SI2-SSI (2018): Collaborative Research: A Software Infrastructure for MPI Performance Engineering: Integrating MVAPICH and TAU via the MPI Tools Interface

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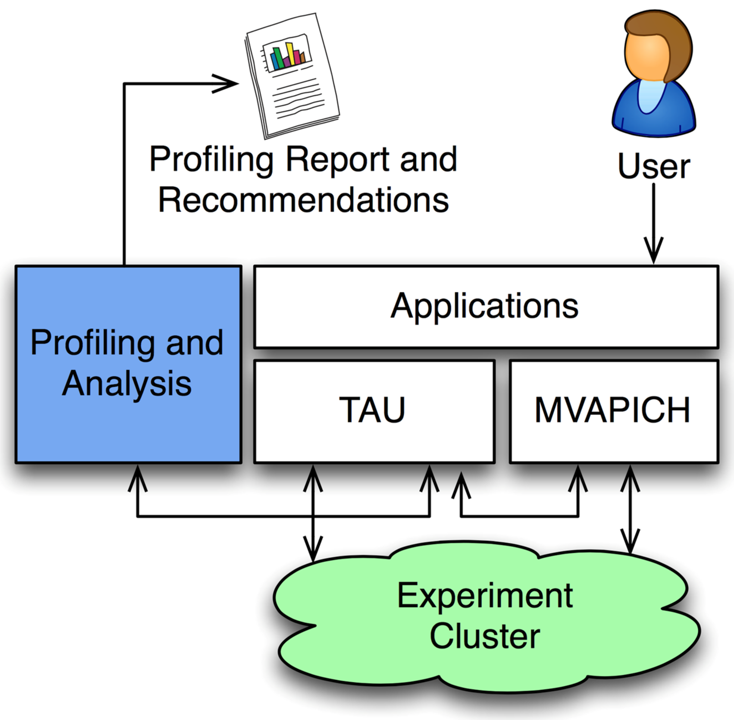
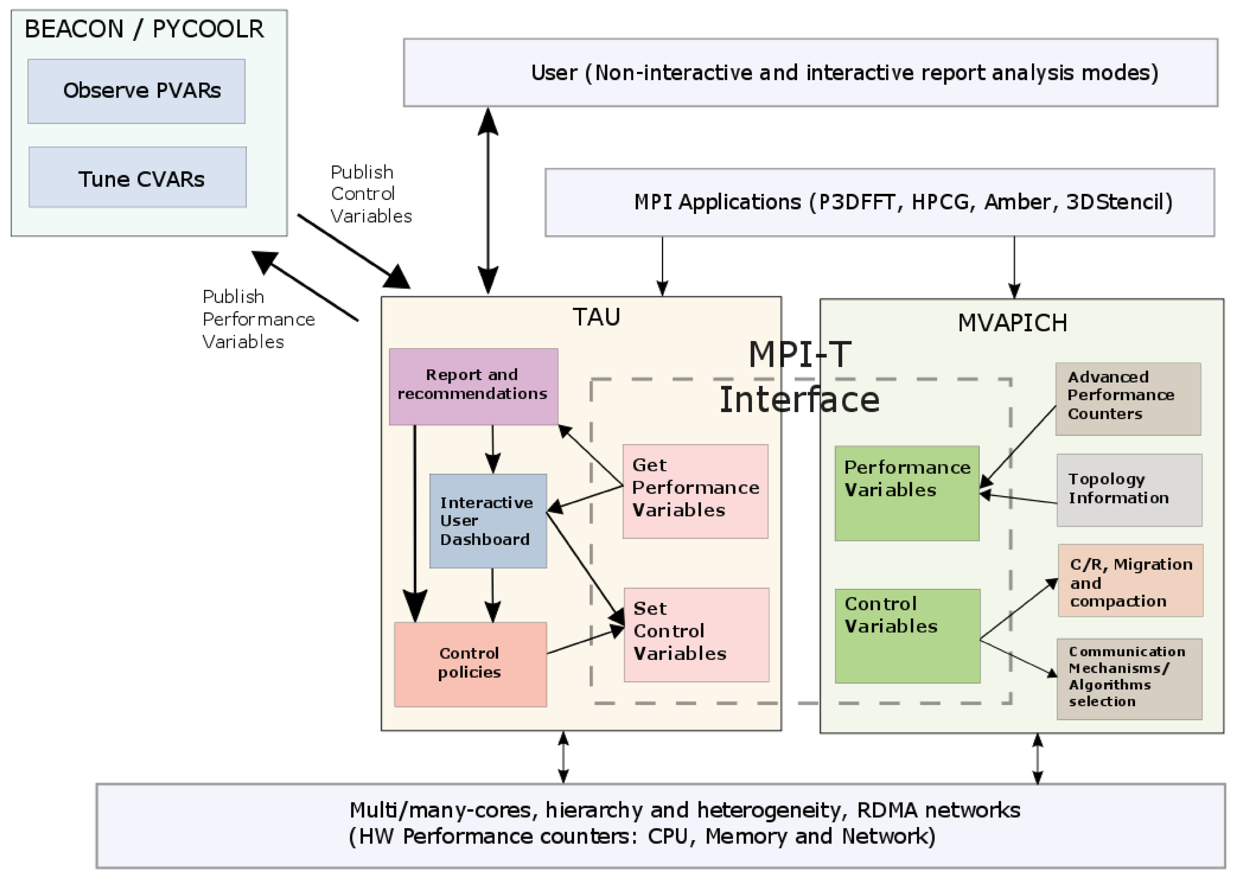
Research Challenges

