Dynamic inter-core scheduling in Barrelfish

avoiding contention with malleable domains

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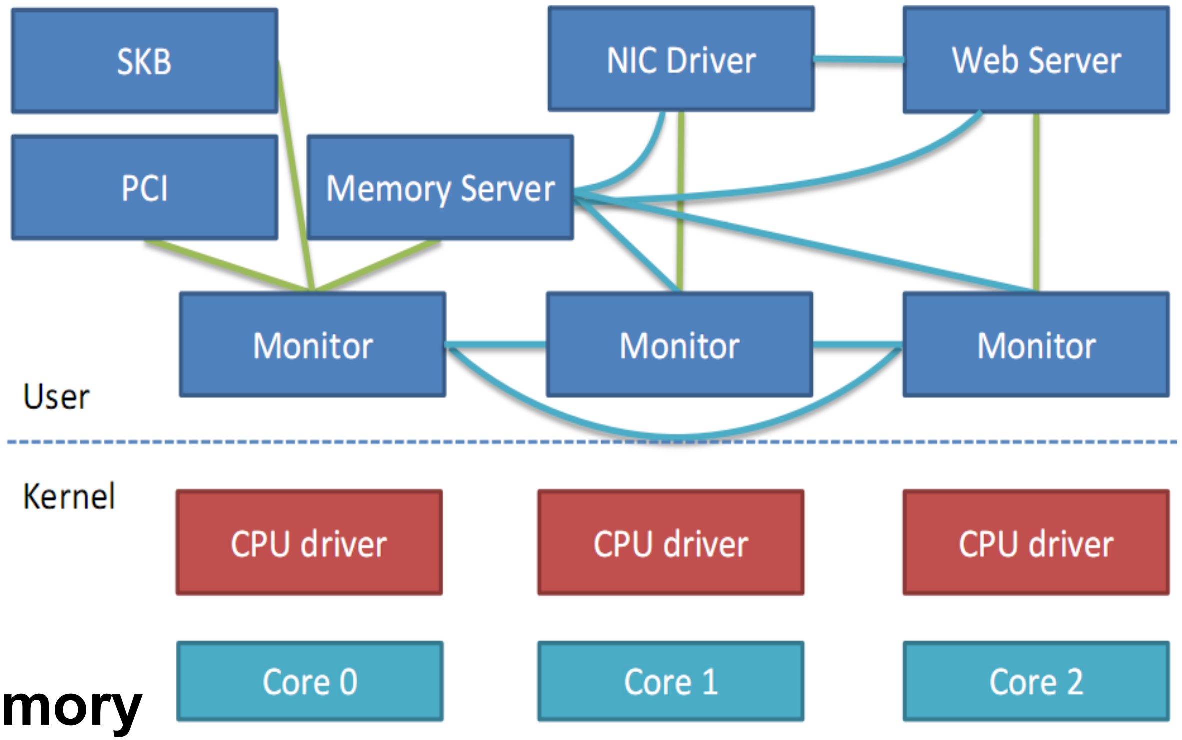
Outline

- Introduction
- Scheduling & Programming models
- Malleability
- Future work

Barrelfish: a multi-kernel OS

- **message based communication**
- replication and consistency
- heterogeneity



- assumes **no shared-memory**
- provides **no** system-wide **resource management**

Overall Goals

- Allow for shared memory based parallel programming models
  - OpenMP, Wool, Cilk++
  - take advantage of the underlying hardware architecture.
- … while exploiting the message passing nature of Barrelfish
  - scalability
  - portability

This project...

- Perform resource management in order to increase throughput and minimize contention in Barrelfish

