Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA

Understanding applications with Paraver

Judit Gimenez
judit@bsc.es

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Same code, different performance…

Is it me, or is it the machine?

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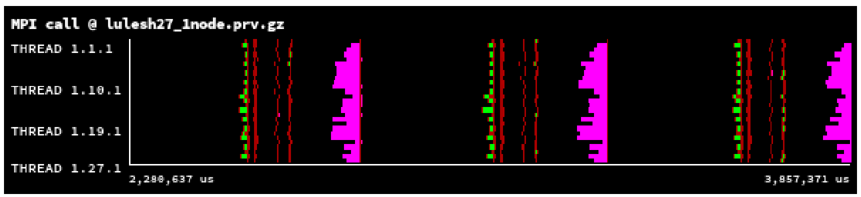
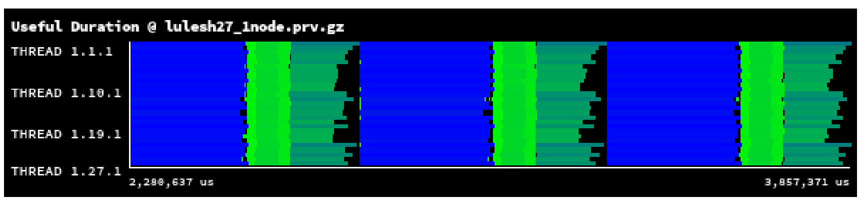
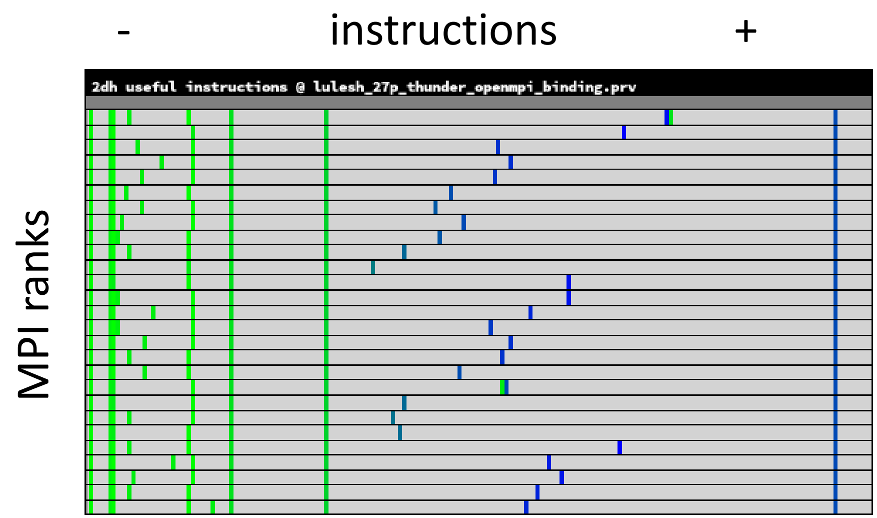
My favorite trainings default app : Lulesh 2.0

- Easy to install and does not require large input files
- Iterative behaviour, well balanced except one region due to instructions unbalance







- Requires a cube number of MPI ranks

  → my target = 27 ranks; no nodes/sockets sized 27 :)
  - No OpenMP
- Expected problem: some extra unbalance due to the unbalanced mapping

Same code, different behavior

Code	Parallel efficiency	Communication efficiency	Load Balance efficiency
lulesh@machine1	90.55	**99.22**	91.26
lulesh@machine2	**69.15**	99.12	**69.76**
lulesh@machine3	70.55	96.56	73.06
lulesh@machine4	83.68	95.48	87.64
lulesh@machine5	**90.92**	98.59	**92.20**
lulesh@machine6	73.96	97.56	75.81
lulesh@machine7	75.48	**88.84**	84.06
lulesh@machine8	77.28	92.33	83.70
lulesh@machine9	88.20	98.45	89.57
lulesh@machine10	81.26	91.58	88.73

Warning::: Higher parallel efficiency does not mean faster!

Huge variability and worse than expected. Can I explain why?

Now same machine… still different behavior

Playing with MPI @ A MPI	Parallel efficiency	Communication efficiency	Load Balance efficiency
IMPI	**85.65**	95.09	**90.07**
MPT	70.55	**96.56**	73.06

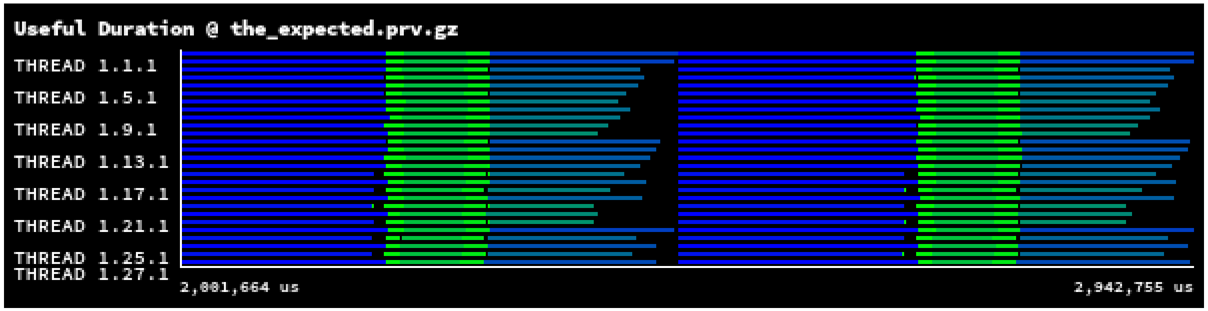
Playing with binding @ B configuration	Parallel efficiency	Communication efficiency	Load Balance efficiency
default	**81.26**	91.58	**88.73**
binding	75.10	**97.44**	77.07

Playing with both @ C MPI / configuration	Parallel efficiency	Communication efficiency	Load Balance efficiency
BullMPI / default	84.00	93.41	**89.35**
OpenMPI / default	79.45	**98.35**	80.73
OpenMPI / binding	82.10	95.08	86.35
BullMPI / binding	**85.15**	96.59	88.18

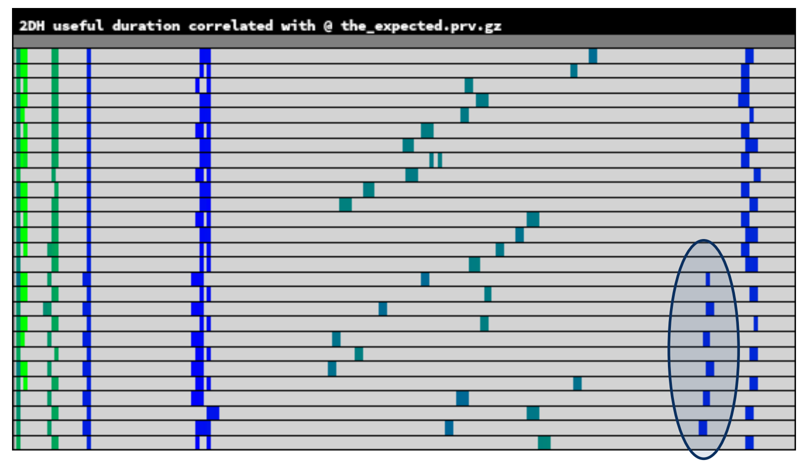
The expected

- Balance between nodes and across sockets

Parallel eff. 90.55%
Comm 99.22%
LB 91.26%



- Using 2 nodes x 2 sockets
- 3 sockets with 7 ranks, 1 socket with 6 ranks → small time unbalance



