TECHNISCHE UNIVERSITÄT DRESDEN

Center for Information Services and High Performance Computing (ZIH)

Extending the Functionality of Score-P through Plugins: Interfaces and Examples

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Center for Information Services &
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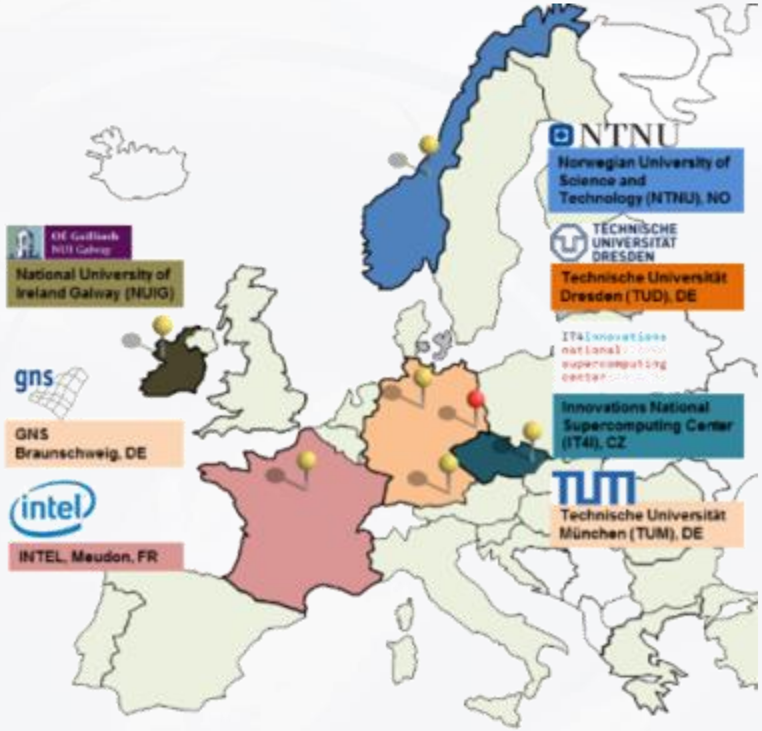
READEX

- Technische Universität Dresden (Coordinator), Germany
- Norwegian University of Science and Technology, Norway
- IT4Innovations, Czech Republic
- Technische Universität München, Germany
- Intel European Exascale Labs, France
- GNS Braunschweig, Germany
- National University of Ireland Galway, Ireland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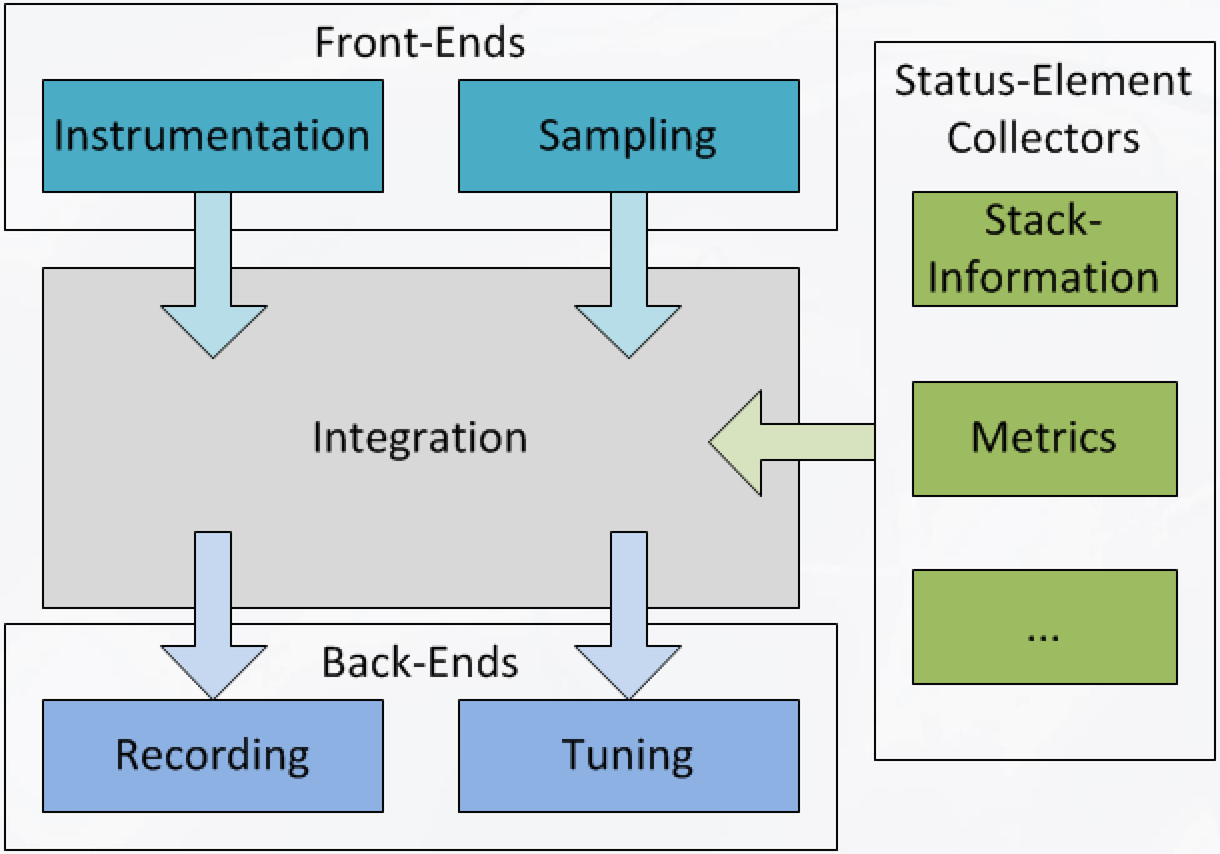
General Overview Measurement/Tuning Infrastructure

