MPI Topologies
Graph Topology

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As said before;

- ✓ The first part of MPI : Basic MPI
- ✓ The second part of MPI : Advanced MPI

Advanced MPI

- Contains;

- MPI Topologies

- Analysis of benefits

MPI Topologies

Introduction

- ✓ Provide avaliable naming need of a process in a group of processes
- ✓ It is an attribute of processes only in the group
- ✓ Helps runtime systems in organizing processes onto processors(hardware)
- ✓ The term “Virtual Topology” gives this main idea: machine independent
- ✓ Benefits of MPI topologies:
    - Applications have specific communication patterns
    - Topologies advice plans to the program when it’s running

MPI Topologies

- ✓ There are two types of MPI topologies
- ➢ Cartesian Topology
- ➢ Graph Topology

Graph Topology

- What we will see about!!!
- Introduction
- Elements of Graph Topology
- Important tips of Graph Topology
- Main MPI Graph Functions
- Example

Graph Topology

- Introduction

- Firstly, graph topology, gives opportunity to make optional connections between processes to programmers

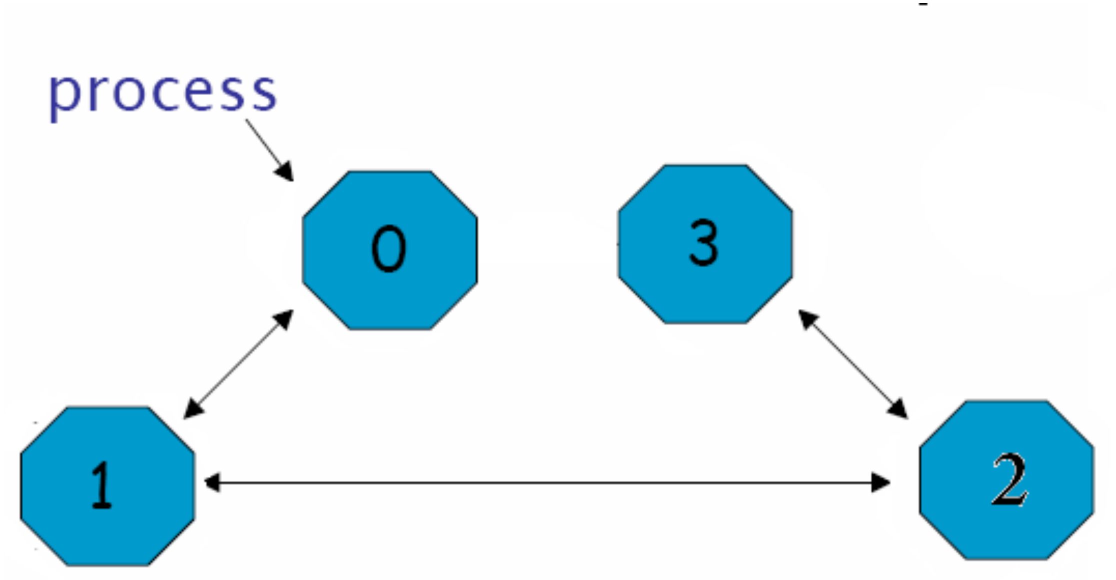
- We use hierarchical systems which are given by graph topology for solving weakness problem of MPI topology.

- **More generally, the process organizing is described by a graph**

Graph Topology

- Elements of Graph Topology

  - Communication link
  - Nodes in the graph
  - Neighbours of per node
  - Type of mapping



