8 Generalizations

Beyond the basic problem formulation introduced in Section 4, there are other kinds of constraints and objectives arising in practical DAB network planning which are not yet addressed in our present version of the DABTool system, but will be considered for future extensions. Some of these are sketched out in the following.

Restricted Block Assignments Just as in classical channel assignment planning, it may be necessary to restrict the set of available frequency blocks available at certain vertices. The main reason for this are other types of broadcast services using up certain frequencies in the neighborhood of the corresponding area. For instance, in most countries the new DAB network must coexist with existing FM or TV networks for quite some time, and hence it is necessary to protect the frequencies used by these services. Such conditions can be formulated by introducing a set C_v of available channels for each area $v \in V$. The block assignment f will then have to satisfy the additional constraint $f(v,B) \in C_v\ \forall\ (v,B) \in \mathcal{B}$, which leads to a generalized graph coloring problem known as the *list coloring problem* [11]. While many graph coloring heuristics can be extended to handle list coloring quite easily, the design of effective ensemble packing strategies which take into account the coloring restrictions is an open problem.

Admissible color sets for *services* instead of vertices are also a practical requirement to be considered, since DAB is currently transmitted in two separate frequency bands, the VHF band and the L band. For technical reasons, the latter incurs much higher running costs (typically 4-5 times the costs of a DAB network in the VHF range), and is therefore considered suitable only for covering smaller geographical regions. Hence in real-world planning scenarios, one usually distinguishes "local" services such as city radios, which should be collected in ensembles assigned to L band frequencies. In general, such requirements can be formulated in terms of given color sets $C_s : s \in S$ by adding the constraints $f(v,B) \in \bigcap_{s\in B} C_s\ \forall\ (v,B) \in \mathcal{B}$ to the problem statement. If the color sets are overlap-free (i.e., $C_s \cap C_{s'} \in \{\emptyset, C_s\}\ \forall\ s, s' \in S$), then the problem actually decomposes into several ordinary ensemble planning problems, one for each color set. However, if the color sets are allowed to overlap in a non-trival manner then more elaborate solution techniques will be needed.

Maximization of Free Bandwidth In general, there may be many different optimal or good solutions for a given instance of the ensemble planning problem, and hence we might be interested to find solutions with certain desirable properties. For instance, even an optimal solution might be further improved by increasing the "free bandwidth" still available in the constructed ensembles for additional services without having to modify the existing block assignment. A suitable measure for the free bandwidth is the following quantity which we might add as a secondary objective function to be maximized:

$$\sigma_M(\mathcal{B}, f) = \sum_{i\in f(\mathcal{B})} \sum_{B\in\mathcal{B}_i} (M - \mu_B). \qquad (12)$$