DESIGN AND IMPLEMENTATION OF THE EVOLVING ITALIAN TOLL NETWORK:

METHODOLOGIES AND COMPUTER TOOLS

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ABSTRACT

The introduction of digital switching and transmission techniques in the Italian toll network calls for an integrated and dynamic planning methodology, in order to investigate the possible structural modifications and the optimal evolution path from the existing configuration.

The paper presents in a comprehensive frame a set of interconnected computer tools properly designed for both switching and transmission aspects of the toll network planning.

It is pointed out how the interactive application of these computer procedures easily allows to investigate several different alternatives and to check performances and investments for each input hypothesis.

1. INTRODUCTION

Recent technological innovations in both transmission and switching areas have stimulated continuous efforts for improving planning criteria and optimization methods of telephone networks. Among the many driving motivations the following reasons can be mentioned:

- timing and modalities of introducing digital switching in a widely developed analog network must be carefully studied in order to fully and economically exploit all the potential benefits of the new technologies;
- because of graduality constraints, such as industrial reconversion and financial limitations, the transient stage of a mixed analog-digital network can spread over a quite long period, then calling for planning and managing all the relevant evolutionary aspects;
- the rapidity of technological changes not only regards the functional and operational performances of the new systems, but also involves cost trend uncertainties; those factors, in addition to the variability of the network demand forecasts (e.g. new services), require that many different scenarios must be envisaged and investigated, as different paths and strategies can be followed toward the long term ISDN target.

Firstly, these considerations make evident that general rules cannot be applied for guiding the modernization process, but new methods and flexible computer tools are needed to quantitatively assess the most realistic scenarios and to effectively orient the short and medium term decisions. By other words, the implementation activities cannot be any more seen as consecutive steps of a static plan framework, but they have to derive year by year from a dynamic and iterative process, within which both internal and external network variables should be continuously updated and accounted for.

Secondly, it is easily understood that the traditional splitting of the planning process in separate self-contained disciplines relevant to each network component cannot assure a cost-effective and harmonic evolution; on the contrary, an integrated methodology is needed, accounting for all the mutual interactions, mainly between transmission and switching modernization processes.

It must however be considered that an overall network optimization approach, even if flexible, would involve an intrinsic high complexity and as well the risk by the planner of losing a complete interpretation and control on the output results. The most suitable way of implementing a dynamic and integrated planning methodology is, therefore, the adoption of a modular structure of interconnected computer tools, each of them devoted to the optimal dimensioning of a given facility or to the evaluation of a given performance criterion. The dynamic feature can be allocated in each modulus, thus allowing to evaluate the overall evolution or performance of each network element over a given study period and starting from the present status; the integration feature derives from the interconnection among those moduli, so that mutual interactions among network elements can be easily investigated through an iterative application of the whole procedure under different input hypotheses.

A similar philosophy has been successfully followed in approaching the local network planning aspects: a set of computer tools named SWITCH-TRUNK-TRANET were implemented and they are currently applied to a representative sample of Districts of the Italian network (1-5).

This paper deals with the evolutionary aspects of the Italian toll network and, consistently with this same planning methodology, presents in a comprehensive frame the set of computer tools
properly developed for the toll network environment. While the relevant algorithms are separately described in other papers, emphasis is put on the underlying aspects of the present network configuration, and as well on the main expected answers from the extensive application of these new planning tools.

2.- EVOLUTION ASPECTS OF THE ITALIAN TOLL NETWORK

The Italian telephone network (serving about 15 million subscribers) is presently structured on five switching levels as sketched in fig.1. The whole territory is subdivided into 231 District areas of univocal numbering and identified by different area codes; the toll network then consists of three hierarchical levels on 231 District Centers (CD), 21 Compartment Centers (CC) and 2 higher-level Transit Centers (TC).

As the toll network is concerned the introduction of digital switching has already started by following the pragmatic approach of facing the most critical situations in terms of building exhaustion or obsolescence of the existing plants: by the end of 1983 the expected total number of in service digital switches will be about 20, fifty fifty located at CD and CC level. The most part of these interventions consists in creating a digital nucleus overlaying the analog section often in the same building; only two replacement occur because of obsolescence of the existing plant. By the end of 1983 the percentage of digital connections will reach about the 10% of the total.

More massive will be the digitalization of the toll switching during the next few years, as in fact the presence of a digital nucleus is foreseen in all the nodes by the end of 80's. Therefore, not only a great effort must be now undertaken to efficiently planning and managing the digitalization process, but the opportunity can be also taken of sensible modifications of the structure itself of the network in order to fully exploit all the digital capabilities.

As a matter of fact, a previous study (6) has been carried out on considering various target configurations of the toll network by reducing the number of District Centers (from 231 to 98) and by using all the routing flexibility of local digital switches. It is remarkable that in a fully digital network the correspondence between functional and hierarchical switching levels is disappearing, as digital exchanges are able to provide all the required functions only by software rearrangements, while expensive hardware implications would have been required by electromechanical switches. That study showed that in a static long-term optimization a sensible economical advantage could be achieved by grouping in a single toll center more neighbouring Cd's and by handling as a large metropolitan area the corresponding District area.

