Complex Service Provisioning in Collaborative Cloud Markets

4th European Conference ServiceWave 2011
- Poznan, Poland -

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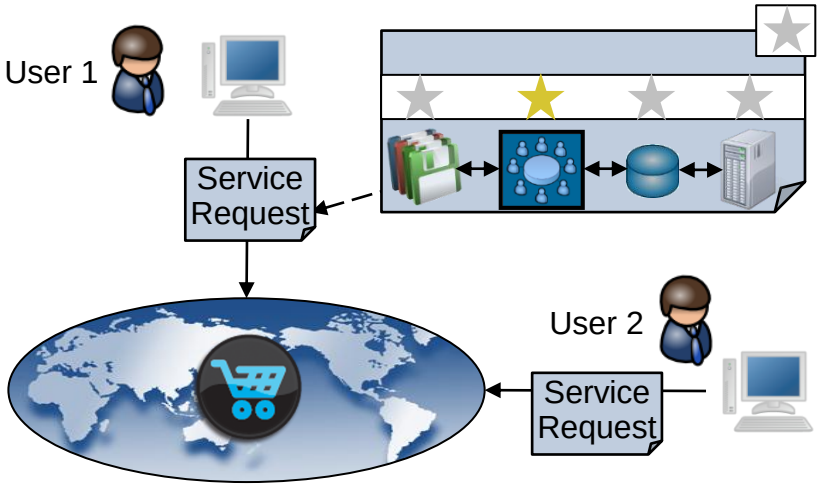

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Outline

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Introduction
- Motivation
- Background

Complex Service Provisioning
- Market Model
- Negotiations
- Collaboration Partner Selection

Evaluation

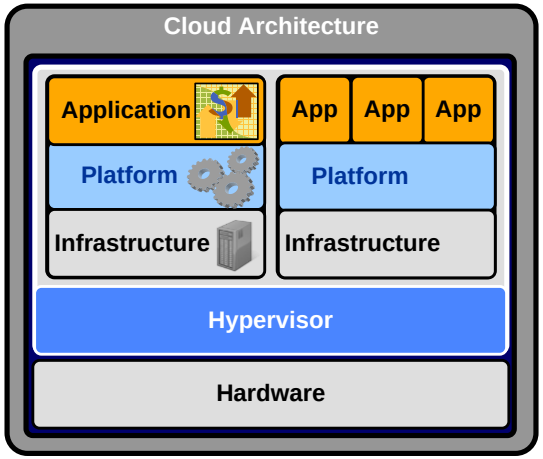
Conclusion and Outlook

Motivation

Cloud Computing [NIS10]

- "On-demand network access"
- "Shared pool of configurable resources"
- "Rapidly provisioned and released"
- "Minimal management effort"

→ High level of flexibility



But…

- No market-based trading of services
- No quality guarantees according to individual business constraints

Obstacles [BYV+09, BRC10]

- No open standards and interfaces
- Limited support for dynamic negotiations
- No collaboration support

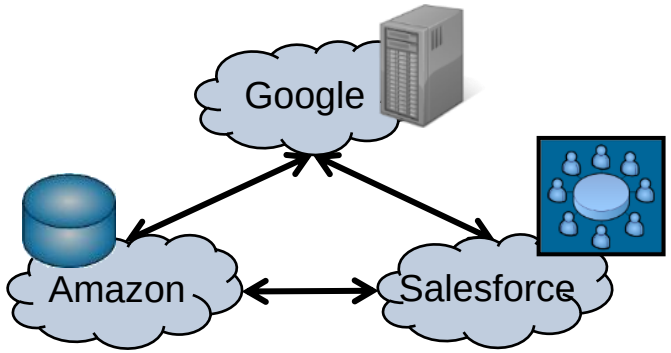


Image source: based on http://www.rationalsurvivability.com/blog/wp-content/media/2009/09/virtualization.jpg

Cloud Computing… What‘s Next?

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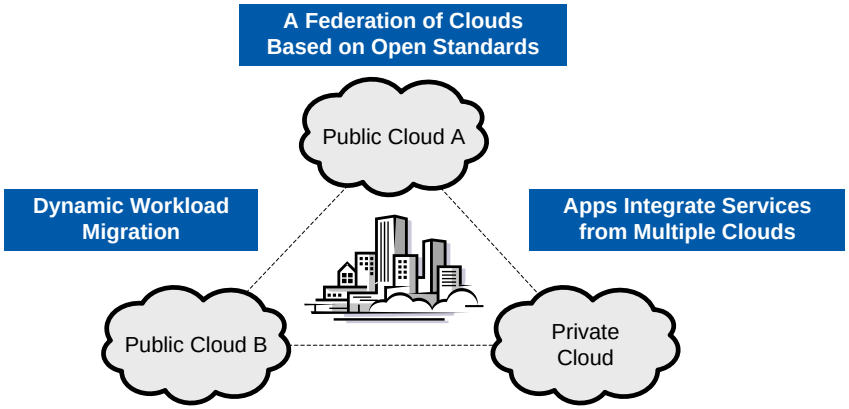
Cloud Federation

