Network Virtualization issues on Market Oriented Cloud Computing

Presented By

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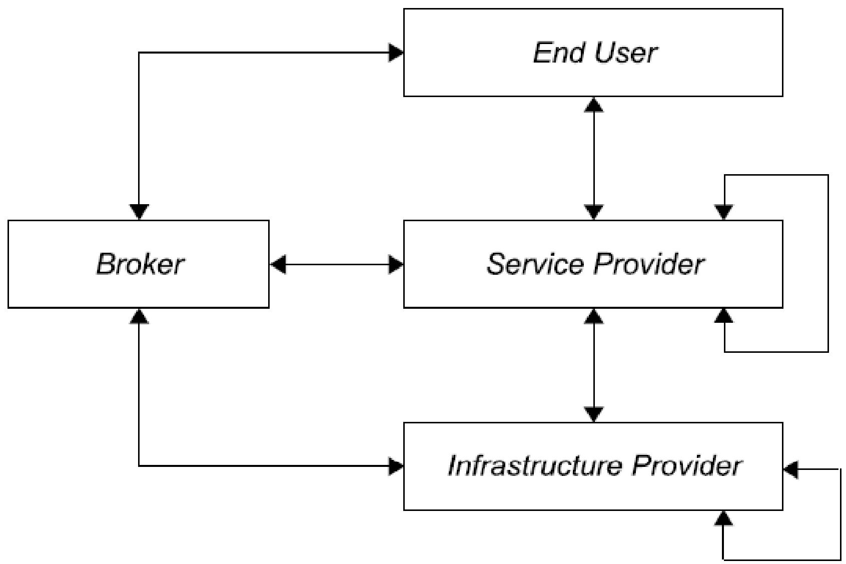
Motivation

- Due to the existence of multiple stakeholders with conflicting goals and policies, alterations to the existing Internet are now limited to simple incremental updates; deployment of any new, radically different technology is next to impossible.
- To fend off this ossification once and for all, network virtualization has been propounded as a diversifying attribute of the future inter-networking paradigm.
- By allowing multiple heterogeneous network architectures to cohabit on a shared physical substrate, network virtualization provides
  - flexibility
  - promotes diversity
  - promises security and increased manageability

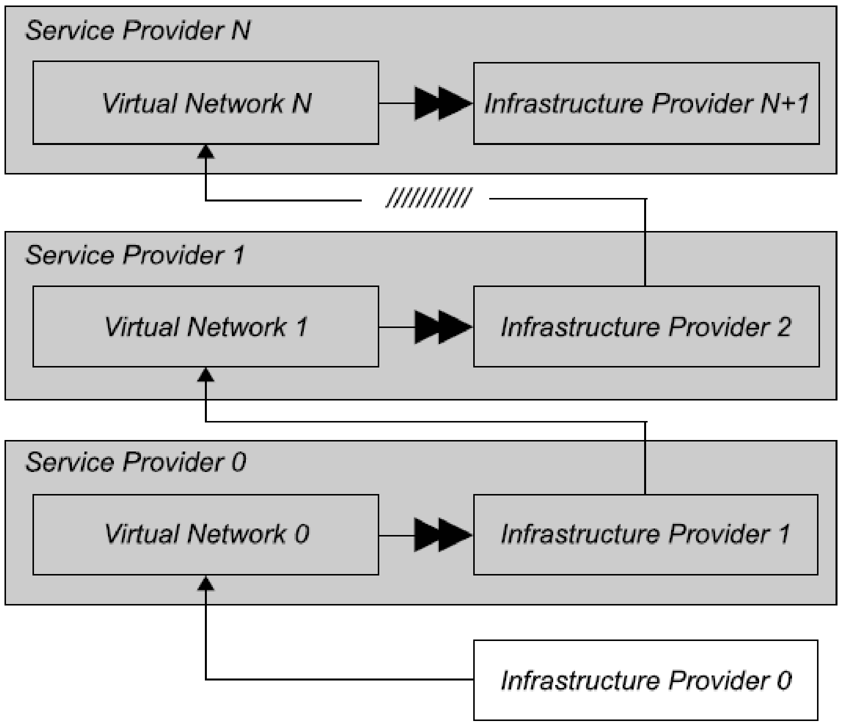
Definition

- ***Network virtualization***
  - *is a networking environment that allows multiple service providers (SP) to dynamically compose multiple heterogeneous virtual networks that co-exist together in isolation from each other,*
  - *and to deploy customized end-to-end services on-the-fly as well as manage them on those virtual networks for the end-users by effectively sharing and utilizing underlying network resources leased from multiple infrastructure providers (InP).*
- The role of the traditional ISPs has been divided now into the followings:
  - Infrastructure providers (InP), who manages the physical infrastructure, and Service providers (SP), who create virtual networks by aggregating resources from multiple InP's and offer end-to-end services to the end users.
  - ***By decoupling SPs from InP's, network virtualization introduces flexibility for innovation and change.***

Figure 1: Reference Business Model



(a) Relationship between Players



(b) Hierarchy of Roles

Infrastructure Provider (InP)

- InPs deploy and actually manage the underlying physical network resources in the network virtualization environment.
- They are in charge of the operations and maintenance of the physical infrastructure and offer their resources through programmable interfaces to different service providers.
- They do not offer direct services to end users.
- InP's distinguish themselves through the quality of resources they provide, the freedom they delegate to their customers (i.e. service providers), and the tools they provide to exploit that freedom.
- InP's communicate and collaborate among themselves, based on specific agreements, to create the complete underlying network.
- Those offering connectivity to SP's through different networking technologies, e.g. optical fiber, or satellite, are known as the facilities providers.
- On the other hand, InP's connecting customer premise equipments (CPEs) to the network are the access providers.

Service Provider (SP)

- Service providers (SPs) lease resources from multiple facilities providers to create virtual networks and deploy customized protocols by programming the allocated network resources to offer end-to-end services to the end users.
- A service provider can also create child virtual networks by partitioning its resources.
- It can then lease those child networks to other service providers, practically taking the role of an infrastructure provider creating a hierarchy of roles

