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ADVANCEMENTS IN COGNITIVE RADIO NETWORKS

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ABSTRACT In the powerful scene of remote correspondence, the previous ten years has seen a remarkable flood sought after for radio range driven by the quick expansion of new remote gadgets and applications. Nonetheless, the predominant fixed range task strategy has demonstrated to be a bottleneck, bringing about wasteful usage, especially with a significant piece of authorized range lying underutilized. Perceiving the squeezing need for a change in perspective, administrative bodies are returning to their strategies and effectively looking for creative correspondence innovations to address this range shortage. Enter Mental Radio Organizations (CRNs) - a groundbreaking arrangement intended to explore and improve range assets wisely. CRNs influence progressed procedures, for example, clever range detecting and dynamic allotment, enabling them to entrepreneurially access underutilized recurrence groups. This paper embraces a basic assessment of the difficulties imbued in conventional range the executives works on, highlighting the basic for more versatile and effective range use. By digging into the major standards of CRNs, including range detecting procedures and dynamic portion techniques, the exploration intends to give a nuanced comprehension of their capacities. Vital perspectives like impedance alleviation, range advancement, and in general organization execution improvement are complicatedly investigated. This thorough review not just catches late progressions in mental radio examination yet additionally fills in as a huge commitment to the continuous talk on the development of remote correspondence innovations. As the interest for range assets proceeds with its vertical direction, CRNs arise as a promising boondocks, offering creative arrangements and making way for a more range effective future in remote correspondence.

INDEX TERMS Cognitive Radio Networks (CRNs), Spectrum Scarcity, IoT Connectivity, Dynamic Spectrum Allocation, Interference Mitigation, Intelligent Spectrum Sensing, 5G Integration, Adaptive Spectrum Access, Future Wireless Technologies, Scalability, Security Concerns.

INTRODUCTION

The utilization of radio range assets and the guideline of radio outflows are composed by public administrative bodies like the Government Interchanges Commission (FCC). The FCC relegates range to authorized holders, otherwise called essential clients, on a drawn out reason for enormous geological districts. The wasteful utilization of the restricted range requires the advancement of dynamic range access methods, where clients who have no range licenses, otherwise called optional clients, are permitted to utilize the briefly unused authorized range. As of late, the FCC has been thinking about additional adaptable and complete purposes of the accessible range , using mental radio innovation. Mental radio is the key empowering innovation that empowers cutting edge correspondence organizations, otherwise called dynamic range access (DSA) organizations, to use the range all the more proficiently in a shrewd style without obstructing the essential clients.

Mental capacity in cognitive radio involves detecting and gathering data about transmission frequency, bandwidth, power, etc. Reconfigurability allows rapid adjustment based on this data for optimal performance. This paper advocates for Cognitive Radio Networks (CRNs) to overcome traditional spectrum management limits, emphasizing dynamic spectrum sensing and allocation for improved efficiency and reliability in wireless communication. The research aims to contribute to a spectrum-efficient future in wireless communication technologies.

RELATED WORK

Cognitive radio (CR) tackles wireless spectrum congestion for massive IoT connectivity. Reinforcement Learning (RL)-based spectrum-sensing approaches adapt to IoT dynamics. Proposed is a scalable, partially cooperative algorithm resilient to falsification attacks, optimizing rewards. It outperforms existing algorithms in accuracy and overhead, suitable for massive IoT. Recent communication technology developments congest unlicensed spectrum, affecting low-powered IoT wireless sensor networks.

Cognitive radio (CR) networks offer a low-cost solution to efficiently utilize underutilized licensed spectrum. This paper proposes a hidden Markov model-based primary user detection model for Cognitive Radio-based IoT, introducing algorithms for free channel detection and efficient allocation of detected channels. Simulation results demonstrate CR-IoT outperforming traditional networking schemes.

A novel spectrum sensing method for CR-IoT networks addresses Gaussian mixture noise. It employs a nonlinear Gaussian kernel function to map signals into a high-dimensional space, constructing a kernelized test statistic. Analytical expressions for false alarm and detection probability under Gaussian mixture noise are derived, with the decision threshold based on false alarm probability. Simulations show superior performance of the MIMO spectrum sensing method over existing detectors.

