市場原理に基づく分散計算サービスの割り当て方法

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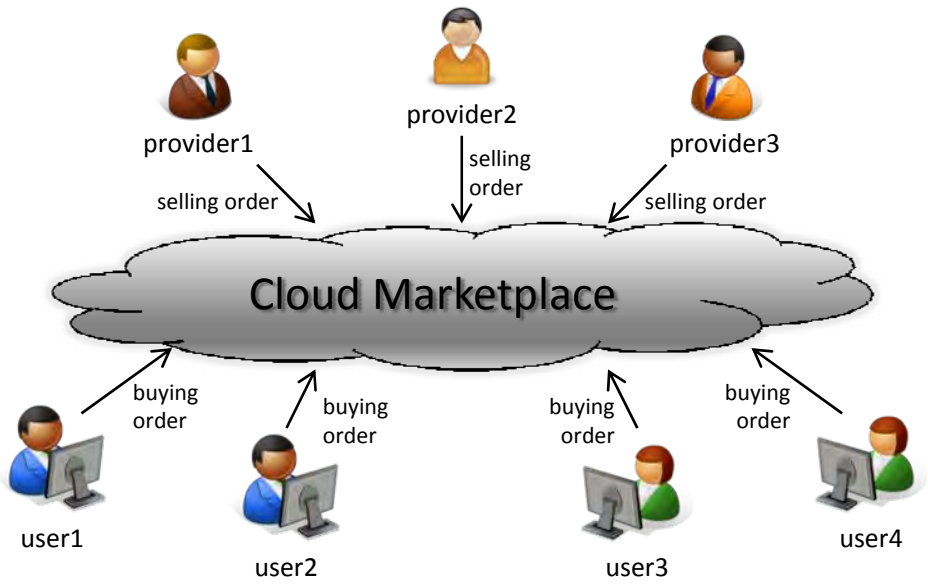
Agenda

1. Motivation
2. Background
3. Proposed Market Mechanism
4. Simulator
5. Evaluation
    1. Verifying the combinational allocations
    2. Estimating scalability
6. Related Work
7. Conclusion

Motivation

- **Cloud computing** spreads rapidly to business community
  - Computing resources are virtualized and distributed as services
  - "Resource" can be hardware, software, bandwidth, etc.
- **It's difficult to allocate resources efficiently**
  - Among hundreds of providers and thousands of users
  - Satisfying QoS and budget limitation
- **Market-based Allocation** is a promising approach
  - Discussed for a decade
  - Providers/users sell/buy the resources in a marketplace
  - Price is determined through fair competition
  - Not yet realized, but should be needed in the near future



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  - Price is determined through fair competition
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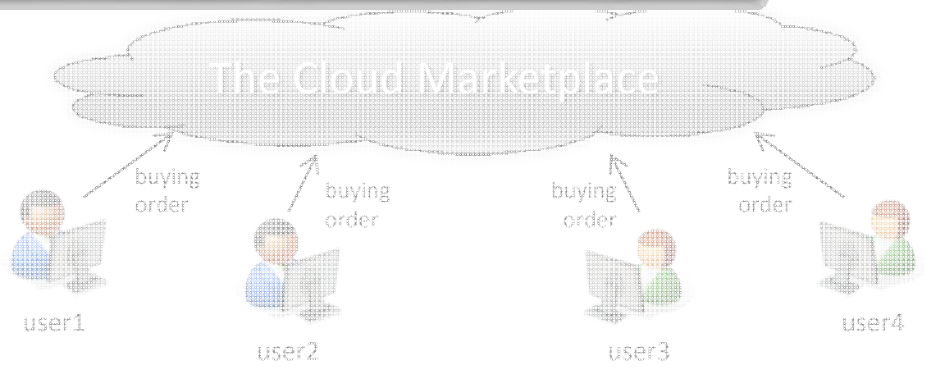
Our goal is...

- ✓ To propose a market mechanism to allocate resources efficiently in the cloud computing environment



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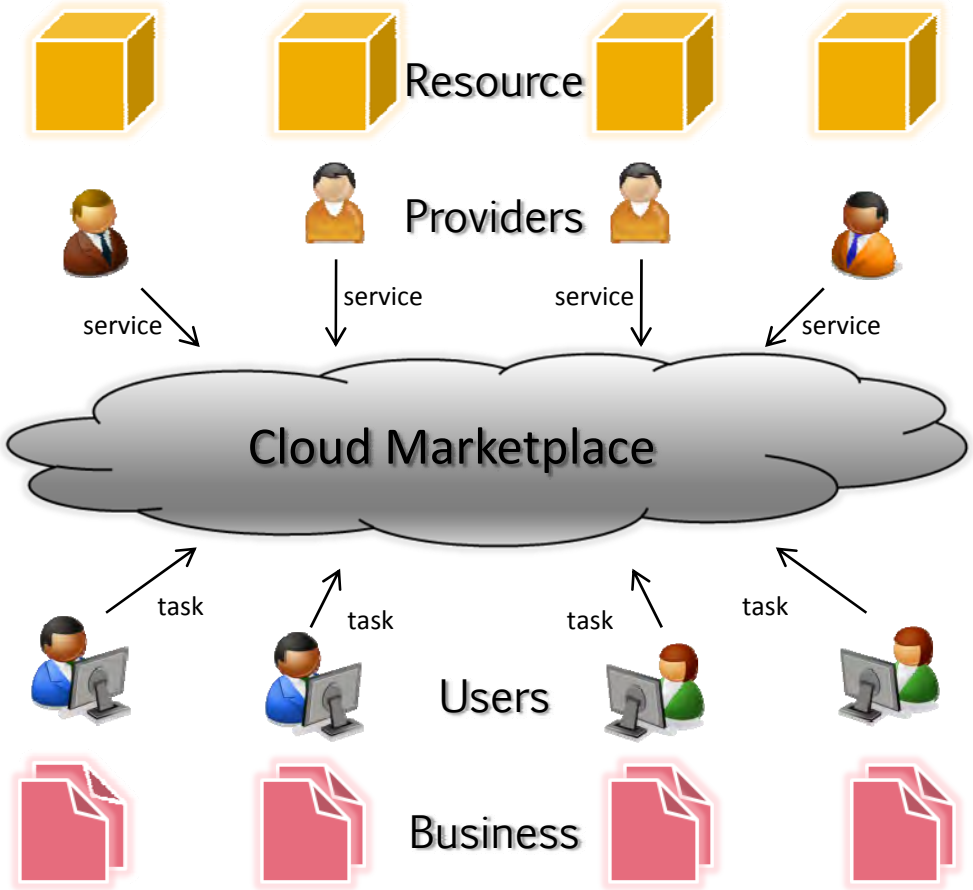
Cloud Computing Environment

