Parallel Computing for Science & Engineering Spring 2013: MPI point-to-point 1

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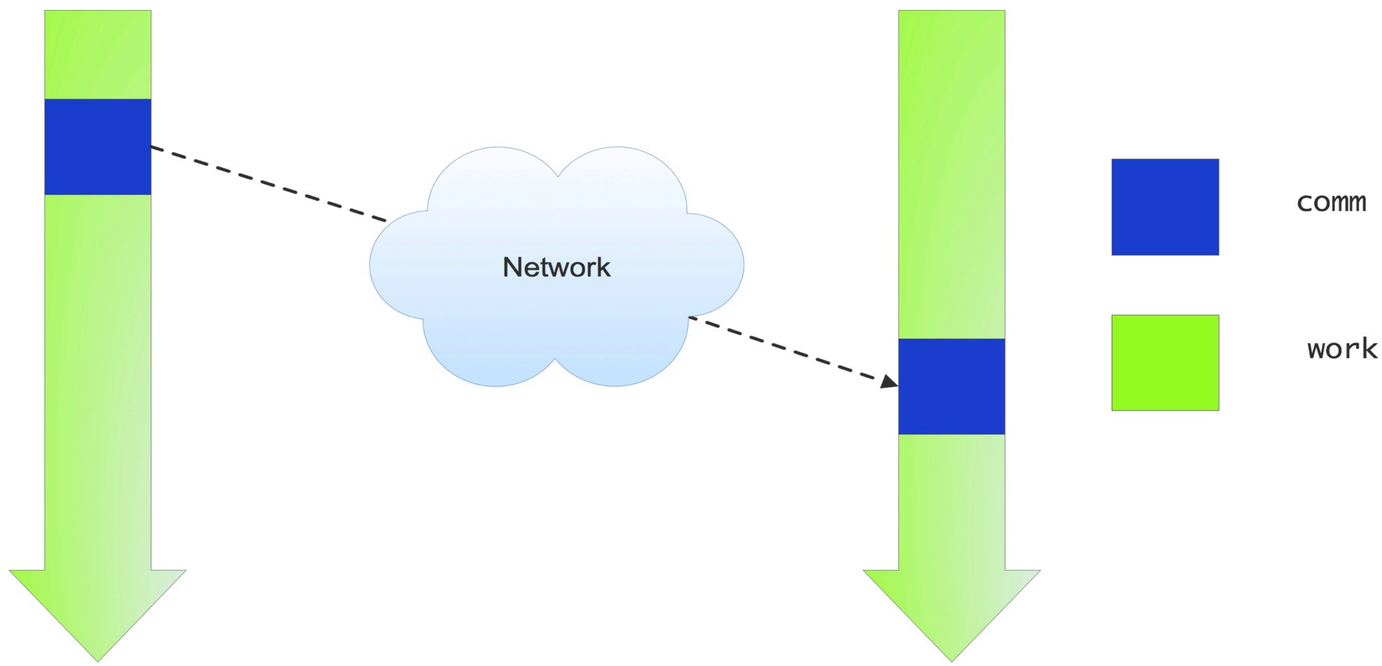
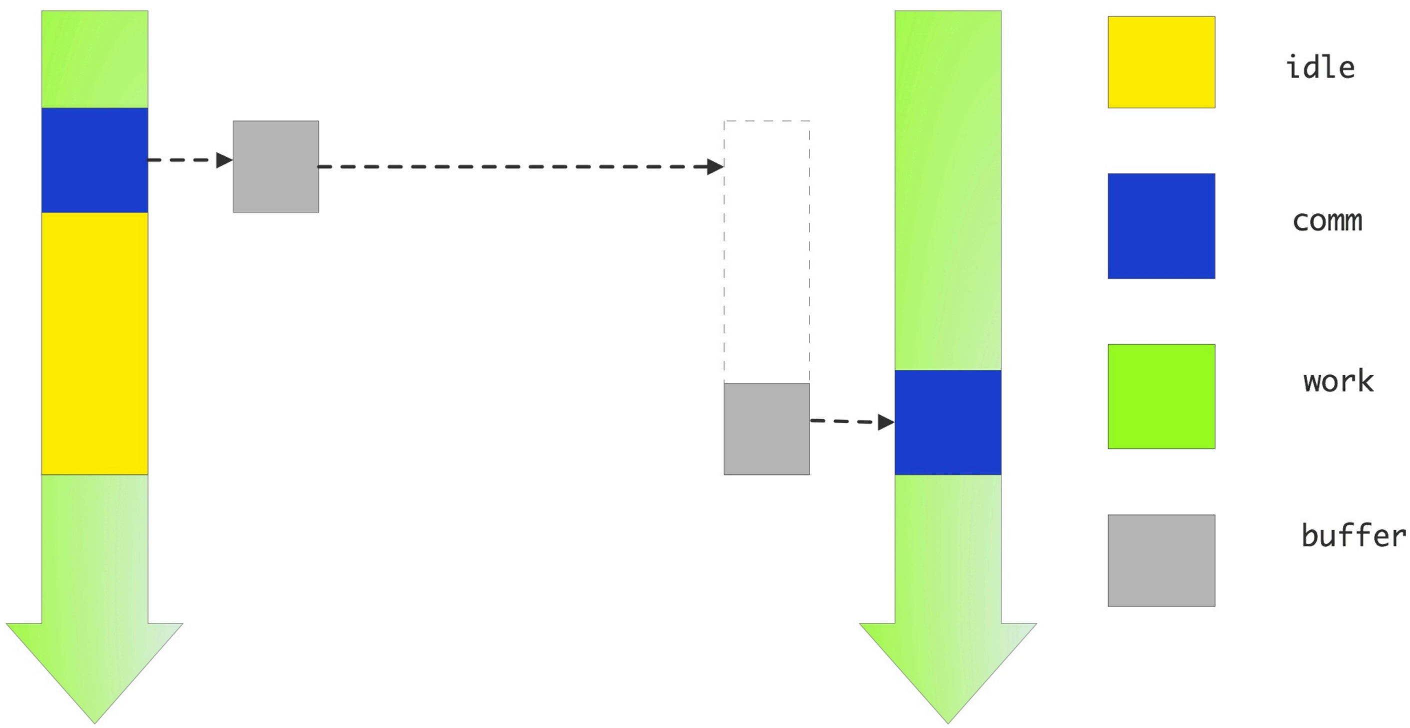
Life would be simple if....

