Large Scale System Monitoring and Analysis on Blue Waters Using OVIS

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Outline

- Motivation for Continuous Whole System Monitoring
- Data of Interest
- Monitoring Requirements
- Overview of OVIS Data Collection and Transport
- Enhancements to Meet Requirements
- Application Impact Testing & Results
- A Look at the Data
- Conclusions & Future Work

Motivation

Gain insight into resource utilization/bottlenecks (e.g. network bandwidth/hotspots, file system utilization/contention, memory utilization)

- Debugging
- Anomaly detection
- Historical comparison
- Intelligent job placement

Data of Interest

- High Speed Network Performance Counters
  - Traffic
  - Contention
  - Link Status
- Lustre File System Statistics
- LNet traffic
- CPU load
- Memory being used

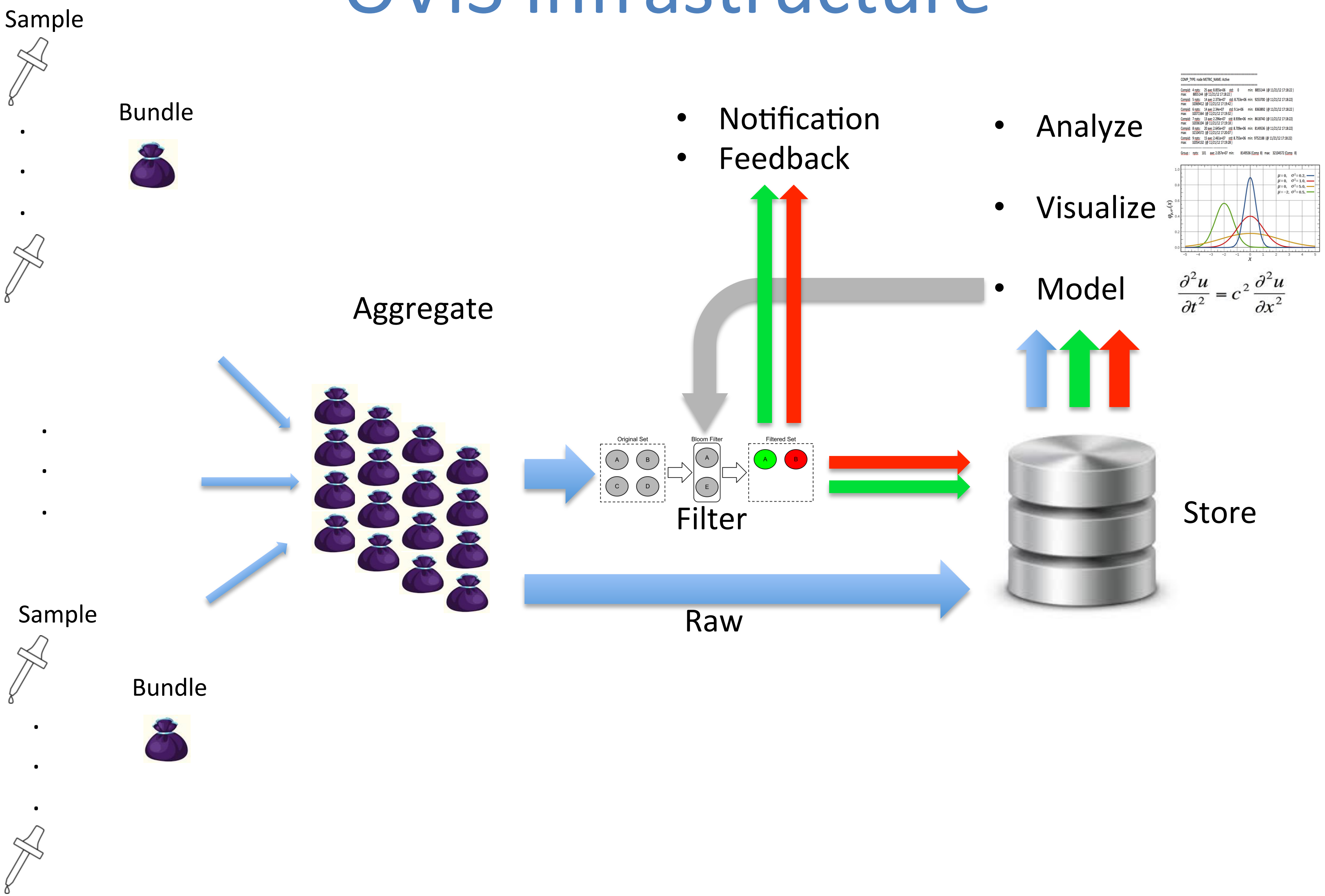
Blue Waters Monitoring Requirements

- Need to collect High Speed Network performance metrics to understand network contention and impact on applications
- Would like to collect at one minute intervals
- All data collection synchronized to provide "snapshots" of the system
- Quantify monitoring impact on large scale applications

OVIS Functional Components

- Lightweight Distributed Metric Service (LDMS)
  - Sample, aggregate, transport, and store data
- Analysis
- Modeling
- Visualization
- Notification and Feedback

OVIS Infrastructure



Sample

Bundle

Sample

Bundle

Aggregate

Filter

Raw

Store

- Notification
- Feedback

- Analyze

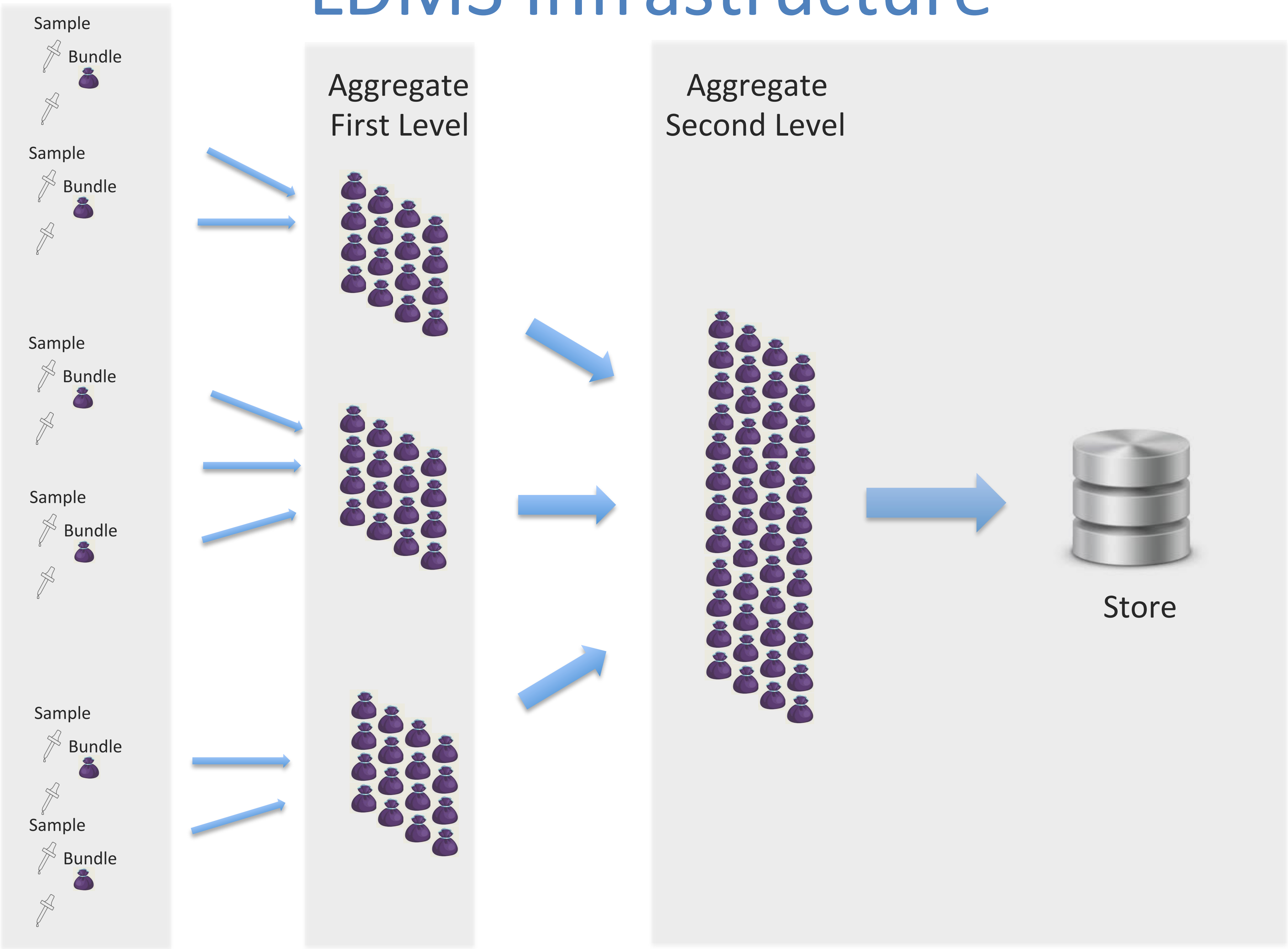
```
===================================================
COMP_TYPE: node METRIC_NAME: Active
===================================================
Compid:  4 npts:    25 ave: 8.855e+06    std:    0          min:  8855144  (@ 11/21/12 17:18:22 )
max:      8855144  (@ 11/21/12 17:18:22 )
Compid:  5 npts:    14 ave: 2.373e+07    std: 8.753e+06 min:  9253700  (@ 11/21/12 17:18:22)
max:     32069412  (@ 11/21/12 17:19:42 )
Compid:  6 npts:    14 ave: 2.34e+07     std: 9.1e+06     min:  8363892  (@ 11/21/12 17:18:22 )
max:     32071564  (@ 11/21/12 17:19:32 )
Compid:  7 npts:    13 ave: 2.296e+07    std: 8.939e+06  min:  8618740  (@ 11/21/12 17:18:22)
max:     32036104  (@ 11/21/12 17:19:18 )
Compid:  8 npts:    20 ave: 2.645e+07    std: 8.709e+06  min:  8149536  (@ 11/21/12 17:18:22)
max:     32104572  (@ 11/21/12 17:20:07 )
Compid:  9 npts:    15 ave: 2.461e+07    std: 8.755e+06  min:  9752188  (@ 11/21/12 17:18:22)
max:     32054132  (@ 11/21/12 17:19:28 )
------------------- ---------- ------------
Group :   npts:    101    ave: 2.057e+07  min:      8149536 (Comp  8)   max:   32104572 (Comp  8)
```

