Hindawi
International Journal of Distributed Sensor Networks
Volume 2023, Article ID 7225260, 16 pages
https://doi.org/10.1155/2023/7225260

Research Article

Cognitive Radio Spectrum Sensing-Based QAM Technique Using Blockchain

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Received 21 March 2023; Revised 23 September 2023; Accepted 5 October 2023; Published 21 October 2023

Academic Editor: Antonio Lazaro

Cognitive radio (CR) is a novel concept developed to solve concerns such as spectrum underutilization and scarcity. Spectrum detection methods are employed in the blockchain-based CR to make optimum use of the spectrum reserves. In this paper, an attempt is made to evaluate the effectiveness of an energy sensor using collaborative spectrum detection. Wideband is defined as the frequency range between 470 MHz and 790 MHz, and additive white Gaussian noise (AWGN) is employed. The probability of detection (P_d) under different situations is examined using detection in the receiver operational curve (ROC). According to the findings, the P_d increases with the number of samples. This form of sensing, which is thought to be the easiest and best, uses energy-detecting spectrum sensing. To address ambiguity, the M-ary QAM technique is provided, which increases aggregate effectiveness in terms of the percentage of false alarm (P_f) and probability of missed detection (P_m) by 5% at a comparable delay period. When CR encounters shadowing and impacts situations, the client cannot tell the difference between an underutilized zone and fading. In comparison to the existing model, this study increases the likelihood of detecting a 3 dBm SNR for a 64-QAM modulated signal by at least 15%.

1. Introduction

The spectrum has gotten more crowded because of the communication application's fast growth. Even if the spectrum is allotted to certain users, this does not mean that it is always being used most effectively. This is the rationale behind permitting unauthorized users to use authorized bands under the assumption that there will not be any interference. Mitola invented this paradigm, which is known as cognitive radio (CR) [1]. CR appears as an appealing resolution to the spectral saturation issue by allowing the spontaneous usage of frequency bands that are not frequently utilized by authorized clients [2]. The concept's essential feature is CR's capacity to quantify, detect, develop, and be mindful of factors relating to radio channel features, spectrum and power accessibility, user needs and applications, and other functional restrictions. According to the language of CR, primary users (PU) are those who have higher priority when using a specific portion of the spectrum. In contrast, secondary users (SU) or cognitive users (CU), who are given less priority, make use of this spectrum to avoid interfering with major users. As a result, SU needs CR skills such as the capacity to properly detect the spectrum to know whether PU is utilizing it and to alter radio settings to exploit the unutilized section of the frequency [3].

CRs are described as "a software-defined radio (SDR) that also observes its environment, tracks changes, and responds upon its findings" in Jondral's study [4]. More particularly, the users of CR technology will be able to use the following [5]:

(i) Spectrum sensing: detecting which sections of the spectrum are accessible and identifying permitted clients while functioning in an authorized zone

(ii) Spectrum management: choosing the preeminent conduit that is open

(iii) Spectrum allocation: governing additional customers' utilization of this band

(iv) Spectrum mobility: when an authorized client is located, leave the connection

(v) Cognitive spectrum sensing: clients having greater precedence or acquired privileges to utilize a certain piece of the spectrum are known as "PU" in CR. A crucial component of CR communications is spectrum sensing, which enables the CR to adapt to its surroundings by spotting unused bandwidth. Finding the PU who are receiving information inside the bounds of a CR is an especially effective method for determining whether a certain region of the spectrum is accessible. The most critical and challenging obstacle in spectrum sensing is the buried terminus problem, which occurs while the CR is shaded or when there is excessive multipath attenuation. Over the detection route, the CR is cast in the shadow of a towering structure. Because the PU cannot be identified in this case, the CR may utilize the network while the PU is still operational. To alleviate this difficulty, many CRs might be built to collaborate on spectrum sensing. Cooperative spectrum detection may be done in general, as discussed below.

   (a) Each CR individually does its own local spectrum sensing measurements before determining whether the PU is there

   (b) A common receiver is then forwarded in all the CR decisions

   (c) This combines all of the CR determinations and comes to a concluding conclusion about whether the PU is present or not

CR can continuously adjust to the surrounding spectral surroundings. Each CR may face a variety of spectrum conditions, such as distinct PU activities because the resultant tools in a CR network are geographically scattered. This CR network is shown under different circumstances. As can be observed, CR_1 is situated inside the transmission range of PU_1, but CR_2 is situated inside the spectrum of propagation of PU_2. Since both PUs have the potential to function independently throughout a broad frequency range spectrum, it is quite likely that some spectrum bands will not be continuously used by the major systems. As a result, CR_1 and CR_2, respectively, can detect the varied spectrum holes of the PU_1 and PU_2, as shown in Figure 1. For example, the frequency bands that are now open for CR_1 are s_0 and s_1, whereas those that are open for CR_2 are s_2 and s_3. Furthermore, the number of open channels and channel identities varies from CR to CR within the system. Regardless of whether one of the PUs reuses any of the routes, the CR system may then employ several spectrum opportunities to provide uninterrupted delivery [6].

Traditional wireless networks used point-to-point or point-to-multipoint arrangements. Collaborative connectivity and computing allow portable connection individuals or hubs to pool assets and collaborate by using decentralized transfer, in which every client's data is transmitted out not only by themselves but also by the cooperating peers [7] in contrast to traditional direct interactions. A new paradigm for communication that promises considerable benefits is cooperative communication and cooperative networking.

Clusters or consumers in a blockchain system might be desktops, mobile phones, or any other form of computational tool. A block is a grouping of occurrences. The linkages connecting the units create an assembly of units [8]. Extracting is the procedure of adding a block to the network. Miners are hubs that carry out processing activities. Each additional activity is disseminated to all locations in the system, and every single site produces its block by assembling new events and computing the evidence of effort for each issue. Miners are responsible for validating interactions, disseminating operations, and vying for the chance to build a block [9]. Miners that contribute to the construction of a fresh block are compensated.

In this manner, their contributions to managing the blockchain are recognized. Miners collaborate to create a consensus by verifying the block, publishing the newly constructed block, and validating operations [10, 11]. Out of all contending competitors who participate in block creation, the individual who accomplishes all sophisticated statistical estimations of a given complexity degree receives recognition for subsequent transaction development and inclusion in the blockchain [12]. Figure 2 illustrates the architecture of blockchain.

The following lists the benefits and drawbacks of utilizing blockchain: immutability (the inability to remove or replace data that has been recorded), transparency (users of the network can confirm information stored in the blockchain), censorship (no one party has complete control over), and traceability (the ease with which network changes can be tracked). The drawbacks are performance and speed (less rapid than a typical traditional database), high compared to a standard implementation coast, and data modification (prevents data from being easily changed once it has been recorded).

As a way of protecting spectrum allocation and enablement in the CR system, a blockchain validation framework is being created. For contending cognitive radios that require portable connectivity, the spectrum pooling approach is used as a medium accessibility technique. The digital ledger also serves as a decentralized repository that is available to anyone concerned, with any committed site amending the same.

Cooperative spectrum sensing (CSS) methods based on the IEEE802.22 standard have also been introduced. Two performance metrics, P_{d} and P_{f}, as well as a perceptual learning model, were used to investigate and evaluate cooperative spectrum sensing performance [13]. One method for detecting robustness is the use of the trustworthy factor [14]. The joint optimum model offers a way to reduce the

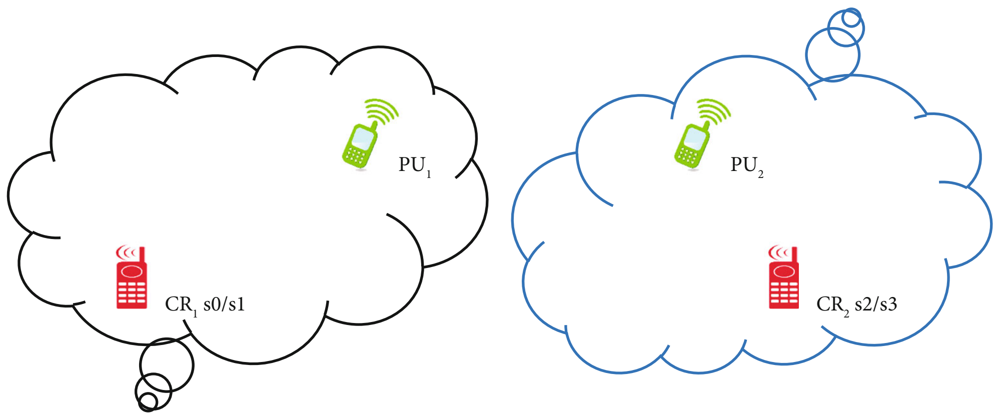

Figure 1: CR and PU are in operation independently.