- Processors would just send and receive, and the network would DWIM



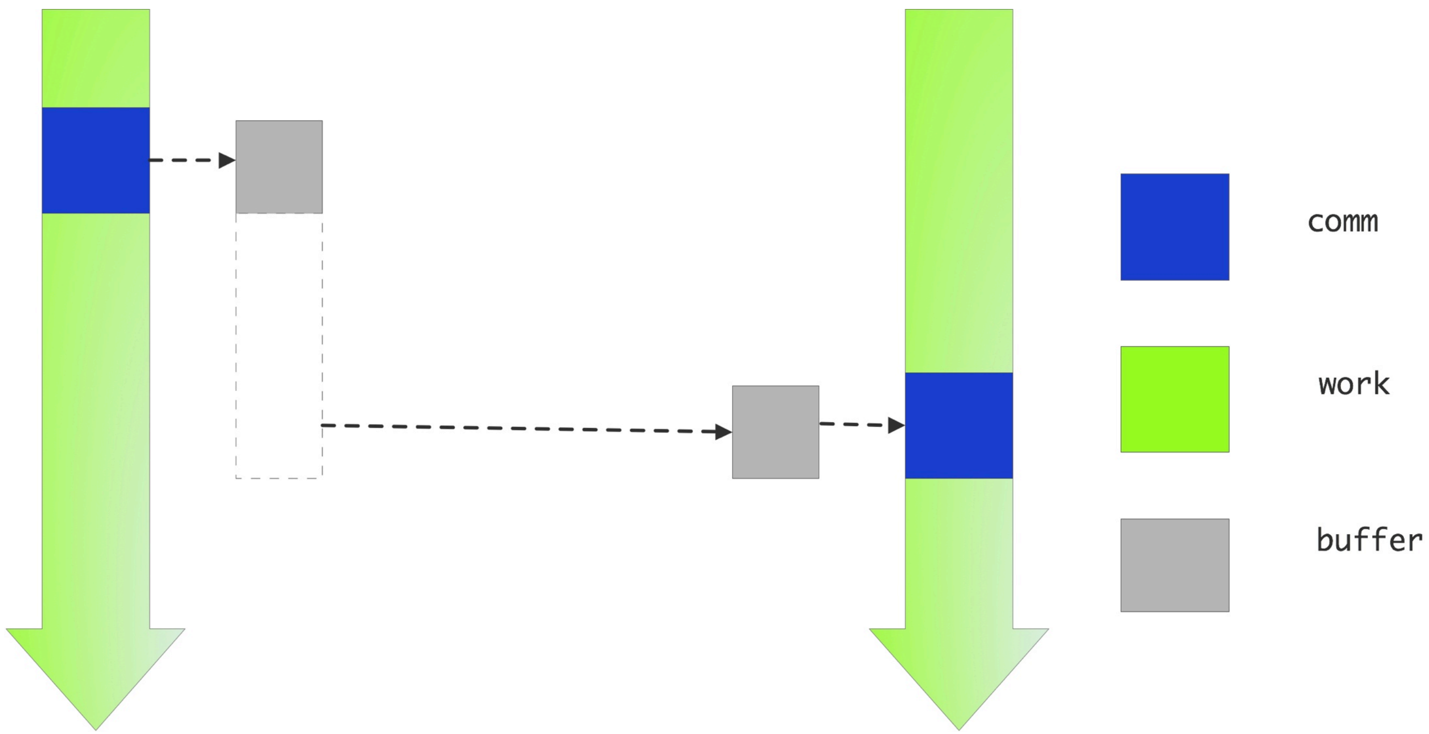
Unfortunately

- Data has to be somewhere: on one process or the other

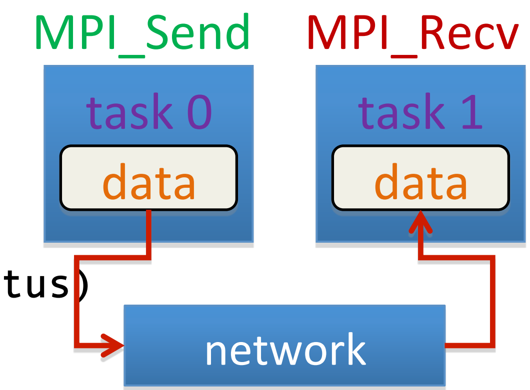


Non-blocking solution

- Create a buffer and let the send data sit there until someone picks it up



Blocking Send/Receive



Generic Syntax

- `MPI_Send(buf, count, datatype,       dest, tag, comm)`
- `MPI_Recv(buf, count, datatype, source, tag, comm, status)`
- **When MPI sends a message, it doesn't just send the contents; it also sends an *envelope* describing the contents:**

Argument	Description
buf	initial address of send/receive buffer (reference)
count	number of items to send (integer)
datatype	MPI data type of items to send/receive
dest	MPI rank of task receiving the data (integer)
source	MPI rank of task sending the data (integer)
tag	message ID (integer)
comm	MPI communicator (set of exchange processors)
status	returns information on the message received

Parts of a P-2-P Communication:
- Data
- Send to/Recv from
- Message ID

Details

`buffer`	data (address in C, name of array/value in Fortran)
`count`	Length of source array (in elements, 1 for scalars)
`datatype`	Data Type: e.g. `MPI_INT` (C), `MPI_INTEGER` (F90), `MPI_DOUBLE_PRECISION` (F90), `MPI_DOUBLE` (C), etc.
`source`	Rank (proc #) of source in communicator group
`tag`	Message identifier (arbitrary integer)