- Collaboration of multiple clouds
- Vendor specific



InterCloud (Cisco) [Rub10]

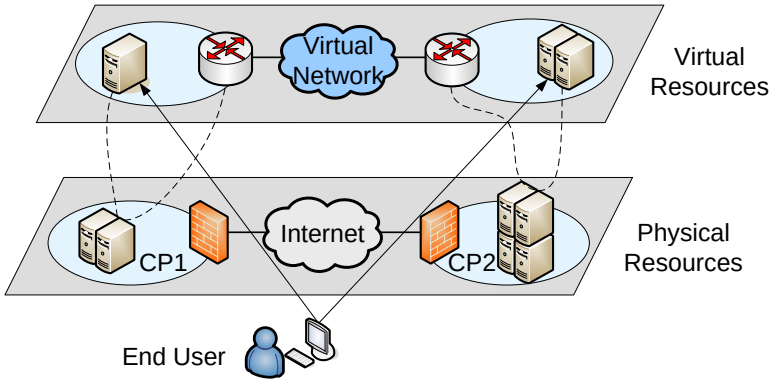
- Federation based on open standards
- Focus on transparent interoperability

Sky Computing [KTMF09]

- Multiple resources from different clouds
- Connectivity using network virtualization

Network Virtualization [KTMF09]

- Overcome connectivity limitations of VMs
- Pro: Single logical network (transparency)
- Con: Enhanced effort in network administration

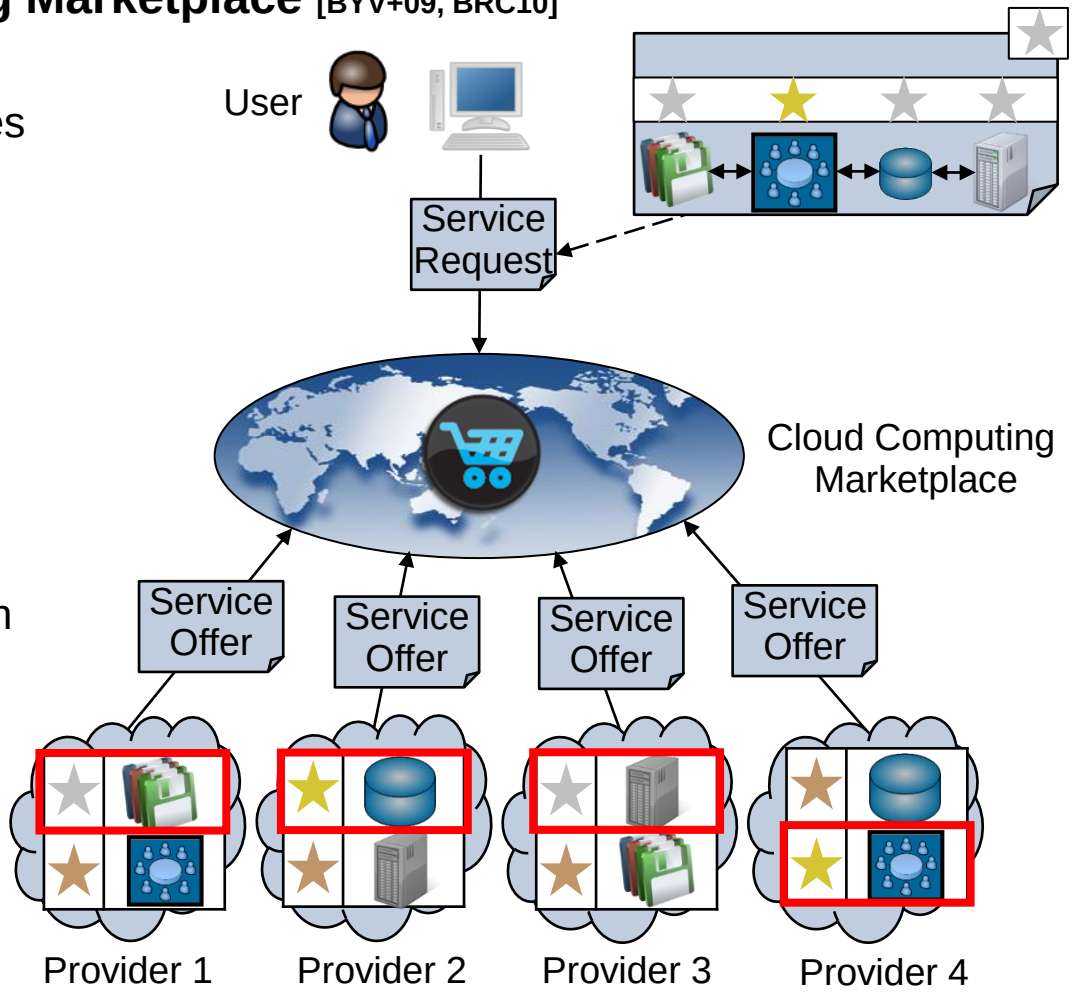


Scenario

Vision: Global Cloud Computing Marketplace [BYV+09, BRC10]

