Charm++, what's that?!

Les Mardis du dev'

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Outline

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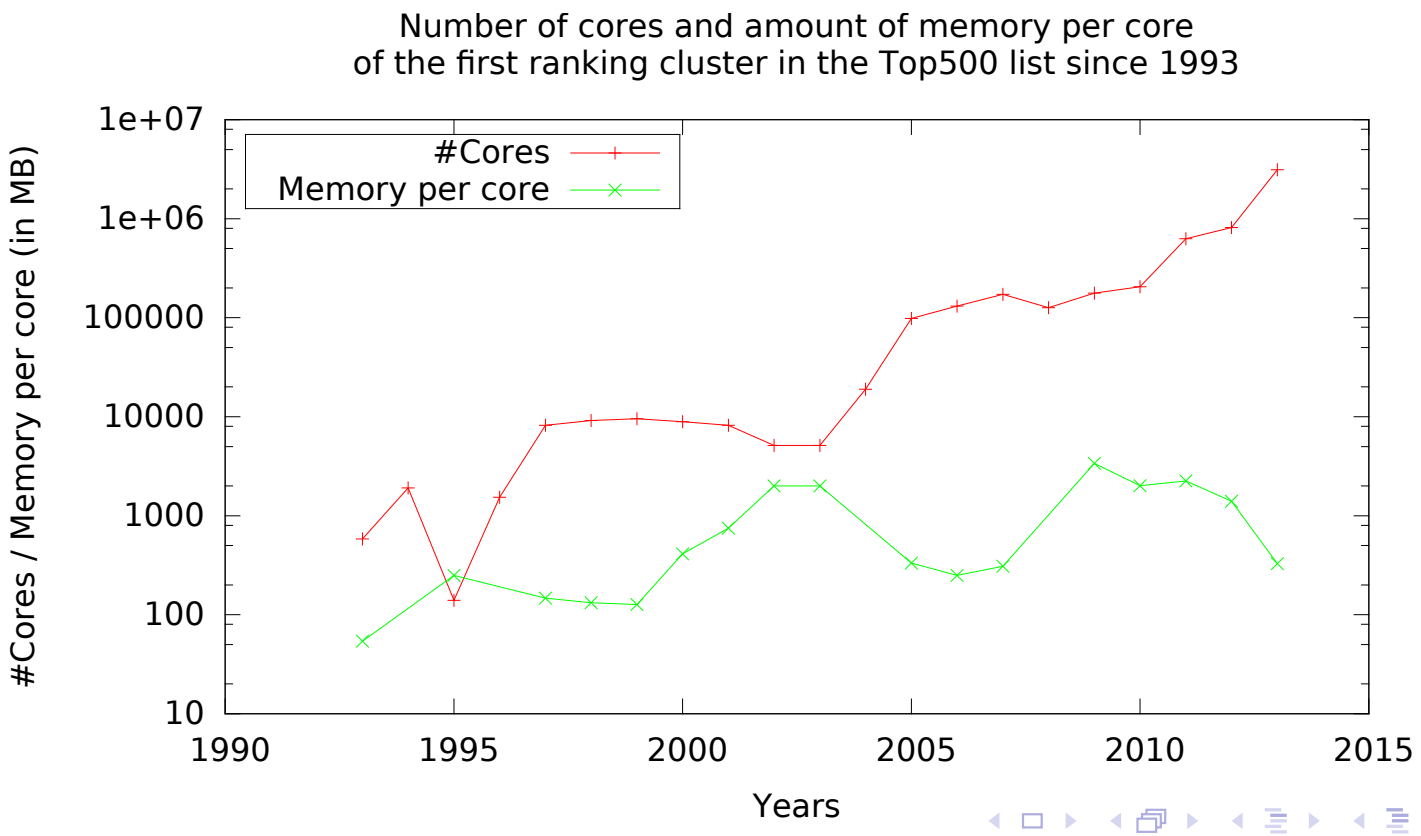
Parallel programming

- Decomposition
  - What to do in parallel
- Mapping
  - Which processor execute each task
- Scheduling
  - The order
- Machine dependent expression
  - Express the above decisions for the particular parallel machine

Scalable execution of parallel applications

- Cluster computing
- Number of cores is increasing
- But **memory per core** is decreasing (or increasing slowly)
- Applications need to communicate more and more...



How to communicate between nodes?

