SERVICE PROTECTION FOR DIRECT FINAL TRAFFIC IN DDD-NETWORKS

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ABSTRACT

In this paper the following three principles for service protection in the final route of alternate routing systems are discussed:
- the priority reservation system
- the use of a separate high usage route for the direct final traffic in the final route
- the use of a separate overflow route for the direct final traffic in the final route.

These principles are compared with regard to the resulting probabilities of loss for traffic with overflow possibility or for direct final traffic, resp., and with regard to the overload capability in the case of cable breakdown or overload of a high usage route.

1. INTRODUCTION

In hierarchical direct distance dialling (DDD) networks with alternate routing, the final routes carry traffic overflowing from high usage routes as well as "final traffic", which can use the final route only (see Fig. 1, final route "upwards the hierarchy" from TS1 to TP1).

The overall probability of loss of those calls, which can be alternately routed, may be considerably smaller than the probability of loss of the final traffic.

To final trunkgroups "downwards the hierarchy" (see Fig. 1 from TS2 to L2) usually traffic is offered, which flows via high usage routes and furthermore traffic, which uses the final route up and down the hierarchy only. In this case the smoothed traffic from a high usage route and the traffic of the final route have the same trunkgroup from TS2 to L2 downwards the hierarchy. The probability of loss for smoothed traffic is smaller than for random traffic or for peaked traffic.

Therefore the difference of the overall probability of loss between calls with or without overflow possibility, resp., is further increased.

Moreover calls, which have to use the final route exclusively are switched via a number of trunkgroups in tandem, which is greater than that, which calls, switched via high usage routes, have to use.

The above mentioned facts can cause considerably different values for the point-to-point probability of loss in the network.

In the case of overload or of a breakdown of a high usage route, in particular the probability of loss of the final traffic, which has no overflow possibility, will increase considerably and can be a multiple of the engineered value.

This problem is well known and discussed in many publications, e.g. 1, 2, 3, 7, 13. Two principles to enhance the overload capability and to reduce the


413/1 ITC 7
differences of the point-to-point probability of calls at engineered load throughout the network, as suggested in these publications.

Nevertheless for complex network structures in practice it will be impossible to realize strictly equal point-to-point probabilities of loss. Thus, dimensioning rules have to be applied, which guarantee a certain prescribed minimum grade of service for the final traffic, i.e. for this traffic, which will have the greatest overall probability of loss. Methods for the dimensioning of networks with alternate routing are described in e.g. [6,9,10,11,12,15].

In this paper basic investigations on the two published principles of service protection [1,2,4,7] and a third new principle are performed with regard to the resulting probability of loss of final traffic or of traffic with overload possibility, respectively, as well as to the overload capability of a DDD network in case of cable breakdown or high usage route overload.

2. THE PRINCIPLES OF SERVICE PROTECTION

2.1 The priority reservation system (PRS) /8,13/

Preferential service to the final traffic is given for a high-priority service requests from overfloeing calls when more than a specified number \( n_3 \) of trunks in the final route are busy. Requests from calls of the final traffic are served as long as there are any idle trunks.

A call, overflowing from a high usage route, arriving in the state \( x_3 \) trunk busy of the final route with \( n_3 \) trunks, is lost, if \( n_3 \neq x_3 \neq n_3 \).

The number of trunks \( n_3 \) can be chosen such, that the overall probability of loss for the considered overflowing and final traffic is nearly equalized.

2.2 Service protection by the use of a separate high usage route for the final traffic /1,2,7/ (SPH)

In Fig. 2a an arrangement is shown, where the final route upwards the hierarchy is split into a separate high usage route for the final traffic with \( n_2 \) trunks and a common final route for all overflowing traffic with \( n_1 \) trunks. The \( n_2 \) trunks are only available for the final traffic.

The traffic overflowing from the \( n_1 \) trunks is now restricted to the common \( n_2 \) trunks. Therefore the probability of loss \( B_1 \) of the overflowing traffic increases and \( B_1 \) of the final traffic decreases - compared with the probability of loss of a system without service protection (Fig. 3a).

2.3 Service protection by the use of a separate overflow route for the final traffic /5,6/ (SPO)

In Fig. 2b an arrangement is shown, where the final route now is split into a common final route with \( n_2 \) trunks and a separate overflow route with \( n_2 \) trunks. The overflow route is reserved for final calls only, which cannot be handled by the common final route. As this overflow route is exclusively available for the overflowing calls of the final traffic, \( B_2 \) decreases and \( B_1 \) increases compared with the probabilities of loss \( B_2 \) and \( B_1 \) in a system without service protection (Fig. 3a).