- Users want
  - Combination of multiple resources
  - Individual quality guarantees
- Providers have
  - Not all requested resource types
  - Different quality strengths
  - Limited resource capacities

→ Requires negotiation & collaboration



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Market Model: Structure

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Service Provisioning

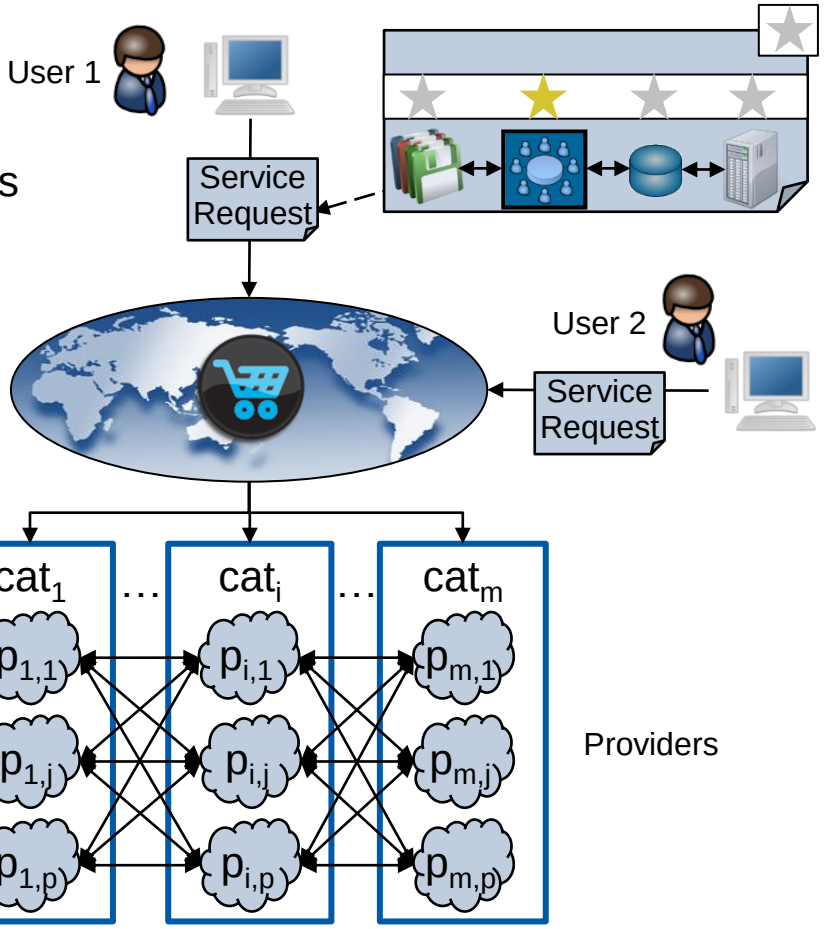
- Users submit requests to marketplace
- Providers offer different service types
- Brokers act on behalf of users to acquire services

Service Request

- Set of m different functional cloud services
- Parameters for each service and bundle

Service Selection

- Brokers in the marketplace
  - Conduct negotiation with providers
  - Select collaboration partners
- Collaboration partner must be selected from each of the m categories



Market Model: Actors

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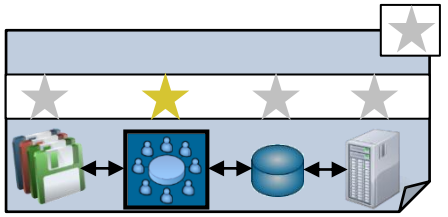
Users

- Private utility functions

$$UCat_i(S_{i,j}) = wCatPr_i * Pr_{i,j} + wCatQ1_i * \sqrt{Q1_{i,j}} + wCatQ2_i * \sqrt{Q2_{i,j}}$$

- Thresholds on service and bundle level



Providers

- Service $s_{i,j}$ with parameters price ($Pr_{i,j}$) and two quality parameters ($Q1_{i,j}$ and $Q2_{i,j}$)
- Can vary quality levels based on individual cost functions

$$UCP_{i,j}(S_{i,j}) = Pr_{i,j} + CFQ1_{i,j} * Q1_{i,j} + CFQ2_{i,j} * Q2_{i,j}$$

- Connections between providers have an influence on bundle quality

Parameter	Provider Utility	User Utility	Aggregation
$Pr_{i,j}$	Positive	Negative	Additive
$Q1_{i,j}$	Negative	Positive	Additive
$Q2_{i,j}$	Negative	Positive	Min-Operator

