Journal of the Nigerian Association of Mathematical Physics
Volume 54 **(January *2020 Issue*), pp109 – 112**

MODEL ON OPTIMIZING PRIMARY SPECTRUM ALLOCATION USING COGNITIVE RADIO

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Abstract

This paper presents Model on optimizing primary spectrum allocation using cognitive radio. A theoretic dynamic spectrum access algorithm that improves upon an hedonic coalition formation algorithm for spectrum sensing and access for frequency modulation radio spectrum is presented. The modified algorithm is tailored to eliminate interference, faster convergence and makes use of a simultaneous multi-channel sensing and access technique. Results to demonstrate the performance improvements of the adapted algorithm are presented and the use of different decision rules are investigated revealing that the primary spectrum can be used without interference with the secondary user. The algorithm that was developed could be a key for prospective primary spectrum networks to be used.

***Keywords*:** Cognitive Radio (CR), Spectrum, Secondary Users (SUs), Primary users (PUs).

1. Introduction

Smart Devices (SD), which are also referred to as the Internet of Things (IoT) are increasing every day and are gaining focus because most organizations and individuals are using these devices. Internet of Things refers to billions of physical machines around the globe that are linked to the internet, assembling and sharing data [1]. Any physical entity can be transformed into an Internet of things machine if it can be linked to the Internet/Ethernet and controlled [2].

As of 2016, the prediction of the Internet of things has advanced due to a convergence of numerous technologies, as well as wireless communication, real-time analytics, machine learning, product sensors, and embedded systems. The acceptance of Radio Frequency Identification (RFID) tags (low power chips that can communicate wirelessly), resolved some of this concern. The accessibility of broadband internet, cellular and wireless networking also helps in facilitating the growth of Internet of Things [2]. The Internet of Things also finds application in checking electric grid, telecommunication at real time, and help to encourage healthy living by use of consumer machines such as linked scales or wearable heart check [2, 3].

With the advancement in communication technology, the IoT machines have introduced a new class of low-power short-range wireless machines which uses radio spectrum for the switching of information [4]. The requirement for these machines are creating irresistible demand on the radio spectrum (secondary licensing) [4]; thereby causing a shortage of frequency. Other wireless devices that use secondary spectrum have been facing interference [5, 6], since some range of spectrum are free (secondary spectrum), any user can use any spectrum that he/she assume better for his/her machine not considering other users [7].

The number of Internet of Things machines is predicted to reach 200 billion by the year 2020 [4, 7]. This rapid growth of the internet of things machines is introducing high demand for the switching of information. Hence with the discovery, it also brings the crisis; communication field frequency insufficiency which is at present becoming an extreme crisis as man discovers appliances every day. To compensate this extraneous demand for radio spectrum, each application needs frequency to function. According to [4], there are limited amount of frequency obtainable for proper throughput communication (secondary user). As a result of this, Primary frequency needs to be analyzed to locate any vacant spectrum that IoT machines need to utilize, to solve the shortage of radio frequency and throughput.

Cognitive radio (CR) device have been proven using a novel method to identify free and used radio spectrum, if IoT machines will be able to regulate their machines parameters, such as transmit (broadcast) power and frequency, to optimize their throughput at the same time minimizing intrusion to the primary spectrum license user, with the help of cognitive radio, we can predict the spectrum hole and use the free spectrum [8].

This study will have a significant impact on spectrum allocation to a secondary user, a method that will use the underutilized spectrum in the primary spectrum through a novel use of CR devices.

To communicate between IoT devices over a 2.4/5GHz radio frequency, it becomes problematic when other nearby devices is using that frequency [9]. According to [10], proposed a variant of the Open Systems Interconnection (OSI) model for the IoT architecture. The first layer is split between Existed Alone Application System Layer and Edge Technology Layer/Access Layer, the second, third, fourth, and fifth layers are Backbone Network Layer, Coordination Layer, Middleware Layer and Application Layer respectively, each of these different layers possesses its enabling technology.

According to Experts, 30 billion connected devices will exist by 2020; these many devices competing for wireless spectrum will cause severe congestion [11]. Alleviating spectrum congestion is the primary reason for incorporating CR in IoT.

