Department of CS & IT, The University of Lahore, Islamabad, Pakistan
[b] Department of CS, Foundation University, Islamabad, Pakistan
[c] School of Computer Science and Engineering, SCE, Taylor's University, Malaysia
[d] College of Computer Sciences and IT, King Faisal University, Saudi Arabia
[e] Barani Institute of Sciences Sahiwal Campus ARID Agriculture University
[f] Vels Institute of Science, Technology & Advanced Studies, Chennai, 600117, India

Article History: Received: 10 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 20 April 2021

Abstract: Multimedia applications and platforms are widely being accepted in industry, business and academia as an alternative to classical communication equipment and techniques. Applications and platforms like distance learning, video conferencing, instant messaging, on-demand entertainment and group collaborations are the general usage areas. Advancement in the multimedia industry evolved around the development of infrastructure for delivery and algorithms for content compression. Though, end to end quality is not only affected by such factors. Customer Premises Equipment (CPE) and their particular configurations also play a vital role in the customer's perceived quality i.e. Quality of Experience (QoE). An effort was required to identify the most influential parameters affecting an interactive communication application. Experiments conducted using Design of Experiment (DOE) technique which helped in the sensitivity analysis. In this study, three parameters Resolution Limit (RL), Scaling Factor (SF) and Frames per Seconds (FPS) were identified from the literature. The experiment was conducted in a controlled environment as per the L9 orthogonal array. Correlation and Fleiss Kappa were used for data validation whereas Signal to Noise Ratio (SNR) analysis was performed to identify the most influential parameter. SNR analysis helped us conclude that FPS is the most influential parameter that affects video quality at the CPE.

Keywords: Multimedia applications; IP networks; QoE; QoS; Taguchi orthogonal arrays; SNR; Fleiss Kappa.

1. Introduction

Multimedia technology has received attention and became an unavoidable part of our life. With the recent development in digital data compression technologies, digital broadcasting replaced radio broadcasting and analogue television communications. This paradigm shift produced many enhancements such as better noise immunity, better quality, digital broadcasting better resolution and other interaction proficiencies.

With the advancement in technology communications established over IP is growing rapidly. The speedy deployment of cable/DSL internet made internet usage more prevalent. One substantial example is the replacement of public switched telephone networks (PSTNs) to the global use of voice over IP (VoIP). Digital broadcasting services include high definition television (HDTV), enhanced definition television (EDTV) and digital video broadcasting (DVB). The local area networks Wi-Fi 802.11 enable users with services like file sharing a connection with home electronic devices (e.g. personal digital assistants PDAs, computers, tablets, smart television and smartphones). The increasing demand for internet introduced Wi-Fi usage among individuals. This networking paradigm reflects two trends, a shift from digital broadcasting to multimedia streaming over IP networks and shift from wired internet to wireless internet.

Current trends reflect that more people are switching towards video on demand (VOD) rather than traditional TV or radio broadcasting. This switching shows a major move from "content push" to "content pull". Recent studies highlighted that users prefer IPTV over traditional TV mostly due to the popularity of VOD service. The WLAN technologies IEEE.11 a/b/g/n are being deployed everywhere at reasonable costs. This technology made sending and receiving data over the internet very easy and convenient. This networking of computer peripherals is done over various electronic appliances at various bitrates (Tao et al., 2008).

In the present context, the multimedia service now shifting from audiovisual material delivered at a relatively low rate to high definition. The measure of the overall performance of the multimedia service is also essential. To measure the effectiveness of the multimedia presentation in terms of quality, there are different kind of methods that exist for evaluating the quality of experience (QoE). Quality of service (QoS) measurement parameters are also being used to infer QoE which is an effort to gauge user's experience. The quality of the multimedia technologies was also measured using different quality metrics but actually, users are the real customers of the service. So, it is very important to envision the quality from their perception.

The HD multimedia applications require high bandwidth and consist of exhaustive computations (Ye et al., 2015). The deployment of such applications, if not applied properly, will negatively affect user perception. In this research, we tried to identify the most influential video quality parameters concerning the QoE of the user. An experiment was carried out in a controlled environment over the testbed that helped us in controlling multiple parameters. From the experimental results, the most influential parameters were identified. The video parameters selected for experiments were resolution limit (RL), scaling factor (SF) and frames per second (FPS). Some of these parameters are discussed in section II.