Market Model: Objectives

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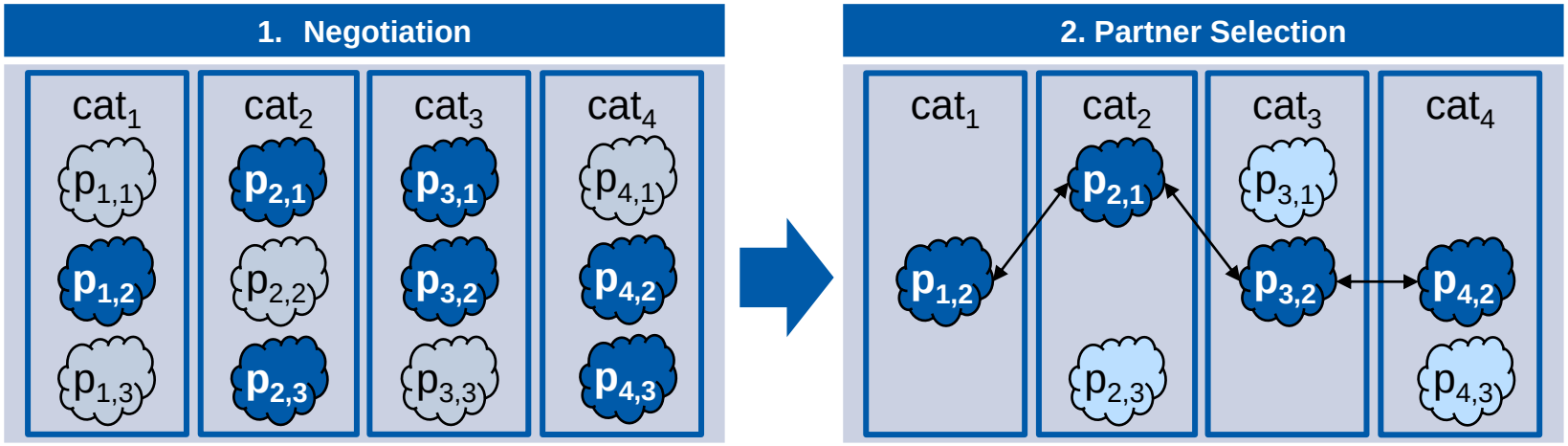
Goal

→ Maximize user‘s utility under price and quality constraints

Two-Step-Approach

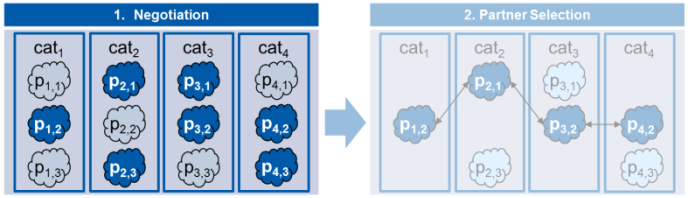
1. Conduct negotiations with providers in each category
2. Select collaboration partners to provide the service composition

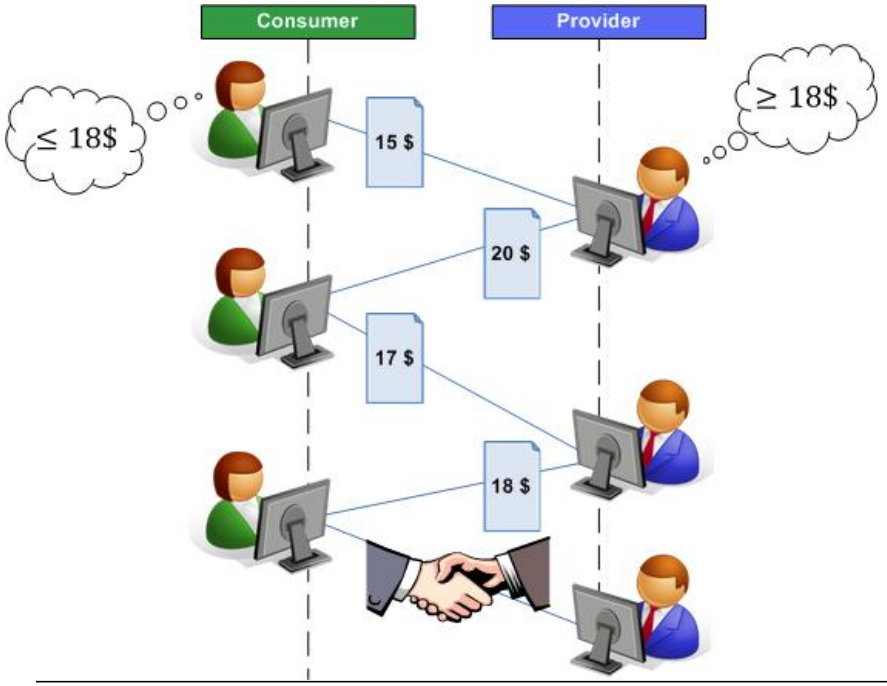


Negotiations

Negotiation Characteristics

- Multiple parties with conflicting interests
- Agreement should be reached
- Each party may apply a different strategy
- Rules for interaction required





