

Using NetLogger for Distributed Systems Performance Analysis of the BaBar Data Analysis System

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Abstract

Developers and users of high-performance distributed systems often observe performance problems, the reasons for which are rarely obvious. Bottlenecks can occur in any of the components along the paths through which the data flows: the applications, the operating systems, the hosts, or the network. We have developed a methodology, known as NetLogger, for detailed, end-to-end, top-to-bottom monitoring and analysis of all system components. NetLogger is being added to the data analysis systems that are used at the Stanford Linear Accelerator Center (SLAC) for the *BaBar* Project, and some initial results are presented in this paper.

Keywords: performance analysis, NetLogger, BaBar

1.0 Introduction

Developers and users of high-performance distributed systems often observe performance problems such as unexpectedly low throughput or high latency. The reasons for the poor performance can be manifold and are frequently not obvious. It is often difficult to track down performance problems because of the complex interaction between the many distributed system components, and the fact that performance problems in one place may be most apparent somewhere else. Bottlenecks can occur in any of the components along the paths through which the data flow: the applications, the operating systems, the device drivers, the network adapters on any of the sending or receiving hosts, and/or in network components such as switches and routers. Sometimes bottlenecks involve interactions among several components or the interplay of protocol parameters at different points in the system, and sometimes they are due to unrelated network activity impacting the operation of the distributed system.

It has been our experience that wide-area distributed system developers and users often assume performance problems are due to network congestion. However in our experience, this is often not true. Having analyzed many distributed applications over the past 10 years, we have observed that performance problems are due more often to application design problems, followed by network problems or host problems. Application problems include inefficient use of remote services and communication mechanisms, such as a lack of TCP tuning [7]. Therefore it is equally important to instrument and monitor the applications, not just the hosts and networks.

To characterize the performance of distributed applications, we have developed a methodology for detailed, end-to-end, top-to-bottom monitoring and analysis of significant events. This allows coordinated monitoring of applications, networks, and hosts.

2.0 NetLogger

We have developed a methodology, known as *NetLogger*, for monitoring, under actual operating conditions, the behavior of all the elements of the application-to-application communication path in order to determine exactly what is happening within a complex system [6]. Distributed application components are instrumented to perform precision timestamping and event logging at every critical point (e.g., all I/O and any significant computational routine). The events are correlated with host and network monitoring to characterize the performance of all aspects of the system in detail. NetLogger is designed to facilitate identification of bottlenecks and help with performance tuning.

The NetLogger Toolkit is a set of tools which make it easy for distributed applications to log interesting events at every critical point. NetLogger also includes tools for host and network monitoring. The approach is novel in that it combines network, host, and application-level monitoring to provide a complete view of the entire system.

NetLogger Toolkit contains the four components: the NetLogger message format, the NetLogger client library, NetLogger visualization tools, and NetLogger host and network monitoring tools.

In addition to these NetLogger components, an additional critical component is a mechanism for synchronizing the clocks of all hosts in the distributed system. NTP (Network Time Protocol) [4] or a GPS host clock is required for this.

The NetLogger message format is a simple ASCII format, which is an IETF draft standard format called ULM (Universal Logger Message) [1]. The NetLogger Toolkit includes application libraries (in C, C++, Java, Perl, Python, and Fortran) for generating NetLogger messages. Using these libraries one can send log messages to a local file, a remote host, the syslog daemon, or local memory. NetLogger also includes wrappers for several system monitoring utilities, such as *vmstat*, *iostat*, and *netstat*.

Event Log Analysis and Visualization Tools

Exploratory, interactive analysis of the log data—especially analysis of the graphical representations of individual, exceptional events—has proven to be the most important means of identifying the causes of specific behaviors. In particular, the ability to distinguish, manipulate, and analyze log event plots is critical to isolating the locations of (and thereby the reasons for) unexpected behavior.

NetLogger builds *lifelines* by combining specified events from a given set of processes, and represents them as lines on a graph. The graph plots time (i.e., the timestamp from the event log) against a set of events. For example, in a client-server distributed system, each request-response transaction might be represented as a lifeline; the events on the lifeline might include the request's dispatch from the client, its arrival at the server, the commencement of server processing of the request, the dispatch of the response from the server to the client, and the arrival of the response at the client.

We have developed a tool called *nlv* (NetLogger Visualization) for interactively viewing the NetLogger event files. *nlv* can display several types of NetLogger events. The user can combine multiple different sequences of events, servers, and graph types (lifeline, load-line, or point) on a single graph; the display can be modified to show an arbitrary subset of these elements. *nlv* graphing primitives are shown in Figure 1. The *point* type is used to graph events such as TCP retransmits that happen at a certain point in time. The *load-line* type is used to graph events such as CPU load that vary over time. The *lifeline* type is used to follow processing flow through time, as described above. *nlv* provides the ability to play, pause, rewind, slow down, zoom in/out, and so on. Figure 2 shows a sample *nlv* session. *nlv* can be run post-mortem on a log file collected after the application is finished, or can be run in “real-time,” analyzing live applications.

