TECHNISCHE UNIVERSITÄT DRESDEN

Performance Analysis with Vampir

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Center for Information Services & High Performance Computing

Disclaimer

Performance tools will not automatically make you code run faster. They help you understand, what your code does and where to put in work.

Agenda

Welcome to the Vampir Tool Suite

- Parallel Performance Analysis Approaches
- Mission
- Event Trace Visualization

The Vampir Workflow

- Score-P: Instrumentation & Run-Time Measurement
- Vampir & VampirServer

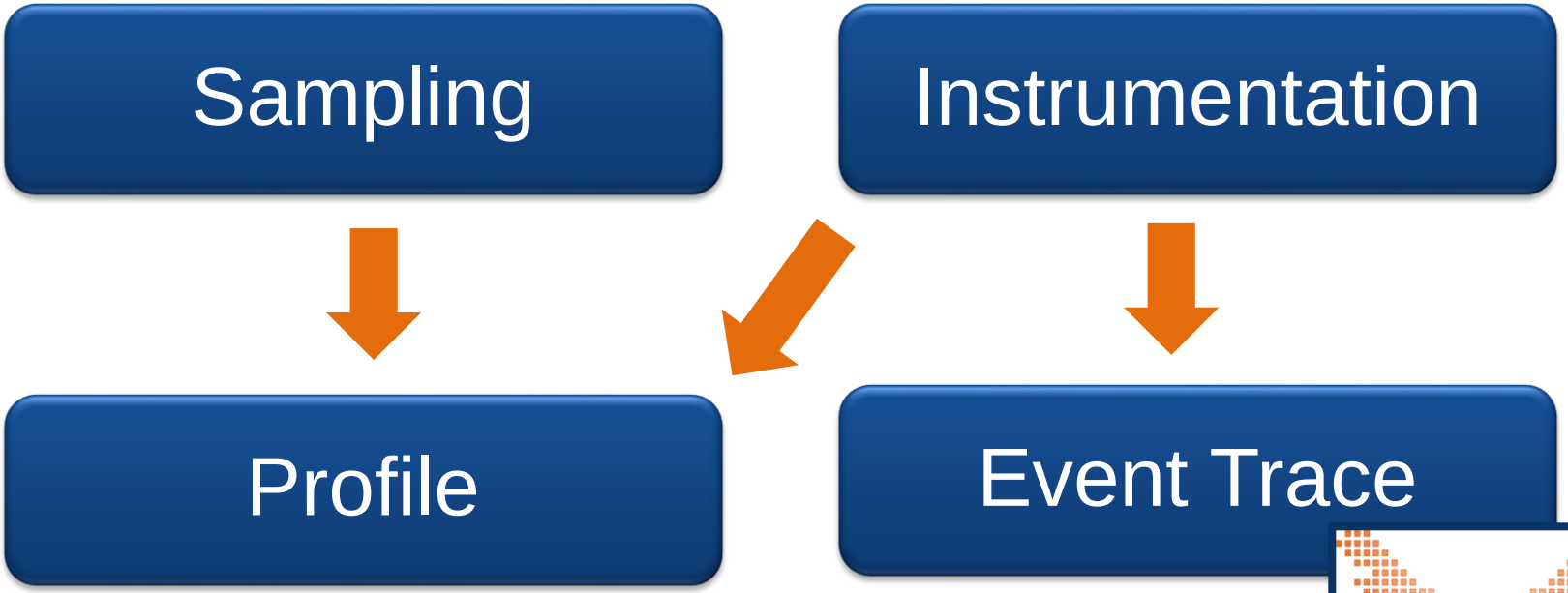
Vampir Performance Charts

Vampir Demo

- Tracing and Visualizing NPB-MZ-MPI / BT

Conclusions

Parallel Performance Analysis Approaches

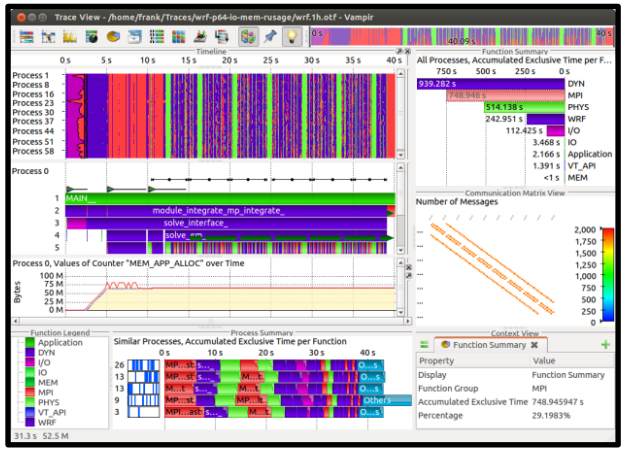


Concise data sets
Good overview
Limited detail
No outliers

Extensive data sets
Most detailed

Mission

- Visualization of dynamics of complex parallel processes
- Requires two components
  - Monitor/Collector (Score-P)
  - Charts/Browser (Vampir)



Typical questions that Vampir helps to answer:

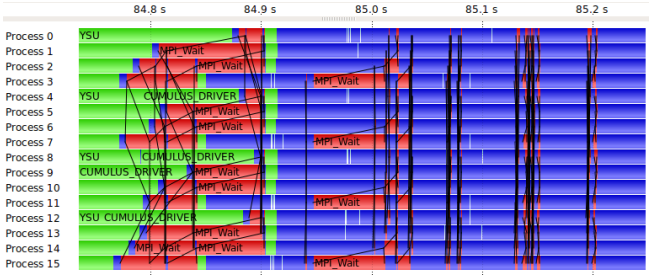
- What happens in my application execution during a given time in a given process or thread?
- How do the communication patterns of my application execute on a real system?
- Are there any imbalances in computation, I/O or memory usage and how do they affect the parallel execution of my application?

Event Trace Visualization with Vampir

- Show dynamic run-time behavior graphically at any level of detail
- Provide statistics and performance metrics

