ABSTRACT

The Portuguese PTT are going to introduce a new switching system in the trunk network. Alternative routing will be allowed and so it is necessary to study carefully the routing problem and to choose suitable dimensioning methods. Also to avoid extensive manual calculations a computer-based procedure is advisable.

This paper describes the main features of a computerised network design system called "ORIP", for the initial planning and future growth of the new trunk network. The system takes into account overload conditions and modular engineering.

INTRODUCTION

The introduction of a new trunk network in the Portuguese telephone system brings up new questions and problems. In particular, the use of alternative routing increases the planning task both in quantity and complexity.

This paper deals with the main points of a computer tool, called ORIP (Optimização, Rede, Inteúrbana Portuguesa), which has been designed for the planning and optimisation of the network.

The following aspects were considered in ORIP project:

a) - The choice of the routing pattern for the traffic between any two exchanges.

b) - The choice of suitable dimensioning methods which take account of the new switching system used (link system with grading).

c) - The optimisation of the network taking into account:
   - Traffic forecasts
   - Costs
   - Routing rules
   - Grade of service requirements
   - Dimensioning methods
   - Existing network
   - Overload conditions
   - Modular engineering

d) - The development of several planning aids.

Fig. 1 shows the basic framework of ORIP. It is assumed that the expected busy hour traffics between any two exchanges at a specified future date, are known. The same applies to the marginal costs, i.e. the estimates of the costs per additional circuits for all possible routes.

This data enters the calculation process in the form of matrices, the so-called traffic matrix and cost matrix.
ROUTING ALGORITHM

The aim of a routing algorithm is to decide a priori the routing of certain traffic streams, in order to avoid excessive and useless calculations during the optimisation process. In principle, the optimising algorithm can study the different types of routing for every exchange, and then choose the cheapest. Nevertheless the size of this task can be reduced by taking into account the values of traffic involved, practical considerations and constraints. For example, the number of outgoing routes from each exchange is limited by the capability of the switching system used. Overload conditions can also impose some special routings via service protection groups.

A practical routing algorithm can be designed bearing in mind parameters such as traffic, minimum number of circuits on high usage routes, minimum and maximum limits for the loss, etc. Furthermore some criterion has to be found to deal with the capability of the switching system.

The routing algorithm used by ORIP can be formulated as follows:

Let $A_{ij}$ be the traffic between the exchanges $i$ and $j$ in the network. $P_{ij}$ is the cost ratio between tandem and direct route $i, j$ (fig. 2).

$$P_{ij} = \frac{C_{ik} + C_{kl} + C_{lj}}{C_{ij}}$$

$$P_{ij} = \frac{C_{ik} + C_{kj}}{C_{ij}}$$

Fig. 2 - Routing pattern

1 - If $A_{ij} \leq 2$ erlangs, then $A_{ij}$ is carried on the tandem routes.

2 - If $A_{ij} \geq 50$ erlangs, then $A_{ij}$ is carried on a direct route with availability 40. This value of traffic can be offered to 60 circuits (1 PCM supergroup or 2 PCM groups) with a loss of 3%.

3 - If $2 \leq A_{ij} \leq 50$ erlangs, then the routing of $A_{ij}$ will be defined during the optimisation process.

4 - For each $i, i=1,2,...,N$ where $N$ is the total number of P.C. (Primary Center) in the network, the following relation has to be observed

$$ND + 2 (D_1 + 1) \leq C_1$$

with

- $ND$ - number of non-defined routes
- $D_1$ - number of direct routes
- $C_1$ - maximum number of routes with availability 20 allowed by the switching system (normally $C_1 = 12$).

5 - If the above relation is not satisfied, the number of non-defined routes $ND$ has to be decreased by changing some of them to tandem, one at a time. A simple criterion is suggested: for the non-defined routes one calculates the products $Q_{ij} = A_{ij} \times P_{ij}$. The route with less $Q$ will be changed to tandem.

DIMENSIONING METHODS

The switching system used both in the Primary Center (P.C.) and Secondary Center (S.C.) is built up as two stage link system with expansion in the A stage. In order to attain a compromise between accuracy and simplicity, regarding the amount of calculations involved, two simple models were chosen: the deformed Erlang distribution for the primary routes (fig.3) and the truncated negative binomial distribution for the secondary routes (fig. 4). Both models use the geometric group concept for the loss function.

$P_1(v) = P_1(0) \left[ \frac{A^v}{V^v} \right]_{s=0}^{\pi} \left[ 1 - W(s) \right]$  

Fig. 3 - A model for primary routes

$P_2(v) = \left( -b \right)^{v} \left( -c \right)^{s} \sum_{s=0}^{\pi} \left( V \right)^{v} \left( N \right)^{s} \left( -b \right)^{s} \left( -c \right)^{s}$  

Fig. 4 - A model for secondary routes

These models are presented by Wallstron (1) (2) (3) and can be used to solve practical alternative routing problems, particularly when link systems are involved. The essential features of the models are the description of the non-Poissonian call processes by a state-dependent call intensity function and the calculation of the mean and variance of overflow traffics using binomial moments.
Furthermore they extend Jacobaeus' theories (4) to alternative routing problems taking into account the interdependence between stages.

The new work was to rewrite all the formulæ in terms of probability ratios, which leads to a suitable form for computation purposes.

