Proceedings of the International Conference on Paradigms of Computing, Communication and Data Sciences

PCCDS 2020
Algorithms for Intelligent Systems

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Foreword

It is a matter of great pleasure to record that the International Conference on Paradigms of Computing, Communication and Data Sciences—PCCDS 2020 has been organized in Online mode by the Department of Computer Engineering, National Institute of Technology, Kurukshetra, during May 01–03, 2020.

The conference theme Computing, Communication and Data Sciences covered broad spectrum of topics of the current interest to multidisciplinary researchers, academicians and professionals. The recent trends, applications and future challenges of technology were highlighted by distinguished experts from India and abroad. The accepted papers and presentations in the conference were of high quality. The proceedings of the conference would be published by Springer Nature Singapore Pte Ltd. under the ‘Algorithms for Intelligent Systems’ series. This proceeding would prove to be an excellent research reference in above areas.

Prof. Mayank Dave, Prof. Jemal Abawajy, Dr. Ritu Garg, Dr. Mohit Dua, Dr. Ankit Jain and Dr. Bharati Sinha deserve appreciation for organization and conduct of this conference. The effort of their team and institutional support is commendable.

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Preface

International Conference on Paradigms of Computing, Communication and Data Sciences (PCCDS 2020) was organized by the Department of Computer Engineering at National Institute of Technology, Kurukshetra, India, from May 1 to 3, 2020. The event was technically sponsored by Technical Education Quality Improvement Program (TEQIP-3) of Government of India. The conference received 259 papers, out of which 80 contributions were finally selected for publication in conference proceedings.

The conference theme Computing, Communication and Data Sciences served as an invitation to discuss recent trends that are being followed and future challenges that are being faced by various researchers, academicians and professionals from all over the world. It particularly encouraged the interaction of researchers to build an academic community in an informal setting to present and discuss their developed works.

The papers selected for the conferences were grouped as per the theme of the conference—32 in Computing, 20 in Communication and 28 in Data Sciences. The papers were presented in 12 conference sessions spread over three days. The contributed papers cover all the latest aspects of intelligent applications that are being developed in different fields of computer engineering, electrical engineering and electronics and communication engineering.

In addition to the contributed papers, five invited keynote speeches were delivered by Prof. Jemal Abawajy from Deakin University, Australia; Dr. Sriparma Saha from Indian Institute of Technology, Patna, India; Dr. Jagdish Chand Bansal from South Asian University, New Delhi, India; Dr. Maanak Gupta from Tennessee Technological University, TN, USA; and Dr. Utkarsh Shrivastava Western Michigan University, USA. We express our deep appreciation and thanks to all the keynote speakers.

We thank all reviewers, authors and participants for their contributions. We hope that these proceedings being published under the book series ‘Algorithm for
Intelligent Systems’ by Springer Nature, Singapore, will furnish as an excellent reference book to scientific groups all over the world. We also trust that this book will stimulate further study and research in all thematic areas.

Kurukshetra, India
Kurukshetra, India
Kurukshetra, India
Geelong, Australia

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Ritu Garg
Jemal Hussien
Acknowledgements

Success in life is never attained single handedly. Our deepest gratitude to the ‘Algorithms for Intelligent Systems’ series editors Dr. Jagdish Chand Bansal, Prof. Kusum Deep and Prof. Atulya K. Nagar for their support and encouragement throughout the conference organizing and publishing work. Words are not enough to express our gratitude to Team Springer Nature, especially Aninda Bose, Senior Publishing Editor, Springer Nature, for his insightful comments and administrative help at various occasions. We are also thankful to Ms. Silky Abhay Sinha for her regular communication that helped us in maintaining the deadlines of the proceedings. We would also like to thank all the member of Advisory Committee, members of Technical Program Committee, reviewers, session chairs and participants for their stimulating questions and invaluable feedback. We are thankful to Director, National Institute of Technology, Kurukshetra, for providing much-needed encouragement and extending necessary facilities. We are thankful to Prof. Sathans, Coordinator, TEQIP-3, for providing sponsorship for the conference. Our sincere thanks go to our department colleagues, especially Department Advisory Committee (DAC), and all those who have directly and indirectly provided us moral support and other kind of help.
Contents

