A Flexible Scheduling Framework (for Linux): Supporting Multiple Programming Models with Arbitrary Semantics

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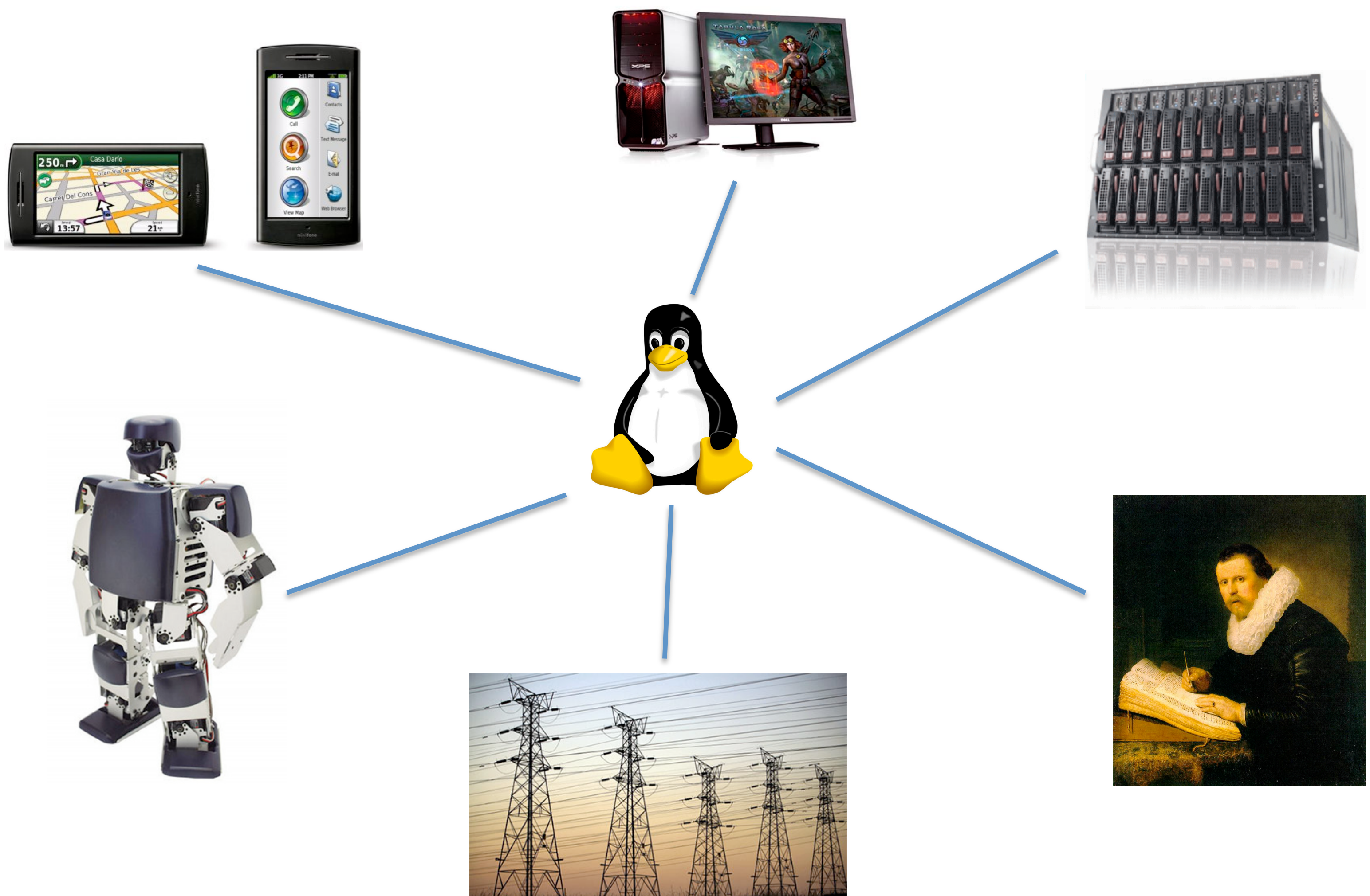
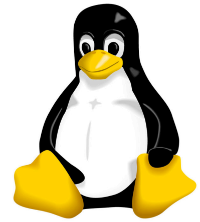
Overview

- Growing trend toward single systems with wide range of semantics
- Linux is used in many application areas, and is attractive for new research and development
- Priority-based systems have a difficult time supporting multiple, competing semantics
  - Performance management
- Non-priority based scheduling requires general treatment of system components
- *Proxy Execution: General treatment of CC*

