VI-HPS productivity tools suite

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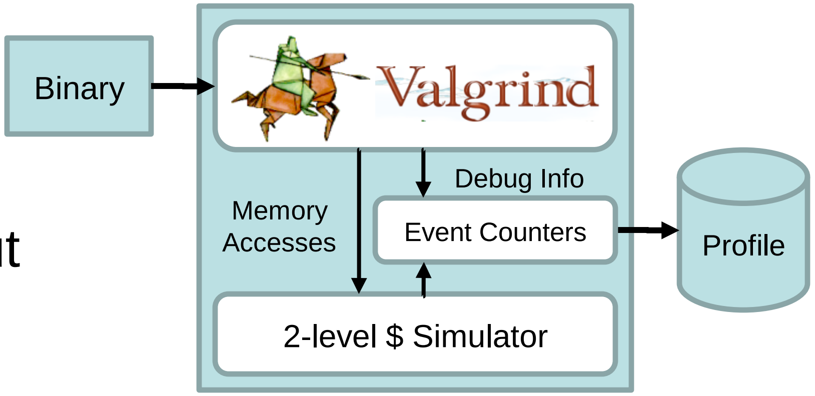
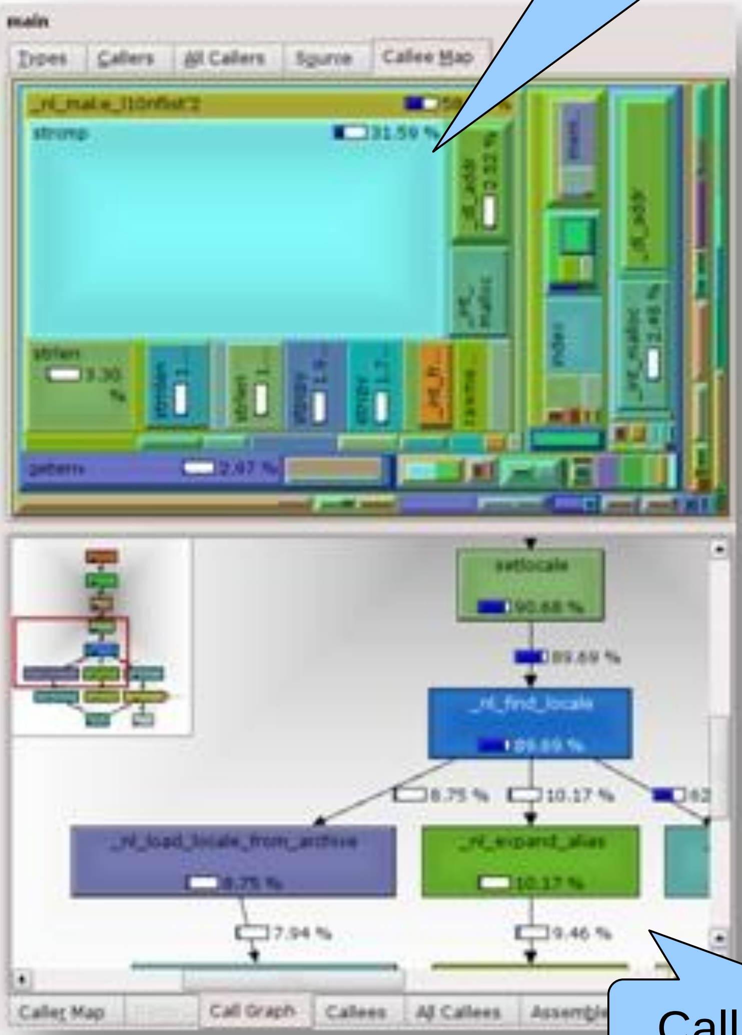
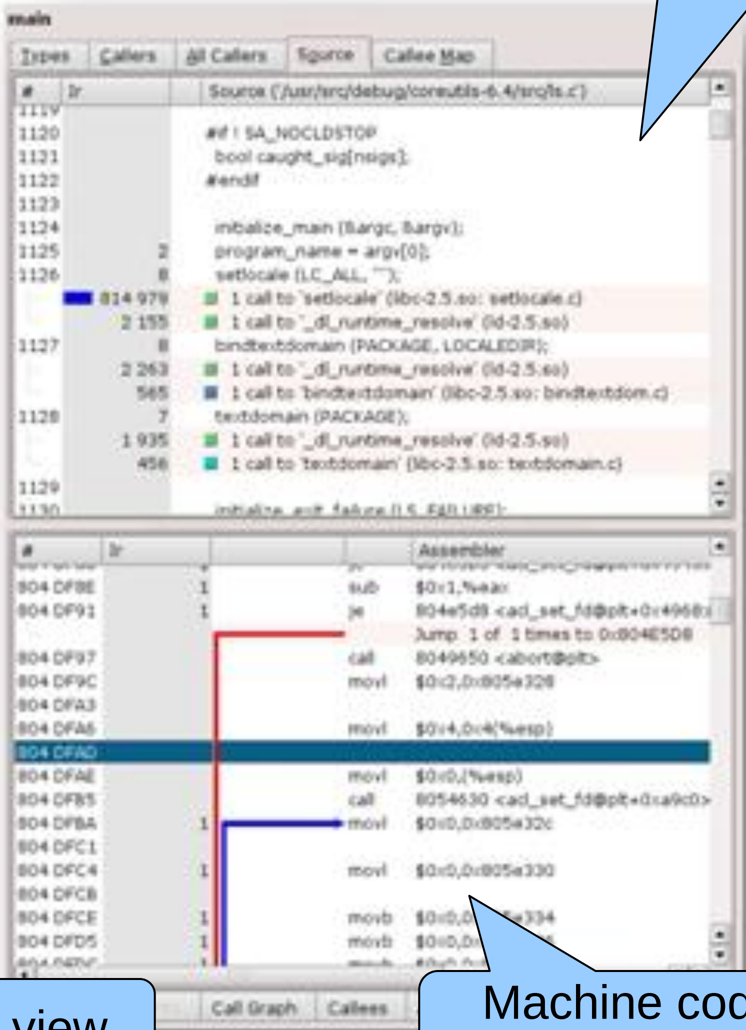
KCachegrind

- Cachegrind: cache analysis by simple cache simulation
  - Captures dynamic callgraph
  - Based on valgrind dynamic binary instrumentation
  - Runs on x86/PowerPC/ARM unmodified binaries
    - No root access required
  - ASCII reports produced
- [KQ]Cachegrind GUI
  - Visualization of cachegrind output
- Developed by TU Munich
  - Released as GPL open-source
  - http://kcachegrind.sf.net/



KCachegrind GUI





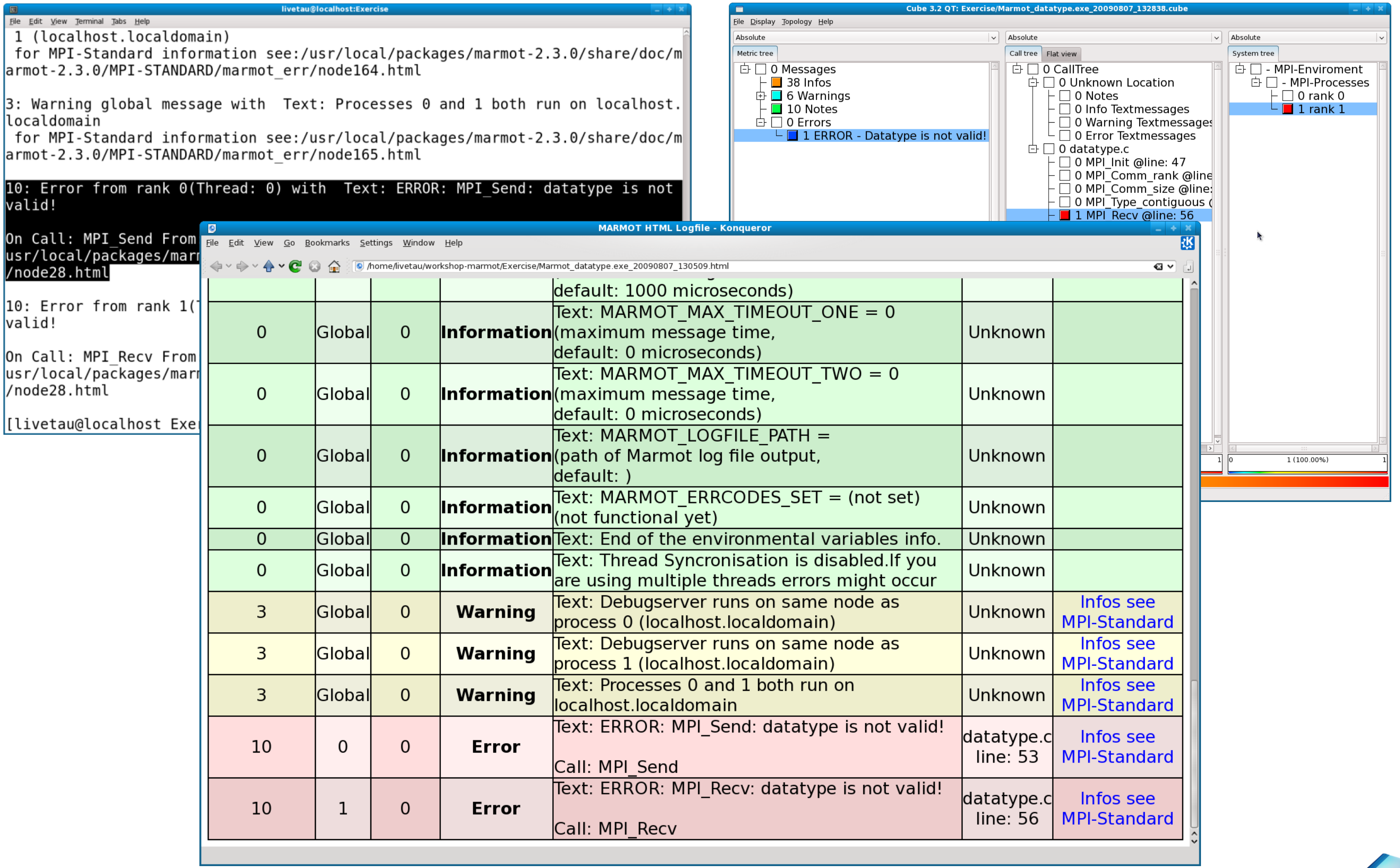
```
#     Ir         Source ('/usr/src/debug/coreutils-6.4/src/ls.c')
1119
1120               #if ! SA_NOCLDSTOP
1121                bool caught_sig[nsigs];
1122               #endif
1123
1124                initialize_main (&argc, &argv);
1125          2     program_name = argv[0];
1126          8     setlocale (LC_ALL, "");
        814 979    1 call to 'setlocale' (libc-2.5.so: setlocale.c)
          2 155    1 call to '_dl_runtime_resolve' (ld-2.5.so)
1127          8     bindtextdomain (PACKAGE, LOCALEDIR);
          2 263    1 call to '_dl_runtime_resolve' (ld-2.5.so)
            565    1 call to 'bindtextdomain' (libc-2.5.so: bindtextdom.c)
1128          7     textdomain (PACKAGE);
          1 935    1 call to '_dl_runtime_resolve' (ld-2.5.so)
            456    1 call to 'textdomain' (libc-2.5.so: textdomain.c)
1129
1130                initialize_exit_failure (LS_FAILURE);
```

```
#           Ir          Assembler
804 DF8E     1    sub    $0x1,%eax
804 DF91     1    je     804e5d8 <acl_set_fd@plt+0x4968>
                         Jump 1 of 1 times to 0x804E5D8
804 DF97          call   8049650 <abort@plt>
804 DF9C          movl   $0x2,0x805e328
804 DFA3
804 DFA6          movl   $0x4,0x4(%esp)
804 DFAD
804 DFAE          movl   $0x0,(%esp)
804 DFB5          call   8054630 <acl_set_fd@plt+0xa9c0>
804 DFBA     1    movl   $0x0,0x805e32c
804 DFC1
804 DFC4     1    movl   $0x0,0x805e330
804 DFCB
804 DFCE     1    movb   $0x0,0x805e334
804 DFD5     1    movb   $0x0,0x
```

