SERVICE PROTECTION FOR DIRECT FINAL TRAFFIC IN DDD-NETWORKS

Lothar Katzschner
University of Stuttgart
Stuttgart, Federal Republic of Germany

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.

Beitrag des Instituts für Nachrichtenvermittlung und Datenverarbeitung der Universität Stuttgart zum 7th International Teletraffic Congress Stockholm vom 13.-20. Juni 1973

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 hunt 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.

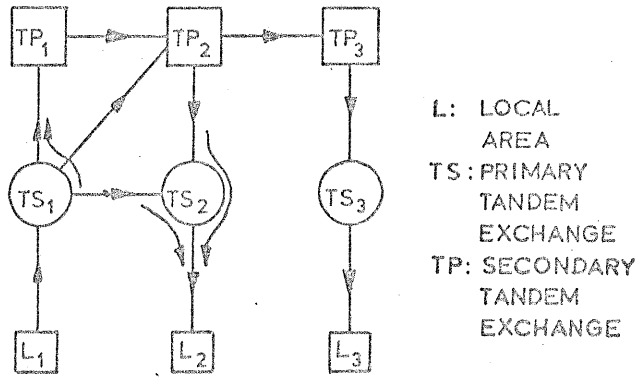


Fig.1 Example for a simple hierarchical network with alternate routing

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./1,2,4,7,13/. Two principles to enhance the overload capability and to reduce the differences of the point-to-point probability of [illegible]s at engineered load throughout the network [illegible] suggested in these puplications.

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. /8,9,10,11,12,15/

In this paper basic investigations on the two published principles for 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 overflow possibility, resp., 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) /4,13/

Preferential service to the final traffic is given by denying service requests from overflowing calls when more than a specified number n_{21} 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_2 trunks busy" of the final route with n_2 trunks, gets lost, if $n_{21} \leq x_2 \leq n_2$.

The number of trunks n_{21} 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_{22} trunks and a common final route for all overflowing traffics with n_{21} trunks. The n_{22} trunks are only available for the final traffic. The traffic overflowing from the n_1 trunks is now restricted to the common n_{21} trunks. Therefore the probability of loss B_{1u} of the overflowing traffic increases and B_{2u} 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_{21} trunks and a separate overflow route with n_{22} trunks. The overflow route is reserved for final calls only, which cannot be handled by the common final route. As this overflow route is exclusivly available for the overflowing calls of the final traffic, B_{2u} decreases and B_{1u} increases – compared with the probabilities of loss B_{2u} and B_{1u} 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_{2u}, n_{21} and for given offered random traffics A_{1u} and A_{2u} do not exist for none of the three principles.

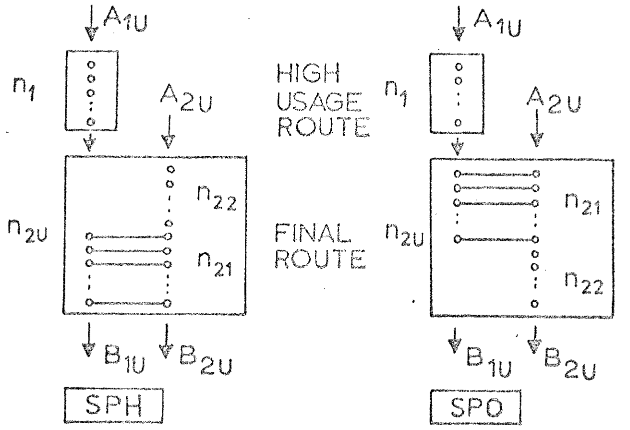
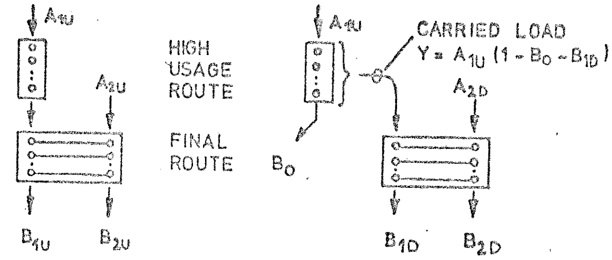


