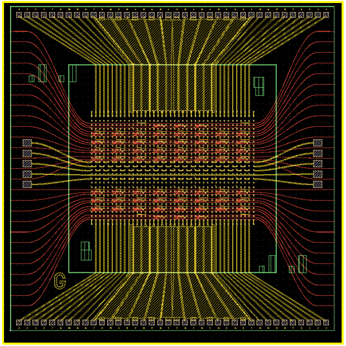
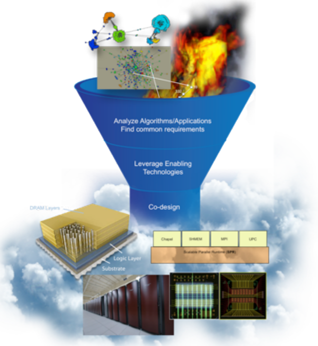
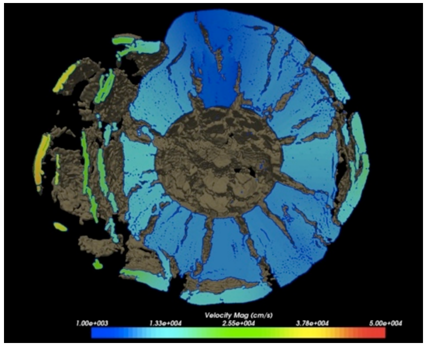
Exceptional service in the national interest

