Global Resource Capacity Algorithm with Path Splitting for Virtual Network Embedding

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Virtual Network Embedding

- Network virtualization enables support and deployment of new Internet services and applications.
- Virtual Network Embedding (VNE) problem deals with mapping virtual nodes and links onto substrate nodes and paths, respectively.

Objectives

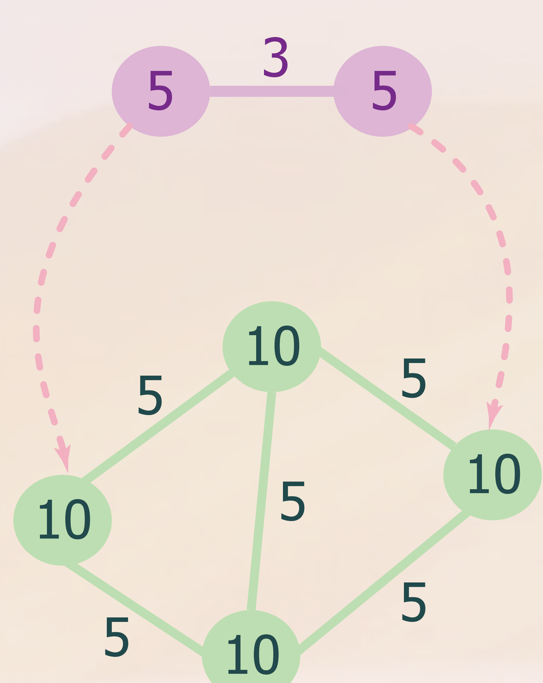
- VNE algorithms maximize the revenue of infrastructure providers while minimizing the cost of the embedding:

$$\mathbf{R}(G^{\Psi_i}) = w_c \sum_{n^{\Psi_i} \in N^{\Psi_i}} \mathcal{C}(n^{\Psi_i}) + w_b \sum_{e^{\Psi_i} \in E^{\Psi_i}} \mathcal{B}(e^{\Psi_i})$$

$$\mathbf{C}(G^{\Psi_i}) = \sum_{n^{\Psi_i} \in N^{\Psi_i}} \mathcal{C}(n^{\Psi_i}) + \sum_{e^{\Psi_i} \in E^{\Psi_i}} \sum_{e^s \in E^s} f_{e^s}^{e^{\Psi_i}}$$

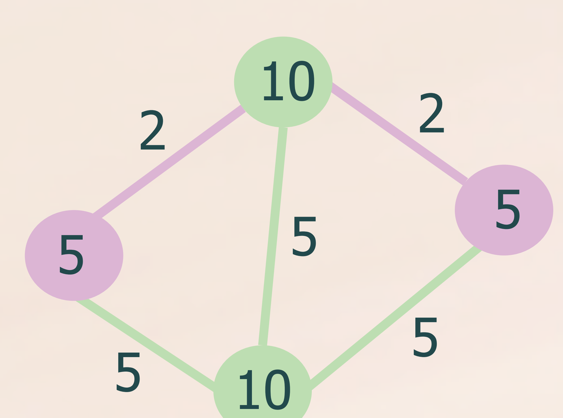
$$p_a^\tau = \frac{|\Psi^a(\tau)|}{|\Psi(\tau)|}$$

- Substrate network graph: $G^s(N^s, E^s)$
- Resources:
  - substrate nodes: CPU capacity $\mathcal{C}(n^s)$
  - substrate links: bandwidth $\mathcal{B}(e^s)$
- Virtual network graph: $G^{\Psi_i}(N^{\Psi_i}, E^{\Psi_i})$
- Resource requirements:
  - virtual nodes: CPU capacity $\mathcal{C}(n^{\Psi_i})$
  - virtual links: bandwidth $\mathcal{B}(e^{\Psi_i})$
- w_c : weight for CPU requirements (= 1)
- w_b : weight for bandwidth requirements (= 1)
- $f_{e^s}^{e^{\Psi_i}}$: total bandwidth of the substrate link e^s allocated to virtual link e^{Ψ_i}
- $|\Psi^a(\tau)|$: number of accepted Virtual Network Requests (VNRs) in a given time interval τ
- $|\Psi(\tau)|$: number of VNRs that arrived in τ

