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Channel measurement-based access point selection in IEEE 802.11 WLANs

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ABSTRACT

With the wide deployment of IEEE 802.11 Wireless Local Area Networks, it has become common for mobile nodes (MNs) to have multiple access points (APs) to associate with. With the Received Signal Strength Indicator (RSSI)-based AP selection algorithm, which is implemented in most commercial IEEE 802.11 clients, the AP with the best signal strength is selected regardless of the candidate AP's available throughput, resulting in unbalanced distribution of clients among the APs in the network. Several studies have shown performance improvement in not just the new MN (nMN), but also the network as a whole when the selection process considers the current load status of candidate APs. However, the proposed algorithms in these studies assume that there are no hidden terminal problems that severely affect the performance of the network. Hidden terminal problems frequently occur in wireless networks with unlicensed frequencies, like IEEE 802.11 in the 2.4 GHz band. Moreover, none of the previous studies have considered frame aggregation, a major improvement in transmission efficiency introduced and widely deployed with the IEEE 802.11n standard. In this paper, we propose a new AP selection algorithm based on the estimation of available throughput calculated with a model based on the IEEE 802.11 distributed coordination function in consideration of hidden terminal problems and frame aggregation. The proposed algorithm is evaluated through extensive simulation, and the results show that the nMN with the proposed AP selection algorithm can achieve up to 55.84% and 22.31% higher throughput compared to the traditional RSSI-based approach and the selection algorithm solely based on the network load, respectively.

1. Introduction

With the wide deployment of IEEE 802.11 Wireless Local Area Networks (WLANs), it is common for mobile nodes (MNs) like smartphones and laptops to face multiple access points (APs) at the time of connection. Most commercial 802.11 clients scan wireless channels to detect nearby APs and associate with an AP with the strongest Received Signal Strength Indicator (RSSI). Recent studies [1,2] have shown that such RSSI-based selection can cause unbalanced MN distribution on APs across a network. Moreover, this can greatly affect the performance of not only the nMN, but also the already associated MNs.

AP selection is a popular research topic in both academia and industry [1–10], with a goal of providing a network environment with maximum performance and fairness across networks. [3,4] proposed a scheme that collects the ratings of APs from MNs when communicating with APs and makes a selection based on the ratings cached in the MNs. Such ratings-based mechanisms only work when the network status remains similar over time. [5] considers channel condition in the

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selection algorithm and [7–9] sought to predict an AP's load based on the delays between probe request and response transmissions that are used as a metric in their selection algorithm. Unfortunately, [5] and [7–9] analyze neither the network status, such as packet error rate, nor throughput of the network, which lacks precise prediction. [6] proposed a distributed AP selection process using game theory, but under the assumption that all MNs have identical status. The authors of [1,2,10] proposed an algorithm that assumes the available throughput of the candidate APs by dividing the bandwidth by the number of associated MNs; however, this model only considers the saturated condition when all of the MNs in the network transmit continuously. Although [1,10] analytically calculated the packet collision probability in the medium access control (MAC) layer, none of the aforementioned studies provide a numerical analysis of the available throughput of the network. Additionally, none of the studies considered hidden terminal problems that can severely affect not only the nMN's performance, but also the entire network's.

Performance analysis of IEEE 802.11 has also been a popular academic research topic [11–16]; however, no previous studies, to the best our knowledge, proposed a suitable theoretical model to obtain the available throughput for the AP selection mechanism. The authors of [11–15] proposed analytical models to determine network throughput under unsaturated conditions by extending Bianchi's two-dimensional Markov chain modeling of the IEEE 802.11 Distributed Coordination Function (DCF) under saturated conditions [16]. Although the models of the IEEE 802.11 DCF in the aforementioned studies show higher accuracy compared to the methods used in the AP selection algorithms, there are limitations in their direct adoption in the AP selection algorithm. [11] used the temporary variable q to express the degree of load; however, q can only be found if the current status of all of the MNs in the network is known. [12,13] used the packet generation rate of each MN in their analysis models, which is difficult to gather for a joining MN. [14] proposed a model that predicts network throughput based on channel utilization, which is measured by physical carrier sensing and channel monitoring. The model in [14], however, has the same problem of requiring every MN to know all of the others in the network. Also, the hidden terminal problems are not considered in their models. Some studies have taken hidden terminals into account in their models [15,17]; however, they have similar limitations to other studies, as follows. [15] extended [11] to consider the hidden terminal problems in the model, with the requirement of knowing the current status of every MN in the network. [17] proposed an analytical model that considers hidden terminals, but is limited to saturated conditions.

In this paper, we develop a mathematical model of an IEEE 802.11 DCF access scheme that analytically derives the available throughput of a joining MN (i.e., nMN), in both saturated and non-saturated conditions considering hidden terminals from nearby APs as well as the frame aggregation technique by extending the model in [14]. Then, the model that we have proposed provides a distributed algorithm that enables each MN to estimate the maximum available throughput for all candidate APs and to select the AP that can provide the highest throughput. The performance of the proposed algorithm is evaluated through extensive simulation. Results obtained indicate that the mathematical model that we have proposed provides throughput estimation with reasonable computation power, and prove that the throughput of the nMN is based only on channel utilization and average busy duration measured at the MN and a particular AP, regardless of the number of existing MNs connected to the AP.

Our main contributions are as follows:

- To the best of our knowledge, there is no previous proposal that considers contention, hidden terminals and frame aggregation, as we do, in theoretically modeling the available throughput of IEEE 802.11 WLANs.
- The proposed algorithm is designed to be implemented on MNs in a distributed manner so that there is no additional control framework or manager to share the information. In addition, the algorithm requires no complex computation, such as mathematical recursion or multiple integrations.

The remainder of this paper is organized as follows: Section 2 describes the background of this paper. Section 3 presents the mathematical model used to estimate AP throughput and proposes our AP selection algorithm. Sections 4 and 5 present the simulation results and the concluding remarks.

2. Background

The performance of the IEEE 802.11 network has improved with the ratification of new standards. For example, frame aggregation introduced in IEEE 802.11n [18] significantly increases channel utilization efficiency by reducing 802.11 overhead, both physical (PHY) and MAC layers. However, such advances are not considered in most of the AP selection algorithms available both academically and commercially. As well as the advances, wide deployment of the IEEE 802.11 devices increases possibility to interfere with other devices, especially hidden terminals. Hidden terminals in the same or adjacent channels can affect not only the performance of a single MN, but also of the network as a whole; however, they are not considered in most AP selection algorithms as well.

2.1. Frame aggregation

Frame aggregation, which was proposed in [19], improves overall throughput with simple optimization to minimize the non-transmission time. Two types of frame aggregation are defined in the standard [18], the aggregated MAC-level service data unit (A-MSDU) and the aggregated MAC-level protocol data unit (A-MPDU). A-MSDU optimizes the MAC header