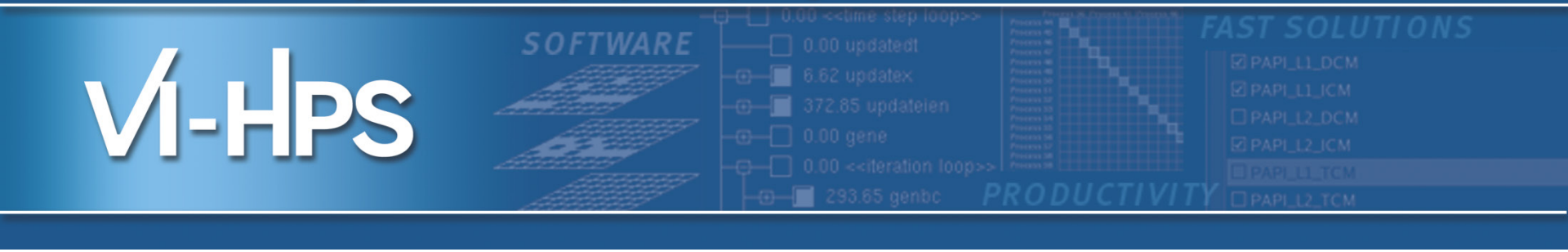

Automatic trace analysis with Scalasca

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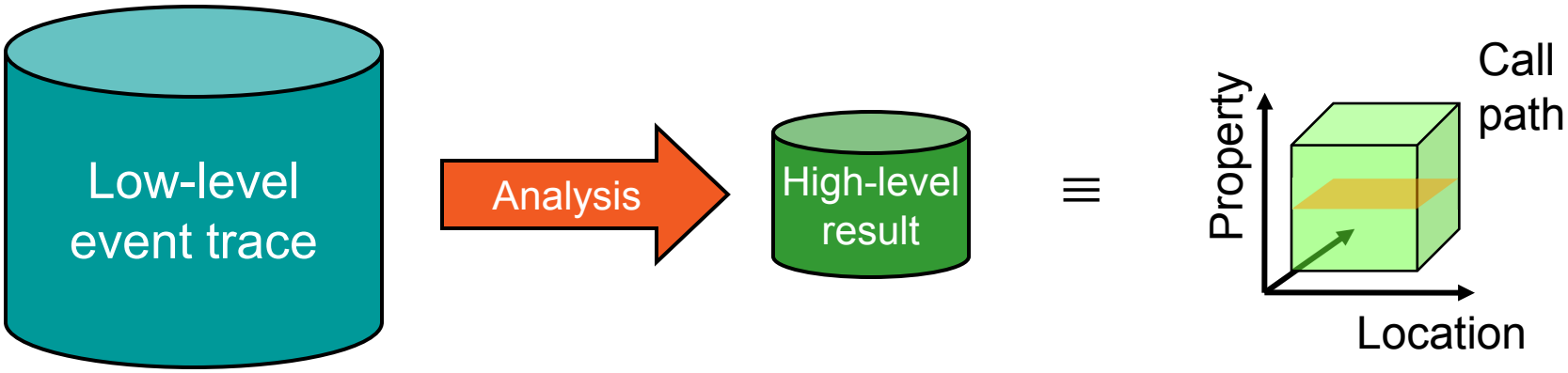
Jülich Supercomputing Centre

scalasca

- Idea
  - Automatic search for patterns of inefficient behaviour
  - Classification of behaviour & quantification of significance



  - Guaranteed to cover the entire event trace
  - Quicker than manual/visual trace analysis
  - Parallel replay analysis exploits available memory & processors to deliver scalability

The Scalasca project: Overview

- Project started in 2006
  - Initial funding by Helmholtz Initiative & Networking Fund
  - Many follow-up projects
- Follow-up to pioneering KOJAK project (started 1998)
  - Automatic pattern-based trace analysis
- Now joint development of
  - Jülich Supercomputing Centre
  - German Research School for Simulation Sciences

The Scalasca project: Objective

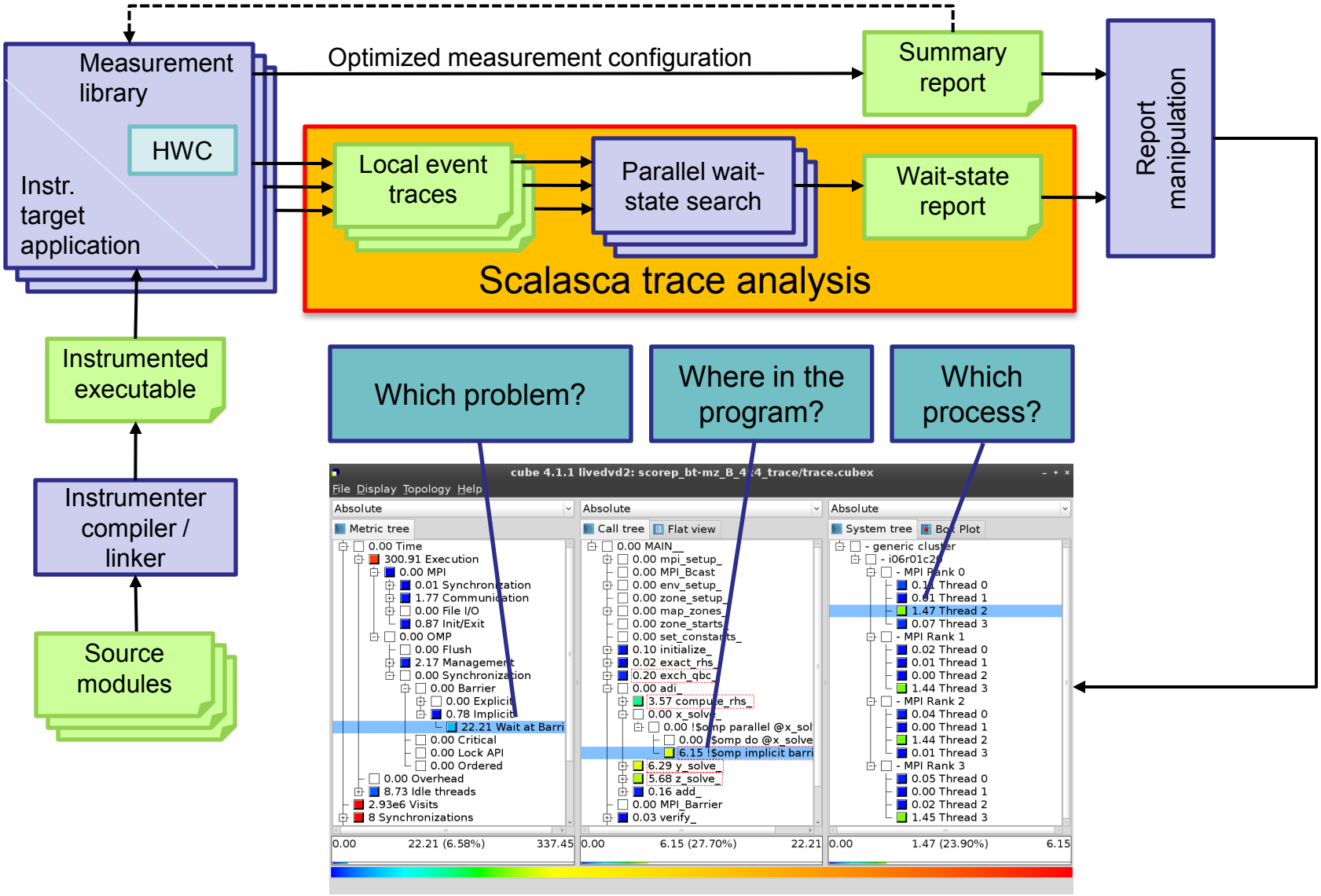
- Development of a **scalable** performance analysis toolset for most popular parallel programming paradigms
- Specifically targeting **large-scale** parallel applications
  - such as those running on IBM BlueGene or Cray XT systems with one million or more processes/threads
- Latest release in March 2013: Scalasca v1.4.3
- Here: Scalasca v2.0-rc with Score-P support
  - release targeted with Score-P v1.2 in summer

