A COMPUTER PROCEDURE FOR OPTIMAL DIMENSIONING OF EVOLVING TOLL NETWORKS UNDER CONSTRAINTS

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ABSTRACT

Telephone systems nowadays grow and evolve more and more quickly, as switching and transmission digital facilities change the existing scenario, offering new possibilities and rising new problems. According to these technological changes, new different network planning criteria must be implemented and, as far as possible, integrated within the present methods. This is the aim of the paper, which describes a two-phase design procedure of any hierarchical network structure. In the first step the network is dimensioned, attempting the minimum cost under plant constraints and for a given routing scheme. In the second step the point-to-point grade of loss is evaluated to examine the network susceptibility to equipment failures, traffic overload and traffic forecast distortions. Trunk groups are then assembled into transmission links by accounting for modular size and the point-to-point grade of service (GOS) is computed; if it doesn't meet a specified distribution, circuit modules are properly added to the links.

1. THE PROBLEM

The introduction of the new technology in both transmission and switching areas changes the main design parameters and calls for considering a new network with different structure and traffic routings.

Unfortunately, the criteria so far used, are not now sufficient to meet the new network requirements; in particular, the following differences can be pointed out:

a) a different ratio between transmission and switching costs;

b) a different trunk group modularity (30 for PCM instead of 12 for FDM) involves not only a significant increase of the average size of trunk groups, but also a decrease of the number of high-usage links and a lower capability of reacting to traffic overloads;

c) new performances of the switching system, which the network design must be able to account for;

d) the availability of large exchanges for mixed toll-local traffic;

e) new attention to the quality of service and network vulnerability aspects.

In spite of this demand of change, other conservative needs must be considered. In a well-developed country the transmission and switching plants are widely diffused on the territory and have reached a considerable amount. Consequently it is clear that there is a resistance to the structural changes and a natural trend to growth the existing plants.

Further constraints, of different weight in each country could prevent the system from changing in few years, even if economically justified: supplying constraints from the Manufactures and investment limitations for the Operating Companies are typical examples. Therefore, the main problem is to reach a trade off between these two opposite requirements.

On approaching these problems, different methods have been so far followed in Italy:

a) dimensioning of the network in a medium-long term prospective to provide the number of circuits of trunk groups on the basis of average occupancies a priori fixed (1);

b) annual design of the network under all the constraints of the existing plants, but disregarding costs and future network configuration;

c) studies of new structures (2), by optimizing the costs, but disregarding either the existing network and the relevant constraints.

In practice, different algorithms and hypotheses were used in these previous activities as separately corresponding to the planning, design and study objectives. For overcoming these difficulties and reaching an integrated method, a chain of interconnected computer tools has been implemented able to:

a) provide economical optimization, by taking into account both existing plants and switching and transmission constraints;

b) size the network in a long term prospective: it means to enter in a chain of planning...
procedures providing cost figures and grade of service in all the considered alternatives (e.g. different configurations, routings, busy hours);

c) analyze any alternate-route hierarchical structure.

d) plan the network from the short to the long-term by the same tool so to assure a coherent evolution.

3. DESCRIPTION OF THE COMPUTER PROCEDURE

The flow-chart of the procedure is plotted in fig. 1, as consisting of three steps.

The first one, named INPUT, provides the characteristics of each switching node, the transmission network topology, the switching and transmission costs etc. The second one, named TRUDIM, optimizes the network and its output is the matrix of links between each node-pair. The third one, named GOSEV, analyzes the network as previously dimensioned and evaluates the point-to-point grade of loss in normal, overload and failure conditions. Then, the previously determined circuits of each trunk group are adjusted in order to achieve modular sizes (12 or 30) of the transmission link and to meet a given point-to-point GOS requirement.

Only by changing the input data, this same procedure can be flexibly applied both for short and long-term evolution studies.

3.1 Input

As a large amount of input data is required, a data-base is used containing:

a) Traffic matrix between source nodes and destinations.

b) Transmission costs matrix providing the transmission cost per trunk for each link.

c) Switching cost; also in this case plant by plant provided.

d) Network structure; the procedure accepts in input any network structure of hierarchical and alternate-route type. The program can deal with any routing for point-to-point traffics. To do that, the computer program has to know where every overflow traffic must be routed; this information is written for each link in the data base.