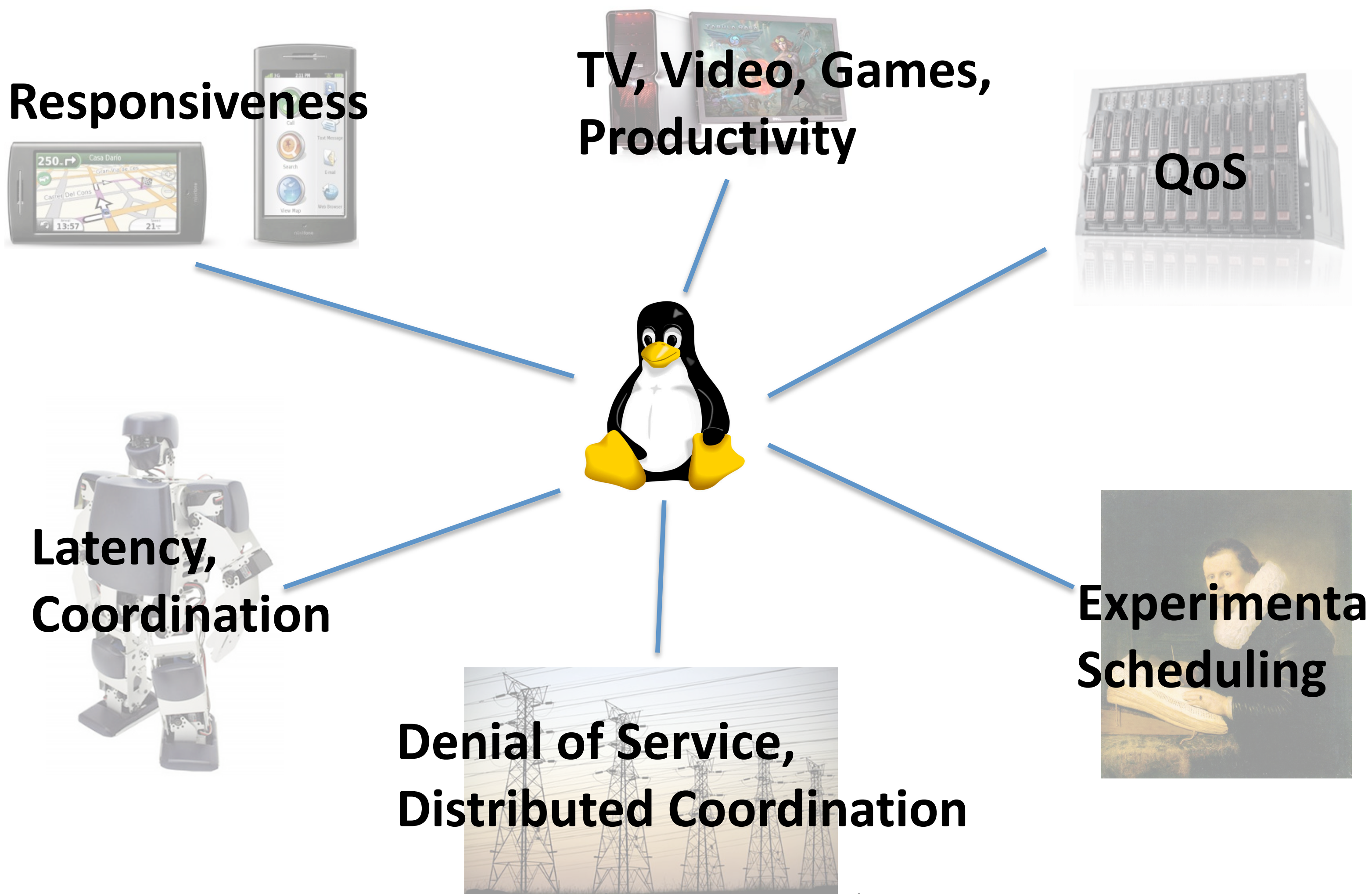
Single System, Multiple Semantics



…But why use  ?

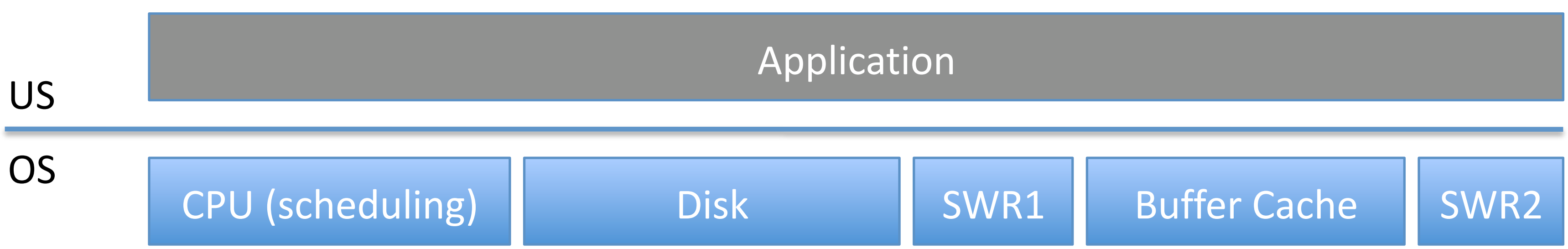
- Economic pressure to select cheap solutions
  - Need strong justification for custom systems
  - Hence increasing popularity of Linux as a standard platform.
- Cost and complexity justify multiple applications sharing HW platforms
  - Multi-core and MHz increases make sharing attractive
- *With multiple applications, satisfying all their constraints becomes complex*

Application Semantic Explosion



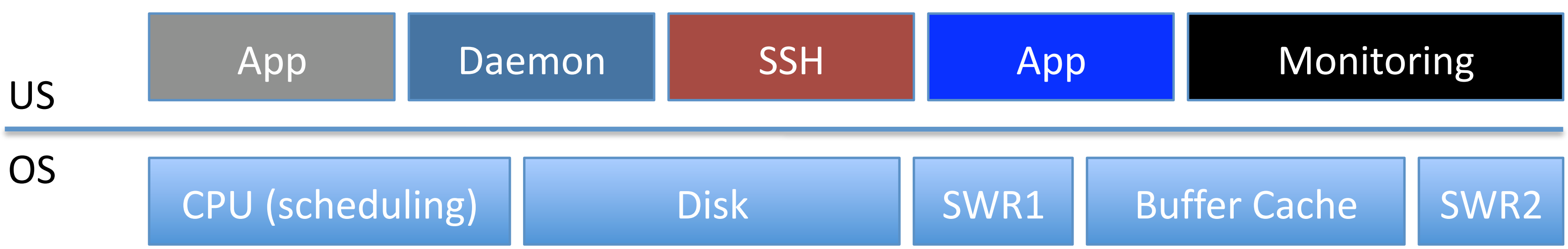
Performance Management

- Computations use resources, and this affects their behavior
- Managing performance requires managing many system components
  - CPU (thread scheduling), Disk scheduler
  - Software-based resources (e.g. Buffer Cache)
- One application has no competition
  - Ignoring system-level computations



