Opportunistic Scheduling of Secondary Users in Cognitive Radio Network Using Adaptive Control System

Muhammad Saleem Khan, Muhammad Shoaib Hanif, Shahzadi Tayyaba, Haroon Rasheed, Muhammad Waseem Ashraf

***Abstract*—The concept of cognitive radio is still adolescent and there are a lot of issues that need to be address in future for successful implementation in practical use. This paper presents the scheduling algorithm of secondary user to ensure the effective utilization of spectrum. For selection of appropriate secondary user four deterministic parameters mobility, distance, spectrum and hold time are considered and priority queues with five levels are formulated by applying fuzzy rules on these four variables. Hybrid approach of underlay and overlay spectrum sharing is implemented on the base of collision rate among the users of the cognitive network.**

***Index Terms*—Fuzzy Logic, Fuzzy Rule Spectrum sharing, Unlicensed user, Spectrum holes, Throughput, Opportunistic.**

I. INTRODUCTION

Cognitive Radio Networks (CRNs) have distinctive features as comparison to traditional wireless networks such as in CRNs secondary or unlicensed user access the spectrum dynamically that's mean if primary or licensed user demands for the channel for transmission then secondary user have to leave that channel and look for the other available channel or have to wait for that channel[1] and transmission time of the secondary users is not fixed but depends upon the activity of the primary users[2]. Therefore unlicensed users can only access the specific spectrum band when they are free from the licensed users [3]. So because of these distinctive features existing schemes of traditional wireless networks cannot be implemented to cognitive radio networks that's why scheduling scheme to deal with the scheduling problem in traditional networks need to be reassessed for the CRNs. Spectrum sharing is one of the four basic functions of cognitive radio networks that refer to spectrum scheduling of the secondary users[4-6], and comparison of different scheduling techniques have shown that spectrum scheduling is the key factor for the maximum throughput and optimal utilization of the resources of CRNs [7].

M.S. Khan, M.S. Hanif, M.W. Ashraf GC University Lahore, S. Tayyaba University of Lahore, H. Rasheed Bahria University Karachi, Pakistan. Email: fasilwaseem@yahoo.com. Manuscript received March 14, 2014; revised July 07, 2014 and September 17, 2014.

It is necessary for a cognitive radio to access any available channel from the targeted free spectrum band, make possible network communication by operating complete or specific part of the channel[8], sharing the free spectrum among secondary users by applying the scheduling techniques, and error correction schemes to obtain the best throughput.

Because secondary users don't have any licensed channel like primary user so for the communication they have to wait for the spectrum that is free from primary user and can opportunistically access this free spectrum. To avoid from the interference among the cognitive users we need to implement sophisticated scheduling technique. The implementation of reliable scheduling technique is much necessary because the throughput of the network is dependent on this technique. Best technique used for scheduling will increase the network throughput as well as make possible the optimal utilization of the resources of the network.

II. PROPOSED MODEL

For selection of appropriate unlicensed user for the spectrum access four determining parameters are considered such as mobility of unlicensed users, distance between the licensed user and unlicensed user, ratios of the spectrum required and hold time of unlicensed user.

A. Mobility

Mobility is an important parameter because if the mobility is high then there will be more chances of secondary user to change the position. It will cause Doppler Effect.

$$f_D = (V\cos\theta / c)\, fc \qquad (1)$$

Here f_D is Doppler shift, θ is the arrival angle of the received signal, c is the wave velocity and fc is the carrier frequency. If the mobility is high there can be degradation of Quality of service due to non-availability of the channel [9]. The velocity can be calculated from the given formula. Doppler shift is given by by eq. 2 and 3.

$$f = f_m \cos\phi$$

 ISSN – 1999-4974

(2)

and

$$fm=v/\lambda \quad (3)$$

Here f_m is the carrier frequency is the mobile velocity, φ is the angle and λ is the carrier wave length. It has three membership functions slow, moderate and fast.

B. Distance

Distance of the secondary user is another important factor because secondary user at a closer distance should be given priority to access spectrum, which depends upon the SNR, γ_s, at the secondary user given by eq. 4.

$$\gamma_s = 10 \log((P1\ g(R))/ \sigma 2) \quad (4)$$

Where P1 is the transmit power user, σ is the noise power and R is the distance between the primary and the secondary user, which can be calculated from the given formula and mapped into three membership function near, moderate and far in fuzzy logic controller.