Marmot

- Tool to check for correct MPI usage at runtime
  - Checks conformance to MPI standard
    - Supports Fortran & C bindings of MPI-1.2
  - Checks parameters passed to MPI
  - Monitors MPI resource usage
- Implementation
  - C++ library gets linked to the application
  - Does not require source code modifications
  - Additional process used as DebugServer
  - Results written in a log file (ASCII/HTML/CUBE)
- Developed by HLRS & TU Dresden
  - Released as open-source
  - http://www.hlrs.de/organization/av/amt/projects/marmot

Marmot logfiles



```
 1 (localhost.localdomain)
 for MPI-Standard information see:/usr/local/packages/marmot-2.3.0/share/doc/m
armot-2.3.0/MPI-STANDARD/marmot_err/node164.html

3: Warning global message with  Text: Processes 0 and 1 both run on localhost.
localdomain
 for MPI-Standard information see:/usr/local/packages/marmot-2.3.0/share/doc/m
armot-2.3.0/MPI-STANDARD/marmot_err/node165.html

10: Error from rank 0(Thread: 0) with  Text: ERROR: MPI_Send: datatype is not
valid!

On Call: MPI_Send From
usr/local/packages/marm
/node28.html

10: Error from rank 1(
valid!

On Call: MPI_Recv From
usr/local/packages/marm
/node28.html

[livetau@localhost Exe
```

Cube 3.2 QT: Exercise/Marmot_datatype.exe_20090807_132838.cube
File Display Topology Help
Absolute
Absolute
Absolute
Metric tree
Call tree
Flat view
System tree

```
Metric tree:
0 Messages
  38 Infos
  6 Warnings
  10 Notes
  0 Errors
    1 ERROR - Datatype is not valid!

Call tree:
0 CallTree
  0 Unknown Location
    0 Notes
    0 Info Textmessages
    0 Warning Textmessages
    0 Error Textmessages
  0 datatype.c
    0 MPI_Init @line: 47
    0 MPI_Comm_rank @line
    0 MPI_Comm_size @line:
    0 MPI_Type_contiguous (
    1 MPI_Recv @line: 56

System tree:
- MPI-Enviroment
  - MPI-Processes
    0 rank 0
    1 rank 1
```

0
1 (100.00%)
1
MARMOT HTML Logfile - Konqueror
File Edit View Go Bookmarks Settings Window Help
/home/livetau/workshop-marmot/Exercise/Marmot_datatype.exe_20090807_130509.html

				default: 1000 microseconds)		
0	Global	0	**Information**	Text: MARMOT_MAX_TIMEOUT_ONE = 0 (maximum message time, default: 0 microseconds)	Unknown	
0	Global	0	**Information**	Text: MARMOT_MAX_TIMEOUT_TWO = 0 (maximum message time, default: 0 microseconds)	Unknown	
0	Global	0	**Information**	Text: MARMOT_LOGFILE_PATH = (path of Marmot log file output, default:)	Unknown	
0	Global	0	**Information**	Text: MARMOT_ERRCODES_SET = (not set) (not functional yet)	Unknown	
0	Global	0	**Information**	Text: End of the environmental variables info.	Unknown	
0	Global	0	**Information**	Text: Thread Syncronisation is disabled.If you are using multiple threads errors might occur	Unknown	
3	Global	0	**Warning**	Text: Debugserver runs on same node as process 0 (localhost.localdomain)	Unknown	Infos see MPI-Standard
3	Global	0	**Warning**	Text: Debugserver runs on same node as process 1 (localhost.localdomain)	Unknown	Infos see MPI-Standard
3	Global	0	**Warning**	Text: Processes 0 and 1 both run on localhost.localdomain	Unknown	Infos see MPI-Standard
10	0	0	**Error**	Text: ERROR: MPI_Send: datatype is not valid! Call: MPI_Send	datatype.c line: 53	Infos see MPI-Standard
10	1	0	**Error**	Text: ERROR: MPI_Recv: datatype is not valid! Call: MPI_Recv	datatype.c line: 56	Infos see MPI-Standard

MUST

- Next generation MPI runtime error detection tool
  - Successor of the Marmot and Umpire tools
  - Initial merge of Marmot's many local checks with Umpire's non-local checks
  - Improved scalability expected in future
  - Exploits CMake, GTI & PnMPI infrastructure

- Developed by TU Dresden, LLNL & LANL
  - BSD license open-source initial release in November 2011
  - http://tu-dresden.de/zih/must/

PAPI

- Portable performance counter library & utilities
  - Configures and accesses hardware/system counters
  - Predefined events derived from available native counters
  - Core component for CPU/processor counters
    - instructions, floating point operations, branches predicted/taken, cache accesses/misses, TLB misses, cycles, stall cycles, …
    - performs transparent multiplexing when required
  - Extensible components for off-processor counters
    - InfiniBand network, Lustre filesystem, system hardware health, …
  - Used by multi-platform performance measurement tools
    - Periscope, Scalasca, TAU, VampirTrace, ...
- Developed by UTK-ICL
  - Available as open-source for most modern processors
    http://icl.cs.utk.edu/papi/

PAPI preset counters (and their definitions)

- juropa$ ***papi_avail***
- Available events and hardware information.

```
----------------------------------------------
PAPI Version             : 4.1.0.0
Vendor string and code   : GenuineIntel (1)
Model string and code    : Intel(R) Xeon(R) CPU
X5570 @ 2.93GHz (26)
CPU Revision             : 5.000000
CPUID Info               : Family: 6  Model: 26
Stepping: 5
CPU Megahertz            : 1600.000000
CPU Clock Megahertz      : 1600
Hdw Threads per core     : 2
Cores per Socket         : 4
NUMA Nodes               : 2
CPU's per Node           : 8
Total CPU's              : 16
Number Hardware Counters : 16
Max Multiplex Counters   : 512
----------------------------------------------
    Name        Code    Avail Deriv Description
```

- **PAPI_L1_DCM** 0x80000000 Yes No
  Level 1 data cache misses
- **PAPI_L1_ICM** 0x80000001 Yes No
  Level 1 instruction cache misses
  ...

- Of 107 possible events, 35 are available, of which 9 are derived.

- juropa$ ***papi_avail -d***
- ...
  ```
  Symbol       Event Code  Count   |Short Descr.|
   |Long Description|
   |Developer's Notes|
   |Derived|
   |PostFix|
   Native Code[n]: <hex> |name|
  ```
- **PAPI_L1_DCM** 0x80000000 1 |L1D cache misses|
  |Level 1 data cache misses|
  ||
  |NOT_DERIVED|
  ||
  Native Code[0]: 0x40002028 |*L1D:REPL*|
- **PAPI_L1_ICM** 0x80000001 1 |L1I cache misses|
  |Level 1 instruction cache misses|
  ||
  |NOT_DERIVED|
  ||
  Native Code[0]: 0x40001031 |*L1I:MISSES*|
- **PAPI_L2_DCM** 0x80000002 2 |L2D cache misses|
  |Level 2 data cache misses|
  ||
  |*DERIVED_SUB*|
  ||
  Native Code[0]: 0x40000437 |*L2_RQSTS:MISS*|
  Native Code[1]: 0x40002037 |*L2_RQSTS:IFETCH_MISS*|
- ...

PAPI native counters (and qualifiers)

- juropa$ papi_native_avail
- Available native events and hardware information.
- ...
- Event Code   Symbol | Long Description |

```
--------------------------------------------------------------------------------
0x40000000   UNHALTED_CORE_CYCLES  | count core clock cycles whenever the cloc |
             | k signal on the specific core is running (not halted). Alias to e |
             | vent CPU_CLK_UNHALTED:THREAD                                       |
--------------------------------------------------------------------------------
0x40000001   INSTRUCTION_RETIRED  | count the number of instructions at retire |
             | ment. Alias to event INST_RETIRED:ANY_P                            |
--------------------------------------------------------------------------------
...
```

-
```
--------------------------------------------------------------------------------
0x40000086   UNC_SNP_RESP_TO_REMOTE_HOME  | Remote home snoop response - LLC d |
             | oes not have cache line                                            |
  40000486   :I_STATE  | Remote home snoop response - LLC does not have cache  |
             | line                                                               |
  40000886   :S_STATE  | Remote home snoop response - LLC has  cache line in S |
             |  state                                                             |
  40001086   :FWD_S_STATE  | Remote home snoop response - LLC forwarding cache |
             |  line in S state.                                                  |
  40002086   :FWD_I_STATE  | Remote home snoop response - LLC has forwarded a  |
             | modified cache line                                                |
  40004086   :CONFLICT  | Remote home conflict snoop response                     |
  40008086   :WB  | Remote home snoop response - LLC has cache line in the M s |
             | tate                                                               |
  40010086   :HITM  | Remote home snoop response - LLC HITM                      |
--------------------------------------------------------------------------------
Total events reported: 135
```

