On-line Application-specific Tuning with the Periscope Tuning Framework and the MPI Tools Interface

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Overview

Introduction

Periscope Tuning Framework

MPI Tools Interface

MPICH Patches

MPIT Plugin

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Conclusion

Introduction

MPI Runtime parameters:

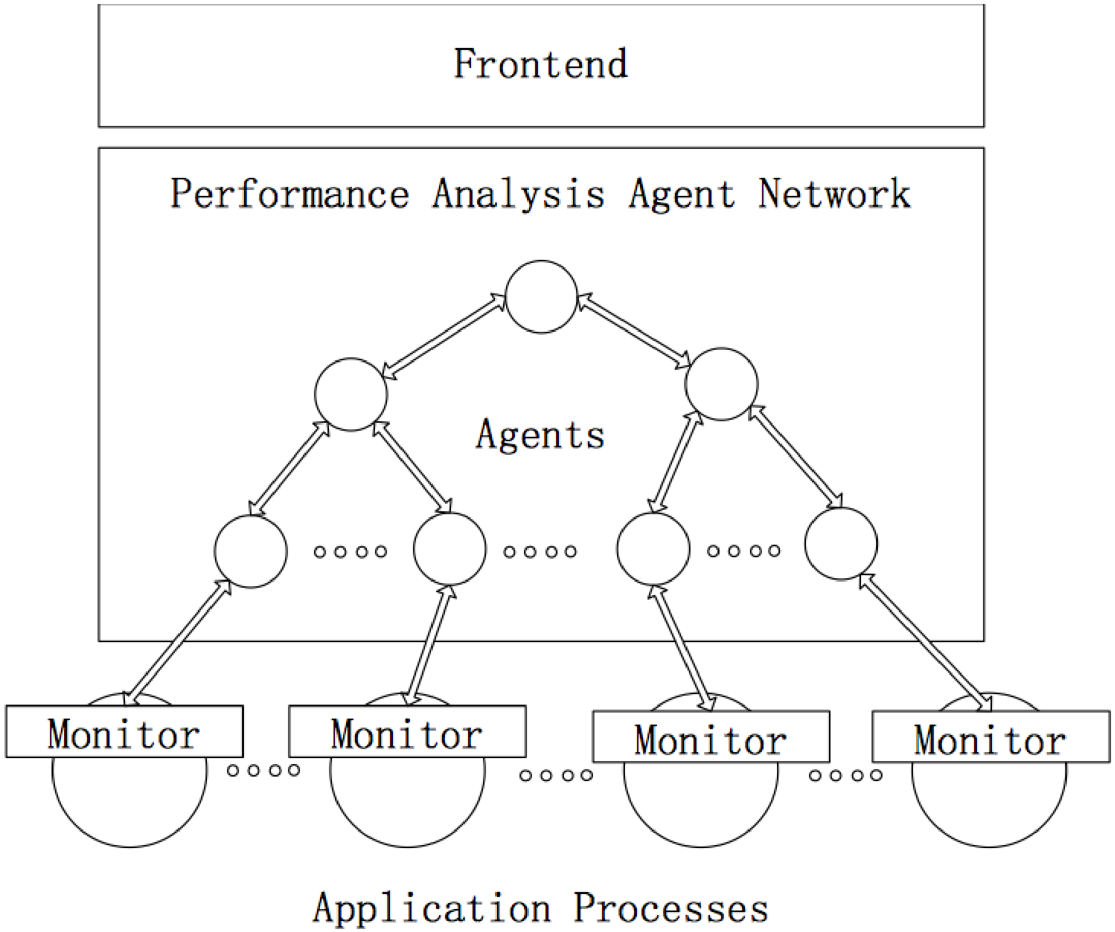
- Certain parts of MPI implementations are already configurable
  - Protocol thresholds, collective algorithms, buffer and queue sizes, ect.
- These parameters can be adjusted for better performance

Advantages:

- The modification of application sources is not necessary
- MPI runtime parameters can be changed without the need to recompile or relink the applications
  - Additionally, these changes can be performed quickly when online access is available (through MPI-T or proprietary interfaces)

Overview

Periscope Tuning Framework



Periscope components:

- Frontend
- Communication Agents
- Analysis Agents
- Monitoring Request Interface (MRI)
  - Replaced with Score-P

