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A Mathematical Formulation for Frequency Spectrum in Cognitive Network

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Abstract: ***Cognitive networks were developed to solve the current challenges in wireless networking by using established wireless spectrum because of the limited bandwidth available and the inefficiency of spectrum use. The CN with the fundamental ability of cognitive radio provides the spectrum-conscious model of wireless connections. This research provides a concept in a functional web environment to incorporate CRNs. The algorithm for the cluster head facilitates communication between secondary users, improves spectrum hole identification and thus allows spectrum use more effective. The developed spectrum analysis scheme was evaluated using the current measuring method on four radio technology (FM Broadcast, GSM-900 DL, DCS-1800 DL and UHF TV). The efficiency of radio technology networks was found to be very close. The CR signal strength varies while the signal power and the SIR are monitored continuously. The computation results show a substantial improvement of the PU's throughput from 19.6 to 61.1%. The efficiency of power has been increased from 76.66% to 86.82% for FM Broadcast, 76.91% to 86.82% for GSM-900, 78.19% to 89.04% for DCS-1800 and 78% to 88.55% for UHF TV. The lower the interference, the better reception of the signal of the secondary users. The best signal response was at 12decibel, and the interference was able to reduce from 95% to 25%.***

Keywords: ***Algorithm, Cognitive Network, HMM, MCPA and Spectrum.***

I. INTRODUCTION

The radio spectrum can be handled more efficiently by using the spectrum gaps in critical permitted frequency bands by subscribers of adaptive radio networks. Recent studies show that even in metropolitan geographical areas, the radio spectrum is rarely used by approved consumers. This spectrum use can be significantly improved by allowing secondary (non-primary system) users to access spectrum gaps, i.e., non-licensed users 'frequency bands. With time the odds of spectrums shift according to the cerebral radio position. To order to avoid chaotic and volatile use of the spectrum as in current non-licensed bands, the overall power transmission production and total power use of transmitters is difficult in a heterogeneous cognitive network. The development of a model based on the Orthogonal Frequency Division (OFDM) has been developed to ensure optimal power transfer,

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statistical representation for heterogeneous network constraints, frequency spectrum structure. The system was developed using secret Markov (HMM) models to model the spectrum use of licensed radio bands and to simulate them. The system proposed will automatically pick various licensed bands for use by the licensed users with significantly reduced interference. The CR will use them more effectively by calculating how long spectral lifts of primary users will last before the leading consumer of that unit, which it is currently occupying, ceases traffic. For complex spectrum allocation in cognitive radio networks, Markov based channel prediction algorithm (MCPA) has been created. The Markov-based MCPA approach will, however, avoid such possible collisions almost wholly, as the channel is abandoned by the CR before a primary consumer begins transmitting the information.

II. LITERATURE REVIEW

Cognitive radio network solutions, demonstrates heterogeneous wireless networking infrastructure and sophisticated spectrum connectivity, for mobile applications, to high-speed performance growing complexity of the network architecture, increasing network complexity and network operation, the fluctuating value of the bandwidth available to it, the variety of service quality (QoS) criteria in a wide range of applications, etc. Could also face difficulties. These problems are solved, and the new network architecture can be tackled through advanced technologies by spectrum management functions. This explores the CR system and focuses on particular concepts such as spectral synthesis, spectrum regulation, access to spectrum and spectrum exchange. Different self-organisation paradigms of the CRN are examined and contrasted, including Media Access Control (MAC) and network layer operations. The survey also suggests new directions and highlights CRN problems.

They are improving 5G mobility networks sustainability and Energy saving at DWDM rings (Wong 2017. The main advantage of this technique is a continuous fibre breakdown power, even if AE-BSs sleep. Therefore, the shutdown and duty may be without waiting for the AE-BS to return to the active state. A promising means of improving the use of spectrum trousers is the cognitive radio concept. (Dianjie, L., H. 2017).

