MICAN: AN ALGORITHM TO DIMENSION SWITCHING NETWORKS WITH ADAPTIVE ROUTING USING IMPLIED COST METHODOLOGY

by

J.CHIFFLET(©), N.IKEUCHI(©©), P.-D.LANSARD(©)

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The objective of this paper is to present a new tool aimed to design switching networks with various state dependent routing strategies and multi-period traffic data. After having compared different potential methods, such as ECCS method and Implied Cost Methodology, the best solution is found by selecting and merging these different approaches. We present results on a 17 nodes real network with 2 periods.

1. INTRODUCTION

The objective of this paper is to present a new tool aimed to dimension the upper part of a telecom network assuming that, within this network, the calls are routed following an adaptive strategy.

In order to make preliminary studies, FRANCE TELECOM, and NIPPON TELEGRAPHS AND TELEPHONE CORPORATION have decided to join their researching efforts in view of defining an appropriate method to dimension the backbone part of their networks in case of adaptive routing strategies. The results presented hereafter were obtained by a common team between CNET(FT) and ECL(NTT).

The goal of that team was to build a computerized tool called MICAN which may be used to compare different technics in order to dimension adaptive networks with about 60 nodes. This number of nodes corresponds to the common size of the transit networks of both FRANCE and JAPAN.

After having compared different potential methods, it was found that the most appropriate one, for the purpose of the present study, was a DCR-like case (DCR : Dynamic Control Routing from BNR). In addition the usage of implied costs, in this area, were found quite effective and thus it was decided to try to gain the best from them.

MICAN (Method including Implied Costs for Adaptive Network) was so designed that it includes different potential algorithms for the different stages of the computation. The best solution is found by selecting and merging different approaches which are going to be called method A and method B.

Such a tool does not run very fast without good technics to speed up the processes. Such an acceleration is also proposed in this paper.

After having explained the different methods which were compared on a 17 nodes x 2 periods network, we present MICAN method and computerized tool. Finally we give some first results on the FRANCE TELECOM transit network.

2. MICAN OVERVIEW

The general idea in MICAN is to divide the full process of dimensionning the network into 3 stages:
- first to initiate the size of each bundle and, in each bundle, the sizes of each trunk group,
- second to allocate the overflowing traffic to each trunk group of each bundle,
- third to recompute the size of each trunk group within each bundle.

For each of the stages, different methods may be used by parameter selections.

The initialization stage is done by sizing each bundle (*) for the period where the total outgoing traffic from the node is maximum and by sizing each trunk group with a ECCS-like method (cf: TRUITT or PRATT).

Remarque: It is to be noticed that we never consider any opportunity of having a crank back capability in our studies.

(*) An outgoing (resp : incoming) bundle is the set of all trunk groups issue from a node i (resp : the set of transit nodes) to the set of transit node (resp : a node i).

3. METHOD A: DCR, THE BNR APPROACH

3.1 The reasons

We first explain why DCR was our first choice.

Our aim was to consider a set of exchanges out of which some of them offer transit capabilities to the others. Thus the BNR approach where some exchanges (nodes X) are just traffic sources and sinks and some other exchanges (nodes T) are not only traffic sources and sinks but also tandem nodes for some given pairs, revealed to be convenient for our work.
Next, since it is now well accepted that an adaptive routing is quite well approached by a load sharing method on the second choice after a fixed first choice on the direct trunk group where it exists, we first applied the DCR algorithm to such an approach by using the method proposed by CAMERON [1] & [2].

Also of great interest is the concept of bundles used in DCR which is very efficient for representing the traffic flows.

In addition, the fact that DCR is also valid with more than one period was in favor of our choice of DCR approach to begin with.

This case will give us a reference point for the other approaches we will try.

### 3.2 Allocation of traffic within each bundle

After each trunk group of a given bundle is sized, the allocation of overflowing traffic for each period is done using the formula worked out by J. REGNIER in [3]. This formula uses the expectation of idle trunk capacities which reflects mainly the HPR (***) ideas.

(**) HPR : High Performance Routing, it is the BNR project for adaptive routing. The corresponding algorithm is DCR.

### 3.3 Dimensioning stage

When the global size of each bundle is updated, the exact size of each trunk group within that bundle is determined step by step.

For this purpose, let us consider, for each trunk group, the ratio \( r_{ij} \) of the cost of one trunk \( c_{ij} \) over the last trunk capacity \( l_{t_{ij}} \) (cf: ECC’S method).

One trunk is subtracted from the alternative path whose \( r \) is maximum and one additional trunk is put on the path whose \( r \) would be minimum if adding an extra trunk. Then an ending procedure is used in order to enable the convergence.

### 4.METHOD B: USAGES OF IMPLIED COSTS

#### 4.1 The reasons

Several recent papers show a great deal of interest for this new family of methods. Thus it appeared to us that the introduction of such approaches should bring some interesting results.

Therefore, within MICAN, we have introduced applications of implied costs theory in the second and the third stages.

