Topology-aware Virtual Network Embedding for Virtualized HPC Centers

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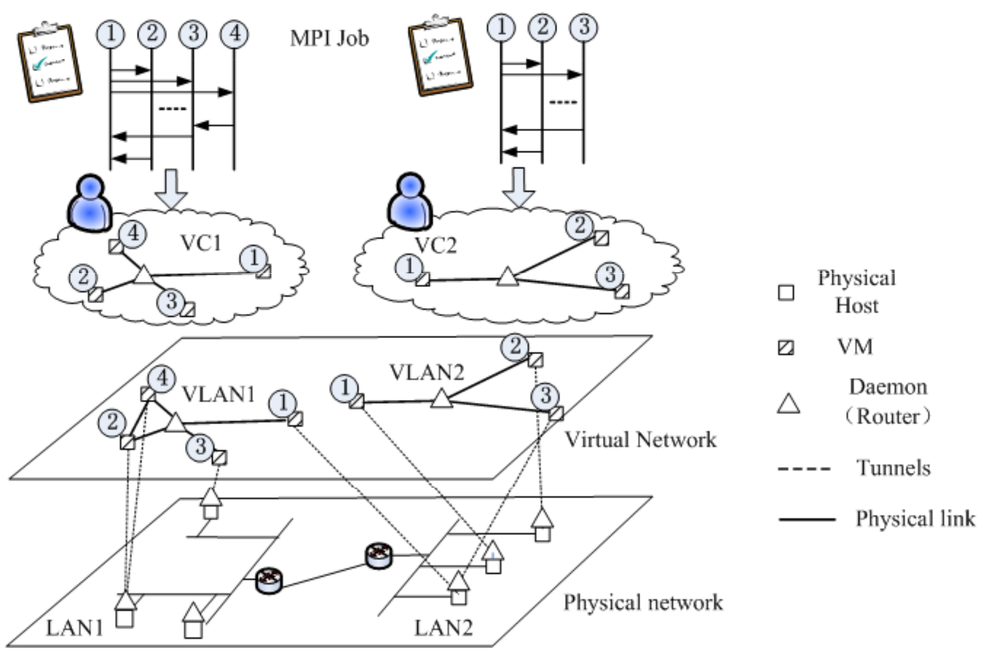
Overview

New generation virtualization technologies, such as Virtual Cluster (VC), Virtual Network (VN) and virtual resource manager accelerate the evolution of HPC centers.

Novel virtualized HPC centers are built on top of virtualization layer and provide Virtual Clusters (VCs) as execution environments for distributed applications.

In such environments, Virtual nodes are dynamically mapped onto physical nodes which improves the compatibility and flexibility of HPC centers.



Virtual Network Embedding (VNE) [1,2]: Map virtual resources (nodes and links) onto physical resources (nodes and links) according to resource requirements of VCs (applications).

Virtual network embedding algorithm should consider the network topology of :

- **Virtual network topology ---- VC (application) requirements;**
- **Physical network topology ---- substitute resources.**

This work presents a topology-aware solution for virtual network embedding problem:

- **One-stage [3,4] mapping: map nodes and links together**
- **Based on "Sub-graph Isomorphism Search[5]"**
- **Virtual network topology: mapping order**
- **Physical network topology: resource order**

Model

Physical Network $G_S = (N_S, E_S, A_S^n, A_S^e)$

Virtual Network $G_V = (N_V, E_V, A_V^n, A_V^e)$

Virtual Network Embedding $M: G_V(N_V, E_V) \rightarrow G_S(N_S', P_S')$

Revenue $$R(G_V(t)) = \sum_{e_V \in E_V} BW(e_V) + \sum_{n_V \in N_V} CPU(n_V)$$

Cost $$C(G_V(t)) = \sum_{e_V \in E_V} (BW(e_V) \bullet length(M(e_V)) + \sum_{n_V \in N_V} CPU(n_V)$$

Embedding Quality $$R/C = \frac{R(G_V(t))}{C(G_V(t))}$$

Long-term $$\lim_{T \rightarrow \infty} \frac{\sum_{t=0}^{T} R(G_V(t))}{T}$$

Objective: Satisfy resource requirements (VCs) & Improve system efficiency

Solution

Existing node evaluation $CB(n) = CPU(n) \bullet \sum_{e \in E(n)} BW(e)$

NODE EVALUATION:

- **Virtual node:** Consider the influence of neighbor nodes (direct and indirect)

$$TR(n') = \frac{CB(n')}{Dis(n, n')} \qquad sumTR(n) = \sum_{n' \in N'} TR(n') + CB(n)$$

✓ Important nodes get mapped first, Mapping order
✓ Mapping quality

- **Physical node:** Consider directly connected neighbors $N_S'(G_V^{sub})$

$$R(n) = \frac{CB(n)}{\sum_{n' \in N_S'(G_V^{sub})} Dis(n, n')}$$

✓ Quality: Important virtual nodes get better resource
✓ Performance: Success ratio of Mapping Algorithm, reduce backtracking

✓ Experiment results comparing with most related work[4].

Reference

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[4] Jens Lischka and Holger Karl. A virtual network mapping algorithm based on subgraph isomorphism detection [C]. Proceedings of Pattern Analysis and Machine Intelligence the 1st ACM workshop on virtualized infrastructure systems and architectures pages 81-88, ACM, 2009.

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