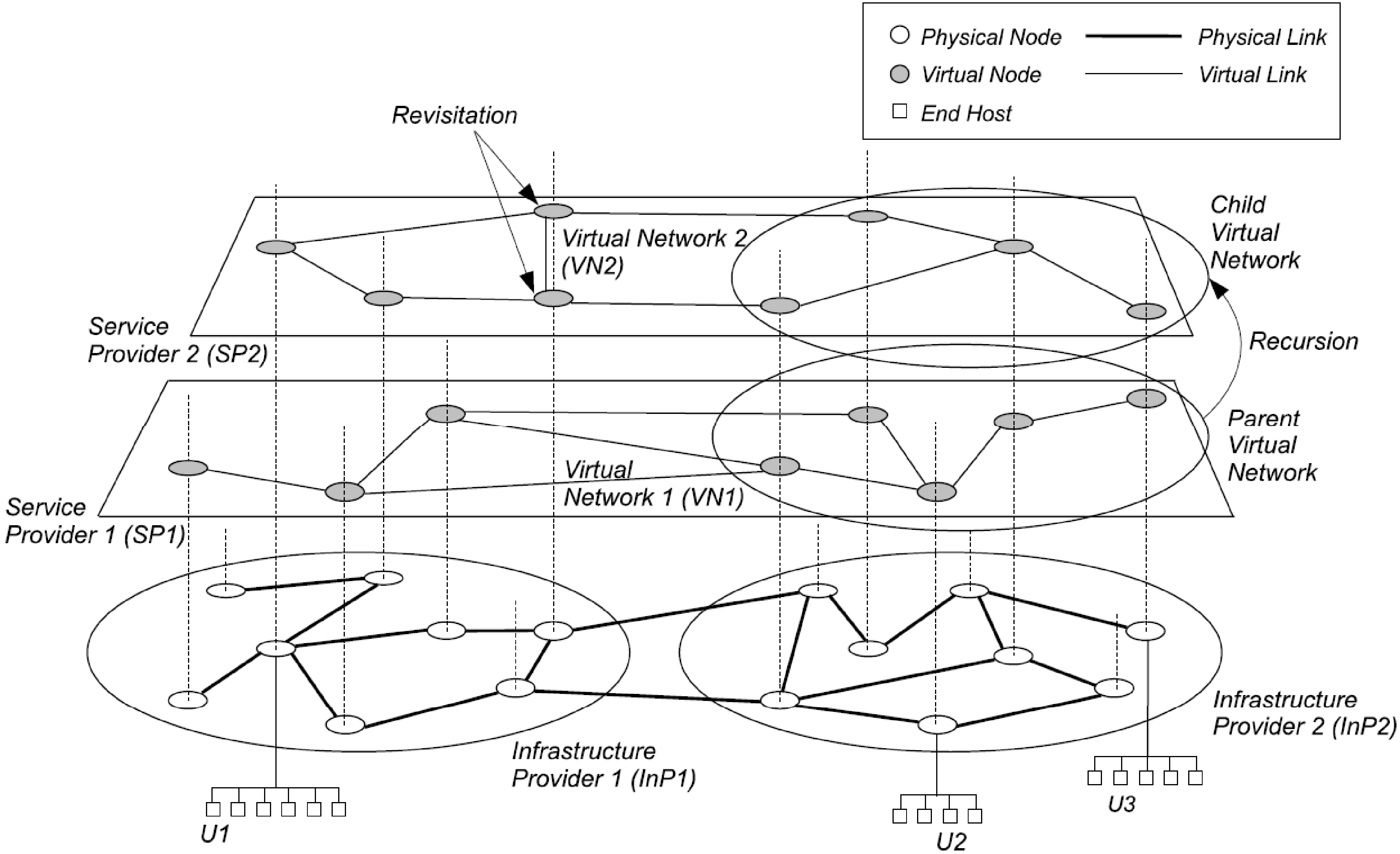
End User

- End users in the network virtualization environment are similar to the end users in the existing Internet, except that the existence of multiple virtual networks from competing service providers enables them to choose from a wide range of services.
- Any end user may connect to multiple service providers for different services.
- End users are the target recipients of the services provided by the SPs.
- Services are offered on the basis of terms and conditions on behalf of both the SPs and the customers.

Broker

- Brokers play a pivotal role in the network virtualization economy. They act as mediators between infrastructure providers, service providers, and end users in the network virtualization marketplace.
- Service providers buy (lease) resources from infrastructure providers to create virtual networks and sell services deployed on those virtual networks to interested end users through brokers.
- Their presence simplify the process of matching service providers' requirements to available resources by aggregating offers from multiple infrastructure providers.
- Similarly, they also allow end users to select desirable services from a wide range of service providers.

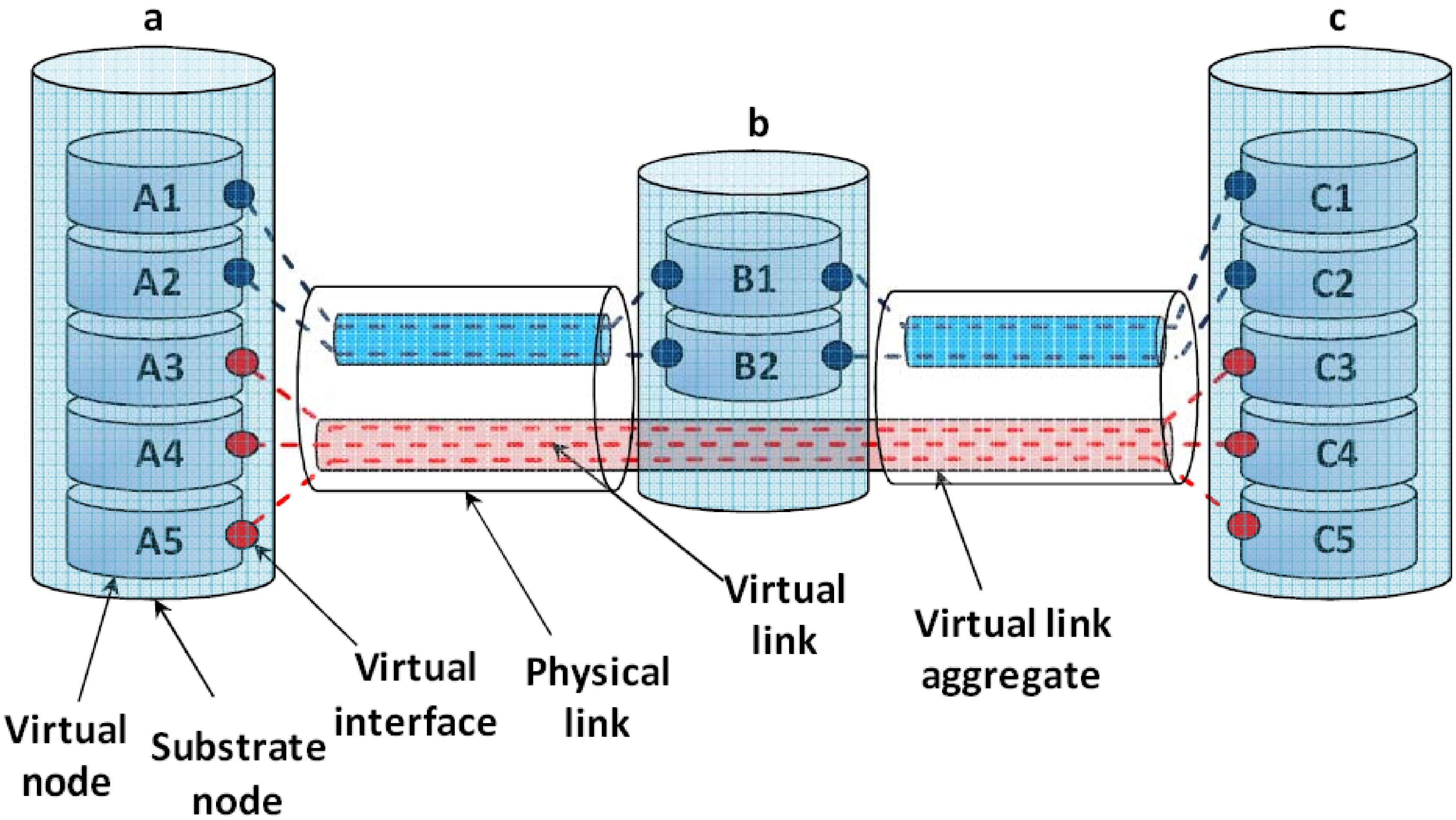
Fig. 2: Network Virtualization Architecture



