



Advanced MPI

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Any downsides to using blocking calls?



Any downsides to using blocking calls?

- Performance: the receiver blocks for a message and cannot do anything else while waiting for a message

Non-blocking point-to-point calls

- Most important routines: `MPI_Isend` and `MPI_Irecv`
- Two parts to a non-blocking operation:
 - Posting: post the non-blocking operation
 - Completion: wait for its results at a later point in the program — done via calls to `MPI_Wait` or `MPI_Test`
- Can help facilitate overlap of computation with communication

MPI_Isend: Non-blocking pt2pt send

```
int MPI_Isend( const void *buf, int count, MPI_Datatype datatype,  
int dest, int tag, MPI_Comm comm, MPI_Request *request )
```

buf: address of send buffer

count: number of elements in send buffer

datatype: datatype of each send buffer element

dest: rank of destination process

tag: message tag

comm: communicator

request: communication request

MPI_Irecv: Non-blocking pt2pt receive

```
int MPI_Irecv( void *buf, int count, MPI_Datatype datatype, int
source, int tag, MPI_Comm comm, MPI_Request *request )
```

buf: address of receive buffer

count: maximum number of elements in receive buffer

datatype: datatype of each receive buffer element

source: rank of source process

tag: message tag

comm: communicator

request: communication request

MPI_Wait: blocking call

```
int MPI_Wait( MPI_Request *request, MPI_Status *status )
```

request: communication request

status: status object

Request object is an opaque object in MPI “system” memory associated with a particular communication operation. It links the posting to the completion.

- Status object can provide information about:
 - count: number of received entries
 - MPI_SOURCE: source of the message
 - MPI_TAG: tag value of the message
 - MPI_ERROR: error associated with the message
- If you don't want to inspect it, you can use MPI_STATUS_IGNORE

Using non-blocking send/recv

```
int main(int argc, char *argv[]) {  
    ...  
    MPI_Comm_rank(MPI_COMM_WORLD, &myrank);  
    MPI_Request req;  
    MPI_Status stat;  
    ...  
    if (myrank % 2 == 0) {  
        data = myrank;  
        MPI_Isend(&data, 1, MPI_INT, myrank+1, 0, ..., &req);  
    } else {  
        data = myrank * 2;  
        MPI_Irecv(&data, 1, MPI_INT, myrank-1, 0, ..., &req);  
  
        ...  
        MPI_Wait(&req, &stat);  
        printf("Process %d received data %d\n", myrank, data);  
    }  
    ...  
}
```

0

1

2

3

Time 

Using non-blocking send/recv

```
int main(int argc, char *argv[]) {  
    ...  
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    } else {  
        data = myrank * 2;  
        MPI_Irecv(&data, 1, MPI_INT, myrank-1, 0, ..., &req);  
  
        ...  
        MPI_Wait(&req, &stat);  
        printf("Process %d received data %d\n", myrank, data);  
    }  
    ...  
}
```

0 data = 0

1 data = 2

2 data = 2

3 data = 6

Time 

Using non-blocking send/recv

```
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        ...  
        MPI_Wait(&req, &stat);  
        printf("Process %d received data %d\n", myrank, data);  
    }  
    ...  
}
```



