Virtual Network Embedding: A Survey

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Introduction

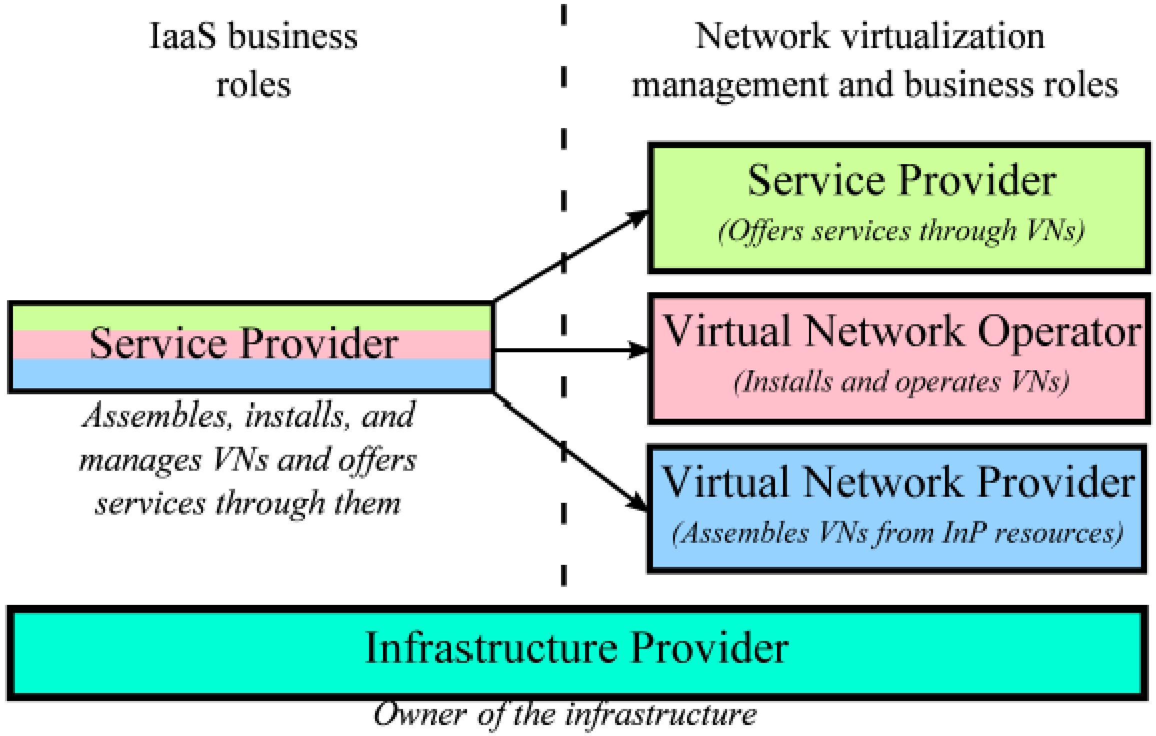


Fig. 1. Future Internet business model

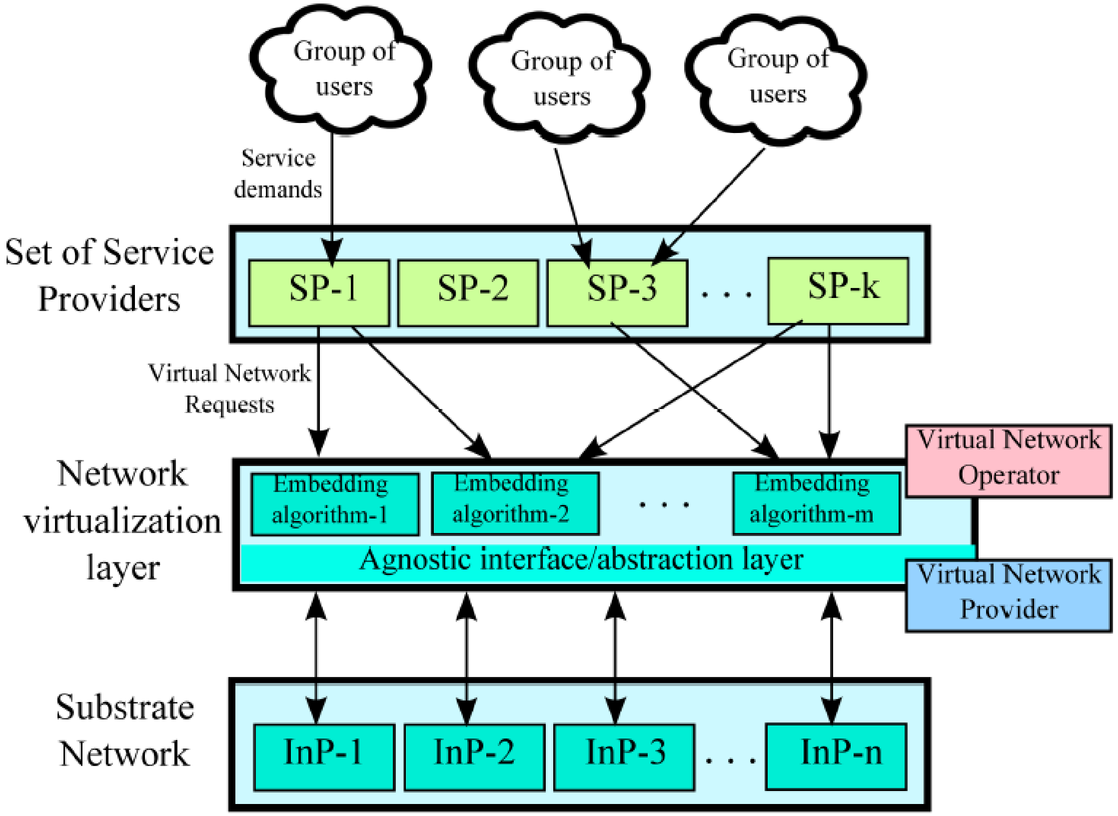


Fig. 2. Resource allocation in future Internet

Virtual Network Embedding

Problem Formula

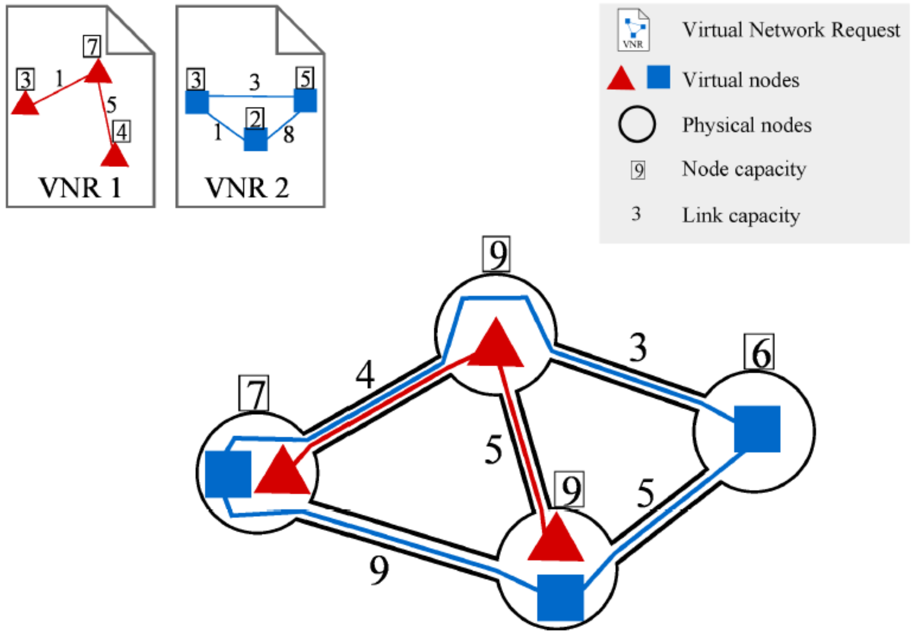


Fig. 3. Two virtual networks mapped onto one substrate network

TABLE I
TERMINOLOGY USED THROUGHOUT THIS PAPER

Term	Description
$SN = (N, L)$	SN is a substrate network, consisting of nodes N and links L
