A Power-saving Extension for 802.11-based Protocols

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***Abstract*—Recent developments around WiFi indicate, that it will eventually start taking new roles in our daily life, traditionally taken by sensor network protocols and Bluetooth. However, its channel access mechanism is may not be effective in new environments. CSMA-CA is, probably, the most controversial access method, especially in implementation by WiFi. It has poor spectral efficiency and practically forces the devices to be online for all transmissions and all contentions. The question is what could we do for WiFi to improve efficiency under new conditions, without making it too fragile or too complicated?**

In this work, we present a novel approach to WiFi improvements, that aims to be a middle-ground between fragile strict scheduling and power-hungry nature of contention-based access. The proposed procedure aims at improving the network's awareness of its future with each packet sent, while not enforcing any specific structure or strict scheduling. At the moment, the procedures involved are under heavy development, but already show promising results.

***Index Terms*—Wireless MAC, WiFi, distributed scheduling, random multiple access.**

I. Introduction

LATEST developments around WiFi are an evolution from a cheap solution for wireless Internet access into a full-featured short-range radio system. In particular, WiFi Direct [1], which provides capabilities to publish and discover services, is already available on most modern terminals, and is pushed as a default radio for proximity-based services in 3GPP [2], [3]. In addition, 802.11ah aims at applications, traditionally served by sensor networks, while 802.11p attempts to resolve problems typical for vehicular networks with dedicated signaling channels. The list goes on, yet the question we need to ask is if WiFi in its core design is actually suitable for the challenge ahead?

WiFi is associated with history of inefficiency claims. On the other side, nobody usually praises WiFi for ability to deal with unpredictable interference, typical in 2.4 GHz ISM bands. Most of the time, even against all odds, WiFi "works", even though most other protocols would give up long ago. The key feature that allows WiFi to do that is simplicity of the access procedure. It is difficult to reliably disrupt WiFi operation with anything but constant jamming.

WiFi was designed for unlicensed bands, but similar protocol may be needed in a licensed bands for D2D communications, where multiple mobile short-range transmitters must share resources, and strict control is not feasible. For instance, experimental FlashLinq protocol [4] relies on distributed access control with verification through carrier sensing, even though all terminals operate in a licensed band.

One can come up with WiFi improvement schemes for particular situations, e.g. where another network assists WiFi in connection establishment and other similar tasks [5]. Such potential has been well studied by various research groups, including our own, with results showing that under network assistance WiFi Direct can provide efficient proximity-based data transfer service for LTE UE's [6]. However, this does nothing to actual data transfers. Actions could be taken to implement global scheduling for LTE-assisted WiFi, similarly to FlashLinq, but presence of uncontrolled terminals in the network limits applicability of such approaches, making D2D communications less attractive than they probably could be. As a result, we are now proposing a simple software extension for 802.11 protocol, that improves the network's awareness about its own operating conditions, and potentially provides the required middle-ground between pure random multiple access and coordinated operation in 802.11 protocols.

II. Proposed adjustment to 802.11 protocol

We assume operation in ad-hoc scenarios where PCF is not applicable. Our primary target is low-power devices, which can not afford the high power expense of constant carrier sensing and decoding every single packet on the air. The challenge lies in creation of a procedure, that enables nodes to do the following:

1) plan their transmissions ahead, and reliably inform their neighbors about such plans, thus avoiding excess contention
2) sleep as much as possible between transmissions, instead of wasting power in every single contention interval

We intend to use an alternative approach to scheduling. Normally, the schedule formation is a process that is performed by cluster head nodes, and every other node needs to adhere to the published schedule. This makes system more efficient, but does not make it simple and reliable. For instance, cluster heads need to communicate to make sure their schedules do not cause collisions.

In the research there have been several attempts to address distributed scheduling, through broadcasting of relevant information together with data packets or as part of a separate protocol [7], yet scalability of such approaches is questionable. All schedules are based on distribution of knowledge among nodes, and nodes strictly adhering to the schedule. But if the nodes are incapable of adhering with the schedule, or there are

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unpredictable transmissions present, the schedule is disrupted. It is especially true if the only copy of the schedule is available.

