DIMENSIONING OF TRUNK NETWORKS
ACCORDING TO A UNIFORM OVERLOAD CAPACITY CRITERION
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ABSTRACT

The paper deals with the problem of avoiding unacceptable blockings in trunk networks with alternative routing in situations with traffic load above the normal busy hour level, ("overload situations). In the Danish trunk network two measures are taken to avoid troubles from overloads in the trunk network:

1. Abandoning of multi alternative routing in favor of a single stage alternative routing principle.
2. Application of service-protection trunk groups for first routed traffic to transit exchanges.

After the introduction of these measures it was natural to study the two problems which are the subject of this paper:

1. Dimensioning of service-protection trunk groups for first routed traffic to transit exchanges.
2. Optimization of trunk networks in which service-protection trunk groups for first routed traffic are applied.

The investigations indicated that the overload capacity of the network may be unacceptable if the dimensioning of service-protection trunk groups is done according to the traditional "optimization" method, comparing the cost of the first choice route with the cost of the alternative route.

The investigation further indicated that the use of individual values of the "economic load on the last trunk" for direct first choice routes to networks, which doubtfully could be characterized as optimum because the individual traffic items meet different congestion, i.e. the network has different quality regarding traffic offered to different destinations.

1. INTRODUCTION

Several papers have in the course of time dealt with the problem that the individual items of the traffic meet different congestion in the network.

I.TANGE deals with this problem in an article in TELE no.1, 1957: "Optimum Methods for Determining Routes and Numbers of Lines in a Telephone Network With Alternative Traffic Facilities" (Ref.1). In the article it is proposed to apply a number of individual trunks for the traffic which is to be routed directly to the transit exchange.

In a paper to the 4th International Teletraffic Congress in London: "Simplified Engineering of Single-Stage Alternate Routing Systems" (Ref.2), R.J.WILKINSON mentions the so called "service protection finals for first-routed traffic to tandem offices". The purpose obviously is to reduce the congestion for the traffic, which is not offered primarily to a direct "high-usage" group.

WEBER mentions in a paper to the 4th International Teletraffic Congress in London titled "Some Aspects of Routing and Control in Communication Networks" (Ref.3), a measure called "trunk reservation" which reminds of the measures mentioned in the two previously mentioned papers.

In the traffic routing plan which I dealt with in my paper to the 5th International Teletraffic Congress in New York (Ref.4), service-protection-finals for first routed traffic to tandem offices was recommended to be used consistently to reduce blockings in overload situations.

In an article in NTZ-Communication Journal, Nov.1968: "Problems of Traffic Theory in the Design of International Direct Distance Dialling Networks" (Ref.5) A.LOTZE draws the attention to the importance of the overload problems in networks with alternative Routing.

2. DESCRIPTION OF SERVICE PROTECTION TRUNK GROUPS FOR FIRST ROUTED TRAFFIC TO TRANSIT EXCHANGES

The use of service-protection trunk groups for first routed traffic to transit exchanges has as purpose to reserve a number of trunks to the transit exchange for traffic which is not primarily offered to a direct "high usage" group (Fig.1). The purpose is achieved by dividing the trunks to the transit exchange into two groups. To the first group, the service-protection group, traffic is offered to destinations which can be reached from the transit exchange exclusively.

![Fig.1](attachment:image)
To the final trunk group overflow traffic is routed from the direct high usage groups as well as from the service protection group.

By this arrangement the overflow traffic from the high usage groups cannot completely quell the transit traffic by occupying all the trunks to the transit exchange.

3. DIMENSIONING OF SERVICE-PROTECTION TRUNK GROUPS

The application of service-protection trunk groups to transit exchanges raises a dimensioning problem.

As the service-protection trunks pass exact the same distance as the trunks in the final, the cost per circuit in both of the two trunk groups is the same.

If an isolated system consisting of a service-protection trunk group with overflow to a final trunk group (Fig.2) is considered, it is easy to realize that the cost ratio 1/f does not render any direction how to divide the number of trunks to the transit exchange between the two trunk groups.

If a system consists of a number of direct high usage groups and a service-protection group with overflow to the same final (Fig.3), a formal calculation can be carried out to determine the number of trunks in the service-protection group. This calculation is not a real optimization even if it is done just as the optimization calculations for determining the number of trunks in the direct high usage groups.

