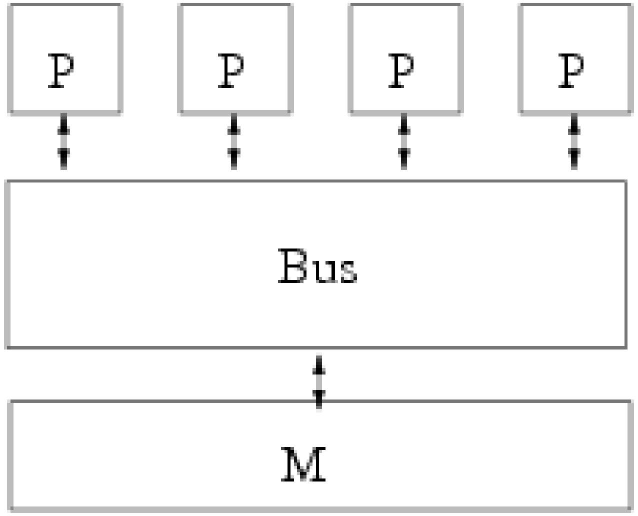
PARA2012 – Elmer Tutorial

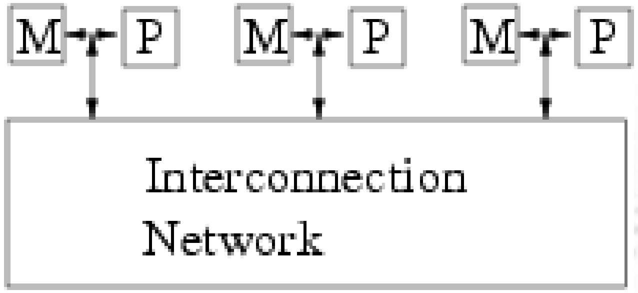
Introduction to Parallel Computations with Elmer

CSC – IT Center for Science ltd.

