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Towards voice/video application support in 802.11e WLANs: A model-based admission control algorithm

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A B S T R A C T

Supporting emergent voice/video applications in all wireless technologies is a requirement in the Next Generation Network (NGN) where Wireless Local Area Networks (WLANs) is a main component. For this type of applications, QoS needs to be fully maintained in order to assure user satisfaction. Actually, QoS control in 802.11e WLANs to support real time voice/video services remains an open problem. All the solutions that only aim to enhance the performance of the Enhanced Distributed Channel Access (EDCA) mechanism cannot resolve the performance degradation problem once the channel becomes saturated. Hence, an efficient admission control scheme in EDCA is the key to guarantee the QoS required by voice/video services in WLANs. In this paper, we propose a model-based admission control algorithm that is located within the QoS Access Point (QAP). An accurate analytical model is used to predict the QoS metrics that can be achieved once a new flow is introduced in the WLAN. Based on this prediction and on the QoS constraints of already admitted (active) flows as well as of the new flow, the QAP takes the appropriate decision for the new flow. The proposed admission control scheme is fully compatible with the legacy 802.11e EDCA MAC protocol. It is validated numerically and through simulations using several realistic usage scenarios.

1. Introduction

In order to support high throughput applications (video), a new generation of WLANs is going to be standardized in the upcoming years. This shows the importance of supporting voice/video applications by this kind wireless technology as it is the case of other wireless mobile networks (NGN). Standards offering high throughput are a requirement for the future of internet services. These standards coupled to QoS aware mechanisms can constitute a solution to the major problems in today's standards. In 802.11e access mechanism EDCA, there is no guaranty in terms of throughput and delay assurance for voice/video services. Before the network gets saturated, there is no QoS problem. The problem arises once the network starts to reach saturation and a high number of flows share the limited channel resources. At each new flow arrival, the existing flows loose a certain degree of their already achieved performance. This is due to the fact that channel resources have to be distributed among different active flows according to their priority. This means that voice/video services which are unable to adapt their flows to this resource limitation cannot be supported correctly. Therefore, a resource management solution, controlling the number of active flows in a given WLAN is required. Hence, there is a compelling need for an efficient admission control mechanism capable of maintaining the QoS required by voice/video applications.

Many proposals for an admission control scheme exist in the literature [3–17]. We mainly distinguish those based on measurements and those based on analytical models. The former are limited by their inability to guaranty the required performance to flows in terms of throughput and delay assurance. Indeed, measurement-based approaches are based on the current channel utilization conditions measurements, which make them unable to map these measurements to the required performance metrics. These mechanisms have also another important limitation related to the fact that they cannot measure the new channel conditions resulting from the introduction of the new flow without really introducing this new flow. On the other side, the model-based admission control schemes are mainly limited by the analytical model upon which they are built to make their decision. This later is either developed under the saturation conditions assumption and therefore it is not suitable to be used in an efficient admission control procedure as this one is supposed to be used to avoid such saturation, or it suffers from some limitations when it was developed and therefore has a low degree of accuracy (missing of one or more of the three EDCA differentiation

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parameters, missing or partial modeling of some important features of the EDCA procedure, etc.).

In this article, we propose an admission control mechanism which is based on our new analytical model developed in [1,2]. This later was developed with two main objectives: (1) to provide a sufficient degree of accuracy and precision and (2) to have a low computational overhead in order to be suitable for the usage in an admission control algorithm. The analytical model we developed is applicable to all traffic conditions going from non-saturation to complete saturation. It can predict the achievable throughput and the mean access delay per Access Category (AC) for any configuration of the three EDCA differentiation parameters: Arbitration Inter Frame Space (AIFS), Contention Window (CW) sizes, and Transmission Opportunity Limit (TXOPLimit). Our analytical model outperforms already existing models in the literature as it was demonstrated extensively in [1,2]. Note also that parts of this article had also been published in [3]. Differently from [3], this article contains the complete study and procedure going from the design of the accurate analytical model and its validation results to the design, discussion and validation of the admission control mechanism. The validation part of the proposed admission control algorithm also contains more extensive results for wide range of realistic usage scenarios.

