High Fidelity Data Collection and Transport Service Applied to the Cray XE6/XK6

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Outline

- Motivation
- High-level Overview of Data Collection and Transport
- Case Study: Resource-Aware Application
- Enhancements
- Overhead
- Summary & Future Work

Motivation

Gain insight into resource utilization/bottlenecks (e.g. network bandwidth/hotspots, CPU utilization, Memory footprint/bandwidth)

- Intelligent job placement
- Run-time workload partitioning/adaptation
- Historical comparison
- Anomaly detection

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Monitoring System and Application Resource Utilization

- Typical monitoring systems target failure detection, uptime, and resource state/trend overview:
  - Information targeted to system administration
  - Collection intervals of minutes
  - Relatively high overhead (both compute node and aggregators)
- Application profiling/debugging/tracing tools:
  - Collection intervals of sub seconds (even sub-millisecond)
  - Typically requires linking, not run under real-world conditions (i.e. tools perturb the application profile)
  - Limits on scale
  - Don't account for external applications competing for the same resource
- Lightweight Distributed Metric Service (LDMS):
  - Continuous data collection, transport, storage as a system service
  - Targets system administrators, users, and applications
  - Enables collection of a reasonably large number of metrics with collection periods that enable job-centric resource utilization analysis and run-time anomaly detection
  - Variable collection period (~seconds)
  - On-node interface to run-time data

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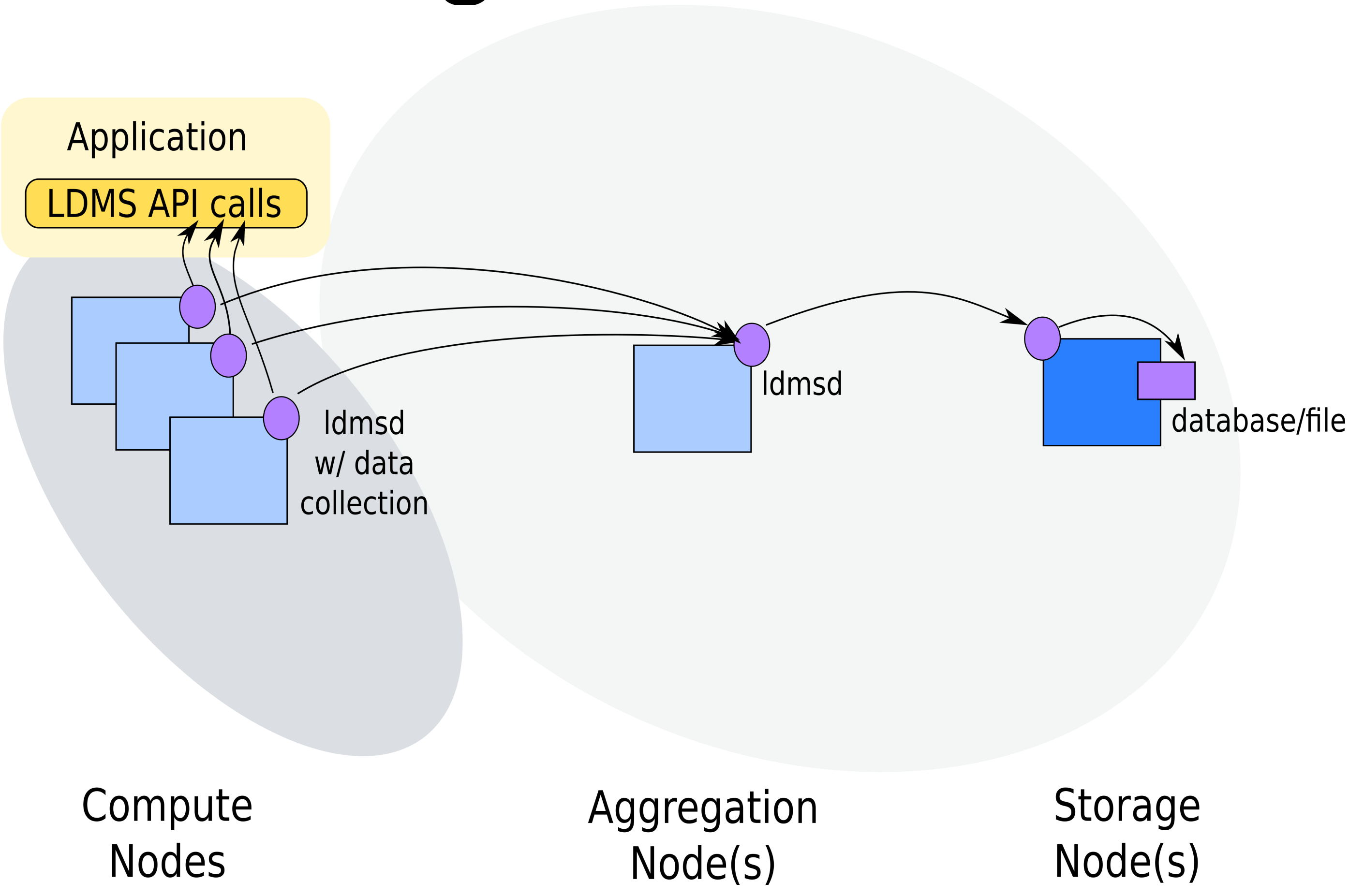
LDMS High Level Overview



