Isolation with Flexibility: A Resource Management Framework for Central Servers

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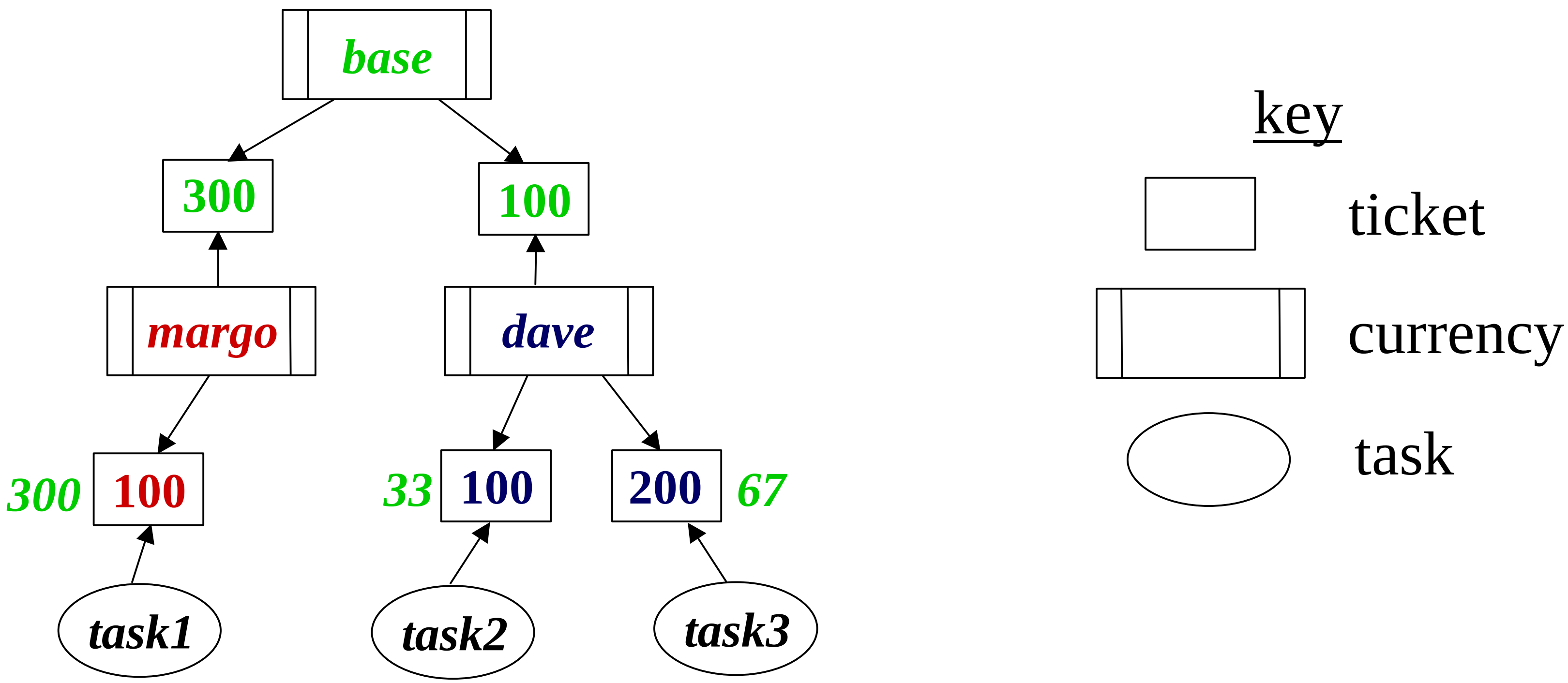
Resource Management on Central Servers

- Users are increasingly competing for the resources of central servers.
  - virtually hosted Web sites
  - centralized databases
  - thin-client computing
- Resource management goals:
  - provide resource principals with resource shares that reflect their relative importance
  - meet applications’ differing resource needs

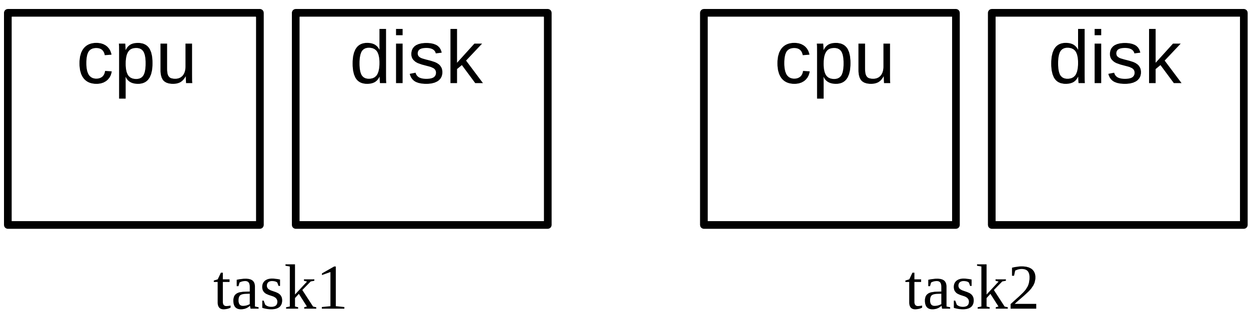
Lottery Scheduling Framework [Waldspurger & Weihl]

- Tickets encapsulate resource rights.
  - Proportional-share approach
- Currencies issue tickets.
  - Use to group and isolate resource principals



Secure Isolation vs. Flexible Allocation

- The resource shares protected by isolation may not correspond to the actual needs of applications.