After this introduction, in Section 2, we discuss the different approaches used in the conception of admission control schemes in EDCA, their advantages and their limitations. Some existing admission control mechanisms in the literature are also discussed in this section. Our analytical model, on which the admission control algorithm is based, is presented in Section 3 with the focus on the main contributions that distinguish our model from the others. Section 4 contains the validation of the analytical model. In Section 5, we present our approach for an admission control scheme based on the analytical model. A set of realistic scenarios to validate the admission control solution and to show its reaction in the presence/absence of non-real time applications with the real time applications, are realized and the results are discussed in Section 6. Conclusions and perspectives close this paper.

2. Related work and motivations

Existing admission control schemes for EDCA can be classified into three categories: measurement-based, model-based and hybrid. In the following, we discuss advantages and limitations of each of these three approaches while studying in details some model-based admission control proposals.

2.1. Measurement-based admission control

In this category, we cite the work of [4–8]. Using such mechanism, the QAP measures at each measurement interval the channel conditions. Based on the values obtained, it makes its decision to accept or reject the upcoming flow. Such mechanisms have the following two advantages:

- Complex numerical computation is avoided. Simple computation of additional loads that could be generated by the activation of the new flow is done. These additional loads are then compared to the measured residual capacity of the channel.
- Measurements give more precision than numerical estimations.

However, this approach suffers from multiple limitations which can be summarized by:

- The QAP cannot consider the real QoS requirements in terms of throughput and delay as a decision criteria. In fact, the measurements cannot be mapped to QoS metrics and there are no means to be sure that the QoS requirements will be guaranteed.
- The measurements can only give the channel utilization conditions. They cannot give the achievable values of throughput and access delay.
- It is very hard to choose the measurement interval value. This value must be sufficiently high to reflect the steady state functioning regime, and at the same time, it must be sufficiently low to reflect any change in the channel conditions. This compromise is difficult to reach and there is no precise solution explaining what the best measurement interval value is.
- It is often necessary to use signaling between the QAP and the QSTAs (QoS STAtions) to share measured information.

2.2. Analytical-model-based admission control

Using this approach, the QAP is based on numerical computation to predict the performance metrics before making any decision. For these mechanisms, we note:

- From one side, a high response time when the analytical model is computationally complex.
- From the other side, an accuracy problem if the model is not accurate, it is based on severe approximations or it does not reflect correctly the protocol behavior.

This is despite the following advantages:

- The decision and the processing are made only within the QAP. This later has no need to gather information from the QSTAs. Hence, there is no need for signaling that increases the control load in a limited resources network.
- The decision is based on the real QoS requirements of flows. In fact, the QAP uses the predicted performance metrics if the new flow is admitted. Based on these predictions and on the QoS requirements of the new flow and the already active flows, the QAP decide to reject or admit the new flow.
- The QoS metrics are predicted analytically without the need to introduce the new flow.

In the following, we discuss more in detail different solutions that had been proposed in this category. First, the solution of [9–11] use an analytical model limited by the saturation conditions. These admission control mechanisms are not efficient because they are based on the achievable values of QoS metrics in the saturation conditions. These are the asymptotic values that are far from the optimal achievable values in the network as demonstrated in [1,2].

For the works that that are not limited by the saturation assumption, we have [12–14]. In [12], the decision criteria is the access delay. The objective of the proposed admission control is to maintain the network far from the saturation state. The authors of [12] affirm that the used analytical model overestimates the access delay and therefore the decisions are made with a certain security margin. We agree that this margin permits to be sure that the network is still far from the saturation state and therefore performs better. But, this overestimation – if large – may cause the rejection of new flows even if the network can serve them.

Similarly, in [13], the delay constitutes the decision criteria. In fact, the authors suppose that an admission control based on the achievable access delay is better than one which is based on the achievable throughput. This is because the need of bandwidth comes after the need of low delays. This affirmation does not hold in all situations, we think that it depends on different factors: mainly traffic types, EDCA parameters configuration and QoS constraints of active flows. We argue that it is not sufficient to use only the access delay as decision criteria. It is necessary that the