Sandia National Laboratories

EXTREME-SCALE COMPUTING GRAND CHALLENGE







Opportunities for Integrating Tasking and Communication Layers

Dylan Stark

Brian Barrett

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2011-XXXXP

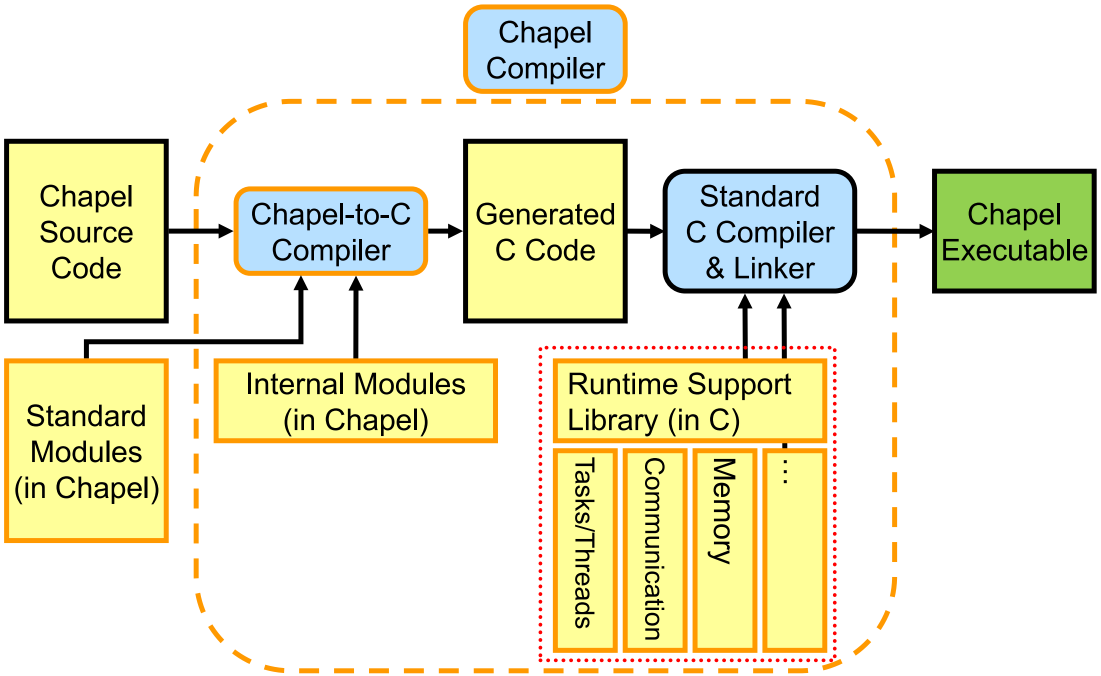
My Objectives for this Talk

1. Review how Chapel operates over multiple locales

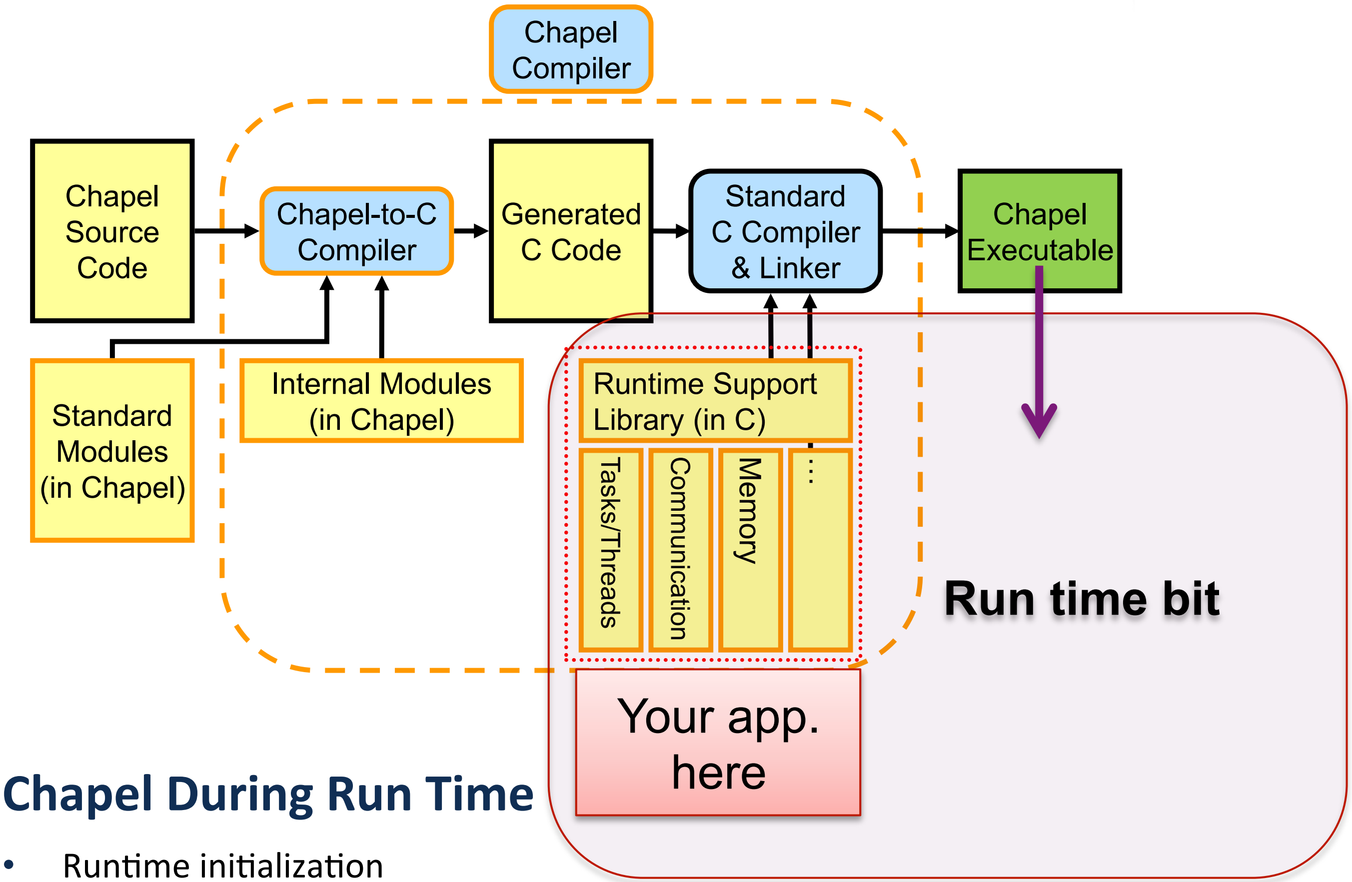
2. Describe our unified runtime attempt

3. Talk about opportunities for Chapel to benefit from such an approach

Chapel Compilation Architecture

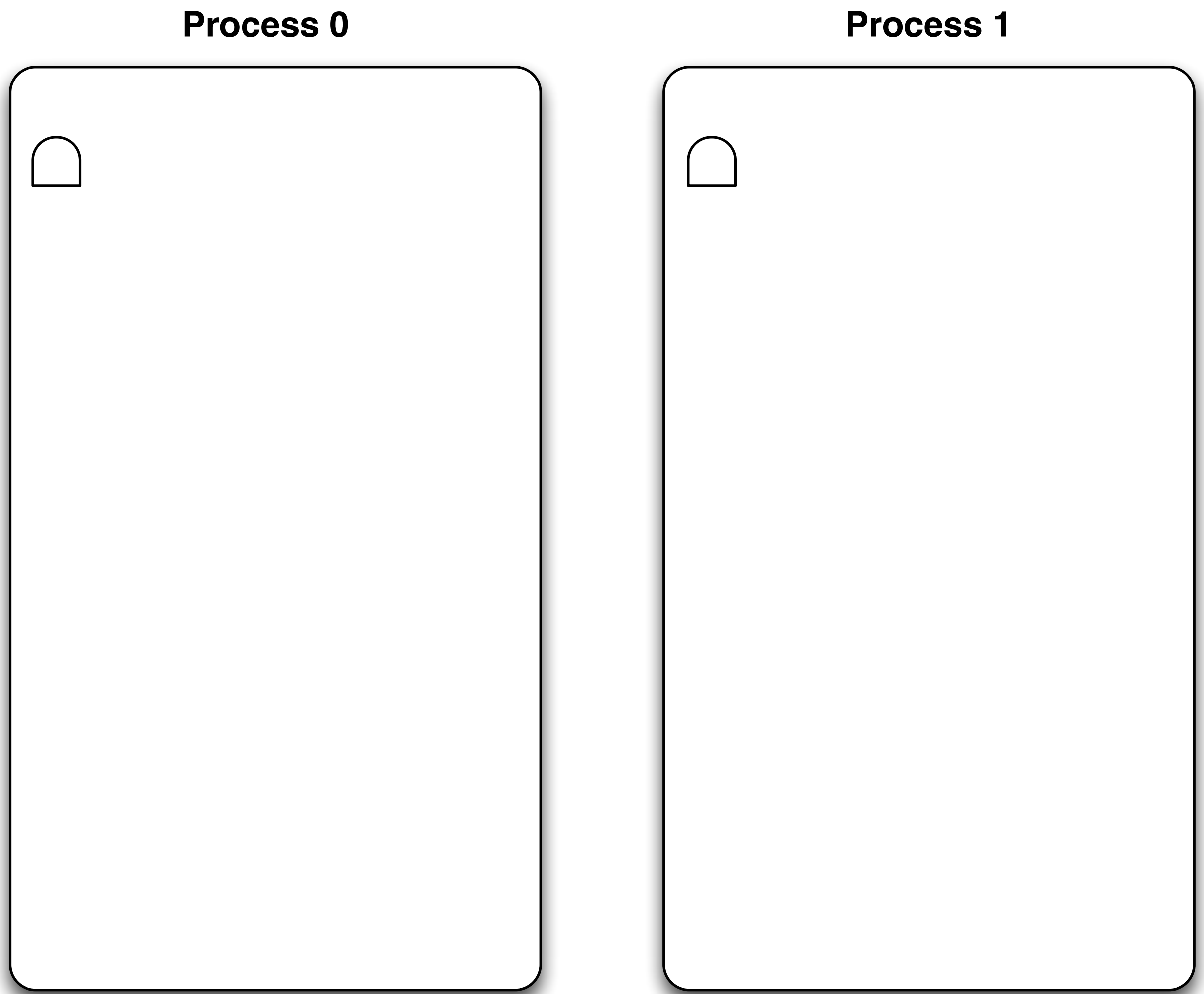


Chapel Compilation Architecture



Chapel During Run Time

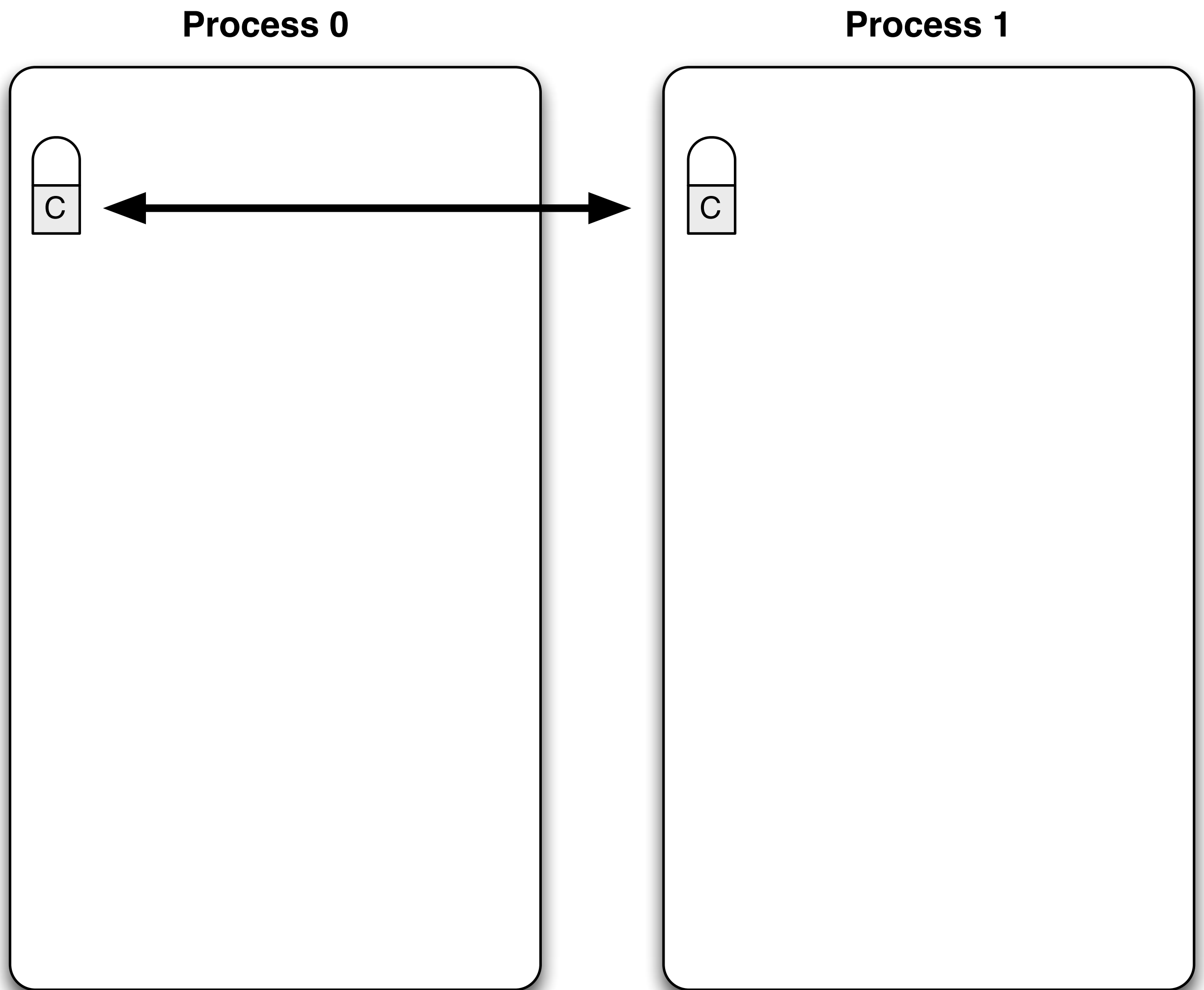
- Runtime initialization
- Data movement
- Work Migration



Parallel Job Launch

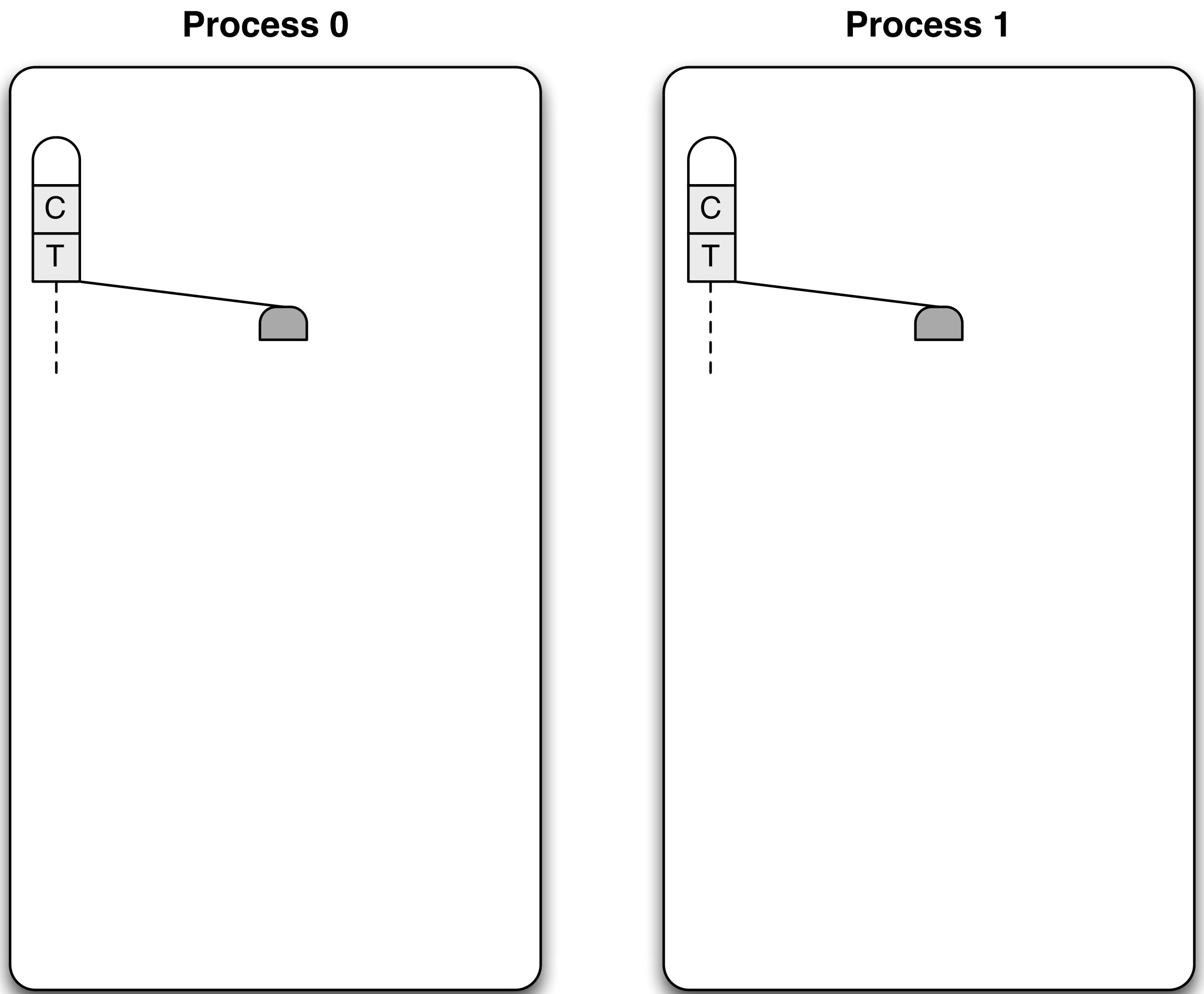
- (Skipping the details)
- SPMD to the runtime
- OS Process == Locale

