DataStager: Scalable Data Staging Services for Petascale Applications

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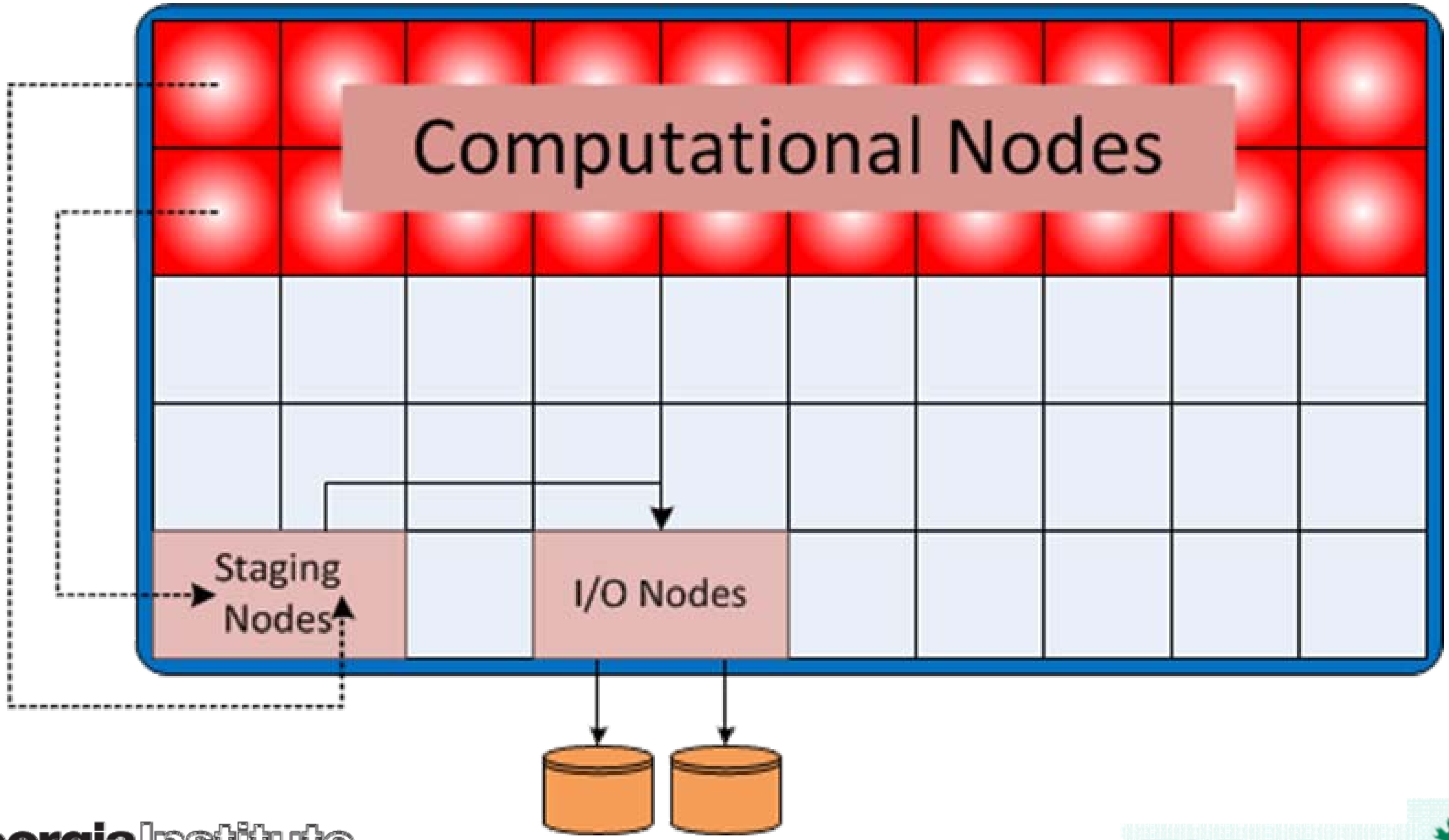
Motivation

- Increases in computational capacity
- Corresponding increase in data size
- I/O performance becoming a bottleneck at scale
- Information extraction increasing in importance
- Motivating application GTC

Data Staging Overview



Outline

- Data Staging Overview
- Advantages and Design highlights
- DataStager Architecture
- Scalable data movement
- Managing data transfers
  - Scheduling policies
- Evaluation
- Conclusion and the future