- Only the current data
Is retained on-node

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LDMS Functional Overview

- Data is bundled into “Metric Sets” – this is the granularity of storage and query
- Metric Sets have associated Data and Meta-data and include generation numbers for both
  - Meta-data is only transmitted during initial setup and when change occurs
- Run-time plugin add, start, stop
  - Add new collection components
  - Start collection – begin scheduling data collection and make data visible to queries
  - Stop collection – stop scheduling data collection, last data set still visible to queries – no CPU overhead associated with this as no collection scheduled
  - Modify collection frequency – change the length of time between collection on a per data set basis
- Queries can be either host local or remote
- Socket or RDMA transport options

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LDMS Dataset Example

- **shuttle-cray.ran.sandia.gov_1/meminfo**
- U64 1 component_id
- U64 160032 MemFree
- U64 181728 Buffers
- U64 3443332 Cached
- U64 33076 SwapCached
- U64 2987544 Active

- **shuttle-cray.ran.sandia.gov_1/procstatutil**
- U64 1 component_id
- U64 1826564 cpu0_user_raw
- U64 699631 cpu0_sys_raw
- U64 663843760 cpu0_idle_raw
- U64 201018 cpu0_iowait_raw

- **shuttle-cray.ran.sandia.gov_1/vmstat**
- U64 1 component_id
- U64 40008 nr_free_pages
- U64 122286 nr_inactive_anon
- U64 321902 nr_active_anon
- U64 465532 nr_inactive_file
- U64 424986 nr_active_file

- Metric sets:
  - (datatype, value, metricname) tuples
  - Associated with a unique component_id
- API:
  - *ldms_get_set,*
  - *ldms_get_metric ldms_get_u64*
- Same API for on-node and off-node (aggregator) transport

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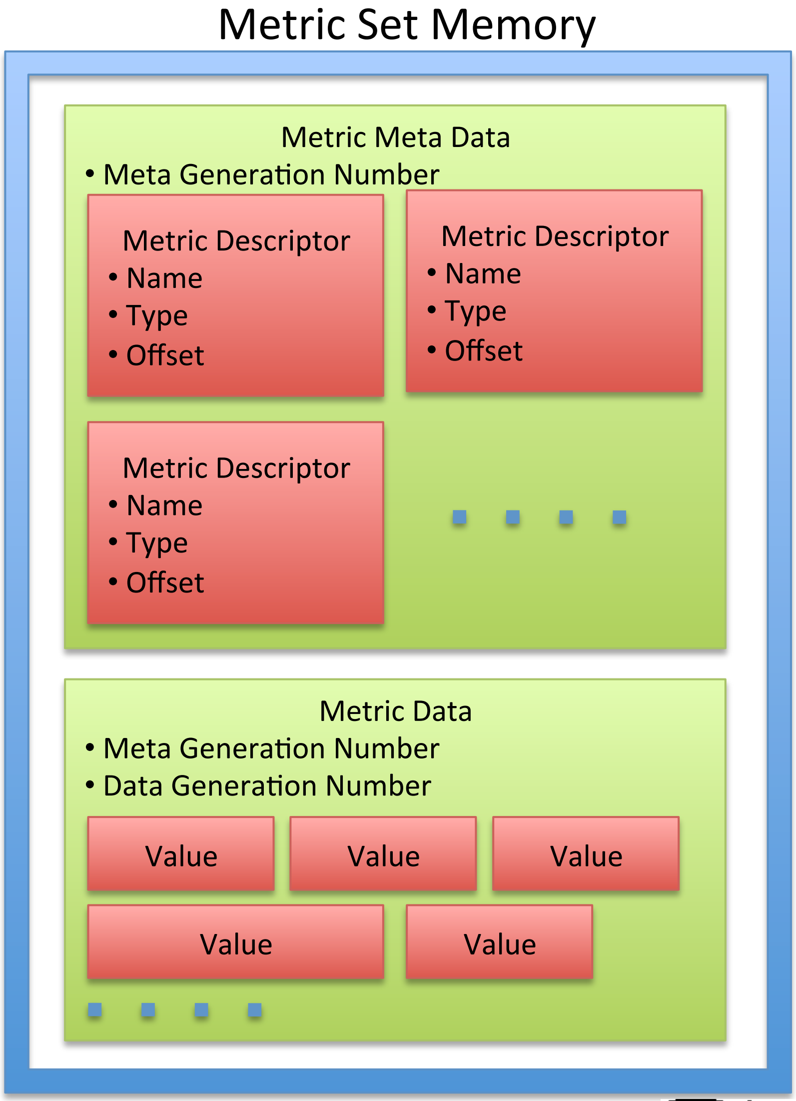
Metric Set Format

- Meta data generation number bumped whenever metrics are added or removed
- Data generation number changes whenever a value changes
- Meta data generation number is included with metric data to detect when cached local meta-data is stale

