Welcome to the 2017 Charm++ Workshop!

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A bit of history

- This is the 15th workshop in a series that began in 2001


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A Reflection on the History

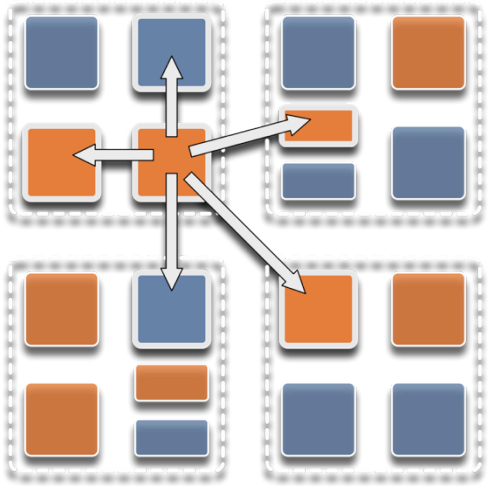
- Charm++, the name, is from 1993
- Most of the foundational concepts : by 2002
- So, what does this long period of 15 years signify?
- Maybe I was too slow
- But I prefer the interpretation:
  - We have been enhancing and adding features based on large-scale application development.
    - A long co-design cycle
  - The research agenda opened up by the foundational concepts is vast
  - Although the foundations were done in 2002, the fleshing out of adaptive runtime capabilities is where many intellectual challenges, and engineering work, lay.

What is Charm++?

- Charm++ is a generalized approach to writing parallel programs
  - An alternative to the likes of MPI, UPC, GA etc.
  - But not to sequential languages such as C, C++, Fortran
- Represents:
  - The style of writing parallel programs
  - The runtime system
  - And the entire ecosystem that surrounds it
- Three design principles:
  - Overdecomposition, Migratability, Asynchrony

Overdecomposition

- Decompose the work units & data units into many more pieces than execution units
  - Cores/Nodes/..
- Not so hard: we do decomposition anyway



Migratability

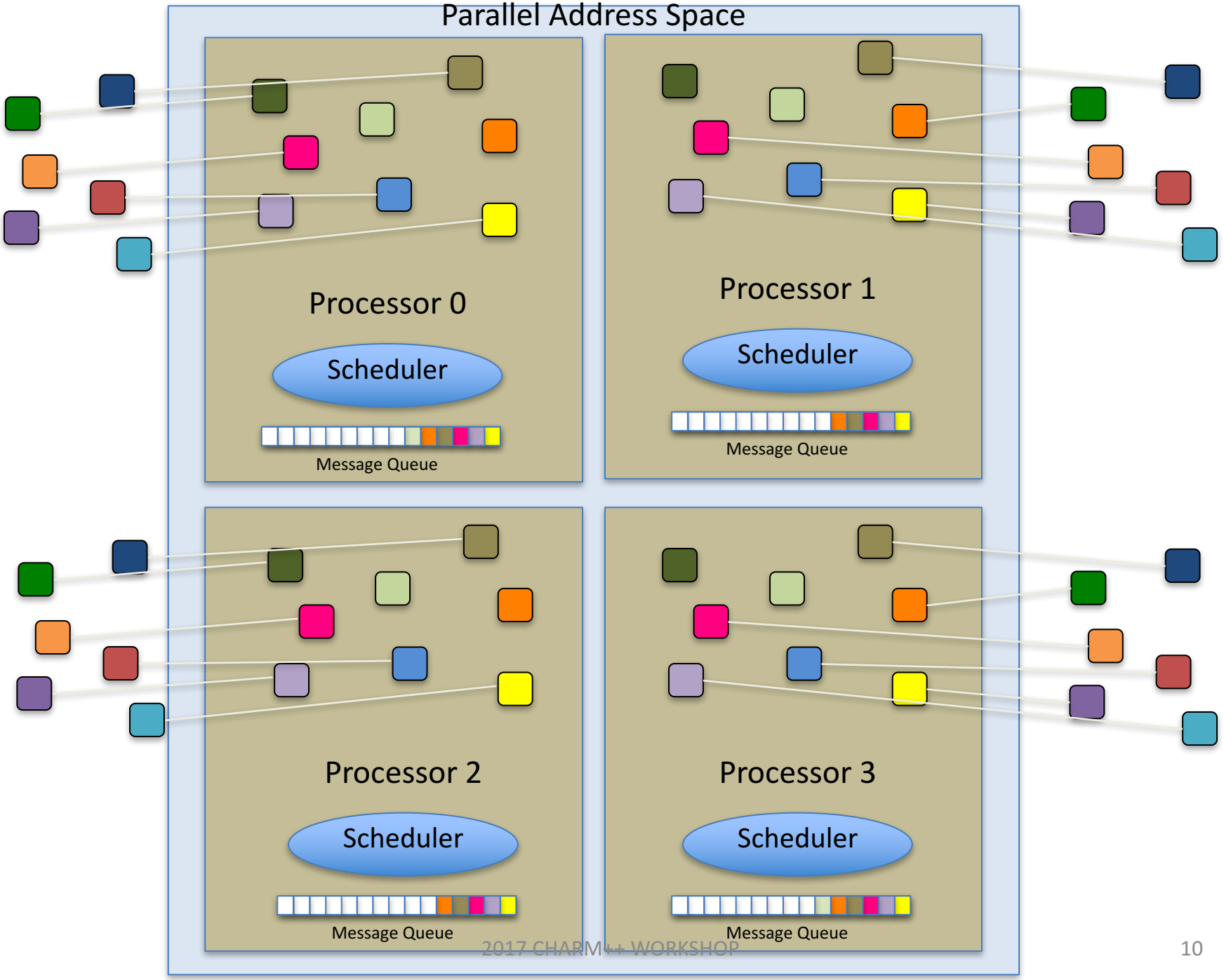
- Allow these work and data units to be migratable at runtime
  - i.e. the programmer or runtime, can move them
- Consequences for the app-developer
  - Communication must now be addressed to logical units with global names, not to physical processors
  - But this is a good thing
- Consequences for RTS
  - Must keep track of where each unit is
  - Naming and location management