Graph Topology

- Elements of Graph Topology

  - Nodes:Processors

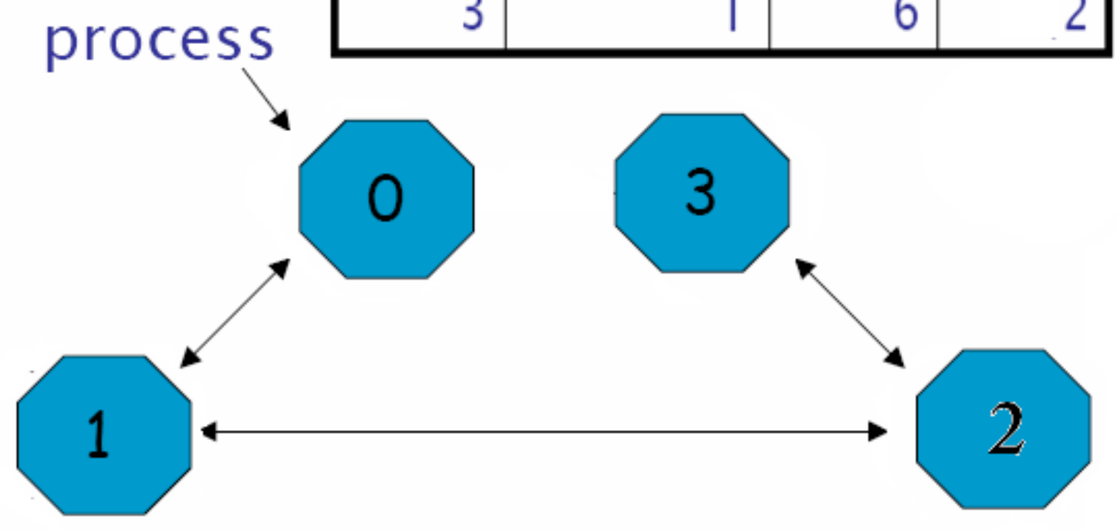
  - Lines: Communicators
between nodes

  - Arrows:Show origins and
destinations of links

  - Index: array of integers

describing node degrees

Node	*Nneighbors*	*index*	*edges*
0	1	1	1
1	2	3	0,2
2	2	5	1,3
3	1	6	2



Graph Topology

- Important tips of graph topology

- ✓ Graph topology can only be used in intra-communicators.
- ✓ Number of graph nodes must not be more than number of processors.
- ✓ In a graph, communication speed may increase if process addressing reordered by system.
- ✓ One node can be neighbour of another when opposite can not be. This means asymmetric structure can be used.
- ✓ For only IBM, Graph topologies must be symmetric.If x is neighbour of y ,then y is neighbour of x.

Graph Topology

- Main MPI Graph Functions

❖ MPI_GRAPH_CREATE :

✓ creates communicator with user-defined graph topology

✓ Usage:

int MPI_Graph_create(MPI_Comm *comm_old*, **int** *nnodes*, **int** **index*, **int** **edges*, **int** *reorder*, **MPI_Comm** **comm_graph* **);**

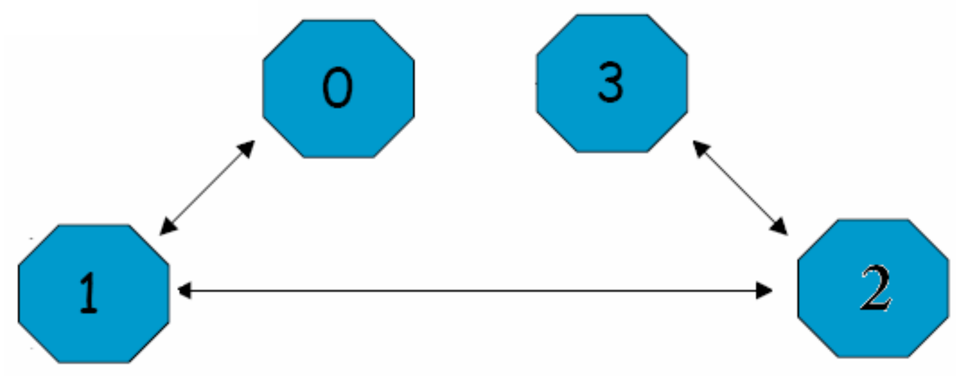
✓ Parameters

- *comm_old*
  - [in] input communicator without topology (handle)
- *nnodes*
  - [in] number of nodes in graph (integer)
- *index*
  - [in] array of integers describing node degrees
- *edges*
  - [in] array of integers describing graph edges
- *reorder*
  - [in] ranking may be reordered (true) or not (false) (logical)
- *comm_graph*
  - [out] communicator with graph topology added (handle)

Graph Topology

- Main MPI Graph Functions

❖ : **MPI_Graph_create Usage Example**



Node	Nneighbors	index	edges
0	1	1	1
1	2	3	0,2
2	2	5	1,3
3	1	6	2

- #include "mpi.h"
- MPI_Comm graph_comm;
- int nnodes = 4; /* number of nodes */
- int index[4] = {1, 3, 5, 6}; /* index definition */
- int edges[6] = {1, 0, 2, 1, 3, 2}; /* edges definition */
- int reorder = 1; /* allows processes reordered for efficiency */
- MPI_Graph_create(MPI_COMM_WORLD, nnodes, index, edges, reorder,
- graph_comm);