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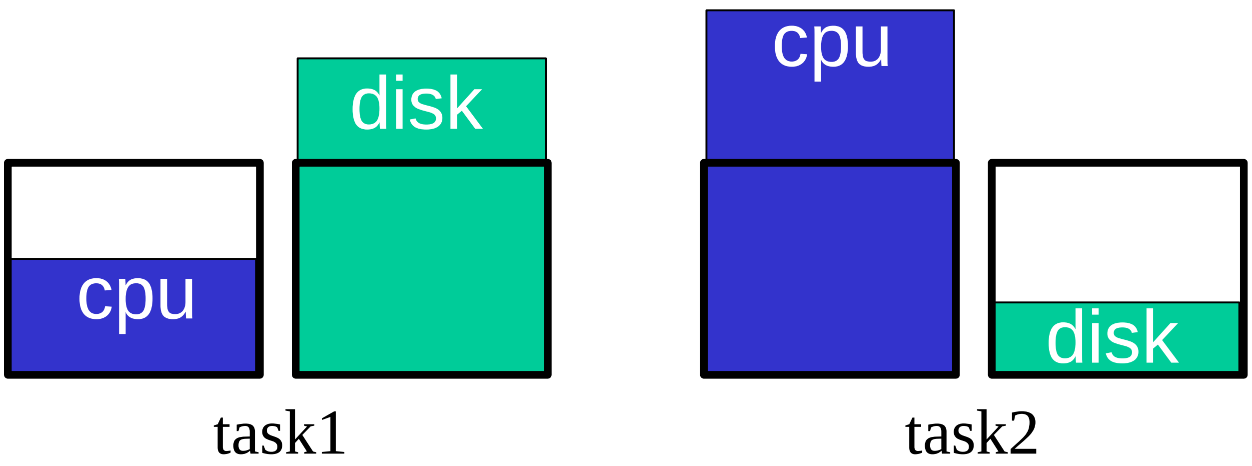


- **Ideal:** give resource principals the flexibility to safely adjust their own allocations while preserving secure isolation.

Our Extended Framework

- Increased flexibility in adjusting resource rights
- Multiple resources
- Access controls
- Hard and soft resource shares

Talk Outline

- Problem description
- **Extended lottery-scheduling framework**
  - securely managing multiple resources
  - isolation with increased flexibility
- Prototype implementation
- Performance results
- Conclusions

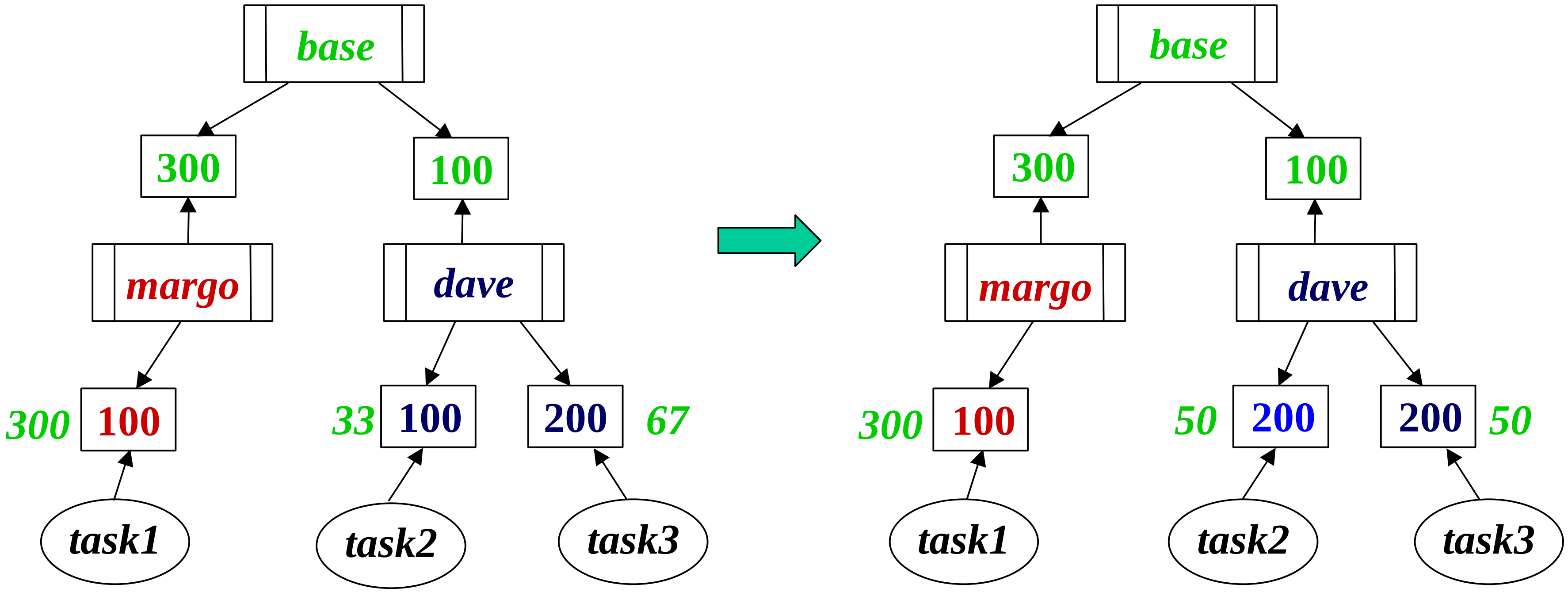
Securely Managing Multiple Resources

- Resource-specific tickets
  - CPU tickets, disk tickets, etc.
- Access controls
  - encapsulated in a *broker* associated with each currency
  - A currency's *mode*, like a UNIX file mode, specifies who may perform various operations on it.
- Soft *and* hard resource shares
  - soft: *A* receive twice the share of *B*.
  - hard: *C* should receive 20% of the resource.