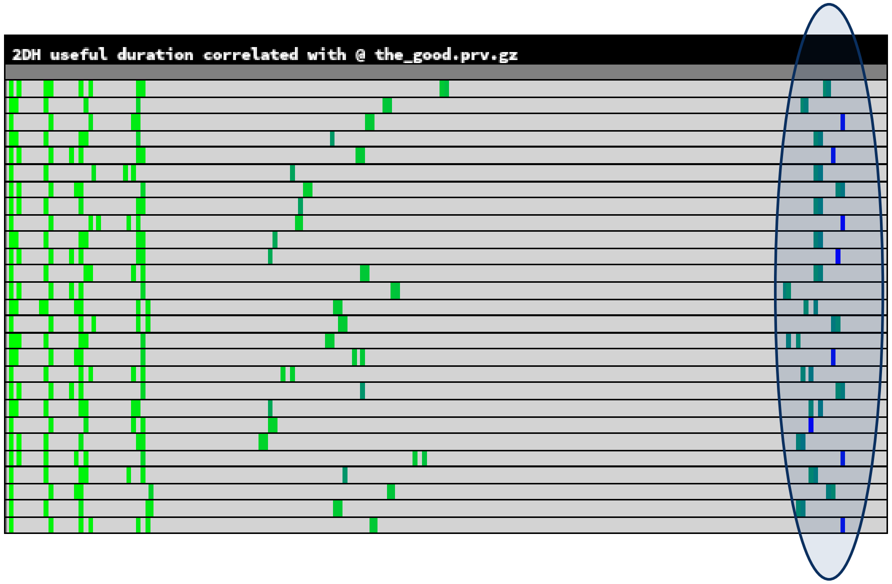
Less frequent than expected!

6 guys with more resources

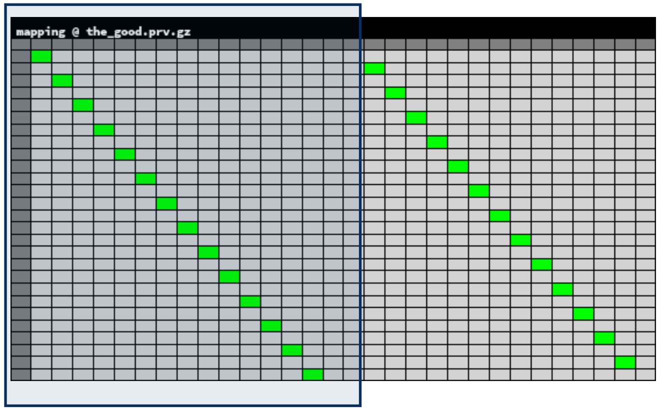
The good

Parallel eff. 90.92%
Comm 98.59%
LB 92.20%

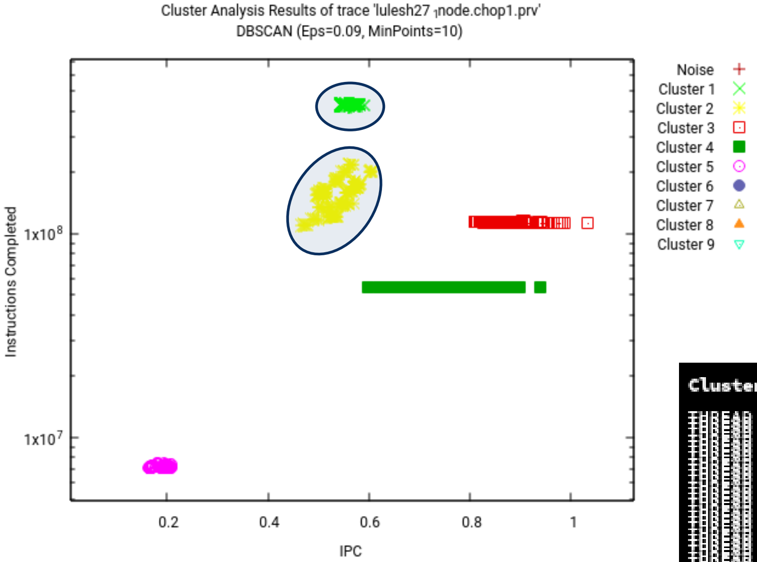
- 27 fits in a node



Alternate between sockets



first socket

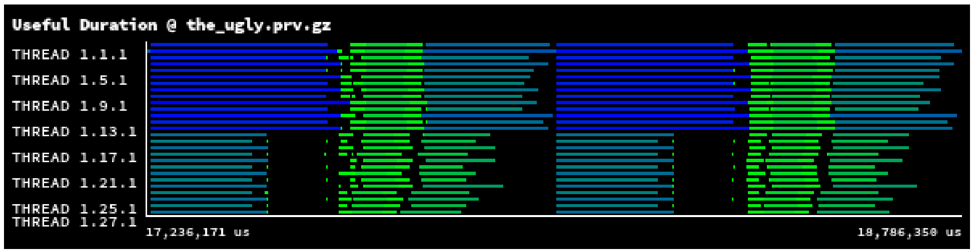


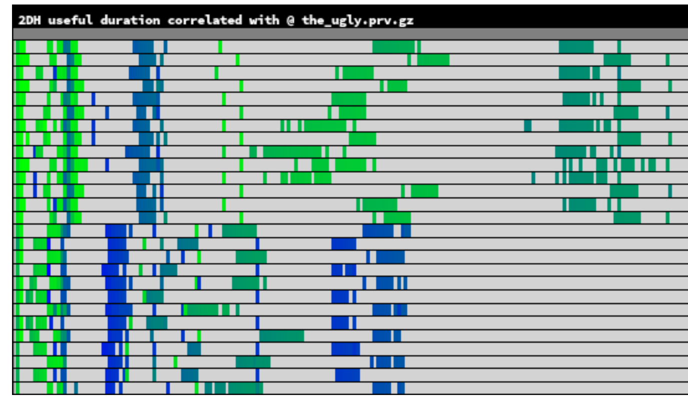
Small IPC variability in the 2 main regions