Part I Computing

1 Real-Time Implementation of Enhanced Energy-Based Detection Technique ........................................... 3
   Vatsala Sharma and Sunil Joshi

2 Pipeline Burst Detection and Its Localization Using Pressure Transient Analysis ..................................... 13
   Aditya Gupta and K. D. Kulat

3 Improving Machine Translation Using Parts-Of-Speech Tags and Dependency Parsing ............................. 27
   Apoorva Jha and Philemon Daniel

4 Optimal Strategy for Obtaining Excellent Energy Storage Density in Polymer Nanocomposite Materials ........ 37
   Daljeet Kaur, Tripti Sharma, and Charu Madhu

5 A Study of Aging-Related Bugs Prediction in Software System .......................................................... 49
   Satyendra Singh Chouhan, Santosh Singh Rathore, and Ritesh Choudhary

6 Mutual Authentication of IoT Devices Using Kronecker Product on Secure Vault .................................. 63
   Shubham Agrawal and Priyanka Ahlawat

7 Secure and Decentralized Crowdfunding Mechanism Based on Blockchain Technology ............................ 79
   Swati Kumari and Keyur Parmar

8 Efficient Use of Randomisation Algorithms for Probability Prediction in Baccarat Using: Monte Carlo and Las Vegas Method .............................................................. 91
   Avani Jindal, Janhvi Joshi, Nikhil Sajwan, Naman Adlakha, and Sandeep Pratap Singh
9 Comparative Analysis of Educational Job Performance Parameters for Organizational Success: A Review .............. 105
Sapna Arora, Manisha Agarwal, and Shweta Mongia

10 Digital Anthropometry for Health Screening from an Image Using FETTLE App .................................................. 123
Roselin Preethi and J. Chandra Priya

11 Analysis and Redesign of Digital Circuits to Support Green Computing Through Approximation .................. 137
Sisir Kumar Jena, Saurabh Kumar Srivastava, and Arshad Husain

12 Similarity-Based Data-Fusion Schemes for Missing Data Imputation in Univariate Time Series Data .................. 149
S. Nickolas and K. Shobha

13 Computational Study on Electronic Properties of Pd and Ni Doped Graphene .................................................. 167
Mehak Singla and Neena Jaggi

14 Design of an Automatic Reader for the Visually Impaired Using Raspberry Pi ............................................. 175
Nabendu Bhui, Dusayanta Prasad, Avishek Sinha, and Pratyay Kuila

15 Power Maximization Under Partial Shading Conditions Using Advanced Sudoku Configuration .................. 189
Gunjan Bharti, Venkata Madhava Ram Tatabhatla, and Tirupathiraju Kanumuri

16 Investigations on Performance Indices Based Controller Design for AVR System Using HHO Algorithm ............... 207
R. Puneeth Reddy and J. Ravi Kumar

17 Ethereum 2.0 Blockchain in Healthcare and Healthcare Based Internet-of-Things Devices .................. 225
Vaibhav Sagar and Praveen Kaushik

18 IoT-Based Solution to Frequent Tripping of Main Blower of Blast Furnace Through Vibration Analysis ............. 235
Kshitij Shinghal, Rajul Misra, and Amit Saxena

19 A Survey on Hybrid Models Used for Hydrological Time-Series Forecasting ............................................. 247
Shivashish Thakur and Manish Pandey

20 Does Single-Session, High-Frequency Binaural Beats Effect Executive Functioning in Healthy Adults? An ERP Study .......... 261
21 Optimized Data Hiding for the Image Steganography Using HVS Characteristics ........................................ 275
Sahil Gupta and Naresh Kumar Garg