$VNR^i = (N^i, L^i)$	VNR^i denotes the i^{th} Virtual Network Request, consisting of nodes N^i and links L^i
$\dot{R} = \prod_{j=1}^{m} R_j$	$\dot{R}$ contains resource vectors for all resources $R_1, \ldots, R_m$
$cap : N \cup L \to \dot{R}$	The function cap assigns a capacity to an element of the substrate network (either node or link)
$dem_i : N^i \cup L^i \to \dot{R}$	The function dem_i assigns a demand to an element of VNR^i (either a node or a link)
$f_i : N^i \to N$	f_i is the function that maps a virtual node of VNR^i to a substrate node (VNoM)
$g_i : L^i \to SN' \subseteq SN$	g_i is the function that maps a virtual link of VNR^i to a path in the substrate network (VLiM)

Virtual Network Embedding Taxonomy

- Static v.s. Dynamic
- Centralized v.s. Distributed
- Concise v.s. Redundant

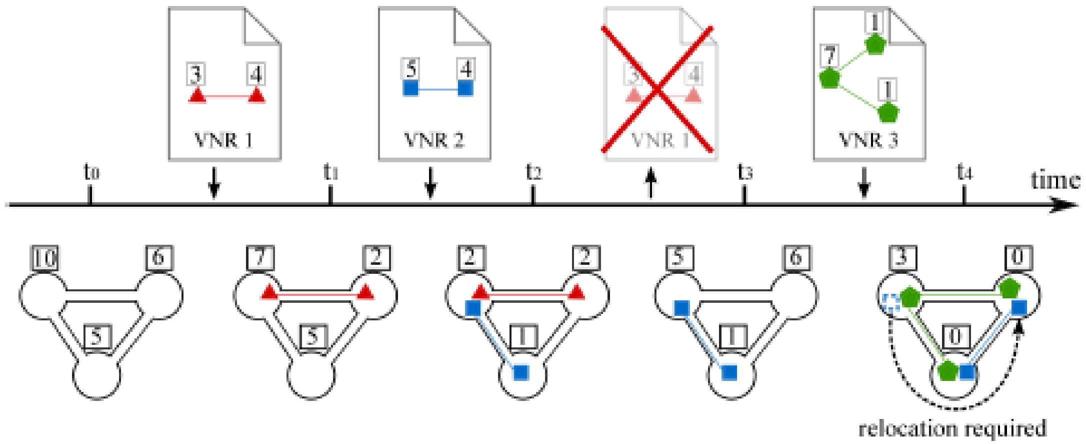
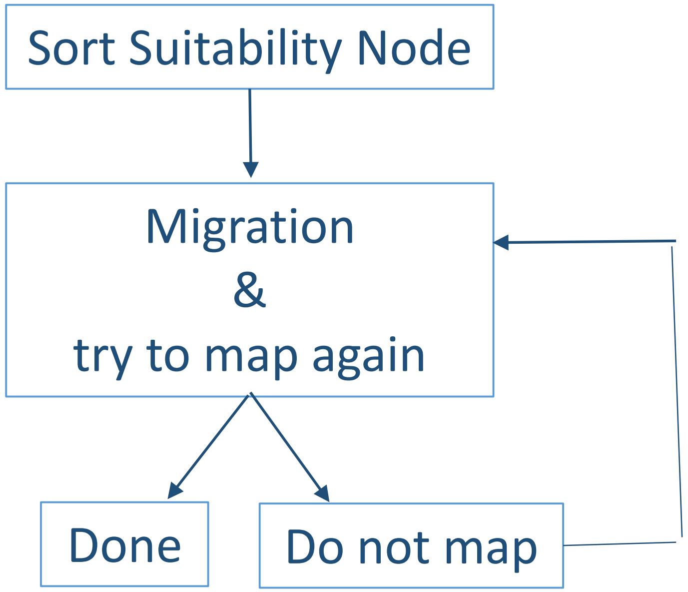


Fig. 4. Relocation of mapped VNRs in online VNE



Virtual Network Embedding Taxonomy

- Static v.s. Dynamic
- Centralized v.s. Distributed
- Concise v.s. Redundant

- Centralized
  - Global vision
  - Low reliability
  - Overwhelmed the number of VNRs to handles
- Distributed
  - Trade-off between communication cost & quality of embedding

