End-to-End Monitoring and Grid Troubleshooting

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The Problem

- Assume a Grid job is:
  - submitted to a resource broker, uses a reliable file transfer service to copy several files, then runs the job.
- This normally takes 15 minutes to complete. But…
  - two hours have passed and the job has not yet completed.
- What, if anything, is wrong?
  - Is the job still running or did one of the software components crash?
  - Is the network particularly congested? Broken TCP stack?
  - Is the CPU particularly loaded?
  - Is there a disk problem?
  - Was a software library containing a bug installed somewhere?

The Solution

- End-to-End Monitoring
  - All components between the application endpoints must be monitored.
- This includes:
  - software (e.g., applications, services, middleware, operating systems)
  - end-host hardware (e.g., CPUs, disks, memory, network interface)
  - networks (e.g., routers, switches, or end-to-end paths)

Monitoring Components

- A complete End-to-End monitoring framework includes:
  - Instrumentation Tools
    - Facilities for precision monitoring of all software (applications, middleware, and operating systems) and hardware (host and network) resources
  - Monitoring Data Publication
    - Standard schemas, discovery and publication mechanisms, and access policies for monitoring event data are required
  - Sensor Management
    - The amount of monitoring data produced can quickly become overwhelming
    - A mechanism for activating sensors “on demand” is required
  - Data Analysis Tools
    - event analysis and visualization tools
  - Event Archives
    - Historical data used to establish a baseline to compare current and predict future performance

Uses for Monitoring Data

- Troubleshooting and Fault Detection
  - Detect failures and recovery
- Performance analysis and tuning
  - Better program design (e.g.: will better pipelining of I/O and computation help?)
  - Network-aware Applications (TCP buffer size tuning, # of parallel streams, etc.)
- Debugging
  - Complex, multithreaded, distributed programs are difficult to debug without the proper monitoring data
- Guiding scheduling decisions
  - Grid Schedulers
    - Find the best match of CPUs and data sets for a given job
  - Grid Replica Selection
    - Find the “best” copy of a data set to use
- Auditing and intrusion detection

Grid Troubleshooting Example

- Step 1: insert instrumentation code during the development stage
  - to ensure the program is operating as expected
- Step 2: establish a performance baseline for this service, and store this information in the monitoring event archive.
  - Include system information such as processor type and speed, OS version, CPU load, disk load, network load data, etc.
- Step 3: put service into production, and everything works fine
  - Until…..
- One day users start complaining that service X is taking much longer than previously

Grid Troubleshooting Example

- To collect data for analysis, one must:
  - Locate sources of relevant monitoring data, and “subscribe” to that data.
  - Activate any missing sensors, and subscribe to the their data.
  - Activate debug-level instrumentation in the service, and subscribe.
  - Locate monitoring data in the monitoring event archive for the baseline test from when things were last working.
- Data analysis can be then begin:
  - Check the hardware and OS information to see if anything changed.
  - Look at the application instrumentation data to see if anything looks unusual.
  - Look at the system monitoring data to see of anything looks unusual (e.g., unusually high CPU load).
  - Correlate the application and middleware instrumentation data with the host and network monitoring data.

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Troubleshooting Example: Step 1: Generate Grid Job "Lifeline"