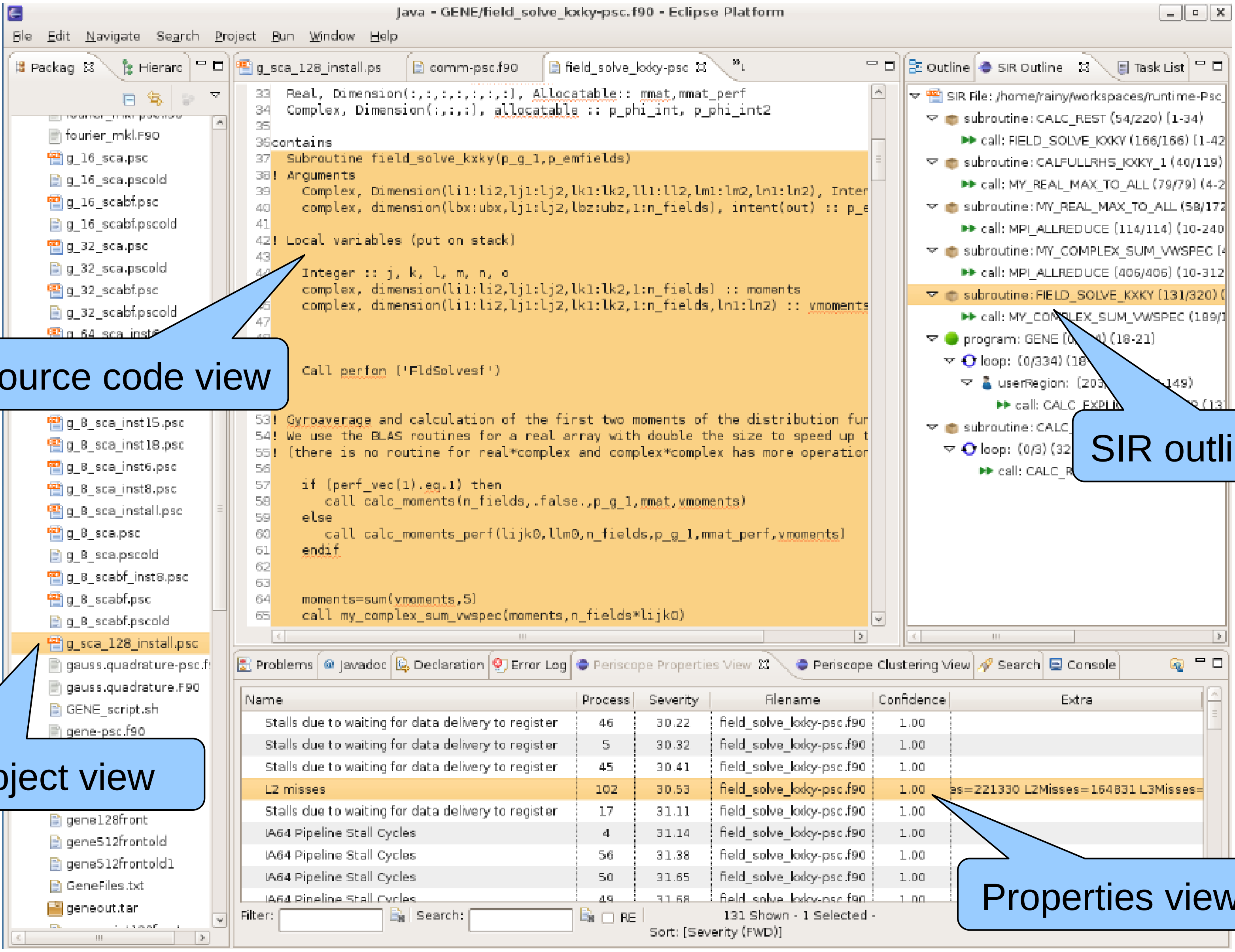
Periscope

- Automated profile-based performance analysis
  - Iterative on-line performance analysis
    - Multiple distributed hierarchical agents
  - Automatic search for bottlenecks based on properties formalizing expert knowledge
    - MPI wait states, OpenMP overheads and imbalances
    - Processor utilization hardware counters
  - Clustering of processes/threads with similar properties
  - Eclipse-based integrated environment
- Supports
  - SGI Altix Itanium2, IBM Power and x86-based architectures
- Developed by TU Munich
  - Released as open-source
  - http://www.lrr.in.tum.de/periscope

Periscope properties & strategies (examples)

- MPI
  - Excessive MPI communication time
  - Excessive MPI time due to many small messages
  - Excessive MPI time in receive due to late sender
  - …
- OpenMP
  - Load imbalance in parallel region/section
  - Sequential computation in master/single/ordered region
  - ...
- Hardware performance counters (platform-specific)
  - Cycles lost due to cache misses
    - High L1/L2/L3 demand load miss rate
  - Cycles lost due to no instruction to dispatch
  - ...

Periscope plug-in to Eclipse environment



fourier_mkl.F90
g_16_sca.psc
g_16_sca.pscold
g_16_scabf.psc
g_16_scabf.pscold
g_32_sca.psc
g_32_sca.pscold
g_32_scabf.psc
g_32_scabf.pscold
g_8_sca_inst15.psc
g_8_sca_inst18.psc
g_8_sca_inst6.psc
g_8_sca_inst8.psc
g_8_sca_install.psc
g_8_sca.psc
g_8_sca.pscold
g_8_scabf_inst8.psc
g_8_scabf.psc
g_8_scabf.pscold
g_sca_128_install.psc
gauss.quadrature-psc.f
gauss.quadrature.F90
GENE_script.sh
gene-psc.f90
gene128front
gene512frontold
gene512frontold1
GeneFiles.txt
geneout.tar

```
  Real, Dimension(:,:,:,:,:,:,:), Allocatable:: mmat,mmat_perf
  Complex, Dimension(:,:,:), allocatable :: p_phi_int, p_phi_int2

contains
  Subroutine field_solve_kxky(p_g_1,p_emfields)
! Arguments
    Complex, Dimension(li1:li2,lj1:lj2,lk1:lk2,ll1:ll2,lm1:lm2,ln1:ln2), Inter
    complex, dimension(lbx:ubx,lj1:lj2,lbz:ubz,1:n_fields), intent(out) :: p_e

! Local variables (put on stack)

    Integer :: j, k, l, m, n, o
    complex, dimension(li1:li2,lj1:lj2,lk1:lk2,1:n_fields) :: moments
    complex, dimension(li1:li2,lj1:lj2,lk1:lk2,1:n_fields,ln1:ln2) :: vmoments



    Call perfon ('FldSolvesf')


! Gyroaverage and calculation of the first two moments of the distribution fur
! We use the BLAS routines for a real array with double the size to speed up t
! (there is no routine for real*complex and complex*complex has more operatior

    if (perf_vec(1).eq.1) then
       call calc_moments(n_fields,.false.,p_g_1,mmat,vmoments)
    else
       call calc_moments_perf(lijk0,llm0,n_fields,p_g_1,mmat_perf,vmoments)
    endif


    moments=sum(vmoments,5)
    call my_complex_sum_vwspec(moments,n_fields*lijk0)
```

```
SIR File: /home/rainy/workspaces/runtime-Psc_
  subroutine: CALC_REST (54/220) (1-34)
    call: FIELD_SOLVE_KXKY (166/166) (1-42
  subroutine: CALFULLRHS_KXKY_1 (40/119)
    call: MY_REAL_MAX_TO_ALL (79/79) (4-2
  subroutine: MY_REAL_MAX_TO_ALL (58/172
    call: MPI_ALLREDUCE (114/114) (10-240
  subroutine: MY_COMPLEX_SUM_VWSPEC (4
    call: MPI_ALLREDUCE (406/406) (10-312
  subroutine: FIELD_SOLVE_KXKY (131/320) (
    call: MY_COMPLEX_SUM_VWSPEC (189/1
  program: GENE (0/ 4) (18-21)
    loop: (0/334) (18
      userRegion: (203/ -149)
        call: CALC_EXPLI (13
  subroutine: CALC_
    loop: (0/3) (32
      call: CALC_R
```

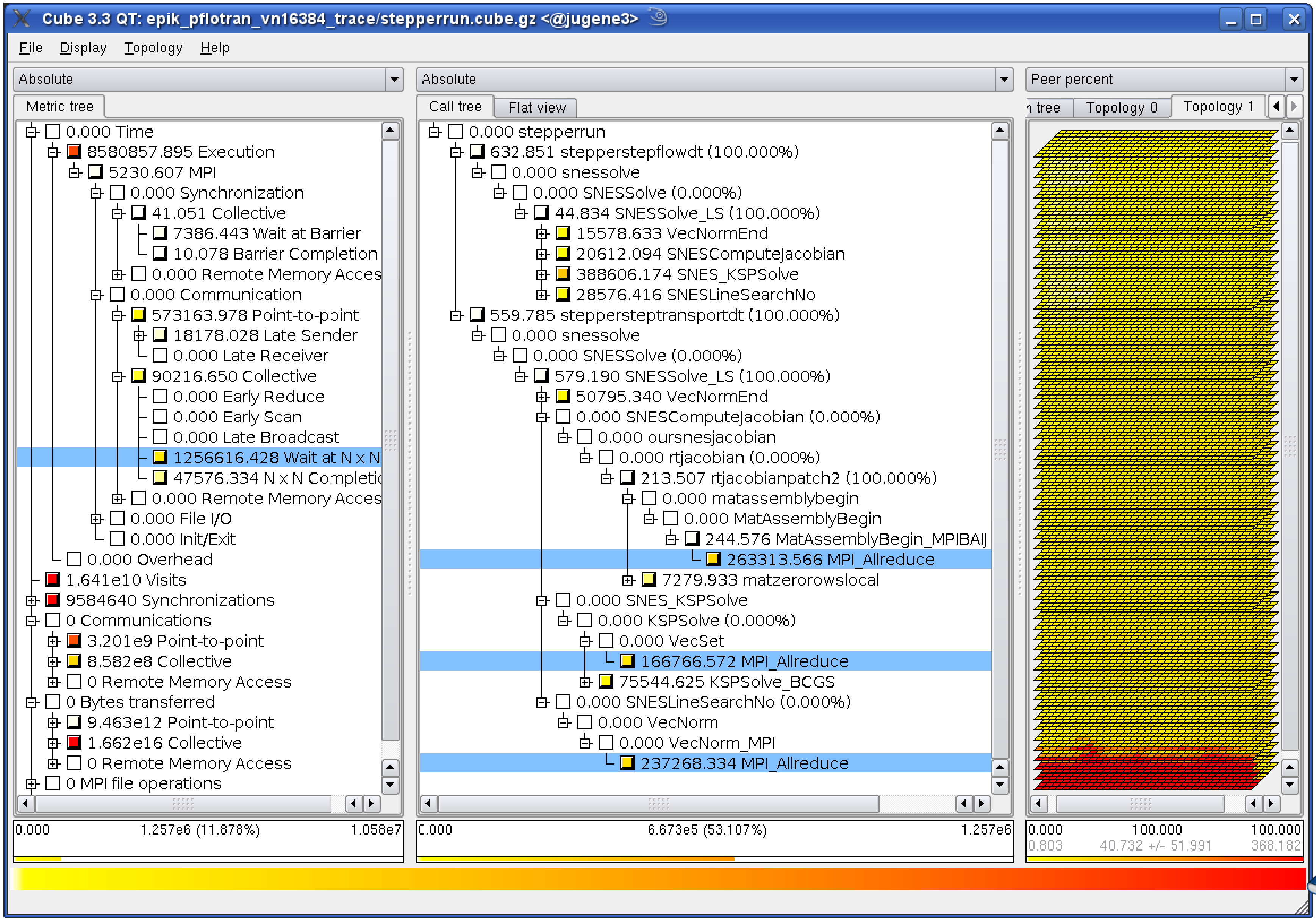
Name	Process	Severity	Filename	Confidence	Extra
Stalls due to waiting for data delivery to register	46	30.22	field_solve_kxky-psc.f90	1.00	
Stalls due to waiting for data delivery to register	5	30.32	field_solve_kxky-psc.f90	1.00	
Stalls due to waiting for data delivery to register	45	30.41	field_solve_kxky-psc.f90	1.00	
L2 misses	102	30.53	field_solve_kxky-psc.f90	1.00	es=221330 L2Misses=164831 L3Misses=
Stalls due to waiting for data delivery to register	17	31.11	field_solve_kxky-psc.f90	1.00	
IA64 Pipeline Stall Cycles	4	31.14	field_solve_kxky-psc.f90	1.00	
IA64 Pipeline Stall Cycles	56	31.38	field_solve_kxky-psc.f90	1.00	
IA64 Pipeline Stall Cycles	50	31.65	field_solve_kxky-psc.f90	1.00	
IA64 Pipeline Stall Cycles	49	31.68	field_solve_kxky-psc.f90	1.00	

