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CR System with Efficient Spectrum Sensing and Optimized Handoff Latency to Get Best Quality of Service

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Abstract: A wireless communication technology called Cognitive Radio (CR) makes use of the environment. White hole detection indicates that unitized spectrum identification is crucial. Here, effective spectrum sensing is crucial. In this article, a new threshold for effective spectrum sensing is developed. The CR system is a secondary user of unutilized spectrum Unused spectrum is used by the CR system as a secondary user. Power is wasted during unnecessary handoffs. To maintain the level of service, optimized handoff is required. The second step of this paper provided a new algorithm for CR systems' handoff optimization. Rapid decision-making and preparation are undertaken as part of a proactive handoff strategy for channel allocation.

The system has considered two parameters, first one is maximum idle to busy ratio and second is minimum handoffs it saves the power to get optimized handoff delay

***Index Terms**: Cognitive Radio, Spectrum detection, RSS, Fuzzy Logic, ANN, Handoff.*

1. Introduction

We are having a shortage problem right now, so the bandwidth that is available should be used wisely. The users will be able to figure out spectrum tracking, spectrum control, spectrum sharing, and spectrum movement with the help of cognitive radio technology [22] [25]. Spectrum perception, spectrum analysis, and spectrum choice are the three main parts of the thinking loop [18]. Spectrum sense is the method used to figure out which frequencies are being used. Spectrum detection is important for the success of CR. The energy detecting method is used to measure the range. The method for detecting energy is simple, and the efficiency of the identification relies on the amount of the selection threshold [1]. IEEE 1900 is a standard for CR networks that was made by IEEE [19]. It shows how dynamic and opportunistic band access is used in different kinds of applications. In these circumstances, sensors may sometimes function alone or may cooperate to establish a small network of sensors that communicates information about the available spectrum using various interfaces recommended by IEEE 1900.6 standards. The data storage interface is used to store information that has been sensed. To use cognitive skills, people use the cognitive engine interface. This tool is also used to put radio access rules into place. Use a sensor device to get details about what is being sensed. Information must be shared between different platforms [19]. 4G is the next step for high-speed mobile internet. End-to-end IP and high-quality live video are two things that are likely to make 4G stand out. 4G is a global standard that makes it possible to move around the world. With the help of cognitive radio [20], this is possible.

Figure 1 gives accuracy v/s complexity graph of different spectrum methods.

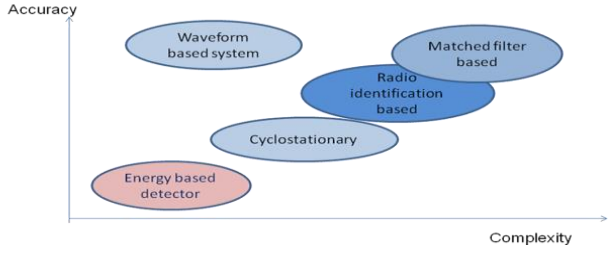

Fig: 1 accuracy v/s complexity

An analogue TV, digital TV, and low power licenced users, such as wireless microphones, are all detectable by a

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spectrum detecting device that is part of the IEEE 802.22 Wireless Regional Area Network (WRAN) standard. Figure 2 depicts the operation of IEEE 802.22. In the unused portions of the terrestrial TV broadcast bands, the IEEE 802.22 Wireless Regional Area Network (WRAN) Working Group is developing a standard for a point-to-multipoint fixed wireless access network that will operate globally. Figure 3 shows that the size of a WRAN cell is between 17.1 and 32.4 km. WRAN BS power is 36dBm EIRP [14]. We liked the energy sensing method because it was easy to understand. Our new cutoff equation has helped us improve the accuracy of this method. We've made an adjustable cutoff and thought about the spectrum sensing confidence (SSC). The chance that our system will find something is close to 100%. So, we have improved how well the information is picked up. Bit rate (BR) and received signal strength (RSS) are two other things we've thought about. We chose BR at random, and we used a distance method to figure out RSS. We have made a Fuzzy Logic Controller (FLC) with a triangular mathematical function by using these values. Neural Network (NN) trains the patterns of FLC. If the handoff decision is 'Y' (yes), then the other FLC worked with the data minimum number of handoffs (p1) and maximum rest to busy ratio (p2). NN trains patterns, which leads to the best use of channels. Figure 4 shows the model we came up with. A WRAN cell is split into microcells. We've put this WRAN into seven groups, which are made up of 49 microcells each.

