Improved Channel Access in Network Assisted WLAN Deployments

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***Abstract*—Recent progress in radio technology allows us to develop novel network architectures and topologies. Following the studies on IEEE 802.11 channel access optimization, author presents an approach for the implementation of network-assisted access parameters distribution. In this work it is shown how cellular network can be used to manage WLAN connections.**

I. Introduction

Modern Wireless Local Area Networks (WLANs) are widely spread all over the world. Based on deployment and service low costs, simple access protocols and module equipment on most of the devices, IEEE 802.11 (WiFi) took its niche in short-range wireless communication. Moreover, it uses unlicensed bands (mostly 2.4 GHz) and allows a high speed connection between users without any additional equipment. Based on previous editions current protocol [1] introduces an advanced Medium Access Control (MAC) mechanism which supports a wide spectrum of Physical (PHY) layer features.

However, based on the growing amount of requests from mobile operators to improve the capacity of their current deployment by offloading a certain number of active connections without any additional network equipment or/and extra cost as a result. There exists a way how assisted WLAN deployments can be controlled and improved by cellular network. Existing research observes such a question from different points of view, such as user's throughput improvement or energy efficiency. Actually, performance evaluation of such a technology is defined as a pursuit research area based on different approaches, such as simulation, analysis and measurement and ideally - their combinations. We assume that main benefit that could be obtained by the network assisted WLANs is in the novel scheduling and to consider such a problem a combination of methods may be used.

Related performance benefits of network-assisted traffic offloading are already researched in the way of employing WiFi Direct connectivity [2] as well as relying on anchor access points as part of cellular architecture [3]. The practical gains of such an integration of WLAN connectivity with modern cellular networks would continue over the following years. This can result in improvements of current 802.11 random medium access protocols with cellular-assisted.

All mentioned above calls for revisiting existing WiFi evaluation models to define how network assistance may optimize real-time WLANs' configuration. In this work a saturated model based on regenerative cycle analysis approach is observed in contrast to Markov chain based ones [4], [5] that are difficult to scale with even a small number of the parameters. We arrive at a decision that our model remains very accurate for a wide range of practical protocol settings.

Finally, the main focus is currently made on the technology prototype to continue our previous work [6]. It is based on the LINUX machine equipped with an open source WiFi driver [7] and running iperf server [8] on it. The point of using this tool is in the ease of Access Point (AP) setup and the opportunity of distributing channel quality (number of connected users, maximum throughput, etc.) to end users.

II. System model

For the analytical and simulation research it is decided to use a static model with M users to analyze the uplink from the successful transmission probability and throughput points of view. As all the users and AP use the same channel and the system is assumed as synchronized and slot-divided, there may appear exactly three events: a *collision* if there are two or more users transmitting their packets in the same *slot* by contrast to *success* when there is only one transmitting user or *idle* if there is no one to transmit. All users have saturated queues of packets. Such type of traffic leads to the worst situation and delivers to obtain an achievable saturation throughput.

Based on IEEE 802.11 standard, a collision resolution process is well known as Binary Exponential Backoff (BEB) and the results may vary based on the access mechanism being used. In Basic mechanism, an aggregated block of data with the same preamble is transmitted immediately after waiting for the Arbitration Inter-Frame Spacing (AIFS) time and the random Backoff Time without any channel without prior listening to the channel. The Request-To-Send / Clear-To-Send (RTS/CTS) access scheme is based on 4-way handshake when the communicating users implicitly reserve the channel by exchanging two short signaling frames. This mechanism is widely used in modern WLAN deployments and solves problems associated with hidden terminals as well as reduces collision time.

An RTS/CTS access mechanism can be shortly summarized as follows: aggregated data frame should be included in Transmit Opportunity (TXOP) time with the required Short Inter-Frame Spacings, the acknowledgment, and the RTS/CTS frames. If necessary, a user may also release the unused TXOP time by sending the Contention-Free End frame.

