

Parallel Computing - MPI

Message Passing Interface



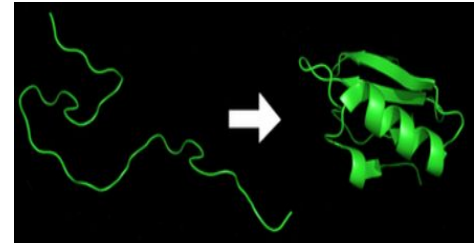
By : Om Jadhav
HPC - Tech, CDAC Pune

Agenda

- **Why Parallel Computing ?**
- **Why we need ever-increasing Performance ?**
- **Parallel programming Architectures/Model ..**
- **MPI - Message Passing Interface**
 - **What is MPI ?, Need and Evolution of MPI.**
 - **MPI program - Compile and Execution**
 - **MPI Program Structure**
 - **MPI Routines**
 - **.....**

Why we need Ever-Increasing Performance ?

- Accurate medical imaging
- Fast and accurate web searches
- Realistic computer games, Entertainment
- Climate modeling
- Protein folding
- Artificial Intelligence
- Energy research
- Data analysis
-

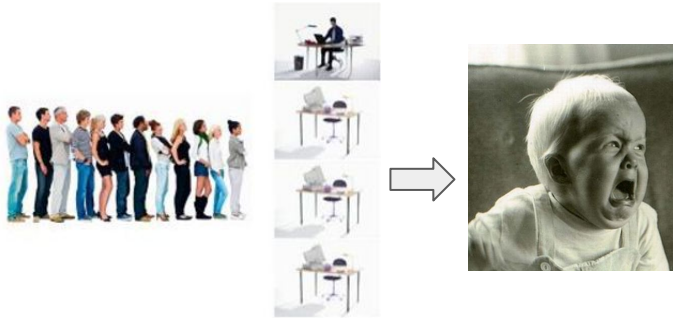


Why Parallel Computing ?

- Aren't single processor systems fast enough ?

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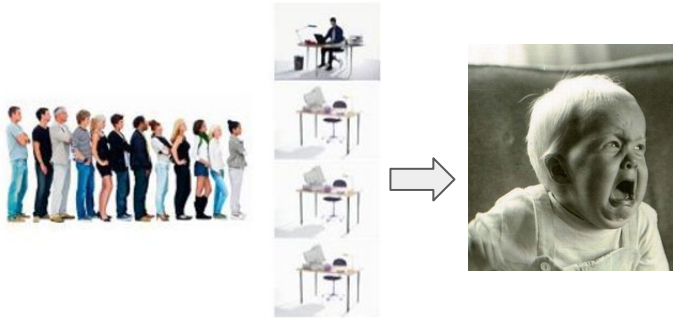
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Serial Computing

Why Parallel Computing ?

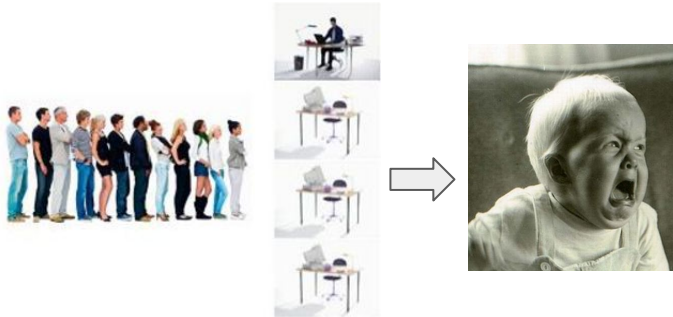
- Aren't single processor systems fast enough ?
- Why to build parallel systems ? Why build systems with multiple processors ?



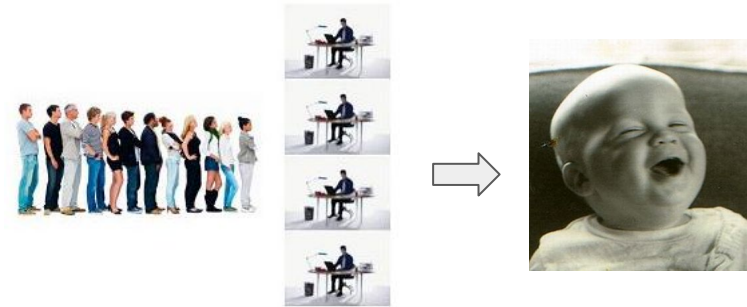
Serial Computing

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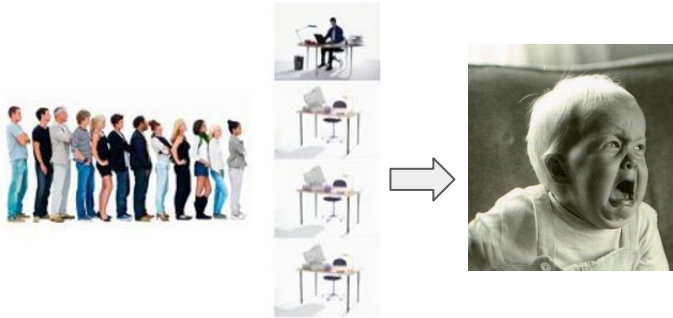
Serial Computing



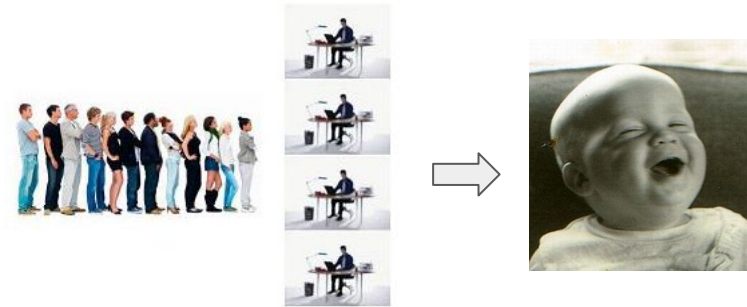
Parallel Computing

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- Aren't single processor systems fast enough ?
- Why to build parallel systems ? Why build systems with multiple processors ?
- Why can't we write programs that will automatically convert serial programs to parallel programs ?



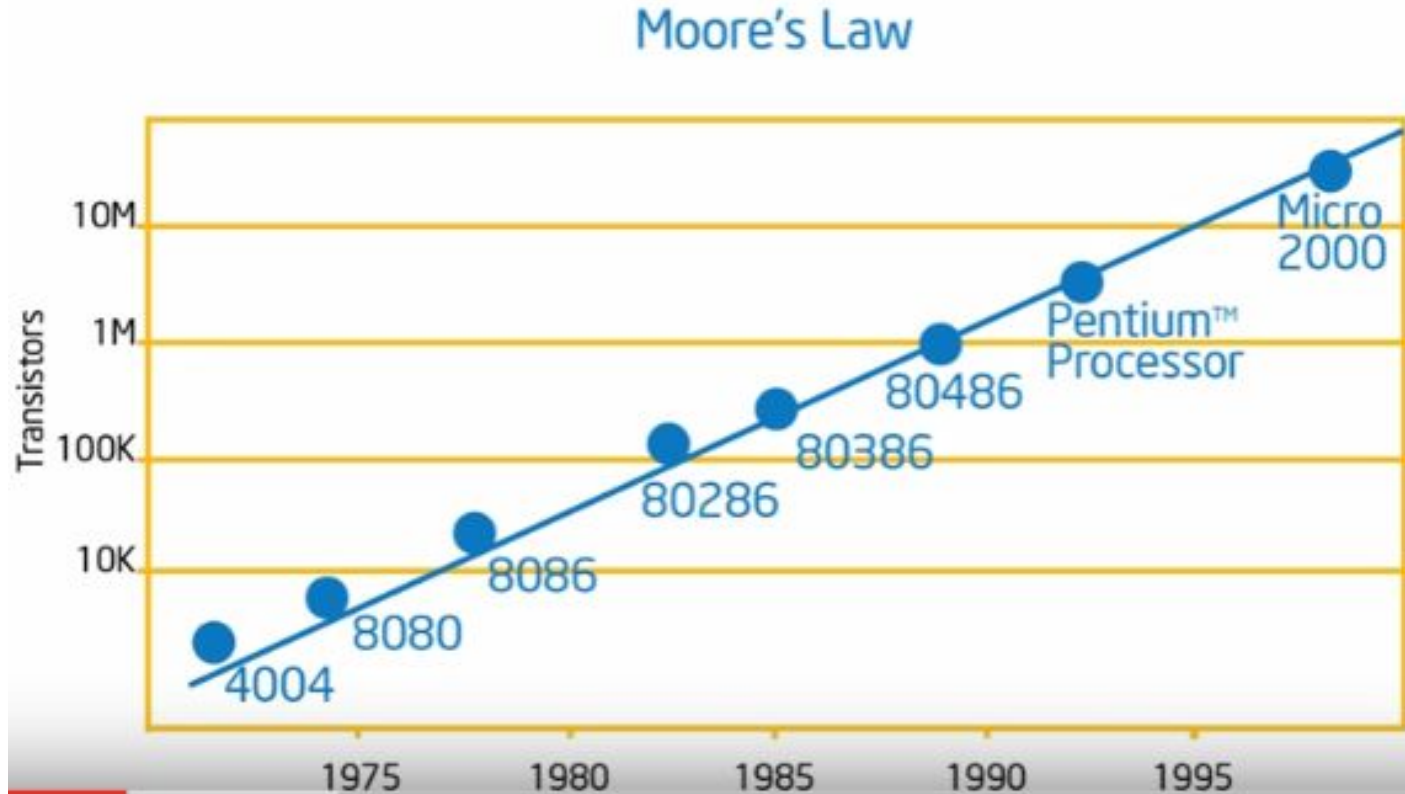
Serial Computing



Parallel Computing

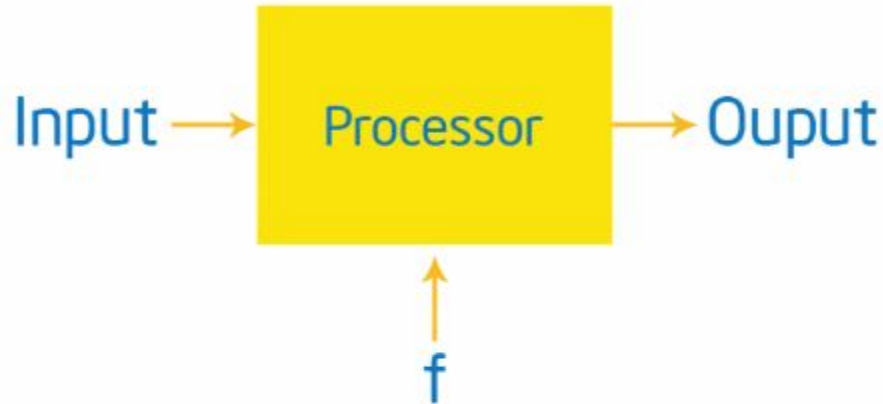
What Moore's Law tells.. ?

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Uniprocessor ?

