Coexistence of LTE and WiFi Heterogeneous Networks via Inter Network Coordination* †

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ABSTRACT

Fast increases in mobile data demand and inherently limited RF spectrum motivate the use of dynamic spectrum sharing between different radio technologies such as WiFi and LTE, most notably in small cell (HetNet) scenarios. In our project, we propose an inter-network coordination architecture which facilitates dynamic spectrum management in the HetNets for interference mitigation and efficient spectrum utilization. We aim to model interference between LTE and WiFi networks through experimental evaluation using the ORBIT testbed and the USRP/GNU radio platform. We further propose to study the performance of cooperative algorithms between LTE and WiFi network involving logically centralized system level optimization for maximizing throughput subject to certain constraints.

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design—*Wireless Communication*

General Terms

Design, Measurement, Optimization, Performance

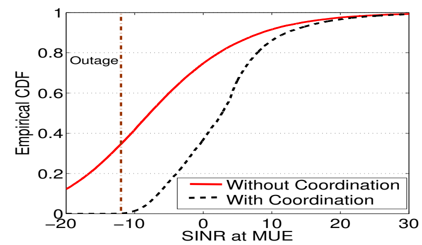
Keywords

WiFi, LTE, HetNet, dynamic spectrum access

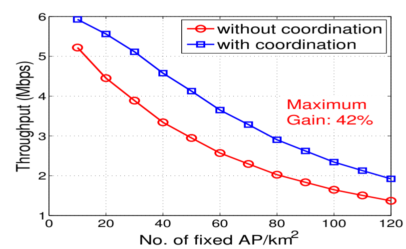
1. MOTIVATION

Exponential growth in mobile data usage is driven by the fact that Internet applications of all kinds are rapidly migrating from wired PCs to mobile smartphones, tablets, mobile APs and other portable devices. To meet such a high demand, mainly two solutions have been proposed - (1) Deployment of small cells - which can multiply wireless data capacity by frequency reuse and provide data connectivity at areas with no cellular coverage; (2) adding more spectrum for mobile services. Recently, Qualcomm has proposed to enable LTE in 2.4 and 5 GHz unlicensed bands as a secondary carrier for downlink-only and/or uplink and downlink [1]. Also both LTE and WiFi based small cell services are expected to be offered in the 3.5 Ghz shared use band currently utilized for military and satellite operations [2]. Thus, in the near future, dense deployment of LTE and WiFi based small cells may be expected to coexist in shared spectrum. This leads to heterogeneous networks (HetNets) scenarios with (1) multi-radio access technologies (multi-RAT) intra-network (operated by a single operator) or (2) multi-RAT inter-network (multiple operators). For efficient spectrum utilization in HetNets, coordinated dynamic spectrum management is required which is (1) effective in high interference scenarios; (2) scalable to high density networks; and (3) applicable to mobile nodes.

Our past works [3] and [4] studied coordination techniques for single-RAT intra-network and inter-network respectively. In study [3], we exploited approximate geo-location infor-



(a) Coordination in femto-macro network via adaptive transmission power



(b) Coordination in mobile-fixed WiFi networks via adaptive frequency selection

Figure 1: Gain via network coordination

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mation to adapt transmission power at femtocell to improve throughput performance at macrocell and femtocell users through central coordination. On the other hand, we studied the independent deployment of WiFi based mobile APs in [4] where a mobile AP creates dynamic interference as it moves in and out of range of other fixed or mobile APs. Thus, we proposed adaptive frequency selection technique at the mobile AP based on the mobile speed in response to change in the interference map around it. Fig. 1 shows that 1.5x gains in client throughput can be achieved through network coordination in both the cases.

2. LTE-WIFI COEXISTENCE

2.1 Challenges

Coordination between multi-RAT networks with LTE and WiFi is challenging due to the difference in medium access control layer of two technologies. WiFi is based on the distributed coordination function where each transmitter senses the channel energy for transmission opportunities and collision avoidance. In contrast, LTE can be considered as a time division multiple access network in which data packets are scheduled in the successive time frames. Also, LTE does not assume that spectrum is shared and consequently does not employ any sharing features in the channel access mechanisms. Thus, the coexistence performance of both LTE and WiFi would be unpredictable and may lead to unfair spectrum sharing or shutting off of one of the technologies.