A specific spectrum detection module is also used in the cognitive network design to assess the presence of other networks and users. Being mindful that these subsystems do not always represent a single device but rather have components distributed across a network. Also, cognitive radio is called cognitive radio network.

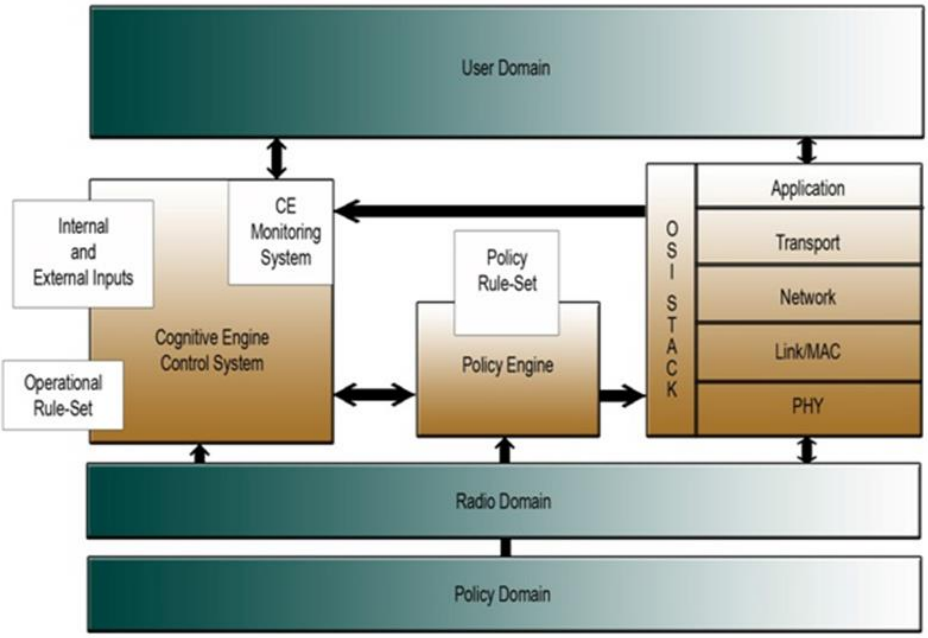

Figure 1: Cognitive Radio Concept Architecture. (Devillers, B., et al2018)

Alongside this new edibility, the challenge is to understand the limits of protocols and transmission schemes, so that these cognitive capacities are exploited fully. In particular, the theoretical limits have to be well understood for the design of practical and efficient protocols. They then identify various scenarios, theories, and associated forms of cognitive activity taken into account concerning hypothesis limit knowledge (Haykin, 2015).

2.1 Orthogonal Frequency Division Multiplexing (OFDM)

The OFDM is, conceptually, a complex frequency multiplexing division with the added restriction that the signals of all transmitters are orthogonal. In OFDM orthogonal sub-carriers have the sub-carrier frequencies selected, so there are no inter-carrier bands, and cross-talking between sub-channels is avoided. The configuration of the transmitters and receiver is thus greatly simplified; unlike regular FDM, for each sub-channel, a separate filter is not required.

The OFDM systems are, in reality, implemented by using the Fast Fourier Transform (FFT) and IFFT blocks that are mathematically equivalent but more effective in implementing DFT and IDFT models. Quelling symbols in an OFDM device are handled as often on the transmitter (e.g., QPSK or QAM symbols in one carrier systems).

