BSC Tools
Hands-On

Judit Giménez, Lau Mercadal (lau.mercadal@bsc.es)
Barcelona Supercomputing Center

Extrae

Extrae features

- Parallel programming models
  - MPI, OpenMP(*), pthreads, OmpSs, CUDA, CUPTI, OpenCL, Java, Python…
- Platforms: Intel, Cray, BlueGene, Fujitsu Sparc, MIC, ARM, Android…
- Performance Counters
  - Using PAPI and PMAPI interfaces
- Link to source code
  - Callstack at MPI routines
  - OpenMP outlined routines and their containers
  - Selected user functions
- And more: Sampling, IO, memory allocation…
- User events (Extrae API)

No need to recompile / relink!

(*) GNU, IBM, Intel, OMPT

Extrae overheads

	Average values	CoolMUC-3
Event	150-200 ns	130 ns
Event + PAPI	750 ns – 1 us	850 ns
Event + callstack (1 level)	600 ns	1.3 us
Event + callstack (6 levels)	1.9 us	3.1 us

How does Extrae work?

- Symbol substitution through LD_PRELOAD
  - Specific libraries for each combination of runtimes
    - MPI
    - OpenMP
    - OpenMP+MPI
    - OmpSs
    - …

Recommended

- Dynamic instrumentation
  - Based on DynInst (developed by U.Wisconsin/U.Maryland)
    - Instrumentation in memory
    - Binary rewriting

- Static link (i.e., PMPI, Extrae API)

Using Extrae in 3 steps

1. Adapt the job submission script

2. [Optional] Tune the Extrae XML configuration file
   - Examples distributed with Extrae at $EXTRAE_HOME/share/example

3. Run with instrumentation

- For further reference check the **Extrae User Guide:**
  - https://tools.bsc.es/tools_manuals

Log in and copy the examples to your work directory

@ your laptop

```
> ssh -Y <USER>@lxlogin8.lrz.de

> cp -r /home/hpc/a2c06/lu23vet/tools-material ./

> ls -l $HOME/tools-material
   ...apps
   ...extrae
   ...slides
   ...traces
```

Here's a copy of these slides

Step 1: Adapt the job script to load Extrae with LD_PRELOAD

```
> vi $HOME/tools-material/extrae/job.slurm
```

```
#!/bin/sh

#SBATCH -J lulesh2
#SBATCH -o lulesh2_%j.out
#SBATCH -e lulesh2_%j.err
#SBATCH --ntasks=64
#SBATCH --ntasks-per-core=1
#SBATCH --time=00:15:00
#SBATCH --cluster=mpp3
#SBATCH --reservation=TuningWorkshop
#SBATCH --exclusive

export OMP_NUM_THREADS=1

# run the script
mpiexec ../apps/lulesh2.0 -i 10 -s 65 -p
```

Step 1: Adapt the job script to load Extrae with LD_PRELOAD

```
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```

```
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#SBATCH --reservation=TuningWorkshop
#SBATCH --exclusive

export OMP_NUM_THREADS=1
export TRACE_NAME=lulesh2_64p.prv

# run the script
mpiexec ./trace.sh ../apps/lulesh2.0 ...
```

Step 1: Adapt the job script to load Extrae with LD_PRELOAD

```
> vi $HOME/tools-material/extrae/trace.sh
```

```
#!/bin/sh

#SBATCH -J lulesh2
#SBATCH -o lulesh2_%j.out
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#SBATCH --ntasks=64
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#SBATCH --reservation=TuningWorkshop
#SBATCH --exclusive

export OMP_NUM_THREADS=1
export TRACE_NAME=lulesh2_64p.prv

# run the script
mpiexec ./trace.sh ../apps/lulesh2.0 ...
```

```
#!/bin/bash

# Configure Extrae
export EXTRAE_HOME=/home/hpc/a2c06/lu23vet/ \
                 bsctools/extrae/3.5.2-impi_2017
source ${EXTRAE_HOME}/etc/extrae.sh
export EXTRAE_CONFIG_FILE=./extrae.xml

# Load the tracing library (choose C/Fortran)
export LD_PRELOAD=$EXTRAE_HOME/lib/libmpitrace.so
#export LD_PRELOAD=$EXTRAE_HOME/lib/libmpitracef.so

# Run the program
$*
```

Pick a tracing library

Step 1: LD_PRELOAD library selection

Library	Serial	MPI	OpenMP	OmpSs	pthread	CUDA
libseqtrace	✓					
libmpitrace[f][1]		✓				
libomptrace			✓			
libnanostrace				✓		
libpttrace					✓	
libcudatrace						✓
libompitrace[f] [1]		✓	✓			
libnanosmpitrace[f] [1]		✓		✓		
libptmpitrace[f] [1]		✓			✓	
libcudampitrace[f] [1]		✓				✓

[1] include suffix "f" in Fortran codes

Step 3: Run with instrumentation

@ CoolMUC-3

```
> cd $HOME/tools-material/extrae

> sbatch job.slurm
```

- Check the state with:

@ CoolMUC-3

```
> squeue -u ${USER}
```

Step 2: Extrae XML configuration: extrae.xml

```
<mpi enabled="yes">
  <counters enabled="yes" />
</mpi>

<openmp enabled="yes">
  <locks enabled="no" />
  <counters enabled="yes" />
</openmp>

<pthread enabled="no">
  <locks enabled="no" />
  <counters enabled="yes" />
</pthread>

<callers enabled="yes">
  <mpi enabled="yes">1-3</mpi>
  <sampling enabled="no">1-5</sampling>
</callers>
```

Trace MPI calls + HW counters

Trace call-stack events @ MPI calls

Step 2: Extrae XML configuration: extrae.xml (II)

