Network Contention Aware HPC job scheduling with Workload Precognition

Xu Yang[*#], John Jenkins[+], Misbah Mubarak[+], Robert Ross[+] , Zhiling Lan[*]

*Illinois Institute of Technology, Chicago, IL, USA

+Argonne National Laboratory, Argonne, IL, USA

xyang56@hawk.iit.edu

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Background

- Scale of supercomputers increases

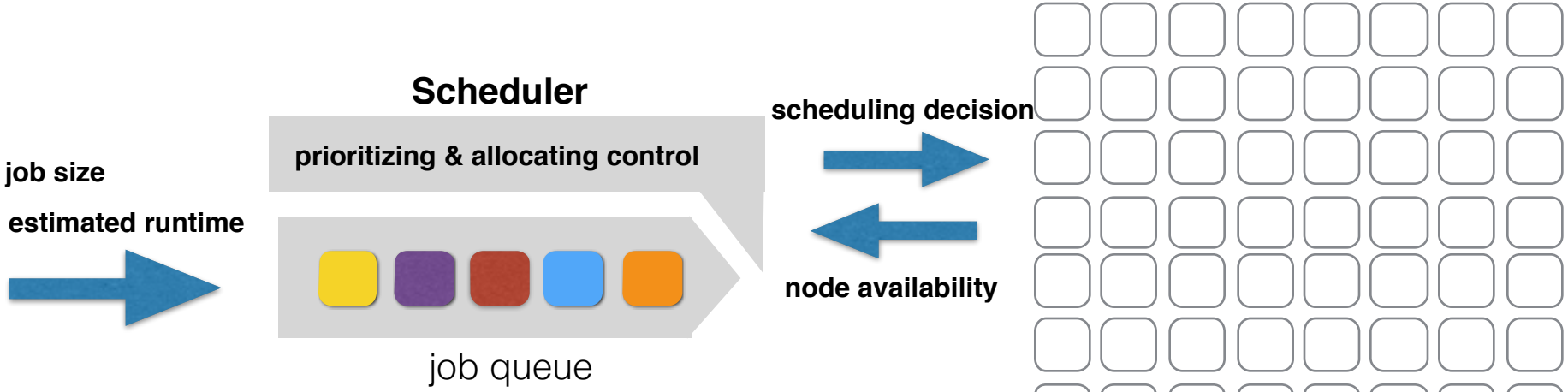
	NO. of Nodes (core/node)	CPU Type (Clock Speed GHz)	Peak Tflop/s (Gflop/s/core)	Network Topology	Link bw (GB/s)	Injection (GB/s)
Intrepid (2007)	40960 (04)	PowerPC450 (0.85)	557 (3.5)	3D torus	0.425	2.55
Mira (2012)	49152 (16)	PowerPC A2 (1.6)	10066 (12.8)	5D torus	2.000	20.00

- Concurrently running applications

1. Network Contention
   - allocation shape
   - communication pattern
2. Performance variability (up to 70%)

Background

Traditional batch scheduler



- Scheduling Policies
  1. FCFS—first come first serve
  2. STF—shortest runtime first
  3. FCFS/ Easy backfilling
  4. others based on different priorities

All these policies are priorities based. Priorities could be arrival time, runtime, size, user, etc

Background

Two types of allocation schemes on Torus system:

1. Non-contiguous (Cray XT)
   - no fragmentation
   - inter-process communication less efficient
   - network contention