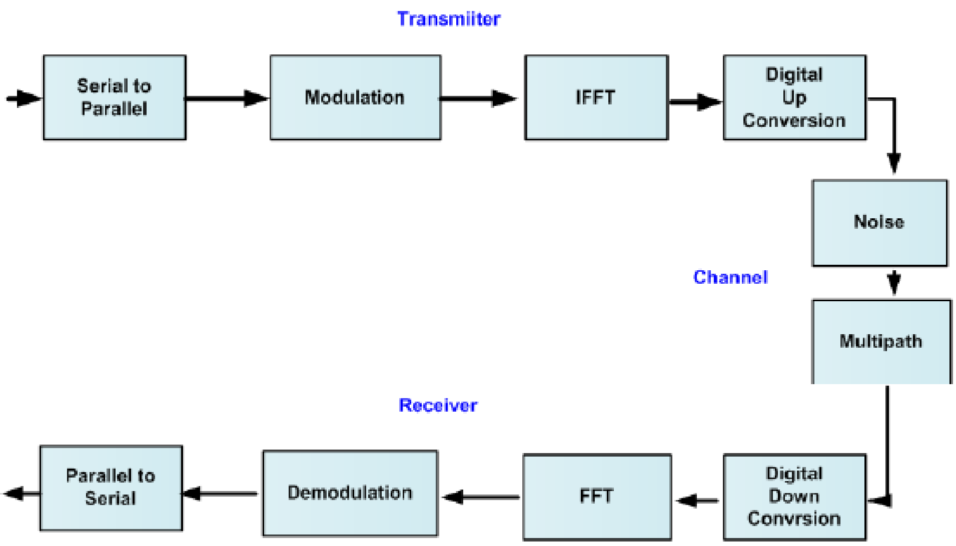

Figure 2: Orthogonal Frequency Division Multiplexing (OFDM) Architecture. (Hubert, A. et al., 2015)

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The symbols are often used as inputs to the time domain of an IFFT block that binds the signal. At a time when N is the number of subcarriers in the system, the IFFT takes N-symbols. Both N-input symbols have a T-second symbol duration. Note the orthogonal sinusoids are critical features in IFFT. Each of these sinusoids has a different frequency. For the following sinusoidal basis, increasing input symbol behaves like the combined weight. All N sinusoids are summed in the IFFT production. The IFFT block thus provides an easy way in which data is modulated in orthogonal subcarriers.

A single OFDM symbol is the set of N samples from IFFT. The OFDM symbol duration is NT, where T is the above IFFT input symbol time. The time-domain signal originating from the IFFT is sent across the channel after some additional processing. An FFT block is used at the receiver to process and carry the transmitted signal into the frequency domain. The FFT output is ideally the first symbols sent to the transmitter to the IFFT. When the samples of FFT output are positioned in the complex plane, a pattern is created. Such symbols are used to enter a signal in an IFFT block's time domain. At N of the IFFT, the amount of subcarriers is N simultaneously in the method. A T-second symbol time is given for each N input symbol.

Consider that orthogonal sinusoid are the essential functions of IFFT. Each has a different frequency of these sinusoids. For the corresponding sinusoidal base unit, each input symbol acts as a combined weight. The length of the OFDM symbol is NT, and T is the IFFT entry symbol above. The time-domain signal that arises from IFFT is sent across the screen after specific additional processing.

There is however no definition of a cluster for the time-domain signal. When putting on the complicated plane, the time-domain signal is a dispersion with no typical structure. The receiver must be interpreted in frequency (for example, symbol slicing) using the constellation principle (Joseph, 2015).

But the time-domain signal is not recognised as a band. The time-domain signal is a distributed symbol with no usual form when viewed on a complicated axis. In the frequency domain, all sorting of receivers using the constellation principle (for example slicing symbols).

2.3 Merits of OFDM

Because of its wide range of benefits, OFDM is used in a variety of high data rate wireless networks.

i. As the whole channel has many narrow-scale signals, OFDM primarily gains from its sensitivity to an inevitable loss than the single carrier networks.
ii. OFDM also has the benefit of being extremely resilient to intersymbol and interframe interference.
iii. The symbols lost by signal frequency selectivity and narrow-band filtering can be recovered by the use of appropriate channel encoding and interleaving. Not all the records are compromised.

One of the issues of CDMA systems was the difficulty of a frequency equalisation to be used across the whole array. The advantage of OFDM is that multiple sub-channels facilitate channel equalisation.

