Chapter XXV
How to Plan for an Upgrading Investment in a Data Network?

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ABSTRACT

We illustrate how a mobile data network operator can plan an upgrading investment to anticipate explosions of the demand, taking into account the expected profit and the customer satisfaction. The former parameter grows with the demand, whereas the latter sinks if the demand is too high, as throughput may collapse. As the equipment price decreases with time, it may be interesting to wait rather than to invest immediately. We then propose and discuss two methods that help in making the decision. The first one is an actualization algorithm, where the upgrade should be performed when the loss of profit, derived analytically, exceeds the expected discount. The second is a real option-like strategy to hedge against the risk that the investment has to be anticipated. The evaluation of the investment date is then performed, in the latter, by a backward dynamic programming approach, using recent improvements based on least-squares estimations, whereas, in the former, a forward actualizing algorithm is investigated through simulations.

INTRODUCTION

As new multimedia applications are introduced in the market, the traffic is significantly growing in mobile networks. In particular, data flows are growing exponentially, as they have been doing since the middle 90s in the Internet. To face these soaring volumes of data to be transferred, mobile operators must periodically upgrade their equipments to offer higher throughputs and avoid blocking problems. However as the demand does not increase steadily and must be considered as partly random, the upgrade dates are difficult to be forecast (Morlot, et al., 2007).

In this chapter, we consider upgrade investments in a **HSDPA** (*High Speed Downlink Packet*

Access) **cellular network**. Note that, when demand increases, the data communication duration becomes longer and longer for each user until the network is saturated. The individual throughput experienced in the network may become very small.

On the other hand, as the demand rises, the operator increases its profit. When the network starts experiencing saturation problems, throughput and profit may fall. The operator must then upgrade its network by adding new frequency carriers, facing the following trade-off:

- The later the investment, the lower individual throughputs and customer satisfaction. Permanent non-satisfaction will result into churn and additional loss of profit.
- The sooner the investment, the more expensive the costs of upgrade elements.

This chapter aims at modeling analytically the trade-off. We first derive analytical values for capacity, individual throughput and satisfaction as a function of the demand, and use them to calculate operator's profit, taking into account randomness of the rising demand, and decrease of network element costs according to time. We then propose two decision-making methods.

In the first method, we develop an **actualization algorithm** that calculates the optimal investment time using the above described analytical modeling, as in our previous work (Morlot et al. (2007)). We base our method on the idea that the upgrade should be performed when the loss of profit, derived using analytical capacity expressions, exceeds the expected discount. As time goes by, we have realizations of the daily demand. These values can thus be used to derive a more precise optimal date than the one we found at time $t = 0$ assuming demand randomness. Instead of calculating expectations, we can now take in account what *really* happens during the period. This is the idea of the actualization algorithm, where the expected investment time is calculated using simulations.

We then introduce a second, more analytical method, based on real options to hedge against the risk that demand evolves in an unexpected way, leading to a premature investment decision or a too late one. To perform that, we model the investment as a virtual American call that gives its owner (the mobile operator) the right, but not the obligation, to buy an equipment, until a maturity date. Given the profit analytical model and the option's parameters, we propose a backward dynamic programming method to obtain the expected best investment date.

BACKGROUND

The problem of investment under uncertainty has been investigated in several domains. Longstaff & Schwartz (2001) introduced a pricing method for american options in general (this method has been approved in Protter, Clément & Lamberton (2002)). In Laughton (1991), the authors introduced a real options method to evaluate investments in oil fields. A real options framework was also proposed for evaluating investments in sustainable development projects (see Salahaldin & Granger (2005) and Salahaldin (2007)). For a detailing of real option types and correlated bibliography, see Trigeorgis (1993), and for a general economic introduction, see Dixit & Pindyck (1994).

In the telecommunications field, the applications were scarce, although real options are relevant to telecommunications in several areas: strategic evaluation, estimation and cost modelling, as indicated in Alleman (2002).

D'Halluin, Forsyth & Vetzal (2007) presented a work on a method to determine the best investment date in a wireless network. His approach was based on dynamic programming, but he didn't introduce any risk hedging method nor an option pricing. This chapter aims at showing, using the example of an **HSDPA data network**, how the investment decision can be evaluated based on a calculation of the expected profit.