A MULTIHOURL NETWORK PLANNING METHODOLOGY WITH FHR AND DNHR STRATEGIES

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Digital networks give the possibility of developing new methodologies in network planning. In fact, the performances of the digital switching systems allow the introduction of DNHR strategies. Our work deals with traffic forecasting and junction network optimization modules, developed to be used in network planning with DNHR, and their integration into a CAPP - Computer Aided Planning Package already available for the Lisbon FHR network. We will present the new planning methodology, affected by the existence of FHR and DNHR, and we will show how the multihour problem is solved.

1. INTRODUCTION

The Lisbon area is served by a mixed density metropolitan network, composed by one high density sub-network, in a business and office urban area, and five medium density sub-networks, located in the suburbs, with distinct traffic behaviour resulting from different activities: office, business, industry and residence.

Presently, the Lisbon network has a hierarchical structure. It is planned that, in a near future, the higher level network will be almost digitalized, however, the introduction of SPC exchanges in the lower level sub-networks will not be so fast.

The traffic among the six sub-networks will be carried through digital tandem exchanges. The local digital exchanges of Lisbon urban area and those tandem centres are considered to be at the higher hierarchical level. The traffic forecasting and junction network optimization modules were applied at this level.

To accomplish our study, an extended analysis of traffic profiles were
carried out, which showed a remarkable non-coincidence of traffic busy hours between sub-networks; economical comparative studies have been performed in order to apply the DNHR strategy to the higher level network, maintaining the FHR strategy applied to the lower level sub-networks (fig.1)

2. TRAFFIC FORECASTING SYSTEM

In this section we will describe the main steps of the traffic forecasting system whose block diagram is represented in fig.2. It is composed by four specialized modules, whose functions will be analyzed considering that all the available junction daily traffic profiles are organized in a traffic data base.

This forecasting system establishes the monthly and yearly forecasted matrices to be used in the multihour junction network optimization module.

LAG - Load Agregation

This module should be applied whenever we are dealing with tandem exchanges. To accomplish our study, the integration of traffic load profiles in order to get the sub-network profiles is required.

![Traffic forecasting diagram](image)

RPL - Representative Load Profiles

The monthly and yearly load profiles are established, in this module, as follows:

The monthly load profile is determined using the mean value, \( X_{hm} \), and the standard deviation, \( SDX_{hm} \), of the traffic load observed at the same hour, \( h \), for all working days of each month, \( m \), and building a traffic profile composed by \( X_{hm} + SDX_{hm} \).

For each year, \( y \), the representative load profile is calculated as

\[
X_{hy} = \text{Max} \ ( X_{hm} + SDX_{hm} ), \text{ for all } h \text{ and } m
\]

These options are due to the fact that a large amount of traffic data has been collected from stronger exchanges.
LSS - Load Set Period Selection

We will define a load set period as the time interval in which routing remains unchanged.

We are interested in choosing the convenient number of load set periods and in reducing the number of traffic matrices, to be used by the forecasting module. Figure 5 represents the monthly load set selection process diagram.

For each month, this selection is accomplished using the concept of "proximity" of a traffic matrix to a set of traffic matrices, described in ref. [1].

Let R be the set of the traffic matrices obtained from the monthly traffic profiles, carried out in the RLP module, and S be the set of the N selected matrices. The remaining periods, non coincident with those of the S matrices, will be assigned to them using the minimum "global traffic increment" concept, between traffic matrices (see ref. [1]).

These load sets, as we have just defined for each month, as well as those referring to the same month of the previous years, will then be used to define the load sets for the monthly forecasting procedure. This definition, will be achieved by applying a 0-1 programming algorithm to solve the cover problem, inherent to this case.

With the same method, and starting from the yearly load representative profiles, we define the load sets for yearly forecasts.

FRC - Forecasting

Two forecasting methods are considered. One for short-term and another for medium-term forecasts. Let us briefly look at each one.

Short-term forecasts:

For each one of the N selected matrices associated with the load set periods, we will use a point-to-point forecasting procedure, based on Kalman filtering, to get the one, two and three months ahead forecasted matrices. Kalman filters are then applied to the monthly historical point-to-point data.

This forecasting method is a consequence of the improvements we have been introducing in previous works, in the traffic forecasting domain (ref. [2]), namely, in the maximization of the likelihood function that enables to reach the model’s covariance matrices Q and R. In fact, the maximum of the likelihood function is now determined using a Fibonacci multidimensional search. Also, in the model’s structure, we can either consider a deterministic time varying input, to account for the seasonal effects, or to include them in the transition matrix $\Phi_k$. This last option lead us to a discrete linear system described by the state-space equations:

Fig. 3 - Selection process diagram

3.2A.3.3
Medium-term forecasts:

As an alternative to the classical methods, already available for traffic forecasting matrices, we also developed an empirical Bayesian forecasting procedure, we are, briefly, going to refer.

For each one of the matrices, selected for yearly forecasts, we group together the elements with similar behaviour, as far as the profile and load are concerned. For each group element, forecasts for several years ahead are determined using the empirical estimator:

\[ x(t+1) = (1-B).x(t) + B.x(t) \]

where \( x(t) \) is the group mean and B is the shrinking factor,

\[ B = \frac{N-3}{N-1} \frac{\hat{\sigma}^2}{\hat{\sigma}^2 + \hat{\Sigma}^2} \]

\( \hat{\sigma}^2 \) is the sample variance of the element,

\( \hat{\sigma}^2 \) is the maximum likelihood estimate of the variance of the estimator's a priori distribution,

N is the number of the group elements.