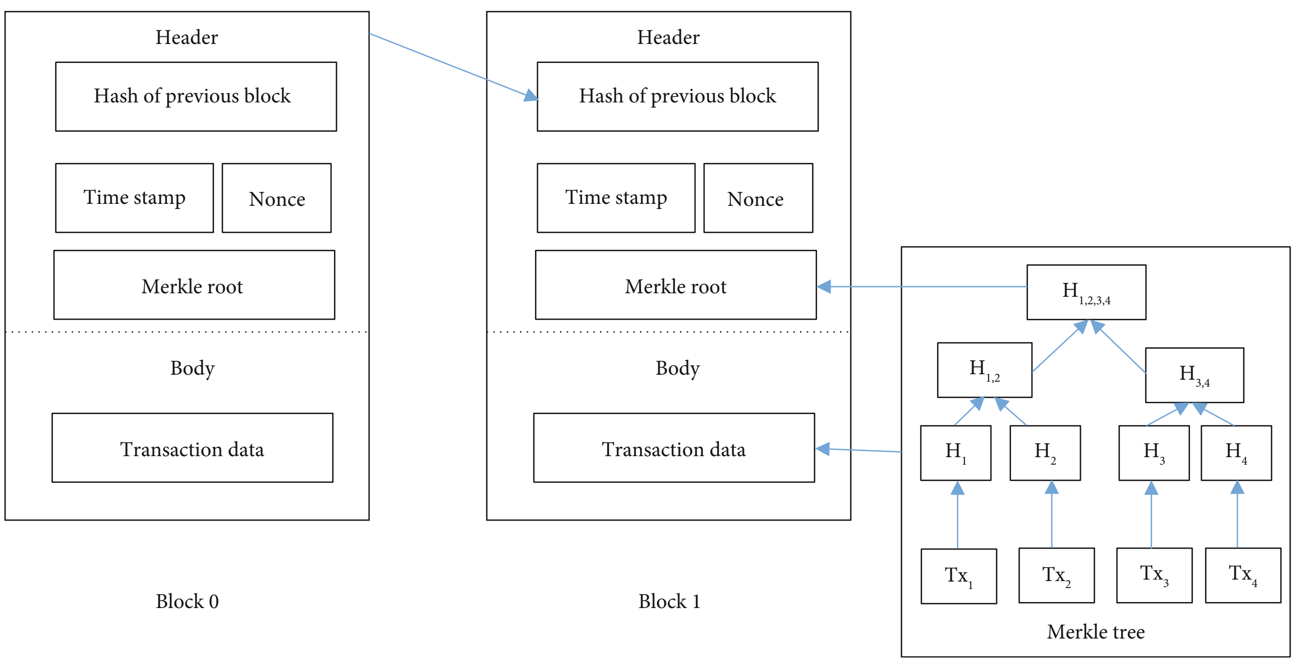

Figure 2: Basic architecture of blockchain.

overhead issue that arises during sensing. The polyblock method has been devised to increase system throughput [15, 16].

With the help of CR, which improves radio spectrum use, the interference issue can be solved. The CR has primarily introduced three significant tasks, with radio-scene analysis:

(i) The first task related to this availability of spectrum holes can be determined

(ii) The second role of CR is channel identification, which informs the transmitter section of the channel's capacity availability

(iii) The third task that the cognitive radio can carry out is the transmission of power control and spectrum management

Radiosensitivity can be increased, and PU can be found using methods based on digital signal processing. In the process of individual sensing, fading and shadowing are impediments to the detection of a PU. One way to reduce the likelihood of interference is to make a shared decision. One of the elements that can change the signal's phase and amplitude is fading. Rayleigh, Nakagami-n, Rice, and Log-normal are some of the different fading models that can be used to study SS systems. Energy detector spectrum sensing approach results have been improved for a variety of variations in SNR, one of the factors that play a key role in accurate sensing.

The cyclic characteristics and correlation methods utilized in the matched filter spectrum sensing technique are included in the cyclostationary spectrum sensing method. The more complex method is cyclostationary compared to others. The most preferable method is a matched filter compared to an energy detector (ED). The matching filter approach has the disadvantage of requiring comprehension of the PU signal information. Other methods are wavelet-based and eigenvalues. Compared to all the techniques, the ED is more comfortable since there is no need for a previous understanding of the information, and its complexity and computational cost are low.

The CR user gives the fusion centre (FC) the information of the PU; this method is cooperative sensing. The key requirement in the detecting technique is connectivity, which is classified as wideband or narrowband. The bandwidth of the zone is regarded as high in the wideband detection strategy, which implements both the sub-Nyquist and the Nyquist techniques.

The balance of the content is organized in the following manner: Section 2 explains the related work. Section 3 presents the scenario, and the methodology of the blockchain-enabled CR network and the ED of CR is in Section 4. The results are discussed in Section 5. The contributions and the possibilities of future research are discussed in Section 6. The abbreviations used in this article are listed in Table 1.

Table 1: List of abbreviation.

Acronyms	Description
Abs	Absolute function
AWGN	Additive white Gaussian noise
BPSK	Binary phase shift keying
cdf	Cumulative distribution “gamainv” function
CR	Cognitive radio
CU	Cognitive users
CSS	Cooperative spectrum sensing
ED	Energy detection
FC	Fusion centre
OFDM	Orthogonal frequency division multiplexing
P_d	Probability of detection
PDF	Probability density function
P_f	Probability of false alarm
P_m	Probability of miss detection
PU	Primary users
QAM	Quadrature amplitude modulation
QoS	Quality of service
ROC	Receiver operating characteristics
SDR	Software-defined radio
SNR	Signal to noise radio
SS	Spectrum sensing
Std	Standard deviation
SU	Secondary users

2. Related Work

The linked research has shown that the radio spectrum is not being used properly. A thorough discussion of the various spectrum sensing techniques has been given here. A sensing method can be chosen based on the type of application. The greatest technique for finding spectrum gaps and making greater use of unused frequency regions in the spectrum is called CR.

The four fundamental CR functions are sensing, management, mobility, and sharing. The sensing method must be chosen based on the frequency range and sharing, and mobility processes will be carried out following their usage. Additionally, management procedures will be taken into account for optimum spectrum utilization [17, 18]. Among the 4 fundamental activities of CR, greater attention is given to the detecting procedure, which includes the discovery of underutilized zones and their eventual use by additional clients. Many spectrum identification techniques have been developed depending on the transmitter mechanism, such as the energy sensor or blind identification technique [19, 20].

The frequency range is smaller, meaning it follows a narrowband sensing method. During this time, the bandwidth is less than the coherence one [21, 22]. The spectrum detection notion may be examined based on parameters like frequency, time, and geographical location [23]. Based on the band of accessibility, the methods used for sensing are underlay, interweave, and overlay in the CR [24]. Raghu and Elias explained the utilization of P_d, P_f, and ED sensing, which can be succinctly summarized. Based on the threshold, the performance of various SS techniques can be measured by the receiver operating characteristics. One of the key parameters to minimize the sensing time and reduce the complexity of the hardware is the filter value and bandwidth [25].

Kumar and NandhaKumar discovered that introducing filters at the receiver-transmitter location improves OFDM spectrum utilization [26]. Zeng and Liang suggested the noise control strategies: typical eigenvalue to the lowest eigenvalue proportion and highest eigenvalue to the lowest eigenvalue proportion [27]. Dempster-Shafer concept was proposed to assess the level of dependability via a collaborative spectrum detection approach. By utilizing several power spectral density approaches, it is possible to improve signal rate detection at various frequencies [28].

Numerous researchers have investigated the identification of malicious users in CR networks through a range of traditional and machine learning techniques. Following the identification of PU during the spectrum sensing phase, centrally handling spectrum data becomes challenging due to the massive device connectivity of 5G and 6G systems, which also generate more scattered and voluminous data. The massive amount of spectrum sensing data generated in the CR network presents serious challenges for controlling, including attacks by SU or CU and FC design with single-factor failure. Concerns about reliability, security, privacy, and attack vulnerability are just a few of the problems the centralized FC faces. A novel technology that presents fresh avenues for study to address this problem is the blockchain-enabled CR network.