Graph Topology

- Main MPI Graph Functions

❖ MPI_GRAPH_NEIGHBORS_COUNT

✓ Returns the number of neighbors of a node associated with a graph topology

✓ Usage:

int MPI_Graph_neighbors_count(MPI_Comm *comm*, **int** *rank*, **int** **nneighbors* **);**

✓ Parameters:

- *comm*
  - [in] communicator with graph topology (handle)
- *rank*
  - [in] rank of process in group of comm (integer)
- *nneighbors*
  - [out] number of neighbors of specified process (integer)

Graph Topology

- Main MPI Graph Functions

❖ MPI_GRAPH_NEIGHBORS

✓ **Returns the neighbors of a node associated with a graph topology**

✓ Usage:

int MPI_Graph_neighbors(MPI_Comm *comm*, **int** *rank*, **int** *maxneighbors*, **int** **neighbors* **);**

✓ Parameters

- *comm*
  - [in] communicator with graph topology (handle)
- *rank*
  - [in] rank of process in group of comm (integer)
- *maxneighbors*
  - [in] size of array neighbors (integer)
- *neighbors*
  - [out] ranks of processes that are neighbors to specified process (array of integer)

Graph Topology

- Main MPI Graph Functions

❖ **MPI_Graph_neighbors_count, MPI_Graph_neighbors**

C :

Node	*Nneighbors*	*index*	*edges*
0	1	1	1
1	2	3	0,2
2	2	5	1,3
3	1	6	2

```
int node, my_neighbors, my_edges(2);
..
..
MPI_Comm_rank(graph_comm, &node);
..
..
MPI_Graph_neighbors_count(graph_comm, node, &my_neighbors);
MPI_Graph_neighbors(graph_comm, node, Nneighbors, my_edges);
```

Input node=2 Output my_neighbors=2 my_edges={1,3}

Graph Topology

- Main MPI Graph Functions

❖ **MPI_GRAPH_GET :**

✓ **Retrieves graph topology information associated with a communicator**

✓ **Usage:**

int MPI_Graph_get(MPI_Comm *comm*, **int** *maxindex*, **int** *maxedges*, **int** **index*, **int** **edges* **);**

✓ **Parameters**

- *comm*
  - [in] communicator with graph structure (handle)
- *maxindex*
  - [in] length of vector index in the calling program (integer)
- *maxedges*
  - [in] length of vector edges in the calling program (integer)
- *index*
  - [out] array of integers containing the graph structure

  edges
  - [out] array of integers containing the graph structure

Graph Topology

- Main MPI Graph Functions

❖ **MPI_GRAPHDIMS_GET** :

✓ Retrieves graph topology information associated with a communicator

✓ **Usage**:

int MPI_Graphdims_get(MPI_Comm *comm*, **int** **nnodes*, **int** **nedges* **);**

✓ **Parameters**

- *comm*
  - [in] communicator for group with graph structure (handle)
- *nnodes*
  - [out] number of nodes in graph (integer)
- *nedges*
  - [out] number of edges in graph (integer)

Graph Topology

- Main MPI Graph Functions
- C :

```
int nnodes, nedges, index[4], edges[6];
..
..
MPI_Graphdims_get(graph_comm, &nnodes, &nedges);
MPI_Graph_get(graph_comm, nnodes, nedges, index, edges);
```

Output

nnodes=4

nedges=6

index= {1,3,5,6}

edges={1,0,2,1,3,2}

Node	*Nneighbors*	*index*	*edges*
0	1	1	1
1	2	3	0,2
2	2	5	1,3
3	1	6	2

Graph Topology

- Main MPI Graph Functions

❖ MPI_TOPO_TEST :

✓ Determines the type of topology (if any) associated with a communicator

✓ Usage:

int MPI_Topo_test(MPI_Comm *comm*, **int** **topo_type* **);**

✓ Parameters

- *comm*
  - [in] communicator (handle)
- *top_type*
  - [out] topology type of communicator comm (integer).
  - If the communicator has no associated topology, returns MPI_UNDEFINED.