```
<counters enabled="yes">
  <cpu enabled="yes" starting-set-distribution="cyclic">
    <set enabled="yes" domain="all" changeat-time="0">
      PAPI_TOT_INS,PAPI_TOT_CYC,PAPI_L1_DCM
    </set>
    <set enabled="yes" domain="all" changeat-time="0">
      PAPI_TOT_INS,PAPI_TOT_CYC,PAPI_BR_INS
    </set>
    <set enabled="yes" domain="all" changeat-time="0">
      PAPI_TOT_INS,PAPI_TOT_CYC,PAPI_BR_MSP
    </set>
    <set enabled="yes" domain="all" changeat-time="0">
      PAPI_TOT_INS,PAPI_TOT_CYC,PAPI_SR_INS
    </set>
    <set enabled="yes" domain="all" changeat-time="0">
      PAPI_TOT_INS,PAPI_TOT_CYC,PAPI_LD_INS
    </set>
  </cpu>
  <network enabled="no" />
  <resource-usage enabled="no" />
  <memory-usage enabled="no" />
</counters>
```

Define which HW counters are measured

Step 2: Extrae XML configuration: extrae.xml (III)

```
<buffer enabled="yes">
  <size enabled="yes">5000000</size>
  <circular enabled="no" />
</buffer>

<sampling enabled="no" type="default" period="50m" variability="10m" />

<merge enabled="yes"
  synchronization="default"
  tree-fan-out="16"
  max-memory="512"
  joint-states="yes"
  keep-mpits="yes"
  sort-addresses="yes"
  overwrite="yes">
  $TRACE_NAME$
</merge>
```

Trace buffer size

Enable sampling

Merge intermediate files into Paraver trace

Check the resulting trace

- After the execution you will get the trace (3 files):

@ CoolMUC-3

```
> ls -l $HOME/tools-material/extrae
   ...
   lulesh2_64p.pcf
   lulesh2_64p.prv
   lulesh2_64p.row
```

- Copy these files to your computer

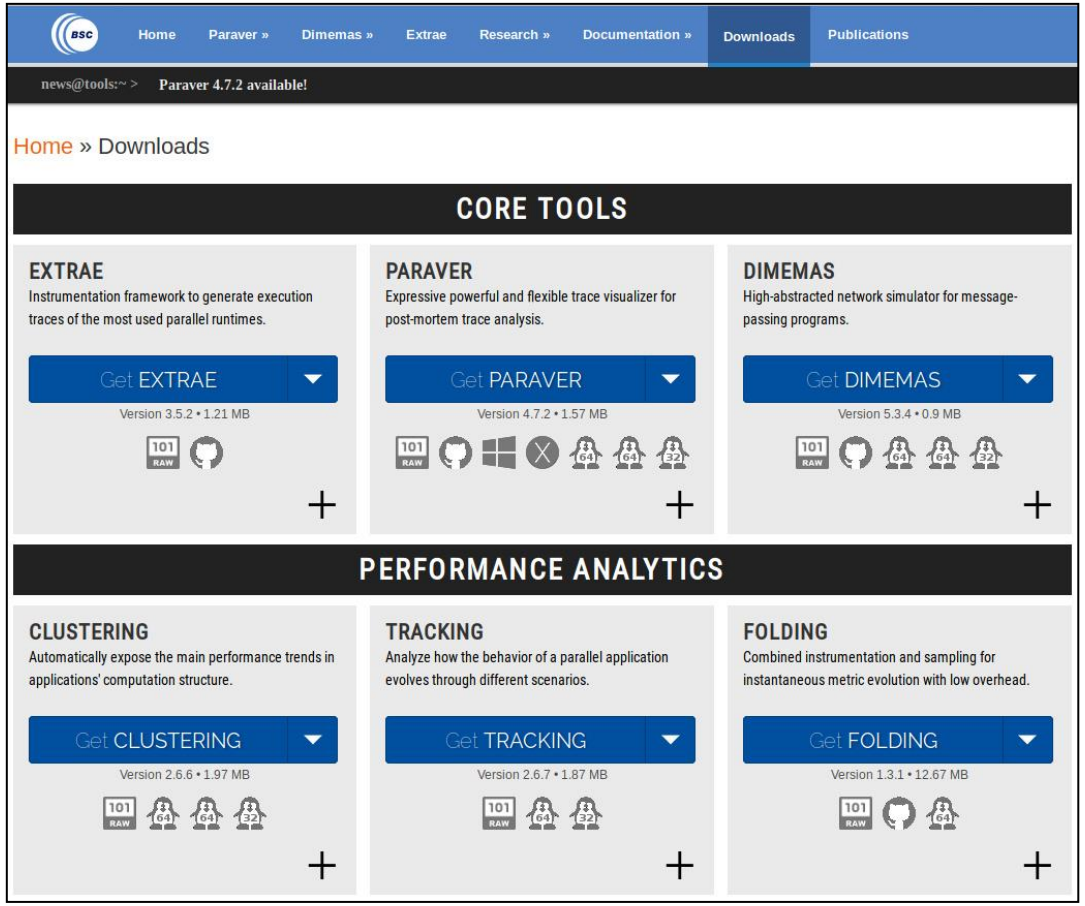
@ your computer

```
> scp <USER>@lxlogin8.lrz.de:$HOME/tools-material/extrae/ \
      *.{pcf,prv,row} $HOME
```

Paraver

Installing Paraver

- Download the Paraver binaries from our website



Installing Paraver

- Or copy them from CoolMUC-3:

@ your computer