Interrupt workload, create initial status

Collect current status of workload



Provide status information

Act depending on status

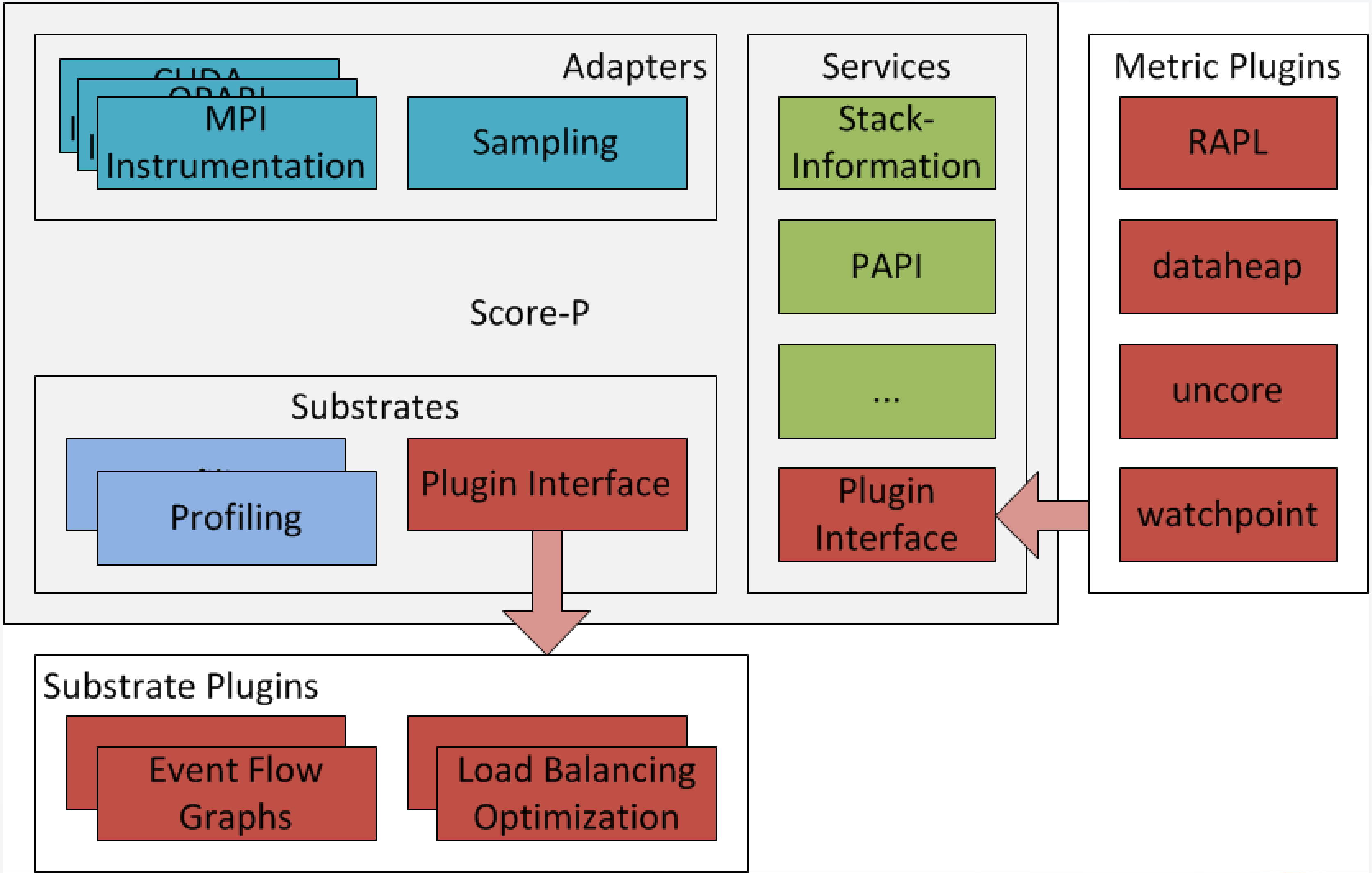
Demands (Metrics)

- Performance counter metrics
  - Get information on performance bottlenecks and dynamism
  - Part of Score-P
  - PAPI
  - perf
- Non traditional information
  - Open interface for different metrics
  - Power consumption information
  - Different scopes
  - Score-P Metric Plugins interface already available
  - Comparable to VampirTrace plugins [STHI11]

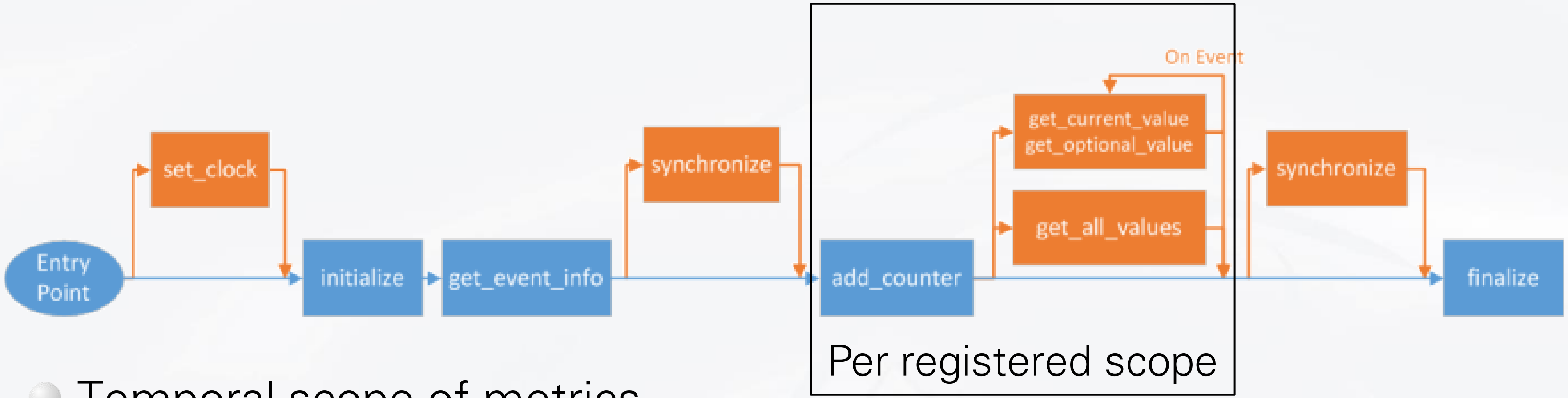
Demands (Back-Ends)

- Consume program events
  - Act according to specific **regions**
  - Act according to **metrics**
  - Act depending on **location**
  - Act on instructions from **Online-Access** server
  - READEX Runtime Library
- Goal: Adapt HW/SW environment to increase energy efficiency
  - Independent of READEX
  - Different for different architectures → exchangeable