Flexible Allocation vs. Secure Isolation

- Currencies impose both upper *and* lower limits on resource allocations.
- Other resource-management frameworks impose similar limits through currency-like abstractions.
  - Rialto's *activities* [Jones et al., 1997]
  - Eclipse's *reservation domains* [Bruno et al., 1998]
  - *Software Performance Units* [Verghese et al., 1998]
  - *Resource containers* [Banga et al., 1999]

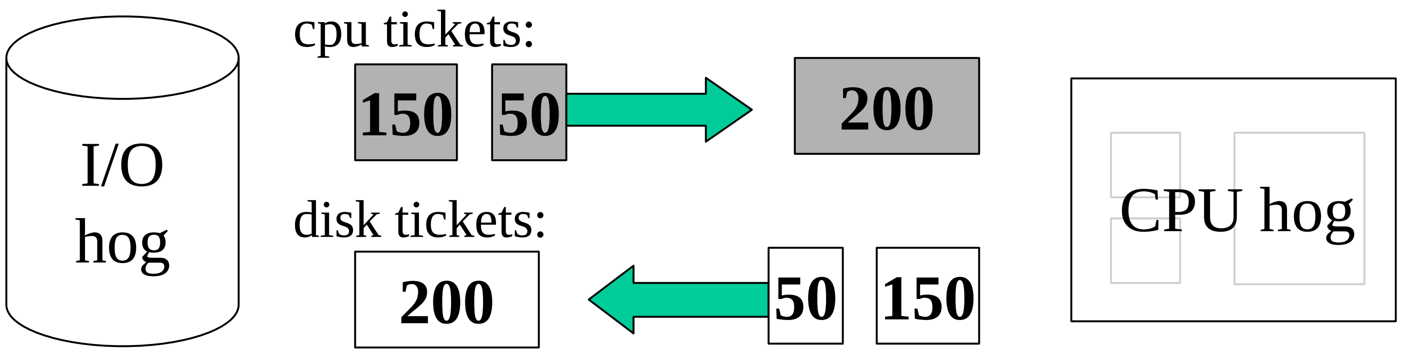
Problem: Currencies Impose Upper Limits



- Essential to providing isolation
- May be unnecessarily restrictive

Solution: Ticket Exchanges

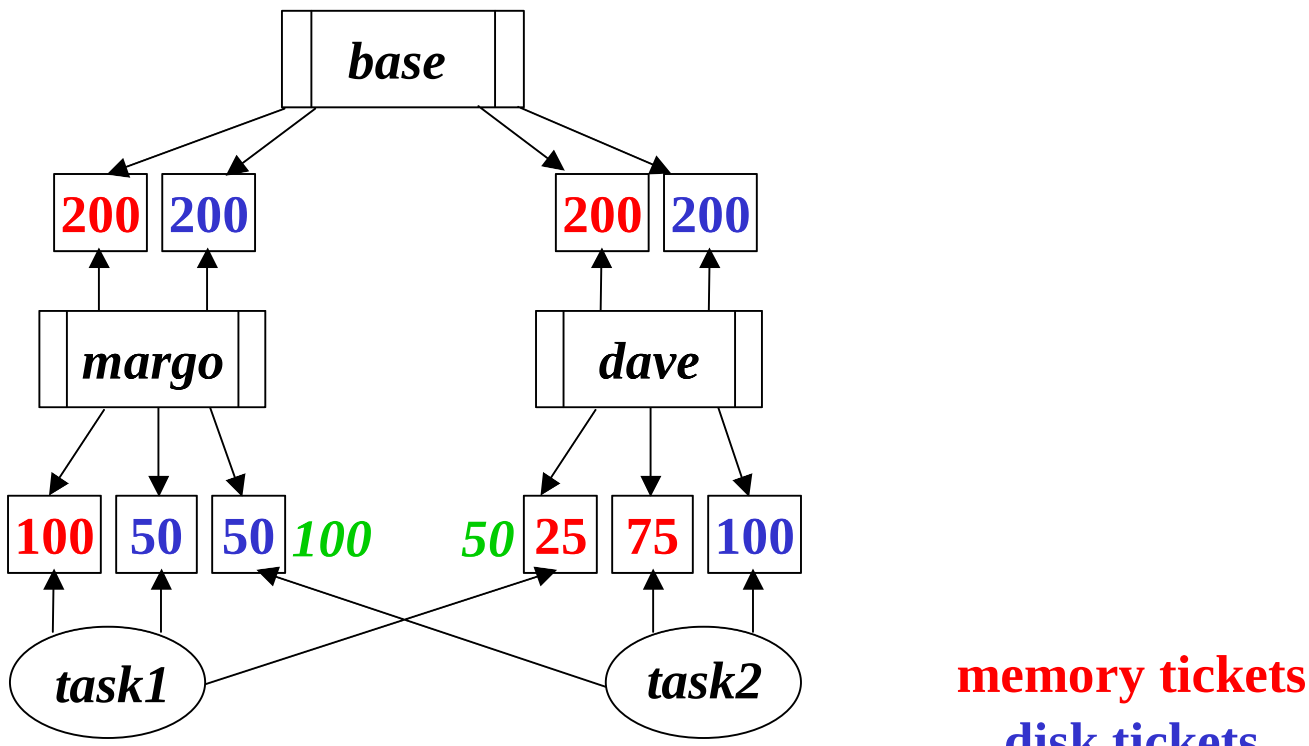
- Allow applications to safely modify their resource rights



- Take advantage of applications' differing resource needs
- Other principals' resource rights are not affected.

