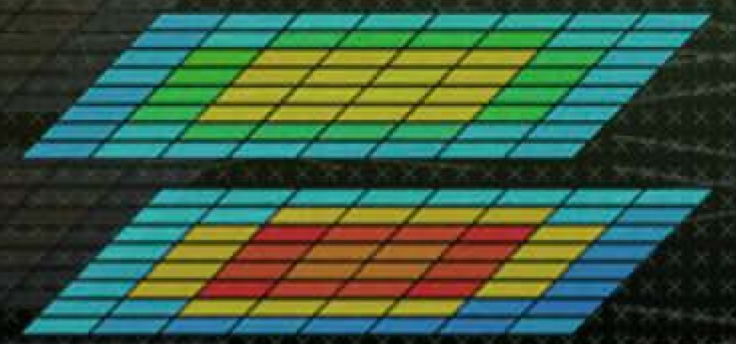
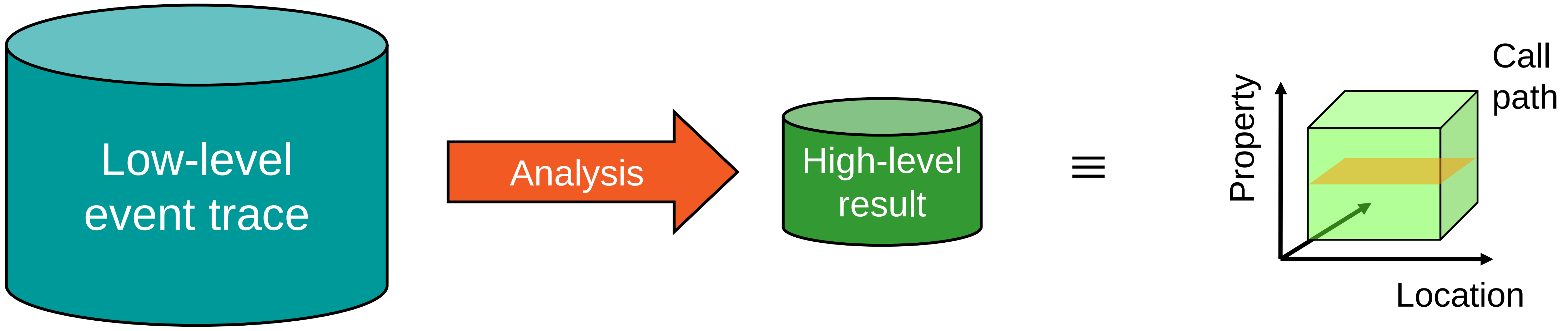


Automatic trace analysis with Scalasca

Brian Wylie
Jülich Supercomputing Centre

Automatic trace analysis

- 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
  - Technische Universität Darmstadt - Laboratory for Parallel Programming

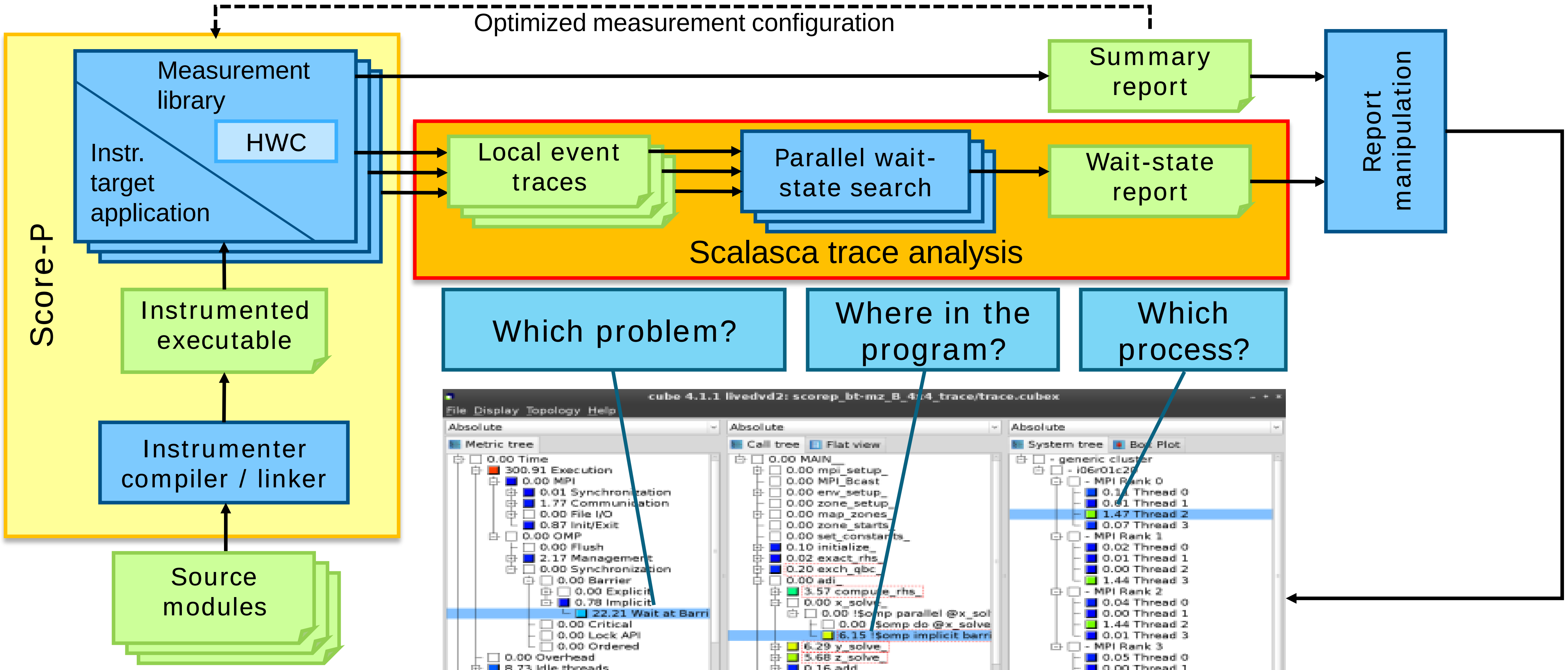
The Scalasca project: Objective

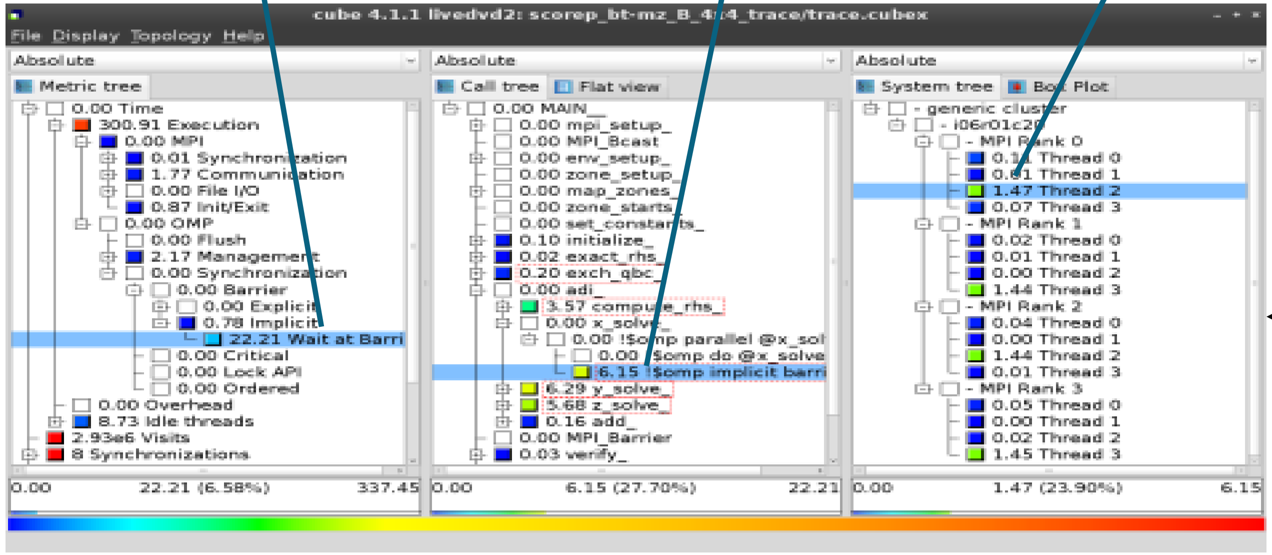
- Development of a **scalable** performance analysis toolset for most popular parallel programming paradigms
- Specifically targeting **large-scale** parallel applications
  - such as those running on K computer, IBM BlueGene or Cray systems with one million or more processes/threads
- Latest release:
  - Scalasca v2.2 coordinated with Score-P v1.4 (January 2015)
    - initial support for Intel Xeon Phi (native mode only)
    - full support for traces in SIONlib format (if configured for OTF2)
    - basic support for POSIX threads and OpenMP tasking
    - added lock contention and root-cause/delay analysis
  - Scalasca v2.2.2 coordinated with Score-P 1.4.2 (June 2015)
    - bug-fixes and optimisations

Scalasca 2.2 features

- Open source, New BSD license
- Fairly portable
  - IBM Blue Gene, Cray XT/XE/XK/XC, SGI Altix, Fujitsu FX10/100 & K computer, Linux clusters, Intel Xeon Phi (native MIC) ...
- Uses Score-P instrumenter & measurement libraries
  - Scalasca 2 core package focuses on trace-based analyses
  - Supports common data formats
    - Reads event traces in OTF2 format
    - Writes analysis reports in CUBE4 format
- Current limitations:
  - Unable to handle traces containing CUDA or SHMEM events, or OpenMP nested parallelism
  - PAPI/rusage metrics for trace events are ignored

