CSMA Interaction Detection and Capacity Estimation in Cognitive Radio Networks

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ABSTRACT

Estimation of the available capacity in a multiple hop route in cognitive radio networks is challenging. Several complex problems like channel assignment, interference estimation and routing effects needs to be addressed. In this demonstration, we exhibit a capacity estimation engine that determines the available capacity of the routes in a dynamic cognitive radio network using USRP and WARP software-defined radios. In addition to the available capacity, we show the various types of MAC interference and its effect in the network. The tool demonstrates a fundamental capacity estimation block, which provides valuable input to higher level applications like routing, network provisioning and monitoring. A scheduling aware routing algorithm that exploits the capacity estimation engine and scheduling interactions is shown as an example application.

Categories and Subject Descriptors

C.2.3 [**Network Operations**]: Network monitoring, Network measurement; C.4 [**Performance of Systems**]: Measurement techniques

General Terms

Algorithms, Experimentation, Measurement, Performance

Keywords

Wireless, CSMA, Interference, Software-defined radio, Capacity Estimation

1. DEMONSTRATION DESCRIPTION

Explosive growth of the number of wireless devices and associated applications has drastically increased in the recent years. This has lead to a great demand for the sparse capacity of wireless networks, especially in the license-free ISM bands. Cognitive radio networks is a promising avenue of research to solve the above problem. Instead of allowing the devices to access only a part of the spectrum, these networks open the possibility of utilizing unused spectrum, thus increasing spectrum efficiency.

However, a number of problems need to be addressed for building an efficient cognitive radio network. Several fundamental problems like dynamic spectrum access and interference mitigation mechanisms need to be addressed in these networks. The effectiveness of the mechanisms employed to solve the above problems have significant implications on the performance metrics for the higher level applications.

Many higher layer applications, in both wired and wireless network, judge the performance of the connection by evaluating the available capacity of the end-to-end route [1]. Several complex problems like channel assignment, interference estimation under CSMA protocol and routing effects needs to be addressed to solve this problem.

We demonstrate a capacity estimation engine that determines the available capacity of the routes in a dynamic cognitive radio network using GNU Radios (USRP) [2] and WARP [2] software-defined radios. In addition to the available capacity, we demonstrate various types of MAC interference and its effect on the available capacity. We use a scheduling-aware routing algorithm to choose the best route on which the available capacity and MAC interactions are measured.

The system employs a two-phase measurement methodology. Phase 1 computes a coarse-grained interference metric through a spectrum sensing mechanism. Phase 2 determines the specific interference patterns in a given spectrum. We use these modules, in conjunction with popular bandwidth estimation methodologies, to estimate the capacity of a route. The tool demonstrates a fundamental capacity estimation block, which provides valuable input to higher level applications like routing, network provisioning and monitoring. We also show a scheduling-aware routing protocol that selects an efficient route based on the estimated capacity and the MAC interactions.

2. DEMONSTRATION DESCRIPTION

In this section, we describe the scenario and the functionality of the system.

2.1 Scenario

Each wireless node in the network is equipped with three wireless devices: data packets are transmitted over the WARP board, channel sensing is performed by GNU Radio and a 802.11 based protocol is used as a control channel. The central co-ordinator controls the operations of the nodes

[1]Most of the existing literature, especially in wired networks, use the term *bandwidth* to denote the *capacity* (referred in units bits per second). In this document, we use the term *capacity* to denote this metric since bandwidth refers to the width of the frequency band; a commonly used metric in cognitive radio networks.

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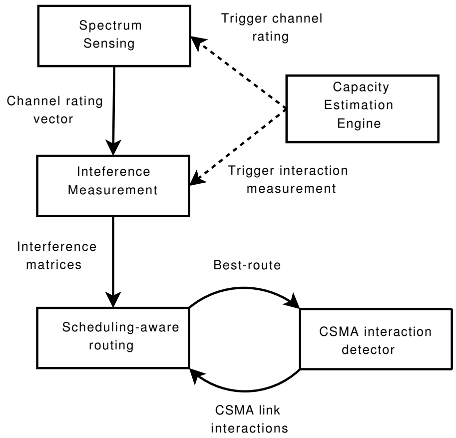

Figure 1: Components of capacity estimation tool

through the control channel. A centralized routing algorithm is used to compute an efficient route between the source and the destination and the capacity is constantly estimated over the routes. We emulate various interference patterns by forcing an interferer node to transmit packets at a given power level. The capacity estimates and the current interference patterns are displayed at the monitoring station.

2.2 System description

Figure 1 shows the interaction between variouscomponents of the capacity estimation tool. The *Spectrum Sensing* component consists of GNU Radio device that sweeps a given set of channels and records interference metrics on the spectrum like power spectral density and busy-periods on a channel. The output of this module is a *channel rating vector* which records an ordered list of the best-channels seen at each node. The channel rating vector is sent to the co-ordinator, where the best-channel is negotiated for the route between source and destination. This channel rating vector gives a coarse-grained estimate of the interference level, without specific information about the CSMA scheduling effectiveness.

The selection of the best-channel triggers the *Interference measurement protocol*, which builds the various interference matrices that are required for computing the scheduling effectiveness. We compute three matrices: (1) An edge-matrix that specifies if two nodes can communicate with each other; (2) A carrier sensing matrix which describes if two nodes can sense each other; and (3) A collision matrix which computes if concurrent transfer from sender and interferer can cause collision at a given receiver.

A *scheduling-aware routing* algorithm computes the best available route based on the channel rating vector and the interference matrices and produces the best route on the given channel. The set of active links, which consists of all links that are active in the network including the links in the route, is used by the *CSMA interaction detector* model to compute the interactions between the active links [1, 6]. This value is fed back to the scheduling-aware routing algorithm to mutually exclude the conflicting links and re-compute the best route [3].

The *Capacity Estimation Engine* constantly monitors the available capacity on the route through standard approaches [4, 5]. This tool is modified to trigger channel selection if the measured available capacity is lesser than a certain factor of the expected value.

3. DEMONSTRATION REQUIREMENTS

This section briefly describes the requirements for the demonstration. The demonstration requires 8 laptops, a standard 802.11 wireless router and a set of 7 WARP boards and GNU radios. The demonstrators will take the responsibility of bringing the above items to the conference site. One wired internet connection, a power extension cords (a total of 25 sockets) is requested from the conference organizers. The demonstration area required is approximately $4\,\text{m} \times 2\,\text{m}$.

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