Asynchrony: Message-Driven Execution

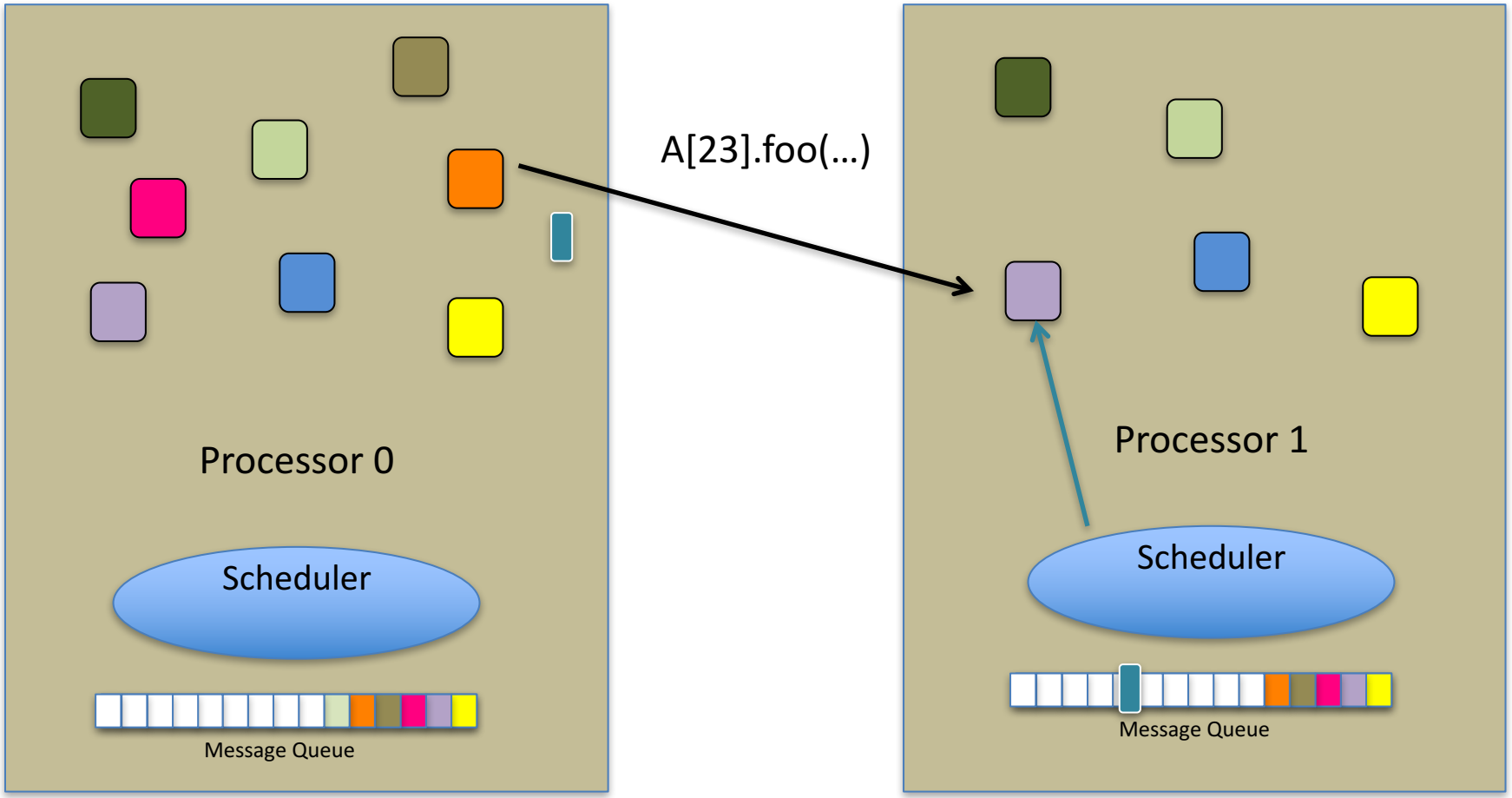
- With over decomposition and Migratibility:
  - You have multiple units on each processor
  - They address each other via logical names
- Need for scheduling:
  - What sequence should the work units execute in?
  - One answer: let the programmer sequence them
    - Seen in current codes, e.g. some AMR frameworks
  - Message-driven execution:
    - Let the work-unit that happens to have data ("message") available for it execute next
    - Let the RTS select among ready work units
    - Programmer should not specify what executes next, but can influence it via priorities

