Eurasian Journal of Analytical Chemistry
ISSN: 1306-3057 OPEN ACCESS 2017 12 (4): 44-51

Multiple Relay Orthogonal Frequency Division Multiplexing for Total throughput Maximization

R. Elankavi, Dr.R. Udayakumar

Received: 04 December 2016 ▪ Revised: 07 January 2017 ▪ Accepted: 06 February 2017

Abstract: Efficient utilization of radio resources in wireless networks is crucial and has been investigated extensively. This letter considers a wireless relay network where multiple user pairs conduct bidirectional communications via multiple relays based on orthogonal frequency-division multiplexing (OFDM) transmission. The joint optimization of channel and relay assignment, including subcarrier pairing, subcarrier allocation as well as relay selection, for total throughput maximization is formulated as a combinatorial optimization problem. Using a graph theoretical approach, we solve the problem optimally in polynomial time by transforming it into a maximum weighted bipartite matching (MWBM) problem. Simulation studies are carried out to evaluate the network total throughput versus transmit power per node and the number of relay nodes

Keywords: OFDM, MWBM, Multi Relay Multi Pair Two Way Communication.

INTRODUCTION

Relay-assisted communication can improve the system overall performance in wireless networks, such as coverage extension, power saving, and throughput enhancement. Combining relaying architecture with orthogonal frequency-division multiplexing (OFDM)-based transmission is a powerful technique to enable high date rates over broadband wireless networks. To fully exploit the potential of OFDM-based relay networks, it is crucial to design efficient resource allocation schemes, including determining which relay node to cooperative with, which set of subcarriers to operate on, and with how much power to transmit the signals. Resource allocation has attracted extensive attention recently in a variety of OFDM-based relay networks.

Diversity techniques is mainly used for overcome the fading problem in wireless communication, this problem is occurs due to No clear Line Of Sight (LOS) between transmitter and receiver, the signal is reflected along multiple paths before finally being received. These introduce phase shifts, time delays, attenuations, and distortions that can destructively interfere with one another at the aperture of the receiving antenna. There are several wireless Diversity schemes that use two or more antennas to improve the quality and reliability of a wireless link.

In this work, we consider an OFDM-based network where multiple relays help multiple pairs of source nodes to conduct Bidirectional communications. The aim of the project lies in maximizing the system total throughput by optimally coordinating the relay and subcarrier assignment among the multiple pairs of two-way users. The joint optimization problem of subcarrier pairing based subcarrier assignment and relay selection for multiple two-way users is considered as a combinatorial optimization problem. Hence graph based approach is implemented to establish the equivalence between the proposed problem and a maximum weighted bipartite matching (MWBM) problem. Then the problem is solved by the corresponding graph based algorithm optimally in polynomial time.

This describes the wireless relay network where multiple user pairs conduct bidirectional communications via multiple relays based on orthogonal frequency-division multiplexing (OFDM) transmission. The joint optimization subcarrier pairing is implemented for the subcarrier allocation and relay selection. A graph based approach, is used to solve the problem optimally in polynomial time by transforming it into a maximum weighted bipartite matching (MWBM) problem. Total throughput against

R. Elankavi, Assistant Professor, Department of Computer Science and Engineering, BIST, BIHER, Bharath Institute of Higher, Education & Research, Selaiyur, Chennai. E-mail: kavirajcse@gmail.com

Dr.R. Udayakumar, Professor, Department of IT, BIST, BIHER, Bharath Institute of Higher, Education & Research, Selaiyur, Chennai. E-mail: rsukumar2007@gmail.com

transmit power per node and the number of relay nodes is evaluated through which the performance of the system is analyzed for different number of subcarriers.

OFDMA

Orthogonal Frequency-Division Multiple Access (OFDMA) is a multi-user version of the popular orthogonal frequency-division multiplexing (OFDM) digital modulation scheme. Multiple access is achieved in OFDMA by assigning subsets of subcarriers to individual users as shown in the illustration below. This allows simultaneous low data rate transmission from several users.