Score-P overview



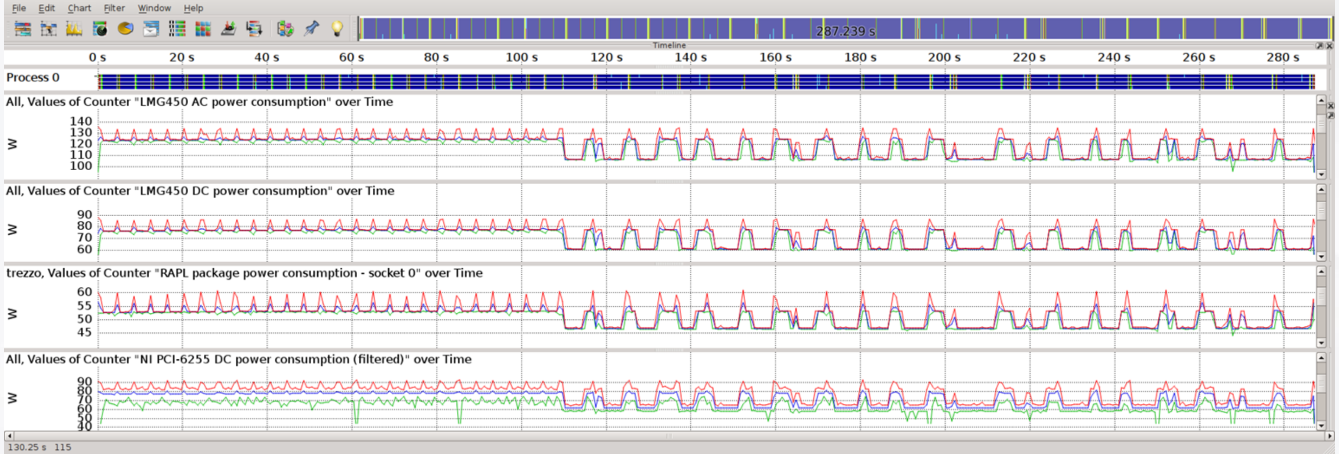
Metric Plugins



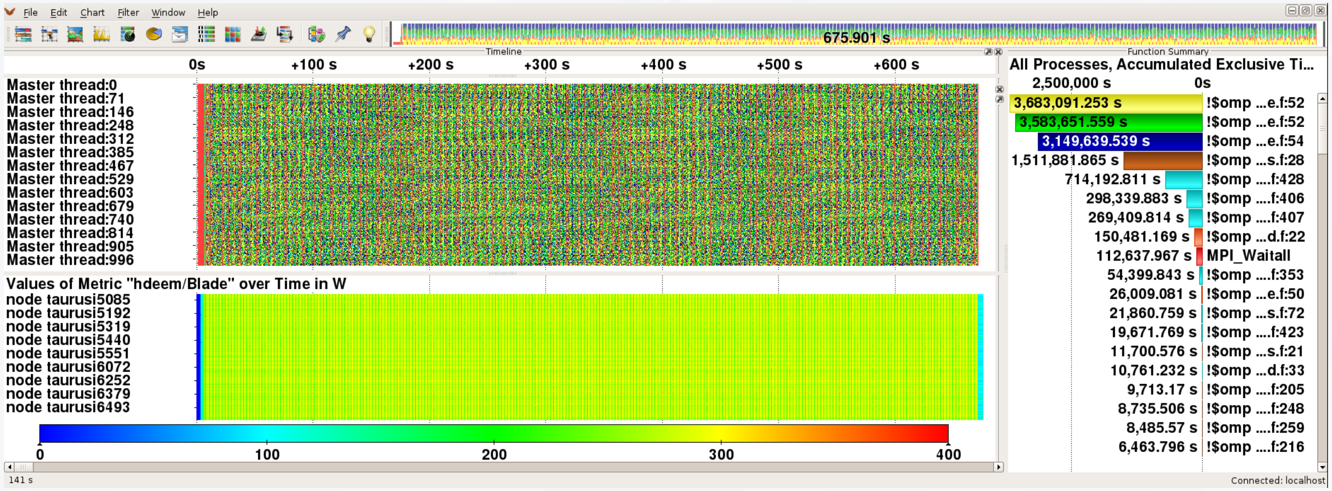
Per registered scope

- Temporal scope of metrics
  - synchronous/strictly synchronous/asynchronous
  - Instantaneous/backward-related/forward-related
- Spatial scope of metrics
  - Per thread/process/computing node/system
- `SCOREP_METRIC_PLUGINS=foo # libfoo.so`
- `SCOREP_METRIC_FOO=bar # event bar in libfoo`
- Plugins on https://github.com/score-p/

Examples Power Consumption


File Edit Chart Filter Window Help
287.239 s
Timeline
0 s
20 s
40 s
60 s
80 s
100 s
120 s
140 s
160 s
180 s
200 s
220 s
240 s
260 s
280 s
Process 0
All, Values of Counter "LMG450 AC power consumption" over Time
W
140
130
120
110
100
All, Values of Counter "LMG450 DC power consumption" over Time
90
80
70
60
trezzo, Values of Counter "RAPL package power consumption - socket 0" over Time
60
55
50
45
All, Values of Counter "NI PCI-6255 DC power consumption (filtered)" over Time
90
80
70
60
50
40
130.25 s 115

SPEC OMP applu, measurements with ZES-ZIMMER LMG 450/dataheap, RAPL, and HAEC infrastructure [HIS+13]



All Processes, Accumulated Exclusive Ti...

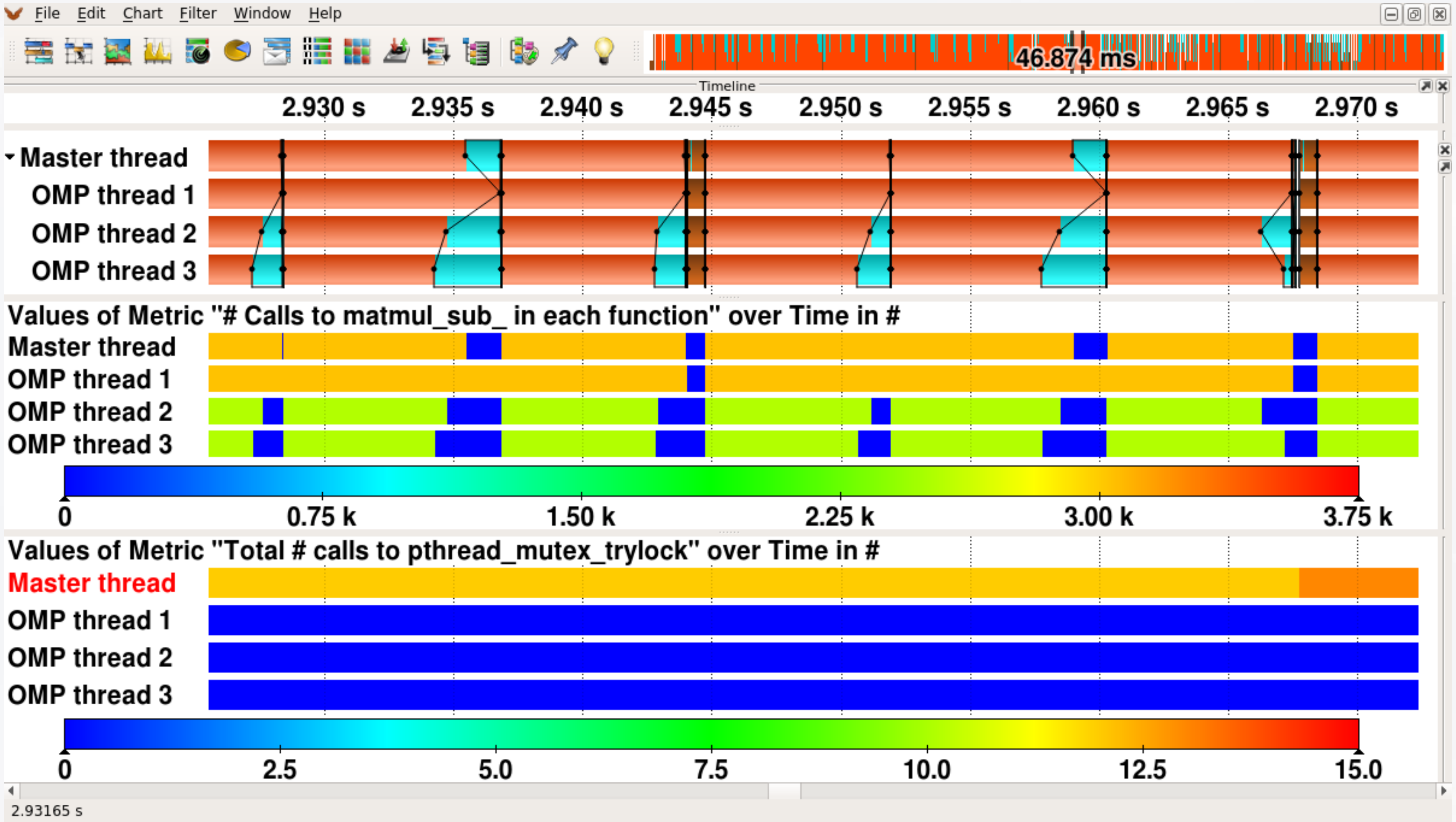
2,500,000 s	0s
3,683,091.253 s	!$omp ...e.f:52
3,583,651.559 s	!$omp ...e.f:52
3,149,639.539 s	!$omp ...e.f:54
1,511,881.865 s	!$omp ...s.f:28
714,192.811 s	!$omp f:428
298,339.883 s	!$omp f:406
269,409.814 s	!$omp f:407
150,481.169 s	!$omp ...d.f:22
112,637.967 s	MPI_Waitall
54,399.843 s	!$omp f:353
26,009.081 s	!$omp ...e.f:50
21,860.759 s	!$omp ...s.f:72
19,671.769 s	!$omp f:423
11,700.576 s	!$omp ...s.f:21
10,761.232 s	!$omp ...d.f:33
9,713.17 s	!$omp f:205
8,735.506 s	!$omp f:248
8,485.57 s	!$omp f:259
6,463.796 s	!$omp f:216