- Open source, New BSD license
- Portable
  - IBM BlueGene, IBM SP & blade clusters, Cray XT, SGI Altix, Fujitsu FX10 & K computer, NEC SX, Intel Xeon Phi, Solaris & Linux clusters, ...
- Supports parallel programming paradigms & languages
  - MPI, OpenMP & hybrid MPI+OpenMP
  - Fortran, C, C++
- Integrated instrumentation, measurement & analysis toolset
  - Runtime summarization (callpath profiling)
  - Automatic event trace analysis

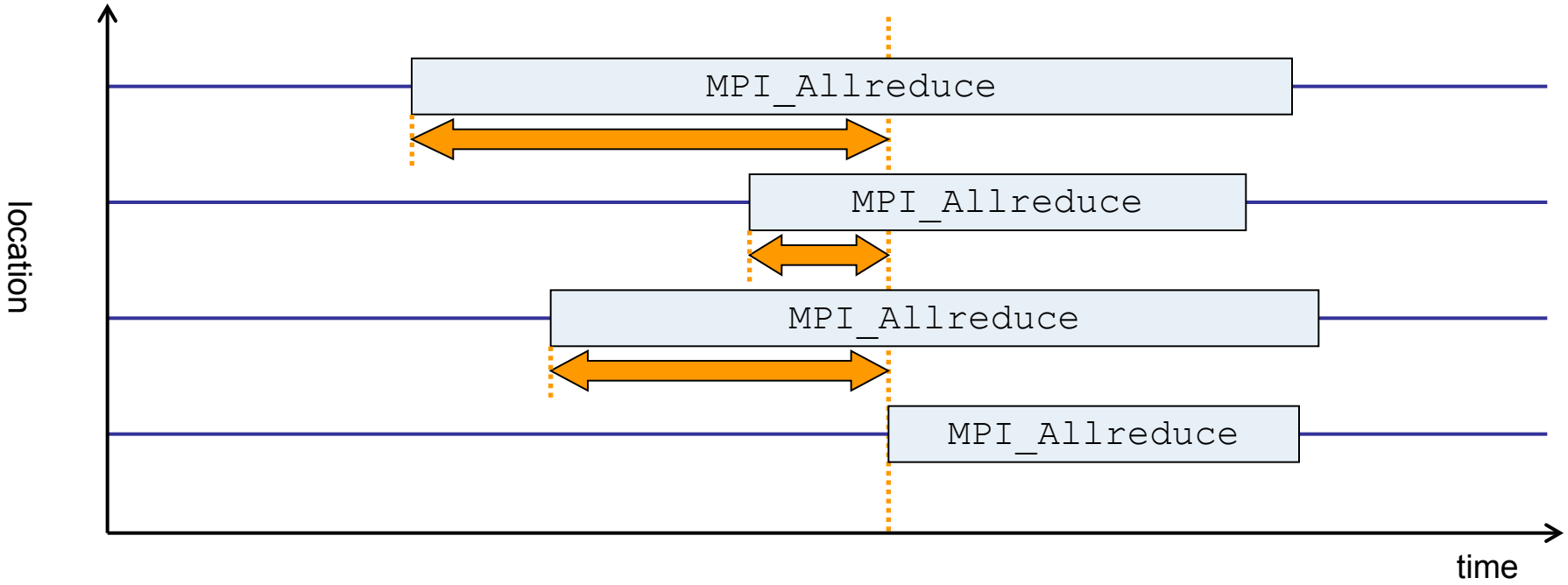
Scalasca 2.0 features

- Open source, New BSD license
- Uses Score-P instrumenter & measurement libraries
  - Scalasca 2.0 core package focuses on trace-based analyses
  - Generally same usage as Scalasca 1.4
- Supports common data formats
  - Reads event traces in OTF2 format
  - Writes analysis reports in CUBE4 format
- Still aims to be portable
  - But not widely tested yet
  - Known issues
    - Unable to handle OTF2 traces containing CUDA events
    - Trace flush & pause event regions not handled correctly
    - OTF2 traces created with SIONlib not handled correctly