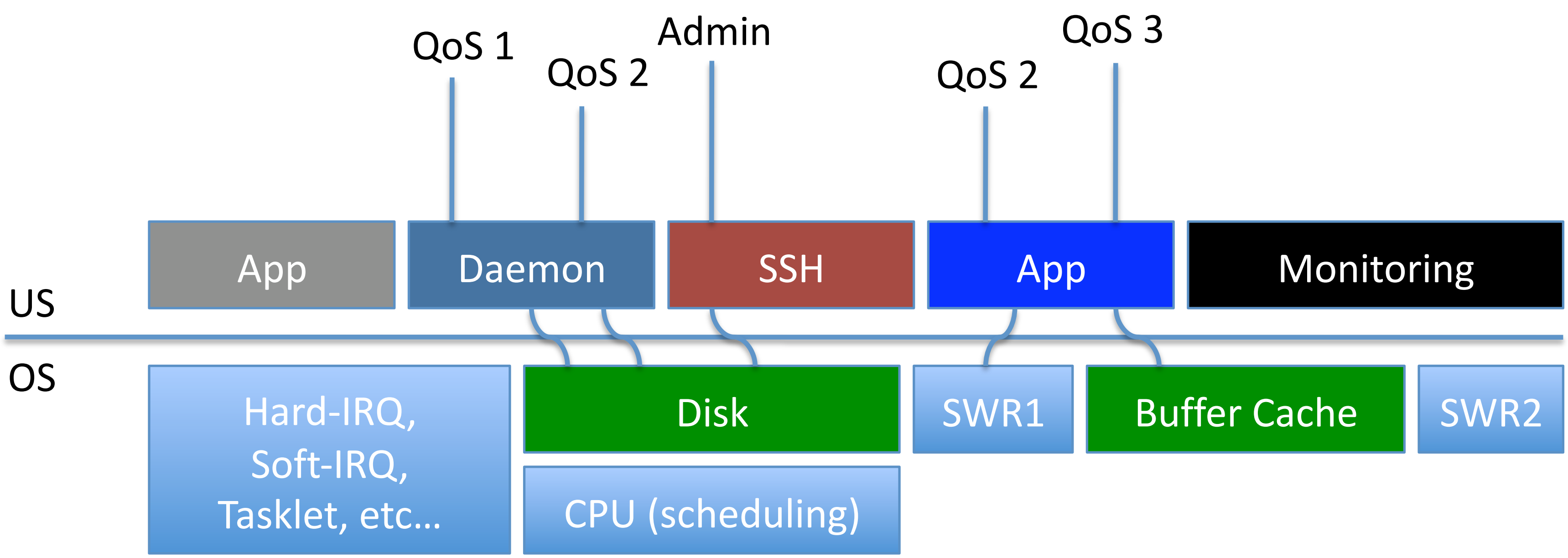
Performance Management

- Real systems have multiple applications, with a range of semantics
- Computations compete with each other for shared resources
  - CPU, Disk, Network
  - SW-based (e.g. buffer cache)
- *Managing the performance of the system requires that the interaction among computations be managed*



Performance Management

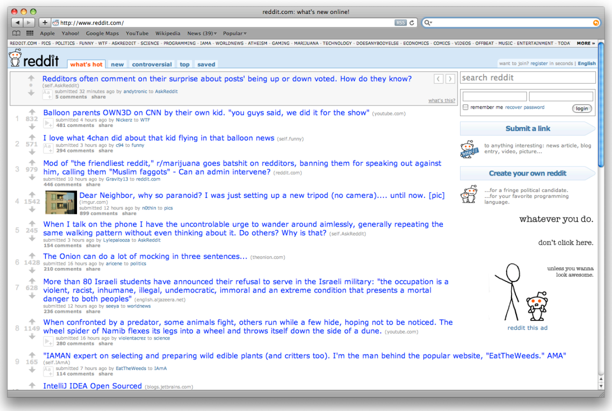
- Multiple applications with multiple semantics share many resources
- Servers multiplex client connections with competing policies (e.g. QoS)
- Context-borrowing computations under hard-wired scheduling policies
- *Managing interaction among computations requires managing semantic/ policy conflicts*