This paper consists of the following sections. Section I presents the introduction. Section II presents related work. Section III discussed the description of the experimental work. Section IV presents data validation. Section V presents results and analysis. Section VI is the conclusion and future work.

2. Related Work

Multimedia has provided many technological enhancements over the decade. Starting from wired internet through wireless networks to fourth-generation (4G), a great revolution has been made. With these advancements, people started viewing contents online either at home or on the move. This content viewing on the move has opened many avenues in business and multimedia technology. As multimedia being a resource-hungry technology suffered from artefacts in video/audio content due to misconfigured or poor resources. Even with high internet speed people complaints about lossy transmission on television and radio, which resulted in a loss of revenue for the service providers.

Different multimedia applications have different requirements to fulfil their performance needs. Advancement in transcoding and compression techniques will reduce the effects but with the latest technology user expectations risen a well. Performance satisfaction plays an important role for content providers. When the deployed service performance is not satisfactory for the users, it is the solemn need of service provider to address such issues. Performance and multimedia quality is affected by various parameters/factors and their combined effect cannot be neglected.

In a broader perspective, many parameters affect the overall video quality. Yan et al. investigated the problems that are in the way of evaluating video quality over IP networks (Ye et al., 2015). Because with the advancement in technology videos transmitted through IPs became the most prevalent solution for the service providers. Different parameters associated with spatial resolution including higher frame rates, higher sample bit depths, and a wider colour range were discussed. They worked on on-demand UHD video streaming using the latest video compression and delivery technology. Dhiraj et al. worked on the storage size of the video through different video compression standards i.e. MPEG-2, MPEG-4, H.26x, x264 etc (More et al., 2015). It was inferred that Spatio-temporal correlation plays an important role in video content. It reduces the size of data through bitstream. The homogeneity coefficient classifies the blocks into fast and slow motion. The video content including the quality parameters of the video, no. of bits required to encode and computation time were checked through set threshold values. The suitable appropriate threshold value for performance was determined by comparing all the parameters. It was concluded that fast motion videos keep the bitrate and PSNR somewhat at the same values. Claypool et al. discussed that with the advancement in technology computer and networks present the opportunity for the video to be available on move (Claypool & Tanner, 1999). Online video content suffers from packet loss, jitter and low-quality video (Joskowicz & Sotelo, 2013). The author provided a study on the effects of delay, jitter, packet delay, etc. they set up experiments and measured the effects of different parameters. Results indicate a sheer drop in the video quality because of jitter and packet loss (Chen et al., 2016).

Parameters across the domain of compression, network and customer premises equipment (CPE) affect the overall quality. Customer premises equipment is one of the domains which has been neglected. It is one of the most important domains which affect user's perceptions and hence further research is required to fully understand combined and individual effect of parameters from this domain. The resolution, frames per second and scaling factor are few parameters in literature. Kim et al. proposed a method to evaluate the QoE measurement through QoS parameters (Kim et al., 2008). Delay, jitter, packet loss rate, packet error rate, bandwidth and call success rate were used to measure QoE and QoS. Correlation method was used to describe the QoE and QoS model which resulted in a QoS-QoE correlation model. Stephen R et al. provided a study based on the user's perception of the information assimilation and subjective satisfaction on multimedia quality (Gulliver & Ghinea, 2007). The factors on which results from the users were gathered are delay, jitter, etc. Further, an eye-tracking assessment of multimedia quality through user perception was discussed. Based on the eye movement of the user results show that users are not satisfied with delay and jitter.

RL is the number of pixels that each picture frame is comprised of. One video stream continuously displays frames one after another because video stream is comprised of several picture frames. FPS is a term which is used for motion aspect of the multimedia video. These two parameters are closely related to video quality. High resolution and high FPS result in high video quality. In the researchers discussed that hundreds or thousands FPS can be recorded by high-speed digital cameras which require high bandwidth and storage (Nazari et al., 2013). A near-lossless compression model is proposed which can be effectively used for compressing videos sequences. In (Alferidah at el., 2020) explained its security issues as well, while (Z. A. Almusaylim at el.,) discusse the video quality at run time, while uploading to the cloud. In this research, we focused on three parameters FPS, RL and SF.

