A TRAFFIC ROUTING STRATEGY
DESIGNED FOR OVERLOAD PROTECTION
DOWNWARDS THE HIERARCHY

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ABSTRACT

In a paper presented at the 5th International Teletraffic Congress named "A New Danish Traffic Routing Plan With Single Stage Alternate Routing and Consistent Use of Service Protection Finals for First Routed Traffic to Tandem Offices" it was outlined how the overload protection problem was solved in the Danish toll network. The presupposition was given that no additional devices or signalling facilities had to be added to the existing exchange equipment.

However, the maximum gain in circuit economy downwards the hierarchy was not achieved.

This paper deals with a proposal for a network structure applying a routing strategy which improves the circuit economy retaining good overload conditions downwards the hierarchy.

The proposal is based on investigations of equations for the congestion of the network.

1. INTRODUCTION

The use of alternate routing in trunk networks makes possible a heavy loading of the trunk groups. This often causes trouble as unacceptable blockings occur when the traffic load increases above the average load level. Optimization of networks is normally done by calculations based on mean values of traffic measurements or values little above the mean values, with no regard to the fact that these traffic values are a very poor description of real traffic. Networks elaborated from optimizations of that kind often show unrealistic values of the average load per circuit, and the estimate of the efficiency of the networks are too optimistic.

The development of methods for avoiding blockings in trunk networks in heavy load situations ("overload" situations) has followed two principal lines. The one is characterized by providing devices for supervision and control of the load conditions in the network. The other is characterized by arranging the routing configuration in such a way that the overload performance is given priority to the circuit economy at average load level. Methods of the former kind are described in references 1 and 2. Methods of the latter kind are described in references 3 and 4.

In the traffic routing plan dealt with in my paper to the 5th International Teletraffic Congress in New York the good overload performance of the network was obtained by applying service protection finals to tandem exchanges and by applying only one, but always one alternate route. The network was divided into "Final Systems", e.g. mutually independent sections and the circuit economy was improved by trunk provisioning rules which were especially adapted to the routing configuration applied.

2. THE PROBLEM

A study in details of the Danish traffic routing plan dealt with in New York shows that the conditions upwards the hierarchy primarily was the subject of the paper, while the conditions downwards the hierarchy only peripherally was mentioned.

During the application in practice it was found that a possible increase in circuit economy was likely. This fact was the reason why the considerations dealt with in this paper were done.

The problem will be dealt with by reference to the figures below using the following terms:

Exchanges (Central Offices): $C_1, C_2, C_3$ and $C_4$

Transit exchange (Tandem Office): $T$

Transit exchange for primary trunks (Tandem Office for High Uses): $T_p$

Transit exchange for secondary trunks (Tandem Office for Finals): $T_s$

Trunk group between $C_1$ and $C_2$: $N_{12}$

- - $T - C_3$: $N_{T3}$

- - $T_p - C_4$: $N_{Tp4}$

Congestion from origination to destination:

E.g. congestion from $C_1$ to $C_2$: $B_{C12}$
Congestion caused by a trunk group:

E.g. congestion caused by $N_{12}$

Exchange to exchange congestion prescribed:

Congestion prescribed for direct trunk groups:

Congestion caused by a final:

The simple "network" shown in fig.1 has the following equation for the congestion of the traffic from $C_1$ to $C_2$:

$$B_{C12} = B_{N12} = B \text{ (1)}$$

The equation for the congestion of the traffic from $C_1$ to $C_2$ related to the network shown in fig.2 is as follows:

$$B_{C12} = B_{N1T} + B_{NT2} - B_{N1T} B_{NT2} \text{ (2)}$$

In this case a decent assumption would be that the congestion upwards the hierarchy should be equal to the congestion downwards the hierarchy.