Using non-blocking send/recv

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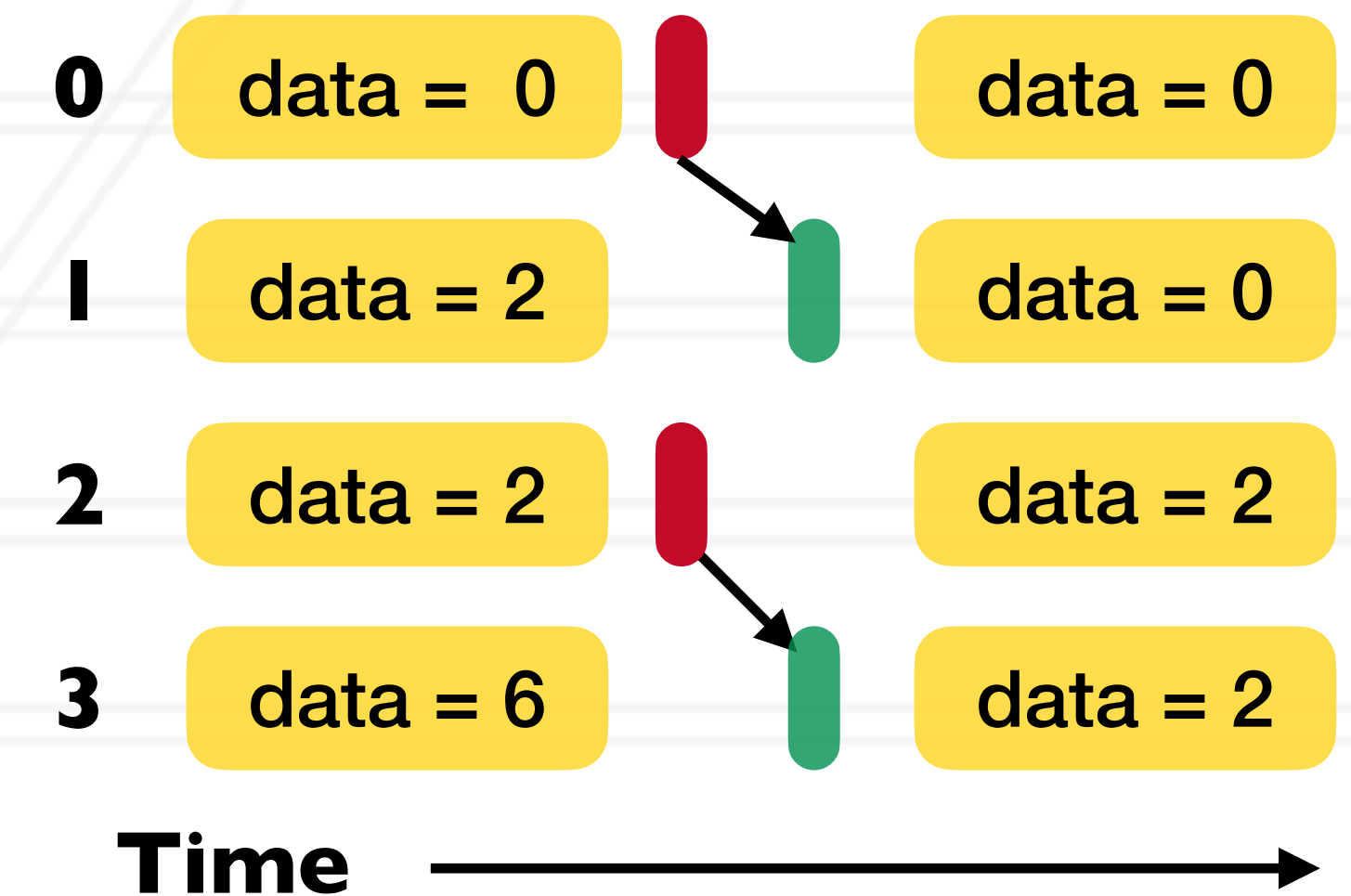
        ...
        MPI_Wait(&req, &stat);
        printf("Process %d received data %d\n", myrank, data);
    }
    ...
}
```



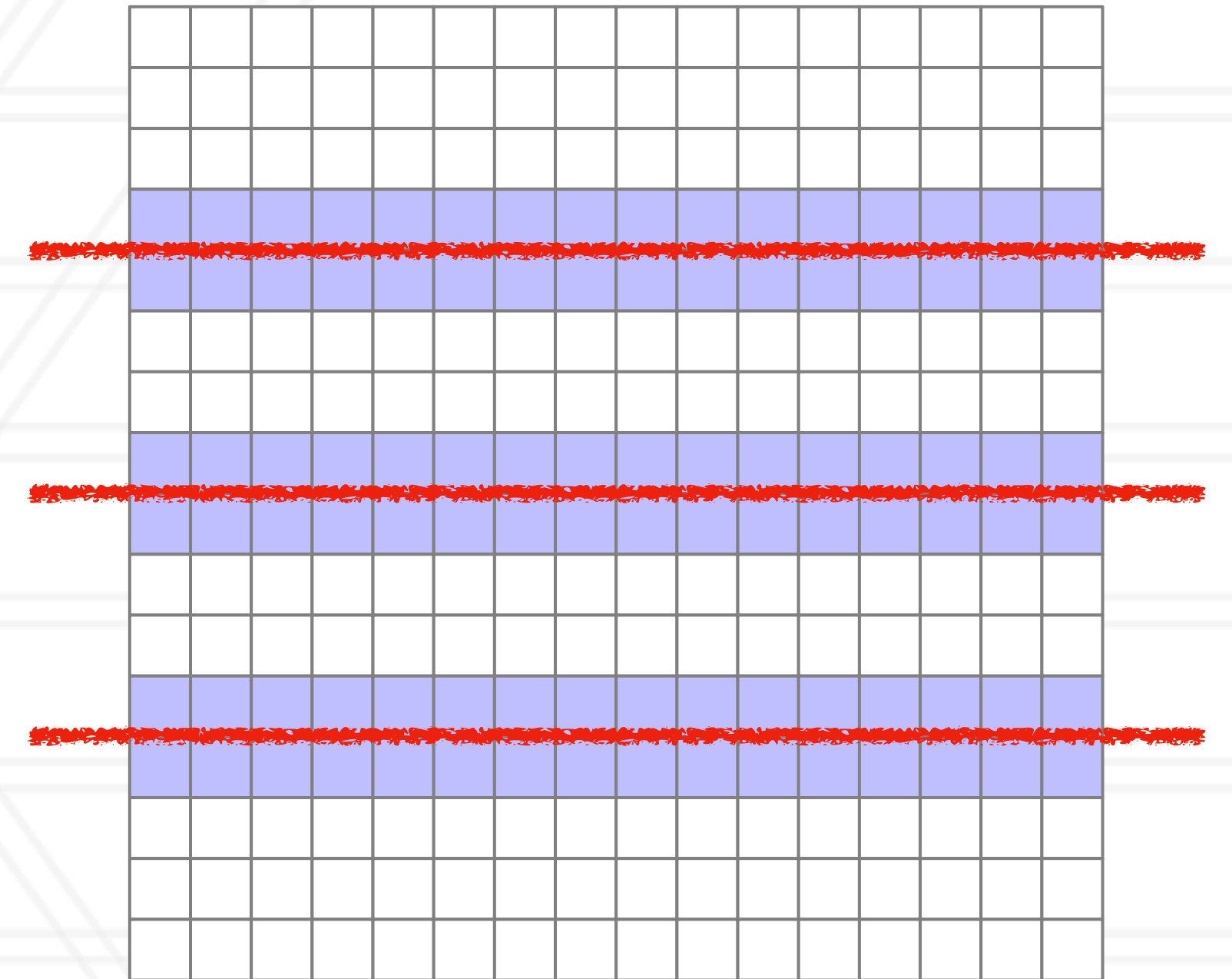
Using non-blocking send/recv

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        data = myrank * 2;
        MPI_Irecv(&data, 1, MPI_INT, myrank-1, 0, ..., &req);
    }

    ...
    MPI_Wait(&req, &stat);
    printf("Process %d received data %d\n", myrank, data);
}
...
```