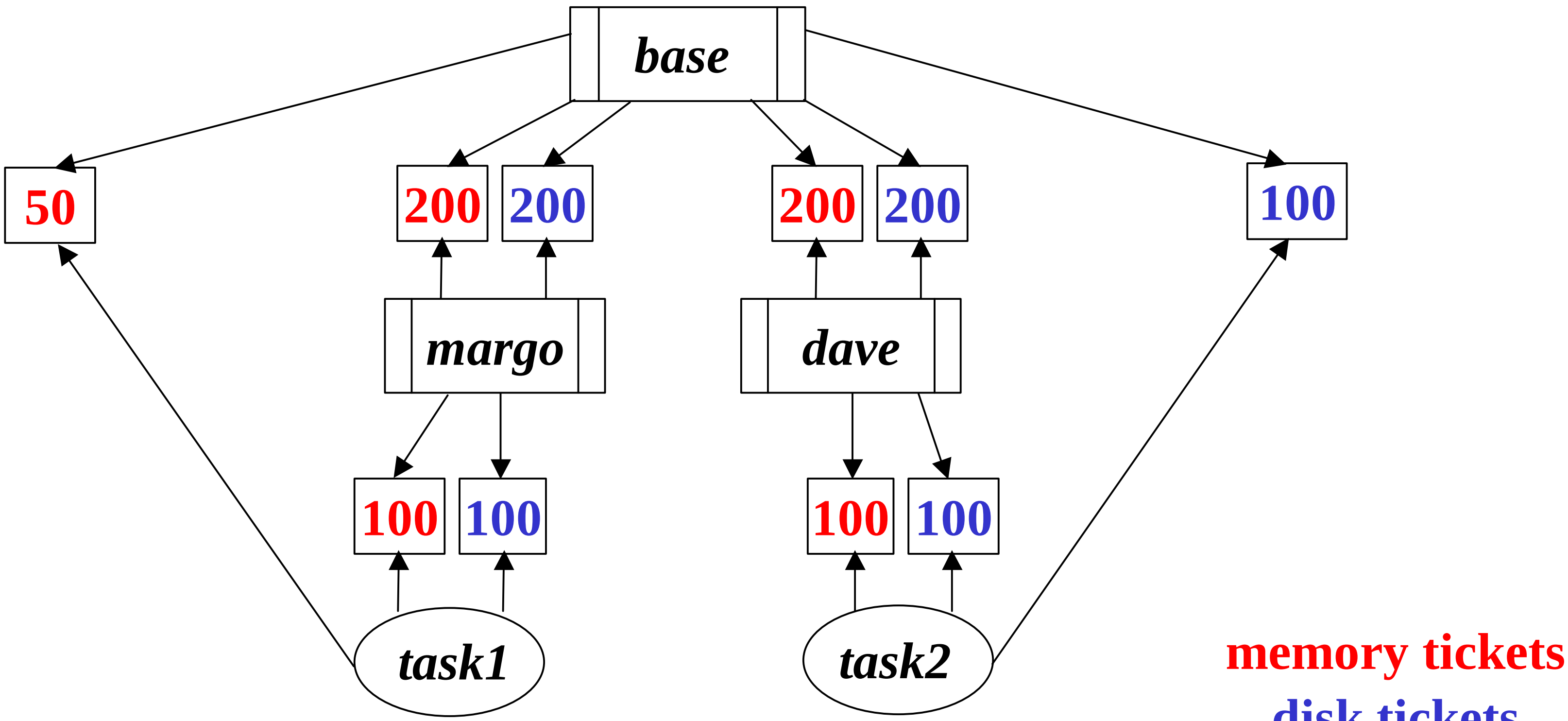
Carrying Out an Exchange

- Problem:
  - Exchanged tickets should have a fixed base value.
  - The value of subcurrency tickets can change.



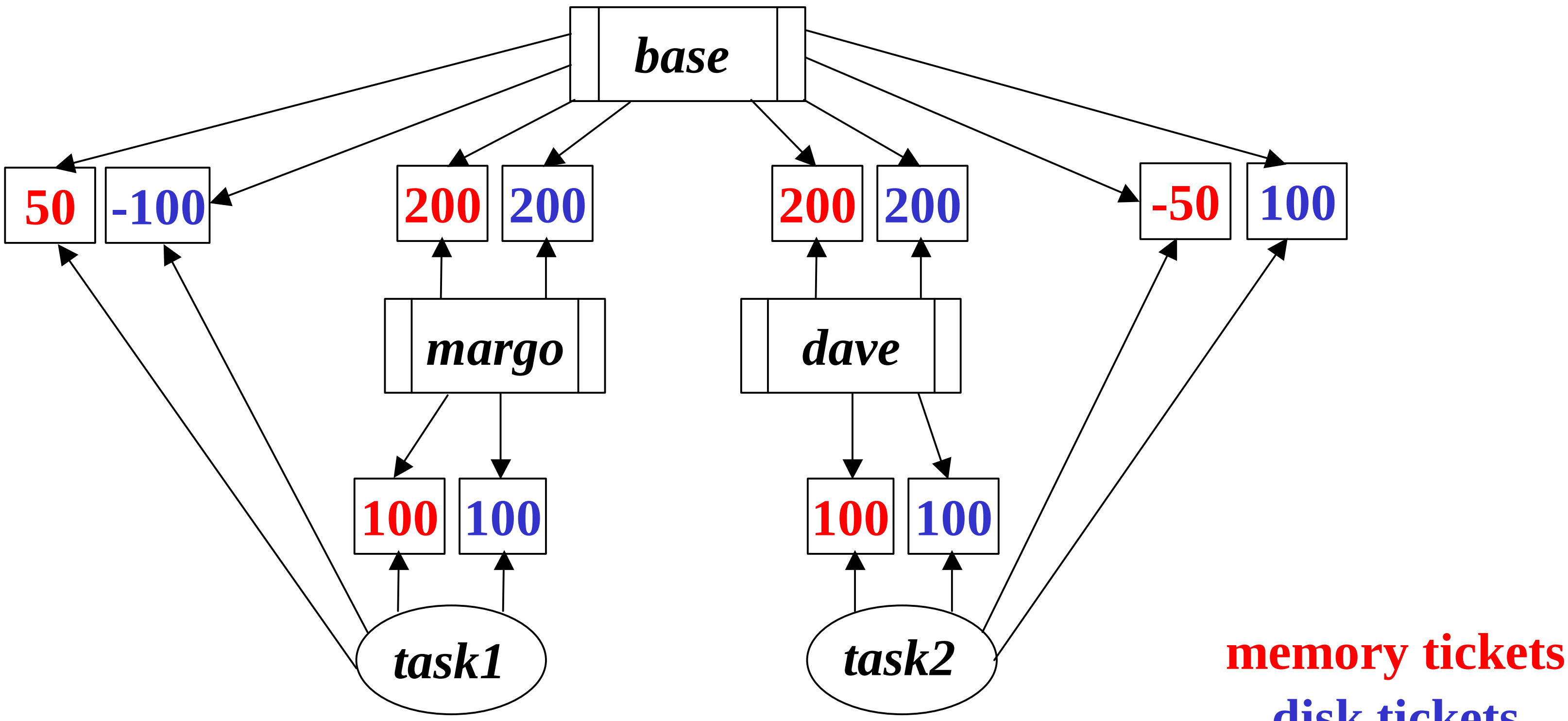
Carrying Out an Exchange

- Need to use base-currency tickets.
  But how can we remove the tickets that are traded away?