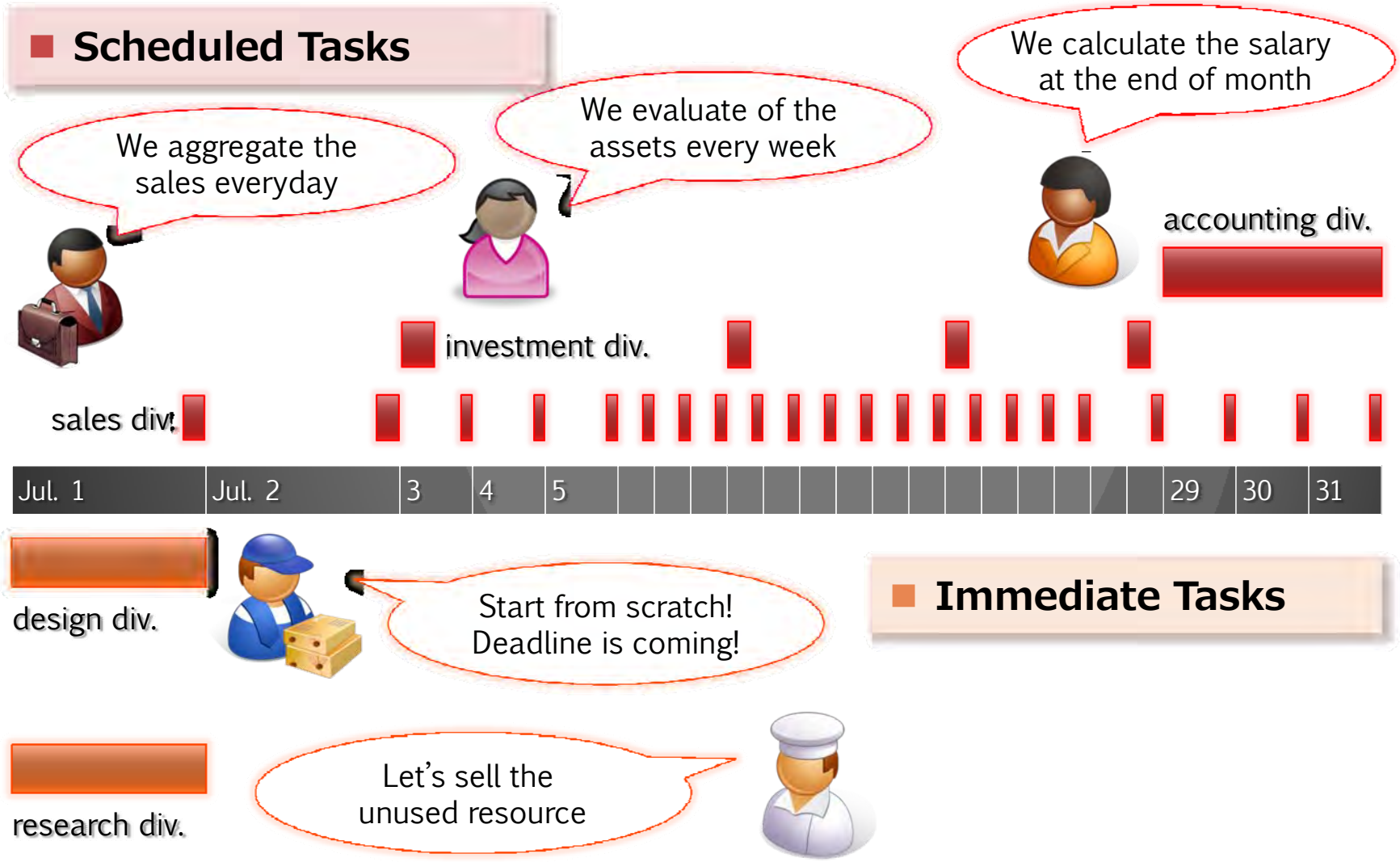


2. Requirements by economy

1. Requirements by users

Requirements by Users (1)

- Typical use of cloud services in a company



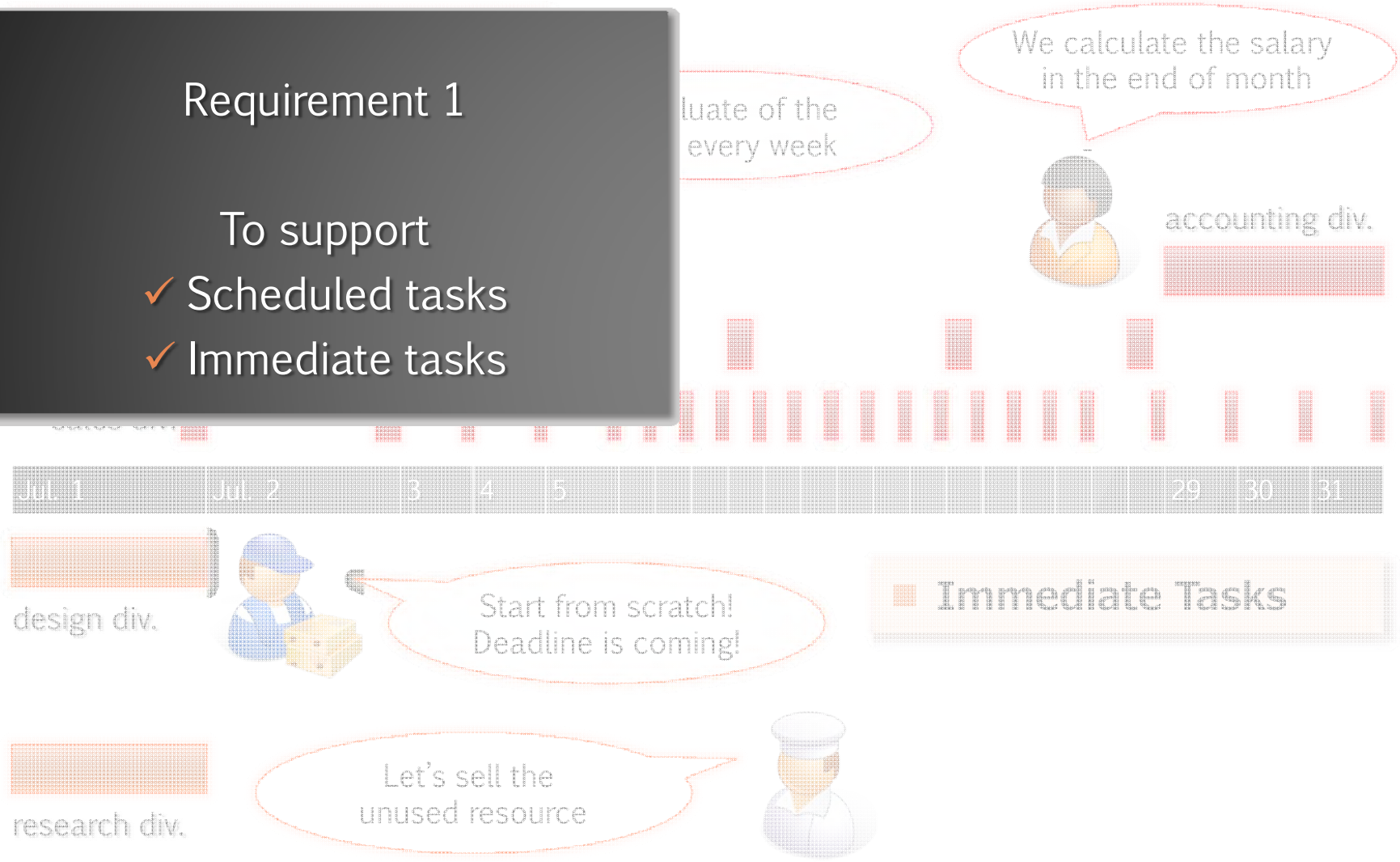
Requirements by Users (1)

- Typical use of cloud services in a company

Requirement 1

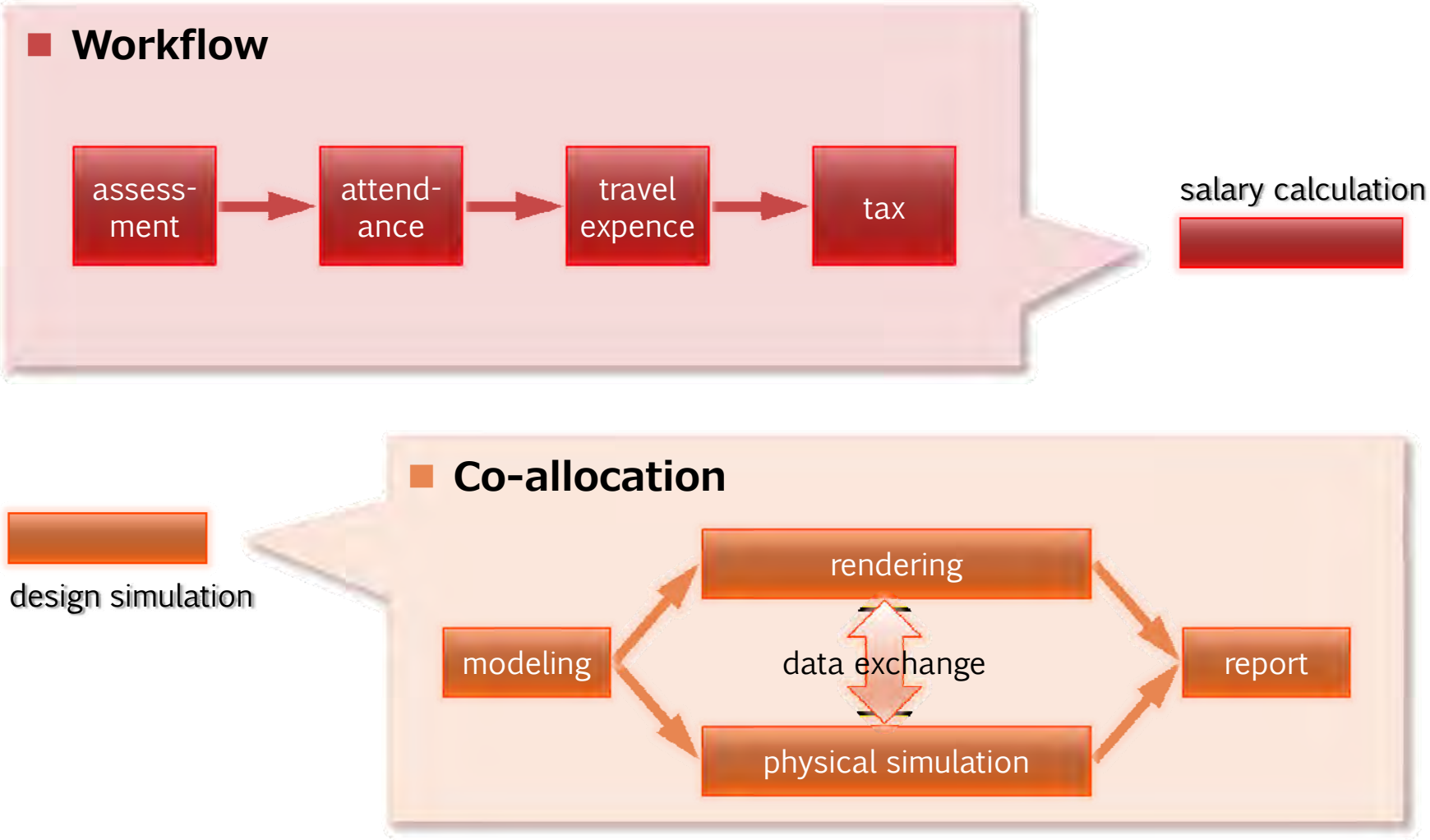
To support

- ✓ Scheduled tasks
- ✓ Immediate tasks



Requirements by Users (2)