2.2 System Optimization

To overcome LTE-WiFi coexistence challenges and obtain the benefits of shared spectrum, we propose a dynamic spectrum management via logically centralized network optimization, with the objective of maximizing spectrum utility (U) [bits/sec/Hz/km^2] subject to applicable constraints. We aim to exploit bandwidth (BW) (LTE only) and frequency diversity at LTE and WiFi with the following formulation:

$$\begin{aligned} \text{maximize} \quad & U(\mathbf{C},\mathbf{D},\mathbf{B}) & \\ \text{subject to} \quad & r_{ik}(\mathbf{C},\mathbf{D},\mathbf{B}) \geq r_{i,\min}, & \forall i,k, \\ & r_{jl}(\mathbf{C},\mathbf{D},\mathbf{B}) \geq r_{j,\min}, & \forall j,l, \\ & \mathbf{C}_i \in C_w, & \forall i, \\ & \mathbf{D}_j \in D_L, \mathbf{B}_j \in B_L, & \forall j, \end{aligned} \tag{1}$$

where optimization variables are $\mathbf{C},\mathbf{D},\mathbf{B}$. Here, r_{ik} is throughput at client k of WiFi i with the minimum throughput constraint of $r_{i,min}$; r_{jl} is throughput at client l of LTE j with the minimum throughput constraint of $r_{j,min}$. Assuming N_1 and N_2 are number of WiFi and LTE networks respectively, $\mathbf{C} \in \mathbf{R}^{N_1}$ describes channel numbers to which WiFi networks are connected, $\mathbf{D} \in \mathbf{R}^{N_2}$ and $\mathbf{B} \in \mathbf{R}^{N_2}$ describe channel numbers and BWs used by LTE networks respectively. C_w, D_L, B_L represent the list of acceptable WiFi channel numbers, LTE channel numbers and BWs respectively.

Given $\{\mathbf{C},\mathbf{D},\mathbf{B}\}$, calculating r_{ik} and r_{jl} is a non-trivial task. At a WiFi client, r_{ik} is function of MAC interference and LTE-WiFi interference. On the other hand, r_{jl} is a function of LTE-LTE and LTE-WiFi interference. We define MAC interference as the effect of change in throughput at the WiFi client due to co-channel WiFi APs in CSMA and interference range. LTE-WiFi and LTE-LTE interference depends on transmission power of interfering AP/BS, distance between the client and interfering AP/BS, and overlapping BW.

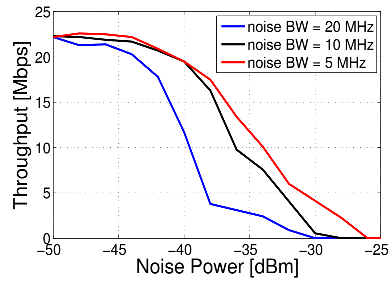

Figure 2: Performance of WiFi as a function AWGN bandwidth overlapping and power level.

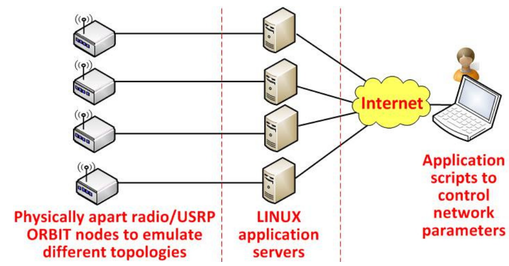

Figure 3: ORBIT experimental setup

2.3 Experimental Setup

In the literature, there are no previous studies experimentally evaluating the coexistence performance of LTE-WiFi. In baseline experiment, the throughput performance of a WiFi client varies as the BW and power level of the additive white Gaussian noise (AWGN) vary (refer Fig.2). This emphasize the necessity to characterize the impact of WiFi and LTE on each other given various topologies, channel assignment, BW allocation etc. scenarios. For the experiment, we use the ORBIT testbed and USRP/GNU radio platforms available at WINLAB as shown in Fig.3. Thus, we propose to apply the experimental characterization of LTE-WiFi coexistence in the system level optimization given in eq.1. Our goal is to obtain a set of LTE-WiFi interference measurements that can be used to run the proposed optimization model and other alternatives to be developed in the future. We will also develop further the protocol framework needed to enable logically centralized optimization involving multiple autonomous networks.

3. REFERENCES

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