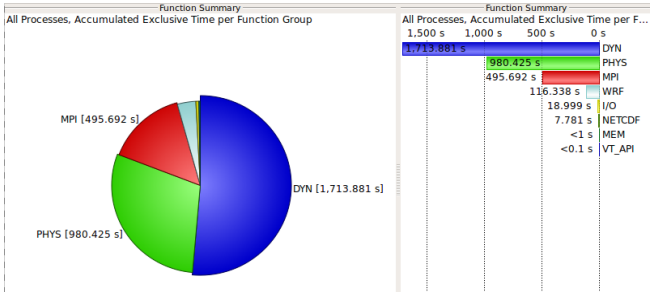
Timeline charts

– Show application activities and communication along a time axis



Summary charts

– Provide quantitative results for the currently selected time interval



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Vampir Hands-on

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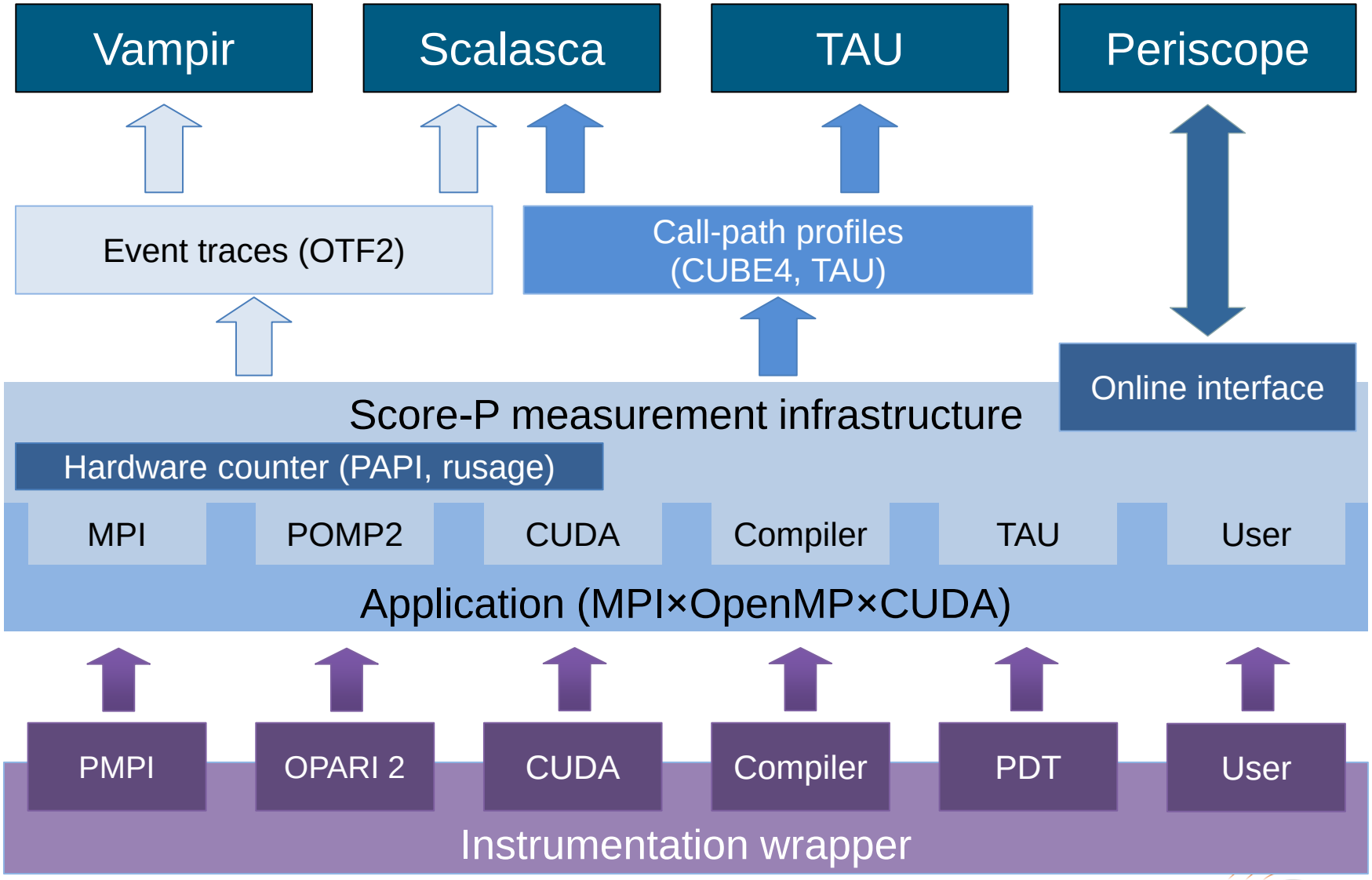
Score-P: Instrumentation & Run-Time Measurement

- Scalable Performance Measurement Infrastructure for Parallel Codes
- Supports a number of analysis tools
  - Periscope, Tau, Scalasca, Vampir
- Comes together with:
  - New Open Trace Format Version 2
  - CUBE4 profiling format
  - Opari2 instrumentor
- New BSD Open Source license

Score-P: Functionality

- Provide typical functionality for HPC performance tools
- Instrumentation (various methods)
  - Score-P compiler wrapper
- Flexible measurement without re-compilation:
  - Basic and advanced profile generation
  - Event trace recording
  - Online access to profiling data
- MPI, OpenMP, CUDA, and hybrid parallelism (and serial)

Score-P: Architecture



Score-P: Measurement Options

- Measurements are configured via environment variables:

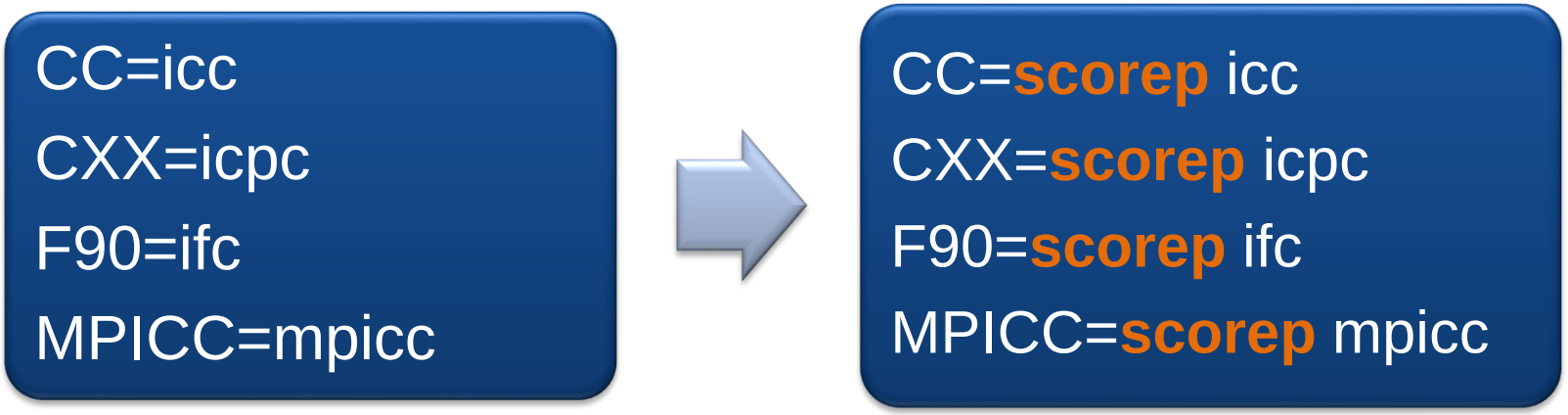
```
% scorep-info config-vars --full

SCOREP_ENABLE_PROFILING
  [...]
SCOREP_ENABLE_TRACING
  [...]
SCOREP_TOTAL_MEMORY
  Description: Total memory in bytes for the measurement system
  [...]
SCOREP_EXPERIMENT_DIRECTORY
  Description: Name of the experiment directory
  [...]
SCOREP_FILTERING_FILE
  Description: A file name which contain the filter rules
  [...]
SCOREP_METRIC_PAPI
  Description: PAPI metric names to measure
  [...]
SCOREP_METRIC_RUSAGE
  Description: Resource usage metric names to measure
```

- Profiles can be analyzed with **scorep-score**
  - Helps to define appropriate filters for a tracing run