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Application Events

Copy output data

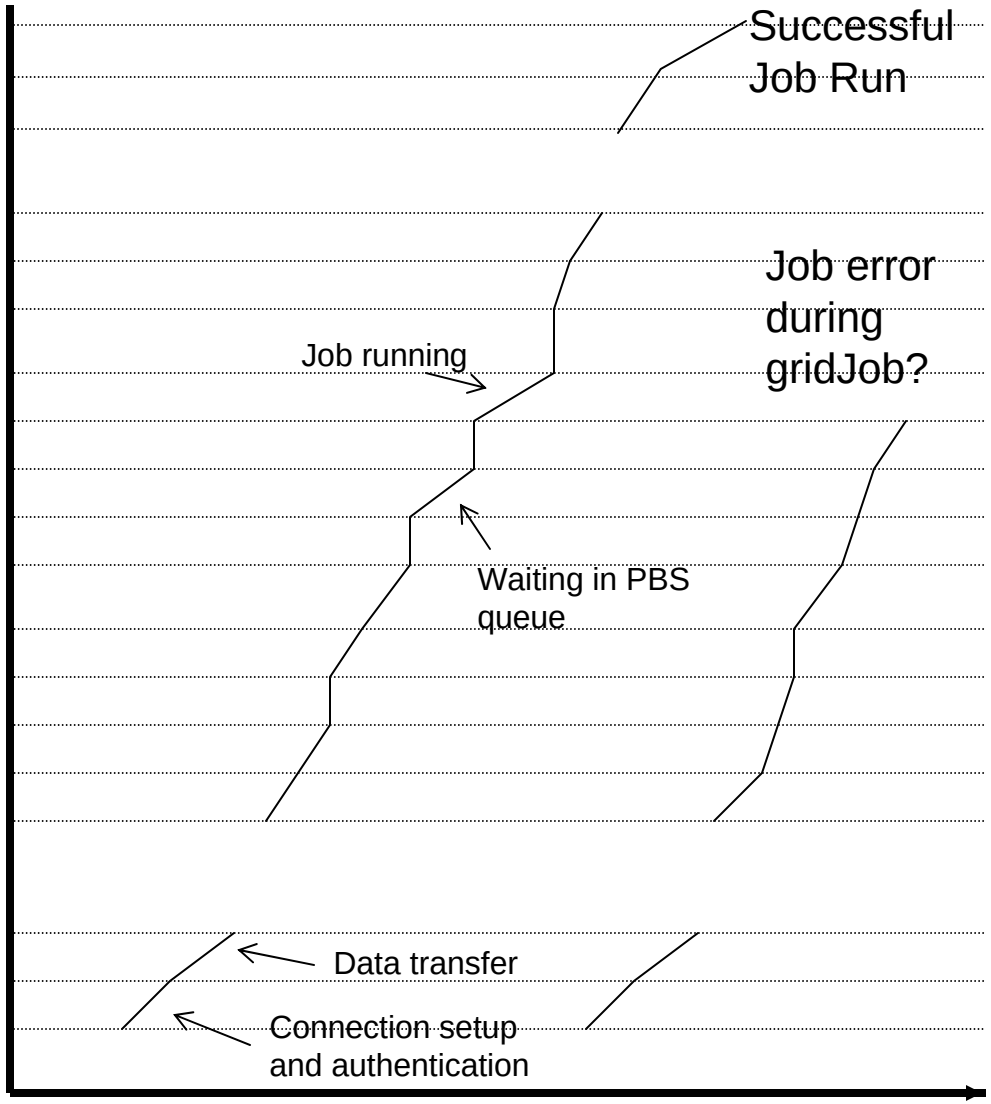
Run Grid Job

Copy input data

GlobusUrlCopy.put.end
GlobusUrlCopy.put.transferStart
GlobusUrlCopy.put.start

GlobusJobRun.end
jobManager.end
jobManger.jobState.done
gridJob.end
gridJob.start
jobManager.jobState.active
jobManager.jobState.pending
akentiAuthorization.end
akentiAuthorization.start
gateKeeper.end
jobManager.start
gateKeeper.start
GlobusJobRun.start

GlobusUrlCopy.get.end
GlobusUrlCopy.get.transferStart
GlobusUrlCopy.get.start



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Step 2: Add detailed application instrumentation, (1st example)

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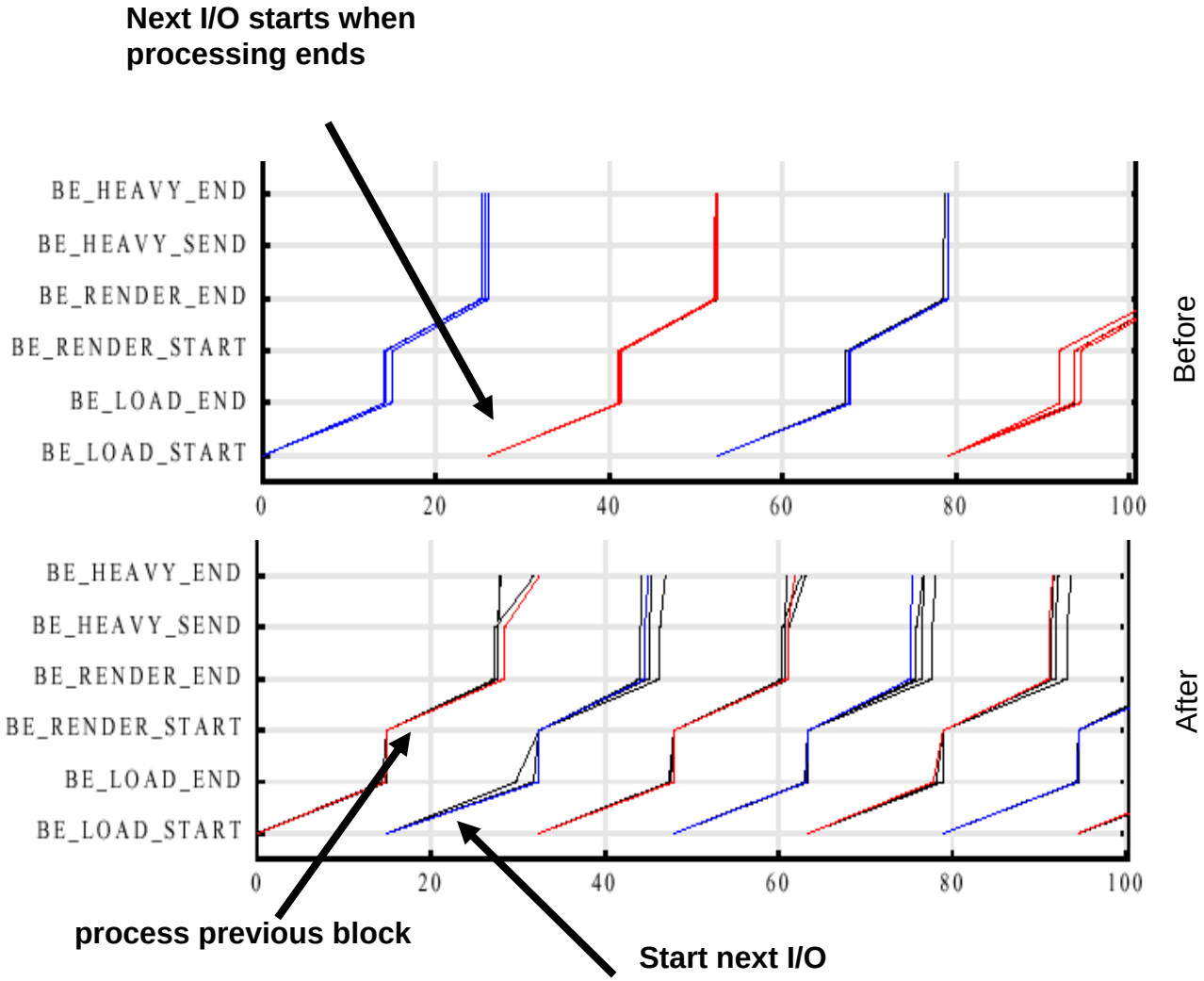
- I/O followed by processing
- overlapped I/O processing