NPB-MZ benchmark BT, Class F, 1024 nodes, measurement with HDEEM [HIS+14]

Example Watchpoints

- Synchronous
  - Register variables or functions that shall be watched
  - Watch for number of read/write/execute access to variable
  - E.g., `SCOREP_METRIC_PERFBREAKPOINT_PLUGIN=x_pthread_mutex_trylock` to watch the number of calls of `pthread_mutex_trylock`
  - Statistic information on accesses to global variables
- Asynchronous
  - Register variables whose content will be watched
  - Parse binary with libbfd, find local & global variables
  - E.g., `SCOREP_METRIC_WATCHPOINT_PLUGIN=foo:uint64_t:bar` registers the content of the local variable `bar`, defined in function `foo`
  - High overhead (from kernel infrastructure), for debugging purposes

Example Watchpoints (Synchronous)



NPB-OpenMP benchmark BT, CLASS W, 4 Threads

Example Watchpoints (Asynchronous)

- OpenMP parallel program, 2 Threads
- Threads concurrently write their loop iteration to a global variable
- Depending on scheduling strategy, the content of the global variable changes over time

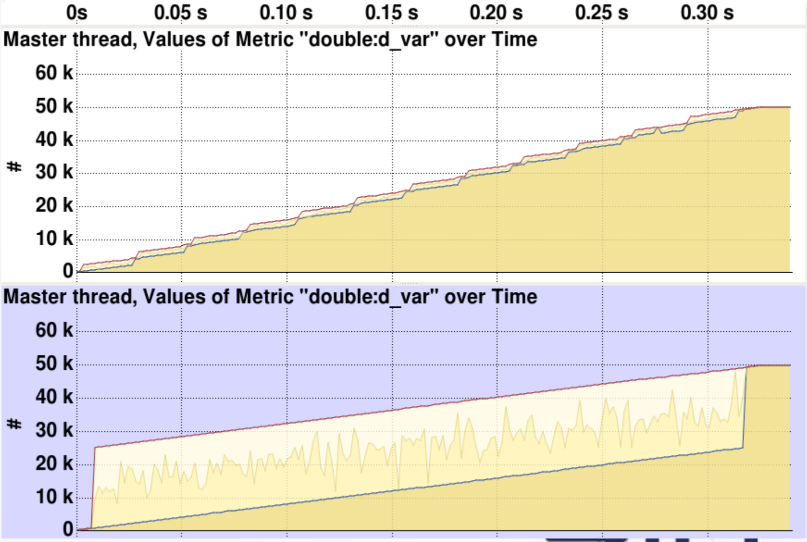
```
static double d_var=0;
void func( int i ){
    d_var=0.5*i;
}
int main( int argc, char** argv ){
    int i=0;
#pragma omp parallel for schedule(runtime)
    for(i=0;i<100000;i++){
        func(i);
    }
    return 0;
}
```

- White:

  `OMP_SCHEDULE=dynamic,4096`

- Purple:

  `OMP_SCHEDULE=static`



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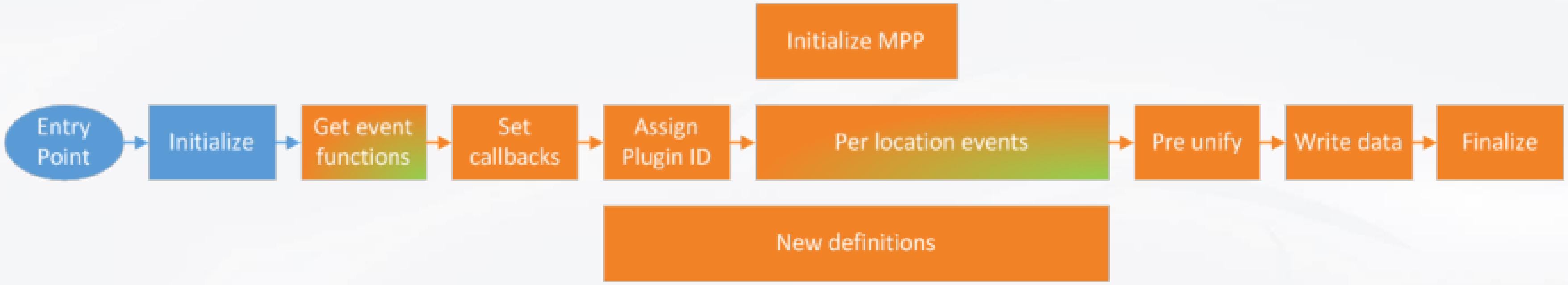
Substrate Plugins