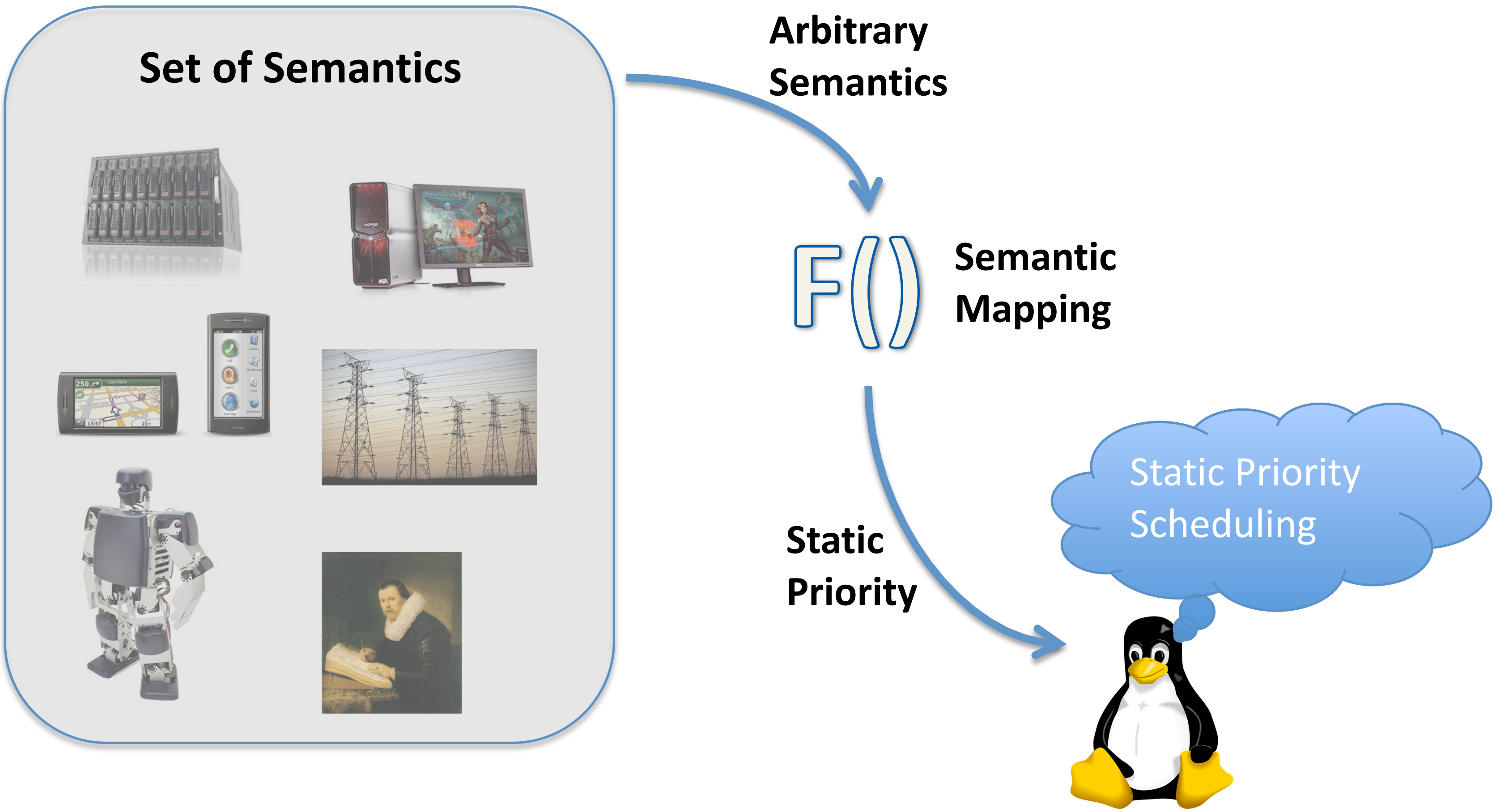
Goal: Precise Computation Control – It's Easy, Right?

