A DYNAMIC ASSIGNMENT METHOD FOR TRUNK RESERVATION PARAMETERS IN CIRCUIT NETWORKS.

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This paper presents an algorithm optimizing trunk reservation parameters, which can be able to be associated with a supervision system for an adaptative assignment of values to these parameters in a circuit network. Some applications of the method and the results obtained in simulation studies are shown.

1. INTRODUCTION

The evolution of the switching and transmission techniques provides more and more facilities to execute network functions such as routing. According to this evolution, hierarchical routing is evolving to some more complex procedures in which path selection is dynamic and dependent on the network load. In nonhierarchical routing, a better utilization of network elements is possible sharing out the traffic onto the existing paths between the call origin and its destination. In such a way a saving is made and a better performance is offered.

On the other hand, instabilities may appear if this kind of routing is used, because the number of links used by an overflowing call is greater than that used by a direct call. In full meshed networks, overflowing calls take up double the resources and, in case of high network loads, block directly routed calls, causing them to overflow and, in turn, to block other direct calls. In this situation, which increases in frequency with the number of alternative paths, total carried traffic decreases.

This problem has already been studied in detail by other authors [1-14] and trunk reservation has been proposed as a suitable protection procedure.

With this procedure, calls are not allowed to overflow onto a route unless the number of available circuits in it is greater than a given threshold. This threshold, or trunk reservation, is usually assigned assuming a static traffic situation without considering that optimum reservation value depends dynamically on the traffic fluctuations. In some cases, dynamical assignment of this values is considered [2,3].

Restriction of overflowing traffic is not the only possible application of the trunk reservation procedure. This could be used in any case in which we want to distinguish different kinds of traffic with different priority levels on the same link. For each priority level, a trunk reservation value is assigned. The lower the priority level the greater this value must be. The highest priority traffic would have trunk reservation value zero.

In any case, the problem is to estimate the optimum reservation threshold for each type of traffic, taking into account that it is a function of the network load.

Optimization methods for these trunk reservation values are still under discussion. This paper proposes an algorithm to derive these parameters from the offered high priority traffic volume.

Due to its simplicity, this algorithm associated to a traffic supervision system allows the dynamic alteration of these values, in accordance with the actual load in the network. Alternatively, they could be set up in fixed values based only on the traffic forecast.

2. ANALITICAL MODELLING

2.1 Definition of terms.

Let us consider a link carrying two types of traffic.

Let us call:

\[ C \]: Link capacity (number of circuits)
\[ A_1 \]: Offered type 1 traffic
\[ A_2 \]: Offered type 2 traffic
\[ f_1 \]: Revenue attributable to the link for carrying a type 1 call.
2.2 Hypothesis.

The holding time for both types of traffic has an exponential distribution with the same mean value.

The interarrival time for type 1 traffic has an exponential distribution.

For Type 2 traffic we want to consider a wide range of cases. In order to achieve this goal, we will analyze 3 different models for representing this traffic:

-Model 1: Interarrival time very high. The possibility of finding a call being offered to the link during the holding time of another call is zero.

-Model 2: Interarrival time is very low. The possibility of finding more than \( t \) free circuits in the link is zero.

-Model 3: Interarrival time has an exponential distribution.

2.3 Theoretical optimization.

2.3.1 Model 1.

Let us assume that a type 2 call is offered to the link when there are \( x+1 \) free circuits. If we accept the call, \( x \) free circuits will remain.

Let us call:

\( q_x \): Probability of losing a type 1 call before the type 2 call is removed, knowing that there are \( x \) free circuits.