Scalasca workflow

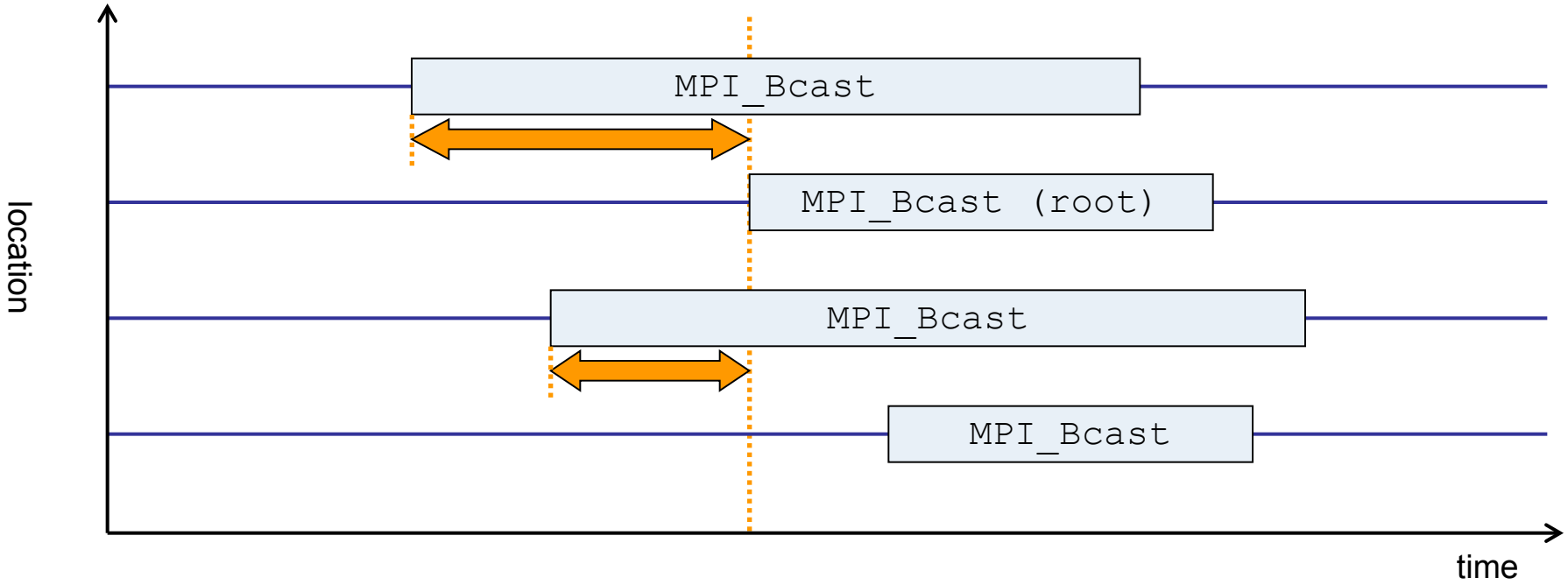


Example: Wait at NxN



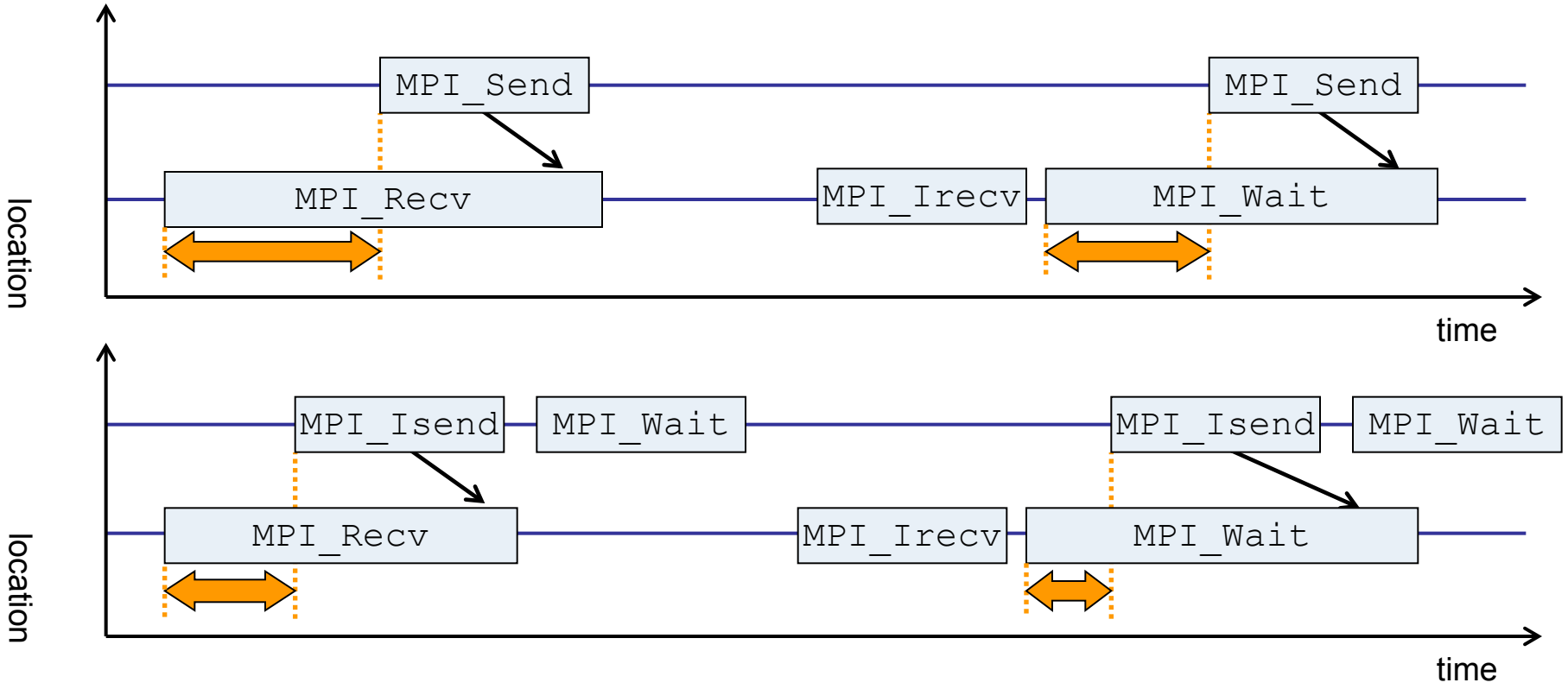
- Time spent waiting in front of synchronizing collective operation until the last process reaches the operation
- Applies to: MPI_Allgather, MPI_Allgatherv, MPI_Alltoall, MPI_Reduce_scatter, MPI_Reduce_scatter_block, MPI_Allreduce

Example: Late Broadcast

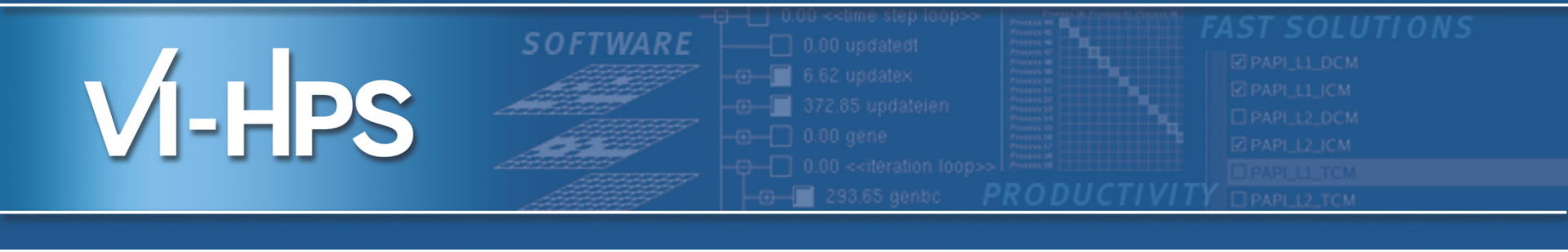


- Waiting times if the destination processes of a collective 1-to-N operation enter the operation earlier than the source process (root)
- Applies to: MPI_Bcast, MPI_Scatter, MPI_Scatterv

Example: Late Sender



- Waiting time caused by a blocking receive operation posted earlier than the corresponding send
- Applies to blocking as well as non-blocking communication



Hands-on: NPB-MZ-MPI / BT

scalasca

Scalasca compatibility command: *skin*

- Scalasca application instrumenter

```
% skin
Scalasca 2.0: application instrumenter using scorep
usage: skin [-v] [-comp] [-pdt] [-pomp] [-user] <compile-or-link-cmd>
   -comp={all|none|...}: routines to be instrumented by compiler
          (... custom instrumentation specification for compiler)
   -pdt:  process source files with PDT instrumenter
   -pomp: process source files for POMP directives
   -user: enable EPIK user instrumentation API macros in source code
   -v:    enable verbose commentary when instrumenting

   --*:   options to pass to Score-P instrumenter
```