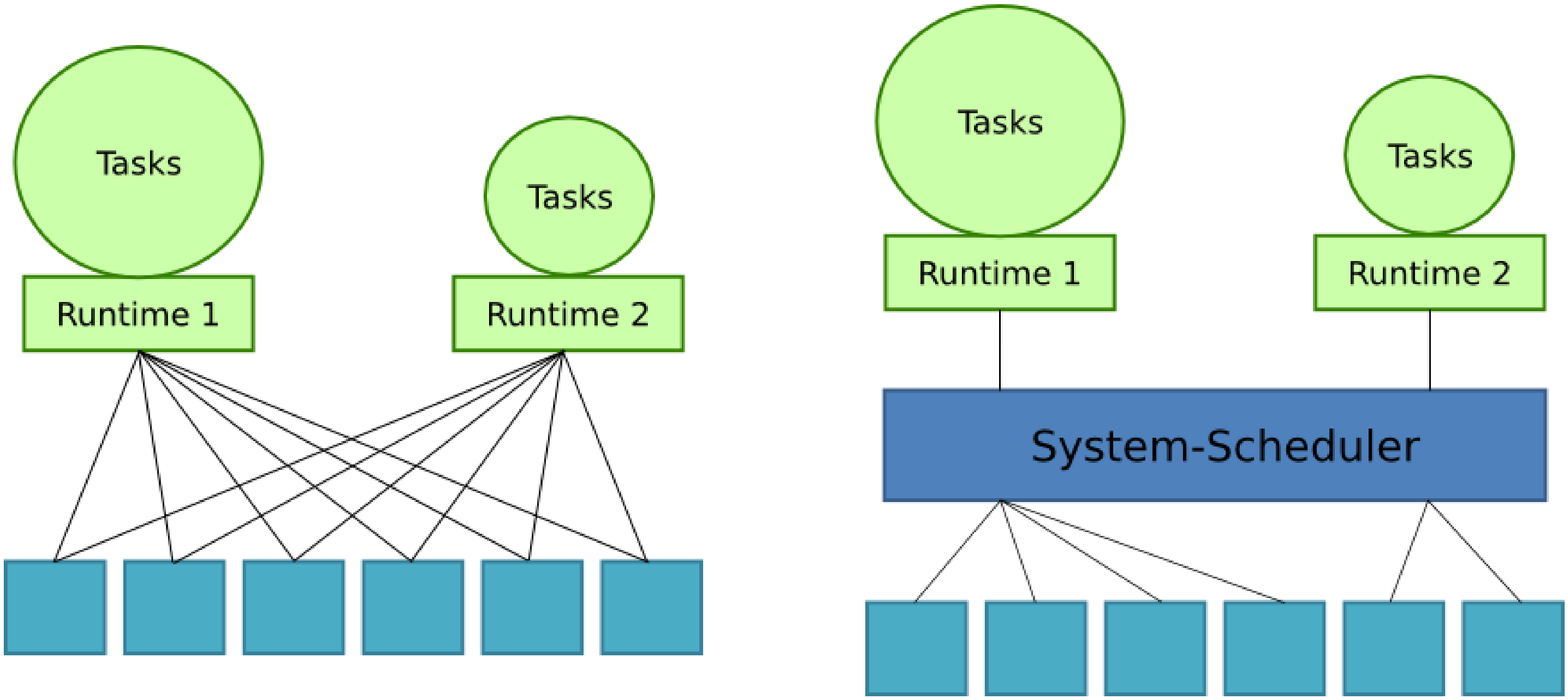
  - Inter-core scheduling
    - system-wide load balancing
  - Dynamic scheduling
    - malleable resource allocation
  - In a multiprogrammed context

Motivation

- Current parallel programming models:
  - focus on running in isolation
  - minimal operating system support
  - can be wasteful in a multiprogrammed context
- Many real-life applications:
  - exhibit fluctuating parallelism throughout their execution
  - are not that parallel from the start