Filter: Search: RE 131 Shown - 1 Selected -
Sort: [Severity (FWD)]

Scalasca

- Automatic performance analysis toolset
  - Scalable performance analysis of large-scale applications
    - particularly focused on MPI & OpenMP paradigms
    - analysis of communication & synchronization overheads
  - Automatic and manual instrumentation capabilities
  - Runtime summarization and/or event trace analyses
  - Automatic search of event traces for patterns of inefficiency
    - Scalable trace analysis based on parallel replay
  - Interactive exploration GUI and algebra utilities for XML callpath profile analysis reports
- Developed by JSC & GRS
  - Released as open-source
  - http://www.scalasca.org/

Scalasca automatic trace analysis report



Cube 3.3 QT: epik_pflotran_vn16384_trace/stepperrun.cube.gz <@jugene3>

File Display Topology Help

Absolute | Absolute | Peer percent

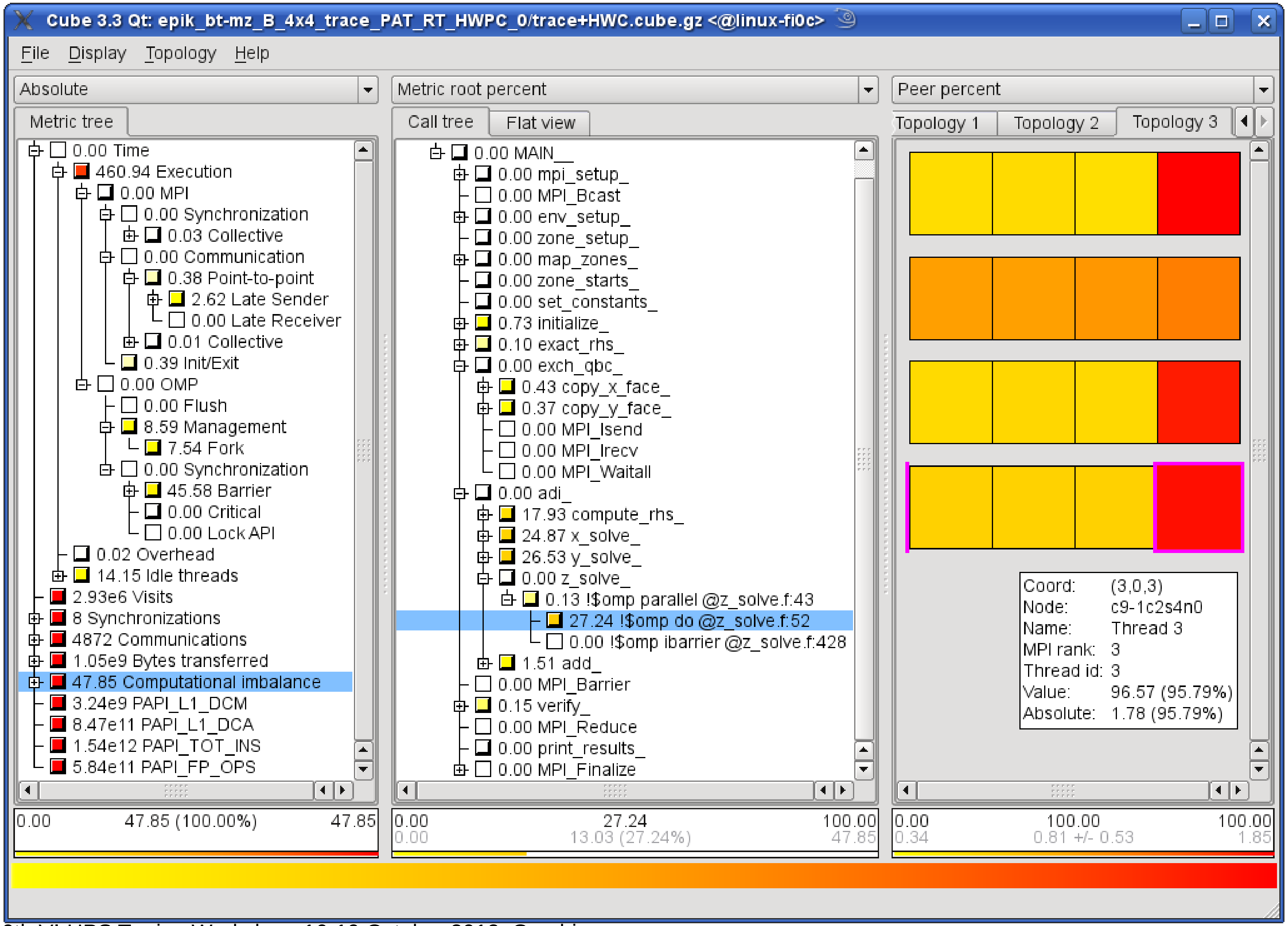
Metric tree | Call tree | Flat view | tree | Topology 0 | Topology 1

```
0.000 Time
  8580857.895 Execution
    5230.607 MPI
      0.000 Synchronization
        41.051 Collective
          7386.443 Wait at Barrier
          10.078 Barrier Completion
        0.000 Remote Memory Acces
      0.000 Communication
        573163.978 Point-to-point
          18178.028 Late Sender
          0.000 Late Receiver
        90216.650 Collective
          0.000 Early Reduce
          0.000 Early Scan
          0.000 Late Broadcast
          1256616.428 Wait at N x N
          47576.334 N x N Completi
        0.000 Remote Memory Acces
      0.000 File I/O
      0.000 Init/Exit
  0.000 Overhead
1.641e10 Visits
9584640 Synchronizations
0 Communications
  3.201e9 Point-to-point
  8.582e8 Collective
  0 Remote Memory Access
0 Bytes transferred
  9.463e12 Point-to-point
  1.662e16 Collective
  0 Remote Memory Access
0 MPI file operations
```

```
0.000 stepperrun
  632.851 stepperstepflowdt (100.000%)
    0.000 snessolve
      0.000 SNESSolve (0.000%)
        44.834 SNESSolve_LS (100.000%)
          15578.633 VecNormEnd
          20612.094 SNESComputeJacobian
          388606.174 SNES_KSPSolve
          28576.416 SNESLineSearchNo
  559.785 steppersteptransportdt (100.000%)
    0.000 snessolve
      0.000 SNESSolve (0.000%)
        579.190 SNESSolve_LS (100.000%)
          50795.340 VecNormEnd
          0.000 SNESComputeJacobian (0.000%)
            0.000 oursnesjacobian
              0.000 rtjacobian (0.000%)
                213.507 rtjacobianpatch2 (100.000%)
                  0.000 matassemblybegin
                    0.000 MatAssemblyBegin
                      244.576 MatAssemblyBegin_MPIBAIJ
                        263313.566 MPI_Allreduce
                  7279.933 matzerorowslocal
          0.000 SNES_KSPSolve
            0.000 KSPSolve (0.000%)
              0.000 VecSet
                166766.572 MPI_Allreduce
              75544.625 KSPSolve_BCGS
          0.000 SNESLineSearchNo (0.000%)
            0.000 VecNorm
              0.000 VecNorm_MPI
                237268.334 MPI_Allreduce
```

```
0.000        1.257e6 (11.878%)        1.058e7
0.000        6.673e5 (53.107%)        1.257e6
0.000        100.000                  100.000
0.803        40.732 +/- 51.991        368.182
```

Scalasca hybrid analysis report



Cube 3.3 Qt: epik_bt-mz_B_4x4_trace_PAT_RT_HWPC_0/trace+HWC.cube.gz <@linux-fi0c>

File Display Topology Help

Absolute | Metric root percent | Peer percent

Metric tree | Call tree | Flat view | Topology 1 | Topology 2 | Topology 3

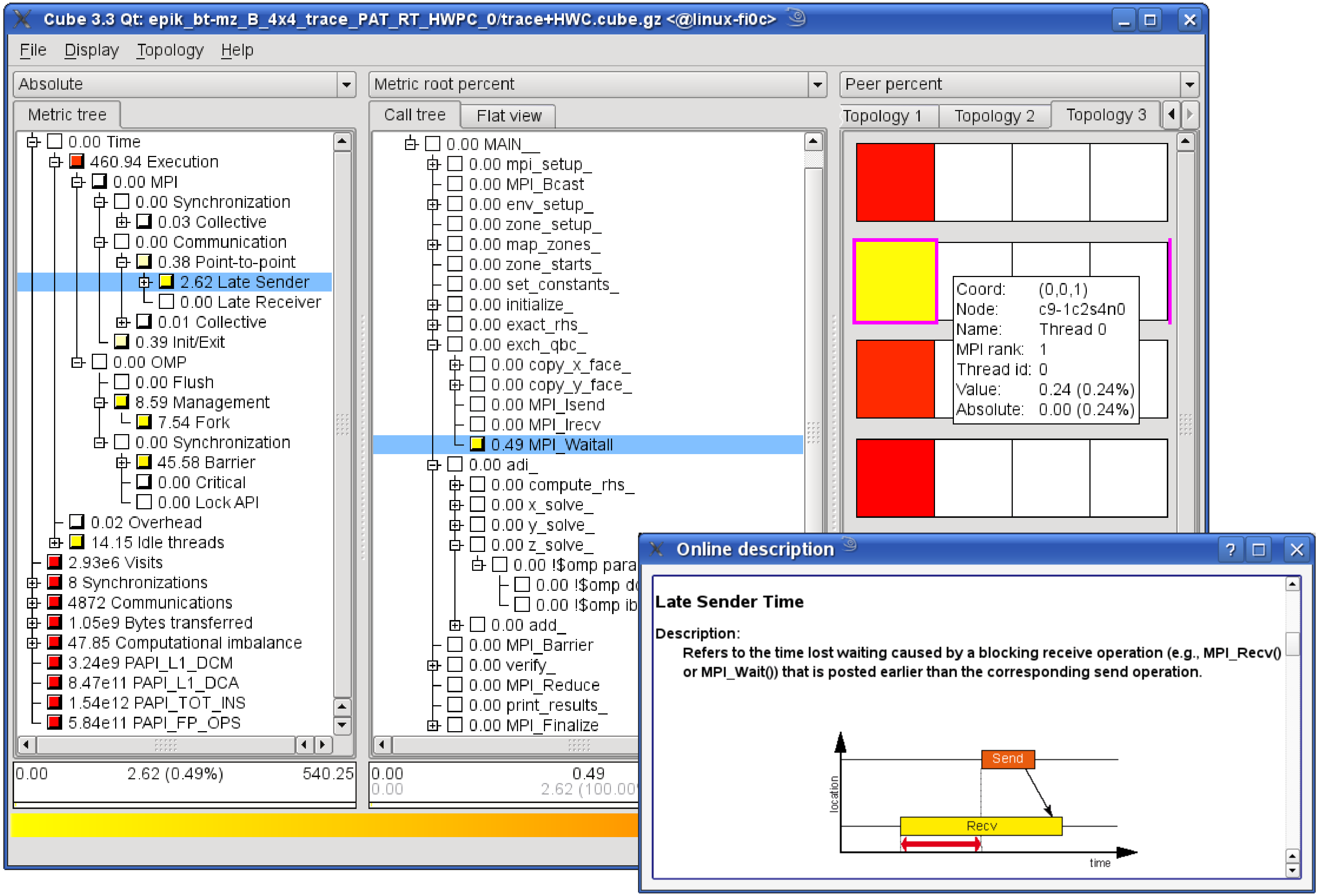
```
0.00 Time
  460.94 Execution
    0.00 MPI
      0.00 Synchronization
        0.03 Collective
      0.00 Communication
        0.38 Point-to-point
          2.62 Late Sender
          0.00 Late Receiver
        0.01 Collective
      0.39 Init/Exit
    0.00 OMP
      0.00 Flush
      8.59 Management
        7.54 Fork
      0.00 Synchronization
        45.58 Barrier
        0.00 Critical
        0.00 Lock API
    0.02 Overhead
    14.15 Idle threads
2.93e6 Visits
8 Synchronizations
4872 Communications
1.05e9 Bytes transferred
47.85 Computational imbalance
3.24e9 PAPI_L1_DCM
8.47e11 PAPI_L1_DCA
1.54e12 PAPI_TOT_INS
5.84e11 PAPI_FP_OPS
```

```
0.00 MAIN__
  0.00 mpi_setup_
  0.00 MPI_Bcast
  0.00 env_setup_
  0.00 zone_setup_
  0.00 map_zones_
  0.00 zone_starts_
  0.00 set_constants_
  0.73 initialize_
  0.10 exact_rhs_
  0.00 exch_qbc_
    0.43 copy_x_face_
    0.37 copy_y_face_
    0.00 MPI_Isend
    0.00 MPI_Irecv
    0.00 MPI_Waitall
  0.00 adi_
    17.93 compute_rhs_
    24.87 x_solve_
    26.53 y_solve_
    0.00 z_solve_
      0.13 !$omp parallel @z_solve.f:43
        27.24 !$omp do @z_solve.f:52
        0.00 !$omp ibarrier @z_solve.f:428
    1.51 add_
  0.00 MPI_Barrier
  0.15 verify_
  0.00 MPI_Reduce
  0.00 print_results_
  0.00 MPI_Finalize
```

```
Coord:     (3,0,3)
Node:      c9-1c2s4n0
Name:      Thread 3
MPI rank:  3
Thread id: 3
Value:     96.57 (95.79%)
Absolute:  1.78 (95.79%)
```

```
0.00   47.85 (100.00%)   47.85
0.00   27.24             100.00
0.00   13.03 (27.24%)    47.85
0.00   100.00            100.00
0.34   0.81 +/- 0.53     1.85
```