The ugly

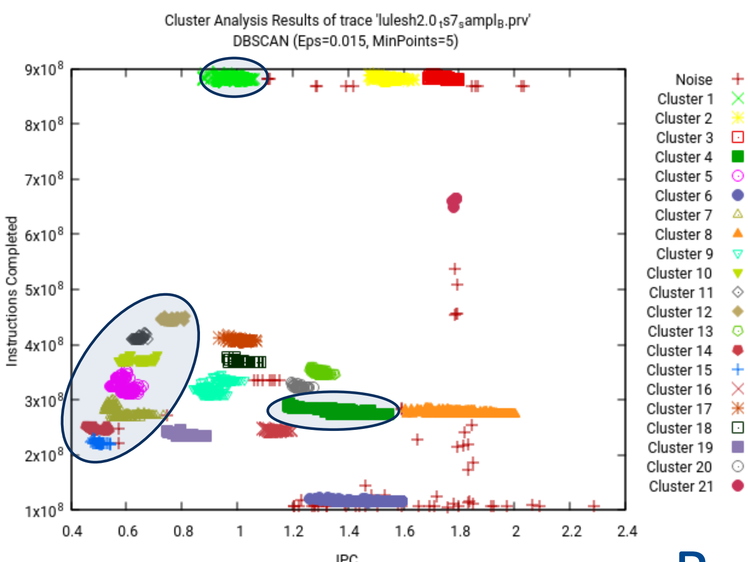
- Same code! but now two trends (one per node)

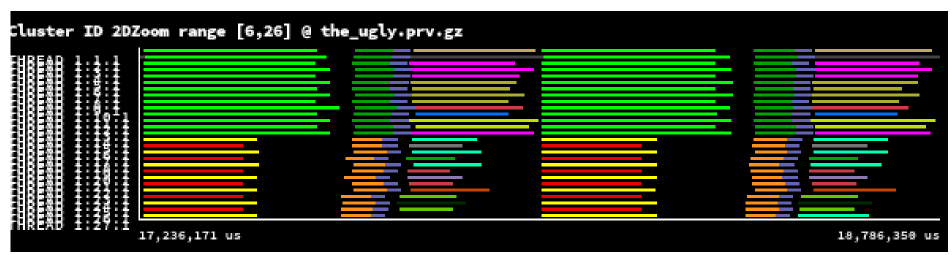
Parallel eff. 69.15%
Comm 99.12%
LB 69.76%





Slow node → significant lower IPC for almost all the regions

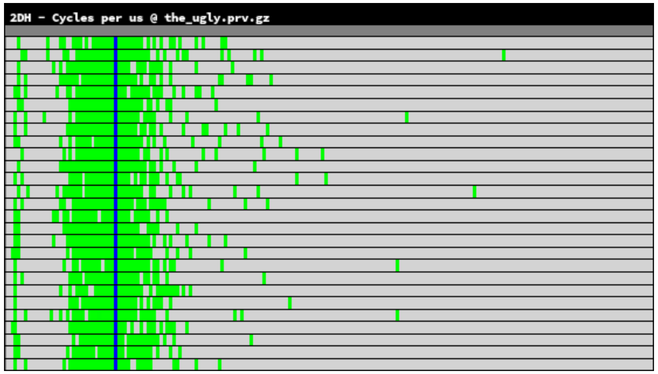


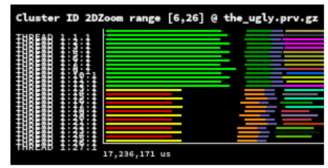


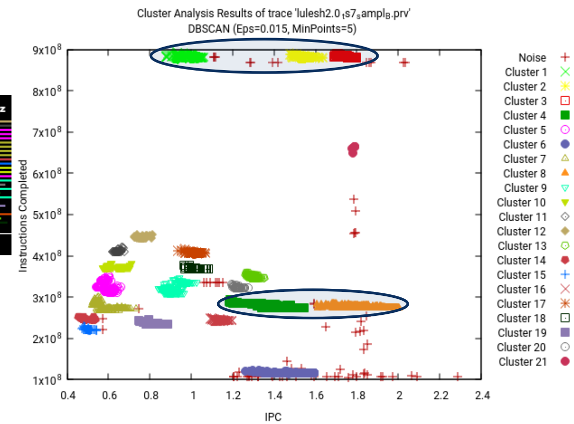
But all nodes are equal!

The ugly

Clock frequency sanity check







Insight checking hardware counters differences

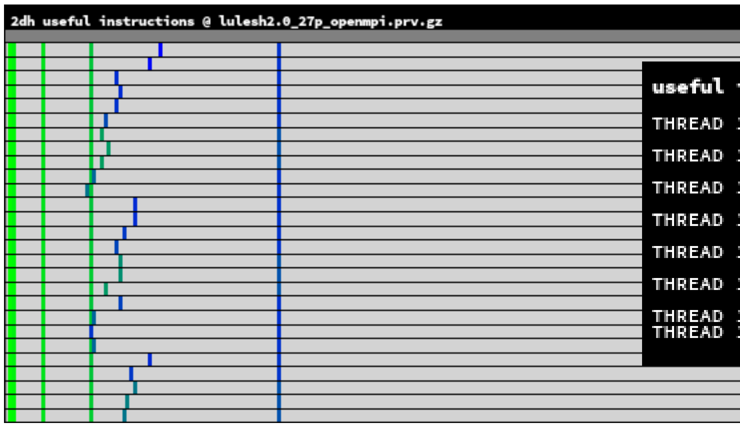
Cluster Name	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 8
Avg. Duration	347038882	218366724	191517484	76087437	57184253
PAPI_L1_DCM	*4253914*	*6369746*	*6360328*	*2195915*	*1540034*
PAPI_L2_DCM	*1647293*	*1984225*	*1864857*	*448603*	*258565*
PAPI_L3_TCM	*945265*	*1399329*	*1390967*	*160690*	*111273*
PAPI_TOT_INS	881368852	880939731	881303626	275104547	274379604
PAPI_TOT_CYC	900031546	566347103	496687512	197363737	148307597
RESOURCE_STALLS:SB	**257407726**	**154854806**	**106684134**	**74990020**	**38463538**
RESOURCE_STALLS:ROB	3191720	3170735	2722761	2684869	562054
RESOURCE_STALLS:RS	43484959	63717139	63017342	38768779	32699838

Guess: Memory problem – confirmed by sysadmin tests!

