International Journal of Scientific and Technical Advancements

ISSN: 2454-1532

Performance Evaluation of Watermarking Technique based on the DWT and Modified SVD

Rupali Nayyar[1], Randhir Singh[2], Ritika[3]
[1]M.Tech. Student, Department of ECE, S.S.C.E.T, Badhani, Pathankot, India-145001
[2]Associate Professor (HOD), Department of ECE, S.S.C.E.T, Badhani, Pathankot, India-145001
[3]Assistant Professor, Department of ECE, S.S.C.E.T, Badhani, Pathankot, India-145001
Email address: rupalinayyar33@gmail.com, errandhirsend@gmail.com, er.ritika88@gmail.com

Abstract— Watermarking is the process to cover some information that is called watermark or tag into the first data such that watermark can be extracted or noticed later to produce an assertion concerning the object. The audio watermarking schemes have now been widely used to fix the copyright defense issues of digital audio related to illegal application or distribution. This paper proposes the robustness and imperceptibility characteristics of a good watermarking algorithm by greatly improving the visual quality of the watermarked audio and being robust against common signal processing operations and attacks. Also the watermark scrambling by using the Arnold transform is used to protect watermark further. Arnold transform has changed the watermark in such a way that it becomes meaningless for the hackers or crackers. Various kind of multiple attacks are also considered to evaluate the effectiveness of the proposed technique.

Keywords— Audio signal, arnold transform, digital audio watermarking technique and DCT.

I. Introduction

Audio watermarking involves a process of embedding into host audio signal a perceptually transparent digital signature, carrying a message about the host data in order to mark its ownership. The aim in watermarking systems is to ensure the robustness of the hidden message; the presence of the embedded message itself does not have to be secret [11], [12], [13]. The watermark is always present in the signal, even in illegal copies of it and the protection that is offered by the watermarking system is therefore of a permanent kind. The word steganography was originated from Greek which means covered writing. Steganography is the oldest form of covert channel. Depending upon the cover multimedia object for embedding the propriety information, the watermarking schemes are categorized as audio, video, image or text watermarking. Watermarking of audio media is far more challenging as compared to any other type of media (*viz.* image, video etc) .The reason is the wide dynamic range of audio signal as compared to the others. In addition, the Human Auditory System (HAS) is far more complex. The HAS perceives sounds over a wide range of frequencies from an order of Hertz to kilo Hertz. In terms of the power this range is of the order of power of 10. The sensitivity of the HAS to the additive Gaussian noise is high as well which implies that a small disturbance at some frequency will be audible to the ear. So it's a big challenge to embed information without making any perceptual change in the audio. The typical audio watermarking scheme comprises of two modules: One is the Encoding/Embedding module which is used to embed watermark without degrading the quality of the resultant audio produced which is called the watermarked audio. The second module is the Decoding/Extraction/Detection module which requires the watermarked audio as an input to extract/detect the watermark.

II. Applications OF Audio Watermarking

A watermarking system can be designed to meet a specific application requirement. But it's desirable that it should work for all the applications where the expectations from the watermarking system are different. When we are saying watermarking system, it comprises of coding and decoding modules. The different watermarking applications are

1. *Ownership protection:* the objective is to embed the information n that identifies the owner of the digital media in order to prevent the other parties claim the copyright. The utmost requirement is a high level of robustness and unambiguous watermark to still resolve rightful ownership if other parties embed additional watermarks.
2. *Fingerprinting:* The objective is to convey information about the legal recipient rather than a source of digital media, in order to identify single distributed copy of the digital media. In this sense it is sometimes referred to as destination based watermarking.
3. *Authentication and tamper detection*: The objective is to detect modification of the data. It is achieved through fragile watermark which are having low robustness to certain modifications.
4. *Copy protection:* The objective is to find a mechanism to disallow unauthorized copy of the digital media. This can only be efficiently implemented in a closed system.
5. *Broadcast monitoring:* A watermark is embedded into the multimedia on behalf of the service provider to track whether they are getting the exact airtime that they have purchased from broadcasting firms.