  - Provides compatibility with Scalasca 1.X
  - Generally use Score-P instrumenter directly

Scalasca convenience command: *scan*

- Scalasca measurement collection & analysis nexus

```
% scan
Scalasca 2.0: measurement collection & analysis nexus
usage: scan {options} [launchcmd [launchargs]] target [targetargs]
      where {options} may include:
  -h    Help: show this brief usage message and exit.
  -v    Verbose: increase verbosity.
  -n    Preview: show command(s) to be launched but don't execute.
  -q    Quiescent: execution with neither summarization nor tracing.
  -s    Summary: enable runtime summarization. [Default]
  -t    Tracing: enable trace collection and analysis.
  -a    Analyze: skip measurement to (re-)analyze an existing trace.
  -e exptdir   : Experiment archive to generate and/or analyze.
                 (overrides default experiment archive title)
  -f filtfile  : File specifying measurement filter.
  -l lockfile  : File that blocks start of measurement.
```

Scalasca convenience command: *square*

- Scalasca analysis report explorer

```
% square
Scalasca 2.0: analysis report explorer
usage: square [-v] [-s] [-f filtfile] [-F] <experiment archive
                                                | cube file>
   -F           : Force remapping of already existing reports
   -f filtfile  : Use specified filter file when doing scoring
   -s           : Skip display and output textual score report
   -v           : Enable verbose mode
```

Automatic measurement configuration

- **`scan`** configures Score-P measurement by setting some environment variables automatically
  - e.g., experiment title, profiling/tracing mode, filter file, …
  - Precedence order:
    - Command-line arguments
    - Environment variables already set
    - Automatically determined values
- Also, **`scan`** includes consistency checks and prevents corrupting existing experiment directories
- For tracing experiments, after trace collection completes then automatic parallel trace analysis is initiated
  - uses identical launch configuration to that used for measurement (i.e., the same allocated compute resources)

BT-MZ summary measurement

- Run the application using the Scalasca measurement collection & analysis nexus prefixed to launch command

```
% cd bin.scorep
% OMP_NUM_THREADS=4 scan -f scorep.filt  aprun -n 4 -d 4 ./bt-mz_B.4
S=C=A=N: Scalasca 2.0 runtime summarization
S=C=A=N: ./scorep_bt-mz_B_4x4_sum experiment archive
S=C=A=N: Thu Sep 13 18:05:17 2012: Collect start
aprun -n 4 -d 4 ./bt-mz_B.4

 NAS Parallel Benchmarks (NPB3.3-MZ-MPI) - BT-MZ MPI+OpenMP Benchmark

 Number of zones:   8 x   8
 Iterations: 200    dt:   0.000300
 Number of active processes:     4

 [... More application output ...]

S=C=A=N: Thu Sep 13 18:05:39 2012: Collect done (status=0) 22s
S=C=A=N: ./scorep_bt-mz_W_4x4_sum complete.
```

- Creates experiment directory ./scorep_bt-mz_B_4x4_sum

BT-MZ summary analysis report examination

- Score summary analysis report

```
% square -s  scorep_bt-mz_B_4x4_sum
INFO: Post-processing runtime summarization result...
INFO: Score report written to ./scorep_bt-mz_B_4x4_sum/scorep.score
```

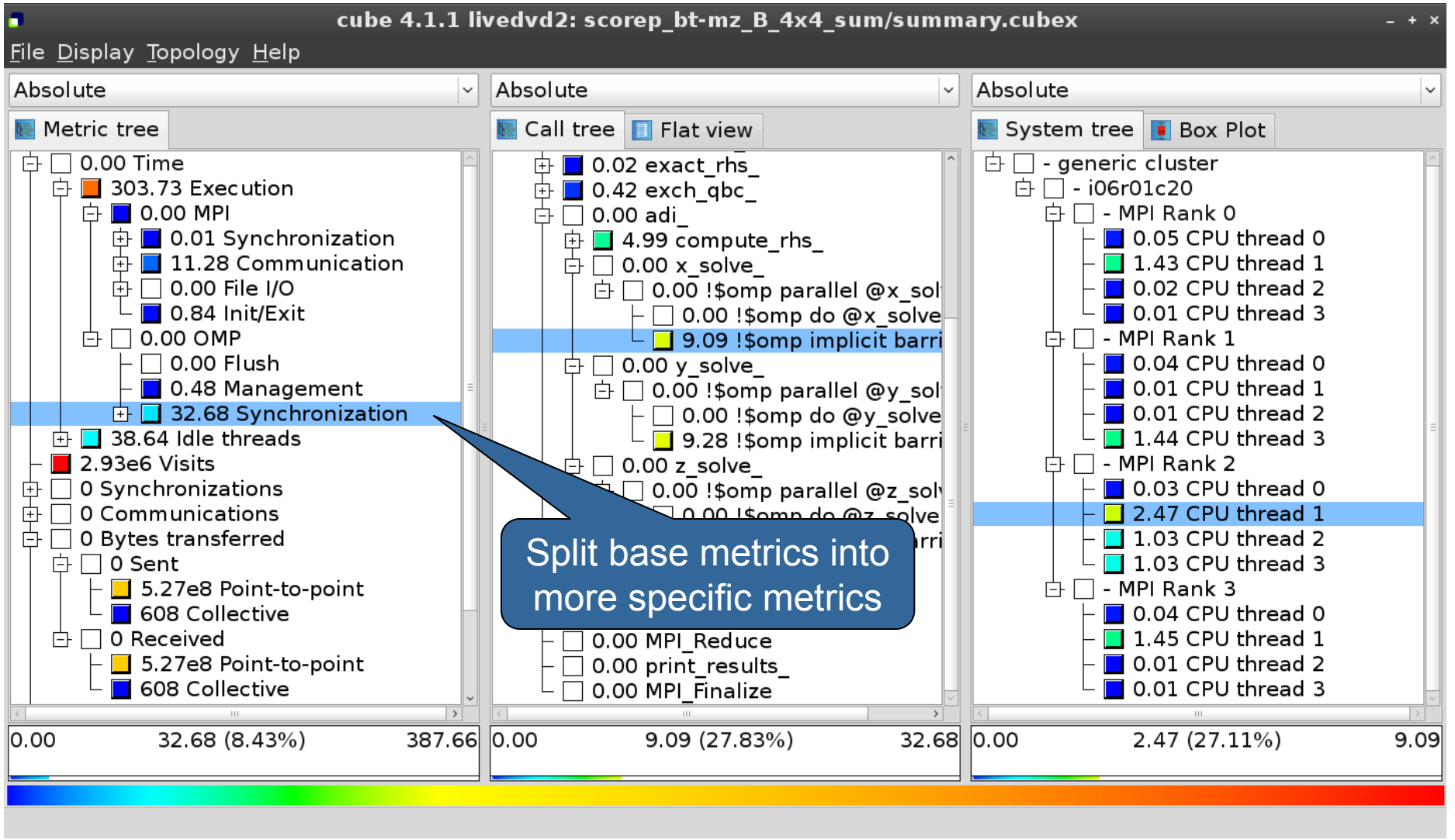
- Post-processing and interactive exploration with CUBE

```
% square  scorep_bt-mz_B_4x4_sum
INFO: Displaying ./scorep_bt-mz_B_4x4_sum/summary.cubex...

                [GUI showing summary analysis report]
```

- The post-processing derives additional metrics and generates a structured metric hierarchy

Post-processed summary analysis report



BT-MZ trace measurement collection...