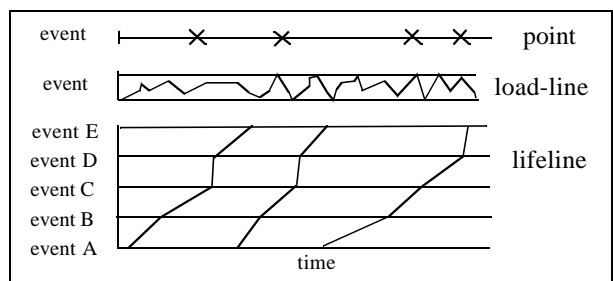


Figure 1: *nlv* graphing primitives

3.0 BaBar Data Analysis

The BaBar detector was built at SLAC to study the millions of B mesons produced by the PEP-II storage ring. The BaBar collaboration consists of around 600 physicists and engineers from 85 institutions in 9 countries. The computing environment for the BaBar data analysis is very complex, and consists of many (i.e., 100-300) compute nodes, all sending results to a single database [2]. In the early production system, the time to place selected events into the Objectivity [5] database was very inconsistent, varying from 2 to 300 seconds. There was a very large amount of monitoring built into the BaBar software, yet it was quite difficult to correlate all

the log data to provide any insight into exactly why some nodes occasionally took several hundred seconds to update the database.

We are planning to fully instrument the BaBar system with NetLogger instrumentation, but as a first step we used the existing log files and converted them to the NetLogger/UML format used by the NetLogger exploratory log file analysis tools. This proved to be very useful, as it was much easier to correlate logged events using NetLogger.

4.0 Results

Figure 2 shows the NetLogger *nlv* tool for some of the BaBar data. *nlv* proved to be a very effective tool for interactively exploring the log files. Some of the most useful features of *nlv* include the ability to color events based on which compute node it was from, and the ability to color groups of nodes together (i.e., color nodes 140-149 the same color). *nlv* allows the user to click on a graph element to get more information from the log-file about that event, such as the node number or an Objectivity error (see Figure2). *nlv* also allows the user to turn on/off sets of events, so it is easy to look at results of just one node, or the results of several overlaid nodes. *nlv* uses the gnuplot [3] library for generating output, so event plots can easily be saved in a large number of formats, including Postscript, GIF, JPEG, and MIF. The MIF output was used for Figure 3.