A first application field of the new proposed methodology will be then a deeper analysis of this structural aspects in a dynamic way, thus
including the evolution path from the existing configuration and all the relevant constraints.

Another structural modification presently envisaged regards the possible transition from the present three-level to a two-level toll network hierarchy, by eliminating the TC level and merging their functions into all or part of the CC nodes (7). A possible routing structure is, as an example, shown in fig.2, where for the CD1-CD2 traffic relation a third Compartment Center CC* can be involved with different possible priorities in the routing selection. Moreover the trunk group linking CC* to CD2 is a final one in order to improve the point-to-point grade of service.

Apart from the scale economies achievable by merging many transit functions in a single digital CC exchange, the routing flexibility allowed by such a non-hierarchical scheme must be thoroughly investigated also with reference to the objective of improving network reliability and performances. For instance, the CC* transit function could be provided in a programmable way on a per hour or per season basis or, as a limiting case, it could be dynamically allocated for overcoming local overload or failure conditions; in any case both the number and the location of these special CC nodes must be optimized according to the performance objectives.

Note that these latter considerations must be seen within the overall modernization from the network operation and management point of view; the common channel signalling CCITT n.7 will provide the needed vehicle for these improvements.

As far as the mixed analog-digital transient stage is concerned, an additional structural aspect is the interworking between the analog and the digital network. While the minimization of A/D conversion points would lead to confine the interconnections at the higher-level nodes (CC), an overall cost optimization could require a proliferation of these interconnections down till the local level exchanges. That also depends on the different timing and rate of digitalization at the different network levels and territory areas. This problem is also related to the parallel digitalization of the long distance transmission media and to the requirements from new special services, such as the digital connectivity.

Finally, the rapid evolution of the satellite technology could lead, in a medium-term perspective, to the possible use of a satellite system also in a small-medium size domestic environment (8). Besides the wideband services capability, this satellite system could prove economical for telephony when integrated with the terrestrial network; this integration could involve not negligible effects not only on the sizing of the switching nodes but also on the required routing flexibility.

3. PLANNING TOOLS

The general structure of the interconnection among the adopted computer tools is summarized in fig.3. The basic concept of this toll network planning approach is to link automatic procedures of nodes evolution optimization trunk groups dimensioning and transmission network planning. The linkage is made by three data flows: the main one brings the output of each block to the input of the next one, while the remaining two refer to costs and network data-base. This data-base mainly contains

- for each node:
  - characteristics of each switching machine (type, size, maximum capacity) and of the relevant building (floor space capacity and present occupancy)
  - amount of the trunk interfaces, classified per function, signalling type and analog/digital nature of the transmission facility;

- for the whole trunking network:
  - the existing configuration and size of the trunk groups and the present traffic matrix
  - the transmission network topology and the distance matrix
  - the forecasted traffic matrix at fixed time intervals (e.g. 5 years);

- for each transmission link:
  - types and sizes of all the transmission facilities and the relevant transmission systems
  - utilization degree of each transmission system and facility;

- for each switching system:
  - (electromechanical and digital)
    - trunk capacity and traffic handling capability
    - cost profile and maintenance expenses;

- for each transmission facility:
  - (analog and digital)
    - purchasing and maintenance cost per Km.
    - cost of the relevant transmission equipments (line terminal, regenerators, etc.).

A variable input of the overall planning process is the definition of a selected alternative of routing criteria, network hierarchy, number and location of the nodes in each hierarchical level. By this way the planner can test various modifications and evolution patterns of the existing network configuration. The main functional blocks of the optimization process are outlined in the following.

The first procedure named SWINOD carries out the optimization of the evolution of each switching node starting from the existing status. Based upon a graph representing the whole machine, for each switching function SWINOD selects the connection path and sizes every branch of the graph according to the traffic demand. The optimal solution is, then, obtained by comparing different alternatives regarding both the timing and the type of interventions (partial or total replacement or overlay for each function, grouping of two or more nodes, etc.). This procedure includes an interactive phase through which the
fig. 3

INTERCONNECTION SCHEME OF THE PLANNING COMPUTER TOOLS
user can choose the alternative or change the constraints (supplying or financial limitations).

The application node by node of the SWINOD procedure provides the yearly configuration of all the traffic sources, i.e. the basic input to the next TRUDIM procedure, where the optimal dimensioning of the trunking network is accomplished. The optimization algorithm, based upon an extension of the Pratt's method (9), can size each trunk group of the more general hierarchical network under constraints.

After the modulus-one optimization the point-to-point grade of service is evaluated by the GOSEV block and compared with a target performance. The result of this comparison drives the adjustment of the trunk sizes to the given modularity (e.g. 30 for PCM), so that a cost/performance trade-off is achieved (10).

