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A strategy-proof auction mechanism for service composition based on user preferences

Key words: Combinatorial reverse auction; Service composition; User preference; Strategy-proof; Dynamic pricing

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Motivation

1. Because every service has multiple attributes, the service composition problem is a multi-attribute decision-making problem, which leads to great challenges in selecting preferred services from a wide range of services.
2. Auction is a popular dynamic pricing mechanism that is widely used in cloud computing. Although Vickrey- Clark-Groves (VCG) can solve the issue of untruthful service cost, the services' QoS at the winner determination and payment calculation stage is not considered.
3. Users have diverse QoS preferences. It is difficult to design winner determination and pricing mechanism by considering user preferences in the auction mechanism, and ensure the truthful service cost of the offer from the service provider.

Main idea

1. Each QoS attribute has a different unit; every QoS attribute value of a service must be normalized to a dimensionless quantity in interval [0, 1], which is an additional score.

2. The total additional score and additional cost are determined according to the user's preferences. The additional cost is added to the reported cost to obtain the virtual cost.

3. The smaller the virtual cost is, the better the overall performance of the service will be. The services' prices are calculated based on the virtual costs referring to the VCG mechanism.

Method

1. QoS normalization and service virtual cost calculation

Each QoS attribute has a different measurement unit. Every QoS attribute value of a service must be normalized to a dimensionless quantity in interval [0, 1], which is an additional score.

$$q'_{i,j,k,d}=\begin{cases}\dfrac{q_{i,j,k,d}-\min q_{i,d}}{\max q_{i,d}-\min q_{i,d}}, & \max q_{i,d}\neq \min q_{i,d},\\ 1, & \max q_{i,d}=\min q_{i,d}.\end{cases}$$

Positive

$$q'_{i,j,k,d}=\begin{cases}\dfrac{\max q_{i,d}-q_{i,j,k,d}}{\max q_{i,d}-\min q_{i,d}}, & \max q_{i,d}\neq \min q_{i,d},\\ 1, & \max q_{i,d}=\min q_{i,d}.\end{cases}$$

Negative

The virtual cost of every service can be calculated using the simple additive weighting method. The weight value ultimately depends on user preferences.

$$\mathrm{vc}_{i,j,k}=c_{i,j,k}+v\sum_{d=1}^{f}\omega_d q^{*}_{i,j,k,d},$$

Method (Cont'd)

2. Winner determination

The objective function of winner determination is to minimize the total virtual cost of the service composition, which is equivalent to maximizing the overall performance of service composition.

$$\min \sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{r} \mathrm{vc}_{i,j,k} x_{i,j,k} = \min \sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{r} \left(c_{i,j,k} + v \sum_{d=1}^{f} \omega_d q^{*}_{i,j,k,d} \right) x_{i,j,k}$$

where $x_{i,j,k}$ is the decision variable. When $x_{i,j,k}$=1, $b_{i,j,k}$ is selected; when $x_{i,j,k}$=0, $b_{i,j,k}$ is not selected.

Method (Cont'd)

3. Payment calculation

We propose a new payment calculation method based on the VCG mechanism. The services' prices are calculated based on the virtual costs, considering the QoS and the reported cost, whereas VCG considers only the reported cost.

$$p_{i,j,k} = \sum_{b_{i',j',k'} \in \mathrm{WS}^{i,j,-k}} \mathrm{vc}_{i',j',k'} - \sum_{b_{i*,j*,k*} \in \mathrm{WS},\, j* \neq j} \mathrm{vc}_{i*,j*,k*}.$$

Method (Cont'd)

4. Desirable property analysis

Theorem 1 The SCAUP achieves truthfulness.

$b_{i,j,k}$ cannot improve its utility by reporting higher or lower cost (i.e., untruthful cost).

Theorem 2 The SCAUP achieves individual rationality.

$$
\begin{aligned}
\mathrm{usp}_k &= \sum_{b_{i,j,k}\in \mathrm{WS}^k} p_{i,j,k} - \sum_{b_{i,j,k}\in \mathrm{WS}^k} c_{i,j,k} \\
&= \sum_{b_{i,j,k}\in \mathrm{WS}^k} \left(\sum_{b_{i',j',k'}\in \mathrm{WS}^{i,j,-k}} \mathrm{vc}_{i',j',k'} - \sum_{b_{i*,j*,k*}\in \mathrm{WS},\, j*\neq j} \mathrm{vc}_{i*,j*,k*} \right) - \sum_{b_{i,j,k}\in \mathrm{WS}^k} c_{i,j,k} \\
&\geq \sum_{b_{i,j,k}\in \mathrm{WS}^k} \left(\sum_{b_{i*,j*,k*}\in \mathrm{WS},\, j*\neq j} \mathrm{vc}_{i*,j*,k*} + \mathrm{vc}_{i,j,k} - \sum_{b_{i*,j*,k*}\in \mathrm{WS},\, j*\neq j} \mathrm{vc}_{i*,j*,k*} \right) - \sum_{b_{i,j,k}\in \mathrm{WS}^k} c_{i,j,k} \\
&= \sum_{b_{i,j,k}\in \mathrm{WS}^k} \mathrm{vc}_{i,j,k} - \sum_{b_{i,j,k}\in \mathrm{WS}^k} c_{i,j,k} \geq 0.
\end{aligned}
$$

