TRAFFIC DESIGN OF TELECOMMUNICATION NETWORK WITH BOTH-WAY CIRCUIT OPERATION

Akira TODA

Network Technology Department
NTT Network Systems Development Center
Tokyo, Japan

This paper clarifies the traffic problems of both-way circuit operation and provides a guide to the traffic design of telecommunication networks which puts emphasis on circuit dimensioning and traffic control.

1. INTRODUCTION

The common channel signaling system makes it easy to apply both-way circuit operation and, therefore, a telecommunication network can be operated more efficiently. The impacts of both-way circuit operation on the traffic design of telecommunication networks are as follows.

(1) Reduction in the number of circuits through the efficiency of large groups; this is accomplished by dimensioning the number of circuits for the sum of both direction traffic.

(2) Reduction in the number of circuits by mixing the non-coincident busy hour traffic; the busiest hours of traffic between two offices may differ according to their directions. Therefore, a smoothing effect may be obtained by superimposing the non-coincident busy hour traffic, which reduces the number of circuits.

(3) Intensification of traffic fluctuation endurance; traffic fluctuation in one direction can be concealed if traffic in the other direction is less than its busy hour traffic. On the other hand, the blocking probability in one direction may degrade through an unusual traffic increase in the other direction.

An effective circuit dimensioning method is required to make good use of the advantages of both-way circuit operation. Moreover, a traffic strategy is also required to protect against a service degradation due to unusual traffic increases.

This paper clarifies the traffic problems of both-way circuit operation and provides a guide to the traffic design of telecommunication networks which puts emphasis on circuit dimensioning and traffic protection strategy. Since a detailed description would require more space than permitted, the numerical results will be restricted to a bare summary.

2. BOTH-WAY CIRCUIT DIMENSIONING[1]

2.1 Problems In Number Of Both-way Circuit Dimensioning

As shown in Fig. 1, in both-way circuit dimensioning, calculation of a variable requires the values of the variable itself when both-way circuit operation is applied to an alternate routing network. Therefore, exact dimensioning of the number of both-way circuits in an alternate routing network requires solving non-linear simultaneous equations with many mutually related variables, such as offered traffic, carried traffic, and the number of circuits. It is difficult to adopt such a dimensioning method for actual complicated, large-
scale direct distance dialing (DDD) network.

2.2 The Equivalent Overflow Traffic Method (EOTM)

The problems described in Sec. 2.1 can be effectively solved by cutting the mutual relations among variables. The EOTM proposed in this paper enables the number of both-way circuits to be determined by using the offered/overflow traffic to and from one-way circuits, which is obtained in dimensioning the number of one-way circuits by the current method. The EOTM determines the number of circuits on each route by use of an approximation based on the assumption that the traffic offered to each route obtained for one-way circuit operation is not influenced by the both-way circuit operation. The dimensioning method is thus greatly simplified. The EOTM dimensioning procedure is as follows.

1. Offered traffic \(a_1, a_2\) and overflow traffic \(b_1, b_2\) to and from each route are calculated by the current dimensioning method for one-way circuits.
2. The number of both-way high-usage circuits \(n\) is sized in such a way that overflow traffic from the both-way circuit groups is equal to the sum of overflow traffic \(b_1 + b_2\) from the two one-way groups \(n_1, n_2\). The term EOTM comes from this procedure.
3. The number of both-way final circuits is sized by the sum of traffic offered to the route, i.e., upward and downward traffic, including overflow traffic obtained by procedure (1), in such a way that the blocking probability is less than the standard value.

2.3 Accuracy Comparison For EOTM And Exact Dimensioning Method (EDM)

2.3.1 Study subjects for EOTM

The EOTM makes it easy to size a both-way circuit group. However, to use the EOTM as an actual dimensioning method, grade-of-service and economy problems must be studied by comparing the EOTM with the exact dimensioning method (EDM) using non-linear simultaneous equations.

![Dimensioning procedure for the number of both-way circuits.](image1)

![Evaluation from the grade-of-service viewpoint.](image2)
(1) Grade-of-service; since the traffic stream (traffic offered to each route) changes in both-way circuit operation, the number of both-way circuits dimensioned by the EOTM may not satisfy the grade-of-service standard.

(2) Economic benefit; the EOTM may overdimension alternate circuit groups, because the overflow traffic b_i from a both-way circuit group is not used for dimensioning the number of alternate circuits, even if b_i is smaller than the overflow traffic b_i from a one-way circuit group.

2.3.2 Evaluation from the grade-of-service viewpoint

Evaluation is performed based on the triangular network model with plural high-usage routes, shown in Fig. 2. In this model, the numbers of high-usage and final circuits are sized as follows.