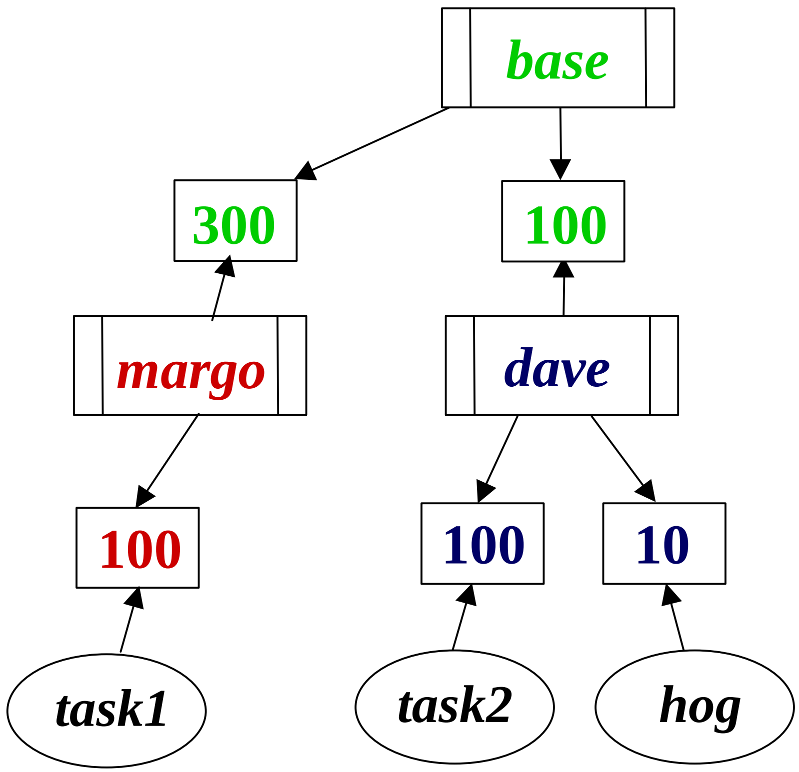
Carrying Out an Exchange

- Solution: use *negative* tickets that reduce a principal's base value.



Problem: Currencies Impose Lower Limits

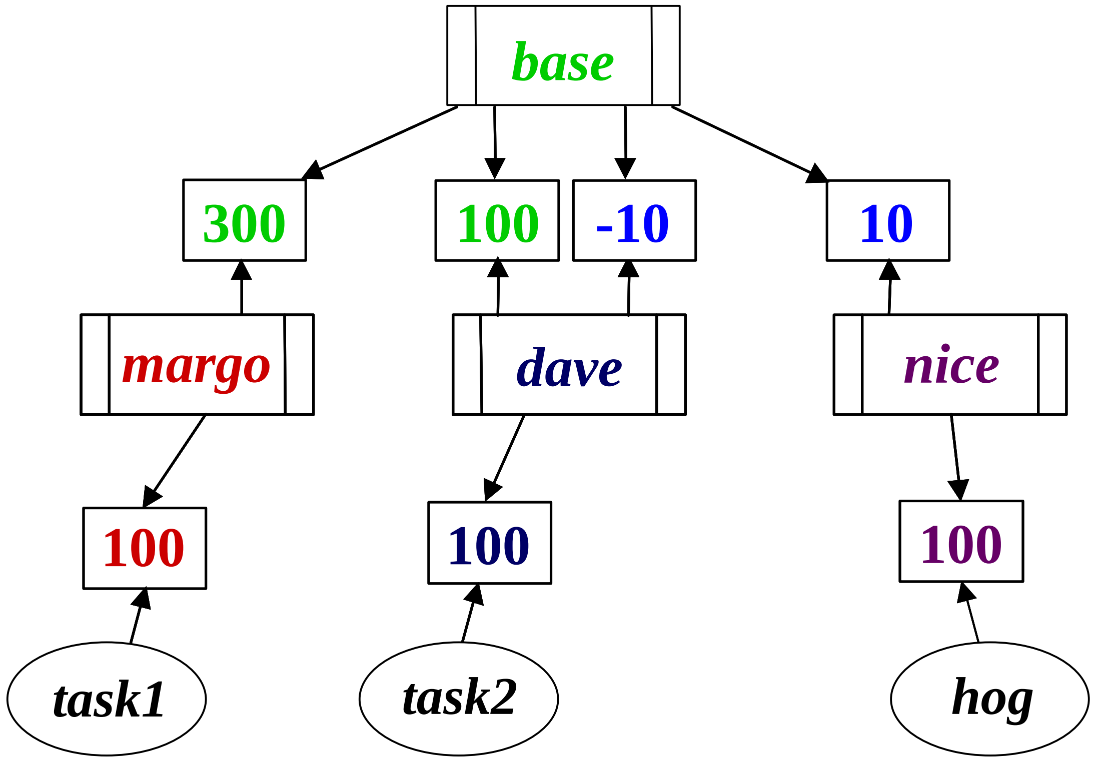
- Difficult to support the semantics of `nice`



- *hog* can still end up with *all* of my resource rights.

Solution: Transfer Resource Rights

- Employ the same ticket-exchange system call.



