An Efficient Spectrum Decision Making Framework for Cognitive Radio Networks

Bhagyashree Anil Dere, Sheetal Bhujade

Abstract- This review paper is based on the spectrum decision framework for cognitive radio networks. Cognitive radio networks have been proposed as a solution to both spectrum inefficiency and spectrum scarcity problems. However, they face to a unique challenge based on the fluctuating nature of heterogeneous spectrum bands as well as the diverse service requirements of various applications. In this paper, a spectrum decision framework is proposed to determine a set of spectrum bands by considering the application requirements as well as the dynamic nature of spectrum bands. To this end, first, each spectrum is characterized by jointly considering primary user activity and spectrum sensing operations. Based on this, a minimum variance based spectrum decision is proposed for real-time applications, which minimizes the capacity variance of the decided spectrum bands subject to the capacity constraints. For best-effort applications, a maximum capacity-based spectrum decision is proposed where spectrum bands are decided to maximize the total network capacity.

Index Terms- spectrum decision framework, cognitive radio networks, spectrum scarcity, network capacity.

I. INTRODUCTION

Today's wireless networks are characterized as a static spectrum assignment policy. Recently, because of the increase in spectrum demand, this policy is faced with spectrum scarcity at particular spectrum bands. On the contrary, a large portion of the assigned spectrum is still used sporadically leading to underutilization of the significant amount of spectrum [9]. Hence, dynamic spectrum access techniques have recently been proposed to solve these spectrum inefficiency problems. The key enabling technology for dynamic spectrum access techniques is the cognitive radio technology, which provides the capability to share the wireless channel with licensed users (or primary users) in an opportunistic manner [1]. Cognitive radio (CR) networks are envisioned to provide high bandwidth to mobile users via heterogeneous wireless architectures and dynamic spectrum access techniques. CR networks, however, impose unique challenges because of the high fluctuation in the available spectrum as well as the diverse quality-of-service (QoS) requirements of various applications. To address these challenges, first, CR networks are required to determine which portions of the spectrum are available, called spectrum sensing [2], [10].

Furthermore, how to coordinate multiple CR users to share the spectrum band, called spectrum sharing, is another important issue in CR networks [7], [16]. Although all these efforts enable CR users to exploit spectrum opportunities effectively, the heterogeneous spectrum environment introduces a new critical issue in CR networks. Generally, CR networks have multiple available spectrum bands over a wide frequency range that show different channel characteristics, and need to support applications with diverse service requirements. Therefore, once available spectrum bands are identified through spectrum sensing, CR networks need to select the proper spectrum bands according to the application requirements.This process is referred to as spectrum decision, which constitutes an important but yet unexplored topic in CR networks. . To decide on spectrum bands properly, CR networks need to consider all available spectrum bands show different characteristics in the CR network. To select the proper spectrum, the CR network needs to characterize available spectrum bands by considering current radio conditions as well as the primary user (PU) activity. The CR network needs to provide a dynamic decision framework to consider all possible events that prevent reliable communications by closely interacting with other CR functionalities such as spectrum sensing and spectrum sharing. According to the PU activities, total capacity in CR networks varies over time, which makes it more difficult to decide on spectrum bands while maintaining the service quality of other CR users. Thus, the CR network should perform spectrum decision adaptively.

II. LITERATURE REVIEW

Most of theresearch on spectrum sharing in CR networks has mainly focused on how to efficiently allocate either spectrum orpower among CR users subject to interference constraints.For spectrum allocation, a global optimization scheme isdeveloped based on graph theory [17]. However, wheneverthe network topology changes according to the nodemobility, the network needs to completely recomputed spectrum assignment leading to a higher computational and communication overhead. To solve this problem, adistributed spectrum allocation based on local bargaining isproposed in [4], where CR users negotiate spectrum assignment within local self-organized groups. For their source-constrained networks such as sensor and ad hocnetworks, a rule-based spectrum management are proposed, where CR users access the spectrum independently accordingto both local observation and predetermined rules [5].

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In [20], a dynamic channel selection scheme is developed fordelay-sensitive applications based on a priority queuing analysis and a decentralized learning algorithm. Power allocation among CR users competing the samespectrum is another important issue in spectrum sharing. In [12], an optimal power allocation scheme is proposed toachieve ergodic and outage capacity of the fading channelunder different types of power constraints and fadingmodels. In [22], joint beam-forming and power allocationtechniques are presented to maximize the user capacitywhile ensuring the QoS of primary users. Game theoryprovides an efficient distributed spectrum sharing schemeby describing the conflict and cooperation among CR users,and hence allowing each user to rationally decide on its bestaction. Thus, it has been widely exploited for both channelallocation [16] and for power allocation [7].