Basic Network Virtualization Elements

- In the network virtualization environment (NVE), the basic entity is a virtual network (VN).
- Each *VN* is composed and managed by a single service provider.
- Each VN is a collection of virtual nodes (VNode) connected together by a set of virtual links (VLink) forming a virtual topology.
- At the substrate level, the substrate node (or physical node) is network equipment capable of supporting VNode by means of any virtualization technology. A single substrate/physical node typically contains a number of VNodes
- Physical resources of a substrate/physical node (e.g. CPU, memory, storage capacity, link bandwidth) are partitioned into slices and each slice is allocated to a Vnode according to a set of requirements.
- A virtual link (VLink) in the virtual network may span over one or more connected physical links i.e. a path in the underlying physical topology.

Fig. 3: Basic Network Virtualization Elements



Some Terminologies

- ***Concurrence:***
  - Concurrence of VN’s means that multiple VN’s’from different service providers can coexist together, spanning over part or full of the underlying physical networks provided by one or more InP’s
  - To put it simply, an InP might cater to multiple service providers and a service provider might use resources from different InP’s.
- ***Recursion:***
  - While VN’s can be concurrent, in some cases, it might also be necessary to create and maintain one or more VN’s within another VN creating a virtual network hierarchy with parent-child relationship. This is known as recursion as well as nesting of virtual networks.
  - In Figure 1(b), `Service Provider 0' has created a virtual network on top of an actual physical network provided by `Infrastructure Provider 0', and has leased away a portion of the allocated resources to `Service Provider 1', to whom it appears as `Infrastructure Provider 1'. This hierarchical construct can continue until cumulative overhead of creating child virtual networks makes further subdivision impossible.

Some Terminologies (Cont'd)

- ***Inheritance:***
  - Child virtual networks, i.e. networks derived from other networks, can inherit architectural components from their parents.
  - Also, constraints on a parent virtual network automatically translate to similar constraints on its children.
  - In Figure 2, constraints due to InP2 will automatically be transferred to SP2 from SP1 through inheritance.
- ***Revisitation:***
  - Revisitation allows a physical node in the underlying infrastructure to host multiple virtual nodes of a single virtual network.
  - Use of multiple logical routers to handle diverse functionalities in a complex network can be a great relief for network operators. It can also be useful for creating test bed networks.
  - In Figure 2, we can see an illustration of revisitation in VN2.

Design Goals

- Flexibility
- Manageability
- Scalability
- Security, Privacy, and Isolation
- Programmability
- Heterogeneity
- Experimental and Deployment Facility
- Legacy Support

Network Virtualization Projects

Characteristics:

- *Networking technology*
  - Targeted technology for virtualization
- *Layer of virtualization*
  - Particular layer in the network stack where virtualization is introduced
- *Architectural domain*
  - Specific problem domain that virtualization addresses
- *Level of virtualization*
  - Granularity at which virtualization is realized

Existing Projects (1)

Project	Architectural Domain	Networking Technology	Layer of Virtualization	Level of Virtualization
VNRMS	Virtual network management	ATM/IP		Node/Link
Darwin	Integrated resource management and value-added services	IP		
Tempest	Enabling alternate control architectures	ATM	Link	
NetScript	Dynamic composition of services	IP	Network	Node
Genesis	Spawning virtual network architectures		Network	Node/Link

Existing Projects (2)

Project	Architectural Domain	Networking Technology	Layer of Virtualization	Level of Virtualization
VNET	Virtual machine Grid computing		Link	Node
VIOLIN	Deploying on-demand value-added services on IP overlays	IP	Application	Node
X-Bone	Automating deployment of IP overlays	IP	Application	Node/Link
PlanetLab	Deploy and manage overlay based testbeds	IP	Application	Node
UCLP	Dynamic provisioning and configuration of lightpaths	SONET	Physical	Link

Existing Projects (3)

Project	Architectural Domain	Networking Technology	Layer of Virtualization	Level of Virtualization
AGAVE	End-to-end QoS-aware service provisioning	IP	Network	
GENI	Creating customized virtual network testbeds	Heterogeneous		
VINI	Evaluating protocols and services in a realistic environment		Link	
CABO	Deploying value-added end-to-end services on shared infrastructure	Heterogeneous		Full

Key Future Research Directions

- Instantiation
  - Concerned with issues related to successful creation of virtual networks
- Logistics
  - Deals with operations of virtual networks and virtual components
- Management
  - Manages co-existing virtual networks
- Interactions
  - Handles interactions between players in the *network virtualization environment*

Instantiation (1)

- Interfacing
  - Request format for a virtual network
  - Make programmability of the network elements available

- Signaling and Bootstrapping
  - Request for a virtual network
  - Bootstrap the customized network onto the physical network elements
  - Use a *separate* network (e.g. Genesis) or *out-of-band* communication mechanism

- Accounting
  - Prohibit overbooking of network resources through *admission control*
  - *Distributed rate limiting*
  - Applied on *complete* virtual networks

Instantiation (2)

- Topology Discovery
  - Within an InP administrative domain and across InP boundaries
  - *Event-based* and *periodic* topology discovery (e.g. UCLP)
  - Separate discovery plane (e.g. CABO)

- Virtual Network Mapping
  - Within single InP domain and across InP boundaries
  - Known to be a *NP-Hard* problem
  - *Heuristic*-based solutions
  - Two versions of the problem
    - *Offline,* where all the requests are known in advance
    - *Online,* where requests arrive dynamically

Logistics (1)