Negotiation Requirements

- Multiple-issues support
- Multi-provider support
- Automated negotiation

Selected Negotiation Approaches

- Contract net protocol
- English auction

Negotiations: Approaches

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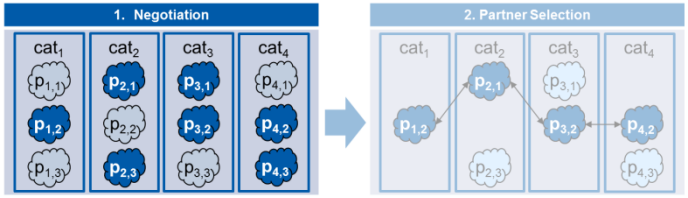
Contract Net Protocol (CNP) [Smi80]

- Initially proposed by Smith (1980)
- Originally used for task distribution



Procedure

(1) Providers receive parameter thresholds

(2) Providers use thresholds to determine best price and prepare their offer

(3) Marketplace/broker selects best offer based on user's utility function

Provider Strategy

→ Minimize own utility to minimize price

Providers' Price Calculation

$$Pr_{i,j}^{CNP} = -CFQ1_{i,j} * ThCatQ1_i - CFQ2_{i,j} * ThCatQ2_i$$

Pros

- Simple implementation
- Decision after one round

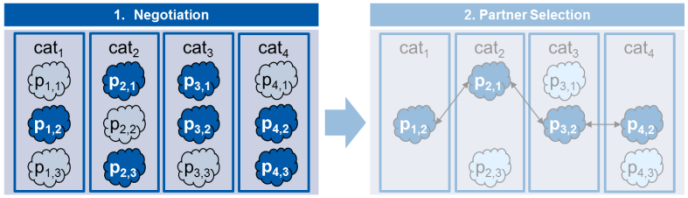
Cons

- Optimization on provider side only focuses on price

Negotiations: Approaches (cont.)

English Auction (EA) [PRAK11]

- Bidders bid for a good over several rounds
- Bids must exceed the currently highest bid
- Highest bid wins the auction



Procedure

(1) Providers receive parameter thresholds and utility function of user

(2) Providers make a minimal increase of their offer or leave the negotiation

(3) Publication of best offer at end of each round → goto (2)

(4) Closing and service selection when no more offers are made

Provider Strategy

→ Minimal increase or adjust to thresholds

Pros

- Optimization on provider side considers user's utility function

Cons

- Implementation more complex
- Decision after multiple rounds

Providers' Price Calculation [DASK02]

$$Pr_{i,j}^{EA} = \frac{\frac{wCatQ1_i^2}{|wCatPr_i|} + \frac{wCatQ2_i^2}{|wCatPr_i|} - UCat_i(S_i^{BestOffer}) - DiffOff}{-wCatPr_i}$$

Collaboration Partner Selection

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Objective Function (Maximize):

$$\sum_{i=1}^{m} \sum_{j \in S_i^{Val}} x_{i,j}(wBuPr * Pr_{i,j} + wBuQ1 * Q1_{i,j} + wBuQ2 * Q2_{i,j}) + \sum_{i=1}^{m-1} \sum_{j \in S_i^{Val}} \sum_{k \in S_{i+1}^{Val}} y_{i,j,i+1,k}(wBuPr * CPr_{i,j,i+1,k} + wBuQ1 * CQ1_{i,j,i+1,k} + wBuQ2 * CQ2_{i,j,i+1,k}) \quad (1)$$

Constraints:

$$ThBuPr \geq \sum_{i=1}^{m} \sum_{j \in S_i^{Val}} x_{i,j} * Pr_{i,j} + \sum_{i=1}^{m-1} \sum_{j \in S_i^{Val}} \sum_{k \in S_{i+1}^{Val}} y_{i,j,i+1,k} * CPr_{i,j,i+1,k} \quad (2)$$

$$ThBuQ1 \leq \sum_{i=1}^{m} \sum_{j \in S_i^{Val}} x_{i,j} * Q1_{i,j} + \sum_{i=1}^{m-1} \sum_{j \in S_i^{Val}} \sum_{k \in S_{i+1}^{Val}} y_{i,j,i+1,k} * CQ1_{i,j,i+1,k} \quad (3)$$