Fig.2a,b The service protection principles SPH and SPO in the final route



traffic flow upwards the hierarchy

traffic flow downwards the hierarchy

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 explicite 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

$$(n_1 + 1)\cdot(n_{21} + 1)\cdot(n_{22} + 1)$$

for the principles SPH and SPO and

$$(n_1 + 1)\cdot(n_{2u} + 1)$$

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 characteritic 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 overflowing 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.4 an example is studied. The number of trunks in the final route and the offered traffics A_{1u}, A_{2u} be fixed parameters ($A_{1u} = 21$, $A_{2u} = 5$, $n_1 = 20$, $n_{2u} = 18$). The trunkgroups are dimensioned according to a probability of loss $B_{2u} = 1\%$ for the final offered traffic.

The diagram shows the dependence of the probability of loss B_{1u} as a function of B_{2u}, which is obtained, when the number n_{22} of trunks in the final route, only available for the final traffic, is increased trunk by trunk, beginning with $n_{22} = 0$. In the same way n_{21} is reduced, thus $n_{2u} = n_{21}+n_{22}$ 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_{2u} of the offered final traffic A_{2u}, this principle yields the lowest total loss B_{1u} for the alternately routed traffic A_{1u}.

If, for example, we demand a probability of loss $B_{2u} \approx 0.4\%$ for the final traffic, we can realize this in the following way:

Principle	$B_{1u}/\%$	$B_{2u}/\%$	n_{21}	n_{22}
PRS	0.88	0.43	17	1
SPH	1.58	0.38	10	8
SPO	1.09	0.36	16	2

$A_{1u} = 21$

$A_{2u} = 5$

$n_1 = 20$

$n_{2u} = 18$

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_{2u} generally holds:

$$n_{21}(SPH) \leq n_{21}(SPO) \leq n_{21}(PRS).$$

For this reason the PRS should be preferred, if a maximum of carried traffic is prescribed. A certain disadvantage is the additional equipment to count the momentarily established calls in the final route and to control the acceptance of overflowing 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.4 the common point of all curves on the right represents the two values for

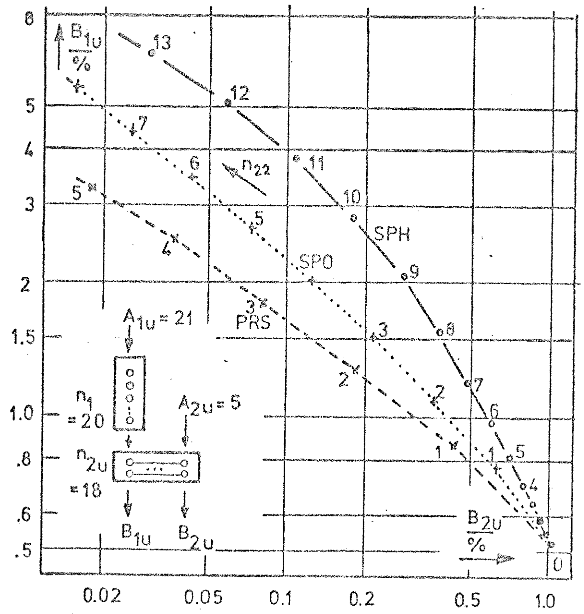


Fig.4 The probability of loss B_{1u} as a function of B_{2u} for the principles PRS, SPH and SPO. Parameter is the number of trunks n_{22}, available for the final traffic only (application upwards the hierarchy)

B_{1u} and B_{2u}, when no service protection is applied. The overall probability of loss B_{2u} of the final traffic is in this example about two times higher than that of the alternately routed traffic A_{1u}.