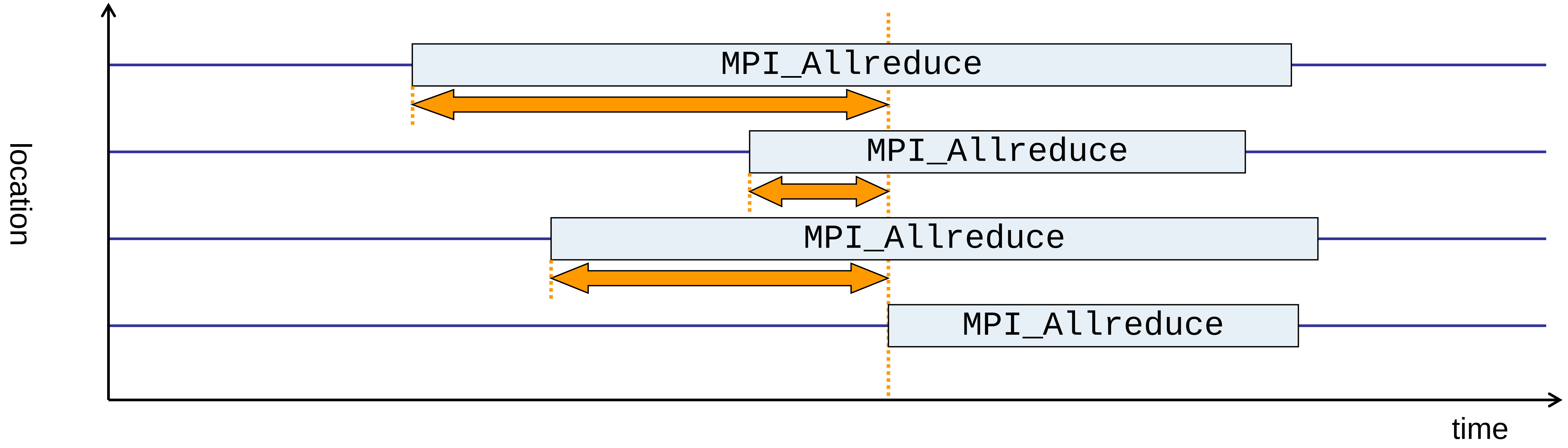
Scalasca workflow





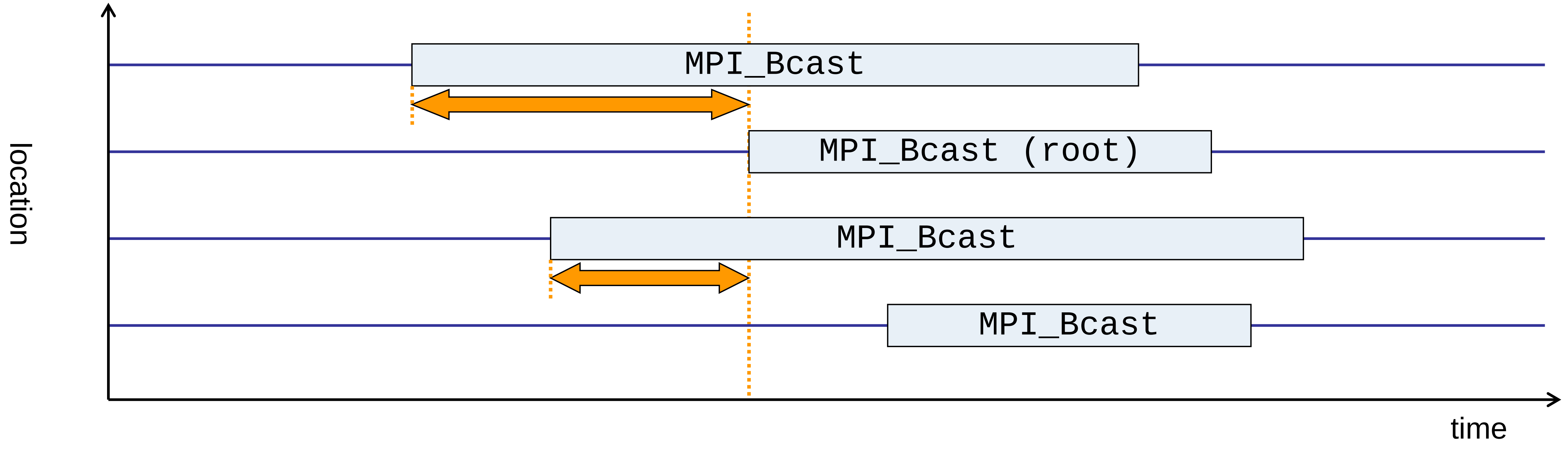
```
cube 4.1.1 livedvd2: scorep_bt-mz_B_4x4_trace/trace.cubex

0.00 Time                         0.00 MAIN__                               - generic cluster
  300.91 Execution                  0.00 mpi_setup_                           - i06r01c20
    0.00 MPI                        0.00 MPI_Bcast                              - MPI Rank 0
      0.01 Synchronization          0.00 env_setup_                               0.11 Thread 0
      1.77 Communication            0.00 zone_setup_                              0.01 Thread 1
      0.00 File I/O                 0.00 map_zones_                               1.47 Thread 2
      0.87 Init/Exit                0.00 zone_starts_                             0.07 Thread 3
    0.00 OMP                        0.00 set_constants_                         - MPI Rank 1
      0.00 Flush                    0.10 initialize_                              0.02 Thread 0
      2.17 Management               0.02 exact_rhs_                               0.01 Thread 1
      0.00 Synchronization          0.20 exch_qbc_                                0.00 Thread 2
        0.00 Barrier                0.00 adi_                                     1.44 Thread 3
          0.00 Explicit               3.57 compute_rhs_                         - MPI Rank 2
          0.78 Implicit               0.00 x_solve_                               0.04 Thread 0
            22.21 Wait at Barri         0.00 !$omp parallel @x_sol                0.00 Thread 1
        0.00 Critical                     0.00 !$omp do @x_solve                  1.44 Thread 2
        0.00 Lock API                     6.15 !$omp implicit barri               0.01 Thread 3
        0.00 Ordered                  6.29 y_solve_                             - MPI Rank 3
    0.00 Overhead                     5.68 z_solve_                               0.05 Thread 0
    8.73 Idle threads                 0.16 add_                                   0.00 Thread 1
  2.93e6 Visits                     0.00 MPI_Barrier                              0.02 Thread 2
  8 Synchronizations                0.03 verify_                                  1.45 Thread 3

0.00   22.21 (6.58%)   337.45     0.00   6.15 (27.70%)   22.21     0.00   1.47 (23.90%)   6.15
```

Example: Wait at NxN



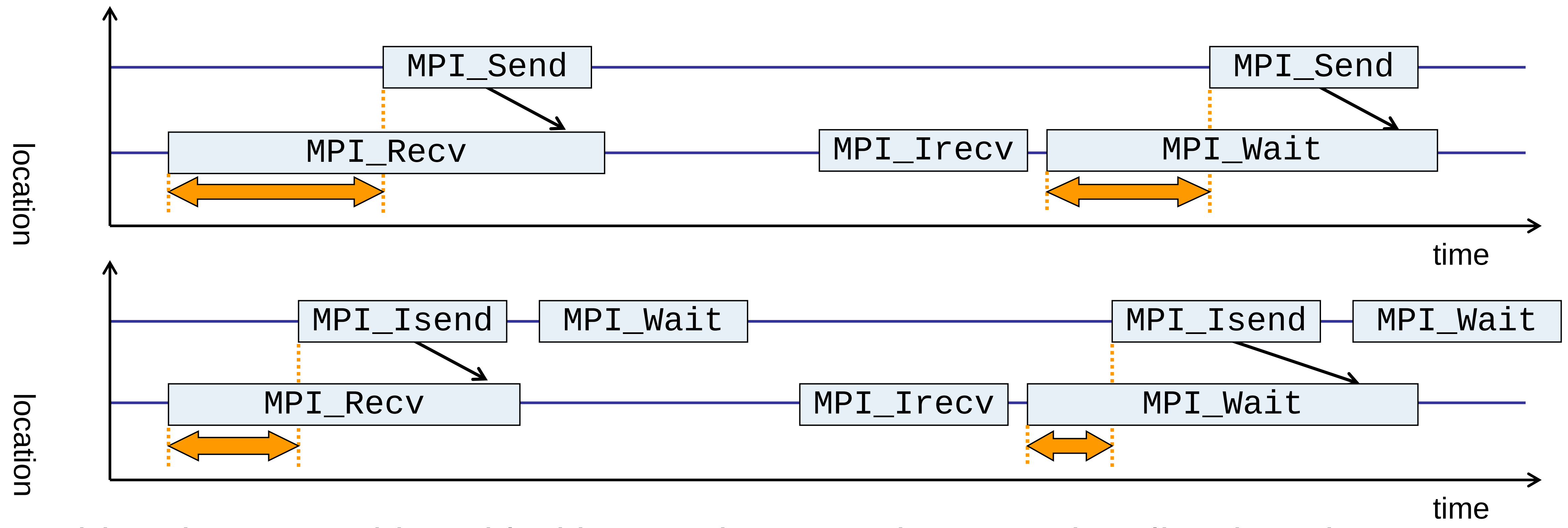
- Time spent waiting in front of synchronizing collective operation until the last process reaches the operation
- Applies to: MPI_Allgather, MPI_Allgatherv, MPI_Alltoall, MPI_Reduce_scatter, MPI_Reduce_scatter_block, MPI_Allreduce

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 command – One command for (almost) everything

```
% scalasca
Scalasca 2.2
Toolset for scalable performance analysis of large-scale parallel applications
usage: scalasca [OPTION]... ACTION <argument>...
    1. prepare application objects and executable for measurement:
       scalasca -instrument <compile-or-link-command> # skin (using scorep)
    2. run application under control of measurement system:
       scalasca -analyze <application-launch-command> # scan
    3. interactively explore measurement analysis report:
       scalasca -examine <experiment-archive|report>  # square

Options:
   -c, --show-config  show configuration summary and exit
   -h, --help         show this help and exit
   -n, --dry-run      show actions without taking them
       --quickref     show quick reference guide and exit
   -v, --verbose      enable verbose commentary
   -V, --version      show version information and exit
```

- The '`scalasca -instrument`' command is deprecated and only provided for backwards compatibility with Scalasca 1.x., recommended: use Score-P instrumenter directly

Scalasca compatibility command: skin

```
% skin
Scalasca 2.2: application instrumenter (using Score-P instrumenter)
usage: skin [-v] [-comp] [-pdt] [-pomp] [-user] [--*] <compile-or-link-command>
  -comp={all|none|...}: routines to be instrumented by compiler [default: all]
                 (... custom instrumentation specification depends on compiler)
  -pdt:  process source files with PDT/TAU 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
```

- Scalasca application instrumenter
  - Provides compatibility with Scalasca 1.x
  - Recommended: use Score-P instrumenter directly

Scalasca convenience command: scan

```
% scan
Scalasca 2.2: 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.
  -m metrics   : Metric specification for measurement.
```

