Market-based Resource Allocation for Distributed Computing

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Abstract

Market-based resource allocation is expected to be an effective mechanism to allocate resources in a cloud computing environment, where the resources are virtualized and delivered to users as services. In this paper we propose a market mechanism to efficiently allocate multiple computation/storage services among multiple participants. The proposed mechanism enables the users to (1) order a combination of arbitrary services with a co-allocation or a workflow manner, and (2) receive future/current services at the forward/spot market.

The Market Model

Assumptions

- ✓ The amount of a service can be measured in throughput (e.g. *MIPS* for a computation service or *GB/h* for a data processing service)
- ✓ A provider's resource can be divided into arbitrary fraction
- ✓ A task can be divided into sub-tasks and executed on multiple resources
- ✓ A task can be suspended, resumed and/or migrated during the runtime

Forward Market

- ✓ Deals with advance reservations per pre-defined timeslots
- ✓ Makes contracts periodically (clearinghouse auctions)

Bidding Language

- ✓ Allows users to combine arbitrary resources (allocated all or nothing)

for Users

- Valuation
  - Resource Type
  - Quantity
  - Earliest Timeslot
  - Latest Timeslot
  - Total Length
  - ...

for Providers

- Valuation
  - Resource Type
  - Quantity
  - Earliest Timeslot
  - Latest Timeslot

Allocation Scheme

- ✓ Maximizes total welfare = Σ(buyer's valuation – seller's valuation)
- ✓ Formulated as a mixed integer program

maximize

$$w = \sum_{j=1}^{|N|} v_j u_j - \sum_{i=1}^{|N|}\sum_{j=1}^{|M|}\sum_{k=1}^{|G|}\sum_{t=1}^{T} v_i y_{i,j,k,t} \quad (1)$$

s.t.

$$\sum_{k=1}^{|G|} x_{j,k} - |G|\, u_j = 0 \qquad 1 \le j \le |N| \quad (2)$$
$$\sum_{t=1}^{T} z_{j,k,t} - l_{j,k}\, x_{j,k} = 0 \qquad 1 \le j \le |N|, 1 \le k \le |G| \quad (3)$$
$$\sum_{j=1}^{|N|} y_{i,j,k,t} \le 1 \qquad 1 \le i \le |M|, 1 \le k \le |G|, 1 \le t \le T \quad (4)$$
$$q_{j,k} z_{j,k,t} - \sum_{i=1}^{|M|} q_{i,k} y_{i,j,k,t} = 0 \qquad 1 \le j \le |N|, 1 \le k \le |G|, 1 \le t \le T \quad (5)$$
$$(a_{j,k} - t) z_{j,k,t} \le 0 \qquad 1 \le j \le |N|, 1 \le k \le |G|, 1 \le t \le T \quad (6)$$
$$(t - d_{j,k}) z_{j,k,t} \le 0 \qquad 1 \le j \le |N|, 1 \le k \le |G|, 1 \le t \le T \quad (7)$$
$$(a_{i,k} - t) \sum_{j=1}^{|N|} y_{i,j,k,t} \le 0 \qquad 1 \le i \le |M|, 1 \le k \le |G|, 1 \le t \le T \quad (8)$$
$$(t - d_{i,k}) \sum_{j=1}^{|N|} y_{i,j,k,t} \le 0 \qquad 1 \le i \le |M|, 1 \le k \le |G|, 1 \le t \le T \quad (9)$$
$$u_j \in \{0,1\} \qquad 1 \le j \le |N| \quad (10)$$
$$x_{j,k} \in \{0,1\} \qquad 1 \le j \le |N|, 1 \le k \le |G| \quad (11)$$
$$z_{j,k,t} \in \{0,1\} \qquad 1 \le j \le |N|, 1 \le k \le |G|, 1 \le t \le T \quad (13)$$
$$0 \le y_{i,j,k,t} \le 1 \qquad 1 \le i \le |M|, 1 \le j \le |N|, 1 \le k \le |G|, 1 \le t \le T \quad (14)$$

where

- $M = \{m_1, \ldots, m_{|M|}\}$, $m_i = \{v_i, S_i\}$: selling orders
- $N = \{n_1, \ldots, n_{|N|}\}$, $n_j = \{v_j, S_j\}$: buying orders
- $G = \{g_1, \ldots, g_{|G|}\}$: services
- $1 \le t \le T$: timeslots
- v_i and v_j : valuation
- u_j : the number of services with $q_{j,k} > 0$
- $q_{j,k}$: quantity of service g_k
- $a_{j,k}$: arrival time; $d_{j,k}$: deadline; $l_{j,k}$: total length — for buying order
- $e_{j,k}$: timeslot — for selling order
- $S_j = \{(g_k, q_{j,k}, a_{j,k}, d_{j,k}, l_{j,k}) \mid 1 \le k \le |G|\}$: a buying order
- $S_i = (g_k, q_{i,k}, e_{i,k})\,;\ 1 \le k \le |G|$: a selling order

