A quick introduction to MPI (Message Passing Interface)

M1IF - AlgoPar

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Introduction

- Standardized and portable message-passing system.
- Started in the 90's, still used today in research and industry.
- Minimalistic : good theoretical model.
- Minimalistic : good performances on HPC networks (InfiniBand ...).

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De facto standard for communications in HPC applications.

APIs:

- C and Fortran APIs.
- C++ API deprecated by MPI-3 (2008).

Environment:

- Many implementations of the standard (mainly OpenMPI and MPICH)
- Compiler (wrappers around gcc)
- Runtime (mpirun)

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Compiling:

gcc	→	mpicc
g++	→	mpic++ / mpicxx
gfortran	→	mpifort

Executing:

mpirun -n <nb procs> <executable> <args>

ex : mpirun -n 10 ./a.out

note: mpiexec and orterun are synonyms of mpirun

see `man mpirun` for more details

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Context limits

All MPI call must be nested in the MPI context delimited by `MPI_Init` and `MPI_Finalize`.

```
#include <mpi.h>

int main(int argc, char *argv[])
{
    MPI_Init(&argc, &argv);

    // ...

    MPI_Finalize();

    return 0;
}
```

Context awarness

```c
#include <stdio.h>
#include <mpi.h>

int main(int argc, char *argv[])
{
	int rank, size;

	MPI_Init(&argc, &argv);

	MPI_Comm_rank(MPI_COMM_WORLD, &rank);
	MPI_Comm_size(MPI_COMM_WORLD, &size);

	printf("Hello from proc %d / %d\n", rank, size);

	MPI_Finalize();

	return 0;
}
```

Code:

```
printf("[%d]␣step␣1\n", rank);
MPI_Barrier(MPI_COMM_WORLD);
printf("[%d]␣step␣2\n", rank);
```

Output:

```
[0] step 1
[1] step 1
[2] step 1
[3] step 1
[3] step 2
[0] step 2
[2] step 2
[1] step 2
```

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Point to point communication

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Send and Receive

Sending data:

```
int MPI_Send(const void*   data,
             int           count,
             MPI_Datatype  datatype,
             int           destination,
             int           tag,
             MPI_Comm      communicator);
```

Receiving data:

```
int MPI_Recv(void*         data,
             int           count,
             MPI_Datatype  datatype,
             int           source,
             int           tag,
             MPI_Comm      communicator,
             MPI_Status*   status);
```

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Exemple

```c
int rank, size;
MPI_Comm_rank(MPI_COMM_WORLD, &rank);
MPI_Comm_size(MPI_COMM_WORLD, &size);

int number;
switch(rank)
{
  case 0:
    number = -1;
    MPI_Send(&number, 1, MPI_INT, 1, 0, MPI_COMM_WORLD);
    break;
  case 1:
    MPI_Recv(&number, 1, MPI_INT, 0, 0, MPI_COMM_WORLD,
                 MPI_STATUS_IGNORE);
    printf("received␣number:␣%d\n", number);
    break;
}
```

Asynchronious communications

Sending data:

```
int MPI_Isend(const void*   data,
              int           count,
              MPI_Datatype  datatype,
              int           destination,
              int           tag,
              MPI_Comm      communicator,
              MPI_Request*  request);
```

Receiving data:

```
int MPI_Irecv(void*         data,
              int           count,
              MPI_Datatype  datatype,
              int           source,
              int           tag,
              MPI_Comm      communicator,
              MPI_Request*  request);
```

Other function

- MPI_Probe, MPI_Iprobe
- MPI_Test, MPI_Testany, MPI_Testall
- MPI_Cancel
- MPI_Wtime, MPI_Wtick

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Simple datatypes

MPI_SHORT	short int
MPI_INT	int
MPI_LONG	long int
MPI_LONG_LONG	long long int
MPI_UNSIGNED_CHAR	unsigned char
MPI_UNSIGNED_SHORT	unsigned short int
MPI_UNSIGNED	unsigned int
MPI_UNSIGNED_LONG	unsigned long int
MPI_UNSIGNED_LONG_LONG	unsigned long long int
MPI_FLOAT	float
MPI_DOUBLE	double
MPI_LONG_DOUBLE	long double
MPI_BYTE	char

Complexe datatypes

Composed structure:

- Structures;
- Array.

Possibilities are almost limitless ...

... but sometimes difficult to setup.

