Optimizing the investments in mobile network technologies and designing of offers

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1 Context and stakes

An increase in the number of users as well as in users demands leads to exponential traffic growth. This traffic growth pushes telecommunication companies to expand their network through important investments (several billion to improve the mobile network in the last six years). They want indeed to satisfy the request of their subscribers in speed and volume to remain competitive. However, excessive or useless investments over the time horizon should be avoided. As a service provider, operators can use subsidies to avoid unnecessary investments. This has led to the design of mobile master plans, whose modeling under a Mixed Integer Linear formulation has been studied in [3]. This modeling integrate both subscriber and network investments. They consider two types of network investments : densification (new pieces of equipment on an existing site) and coverage extension by installing the new technology. These three types of investments are jointly optimized at each period of the time-horizon while satisfying capacity and strategical guidelines constraints (see [2]).

The model from [3] tackles the case of a new generation to be installed on existing sites. However, mobile networks evolve fast. 4G will become the leading mobile network technology worldwide by the number of connections (more than 3 billion) in 2019 according to the GSM association [1]. This global number hides important disparities. In European countries, 4G is fully deployed, and first 5G experiments have already started in big cities. However, 4G deployment (sometimes with pure 4G sites) is still in progress in other countries, especially in Africa. Telecommunication companies are worldwide groups and hence face different situations in their different countries affiliates. Moreover, 5G arrival comes with a change of paradigm and the migration from a macro-cell network to a multi-scaled cell network. Some of the frequencies used for 5G are indeed of very low range and thus push to use microcell networks, where small relay antennas are used in addition to a bigger antenna. The microcell networks sites will be cheaper but will be far more numerous in order to cover the whole territory. Another limitation of [3] is that each telecommunication site is associated with its own pool of subscribers, which assumes that there is no overlapping between sites coverage. This assumption leads to overdimensioning since sites coverage overlapping exists in real networks and hence a technology installed on a neighbor site could have been sufficient to serve the subscribers. Allowing the possibility of installing new sites and assessing the earnings due to sites coverage overlapping in dimensionning, are hence important stakes for an operator.

2 Contributions

Our modeling contribution over our previous work [3] is two-fold. First, we model the sites coverage overlapping. We consider that the territory is divided in areas. Subscribers from an area can be served by a given technology on a given site if the range condition is satisfied. We introduce a multi bipartite graph to model this range condition, with an edge (labeled with a network technology) between an area and a site if this area can be served by the site for this technology. Second, we model the possibility of installing new sites (equipped only with the newest technology) on the areas not yet equipped. We provide a mixed integer formulation that tackles the two cases, and linearize it in a classical way. We reinforce the model with several valid inequalities. We prove the NP-hardness of our formulation, even in the case of a single generation, single module and mono period framework, by a reduction to the set covering problem.

Computational tests have been performed on real life instances. On the one hand, we have shown that taking into account the overlapping reduces computational times and gaps despite a large number of optimization variables in the formulation. On the other hand, the use of micro-cells has shown the scalability limits of the Branch-and-Bound approach for modeling the problem. Beyond this limit, heuristics have to be designed since the problem becomes out of memory. On a business point of view, our results enlighten the important savings allowed by sites coverage overlappings.

Références

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