High Priority

Low Priority

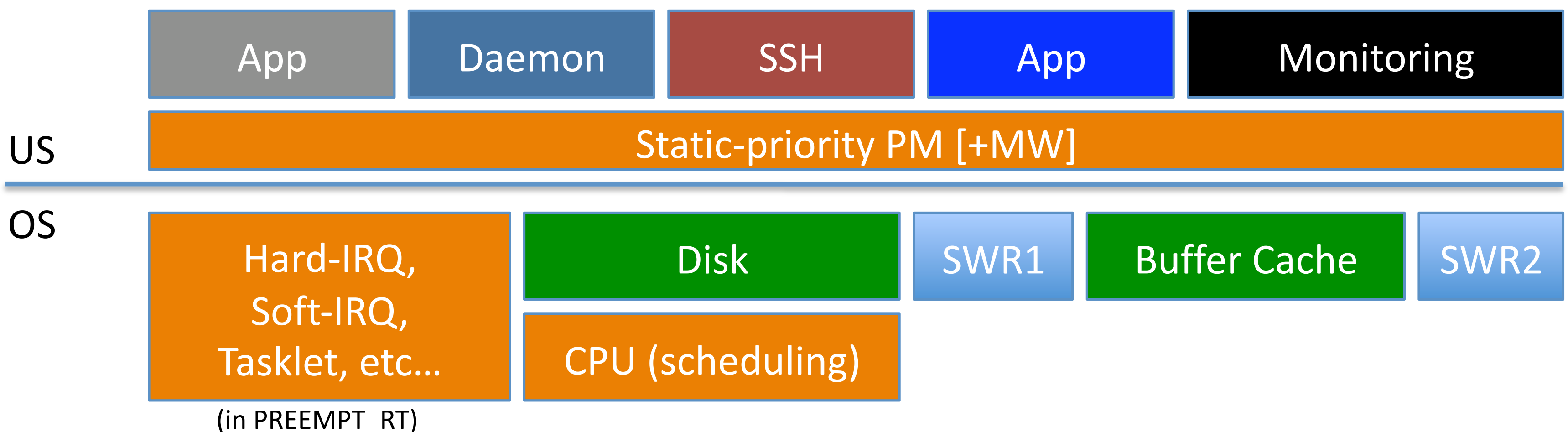


Semantic Mappings: A Developers Job



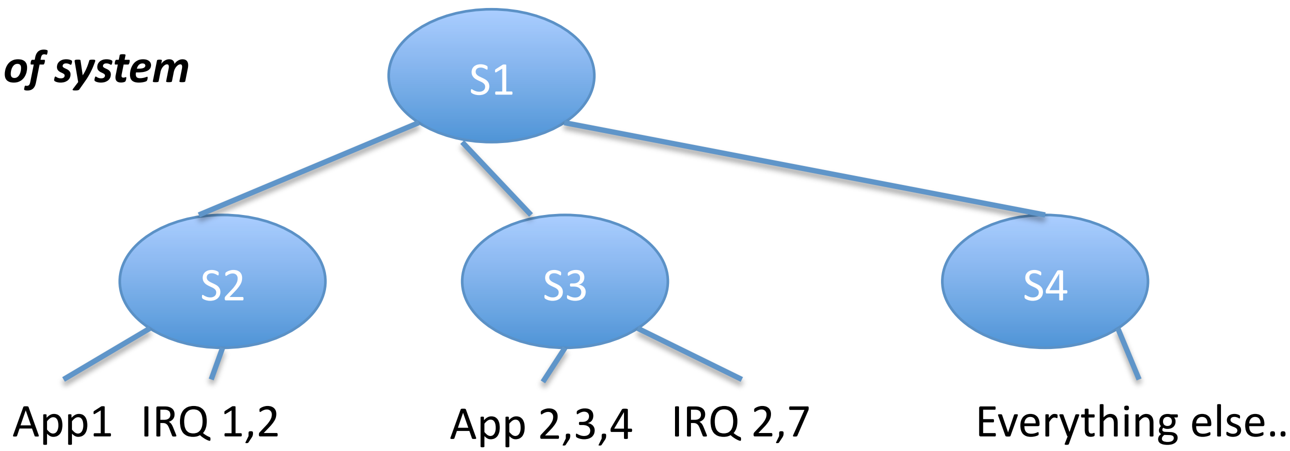
Semantic Mappings

- Application developers map their semantics onto priority-based PM
- Complex mappings are difficult to create, understand, model, and verify
- Developers have no other choice
  - Priority is ubiquitous and well-understood
  - Application developers lack knowledge and resources to create new thread scheduler

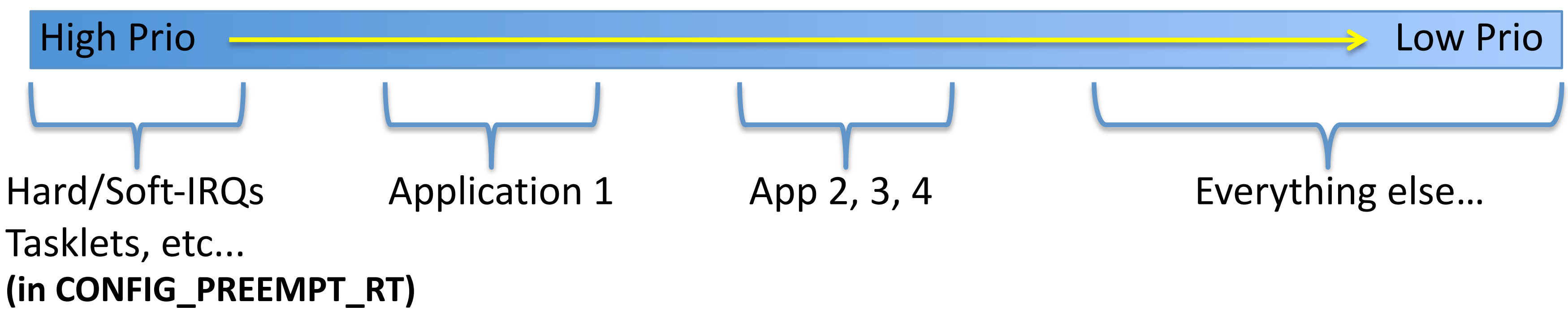


Semantic Mapping: Problems Masked

Logical representation of system semantics

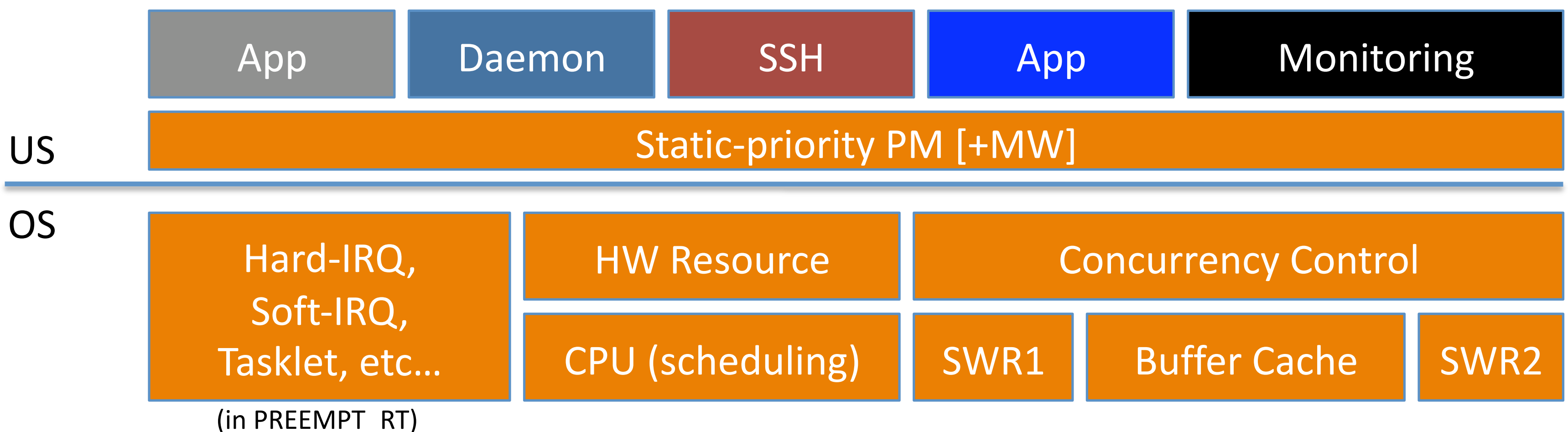


Reality: complex mappings, priority overlaps



Semantic Integration

- So how do we manage shared resources with many concurrently existing semantics?
- A resource is generally built in support of an assumed system semantics
  - E.g. priority-aware implementations
- Semaphores commonly manage access to shared resource
  - Integrated with scheduling via PI protocol