$$B_{N1T} = B_{NT2} = \frac{B}{2} \text{ (3)}$$

Fig.3 shows the simplest possible network applying alternate routing. The congestion values are as follows:

$$B_{C12} = B_{N12} B_{N1T} + B_{N12} B_{NT2} - B_{N12} B_{N1T} B_{NT2} = B_{d} B_{s} + B_{d} B_{s} \text{ (4)}$$

Assuming that the congestion upwards the hierarchy should be equal to the congestion downwards the hierarchy we find:

$$B_{d} = B_{d} \text{ (5)}$$

In practice direct trunk groups as $N_{12}$ do not exist between all exchanges. Fig.4 shows a network without a direct trunk group between $C_1$ and $C_3$. For service-protection reasons the trunk group $N_{1T}$ is split up into two, a "primary transit trunk group" ($N_{1TP}$) and a "secondary transit trunk group" ($N_{1TS}$). This arrangement secures that overflow from $N_{12}$ and other direct trunk groups do not completely block the route between $C_1$ and $T$ which is the only possible way for the traffic with origination $C_1$ and destination $C_3$. The

$$splitting up of N_{1T} into N_{1TP} and N_{1TS} secures that N_{1TP} is available for the traffic destined C_3 exclusively.$$
congestion $\frac{B}{2}$, even if part of the traffic might be content with the higher probability of congestion, $\frac{B}{2B_d}$. 

3. PROPOSAL FOR A NEW ROUTING STRATEGY

The fact that certain parts of the traffic meet a lower congestion than necessary indicates that a gain in circuit economy may be possible. Studying the congestion in different network configurations it will be noticed that the possible gain in circuit economy may be obtained if the traffic having access to direct trunk groups could be separated from the traffic having access to the transit routes only. Separation of the two kinds of traffic mentioned is possible if the tandem exchange T is divided into two sections as shown in fig. 5. The section of the transit exchange handling first routed traffic only is named Primary Transit-Exchange and denoted $T_p$. The section of the transit exchange handling overflow traffic only is named Secondary Transit-Exchange and denoted $T_s$.

The congestion conditions of the network shown in fig. 5 is elucidated by the following equations:

$$B_{C12} = B_{12} N_{ITs} + B_{12} N_{Ts}$$

$$B_{C13} = B_{12} Tp B_{NITs} + B_{12} Tp B_{NTs} + B_{12} Tp B_{NTs} + B_{12} Tp B_{NTs}$$

A derivation of the equations is given overleaf.

If the congestion aimed at for the kinds of trunk groups in question is as follows, it is found that the congestion through the network for all of the traffic items is $B$.

### Direct trunk groups

$B_d$

### Primary transit trunk groups

$\frac{B}{2B_d}$

### Secondary transit trunk groups

$\frac{B}{2B_d}$

These congestion values inserted in (15) and (16) yield:

$$B_{C12} = B_d \frac{B}{2B_d} + \frac{B_d B}{2B_d} = B$$

(17)

$$B_{C13} = \frac{B_d}{2} \frac{B}{2B_d} + \frac{B_d}{2} \frac{B}{2B_d} + \frac{B_d}{2} \frac{B}{2B_d} = B$$

(18)

The equations (15), (16), (17) and (18) referring to fig. 5 show that a combination of a suitable network configuration with an adequate routing strategy and a decent choice of congestion aimed at for the different kinds of trunk groups causes congestion values for the different traffic items through the network with a high degree of equality. In the network no traffic item is routed via a trunk group which is dimensioned for a congestion lower than necessary.

The network configuration with associated routing strategy described foremost is of interest in regions where the number of exchanges interconnected by direct trunk groups are relatively big and the number of exchanges interconnected by transit routes only are relatively small.

Realization of the routing strategy proposed necessitates separation of first routed traffic through the transit exchange from the overflow traffic. This can be done
either by dividing the transit exchange into two parts or by marking the trunk groups carrying first routed traffic with a mark different from a mark used for trunk groups carrying overflow traffic. In practice the latter method is to be preferred as splitting up of the transit exchange causes a very uneven loading of the section carrying overflow traffic.