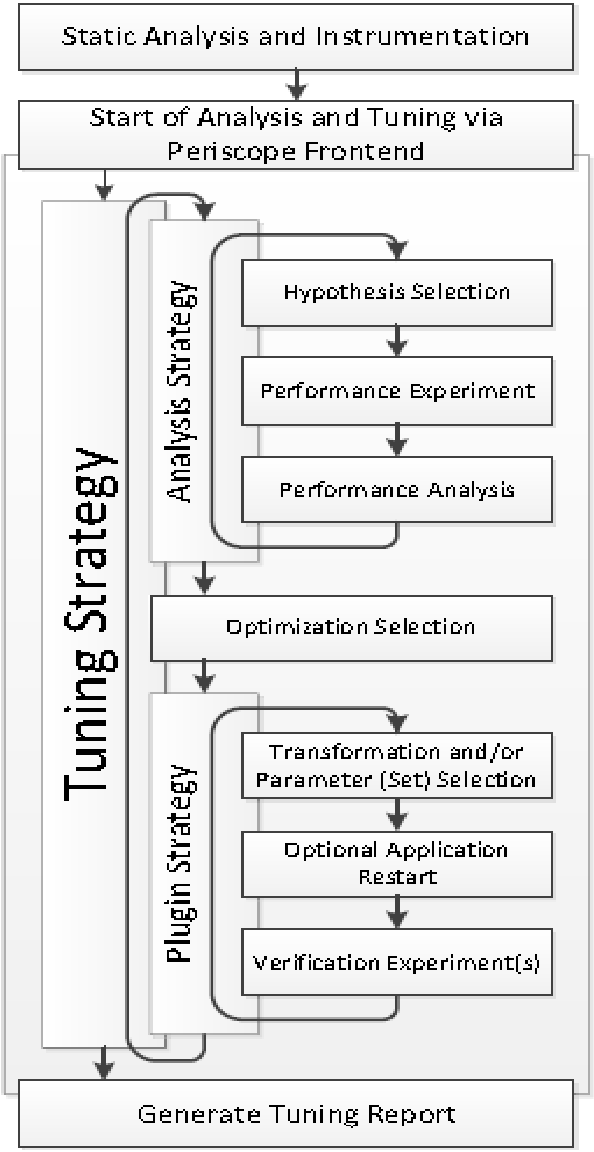
Periscope Tuning Framework

Analysis strategy:

- Runs the application and automatically detect areas of interest
- The type of application and analyses to be performed are dictated by the user and plugins

Tuning strategy:

- Programming model, hardware platform or performance aspect specific
- Can be model based, search based or a combination of both
- Generic flow with specific paths selected by loadable plugins

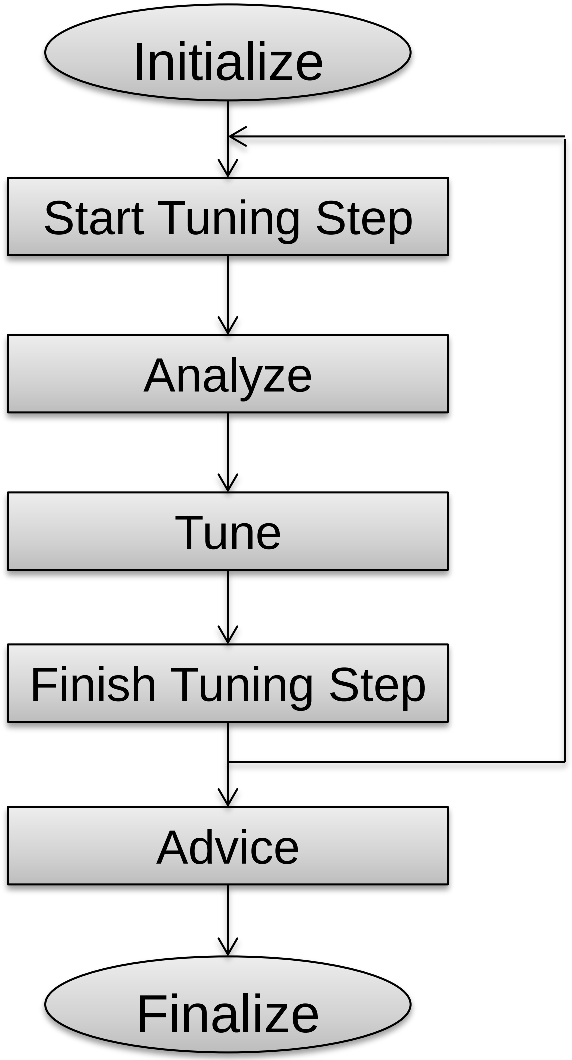


Plugin Flow

- Plugins are shared libraries that implement the plugin interface
  - They are implemented in C++
  - Need to be compiled with compatible tool chains