Accepting the call we can get a revenue \( r_2 \), but we have a probability \( q_x \) of losing a revenue \( r_1 \). The total expected revenue is:

\[
R = r_2 - q_x \cdot r_1
\]  

(2.3)

Then it would be advisable to carry this call if

\[
r_2 - q_x \cdot r_1 > 0
\]  

(2.4)

that is,

\[
w > q_x
\]  

(2.5)

The optimal trunk reservation value will be:

\[
t = \min \left\{ t / w > q_x \right\}
\]  

(2.6)

We can establish the following relation between the terms \( q_x \):

\[
(A_1 + C - x) \cdot q_x = A_1 \cdot q_{x-1} + (C - x - 1) \cdot q_{x+1}, \quad x = 1, \ldots, C - 1
\]  

(2.7)

with the border conditions:

\[
q_0 = 0
\]

\[
(A_1 + C) \cdot q_0 = A_1 + (C - 1) \cdot q_1
\]  

(2.8)

The solution for this system is

\[
A_1 = \frac{(C - x - 1)}{\sum_{i=0}^{C-x-1} \left( A_1^i / i! \right)}
\]

(2.9)

where \( w_x \) is the critical revenue value as defined in (2.2).

So the optimal trunk reservation value is:

\[
t = \min \left\{ x / w_x < w, (1 + \frac{A_1^x}{x!}) \right\}
\]  

(2.10)

2.3.2 Model 2.

Let us call:

\( p(x) = \text{Prob} (x \text{ busy circuits in the link}) \)
In this model, we assume
\[ p(x) = 0 \quad \text{if} \quad x < C-t \]
The stability conditions for the system imply:
\[ A_kp(x) = (x+1)p(x+1), \quad x=0,1,...,C-1 \] (2.11)
with the additional relation:
\[ \sum_{k=0}^{c} p(x) = 1 \] (2.12)
The solution for this system is:
\[ p(x) = \frac{x^m}{x!} \quad \text{with} \quad \sum_{k=0}^{x} A_k^{\alpha}/i! \] (2.13)
The total carried traffic will be
\[ T = \sum_{x=C-t}^{\infty} x.p(x) \] (2.14)
Type 1 carried traffic will be
\[ T_1 = A_1.(1-p(C)) \sum_{x=C-t}^{\infty} x.p(x) \] (2.15)
And then, type 2 carried traffic will be
\[ T_2 = T - T_1 = (C-t).p(C-t) \] (2.16)
The total expected revenue value is a function of the trunk reservation parameter and can be expressed as:
\[ B(t) = r_A.T_1 + r_A.T_2 - T_1.A_2.(1 - \sum_{k=0}^{c} A_k^{\alpha}/i!) + A_2^{-c}/(c-t-1)! + \sum_{k=0}^{c} A_k^{\alpha}/i! \] (2.17)
The optimal trunk reservation value will be:
\[ t = \min \left\{ x / B(x+1) < B(x) \right\} \] (2.18)
This condition \( B(x+1) < B(x) \) is equivalent to:
\[ w_2 < w.(1-(C-x-1)!.(C-x-1-A_1) \sum_{k=0}^{c} A_k^{\alpha}/i!) \] (2.19)

2.3.3 Model 3
This model is already well known from other studies (for instance [11]). The steady-state probabilities are:
\[ p(x) = \begin{cases} (A_1+A_2)^x \quad \text{if} \quad x < C-t \\ (A_1+A_2)^x.A_1^{-c-c} \quad \text{if} \quad x > C-t \end{cases} \]
\[ p(0) = \sum_{i=0}^{c} \frac{(A_1+A_2)^i}{i!} \quad \sum_{i=0}^{c} \frac{A_1^{i}}{i!} \] (2.20)
Type 1 and type 2 carried traffics are:
\[ T_1 = A_1.(1-p(C)) \]
\[ T_2 = A_2 \sum_{i=0}^{c} p(i) \] (2.21)
The total expected revenue is:
\[ B(t) = r_A.T_1 + r_A.T_2 - A_2.A_2 \sum_{i=0}^{c} p(i) \] (2.22)
We maintain the condition (2.18) for the optimal trunk reservation value. In this case, the condition \( B(x+1) < B(x) \) can also be expressed as:
\[ (1+A_2/A_2)^{c-x} \sum_{i=0}^{c} A_2^{i}/i! \quad \sum_{i=0}^{c} A_1^{i} \] (2.23)
If we consider in this expression the limit when \( A_2 \) is zero or infinite we will arrive to expressions (2.10) and (2.19) respectively.

