Introduction of New Exchanges

Mr. T. Fried, ITU

UNION INTERNATIONALE DES TELECOMMUNICATIONS
INTERNATIONAL TELECOMMUNICATION UNION
UNION INTERNACIONAL DE TELECOMUNICACIONES

INTRODUCTION OF NEW EXCHANGES

New exchanges should be introduced in the network if this will decreas the total network cost. Such a new exchange at any given location (x,y) in the area, assuming optimal boundaries, will generally

- **decrease** the cost of the **subscriber's network** due to shorter and less expensive cables;
- **increase** the cost of the **junction network** due to the fact that the efficiency of the interexchange routes decreases with decreasing traffic;
- **increase** the cost of **buildings** and **exchanges.**

Naturally, only those locations where the net profit, ie the total cost change, is positive, need be considered, and of all such locations we are interested in those showing maximum profits. Theoretically, one could calculate a **"profit function"**, F(x,y) ,throughout the area, select the location with the highest F-value, correct F in the vicinity of the selected location, select another location which now has the highest F-value,and so on as long as there are positive F-values in the area. Examples of such "profit functions" are shown in the figures at the end of this section, showing F(x,y) for the initial configuration, and after introduction of new exchanges at the most profitable locations.

This method is, however, practically not feasible due to the large amount of calculations required. We are therefore forced to radically reduce the number of locations for which F(x,y) is calculated.

As the economic loss in the *trunk network* is not greatly affected by the exact position of an exchange, the obvious thing to do is to look for locations where the gain in the *subscriber's network* is high. As the highest gains will occur where subscribers have to use long and expensive cables, and these are usually found at the edges of the exchange areas,ie along the exchange boundaries, we may assume that suitable locations may be found where two or more **exchange area boundaries intersect**. This will substantially decrease the number of points to be investigated, and consequently the computational effort will be reduced significantly.However, these intersection points thus found are not the optimal locations for new exchanges, due to the influence of the junction network and the irregularities of the actual subscriber distribution, but are usually close enough to serve as an first approximation in the procedure outlined below.

Step 1 : Find the *intersection points* between the boundaries of all exchanges, existing or planned in a previous iteration.

Step 2 : For *each* such point,

- find tentative area boundaries;
- optimize the location according to these boundaries;
- repeat this iterative process until no significant changes occur, or until a predetermined number of improvements has been made, or until the location approaches too closely the location of a previously calculated point (in which case the two solutions would become practically identical).

Step 3 : Having thus arrived at the **local optimum** for this point, the **change in the total network cost** can be estimated; the cost change concerns

- the subscriber network,
- the junction network,
- exchanges and buildings,

and the calculations have to be made for the tentative new exchange, as well as for the surrounding exchanges whose areas have been affected.

Step 4 : Steps 2 and 3 are carried out for every one of the points found in Step 1, and/or for points specified by other methods, such as defining them in the input data. The **total profit** for each such point is then investigated to determine which point, or combination of points, should be introduced as new exchange.

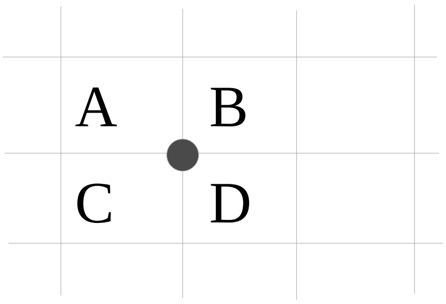
The figures at the end of this document show the intersection points,and the "profit function" for a small network. They also show 3 consecutive iterations of the introduction of exchanges.

Intersection points of boundaries

Intersection points are calculated between all area boundaries. Such boundaries can be

- **exchange boundaries**, seperating two exchange areas;
- **total area boundaries**, seperating the arae under consideration from the area outside;
- boundaries of **enclosed areas** not under consideration, such as parks, lakes, etc.

To find these intersection points is rather simple for the case where each grid element belongs entirely to a given exchange. Consider the combination of 4 grid elements arranged on 2 consecutive rows as follows:



The center of this combination is an intersection point if the elements A,B,C and D belong to **3 or 4 different** exchanges (the area outside,and enclosed areas are considered as an "exchange" in this context).

