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Traffic Pattern Modeling for Cognitive Wi-Fi Networks

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Abstract

The cognitive radio is a technology that efficiently uses the spectrum allowing the secondary users to use the spectral opportunities from the licensed bands without interfering with the primary users' communications. The purpose of this article is to analyze and compare the development of three prediction algorithms based on time series during the spectral handoff. In order to assess the algorithms, three evaluation metrics are measured under four different scenarios, according to the service class and the traffic level. According to the obtained results, the mobile averages algorithm is the one with the best performance when it comes to predicting the primary users' behavior which allows the interference level to be lowered 70%, however, it increases the channel's changes rate in 38%.

Keywords: cognitive radio networks, handoff, prediction, spectrum opportunities, time series.

INTRODUCTION

Over the last few tears, Wireless networks have been of a great interest for investigation purposes due to the growth of the technologies the spectrum uses for communicating. The users demand and evolution of technologies indirectly causes a frequency band shortage, which turns the spectrum assignment into a more complex process every time. [1].

The dynamic access to the spectrum is a technology that aims to take advantage of those licensed frequency bands that are not currently being used in order to use them without causing impacts to the licensed users 2] setting a challenge in terms of the study of the spectrum's efficient use [2]–[6].

The cognitive radio is raised as a new generation network which is capable of changing its transmission parameters in function of its interaction in order to give place to the active negotiation or communication with other spectrum users. [7]. This technology increases the band width capacity and the dynamic access to the spectrum, guaranteeing there will not be any interferences among licensed primary users. [5], [8].

The purpose of this paper is to complete the spectrum's handoff before the arrival of the PU, and the SU should have moved to another channel in order to avoid interference. In order to achieve this goal it is necessary to carry out two processes: detection, where it is required to establish a contingency channel to make a spectral jump before the arrival of the PU; the second process is the handoff itself, which performs a spectral jump through the prediction of PU's arrival in order to evacuate the channel before any interference occurs. The advantages of this model are numerous, which causes a low latency because spectral jump occurs before any interference, this issue produces a delay, but only when there is a channel change, it reduces the number of spectral jumps since there is a defined handoff strategy. [9].

This article presents a comparative EVALUATION of three time series models: AR, MA and ARMA, in the prediction of spectral opportunities for cognitive radio networks in the the Wi-Fi frequency band. The performance of the three time series models will also be contrasted with a purely reactive model (without prediction). For the performance EVALUATION, two application classes were taken into account: Real Time (RT) and Best Effort (BE), two levels of traffic: High Traffic (HT) and Low Traffic (LT), and six evaluation metrics (EM): Number of Average Accumulated Handoff (AAH), number of Average Accumulated Failed Handoff (AAFH), number of Average Accumulated without Interference Handoff (AAPH), Average Accumulated Interference Handoff (AAIH), number of Average Accumulated Perfect Handoff (AAEH) and number of Average Accumulated Anticipated Handoff (AAUH).

The rest of the document is structured as follows. In Section II, a description of the time series models used in this work is presented. Section III describes the experiments and simulations made. Finally, the conclusions are drawn in Section IV.

TIME SERIES

The time series which main purpose is to develop statistical models to explain the behavior of a random variable that varies over time, allowing to estimate future forecasts of the random variable. [9].

Due to time series which are suitable models for correlated series and several studies have shown that the traffic is correlated, it was decided to select the AR, MA and ARMA models.

