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Fuzzy-logic-based channel selection in IEEE 802.22 WRAN

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ABSTRACT

IEEE 802.22 WRAN standard does not specify algorithm for selecting *operating* channel from *backup* channel list and prioritizing the *backup* and *candidate* channels. Because all the channels in the *backup* and *candidate* channels list are not with the same properties, selecting channels randomly from the list may decrease the networks performance. We propose an approach of ranking channel according to behavior of primary users on the channel and RSSI value. It utilizes fuzzy-logic-based algorithm for prioritizing channels in the *backup* and *candidate* channels list. Performances of the networks with fuzzy-logic-based channel selection and random channel selection are compared.

1. Introduction

In the IEEE 802.22 wireless regional area network (WRAN) [1], channels are classified into two categories, namely available channels and unavailable channels. Channels that are currently used by any primary user (PU) such as analog TV, digital TV or wireless microphones are the unavailable channels.

The available channels are categorized in the following channels. (i) Operating, (ii) Backup, (iii) Candidate, (iv) Protected (v) Occupied, and (vi) Unclassified. The base station (BS) maintains all the available channel sets and the customer-premises equipment (CPE) maintains only operating, backup, and candidate channel lists.

The update duration of these lists are different among themselves, and also between BS and CPE. For example, on the CPE side, the operating set is confirmed by every received superframe control header (SCH), backup and candidate sets are updated after receiving the downstream channel descriptor (DCD) message, and the protected set is updated after receiving the channel occupancy update (CHO-UPD) message. After synchronization, BS sends a CHO-UPD message to update the occupied channel set for the newly connected CPEs. In case of BS, channel sets are updated after each quiet period either periodically or demand-based [2].

IEEE 802.22 WRAN standard does not specify the algorithm for selecting the operating channel from the *backup* channel list and the *backup channel* from the *candidate* channel list. If the channels are selected randomly, there is a possibility of selecting channels with lower quality affecting the network performance. To mitigate such possibilities, we propose a fuzzy-logic-based approach for ranking channels according to behavior of PUs on the channel. The proposed fuzzy-logic-based approach prioritizes channels and helps to promote and demote the channels to and from operating, backup and candidate channels.

Fuzzy-logic is applied in various telecommunications domains, because it is useful in very complex processes. Recently, it has been popular for decision making process in cognitive networks [3–11]. With the anticipation that IEEE 802.22 WRAN has cognitive radio conception [12],

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integrating artificial decision making system for channel selection may enhance the systems performance.

2. Fuzzy-logic-based channel selection

To mitigate the complexity of the algorithm, the proposed algorithm uses two fuzzy logic controllers (FLCs). First fuzzy logic controller (FLC-1) considers the behavior of the PUs on the channel, such as how often PUs come on the channel, and once they arrive on the channel, how long they occupy the channel.

Figs. 1–3 show the fuzzy inference system (FIS) of FLC-1. In this Mamdani-type FIS, there are two membership functions as shown in Figs. 1 and 2. First input is behavior

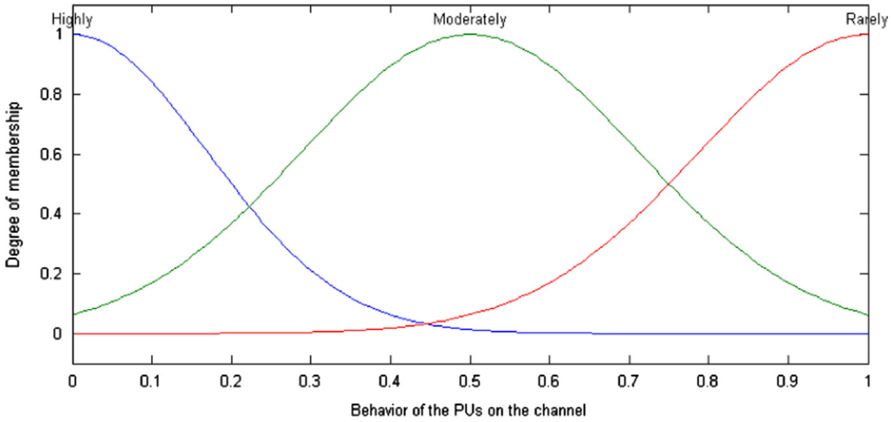

Fig. 1. MF showing how often PUs come on the channel.

