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# Distributed Computing - MPI

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Outline
Recap
One-sided Comm
Dynamic
I/O
PDE

## Outline

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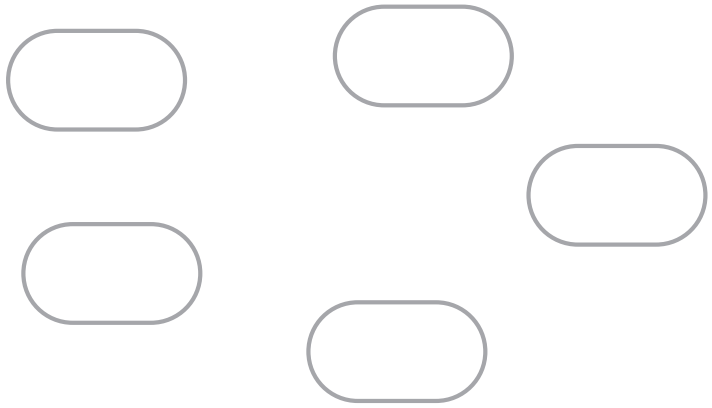
# Distributed computing







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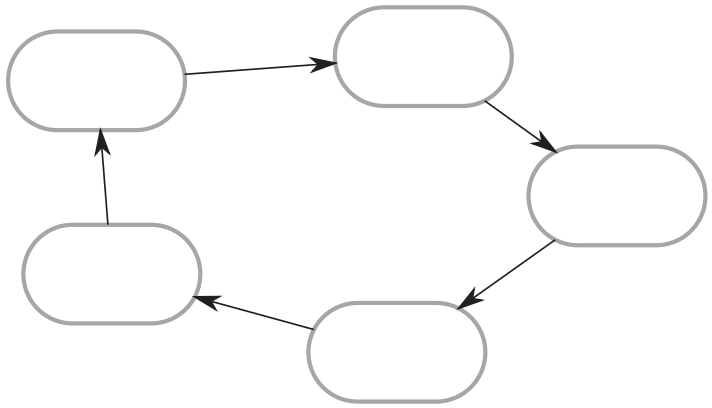

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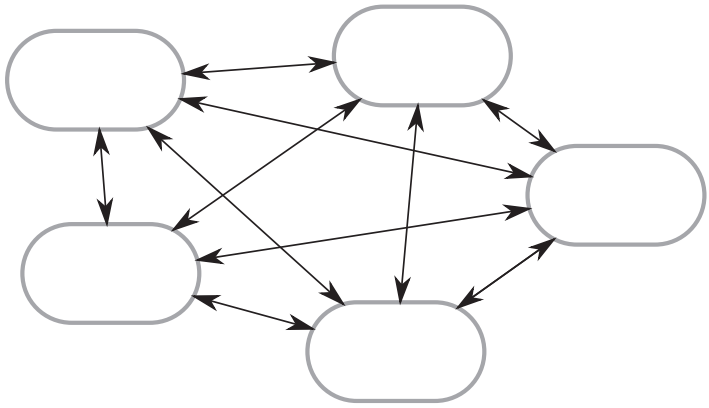
# Distributed computing







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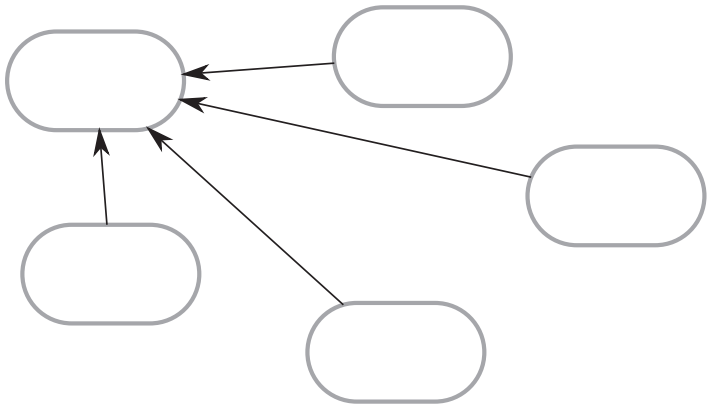

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## Distributed computing

You know how to communicate with MPI!