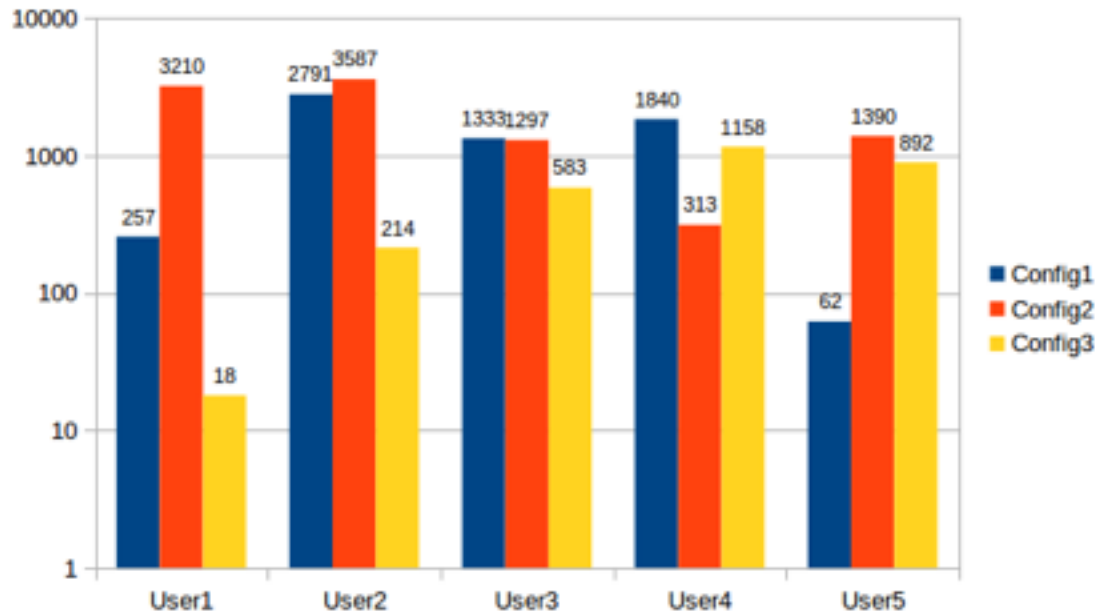
2. Partition based scheduling system(IBM BlueGene/P, Q)
   - preserve locality
   - reduce network contention
   - fragmentation and low network utilization

Both have limited knowledge about Job and System:

- job information, such as arrival time, expected runtime, size
- system information, such as network topology, node availability

Observation

- Job Communication Pattern
  1. Nearest Neighbor
  2. P2P
  3. All to All
  4. Collectives



- Repetitive Workload
  1. stable user group
  2. limited application sets

The repetitive job submissions on Mira in 2014 (March-September). The percentage of repetitive submissions from certain user can be as much as 90%.

Motivation

- Compact allocation is not necessary for every application, depends on their communication pattern
- Job Scheduler should take jobs' communication information for making scheduling decisions
  1. preferable allocation shape
  2. better task mapping
- Quantified analysis is needed for
  1. bandwidth requirement for job with specific communication pattern
  2. network contention between concurrently running jobs
  3. performance loss, i.e. extended job run time, lower system throughput

This is where CODES come to rescue!

CODES Job Allocation

- Things that CODES extension capable of
  1. Concurrently running jobs with given network topology
  2. Locate network contention
  3. Performance variability analysis
- Workload
  - DOE full apps and associate min-apps