- To enable additional statistics and pattern instance tracking, set SCAN_ANALYZE_OPTS="-i s"

```
% export SCAN_ANALYZE_OPTS="-i -s"
```

- Re-run the application using Scalasca nexus with "**-t**" flag

```
% OMP_NUM_THREADS=4 scan -f scorep.filt -t  aprun -n 4 -d 4 ./bt-mz_B.4
S=C=A=N: Scalasca 2.0 trace collection and analysis
S=C=A=N: ./scorep_bt-mz_B_4x4_trace experiment archive
S=C=A=N: Thu Sep 13 18:05:39 2012: Collect start
aprun -n 4 -d 4 ./bt-mz_B.4
 NAS Parallel Benchmarks (NPB3.3-MZ-MPI) - BT-MZ MPI+OpenMP Benchmark

 Number of zones:   8 x   8
 Iterations: 200    dt:   0.000300
 Number of active processes:     4

 [... More application output ...]

S=C=A=N: Thu Sep 13 18:05:58 2012: Collect done (status=0) 19s
 [.. continued ...]
```


BT-MZ trace measurement ... analysis

- Continues with automatic (parallel) analysis of trace files

```
S=C=A=N: Thu Sep 13 18:05:58 2012: Analyze start
Aprun -n 4 -d 4 scout.hyb -i -s ./scorep_bt-mz_B_4x4_trace/traces.otf2
SCOUT   Copyright (c) 1998-2012 Forschungszentrum Juelich GmbH
        Copyright (c) 2009-2012 German Research School for Simulation
                                Sciences GmbH

Analyzing experiment archive ./scorep_bt-mz_B_4x4_trace/traces.otf2

Opening experiment archive ... done (0.002s).
Reading definition data    ... done (0.004s).
Reading event trace data   ... done (0.669s).
Preprocessing              ... done (0.975s).
Analyzing trace data       ... done (0.675s).
Writing analysis report    ... done (0.112s).

Max. memory usage         : 145.078MB

Total processing time     : 2.785s
S=C=A=N: Thu Sep 13 18:06:02 2012: Analyze done (status=0) 4s
```

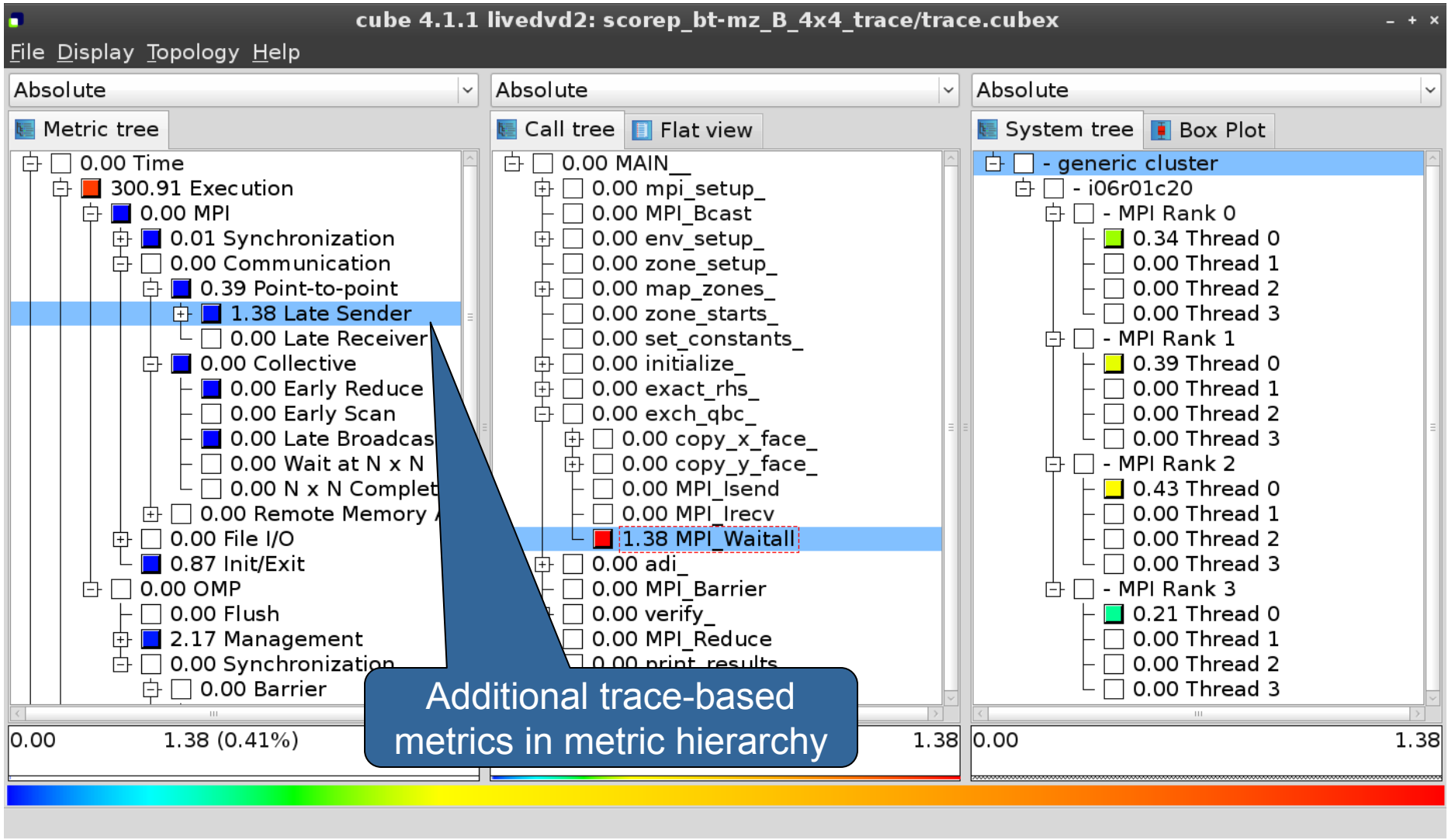

BT-MZ trace analysis report exploration

- Produces trace analysis report in experiment directory containing trace-based wait-state metrics

