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Global optimization models in data networks: a case study[☆]

M.M. Ali[1]

School of Computational and Applied Mathematics, Witwatersrand University, Private Bag-3, WITS-2050 Johannesburg, South Africa

Abstract

In this paper we present a methodology for a rural and semi-urban data network placement. In order to optimally place the network and to ensure that the network is realistic and viable we address four key issues, namely, the demographic and socio-economic issues, geographical estimation, optimization of the network placement and financial optimization. A digital representation of the map of the region where the network has to be placed is used. A continuous optimization algorithm is applied to optimally place the backbone rings, and a combinatorial optimization algorithm is applied to obtain the optimal rollout order for the network. Mathematical formulations for both the optimization problems are presented. Optimal financial indicators are obtained.

Keywords: Data network; Geographical estimation; Continuous optimization; Combinatorial optimization; Point of presence; Backbone; Ring topology; Rollout order; Net present value; Internal rate of return

1. Introduction

Data communication networks are becoming critical components of economic growth for an evolving global information society. The establishment of modern, reliable and rapidly expanding communication infrastructures contributes considerably to the promotion of a variety of activities of economic expansion [1]. Telecommunication Networks and the Internet offer a unique opportunity for rural development, but in the Southern African region the opportunity has not been fully realised. The vast majority of the rural people in the region do not have access to Telecommunication Networks and the Internet and as a result

☆ This network is a combined telephone and data network such as Voice over Internet Protocol (VIP).

1 Visitor at the Institute for Mathematics and its Applications, University of Minnesota, USA.
E-mail address: mali@cam.wits.ac.za (M.M. Ali).

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they have been denied the economic and quality of life opportunities that these technologies have created. In recent times, opportunities have been created to bring many rural people in contact with such data networks as a result of deregulated markets and government initiatives.

Our current research forms part of a network placement project involving a Southern African rural and semi-urban region of 500 kilometers (km) $\times$ 500 km, where an entire network has to be serviced. We first collected the socio-economic data, then created a computational environment where the network was optimized with respect to its placement and profitability. In our solution approach we look first at a hierarchy of the problem. We then solve all the individual subproblems in the hierarchy one by one, feed the results of one subproblem into the next as input data, and lastly assess the profitability from the final results. Our methodology addresses four core problem specific issues. The first issue we consider is the socio-economic estimation. The second issue is the geographical estimation of the entire region. Thirdly, we have proposed a modified global optimization algorithm to tackle the optimization problem involving the network placement, in particular, the placement of backbone rings. Finally, we have derived a mathematical model for the profits which we have optimized using a combinatorial optimization algorithm to obtain a rollout order of the network. In related work [2], the optimization of the backbone ring placement and a clustering algorithm in the context of telecommunication are reported. The optimization problems involved in the third and fourth issues are multimodal, i.e., there are a number of local minima for each problem. We have therefore used global optimization algorithms to solve these problems. A global optimization algorithm is an algorithm that is designed to obtain the global minimum value (the very best minimum) of a minimization problem with more than one minimum.

The aim of this research is to assist the network providers (investors). Therefore, we combine all four issues in a computational environment that can assess the commercial viability optimally. Although our approach is directed at solving a particular problem, the methodology can be applied to solve any network placement problem (including telecommunication networks) where the financial aspects can be incorporated.

In Section 2, we discuss the demographic and socio-economic issues. In Section 3, an analysis of the geography of the region is given. In Section 4, the optimization problem involving the backbone placement of the network is presented. A combinatorial optimization problem involving the rollout order is derived in Section 5. In the same section, data for the combinatorial optimization problem is presented. Numerical results are presented in Section 6 and conclusions are given in Section 7.

2. Demographic and socio-economic data

We have investigated some demographic and socio-economic data that directly or indirectly affect the viability of the network in our study. The demographic data measures the population density, which is the subscriber base, hence it provides knowledge of the operator's (investor's) market size (teledensity). The study of population also identifies key locations for installation of telecommunication equipment as well as the distribution and concentration of the types of user, e.g. business and household users (using telephone, fax or computer) and their demand per year. We have taken into account the literacy and unemployment rate (telepropensity), as they are good indicators of the necessary extent and nature of the network. The study of the economic domain is also important in identifying key indicators used to determine if a network is viable in an area. We considered the gross domestic product (GDP) per capita to be the most useful predictor of land-line telephone penetration.