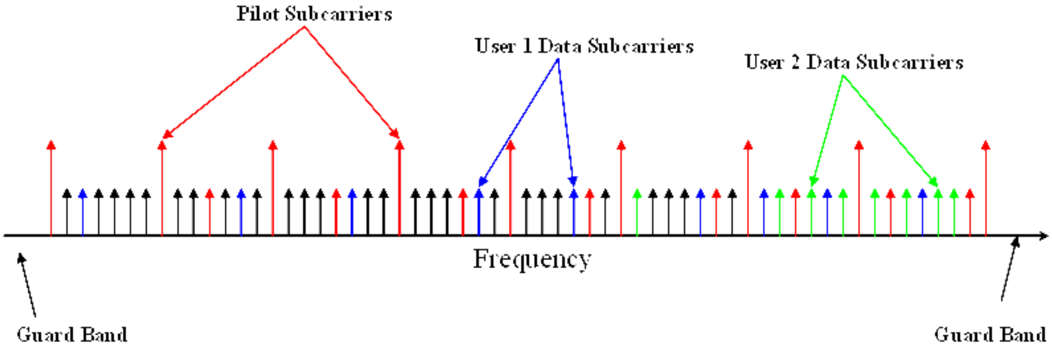


Fig. 1: OFDMA Frequency Illustration

ORDM

Orthogonal frequency-division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. OFDM has developed into a popular scheme for wideband digital communication, whether wireless or over copper wires, used in applications such as digital television and audio broadcasting, DSL broadband internet access, wireless networks, and 4G mobile communications. OFDM is essentially identical to coded OFDM (COFDM) and discrete multi-tone modulation (DMT), and is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. The word "coded" comes from the use of forward error correction (FEC).

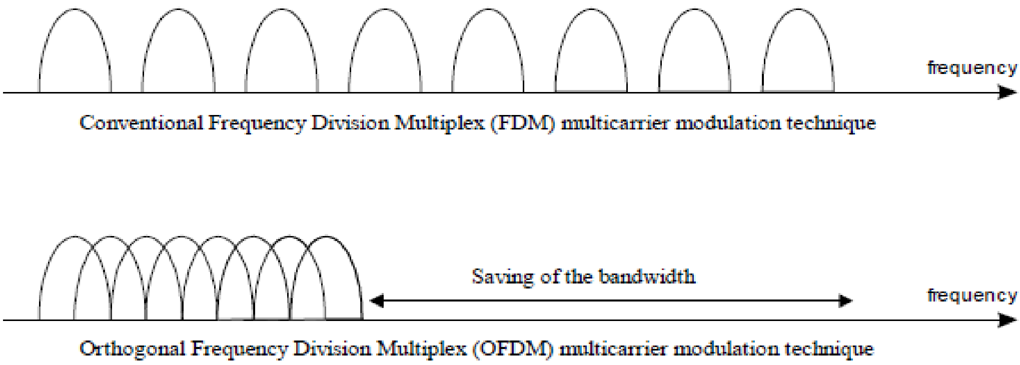


Fig. 2: Conventional and Orthogonal Frequency Division Multiplex

PROPOSED SYSTEM

In the proposed system, we consider an OFDM-based network where multiple relays help multiple pairs of source nodes to conduct bidirectional communications. Our aim is to maximize the system total throughput by optimally coordinating the relay and subcarrier assignment among the multiple pairs of two-way users. Compared with the existing works, our problem involves two major technical challenges. The first one is the subcarrier pairing and assignment. Though the optimal subcarrier pairing has been found for one-way relaying, only heuristic subcarrier pairing methods are available for two-way relaying. In addition, the problem is more involved in the multiuser scenario since subcarriers should not only be carefully paired for each two-way link but also be assigned adaptively for different users. The second challenge lies in the fact that subcarrier pairing and relay selection are tightly coupled, i.e., different relay selections lead to different subcarrier pairing and assignment, and vice versa. For instance, a bad pair of subcarriers in two hops for one relay and one user pair may be good for the same user pair if another relay is selected to them or good for the same relay if another user pair is selected. It is thus necessary to consider them jointly, which can be referred to as subcarrier-to-relay to- user assignment.

