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# DECISION SYSTEM FOR RULE BASED SPECTRUM HANDOFF PROCESS OF SECONDARY USERS

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**Abstract**

*Cognitive radio network is one of the leading technologies in the field of next generation wireless networks. Opposite to stable spectrum assignments in traditional wireless networks, cognitive radio networks are employed on the basis of dynamic spectrum allocation. In the dynamic spectrum allocation process, spectrum handoff is defined as spectrum band altering of secondary users. In this study, fuzzy logic based spectrum handoff decision system for secondary users are proposed. Our system composes of three input parameters and an output parameter. The possibility of spectrum handoff as the output parameter is obtained from input parameters, i.e. spectrum usage intensity of primary users, data rate of secondary users and noise effect in the environment. The effect of each input parameters to the output are investigated separately. It is observed from the obtained results that spectrum usage intensity of primary users dominate the other input parameters.*
**Keywords:** Cognitive radio, Fuzzy logic, Spectrum handoff

# İKİNCİL KULLANICILARIN KURAL TABANLI SPEKTRUM EL DEĞİŞTİRME İŞLEMİ İÇİN KARAR SİSTEMİ

**Öz**

*Bilişsel radyo ağları, gelecek nesil kablosuz ağlar alanında öne çıkan teknolojilerden biridir. Geleneksel kablosuz ağlardaki sabit spektrum atamalarına karşılık, bilişsel radyo ağları dinamik spektrum tahsis esasına göre çalışmaktadır. Dinamik spektrum tahsis işlemlerinde, ikincil kullanıcıların spektrum bandı değiştirmesi spektrum el değiştirme olarak tanımlanmaktadır. Bu çalışmada, ikincil kullanıcılar için bulanık mantık tabanlı spektrum el değiştirme karar sistemi önerilmiştir. Sistemimiz, üç giriş parametresi ve bir de çıkış parametresinden oluşmaktadır. Çıkıştaki spektrum el değiştirme olasılığı; birincil kullanıcıların ortam kullanım yoğunluğu, ikincil kullanıcıların veri oranı ve ortamdaki gürültü etkisi giriş parametrelerine göre elde edilmektedir. Her bir giriş parametresinin çıkışa olan etkisi ayrı ayrı irdelenmiştir. Elde edilen sonuçlardan, birincil kullanıcıların spektrum kullanım yoğunluğunun diğer giriş parametrelerinden daha baskın olduğu gözlemlenmiştir.*
**Anahtar Kelimeler:** Bilişsel radyo, Bulanık mantık, Spektrum el değiştirme

## 1 Introduction

In cognitive radio networks, primary users should not be exposed to any attempt by the secondary users [1-3]. In the meantime of transmission of a secondary user; if the channel is required by a primary user, the channel must be emptied [4-6]. In this case, the secondary user needs to cut the transmission or carry on the transmission through another available channel in order to empty the frequency channel [7-8]. Moving from one channel to the other channel for secondary users in order to carry on the transmission is defined as spectrum handoff [9-12]. By means of the methods and techniques used for the spectrum handoff process, secondary users are ensured to be transferred to other channels without interrupting their transmissions [2, 3].

In the environment of the empty spectrum channels, the most appropriate channels must be offered to the secondary users according to their requirements [2]. In this case, taking some specific parameters and transmission requirements of secondary users are inevitable for selecting the most appropriate channel among all the channels [3]. For these reasons, the channel characteristics and user requirements are concerned to be evaluated with multi-parameter and decision making mechanisms [10-16].

Artificial intelligence based approaches are often used in wireless networks for decision-making processes [11]. For example; Ahmed et al. proposed a new fuzzy logic based system for estimating the gain of the candidate channels in cognitive radio networks [2]. They also incorporate the SINR (Signal Interference to Noise Ratio) with primary user interference to take handoff decision. Besides, they claim that quality aware channel selection along with primary user susceptibility is important to improve the throughput of cognitive radio networks.

Maheshwari and Singh investigated a fuzzy logic based spectrum handoff process and assignment approaches that increase the channel utilization and avoids frequent channel switching in cognitive radio networks [12]. In their study, the approach considers interference as well as bit error and signal strength with the purpose of find quality channel. Moreover, based on generated fuzzy patterns of channel quality, the neural network is trained with the aim of estimating the channel gain.