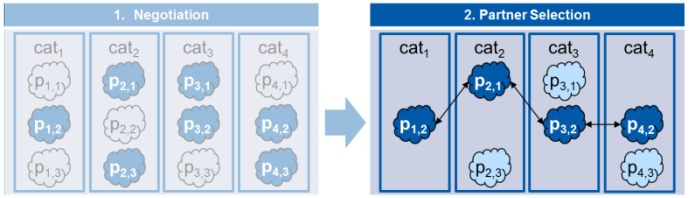
$$ThBuQ2 \leq \sum_{i=1}^{m} \sum_{j \in S_i^{Val}} x_{i,j} * Q2_{i,j} \quad (4)$$

$$ThBuQ2 \leq \sum_{i=1}^{m-1} \sum_{j \in S_i^{Val}} \sum_{k \in S_{i+1}^{Val}} y_{i,j,i+1,k} * CQ2_{i,j,i+1,k} \quad (5)$$

$$\sum_{j \in S_i^{Val}} x_{i,j} = 1 \forall i \in (1, \ldots, m) \quad (6)$$

$$\sum_{j \in S_i^{Val}} \sum_{k \in S_{i+1}^{Val}} y_{i,j,i+1,k} = 1 \forall i \in (1, \ldots, m-1) \quad (7)$$

$$x_{i,j} + x_{i+1,k} - y_{i,j,i+1,k} \leq 1 \forall i \in (1, \ldots, m-1) \wedge \forall j \in S_i^{Val} \wedge \forall k \in S_{i+1}^{Val} \quad (8)$$



Approach

- Select one service from each category
- Selection based on properties of services and connections between services
- Composition must maximize user utility

→ Can be modeled as optimization problem

→ Can be solved optimally using techniques from the field of Operations Research (e.g., branch-and-bound) [HL05]

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Evaluation: Setup

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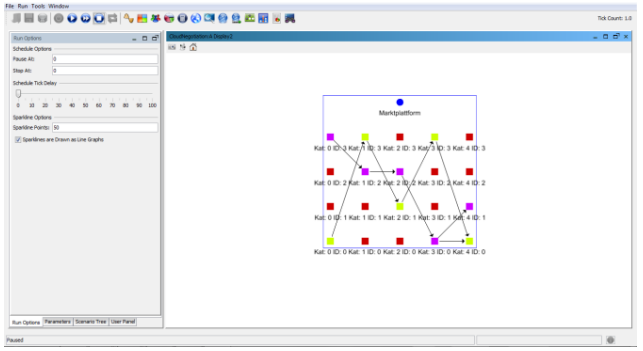
Scenarios

- Five functional categories
- Static weights for user's utility function
- Thresholds and cost parameters determined by random
- 2, 4, 6, 8, and 10 providers in each category
- Minimal increase of bids is 0.5 units

→ 20 test cases for each scenario



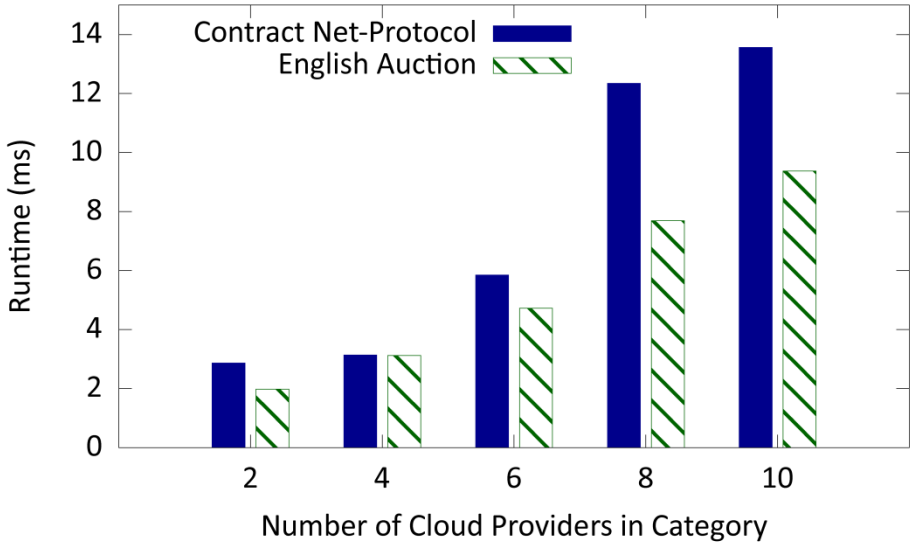
Category		Bundle	
Parameter	**Values**	**Parameter**	**Values**
$CFQ1_{i,j}$, $CFQ2_{i,j}$	[0;1]		
$wCatPr_i$	-1	*wBuPr*	-1
$wCatQ1_i$, $wCatQ2_i$	2	*wBuQ*1, *wBuQ*2	0.5
$ThCatPr_i$	[15;20]	*ThBuPr*	[15;20] $* m$
$ThCatQ1_i$	[0;5]	*ThBuQ*1	[0;3] * *m*
$ThCatQ2_i$	[0;5]	*ThBuQ*2	[0;1]