Scalasca automatic trace analysis report



Cube 3.3 Qt: epik_bt-mz_B_4x4_trace_PAT_RT_HWPC_0/trace+HWC.cube.gz <@linux-fi0c>

File Display Topology Help

Absolute | Metric root percent | Peer percent

Metric tree:

```
0.00 Time
  460.94 Execution
    0.00 MPI
      0.00 Synchronization
        0.03 Collective
      0.00 Communication
        0.38 Point-to-point
          2.62 Late Sender
          0.00 Late Receiver
        0.01 Collective
      0.39 Init/Exit
    0.00 OMP
      0.00 Flush
      8.59 Management
        7.54 Fork
      0.00 Synchronization
        45.58 Barrier
        0.00 Critical
        0.00 Lock API
  0.02 Overhead
  14.15 Idle threads
2.93e6 Visits
8 Synchronizations
4872 Communications
1.05e9 Bytes transferred
47.85 Computational imbalance
3.24e9 PAPI_L1_DCM
8.47e11 PAPI_L1_DCA
1.54e12 PAPI_TOT_INS
5.84e11 PAPI_FP_OPS
```

0.00 2.62 (0.49%) 540.25

Call tree / Flat view:

```
0.00 MAIN__
  0.00 mpi_setup_
  0.00 MPI_Bcast
  0.00 env_setup_
  0.00 zone_setup_
  0.00 map_zones_
  0.00 zone_starts_
  0.00 set_constants_
  0.00 initialize_
  0.00 exact_rhs_
  0.00 exch_qbc_
    0.00 copy_x_face_
    0.00 copy_y_face_
    0.00 MPI_Isend
    0.00 MPI_Irecv
    0.49 MPI_Waitall
  0.00 adi_
    0.00 compute_rhs_
    0.00 x_solve_
    0.00 y_solve_
    0.00 z_solve_
      0.00 !$omp para
        0.00 !$omp do
        0.00 !$omp ib
    0.00 add_
  0.00 MPI_Barrier
  0.00 verify_
  0.00 MPI_Reduce
  0.00 print_results_
  0.00 MPI_Finalize
```

0.00 0.49
0.00 2.62 (100.00

Topology 1 | Topology 2 | Topology 3

```
Coord:      (0,0,1)
Node:       c9-1c2s4n0
Name:       Thread 0
MPI rank:   1
Thread id:  0
Value:      0.24 (0.24%)
Absolute:   0.00 (0.24%)
```

Online description

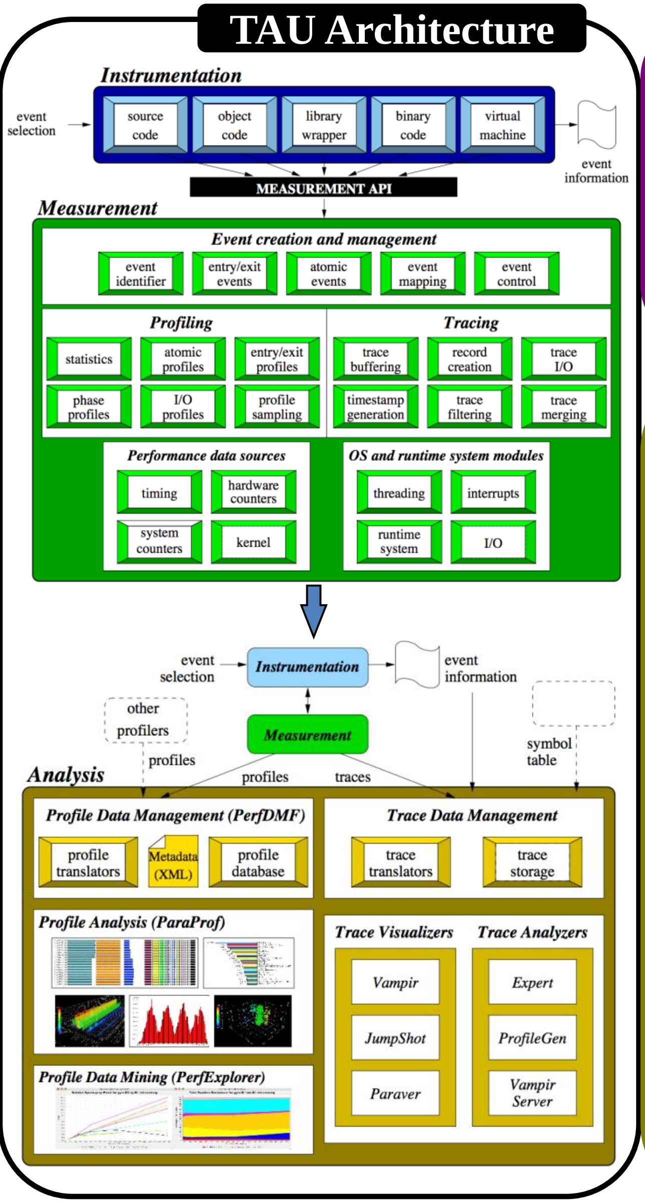
Late Sender Time

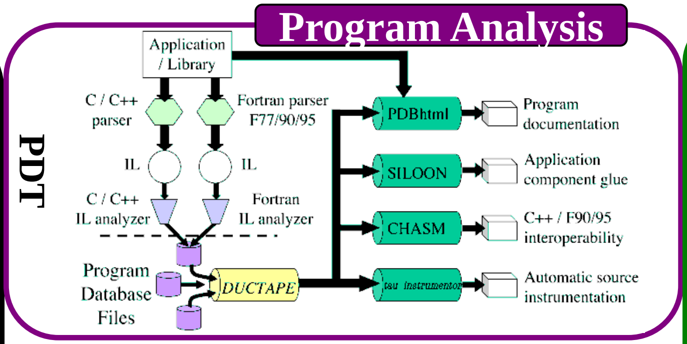
Description:
Refers to the time lost waiting caused by a blocking receive operation (e.g., MPI_Recv() or MPI_Wait()) that is posted earlier than the corresponding send operation.

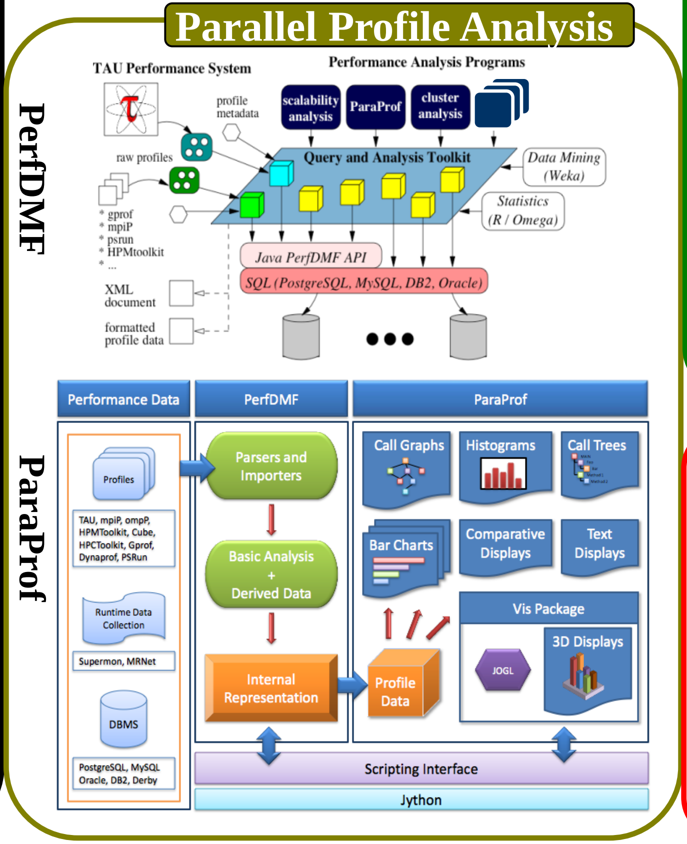
TAU Performance System

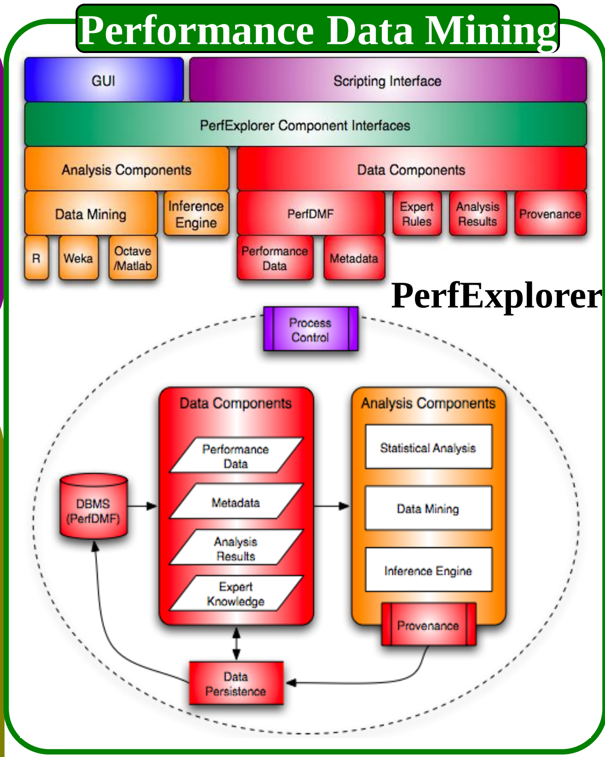
- Integrated performance toolkit
  - Instrumentation, measurement, analysis & visualization
    - Highly customizable installation, API, envvars & GUI
    - Supports multiple profiling & tracing capabilities
  - Performance data management & data mining
  - Targets all parallel programming/execution paradigms
    - Ported to a wide range of computer systems
  - Performance problem solving framework for HPC
  - Extensive bridges to/from other performance tools
    - PerfSuite, Scalasca, Vampir, ...
- Developed by U. Oregon/PRL
  - Broadly deployed open-source software
  - http://tau.uoregon.edu/