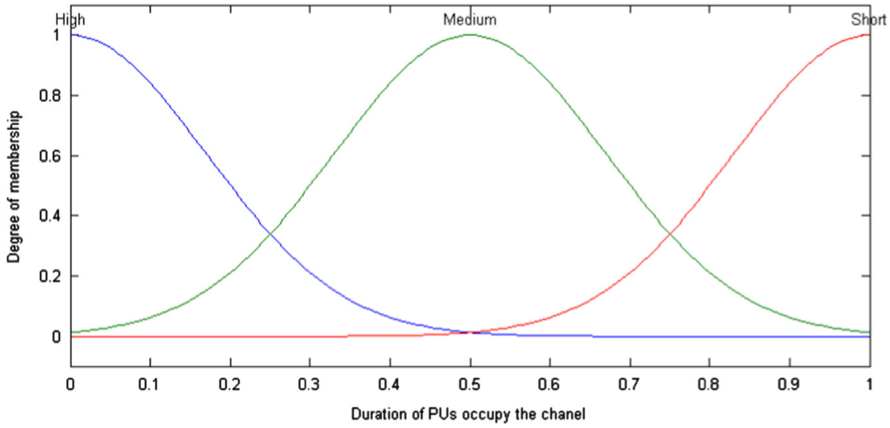

Fig. 2. MF showing for how long PUs occupy the channel once they arrive.

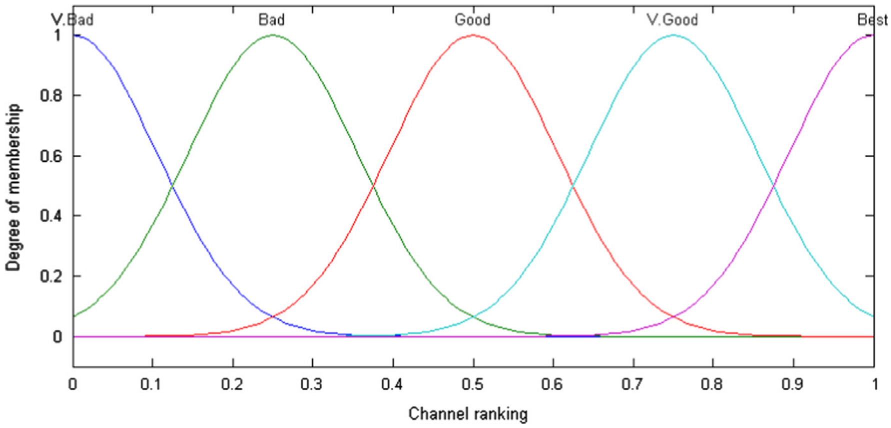

Fig. 3. Output MF plot.

of PUs, and the second is for tenure of PUs. Each of these membership functions has three input values as in Figs. 1 and 2.

Table 1
Fuzzy inference rules contained in the fuzzy logic controller-1 fuzzy rule base.

Rule	How often PUs come on the channel?	For how long PUs occupy the channel?	Decision
1	Rarely	Short	Best
2	Rarely	Medium	Very Good
3	Rarely	High	Good
4	Moderately	Short	Very Good
5	Moderately	Medium	Good
6	Moderately	High	Bad
7	Frequently	Short	Good
8	Frequently	Medium	Bad
9	Frequently	High	Very Bad

The FIS has nine rules and the output membership function has five output values as shown in Fig. 3. Fuzzy inference rules and decision contained in the FLC-1 fuzzy rule base are given in Table 1.

Figs. 4–6 show the FIS of the second fuzzy logic controller (FLC-2). In this FIS, there are two input membership functions with three inputs and one output membership function with five outputs. Fig. 4 shows the average idle duration of the channel in the history. This membership function has three input values, 'high', 'moderate' and 'low'. 'High' means this channel has long average idle time, followed by 'moderate' and 'low' average idle time.