- Visualize

- Model

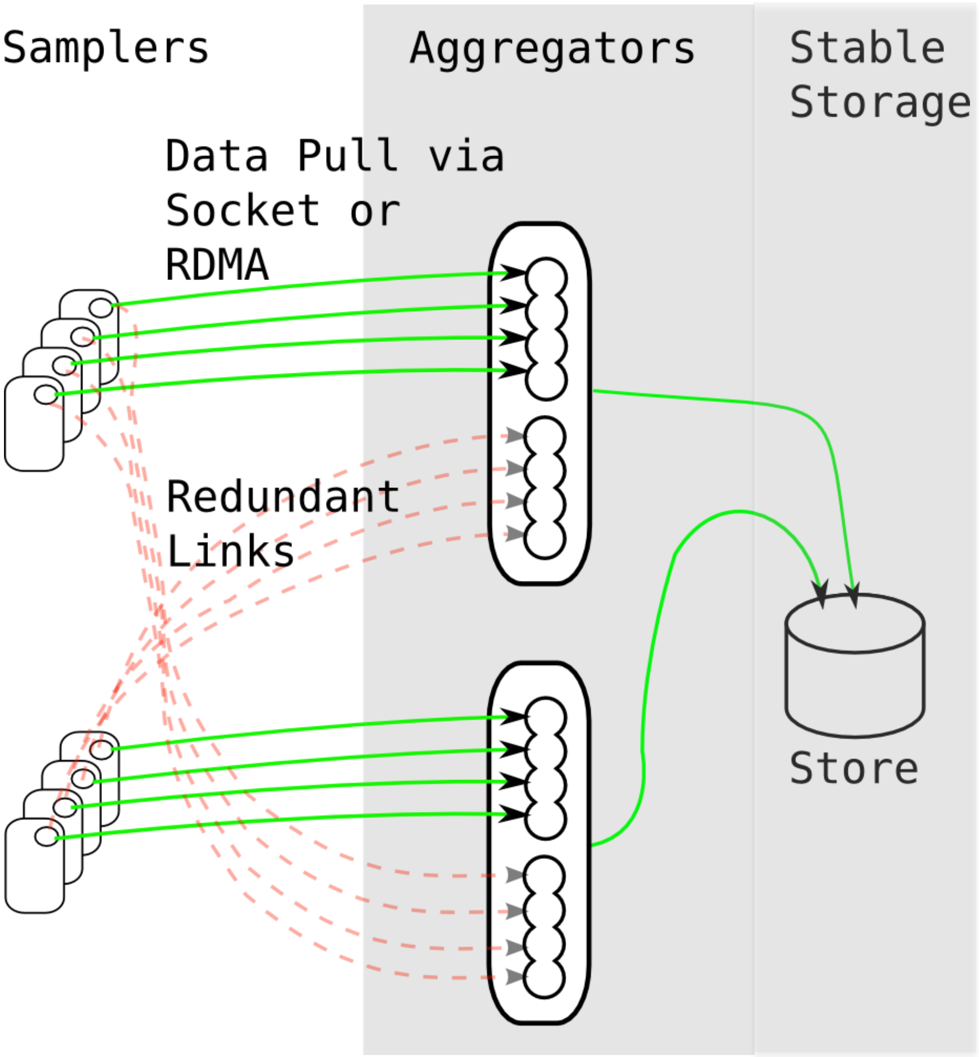
$$\frac{\partial^2 u}{\partial t^2} = c^2 \frac{\partial^2 u}{\partial x^2}$$

LDMS Infrastructure



Generic LDMS Configuration

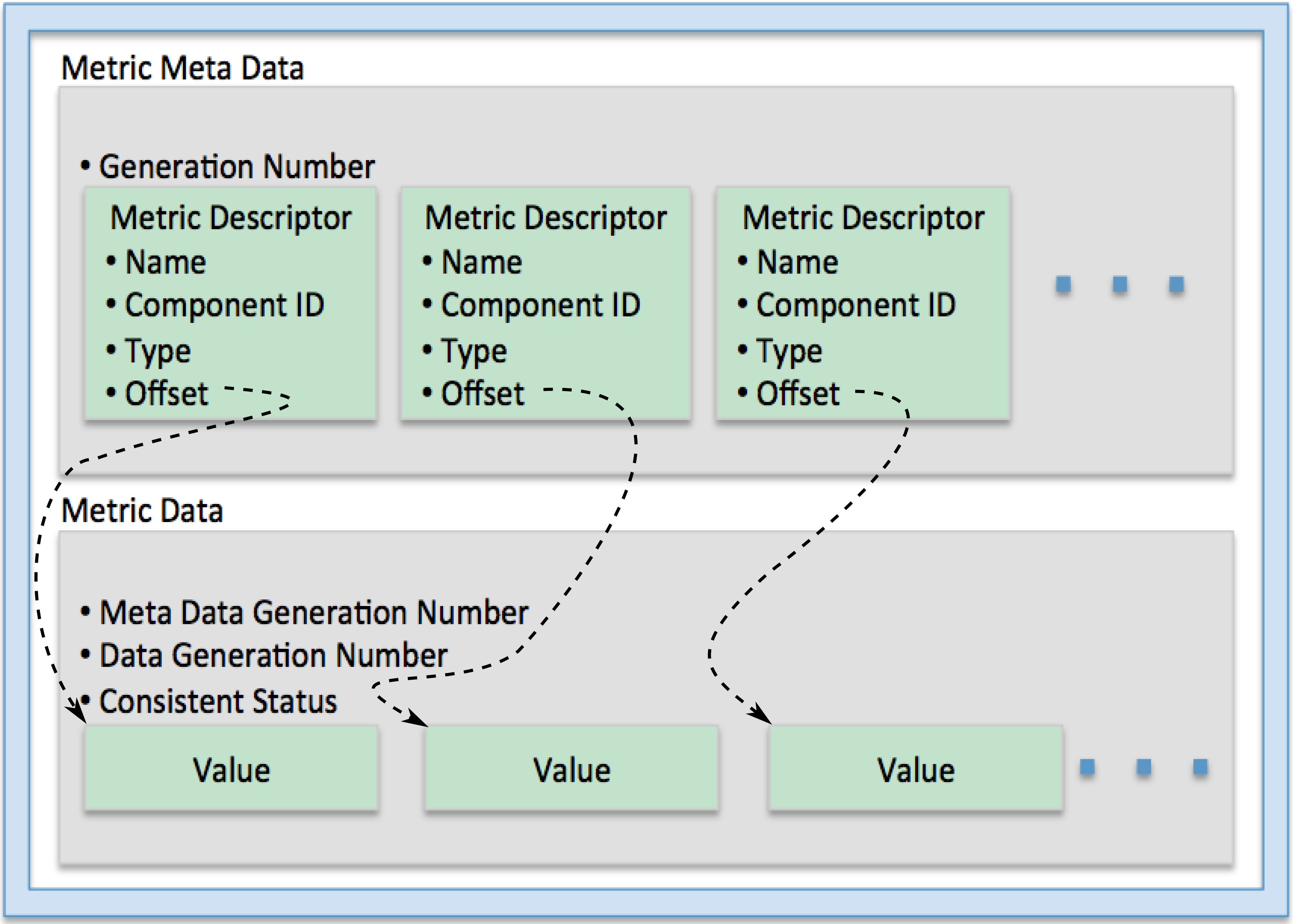
- Samplers collect data and bundle into metric sets
- Aggregators pull metric set data from Samplers over Socket or RDMA connections
  - Redundant inactive links can be defined for fast failover
- Aggregators can be daisy chained to provide hierarchy and/or network transition
- Aggregators can load storage plugins and push data to stable storage in a variety of formats