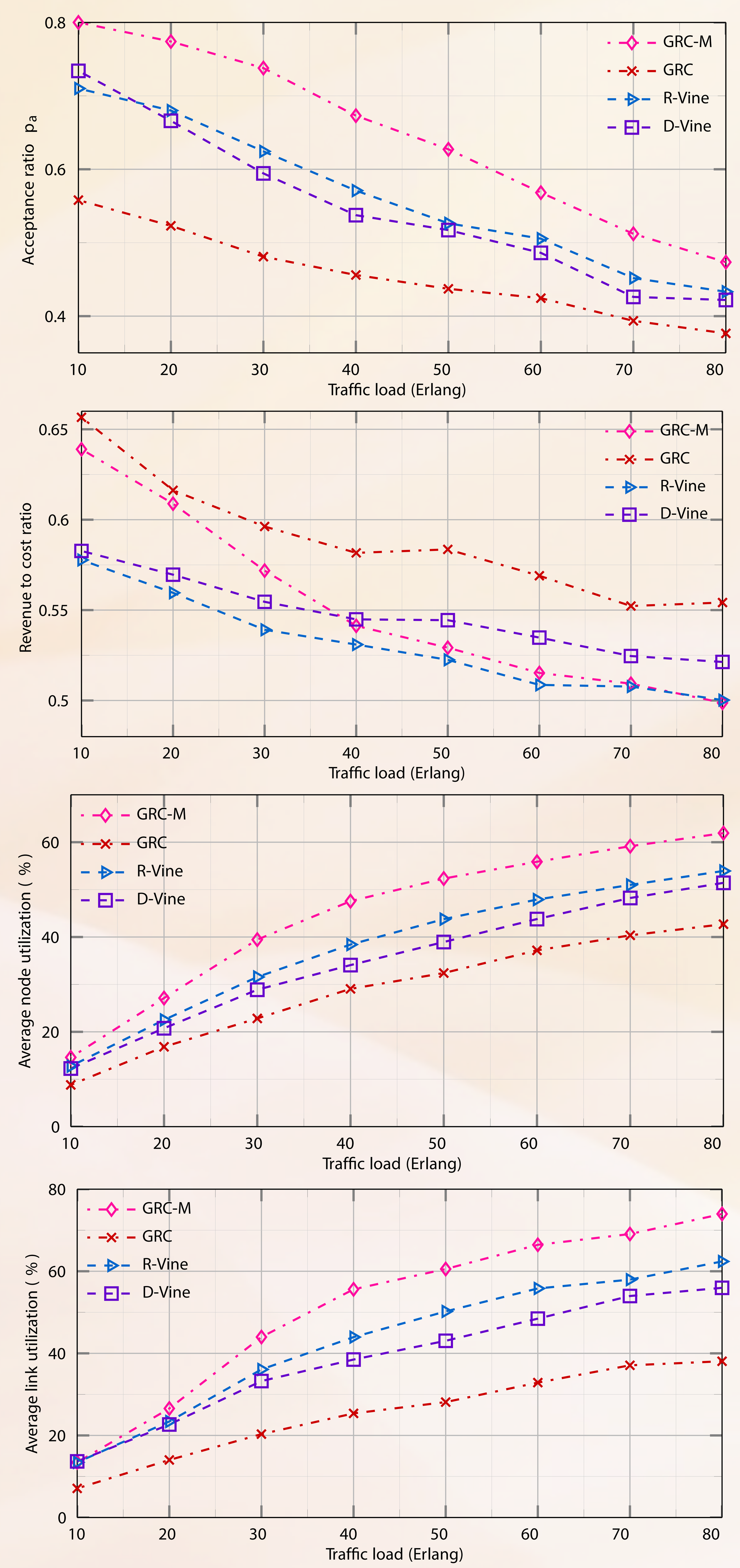


$\mathbf{R} = 13 \; (5 + 5 + 3)$

$\mathbf{C} = 16 \; (5 + 5 + 3 + 3)$



Performance Comparison



Performance of algorithms for various VNR traffic loads

GRC-M Algorithm

- GRC-M employs the Global Resource Capacity (GRC) for virtual node mapping while using the Multicommodity Flow algorithm for identifying the link mappings.
- GRC algorithm is effective in calculating the embedding potential of substrate nodes.
- MCF algorithm enables path splitting, which improves resources utilization.
- GRC algorithm calculates the embedding capacity $r(n_i^s)$ for a substrate node n_i^s:

$$\mathbf{r} = (1 - d)\hat{\mathbf{c}} + d\mathbf{M}\mathbf{r}$$

- Objective of the MCF algorithm:

$$\text{minimize} \quad \sum_{e^s \in E^s} \frac{1}{\mathcal{B}(e^s) + \epsilon} \sum_{e^{\Psi_i} \in E^{\Psi_i}} f_{e^s}^{e^{\Psi_i}}$$

Simulation Environment

- The developed VNE simulator (VNE-Sim) is based on the discrete event system specification framework.
- The substrate graph is composed of 50 nodes that are randomly placed on a 25×25 grid.
- Virtual network requests arrive according to a Poisson process.
- The maximum permissible distance for embedding VNR nodes is uniformly distributed between 15 and 25 distance units.

Conclusion

- The proposed GRC-M algorithm was compared to the existing GRC, R-Vine, and D-Vine algorithms in terms of acceptance ratio, revenue to cost ratio, and average node and link utilizations.
- GRC-M achieves:
  - the highest acceptance ratio in all simulation scenarios and thus enables embedding additional virtual network requests onto substrate network
  - a comparable revenue to cost ratio
  - the highest substrate node and link utilizations.

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