3. Description of the Experiment

This section gives an overview of the research hypothesis, experimental design, participants along with experimental material and instrument. In Fig.1. The flow diagram represents the experimental flow which consisted of two phases. Experiment planning and experiment implementation which needs to be done in a controlled environment. The experiment planning phase includes identification of most influential parameters, planning of experiments using DOE, participants and population selection and designing of experimental material and instrument. The experimental conduction phase consists of Feedback capturing and data validation using correlation and Fleiss Kappa, analysis using signal to noise ratio (SNR) analysis. This analysis helped us in identifying the most influential video quality parameter. The details of the experiment are discussed in section A, B, C, D, E and F.

3.1 Research Hypothesis

Our research hypothesis is "Identification of most influential parameters that affect the streaming quality of interactive video service". The context of this research is to survey the literature for identifying the video quality parameters. The experiment was conducted in a controlled environment on the identified parameters from the literature.

3.2 Experimental Design

The experimental design for this research is based upon the Taguchi experimental design. Taguchi orthogonal arrays were used for the development of experimental designs (Yu et al., 2010). To find out the influential parameters, it was essential to find out a relationship between user perception and influential parameters (Unal & Dean, 1991). Taguchi orthogonal arrays helped find out the most influential parameters for CPE domain for interactive video service. Taguchi also proposed a number of the signal to noise ratios, one of which is "Larger the better". For analysis purpose signal to noise ratio was calculated with loss function set to "larger the better". This analysis helped find out the order of the most influential parameters.

3.3 Participants

The video quality can be evaluated by objective measurements and subjective tests. Subjective tests capture such feedback evaluations regarding a particular service human are performed in a controlled experimental setting. To establish a baseline for evaluation and identifying the most influential parameters end user's perception can be effectively evaluated using subjective tests. So, in this research, we used subjective tests to identify the most influential video quality parameter. The 20 participants between 18-48 years' age group were selected for this experiment. The male-female ratio was 60% and 40%. The participants for this experiment were general public (users) form all fields of life including business people, academia, industry and students. The reason for selecting general public users for experiments was: we wanted to look at service quality from a user's perspective keeping in mind the concept of quality of experience (QoE). The participants in this study rated the experiments containing particular configuration during the video conferencing. The participants answered the rating/feedback forms during testbed, to rate the parameters based upon different combination setting of experiments.

3.4 Experimental material and instrument

For conducting experiments, a video conferencing software was used. The conference program was comprised of conversations and games were arranged among different group of participants. The conference call was held between two participants. Each conversation lasted for almost 30-40 minutes. The computers used for the experiments were Intel core i7 CPU machines with a processing speed of 3.4 GHz running a 64-bit windows 8. The system has Intel HD graphics integrated. The webcam used for experimentation were A4TECH 1080p Full-HD webcam.

3.5 Parameters

The parameters that were selected for the experiments were RL, SF and FPS. Each parameter was studied separately. These parameters were mostly reported in the literature which effected the video quality(Nazari et al., 2013), (Claypool & Tanner, 1999).

3.6 Test Layout

To conduct this experiment, the L9 orthogonal array consisted of 3 columns that were used as parameters. Each experiment was repeated thrice, which resulted in 3 ratings from every participant's conversation. Table 1. shows the video parameters for experimentation. The feedback was comprised of 1 to 5 Likert scale, with 1 being the worst quality and 5 being the best video quality. The time for the whole experiment was around 30-40 minutes including 5-minute initial experimental setup on TrueConf application.

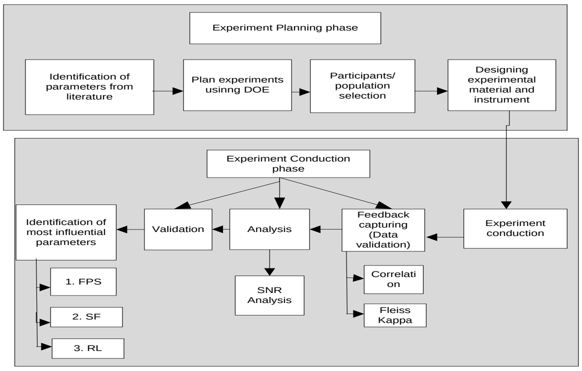

Figure 1 Experimental Design

4. Data Validation

After data collection from participants during experiments, data validation was performed to check for the validity of the results. Following methods were used to check the validation of results.