- A task may be a combination of subtasks



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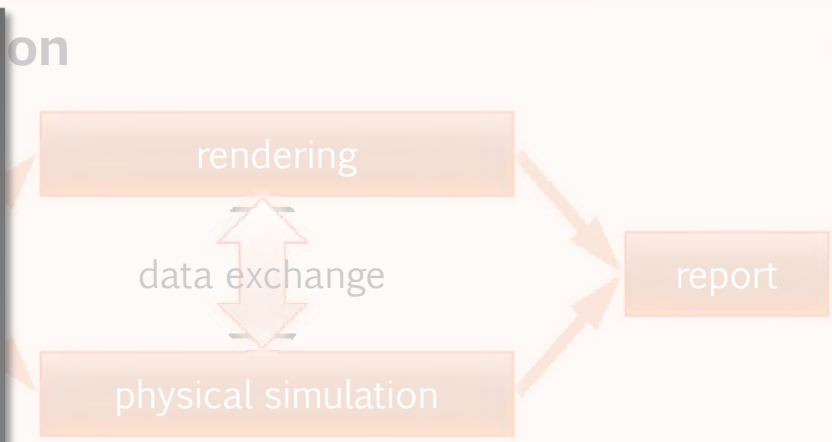

Requirement 2

To support

✓ Combination for workflow

✓ Combination for co-allocation

Requirements by Economy (1)

- For a market mechanism, **auction theory** is used to get an **efficient** outcome
  - Economic efficiency means a **Pareto-optimal allocation**
    - Where no resource is wasted
  - **Maximizing the total welfare** generated by the trading is a sufficient condition for economic efficiency

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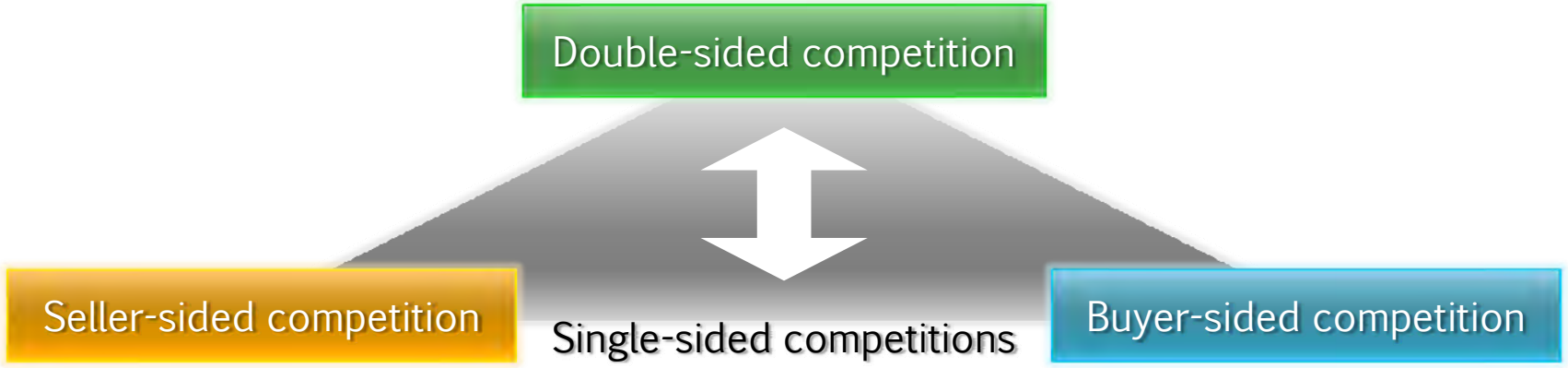
Requirement 3

To support

✓ Pareto-optimal allocation with no wasted resources

Requirements by Economy (2)

- **Auction schemes** are classified as:



  - **Double-sided competition** is better to encourage a fair exchange
    - Where no advantage is given on either side

Requirements by Economy (2)

- Auction schemes are classified as:

  - Double-sided competition is bet
    - Where no advantage is given on

Requirement 4

To support

✓ Double-sided competition with no advantage on either side

Our Approach

- To meet these requirements we employed…

Forward Market & Spot Market

To support
- ✓ Scheduled tasks
- ✓ Immediate tasks

Mixed Integer Programming

To support
- ✓ Pareto-optimal allocation with no wasted resources

Combinational Double Auction

To support
- ✓ Combination for workflow
- ✓ Combination for co-allocation

To support
- ✓ Double-sided competition with no advantage on either side

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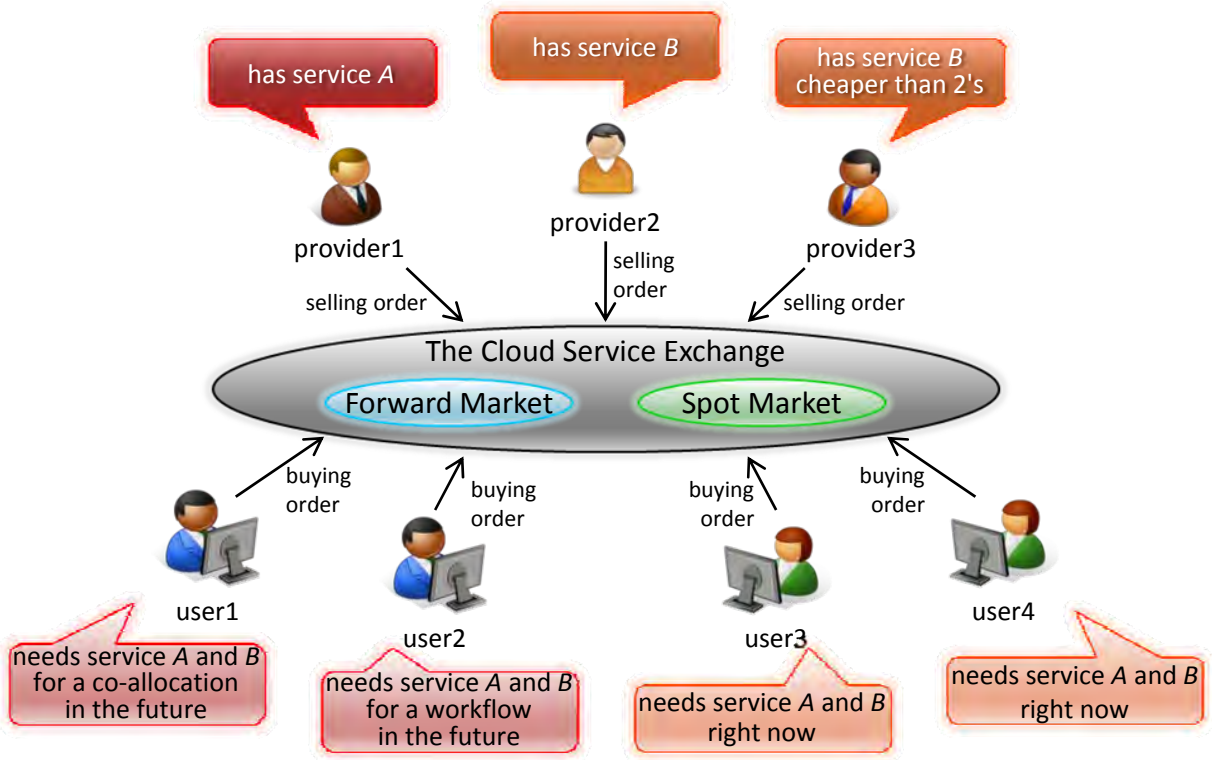
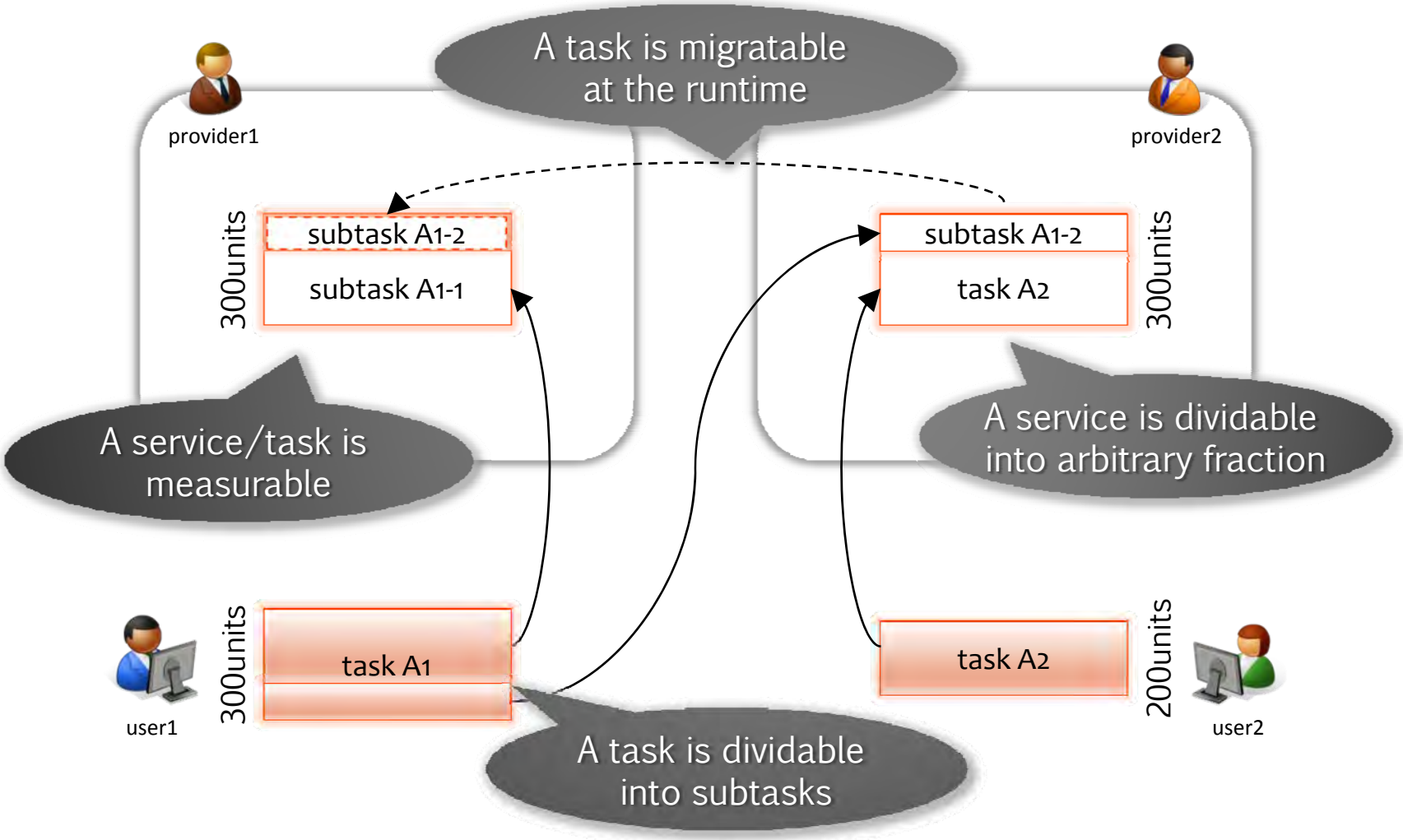
Proposed Market Mechanism – Overview (1)

- Overview
  - There is a centralized marketplace “the Cloud Service Exchange”
  - The exchange has the **forward market** and the **spot market**
  - Providers/Users send selling/buying orders to the markets according to their own strategies



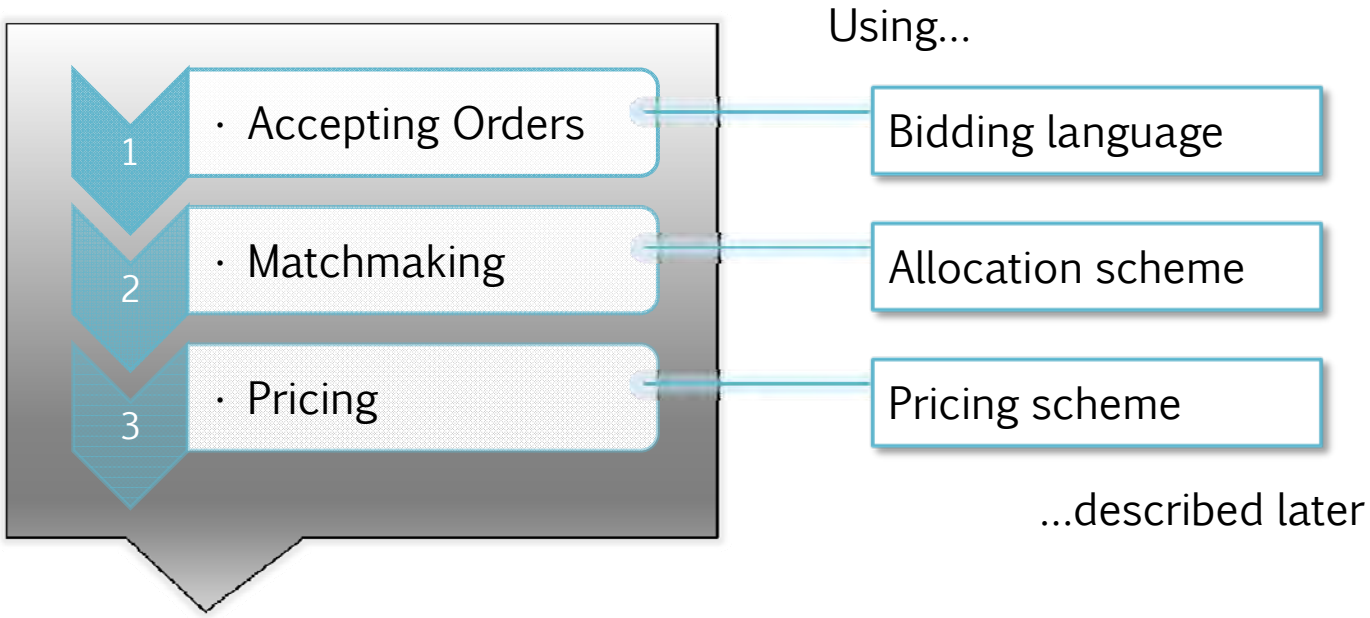
Proposed Market Mechanism – Overview (2)