Vampir Tool Suite Workflow

1. Instrument your application with Score-P

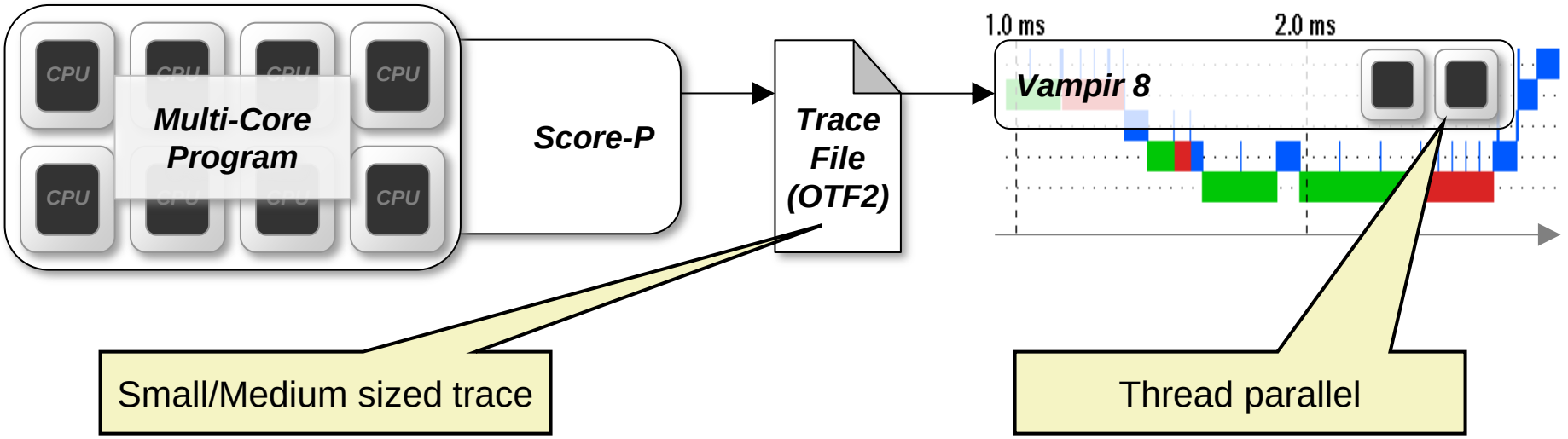


2. Perform a measurement run with **profiling enabled**
3. Use **scorep-score** to define an appropriate filter
4. Perform a measurement run with **tracing enabled** and the filter applied
5. Perform in-depth analysis on the trace data with **Vampir**

Vampir – Visualization Modes (1)

Directly on front end or local machine

```
% vampir
```

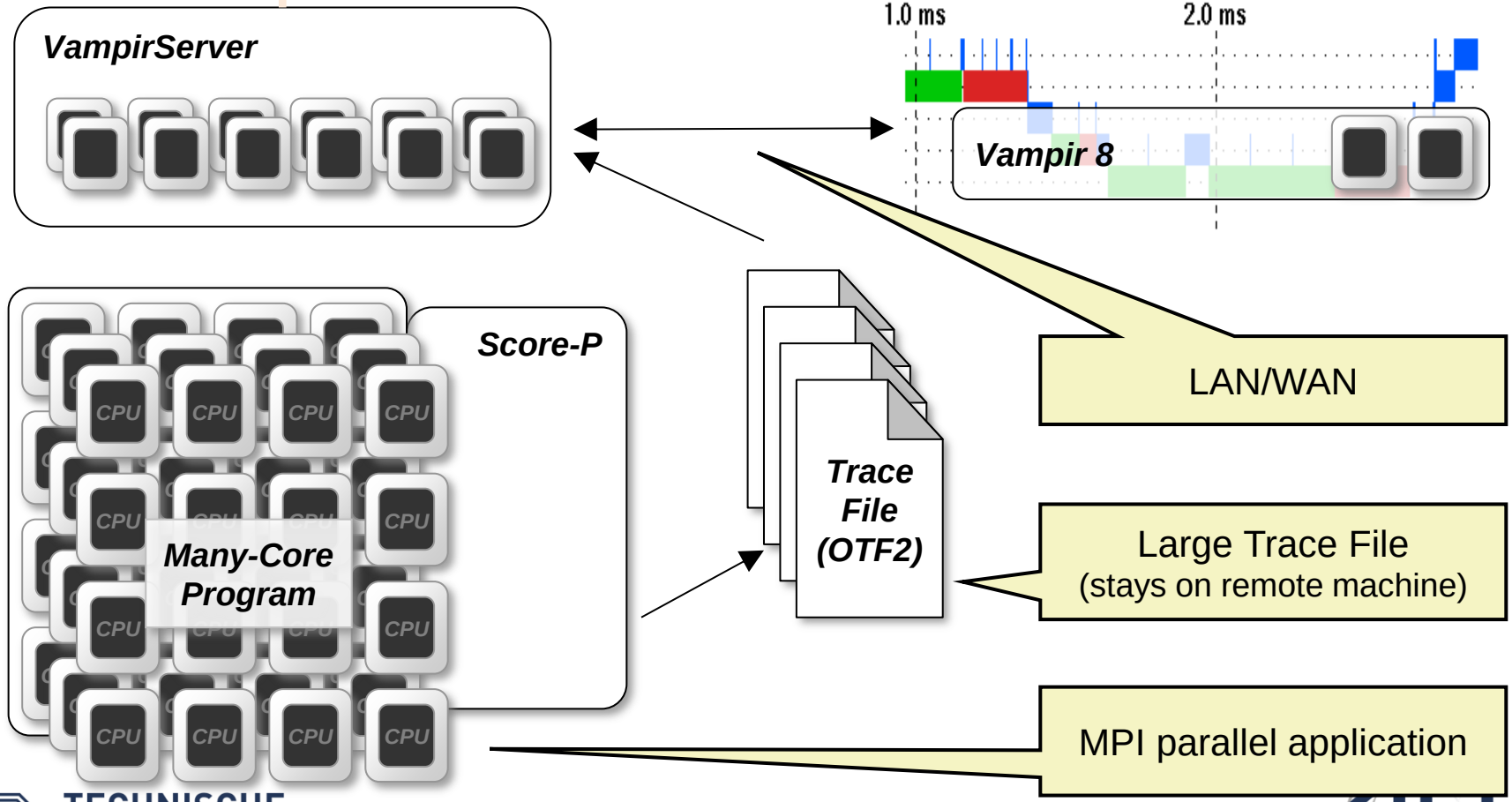


Vampir – Visualization Modes (2)

On local machine with remote VampirServer

```
% vampirserver start -n 12
```

```
% vampir
```



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Main Charts of Vampir

Timeline Charts:

 Master Timeline

 Process Timeline

 Counter Data Timeline

 Performance Radar

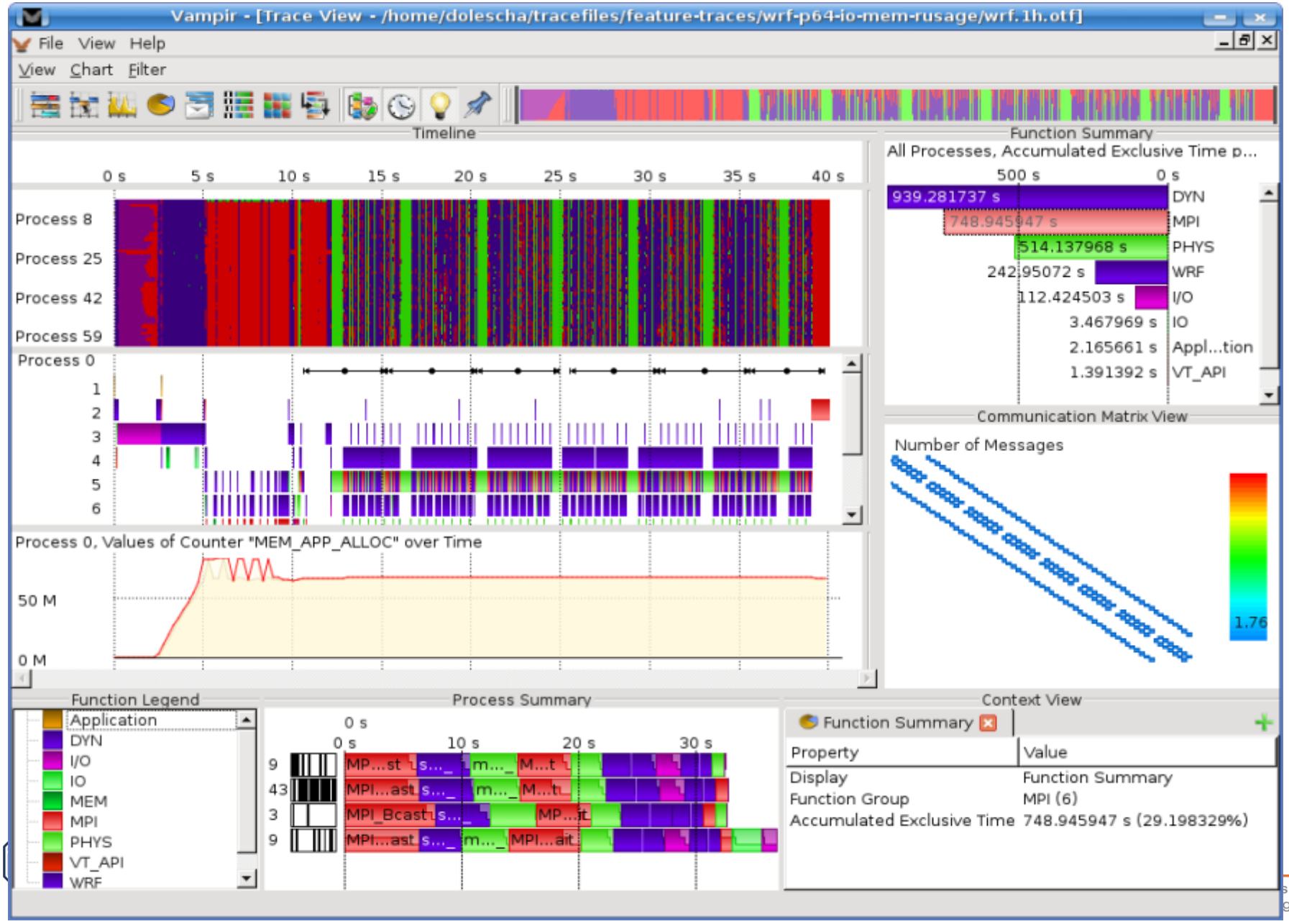
Summary Charts:

 Function Summary

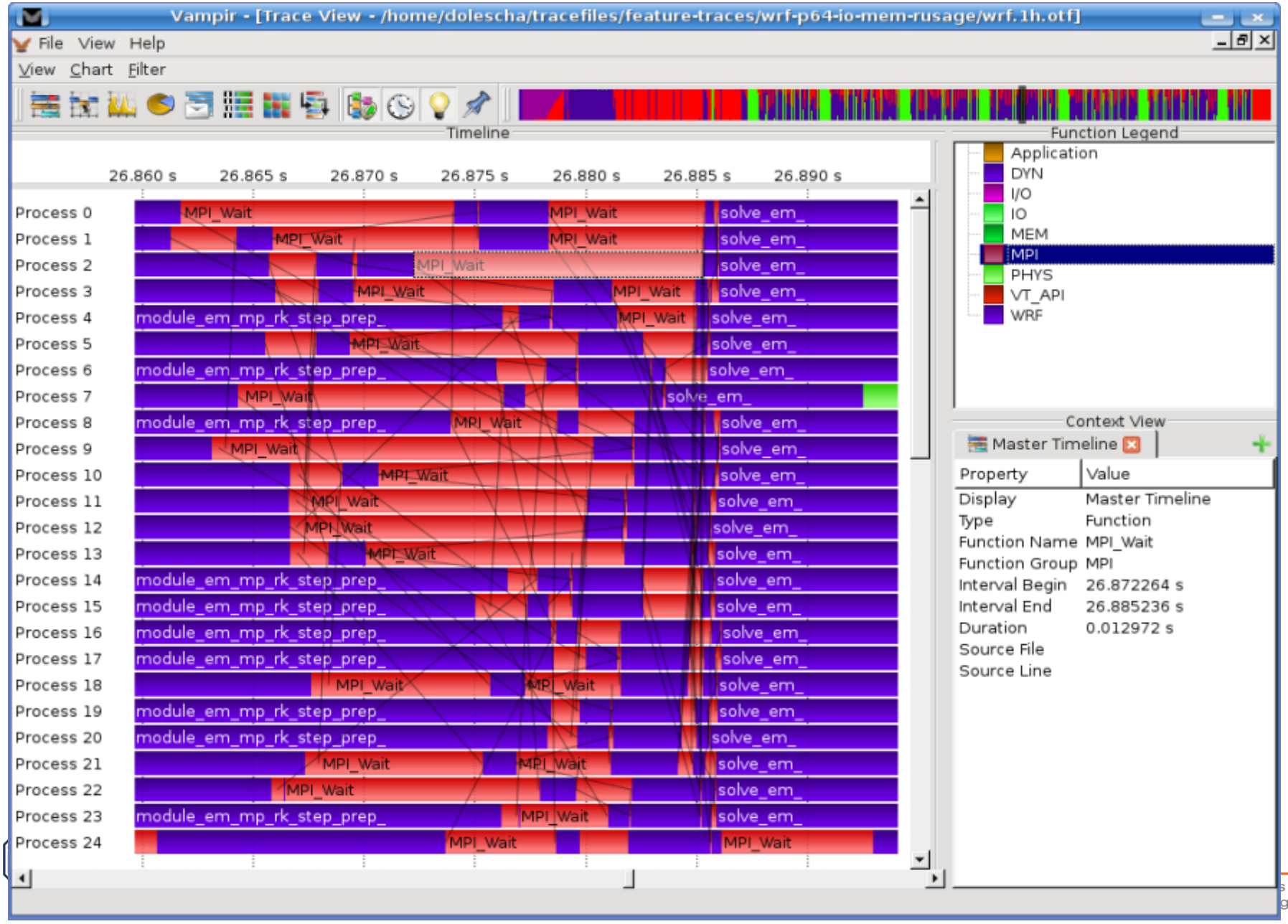
 Process Summary

 Communication Matrix View

Vampir: Charts for a WRF Trace with 64 Processes

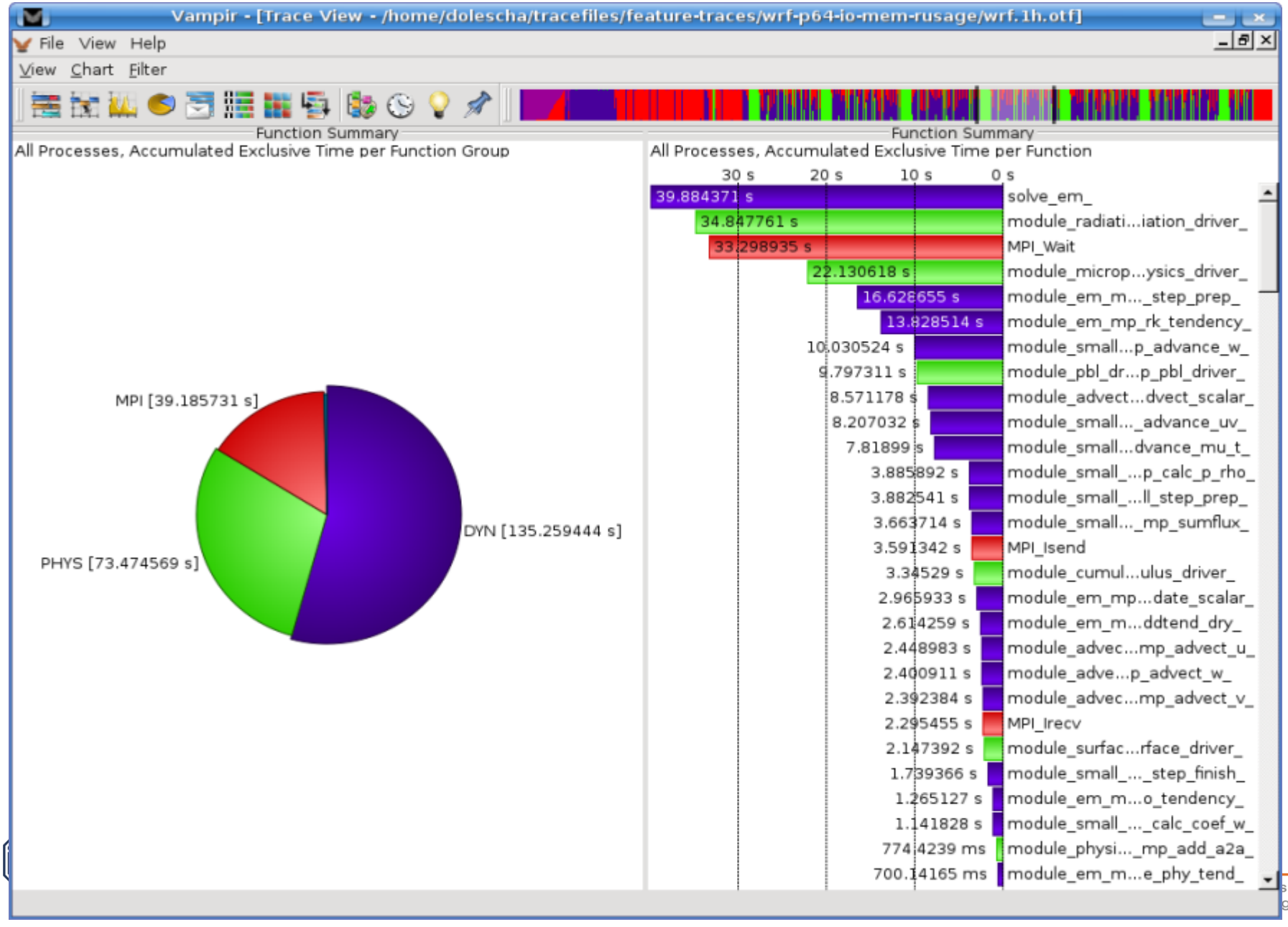


Master Timeline

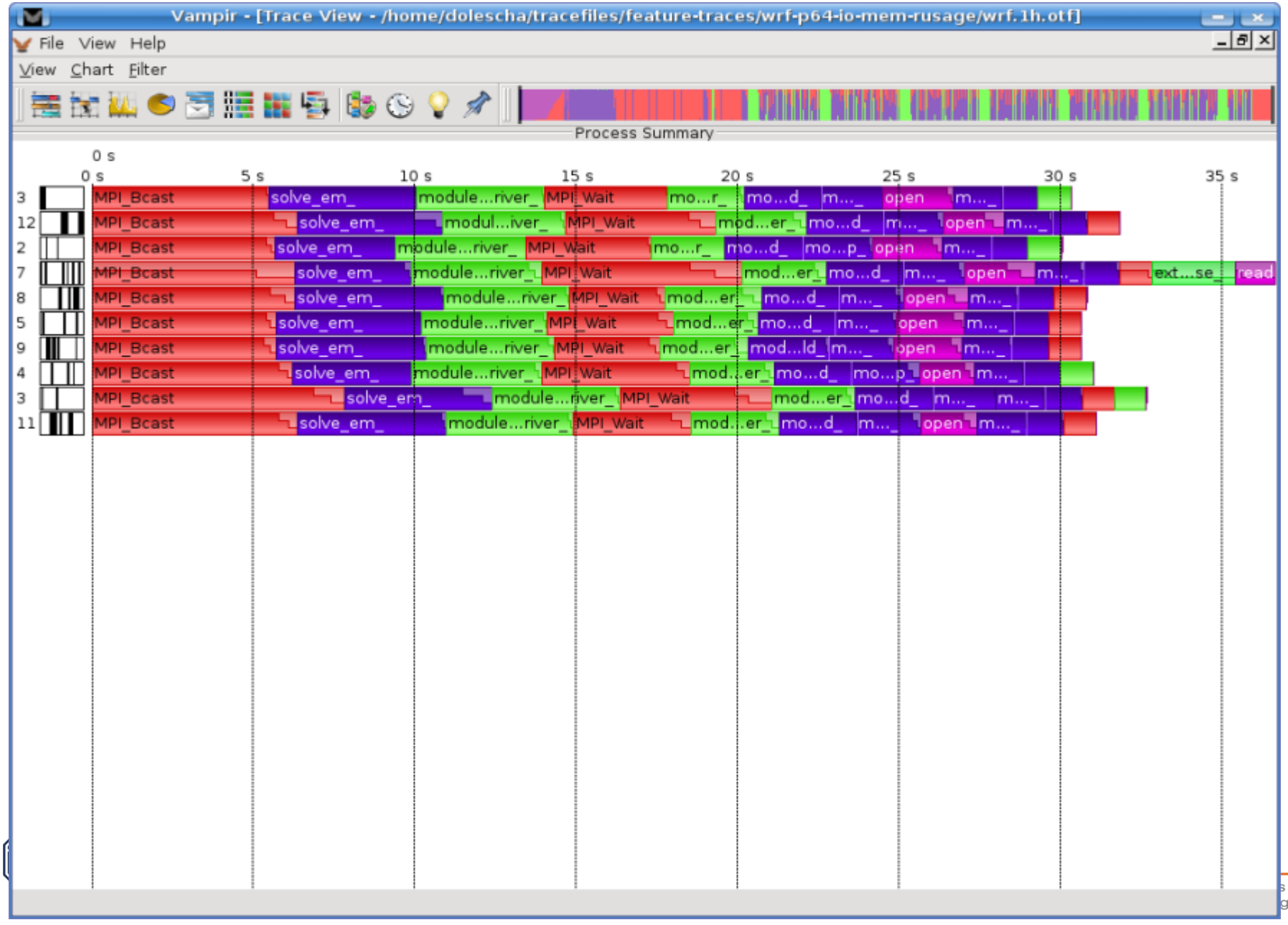


Process and Counter Timeline

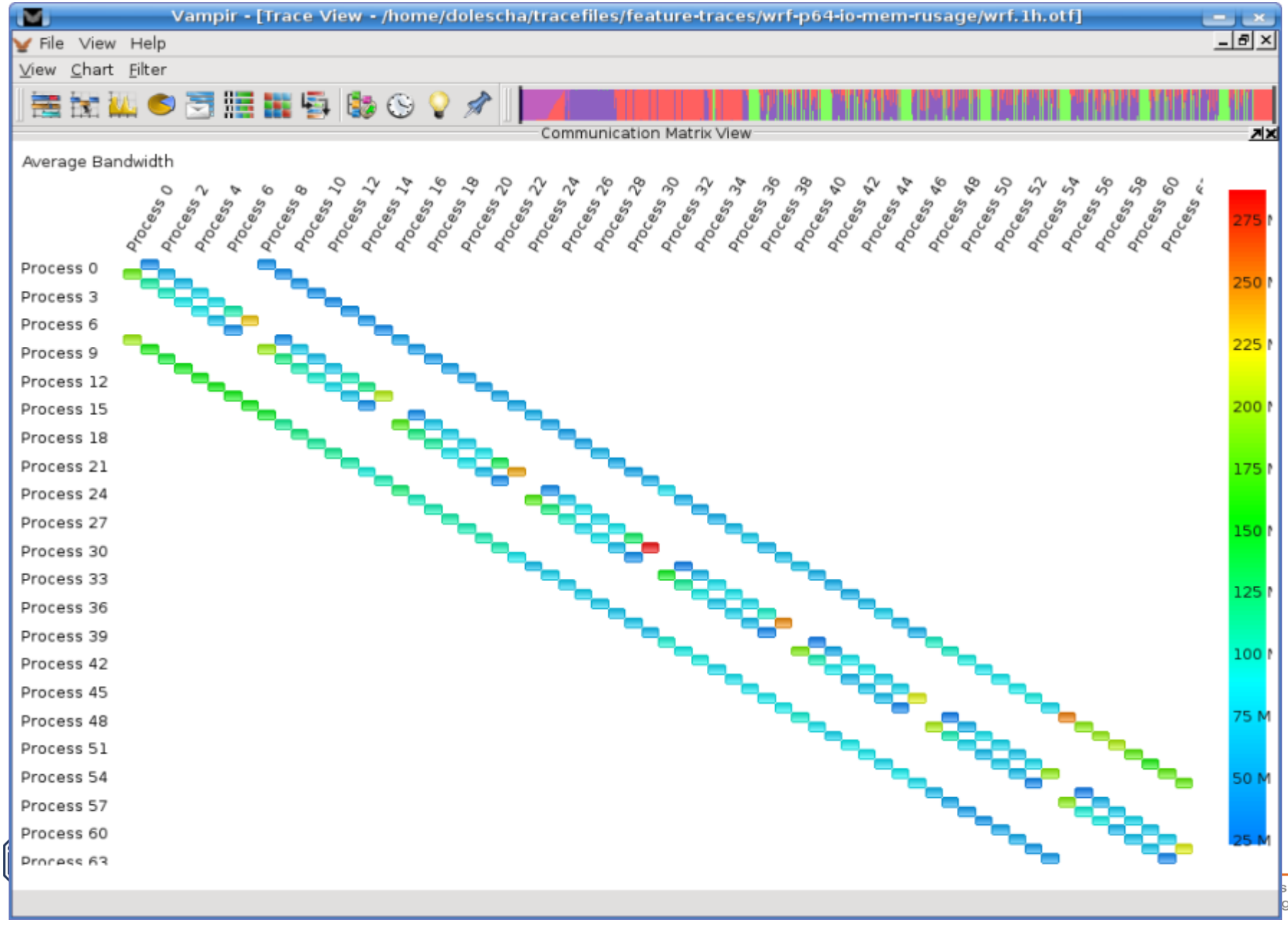
Function Summary



Process Summary



Communication Matrix



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Vampir Demo: NPB-MZ-MPI / BT

- The NAS Parallel Benchmark suite (MPI+OpenMP version)
  - Available from: http://www.nas.nasa.gov/Software/NPB
  - 3 benchmarks in Fortran77 (bt-mz, lu-mz, sp-mz)
  - Configurable for various sizes & classes (S, W, A, B, C, D, E)
- Benchmark configuration for demo:
  - Benchmark name: **bt-mz**
  - Number of MPI processes: **NPROCS=4**
  - Benchmark class: **CLASS=W**
  - What does it do?
    - Solves a discretized version of unsteady, compressible Navier-Stokes equations in three spatial dimensions
    - Performs 200 time-steps on a regular 3-dimensional grid

NPB-MZ-MPI / BT Build

- Connect to Mira and add Vampir to the SoftEnv system

```
% vi .soft
  +vampir
% resoft
```

- Copy sources to working directory

```
% cp /projects/Tools/vampir/tutorial/NPB3.3-MZ-MPI.tar.gz .
% tar xzvf NPB3.3-MZ-MPI.tar.gz
% cd NPB3.3-MZ-MPI
```

- Compile the benchmark:

```
% make bt-mz CLASS=W NPROCS=4
cd BT-MZ; make CLASS=W NPROCS=4 VERSION=
make: Entering directory 'BT-MZ'
cd ../sys; cc  -o setparams setparams.c
../sys/setparams bt-mz 4 W
mpixlf77_r -c  -O3 -qsmp=omp -qextname=flush bt.f
 [...]
Built executable ../bin/bt-mz_W.4
make: Leaving directory 'BT-MZ'
```

NPB-MZ-MPI / BT Reference Execution

- Copy jobscript and launch as a hybrid MPI+OpenMP application

```
% cd bin
% cp ../jobscript/mira/run.sh .
% less run.sh
  export OMP_NUM_THREADS=4
  runjob -n 4 -p 4 --block $COBALT_PARTNAME --env-all : bt-mz_W.4
% qsub -A <projid> -t 10 -n 1 --mode script run.sh
% cat <jobid>.outpout
  NAS Parallel Benchmarks (NPB3.3-MZ-MPI) - BT-MZ MPI+OpenMP Benchmark
  Number of zones:   4 x   4