- See Petrou et al., 1999 for an alternate solution.

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Extended Framework in VINO

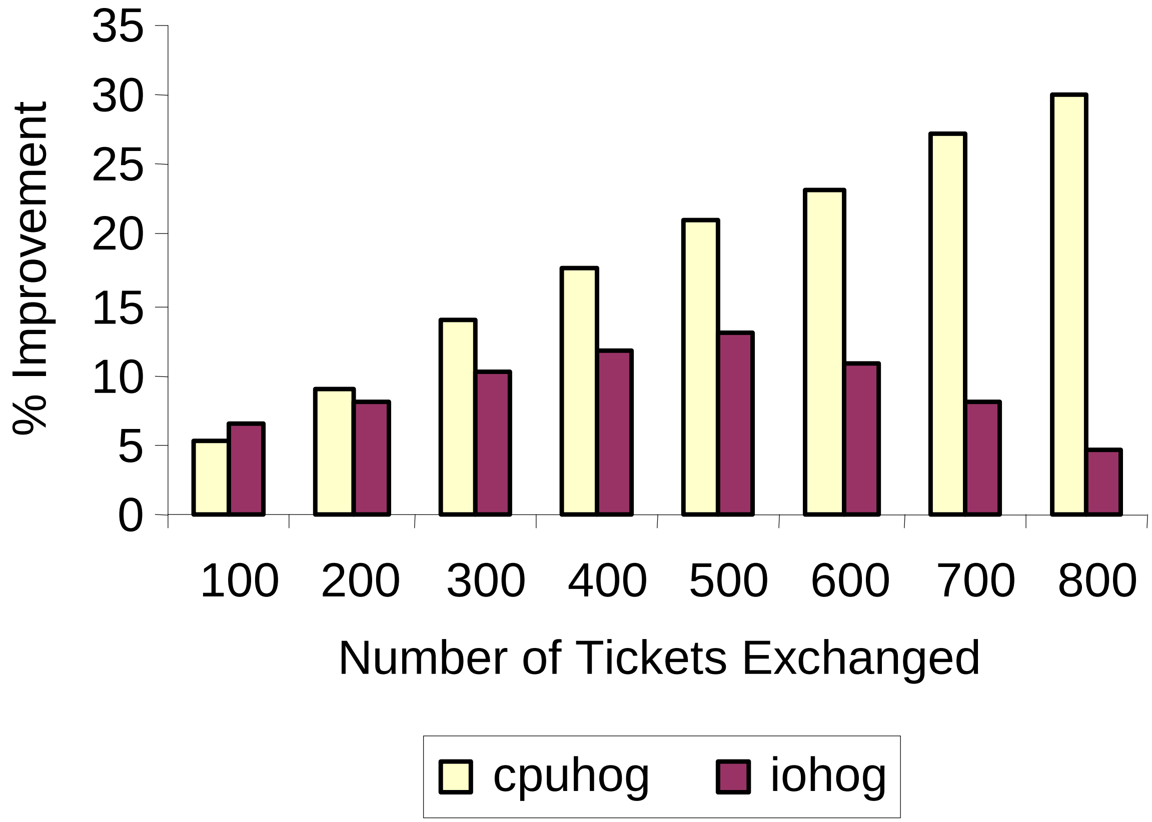
- Full support for tickets and currencies
- System-call interface and utilities for creating currencies, funding them, unfunding them, etc.
- One currency per user
  - maintain a mapping from user id to currency id
  - re-fund process when it changes its *real uid*

Managing Multiple Resources

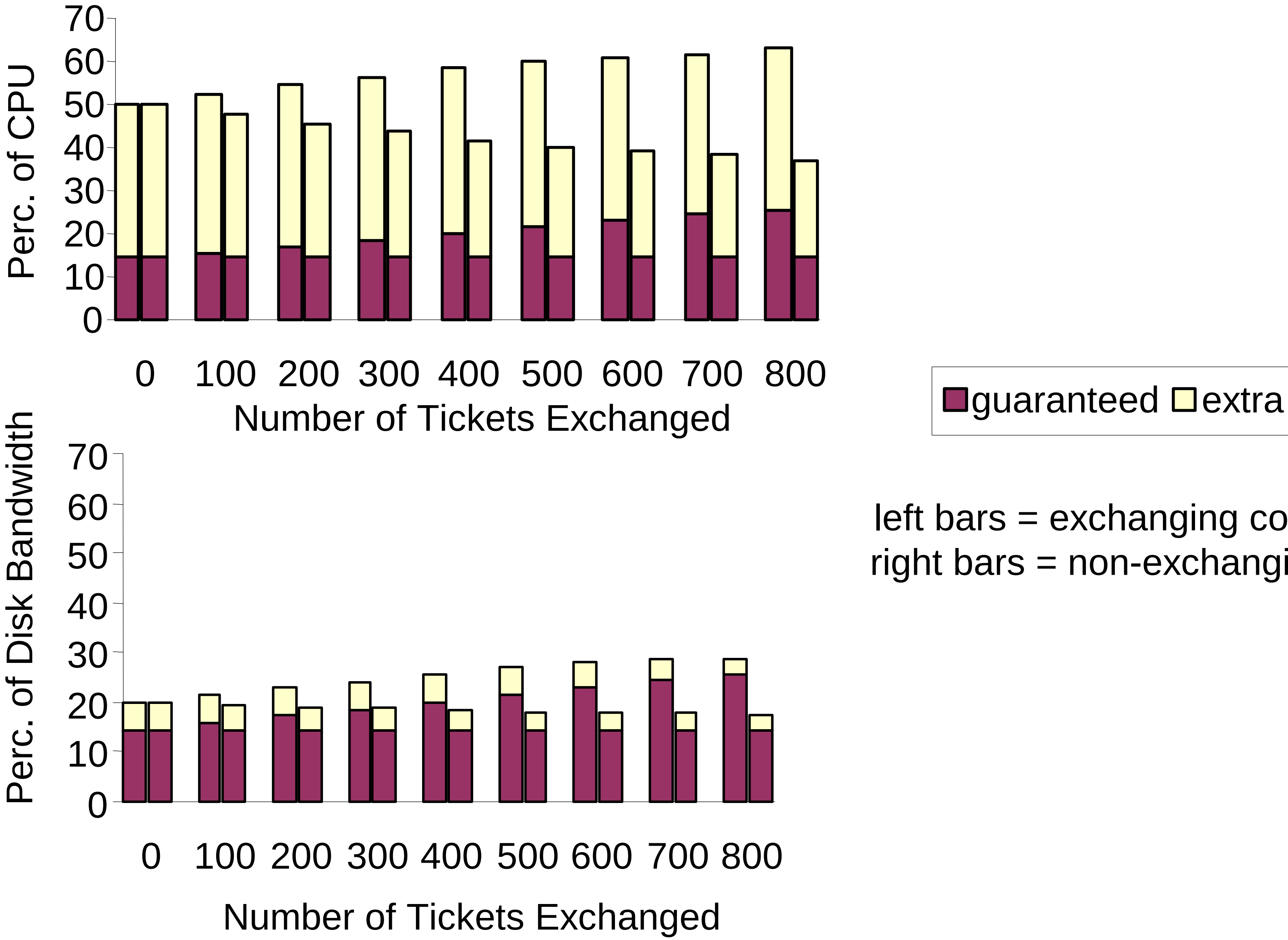
- CPU Time
  - original randomized lottery algorithm
  - compensation tickets and ticket transfers
- Disk Bandwidth
  - YFQ algorithm (Bruno et al., 1999)
  - similar to weighted fair queuing
- Memory (limited solution)
  - only give memory tickets to privileged processes that explicitly request them
  - pageout daemon skips pages owned by processes with less than their guaranteed shares