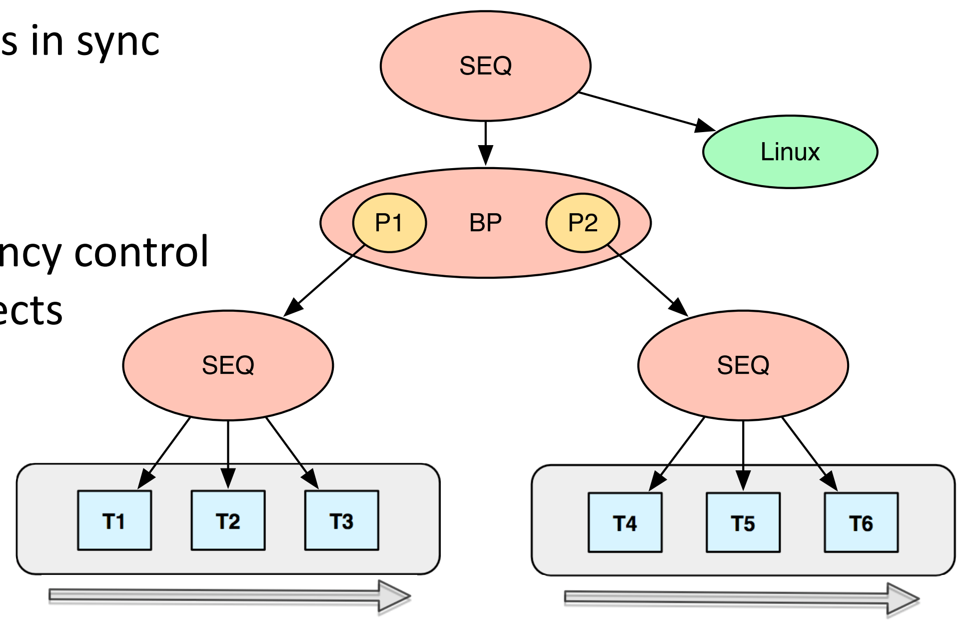


Solution: Directly Represent Scheduling Semantics

- *Group Scheduling*
  - *A particular solution*
  - Hierarchic scheduling framework at KU
- Represent semantics *directly*
  - No mappings, application scheduling state directly fuels schedulers
- Relationship between application semantics explicitly represented by the hierarchy structure

Direct Representation: Frame Progress

- Multiple pipelines processing frames
- Each pipeline has different performance characteristics
- Goal: Pipelines finish processing frames in sync