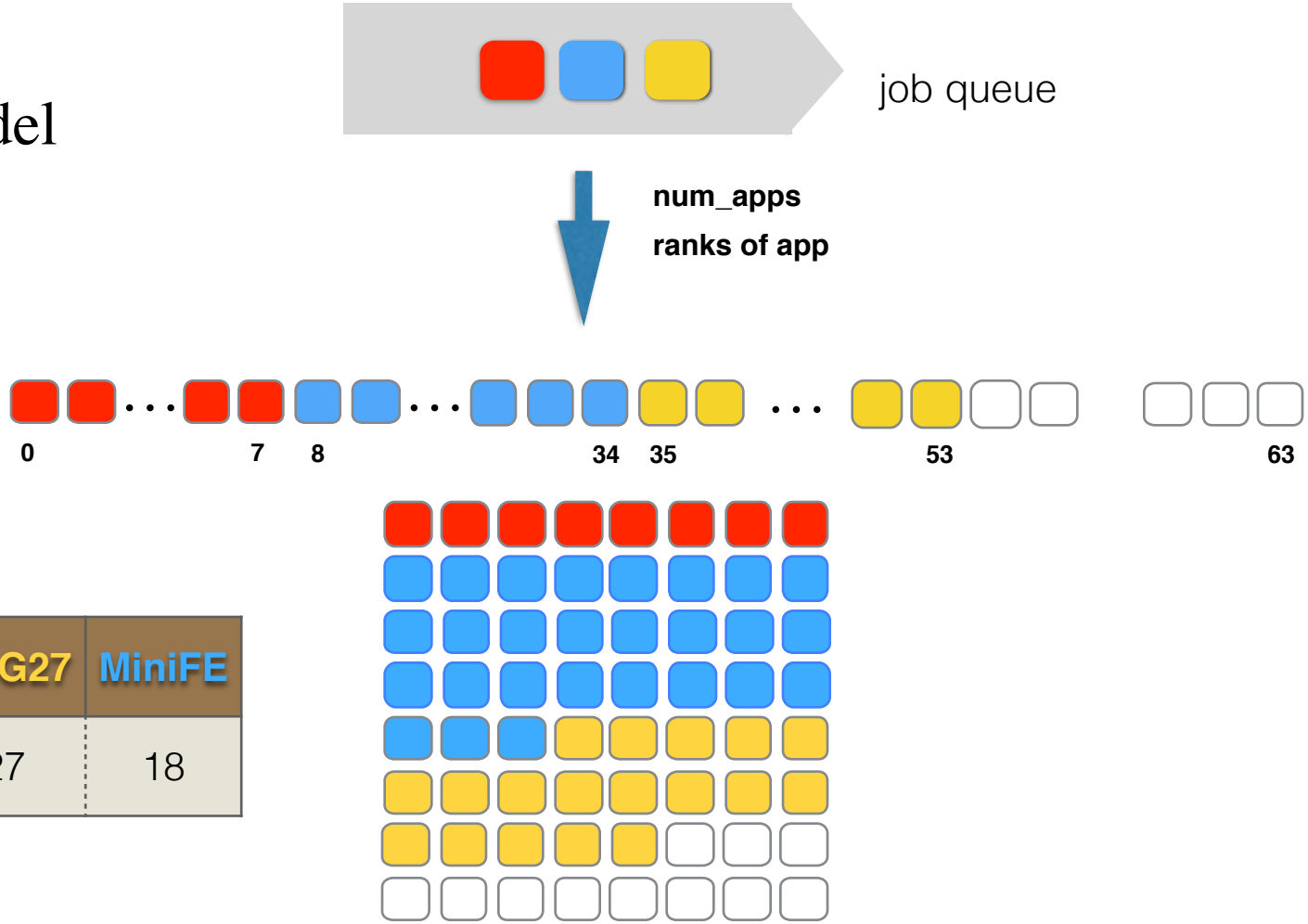
http://portal.nersc.gov/project/CAL/designforward.htm