`communicator`	Group of processors
`status`	Information about message
`ierr`	Error (argument in Fortran, returned in C)

	C	Fortran
status	`MPI_Status mystat;`	`integer mystat(MPI_STATUS_SIZE)`
datatype	`MPI_Datatype mytype;`	`integer mytype`
comm.	`MPI_Comm mycomm;`	`integer mycomm`

Language Example

- C

```
ierr=MPI_Send(&a[0],cnt,type,dest,tag,com);
```

- F

```
call MPI_Send( a,   cnt,type,dest,tag,com,ierr)
```

- C

```
ierr=MPI_Recv(&b[0],cnt,type, src,tag,com,&status);
```

- F

```
call MPI_Recv( b,   cnt,type, src,tag,com, status,ierr)
```

- Call blocks until send data of *a* has been sent or copied to a buffer. Recv's block until data is in *b*.

P-2-P Example

```
#include <mpi.h>
int main(int argc, char* argv[]){
MPI_Comm Comm=MPI_COMM_WORLD;
int npes,iam=-1,ierr;

ierr=MPI_Init(&argc, &argv);
ierr=MPI_Comm_size(Comm,&npes);
ierr=MPI_Comm_rank(Comm, &iam);




ierr=MPI_Finalize();

printf("iam=%d\n",iam);
}
```

P-2-P Example

```
#include <mpi.h>
int main(int argc, char* argv[]){
MPI_Comm  Comm=MPI_COMM_WORLD;
MPI_Status status;
int npes,iam=-1,ierr,irec=-1;
ierr=MPI_Init(&argc, &argv);
ierr=MPI_Comm_size(Comm,&npes);
ierr=MPI_Comm_rank(Comm, &iam);

if(iam==0)
        ierr=MPI_Send(&iam, 1,MPI_INT, 1,9, Comm);
if(iam==1)
        ierr=MPI_Recv(&irec,1,MPI_INT, 0,9, Comm,&status);
ierr=MPI_Finalize();

printf("iam=%d, received=%d\n",iam,irec);
}
```