Proposing an energy-efficient Cognitive Radio Sensor Network (CRSN) for IoT, our k-hop clustering (k-SACB-WEC and k-SACB-EC) and neighbor discovery algorithm optimize energy use. Simulation results show k-SACB-WEC outperforms others, generating 40% fewer clusters and achieving 100% higher network stability compared to NSAC, PSEP, SAC-WCM, and CogLEACH.

In cognitive IoT MIMO systems, our scheme identifies transmit-antenna number amidst Gaussian noise and impulsive interference (SαS). It characterizes the generalized correlation matrix using higher-order moments of eigenvalues, and an advanced clustering algorithm enables transmit-antenna detection without prior signal information. Simulations confirm feasibility in the presence of both Gaussian noise and SαS interference.

A priority-based scheme for Cognitive Radio-enabled Internet of Things (CR-IoT) to address wireless channel access challenges aims to reduce blocking probability for higher-priority secondary user (SU) calls while maintaining channel utilization. The scheme evaluates licensed channel availability based on primary users' activities, utilizes a Markov chain model for estimating SU call arrival rates, and dynamically reserves channels. Comparative analysis shows the proposed scheme outperforms non-priority and fair proportion schemes.

A novel hybrid underlay-interweave mode scheme for cognitive radio networks (CRNs) to enhance spectrum utilization efficiency (SUE) for 5G-based IoT devices. Leveraging continuous time Markov chain modeling, the analysis explores SUE-related quality of service parameters, incorporating dynamic channel reservations, varying channel failure rates, and multi-level network traffic loads. The proposed multi-attribute based fairness algorithm ensures equitable resource utilization among secondary users (SUs), demonstrating significant improvements in SUE and fairness compared to existing approaches.

IoT faces spectrum scarcity; our solution, an asymmetric asynchronous channel hopping mechanism in cognitive radio networks, improves rendezvous efficiency. Simulations show superior performance over existing algorithms, enhancing rendezvous degree, time efficiency, and throughput.

Clustering is an effective method to manage communications in cognitive radio sensor networks (CRSNs). This letter proposes a network stability-aware clustering (NSAC) protocol for CRSNs. Spectrum dynamics and energy consumption are for the first time simultaneously integrated into the protocol design of NSAC. Extensive simulations show that the proposed NSAC protocol obviously outperforms existing methods in the aspects of network stability and energy consumption.

Addressing IoT spectrum challenges, the paper advocates for cognitive radio's opportunistic use of licensed spectrum in less crowded areas. Emphasizing dynamic spectrum access, it explores the synergy with IoT technologies, covering spectrum sensing, machine learning-based sensing, and open research topics. The paper serves as a guide for new researchers in Cognitive Radio Networks.

Mitola and Maguire introduced cognitive radio (CR) for flexible spectrum access, merging software-defined radio and artificial intelligence (AI). This chapter reviews AI techniques applied in CR over the last three years, detailing the cognition cycle, key CR tasks, and associated challenges. It categorizes AI methods based on learning types (supervised or unsupervised) and outlines their applications in various CR tasks. The focus is on presenting a state-of-the-art overview of AI's role in advancing cognitive radio technology.

Cognitive Radio Networks (CRN) as a solution to spectrum scarcity, allowing unlicensed users dynamic access to licensed spectrum. The study, implemented in Matlab, details CRN operations, including spectrum sensing, decision-making, and sharing. Results, graphically depicted, cover channel occupancy, spectrum hole detection, channe freeing, signal noise addition, and signal suppression.

Cognitive Radio Networks (CRN) used for enhanced spectrum efficiency, allowing secondary users access to unused licensed spectrum. Emphasizing spectrum sensing, it reviews conventional and modern techniques, including machine learning-based approaches for different signal types and discusses the need for additional research in 5G cognitive radio networks.

The use of Full-Duplex Cognitive Radio Networks (FD-CRNs) to address resource constraints in wireless systems. It highlights the advantage of FD-CRNs over Half-Duplex (HD) systems, allowing simultaneous range detection and transmission. The review covers system models, antenna structures, self-interference separation (SIS) techniques, range detection methods, security requirements, and Full-Duplex Medium Access Control (FD-MAC) conventions. The paper outlines challenges and future research directions for enhancing FD operations in CRNs.

Surveying spectrum sensing in cognitive radio networks, the paper analyzes conventional techniques, highlights limitations, and introduces compressive sensing for improved efficiency. The

Comprehensive methodology explores the last decade's research efforts, emphasizing sensing matrix, sparse representation, and recovery processes to enhance compressive sensing performance.

