MATRIX:DJLSYS

EXPLORING RESOURCE ALLOCATION TECHNIQUES FOR DISTRIBUTED JOB LAUNCH UNDER HIGH SYSTEM UTILIZATION

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  - Resource State Change Callback
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Proposal

- Resource State Change Callback
- Compare and Swap
- Socket Level Thread Safe
- Distributed Monitoring
- Cache and Buffer Management

Introduction

- SLURM++: A distributed job launch prototype for extreme-scale ensemble computing (IPDPS14 submission)

Job Management Systems for Exascale Computing

- Ensemble Computing
- Over-decomposition
- Many-Task Computing
- Jobs/Tasks are finer-grained
- Requirements
  - high availability
  - extreme high throughput (1M tasks/sec)
  - low Latency

Current Job Management Systems

- Batch scheduled HPC workloads
- Lack the support of ensemble workloads
- Centralized Design
  - Poor Scalability
  - Single-point-of-failure
- SLURM maximum throughput of 500 jobs/sec
- Decentralized design is demanded

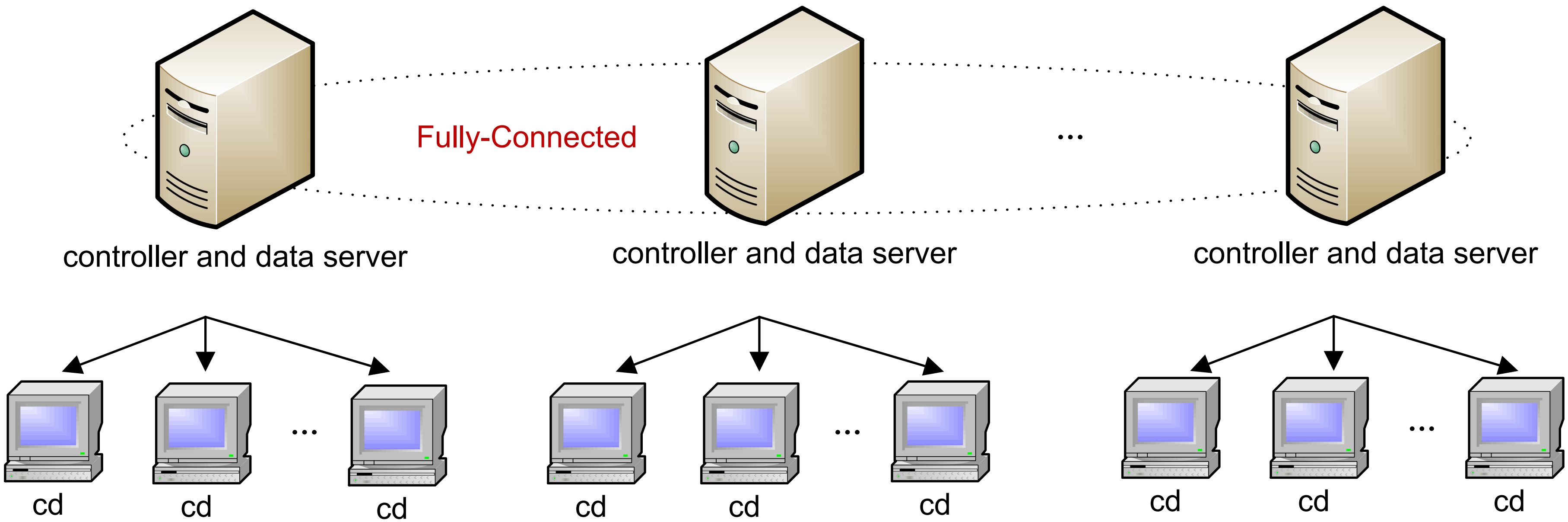
Goal

- Architect, and design job management systems for exascale ensemble computing
- Identifies the challenges and solutions towards supporting job management systems at extreme scales
- Evaluate and compare different design choices at large scale

Contributions

- Proposed a distributed architecture for job management systems, and identified the challenges and solutions towards supporting job management system at extreme-scales
- Designed and developed a novel distributed resource stealing algorithm for efficient HPC job launch
- Designed and implemented a distributed job launch prototype SLURM++ for extreme scales by leveraging SLURM and ZHT
- Evaluated SLURM and SLRUM++ up to 500-nodes with various micro-benchmarks of different job sizes with excellent results up to 10X higher throughput

SLURM Architecture



- Controllers are fully connected
- Ratio and Partition Size are configurable for HPC and MTC
- Data servers are also fully connected

Job and Resource Metadata

Key	Value	Description
controller id	number of free node, free node list	The free (available) nodes in a partition managed by the corresponding controller
job id	original controller id	The original controller that is responsible for a submitted job
job id + original controller id	involved controller list	The controllers that participate in launching a job
job id + original controller id + involved controller id	participated node list	The nodes in a partition that are involved in launching a job

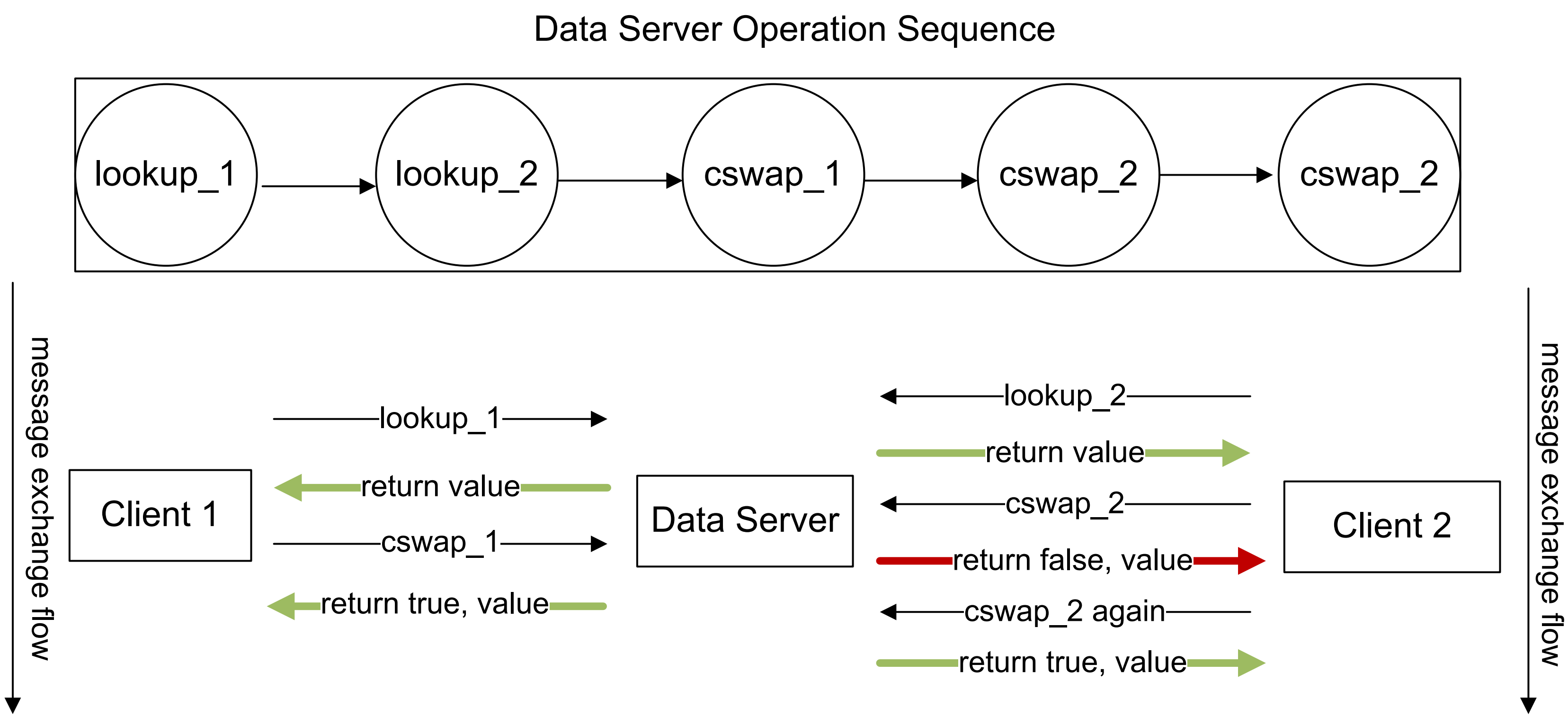
SLURM++ Design and Implementation

- SLURM description
- Light-weight controller as ZHT client
- Job launching as a separate thread
- Implement the resource stealing algorithm
- Developed in C
- 3K lines of code + SLURM 50K lines of code + ZHT 8K lines of code