The 6 Basic MPI Call Summary

- MPI is used to create parallel programs based on message passing
- Usually the same program is run on multiple processors
- The 6 basic calls in MPI are

```
MPI_Init(&argc, &argv);
MPI_Comm_Rank(MPI_COMM_WORLD,&myid);
MPI_Comm_Size(MPI_COMM_WORLD,&numprocs);
MPI_Send(buffer,count,MPI_TYPE, dest,tag,MPI_COMM_WORLD);
MPI_Recv(buffer,count,MPI_TYPE, src, tag,MPI_COMM_WORLD,&stat);
MPI_Finalize();
```

MPI_TYPE is an MPI Parameter or User Data Type
buffer is passed by reference

MPI_SendRecv

```
MPI_SendRecv(senddat,sendcount,sendtype, dest,sendtag,
             recvdat,recvcount,recvtype, src, recvtag,
             comm, status)
```

- Initiates send and receive at the same time.
- Completes when both send and receive buffers are safe to use
- Useful for communications patterns where each node sends and receives messages (two-way communication). Good for avoiding deadlock, implementing shifts/rings.
- Executes a **standard mode** send & receive operation for dest and src, respectively.
- The send and receive operations use the same communicator, but have distinct tags.

Bidirectional Communication with MPI_Sendrecv

- C

```
ierr=MPI_Sendrecv(&sb[0],scnt,stype,dest,stag,
                  &rb[0],rcnt,rtype, src,rtag,
                  MPI_COMM_WOLRD,&status);
```

- Fortran

```
call MPI_Sendrecv( sb,  scnt,stype,dest,stag,
                   rb,  rcnt,rtype, src,rtag,
                   MPI_COMM_WOLRD, status,ierr)
```

Blocking vs Non-blocking

Blocking

- A blocking send routine will only return after it is *safe* to modify the data area.
- *Safe* means that modifications in the data area will not affect the data to be sent.
- *A Safe send* does not imply that the data was actually received.
- A blocking send can be either synchronous or asynchronous.

Non-blocking

- Send/receive routines return immediately.
- Non-blocking operations request the MPI library to perform the operation when possible.
- It is **unsafe** to modify the data area until the requested operation has been performed. There are *wait* routines used to do this (MPI_Wait)
- Primarily used to overlap computation with communication

Blocking vs non-Blocking Routines

Description	Syntax for C bindings
Blocking send	`MPI_Send(buf, count, datatype, dest, tag, comm)`
Non-blocking send	`MPI_Isend(buf,count, datatype, dest, tag, comm, request)`
Blocking receive	`MPI_Recv(buf, count, datatype, source, tag, comm, status)`
Non-blocking receive	`MPI_Irecv(buf,count, datatype, source, tag, comm, request)`
Wait for completion	`MPI_Wait(request, status)`

request: used by non-blocking send and receive operation.

Non-blocking Communication

- Non-blocking send
  - send call returns immediately
  - send actually occurs later
- Non-blocking receive
  - receive call returns immediately
  - when received data is needed, call a wait subroutine
- Non-blocking communication used to overlap communication with computation (and communication with communication!).
- Can be used to prevent deadlock.

Non-blocking Send with MPI_Isend

- C

```
MPI_Request request;
ierr = MPI_Isend(&data, count, datatype,
                 dest, tag,   comm, &request);
```

- Fortran

```
integer request
call MPI_Isend(   data, count, datatype,
                  dest, tag,   comm,  request, ierr)
```

- `request` is the id for the message call
- Don't use **data** area until communication is complete

Non-blocking Receive with MPI_Irecv

- C

```
MPI_Request request;
ierr = MPI_Irecv(&data, count, datatype,
                 source, tag,   comm, &request);
```

- Fortran

```
integer request
call MPI_Irecv(   data, count, datatype,
                source, tag,   comm,  request, ierr)
```

- `request` is an id for communication
- Note: There is **no status parameter**.
- Don't use **`data`** area until communication is complete

MPI_Wait Used to Complete Communication

- `request` from `MPI_Isend` or `MPI_Irecv`
  - the completion of a send operation indicates that the sender is now free to update the data in the send buffer
  - the completion of a receive operation indicates that the receive buffer contains the received message
- `MPI_Wait` blocks until message specified by `request` completes

MPI_Wait Usage

- C

```
MPI_Request request;
MPI_Status status;
...
ierr = MPI_Wait(&request, &status)
```

- Fortran

```
integer request
integer status(MPI_STATUS_SIZE)
...
call MPI_Wait(   request,  status, ierr)
```