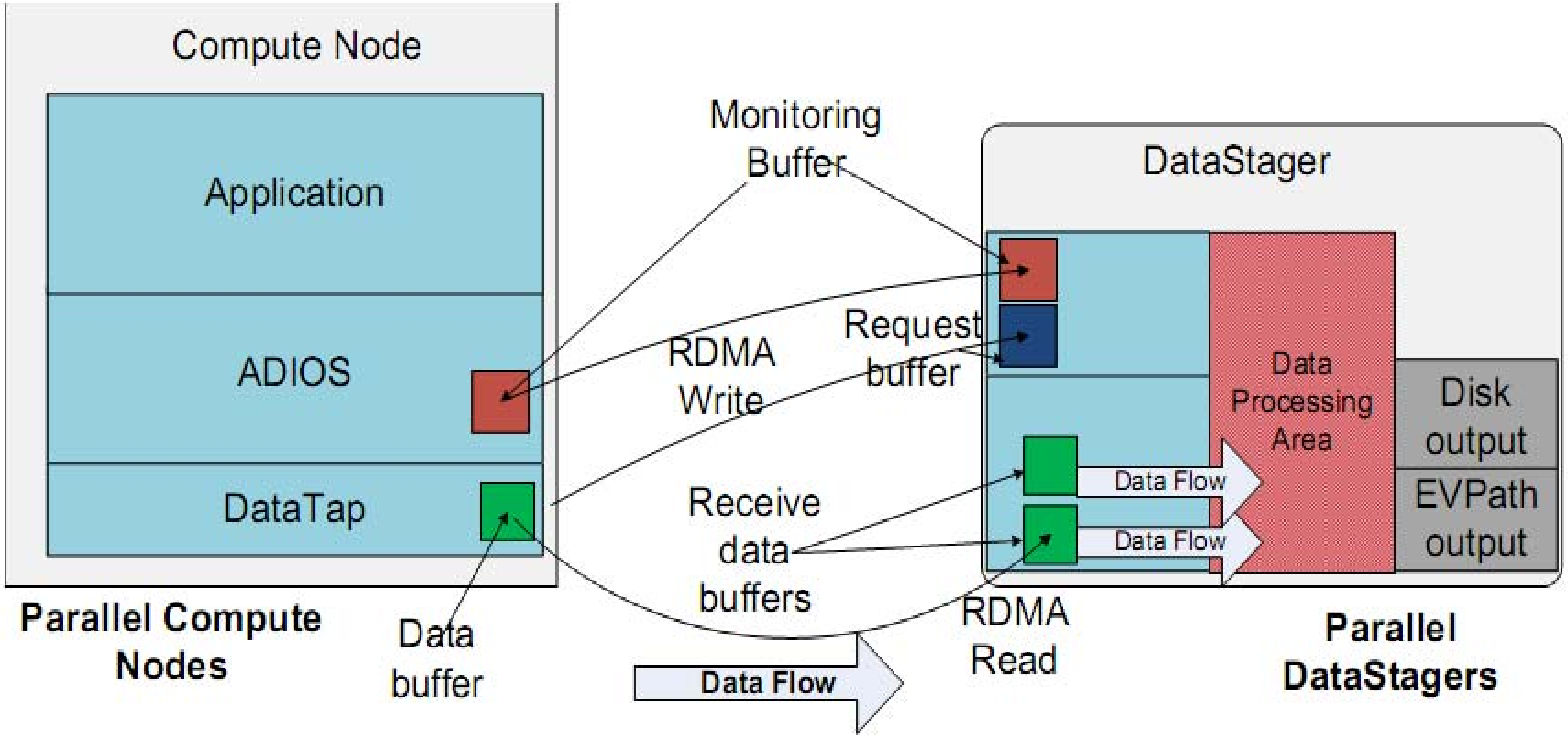
DataStaging Advantages

- Reduces performance linkage between I/O subsystem and application
- Enables optimizations based on dynamic number of writers
- High bandwidth data extraction from application

Design Highlights

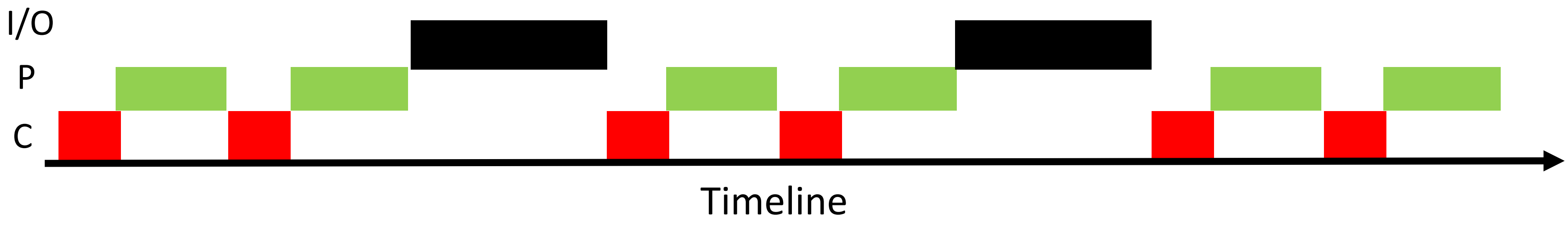
- Server directed asynchronous I/O
- ADIOS compatibility
- Structured Data Transport
- Minimal Runtime impact
- Utilize available RDMA transports
  - Implementation on Cray XT and Infiniband

DataStager Architecture



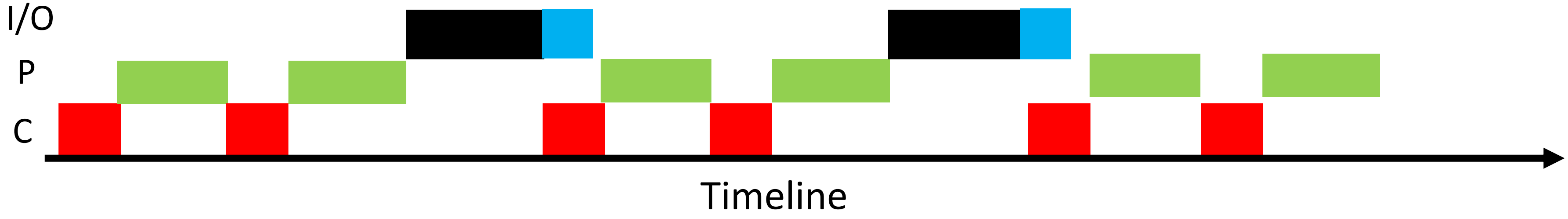
Data Movement

- Ideal synchronous (POSIX) output
- No buffering of data
- Transfer completes when function returns
- Application runtime is greatly impacted by actual output bandwidth
- Requires disabling file system buffering and has a huge performance impact