In the case where a grid element can be split between 2 or more exchanges, the problem is to find the intersection between the straight lines approximating the exact boundaries (See document “Exchange Locations and Boundaries”).

Boundary calculation for tentative exchanges

In the course of the optimization process a large number of tentative exchanges will be investigated. To speed up the calculations,boundaries are investigated according to a somewhat simplified method. This method disregards the influence of exchange, building, and junction network costs, and places the boundaries equidistant to the adjacent exchanges. Moreover, these equidistant lines are then rounded to the nearest grid element.

For any grid element (i,j) within these boundaries, the following steps are then carried out :

- calculation of distance, cable type and cost to the "old" exchange;
- same for the new exchange;
- the cost decrease for grid element (i,j) is found by multiplying the difference between these cost by the number of subscribers , sub(i,j);
- summing these cost decreases for all (i,j) considered for the new exchange gives the total decrease in the subscriber network for this tentative exchange
- for the purpose of estimating the changes in the **junction network**, an array NESUB(L,I) is set up containing the number of subscribers of traffic zone I taken from "old" exchange L.
- for the purpose of **improving exchange locations** the sums of S(i,j), weighted by the cost/km of the proper cable, are stored for each row and column of the grid.

Improving location for tentative exchange

Again, to save time, the exact method described in Chapter 2.3 **Locations** is not used in this procedure. The simplified method, disregarding the influence of the junction network, finds the **center of gravity**, ie the point where there is a balance of subscribers to the left and the right, and above and below. As described in the previous section, the subscribers have been weighted by the cost/km of the cable to be used for each grid element.

Cost changes in junction network

The cost changes in the junction network resulting from the tentative introduction of a new exchange are estimated as follows :

Routes between "old" exchanges

For any "old" exchange, L , we have two sets of values describing the number of subscribers for a given traffic zone , I :

NSUB(L,I) = subscribers of traffic zone I belonging to exchange L before introducing the new exchange;

NESUB(L,I) = subscribers of traffic zone I moved from exchange L to the new exchange.

The number of subscribers of traffic zone I belonging to exchange L after the introduction of the new exchange is thus NSUB(L,I) - NESUB(L,I)

So,between "old" exchanges L and M the traffic previous to introducing the new exchange was

$$A_{LM} = \sum_{\mathrm{I,J}} \left[NSUB(L,I) \cdot NSUB(M,J) \cdot a_{IJ} \right]$$

where a[IJ[is the traffic from one subscriber in traffic zone I
to one subscriber in traffic zone J.

The traffic from L to M after introducing the new exchange is

$$A^{*}_{LM} = \sum_{\mathrm{I,J}} \left[NSUB(L,I) - NESUB(L,I) \right] \cdot \left[NSUB(M,J) - NESUB(M,J) \right] \cdot a_{I,J}$$

The cost change for this pair of exchanges is then estimated as

$$(\mathrm{A}^{*}_{\mathrm{LM}} - \mathrm{A}_{\mathrm{LM}}) \cdot \text{(cost per erlang L to M)}$$

where "cost/erlang" has been calculated in the previous iteration.

Routes between the new and "old" exchanges

The traffic from the new exchange,E, to any "old" exchange L can be written as

$$A_{EL} = \sum_{\mathrm{I,J}} SUBNE(I) \cdot \left[NSUB(L,J) - NESUB(L,J) \right] \cdot a_{IJ}$$

where SUBNE(I) denotes the subscribers of traffic zone I belonging to the new exchange. Obviously,

$$SUBNE(I) = \sum_{\mathrm{K}} NESUB(K,I)$$

The traffic from L to the E is calculated in a similar fashion.

The cost per circuit between E and L are then calculated as usual.

The direct route between E and L can now be dimensioned in the usual way, based on traffic,grade of service and routing constraints.The effect of overflow traffic to other parts of the network is, again, estimated by using the "cost/erlang" values obtained in the previous iteration.

Summing up all the cost changes will give the desired estimate of the overall change in the junction network.