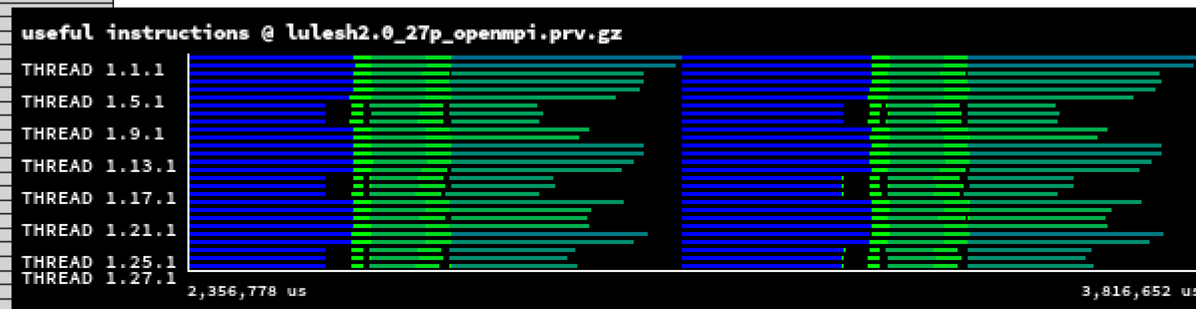
The unbalanced

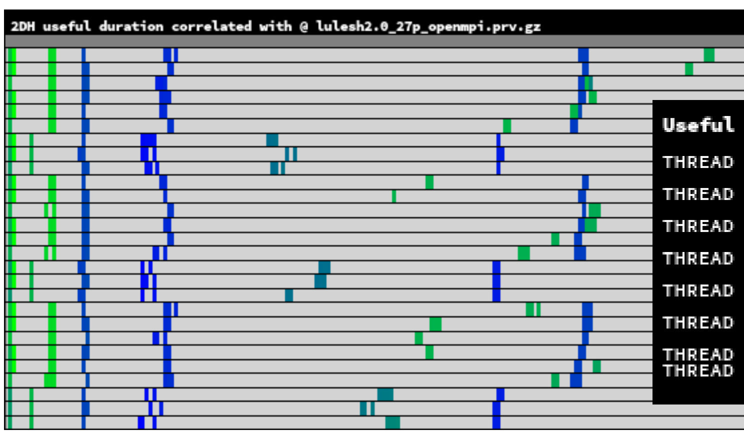
- Balance between nodes not between sockets