Compare and Swap

- Use case
  - When different controllers try to allocate the same resources
  - Naive way to solve the problem is to add a global lock for each queried key in the DKVS
  - Atomic compare and swap operation in the DKVS that can tell the controllers whether the resource allocation succeeds
  - SLURM++ uses it to contend nodes resources
- Standard compare-and-swap:
  - *compare_swap(key, seen_val, new_val)*
- Augument standard compare-and-swap
  - *compare_swap(key, seen_val, new_val, queried_val)*
  - queried_val saves one lookup
- Problem!
  - Not atomic: lookup, compare, insert, lookup
  - Need NOVOHT supports atomicity

Compare and Swap



Compare and Swap Workflow

compare_swap API reference

- int c_zht_compare_swap(const char *key, const char *seen_value, const char *new_value, char *value_queried), in C
- int compare_swap(const string &key, const string &seen_val, const string &new_val, string &result)
  - Return 0(zero), if SEEN_VALUE equals to value lookuped by the key, and set the value to NEW_VALUE returned
  - Return non-zero, if the above doesn't meet, and VALUE_QUERIED
  - SEEN_VALUE: value expected to be equal to that lookuped by the key
  - NEW_VALUE: if equal, set value to NEW_VALUE
  - VALUE_QUERIED: if equal or not equal, get new value queried

Resource State Change Callback

- Use case
  - A controller needs to wait on specific state change before moving on
  - Inefficient when client keeps polling from the server
  - The server has a blocking state change callback operation
  - SLURM++ uses it to monitor if job's finished when job's stolen and run by other controller since there are no direct communication between controllers
- Idea: if key's value changed, notify change of client

Resource State Change Callback

- Implementation
  - For every call, launch worker thread in server
  - Block client
  - Notify client when states changed
  - Lease-based approach to deal with states-never-changed
  - User-defined interval to poll states
    - SCCB_POLL_INTERVAL

state_change_callback API reference

- int c_state_change_callback(const char *key, const char *expeded_val, int lease), in C
- int state_change_callback(const string &key, const string &expected_val,int lease), in C++
  - monitor the value change of the key, block or unblock ZHT client
  - EXPECDED_VAL: the value expected to be equal to what is lookuped by the key, if equal, return 0(zero), or keep polling in server-side and block ZHT client
  - LEASE: the lease in milliseconds after which ZHT client will be unblocked.

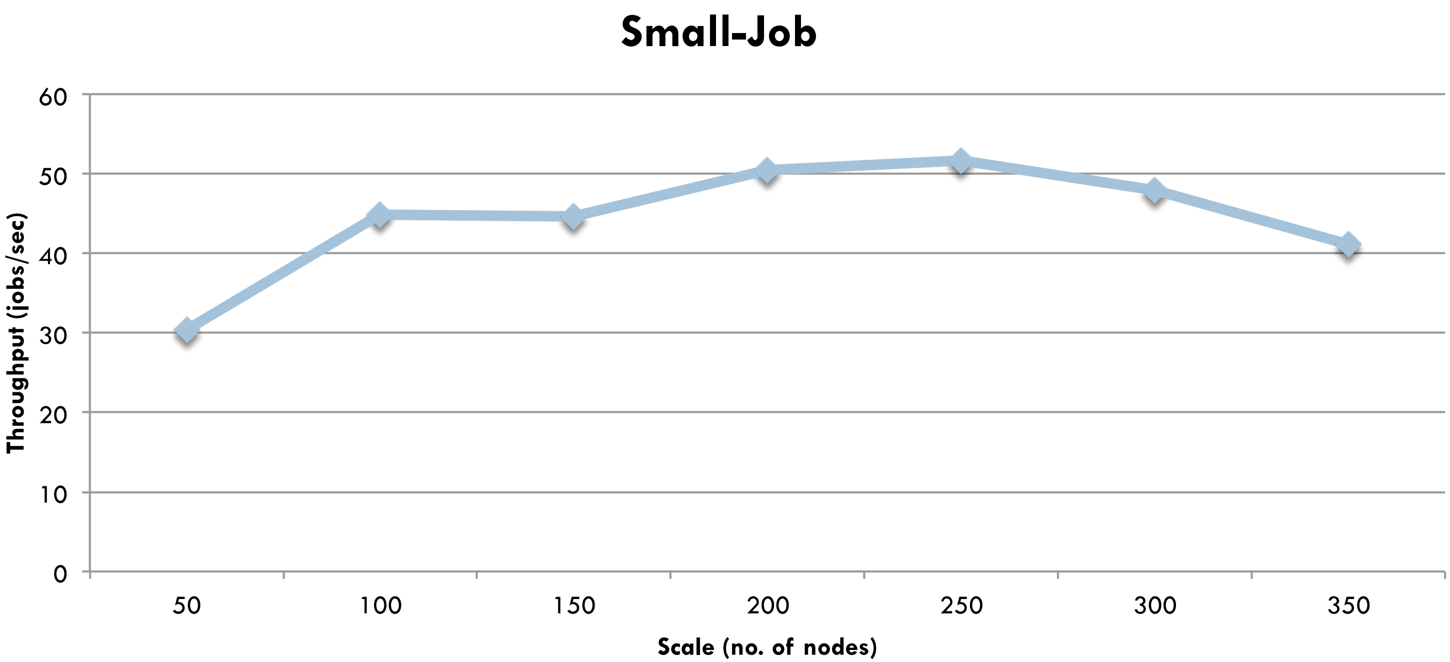
Thread Safe

- Operation Level
  - Insert, lookup, append, remove, compare_swap, state_change_callback, all shared a single mutex
  - Performance killer
- Socket Level
  - Distinct mutex attached to every socket connection
  - Network related concurrency issues come from shared socket over which send/receive overlapped

ZHT Client Lock Exception Safe

- lock_guard class
  - Constructor lock_guard(pthread_mutex_t *mutex) { lock(mutex); }
  - Destructor ~lock_guard() { unlock(mutex); }
  - Even if ZHT client crashed, Destructor will always be called, and release the lock

