

Chapter LVII

Designing a New Service Overlay on a Carrier Network Using the Efficient Frontier

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ABSTRACT

The network carrier must utilize the full potential of existing physical infrastructure before any new investments can be considered. Much work has been done to develop optimal design methodologies that generate a “best” design but designs often have to be changed to meet operational considerations, potentially mitigating any optimization benefits. This work proposes to expand the optimal network design process by applying a process borrowed from Finance and Operations Research/Management Science literature known as the Efficient Frontier or production frontier analysis. Using this idea, a portfolio of designs differing in cost, and number, size and location of nodes will be developed and from that the efficient frontier will be defined. By comparing any subsequent design to the frontier, the network designer can have an understanding of the impact of changes in the design strategy to the long-term cost effectiveness.

I. INTRODUCTION

Mitigating the risk of expanding a network in today’s economic climate requires that the network carrier utilize the full potential of existing infrastructure before any new investments are

considered. The design of actual networks is the product of multidimensional constructs of performance and reliability optimized around a certain factor or factors such as cost or reliability. Typically, a methodology is created to define near optimal solution depending upon the constraint

parameters to be considered. Much work has been done to develop optimal design methodologies using one or multiple objectives but these problems are intractable and NP-hard and can require complex computational solutions that are often best approximations (Yun et al, 2001). Even after the optimal design has been developed, during implementation the design often has to be changed to meet operational considerations, potentially mitigating any optimization benefits. Design of telecommunications networks is a complex, usually iterative, process with several objective functions such as low cost, reliability, security, and survivability. To find the optimized design, an exhaustive analysis must examine every possible combination of all parameters thereby proving the best fit to meet the specified design characteristics. Finding near-optimal solutions requires fast heuristic algorithms, establishing acceptable constraints or bounds and then “relaxing” these constraints so the solutions can be found with reasonable resources and time (Kennington et al 2007). The bulk of published research and literature in mathematical modeling and optimization deals with ways of making this very complex problem simpler and easier to solve. Mathematical modeling and optimization are well-developed and mature areas of research with a variety of articles available for the interested reader who is referred to Bertsekas (1998), Sanso and Soriano (1999), Grover and Doucette (2001), and Kennington et al (2007) for broader overviews.

This paper is intended to discuss the impact of applying the efficient frontier concept to network design of a new service overlay and assumes that a method for defining the optimal network design has been adopted. The method used to calculate the optimal design and cost of the case studies in this chapter will be presented, but that method is not the main focus of this effort. Applying the concept of the efficient frontier is the main focus of this chapter.

Using the efficient frontier or production frontier, a concept borrowed from finance, agriculture

economics, and operations research literature, a design process can be established that creates not just a single optimal solutions but also a set of solutions, (Markowitz, 1959 and Farrell, 1957). A brief discussion of the Efficient Frontier concept will be presented but interested readers are referred to Fare et al (1994) and Copeland et al. (2005) for mosolutions for the problem. By developing a set of optimal solutions using design heuristics that best fit the given project, an envelope of cost functions is created. The lower boundary of this envelope is the efficient frontier or suite of “best” designs as far as the parameters used for the optimization. The efficiency of any design is the relationship of the final cost of a design to the frontier. Evaluating the distance any point is from the efficient frontier gives a measure of how efficient the design is as related to the parameters used in the optimization. If the cost of a design lies upon the frontier it is considered efficient, the further off the frontier, the less efficient the design. By understanding the impact of design changes to the final cost of the network, well-informed design changes can be implemented with regard to final or long-term cost.

Complicating the design process for communication networks is that there are often multiple objectives such as reliability, security, and recoverability in addition to low cost. For multiple-objective optimization problems a set of Pareto-optimal solutions can usually be defined (Sawaragi et al 1985 and Koopmans 1951). The set of Pareto solutions becomes the efficient frontier for the design process. Pareto optimal solutions do not necessarily optimize all objective functions but create a set of candidate solutions that can be individually evaluated for use. The input parameters to these problems are usually arrived at through analysis related to the subject area being investigated (Yun et al 2001). The method presented by Yun et al (2001) involves extensive mathematical multiple objective optimization utilizing much computational resources. This paper presents a similar process in that an efficient

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