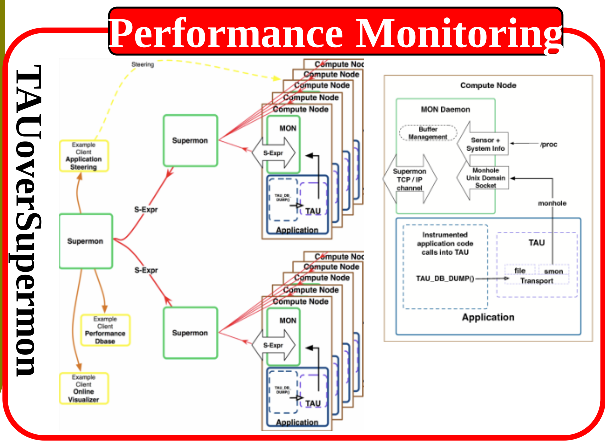
TAU Performance System components



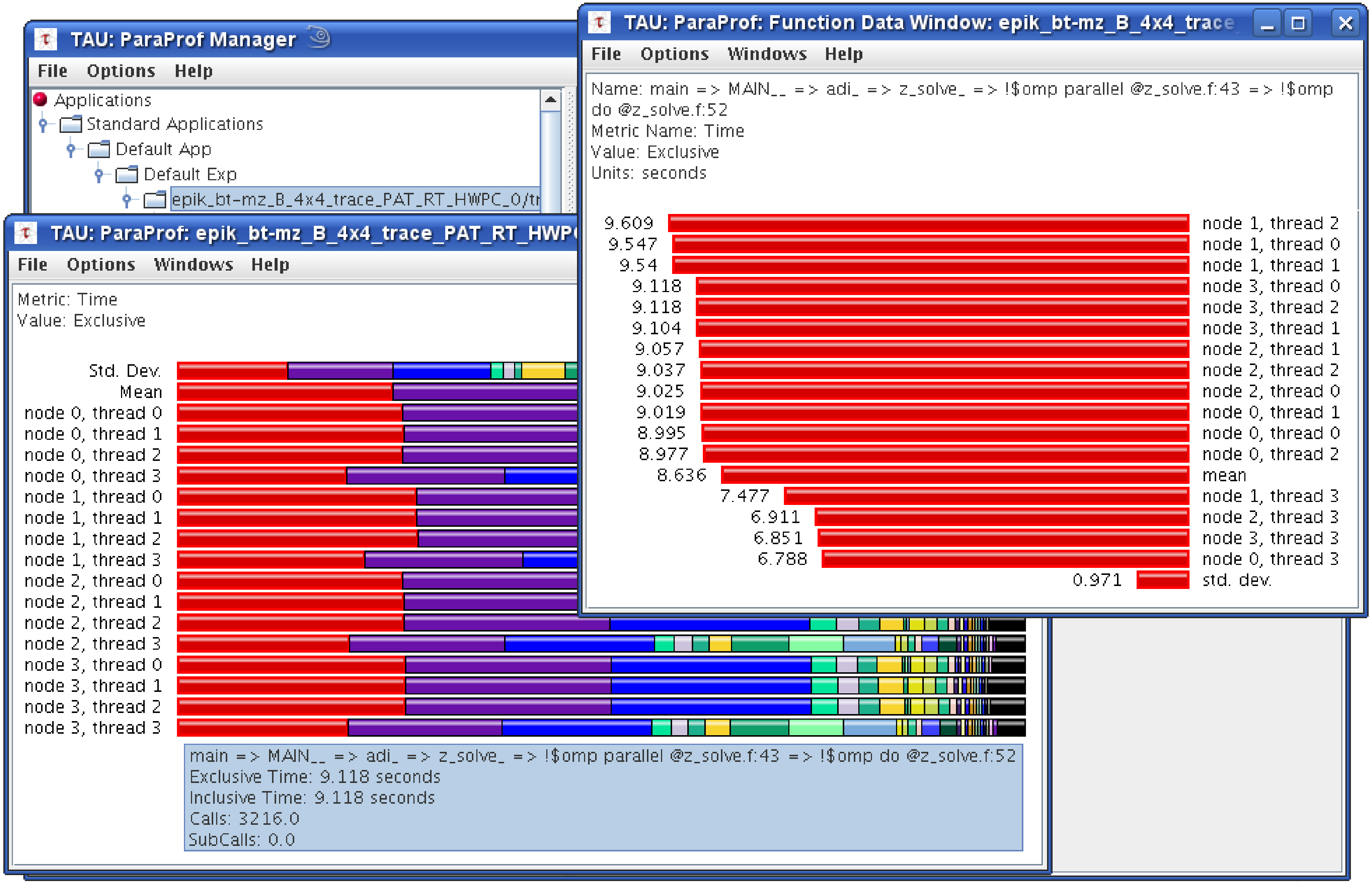








TAU ParaProf GUI displays (selected)


TAU: ParaProf Manager
File Options Help
Applications
Standard Applications
Default App
Default Exp
epik_bt-mz_B_4x4_trace_PAT_RT_HWPC_0/tr
TAU: ParaProf: epik_bt-mz_B_4x4_trace_PAT_RT_HWP
File Options Windows Help
TAU: ParaProf: Function Data Window: epik_bt-mz_B_4x4_trace
File Options Windows Help

Metric: Time
Value: Exclusive

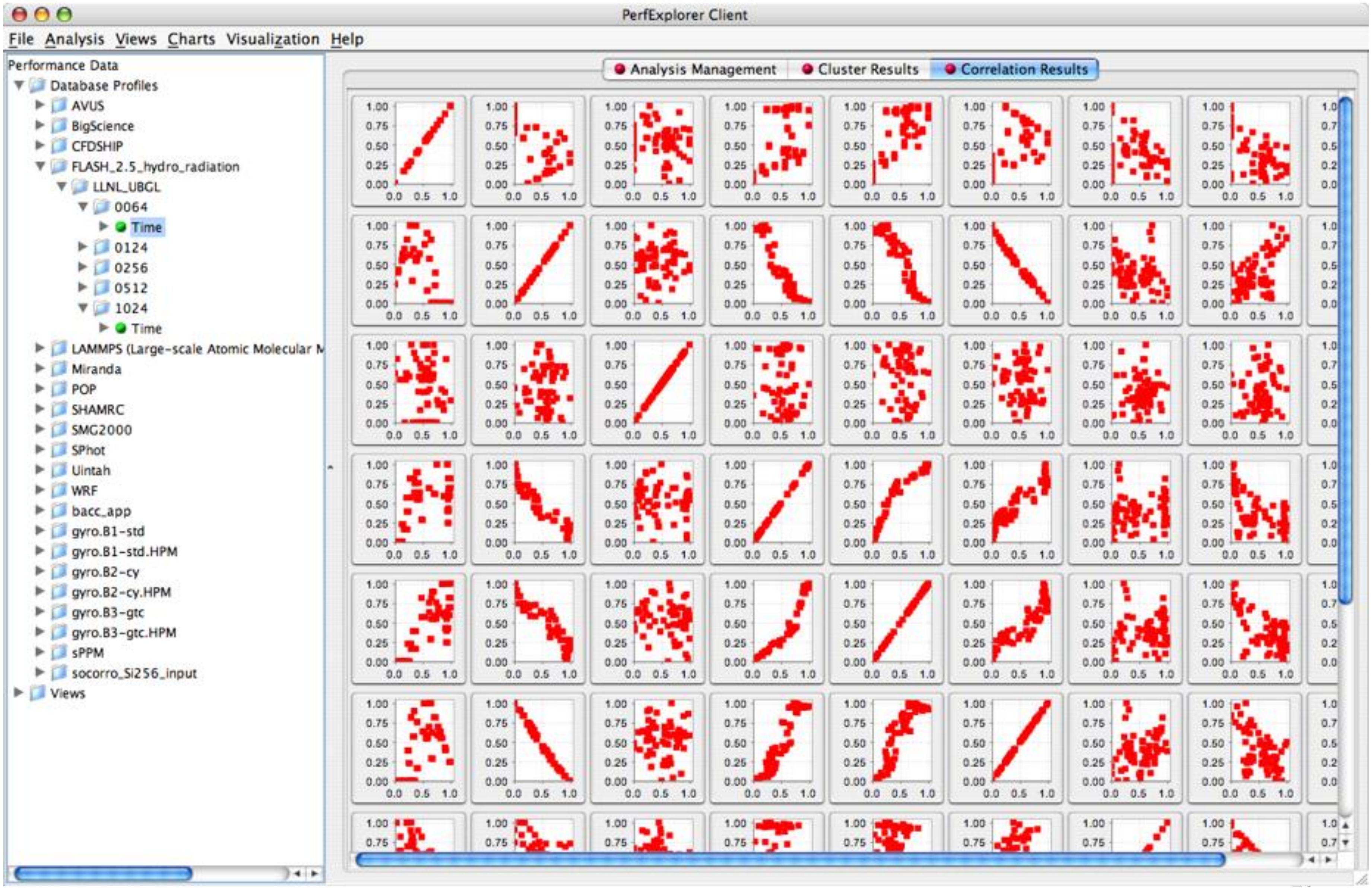
Std. Dev.
Mean
node 0, thread 0
node 0, thread 1
node 0, thread 2
node 0, thread 3
node 1, thread 0
node 1, thread 1
node 1, thread 2
node 1, thread 3
node 2, thread 0
node 2, thread 1
node 2, thread 2
node 2, thread 3
node 3, thread 0
node 3, thread 1
node 3, thread 2
node 3, thread 3

main => MAIN__ => adi_ => z_solve_ => !$omp parallel @z_solve.f:43 => !$omp do @z_solve.f:52
Exclusive Time: 9.118 seconds
Inclusive Time: 9.118 seconds
Calls: 3216.0
SubCalls: 0.0

Name: main => MAIN__ => adi_ => z_solve_ => !$omp parallel @z_solve.f:43 => !$omp do @z_solve.f:52
Metric Name: Time
Value: Exclusive
Units: seconds

```
9.609  node 1, thread 2
9.547  node 1, thread 0
9.54   node 1, thread 1
9.118  node 3, thread 0
9.118  node 3, thread 2
9.104  node 3, thread 1
9.057  node 2, thread 1
9.037  node 2, thread 2
9.025  node 2, thread 0
9.019  node 0, thread 1
8.995  node 0, thread 0
8.977  node 0, thread 2
8.636  mean
7.477  node 1, thread 3
6.911  node 2, thread 3
6.851  node 3, thread 3
6.788  node 0, thread 3
0.971  std. dev.
```

