Network Virtualization

- Rapid technological progress
  - New optical fiber technology (e.g. DWDM)
  - Virtual router infrastructures (e.g. CSR-1)

- Benefits
  - Sharing of physical network equipment
  - “On-demand“ bandwidth allocation
  - Security, reliability, independence
Challenge

- Provisioning of bandwidth
  - In the right amount
  - At the right location
  - At the right time

- Suitable business models needed
  - Targeted at on-demand bandwidth provisioning
  - Providing appropriate incentives for providers and customers
  - Maximizing overall social welfare

Goal: Develop an appropriate market infrastructure for trading virtual network services on-demand

Are we ready for a new Bandwidth Market?

- A short history of bandwidth trading
  - Electronic markets for bandwidth emerged late 1990’s
  - Seriously hit by the economic downturn in 2001
  - Today, bandwidth normally provided under the umbrella of long-term bilateral agreements

- New situation today
  - Technology: Network virtualization allows to provide bandwidth much easier and faster („on-demand“)
  - Concepts: P2P-based infrastructures enable the trading of services in a fully decentralized and scalable manner
Market Requirements

- Functional requirements
  - Enable **buying** and **selling** virtual network services for different applications
  - **On demand** as well as **in advance**
  - Among **multiple** providers and customers
  - Support **reselling** of virtual network services

- Performance requirements
  - **Economically efficient allocation** of physical network resources (maximize benefit through its use)
  - **Robustness** against individual failures and attacks
  - **Scalability** up to a large number of providers and customers
Centralized versus Decentralized Marketplace

- **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 and scalable**

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Virtual Network Service

- **Definition:**
  - A virtual link between any two sites, or combination thereof
  - Within a single provider domain or across several domains

- **Service Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth</td>
<td>May be fixed, variable, or at discrete levels</td>
</tr>
<tr>
<td></td>
<td>Best effort or guaranteed</td>
</tr>
<tr>
<td>QoS</td>
<td>In terms of expected service uptime/availability rate</td>
</tr>
<tr>
<td>Start-time</td>
<td>May be starting at regular intervals</td>
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<tr>
<td></td>
<td>=&gt; Ability to reserve ahead and resell services</td>
</tr>
<tr>
<td>Duration</td>
<td>May be dynamic or fixed, e.g. 1 day</td>
</tr>
<tr>
<td>Price</td>
<td>As offered by the provider / customer</td>
</tr>
</tbody>
</table>
Virtual Network 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

Market Design: Basic Concept

- Each service is traded in a Double Auction
- Each auction is mapped onto a set of brokers
Market Design: P2P Overlay

Each peer has a unique node ID, peers form a structured P2P overlay network.

Services have unique service ID.

N peers numerically closest to service ID form a broker set.

Implementation and Node Architecture

BWProv / BWCust application serve as the bidding agent.

Additionally, they allow to configure and monitor the service according to the outcome of a successful transaction.

The service description is used as input to calculate a unique service ID.

The distributed search component ("S") enables to publish and search for service descriptions.
Application Example (1)

Virtual network environment with 2 optical links provided by 2 different providers.

Application Example (2)

All providers and customers have a node in their domain with PeerMart installed and connected to the Internet. The node is able to access the network equipment.

Virtual network environment with 2 optical links provided by 2 different providers.
Conclusion and Future Work

- **Conclusion**
  - **Fully** decentralized auction is a suitable market infrastructure for trading virtual network services
  - Combination of
    - Economic efficiency of double auctions
    - Technical performance and robustness of P2P networks
  - Approach is economically and technically feasible

- **Future work**
  - Who to blame if there is a problem?
  - How to deal with similarity in the service model?
Thank you for your attention!