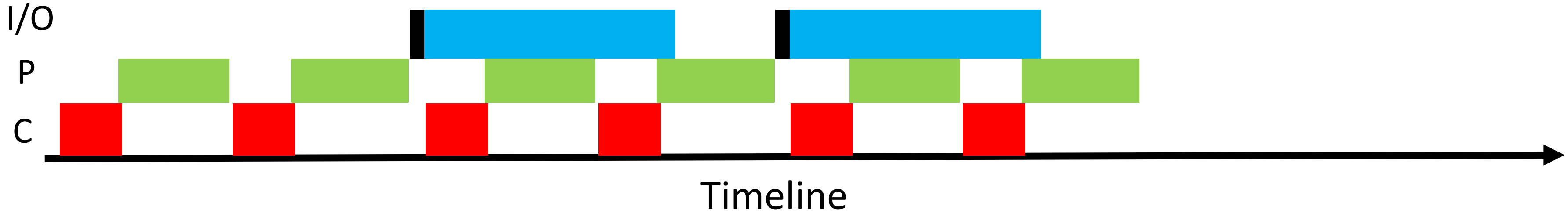
Data Movement

- Actual synchronous (POSIX) output
- Output data is partially buffered
- High throughput background transfer as Lustre drains the buffer
- Application runtime is impacted by the interference from the background data transfer



Data Movement

- Asynchronous data output (DataStager)
- All the data is buffered
- Blocking time is only the time taken to buffer data
- Data is transferred in the background concurrently with application execution
- Application runtime is impacted by the interference from the background data transfer



Management of Transfers

- Artifact of server directed I/O
  - DataTap issues a request to DataStager
  - Requests from all client nodes are queued
  - DataStager checks available buffer space on staging node
- Scheduling of data movement to reduce overhead
  - Requests are serviced in order of scheduling policy
  - Multiple requests are serviced simultaneously

Schedulers

- Constant drain scheduler (CD)
  - Transfer data as fast possible
  - Highest throughput
  - Impact on application runtime from interference

Schedulers

- State aware congestion avoidance (PA)
  - For applications with regular patterns
  - Partition application runtime into *phases*
  - Only transfers data in *computation* phase
  - Avoids interference with intra-application MPI communication

Schedulers

- Attribute aware in-order scheduler
  - Uses data attributes to order movement
  - Creates ordered data stream

Schedulers

- Rate limiting scheduler (Con_X)
  - Limits concurrent transfers to X
  - Applies to irregular applications where state aware scheduler cannot accurately predict phase
  - Reduces interference by limiting bandwidth usage

Schedulers

- Multiple schedulers can be used together
- Rate limiting + state aware (PA_Con_X)
  - Can work across range of application behaviors
  - Further reduce impact from background I/O