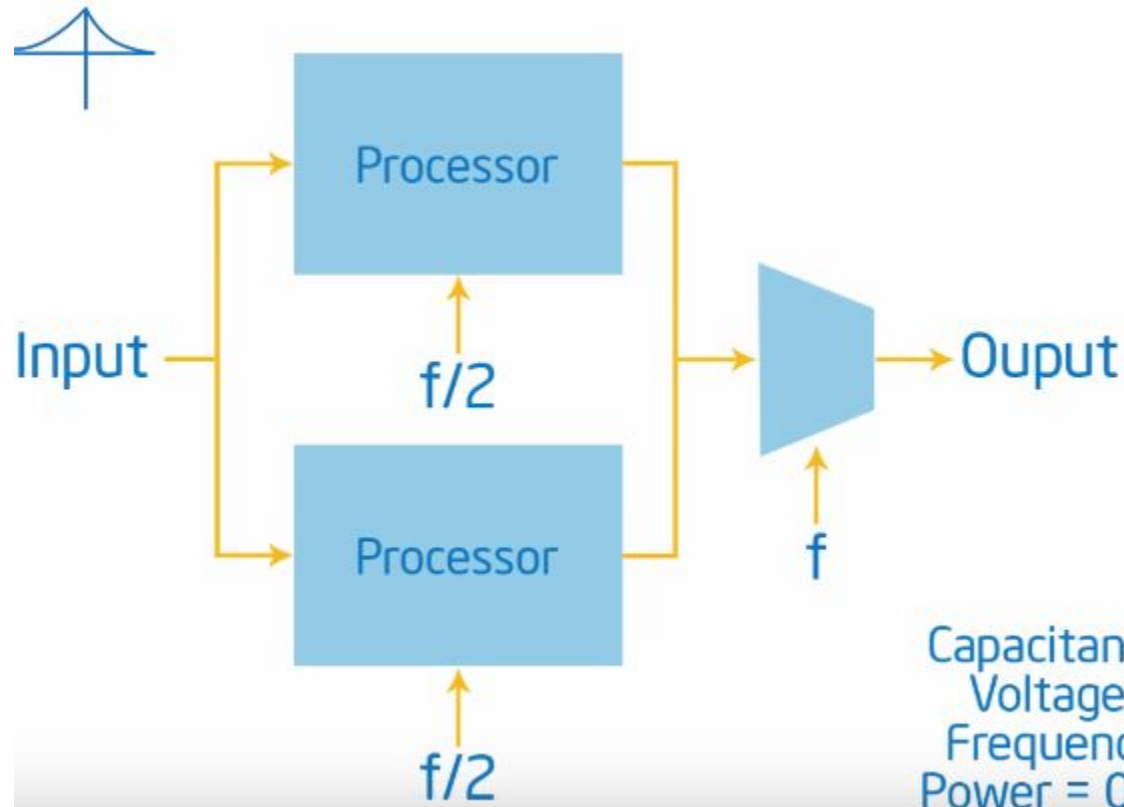
Uniprocessor ?



Capacitance = C
Voltage = V
Frequency = f
Power = CV^2f

Parallel Architecture ?

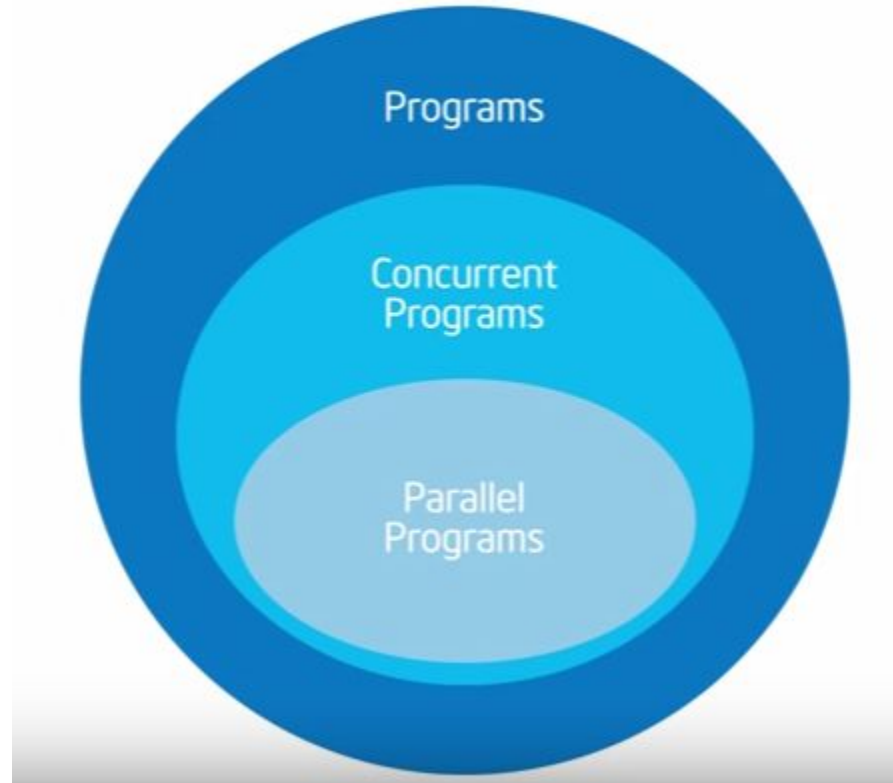
Parallel Architecture ?



Capacitance = $2.2C$
Voltage = $0.6V$
Frequency = $0.5f$
Power = $0.396CV^2F$

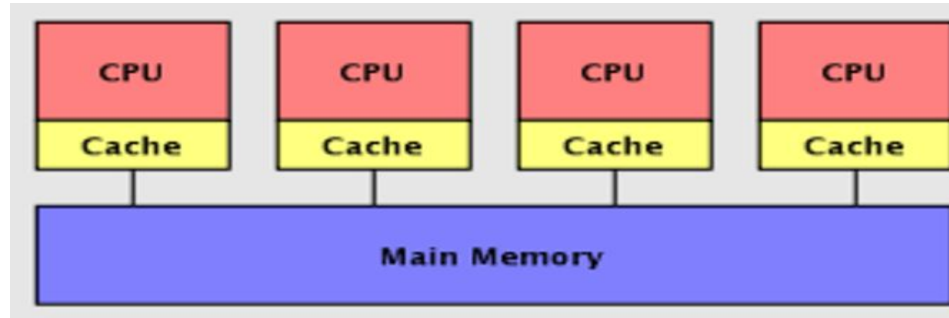
Parallel program

Parallel program



Parallel Programming Models..

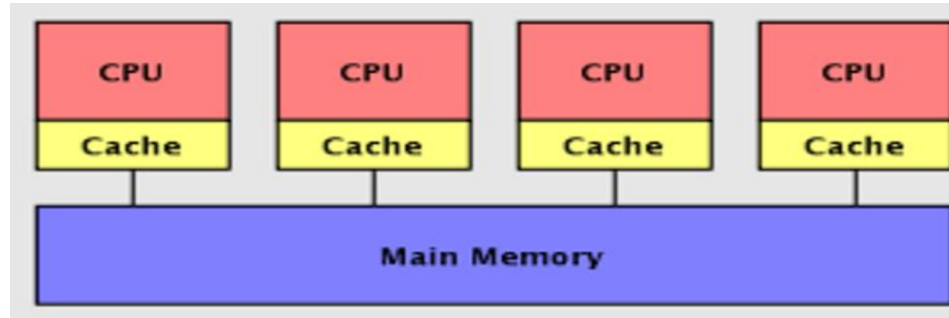
❑ Shared-memory Model



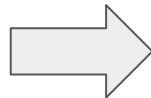
- **UMA - Uniform Memory Access**
- **NUMA - Non-Uniform Memory Access**

Parallel Programming Models..

❑ Shared-memory Model



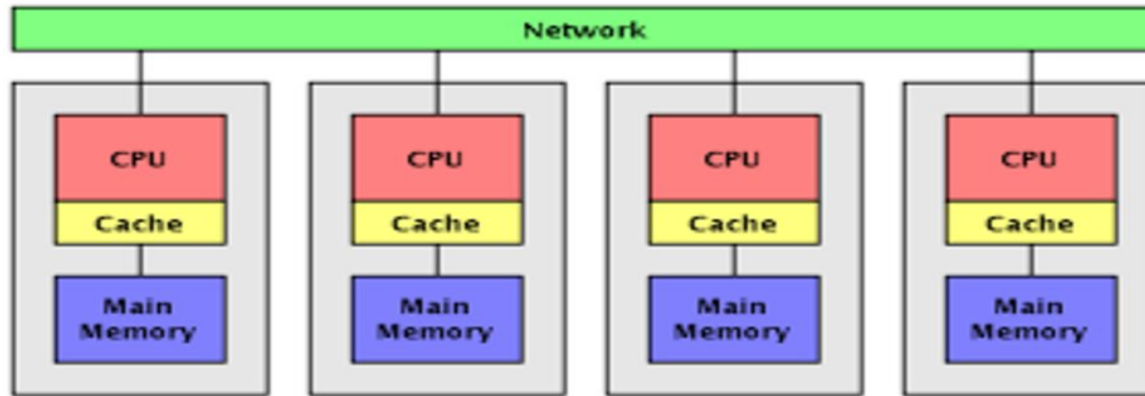
- UMA - Uniform Memory Access
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❖ **openMP**
❖ **Pthreads ...**

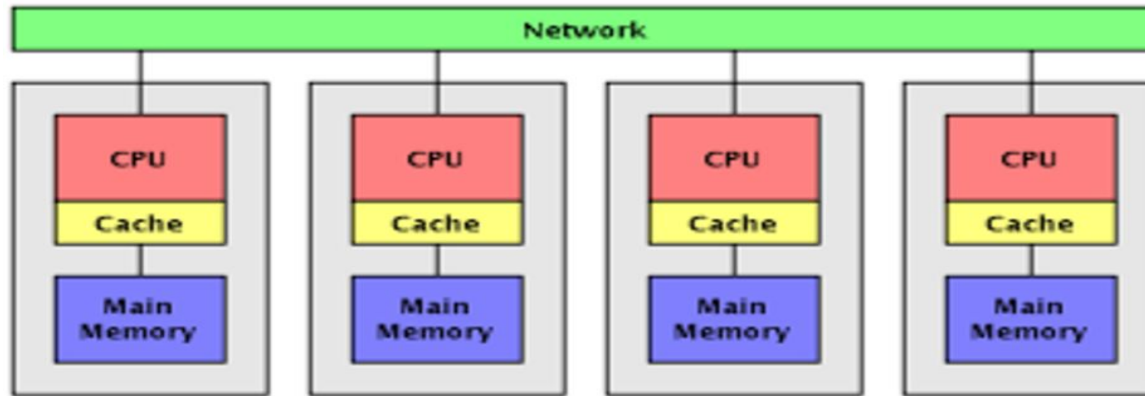
Parallel Programming Models..

❑ Distributed-memory Model



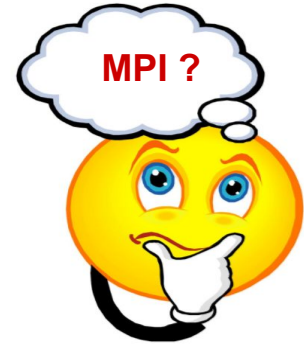
Parallel Programming Models..

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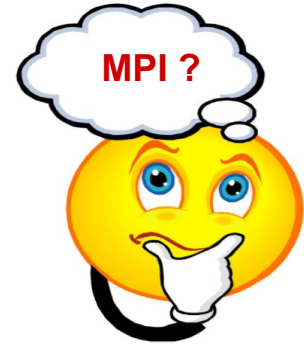
❖ MPI - Message Passing Interface

MPI - Message Passing Interface



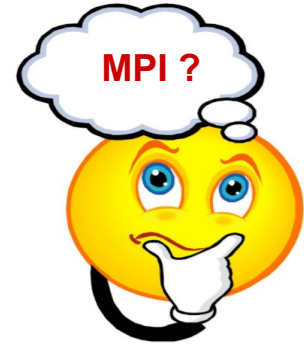
MPI - Message Passing Interface

- The Message Passing Interface Standard (MPI) is a message passing library standard based on the consensus of the MPI Forum