- Message passing paradigm
- Inter-process communication
- MPI, SOAP, Charm++

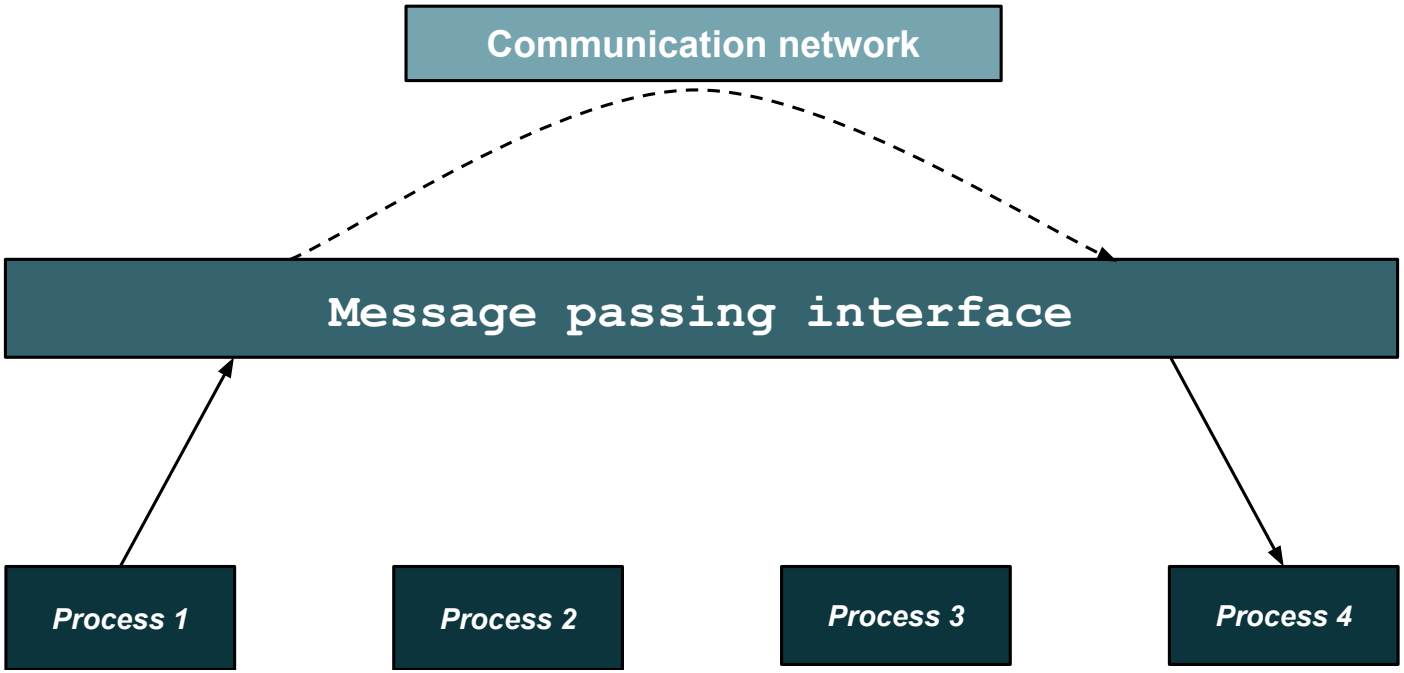


Figure : Communication from process 1 to process 4 with a message passing interface

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Wat? Charm++?
WTF iz that?

Presentation

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- High-level abstraction of parallel programming
- C++, Python

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  - Messages sent/received asynchronously to the code execution

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- Parallel
  - Chunks of code
  - Messages
- Programming paradigm
  - Way of writing program
  - Features and structures added on top of C++

What is a Charm++ Program?

- Collection of communicant chare objects, included the "main" chare (global object space)
- No importance about the number of PU or the type of interconnect (RTS)
- Send a message by calling another chare's entry point function (reception point)
  - returns immediately from the perspective of the calling chare