Virtual Network Embedding Taxonomy

- Static v.s. Dynamic
- Centralized v.s. Distributed
- Concise v.s. Redundant

- Redundant
  - Trade-off between reliability & embedding cost

Computing Optimized Embedding
Main Embedding Objectives

- Provide Qos-compliant Embedding
- Maximize the Economical Profit of the Inp
- Provide Survivable VNEs

Computing Optimized Embedding Problem Decomposition and Coordination

- Uncoordinated VNE

■ Main goal : maximize the long-term average revenue

■ Stage : VNoM
virtual node with bigger demands
substrate nodes with bigger resources

■ Stage : VLiM
Single path mapping : K-shortest path
Multiple path mapping :Multicommodity Flow Problem

Computing Optimized Embedding Problem Decomposition and Coordination

- Coordinated VNE

▪ One stage

▪ BFS

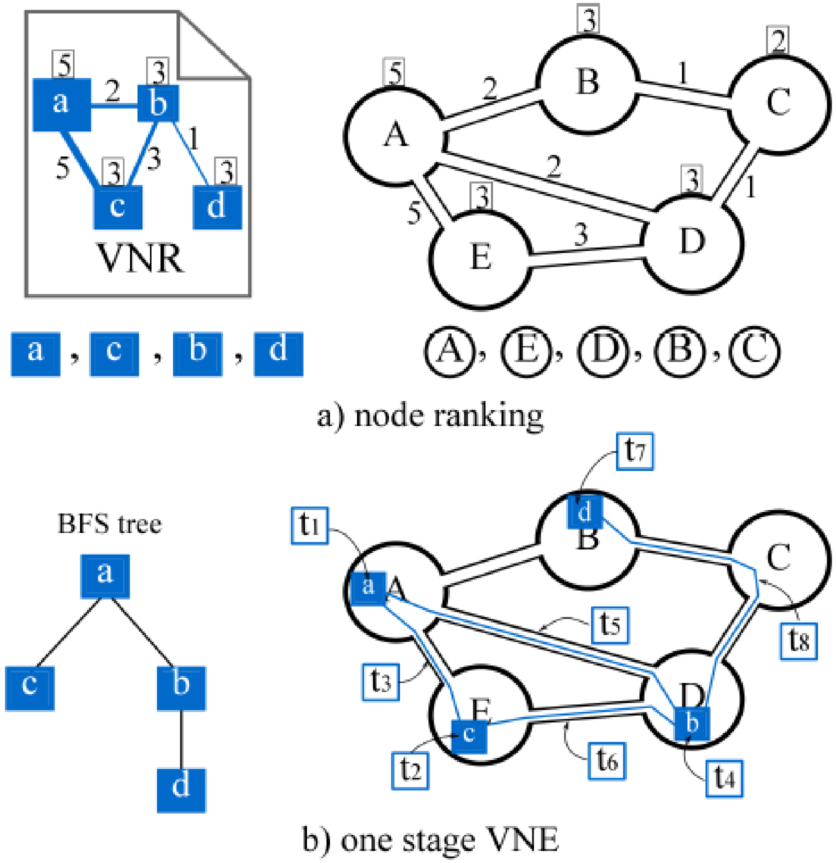


Fig. 7. VNE in one stage, as proposed in [37]