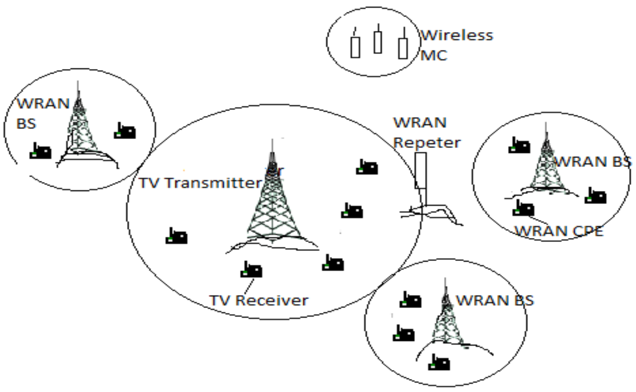


Fig 2. Scenario IEEE 802.22

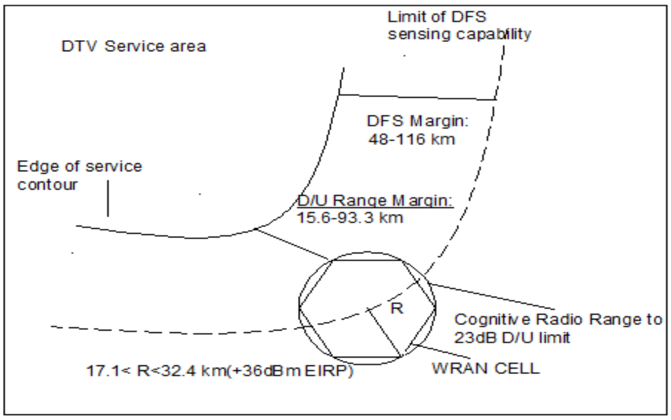


Fig 3. Location of WRAN cell

Each microcell is having different number of costmer primises equipments (CPEs).

In this study, we provide a system that provides reduced handoff delay. The remainder of the essay is structured as follows. Related work is explained in Section II. System model is presented in Section III. The article is concluded with Section IV simulation findings.

2. Related Work

Reference [1] looks at the energy monitor that is often used to find unknown signs that carry information. The programme just compares the energy (or power) in a moving window to a boundary. The references [3,4] explain what white areas are. White spots are the parts of a licenced frequency band that are not being used. This new way of networking is described in Reference [5], and it is called Dynamic Spectrum Access (DSA). Spectrum sensing method is described in Reference [10], which says that it can achieve higher output and lower delay. The references [11, 12, and 13] explain how the MRSS methods should be used. Different types of modulation are used to explain the effects of inphase (I) and quadrature (Q) gain and phase difference. They come to the conclusion that the quadrature-phase voltage-controlled oscillator (VCO) should be set up so that the I and Q phases are always opposite each other. [2] [23] gives a reference to IEEE 802.22 is the first standard used all over the world that is built on the technology of "cognitive radio." Reference [14] recommended that proactive decision spectrum handoff latency be reduced [24] by target channel sequence selection, which may realise the lowest probability of spectrum handoff failure and realise a desired anticipated number of handshake attempts before success. Reference [17] contrasts the advantages and disadvantages of several handoff techniques, including none, pure reactive, pure proactive, and mixed handoff. He also suggests using an adaptable multiple handoff strategies method to get the best performance in a dynamic spectrum environment. Reference [6] used a fuzzy-based method to make good choices about spectrum handoff in a situation with unclear, incomplete, and different kinds of information. He worked on building with no central control. With all of the above work in mind, any CR system must have an optimized handoff. If the spectrum is felt correctly, there is a 100% chance of discovery. With our changed sensitivity formula, we can identify signals between 20dB and - 20dB. We have thought about fuzzy logic [23] with centralized design and ANN [9] [21] for handoff choice in CR network [8]. As far as I know, no one has done this kind of work before.

3. Proposed System Model

The suggested plan for the system is based on the following ideas.

1) Each microcell is a small piece of land. A cluster is made up of the seven cells.

For cognitive radio operation, the TV UHF band (Tf) from 470 MHz to 890 MHz with a 6 MHz bandwidth (70 channels) is used.

CPEs are fixed and come with their own intelligence systems.

"BS and CPE do distributed sensing." The results of sensing are kept in a data cache that is regularly updated.

The proposed system model is illustrated in figure 4.

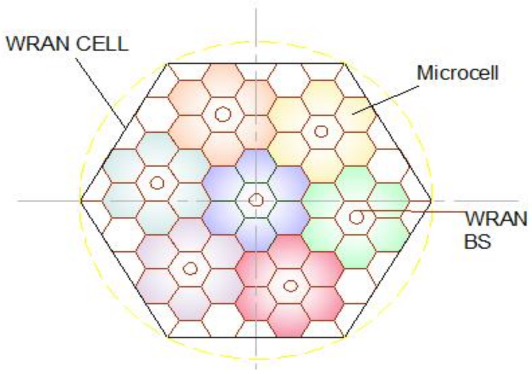


Fig 4. Proposed System model

In which a cluster contains seven cells. Each cell contains different number of CPEs. PUs are mobile, as PU appears in the particular cell and using the same channel as CPE is using then priority is given to PU, CPE will vacate the channel. Otherwise if PU appears at a channel not using by CPEs then there is no necessity of handoff. Figure 5 gives proposed system architecture with system input, process and output.