- Virtual Routers
  - Multiple logical routers inside one physical router
  - Issues of interest
    - Performance
    - Scalability
    - Migration (e.g. VROOM)
- Virtual Links
  - Similar to tunnels in VPNs
  - Cross-InP virtual links
  - *Link scheduling* (e.g. DaVinci)

Logistics (2)

- Resource Scheduling
  - Maximize *degree of co-existence*
  - Schedule CPU, Disk and Link b/w

- Naming and Addressing
  - Generic naming and addressing for all the virtual networks
  - *Überhoming*
    - *Allows end users in a network virtualization environment to simultaneously connect to multiple VNs through multiple InPs using heterogeneous technologies to access different services.*
  - *Identity-based* routing

- Failure Handling
  - Isolate failures
  - Prevent *cascading* failures

Management (1)

- Mobility Management
  - Geographic mobility of the end user devices
  - Mobility of the virtual routers through migration techniques
  - Logical mobility of the end users in different virtual networks
- Configuration and Monitoring
  - Enable virtualization from the level of NOCs to lower level network elements

Management (2)

- Management Frameworks
  - Generic management framework for the service providers
  - Interface between multiple management paradigms
  - Draw clear line between the management responsibilities of the InPs and the SPs

- Self-* Properties
  - *Self-configuration* and *self-optimization* for maximizing virtual resource utilization
  - *Self-protection* and *self-healing* to survive malicious attacks

Interaction

- Networking Technology Agnostic Virtualization
  - Virtualization *on* and *across* optical, wireless and sensor technology among other technologies
  - Transparently create end-to-end virtual networks across heterogeneous technologies

- *Inter-VN Communication*
  - *Sharing of resources and information between multiple virtual networks*
  - *Creating compound virtual networks*
  - *Interoperability among VNs (4WARD project)*

- *Network Virtualization Economics*
  - *Trade node resources (e.g. processing power, memory) in addition to bandwidth*
  - *Centralized, decentralized and hybrid markets (Ex: PeerMart)*

Recent Research Issues (1)

- ***Network Virtualization: The missing piece in Cloud computing***
  - *Current service platforms or frameworks, e.g., Cloud* solutions, do not take the infrastructure, necessary for the execution of the service, sufficiently into consideration.
  - They take resources like network connectivity for granted and do not provide an integrated networking approach considering Quality of Service (QoS) or other real-time aspects of the message exchange between possibly thousands of components.
  - This paper presents the concept of a fully managed network virtualization framework to provide the required connectivity between components within a virtualized service platform respecting all service requirements, e.g. as expressed by interactive real-time services, on transport layer.

Recent Research Issues (2)

- ***Virtual Network Interoperability in Future Internet***
  - The interoperability between virtual networks is one of the crucial issues in the design of Future Internet
  - By default the VNets are isolated and there is no intercommunication between them
  - The Folding Point concept is proposed to enable interconnection among Vnets. It is responsible for
    - Providing a secure connection between the Vnets
    - Insuring security in terms of authentication and authorization
    - Policy enforcement at the border of the Vnets
    - Translation of protocols: e.g. conversion of naming, addressing and data formats

Recent Research Issues (3)

- ***Mechanism Design for Network Virtualization***
  - A major challenge is the VN embedding problem that deals with ecient mapping of virtual nodes and virtual links onto the substrate network resources.
  - Most previous research on this problem has focused on designing heuristic and approximation algorithms for the VN embedding problem.
  - However a common aspect of these previous results is that they assume that the different stake-holders in the network virtualization environment do not act in strategic ways.
  - In this paper, the authors propose to utilize mechanism design to address this issue. Mechanism design is a branch of micro-economics that deals with protocols and algorithms for aligning the conflicting preferences of self interested agents with the global objective of a central designer.
  - Specifically the author show that the celebrated Vickrey Clarke Groves (VCG) mechanism can be used to find the optimal cost minimizing embedding of a virtual network on top of a substrate network, where different parts of the substrate network are owned by strategic agents.