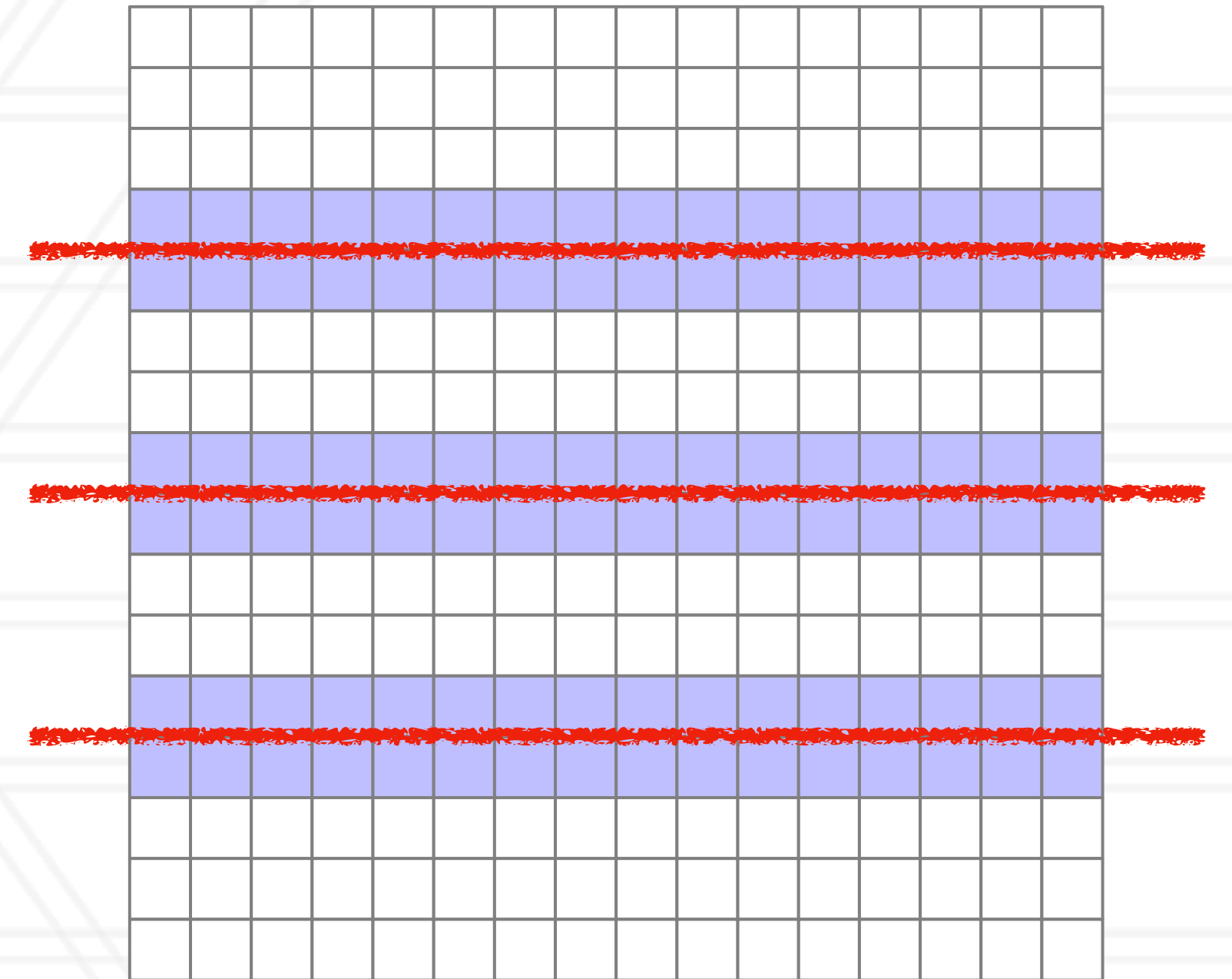


2D stencil computation



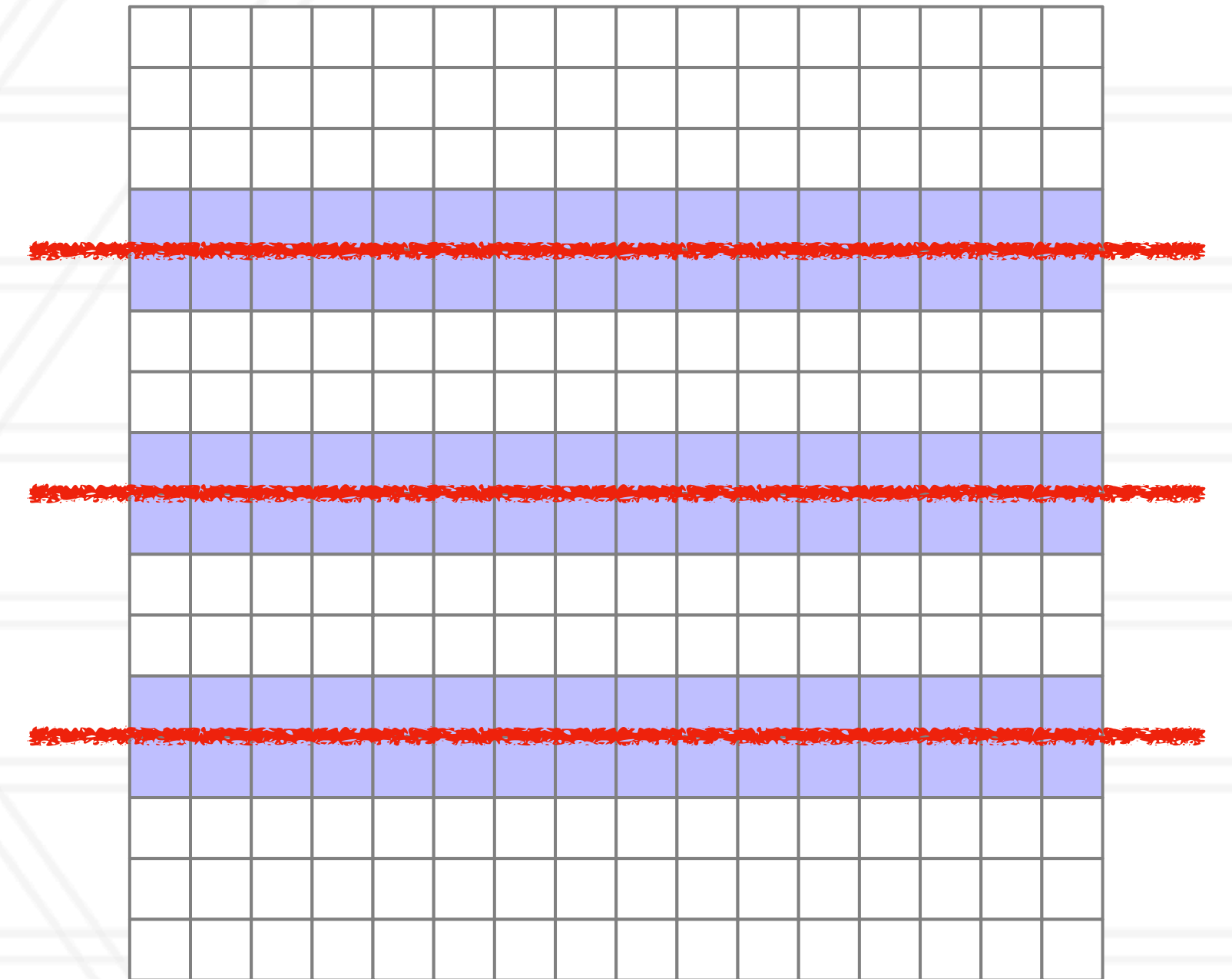
2D stencil computation

```
int main(int argc, char *argv) {  
    ...  
  
    for(int t=0; t<num_steps; t++) {  
  
        MPI_Irecv(&data1, 16, MPI_DOUBLE, (myrank-1)%4, 0, ...);  
        MPI_Irecv(&data2, 16, MPI_DOUBLE, (myrank+1)%4, 0, ...);  
  
        MPI_Isend(&data3, 16, MPI_DOUBLE, (myrank-1)%4, 0, ...);  
        MPI_Isend(&data4, 16, MPI_DOUBLE, (myrank+1)%4, 0, ...);  
  
        MPI_Waitall(...);  
  
        compute();  