Parallel eff. 79.45%
Comm 98.35%
LB 80.73%

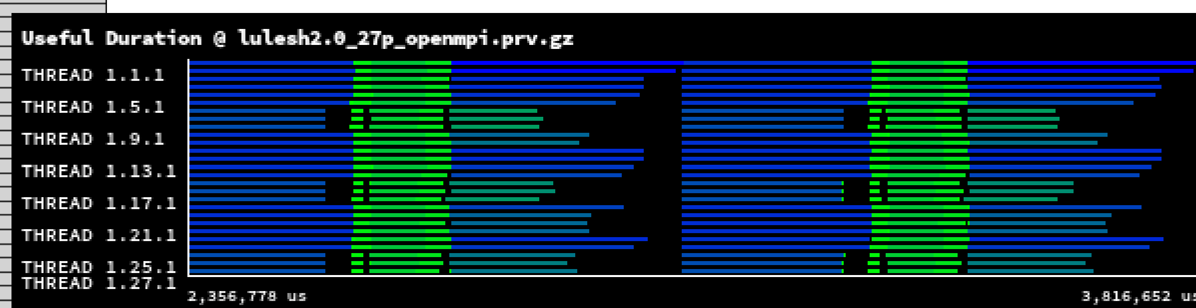


What lulesh does





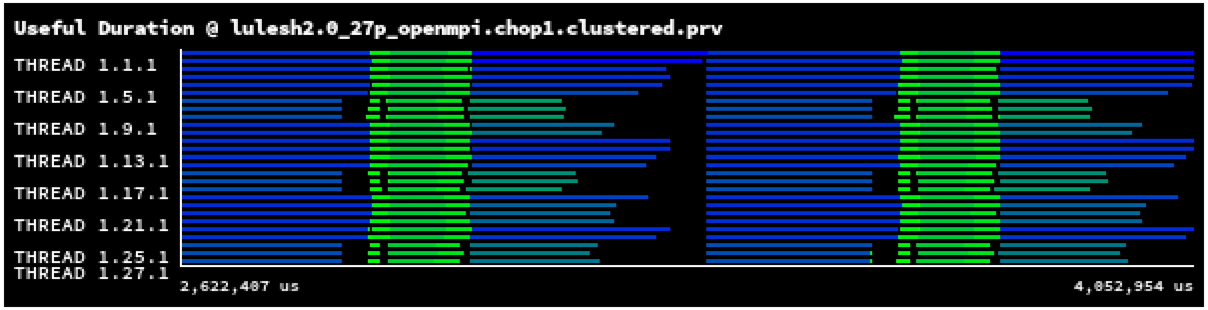
What the machine does running lulesh

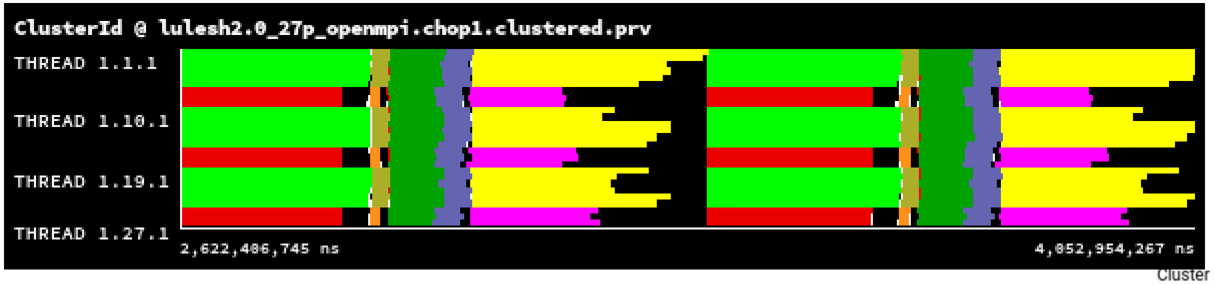


Balance between nodes → 9 per node

Fill first a socket→ 6 + 3

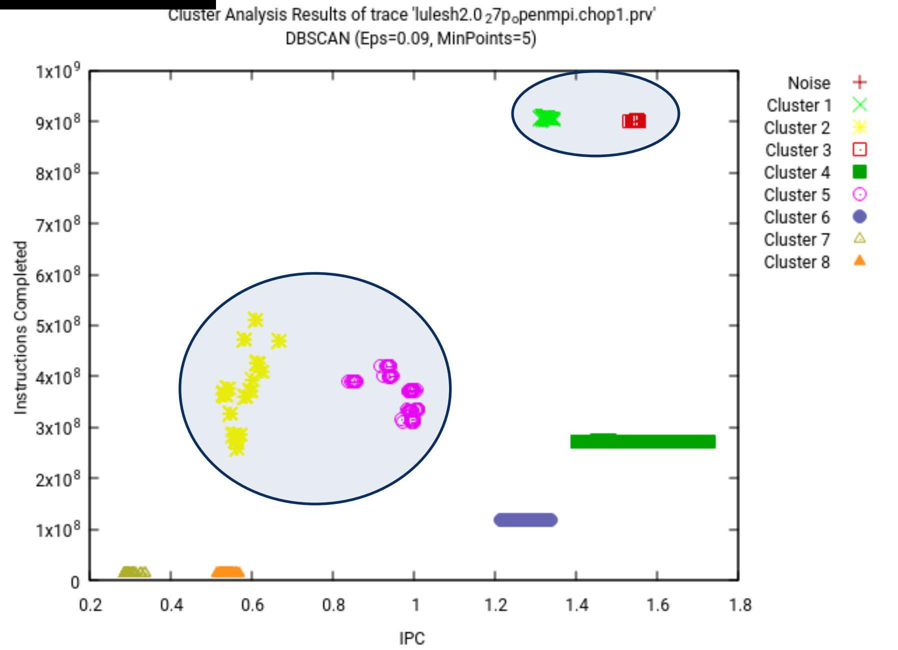
The unbalanced





Two main regions suffer the penalty of the different socket occupancy

Most frequent behaviour!



The bipolar

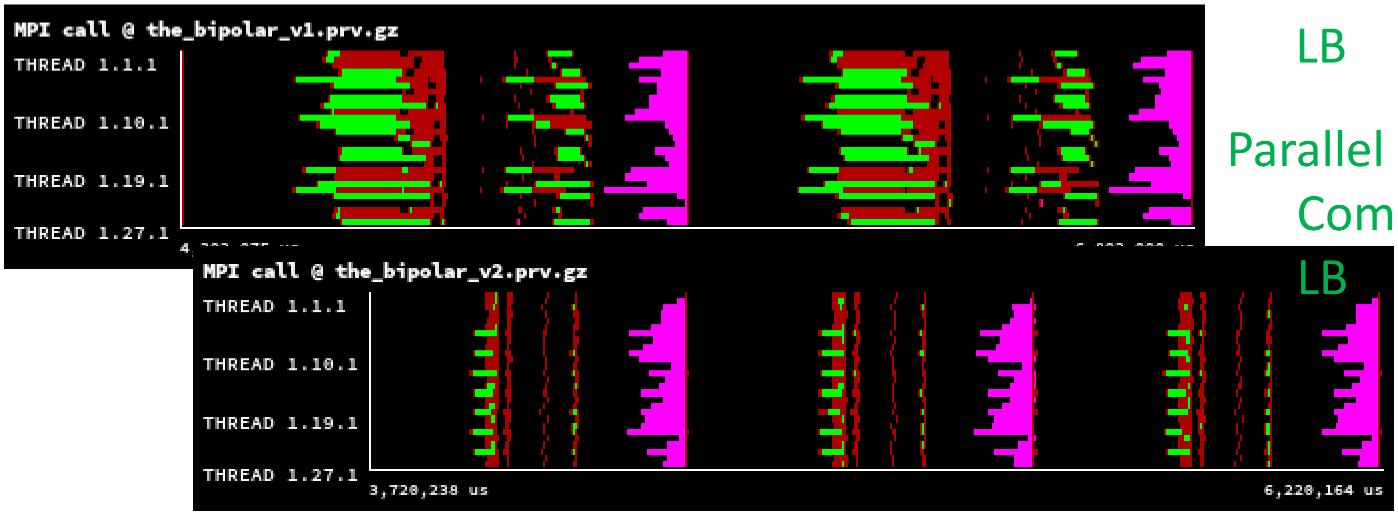
- MPI modify the computing phases behavior!

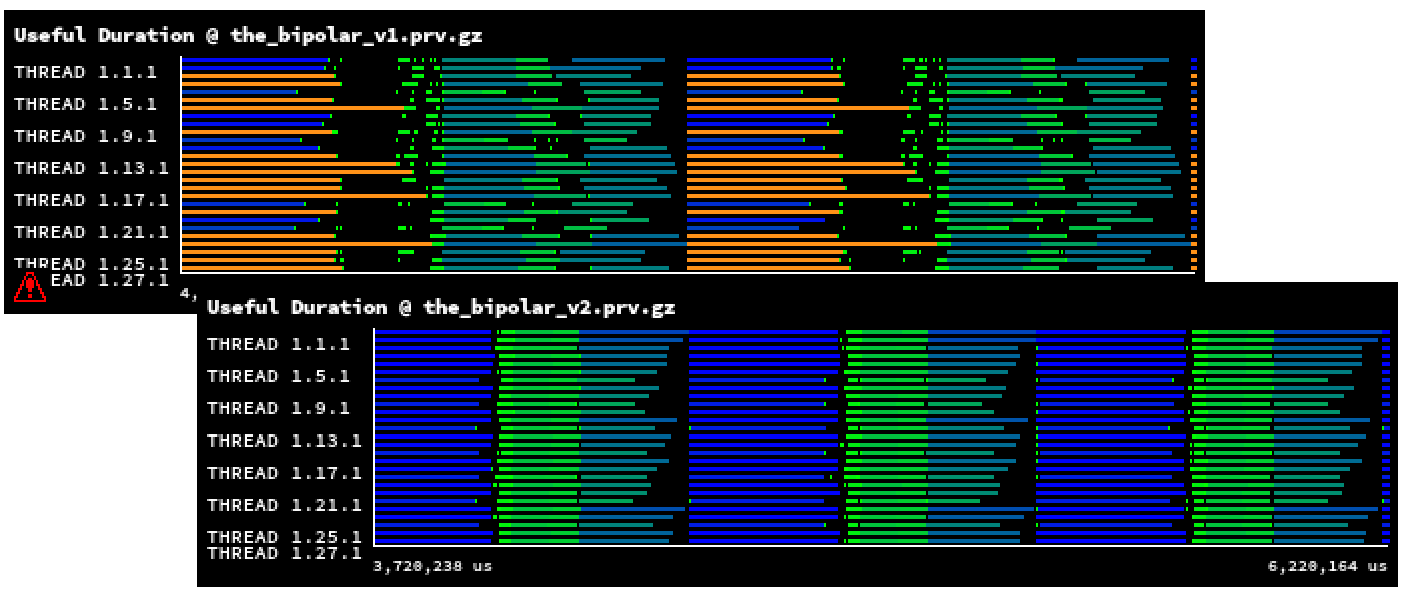
Parallel eff. 70.55%
Comm 96.56%
LB 73.06%