almost a 2:1 speedup

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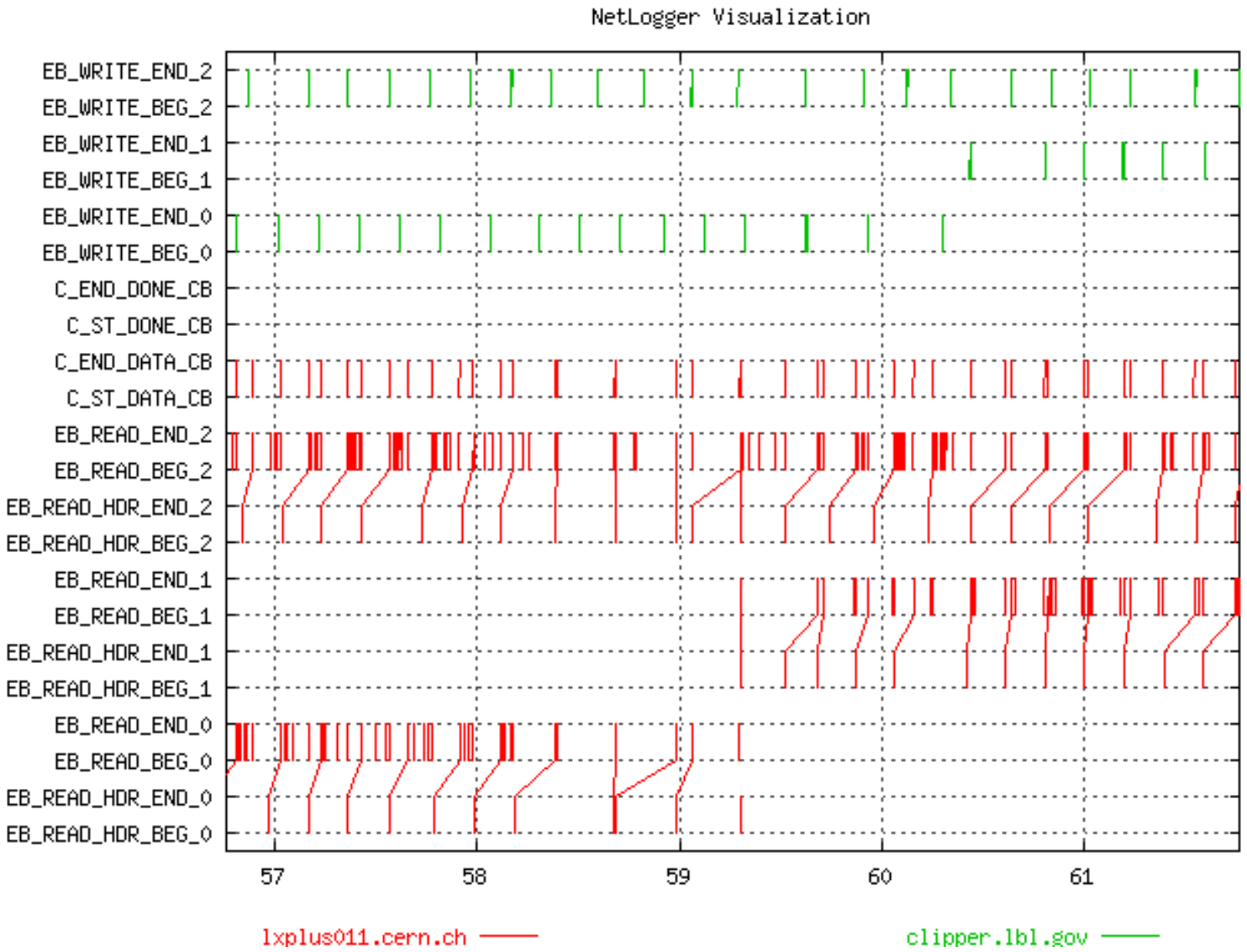
Step 2: Add detailed application instrumentation, (2nd example)