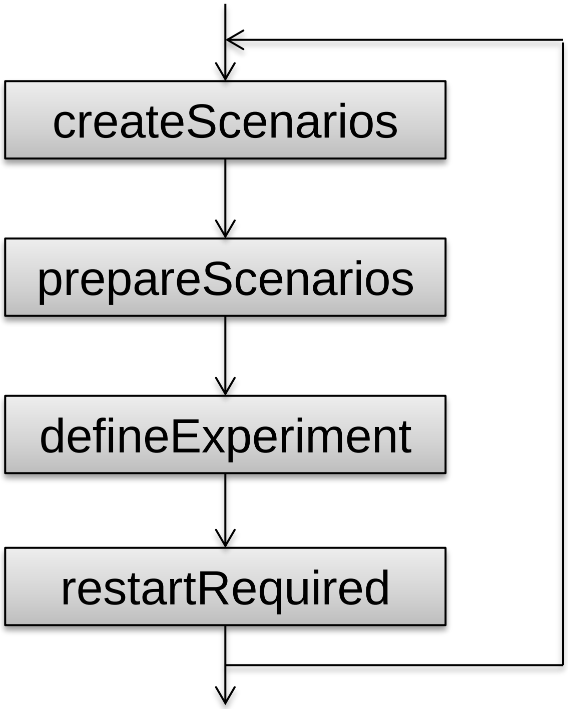
- Plugins indicate which path to follow in the analysis and tuning process
  - Most operations are optional

- Important when developing a plugin:
  - Relevant analyses
  - Modeling possibilities
  - Parameters that impact performance
  - Required application restarts



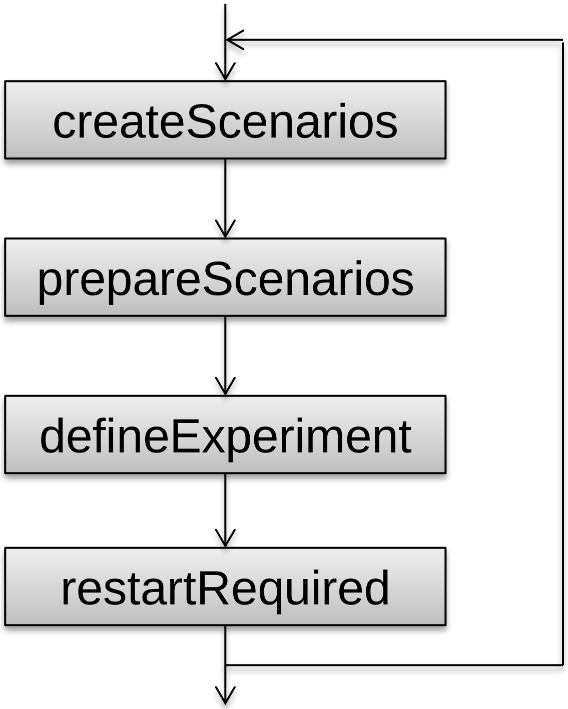
Plugin Flow

- Scenarios
  - Data objects that contains relevant data for an experiment:
    - Concrete values for relevant parameters
    - Where to set these parameters
    - Which performance properties to detect
    - Where to measure the effects
  - Scenario creation and manipulation is one the main tasks of a plugin
- Scenario lifetime
  - Scenarios move between pools as they are processed by plugins and the Frontend
    - Created (CSP), prepared (PSP), experiment (ESP), and finished (FSP) scenario pools



Plugin Flow

- createScenarios
  - Scenarios are created purely based on the number of parameters and their ranges
  - This operation can be offloaded to a search algorithm
- prepareScenarios
  - Preparation for the scenarios, if necessary
  - Examples include: compilation, environment settings, runtime options, ect.
- defineExperiment
  - The scenarios are mapped to the execution environment
  - This includes processes or threads, code regions, ect.
- restartRequired
  - Request a restart if required by the experiment



Periscope Tuning Framework (PTF) Summary

- Runtime environment
  - Hierarchy of communication agents
    - Leaf and aggregation agents
  - Monitoring library linked to the application
- Generic framework
  - Allows for different types of automatic tuners
  - Mixed analysis, modeling and empirical approaches possible
- Plugin interface
  - Predefined general flow; specific path selected by plugins
  - Plugins are loadable components
    - Can be implemented by third parties and be closed source
  - Plugins dictate which operations to perform, depending on the aspect to tune
    - *Parameters can be set online or require a restart*

Overview

MPI Tools Interface

MPI-3 interface that allows for:

- Performance variables (PVAR)
  - State of the MPI library
    - Message queues
    - Configuration parameter values
  - Performance counters
    - Aggregated traffic
    - Current set parameter values
- Control variables (CVAR)
  - Configurable at runtime
    - Mostly restricted to before MPI_Init
  - Isolation through sessions, where applicable
- Implementers are free to decide what to expose with MPIT

