ITU Seminar

Warsaw, Poland , 6-10 October 2003

Session 4.2

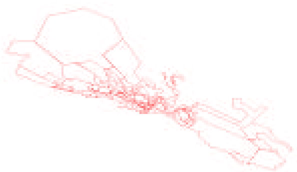
Switching/Routing

planning

Switching planning

Location problem :

Optimal placement of exchanges, RSU, routers, DSLAM, etc.



subscribers/users in areas/zones

subscribers/users in locations/sites

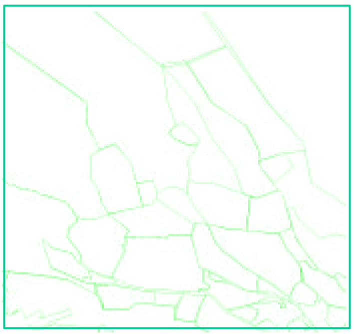
Boundaries problem :

Optimal service areas of exchanges, RSU, routers, DSLAM, etc.

Switching planning

Location problem

Subscriber zones / subscriber grid model



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Switching planning

Location problem

Theoretically for the set of optimal location (X_E, Y_E) the partial derivatives of the total network cost function, C, with regard to X_E and Y_E are equal to zero :

$$\left.\begin{aligned} \partial C/\partial X_E &= 0 \\ \partial C/\partial Y_E &= 0 \end{aligned}\right\} \text{for } E = 1,2,\ldots \text{NEX}$$

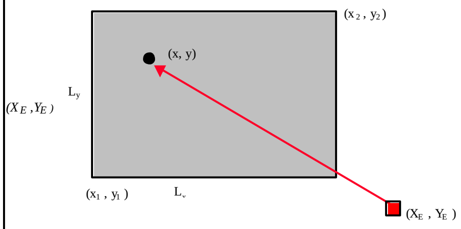
Different methods for solving this 2*E equation system could be employed depending upon the methods of ***measuring the distances*** in the network

In the most complicated case we get a system of 2*NEX ***non-linear equations***
If $\partial C/\partial X_E$ and $\partial C/\partial Y_E$ are expanded into Taylor-series this leads to a system of 2*NEX ***linear equations*** in ΔX_F and ΔY_F , which can easily be solved by ***standard methods***

Switching planning

Location problem - distance measurement methods

Mean distance from exchange to grid element :



The *mean distance* from to the rectangle can then be found from:

$$D = \frac{1}{area} \int_{x_1}^{x_2} \int_{y_1}^{y_2} d\,(X_E, Y_E, x, y)\, dx\, dy$$

along the cathetie :

$$D(X_E, Y_E, x, y) = |X_E - x| + |Y_E - y|$$

along the hypotenuse :

$$D(X_E, Y_E, x, y) = \sqrt{(X_E - x)^2 \cdot L_x^2 + (Y_E - y)^2 \cdot L_y^2}$$

Switching planning

Simplified method for location optimization

Based on the access network cost S_j only :

$$S_j = \sum_i sub(i,j) \cdot C_s(D_E) \qquad for\ (i,j) \in E$$

For optimal locations (X_E, Y_E) the partial derivatives of the cost function $C = S_j$ with regard to X_E and Y_E are equal to zero :

$$\left.\begin{array}{l} \partial C / \partial X_E = 0 \\ \partial C / \partial Y_E = 0 \end{array}\right\} \quad for\ E = 1,2,\dots NEX$$

For a case with one location only for X_E we get:

$$\P C / \P X_E = \sum_{(i,j) \in E} \left[sub(i,j) \cdot C_c(D_E) \cdot \P D_E / \P X_E \right]$$

the partial derivative depends only on the distance

Switching planning

Simplified method for location optimization

With simplified distance method along the cathetie :

$$D(X_E, Y_E, i, j) = |X_E - j| + |Y_E - i|$$

We get :

$$\partial C / \partial X_E = \sum_{(i,j)\in E} sub(i,j) \cdot C_c(D_E) \cdot \begin{cases} -1 \; if \; j \geq X_E \\ \;\;1 \; if \; X_E \geq j \end{cases}$$

Thus :

$$\sum_{(i,j)<X} sub(i,j) \cdot C_c(D_E).(+1) + \sum_{(i,j)>X} sub(i,j) \cdot C_c(D_E).(-1) = 0$$

Or :

$$\sum_{(i,j)<X} sub(i,j) \cdot C_c(D_E) = \sum_{(i,j)>X} sub(i,j) \cdot C_c(D_E)$$