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Collective communications

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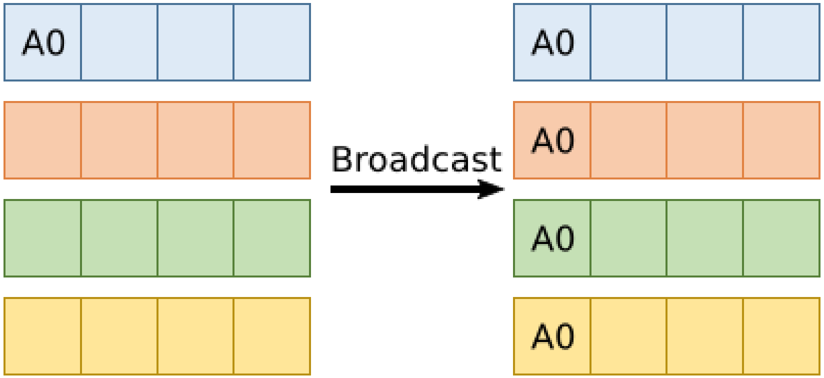
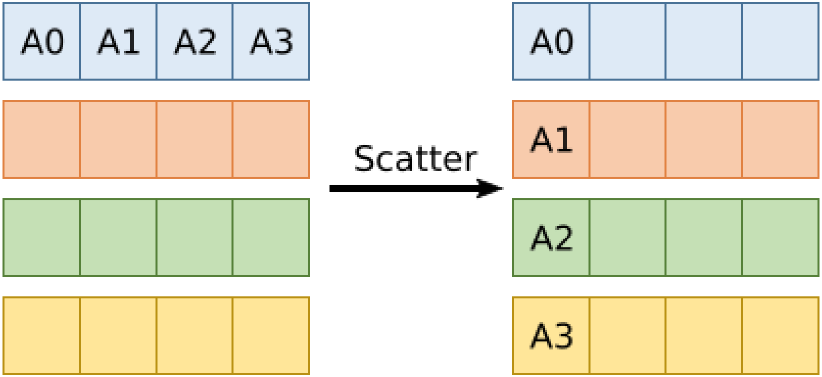
Broadcast



Broadcast

```
int MPI_Bcast(void*         data,
              int           count,
              MPI_Datatype  datatype,
              int           root,
              MPI_Comm      communicator);
```

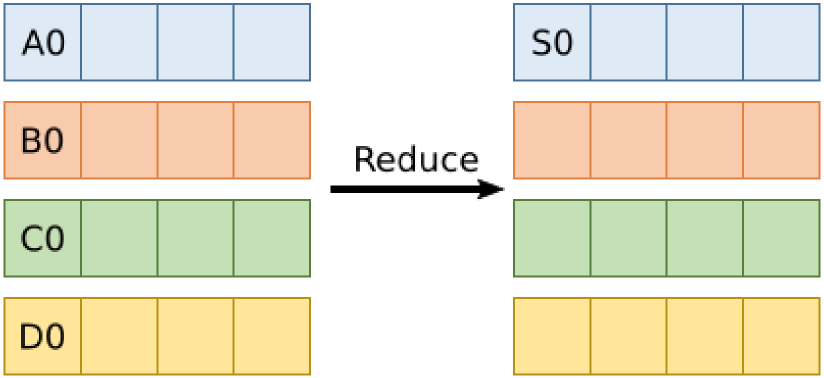
Scatter



Scatter

```
int MPI_Scatter(const void*   sendbuf,
                int           sendcount,
                MPI_Datatype  sendtype,
                void*         recvbuf,
                int           recvcount,
                MPI_Datatype  recvtype,
                int           root,
                MPI_Comm      communicator);
```

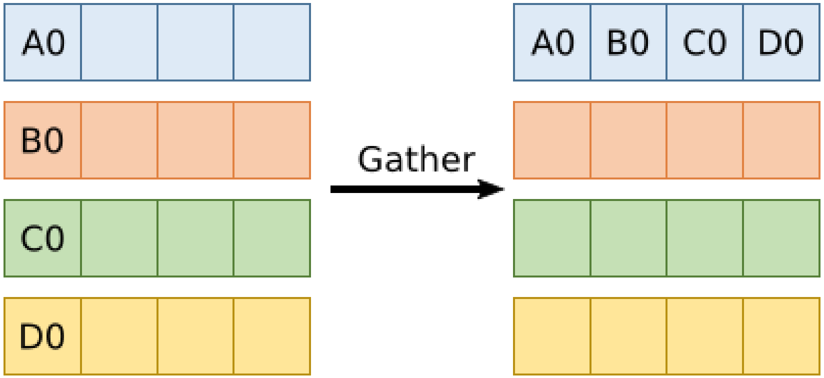
Reduce



Reduce

```
int MPI_Reduce(const void*   sendbuf,
               void*         recvbuf,
               int           count,
               MPI_Datatype  datatype,
               MPI_Op        operator,
               int           root,
               MPI_Comm      communicator);
```