Nabil and Nainay proposed a fuzzy inference based scheme for distributing the sensing task among cognitive radio users [13]. In their work, proposed scheme is proven to reduce the overall sensing error probability compared to two other cooperative sensing mechanisms by means of the simulations.

In our study, spectrum handoff process which uses fuzzy logic based decision making mechanism for secondary users in cognitive radio networks are investigated.

## 2 Spectrum Handoff Decision Mechanism

In the proposed system; medium usage intensity of primary users, data rate of secondary users and noise effect in the environment are determined as input parameters. SNR (Signal to Noise Ratio) parameter is used to measure the noise effect in the spectrum.

### 2.1 Rule Based Spectrum Handoff Process

In Table 1, five sample rules are given from the rule table which is consisting of 27 rules in total. According to the rules, the spectrum handoff probability results are acquired.

As can be understood from the rules given in the table, although the output parameter is directly proportional to the data rate and the noise effect, it is inversely proportional to the medium usage intensity of primary users.

Table 1. Examples from the rule table.

| |
|---|
| If (data rate is low) and (channel usage probability of primary users is high) and (SNR is low) then (spectrum handoff probability is very low) |
| If (data rate is low) and (channel usage probability of primary users is moderate) and (SNR is high) then (spectrum handoff probability is moderate) |
| If (data rate is moderate) and (channel usage probability of primary users is moderate) and (SNR is moderate) then (spectrum handoff probability is moderate) |
| If (data rate is high) and (channel usage probability of primary users is low) and (SNR is moderate) then (spectrum handoff probability is very high) |
| If (data rate is high) and (channel usage probability of primary users is low) and (SNR is high) then (spectrum handoff probability is very high) |

### 2.2 Membership Functions

In Figure 1, the membership functions of the medium usage intensity of primary users are shown. For channel usage; 3 different levels, namely, low, moderate and high were determined. Since the channel usage parameter expresses a probability value, the unit is selected as %. The boundaries of the moderate level are determined between 15 and 85.

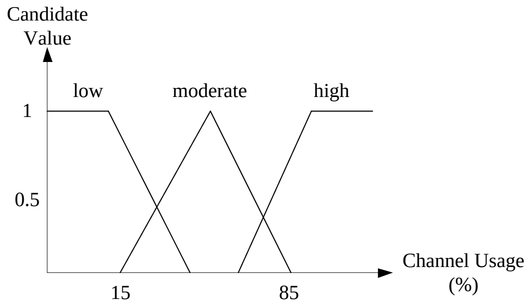


Figure 1. Membership functions illustrating the channel usage probability of primary users.

In Figure 2, the membership functions of the data rate of the secondary users are given. For data rate, three different levels were used, i.e., low, moderate and high.

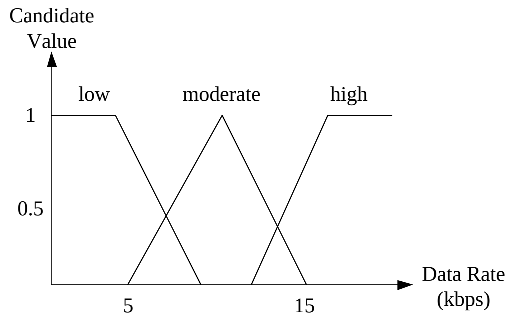


Figure 2. Membership functions illustrating the data rate of secondary users.

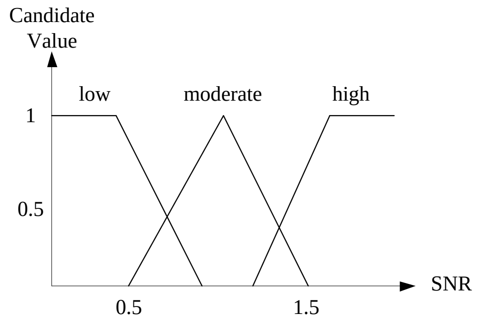


Figure 3. Membership functions illustrating the SNR value of secondary users' signals.

In Figure 3, the membership functions indicating the SNR value of the secondary user signals are shown. For SNR value, three different levels were determined as low, moderate and high. The intervals of moderate level were chosen between 0.5 and 1.5. A high value of SNR means that the signal power is higher than the noise power.

