THE ALGORITHM APPLICATION FOR TELECOMMUNICATION ROUTING

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ABSTRACT: **In telecommunication networks, routing is an important issue. For this reason, we study to apply some efficient algorithms on the Mobile Station Roaming Numbers routing.**

1 Architecture of the GSM network

A GSM network is composed of several functional entities, whose functions and interfaces are defined. Figure 1 shows the layout of a generic GSM network. The GSM network can be divided into three broad parts. The Mobile Station is carried by the subscriber, the Base Station Subsystem controls the radio link with the Mobile Station. The Network Subsystem, the main part of which is the Mobile services Switching Center, performs the switching of calls between the mobile and other fixed or mobile network users, as well as management of mobile services, such as authentication. Not shown is the Operations and Maintenance center, which oversees the proper operation and setup of the network. The Mobile Station and the Base Station Subsystem communicate across the Um interface, also known as the air interface or radio link. The Base Station Subsystem communicates with the Mobile service Switching Center across the A interface.

```
,---------------------------------------------------------------------------,
|         Um                           A                                     |
|      Interface       A-bis       Interface                                 |
|          |         Interface         |  ,--------------------,             |
|                                         |  ,-----,  ,-----,  |             |
|          |  ,----------|----------,  |  |  | VLR |  | HLR |  |  ,-------,  |
| ,-----,     |  ,-----,            |     |  `-----'  `-----'  |  | Other |  |
| | SIM |  |  |  | BTS | | ,-----,  |  |  |  ,-----,           |  | MSCs  |  |
| `--,--'     |  `-----'---|     |  |     |  |     |--------------'-------'  |
|    |     ,  |     :    | | BSC |-----------| MSC |           |             |
| ,-----, /|  |  ,-----,---|     |  |     |  |     |--------------,------,   |
| | MS  |' | ,---| BTS | | `-----'  |  |  |  `-----'           |  / PSTN / \  |
| `-----'  |/ |  `-----'            |     |  ,-----,   ,-----, | \  ISDN  /  |
|          '  `----------|----------'  |  |  | EIR |   | AC  | |  `------'   |
|                                         |  `-----'   `-----' |             |
|          |  Base Station Subsystem      `--------------------'             |
|                                           Network Subsystem                |
`----------------------------------------------------------------------------'
SIM  Subscriber Identity Module        HLR  Home Location Register
MS   Mobile Station                    VLR  Vistor Location Register
BTS  Base Transceiver Station          EIR  Equipment Identity Register
BSC  Base Station Controller           AC   Authentication Center
MSC  Mobile services Switching Center  PSTN Public Switched Telecomm Network
VLR  Visitor Location Register         ISDN Integrated Services Digital Network
```

Figure 1

2. GSM Call Routing

When a mobile subscriber roams into a new location area (new VLR), the VLR automatically determines that it must update the HLR with the new location information, which it does using an SS7 Location Update Request Message. The Location Update Message is routed to the HLR through the SS7 network, based on the global title translation of the IMSI that is stored within the SCCP Called Party Address portion of the message. The HLR responds with a message that informs the VLR whether the subscriber should be provided service in the new location.

When a user dials a GSM mobile subscriber's MSISDN, the PSTN routes the call to the Home MSC based on the dialed telephone number. The MSC must then query the HLR based on the MSISDN, to attain routing information required to route the call to the subscribers' current location.

The MSC stores global title translation tables that are used to determine the HLR associated with the MSISDN. When only one HLR exists, the translation tables are trivial. When more than one HLR is used however, the translations become extremely challenging, with one translation record per subscriber (see the example below). Having determined the appropriate HLR address, the MSC sends a Routing Information Request to it.

When the HLR receives the Routing Information Request, it maps the MSISDN to the IMSI, and ascertains the subscribers' profile including the current VLR at which the subscriber is registered. The HLR then queries the VLR for a Mobile Station Roaming Number (MSRN). The MSRN is essentially an ISDN telephone number at which the mobile subscriber can currently be reached. The MSRN is a temporary number that is valid only for the duration of a single call.

The HLR generates a response message, which includes the MSRN, and sends it back across the SS7 network to the MSC. Finally, the MSC attempts to complete the call using the MSRN provided.

3. Finding the optimal trunk selection for MSRN routing

The key thing here is how to select the trunk routing optimally to route the MSRN. It has to consider many factors. Since the network has complicated connections, routing selection will have to deal with a lot of factors: 1. the number of trunks for each trunk group. 2. the number of direct connecting nodes. 3. the capacity for each trunk group. 4. the traffic flow change in that area. 5. The stability of the trunk. 6. the technology of the transmission.

I plan to apply some efficient algorithms which I have learned from this course on this MSRN routing selection. Considering all these factors, I will convert them as several weights on the trunk connection when I apply the algorithms.

Let's say we have a connected graph $G=(V, E)$. V stand for MSC nodes in the network. E stand for the trunk groups. Each edge e is a trunk group, with a given available trunk Devices D_e.

For each pair of nodes $u, v \in V$, we want to select a single u-v path P on which this pair will routing the MSRNs to each other. The path available trunk Devices D(P) is the minimum available trunk Devices of any edge it contains; that is , $D(P) = \min(D_e), e \in P$. The best achievable trunk resource for the pair u, v in G is simply the maximum, over all u-v path P in G, of the value D(P).