Ticket Exchanges: CPU and Disk

- Each program starts with 1000 tickets per resource.
- Also run one extra cpuhog and four extra iohogs.



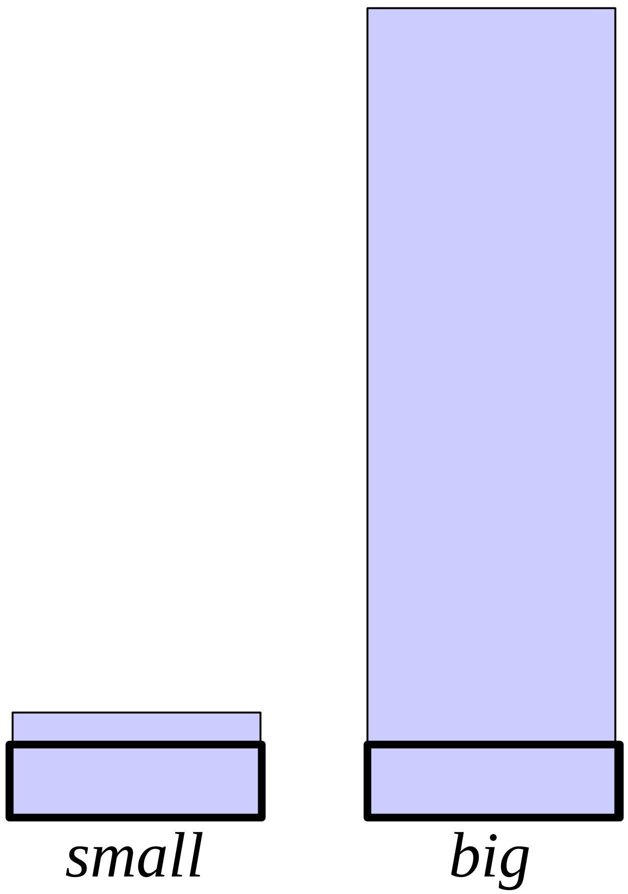
Resource Rights Are Preserved



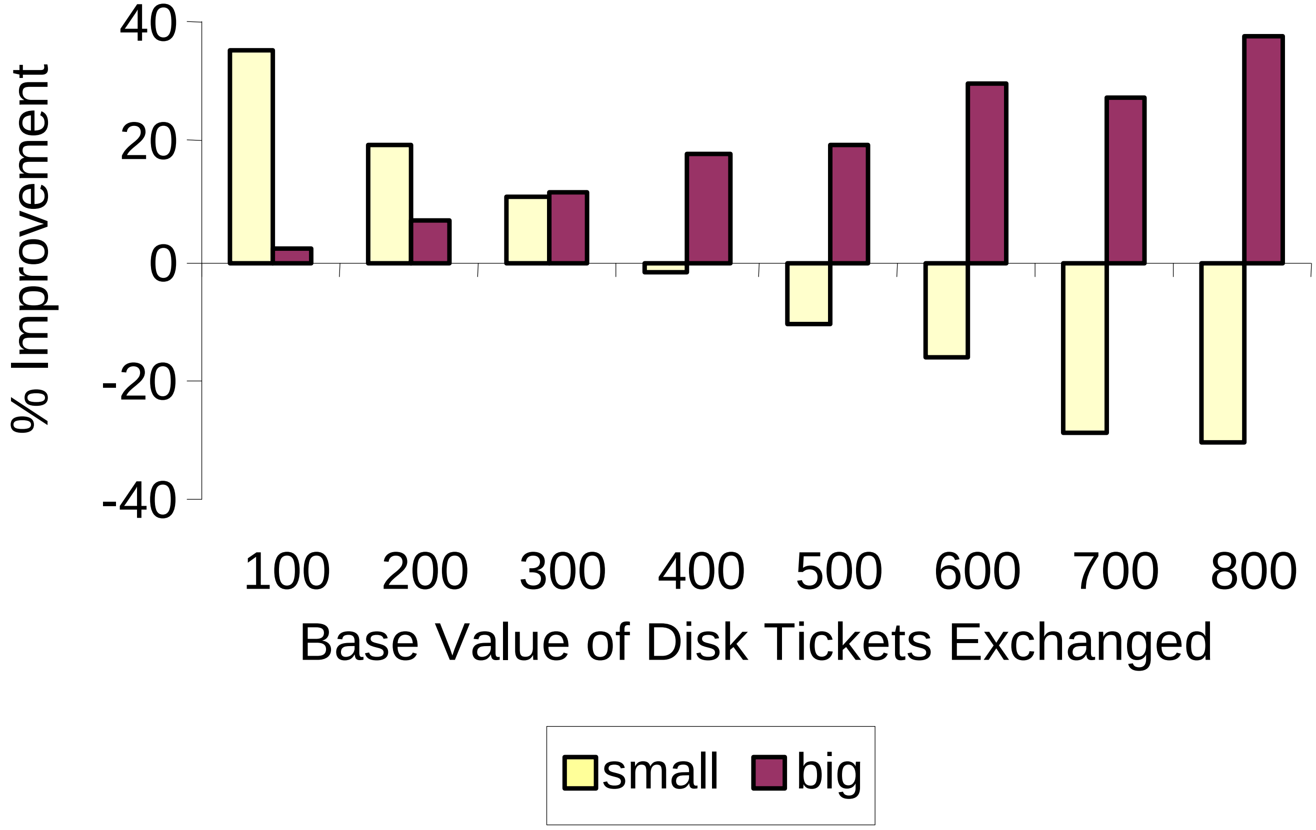
left bars = exchanging copy
right bars = non-exchanging

