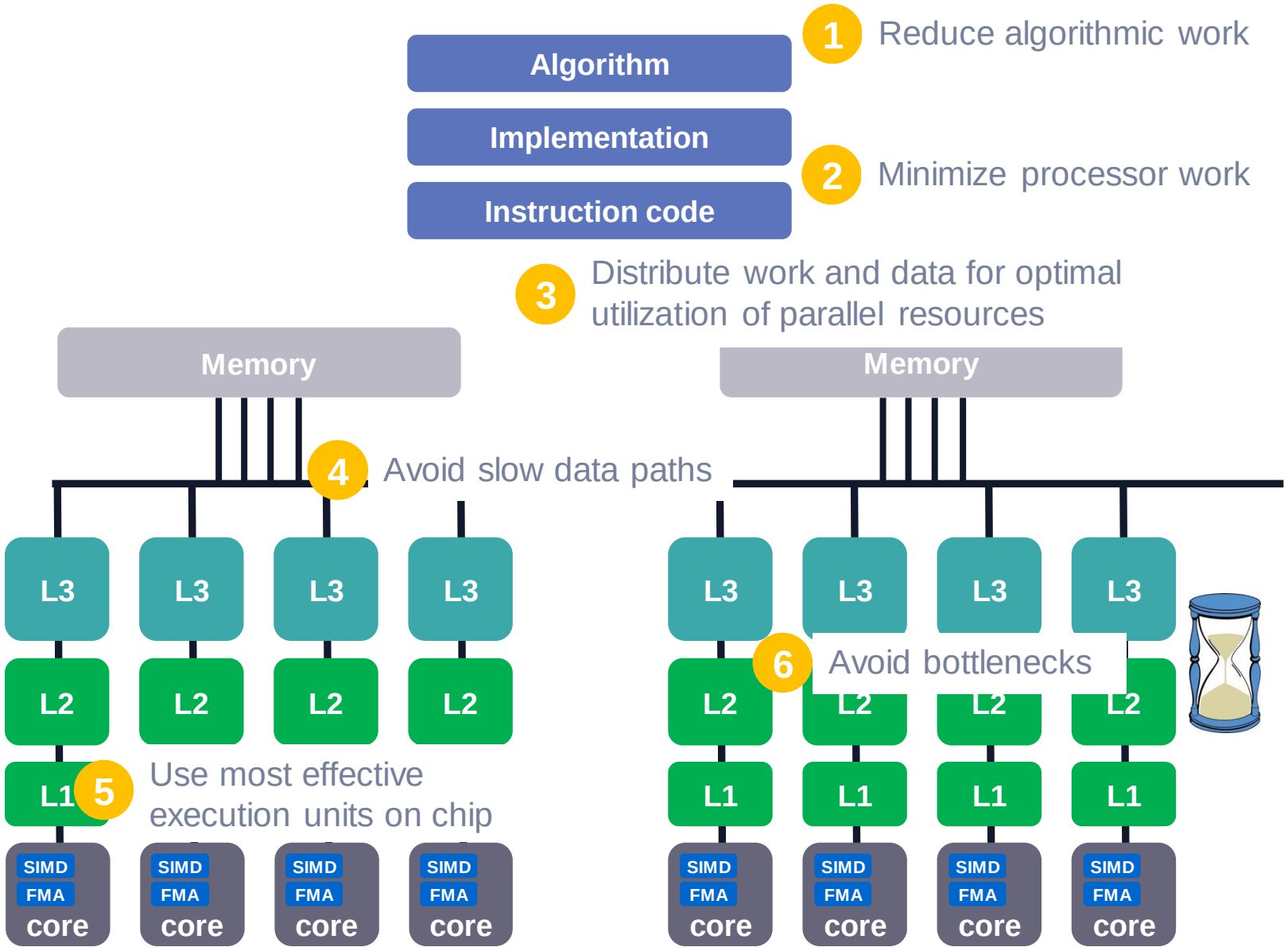
NHR FAU

FAU Friedrich-Alexander-Universität Erlangen-Nürnberg

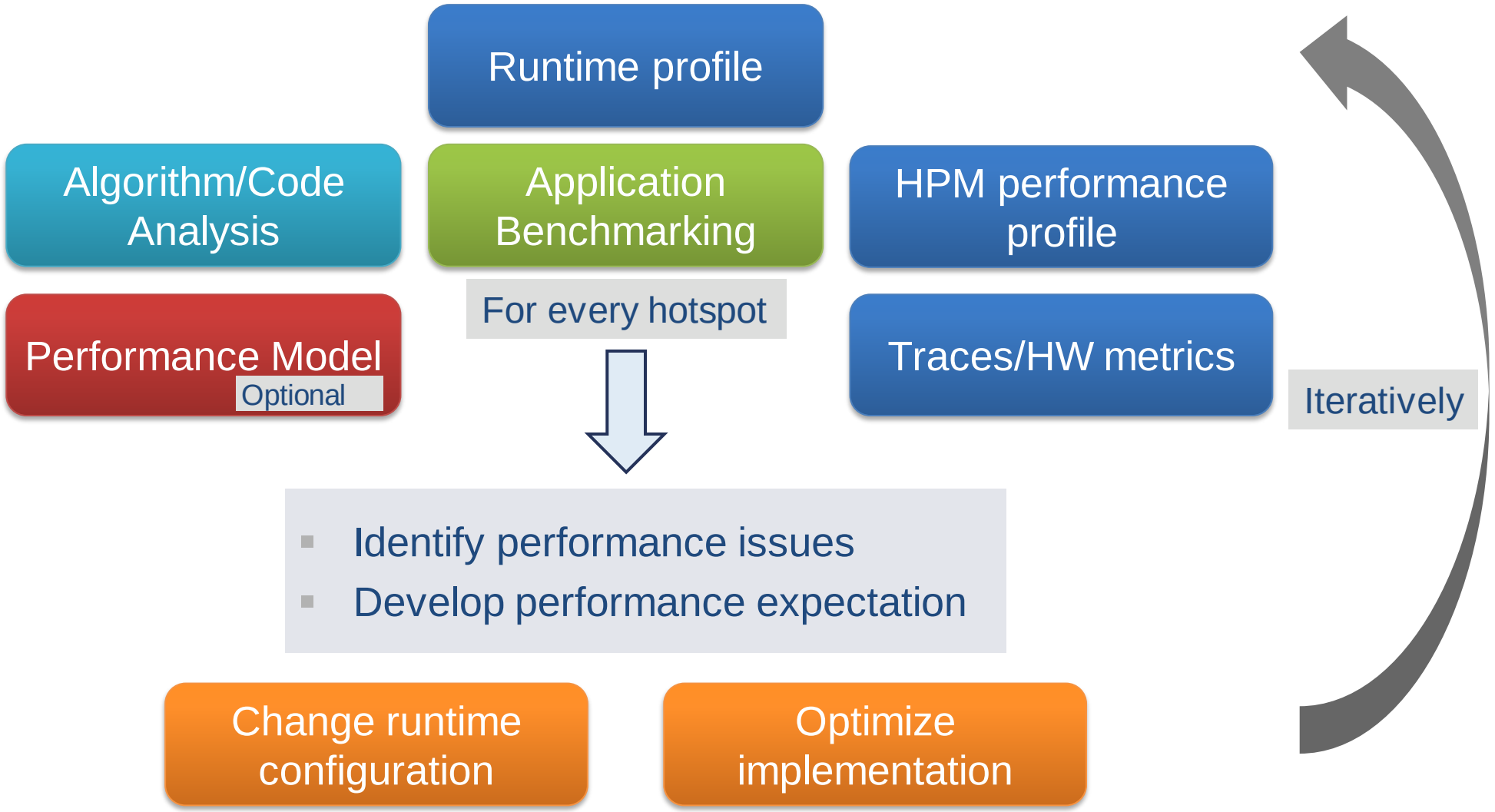
# Performance Engineering

Basic skills and knowledge

# Optimizing code: The big Picture



# Performance Engineering process



# Runtime profiling with gprof

Instrumentation based with gprof

Compile with **-pg** switch:

```
icc -pg -O3 -c myfile1.c
```

Execute the application. During execution a file **gmon.out** is generated.

Analyze the results with:

```
gprof ./a.out | less
```

The output contains three parts: A flat profile, the call graph, and an alphabetical index of routines.

The flat profile is what you are usually interested in.