The proposal is to put a copy of the schedule into each packet sent by all nodes. The outcomes are two-fold: some overhead will be added to each transmission, yet any packet allows one to get up to speed with what is going on in the network. For a sensor network such protocol would be considered wasteful due to small data size, but in 802.11 setting such solution is not so wasteful. In particular, adding 100 bytes of schedule information to each packet (including ACK's) would correspond to approximately 40 milliseconds of air time in case of WiFi (at 54Mbps, assuming just 2 nodes communicating), or 30 microseconds for each access attempt. The schedule can be easily compressed, and it only holds events happening around one node, thus it easily fits into 100 bytes.

This simple estimation shows, that attaching an entire schedule of the network to each and every transmission is indeed feasible. As a result, a signaling scheme was designed, that essentially mimics the conventional 802.11 RTS-CTS procedure. The new signaling scheme distinguishes three states of the channel with respect to a given node's view on a given time instant in the future:

1) Active (transmitting/receiving)
   a) TX and RX occupy channel in both directions for 802.11 due to the ACK reception requirement.
   b) This state is also assigned to request and confirmation (RTS and CTS) signals
2) Idle (not occupied with anything)
3) Jammed (there is a source of signal nearby that prevents this node from communicating)

The above states are assigned to the future time observations by each node participating, and then broadcast with every channel access. This ensures that any node wishing to access the channel may mark it as occupied in the future and thus experience less contention. In addition, the future transmitter needs not be active to broadcast the schedule, as every node that accesses the channel for its own transmissions acts as a repeater, maintaining the schedule in its immediate neighborhood, where it applies. To enter the schedule, node transmits using contention-based access in the gap between scheduled transmissions, which means extension can work with legacy devices. Should this happen the scheduled transmitter would not transmit during reserved time, and the schedule would resume as usual.

Let us consider an example presented in Figure 1. The initial schedule is a combined knowledge about future of the channel by all devices in the marked area. At instant 1 node A wakes up, catches the tail of latest transmission before him to synchronize the schedule, and transmits his view, which consists of 2 active slots and a slot jammed by node B. At moment 2, the node B transmits its packet, informing everyone around him about future transmission. The violet node C is an "intruder", and prevents the cyan node from transmitting preallocated its time, so it is forced to skip access and the node A transmits instead. Then, since node D is no longer in the schedule, it is forced to use conventional CSMA to force himself back in. An accurate time synchronization is not required for such system, as long as the data packets all occupy approximately same amount of time to be delivered. Any potential empty space can be utilized for CSMA access by legacy nodes.

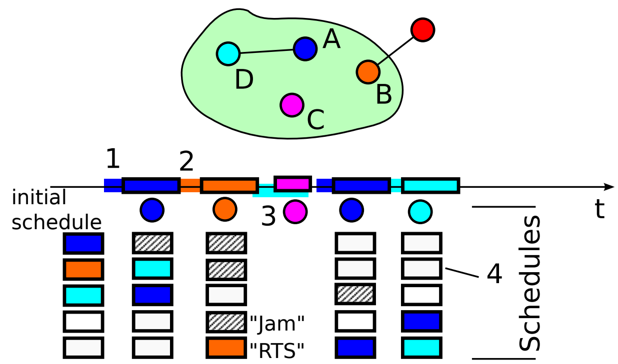

Figure 1. Example operation of a proposed extension

III. Some preliminary results

Preliminary study indicates that the suggested WiFi extension could significantly improve power efficiency of the devices, as well as potentially relieve the congestion. That would be very beneficial for small-scale battery powered devices, allowing them to sleep between access attempts. The specific numbers are still too early to call, but in a static channel conditions the proposed scheme can greatly reduce the number of packets that one needs to decode. For example, for 50 subscribers in collision domain the rate changes from 50% (everything but ACK's) down to a more reasonable 10%.

We are constantly working on the improvements of the extension as far as algorithms are concerned, as well as on its analysis. As it appears, in the absence of "intruder" nodes, the proposed procedure is analytically tractable. Unlike conventional backoff-based access, the proposed algorithm does not change the behavior as a result of access attempt, making it memoryless, which means analytical evaluation should be applicable here.

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