22 Impact of Imperfect CSI on the Performance of Inhomogeneous Underwater VLC System .................................. 287
Rachna Sharma and Yogesh N. Trivedi

23 Pre-configured (p)-Cycle Protection for Non-hamiltonian Networks ................................................................. 299
Vidhi Gupta, Rachna Asthana, and Yatindra Nath Singh

24 A Novel Approach to Multi-authority Attribute-Based Encryption Using Quadratic Residues with Tree Access Policy ...... 311
Anshita Gupta and Abhimanyu Kumar

25 An Improvement in Dense Field Copy-Move Image Forgery Detection ............................................................ 323
Harsimran Kaur, Sunil Agrawal, and Anaahat Dhindsa

26 Scheduling-Based Energy-Efficient Water Quality Monitoring System for Aquaculture .......................................... 337
Rasheed Abdul Haq and V. P. Harigovindan

27 A Study of Code Clone Detection Techniques in Software Systems ................................................................. 347
Utkarsh Singh, Kuldeep Kumar, and Deepak Kumar Gupta

28 An Improved Approach to Secure Digital Audio Using Hybrid Decomposition Technique ........................................... 361
Ankit Kumar, Shyam Singh Rajput, and Vrijendra Singh

29 Study on the Negative Transconductance in a GaN/AlGaN-Based HEMT ............................................................. 377
Sujit Kumar Singh, Awnish Kumar Tripathi, and Gaurav Saini

30 Hybrid Anti-phishing Approach for Detecting Phishing Webpage Hosted on Hijacked Server and Zero-Day Phishing Webpage .... 389
Ankush Gupta and Santosh Kumar

31 FFT-Based Zero-Bit Watermarking for Facial Recognition and Its Security .......................................................... 403
Ankita Dwivedi, Madhuri Yadav, and Ankit Kumar

32 Comparative Analysis of Various Simulation Tools Used in a Cloud Environment for Task-Resource Mapping .............. 419
Harvinder Singh, Sanjay Tyagi, and Pardeep Kumar
Part II Communication

33 Study of Spectral-Efficient 400 Gbps FSO Transmission Link Derived from Hybrid PDM-16-QAM With CO-OFDM ........... 433
Mehtab Singh and Jyoteesh Malhotra

34 $4 \times 10$ Gbps Hybrid WDM-MDM FSO Transmission Link .... 443
Mehtab Singh and Jyoteesh Malhotra

Sandeep Kumar Patel and Avtar Singh

36 Modulation Techniques for Next-Generation Wireless Communication-5G ........................................... 473
Sanjeev Kumar, Preeti Singh, and Neha Gupta

37 Muscle Artifact Detection in EEG Signal Using DTW Based Thresholding ........................................... 483
Amandeep Bisht and Preeti Singh

38 Human Activity Recognition in Ambient Sensing Using Sequential Networks ........................................... 493
Vinay Jain, Divyanshu Jhawar, Sandeep Saini, Thinagaran Perumal, and Abhishek Sharma

39 Towards the Investigation of TCP Congestion Control Protocol Effects in Smart Home Environment ............ 503
Pranjal Kumar and P. Arun Raj Kumar

40 Efficient Information Flow Based on Graphical Network Characteristics ................................. 515
Rahul Saxena, Mahipal Jadeja, and Atul Kumar Verma

41 Tunable Optical Delay for OTDM ............................... 527
P. Prakash, K. Keerthi Yazhini, and M. Ganesh Madhan

Raj Vikram, Sonal Kumar, Ditipriya Sinha, and Ayan Kumar Das

43 SG_BIoT: Integration of Blockchain in IoT Assisted Smart Grid for P2P Energy Trading ...................... 553
J. Chandra Priya, V. Ramanujan, P. Rajeshwaran, and Ponsy R. K. Sathia Bhama