- Scalasca measurement collection & analysis nexus

Scalasca advanced command: scout - Scalasca automatic trace analyzer

```
% scout.hyb --help
SCOUT   Copyright (c) 1998-2015 Forschungszentrum Juelich GmbH
        Copyright (c) 2009-2014 German Research School for Simulation
                                Sciences GmbH

Usage: <launchcmd> scout.hyb [OPTION]... <ANCHORFILE | EPIK DIRECTORY>
Options:
  --statistics       Enables instance tracking and statistics [default]
  --no-statistics    Disables instance tracking and statistics
  --critical-path    Enables critical-path analysis [default]
  --no-critical-path Disables critical-path analysis
  --rootcause        Enables root-cause analysis [default]
  --no-rootcause     Disables root-cause analysis
  --single-pass      Single-pass forward analysis only
  --time-correct     Enables enhanced timestamp correction
  --no-time-correct  Disables enhanced timestamp correction [default]
  --verbose, -v      Increase verbosity
  --help             Display this information and exit
```

- Provided in serial (.ser), OpenMP (.omp), MPI (.mpi) and MPI+OpenMP (.hyb) variants

Scalasca advanced command: clc_synchronize

- Scalasca trace event timestamp consistency correction

```
Usage: <launchcmd> clc_synchronize.hyb <ANCHORFILE | EPIK_DIRECTORY>
```

  - Provided in MPI (.mpi) and MPI+OpenMP (.hyb) variants
  - Takes as input a trace experiment archive where the events may have timestamp inconsistencies
    - e.g., multi-node measurements on systems without adequately synchronized clocks on each compute node
  - Generates a new experiment archive (always called ./clc_sync) containing a trace with event timestamp inconsistencies resolved
    - e.g., suitable for detailed examination with a time-line visualizer

Scalasca convenience command: square

```
% square
Scalasca 2.2: analysis report explorer
usage: square [-v] [-s] [-f filtfile] [-F] <experiment archive | cube file>
   -c <none | quick | full> : Level of sanity checks for newly created reports
   -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
   -n                       : Do not include idle thread metric
```

- Scalasca analysis report explorer

Automatic measurement configuration

- scan configures Score-P measurement by automatically setting some environment variables and exporting them
  - 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)

Performance Analysis Steps

- 0.0 Reference preparation for validation

- 1.0 Program instrumentation
- 1.1 Summary measurement collection
- 1.2 Summary analysis report examination

- 2.0 Summary experiment scoring
- 2.1 Summary measurement collection with filtering
- 2.2 Filtered summary analysis report examination

- 3.0 Event trace collection
- 3.1 Event trace examination & analysis

Setup environment

- Ensure scalasca found on PATH
  - on login nodes for experiment examination & post-processing:

```
% source /home/S11505/shared/tools/setup.sh
% which scalasca
/home/S11505/shared/tools/JSC/scalasca/REL-2.2.2-tls/bin/scalasca
```

  - on compute nodes within jobscripts:

```
# add Scalasca backend PATH for K/FX10/FX100 compute nodes
export PATH=/home/S11505/shared/tools/JSC/scalasca/REL-2.2.2-tls/backend/bin:$PATH
```

- Change to directory containing NPB3.3-MZ-MPI sources
- Existing Score-P instrumented executable in bin.scorep/ directory can be reused

BT-MZ summary measurement collection...

```
% cd bin.scorep
% cp ../jobscript/fx10/scalasca2.sh .
% vi scalasca2.sh

 [...]

export OMP_NUM_THREADS=4
CLASS=B
NPROCS=8
EXE=./bt-mz_$CLASS.$NPROCS

export SCOREP_FILTERING_FILE=../config/scorep.filt
#export SCOREP_TOTAL_MEMORY=78M

scalasca -analyze -s  mpiexec -np $NPROCS  $EXE
```

- Change to directory with the executable and edit the job script

default '-s' option is for summary profile collection

```
% pjsub ./scalasca2.sh
```

- Submit the job

BT-MZ summary measurement

```
S=C=A=N: Scalasca 2.2 runtime summarization
S=C=A=N: ./scorep_bt-mz_B_8x4_sum experiment archive
S=C=A=N: Thu Sep 13 18:05:17 2012: Collect start
mpiexec -np 8 ./bt-mz_B.8

 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:     8

 [... 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_B_8x4_sum complete.
```

- Run the application using the Scalasca measurement collection & analysis nexus prefixed to launch command
- Creates experiment directory: ./scorep_bt-mz_B_8x4_sum

BT-MZ summary analysis report examination

- Score summary analysis report

```
% square -s  scorep_bt-mz_B_8x4_sum
INFO: Post-processing runtime summarization result...
INFO: Score report written to ./scorep_bt-mz_B_8x4_sum/scorep.score
```

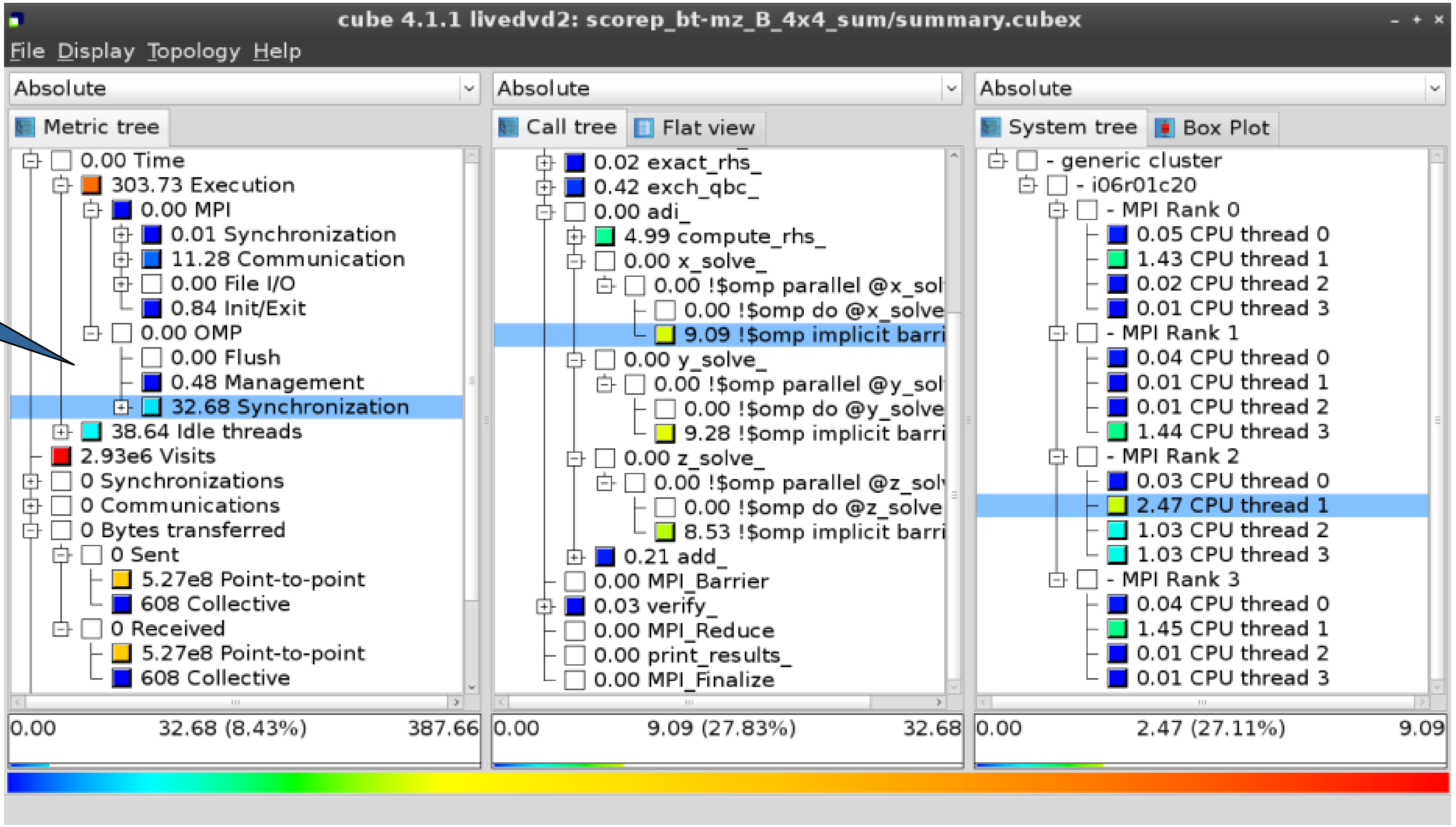
- Post-processing and interactive exploration with CUBE

```
% square  scorep_bt-mz_B_8x4_sum
INFO: Displaying ./scorep_bt-mz_B_8x4_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

Split base metrics into more specific metrics


cube 4.1.1 livedvd2: scorep_bt-mz_B_4x4_sum/summary.cubex

File Display Topology Help

Absolute | Absolute | Absolute

Metric tree | Call tree | Flat view | System tree | Box Plot

```
Metric tree                         Call tree                                  System tree
0.00 Time                           0.02 exact_rhs_                            - generic cluster
  303.73 Execution                  0.42 exch_qbc_                               - i06r01c20
    0.00 MPI                        0.00 adi_                                      - MPI Rank 0
      0.01 Synchronization            4.99 compute_rhs_                              0.05 CPU thread 0
      11.28 Communication             0.00 x_solve_                                  1.43 CPU thread 1
      0.00 File I/O                     0.00 !$omp parallel @x_sol                   0.02 CPU thread 2
      0.84 Init/Exit                      0.00 !$omp do @x_solve                     0.01 CPU thread 3
    0.00 OMP                              9.09 !$omp implicit barri                - MPI Rank 1
      0.00 Flush                      0.00 y_solve_                                  0.04 CPU thread 0
      0.48 Management                   0.00 !$omp parallel @y_sol                   0.01 CPU thread 1
      32.68 Synchronization               0.00 !$omp do @y_solve                     0.01 CPU thread 2
  38.64 Idle threads                      9.28 !$omp implicit barri                  1.44 CPU thread 3
2.93e6 Visits                         0.00 z_solve_                                - MPI Rank 2
0 Synchronizations                      0.00 !$omp parallel @z_sol                   0.03 CPU thread 0
0 Communications                          0.00 !$omp do @z_solve                     2.47 CPU thread 1
0 Bytes transferred                       8.53 !$omp implicit barri                  1.03 CPU thread 2
  0 Sent                              0.21 add_                                      1.03 CPU thread 3
    5.27e8 Point-to-point           0.00 MPI_Barrier                               - MPI Rank 3
    608 Collective                  0.03 verify_                                     0.04 CPU thread 0
  0 Received                        0.00 MPI_Reduce                                  1.45 CPU thread 1
    5.27e8 Point-to-point           0.00 print_results_                              0.01 CPU thread 2
    608 Collective                  0.00 MPI_Finalize                                0.01 CPU thread 3

0.00   32.68 (8.43%)   387.66      0.00   9.09 (27.83%)   32.68          0.00   2.47 (27.11%)   9.09
```

Performance Analysis Steps

- 0.0 Reference preparation for validation

- 1.0 Program instrumentation
- 1.1 Summary measurement collection
- 1.2 Summary analysis report examination

- 2.0 Summary experiment scoring
- 2.1 Summary measurement collection with filtering
- 2.2 Filtered summary analysis report examination

- 3.0 Event trace collection
- 3.1 Event trace examination & analysis

BT-MZ trace measurement collection...

