ITU Seminar

Bangkok, Thailand , 11-15 November 2002

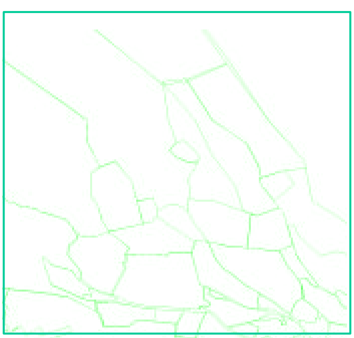
Session 4.2

Switching/Routing
and
Transmission planning

Switching planning

Location problem

Subscriber zones / subscriber grid model



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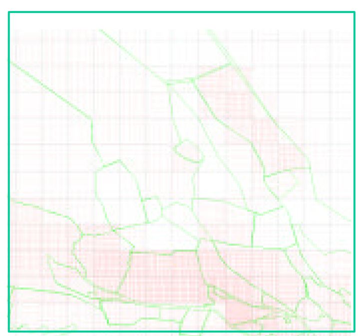


Switching planning

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 :

$$\left.\begin{array}{l} \P C / \P X_E = 0 \\ \P C / \P Y_E = 0 \end{array}\right\} \text{for E} = 1,2, \ldots \text{NEX}$$

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

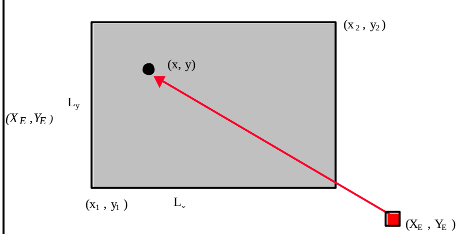
In the most complicated case we get a system of 2**NEX* ***non-linear equations***

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 :

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

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

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

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 :

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

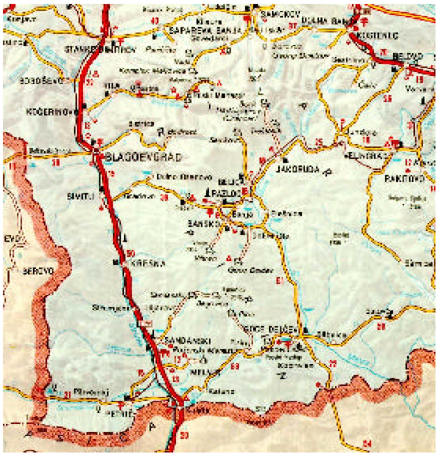
Finally if disregard the tr. media cost (same everywhere) we get:

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

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

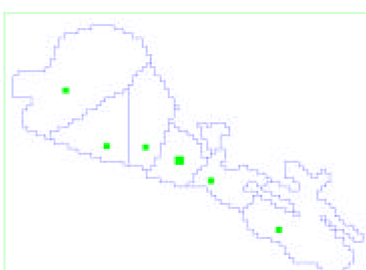
Heuristic methods - eliminate the obvious senseless combinations and investigate only some of the combinations

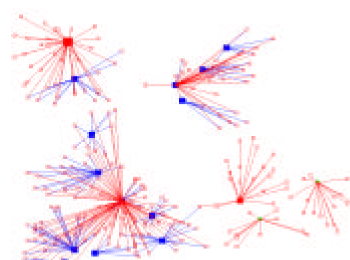
Probabilistic methods for location optimization - simulated annealing / simulated allocation

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

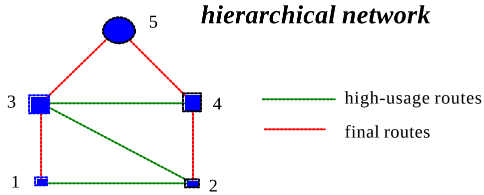
The decision for the boundary can be made simply by comparison for every grid/node element *(i,j)* – the value *C(E)* is calculated for every exchange /node *E* and the lowest *C(E)* then determines *E*

Routing planning

transiting of traffic

Direct routing

hierarchical network

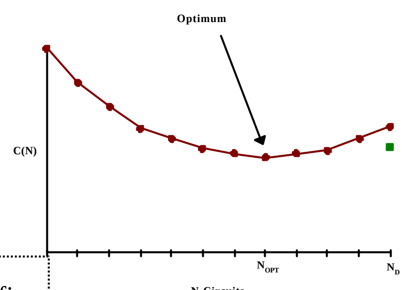


Dual homing (load sharing)

alternative routes

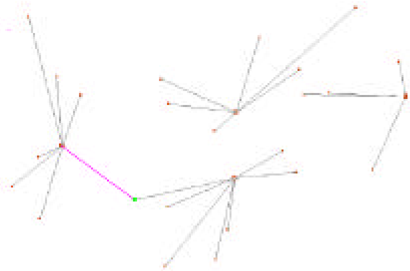
Primary routes with Poisson-type offered traffic

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



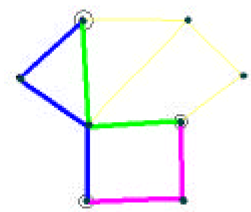
Routing planning

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

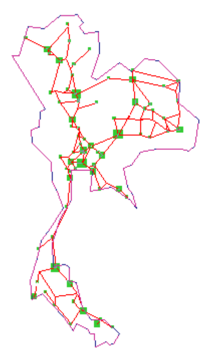
Combinatorial optimization



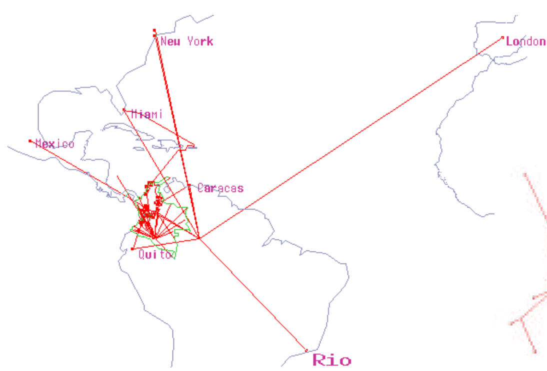
methods for ***non-hierarchical routing*** optimize routing and simultaneously optimally dimension link capacities