In TVUHF total 70 channels are available; each cell has allotted 10 channels. Figure 6: gives microcell with different CPEs.

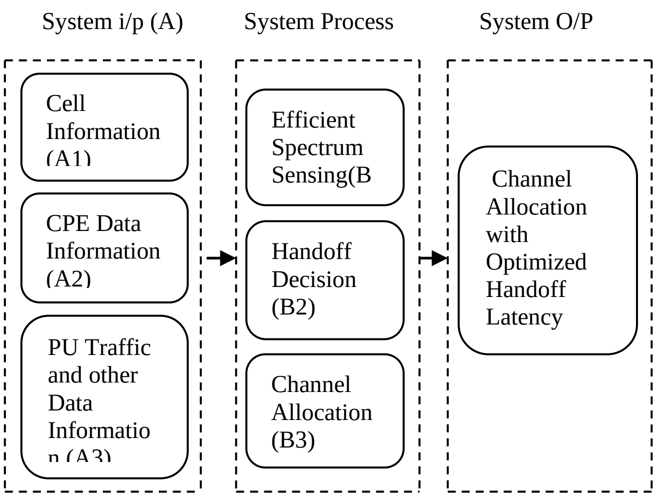


Figure 5. Proposed system Architecture.

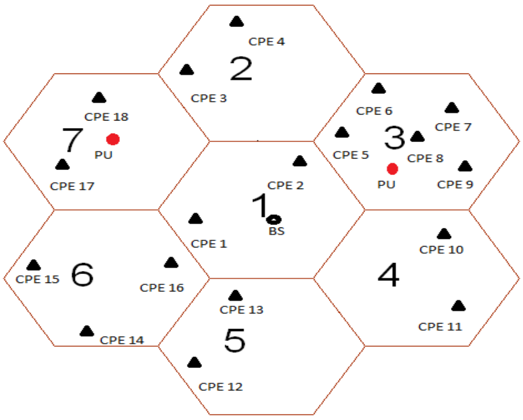


Fig 6: Cluster of microcell.

A) System Input:

$$G = \{\{G_i\} \mid 1 \leq i \leq R\} \quad ..(1)$$

$$C = \{r, loc, ch \mid \{M_c\} \mid 1 \leq i \leq 7\} \quad ..(2)$$

$$M_c = \{Id, r, loc, ncep, RSS, BR\} \quad ..(3)$$

Where

G_A=Geographical area

C=cell

R=rational number

M_c=microcell

RSS=received signal strength

BR=bit rate

r=radius

loc=GPS location

Users

$$U = \{\{P_u\}, \{S_u\}\} \quad ..(4)$$

P_u= Primary user

S_u=secondary user

In a cluster total 18 CPEs distributed as shown in fig.4. All CPEs are smart in their own right. CPEs are updated with their numbers, such as RSS, BR, the channel in use, the current frequency in use, and the previous channel and frequency.

$$RSS = P0 - 10n\log_{10}\frac{d1}{d0} \quad ..(5)$$

do = 10 reference distance

d1 = CPE distance from base station

P0 = minimum power=10 assumed

n = path loss=2 assumed

d1≥ d0

PU Information on Traffic and Other Things

This plan is based on a common one described in [24]. Here are the things that this model is based on: A group of 49 hexagonal cells makes up the topological model.

1. There are 70 stations on the network as a whole.

2. Calls come in based on a Poisson process, with a mean number of calls per hour.

3. The length of calls is spread out exponentially, with a mean of x.

4. The time between two arrivals has a negative exponential distribution with a mean of x 5. The main part of the network model is the link, which is a way for a base station and a cell to talk to each other over a channel.

B) System Process

i) Efficient Spectrum Sensing

Efficient spectrum sensing

$$Ys(t) = n(t)....<\lambda_n....H0...PUabsent \quad ..(6)$$

$$Ys(t) = s(t)+n(t)....>\lambda_n....H1...PUpresent \quad ..(7)$$

Comparing energy of the signal with new threshold and decide PU present or not, New threshold

$$\lambda_n = 10\log[Q^{-1}(pfa)(\sqrt{2N}+N)]\left(\sqrt{\frac{\sigma}{100}}\right)^2 \xi \quad ..(8)$$

Where

ξ = multiplication factor

If PU isn't really there, the handoff doesn't need to happen. Single band handoff uses about 96.06% of the average amount of energy used for getting or 110.75% of the average amount of energy used for sending.

Again, we've changed this formula so that it doesn't use the Q inverse function and doesn't depend on pfa or the number of samples. This method also gives accurate PU identification from a signal-to-noise ratio of 20 dB to -20 dB.

$$\lambda_m = 30+10\log_{10}(2\pi mf\sigma) \quad ..(9)$$

where

mf = modification factor

$$mf = 0.005(SNR)+0.48 \quad ..(10)$$

ii) Handoff Decision

Using Fuzzy Logic and Neural Network quick decision for Handoff. Figure 7 gives FLC for handoff decision.