## 3 Performance Evaluation

In order to evaluate the performance of our system, spectrum handoff probabilities were obtained by holding the different input parameters constant at each time. The results obtained with ten users in total are given with five user graphs to provide a more meaningful interpretation.

### 3.1 Numerical Results

In Table 2 and Table 3, sample results obtained from MATLAB software are shown. For example; when the medium usage intensity of primary users is 7%, the data rate of the secondary users is 18 kbps and the SNR value is 0.18 then the spectrum handoff probability is 93%.

Table 2. Sample results from simulation model.

| Probability (%) | Spectrum Usage (%) | Data Rate (kbps) | SNR (dB) |
|---|---|---|---|
| 93 | 7 | 18 | 0.84 |
| 50 | 12 | 2 | 2 |
| 27 | 90 | 7 | 0.46 |

Table 3. Sample results from simulation model.

| Probability (%) | Spectrum Usage (%) | Data Rate (kbps) | SNR (dB) |
|---|---|---|---|
| 54 | 40 | 13 | 0.77 |
| 50 | 63 | 10 | 1.21 |

In the simulation results obtained from the system, spectrum handoff probability values which are very close to each other are optimized individually.

### 3.2 Graphical Results

In Figure 4, different spectrum handoff probabilities are obtained according to varying medium usage intensity of primary users by keeping the noise effect in the environment and the data rate values of the secondary users constant.

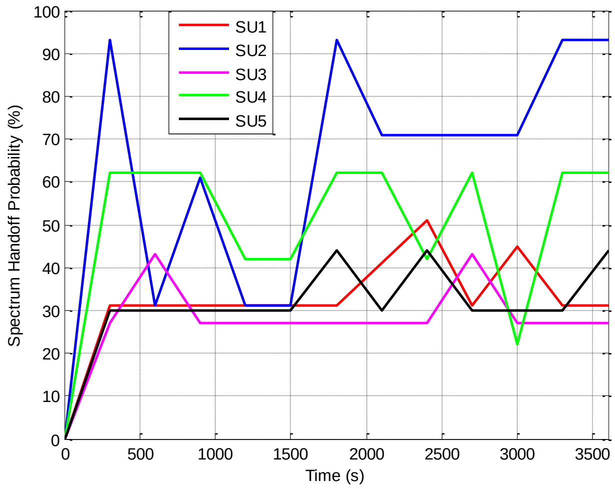


Figure 4. Spectrum handoff probabilities according to the medium usage intensity of primary users.

In Figure 5, spectrum handoff probability values according to varying medium usage intensity of primary users are shown when the noise effect in the environment and the data rate of the secondary users are constant.

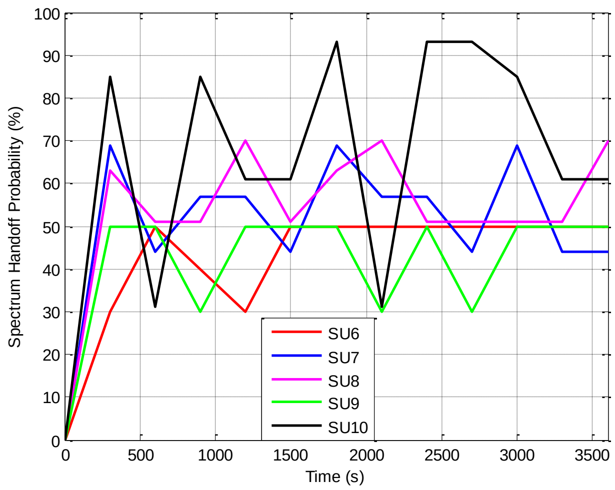


Figure 5. Spectrum handoff probabilities according to the medium usage intensity of primary users.

In Figure 6, the medium usage intensity of primary users and noise effect are kept constant. Spectrum handoff possibilities are given for the first five users. When the probability values of the concerned five users are examined over the duration of the simulation, it is seen that it changes between 10% and 50%.