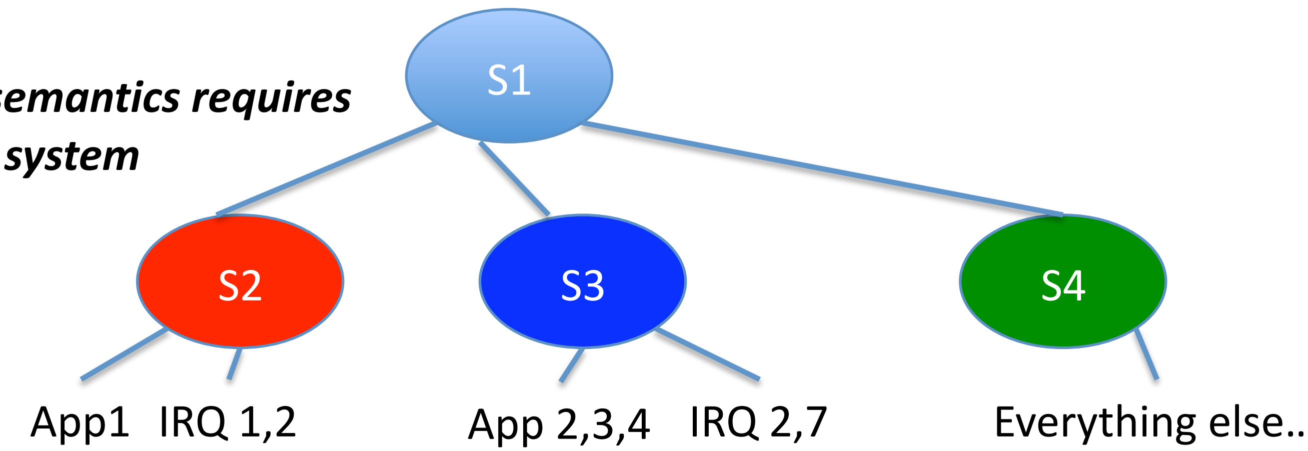


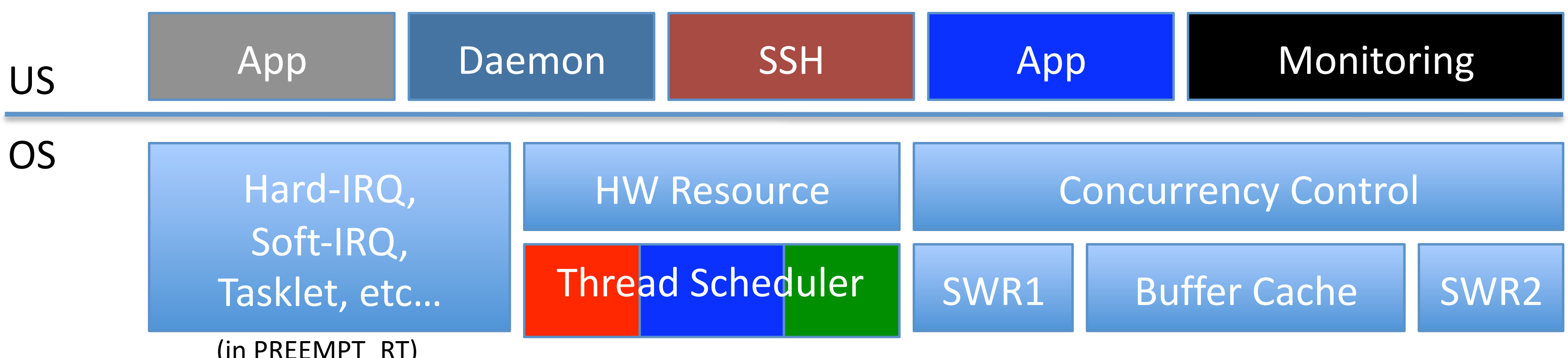
- Can be done with user-space concurrency control
- Locks are used for their scheduling affects

- Instead, directly represent the pipeline progress (application state) within the scheduler
- Clear, unambiguous, easily modeled implementation

Integration Difficulty

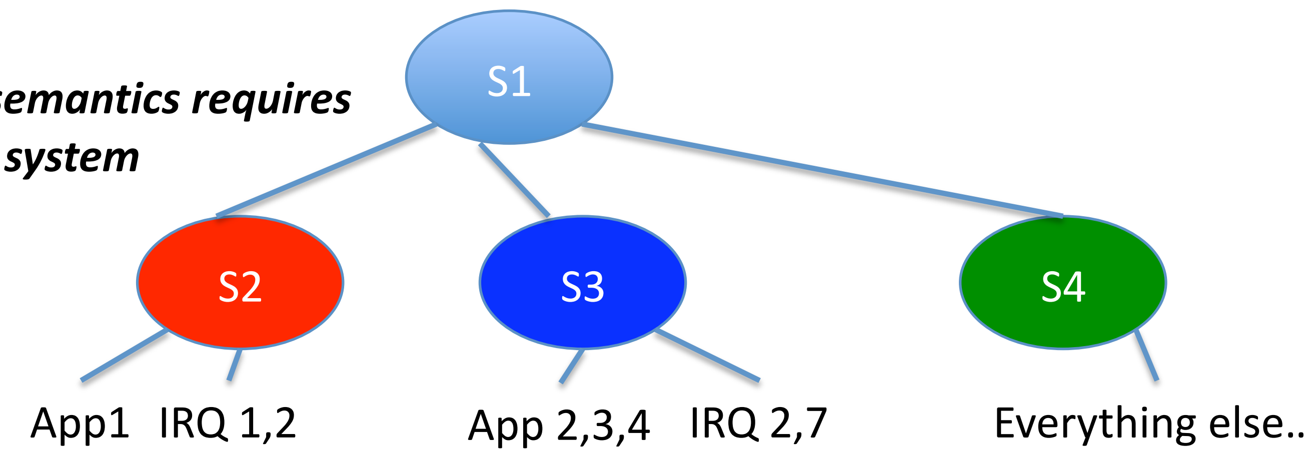
Directly representing semantics requires general integration of system components

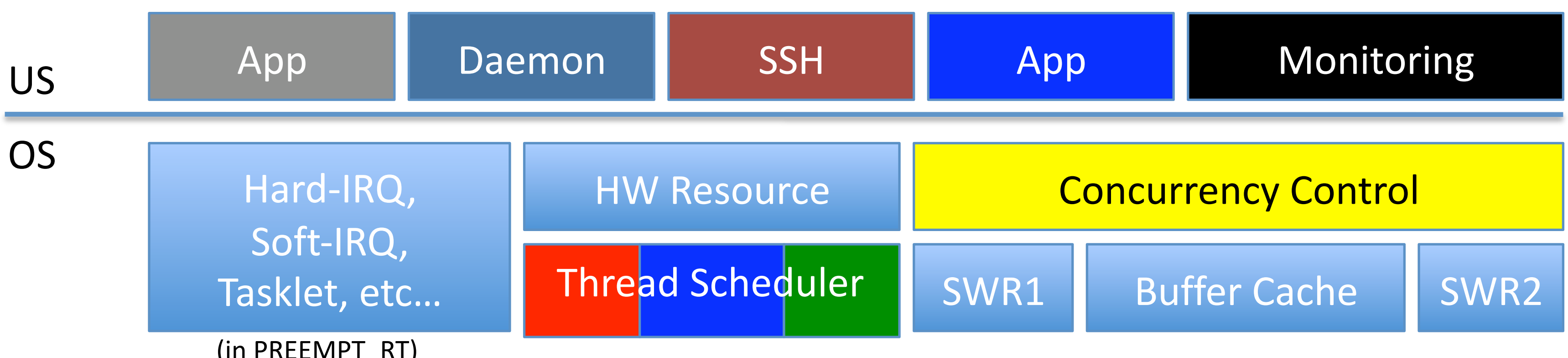




Concurrency Control Integration

Directly representing semantics requires general integration of system components