Evaluations

- Runtime
- Relative user utility
- Best user utility

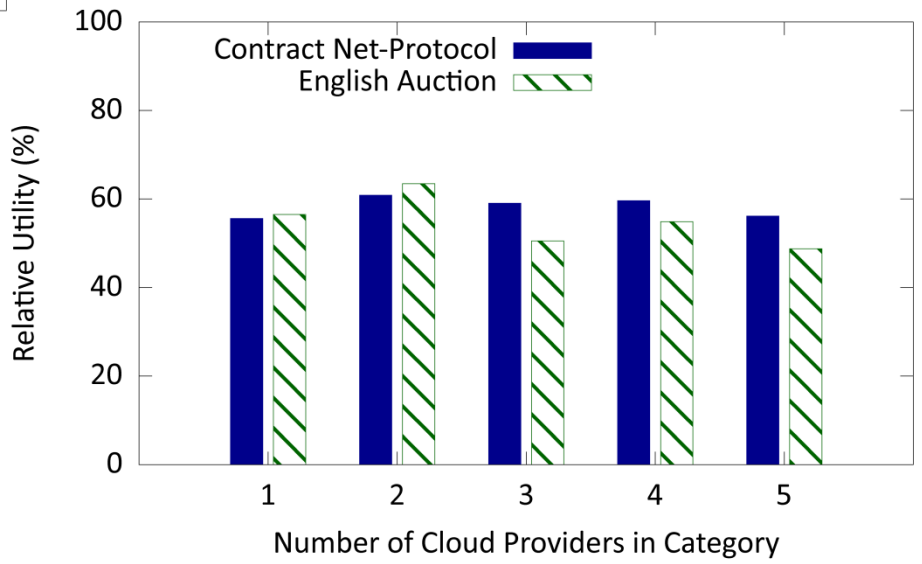
Image source: screenshot of our agent-based implementation in Repast Simphony, http://repast.sourceforge.net/

Evaluation: Runtime & Relative Utility

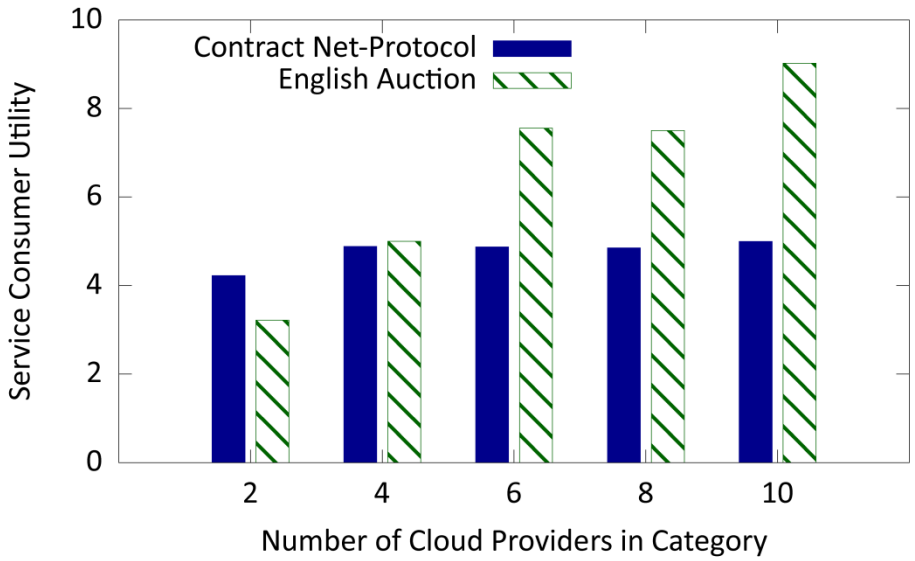


- Although the price is in the focus, CNP shows good median values
- EA values slightly decrease with an increasing number of providers

- Runtime between 1.9 and 13.6 ms
  → Dynamic collaboration support
- CNP with higher runtime
  → CNP with more valid solutions



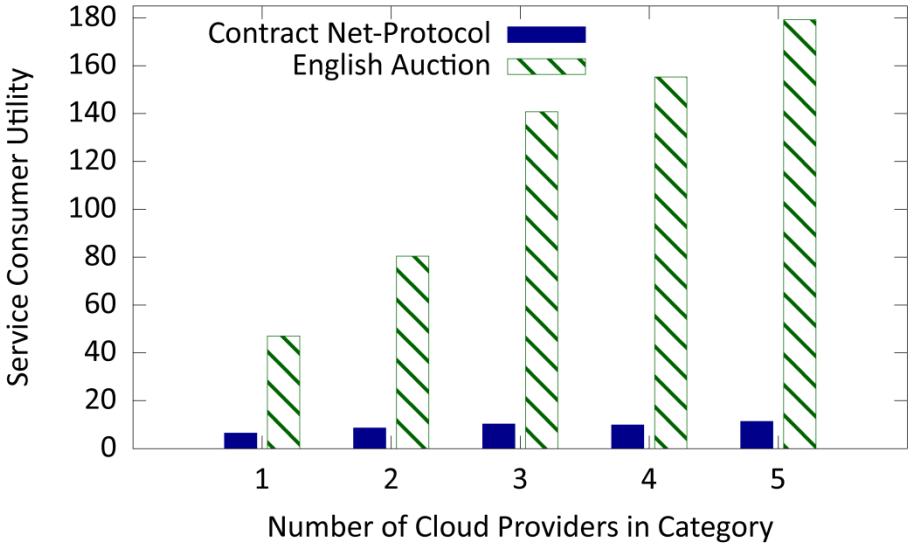
Evaluation: Best Utility (Category vs. Bundle)



