Virtual Topologies

Engineering and Physical Sciences Research Council

Natural Environment Research Council

Reusing this material

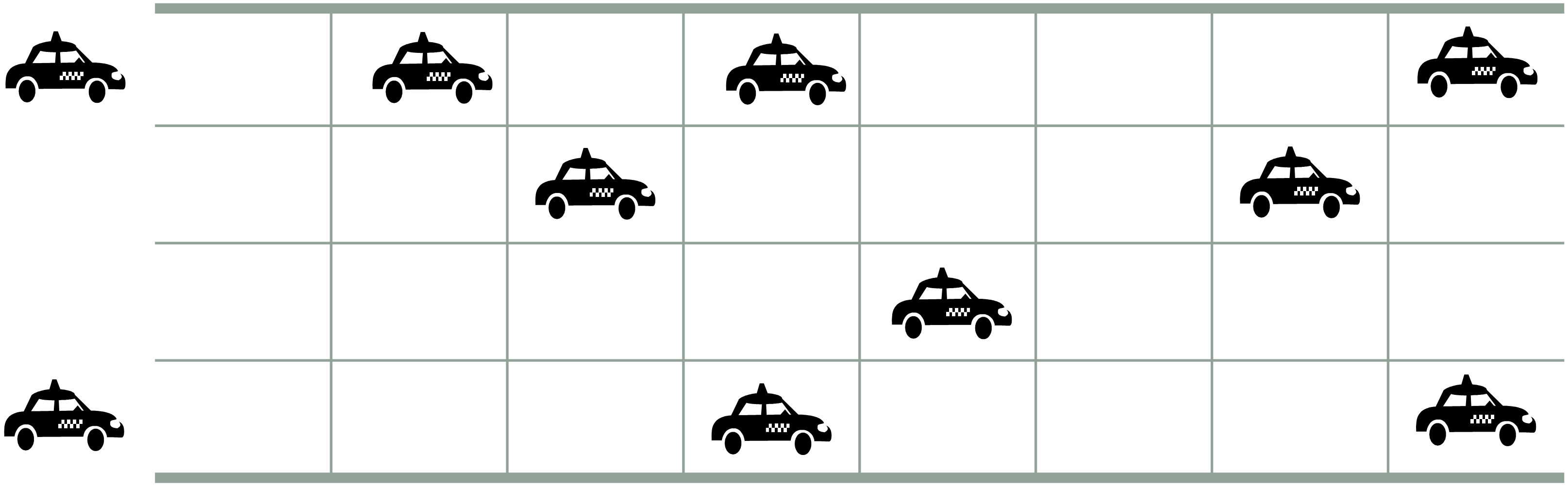
Virtual Topologies

- Convenient process naming.
- Naming scheme to fit the communication pattern.
- Simplifies writing of code.
- Can allow MPI to optimise communications.

How to use a Virtual Topology

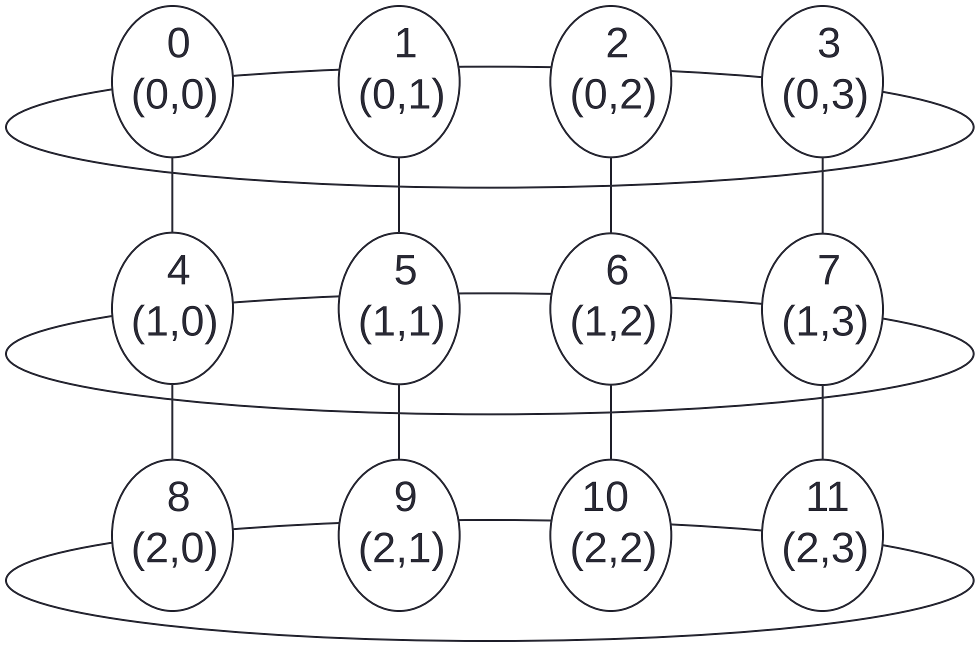
- Creating a topology produces a new communicator.
- MPI provides “mapping functions”.
- Mapping functions compute processor ranks, based on the topology naming scheme.