Fig 7 FLC for handoff decision.

Training is based on the following factors: 1) SSC 2) RSS. 3) BR. A fuzzy set is a very easy way to show that something is unsure. It is simple enough that implementation will be easy and spectrum movement will happen quickly [6]. Fuzzy logic uses Fuzzy Logic Controllers (FLC) to make decisions about how things should be done. FLC was made to make a meaningful decision about whether or not a spectrum handoff should happen. Each language input variable is described by a term set of three fuzzy sets, "Low," "Medium," and "High," in that order. The term set for language output variables is made up of two fuzzy sets: 'Y' and 'N'.

Table 1 shows fuzzy rules for deciding when to hand off. With the help of the normalisation equation, the original values are put on a range from 0 to 1. "Low" means that the number of the language is between 0 and 2.5, and its pattern is "0000." "Medium" means that its number is between '2.5' and '7.5' and that its pattern is '0101'. "High" means that it has a number between "7.5" and "1."

Membership Function

Figure 8, Figure 9, Figure 10 give triangular membership function for SSC, BR, RSS respectively.

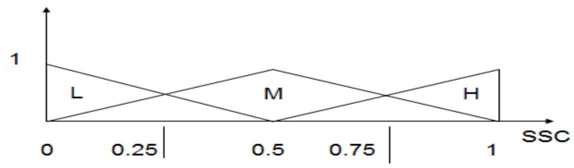


Fig 8. membership function for SSC.

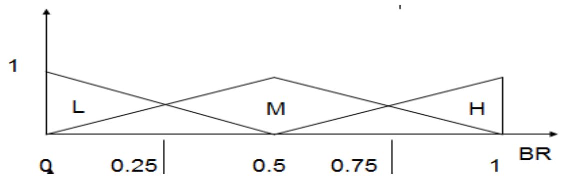


Fig 9. membership function for BR.

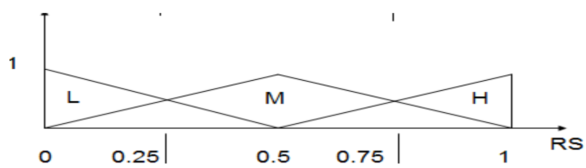


Fig 10. membership function for RSS.

$$\mu_f(x,a,b,c) = \begin{cases} 0 & \text{if } x < a \\ (x-a)/(b-a) & \text{if } a \le x \le b \\ (c-x)/(c-b) & \text{if } b \le x \le c \\ 1 & \text{if } x > c \end{cases}$$ ..(10)

$$P_1 = \{x \mid x \in R, 1 \le x \le 100\}$$ ..(11)

$$P_2 = \{x \mid x \in R, 5 \le x \le 70\}$$ ..(12)

$$P_3 = \{x \mid x \in R, -95 \le x \le -10\}$$ ..(13)

Normalize P1, P2, P3, 0 to 1

P1 SSC = (P1- 10) /90

P2 BR = (P2- 5) / 65

P3 RSS = ((P3- (-95)) / (-10-(-95))

	If			Then
Fuzzy Rule	P1	P2	P3	Hd
1-9	H	H,M,L	H,M,L	Y
10-11	M	L	L,M	Y
12	M	L	H	Y
13	M	H	L	Y
14	M	M	L	Y
15	L	L	L	Y
16-21	L	L,H,M	H,M	N
22-25	M	H,M	H,M	N
26	L	H	L	N
27	L	M	L	N

Table: 1 Fuzzy Rules for Handoff Decision

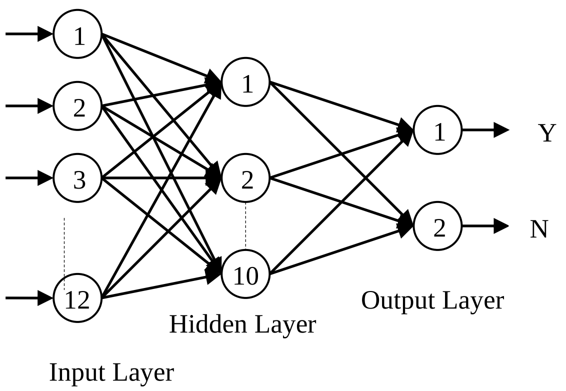


Fig 11: ANN

Figure 11 gives artificial neural network (ANN). ANN has input as patterns, 10 hidden inputs and two outputs are used. 10000 iterations are required to train the ANN 100%

iii) Spectrum Handoff Process

Effective spectrum sense with a 100% chance of discovery. A proactive approach for handing off is used [16]. So there isn't much time between calls. The handoff process is shown in Figure 12.

Figure 13 shows that when the handoff choice is "N," the CPE or SU keeps sending data on the same channel. When the handoff choice is "Y," FLC2 searches for a backup channel. Minimum handoff (p1) and highest idle-to-busy ratio (p2) are used to find out which channel is being used. Each language input variable is described by a term set of three fuzzy sets, "Low," "Medium," and "High," in that order. The term set of language output variables is made up of three fuzzy sets: 'B', 'C', and 'N'.

