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A Review: Dynamic Spectrum Access protocols in Cognitive Radio Networks

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***Abstract*- To fully utilize the insufficient spectrum resources Dynamic spectrum access (DSA) has become a promising approach. In this paper, for DSA we have investigated continuous-time Markov models with both the interactions between primary and secondary users in open spectrum wireless networks including both queuing and no queuing cases, DSA with perfect sensing (PS) and imperfect sensing (IS), DSA scheme and the effects of imperfect spectrum sensing (i.e. miss-detection and false alarm), a primary-prioritized Markov approach for DSA. Advantages, drawbacks, and further design challenges of cognitive MAC protocols are discussed. Analytical results are derived based on the Markov models. To compare the performances of these protocols, simulation results are presented. The DSA with PS model is solved explicitly using a two-dimensional Markov chain, while the DSA with IS model is solved numerically using a two-dimensional Markov chain. Numerical results illustrate that the effect of DSA with IS as compared with DSA with PS. Since, miss-detection would lead to collision between primary and secondary users, optimal access probabilities for secondary users have been derived, so that the QoS of primary users in terms of collision probability is guaranteed.**

Keywords- DSA, spectrum, imperfect sensing, MAC protocols, miss-detection, false alarm

1. INTRODUCTION

Nowadays, the electromagnetic spectrum assigned to wireless networks depends on many factors like on the purpose, the geographical region, the particular carrier, and many others. This spectrum assignment is controlled by governmental agencies such as the Federal Communications Commission (FCC) in United Sates (US). FCC is responsible for allocating frequencies and call signs, managing the broadcast spectrum, and regulating other technical issues such as interference with electronics equipment. They assign the spectrum to licensed holders on a long-term basis. Since limited availability of spectrum and inefficiency in spectrum usage arises a need to change the way in which devices uses the spectrum. The most enabling technology for proper utilization of spectrum opportunistically and dynamically is Cognitive Radio Networks (CRNs). In CRNs the nodes (devices) equipped with the spectrum are easily movable radios that sense the availablespectrum band, reconfigure the radio frequency, switch to selected frequency and use it efficiently without interfering with primary users.

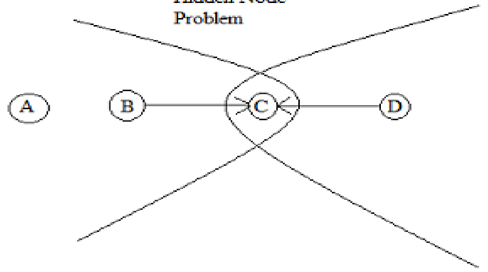
CRNs focus on providing high bandwidth to mobile users via heterogeneous wireless architectures and dynamic spectrum techniques. “Cognitive Radios” are the nodes that can change itself according to its environment in which it operates”. CR is an intelligent wireless communication system that is aware of its surrounding environment in which it operates (i.e., outside world) and uses the methodology of understanding-by-building to learn from the environment and adapt its internal states to statistical variations by making corresponding changes in certain operating parameters (e.g., transmit-power, carrier-frequency, and modulation strategy) in real-time, with two primary objectives in mind:-

1. “Highly reliable communications whenever and wherever needed and
2. Efficient utilization of the radio spectrum."

CR are allowed to access the spectrum opportunistically that is licensed to primary users without causing any interference or collisions to primary users as well as among themselves. The ultimate objective of CR is to obtain the best available spectrum band through cognitive *capability* and *reconfigurability*. *Cognitive capability* is defined as the ability of the device to sense, understand, and be aware of the conditions related to the surrounding environment, e.g., presence of the primary users, information about transmission frequency, bandwidth, transmission power and modulation among others. *Reconfigurability* is the secondary user’s capacity to make decisions and rapidly adapt their operation parameters accordingly. In order to take advantages of CR techniques we must find the unused portions of the spectrum also known as spectrum holes or white spaces. If these bands are later used by a PU, the CR device has the choice of either moving to another spectrum hole or staying in the same band but adapting its transmission power or modulation scheme in order to avoid the interference to PUs. The cognitive radio cycle is shown in Fig. 1.

