Scalable Online Parallel Performance Measurement Over a Cluster Monitor

TAU / Supermon

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Introduction

Online or Real-time application performance monitoring allows tracking performance characteristics during execution as opposed to doing so post-mortem. This opens up several possibilities otherwise unavailable such as real-time visualization and application performance steering. These enable adaptation and control of long-running applications.

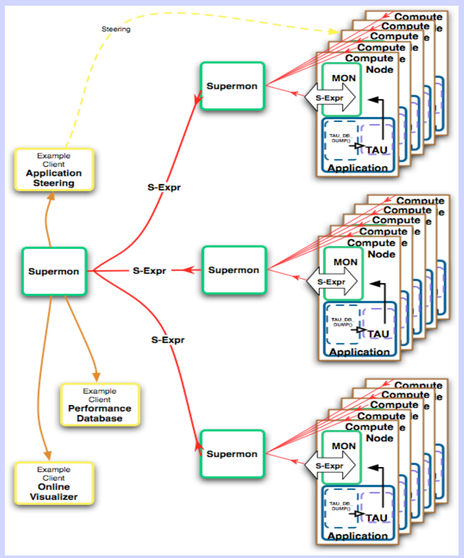
Two fundamental components that constitute an online application performance monitor are the measurement and transport systems. The former captures performance metrics of individual contexts (processes, threads). The latter enables querying the parallel/distributed state from the different contexts. The transport may also be used to control the measurement system. As HPC systems grow in size and complexity, the scalability and overhead of the online performance monitor become increasingly important considerations.

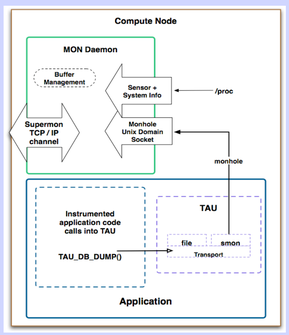
Approach and Rationale

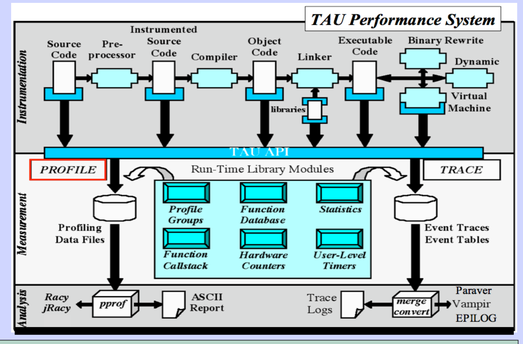
We adapt two existing, mature systems - Tuning and Analysis Utility (TAU) and Supermon - to solve the problem of scalable, low-overhead online performance monitoring of parallel applications. TAU performs the role of the measurement system and is adapted to use Supermon as the transport from which sinks query the distributed performance state. Alternate approaches could have been to use the traditional method of performance data transport, namely using a network filesystem or to invent a new transport completely within TAU.

The rationale behind our current approach is as follows: **i)** Using a traditional transport incurs high overhead (as the graphs demonstrate), **ii)** Keeping the transport outside TAU makes available a light-weight online transport to systems other than TAU (or even performance monitors) that want to use it, **iii)** No new components are added to the system as a cluster-monitor is typically present already, **iv)** This allows close correlation between system-level information (such as from the OS and hardware sensors) with application performance as the cluster-monitor already reports the former and **v)** Lastly, Supermon is light-weight and scalable due to its hierarchical structure.

TAU over Supermon: Architecture







TAU Parallel Performance System

TAU is an integrated toolkit for parallel performance instrumentation, measurement, analysis, and visualization of large-scale parallel applications. TAU provides robust support for multi-threaded, message passing, or mixed-mode programs. Multiple instrumentation options are available, including automatic source instrumentation. The TAU measurement system supports parallel profiling and tracing. It has been widely ported to many platforms and is used extensively by parallel applications. TAU supports a online performance data retrieval API that allows the application to store its performance state anytime during execution.