The latter method causes some changes in the equations elucidating the congestion of the traffic items as the trunk $N_{TS}$ between the sections of the transit exchange does not exist. The congestion values referring to fig. 6 are as follows:

\begin{align*}
B_{C12} &= B_{N12} B_{N1TS} + B_{N12} B_{NTs2} \\
B_{C13} &= B_{N1TP} B_{N1Ts} + (B_{N1TP} + B_{NTp}) B_{NTs3}
\end{align*}

(19) (20)

The derivation of equation (20) is given overleaf. If the congestion through the network is desired to be $B$, the congestion of the trunk groups should be as follows:

Direct trunk groups $B_d$

Primary transit trunk groups

- upwards the hierarchy $\frac{B_d}{2}$
- downwards the hierarchy $\frac{B_d}{2}$

Secondary transit trunk groups $\frac{B_d}{2B_d}$

These congestion values inserted in (19) and (20) yield:

\begin{align*}
B_{C12} &= B_d \frac{B}{2B_d} + B_d \frac{B}{2B_d} = B \\
B_{C13} &= 2B_d + (\frac{B_d}{2} + B_d) \frac{B}{2B_d} = B
\end{align*}

However the splitting up of the transit exchanges can be used in cases where more regions are to be considered. In fig. 7 two regions with a network configuration as described are shown. Without disturbing the advantages of the routing strategy the transit exchange for overflow traffic may be common for more transit exchanges for first routed traffic as shown in fig. 8.

It should be noticed that the network as a whole is split up into two, one network consisting of trunk groups carrying first routed traffic, and another consisting of trunk groups carrying overflow traffic exclusively.

By the proposed network configuration and routing strategy it should be noticed that the second choice routes (which are the final routes as no further alternate choice occurs) may be dimensioned according to a relatively high congestion value. Commonly trunk groups for first routed traffic and high uses are considered identical subjects, as well as finals are considered always to be low loss trunk groups. By the routing strategy in question this is shown not to be a matter of course. As an example congestion values for the trunk groups may be chosen as follows:
Exchange to exchange congestion aimed at: \( B = 0.002 \)
Direct trunk groups congestion: \( B_d = 0.05 \)
Primary transit trunk groups congestion: \( B_p = 0.025 \)
Finals = Secondary transit trunk groups congestion: \( B_s = 0.02 \)

By the network configuration shown in fig.6, the primary trunk groups downwards the hierarchy however may be dimensioned according to \( B_d = 0.05 \).

Application of the congestion values mentioned for the finals do not mean that the number of trunks can be chosen by using the congestion value calculated by the Erlang loss formula. The \( B \)-values used must be considered as the congestion actually met in the network which is not identical to the congestion calculated by the Erlang congestion formula. The trunk provisioning of the finals is supposed to be done in accordance with the Equivalent Random Method.

By the routing strategy proposed the dimensioning of the trunk groups is assumed to be done at an equal congestion base. That means that identical values of \( B_d \) must be used for all the direct trunk groups belonging to the network. Correspondingly identical congestion values must be used for all finals belonging to the same network.

However, the advantages of the routing strategy proposed may be achieved, even if variations inside narrow intervals are allowed for the congestion values. This limitation agrees well with the fact that the service protection effect is to be achieved only if the congestion values aimed at for the different trunk groups belonging to a certain kind do not differ too much.

Derivation of equations (referring to fig.5).