Elmer Team

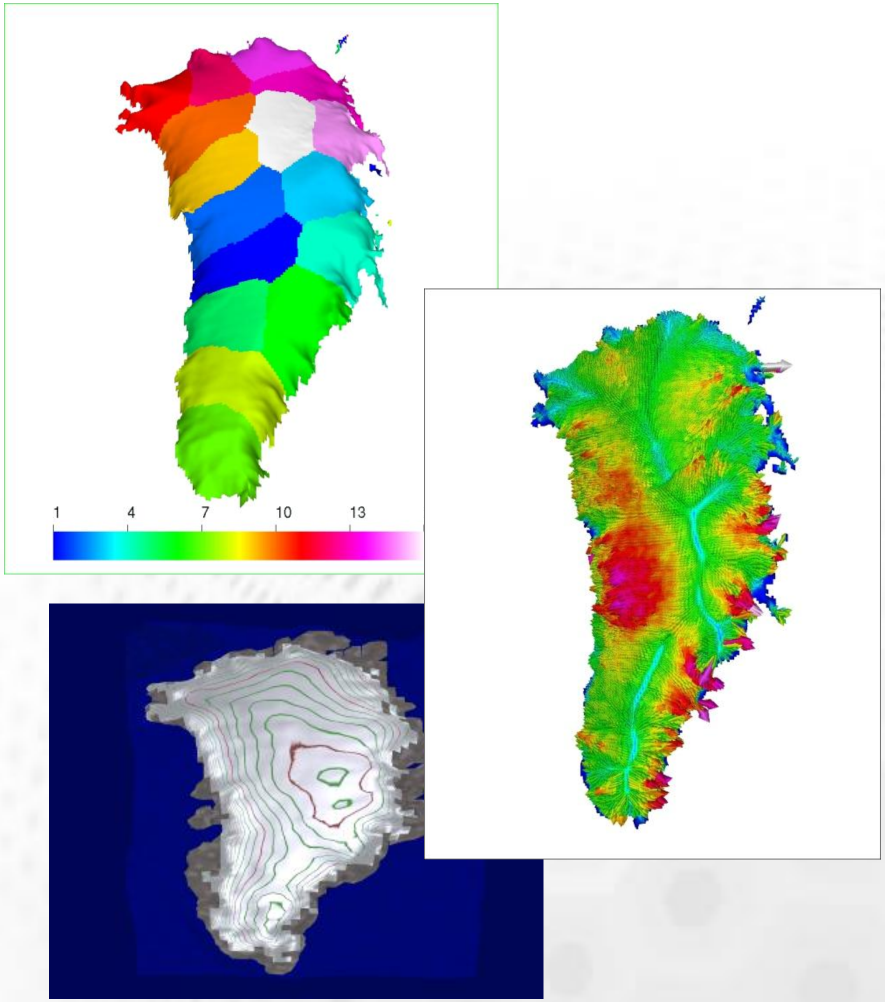
Motivation





Motivation

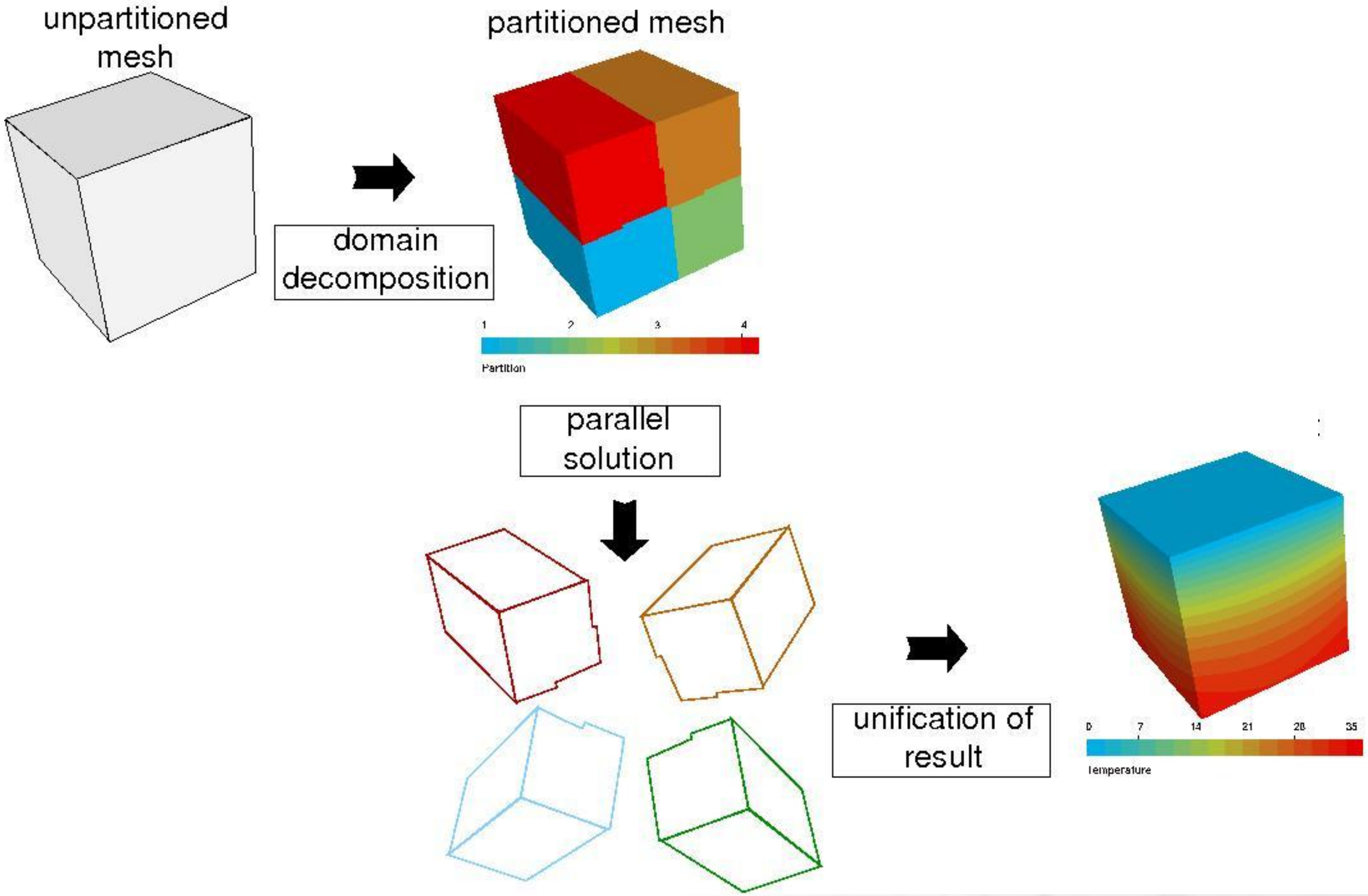
- Grand challenges
- Pre-processing:
  - Often bottleneck
  - Automated meshing
- Post-processing:
  - Parallel post processing: ParaView
  - Reduced and processed data (reduction in size)