- Correlation between a pair of participants

The correlation is one of the useful statistical methods. A correlation provides a single number which shows the relationship among multiple participants/raters. In this research, data gathered on video quality parameters during the experiment was validated using correlation. The correlation was calculated to check the response agreement between two participants/raters. The positive correlation shows the maximum agreement between participant's responses.

- Fleiss Kappa

Fleiss Kappa is another statistical measure which is used to evaluate the concordance or agreements between multiple participants/raters. By concordance here, we mean the measurement of participant's agreement on different configuration settings during the feedback.

Table 1. Video Parameter design for experimentation

P'	0.877
P'_e	0.5
$P' - P'_e$	0.377
$1 - P'_e$	0.5

□□	0.754

The formula to find Fleiss Kappa is $K = \frac{P' - P'_e}{1 - P'_e}$

$P' - P'_e$ presents the degree of agreement among participants we achieved above chance. $1 - P'_e$ presents the agreement among participants that was attainable above chance. As Fleiss Kappa is used with binary ratings. So, if the value of K=1 then it means that participants are in a close concordance and if the value of K≤0 then there is no concordance between participants/raters. Signal to Noise Ratio (SNR) analysis

Table 2 Value of k calculated using Fleiss Kappa

Exp. No.	RL*	SF*	FPS *
1	640x480	1.0x	10
2	640x480	0.5x	15
3	640x480	0.25x	25
4	1280x720	1.0x	15
5	1280x720	0.5x	25
6	1280x720	0.25x	10
7	1920x1080	1.0x	25
8	1920x1080	0.5x	10
9	1920x1080	0.25x	15

SNR is the measurement of audio signal level compared to the noise level present in data. In our experiment, the SNR was the ratio of useful data during the TrueConf program conversation and the irrelevant data or distortion that interfered during the conversation.

5. Results and Analysis

After data validation analysis was performed on the gathered data from experiments. This section discusses the results of the experiment.

5.1 Correlation

The correlation was calculated among the 20 participants who rated the parameters. Fig. 2. shows the results of correlation in a radar chart. R1-R20 were 20 participants who rated the parameters. 0.1-0.80 was a rating scale. The correlation between R1 and R2 was 0.50. The correlation between R3 and R19 was 0.59. Similarly, the correlation between R13 and R18 was 0.56. R10, R14 and R6 had 0.68 correlation. The highest correlation was found between R14 and R17 and it was 0.76. The highest value of correlation here shows the close response agreement between R14 and R17. Fig. 3. shows the main effect plots of SNR. When the plot changes from level 2-3 the effect on overall quality seems to be significant. C3 is more negatively impacting SNR. It is evident from Fig. 3. that level 3 of FPS is much lower than that of the other two parameters. So, we concluded that FPS is the most influential parameter which adversely affects video quality.

- Fleiss Kappa

After validation, the value of K was calculated using Fleiss kappa formula (Massey et al., 2011). Table 2. Shows the calculated values. The degree of agreement achieved above chance $P' - P'_e$ is 0.377. The degree of agreement among participants that is attainable above chance $1 - P'_e$ is 0.5. The calculated value of K by using the formula given in section 4.2 is 0.754 which is almost near 1. So, after this calculation, we concluded that there is a close concordance between the participants/raters.