Changes in exchange and building costs

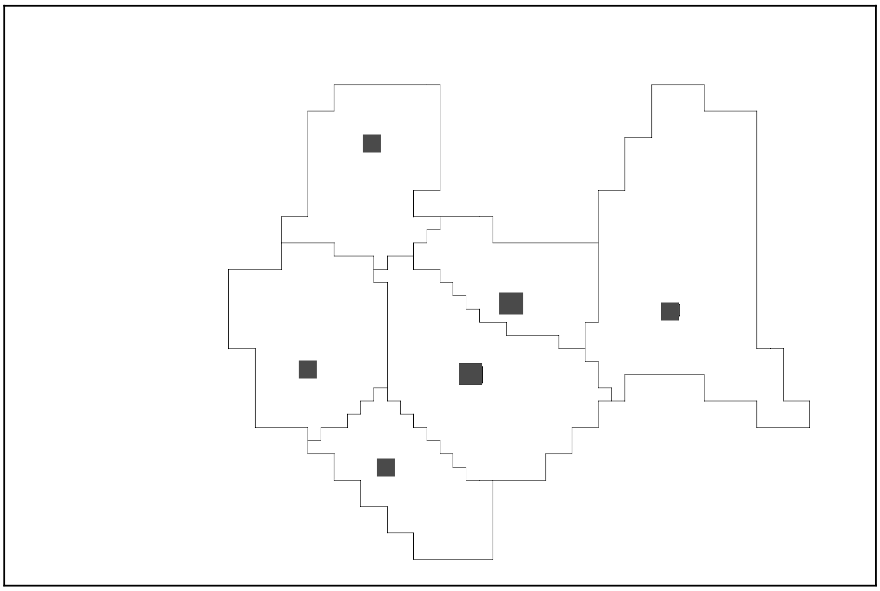
"Old" exchanges having lost subscribers to the new exchange are reconfigured on the basis of the new subscriber and circuit requirements, and the cost changes calculated. The same is done for the configuration and cost of the building.

The new exchange is costed in the usual way.

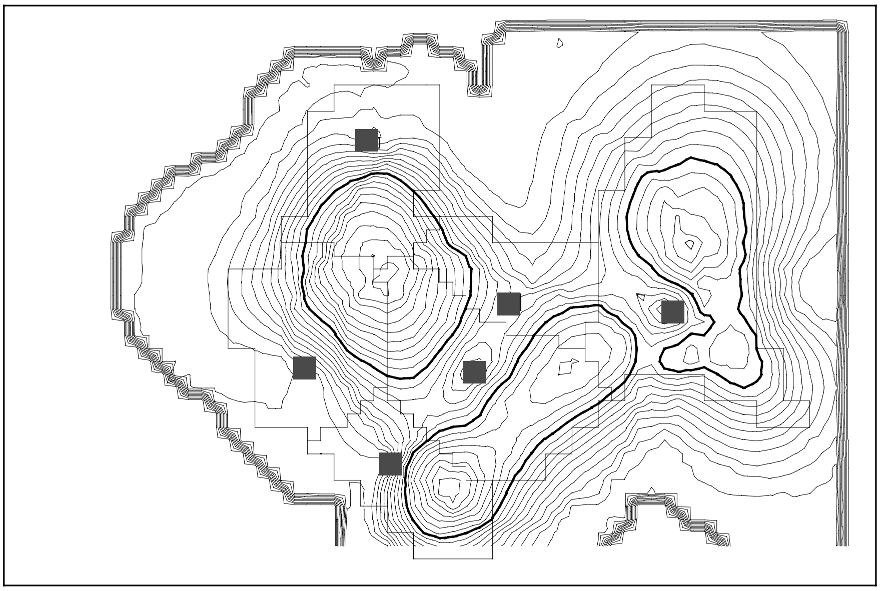
The figures on the following pages show

- the initial network configuration, with exchanges and boundaries;
- the profit function for this initial configuration; the lines in the "fingerprints" connect point of equal cost, which means that placing a new exchange at any point on a given line would have the same economic consequences for the network. The thicker lines surrounding the optimal locations correspond to a zero-cost line, which means that placing an exchange on such a line would alter the configuration of the network, but would not change the overall network cost;
- new profit functions after introducing exchanges at profitable locations.