(1) Number of high-usage circuits; the number of one-way circuits is sized by the LTC* method under the condition that Poisson traffic (mean value a_i, peakedness factor Z_01=1) is offered to the high-usage circuit group. The EOTM determines the number of both-way circuits by the mean overflow traffic obtained from the above calculation.

(2) Number of final circuits; the EOTM sizes the number of both-way final circuits by the mean and the variance for overflow traffic from a one-way high-usage circuit group to which Poisson or non-random traffic is offered. In the EDM, the means and the variances for overflow traffic from the both-way high-usage circuit group are calculated by the formula shown in Refs. [2] and [3], when offered traffic is Poissonian, or by the numerical analysis program, [4] when offered traffic is non-random. Both methods use the Equivalent Random Method. [5]

In order to simplify the analysis, the traffic offered to the final circuits is assumed to be composed only of the overflow traffic. Here, non-linear simultaneous equations are not used even in EDM, since the network model has a simple triangle form and the number of both-way high-usage circuits is made equal for both methods.

Figure 2 shows an example of evaluation results. This figure shows the number of both-way final circuits required to carry overflow traffic in such a way that blocking probability is less than 0.01, when the peakedness factors (Z_01, Z_02) of traffic offered to both-way high-usage circuit groups are equal to each other and the ratio (a_1:a_2) changes under the condition that the sum of a_1 and a_2 is fixed.

The following conclusions can be derived from the evaluation.

(i) The EOTM overdimensions independently of the traffic volumes and of the number of high-usage routes, when a_1 is equal to a_2.

(ii) The number of final circuits sized by EOTM can be smaller than those sized by EDM when the ratio (a_1:a_2) grows larger.

(iii) The EOTM satisfies the grade-of-service standard except in the condition that the number of high-usage routes on which a_1 is larger than three times a_2 is more than five.

2.3.3 The economic benefit

The model is a two-hierarchical structure network with plural high-usage routes, as shown in Fig. 3. The following five methods of dimensioning the number of circuits are compared.

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTC</td>
<td>One-way circuit dimensioning by the LTC method.</td>
</tr>
<tr>
<td>SIT</td>
<td>One-way circuit dimensioning by the relaxation method which heuristically searches for the optimum solution.</td>
</tr>
<tr>
<td>EOTM_LC</td>
<td>EOTM by use of the LTC results.</td>
</tr>
<tr>
<td>EOTM_IT</td>
<td>EOTM by use of the SIT results.</td>
</tr>
<tr>
<td>BIT</td>
<td>EDM with the relaxation method.</td>
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</tbody>
</table>

* LTC; Last Trunk Capacity or Economic CCS (calls of 100 seconds duration).
Figure 4 shows that the EOTM\textsubscript{LC} has an economic advantage, and that the difference between the EOTM and the EDM is not so large.

3. TRAFFIC PROTECTION CONTROL STRATEGIES

3.1 Traffic Protection Problems

Since a circuit group is shared by outgoing traffic $A_1$ and incoming traffic $A_2$ in both-way circuit operation, traffic flow in one direction tends to be disturbed by increased traffic flow in the other direction. In a both-way circuit-operated network under a focused overload, it is difficult to carry outgoing traffic from the focused area.

3.2 Traffic Protection Control Strategies

There are four strategies for both-way circuit operation.

(1) LUCN (Method for limiting the number of usable circuits)[6],[9]; this method puts restrictions on the number of usable circuits $R_i$ for each call.

(2) TSM (Three-segments method)[7]; this method physically divides both-way circuit groups into three segments: a segment only for incoming traffic, a segment only for outgoing traffic, and a common-use segment.

![Network Model](https://via.placeholder.com/150)

Fig. 3 - Network model.

![Circuit Selection Algorithm](https://via.placeholder.com/150)

Fig. 5 - RDM circuit selection algorithm.

![Relative Comparison](https://via.placeholder.com/150)

Fig. 4 - Relative comparison among dimensioning method in total number of circuits.
3. RDM (Reservation-domain method)[8],[9]; this is a kind of trunk reservation method. Idle circuits are reserved for incoming or outgoing traffic only when the number of used circuits at that time is less than a pre-specified limit for each direction of traffic. The pre-specified limit is called the "Number of circuits for cancelling reservation" or "Reservation-domain." Figure 5 shows the RDM circuit selection algorithm.

4. PNM (P-NP method)[9]; both-way circuits are classified into priority group (P-group) and non-priority (NP-group) for the resolution of collisions during both-way circuit hunting. Specifically, P-group and NP-group are determined by circuit number parity. P-group for one direction corresponds to NP-group for the other direction. When a collision occurs, the office with low priority tries to select another circuit. At first, each office tries to select a circuit in its P-group. PNM replaces the logical domains in RDM with physical P-group (R₁) and NP-group (R₂).

