THE SUBOPTIMAL ALTERNATE ROUTING PRACTICE WITH NON-COINCIDENT BUSY HOURS

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1. ABSTRACT
The dimensioning of alternate routing is often based on assumptions about the optimum to be reached at the future time. However, usually the resulting theoretical optimum is not reached because in practice all important parameters have not been included in the calculations. For example the initial cost of a new route, the non-coincidence of the busy hours of different traffic flows, and the uncertainty in making forecasts are the most important, especially in the local area trunk network. The planner can make a choice between the following strategies:
- to make plans for building all the alternate routes which may turn out to be profitable in the future, or
- to make plans for building only those routes which are profitable with certainty.

This paper deals with the influence of the parameters on small traffic flows (max. 30 E1) in the case of overflow, from a single high-congestion route. Some practical rules for these dimensioning techniques are given.

2. INTRODUCTION
The traffic $A_{12}$ is offered from exchange 1 to exchange 2, either directly (abbr. D) with a congestion B, or entirely over tandem exchange T parallel with a basic traffic $A_0$ (abbr. T) or mainly directly, but with an overflow via transit exchange T (high congestion, abbr. H).

Following the Wilkinson principle /2/, and using the Bretschneider /3/ tables and curves one can calculate how many extra circuits $\Delta n$ there are needed on the route $1 - T$, when at a constant offer $A_{12}$ on varying sizes of the route $n_{12}$ brings a varying overflow.

The size of basic traffic $A_0$ does not significantly influence the need for extra circuits $\Delta n$ (Fig. 2), if $A_0$ is clearly greater than $A_{12}$. Therefore the calculations in the following are made only with $A_0 = 50$ Erl, when $A_{12} = 30$ Erl. The routes 1 - T and T - 2 are assumed to be similar. The congestion between two exchanges will in the following be $B = 1\%$.

The ratio for the costs $C_{12}$ for one circuit directly from 1 to 2 and $C_{1T} + C_{T2}$
for one circuit over T is

$$\epsilon = \frac{C_{12}}{C_{1T} + C_{T2}}$$  \hspace{1cm} (1)

Although the normal limits for $\epsilon$ are 0 and 1, in practice, however, concerning area networks $\epsilon = 0,25...0,75$, mostly.

The costs for the circuits in the direct route and the costs for the extra circuits in the low congestion route make the total costs of the system /1/:

$$C(n) = \Delta n (C_{1T} + C_{T2}) + n_{12}C_{12}$$  \hspace{1cm} (2)

Fig. 3. The total costs for the circuits $C(n)$ as a function of the size of the direct route $n_{12}$, when $A_{12}$ and $\epsilon$ are constants.

Fig. 4. Examples of some cases for T, D and optimal H, when $A_{12}$ is constant.

a) $\epsilon = 0,50$: $H_{opt}$ does not deviate much from D.

b) $\epsilon = 0,75$: D is the worst, the gain for $H_{opt}$ diminishes.

$\Delta C_D$ in Fig. 4 shows the gain $K$ which is reached using D-routing instead of T-routing. $\epsilon$ for the different values of $C_T = C(0)$ and $n_D$ can be calculated:

$$\epsilon = \frac{C(0) - K}{(C_{1T} + C_{T2})n_D}$$  \hspace{1cm} (3)

The required gain $K$ can be used for the initial costs of a direct route. It has a significant influence on the value of $\epsilon$, which still allows an economic use of D-routing instead of T-routing, Fig. 5.

Fig. 5. D-routing is more economic than T-routing on the right side of the curves, depending greatly on the initial cost $K$ for a route, when no $H$-routing is used.

The gain of $H$-routing varies with $n_{12}$, $A_{12}$ and $\epsilon$, as is seen in Fig. 3. For a constant $n_{12}$, the gain will be little or negative at small offered traffic $A_{12}$, but grows with it. For $B \leq 1$ % the routing works as D. For greater $A_{12}$, the gain is soon reached. Fig. 6.

Fig. 6. The gain $\Delta C$ for $H$-routing for constant route size $n_{12} = 20$, when $A_{12}$ varies. In order to reach economic $H$-routing, a certain $A_{12}$ value must be exceeded.

3. NON-COINCIDENT BUSY HOURS

The busy hours for different traffic flows seldom occur simultaneously or repeatedly during the same weeks from one year to another. When two traffic flows are combined, the result will be smaller than the sum of the parts. /4/.