From the traffic A_{1u} about $0.2A_{1u}$ is offered as overflow to the final route. Neglecting the peakedness of this overflow and without service protection one would obtain $B_{1u} = 0.2B_{2u}$, e.g. $B_{1u} \approx 0.2 \cdot 0.01 = 0.2\%$. Because of the peakedness (variance to mean ratio) of the overflow one finds $B_{1u} = 0.5\%$ by exact calculation (see Fig.4).

The final route be dimensioned such that the engineered loss for $B_{2u} \approx 1\%$ is obtained without service protection. It should be possible to reduce slightly the trunks in the final route by means of service protection. This reduction is, however, comparatively small, as will be shown in the following example:

The total number n_{2u} of trunks in the final route in the example of section 4.1.1 is reduced by one trunk from 18 to 17.

From this reduced number $n_{2u} = 17$ one has now to separate ≥ 1 trunks in order to make them accessible for the final traffic A_{2u} only. This has to be performed such that B_{2u} remains $\approx 1\%$ and furthermore that the overall probability of loss B_{1u} does not exceed $\approx 1\%$.

We find the following results:

Principle	$B_{1u}/\%$	$B_{2u}/\%$	n_{21}	n_{22}	n_{2u}
PRS	1.26	0.66	16	1	17
SPH	1.20	1.03	12	5	17
SPO	1.09	0.97	16	1	17
No s. prot.	0.76	1.68	17	0	17
No s. prot.	0.52	1.05	18	0	18

$A_{1u} = 21$, $A_{2u} = 5$, $n_1 = 20$.

In the case of PRS with one trunk reserved for the final traffic, in this example the probability of loss 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 ≈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 in the final route is fixed for each principle and chosen according to the example in section 4.1.1. The common n_{21} 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 for 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.

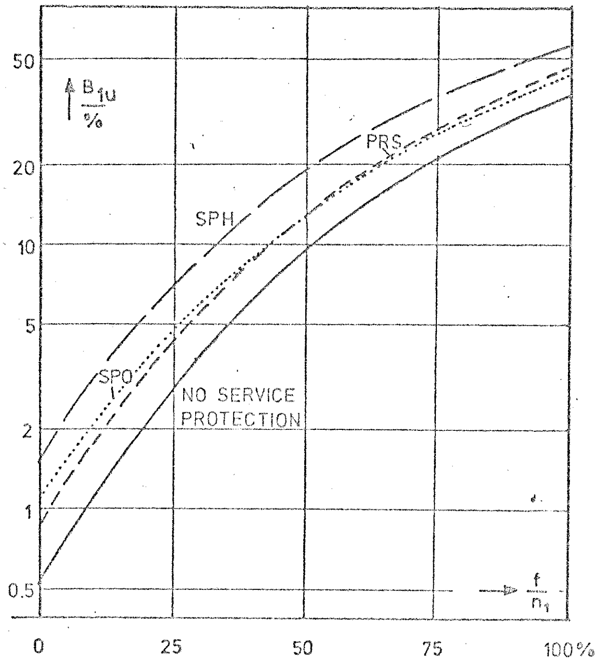


Fig.5a The probability of loss B_{1u} as a function of the faulty trunks f in the high usage route.
($A_{1u} = 21$, $A_{2u} = 5$, $n_1 = 20$, $n_{2u} = 18$)

