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Programming with MPI & OpenMP

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High-Performance Computing Infrastructure for South East Europe's Research Communities

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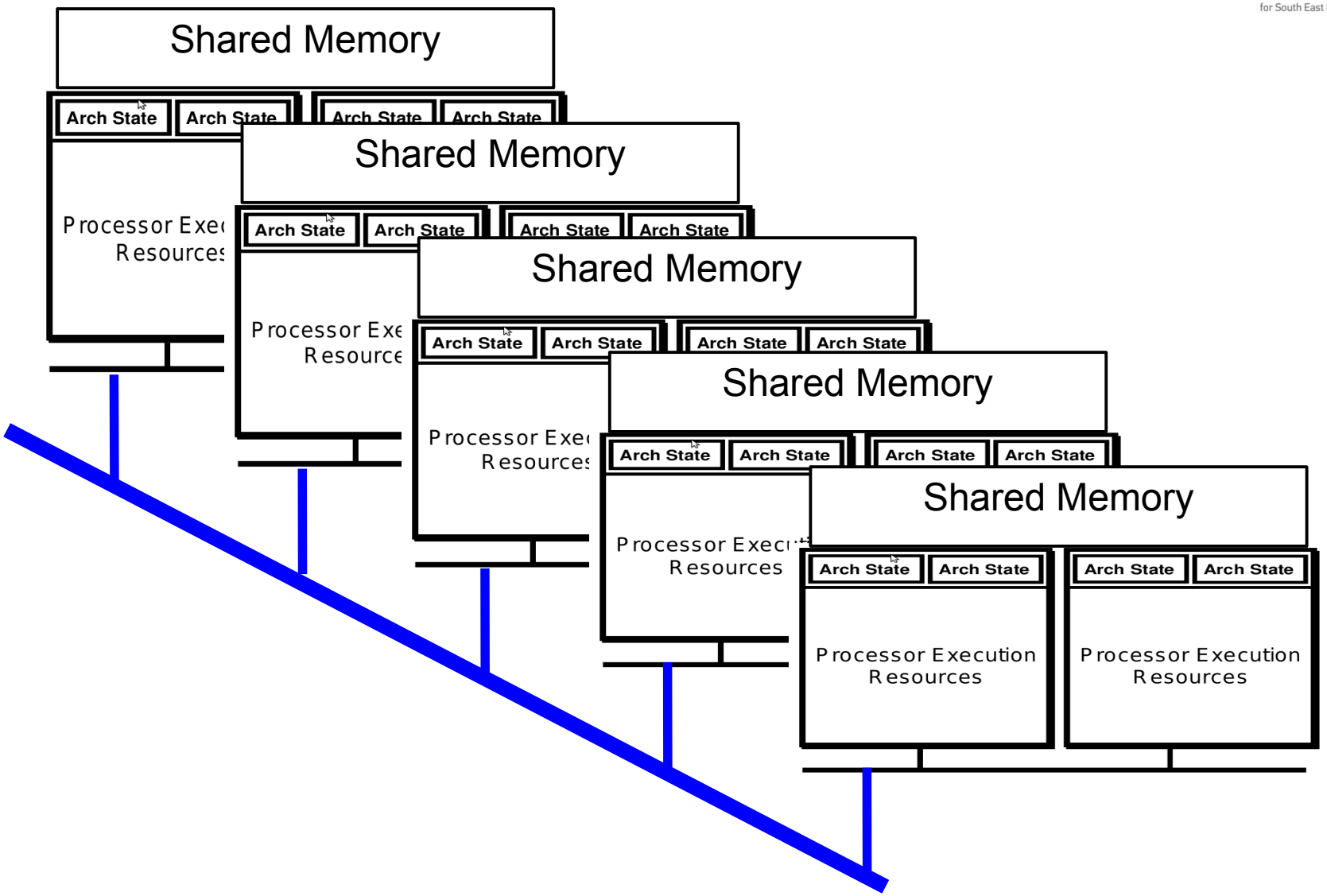
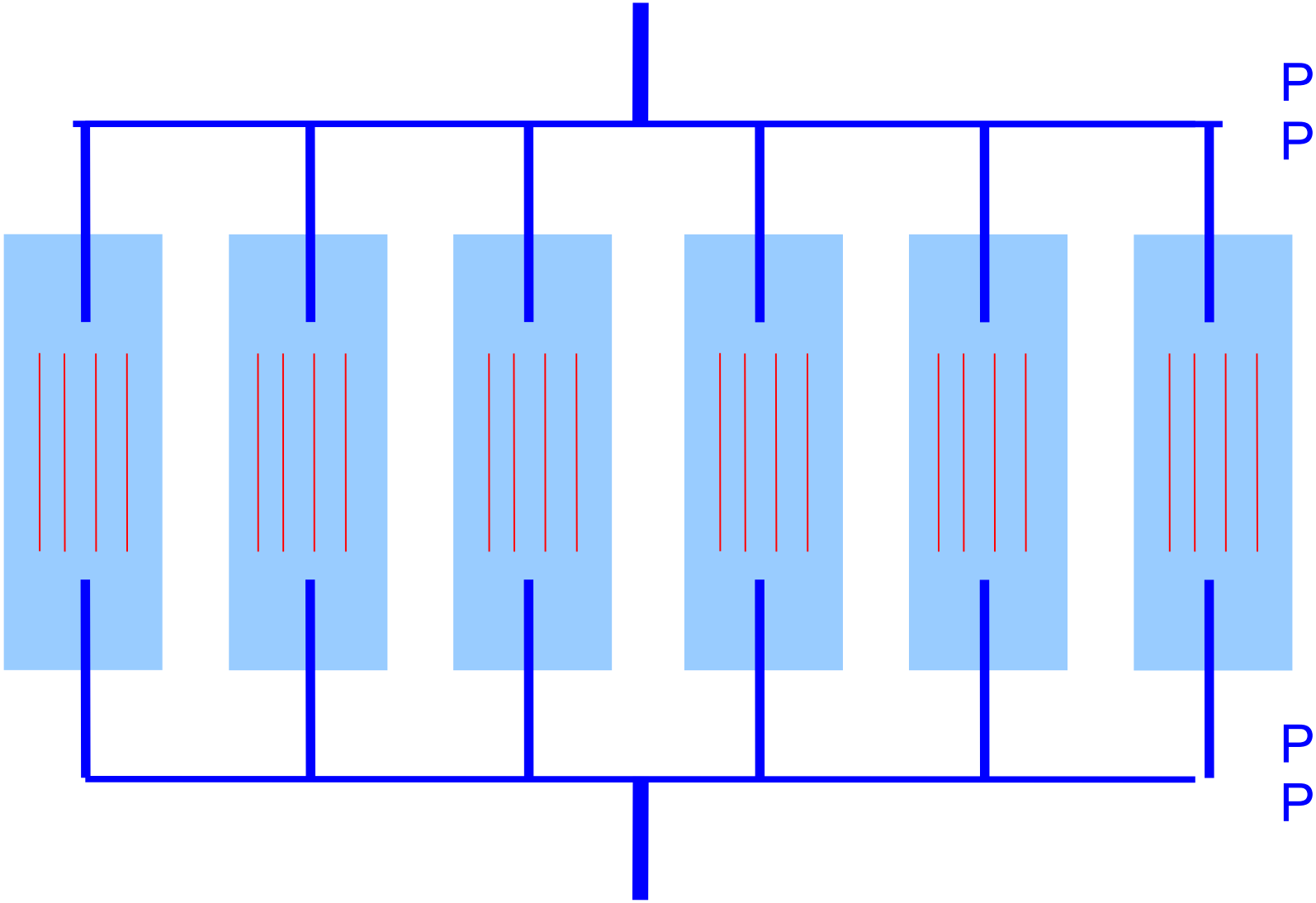
The HP-SEE initiative is co-funded by the European Commission under the FP7 Research Infrastructures contract no. 261499