Current Implementations

Open MPI:

- Hundreds of parameters available
  - Point to point and collectives thresholds
  - Many other Open MPI specific parameters
- CVARs writable before MPI_Init only

MPICH:

- Several changes were done internally since 1.5 (documented in MPICH's website)
  - Improved efficiency
  - Conforms better to the standard
- Parameters relevant to point to point and collectives

Overview

MPICH Patches

- Motivation: quick online updates to parameters
  - Slight degradation of performance acceptable
  - Some correctness constraints handled by our tool
- Based on MPICH 1.5.x (unfortunately)
  - Most features were marked as experimental
  - YAML files processed at configuration
  - *Our patches no longer compatible with the trunk*
- Created extra CVARs
  - Explicit selection of internal collective algorithms
    - MPICH deals with thresholds instead
  - Can be changed at runtime
    - Restrictions handled by the plugin, where applicable

MPICH Patches

Point to point:

- These are in general safe to change per point to point operation
  - Sender specifies how to handle the payload in the message itself (active messages)
- These changes required extra care with the nemesis implementation
  - Some operations can be replaced by function pointers
    - Luckily, these replacements are done once, at initialization
  - Sets of CVARS for intra- and inter-node
    - Typically shared memory and network variants
- Eager and LMT thresholds, depending on the platform

MPICH Patches

Collectives:

- 8 blocking collectives, 8 non-locking collectives
- Algorithm selected explicitly, and not through thresholds
- Correctness ensured by the PTF plugin
  - Some algorithms have certain requirements for correctness
    - For example: powers of 2 process counts in the communicator
  - Internal algorithm must match in all participating processes

PVARS:

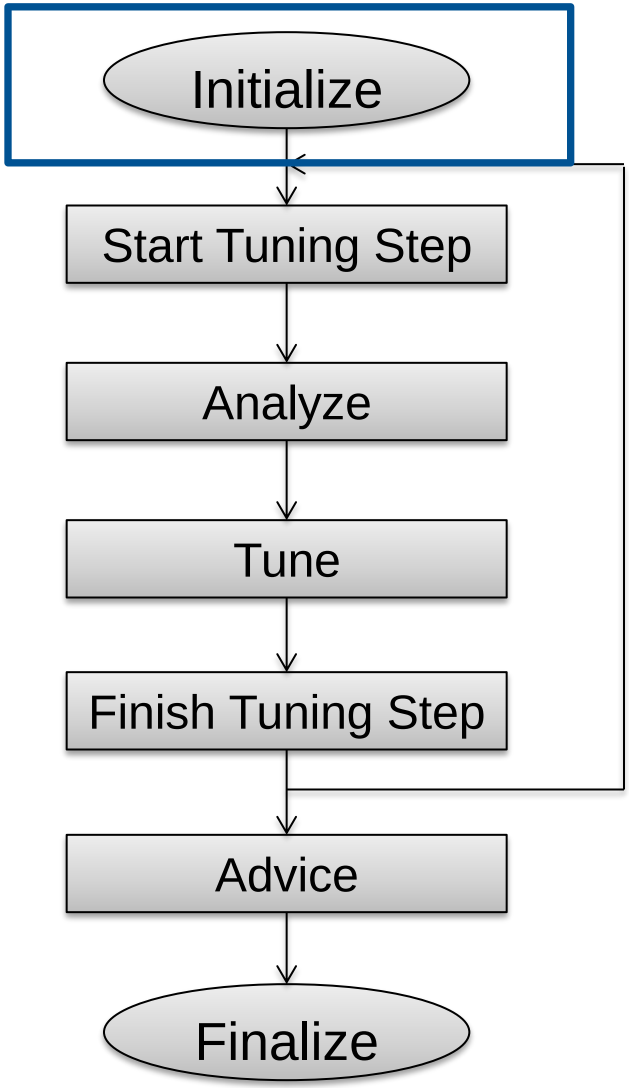
- Additional low level network traffic counters exposed
  - Expose data not visible at the PMPI level
    - Point-to-point traffic generated by collectives
    - Exact traffic generated at the BTL (Channel in MPICH), includding overheads

Overview

MPIT Plugin

Initialization:

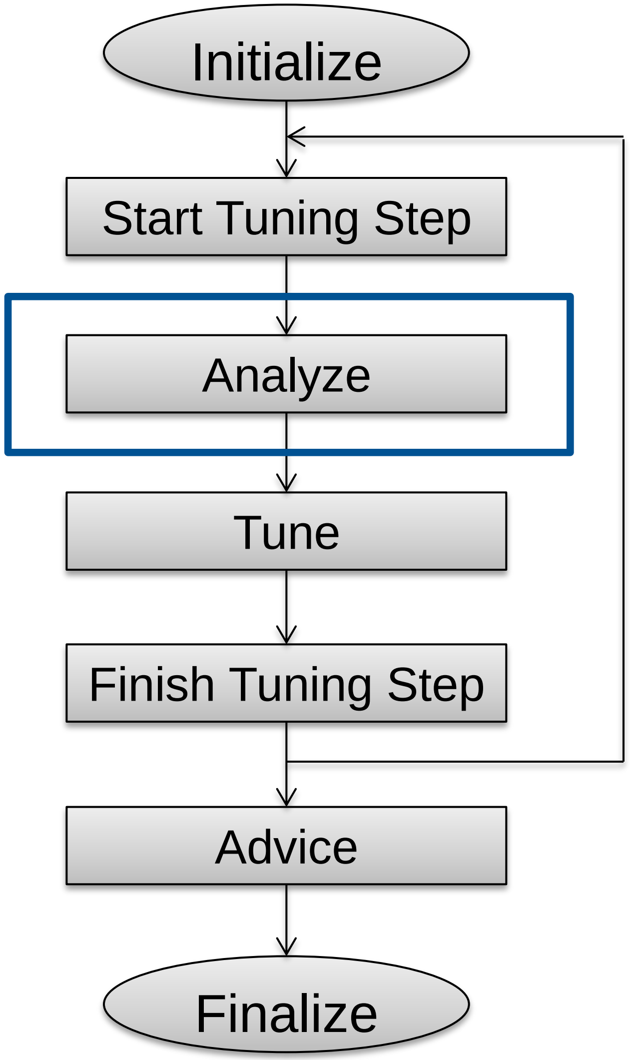
- The plugin acquires static information about the application
  - MPI_Init and MPI_Finalize locations
  - Point to point calls
  - Collective operation calls
  - Currently one-sided operations are not supported
- MPI_Init, MPI_Finalize and not supported operations are filtered out



MPIT Plugin

Analysis:

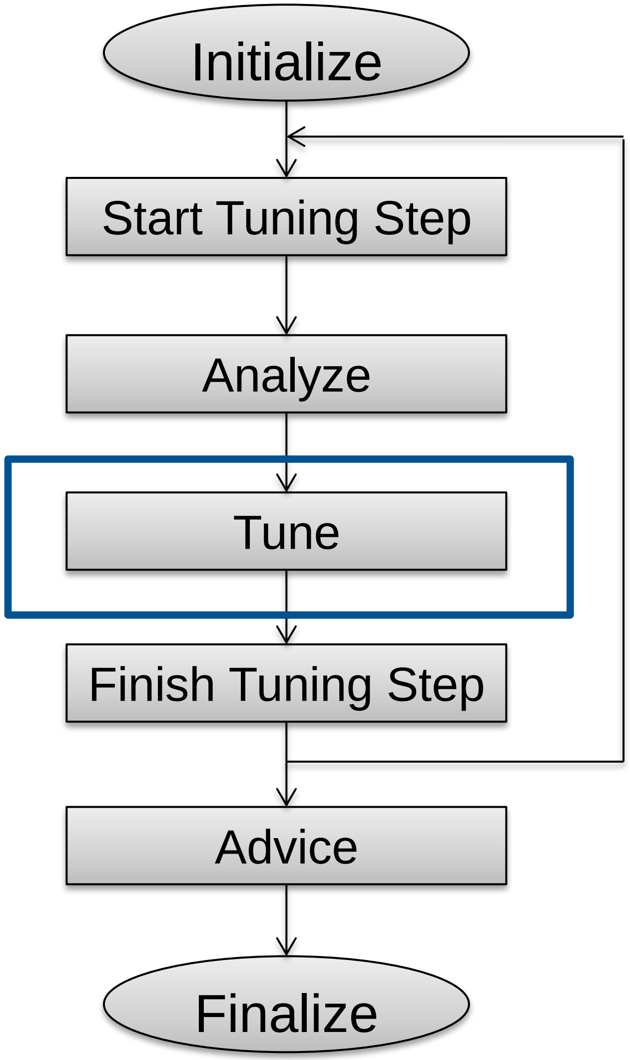
- An MPI analysis is requested, in order to evaluate the following performance properties of the application:
  - Near threshold dependency,
  - Frequent MPI call,
  - Late sender condition, etc.
- The analysis results are processed and a search space and related data structures are prepared
- *This analysis is only performed in the first tuning step, for this plugin*