    }  
    ...  
}
```



2D stencil computation

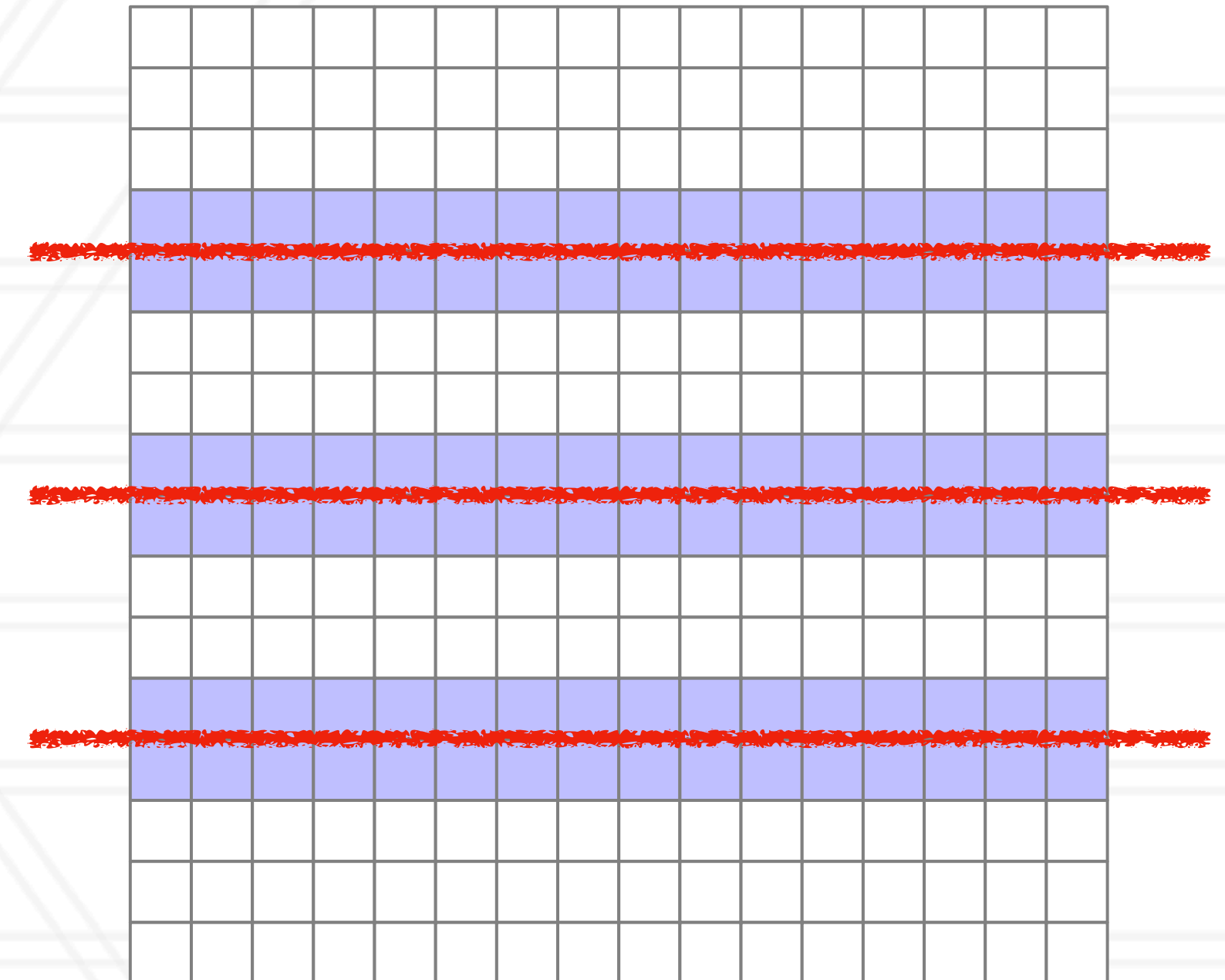
```
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    ...  
  
    for(int t=0; t<num_steps; t++) {  
  
        MPI_Irecv(&data1, 16, MPI_DOUBLE, (myrank-1)%4, 0, ...);  
        MPI_Irecv(&data2, 16, MPI_DOUBLE, (myrank+1)%4, 0, ...);  
  
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        MPI_Waitall(...);  
  
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    }  
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}
```