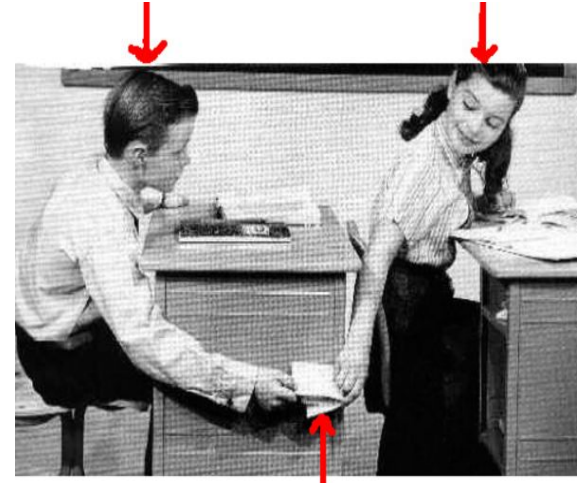
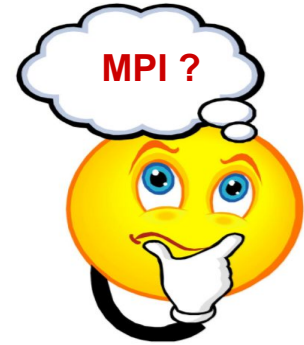
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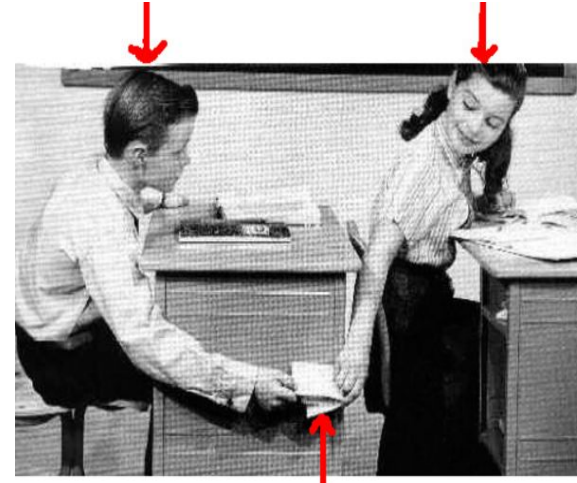
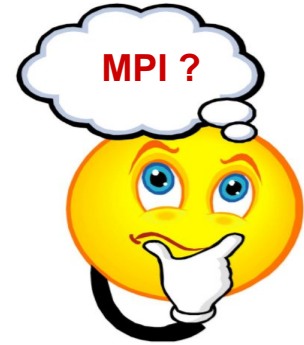
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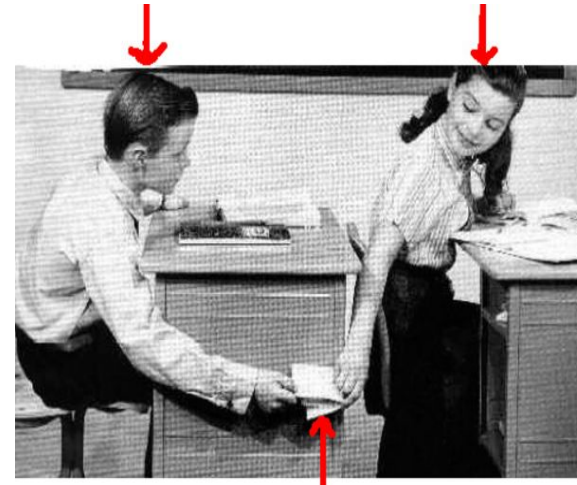
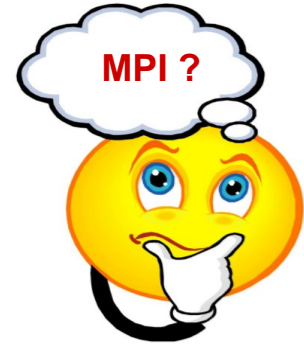
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- In MPI a Message is passed from one process to another process
- MPI is based on Routines.
- MPI is not an IEEE or ISO standard, but has in fact, become the "industry standard" for writing message passing programs on HPC platforms.



MPI - Development

- The MPI standard has gone through a number of revisions, with the most recent version being MPI-3.x
 - MPI-3.1 - Jun 2015
 - MPI-3.0 - Sep 2012 Standard was approved
 - MPI-2.2 - Sep 2009
 - MPI-2.1 - Sep 2008
 - MPI-1.3 - May 2008
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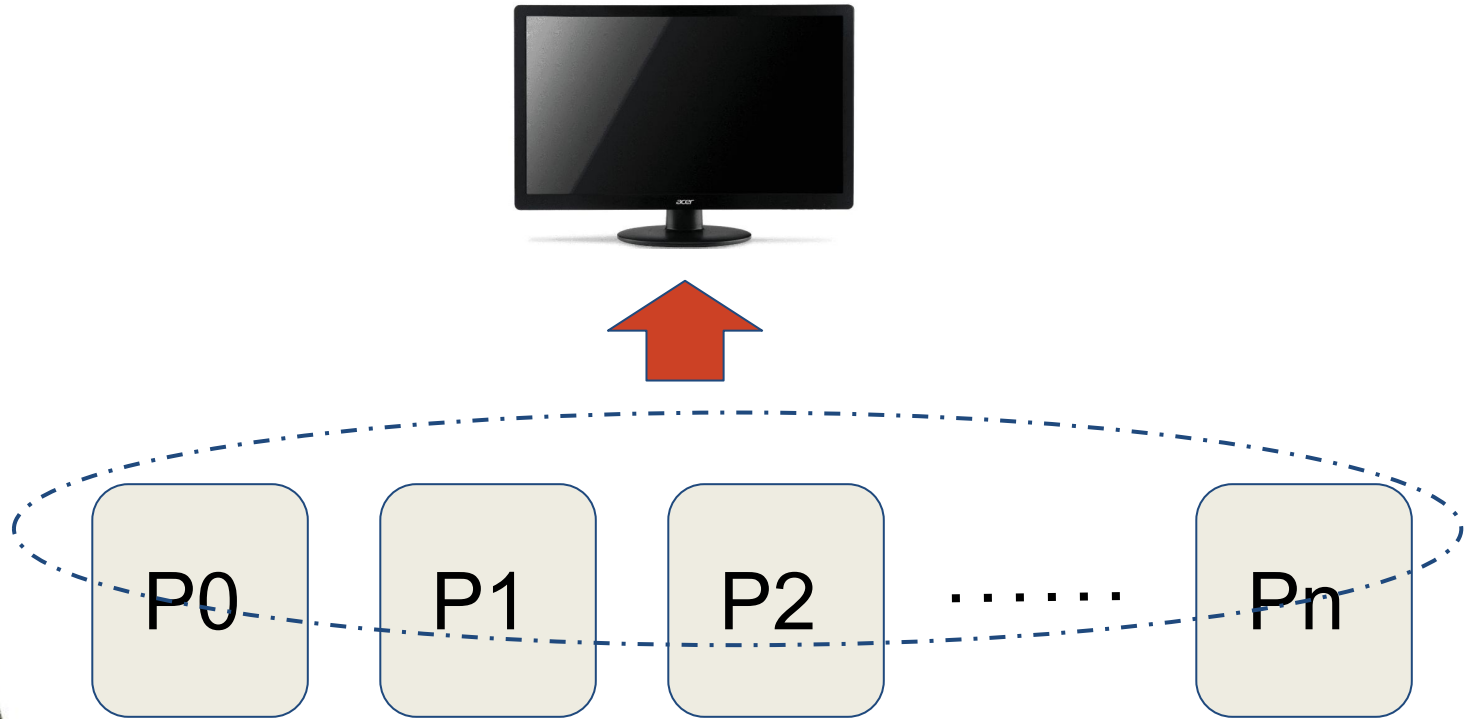
Wait....
..Answer me first



- ❖ What is Process ?
- ❖ Is MPI a new programming Language ..?

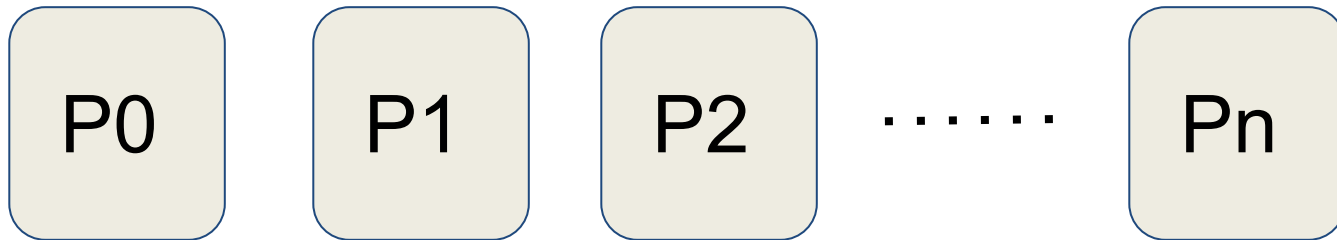


The Goal ..?

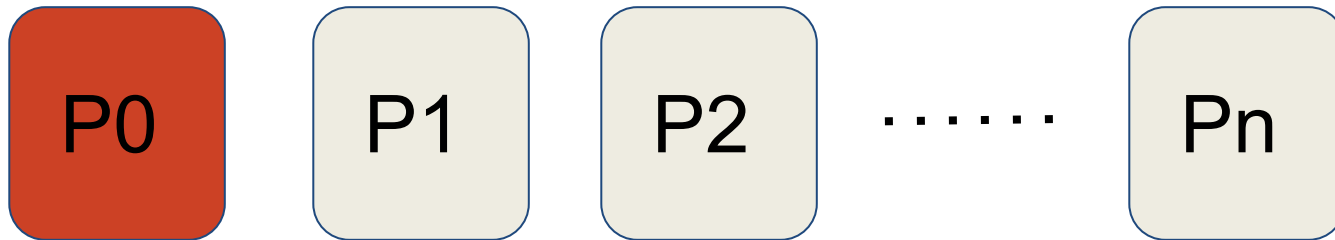


How to Achieve it ..?