Speaking more precisely and according to the IEEE 802.11 specifications, after the first AIFS time, a Backoff Counter

(BC) value is chosen as a uniform-distributed random variable in between 0 and $W_0 - 1$. W_i is also known as Contention Window (CW). The BC is decremented after each idle slot. When BC reaches zero, the appropriate user tries to transmit. Retransmission Counter (RC) value is chosen according to the standard. If there is more then one attempt at the same slot, a collision would be produced at the AP, so the retransmission should be needed. Hence, the value of the CW is doubled ($W_i = 2W_{i-1}$) to reduce the chances of subsequent collisions and the BC is selected again. Anyway, CW growth is limited by its maximum value (W_{max}). Moreover, specific user can continue retransmission attempts even after CW_{max} was reached, until RC will be zero. When every packet is successful or discarded, the CW is set back to its initial value W_0. Finally, we can define $W_{max} = 2^m W_0$, where m is often named the backoff stage.

Generalizing, the random Backoff protocol can be entirely described by only two parameters: Backoff stage m and initial Backoff window W_0. In addition, RC is introduced to describe Short Retry Limit, as far as we assume that channel is error free and the collision may appear only during RTS frame. In summary, it is assumed that all the users use the same access mechanism (RTS/CTS) across cluster, transmit the same type of data (identical AIFS) and the same size of data (identical TXOP), so it is possible (as we demonstrate in [6]) to receive the accurate saturation throughput results.

Anyway, similar analysis was observed in well-known work [9] but the system stays stable and fair only with some specific parameters. For example, with small initial backoff window W_0 or large numbers of users M, some users would capture the channel resources by obtaining better transmission probability. In contemporary WiFi deployments backoff parameters W_0 and m should be controlled by AP so that channel access would remain fair. And that is a purpose to develop a technology prototype for measurement and its further comparison with analytical and simulation results. Actually, less detailed and scalable analytical models have already been shown to agree well with field trials and measurements [10].

III. Current work

Currently developed powerful simulation and analysis tool can be improved by addition a measurement part to it. Simulator is a flexible tool that captures the essential features of WiFi operation. It is calibrated with Bianchi's results reproduced from [9] and it leads us to an assumption that our results can be considered trustworthy. Also, for our current needs 802.11n timings with the data rate of 65 Mbps are included to evaluate estimated throughput. Lossy and lossless systems are implemented according to the standard. In that case our tool can obtain maximum probability of the transmission success and/or maximum throughput on the user side or generally for the entire system.

Basically, present version of the technology prototype can be observed in Fig. 1. The main benefit of this tool except all above is a *fake load* opportunity of such a model, e.g. it is possible to emulate a number of users based on changing MAC parameters for a traffic generator on the side of only one user. Moreover, that statistics should be stored inside cellular network, that in its turn would optimize access parameters for

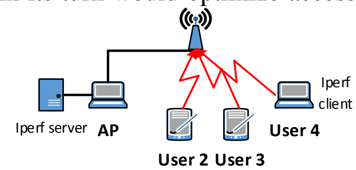

Fig. 1. Technology prototype topology

users having both WLAN and cellular connections. Current work is to estimate the extent of such improvement.

The usage of our prototype assumes modification of the current access protocol on the user side. Simplified model is shown in Fig. 2. Mainly, AP collects data about current number of users inside the WLAN and sends a broadcast service message (beacon) based on which every user updates his backoff parameters. Moreover, cellular network can obtain information about quality of the channel and number of users, so proper parameters may be sent to users if necessary. Accordingly, the entire system stays fair.

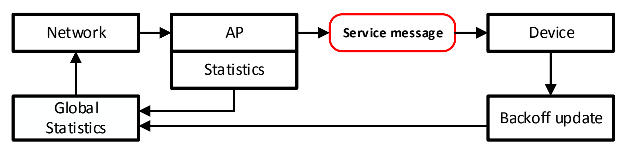

Fig. 2. Simplified optimization algorithm

In summary, this abstract observes details of a simulation-analytical framework for the performance evaluation of assisted IEEE 802.11 protocol for realistic parameters and system settings, that is currently been improved by the technology prototype. We are convinced that cellular network assistance over WLAN deployments will further improve the usage of future WiFi networks.

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