2D stencil computation

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        MPI_Isend(&data3, 16, MPI_DOUBLE, (myrank-1)%4, 0, ...);  
        MPI_Isend(&data4, 16, MPI_DOUBLE, (myrank+1)%4, 0, ...);  
  
        MPI_Waitall(...);  
  
        compute();  
    }  
    ...  
}
```

Wraparound



Other MPI calls

- `int MPI_Test( MPI_Request *request, int *flag, MPI_Status *status )`
 - `flag` is set to true if the operation has completed
- `int MPI_Waitall( int count, MPI_Request array_of_requests[], MPI_Status *array_of_statuses[] )`
 - Waits for all given MPI requests to complete
- `MPI_Waitany`
 - Waits for any specified MPI request to complete

Collective operations

- All processes in the communicator participate in the operation

Collective operations

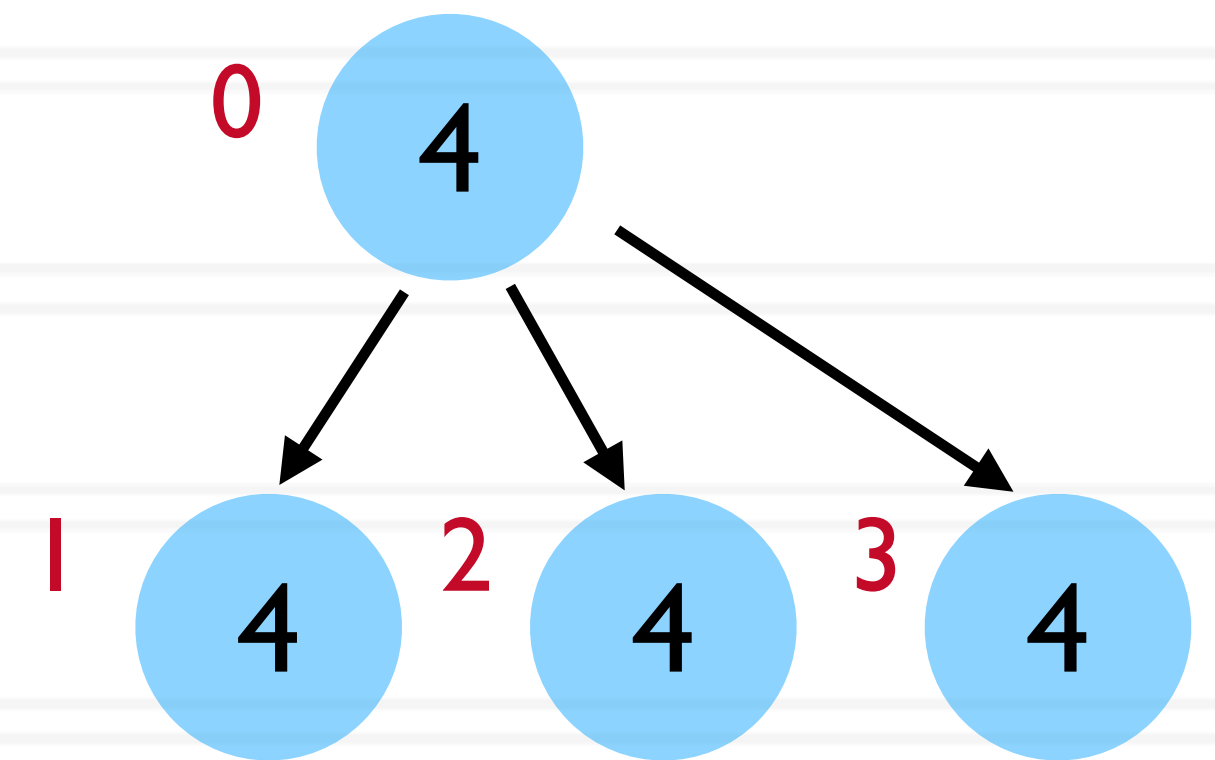


Collective operations

- `int MPI_Barrier( MPI_Comm comm )`
 - Blocks until all processes in the communicator have reached this routine

