TRUNK RESERVATION AND GRADE OF SERVICE ISSUES IN CIRCUIT SWITCHED INTEGRATED NETWORKS

Per LINDBERG, Krister NIVERT, Barbro SAGERHOLM
Televerket, Sweden

Analytic methods are presented enabling the dimensioning and optimisation of circuit switched networks in which one multi-slot service is integrated with a single-slot service. Some results obtained in studying single circuit groups are extended to networks and verified by simulation. Networks are dimensioned and optimised for the different design strategies dedicated and integrated networks and end-to-end blockings are calculated to ensure comparable service levels.

INTRODUCTION

To justify the development of existing software, so that some calls may have access to a set of simultaneous connections between origination and destination, it will be necessary to investigate the improved network economy with such arrangements. The major traffic engineering problem identified in this area is control of the grade of service for the demands sharing the same capacity.

In [Lindberger 5th ITC sem] some preliminary results indicate the possibility of substantial savings in connection with integrated multiple bit rate switching. These results are obtained from single circuit group calculations. The intent with this study is to extend the analytical methods, and to apply them to a real size network. The efficiency and overall grade of service aspects of different service protection methods will be discussed as well as the implications of substantially different holding times for the two classes of calls.

The typical situation for implementation of integrated multiple bit rate switching may be debated. Two examples come to mind immediately namely different bit rates in circuit switched data networks and video service integrated with voice. There may be other examples more or less probable in the future. It is not the intention here to point out the best candidate services for integration only estimate if savings are large enough to further pursue the investigation of integrated multiple bit rate switching. It should be kept in mind that savings in terms of fractions of network or component costs have to be compared with the expense of these networks or components and are obviously more attractive the higher the expenses are.

MULTI-SLOT CONNECTIONS

The simplest way to establish multi-slot connections in a circuit switched network is to route them as a number of independent single-slot connections. This may however cause certain time slot integrity problems if several multiplexes with different propagation times are involved. To avoid this it is seen essential to restrict the selection of circuits for multi-slot connections to one primary multiplex. In [Roberts ISS '84] it is shown, provided that a sequential selection method is applied, that this restriction decreases the efficiency of the circuit group with around 3% for multi-slot modules around 6, as compared to independent routing. More efficient selection methods may improve this figure but have not been investigated so far. Since all other control functions have to be executed in a dedicated multi-slot network, the increased complexity is represented by this efficient selection method for multi-slot connections. The cost of this complexity has not been possible to establish but should be balanced against the possible gains in the transmission plant. The gain in using the same control equipment for both services is obtainable without traffical integration and is held outside this study.

5.4A.3.1
SERVICE PROTECTION

To enable reasonable grade of service for both demands, service protection measures are necessary. The multi-slot traffic must be protected against single-slot calls and short holding time calls may require protection against long congestion periods. Two methods to equalize grade-of-service between single- and multi-slot traffic have been considered viz state reservation and partial sharing. State reservation implies that a certain number of states are reserved for priority traffic and non priority traffic is blocked when the system is in any of these protected states. In partial sharing the non priority traffic is blocked when the number of simultaneous occupations of this kind exceeds a predefined number.

Comparative studies show that with typical traffic mixes and circuit group sizes state reservation is more efficient than partial sharing in the sense that better equalization is obtained at a lower expense. In consequence the selected method is state reservation.

In our case the multi-slot traffic has priority and the reservation parameter is the multi-slot module minus one. In this state no calls can be carried in either service, thus time congestion appears simultaneously for both services and grade of service is equalized. Overflow single-slot traffic may then experience additional reservation to protect the first offered traffic parcels from the overflow. No overflow multi-slot traffic is handled in the integrated network.

TRAFFIC MODEL AND ALGORITHMS USED

A two-parameter model for overflow traffic is used. In basic traffic calculations the ERT-technique is used with an accurate approximate expression for the equivalent traffic. This formula was given in [Lindberg ITC 11], however with one misprint. The correct one is

\[ A^* = MZ + Z(Z-1)(2+\gamma\beta) \]

where

\[ \gamma = (2.36Z-2.17)\log(1+\frac{Z-1}{M(Z+1.5)}) \]

and

\[ \beta = Z/(1.5M+2Z-1.3) \]

State reservation is handled by an algorithm giving the result when adding reserved states to the reduced group. Also several reservation parameters for one circuit group can be handled. Non Poisson nonpriority traffic is handled by an approximative assumption extending results for the Poisson case.