III. Watermarking Techniques

1. *Discrete cosine transform:* The DCT switches or turns a sign from spatial domain into a frequency domain. DCT is real-valued and offers a much better approximation of a sign with several coefficients. This process reduces how big the

Rupali Nayyar, Randhir Singh, and Ritika, "Performance evaluation of watermarking technique based on the DWT and modified SVD," *International Journal of Scientific and Technical Advancements*, Volume 3, Issue 1, pp. 01-06, 2017.

standard equations by discarding higher volume DCT coefficients. Crucial architectural information is contained in the paid down volume DCT coefficients. DCT is widely found in information force techniques such as for example for instance JPEG and MPEG. The important advantages of DCT contain its large energy compaction houses and accessibility to rapidly calculations for the computation of transform.

2. Discrete wavelet transform: The DWT is just something of filters. You will get two filters included, one could be the “wavelet filter”, and the other could be the “scaling filter” .The wavelet filtration is just a large go filtration, as the scaling filtration is just a low go filter. After using a 1-level DWT on a picture, we've the approximation sub-band LL, the exterior sub-band LH, the straight sub-band HL, and the diagonal sub-band HH. Moreover, if we wish to use a 2-level DWT on the picture, we just only use still another 1-level DWT on the approximation sub-band LL. DWT is preferred, because it provides equally a parallel spatial localization and a volume distribute of the watermark within the host picture.

3. Arnold transformation: Image Scrambling Discovers Change of the Picture, Which Rearranges The Spatial Position Of The Pixels Relating To Some Axioms, And Makes Picture Distortion For The Goal Of Security. Arnold Change Is Applied To Battle Watermarking Image. This Is A Change Proposed By Arnold In His Erotic Theory Named Cat-Face Transformation.

IV. Related Work

Wei FOO et al. (2001) [1] offered an flexible algorithm for audio watermarking which uses match hiding method. The algorithm has been split into two parts—encoder style and decoder design. In the encoder section, segmentation is performed on the original audio signal.

Seok et al. (2002) [2] mentioned the basic needs required for sound watermarking algorithm. An algorithm applying Primary Routine Distribute Selection (DSSS) has been discussed. This algorithm requires benefit of the masking convenience of HAS. This removal is blind strategy which employs brightening procedure.

Tsai et al. (2003) [3] planned a smart sound watermarking algorithm that is depends upon the houses of Individual Auditory System (HAS). It uses the techniques contained in Neural communities as properly and works in DCT domain. This is a blind sound watermarking technique.

Cvejic et al. (2003) [4] gave a algorithm in 2003 which will be also on the basis of the wavelet domain. Music indicates is inputted in to the filtration to acquire the wavelet coefficients. Simultaneously, it's passed on for masking examination as well to determine where in actuality the embedding of the watermark can be done.

In- Kwon Yeo et al. (2003) [5] presented the modified patchwork algorithm (MPA), a statistical technique for an audio watermarking algorithm in the transform (not only discrete cosine transform (DCT), but also DFT and DWT) domain. The MPA is an enhanced version of the conventional patchwork algorithms.

Sriyingyong et al. (2006) [6] offered an algorithm which employs DWT alongside Adaptive Tabu Search (ATS). ATS maintains logs of all measures beginning research to solution. It even has capacity of doing backtracking. Binary picture is developed into 1-D matrix and then encrypted. Sound indicates is decomposed.

Shijun Xiang et al. (2007) [7] present a multibit robust audio watermarking solution for such a problem by using the insensitivity of the audio histogram shape and the modified mean to TSM and cropping operations. We address the insensitivity property in both mathematical analysis and experimental testing by representing the histogram shape as the relative relations in the number of samples among groups of three neighboring bins.

Ercelebi et al. (2009) [8] put ahead an algorithm for audio watermarking by which watermark is embedded in the reduced frequency element of the audio signal. In raising centred implementation of DWT has been used. The watermark is embedded in reduced frequency approximation coefficients which match high energy.

Yan yang et al. (2009) [9] offered a story music watermarking algorithm. This Algorithm uses DCT transform. The electronic music indicates after subjection is altered applying DCT transform. Simultaneously, binary image is paid down dimensionally and transferred through pseudo-random compositor. The turned image is stuck into the altered music indicate where Inverse DCT algorithm is applied and watermarked music indicate is obtained.