2.4 Spectrum Challenges

The spectrum of radio frequency (RF) is a limited natural resource that is regulated by physics laws. In theory, the RF begins at around 9KHz and extends to 3000GHz. But not all parts of the spectrum are suitable for all requirements on a practical scenario. Even within this practically usable range, cost-effective equipment may still be available in smaller / limited frequency bands for a particular application. The Nigerian Frequency Allocation Table allocates the electromagnetic spectrum and sets out the frequency allocations available in Canada for radio services.

The Canadian Table is based on the final provisions of the Final Acts issued by the International Telecommunications Union (ITU) at the various World Radio communications Conferences (WRC). The spectrum allocation policy relates to the command and control process by which the state will decide: ration spectrum, define spectrum technology and facilities, apply strict M&A requirements and assign unshareable rights to spectrum holders, etc. This method for continuous spectrum allocation triggers small frequency bands at different times and places.

Section 2.5 illustrates the wireless communications spectrum and wide frequency range (Lee et al., 2015). Most fractions of the radio spectrum are authorised to standard radio transmission systems. Furthermore, realistic calculations show that most approved bands are either not used in different geographic areas or are typically used partly. According to the FCCs, the range of use of the licensed spectrum band at different times and sites range from 15 to 85% (Li et al., 2015).

With rising wireless connections and high data-rate networks, competition for bandwidth and spectrum congestion is becoming crucial in the next wide-ranging world. Multiple wireless standards-based devices are increasingly demanded by performance, high reliability, high service quality, usability, and wireless service diversity. Therefore, despite user requirements such as high multimedia data rate delivery and variety of communication technologies, future broadcasting networks must face greater spectrum scarcity.

The underuse of several frequency bands opens up the opportunity for spectrum troughs to be identified and exploited. A spectrum hole is the primary user's (PU) frequency band, but the operator does not operate the band in a specific location and time (Li et al., 2017). If a secondary user (SU) can enter a spectrum hole, then the use of the spectrum is much improved.

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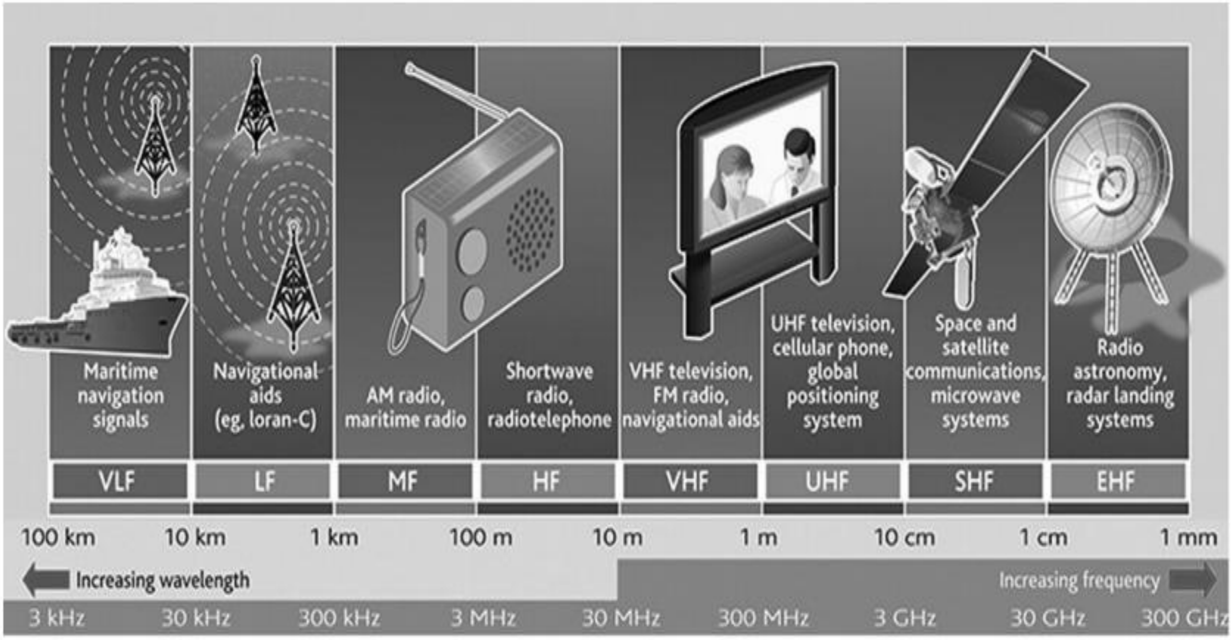