Supermon Cluster Monitor

Supermon is a scalable monitoring system for high performance computing systems. Its current implementation includes a set of socket-based servers that gather and organize monitoring data based on symbolic expressions (s-exprs). Its architecture is hierarchical, that is, each node is treated as a leaf node in a tree, while a series of data concentrators gather data from the nodes and transport it to a root. The root then provides data to clients.

The Supermon system consists of several components. **A.** Within the compute-node OS is a **kernel-module** that exports system-level parameters, locally, as a file in the /proc psuedo-filesystem. **B.** On each compute node is the **mon daemon**. It reads the file under /proc and makes available the system-level metrics as s-exprs over the network via TCP/IP. **C.** Mon also listens on a Unix Domain Socket locally accepting data from any other sources. This interface to mon is called the **monhole**. **D.** On the service node(s), there is the **supermon daemon**. This talks to all the 'mon' daemons on the compute nodes and queries and collects the data from them. This data includes the system-level parameters as well as data submitted through the monhole interface. Supermon then makes this data available as another s-expression to any interested clients.

Adapting Supermon and TAU

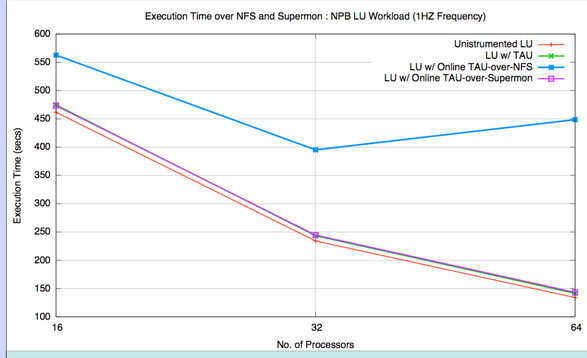
Supermon: The Mon daemon provides the Unix Domain Socket based **monhole** interface for external sources to inject data. Due the monhole not having been exercised much it had to be tested and bug-fixed before TAU could use it. Next its buffering characteristics needed to be made more flexible. Only a simple and efficient 'replace-read' policy was available. This had several advantages - i) slow sinks will not cause infinitely large buffers to be maintained at the mon daemon and ii) multiple sinks can query the data simultaneously without race conditions. But its cons include the problem of data-loss for even transient slowdowns of sinks and bandwidth wastage when sink query rate becomes greater than data generation rate. Even a small configurable buffer can alleviate the former, whereas a 'replace-drain' strategy when using a single client can remedy the latter. A runtime-configurable buffer strategy was put in place. The repair mechanism for hierarchical topologies was also fixed.

TAU: TAU assumed the presence of an underlying transport (such as a network filesystem) as its data storage used the standard library's buffered file I/O routines. We made the notion of 'transport' a first-class entity by creating a generic transport class. Then two concrete implementations of this transport class, one for the default standard library-based file I/O and the other that used the monhole-interface underneath were created. The type and nature of the transport being used is kept hidden from the rest of the TAU code-base. The type of transport can be fixed statically at compile-time or can be communicated to the application via an environment variable at application startup. This framework also allows adding new custom transports to TAU in future.

Performance and Scalability

Experiment Configurations

We compare the performance of the NAS Parallel LU (Class B) application benchmark under different configurations, including: 1. vanilla un-instrumented LU, 2. LU instrumented with TAU to generate post-mortem measurement data, 3. LU instrumented with TAU for online measurement using NFS as the transport and 4. Online TAU instrumented-LU measurement over Supermon transport. Online measurement is performed at a frequency of 1 Hertz. We repeat each of the runs over 16, 32 and 64 nodes to examine scalability. The Chiba City cluster from Argonne National Lab, with Pentium III dual-CPU SMP Linux nodes running Ethernet, serves as our test environment.



Experimental Results

At left we plot the runtime of the LU benchmark under the different configurations as processor count increases. In addition, plotted below is the percentage of dilation observed over the un-instrumented LU.