Lalitha et al. (2011) [10] proposed an algorithm which uses DWT-SVD technique of audio-watermarking. The DCT-SVD has been compared with DWT-SVD as well. The DWT-SVD algorithm proves to be more robust than DCT-SVD algorithm. Al-haj et al. (2011) [11] set forward a DWT-centered sound watermarking algorithm. Following converting the 2-D gray scale picture in to 1-D vector, it is normalized and then a 2- level DWT transform is applied on the signal and the subbands are produced.

Bai Ying Lei et al. (2011) [12] propose a new, blind and robust audio watermarking scheme based on SVD–DCT with the synchronization code technique. We embed a binary watermark into the high-frequency band of the SVD–DCT block blindly. Chaotic sequence is adopted as the synchronization code and inserted into the host signal.

Lalitha et al. (2013) [13] proposed a DWT-Arnold transform centered music watermarking algorithm. Following sampling and dividing the music signal, DWT is applied on the initial music signal to provides facts and approximation sub-bands. Following applying Arnold transform alongside DWT on the picture, it's stuck into the developed music signal.

V. Gaps in Literature

1. The effect of the multiple attacks on a given watermarked audio signal has been neglected by the most of the existing researchers.

2. Most of the researchers has used Standard SVD, the use of improved or modification SVD has been ignored in the most of existing research.

Rupali Nayyar, Randhir Singh, and Ritika, “Performance evaluation of watermarking technique based on the DWT and modified SVD,” *International Journal of Scientific and Technical Advancements*, Volume 3, Issue 1, pp. 01-06, 2017.

3. The use of the watermark scrambling has also been ignored in the majority of the existing research.

VI. Results

A. *Results Methodology*

Watermark Embedding Process:
Step1. Take input cover audio and input watermark image.
Step2. Apply DWT on input cover audio. On other side perform Arnold transform.

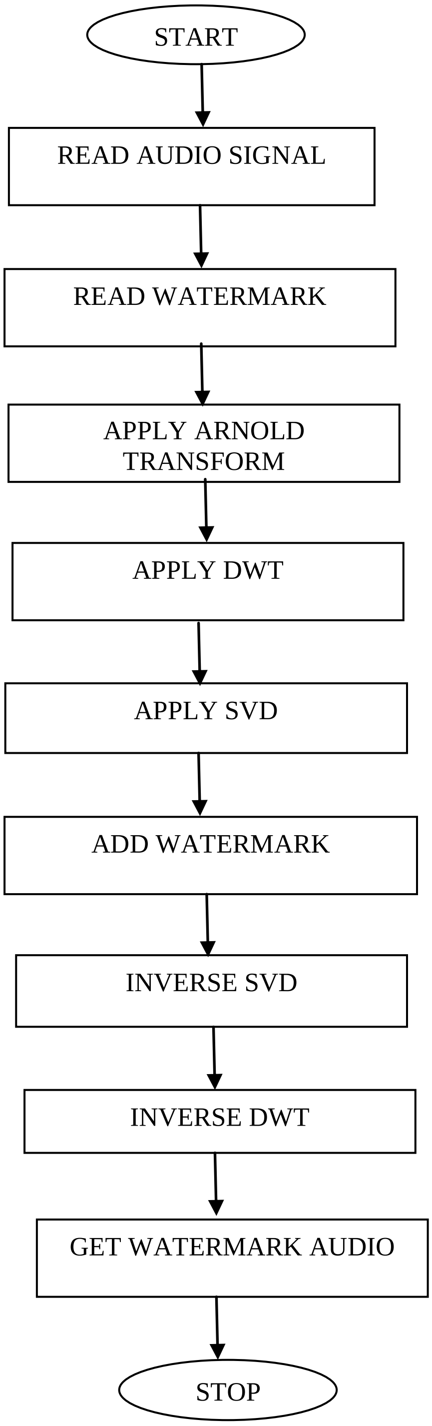

Fig. 1. Methodology of the work.