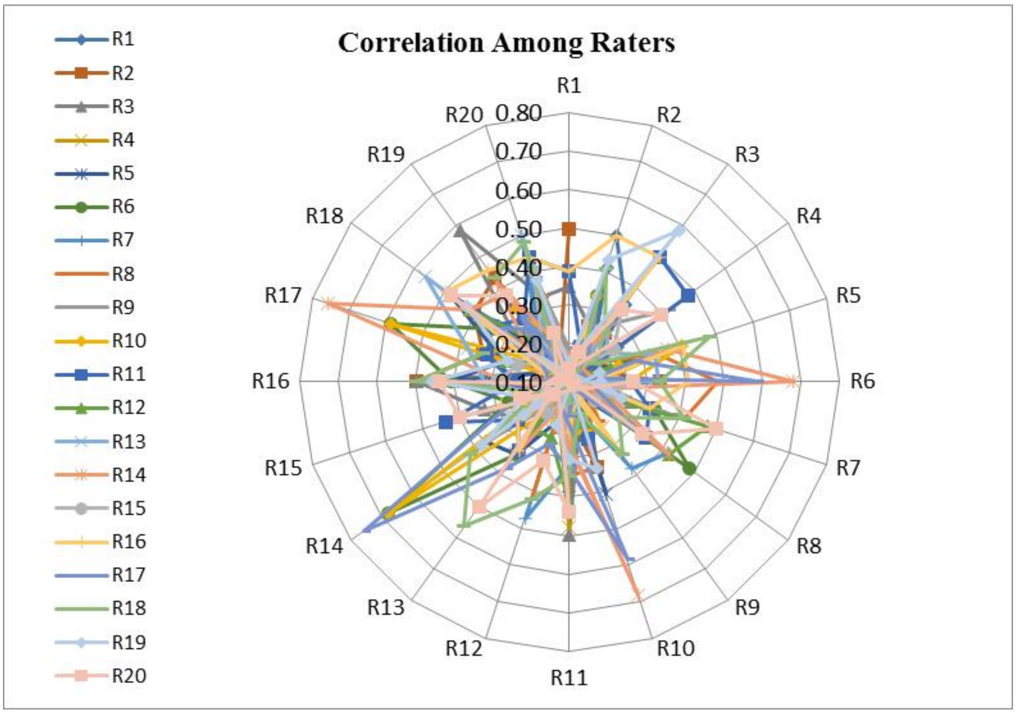

Figure 2 Correlation among raters

6. Signal to Noise Ratio

The signal to noise ratio was calculated by conducting three trials of experimentation at a particular configuration. Table 4. presents the mean and SNR values of these three trials. It can be analyzed that SNR value for all experiments was between 10-11. The SNR ratio is low which shows that there were chances of minimal loss. Fig. 3. Shows the SNR plot of mean values from Table 3.

Table 3. Rank table of video parameters

Level	RL*	SF*	FPS*
1	10.54	10.62	10.66
2	10.66	10.54	10.75
3	10.63	10.66	10.41
Δ	0.12	0.13	0.34
Rank	3	2	1

Table 4. Mean and SNR values of Experiments per trial

T1	T2	T3	Mean	SNR
3.90	3.50	3.20	3.53	10.88
3.15	3.20	3.80	3.38	10.49
3.00	3.05	3.90	3.32	10.23
3.10	3.65	3.55	3.43	10.65
3.20	3.20	3.85	3.42	10.58
3.65	3.10	3.70	3.48	10.75
3.10	3.90	3.05	3.35	10.34
3.25	3.40	3.45	3.37	10.54
3.70	3.30	3.70	3.57	11.01

Table 3. shows the rank of video parameters after experiments. The table shows that the delta value of RL was 0.12. SF was 0.13 and FPS was 0.34. The delta value of FPS was higher which shows that it is the most influential video quality parameter.

The pie chart in Fig. 4. Shows that the FPS is the most influential factor which affects the quality most as compared to the RL and SF. So, here our hypothesis comes true we were successful in figuring out the most influential parameter that affects the video quality.