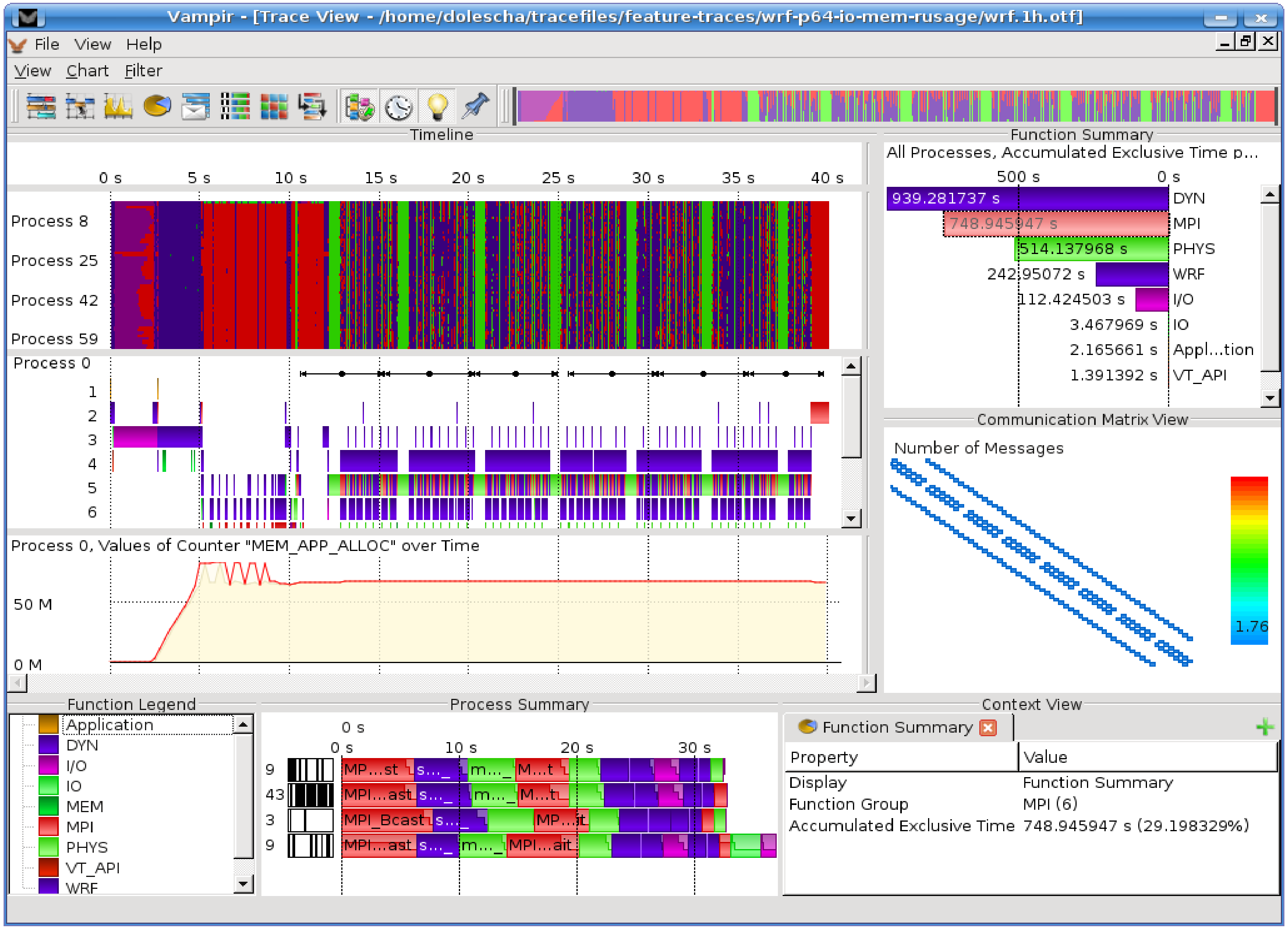
TAU PerfExplorer data mining



Vampir & VampirTrace

- Interactive event trace analysis
  - Alternative & supplement to automatic trace analysis
  - Visual presentation of dynamic runtime behaviour
    - event timeline chart for states & interactions of processes/threads
    - communication statistics, summaries & more
  - Interactive browsing, zooming, selecting
    - linked displays & statistics adapt to selected time interval (zoom)
    - scalable server runs in parallel to handle larger traces
- Developed by TU Dresden ZIH
  - Open-source VampirTrace library bundled with OpenMPI 1.3
  - http://www.tu-dresden.de/zih/vampirtrace/
  - Vampir Server & GUI have a commercial license
  - http://www.vampir.eu/

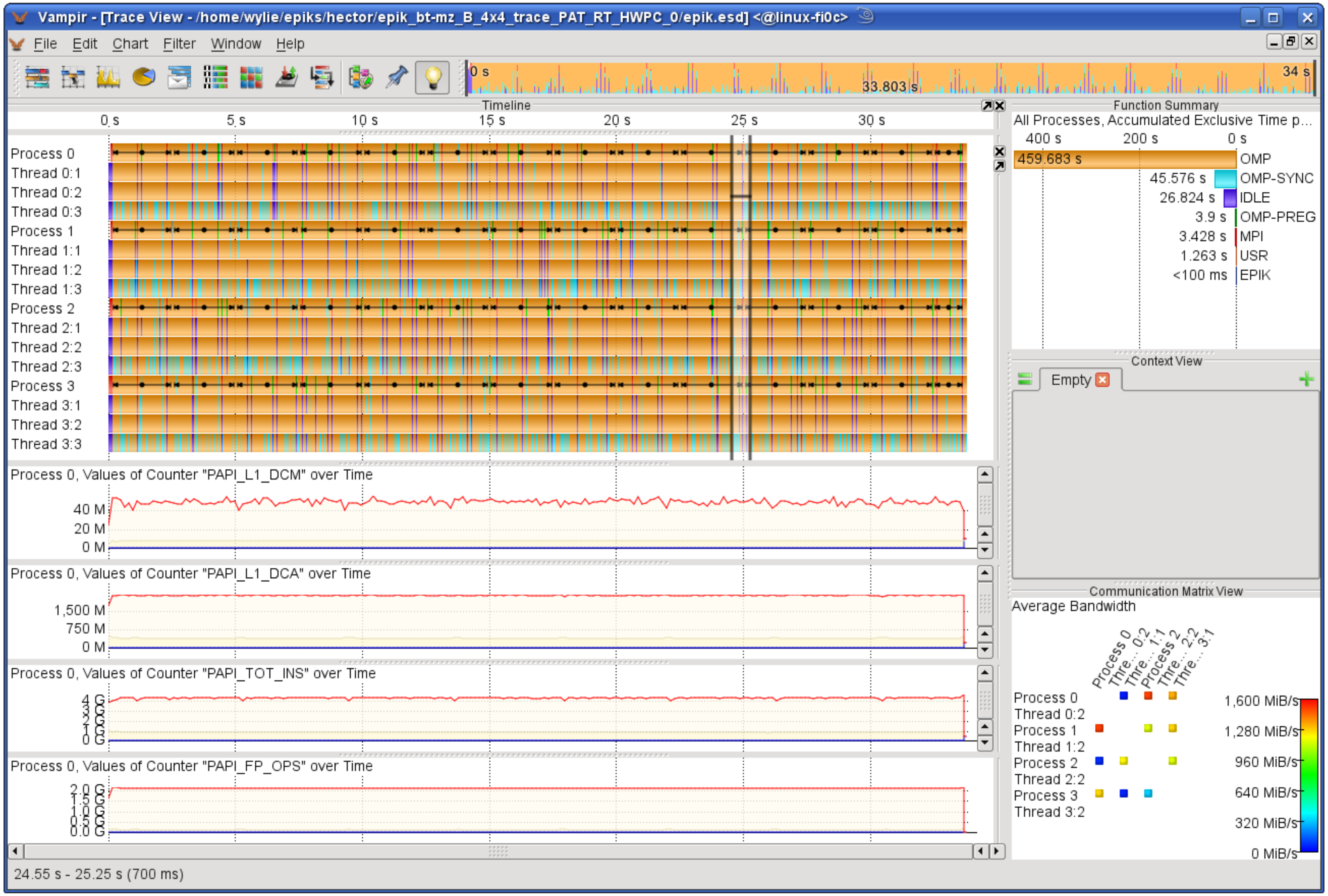
Vampir interactive trace analysis GUI


Vampir - [Trace View - /home/dolescha/tracefiles/feature-traces/wrf-p64-io-mem-rusage/wrf.1h.otf]
File View Help
View Chart Filter
Timeline
0 s 5 s 10 s 15 s 20 s 25 s 30 s 35 s 40 s
Process 8
Process 25
Process 42
Process 59
Process 0
1
2
3
4
5
6
Process 0, Values of Counter "MEM_APP_ALLOC" over Time
50 M
0 M
Function Summary
All Processes, Accumulated Exclusive Time p...
500 s 0 s
Communication Matrix View
Number of Messages
1.76
Function Legend
Application
DYN
I/O
IO
MEM
MPI
PHYS
VT_API
WRF
Process Summary
0 s
0 s 10 s 20 s 30 s
9
43
3
9
MP...st s..._ m..._ M...t
MPI...ast s..._ m..._ M...t
MPI_Bcast s..._ MP...it
MPI...ast s..._ m..._ MPI...ait
Context View
Function Summary

