AN INTERACTIVE COMPUTER AIDED PLANNING PACKAGE FOR RURAL TELEPHONE NETWORKS


* Departamento de Eng.Electrotécnica
Universidade de Coimbra
3000 COIMBRA,PORTUGAL

** Centro de Estudos de Telecomunicações
Sítio das Palhas
3800 AVEIRO,PORTUGAL

Abstract: An interactive software system for decentralised rural telephone network planning has been developed at the Department of Electrical Eng.Science of the University of Coimbra under a contract of cooperation with the Research Centre of the Portuguese Telecom Administration. The paper describes the features of the planning methodology together with an example of application.

1. INTRODUCTION

In general the planning of telecommunication networks is a difficult task — as a result of the large number of factors involved and their interdependency — requiring sophisticated mathematical tools and powerful computational means. However for rural telephone networks and due to their smaller dimension and special characteristics it is possible to develop computer tools for decision aiding based on microcomputers and incorporating the capacity of dialogue with the decision maker [2].

2. CHARACTERISATION OF THE PROBLEM

A rural network is characterised by a low subscriber density, a low average traffic per subscriber line and by the geographical discontinuity of the population agglomerates. In general the traffic is mainly directed towards the administrative and economical centre of the area.

Due to the sparsity in the subscribers distribution the "weight" of the subscribers lines is very important in terms of network cost, leading to a ratio between the costs of the transmission and switching equipments higher than for urban networks.

In general the rural network (static) problem consists in obtaining (for a given geographical area and a given demand forecast for the planning period) the structure of the network (number and location of exchanges as well as service areas) and determining the type and amount of equipment necessary for guaranteeing a compromise between cost minimisation and quality of service criteria.

As for the representation of the network we should take into account that incorporating in the model all its characteristics and peculiarities leads to a higher reliability in the results at the cost of an increased complexity of the model. Due to the diversity of the rural networks that we may encounter the consideration of a very high number of peculiarities may lead to the reduction of the model's applicability. In such cases it may be preferable to use heuristic type methods which are more simple and flexible and which easily enable to incorporate the decision agent experience in the planning process. On the other hand the characteristics of the rural networks make it advisable the use
of a decentralised decision process recurring to a computing system previously
developed. The rural network planning process requires then, in our opinion,
the adoption of algorithms and representation models which are flexible and easy
to adapt to decentralised and interactive planning, trying not to sacrifice the
rigour of the method.

3. DESCRIPTION OF MODEL

3.1 Nomenclature for the rural network

A rural network, as well as any local network comprises the subscribers' lines
equipments, the junction circuits, the switching equipments (exchanges and some-
times concentrators) and eventually digital multiplexes.

In this study we have adopted the nomenclature of the Portuguese operator for the
local network. This includes the following functional elements (see fig. 1):
local exchange, service area, subscriber line, distribution point ("PD" — point
of the network where the local cables are split into pairs of circuits destina-
ted to a group of subscribers), junction circuits, primary centre, partition
point (equipment located on a point of the cable network which allows the con-
nection of any incoming pair to any outgoing pair; the partition points may
be considered as primary or secondary and they are used for enabling a more fex-
ible and economical management of the cable network), main cable, distribution
cable and concentrator.

![Diagram](image)

FIGURE 1
Nomenclature for the local network

3.2 Outline of the Model

The interactive computational procedure may be divided in four phases. In what
follows a subscriber will be designated by the symbol "pp".

Phase I: Taking as basis the existing network, the demand estimate for the
"target" year (probable "pp") and the subscribers' terminals for the near future
(pending "pp") the user constructs on the computer screen an approximate represen-
tation of the subscribers' distribution which must be served by the network
(example in fig. 2). In order to facilitate the visualisation in more dense
zones we may assign a "weight" (number of subscribers) to each point of such
zones. In this phase the user has at his disposal four partial "windows" which
represent adequate subdivisions of the planning area.
Beyond the subscribers distribution the user must represent all the relevant information regarding the existing network (distribution and partition points, cross-connection points, switching centres and concentrators).

Each type of "point" in the representation of the network may be inserted with the cursor by previously selecting the corresponding item in a 'pull-down menu' (see section 4).

Phase II: The subscribers are aggregated (according to pre-defined criteria and/or decisions made by the user) in zones of distribution points ("PD"), serving groups of subscribers. Once a closed region has been defined on the screen the program calculates the number and location of "PDs" necessary for serving the "pp" within that region (ex. in fig. 3).

Phase III: The "PD's" are aggregated in 'elementary demand zones', in a way analogous to the one described in phase II. Each of these demand zones corresponds to a point designated as centre of demand (see fig. 4) placed on the centre of gravity of the zone, whose 'weight' represents the total number of associated subscribers.

The whole interactive process of representation of the demand ends when the user considers that the nodes obtained after phase III (which may include local exchanges, partition points, cross-connections points and concentrators, as well as centres of demand) reflects the topological and physical conditions of the network.
Aggregation of subscribers in "PD's" regions.

network. Note that the program is conceived as a 'network editor', including functions for deleting points (of any type) previously introduced.