In order to improve spectrum sensing precision, the suggested work provides a secure CSS technique based on a blockchain-enabled CR network and ED while fending off fading and shadowing attacks. With the current one, there is no storage for the sensor data. Consequently, the CUs misuse the sensing data. Under this architecture, the CUs can access the data and exploit the unused spectrum details whenever they need to because they are stored in the blockchain.

The following are the primary contributions made in this paper:

(i) Establishing a CR network with blockchain capabilities

(ii) Noise detection and the double-threshold spectrum ED approach are proposed

3. Scenario

To find out the state of the spectrum bands, each CR user performs spectrum sensing and sends the information to the blockchain network. Sadly, the spectrum sensing data obtained from CU provides the original state of the PU spectrum band. These CUs are demining a CR network's efficacy. After receiving information from spectrum sensing, blockchain was used to store information on idle spectrum bands, spectrum access history, spectrum mining and bidding, and spectrum auction results. Blockchain provides a reliable and safe environment that ensures the accuracy and consistency of data stored, allowing for the collaborative management of resources among different subjects.

As with the suggested approach, begin by creating blocks of PUs and CUs. Next, use an energy-detecting method to determine the spectrum. Thirdly, the participating nodes are verified using a blockchain. At last, CU is recognized as a reliable user. These actions are explained in Figure 3.

(i) Block creation: at the outset, PUs and CUs are converted into blockchain blocks. For this, a distributed ledger of nodes containing details about PU and SU credentials is created. There will be a private key and a public key. Details on shared data relating to different units in CR networks, such as whether a unit is CU or PU, are included in public key information. On the other hand, node-specific data like its location and authentication code are stored in private keys

(ii) ED: in spectrum sensing, this is where the energy detection method is mostly used. We suppose that there is a bandwidth of W Hz and that the sampling rate of the receiving signal is t. We propose two theories: while hypothesis 1 indicates that the signal is both detected and a combination of noise and the signal delivered by the PU, hypothesis 0 reveals that the signal is detected and is only noise

(iii) CU detection: the recommended method, which uses digital signatures to verify participating nodes based on their public and private keys, finds reliable users and CUs after all the steps for spectrum detection among nodes have been completed. Two different types of mistakes can cause errors in the identification of legitimate users and SU: shadowing and fading

By utilizing blockchain technology, the proposed double-threshold spectrum energy detection approach improves CSS network security and spectrum management. When the units of the CR network program are constructed, identify the energy. Clients who are allowed and those who are hostile are segregated once the nodes have completed the required process of identification. The suggested method enables client verification by using digital signatures to authenticate CSS units while taking into consideration both combined confidential and accessible identities. False alarms and missed detections were the two kinds of problems that occurred during the identification of a CU and PU. Network performance is enhanced by the suggested morphology, spectrum regulation, and CSS.

3.1. Cognitive Radio (CR).

CR concept strives for optimal spectrum effectiveness and usage by using enhanced variable spectrum accessibility methods. The approach to achieving optimal spectrum effectiveness is to give the capacity to distribute the wireless connection with authorized consumers in the best approach achievable, which may be accomplished via adaptive and successful spectrum administration approaches [29]. The intriguing aspect of CR innovation is that phones will naturally utilize overlooked airwaves. CR confers intelligence by allowing users to make use of accessible capabilities from nearby mobile computing systems and connect with networks of chosen conventions avoiding ambiguity in determining the proper wireless connection for voice, footage, or information transfer.

To optimize bandwidth utilization, next-generation systems need intelligent equipment such as CR to be capable of producing models based on their location, systems, clients, and larger surroundings. Cognitive capacity is described as technology that allows a device to receive or perceive data from its aural environment and adjust to changing conditions and past judgments. The CR's reconfigurability enables it to be proactively self-programmed in response to the radios surroundings, and its adaptable capability to travel across shifting radio situations distinguishes it as the best adaptable radio yet [5].

Spectrum detecting, administration, collaborating, and movement influence the actual level and air interaction of CR. The first phase in spectrum sensing is to observe the functioning atmosphere and identify white spaces, also known as spectrum holes, as illustrated in Figure 4.

Persistent surveillance is required in CR spectrum detection since one-time monitoring is insufficient to provide the QoS. Duration, precision, and sensing area are a few features that should be retained low/high to ensure outstanding QoS. The most common problems with spectrum detection are erroneous alerts, which occur when a main person is identified when there is no prime client present, and missing identification, which occurs when white space becomes visible even when an initial client exists, as shown in Figures 5(a) and 5(b).

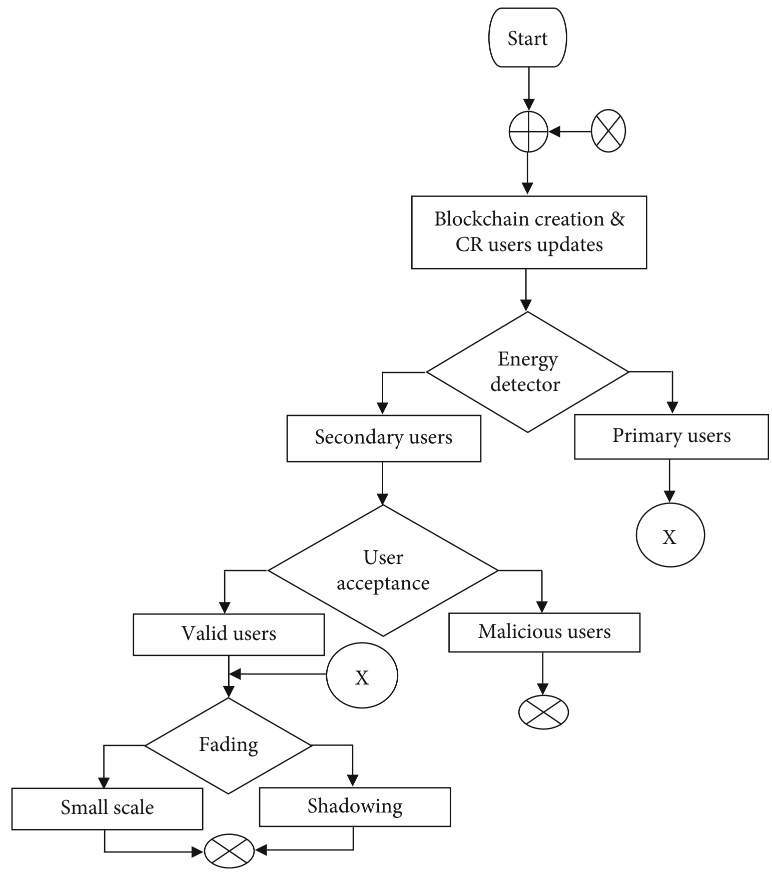

Figure 3: Flow diagram of proposed work.

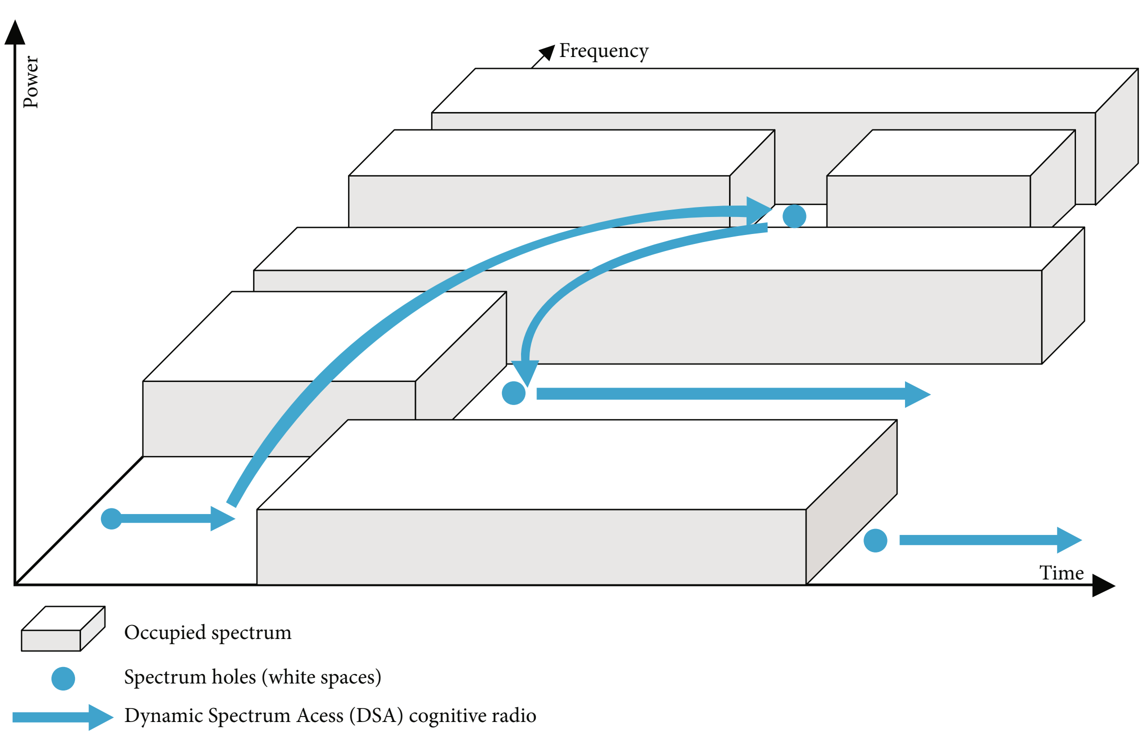

Figure 4: CR spectrum holes.