Ticket Exchanges: Memory and Disk

- *small*: 4-MB database (70,000 entries)
  big: 64-MB database (2^{20} entries)
- Limit memory (11.1 MB for users) and run four iohogs

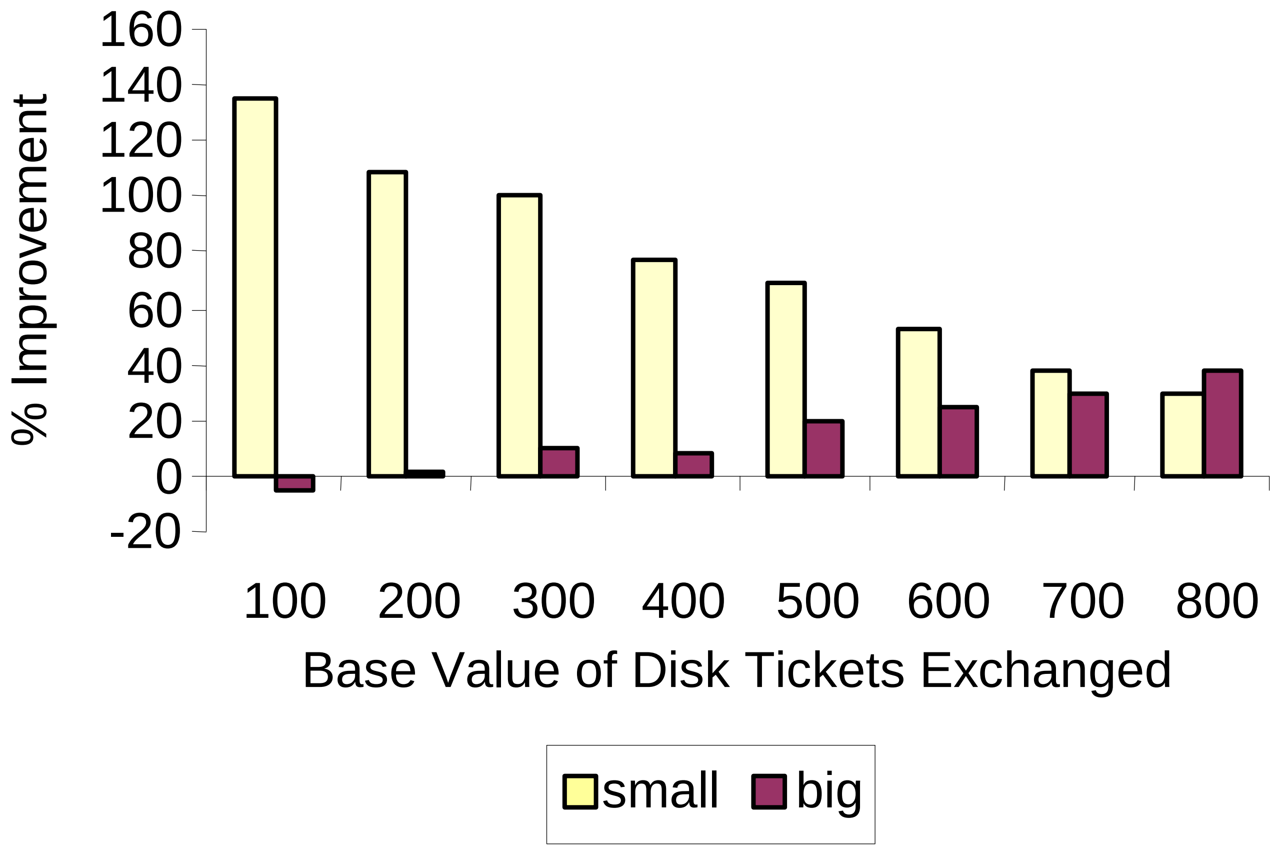


Trading 200 Memory Tickets from *Big* to *Small*



At start: mem. tickets worth 1375 and disk tickets worth 1667.
Small proposes exchange after 10,000 queries.

Trading 400 Memory Tickets from *Big* to *Small*



At start: mem. tickets worth 1375 and disk tickets worth 1667.

Small proposes exchange after 10,000 queries.

Conclusions

- We *can* provide isolation with greater flexibility.
- The best resource allocations for an application depend on the activity of the applications with which it is competing.
- Applications can achieve performance improvements by taking advantage of their differing resource needs.