44 Software Defined Network: A Clustering Approach Using Delay and Flow to the Controller Placement Problem ............ 565
Anilkumar Goudar, Karan Verma, and Pranay Ranjan
<table>
<thead>
<tr>
<th>Page</th>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>Netra: An RFID-Based Android Application for Visually Impaired</td>
<td>Pooja Nawandar, Vinaya Gohokar, and Aditi Khandewale</td>
<td>575</td>
</tr>
<tr>
<td>46</td>
<td>Efficient Routing for Low Power Lossy Networks with Multiple Concurrent RPL Instances</td>
<td>Jinshiya Jafar, J. Jaisooraj, and S. D. Madhu Kumar</td>
<td>585</td>
</tr>
<tr>
<td>47</td>
<td>Deep Learning-Based Wireless Module Identification (WMI) Methods for Cognitive Wireless Communication Network</td>
<td>Sudhir Kumar Sahoo, Chalamalasetti Yaswanth, Baratham Ramkumar, and M. Sabarimalai Manikandan</td>
<td>595</td>
</tr>
<tr>
<td>48</td>
<td>Style Transfer for Videos with Audio</td>
<td>Gaurav Kabra and Mahipal Jadeja</td>
<td>607</td>
</tr>
<tr>
<td>49</td>
<td>Development of Antennas Subsystem for Indian Airborne Cruise Missile</td>
<td>Ami Jobanputra, Dhruv Panchal, Het Trivedi, Dhyey Buch, and Bhavin Kakani</td>
<td>619</td>
</tr>
<tr>
<td>50</td>
<td>A Literature Survey on LEACH Protocol and Its Descendants for Homogeneous and Heterogeneous Wireless Sensor Networks</td>
<td>Anish Khan and Nikhil Marriwala</td>
<td>631</td>
</tr>
<tr>
<td>51</td>
<td>Performance Study of Ultra Wide Band Radar Based Respiration Rate Measurement Methods</td>
<td>P. Bhaskara Rao, Srinivas Boppu, and M. Sabarimalai Manikandan</td>
<td>645</td>
</tr>
<tr>
<td>52</td>
<td>Secure Architecture for 5G Network Enabled Internet of Things (IoT)</td>
<td>Voore Subba Rao, V. Chandra Shekar Rao, and S. Venkatramulu</td>
<td>659</td>
</tr>
<tr>
<td></td>
<td><strong>Part III Data Sciences</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>Robust Image Watermarking Using DWT and Artificial Neural Network Techniques</td>
<td>Anoop Kumar Chaturvedi, Piyush Kumar Shukla, Ravindra Tiwari, Vijay Kumar Yadav, Sachin Tiwari, and Vikas Sakalle</td>
<td>675</td>
</tr>
<tr>
<td>54</td>
<td>Fraud Detection in Anti-money Laundering System Using Machine Learning Techniques</td>
<td>Ayush Kumar, Debachudamani Prusti, Daisy Das, and Shantanu Kumar Rath</td>
<td>687</td>
</tr>
<tr>
<td>55</td>
<td>A Smart Approach to Detect Helmet in Surveillance by Amalgamation of IoT and Machine Learning Principles to Seize a Traffic Offender</td>
<td>Gaytri, Rishabh Kumar, and Uppara Rajnikanth</td>
<td>701</td>
</tr>
</tbody>
</table>
56 Botnet Detection Using Machine Learning Algorithms ............ 717
Chirag Joshi, Vishal Bharti, and Ranjeet Kumar Ranjan

57 Estimation of Daily Average Global Solar Radiance Using
Ensemble Models: A Case Study of Bhopal, Madhya Pradesh
Meteorological Dataset ........................................... 729
Megha Kamble and Sudeshna Ghosh

58 Text Localization in Scene Images Using Faster R-CNN
with Double Region Proposal Networks ......................... 739
Pragya Hari and Rajib Ghosh