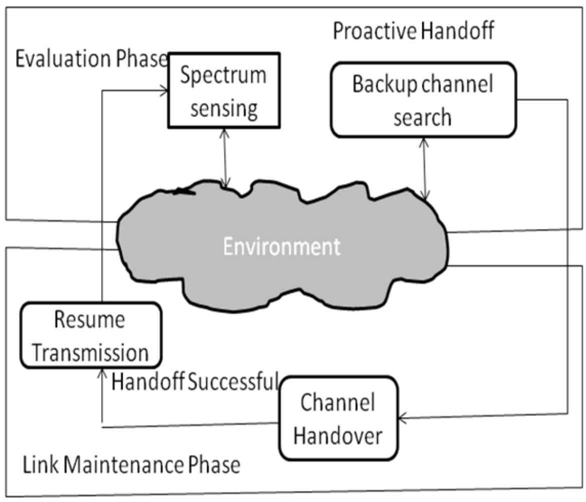


Fig 12. Handoff Process

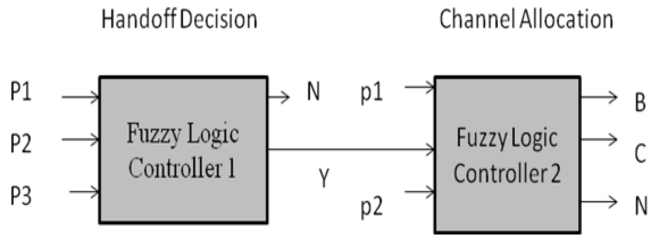


Figure 13. FLC for optimized handoff Latency

Membership Function for FLC2

Figure 14 and figure 15 gives membership function for FLC2 respectively.

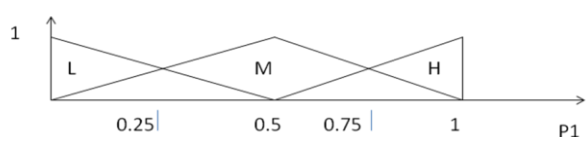


Fig 14 membership function for p1

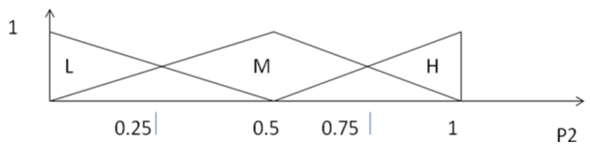


Fig 15 membership function for p2

μ_f (x, a, b, c) =

$$\begin{cases} 0 & if\ x < a \\ (x-a)/(b-a) & if\ a \le x \le b \\ (c-x)/(c-b) & if\ b \le x \le c \\ 1 & if\ x > c \end{cases} \quad ..(14)$$

$$p1 = \{x \mid x \in R, 0 \le x \le 1\} \quad .(15)$$

$$p2 = \{x \mid x \in R, 0 \le x \le 1\} \quad ..(16)$$

Table 2 provides fuzzy rules for FLC2 and lists candidate and backup channels while taking into account the minimum handoff time and maximum idle to busy ratio.

Table: 2 Fuzzy Rules for FLC2

	If		Then
Fuzzy Rule	p1	p2	Channel Allocation
1	L	H	B
2	H	H	C
3	H	M	C
4	M	H	C
5	M	M	C
6	L	M	C
7	M	L	N
8	H	L	N
9	L	L	N

Number of channels= N, Current channel= M Assigned channel= Bk

$$B_k = B_k \in \{1,2,3,....N\}_{k=1}^{M} M \le N \quad ..(17)$$

Fc=Fk then Hd= 'Y'

p1= Handoff, p2= ibratio

Optimized Handoff Channel= ϑ

$$\vartheta = \arg\min p1 and \arg\max p2..........\vartheta \in N \quad ..(18)$$

Table: 3 give system parameters notations.

Table: 3 System Parameters

Sr.No.	Parameters	Descriptions
1	Tc, N	TVUHF channels
2	Tf	TVUHF frequencies
3	P3,RSS	received signal strength
4	P2,BR	bit rate
5	P1,SSC	signal sensing confidence
6	Cch	current channel
7	Pch	previous channel
8	Cfc	current frequency
9	Pfc	previous frequency
10	Cell id	cell identification
11	CR id,CPE, SU	Customer premises equipments, secondary users
12	ϑ, Bk	allocated channel
13	PU id	primary user identification
14	At	arrival time
15	Ht	Holding time
16	H0	hypothesis primary absent
17	H1	hypothesis primary present
18	pcch	primary current channel
19	pcid	primary cell identification
20	λ	threshold
21	p1,Hd	handoff
22	p2, i/b ratio	Idle to busy ratio
23	N	Number of channels
24	Bk	Current channel
25	pfa	False alarm probability
25	Pd	Detection probability
26	BW	bandwidth
27	σ_s	Signal power
28	σ_n	Noise power
29	λ_n	New threshold
30	Pk	Spectral density
31	ξ	multiplying factor
32	BS	Base station

4. Simulation Results

i) Cell Information:

Channels allocated randomly consecutive ten for each cell. These are, for cell 1: 1 to 10 channels. For cell 2: 61 to 70 channels. For cell 3: 21 to 30 channels. For cell 4: 31 to 40 channels. For cell 5: 51 to 60 channels. For cell 6: 41 to 50 channels. For cell 7: 11 to 20 channels.

ii) CPE Information

Table gives simulation at cell 3. All CPEs have self intelligence.