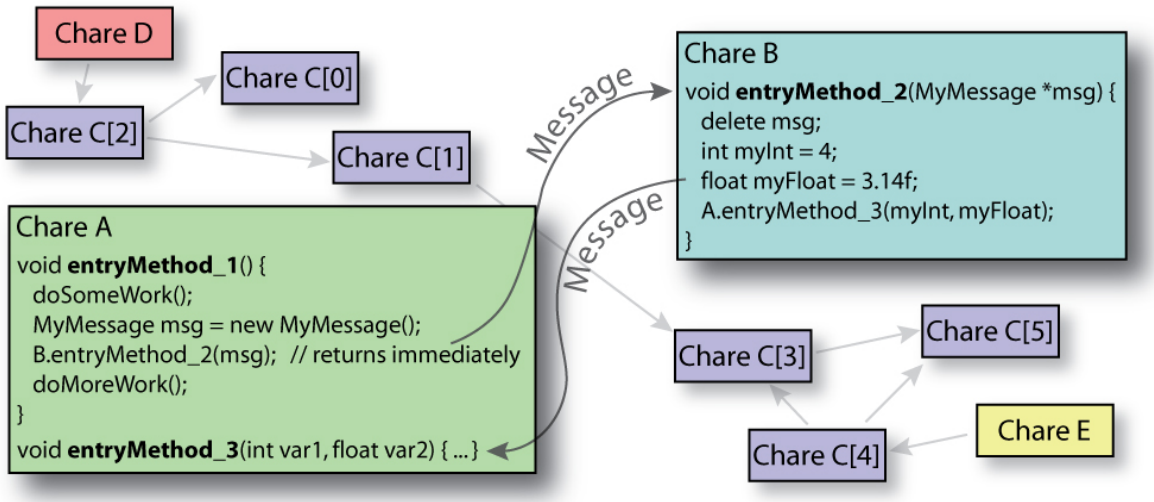


Figure : User's view of a Charm++ Application
(Credits : http://charm.cs.illinois.edu)

The Charm++ Compilation and the Runtime System

- First strenght: it works!
- Application written as a collection of communicating objects
- Compilation, execution : Specific target platform, physical resources (-np)
- RTS manages the details of the physical resources...
- ... and can take some decisions about :
  - Mapping chare objects to physical processors
  - Load-balancing chare objects
  - Checkpointing
  - Fault-tolereance
  - ...

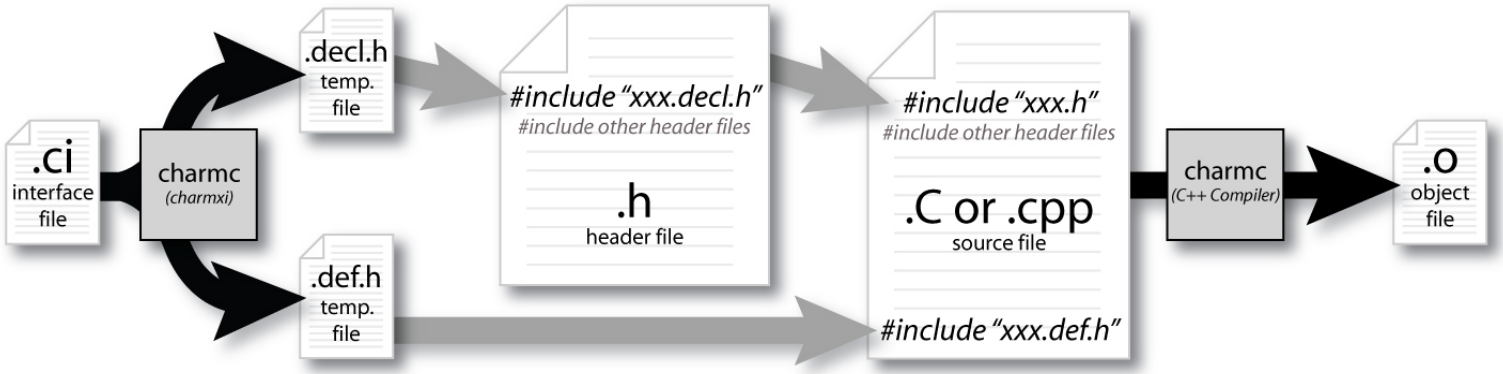


Figure : Compilation Process for a Chare Class(Credits : http://charm.cs.illinois.edu)

Outline

Listing 1: Hello.h

```
#ifndef __MAIN_H__
#define __MAIN_H__

class Main : public CBase_Main {

  public:
  Main(CkArgMsg* msg);
  Main(CkMigrateMessage* msg);

};

#endif //__MAIN_H__
```

Listing 2: Hello.ci

```
mainmodule main {

  mainchare Main {
    entry Main(CkArgMsg* msg);
  };

};
```