- Assumption on Services and Tasks



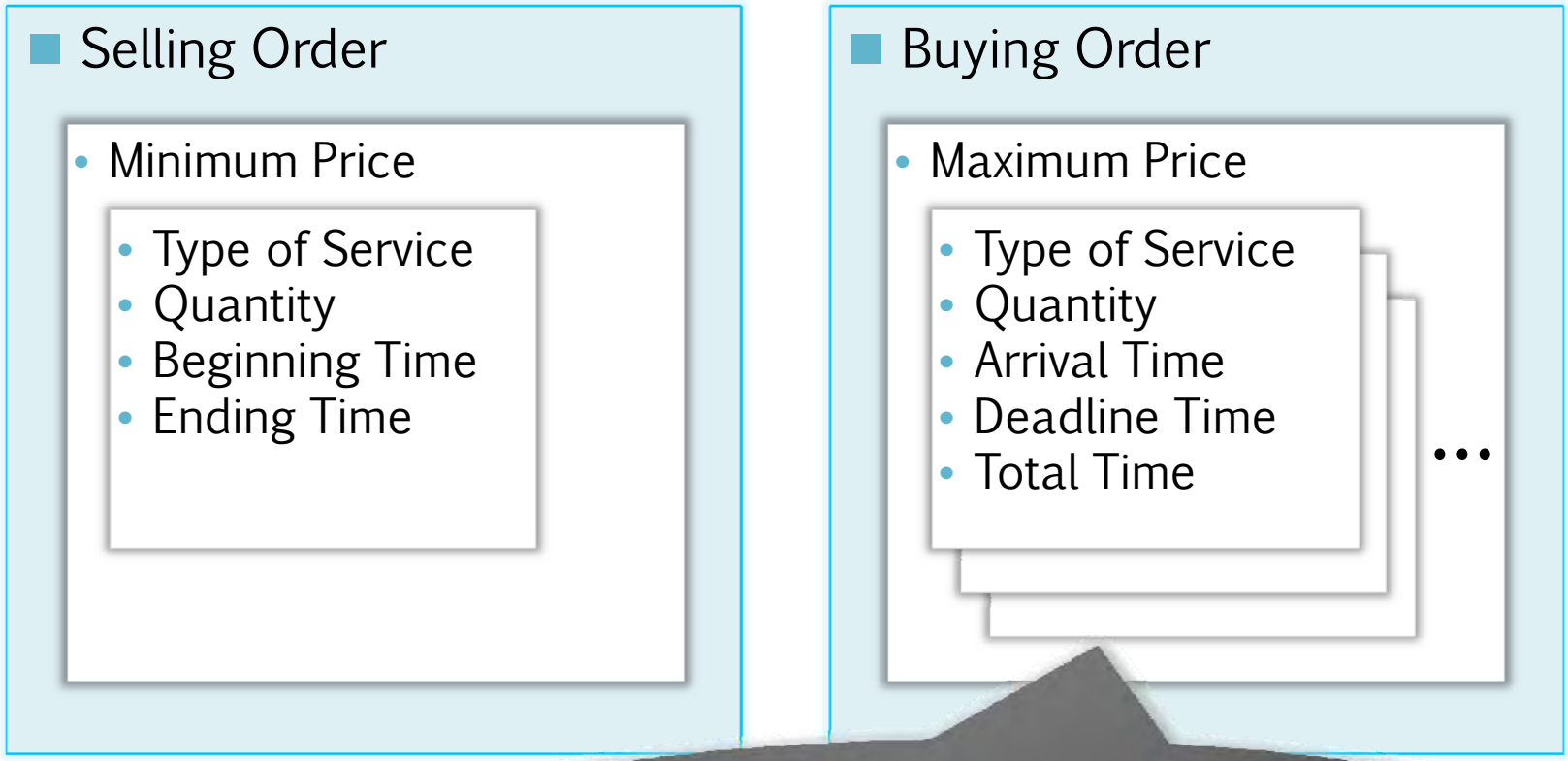
Proposed Market Mechanism – Forward Market (1)

- Forward market
  - Accepts orders at any time
    - An order includes services used in **future timeslots** (e.g. 720 timeslots)
  - Performs matchmaking periodically (e.g. every 24 hours)
  - Determines the trading price for each match



Proposed Market Mechanism – Forward Market (2)

- Bidding language to make orders



A buying order includes multiple services and a single price to express a combination

Proposed Market Mechanism – Forward Market (3)

- Allocation scheme for matchmaking
  - Maximizes the total welfare by optimization with mixed integer programming

Objective Function

$w = \Sigma$(buying order price – selling order price) $\rightarrow$ max.

Variables

$u_j = \{0,1\}$: whether user j's order is fulfilled

$x_{j,k} = \{0,1\}$: whether user j could buy service k

$z_{j,k,t} = \{0,1\}$: whether user j could buy service k on timeslot t

$y_{i,j,k,t} = [0,1]$: percentage of service k sold by provider i to user j on timeslot t

Proposed Market Mechanism – Forward Market (4)

- Pricing scheme to determine the trading price
  - Distributes the welfare generated by the trading
  - An extended K-pricing scheme is used to calculate the distribution

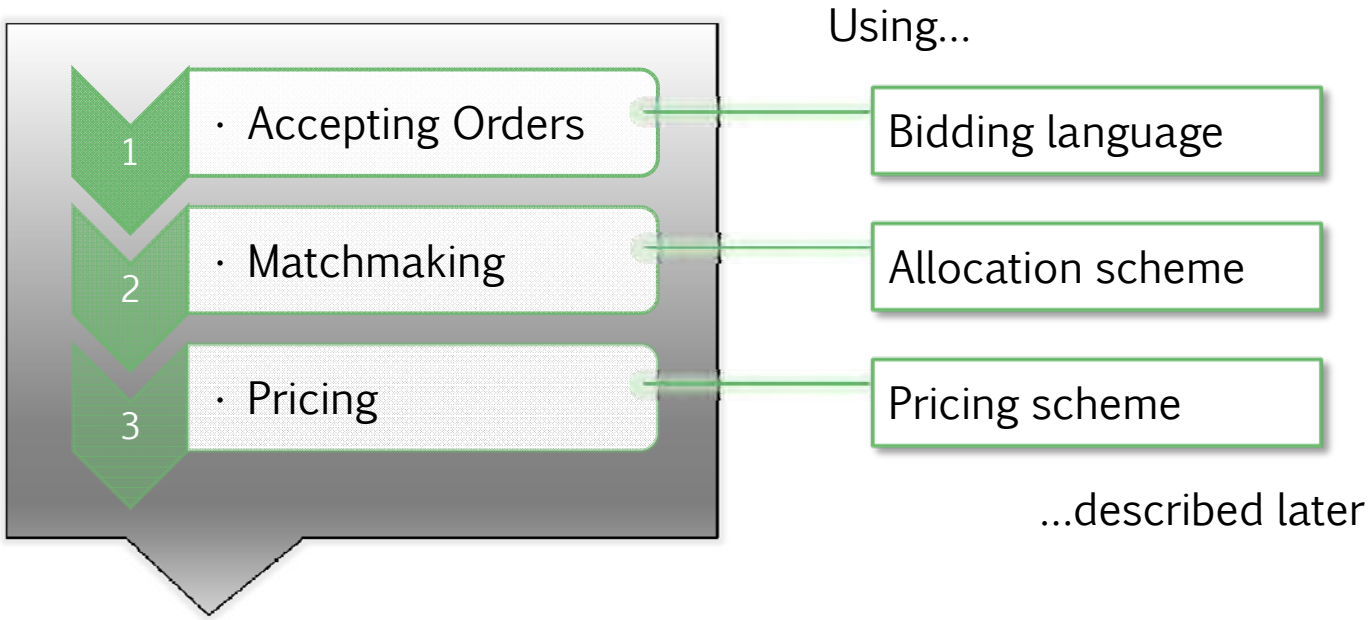
$$w_i = v_i - \sum_{}^{|N|} \sum_{}^{|G|} \sum_{}^{T} v_i y_{i,j,k,t}, \qquad (14)$$

- Details described on the paper

$$p_{i,j} = \sum_{k=1} \sum_{t=1} v_i y_{i,j,k,t} + K \sum_{k=1} \sum_{t=1} w_j r_{i,j,k,t}. \qquad (17)$$

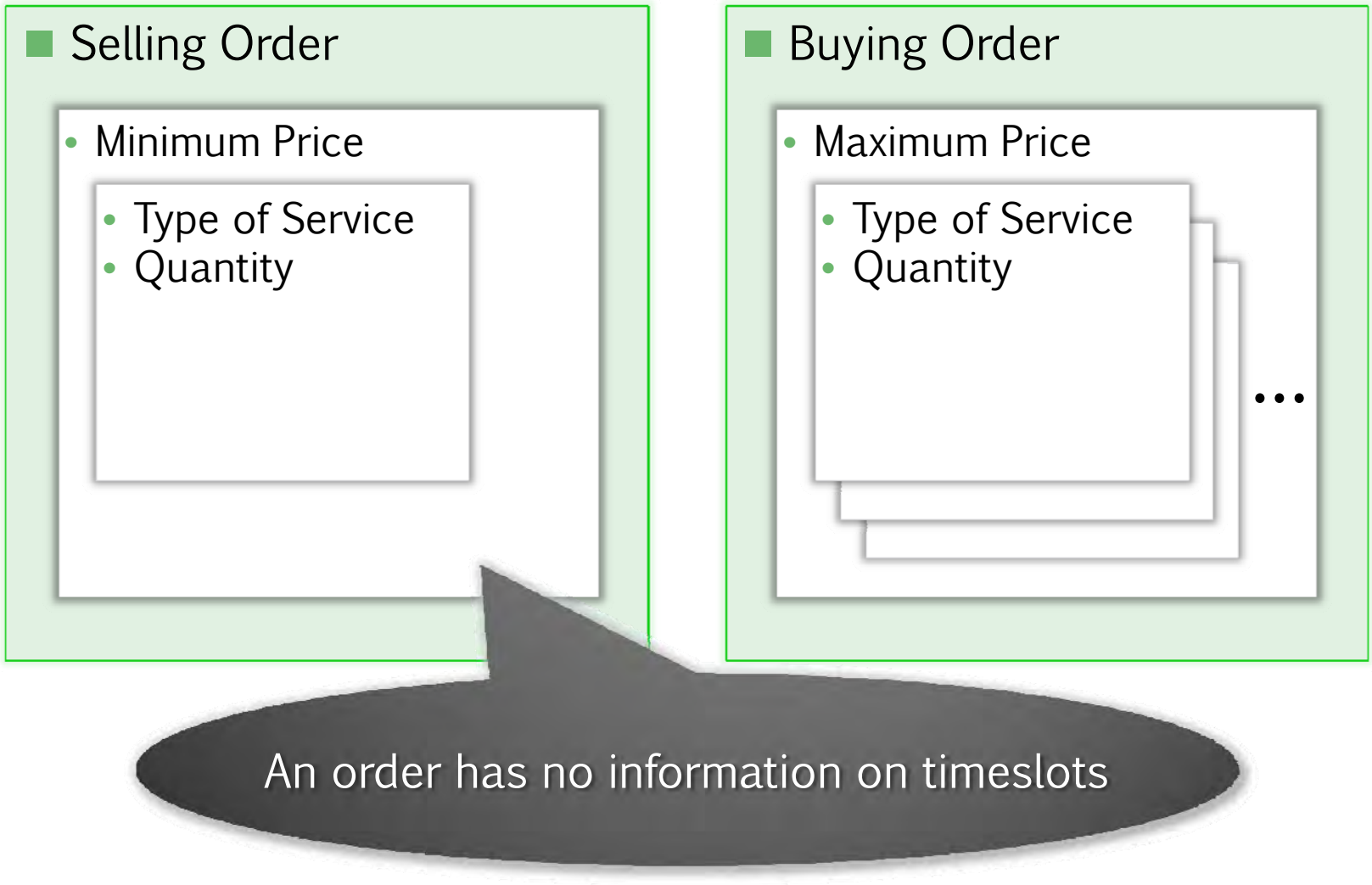
Proposed Market Mechanism – Spot Market (1)