Figure 3: Radio Spectrum. (Liaoyuan, 2010)

2.5 Cognitive Radio Technology

Cognitive radio technology is the primary technology for the complex operation of the xG network. The Radio Cognitive is an environmentally friendly radio that can change its settings. This term can be used to describe two cognitive radio characteristics (Nicola et al., 2016):

i. Cognitive capability: This is the processing or detection by radio technology of radio information. This can not be accomplished simply by power control within a frequency band, but more sophisticated techniques are needed to track and avoid the time, and dimensional radio environment changes. The spectrum parts that are not used at a given time or place can be calculated using this. This allows the best spectrum and operating parameters to be selected.

ii. Reconfigurability: Cognitive abilities ensure the capacity to understand the spectrum and reconfigure the network system to provide dynamic content for broadcasting. In particular for transmission, cognitive radio is available, reception and use of different communication technologies that support hardware (Salfner et al., 2010). In particular, cognitive radios can be used.

2.6 Cognite Radio Functionality

In line with environmental changes, including cognitive flexibility and re-configuration, two CRNs are specified, enabling CR users to dynamically control the spectrum that is available in the radio environments (Safdar et al., 2017). The use of spectrum sharing, spectrum control, spectrum sharing and spectro-mobility apps can be made prompt in CR technologies.

2.7 Spectrum management

Considering the dynamic spectrum characteristics of all spectrum bands, CRNs must identify the best spectrum band. The study of the spectrum helps to classify different specimen bands (Song, 2012). In addition to tracking the spectral analysis of local CR consumers, data on Primary Network spectrum are also presented (Syed et al., 2013). Spectrum analyses are performed. The decision on the spectrum, on the other hand, chooses the sample pieces, the spectral analysis results and the device criteria decisions. The decision The regulatory capacities of multi-user and multi-CRNs should be assisted in the area of spectrum management for some applications (Raghu et al., 2018).

2.8 Spectrum mobility

If there is a deterioration of actual channel condition or if the primary user has the same speed band (Jang, 2017). (Xu, 2014). Given the evolving mode of operation of the Network Protocol due to changes in operating frequencies, the CRNs must ensure timely and smooth spectrum transmission and limit the degradation in user-perceived applications. Current Communication can, therefore, be sustained only with minimum degradation inefficiency, with the availability, through spectral sensor algorithms, of latency information of the spectrum movement.

2.9 Spectrum sharing

CRN spectrum access should be coordinated to prevent collisions between users who are not licensed, as multiple users may attempt spectrum exposure. Similar to issues with spectrum transmission in the generic Mac protocol, CR users' spectrum sharing reflects a new challenge, as they operate in close cooperation with authorised users. The latter still has a wide variety of different types of devices available (Wang et al. 2010). The existing spectrum sharing includes four distinct aspects: architecture, spectrum distribution, access to spectrums and scope. As bandwidth and equity in spectrum sharing are typically undermined, sophisticated techniques for contrasting co-operative and non-cooperative solutions should be used.

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2.10 Concept of the Heterogeneous Wireless Networks

The goal of the project is to increase the reliability of services, such as power or spectrum transmission, for wires networks. In addition to valid spectrum transfers on heterogeneous wireless networks, however, efficiency can be increased. For example, if several radio networks require more efficient use of the spectrum than in a radio store, they choose less busy or more secure radios. That is, traffic loads are balanced, and the spectrum efficiently used between multi-access networks. These decide which users use which radio networks to load stability. The parameters for this evaluation are dependability quality. With wireless communications and the essential and urgent dimension in several cooperative radio networks, this study is designed to achieve similar reliability.