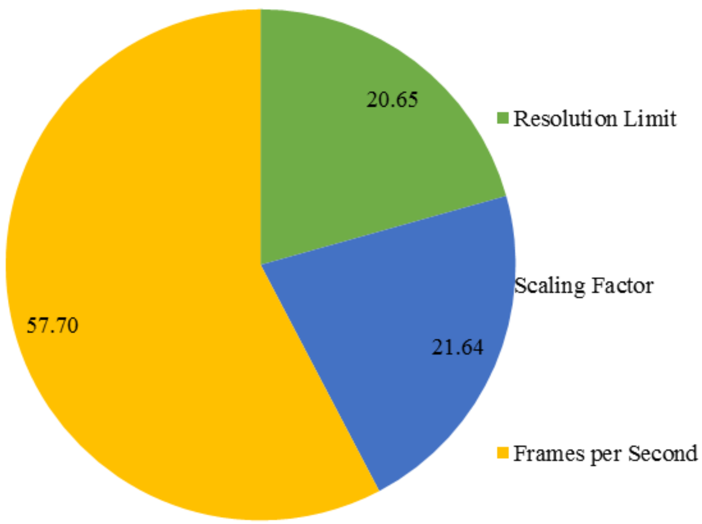

Figure 3 Parameter impact on the quality

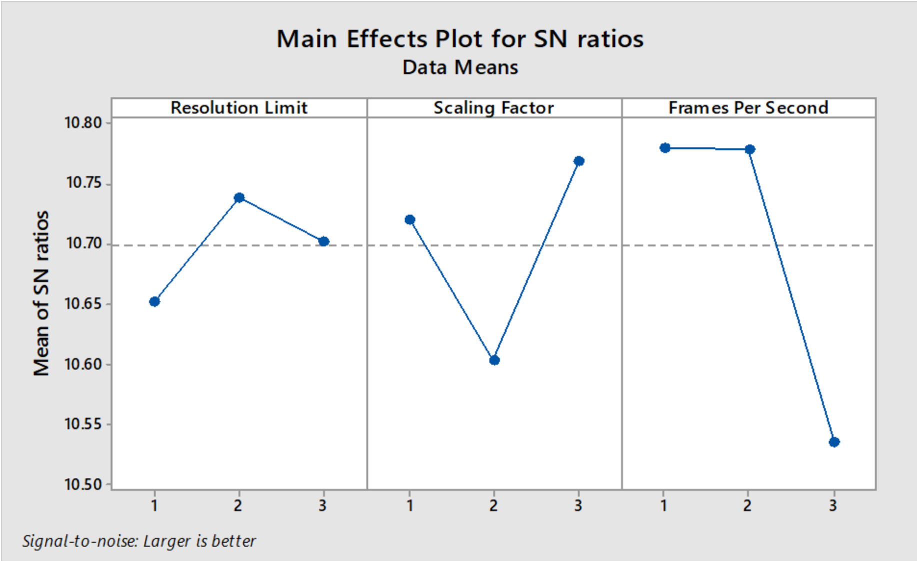

Figure 4 SNR Plot of mean values

7. Conclusion and Future Work

When it comes to technology, multimedia is one of the widely used technologies these days. Multimedia video processing is affected by some distortions which impact the user's perception negatively. QoS is an important task for service providers and network providers to satisfy customers. Video quality is affected by several parameters, we studied three parameters in detail from literature i.e. resolution limit, scaling factor and frames per second.

In this study, we conducted an experiment where 20 participants between 18-48 years' were required to evaluate an interactive video communication session. It was aimed to capture customer perception of interactive video. These subjective responses were validated using correlation and Fleiss kappa. To identify the most influential parameters SNR analysis was conducted based on the effect of parameters on SNR, the particular parameter that had the most effect on SNR with varying levels was identified as the most influential parameter. Results showed that there was a high correlation among customer's feedback and FPS came up to be the most influential parameter.

In future, we intend to develop a mathematical model that can help service providers to predict QoE score. This capability to predict or perceive user perception can enable service providers in providing a quality service, which will in return increase profit margins for service providers.

References

1. Alferidah, D.K. and Jhanjhi, N.Z., 2020. *A Review on Security and Privacy Issues and Challenges in Internet of Things. International Journal of Computer Science and Network Security IJCSNS, 20(4), pp.263-286.*
2. Aroulanandam, V.V., Latchoumi, T.P., Bhavya, B., Sultana, S.S. (2019). Object detection in convolution neural networks using iterative refinements. Revue d'Intelligence Artificielle, Vol. 33, No. 5, pp. 367-372. https://doi.org/10.18280/ria.330506
3. Arunkarthikeyan, K. and Balamurugan, K., 2020, July. Performance improvement of Cryo treated insert on turning studies of AISI 1018 steel using Multi objective optimization. In 2020 International Conference on Computational Intelligence for Smart Power System and Sustainable Energy (CISPSSE) (pp. 1-4). IEEE.
4. Bhasha, A.C., Balamurugan, K. End mill studies on Al6061 hybrid composite prepared by ultrasonic-assisted stir casting. Multiscale and Multidiscip. Model. Exp. and Des. (2020). https://doi.org/10.1007/s41939-020-00083-1
5. Claypool, M., & Tanner, J. (1999). *The effects of jitter on the perceptual quality of video. Proceedings of the Seventh ACM International Conference on Multimedia (Part 2), 115–118.*