Table: 4 CPE Information

CRid	BR	RSS	pch	pfc (MHz)	cch	Cfc (MHz)	cellid
1	43	-32.12	0	0	1	470	1
2	32	-37.19	0	0	9	518	1
3	51	-59.74	0	0	61	830	2
4	40	-62.11	0	0	64	848	2
5	44	-58.49	25	614	24	608	3
6	48	-61.25	0	0	26	620	3
7	23	-51.22	0	0	27	626	3
8	49	-57.22	0	0	28	632	3
9	32	-61.17	0	0	29	638	3
10	29	-62.82	0	0	34	668	4
11	33	-57.95	0	0	37	686	4
12	31	-47.87	0	0	57	806	5
13	30	-58.17	0	0	58	812	5
14	25	-50.63	0	0	43	722	6
15	47	-62.00	0	0	50	764	6
16	31	-58.30	0	0	48	752	6
17	30	-62.66	0	0	16	560	7
18	43	-57.24	0	0	12	536	7

iii) PU Traffic and Other Data Input: table 5 gives the traffic of PU using Poisson distribution.

Table: 5 PU Information

PUid	Cellid	ht	Fc MHz	Channel No.	Call Status
0.043	26	216.972	794	55	0
3.2172	7	172.5913	554	15	0
5.8075	9	114.5197	608	24	0
12.1558	29	327.3637	482	3	0
14.9457	33	46.3676	686	0	1
29.1108	16	11.1802	692	0	1
30.4581	17	87.0389	728	44	0
43.8669	38	94.4489	848	64	0
44.2234	30	42.635	704	0	1
55.2776	33	183.8398	800	56	0
55.9157	38	556.165	716	42	0
57.7028	24	162.3334	836	62	0
62.734	25	254.1938	734	45	0
67.262	9	19.4308	608	0	1
80.1192	3	35.6119	614	25	0
80.8256	27	193.6747	878	69	0
82.153	1	385.9203	512	8	0
92.8166	2	79.0441	878	69	0
95.0508	11	243.7451	812	58	0
95.1629	1	26.5593	506	7	0
98.5552	22	185.6052	812	58	0
101.9604	19	160.7377	812	58	0

B) System Process

i) Efficient Spectrum Sensing

A new threshold formulation is developed by a careful investigation of the SNR, pfa, and multiplication factor. Formula modified is (10). Figure: 16 gives pfa analysis using new threshold formulation and taking multiplication factor =0.58 and SNR=-10dB

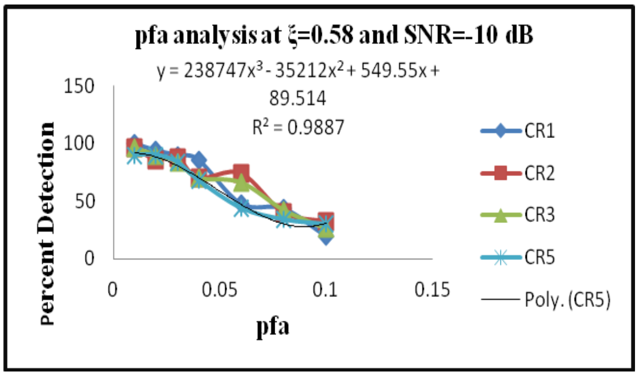


Fig:16 pfa Analysis

Figure:17 gives SNR analysis by using new threshold formulation , multiplication factor=0.58 and pfa=0.01

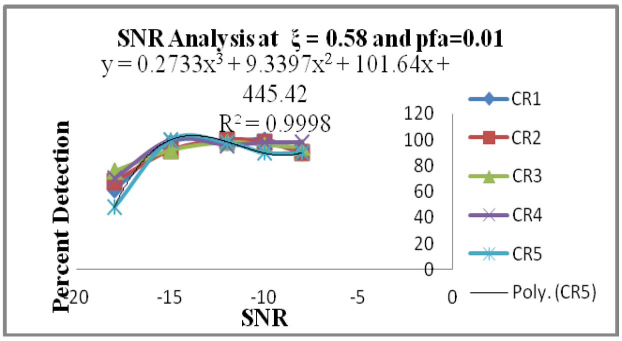


Fig: 17 SNR Analysis

Figure:18 gives percent detection analysis for different multiplying factor . At mutiplying factor = 0.58 we get regration factor = 0.96.