Parallel eff. 85.65%
Comm 95.09%
LB 90.07%

MPT

IMPI



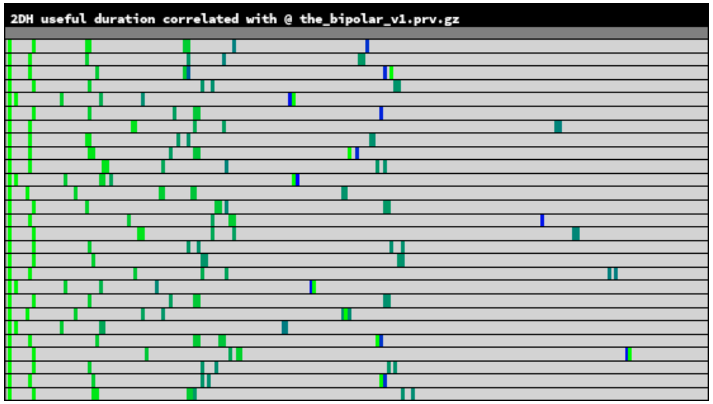


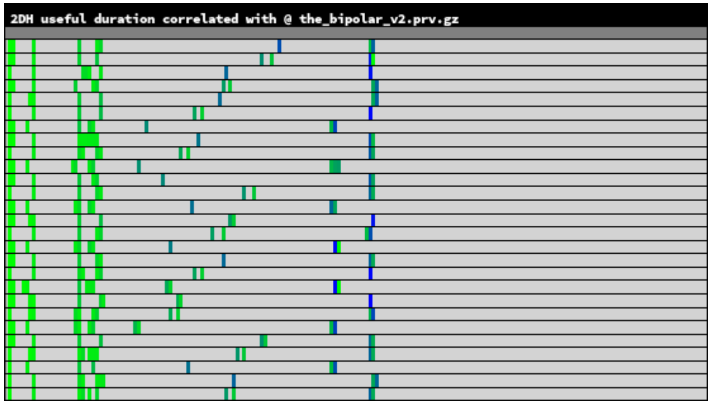
The bipolar

MPT

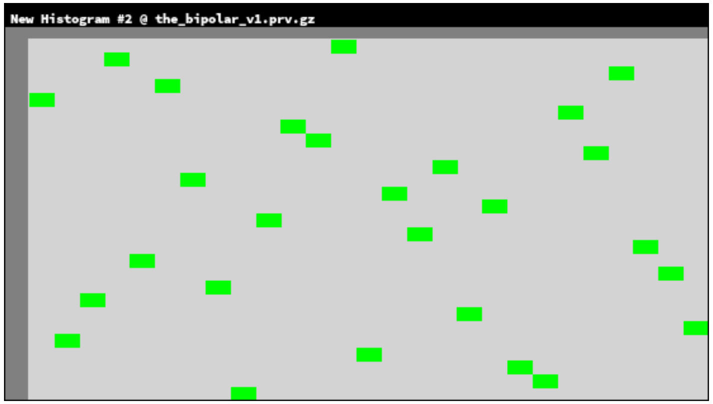
IMPI

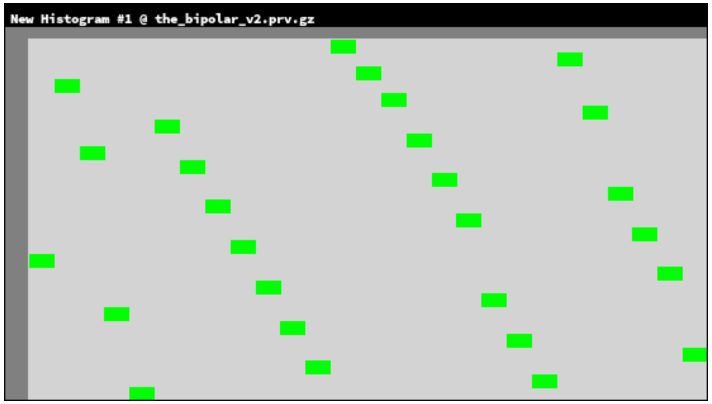
Histogram of useful duration





Process mapping “photo”



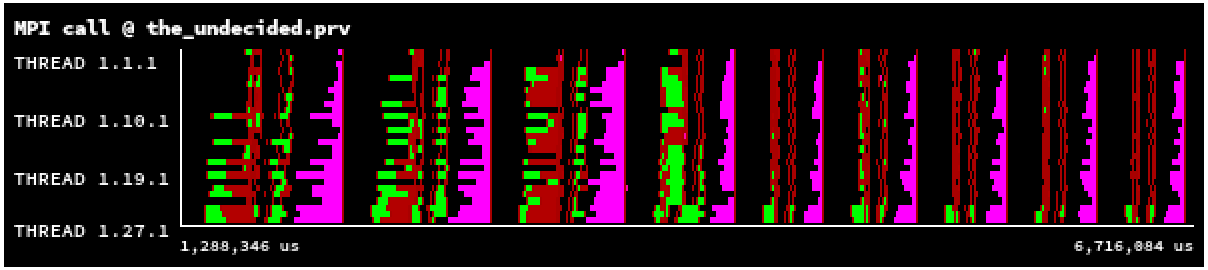


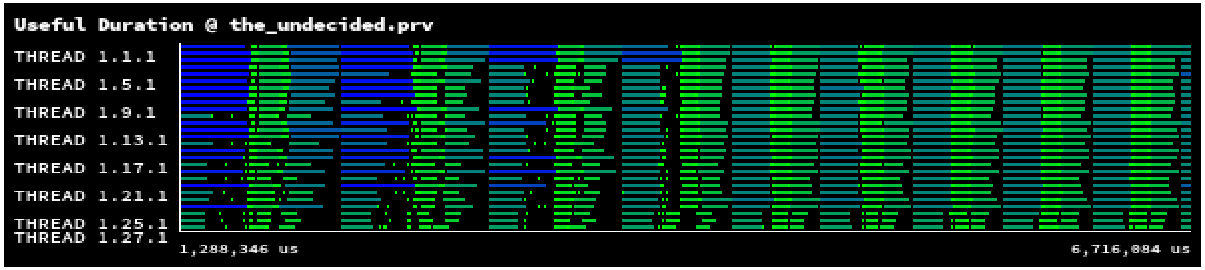
… because it can select a different mapping / binding