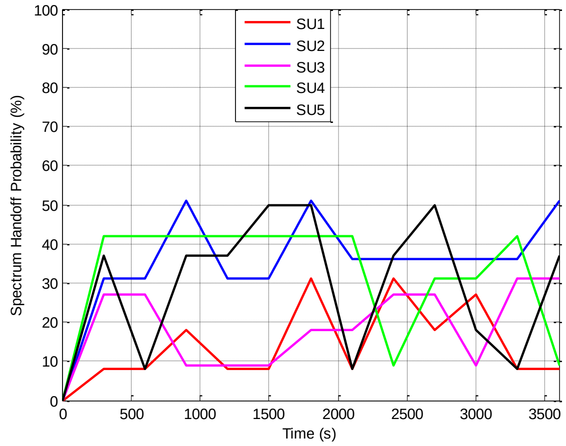


Figure 6. Spectrum handoff probabilities according to the data rate of secondary users.

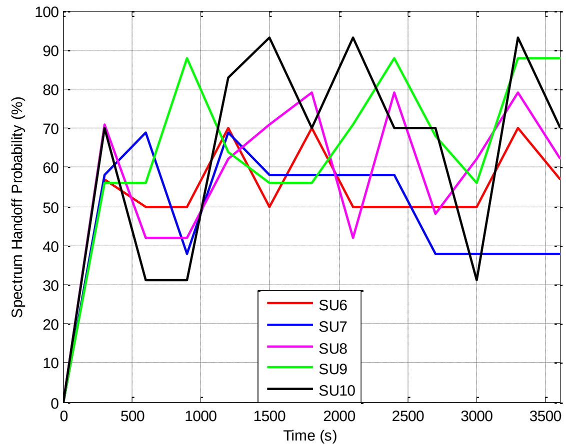


Figure 7. Spectrum handoff probabilities according to the data rate of secondary users.

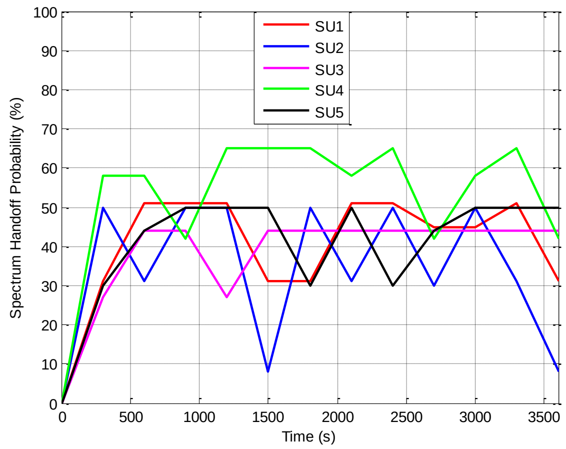


Figure 8. Spectrum handoff probabilities according to noise effect in the environment.

In Figure 7, the medium usage intensity of primary users and noise effect are kept constant. Spectrum handoff possibilities are given for users other than the first five users, i.e., the last five users.

In Figure 8, the medium usage intensity of primary users and the data rate of the secondary users are kept constant. It has been observed that the spectrum handoff probabilities for the first five users vary between 10% and 65%.

In Figure 9, the medium usage intensity of the primary users and the data rate of the secondary users are kept constant. For the other five users, spectrum handoff rates were detected to vary between 10% and 90%.

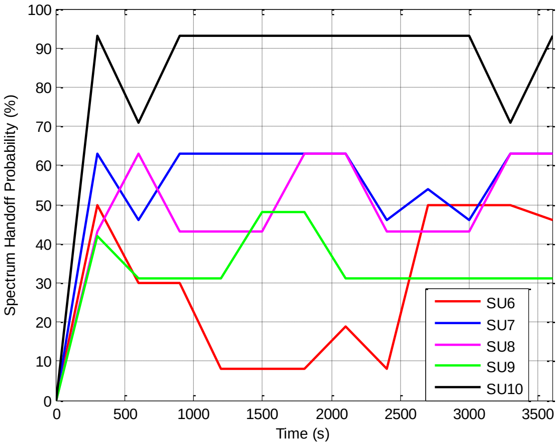


Figure 9. Spectrum handoff probabilities according to noise effect in the environment.

## 4 Conclusion

In our work, a fuzzy logic based spectrum handoff decision mechanism in which the output parameter is probability of spectrum handoff is proposed. Input parameters of the system are determined as medium usage intensity of primary users, data rate of secondary users and noise effect in the environment. By examining the effect of each input parameter separately, it is investigated that which input parameter how much influences the spectrum handoff ratio. As a result, it has been determined that medium usage intensity of primary users is dominant over the other three input parameters. In future works, the fuzzy logic based system may be designed with different input parameters.