**Traffic offered**

<table>
<thead>
<tr>
<th>Offered to</th>
<th>Traffic load</th>
</tr>
</thead>
<tbody>
<tr>
<td>( A_{12} )</td>
<td>( A_{12} )</td>
</tr>
<tr>
<td>( A_{12} )</td>
<td>( (1-B_{N12}) )</td>
</tr>
<tr>
<td>( A_{12} )</td>
<td>( (1-B_{N12}) )</td>
</tr>
<tr>
<td>( A_{12} )</td>
<td>( N_{Ts} )</td>
</tr>
<tr>
<td>( A_{12} )</td>
<td>( B_{N12} )</td>
</tr>
<tr>
<td>( A_{12} )</td>
<td>( (1-B_{TTp3}) )</td>
</tr>
<tr>
<td>( A_{12} )</td>
<td>( (1-B_{TTp3}) )</td>
</tr>
<tr>
<td>( A_{12} )</td>
<td>( (1-B_{TTp3}) )</td>
</tr>
</tbody>
</table>

**Total traffic rejected from \( C_1 \) to \( C_2 \):**

\[ A_{12} B_{N12} = A_{12} B_{N12} (1-B_{N12}) + A_{12} B_{N12} (1-B_{N12}) B_{NTs} \]

As \( B_{N12} B_{N12} B_{NTs} < B_{N12} B_{NTs} \) the following approximation is done:

\[ A_{12} B_{N12} B_{N12} + B_{N12} B_{NTs} \approx A_{12} B_{N12} B_{N12} + B_{N12} B_{NTs} \]

This yields: \( B_{N12} \approx B_{N12} \)

**Conclusion**

By the network configuration and the routing strategy proposed an improvement in circuit economy is achieved by retaining good overload conditions downwards the hierarchy. Besides it is shown that the possibility of designing networks having characteristics useful for certain purposes by far is emptied.

**References**

Derivation of equation (20) (referring to fig.6).

<table>
<thead>
<tr>
<th>Traffic offered</th>
<th>Offered to</th>
<th>Traffic load</th>
<th>Proceeded to</th>
<th>Traffic rejected (underlined) or overflow-traffic</th>
<th>Overflowing to</th>
</tr>
</thead>
<tbody>
<tr>
<td>( A_{13} )</td>
<td>( N_{1Tp} )</td>
<td>( A_{13}(1-B_{N1Tp}) )</td>
<td>( N_{1Tp} )</td>
<td>( A_{13} B_{N1Tp} )</td>
<td>( N_{1Tt} )</td>
</tr>
<tr>
<td>( A_{13} N_{1Tt} )</td>
<td>( N_{1Tt} )</td>
<td>( A_{13} B_{N1Tt}(1-B_{N1Tt}) )</td>
<td>( N_{1Tt} )</td>
<td>( A_{13} B_{N1Tt} )</td>
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<tr>
<td>( A_{13}(1-B_{N1Tp}) )</td>
<td>( N_{1Tt} )</td>
<td>( A_{13}(1-B_{N1Tp})(1-B_{N1Tp}) )</td>
<td>( N_{1Tt} )</td>
<td>( A_{13} B_{N1Tt} )</td>
<td>( N_{1Tt} )</td>
</tr>
<tr>
<td>( A_{13}(1-B_{N1Tp})N_{Tp3} )</td>
<td>( N_{Tt} )</td>
<td>( A_{13}(1-B_{N1Tp})(1-B_{N1Tp})N_{Tt} )</td>
<td>( N_{Tt} )</td>
<td>( A_{13} B_{N1Tt} )</td>
<td>( N_{Tt} )</td>
</tr>
<tr>
<td>( A_{13} B_{N1Tt}(1-B_{N1Tt}) )</td>
<td>( N_{Tt} )</td>
<td>( A_{13} B_{N1Tt}(1-B_{N1Tt})(1-B_{N1Ts}) )</td>
<td>( N_{Tt} )</td>
<td>( A_{13} B_{N1Tt} )</td>
<td>( N_{Tt} )</td>
</tr>
</tbody>
</table>

Ignoring all products of 3 or more \( B \)-values, the approximated equation is as follows:

\[
P_{C13} = A_{13} B_{N1Tt} R_{N1Ts} + A_{13} (1-B_{N1Tt})N_{Tt} + A_{13} B_{N1Tt} (1-B_{N1Ts})N_{Tt} \tag{20}
\]