The graphs clearly highlight the following:

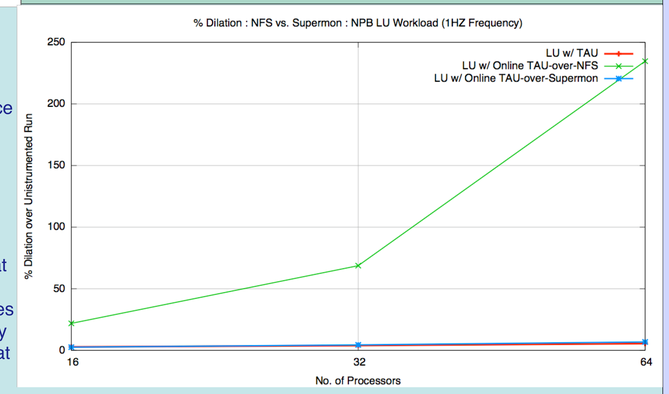
1. Overhead of obtaining post-mortem Tau measurements is < 6%.
2. TAU overhead grows logarithmically over number of CPUS.
3. Overhead of online performance measurement/data-retrieval using NFS grows super-linearly and is as high as 70%.
4. Overhead of online performance measurement/data-retrieval using Supermon also shows logarithmic growth. It is also very close to the TAU overhead, hence provides online measurement almost for free.
5. As CPU count grows, the savings obtained from Supermon transport over NFS grows super-linearly.

Increasing Scalability Further

We outline three methods that are works-in-progress to further improve the scalability of this system. The methods either try to reduce the number of nodes touched per-query or try to reduce the data generated per node per query.

1. Optimal Schedule

The entire suite of data provided by the cluster includes values that vary over time at different scales. For example, values such as temperature, fan behavior, and various system power voltages vary at a much coarser grain than cpu utilization. If a user wishes to look at both values, it is wasteful to repeatedly sample the coarse grain values that change slowly over time while gathering other data. Therefore, by applying a-priori knowledge of the variables to sample and the rates at which they are relevantly changing, one can derive a sampling schedule to gather exactly what data is changing at any given time. For TAU data, only the measurements of those routines (/events) that have changed since the last query will be returned.



2. Sampling Contexts

Instead of querying every node at every interval, we can sample the cluster-address space and the application namespace the MPI Ranks). When such a 'sampled' query goes out to the mon-daemons, they can each first ask a 'sampler' if this query should be satisfied before replying. A default sampler may reply TRUE with probability 'k*(1/N)' , where 'N' is the number of contexts (e.g. MPI Ranks) and 'k<=N' is a configurable constant. Irrespective of the number of nodes in the system, this will bound, on average, the number of nodes touched per query. More sophisticated sampling techniques can be applied.

3. Data Aggregation with Hierarchical Topology

Constructing the transport hierarchically (i.e. a tree) can improve scalability. The leaves would be the actual mon daemons (and the application contexts). But sending data loss-less over the tree will simply lead to the total amount of data being magnified (every internal node retransmits data again) - something we want to avoid. Therefore some type of 'aggregation' is required to go along with the hierarchical structure. The aggregation strategy may depend on the level (or depth) of the internal node in the tree. A deep internal node may find the average (or max, sum) of the data from its children, but higher level internal-nodes may resort to loss-less aggregation.

Future Work

We would like to pursue the below efforts in future:

1. Implement and evaluate strategies listed to improve scalability further.
2. Experiment on very large scale platforms such as BGL (already ported).
3. Implement measurement control using Supermon as a reverse channel from sink to application.
4. Add new custom transports to TAU such as MRNet from University of Wisconsin.
5. Correlate application performance with system-level metrics (e.g. sensors).

Conclusion

We have detailed recent work in creating a large-scale online application performance monitor by using Supermon as the the underlying transport for the TAU system. The rational behind our approach and the architecture of the system are both explained. Our experimental results suggest that this strategy is far better than using a traditional NFS as the transport both in terms of performance and scalability. We have also listed several strategies we are experimenting with to improve scalability further.

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