Creating an MPI programming infrastructure that can integrate performance analysis capabilities more directly, through the MPI Tools Information Interface, monitor Performance metrics during run time, and deliver greater optimization opportunities for scientific applications.



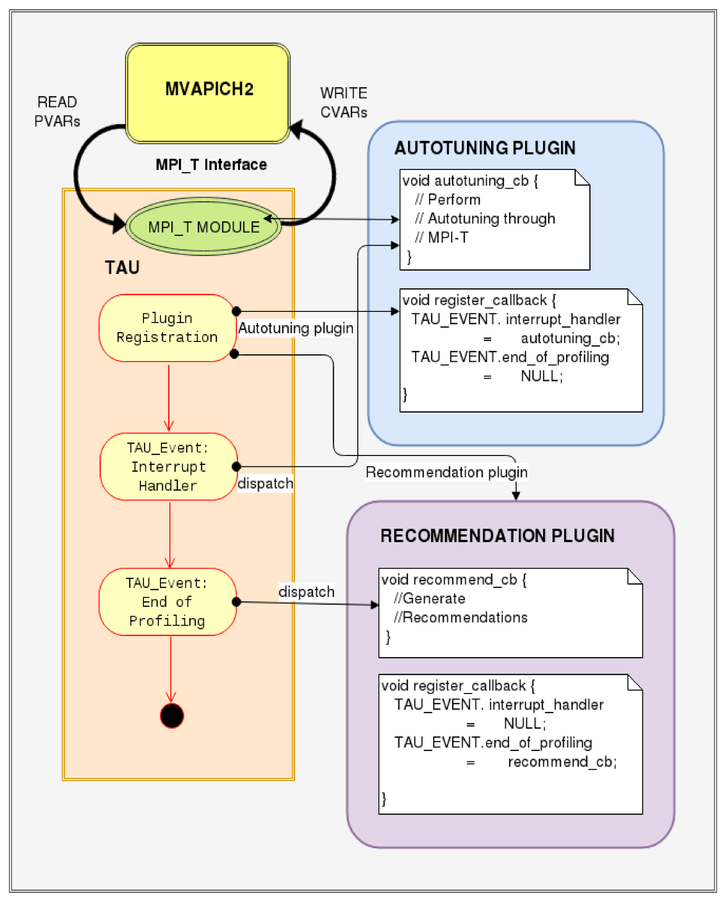
Proposed Approach



- Recommendation module and control policies are realized using a generic plugin architecture inside TAU
- Plugin design allows custom policy modules to be implemented and loaded as needed

TAU Plugin Infrastructure Design

- Plugins are written in C/C++ and implemented as shared library modules
- Plugins register callbacks to salient user-defined events in TAU
- Using the environment variables TAU_PLUGINS and TAU_PLUGINS_PATH, multiple plugins can be loaded in order



- Plugin events currently supported are:
  - FUNCTION REGISTRATION
  - ATOMIC EVENT REGISTRATION
  - ATOMIC EVENT TRIGGER
  - INTERRUPT TRIGGER
  - END OF EXECUTION
- Plugins can register callbacks for more than one event