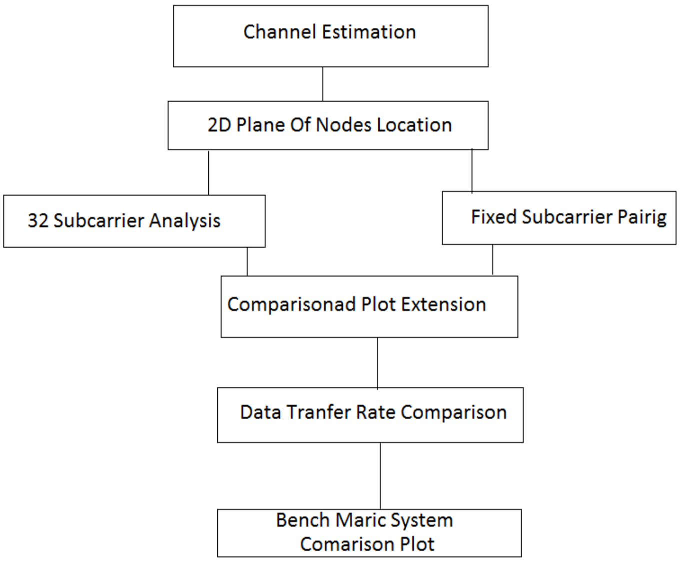


Fig. 3: Block Diagram for Proposed System

Proposed System Advantages

i. The channel estimation is perfect as the channel between different links experience independent fading.
ii. OFDM is very easy and efficient in dealing with multi-path and Robust again narrow-band interference

As OFDM-based network supports multi relay-multi pairs of source node to conduct bidirectional communications, it maximizes the throughput optimally.

OFDM-Based Wireless Network

i. System Module
ii. Problem Formulation
iii. Graphical Approach
iv. Simulation Result

System Module

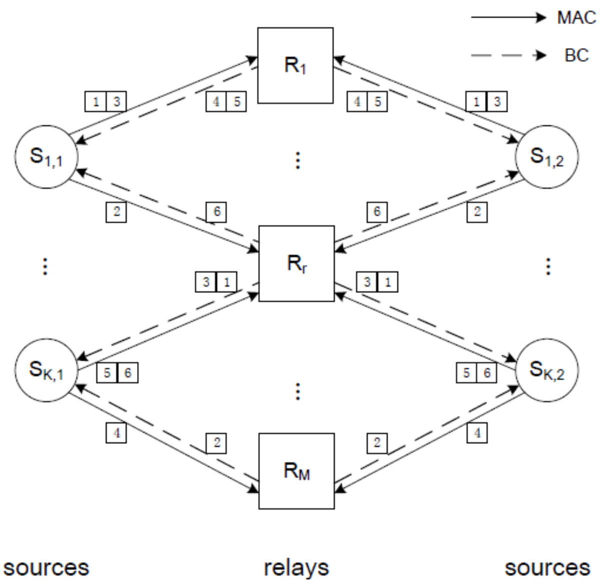


Fig. 4: OFDM-Based Wireless Network with K Pairs of Users and M Relays

An OFDM-based wireless network with K pairs of users and M relays is shown in Fig.6. where each user pair exchange information via the relays. Each node operates in a half-duplex mode. For simplicity, the amplify and- forward (AF) two-way relay strategy is adopted. The wireless fading environment by large-scale path loss and shadowing, along with small-scale frequency-selective fading is considered.

Problem Formulation

The subcarriers are n and n' in the first and second phase respectively. If the user pair k is assigned with subcarrier n and sends signals to relay r in the first phase, the relay r then broadcasts the amplified received signals on subcarrier n' in the second phase,

The achievable sum rate is given by,

$$R_{k,r}^{n,n'} = \frac{1}{2}C\left(\frac{\gamma_{k1,r}^{n}\gamma_{rk_2}^{n'}}{1+\gamma_{rk_2}^{n'}+\gamma_{k_1r}^{n}+\gamma_{k_2r}^{n}}\right)+\frac{1}{2}C\left(\frac{\gamma_{k_2r}^{n}\gamma_{rk_2}^{n'}}{1+\gamma_{rk_1}^{n'}+\gamma_{k_1r}^{n}+\gamma_{k_2r}^{n}}\right)$$

Where $C(x) = \log(1+x)$ and γ_{ij}^{n} denotes the instantaneous signal-noise ratio (SNR) from node i to node j over subcarrier n, assuming that all the nodes have the unit noise variance.