- Start with Chapel-defined main() defined in `runtime/src/main.c’



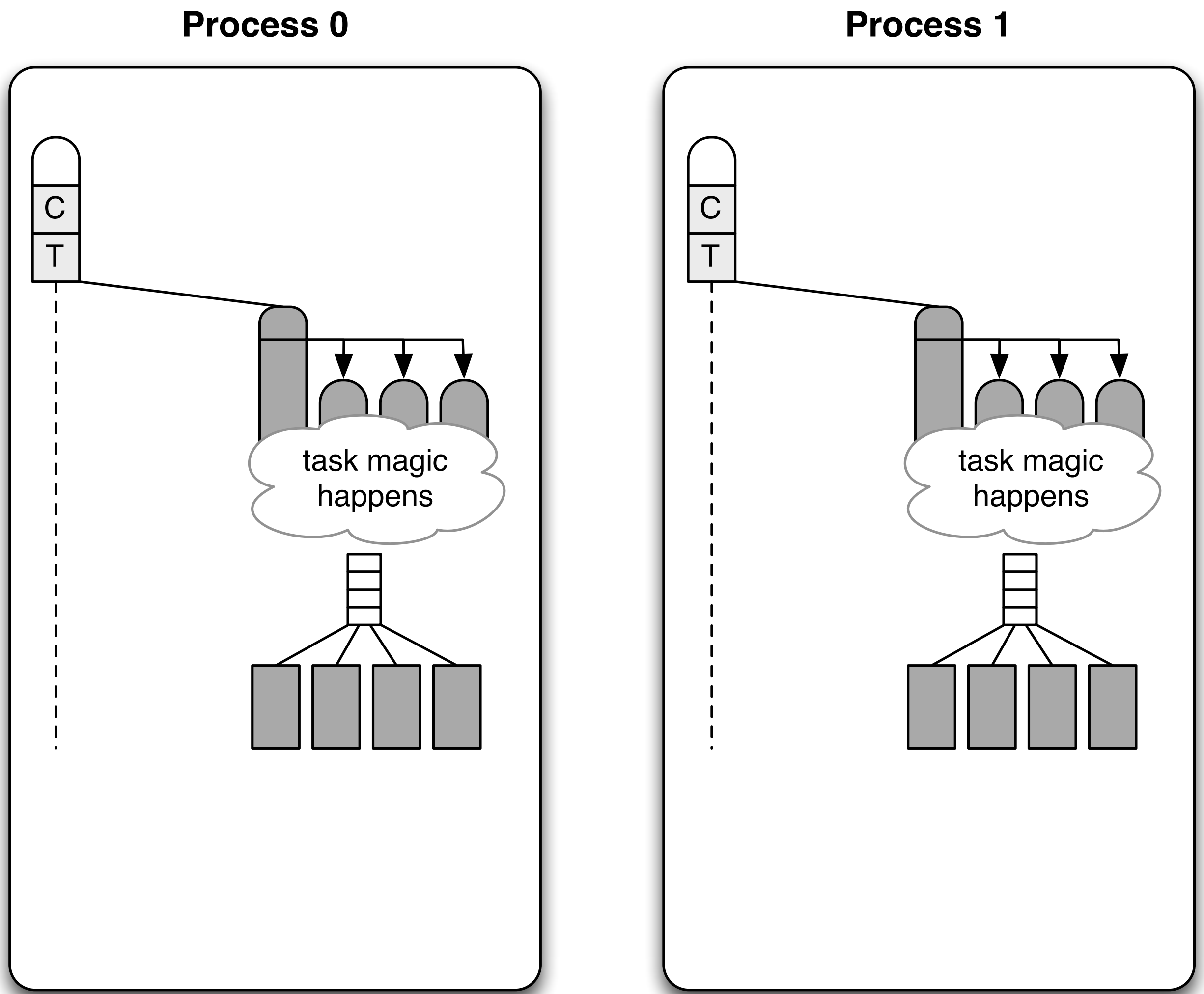
Comm. Layer Initialization

- (CHPL_COMM=gasnet)
- Shim calls chpl_comm_init()
- Registers active message handlers
- Sets up shared memory segments



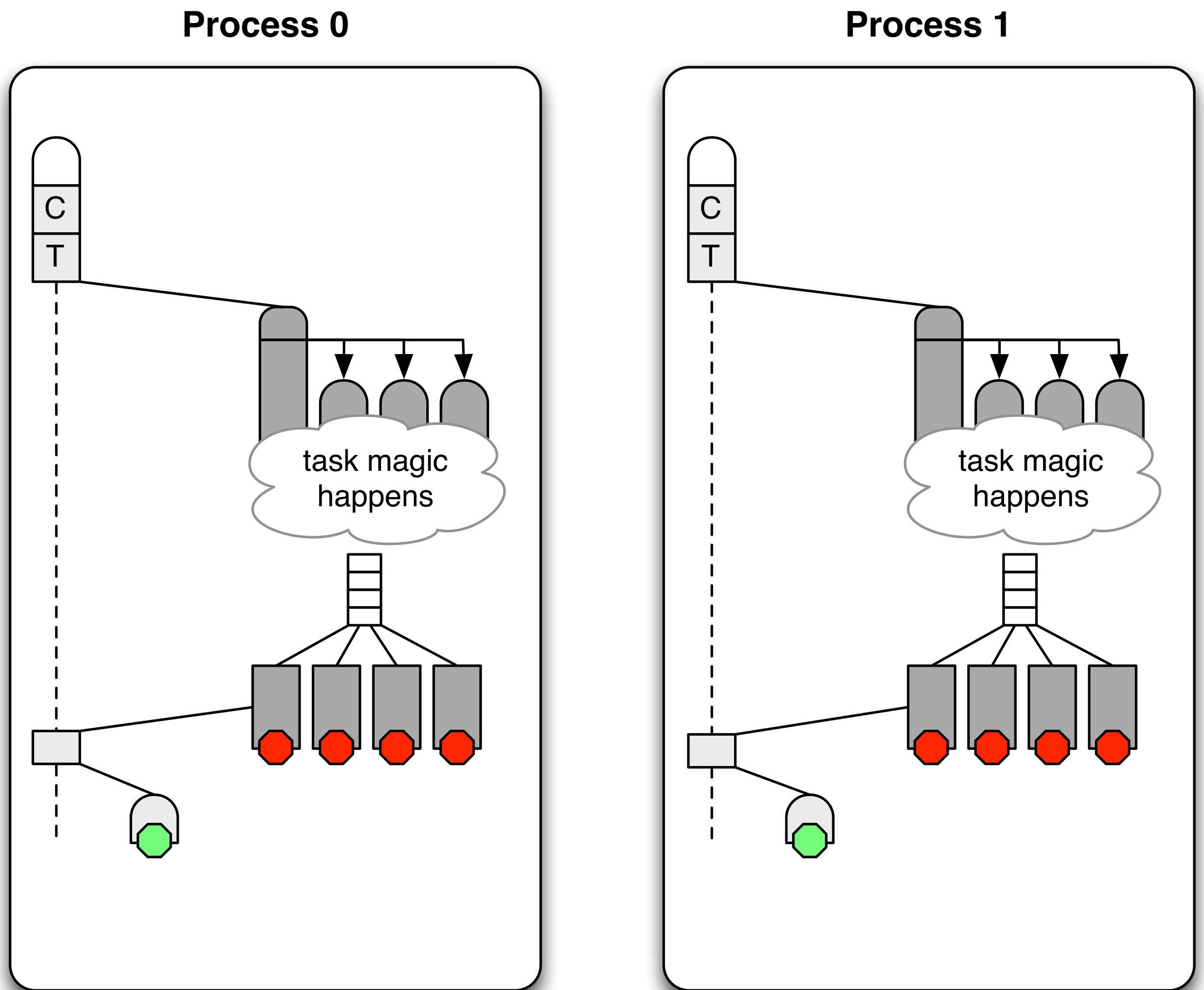
Task Layer Initialization

- (CHPL_TASKS=qthreads)
- Shim calls chpl_task_init()
- Gathers information about the local resources and application requirements
- Forks a Pthread for Qthreads