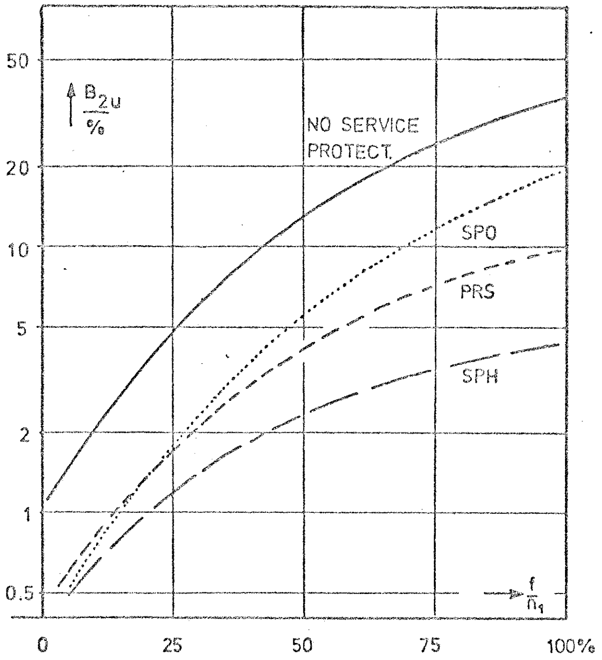


Fig.5b The probability of loss B_{2u} as a function of the faulty trunks f in the high usage route.
($A_{1u} = 21$, $A_{2u} = 5$, $n_1 = 20$, $n_{2u} = 18$)

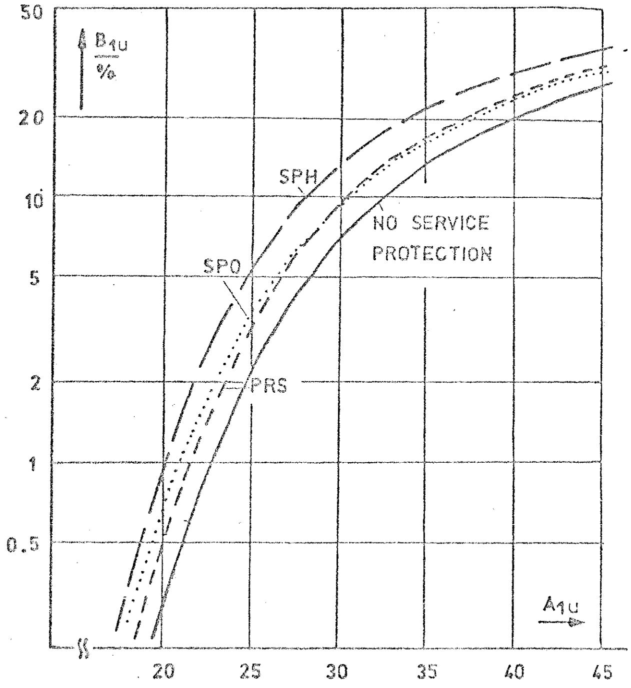


Fig.6a The probability of loss B_{1u} as a function of the traffic A_{1u} offered to the high usage route.
($A_{2u} = 5$, $n_1 = 20$, $n_{2u} = 18$)

The diagrams 6a,b show that none of the three principles can avoid the significant growth of the probabilities of loss, especially of B_{2u}, 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

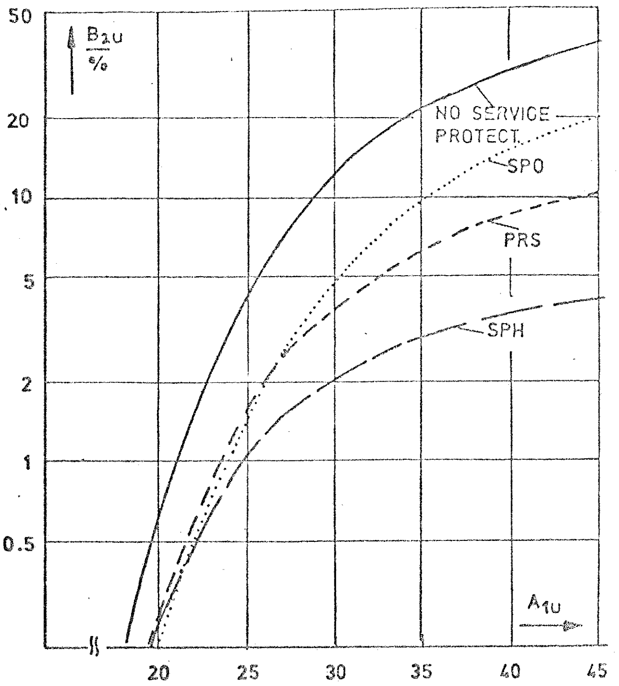


Fig.6b The probability of loss B_{2u} as a function of the traffic A_{1u} offered to the high usage route.
($A_{2u} = 5$, $n_1 = 20$, $n_{2u} = 18$)