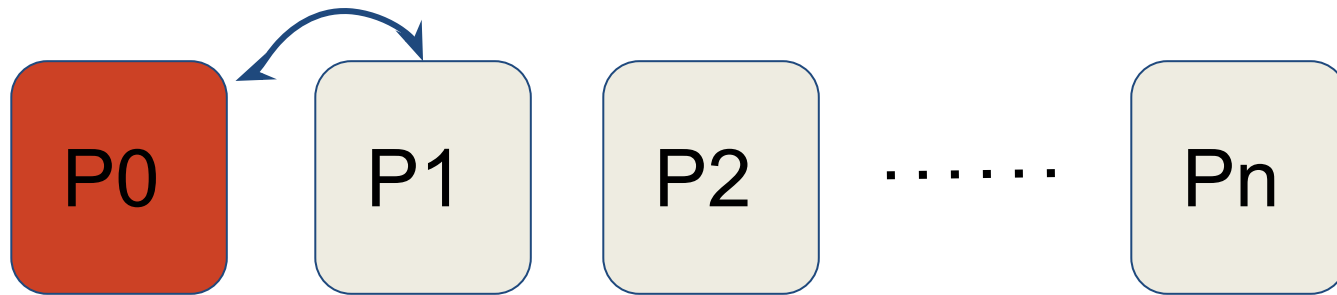
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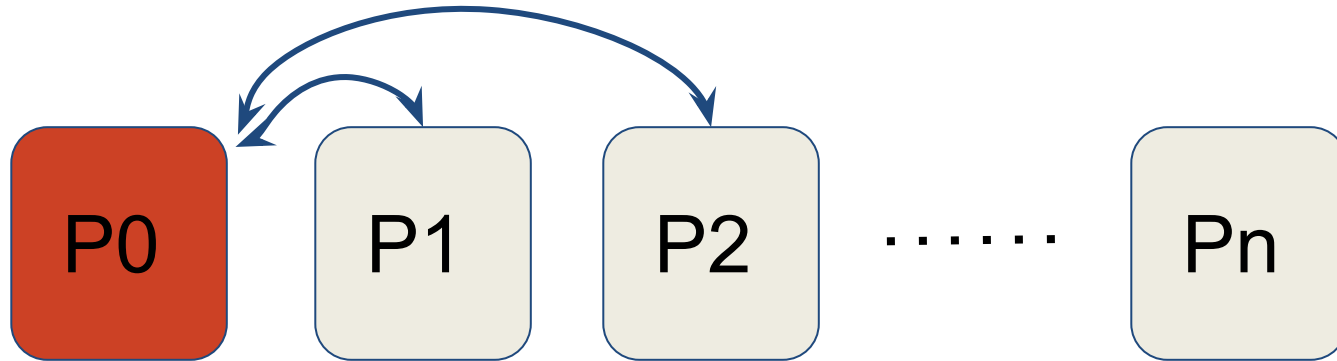
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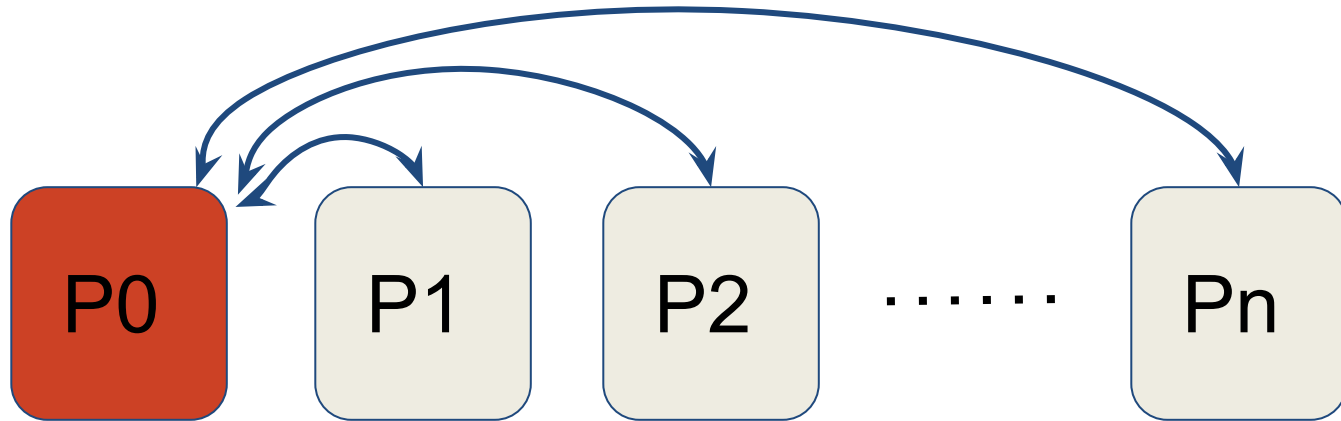
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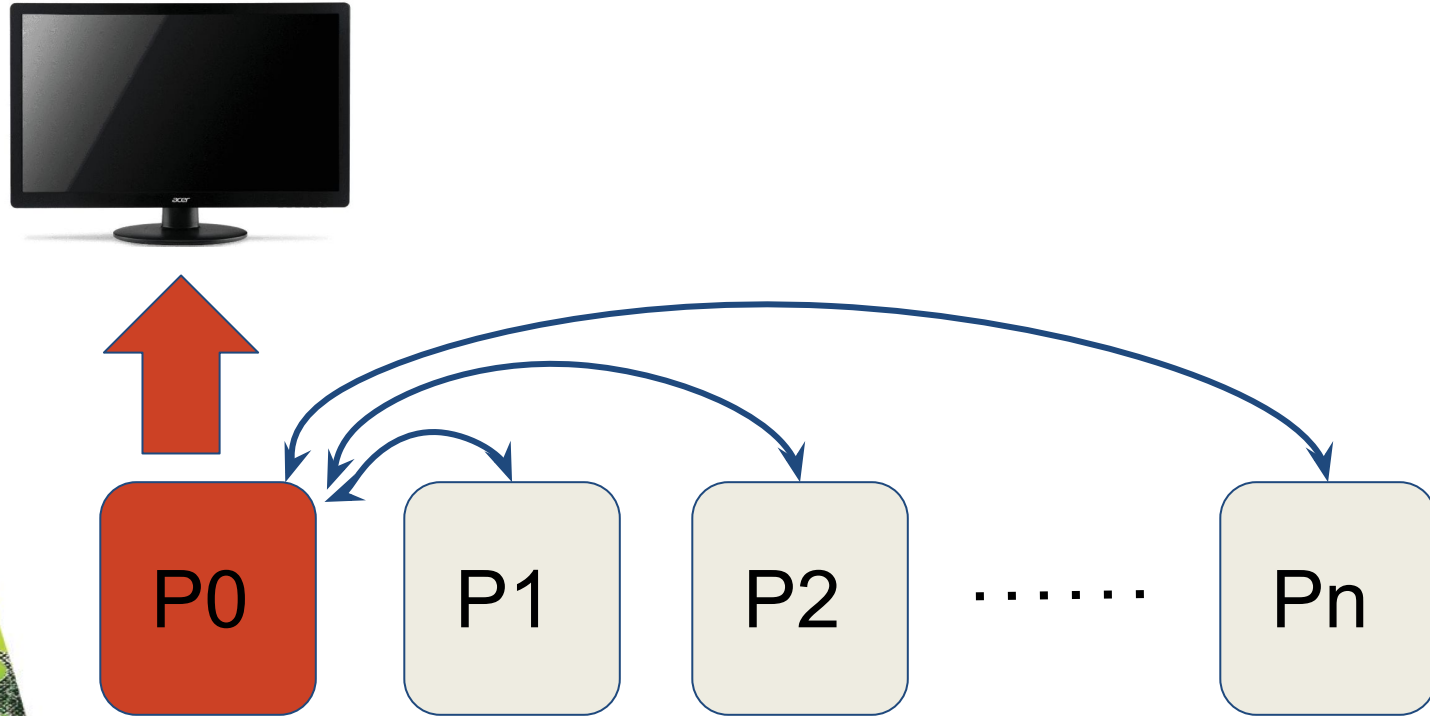
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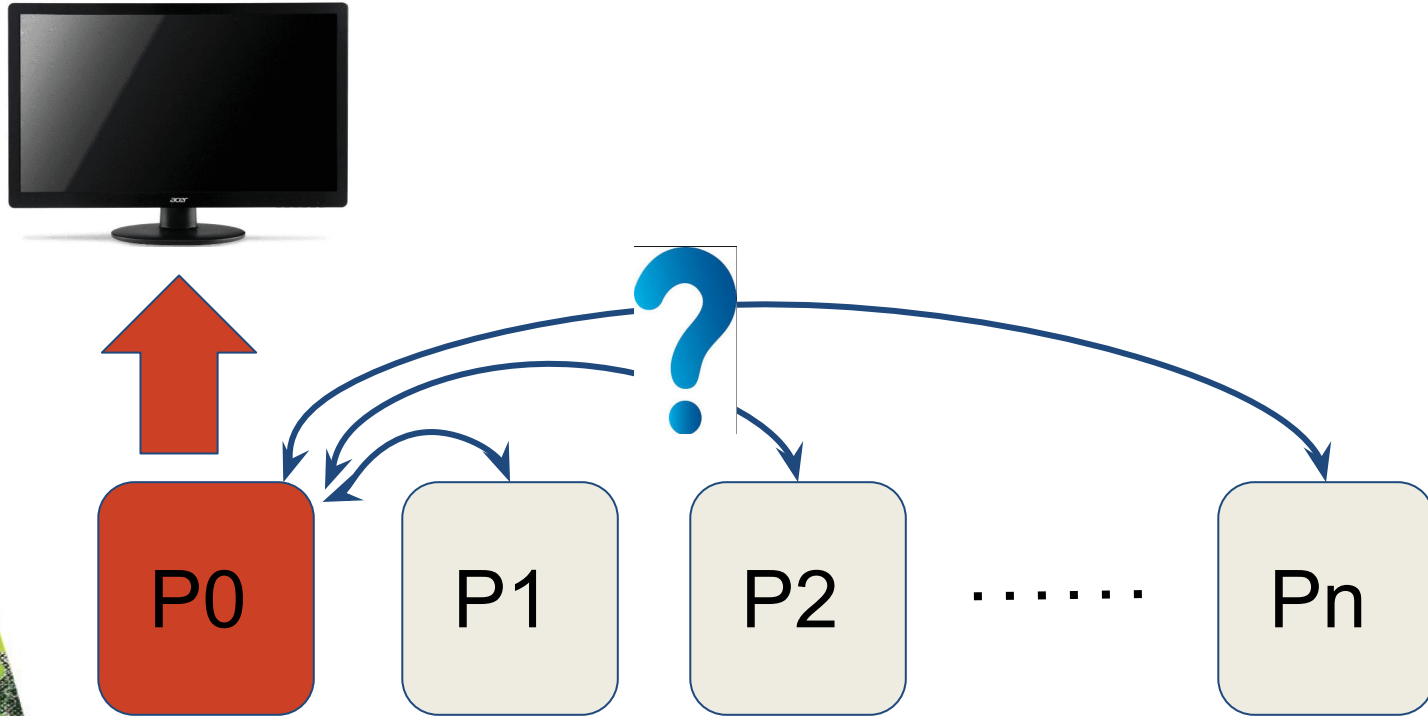
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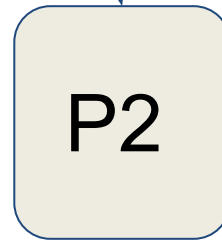
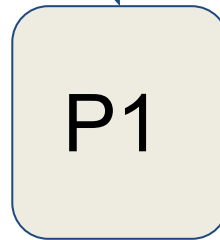
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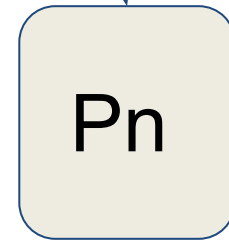
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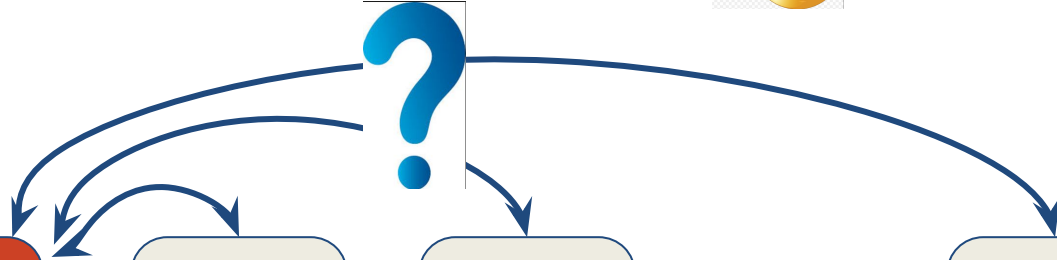
How ..?



.....

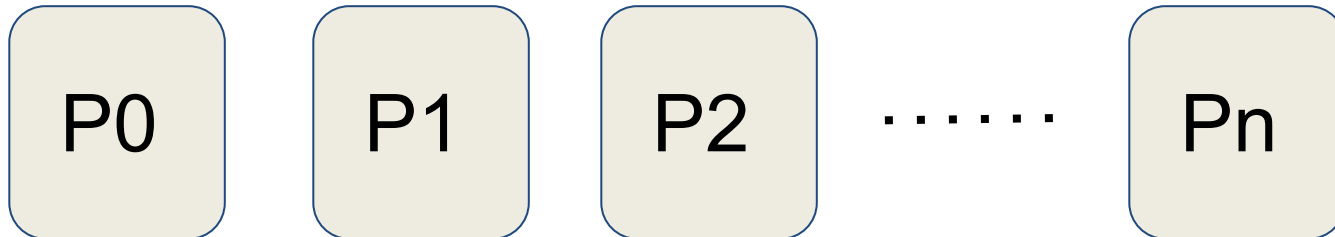


MPI



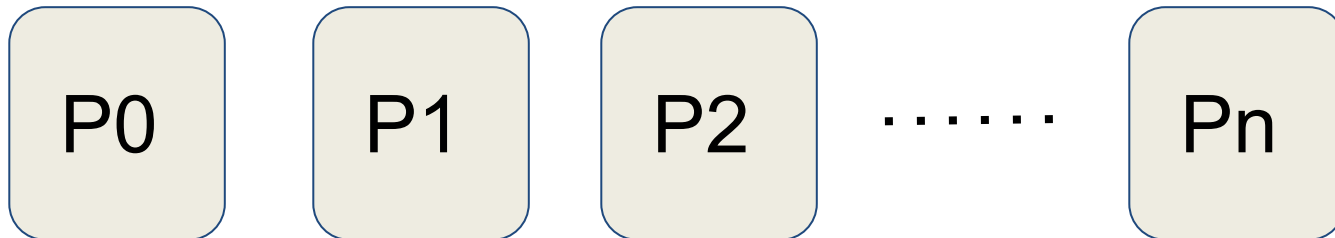
How MPI Works ..?