3. THE CALCULATION OF THE PROBABILITIES OF LOSS

Explicit solutions for the probabilities of loss for a given configuration \( n_1, n_2 \) and for given offered random traffic \( A_{1U} \) and \( A_{2U} \) do not exist for none of the three principles.

Fig. 2a,b The service protection principles SPH and SPO in the final route

Fig. 3a,b The two simplified structures investigated in the paper

In the case of SPH and SPO an explicit solution could be achieved by solving a three-dimensional difference equation with non-constant coefficients.

This problem has not yet been solved even in the case with \( n_1 = 0 \), where the difference equation is only two-dimensional.

For the PRS exists an explicit solution only for the probabilities of loss if \( n_1 = 0 \). In the case with \( n_1 \neq 0 \) a two-dimensional difference equation with non-constant coefficients has to be solved.

An explicit solution, if ever obtained, would be, as usually, not suitable for practical computations.

To compare nevertheless the efficiency of the three principles, the probabilities of loss have been computed numerically by solving a set of linear equations. The number of unknowns are \( (n_1 + 1) \cdot (n_2 + 1) \cdot (n_2 + 1) \) for the principle SPH and SPO and \( (n_1 + 1) \cdot (n_2 + 1) \) for the principle PRS.

Systems with trunkgroups consisting of up to 30..40 trunks can easily be calculated on a medium size computer.

For practical dimensioning of the systems SPH and SPO also approximate calculation methods, especially the "Equivalent Random Traffic" method /3,14/ can be applied.

However, in order to compare the efficiency of the three service protection principles, an exact calculation has been preferred. As the characteristic grade of service values of the three principles do not differ remarkably, approximate calculations could lead to insufficient results.
4. THE COMPARISON OF THE THREE PRINCIPLES

4.1 Application in the final route "upwards the hierarchy"

4.1.1 The comparison with regard to the maximum carried load for given total number of trunks

If overflows in traffic and final traffic hunt the same final route in an alternate routing network, the traffic with overflow possibility has a considerably lower overall loss than the final traffic. To balance the losses, service protection principles may be applied.

Now the problem arises, which principle should be preferred.

In Fig. 1 an example is studied. The number of trunks in the final route and the offered traffic $A_{u2}$ are fixed parameters $(A_{u1} = 21, A_{u2} = 5, n_1 = 20, n_2 = 18)$. The trunkgroups are dimensioned according to a probability of loss $B_{u2} = 1/4$ for the final offered traffic.

The diagram shows the dependency of the probability of loss $B_{u1}$ as a function of $B_{u2}$, which is obtained when the number $n_{21}$ of trunks in the final route, only available for the final traffic, is increased trunk by trunk, beginning with $n_{21} = 0$.

In the same way $n_{21}$ is reduced, thus $n_{21} = n_{21}'/n_{21}$ remaining constant (as the number of trunks are integer values, only the marked points on the curves mean realizable structures).

It is evident that the principle, which results in the lowest curve, will be the most efficient. For a demanded loss $B_{u2}$ of the offered final traffic $A_{u2}$, this principle yields the lowest total loss $B_{u1}$ for the alternately routed traffic $A_{u1}$.

If, for example, we demand a probability of loss $B_{u2} = 0.4$ for the final traffic, we can realize this in the following way:

<table>
<thead>
<tr>
<th>Principle</th>
<th>$B_{u1}$/%</th>
<th>$B_{u2}$/%</th>
<th>$n_{21}$</th>
<th>$n_{22}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRS</td>
<td>0.88</td>
<td>0.43</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>A_{u1} = 21</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A_{u2} = 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPH</td>
<td>1.58</td>
<td>0.36</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>n_{1} = 20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n_{21} = 16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPO</td>
<td>1.09</td>
<td>0.36</td>
<td>16</td>
<td>2</td>
</tr>
</tbody>
</table>

It is plausible that this principle provides the lowest overall probability of loss, where the common trunkgroup with $n_{21}$ trunks of the final route has the maximum number of trunks. It can be shown, that for a prescribed $B_{u2}$ generally holds: $n_{21}^{(SPH)} < n_{21}^{(SPO)} < n_{21}^{(PRS)}$.

For this reason the PRS should be preferred, if a maximum of carried traffic is prescribed. A certain disadvantage in the additional equipment to count the momentarily established calls in the final route and to control the acceptance of overflooding calls.