**OPTIMISATION OF THE NETWORK**

The optimisation of the network under the parameter "cost", is achieved by using the approximate solution for the optimising equation, suggested in (3).

\[
- \frac{\partial M}{\partial N_1} = \frac{C_1}{C_2} + \frac{C_3}{\beta_{z2} \beta_{z3}}
\]

\[\beta_{z2} \text{ and } \beta_{z3} \text{ are the marginal capacities of the tandem routes but taken with constant peakedness factor.}\]

As far the marginal capacity is concerned, the key factors are the peakedness of the traffic offered and the availability of the route. The traffic itself just defines the area of working of the system, i.e. grading or not grading.

Bearing this in mind a simple procedure for estimating the marginal capacities of the tandem routes was developed. Taking account of the different conditions (average inlet load, availability, traffic), the traffic model for tandem routes was worked out in order to find a relationship between marginal capacity and peakedness factor. Fig. 6 shows some of the results.

For the common range of peakedness factors and in the case of grading a linear relationship is a good approach. On the other hand in the non-grading case a better fit is obtained by a negative exponential function.

This relationship is put on a table and used during the optimisation process, which decreases significantly the computation time. For the Portuguese Trunk network with 53 exchanges, a typical run of 5 iterations needs 35 seconds of CPU time in a CDC (CYBER 730).

\[\text{Fig. 6 - Marginal capacity as a function of the peakedness factor}\]
OVERLOAD ANALYSIS

When alternative routing is used, and in all cases of routes working with a high efficiency some attention has to be paid to the effects of overloads. These effects are particularly important for traffic offered directly to the tandem routes, the so called first routed traffic.

To avoid troubles from overload, several measures can be taken. A preventive technique is used by ORIP to deal with overloads. In each iteration the traffics on high usage routes from a particular exchange i, are increased by a certain amount, say 25%. Then the total overflow traffic is calculated and the loss BT for first-routed traffic determined.

If this loss is greater than a certain fixed value BTM (in our case BTM = .04), some action has to be taken. The algorithm studies two possible solutions:

a) - The introduction of a S.P.G. (Service Protection Group)

b) - The change of a high usage route to a direct route.

\[
OV = \frac{R' - R}{R} \cdot A_{ij}
\]

i.e., the relative increase of overflow traffic times the offered traffic. The route with higher overload factor is changed to direct.

The necessary adjustments on the tandem routes are made and the costs CSP (cost with service protection group) and CD (cost with a direct route) calculated. The cheaper solution is then chosen.

The minimum number of iterations is controlled by the user but the end of the optimisation process is determined by the overload criterion.

ORIP, THE COMPUTER ALGORITHM

ORIP is written in Fortran comprising at the moment approximately 2000 lines of code. The system is divided into main subsystems: The Network Calculation Subsystem (NCS) and the Planning Aid Subsystem (PAS). The first one deals with the calculation and optimisation of the network; the second one is concerned with the manipulation of the results and the provision of a large amount of information about the network.

Figure 8 gives a block diagram of the system. The results of NCS are stored on disk in order to be used by PAS. The main subroutines are available in individual programs which allows a particular result to be checked whenever necessary.

Table 1 describes the subsystems of ORIP.

<table>
<thead>
<tr>
<th>NCS</th>
<th>NETWORK CALCULATION SUBSYSTEM</th>
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<tbody>
<tr>
<td>RCS</td>
<td>Routing Calculation Subsystem</td>
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<tr>
<td>CRES</td>
<td>Cost Ratio Engineering Subsystem</td>
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<td>OAS</td>
<td>Overload Analysis Subsystem</td>
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<td>MES</td>
<td>Modular Engineering Subsystem</td>
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<th>PAS</th>
<th>PLANNING AID SUBSYSTEM</th>
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<td>RDS</td>
<td>Route description Subsystem</td>
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<td>SAS</td>
<td>Statistical Analysis Subsystem</td>
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<tr>
<td>ESS</td>
<td>Exchange Specification Subsystem</td>
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Table 1 - Subsystems of system ORIP
CONCLUSION

The main aspects of ORIP, a computer tool for the planning of the Portuguese trunk network, were presented.

There was no intention of describing all the problems involved with the optimisation of an alternative routing network, which are well known (3) (5) (6). The aim has been to suggest a set of simple ideas which can be used to build up a fast optimisation algorithm taking into account the existing constraints of a network.

Similar algorithms are usually developed for long term or at least medium-term planning and assuming an ideal scenario.

The introduction of the overload analysis during the optimisation process is, I think, a new approach to the problem.

REFERENCES


4 - JACOBÆUS, C. - "A study on congestion in link systems" Ericsson Tech. 1950, 48, pp 1-70


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Q.1 (Caballero)
1. Are you expecting to improve the algorithm to consider both way trunking?
2. You use a classical optimization equation. How do you deal with the cases where this equation is not satisfied, for instance at the boundaries points?

A.1 (Nordeste)
1. No. The switching system is a crossbar system and doesn't provide bothway trunks.
2. The algorithm was designed taking into account the use to solve practical problems. In certain cases, it is necessary to take heuristic decisions based on practical considerations. For instance, if the number of circuits on a light usage route is less than the existing one, the algorithm considers the number of installed circuits as the optimum number.