Listing 3: Hello.C

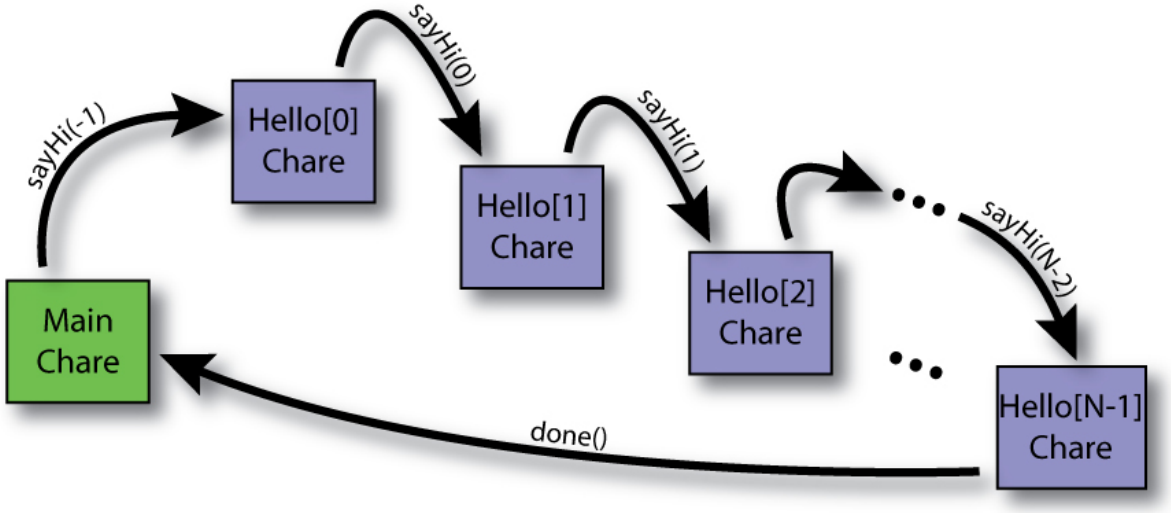
```
#include "main.decl.h"
#include "main.h"

// Entry point of Charm++ application
Main::Main(CkArgMsg* msg) {

  // Print a message for the user
  CkPrintf("Hello World!\n");

  // Exit the application
  CkExit();
}

// Constructor needed for chare object
// migration (ignore for now)
// NOTE: This constructor does not need
// to appear in the ".ci" file
Main::Main(CkMigrateMessage* msg) { }

#include "main.def.h"
```

Listing 4: 1Darray.ci

```
mainmodule hello {
  readonly CProxy_Main mainProxy;
  readonly int nElements;

  mainchare Main {
    entry Main(CkArgMsg *m);
    entry void done(void);
  };
  array [1D] Hello {
    entry Hello(void);
    entry void SayHi(int from);
  };
};
```

Listing 5: 1Darray.C

```
#include <stdio.h>
#include "hello.decl.h"

/*readonly*/ CProxy_Main mainProxy;
/*readonly*/ int nElements;

/*mainchare*/
class Main : public CBase_Main
{
  public:
  Main(CkArgMsg* m)
  {
    if(m->argc >1 )
      nElements=atoi(m->argv[1]);
    delete m;
    CkPrintf("Run on %d processors for %d el.\n",
             CkNumPes(),nElements);
    mainProxy = thisProxy;

    CProxy_Hello arr = CProxy_Hello::ckNew(nElements);
    arr[0].SayHi(-1);
  };

  void done(void)
  {
    CkPrintf("All done\n");
    CkExit();
  };
};

/*array [1D]*/
class Hello : public CBase_Hello
{
  public:
  Hello()
  {
    CkPrintf("Hello %d created\n",thisIndex);
  }

  Hello(CkMigrateMessage *m) {}

  void SayHi(int from)
  {
    CkPrintf("\"Hello\" from Hello chare #%d on "
             "processor %d (told by %d).\n",
             thisIndex, CkMyPe(), from);

    if (thisIndex < nElements-1)
      thisProxy[thisIndex+1].SayHi(thisIndex);
    else
      mainProxy.done(); // Done!
  }
};
```