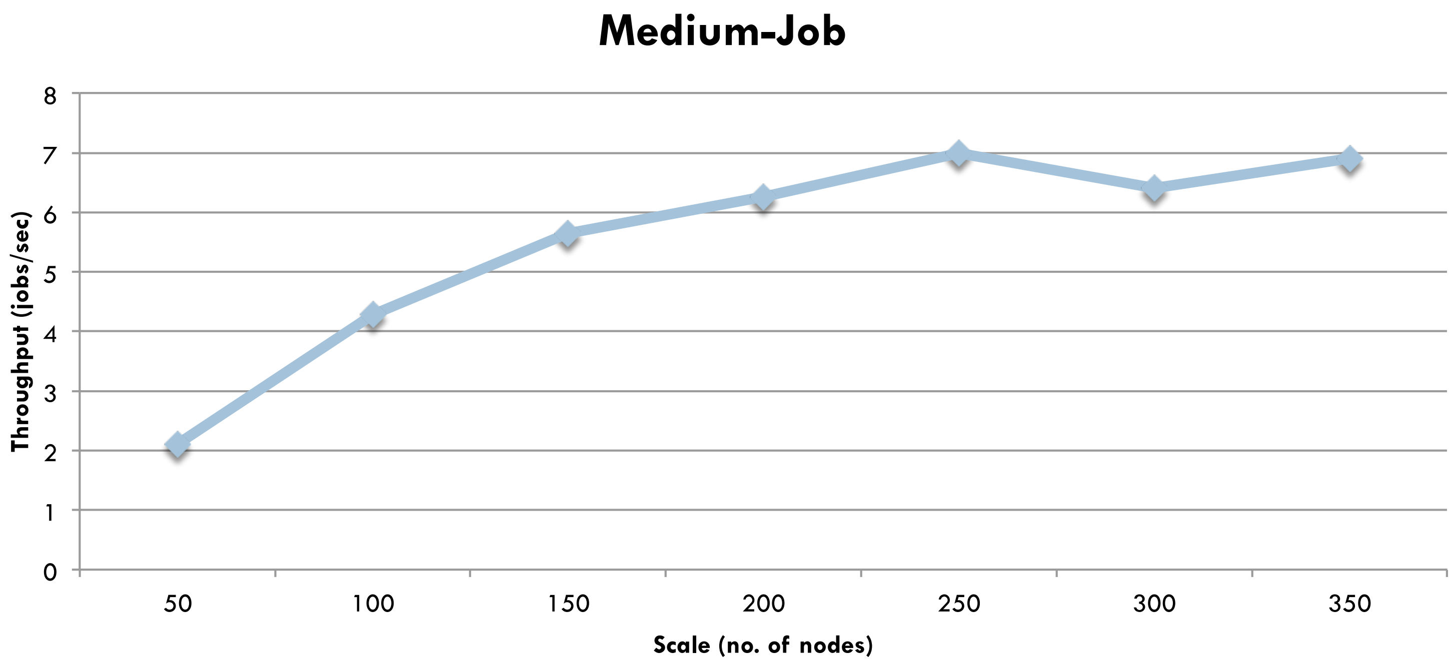
SLURM Baseline Benchmark



Small-Job Workload

- For N nodes, submit N jobs, e.g., 50 jobs submitted for 50 nodes scale
- Each job requiring just 1 node, MTC job
- Each job runs 1 task (sleep 0)

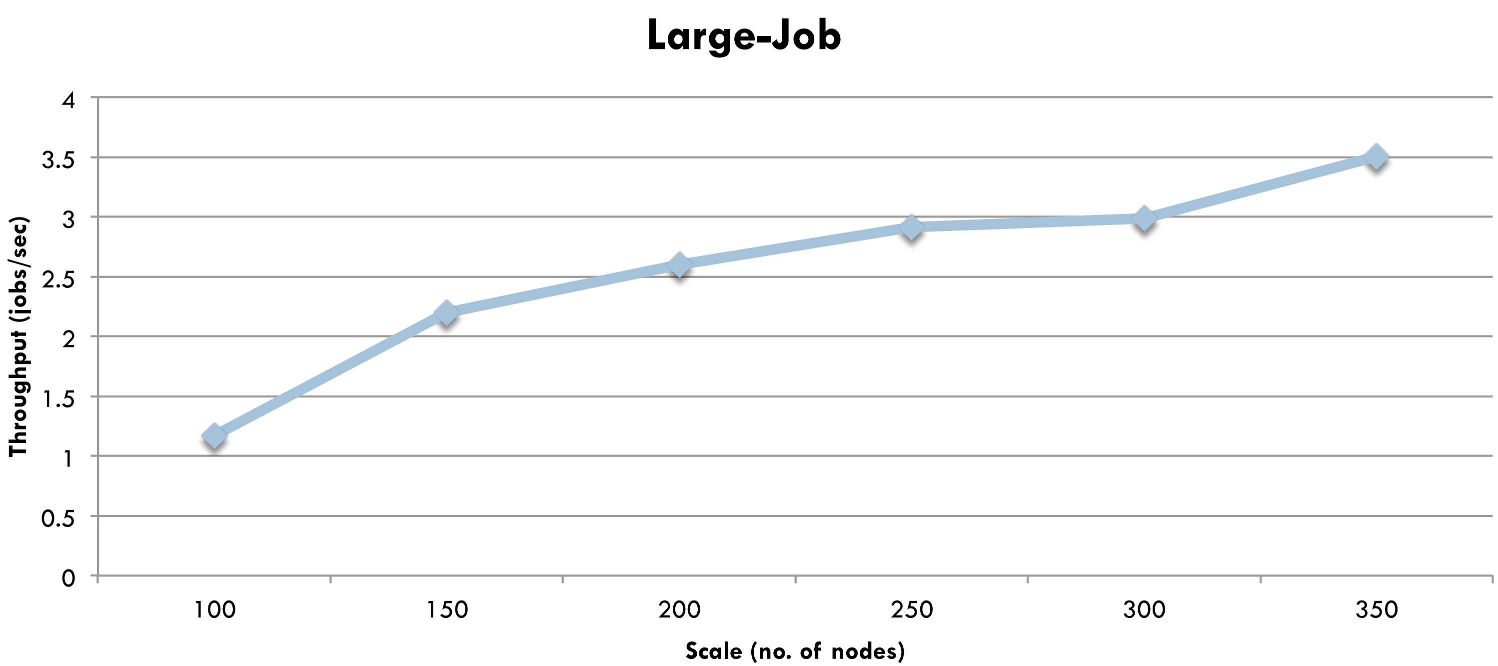
SLURM Baseline Benchmark



Medium-Job Workload

- For N nodes, submit N jobs, e.g., 50 jobs submitted for 50 nodes scale
- Each job requiring a random (1~50) number of nodes, HPC job
- Each job runs 1 task (sleep 0)