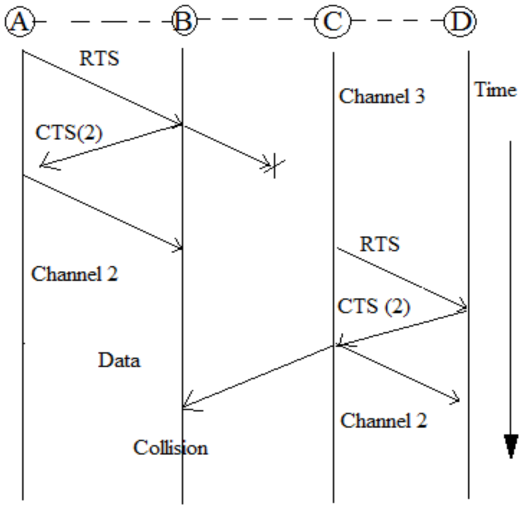
ISSUES IN COGNITIVE RADIO NETWORKS

1. Hidden terminal problem

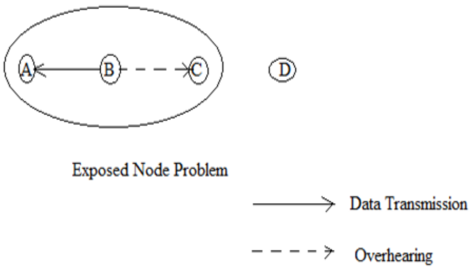


Single Channel Hidden Terminal Problem

2. Multi-channel hidden terminal problem



3. Exposed node problem



Single Channel Exposed Node problem

4. False alarm and misdetection
5. Selfish misbehaviour

To allocate the available bandwidth in an intelligent manner Dynamic spectrum Access (DSA) has been

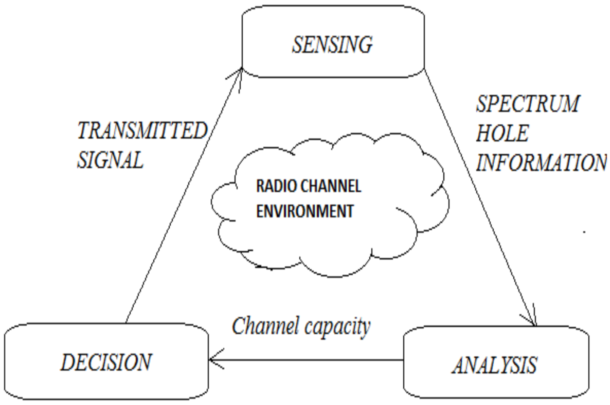


Fig. 1 Cognitive Radio Cycle

used [1]. In this paper, for DSA we have investigated continuous-time Markov models with both the interactions between primary and secondary users in open spectrum wireless networks including both queuing and no queuing cases, DSA with perfect sensing (PS) and imperfect sensing (IS), DSA scheme and the effects of imperfect spectrum sensing (i.e. miss-detection and false alarm), a primary-prioritized Markov approach for DSA.