Phase detection

- Uses ADIOS user specified hints

  adios_start_calculation

  adios_end_calculation

- DataStager maintains application timing information

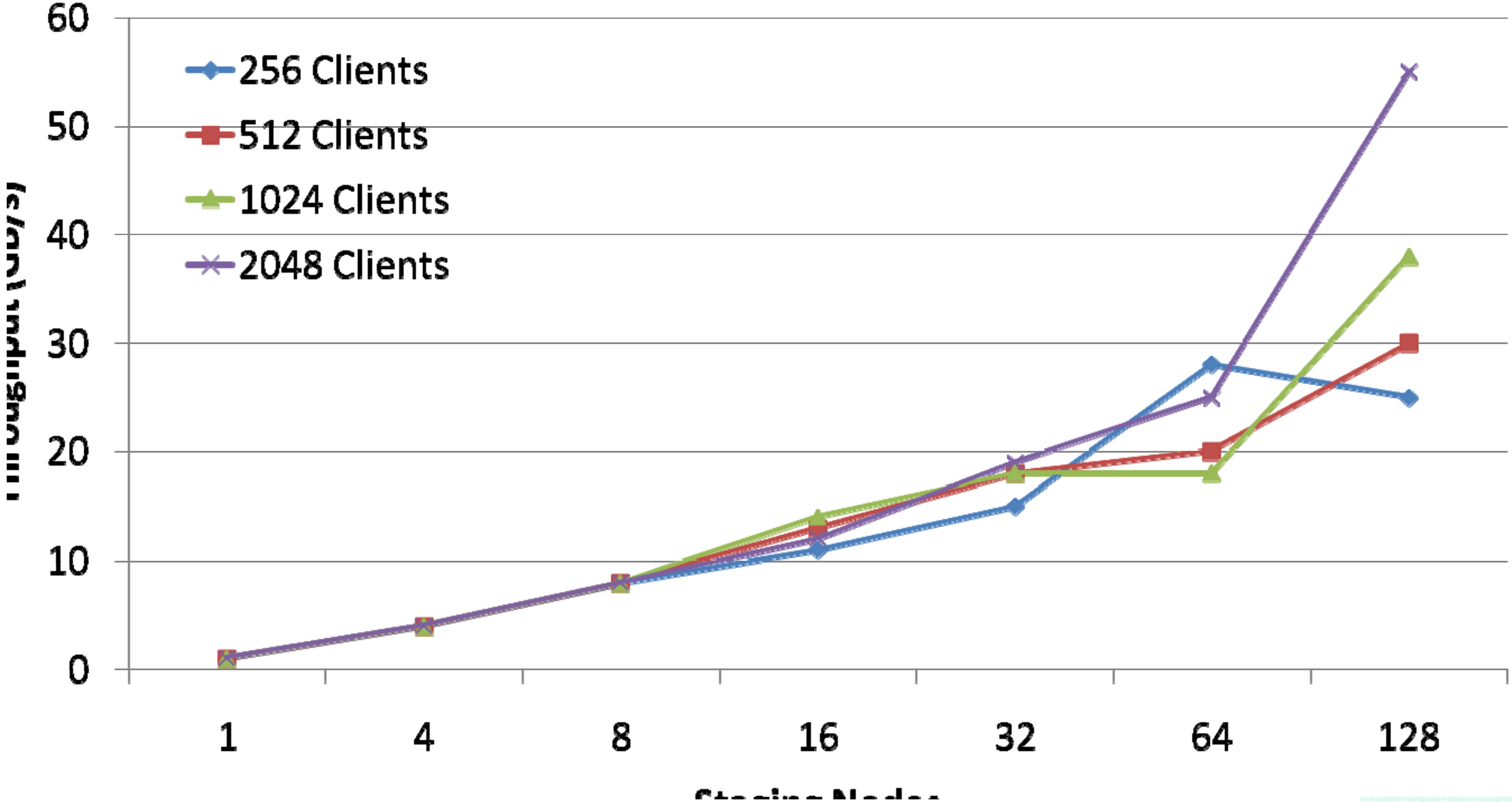
Evaluation

- Full application benchmark
  - Measure real application overhead
  - Not bandwidth
- Gyrokinetic Turbulence Code
  - Particle-in-cell
  - Scalable
  - We use *weak scaling* – 180 MB output/process
- All benchmarks on Jaguar at ORNL
  - Quad core, 2 GB/core
  - Seastar2 interconnect