59 Event Classification from the Twitter Stream
Using Hybrid Model ............................................... 751
Neha Singh, M. P. Singh, and Prabhat Kumar

60 Using an Ensemble Learning Approach on Traditional
Machine Learning Methods to Solve a Multi-Label
Classification Problem ............................................. 761
Siddharth Basu, Sanjay Kumar, Sirjanpreet Singh Banga,
and Harshit Garg

61 Automatic Building Extraction from High-Resolution Satellite
Images Using Deep Learning Techniques ........................ 773
Mayank Dixit, Kuldeep Chaurasia, and Vipul Kumar Mishra

62 Epileptic Seizures Classification Based on Deep
Neural Networks ..................................................... 785
Annangi Swetha and Arun Kumar Sinha

63 Analysis for Malicious URLs Using Machine Learning and Deep
Learning Approaches ............................................... 797
Santosh Kumar Birthriya and Ankit Kumar Jain

64 Engaging Smartphones and Social Data for Curing Depressive
Disorders: An Overview and Survey ............................... 809
Srishti Bhatia, Yash Kesarwani, Ashish Basantani, and Sarika Jain

65 Transfer Learning Approach for the Diagnosis of Pneumonia
in Chest X-Rays ....................................................... 821
Kuljeet Singh Sran and Sachin Bagga

66 Physical Sciences: An Inspiration to the Neural
Network Training ...................................................... 833
Venkateswarlu Gudepu, Anshita Gupta, and Parveen Kumar

67 Deep Learning Models for Crop Quality
and Diseases Detection ............................................. 843
Priyanka Sahu, Anuradha Chug, Amit Prakash Singh, Dinesh Singh,
and Ravinder Pal Singh
<table>
<thead>
<tr>
<th>Page</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>68</td>
<td>Clickedroid: A Methodology Based on Heuristic Approach to Detect Mobile Ad-Click Frauds</td>
<td>Pankaj Kumar Keserwani, Vedant Jha, Mahesh Chandra Govil, and Emmanuel S. Pilli</td>
</tr>
<tr>
<td>69</td>
<td>Machine Translation System Using Deep Learning for Punjabi to English</td>
<td>Kamal Deep, Ajit Kumar, and Vishal Goyal</td>
</tr>
<tr>
<td>70</td>
<td>The Agile Deployment Using Machine Learning in Healthcare Service</td>
<td>Shanu Verma, Rashmi Popli, and Harish Kumar</td>
</tr>
<tr>
<td>71</td>
<td>Pneumonia Detection Using MPEG7 for Feature Extraction Technique on Chest X-Rays</td>
<td>Abhishek Sharma, Nitish Gangwar, Ashish Yadav, Harshit Saini, and Ankush Mittal</td>
</tr>
<tr>
<td>72</td>
<td>Comparative Study of GANs Available for Audio Classification</td>
<td>Suvitti and Neeru Jindal</td>
</tr>
<tr>
<td>73</td>
<td>Extractive Summarization of EHR Notes</td>
<td>Ajay Chaudhary, Merlin George, and Anu Mary Chacko</td>
</tr>
<tr>
<td>74</td>
<td>Feature Selection and Hyperparameter Tuning in Diabetes Mellitus Prediction</td>
<td>Rashmi Arora, Gursheen Kaur, and Pradeep Gulati</td>
</tr>
<tr>
<td>75</td>
<td>Contribution Title a Correlational Diagnosis Prediction Model for Detecting Concurrent Occurrence of Clinical Features of Chikungunya and Zika in Dengue Infected Patient</td>
<td>Rajeev Kapoor, Sachin Ahuja, and Virender Kadyan</td>
</tr>
<tr>
<td>76</td>
<td>Image Filtering Using Fuzzy Rules and DWT-SVM for Tumor Identification</td>
<td>Rahul Dubey and Anjali Pandey</td>
</tr>
<tr>
<td>77</td>
<td>Multi-Class Classification of Actors in Movie Trailers</td>
<td>Prashant Giridhar Shambharkar, Gaurang Mehrota, Kanishk Singh Thakur, Kaushal Thakare, Mohammad Nazmus Doja</td>
</tr>
<tr>
<td>78</td>
<td>Analysis of Machine Learning and Deep Learning Approaches for DDoS Attack Detection on Internet of Things Network</td>
<td>Aman Kashyap and Ankit Kumar Jain</td>
</tr>
<tr>
<td>79</td>
<td>Image Retrieval Systems: From Underlying Feature Extraction to High Level Intelligent Systems</td>
<td>Shefali Dhingra and Poonam Bansal</td>
</tr>
</tbody>
</table>
80  A Combined Model of ARIMA-GRU to Forecast Stock Price . . . . 987
    Sangeeta Saha, Neema Singh, Biju R. Mohan, and Nagaraj Naik