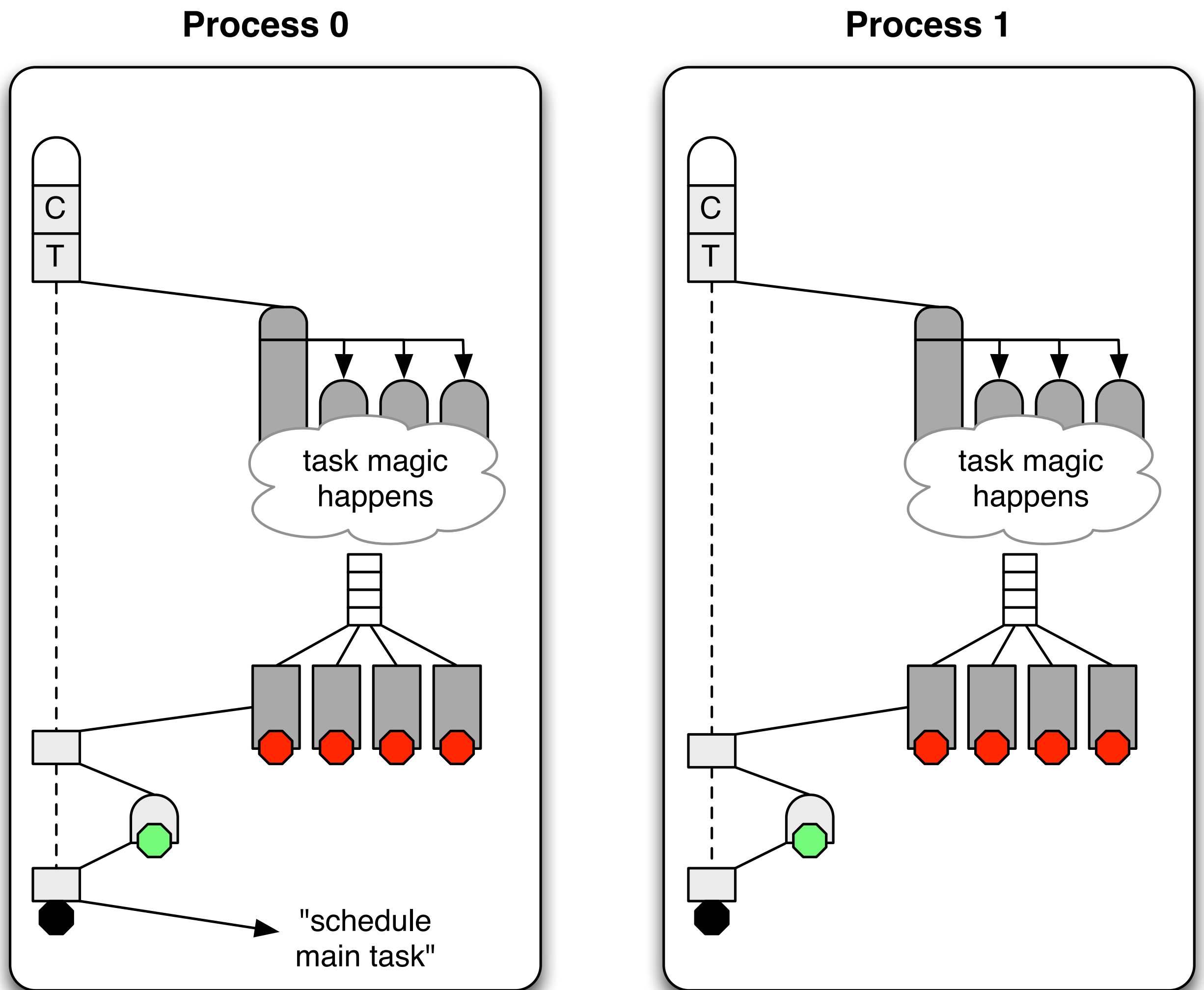
Task Layer Initialization

- Qthreads is initialized in aux. Pthread context
- Number of worker threads equals number of cores
- Control returns to main Chapel RS thread



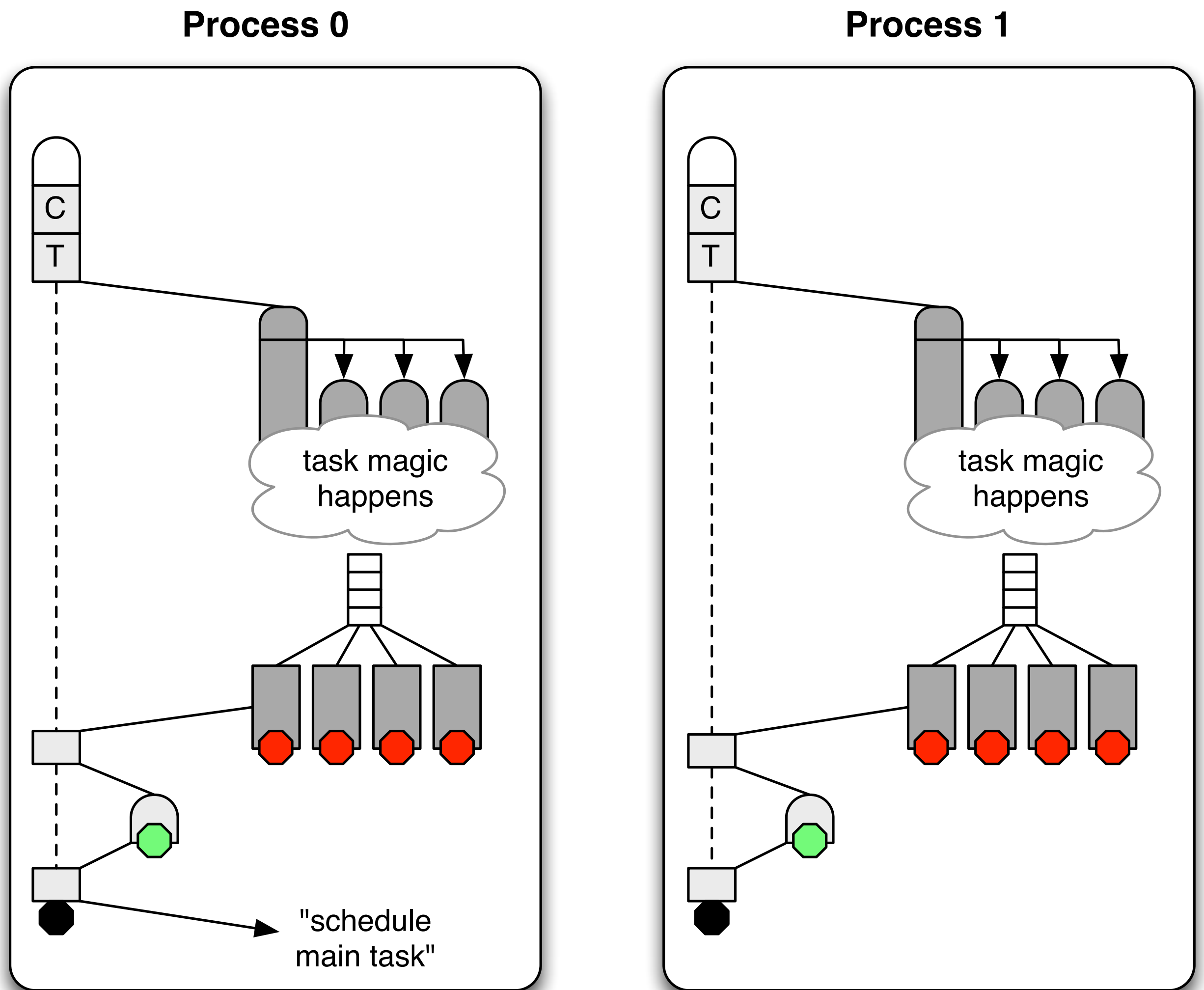
Progress Engine Start Up

- Another Pthread for a progress engine
- Loop polling GASNet
- chpl_task_yield() converted to OS sched_yield()