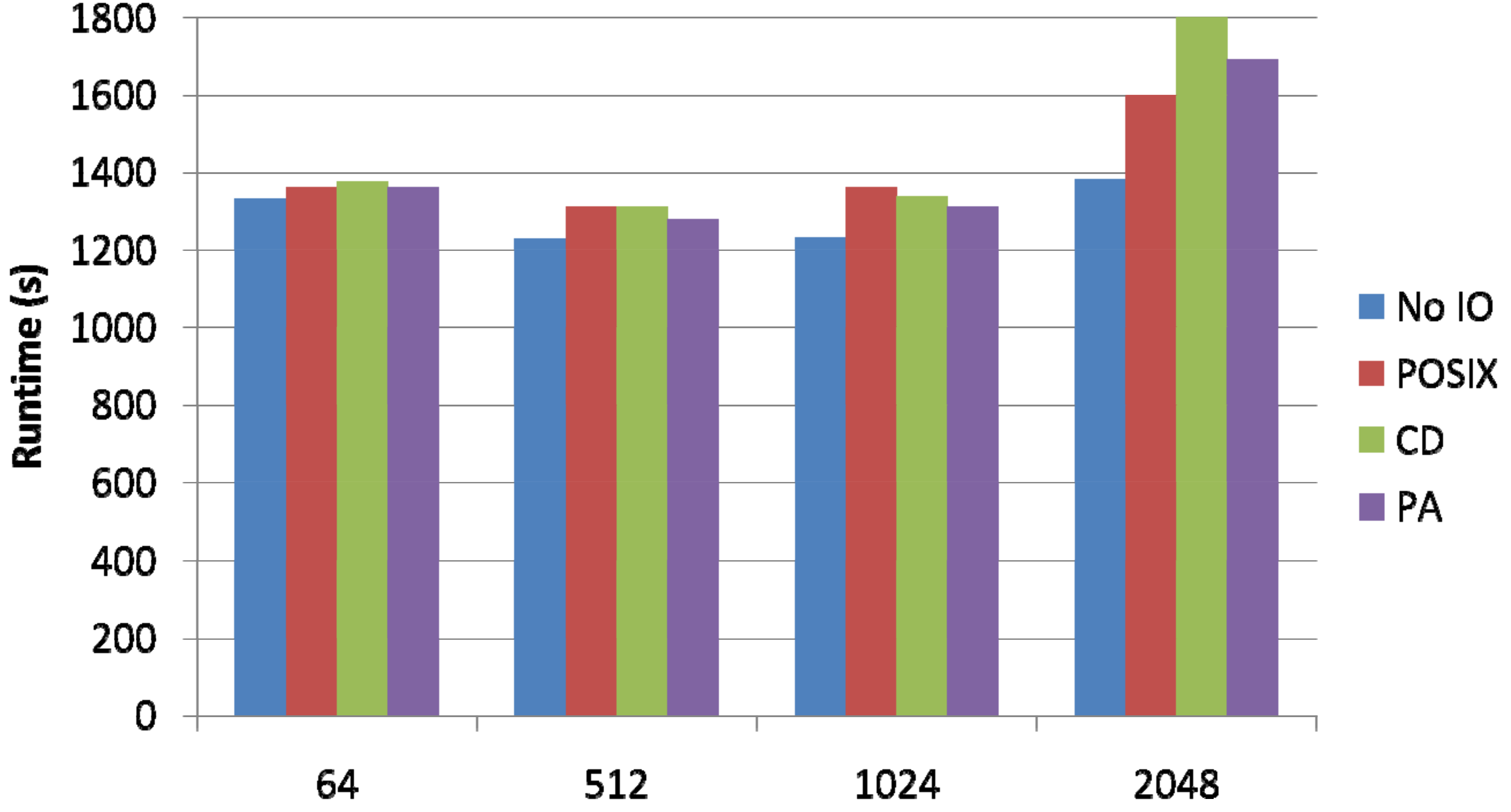
Abbreviations

- Continuous drain scheduler – CD
- State aware scheduler – PA
- Concurrency limiting – Con_X
  - X is 1 or 4
- Combination Scheduler
  - PA_Con_X