Collective operations

- `int MPI_Barrier( MPI_Comm comm)`
 - Blocks until all processes in the communicator have reached this routine
- `int MPI_Bcast( void *buffer, int count, MPI_Datatype datatype, int root, MPI_Comm comm )`
 - Send data from root to all processes of the communicator
 - Buffer represents what is being sent on root but where things will be written on other processes



Collective operations

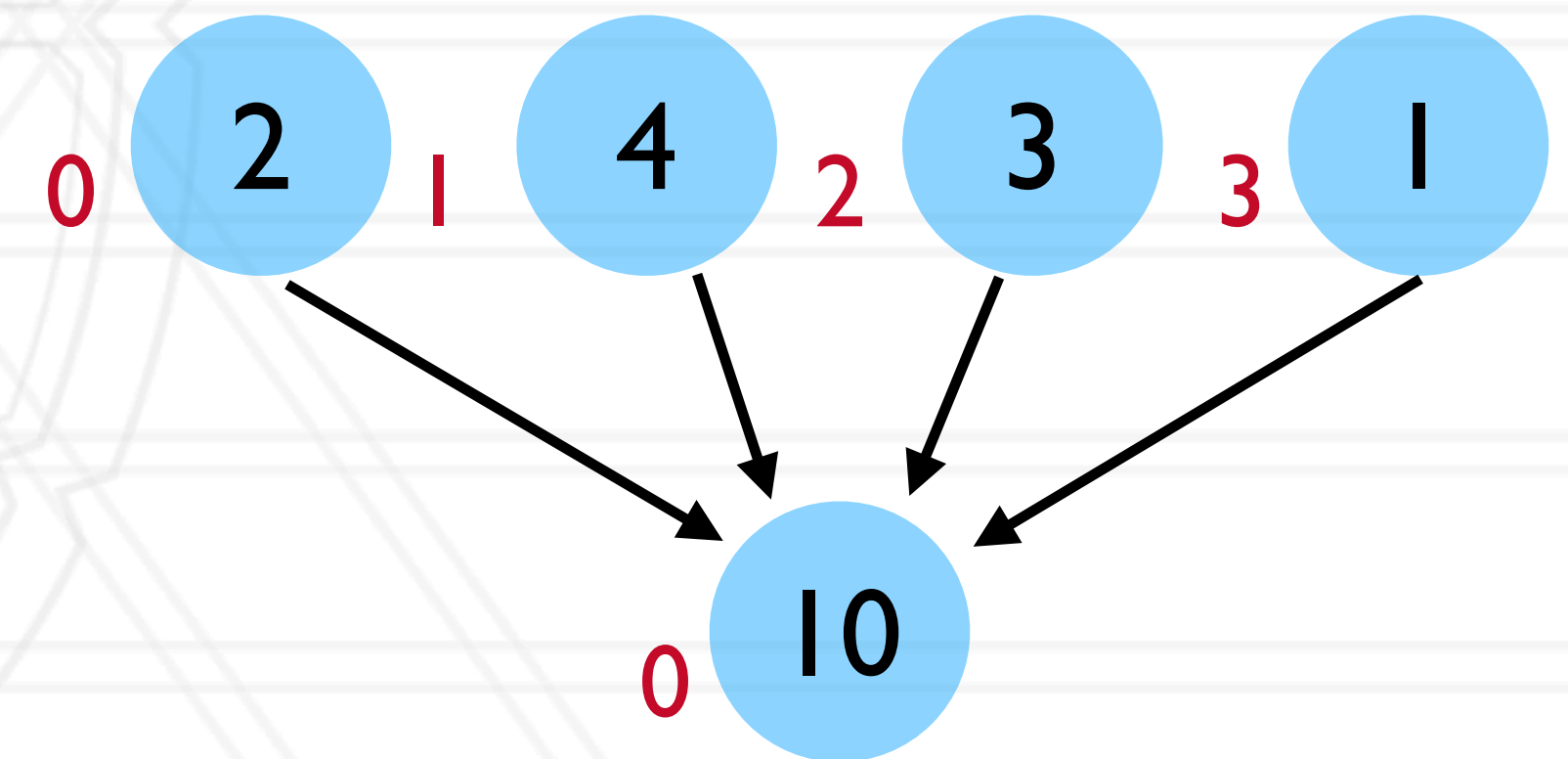


Collective operations

- `int MPI_Reduce( const void *sendbuf, void *recvbuf, int count, MPI_Datatype datatype, MPI_Op op, int root, MPI_Comm comm )`
 - Reduce data from all processes to the root
 - sendbuf should be valid on all processes
 - Recvbuf only needs to exist on root

Collective operations

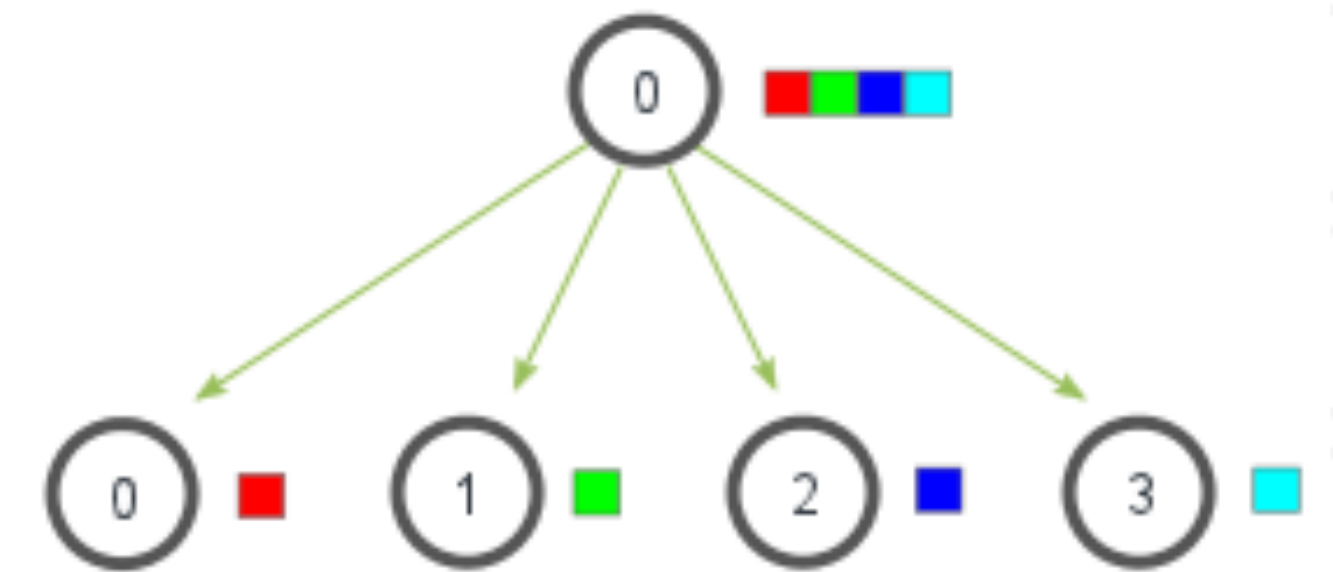
- `int MPI_Reduce( const void *sendbuf, void *recvbuf, int count, MPI_Datatype datatype, MPI_Op op, int root, MPI_Comm comm )`