The SPO principle yields probabilities of loss, which are only slightly higher than those of the PRS.

The probabilities of loss of the SPH, however, are noticeably higher. But both principles SPO and SPH do not need additional equipments for control.

These characteristic properties of the three principles have been shown in many other examples, too, which are not presented here.

4.1.2 The comparison of the three principles with regard to a saving of trunks in the final route

In the diagram Fig. 1 the common point of all curves on the right represents the two values for $A_{u1} = 21, A_{u2} = 5, n_{21} = 20$. $B_{u1}$/% $B_{u2}$/% $n_{21}$ $n_{22}$ $n_{23}$

<table>
<thead>
<tr>
<th>Principle</th>
<th>$B_{u1}$/%</th>
<th>$B_{u2}$/%</th>
<th>$n_{21}$</th>
<th>$n_{22}$</th>
<th>$n_{23}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRS</td>
<td>1.26</td>
<td>0.66</td>
<td>16</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>SPH</td>
<td>1.20</td>
<td>1.03</td>
<td>12</td>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td>SPO</td>
<td>1.09</td>
<td>0.97</td>
<td>16</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>No s. prot.</td>
<td>0.76</td>
<td>1.68</td>
<td>17</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td>No s. prot.</td>
<td>0.52</td>
<td>1.05</td>
<td>18</td>
<td>0</td>
<td>18</td>
</tr>
</tbody>
</table>

413/3
In the case of PRS with one trunk reserved for the f-sal traffic, in this example the probability of \( f \geq B_{1u} \) is already considerably greater than 1%, the probability of loss \( B_{2u} \) obviously smaller than 1%.

The use of SPO yields in this example a good balance of the probabilities of loss \( B_{1u} \) and \( B_{2u} \), which both hold moreover the demanded value of \( \approx 1\% \).

SPH yields \( B_{1u} = 1.2\% \), which is already greater than 1%.

As for all three principles \( B_{1u} \) or \( B_{2u} \) already slightly exceed 1% in this example, a reduction of one trunk only (reduction of about 5%) in the final route is possible. But it will be shown in the next section that the more important advantage of the use of service protection will be an enhanced overload capability.

4.1.3 The comparison of the three principles with regard to the overload capability

In the diagrams Fig. 5a,b the probabilities of loss \( B_{1u} \) and \( B_{2u} \) are shown for the case of a failure of \( f = 1, 2, \ldots, n_1 \) trunks of the high usage route, that means, the number of trunks in the high usage route is reduced trunk by trunk. The number of trunks, which are reserved for the final traffic \( f \), the final route is fixed for each principle and chosen according to the example in section 4.1.1. The common \( n_1 \) trunks in this example have been dimensioned such that the engineered loss \( B_{2u} = 1\% \) is obtained.

The diagrams Fig. 6a,b show the same example, but now \( n_1 \) is a fixed parameter. The probabilities of loss are shown as a function of the traffic \( A_{1u} \) offered to the high usage route with \( n_1 \) trunks.

These diagrams demonstrate the overload behaviour of a system without service protection or with one of the three protection principles, resp. The typical behaviour of the probabilities of loss is the same one in the case with failures of trunks as in the case of overload.

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Fig. 5a The probability of loss \( B_{1u} \) as a function of the faulty trunks \( f \) in the high usage route.
\( (A_{1u} = 21, A_{2u} = 5, n_1 = 20, n_{2u} = 18) \)

Fig. 5b The probability of loss \( B_{2u} \) as a function of the faulty trunks \( f \) in the high usage route.
\( (A_{1u} = 21, A_{2u} = 5, n_1 = 20, n_{2u} = 18) \)

Fig. 6a The probability of loss \( B_{1u} \) as a function of the traffic \( A_{1u} \) offered to the high usage route.
\( (A_{2u} = 5, n_1 = 20, n_{2u} = 18) \)

The diagrams 6a,b show that none of the three principles can avoid the significant growth of the probabilities of loss, especially of \( B_{1u} \), if \( A_{1u} \) exceeds the engineered value. If e.g. \( A_{1u} \) increases from 21 to 25 Erl (19 %) the probabilities of loss \( B_{1u} \) and \( B_{2u} \) rise at 400 %.

In the case of heavy overload, however, the probability of loss \( B_{2u} \) for the final traffic can be reduced remarkably by using service protection.
The SPH principle, however, leads in the case of overload or faulty trunks within one of the separate trunk groups $n_1$ or $n_2$, to the highest increase of loss for that traffic which causes the overload.