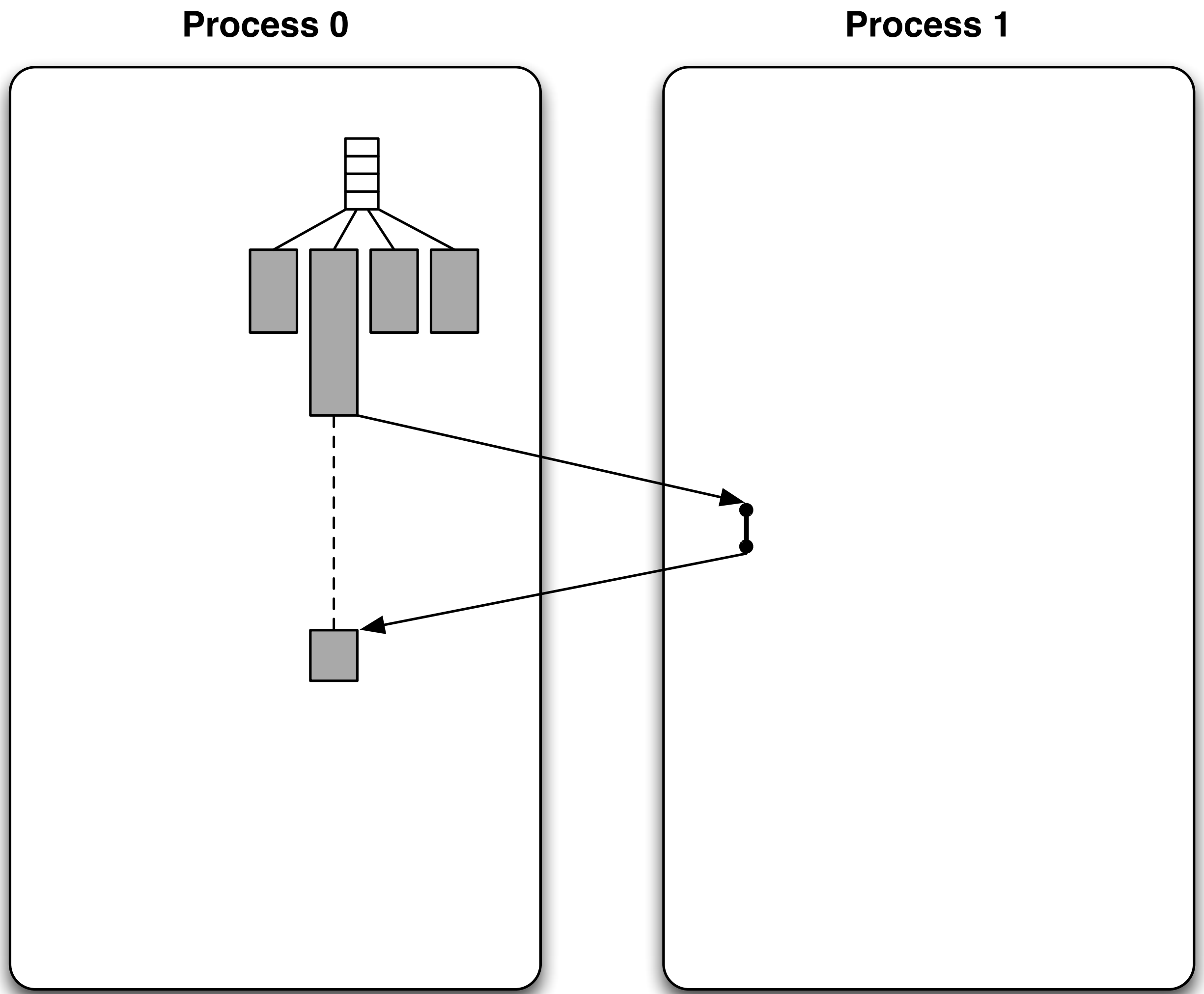
Application Initiation

- Compiler-generated chpl_main() called to start application code
- Spawned as a task into the tasking layer (from outside)
- Caller “suspends” waiting for that task (really a Pthread mutex block)



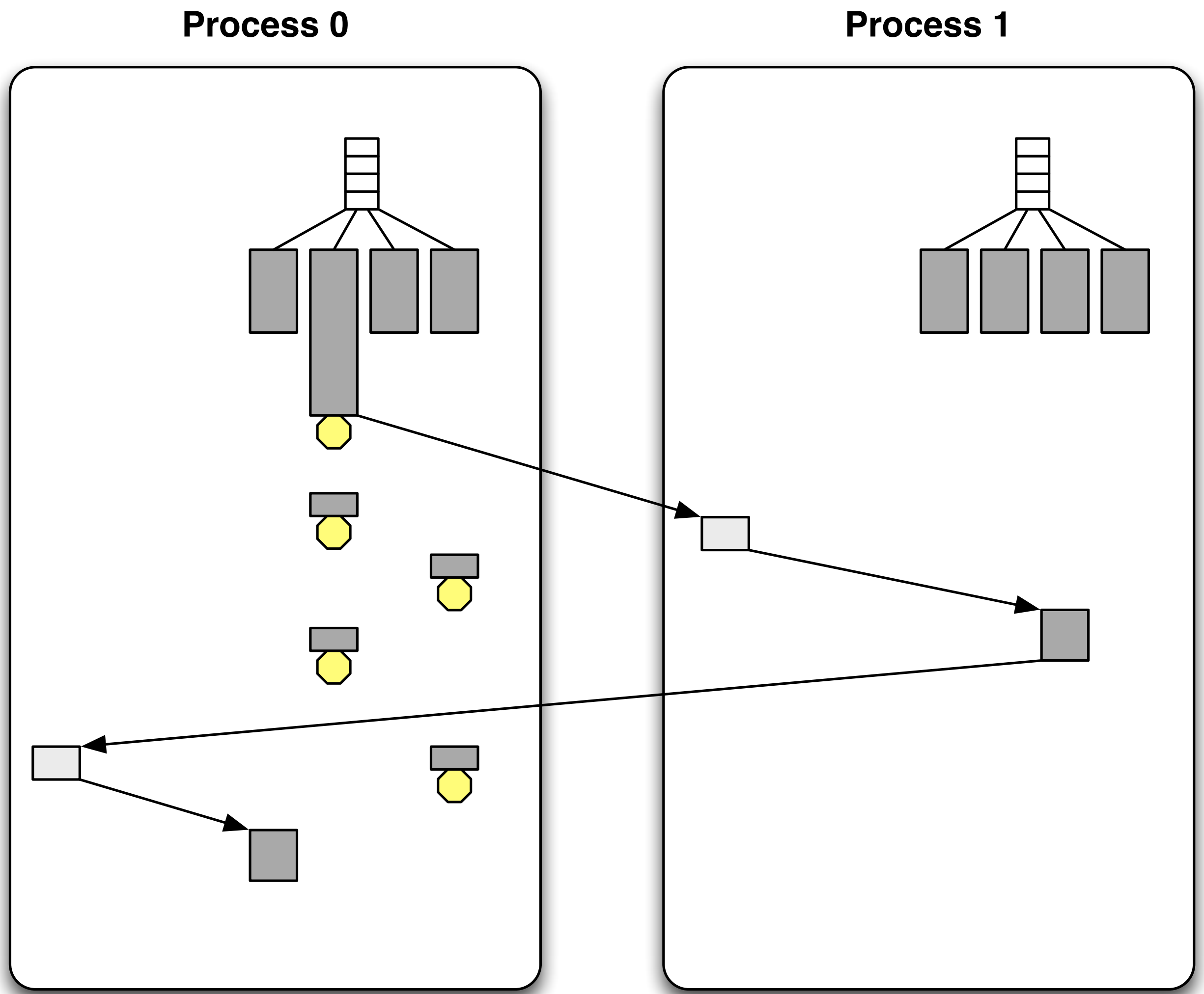
Observations from Runtime Initialization

- Could do better at managing compute resources
- Calls from to the tasking layer from outside of tasks can have asymmetric performance characteristics



Data Movement

- Put and get operations are implemented in the comm. layer
- Direct mapping to GASNet
- Of note: core **blocked** during operation