#### 4.2 The traffic model

Consider a network represented as a graph fully meshed or not. Calls arrive at Poisson rate \( \lambda_{ij} \) on the link \( i-j \), and if blocked the overflowing traffic can be distributed, using the load sharing coefficients, over a set of available two-link paths. For example in a fully connected network of \( N \) nodes, the two-link alternatives between the \( (i,j) \) node pair will be some tandem paths \( [i-t,i-j] \) via the tandem node \( t \). As in the case of DCR, \( N-2 \) alternative paths can be used. The followings only consider a fully connected transit network, but the equations are still valid for any network with two-link alternatives.

Each link \( i-j \) has a capacity \( n_{ij} \) and a blocking probability \( b_{ij} \), we note \( a_{ij} \) the offered traffic and \( a_{ij}^{t} \) the proportion of overflowing traffic from the \( i-j \) link which use the \( [i-t-i-j] \) tandem path.

![Fig 1](image)

The offered traffic to the \( i-j \) link has three components as it is shown in Fig.1

\[
a_{ij} = a_{ij}^{1} + a_{ij}^{2} + a_{ij}^{3}
\]

\[
a_{ij} = \lambda_{ij} + \sum_{l} r_{il} \alpha_{il}^{1}(1-b_{il})b_{il} + \sum_{m} r_{mj} \alpha_{mj}^{2}(1-b_{mj})b_{mj}
\]
4.3 Implied costs

Suppose that calls which are first offered to link $i-j$ have an associate worth $o_{ij}$ (in our model $o_{ij} = \text{cte} = \omega$ for all links $i-j$), the return from the network $W = W(a,n)$ is given by:

$$W = \sum_{i,j} o_{ij} a_{ij} (1 - L_{ij})$$

where:

$$L_{ij} = b_{ij} \sum_{i} \alpha_{ij}^t b_{ij}$$

The implied cost methodology developed by KELLY \[4\] and KEY \[5\] gives a way of calculating the derivatives of this quantity with respect to $n$ and $a$ by means of a simple set of fixed point equations.

In our model we obtain the following equation:

$$\frac{\partial W(a,n)}{\partial n_{ij}} = \text{cin}_{ij} = \eta_{ij}(1 - \sum_{i} \alpha_{ji}^t b_{ij} (\omega - \text{cin}_{ji})) +$$

$$\sum_{s} \text{tr}_{ij} b_{ij} \alpha^t_{ji} (1 - b_{si})(\omega - \text{cin}_{si})$$

where:

$$\eta_{ij} = \text{erl}[n_{ij} - L_{ij}] - \text{erl}[n_{ij} a_{ij}] \quad \text{erl} \ldots = \text{erlang function}$$

$$\frac{\partial W(a,n)}{\partial a_{ij}} = \text{virs}_{ij} = (1 - b_{ij})(1 - b_{ij})(\omega - \text{cin}_{ji} - \text{cin}_{ij})$$

4.4 Allocation of traffic within each bundle

In this case, the load sharing coefficients are computed by means of the vlr$ij^t$ introduced in section 3. This vlr value may be considered as the revenue yielded by an extra call successfully routed on a given path.

The general idea is to add some traffic on the path whose vlr is the highest and to subtract some traffic from the paths whose vlr are lower.

Nevertheless it was found necessary to try to keep to an equilibrium so that the dispersion of the traffic is not too large. In order to achieve that, the two paths whose vlr are the highest are almost offered the same amounts of traffic.

4.5 Dimensioning stage

In this case, the algorithm is about the same as the one with Method A, but the computation of the expected idle trunk capacity on each alternative path is replaced by the the computation of the implied cost, cin, for each path. Thus, for each step, one trunk is substracted from the path where the cin is minimum (where $r$ is maximum) and one trunk is added to the path whose cin would be maximum (whose $r$ would be minimum) if adding an extra trunk on each alternative path.

Afterwards an ending procedure is added in order to stop the process in good conditions.

4.6 Implied costs and modularity aspects

In case of modularity of $m (>1)$ trunks, we used the approximations suggested by TIBAS & LEOURGES in a companion paper \[6\].

5. MICAN RESULTS

5.1 General considerations

The results which are presented below where obtained on a SUN4 computer for the 17 nodes network, and on a CONVEX computer for the 58 nodes network.

The routines are written in FORTRAN.

We first made comparisons on small networks of 6 nodes, but then in order to assess our point of view we preferred to conduct more accurate comparisons on a 17 nodes network with 2 periods. Moreover this is a real network from the city of MARSEILLES in the south part of FRANCE. This network comprises 10 X-nodes and 7 T-nodes.

Later on we began to try to use MICAN on larger networks. Section 5.4 will give the first available results.
5.2 Results for the 17 nodes network

The results are shown in Figure 2. This is a crossed table where the columns give the chosen method for allocation traffic stage and the rows give the chosen method for the dimensioning stage.