- Spot market
  - Accepts orders at any time
    - An order includes services for **immediate timeslot**
  - Performs matchmaking periodically (e.g. every 24 hours)
  - Determines the trading price for each match



Proposed Market Mechanism – Spot Market (2)

- Bidding language to make orders



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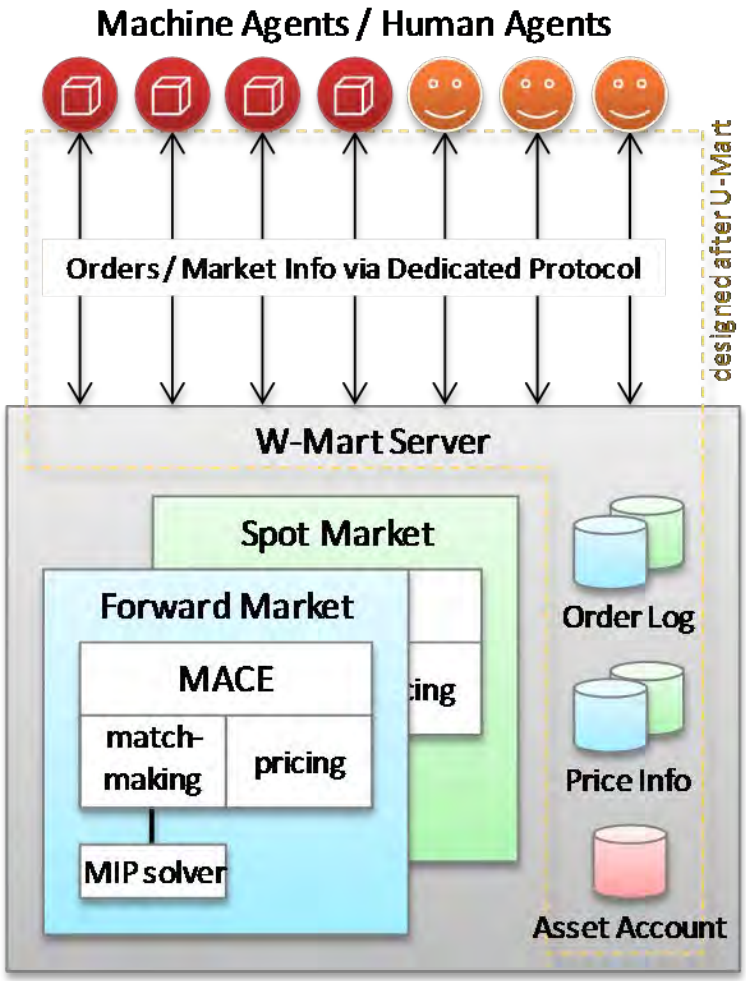
Implementation of Simulator

- Market Simulator **W-Mart**
  - Developed to perform multi-agent simulations
  - Designed after U-Mart architecture
  - Markets are built on MACE framework
  - Two markets run on separate threads



U-Mart [2]

- ✓ Java test bed of artificial market
- ✓ Used in education of economics
- ✓ Machines and humans participate equally

MACE [1]

- ✓ Java framework for combinational auctions
- ✓ Developed for CATNETS project
- ✓ CPLEX is used as the backend MIP solver

[1] B Schnizler, D Neumann, D Veit, and D Weinhardt, "Trading grid services – a multi-attribute combinatorial approach," European Journal of Operational Research, vol. 187, no. 3, pp. 943-961, 2008.

[3] H Sato, Y Koyama, K Kurumatani, Y Shiozawa, and H Deguchi, "U-Mart: A Test Bed for Interdisciplinary Research in Agent Based Artificial Market," in Evolutionary Controversies in Economics, pp. 179-190, 2001.

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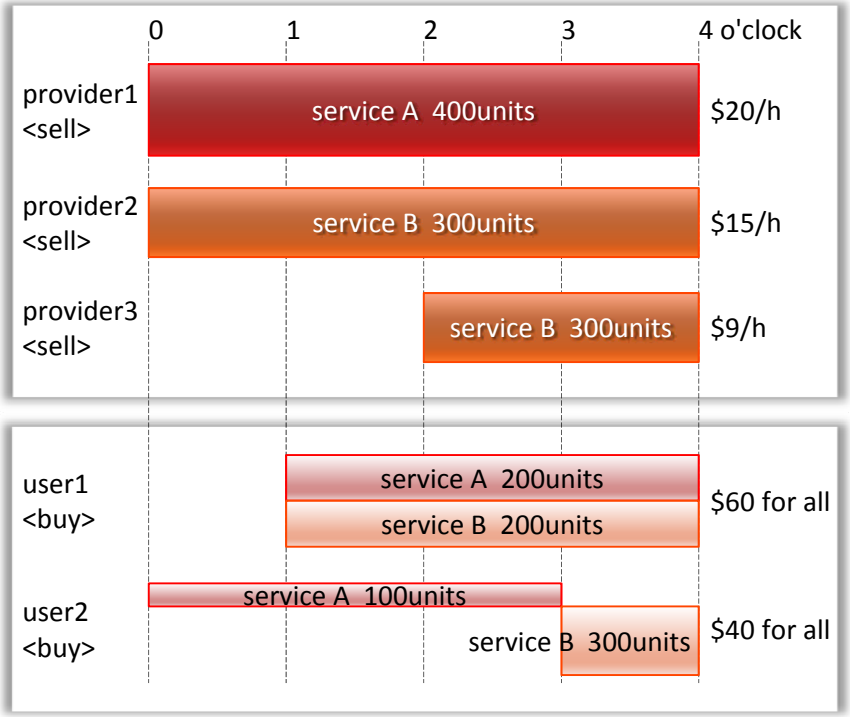
Verifying the Combinational Allocation (1)