Finally if disregard the tr. media cost (same everywhere) we get:

$$\boxed{\sum_{(i,j)<X} sub(i,j) = \sum_{(i,j)>X} sub(i,j)}$$

Switching planning

Example locations

$R1 = 81 + 326 + 81 = 488$ $S1 = R1 = 488$

$R2 = 122 + 407 + 163 = 692$ $S2 = S1 + R2 = 1180$

$R3 = 81 + 366 + 204 = 651$ $S3 = S2 + R3 = 1183$

$R4 = 156 + 40 + 323 + 284 + 122 = 925$ $S4 = S3 + R4 = 2756$

$R5 = 391 + 236 + 323 + 323 + 326 + 41 + 43 + 43 = 1726$

$S5 = S4 + R5 = 4482$

$R6 = 234 + 235 + 194 + 150 + 132 + 190 + 222 + 188 = 1545$

$S6 = S5 + R6 = 6027$

$R7 = 38 + 208 + 326 + 310 + 240 + 283 + 317 + 317 = 2039$

$S7 = S6 + R7 = 8066$

$S_{TOT} = S7$

$S_Y = S_{TOT}/2 = 8066/2 = 4033$

0	0	81	326	81	0	0	0	*R1*
0	0	122	407	163	0	0	0	*R2*
0	0	81	366	204	0	0	0	*R3*
156	40	323	284	122	0	0	0	*R4*
391	236	323	323	326	41	43	43	*R5*
234	235	194	150	132	190	222	188	*R6*
38	208	326	310	240	283	317	317	*R7*

Optimum location according to the simplified method is the median of the accumulated subscribers sum – 4033 is within row **5 (Y=R5)**

Switching planning

Location problem

Graph model (subscribers in nodes)

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Switching planning

Location problem - graph model

Graph model presents network nodes and links connecting these nodes - cost function, *C*, is a ***discrete function*** over all node locations, i.e. it is not possible to use partial derivatives of *C*

Obvious solution is to calculate the total network cost, *C*, for ***all combinations*** (solutions) and find the smallest *C = Cmin*

Distances calculation as distances on graph – ***shortest path*** problem and corresponding algorithms

For *n* nodes and *N* equipment items $\frac{n!}{(n-N)!\,N!}$ cost combinations

Switching planning

Location problem - graph model

Check all combinations - for very small networks - pointless to investigate many of the combinations

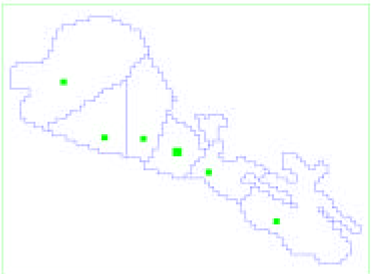
Heuristic methods - eliminate the obvious senseless combinations and investigate only some of the combinations

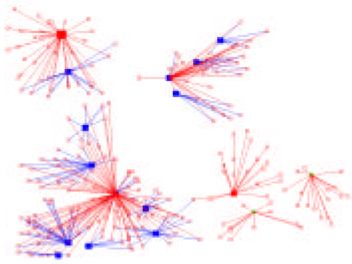
Probabilistic methods for location optimization - Simulated annealing / Simulated allocation / Genetic algorithms

Switching planning

Boundaries problem

grid model





graph model

Switching planning

Boundaries problem

Boundary optimization is finding service/exchange area boundaries in such a way that total network costs is minimized

The cost of connecting one subscriber at location (x,y), belonging to traffic zone K, to an exchange/node E at (x_E, y_E) can thus be expressed as :

$$C(E) = C_j(K,E) + C_b(E) + D_E \cdot C_s(D_E) + C_f$$

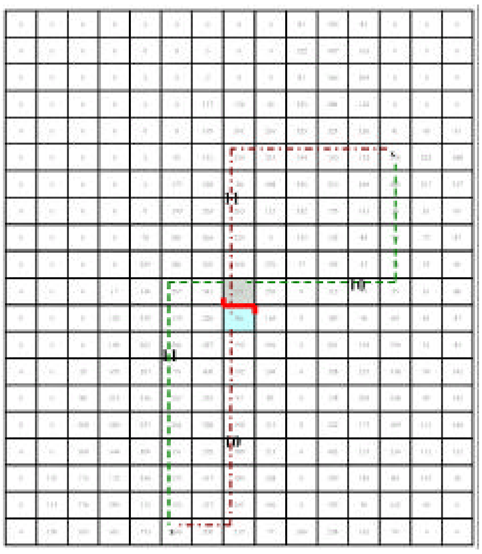
It depends of the cost of connecting the subscriber, the average exchange cost per subscriber, the backbone network cost of any subscriber