One of the most revolutionary applications of CR is addressing spectrum scarcity in wireless communications. The spectrum is scarce primarily because of the way it is licensed, CR provides the technical framework for spectrum sharing of the underutilized spectrum [12, 13], the underutilized spectrum for use by CIoT devices will be key to the future success of ever-increasing IoT networks.

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Review of the spectrum scarcity research was conducted to prove that spectrum scarcity is indeed a pseudo situation [14]. It is pseudo in the sense that the spectrum remains idle or vacant majority of the time. However, it cannot be utilized by anyone but the primary license holder.
This study focused on developing FM frequency allocation to the secondary user without interference.

2.0 Algorithm Model System Architecture

There are two types of network architectures in the FM spectrum system; the allocated spectrum and the unallocated spectrum, as we know, the entire spectrum is made up of several channels. There is FM spectrum channel in total which can be represented as M, and there is allocated FM which can be represented as K and there are unallocated FM spectrum which can be represented as L; with set PUs $K\in\{1, \ldots, K\}$ and SUs as $L\in\{1, \ldots, L\}$. The PU operation in different channel can either be 1 or 0 which denote PUi, $i\in K$, and the bitrates of such a channel can be represented as Bi which is not relevant in this model, Figure 1 represent M spectrum =K + L, which can be denoted as M = 100 Channel, if K = 12, that means L (unallocated) = 100 – 12 = 88 channel.

3.0 Channel Occupancy Model

A model is used to represent the status of each channel as discussed in System Architecture, in which there is intermittent channel switching between unallocated idle and unallocated busy, to avoid interference with the PUs allocated and to track the spectrum before transmission, The SUs perform spectrum sensing, this is necessary because the SUs are using the free spectrum of PUs and that means each SUs can be represented by SUj, $j\in L$, for a SU can access one frequency of the M channels where it is 0. If PUi is 1 in the spectrum of interest i, $i\in K$ is denoted by H1i; if PUi is absent, this denoted by H0i, but this assumption will not be since, if the FM station allocated are made constant, that means the model will improve to SUi; which means when SU is busy, it will denote H1i, and when it is idle, it will be SU0i. This assumption was made that every user is entitled to only one transceiver operating in half duplex; it is required of the SU to have spectrum nimbleness with embedded dynamic frequency selection. The likelihood of the SUi being active is connoted as SU1i; the likelihood of it being inactive is connoted as SU0i; that shows SUH1i + SUH0i = 1, Figure 2 shows the chain representation of the model.

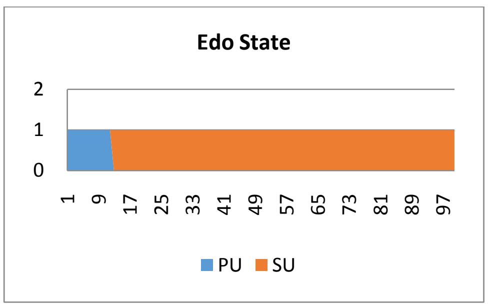

Figure 1: denote the total number of FM stations

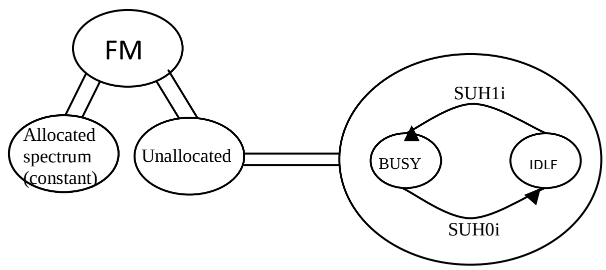

Figure 2: Show the chain representation of the develop

From Figure 2 there are some probability discretions as regarding the resolution of active (busy) and inactive (idle).
First system probability discretion is that channel i is idle and PUi is constant, true negative, which means the probability P0/0i = PH0i(1 – Pf,i)
Second system determination is that the channel SUi is occupied and PUi remains constant that is a false positive occurring with a probability P1/0i = PH1i,Pfi.
Third system determination is that channel PUi is dormant while SUi is functional, that is false negative occurring with a probability P0/1i = PH1i(1 – Pfi)
Fourth system determination is that channel PUi is active as SUi (means all unallocated FM station) is active that means a true positive occurring with a probability P1/1i = PH1i,Pfi
As indicated, the algorithm presented in Channel Occupancy Model shows notable improvements in the alliance formation algorithm, which forms the basis of the alliance. The model convergence time is quicker in decision making. These comes as a result of putting PU as constant, while multiple SUs are allowed to sense channel more than one time. Both the processes of channel sensing and access can be performed by Multiple SUs at a time while the same channels in the PU (constant) spectrum are not sensed or accessed. The outcome thus is that there is no discord or interference of PU in the network.