III. IMPLEMENTATION CHALLENGE IN SPECTRUM DECISION

All of the previous research explained above has mainlyaddressed spectrum sharing issues where all operationsare performed within the same spectrum band or acrosscontiguous channels. Furthermore, to adapt the fast timevaryingchannels, they are generally designed as a shorttermoperation, such as a packet-based or a time-slot based scheduling. However, CR networks necessitate an additional resource allocation capability when primary users are detected or CR users newly begin their sessions, whichare relatively long-term events. Thus, this capability shouldconsider longer-term channel characteristics, compared tospectrum sharing. In addition, since available spectrumbands are distributed over a wide frequency range, thisfunction needs to be implemented as an inter-spectrumoperation. However, this operation inevitably introduces an additional switching delay leading to service quality degradation. Thus, it is not desirable to extend existing spectrum sharing solutions designed to adapt to the fasttime-varying channel to the long-term interspectrum operation.This unique challenge in CR networks has not beenaddressed in previous research.

IV. PROPOSED SYSTEM MODEL

A novel capacity model is developedto describe unique characteristics in CR networks byconsidering PU activity as well as sensing capability.Accordingly, two different decision schemes are introduced.To satisfy the delay constraints in real-time applications, wepropose a minimum variance-based spectrum decision(MVSD) scheme that selects spectrum bands to minimizecapacity variation. For best-effort applications, we propose amaximum capacity-based spectrum decision (MCSD) scheme to maximize the total network capacity. Bothdecision schemes are controlled by a proposed resource management based on the current network condition. System Model in this paper, we consider an infrastructure-based CRnetwork that has a centralized network entity, such as abase-station. The base-station exerts control over all CRusers within its transmission range. CR users perform the observations and analysis on radio environments and feed them to the central base-station, which decides on spectrum availability and

spectrum allocation. Each CR user has multiple software-defined radio (SDR) transceivers toexploit multiple spectrum bands over a wide frequencyrange by reconfiguring the operating frequency throughsoftware operations. Here, we assume frequency division duplex (FDD) systems where uplink and downlink channelsare separated. Thus, the proposed decision scheme canbe applied to each link independently.When primary users appear in the spectrum band, CRusers need to move to a new available band, resulting in a temporary communication break. To solve this problem, weassume that multiple noncontiguous spectrum bands can besimultaneously used for the transmission in the CR network.This method can create a signal that is not only capable of high data throughput, but is also immune to thePU activity. Even if a primary user appears in one of the current spectrum bands, the rest of them will maintain current transmissions [1].The control channel plays an important role in exchanging information regarding sensing and resourceallocation. Several methods are presented in [3], one ofwhich is assumed to be used as the common controlchannel in our proposed method.
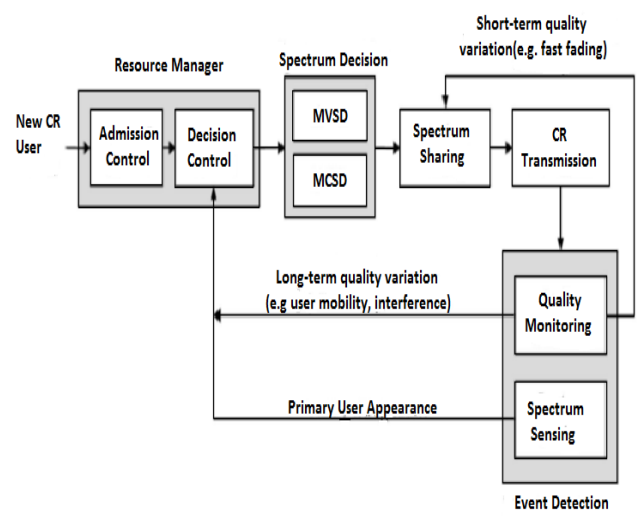

Figure 1. The proposed spectrum decision framework model

V. DECISION FRAMEWORK OVERVIEW

The proposed spectrum decision framework model shown in Figure 1. consist of resource manager determines if the CR network accepts a new incoming CR user or not. If a new CR user is allowed to transmit, it is assigned to the proper spectrum bands through spectrum decision. Since there may be multiple CR users competing the same spectrum, spectrum sharing coordinates those multiple accesses to prevent collisions, and accordingly to achieve the maximum capacity. In the event detection, current spectrum bands and users connections are monitored to detect decision events. The event detection consists of two main tasks: spectrum sensing and quality monitoring. When events are detected, the CR network reconfigures its resource allocation to maintain the service quality.