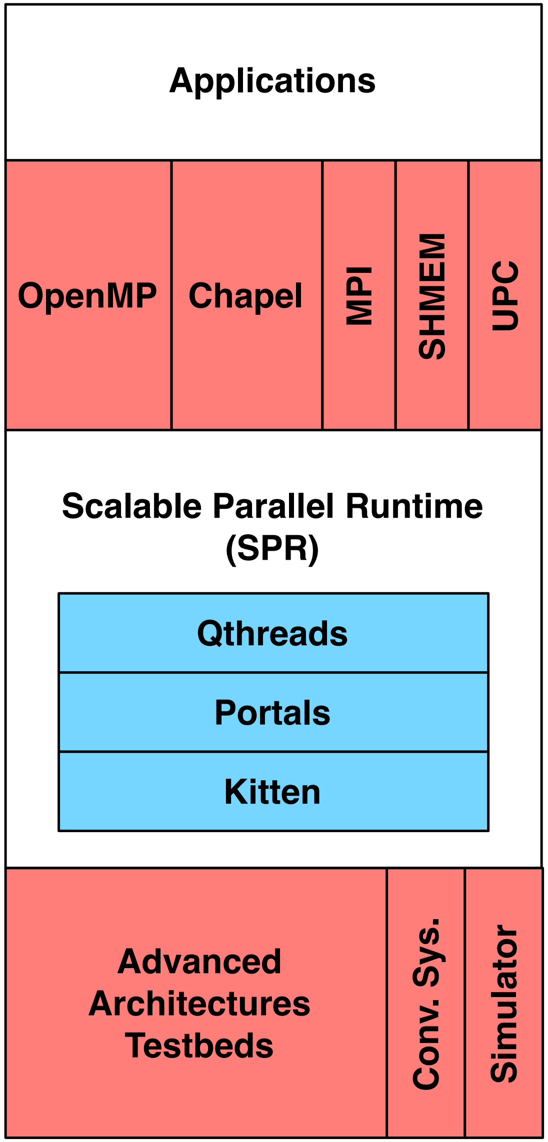


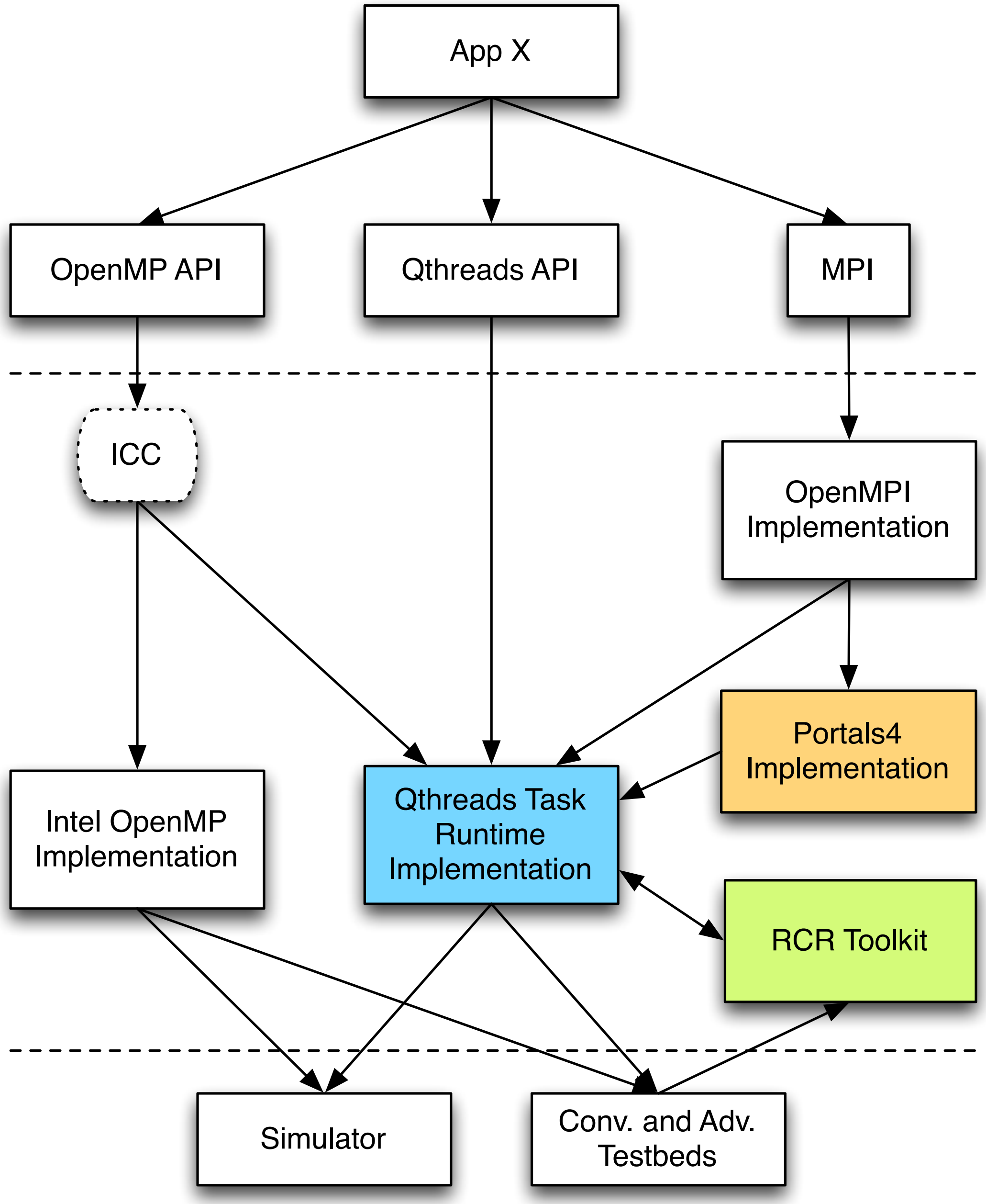
Work Migration

- 3 types: blocking, non-blocking, and “fast” remote fork
- Calling task loops – polling GASNet for completion and yielding
- Scheduler **interference** on the call side

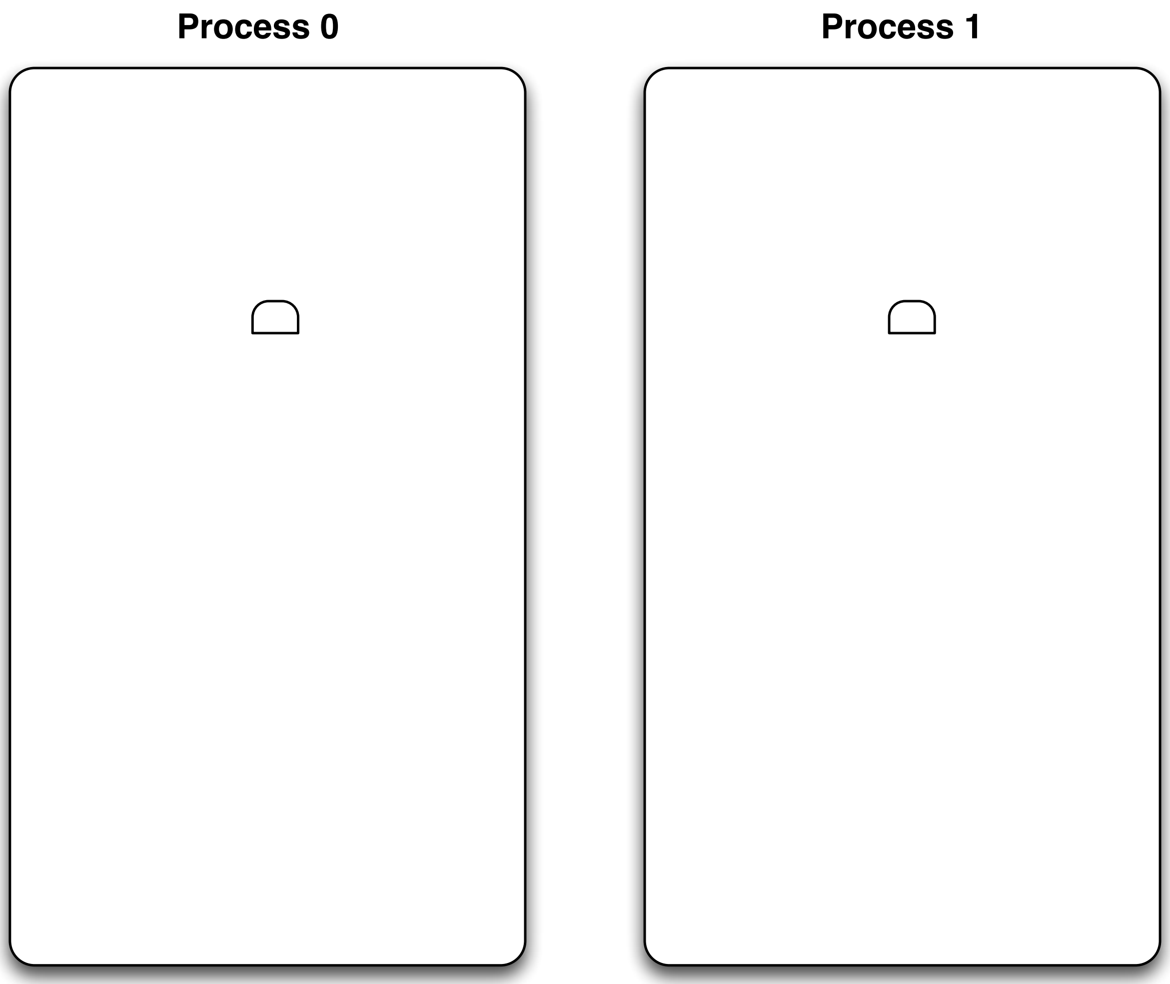
A Unified Runtime Example

- **Qthreads: Lightweight threading interface**
  - Scalable, lightweight scheduling on NUMA platforms
  - Supports a variety of synchronization mechanisms, including full/empty bits and atomic operations
  - Potential for direct hardware mapping
- **Portals 4: Lightweight communication interface**
  - Semantics for supporting both one-sided and tagged message passing
  - Small set of primitives, allows offload from main CPU
  - Supports direct hardware mapping
- **Kitten: Lightweight OS kernel**
  - Builds on lessons from ASCI Red, Cplant, Red Storm
  - Utilizes scalable parts of Linux environment
  - Primarily supports direct hardware mapping