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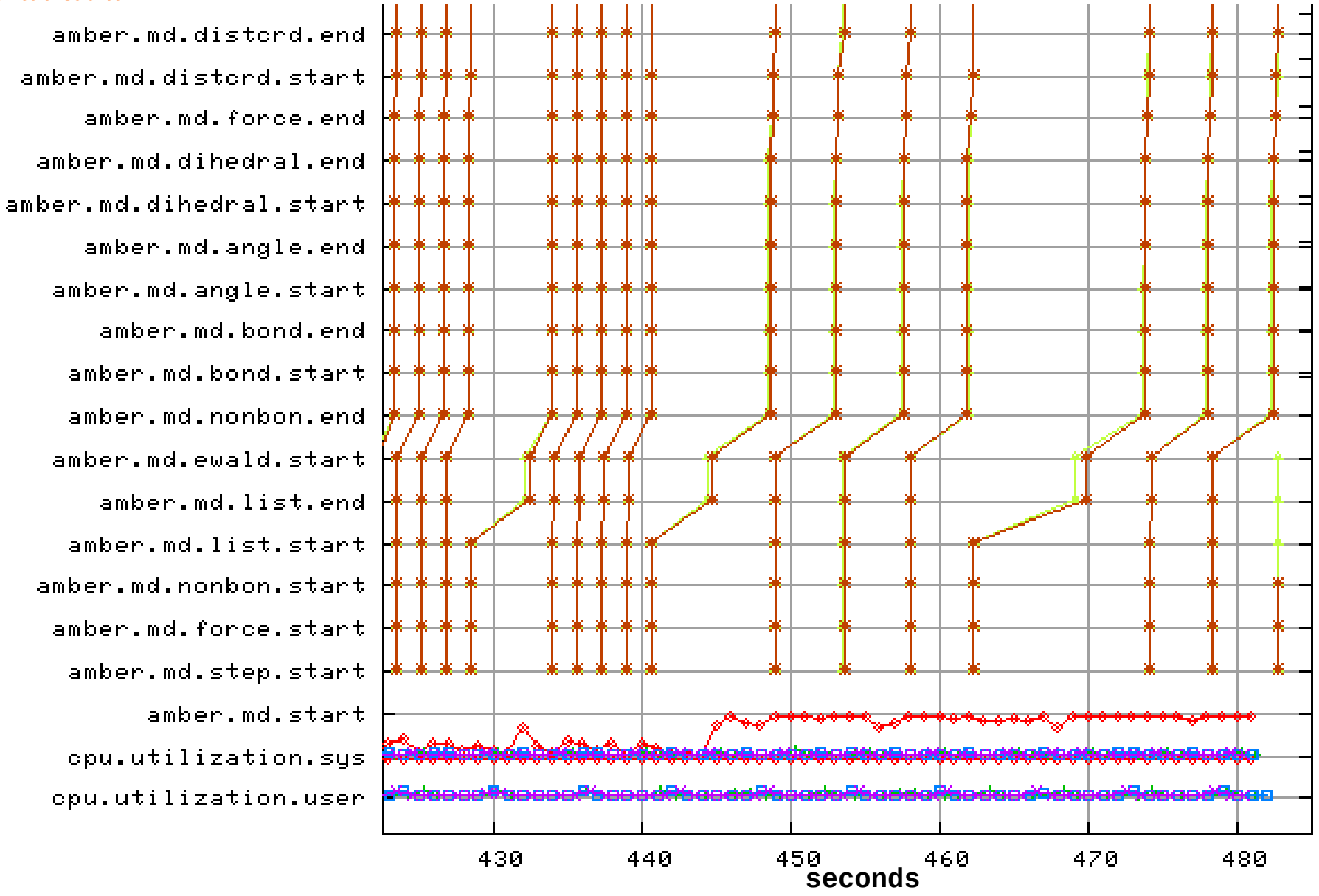
Step 3: add host monitoring

(e.g.: CPU load or TCP retransmits)



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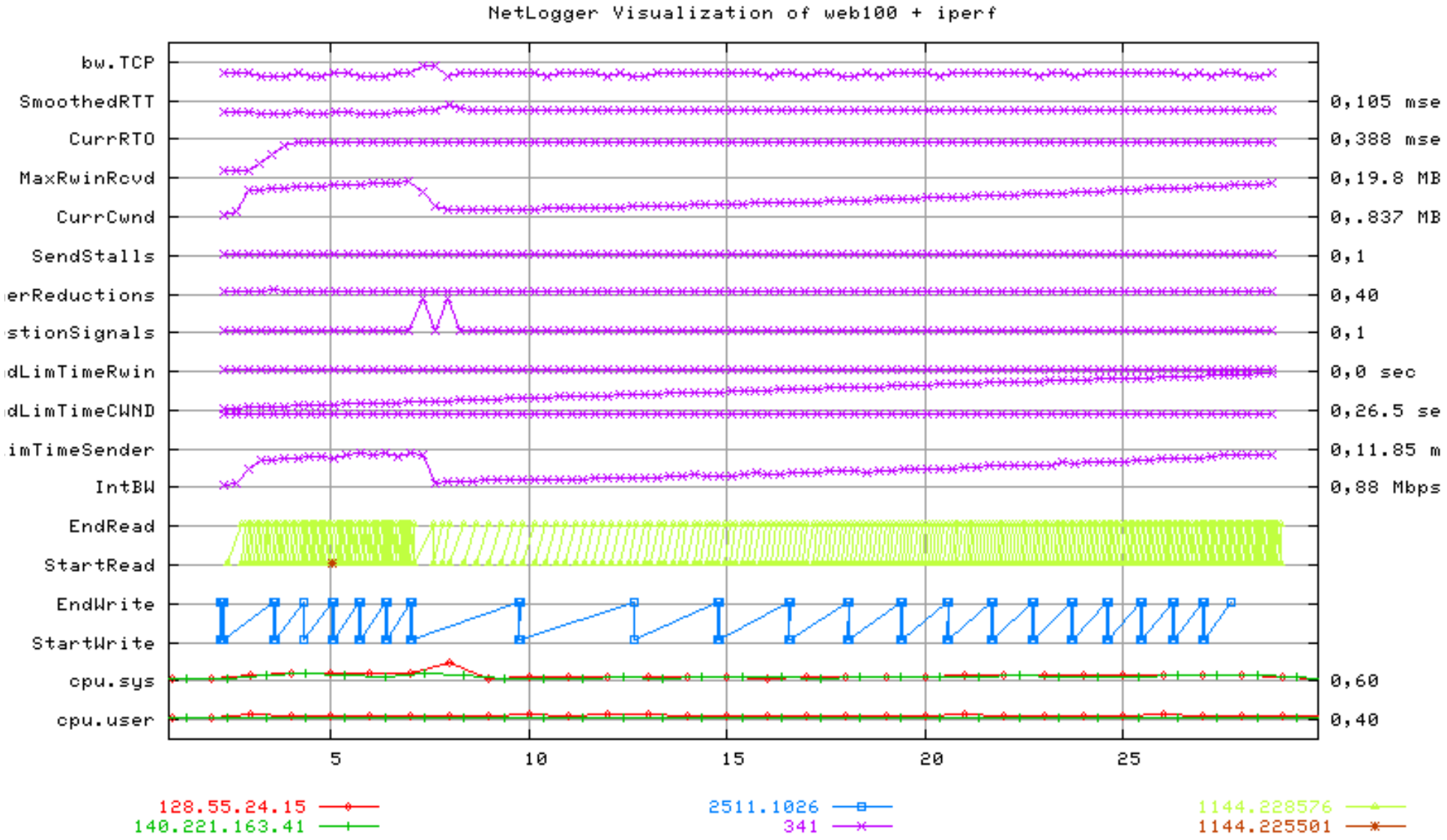
Step 4: add TCP monitoring