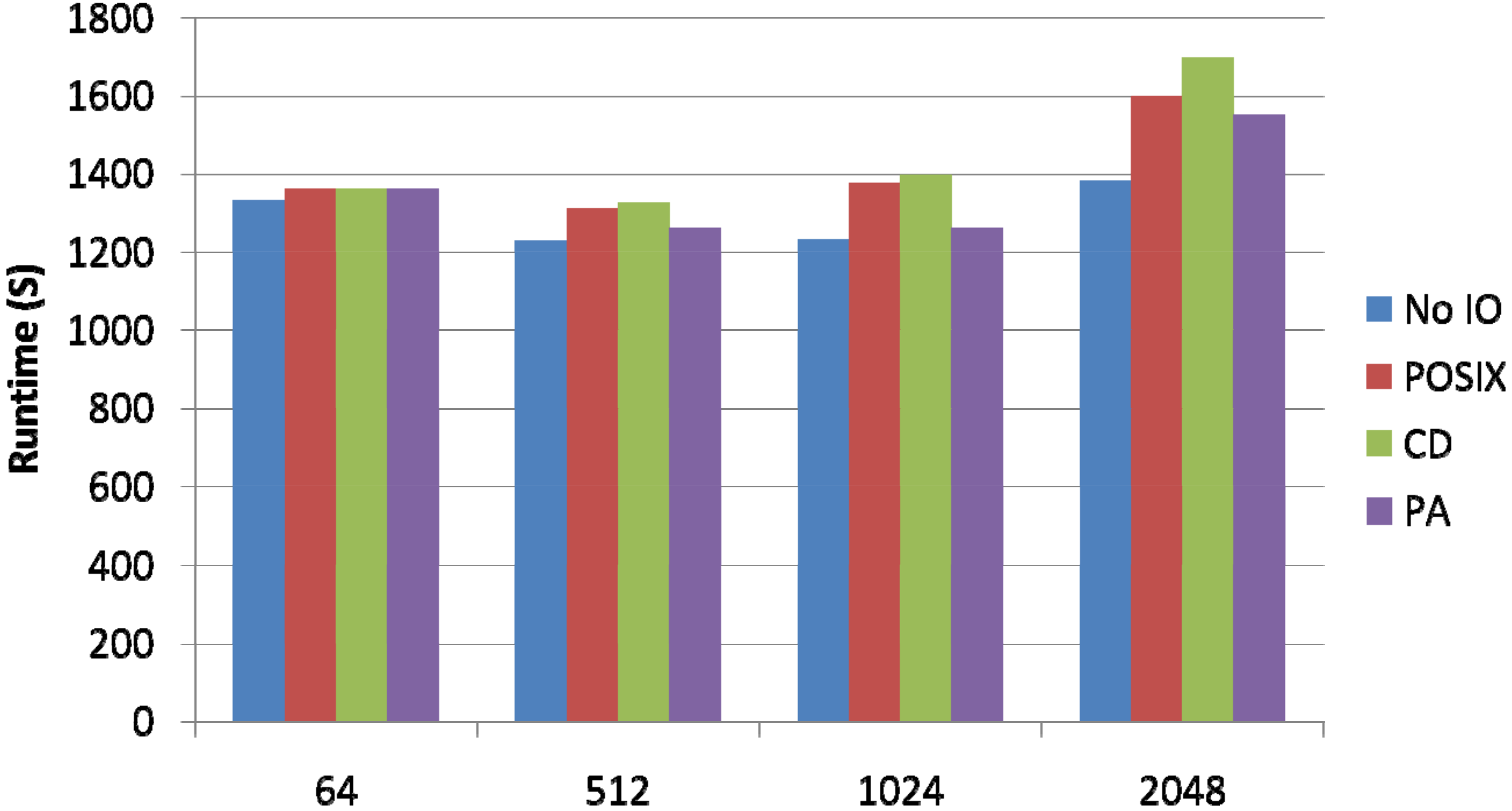
DataStager Maximum Throughput



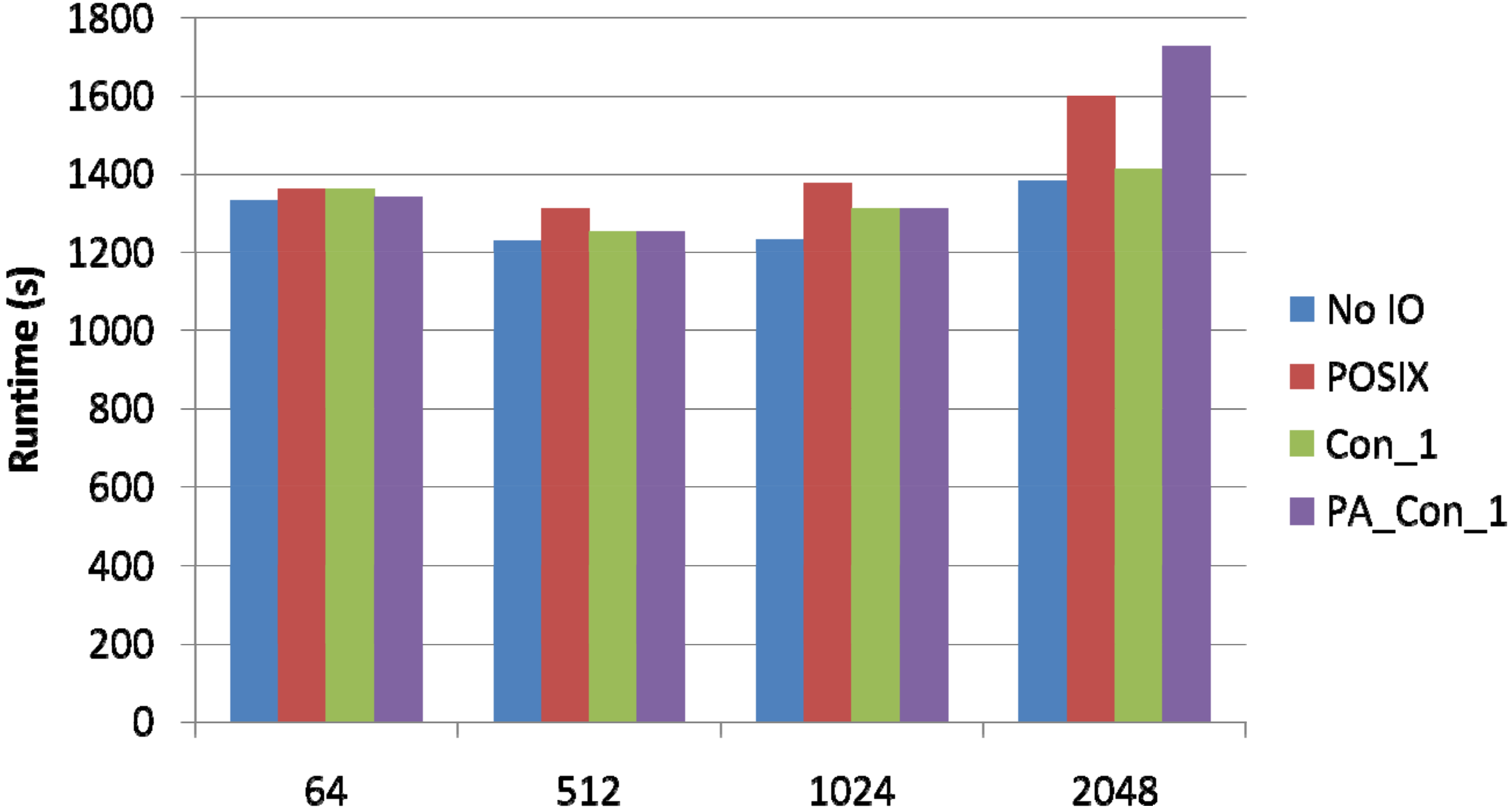
4 staging nodes



16 staging nodes



Advanced Scheduling (4)