Note that the cost of an yearly increment on a switching or transmission facility varies, in general, with the actual size of the existing facility. In the first step of the overall procedure the incremental costs are referred to the initial size of each plant. At the end of the first iteration process the actual size of each plant is updated and that can allow to iterate the overall procedure with more accurate incremental costs. In particular, as far as the switching plants are concerned, the size information is obtained from the output of TRUDIM-GOSEV and updates the cost file in the data base, as shown by the right-hand flow in fig.3.

While SWINOD works over the whole study period, TRUDIM and GOSEV provide the optimal trunking network at a given year t; so, as indicated in fig.3, the application of these two blocks is iterated for each time interval t, which the forecasted traffic matrix is referred to.

At this stage the evolution of the circuit demand of the whole network is known; the last two blocks in fig.3 regard the transmission network planning. According to an initial criterion of circuit routing (e.g. shortest path) the TRANET procedure (3) satisfies the circuit demand in the most economical way by exploiting the spare capacities and/or planning the installation of new ones. The planning of new facilities is determined by minimizing the PWAC of interventions jointly relevant to systems of each link and facilities of each branch in the topological graph representing the transmission network.

Finally, the minimum cost solution is tested from the network reliability point of view in the NETREL block, by accounting for the different failure rates of the involved transmission systems and facilities (11). If the network availability target is not satisfied, the circuit routing criterion is iteratively changed in order to achieve a good cost/performance trade-off. Transmission planning of course originates a second cost feedback by updating the transmission cost file in the data-base.

4. CONCLUSIONS

The digitalization of the Italian toll network, already started in the last years by the introduction of digital switching in few large nodes with the aim at solving some peculiar problems, will spread in a massive size throughout the whole territory looking at the continuously increasing cost ratio of electromechanical systems versus digital ones and at the synergistic effects due to the parallel digitalization in the transmission field.

This rapid technological change, besides the economical advantages, offers the opportunity of modifying the network structure itself by exploiting the routing and operation flexibility allowed by the digital switching; that can also involve that the present dimensioning and implementation criteria should be reviewed.

The paper has presented an integrated methodology enabling to drive and manage all the implementation and design aspects relevant to the network evolution process. In particular, the main goals of this approach can be so summarized:

- provide a dynamic optimization of the overall network starting from the existing configuration and accounting for different constraints;
- evaluate different network structure alternatives relevant to the routing policy and the number of switching nodes in terms of cost, point-to-point grade of service, overload protection, etc.;
- determine the timing and the modalities for introducing digital exchanges and transmission facilities within an integrate framework accounting for the mutual interactions;
- derive both the long-term and the short-term network plans by the same tool so to assure a coherent evolution.

References

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Q.1 (W. Pernau)
Reduction from 231 to 98 District Center switches implies drastic change to network structure. Is account being taken in this plan of existing transmission network structure, network reliability, network operations?

A.1 (Filippini, Mazzei, Miranda)
The paper based on the mentioned reduction was obtained by a static optimization method, while the procedure now exposed takes into account the network constraints, first of all the existing facilities. If you consider the Italian topography and the very high number of present district areas you can agree with us that such a reduction is not as drastic as you fear. Anyway the target is valid for the overlaid digital network.

Q.2 (A. David)
To what extent do you do joint facility and traffic planning? How big are the economic advantages of doing it jointly?

A.2 (Filippini, Mazzei, Miranda)
The target in joining traffic routing and circuit routing procedures was the desired overall network availability at the minimum cost. At present our results cannot give a measure of economic advantages, since they are not yet complete.

Q.3 (Calallers)
Do you consider two-way trunking? Do you plan to do so in the future? How - what methodology?

A.3 (Filippini, Mazzei, Miranda)
The exposed methodology is a general one: you can consider two way trunk groups provided the procedure dimensioning the network is able to take them into account.
Q.4 (Cameron)

How strong is the linkage between transmission cost and switching cost; i.e. by what amount does switching evolution cost change in iteration #2 after optimal transmission plan has been found for iteration #1?

A.4 (Filippini, Mazzei, Miranda)

More than on costs the linkage is based on overall network availability: the change in switching evolution is expected in the size of the tandem exchanges after modularity adjustment and circuit routing operated by NETREL. That's why the first level to be completed with digital exchanges will be the tandem level.

Q.5 (W. Pernau)

In your paper you describe the introduction philosophy of toll digital exchanges in the Italian trunk network. In order to minimize total costs (e.g. minimum of AD and DA conversions) one has to simultaneously take into account the introduction of local digital exchanges. Have you a concept of a co-ordinated introduction of trunk and local exchanges?

A.5 (Filippini, Mazzei, Miranda)

Dynamic planning studies for the introduction of digital switching at local levels are carried out by other interconnected computer tools mentioned in references 1 to 5.

The application to an entire district area, including the toll centre, which all the local offices are connected to, has shown the importance of the local toll synergy, so that, as a general rule, at present the timing for local digitalization is determined by the toll switching digitalization; that has confirmed the top to bottom strategy of introduction.