Challenges

- How to getting developers to instrument their applications/middleware?
  - Issue: Getting common message formats and common "Grid IDs" into all log messages
- How to export network monitoring data to Application/middleware?
  - Issues: Schemas, APIs, prediction, derived metrics, ….

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For More Information

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- http://dsd.lbl.gov/NetLogger/
  - All software components are available for download under DOE/LBNL open source license (BSD-style)
- email: BLTierney@LBL.GOV
- Other Useful URLs:
  - http://dsd.lbl.gov/NMWG/ (GGF Network Measurement WG)
  - PFLDnet 2004: http://dsd.lbl.gov/PFLDnet2004/program.htm
  - TCP Tuning: http://dsd.lbl.gov/TCP-tuning/TCP-tuning.html

Extra Slides

Grid Job ID

- In order to graphically link events from several Grid components
  - monitoring events for the same “job” needs the same “Grid Job ID” (GID)
- We have instrumented the following pyGlobus components with NetLogger with a GID
  - globus-job-run, globus-url-copy, Globus gatekeeper Globus job manager
  - globus-job-run generates the GID using *uuidgen*
  - GID passed to gatekeeper via RSL

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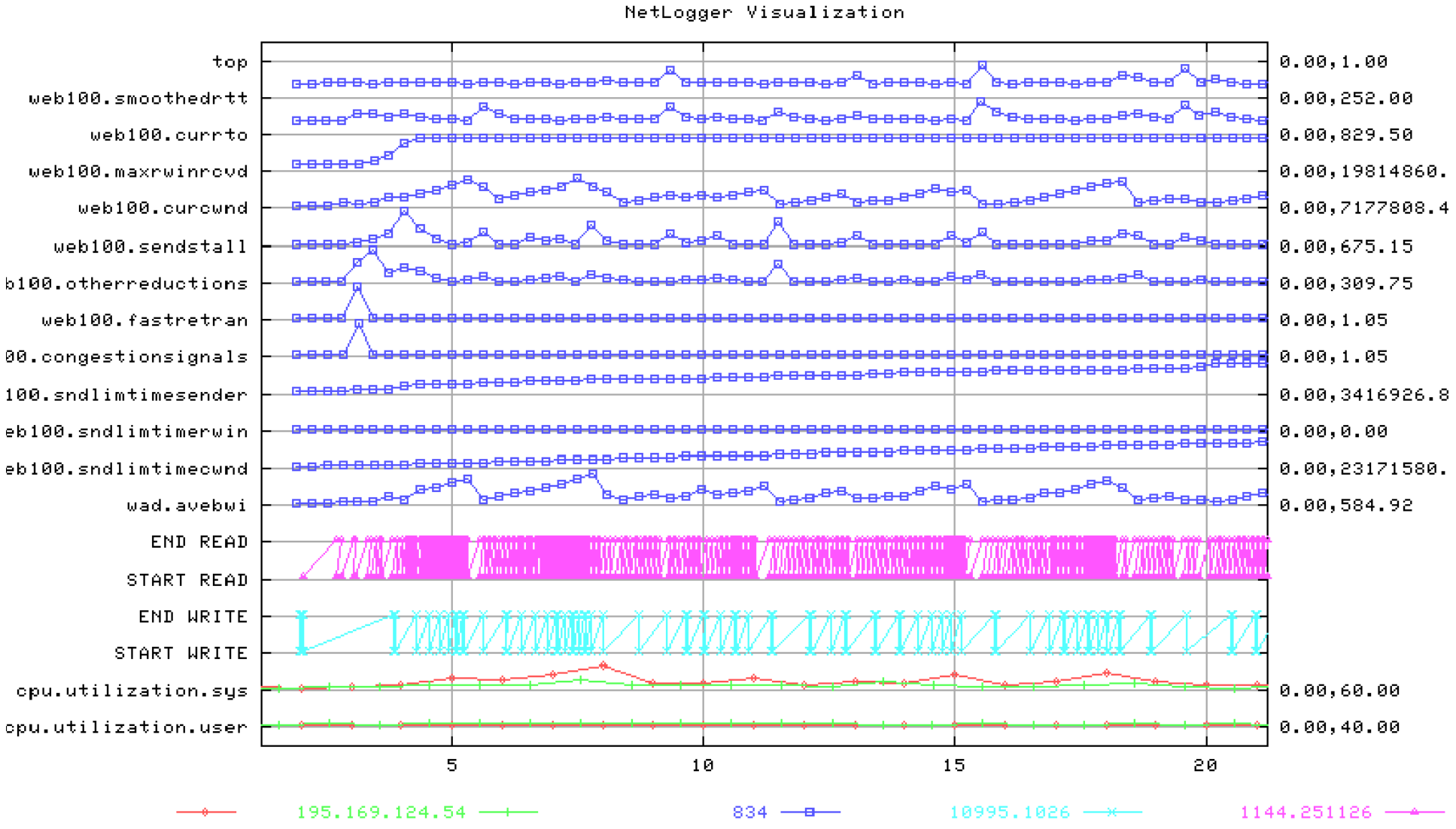
Step 3b: add more TCP monitoring