Computing Optimized Embedding Problem Decomposition and Coordination

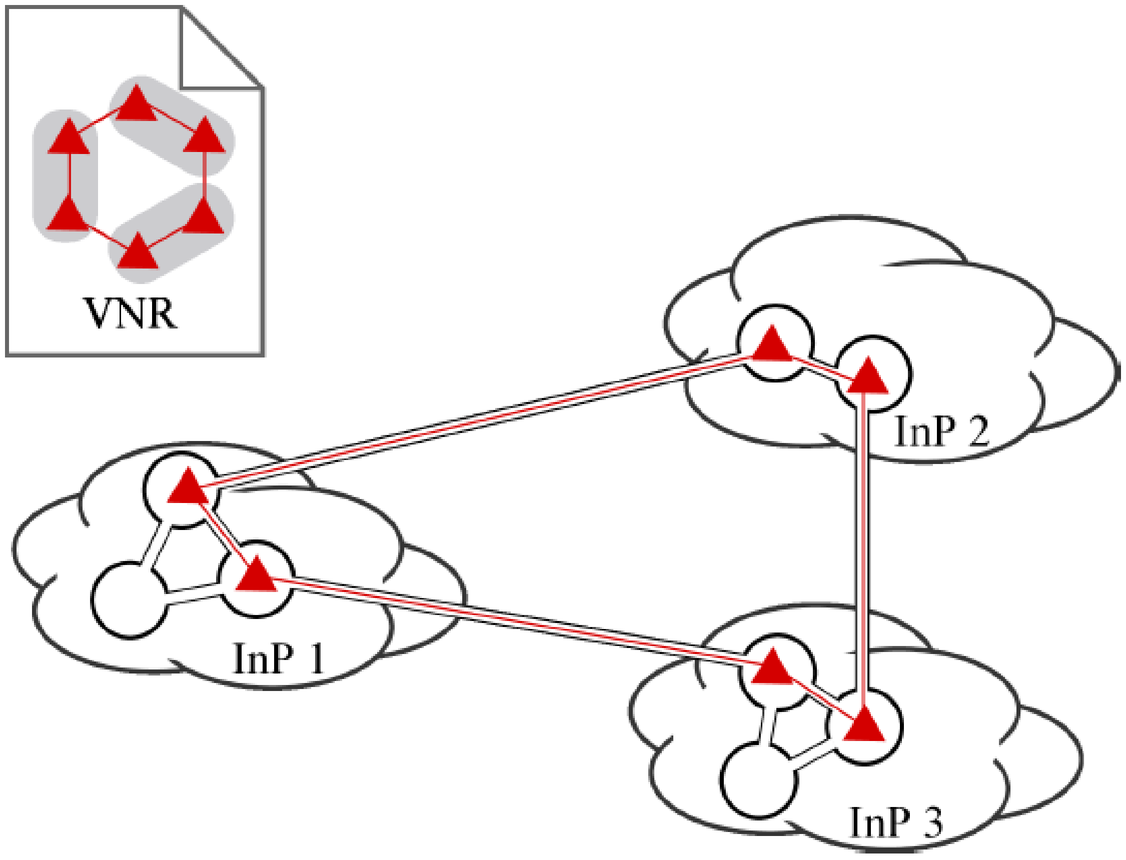


Fig. 8. Inter-InP VNE process

- InterInP Coordination
  - Split VNRs in several sub-request

Computing Optimized Embedding Optimization Strategies

- Exact solution
  use ILP to seek
  minimization of the embedding cost &
  maximization of the acceptance ratio
- Heuristic solution
  optimality for short execution time
  Subgraph Isomorphism Detection Problem

