ABSTRACT
The development of computer aided junction network planning systems have been directed to the establishment of a fast and accurate forecasting dynamic methodology. The objective is to define the short, medium and long term networks, which is performed in two complementary phases. Firstly, the long term network and the optimal provisioning periods are established considering the present network as being totally saturated. Secondly, an optimized administration of the existing network (annual) is done in agreement with the first phase, which guarantees an evolution in the horizon network sense.

INTRODUCTION
The SIRIUS methodology (figure 1) defines the evolution of the junction network, minimizing the switching costs and the transmission costs during the studied period, in agreement with an optimized administration of the existing network, to satisfy the traffic demand under a prescribed quality of service and the technical plans: routing plan, transmission plan, and numbering plan.

The junction network planning is performed in two complementary phases, with the consequent establishment of the short, medium and long term networks.

The first phase of the SIRIUS methodology, defines the long term network (15 to 20 years) and all the evolution, considering the present network as being totally saturated. Economical optimization criterions are used.

The second phase defines the short term networks (annual) in agreement with an optimized administration of the existing network, in order to delay the switching and transmission equipment acquisition, and an evolution in the horizon network sense.

The global optimization of the junction network is a complex process of difficult treatment. It's possible to divide the study of the junction network into two parts: The functional network in volving the logical organization from the viewpoint of how the traffic is routed; and the physical network that refers to the topological layout. The nexus between functional and physical networks, basically the transmission costs, is not enough to demand the global optimization. So, this problem is solved by treating these two aspects in a separate way, but never loosing the global sense of the process.
modularity, the traffic matrix and the imposed restrictions (to the absolute equipment or to force some routing schemes) are also data that supply the functional module. The results are the selection of routing schemes, the number and location of the transit centers and their capacities, the size of the functional routes and the characteristic parameters that define the selected links. This information per link is converted in information per physical route (arc) to supply the physical network optimization.

The junction network optimization is concluded when the transmission costs are almost the same in two consecutive large iterations and the optimal network is reached.

2.2 Functional network
2.2.1 Data organization

The information corresponding to input and output data is organized in a logical and systematic sequence. In this way the input data is divided into six groups:

- The general data - A general description of the network to be studied is given and the quality service criterions are defined. The running modes are specified, providing the computer program with information about the data flux in the general algorithm. The precision of the optimization algorithms are also specified.

- The functional routing data - The information is arranged by functional route with dimension equal to the square of the number of local exchanges. The traffic matrix of the horizon year is estimated by the traffic engineering department and automatically transferred to this group of information. The planner defines the functional routing schemes, the patterns and the reference of the transit centers allowed or forbidden.

- The link data - In this group, every possible link is described and the information is arranged by local exchange to local exchange, local exchange to tandem, tandem to tandem and tandem to local exchange. The minimum and the maximum number of circuits, the initial traffic of the transit links (mean and variance) and availability are specified. The transmission equipment and the marginal transmission costs are estimated by the physical network optimization and automatically transferred to this group of information. They are not available in the first iteration of the switching/transmission procedure.

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- The central data - The topological localization, the switching equipment, the minimum and the maximum transit capacity are specified.

- The topological layout data - A description of arcs and nodes is given, referring to the distance.

- The costs data - The switching costs are given per incoming and outgoing circuit at each local exchange and tandem, in the network. At each tandem the switching costs are also given per erlang of traffic that passes through. The transmission costs are given per circuit and per circuit x km. They are used to initiate the switching/transmission optimization or to make an economic evaluation on new links in other iterations. The equipment modularity is also referred.

In the same way, the output data is divided into three complementary groups:

- The functional routing results - The optimized routing plan is obtained from the allowed configurations. The transmission attenuation point to point is also estimated.

- The link results - A complete description of the high and low usage links, such as transmission equipment, number of circuits, traffic, congestion, transmission attenuation, costs, etc., is obtained.
The statistical data - Finally, statistics on functional patterns, links, transmission attenuation and costs are presented.

The information about the number of circuits calculated in every link is automatically transferred to the functional/physical interface.

2.2.2 Algorithm

The general algorithm of the functional network optimization is heuristic, with a modular organization, involving fast and accurate optimization routines (figure 3). A general description of the principal modules is presented:

Data read - This program selects the group of data required by the functional network optimization from the common access file and makes a complete validity test.

Link marginal costs - The estimation of the link marginal transmission costs is a result of the physical network optimization and is not available in the first iteration of the functional/physical procedure, or when treating new links. The problem of transmission equipment initialization is solved in two elementary operations. Firstly, the shortest way through a minimum number of nodes is calculated to the links. Secondly, with this distance and the switching equipment technology, the optimal transmission equipment is defined by an empirical criterion and the respective marginal transmission costs are estimated.

The marginal switching costs are also estimated.

The present value of annual charges criterion is used to quantitatively measure the economics involved in each alternative, because it's necessary to consider equipment having different characteristics of life, purchasing costs, operation and maintenance expenses.

Initial solution - This module calculates the high or low usage direct routes and the consequent traffic in transit links to initiate the optimization procedure. The Rapp's solution is used for alternate routing. The single routing initialization takes the optimal routing from the allowed configurations, admitting a maximum efficiency in the involved transit links.

Alternative routing optimization - The routing is optimized, taking into account the allowed or defined patterns, by an iterative calculation procedure propose by 'B. Wallström' [6].

Single routing optimization - A heuristic procedure is used, which calculates the optimal routing in each iteration from the allowed configurations and from the network established in the previous iteration [12].

The general algorithm has proved that the total cost of the network optimized with mixed routing criterions, pratically doesn't change after one or two iterations.