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
- RDMA over Gemini transport is utilized for Blue Waters

Metric Set Memory



Metric Meta Data

- Generation Number

Metric Descriptor

- Name
- Component ID
- Type
- Offset

Metric Descriptor

- Name
- Component ID
- Type
- Offset

Metric Descriptor

- Name
- Component ID
- Type
- Offset

Metric Data

- Meta Data Generation Number
- Data Generation Number
- Consistent Status

Value

Value

Value

LDMS metric set Example (meta data)

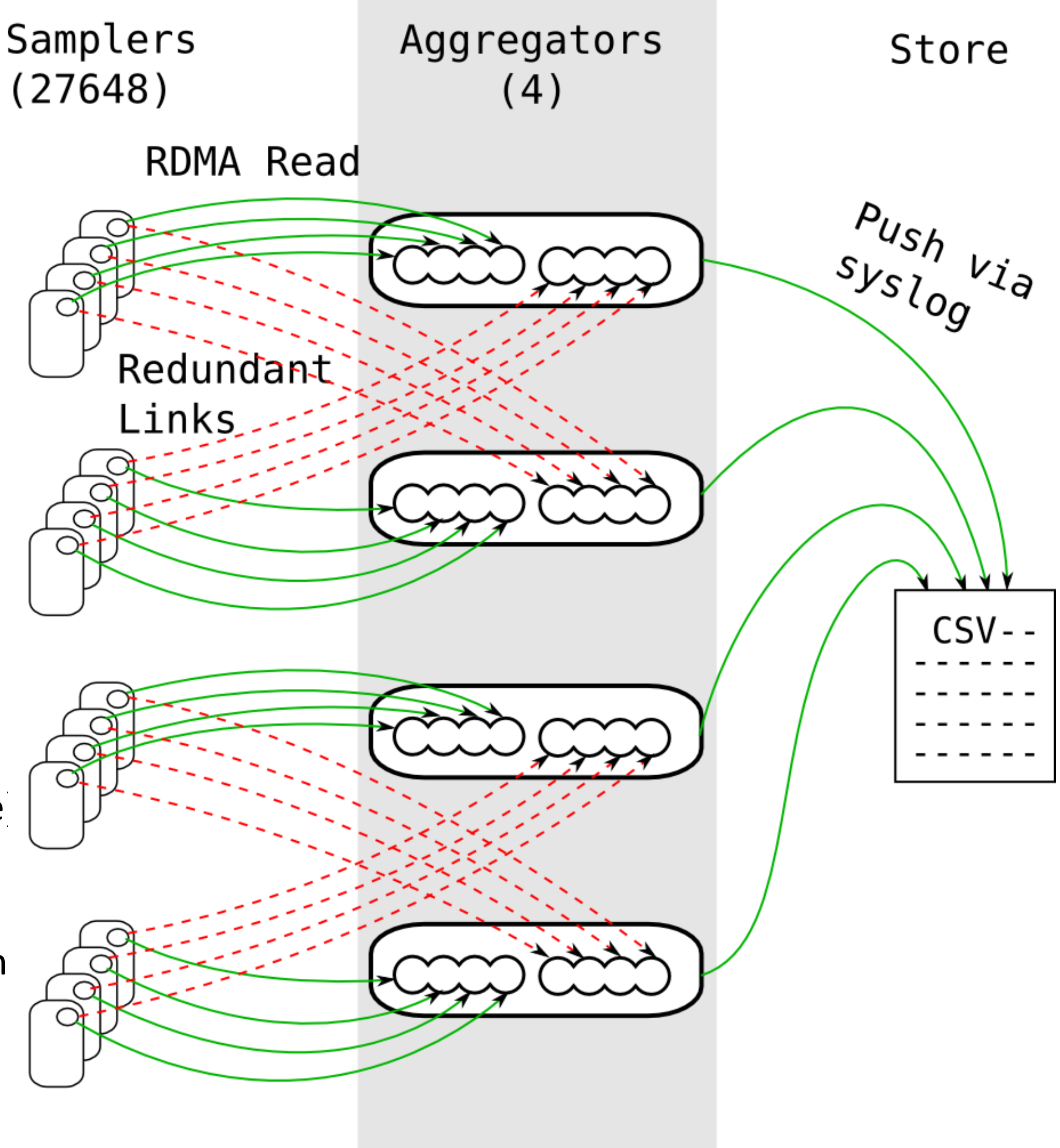
```
# ldms_ls -h nid00044 -x ugni -p 412 -v
nid00044/cray_system_sampler_r: consistent, last update: Wed Apr 09 08:55:20
2014 [727us]
  METADATA --------
           Size : 13560
          Inuse : 7144
   Metric Count : 130
             GN : 131
  DATA ------------
      Timestamp : Wed Apr 09 08:55:20 2014 [727us]
     Consistent : TRUE
           Size : 1088
          Inuse : 1088
             GN : 1735
  -----------------
```

LDMS metric set Example (data)

```
# ldms_ls -h nid00044 -x ugni -p 412 -l
nid00044/cray_system_sampler_r: consistent, last update: Wed Apr 09 08:52:40 2014 [726us]
 U64 1              nettopo_mesh_coord_X
 U64 1              nettopo_mesh_coord_Y
 U64 6              nettopo_mesh_coord_Z
 U64 3265901109447    X-_traffic (B)
 U64 21509840670687   Y-_traffic (B)
 U64 53884897461291   Z+_traffic (B)
  U64 89887627257      X-_packets (1)
 U64 475674895649     Y-_packets (1)
 U64 1333216704813    Z+_packets (1)
 U64 40775903446      X-_inq_stall (ns)
 U64 711117651410     Y-_inq_stall (ns)
 U64 544039347642     Z+_inq_stall (ns)
 U64 48              X-_sendlinkstatus (1)
 U64 24              Y-_sendlinkstatus (1)
 U64 24              Z+_sendlinkstatus (1)
  U64 191              X-_SAMPLE_GEMINI_LINK_BW (B/s)
 U64 306              Y-_SAMPLE_GEMINI_LINK_BW (B/s)
 U64 344              Z+_SAMPLE_GEMINI_LINK_BW (B/s)
 U64 1              X-_SAMPLE_GEMINI_LINK_USED_BW (% x10e6)
 U64 2              Y-_SAMPLE_GEMINI_LINK_USED_BW (% x10e6)
 U64 2              Z+_SAMPLE_GEMINI_LINK_USED_BW (% x10e6)
 U64 19              X-_SAMPLE_GEMINI_LINK_PACKETSIZE_AVE (B)
 U64 19              Y-_SAMPLE_GEMINI_LINK_PACKETSIZE_AVE (B)
 U64 19              Z+_SAMPLE_GEMINI_LINK_PACKETSIZE_AVE (B)
 U64 0              X-_SAMPLE_GEMINI_LINK_INQ_STALL (% x10e6)
 U64 0              Y-_SAMPLE_GEMINI_LINK_INQ_STALL (% x10e6)
 U64 0              Z+_SAMPLE_GEMINI_LINK_INQ_STALL (% x10e6)
 U64 13071017859520   totaloutput_optA
 U64 1551040415605    read_bytes#stats.snx11024
 U64 111681033094     write_bytes#stats.snx11024
 U64 33185713        open#stats.snx11024
 U64 33459578        close#stats.snx11024
  U64 200              loadavg_latest(x100)
 U64 203              loadavg_5min(x100)
 U64 2              loadavg_running_processes
 U64 217              loadavg_total_processes
 U64 32069868        current_freemem
 U64 180128670       SMSG_ntx
 U64 84138092941      SMSG_tx_bytes
 U64 179201767       SMSG_nrx
 U64 62591572089      SMSG_rx_bytes
 U64 2463841         RDMA_ntx
 U64 166910425701     RDMA_tx_bytes
 U64 5995457         RDMA_nrx
 U64 265128956892     RDMA_rx_bytes
 U64 207633071910     ipogif0_rx_bytes
 U64 116299863623     ipogif0_tx_bytes
```