```
> scp <USER>@lxlogin8.lrz.de:/home/hpc/a2c06/lu23vet/
  tools-packages/<VERSION> $HOME
```

Pick your version

Linux 64 bits	`wxparaver-4.7.2-Linux_x86_64.tar.bz2`
Linux 32 bits	`wxparaver-4.7.2-Linux_i686.tar.bz2`
Mac	`wxparaver-4.7.2-mac.zip`
Windows	`wxparaver-4.7.2-win.zip`

Installing Paraver

- Uncompress the package into your home directory:

@ your computer

```
> tar xf wxparaver-4.7.2-Linux_x86_64.tar.bz2

> ln -s $HOME/wxparaver-4.7.2-Linux_x86_64 $HOME/paraver
```

- Download Paraver tutorials and uncompress into the Paraver directory
  - https://tools.bsc.es/sites/default/files/documentation/paraver-tutorials-20150526.tar.gz

@ your computer

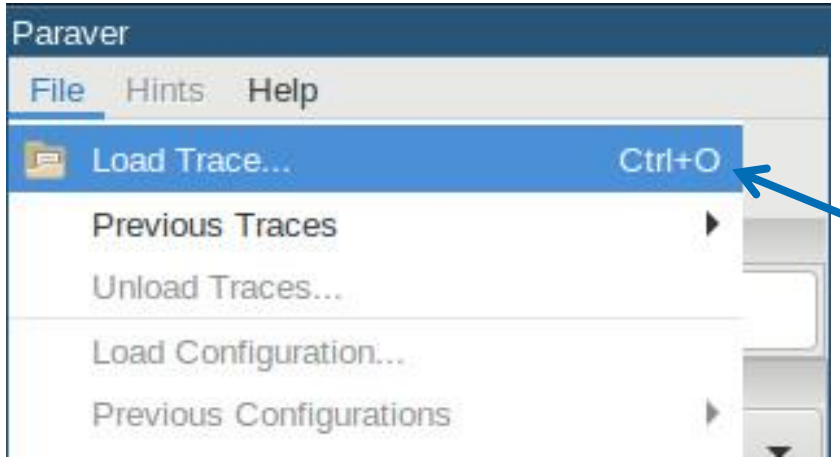
```
> tar xf $HOME/paraver-tutorials-20150526.tar.gz

> mv paraver-tutorials-20150526 $HOME/paraver/tutorials
```

Check that everything works

- Start Paraver

