M2 Internship: Graph Algorithms for Fair Wi-Fi Channel Allocation

LIP (Laboratoire de l'Informatique du Parallélisme)
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Required background: Graph theory, algorithms, computational complexity.

The goal of this internship is the study of graph optimization problems which arise in the context of Wi-Fi channel allocation. This subject is a collaboration of two research teams of the laboratory: HowNet (Anthony Busson) studying (among others) networks, and MC2 (Pierre Bergé, Carl Feghali, Rémi Watrigant) studying (among others) graph algorithms.

Wireless Local Area Networks (WLANs), especially Wi-Fi, are widely deployed in a variety of situations: homes, corporate or campus networks, public areas, etc [1]. For most of these deployments, the Wi-Fi network is composed of several Access Points (AP) that are seen by the users as a single logical Wi-Fi network (eduroam is a well known example of such a network). These AP are often densely deployed to ensure i) a proper coverage of the area (to guarantee that a user will always find an AP in its radio range) and ii) a high throughput (the throughput is strongly correlated to the distance between the user and its AP). This densifcation leads to conflicts between AP. A conlict appears when two AP are in the radio range of each other. These conflicts may have several harmful impact on the performance: a global throughput decrease, and unfairness. To mitigate the number of conflicts and their impacts, different channels/frequencies may be allocate to the AP.

These Wi-Fi based wireless networks can easily be represented by a conflict graph, where each AP is a vertex, and edges represent interference between them. A channel allocation corresponds directly to a coloring of this graph. Due to the small number of available channels compared to the number of AP and the density of the conflict graph, finding a proper coloring of the input graph, that is a coloring where each color class induces an independent set (*i.e.* a set of vertices inducing an edgeless graph) is hopeless, and we will thus have to organize each channel in a way that the throughput of each AP is as high as possible. Some recent work [2] suggests that this throughput is directly related to the structure of the independent sets of each color class. For instance, it is high if each vertex of the class belongs to an independent set of maximum size. The goal of this internship is to study graphs enjoying a fair distribution of their independent sets, and the combinatorial problems related to this property. It appears that such graphs have a strong connection with some known graph classes such that *well-covered graphs* or *extendable graphs* [3].

Depending on the preferences of the candidate, different aspects of the problem can be studied:

- Structure analysis of the graphs enjoying a fair distribution of its independent sets.
- Algorithmic complexity of the related problems. It includes: finding efficient algorithms or corresponding lower bounds (hardness results), studying which graph classes, parameters or graph decompositions can make the problems easier to solve (it is likely that real-world instances have a geometric flavor, *e.g.* they might be close to disk graphs).
- Practical aspects: designing and implementing efficient exact algorithms or heuristics for finding a good channel allocation. It also includes the random generation of graphs simulating real-world wireless networks.
- Network simulations: implementing these channel allocations in the network simulator ns-3 to evaluate the performance of the algorithms in a high realistic context.

Depending on the success of the internship, this subject can be the starting point of a Ph.D. thesis.

References

[1] Matthew S. Gast. *802.11 wireless networks - the definitive guide: creating and administering wireless networks.* O'Reilly, 2002.

[2] Soung Chang Liew, Cai Hong Kai, Hang Ching Leung, and Piu Wong. Back-of-the-envelope computation of throughput distributions in csma wireless networks. *IEEE Transactions on Mobile Computing*, 9(9):1319–1331, 2010.

[3] Michael D. Plummer. Some covering concepts in graphs. *Journal of Combinatorial Theory*, 8(1):91–98, 1970.