Author Index. .......................................................... 999
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Part I
Computing
Chapter 1
Real-Time Implementation of Enhanced Energy-Based Detection Technique

Vatsala Sharma and Sunil Joshi

1 Introduction

Next-generation networks have increased the demand of spectrum. Efficient spectrum utilization is needed to meet the user demand. Cognitive radio technology is used to opportunistically access the available spectrum band also known as spectrum holes. Sensing of spectrum is very crucial to exploit the spectrum bands that are not in use in any cognitive radio environment. Many detection techniques have been studied in literature so far. Commonly studied and analyzed detection methods include energy-based detection, feature-based detection, matched filter-based detection, Eigen value-based detection, etc. Energy-based detection is the most commonly researched technique by the researchers [1] due to its ease of implementation.

The basis of energy detection techniques comes from the work done by Urkowitz [2]. It is a non-coherent technique which can blindly detect unknown signals without any information about the characteristic features of signal transmitted by licensed primary user. It works on the principle of binary hypothesis testing given by [2],

\[
C(T) = A(T) + B(T) : Z_0
\]

\[
C(T) = B(T) : Z_1
\]

(1)

where \(C(T)\) denotes the signal at the receiver node from the secondary user, \(A(T)\) is the signal broadcast from the primary node and \(B(T)\) is the error signal. \(Z_0\) and \(Z_1\) symbolize the binary hypothesis results of the existence and non-existence of information signal, respectively. That is \(Z_0\) symbolizes that the channel band is in use by the primary node and thus channel is busy while \(Z_1\) symbolizes that the primary node information signal does not exist; therefore, channel is idle.

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Cooperation among cognitive (secondary) nodes enhanced the detection accuracy of energy-based detection [3]. The traditional method of energy-based detection technique with cooperation among secondary generally compares the measured energy of received signal with a predefined single threshold value. Further, researchers optimized the detection accuracy by using double threshold and triple threshold-based energy detection [4]. In double threshold detection, two threshold values are defined and compared with the test statistics and decision of existence and non-existence of primary user is taken accordingly [5] while three threshold values are considered in case triple threshold-based energy detection [6]. Researchers proved that increasing the threshold value results in improved detection accuracy also with low SNR regimes [7]. The proposed design based on energy measurements along with cooperation among secondary users is optimized using multiple threshold values. The proposed algorithm is implemented in real time using wireless access research platform. As per our best knowledge, the multiple threshold-based energy detection technique is not studied so far in literature till date.

The following sections in the remaining paper are abides by Sect. 2 that explains the system architecture of the aimed energy-based detection technique and the test statistics used to analyze its performance. In Sect. 3, the proposed design is implemented in real-time scenario using wireless access research platform. The methodology and the steps of implementation are explained in detail. The following Sect. 4 analyzes the performance based on detection accuracy of the proposed energy detection technique with the help of simulation results. The post-implementation simulation results are also explained. Last but not least, the conclusion of the paper is discussed.