```
> $HOME/paraver/bin/wxparaver
```

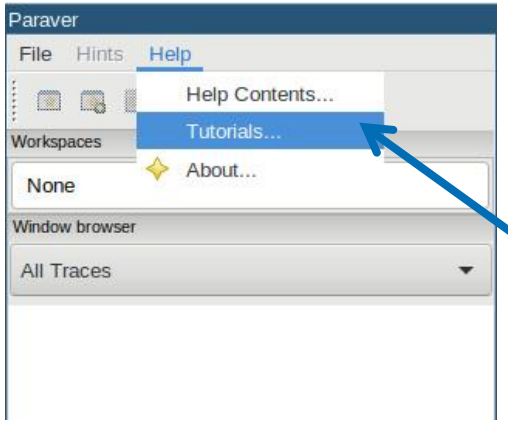
- Load the trace



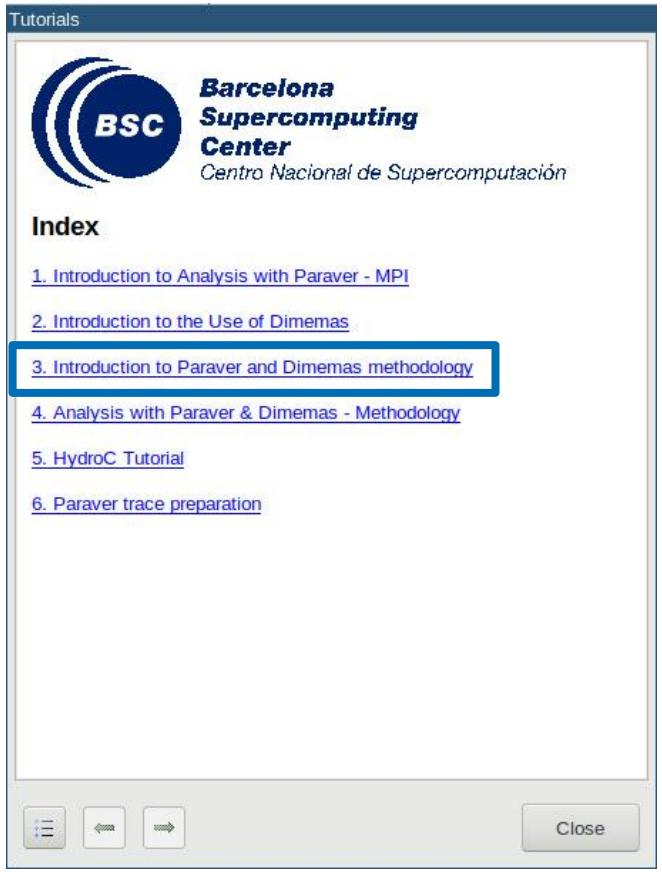
Click on File → Load Trace
Browse to "lulesh2_64p.prv"

Check that everything works

- Check that tutorials are available & follow #3

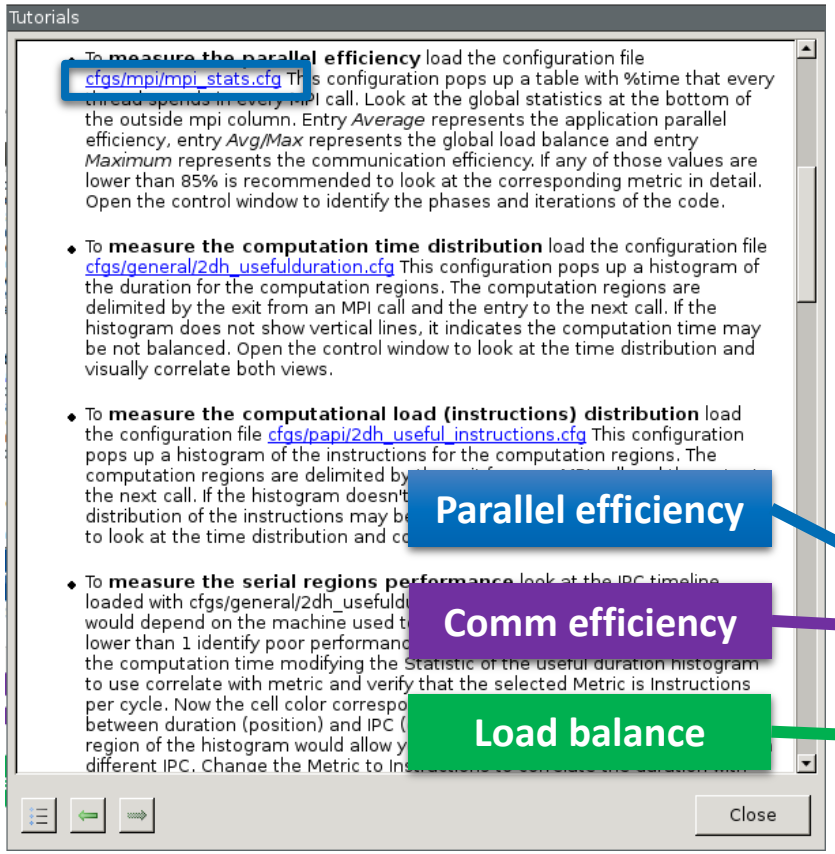


Click on Help → Tutorials



Measure the parallel efficiency

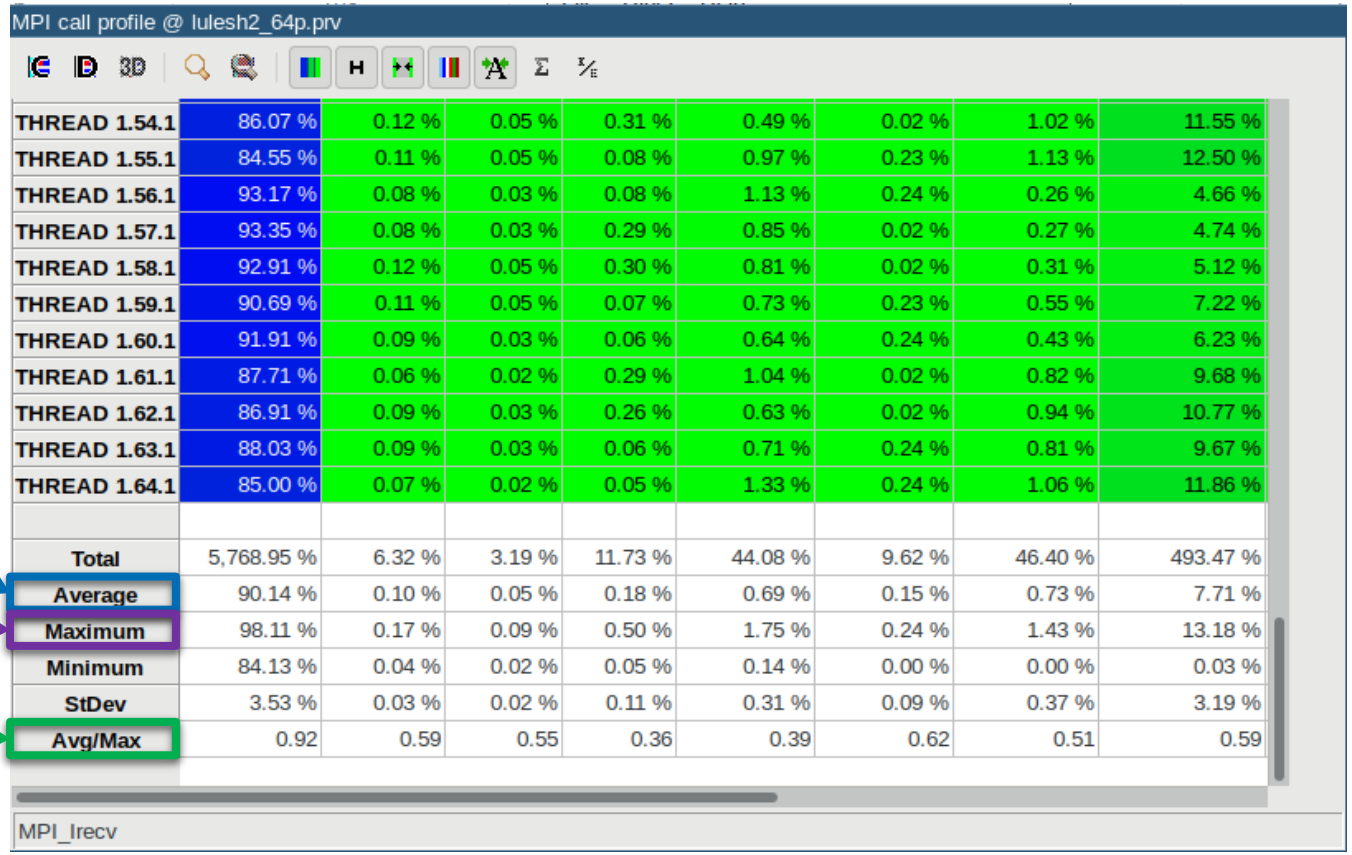
- Click on the "mpi_stats.cfg"
  - Check the Average for the column labeled "Outside MPI"



Parallel efficiency

Comm efficiency

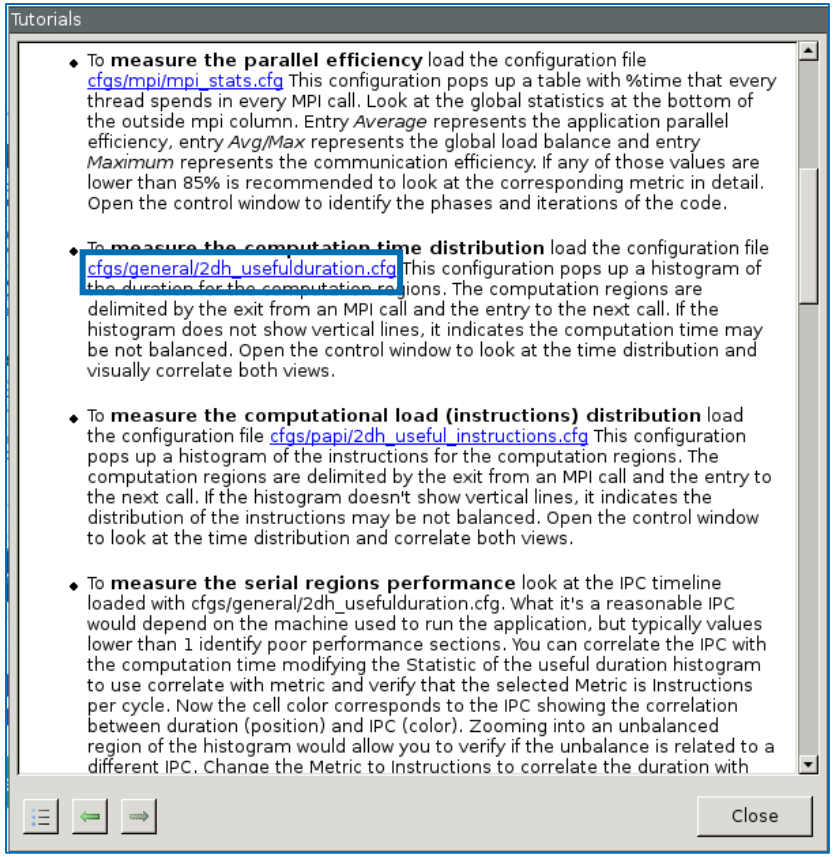
Load balance

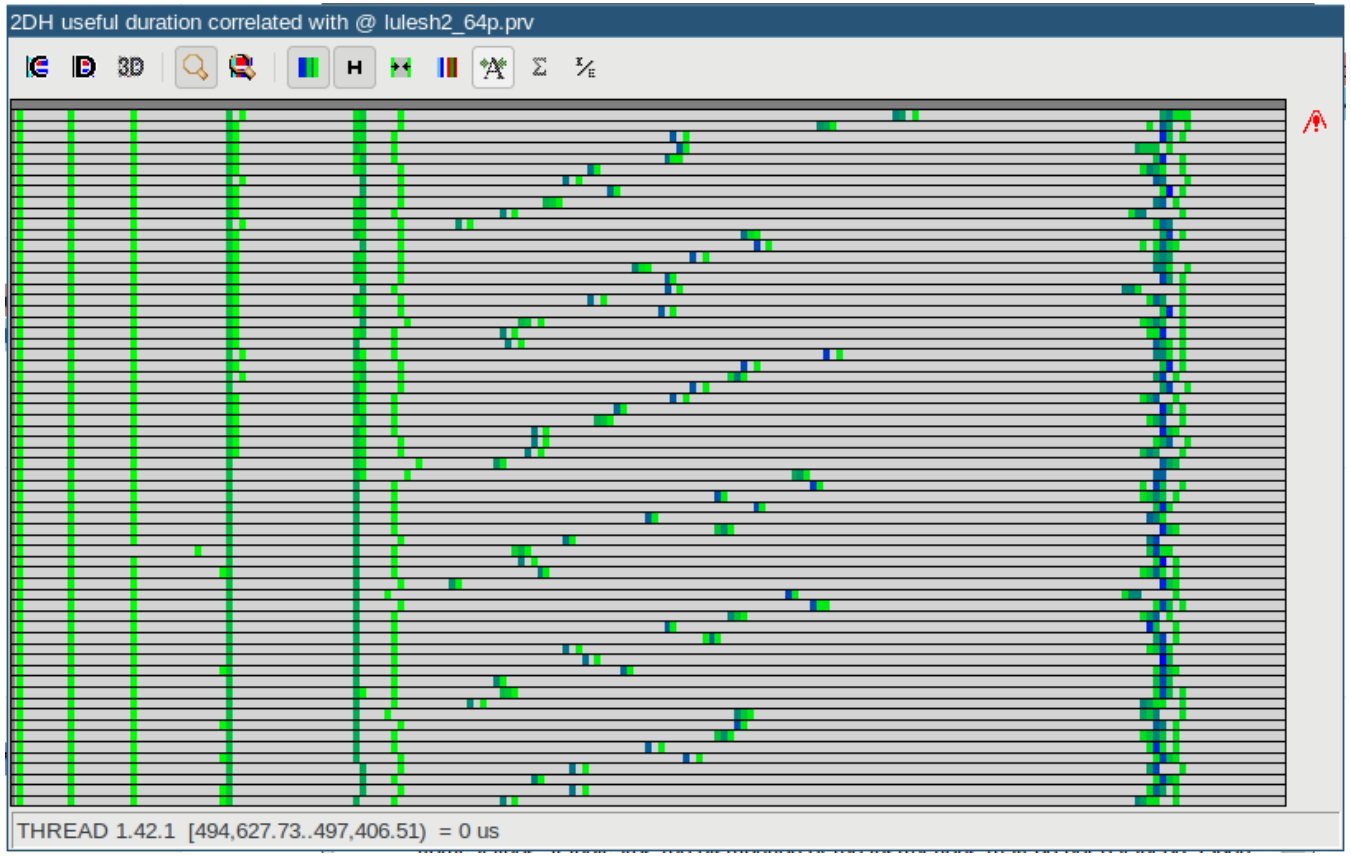


THREAD 1.54.1	86.07 %	0.12 %	0.05 %	0.31 %	0.49 %	0.02 %	1.02 %	11.55 %