Blue Waters Configuration

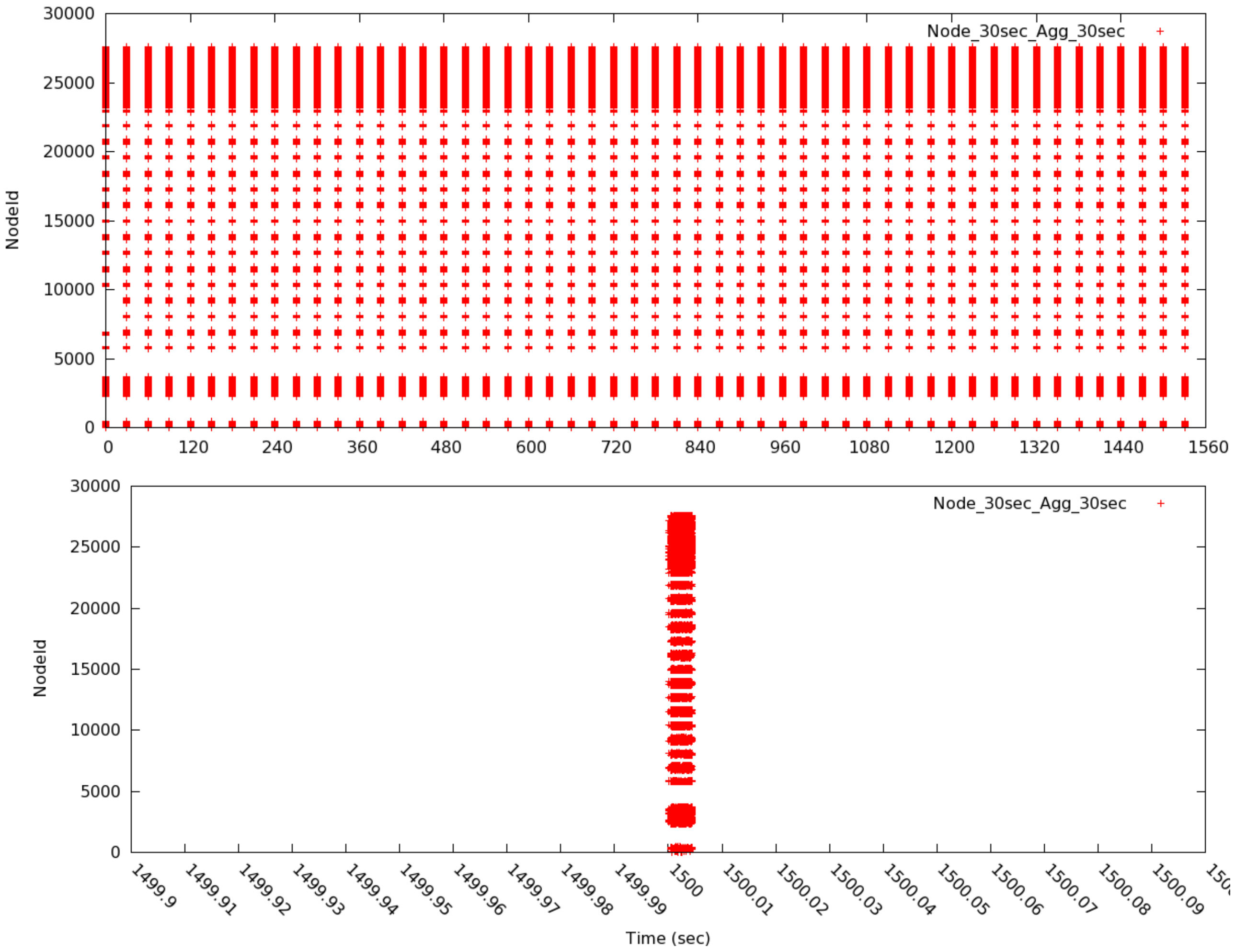
- All metric sets identical independent of node
  - 194 metrics
- Sample period
  - 60 seconds (normal)
  - 1 second (high)
- Each aggregator primary for 6912 nodes
  - Pull model using RDMA read
- Each aggregator secondary for 6912 nodes
  - RDMA connection established
- In event of failover aggregator collects from 13824 nodes
- Data is pushed to store (MySQL database using syslog-ng
- One day data set for 60 second collection period contains ~35 million data points per metric and 6.8 billion data points overall



Blue Waters Related Enhancements

- Synchronization
- Minimize Image Footprint
- Node type independent metric set
- Single Metric Set
  - Single Time Attribution
- Storage
  - CSV
  - Split sec and fraction with comma

Synchronous Collection



Synchronized collection across all nodes:

- Enables a coherent system snapshot

Asynchronous option spreads network load

Synchronous:

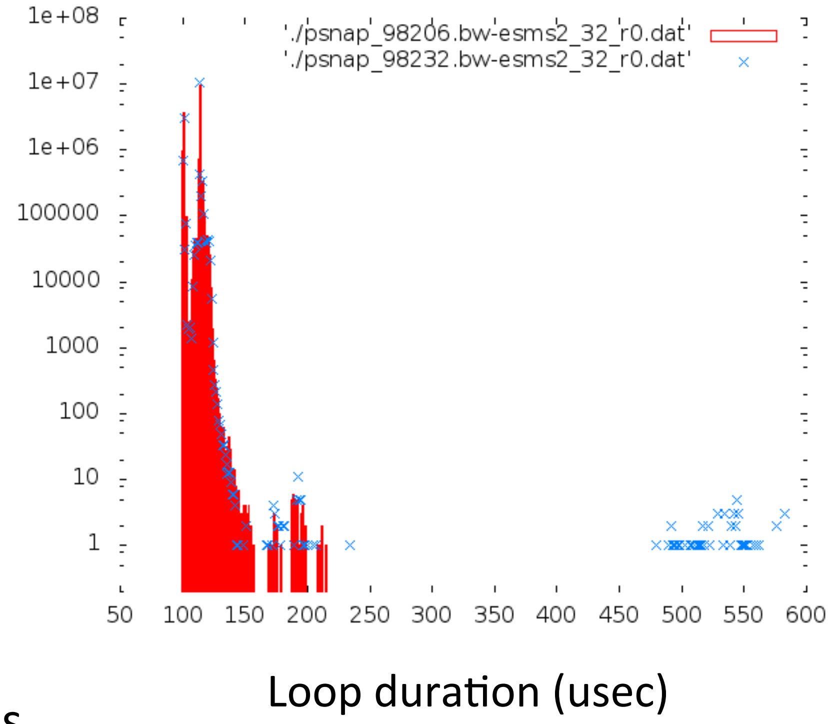
- Variance in collection timestamps ~ 4ms

Note: Clock skew not accounted for

Collection occurrences over 10000 nodes on Blue Waters

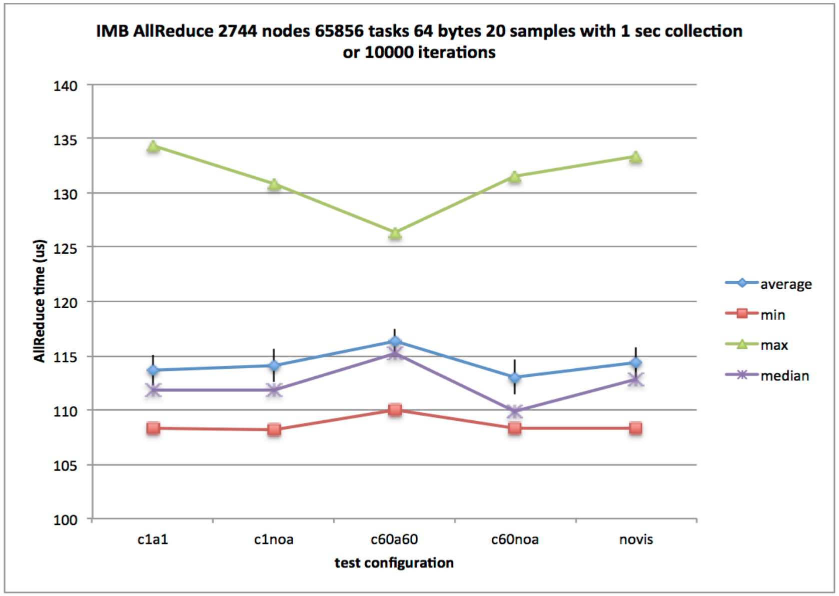
Impact Testing: Benchmarks

- PSNAP
  - No sampling (red)
  - 1 sec sampling (blue)
  - 60/16M points shifted by sampling time of ~450 usec
  - *Effect on app mitigated by synchronized sampling*
- Cray’s LinkTest
  - 10,000 iterations of 8kB messages.
  - The no sampling result is 1.7427 msec/packet
  - Sampling result is 20 nanoseconds shorter
  - *No statistical significance*