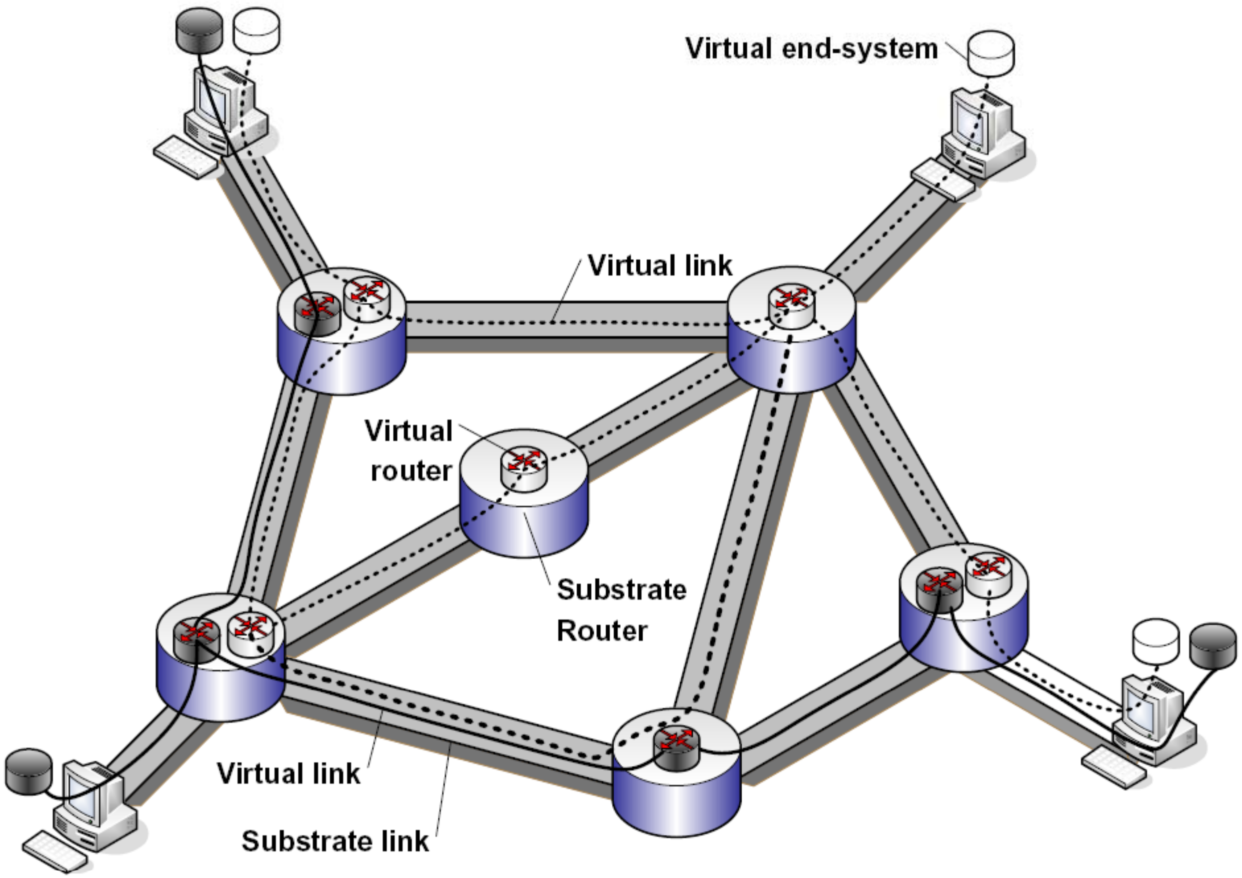
Our Research Issue

- In an Internet scale network virtualization environment, it is not economically feasible to pool all network resources with one infrastructure provider (InP) that will be solely responsible for resource allocation to service providers (SPs).
- As a result the physical resources will be distributed across a number of infrastructure providers.
- So there is a need of an efficient market mechanism for dynamic network virtualization environments (DNVE) where service providers (SPs) and infrastructure providers (InPs) can buy and sell substrate network resources for creating VN in the presence of brokers who monitor the market and determine market clearing prices.
- In DVNE, virtual networks providing basic services also can be dynamically aggregated and combined together to create compound virtual networks for composite services.

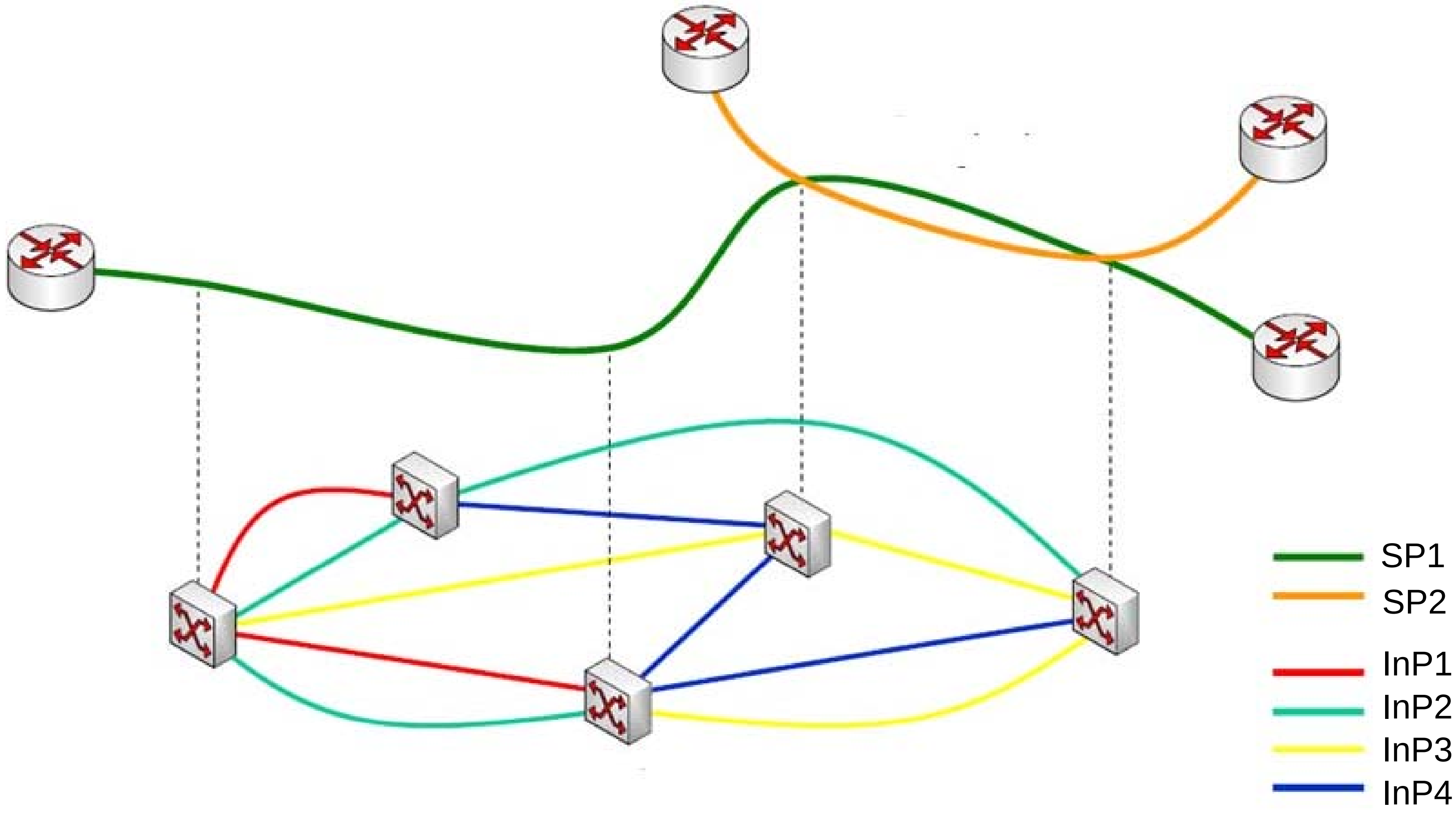
Background of Market Computing

- Electronic marketplaces for trading bandwidth emerged since the late 1990's
  - Market mechanisms were developed to allow companies to trade bandwidth just as other commodities
- Seriously hit by the economic downturn in 2001
  - Trading markets disappeared with the bursting of the telecom bubble
- Today, bandwidth normally provided under the umbrella of longterm bilateral agreements
  - Between individual providers and customers

