Cognitive Radio for Home Networking

V. Atanasovski[††], D. Denkovski[††], T. Farnham[◇], L. Gavrilovska[††], A. Gefflaut[†], V. Kolar[⋆], P. Mähönen[⋆], E. Meshkova[⋆], B. Motz[◇], J. Nasreddine[⋆], V. Pavlovska[††], M. Petrova[⋆], S. Quadri[◇], K. Rerkrai[⋆], M. Sooriyabandara[◇], A. Steinmetzler[†], Z. Wang[†]
[⋆] Institute for Networked Systems, RWTH Aachen University, Germany
[†] European Microsoft Innovation Centre, Germany
[◇] Toshiba European Research Laboratory, UK
[††] Faculty of Electrical Engineering, Ss. Cyril and Mehtodius, Skopje, Macedonia
email: jad@inets.rwth-aachen.de

***Abstract*—Cognitive Radios have emerged as one of the most promising methods to increase wireless system efficiency through dynamic spectrum access combined with 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. We demonstrate a prototyping framework that is built around realistic home networking scenarios. The demonstration has two purposes. First, it demonstrates how a set of different implemented and integrated components can systematically manipulate transmission parameters to achieve local area optimization. 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 streams and data communication connections are competing against each other.**

I. Introduction

Cognitive Radio (CR) is a promising paradigm to solve the capacity problems that actual 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 CR 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 have been considering emergency and military applications, 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. A cooperation project, ARAGORN, between academia and industry has been developing CR technologies that can be used immediately to enhance ISM-band operations, and have also long-term impact in DSA context [1]. In this demonstration we will showcase solutions we have developed in this project especially for home networking. As far as we are aware of this is the first public demonstration of usability of CR networks in such context.

II. Demonstration Description and Background

A. Motivation

Wireless home networking is becoming a pervasive technology, and currently more than 50% 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 units 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 networks. This development is putting a strong pressure on the existing systems, as 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 home networks. This problem is also made harder by the fact that there is typically no coordination among the networks in the neighborhood.

In ARAGORN demonstration we will use a typical home network setting and show through structured sub-demos how CR techniques can be used to enhance user experience and network capacity. It is divided to three separate parts demonstrating: (1) Dynamic Spectrum Access (DSA), (2) Dynamic Adaptation and Coordination (DAC), and (3) Cognitive Resource Management (CRM). These three parts are using common off-the-shelf hardware to demonstrate how the overall ARAGORN concept can be transparently integrated with various radio technologies or future software defined radios.

B. Demonstration Overview

The main emphasis of the demonstration is to show how CR home network will adapt to different situations using various methods such as DSA, cross layer optimization, application adaptation and policy based prioritization. Part of the demonstrator is to show also how home networks can include learning components. The different parts of the demonstration will be presented in sequential order to demonstrate how developed 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 demonstrating 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), developed over-the-air protocol for reporting measurement information,

and also policy based spectrum access controller. The DSA section is enhanced by a policy based framework that includes the use of the Prolog based Policy Reasoner from SRI, our extended CoRAL based policy language, and protocol to exchange such policies between devices [3].

The *Dynamic Adaptation and Coordination* part shows dynamic reaction to congestion and interferences and how CRs can reconfigure themselves to utilize free spectrum and deal with congestion. It performs dynamic link and flow optimization, where negotiation of radio parameters and improved spectrum usage is achieved through the support of spectrum awareness demonstrated previously. 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]. It shows how a pre-trained pattern recognition software can be used to classify and solve network problems in typical user scenarios (interferences, bad signal quality, etc.).

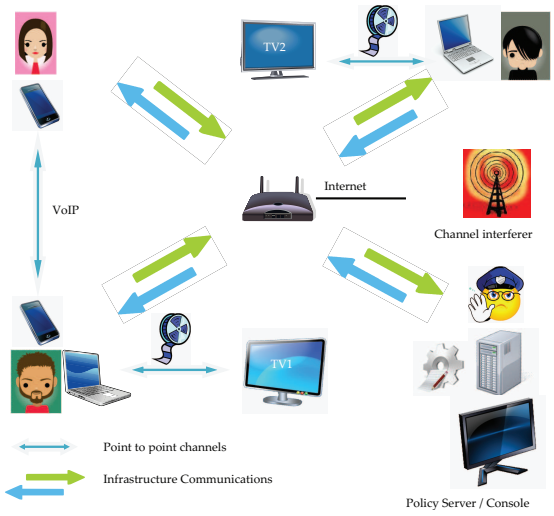

Fig. 1. Conceptual architecture of ARAGORN demonstrator.

III. Demonstration Setup and Components

A. Logical Architecture

The logical architecture of ARAGORN demonstration includes all the major components that one would find out in a realistic home network (cf. Figure 1). We deploy policy server, several spectrum measurement devices (”Sniffers”), and user devices that include the implementation of a network stack and a CRM as the key element supporting the cognitive facilities.

B. Setup and Devices

The demonstration setup consists almost exclusively of commercially available hardware components, which are integrated together through custom made software and interfaces. The applications and user interfaces are based on standard devices such as media server and streaming software, television sets and PCs. The policy server runs on an ordinary PC. The core reasoning engine is from SRI, but the policy language is extended beyond the original CoRAL. Most of the user devices are running Windows as operating system, but the network interface functionalities are extended by using virtual interface technology. The CRM and all the dynamic adaptation software are developed by the ARAGORN consortium, and can be run on different operating systems. The demonstration is focused on home networking in 2.4 and 5 GHz frequency bands. The most challenging high-light application in terms of bandwidth and quality requirements is high definition video streaming while other Internet and VoIP application links are active.

The reconfigurable radio parts use several platforms in the setup. The reason is that we want to demonstrate (a) that the developed techniques are applicable for different hardware setups, and (b) to showcase how different radio capabilities affect the end results and a number of adaptation options we have at our disposal. The used radios include Atheros IEEE 802.11 chipsets with modified device drivers that allow better access to low-level functionalities [5], USRP (Universal Software Radio Platform) radios, WiSpy equipments that are used as spectrum monitoring devices. We have also a separate PC driven source to generate background interference.

The demonstrator system integrates various pieces of software and hardware under the control of a common CRM framework responsible for configuration and optimization. The prototype demonstrates how resource management can be achieved stepwise even under severe interference and several high-speed wireless multi-media connections. More specifically, we show how the CRM gradually reconfigures radios, network layer parameters 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 the quality of applications, e.g. by trans-coding videos, is changed based on specified policies that are provided by the policy server.

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