- CNP utility nearly constant for all scenarios and decreases for bundle
- EA leads to highest utility and has similar distribution in both cases
- EA utility increases with competition

Summary

- CNP: minimal requirements and price most important
- EA: many providers and high utility desired



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Contributions

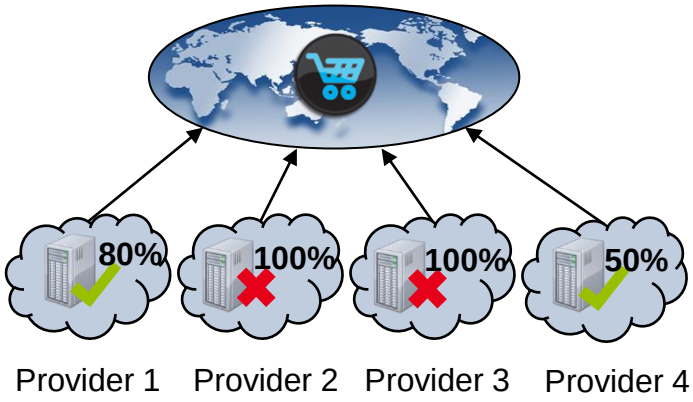
- Generic cloud market model for negotiation and collaboration
- Adaptation, implementation and evaluation of selected negotiation mechanisms

Conclusion

- Both negotiation mechanisms applicable in a dynamic collaborative setting
- No single negotiation mechanism preferable in all settings

Outlook

- Enhancement of model by considering resource constraints of providers
- Concurrent negotiation and collaboration partner selection
- Evaluation of further negotiation mechanisms



Further Questions?

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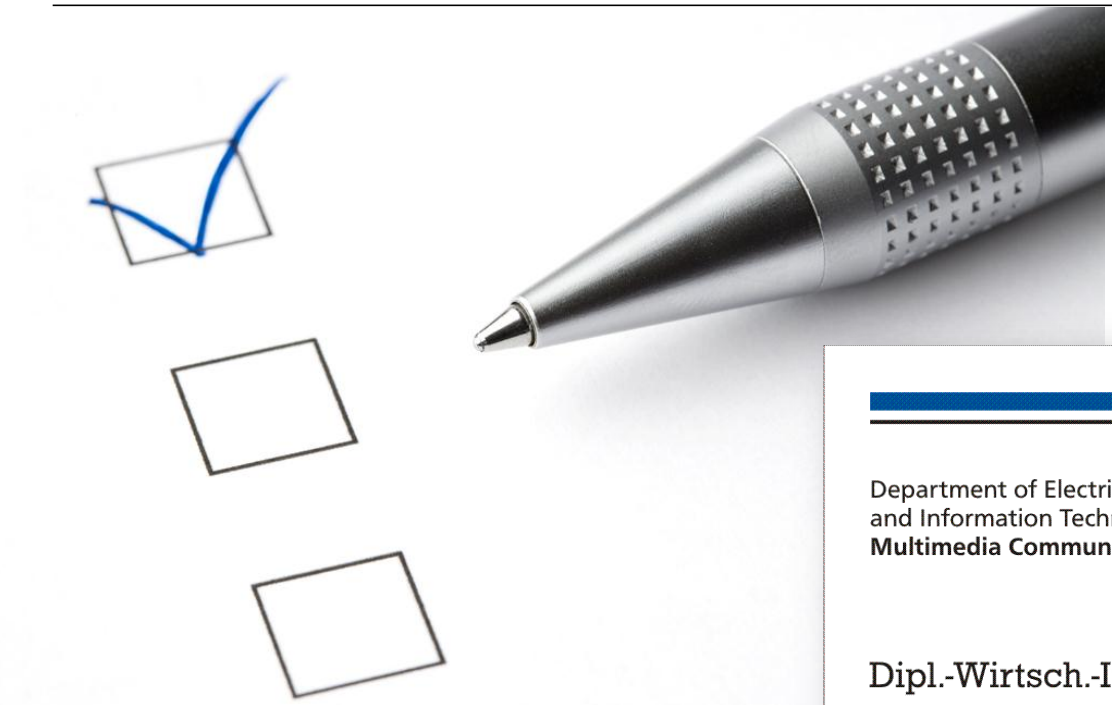

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