First the blocking is computed for a group without reservation with the size reduced by the reservation parameter. Individual blockings are obtained by Wallström's splitting formula [Lindberger ITC10], [Reneby ITC10].

\[ B_i \approx B(B+(1-B)Z_i/Z) \]

Our tests have proved this very simple formula to be at least as accurate as those of [Akimaru ITC10], [Fredericks ITC10] and [leGall ITC11].

Assuming that the relations between the previous states are not changed, we can add the reserved states for the Poisson priority traffic and easily calculate their probability. The assumption also gives an approximation of the blocking for the nonpriority traffic. With \( A_0 \) being the Poisson priority traffic, \( B_0 \) and \( B_1 \) the blockings of priority and nonpriority traffic respectively we get when adding a reserved state \( n+1 \)

\[ B_{0,n+1} = \frac{q}{1+q} \quad B_{1,n+1} = \frac{B_1,n^+q}{1+q} \quad \text{where} \quad q = \frac{A_0 B_0,n}{n+1} \]
Non Poisson priority traffic is handled by a Hayward transformation, that requires algorithms for handling a non-integer reservation parameter. This is solved by an interpolation formula based on a geometric series.

A real challenge in this work was to get an algorithm for the integration of both single- and multi-slot traffic. For use in a large network calculation and optimisation this algorithm must be fast, accurate and reliable for all sizes of input parameters.

By a program solving the state equations on one integrated circuit group, different integration strategies have been compared. The result (Figure 1) heavily supports the suggestion of [Lindberger 5th ITC sem] to use state reservation to protect the multi-slot traffic. In order to obtain the same blocking states for single- and multi-slot the simple rule is to reject single-slot calls when the number of idle circuits is less than the multi-slot module.

In figure 2 is shown how the efficiency of integration with this strategy depends on the mean holding time ratio Tmulti-slot/Tsingle-slot. It is quite reasonable to believe that this ratio could be as high as 20 in some applications. From figure 2 it is apparent that it would be a small error to make the calculations by allowing the quotient to tend to infinity.

This approach allows us to easily extend the algorithms for single-slot traffic to the integrated case. For each multi-slot state the single-slot traffic will take a local state equilibrium, which is easily calculated by the previous formulas. Knowing for each multi-slot state the conditional blocking probability and assuming Poisson multi-slot traffic, the multi-slot state probabilities and the blockings are easily calculated.

Let

\[ B_T(n) = \text{time congestion when only the single-slot traffic is offered to } n \text{ circuits (}=1 \text{ if } n<0) \]

\[ d = \text{multi-slot module integer number of single-slot circuits for one multi-slot call} \]

\[ a = \text{multi-slot call intensity per holding time} \]

\[ N = \text{total number of circuits (single-slots; channels)} \]

\[ P_k = \text{probability of } k \text{ multi-slot calls being carried} \]
Then $P_k$ is after normalisation obtained by the equations

$$kP_k = a(1-B_T(N-dk+1))P_{k-1}$$

and the blocking of multi-slot traffic is

$$B_{\text{multi}} = \sum_{k=0}^{[N/d]} B_T(N-dk-d+1)P_k$$

The blocking of different single-slot traffic streams are obtained by corresponding formulas.

**LONG HOLDING TIMES**

The efficiency of integration as stated above is based on the assumption that the multi-slot traffic has a 20 times longer holding time than has the single slot traffic. Such a ratio is advantageous for the integration and improves the savings about 2%. A weak point in current grade-of-service standards is however observed in that certain periods will suffer extremely high congestion. Their frequency is low enough to comply with probability limits of say 1% blocking but when they appear they may be an unacceptable disturbance. The situation is caused by the the long holding times for priority traffic and may be overcome by inhibiting the state reservation when the priority traffic exceeds a certain state. Investigations show promising effects but in lack of concrete formulation of target values no firm results are obtained.

**CIRCUIT GROUP RESULTS**

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<th>Nsep</th>
<th>Nint</th>
<th>Nps</th>
<th>Nr1</th>
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<td>4</td>
<td>5</td>
<td>8</td>
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</tbody>
</table>

**APPROXIMATE DIFFERENCES BETWEEN THE STRATEGIES**

| Nint | savings compared to separate groups | 5-7% |
| Nps | additional savings to the previous | 0-2% |
| Nr1 | additional savings to the previous | 1-3% |
| Nr20 | additional savings to the previous | 2-3% |
LEGEND

A1 Offered single-slot traffic
A2 Offered multi-slot traffic expressed as single-slot erlangs.
   A multi-slot call is supposed to occupy 6 circuits.
Number of required circuits
Nsep two separate groups.
Nint integrated group dimensioned at 1% blocking for multi-slot traffic.
Nps GoS equalisation by partial sharing.
Nr1 GoS equalisation by state reservation holding time ratio 1
Nr20 GoS equalisation by state reservation holding time ratio 20

TEST NETWORKS

Three test networks have been used in the study. One is small with 12 nodes and unusually large traffic relations. Despite its size it contains a wide range of routing cases.