MPIT Plugin

Tuning:

- Odd steps:
  - Tune point to point parameters
    - Inter- and intra thresholds
    - Eager, and LMT if enabled
- Even steps:
  - Each internal collective is evaluated
    - Per enabled call site (code region)
- In both cases:
  - Collect low level BTL byte values
    - In contrast to PMPI based tools
  - Update a communication matrix



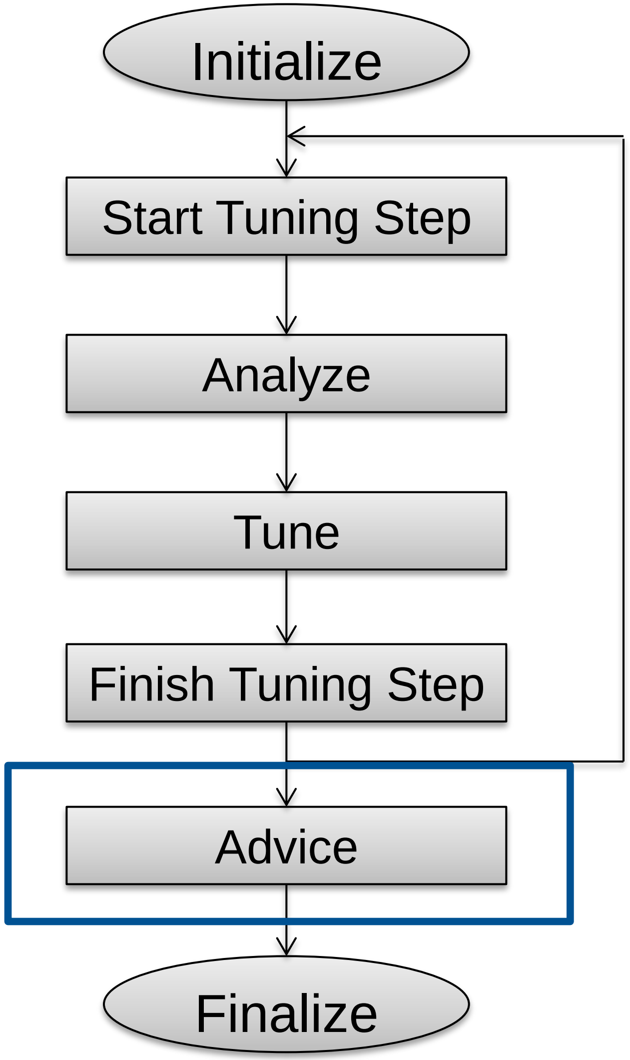
MPIT Plugin

Tuning steps:

- The number of pair of tuning steps is configurable:
  - Correlation between parameters for point to point communication and collectives
  - Measurement samples; variance reduction

Advice:

- Generates a summary of the search
- Posts the best found values for each MPI call explored
- Performs a bandwidth reduction on the communication matrix (with raw BTL values) and outputs a recommended topology (a hostfile for SuperMUC)



Overview

Test Systems

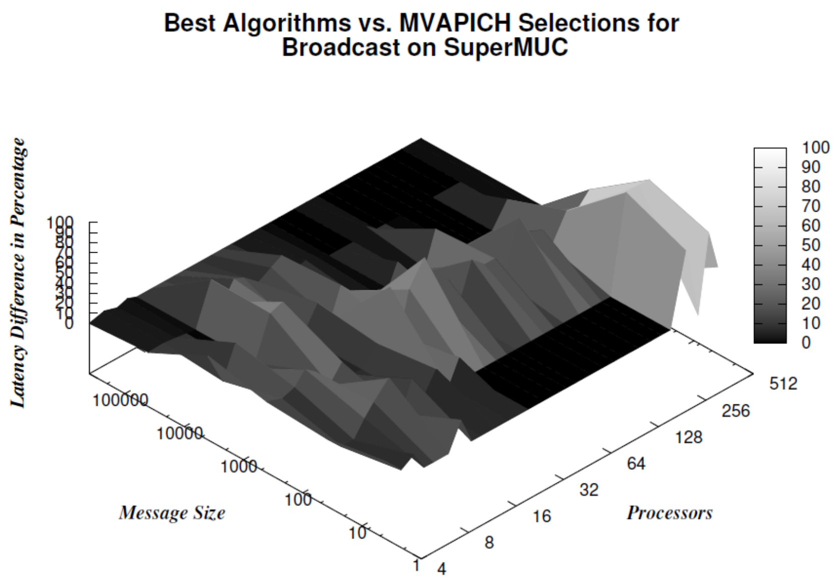
SuperMUC specifications:

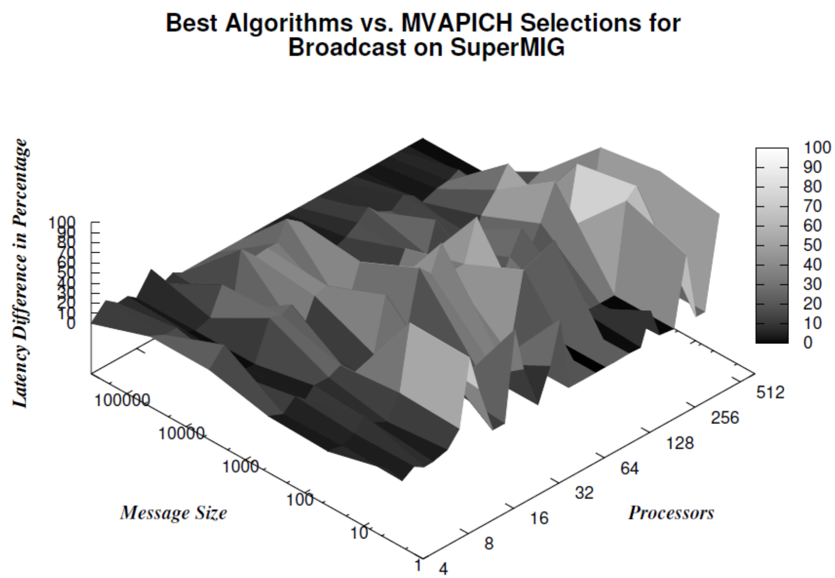
- CPU:
  - Xeon E5-2680
  - 20M Cache,
  - 8 Cores
    - 2.7 GHz
    - 3.5 GHz
- Thin nodes:
  - 2 * 8 cores
  - 32GB RAM
  - Infiniband FDR10

SuperMIG specifications:

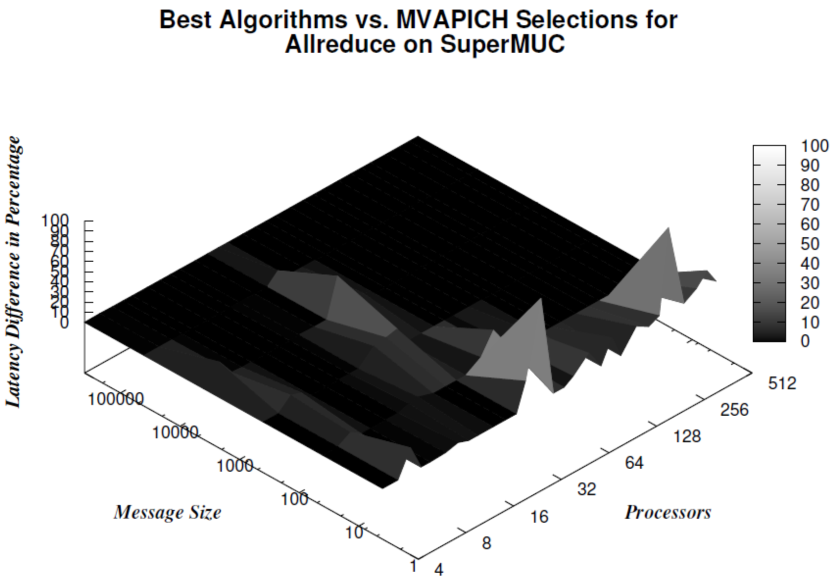
- CPU:
  - Xeon E7-4870
  - 30M Cache,
  - 10 Cores
    - 2.4 GHz
    - 2.8 GHz
- Fat nodes:
  - 4 * 10 cores
  - 256GB RAM
  - Infiniband FDR10