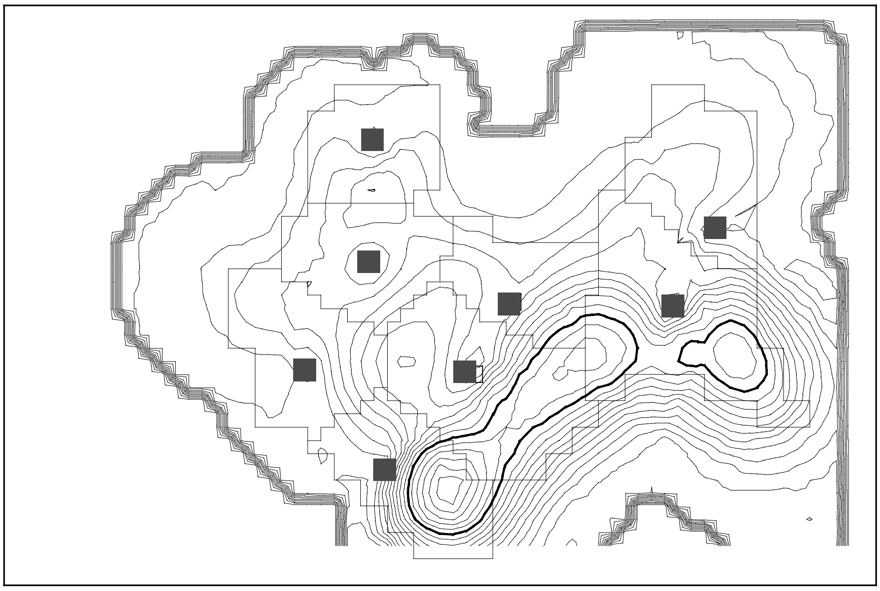
The initial configuration, showing exchange locations and boundaries:



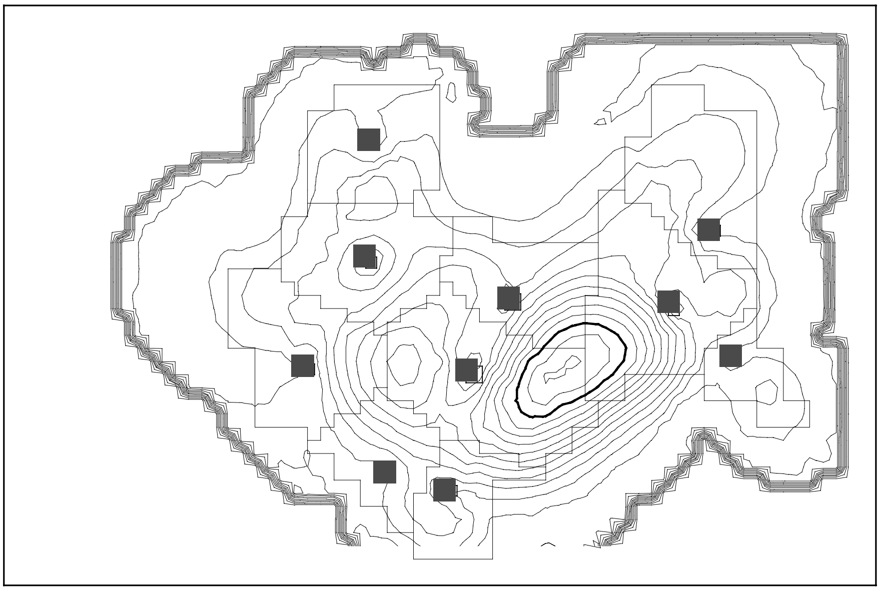
The same configuration, now showing the “profit function. Three profitable areas can be seen.



Two new exchanges are selected, and the new profit function is calculated.



Two profitable areas remain, and two new exchanges are introduced accordingly:



Only one profitable area remains, but the potential profits are not very high.

As described earlier, the search for new exchange locations starts always at the intersection of exchange boundaries. In the figures shown above, it can be seen seen that these intersection points are usually quite close to the local optimum areas. This makes the procedure fast and accurate.