Step3. Compute the Low layer of the high frequency subband HH of the input cover audio.
Step4. Apply SVD to input cover audio for further decompose and extract the singular values.
Step5. Perform Arnold transform on SVD by using input watermark image. This transform gives the Scrambled watermark.
Step6.After Arnold Transform, apply SVD on the scrambled watermark.
Step7. Modify the singular value of decomposed input cover audio with singular value of the scrambled watermark using scaling factor.
Step8. Combine the orthogonal matrix of the input cover image with the modified singular matrix of the scrambled watermark.
Step9. Compute the inverse SVD and apply an inverse DWT to the decomposed audio, using scrambled watermark to get the watermarked audio.
Watermark Extraction Process:
Step1. The Received watermarked audio consider without attack.
Step2. Take DWT of the watermarked audio and calculate the values of bands.
Step3. Extract high frequency subband i.e. HH.
Step4. Perform Arnold Transform on the singular value decomposed input cover audio.
Step5. The obtained watermark image is the hidden image.

B. *Performance Analysis*

This paper has designed and implemented the proposed technique in MATLAB tool u2013a. Some well-known audio performance parameters for digital audios have already been selected to prove that the performance of the proposed algorithm is very much better than the existing methods.

A comparison is drawn between all the parameters and a respective tables and figure shows all the results.

1)Mean error evaluation

As mean error have to be reduced which means proposed algorithm is showing the better results compared to the available methods as mean error is less in all of the cases. Table I shows the quantized analysis of the mean error.

TABLE I. Mean error evaluation.

Input Speech Signal	Existing	Proposed
1	2.4388	0.0015
2	3.3090	0.0020
3	2.5315	0.0014
4	2.3740	0.0014
5	2.1979	0.0015
6	2.1290	0.0014
7	2.0864	0.0016
8	3.8410	0.0015
9	2.2635	0.0015
10	2.0202	0.0014

The figure 2 shows the quantized analysis of the mean error of various audios using watermarking by Existing Technique (Blue color) and watermarking by Proposed Approach (Red Color). It has clearly shown from the table that

Rupali Nayyar, Randhir Singh, and Ritika, "Performance evaluation of watermarking technique based on the DWT and modified SVD," *International Journal of Scientific and Technical Advancements*, Volume 3, Issue 1, pp. 01-06, 2017.

there is decrease in MSE value of audios with the usage of proposed method over other methods in all audios. This decrease represents improvement in the objective quality of the audio.

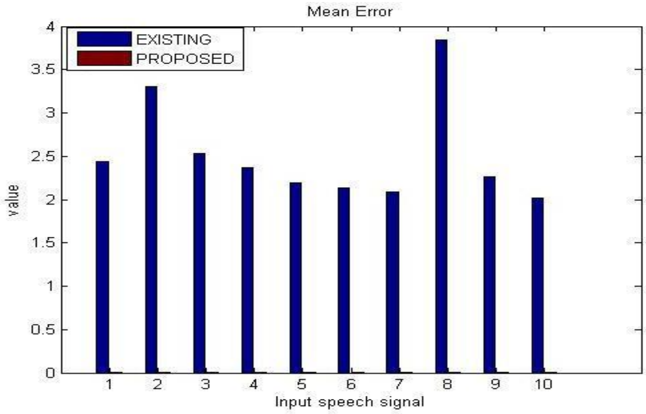

Fig. 2. ME of existing technique & proposed approach for different audios.

2) Mean square error evaluation

As mean square error have to be reduced which means proposed algorithm is showing the better results compared to the available methods as mean square error is less in all of the cases. Table II shows the quantized analysis of the mean square error.

TABLE II. Mean square error evaluation.

Input Speech Signal	Existing	Proposed
1	24.0212	2.2833
2	36.3772	3.2464
3	6.0710	2.2363
4	7.1249	2.1828
5	5.1468	2.3159
6	4.7831	2.2451
7	4.6878	2.4342
8	29.1023	2.3990
9	4.6109	2.3349
10	4.0417	2.2192

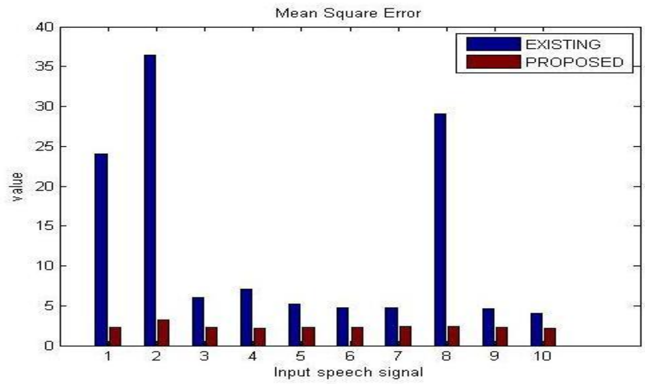

Fig. 3. MSE of existing technique & proposed approach for different audios.