C. Spectrum

The third factor is the ratio of the required spectrum to the available spectrum which gives spectrum efficiency given by eq. 5.

$$\eta_s =(BWS/BWa) * 100\ \% \quad (5)$$

Where BWs is the required spectrum and BWa is the available spectrum. It is mapped into three membership functions low, medium and high.

D. Hold Time

This is the expected time duration a secondary user can occupy the licensed channel without any interruption. If this is high (long) a channel can be assigned to user with high priority queue [10]. It has three membership functions as short, moderate and far.

E. Output Parameter

Keeping in consideration the velocity, distance, spectrum and hold time we need the desired output that is the priority of the secondary user. By making all possible combination of different values of the input membership function we have different value for the priority.

F. Priority

The grading of the secondary users to get the available spectrum is called priority. If the priority is high then secondary user have more chances to get the free spectrum and if priority is low then he have to wait till it gets high priority that will increase as its wait time increases. It is mapped in fuzzy controller with five different membership functions those are very low, low, moderate, high and very high. This represents the different priority levels of secondary users.

G. Fuzzy Rules

By making all possible combinations of velocity, distance and spectrum and their effect on priority of secondary users we have 81 rules as following If (Spectrum is Low) and (Mobility is Slow) and (Distance is Near) and (Hold_Time is Short) then (Priority is Moderate) (1)

Spectrum Access Technology Base Technique

The second categorization of spectrum sharing techniques for CRNs is based on technology that is further classified as overlay spectrum sharing and underlay spectrum sharing as explained following

H. Overlay Spectrum Sharing

The spectrum sharing technique in which a node accesses a part of spectrum that is not being utilized by spectrum [11, 12] is called overlay spectrum sharing. Overlay spectrum sharing technique minimize the interference with licensed users by utilizing a small portion of licensed user as shown Figure1.

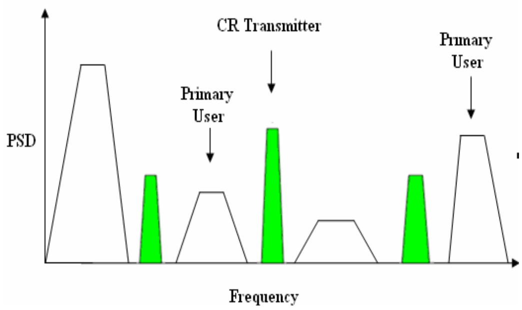

Fig. 1. Overlay Spectrum Sharing

I. Underlay Spectrum Sharing

The spectrum sharing technique in which uses a certain portion regarded as noise by the licensed users. After acquiring the spectrum allocation map CR node starts its transmission to this specific portion of spectrum as shown in Figure2.

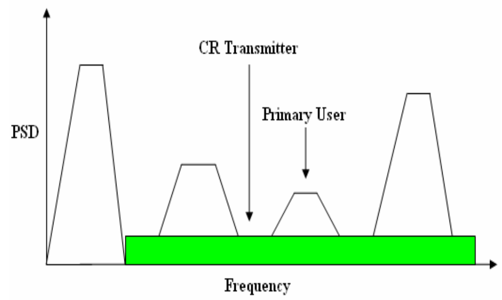

Fig. 2. Underlay Spectrum Sharing

Overlay spectrum sharing technique try to find the spectrum holes and dynamic spreading techniques are required for underlay spectrum sharing techniques to ensure interference free operation between primary and secondary users. Considering the tradeoff between system complexity and performance, hybrid techniques may be considered for the spectrum technique. As a result of hybrid approach maximum numbers of users can be accommodated for transmission. And decision of selection the underlay or overlay approach is done on the base of knowledge provided about the collision rate among the secondary and primary users.