2 System Architecture

The architecture of the system consists of single primary node, three cognitive users (secondary users) and a decision center as depicted in Fig. 1. Every secondary user exhibits energy-based detection evaluation for sensing the channel with different thresholds. The energy measured by secondary users (SUs) compares the measured value with the predefined threshold values \( \lambda \) and thus decides the existence of primary user (PU). The conclusion is forwarded to the fusion center where the final result is hard combined to analyze the occurrence of primary node signal transmission.

The hard fusion schemes include majority \((k\text{-by-}n)\) rule, OR-based rule and AND-based rule [8]. OR rule is used mostly in multiple decision fusion during fading environment. AND rule is mostly used in hardware implementations to avoid high data rates which cause data overhead. Above all, majority rule performs better than both AND and OR rule-based hard fusion schemes [9].

The energy-based detector works on the principle of non-coherent detection, that is, it can determine un deterministic signals. In this technique, the incoming signal energy of the broadcasted signal is observed and equated with the reference value of threshold. The received signal is converted to digital IQ format in case the signal
is analog followed by its FFT transformation as depicted in Fig. 2. The energy of the signal is measured using square law device followed by evaluating the average value of the same. The measured value is equated with predefined values $\lambda_i$ known as threshold. The test statistics defined for energy detection is given by [10].

$$T_i = \sum_{t=1}^{k} \left( \frac{|y_i(t)|}{\sigma_n} \right)^2,$$  

where $t$ is the indices of samples considered, $k$ notify the count of samples, $i$ notify the count of cognitive nodes (secondary users) and $\sigma_n$ defines the noise variance of the complex AWGN noise which is circularly symmetric. If the detected signal energy received at the cognitive node is larger than the reference value of signal threshold, it detects the spectrum band is utilized by the primary node, otherwise the signal is absent and the channel is vacant.
The architecture of the aimed design is analyzed that depends on multiple thresholds is done on the basis of detection parameters. Detection probability is denoted as \( P_d \) and defined as correct detection of primary user signal when primary user is transmitting, whereas false alarm probability denoted as \( P_f \) can be described as sensing the of presence of signal transmitted by primary user while the exact signal with information from primary node is not transmitting. Mathematically, the detection probability for \( i \)th secondary node should be expressed by Eqs. (3) and (4) expresses the false alarm probability for \( i \)th secondary user [11, 12].

\[
P_d = P\{T_i \geq \lambda_i | B_1\} = Q_u\left(\sqrt{2\gamma_i}, \sqrt{\lambda_i}\right)
\]

\[
P_f = P\{T_i \geq \lambda_i | B_0\} = \frac{\Gamma(u, \lambda_i/2)}{\Gamma(u)}
\]

where \( \lambda \) notify the reference value of threshold by which the result of test statistic is compared, \( \gamma \) is notified as the value of signal to noise ratio for signal present at the cognitive node, \( Q_u \) represents Marcum \( Q \)-function in its generalized form, \( \Gamma(.,.) \) and \( \Gamma(.) \) notifies gamma functions incomplete and complete, respectively.

3 Hardware Implementation

Real-time implementation of optimized energy detection technique is done using WARP v3 kit (wireless access research platform) invented by the researchers of Rice University. It operates on ISM bands. The hardware implementation is done using two WARP nodes with one radio acting as primary user and rest acting as secondary users. The primary node transmits the signal that is found by the cognitive (secondary) nodes. The transmitter block with its process description is given in Fig. 3, whereas the receiver block diagram which is just reverse of transmitter block is presented in Fig. 4. At the transmitter end, the signal is generated by a random source in IQ bit format. Then the signal is modulated followed by interpolation to increase the sampling frequency and up conversion. At the receiver end, the signal received is decimated to recover the actual sampling frequency of the signal followed by energy-based detector. The traditional energy-based detection method includes

![Fig. 3 Block diagram of WARP transmitter node](image_url)
the calculation of the energy of the recovered signal using fast Fourier transform and compared with the threshold to obtain decision bit at the fusion center.