 - Reduce data from all processes to the root
 - sendbuf should be valid on all processes
 - Recvbuf only needs to exist on root
- `MPI_Allreduce`
 - Can be used to send the result back to **all** processes



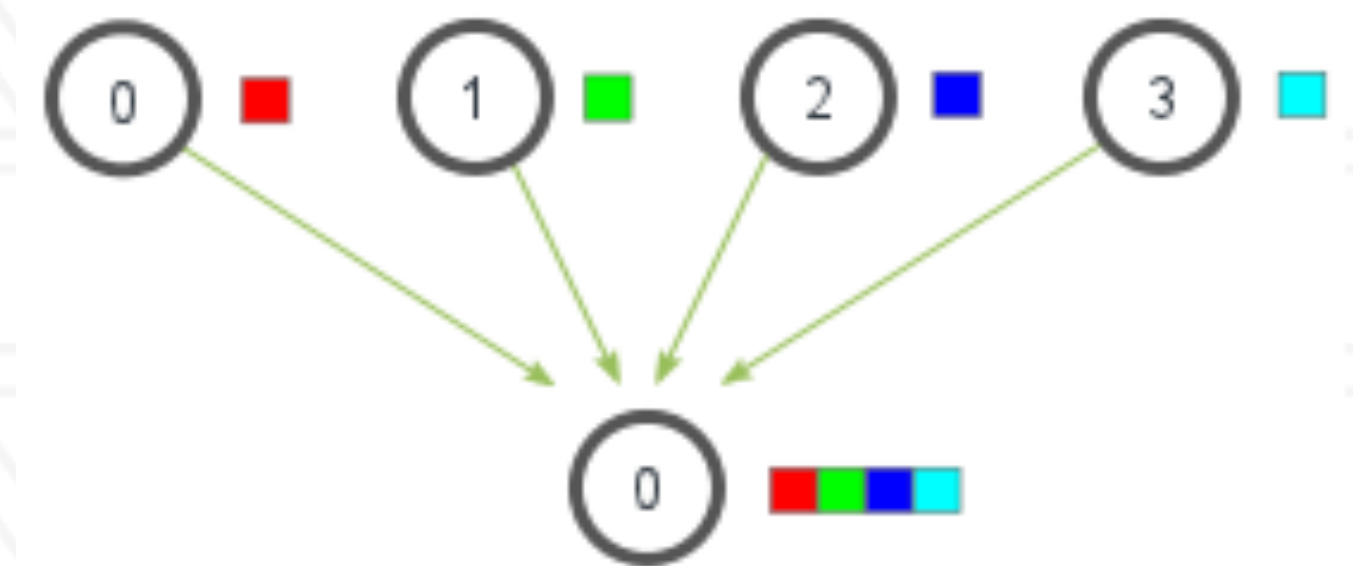
Collective operations

- `int MPI_Scatter( const void *sendbuf, int sendcount, MPI_Datatype sendtype, void *recvbuf, int recvcount, MPI_Datatype recvtype, int root, MPI_Comm comm)`
 - Send distinct data from root to all processes
- `int MPI_Gather( const void *sendbuf, int sendcount, MPI_Datatype sendtype, void *recvbuf, int recvcount, MPI_Datatype recvtype, int root, MPI_Comm comm)`
 - Gather distinct data from all processes to the root
- **MPI_Scan: Computes prefix sum**

MPI_Scatter



MPI_Gather



<https://mpitutorial.com/tutorials/mpi-scatter-gather-and-allgather/>

Other MPI calls

- `double MPI_Wtime ( void )`
 - Returns elapsed time in seconds since an arbitrary time in the past

