Title of Thesis: Radio Resource Management in Wireless Networks

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Abstract

Resource management of wireless networks is a broad topic involving a number of thrust areas pertaining to a number of different network technologies whose usage is to be optimized. Resource management is required for all types of wireless networks such as cellular networks, WLANs, mobile ad hoc networks and sensor networks.

Radio resource management (RRM) strategies are employed for an utmost efficient utilization of the air interface resources in the Radio Access Network. The system performance can be improved by applying intelligent RRM scheme in wireless networks. So, distributed solutions to the resource management are motivated by the need to cope with the complexity in modern wireless communication networks.

Since Dynamic Spectrum Access (DSA) technology helps to minimize unused spectrum wastage, it is certainly a promising approach for alleviating spectrum scarcity that wireless communication faces today. In short, it aims at re-using sparsely occupied/utilized frequency bands, while causing no (or insignificant) interference to the actual licensees.

There is a tight relationship between efficient spectrum management and Cognitive Radio (CR). Flexible spectrum management is needed for wireless devices that operate in either the licensed band or the unlicensed band, or both. CR will provide the technical means for determining, in real-time, the best band and best frequency to provide the services desired by the user at any time. It is aimed at relieving the situation of scarcity by identifying and exploiting the underutilized radio spectrum.

The advances of CR technologies make more efficient and intensive spectrum access possible. The first task of the CR system is to sense the wireless environment over the electromagnetic frequency band and identify the occupied bands and hence the existence of spectrum holes. This task is performed so that the secondary users can invisibly utilize the band without interfering with the licensed users. The main challenge of this task is in the identification and detection of primary user (PU) signals in noisy radio environments. Primary user (PU) detection is based on the detection of a weak signal from a primary transmitter through the local observations of CR users. Three schemes are generally used for transmitter detection; Matched Filter (MF), Energy Detection (ED), and Cyclostationary Detection (CSD).

Horizontal Spectrum Sharing in the unlicensed spectrum band has been studied in the first part of this thesis. Spectral sensing and management for three types of wireless signals within the IEEE802 family (Wi-Fi, Zig-Bee and Bluetooth) are simulated and examined. A simulation system is designed and ED has been used to detect the presence of these signals in the radio environment. New user tries to exploit efficiently the spectrum when the channel is idle. The simulation results show that delay time for changing the status between exploiting and vacating the channels is negligible. Error detection was seen in a limited range of SNR because of using fixed threshold level. Vertical Spectrum Sharing for licensed spectrum has been also studied. With the expected growth of WiMAX, GSM and CDMA networks, the number of interference cases will increase. So, coordination carried out among public mobile networks and GSM operators, shows that there exist remedies to differentiate them when deployed in adjacent frequencies and in close geographical vicinity. To differentiate and discriminate among WiMAX, GSM and CDMA signal, an expanding of the function of Hop Rate Detector (HRD) or Bouncy Detector (BD) has been implemented using Matlab simulation. These noisy signals have been simulated, and it is shown that the BD can work to differentiate among their shapes accurately with negligible error even with low SNR values. This along with it's simplicity, is a big advantage of the BD over conventional methods (i.e. MF, ED and CSD), which suffers from many problems like design complexity, difficulty in fixing the threshold level values and high false alarm probability in noisy environment. After this stage, a CR has

been used to opportunistically fill the discovered gaps of unused spectrum to improve the spectral efficiency for the signals already detected earlier. It is for the first time to the best of my knowledge, that the behaviour of these three systems was examined together in one system. The Periodogram Energy Detector (PED) was used to detect the presence of the PUs after these signals passed through the BD. The simulation results of the detection and the exploitation of an idle channel were noted to be error-free at high value of SNR. However, it was observed that some errors occurred only with low values of SNR. Negligible delay times were observed between PU and SU occupying and vacating the channel.

Using Fuzzy Logic (FL) control system in CR systems has been a challenging task. Although FL is suitable for CR network because of the uncertainty involved, the design generally becomes very complicated because of the 'curse of dimensionality'. Hierarchical Fuzzy System (HFS) can be used to solve this problem. The number of fuzzy rules could be a linear or nearly-linear function of the number of inputs by arranging the inputs in hierarchical ways and allowing the consequent part of a rule to be an antecedent to the next step.

A collaborative sensing is discussed using FLS as an effort for mitigating challenges of spectrum sensing arising due to channel fading. A novel two levels HFS has been implemented to accomplish cooperative spectrum sensing (CSS) and then opportunistic spectrum access (OSA) in first and second levels respectively. Three separate branches each of two levels HFS for three PUs (i.e. CPFSK, 8QAM and 8FSK) have been designed. The first level controllers estimate cooperatively the probability of presence of these PUs using nine SUs (i.e. CSS). The second level controllers estimate the percentage ratio of possibility of allocating the idle channel(s) (Poss. of Allo. Ch.) to the SUs (i.e. OSA). In this thesis, the antecedents for second level FLS are proposed as follows:

Antecedent 1: Waiting Time (TW): The time since the last accessing to the idle channel.

Antecedent 2: Secondary User Power (PSU): The transmitted power value for the SU.

Antecedent 3: The Percentage Ratio of Spectral Utilization (%Uspec.): The ratio of the spectral band from overall available spectrum needed by the SU for its transmission.

The simulation results indicate that FL can be used in CSS to provide additional flexibility in decision making and in OSA to allow the most suitable SU to occupy the available band.

To mitigate the effects of channel fading and to improve the performance of the system when PU(s) and/or SU(s) are mobile, all SU nodes are asked to detect the presence of PU in an organized manner by adding a proposed Hopping Sequence (HS) module to FLS.

The all SUs are divided into hopping groups depending on the number of PUs and SUs. The number of hoping groups is equal to the number of PUs. Sequentially, some of SU nodes are chosen to detect PUs in the first time slot and another group of SU nodes are chosen in second time slot and so on, depending on the number of SUs, number of PUs and the sequence design. The process goes on till all the SUs go through checking all the PU band(s).

To implement the HS module, two different hopping sequences are proposed- Random Hopping (RA-H) (i.e. randomly choosing the SU), and Sequential Hopping (SE-H) (i.e. choosing SU's sequentially in orderly manner).

Three possible scenarios with four examples were discussed and different sequences were designed depending on the total number of SUs and PU(s) as given below:

Only one PU and more than one SU.

More than one PU, but the number of SUs is greater than PUs.

Equal number of PUs and SUs.

The simulation results show enhancement in the accuracy of estimating the probability of PU presence (pPU) over conventional cooperative sensing because all the SU detectors irrespective of their positions, contribute in detecting the band(s) of PU(s) and hence are more effective in a scenario when all or some of the PUs/SUs are mobile. This is also helps to mitigate the hidden node problem.