```
% cd bin.scorep
% cp ../jobscript/fx10/scalasca2.sh .
% vi scalasca2.sh

 [...]

export OMP_NUM_THREADS=4
CLASS=B
NPROCS=8
EXE=./bt-mz_$CLASS.$NPROCS

export SCOREP_FILTERING_FILE=../config/scorep.filt
export SCOREP_TOTAL_MEMORY=168M
export SCOREP_METRIC_PAPI=PAPI_TOT_INS,PAPI_TOT_CYC


scalasca -analyze -t  mpiexec -np $NPROCS $EXE



% pjsub ./scalasca2.sh
```

- Change to directory with executable and edit job script

use '-t' option for trace collection & analysis

- Submit the job

BT-MZ trace measurement ... collection

```
S=C=A=N: Scalasca 2.2 trace collection and analysis
S=C=A=N: Fri Sep 20 15:09:59 2013: Collect start
mpiexec -np 8 ./bt-mz_B.8

 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:     8

 [... More application output ...]

S=C=A=N: Fri Sep 20 15:10:16 2013: Collect done (status=0) 28s
```

- Starts measurement with collection of trace files ...

BT-MZ trace measurement ... analysis

```
S=C=A=N: Fri Sep 20 15:09:59 2013: Analyze start
mpiexec -np 8 scout.hyb ./scorep_bt-mz_B_8x4_trace/traces.otf2

Analyzing experiment archive
                   ./scorep_bt-mz_B_8x4_trace/traces.otf2

Opening experiment archive ... done (0.019s).
Reading definition data    ... done (0.178s).
Reading event trace data   ... done (2.068s).
Preprocessing              ... done (3.789s).
Analyzing trace data       ...
  Wait-state detection (fwd)      (1/4) ... done (2.889s).
  Wait-state detection (bwd)      (2/4) ... done (1.136s).
  Synchpoint exchange (fws)       (3/4) ... done (0.813s).
  Critical-path & delay analysis  (4/4) ... done (0.568s).
done (5.413s).
Writing analysis report    ... done (1.994s).

Total processing time: 34.812s
S=C=A=N: Fri Sep 20 15:10:16 2013: Analyze done (status=0) 39s
```

- Continues with automatic (parallel) analysis of trace files

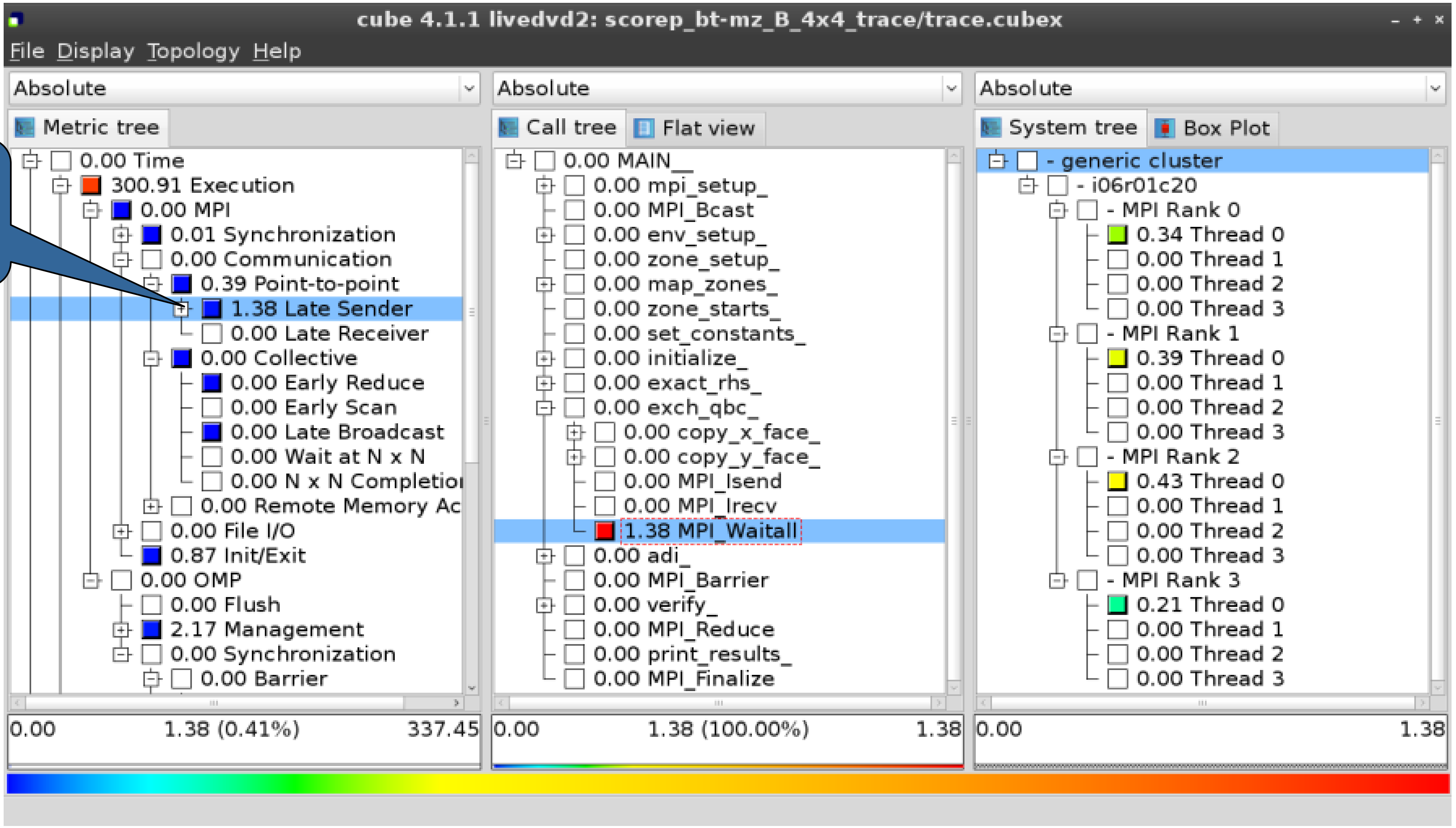
BT-MZ trace analysis report exploration

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

```
% square  scorep_bt-mz_B_8x4_trace
INFO: Post-processing runtime summarization result...
INFO: Post-processing trace analysis report...
INFO: Displaying ./scorep_bt-mz_B_8x4_trace/trace.cubex...

            [GUI showing trace analysis report]
```

Post-processed trace analysis report

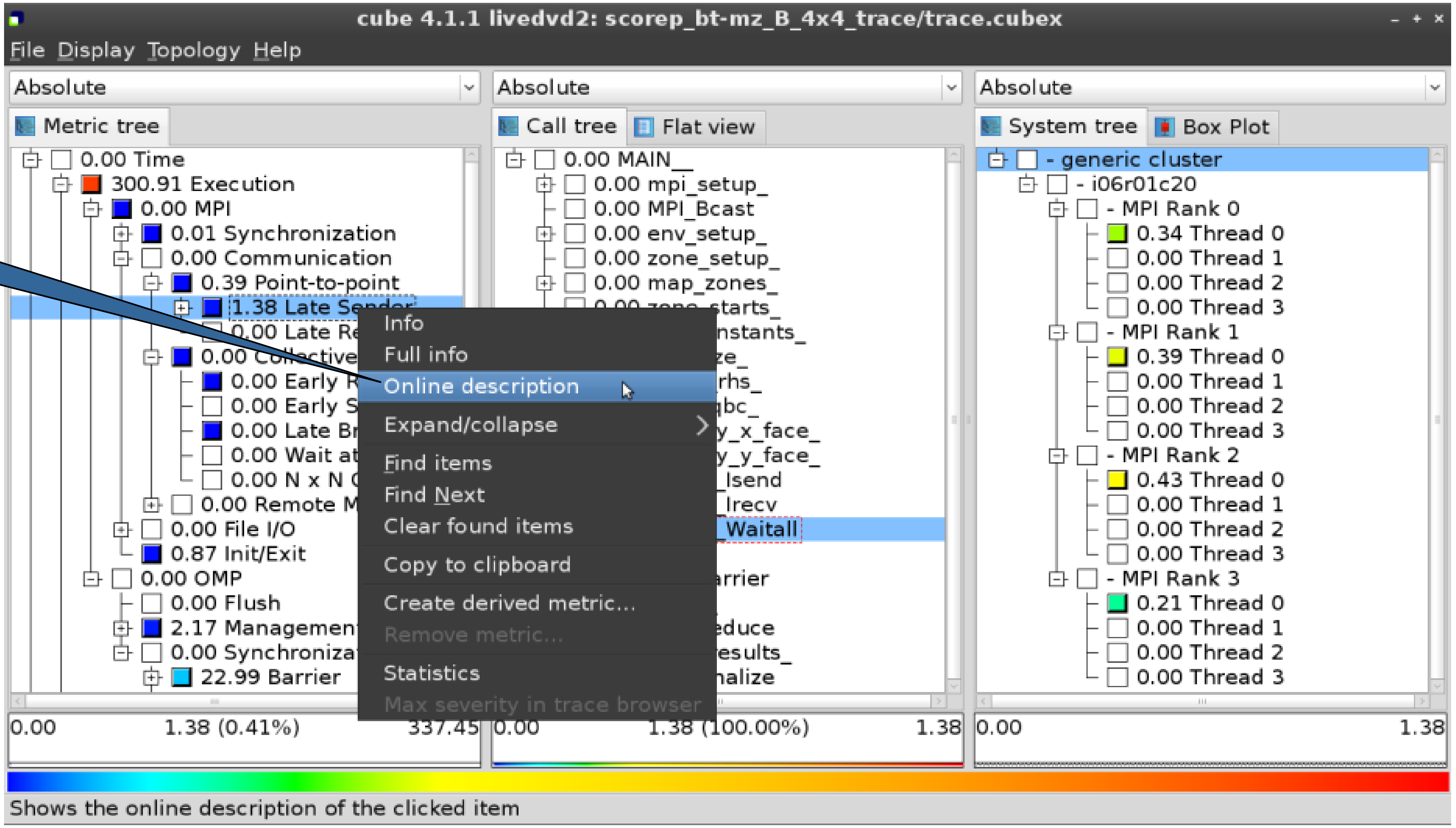
Additional trace-based metrics in metric hierarchy


cube 4.1.1 livedvd2: scorep_bt-mz_B_4x4_trace/trace.cubex
File Display Topology Help
Absolute
Metric tree
Call tree
Flat view
System tree
Box Plot