  Iterations:  200   dt:   0.000800
  Number of active processes:     4
  Total number of threads:     16   (  4.0 threads/process)

  Time step    1
  Time step   20
   [...]
  Time step  200
  Verification Successful

  BT-MZ Benchmark Completed.
  Time in seconds = 2.27
```

Hint: save the benchmark output (or note the run time) to be able to refer to it later

NPB-MZ-MPI / BT Instrumentation

Edit config/make.def to adjust build configuration

- Modify specification of compiler/linker: MPIF77

```
#            SITE- AND/OR PLATFORM-SPECIFIC DEFINITIONS
#---------------------------------------------------------------------
# Items in this file may need to be changed for each platform.
#---------------------------------------------------------------------
...
#---------------------------------------------------------------------
# The Fortran compiler used for MPI programs
#---------------------------------------------------------------------
#MPIF77 = mpixlf77_r

# Alternative variants to perform instrumentation
...
MPIF77 = scorep mpixlf77_r

# This links MPI Fortran programs; usually the same as ${MPIF77}
FLINK   = $(MPIF77)
...
```

Uncomment the Score-P compiler wrapper specification

NPB-MZ-MPI / BT Instrumented Build

- Return to root directory and clean-up

```
% make clean
```

- Re-build executable using Score-P compiler wrapper

```
% make bt-mz CLASS=W NPROCS=4
cd BT-MZ; make CLASS=W NPROCS=4 VERSION=
make: Entering directory 'BT-MZ'
cd ../sys; cc  -o setparams setparams.c
../sys/setparams bt-mz 4 W
scorep mpixlf77_r -c  -O3 -qsmp=omp -qextname=flush bt.f
 [...]
cd ../common; scorep mpixlf77_r -c -O3 -qsmp=omp -qextname=flush timers.f
scorep mpixlf77_r -O3 -qsmp=omp -qextname=flush -o ../bin.scorep/bt-mz_W.4
bt.o initialize.o exact_solution.o exact_rhs.o set_constants.o \
adi.o rhs.o zone_setup.o x_solve.o y_solve.o exch_qbc.o \
solve_subs.o z_solve.o add.o error.o verify.o mpi_setup.o \
../common/print_results.o ../common/timers.o
Built executable ../bin.scorep/bt-mz_W.4
make: Leaving directory 'BT-MZ'
```