Let us consider the set of binary variables $\rho_{k,r}^{n,n'} = \{0,1\}$ for all k, r, n, n' Where $\rho_{k,r}^{n,n'} = 1$ means that subcarrier n in the first phase is paired with subcarrier n' in the second phase assisted by relay r for user pair k, else $\rho_{k,r}^{n,n'} = 0$ otherwise. As assumed above, each subcarrier can be assigned to one user pair and one relay, in the first and second phases, respectively to avoid interference. Therefore, $\rho_{k,r}^{n,n'}$ must satisfy the following constraints:

$$\sum_{k\in\mathcal{K}}\sum_{r\in\mathcal{M}}\sum_{n'\in\mathcal{N}}\rho_{k,r}^{n,n'} \le 1, \quad \forall n\in\mathcal{N},$$

$$\sum_{k\in\mathcal{K}}\sum_{r\in\mathcal{M}}\sum_{n\in\mathcal{N}}\rho_{k,r}^{n,n'} \le 1, \quad \forall n'\in\mathcal{N}.$$

The main objective is to maximize the system total throughput by optimally pairing subcarriers in the two phases and selecting the best relays and the best paired subcarriers for each user pair. Mathematically, this can be formulated as (**P1**):

$$\mathbf{P1}: \quad \max\sum_{k\in\mathcal{K}}\sum_{r\in\mathcal{M}}\sum_{n\in\mathcal{N}}\sum_{n'\in\mathcal{N}}R_{k,r}^{n,n'}\rho_{k,r}^{n,n'} \quad s.t. \ (2),(3).$$

Note that it can be easily modify the objective function in **P1** to weighted sum of all user rates without affecting the algorithm design if fairness is considered.

Graphical Approach

Problem **P1** is a combinatorial optimization problem and the optimal solution can be obtained by exhaustive search. The complexity is exponential and thus prohibitive when K, M, and N are large. In this section, a graph based approach was proposed to solve the problem optimally in polynomial time.

By observing the summation in the objective function of **P1**, it is easy to find that there is at most one non-zero element for a given subcarrier pair (n, n') due to the constraints. Based on the observation, it is defined as,

$$R(n,n') = \max_{k\in K, r\in M} R_{k,r}^{n,n'}$$

for each possible subcarrier pair (n, n').

The associated user pair and relay node that take the maximum for each subcarrier pair (n, n') are denoted as k^* and r^*, respectively. Consequently, we can transform the original problem **P1** to the following simplified problem (**P2**) without loss of optimality.

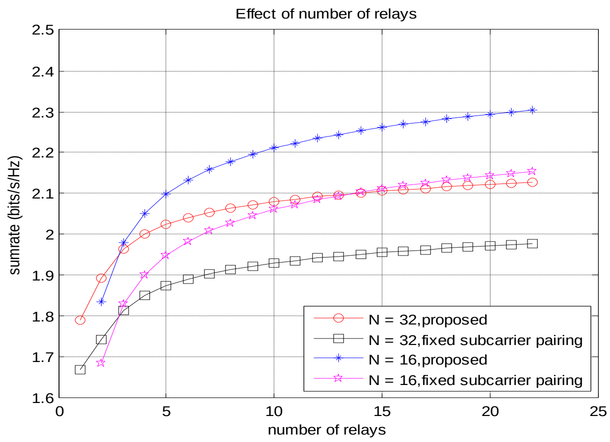
$$\mathbf{P2}: \max\sum_{n\in N}\sum_{n'\in N}R(n,n')\rho_{k^*,r^*}^{n,n'}$$

$$\text{s.t.} \sum_{n'\in N}\rho_{k^*,r^*}^{n,n'} \le 1, \quad \forall n\in N$$

$$\sum_{n\in N}\rho_{k^*,r^*}^{n,n'} \le 1, \quad \forall n'\in N$$

In what follows, we show that the simplified **P2** is equivalent to a maximum weighted bipartite matching (MWBM) problem. Before we proceed, we review some preliminaries of MWBM.

Simulation Result



CONCLUSIONS

In this work, we investigated the joint optimization of subcarrier-pairing based subcarrier assignment and relay selection for multi-relay multi-pair two-way relay OFDM networks. The problem was formulated as a combinatorial optimization problem. We proposed a bipartite matching approach to solve the problem optimally in polynomial time. The work assumed the amplify-and-forward based non regenerative relay strategy. The similar problem based on more advanced regenerative two-way relay strategies can be considered in the future work. The results are shown for the use of different number of subcarriers.

ACKNOWLEDGMENTS

I thank SPECTRUM SOLUTIONS, Pondicherry to help me for creating this paper with their Sincere Guidance and Technical Expertise in the field of communication.