III. Spectrum Scheduling Algorithm

On the base of result of fuzzy logic control system keeping in consideration the four parameters velocity, distance, spectrum and hold time. We have 5 different queues of user with different priority as very low, low, moderate, high and very high. Spectrum will be assigned to the users those are in top priority queue with very high priority. And next we if apply hybrid approach underlay and overlay combined then we need to see the collision rate of secondary users with the primary users. If the collision rate is very high then it's better to choose underlay spectrum scheduling and if this collision rate is low then it is best to choose the overlay spectrum scheduling. If collision with the primary user or with other secondary is high then secondary user cannot use the spectrum for their complete transmission because they have to leave the channel if primary user arrives back and demands for the channel. It is because a primary user cannot be scheduled if he demands for the channel and the secondary user have to leave the channel even his transmission on the last stages. That's why underlay spectrum sharing is preferred for such kind of scenario in which secondary user uses a small portion of the spectrum consecutively his specified spectrum frequency even during primary user demands for that channel. This way we can make best utilization of the spectrum when there is high collision rate among the users. The other case is that when there is very low collision rate among the users of the network then it is best to choose the overlay spectrum scheduling technique because this will utilize the spectrum efficiently and will increase the throughput of the system. Follow diagram of the purposed scheduling scheme is show in Figure3.

If the system keep the indexing of the collision rate of different areas with keeping and also keeping in consideration the time change and implement one of the technique (e.g. overlay or underlay) as of the requirement of the time and area the system throughput will increase.

IV. Simulation Results

The system is designed for four fuzzy input variables

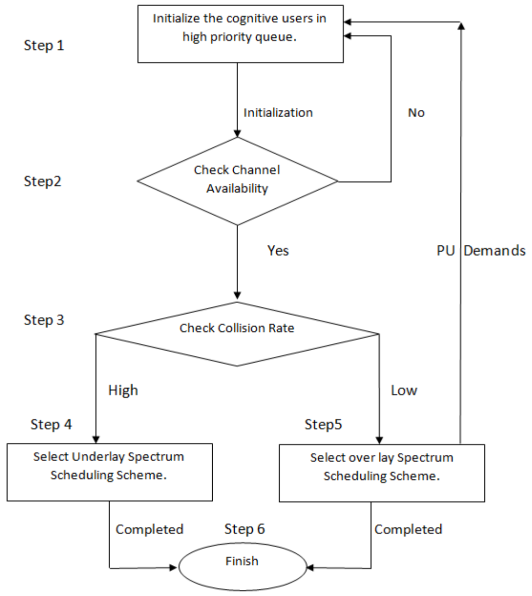

Fig.3. Scheduling algorithm for secondary users in high priority queue

TABLE I. Membership Functions of Input Variables

Spectrum	MF	Mobility	MF	Distance	MF	Hold Time	MF
0-5	Low	0-5	Slow	0-5	Near	0-5	Short
0-10	Medium	0-10	Moderate	0-10	Moderate	0-10	Moderate
5-10	High	5-10	Fast	5-10	Fart	5-10	Long

Those are spectrum, mobility distance and hold time. The membership functions for these variables are given below in Table I. Now we simulate system using these four input parameters and have different priority queues of users based on the result and then will apply priority based scheduling technique to secondary users to assign spectrum. Priority of the secondary user will increase with time to avoid from starvation of the users in low priority queue.

A. *Fuzzification*

In purposed system there are four input fuzzy variables those are spectrum, mobility, distance and hold time. The value of each variable will lie in one of the three regions. After the fuzzification process we get eight linguistic values for four fuzzy variables. These linguistic values are the mapping values of the fuzzy input variables with the membership functions occupied in the regions. As shown in Figure4, f1 and f2 corresponds to the linguistic value of spectrum, f3 and f4 represents mobility, f5 and f6 for distance and f7 and f8 for hold time. The mapping of input

 ISSN – 1999-4974

fuzzy variables with the functions in five regions is listed in Table II.