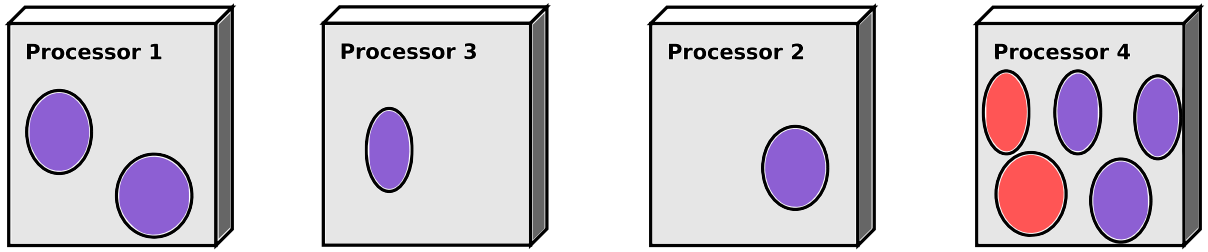

```
$ ./charmrun +p3 ./hello 10
Running "Hello World" with 10 elements using 3 processors.
"Hello" from Hello chare # 0 on processor 0 (told by -1).
"Hello" from Hello chare # 1 on processor 1 (told by 0).
"Hello" from Hello chare # 2 on processor 2 (told by 1).
"Hello" from Hello chare # 3 on processor 0 (told by 2).
"Hello" from Hello chare # 4 on processor 1 (told by 3).
"Hello" from Hello chare # 5 on processor 2 (told by 4).
"Hello" from Hello chare # 6 on processor 0 (told by 5).
"Hello" from Hello chare # 7 on processor 1 (told by 6).
"Hello" from Hello chare # 9 on processor 0 (told by 8).
"Hello" from Hello chare # 8 on processor 2 (told by 7).
```