```
Metric tree                      Call tree                      System tree
0.00 Time                        0.00 MAIN__                    - generic cluster
  300.91 Execution                 0.00 mpi_setup_                - i06r01c20
    0.00 MPI                       0.00 MPI_Bcast                   - MPI Rank 0
      0.01 Synchronization         0.00 env_setup_                    0.34 Thread 0
      0.00 Communication           0.00 zone_setup_                   0.00 Thread 1
        0.39 Point-to-point        0.00 map_zones_                    0.00 Thread 2
          1.38 Late Sender         0.00 zone_starts_                  0.00 Thread 3
          0.00 Late Receiver       0.00 set_constants_              - MPI Rank 1
        0.00 Collective            0.00 initialize_                   0.39 Thread 0
          0.00 Early Reduce        0.00 exact_rhs_                    0.00 Thread 1
          0.00 Early Scan          0.00 exch_qbc_                     0.00 Thread 2
          0.00 Late Broadcast        0.00 copy_x_face_                0.00 Thread 3
          0.00 Wait at N x N         0.00 copy_y_face_              - MPI Rank 2
          0.00 N x N Completion      0.00 MPI_Isend                   0.43 Thread 0
      0.00 Remote Memory Ac          0.00 MPI_Irecv                   0.00 Thread 1
      0.00 File I/O                  1.38 MPI_Waitall                 0.00 Thread 2
      0.87 Init/Exit               0.00 adi_                          0.00 Thread 3
    0.00 OMP                       0.00 MPI_Barrier                 - MPI Rank 3
      0.00 Flush                   0.00 verify_                       0.21 Thread 0
      2.17 Management              0.00 MPI_Reduce                    0.00 Thread 1
      0.00 Synchronization         0.00 print_results_                0.00 Thread 2
        0.00 Barrier               0.00 MPI_Finalize                  0.00 Thread 3

0.00   1.38 (0.41%)   337.45     0.00   1.38 (100.00%)   1.38     0.00   1.38
```

Online metric description

Access online metric description via context menu

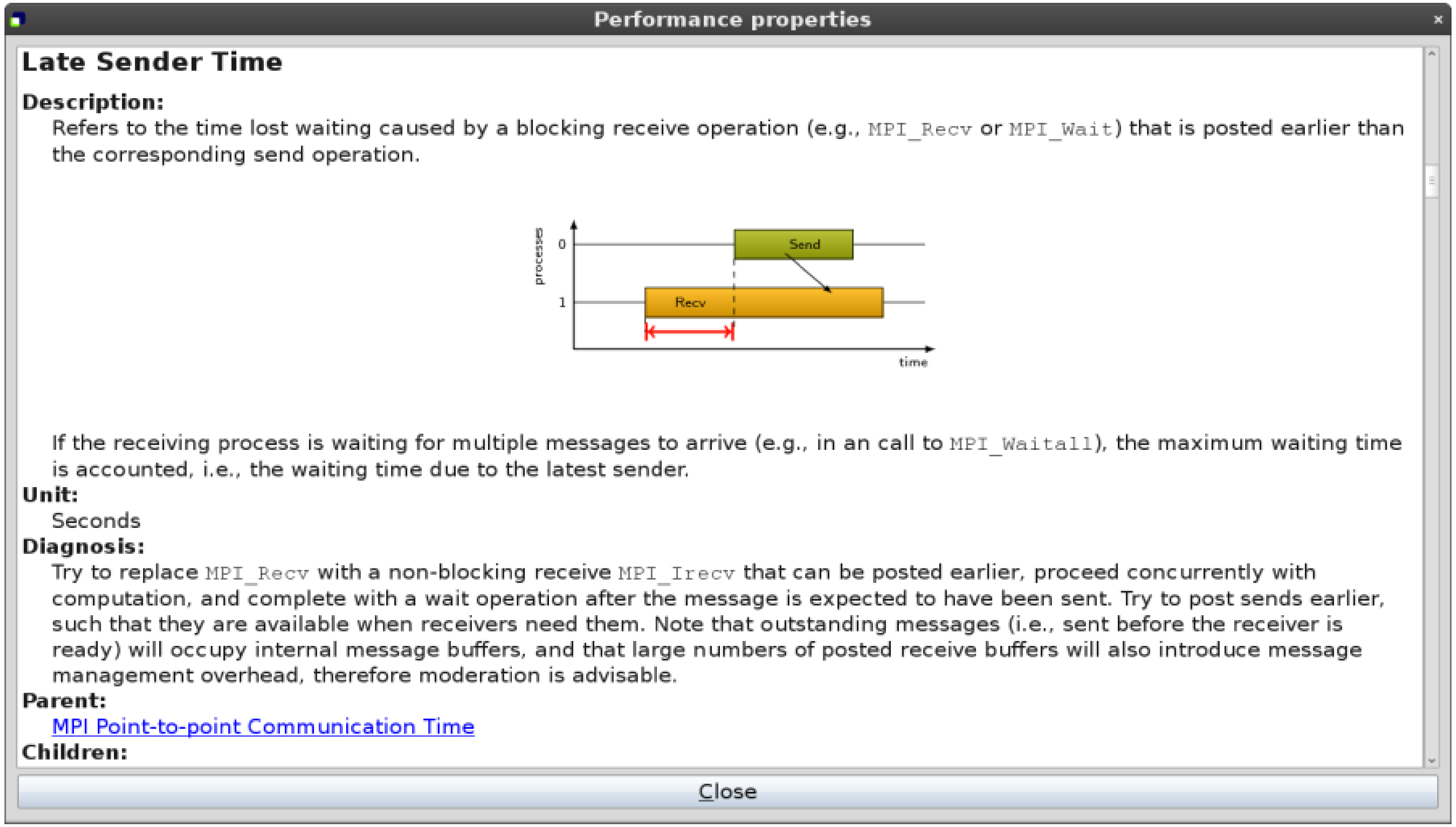


cube 4.1.1 livedvd2: scorep_bt-mz_B_4x4_trace/trace.cubex

```
Absolute                          Absolute                      Absolute
Metric tree                       Call tree | Flat view         System tree | Box Plot
0.00 Time                         0.00 MAIN__                   - generic cluster
  300.91 Execution                  0.00 mpi_setup_               - i06r01c20
    0.00 MPI                        0.00 MPI_Bcast                  - MPI Rank 0
      0.01 Synchronization          0.00 env_setup_                   0.34 Thread 0
      0.00 Communication            0.00 zone_setup_                  0.00 Thread 1
        0.39 Point-to-point         0.00 map_zones_                   0.00 Thread 2
          1.38 Late Sender          0.00 zone_starts                  0.00 Thread 3
          0.00 Late Re              nstants_                        - MPI Rank 1
        0.00 Collective             ze_                               0.39 Thread 0
          0.00 Early R              rhs_                              0.00 Thread 1
          0.00 Early S              qbc_                              0.00 Thread 2
          0.00 Late Br              y_x_face_                         0.00 Thread 3
          0.00 Wait at              y_y_face_                       - MPI Rank 2
          0.00 N x N C              Isend                             0.43 Thread 0
        0.00 Remote M               Irecv                             0.00 Thread 1
      0.00 File I/O                 Waitall                           0.00 Thread 2
      0.87 Init/Exit                                                  0.00 Thread 3
    0.00 OMP                        arrier                          - MPI Rank 3
      0.00 Flush                                                      0.21 Thread 0
      2.17 Managemen                educe                             0.00 Thread 1
      0.00 Synchroniza              esults_                           0.00 Thread 2
        22.99 Barrier               nalize                            0.00 Thread 3
0.00   1.38 (0.41%)   337.45      0.00   1.38 (100.00%)   1.38      0.00   1.38
```

Shows the online description of the clicked item

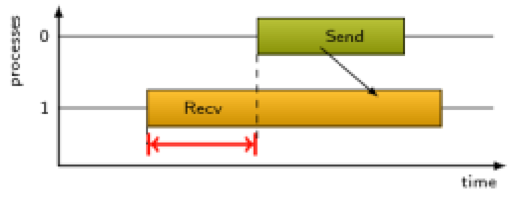
Online metric description



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.

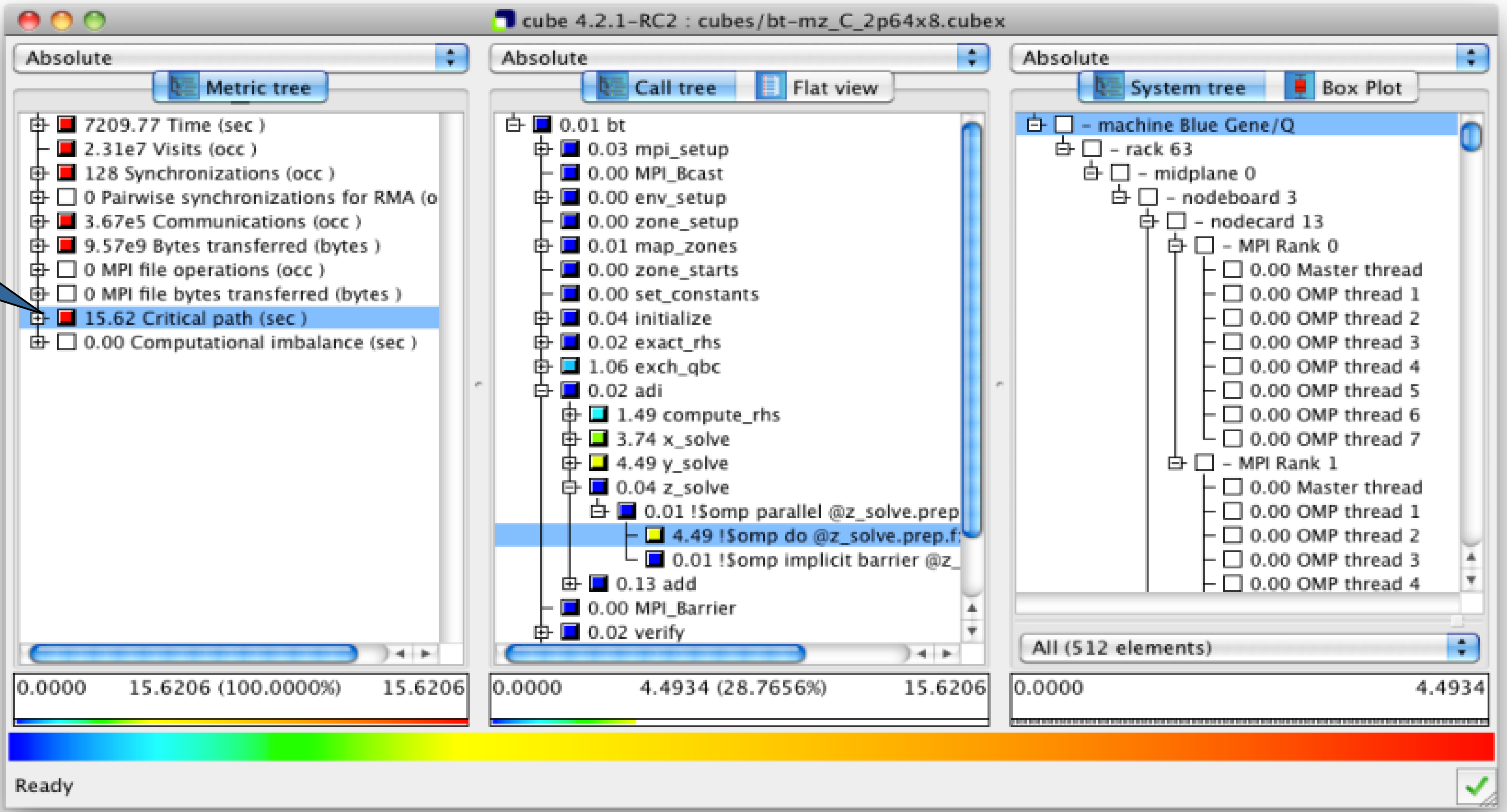
Parent:

MPI Point-to-point Communication Time

Children:

Critical-path analysis

Critical-path profile shows wall-clock time impact


cube 4.2.1-RC2 : cubes/bt-mz_C_2p64x8.cubex

Absolute | Metric tree