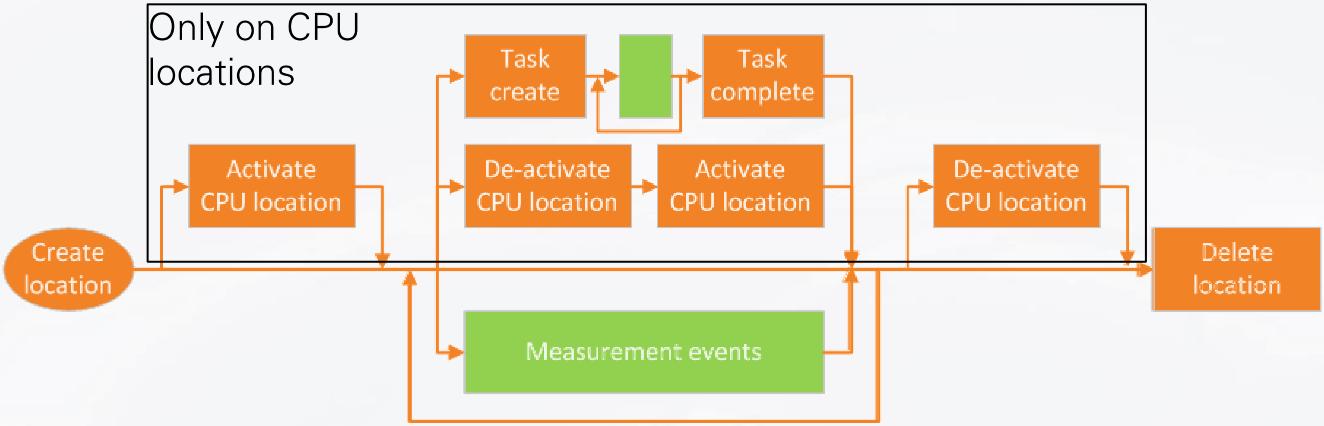


Per process calls to Substrate plugins

- Based on internal Substrate infrastructure
  - Management functions – related to Score-P internal processing
  - Event functions – related to program internals
- Only two non-optional functions
- Callbacks for plugins to get metadata for events from Score-P
- `export SCOREP_SUBSTRATE_PLUGINS=foo`

```
# load libscorep_substrate_foo
```

Substrate Plugins



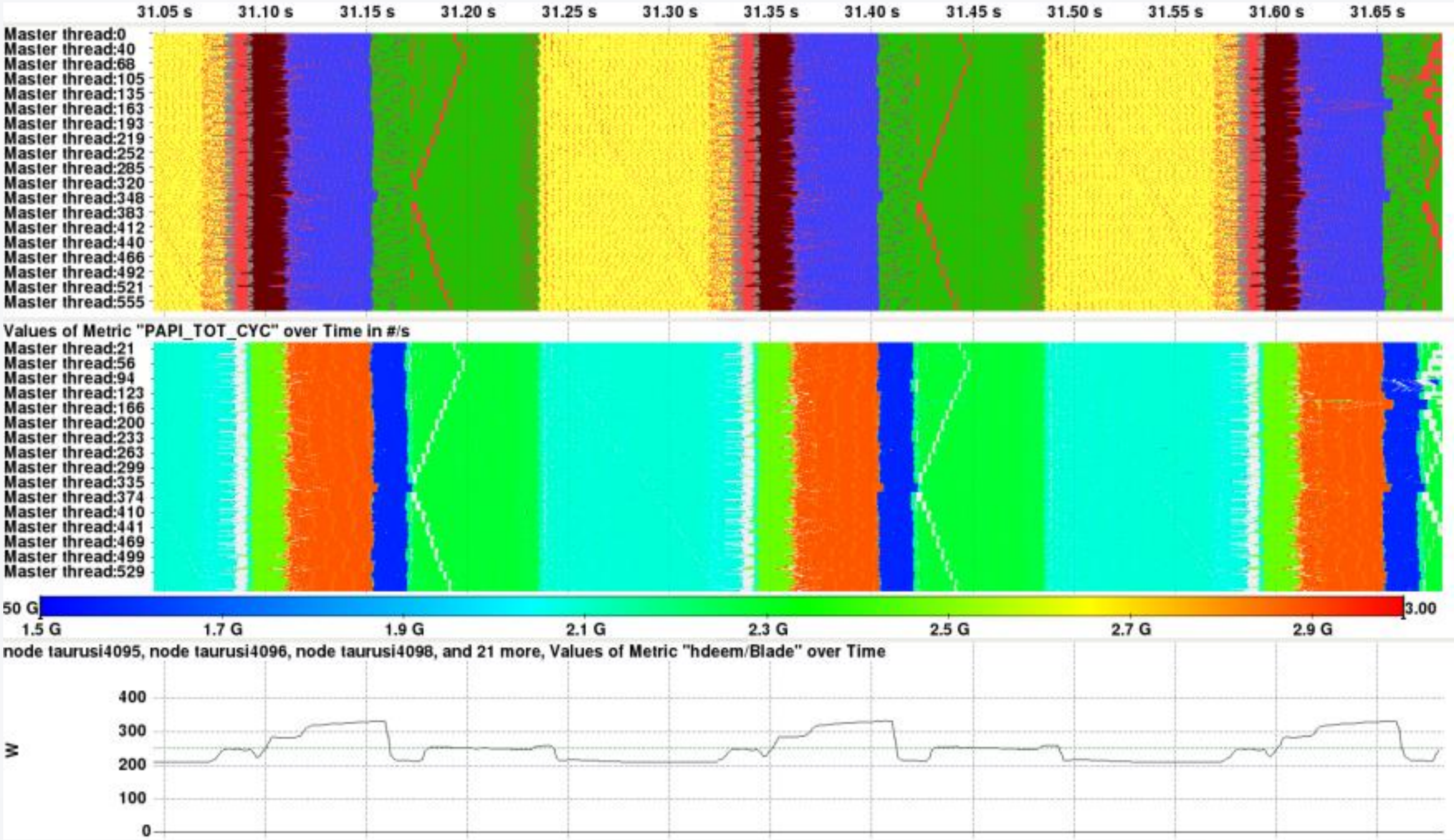
Per location calls to Substrate plugins

- Calls for CPU locations
- All measurement events get location and timestamp
- Plugins can use callbacks to get metadata from handles (e.g., name of entered region, type of location, …)
- Support for storage of location specific data in Score-P (thread local storage)