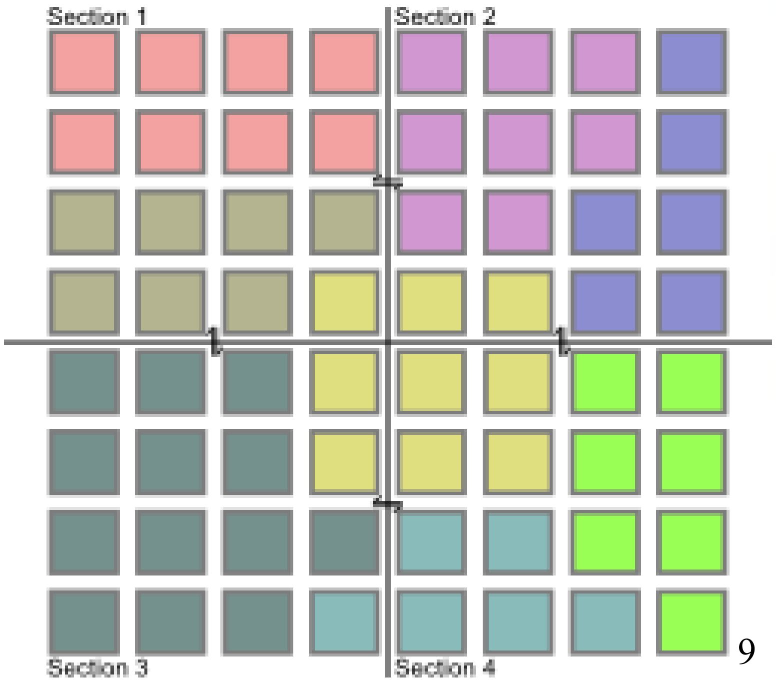
Scheduling

- Split into two cooperating levels
- System level,
  - aware of the global state and the availability of diverse resources
- User level,
  - aware of the parallelism in the application


Tasks
Tasks
Runtime 1
Runtime 2
Tasks
Tasks
Runtime 1
Runtime 2
System-Scheduler

System scheduler

- Accept feedback on process efficiency
- Modify the allotment of cores (domain) of each process for maximum resource utilization
- Distributed service
  - multiple instances overlook distinct segments
  - processes can span multiple segments



User-level scheduler

- Integrated into the application run time
- Schedules a process' threads in its domain
- Provides feedback on per core **efficiency**, to the system scheduler [1]
  - metric: ***wasted cycles***

    “cycles spent while not having work”

[1] Kunal Agrawal, Charles E. Leiserson, Yuxiong He, and Wen Jing Hsu. Adaptive work-stealing with parallelism feedback. ACM Transactions on Computer Systems, 26(3):1-32, September 2008.

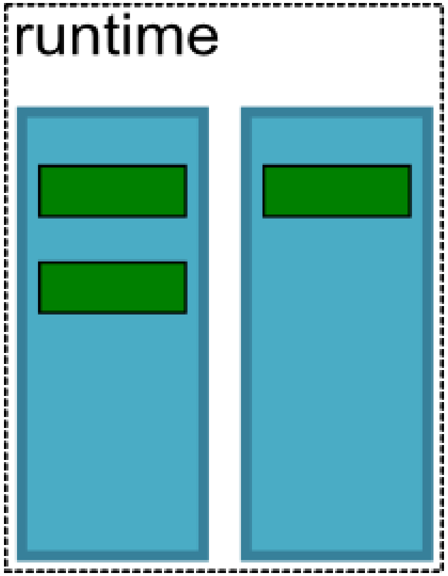
User level scheduler, cont'd

- Capture average & worst thread efficiency
- Over a fixed interval classify on two criteria:
  - *inefficient* or *efficient*: utilization of workers
  - *satisfied* or *deprived*: system contention

  - **inefficient**: overestimation, desire *decreased*
  - **efficient & satisfied**: underestimation, desire *increased*
  - **efficient & deprived**: balanced, desire *unchanged*
- Forward new desire and classification

Shared memory programming models (OpenMP, Wool, Cilk++)

- Focusing on the task-based paradigm
  - work-stealing models scale easily
- Wool already ported
  - *application state in the stack*
- Cilk++ requires a custom compiler
  - *application state in the heap*