Furthermore, evaluate assurance as a potential target, based on the availability of data packages and the possibility of users reaching service quality for radio links. The ultimate aim of this project's assessment feature is, by organising N communication systems that require an immediate transition of the service to a single communication system, to make package deliveries available rather than n-th. Frequency quality is used to lower the risk of service loss in contrast with cooperative systems by less than 1/N-multiple.

III. METHODS

Mathematical Formulation for Cognitive Network

This research project will have a heterogeneous network of three different networks. Mathematical expression formulation in the heterogeneous network. The stations of the base are focused on a process of developing the real-time model of the Poisson Point Process (PPP);

λ is the BSs density;

P = Energy conversion.

The device incorporates telephone, main and mobile networks. Due to its transfer rate, the base station requires maximum Energy and requires a more significant power volume for transmission. One BS can be measured for use, according to Bien & Park (2016). The three parameters: low transmittance capacity of the base station leads to higher amplifier power ratings.

$$Q_{Total} = \psi Q_{transmit} + Q_{constant} \quad \text{equation (3.1)}$$

Q_{Total} = Total power absorbed by the base station of Macro.

$Q_{transmit}$ = Energy distributed from the Full Macro base station.

$Q_{constant}$ = Constant energy consumption; due to the power used for signal processing and other sources such as the refrigeration at the facility.

ψ This is due to the loss of feeders, numerous disruptions and the cooling of the building. Assumption1: ψ When there is no damage, it is continuous.

Any randomly selected consumer from which an average signal of average power is obtained at some point:

$$y_i = P_i h_{\alpha i} \|\alpha_i\|^{-\alpha} \quad \text{equation (3.2)}$$

When α is between 2 and 4, it is an exponent of regular path depletion (if values below 2 or exceed 4, the result will be non-linear. There is, therefore, an average energy intake of i^{th}, I is the number of subscribers, h is the power factor.

$$P_{HetNet,i} = \lambda_i (P_{static,i} + \gamma_i P_{\tau x_i}) \quad \text{(Raghu, 2018) equation (3.3)}$$

When BS length, constant energy usage, scaling factor of different losses and power output of the RF are λ_i, $P_{static,i} \gamma_i$, $P_{\tau x_i}$.

Equation (3.4) $P_{HetNet,i} = \lambda_i (P_{static,i} + \gamma_i P_{\tau x_i} K)$ adjusted in which K attenuation happens when the frequency allocation control is transmitted via cognitive radio.

Assumption2: the relation of all the Macro stations to the base station;

The interference signal and the amount of noise (SINR) is determined thus.

$$SINR_{x_i} = \frac{P_i h_{x_i} \|x_i\|^{-\alpha}}{I + \sigma^2} \quad \text{equation (3.5)}$$

Where I = interference received by x_i

σ^2 = AWGN Power in the Ith tier.

IV. RESULTS

Table1: SIMULATION PARAMETERS FOR MACRO CELLS (Source: Author Field Works)

The layout of cellular Network	Hexagonal Grid, 3 Sectors per site
Inter-Site Distance	500m
UE Power Class	23dBm (200mW)
UE distribution	80% inside the building, 20% outdoor

Table 2: SIMULATION PARAMETERS FOR PICO CELLS (Source: Author Field Works)

Carrier Frequency	2000MHz
Bandwidth	L=38.2+30 log 10®; R in m
Max Pico TX Power 24dBm	24.3dBm
Antenna Gain	0 dBi or 2.4 dBi
Outdoor wall penetration loss	10.1dB
Pico BS noise figure	6.2dB
Minimum Separation UE to Pico BS	2.3m

Table 3: SIMULATION PARAMETER FOR FEMTO CELL (Source: Author Field Works)