# Runtime profile with gprof: Flat profile

Time spent in routine itself

How often was it called

How much time was spent per call

```
Each sample counts as 0.01 seconds.
  %   cumulative   self              self     total
 time   seconds   seconds    calls   s/call   s/call  name
 66.86     26.14    26.14      502     0.05     0.05  ForceLJ::compute(Atom&, Neighbor&, Comm&, int)
 30.77     38.17    12.03       26     0.46     0.46  Neighbor::build(Atom&)
  1.43     38.73     0.56        1     0.56    38.46  Integrate::run(Atom&, Force*, Neighbor&, Comm&, Thermo&, Timer&)
  0.36     38.87     0.14     2850     0.00     0.00  Atom::pack_comm(int, int*, double*, int*)
  0.15     38.93     0.06     2850     0.00     0.00  Atom::unpack_comm(int, int, double*)
  0.13     38.98     0.05       26     0.00     0.00  Atom::pbc()
  0.10     39.02     0.04                             __intel_ssse3_rep_memcpy
  0.08     39.05     0.03       25     0.00     0.00  Atom::sort(Neighbor&)
  0.08     39.08     0.03        1     0.03     0.03  create_atoms(Atom&, int, int, int, double)
  0.05     39.10     0.02       26     0.00     0.00  Comm::borders(Atom&)
  0.00     39.10     0.00  1221559     0.00     0.00  Atom::pack_border(int, double*, int*)
  0.00     39.10     0.00  1221559     0.00     0.00  Atom::unpack_border(int, double*)
  0.00     39.10     0.00   131072     0.00     0.00  Atom::addatom(double, double, double, double, double, double)
  0.00     39.10     0.00     1025     0.00     0.00  Timer::stamp(int)
  0.00     39.10     0.00      502     0.00     0.00  Thermo::compute(int, Atom&, Neighbor&, Force*, Timer&, Comm&)
  0.00     39.10     0.00      500     0.00     0.00  Timer::stamp()
  0.00     39.10     0.00      475     0.00     0.00  Comm::communicate(Atom&)
  0.00     39.10     0.00       26     0.00     0.00  Comm::exchange(Atom&)
  0.00     39.10     0.00       25     0.00     0.00  Timer::stamp_extra_stop(int)
  0.00     39.10     0.00       25     0.00     0.00  Timer::stamp_extra_start()
  0.00     39.10     0.00       25     0.00     0.00  Neighbor::binatoms(Atom&, int)
  0.00     39.10     0.00        7     0.00     0.00  Timer::barrier_stop(int)
  0.00     39.10     0.00        1     0.00     0.00  create_box(Atom&, int, int, int, double)
  0.00     39.10     0.00        1     0.00     0.00  create_velocity(double, Atom&, Thermo&)
```

Output is sorted according to total time spent in routine.

# Sampling-based runtime profile with perf

Call executable with perf:

```
perf record -g ./a.out
```

Analyze the results with:

```
perf report
```

Advantages vs. gprof:

- Works on any binary without recompile
- Also captures OS and runtime symbols

```
Samples: 30K of event 'cycles:uppp', Event count (approx.): 20629160088
Overhead  Command          Shared Object          Symbol
  64.19%  miniMD-ICC       miniMD-ICC             [.] ForceLJ::compute
  31.54%  miniMD-ICC       miniMD-ICC             [.] Neighbor::build
   1.47%  miniMD-ICC       miniMD-ICC             [.] Integrate::run
   0.67%  miniMD-ICC       [kernel]               [k] irq_return
   0.40%  miniMD-ICC       miniMD-ICC             [.] Atom::pack_comm
   0.35%  mpiexec          [kernel]               [k] sysret_check
   0.21%  miniMD-ICC       miniMD-ICC             [.] create_atoms
   0.18%  miniMD-ICC       miniMD-ICC             [.] Atom::unpack_comm
   0.15%  miniMD-ICC       [kernel]               [k] sysret_check
   0.15%  miniMD-ICC       miniMD-ICC             [.] Comm::borders
   0.10%  miniMD-ICC       miniMD-ICC             [.] __intel_ssse3_rep_memcpy
   0.09%  miniMD-ICC       miniMD-ICC             [.] Atom::sort
   0.07%  miniMD-ICC       miniMD-ICC             [.] Neighbor::binatoms
```

# Command line version of Intel Amplifier

Works out of the box for MPI/OpenMP parallel applications.

