A Hybrid Management Substrate Structure for Adaptive Network Resource Management

D.Tuncer, M.Charalambides, H. El-Ezhabi and G.Pavlou
Department of Electronic & Electrical Engineering
University College London, UK

ManFi
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In-network Management Approach

• In-network management framework for dynamic reconfiguration of network resources in fixed backbone networks.

• Coordinated decision-making process distributed across network edge nodes, organised into a management substrate (MS).

• Logical structure used to facilitate the exchange of information between distributed decision-making points.
Substrate Structure

• The structure can influence the performance in terms of:
  ➢ Communication overhead (delay and volume of signalling messages)
  ➢ Volume of information to be maintained at each MS node.

• Previous work [1] has investigated simple structures

Hybrid Substrate Structure

- Development of algorithms to compute the ring and hybrid structures with the objective of minimizing the communication overhead between MS nodes.
Substrate Characteristics

• We define the communication overhead by the volume of signalling messages and the delay.

• We model the delay between two MS nodes by a logical link cost as follows.

\[ C_{LL}(i,j) = \sum_{l \in \mathcal{L}} \delta_{ij}^l \cdot c(l) \]

where

\[ c(l) = c_\alpha(l) \cdot c_\varphi(l) \]

Administrative cost

Link distance factor

\[ c_\varphi(l) = \frac{d_l}{\min_{l \in \mathcal{L}} (d_l)} \]
Ring Construction Algorithm

• **Objective:** to determine the order according to which nodes are connected in the ring, so that the total delay is minimized.

• This problem is similar to the Travelling Salesman Problem.

• We use the Nearest Neighbours tour construction algorithm.

  ➢ **Main principle:** select node $j$ as the successor of node $i$ such that the communication cost $C_{LL}(ij)$ is the lowest.
Multiple Rings Construction Algorithm

- **Objective**: to determine how to partition MS nodes into clusters and compute the resulting sub-rings.
- Nodes are clustered based on their proximity w.r.t. the logical link cost.
- The algorithm provides a set of clusters and the ring structure within each cluster.
- Parameters of the algorithm: clustering threshold, logical link cost model and initial node selection criteria.
Intermediate Entity Selection Algorithm

- **Objective:** to determine which node to select in each cluster to act as a proxy, i.e. interface between the different sub-rings.

- Proxy nodes are selected according to their proximity to other sub-rings w.r.t. the logical link cost.

- The proxy node in a sub-ring is the one which is the closest, on average, to every other remote nodes in the substrate.
Communication Protocol

- Two modes of communication:
  - Local sub-ring communication
  - Remote sub-ring communication
- The overhead depends on the mode of communication.
- The number of signalling messages is proportional to the number of sub-rings, in the worst case.
Performance Evaluation

- We evaluated the performance based on the Abilene and GEANT network topologies.
- We investigated the performance of the proposed construction algorithms and the influence of the input parameters on the obtained structures.
- We evaluated the performance in terms of delay obtained with the full-mesh, ring and hybrid structures.
Nearest Neighbour Algorithm Performance

- Comparison to optimum of the cost obtained with:
  - a random ring structure
  - the structure computed by the Nearest Neighbour Algorithm
## Influence of Input Parameters

<table>
<thead>
<tr>
<th>Cost $C_{LL}$</th>
<th>Threshold $\theta$</th>
<th>Initial Node</th>
<th>Rings Size</th>
<th>GEANT Topology</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_{1 \times D}$</td>
<td>$\theta_{\text{Avg}}$</td>
<td>Lowest</td>
<td>4,6,3,2,2,2</td>
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<tr>
<td>$M_{1 \times D}$</td>
<td>$\theta_{\text{Avg}}$</td>
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<tr>
<td>$M_{1 \times D}$</td>
<td>$\theta_{\text{HalfMax}}$</td>
<td>Lowest</td>
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<tr>
<td>$M_{1 \times D}$</td>
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<tr>
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<tr>
<td>$M_{W \times D}$</td>
<td>$\theta_{\text{Avg}}$</td>
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<tr>
<td>$M_{W \times D}$</td>
<td>$\theta_{\text{HalfMax}}$</td>
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<td>15,6</td>
<td></td>
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<tr>
<td>$M_{W \times D}$</td>
<td>$\theta_{\text{HalfMax}}$</td>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost $C_{LL}$</th>
<th>Threshold $\theta$</th>
<th>Rings Size</th>
<th>Selected IE Nodes</th>
<th>$\Delta$</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

### Abilene Topology

<table>
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<th>Cost $C_{LL}$</th>
<th>Threshold $\theta$</th>
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<th>Selected IE Nodes</th>
<th>$\Delta$</th>
</tr>
</thead>
<tbody>
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<td>2,6,7,11</td>
<td>1.68</td>
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<td>$M_{W \times D}$</td>
<td>$\theta_{\text{HalfMax}}$</td>
<td>3,2,3,3</td>
<td>2,6,7,11</td>
<td>1.68</td>
</tr>
</tbody>
</table>
Delay Comparison

- Comparison of the delay obtained when MS nodes are organized in a full-mesh structure to the delay:
  - in a ring structure
  - in a hybrid structure

![Bar charts showing delay comparison between Hybrid vs. Full-Mesh and Ring vs. Full-Mesh for Abilene and GEANT](chart.png)
Conclusion

• We presented an in-network resource management framework to support distributed decision-making process.

• We investigated the use of an hybrid structure to logically connect decision-making points.

• We described different algorithms to build the proposed structure with the objective of minimizing communication overheard.

• Future work could investigate how the proposed framework could be extended to different environments (e.g. SDN).