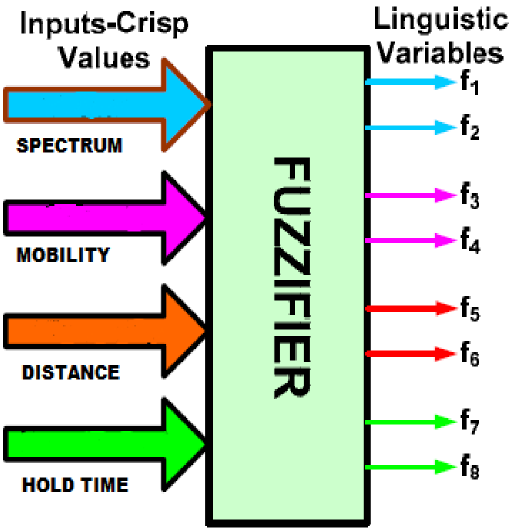

Fig. 4. Fuzzifier showing 4 inputs crisp values and 8 outputs linguistic variables

TABLE II. Linguistic values of fuzzifier outputs in all regions

Input Variables	Linguistic Fuzzifier Output	Region 1	Region 2	Region 3
Spectrum	f1	Low	Medium	High
	f2	Medium	High	High
Mobility	f3	Slow	Moderate	Fast
	f4	Moderate	High	High
Distance	f5	Near	Moderate	Far
	f6	Moderate	Far	Far
Hold Time	f7	Short	Medium	Long
	f8	Medium	Long	Long

B. Inference Engine

The inference engine consists of sixteen AND operators, these are not the logical ANDs but select minimum value input for the output. This inference engine accepts eight inputs from fuzzifier and applies the min-max composition to obtain the output R values. The min-max inference method uses min-AND operation between the four inputs.

The sign ^ between the membership function values is used for Min-ANDing process. In this process we get the minimum of the function values being ANDed. This interpretation is used in Mamdani-min process. Figure5 shows interference process.

C. Rule Selector

Crisp values of spectrum, mobility, distance and hold time are given to rule selector as input and as output rule selector gives the singleton values of output function by applying the algorithm. To get the singleton values of these four input variables sixteen rules are required specified by

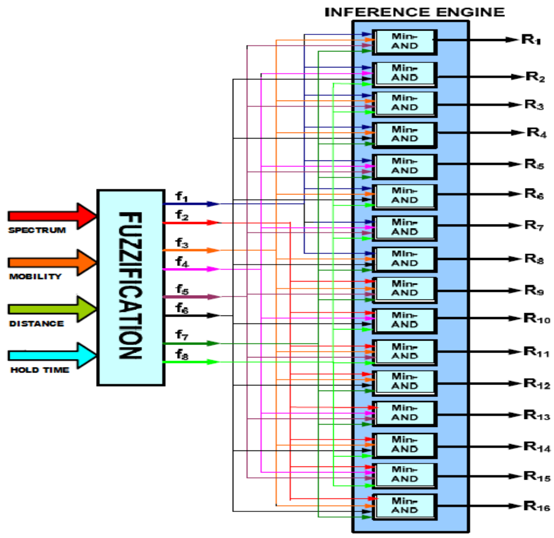

Fig. 5. Block diagram of inference process

the division of the regions.

D. Defuzzification

Defuzzification process gives the crisp value output by estimating the input values. Defuzzifier takes the input values and gives crisp output value by estimating with the help of center of coverage method using this formula Σ Si * Ri / Σ Ri . In this system 32 input variables are given to fuzzifier where 16 are the values obtained from interference engine and the other 16 are singleton values from the rule selector. From defuzzifier we have one output variable that is the priority of the secondary user as shown in Figure6.

Output variable "Priority" is dependent on four input values and there will be effect on the value of output variable if any change occurs in four of the input variables.

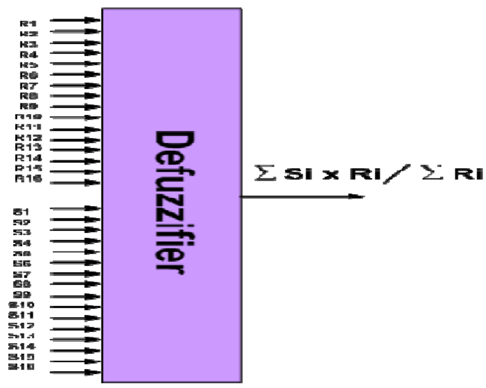

Fig. 6. Defuzzifier for the system

 ISSN – 1999-4974

Result obtained from Matlab simulation of the system shows that in which we have all possible combinations of input variables and their effect on the priority. Now we will see the effect of two input variables together on the priority as shown in Figure7. We have mobility and spectrum and their corresponding output priority.