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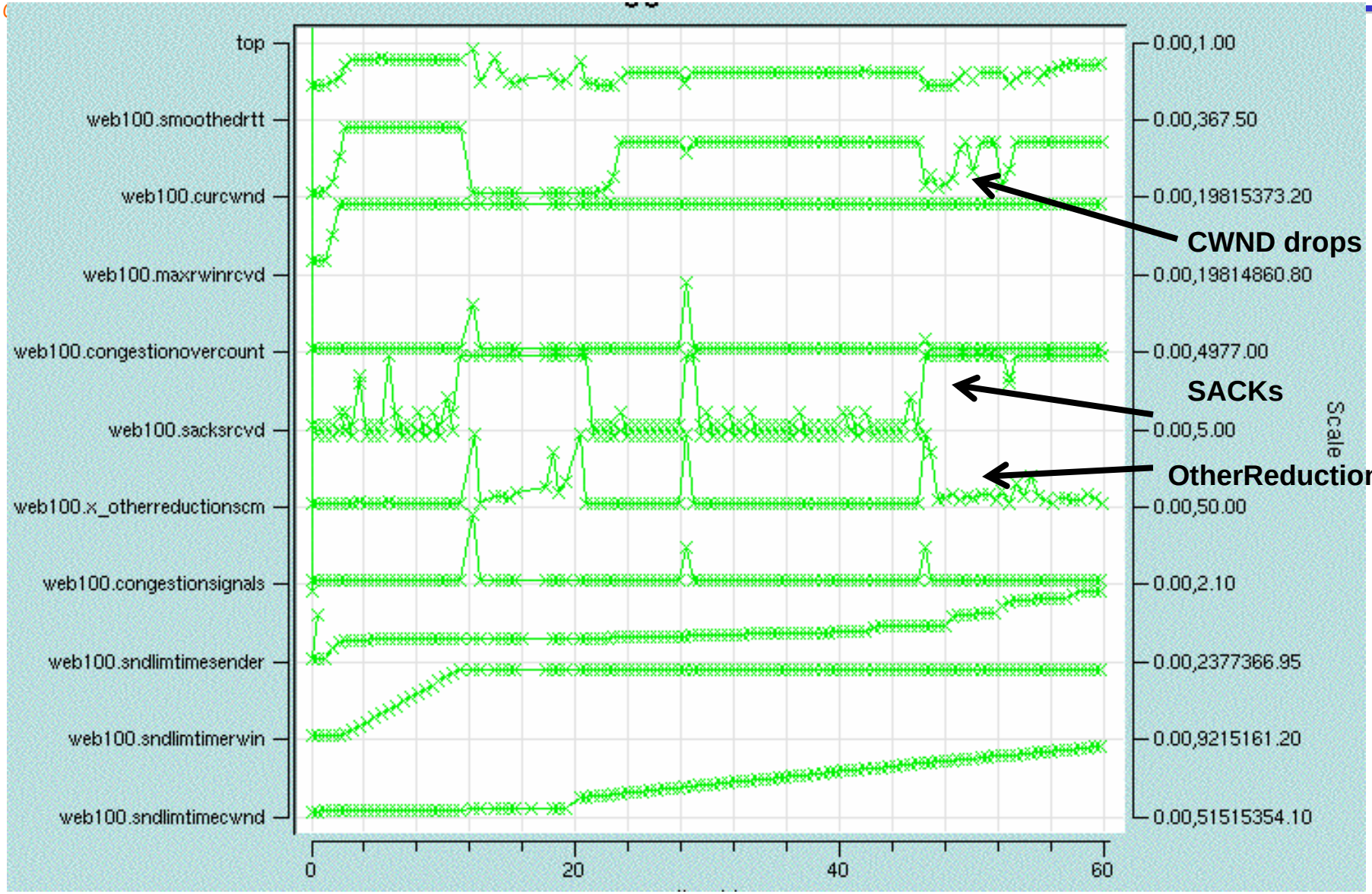
Detailed TCP Analysis: Correlation of Sack and OtherReductionsCM