The decision for the boundary can be made simply by comparison for every grid/node element (i,j) – the value $C(E)$ is calculated for every exchange /node E and the lowest $C(E)$ then determines E

Switching planning

Example boundaries

- ❖ Grid element with 271 subscribers on a distance of 10 steps to upper exch. and 11 lo lower exch. – attach to service area of upper exch.
- ❖ Grid element with 86 subscribers on a distance of 11 steps to upper exch. and 10 lo lower exch. – attach to service area of lower exch.
- ❖ Boundary between grid elements 271 and 86

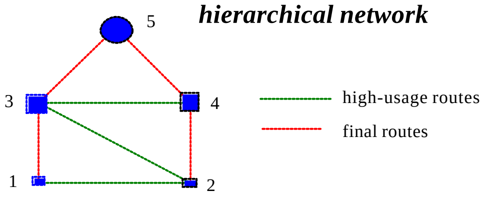


Routing planning

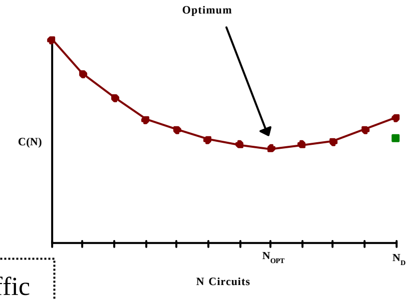
transiting of traffic

Direct routing

hierarchical network



High-usage route – part of the traffic is carried on the direct route and the rest of the traffic overflows through a tandem



Dual homing (load sharing)

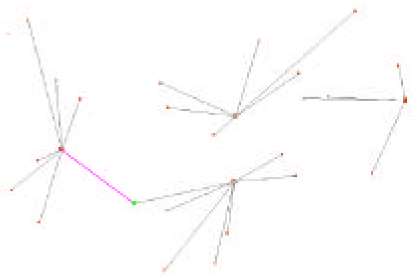
alternative routes

Primary routes with Poisson-type offered traffic

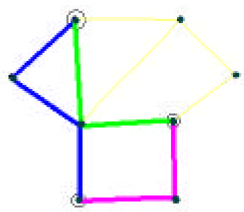
Routing planning

Dual homing (load sharing) - overflowing traffic is divided with predefined coefficient *a*

Disjoint Routing Problem of Virtual Private Networks (VPN) – demands must be routed through a network so that their paths do not share common nodes or links



Combinatorial optimization



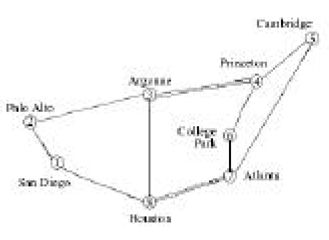
methods for ***non-hierarchical routing*** optimize routing and simultaneously optimally dimension link capacities

disjoint routing

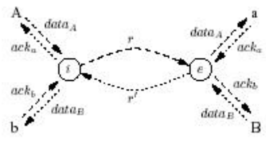
Routing planning

IP networks typically use **OSPF** to find ***shortest routes*** between points – result could be that links on shortest routes are congested while other links remain idle

Traffic engineering in **MPLS** means that traffic flows can be controlled in order to balance link loads.
Quality of service control in MPLS means that bandwidth can be reserved for traffic flows.



LSP design problem



all packets of a flow may follow the same path, the so-called ***label switched path*** LSP

Packet flow in the forward and reverse directions

Routing planning

LSP design problem

OPT1
A possible optimization criterion when computing LSP designs is the minimization of the maximum arc load

For a given traffic matrix T find a LSP design P such that

$$M(P,T) \to \min .$$

As a result arcs with high utilization are avoided whenever possible, so that the traffic is more uniformly distributed

heuristic optimization algorithms

OPT2
A second optimization principle is to set up the LSP design for the traffic demands along the shortest possible paths like in standard IP routing,

For a given traffic matrix T find a LSP design P such that

$$\sum_{a \in A} l_{P,T}(a) \to \min .$$

The paths contained in a solution P are shortest paths in terms of number of arcs used