Cognitive Radio for Home Networking

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***Abstract*—Cognitive Radios have emerged as one the most promising methods to increase wireless system efficiency through dynamic spectrum access combined with other cross-layer optimization methods. Most of the research prototypes and demonstrations have so far focused on either general platforms or scenarios that are predominantly taken from military or emergency communications domain. In this demonstration we show the prototype environment that is build around realistic home networking scenarios. The demonstration has two purposes. First, it demonstrates how a set of different implemented and integrated components can achieve local area optimization both in frequency allocation and other domains. Second, it shows the viability and attractiveness of cognitive radio methods for future commercial home networking devices. The demonstration showcases dynamic spectrum allocation and policy based behavioral changes in a home environment, where several multimedia stream and data communication connections are competing against each other.**

I. Introduction

Cognitive Radio (CR) is a promising new paradigm to solve the capacity problems that present day wireless networks are facing under the ever increasing number of users and applications. Major part of the work in the field is done towards enabling efficient Dynamic Spectrum Access (DSA) under different assumptions. Mitola's original vision of cognitive radio goes, however, well beyond DSA, and calls for smart and context sensitive behavior and optimization to be done at the system level.

A lion's share of prototyping or scenarios of CRs have been focused on emergency and military scenarios, or alternatively primary-secondary use cases in wide-area networking, such as TV-band reuse for IEEE 802.22. Moreover, most of the public demonstrations have been quite generic. Our cooperative project, ARAGORN, between academia and industry has been developing CR technologies that can be used in to enhance ISM-band operation of home networks, and also applied in general DSA context [1]. In this demonstration we will showcase solutions we have developed especially for home networking. As far as we are aware of this is the first public demonstration of usability of cognitive radio networks in such context.

II. Demonstration Description and Background

A. Motivation

Wireless home networking is becoming a pervasive technology, and currently more than 50% or more of European and American households, are already using WiFi technology inside their houses. According to market research data published by ABIresearch [2], the Wi-Fi access point shipments in 2010 alone will exceed 70 million and an overwhelming 90% will be targeted to SOHO and consumer markets. Parallel to this, different multimedia and internet applications are rapidly increasing and penetrating home network markets. This development is putting a strong stress on the existing systems, because the spectrum in ISM-bands is not only limited, but users are often technically not capable of, or interested in, making any complicated optimization for their networks. This problem is also made harder by the fact that there is typically no coordination among the networks in the neighborhood.

In this demonstration we will setup a sub-set of a demanding, typical home network and show through structured demonstration steps how CR techniques can be used to enhance user experience and the network capacity of such future home networks. The demonstration is divided to three separate sections demonstrating: (1) Dynamic Spectrum Access (DSA), (2) Dynamic Adaptation and Coordination (DAC), and (3) Cognitive Resource Management (CRM). These three sections use common hardware, and show also how the overall ARAGORN concept can be transparently integrated with various radio technologies or future software defined radios.

B. Demonstration Overview

Each of the sub-demonstrations will be shown sequentially in order to showcase how different solutions and modules work together to enhance network performance. We will shortly outline each of these parts.

The *Dynamic Spectrum Access* part is focused on showing how the developed spectrum sensing framework enables dynamic selection of free spectrum (channel) for the best user experience. The demonstration includes several different spectrum monitoring devices (from very low cost WiFi-band scanners to more advanced wideband detectors), a new over-the-air protocol for reporting measurement information, and a policy based spectrum access controller. The DSA section is combined with a policy framework that includes the use of the Prolog based Policy Reasoner from SRI. We have extended CoRAL based policy language, and demonstrate also a new protocol to exchange policies between devices [3].

The *Dynamic Adaptation and Coordination* sub-demonstration shows dynamic reaction to congestion and interferences. Specifically, it shows how the radios can reconfigure themselves to utilize free spectrum and deal

with congestion. It performs dynamic link optimization. The negotiation of radio parameters and improved spectrum usage is achieved through the support of spectrum awareness demonstrated in the previous step. One novel aspect of this demonstration is that it shows how dynamic reaction to policy restrictions is not only regulation based, but can also be driven by user and application priorities and preferences.