Impact Testing: Applications

- Intel MPI Benchmark
  - *No correlation of performance with sampling*
- MILC
  - 2774 node run 50 steps
  - 5 phases + Step time
  - *No statistically significant impact*



MILC/ CG	novis	c60noa	c60a60	c1noa	c1a1
Ave	5.20e-3	5.21e-3	5.20e-3	5.20e-3	5.19e-3
Min	5.00e-3	5.20e-3	5.00e-3	5.01e-3	5.00e-3
Max	5.43e-3	5.44e-3	5.44e-3	5.45e-3	5.41e-3

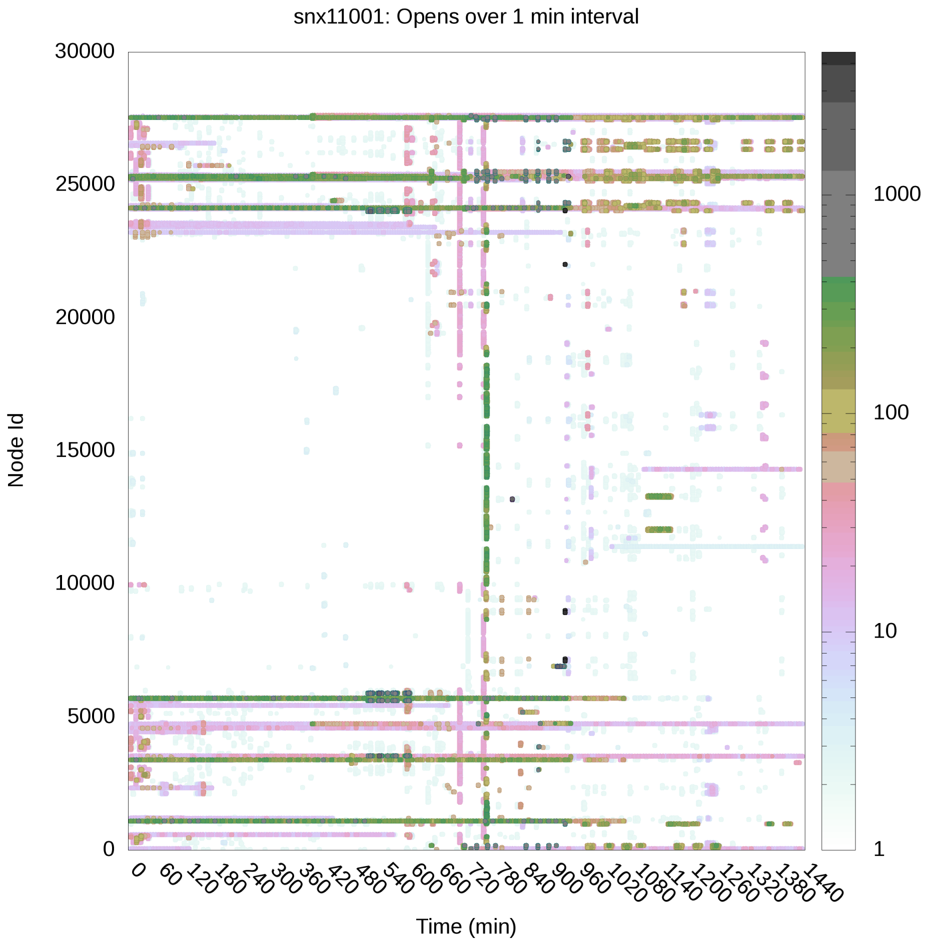
Impact Testing: Applications

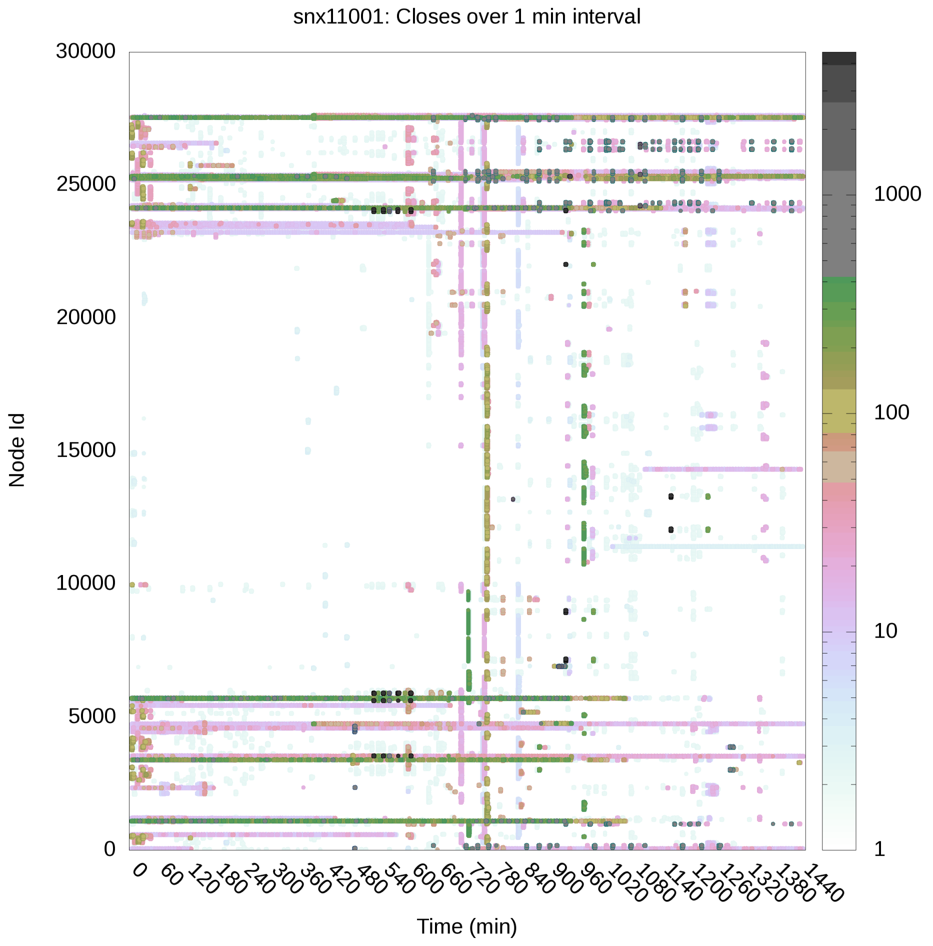
- SNL MiniGhost
  - Instrumented for runtime, communication time, time which includes the barrier
  - 8192 nodes, 3 reps
  - *No statistically significant impact*