Computing Optimized Embedding Metrics

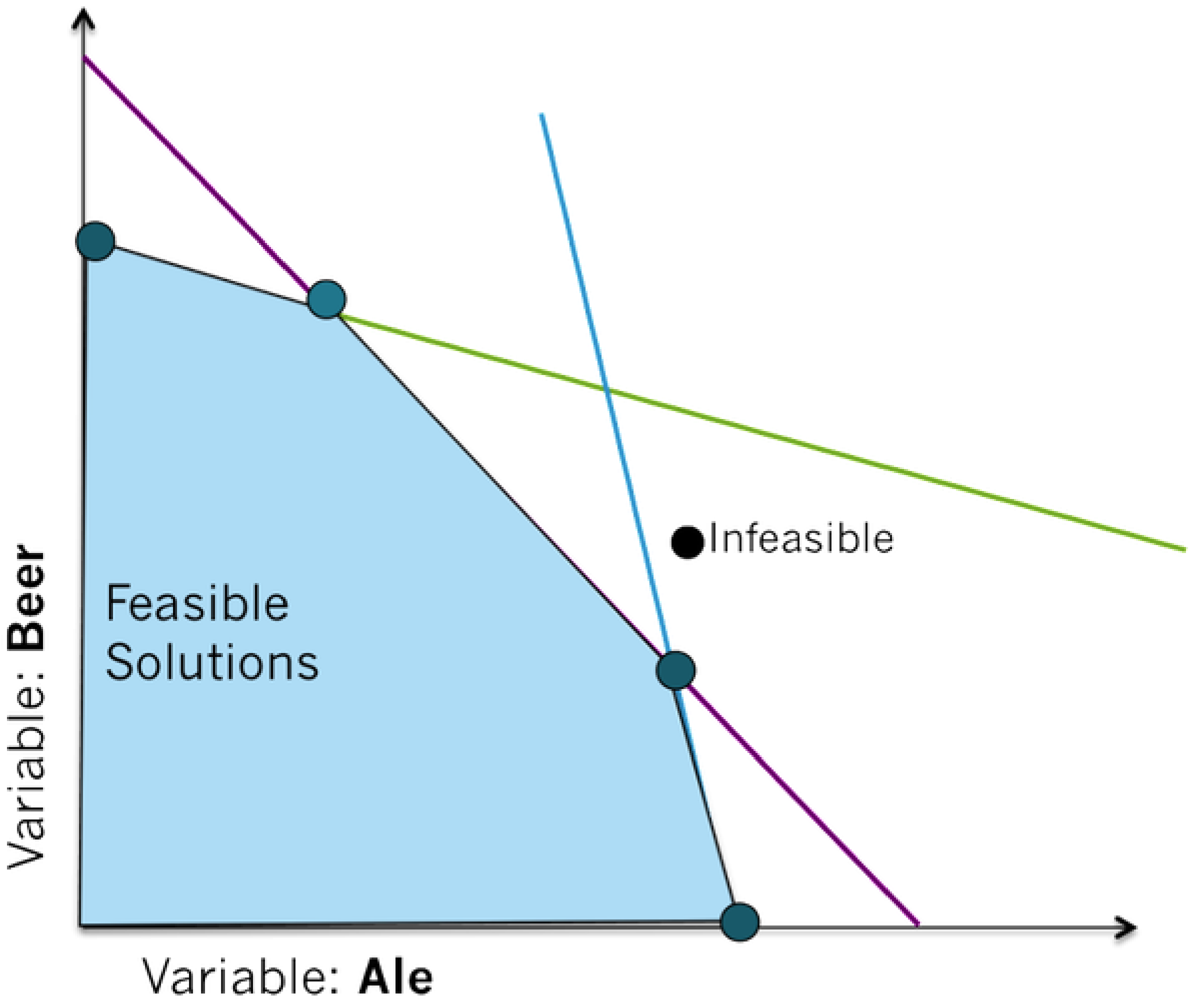
TABLE II
METRICS FOR VIRTUAL NETWORK EMBEDDING

Optimization goal	Metric	Description
Quality of Service	Path length	Describes the number of substrate links that are spanned by a virtual link on average
	Stress level	Describes the number of virtual entities realized by a substrate entity
	Utilization	Describes the sum of all spent substrate resources due to VNE divided by the sum of all provided substrate resources
	Throughput	Describes the data rate achievable between virtual nodes
	Delay	Describes the time a packet needs to travel across a virtual link
	Jitter	Describes the variance in inter-arrival times of packets on a virtual link
Resource spending	Cost	Describes the sum of all spent substrate resources for embedding VNRs
	Revenue	Describes the sum of all demanded resources of VNRs
	Cost/Revenue	Describes the ratio between spent substrate resources and provided virtual resources
	Acceptance ratio	Describes the number of VNRs that could be embedded
Resilience	Number of backups	Describes the number of available backup resources
	Path redundancy	Describes the diversity of paths in multi-path embeddings
	Cost of resilience	Describes the number of additional nodes required to maintain re-siliency
	Recovery blocking probability	Describes the ratio of unrecoverable failure scenarios vs. all failure scenarios
	Number of migrations	Describes the number of virtual nodes that have to be moved in case of failure
Other	Runtime of the algorithm	Describes the time a VNE algorithm will take for an embedding of a certain size
	Number of coordination messages	Describes the number of messages that have to be exchanged in a distributed environment in order to complete the embedding
	Active substrate nodes	Describes the number of substrate nodes that have to be powered on in order to realize the hosted virtual infrastructures

Future Research Direction

- Distributed VNE
- Green Networking
- Wireless Network

Q&A



Linear Programming