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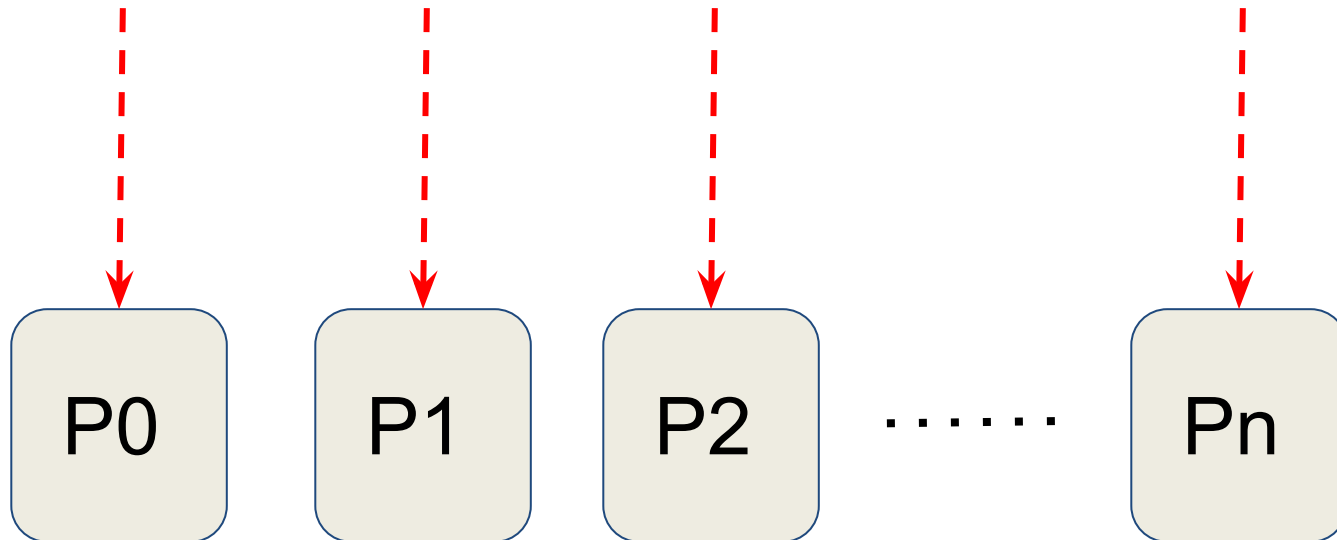
How MPI Works ..?

- ❖ **Creates Instances of same program on Every Processor involved..!**



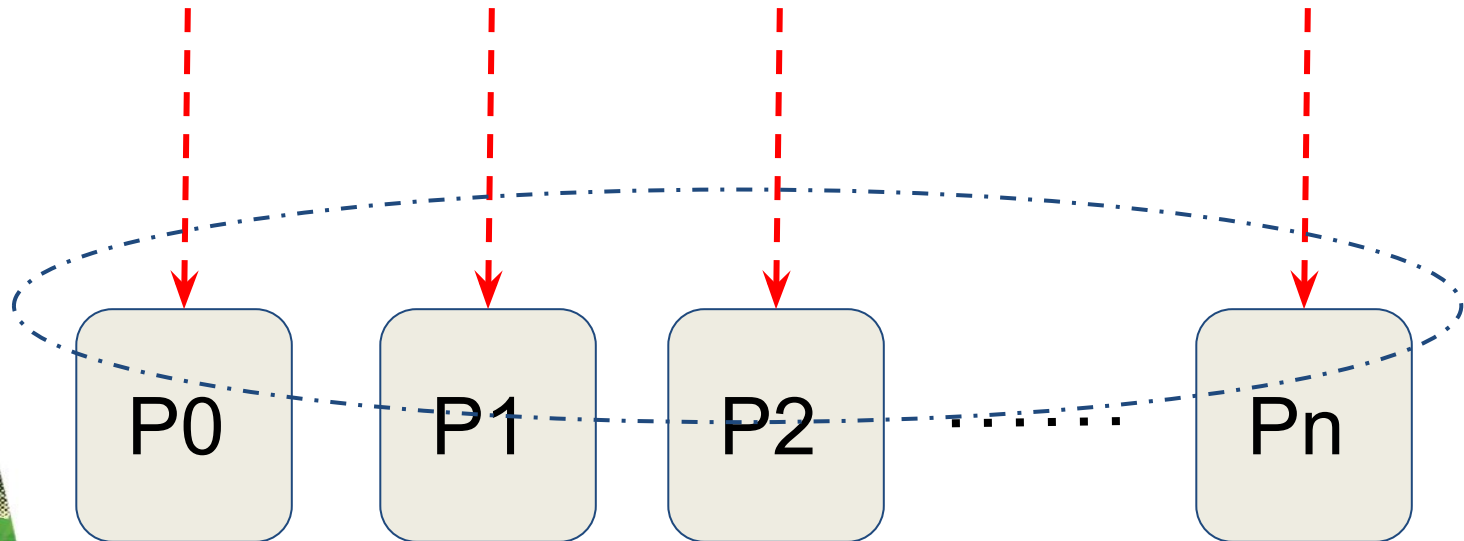
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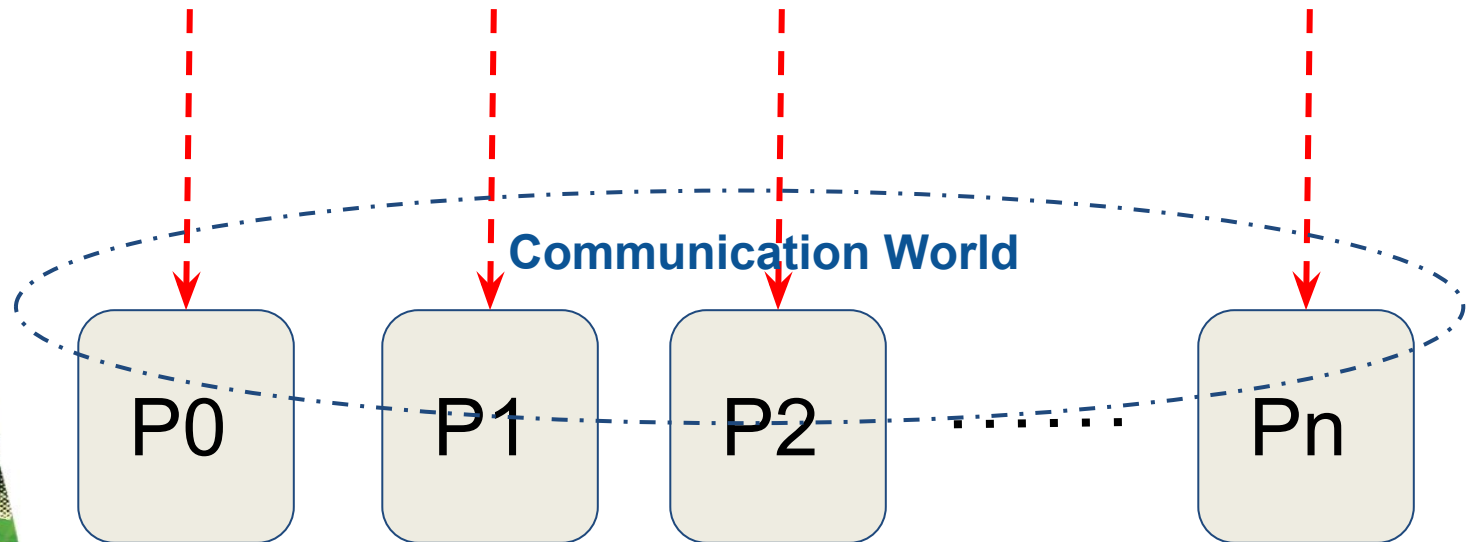
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❖ Got it ?

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❖ Got it ?



❖ Let's try to understand with example...

❖ Got it ?



❖ Let's try to understand with example...



Welcome to the World of Parallel Computing ...!

```
#include<stdio.h>
#include<string.h>
#include<mpi.h>
#define MASTER = 0
Int main(void)
{
    char greeting[MAX_STRING];
    int    comm_sz ;
    int    my_rank ;

    MPI_Init(NULL, NULL);
    MPI_Comm_size(MPI_COMM_WORLD, &comm_sz);
    MPI_Comm_rank(MPI_COMM_WORLD, &my_rank);
```

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➔ **#include<mpi.h>**

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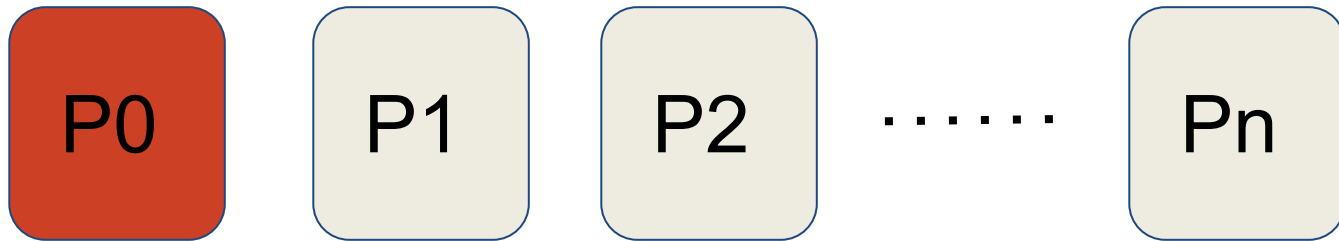
```
➔ MPI_Comm_rank(MPI_COMM_WORLD, &my_rank);
```

```
if(my_rank != MASTER)
{
    sprintf(greeting, "Welcome to the world of Parallel Computing. I am Process no %d out of %d", my_rank, comm_sz);
    MPI_Send(greeting, strlen(greeting)+1, MPI_CHAR, 0, 0, MPI_COMM_WORLD) ;
}
```

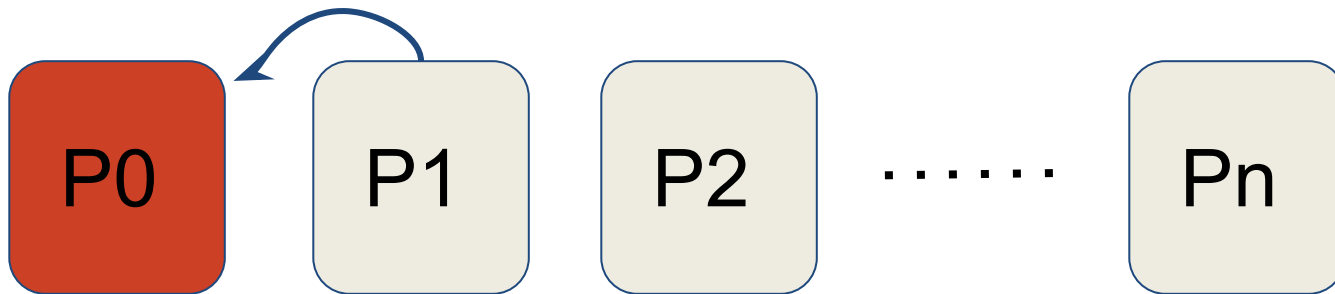


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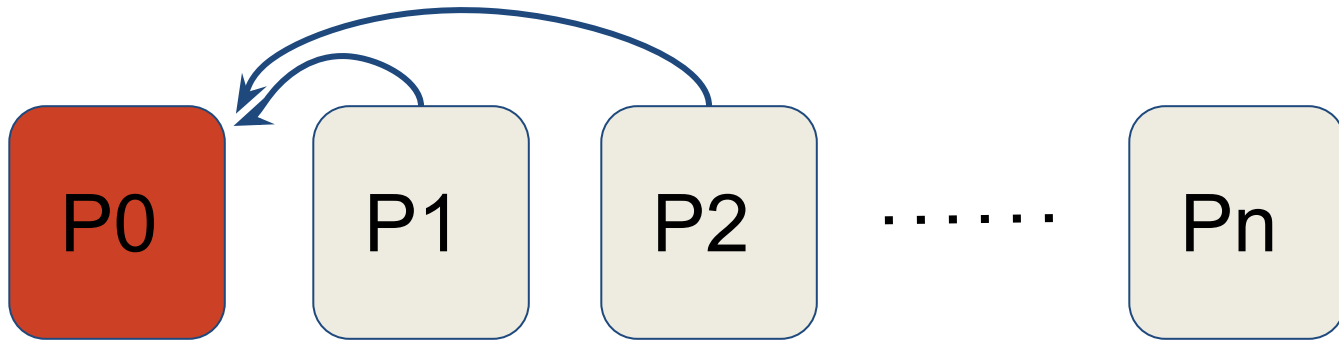
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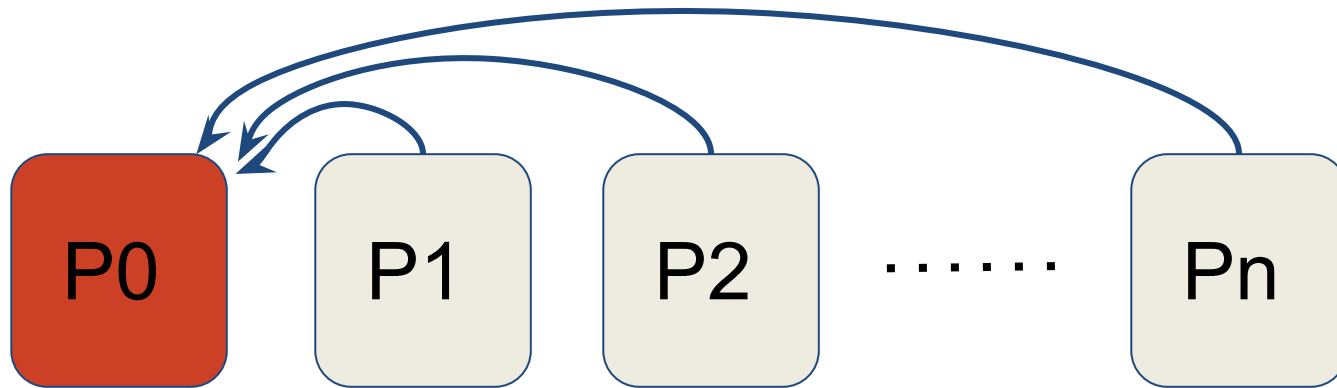
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}
```