Example usage with MPI:

```
mpirun -np 2 amplxe-cl -collect hotspots -result-dir myresults -- a.out
```

- Compile with debugging symbols
- Can also resolve inlined C++ routines
- Many more collect modules available including hardware performance monitoring metrics

```
Elapsed Time: 8.650s
    CPU Time: 8.190s
        Effective Time: 8.190s
            Idle: 0.020s
            Poor: 8.170s
            Ok: 0s
            Ideal: 0s
            Over: 0s
        Spin Time: 0s
        Overhead Time: 0s
    Total Thread Count: 2
    Paused Time: 0s

Top Hotspots
Function                       Module      CPU Time
-----------------------------  ----------  --------
ForceLJ::compute_fullneigh     miniMD-ICC    4.940s
Neighbor::build                miniMD-ICC    2.820s
Integrate::finalIntegrate      miniMD-ICC    0.100s
Integrate::initialIntegrate    miniMD-ICC    0.060s
__intel_ssse3_rep_memcpy       miniMD-ICC    0.040s
[Others]                       N/A           0.230s
```

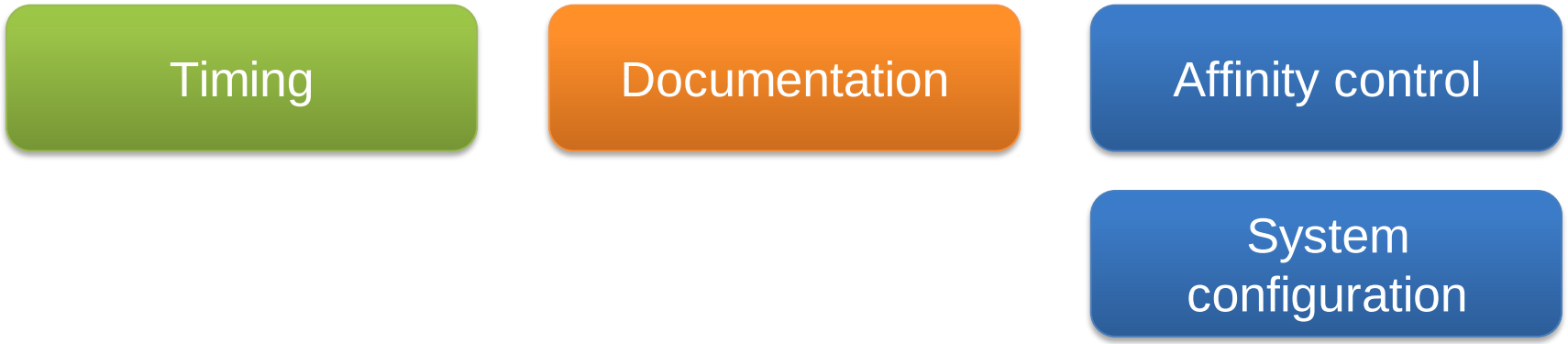
# Application benchmarking preparation

- Discuss and prepare relevant benchmark test case(s)
  - Short turnaround time
  - Representative of real production runs
- For long term multi-site PE projects you may extract a proxy application
  - Simplified version of app (or a part of it) that still captures the relevant performance behavior
- Define an application-specific performance metric
  - Should avoid “trivial” dependencies on problem parameters (see later)
  - Common choice: Useful work performed per time unit

# Application benchmarking components

Performance measurements must be accurate, deterministic and reproducible.

Components for application benchmarking:




Always run benchmarks on an exclusive system!

# Timing within program code

For benchmarking, an accurate wall-clock timer (end-to-end stop watch) is required:

- **`clock_gettime()`** POSIX compliant timing function
- **`MPI_Wtime()`** and **`omp_get_wtime()`** Standardized programming-model-specific timing routines for MPI and OpenMP