THREAD 1.55.1	84.55 %	0.11 %	0.05 %	0.08 %	0.97 %	0.23 %	1.13 %	12.50 %
THREAD 1.56.1	93.17 %	0.08 %	0.03 %	0.08 %	1.13 %	0.24 %	0.26 %	4.66 %
THREAD 1.57.1	93.35 %	0.08 %	0.03 %	0.29 %	0.85 %	0.02 %	0.27 %	4.74 %
THREAD 1.58.1	92.91 %	0.12 %	0.05 %	0.30 %	0.81 %	0.02 %	0.31 %	5.12 %
THREAD 1.59.1	90.69 %	0.11 %	0.05 %	0.07 %	0.73 %	0.23 %	0.55 %	7.22 %
THREAD 1.60.1	91.91 %	0.09 %	0.03 %	0.06 %	0.64 %	0.24 %	0.43 %	6.23 %
THREAD 1.61.1	87.71 %	0.06 %	0.02 %	0.29 %	1.04 %	0.02 %	0.82 %	9.68 %
THREAD 1.62.1	86.91 %	0.09 %	0.03 %	0.26 %	0.63 %	0.02 %	0.94 %	10.77 %
THREAD 1.63.1	88.03 %	0.09 %	0.03 %	0.06 %	0.71 %	0.24 %	0.81 %	9.67 %
THREAD 1.64.1	85.00 %	0.07 %	0.02 %	0.05 %	1.33 %	0.24 %	1.06 %	11.86 %