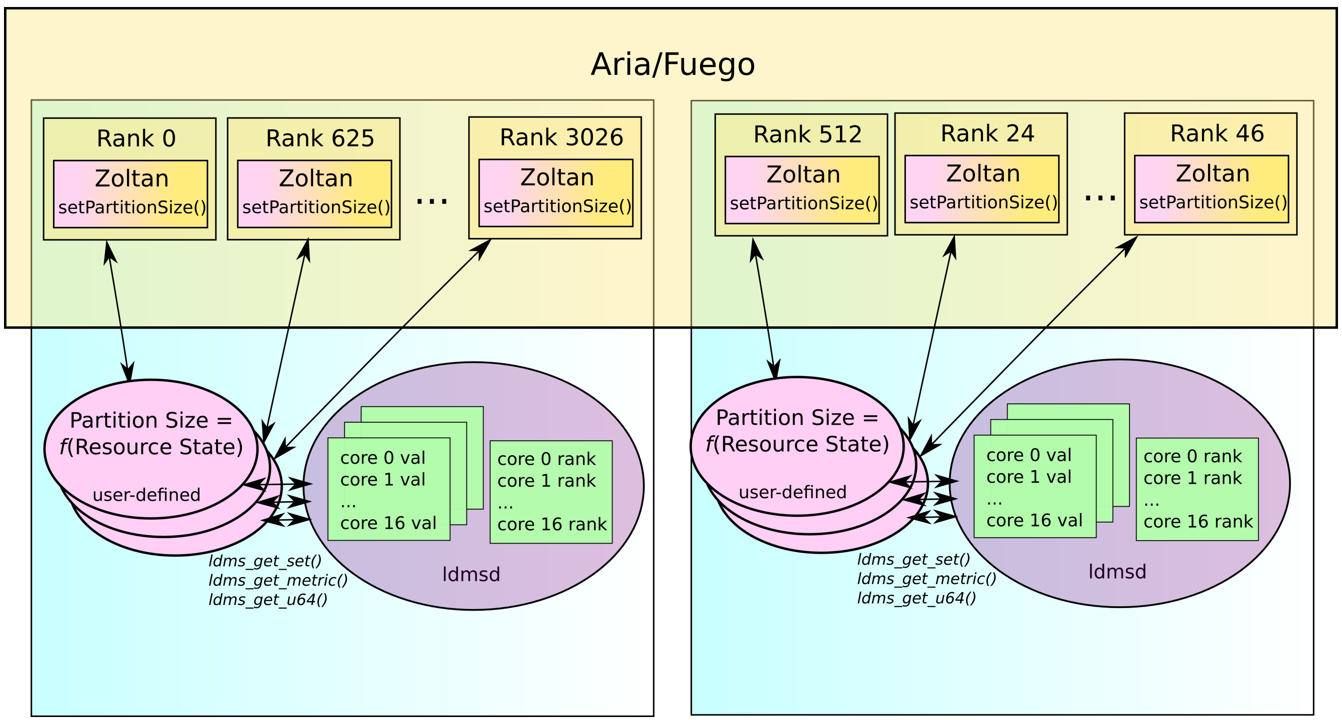


Current Data Collectors/Storage

- /proc
  - meminfo, vmstat, stat, interrupts, pid/(stat, statm)
  - Kgnilnd (Cray specific)
- gemctrs (Cray specifc)
  - Gemini Tile and NIC counters
- nicctrs (Cray specific)
  - Gemini NIC counters
- perf_event
  - Generic interface for acquisition of hardware counters e.g. data cache misses, instruction cache misses, hyper-transport bandwidth (AMD)
- rsyslog (Cray specific)
  - SEDC (RAS) and ALPS data
- Lmsensors (/sys)
  - Temperatures, fan speeds, voltages
- Flat File, MySQL, CSV, Custom

Case Study: Resource-Aware Application

- Performance of an application depends on capabilities of the hardware and system software resources and on how the application utilizes them.
- Assess the viability of enabling distributed HPC applications to utilize node level monitoring information to make run-time load balancing decisions.



- SIERRA Applications repartition using Zoltan
- Augment Zoltan to acquire and utilize data from LDMS
- Utilize remote analysis of data to determine metrics of interest