The figure 3 describes the quantized analysis of the mean square error of various audios using watermarking by Existing Technique (Blue color) and watermarking by Proposed Approach (Red Color). It has clearly shown from the table that there is decrease in MSE value of audios with the usage of proposed method over other methods in all audios. This decrease represents improvement in the objective quality of the audio.

3) Peak signal to noise ratio evaluation

As PSNR have to be maximized; so the main goal is to increase the PSNR as much as possible. Table III has clearly shown that the PSNR is maximum in the case of the proposed algorithm therefore proposed algorithm provides better results compared to the available methods.

TABLE III. Peak signal to noise ratio evaluation.

Input Speech Signal	Existing	Proposed
1	20.5189	40.9596
2	16.9142	37.9028
3	32.4656	41.1403
4	31.0752	41.3506
5	33.9000	40.8363
6	34.5367	41.1062
7	34.7114	40.3895
8	18.8523	40.5302
9	34.8551	40.7654
10	35.9996	41.2068

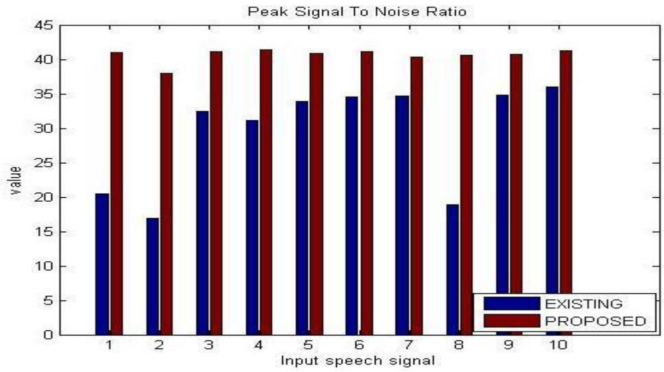

Fig. 4. PSNR of existing technique & proposed approach for different audios.

The figure 4 has shown the quantized analysis of the peak signal to noise ratio of various audios using watermarking by Existing Technique (Blue Color) and watermarking by Proposed Approach (Red Color). It has clearly shown from the table that there is increase in PSNR value of audios with the usage of proposed method over other methods. This increase represents improvement in the objective quality of the audio.

4) Root mean square error evaluation

As root mean square error have to be reduced which means proposed algorithm is showing the better results compared to the available methods as root mean square error is less in all cases. Table IV has clearly shown that the RMSE is minimum in the case of the proposed algorithm therefore proposed algorithm provides better results compared to the available methods.

Figure 5 shows the quantized analysis of root mean square error of various audios using watermarking by Existing Technique (Blue color) and watermarking by Proposed Approach (Red Color). It has clearly shown from the table that there's decrease in RMSE values of audios with the usage of proposed method around other methods in all the audios. This decrease represents improvement in the objective quality of the audio.

TABLE IV. Root mean square error evaluation.

Input Speech Signal	Existing	Proposed
1	4.9011	1.5111
2	6.0313	1.8018
3	2.4639	1.4954
4	2.6692	1.4774
5	2.2687	1.5218
6	2.1870	1.4984
7	2.1651	1.5615
8	5.3947	1.5489
9	2.1473	1.5280
10	2.0104	1.4897

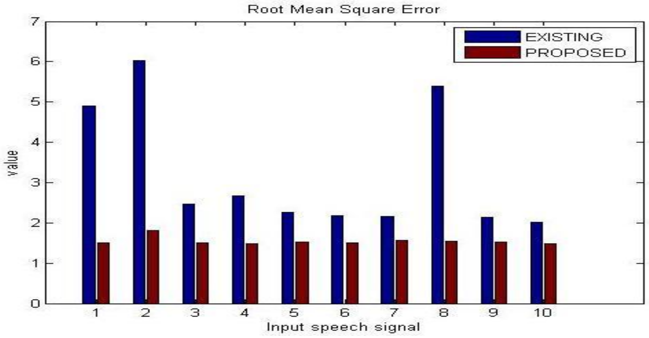

Fig. 5. RMSE of Existing Technique & Proposed Approach for different audios.