AR model:

AR model is based on series time observations. AR indicates the current value of the series, depending on p (past values), where p establishes the Lags number to make predictions. The p order is given by the Equation (1). [10].

$$X_t = \phi_0 + \phi_1 X_{t-1} + \ldots + \phi_p X_{t-p} + \varepsilon_t \tag{1}$$

MA model:

MA model applies a function in order to smooth the original time series through average elements subset; this model assumes linearity and the current value of series is given by the smoothing function. Order q MA is given by the Equation (2). [10].

$$X_t = \theta_0 - \theta_1 \varepsilon_{t-1} - \ldots - \theta_q \varepsilon_{t-q} - \varepsilon_t \tag{2}$$

ARMA model:

ARMA takes both AR and MA models, and it's given by Equation (3). [10].

$$\begin{aligned} X_t = {} & \phi_0 + \phi_1 X_{t-1} + \ldots + \phi_p X_{t-p} \\ & + \varepsilon_t + \theta_0 - \theta_1 \varepsilon_{t-1} - \ldots - \theta_q \varepsilon_{t-q} - \varepsilon_t \end{aligned} \tag{3}$$

EXPERIMENTS AND SIMULATIONS

With the captured occupancy spectrum data, the behavior of the primary users was modeled and a dichotomous time series was constructed (1 available channel, 0 unavailable channels) for each frequency channel of the Wi-Fi band, between 2.4 GHz and 2.5 GHz. The occupancy spectrum information was determined with the energy detection technique using a spectrum analyzer and the false alarm probability model. [11].

Later, a simulation environment was developed based on the dichotomous time series (time step 1/3s), previously obtained. Where the proposed spectrum handoff algorithm selects the channel objective in accordance with the historic information of the decision criteria; if the mentioned channel is unavailable a second channel is selected from its classification list, and so on. Each time step saves the corresponding information of the used frequency and handoffs, in order to subsequently calculate the evaluation metrics. [12].

In the performance evaluation, two types of applications were considered: Real Time (RT) and Best Effort (BE), two traffic levels: High Traffic (HT) and Low Traffic (LT), in order to create four scenario types: Wi-Fi RT HT, Wi-Fi RT LT, Wi-Fi BE HT and Wi-Fi BE LT; and six evaluation metrics (EM): AAH (Fig. 1), AAFH (Fig. 2), AAPH (Fig. 3), AAIH (Fig. 4), AAEH (Fig. 5) and AAUH (Fig. 6).

