G-Commerce:
A Study of Market Economies For the Grid

Rich Wolski

James Plank

John Brevik

Todd Bryan

University of Tennessee

Resource Allocation under GrADS

- Applications (through their schedulers) “contract” with resources for service
  - Performance contracts
    - → Application resource specification
    - → Execution monitoring and control
- Resource specification contract
  - Current ScaLAPACK demo
- Violations may cause the scheduler to acquire and release resources
  - Cactus migration
- *What if there are many schedulers and contracts at work simultaneously?*

Performance Economic Questions

- Will Grid resource allocations be stable?
  - We are building a system that enables dynamic allocation and release under program control.
  - Resource reservations may make the problem worse, not better.
- What is the overall efficiency of the Grid?
  - We don't really have a way to evaluate how well the Grid is working in the aggregate.
- What resource allocation protocols ensure the best overall performance?
  - Our current set of performance-only allocation rules work well if the Grid is over-supplied.
  - In an over-demand case, the results may be

Approach

- Start with theory and simulation
  - Build an experimental framework for Grid market economies based on GrADS Prototypes
  - Identify and test different economic formulations
- Then build the infrastructure necessary to transact business
  - Leverage GrADSoft tools
  - Use MacroGrid and MicroGrid to verify the results

Formulating a Performance Economy

- Transaction Model
  - What is the mechanism that controls the trade of goods? => performance contract
- Cost Model
  - How is the cost-benefit ratio defined for each agent in the economy?
    - $\rightarrow$ need a producer cost model and a consumer cost model
    - $\rightarrow$ Determines supply and demand
- Pricing Model
  - How are the "prices" that determine transactions set?

Global Assumptions

- All agents make decisions based solely on self-interest
- Fictitious currency
  - $G (Pronounced “Grid Bucks”)
- Producers and consumers are motivated to accumulate $G
- Producers and consumers are separate entities
  - Respending does not occur (to be investigated later)
- Agents, in aggregate, act rationally with respect to price
  - Lower price => less supply and greater demand

Transaction Model

- Performance contract
  - A job consists of a list of resource requirements
  - Resource requirement is a tuple:
    - → (amount, duration)
  - Producers and consumers negotiate over amount
    - → A job will execute to completion once a transaction is initiated
  - Price at the time the contract is signed persists for the duration
  - Entire contract must be negotiated before transaction is initiated
  - No violations (for now)

Cost Model

- Designed to reflect possible PACI behavior
  - Producers (PACI sites) sell a fraction of total resource only if it is a good deal on the average
  - Consumers (PACI users) buy based on how much work they have to do until their next allocation

  → Opportunistic bargain hunters

Pricing Model

- Two alternatives: auctions and markets
- Auctions
  - Easy to implement
  - No need for global information (maybe)
  - No provable stability or equilibrium properties
  - Generally favor the seller
- Markets (dynamic pricing)
  - Provable stability and equilibrium characteristics
  - Accurately (fairly) reflect value
  - Requires global state information
  - More difficult to understand and implement than auctions

First Study: Markets versus Auctions

- Transaction Model: performance contracts
- Cost Model: PACI-inspired producers and consumers
  - Diurnal job cycle
  - Opportunistic consumers
  - Producers use historical profit
- Compare
  - Resource allocation stability
  - Equilibrium (value accuracy)
  - Resource efficiency

  for a hypothetical Grid

Markets

- Theory
  - Equilibrium Price: a price that equalizes supply and demand
  - Smale (1976) provides a constructive method for determining the equilibrium price based on Newton-Raphson
  - First Bank of G: implementable Smale
- Practice
  - Nothing is continuous => optimality is impossible
  - Simulation is generally the final arbiter

You've Got Smale

- Smale
  - $\mathbf{z}(\mathbf{p})$: vector of excess demand values at price vector $\mathbf{p}$ **=** demand - supply
  - $\mathbf{D}_z(\mathbf{p})$: Jacobian matrix $[\delta z_i / \delta p_j]$
  - Solve differential equation**:** $\mathbf{D}_z(\mathbf{p}) * d\mathbf{p}/dt = -\lambda * \mathbf{z}(\mathbf{p})$
  - Tricky part: determining the Jacobian strictly by observation
- First Bank of G: implementable Smale
  - Uses linear curve-fit to “sense” Jacobian
  - simulator or the NWS as a source of supply and demand information
- Compare to a version of Smale's method that polls for price differentials