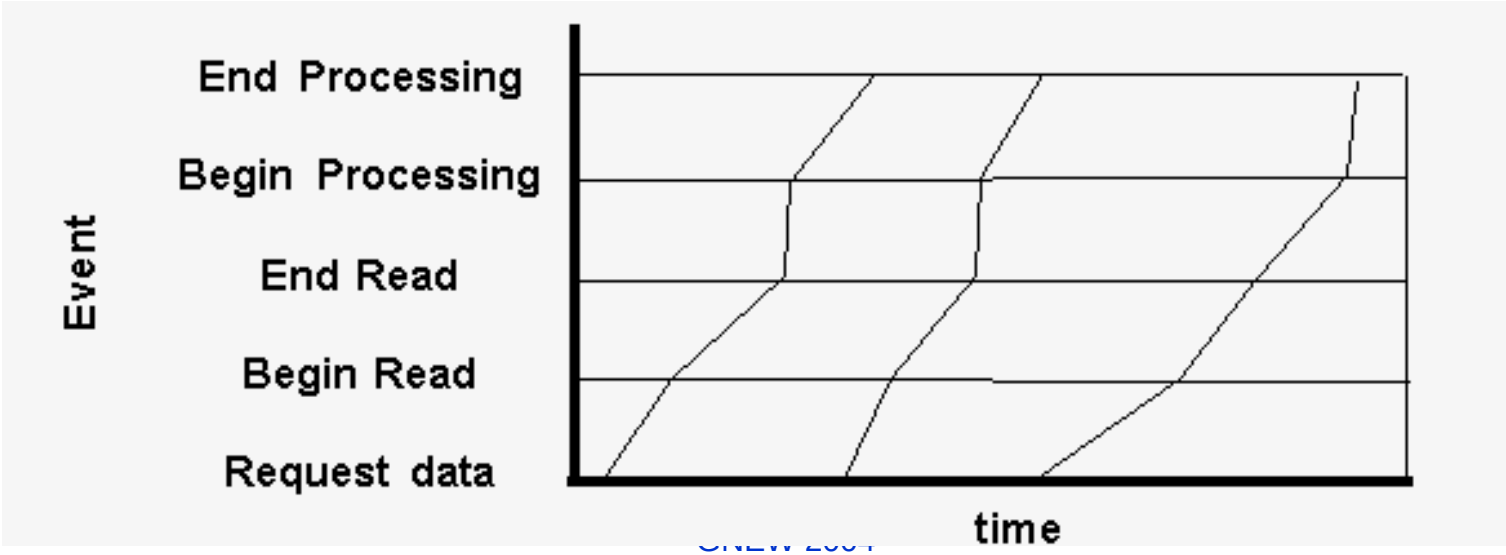
NetLogger Toolkit

NetLogger Toolkit

- We have developed the NetLogger Toolkit (short for Networked Application Logger), which includes:
  - tools to make it easy for distributed applications to log interesting events at every critical point
    - NetLogger client library (C, C++, Java, Perl, Python)
    - Extremely light-weight: can generate > 900,000 events / second on current systems (9000 events / sec with 1% app. perturbation)
  - tools for host and network monitoring
  - event visualization tools that allow one to correlate application events with host/network events
  - NetLogger event archive and retrieval tools
- NetLogger combines network, host, and application-level monitoring to provide a complete view of the entire system.

NetLogger Analysis: Key Concepts

- NetLogger visualization tools are based on time correlated and object correlated events.
  - precision timestamps (default = microsecond)
- If applications specify an "object ID" for related events, this allows the NetLogger visualization tools to generate an object "**lifeline**"
- In order to associate a group of events into a "lifeline", you must assign an "object ID" to each NetLogger event
  - Sample Event ID: file name, block ID, frame ID, Grid Job ID, etc.



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Sample NetLogger Instrumentation


```
log = netlogger.open("x-netlog://log.lbl.gov","w")
done = 0
while not done:
  log.write(0,"EVENT_START","TEST.SIZE=%d",size)
  # perform the task to be monitored
  done = do_something(data,size)
  log.write(0,"EVENT_END")
```

- Sample Event:

```
DATE=20000330112320.957943 HOST=gridhost.lbl.gov \
PROG=gridApp LVL=1 NL.EVNT=WriteData SEND.SZ=49332
```