Nonblocking Examples

Two-way Communication: Deadlock

Deadlock 1 (always deadlocks)

```
other = 1-mytid
call MPI_Recv(   recvbuf,count,MPI_REAL,
   other,tag,MPI_COMM_WORLD,status,ierr)
call MPI_Send(   sendbuf,count,MPI_REAL,
   other,tag,MPI_COMM_WORLD,ierr)
```

Deadlock 2 (deadlocks when system buffer is too small)

```
other = 1-mytid
call MPI_Send(   sendbuf,count,MPI_REAL,
   other,tag,MPI_COMM_WORLD,ierr)
call MPI_Recv(   recvbuf,count,MPI_REAL,
   other,tag,MPI_COMM_WORLD,status,ierr)
```

Two-way Communication: Solutions

Solution 1 (but this doesn't allow bidirectional communication)

```
if (rank==0) then
   call MPI_Send(  sendbuf,count,MPI_REAL, 1,tag,MPI_COMM_WORLD,ierr)
   call MPI_Recv(   recvbuf,count,MPI_REAL, 1,tag,MPI_COMM_WORLD,status,ierr)
elseif (rank==1) then
   call MPI_Recv(    recvbuf,count,MPI_REAL, 0,tag,MPI_COMM_WORLD,status,ierr)
   call MPI_Send(   sendbuf,count,MPI_REAL, 0,tag,MPI_COMM_WORLD,ierr)
endif
```

Solution 2

```
other = 1-mytid
call MPI_SendRecv(   sendbuf,sendcount,sendtype,other,sendtag,
   recvbuf,recvcount, recvtype,other,recvtag,MPI_COMM_WORLD,status,ierr)
```

Two-way Communication: Solutions

Solution 3

```
other = 1-mytid
call MPI_ISend(   sendbuf,count,MPI_REAL,
   other,tag,MPI_COMM_WORLD,req1,ierr)
call MPI_IRecv(   recvbuf,count,MPI_REAL,
   other,tag,MPI_COMM_WORLD,req2,ierr)
call MPI_Wait(   req1,status,ierr)
call MPI_Wait(   req2,status,ierr)
```

Solution 4 (buffered sends are not part of this class)

```
if (rank==0) then
   call MPI_BSend(   sendbuf,count,MPI_REAL,1,tag,MPI_COMM_WORLD,ierr)
   call MPI_Recv(      recvbuf,count,MPI_REAL,
   0,tag,MPI_COMM_WORLD,status,ierr)
elseif (rank==1) then
   call MPI_BSend(   sendbuf,count,MPI_REAL,1,tag,MPI_COMM_WORLD,ierr)
   call MPI_Recv(      recvbuf,count,MPI_REAL,
   0,tag,MPI_COMM_WORLD,status,ierr)
endif
```

Two-way Communications Summary

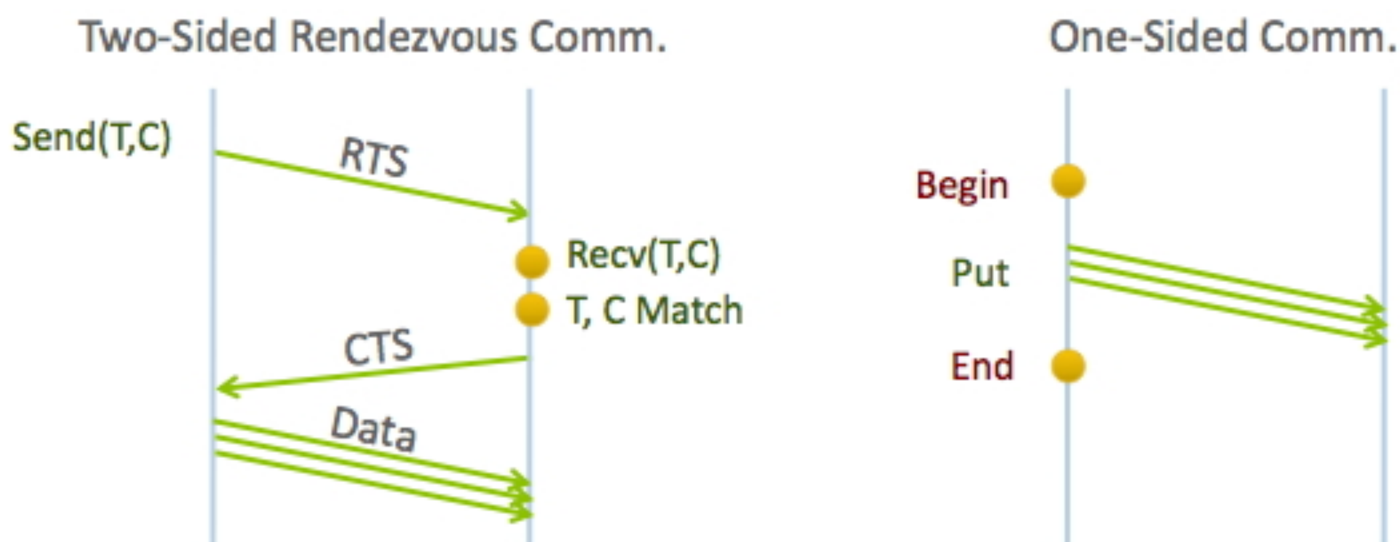
	CPU 1	CPU 2
Deadlock 1	Recv/Send	Recv/Send
Deadlock 2	Send/Recv	Send/Recv
Solution 1	Send/Recv	Recv/Send
Solution 2	SendRecv	SendRecv
Solution 3	Isend/Irecv/Wait	Isend/Irecv/Wait
Solution 4	Bsend/Recv	Bsend/Recv