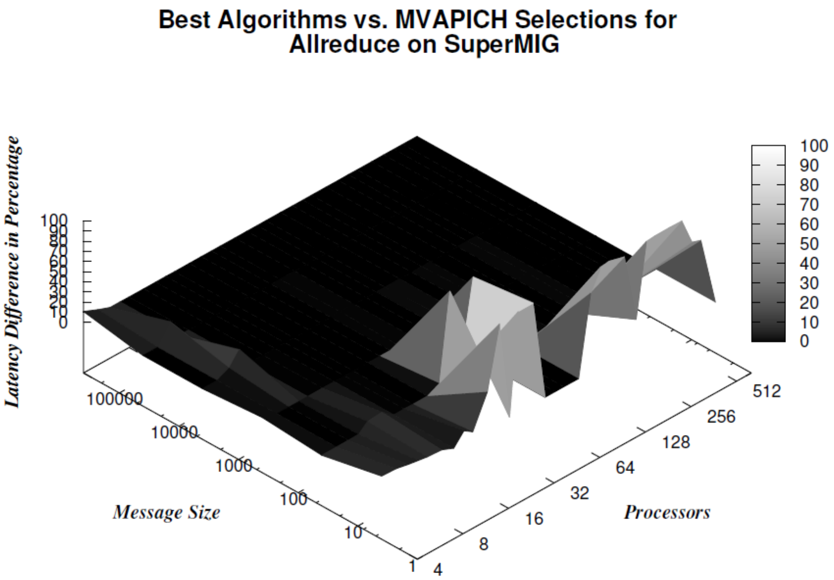
MPI_Broadcast



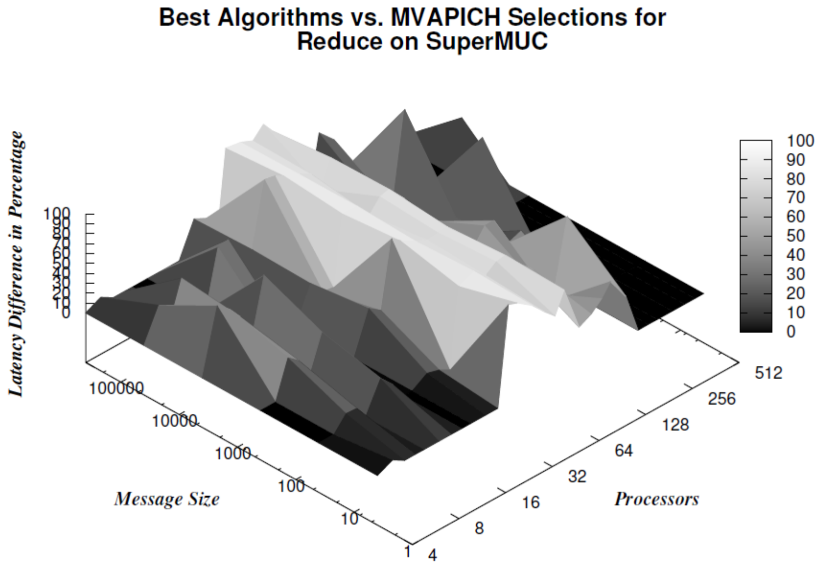


MPI_Allreduce





MPI_Reduce


Best Algorithms vs. MVAPICH Selections for
Reduce on SuperMUC
Latency Difference in Percentage
Message Size
Processors
100
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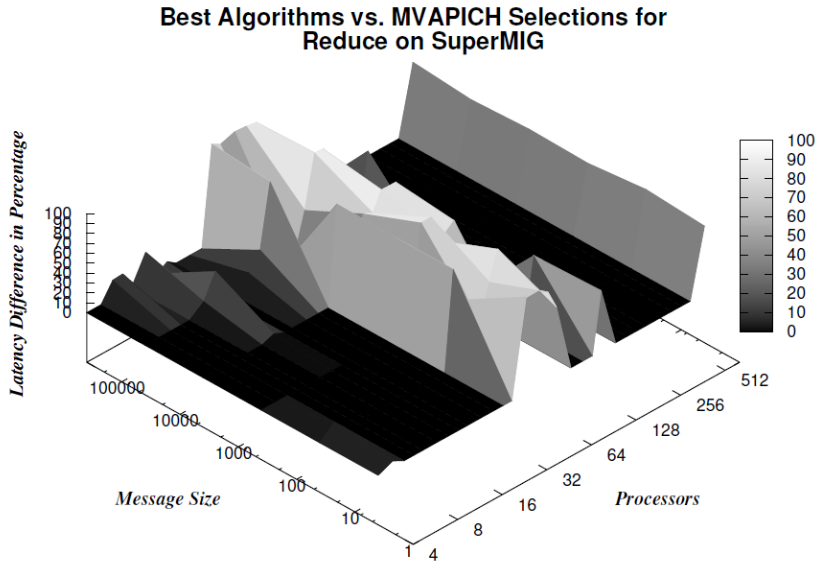
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Overview

Conclusion

MPI-T:

- The interface has been great addition for tool developers
- CVARS can be, in many cases, safely modified at runtime
  - This can be used to accelerate the search process of automatic tuners

Runtime parameters:

- Require no change to the application source code
- Once an application is built with a supporting MPI library, no additional recompiles or relinks are necessary
- Can have significant effects in performance, but only under certain conditions (as seen with the parameter sweeps)

Periscope Tuning Framework:

- Generic framework for automatic tuning
- Supports the mixed use of analyses, modeling and search approaches