Traffic model with multiple lanes



Example

A 2-dimensional Cylinder



Topology types

- Cartesian topologies
  - each process is “connected” to its neighbours in a virtual grid.
    - boundaries can be cyclic, or not.
    - optionally re-order ranks to allow MPI implementation to optimise for underlying network interconnectivity.
  - processes are identified by cartesian coordinates.
- Graph topologies
  - general graphs
  - not covered here

Creating a Cartesian Virtual Topology

- C:

```
int MPI_Cart_create(MPI_Comm comm_old,
           int ndims, int *dims, int *periods,
           int reorder, MPI_Comm *comm_cart)
```

- Fortran:

```
MPI_CART_CREATE(COMM_OLD, NDIMS, DIMS,
           PERIODS, REORDER, COMM_CART, IERROR)

INTEGER COMM_OLD, NDIMS, DIMS(*), COMM_CART, IERROR
LOGICAL PERIODS(*), REORDER
```

Balanced Processor Distribution

- C:

```
int MPI_Dims_create( int nnodes, int ndims,
                     int *dims )
```

- Fortran:

```
MPI_DIMS_CREATE(NNODES, NDIMS, DIMS, IERROR)

INTEGER NNODES, NDIMS, DIMS(*), IERROR
```

MPI_Dims_create

- Call tries to set dimensions as close to each other as possible

dims before call	function call	dims on return
(0, 0)	**`MPI_DIMS_CREATE( 6, 2, dims)`**	(3, 2)
(0, 0)	**`MPI_DIMS_CREATE( 7, 2, dims)`**	(7, 1)
(0, 3, 0)	**`MPI_DIMS_CREATE( 6, 3, dims)`**	(2, 3, 1)
(0, 3, 0)	**`MPI_DIMS_CREATE( 7, 3, dims)`**	erroneous call

- Non-zero values in dims sets the number of processors required in that direction
  - WARNING: make sure dims is set to zero before the call

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Cartesian Mapping Functions

Mapping process grid coordinates to ranks

- C:

```
int MPI_Cart_rank( MPI_Comm comm,
                   int *coords, int *rank)
```

- Fortran:

```
MPI_CART_RANK (COMM, COORDS, RANK, IERROR)
INTEGER COMM, COORDS(*), RANK, IERROR
```

Cartesian Mapping Functions

Mapping ranks to process grid coordinates

- C:

```
int MPI_Cart_coords(MPI_Comm comm, int rank,
                    int maxdims, int *coords)
```

- Fortran:

```
MPI_CART_COORDS(COMM, RANK, MAXDIMS, COORDS,IERROR)

INTEGER COMM, RANK, MAXDIMS, COORDS(*), IERROR
```

Cartesian Mapping Functions

Computing ranks of my neighbouring processes
Following conventions of **`MPI_SendRecv`**

- C:

```
int MPI_Cart_shift(MPI_Comm comm,
                   int direction, int disp,
                   int *rank_source, int *rank_dest)
```

- Fortran:

```
MPI_CART_SHIFT(COMM, DIRECTION, DISP,
               RANK_SOURCE, RANK_DEST, IERROR)

INTEGER  COMM, DIRECTION, DISP,
         RANK_SOURCE, RANK_DEST, IERROR
```

Notes for MPI_Cart_shift()

- `rank_source` is **not** your rank!
  - it is an output not an input
- For message round a ring
  - `rank_source` would be rank-1
  - `rank_dest` would be rank+1
- Different convention to MPI_Cart_coords()
  - your are implicitly asking for *your* neighbours

Non-existent ranks

- What if you send or receive from a non-existent process?
  - e.g. look off the edge of a non-periodic grid?

- MPI returns a NULL processor
  - rank is **`MPI_PROC_NULL`**

- **`MPI_PROC_NULL`** is a black hole
  - sends and receives complete immediately
  - send buffer disappears, receive buffer isn’t touched
  - like UNIX **`/dev/null`**

Cartesian Partitioning

- Cut a grid up into “slices”.
- A new communicator is produced for each slice.
- Each slice can then perform its own collective communications.
- **`MPI_Cart_sub`** and **`MPI_CART_SUB`** generate new communicators for the slices.
  - Use array to specify which dimensions should be retained in the new communicator.

Partitioning with MPI_CART_SUB

- C:

```
int MPI_Cart_sub ( MPI_Comm comm,
         int *remain_dims,
         MPI_Comm *newcomm)
```

- Fortran:

```
MPI_CART_SUB (COMM, REMAIN_DIMS,
               NEWCOMM,IERROR)

INTEGER  COMM, NEWCOMM, IERROR
LOGICAL  REMAIN_DIMS(*)
```

Exercise

- See Exercise 7 on the sheet
- Rewrite the exercise passing numbers round the ring using a one-dimensional ring topology.