Dynamic Frequency Selection through Collaborative Reporting in WLANs

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ABSTRACT

The tremendous growth of 802.11 WLANs has resulted in congestion of the limited unlicensed spectrum, especially in densely populated urban areas. The performance experienced by end-users in such deployments is significantly degraded due to contention and interference among adjacent cells. In order to address this challenge, various studies have proposed mechanisms for allocating the available number of channels to cells. In infrastructure 802.11 WLANs, channel selection is performed solely by the AP. Most implemented approaches result in static channel assignments, which is not consistent with the dynamic nature of the wireless medium. In this demo, we present a frequency selection algorithm implemented in the Mad-WiFi open source driver that dynamically switches the operational channel by taking into account both channel as well as traffic conditions. The proposed algorithm features a collaborative reporting mechanism, which enables nodes of the cell, as well as nodes belonging to different cells, to contribute to interference measurements. Based on this mechanism the APs decide on frequency selection more accurately and moreover manage to detect "hidden" APs. Compared to current approaches our algorithm manages to improve total network throughput, up to a factor of 7.5. For the purposes of this demo we use a graphical user interface to demonstrate an online frequency selection experiment that is remotely executed in NITOS wireless testbed.

1. INTRODUCTION

Several approaches on frequency selection in infrastructure WLANs have been proposed in the recent literature [1],[2],[3],[4] that assign operating frequencies to APs so as to improve throughput performance. Our work in [5] proposes an algorithm that incorporates several unexploited features that affect total network interference and results in a distributed protocol that dynamically selects the operating channel.

We start by considering the degree of overlap among adjacent channels based on the notion of I_{factor}, introduced in [6]. Another important feature of the proposed scheme is its ability to adapt to varying traffic conditions. In order to estimate the level of contention on each available channel, we introduce the notion of Channel Occupancy Time (COT), which describes the amount of time that each channel has been busy during intervals of fixed duration. Moreover, we incorporate a collaborative reporting mechanism to enable both STAs of each Basic Service Set (BSS), as well as nodes belonging to different BSSs to participate in interference estimation. Based on this collaborative mechanism, the APs obtain more accurate results in terms of channel quality and moreover they manage to detect "hidden" APs that cause interference.

In this demo, we will present an online experiment that demonstrates the salient features that compose the proposed algorithm. This experiment will be remotely executed in a wireless testbed and the experimental results will be illustrated through a graphical user interface.

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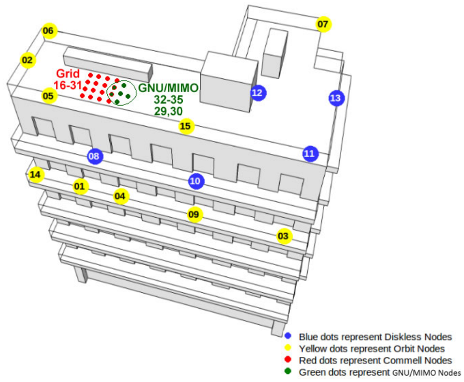
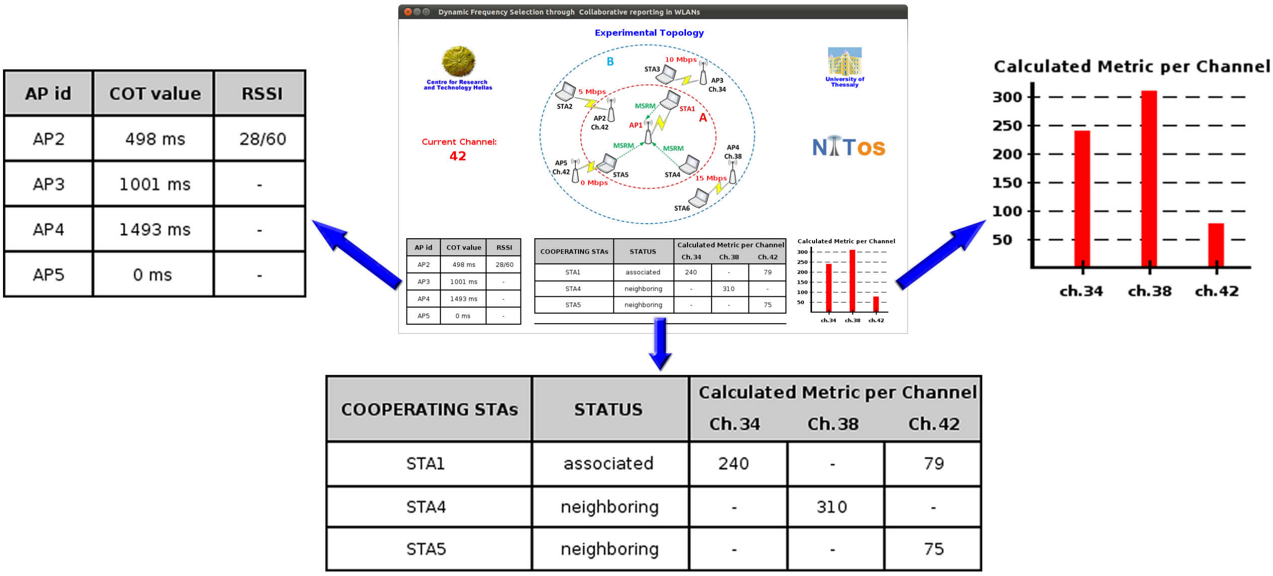