The second membership function shows the recent idle duration of the channel as shown in Fig. 5. In this scenario recent value is more significant than the old value. Therefore longer the recent idle time of the channel, better the channel. This membership function also has three input values, 'high', 'medium' and 'low'. In this, 'high' means this channel has the longest idle time recently, followed by 'medium' and 'low'.

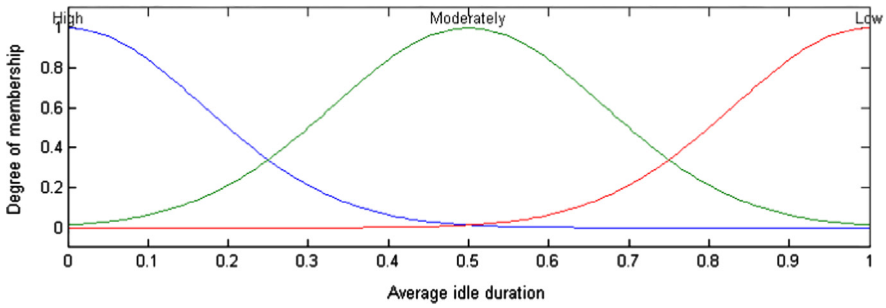

Fig. 4. MF showing average idle duration of the channel.

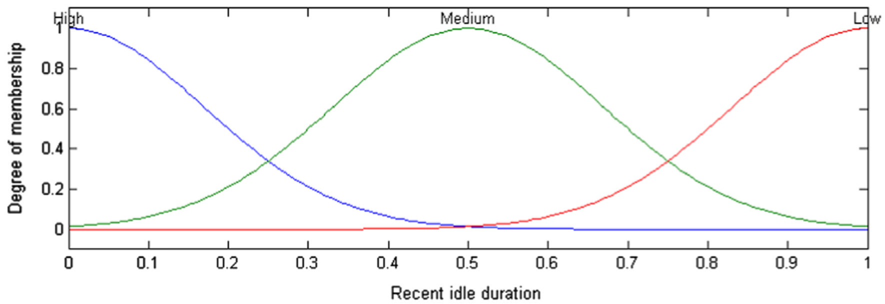

Fig. 5. MF showing recent idle duration of the channel.

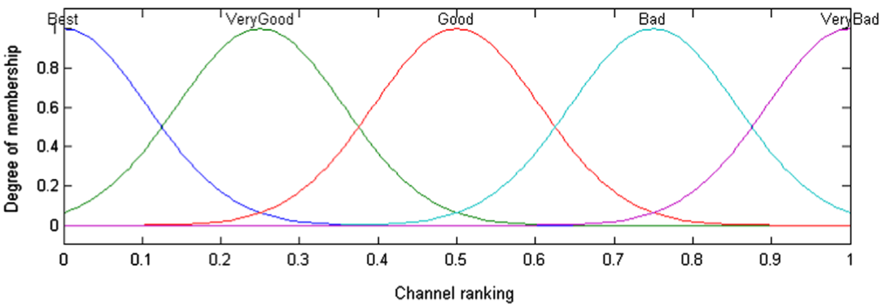

Fig. 6. Output MF plot.

Fig. 6 shows the plot of the output membership function. This is the channel ranking output with the five output values, numbered between one (best) and zero (very bad).

Table 2 lists fuzzy inference rules contained in the FLC-2 fuzzy rule base. As given in the rule 3 of the Table 2, if average idle time is 'high' and recent idle time is 'low', the decision is bad, because the significance of the latest value is higher. Similarly, in rule 7 and rule 8, if the average idle time is 'low' and recent idle time is 'high' or 'medium', the decision is 'very good' or 'good'.

3. Simulation results

Figs. 7 and 8 show the simulation results of the proposed fuzzy-logic-based channel selection algorithm.

In Fig. 7, the channel ranking with various tenure and behavior of PUs is plotted.