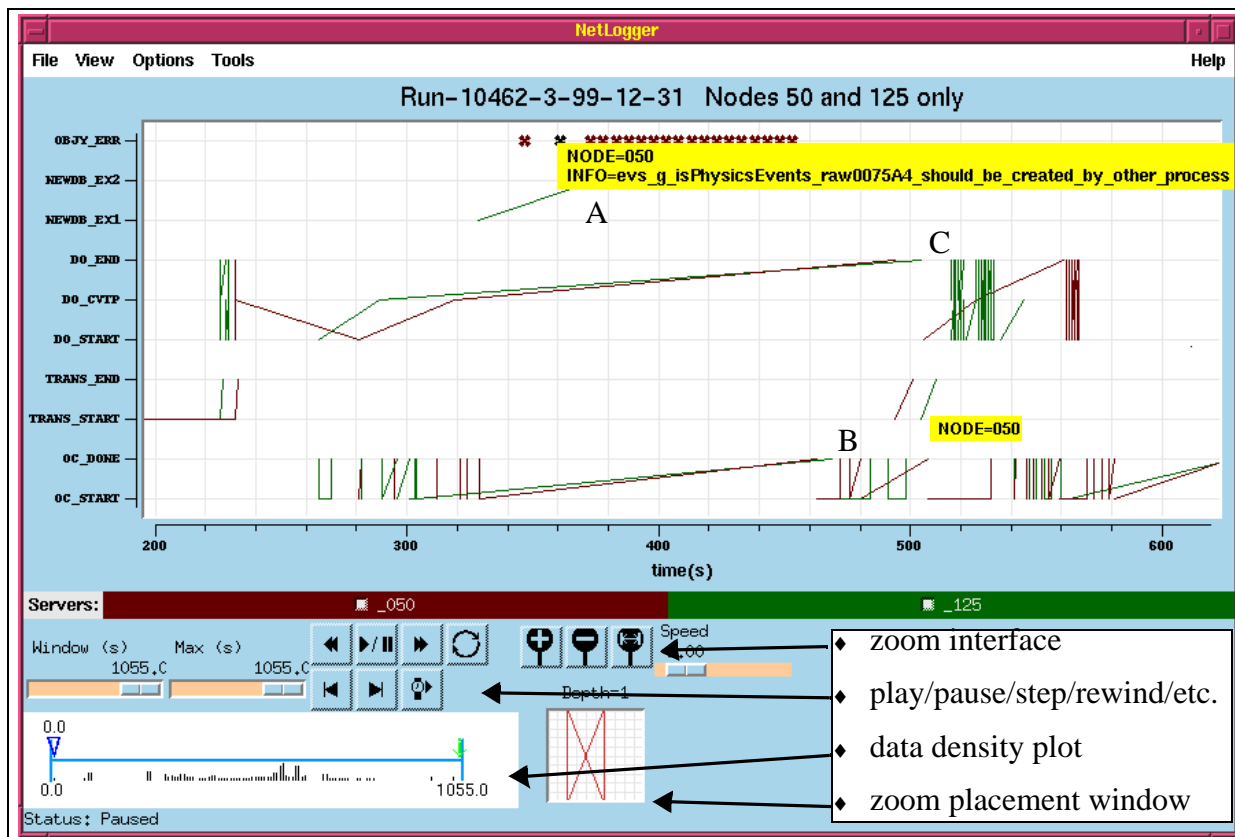


Figure 2: *nlv* screen dump showing Objectivity errors: nodes 50 and 125

Figure 3 shows the results for a single compute node. This plot shows four NetLogger “event sets”: *open container*, *transaction commit*, and *OprBdbEventOutput* (send event to Objectivity), represented as lifelines, and *reacquire lock*, represented by a point. Using this plot it is very easy to understand why some of the *OprBdbEventOutput* events took longer than others. The *OprBdbEventOutput* events near the beginning took longer because a new containers needed to be opened, and there was a pause in performing *OprBdbEventOutput* events while a transaction was committed.

Figure 2 shows a plot with several Objectivity errors. The Objectivity error from the log file is displayed by clicking on the error event in the graph. Note the location of points **A**, **B**, and **C** in Figure2. At the same time

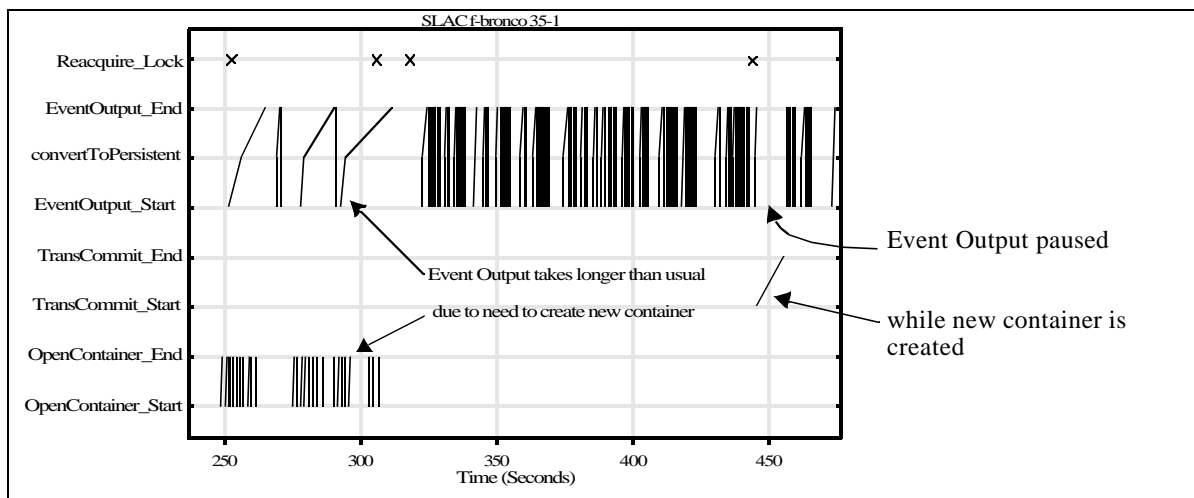


Figure 3: Normal operation showing correlation of events: node 140

that these two nodes took over 100 seconds to send an event to the database, most other nodes (not shown) were able to send events in 2-3 seconds. It is expected that sometimes it will take longer to place new events into the database (**C**) because new containers must be created (**B**), and it also expected that sometimes takes longer to create a new container because a new database must be created (**A**). What was quite surprising in this picture was that there was a 100 second pause between **A** and **B**, and a 30 second pause between **B** and **C**. This was due to a deadlock problem that has since been fixed. This figure also shows the ability to click on a object and get the node number, and shows a number of the *nlv* user interface features.

5.0 Conclusions and Future Work

Our initial work with NetLogger has been very promising, and *nlv* provides a very useful way to view the correlation of logged events. The next step is to add host monitoring, such as CPU and memory usage, and then add NetLogger messages directly into the BaBar software. NetLogger is available for download from <http://www-didc.lbl.gov/NetLogger/>.

6.0 Acknowledgments

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