The *Cognitive Resource Management* part demonstrates the use of limited machine learning as a part of CRM architecture [4]. We show a pre-trained pattern recognition software that will be used for solving networking problems and CRM that learns about suitable device configurations and/or suitable network policies for given contexts

Overall the key aspect of the overall demonstration is to show how be advance through increasing interference and congestion from pure DSA to adaptive link negotiation and end in the most severe cases to change application setups.

III. Demonstration Setup and Components

A. Logical Architecture

The logical architecture of ARAGORN demonstration includes all the major components that one would find in a realistic home network (cf. Figure 1). We deploy Policy Server, Spectrum Measurement Devices (”Sniffers”), and user devices that include the implementation of a network stack and a Cognitive Resource Manager as the key element supporting the cognitive facilities.

B. Setup and Devices

The demonstration setup is based almost exclusively on existing hardware, which have been integrated by CRM and specialized software interfaces. The user devices are based on realistic standard systems such as media servers, televisions, and PCs. The policy server runs on an ordinary PC, and the core reasoning engine is a Prolog version from SRI (with out own language extensions). Most of the user devices are running Windows as operating system, but the network interface functionalities are extended by using *virtual interface technology*. The Cognitive Resource Manager and all the dynamic adaptation software are developed by the project consortium, and can be run on different operating systems. Our most challenging high-light application, in terms of bandwidth and latency requirements, is High Definition video streaming while internet and VoIP links are active in high interference environment.

The reconfigurable radio parts use several platforms in the demonstration. The reason is that we want to demonstrate (a) that the developed techniques are applicable for different hardware platforms, and (b) to showcase how different radio capabilities affect the end results. The used radios include Atheros IEEE 802.11 chipsets with modified device drivers that allow better access to low-level functionalities USRP (Universal Software Radio Platform) radios from Ettus Research, WARP-boards (SDR solution developed by Rice University), CalRadios and WiSpy equipments that are used as spectrum monitoring devices. Also one laboratory quality

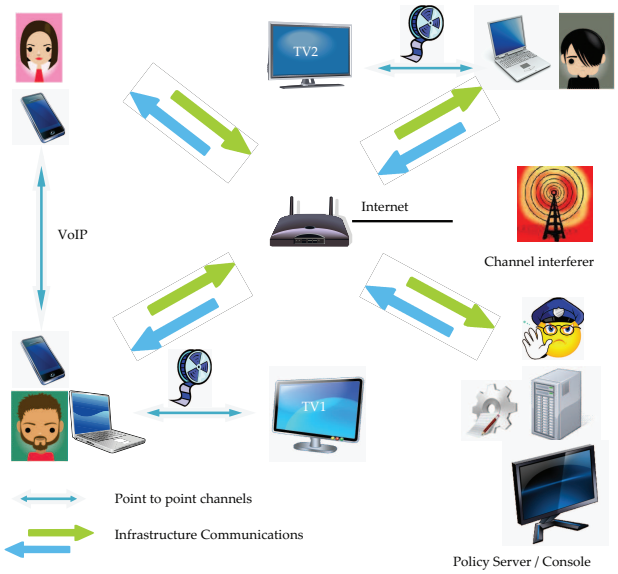

Fig. 1. Conceptual architecture of ARAGORN demonstrator.

broadband capable spectrum monitor is used as a control and monitoring device in the demo setup. As a home networking demonstrator we are mostly using 2.4 and 5 GHz ISM-bands.

The demonstrator system integrates various pieces of software and hardware under the control of a common Cognitive Resource Manager (CRM) framework responsible for configuration and optimizations. The prototype demonstrates how resource management can be achieved stepwise even under the condition of severe interferences and several high-speed wireless multi-media connections. More specifically, we show how the CRM gradually reconfigures radios, network layer and applications. The first level of adaptation is done by dynamic spectrum allocation, once this resource is exhausted different cross-layer optimization methods are employed, and finally if nothing else can be done quality of applications, e.g. by transcoding videos, is changed based on *specified policies that are provided by the Policy Server*.

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