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

For example, if A_{1u} grows from 21 to 45 Erl, the application of PRS 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 $B_{2u,\infty} = B_{2u}(A_1 \to \infty)$ can be chosen. For SPH and SPO we get evidently

$$B_{2u,\infty} = E_{1,n_{22}}(A_2),$$

because the common used final route is occupied at any time by calls of the offered traffic A_{1u}. In our example in section 4.1.1 we get

$$B_{2u,\infty}(\mathrm{SPH}) = E_{1,8}(5) = 0.07 \quad \text{and}$$

$$B_{2u,\infty}(\mathrm{SPO}) = E_{1,2}(5) = 0.67.$$

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

$$B_{2u,\infty}(\mathrm{PRS}) = \frac{\dfrac{A_{2u}^{n_{2u}-n_{21}}}{n_{2u}\cdot(n_{2u}-1)\;\ldots\;(n_{21}+1)}}{\displaystyle\sum_{i=n_{21}}^{n_{2u}} \frac{A_{2u}^{n_{2u}-i}}{n_{2u}\cdot(n_{2u}-1)\;\ldots\;(i+1)}}$$

In our example with $n_{2u} = 18$ and $n_{21} = 17$ we get for the PRS:

$$B_{2u} = 0.217.$$

The PRS, 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 presribed, which yields uniform probabilities of loss B_{1u} and B_{2u} (or 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.

The SPH principle, however, leads in the case of overload or faulty trunks within one of the separate trunkgroups n_1 or n_{22} 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 traffics A_{1u} and A_{2u} is restricted to their overflow probability.

Provided that there is no breakdown of the final route, the PRS and above all the SPO principle (because of its simple realization) 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 TS2 to L2). The traffic carried by a high usage route is smoothed, whereas under engineered load conditions the traffic A_{2D} offered to the next section of the final route is peaked. This is the reason why the offered traffic A_{2D} 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_{1D} as a function of B_{2D} is depicted in Fig.7. As parameter on the curves for the service protection principles PRS, SPO and SPH one finds the number of individual trunks n_{22} for the final traffic ($A_{1u} = 10$, $A_{2D} = 2$, $n_1 = 11$, $n_{2D} = n_{22} + n_{21} = 15$).

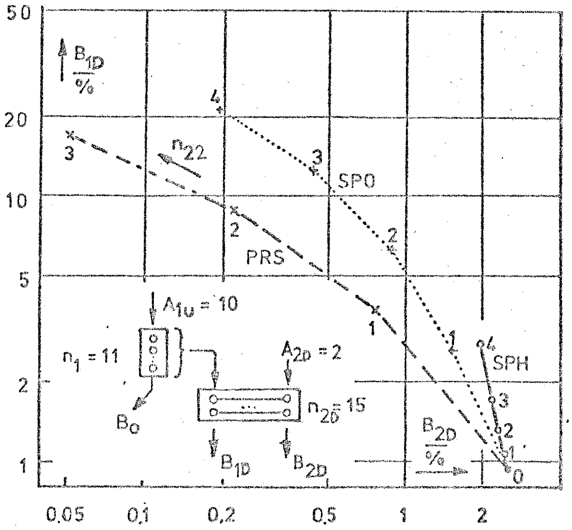


Fig.7 The probability of loss B_{1D} as a function of B_{2D} for the principles PRS, SPH and SPO. Parameter is the number of trunks n_{22}, available for the final traffic only (application downwards the hierarchy)

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_1.

