# CATV NETWORK PLANNING, A SYSTEMATIC APPROACH

A.C.Martelleto, H.P.Pinheiro, M.CarneiroS., P.B.França, P.D.Silveira

Inter Net Comunicações
Av. José de Souza Campos , 304
Campinas-SP BRAZIL 13.092-020

*Abstract*

*This paper describes a proposed methodology for CATV distribution network planning, its mathematical model, and a discussion of some results obtained in this application.*
*The methodology has been applied in two operations: NET São Carlos and NET Franca (cities in the state of São Paulo, BRAZIL) where there were no CATV services and the networks are in process of construction.*

## INTRODUCTION

Computational tools used in support of decision-making have enjoyed greater and greater usage in several productive sectors of the economy. Several factors are contributing to the expansion of these computational systems. Among them is an endless increase in computer processing power coupled with a corresponding reduction in cost, the improved applicability of mathematical modeling, and the evolution of solution techniques. The main factor, unquestionably above all else, is the increasing necessity to work with optimized solutions which minimize implementation costs adjusted to specific quality levels.

The search for optimized solutions within systemic approaches has become increasingly difficult as the magnitude of the systems grow and more control variables are included. In these cases, most of the time, it is appropriate to recur to other types of resources. The construction of mathematical models and the development of optimization tools and artificial intelligence for model resolution have become one of the most studied technique around the world.

Networks are among the systems which are most frequently studied. The great number of applications in strategic areas such as electrical power, telecommunications and transportation, associated with the easy and applicable systems representation through graphs and powerful problem resolution algorithms, turn them into excellent objects to be treated by support tools in decision making.

In the CATV area, the outside plant is an important system component representing sizable investments in initial cost and operation. In this context, it is not enough just to identify potential subscribers, install the network and pray that everything works out.

This paper presents a mathematical model and its resolution, using optimization algorithms and knowledge-based heuristics, creating an expert system for the problem of CATV planning.

The methodology is designed to:

(1) allow a systemic approach to the problem;

(2) consider present requirements of cost minimization and quality improvement ;

(3) visualize long term aspects focusing on the market and technology (new services, opticalization, digitalization, etc).

## MATHEMATICAL MODEL

The problem is modeled mathematically, through a graph, composed by a set N= { 1,2,... n} nodes and a set M= { 1,2,..., m} branches. Each node represents a utility pole of the area under study and associated to it is a demand composed by the number of potential homes that receive signal from that pole. The branches represent the possible connections between the poles and have as a characteristic their length. They also form the set of possible ways for the routing of trunks and feeders.

Several problems have to be solved through the use of this graph. They include the location of hubs, the routing of fiber optics, the routing of trunk lines, feeders, the control of the signal, and others. If you deal with the problem in a general way, an extremely complex model is created. The problem becomes so complex that one can antecipate major difficulties in determining its solution. Eventually we realize that it is impossible to use techniques of mathematical programming (MP). To soften the diversity aspect of the problem and its dimension, the general problem was subdivided into parts that ended up producing a graph composed of two levels (Figure 1).

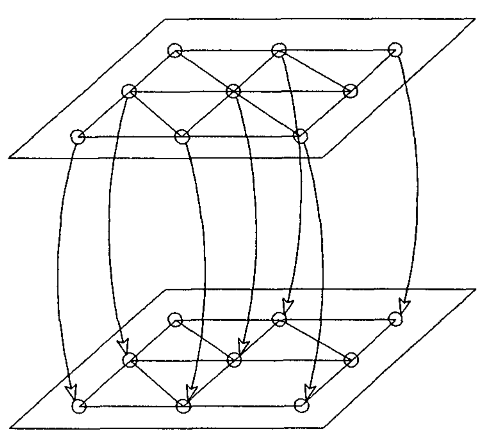

FIGURE 1 Representation of the mathematical model

On the first level, the problems of location of hubs and of routing of fibers are modeled. On the second level, the problem of the design of the network of a cell, which is delimited by the area of influence of a hub positioned on the above level. Since these hubs are the signal feeding points of the cell, connecting arcs are created to link these nodes to their corresponding ones on the bottom level. This will "allow" the entrance of the signal to each of the cells. It is possible to define which nodes will shelter a hub and which will not. For the latter the link by connecting arcs between the top and the bottom levels are not made. In Figure 1, for example, two of the nodes will most probably not shelter a hub. In the final solution, only the arcs that represent chosen hubs will be present.

The great number of variables, along with concavous cost functions (installation cost), make it difficult to approach the problem through MP. A resolution to the problem is accomplished in a hierarchical form. First, the top level problems are solved (location of hubs and routes of fibers), and then the design of each cell is accomplished. In order to relate the solution obtained on the top level with the one of the bottom level, producing a complete solution, a heuristic methodology is proposed. This methodology also approaches the problem of the number of hubs.