NetLogger Activation Service

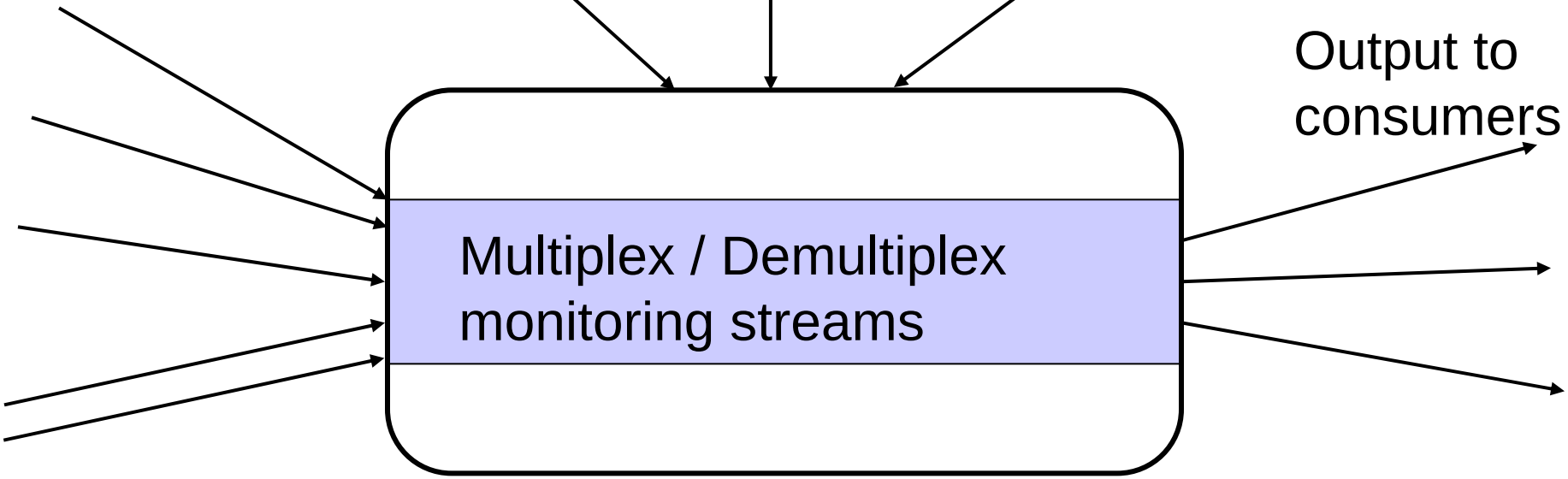
- Do not want all monitoring data collected all the time
  - Potentially way too much data
  - Need to adjust the level of monitoring as needed for:
    - Debugging
    - Performance tuning
    - Error analysis
- NetLogger Activation Service addresses this issue
  - NetLogger-based sensors register with the activation service
  - Very useful debugging tool for MPI / PC cluster-based jobs

NetLogger Filter and Activation Service

Subscription A: send me all monitoring data for Grid Job # 23

Subscription B: send all level 0 monitoring data to archive at host a.lbl.gov

Subscription C: change the logging level of program *ftpd* to level 2, and send me the results



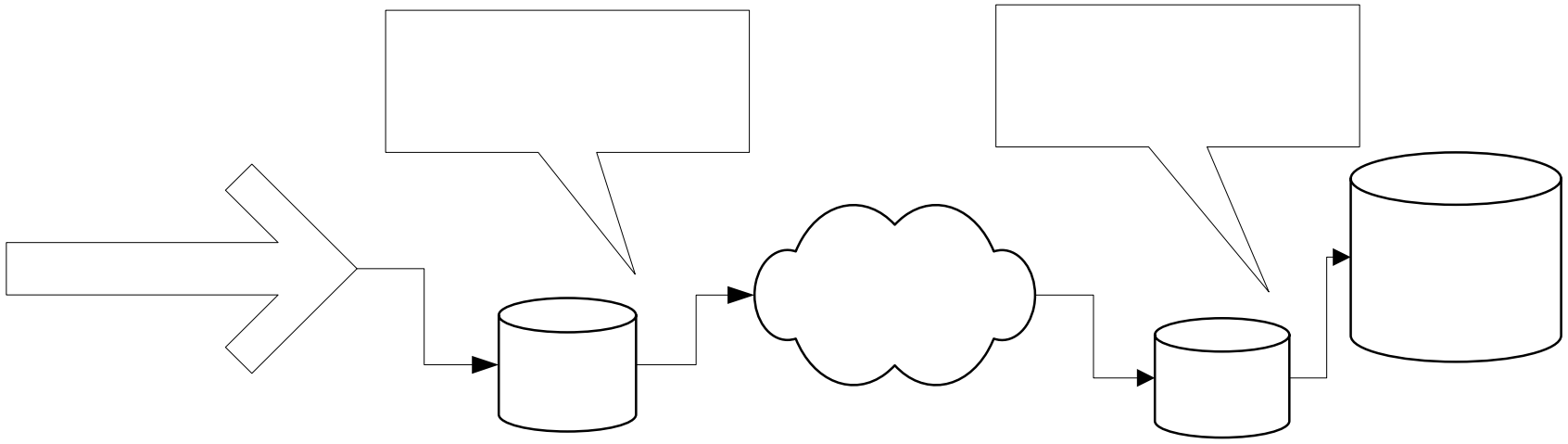
Incoming monitoring data:

- application,
- middleware,
- host

NetLogger Filter and Activation Service

NetLogger Archive Architecture

- Architecture must be scalable and capable of handling large amounts of application event data,
- None of the components can cause the pipeline to “block” while processing the data, as this could cause the application to block
  - For example, instrumented FTP server could send > 6000 events/second to the archive (500 KB/sec (1.8 GB/hr) of monitoring event data)



NetLogger Tools

- nlforward: Log file forwarder
  - forwards a single NetLogger file or directory of files to an output URL

- netlogd: TCP socket server daemon
  - accepts one or more NetLogger TCP streams and writes them to one or more NetLogger output URL's

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Conclusions

- Ability to allow a Grid User or developer to easily “drill down” from high-level to low-level analysis it needed
- Grid ID is essential for correlating events