The calculation method referred to is the very well known traditional calculation where the cost of routing by a direct route is compared with the cost of routing by the alternative route.

4. TRADITIONAL OPTIMIZATION

By the traditional optimization method the calculation is based on a known or assumed value of the marginal capacity, a, for the final route by adding one trunk. Further the cost ratio, f, of the direct route versus the alternative route is to be considered by the calculation. It is economical to provide N trunks in the direct high usage group if the load, F, on the last trunk is larger or equal to a·f erlangs.

\[ F = a \cdot f \] erlangs

If as an example \( a = 0.8 \) and \( f = 1/2 \) it is found that \( F = 0.8 \cdot 1/2 = 0.4 \) erlangs.

If a corresponding calculation is carried out for the service-protection group it is obvious that \( f = 1/1 \). It is then found that

\[ F = 0.8 \cdot 1/1 = 0.8 \] erlangs.

As seen in the example a formal "optimization" calculation with the purpose to determine the number of trunks in service-protection groups normally gives values of "the economic load on the last trunk" which are considerable larger than the values found for the direct high usage groups.

When the differences in the values of "the economic load on the last trunk" is large for trunk groups with traffic that overflows to the same final group, then the differences in congestion of the traffic offered to the trunk groups will be large too. This is illustrated by the examples shown in Fig.4 and Fig.5.

In Fig.4 is shown a simple trunk network with an offered traffic load corresponding to the normal traffic level (busy season, average busy hour load).

In Fig.5 is shown the same network with a traffic load corresponding to a high day traffic load which in this case is assumed to be 25 % above the normal traffic level.

The example in Fig.4 shows that the congestion of the individual traffic items spreads from 0.2 % to 4.8 %, the average being 1.2 %.

The example in Fig.5 shows that the congestion of the individual traffic items at this high traffic level spreads from 1.0 % to 28 %, whereas the average congestion is about 9.5 %.

Congestion of 28 % is to be considered unacceptable and it must be noticed that the purpose of the service-protection is not achieved by the dimensioning method applied.

Generally it must be noticed that the service-protection effect is the less effective the higher the value of "the economic load of the last trunk".

5. THE EFFECT OF INDIVIDUAL OPTIMIZATION OF DIRECT HIGH USAGE TRUNK GROUPS

It is not only by comparing traffic on direct high usage groups with traffic on service-protection groups that differences in congestion are found. Among direct high usage groups mutual differences in congestion also occur for traffic offered to the individual trunk groups.

The effect in practice of these differences will depend on several factors, but it is evident that the risk exists that traffic offered to high usage groups which are dimensioned according to high cost ratios also meet high congestion at the same time as traffic offered to other high usage groups, which are dimensioned according to lower cost ratios, meet congestion, which is considerably lower than necessary.

When congestion lower than necessary occurs, it must be realized that an unnoticed reserve in the network may exist.

Therefore the spread in congestion of the individual traffic items, especially at high day traffic levels must be taken into consideration by judging if the network is optimum.
### Originating exchange

<table>
<thead>
<tr>
<th>Trunk Group</th>
<th>Number of Trunks</th>
<th>Erlangs</th>
</tr>
</thead>
<tbody>
<tr>
<td>High usage</td>
<td>27</td>
<td>19.46</td>
</tr>
<tr>
<td>Service-protection</td>
<td>5</td>
<td>18.30</td>
</tr>
<tr>
<td>Transit exchange</td>
<td>5</td>
<td>4.76</td>
</tr>
</tbody>
</table>

### Traffic Distribution

- **Traffic offered**: 25.0 Erlangs
- **Traffic carried to destination**: 11.0 Erlangs
- **Overflow**: 11.0 Erlangs

### Loss Calculation

- **Loss from final**: 0.04 Erlangs
- **Loss from transit exchange**: 0.67 Erlangs
- **Loss from service protection group**: 1.75 Erlangs

### Service-protection group

- **Traffic offered**: 4.50 Erlangs
- **Traffic carried to destination**: 4.50 Erlangs

### Diagram

- **High usage trunk group**: 27 trunks, 19.46 Erlangs
- **Service-protection group**: 5 trunks, 18.30 Erlangs
- **Transit exchange**: 4.76 Erlangs