Graph Topology

- Example:

- #include "stdafx.h"
- #include "mpi.h"
- #include <stdio.h>
- #include <stdlib.h>

- int main(int argc, char *argv[])
- {
-     int errs = 0, i, k, neighbourNumber,j;
-     int wsize = 5;
-     int topo_type;
-     int *index, *edges, *outindex, *outedges,*neighbours;
-     MPI_Comm comm1, comm2;
-     MPI_Init(&argc, &argv);   //preparation of environment of MPI
-     MPI_Comm_size(MPI_COMM_WORLD, &wsize); // Get the number of Processors

Graph Topology

- Example:

```
if (wsize >= 3) { // If Processor number is more than 3 we can make a graph.
        index = (int*)malloc(wsize * sizeof(int) );
        edges = (int*)malloc(wsize * 2 * sizeof(int) );
        // allocate memory for arrays

        if (!index || !edges) {
            printf( "Unable to allocate %d words for index or edges\n", 3 *
  wsize ); //Error Control if we cannot allocate memory
            fflush(stdout);//buffer ı boşaltır
            MPI_Abort( MPI_COMM_WORLD, 1 );
        }
```

Graph Topology

- Example:

```
index[0] =2; // We are filling index values of the graph
index[1]=5;
index[2]=6;
index[3]=8;
index[4]=10;

edges[0]=1; // We are filling edge values of the graph
edges[1]=4;
edges[2]=0;
edges[3]=2;
edges[4]=3;
edges[5]=1;
edges[6]=1;
edges[7]=4;
edges[8]=0;
edges[9]=3;
```

Node	Nneighbors	index	edges
0	2	2	1,4
1	3	5	0,2,3
2	1	6	1
3	2	8	1,4
4	2	10	0,3

Graph Topology

- Example:

```
MPI_Graph_create( MPI_COMM_WORLD, wsize, index, edges, 0, &comm1 );
//We are creating our graph
//MPI_COMM_WORLD is the communicators group we are going to use.
// wsize is the number of processors
// index and edges are the arrays that we are creating our graphs with.
// 0 used if we don’t want to order processes in the group.
//comm1 is the communicator which represents the graph.

MPI_Comm_dup( comm1, &comm2 );
 // We duplicated our graph.

MPI_Topo_test( comm2, &topo_type );
// Get the type of Toplogy we are using.

printf( "The Topology Type of Graphs is %s" , &topo_type);
```

Graph Topology

- Example:

```
if (topo_type != MPI_GRAPH) { // If Topology type is not graph stop process.
        errs++;
        printf( "Topo type of duped graph was not graph\n" );
        fflush(stdout);
}
else {// If Topology type  is graph continue our program
        int nnodes, nedges;
        MPI_Graphdims_get( comm2, &nnodes, &nedges );
// With using Graphdims we are getting dimensions of index array and edge array.
        if (nnodes != wsize) {
// And we are controlling if Node number obtained from graphdims same with the number
// of processors
            errs++;
            printf( "Nnodes = %d, should be %d\n", nnodes, wsize );
            fflush(stdout);
        }
        if (nedges != 2*wsize) {
           errs++;
           printf( "Nedges = %d, should be %d\n", nedges, 2*wsize );
           fflush(stdout);
        }
```

Graph Topology

- Example:

```
//We are going to obtain arrays that we created graph with. We will use Graphget functions.
        outindex = (int*)malloc(wsize * sizeof(int) ); //allocate memory for arrays
        outedges = (int*)malloc(wsize * 2 * sizeof(int); //allocate memory for arrays

        MPI_Graph_get( comm2, wsize, 2*wsize, outindex, outedges );
       // Comm2 is the Communicator we will get arrays from.
       // wsize and 2* wsize are the lenghts of arrays.
       // outindex and outedges are the arrays to write graph information.
         for (i=0; i<wsize; i++) {
       // We are controlling arrays we obtained with Graph_get if they are same with input
       //arrays.
             if (index[i] != outindex[i]) {
                 printf( "%d = index[%d] != outindex[%d] = %d\n", index[i], i, i, outindex[i] );
                 fflush(stdout);
                 errs++;
             }
         }
         for (i=0; i<2*wsize; i++) {
             if (edges[i] != outedges[i]) {
                 printf( "%d = edges[%d] != outedges[%d] = %d\n", edges[i], i, i, outedges[i] );
                 fflush(stdout);
                 errs++;
             }
         }
```