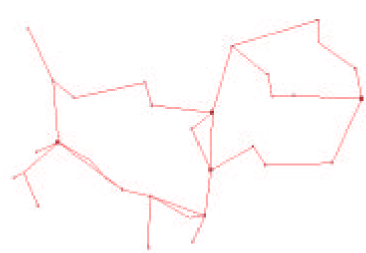
disjoint routing

Transmission planning



Based on circuit/bandwidth matrix and transmission node/link data





Transmission planning

Optimization of ring/mesh protected transport networks

Two types of nodes could be distinguished in the network :
- traffic access nodes –
  represent the abstract traffic entry points (e.g. local exchange)
- transmission nodes –
  represent the actual network nodes (e.g. ADMs or DXCs)

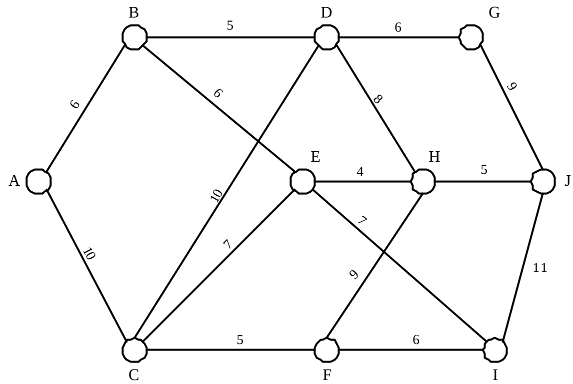
Requirements to the topology for protection -
- ring or mesh topologies, multi-ring structures, hybrid ring-mesh topologies
- different protection schemes: path protection, link protection, path diversity

In the optimization methods are solved combinatorial problems usually with heuristic algorithms and based on the shortest path approach

Transmission planning

Shortest path problem

- to determine the "shortest path" between any two nodes as minimum distance
- to determine the minimum cost path between two nodes



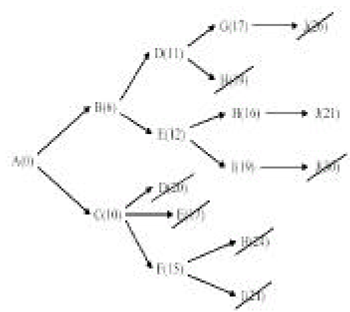
Transmission planning

➢ examine the adjacent nodes and label each one with its distance from the source node

➢ examine nodes adjacent to those already labeled; when a node has links to two or more labeled nodes, its distance from each node is added to the label of that node; the smallest sum is chosen and used as the label for the new node

➢ repeat above until either the destination node is reached (if the shortest route to only one node is required) or until all nodes have been labeled (if the shortest routes to all nodes are required)

***Shortest path problem* – algorithm of Dantzig**



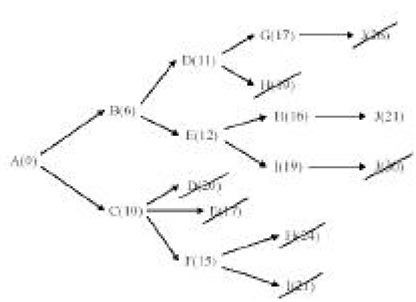
Transmission planning

Shortest path problem

✓ shortest path from *A* to *J*

✓ all partial paths contained in the path from *A* to *J-(ABEHJ)*: *(AB), (ABE), (ABEH), (BE), (BEH), (BEHJ), (EH), (EHJ), (HJ)* are optimal paths, e.g. from *B* to *J*, the optimal path is *(BEHJ)*

✓ every optimal path consists of partially optimal paths



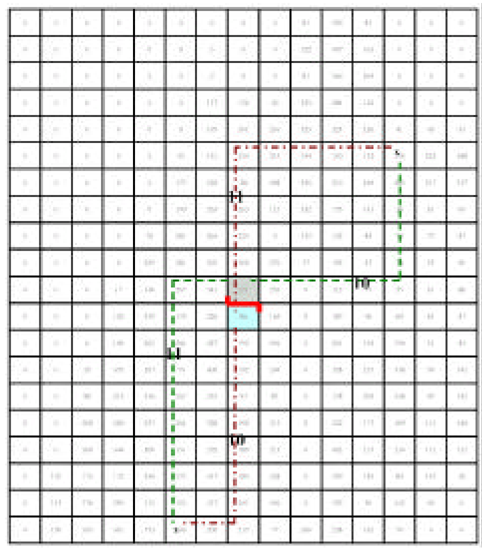
Switching planning

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



Switching planning

Example locations

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

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

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

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

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

$S5 = S4 + R5 = 4482$

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

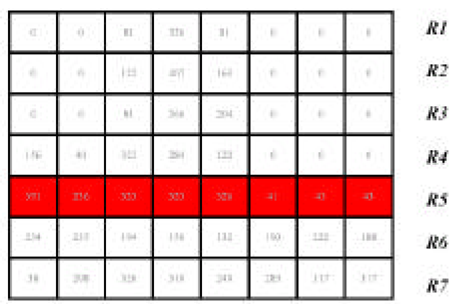
$S6 = S5 + R6 = 6027$

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

$S7 = S6 + R7 = 8066$

$S_{TOT} = S7$

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



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