- Communicators
- Sending/Receiving data
- Synchronous/Blocking modes
- Other Point-to-Point Functions
- Global for synchronization
- Global for communication



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# Problems with Send/Recv

What issues are expected when using Send and Recv functions?





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# Problems with Send/Recv

What issues are expected when using Send and Recv functions?

- Send/Recv match
- Handshaking overhead
- Extra buffers

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# One-sided Communication

- Direct access to the remote memory (RMA)
- No hand-shaking procedure
- Flexible and dynamic data distribution
- Hardware optimization
- No extra buffers





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# One-sided Communication

- Create accessing window
- Accessing pattern
- Sync (fence)
- Reduction (MPI_Accumulate())
- Lighter syncs

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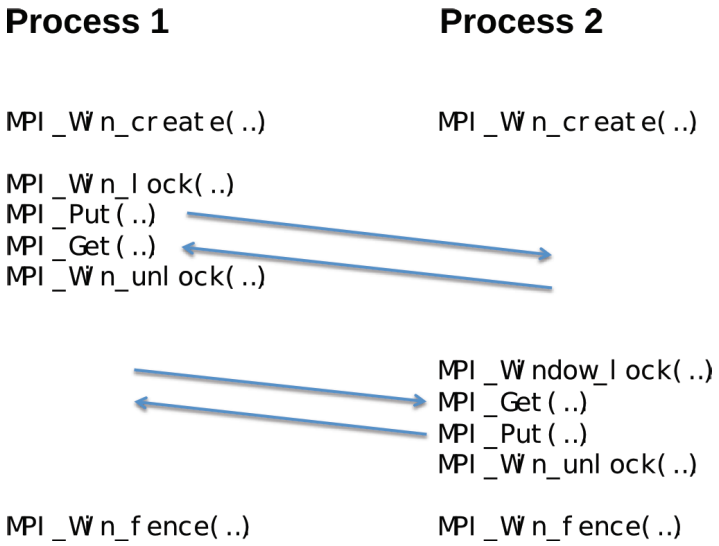
## One-sided Communication



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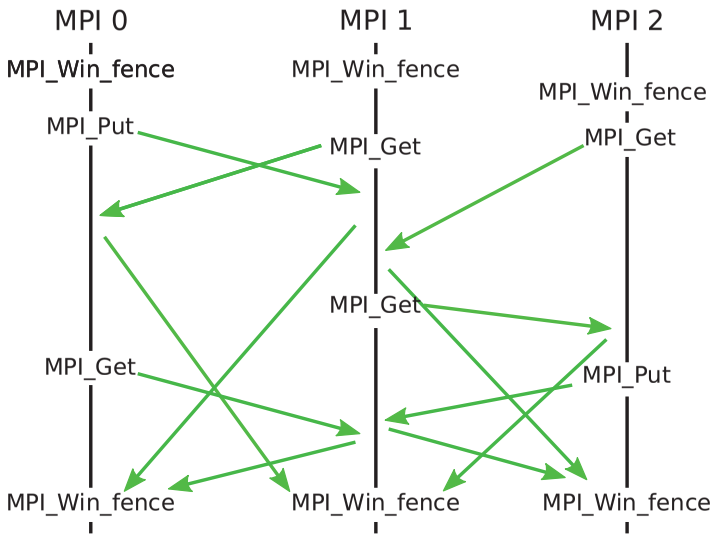
## One-sided Communication



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## Access Epoch

- Lighter/local than fence
- Epoch: time-frame when a local window may be used for RMA

Origin

- MPI_Win_start
- MPI_Win_complete

Target

- MPI_Win_post
- MPI_Win_wait



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# Dynamic Process Creation

A MPI process can spawn new MPI processes at run time which starts running a new program.

- MPI_Comm_spawn(...);
- MPI_Comm_spawn_multiple(...) (MPMD)



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# Code Example

```
// Parent program
MPI_Init(...);
MPI_Comm childcomm;
MPI_Comm_spawn("childprog",arg,nproc,...,
               &childcomm);
MPI_Send(data,count,type,0,tag,childcomm);
...
MPI_Recv(data,count,type,0,tag,childcomm,status);
MPI_Comm_free(&childcomm);
MPI_Finalize();
```