Total Runtime	novis	c1a1
Rep1	98.5	92.3
Rep2	95.3	90.2
Rep3	91.8	90.8

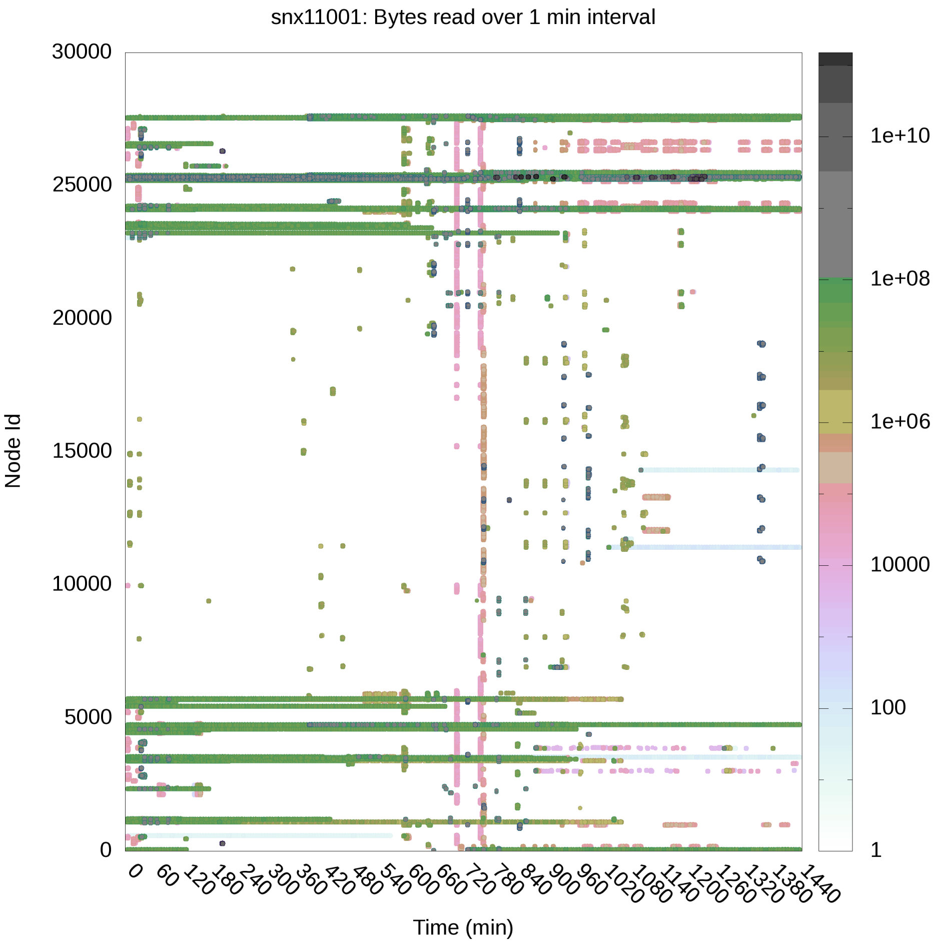
A Look at the Data

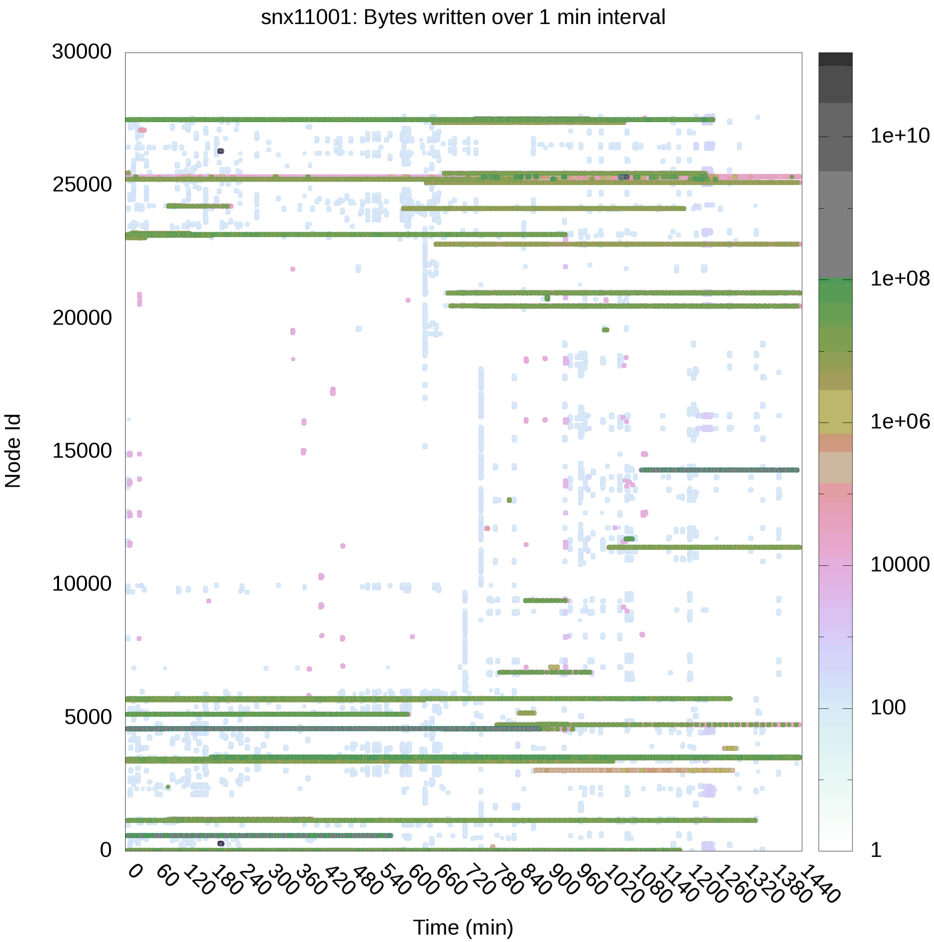
Lustre Opens/Closes





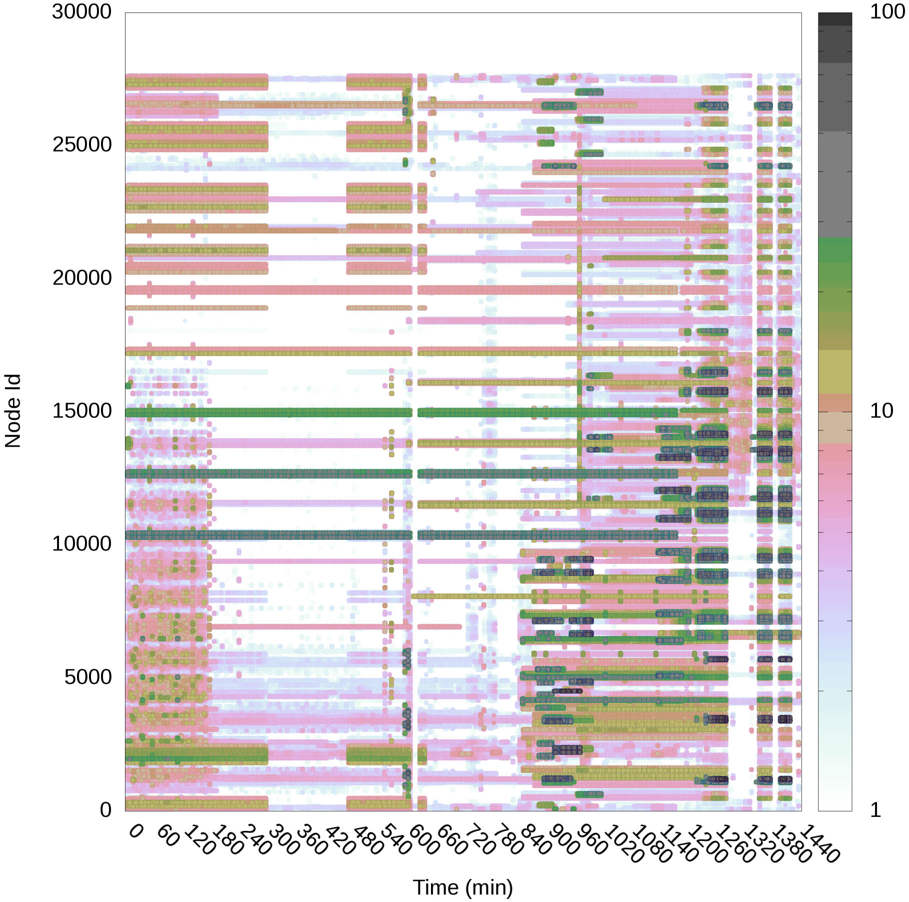
Lustre Reads/Writes



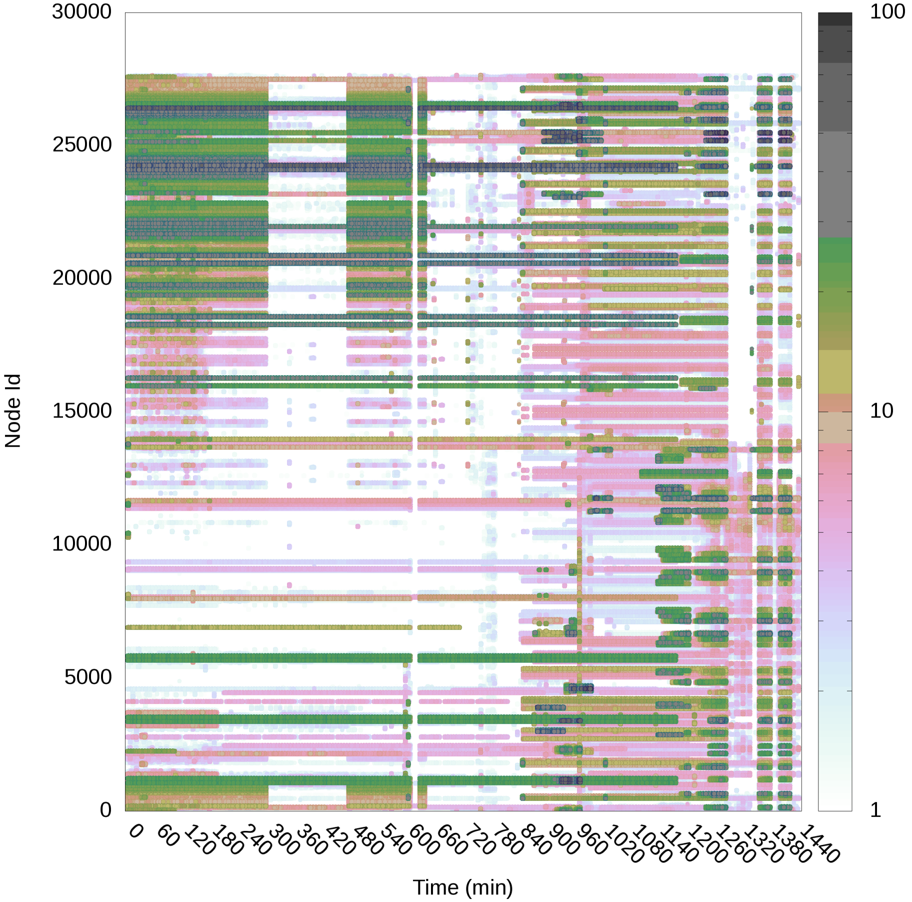


HSN Output Stalls (X)