## 5 Acknowledgment

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## 6 References

[1] Akyildiz I. F., Lee W. Y., and Chowdhury K. R., "CRAHNS: Cognitive Radio Ad Hoc Networks", *Ad Hoc Networks*, vol. 7, pp. 810-836, 2009.

[2] Ahmed E., Yao L. J., Shiraz M., Gani A., and Ali S., "Fuzzy based Spectrum Handoff and Channel Selection for Cognitive Radio Networks", *IEEE International Conference on Computer, Control, Informatics and its Applications*, pp. 23-28, 2013.

[3] Giupponi L., and Neira A. I. P., "Fuzzy based Spectrum Handoff in Cognitive Radio Networks", *IEEE International Conference on Cognitive Radio Oriented Wireless Networks and Communications*, pp. 1-6, 2008.

[4] Kaur P., Uddin M., and Khosla A., "Fuzzy Based Adaptive Bandwidth Allocation Scheme in Cognitive Radio Networks", *IEEE International Conference on ICT and Knowledge Engineering*, pp. 41-45, 2010.

[5] Rout A., Sethi S., and Banerjee P. K., "Fuzzy Based Reliable and Efficient Communication in Cognitive Radio Ad Hoc Network", *IEEE International Conference on Control, Instrumentation, Energy & Communication*, pp. 494-497, 2014.

[6] He Q., Feng Z., and Zhang P., "Reasoning Through Fuzzy Logical for Reconfiguration in Cognitive Radio Network", *IEEE International Conference on Wireless Communications and Signal Processing*, pp. 1-5, 2011.

[7] Tabakovic Z., Grgic S., and Grgic M., "Fuzzy Logic Power Control in Cognitive Radio", *IEEE International Conference on Systems, Signals and Image Processing*, pp. 1-5, 2009.

[8] Mustafa W., Yu J. S., Andersson E. R., Mohammed A., and Kulesza W. J., "Fuzzy based Opportunistic Power Control Strategy in Cognitive Radio Networks", *IEEE International Symposium on Applied Sciences in Biomedical and Communication Technologies*, pp. 1-5, 2010.

[9] Çalhan A., and Çeken C., "An Optimum Vertical Handoff Decision Algorithm Based on Adaptive Fuzzy Logic and Genetic Algorithm", *Wireless Personal Communications*, vol. 64, pp. 647-664, 2012.

[10] Ejaz W., Hasan N. U., Aslam S., and Kim H. S., "Fuzzy Logic based Spectrum Sensing for Cognitive Radio Networks", *IEEE International Conference on Next Generation Mobile Applications, Services and Technologies*, pp. 185-189, 2011.

[11] Le H. S. T., and Ly H. D., "Opportunistic Spectrum Access using Fuzzy Logic for Cognitive Radio Networks", *IEEE International Conference on Communications and Electronics*, pp. 240-245, 2008.

[12] Maheshwari P., and Singh A. K., "A Fuzzy Logic based Approach to Spectrum Assignment in Cognitive Radio Networks", *IEEE International Advance Computing Conference*, pp. 278-281, 2015.

[13] Nabil M., and Nainay M. E., "Fuzzy based Assignment Algorithm for Channel Sensing Task in Cognitive Radio Networks", *IEEE Symposium on Computers and Communication*, pp. 1-6, 2016.

[14] Bayrakdar M. E., Bayrakdar S., Yücedağ İ., and Çalhan A., "Bilişsel Radyo Kullanıcıları için Bulanık Mantık Yardımıyla Kanal Kullanım Olasılığı Hesabında Farklı Bir Yaklaşım", *Düzce Üniversitesi Bilim ve Teknoloji Dergisi*, vol. 3, pp. 88-99, 2015.

[15] Bayrakdar M. E., and Çalhan A., "Fuzzy Logic based Spectrum Handoff Decision for Prioritized Secondary Users in Cognitive Radio Networks", *IEEE Fifth International Conference on Digital Information Processing and Communications*, pp. 71-76, 2015.

[16] Bayrakdar M. E., and Çalhan A., "Bilişsel Radyo Ağlarında Kural Tabanlı Spektrum El Değiştirme Karar Mekanizması", *Akıllı Sistemlerde Yenilikler ve Uygulamaları Sempozyumu*, pp. 05-08, 2016.