6. Chinnamahammad Bhasha, A., Balamurugan, K. Fabrication and property evaluation of Al 6061 + x% (RHA + TiC) hybrid metal matrix composite. SN Appl. Sci. **1,** 977 (2019). https://doi.org/10.1007/s42452-019-1016-0
7. Deepthi, T. and Balamurugan, K., 2019. Effect of Yttrium (20%) doping on mechanical properties of rare earth nano lanthanum phosphate (LaPO4) synthesized by aqueous sol-gel process. Ceramics International, 45(15), pp.18229-18235.
8. Gulliver, S. R., & Ghinea, G. (2007). *The perceptual and attentive impact of delay and jitter in multimedia delivery. IEEE Transactions on Broadcasting, 53(2), 449–458.*
9. Joskowicz, J., & Sotelo, R. (2013). *Considerations on packet loss incidence on the perceived video quality in digital television. Workshop on Communications-IEEE LATINCOM, 1.*
10. Kim, H. J., Lee, D. H., Lee, J. M., Lee, K. H., Lyu, W., & Choi, S. G. (2008). *The QoE evaluation method through the QoS-QoE correlation model. 2008 Fourth International Conference on Networked Computing and Advanced Information Management, 2, 719–725.*
11. Latchoumi, T.P. and Kannan, V.V., 2013. Synthetic Identity of Crime Detection. International Journal, 3(7), pp.124-129.
12. Loganathan, J., Latchoumi, T.P., Janakiraman, S. and parthiban, L., 2016, August. A novel multi-criteria channel decision in co-operative cognitive radio network using E-TOPSIS. In *Proceedings of the International Conference on Informatics and Analytics* (pp. 1-6). https://doi.org/10.1145/2980258.2982107
13. Massey, A. K., Smith, B., Otto, P. N., & Antón, A. I. (2011). A*ssessing the accuracy of legal implementation readiness decisions. 2011 IEEE 19th International Requirements Engineering Conference, 207–216.*
14. More, D., Deshmukh, A., & More, V. N. (2015). *Effects of different threshold values in content aware motion estimation algorithm on H. 264. 2015 International Conference on Pervasive Computing (ICPC), 1–6.*
15. Nazari, N., Shams, R., Mohrekesh, M., & Samavi, S. (2013). *Near-lossless compression for high frame rate videos. 2013 21st Iranian Conference on Electrical Engineering (ICEE), 1–6.*
16. Tao, S., Apostolopoulos, J., & Guérin, R. (2008). *Real-time monitoring of video quality in IP networks. IEEE/ACM Transactions on Networking, 16(5), 1052–1065.*
17. Unal, R., & Dean, E. B. (1991). *Taguchi approach to design optimization for quality and cost: An overview.*
18. Ye, Y., He, Y., & Xiu, X. (2015). *Manipulating ultra-high definition video traffic. IEEE MultiMedia, 22(3), 73–81.*
19. Yu, H., Chung, C. Y., & Wong, K. P. (2010). *Robust transmission network expansion planning method with Taguchi's orthogonal array testing. IEEE Transactions on Power Systems, 26(3), 1573–1580.*
20. Z. A. Almusaylim, N. Zaman and L. T. Jung, "*Proposing A Data Privacy Aware Protocol for Roadside Accident Video Reporting Service Using 5G In Vehicular Cloud Networks Environment," 2018 4th International Conference on Computer and Information Sciences (ICCOINS), Kuala Lumpur, Malaysia, 2018, pp. 1-5, doi: 10.1109/ICCOINS.2018.8510588.*