II. RELATED WORK

Dynamic spectrum access helps in minimizing the unused spectrum bands [1]. Two schemes with queueing and without queueing are considered. These schemes assume perfect sensing. Scheme without queueing in [1] as DSA with perfect sensing (PS) classified for two radio systems. The arrival processes and departure processes of the two radio systems are all assumed to be Poissonian. The problem considered here is at the *spectrum level* and not at the *frequency channel level*. This case is also extended to spectrum level when *imperfect sensing* (IS) of the frequency channels of the spectrum are considered. In [2], the steady state probability of the Markov chain is explicitly expressed as a closed-form expression. The DSA scheme with IP for a special case is formulated using a two-dimensional Markov chain and the flow balance equations are explicitly formulated which can be solved using linear algebraic equations solution. The effect of *probability of false alarm* and *probability of misdetection* in the frequency spectrum channels are evaluated. A primary-prioritized Markov approach for dynamic spectrum access has been proposed in [3]. A model for the interactions between the primary users (legacy spectrum holders) and the secondary users (unlicensed users) as continuous-time Markov chains (CTMC), by which we can capture the system evolution dynamics, especially the effect of the primary user's activities on the secondary users. In this paper, we assume that when primary users exist in some spectrum band, secondary users cannot operate in the same band simultaneously. Further, in order to coordinate secondary spectrum access in a fair and efficient manner, dynamic spectrum access under different criteria is proposed based on the CTMC models. In the proposed approach, the spectrum access of different users is optimally coordinated through the modeling of secondary spectrum access statistics to alleviate mutual interference. We focus on the proportional-fair (PF) spectrum access approach to achieve the optimal tradeoff between spectrum utilization efficiency and fairness. The proposed PF spectrum access approach can achieve better performance than the CSMA-based scheme, and can be generalized to spectrum sharing among multiple secondary users. In [4], efficiently and fairly sharing the spectrum among secondary users has become an important issue, especially when multiple dissimilar secondary users coexist in the same portion of the spectrum band. Firstly, two new DSA schemes in the absence and presence of buffering mechanism for the secondary users has been proposed. Secondly, the system's evolutionary behavior, including the primary user's activities, is thoroughly captured through CTMC modeling. Moreover, the effects of spectrum sensing errors into our schemes. By deriving the optimal access probabilities for the secondary users, the QoS of the primary users in terms of collision probability is guaranteed and a good tradeoff between the spectrum efficiency and fairness is achieved.
In [5], a dynamic spectrum access network where multiple secondary users are allowed to access the temporarily

unused licensed spectrum bands in an opportunistic way. In particular, we consider the scenario where *M* secondary users coexist with one primary user, and the secondary users contend to access the free band. To achieve the maximum utilization of the spectrum band without causing extra interference to the primary user, it is assumed that the secondary users are capable of detecting the primary user's activities with spectrum sensors, i.e., the arrival and departure of primary user in the spectrum band. We also assume that the secondary users are not permitted to share the spectrum band simultaneously because the interference would result in throughput degradation. In [6] a MMAC protocol for CR networks (MMAC-CR) has been proposed. This MMAC protocol is based on the SRV scheme [7]. By allowing the terminals to enter a doze state when no communication is taking place, the MAC protocol achieves energy-efficient communication. Furthermore, the sensing algorithm relies on two phases: 1) a low power inaccurate scan and 2) a high-power accurate scan. By using the low-power scan for periodically scheduled scans and only using the accurate scan when the low-power scan detects a change, the sensing algorithm also achieves energy-efficient operation.

III. CONCLUSION

It is shown that continuous time Markov chain models are accurate in predicting the behavior of open spectrum access under the assumption that the arrival traffic has Poisson distribution. Dynamic spectrum access in wireless networks is observed to outperform the fixed spectrum access counterpart. The Markov model investigated

in this paper matches the simulated performance of an agile radio accurately. Analytical formulations of dynamic spectrum access with perfect sensing and imperfect sensing are presentenced. Numerical results demonstrated the effect of DSA with imperfect sensing over DSA with perfect sensing under the influence of probability of false alarm and probability of misdetection. In primary-prioritized Markov approach for dynamic spectrum access, the simulation results show that the proposed spectrum access with PF criterion can achieve up to 95% performance gain over a CSMA-based random access approach, and also achieves the optimal tradeoff between efficient spectrum utilization and fairness. PF criterion can achieve a good fairness between secondary users. Future work includes joint optimization of spectrum sensing and dynamic spectrum access. Performance metrics such as fairness, spectrum efficiency and average waiting time are developed for secondary users.

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