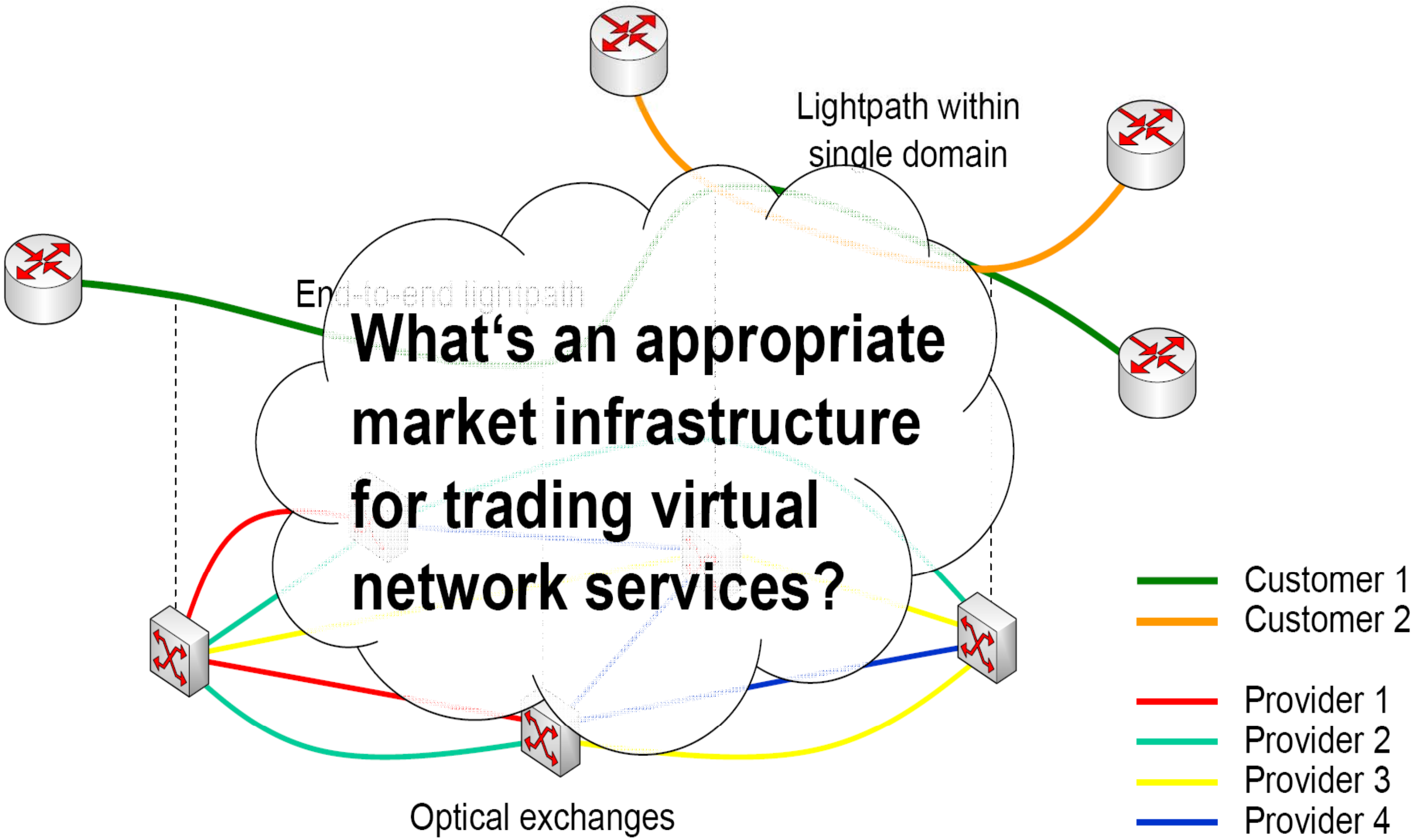
Network Virtualization within one Provider



Overview of Dynamic Peering



Overview of Dynamic Peering

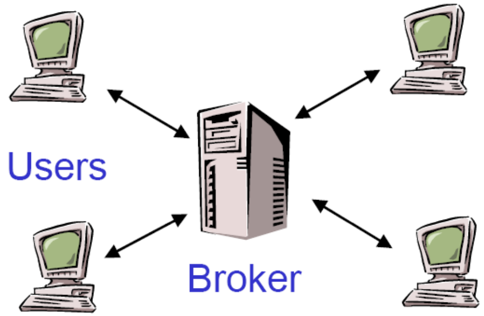


Market Computing Requirements

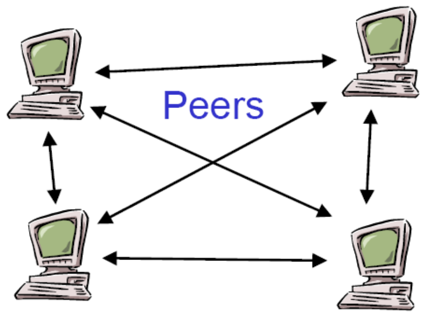
- Functional requirements
  - Allow customers and providers to buy and sell bandwidth services for different applications
  - Support the trading of bandwidth on demand as well as in advance
  - Allow the trading of bandwidth among multiple providers and customers
  - Support the reselling of bandwidth services
- Performance requirements
  - Lead to an economically efficient allocation of bandwidth services
- Bandwidth allocation should maximize the benefit through its use
  - Be robust against individual failures and attacks
  - Be scalable up to a large number of providers and customers

Marketplace type

- Centralized Marketplace
  - \+ Efficiency
  - \- Single Point of Failure
  - \- Vulnerable against attacks
  - \- Scalability?



- Fully Decentralized Marketplace
  - \+ Extensibility
  - \+ Fault-tolerance
  - \- Vulnerable against selfish and malicious behavior of peers
  - \- Efficiency?



A suitable marketplace needs to be efficient <u>and</u> scalable

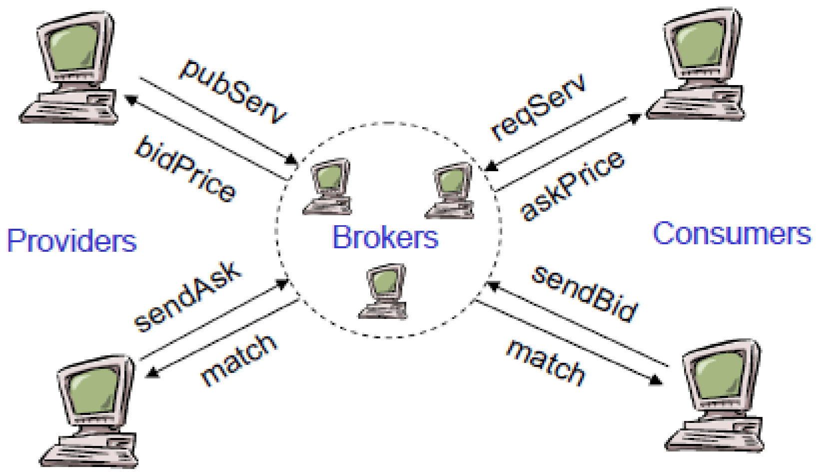
Key Tech. for Bandwidth Market

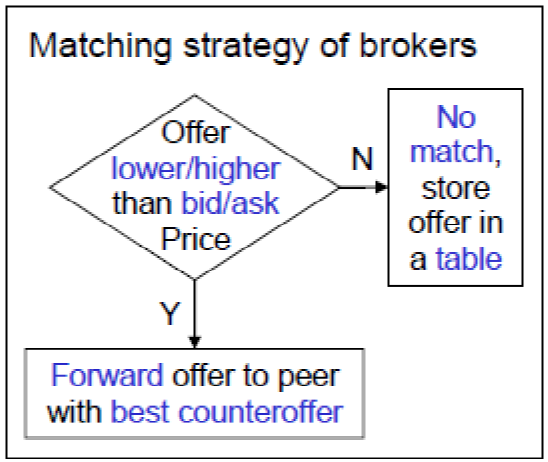
- Network virtualisation
  - Allows to allocate bandwidth much easier and faster
    - May become a key driver for “on-demand” bandwidth trading
  - Enables transparent sharing of physical network equipment
  - Offers numerous benefits to customer and provider
    - *E.g., security, flexibility, reliability, independence, multiplexing*