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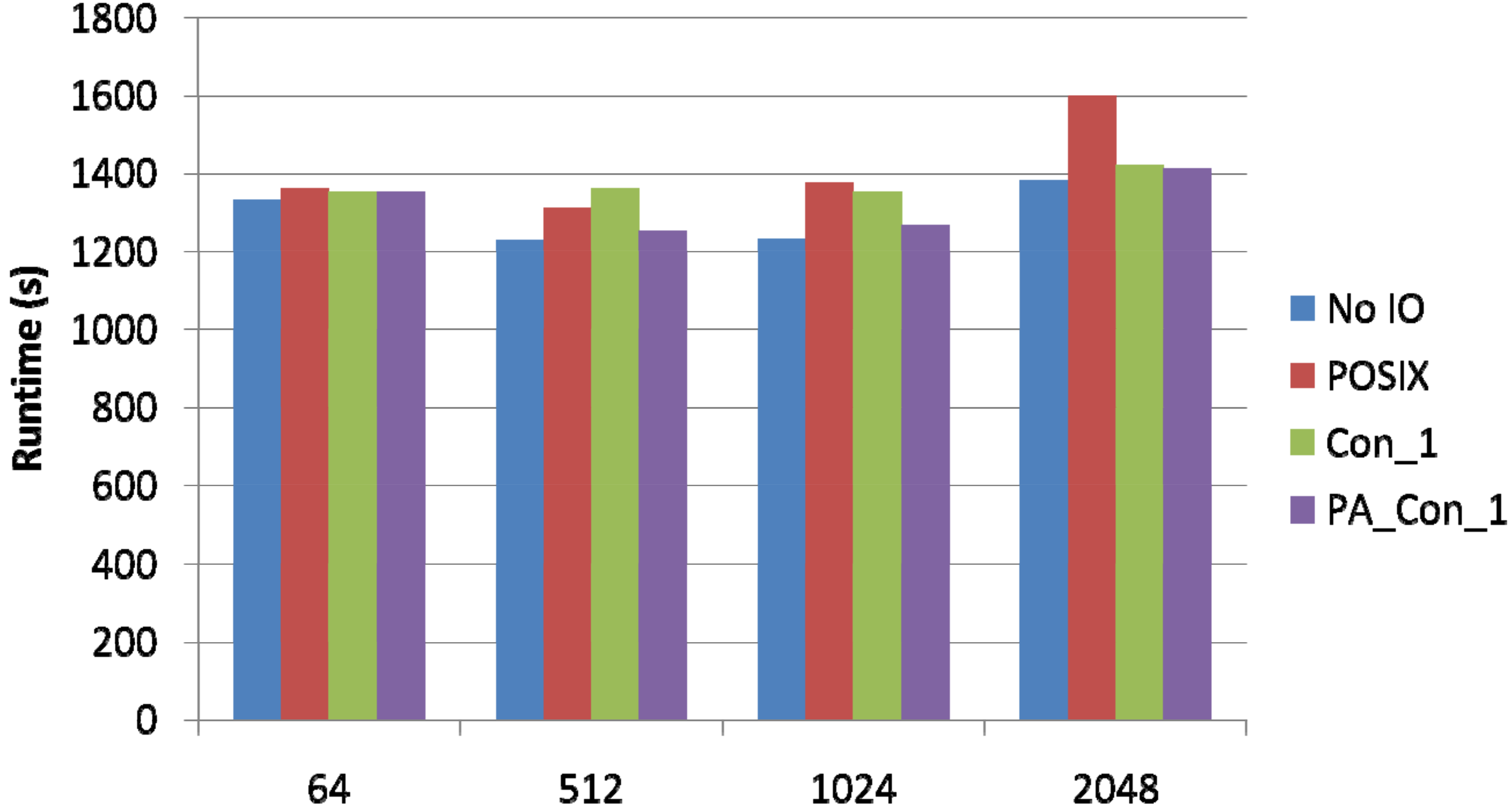
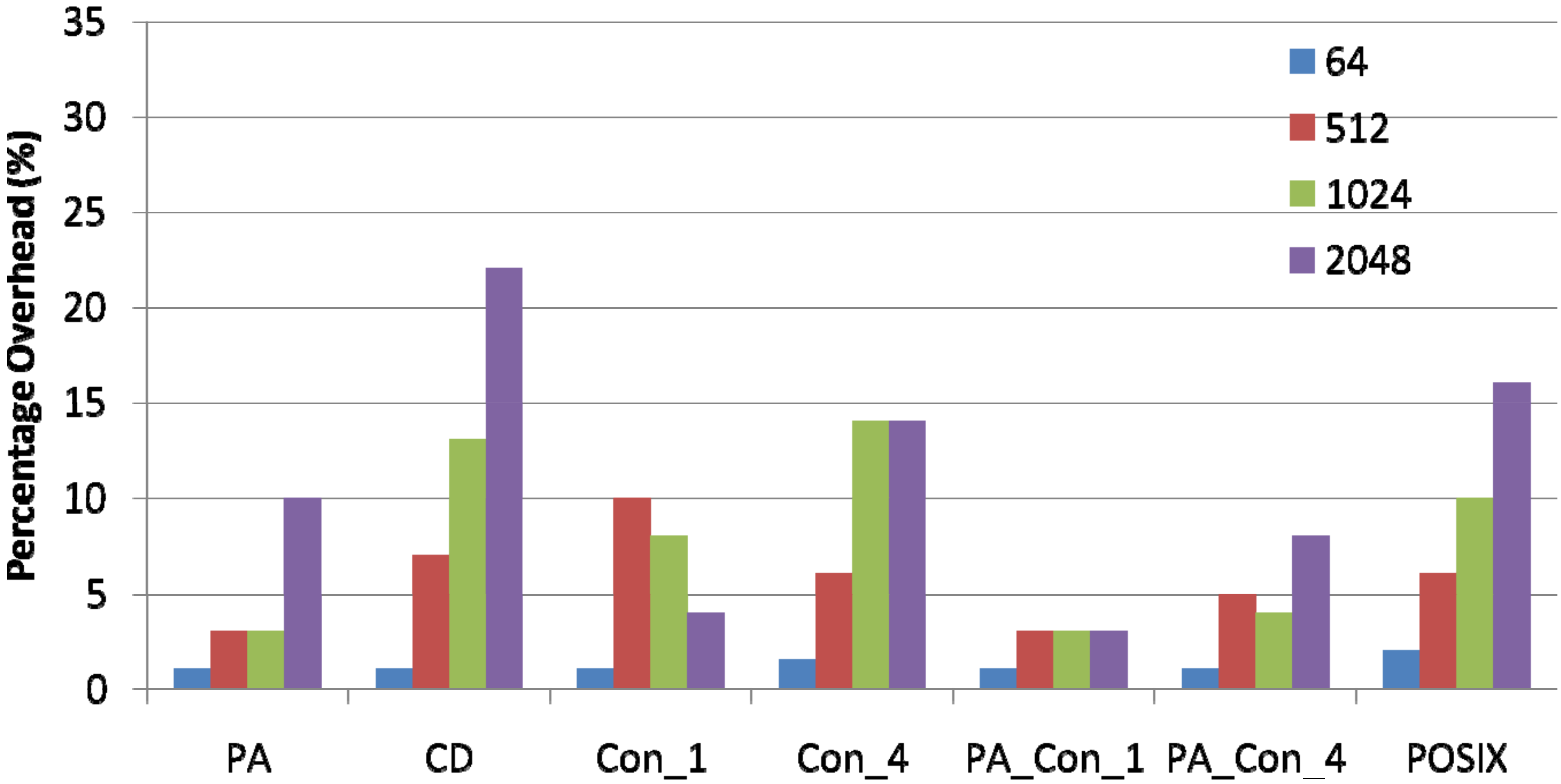
Advanced Scheduling (16)



