CSCS
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Message Passing Interface (MPI)

Summer School 2017 – Effective High Performance Computing

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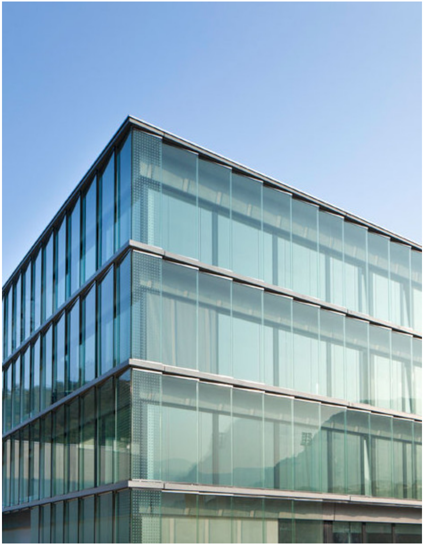
Previous course summary

- Point-to-point communication
- Blocking and non-blocking communication
- Transfer modes

Course Objectives

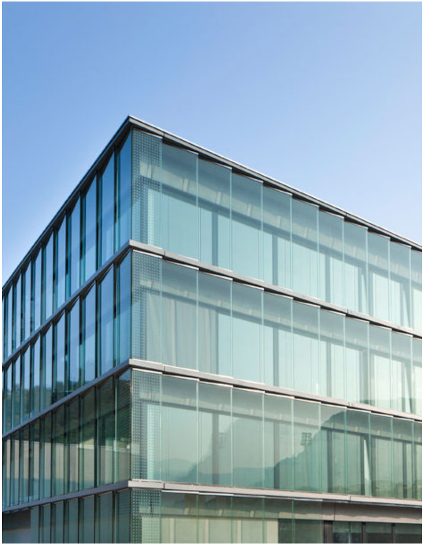
- The understanding of a collective operations
- Knowledge of the different collective operations

General Course Structure



- An introduction to MPI
- Point-to-point communications
- Collective communications
- Topology
- Datatypes

General Course Structure



- An introduction to MPI
- Point-to-point communications
- Collective communications
  - Collective communications
  - Barrier
  - Broadcast
  - Scatter/Gather
  - All to all
  - Reduction
  - Global collective operations
  - Non-blocking coll-op
- Topology
- Datatypes

Collective communications

Collective operations

Communications involving a group of processes part of a communicator.

Different algorithms: $1 \longrightarrow N$, $N \longrightarrow 1$ or $N \longrightarrow N$ $(1 \longrightarrow 1 = \text{pt2pt})$.

Example:

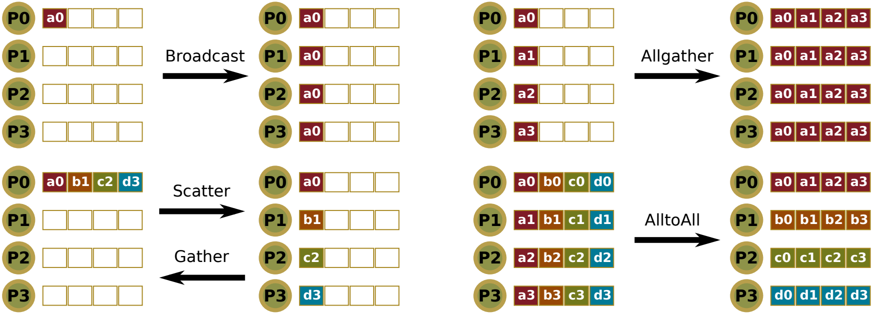
- Barrier Synchronization
- Broadcast
- Gather/Scatter
- AlltoAll
- Reduction (sum, max, prod, . . .)

Features:

- All processes must call the collective routine, one is the root
- No tags

The MPI library should use the most efficient communication algorithm for the particular platform.

Collective operations schemes



Broadcast

P0	a0				P0	a0			
P1					P1	a0			
P2					P2	a0			
P3					P3	a0			

Scatter

Gather

P0	a0	b1	c2	d3	P0	a0			
P1					P1	b1			
P2					P2	c2			
P3					P3	d3			

Allgather

P0	a0				P0	a0	a1	a2	a3
P1	a1				P1	a0	a1	a2	a3
P2	a2				P2	a0	a1	a2	a3
P3	a3				P3	a0	a1	a2	a3

AlltoAll

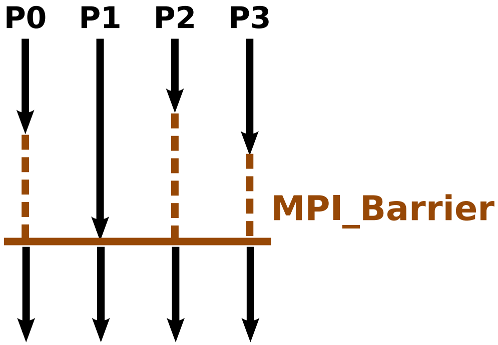
P0	a0	b0	c0	d0	P0	a0	a1	a2	a3
P1	a1	b1	c1	d1	P1	b0	b1	b2	b3
P2	a2	b2	c2	d2	P2	c0	c1	c2	c3
P3	a3	b3	c3	d3	P3	d0	d1	d2	d3

Barrier

Stop processes until all processes within a communicator reach the barrier.