First, taking a look at the top level, the problem is modeled as an incapacitated location problem that defines the location of hubs and their areas of influence. The fiber optics routes that will be used to feed the hubs are modeled through a minimal spanning tree problem.

On the bottom level, the design of each of the cells is accomplished. At first, the design is done with a topological view that seeks to "discipline" the network and to generate an initial solution. It can, however, be unachievable or present poor results with regard to RF signal level.. To improve this resolution, heuristic changes based on engineering rules (expert system) that propose to allocate equipment and redefine the "microcells", taking into account the signal level, are being developed.

The topological solution consists of subdividing each of the influence regions of a hub into microcells, making the routing of feeder lines in each of them and defining the feeding points of each microcell through the trunk line. The number of generated microcells follows the criteria of number of homes and maximum distance of servicing.

The division into microcells is modeled in a similar way to the problem of hub locations. The routing of the secondary feeders is done through a shortest path problem, while the connection of the primary network to the microcells is modeled as a Steiner problem.

## RESOLUTION METHODOLOGY

The resolution methodology is composed of several heuristic procedures and consists of increasing the number of hubs by 1 and producing a thorough solution. It is represented in Figure 2.

The following operation provides an estimate of the initial number of hubs:

$$\lceil ST/SC \rceil = Hi$$

where
ST : means the total number of homes
SC : the maximum number of the homes for one cell
Hi : initial number of hubs
and $\lceil \, . \, \rceil$ represents the minor integer higher than the quotient of the division.

The initial number of hubs is disposed in the graph so as to minimize the criterion demand x distance. This way, the aim is to place the hubs at the baricenter of the "charge". As the process of location the hubs occurs, the area of influence of each one of them is defined. Some cells, however, are likely not to respect the maximum number of subscribers. That being the case, one rule is created which allows the process to continue or to increase the number of hubs by 1, providing it with a new division. Due to the criterion used at this part of the program, the cells with many homes tend to suffer new divisions. The generated rule consits basically in checking if the "excess" of homes is diluted through the cells that burst the limit or is concentrated in some specific cells. If the problem is that of dilution, the process is allowed to continue. Otherwise, the number of hubs is increased. It is helpful to observe that the decision maker itself is able to tell the program to continue or to increase the number of hubs. After the hubs are located and the areas of influence defined, the process continues. The hubs are fed from the headend using fiber optics. At this point, the criterion is to minimize the length of fiber while making the direct connection between the points. This process shows a sequence of connections (the fiber´s route) and defines the number of pairs of fiber in each segment. To make this system reliable, it is required that the head-end degree be $\geq$ 3 at the generated tree. In other words, at least 3 branches must leave the tree at the head-end. In the future, features of disjoint paths and rings are likely to be included to feed each separate hub, which would make it significatively more reliable.

Having reached that solution, it became possible to define which connecting arcs are active, that is to say, which ones emit signal to a specific area. From this point on, the network design takes place.

The topological solution for the design at one of the cells consists of subdividing the cells into microcells, all with a similar number of customers, and all customers within a pre-established distance limit. As in the case of hub locations, these two conditioning aspects represent a decisive factor in the number of microcells to be generated. However, the network installation cost, based on the amount of cables used and equipment cost, becomes an important factor.