5) Bit error rate evaluation

As bit error rate have to be reduced therefore the proposed algorithm is showing the better results compared to the available methods as bit error rate is less in all the cases. Table V has clearly shown that the BER is minimum in the case of the proposed algorithm therefore proposed algorithm provides better results compared to the available methods.

TABLE V. Bit error rate evaluation.

Input Speech Signal	Existing	Proposed
1	0.0487	0.0244
2	0.0591	0.0264
3	0.0308	0.0243
4	0.0322	0.0242
5	0.0295	0.0245
6	0.0290	0.0243
7	0.0288	0.0248
8	0.0530	0.0247
9	0.0287	0.0245
10	0.0278	0.0243

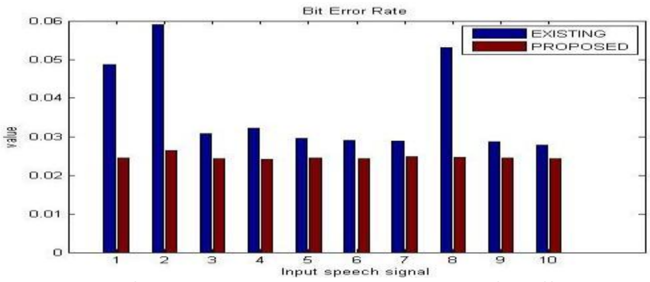

Fig. 6. BER of existing technique & proposed approach for different audios.

Figure 6 shows the quantized evaluation of the bit error rate of various audios using watermarking by Existing Technique (Blue color) and watermarking by Proposed Approach (Red Color). It has clearly shown from the plot that there is decrease in BER value of audios with the usage of proposed technique around other methods in all the audios. This decrease represents improvement in the objective quality of the audio.

6) Structural similarity index metric

As SSIM have to be maximized; so the main aim is to increase the SSIM. Table VI has clearly shown that the SSIM is maximum in case of the proposed algorithm thus proposed algorithm provides better results compared to the available methods.

TABLE VI. Structural similarity index metric.

Input Speech Signal	Existing	Proposed
1	0.9513	0.9756
2	0.9409	0.9736
3	0.9692	0.9757
4	0.9678	0.9758
5	0.9705	0.9755
6	0.9710	0.9757
7	0.9712	0.9752
8	0.9470	0.9753
9	0.9713	0.9755
10	0.9722	0.9757

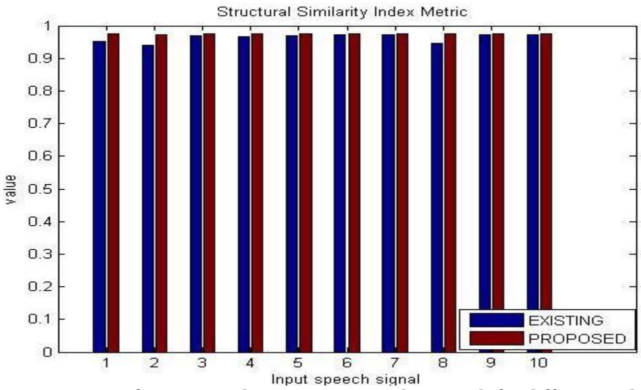

Fig. 7. SSIM of existing technique & proposed approach for different audios.

Figure 7 indicates the quantized analysis of the Structural Similarity Index Metric of different audios using watermarking by Existing Technique (Blue Color) and watermarking by Proposed Approach (Red Color). It has clearly shown from the table that there's increase in SSIM values of audios with the usage of proposed method over other methods. This increase represents the improvement in the objective quality of the audio signal.