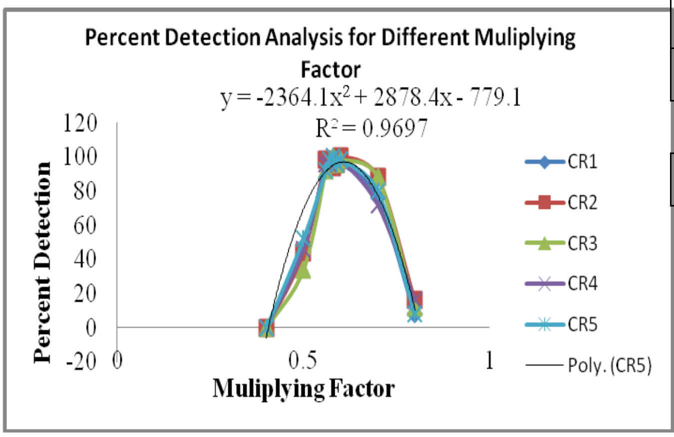


Fig :18 percent detection analysis for different M.F.

Power of primary signal is calculated and compared with new threshold. If power is greater than threshold, then call status is 1 otherwise 0. It is shown in spectrum of signal in cell no. 3. Figure:19 gives sensed spectrum at cell number .3

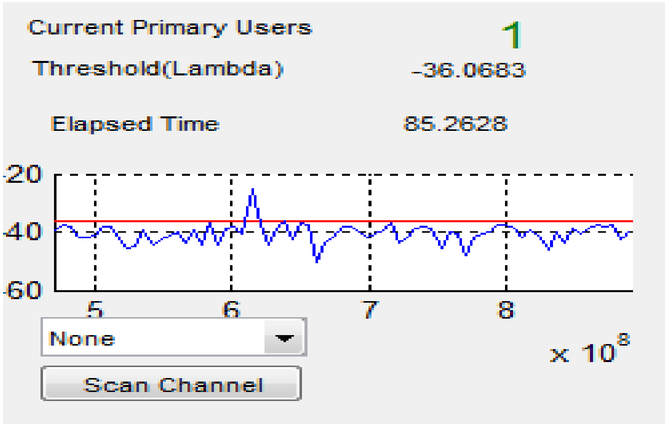


Fig: 19 sensed spectrum at cell number 3

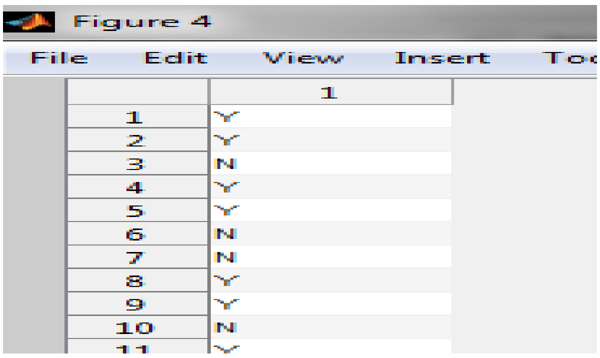
ii) Handoff Decision

SSC, BR, and RSS parameters are used to create fuzzy rules. The 12-bit pattern created by the fuzzy rule is displayed in table at row 7. ANN is used to train this pattern. For 100% training 10000 iterations are required. Output obtained from ANN is shown in figure 17. Detail output of Handoff Decision shown in figure 18.

Table: 6 Generated Pattern by FLC1

	P1				P2				P3			
1	1	0	1	0	1	0	1	0	1	0	1	0
2	1	0	1	0	1	0	1	0	0	1	0	1
3	1	0	1	0	1	0	1	0	0	0	0	0
4	1	0	1	0	0	1	0	1	1	0	1	0
5	1	0	1	0	0	1	0	1	0	1	0	1
6	1	0	1	0	0	1	0	1	0	0	0	0
7	1	0	1	0	0	0	0	0	1	0	1	0
27	0	0	0	0	0	1	0	1	0	0	0	0

Fig: 20 output from ANN



Testing analysis: [20]

Table: 7 True/False positive & negative values

TP	TN	FP	FN
52	48	0	0

TP number of true positive value

TN number of true negative value

FP number of false positive value

FN number of false positive value

Accuracy = (TP +TN) /(TP+ TN+FP+FN)

= 52+48/52+48+0+0

= 1

Precision = TP/(TP+FP)

= 52/52+0

= 1

Sensitivity = TP/(TP+FN)