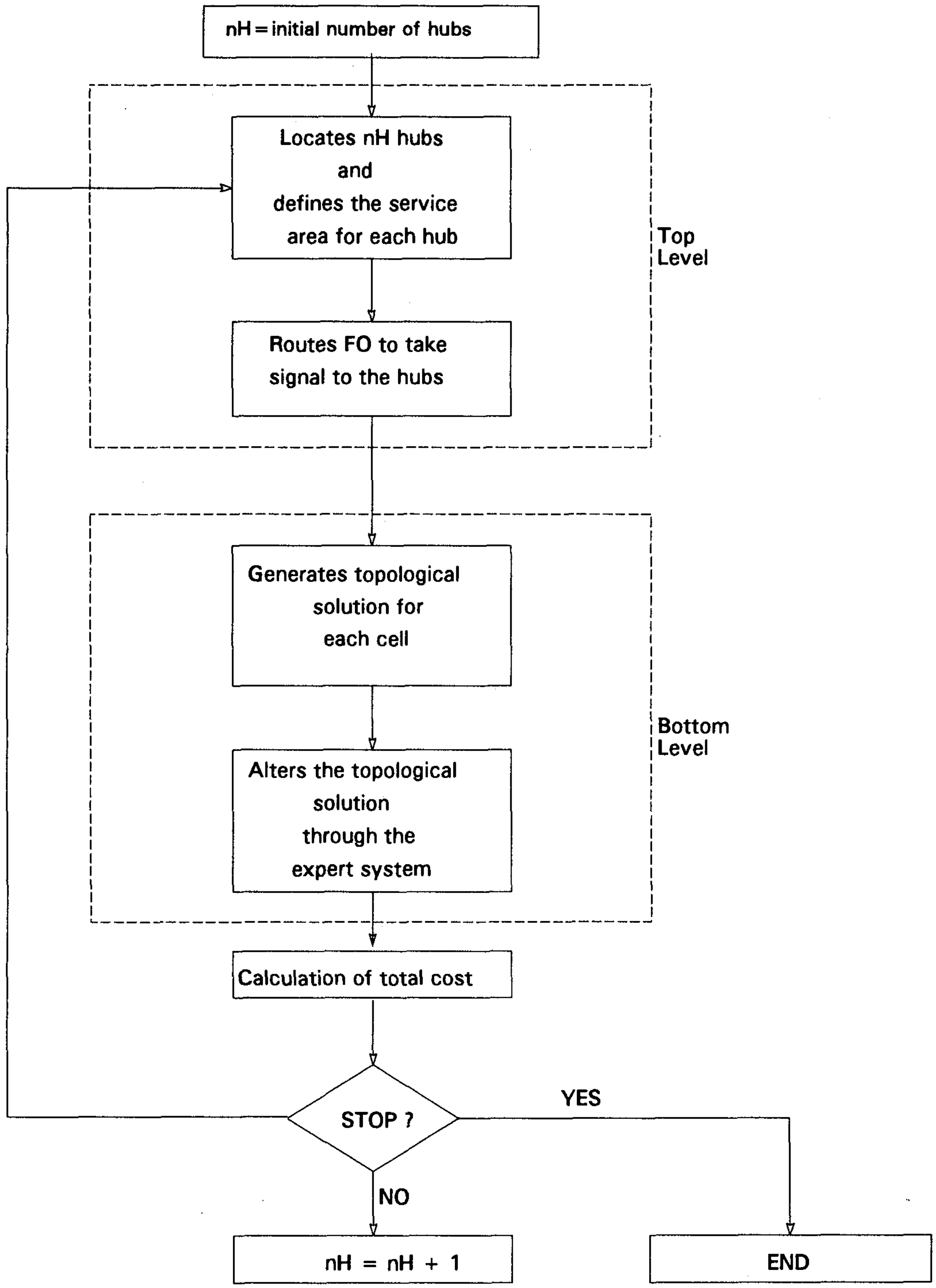


FIGURE 2 Methodology represantation

One might expect that the greater the number of microcells the less one should spend on distribution and the more one would spend on trunk. From the commitment to these figures and the obedience to other rules -- the number of subscribers, for instance -- the solution is reached. In fact, this cost will only be known after the second step of the process, which consists of changing the solution to assure adequate signal level to all potential consumers and the wise use of installation equipment, departing from the topological solution by the means of engineering rules and heuristics of change.

It is as if in the topological solution the network were totally passive having at each microcell a point with a signal level equal to 1. The distribution takes place from that point on. The point where the signal is equal to 1 is fed by a trunk. It is likely that there is a need of facilities to guarantee the signal level. Such an equipment allocation is handled by an expert system that tries to change the microcells frontiers for better equipment operation without departing too far from the topological solution which has the lowest cable cost, theoretically.

Having accomplished the design, the final cost of the best solutions (which depend on the number of microcells) are presented to the decision maker.

When all the designs are accomplished, a global cost is estimated and that will be the test for methodology stop.

## RESULTS OBTAINED

The described methodology has been applied by Inter Net, MSO in Brazil. It is not yet consolidated, but its development is in progress. It was applied to two cable operations, in which the FSA network topology was adopted.

For a proper evaluation we followed two lines of application of the methodology: one group applied a conventional approach to the network project and the other the tool herein described. The immediate results of a comparative evaluation show that :

- investment: to adopt the methodology it is imperative the outside plant data availability be in digital form, which today is an imposition. In relation to the computational environment, we have adopted PC standards, available at any operator office.

- performance: the tool allows a simulation of several settings and presents immediate results whereas in the conventional approach it is difficult to change the settings and the obtention of a complete design may take days depending on the availability.

- network costs: the most prominent gain from systemization was in the reduction in distribution cable needed. In some cases a reduction of ten percent in the amount of cables occurred however, it did not result in a reduction in the equipment aspect. There was also an increase to the trunk line and in terms of equipment the amount used was not affected. At the adopted approach, we believe that the knowledge based system with intrinsic rules to the equipment installation is the point that we should focus from now on. As it has already been mentioned, the expert system incorporates the rules defined by its designers and the resolution capacity is related to the endurance of the adopted rules..

- modularity: the systemic approach presented a rather uniform topological solution, which was translated to very similar microcells and with a better servicing in terms of signal to all homes. This feature is very interesting in terms of a future network partitioning with a larger use of fibers, so to speak.

At this moment many hypothesis about the future of the networks are being formulated. Within this context, the engineering teams try to foresee which necessities should be contemplated. However, this difficult task is frequently accomplished based on suppositions. Technologies that some months ago were considered for the future, today are called technologies of the present. As the global economy relies more and more on the movement of information, the decisions have to be made faster and with greater reliability.