System scheduler, cont'd

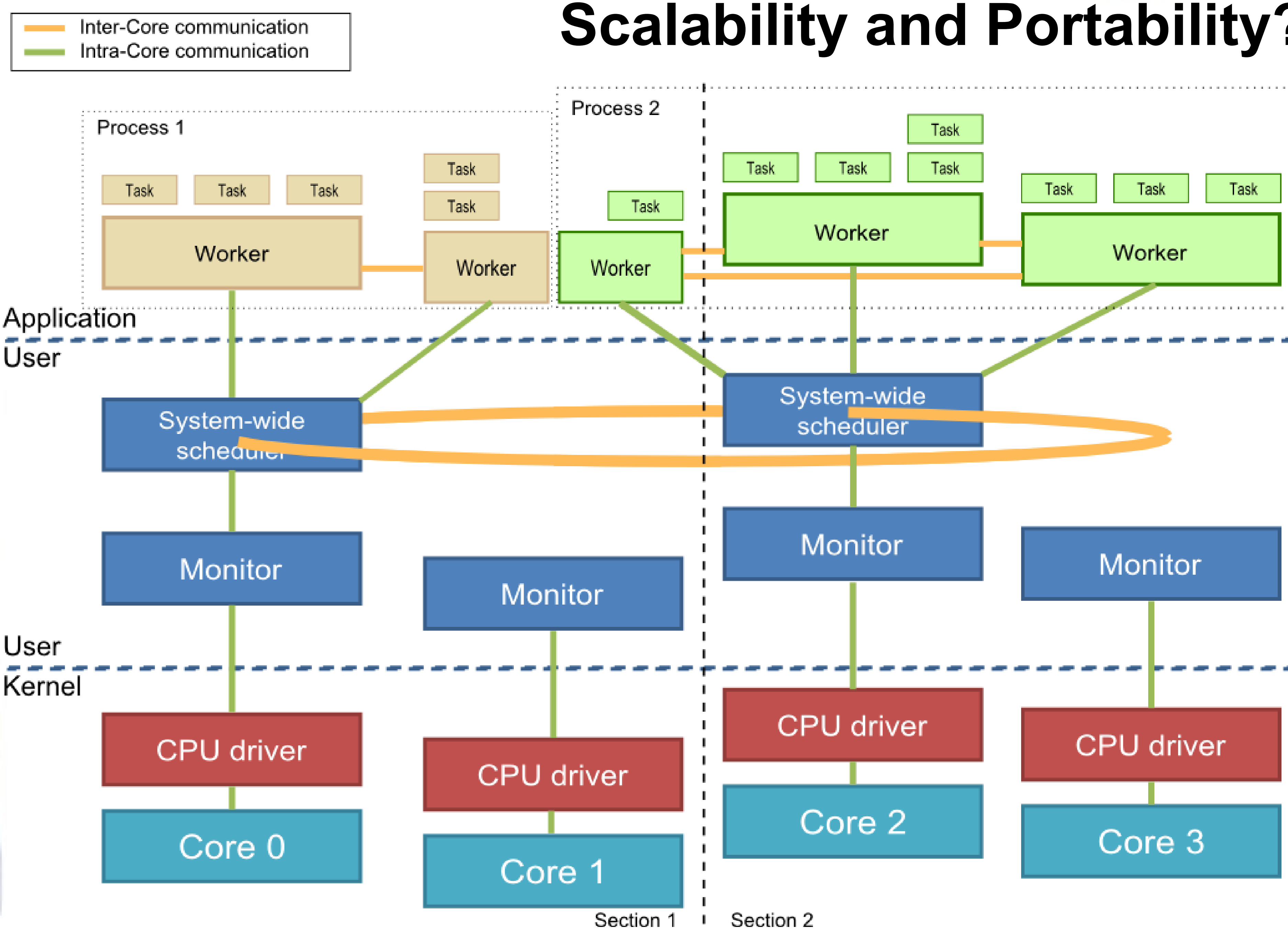
- Over a fixed interval each instance will:
  - increase allotment for its segment's “*efficient and satisfied*” processes
  - extra cores are either idle or taken from its segment's “*inefficient*” processes
  - if needed broadcast a request to other scheduler instances
  - result to time-sharing if not enough “inefficient” processes exist
- Which worker to suspend?

Time sharing not always avoided

- Joining a task requires simultaneous execution of the workers involved
- Phase-lock gang scheduling [1]
  - Efficient gang scheduling for barrelfish

[1] S. Peter et al., “Design principles for end-to-end multicore schedulers,” in Proceedings of the 2nd USENIX conference on Hot topics in parallelism, 2010, p. 10.

Scalability and Portability?