The reference network model, describing all the routing possibilities, is depicted in fig. 2 and, as easily it can be seen, every structure can be derived from this scheme. An interesting characteristic of this model, as discussed later, is to account for the splitting of the nodes in more than one plant for any hierarchical level.
The study of evolution of each exchange has to be previously undertaken by other procedures. The obtained plan of the nodes is one of the inputs to this procedure, so that the overall results for the whole toll network are evaluated (3).

e) Plant constraints; especially in the annual design, the switches must meet many constraints, the most important being:

- building capacity;
- insufficient performances of some switching systems;
- modular size of the switching machines;
- detailed description of the existing network.

3.2 Dimensioning algorithm (TRUDIM)

It is easily understood the importance of having a flexible and modular network design procedure. In spite of the attention always paid in the past for designing flexible tools open to further changes or improvements, the practical experience showed the difficulties encountered in modifying and updating these software tools. If the effort in developing such computer programs is considered, the importance of the software modularity and simplicity is quite obvious.

In particular, we are here dealing with the computer method for trunk network dimensioning. The Pratt's mathematical approach yields a number of optimizing equations equal to the number of high usage routes. The application of this method depends on the network structure and whenever you want to check a new routing alternative, new optimizing equations must be written thus modifying the program.

The aim of our study has been an algorithm, valid for any structure, thus avoiding a new implementation for each network model to be tested. It has been determined a general formula, which yields the economical condition of every trunk group. By using the following definitions:

\[ H = \frac{\delta(A-a)}{\delta N} \quad \text{marginal occupancy} \]
\[ \beta = \frac{\delta A}{\delta N} \quad \text{marginal capacity} \]
\[ \gamma = \frac{\delta a}{\delta A} \quad \text{marginal overflow} \]

we have:

\[ \frac{C_1 + C_2}{H} = C_3 \]

where on the left-hand side there are the marginal cost per erlang of traffic carried by the given trunk group (C_i/H) and by the subsequent routes which convey this carried traffic till to...
destination \((C_3)\); the right-hand side represents the cost per erlang of load overflowing to the alternate routes till to destination \((C_3)\).

The costs \(C_2\) and \(C_3\) are evaluated for each traffic parcel, by adding costs per erlang \(C/\beta\) of every final-choice trunk group multiplied by the relevant part of the erlang. To determine this part of traffic the load carried by every high usage trunk must be computed, i.e. \((1 - \gamma)A_t\), where \(A_t\) is the traffic offered to the link. The load overflowing to the alternate route is equal to \(\gamma\).

This computer tool, by following the path of every traffic parcel, and by adding the cost of every trunk group as above determined, sizes any hierarchical network structure.

The fig.3, where the trunks and the switching nodes are shown, depicts the set of routings of any traffic parcel; this way of routing can be easily implemented for a network of any complexity.

For sake of simplicity, the figure does not show a further structural complication, accounted for in the procedure. In fact, many switching nodes, as it will be seen in following, are split in more than one plant, thus increasing the routing possibilities of any traffic parcel.

If you want to dimension the trunk group \(AB\), the cost \(C_2\) must be computed as relevant to the carried load routed by the patterns from \(B\) to the destination offices. The cost \(C_3\) arises from the overflow of the trunk group, routed to the successive choices.

3.3. Grade of service and modularity (GOSEV)

In these last years it has been pointed out (5,6) that the economical optimization of the network with a given blocking probability on the final choice trunk groups cannot fully assure the network capability of carrying traffic in all the different operation conditions. The revision of the traditional design criteria is especially needed because of the growth of traffic intensity levels and the use of higher capacity transmission facilities.

The PCM modularity of 30 circuits will make higher the convenience threshold for a new trunk group. This effect is important for the Italian network, where (see fig.4) the traffic demands are concentrated on very low values, because of the present high number of the toll centers (2). In particular, the 81% of the traffic relations have values inferior to 1 erlang: it is then clear that the problem of modularity gets a decisive importance in determining the network structure as less will be the resulting number of high-usage trunk groups.

Moreover, this evolution of the existing network caused by the modularity effect is in our approach controlled by considering the point-to-point grade of loss (Bpp) (5), and by starting from the previously obtained matrix of trunk groups among the switching nodes according only to optimization criteria.