Figure 1: NITOS testbed topology representation.

2. EXPERIMENTAL DEMONSTRATION

The experimental platform that will be used for the online execution of the frequency selection experiment is NITOS testbed [7]. NITOS (Network Implementation Testbed for using Open Source platforms) is a large scale wireless testbed that currently consists of 40 operational WiFi nodes. The nodes are equipped with 2 wireless interfaces using Wistron CM9 - mPCI Atheros 802.11a/b/g 2.4 and 5 GHz cards that run Mad-WiFi open source driver [8]. A view of the testbed topology, at the exterior of the University of Thessaly campus building, is shown in Fig. 1. The technologies that are available in NITOS for implementation and testing are WiFi, WiMAX and LTE. Users can perform their experiments by reserving slices (nodes, frequency spectrum) of the testbed through NITOS scheduler, that together with OMF [9] management framework, support ease of use for experimentation and code development.



AP id	COT value	RSSI
AP2	498 ms	28/60
AP3	1001 ms	-
AP4	1493 ms	-
AP5	0 ms	-

COOPERATING STAs	STATUS	Calculated Metric per Channel		
		Ch.34	Ch.38	Ch.42
STA1	associated	240	-	79
STA4	neighboring	-	310	-
STA5	neighboring	-	-	75

Figure 2: GUI Screenshot.

A key feature of NITOS that enables us to use it for our demonstration is that it is remotely accessible. Another characteristic of NITOS is that it is a non-RF-isolated wireless testbed, and thus it offers rich interference conditions. In particular, during experimentation in the 2.4 GHz band, we observed the existence of more than 100 interfering APs operating on different channels. For the purposes of this demo, we decided to utilize only channels of the 5 GHz band which are not utilized by external users in the area, so as to provide for controlled interference conditions. As a result, the effect of channel overlapping will not be taken into account, because channels in the 5 GHz band are non-overlapping.

3. GRAPHICAL USER INTERFACE

A Graphical User Interface (GUI) has been developed in Java Swing that gives a depicted representation of the experimental results in an online way. The GUI periodically collects the necessary data through fetching of actual information from the corresponding nodes. Fig. 2 presents a screenshot of the developed GUI during the execution of the experiment. The experimental topology that consists of 5 nodes operating in AP mode and 6 nodes operating in STA mode is illustrated in the top part of the GUI. Moreover, the current channel selection of AP1, which is is the AP under consideration running our algorithm, is presented at the left part of the GUI. At the bottom left corner of the GUI we present the AP table, which lists the AP IDs of APs that are active during the experiment, the COT values reported in their *Beacon* frames, as well as the Received Signal Strength Indication (RSSI) as calculated at AP1. At the middle bottom part we present the Collaborative Reporting STAs, which lists the nodes whose measurement reports are taken into account by AP1. Finally, at the right bottom part of the GUI we present a plot of the metric values per channel as calculated based on the proposed protocol.