- Forward Market
  - Orders



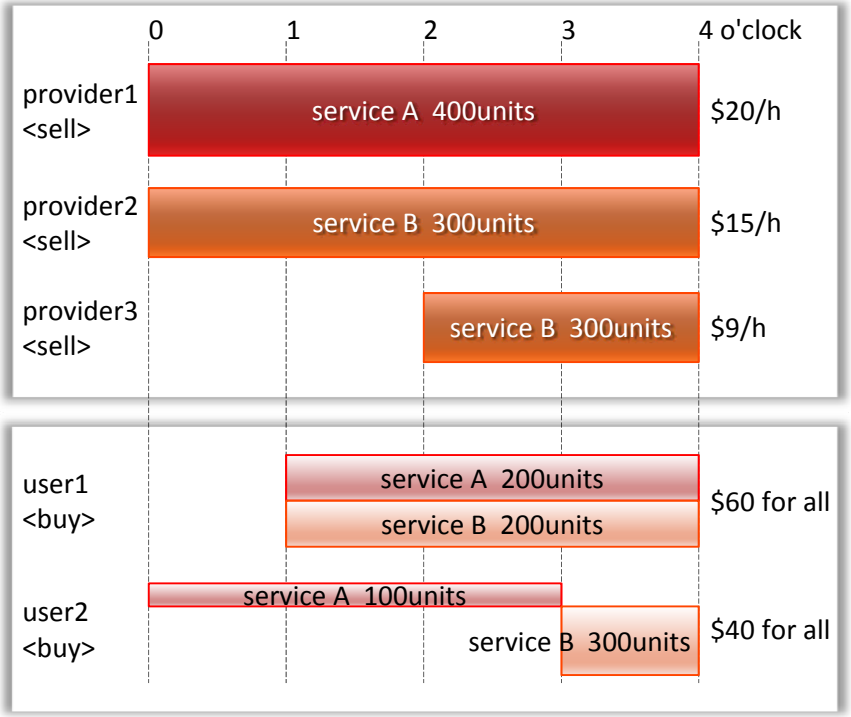
Provider 1 has service A to sell at $20/h or more

User 1 needs co-allocation of service A and B at $60 or less

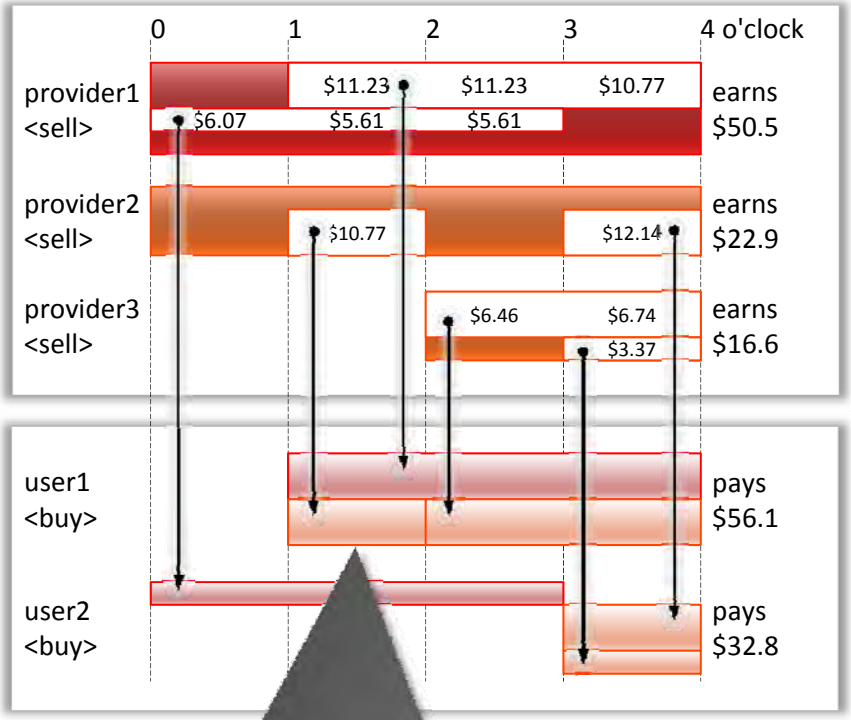
User 2 needs a workflow of service A followed by B at $40 or less

Verifying the Combinational Allocation (2)

- Forward Market
  - Orders



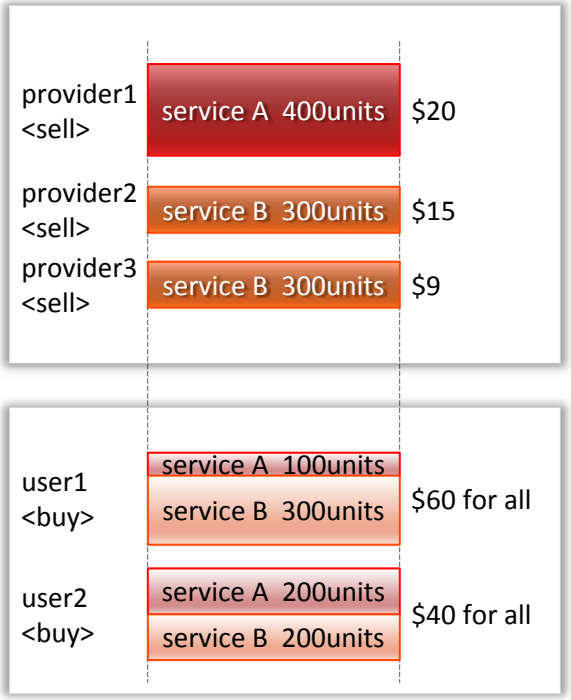
  - Outcome



Provider 2 sells service B to user 1 from 1 to 2 o'clock at $10.77

Verifying the Combinational Allocation (3)

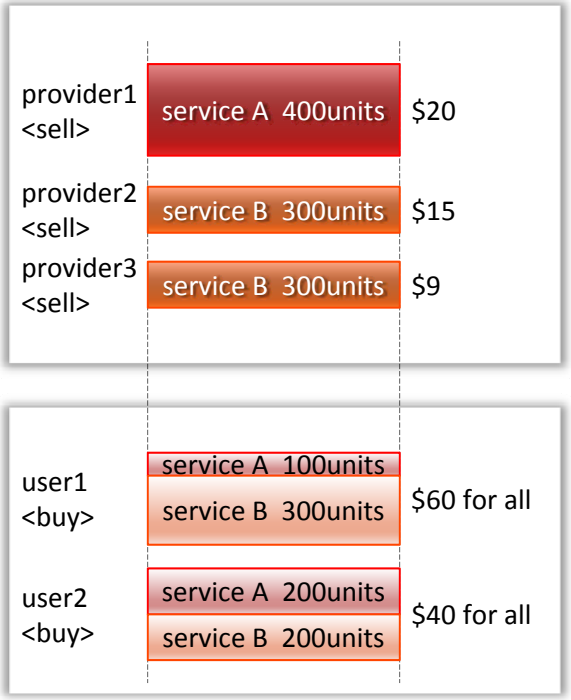
- Spot Market
  - Orders



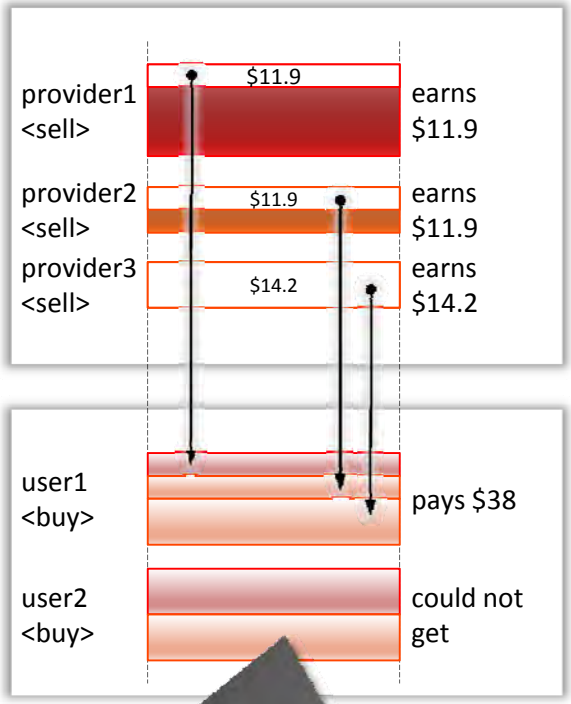
Both user 1 and 2 needs co-allocation of service A and B at different prices (user1 > user2)

Verifying the Combinational Allocation (4)