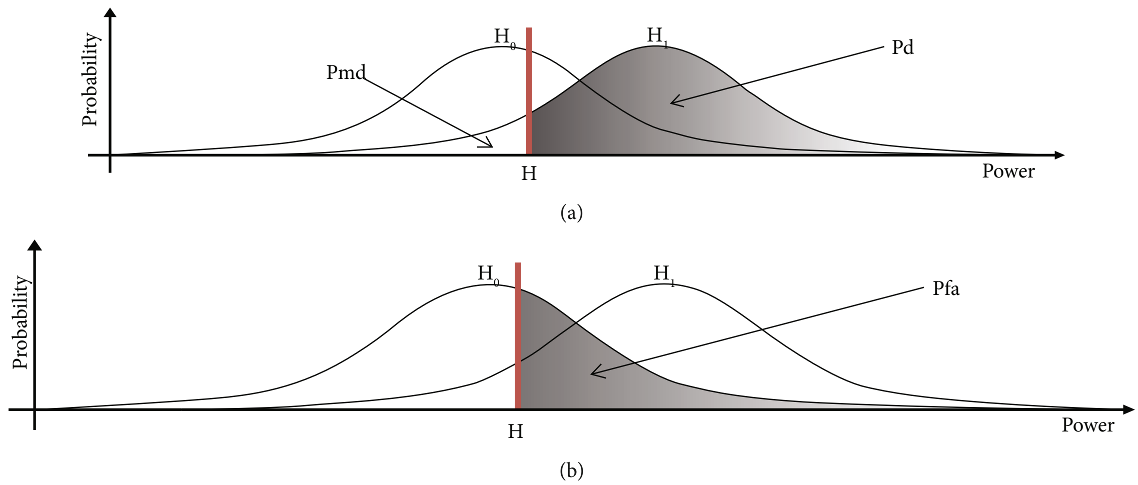

Figure 5: Decision-making of P_d and P_{fa}.

Orienting, planning, and choosing are aspects of spectrum administration that align it to decide the optimal frequency based on prior findings in the spectrum detecting procedure. A new strategy for choosing the most appropriate preference is devised, and eventually, a conclusion is reached.

The real activity for the utilization of the permitted accessible medium to the CU for the necessary duration or unless the PU necessitates that spectrum to maintain QoS is readily essentially depicted by considering the visual representation of this entire process in Figure 4.

Spectrum movement is defined as the rapid and immediate exit of the momentarily accessible band by the CU if any PU attempts to utilize the authorized spectrum and switch over to the previously detected spectrum void. It is considered a particularly essential and vulnerable phase of the entire procedure since lag increases and transfer duration rises, resulting in packet failures or connection errors if applied in cellular systems. CR systems include the property of adapting from all processes, as it remembers from perceptions and choices taken and adjusts to the simulating conditions and choices.

All of these aspects will be challenging to achieve since multiple PUs will use various encryption approaches, information speeds, and transfer abilities in the face of variable dispersion circumstances. Furthermore, distortion from other SU and noise unpredictability cause identifying issues. An important challenge is the concealed terminal issue, which happens when the CR is shaded, suffers from extreme multipath diminishing, or is located within a structure with significant thrust damage. Collaborative connectivity is a potent and growing approach for overcoming the previously mentioned wireless communication drawbacks [30, 31].

Sensing is carried out by several distinct radios inside a CR system in a collaborative CR spectrum sensing system. The central station is activated, and it will receive signal reports from various radios in the network and alter the entire CR network appropriately. The collaboration strategy eliminates entanglement challenges when an individual CR fails to perceive a PU due to difficulties such as PU shadowing; however, the PU serving as a recipient may be capable to perceive the signals from the PU and the CR network.

3.2. Shadowing. The basic principle of collaborative communication is that, in portable surroundings, other devices, which are often alluded to as relays, also collect the information delivered by a particular transmitter from a particular originator to one or more terminals. Their main function is to send back the acquired information.

The centralized network uses the concept of recurrent readings of identical information across various endpoints and communication networks to mix these impulses coming from the point of origin and the collaborators and generate regional diversity. Additionally, distributed spatial processing technology can significantly reduce terminal interference by enabling numerous CR to work together during spectrum sensing.

In general, distributive choice making in wireless detector systems, in which each detector performs its preference and delivers its results to an FC to offer a final choice in line with some fusion regulation, is equivalent to collaborative spectrum detection in CR systems [32]. CR and the fusion centre are dispersed across a greater geographic area than wireless sensor networks. Because reporting channels from the CR to the FC and the PU's detecting pathways to the CR are typically shadowed, this discrepancy poses significantly greater difficulty for cooperative spectrum sensing.

Especially contrasted with wireless sensing systems, CR and FC cover greater topographical regions. Since detection circuits from the PU to the CR and relaying routes from the CR to the FC are typically susceptible to observation, this disparity creates substantially greater issues for coordinated spectral detection. Figure 6 displays a scenario where only one CU, the right side CU, may be able to detect the essential message, rendering the remaining individuals unwilling to tell the difference between a white area and an obscured impact. Collaboration in these circumstances could greatly improve secondary spectrum access.

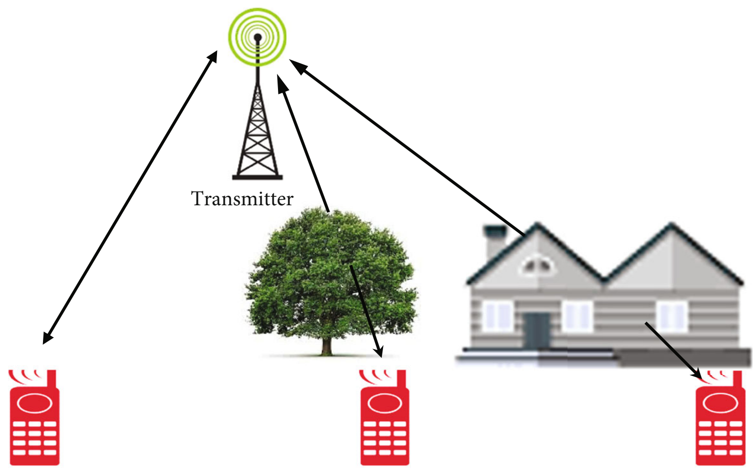

Figure 6: Shadowed effect.

4. Methodology

4.1. Creation of Blockchain with CRN. There are three ways to link the blockchain system to the CR system, each with a unique set of advantages and disadvantages.

Straight from the blockchain system to the CR system: SU and PU should be allowed to participate in blockchain processing alongside other operations. Consequently, every feature of the blockchain, including decentralized transactional confirmation, is available to all clients. Nevertheless, a control channel that users may utilize to communicate transactions and blocks is required for such a setup.

Blockchain system with CR network: a blockchain system devoted to preserving significant information. The CR network clients restricted computing abilities making it challenging for them to gain access to spectrum zones while simultaneously updating the ledger. Mining, for example, is unattainable for SU with a small battery size, as it requires significant utilization of energy. Enabling individuals to delegate the responsibility of recording events to a subsequent blockchain system is one solution to this problem.