3.3 Evaluation Results

The above four traffic protection control strategies are compared in terms of the following measures.

1. Traffic protection ability (or robustness against unusual traffic increase); this measure shows how the grade-of-service (loss probability in the case of telephone networks) for traffic flow in one direction is protected from traffic increases in the other.

2. Efficient utilization of circuits; conventional one-way circuit operation can solve the traffic protection problems. However, one-way circuit operation is inferior to both-way circuit operation from the standpoint of efficient communication network utilization. Therefore, it is necessary to evaluate the traffic protection strategies taking the merits of both-way circuit operation into consideration.

Figures 6 and 7 show examples of evaluation results. We obtain the blocking probability of each call by numerical calculation of steady state equations. Based on these findings, it can be concluded that, in RDM the other traffic can use more circuits if traffic in one direction is small. Further, a circuit selection priority is given to the traffic with the smaller number of used circuits. Therefore, RDM is concluded to be an excellent method with both excellent traffic fluctuation absorption characteristic (efficient utilization of circuits) and traffic protection ability.

3.4 How To Decide RDM Parameters

The traffic protection ability of the RDM depends on the number of circuits

![Fig. 6-RDM and LUCN characteristics at time of unusual traffic increase.](image1)

![Fig. 7-Traffic fluctuation absorption characteristics with RDM and LUCN.](image2)
for cancelling reservations (the reservation-domain) and the number of reserved circuits. It is desirable that these parameters are decided as follows.
(1) The number of circuits for cancelling reservation \( R_i \) of each traffic should be in proportion to value \( A_i \) of each traffic for balancing the blocking probability of each traffic. And, the sum of \( R_1 \) and \( R_2 \) should be minimized on the condition that the sum is more than the number of both-way circuits \( N \). There can exist circuits which can be accessed by neither call when the sum is less than \( N \), and the traffic protection ability deteriorates when \( R_i \) is excessively large. That is, \( R_i \) is decided by the following formula.
\[
R_i = N \times A_i / (A_1 + A_2);
\]
:: means that the fraction of computation result is raised to the next unit.
(2) The number of reserved circuits \( r_i \) would be decided on condition that the blocking probability in one direction does not exceed the limit predetermined \( B' \) when the degree of traffic increase in the other direction is \( X \). The \( B' \) and \( X \) is decided in consideration with the service grades offered by each Administration. Excessive \( X \) (too large) and \( B' \) (too small) are uneconomical, because a large number of reserved circuits are required. One or two reserved circuits may provide sufficient traffic capability.

4. OVERFLOW CHARACTERISTICS FROM A BOTH-WAY CIRCUIT GROUP WITH THE RDM

It is troublesome and requires excessive amounts of computation time to evaluate overflow characteristics from a both-way circuit group with the RDM in a both-way circuit dimensioning for an actual complicated, large-scale network. Therefore, for practical purpose it is desirable to cope with this problem by use of a simple method in which the number of reserved circuits is merely added to the number of both-way circuits dimensioned without consideration of the traffic protection control strategy.

The analysis of overflow characteristics from a both-way circuit group is required for the above study and can be accomplished by the same way used in Refs. [10] and [11]. That is, the steady state equations are formed in the model in which overflow traffics of two kinds of Poisson traffic offered to a finite primary both-way circuit group offer a infinite secondary both-way circuit group. Then, the factorial moments of overflow traffic are led from these steady state equations through the translation of the factorial moment generating function.

Figure 8 shows the overflow characteristics from a both-way circuit group with and without the RDM. Not only mean value but peakedness factor of overflow traffic from a both-way circuit group with the RDM are larger than those without the RDM.

Table 1 shows the number of circuits in a secondary group required to carry overflow traffic from a primary group with and without the RDM, under the condition that blocking probability is less than 0.01. The number of primary circuits without the RDM is \( N \), and the number with the RDM is \( N+r_i (r_1=r_2=1) \). This table shows several results varied the ratio between outgoing \( A_1 \) and incoming traffic \( A_2 \). These results generally show that the simple method described above is applicable for practical use.
5. CONCLUSION

This paper describes important problems involving both-way circuit operation and proposes a solution to these problems. Specifically, the problems are both-way circuit dimensioning, traffic protection control strategy, and overflow characteristics from a both-way circuit group with traffic protection control strategy. Due to limitations of space, certain problems, such as overflow characteristics from both-way circuit group with the RDM offered non-random traffic cannot be described. However, traffic design of telecommunication networks with both-way circuit operation may be carried out by use of the results described in this paper.

In ISDN, a mixture of various kinds of services flow in the same network and require different service qualities. Therefore, the problems described in this paper should be restudied taking this matter into consideration.

REFERENCE