The results from all the secondary user need to be combined to get the final decision. The proposed energy detection technique is based on hard combining decision fusion scheme [13]. Hard combining decision fusion scheme may be AND-based, OR-based or majority rule-based where the final decision depends on the majority of decision [14]. If more number of secondary user results in the decision denoting the involvement of the signal transmitted by primary node, then final result will depict the presence of the signal, and if the majority of secondary users depicts the non-existence of the signal transmitted from primary user, then decision fusion result will show that the primary user is absent [15]. Algorithm to implement energy-based detection with cooperation among secondary users using WARP V3 kit is as follows [16].

Step 1: Define the parameters and initialize to load the global definition to WARP node.
Step 2: Set up the radio parameters to enable WARP node to sense the received signal and trigger the same to start the reception.
Step 3: Read and store the received samples from the WARP node.
Step 4: Reset and disable the WARP node.
Step 5: Calculate the energy using test statistics for the signal received by the WARP node using FFT and plot the FFT of received waveform samples.
Step 6: Plot the IQ bits of the received waveform to notify the existence or non-existence of signal transmitted by primary node.
Step 7: Measure the received signal strength RSSI (dBm) of the received signal and plot as well.
Step 8: Close the socket.

4 Experimental Results

4.1 Results of Simulation of Proposed Algorithm

The analysis of the simulated curves (ROC curves) of the proposed multiple threshold energy detection is done with the help of simulated parameters denoting the detection accuracy with the help of false alarm probability and detection probability. The ROC
curves for probability with false alarm versus probability with detection as shown in Fig. 5 depict that the detection accuracy improves as the value of threshold increases. Since the final decision is the result of the combined decision of all the values at different threshold levels, the overall accuracy of the system is improved.

Detection accuracy of the proposed design is compared with the conventional energy detection based on single threshold value as shown in Fig. 6. The corresponding ROC curve shows that the detection accuracy of the energy detector based on single threshold value is 40% less than the detection accuracy of the enhanced energy detector based on multiple threshold values.

4.2 Results of Real-Time Implementation of Proposed Algorithm

Now, the proposed energy detector is implemented in real-time environment using wireless access research platform and the post-simulation results after the implementation are analyzed. The detection accuracy results of the implemented enhanced energy detector are almost similar compared to the simulation detection accuracy results measured before the hardware implementation as observed in Fig. 7.
Fig. 6 $P_d$ versus $P_f$ curve for cooperative sensing proposed and conventional energy detection schemes

Fig. 7 ROC curve for proposed energy detector before and after the hardware implementation
Finally, the individual region of convergence for detection and false alarm probability is also studied with the help of Fig. 8. It is shown that the detection accuracy of enhanced energy detector improves with increasing value of lambda in both the simulation and implementation results. The little variation is due to the unwanted noise and interference signals during hardware implementation. The simulation curves in the graph with threshold values $\lambda_1\text{ Sim}$, $\lambda_2\text{ Sim}$ and $\lambda_3\text{ Sim}$ represent the ROC curves between false alarm probability versus detection probability before hardware implementation and the ROC curves with threshold values $\lambda_1\text{ Imp}$, $\lambda_2\text{ Imp}$ and $\lambda_3\text{ Imp}$ represent the ROC curves after the hardware implementation.

5 Conclusion

The traditional single and dual threshold-based energy detection techniques have been improved to aim a multiple threshold energy-based detector (MTED). The performance analysis of the developed MTED is done with the help of ROC curve between detection and false alarm probability; also, it is equated with the traditional energy-based detection method. It is observed that the accuracy of detection of the proposed technique is 40% more than the conventional energy detector. The consequence of different threshold values on the accuracy of detection of the aimed detection technique is analyzed using the ROC curves. The slight variation in the