Intelligent cognitive radio dynamically allocates spectrum for unlicensed users, prioritizing interference-free access. The paper addresses security challenges, emphasizing authentication's role in secure spectrum utilization. It outlines existing research, challenges, and countermeasures for enhanced cognitive network security.

Addressing radio spectrum scarcity, the paper underscores Cognitive Radio Networks (CRNs) as intelligent solutions for efficient spectrum allocation. It explores methods in cognitive spectrum sensing, classifying and detailing their methodologies. The comprehensive literature survey highlights existing approaches, merits, and limitations, with a focus on tackling challenges in spectrum allocation.

Integrating Cognitive Radio Network (CRN) and Coordinated Multipoint Joint Transmission (CoMP JT) for 5G communication, the report designs a layered architecture to optimize unused spectrum usage and enhance cellular network performance. The study evaluates the impact of CoMP JT on CRN, specifically Analyzing SINR and TAT in different environments. The comparative analysis draws conclusions based on the results.

Mitola coined Cognitive Radio (CR) in 1998 to intelligently use unused spectrum. Recognizing its potential, the FCC endorsed CR's adaptability based on intelligent data. The paper highlights challenges, emphasizing Dynamic Spectrum Allocation (DSA), with a focus on Reinforcement Learning (RL) for effective spectrum management and improved performance.

The concept of Cognitive Radio (CR) was coined by Mitola in 1998, aiming to utilize unused spectrum holes intelligently. The Federal Communications Commission (FCC) recognized CR's potential to adapt based on intelligent data. The paper identifies challenges in CR frameworks and emphasizes Dynamic Spectrum Allocation (DSA) as a crucial tool. Researchers have explored various methodologies, including game theory and evolutionary algorithms, with a growing focus on Reinforcement Learning (RL) for Spectrum Allocation (SA). RL, known for its trial-and-error learning, is advantageous for effective monitoring, continuous learning, simulation of complex environments, and accessing valuable information, improving DSA performance.

BENCHMARK TABLE

TABLE 1: Table 1 shows the benchmark table. It has detailed comparison of our technique with other techniques. It shows year wise details of work donein Cognitive Radio Networks including the techniques applied and the limitation of each.

Sr.No.	Authors	Year	Techniques	Limitations
1	Sadia Khaf, Muhammad T.Alkhodary, Georges Kaddoum,	2021	spectrum-sensing algorithm, reinforcement learning,	information-sharing overhead, network attacks, sensing data falsification
2	Faizlullah Khan, Ateeq ur Rehman, Mian Ahmad Jan, Izaz Ur Rehman	2019	hidden Markov model	real-world implementation challenges, scalability issues
3	Zhang, Junlin and Liu, Lingjia and Liu, Mingqian and Yi, Yang and Yang, Qinghai and Gong, Fengkui	2020	nonlinear Gaussian kernel function, multiple-input-multiple-output (MIMO)	generalizability, diverse, dynamic IoT network scenarios.
4	Prajapat, Rajendra and Yadav, Ram Narayan and Misra, Rajiv	2021	neighbor discovery algorithm, k-hop clustering schemes	diverse IoT scenarios.
5	Zhang, Junlin and Liu, Mingqian and Zhang, Ning and Chen, Yunfei and Gong, Fengkui and Yang, Qinghai and Zhao, Nan	2022	generalized correlation matrix (GCM), higher-order moments (HOMs) of eigen values, clustering algorithm	Diverse practical scenarios, real-world complexities, Gaussian noise, SαS interference.