```
else
```

```
{
```

```
    printf( "Welcome to the world of Parallel Computing. I am Process no %d out of %d\n", my_rank, comm_sz) ;
```

```
    for(int q=1; q < comm_sz; q++)
```

```
    {
```

```
        MPI_Recv(greeting, MAX_STRING, MPI_CHAR, q, 0, MPI_COMM_WORLD,  
                 MPI_STATUS_IGNORE) ;
```

```
        printf("%s\n", greeting) ;
```

```
    }
```

```
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```

```
MPI_Finalize();
```

```
return 0;
```

```
}/* END */
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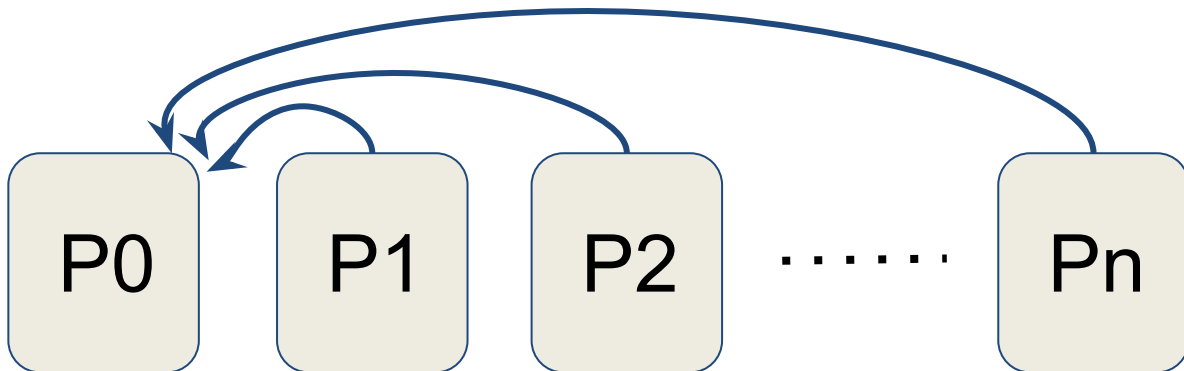
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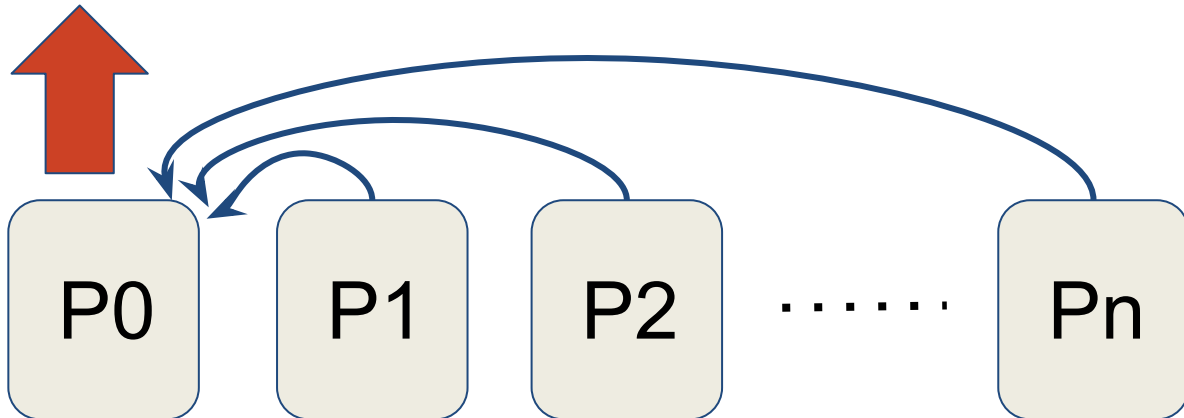
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        printf("%s \n", greeting);
```

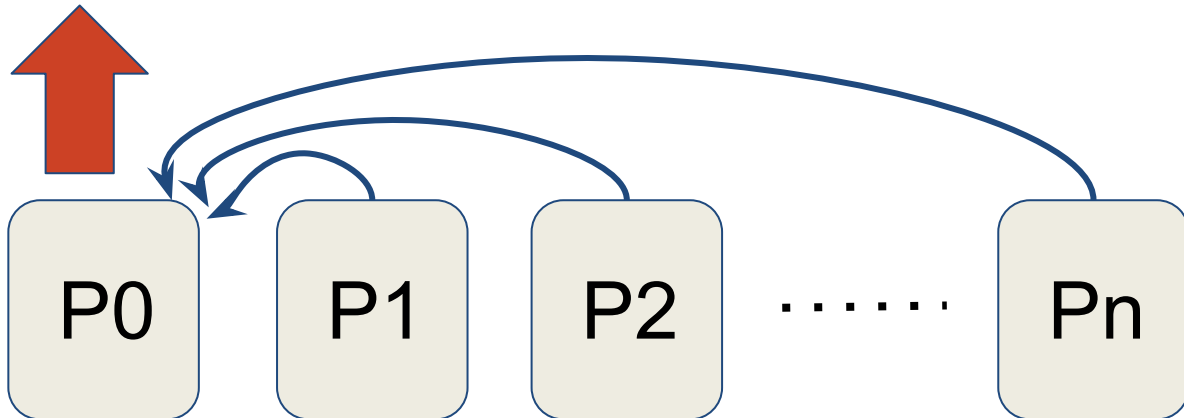
```
    }
```

```
}
```

```
→ MPI_Finalize();
```

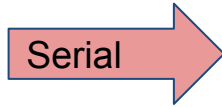
```
    return 0;
```

```
}/* END */
```



❖ How to compile and run it ?

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Serial

- \$ gcc -o test test_serial.c
- \$./test

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Serial

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➤ $ gcc -o test test_serial.c  
➤ $ ./test
```

Parallel

❖ How to compile and run it ?

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Parallel

- \$ mpicc -o mpi_test mpi_test.c
- \$ mpirun -np n ./mpi_test

❖ Output ..

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❖ Output ..

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➤ $ mpicc -o mpi_test mpi_test.c  
➤ $ mpirun -np 4 ./mpi_test
```



Welcome to the world of Parallel Computing. I am Process no 0 out of 4
Welcome to the world of Parallel Computing. I am Process no 1 out of 4
Welcome to the world of Parallel Computing. I am Process no 3 out of 4
Welcome to the world of Parallel Computing. I am Process no 2 out of 4

❖ Got it ?



❖ Got it ?

-np 4



❖ Got it ?