Finally the user must also represent the transmission means (which must in practice approximately follow the roads or paths in order to reduce the installation and maintenance costs) by joining the nodes of the network representation and by introducing in the program the needed characteristics of the possible edges. At this stage of the process a final graph is represented in a 'global window' which condenses (according to the mentioned procedures) the information contained in the auxiliary "windows".

Phase IV: An heuristic algorithm (reviewed in the next paragraph) is then applied to the final graph (representative of the network) which intends to optimise the number of exchanges, their locations, the service areas and the required transmission means capacities.

3.3 Algorithm

From economical considerations it may be concluded that the network for a rural area has almost always a tree structure. This makes attractive the utilisation of an algorithm whose principle is well known and is described below.

The heuristic algorithm may be formalised by the following steps:

Step (0) - An initial number of exchanges (usually the number of existing exchanges) is considered, as specified by the decision agent.

Step (i) - Each node is connected to a switching centre according to the crite-
Calculation of the centres of demand

The first step involves the determination of minimal distance and taking into account the restrictions introduced by the user. As a result, a first definition of the service area is obtained. In this stage, the Dijkstra algorithm [4] is used for determining shortest paths.

Step (ii) - Each exchange whose location was not previously fixed by the decision agent is relocated within its service area previously determined. Every possible relocation is tested and adopted if it leads to a lower value for the objective function (total cost of the network).

Step (iii) - From the new configuration of the network, the service areas are rearranged by evaluating (in terms of the resulting value for the cost function) the possible advantage of connecting each node to another exchange.

Step (iv) - The two phases of the process just described are then repeated iteratively until a situation is achieved where no relocation of the exchanges and no redefinition of the service areas leads to a lower total cost, for a given number of exchanges. With this procedure, we seek to obtain several sub-optimal solutions whose cost is presented in terms of its "present value".

Step (v) - A new exchange is added and the process is repeated from (i) until all the possible configurations for a number of exchanges between the minimum and the maximum have been calculated.

It is important to note that the interactivity of the program means, in this context, that the user is allowed to specify (before running the algorithm):

- the points where an exchange must be located in any solution
- the points where in all solutions no exchanges are allowed to be located
- the sets of points which must be connected to a particular exchange in every
Graph representing the whole feasible network and the resulting solution (heavy lines).

Fig. 5 shows the resulting solution (for two exchanges) from the algorithm for a network — example whose representative graph is also in fig. 5. Relevant information regarding the solutions (namely required switching and transmission capacities for each element of the network and the corresponding partial costs and total costs) are stored in auxiliary files.

Still note that the junction network has also to be computed and its cost must be added to the subscribers network cost. For this purpose the number of junctions between exchanges (no alternative routing is provided) is calculated as a function of the traffic offered by simple inversion of the Erlang-B formula (for ex. see [5]) for the prescribed grade of service.

4. MAIN FEATURES OF THE PROGRAM

The program is written in Pascal and is implemented in a Macintosh II microcomputer. This choice resulted from the interactive and graphical capabilities of this microcomputer and the fact of being easy to use by persons with very low background in computers. As far as possible the proposals for the network evolution resulting from the program are displayed in graphical form in order to allow a quick visualisation of each solution.

Before initiating the study of a given problem, the program activates a dialogue box of the type referred in [3]. The user must then indicate the duration of the planning period, the admitted rate of discount and the files where information on the equipments costs is stored (transmission means and exchanges). When introducing exchanges or transmission means during the various phases of network
editing the user furnishes the relevant information to the program via dialogue boxes which are automatically activated.

The program is organised around 'menus' [3] where each item corresponds to a specific action which is either immediately implemented (for example selecting a window or calculating the location of a centre of demand) or activated by clicking the 'mouse' on the screen (for example placing a "pp" on a given point).

The main 'menus' for controlling the program are the following: "POINT" (this enables to place or eliminate different kinds of points directly on the screen, namely "pps", distribution points, partition points, centres of demand, exchanges, cross connection points); "AREAS" (for activating the different 'windows' and calculating the "PDs", the centres of demand and partition points); INFORMATION"(for drawing the edges of the final graph, choosing the weight for the different points and displaying various type of information regarding the nodes and edges of the graph); "SEARCH" (this activates the algorithm and shows the successive solutions of the iteration); "CONSTRAINT" (this enables to introduce various type of constraints on the nodes of the graph as previously mentioned).

Further details may be found in [6].

5. CONCLUSIONS

An interactive computational system for rural network planning has been presented whose main attractions seem to be: the possibility of making the most of the decision agent experience; adequation to decentralised network planning; flexibility and computational efficiency; easy to use by persons with very little background in computers. In this package conventional algorithmic tools were used. However special emphasis has been placed on the graphical interactivity with the decision maker. This is probably the main innovative feature of this work.

The model here presented is a static planning tool. The development of this work will be directed towards its integration in a algorithm for aiding to optimise the topological evolution of the network and the expansion of the cable network, by introducing dynamic programming and other decision aiding techniques.

REFERENCES AND BIBLIOGRAPHY

[6] Henggeier, Antunes; Climaco, João; Nordeste, Paulo; Diogo, José; Craveirinha, José, "Uma visita Guiada a um Modelo de Planeamento Interactivo de Redes Rurais", 39 Worhsoph Nacional das Telecomunicações, INESC-APDC, Aveiro, Nov. 87 (in portuguese).