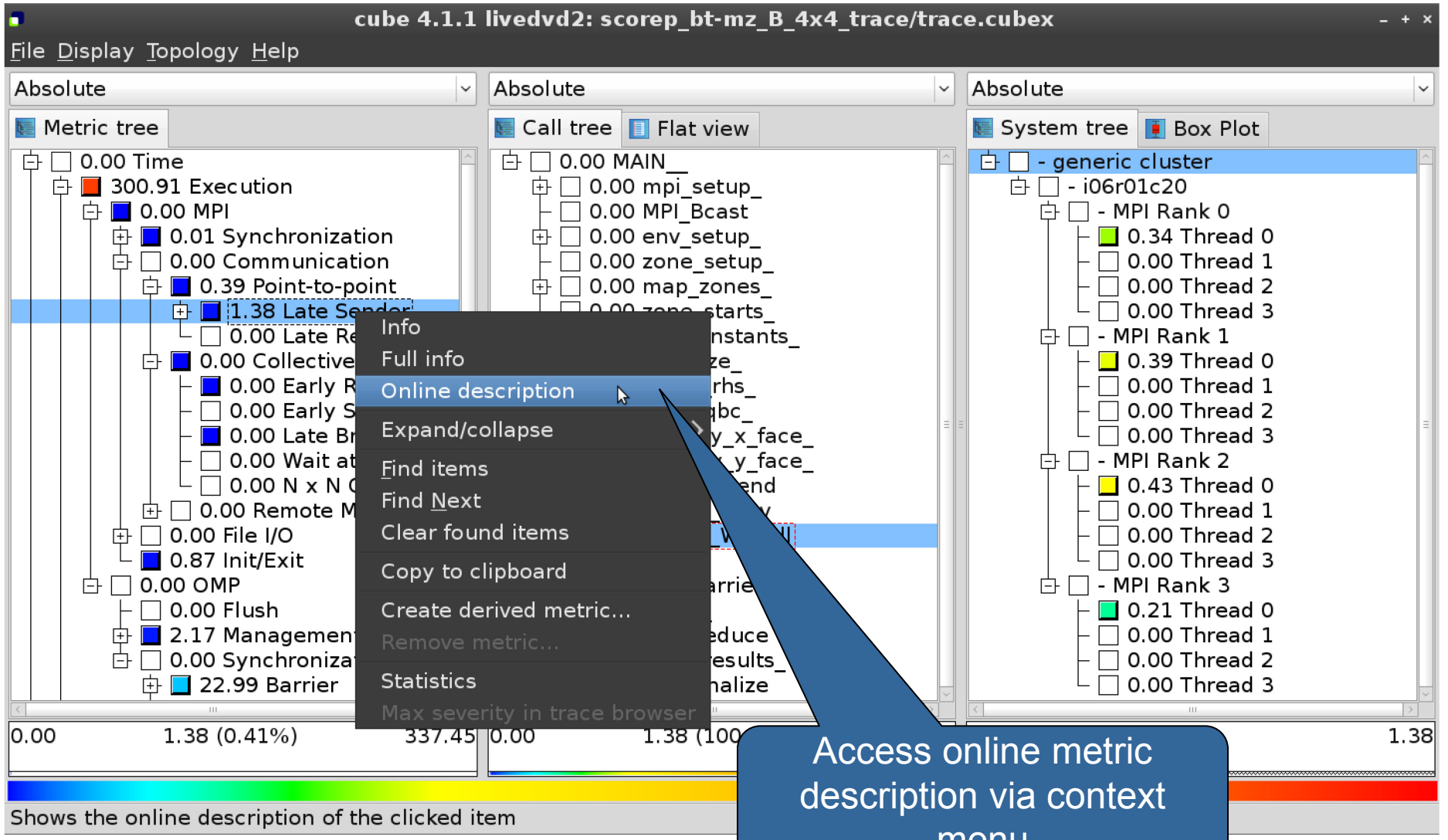
```
% square  scorep_bt-mz_B_4x4_trace
INFO: Post-processing runtime summarization result...
INFO: Post-processing trace analysis report...
INFO: Displaying ./scorep_bt-mz_B_4x4_sum/trace.cubex...

                [GUI showing trace analysis report]
```


Post-processed trace analysis report



Online metric description



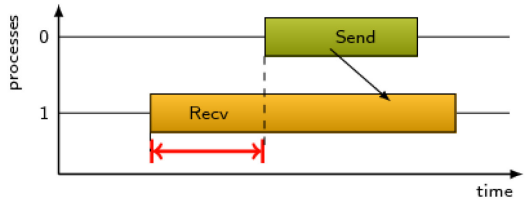
Online metric description

Performance properties

Late Sender Time

Description:

Refers to the time lost waiting caused by a blocking receive operation (e.g., `MPI_Recv` or `MPI_Wait`) that is posted earlier than the corresponding send operation.



If the receiving process is waiting for multiple messages to arrive (e.g., in an call to `MPI_Waitall`), the maximum waiting time is accounted, i.e., the waiting time due to the latest sender.

Unit:

Seconds

Diagnosis:

Try to replace `MPI_Recv` with a non-blocking receive `MPI_Irecv` that can be posted earlier, proceed concurrently with computation, and complete with a wait operation after the message is expected to have been sent. Try to post sends earlier, such that they are available when receivers need them. Note that outstanding messages (i.e., sent before the receiver is ready) will occupy internal message buffers, and that large numbers of posted receive buffers will also introduce message management overhead, therefore moderation is advisable.

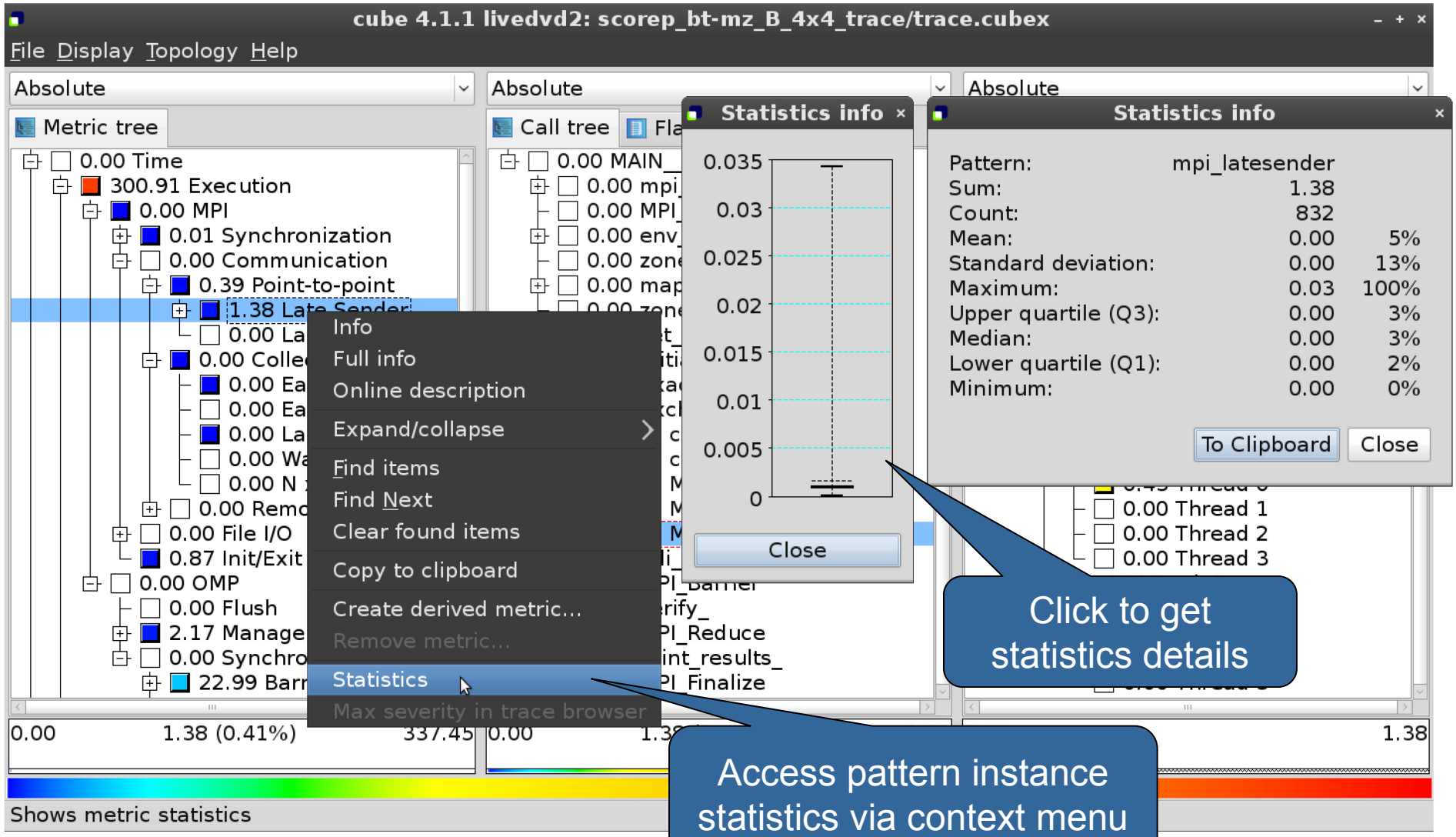
Parent:

MPI Point-to-point Communication Time

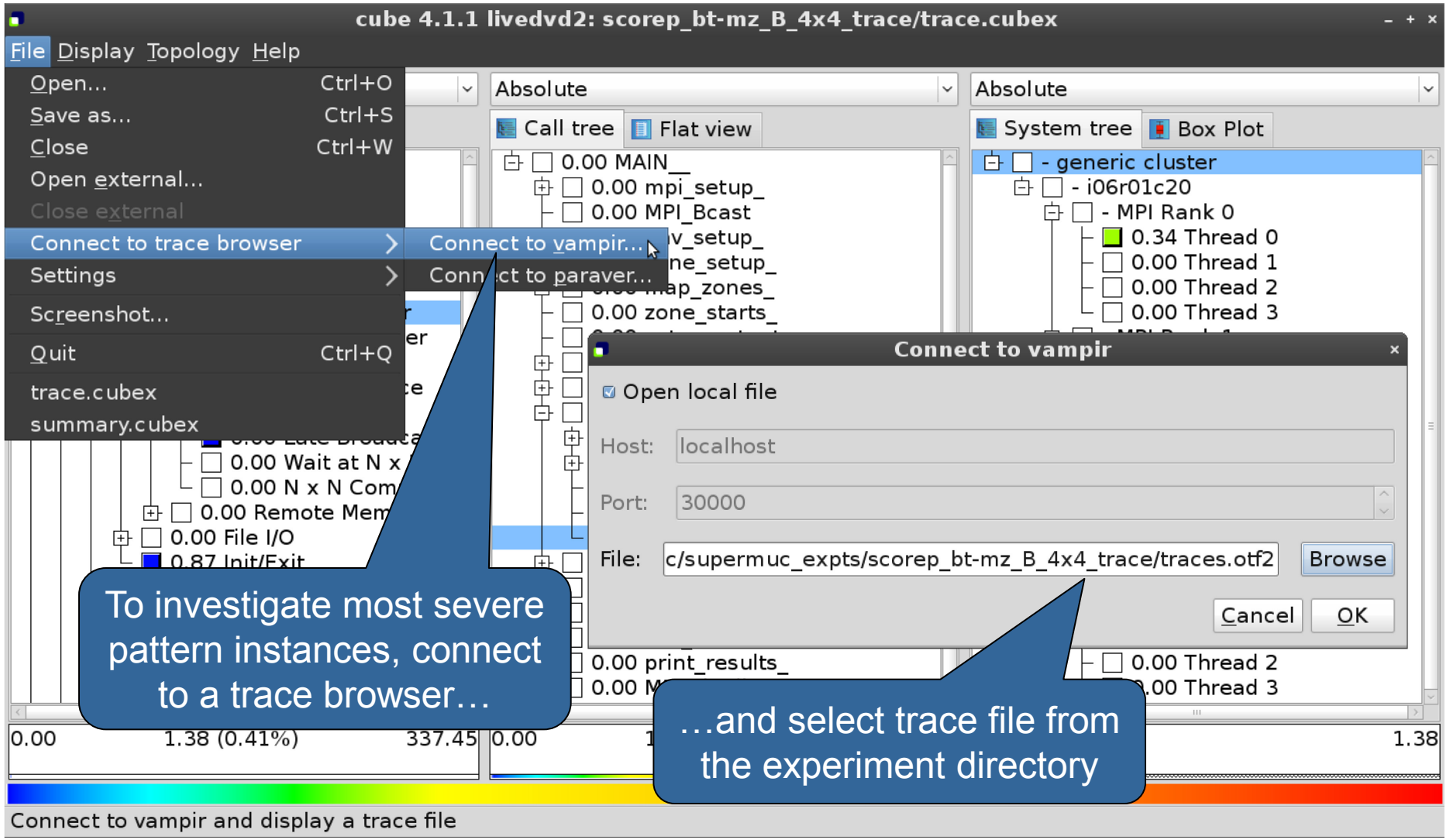
Children:

Close

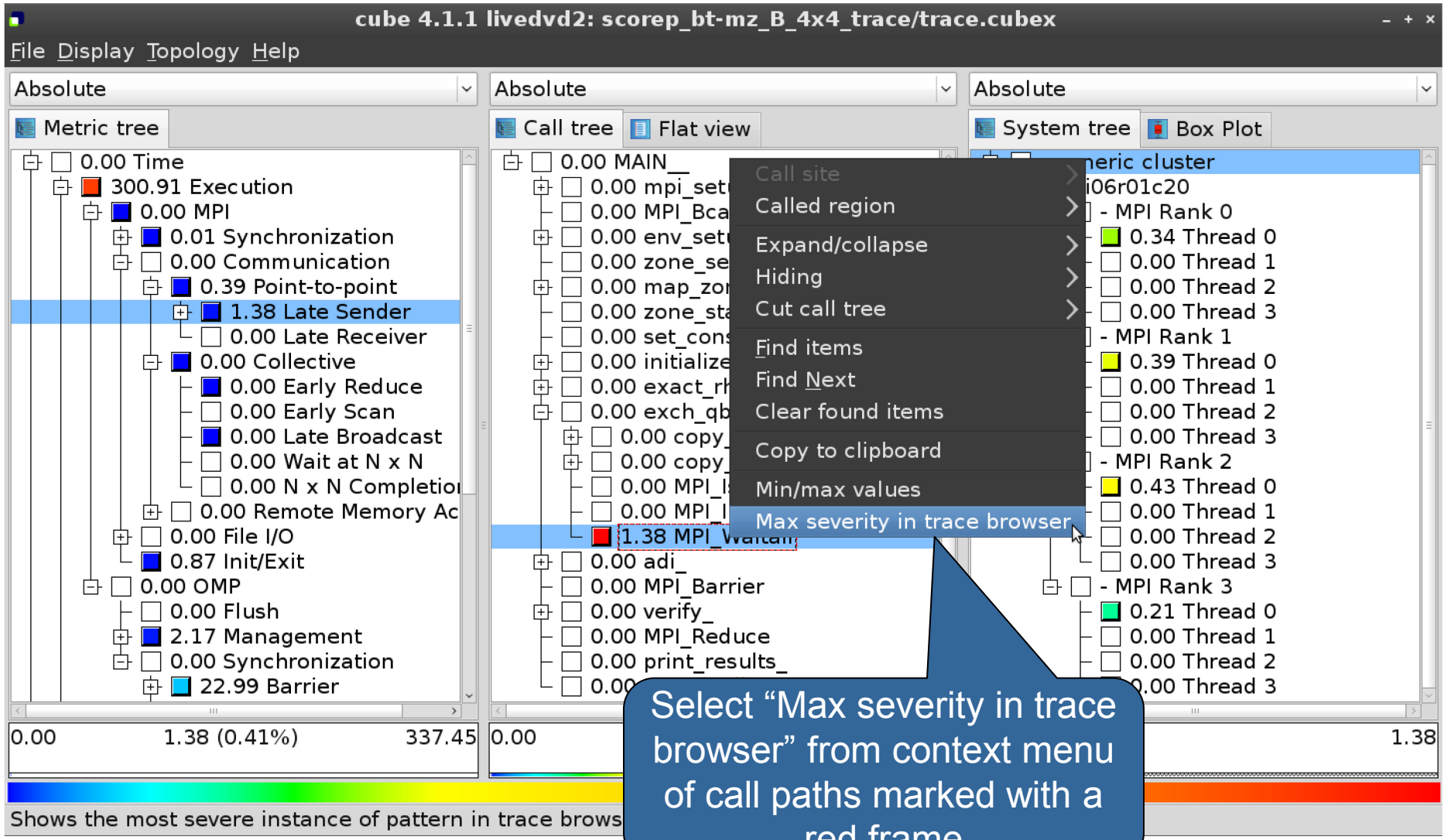
Pattern instance statistics



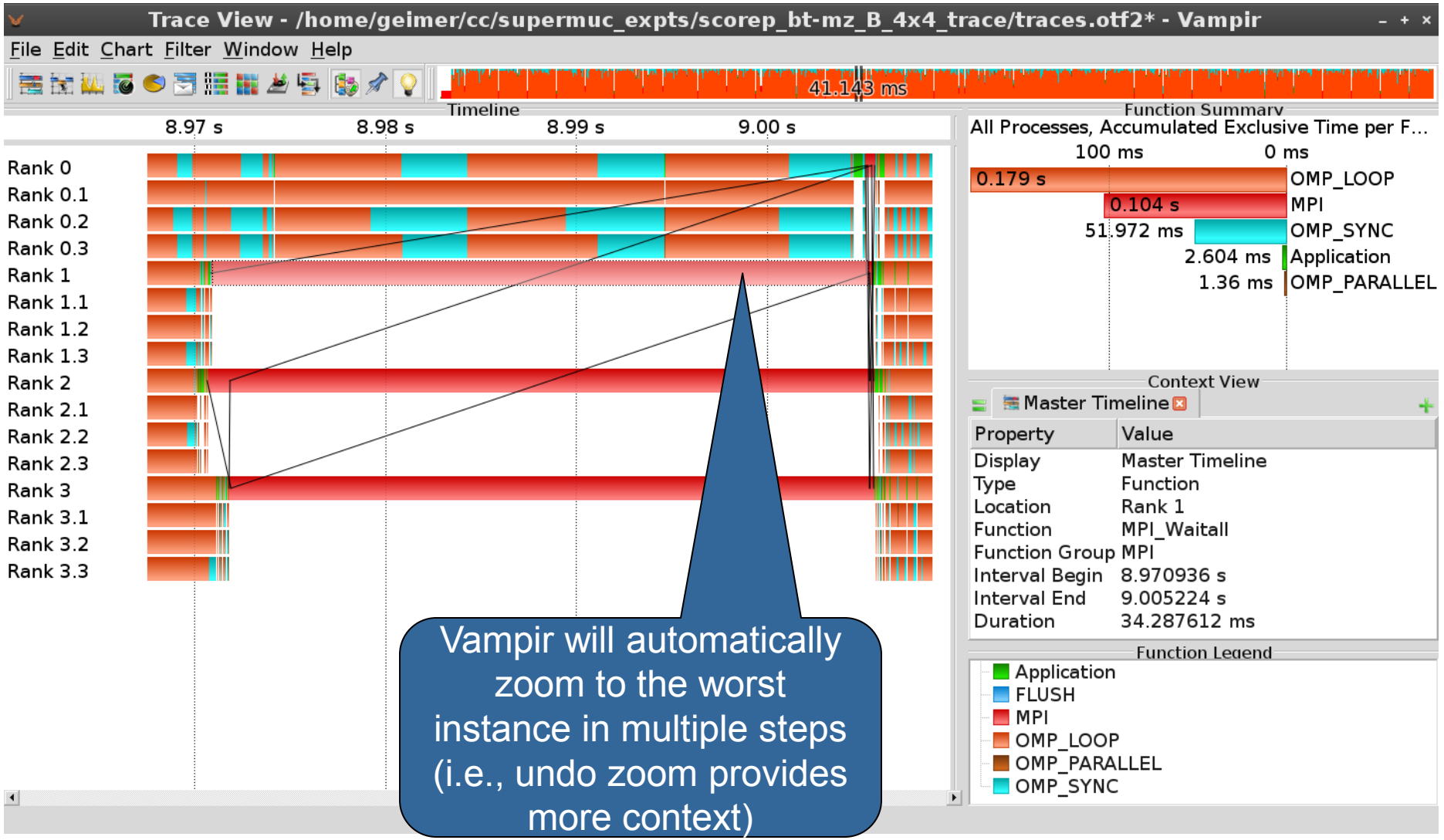
Connect to Vampir trace browser



Show most severe pattern instances



Investigate most severe instance in Vampir



Scalable performance **a**nalysis of **la**rge-**sc**ale parallel **a**pplications

- toolset for scalable performance measurement & analysis of MPI, OpenMP & hybrid parallel applications
- supporting most popular HPC computer systems
- available under New BSD open-source license
- sources, documentation & publications:
  - http://www.scalasca.org
  - mailto: scalasca@fz-juelich.de