Malleable domains

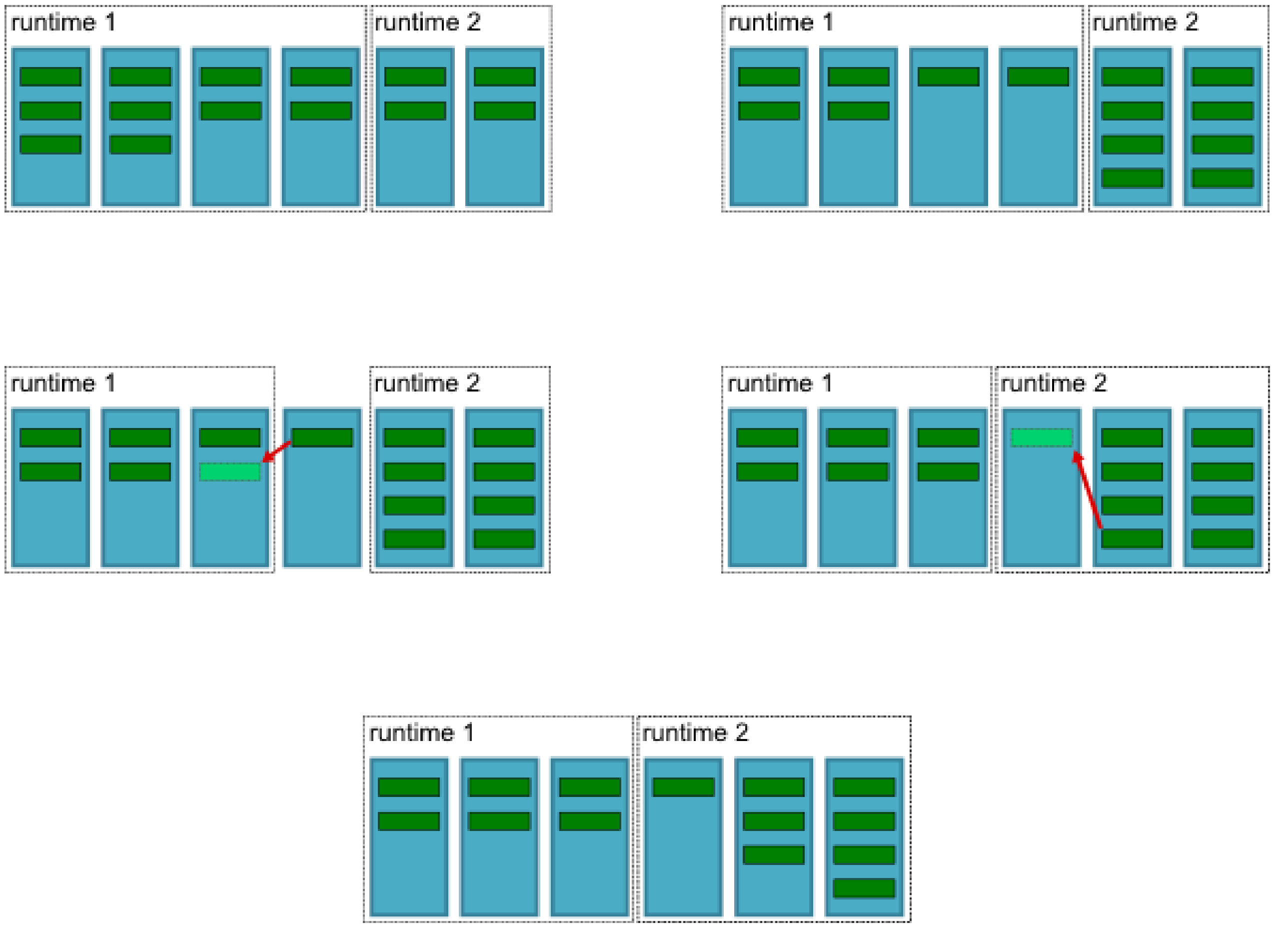
- Load balance the system by modifying the domain of each process
  - unwanted worker-threads are suspended
  - or new ones are added