- Selected Apps
  1. AMG
  2. MiniFE
  3. Crystal Router

CODES Job Allocation

- Network Model

  2D torus



	AMG8	AMG27	MiniFE
NO. of ranks	8	27	18

CODES Job Allocation

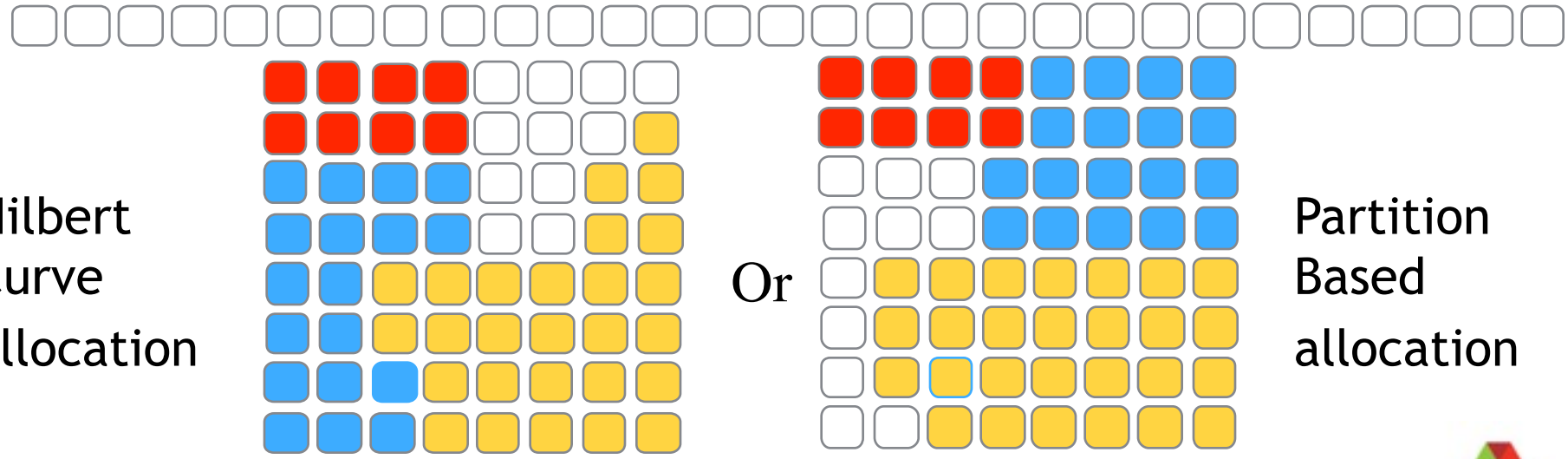
job queue

num_apps
ranks of app

Mapping API

network topology
node availability

mapping decision



Hilbert Curve allocation

Or

Partition Based allocation

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Communication Pattern V.S Alloc Shape

- All to All

  compact allocation with most bandwidth resource

- Nearest Neighbor

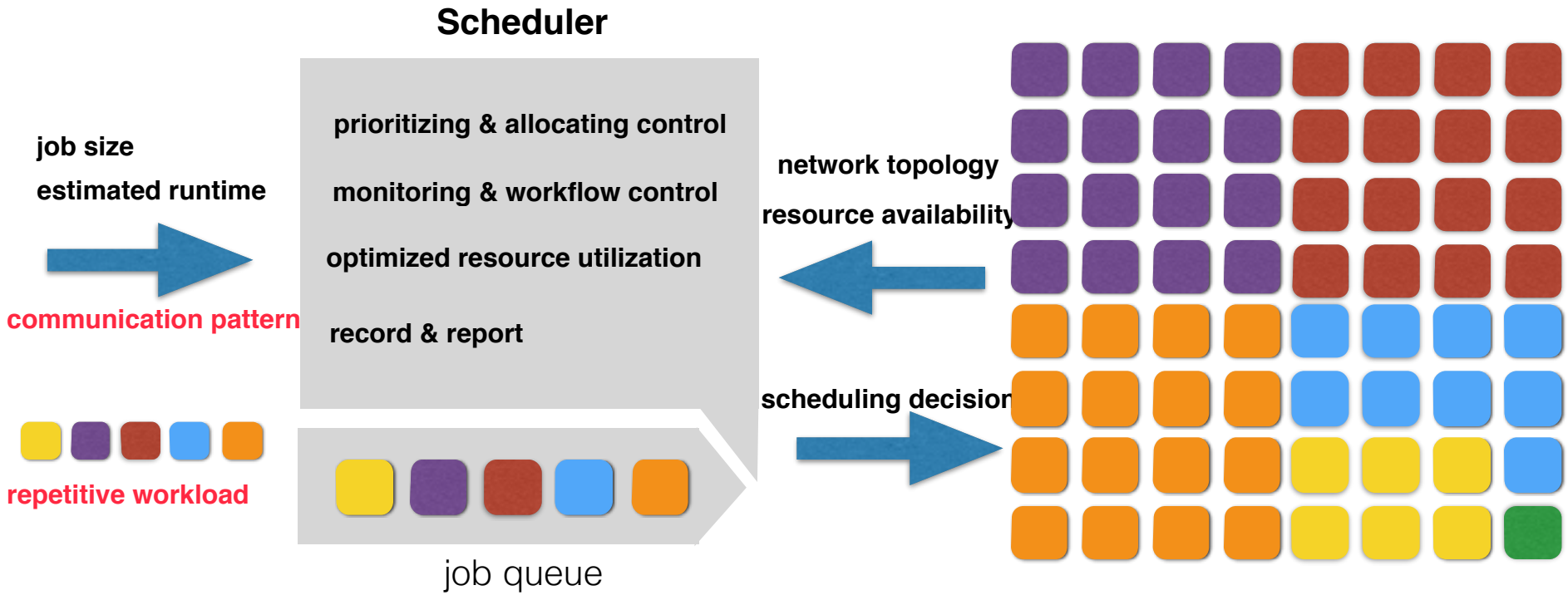
  if no compact allocation available, contiguous allocation will be adequate

- P2P and Collectives

  without heavy communication, can be flexible

Job with different communication patterns should get different allocation shapes

New Scheduler Design



Future Work

- Provide more mapping strategies with different network topologies
- Explore the characteristics of different workloads
- Collective traces from other representative HPC applications