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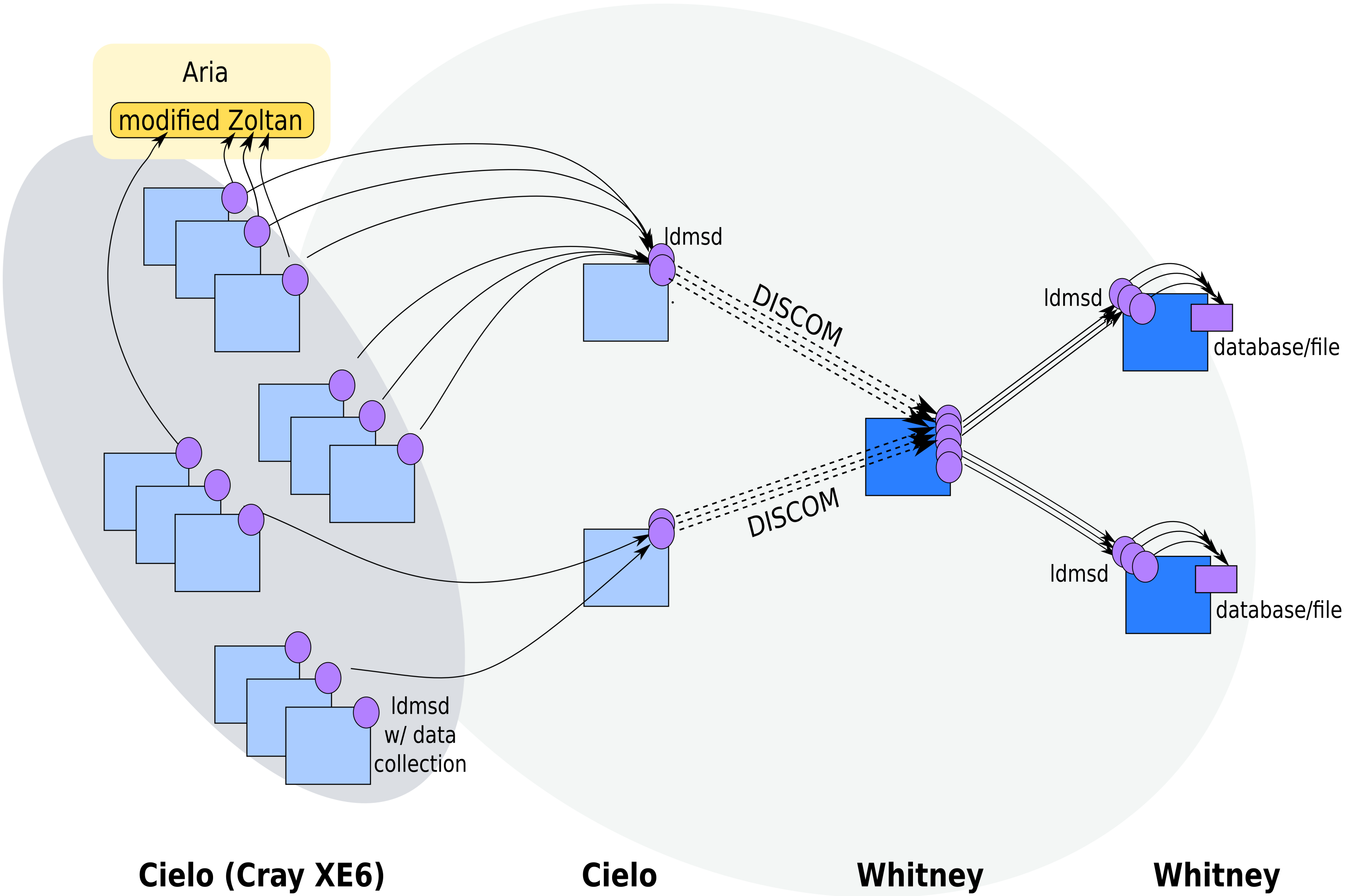
Architecture: LDMS on Cielo



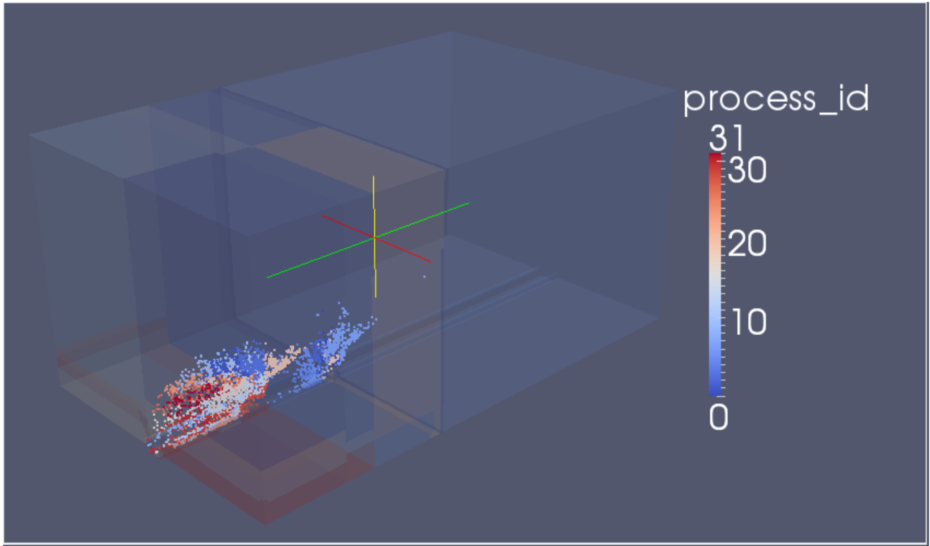
Cielo (Cray XE6)
compute nodes:
subset: 646 nodes, 10336 cores