Typical HPC Architecture



Combined MPI & OpenMP



MPI&OpenMP Source Code

```
#include <mpi.h>
#include <stdio.h>
#include <stdlib.h>
#include <math.h>
typedef struct
{ double thred; double start; double  stop;
} metad; metad   * array, procs;
int main(int argc, char **argv)
{   int rank,size,noel,nopr,ntrd,i,j,k;
  double  sinsin, startime, stoptime;
  long int li, Nruntime;   Nruntime=9999999;
  nopr = 1; ntrd = 1; noel = 1;
  if (argc>1) nopr = atoi(argv[1]); // processes
  if (argc>2) ntrd = atoi(argv[2]); // threads
  if (argc>3) noel = atoi(argv[3]); // base iteration
  MPI_Init(&argc, &argv); // init MPI
  MPI_Comm_rank(MPI_COMM_WORLD, &rank);
  MPI_Comm_size(MPI_COMM_WORLD, &size);
// print inputs & take time in mother process
  if (rank==0)
  {  startime = MPI_Wtime();
     array = malloc(nopr*sizeof(metad));
     for (i=0; i<nopr; i++)
     {  array[i].thred=0; array[i].start=0; array[i].stop =0;
  } }
MPI_Scatter(&array[rank],3,MPI_DOUBLE,&procs,3,MPI_DOU
    BLE,0,MPI_COMM_WORLD);
// run processes inner loops
  procs.start = MPI_Wtime();
#pragma omp parallel for num_threads(ntrd) private(j, k, sinsin)
  for (j=0; j<16*noel/nopr; j++)
          for (k=0; k<Nruntime; k++)
          {  sinsin=sin(k);   }
// end of #pragma
  procs.thred= rank;   procs.stop = MPI_Wtime();
 MPI_Gather(&procs,3,MPI_DOUBLE,array,3,MPI_DOUBLE,0,
    MPI_COMM_WORLD);
// print process runtime vector in mother process
  if(rank==0)
  { for (i=0; i<nopr; i++)
          printf("Iter %d process %f Runtime %f \n",
          i, array[i].thred, array[i].stop - array[i].start);
      stoptime = MPI_Wtime();
      printf("time = %f \n",stoptime-startime);
  } MPI_Finalize(); // close MPI
  return 0; }
```

Comments on the Source

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MPI processes main loop is automatic

Within processes the internal loop is split in threads using PRAGMA directive

Internal loop upper bound multiplied by *noel* to increase iterations > processes * threads

Preparation of Test

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Compilation

build.sh = mpicc -fopenmp $1.c /usr/lib/libm.a -o $1

Script

run.sh = (/usr/bin/time mpirun -np $2 ./$1 $2 $3 $4)