Sensor network: to achieve diversity gain, cooperative spectrum sensing can be carried out via a network of sensors. The third systems stated above may thrive and communicate utilizing an identical customized blockchain concept. In the past, the CR network and a third network, such as the sensor network, have had direct communication. The proposed blockchain creation method is shown in Algorithm 1 as a flowing pseudocode.

4.2. Energy Detection. A MATLAB-based framework for uncooperative and collaborative detecting systems is explored utilizing ED as a spectral detecting approach. To detect vacant frequency zones via PU, SU should perceive and analyse the radio frequency surroundings within their operational region. The noncoherent detection method used by the ED reduces system complexity and costs by not requiring prior knowledge of transmitted data, but on the other side, the issue of noise uncertainty becomes a serious issue.

Utilizing a broad framework for channel perception and an ED technique P_f, this part analyses the link among P_d, P_m, and P_f. The following section goes over the hypothetical testing of this. Spectrum sensing is to ascertain whether its primary owner is currently using a licensed band and, if not, to use those bands as efficiently as possible until the PU can access them. The ED architecture is shown in Figure 7.

To normalize the noise, "$a(t)$" is initially prefiltered using a BPF with "f_c" and "0." The result is then scaled and incorporated over time (T), yielding an estimate of the energy of the acquired oscillation. Finally, to determine if a signal is there or not, "$Z'(t)$" is compared to the predetermined threshold "λ"

$$z(t) = a(\mathrm{t}) + b(t), \tag{1}$$

$$z(i) = a(i) + b(i), \tag{2}$$

where $a(i)$ and $b(i)$ represent their respective digital formats, with $a(t)$ being the received radio signal by the system and $b(t)$ being the AWGN, which degrades the signal $a(t)$, which has a zero mean and variance σ^2. The $Z'(t)$ threshold is determined based on the output's statistical characteristics.

The test statistic $Z'(t)$ is contrasted to the preset barrier utilizing the MATLAB gamma inverse continuous dispersion "gamainv" module (cdf) utilizing Digham's [20] technique.

$$\lambda(j) = \mathrm{gamainv}(1 - P_f(j), x, \mathrm{a}) * 2. \tag{3}$$

With N sample indications, slop variables, $x = 1/2\,N$, and a normalization variable set to one, this function calculates the inverse of the gamma cdf with a corresponding probability set to $1 - P_f$ and numbers within the range [0, 1]. The

1. Input: A group of N primary nodes.
2. The blockchain consists of one primary node, P, and one secondary user node, N-1, from S_1 to S_{k-1}.
3. Output: Blocks are formed on various nodes of the cognitive network.
4. for i = 1 to N
5. If a PU is discovered
6. Assign it as the primary node. Find the signal strength; control is transferred to step 13.
7. else if
8. If a SU is discovered
9. Assign it as a secondary node. Find the signal strength; control is transferred to step 13.
10. else
11. Assign it as a malicious node, and control is transferred to step 2.
12. end if, end if.
13. If SNR is high,
14. The shadowing effect is calculated.
15. Otherwise, the fading effect is calculated.
17. end if, end for, plotting

Algorithm 1: Creation of blockchain for CR users.

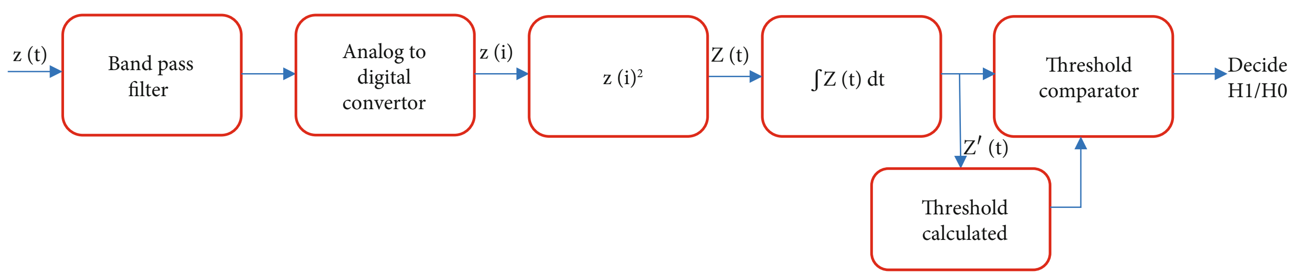

Figure 7: Architecture of an energy detector.

gamainv function and gamma cdf are mathematically related as follows:

$$a = F^{-1}(p|x, y) = \{a : F(a|x, y) = p\}, \quad (4)$$

where p is

$$p = F(a|x, y) = \frac{1}{y^x \wedge(x)} x t^{x-1} e^{-t/y} dt. \quad (5)$$

In addition, gamma cdf is formulated as

$$[A, \mathrm{ALO}, \mathrm{AUP}] = \mathrm{gamacdf}(P, X, Y, x\ \mathrm{cov}, \mathrm{alpha}). \quad (6)$$

Although “ALO” and “AUP” hold their respective probability bottom and top limits, “A” is specified as an outcome parameter. In general, the formula computes credibility restrictions for “P” using “X” and “Y” as input estimations, “x cov” containing the covariance matrix of the input of order 6*6, and “alpha” set to 0.05, signifying 100 (1 – alpha)% competence limits. The energy of the digitized incoming data is measured by analytical communication:

$$e(n) = \frac{\sum \{\mathrm{abs}\{z(i)^2\}\}}{\mathrm{Std}[b(t)2]}, \quad (7)$$

where “***abs***” “stands for the absolute function $\sqrt{\{(\mathrm{real})^2 + (\mathrm{imaginary})^2\}}$, “$\sum$” stands for the total value felt by each node and stored as a row in the matrix, and “***Std***” stands for the standard deviation, in this case, the AWGN channel’s standard deviation. The following comparison between this computed energy, “$e(n)$,” and the thresholds, “λ,” “P_d,” and “P_f,” is measured:

$$P_d = \frac{Q_N/2\left(\sqrt{(\alpha\,(\mathrm{SNR}))/\sigma 2}\,\sqrt{(\lambda/\sigma 2)}\,x\right)}{\wedge N/2}, \quad (8)$$

where “$QN/2$” is the generalized Marcum Q function of the positive integer “x” and the nonnegative real numbers “$\sqrt{(\alpha\,(\mathrm{SNR}))/\sigma 2}$” and “$\sqrt{\lambda/\sigma 2}$”:

$$Q = \mathrm{marcumq}(m, n, o) = \frac{1}{\mathrm{mo}-1}\int_{\mathrm{n}}^{\infty} a^{o} \exp\left(-\frac{a^2 + x^2}{2}\right) I_{o-1}(ma)dx, \quad (9)$$

where I_{o-1} expresses the modified Bessel function of the first kind of order 0-1.

$$P_f = \frac{\wedge(N/2, \lambda/2\sigma 2)}{\wedge N/2}, \quad (10)$$

where σ is the standard deviation, $\sigma2$ is the variance, and $\bigwedge$stand for incomplete gamma function.

Two hypotheses, H_0 and H_1, are put out to test the specified system model for CR ED. Choosing between H_0 and H_1 based on the signal received is the aim of spectrum sensing. The received signal can be described by equations (11) and (12) when the PU is not functioning.

$$y(m) = v(m)\, H_0 \text{ : PU is absent,} \tag{11}$$

$$y(m) = v(m) + k(m)i(m)\, H_1 \text{ : PU is present,} \tag{12}$$

where $y(m)$ is the obtained sign and $y(m)$ is the AWGN connected to it. The signal is sent via channel I at time $k(m)\, i(m)$. Figures 4(a) and 4(b) show the probability density function- (PDF-) based graphic depiction for each of these hypotheses.

In general, two possibilities should be taken into account while assessing a sensing performance. The sensing algorithm's probability of detecting the main signal's existence at hypothesis H_1 is known as the detecting likelihood. Additionally, the P_f identifies when an active PU is determined to be present when it is not. This can happen when there is a lot of noise, which causes the SNR to degrade quickly. Figure 4(a) defines P_d as the PDF greater than the threshold value, while the P_m is the PDF smaller than the estimated threshold. P_m is modelled mathematically as

$$P_\text{m} = 1 - P_\text{d}, \tag{13}$$

where P_m and P_d are mathematically defined in (8). As shown in Figure 4(b), P_f, a numerical expression of the H_0 hypothesis, is used to determine PDF that exceeds the threshold (10).

The proposed ED method, which employs the M-ary QAM method for enhanced noise uncertainty recognition beneath piercing AWGN channels, is shown in Algorithm 2 as a flowing pseudocode. In the result and simulation stage, numerical analysis is done to produce better outcomes.