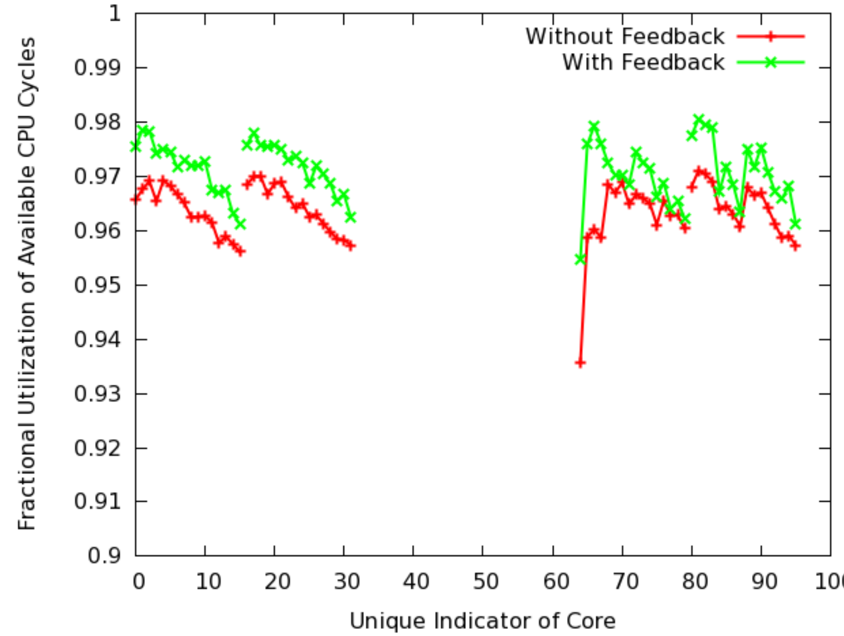
Cielo
viz nodes

Whitney
132

Whitney
admin nodes

Fuego





- Small scale dynamic application
- Particle transport results in load imbalance in changing partition size and location
- Include run-time CPU utilization in partitioning calculation
- Improvement over all processors (but well-balanced to begin with)

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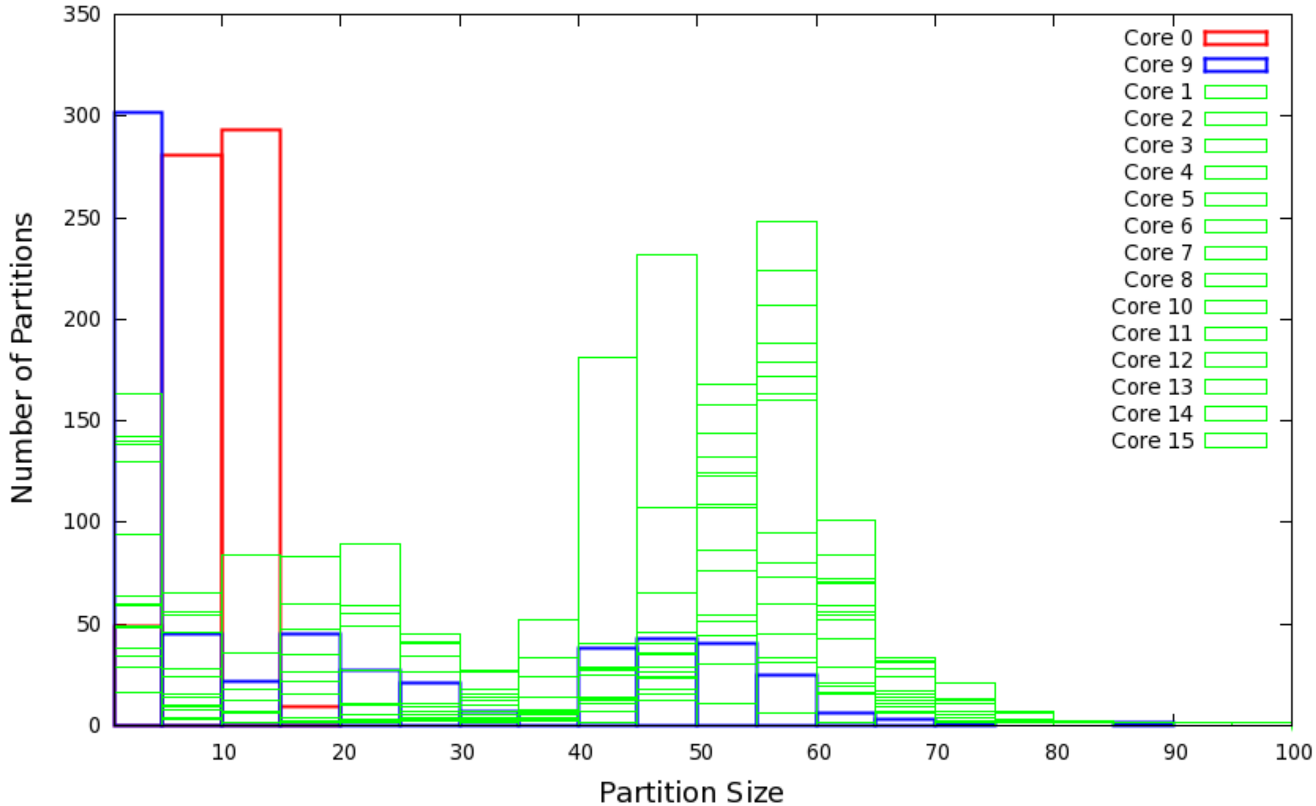
Aria on Cielo: 10112 processors



- Thermal code, generally well balanced
- Off-node post-processing analysis to determine variables of interest
- Processors 0 and 9 exhibit more non-voluntary context switches and interrupts and are assigned smaller partition sizes