Maximum Output Power	20dBm
Propagation Model of the Network	PL(Db)= 128.5+35log10(R/1000), R in meter
Log-Normal Shadowing Standard Deviation	15 Decibel (dB)

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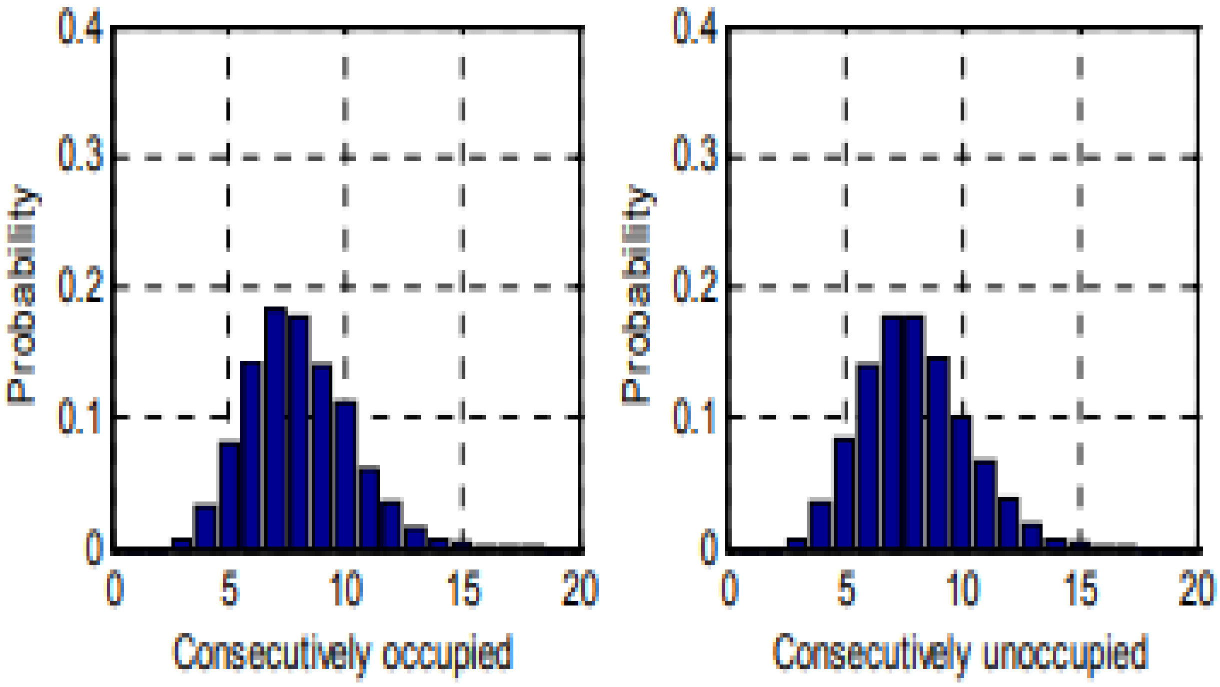

Figure 4.1: Spectrum usage of the primary users

We equate our suggested approach for complicated spectrum assignment based on HMM with the traditional CSMA spectrum assignment process. In the case of CSMA, the CR requires a switch if the primary user does not track operations and ceases because he feels the key user is transmitting data via the main channel. Thus CR-network intervention, which may not be completely avoided using the CSMA method, is likely to deteriorate the SIR of the critical customer. The MCPA approach can, however, almost wholly prevent these possible collisions as the CR leaves the channel before data transmission is started by the primary user. We are undertaking an evaluation of the effect on registered users with these two methods. The CR signal strength varies while the permitted signal power and the SIR are monitored continuously.

Result for using Cognitive radio to Monitor Spectrum

The suggested spectrum analysis scheme is evaluated using the current measuring method on four radio technology, as illustrated in Table 4.4. The efficiency of the same radio technology networks was found to be very close so that an overview of each radio technology is condensed on one channel.

Table 4.4: The detection of bandwidth for various radio technology.