<table>
<thead>
<tr>
<th>METHOD A</th>
<th>METHOD B</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAGE 2</td>
<td></td>
</tr>
<tr>
<td>TOTAL COST 19579.76</td>
<td>TOTAL COST 19277.90</td>
</tr>
<tr>
<td>NB OF TRUNKS 8387</td>
<td>NB OF TRUNKS 8428</td>
</tr>
<tr>
<td>STAGE 3</td>
<td></td>
</tr>
<tr>
<td>TOTAL COST 19588.41</td>
<td>TOTAL COST 19276.93</td>
</tr>
<tr>
<td>NB OF TRUNKS 8386</td>
<td>NB OF TRUNKS 8409</td>
</tr>
</tbody>
</table>

Figure 2 Results for the 17 nodes x 2 periods network

5.3 Discussion

It is clear that the best results of MICAN are obtained by selecting the implied costs method (Method B) for both the stages 2 and 3.

Method B for stage 2 gives always better results than Method A.

As far as stage 3 is concerned, if Method A is used for stage 2, Method B provides worst results.

When Method B is used for stage 2 the results provided by both the two methods for stage 3 are very similar, but the implied cost case needs more computation time since it is a very global method. Thus, within MICAN, it is worthwhile to keep with the Method A for stage 3.

5.4 Results for the 58 nodes network

This network comprises the 58 tandem exchanges and 1200 potential links of the France Telecom transit network. The computation has been done with one time period. In order to save cpu time we first used the method A in the two stages of the dimensioning process. The results are shown in Fig. 3. It is to be noticed that we need 12 iterations to get the first feasible solution.

6. AN IMPROVEMENT: PROJECT

6.1 The Method

Iterative process for dimensioning are heavy on cpu time. Especially in case of large networks finding the true optimum is hard. Therefore, we propose an approach which provides first, feasible solutions, before reaching the same optimum. The main idea is, starting from a feasible solution, to decrease the network cost while moving not too far from the feasible solution region.

The sizing problem in MICAN is to minimize costs subject to achieving grade of service constraints for each bundle and for each time period. Suppose that it costs amount c_{ij} to install a circuit on link i-j, then the problem is to:

\[
\min \sum_{i,j} n_{ij} c_{ij} \\
\text{(P)}
\]

subject to:

\[
\text{carried traffic in bundle}(i) \geq \text{offered traffic to bundle}(i)
\]

for each time-period \( t = 1, \ldots, T \)

Let us consider a relaxation (PR) of the previous problem (P), obtained by adding for a same time-period all the (P) constraints. We also note that if \( w = 1 \) for all links i-j the return function \( W \) is the total carried traffic in the network. Therefore, we can formulate (PR) as the following way:

\[
\min \sum_{i,j} n_{ij} c_{ij} \\
\text{(PR)}
\]

subject to:

\[
W^t(a,n) \geq a^t_{ij} \quad \forall t = 1, \ldots, T
\]

To decrease the objective function, we chose to apply a steepest-descent algorithm on the relaxed problem (PR) for two reasons. One is, in the problem (P), the number of the constraints is proportional to the network size. This is not very convenient in case of large networks. The second is the fact that the necessary data for the calculation of the descent direction are only the implied cost matrix.

Calculation of the direction d:

Defining the matrix B as

\[
B = [\nabla W_1^\text{Tr}, \nabla W_2^\text{Tr}, \ldots, \nabla W_T^\text{Tr}] = [\text{cin}]_{ij}
\]

where \( \nabla W_i = (\partial W_i / \partial n) \) is the tangent to the i-th constraint.

Then the direction d along the tangent to the constraints satisfies:

\[
 B \cdot d = 0
\]

If \( f \) is the objective function,

\[
f = \sum_{i,j} n_{ij} c_{ij}
\]

Then if \( Vf \) is the vector size, the direction to be followed is

\[
d = \{I - B'(BB')^{-1}B\}(-Vf)
\]

which is the orthogonal projection of \(-Vf\) on the space \( Bx = 0 \)
It is clear that the obtained solution may not be a (P)-feasible solution. Nevertheless it appears that this solution is close to feasible region of the problem (P) and therefore provides us a good starting point to perform another cheaper feasible solution with an iterative process approach.

6.2 Results with Project

<table>
<thead>
<tr>
<th>Program</th>
<th>nb of iter</th>
<th>nb of trunks</th>
<th>cost</th>
<th>cpu (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MICAN</td>
<td>12</td>
<td>77515</td>
<td>24237.62</td>
<td>5459.738</td>
</tr>
<tr>
<td>(without Project)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MICAN</td>
<td>4</td>
<td>77753</td>
<td>24591.43</td>
<td>1303.320</td>
</tr>
<tr>
<td>(opt. solution)</td>
<td>8</td>
<td>76004</td>
<td>24164.80</td>
<td>3069.676</td>
</tr>
</tbody>
</table>

(*) second cpu on CONVEX

Fig. 3 Results for the 58 nodes network

The first results we obtained with project are shown in Fig. 3. It is important to note that the results are almost the same or even slightly better. But now, amongst the 8 iterations, we have 2 feasible solutions. Thus, with project, we achieved an interesting improvement since in a shorter time we are able to obtain feasible solutions quite near to the optimum.

7. CONCLUSIONS

We proposed a very flexible tool, MICAN, which can be used for designing switching networks with various state dependent routing strategies and multi-period traffic data on large (up to sixty nodes) fully meshed (or not) networks. We also nowadays apply this tool to real networks.

8. REFERENCES