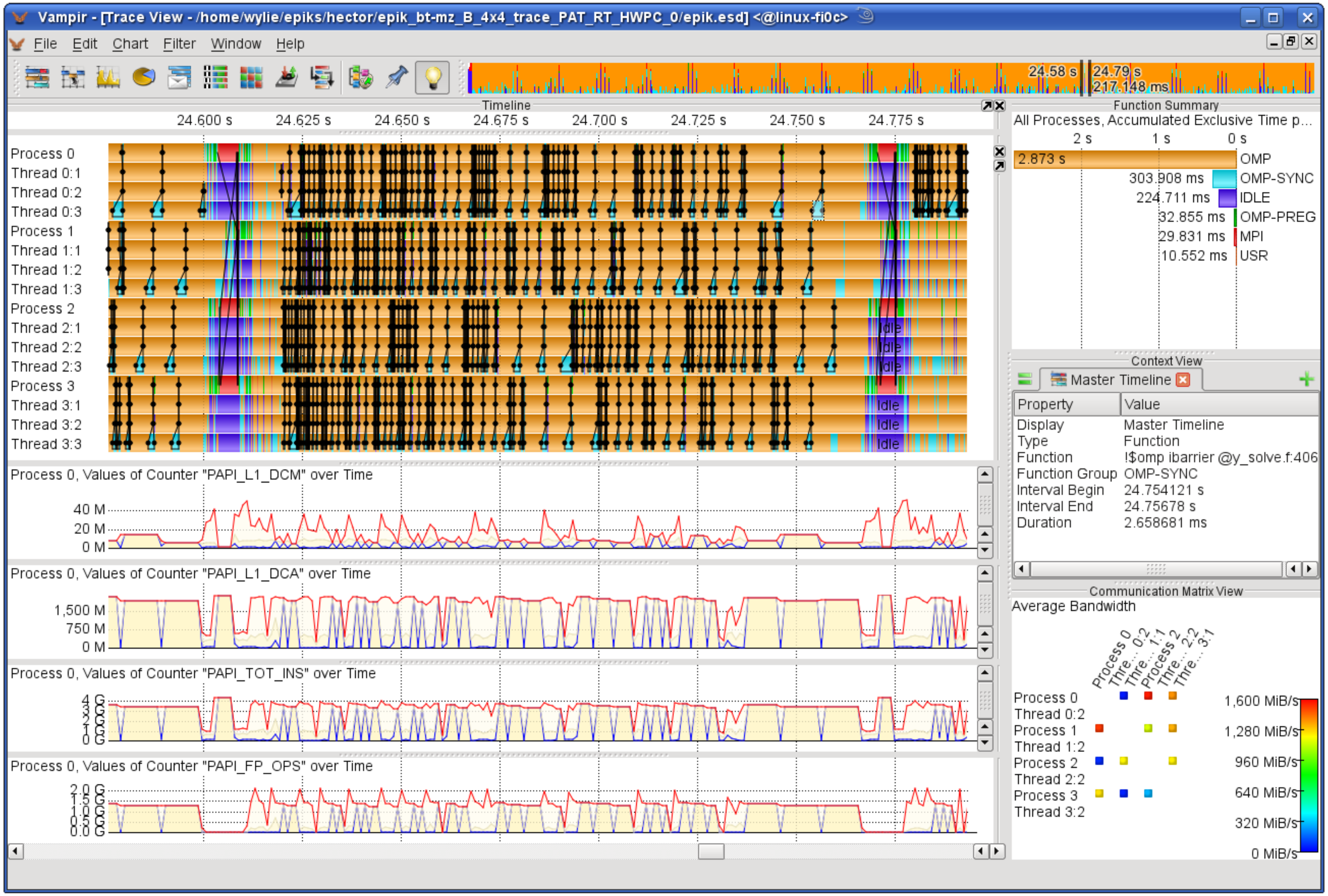
Function	Accumulated Exclusive Time
DYN	939.281737 s
MPI	748.945947 s
PHYS	514.137968 s
WRF	242.95072 s
I/O	112.424503 s
IO	3.467969 s
Appl...tion	2.165661 s
VT_API	1.391392 s

Property	Value
Display	Function Summary
Function Group	MPI (6)
Accumulated Exclusive Time	748.945947 s (29.198329%)

Vampir interactive trace analysis GUI



Vampir interactive trace analysis GUI (zoom)

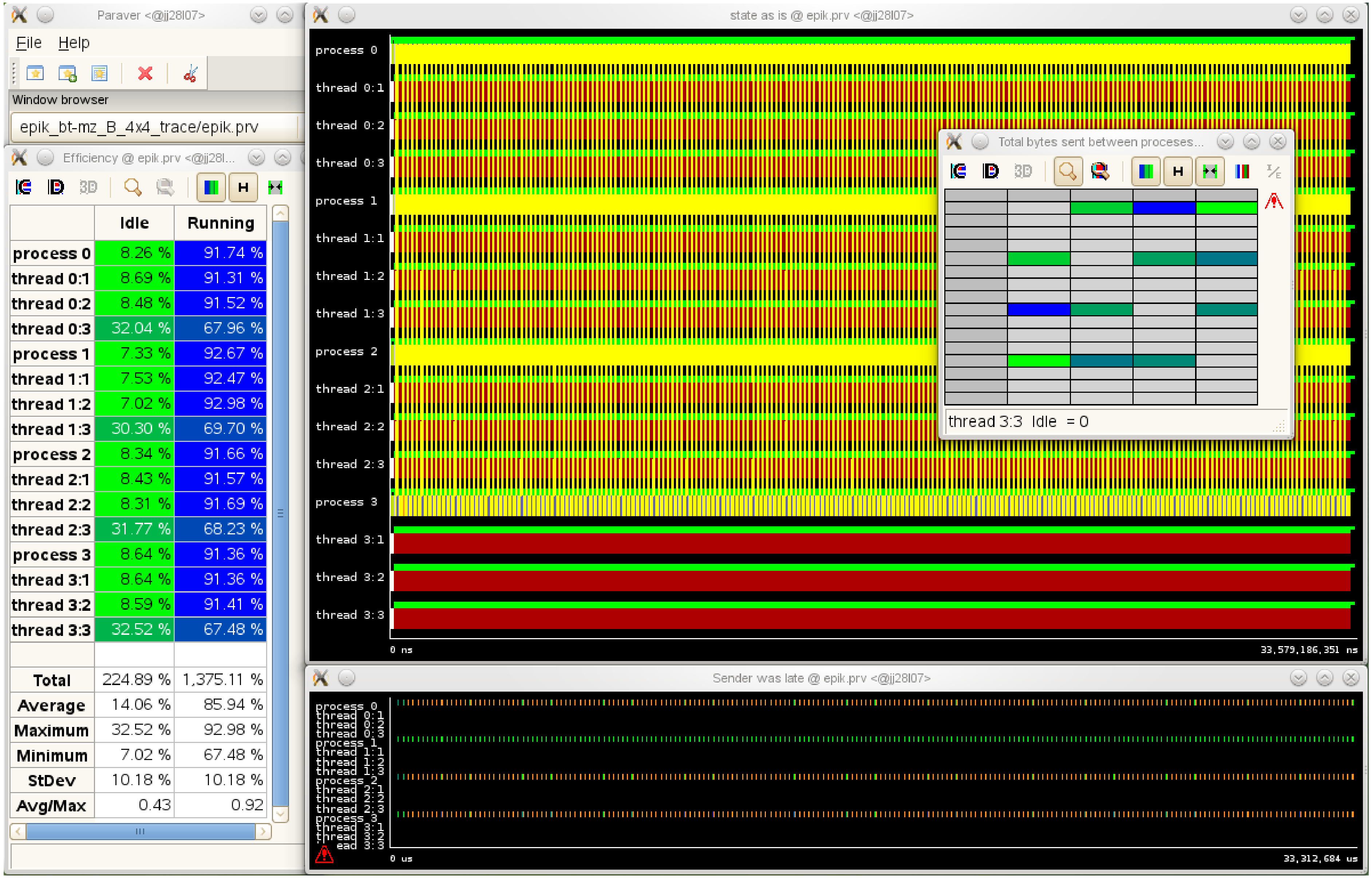


Property	Value
Display	Master Timeline
Type	Function
Function	!$omp ibarrier @y_solve.f:406
Function Group	OMP-SYNC
Interval Begin	24.754121 s
Interval End	24.75678 s
Duration	2.658681 ms

Paraver & Extrae

- Interactive event trace analysis
  - Visual presentation of dynamic runtime behaviour
    - event timeline chart for states & interactions of processes
    - Interactive browsing, zooming, selecting
  - Large variety of highly configurable analyses & displays
- Developed by Barcelona Supercomputing Center
  - Paraver trace analyser and Extrae measurement library
  - Open source available from http://www.bsc.es/paraver/

Paraver interactive trace analysis GUI


Paraver <@jj28l07>
File Help
Window browser
epik_bt-mz_B_4x4_trace/epik.prv
Efficiency @ epik.prv <@jj28l...
state as is @ epik.prv <@jj28l07>
Total bytes sent between proceses...
thread 3:3 Idle = 0
Sender was late @ epik.prv <@jj28l07>
0 ns
33,579,186,351 ns
0 us
33,312,684 us

	Idle	Running
process 0	8.26 %	91.74 %
thread 0:1	8.69 %	91.31 %
thread 0:2	8.48 %	91.52 %
thread 0:3	32.04 %	67.96 %
process 1	7.33 %	92.67 %
thread 1:1	7.53 %	92.47 %
thread 1:2	7.02 %	92.98 %
thread 1:3	30.30 %	69.70 %
process 2	8.34 %	91.66 %
thread 2:1	8.43 %	91.57 %
thread 2:2	8.31 %	91.69 %
thread 2:3	31.77 %	68.23 %
process 3	8.64 %	91.36 %
thread 3:1	8.64 %	91.36 %
thread 3:2	8.59 %	91.41 %
thread 3:3	32.52 %	67.48 %
Total	224.89 %	1,375.11 %
Average	14.06 %	85.94 %
Maximum	32.52 %	92.98 %
Minimum	7.02 %	67.48 %
StDev	10.18 %	10.18 %
Avg/Max	0.43	0.92

MAQAO

- Modular Assembler Quality Analyzer & Optimizer
  - Framework for binary manipulation
    - using plugins and scripting language
  - Tool exploiting framework to produce reports
    - fast prototyping and batch interface
  - STAN static performance model
  - MIL instrumentation language for dynamic analysis
    - building custom performance evaluation tools using HWCs
    - instrumentation of functions, loops, blocks & instructions
- Developed by UVSQ Exascale Computing Research lab
  - Supports Intel x86_64 microarchitecture
  - Available from www.maqao.org

VI-HPS component technologies

- Key tool components also provided as open-source
  - Program development environment
    - Eclipse PTP ETFw, UNITE
  - Program/library instrumentation
    - COBI, OPARI, PDToolkit
  - Runtime measurement systems
    - PnMPI, Score-P, UniMCI
  - Scalable I/O
    - SIONlib
  - Libraries & tools for handling (and converting) traces
    - EPILOG, OTF, PEARL
  - Analysis algebra & hierarchical/topological presentation
    - CUBE

Score-P

- Scalable performance measurement infrastructure
  - Supports instrumentation, profiling & trace collection, as well as online analysis of HPC parallel applications
  - Works with Periscope, Scalasca, TAU & Vampir prototypes
  - Based on updated tool components
    - CUBE4 profile data utilities & GUI
    - OA online access interface to performance measurements
    - OPARI2 OpenMP & pragma instrumenter
    - OTF2 open trace format
- Created by German BMBF SILC & US DOE PRIMA projects
  - JSC, RWTH, TUD, TUM, GNS, GRS, GWT & UO PRL
  - Available as BSD open-source from http://www.score-p.org/

SIONlib

- Portable native parallel I/O library & utilities
  - Scalable massively-parallel I/O to task-local files
  - Manages single or multiple physical files on disk
    - optimizes bandwidth available from I/O servers by matching blocksizes/alignment, reduces metadata-server contention
  - POSIX-I/O-compatible sequential & parallel API
    - adoption requires minimal source-code changes
  - Tuned for common parallel filesystems
    - GPFS (BlueGene), Lustre (Cray), ...
  - Convenient for application I/O, checkpointing,
    - Used by Scalasca tracing (when configured)
- Developed by JSC
  - Available as open-source from
  - http://www.fz-juelich.de/jsc/sionlib/

UNITE

- Uniform integrated tool environment
  - Manages installation & access to program development tools
    - based on software environment management “modules”
    - commonly used on most cluster and HPC systems
    - configurable for multiple MPI libraries & compiler suites
  - Specifies how & where tools packages get installed
    - including integrating tools where possible
  - Defines standard module names and different versions
  - Supplies pre-defined module files
  - Configurable to co-exist with local installations & policies
- Developed by JSC, RWTH & TUD
  - Available as open-source from http://www.vi-hps.org/projects/unite/