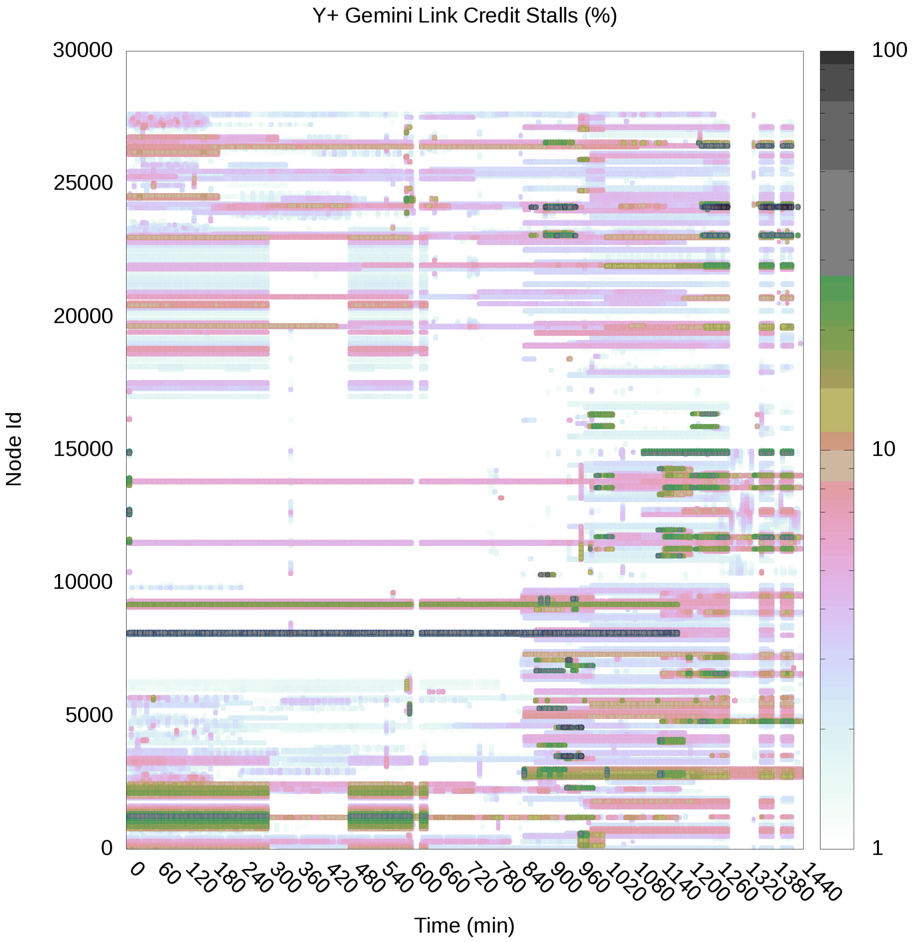
X+ Gemini Link Credit Stalls (%)

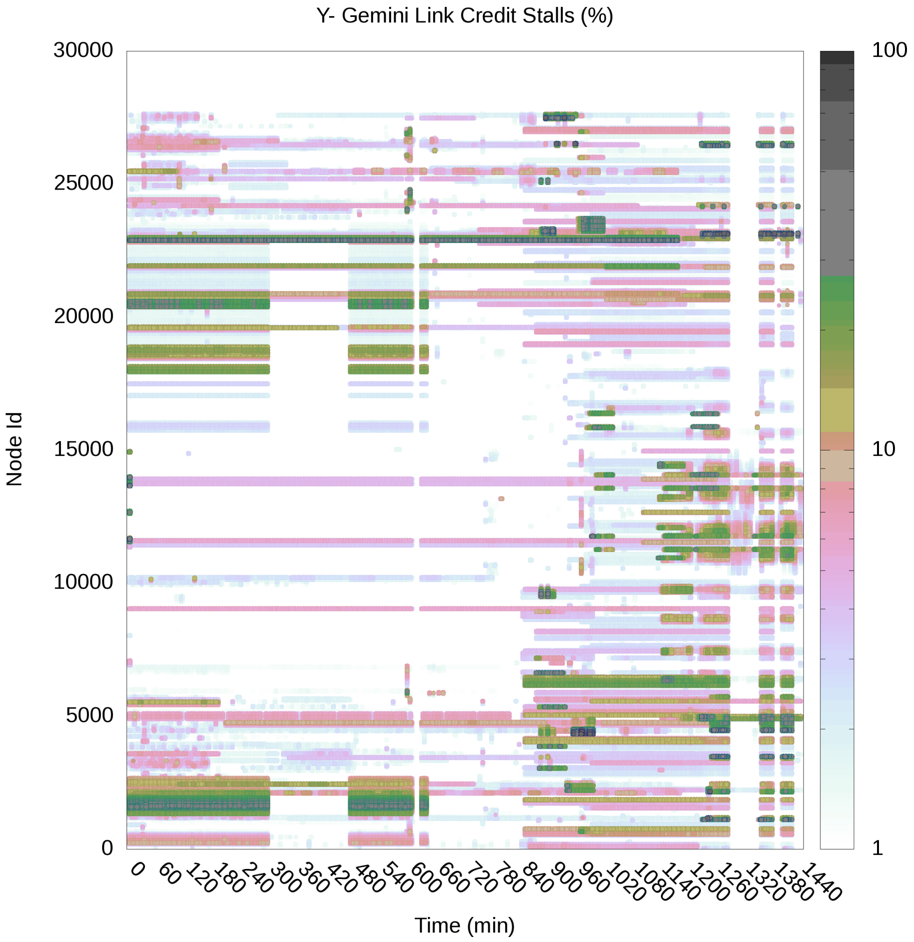


X- Gemini Link Credit Stalls (%)