The PU identification during the sensing process depends on the energy content present in a given band. The important component in determining the threshold value is noise. Noise is incorporated in the processed stream in the receiver section. Noise in SU may be used to identify PU's location. Although the existence of transmissions paired with noise indicates the existence of a PU, the existence of solely noise-oriented information indicates the presence of a vacant zone with no customers [33].

To identify the PU, a binary hypothesis called Neyman-Pearson is utilized. The two types of parameters that make up the Neyman-Pearson are P_d, which represents the PU's actual presence over the given samples, and P_f, which reflects the PU's false existence over the sample. In (1), the P_d is calculated. This research makes use of AWGN, which exhibits a broad frequency spectrum throughout the band.

$$\begin{aligned} P_\text{d} &= \boldsymbol{G_n} \frac{\lambda - \boldsymbol{N}(S_{\sigma^2} + N_{\sigma^2})}{\sqrt{2\text{N}}(S_{\sigma^2} + N_{\sigma^2})}, \\ \lambda &= N_{\sigma^2}\left(G_n^{-1}(P_f)\left(\sqrt{2N} + N\right)\right), \end{aligned} \tag{14}$$

where$G_n$is the Gaussian distribution and$N$is the number of samples (2), that represents the threshold value, which may be computed by$N_\sigma$and$S_\sigma$that stand for noise and signal power, respectively. Here, P_f stands for the false alarm probability, and G_n^{-1} is the inverse Gaussian distribution. During the simulations, the P_f value is held constant at 0.01 to 1. Consideration of the type of modulation is crucial; in this study, 64-QAM (quadrature amplitude modulation) outperforms 32-QAM in terms of improved detection due to its high data rate property. It indicates the presence of an open band.

If the value of P_f in a certain band is not deemed adequate, then accurate PU detection cannot be accomplished. For better PU detection, a fixed value of P_f is therefore taken into consideration [34, 35]. Figure 8 shows the block diagram of the system model of PU using 64-QAM and 32-QAM, respectively. Figure 9 shows that the pulse is adapted by utilizing 32-QAM and 64-QAM, respectively.

Additionally, at SNR levels of 3 dB, -5 dB, and -10 dB, 32-QAM and 64-QAM approaches were employed. QAM has 2 elements, quadrature and stage, which are different in terms of pitch and magnitude [36]. As shown in Figure 9, 64-QAM communicates an array of 6 bits of in-phase and quadrature period, while 32-QAM communicates a group of 5 pieces of in-phase and quadrature mode. Collaborative spectral detection with a twofold variable sensitivity is utilized to assess efficiency [37].

5. Results and Discussion

This section covers the study of simulation results for the creation of blockchain, fading, and shadowing. MATLAB R2021b is used to get simulated results. With P_f on the x-axis and P_m and P_d on the y-axis, ROC arcs illustrate the relationship among P_f, P_d, and P_m when utilized for energy exposure for identifying PU in CR surroundings.

While energy detectors have previously been thoroughly explored [8, 15] with PSK pulse, here, ED is carried out utilizing QAM, increasing the system efficiency. The majority of the models that have been proposed lack a more comprehensive model that incorporates crucial propagation properties as well as other parameters like the number of SU, P_d, and P_f.

Figure 10 shows the cooperative and noncooperative shadowing scenarios. The results of the cooperative and noncooperative shadowing simulations are displayed in four graphs by contrasting the cutoff level in conjunction with the localized SNR factor, which is established at 5 dB. The average normalized SNR, or $\sigma_\text{s}/\sigma_\text{n}$, is described as 5 dB SNR, where σ_s is the mean signal and σ_n is the mean noise.

1. Initialize sampling m = 6, N = 2 * m
2. Avg_SNR ≥5 dB
3. for i = 1 to P_f
4. for MC 2000 (Monte Carlo Iteration Modified)
5. M=64,QAM signal
6. AWGN Random Noise
7. Received signal energy compared with λ
8. if Energy of the received signal ≥ λ(i)
9. Present; Primary user
10. Else
11. Absent; Primary user
12. End if; End for
13. Pd = Marcum q function
14. For all energy of the received signal ≥ λ(i)
15. ++ Primary user
16. End for; Plotting

Algorithm 2: Modified energy detection with M-ary QAM system.

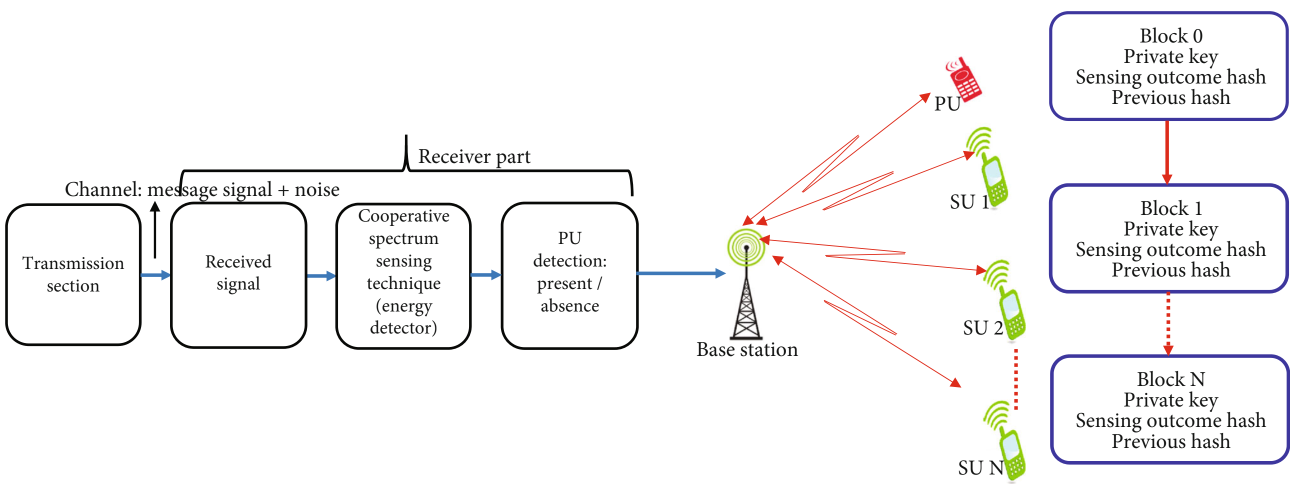

Figure 8: Block diagram of the system model.

The Marcum Q function is used to calculate theoretical values, and the following mathematical expression is used to approximate them:

$$\frac{1}{2}\,\mathrm{erfc}\left[\frac{\left\{\sqrt{2} * \mathrm{erfcinv}\left(2 * P_{\mathrm{f}}(i)\right) - \mathrm{AVG}_{\mathrm{SNR}} * \sqrt{m}\right\}}{\sqrt{2 + 4\left(\mathrm{AVG}_{\mathrm{SNR}}\right)}}\right]. \tag{15}$$

Replicated numbers are calculated by applying the "gamainv" utility, as previously described in Eq. (5). At larger P_{f}, QAM techniques have smoother, nonfluctuating values. At $P_{\mathrm{f}} > 0.1$, QAM exhibits a uniform and lowered P_{d} of 0.02 and becomes constant at $P_{\mathrm{f}} = 0.6$. So it is possible to say that this method of applying the QAM signal reduces the P_{f} and P_{d} by 5%, which enhances the P_{d} by the same proportion.

Simulations are carried out using Monte Carlo random variations, which causes them to fluctuate randomly following the interference condition. The average simulated results indicate that employing the QAM signal over the PSK signal results in reduced P_{f} and P_{d}. Therefore, employing QAM instead of PSK enhances systemic efficiency overall, as it is observed that utilizing QAM, little P_{f} and P_{d} are attained, increasing P_{d} by 5%. Now that the QAM signal has been selected, which is preferable to PSK, different SNR values are tested at SNR 0, 5 dBm.