I thank my guide Mr. K. Karthikeyan, A.P, PRIST University for his great support. The help of Mr.I.D. Soubache, HOD, Department of Electrical and Electronics PRIST University is really immense and once again I thank him for his great motivation.

I thank PRIST University, Pondicherry to provide me such a standard educational environment so that I am able to understand the minute concepts in the field of Engineering and Technology.

REFERENCES

[1] Das, J., Das, M.P., & Velusamy, P. (2013). Sesbania grandiflora leaf extract mediated green synthesis of antibacterial silver nanoparticles against selected human pathogens. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, *104*, 265-270.

[2] Umanath, K.P.S.S.K., Palanikumar, K., & Selvamani, S.T. (2013). Analysis of dry sliding wear behaviour of Al6061/SiC/Al2O3 hybrid metal matrix composites. *Composites Part B: Engineering*, *53*, 159-168.

[3] Udayakumar, R., Khanaa, V., Saravanan, T., & Saritha, G. (1786). Cross layer optimization for wireless network (WIMAX). *Middle-East Journal of Scientific Research*, *16*(12), 1786-1789.

[4] Kumaravel, A., & Rangarajan, K. (2013). Algorithm for automaton specification for exploring dynamic labyrinths. *Indian Journal of Science and Technology*, *6*(5S), 4554-4559.

[5] Pieger, S., Salman, A., & Bidra, A.S. (2014). Clinical outcomes of lithium disilicate single crowns and partial fixed dental prostheses: a systematic review. *The Journal of prosthetic dentistry*, *112*(1), 22-30.

[6] Vijayaraghavan, K., Nalini, S.K., Prakash, N.U., & Madhankumar, D. (2012). One step green synthesis of silver nano/microparticles using extracts of Trachyspermum ammi and Papaver somniferum. *Colloids and Surfaces B: Biointerfaces*, *94*, 114-117.

[7] Khanaa, V., Mohanta, K., & Satheesh, B. (2013). Comparative study of uwb communications over fiber using direct and external modulations. *Indian Journal of Science and Technology*, *6*(6), 4845-4847.

[8] Arputhamary, B., & Arockiam, L. (2015). Data Integration in Big Data Environment. *Bonfring International Journal of Data Mining, 5*(1), 01-05.

[9] Meymari, B.K., Mofrad, R.F., & Nasab, M.S. (2015). High Dynamic Range Receiver System Designed for High Pulse Repetition Frequency Pulse Radar. *International Academic Journal of Innovative Research, 2*(9), 1-20.

[10] Abinaya, R., Abinaya, R., Vidhya, S., & Vadivel, S. (2014). Latent Palm Print Matching Based on Minutiae Features for forensic Applications. *International Journal of Communication and Computer Technologies, 2*(2), 85-87.

[11] Dr. Krishnapriya, G. (2017). Identification of Money Laundering based on Financial Action Task Force Using Transaction Flow Analysis System. *Bonfring International Journal of Industrial Engineering and Management Science, 7*(1), 01to04.

[12] Khanaa, V., Thooyamani, K.P., & Udayakumar, R. (1798). Cognitive radio based network for ISM band real time embedded system. *Middle-East Journal of Scientific Research*, *16*(12), 1798-1800.

[13] Vijayaraghavan, K., Nalini, S.K., Prakash, N.U., & Madhankumar, D. (2012). Biomimetic synthesis of silver nanoparticles by aqueous extract of Syzygium aromaticum. *Materials Letters*, *75*, 33-35

[14] Caroline, M.L., Sankar, R., Indirani, R.M., & Vasudevan, S. (2009). Growth, optical, thermal and dielectric studies of an amino acid organic nonlinear optical material: l-Alanine. *Materials Chemistry and Physics*, *114*(1), 490-494.

[15] Kumaravel, A., & Pradeepa, R. (2013). Efficient molecule reduction for drug design by intelligent search methods. *International Journal of Pharma and Bio Sciences*, *4*(2), B1023-B1029.

[16] Kaviyarasu, K., Manikandan, E., Kennedy, J., Jayachandran, M., Ladchumananandasiivam, R., De Gomes, U.U., & Maaza, M. (2016). Synthesis and characterization studies of NiO nanorods for enhancing solar cell efficiency using photon upconversion materials. *Ceramics International*, *42*(7), 8385-8394.