4.0 Performance

Simulation parameters

The FM frequency spectrum range contains the network nodes distributed in it. The algorithm was used to compare PU and SU for access and dynamic spectrum sensing. The average utility of SUs in the spectrum used depends on the constant (PU) value in each State. Simulation parameters of the different state as shown in Table 2, this was use to vary and decide the resulting outcome on average spectrum SU utility. Table 1 shows the parameters of the default simulation that was used and the results is shown in Figures 3 to 9.

Code

This code was used to display the graph.

```
sp:
val_F=Data
If Data<100 then
R_val=100 – Data
Else
R_val = 100
Goto sp:
End
```

Table 1 Simulation Parameters

Parameter	Description	Value
M	Number of channels	100
K	Number of primary users	Depends on the state
L	Number of secondary users	Depends on the state
PH1,i	Probability of PU active	Constant
PH1,i	Probability of SU active	Varies
PH0,i	Probability of SU inactive	Varies

Table 2: FM radio stations and their percentage utilisation

S/N	State	FM Stations	$S_{Unallocated}$ MHz	Percentage Underutilisation	S/N	State	FM Stations	$S_{Unallocated}$ MHz	Percentage Underutilisation
1	Abia	10	18	90	20	Katsina	4	19.2	96
2	Adamawa	6	18.8	94	21	Kebbi	3	19.4	97
3	Akwa Ibom	8	18.4	92	22	Kogi	5	19	95
4	Anambra	19	16.2	81	23	Kwara	9	18.2	91
5	Bauchi	4	19.2	96	24	Lagos	36	12.8	64
6	Bayelsa	6	18.8	94	25	Nasarawa	8	18.4	92
7	Benue	7	18.6	93	26	Niger	7	18.6	93
8	Borno	6	18.8	94	27	Ogun	17	16.6	83
9	Cross River	7	18.6	93	28	Ondo	15	17	85
10	Delta	14	17.2	86	29	Osun	10	18	90
11	Ebonyi	2	19.6	98	30	Oyo	29	14.2	71
12	Edo	10	18	90	31	Plateau	11	17.8	89
13	Ekiti	4	19.2	96	32	Rivers	18	16.4	82
14	Enugu	13	17.4	87	33	Sokoto	6	18.8	94
15	Gombe	6	18.8	94	34	Taraba	4	19.2	96
16	Imo	11	17.8	89	35	Yobe	1	19.8	99
17	Jigawa	8	18.4	92	36	Zamfara	1	19.8	99
18	Kaduna	19	16.2	81	37	FCT	29	14.2	71
19	Kano	21	15.8	79					

Each state in the Country has an average of 5-12 FM radio stations. Since there are 100 possible radio channels that could be occupied at any given location (latitude and longitude coordinate), that show FM radio channels in Nigeria is 89% underutilized.

5.0 Alliance formation

The number of channels available determines the number of alliance available to join each channel. To aid visualization of the alliances, charts were drawn to show the total FM spectrum. SUs and PUs in the network were generated with the assumption as discussed in Algorithm Model and Channel Occupancy Model and the colour of the node as shown in Figures 3 to 9.

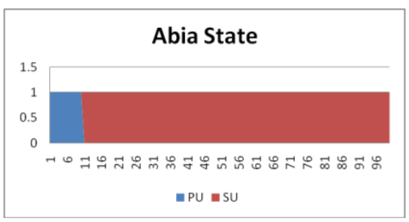

Figure 3: Network representation of Abia State total FM spectrum, PU and SU representation

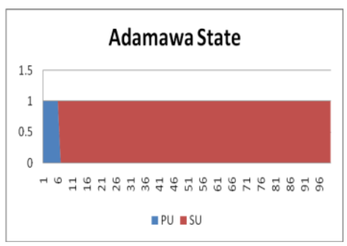

Figure 4: Network representation of Adamawa State total FM spectrum, PU and SU representation