It's getting to be very complicated to keep track of a path for each pair of nodes. Maybe we can find a spanning tree T of G so that for every pair of nodes u, v, the unique u-v path in the tree actually attains the best achievable resource for u, v in G. We will use the idea of MST equivalent to Kruskal's algorithm except that we consider edges in non-increasing order. Thus, the algorithm generates a maximum spanning tree.

Algorithm:

Sort the edges by non-increasing order, let's say $D_{e1} \geq D_{e2} \geq \ldots \geq D_{em}$

Let $T=\emptyset$

For i=1,…m

If there is no cycle in $T \cup \{e_i\}$, let $T \leftarrow T \cup \{e_i\}$

Endfor

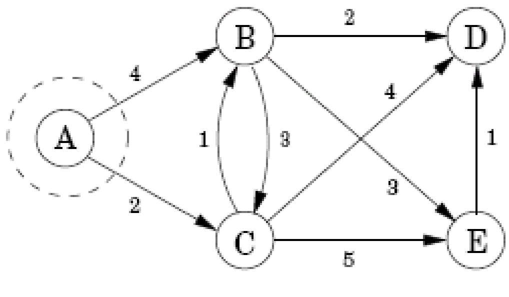
Output T

The edge sorting takes O(m log m) time. The rest steps take linear time. So, the running time of the algorithm is O(m log m).

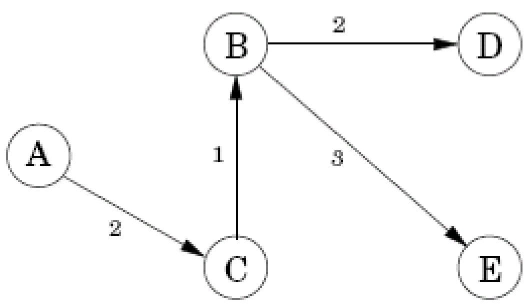
For any $u,v \in V$, let P be the path between u and v in T. Let $e^* = \min W_e, e \in P$. Assume there is another path P' between u and v in G such that $D(P')>D(P)$ (i.e. P' has better achievable resource for u and v). Note that $e^* \notin P'$. Thus, for any $e' \in P' \setminus P$, $D_{e'} \geq D(P') > D(P) = D_{e^*}$. When removing e^* from T, T is divided into two connected components C1 and C2. Since P' is a path from u to v, there is an edge $e' = (u', v') \in P' \setminus P$ such that $u' \in C1$ and $v' \in C2$. Therefore, $T \setminus \{ e^* \} \cup \{e'\}$ defines another spanning tree with large value (since $D_{e'} > D_{e^*}$), which contradicts the maximality of T.

The advantage of the Dijkstra's algorithm is finding the best paths from a single source to each other node in the graph. It's specially beneficial when adding a new MSC node into the network and trying to figure out the best routings between the new node and all other existing MSCs. We define the distance factor Wi for each edge. The Wi value is depended on the transmission equipment, the total amount of trunk

devices, the stability of the transmission system and the transmission technology. The better of these factors, the lower of the distance value Wi. The algorithm maintains a set S of vertices u for which we have determined the lowest distance factor W(u) from s; This is the “explored” part of the graph. Figure 2 shows a GSM network graph with MSC nodes A,B,C,D and E. Initially S={s}, and W(s)=0. Now, for each node v ЄV-S, we determine the most lowest factor path S to some u ЄS, followed by the single edge (u,v). That is, we consider the quantity W’(v) = min W(u) + we. We choose the node v ЄV-S for which this quantity is minimized, add v to S, and define W(v) to be the value W’(v).



(a)



(b)

Figure 2

Algorithm

procedure dijkstra(G; W; s)

Input: Graph G = (V;E), directed or undirected;

positive edge lengths {We : e Є E}; vertex s Є V

Output: For all vertices u reachable from s, dist(u) is set to the distance from s to u.

for all u Є V :

dist(u) = 1 prev(u) = nil

```
        dist(s) = 0
H = makequeue(V ) (using dist-values as keys)
while H is not empty:
        u = deletemin(H)
        for all edges (u; v) Є E:
                if dist(v) > dist(u) + W(u; v):
                dist(v) = dist(u) + W(u; v)
                prev(v) = u
                decreasekey(H; v)
```

For n nodes and m edges graph, the running time for this algorithm takes O(mn) time. By using two algorithms, we get the optimal paths. Combining with factors, we get the best routing path.

4. Paper discussion for Wireless network routing

There is a recent paper titled " Distributed dynamic routing using ant algorithm fortelecommunication networks" by Lu Guoying, Zhang Subing, and Liu Zemin describing a distributed dynamic routing (DDR) approach, and proposing a novel distributed real-time dynamic routing (DRDR) approach which considers not only the utilization of resources but also the load balance in telecommunication networks. In the approach, according to the concrete problems of dynamic routing, they construct a globally-optimizing ant algorithm, which is based on the ability of ants to find the shortest path between their nest and the food source when looking for food, to realize the route optimization. Simulation results show that the proposed approach can realize distributed dynamic routing effectively according to the current traffic states in the networks and the user-specified delay requirements.

5. Open problems and Challenges

When using Dijkstra's algorithm, how to combine all the factors and precisely define the distance factor is one of challenges. Because it covers many factors, It will affect the efficiency of the result. Using the number of available trunks as the weight of edge in Kruskal's algorithm is another open question. Shall we get better result if we choose other factors? All these questions and challenges are waiting for further research and experiments.