Wait types

- MPI_Wait : wait for one request
- MPI_Waitall : wait for an array of requests, good for load balanced tasks, or when all needed
- MPI_Waitany : wait for one in an array of requests, good for unbalanced tasks, or if they can be processed individually
- MPI_Waitsome : wait for any number in an array, much like MPI_Waitany

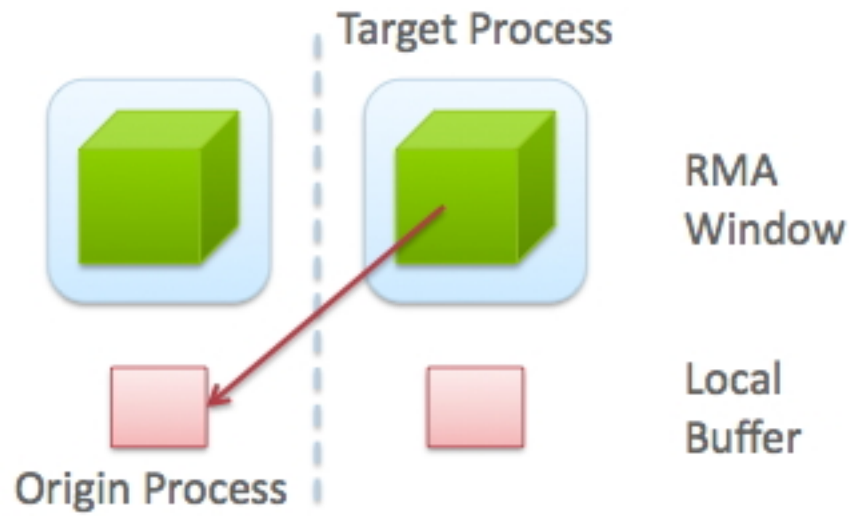
One-Sided or RMA

- It would be nice to avoid that two-way orchestration: just write into another process' memory or read from it
- Less overhead, easier to code



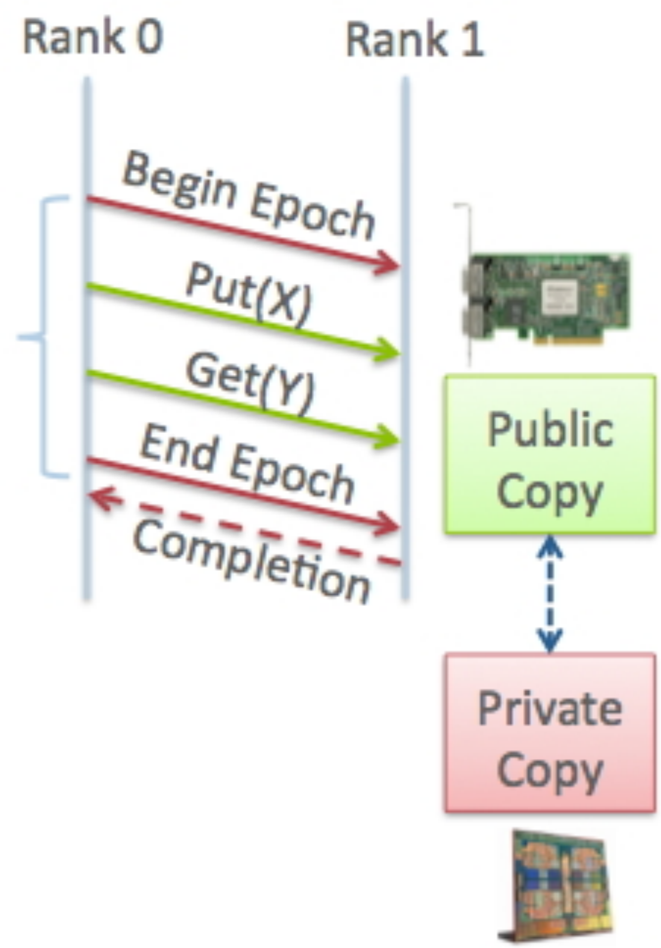
One-Sided concepts

- Target & origin processes: origin issues the call, target does nothing explicit
- Window & local memory: window is accessible to others