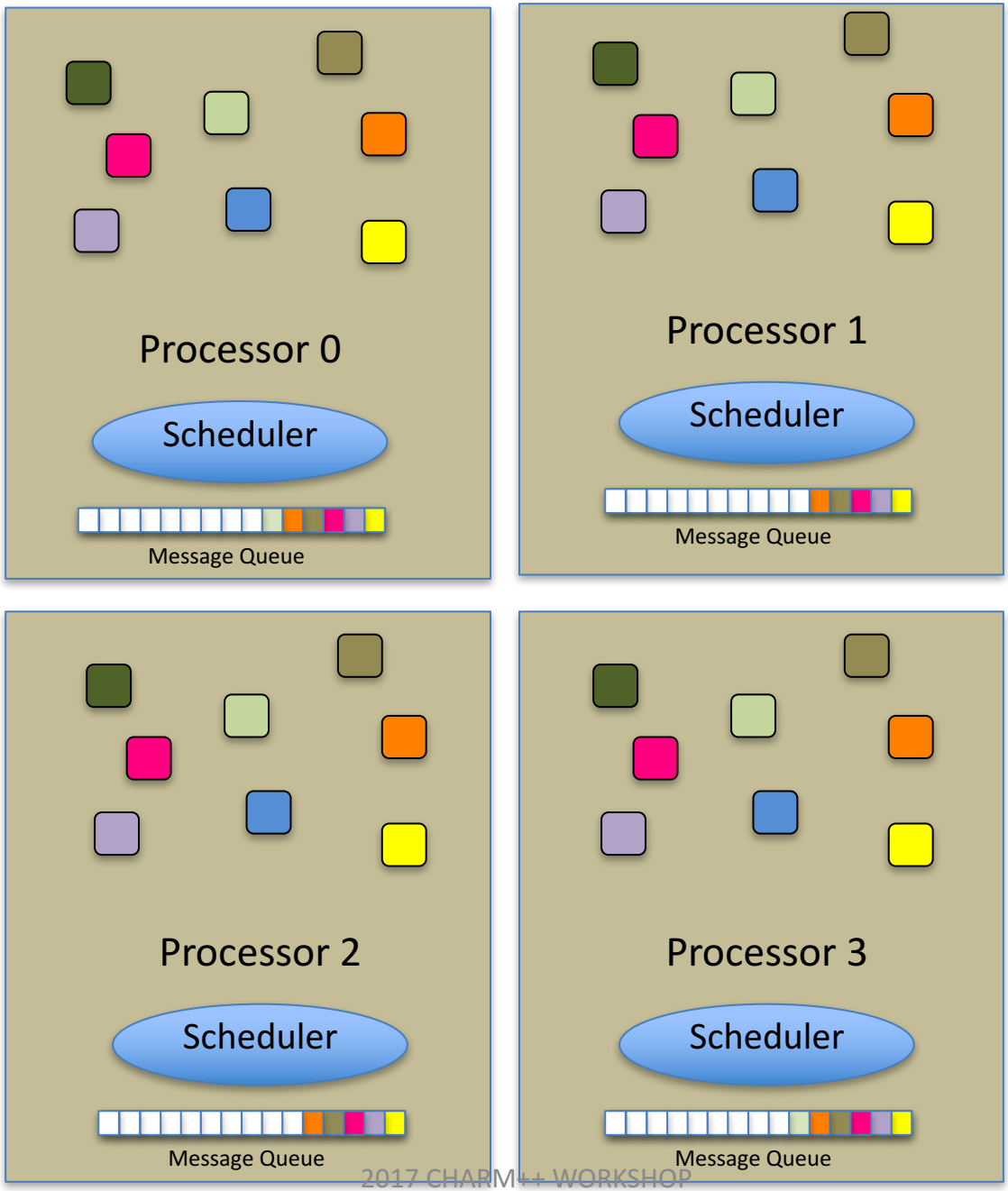
Realization of this model in Charm++

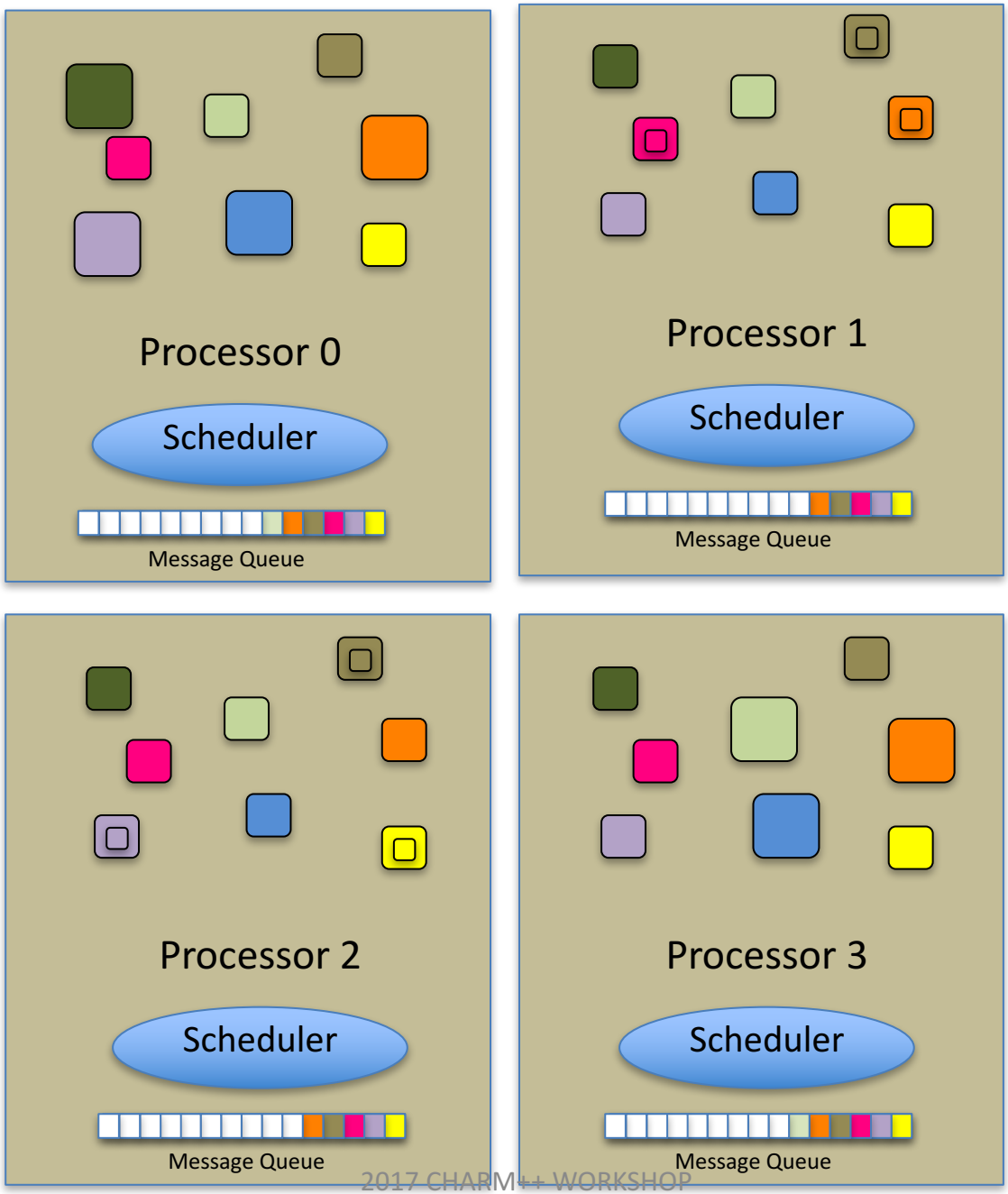
- Overdecomposed entities: chares
  - Chares are C++ objects
  - With methods designated as “entry” methods
    - Which can be invoked asynchronously by remote chares
  - Chares are organized into indexed collections
    - Each collection may have its own indexing scheme
      - 1D, ..7D
      - Sparse
      - Bitvector or string as an index
  - Chares communicate via asynchronous method invocations
    - A[i].foo(….); A is the name of a collection, i is the index of the particular chare.


Parallel Address Space
Processor 0
Scheduler
Message Queue
Processor 1
Scheduler
Message Queue
Processor 2
Scheduler
Message Queue
Processor 3
Scheduler
Message Queue

Message-driven Execution




Processor 0
Scheduler
Message Queue
Processor 1
Scheduler
Message Queue
Processor 2
Scheduler
Message Queue
Processor 3
Scheduler
Message Queue