Parallel Concept of Elmer

- Domain decomposition
- Additional pre-processing step (splitting)
- Every domain is running its ”own” ElmerSolver
- Parallel process communication: MPI
- Slightly different strategies as serial
- Re-combination of ElmerPost output

Parallel Concept of Elmer



unpartitioned mesh

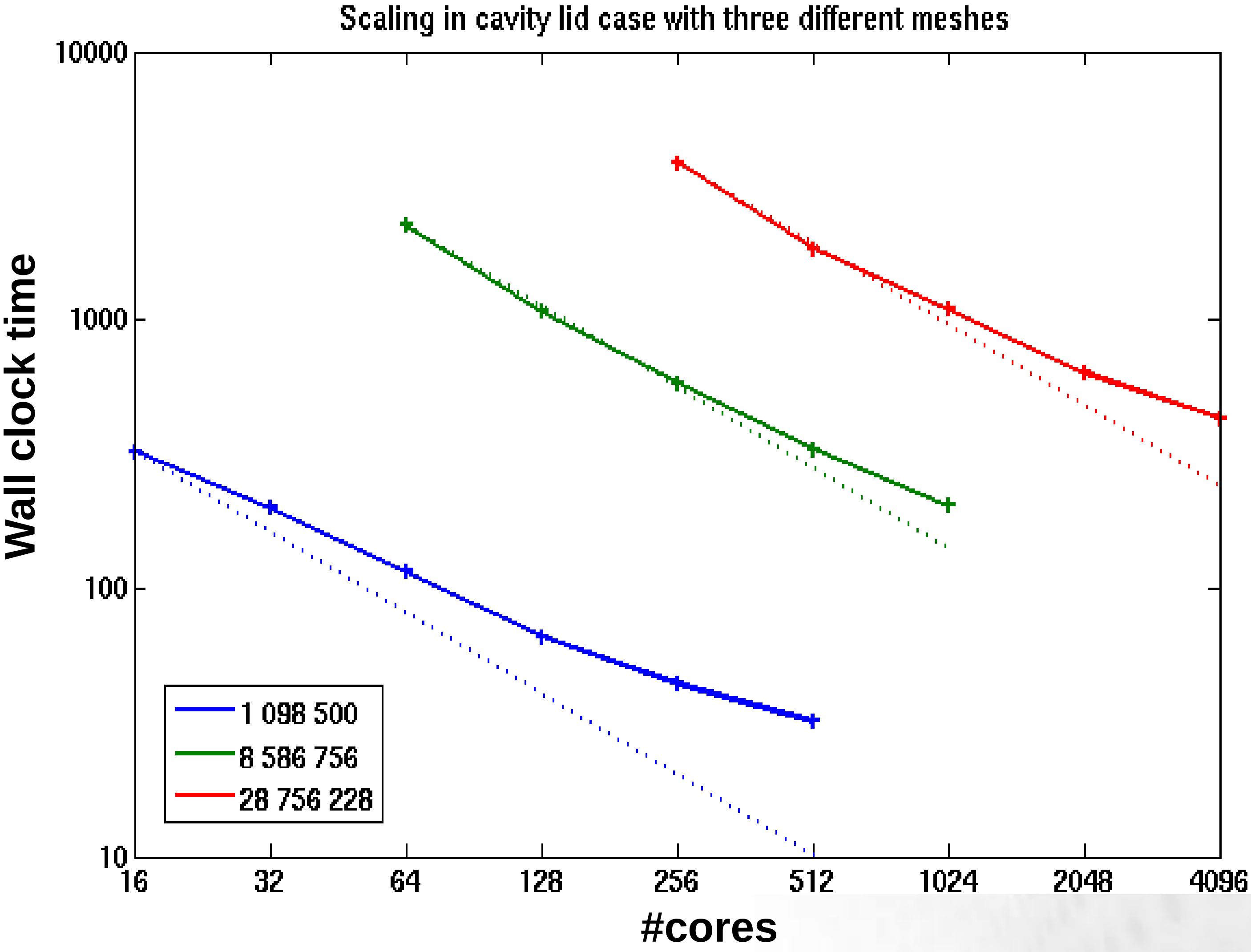
domain decomposition

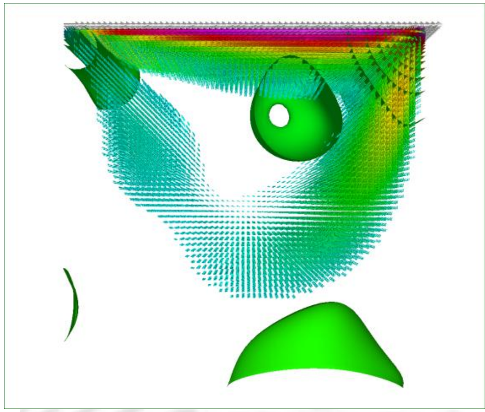
partitioned mesh

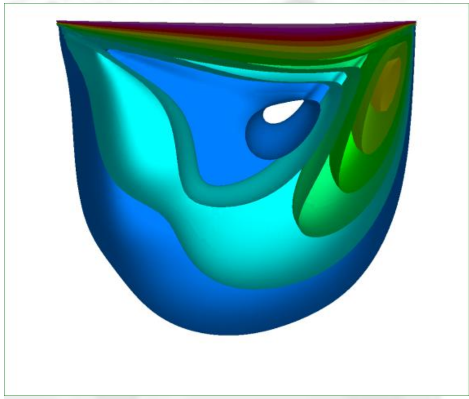
parallel solution

unification of result

Parallel Concept of Elmer







Scaling of wall clock time with DOFs in the cavity lid case using GMRES+ILU0 on louhi (Cray XT 4/5). Simulation Juha Ruokolainen, CSC, visualization Matti Gröhn, CSC .

Elmer parallel mesh

- Serial mesh structure: **`directoryname/`**
  - **Header file** contains general dimensions: **`mesh.header`**
  - **Node file** contains coordinate and ownership of nodes: **`mesh.nodes`**
  - **Elements file** contains composition of bulk elements and ownerships (bodies): **`mesh.elements`**
  - **Boundary file** contains composition of elements and ownerships (boundaries) and dependencies (parents) boundary elements: **`mesh.boundary`**

Elmer parallel mesh

- Parallel mesh structure: **`directoryname/partitioning.`*`N`*`/`**
  - **Header file:**
    `part.1.header, part.2.header, … part.`*`N`*`.header`
  - **Nodes:**
    `part.1.nodes, part.2.nodes, … part.`*`N`*`.nodes`
  - **Elements (bulk):**
    `part.1.elements, part.2.elements, … part.`*`N`*`.elements`
  - **Boundary elements**:
    `part.1.boundary, part.2.boundary, … part.`*`N`*`.boundary`
  - **Shared nodes between partitions:**
    `part.1.shared, part.2.shared, … part.`*`N`*`.shared`

Elmer parallel mesh

- Best way to partition:

  Serial mesh → **`ElmerGrid`** → parallel mesh

- General syntax:

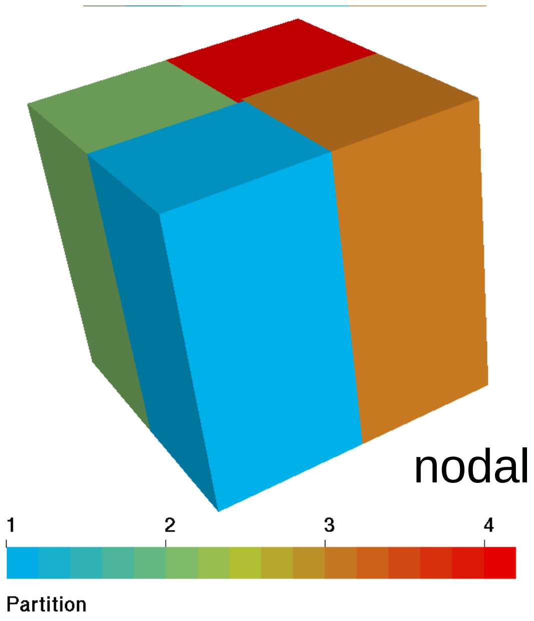
  ```
  ElmerGrid 2 2 existing [partoption]
  ```

- Principle 2 partitioning techniques:
  1. Along Cartesian axis (simple geometries/topologies)
  2. Using METIS library

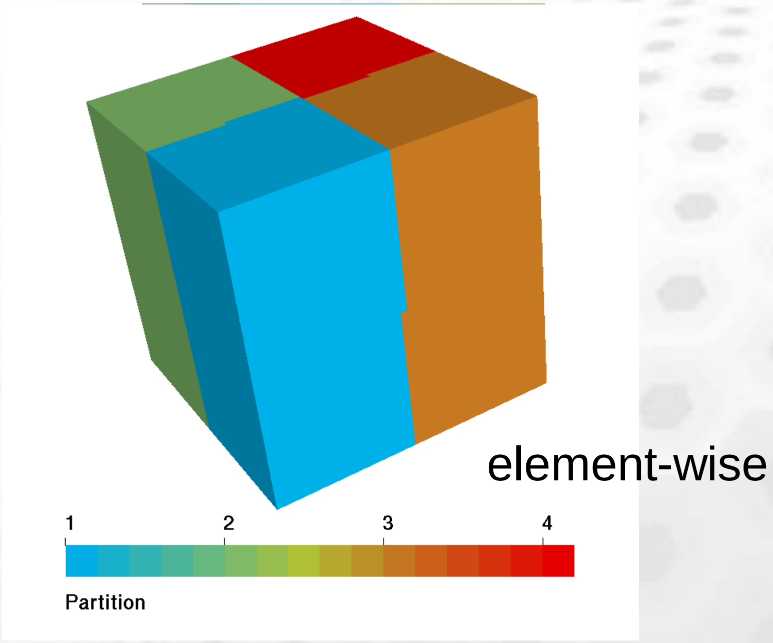
Elmer parallel mesh

Directional decomposition:

`ElmerGrid 2 2 dir -partition` $N_x\ N_y\ N_z\ F$



-partition *2 2 1 0*



-partition *2 2 1 1*

Elmer parallel mesh

Directional decomposition:

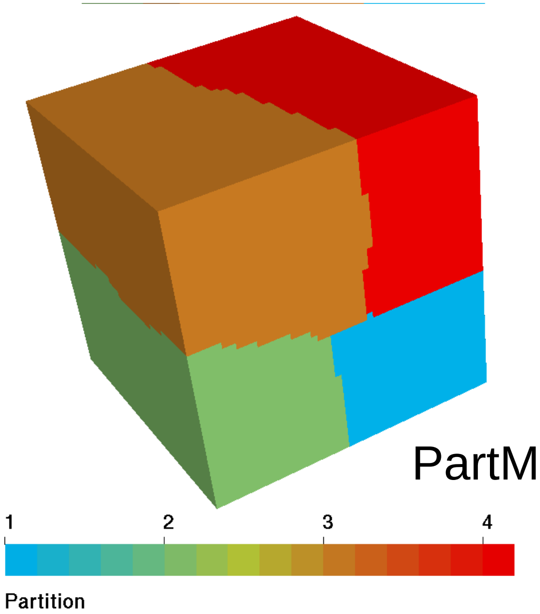
ElmerGrid 2 2 dir -partition N_x N_y N_z F **-partorder** n_x n_y n_z