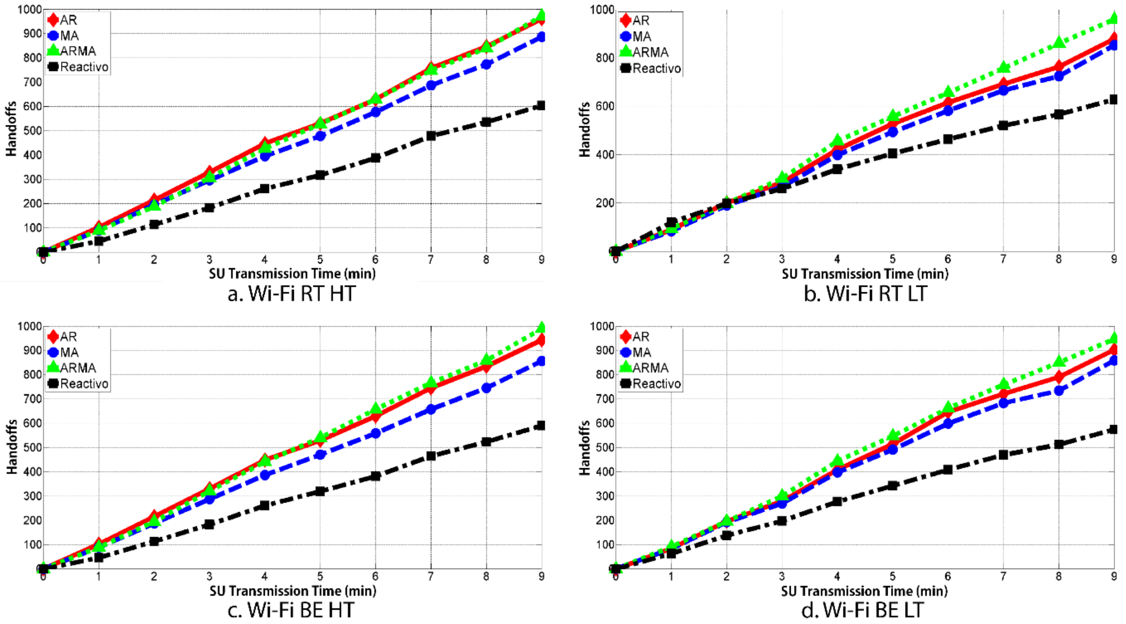

Figure 1: AAH a. Wi-Fi RT HT, b. Wi-Fi RT LT, c. Wi-Fi BE HT, d. Wi-Fi BE LT

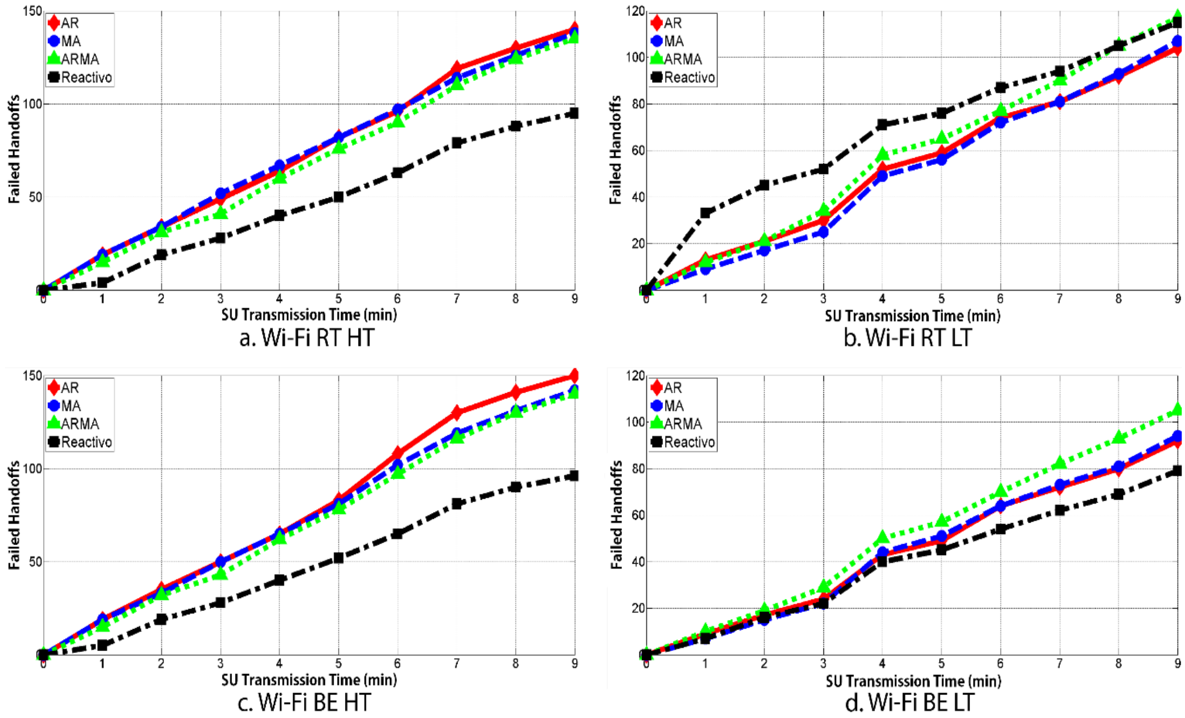

Figure 2: AAFH a. Wi-Fi RT HT, b. Wi-Fi RT LT, c. Wi-Fi BE HT, d. Wi-Fi BE LT

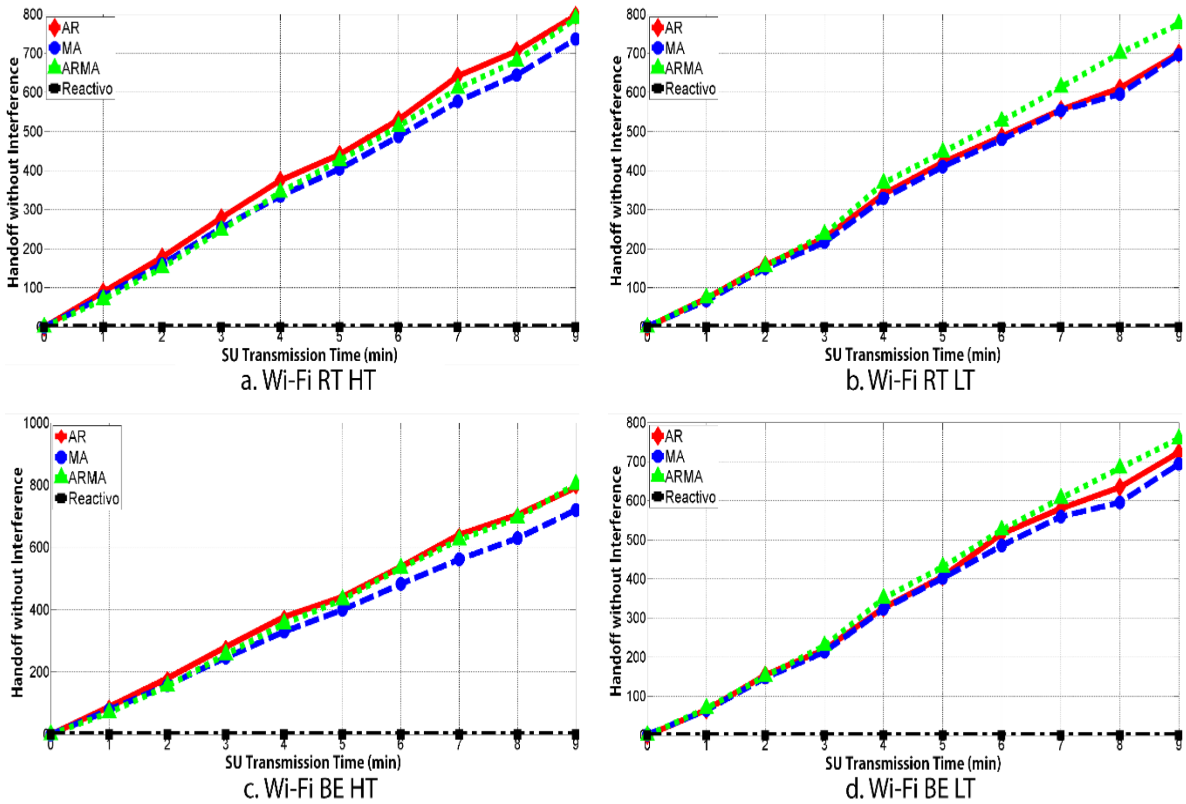

Figure 3: AAPH a. Wi-Fi RT HT, b. Wi-Fi RT LT, c. Wi-Fi BE HT, d. Wi-Fi BE LT

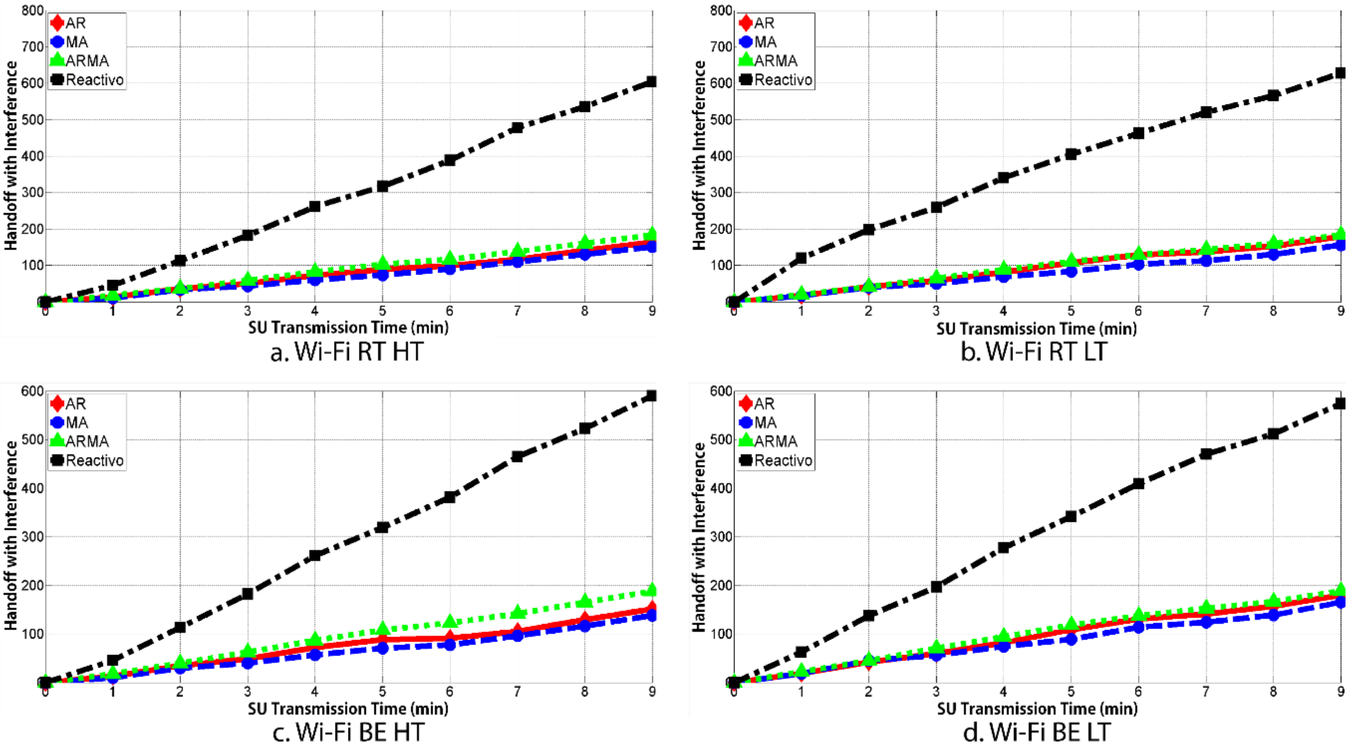

Figure 4: AAIH a. Wi-Fi RT HT, b. Wi-Fi RT LT, c. Wi-Fi BE HT, d. Wi-Fi BE LT

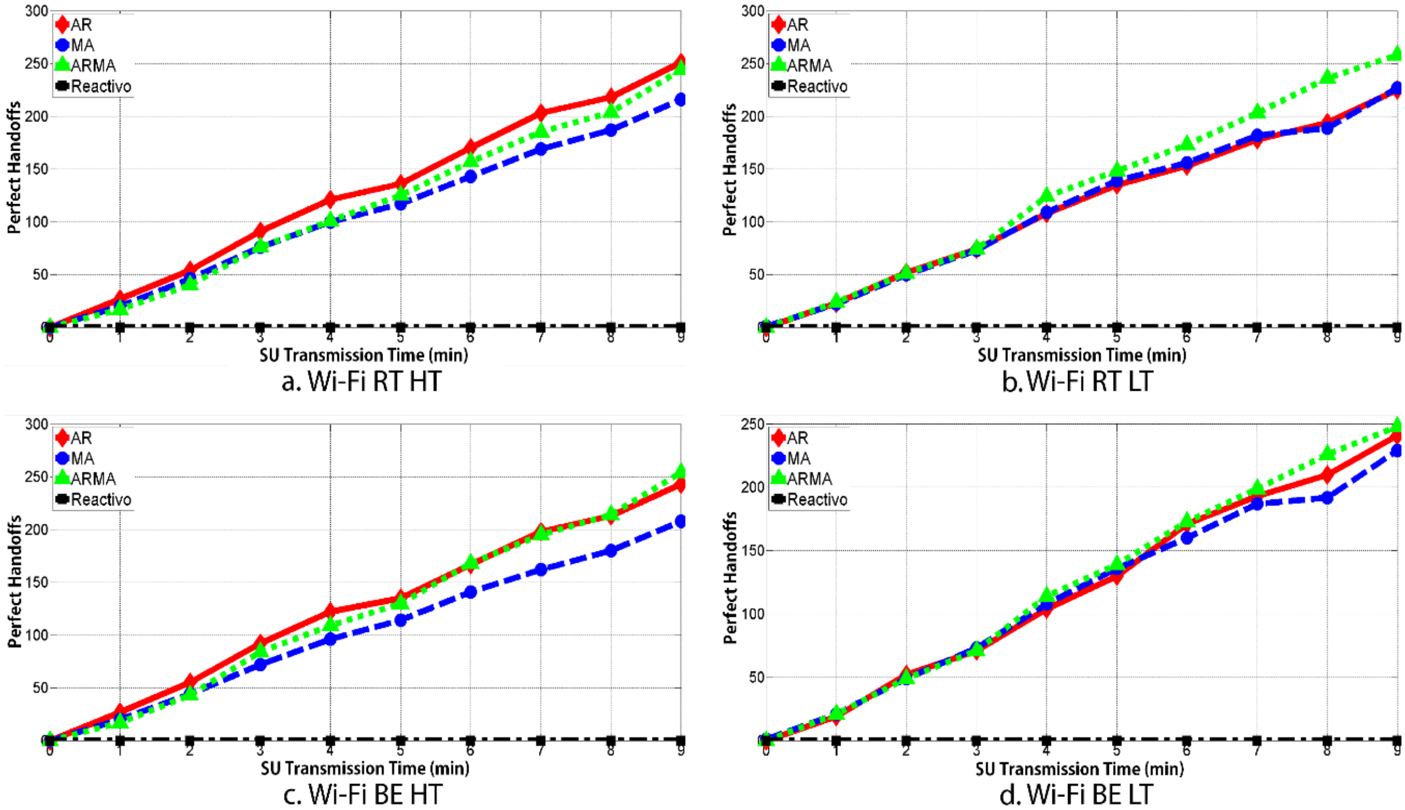