### Traffic Calculation

- **Traffic offered**: 25.0 Erlangs
- **Traffic carried to destination**: 11.0 Erlangs
- **Overflow**: 11.0 Erlangs

### Loss

- **Average loss**: 1.2%

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**In fig. 4 it is assumed that the marginal capacity of the final trunk group is 0.8 Erlangs. It is further assumed that the service criterion is given as a claim of a maximum of 1% loss from an originating exchange to the transit exchange, and also 1% loss from the transit exchange to a destination exchange.**

The calculation of overflow and loss are carried out by "The Equivalent Random Method" (Ref.6). It is assumed that the individual overflow parcels meet the same congestion at the final.

At the high traffic level dealt with in fig. 5 the congestion of the trunk groups from the transit exchange to the destination exchange must be supposed, as the sizes and loads of these trunk groups are not known. A value of 7% is assumed as realistic.
A close examination of fig. 5 shows that the traffic offered to a service-protection trunk group meets a total congestion which is further increased in comparison with the total congestion of the traffic offered to the direct high usage groups. The cause for this is that all the traffic which is offered to a service-protection group is routed by the trunk groups between the transit exchange and the destination exchanges, whereas only part of the traffic which is offered to a direct high-usage group is routed by the trunk groups between the transit exchange and the destination exchanges.

If the transit traffic is routed by a number of trunk groups in series for example in a connection via a number of transit exchanges, this effect is increased. Therefore it is often the important far-distance traffic which is in danger of meeting unacceptable blockings if effective service-protection measures are not taken.

6. INFLUENCE OF THE NETWORK STRUCTURE

In practice the importance of the spread in congestion for the high usage groups is dependent of the network structure.

In alternative routing networks with well equipped "back-bones" (Fig. 6) the disadvantages mentioned scarcely have much importance. The comparison with the severe in networks with many large direct trunk groups and a relatively small amount of first routed traffic to the back-bone network (Fig. 7).

In the network shown in Fig. 6 the overflow traffic is relatively small and the dimensioning of the back-bone network in reality solely determines the quality of the network. When a saving is achieved by the establishment of high usage groups it is tolerated that the congestion of the first routed traffic on the back-bone network increases imperceptibly.

In the course of time however it occurs as a rule that the number of direct trunk groups increases. Besides the size of the direct trunk groups grows. Hence the first routed traffic to the transit exchanges are relatively reduced compared with the overflow traffic. When this development has reached a certain extent, the risk arises that the first routed traffic will be completely quelled by overflow traffic, which occupies all the final trunks. This likely occurs at high traffic days and the need of service-protection measures arises.

Therefore it is chiefly in trunk networks with many large direct high usage groups and a relatively small amount of first routed traffic to the transit exchange that the use of the individual optimization method is doubtful.

The problem pointed out can also be illustrated as follows:

The individual optimization calculation for each direct trunk group causes a spread in the congestion of traffic to different destinations, i.e. a spread in quality.

On the contrary the demand for equal quality for traffic to any destination causes a spread in cost for the direct trunk groups.

7. DIMENSIONING ACCORDING TO UNIFORM OVERLOAD CAPACITY

It is in the busy hour on the high traffic days the demands to the functioning of the network is severe. First and foremost the demands to a public trunk network is that the network equipment can handle the traffic at high traffic days, so that no break-downs occur.

If it is for certain that the technical function of the network on high traffic days is in order the next demand must be that the congestion which the subscribers experience on high traffic days can be tolerated. On the other hand the congestion should for economic reasons be as high as the subscribers can tolerate.

There is no reason for the supposition that the subscribers will be more troubled by congestion of calls to certain destinations in preference to others.

This leads to the idea that a real optimization of a trunk network as starting point must adopt a claim of an uniform overload capacity for the individual traffic items to various destinations.

Dimensioning of trunk networks according to an uniform overload capacity criterion may be based on the following presuppositions:

1. The grade of service should be defined as the congestion of traffic offered at a fixed high traffic level corresponding to a high day busy hour level.

2. The dimensioning of high usage groups should be done in such a way that the congestion of traffic to all destinations is the same by the same defined high day traffic level at which the grade of service is defined.

3. Service-protection trunk groups to transit exchanges should be dimensioned according to a congestion which is half of the congestion according to which the high usage groups are dimensioned (at the high day traffic level).