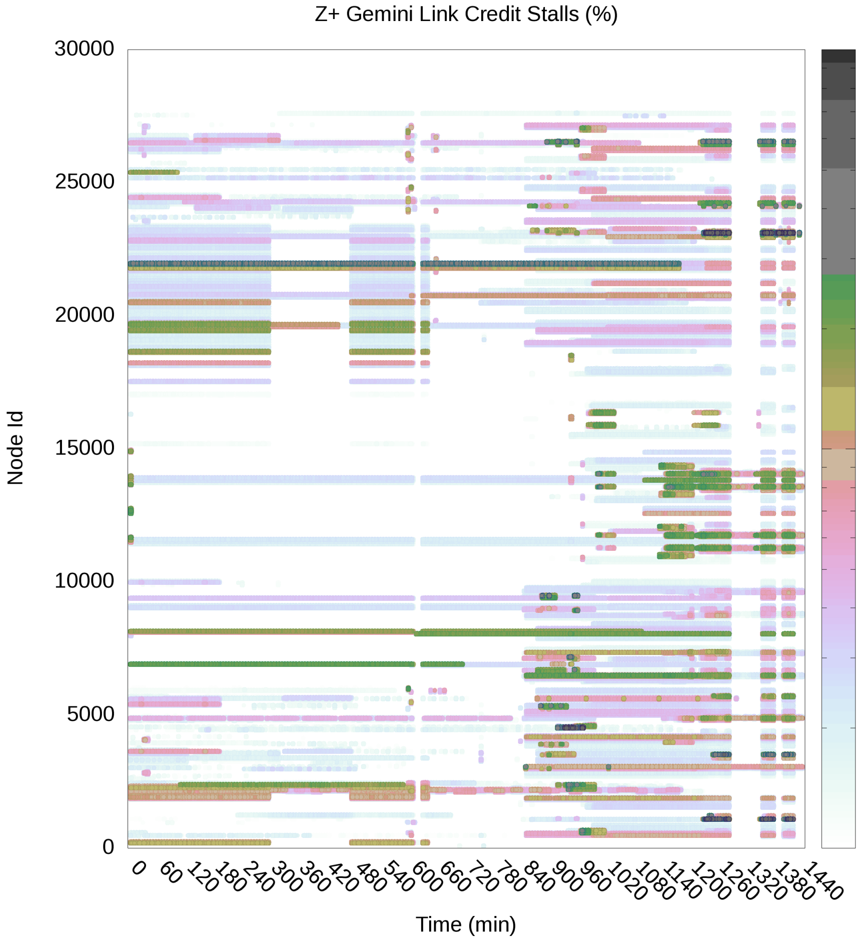


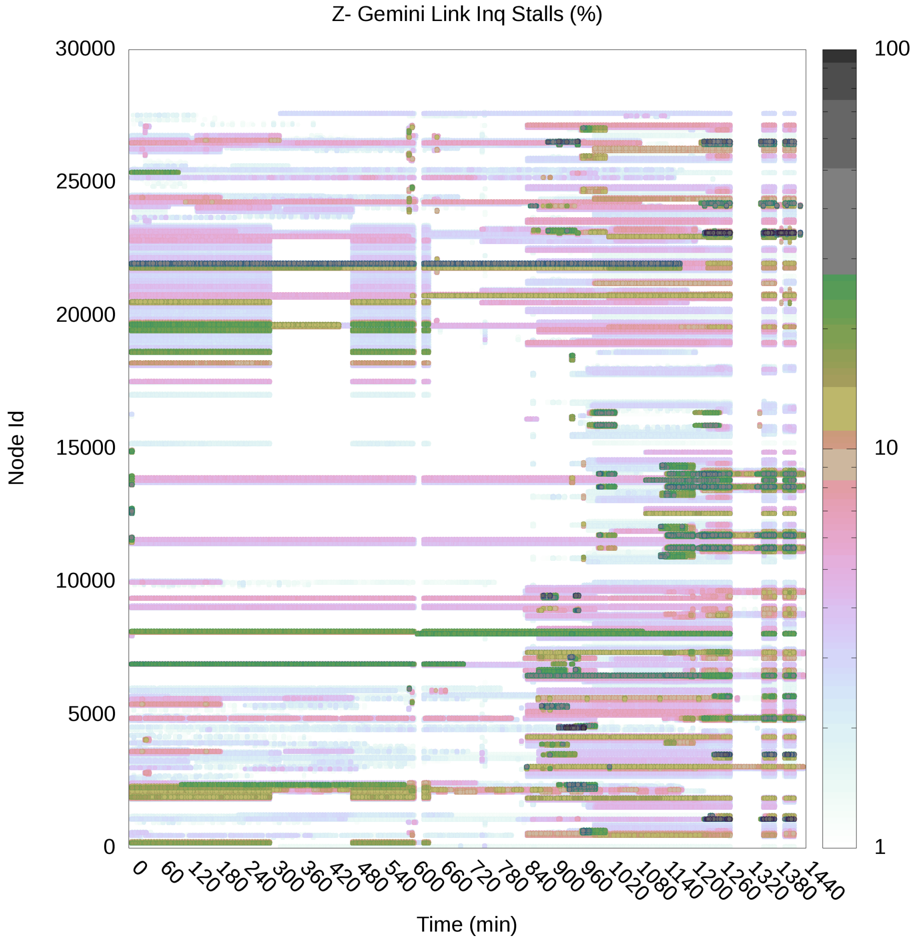
HSN Output Stalls (Y)


Y+ Gemini Link Credit Stalls (%)

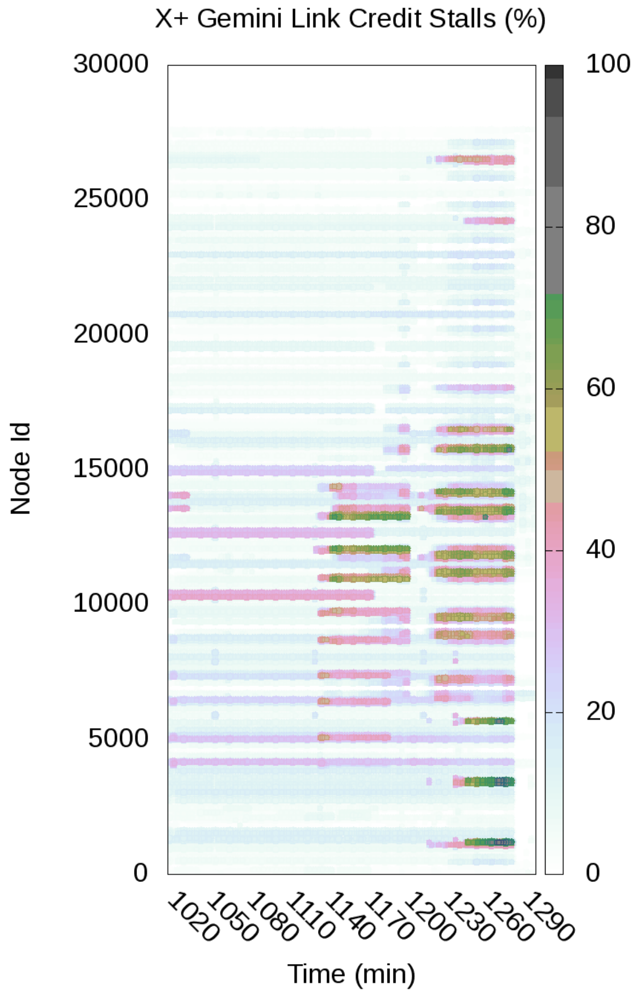

Y- Gemini Link Credit Stalls (%)

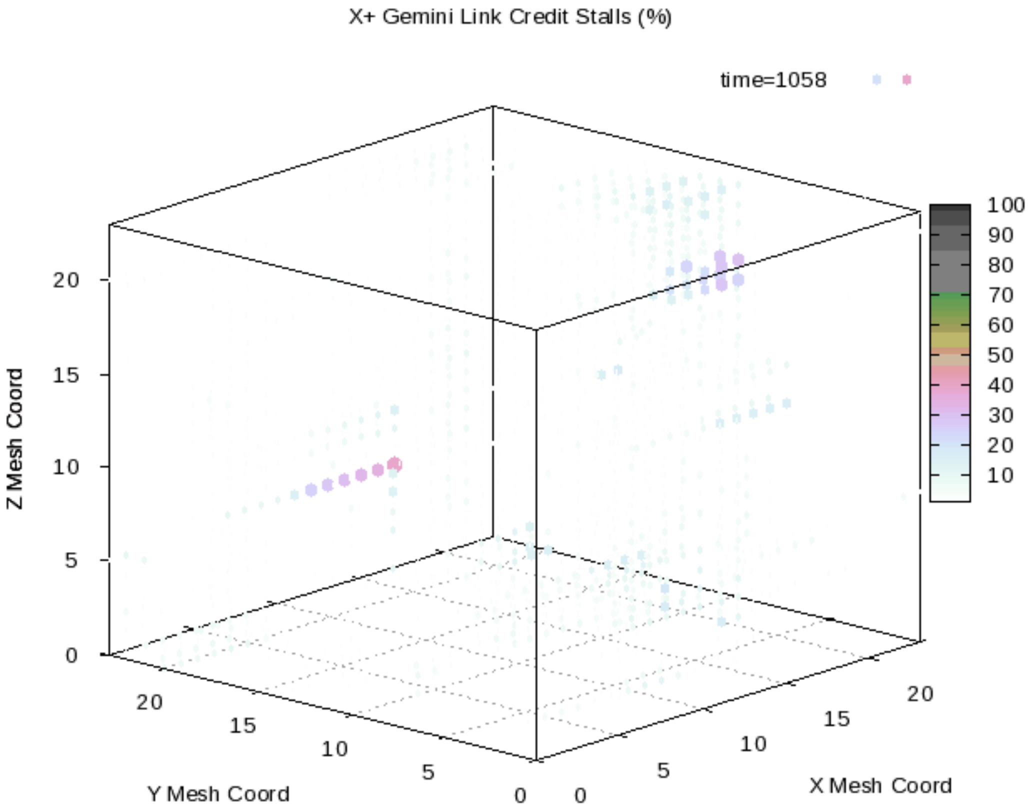
HSN Output Stalls (Z)


Z+ Gemini Link Credit Stalls (%)


Z- Gemini Link Inq Stalls (%)

Mesh Topology Representation
Animation: 4 hrs @ 1059





Conclusions

- The OVIS data collection, transport, and storage infrastructure provides scalable whole system data access with no statistically significant adverse impact to applications
- Whole system snapshots of shared system resource utilization can provide valuable insights to system and application performance
- We need to develop new analysis and visualization tools to fully utilize the new wealth of data we are collecting

Future Work

- More Tools – both run-time and post processing
    - Analysis
    - Visualization
- Log collection without store for diagnostics
- “Derived Data” plugin
- Separate “connect” thread pool

Questions?