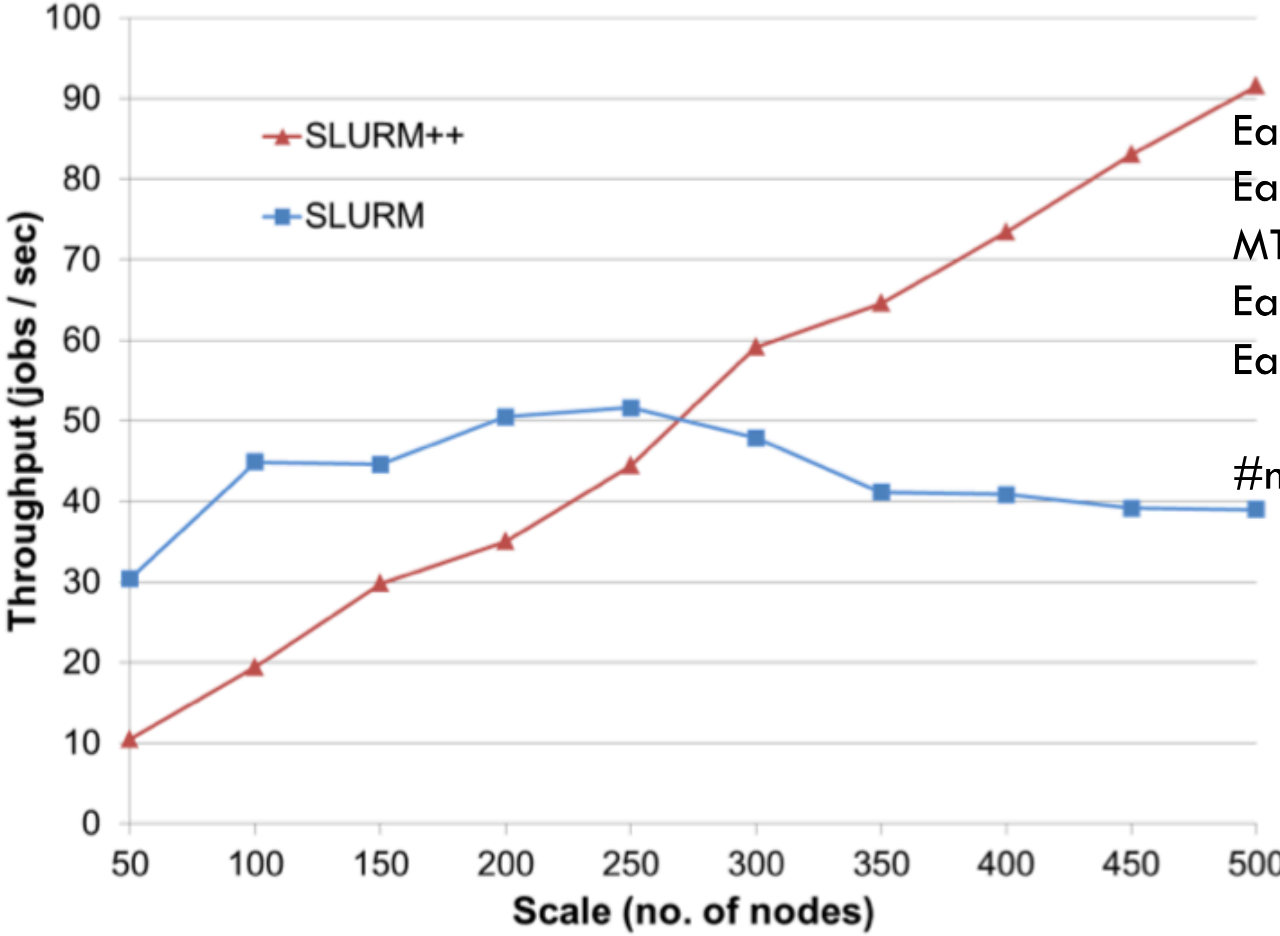
SLURM Baseline Benchmark



Large-Job Workload

- For every scale (100, 150, 200, 250, 300, 350), submit (#scale * 20) jobs, e.g., 20 jobs submitted for 100 nodes scale; 40 jobs submitted for 150 nodes scale; 60 jobs submitted for 200 nodes scale;
- Each job requiring a random (25~75) number of nodes, HPC job
- Each job runs 1 task (sleep 0)

SLURM vs. SLURM++

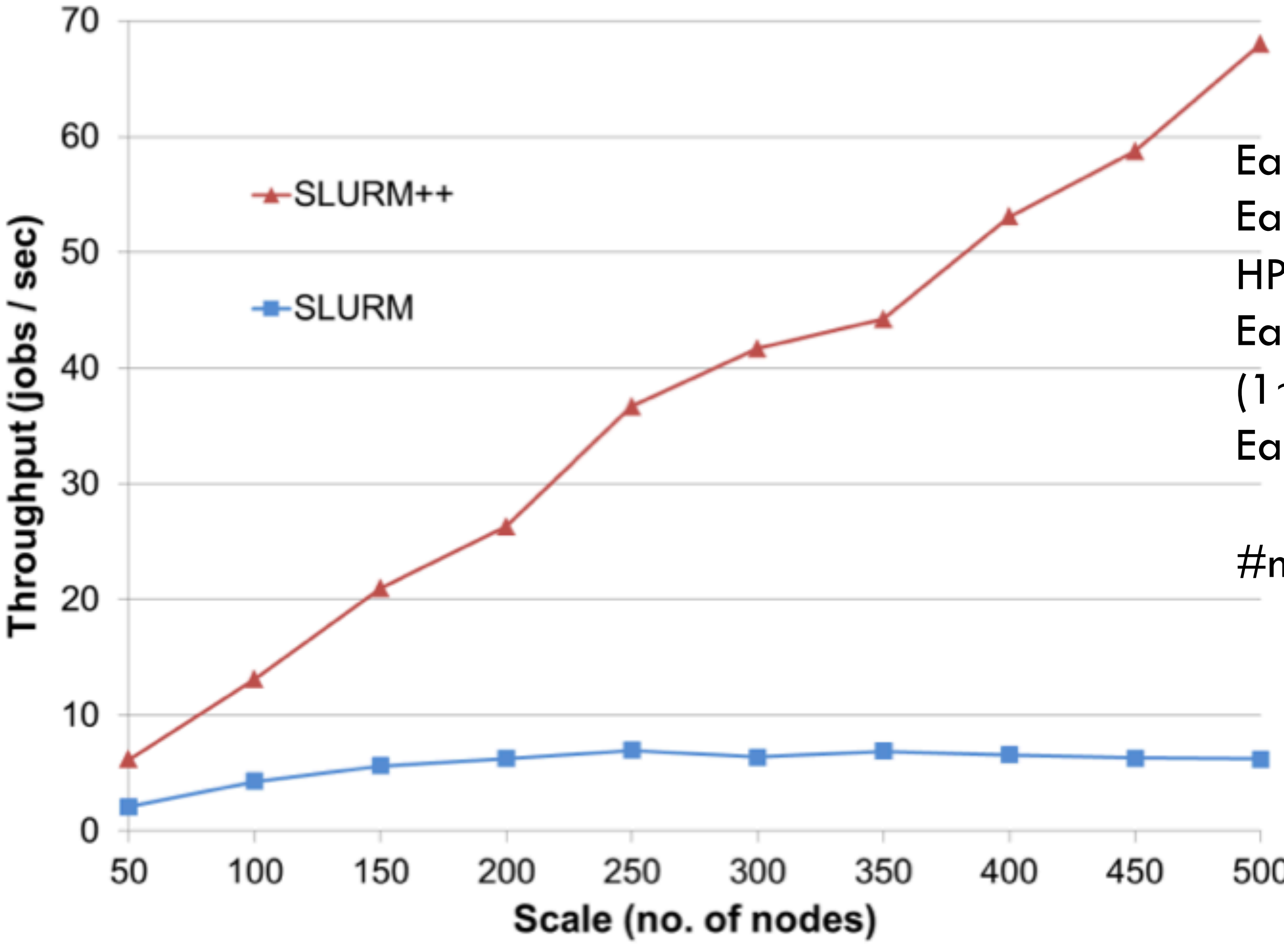


Small-Job Workload

Each controller manages 50 nodes
Each controller launches 50 jobs, MTC job
Each job requiring 1 node
Each job runs 1 task (sleep 0)