Major results

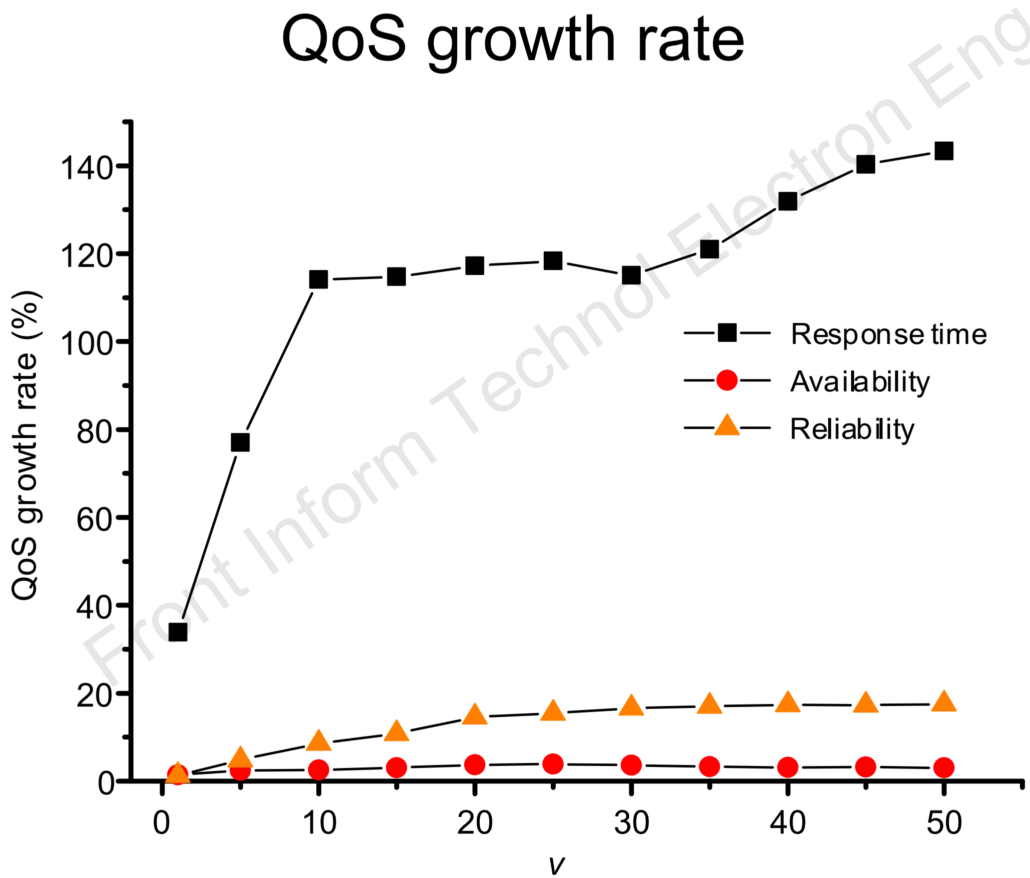

Fig. 5 QoS growth rate based on adjustment factor *v*

Major results (Cont'd)