Processor 0
Scheduler
Message Queue
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Message Queue
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Message Queue
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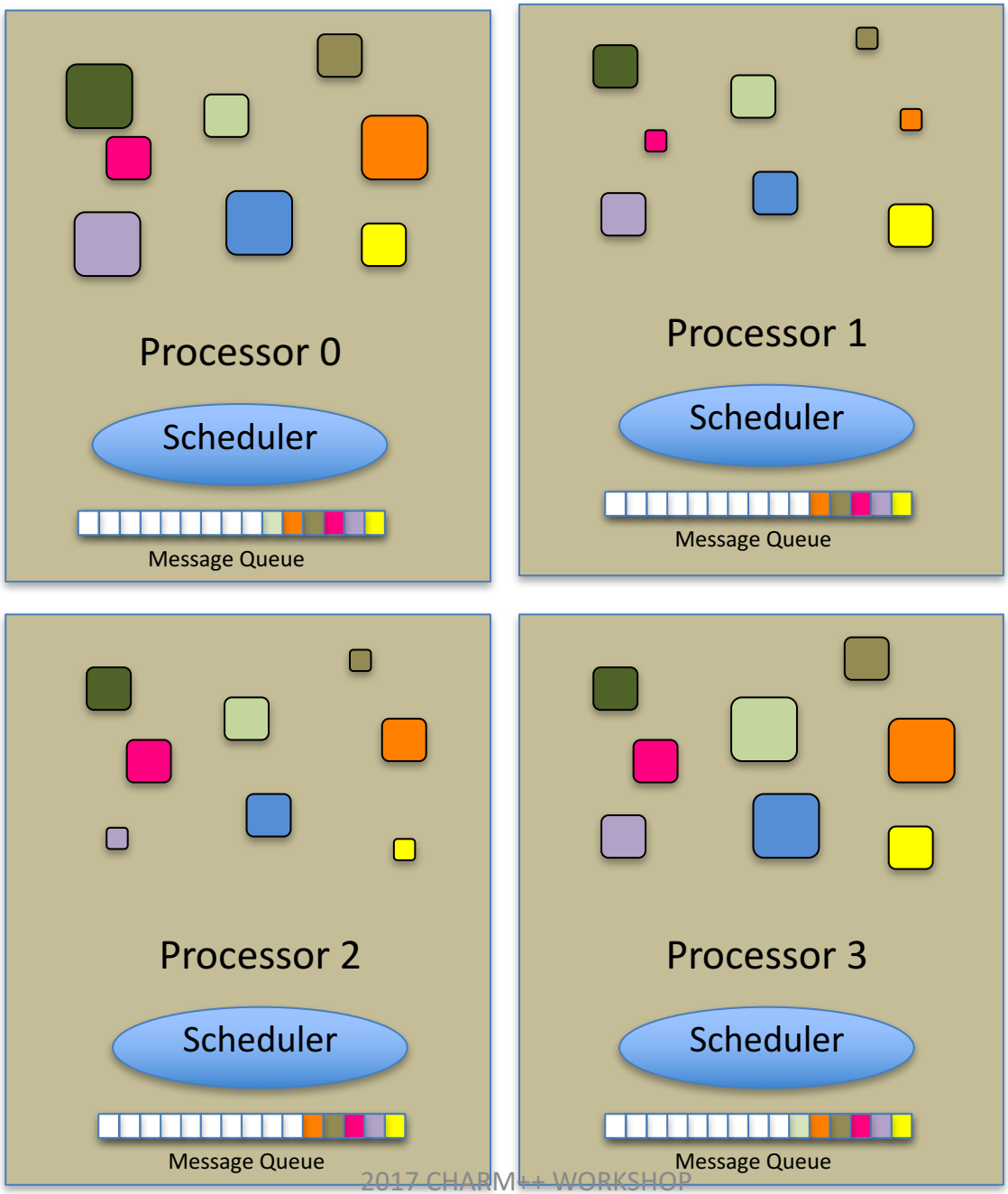
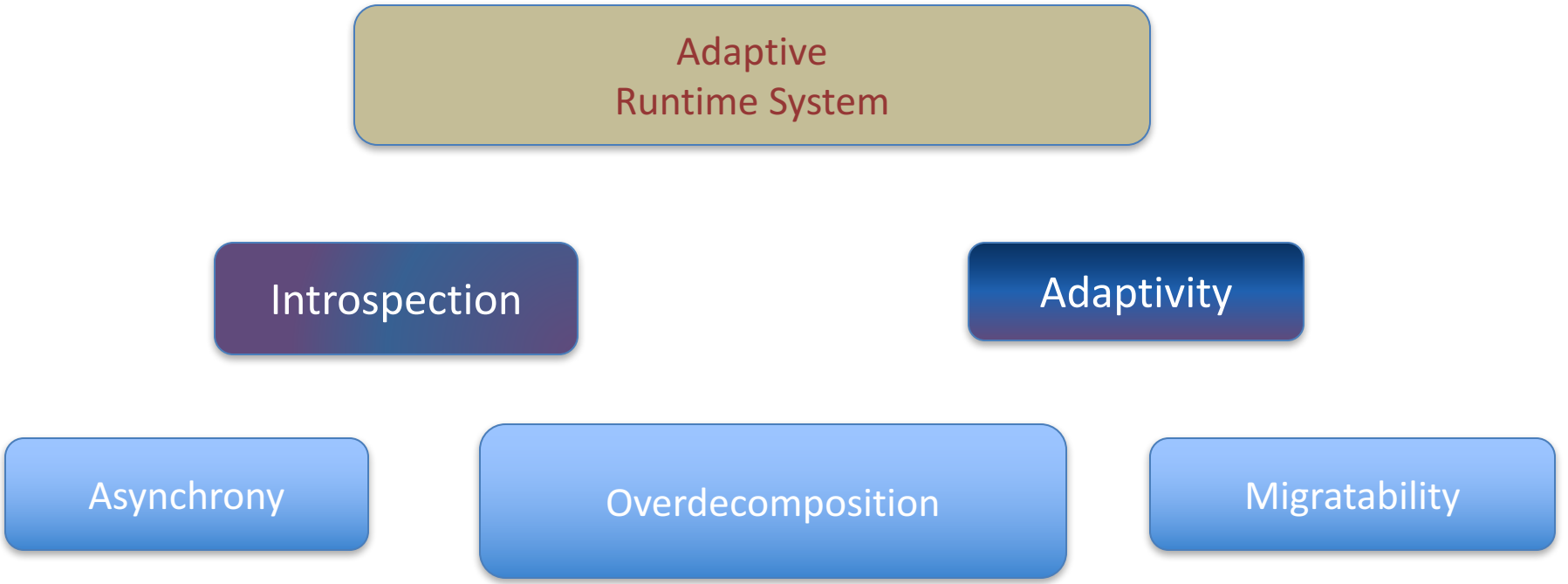
Scheduler
Message Queue


Processor 0
Scheduler
Message Queue
Processor 1
Scheduler
Message Queue
Processor 2
Scheduler
Message Queue
Processor 3
Scheduler
Message Queue

Empowering the RTS



- The Adaptive RTS can:
  - Dynamically balance loads
  - Optimize communication:
    - Spread over time, async collectives
  - Automatic latency tolerance
  - Prefetch data with almost perfect predictability

PPL UIUC

Some Production Applications

Application	Domain	Previous parallelization	Scale
NAMD	Classical MD	PVM	500k
ChaNGa	N-body gravity & SPH	MPI	500k
EpiSimdemics	Agent-based epidemiology	MPI	500k
OpenAtom	Electronic Structure	MPI	128k
Spectre	Relativistic MHD		100k
FreeON/SpAMM	Quantum Chemistry	OpenMP	50k
Enzo-P/Cello	Astrophysics/Cosmology	MPI	32k
ROSS	PDES	MPI	16k
SDG	Elastodynamic fracture		10k
ADHydro	Systems Hydrology		1000
Disney ClothSim	Textile & rigid body dynamics	TBB	768
Particle Tracking	Velocimetry reconstruction		512
JetAlloc	Stochastic MIP optimization		480