Figure 5: AAEH a. Wi-Fi RT HT, b. Wi-Fi RT LT, c. Wi-Fi BE HT, d. Wi-Fi BE LT

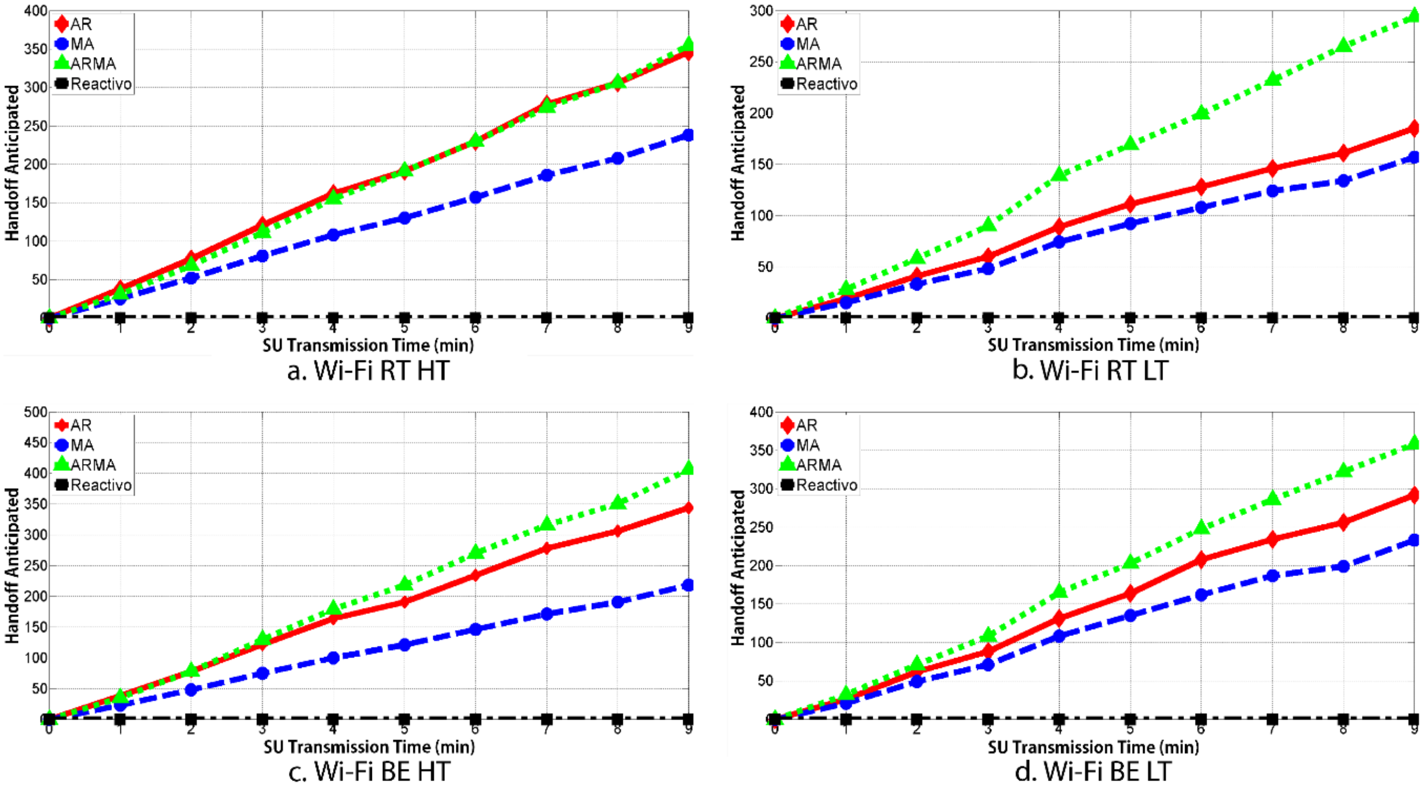

Figure 6: AAUH a. Wi-Fi RT HT, b. Wi-Fi RT LT, c. Wi-Fi BE HT, d. Wi-Fi BE LT

Analyzing the performance of SH's predictive algorithms, among the reactive version, the following is observed: In regards to AAH, it is observed that the Reactive model is the one with the best performance, followed by the MA model. In regards to AAFH, the Reactive model is the one with the best performance