Execution

./run.sh test <process> <threads> <iterations>

Tested in hardware

Dell Inspiron ~ 1 processor 2 cores

Run Example

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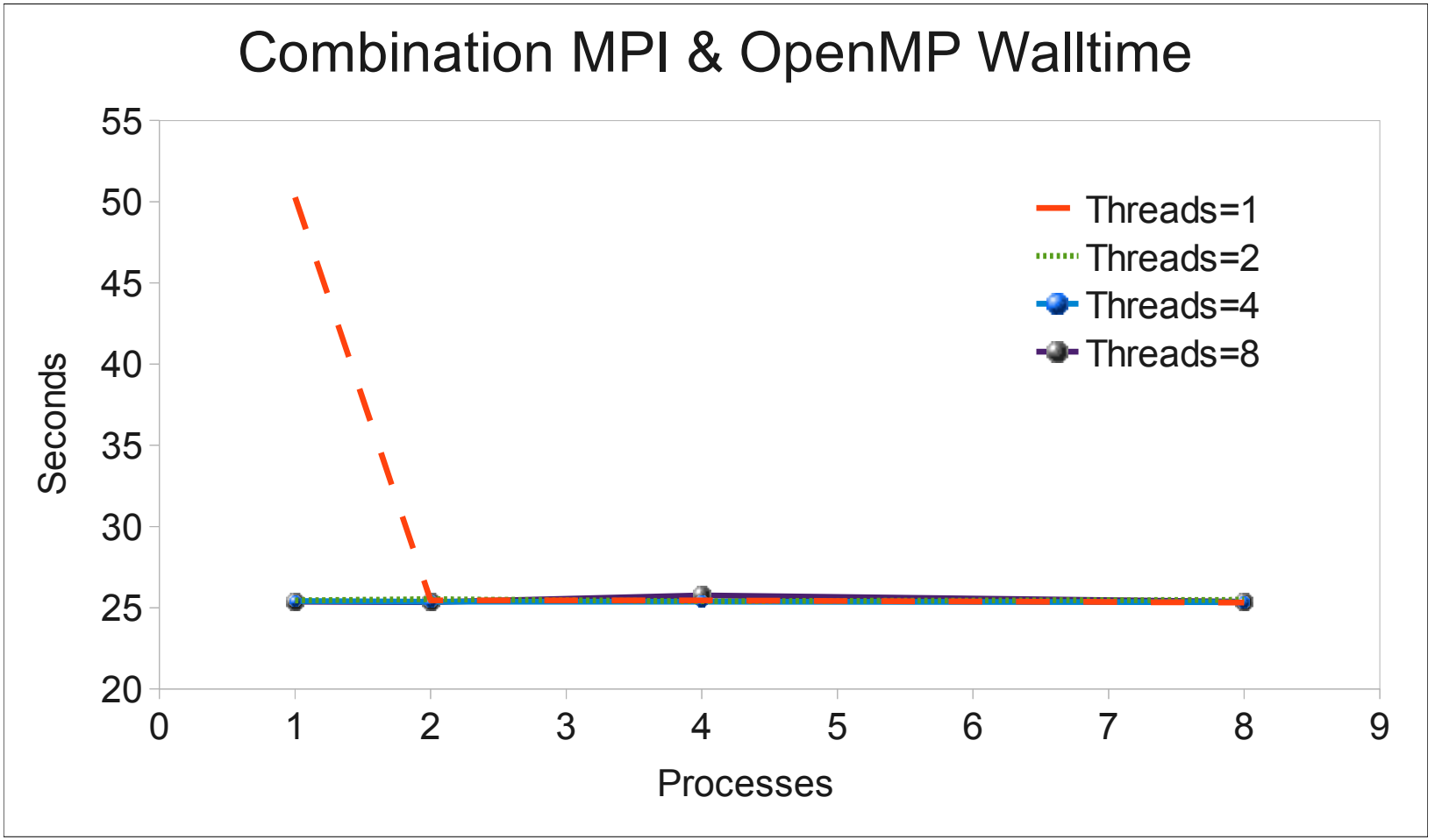
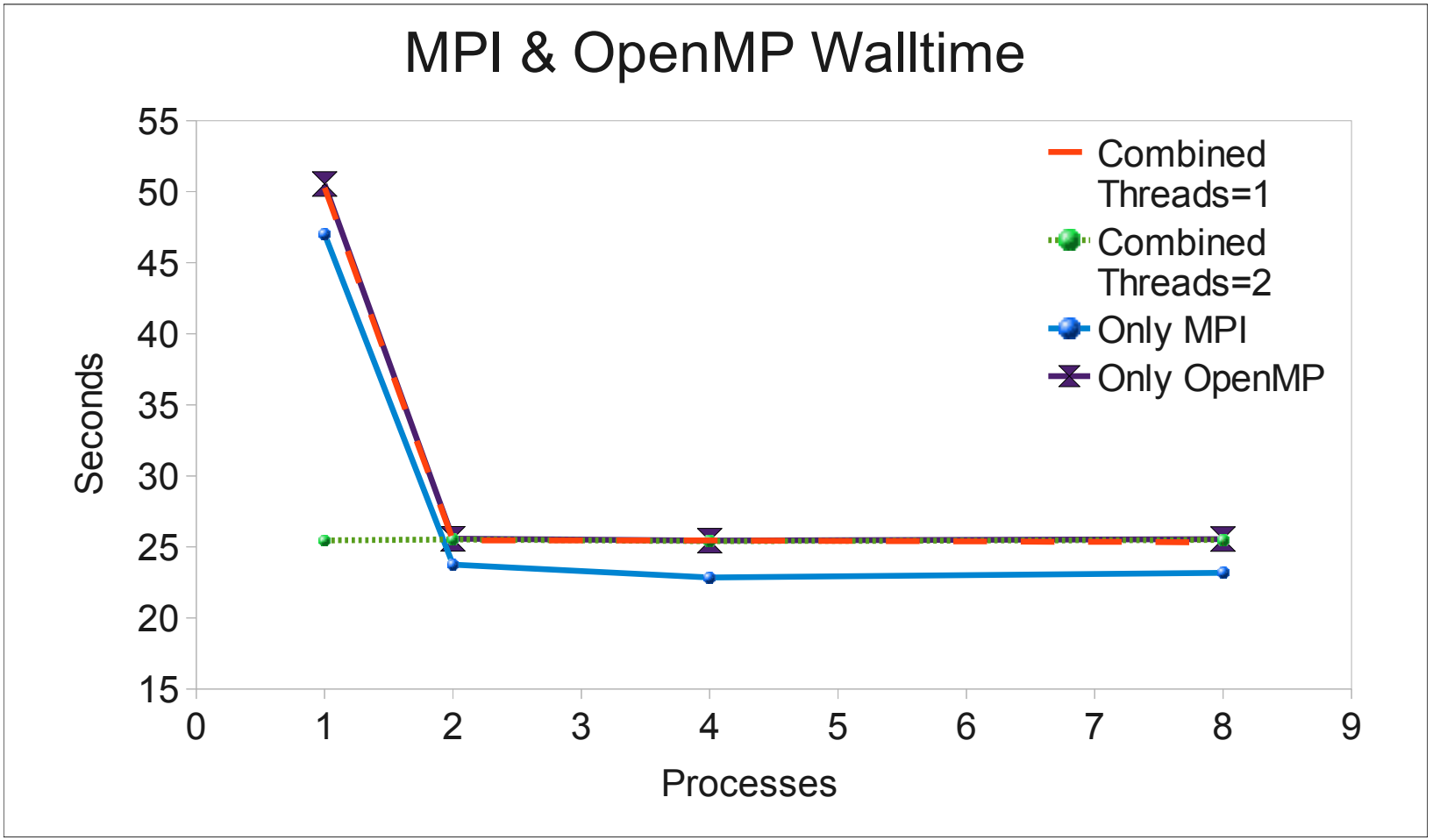
```
$ ./run.sh testime 8 4 4
input nopr=8 ntrd=4 noel=4
Iter 0 process 0.000000 Runtime 25.628089
Iter 1 process 1.000000 Runtime 25.627043
Iter 2 process 2.000000 Runtime 25.142232
Iter 3 process 3.000000 Runtime 25.625365
Iter 4 process 4.000000 Runtime 25.162345
Iter 5 process 5.000000 Runtime 25.624585
Iter 6 process 6.000000 Runtime 25.157813
Iter 7 process 7.000000 Runtime 25.598504
time = 25.628342
```

```
49.35user 0.07system 0:26.74elapsed 184%CPU
(0avgtext+0avgdata 16192maxresident)k
0inputs+5424outputs (27major+11367minor)pagefaults 0swaps
```

Test Walltime Chart



Compared with OpenMP / MPI



Comments on Performance

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Performance ~ number of cores

Difference when

- Processes=1 and threads=1
- Processes>1 or threads>1

in single processor with two cores

Performance dominated from OpenMP

Question – how the Intel architecture is exploited ???

Conclusions on MPI+OpenMP

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Effective when running in

- Multiprocessor system with multicore & shared memory processors
- Distributed cluster / grid of multicore systems

Issue => balancing between MIP ~ OpenMP