Defines the ordering direction (components of vector)

Elmer parallel mesh

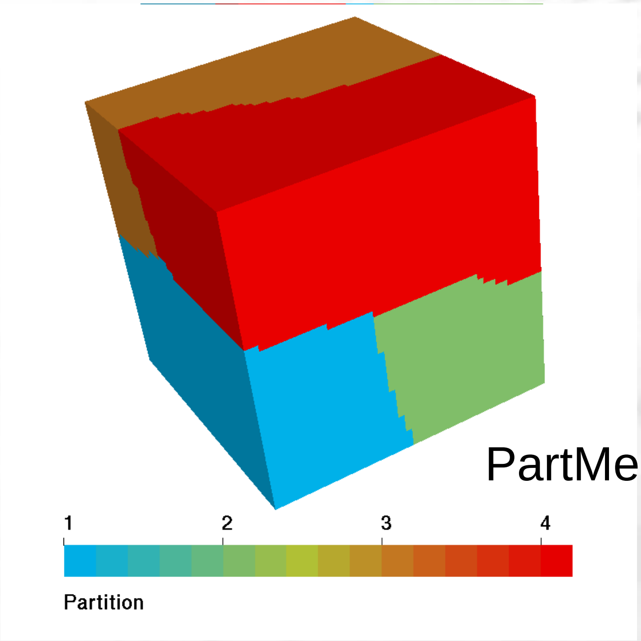
METIS:

```
ElmerGrid 2 2 dir -metis N Method
```



PartMeshNodal

```
-metis 4 0
```



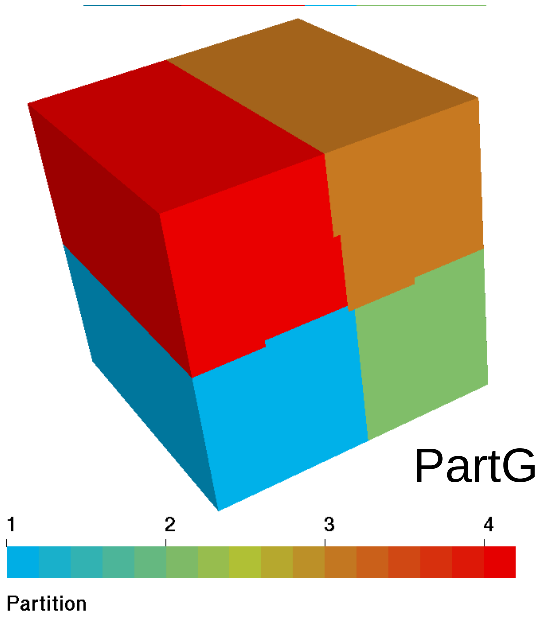
PartMeshDual

```
-metis 4 1
```

Elmer parallel mesh

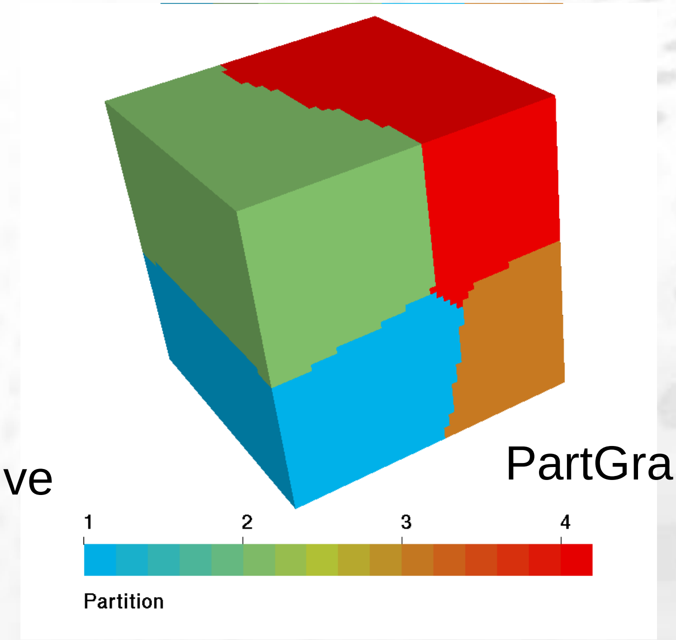
METIS:

`ElmerGrid 2 2 dir -metis` *`N Method`*



PartGraphRecursive

`-metis` *`4 2`*



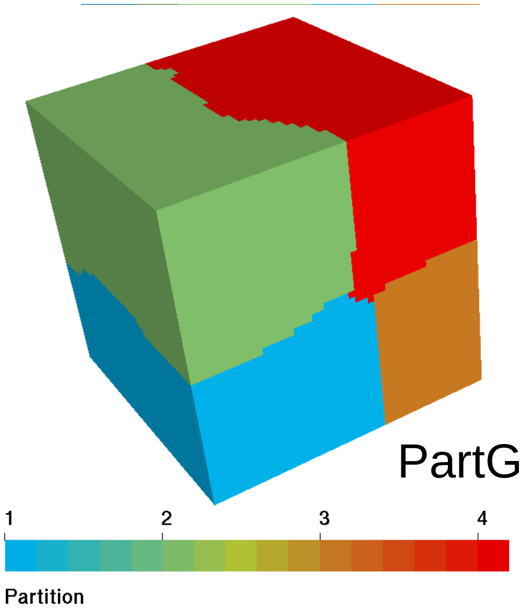
PartGraphKway

`-metis` *`4 3`*

Elmer parallel mesh

METIS:

`ElmerGrid 2 2 dir -metis` *`N Method`*



PartGraphPKway

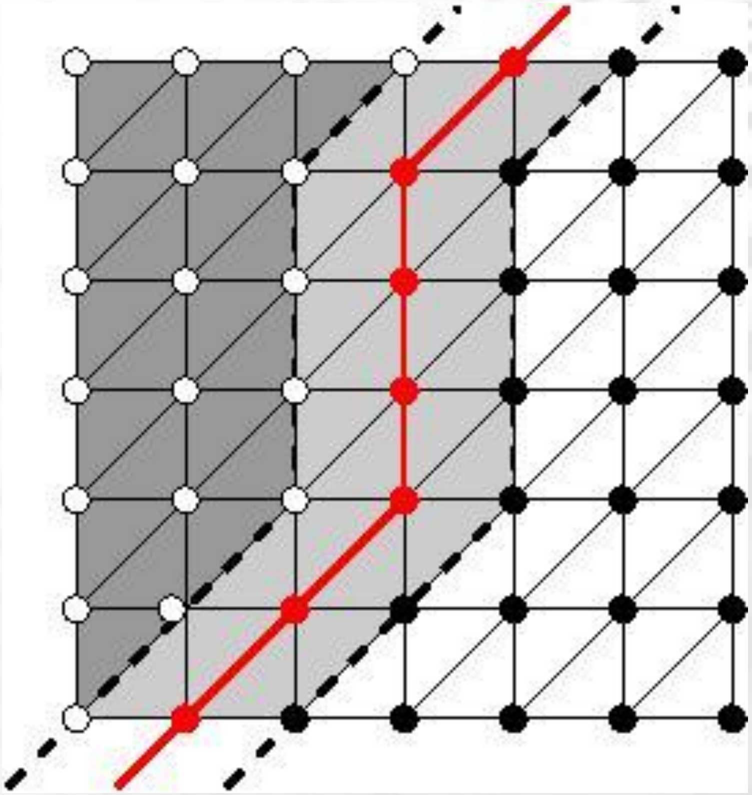
`-metis` *`4 4`*

Elmer parallel mesh

Halo-elements:

```
ElmerGrid 2 2 dir -metis N Method -halo
```

- Necessary if using Discontinuous Galerkin
- Puts ”ghost cell” on each side of the partition boundary



Elmer parallel mesh

More parallel mesh stuff...