- Peer-to-peer networking
  - Support of bandwidth trading in a fully decentralized manner
    - Clear advantages in terms of reliability and scalability
  - P2P-based marketplaces like PeerMart enable the trading of services over the Internet in a technically and economically feasible way

PeerMart: Decentralized Auction Market

- Basic Concept
  - Each service is traded in a Double Auction
  - Each auction is mapped onto a set of broker peers
- Fully decentralized and secure
- PeerMart combines efficiency and scalability
  - Economic efficiency of double auctions
  - Technical performance and robustness of P2P networks
- PeerMart can also support other types of auctions
  - Requires only few adaptations
- Enables reliable, market-based pricing of any service





Major Limitation of PeerMart

- If a VN request requires using network resources that are distributed across multiple InPs, then a participating InP might lease resources that locally optimizes its own resource usage.
- It can misrepresent its resources and local topology in order to maximize its utility. So the resources (nodes and links) selected for mapping the virtual network request might result in a sub-optimal resource allocation, which might not coincide with the virtual network embedding that would result if the InPs were truthful about their internal resources and local topology- **this phenomenon cannot be handled using PeerMart which is a major research issue**
- Also PeerMart is **not suitable to create the compound VNs** for composite services since a large number of conflicts may occur when negotiating among InPs since each InP must agree with the resources/services contributed by other InPs against a set of its own policies. Also the inclusion of collaboration costs with bidding prices may result in paying high prices for service providers

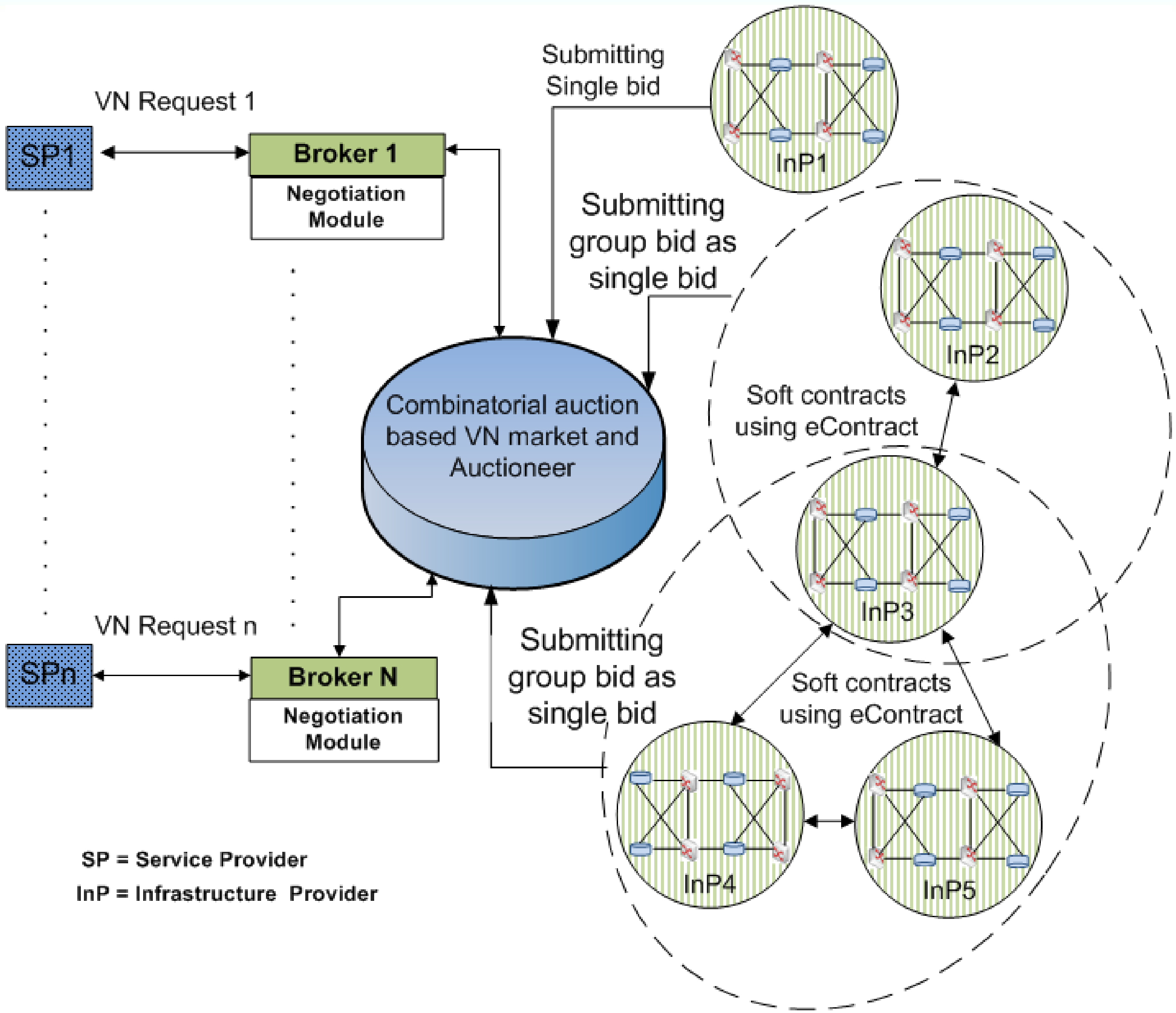
Our Proposed Model

- Basic Concept
  - We propose a novel combinatorial auction (CA)-based network virtualization market model called CANVM where SPs can buy different VNs from different inP's that sell substrate network resources for creating VNs
  - To address the issue of conflict minimization among InPs for creating compound VNs, the existing auction policy of CA is modified
  - The new auction policy in the CANVM model allows a InP to dynamically collaborate with suitable partner InPs to form a group before joining the auction and to publish their group bids as a single bid to completely fulfill the service requirements, along with other InPs, who publish separate bids to partially fulfill the service requirements (policy of existing CA model)
  - Thus using this new market model, there is a little chance that InP's will misrepresent their resources and local topology as they need to compete with others in the market
  - This new approach can also create more opportunities to win auctions for the group since collaboration cost, negotiation time and conflicts among InPs can be minimized