[17] Sengottuvel, P., Satishkumar, S., & Dinakaran, D. (2013). Optimization of multiple characteristics of EDM parameters based on desirability approach and fuzzy modeling. *Procedia Engineering*, *64*, 1069-1078.

[18] Anbuselvi S., Chellaram, C., Jonesh S., Jayanthi L., & Edward J.K.P. (2009). Bioactive potential of coral associated gastropod, Trochus tentorium of Gulf of Mannar, Southeastern India. *J. Med. Sci*, *9*(5), 240-244.

[19] Kaviyarasu, K., Ayeshamariam, A., Manikandan, E., Kennedy, J., Ladchumananandasivam, R., Gomes, U.U., & Maaza, M. (2016). Solution processing of CuSe quantum dots: Photocatalytic activity under RhB for UV and visible-light solar irradiation. *Materials Science and Engineering: B*, *210*, 1-9.

[20] Vakilfard, M., Taheri, A., & Salehifar, M.R. (2014). Implementation of the Satellite Ground Station Control in Real-Time Under Windows. *International Academic Journal of Science and Engineering, 1*(1), 1-9.

[21] Aarthi, S., & Vijay, N. (2014). Sophisticated Data Entry Application using Matchmaking Algorithm through Scanned Images. *International Journal of System Design and Information Processing, 2*(1), 27-29.

[22] Patidar, H.P., & Sharma, N. (2016). Adaptive Approach of DSR and OLSR Routing Protocols Using Optimal Probabilistic Logical Key Hierarchy in MANET. *Bonfring International Journal of Networking Technologies and Applications, 3*(2), 13-20.

[23] Venkateswara Rao, B., and Nagesh Kumar, G.V. (2014). Voltage Collapse Proximity Indicator based Placement and Sizing of Static VAR Compensator using BAT Algorithm to Improve Power System Performance. *Bonfring International Journal of Power Systems and Integrated Circuits, 4*(3), 31-38.

[24] Kumaravel, A., & Udayakumar, R. (2013). Web portal visits patterns predicted by intuitionistic fuzzy approach. *Indian Journal of Science and Technology*, *6*(5S), 4549-4553.

[25] Srinivasan, V., & Saravanan, T. (2013). Reformation and market design of power sector. *Middle-East Journal of Scientific Research*, *16*(12), 1763-1767.

[26] Kaviyarasu, K., Manikandan, E., Kennedy, J., & Maaza, M. (2015). A comparative study on the morphological features of highly ordered MgO: AgO nanocube arrays prepared via a hydrothermal method. *RSC Advances*, *5*(100), 82421-82428.

[27] Kumaravel, A., & Udhayakumarapandian, D. (2013). Consruction of meta classifiers for apple scab infections. *International Journal of Pharma and Bio Sciences*, *4*(4), B1207-B1213.

[28] Sankari, S.L., Masthan, K.M.K., Babu, N.A., Bhattacharjee, T., & Elumalai, M. (2012). Apoptosis in cancer-an update. *Asian Pacific journal of cancer prevention*, *13*(10), 4873-4878

[29] Harish, B.N., & Menezes, G.A. (2011). Antimicrobial resistance in typhoidal salmonellae. *Indian journal of medical microbiology*, *29*(3), 223-229.

[30] Manikandan, A., Manikandan, E., Meenatchi, B., Vadivel, S., Jaganathan, S.K., Ladchumananandasivam, R., & Aanand, J.S. (2017). Rare earth element (REE) lanthanum doped zinc oxide (La: ZnO) nanomaterials: synthesis structural optical and antibacterial studies. *Journal of Alloys and Compounds*, *723*, 1155-1161.

[31] Caroline, M.L., & Vasudevan, S. (2008). Growth and characterization of an organic nonlinear optical material: L-alanine alaninium nitrate. *Materials Letters*, *62*(15), 2245-2248.

[32] Saravanan T., Srinivasan V., Udayakumar R. (2013). A approach for visualization of atherosclerosis in coronary artery. *Middle - East Journal of Scientific Research,* 18(12), 1713-1717.