Radio Technology	Channel Number	F_{start}(MHz)	F_{center}(MHz)	F_{stop}(MHz)	Signal Bandwidth (MHz)	Gain (dB)	Decimation Rate (M)	Sampled Bandwidth (MHz)
FM Broadcasting		94.100 96.500 98.100	94.300 96.700 98.300	94.500 96.900 98.500	0.2	45	64	1
E-GSM(900) DL	27 77 120	940.2 950.2 958.8	940.4 950.4 959	940.6 950.6 959.200	0.2	45	64	1
DCS (1800) DL	527 690	1808.0 1839.6	1808.2 1840.8	1808.4 1841	0.2	45	64	1
UHF Television	U - 29 U - 33	534 566	538 570	542 574	8	45	8	8

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The tests are separately analysed for all four communication technologies. The assessment method requires four models and assigns a particular radio technology. The instruction is then separately implemented, and the identification probabilities (Pd) are then determined using the test data collection. Also, 10-12 minutes are required for the design, epochs, and lot size to be trained (Systems: I7 Intel, Quartet Core Processor; 8 GB RAM), depending mainly on system processors and RAM.

Result based on Throughput Analysis

Energy detection is an important technique for detecting unknown signal in a noise network because of its simple and easy use. Therefore, for energy identification, no previous knowledge of the primary signal is required. The prediction of a signal obtained is expected to be:

H0 : y(n) = u(n),

H1 : y(n) = s(n)+u(n)

Where s(n) is the critical sample signal of the user and u(n) is the additive signal of Gaussian noise (AWGN). H0 shows the absolute lack of value for the second user, while H1 is the primary user. The result is zero (0). The frequency spectrum for the transmitted signal is called fc and bandwidth w and expressed in fs. The primary user is in 4 cases of noise in the s(n) and u(n) channel:

1. The s(n) is a dynamic, CSCG noise modulated PSK signal.
2. s(n) is a modulated signal of BPSK whereas u(n) is a Gaussian noise of real value.
3. All CSCG signals are s(n) and u(n).
4. All s(n) and u(n) are Gaussian signals of real value.

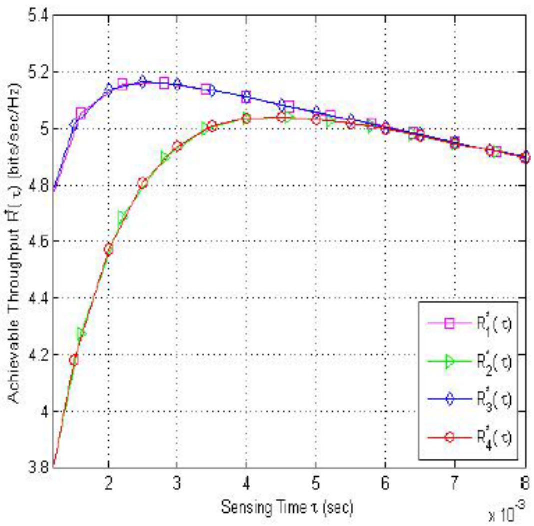

Figure 4.2: Performance toward sensing time for different necessary intqerface conditions and channel noise.

V. CONCLUSION

The proposed technique was able to predict the spectrum occupancy of licensed radio bands, select different licensed bands for its use with significantly less interference the licensed users. HMMs were combined with Markov-based Channel Prediction Algorithm (MCPA) in CN for dynamic spectrum allocation and higher efficiency of the spectrum holes for primary users to improve the accuracy. The MCPA approach can prevent possible collisions as the CN leaves the channel before data transmission was started by the primary user. Five hundred thousand data sets were collected from the Nigeria Communication Commission (NCC) repository. Artificial Neural Network was used to divide the dataset into four stages UHF, FM, GSM 900 and DCS 1800. the FM is for radio stations, UHF is for television stations, GSM 900 is for MTN, GLO, Airtel and DCS-1800 is for Etisalat networks. The combination of the two algorithms was used on MATLAB simulator 2019b.

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