6	Ali, Amjad and Feng, Li and Bashir, Ali Kashif and El-Sappagh, Shaker and Ahmed, Syed Hassan and Iqbal, Muddesar and Raja, Gunasekaran,	2020	Markov chain model,	Markov chain model, validation, diverse IoT scenarios.
7	Khan, Abd Ullah and Abbas, Ghulam and Abbas, Ziaul Haq and Tanveer, Muhammad and Ullah, Sami and Naushad, Alamgir	2020	hybrid underlay-interweave mode scheme, CRNs, continuous-time Markov chain	heterogeneous 5G-based IoT scenarios.
8	Mohapatra, Sulagna and Sahoo, Prasan Kumar and Sheu, Jang-Ping	2019	asymmetric asynchronous channel hopping mechanism, global clock synchronization	assumptions, proposed mechanism, algorithms.
9	Zheng, Meng and Chen, Si and Liang, Wei and Song, Min	2019	Network Stability-Aware Clustering (NSAC) protocol	integrating spectrum dynamics, energy consumption.
10	Omer Al-dhlaimi, Muhammad Al-dhlaimi, Aymen Al-dhlaimi, Maiduc Osiceanu Alexandra	2023	Spectrum sensing, various types, machine learning-based approaches	challenges, integrating cognitive radio
11	Benmammar, Badr and Amraoui, Asma	2021	Maguire's expertise, AI techniques in CR	challenges in implementing AI techniques
12	Ernazar Reypnazarov , Halimjon Khujamatov , Debasis Das , Alisher Shakhobiddinov , Doston Khasanov, and Tazakhan Babazhanova	2023	Matlab-based model, , spectrum sensing, , spectrum hole detection	Challenges in spectrum sensing, noiseinterference, Matlab software dependency,
13	Muhammad Umair Muzaffar & Rula Sharqi	2023	Reviewing spectrum sensing techniques, machine learning approaches, , , spectrum sensing for 5G signals.	Challenge of feature selection in machine learning, reduced performance of legacy techniques at low signal-to-noise ratios
14	Vikas Srivastava, Parulpreet Singh , Praveen Srivastava	2023	FD-CRNs, FD-MAC conventions,	limited exhaustiveness in addressing diverse CRN applications.
15	P Ramakrishnan , P T Sivagurunathan , Dr.N Sathishkumar	2021	conventional spectrum sensing models, sensing matrix design, sparse representation,	Challenges in optimizing compressive sensing for high-dimensional resources
16	M Ramchandran , E N Ganesh	2020	EEISS, game theory	Sensitivity

			model	interference, battery energy levels, constraints
17	Pratibha , Sharmelee Thangjam , Naresh Kumar , Sanjiv Kumar	2021	cognitive radio network security, presentation of countermeasures, focus on attacks at different layers	Scope, may not comprehensively cover all security challenges,
18	Sivagurunathan , Ramakrishnan. , Dr.N.Sathishkumar	2021	Cognitive spectrum sensing contribution to improvement of existing spectrum sensing methods.	Potential missing of new developments post-publication
19	Disashi Valentin, Akhil Gupta, Manmohan sharma	2022	Layered architecture, integration of CRN and CoMP JT, SINR, TAT metrics	potential overlooking of broader performance aspects
20	Dr. Anusha Marouthu, Dr. V. Srikanth, S. Sandeep, M. Jeevan Babu, Dr. D.Haritha	2020	Dynamic spectrum allocation algorithms	constrained findings by chosen algorithms and applications, limited broader applicability

CONCLUSION

In conclusion, this comprehensive survey sheds light on the transformative potential of Cognitive Radio Networks (CRNs) as a groundbreaking solution to the escalating spectrum scarcity challenge in contemporary wireless communication systems. The paradigm shift from traditional allocation methods to adaptive and intelligent approaches is crucial, and CRNs play a pivotal role in enabling this transition. With the burgeoning number of wireless devices and the constraints of limited spectrum availability, cognitive radio technology emerges as a beacon, providing a means for more efficient spectrum utilization through adaptive frequency tuning and intelligent operation.

The survey delves into the essential elements of cognitive radio technology, covering characteristics, functions, network architecture, and applications. A particular emphasis is placed on the importance of spectrum sensing as a fundamental requirement for deploying cognitive radio. Different detection techniques and cooperative spectrum sensing protocols are scrutinized, offering a comprehensive overview of the state-of-the-art in cognitive radio research. Additionally, the survey explores dynamic spectrum management and sharing schemes, encompassing aspects like medium access control, spectrum handoff, power control, routing, and cooperation enforcement.

While the survey highlights the promising future of cognitive radio technology, it also underscores the challenges inherent in designing efficient spectrum management and sharing schemes. The call to action is for ongoing research and innovation to address these challenges and unlock the full potential of CRNs. Future research directions should include a focus on specific CRN applications, real-world performance assessments, integration with emerging technologies like 5G and IoT, and the resolution of scalability and security concerns. The foundational insights provided in this survey serve as a valuable starting point for researchers seeking to drive advancements in wireless communication technologies within the cognitive radio era.

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