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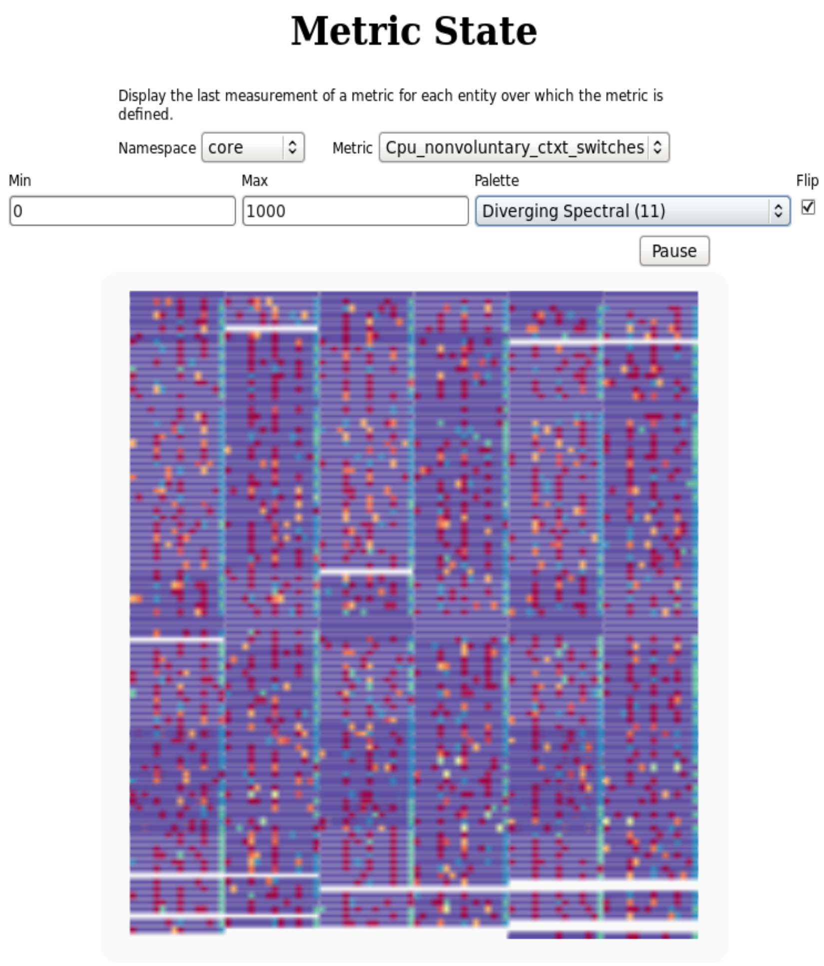
Non-Voluntary Context Switches



- From 8310 processor application run on Cray XE6

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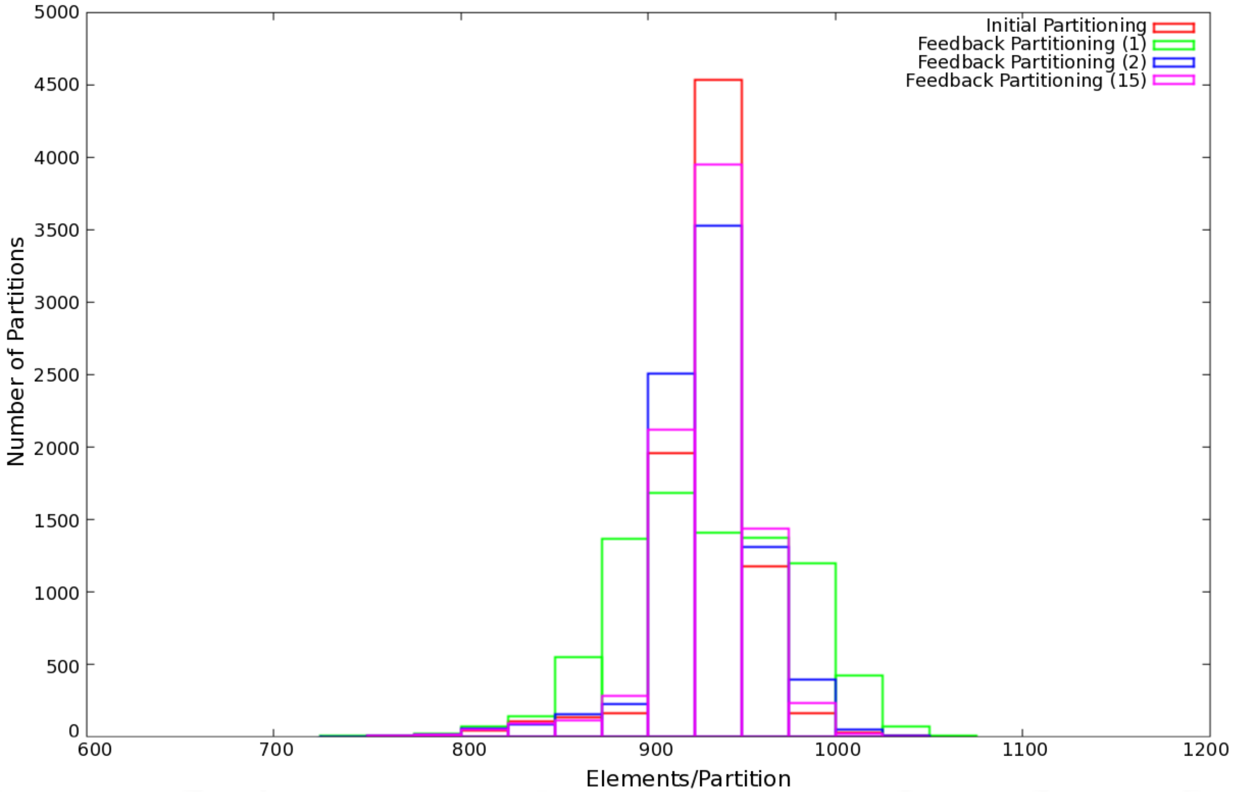
Aria on CDS: 8310 processors