- `-indirect` create indirect connections
- `-periodic` F_x F_y F_z declare the periodic coordinate directions for parallel meshes
- `-partoptim` aggressive optimization to node sharing
- `-partbw` minimize the bandwidth of partition-partition couplings

ElmerSolver parallel

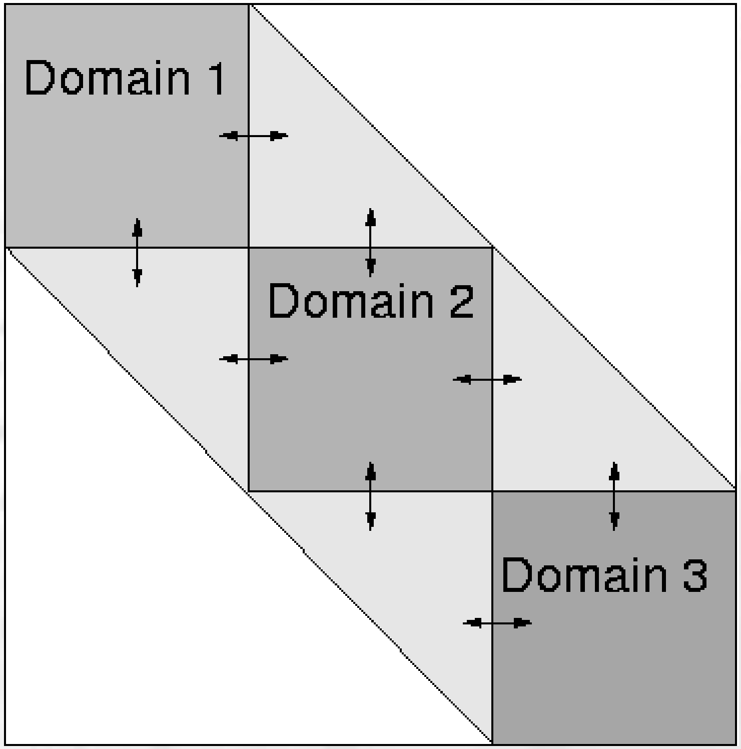
- **`mpirun -np` *`N`* `ElmerSolver_mpi`**
- Might change on other platforms
- Might need a `hostfile`
- Needs a *N*-partition mesh
- Needs `ELMERSOLVER_STARTINFO` to contain the name of the command file
- Optional libraries: Hypre and MUMPS

ElmerSolver parallel

- Different behaviour of ILU preconditioner

- Not available parts at partition boundaries
- Sometimes work
- If not, use Hypre ILU:

```
Linear System Use Hypre
   = Logical True
```



ElmerSolver parallel

- Alternative pre-condtioner in Hypre:
  - ParaSails (sparse approximate inverse preconditioner):

```
Linear System Preconditioning = String
  "ParaSails“
```

  - BoomerAMG(Algebraic Multigrid):

```
Linear System Preconditioning = String
  “BoomerAMG“
```

ElmerSolver parallel

- Alternative Solver:
  - BoomerAMG(Algebraic Multigrid):

```
Linear System Solver = "Iterative"
Linear System Iterative Method =
"BoomerAMG"
```

  - MUMPS (Multifrontal parallel direct solver):

```
Linear System Solver = Direct
Linear System Direct Method = "Mumps"
```

Parallel postprocessing

- Elmer writes results in parallel

  ***name*.0.ep, *name*.1.ep, ... , *name*.*(N-1)*.ep**

  A single one of these files may even be visualized
- ElmerPost: fusing into one file

  ElmerGrid 15 3 *name*

  fuses all timesteps (also non-existing) into a single file called ***name*.ep** (existing files will be overwritten!)
  - Special option for only partial fuse:

    -saveinterval *start end step*