```
7209.77 Time (sec )
2.31e7 Visits (occ )
128 Synchronizations (occ )
0 Pairwise synchronizations for RMA (o
3.67e5 Communications (occ )
9.57e9 Bytes transferred (bytes )
0 MPI file operations (occ )
0 MPI file bytes transferred (bytes )
15.62 Critical path (sec )
0.00 Computational imbalance (sec )
```

Absolute | Call tree | Flat view

```
0.01 bt
  0.03 mpi_setup
  0.00 MPI_Bcast
  0.00 env_setup
  0.00 zone_setup
  0.01 map_zones
  0.00 zone_starts
  0.00 set_constants
  0.04 initialize
  0.02 exact_rhs
  1.06 exch_qbc
  0.02 adi
    1.49 compute_rhs
    3.74 x_solve
    4.49 y_solve
    0.04 z_solve
      0.01 !$omp parallel @z_solve.prep
        4.49 !$omp do @z_solve.prep.f
        0.01 !$omp implicit barrier @z_
    0.13 add
  0.00 MPI_Barrier
  0.02 verify
```

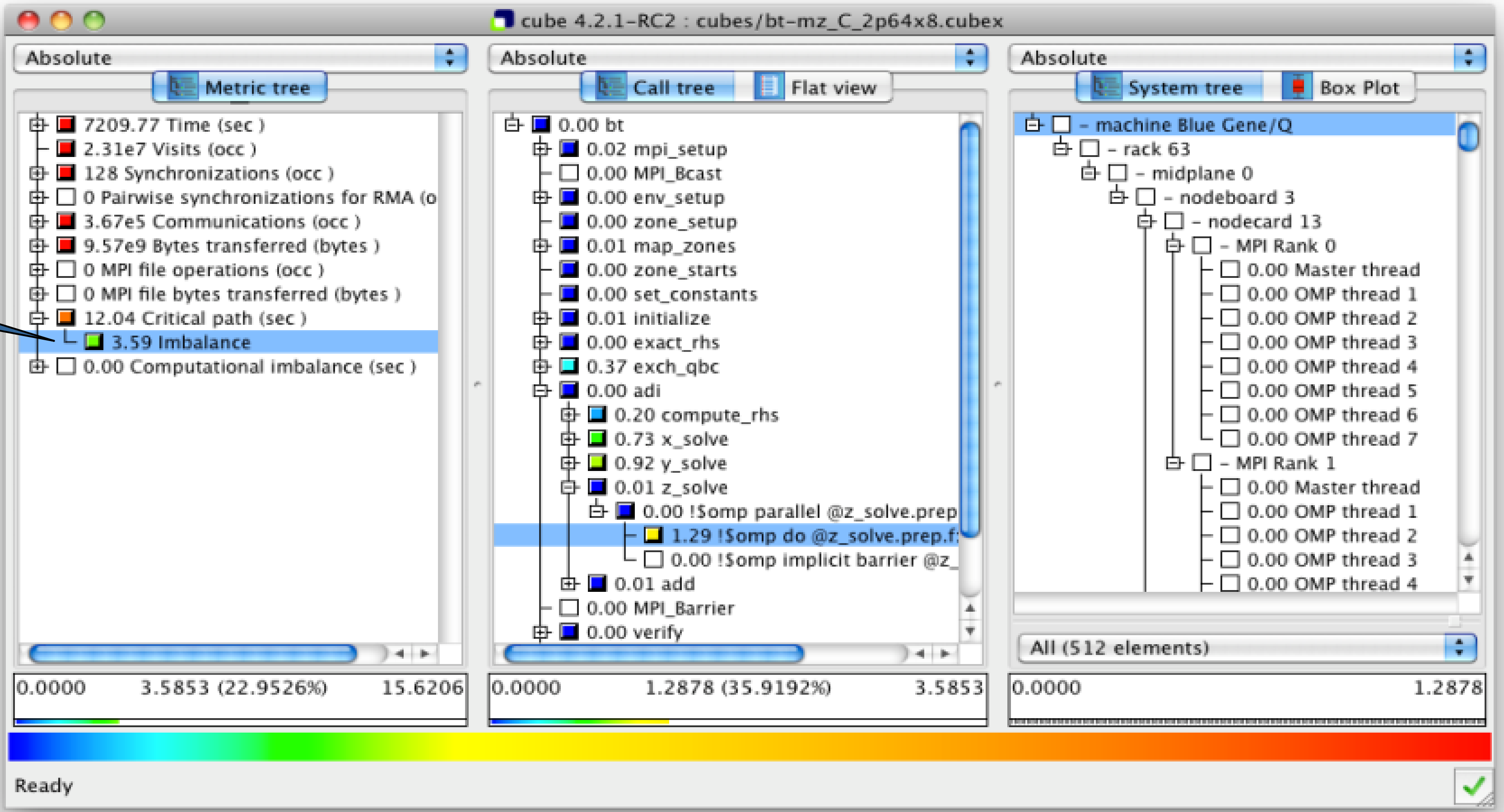
Absolute | System tree | Box Plot

```
- machine Blue Gene/Q
  - rack 63
    - midplane 0
      - nodeboard 3
        - nodecard 13
          - MPI Rank 0
            0.00 Master thread
            0.00 OMP thread 1
            0.00 OMP thread 2
            0.00 OMP thread 3
            0.00 OMP thread 4
            0.00 OMP thread 5
            0.00 OMP thread 6
            0.00 OMP thread 7
          - MPI Rank 1
            0.00 Master thread
            0.00 OMP thread 1
            0.00 OMP thread 2
            0.00 OMP thread 3
            0.00 OMP thread 4
All (512 elements)
```

```
0.0000   15.6206 (100.0000%)   15.6206
0.0000   4.4934 (28.7656%)   15.6206
0.0000   4.4934
Ready
```

Critical-path analysis

Critical-path imbalance highlights inefficient parallelism

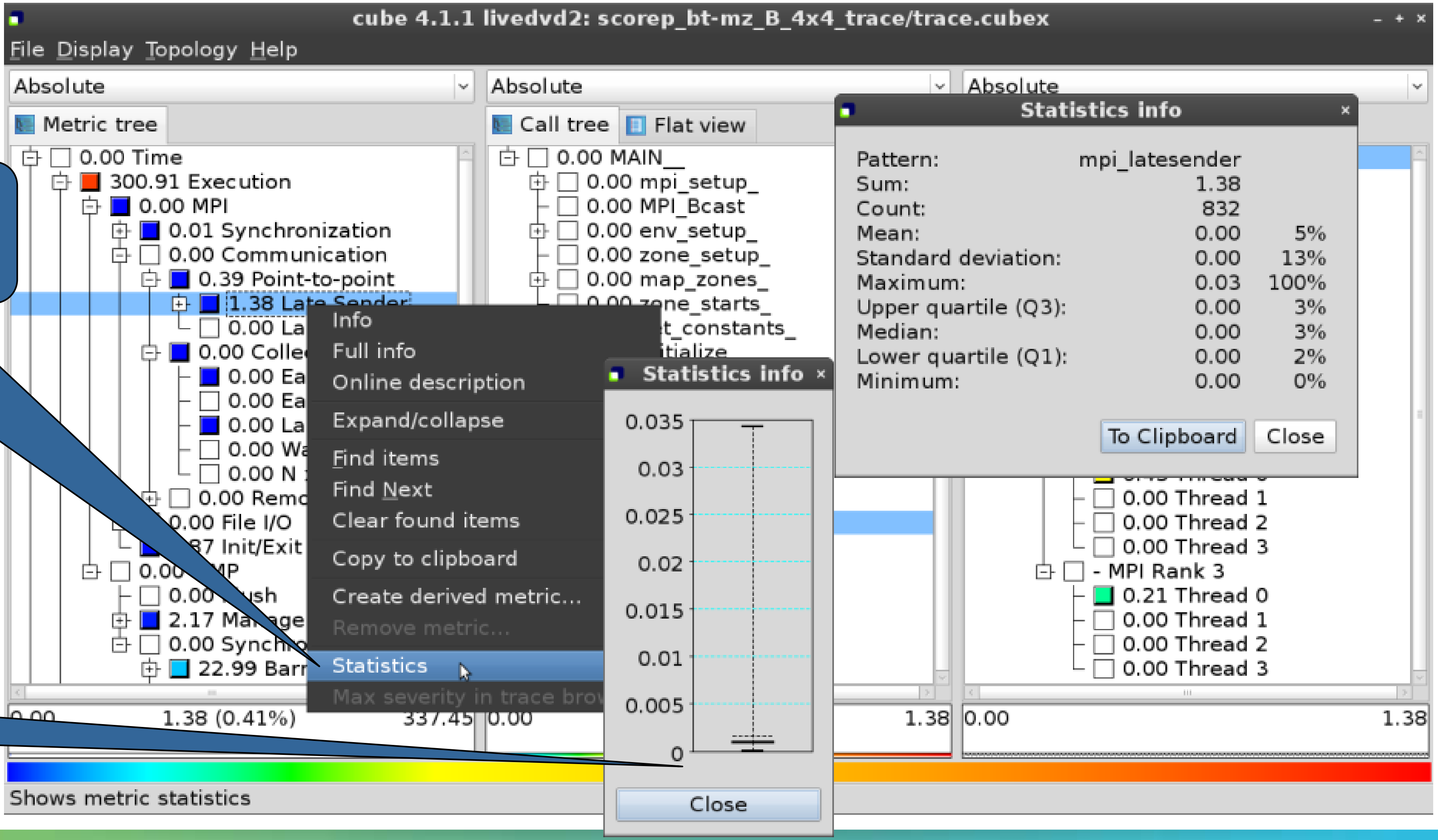