We observe traffic $A_{12}$ during the busy hour of $A_0$. It can depend on the subscribers on that traffic source differ in ratio $\lambda$ (coincidence factor) from its own busy hour value. As in T-routing ($n_{12} = 0$) the traffic flows are fully combined ($A_0 + 4A_{12}$) and in D-routing ($n_{12} = n_D$) totally separated ($A_0$, $A_{12}$), so for $H$-routings the result varies with $n_{12}$ as shown in Fig. 7.
Knowledge about values of coincidence factor $\lambda$ can be collected by measuring the daily traffic profiles simultaneously on separate routes and referring them to the yearly defined busy hours. In the Helsinki area network for traffic routes within 10...30 Erl, values $\lambda = 0.5...1.0$ have been observed and values $\lambda = 0.75...0.9$ are common. When calculating in the German way (Gruppenabzug/4), e.g. a combination of traffic $A_{12} = 10$ Erl and $A_0 = 50$ Erl yields $\lambda = 0.80$.

4. COSTS FOR AN ADDITIONAL ROUTE

Every route brings by its mere existence certain additional costs:

a) constructions for cable and route
b) new routing operations in the exchange, registers, selectors, etc.
c) traffic measurements and valuation of results
d) administrative costs for observing and handling more objects in a more complex way in augmentation work
e) increase in errors in prognoses, resulting in more augmentations
f) increase of total number of circuits as consequence of busy hours in splitted routes

The items e) and f) are more or less depending on the size of the route and will be dealt with later. The items a) to d) can be regarded as a constant total cost $C_{120}$, not depending on the size of the route $12$. The cost is referred to the cost of one circuit over tandem exchange

$$K = \frac{C_{120}}{C_{1T} + C_{T2}}$$

In an area network with trunk lines of 30 km the following values can be determined:
- new cable route 1000...20 000 monetary units
- routing operations in the exchange 400...20 000 m.u.
- traffic measurements 40...400 m.u. yearly, capitalized value 400...4 000 m.u.
- increase in augmentation cost 400...4 000 m.u.

Similarly the cost for one circuit $C_{1T} + C_{T2}$ can be for example 1000...4 000 m.u., thus $K$ can be from 0.5 to over 20. In practice, concerning area trunk network $K$ usually is 2...5.

The basic additional costs are taken into account by subtracting $K$ from the reached gain, Fig. 9. The limit value for $A_{12}$ will thus increase.
5. OTHER FACTORS

Errors in forecasting have an affect of the following art. When forecasting the value for future traffic, a planner more or less intentionally makes assumptions about its variations /5/, prefers to be on the sure side and chooses a higher value than the expected one, the higher the bigger the variations in question are. The relative over-dimensioning for small routes is thus bigger than for big routes. Division of traffic flows \( A_0 \) and \( A_{12} \) on separate routes (D) increases the deviation compared with leading it only via one route (T) with:

\[
\sigma_{D - T} = \sqrt{A_0} + \sqrt{A_{12}} - \sqrt{A_0 + A_{12}}
\]

When \( A_0 = 50 \) Erl and \( A_{12} \) varies from 10 Erl to 30 Erl, the \( \sigma_{D - T} \) results in 2.49 Erl and 3.60 Erl respectively, which means a proportional increase of 25 % and 12 %. Its influence on the optimisation of alternative routing is of a similar art as the one illusarated in Fig. 7: like the dotted line, the variance changes the traffic value to be used as dimensioning basis from T to D routing. The errors in forecasting can thus been taken into account by further decreasing the \( \lambda \)-value.

The same method, to decrease the value of the factor \( \lambda \), can be used also for describing the influence of the stepwise augmentation. When the augmentation steps are optimated by the well-known Wilson's stockformula, the step sizes are proportional to the square root of the volume \( A \). Alternatively for a simplified calculation a decreased value of \( \lambda \) can be used for augmentation step costs.
6. CONCLUSIONS

Every new route results in extra costs for building up the route and for dividing the traffic. The initial costs, including administrative costs, with errors in forecasting and the non-coincidence of busy hours, diminishes the economy of high-congestion, too, compared with a star-formed tandem routing. When these factors are taken into account, it becomes evident that in an area network, single high-congestion routes are motivated for quite cheap direct routes only, and not for traffic less than 10...20 Erls. And the congestion on these routes may be high enough to guarantee the economy.

This was a pure economic examination. When taking into consideration the reliabilities, the direct routes can give some advantages.

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Date: 10 June 1983
Session: 2.2
Paper: 4

Q.1 (Caballero)
   Does your analysis include the modelling of two-way trunking?

A.1 (Parviala)
   Not explicitly. Analysis is independent of whether trunk groups are one-way or two-ways.