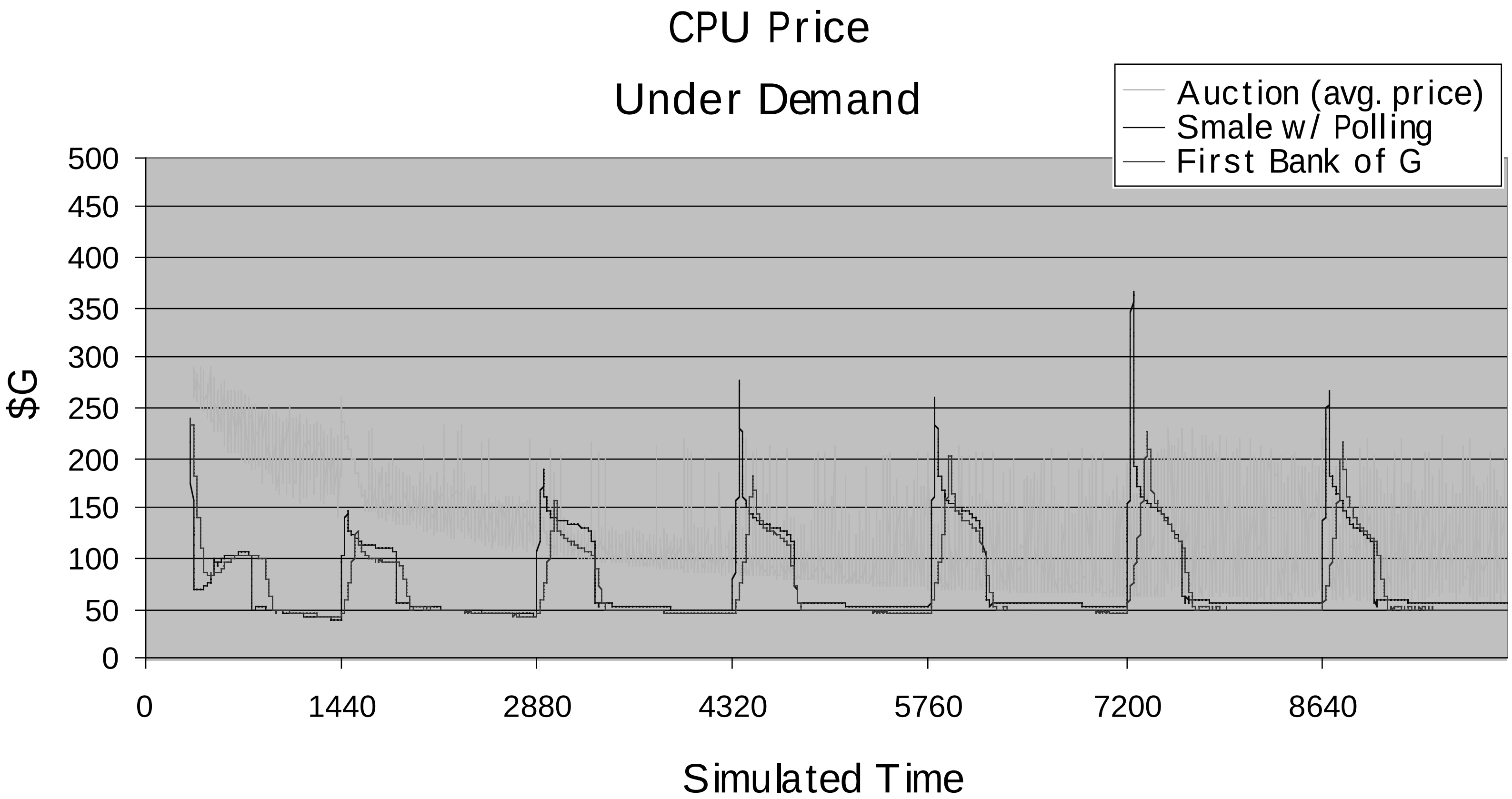
G-Bay

- Theory
  - Uniform Second-price Auction (Vickery, 1961)
    - → Sealed-bid
    - → Highest bidder pays second-highest bid price
  - Reduces seller favoritism
  - Determines a prices that is “closer” to market consensus
- Practice
  - Auctions work well when object that is for sale is unique
    - → If not, buyer must participate in multiple auctions => centralized auction clearing house