```
Metric tree:
7209.77 Time (sec )
2.31e7 Visits (occ )
128 Synchronizations (occ )
0 Pairwise synchronizations for RMA (o
3.67e5 Communications (occ )
9.57e9 Bytes transferred (bytes )
0 MPI file operations (occ )
0 MPI file bytes transferred (bytes )
12.04 Critical path (sec )
  3.59 Imbalance
0.00 Computational imbalance (sec )

0.0000      3.5853 (22.9526%)      15.6206
```

```
Call tree:
0.00 bt
  0.02 mpi_setup
  0.00 MPI_Bcast
  0.00 env_setup
  0.00 zone_setup
  0.01 map_zones
  0.00 zone_starts
  0.00 set_constants
  0.01 initialize
  0.00 exact_rhs
  0.37 exch_qbc
  0.00 adi
    0.20 compute_rhs
    0.73 x_solve
    0.92 y_solve
    0.01 z_solve
      0.00 !$omp parallel @z_solve.prep
        1.29 !$omp do @z_solve.prep.f
        0.00 !$omp implicit barrier @z_
    0.01 add
  0.00 MPI_Barrier
  0.00 verify

0.0000      1.2878 (35.9192%)      3.5853
```

```
System tree:
- machine Blue Gene/Q
  - rack 63
    - midplane 0
      - nodeboard 3
        - nodecard 13
          - MPI Rank 0
            0.00 Master thread
            0.00 OMP thread 1
            0.00 OMP thread 2
            0.00 OMP thread 3
            0.00 OMP thread 4
            0.00 OMP thread 5
            0.00 OMP thread 6
            0.00 OMP thread 7
          - MPI Rank 1
            0.00 Master thread
            0.00 OMP thread 1
            0.00 OMP thread 2
            0.00 OMP thread 3
            0.00 OMP thread 4

0.0000                                 1.2878
```

Pattern instance statistics



Statistics info

Pattern:	mpi_latesender	
Sum:	1.38	
Count:	832	
Mean:	0.00	5%
Standard deviation:	0.00	13%
Maximum:	0.03	100%
Upper quartile (Q3):	0.00	3%
Median:	0.00	3%
Lower quartile (Q1):	0.00	2%
Minimum:	0.00	0%

To Clipboard Close

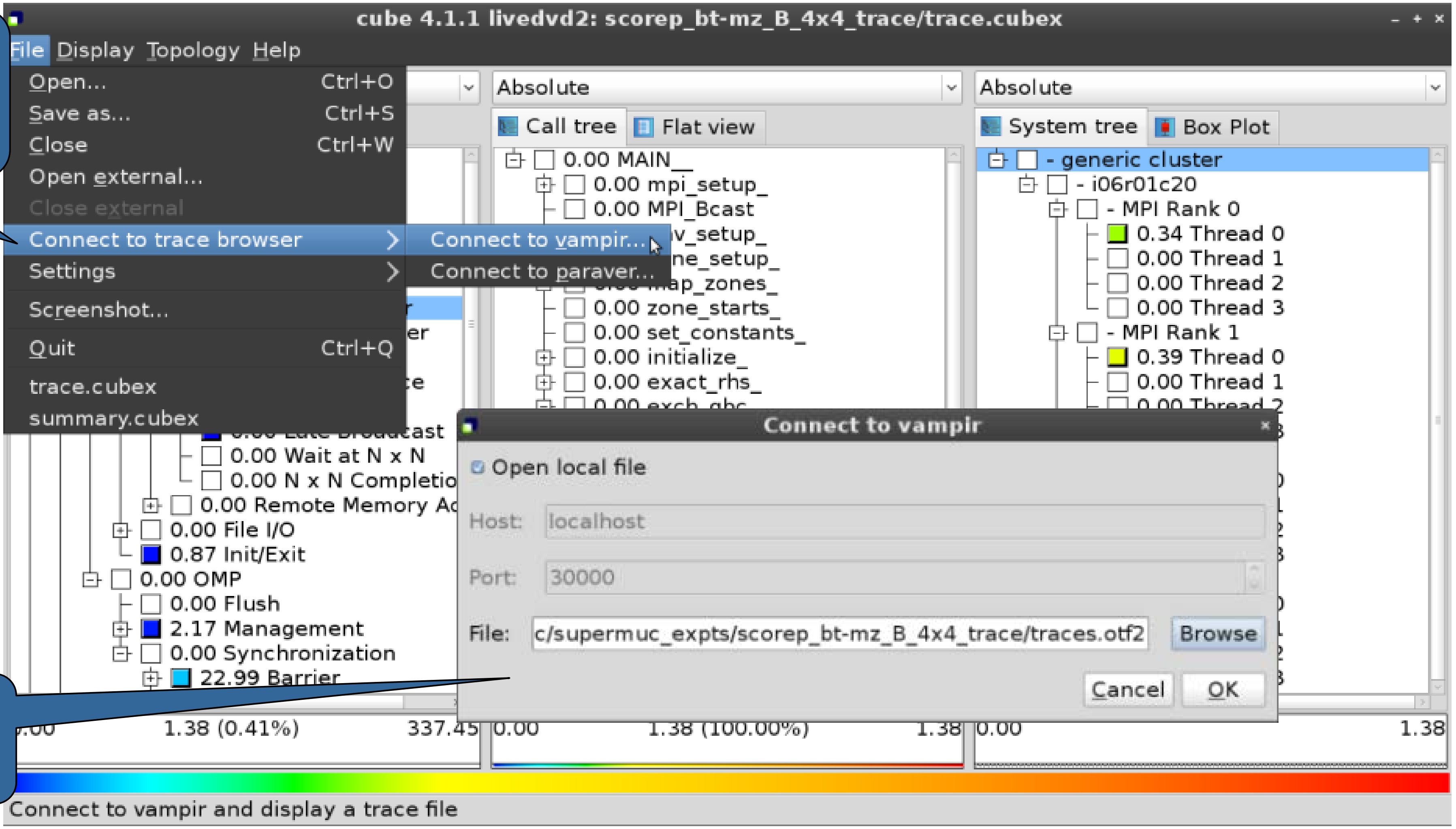
Access pattern instance statistics via context menu

Click to get statistics details

Connect to Vampir trace browser

To investigate most severe pattern instances, connect to a trace browser…

…and select trace file from the experiment directory



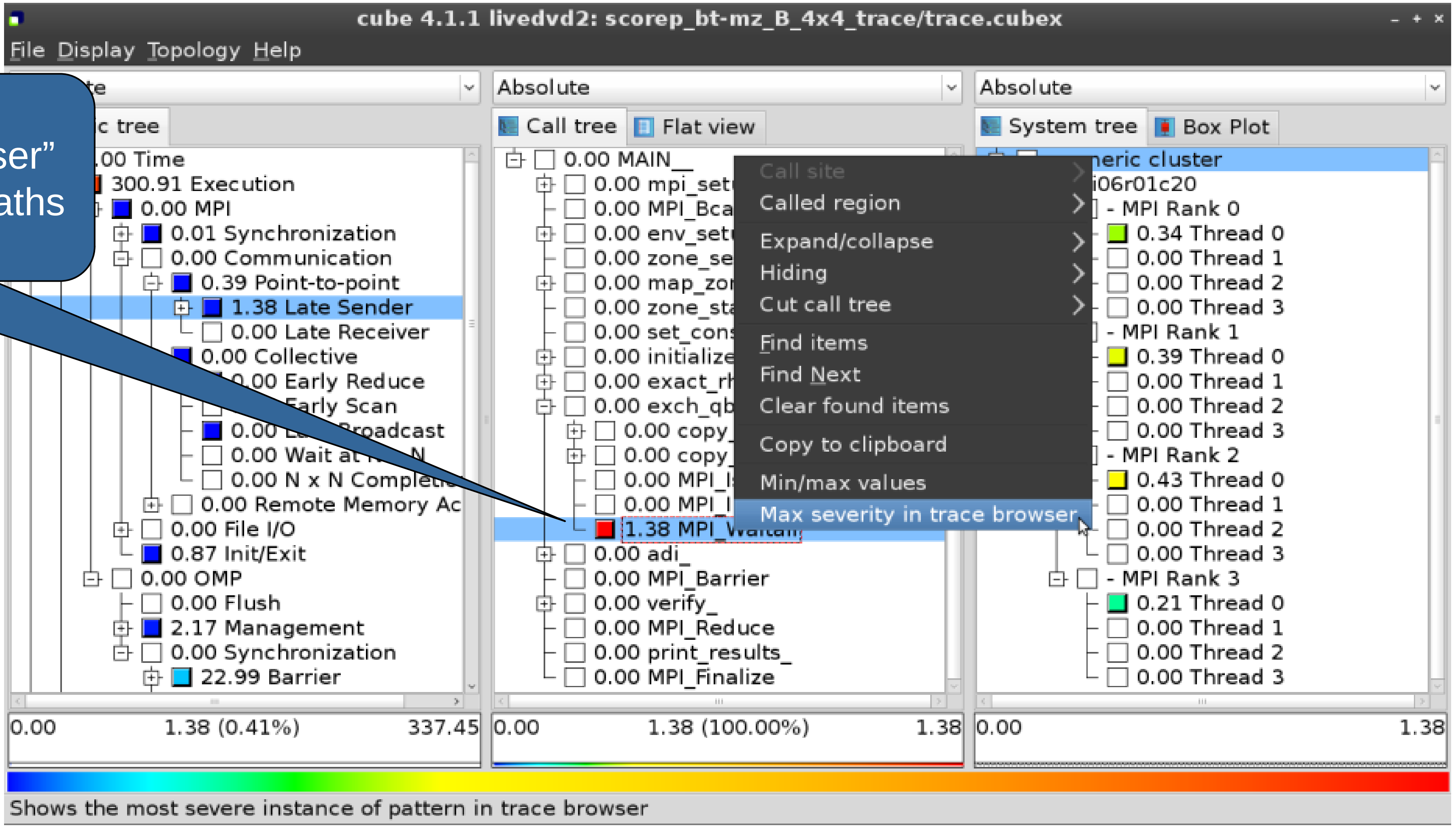
Host: localhost

Port: 30000

File: c/supermuc_expts/scorep_bt-mz_B_4x4_trace/traces.otf2

Show most severe pattern instances

Select
“Max severity in trace browser”
from context menu of call paths
marked with a red frame



cube 4.1.1 livedvd2: scorep_bt-mz_B_4x4_trace/trace.cubex

File Display Topology Help

te | Absolute | Absolute

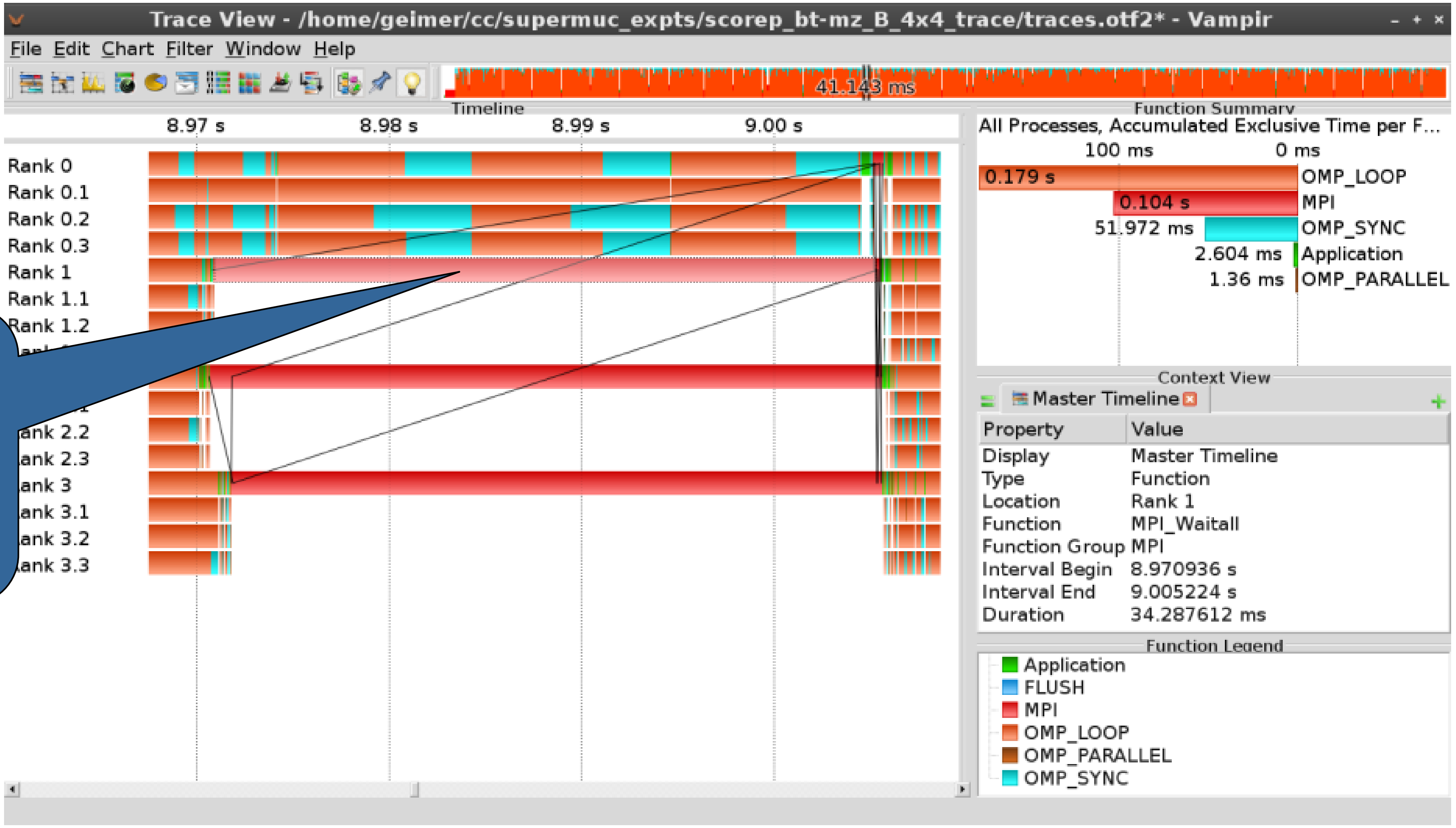
c tree | Call tree | Flat view | System tree | Box Plot