2.3 Physical network

2.3.1 Data organization

The information is organized in four groups corresponding to different sources:

The existing network data - The present physical structures are described, referring to the distance, the transmission equipment, the corresponding links and the existing number of circuits.

The topological layout data - A description of arcs and nodes is given, referring to the distance and to the number of free ducts in conduits.

The functional network data - Some functional network optimization results are automatically transferred to this group of information, from the functional/physical interface. They are the physical routes description in the horizon year and the corresponding links referring to the number of circuits.

The physical network data - The planner may
define the security schemes required and restrictions of the physical network optimization, such as to forbid or to fix some arcs and the transmission equipment, or to impose some physical routing schemes.

The forecasting results are given per arc, referring to the transmission equipment, the corresponding investment period, the new links and the number of circuits, the arcs of integration, the increase of circuits, the transmission attenuation and the transmission costs. Finally, statistics on links, arcs, transmission equipment and costs are presented.

The information regarding transmission equipment, new routing schemes for links, and marginal transmission costs are automatically transferred to the physical/functional interface.

2.3.2 Algorithm

The general procedure for physical network optimization is heuristic with a modular organization and involves fast optimization routines (figure 4). A description of the principal modules is presented:

Optimal transmission equipment and provisioning periods - Economic criterions are used to obtain the optimal transmission equipment, the investment amount, and the optimal provisioning periods from the present till the horizon year satisfying the requested circuits. The demand for circuits in a route is assumed to increase linearly, to determine the economic period of provision, which corresponds to the minimum value of the present worth of all extensions during an unlimited period of time.

Initial solution - An evaluation of the investment costs during the studied periods is done, taking into account the initial topological layout.

Temporary suppression - The suppression of one arc involves the change of the corresponding links to other arcs. This integration is done in terms of the minimum cost, which is calculated by the 'Moore - Dijkstra' algorithm [7]. Starting always from the initial solution, each arc is suppressed and the consequent optimal configuration is economically evaluated.

Definitive suppression - After running every arc the new solution is taken, corresponding to the suppressed arc whose configuration produces the minimum investment costs. Just one arc per iteration is eliminated. In this case the network description and the costs are updated.

The procedure stops when the elimination of any arc produces a higher cost configuration.

3. THE SECOND PHASE - SHORT TERM PLANNING

3.1 Introduction

In this phase the existing network is taken into account in order to delay the switching and the transmission equipment acquisition, in agreement with an optimized administration of the installed equipment.

When the rerouting problem is not solvable, the equipment acquisition is done in accordance with the first phase although shifted in the time; so, the tendency to the horizon network is obtained.

Fig. 4 Physical network optimization

The developed process for short term planning (annual) permits the simultaneous treatment of several networks with hierarchic dependence for several years. Yearly, from the zero year to the horizon year (figure 1).

Data is organized in six files: the routing plan, the links of 'n - 1' year, the functional network, the physical network and the topological layout.

The forecasting results are divided into eight groups: the initial and final results of functional routing, such as routing schemes and
transmission attenuation, the initial and final results of link and sub-link, such as distance, track, traffic, total number of circuits, increase of circuits and category, the results of physical route (arc), such as total and increase number of telephonic and non telephonic circuits, and the results of equipment acquisition.

3.2 Algorithm

The second phase program may run each block in sequence from the 'network 1/year 1' till the 'Last Network/Horizon Year', although the short and medium term blocks are the most important (figure 1).

The running procedure is similar in each block, involving the optimized administration of the existing equipment, the tendency to the horizon network, the planner strategy and the data updating. A description of the principal modules is presented to the 'Network 1/year 1' block (figure 5):

Routing plan - The hierarchal dependence among sub-networks to be studied is defined, as well the single or alternative routing, the patterns allowed or forbidden and the overflows. The planner may fix some routes but a valid routine confirms if the basic plan is fulfilled.

Initial traffic - It's necessary to take into consideration traffic that overflows from routes in the sub-networks not under study to routes in the current block.

Functional network optimization - The routines are similar to the equivalent program in the first phase.

Physical network optimization - The data in the physical network file is quite similar to the equivalent data described in the first phase, although a reference to the unoccupied number of circuits is done in the present network.

The required circuits in each existing link, coming from the annual demand growth, are integrated in the original routing if the respective capacities are sufficient. On the contrary, it's not possible to make the same routing and so, a rerouting is performed in terms of minimum cost, making use of the unoccupied circuits [8].

If it is possible to find a suitable routing scheme for every circuit coming from the annual demand growth in the current block (sub-network), the problem is solvable and the investment is not necessary.

On the other hand, the problem is not solvable and the program may stop or not, making the investments in accordance to the first phase or to the planner strategy. In this case the planner may force some routing schemes, create or eliminate arcs, force some investments, treat several investment hypotheses and compare some of them in a minimum cost base, or let the program calculate the economical solution.

If an investment proposed by the planner is not necessary, it's automatically eliminated by the program.

Fig. 5 The second phase: Short term planning (Annual). "Network 1/Year 1" Block.

4. CONCLUSIONS

The SIRIUS methodology has been successfully applied to the Lisbon network in the short, medium and long term planning. The complete package of programs, previously described, have about 20000 lines of instructions written in Fortran 77. Input and output data is stored in a work disk, occupying about 100 Mbytes.

The complexity encountered when attempting to carry out long term and short term planning, has been successfully reduced by separating the switching and transmission problems, although never losing the global sense of the process, and by treating several networks with hierarchic dependence for several years (annual).

The SIRIUS methodology has proved to be a fast, manageable and practical method for optimizing junction networks in the long and short term planning.
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