- Worker-thread suspension tricky,

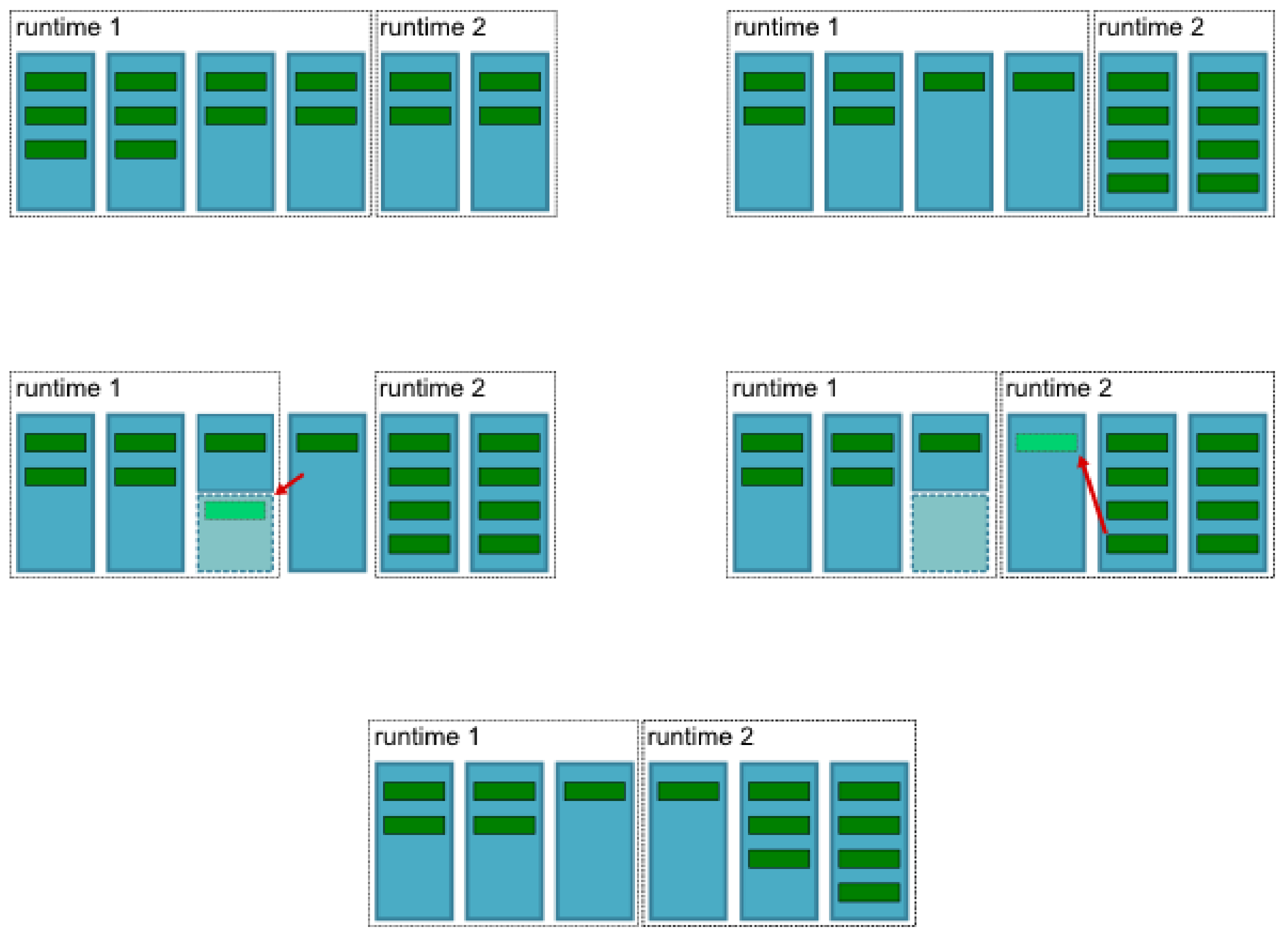
  depends on the run-time in use
  - **lazy-suspension**
  - **immediate-suspension**

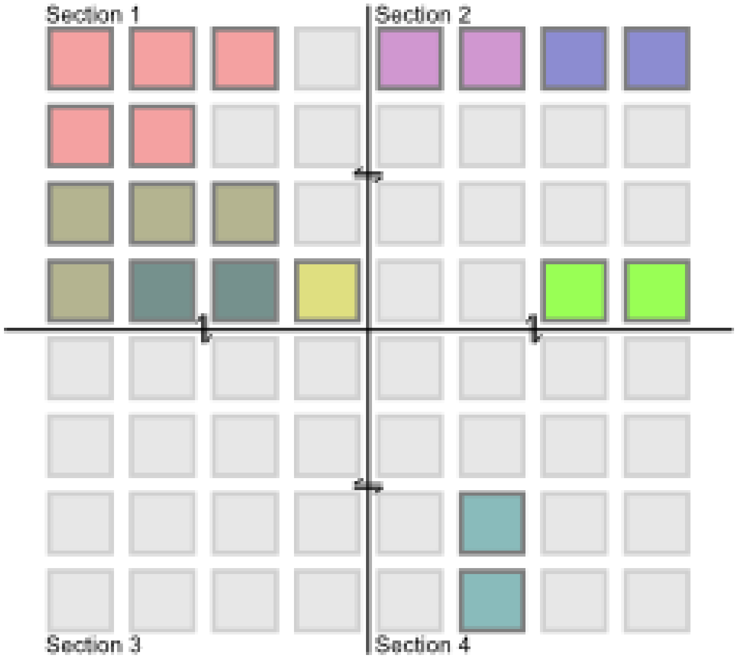
1) Continuation-passing-style: Shared memory is used instead of the CStack.

