RESEARCH ARTICLE OPEN ACCESS

Maximum Utilization Of Spectrum Through Cognitive Radio System Using Fuzzy Logic System

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ABSTRACT

The main challenge to take advantage of spectrum access lies in finding balance in conflicting goals of satisfying performance requirements while minimizing interference. There are many methods were proposed to use spectrum effectively, the method of spectrum access has become the most possible approach to achieve near-optimal spectrum utilization by allowing secondary (unlicensed) users to sense and access available spectrum effectively. Opportunistic spectrum access approaches were enabled by cognitive radios, which are able to sense the unused spectrum and adapt their operating characteristics to the real-time environment. However, a naive spectrum access for secondary users can make spectrum utilization inefficient and increase interference to adjacent users. This paper proposed a novel approach using Fuzzy Logic System (FLS) to control the spectrum access. The linguistic knowledge of spectrum access are based on three descriptors namely spectrum utilization efficiency of the secondary user, its degree of mobility, and distance of the primary user from the secondary users. In this thesis, Opportunistic spectrum access has been attained with the possibility of accessing the spectrum by the secondary user's in order to improve spectrum utilization which is needed for next generation wireless networks.

By this proposed mechanism, spectrum usage could be improved and multiple radio users or wireless links can coexist over the same spectrum. Therefore, it also becomes possible that radio users or wireless links can transmit over unspecific and unfixed spectrum bands.

Keywords:- cognitive radios, Fuzzy Logic System, spectrum access.

I. BASIC CONCEPTS OF COGNITIVE RADIO

Cognitive radio (CR) is a form of wireless communication in which a transceiver can intelligently detect which communication channels are in use and which are not, and instantly move into vacant channels while avoiding occupied ones. This optimizes the use of available radio-frequency (RF) spectrum while minimizing interference to other users.

In its most basic form, CR is a hybrid technology involving software defined radio (SDR) as applied to spread spectrum communications. Possible functions of cognitive radio include the ability of a transceiver to determine its geographic location, identify and authorize its user, encrypt or decrypt signals, sense neighboring wireless devices in operation, and adjust output power and modulation characteristics.

There are two main types of cognitive radio, full cognitive radio and spectrum-sensing cognitive radio. Full cognitive radio takes into account all parameters that a wireless node or network can be aware of. Spectrum-sensing cognitive radio is used to detect channels in the radio frequency spectrum.

The Federal Communications Commission (FCC) ruled in November 2008 that unused portions of the RF spectrum (known as white spaces) are made available for public use. White space devices must include technologies to prevent interference, such as spectrum sensing and geo location capabilities.

The idea for CR was developed by Joseph Mitola at the Defense Advanced Research Projects Agency (DARPA) in the United States. Full cognitive radio is sometimes known as "Mitola radio."

Regulatory bodies in various countries found that most of the radio frequency spectrum was inefficiently utilized. For example, cellular network bands are overloaded in most parts of the world, but amateur radio and paging frequencies are not. This can be eradicated using the dynamic spectrum access.

II. DYNAMIC SPECTRUM ACCESS

Dynamic spectrum access techniques allow the cognitive radio to operate in the best available channel. Radio spectrum is considered as a scarce resource with the growing demand for spectrum-based services because a major portion of the spectrum has been allocated for licensed wireless applications.

The first step in Dynamic spectrum access is the detection of unused spectral bands. Therefore, CR device is used for measuring the RF energy in a channel to determine whether the channel is idle or not. But, this approach has a problem in that wireless devices can only sense the presence of a primary user (PU) if and only if the energy detected is above a certain threshold. Dynamic spectrum access Taxonomy is shown in the Figure 1.1.

Generally, Dynamic spectrum access can be categorized into three models namely:

1. Dynamic Exclusive use model
2. Open sharing model
3. Hierarchical Access model

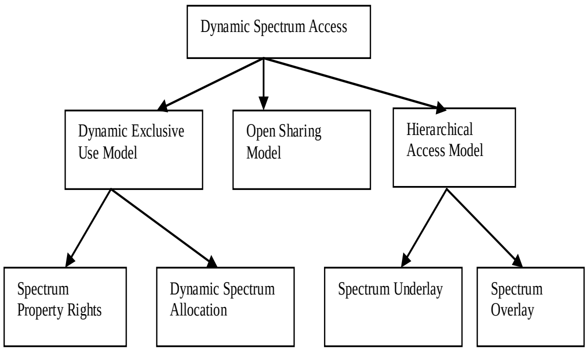

Figure 1.1 Taxonomy of Dynamic Spectrum Access

III. CLASSIFICATION

In deployment, the cognitive radio network is extended to two different types of mechanism: opportunistic spectrum access and spectrum sharing [2], [3], [4],[5]. Both of them are subject to interference constraints but in different ways. In opportunistic spectrum access, the PU link and CR link utilize spectrum exclusively. With the low priority, the CR senses spectrum to seek available spectrum holes before each spectrum utilization cycle. When the spectrum is not utilized by the PU link, the CR link comes to utilize spectrum with a dynamic and opportunistic duration until it is utilized by the PU link again.