More RMA concepts

- Origin vs Target, window vs local mem
- Actions: Put, Get, Accumulate
- Epoch: just like MPI_Wait: you have to make sure data has arrived



RMA routines

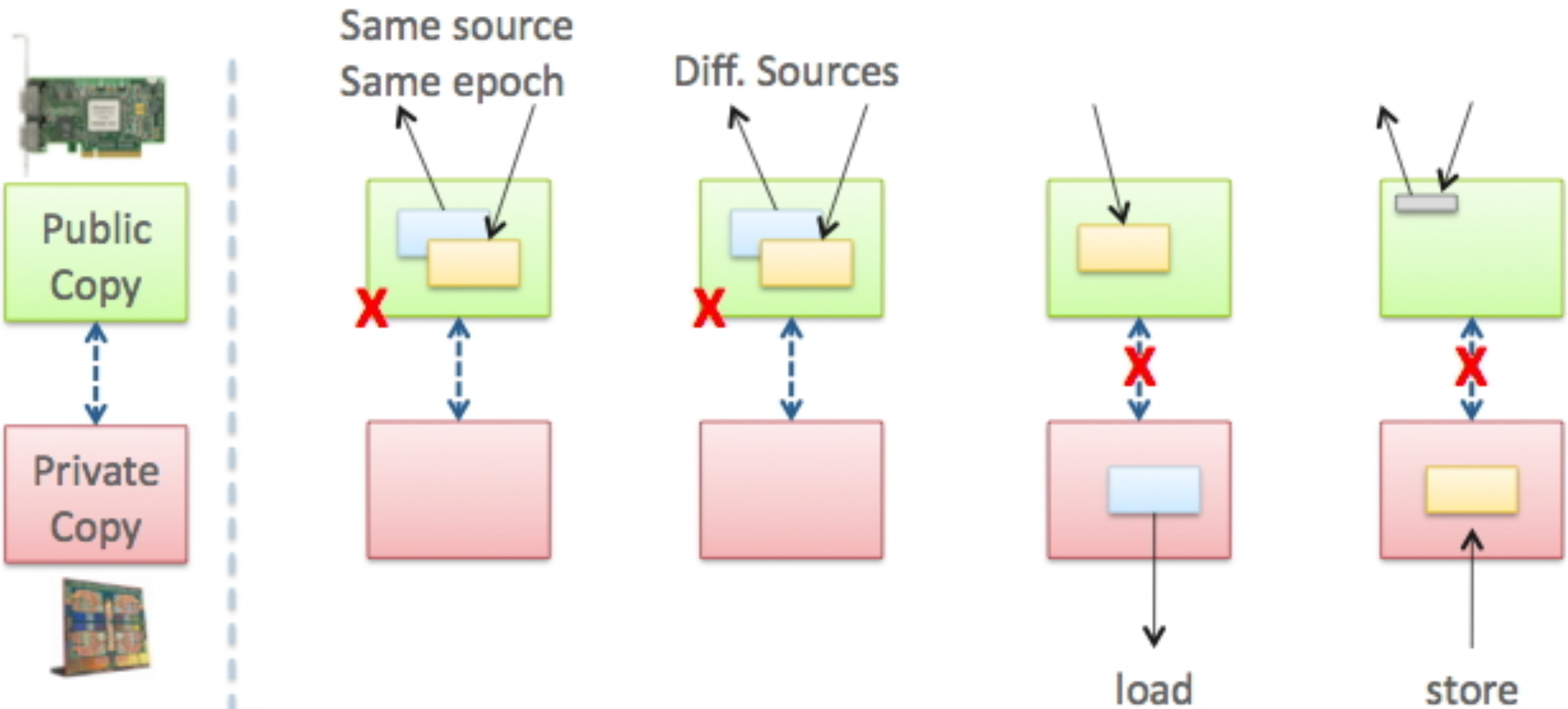
```
int MPI_Win_create(void *base, MPI_Aint size, int disp_unit, MPI_Info info,
   MPI_Comm comm, MPI_Win *win)

MPI_Get( origin_addr, origin_count, origin_datatype,
              target_rank, target_disp, target_count, target_datatype,
              win)

MPI_Win_fence(assert,win)

int MPI_Win_free(MPI_Win *win)
```

Use of fences is one way to synchronize. There are more.