#nodes/50 = #controllers

SLURM vs. SLURM++

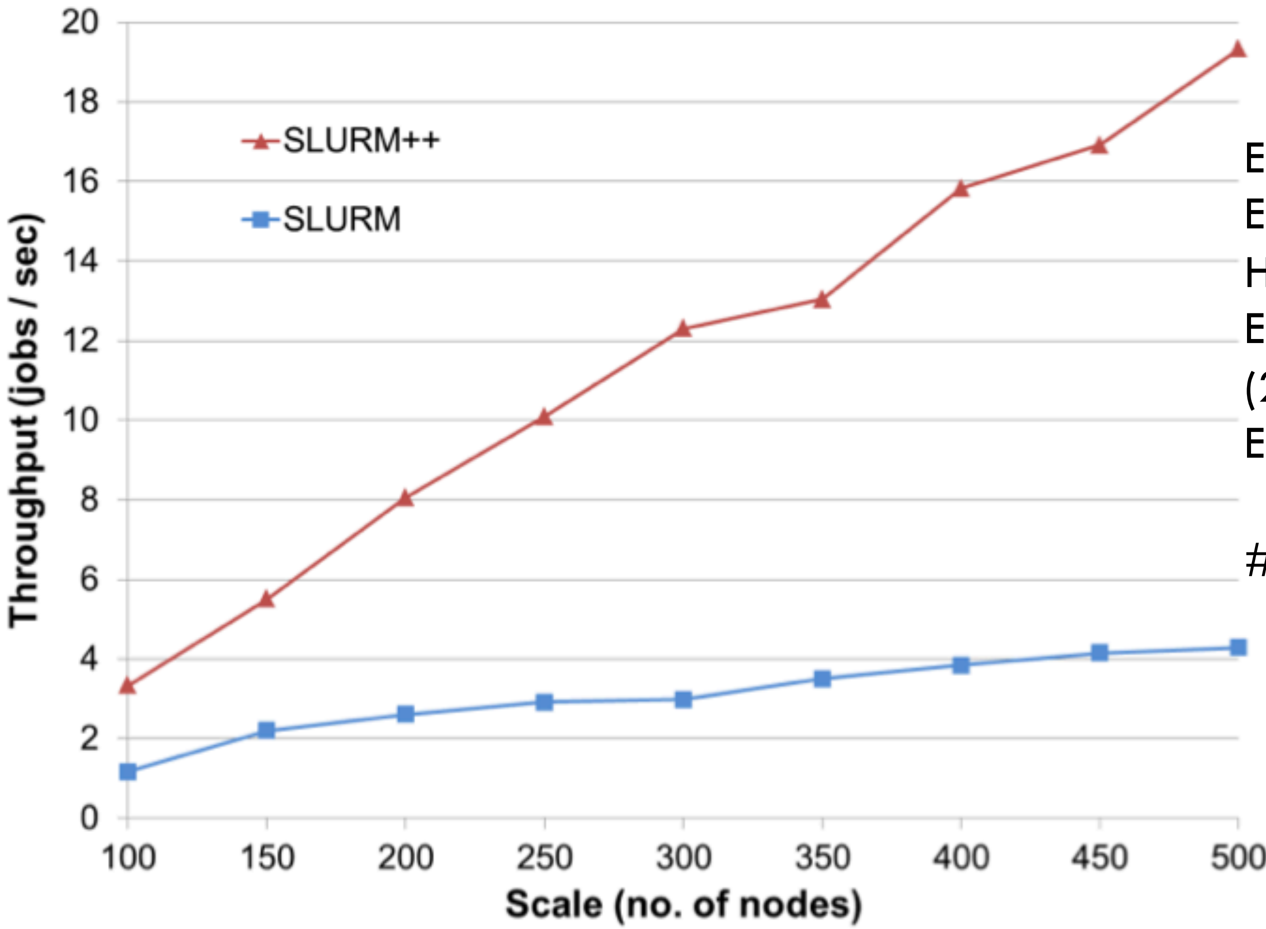


Medium-Job Workload

Each controller manages 50 nodes
Each controller launches 50 jobs, HPC job
Each job requiring a random (1~50) number of nodes
Each job runs 1 task (sleep 0)

#nodes/50 = #controller

SLURM vs. SLURM++

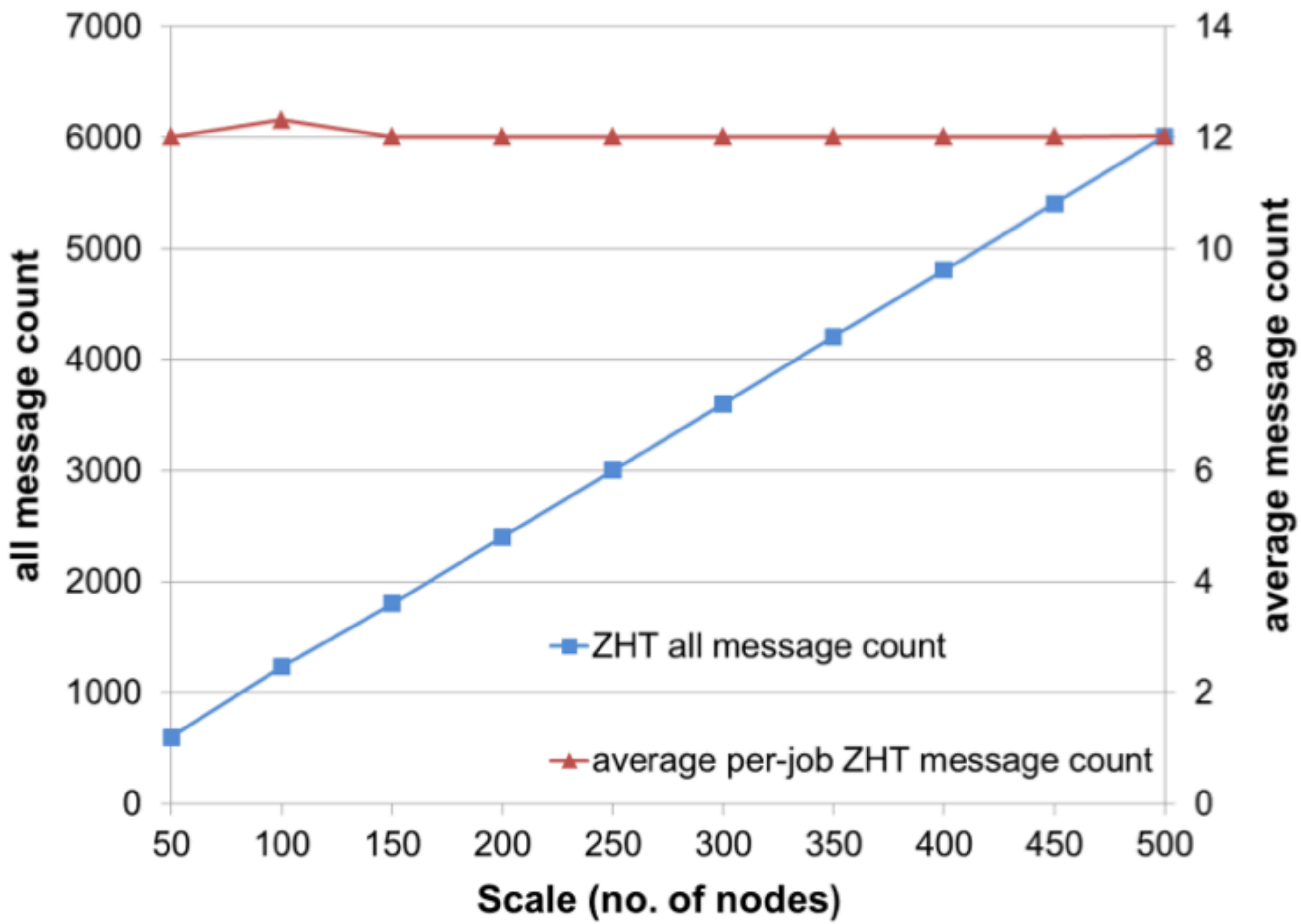


Large-Job Workload

Each controller manages 50 nodes
Each controller launches 20 jobs, HPC job
Each job requiring a random (25~75) number of nodes
Each job runs 1 task (sleep 0)