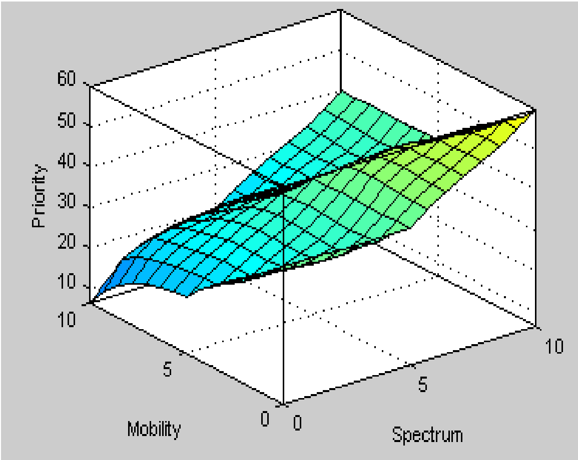

Fig. 7. Mobility and Spectrum Effect on Priority

Similarly all other possible combinations of input and their corresponding effect on output variable priority is show in Figure8 and Figure9.

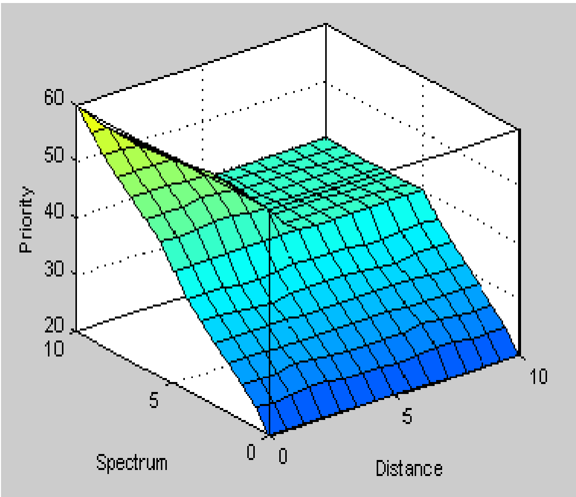

Fig. 8. Distance and Spectrum Effect on Priority

V. Conclusion

In this research a scheduling algorithm is for the secondary users in cognitive radio is developed whose purpose was to increase the performance throughput of the overall network and make assure the fairness among the secondary user for the selection of available channel. For this purpose firstly a priority queue with five different levels of priority (very low, low, moderate, high and very high) on the base of effect of input parameter mobility, spectrum, and distance and hold time. For this fuzzy logic is implemented because fuzzy logic provides a different a

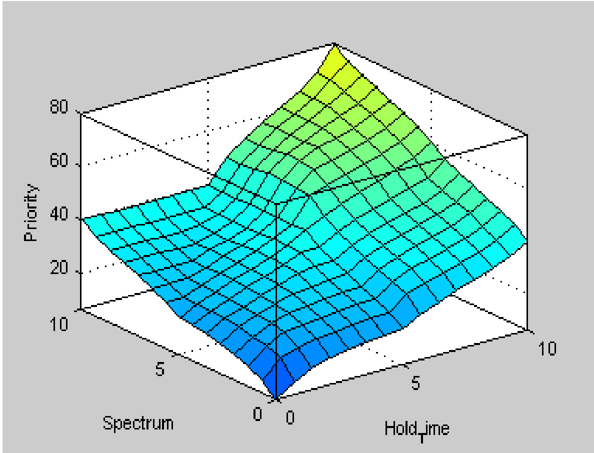

Fig. 9. Hold Time and Spectrum Effect on Priority

different way to solve the problem. In fuzzy logic formulation of rules using the expert's knowledge in the specific domain, the combination of the set and defuzzification is required. In formulation of rules we considered the effect of input parameters and find that if the mobility is high then chances to get the spectrum will be low that's why priority will be low and if mobility is low then priority will be high , and in case of input parameter spectrum if the ratio of the available spectrum to the required spectrum is high then priority of the secondary users will be high and if it is low then priority will be low , in case of distance if secondary user is near to the available spectrum then priority will be high otherwise low and in case of hold time if it is long then priority is low and other case if it is short then priority will be high. By keeping in consideration these four parameters and their effect on the different levels of priority we have 81 rules for all possible combinations on input parameters.