Total	5,768.95 %	6.32 %	3.19 %	11.73 %	44.08 %	9.62 %	46.40 %	493.47 %
Average	90.14 %	0.10 %	0.05 %	0.18 %	0.69 %	0.15 %	0.73 %	7.71 %
Maximum	98.11 %	0.17 %	0.09 %	0.50 %	1.75 %	0.24 %	1.43 %	13.18 %
Minimum	84.13 %	0.04 %	0.02 %	0.05 %	0.14 %	0.00 %	0.00 %	0.03 %
StDev	3.53 %	0.03 %	0.02 %	0.11 %	0.31 %	0.09 %	0.37 %	3.19 %
Avg/Max	0.92	0.59	0.55	0.36	0.39	0.62	0.51	0.59

Measure the computation time distribution

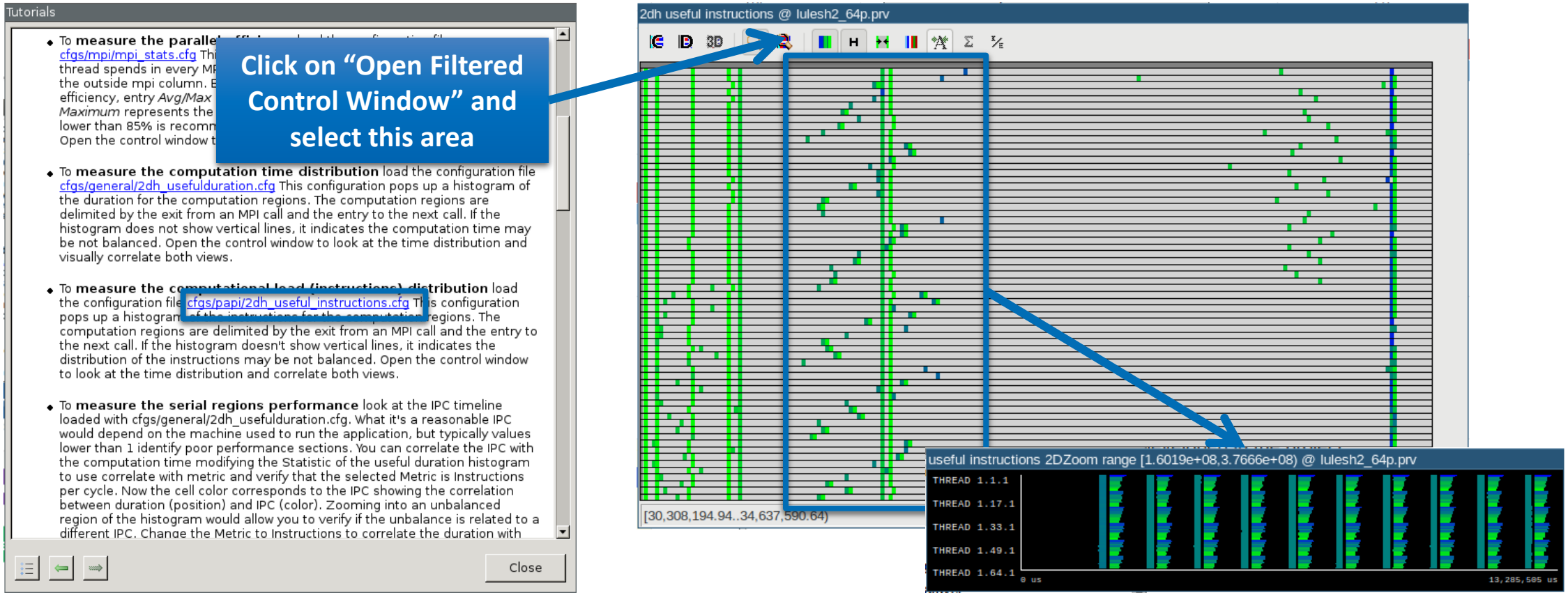
- Click on the “2dh_usefulduration.cfg”





Measure the computation time distribution

- Click on the "2dh_useful_instructions.cfg"



Cluster analysis

Cluster-based analysis

- Run clustering

@ CoolMUC-3