NPB-MZ-MPI / BT Summary Measurement Collection

- Change to the directory containing the new executable before running it and adjust configuration

```
% cd bin.scorep
% cp ../jobscript/mira/* .
% less run_profile.sh
  export SCOREP_ENABLE_TRACING=false
  export SCOREP_ENABLE_PROFLING=true
  export SCOREP_TOTAL_MEMORY=100M
  export SCOREP_EXPERIMENT_DIRECTORY=scorep_bt-mz_W_4x4_sum
  export OMP_NUM_THREADS=4
  runjob -n 4 -p 4 --block $COBALT_PARTNAME --env-all : bt-mz_W.4
% qsub -A <projid> -t 10 -n 1 --mode script run_profile.sh
% cat <jobid>.outpout
  NAS Parallel Benchmarks (NPB3.3-MZ-MPI) - BT-MZ MPI+OpenMP Benchmark
  Number of zones:   4 x   4
    [...]
  Time step  200
  Verification Successful

  BT-MZ Benchmark Completed.
  Time in seconds = 12.74
```

NPB-MZ-MPI / BT Summary Analysis Report Examination

- Creates experiment directory ./scorep_bt-mz_W_4x4_sum containing
  - A record of the measurement configuration (scorep.cfg)
  - The analysis report that was collated after measurement (profile.cubex)

```
% ls
...  scorep_bt-mz_W_4x4_sum
% ls scorep_bt-mz_W_4x4_sum
profile.cubex  scorep.cfg
```

NPB-MZ-MPI / BT Summary Analysis Result Scoring

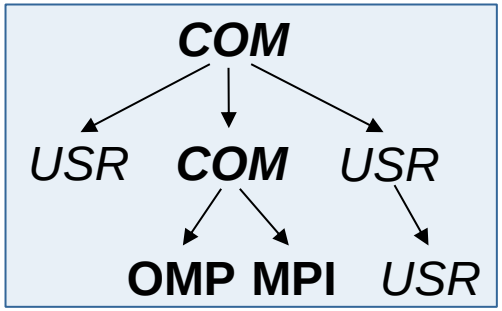
- Report scoring as textual output

```
% scorep-score scorep_bt-mz_W_4x4_sum/profile.cubex
Estimated aggregate size of event trace:                   909683062 bytes
Estimated requirements for largest trace buffer (max_tbc): 235123428 bytes
(hint: When tracing set SCOREP_TOTAL_MEMORY > max_tbc to avoid intermediate flushes
 or reduce requirements using file listing names of USR regions to be filtered.)

flt type         max_tbc         time      % region
     ALL       235123428       419.92  100.0 ALL
     USR       232516724        78.19   18.6 USR
     OMP         5973040       121.45   28.9 OMP
     COM          314710         1.38    0.3 COM
     MPI           88898       218.90   52.1 MPI
```

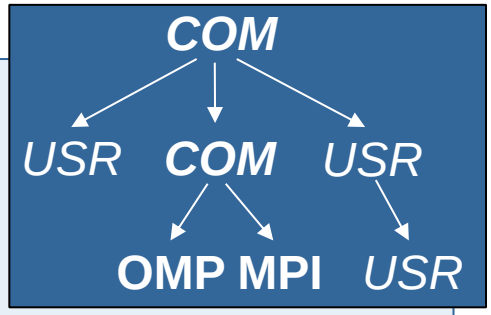
868 MB total memory
224 MB per rank!

- Region/callpath classification
  - MPI (pure MPI library functions)
  - OMP (pure OpenMP functions/regions)
  - USR (user-level source local computation)
  - COM (“combined” USR + OpenMP/MPI)
  - ANY/ALL (aggregate of all region types)



NPB-MZ-MPI / BT Summary Analysis Report Breakdown

- Score report breakdown by region



More than 223 MB just for these 6 regions

```
% scorep-score -r scorep_bt-mz_W_4x4_sum/profile.cubex
 [...]
flt type          max_tbc          time      % region
     ALL        25123428        419.92   100.0 ALL
     USR         2516724         78.19    18.6 USR
     OMP         5973040        121.45    28.9 OMP
     COM          314710          1.38     0.3 COM
     MPI           8898        218.90    52.1 MPI

     USR        72578286         18.80     4.5 matmul_sub
     USR        72578286         20.41     4.9 matvec_sub
     USR        72578286         33.47     8.0 binvcrhs
     USR         6747972          2.91     0.7 lhsinit
     USR         6747972          1.88     0.4 binvrhs
     USR         2939464          0.71     0.2 exact_solution
     OMP          369840          0.14     0.0 !$omp parallel @exch_qbc…
     OMP          369840          0.13     0.0 !$omp parallel @exch_qbc…
     OMP          369840          0.13     0.0 !$omp parallel @exch_qbc…
 [...]
```

NPB-MZ-MPI / BT Summary Analysis Report Filtering

- Report scoring with prospective filter listing 6 USR regions

```
% cat ../config/scorep.filt
SCOREP_REGION_NAMES_BEGIN EXCLUDE
binvcrhs*
matmul_sub*
matvec_sub*
exact_solution*
binvrhs*
lhs*init*
timer_*

% scorep-score -f ../config/scorep.filt scorep_bt-mz_W_4x4_sum/profile.cubex

Estimated aggregate size of event trace:                   20482398 bytes
Estimated requirements for largest trace buffer (max_tbc): 6377242 bytes
(hint: When tracing set SCOREP_TOTAL_MEMORY > max_tbc to avoid intermediat  flushes
 or reduce requirements using file listing names of USR regions to be filte   )
```

20 MB of memory in total,
6 MB per rank!

Advanced Measurement Configuration: Metrics

- Available PAPI metrics
  - Preset events: common set of events deemed relevant and useful for application performance tuning
    - Abstraction from specific hardware performance counters, mapping onto available events done by PAPI internally

```
% qsub -A <projid> -n 1 --mode c1 --proccount 1 -t 10 \
  /soft/perftools/papi/bin/papi_avail
% cat <jobid>.outpout
```

  - Native events: set of all events that are available on the CPU (**platform dependent**)

```
% qsub -A <projid> -n 1 --mode c1 --proccount 1 -t 10 \
  /soft/perftools/papi/bin/papi_native_avail
% cat <jobid>.outpout
```

Note:
Due to hardware restrictions
- number of concurrently recorded events is limited
- there may be invalid combinations of concurrently recorded events

NPB-MZ-MPI / BT Trace Measurement Collection...