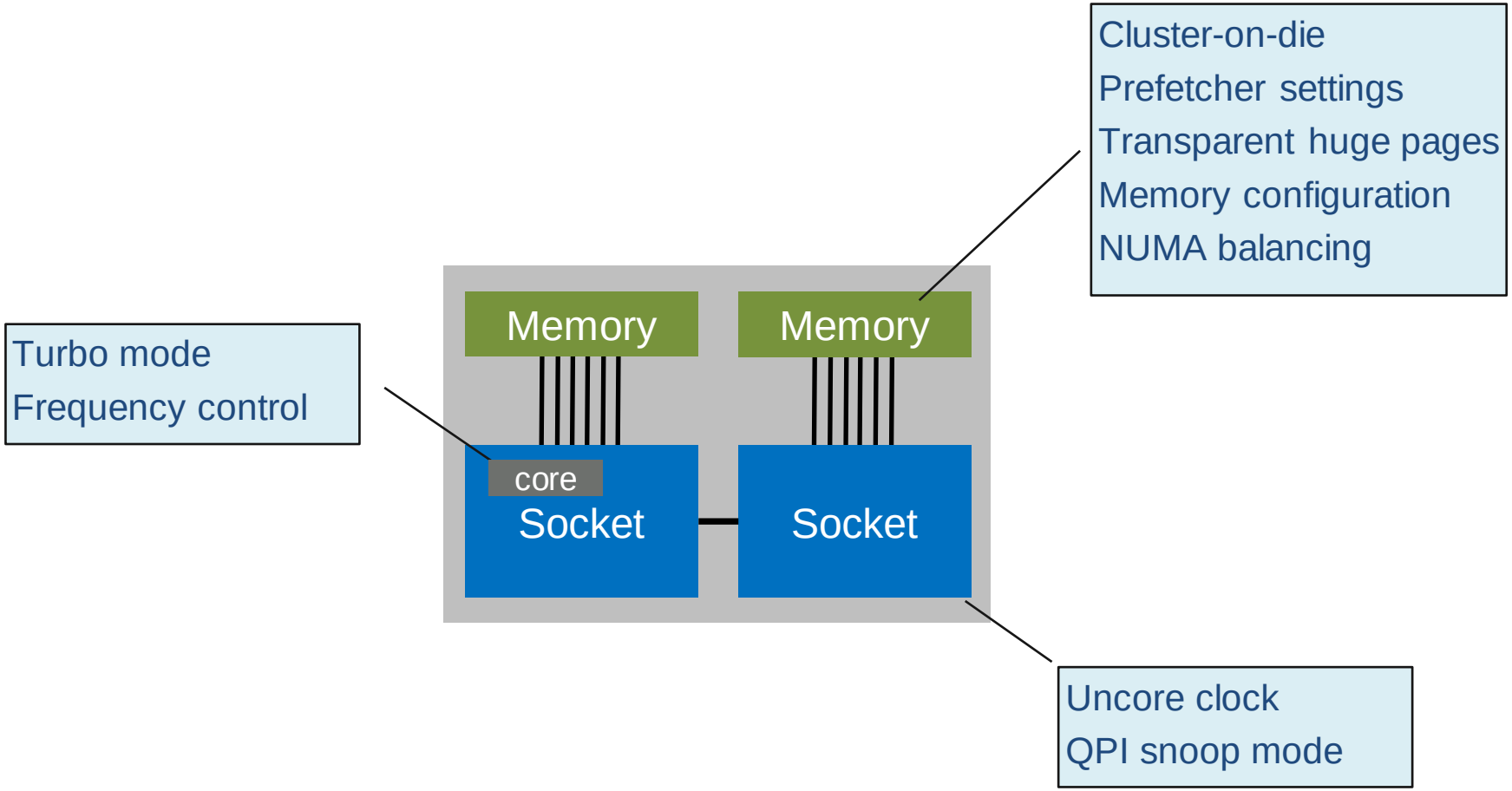
```
#include <stdlib.h>
#include <time.h>

double getTimeStamp()
{
    struct timespec ts;
    clock_gettime(CLOCK_MONOTONIC, &ts);
    return (double)ts.tv_sec + (double)ts.tv_nsec * 1.e-9;
}
```