Outline

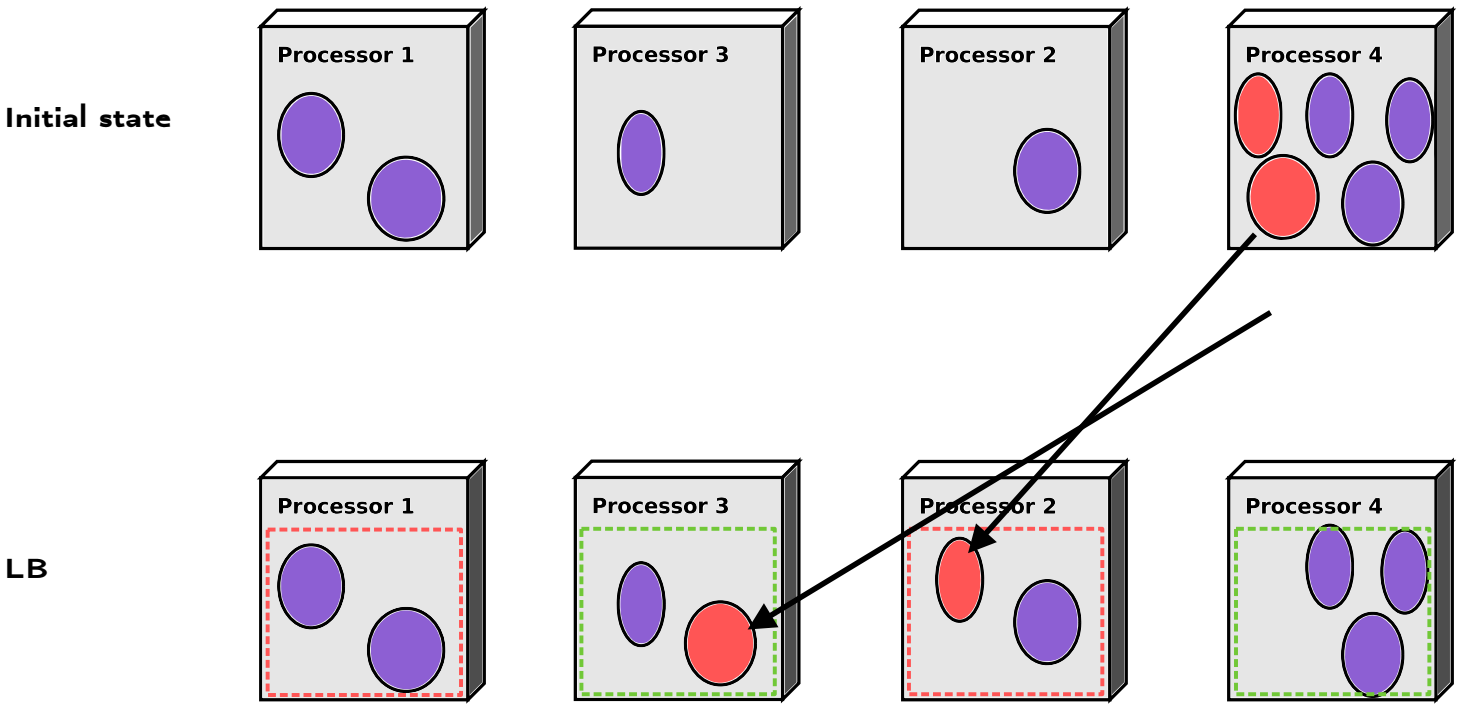
Load-balancing

- Balance the load between the processing units
- Goal : Optimize the CPU consumption, temperature, or other metrics...

Initial state



Charm++ - Load balancing



Listing 6: NewLB.C

```
CreateLBFunc_Def(NewLB, "Create NewLB")

void NewLB::work(BaseLB::LDStats* stats)
{
  CkPrintf("%d chares executed on %d procs\n",
           stats->n_obj, stats->nprocs());
  // Processor array
  ProcArray *parr = new ProcArray(stats);
  // Object graph
  ObjGraph *ogr = new ObjGraph(stats);
  std::vector<Vertex>::iterator v_it;
  std::vector<Edge>::iterator e_it;

  for (v_it=ogr->vertices.begin(); v_it!=ogr->vertices.end(); ++v_it) {
    double load = (*v_it).getVertexLoad();
    for (e_it=(*v_it).sendToList.begin(); e_it!=(*v_it).sendToList.end(); ++e_it) {
      int from = (*v_it).getVertexId();
      int to = (*e_it).getNeighborId();
      if (from != to) {
        CkPrintf ("%d msgs sent from %d to %d\n",
                  (*e_it).getNumMsgs(), from, to);
      }
    }
  }

  ogr->vertices[12].setNewPe(2);
  ogr->convertDecisions(stats);
}
```

Load-balancing

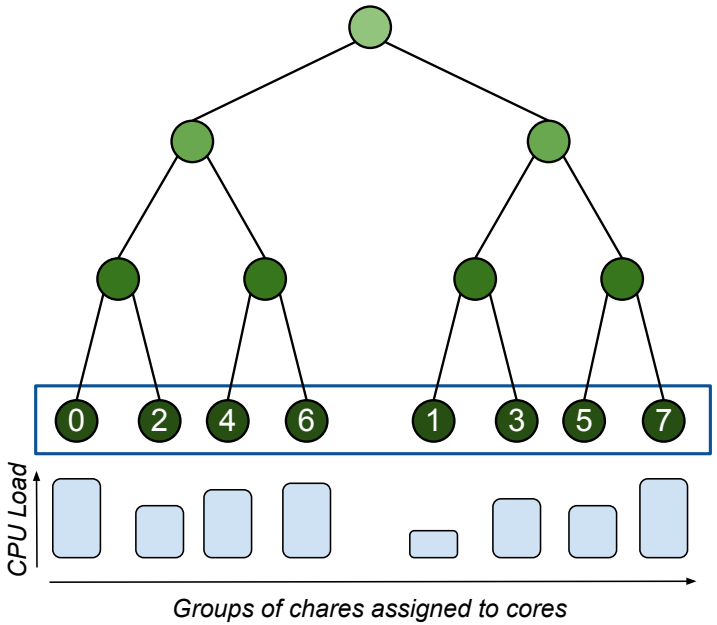
- For iterative applications
- charmrun +p64 ./App +balancer newLB +LBDebug 1 [...]
- Objects can migrate using a pup function (Pack and Unpack)

Listing 7: PUP function

```
class MyClass {
  public:
  int a;
  int *b;

  MyClass() {
    int a = 42;
    int *b = (int *)malloc(a*sizeof(int));
  }

  void pup(PUP::er &p) {
    p|a;
    PUParray(p, b, a);

    if (p.isUnpacking()) {
      b = (int *)malloc(a*sizeof(int));
    }
  }
}
```

Load-balancing

- For iterative applications
- charmrun +p64 ./App +balancer newLB +LBDebug 1 [...]
- Objects can migrate using a pup function (Pack and Unpack)
- Several load balancers
  - GreedyLB
  - RefineLB
  - **Hierarchical load balancers**
  - Thermal aware load balancers...