Examples

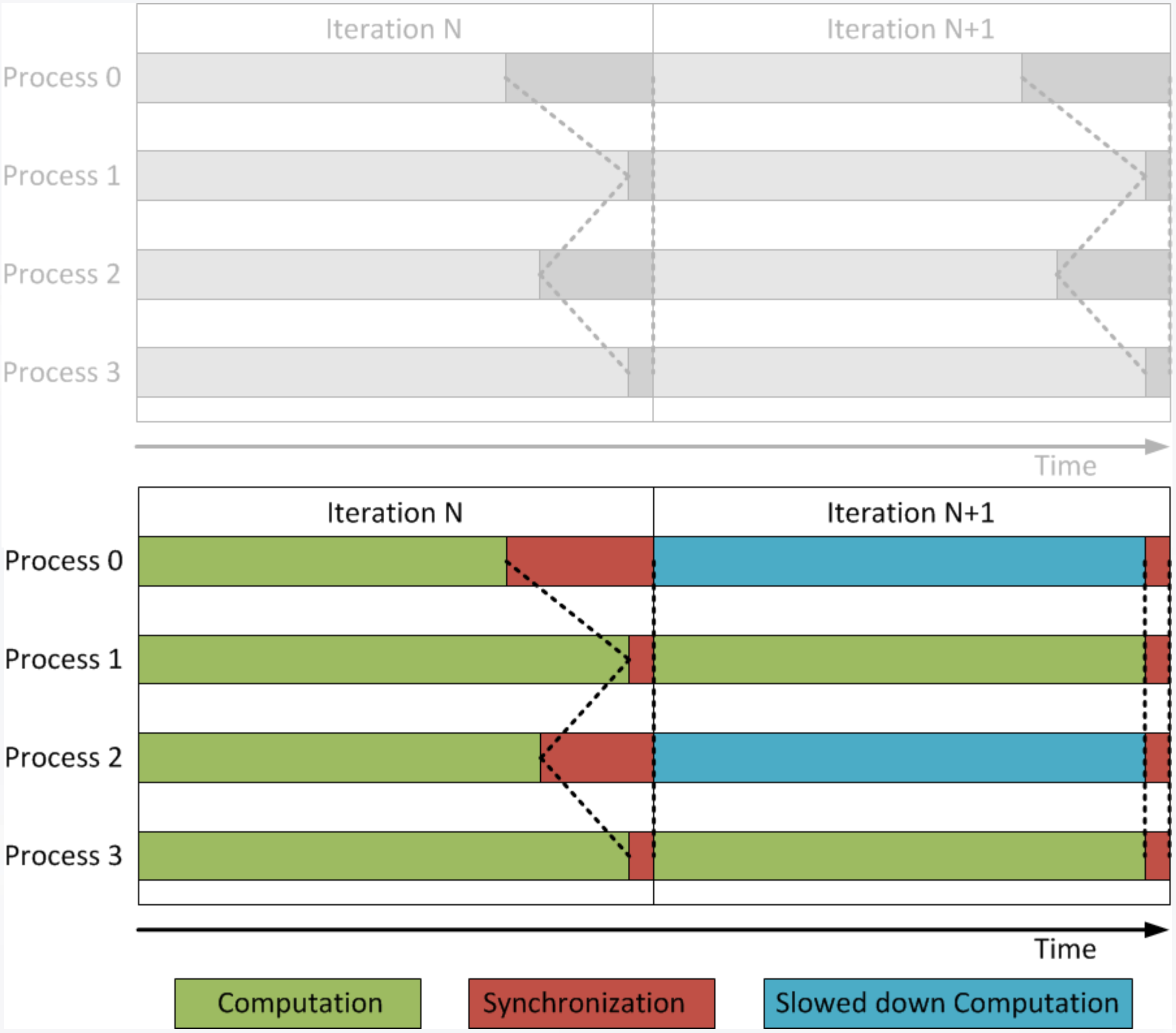
- Per region optimization using libadapt
  - As presented in [SM13]
  - Plugin reads config file and registers for enter/exit events to change HW/SW environment
  - DVFS/DCT/low-level hardware options
- Load balancing using DVFS
  - Like [RLdS+09], plus OpenMP
  - Successive execution of (compute region, synchronization region) pairs
  - Slow down computation to arrive just in time for synchronization
  - Plugin registers for enter/exit events
- Event Flow Graphs
  - Based on [AFL14]
  - Write event flow graph of exclusive regions as graphviz diagram