```
{  
  double starttime, endtime;  
  starttime = MPI_Wtime();  
  
  .... code region to be timed ...  
  
  endtime = MPI_Wtime();  
  printf("Time %f seconds\n",endtime-starttime);  
}
```


Calculate the value of $\pi = \int_0^1 \frac{4}{1+x^2}$

```
int main(int argc, char *argv[])
{
    ...

    n = 10000;

    h = 1.0 / (double) n;
    sum = 0.0;

    for (i = 1; i <= n; i += 1) {
        x = h * ((double)i - 0.5);
        sum += (4.0 / (1.0 + x * x));
    }
    pi = h * sum;

    ...
}
```

Calculate the value of $\pi = \int_0^1 \frac{4}{1+x^2}$

```
int main(int argc, char *argv[])
{
    ...

    n = 10000;
    MPI_Bcast(&n, 1, MPI_INT, 0, MPI_COMM_WORLD);

    h = 1.0 / (double) n;
    sum = 0.0;

    for (i = myrank + 1; i <= n; i += numpes) {
        x = h * ((double)i - 0.5);
        sum += (4.0 / (1.0 + x * x));
    }
    pi = h * sum;

    MPI_Reduce(&pi, &globalpi, 1, MPI_DOUBLE, MPI_SUM, 0, MPI_COMM_WORLD);

    ...
}
```

Protocols for sending message

- Eager

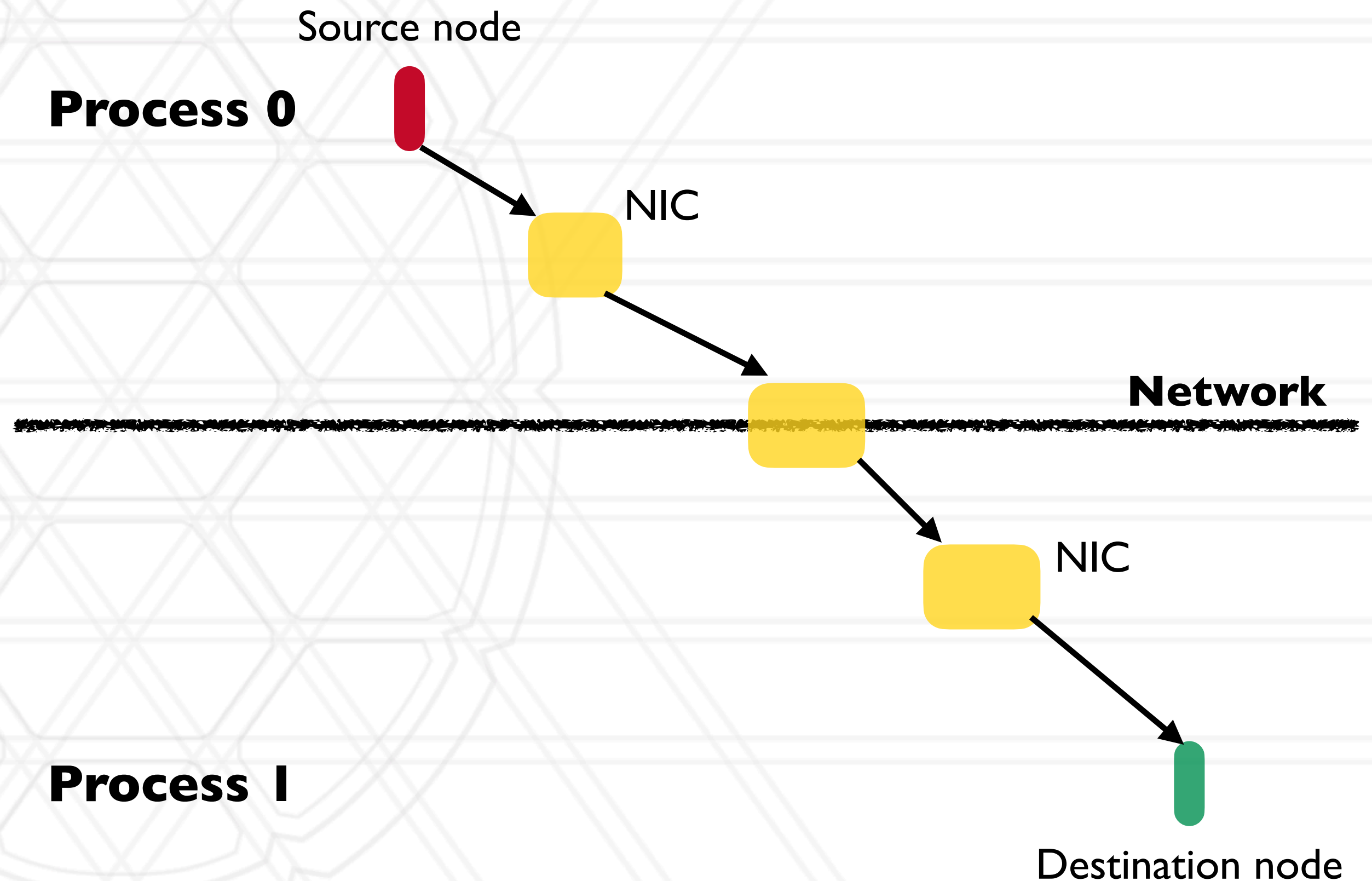
- Message sent assuming destination can store

- Rendezvous

- Message only sent after handshake (receiving ack) with destination

- Short

- Data sent with the message envelope



Other MPI send modes

- Basic mode: `MPI_Send`
- Buffered mode: `MPI_Bsend` — returns immediately and send buffer can be reused
 - Use `MPI_Buffer_attach` to provide space for buffering
- Synchronous mode: `MPI_Ssend` — will not return until matching receive is posted
- Ready mode: `MPI_Rsend` — may be used **ONLY** if matching receive is already posted
- Non-blocking versions of all of the above also exist

<https://www.mcs.anl.gov/research/projects/mpi/sendmode.html>



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