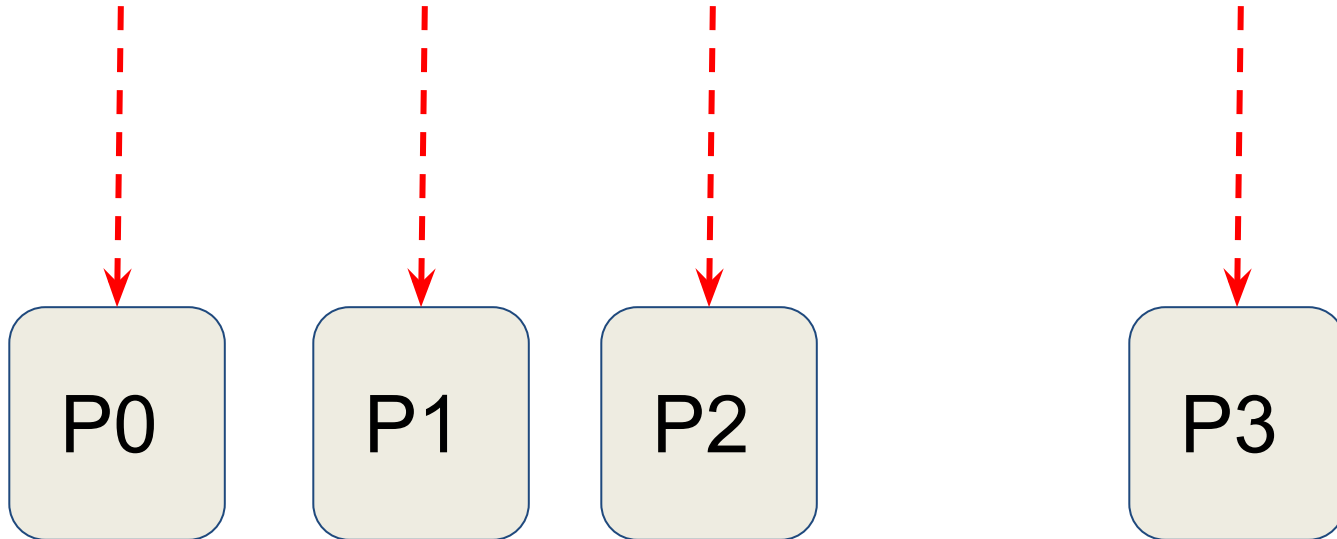
P0

P1

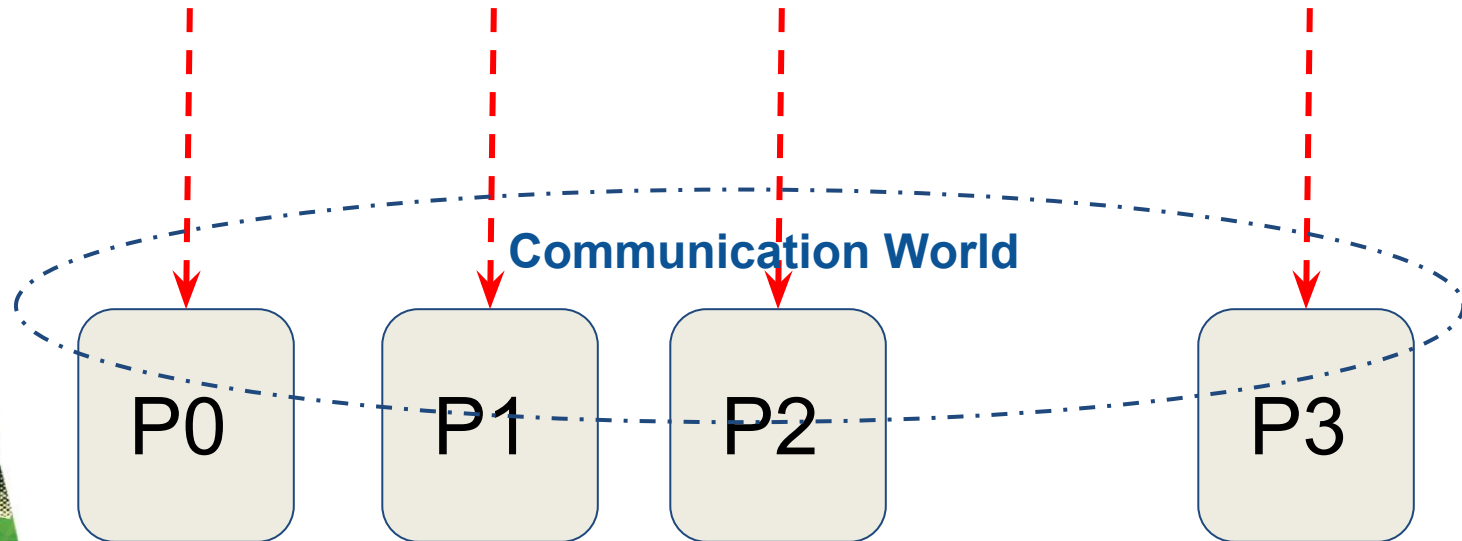
P2

P3

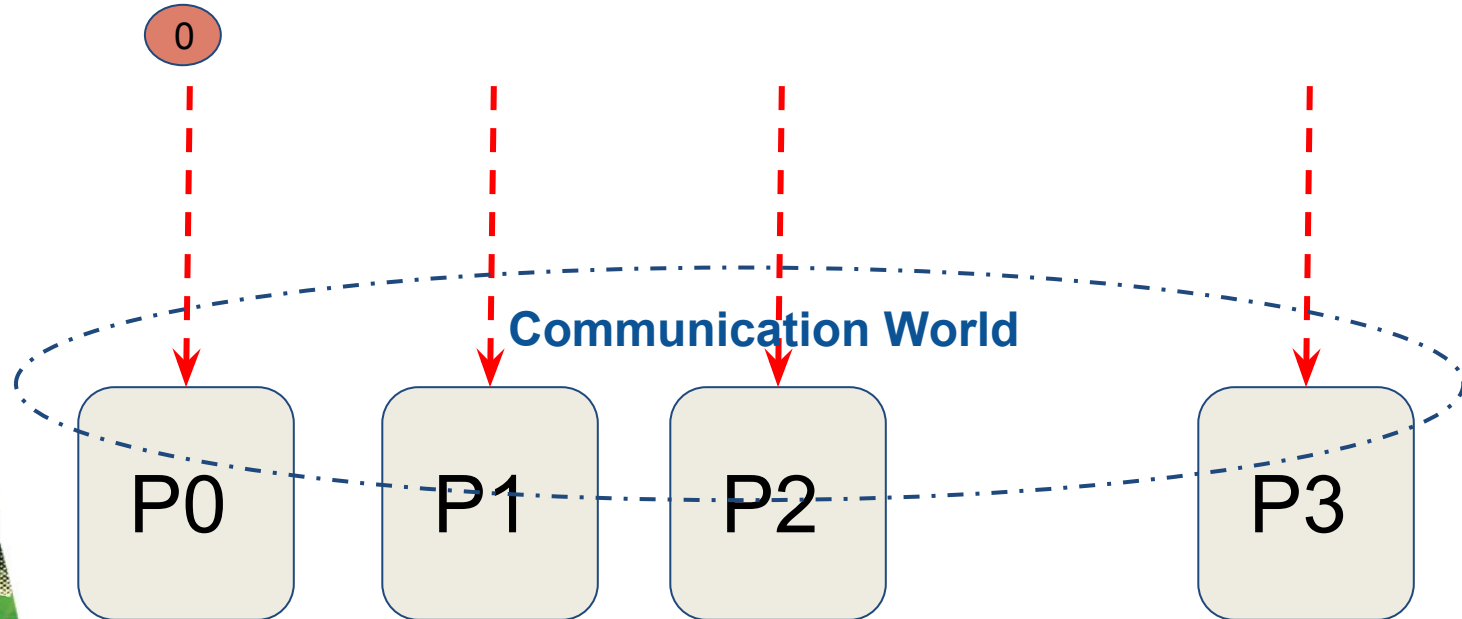
❖ Got it ?



