SCIENCE CHINA
Information Sciences

• **Supplementary File** •

Multi-Objective Network Optimization Combining Topology and Routing Algorithms in Multi-Layered Satellite Networks

Zhuoming LI[1*], Huiyun XIA[1], Yu ZHANG[2], Junqing QI[3], Shaohua WU[4] & Shushi GU[4]

[1]*School of Electronics and Information Engineering, Harbin Institute of Technology, Harbin* 150001*, China;*
[2]*School of Computer Science and Technology, Harbin Institute of Technology, Harbin* 150001*, China;*
[3]*Beijing Institute of Astronautical Systems Engineering, Beijing,*100037*, China;*
[4]*Communication Engineering Research Center, Harbin Institute of Technology (Shenzhen), Shenzhen* 518055*, China*

Appendix A Network initialization

In the network initialization process, the Prim and the Dijkstra algorithm are applied to access other nodes, and α is adopted to adjust the priority between the two algorithms, here $\alpha = 0.5$ [1].

Define node set $T = (t_1, t_2, ..., t_i)$, where t_1 is the central node, and t_i is the last node accessing the network. The following algorithm is used to generate a network tree.

Step 1, spanning tree process, only one node at a time accesses the network.

Step 2, each time selecting a node, the cost between nodes C_{ij} needs to be corrected. If $C_{1j} > \alpha C_{1i} + C_{ij}$, that is, after the correction the cost between current node and the central node is smaller, update the cost, or it will not be updated.

Step 3, each time the rest nodes accessing the network, the node with the lowest link cost C_{ij} is connected to the network until all the nodes are connected to the network.

The pseudo-code of this algorithm is as below.

Algorithm 1: network initialization

Input: The link cost matrix C_{n*n}, α, and the central node.

Output: The node set T.

Assuming that the central node has been selected by calculating the quality factor described in network initialization section in the paper. Add the central node into T, and its index is 1.

Process:

```
1: Choose the nearest node i from the central node.
2: for k = 1:n-1
3:     for j=1:n
4:        if C_1j > αC_1i + C_ij, then
5:        Update the cost C_1j = αC_1i + C_ij
6:        end if
7:     end for
8:   Choose the node with the lowest link cost C_ij to add to T.
9: end for
```

After the network initialization, the initial topology is completed, as depicted in Figure A1. Figure A1 shows that after network initialization, there are only five backbone links connecting all the nodes to ensure connectivity and there is only one link between every two nodes.

* Corresponding author (email: zhuoming@hit.edu.cn)

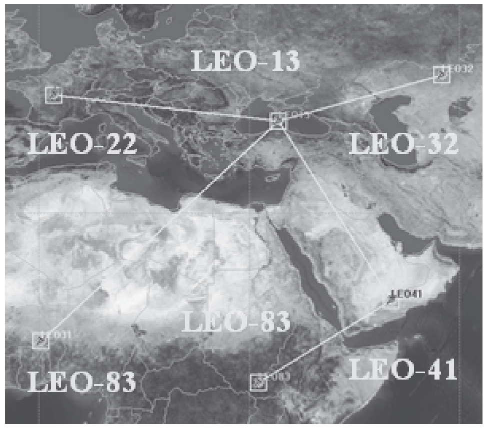

Figure A1 the topology after network initialization

Appendix B The networking optimization combining topology and routing algorithms

Network initialization cannot ensure that any node pair meets the network quality of service and the network stability cannot be guaranteed either. Therefore, a three-objective optimization combining topology and routing algorithms is proposed. The network optimization process combining the topology and routing algorithm can be implemented in the following Algorithm 2.

Algorithm 2: network optimization combining topology and the routing algorithm

---

Input: The link cost matrix C_{n*n}, the link demand matrix R_{n*n}, α, the stability threshold λ_T, the threshold of cost reduction of path (i,j) ΔC_T, and the threshold of requirement reduction of path (i,j) R_{n*n}.

Output: The adjacency matrix A.

Process:

Network initialization implementing Algorithm 1.
Calculate the hop matrix H using Dijkstra algorithm
while(TRUE), do
  if all the values in H is less than 2, then
    Calculate natural connectivity $\overline{\lambda}$
    while $\overline{\lambda} < \lambda_T$, do
      Choose the maximum R_{ij} $(R_{ij} < R_T)$, and create a new link, update $H(i,j) = 1$ and $R(i,j) = R_T$
      Calculate $\overline{\lambda}$
    end
    break
  else
    Traverse H, select the maximum $H(i,j)$
    if $(\Delta C_{ij}{}^p) \cdot R_{ij}{}^{1-p} \geqslant \Delta C_T{}^p \cdot R_T{}^{1-p}$, then
      Create a new link between (i,j) , and update the value of $H(i,j)$ to 1.
    else
      Separate (i,j) into (i,k) and (k,j), and minimize (k,j), let $H(i,k) = 1$ and in the same row or column with $H(i,j)$
    end if
  end if
end

References

1 Hsu C Y, Wu J L C, Wang S T, et al. Survivable and delay-guaranteed backbone wireless mesh network design[J]. Journal of Parallel & Distributed Computing, 2008, 68(3):306-320.