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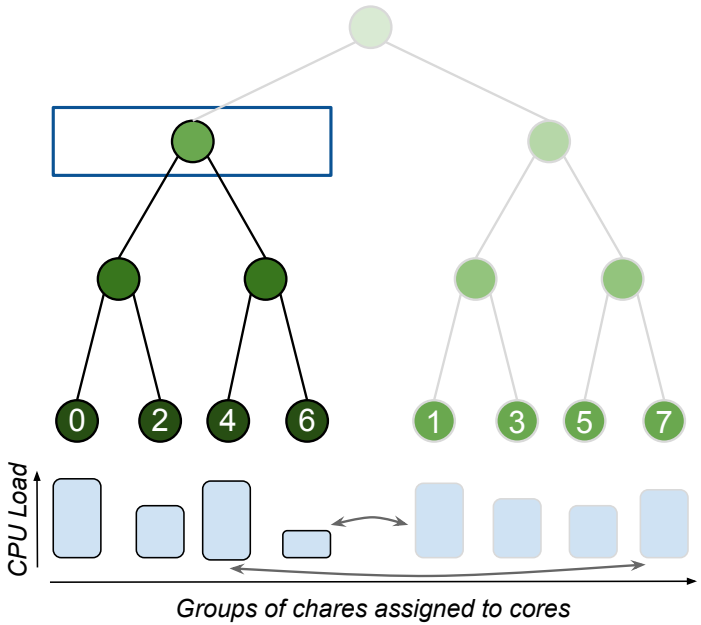

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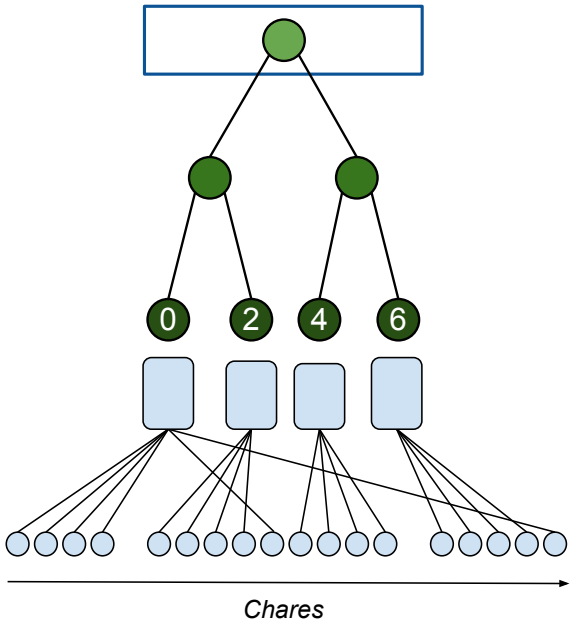