Fences

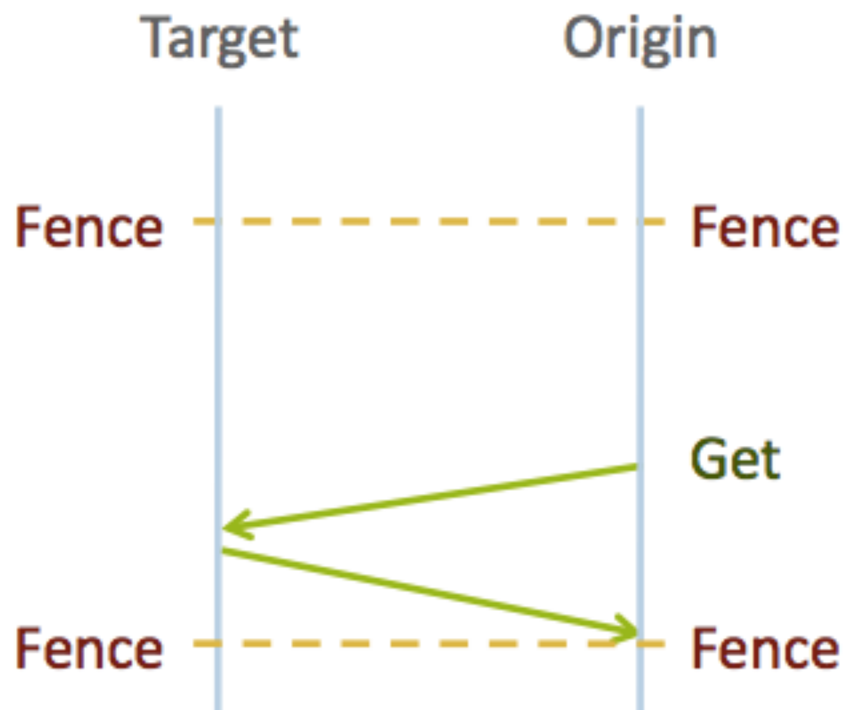
- MPI_Win_fence(assert,win)
- Assertions:
  - MPI_MODE_NOSTORE
  - MPI_MODE_NOPUT
  - MPI_MODE_NOPRECEDE
  - MPI_MODE_NOSUCCEED
- Example:
  MPI_Win_fence(
  (MPI_MODE_NOSTORE|MPI_MODE_NOPRECEDE), win);

RMA limitations



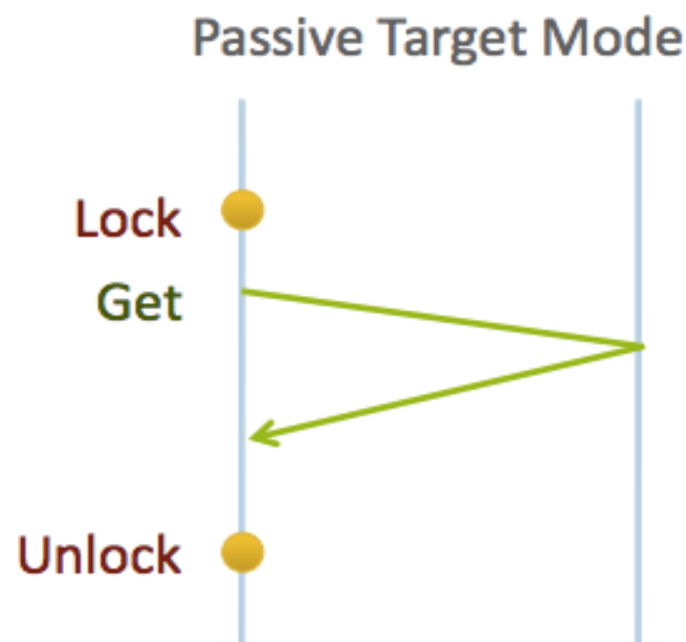
Active target synchronization

- The target does not do any communication calls, but is aware of the epoch



Passive target synchronization

- The origin locks the target window, the target is not involved at all




```
int MPI_Win_lock(int lock_type, int rank, int assert,
      MPI_Win win)

int MPI_Win_unlock(int rank, MPI_Win win)
```

Passive target mode example

```
MPI_Win_create(&other_number,1,sizeof(int),MPI_INFO_NULL,comm,&the_window);
  int target;
  if (mytid!=target) {
     MPI_Win_lock(MPI_LOCK_EXCLUSIVE,target,0,the_window);
     MPI_Accumulate(&my_number,1,MPI_INT,target,0,1,MPI_INT,MPI_SUM,the_window);
     //sleep(1);
     MPI_Win_unlock(target,the_window);
   }
  MPI_Barrier(comm);
  if (mytid==target)
   printf("I got the following: %d\n",other_number);
  MPI_Win_free( &the_window );
```