The undecided

- Same number of instructions per iteration showing a noisy behavior w.r.t time

Parallel eff. 77.28%
Comm 92.33%
LB 83.70%



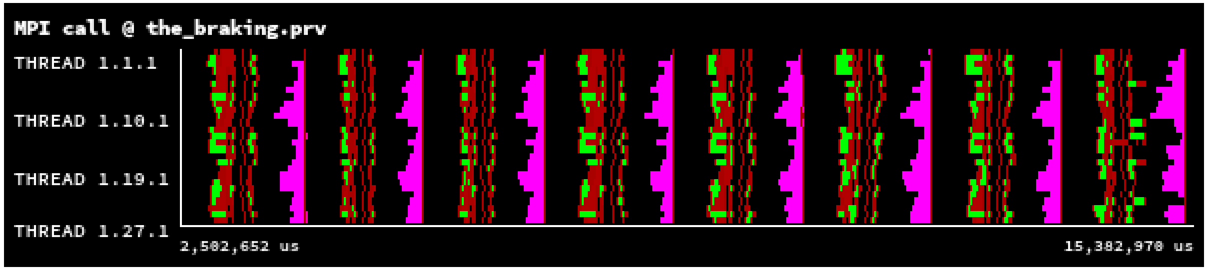


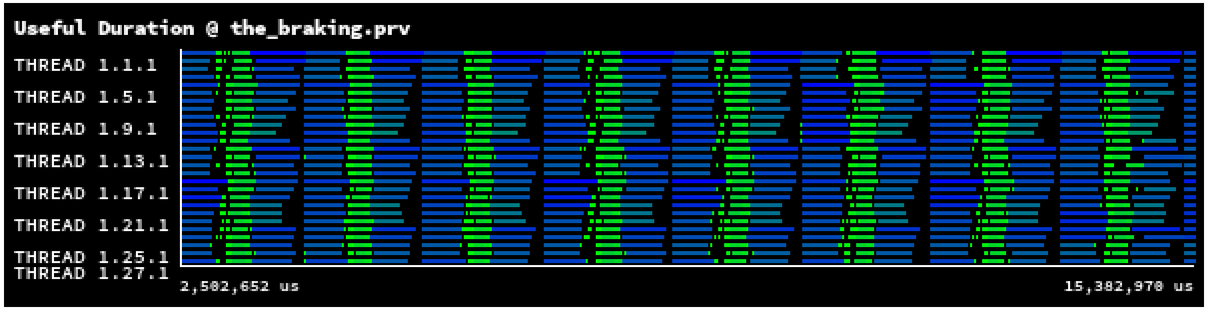
… use to correspond to a system that does unnecessary process migrations