In case of short-term channel variations such as fast fading, the CR network reallocates resources within the spectrum band through spectrum sharing. If a primary user is detected or the current spectrum band cannot provide the predetermined service quality any longer over a long-term period, the CR network switches the spectrum through the resource manager and the spectrum decision.

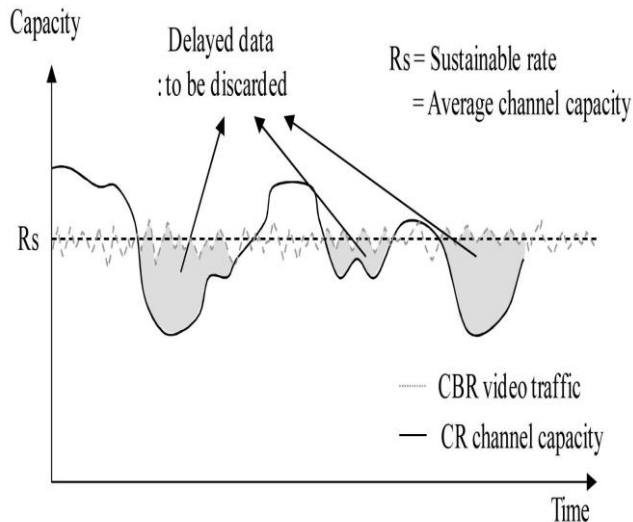## VI. SPECTRUM DECISION FRAMEWORK FOR REAL-TIME APPLICATIONS

Figure 2. Data-loss in real time video applications

Real-time applications are sensitive to delay and jitter. Moreover, they require a reliable channel to support a sustainable rate during the session time. Thus, real-time applications have strict constraints on the delay bound and the sustainable rate. Generally, real-time applications drop the packets not arrived within the delay bound. Even though the network can support sustainable rate Rs on average, packets can be delayed and finally discarded in the receiver due to the variation of channel capacity, as shown in Figure. 2.Unlike conventional wireless networks, the CR network has unique delay factors. When CR users either sense or switch the spectrum, they need to stop transmission temporarily, which prevents the real-time application from maintaining its sustainable rate, leading to delay and jitter. To observe the effect of the delay uniquely shown in CR networks, we assume that a buffering scheme is optimized to absorb delay factors in conventional wireless networks, such as application layer, link layer, and transmission delays. Then, the additional delay factors uniquely introduced by CR networks can directly lead to data losses. For this reason, we use the data loss rate to evaluate the service quality of real-time applications. Also real-time applications are assumed to have a set of discrete sustainable rates and to adjust their rates through the negotiation flexibly.

VII. CONCLUSION

In this review paper, we introduced a framework for spectrum decision to determine a set of spectrum bands by considering the channel dynamics in the CR network as well as application requirements. To this end, first, a novel spectrum capacity model is proposed that considers unique features in CR networks. Based on this capacity model, an MVSD is developed for real-time applications, which determines the spectrum bands to minimize the capacity variance.
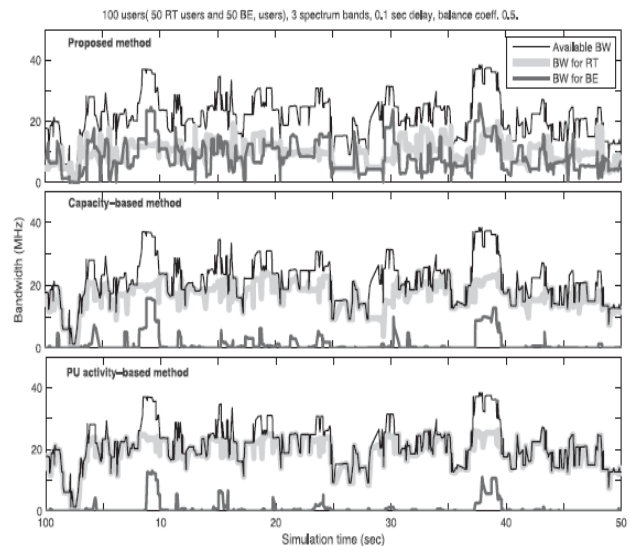

Figure 3. Efficient utilization of bandwidth

VIII. ACKNOWLEDGEMENTS

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