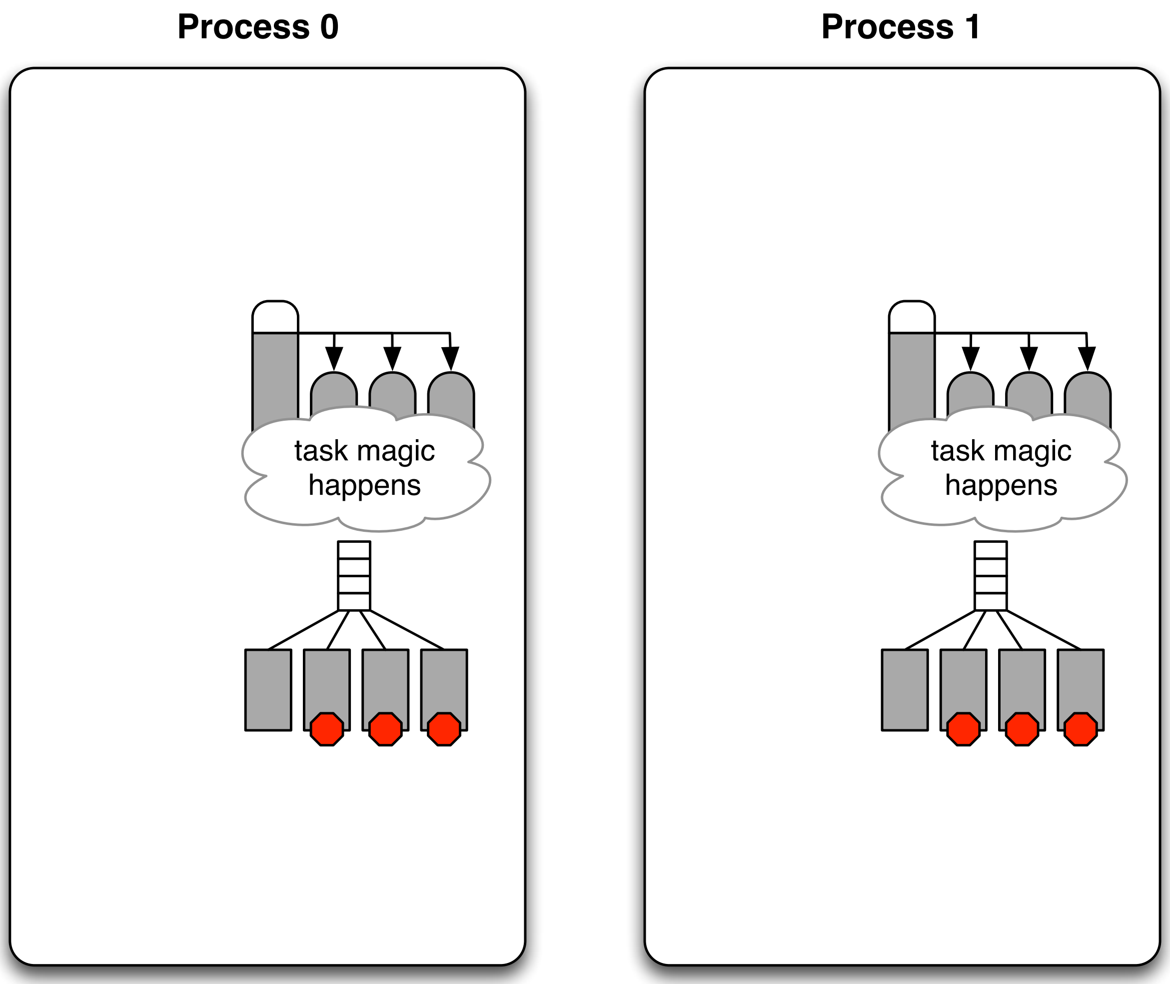



App X
OpenMP API
Qthreads API
MPI
ICC
OpenMPI Implementation
Portals4 Implementation
Intel OpenMP Implementation
Qthreads Task Runtime Implementation
RCR Toolkit
Simulator
Conv. and Adv. Testbeds

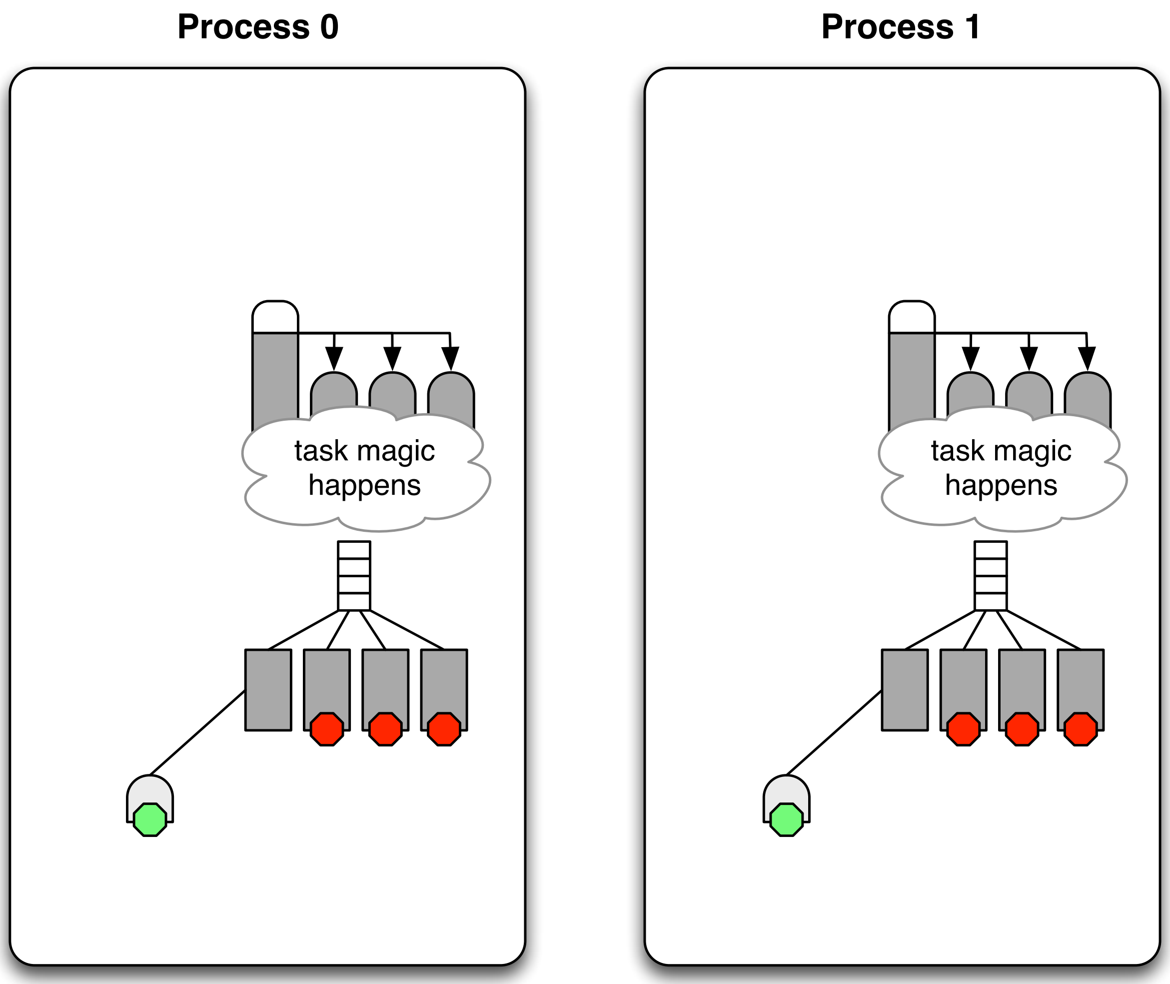
Task & Network Runtime Init.



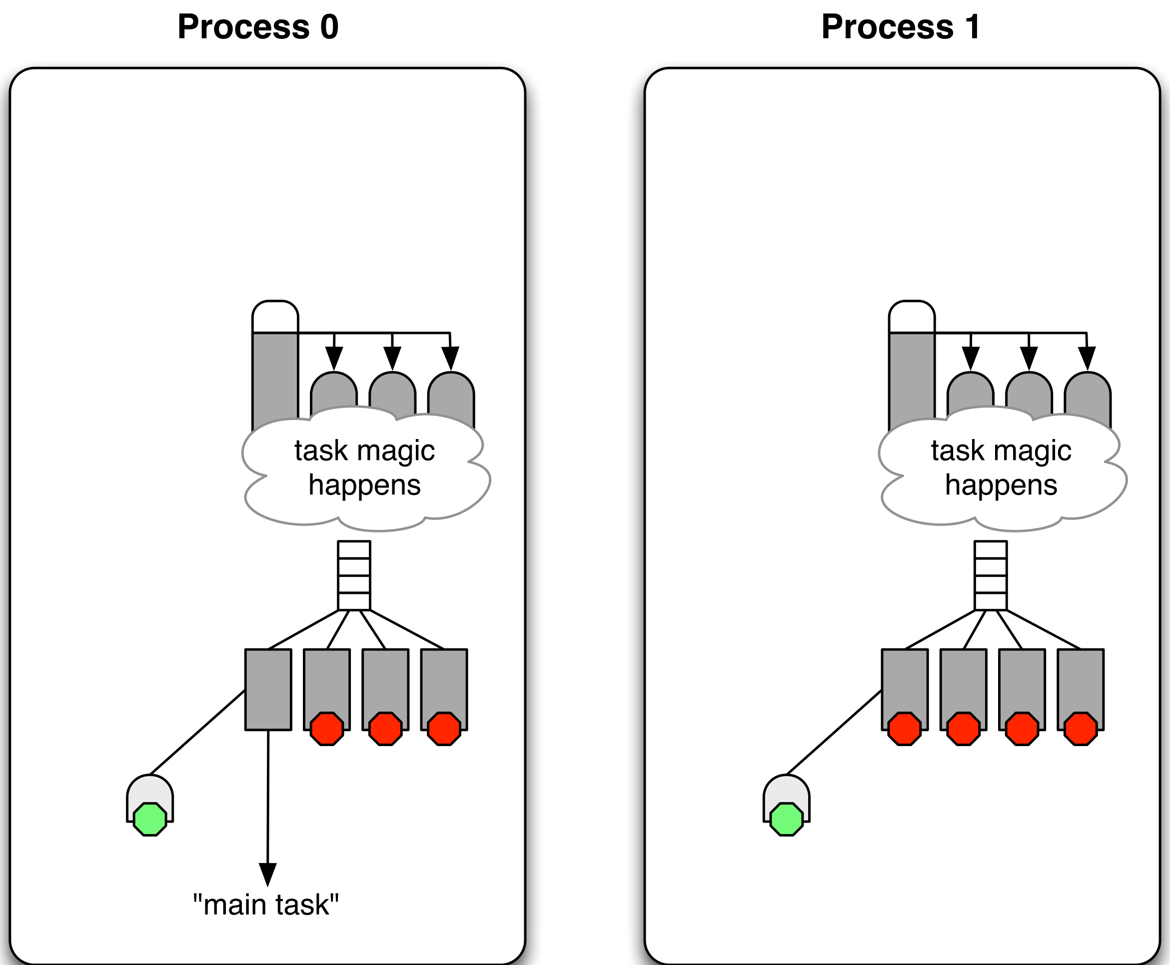
Task & Network Runtime Init.