In this phase the aims are the modularization and the respect of given values of the Bpp parameter. As regards the first objective, the procedure deals with the modularity of the transmission links, i.e. the set of circuits linking two transmission centers even if made up of many trunk groups.

In order to reach the second objective, a mask of the point-to-point grade of loss versus the relation offered traffic \(A_t\) is given (as the example of fig. 5) that has to be met in normal conditions. Therefore, the Bpp for every traffic relation is evaluated as resulting from the previously dimensioned network and the obtained distribution is compared with the assigned Bpp mask.

\[\text{fig.4}\]

\[\text{fig.5}\]
The economical optimization tends, of course, to privilege the higher traffic relations where better Bpp values are generally achieved. The problem of improving the Bpp value for the smallest relations was faced in the past by studying a completely different network structure (7) but no practical application followed. The present procedure is able to solve this problem on the existing structure by simultaneously dealing with the modularity and the routing, as outlined in the following.

The difference between the Bpp distribution mask and the Bpp calculated:

\[ \Delta B_{pp} = B_{pp} - B_{pp} \]

will be, then, positive or negative if respectively the identified r-th relation meets or not the given value of end-to-end loss.

For each trunk group a parameter \( P_g \) is defined being a function of the sum of all the traffic relations \( A_r \) relevant to the same link, the difference \( \Delta B_{pp} \) of the point-to-point grades of loss, the traffic offered to the trunk group. As a transmission link can be composed of several trunk groups, an overall value \( P_l \) is computed as the sum of the \( P_g \)'s of all the relevant trunk groups. On the value of this \( P_l \) parameter is based the roundoff decision on the circuit number with respect to the module size.

The process goes on, as proposed by Beshai-Horn (8), and is repeated until all node pairs meet the end-to-end loss and every transmission link size is modular. The blocking probability of final choice trunk groups have to meet values equal or inferior to a given target value (usually 1%).

It could occur that, at the end of the process, some Bpp does not meet the imposed value. In these cases entire modules have to be added, and, of course, a sensible extracost is incurred. For this reason, much attention must be paid in defining the mask value in order to limit the overall cost of the network.

5. APPLICATION AREAS

The Italian toll network is configured in a 3 level hierarchical structure. There are 231 District Centers (CD), 21 Compartment Centers (CC) and 2 higher-level Transit Centers (TC) as in Fig. 6. Note that, especially in the largest plants, a single CD or CC node can consist of two or three switching machines.

The Fig. 7 illustrates three different ways of linking the final choice trunk group outgoing from CD to its own CC. Suppose that the CC is splitted into 3 switches; the cases, plotted in the figure, are:

1) the final choice trunk group is linked to only a plant;
2) the final choice trunk group is linked to each plant, carrying the same kind of traffic;

3) the district center analyzes the destination and chooses a specified plant.

A similar behavior is exhibited by a trunk group outgoing from \( CD \) to \( CC \), (i and j represent different compartments) split in more than one plant. Some examples are seen in fig.8. It is clear that, although the network is yet hierarchical, the traffic routing can sensibly change, and the structure can be configured in different ways.

Thus in the same network a structure can be investigated more flexible to the overloads and traffic distortions, and as well less vulnerable to switching and transmission equipments failures. Therefore, the traditional dimensioning process so far used (based on a procedure which only verifies the blocking probability and the occupancy), is insufficient.

Work is now in progress by extensively applying this computer procedure to the Italian toll network both for solving the short-term problems and for studying the most proper long-term configurations.

A particular application of this procedure has been already carried out in order to improve the GOS by a slight modification of the present routing scheme; the obtained results (9) prove that a better \( Bpp \) distribution can be achieved without network extracosts.

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References


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Have you tried modelling switch-to-switch incremental trunking cost as a function of transmission facility utilization or the corresponding route? In your opinion, would such a cost model lead to transmission cost savings by encouraging traffic flow onto facilities with low utilization?

A.1 (Gavassuti, Giacobbo, Trimarco)

One of the main goals of our optimization procedure is, for obvious practical reasons, to save and improve the utilization of the network we have previously designed. In fact, we use this method not only for investigation purposes, but also to improve yearly the Italian Toll network. So we take care of the existing network as a constraint and consider any spare capacity of transmission facilities of negligible marginal cost, in order to maximize the already installed transmission media.