On the other hand, in the final route only a maximum of n_1 trunks can be occupied by calls of the offered traffic A_{1u}. Therefore $n_{2D} - n_1$ trunks in the final route are already "reserved" for calls of the offered traffic A_{2D} without any service protection means.

Fig.7 shows that the probability of loss B_{2D} is about 2.3% whereas the traffic via the high usage route has only $B_{1D} = 0.9\%$, when no service protection principle is applied. B_{1D} is the probability for a call of A_{1u} to find an idle trunk in the high usage route but none in the final route.

A_{2D} is assumed to be random traffic for simpler calculation (if A_{2D} is peaked, B_{2D} will even be higher).

The application of PRS or SPO could reduce B_{2D}. But as Fig.7 demonstrates, the probability of loss B_{1D} increases with n_{22} in such a degree that the application of these principles seems to be not useful.

The SPH principle reduces B_{2D} only insignificantly. Nevertheless B_{1D} is increasising remarkably, when n_{22} is augmented.

This example shows (and others, which were investigated but not discussed here) that service protection in the final route downwards the hierarchy will be of no great importance (unless a special network configuration is chosen, e.g./2/).

5. CONCLUSION

Three principles PRS, SPH and SPO for service protection in the final route of an hierarchical DDD network with alternate routing have been discussed. It was shown that the application of these principles upwards the hierarchy provides a better equalization of the probabilities of loss for final and alternately routed traffic as well as service protection for the final traffic in 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 equalization 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.

REFERENCES

/1/ Asgersen,C.: 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.
5. ITC, New York 1967, Prebook, 407-417.

/2/ Asgersen,C.: A traffic routing strategy designed for overload protection downwards the hierarchy.
6. ITC, München 1970, Congressbook, 144/1-6.

/3/ Bretschneider,G.: Die Berechnung von Leitungsgruppen für überfließenden Verkehr in Fernsprechwählanlagen.
NTZ 9 (1956), 533-540.

/4/ Faulhaber, G.R., Dunkl, P.: Design of systems with priority reservation.
5. ITC, New York 1967, Prebook, 219-234.

/5/ Katzschner,L.: Verlustsysteme der Wählvermittlungstechnik mit Prioritäten.
PhD-Thesis, University of Stuttgart,1970.

/6/ Katzschner,L.: Koppelanordnungen zur Realisierung von Prioritäten in Verlustsystemen der Vermittlungstechnik.
NTZ 25 (1972), 43-49.

/7/ Lotze,A.: Problems of traffic theory in the design of international direct distance dialling networks.
NTZ-CJ 7 (1968), 41-46.

/8/ Lotze, A., Schehrer,R.: The design of alternate routing systems with regard to the variance coefficient.
NTZ-CJ 7 (1968), 47-52.

/9/ Lotze, A.: DDD network optimization in field engineering - from theory to application.
7. ITC Stockholm 1973.

/10/ Pratt,C.W.: The concept of marginal overflow in alternate routing.
5. ITC, New York 1967, Prebook, 51-58.

/11/ Rapp,Y.: Planning of junction network in a multiexchange area.
5.ITC, New York 1967, Prebook, 581-586.

/12/ Schehrer, R.: Optimal design of alternate routing systems.
5. ITC, New York 1967, Prebook, 378-398.

/13/ Schwärtzel, H.: Die verkehrsabhängige Regelsteuerung für Leitweglenkung in Fernsprechnetzen.
AEÜ 19 (1965), 150-154.

/14/ Wilkinson,R.I.: Theories for toll traffic engineering in the USA.
1. ITC, Copenhagen (1955), Doc. 43 and
BSTJ 35 (1956), 421-515.

/15/ Wallström,B.: Methods for optimizing alternative routing networks
Ericsson Technics 25 (1969), 3-28