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## Code Example

```
// Child program (started by the parent program)
MPI_Init(...);
MPI_Comm parentcomm;
MPI_Get_parent(&parentcomm);
MPI_Get_rank(MPI_COMM_WORLD,&rank);
If (rank==0) MPI_Recv(data,count,type,0,tag,
             parentcomm,status);
...
If (rank==0) MPI_Send(data,count,type,0,tag,
                      parentcomm);
MPI_Finalize();
```



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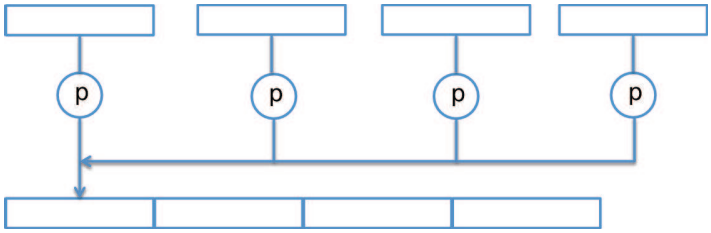
# I/O – Approach 1





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# I/O – Approach 1

Gather all data to process 0 and process 0 writes to file.
Serial operation, lacks scalability and performance.

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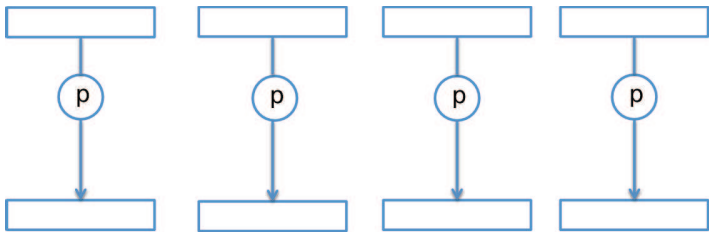
# I/O – Approach 2





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# I/O – Approach 2

Each process writes to a separate file. Good performance but lots of small files to manage. Not a practical solution, what if the number of MPI tasks changes?

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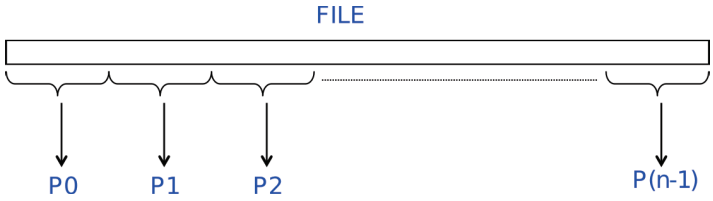
# I/O – Approach 3



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# I/O – Approach 3

MPI allows for several processes to read and write to the same file in parallel

- MPI_File_open(...)
- MPI_File_read(...)
- MPI_File_write(...)
- etc (more than 60 functions)

Portable, scalable and efficient solution!

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# PDE

## 1D Heat problem

$$\begin{aligned} \partial_t u - \nu \partial_x^2 u &= 0 && \text{in } (0,T] \times (0,1) \\ u(0,\cdot) &= u_0(\cdot) && \text{in } (0,1) \quad \text{(Initial condition)} \\ u(\cdot,0) = u(\cdot,1) &= 0 && \text{in } (0,T] \quad \text{(Boundary condition)} \end{aligned}$$

where $\nu > 0$.

Solve it in numerically and in parallel!

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# Head Problem

Math



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# Head Problem

Math

- Check compatibility condition

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# Head Problem

Math

- Check compatibility condition
- Create space grid (def space step)



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# Head Problem

Math

- Check compatibility condition
- Create space grid (def space step)
- Create time grid (def time step)

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## Head Problem

Math

- Check compatibility condition
- Create space grid (def space step)
- Create time grid (def time step)
- Discretize the problem (FD)



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## Head Problem

Math

- Check compatibility condition
- Create space grid (def space step)
- Create time grid (def time step)
- Discretize the problem (FD)
- Explicit method (no LS)

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## Head Problem

Math

- Check compatibility condition
- Create space grid (def space step)
- Create time grid (def time step)
- Discretize the problem (FD)
- Explicit method (no LS)
- Check Stability condition



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## Head Problem

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- Check compatibility condition
- Create space grid (def space step)
- Create time grid (def time step)
- Discretize the problem (FD)
- Explicit method (no LS)
- Check Stability condition $2\nu\tau \leq h^2$

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# Head Problem

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- Create space grid (def space step)
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- Discretize the problem (FD)
- Explicit method (no LS)
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Black-board writting...