The signal with the worst signal quality is the SNR, with the best signals being between 0 and 5 dB; the normalized signal strength is 5 dBm. P_{d} and P_{f} measurements range from 0.0001 to 1. According to simulation, the system performs better when the signal is stronger or there is less noise. According to Figure 10, P_{d} and P_{f} are in the range of 0.9 (about 1) at SNR 0 dBm, and 0.5 at 5 dBm, respectively. The experimental outcome for P_{d} at SNR = 5 dBm has dropped from 0.9 at SNR = 0 dBm to 0.01 at SNR = 5 dBm,

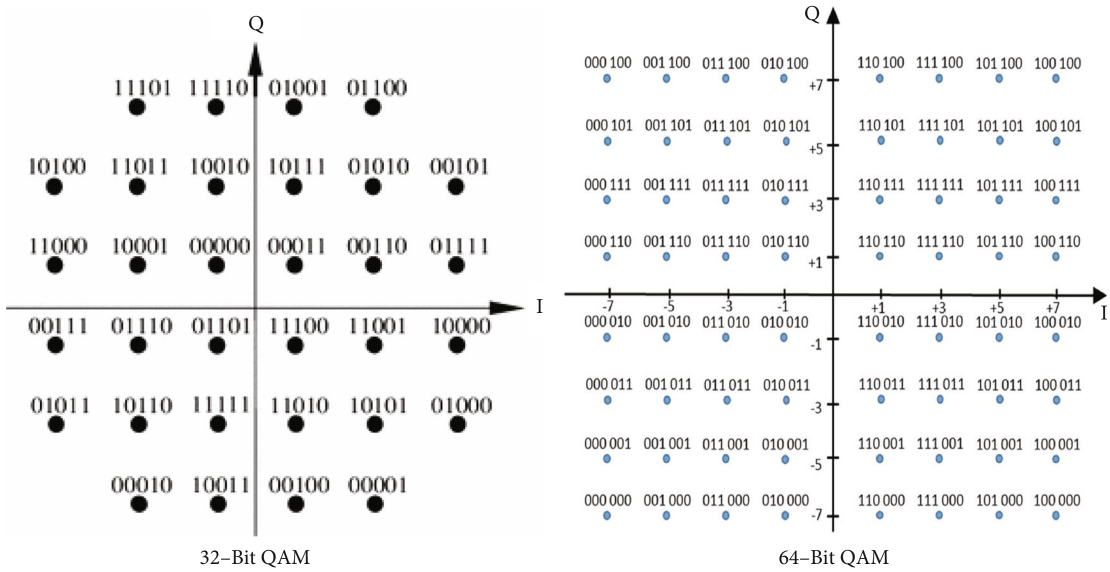

Figure 9: 32- and 64-QAM.

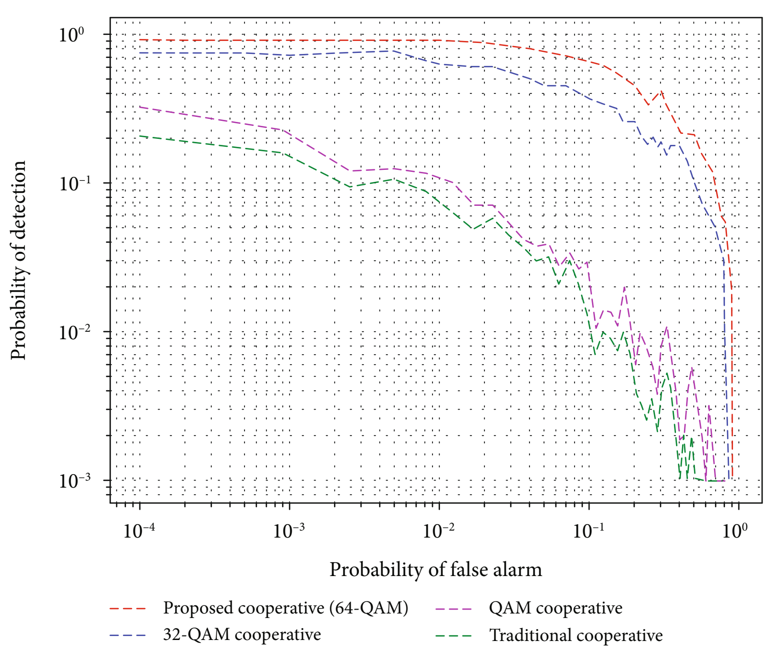

Figure 10: Cooperative shadowing scenario.

indicating a significant decrease in P_d of 89% and a rise in P_d of the same percentage.

The main issues with ED approaches include variability in sound and concealed component issues for scenarios with severe fading as was previously mentioned. As previously explained, the proposed technique addresses the issue of uncertainty in noise; the only issue that remains is the concealed node issue in a heavily faded and shadowed environment.

Therefore, utilizing the fusion detection method, SU participation has been suggested to increase the effectiveness of the CR system. In [38–40], numerous cooperative strategies are offered. The most popular cooperative sensing methods are AND and OR rules, but in this case, the fusion sensing approach covered in the aspect in [41] is suggested, and accommodating CUs are expanded from 11 to 15. [42] calculates the trade-off between the AND and OR detection algorithms. The simulation results for the AWGN channel simulation at CU 15 utilizing the fusion rule for cooperative spectrum sensing are displayed in Figure 11.

The performance of PU detection for fading channel PSK, 32-QAM, and 64-QAM modulated signals under different SNRs of 3 dBm, -5 dBm, and -10 dBm has been analysed in this section. All these simulations are obtained

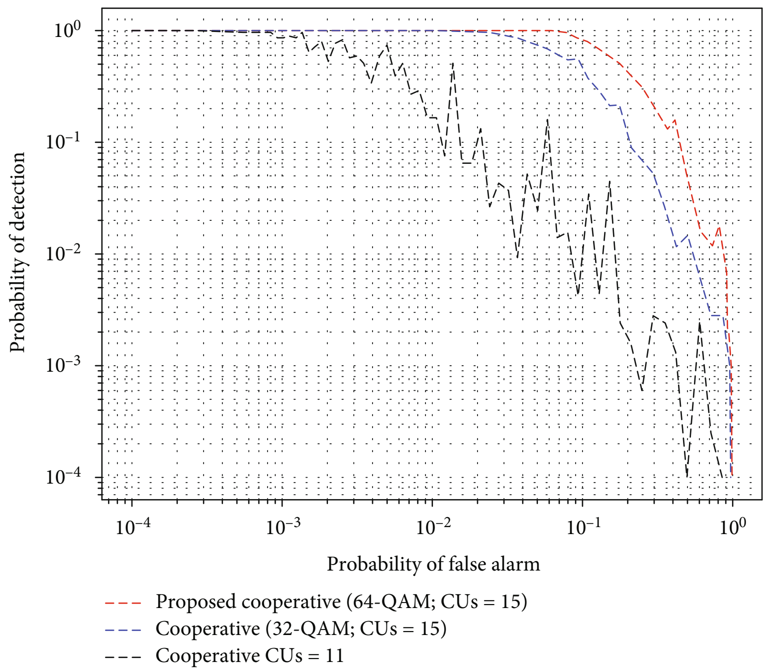

Figure 11: Cooperative shadowing scenario with CUs = 15.

with the help of MATLAB R2021b software, and during these simulations, wideband is used. In practice, the frequency range between 470 MHz and 790 MHz is used for plotting with the AWGN model. Compromisation between P_d and P_f is employed using the ROC curve, as they are two incompatible features. Outputs from the ROC curve have been used to analyse dissimilar assessments of P_d under different P_f states and various assortments of SNR with many examples. Figure 10 displays the P_f vs. P_d curvature for 32-QAM as well as 64-QAM signals for 750 and 1500 samples at -10 dBm SNR.

Figure 12 shows the P_f versus P_d graphs for 32-QAM and 64-QAM channels at -10 dBm SNR for 750 and 1500 samples, correspondingly. Whenever the total quantity of samples is 750 and P_f is presumed to be 0.1, P_d is determined to be 0.85 for 64-QAM transmissions and 0.78 for 32-QAM transmissions. Whenever the number of samples is 1500 and P_f is presumed to be 0.1, P_d is determined to be 1 for 64-QAM data and 0.97 for 32-QAM data.

Whenever the total quantity of samples is 1500 and P_f is set to 0.1, the value of P_d for 64-QAM and 32-QAM transmissions is determined to be 1 and 0.97. Whenever the amount of specimens is 1500 and P_f is set to 0.05, P_d is determined to be 1 for 64-QAM and 0.9 for 32-QAM. Whenever the total quantity of specimens is 1500 and P_f is considered to be 0.4, P_d for a 32-QAM signal is 0.78, and P_d for a 64-QAM signal is 1. Whenever the total amount of specimens is 1500 and P_f is assumed to be 0.2, P_d is determined to be 0.98 for 32-QAM and 64-QAM signals and 1.