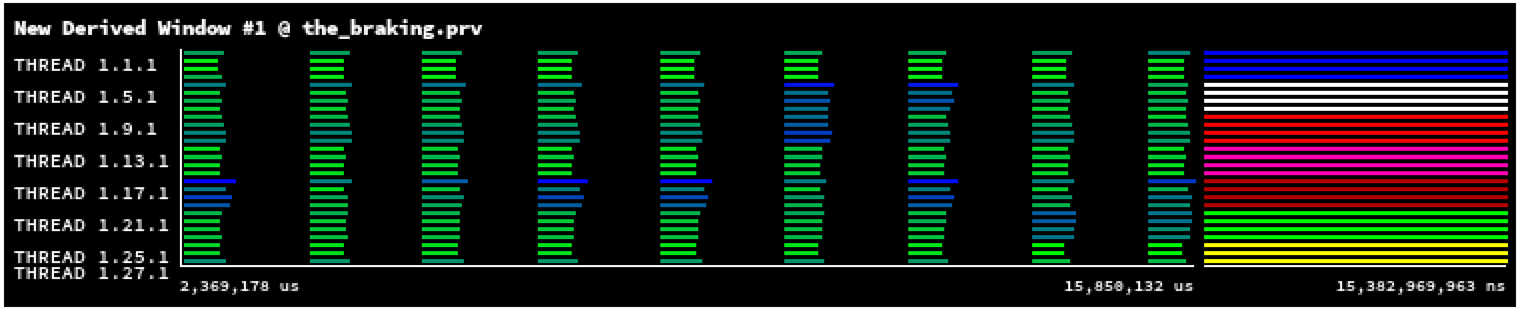
The braking

- But not always noise is caused by migrations

Parallel eff. 75.48%
Comm 88.84%
LB 84.06%



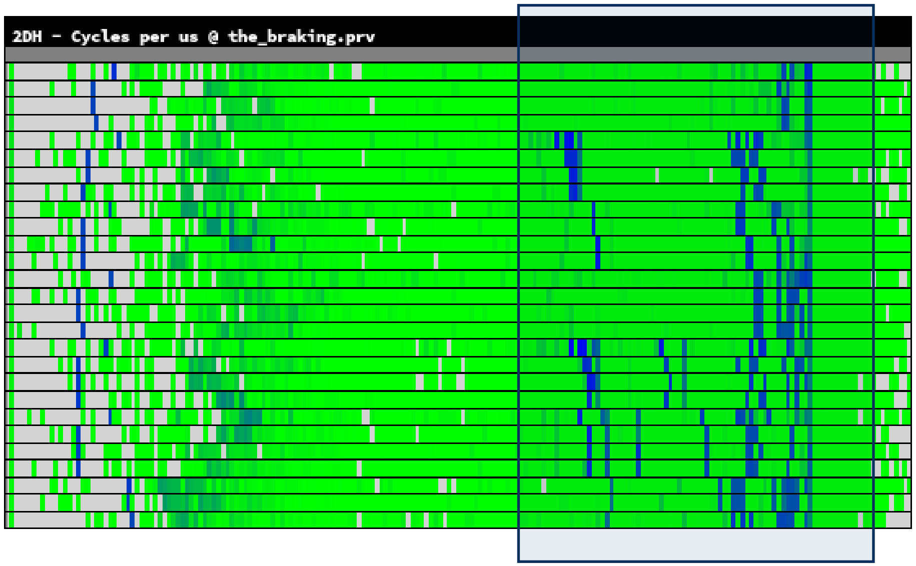




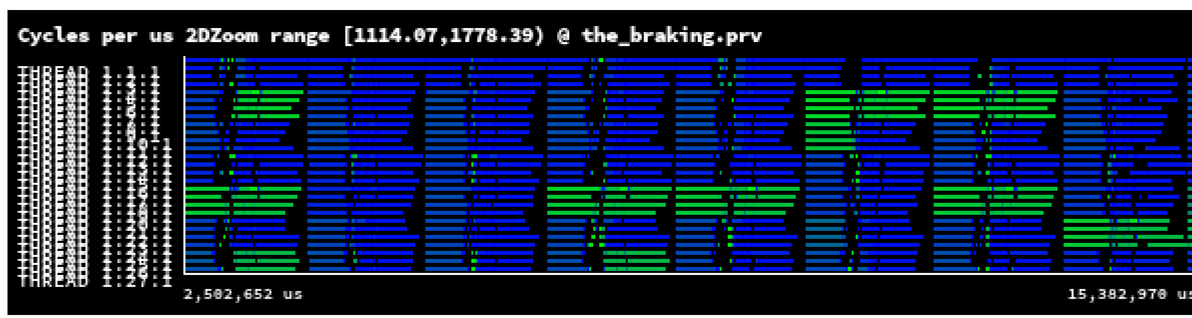
node id

The braking

- Clue: the noise affects to all processes within a node



Histogram of
cycles/us

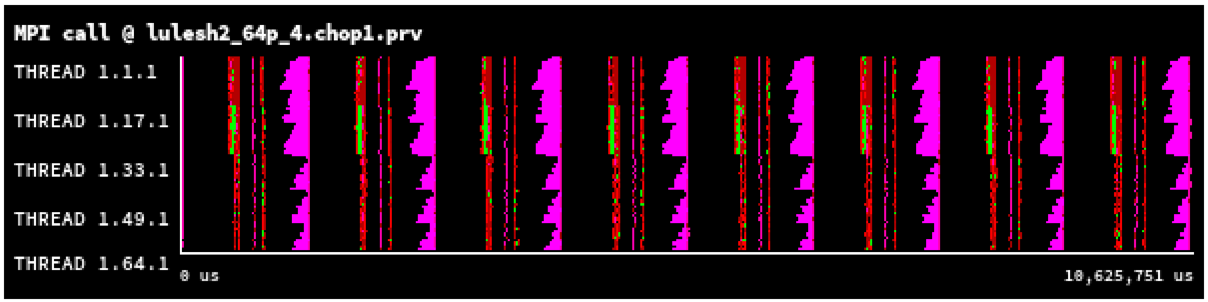


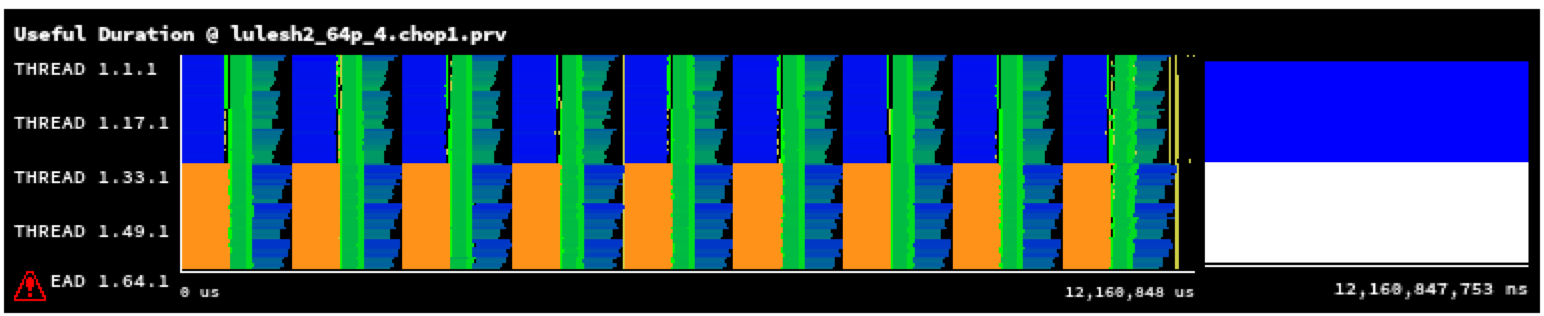
The OS of each node is reducing for a while the clock frequency asynchronously!

The mingling

- Even 64 may have problems

Parallel eff. 85.39%
Comm 97.98%
LB 87.15%



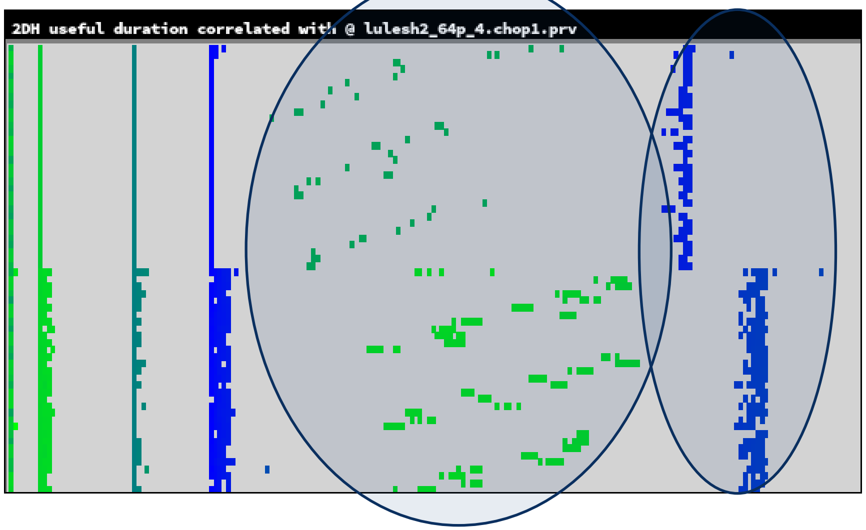


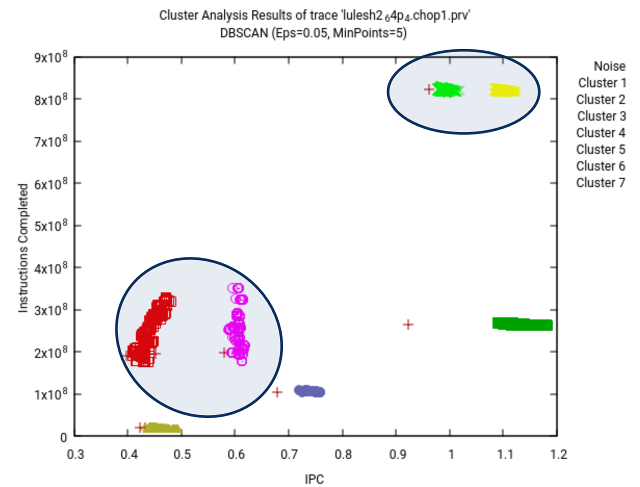
node id

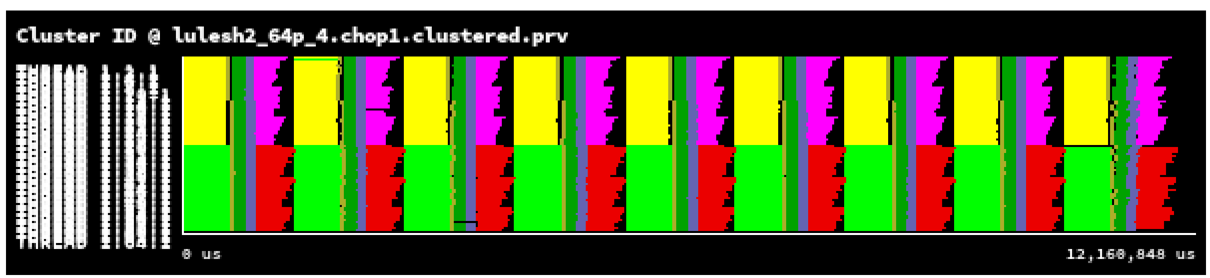
Two trends with a perfectly balanced number of MPI ranks on each node

The mingling

Histogram of useful duration







… without specifications, a request of 64 cores always allocates two nodes BUT one node of each type.

Conclusions

- As code developer, better not to assume machines will do a good job running your code because you did a good job programming your application

- As performance analyst, do not assume where are the bottlenecks, be open minded and equipped with flexible tools (like Paraver ;)

As Bruce Lee said “Be water my friend!”