- Re-run the application using the tracing mode of Score-P

```
% cd bin.scorep
% less run_trace.sh
  export SCOREP_ENABLE_TRACING=true
  export SCOREP_ENABLE_PROFLING=false
  export SCOREP_FILTERING_FILE=../config/scorep.filt
  export SCOREP_TOTAL_MEMORY=100M
  export SCOREP_EXPERIMENT_DIRECTORY=scorep_bt-mz_W_4x4_trace
  export SCOREP_METRIC_PAPI=PAPI_FP_OPS,PAPI_L1_DCM
  export OMP_NUM_THREADS=4
  runjob -n 4 -p 4 --block $COBALT_PARTNAME --env-all : bt-mz_W.4
% qsub -A <projid> -t 10 -n 1 --mode script run_trace.sh
% cat <jobid>.outpout
  NAS Parallel Benchmarks (NPB3.3-MZ-MPI) - BT-MZ MPI+OpenMP Benchmark
  Number of zones:   4 x   4
    [...]
  Time step  200
  Verification Successful

  BT-MZ Benchmark Completed.
  Time in seconds = 3.49
```

NPB-MZ-MPI / BT Interactive Trace Analysis with Vampir

- Download and install VampirClient for target platform

```
# Linux 64bit
$ scp <user>@mira.alcf.anl.gov:/projects/Tools/vampir/vampir-gui/vampir-*-x86_64.bin .
$ scp <user>@mira.alcf.anl.gov:/projects/Tools/vampir/vampir-gui/vampir-remote.license .
$ bash ./vampir-*.bin
```

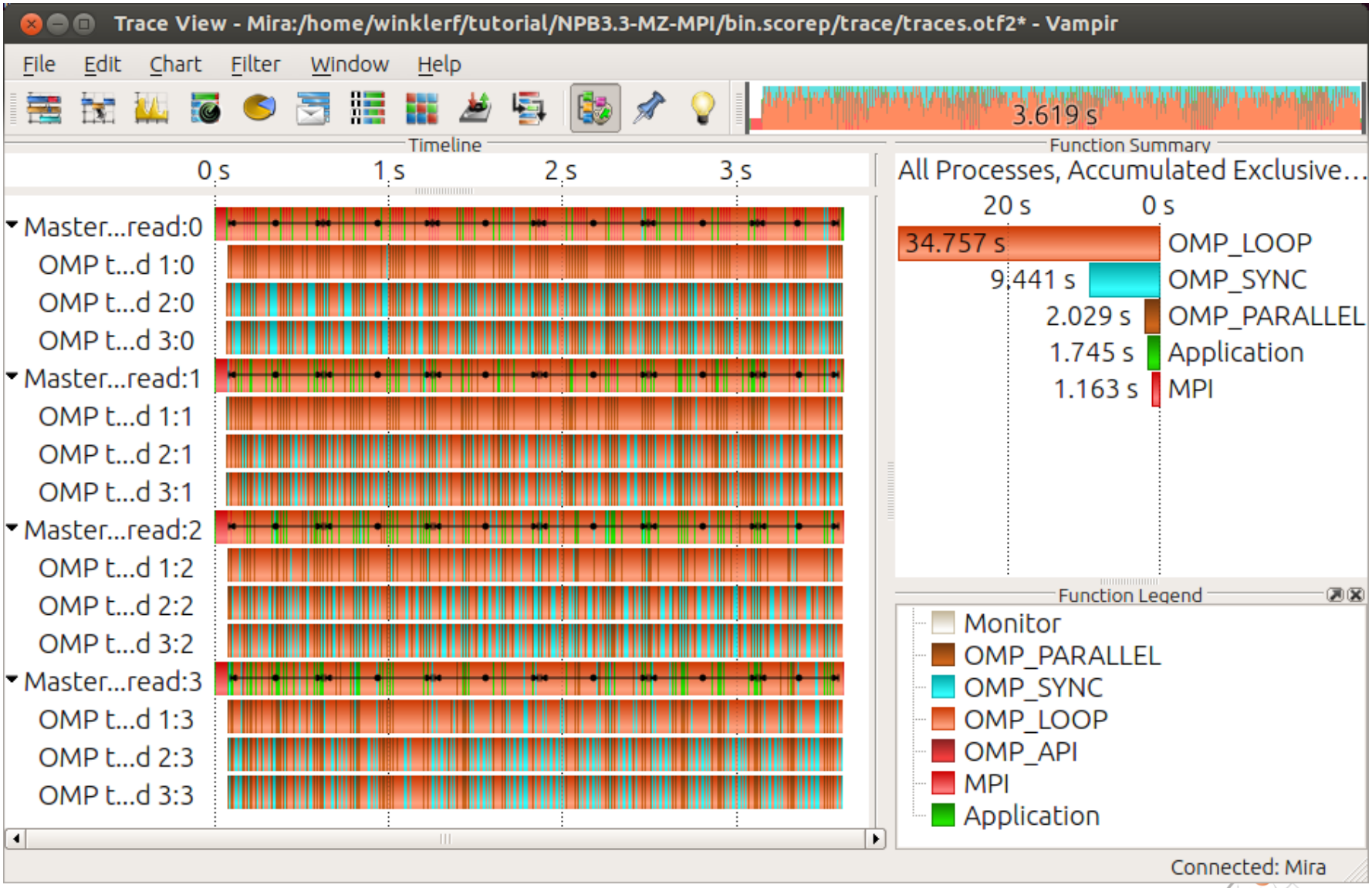
- Start VampirServer and follow output instructions

```
$ vampirserver start -a <projid> -n 16
Launching VampirServer...
Submitting PBS batch job (this might take a while)...
** Project 'tools'; job rerouted to queue 'prod-short'
VampirServer 8.2.1  (r8876)
Licensed to Mira Performance Boot Camp 2014
Running 15 analysis processes... (abort with vampirserver stop 28448)
VampirServer <28448> listens on: Q2G-I5-J01.mira.i2b:30066

Please run:
    ssh -L 30001:Q2G-I5-J01.mira.i2b:30066 <user>@mira.alcf.anl.gov
on your desktop to create ssh tunnel to VampirServer.

Start vampir on your desktop and choose 'Open Other -> Remote File'
    Description: mira,   Server: localhost,   Port: 30001
    Authentication: None
    Connection type: Socket
    Ignore "More Options"
```

NPB-MZ-MPI / BT Trace Analysis with Vampir



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- **Conclusions**

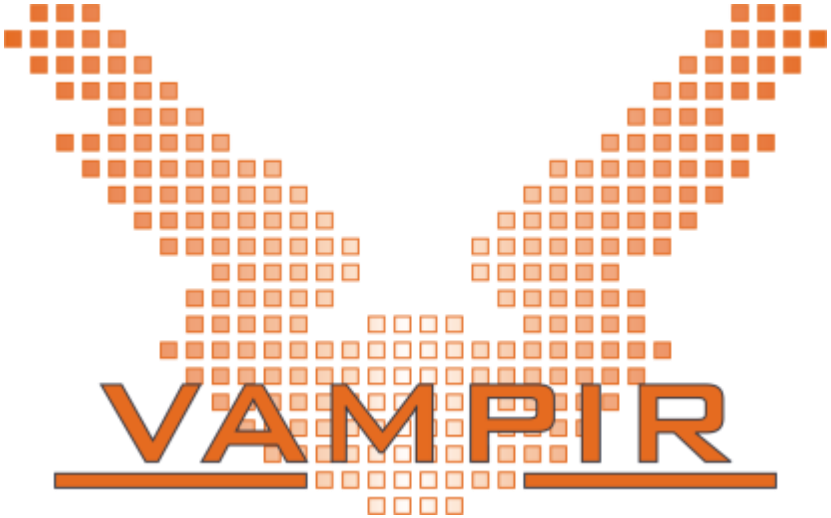
Conclusions

Vampir & VampirServer

- Interactive trace visualization and analysis
- Intuitive browsing and zooming
- Scalable to large trace data sizes (20 TByte)
- Scalable to high parallelism (200000 processes)
- Vampir for Linux, Windows and Mac OS

Score-P

- Common instrumentation and measurement infrastructure for various analysis tools
- Hides away complicated details
- Provides many options and switches for experts



Vampir is available at http://www.vampir.eu

Get support via vampirsupport@zih.tu-dresden.de

Score-P: http://www.vi-hps.org/projects/score-p