Since the collision of two wireless links causes interference to each link, the ideal coexistence is that both wireless links can cooperate perfectly without any collision or idle state. However, due to imperfect channel estimation and dynamic spectrum usage, the ideal coexistence is not easy to implement. Consequently, the interference occurs to each link when the CR link collides with the PU link. The more frequently they collide, the more frequent interference occurs. Thus, the CR link optimizes the duration of spectrum sensing to limit the interference to the PU link [2].

In spectrum sharing, the PU link and CR link utilize spectrum simultaneously. When both wireless links transmit together, the interference occurs constantly to each link and the interference intensity depends on the scale of transmit power. To limit the interference intensity to the PU link and assure the desired QoS on the PU link, the CR link senses the transmission status of the PU link and allocates a proper power scale to transmit [4], [5].

IV. FUZZY LOGIC SYSTEM

Fuzzy logic starts with and builds on a set of user-supplied human language rules. The fuzzy systems convert these rules to their mathematical equivalents. This simplifies the job of the system designer and the computer, and results in much more accurate representations of the way systems behave in the real world.

DUFUZZIFICATION: The output of the fuzzy reasoning is changed into a non-fuzzy number that represents the actual output of the system.

Fuzzy sets theory is an excellent mathematical tool to handle the uncertainty arising due to vagueness.

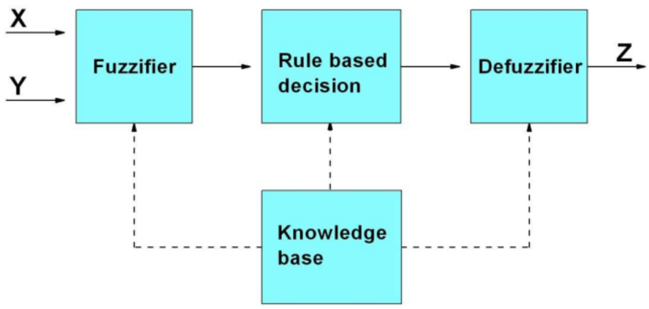

Figure 1.2 The Structure of the Fuzzy Logic System

Since there is a need to "fuzzify" the fuzzy results we generate through a fuzzy system analysis i.e., we may eventually find a need to convert the fuzzy results to crisp results. Here, we may want to transform a fuzzy partition or pattern into a crisp partition or pattern; in control we may want to give a single-valued input instead of a fuzzy input command. The "dufuzzification" has the result of reducing a fuzzy set to a crisp single-valued quantity, or to a crisp set.

PERFORMANCE METRICS

In this section, we discuss about the performance metrics to study the impact of spectrum sharing on the service providers including call blocking rate, Interference, Revenue efficiency, channel utilization, etc.

4.1 CALL BLOCKING RATE

The call blocking rate R_{BL} is defined as the ratio of total blocked calls over total calls processed by all service providers and corresponds to:

$$R_{BL} = \lim \frac{n_{BL}^{(total)}(t)}{n_{processed}^{(total)}(t)}$$

where total blocked calls at time t by all service providers is given by

$$n_{BL}^{(total)}(t) = \sum_{i=1}^{n_{sp}} n_{BL}^{(i)}(t)$$

and the total calls processed is:

$$n_{proccessed}^{(total)}(t) = \sum_{i=1}^{n_{sp}} n_{processed}^{(i)}(t)$$

where n_{sp} is the number of service providers. Here, the call would be blocked, if all the service providers are over-loaded.

SPECTRUM UTILIZATION EFFICIENCY

The Spectrum Efficiency $\eta_s^{n(sp)}$ is defined as the ratio of average busy channels over total channels owned by service providers. It corresponds to

$$\eta_s^{n(sp)} = \lim \frac{1}{t}\int_0^t \frac{n_{busy}^{n(sp)}(t)}{N_{ch-total}^{n(sp)}(t)} dt$$

where $n_{busy}^{n(sp)}(t)$ is the number of channels used at time t for service provider $n_{(sp)}$ and $N_{ch-total}^{n(sp)}(t)$ is the total number of total channels owned by service provider $n_{(sp)}$.

Higher Spectrum efficiency is estimated because the call blocking rate is lower; thus more calls can contribute to the spectrum utilization.

V. CONCLUSION

This allows also other next generation mobile network users to benefit from available radio spectrum, leading to the improvement of overall spectrum utilization and maximizing overall PU and SU networks capacity.

The proposed approach was using a Fuzzy Logic System to detect the effective spectrum access for secondary users via cognitive radio. The secondary users are selected on the basis of spectrum utilization, degree of mobility and distance from secondary users to the primary user. By using the above antecedents, we have calculated the possibility of accessing the spectrum for secondary users.

Here, the call blocking and interference have minimized. So that we can have better and efficient spectrum utilization. Also, we calculated the highest possibility for utilizing (accessing) the spectrum band for the secondary users. Hence, the approach is promising to be implemented practically in future cognitive radio networks.

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