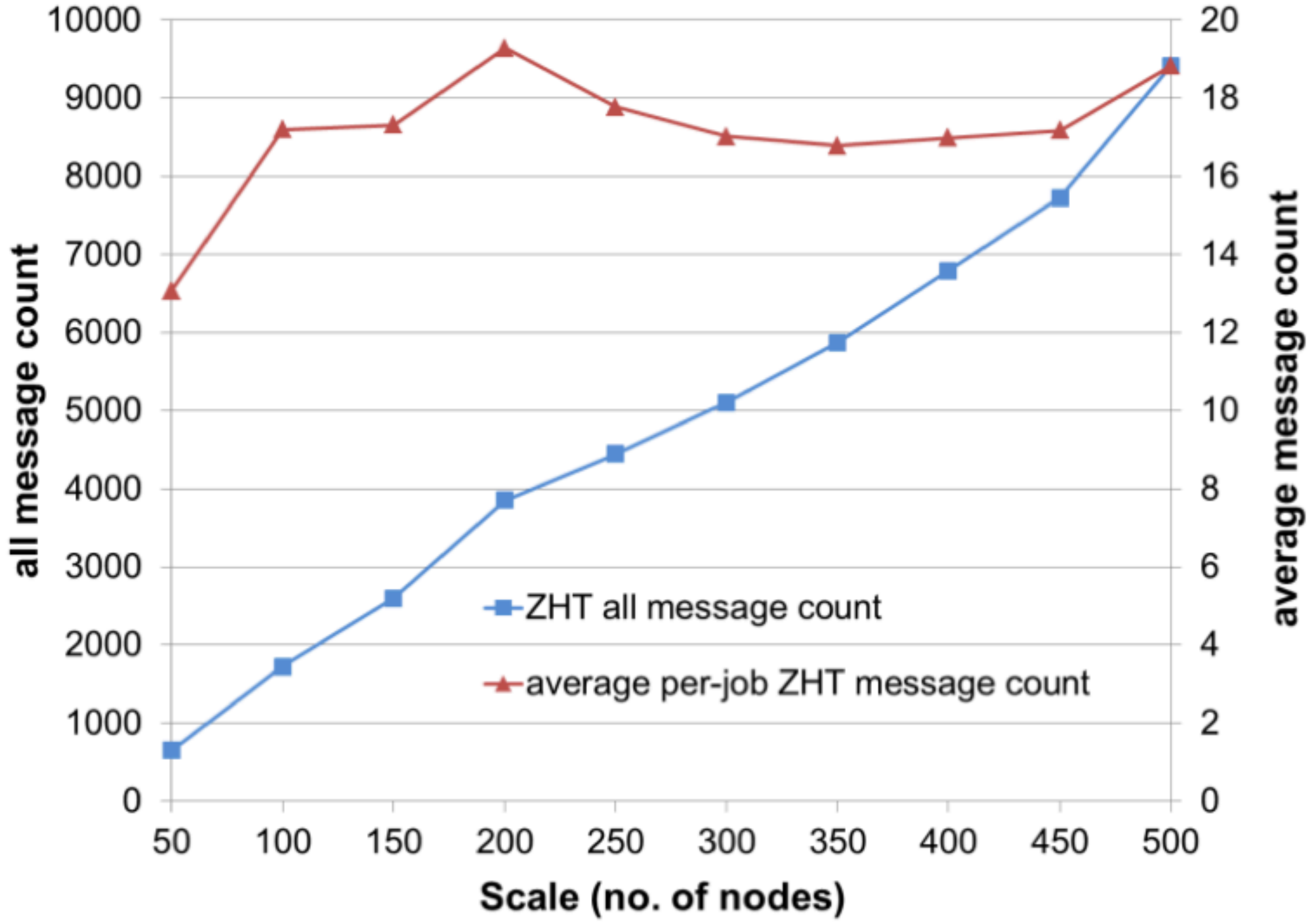
#nodes/50 = #controller

SLURM vs. SLURM++



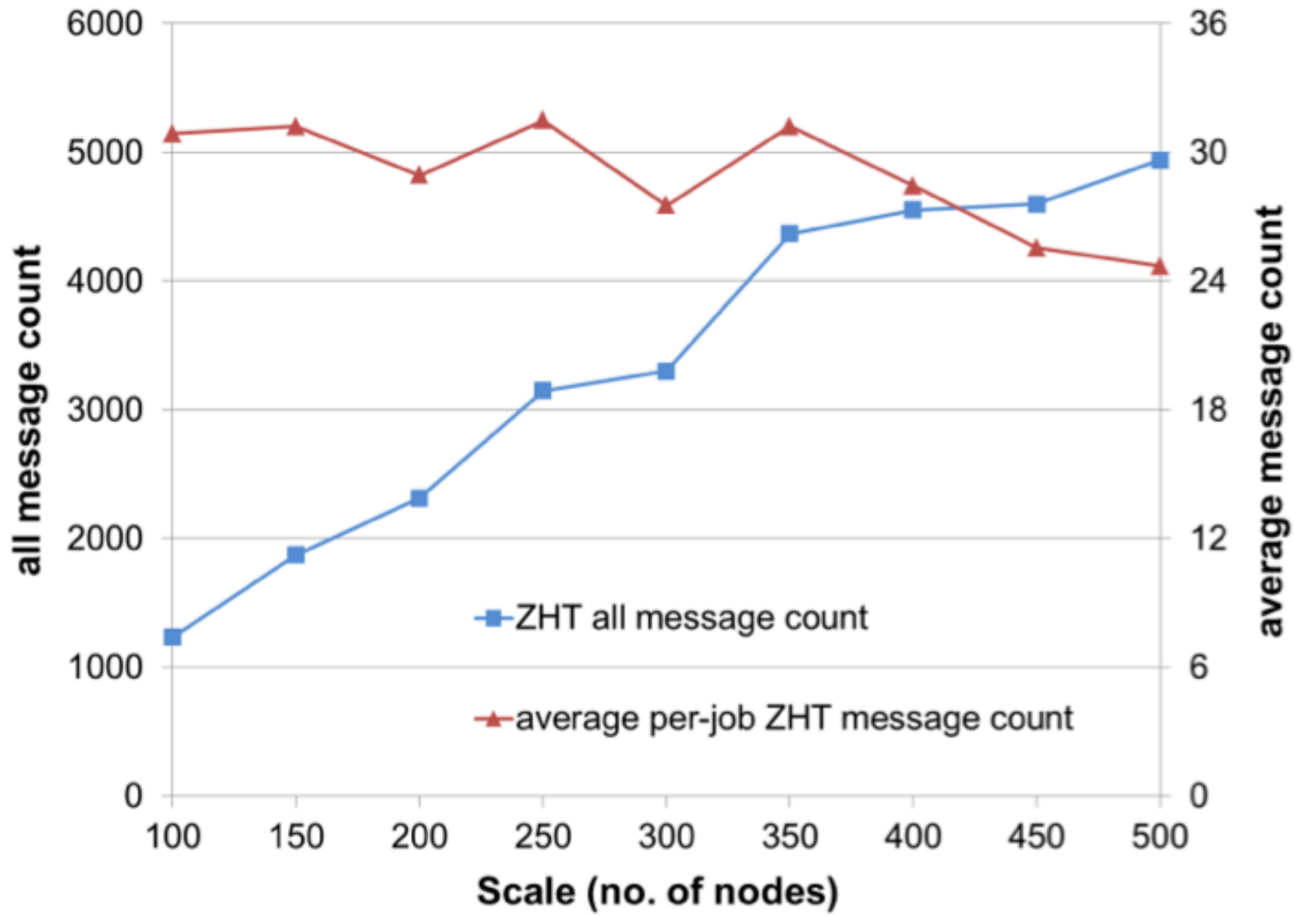
Small-Job; ZHT message count of SLURM++

SLURM vs. SLURM++



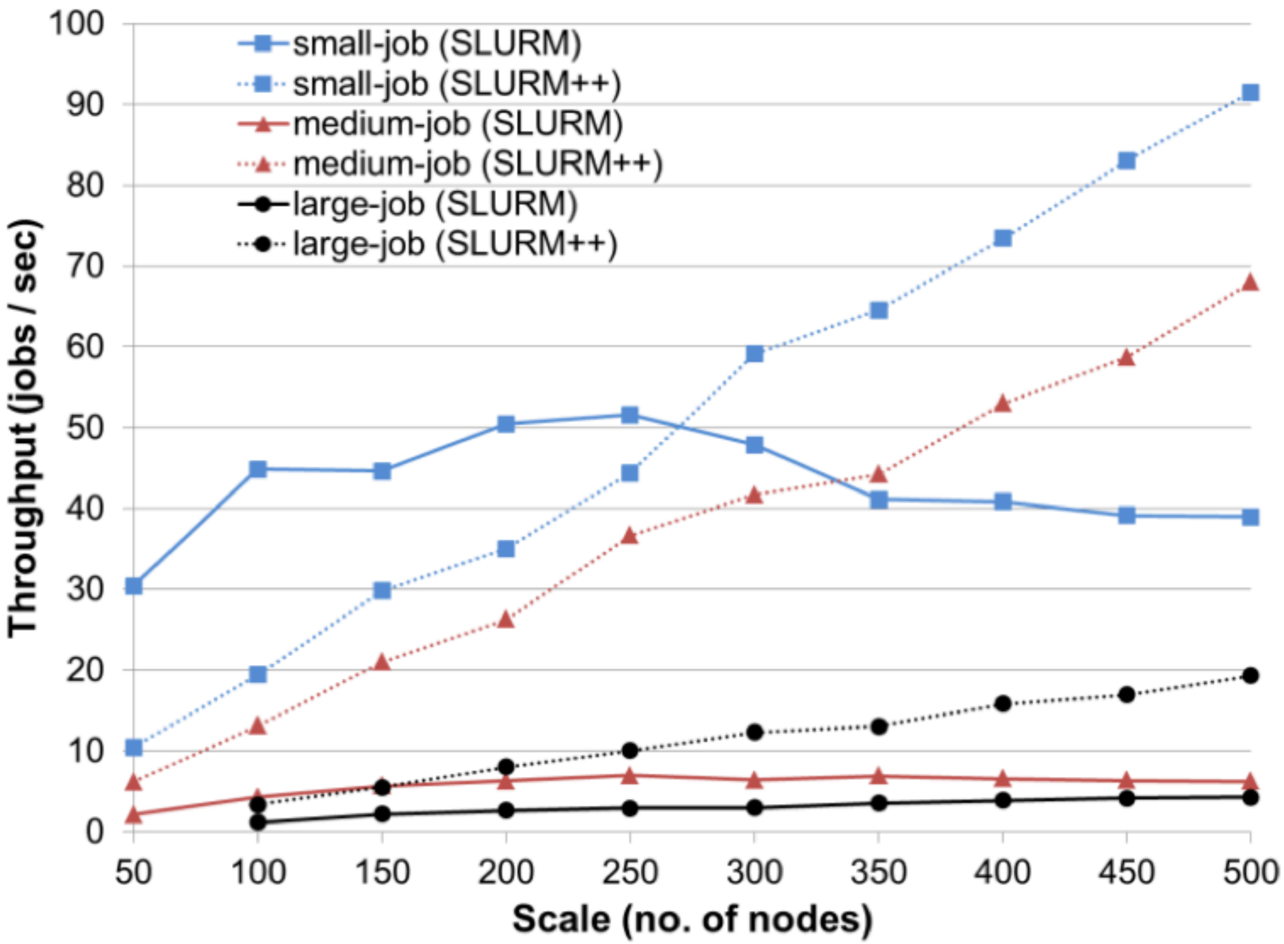
Medium-Job; ZHT message count of SLURM++