The one to three months-ahead forecasts, we have been writing about, will be used to define monthly routing changes and circuit provisoning. On the other hand, yearly forecasts will enable to determine junction network optimization. These methodologies, will be described in the next section.

3. FUNCTIONAL NETWORK OPTIMIZATION

The introduction of DNHR strategy in the switching network optimization has a major impact on the centralization of some processes, such as switch planning, circuit administration and network management. The interactivity of these processes is greater than with FHR strategy and it will contribute, obviously, to increase the operation efficiency, leading to an improved network performance.

In our work, the very short term planning (one to three months-ahead forecasts), including the circuit administration functions of servicing and routing, was integrated with the long and short term planning (annually). With this multihour extension the junction network planning is performed in three complementary phases (fig.4).

The first phase defines the long term network (ten years) and all the evolution, considering the present network as being totally saturated. Economical optimization criteria are used.

The second phase defines the network, annually, in agreement with an optimized administration of the existing network, in order to delay the switching and the transmission equipment acquisition. The evolution
FIRST PHASE:
LONG TERM PLANNING

SECOND PHASE:
SHORT TERM PLANNING

THIRD PHASE:
(one to three months ahead)
- CIRCUIT PROVISIONING
- ROUTING ADMINISTRATION

Fig. 4 - The new methodology

Towards the target network is fulfilled (see ref. [7]).

The third phase is executed monthly and defines the very short term networks (one to three months-ahead). This phase has a major impact on DNHR network operations and allows to perform the routing administration and circuit provisioning, taking into account the existing network and the second phase (one year-ahead forecasted network).

3.1 DATA ORGANIZATION

Input and output data are organized into logical and systematic sequences. This information is obtained from general data bases or specific data files.

A general description of the network to be studied is given and the quality service criteria are defined. The blocking of final links criteria are used with FHR strategy and the node-to-node grade of service criteria are used with DNHR. The running modes are specified, as well as the accuracy required to the optimization algorithms.

The busy-hour traffic matrix, the multihour traffic matrix and the load set period selection obtained with the traffic forecasting system, described in section 2, supplies the network optimization module.

The planner defines the routing constraints corresponding to schemes, patterns and tandem exchanges allowed or forbidden. The link constraints are also described, referring to the minimum and the maximum number of circuits, initial traffic and availability.

The topological localization of the exchanges, the switching equipment, the subscriber enlargement periods, the minimum and the maximum capacity are specified. The topological layout data is collected in order to evaluate the distances corresponding to the links.

The switching and transmission costs are used to make an economic evaluation on new links by empirical criteria (see ref. [7]). The marginal costs of the links already involved with the physical network optimization supplies the functional network optimization with much more accuracy.

The optimized routing plan is obtained from the allowed configurations. In this plan, for each node pair and during each load period (DNHR), the schemes, patterns and overflow sequences are described. The end-to-end grade of service is also estimated for those pairs involved with FHR.

3.2 ALGORITHM

The algorithm of the functional network optimization is heuristic with a modular organization. Transmission and switching marginal costs are estimated in the first module, as it was described in section 3.1.
An initial operating point for the network is defined. The least cost alternative pattern is selected from the allowed configuration and the Truitt's ECCS method is applied (see ref. [5]). For the DNHR network, the node-to-node busy hour offered traffic is used to initialize the optimization procedure. After this step the initial vector of link dimensions is obtained.

The method used to optimize the FHR network was object of a paper already presented to ITC-11 and will not be discussed (see ref. [7]).

The DNHR strategy selected to be applied to the Lisbon higher level network, defines one routing sequence of two link alternative paths, used by each origin/destination pair in each load period. This strategy is less complicated to implement and has practically the same traffic performance as the optimized probabilistic routing.

Fig.5 - DNHR network optimization

The multihour optimization problem is solved iteratively in two steps, starting from the initial vector of link dimensions (see ref. [6]).

Firstly, a multihour optimal dimensioning problem is solved for fixed routing sequences. A new vector of link dimensions is obtained. Secondly, a routing optimization problem is solved, for each load period, maintaining the vector of link dimensions fixed. The resulting sequences minimize the network blocking probability (NBP). The routing constraints are taken into account.

With the new routing sequences for each load period, the multihour optimal dimensioning problem is solved again and these two steps are repeated until the process converges (fig.5). A two-parameter traffic model is assumed.

When the iterative procedure stops, the optimal switching network is reached for a normal point-to-point traffic forecasting. It is necessary to analyse the network behaviour in face of some unpredictable situations and to introduce a suitable protection against any severe degradation of the network performance.

The overload situation and the total failure of each high usage link are analysed. The creation of special links for Poissonian traffic, the oversizing of final groups and the state protection (unspecified trunk reservation) are service protection methods, available to be used in accordance with strategy and equipment limitations. In the last module a traffic sensitivity analysis is performed.

4. CONCLUSIONS

The traffic forecasting system, we have briefly analysed in section 2, was
designed to support the DNHR network optimization. The remaining traffic forecasting procedures are classical and they are a part of the Computer Aided Planning Package, referred in the beginning of this paper.

The CAPP, also includes the DNHR network optimization modules, which are a multihour extension of the Sirius methodology, already developed to be applied to the FHR network (see ref. [7]).

As referred in the Introduction, we have been studying the application of the methodology described above to the Lisbon higher level network. The FHR and DNHR strategies were economically compared when applied to this network. An overload analysis was done; the total cost and network performance was compared for different service protection methods.

This multihour extension allow us to take advantage of the new opportunities offered by SPC exchanges. With this new methodology it is possible to achieve significant economical savings, as well as a more uniform network, under the NNBP (node-to-node grade of service) point-of-view.

REFERENCES