VII. Conclusion

The actual watermarking programmers have already been trusted to fix typically the right of first publication safeguards challenges from electronic persona relating to illegal practice and distribution. A new watermarking technique based on the wavelet domain in combination with the Fast Fourier transform and Arnold transform based SVD has been proposed. This algorithm combines the advantages of these three transforms, therefore have more robust results. The algorithm can help satisfy the robustness and imperceptibility characteristics of a good watermarking algorithm Also the watermark scrambling by using the Arnold transform is used to protect watermark further. Arnold transform has changed the watermark in such a way that it becomes meaningless for the hackers or crackers. Various kind of multiple attacks are also considered to evaluate the effectiveness of the proposed technique. The proposed technique is designed in MATLAB tool with the help of audio processing toolbox. The experiments have clearly shown that the proposed technique outperforms over the available techniques. This work has not considered the use of the Stationary wavelet transform, which has ability to improve the accuracy of the digital audio watermarking techniques. Also this work is limited to the limited number of attacks; therefore in near future we will apply multiple attacks.

REFERENCES

[1] X. Yang, J. Liu, F. Zhao, and N. Vaidya, "A vehicle-to-vehicle communication protocol for cooperative collision warning," in *Proc. Int. Conf. MobiQuitous*, pp. 114–123,2004.

[2] J. J. Blum, A. Eskandarian and L. Hoffman, "Challenges of intervehicle ad hoc networks," *IEEE Transactions on Intelligent Transportation Systems*, vol. 5, no. 4, pp. 347-351, 2004..

[3] Zhao, J.; Cao, G. (2006), "VADD: Vehicle assisted data delivery in vehicular ad hoc networks," *INFOCOM 2006. 25th IEEE International Conference on Computer Communications. Proceedings*, vol., no., pp. 1-12, 2006.

[4] Naumov, Valery, Rainer Baumann, and Thomas Gross. "An evaluation of inter-vehicle ad hoc networks based on realistic vehicular traces." In *Proceedings of the 7th ACM international symposium on Mobile ad hoc networking and computing*, pp. 108-119. ACM, 2006.

[5] M. Dorigo, M. Birattari and T. Stutzle, "Ant Colony Optimization: Artificial Ants as A Computational Intelligence Technique," *IEEE Computational Intelligence Magazine*, vol. 1, no. 4, pp. 28-39, 2006.

[6] Jerbi, M., Senouci, S.-M., Meraihi, R., and Ghamri-Doudane, Y., "An improved vehicular ad hoc routing protocol for city environments," *Communications, ICC '07. IEEE International Conference*, pp. 3972–3979, 2007.

[7] Toor Y, Muhlethaler P, Laouiti A., "Vehicle ad hoc networks: applications and related technical issues," *Communications Surveys & Tutorials, IEEE*, pp. 74-88, 2008.

[8] F. J. Ros, V. Cabrera, J. A. Sanchez, J.A. Martinez and P. M. Ruiz, "Routing in Vehicular Networks," in *Vehicular Networks Techniques, Standards, and Applications*, eds. H. Moustafa and Y. Zhang, Auerbach Publications, US, pp. 109-14, 2009.

[9] Liu Y, Bi J, Yang J., "Research on vehicular ad hoc networks," In *Control and Decision Conference*, 2009. CCDC'09. Chinese 2009 Jun 17, pp. 4430-4435. IEEE.

[10] Härri J, Filali F, Bonnet C., "Mobility models for vehicular ad hoc networks: A survey and taxonomy," *Communications Surveys & Tutorials, IEEE*, pp. 19-41, 2009.

[11] Moustafa, Hassnaa, Sidi Mohammed Senouci, and Moez Jerbi. "Introduction to vehicular networks." *Vehicular Networks*, 2009.

[12] Shrestha, R.K., Moh, S., Chung, I. and Choi, D, "Vertex-based multihop vehicle-to-infrastructure routing for vehicular ad hoc networks," In hicss (pp. 1-7). *IEEE. "Vertex-Based Multihop Vehicle-to-Infrastructure Routing for Vehicular Ad Hoc Networks* (26458)," 2010.