SLURM vs. SLURM++



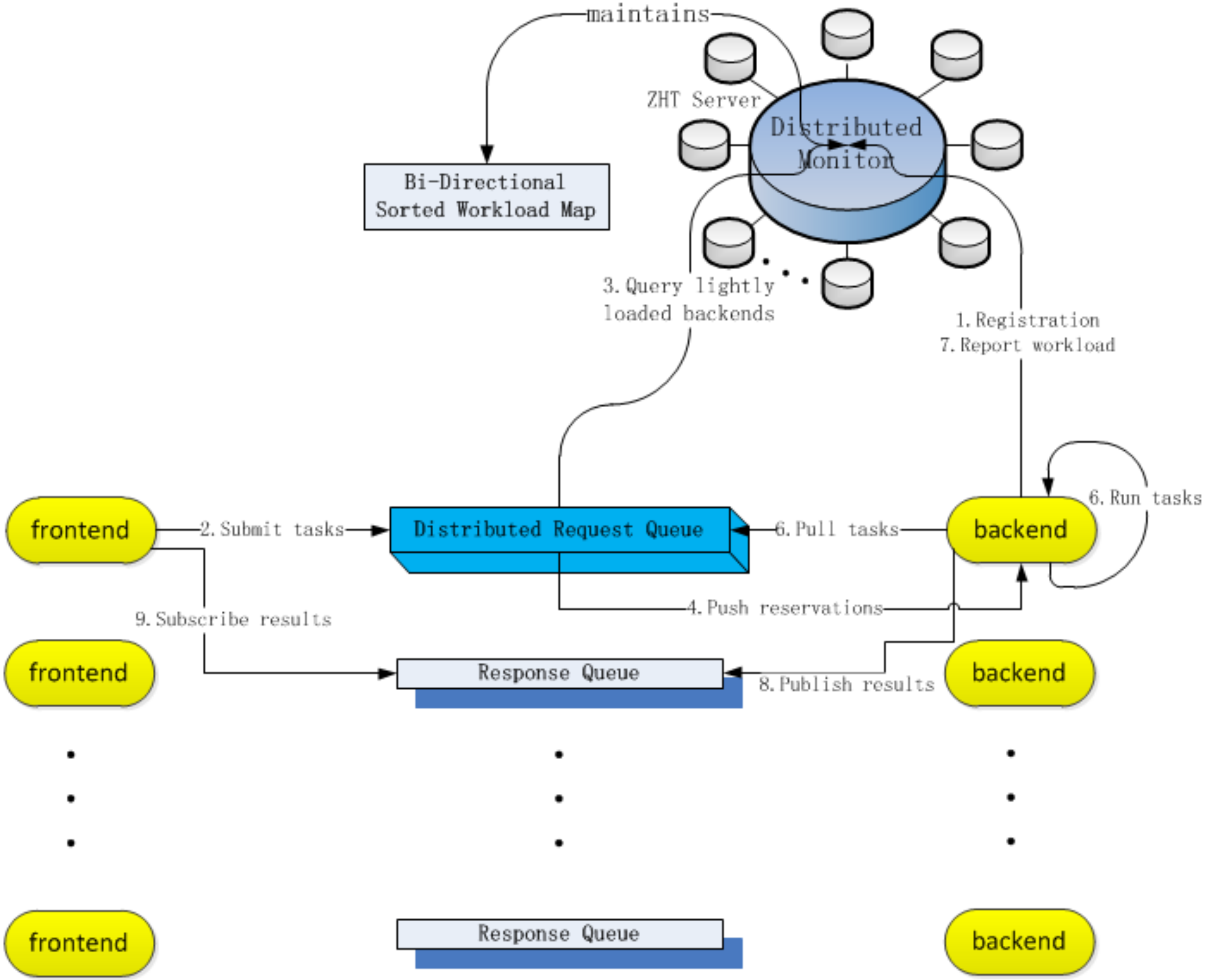
Large-Job; ZHT message count of SLURM++

SLURM vs. SLURM++

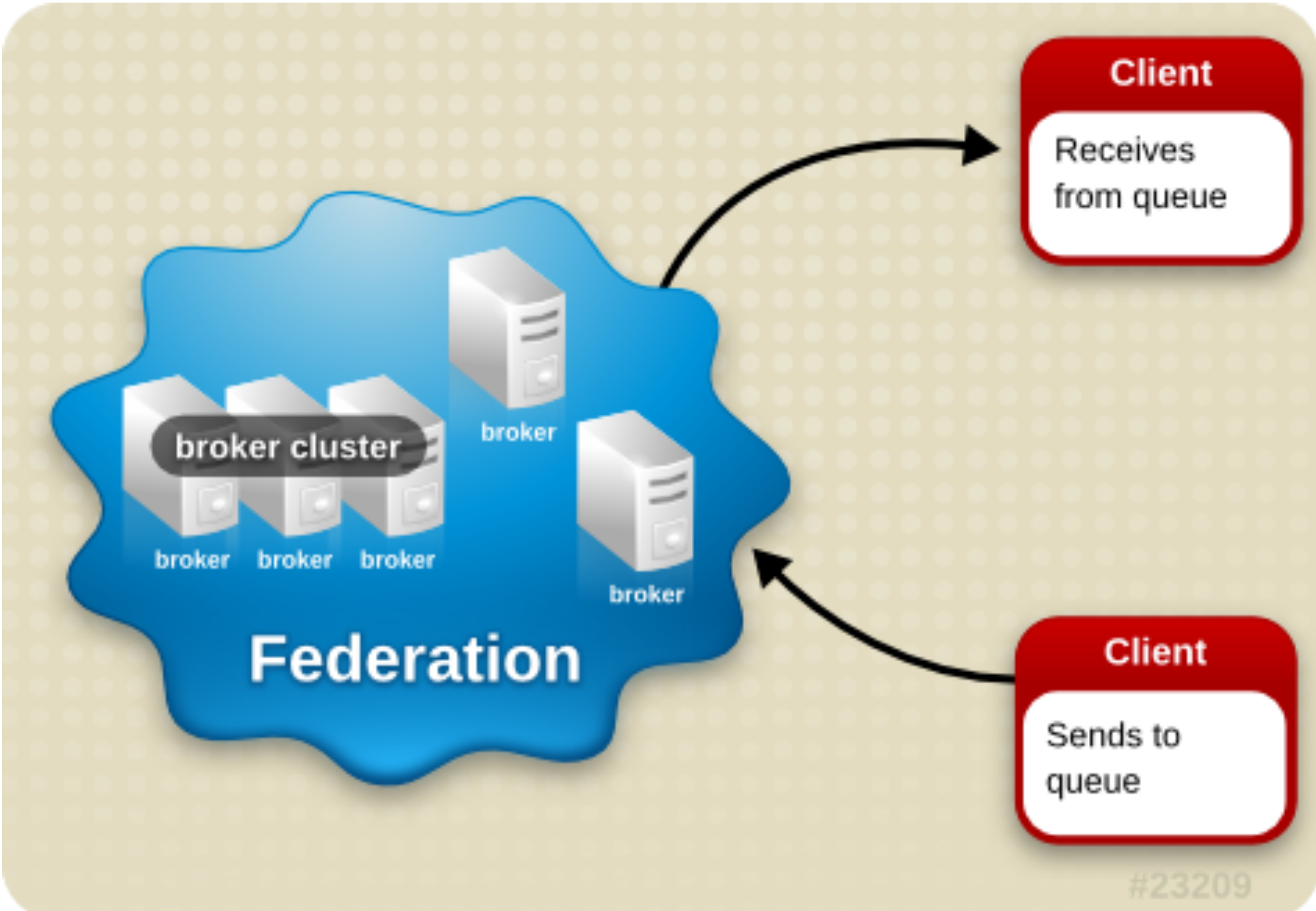


Throughput comparison with different workloads

Distributed Monitoring – ZHT Approach



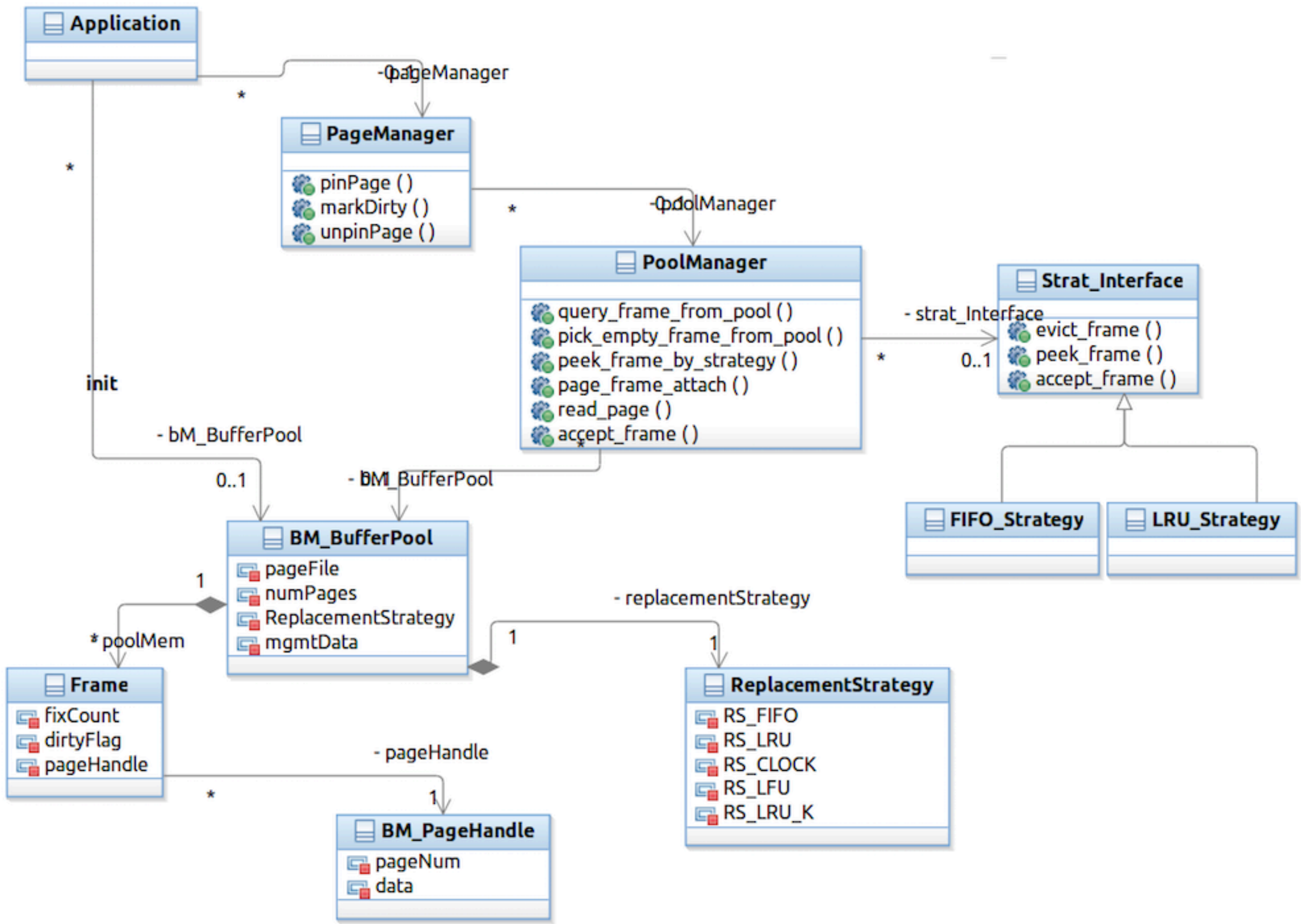
Distributed Monitoring – AMQP Approach



Distributed Monitoring – AMQP Approach

- Federation is used to provide geographical distribution of brokers. A number of individual brokers, or clusters of brokers, can be federated together. This allows client machines to see and interact with the federation as though it were a single broker. Federation can also be used where client machines need to remain on a local network, even though their messages have to be routed out.

Cache



Application
- pageManager
0..1
*
PageManager
pinPage ()
markDirty ()
unpinPage ()
*
- poolManager
0..1
*
PoolManager
query_frame_from_pool ()
pick_empty_frame_from_pool ()
peek_frame_by_strategy ()
page_frame_attach ()
read_page ()
accept_frame ()
- strat_Interface
*
0..1
Strat_Interface
evict_frame ()
peek_frame ()
accept_frame ()
FIFO_Strategy
LRU_Strategy
init
- bM_BufferPool
0..1
- bM_BufferPool
1
BM_BufferPool
pageFile
numPages
ReplacementStrategy
mgmtData
1
* poolMem
Frame
fixCount
dirtyFlag
pageHandle
- replacementStrategy
1
1
ReplacementStrategy
RS_FIFO
RS_LRU
RS_CLOCK
RS_LFU
RS_LRU_K
- pageHandle
*
1
BM_PageHandle
pageNum
data

Libnap Standalone Library

- Libnap: Library for Network Abstracted Protocols
- For new version MATRIX development

Thank you!

Q&A