Social welfare

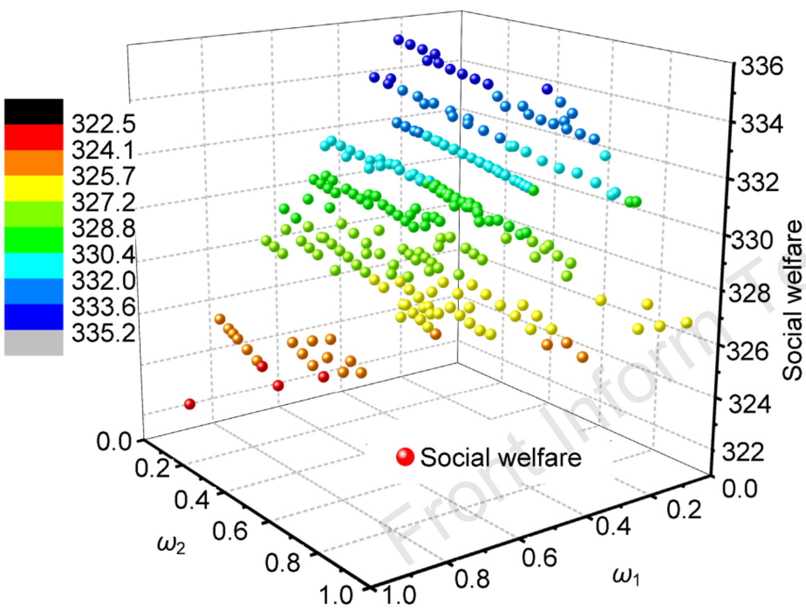

Fig. 6 Social welfare varying with ω_1 and ω_2

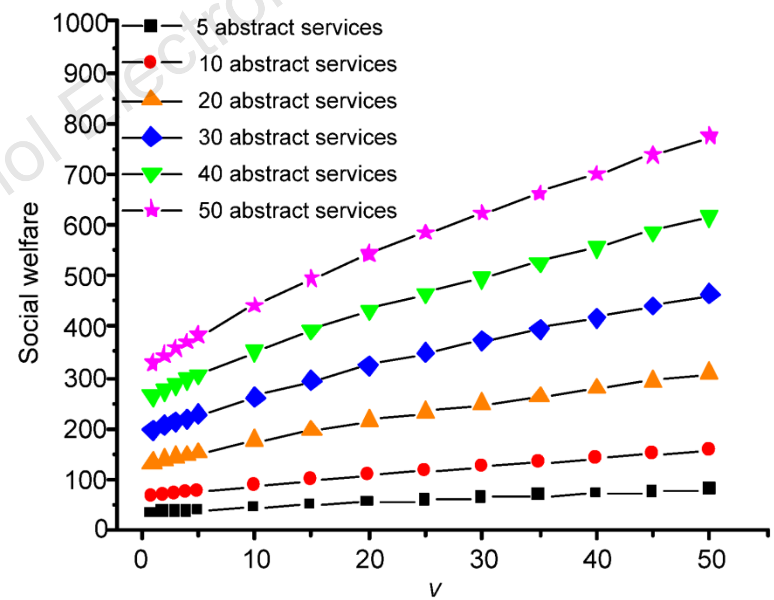

Fig. 7 Social welfare varying with adjustment factor v

Major results (Cont'd)

Success ratio

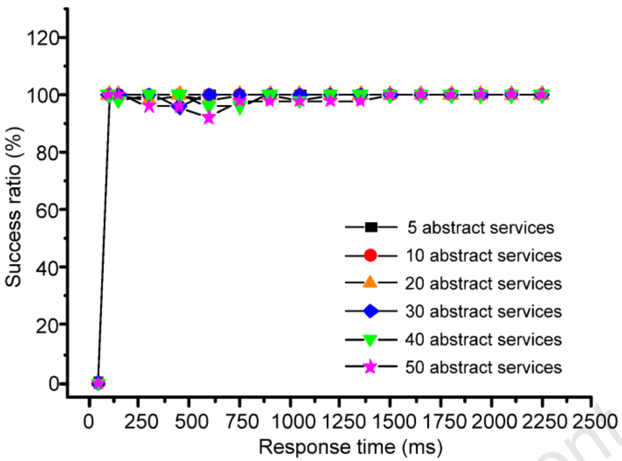

Fig. 12 Success ratio varying with the response time

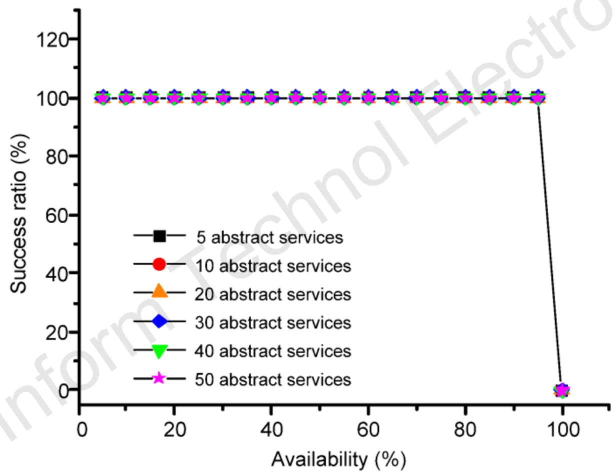

Fig. 13 Success ratio varying with the availability

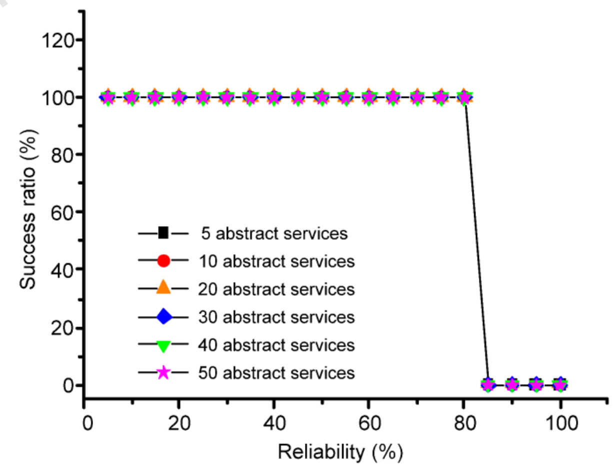

Fig. 14 Success ratio varying with the reliability

Conclusions

1. We have proposed a new service auction mechanism based on user preferences (SCAUP). New winner determination and payment calculation methods were proposed which allow the user to evaluate a service according to preferences.

2. It was proved theoretically that the SCAUP auction mechanism has the strategy-proof property.

3. We conducted experiments based on real data and verified that the SCAUP auction mechanism has the strategy-proof property and can effectively improve the overall QoS level of service composition.