[13] Kohli, Sandhaya, Bandanjot Kaur, and Sabina Bindra. "A comparative study of Routing Protocols in VANET." *Proceedings of ISCET*, 2010.

[14] S. C. Ng, W. Zhang, Y. Zhang, Y. Yang and G. Mao, "Analysis of access and connectivity probabilities in vehicular relay networks," *IEEE Journal on Selected Areas in Communications*, vol. 29, no. 1, pp. 140-150, 2011.

[15] Kim JH, Lee S., "Reliable routing protocol for vehicular ad hoc networks," *AEU-International Journal of Electronics and Communications*, pp. 268-71, 2011.

[16] Venkata, M. D., MM Manohara Pai, Radhika M. Pai, and Joseph Mouzna. "Traffic monitoring and routing in VANETs—A cluster based approach." In *ITS Telecommunications (ITST), 2011 11th International Conference on*, pp. 27-32. IEEE, 2011.

[17] Sharma, Yatendra Mohan, and Dr Saurabh Mukherjee."A contemporary proportional exploration of numerous routing protocols in VANET." *International Journal of Computer Applications*, pp. 0975–8887, 2012.

[18] S. Balaji, S. Sureshkumar and G. Saravanan, "Cluster based ant colony optimization routing for vehicular ad hoc networks," *International Journal of Scientific & Engineering Research*, vol. 4, no. 6, pp. 26-30, 2013.

[19] Kabir, Md Humayun. "Research issues on vehicular ad hoc network." *International Journal of Engineering Trends and Technology (IJETT)*, vol. 6, 2013.

[20] Kazemi, Babak, Masoumeh Ahmadi, and Siamak Talebi. "Optimum and reliable routing in VANETs: An opposition sbased ant colony algorithm scheme." In *Connected Vehicles and Expo (ICCVE), 2013 International Conference on*, pp. 926-930. IEEE, 2013.

[21] Eiza, Mahmoud Hashem, Qiang Ni, Thomas Owens, and Geyong Min. "Investigation of routing reliability of vehicular ad hoc networks." *EURASIP Journal on Wireless Communications And Networking*, no. 1, pp. 1-15, 2013.

[22] Janardhanan, C. M., and C. Sathish Kumar, "Performance analysis of discrete wavelet transform based audio watermarking on Indian classical songs." *International Journal of Computer Applications*, vol. 73, no. 6, 2013.

[23] Manchanda Puneet and Bangar Parvinder. "Modified AODV-R routing protocol." *International Journal of Engineering, Applied and Management Sciences Paradigms*, vol. 16, pp. 2320-6608, 2014.

[24] Da Cunha, Felipe Domingos, Azzedine Boukerche, Leandro Villas, Aline Carneiro Viana, and Antonio AF Loureiro. "Data communication in VANETs: A survey, challenges and applications." PhD diss., INRIA Saclay, 2014.

[25] Y. Xiang, I. Natgunanathan, S. Guo, W. Zhou and S. Nahavandi, "Patchwork-Based audio watermarking method robust to de-synchronization attacks," in *IEEE/ACM Transactions on Audio, Speech, and Language Processing*, vol. 22, no. 9, pp. 1413-1423, 2014.

[26] Hu, Hwai-Tsu, and Ling-Yuan Hsu. "Robust, transparent and high-capacity audio watermarking in DCT domain." *Signal Processing*, pp: 226-235, 2015.

[27] S. Roy, N. Sarkar, A. K. Chowdhury and S. M. A. Iqbal, "An efficient and blind audio watermarking technique in DCT domain," *2015 18th International Conference on Computer and Information Technology (ICCIT)*, Dhaka, pp. 362-367, 2015.

[28] Ito, Toshiki, et al. "Audio watermarking using different wavelet filters." *International Workshop on Digital Watermarking*. Springer International Publishing, 2015.

[29] El-Samie, Fathi E. Abd, et al. "Sensitivity of automatic speaker identification to SVD digital audio watermarking." *International Journal of Speech Technology*, pp. 565-581, 2015.

[30] Dhar, Pranab Kumar, and Tetsuya Shimamura. "Blind SVD-based audio watermarking using entropy and log-polar transformation." *Journal of Information Security and Applications*, pp. 74-83, 2015.