followed by the MA model. In regards to AAPH, it is observed that the MA model is the one with the best performance, closely followed by the AR model. In regards to AAIH, it is observed that the MA model is the one with the best performance. In regards to AAEH, it is observed that the best model is the AR closely followed by ARMA, in regards to AAUH, it is observed that the Reactive model is the one with the best performance followed by MA.

By making a global comparison of each SH algorithm in the four scenarios raised for the Wi-fi network methodology, it is observed that on the general global score, the MA algorithm has the best performance, with a mere 1,4% margin regarding the second one. Therefore, it is interesting to analyze which algorithms are the best in each scenario. In the case of RT in LT, BE in LT and BE in HT, the MA algorithm has the best performance; for RT in HT, the best one is AR, but only with a 0,03% margin regarding MA. According to this, it can be concluded that the MA algorithm dominates in all scenarios for the Wi-Fi network.

CONCLUSIONS

The prediction algorithms in cognitive radio networks allow reducing the interference level in about 70% for stochastic networks such as Wi-Fi. In the Wi-Fi network, the MA algorithm is the best, with a 3, 35% margin over the second one (AR). However, the prediction algorithms have a significant disadvantage which is the increase on the AHH value of 38,46% on Wi-Fi, due to the imprecisions when predicting the algorithm.

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