The large test network used for this study is a realistic representation of a fully digitalised target for the national trunk network in Sweden. It contains 234 nodes arranged in three levels. A hierarchical routing principle is applied for both services.

A scaled down version of this network has been used for extensive calculation and simulation verification purposes. This medium size network has 50 nodes and a traffic matrix of 10000 erlang single-slot traffic.

COMPUTER SYSTEM FOR NETWORK OPTIMISATION AND ANALYSIS

The computer system used for this network study is an extended version of the ordinary optimisation and dimensioning program used for planning the swedish national trunk network (VIADIM).

The VIADIM system [Lindberg ITC 11] can be used for networks with up to 1200 nodes and 16000 circuit groups. The CPU-time for a network of 800 nodes is around 30 minutes on a VAX-8600 computer. (Turn around time about 40-60 minutes).

The extended version of VIADIM is able to optimise, dimension and calculate non-hierarchical network. It takes into account origin dependent routing, and random distributed routing based on given probabilities, over several routing alternatives.

The program does not need to order the circuit groups into any calculation order. Instead it starts with a given blocking (10%) on all circuit groups and by iterations calculates the true offered traffic (mean and variance) and blocking for each circuit group. The optimisation and dimensioning is then added as an outer iteration loop based on calculated offered traffics.

The program will optimise, dimension and calculate a network with integrated nodes and circuit groups, offered a mixture of single- and multi-slot traffics. Each type of traffic is represented by its own traffic matrix and its own routing data.

When optimising and dimensioning the circuit groups the program will also dimension an individual selective state reservation parameters for each circuit group, or take into account several given reservation parameters for each circuit group. Each reservation parameter will be related to individual traffic relations or groups of traffic relations.

As result the program gives the total network costs and the size of each circuit group with its selective state reservation parameters. For each circuit group we get offered and blocked traffic (mean and variance) for each reservation parameter. For each offered traffic matrix we get a corresponding end-to-end blocking matrix.
THE NETWORK STUDY

The study compares the network design strategies dedicated networks and one traffically integrated network.

In the dedicated cases the possibility to introduce high usage circuit groups is exploited in both networks, while in the integrated network only single-slot traffic may have overflow due to algorithmic limitations.

The grade-of-service standard is set at 1% per cluster and is equal for both single- and multi-slot traffic.

The multi-slot traffic is assumed to be 2%, 10% and 50% of the single-slot traffic.

NETWORK RESULTS

<table>
<thead>
<tr>
<th>% multi slot</th>
<th>Strategies</th>
<th>Savings</th>
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<td>Dedicated</td>
<td>Integrated</td>
<td>Absolute</td>
<td>Relative</td>
</tr>
<tr>
<td>12 nodes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2.1</td>
<td>1.2</td>
<td>.9</td>
<td>43%</td>
</tr>
<tr>
<td>10</td>
<td>4.2</td>
<td>2.7</td>
<td>1.5</td>
<td>35%</td>
</tr>
<tr>
<td>50</td>
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<td>13%</td>
</tr>
<tr>
<td>50 nodes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>19.7</td>
<td>10.8</td>
<td>8.9</td>
<td>45%</td>
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<tr>
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<td>234 nodes</td>
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<td>10</td>
<td>146.6</td>
<td>106.1</td>
<td>40.5</td>
<td>28%</td>
</tr>
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</table>

These savings are entirely due to traffical integration. Additional savings are of course obtainable through the sharing of transmission capacities and control equipment. These are however not depending on the ability to simultaneously switch single- and multi-slot calls in the same circuit groups.

CONCLUSIONS

Dimensioning and optimisation methods for integration of two circuit switched services are developed. Their accuracy have been checked by extensive simulation and proves equal to similar methods used for single service networks. Calculations are fast enough to be applied to real size networks.

Comparative studies show that substantial savings may be achieved when integrating a multi-slot and a single-slot service in a circuit switched network. Problems related to imperfect grade-of-service standard formulations are observed but are not considered large enough to endanger the total result.
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