- Processors with higher idle/user cycles are assigned larger partition sizes
- Self-correcting repartitioning: distribution tightens after initial over-correction for idle cycles

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Enhancements

- *ldmsd* plugin interface for collectors and storage
  - Single daemon
- Implemented RDMA over Gemini transport
  - CLE4.0 UP03 – Enabled allocation of System pTag

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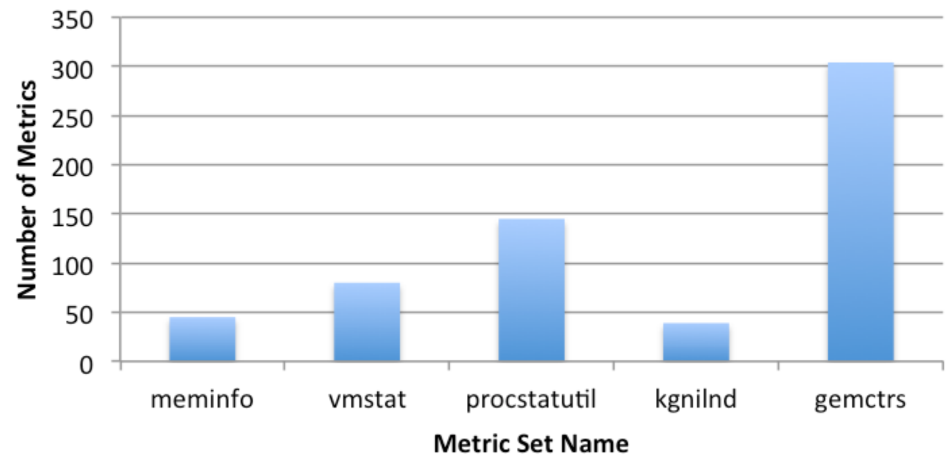
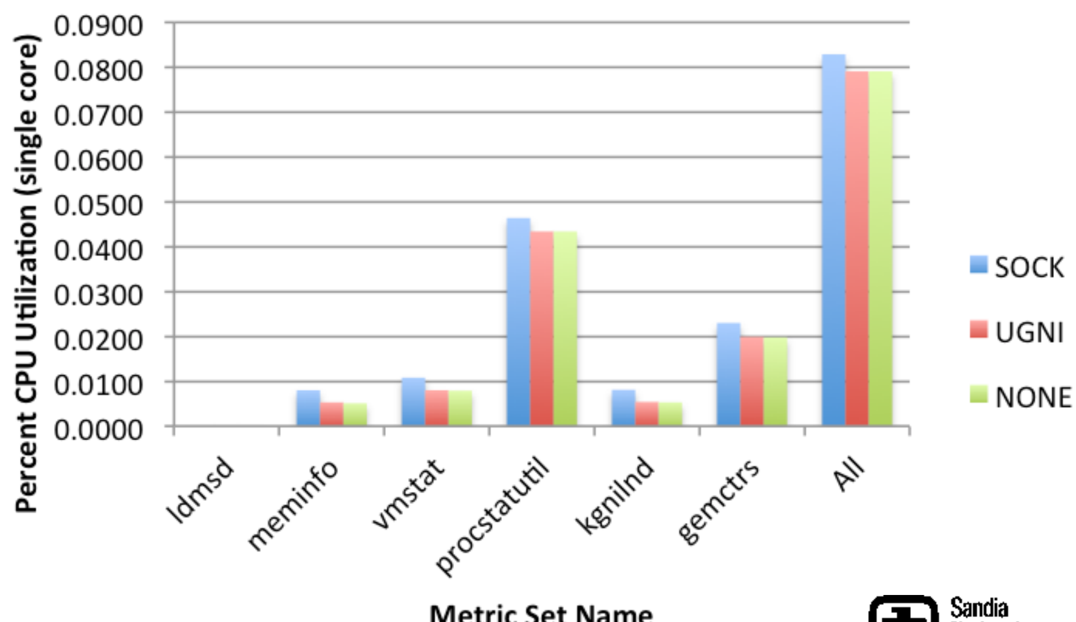
Overhead

Collection interval of 1 second

- CPU overhead increases with number of metrics in a metric set for a particular gathering mechanism (e.g. /proc readers, /sys readers, ioctl calls)
- gemctrs – `ioctl` as opposed to reading from /proc. gemctrs with ~300 metrics has < 1/3rd the overhead of procstatutil but has ~twice the number of metrics