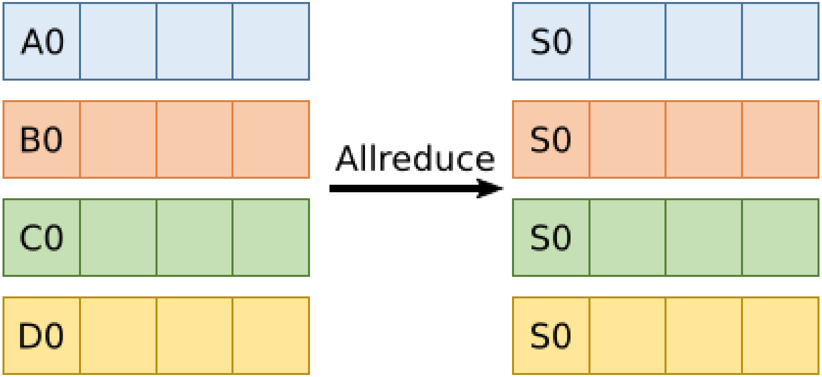
Gather



Gather

```
int MPI_Gather(const void*   sendbuf,
               int           sendcount,
               MPI_Datatype  sendtype,
               void*         recvbuf,
               int           recvcount,
               MPI_Datatype  recvtype,
               int           root,
               MPI_Comm      communicator);
```

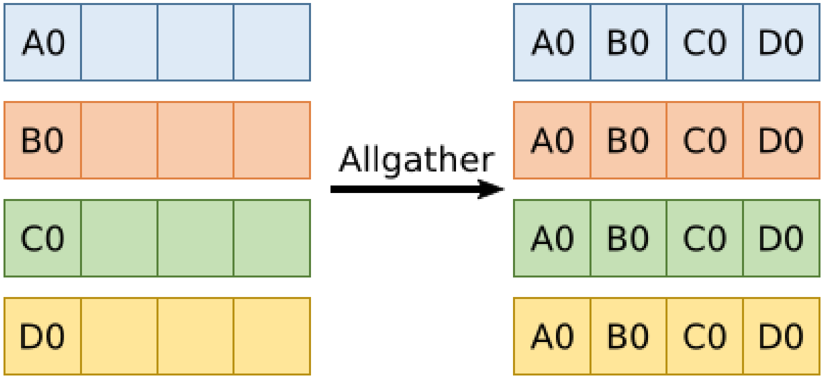
Allreduce



AllReduce

```
int MPI_Allreduce(const void*   sendbuf,
                  void*         recvbuf,
                  int           count,
                  MPI_Datatype  datatype,
                  MPI_Op        operator,
                  MPI_Comm      communicator);
```

Allgather



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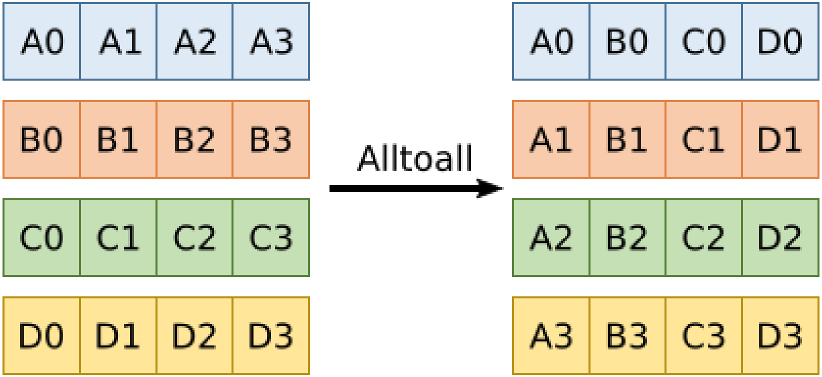
AllGather

```
int MPI_Allgather(const void*   sendbuf,
                  int           sendcount,
                  MPI_Datatype  sendtype,
                  void*         recvbuf,
                  int           recvcount,
                  MPI_Datatype  recvtype,
                  MPI_Comm      communicator);
```

Alltoall


A0
A1
A2
A3
B0
B1
B2
B3
C0
C1
C2
C3
D0
D1
D2
D3
Alltoall
A0
B0
C0
D0
A1
B1
C1
D1
A2
B2
C2
D2
A3
B3
C3
D3

Alltoall

```
int MPI_Alltoall(const void*   sendbuf,
                 int           sendcount,
                 MPI_Datatype  sendtype,
                 void*         recvbuf,
                 int           recvcount,
                 MPI_Datatype  recvtype,
                 MPI_Comm      communicator);
```

Custom communicators

MPI_COMM_WORLD can be split into smaller, more appropriate communicators.

```
int  MPI_Comm_split(MPI_Comm   communicator,
                    int        color,
                    int        key,
                    MPI_Comm*  newcommunicator);
```

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Exemple

```
...
int rank, size;
MPI_Init(&argc, &argv);
MPI_Comm_rank(MPI_COMM_WORLD, &rank);
MPI_Comm_size(MPI_COMM_WORLD, &size);

int      hrank, vrank;
int      hsize, vsize;
MPI_Comm hcomm, vcomm;
MPI_Comm_split(MPI_COMM_WORLD, rank%p, rank, &vcomm);
MPI_Comm_split(MPI_COMM_WORLD, rank/p, rank, &hcomm);
MPI_Comm_rank(hcomm, &hrank);
MPI_Comm_size(hcomm, &hsize);
MPI_Comm_rank(vcomm, &vrank);
MPI_Comm_size(vcomm, &vsize);
...
```

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