If the common final route has a breakdown, the maximum probability of loss of both traffic $A_{1u}$ and $A_{2u}$ is restricted to their overflow probability.

Provided that there is no breakdown of the final route, the FRP and above all the SPO principle (because of its simple realisation) seem to be the best means for service protection of the final traffic in the final route upwards the hierarchy.

4.2 Application in the final route downwards the hierarchy (Fig. 3b)

To the final route downwards the hierarchy traffic is offered from calls, which could use the final route only, as well as traffic from calls, which are switched via a high usage route (see Fig. 1 e.g. traffic offered to the trunkgroup from T2 to L2). The traffic carried by a high usage route is smoothed, whereas under engineered load conditions the traffic $A_{2p}$ offered to the next section of the final route is peaked. This is the reason why the offered traffic $A_{2p}$ has a higher probability of loss than the traffic $A_{2u}$ offered via the high usage route.

Analogously to Fig. 4 the probability of loss $B_{1p}$ as a function of $B_{2p}$ is depicted in Fig. 7. As parameter on the curves for the service protection principles FRP, SPO and SPH one finds the number of individual trunks $n_2$ for the final traffic ($A_{1u} = 10, A_{2u} = 2, n_1 = 11, n_2 n_2 + n_2 = 15$).

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**Fig. 6b** The probability of loss $B_{2u}$ as a function of the traffic $A_{1u}$ offered to the high usage route.

$A_{2u} = 5, n_1 = 20, n_2u = 18$

principles, whereas the probability of loss $B_{1u}$ is only slightly influenced.

For example, if $A_{1u}$ grows from 21 to 45 in the application of FRP reduces $B_{2u}$ from 40 to 10%, whereas $B_{1u}$ increases from 27 to 32% only.

As a criterion for the overload capability the boundary value of the probability of loss $B_{2u}$ can be chosen. For FRP and SPO we get evidently

$$B_{2u}\text{op} = E_{1,n_22}(A_{2p})$$

because the common used final route is occupied at any time by calls of the offered traffic $A_{2u}$.

In our example in section 4.1.1 we get

$$B_{2u}\text{op}(\text{FRP}) = E_{1,8}(5) = 0.07$$

and

$$B_{2u}\text{op}(\text{SPO}) = E_{1,7}(5) = 0.07$$

In the case of FRP we obtain according to /4/:

$$B_{2u}\text{op}(\text{FRP}) = \frac{n_{2u}(n_{2u}-1)...(n_{2u}-i+1)}{1}$$

$$B_{2u}\text{op}(\text{FRP}) = \frac{n_{2u}A_{2u}n_{2u}-1}{1}$$

In our example with $n_{2u} = 18$ and $n_{22} = 17$ we get for the FRP:

$$B_{2u} = 0.217$$

The FRP, which provides the lowest probabilities of loss at engineered load (see Fig. 4), provides also a good protection of the final traffic in the case of overload.

On the other hand a dimensioning of the final route could be prescribed, which yields uniform probabilities of loss $B_{2u}$ and $B_{1u}$ for a probability of loss $B_{2u}$ slightly smaller than $B_{1u}$ not only at engineered traffic loads but also in the case of overload. This aim could be achieved much better with the SPO principle.

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**Fig. 7** The probability of loss $B_{1p}$ as a function of $B_{2p}$ for the principles FRP, SPO and SPH. Parameter is the number of trunks $n_2$, available for the final traffic only (application downwards the hierarchy).

A call of the traffic $A_{1u}$ offered to the high usage route must find an idle trunk as well in the high usage route as in the succeeding final route downwards the hierarchy. So the number of available trunks for the offered traffic $A_{1u}$ cannot be chosen smaller than $n_2$.

On the other hand, in the final route only a maximum of $n_2$ trunks can be occupied by calls of the offered traffic $A_{1u}$. Therefore $n_2 - n_2$ trunks in the final route are already "reserved" for calls of the offered traffic $A_{2p}$ without any service protection means.


5. CONCLUSION

...ree principles FSS, SPH and SPO for service protection in the initial route of an hierarchival DDD network with alternate routing have been discussed. It was shown that the application of these principles upwards increases the hierarchy between the common network configuration as well as service protection for the final traffic of the case of overload of a high usage route.

The SPO principle with a separate overflow trunkgroup for the final traffic behind the common final route provides the best utilization of the probabilities of loss in the case of engineered load and in the case of overload of a high usage route.

An application downwards the hierarchy seems to be less useful.

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