```
> cd $HOME/tools-material/clustering

> ./clusterize.sh ../extrae/lulesh2_64p.prv
```

- If you didn't get your own trace, find one at:

@ CoolMUC-3

```
> cd $HOME/tools-material/traces
```

Looking at the clusters

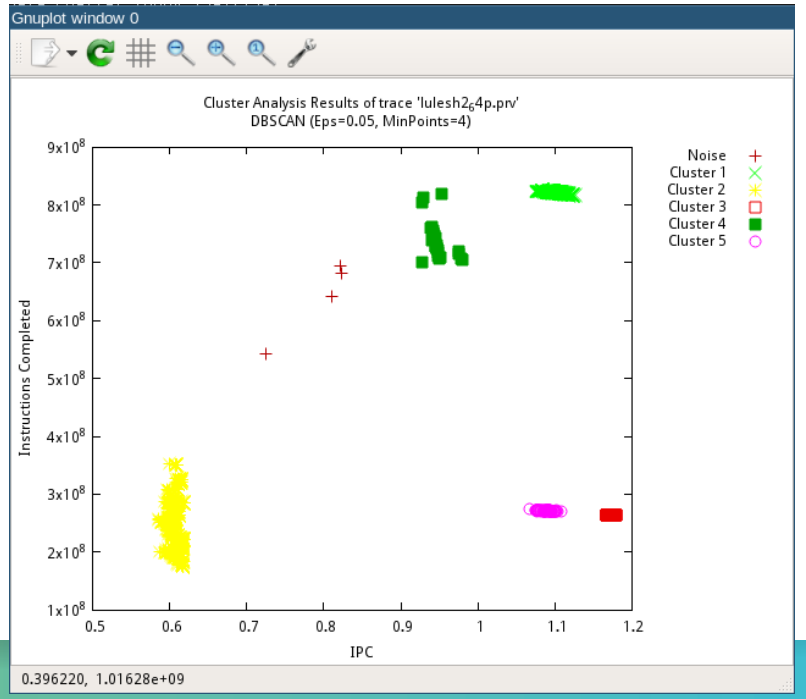
- Check the clustering scatter plot

@ CoolMUC-3

```
> module load gnuplot

> gnuplot lulesh2_64.clustered.IPC.PAPI_TOT_INS.gnuplot
```

- Identify main computing trends
  - Work (Y-axis), Performance (X-axis)

- See the elongated clusters?
  - Large IPC variability
  - Wide range of instructions
  - Indicate potential imbalances



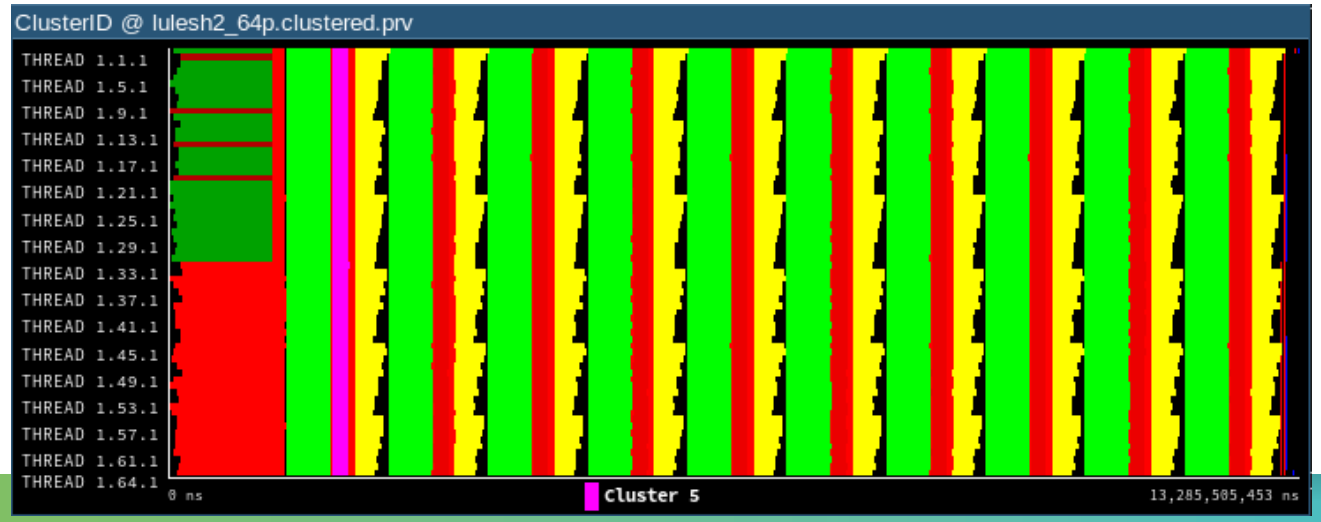
Looking at the clustered trace

- Copy and load the clustered trace with Paraver