Pseudo-code

```
MPI_Barrier(comm)
```



Broadcast

One-to-all communication: same data sent from root process to all other processes in the communicator.

Pseudo-code

```
MPI_Bcast(buf, count, type, root, comm)
```

root rank being the initiator of the collective operation

Scatter

One-to-all communication: different data sent from the root process to all other processes in the communicator.

Pseudo-code

```
MPI_Scatter(sndbuf, sndcount, sndtype,
            rcvbuf, rcvcount, rcvtype, root, comm)
```

sndcount number of elements sent to each process, **not the size of sndbuf**, that should be sndcount times the number of process in the communicator

rcvcount number of element in the receive buffer

The sender arguments are meaningful only for root.

Gather

One-to-all communication: different data collected by the root process, from all others processes in the communicator.

Pseudo-code

```
MPI_Gather(sndbuf, sndcount, sndtype,
           rcvbuf, rcvcount, rcvtype, root, comm)
```

rcvcount the number of elements collected from each process, **not the size of rcvbuf**, that should be rcvcount times the number of process in the communicator

sndcount number of element in the send buffer

The receive arguments are meaningful only for root.

Global exchange: All to All

All-to-all communication: global exchange, all processes exchange their data. Useful for data transposition.

Pseudo-code

```
MPI_Alltoall(sndbuf, sndcount, sndtype,
             rcvbuf, rcvcount, rcvtype, comm)
```

Reduction

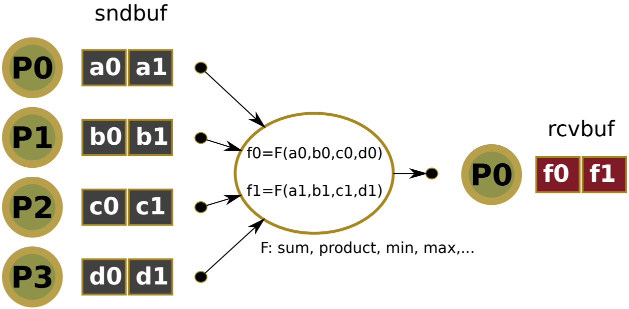
The reduction operation allows to:

- Collect data from each process
- Reduce the data to a single value
- Store the result on the root processes
- Store the result on all processes
- Overlap communication and computation

Reduction

```
Pseudo-code
MPI_Reduce(sndbuf, rcvbuf, count, type, op, root, comm)
```

op parallel operation to perform



F: sum, product, min, max,...

Reduction operators

MPI op	Operation
MPI_MAX	Maximum
MPI_MIN	Minimum
MPI_SUM	Sum
MPI_PROD	Product
MPI_LAND	Logical AND
MPI_BAND	Bitwise AND
MPI_LOR	Logical OR
MPI_BOR	Bitwise OR
MPI_LXOR	Logical exclusive OR
MPI_BXOR	Bitwise exclusive OR
MPI_MAXLOC	Maximum and location
MPI_MINLOC	Minimum and location

Global collective operations

The result of the one-to-all operation is known by all ranks at the end of the operation.

Pseudo-code

```
MPI_Allgather(sndbuf, sndcount, sndtype,
              rcvbuf, rcvcount, rcvtype, comm)

MPI_Allreduce(sndbuf, rcvbuf, count, type, op, comm)
```

The argument **root** is missing, the result is stored in all processes.

Non-blocking collective operations

All collective operations have a non-blocking version.

Example:

Pseudo-code

```
MPI_Ibcast(buf, count, type, root, comm, request)
```

Other functions:

Pseudo-code

```
MPI_Ibarrier, MPI_Igather, MPI_Ireduce, MPI_Iscatter,
MPI_Iallgather, MPI_Iallreduce, MPI_Ialltoall
```

Other functions

- Operations with different buffer sizes:

```
MPI_AlltoAllv, MPI_Gatherv, MPI_Scatterv, MPI_Allgatherv
```

- Neighbor operations, based on topology:

```
MPI_Neighbor_gather, MPI_Neighbor_alltoall
```

- Cummulative per rank reduction:

```
MPI_Scan, MPI_Exscan
```

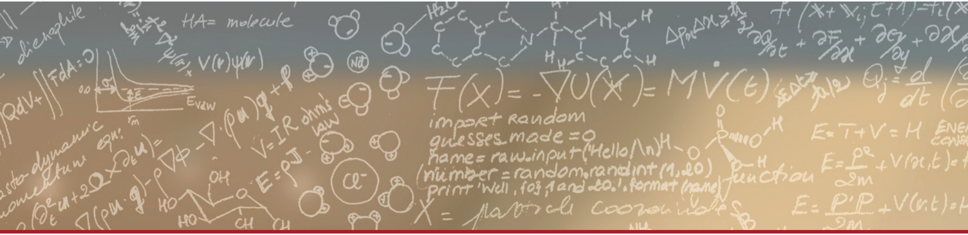
- Create your own operator:

```
MPI_Op_create, MPI_Op_free
```

Practicals

Exercise: 03.MPI_Coll

1. Read from the terminal and broadcast the input
2. Initialise an array and scatter it
3. Reduction operation
4. Reduction with results stored in all ranks (allreduce)



Thank you for your attention.