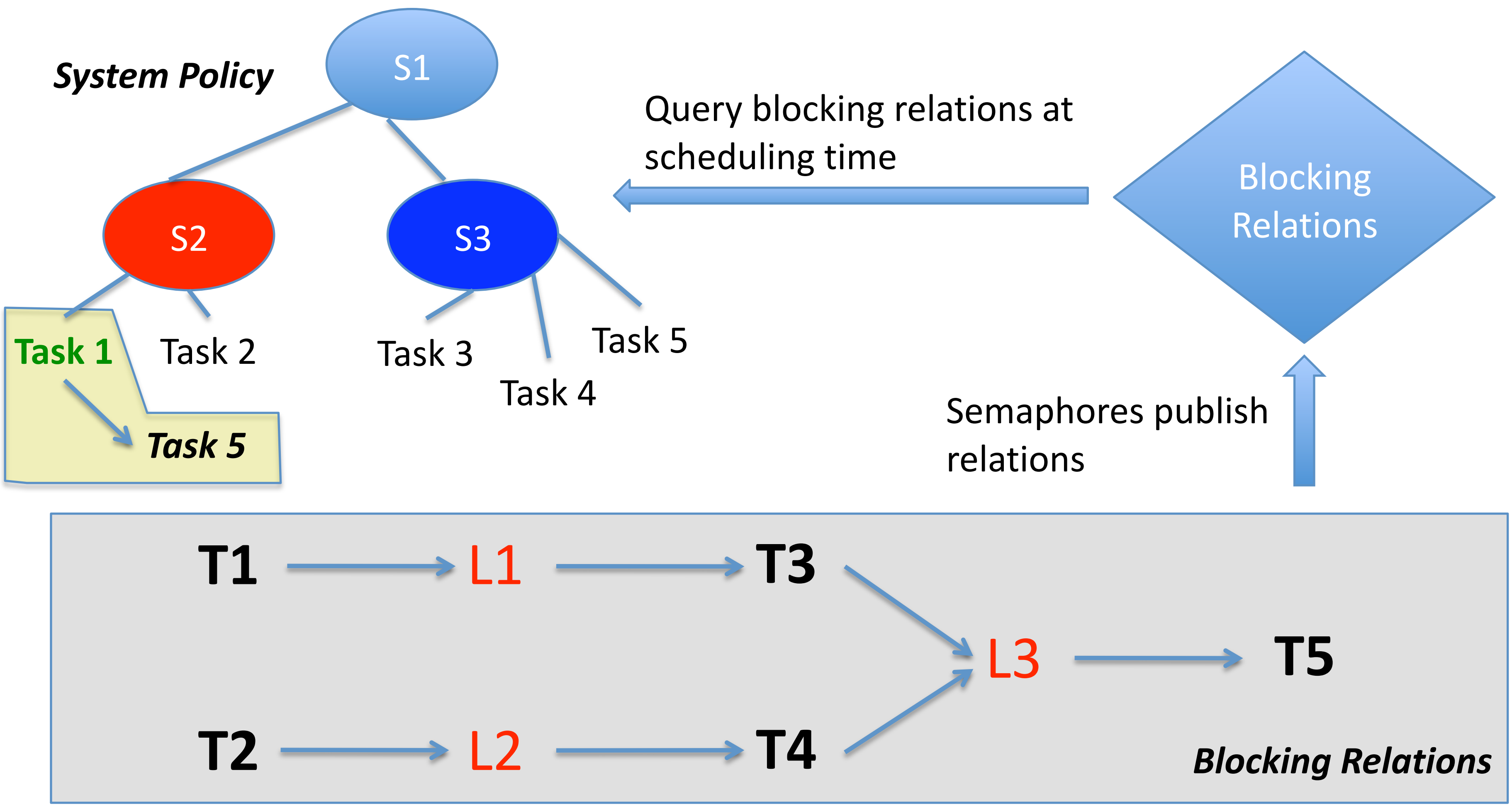
Concurrency Control Integration

- Common approaches assume scheduling semantics
  - Priority inheritance
  - BWI
  - *A semaphore hard-codes this assumption into its implementation*
- Directly represented scheduling semantics may use arbitrary representations
- Hard-coded assumptions don't apply
  - *No mapping, no priority*

Integration Observations

- Blocking relations between computations are independent of semantics
  - Task-2 *blocked on* Lock-1 *owned by* Task-1
- The scheduling hierarchy completely specifies system policy
- Blocking relations *in the context* of system policy have semantic relevance (e.g. PI strategy)
- *Directly representing blocking relations in the scheduler supports semantically independent resolution*

Solution: Directly Represent Blocking Relationships (*Proxy Execution*)



Proxy Execution Challenges

- Complexity in time and space
  - Efficient maintenance/representation of blocking relations
- Scheduler requirements
  - Scalable schedulers use set of relations indirectly
- SMP challenges
  - Relations that span CPUs require special treatment

Evaluation

- It’s difficult to prove a negative
  - Is the solution general (enough)?
- What type of wild semantics can we implement in the framework?
- Performance implications
  - For another talk

Some Results

- Static-priority, CFS, EDF
- Generalized event-based data-flow
  - Scheduler is aware of socket-based event delivery
  - PTIDES
- Guided execution
  - Deterministic execution for reproducible CC testing
    - Lock-step scheduling plans
- Application-specific progress-based scheduling
  - Multiple balanced pipelines

Conclusion

- Continually looking for interesting semantics to implement
- Currently implemented in 2.6.29-rtX

Questions?