2.4 Practical optimization.
In many practical cases, we do not have very much information about the type 2 traffic. Even if we can estimate the average traffic, \( A_2 \), its behaviour is far from being poissonian. Furthermore, if we want to actualize trunk reservation parameters in real time, expressions (2.10), (2.19) or (2.23) can be too complex.
These expressions can be resumed in the following:

$$t = \min \left\{ \frac{x}{w^*_{\infty}} < w.P(x) \right\}$$

(2.24)

In normal conditions, this value $t$ will be small with respect to $C$. In this case, the factor $F$ in any of the three expressions will be very close to 1. Thus we propose using the following simplified expression for selecting the trunk reservation value:

$$t = \min \left\{ \frac{x}{w^*_{\infty}} < w \right\}$$

(2.25)

However, in very high load conditions there is no $x$ verifying $w^*_{\infty} < w$. We must define some upper value to prevent this situation. The best solution for defining this upper value has not yet been achieved, but our studies show that it must be based on expression (2.10). In any case, this problem is not really relevant because it corresponds to traffic loads over 90% of the link capacity.

The critical value $w^*_{\infty}$ can be computed in an iterative way using:

$$w^*_{\infty} = \frac{A_1}{C}$$

(2.26)

$$w^*_{\infty} = \frac{A_1}{C} - w^*$$

This method is a quick and simple one and does not need any input related to the traffic volume and distribution of the low priority calls. Each link may be analyzed without taking into account the network as a whole.

In a full connected network, two links are required for carrying an overflowing call. Thus we can assume that the revenue attributable to each link will be a half of the revenue that could get carrying a direct call. In this case we can apply our method considering $w=0.5$.

We can see in fig 1 the trunk reservation values obtained by this algorithm with different link capacities, as a function of the relation $A_1/C$.

Figure 2 compare the results of this algorithm with the theoretical results of models 1 and 2. We can see that the algorithm is very close to model 1.

3. SIMULATION RESULTS

For the assessment of the trunk reservation method performance, a simplified reference network has been analyzed by means of simulation.

The model represents a symmetrical and fully meshed network, with eight transit nodes. Each pair of nodes is connected by a 60 circuits link and interchanges a traffic of 45 erlangs (nominal value). Thus the traffic rate has been homogenously distributed.

The routing scheme allows each direct call that can not be carried by its direct link to overflow through any other transit node of the network, using a two links path to reach the destination node. The overflowed traffic load is shared among all the possible alternative paths in the network.

The average loss probability is the representative parameter analyzed, making series of cases with different traffic load and different trunk reservation values. The range of traffic variation goes from the nominal value to an overload of 14%.

For the number of reserved circuit we consider two cases:

- Using a number of reserved circuits that remains fixed all through the traffic sweep. The study considers trunk reservation values from 5% up to 10% of the number of circuits.
- Selecting, for each traffic value, the optimal number of reserved circuits given by the application of the algorithm proposed, using expression 2.25.

Figure 3 compares the resultant average loss probability in both cases.

4. APPLICATIONS

The dynamic assignment method for trunk reservation parameters presented in this paper may be used to protect fresh traffic in nonhierarchical networks according to dynamic routing procedures. Trunk reservation parameters in each route are updated depending on network load and making use of the supervision system provided by the routing procedure itself.

In addition, this method allows other applications. For instance, in multiservice networks (ISDN), a traffic control providing more network resources for some special calls may be required. In this way, traffic is classified according to a priority level, and it is possible to offer different grades of service to the user in the same network depending on the type of customer. For each service or customer class we could define a revenue parameter, $r_j$, and a relative revenue, $w_j$, as the result of dividing $r_j$ by the revenue parameter of the highest priority service/customer.

In the same way, in long distance networks we could define revenue parameters as a function of the tariffs. When a call must use several links the revenue must be shared between them. This distribution may be done proportionally to the cost of each link or to the revenue of direct calls in the link or with some other criterium. This procedure, which allows the protection of fresh traffic and the establishment of priority levels in the overflow traffic, may be used in both domestic and international calls.

5. CONCLUSIONS

A new algorithm for optimizing trunk reservation parameters has been discussed. Analytical and simulation results show the advantages of using this algorithm for dynamic updating of values in these parameters. The method may be extended to other applications in which the establishment of priority levels between different traffic streams could be suitable.

REFERENCES