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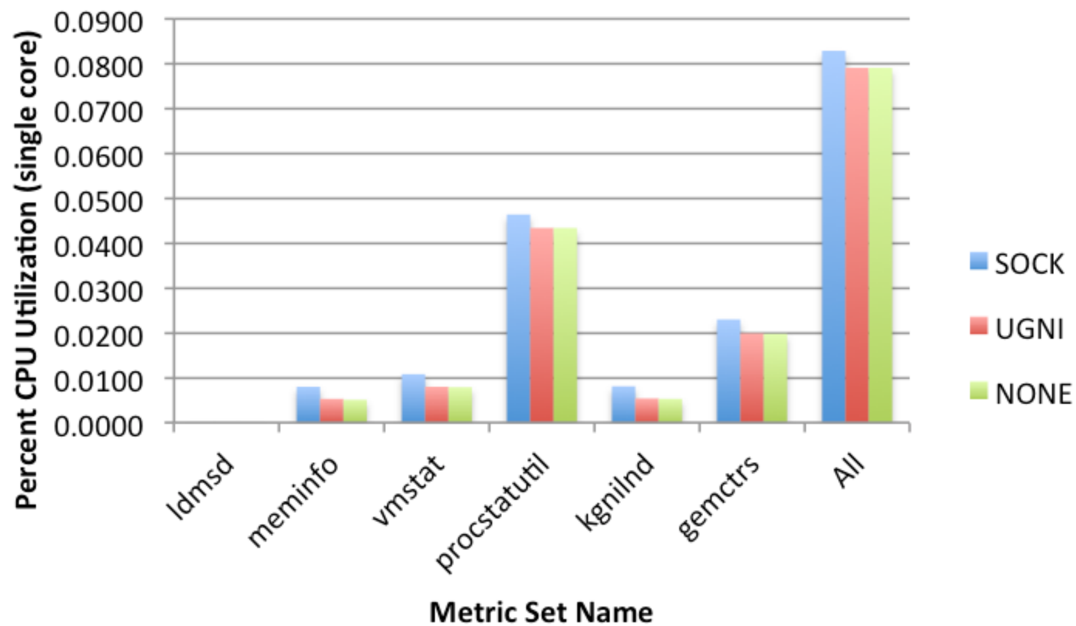
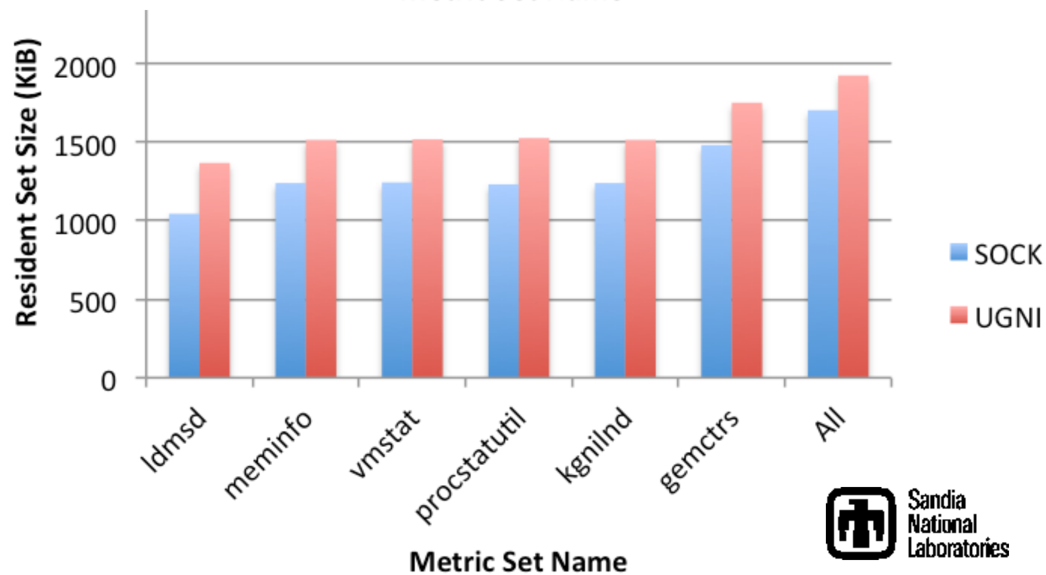
Overhead Summary

CPU Overhead
- Mostly due to data collection vs. transport
- RDMA (UGNI) has none past startup
- SOCK significant if collection overhead is small (e.g. small dataset)



Memory Footprint
- RDMA has a larger memory footprint than SOCK
- Except for `gemctrs`, sampler overhead, over *ldmsd* alone, is about the same



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Summary

- Lightweight Distributed Metric Service:
  - System service that provides low-overhead remote storage of and on-node access to high-fidelity system related data
- Demonstrated viability for use in analysis and runtime repartitioning of production HPC applications on XE6
- Lowest overhead: efficiently gather small set of targeted data of interest and use RDMA for transport
- Adding collector plugins doesn't substantially increase memory footprint (e.g. only increase is data + metadata + accounting)

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Future Work

- Investigate perturbation to large scale applications
  - Priority
  - Kernel collection modules
  - Metric set size
- Presentation of LDMS data in architectural context:
  - Inter-node congestion
  - Intra-node memory bandwidth sharing

Questions?