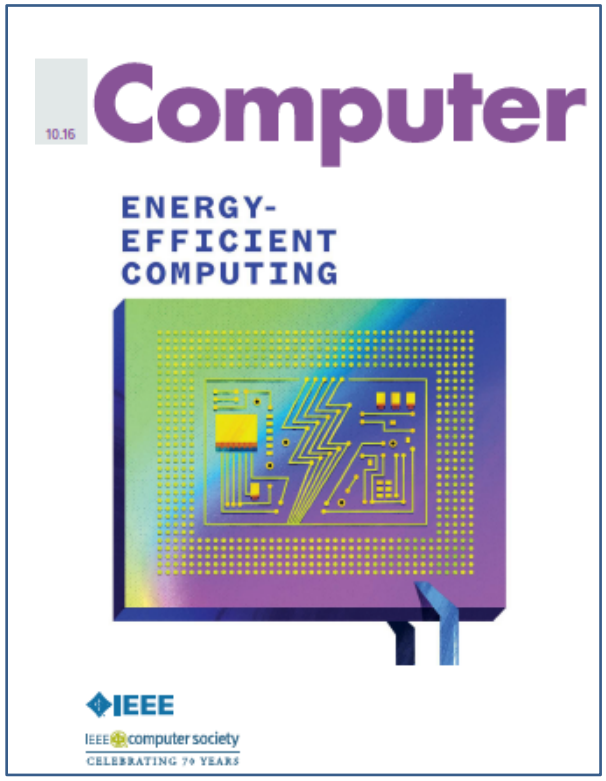
Relevance to Exascale

Intelligent, introspective, Adaptive Runtime Systems, developed for handling application's dynamic variability, already have features that can deal with challenges posed by exascale hardware

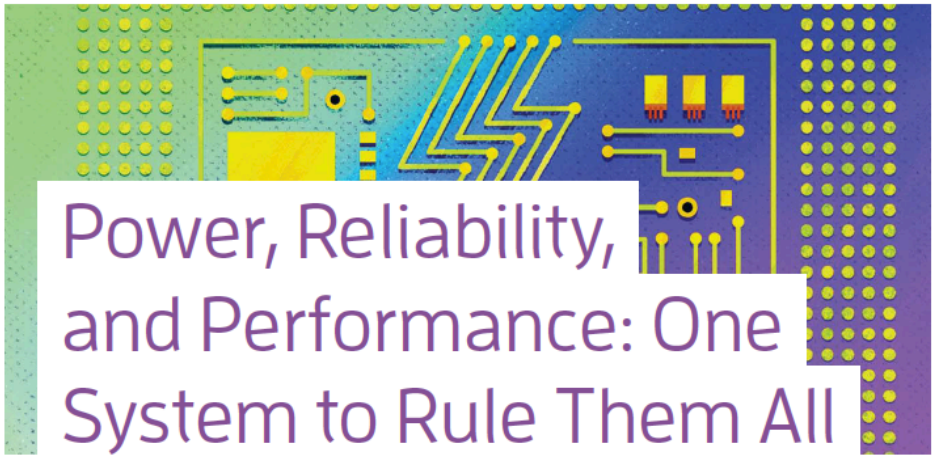
Relevant capabilities for Exascale

- Load balancing
- Data-driven execution in support of task-based models
- Resilience
  - multiple approaches: in-memory checkpoint, leveraging NVM, message-logging for low MTBF
  - all leveraging object-based overdecomposition
- Power/Thermal optimizations
- Shrink/Expand sets of processors allocated during execution
- Adaptivity-aware resource management for whole-machine optimizations

IEEE Computer highlights Charm++ energy efficient runtime



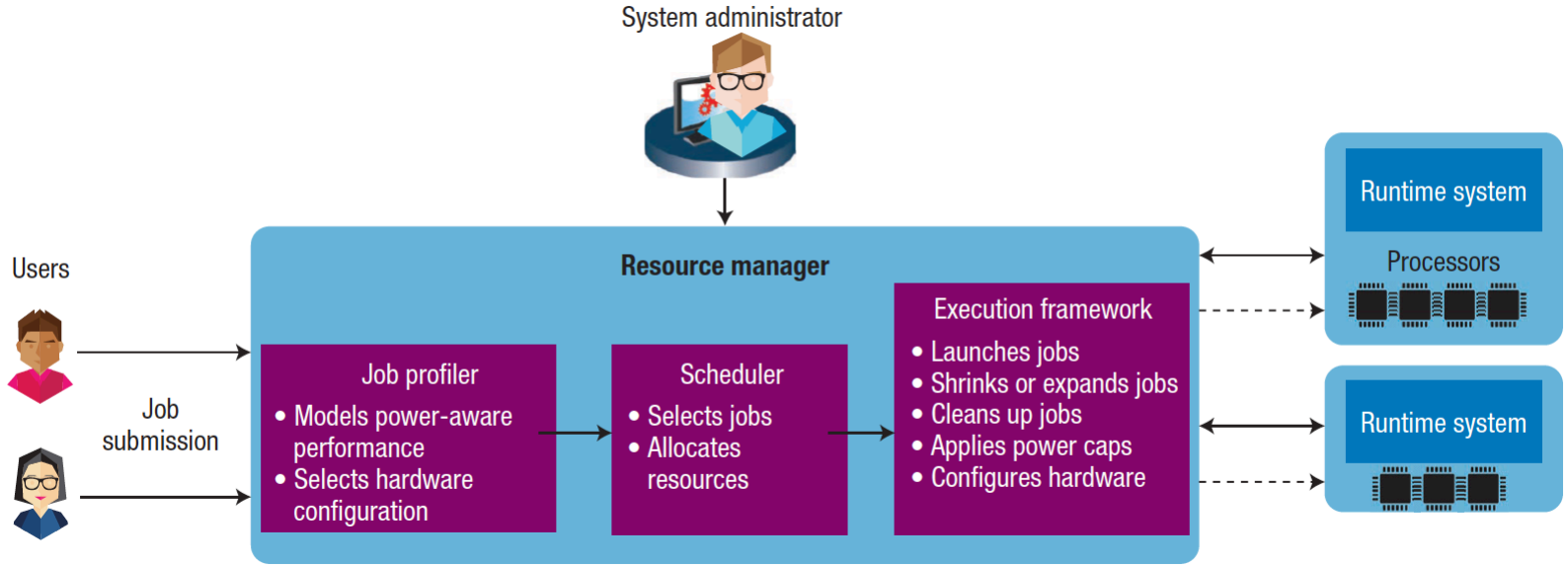
COVER FEATURE **ENERGY-EFFICIENT COMPUTING**