Runtime Overhead comparison for all evaluated scheduling mechanism 16 Stagers



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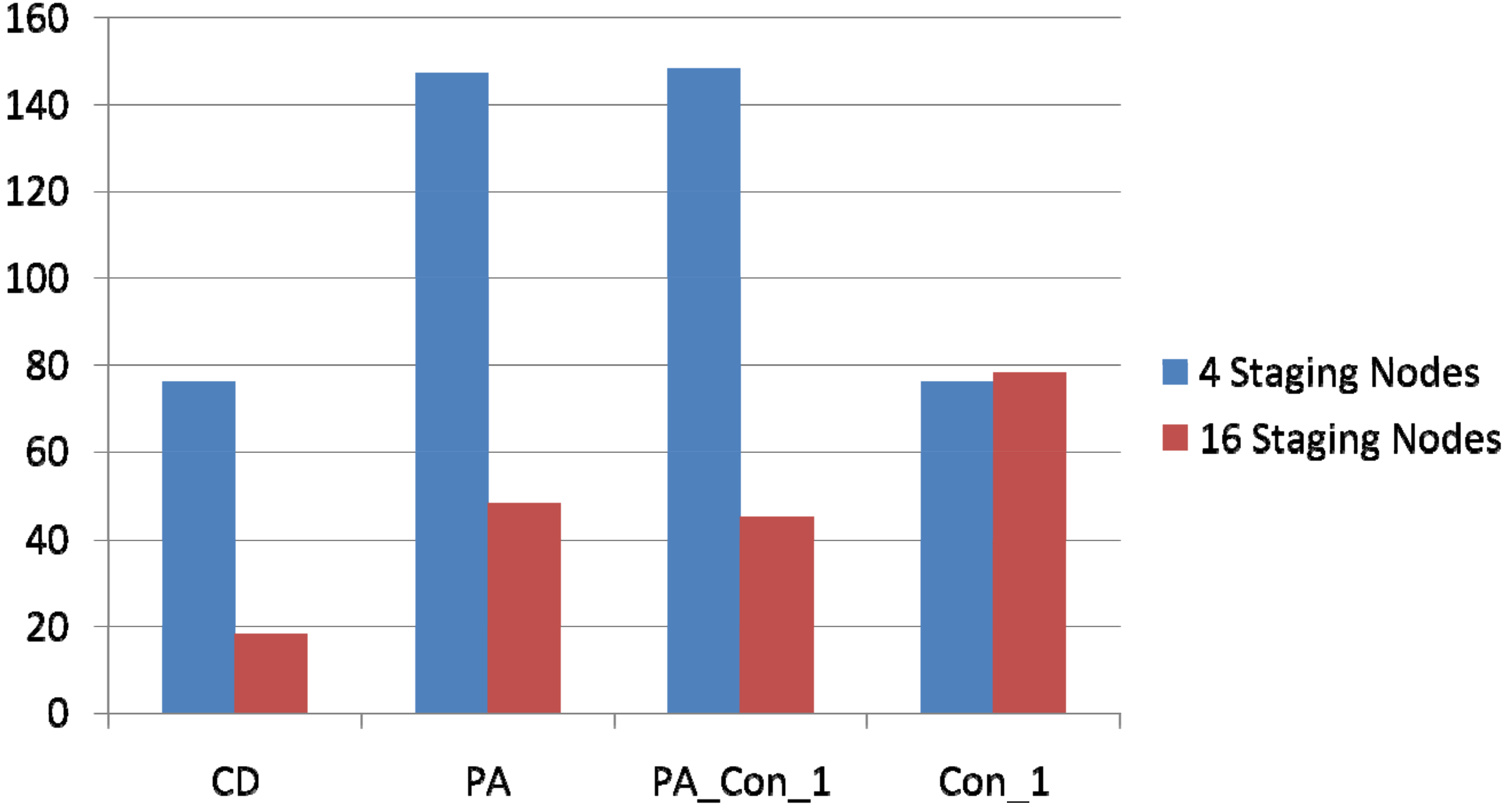
Completion Time



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Conclusions

- Scalable data movement with shared resources requires us to manage the transfers
- Estimating an application's phase enables a low cost mechanism for avoiding interference
- Scheduling properly can greatly reduce the impact of I/O

Future Work

- DataStager is the first component of the larger Data Service approach
- Using staging area for information processing
  - Visualization
  - Data output
  - Application coupling
  - Data analytics
- E2e management of the data pipeline