Autotuning Plugin for SNAP

TAU Autotuning plugin design for freeing unused VBUFs

- Plugin registers a callback for the INTERRUPT TRIGGER event that is triggered when TAU has been configured to collect PVARs at regular intervals by setting TAU_TRACK_MPI_T_PVARS
  - Plugin has access to PVARs that represent the quantity of unused MVAPICH2 Virtual Buffer (VBUF) resources
  - Plugin sets MVAPICH2 CVARs to enable pool control when it detects that the quantity of unused VBUFs has breached a user-defined threshold

Large scale study with SNAP particle transport application that benefits from a higher Eager threshold and freeing of unused VBUFs

- Increasing the Eager threshold improves the point-to-point performance at the cost of increased VBUF memory usage inside MVAPICH2
- VBUF memory usage increases as larger VBUFs may need to be allocated to store Eager messages in transit

Run	Number of Processes	Eager Threshold (Bytes)	Runtime (secs)	Total VBUF Memory (Bytes)
Default	1024	MVAPICH2 Default	47.3	3,322,067
Eager	1024	20,000	42.2	3,787,050
TAU autotuning plugin	1024	20,000	42.9	2,063,421

Policy Engine for MPI_T Plugins

Motivation for a policy engine

- The core tuning / recommendation logic for most plugins would likely to consist of simple condition checks using PVARs and setting of CVARs
- We would like to take advantage of this common structure by:
  - Defining a policy engine (generic autotuning plugin) with PVARs and CVARs templated out
  - Providing a simple JSON-based rule script that plugin writers use to fill in the template parameters for PVARs, CVARs, and custom thresholds used in tuning

Rule design for the policy engine

```
rule {
  num_pvars: ...
  operation: {
    condition: {
      stmt: if,
        leftoperand:pvar1,
        rightoperand:value,
        operator:=,<,>,..
    },
     result: {
        leftoperand:cvar1
        rightoperand:value
        operator:=
     },
     else: {
       leftoperand:cvar1
       rightoperand:value
       operator:=
     }
  }
```

- We use JSON for describing the rule itself:
  - Input: PVARs to be tested for a specific condition
  - Output: CVARs
- In essence, the rule is describing a recursive "if-condition" check with user supplying the operands and operations
- The policy engine reads the rule and computes the actual autotuning / recommendation logic that the rule represents
- Benefits of a policy engine:
  - Code redundancy is avoided
  - Users need not write

Recommendation Plugin for MiniAMR

- Plugin infrastructure can be utilized to generate performance recommendations as metadata on ParaProf
- Recommendation plugin registers a callback for the END OF PROFILING event that is triggered when TAU has finished profiling
  - Plugin has access to all the profiling data collected

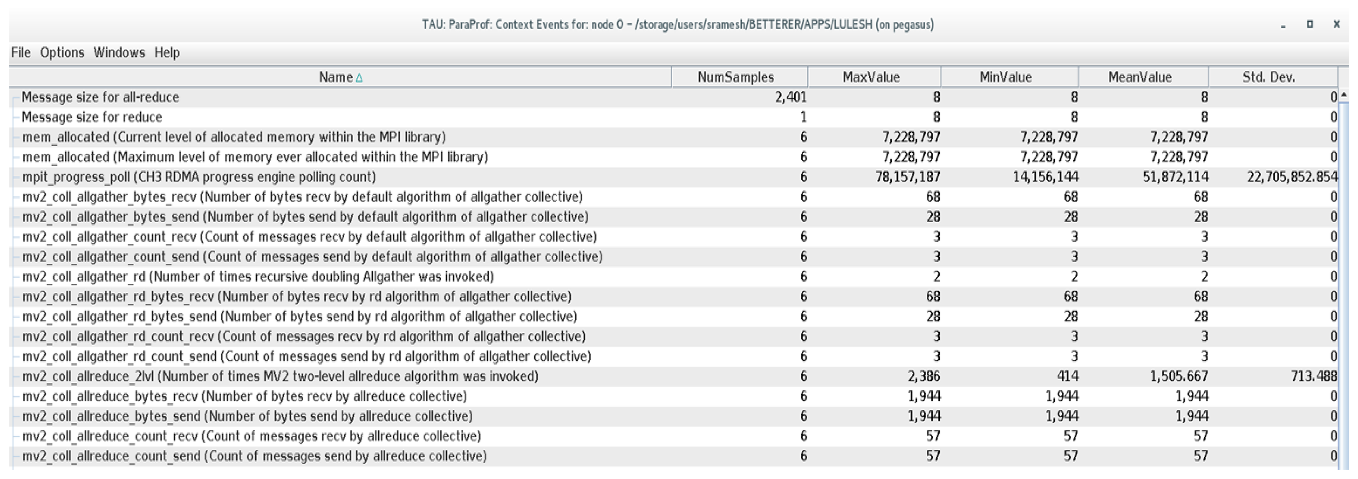
Recommending usage of SHArP hardware offloading of MPI_Allreduce for MiniAMR

