Mobile networks migration optimization

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1 Introduction

The Orange group is a worldwide telecommunications operator with around 157.000 employees, 228 “business countries” and 28 “residential countries” ; mainly in European and African countries. Orange group is both a service provider (owns customers) and a network operator (owns the network). Operations research applications arise at this company in different contexts, like in the design of the networks, in the management of their resources/workforce as well as in the management of customer relationship.

In the last few years we have witnessed a natural growth of data traffic in mobile communications. This growth is a combination of two joint phenomena : the growth of the number of customers and the growth of the Average Usage per User. In a more and more competitive market, Orange has to understand the behavior of customers in order to plan optimally its investment in new mobile generations. In this work, we are interested in investment decision problems for new technologies. Such problems have been treated in the literature but with other targets in mind [1]. We propose here an approach based on the quality of service and coverage that aims a cost minimization for migration to new wireless technologies.

Telecommunications operators need to deal with the rollout and management of several generations of mobile networks on the same geographic sites. Dismantling one generation of mobile network is no easy option since operational teams are reluctant to abandon well-functioning (and robust) technologies for new ones without back-up. Moreover, several services may need old(er) technologies (machine-2-machine, roaming, ...). Hence, different technologies must coexist and Orange group maintains simultaneously 2G and 3G technologies in African affiliates and 2G, 3G and 4G technologies in European affiliates. In this scenario another important issue arrives : the problem of heterogeneous coverage. The migration of base stations to new wireless generation is a very important operational problem for Orange. A key question is : how to drive the evolution of mobile networks (in terms of capacity and coverage) taking into consideration traffic evolution, new services and potential strategical constraints ? By solving the problem presented in this work we hope to shed some light into this question.

2 Problem Definition

We consider a set $T = \{0, 1, 2, \ldots, \bar{t}\}$ of time points dividing the given time horizon into a set $\mathcal{I} = \{I_1, \ldots, I_{\bar{t}}\}$ of $\bar{t}$ equally-sized time periods. Decisions are taken for each time step. Typically the time horizon is a set of $\bar{t}$ years divided into $\bar{t}$ periods of 1 year.

Only two generations, 3G and 4G, of mobile networks (and subscribers) are considered in this work. At the beginning of the time horizon, the whole territory is fully covered by the 3G network while the 4G network is under extension. The feasibility of the network is only based on data traffic. At the end of each time step, the capacity of the network must be sufficient to the traffic imposed by the current set of all users. We assume that the operation area is divided in a set $S = \{s_1, \ldots, s_n\}$ of telecommunication sites. Each site is either a pure 3G site, providing only 3G service, or a 3&4G site, providing both 3G and 4G services. Actually, a pure 3G site can have 4G users but those behave as 3G users.

Subscribers have a known average traffic that increases with time and that, at each time step, is higher for 4G users. Some traffic allocation engineering rules are considered. In a pure 3G site coverage, any type of subscriber's traffic is conveyed by the 3G network. On the other hand, in a site covered by 3G and 4G technologies, the whole 3G subscribers traffic must be conveyed by the 3G network, as well as the whole 4G subscribers traffic must be conveyed by the 4G network. The initial number of 3G and 4G subscribers located at each site is given. These values are calculated considering the peaking hour at each site. The increase in the total number of customers is predicted by marketing services for each time period. These values define a set of uncertain parameters of the problem. For each time period, a range of percentages of increase with respect to Orange current number of customers (3G and 4G) is given. We also assume that 33% of the new customers are 3G subscriptions and 67% of the new customers are 4G subscriptions. New customers are assumed to be allocated to sites proportionally to the number of customers at the end of the previous time step.

The capacity of the network can be increased in two ways : by installing new antennas into an existing site ; by installing new modules in an already installed antenna. The maximum number of modules per antenna of each technology is given. Since the actual policy of Orange is not to invest in old technologies, we assume that only new 4G antennas will be installed. Costs associated with the installation of new antennas as well as new modules are given for each time period.

Current subscribers of a given technology can migrate to a more recent technology service. In the problem treated in this text, this means that, at each time period, a number of 3G subscribers will migrate to the 4G technology. Subsides are offered in order to promote user service upgrades : a subside will be defined for each time period and an upgrade function determines how users respond to the subside offered. More precisely, the upgrade function is the function informing, in percentage, the number of users that respond positively to a given subside and it is defined as a function of both the subside offered and the coverage (i.e., the percentage of 3&4G sites at the end of the previous time period). The upgrade function is assumed to be an increasing function with respect to both the financial subside offered and the coverage.

The design of a multi-period master plan for mobile network consists in deciding, for the given set of time points, how to invest on the evolution of network technologies regarding three aspects : densification, coverage extension and user upgrades. We denote the problem described in this section as the Mobile Master Plan Problem (MMPP).

3 Results and Perspectives

We propose and discuss two alternative ways of describing the upgrade function and an ILP formulation is presented for the deterministic version of the problem. We present a preliminary evaluation of the aforementioned model on real-world data. The results obtained allow us to understand the advantages as well as the computational limitations of our approach. Directions are presented to treat a robust version of the MMPP.

Références

[1] Duan, L. and Huang, J. and Walrand, J. Economic Analysis of 4G Network Upgrade. *Proceeding of IEEE INFOCOM*, 2013.