= 52/52+0

= 1

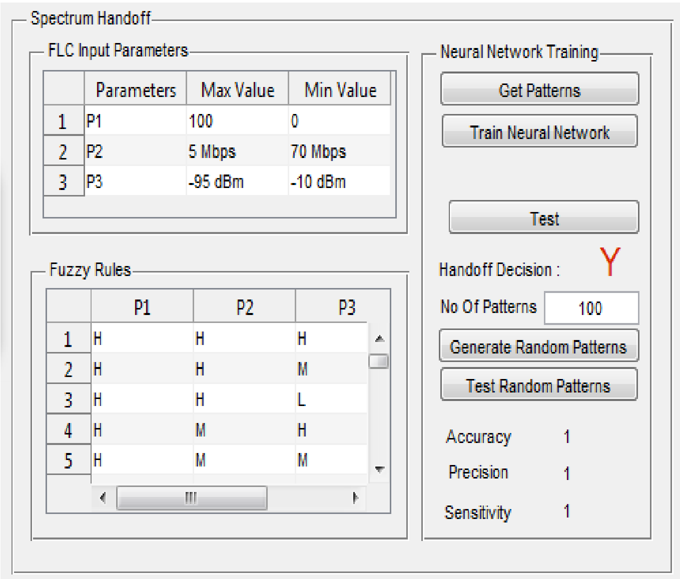


Fig: 21 output of Handoff Decision

iii) Allocation of channels with optimal handoff latency

If FLC1's choice about the handoff is "N," then the CPE will continue to send data as it did before. 'Y' means that FLC2 will work if the handoff choice is 'Y'. FLC2 will work based on two things. The minimum handoff and the highest ratio of idle to busy time are two of these factors. So, table 9 shows the designs that can be made with FLC2. Figure 22 shows the exact result of channel distribution.

Table:8 Generated Pattern through FLC2

	P1				P2			
1	0	0	0	0	1	0	1	0
2	1	0	1	0	1	0	1	0
3	1	0	1	0	0	1	0	1
4	0	1	0	1	1	0	1	0
5	0	1	0	1	0	1	0	1
6	0	0	0	0	0	1	0	1
7	0	1	0	1	0	0	0	0
8	1	0	1	0	0	0	0	0
9	0	0	0	0	0	0	0	0

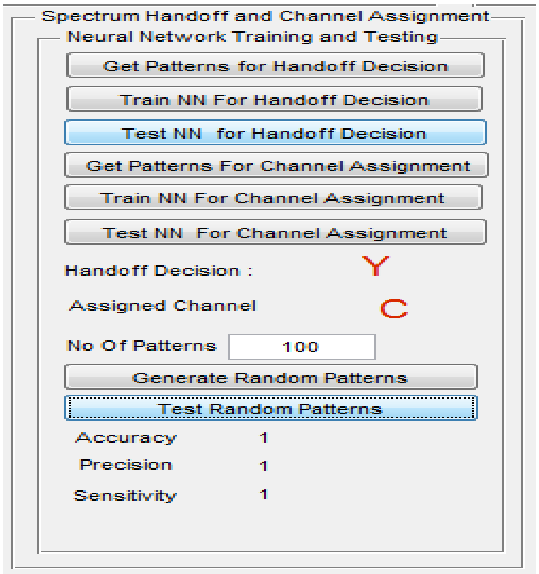


Fig 22 gives channel allocation output

Overall system Graphical User Interface (GUI) is shown in figure 23.

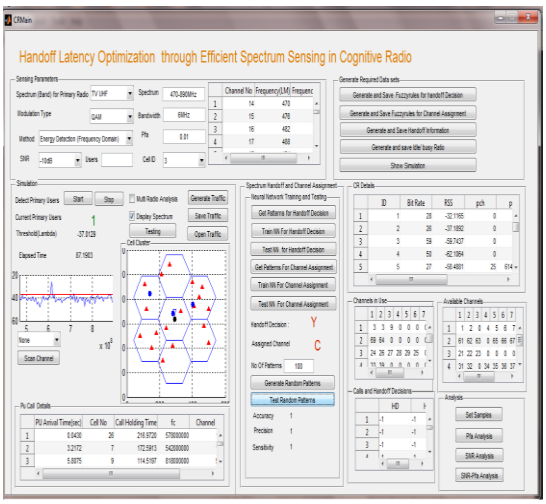


Fig: 23 System Graphical User Interface (GUI)

5. Conclusion

In frequency domain study, the average accuracy of spectrum sense in TVUHF is 96.56% when a new threshold expression is suggested. Analysis of SNR and pfa shows that the proposed design will lead to a stable system. In an intelligent radio network, a new method is proposed that decides when to switch between stations. In this method, the WRAN cell is split into smaller parts called microcells. Each microcell has a different set of CPEs, and each CPE has been well trained with the help of fuzzy logic and ANN. Through a lot of tests with different random patterns, we've found that this spectrum handoff method is easy to understand and takes less time to run. The accuracy, precision, and sensitivity of this suggested method are all 100%. The handoff delay is best with our method. In this method, the minimum handoff (p1) and the highest ratio of idle to busy (p2) are taken into account. We found that the handoff wait time is very small after doing a lot of tests with different random patterns. The next thing we'll do will be to put the system to use in real time.

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