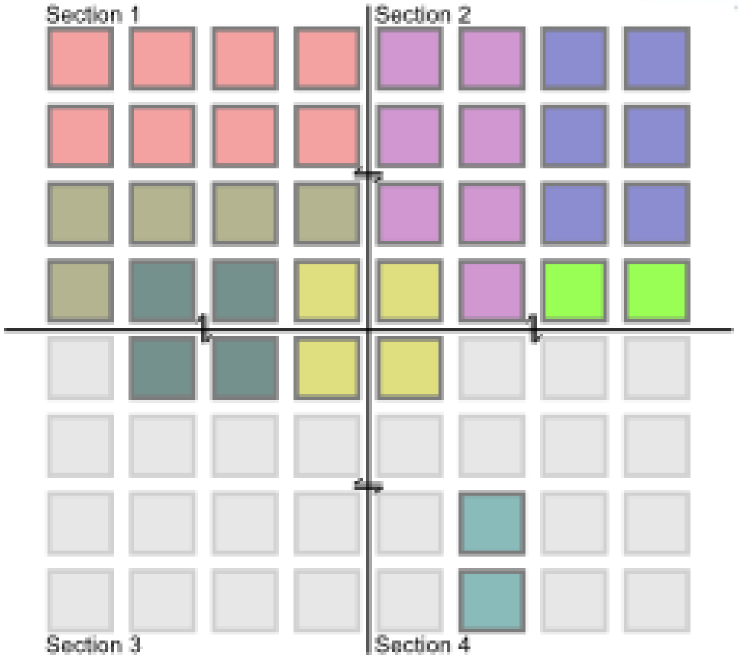
Immediate suspension

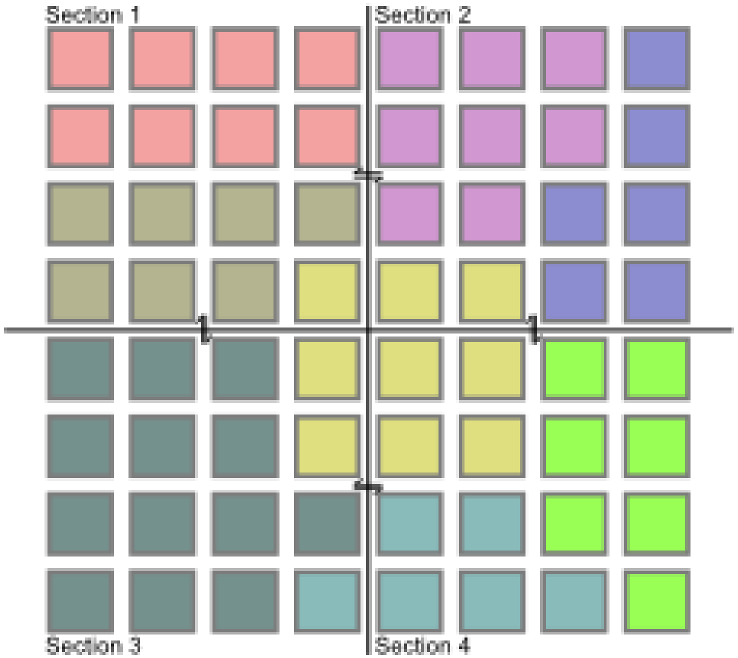


Lazy suspension









- Intelligently migrate processes to avoid contention
- Allot processing resources according to runtime's efficiency & app's parallelism

Future Work

- Evaluation in comparison to other OSs
- Locality aware allotment of cores
- Use core attributes as criteria on heterogeneous systems
- Handle the absence of shared-memory support in the architecture

THANK YOU

Q & A