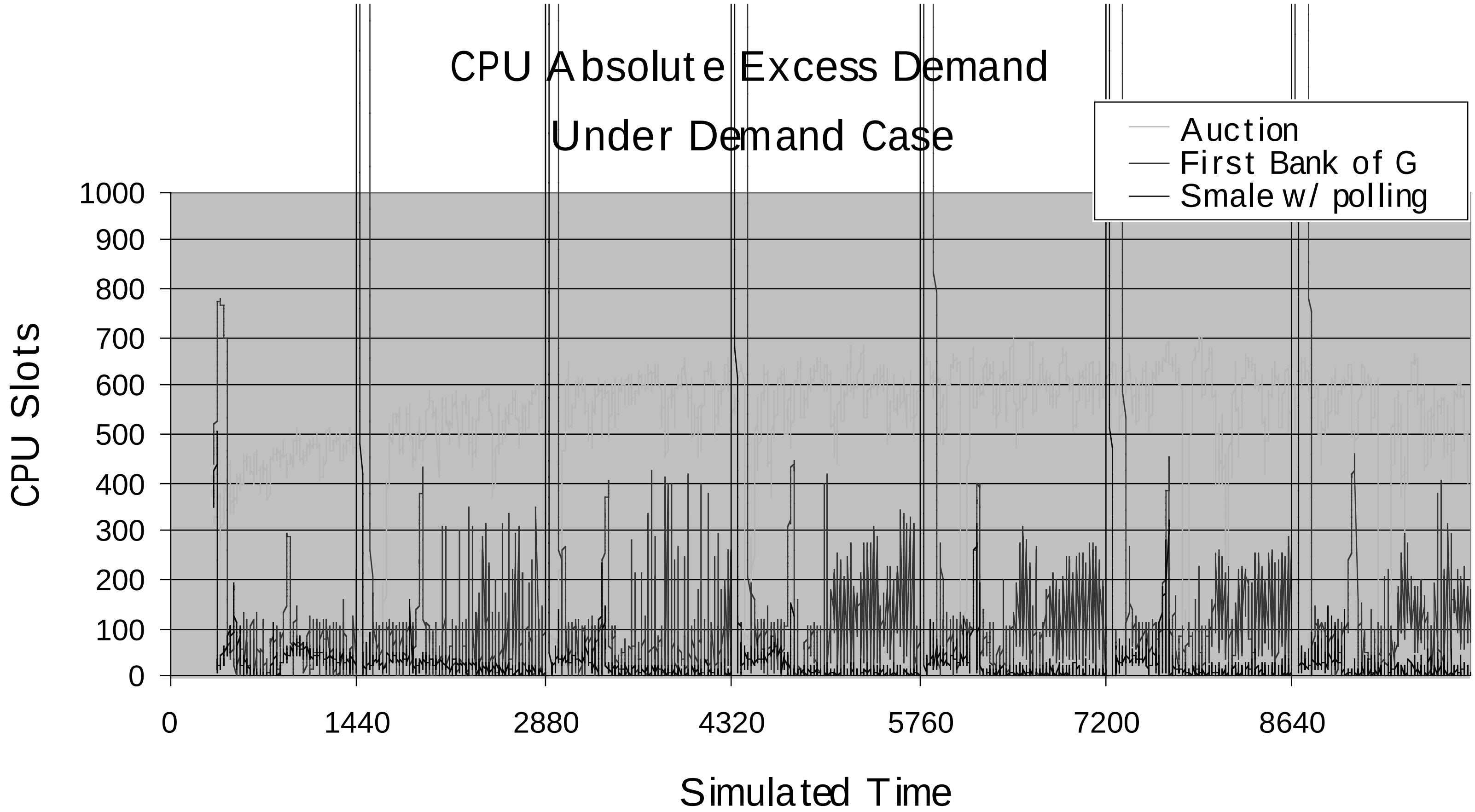
Simulation Parameters

- Two commodities: CPU and Disk
  - One commodity is “easy”
  - Network is still a bit of a mystery
- All jobs require a random quantity of each for a random duration
  - All distributions are uniform (again, for now)
- Under demand and Over demand cases

Price Stability – Under Demand

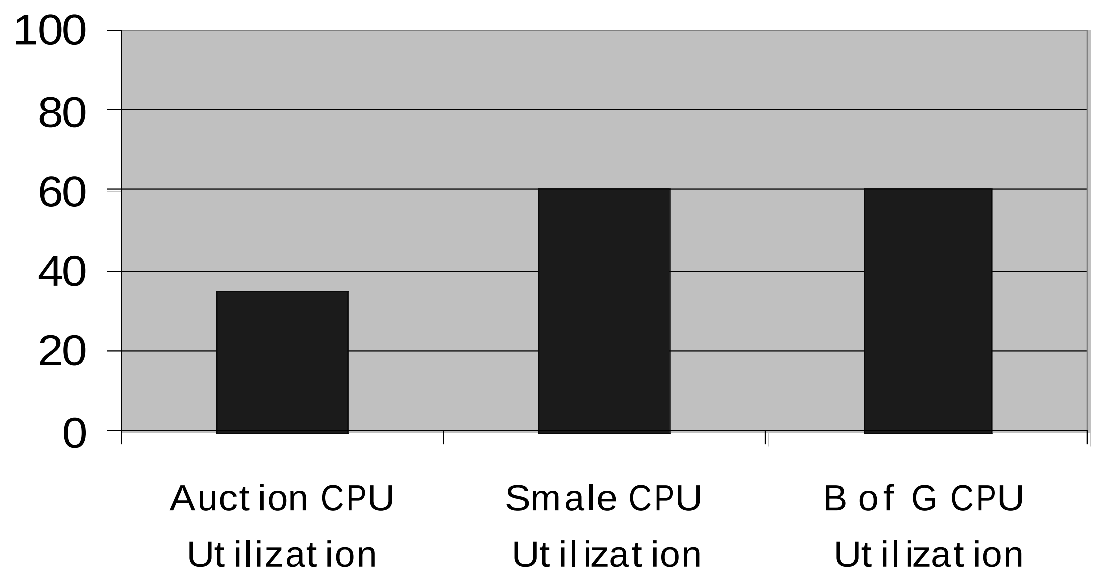


Market and Auction Equilibrium – Under Demand



Resource Utilization

CPU Utilization Under Demand Case



Conclusions

- For G-Commerce, Commodities Markets look better than Auctions (IPDPS-01, JSA)
  - More stable prices
  - Equilibrium
  - No more centralized than Auctions
  - Theoretically tractable
- What we Learned: Anecdotes from the Trading Pits
  - It is really easy to build an oscillating economy
    - $\rightarrow$ Panics happen
    - $\rightarrow$ Performance contracts are a good first step
  - Self-interest is easy to model, but realistic self-interest is hard to model

What's Next?

- ScaLAPACK
  - Currently simulating ScaLAPACK Demo
  - Build a running Economy of ScaLAPACK consumers
    - $\rightarrow$ MacroGrid and MicroGrid
- Stability Theory
  - Dynamical systems approach
- Information consistency
  - Extend equilibrium results to account for imperfect information => decentralization
- Build The First Bank of G for GrADS

People and Leverage

- People
  - James Plank (UTK faculty, not a GrADS participant)
  - John Brevik (postdoc)
  - Todd Bryan (grad. student)
  - Performance contracts team and ScaLAPACK demo team (many, many discussions)
- Leverage
  - NGS Loci (supply and demand information management)
  - NSF Career Award