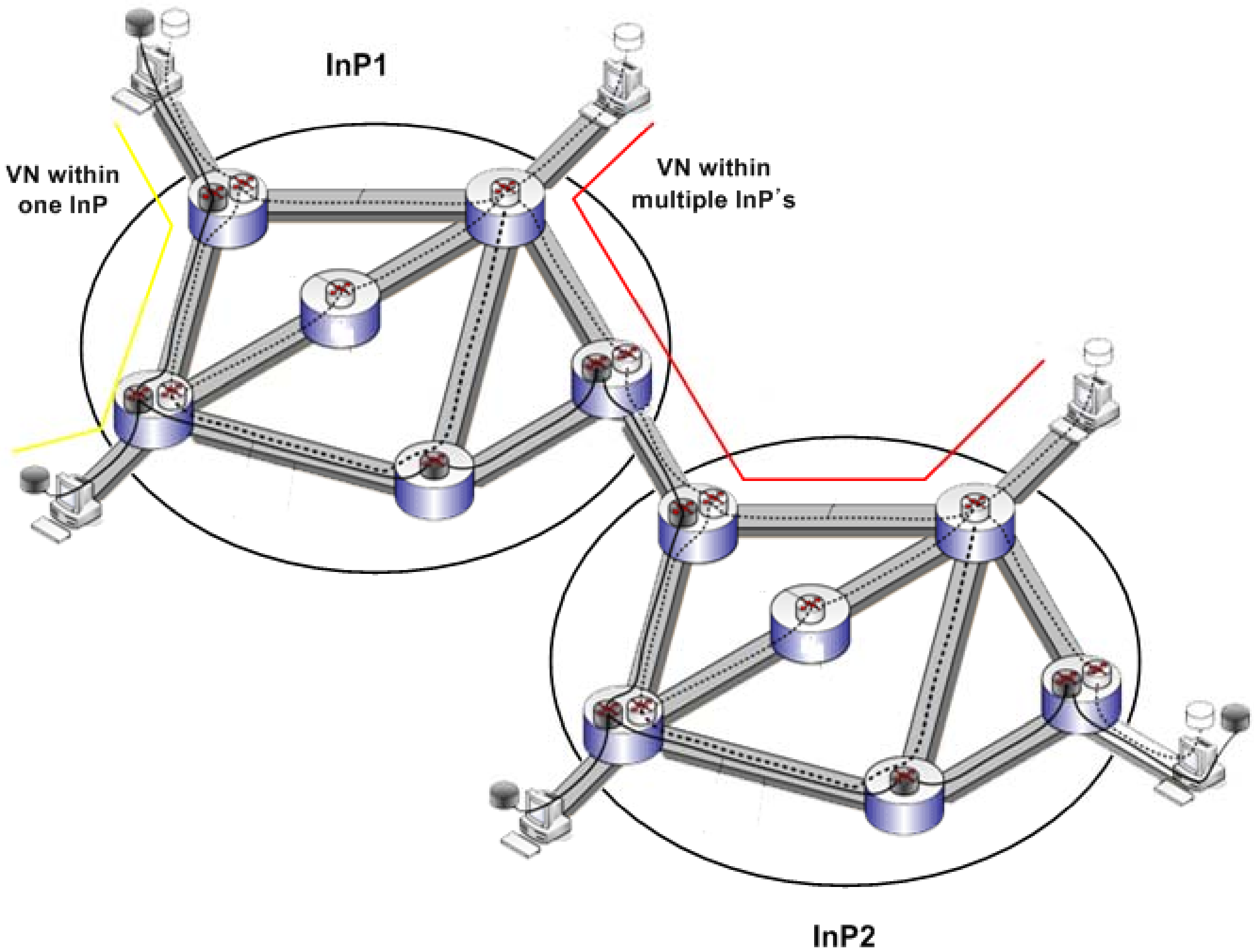
Key Features of Our Model

- Provide economic Efficiency and security
  - Economic efficiency of combinatorial auction for service providers
- Scalability in terms of supporting any number of VN requests per auction
- Minimize conflicts among InP's when creating compound VN's among InPs by using our new auction policy
- Enable dynamic peering platform among InP's that help InPs
  - to maximize their profit by offering existing available resource capabilities to collaborative partners, so they may create compound VN for composite service
  - to migrate the virtual nodes and virtual links to collaborative partners to enhance the reliability in case of substrate nodes or links failure

Proposed Central Market Model for DVNE

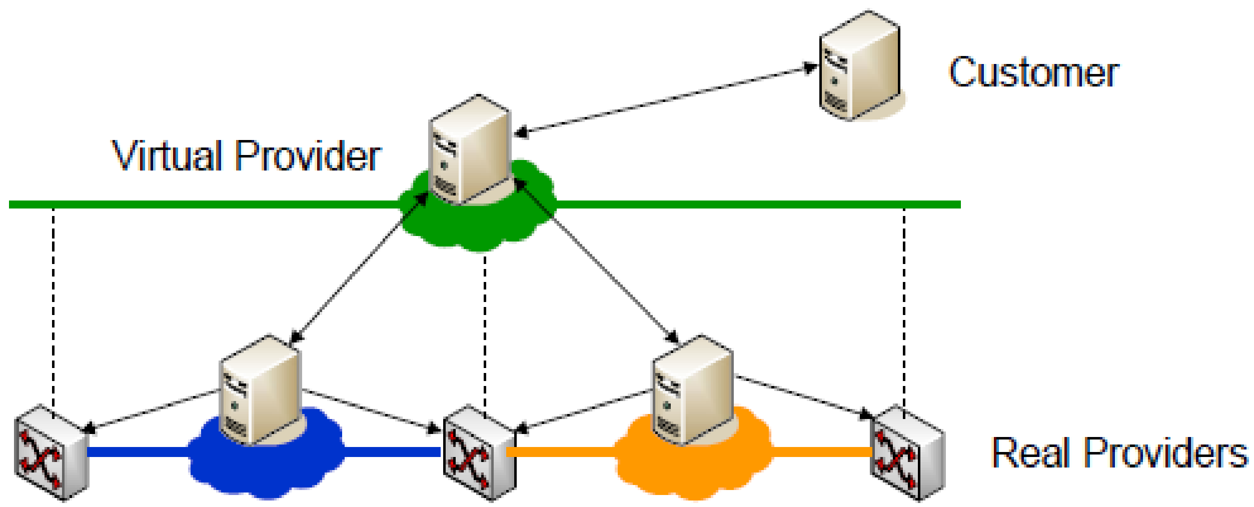


Dynamic Peering among InP's to create VN's



Virtual Network Service

- Virtual provider
  - Definition: an entity reselling a link or a combination of links
  - Allows a customer to resell an unused link
  - Enables to offer end-to-end virtual links across several network providers domains



Conclusion

- Company and Government need to work together on Policy for Market Computing
- Standard Interface to Collaboration Brokers and Agents
- Future Network must be service itself
- Customer based Open IT Infrastructure Design will be one of the primary targets

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