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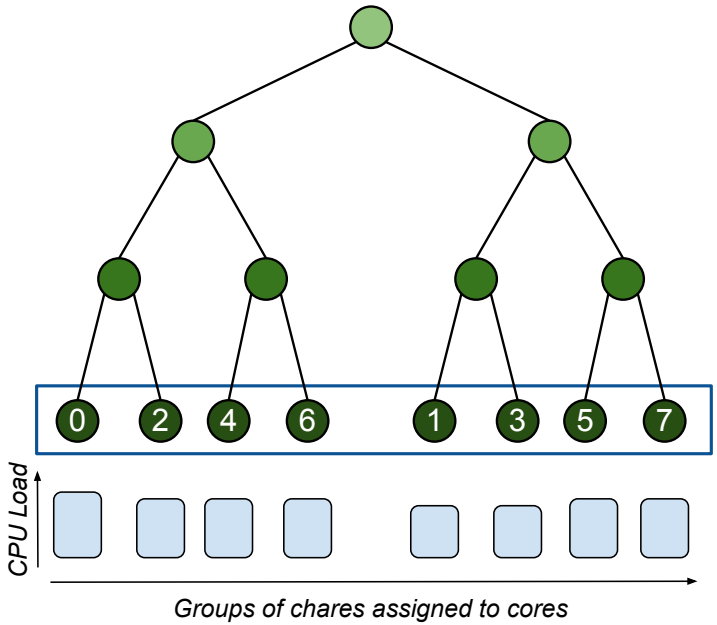
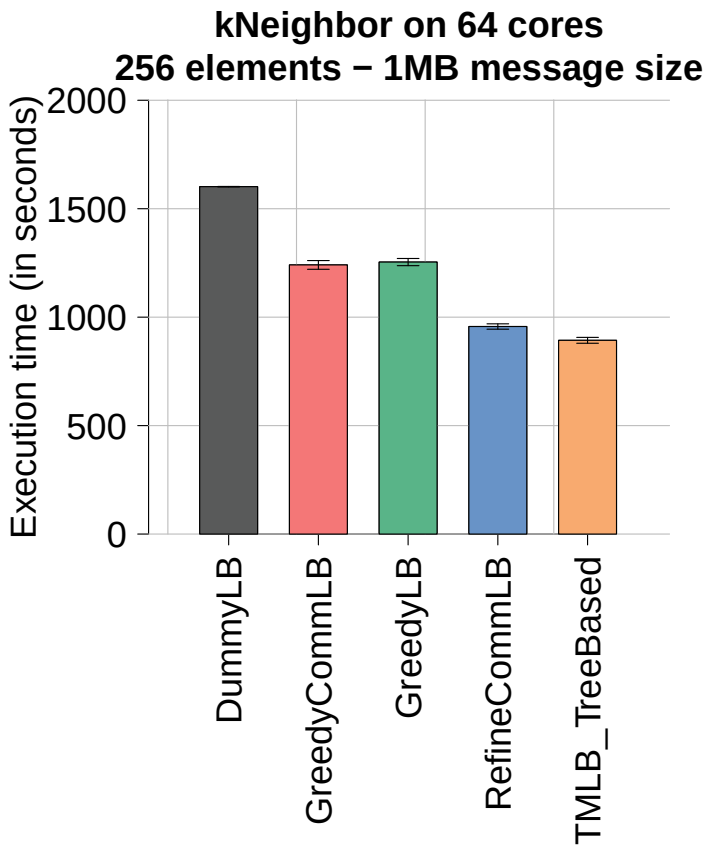


kNeighbor

- Benchmarks application designed to simulate intensive communication between processes
- Experiments on PlaFRIM : 8 nodes with 8 cores on each (Intel Xeon 5550)



Outline

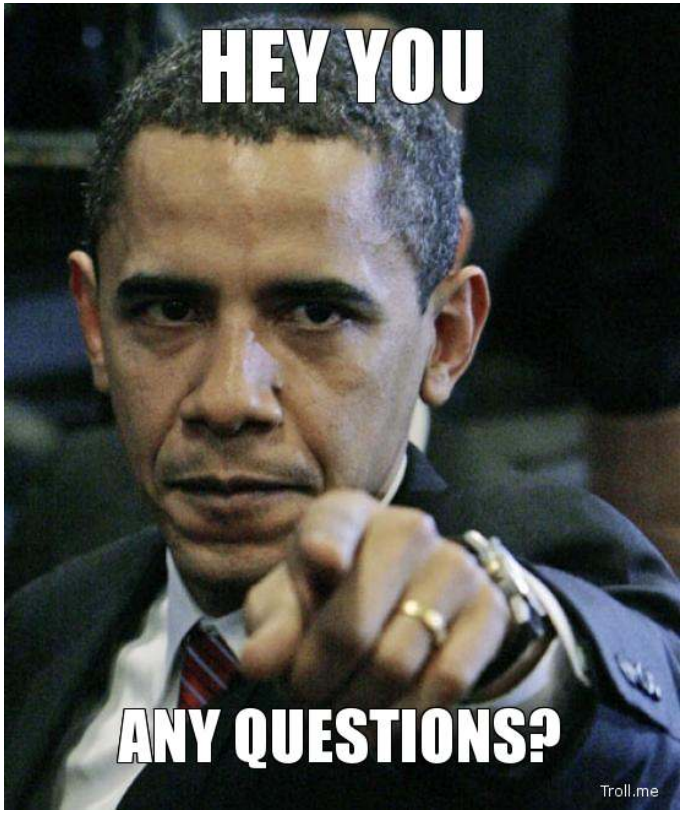
To conclude...

- Charm++, message passing since 1984
- High-level abstraction of a parallel program
- Interesting features : load balancing, fault-tolerance,...
- Useful tools; CharmDebug, Projections
- Used by some important applications : ChaNGa, NAMD, OpenAtom

Want to know more?

- Website : `http://charm.cs.uiuc.edu/`
- Tutorials : `http://charm.cs.illinois.edu/tutorial/TableOfContents.htm`

The End



Thanks for your attention !