```
.00 Time                         0.00 MAIN__                  neric cluster
300.91 Execution                 0.00 mpi_set                 i06r01c20
0.00 MPI                         0.00 MPI_Bca                 - MPI Rank 0
0.01 Synchronization             0.00 env_setu                0.34 Thread 0
0.00 Communication               0.00 zone_se                 0.00 Thread 1
0.39 Point-to-point              0.00 map_zor                 0.00 Thread 2
1.38 Late Sender                 0.00 zone_sta                0.00 Thread 3
0.00 Late Receiver               0.00 set_cons                - MPI Rank 1
0.00 Collective                  0.00 initialize              0.39 Thread 0
0.00 Early Reduce                0.00 exact_rh                0.00 Thread 1
Early Scan                       0.00 exch_qb                 0.00 Thread 2
0.00 Broadcast                   0.00 copy                    0.00 Thread 3
0.00 Wait at N x N               0.00 copy                    - MPI Rank 2
0.00 N x N Completion            0.00 MPI_I                   0.43 Thread 0
0.00 Remote Memory Ac            0.00 MPI_I                   0.00 Thread 1
0.00 File I/O                    1.38 MPI_Waitall             0.00 Thread 2
0.87 Init/Exit                   0.00 adi_                    0.00 Thread 3
0.00 OMP                         0.00 MPI_Barrier             - MPI Rank 3
0.00 Flush                       0.00 verify_                 0.21 Thread 0
2.17 Management                  0.00 MPI_Reduce              0.00 Thread 1
0.00 Synchronization             0.00 print_results_          0.00 Thread 2
22.99 Barrier                    0.00 MPI_Finalize            0.00 Thread 3
```

```
0.00   1.38 (0.41%)   337.45 | 0.00   1.38 (100.00%)   1.38 | 0.00   1.38
```

Shows the most severe instance of pattern in trace browser

Investigate most severe instance in Vampir



Property	Value
Display	Master Timeline
Type	Function
Location	Rank 1
Function	MPI_Waitall
Function Group	MPI
Interval Begin	8.970936 s
Interval End	9.005224 s
Duration	34.287612 ms

Function Legend
- 🟩 Application
- 🟦 FLUSH
- 🟥 MPI
- 🟧 OMP_LOOP
- 🟫 OMP_PARALLEL
- 🟦 OMP_SYNC

Vampir will automatically zoom to the worst instance in multiple steps (i.e., undo zoom provides more context)

Further information

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

scalasca

BT-MZ trace analysis

```
% OMP_NUM_THREADS=4 scan –a mpiexec –np 8 ./bt-mz_B.8
S=C=A=N: Scalasca 2.2 trace analysis
S=C=A=N: Fri Sep 20 15:09:59 2013: Analyze start
mpiexec -np 8 scout.hyb ./scorep_bt-mz_B_8x4_trace/traces.otf2

Analyzing experiment archive
            ./scorep_bt-mz_B_8x4_trace/traces.otf2

Opening experiment archive ... done (0.019s).
Reading definition data    ... done (0.178s).
Reading event trace data   ... done (2.068s).
Preprocessing              ... done (3.789s).
Analyzing trace data       ...
  Wait-state detection (fwd)      (1/4) ... done (2.889s).
  Wait-state detection (bwd)      (2/4) ... done (1.136s).
  Synchpoint exchange (fws)       (3/4) ... done (0.813s).
  Critical-path & delay analysis  (4/4) ... done (0.568s).
done (5.413s).
Writing analysis report    ... done (1.994s).

Total processing time: 34.812s
S=C=A=N: Fri Sep 20 15:10:16 2013: Analyze done (status=0) 39s
```

- Automatic trace analysis of existing experiment archives

BT-MZ trace measurement & time-corrected analysis

```
% SCAN_TRACE_ANALYZER=none  scan –t  mpiexec –np 8 ./bt-mz_B.8
S=C=A=N: Scalasca 2.2 trace collection and analysis
Info: Automatic trace analysis will be skipped!
...
S=C=A=N: Fri Mar 21: 18:00:56 2014: Collect done (status=0) 28s
S=C=A=N: ./scorep_bt-mz_B_8x4_trace complete.
% cd scorep_bt-mz_B_8x4_trace
% mpiexec –np 8 clc_synchronize.hyb ./traces.otf2

        # passes        : 1
        # violated      : 3362
        # corrected     : 1610977
        # reversed-p2p  : 233
        # reversed-coll : 0
        # reversed-omp  : 3129
        # events        : 6287852
        max. error      : 0.000112 [s]
        error at final. : 0.000118 [%]
        Max slope       : 0.010000000
% scan –a –e ./clc_sync  mpiexec –np 8 ../bt-mz_B.8
S=C=A=N: Scalasca 2.2 trace analysis
...
S=C=A=N: Fri Mar 21 18:29:29 2014: Analyze done (status=0) 39s
S=C=A=N: ./clc_sync complete
```

- Generating a time-corrected trace and its analysis