Pricing Scheme

- ✓ Calculates the price which the participants actually pays/earns
- ✓ K-Pricing: Price = (buyer's valuation + seller's valuation) / 2

Spot Market

- ✓ Deals with immediate reservation up to the next timeslot begins
- ✓ Makes contracts continuously (continuous auction)
- ✓ Bidding language, allocation scheme and pricing scheme are similar to the forward market except that they have only one timeslot

Simulator

- ✓ Consists of a centralized exchange and autonomous agents

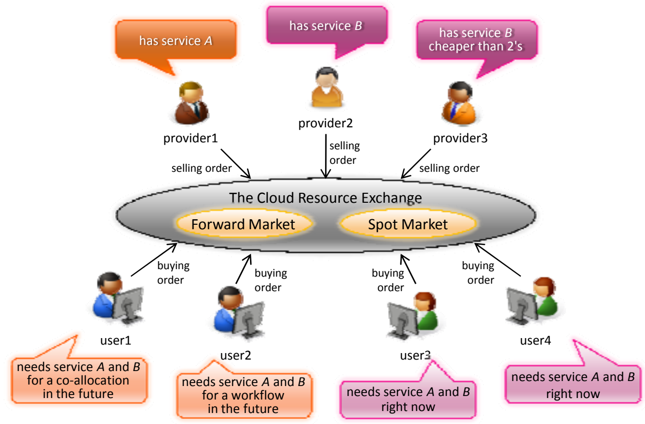
Markets

- ✓ Constructed based on MACE [1]
- ✓ Uses CPLEX or lp_solve as backend solver

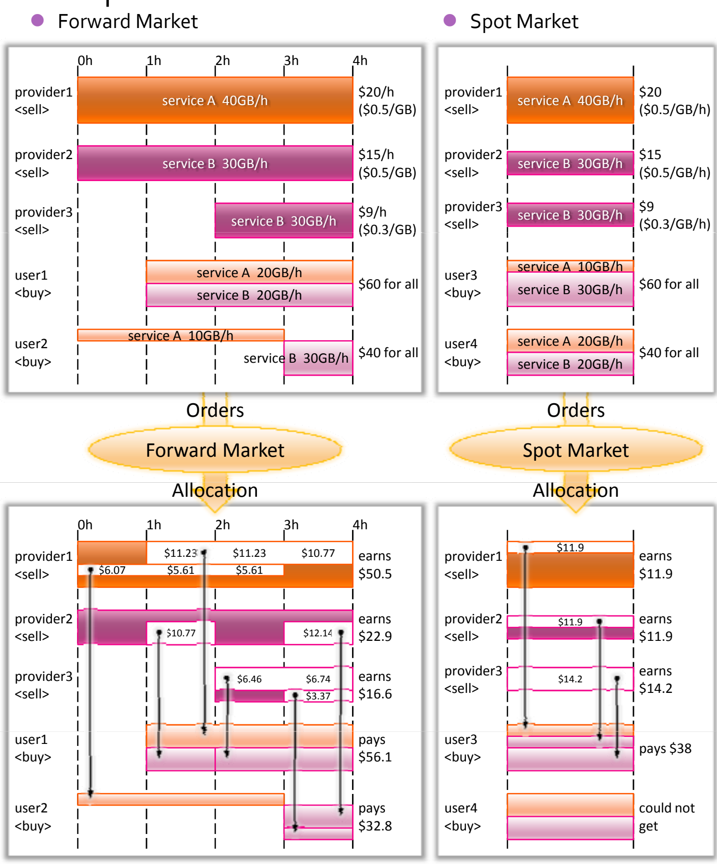
Agents

- ✓ Developed to be compatible with U-Mart [2]
- ✓ Can be either software or real human

Overview



Example



Conclusions & Future Work

- ✓ We proposed a market mechanism to allocate resources in a cloud computing environment
- ✓ Experiment shows that the market mechanism works properly
- ✓ We anticipate that the forward price will serve as a forecast of the spot price; intelligent agents will autonomously avoid the high-priced period which means a tight supply-demand situation
- ✓ We are going to investigate the market behavior and evaluate the performance of the proposed mechanism

References

[1] B. Schnizler, D. Neumann, D. Veit and C. Weinhardt, "Trading grid services – a multi-attribute combinatorial approach," *European Journal of Operational Research*, Volume 187, Issue 3, pp. 943-961, 2008.

[2] 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.