Figure 13 shows the P_f vs. P_d plot for PSK, 32-QAM, and 64-QAM signals for 500 specimens at -5 dBm SNR and 1000 samples at 3 dBm SNR. While the quantity of specimens is 1000 and P_f is taken as 0.05, then P_d is found to be negligible for PSK, 32-QAM, and 64-QAM signals. When the number of samples is 1000 and P_f is regarded as 0.18, P_d is found to be 0.97 for 64-QAM signals, 0.94 for 32-QAM signals, and negligible for PSK signals. When the number of samples is 1000 and P_f is considered 0.2, then the value of P_d is found to be 0.99 for 64-QAM signals, and for 32-QAM signals, it is obtained as 0.95. The PSK signal, the P_d, is considered 0.94. P_f is found to be 0.56.

Figure 13 displays the P_f vs. P_d plot for PSK, 32-QAM, and 64-QAM signals for 500 specimens at -5 dBm SNR, respectively. While the specimens are 500 and P_f is 0.1, then P_d is found to be negligible for PSK, 32-QAM, and 64-QAM signals. When the number of samples is 500 and P_f is considered 0.2, P_d is found to be 0.37 for 64-QAM signals, 0.1 for 32-QAM signals, and negligible for PSK signals. When the number of samples is 500 and P_f is considered 0.4, then the value of P_d is found to be 1 for 64-QAM signals, and for 32-QAM signals, it is obtained as 0.8. The PSK signal, the P_d, is considered 0.93. P_f is found to be 0.76.

These findings imply that the P_d is superior for 64-QAM. Additionally, the bigger the number of specimens, the more accurate the main client identification. The better the identification, the smaller number of P_f.

In this study, the conclusion for the proposed model for shadowing is that these charts are generated by computing the P_d and P_f, comparing the threshold value with the low SNR value, and combining AND and OR logic rules. Cooperation boosts the system's performance overall in terms of P_f and P_d, but when the system becomes chaotic, delayed responses occur in higher networks larger than 15 SU. Cooperative sensing exhibits enhanced performance with an increased number of users, allowing the maximum

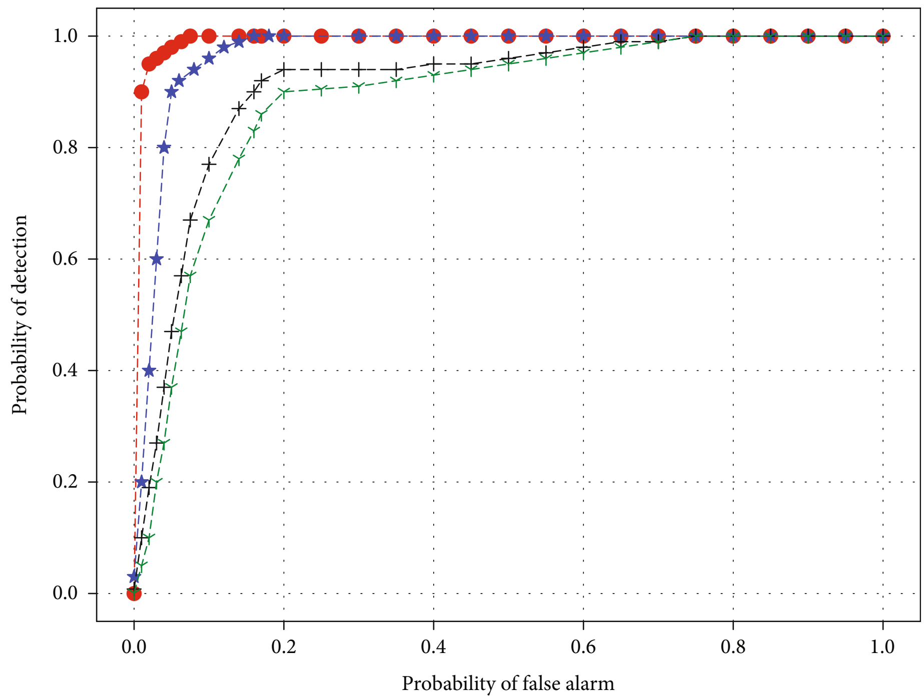

FIGURE 12: P_f vs. P_d SNR of -10 dB.

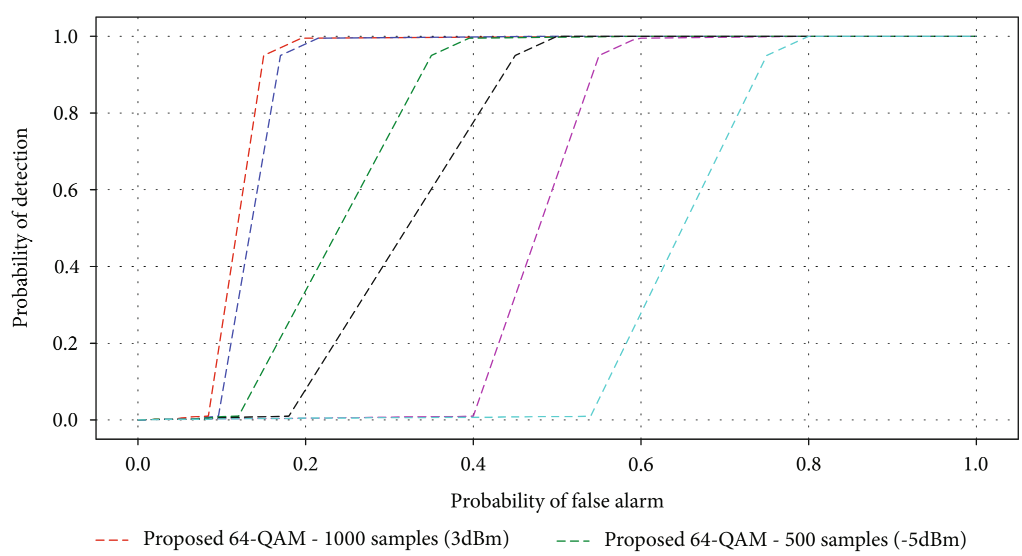

FIGURE 13: P_f vs. P_d SNR of 3 and -5 dB

number of SUs to be elevated to 15 without compromising latency levels below operational thresholds.

64-QAM parallel is also used in place of 32-QAM and PSK, along with using coordinated spectral detection with a proposed adaptive criterion in the fading effect. When compared to the current model, which uses a Simulink model to execute an ED spectrum sensing technique, this work offers a nearly 15% improvement in the P_d at 3 dBm SNR for 64-QAM modulated signals.

6. Conclusion

The M-ary QAM technique is utilized in this study to address the two most typical issues with energy detection noise uncertainty caused by not knowing the signal beforehand and the concealed node problem. Results from the proposed method, which uses a 64-QAM signal instead of a 32-QAM and PSK signal in a cooperative technique, are more accurate. The simulation demonstrates that utilizing a 64-QAM signal reduces P_f and P_d by nearly 5%, which boosts P_d by the same proportion of 5% during the same latency period and eliminates the noise uncertainty issue. Cooperation between the blockchain-enabled CR systems needed to solve the aging and observing; there is a concealed nodal concern. The SNR value drops because of the fading and shadowing noises that the radio environment introduces. A greater SNR value produced by less fading, shadowing, or noise will decrease P_f raising P_d and enhance system performance as a whole. Using a double dynamic threshold, the efficiency of an energy detector using a cooperative spectrum sensing technique has been examined. P_d and P_f parameters acquired under various SNR values were taken into consideration when the ROC was shown. With P_f 0.1, 0.2, and 0.4, various altered pulse patterns using 64-QAM and 32-QAM and PSK were employed in this experiment. In addition to SNR values of -5 dBm, -10 dBm, and 3 dBm, the spectrum sensing has been found to work better with 64-QAM than with 32-QAM and PSK. The P_d likewise drops as the magnitude of SNR does. Additionally, the P_d is determined to be superior to other SNRs for 3 dBm in the results. This technique can be used to improve the detection of primary users and update all the information in the blockchain.

Data Availability

Data sharing does not apply to this article as no datasets were generated or analysed during the current study.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Authors' Contributions

Conceptualization was carried out by S. Nandakumar. Formal analysis, investigation, methodology, software, validation, and writing the original draft were carried out by D. Balakumar. Visualization, supervision, and writing, reviewing, and editing the manuscript were carried out by S. Nandakumar. All authors have read and agreed to the published version of the manuscript.

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