Region Based Optimization

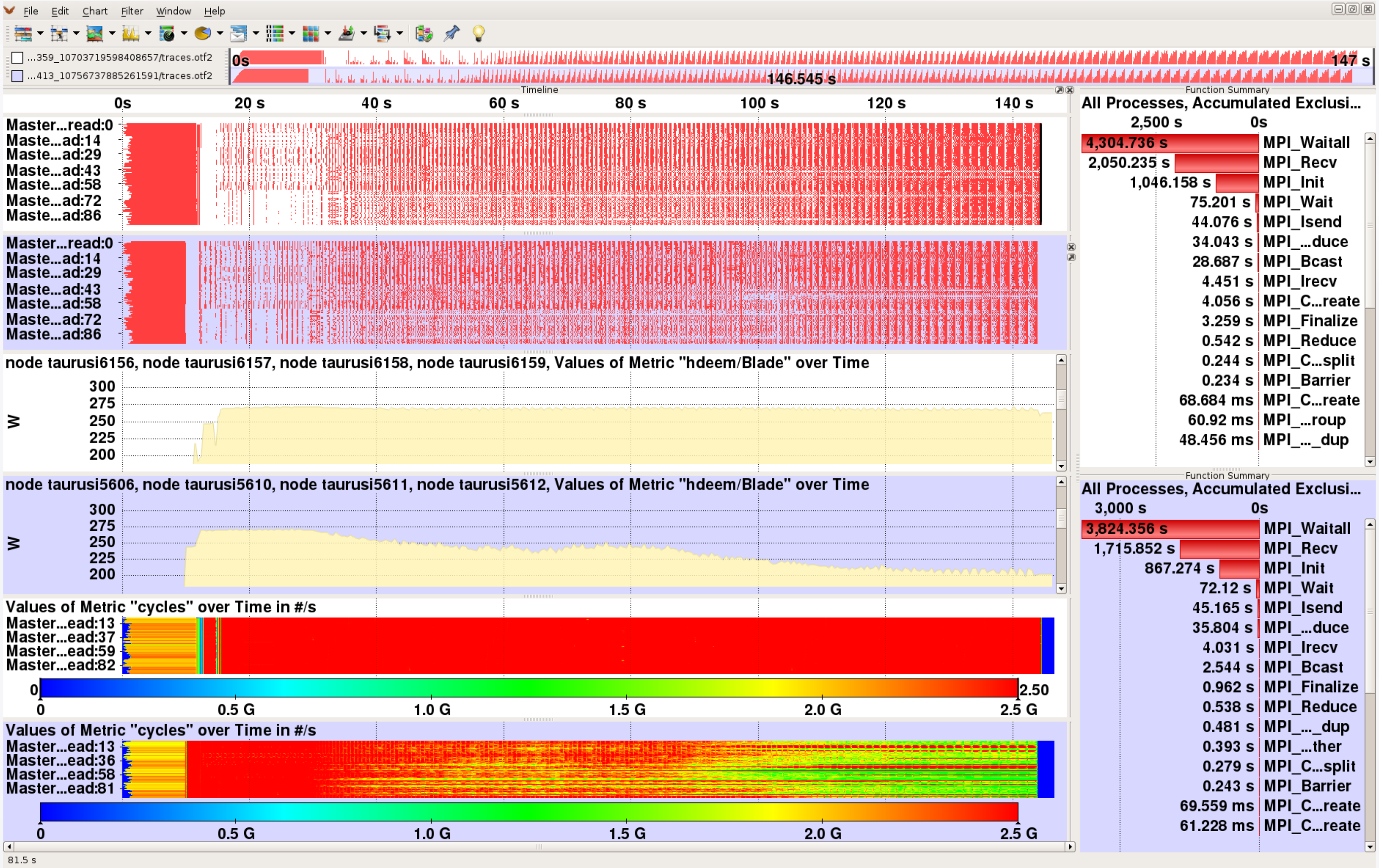


NPB-MPI benchmark BT, Class D, 576 ranks, optimized version: varying frequency and power consumption (HDEEM)

Load Balancing Substrate



Load Balancing SPEC COSMO FD4 via DVFS



All Processes, Accumulated Exclusi...

2,500 s	0s
4,304.736 s	MPI_Waitall
2,050.235 s	MPI_Recv
1,046.158 s	MPI_Init
75.201 s	MPI_Wait
44.076 s	MPI_Isend
34.043 s	MPI_...duce
28.687 s	MPI_Bcast
4.451 s	MPI_Irecv
4.056 s	MPI_C...reate
3.259 s	MPI_Finalize
0.542 s	MPI_Reduce
0.244 s	MPI_C...split
0.234 s	MPI_Barrier
68.684 ms	MPI_C...reate
60.92 ms	MPI_...roup
48.456 ms	MPI_..._dup

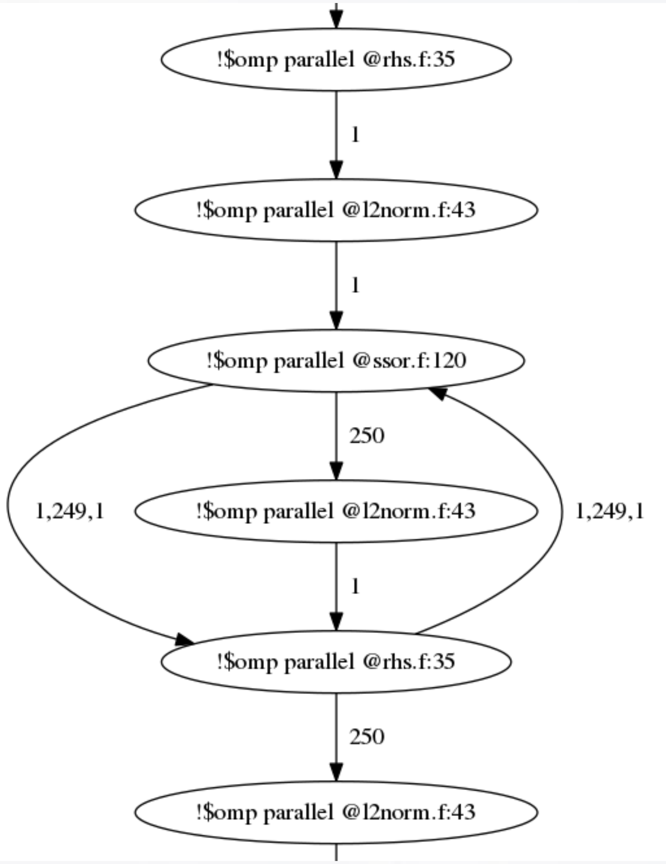
All Processes, Accumulated Exclusi...

3,000 s	0s
3,824.356 s	MPI_Waitall
1,715.852 s	MPI_Recv
867.274 s	MPI_Init
72.12 s	MPI_Wait
45.165 s	MPI_Isend
35.804 s	MPI_...duce
4.031 s	MPI_Irecv
2.544 s	MPI_Bcast
0.962 s	MPI_Finalize
0.538 s	MPI_Reduce
0.481 s	MPI_..._dup
0.393 s	MPI_...ther
0.279 s	MPI_C...split
0.243 s	MPI_Barrier
69.559 ms	MPI_C...reate
61.228 ms	MPI_C...reate

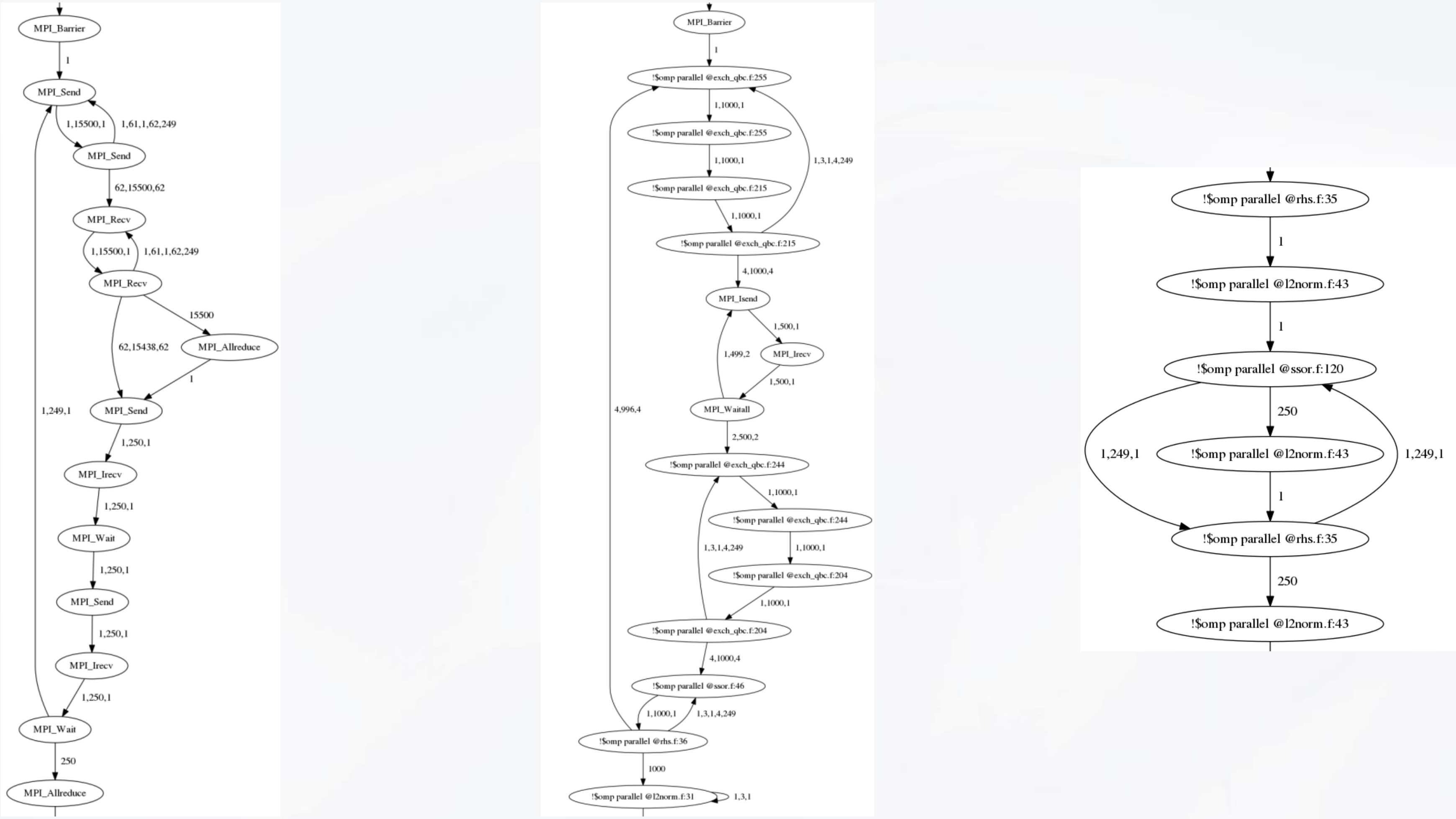
SPEC COSMO FD4 on 4 nodes / 96 ranks, MPI instrumentation, DVFS load balancing, HDEEM