Power, Reliability, and Performance: One System to Rule Them All

Bilge Acun, University of Illinois at Urbana–Champaign
Akhil Langer, Intel
Esteban Meneses, Costa Rica Institute of Technology and Costa Rica National High Technology Center
Harshitha Menon, University of Illinois at Urbana–Champaign
Osman Sarood, Yelp
Ehsan Totoni, Intel Labs
Laxmikant V. Kalé, University of Illinois at Urbana–Champaign

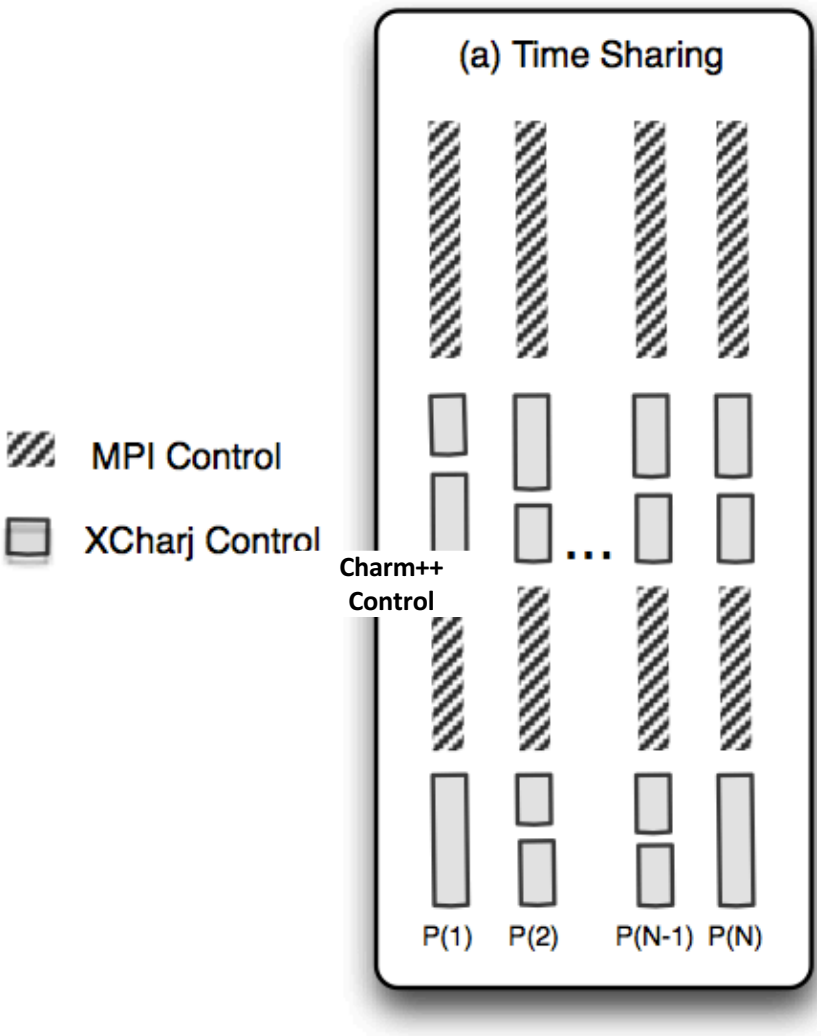
Interaction Between the Runtime System and the Resource Manager



- ✓ Allows dynamic interaction between the system resource manager or scheduler and the job runtime system
- ✓ Meets system-level constraints such as power caps and hardware configurations
- ✓ Achieves the objectives of both datacenter users and system administrators