As we have 5 different levels of priority that will keep the secondary users in different queues there is need to access the spectrum using some spectrum sharing technique. For this we applied the hybrid approach of combination of underlay spectrum sharing technique and overlay spectrum sharing technique that will be chosen on the base of collision rate. If the collision rate is high then underlay spectrum sharing will be chosen and if collision rate is low then overlay spectrum sharing will be implemented. This hybrid approach will increase the throughput of the network by making possible the maximum and efficient utilization of available spectrum bands. Adaptive behavior through which network get can mature with time is implemented by keeping a complete log of the collision rate in different time for different location , with the help of all previous log system can take decision of choosing the spectrum sharing technique without checking the collision rate every time. Because spectrum is just assigned to the users in high priority queue so there was possibility that some user always keep waiting in low priority queues that can be reason of being starved for some users .To remove this possibility of being starved

 ISSN – 1999-4974

in the low priority queues the priority level of the users is increased to its higher level as its waiting time increases. This will maintain the fairness among the secondary users of the network by giving chance to all users to get the spectrum.

VI. Future Work

Concept of cognitive radio is getting still immature and there are a lot of issues that need to be address in future for successful implementation in practical use. Because the main concept behind the cognitive radio is the sharing of licensed spectrum that is in idle state or not being utilized by the licensed user so the privacy and security concerns need to address proper way. In perceptive of scheduling there are many other scenario of practical usage need to investigate and many other factor that need to consider for the selection of suitable channel, firstly need to investigate all possible factor and then later there effect on the selection of channel. After the selection of channel, assurance of successful transmission of secondary user without interrupting the licensed users is also need to address.

References

[1] V. K. Tumuluru, Ping Wang, and D. Niyato, “An Opportunistic Spectrum Scheduling Scheme for Multi-channel Cognitive Radio Networks”, School of Computer Engineering, Nanyang Technological University, Singapore, 2010.

[2] H. J. Kushner and P. A. Whiting. “Convergence of proportional-fair sharing algorithms under general conditions”, IEEE Trans. Wireless Commun., 3(4):1250-1259, 2004.

[3] C. Sun, W. Ze, “Cluster-based cooperative spectrum sensing in cognitive radio systems”, IEEE International Conference Communication, pp. 24-28, 2007.

[4] S. Haykin, “cognitive radio: Brain empowered wireless communications’’, IEEE journal on selected Areas in Communications, Vol. 23, No. 2, pp. 201-220, 2005.

[5] Jon M. Peha, “Sharing Spectrum through Spectrum policy reform and Cognitive Radio” Proceedings of the IEEE special issue on Cognitive Radio.

[6] J. Mitola, “Cognitive radio: An integrated agent architecture for software defined radio”, Doctor of Technology, KTH, Sweden, 2000

[7] T. Mushtaq, M. S. Hanif, M. S. Khan and Otto Koudelka. Spectrum scheduling: the key factor for maximum throughput and optimal resource utilization in cognitive radio network. Accepted 2013, Science International Journal .

[8] R. Urgaonkar and M. J. Neely. Opportunistic scheduling with reliability guarantees in cognitive radio networks. In Proc. IEEE INFOCOM, pages 1301{1309, Phoenix, AZ, Apr. 2008.

[9] M J Kaur, MoinUddin , H K. Verma. Analysis of Decision Making Operation in Cognitive radio using Fuzzy Logic System. . International Journal of Computer Applications Volume 4– No.10, August 2010.

[10] A Dey1,S Biswas1, S Panda,SMondal. A New Fuzzy Rule Based Spectrum Utilization and Spectrum Management for Cognitive Radio, National Conference on Electronics, Communication and Signal Processing, NCECS-2011,19th September 2011.

[11] L. Cao, H. Zheng, Distributed spectrum allocation via local bargaining, in: Proc. IEEE Sensor and AdHocCommu n i c a t io n s a n d Networ k s (SECON) 2005, September 2005, pp. 475–486.

[12] S. Sankaranarayanan, P. Papadimitratos, A. Mishra, S.Hershey, A bandwidth sharing approach to improve licensed spectrum utilization, in: Proc. IEEE DySPAN 2005, November 2005, pp. 279–288.

 ISSN – 1999-4974