Usage:

```
double S, E;
S = getTimeStamp();
/* measured code region */
E = getTimeStamp();
return E-S;
```

https://github.com/RRZE-HPC/TheBandwidthBenchmark/

# System configuration and clock frequency



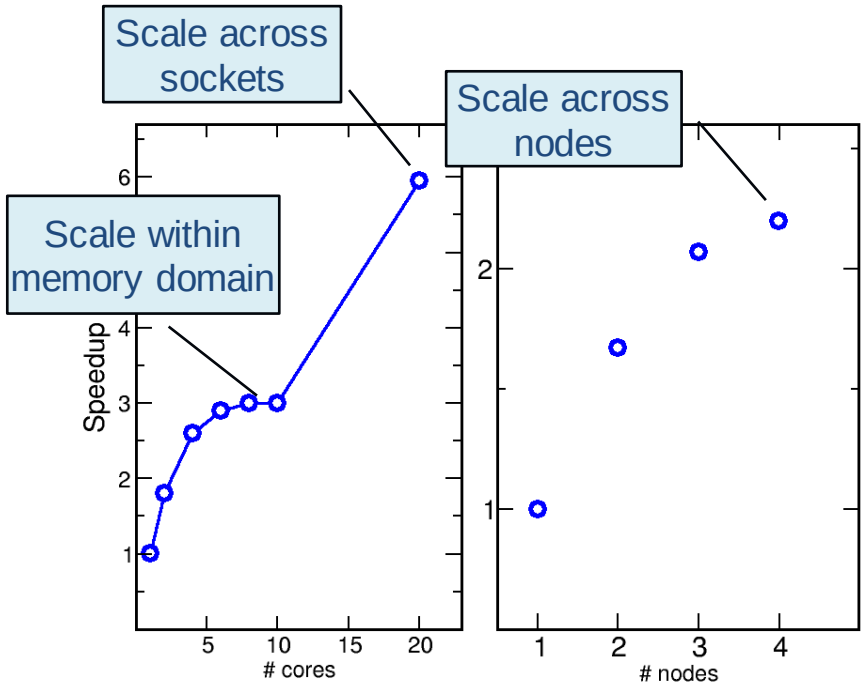

Tool for system state dump (requires Likwid tools):

**https://github.com/RRZE-HPC/MachineState**

# Benchmark planning

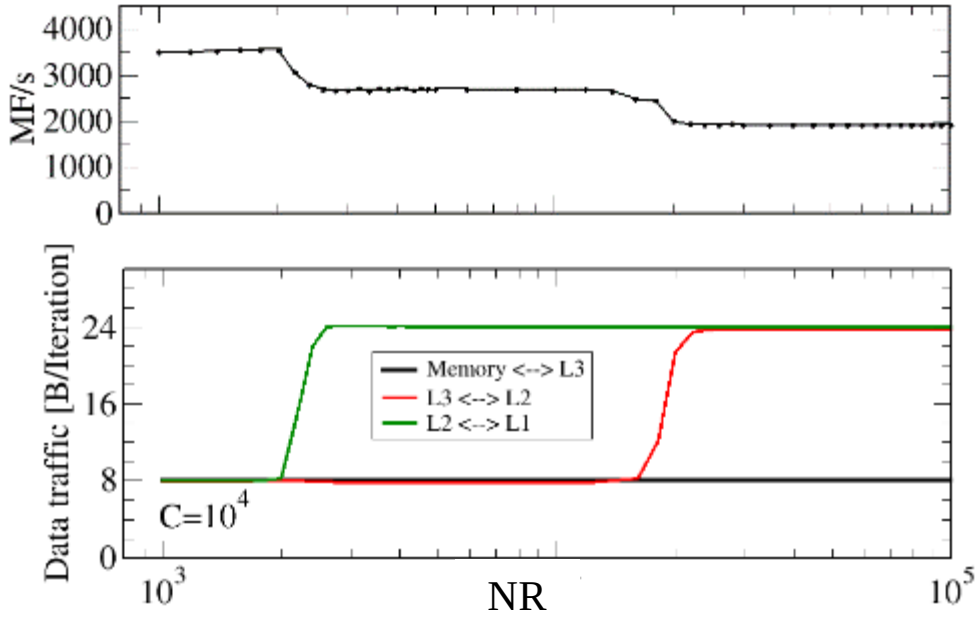
Two common variants:

## Core/node/device count




Choosing the right scaling baseline

## Dataset size




- Measure with one process (to start with)
- Scan dataset size in fine steps
- Verify the data volumes with a HPM tool

# The Performance Logbook

- Manual and knowledge collection how to build, configure and run application
- Document activities and results in a structured way
- Learn about best practice guidelines for performance engineering
- Serve as a well-defined and simple way to exchange and hand over performance projects

The logbook consists of a single markdown document, helper scripts, and directories for input, raw results, and media files.

**https://github.com/RRZE-HPC/ThePerformanceLogbook**