Event Flow Graphs

- Record exclusive functions, no nested calls
- E.g., OpenMP parallel regions
- Node = parallel region with specific stack state
- Edge = possible successor
- Node label: region name
- Edge label:
  - No label: Only transition from node
  - Single number N: on Nth iteration
  - Three numbers i,j,k: transition is taken ith, i+kth,…jth execution of predecessor node
  - …


!$omp parallel @rhs.f:35
1
!$omp parallel @l2norm.f:43
1
!$omp parallel @ssor.f:120
250
1,249,1
!$omp parallel @l2norm.f:43
1,249,1
1
!$omp parallel @rhs.f:35
250
!$omp parallel @l2norm.f:43

Event flow graphs (NPB lu CLASS A, core loop)



(a) MPI (rank 0)

(b) MZ (rank 0, thread 0)

(c) OMP (thread 0)

Summary and Outlook

- Score-P as a common infrastructure for measurement, tuning, and debugging?
- Metric Plugins provide additional status information
- Substrate Plugins make use of Score-P's instrumentation frameworks and metrics to enhance functionality

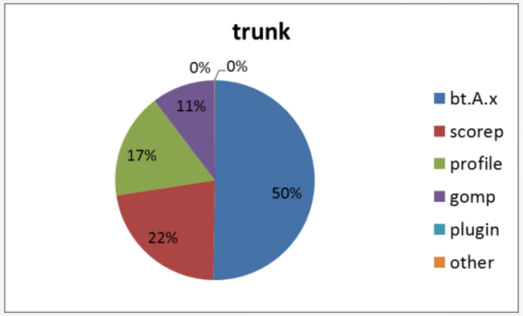
Substrate Plugin Interface **not final**. Any suggestions?

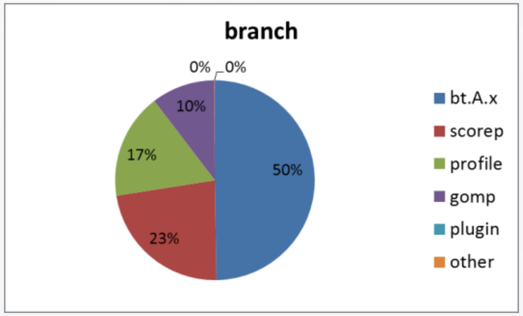
Talk to me in the next coffee break or write an email!

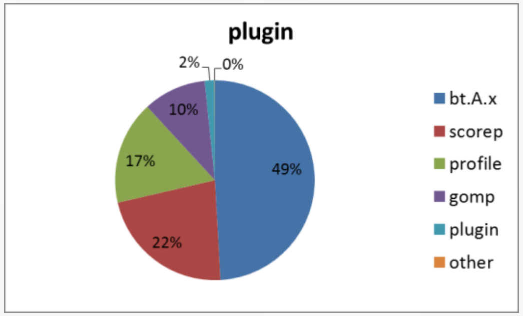
- [RLdS+09] *Barry Rountree, David K. Lownenthal, Bronis R. de Supinski, Martin Schulz, Vincent W. Freeh, and Tyler Bletsch*. Adagio: Making DVS Practical for Complex HPC Applications. In Proceedings of the 23rd international conference on Supercomputing, pages 460–469. ACM, 2009. DOI: 10.1145/1542275.1542340.
- [STHI11] *Robert Schöne, Ronny Tschüter, Daniel Hackenberg, and Thomas Ilsche*. The VampirTrace Plugin Counter Interface: Introduction and Examples. In Euro-Par 2010 Parallel Processing Workshops, volume 6586 of Lecture Notes in Computer Science, pages 501–511. Springer-Verlag, 2011. DOI: 10.1007/978-3-642-21878-1_62.
- [HIS+13] *Daniel Hackenberg, Thomas Ilsche, Robert Schone, Daniel Molka, Martin Schmidt, and Wolfgang E. Nagel*. Power Measurement Techniques on Standard Compute Nodes: A Quantitative Comparison. In Performance Analysis of Systems and Software (ISPASS), 2013 IEEE International Symposium on, pages 194–204. IEEE, 2013.
- [SM13] *Robert Schöne and Daniel Molka*. Integrating Performance Analysis and Energy Efficiency, Optimizations in a Unified Environment. Computer Science - Research and Development, pages 1–9, 2013. DOI: 10.1007/s00450-013-0243-7.
- [AFL14] *Xavier Aguilar, Karl Fürlinger, and Erwin Laure*. MPI Trace Compression Using Event Flow Graphs. In Euro-Par 2014 Parallel Processing, pages 1--12. Springer International Publishing, Cham, 2014. DOI: 10.1007/978-3-319-09873-9_1
- [HIS+14] *Daniel Hackenberg, Thomas Ilsche, Joseph Schuchart, Robert Schöne, Wolfgang E Nagel, Marc Simon, and Yiannis Georgiou*. HDEEM: High Definition Energy Efficiency Monitoring. In Energy Efficient Supercomputing Workshop (E2SC), 2014, pages 1–10. IEEE, 2014. DOI: 10.1109/E2SC.2014.13.

Backup Overhead Plugin

- Compare trunk, branch, branch with minimal registered plugin
- NPB OpenMP, BT Class A, 24 threads on Haswell dual-socket system
- many short regions, high overhead
- 5 measurements, use mean
- Average time increased by 1.5% if plugin registered, otherwise 0 overhead
- Sampling using perf record







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