A channel in which PUs arrive frequently and stays on the channel for a long time is ranked as the worst channel.

Table 2
Fuzzy inference rules contained in the Fuzzy Logic Controller-2 fuzzy rule base.

Rule	Average idle time	Recent (last) idle time	Decision
1	High	High	Best
2	High	Medium	Very Good
3	High	Low	**Bad**
4	Moderate	High	Very Good
5	Moderate	Medium	Good
6	Moderate	Low	Bad
7	Low	High	**Very Good**
8	Low	Medium	**Good**
9	Low	Low	Very Bad

If PUs do not arrive on the channel frequently, and even if they arrive, they utilize the channel for a short period of time, the channel is rank as the best channel. The ranking of the channel is numbered between zero (worst) and one (best).

Fig. 8 shows the channel ranking considering recent idle duration of the channel and average idle duration. Channel ranking is numbered between zero and one. When recent idle duration and average idle duration are the longest, then the channel is ranked as the best channel.

Numbering RSSI values between zero and one, and averaging channel ranking results from FIS, we can determine the best channel among the available channels.

To see the performance of the proposed fuzzy-logic-based channel selection method, we simplify the simulation with the following basic parameters. There is only one BS and 18 CPEs, thus we do not consider the self-coexistence among WRAN systems. Spectrum information is collected from geo-location information system. BS has complete geo-location information and we do not consider the terrestrial geo-location system. BS has full television white space (TVWS) information, therefore there is no need to receive information from database system. CPE spectrum sensor and BS spectrum sensor provide perfect sensing results. CPEs are deployed in the random distance from the BS in 17×17 km^2 area. Channel idle probability is 0.6–1. We consider that there is no wireless microphone (part 74) in the entire WRAN cell in the considered band. If channel i is occupied by an incumbent then CPEs and BS will not operate on channel i, $i+1$ and $i-1$. Maximum allowed effective isotropic radiated power (EIRP) is in the range –64 dBm to +63.5 dBm. For the simplicity, we consider only downlink traffic. We do not consider the fine sensing and fine sensing results.

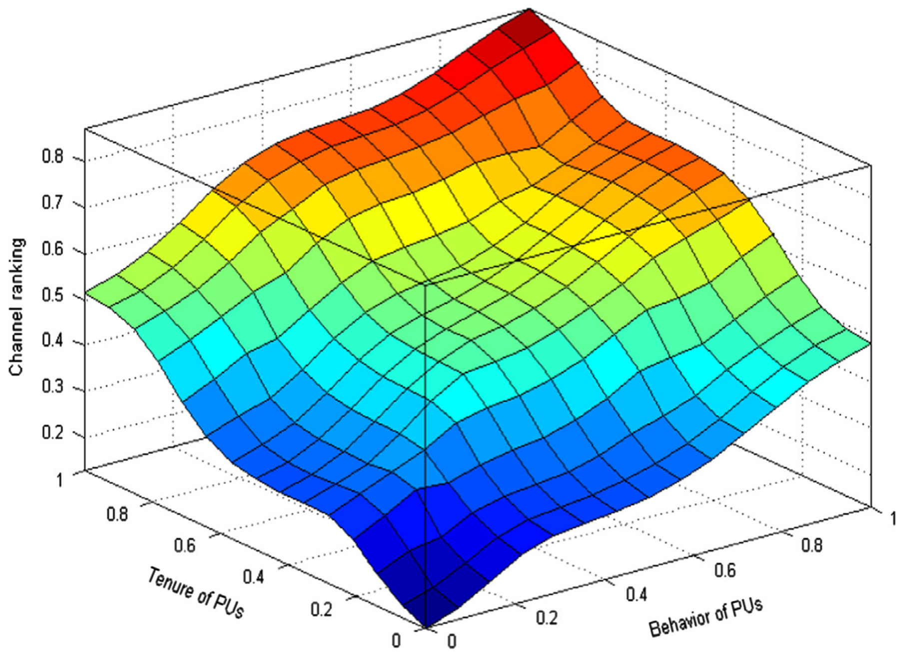

Fig. 7. Channel ranking considering tenure of PUs on the channel and behavior of PUs (FLC-1).