- MVAPICH2 supports hardware offloading of MPI_Allreduce using Mellanox' SHArP protocol (disabled by default)
- MiniAMR uses MPI_Allreduce for small message size (8 Bytes)
  - Prime candidate to benefit from hardware offloading of collectives
- Recommendation plugin combines profiling and message size information gathered by TAU from the PMPI interface to recommend the user to enable MPIR_CVAR_ENABLE_SHARP

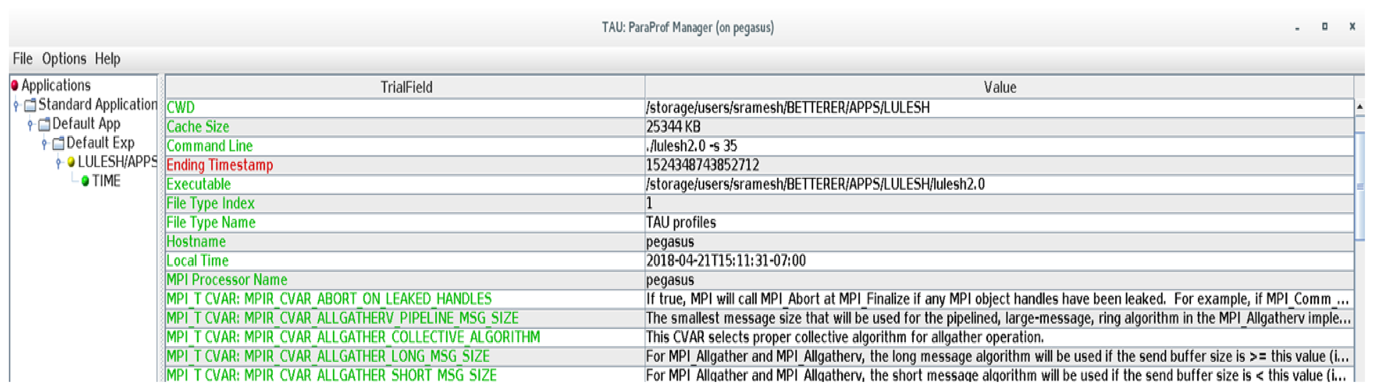
Run	Number of Processes	Runtime (secs)
Default	224	648
SHArP enabled	224	618

Enhanced MPI_T Support in MVAPICH2 and Utilizing it in TAU

- MVAPICH2 has multiple optimized designs for collective operations.
- Choosing the algorithm that deliver the best performance for a given application is complicated and depends on several factors like message size, size of the job, availability of advanced hardware features etc.
- PVARs to measure various aspects of collective algorithm usage like bytes/messages sent/received have been added for all available algorithms for:
  - Alltoall, Alltoallv, Gather, Gatherv, Scatter, Scatterv, Allgather, Allgatherv, Broadcast, Reduce, Allreduce, Reduce_Scatter, and Barrier



- Introduced support for new MPI_T based CVARs to MVAPICH2
  - MPIR_CVAR_USE_BLOCKING - Enables mvapich2 to use interrupt driven mode of communication progress
  - MPIR_CVAR_USE_SHARED_MEM - Enables the use of shared memory for intra-node communication
  - MPIR_CVAR_STRIPING_THRESHOLD - Specifies the message size above which MVAPICH2 begins to stripe the message across multiple rails (if present)
  - MPIR_CVAR_USE_COALESCE - Enables coalescing multiple small messages into a single message to increase throughput
  - MPIR_CVAR_RNDV_PROTOCOL - Specifies rendezvous protocol to be used by MVAPICH2



Future Work & Research Dissemination

- Further enhancing the MPI_T support in MVAPICH2 and co-designing TAU to take advantage of it
  - We are exploring the potential of the MPI Tools Information Interface to support scenarios that require extremely fine-grained tuning, such as:
    - Tuning low-level network protocols at a fine granularity
- Continue to study the benefits of utilizing CVARs exposed by MVAPICH2 at application level on large supercomputing systems
- Study challenges in providing an interactive performance engineering functionality for end users
- Release MVAPICH2 and TAU with enhanced support

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