Graph Topology

- Example:

```
printf( "\n The node count of graph that obtained with MPI_Graphdims_get   Function : " );
 printf( "%d", nnodes );
 printf( "\n Edge count of graph that obtained with MPI_Graphdims_get Function : " );
 printf( "%d", nedges );
printf( "\n-----------------------------------\n");

 printf( "Array of indexes that obtained with MPI_Graph_get Function : " );
 // We are printing arrays obtained with Graph_Get function.
for (i=0;i<wsize;i++)
{
            printf( "%d ,", outindex[i] );
}
printf( "\nArray of Edges that obtained with MPI_Graph_get Function :" );
for ( i=0;i<wsize;i++)
{
            printf( "%d ,", outedges[i] );
}

free( outindex );//returns the memory which was allocated for outindex to system.
free( outedges ); //returns the memory which was allocated for outedges to system.

printf( "\n-----------------------------------\n");
```

Graph Topology

- Example:

```
    for(i=0;i<wsize;i++) // We are going to print each Nodes and their
// neighbours with using arrays that we obtained.
     {
            int temp;
            if(i==0)
                temp=0;
            else
                 temp=index[i-1];

          neighbourNumber=index[i]-temp; //Get each node's neighbour
 // number.
            printf( "\nMy node no is = %d  and I have %d neighbours", i,neighbourNumber);
            printf( "\nMy neighbours are : ");
            for( j=temp; j<index[i];j++)
            {
                        printf("%s,",edges[j]);
            }
            printf("\n");
            }
```

Graph Topology

- Example:

```
printf( "With Using MPI Commands");
printf( "\n------------------------------------\n");

for( k=0;k<wsize;k++)
{
        MPI_Graph_neighbors_count(comm2,k,&neighbourNumber);
//comm2 is the communicator we get graph's info.
//k is the node number.
// neighbourNumber is number of neighbour of "k";
        MPI_Graph_neighbors(comm2,k,neighbourNumber,&neighbours);
//k is the node number.
// neighbourNumber is number of neighbour of "k".
// neighbour is the array neighbours of k will be write.
        printf( "My node no is = %d and I have %d neighbours\n", k,neighbourNumber);
        printf( "My neıghbours are : ");
        for(i=0;i<neighbourNumber;i++)
        {
                printf("%s,",neighbours[i]);
        }
}
```

Graph Topology

- Example:

```
        free( index ); //return the allocated memory to the system.
        free( edges ); // return the allocated memory to the system.
        MPI_Comm_free( &comm2 ); // Empty comm2 and give to system.
        MPI_Comm_free( &comm1 ); //Empty comm1 and give to system.
    }

    MPI_Finalize(); //Finish MPI
    return 0;
}
```

Graph Topology

- Example:

```
The Topology Type of Graphs is MPI_GRAPH
-------------------------------------
The node count of graph that obtained with MPI_Graphdims_get Function : 5
Edge count of graph that obtained with MPI_Graphdims_get Function :10
-------------------------------------
Array of indexes that obtained with MPI_Graph_get Function : 2,5,6,8,10,
Array of Edges that obtained with MPI_Graph_get Function : 1,4,0,2,3,1,1,4,0,3,
-------------------------------------
My node no is 0 and I have 2 neighbours
My neighbours are : 1,4,

My node no is 1 and I have 3 neighbours
My neighbours are : 0,2,3,

My node no is 2 and I have 1 neighbours
My neighbours are : 1,

My node no is 3 and I have 2 neighbours
My neighbours are : 1,4,

My node no is 4 and I have 2 neighbours
My neighbours are : 0,3,
-------------------------------------
With Using MPI Commands
-------------------------------------
My node no is 0 and I have 2 neighbours
My neighbours are : 1,4,

My node no is 1 and I have 3 neighbours
My neighbours are : 0,2,3,

My node no is 2 and I have 1 neighbours
My neighbours are : 1,

My node no is 3 and I have 2 neighbours
My neighbours are : 1,4,

My node no is 4 and I have 2 neighbours
My neighbours are : 0,3,
```

Questions???????

Bibliography

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