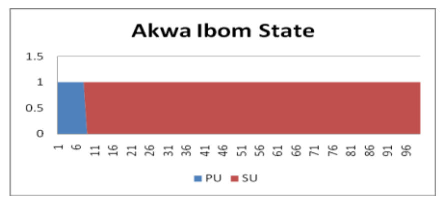

Figure 5: Network representation of Akwa Ibom State total FM spectrum, PU and SU representation

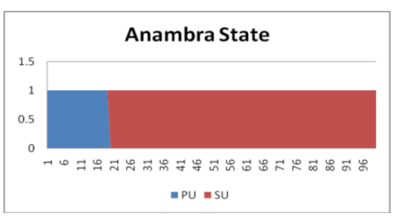

Figure 6: Network representation of Anambra State total FM spectrum, PU and SU representation

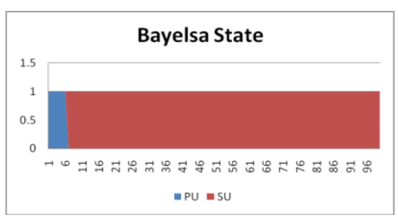

Figure 7: Network representation of Bayelsa State total FM spectrum, PU and SU representation

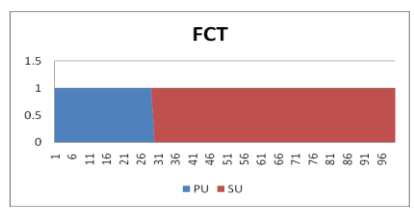

Figure 8: Network representation of Federal capital territory Nigeria total FM spectrum, PU and SU representation.

From the chart that was shown in Figure 3-8, first system decision that channel i is idle and PUi is constant, true negative; which means the probability P0/0i = PH0i(1 – Pf,i) as described in Channel Occupancy Model was use to formulate the results in Figures 3 – 8. It was an indicator that there is free spectrum in the FM station. This indicates how many SUs and PUs are in each alliance. The organizations of PUs and SUs across these alliances are what the spectrum sensing and access algorithm seek to optimize, in reflecting the average utility of the spectrum.

Second system determination is that the channel SUi is occupied and PUi remains constant that is a false positive occurring with a probability P1/0i = PH1i,Pfi, using Abia, Adamawa, Delta State. The assumptions are represented in Figures 10 to 12.

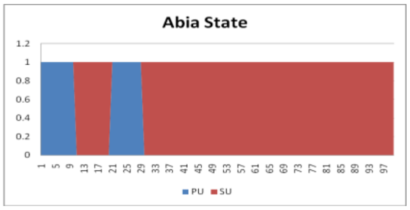

Figure 9: Network representation of Abia State total FM spectrum, PU and SU representation

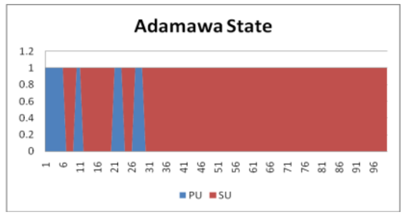

Figure 10: Network representation of Adamawa State total FM spectrum, PU and SU representation

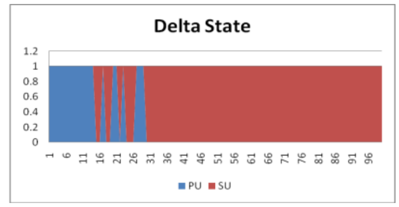

Figure 11: Network representation of Delta State total FM spectrum, PU and SU representation

From the chart in Figures 9 – 11, it was shown that if any spectrum from the secondary user is allocated, it becomes constant, that means the spectrum cannot be reallocated, to any user.

6.0 Conclusion

In this paper, better approaches of spectrum sharing were obtained and analysis was done. Algorithm model with channel occupancy model for multi-channel dynamic access was presented. The details of a collaborative spectrum sharing technique were presented from an analytical perspective, and an adapted algorithm for fast convergence in a hedonic coalition technique was shown. From the technique shown, if compared with another model, that put the primary license holder as parity 1 and secondary user as parity 2, the system will use time to scan if parity 1 is available or when using the spectrum, when parity 1 is active (primary user), the secondary user will disconnect, which will lead to loss of packet. But the performance of the model can operate in the primary user spectrum and secondary user spectrum without causing interference to the primary spectrum. It will be better if NCC approves this model because if implemented, it will protect the primary license holder and will also protect the secondary user.

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