4. DFS EXPERIMENT

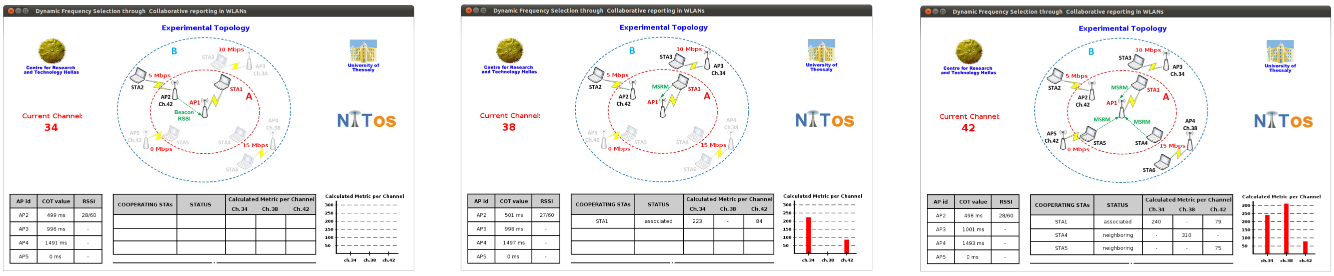
In this experiment we consider a network that consists of 5 APs and 6 STAs. We design a network setup that consists of 4 different BSSs operating on channels of the 5 GHz band. Each one of these 4 BSSs consists of one AP and one associated STA, where AP2 and AP5 are statically assigned Ch. 42, AP3 channel 34 and AP4 Ch.38. These 4 BSSs are used to generate interference conditions of controlled traffic. Moreover, we setup AP1 that runs our algorithm to decide about its operating channel. Through driver level modifications, we limit the set of available channels to the three used by the interfering APs. Among the various phases of the experiment, we sequentially activate the various features of our mechanism, starting from the default algorithm of Mad-WiFi and ending with the full activation of our algorithm. The aim of this experiment is to estimate how different features of our mechanism cope with the interference that we generate. Fig. 3 presents the network state during each phase.

4.1 Phase 1

In the first phase of the experiment, we use the default Mad-WiFi algorithm. The AP chooses to avoid Ch. 42, since this is the only one that offers RSSI values, based solely on its measurements. The original driver performs the scanning in the order 34-38-42 and as a result selects channel 34 as it offers zero RSSI values.

4.2 Phase 2

During the next phase, the client-feedback feature of our mechanism is enabled. This approach involves STA1 in interference estimation as well. The AP manages to detect AP3 operating on Ch.34 through consideration of measurements reported by STA1 and thus decides to avoid it. Consequently, AP1 decides to operate on Ch. 42, which still offers zero RSSI values.



(a) Phase 1. (b) Phase 2. (c) Phase 3

Figure 3: Experiment - Phases.

4.3 Phase 3

In the last phase, we utilize the feature of our implementation that enables STAs belonging to neighboring cells to exchange Measurement Reports. According to this approach, AP1 utilizing measurements from a total of 2 neighboring STAs manages to detect both of AP4 and AP5. As a result it decides to switch its channel to Ch. 42, as this offers the least calculated metric.

Having determined the proper channel selections according to the version of our algorithm that runs in each phase, we proceed with a representation of the throughput performance that each channel selection results in. In order to provide these results, we execute an offline experiment, during which we manually switch among the available channels and repeatedly activate a downlink saturated flow from AP1 to STA1. The results obtained through this offline experiment validate that the proposed scheme results in channel selections that deliver the highest available throughput for all cases.

5. DEMO REQUIREMENTS

For the purposes of this demonstration the following equipment will be required:

- our projector,
- our laptop,
- a desk to place the equipment,
- power supply,
- Ethernet cable.

Moreover, we will require around 20 minutes for setup and test. This demo is eligible for the student demo competition and the lead student is Giannis Kazdaridis from University of Thessaly.

6. CONCLUSIONS

In this demo paper we present an online demonstration of a novel DFS scheme, which results in channel assignments that significantly improve throughput performance by taking into account both channel as well as traffic conditions. Another important feature of our algorithm is a collaborative reporting mechanism that enables neighboring STAs to provide interference measurements to the APs. Through a GUI we present the various characteristics that form our algorithm during the execution of an online frequency selection experiment that runs remotely in NITOS wireless testbed.

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