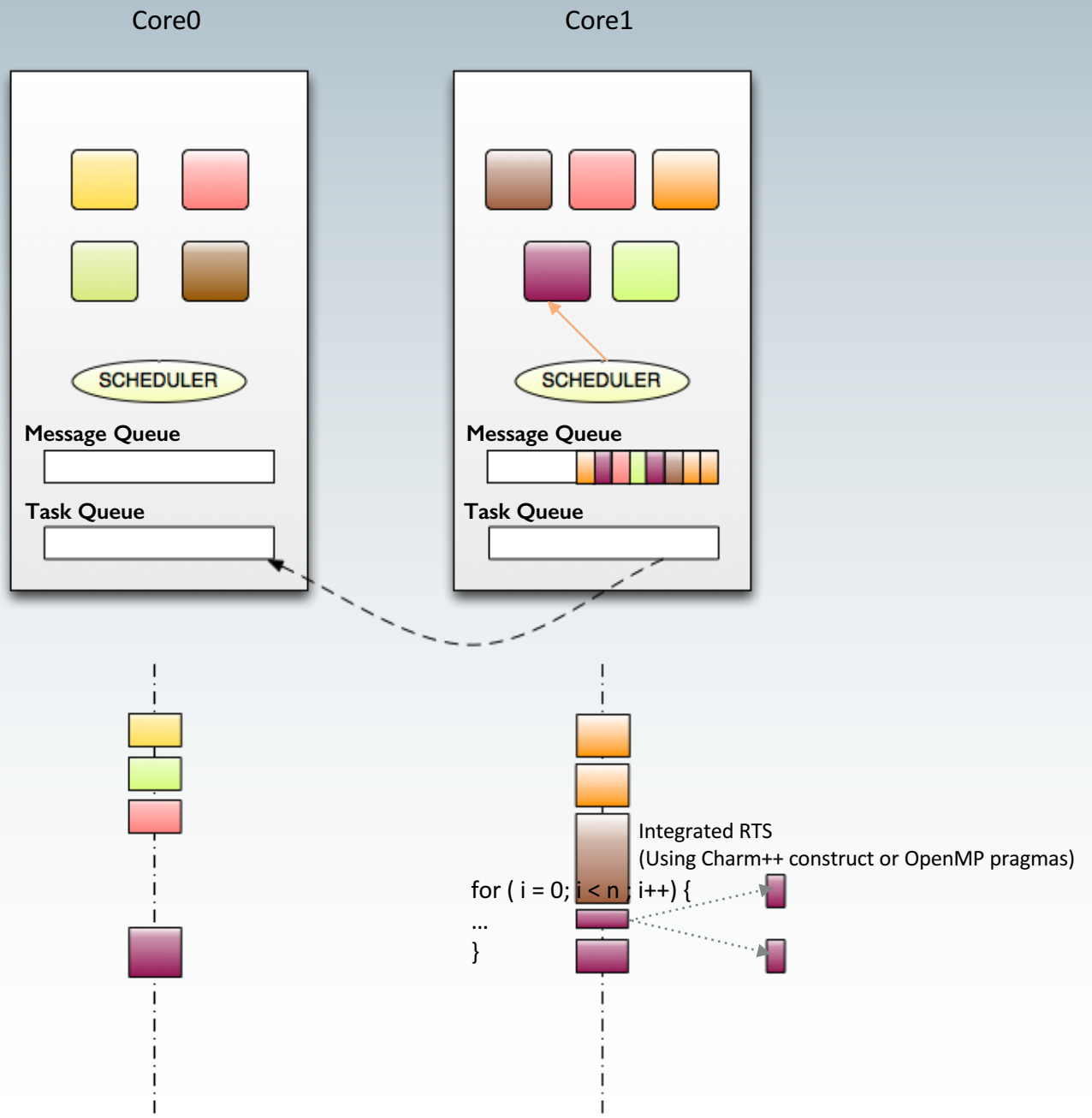
Charm++ interoperates with MPI

So, you can write one module in Charm++, while keeping the rest in MPI



Integration of Loop Parallelism

- Used for transient load balancing within a node
- Mechanisms:
  - Charm++'s old CkLoop construct
  - New integration with OpenMP (gomp, and now llvm)
  - BSC's OMPSS integration is orthogonal
  - Other new OpenMP schedulers
- RTS splits a loop into Charm++ messages
  - Pushed into each local work stealing queue
    - where idle threads within the same node can steal tasks


Core0
Core1
SCHEDULER
Message Queue
Task Queue
SCHEDULER
Message Queue
Task Queue
Integrated RTS
(Using Charm++ construct or OpenMP pragmas)
for (i = 0; i < n ; i++) {
...
}

Recent Developments: Charmworks, Inc.

- Charm++ is now a commercially supported system
  - Charmworks, Inc.
  - Supported by DoE SBIR and small set of initial customers
- Non profit use (academia, US Govt. Labs..) remains free
- We are bringing improvements made by Charmworks into the University version (no forking of code so far)
- Specific improvements have included:
  - Better handling of errors
  - Robustness and ease of use improvements
  - Production versions of research capabilities
- A new project at Charmworks for support and improvements to Adaptive MPI (AMPI)

Upcoming Challenges and Opportunities

- Fatter nodes
- Improved global load balancing support in presence of GPGPUs
- Complex memory hierarchies (e.g. HBM)
  - I think we are well-equipped for that, with prefetch
- Fine-grained messaging and lots of tiny chares:
  - Graph algorithms, some solvers, DES, ..
- Subscale-simulations, multiple simulations
- In-situ analytics
- Funding!

A glance at the Workshop

- Keynotes: Michael Norman, Rajeev Thakur
- PPL taks:
  - Capabilities: load balancing*, heterogenity, DES
  - Algorithms: sorting, connected components
- Languages: DARMA, Green-Marl, HPX (non-charm)
- Applications:
  - NAMD, ChaNGA, OpenAtom, multi-level summation
  - TaBaSCo (LANL, proxy app),
  - Quinoa (LANL, Adaptive CFD)
  - SpECTRE (Relativistic Astrophysics)
- **Panel:** relevance of exascale to mid-range HPC