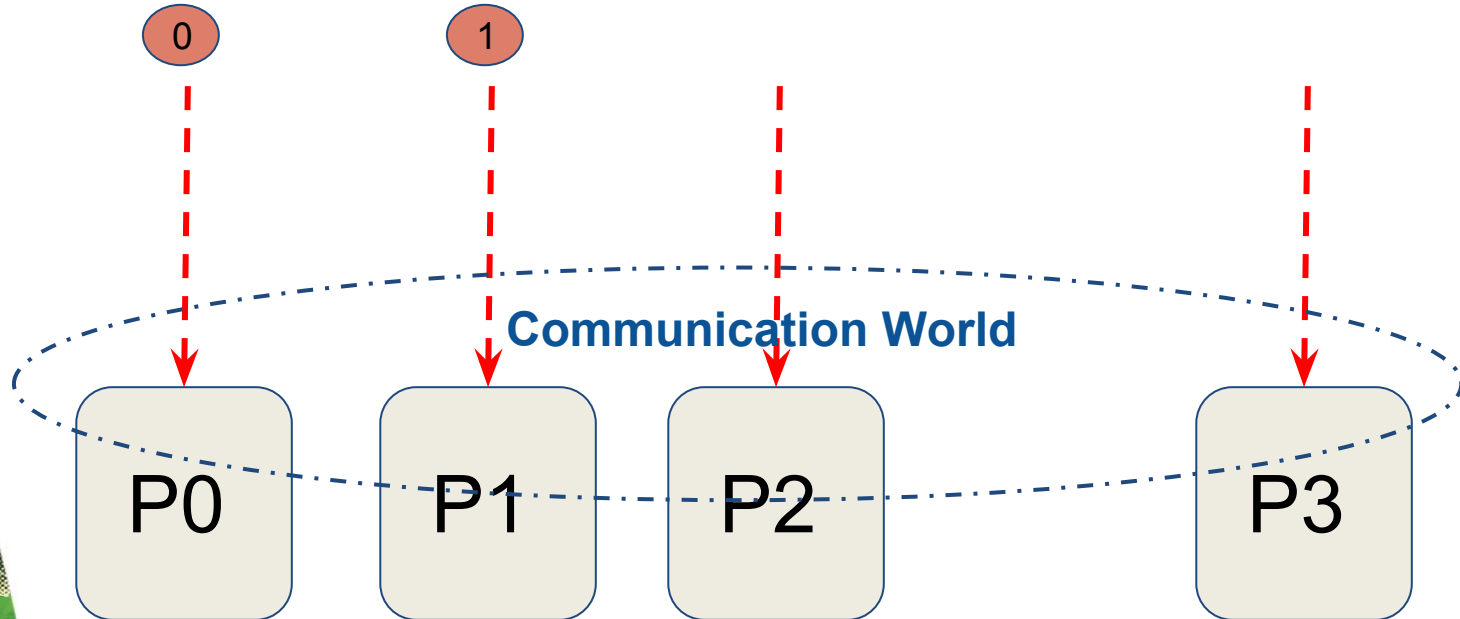
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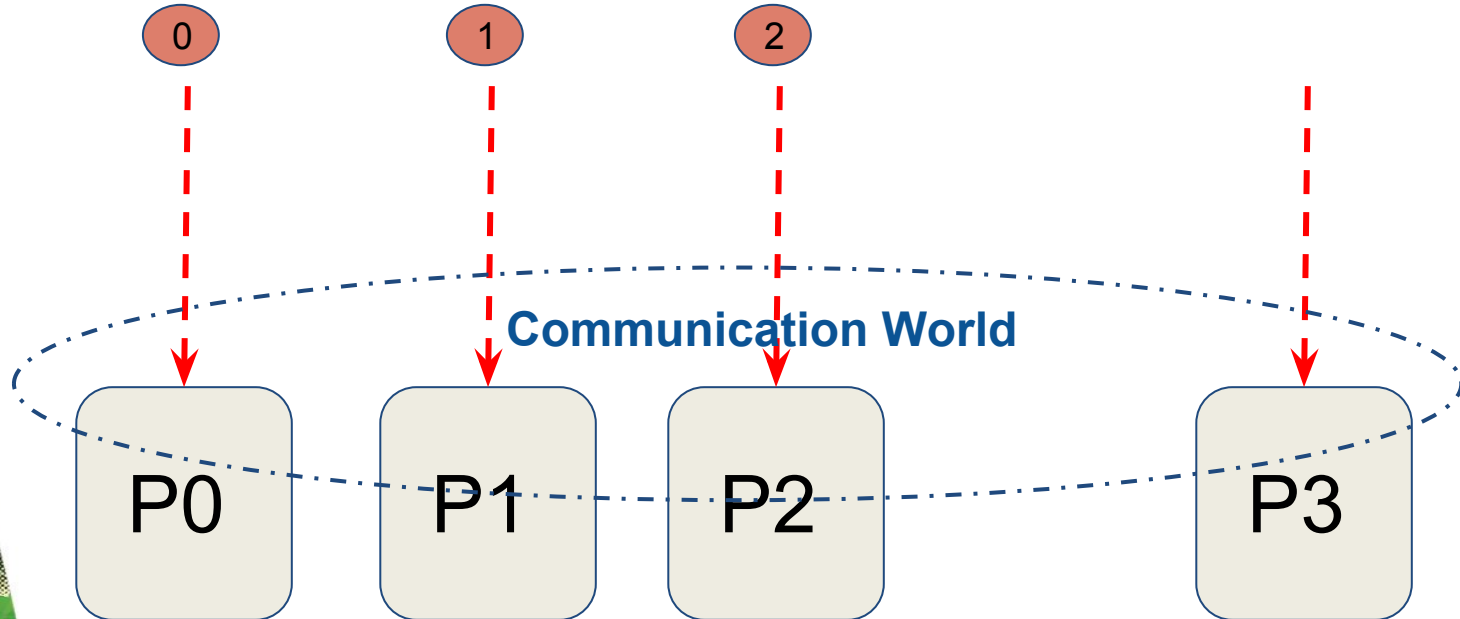
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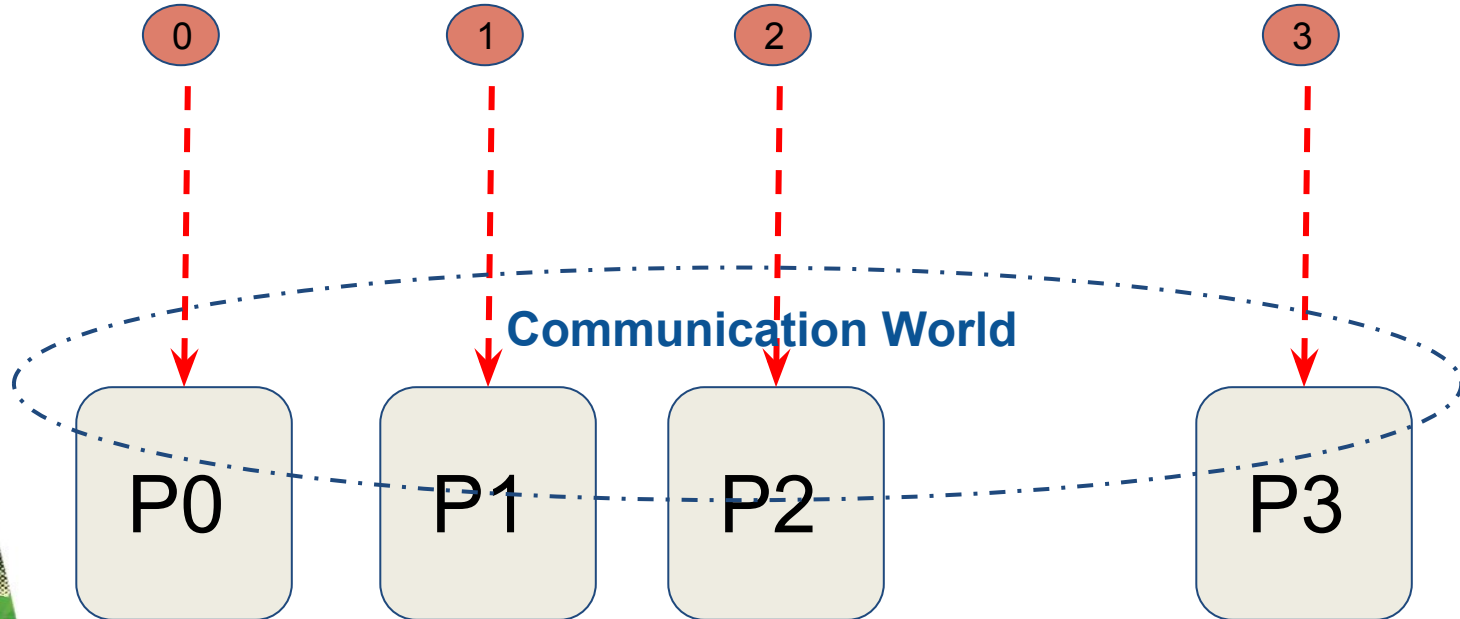
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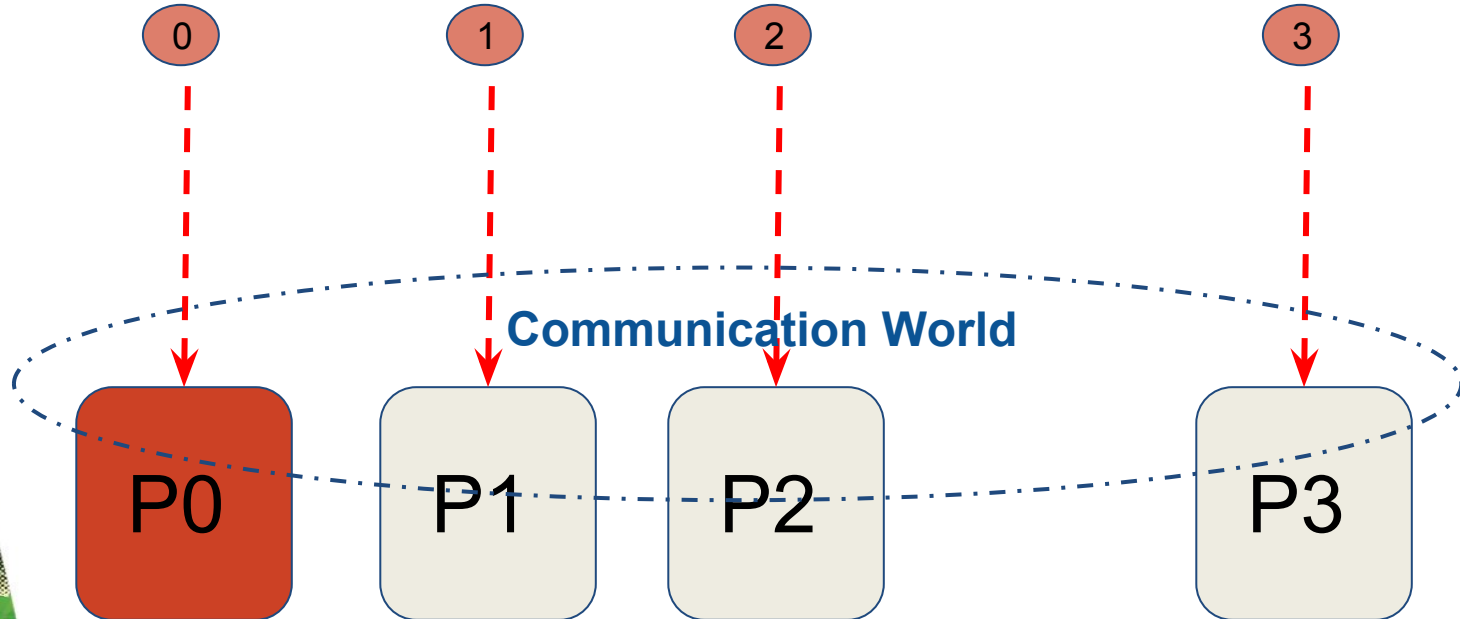
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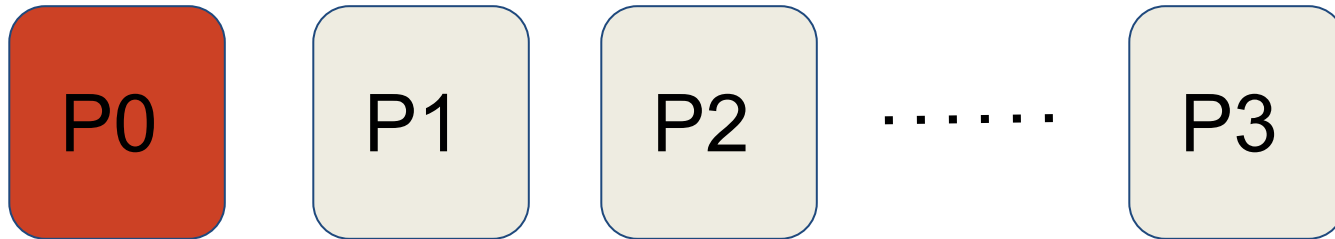
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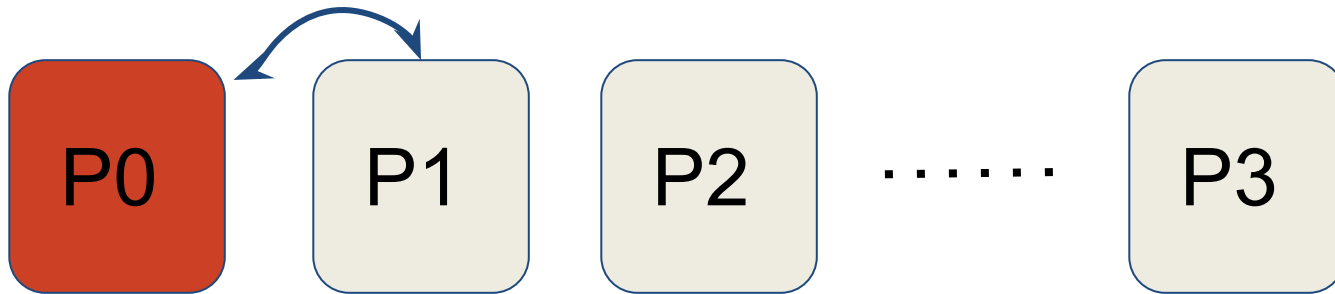
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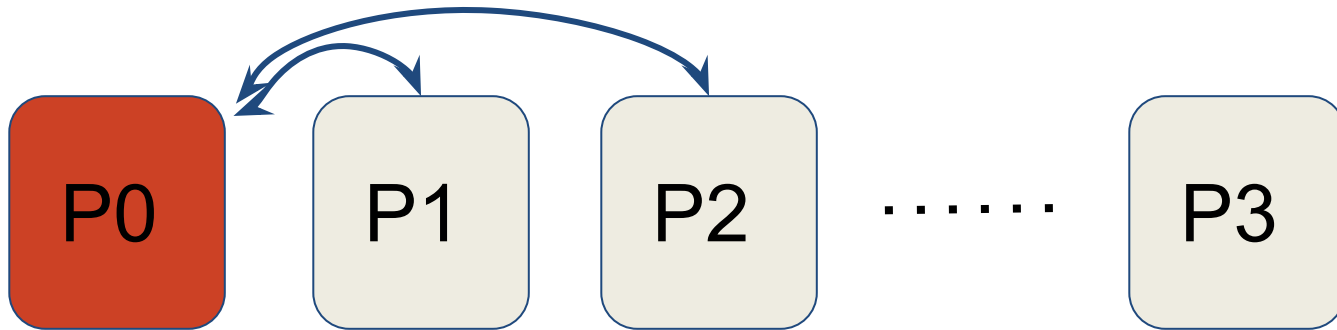
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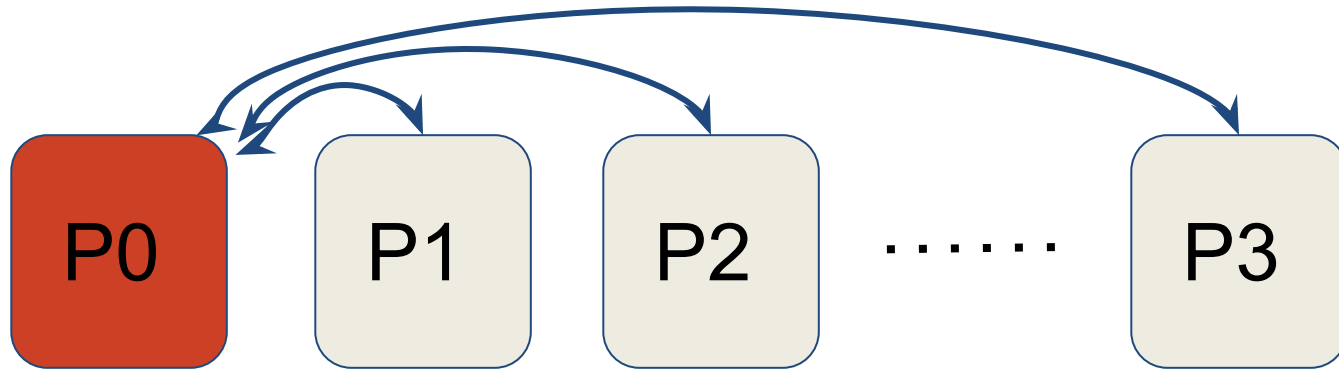
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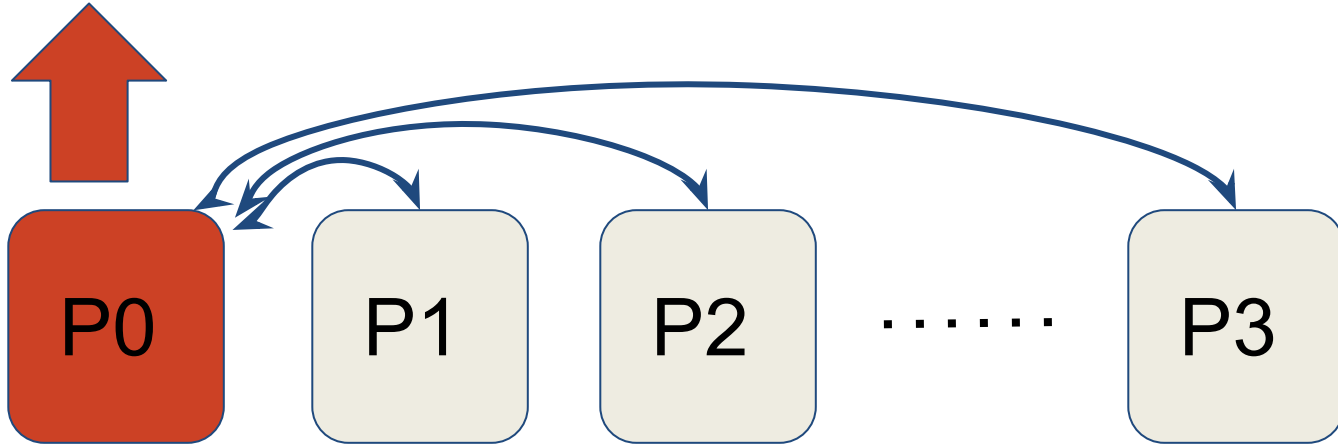
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MPI - Message Passing Interface

MPI is built on 'Routines'

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The basic MPI Routines :-

- ☐ MPI_Init () ;
- ☐ MPI_Comm_rank () ;
- ☐ MPI_Comm_size () ;
- ☐ MPI_Send () ;
- ☐ MPI_Recv () ;
- ☐ MPI_Finalize () ;

- ☐ - - - - -

MPI - Program structure

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```
#include <mpi.h>

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

    /* main part of the program */

    /*
    Use MPI function call depend on your data
    partitioning and the parallelization
    architecture
    */

    MPI_Finalize();
}
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Hope so you got it...!!!

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Recap --

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- **Parallel programming**

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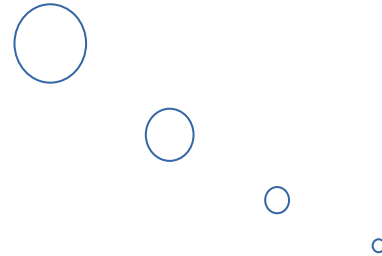
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Open source Versions of MPI -

- Two popular free versions of MPI are MPICH2 and OpenMPI.
 - MPICH - basis for derivative of MPI implementations to meet special purpose needs.
 - **Network Technology support** : One common complaint about MPICH is that it does not support InfiniBand, However, **MVAPICH** and **Intel MPI** - both of which are MPICH derivatives - support InfiniBand. (Cray Seastar, Gemini, Arise, IBM Blue gene,). *MVAPICH2 - preferred implementation in nearly all cases.
 - **Feature support** : -- ☆☆☆☆☆
 - **Process Management** : --☆☆
- **OpenMPI** - targets the common case, both in terms of usage and network conduits.
- **Network Technology support** : openMPI support InfiniBand. (Cray Gemini, *but not by Cray)
- **Feature support** : --☆☆
- **Process Management** : -- ☆☆☆☆☆