[33] Poongothai, S., Ilavarasan, R., & Karrunakaran, C.M. (2010). Simultaneous and accurate determination of vitamins B1, B6, B12 and alpha-lipoic acid in multivitamin capsule by reverse-phase high performance liquid chromatographic method. *International Journal of Pharmacy and Pharmaceutical Sciences*, *2*(4), 133-139.

[34] Udayakumar, R., Khanaa, V., & Saravanan, T. (2013). Synthesis and structural characterization of thin films of SnO 2 prepared by spray pyrolysis technique. *Indian Journal of Science and Technology*, *6*(6), 4754-4757

[35] Anbazhagan, R., Satheesh, B., & Gopalakrishnan, K. (2013). Mathematical modeling and simulation of modern cars in the role of stability analysis. *Indian Journal of Science and Technology*, *6*(5S), 4633-4641.

[36] Caroline, M.L., & Vasudevan, S. (2009). Growth and characterization of bis thiourea cadmium iodide: A semiorganic single crystal. *Materials Chemistry and Physics*, *113*(2-3), 670-674.

[37] Sharmila, S., Jeyanthi Rebecca, L., & Das, M.P. (2012). Production of Biodiesel from Chaetomorpha antennina and Gracilaria corticata. *Journal of Chemical and Pharmaceutical Research*, *4*(11), 4870-4874.

[38] Thooyamani, K.P., Khanaa, V., & Udayakumar, R. (2013). An integrated agent system for e-mail coordination using jade. *Indian Journal of Science and Technology*, *6*(6), 4758-4761.

[39] Caroline, M.L., Kandasamy, A., Mohan, R., & Vasudevan, S. (2009). Growth and characterization of dichlorobis l-proline Zn (II): A semiorganic nonlinear optical single crystal. *Journal of Crystal Growth*, *311*(4), 1161-1165.

[40] Caroline, M.L., & Vasudevan, S. (2009). Growth and characterization of L-phenylalanine nitric acid, a new organic nonlinear optical material. *Materials Letters*, *63*(1), 41-44.

[41] Kaviyarasu, K., Xolile Fuku, Genene T. Mola, E. Manikandan, J. Kennedy, and M. Maaza. Photoluminescence of well-aligned ZnO doped CeO2 nanoplatelets by a solvothermal route. *Materials Letters*, *183*(2016), 351-354.

[42] Saravanan, T., & Saritha, G. (2013). Buck converter with a variable number of predictive current distributing method. *Indian Journal of Science and Technology*, *6*(5S), 4583-4588.

[43] Parthasarathy, R., Ilavarasan, R., & Karrunakaran, C. M. (2009). Antidiabetic activity of Thespesia Populnea bark and leaf extract against streptozotocin induced diabetic rats. *International Journal of PharmTech Research*, *1*(4), 1069-1072.

[44] Hanirex, D.K., & Kaliyamurthie, K. P. (2013). Multi-classification approach for detecting thyroid attacks. *International Journal of Pharma and Bio Sciences,* 4(3), B1246-B1251

[45] Kandasamy, A., Mohan, R., Lydia Caroline, M., & Vasudevan, S. (2008). Nucleation kinetics, growth, solubility and dielectric studies of L-proline cadmium chloride monohydrate semi organic nonlinear optical single crystal. *Crystal Research and Technology: Journal of Experimental and Industrial Crystallography*, *43*(2), 186-192.

[46] Neenu Preetam, I., & Gupta, H. (2014). Cardless Cash Access using Biometric ATM Security System. *International Scientific Journal on Science Engineering & Technology, 17*(10), 893-897.

[47] Revathi, M., Prakash, K., & Suguna, R. (2018). A Systematic Study on Cyber Physical System. *Bonfring International Journal of Research in Communication Engineering, 8*(1), 1-4.

[48] Srinivasan, V., Saravanan, T., Udayakumar, R., & Saritha, G. (2013). Specific absorption rate in the cell phone user's head. *Middle-East Journal of Scientific Research*, *16*(12), 1748-50.

[49] Udayakumar R., Khanaa V., & Saravanan T. (2013). Chromatic dispersion compensation in optical fiber communication system and its simulation. *Indian Journal of Science and Technology,* 6(6), 4762-4766.

[50] Vijayaragavan, S.P., Karthik, B., Kiran, T.V.U., & Sundar Raj, M. (1990). Robotic surveillance for patient care in hospitals. *Middle-East Journal of Scientific Research*, *16*(12), 1820-1824.