- Spot Market
  - Orders



  - Outcome



User 2 lost the competition and bought nothing at all

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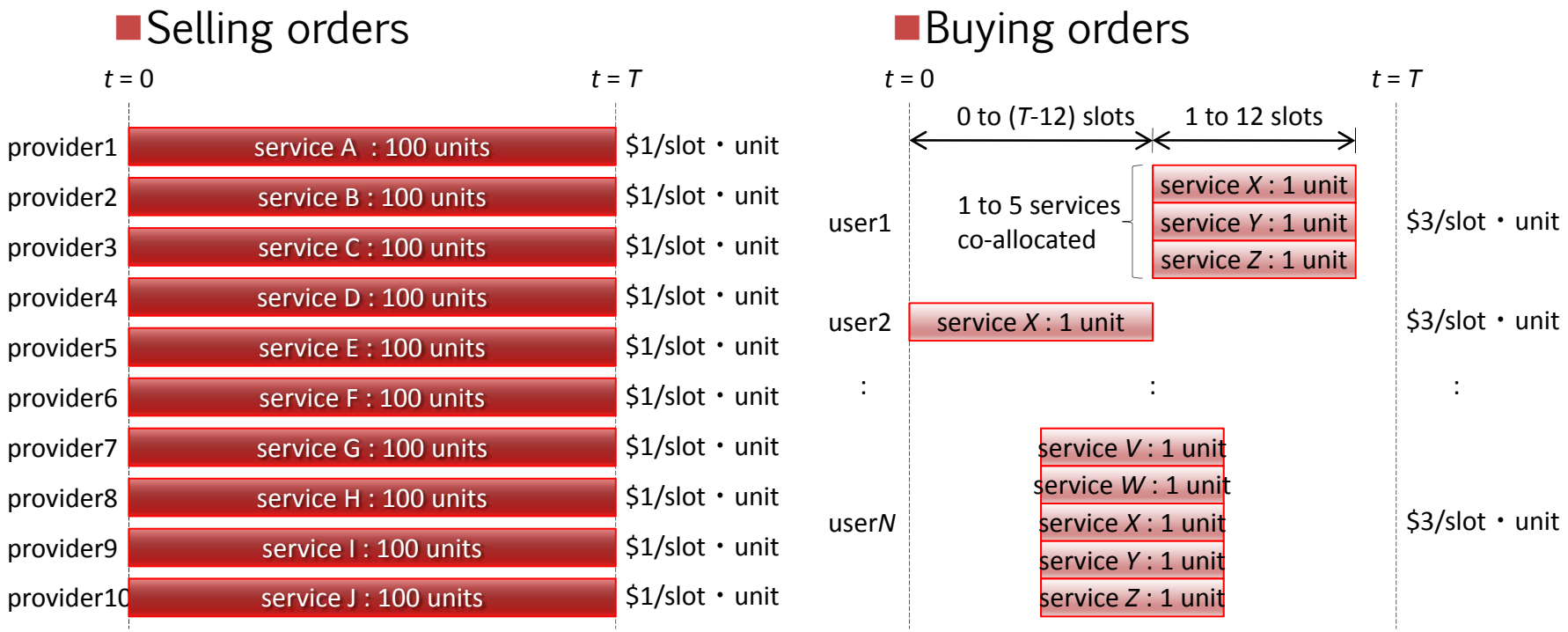
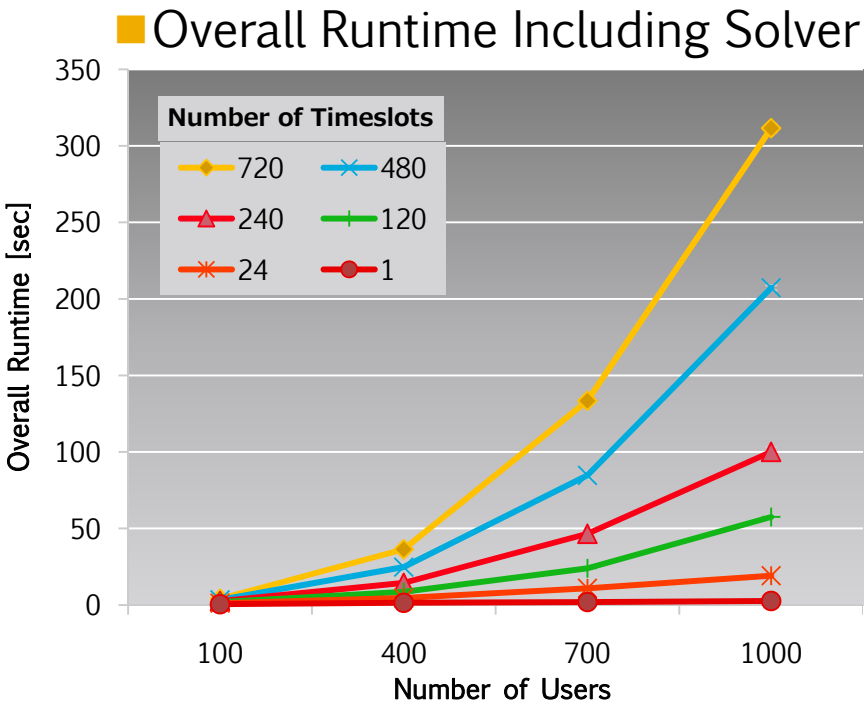
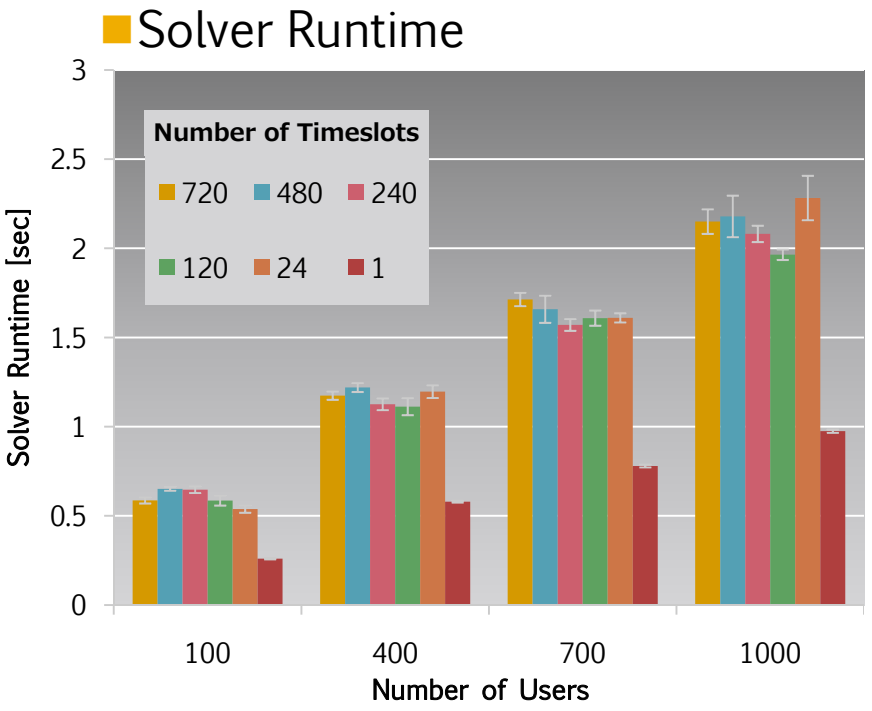
Estimating Scalability (1)

- Scenario
  - 10 providers sell 10 services
  - 100-1000 users buy 1-5 services co-allocated for 1-12 hours
  - Demand/supply ratio = 2%-16%
  - Selling order price < Buying order price

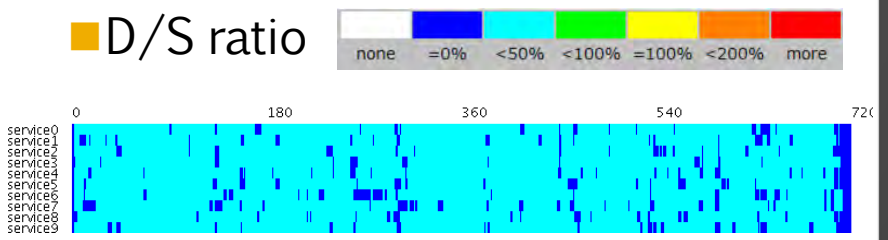


Estimating Scalability (2)





- ✓ The proposed mechanism works efficiently for 1 month forward trading with 10 providers and 1000 users



example: 1000 users, 2.6% average

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Related Work

	Combinational	Predictable & flexible	Double-sided competition	Economic efficiency
Proposed	◎	◎	◎	◎
MACE [1]	△	△	◎	◎
SCDA [2]	×	×	◎	△
Electricity Market	×	◎	◎	△
Stock Market	×	△	◎	△
Commodity Market	×	△	×	×

[1] B Schnizler, D Neumann, D Veit, and D Weinhardt, "Trading grid services – a multi-attribute combinatorial approach," European Journal of Operational Research, vol. 187, no. 3, pp. 943-961, 2008.

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SCDA [2]	×	×	○	△
Electricit Market	×	×	×	△
Stock Market	×	△	○	△
Commodity Market	×	△	×	×

✓ Only the proposed mechanism satisfies these four requirements for the cloud computing environment

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Conclusions and Future Work

Conclusions

- We proposed a market mechanism for resource allocation in the cloud computing environments
- Evaluation showed that the proposed mechanism worked with an acceptable overhead

Future Work

- To investigate the autonomous behavior of the market price using W-Mart simulator
  - What strategy is the best way to trade the services?
  - How can we design a stable and sustainable market?
  - Can we forecast the spot price in the future by observing the forward price?

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