An Algorithm for Optimal Network Planning and Frequency Channel Assignment in Indoor WLANs

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***Abstract*—The increased use of wireless local area networks has led to an increased interference and a reduced performance, as a high amount of access points are often operating on the same frequency channel. This paper presents a network planning algorithm that minimizes the number of access points required for a certain throughput and optimizes the frequency allocated to each AP, leading to reduced interference. The network planning algorithm is based on a heuristic and the frequency planning algorithm on a combination of a greedy algorithm and a Vertex-Coloring-Based Approach. The algorithm provides a good performance and has a limited computation time.**

I. Introduction

An efficient choice of the locations, the transmit power values, and the frequency channels of access points (APs) are three challenges in planning wireless networks. Generally speaking, the goal of the first two aspects is to obtain a high coverage, with a low cost or a low human exposure. A bad assignment of the AP frequencies can however lead to increased interference in the network, lowering the coverage and increasing the exposure due to an increased number of packet retransmissions [1]. Therefore, in this paper, we propose an algorithm for the optimal attribution of IEEE 802.11 WLAN channels to the different APs in a network, thereby choosing from the three available non-overlapping channels (channel 1, 6 and 11 in most of the countries). The algorithm consists of two main parts: an assignment operation based on a coverage-oriented greedy algorithm and an optimization operation based on the vertex-coloring-based approach.

A class of frequency assignment problems has been addressed as the Vertex Coloring Problem (VCP) in [2]. In [3], the frequency assignment problem has been interpreted as the colouring problem. There are three main approaches for the VCP in [4]: Vertex Coloring Based Approach [5], Conflict-Free Set Coloring [6], Measurement-Based Local-Coord Approach [7]. The difference between the frequency assignment problem and the VCP is that the number of colours (the frequency channels for frequency assignment problem) is fixed at 3. Furthermore, in order to obtain three-colour results, the connected (interfering) topology of vertices (APs for our situation) is not fixed.

II. Optimization algorithm

The algorithm will be applied to the building floor depicted in Fig. 1, an office building consisting of drywalls (brown) and concrete walls (grey). The algorithm consists of two phases: optimal network planning and optimal frequency planning.

A. Optimal network planning

In a first phase, a minimal set of WiFi APs and their location is calculated, with the output subject to user-defined coverage restrictions. In some rooms, no coverage is required (e.g., toilets, elevator shaft, kitchen,...). These are indicated with red flags in Fig. 1. All other rooms are assumed to require HD video coverage (required received power of $-68\ dBm$). The path loss model we use to calculate the link-budget is the Simple Indoor Dominant Path Loss (SIDP) model described in [8]. The 95%-shadowing margin is set at 7 dB and the fading margin at 5 dB [8]. For exposure limitation purposes [9], the Equivalent Isotropically Radiated Power (EIRP) of the deployed AP is limited at $5\ dBm$. The algorithm is based on consecutively selecting the best AP from an 'AP pool' (a set of candidate APs), based on a smart AP selection algorithm, followed by an optimization process [10]. Fig. 1 shows the optimal location of the APs, according to the network planning algorithm.

B. Optimal Frequency Assignment

On the set of APs with their specific location (see Fig. 1), the frequency planning algorithm is applied. It consists of the four phases depicted in the flow graph of Fig. 2.

1) **Retrieve plan information**: number, location, and EIRP of all APs, and physical layout information (wall locations and wall types).
2) **Execute assignment operation** (see Fig. 2): in this phase, each of the three non-overlapping channels (1, 6, 11) is assigned a set of APs. Firstly, in order to avoid interference, the coverage area is calculated for each AP based on a certain receiver sensitivity. For our scenario, the initial receiver sensitivity is set at $-100\ dBm$. When the coverage ranges of two APs are overlapping, the algorithm assigns different channels to these APs. Secondly, after having assigned a channel to each AP, the total number of different assigned channels

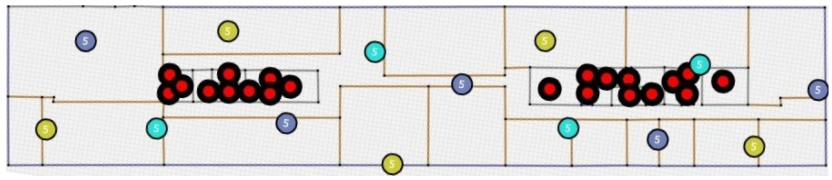

Fig. 1. Optimized network with indication of locations of the APs on the grand plan (90 $m \times 17$ m) and their EIRP (inside dot). Different non-overlapping channels of Wi-Fi are indicated with different colors (channel 1= dark blue, channel 6 = light blue, channel 11 = green). Red flags mark rooms that do not require coverage.

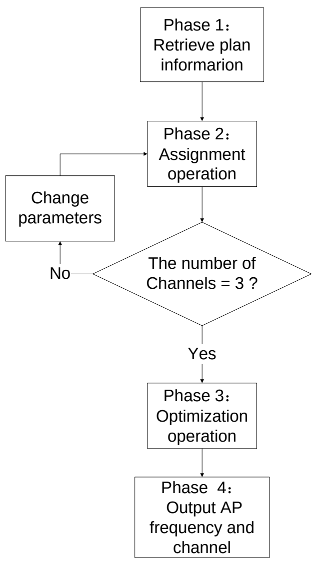

Fig. 2. Flow graph of the frequency planning algorithm

is investigated. If this number is larger than three, the receiver sensitivity is worsened ($+1$ dB) and a new iteration is run. This process continues until a solution with only three channels is obtained. This may require multiple iterations, but the total computation time is still short, due to the use of the fast greedy algorithm [3].

3) **Execute optimization operation**: in this phase, the AP channels are further optimized. Greedy algorithms have the disadvantage that the result can be sensitive to some input parameters of the algorithm (e.g., the input ordering of APs) for the map colouring problem [3]. The distance between a specific AP and a specific channel is defined as the smallest distance between this AP and all APs on the current channel in this phase. The channel of the APs is optimized by assigning the farthest channel to each AP.
4) Write the AP frequency and channel in the plan file and output.

The output of the frequency assignment optimization is also shown in Fig. 1. Different colours represent different frequency channels. Fig. 1 shows that each channel is assigned to 4 or 5 APs. The figure indicates the good performance of the algorithm: each AP is surrounded by APs on another channel. The total computation time for the frequency assignment for the 14 APs is about 140 s. When more simple path loss models such as IEEE 802.11 TGn channel models [11] are used, the computation time reduces to only 0.04 s.

III. Conclusion

In this paper, an algorithm is proposed for optimal network planning and frequency planning. It yields a network satisfying a user-imposed coverage requirement with a minimal number of access points and with a minimal interference between the access points. The frequency planning algorithm is based on a greedy algorithm and on a vertex-coloring approach, in which the coverage range and location of APs are taken into account. This network optimization algorithm is applied to an office environment and shows a good performance, while computation times are kept short.

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