

# Tariff Structures for Pricing Grid Computing Resources

Hemant K. Bhargava

UC Davis

with Adib Bagh

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# market for grid computing resources

## technologies and standards

- rapid, dynamic pooling of heterogeneous resources, mapping of tasks to grid pool.
- “on demand” availability of massive computing power.
- migration of (some) corporate computing to grid environment (internal / external).

## commercial application

- how are these resources priced, allocated, provisioned?
- what are key considerations in a grid market? how do they affect design?

# business and technological perspectives

## demand for grid resources?

- who are the customers? what applications?

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individual-level uncertainty in consumption quantity
- what “features” do they want?

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## demand for grid resources?

- who are the customers? what applications?  
individual-level uncertainty in consumption quantity
- what “features” do they want?  
guarantees: QoS, data privacy, security, availability ...

## implications

- computations will not be costless to provide ... “brand” counts.
- differentiation despite resource pooling
  - in service time (Png-Reitman-1995), queue delay (Tirupati: Dube et al. 2001), congestion (PMP: Odlyzko 1999).
  - in QoS guarantees (Bhargava-Sun 2006).
- suppliers can command pricing power.

# business and technological perspectives

## supply of grid resources

- who will the suppliers be?







# pricing mechanisms

- pay as you go
  - capacity risk?
  - guarantees about availability, QoS?
- flat-fee (reservation) component?
  - attractive due to flat-rate bias (Kridel et al., 1993; Lambrecht and Skiera, 2006; Sundararajan, 2004; Train et al., 1987, 1989; Malmendier and Della Vigna, 2005).
  - but ... light users subsidize heavy users; wasteful use.
- multi-part tariff:  $(F, p)$  or  $(F, Q, p)$ .

## nonlinear pricing and multi-part tariffs

- ability to extract consumer surplus: multi-part tariff is special case of NLP menu  $(Q_1, P_1), (Q_2, P_2) \dots$   
(menu of two-part tariffs is also special case of NLP.)
- timing of decision on consumption quantity
  - NLP... BEFORE realization of demand shock  $\Rightarrow$  inefficient design.
  - multi-part tariff: variable rate allows delayed consumption decision.
- capacity planning: fixed fee makes capacity reservation credible.

# model

## buyers

- type  $\theta \in \Theta$ : private information, seller knows only  $F(\theta)$ .
- task  $\tau_\theta$  requires  $q$  computons,  $q \in [0, b(\theta)]$ .
- wtp =  $V(\theta)$ .
- total tariff paid =  $T(\theta)$ .
- type  $\theta$  buys if  $V(\theta) \geq T(\theta)$ .

# model

## sellers

- choose tariff  $\tau = (F, Q, \rho)$ , installed capacity  $\rho$ .
- if  $\theta$  known: firm's cost to serve type  $\theta$  customer with installed capacity  $\rho$

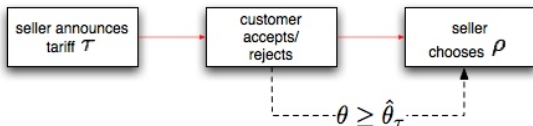
$$C(\rho; \theta) = c_1 \rho + \frac{c_2}{b(\theta)} \int_{\rho}^{b(\theta)} (q - \rho) dq$$

- optimal capacity commitment (given  $\theta$ ):

$$\rho^*(\theta) = \frac{c_2 - c_1}{c_2} b(\theta)$$

# tariff structures under information asymmetry

buyer's type  $\theta$  determines consumption interval  $[0, b(\theta)]$ , firm knows only  $\theta \in [0, 1]$ . with cdf  $\Phi$ .



- firm makes offer  $\tau$ . customer's acceptance of offer reveals  $\theta \geq \hat{\theta}_\tau$ .
- firm makes capacity decision knowing  $\theta \geq \hat{\theta}_\tau$ .

## pay as you go pricing: linear rate $p$

- firm makes offer, buyers chooses/denies offer.
- buyers  $[\hat{\theta}_L, 1]$  where  $\hat{\theta}_L$  solves

$$V(\theta) = p \frac{b(\theta)}{2}$$

- acceptance reveals  $\theta \geq \hat{\theta}_L$ .
- firm's capacity decision based on lower uncertainty.

$$\text{Exp}[C(\rho)] = \frac{1}{1 - \hat{\theta}_L} \int_{\hat{\theta}_L}^1 C(\rho; \theta) d\theta.$$

## multi-part tariff: seller offers $(F, Q, p)$

- buyer chooses or denies offer
- acceptance of offer reveals  $\theta \in [\hat{\theta}_1, 1]$ , where  $\hat{\theta}_1$  solves

$$V(\theta) = F + \frac{p}{b(\theta)} \int_Q^{b(\theta)} (q - Q) dq$$

- seller's capacity decision based on  $\theta \in [\hat{\theta}_1, 1]$ .

$$Exp[C(\rho)] = \frac{1}{1 - \hat{\theta}_1} \int_{\hat{\theta}_1}^1 C(\rho; \theta) d\theta.$$

- $(\theta_1 > \theta_L) \Rightarrow$  better capacity decision!

## menu of three-part tariffs

- seller offers menu  $\{\tau_1 = (F_1, Q_1, p), \tau_2 = (F_2, Q_2, p)\}$ .
- type  $\theta$  prefers  $\tau_1$  to  $\tau_2$  iff

$$\frac{1}{b(\theta)} \geq \left( \frac{F_2 - F_1}{p(Q_2 - Q_1)} - 1 \right) \frac{2}{Q_1 + Q_2}.$$

- reveals whether  $\theta \in [\hat{\theta}(\tau_1), \tilde{\theta}]$  or  $\theta \in [\tilde{\theta}, 1]$   
⇒ tighter bounds on required capacity.
- better capacity decision, but possible loss in surplus.