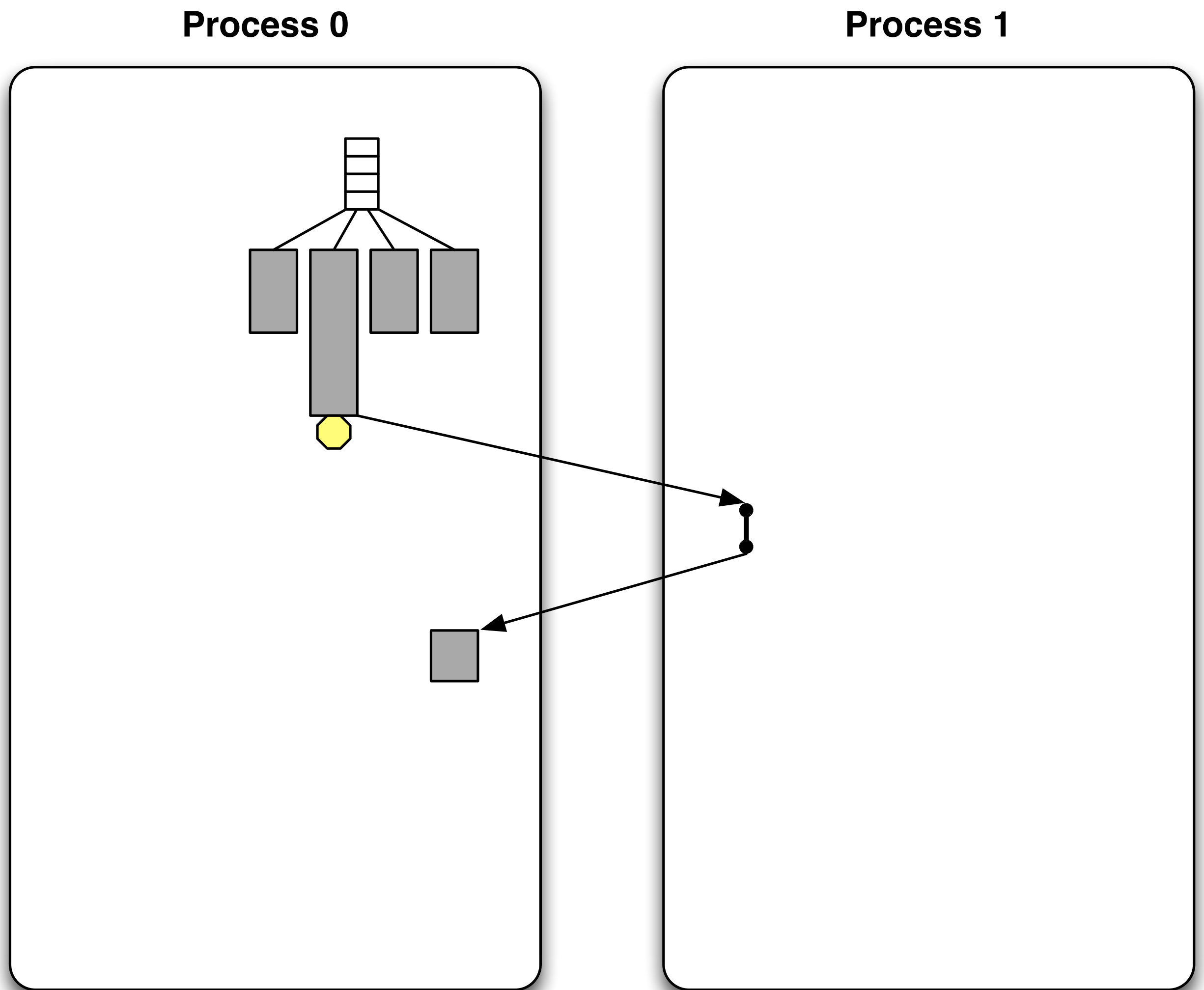


Progress Engine Start Up



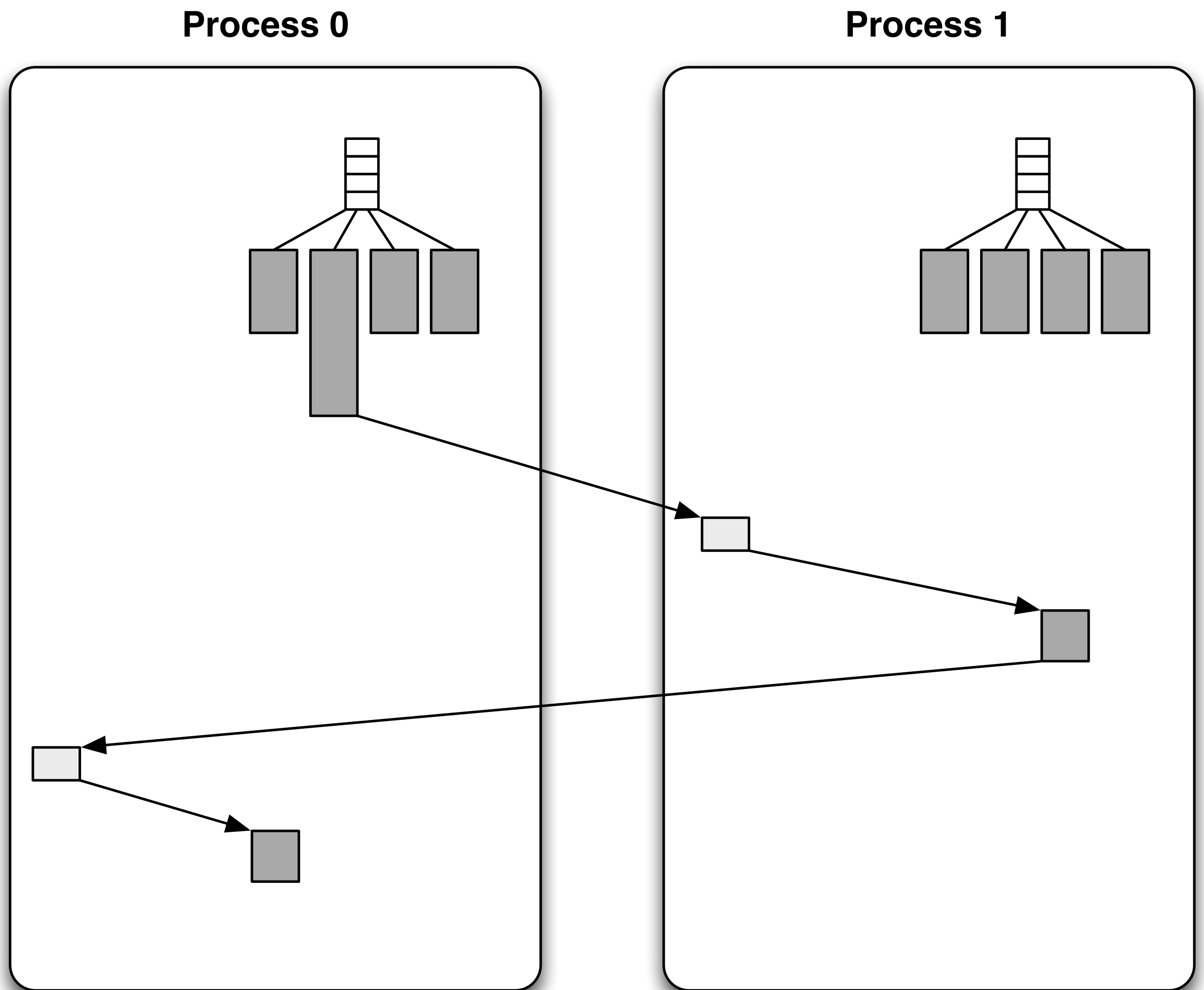
Application initialization





Data Movement in the SPR

- Blocking and non-blocking put and get operations
- Calling task suspends, only resumes after completion event
- Progress engine only responsible for FEB operation



Work Migration in the SPR

- Added qthread_fork_remote(..., rank)
- Remote synchronization managed through FEB semantics
- Messaging using memory pooling

Chapel with a Unified Runtime

- Replaced Qthreads & GASNet with SPR (Qthreads + Portals4)
  - Single point for initializing both platforms: spr_init(SPMD,...)
  - spr_unify() used to transition to single thread of control before application starts
  - Most other interface functions are no-ops (e.g., chpl_task_init(), chpl_comm_post_task_init(), chpl_comm_rollcall(), ...)
  - Direct mappings for data movement and work migration

Chapel with a Unified Runtime

- Both layers now share ...
  - Platform information discovery (to make room for progress engine)
  - Memory management (for activation records, stacks, network packets)
  - Synchronization mechanisms (such as full-empty support)

Chapel with a Unified Runtime

- But just an early **point design**
  - Could have been MPI, MassiveThreads, SHMEM, etc.
  - Could replace progress engine with prioritized tasks
  - Could have optimized for particular hardware
  - Could have ...

Opportunities Moving Forward

- Let third-party implementers worry about
  - Information management (for incr. platform complexity)
  - Coordinated resource management (1 PE today, ? tomorrow)
  - Integrated local and remote task management (beyond command +payload, optimized for new hardware, task/message aggregation)

- Consider that the runtime options are plentiful and just as independent as the application space

Opportunities Moving Forward

- Reorient Chapel Runtime Support shim interface around unified “locality engine” (CHPL_LE=?)
  - Resist early (de facto) standardization
  - Focus on telling runtime what is needed/expected (declarative not imperative)
  - Open up runtime ecosystem to the increasing assortment of unified runtimes (one size won’t fit all)
  - Add coarse-grain “Chapelle” interface (multi-resolution runtime layers?)

- Start a runtime-centric working group to coordinate efforts between compiler writers and RS implementers