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Alternative routing network with a strong back-bone network and a few high usage trunk groups.

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These presuppositions however do not give sufficient guidance for determination of the number of trunks among high usage groups, service-protection groups and final trunk groups. An additional assumption is necessary to determine the traffic load on the high usage groups and on the service-protection groups.

This additional presupposition can be achieved by carrying out a calculation just like the individual optimization calculations by using the average of costs for a number of high usages and the average of costs for a number of alternative routes.

A trunk network dimensioned in this way is optimum in the meaning that the quality of traffic to all destinations will be almost equal under the circumstances that make the most severe demands to the network.

Finally an example of dimensioning a trunk network according to the principles of uniform overload shall be given.

A high day traffic level is defined in such a way that the busy hour traffic offered is 25 % above the busy season average busy hour level.

The network shown in Fig.9 is dimensioned so that the overflow from the high usages is 20 % at the high day traffic level. (This corresponds approximately to a cost ratio of 1/3). The overflow from the service-protection groups is 10 % at the high day traffic level.

A final loss of 7 % as a maximum between originating exchanges and the transit exchange on the one hand and the transit exchange and the destination exchanges on the other hand is aimed at.

After the dimensioning is carried out with figures corresponding to the high day traffic level, the loadings and the losses by the normal traffic level can be calculated. The results are shown in Fig.8.

By comparing Fig.8 with Fig.4, and Fig.9 with Fig.5 it should be noticed that the spread in congestion of the individual traffic items especially at the high day traffic level is essentially reduced.

For example the congestion of the traffic from the destination to one of the exchanges, to which no direct high usage groups exist, is reduced from 4.8 % to 1.4 % at the normal traffic level but from 28 % to 11 % at the defined high day traffic level.

CONCLUSION

Many conditions influence the overload capacity of a trunk network. For instance the switching equipment is of importance. Besides the practice of trunk provisioning is of importance. It is often the case that a trunk network is provided with a reserve with the purpose to avoid too frequently work at each trunk group, so that the number of trunks in service is considerably larger than according to the dimensioning rules.

On the contrary some trunk groups may be under-supplied with trunks.

Therefore it is very difficult to specify how much the disadvantages of using individual optimisations means in practice.

It seems however clear that extreme high loads of service-protection groups as well as of direct high usage groups are unfavourable. The knowledge to the fact that individual optimisations may cause essential spread in congestion for traffic to different destinations indicates that perhaps it is better to use dimensioning rules based on a uniform overload capacity criterion, if the service-protection purpose should be achieved.
**Traffic offered Erlangs**

Originating exchange

<table>
<thead>
<tr>
<th>Traffic offered to final to dest. from T</th>
<th>4.85</th>
<th>2.79</th>
<th>2.59</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.17</td>
<td>1.25</td>
<td>1.16</td>
<td></td>
</tr>
<tr>
<td>4.85</td>
<td>2.79</td>
<td>2.59</td>
<td></td>
</tr>
<tr>
<td>1.26</td>
<td>0.73</td>
<td>0.56</td>
<td></td>
</tr>
<tr>
<td><em>(11.24x)</em></td>
<td>11.97</td>
<td>5.56</td>
<td>5.56</td>
</tr>
</tbody>
</table>

Loss from final: 5.57

Traffic offered to dest. from T: 11.24

Traffic carried to dest. from T: 2.79

Average loss: 5.2%

**Destination exchanges**

- High usage trunk group, number of trunks: 23
  - 20.15 Erl. Loss: 2.26 Erl. 9%
    - 2.52 22.74
- High usage trunk group, number of trunks: 13
  - 10.33 Erl. Loss: 1.01 Erl. 8%
    - 1.16 11.49
- High usage trunk group, number of trunks: 23
  - 20.15 Erl. Loss: 2.26 Erl. 9%
    - 2.52 22.74
- Service-protection trunk group, number of trunks: 15
  - 5.56 Erl. Loss: 0.69 Erl. 11%
    - 1.16 11.49

**Traffic carried to dest. from T**

- 2.79
- 1.25
- 5.98

**Traffic offered to final to dest. from T**

- 5.56

**REFERENCES**


**Fig.9**

Network dimensioned according to an uniform overload capacity. High day traffic level.