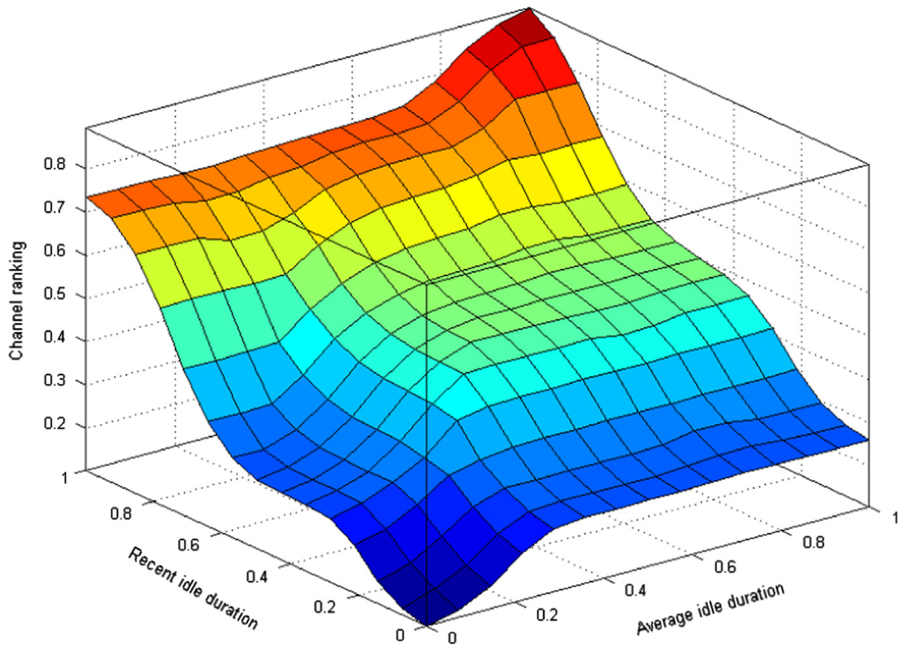

Fig. 8. Channel ranking considering recent idle duration of the channel and average idle duration (FLC-2).

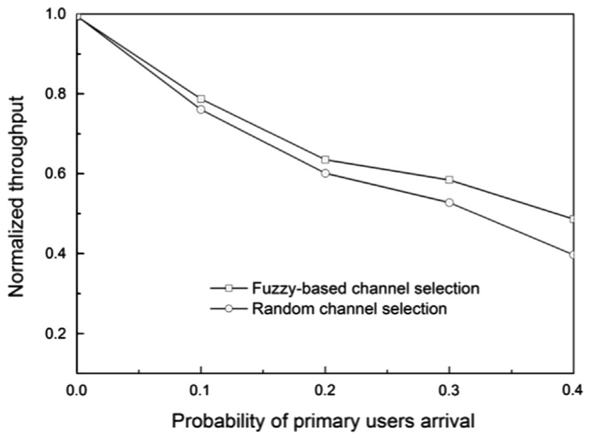

Fig. 9. Normalized throughput of the network with fuzzy-logic-based channel selection and random channel selection.

Fig. 9 shows the normalized throughput of the proposed system. Here, the normalized throughput is defined as the ratio between the average throughput for the entire network and the traffic load. When the channels are idle then normalized throughputs are similar. However, when the probability of PUs' arrival increases the gap between fuzzy-logic-based channel selection and random channel selection increases. This result shows that selecting channel according to the proposed channel selection method provides better performance.

4. Conclusion

In this work, we used fuzzy-logic-based algorithm for prioritizing channels in the backup and candidate channel list in IEEE 802.22 WRAN standard. The result presented in this paper may help for ranking channel, which in fact help for selecting the operating channel from the *backup* channel list, and selecting better channel to promote to backup channel from candidate channels. Similarly, it helps to demote channel from operating to backup and from backup to candidate channels.

The simulation results show that the proposed fuzzy-logic-based channel selection performs better than random channel selection.

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