```
> scp <USER>@lxlogin8.lrz.de:$HOME/tools-material/clustering/ \
      *.{pcf,prv,row} $HOME
```

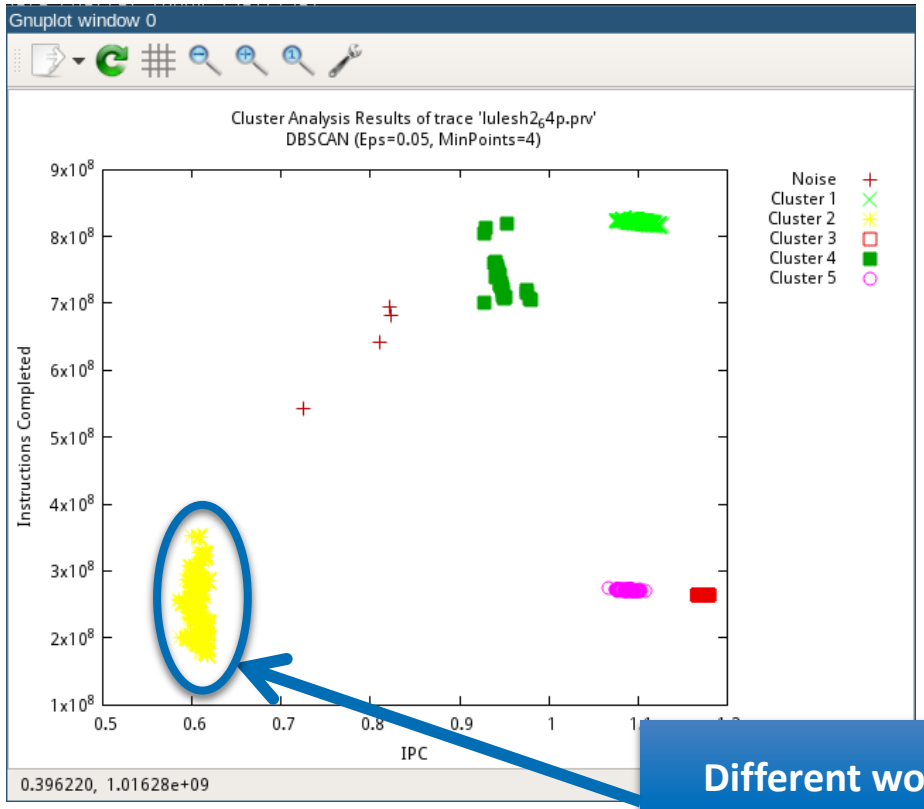
  - File →Load Trace → Browse to **$HOME/tools-material/clustering/lulesh2_64.clustered.prv**

- Display the distribution of clusters over time
  - File → Load configuration → Browse to **$PARAVER_HOME/cfgs/clustering/clusterID_window.cfg**



Looking at the clustered trace

- Correlate scatter-plots and timelines to detect imbalances



Different work, same speed

Dimemas

Simulating with Dimemas

- Simulate an ideal machine

@ CoolMUC-3

```
> cd $HOME/tools-material/dimemas

> ./dimemas.sh ../extrae/lulesh2_64p ideal.cfg
```

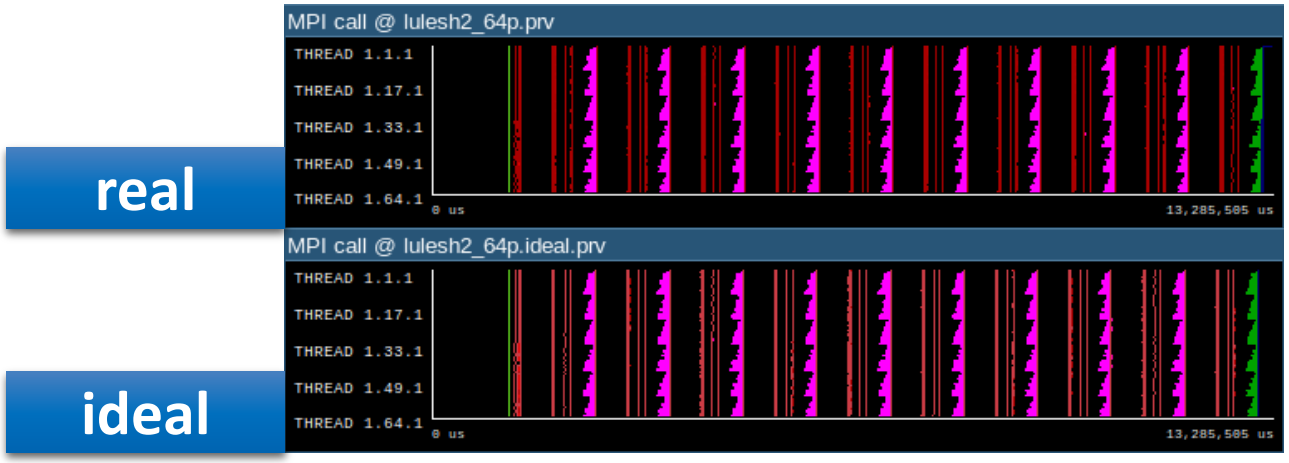
- Copy the simulated trace to your computer

@ your computer

```
➢ scp <USER>@lxlogin8.lrz.de:$HOME/tools-material/dimemas/ \
      *.{pcf,prv,row} $HOME
```

Simulating with Dimemas

- Improves?
  - Compare the original and simulated trace with Paraver
    - Hints -> MPI -> MPI profile
      - Open control window
    - Copy and paste time from real to ideal



- No improvement: Not limited by network → Check serializations

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