A Quick Introduction to MPI

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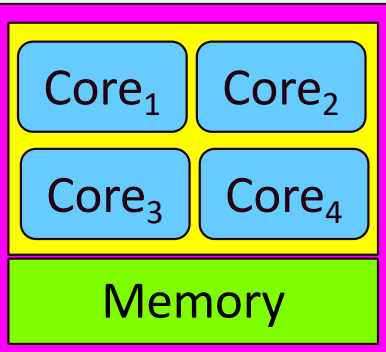
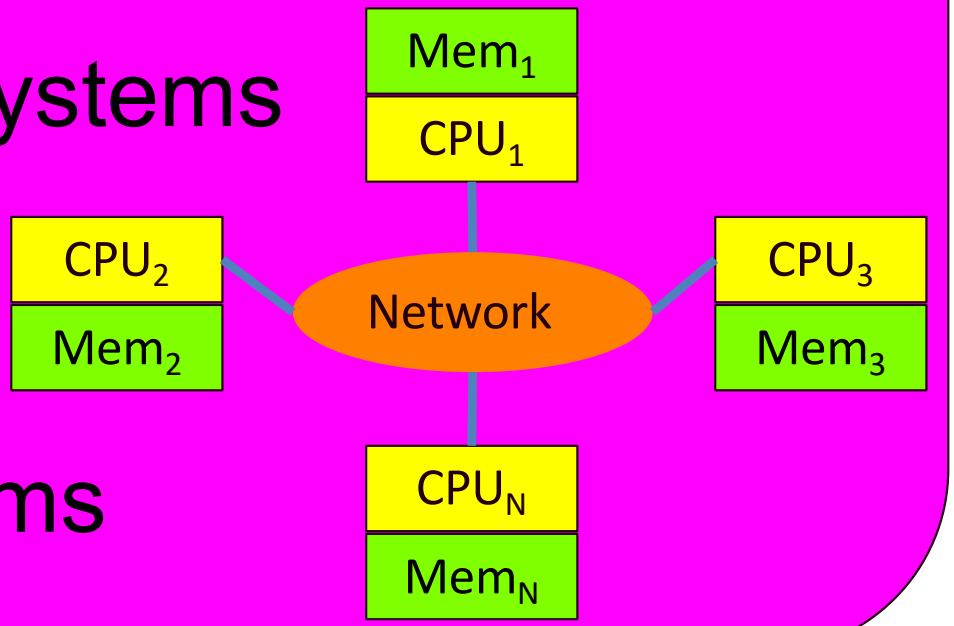
Hardware: A Diverse Landscape

- Shared-memory systems



- Distributed-memory systems



- Heterogeneous systems

What is MPI ?

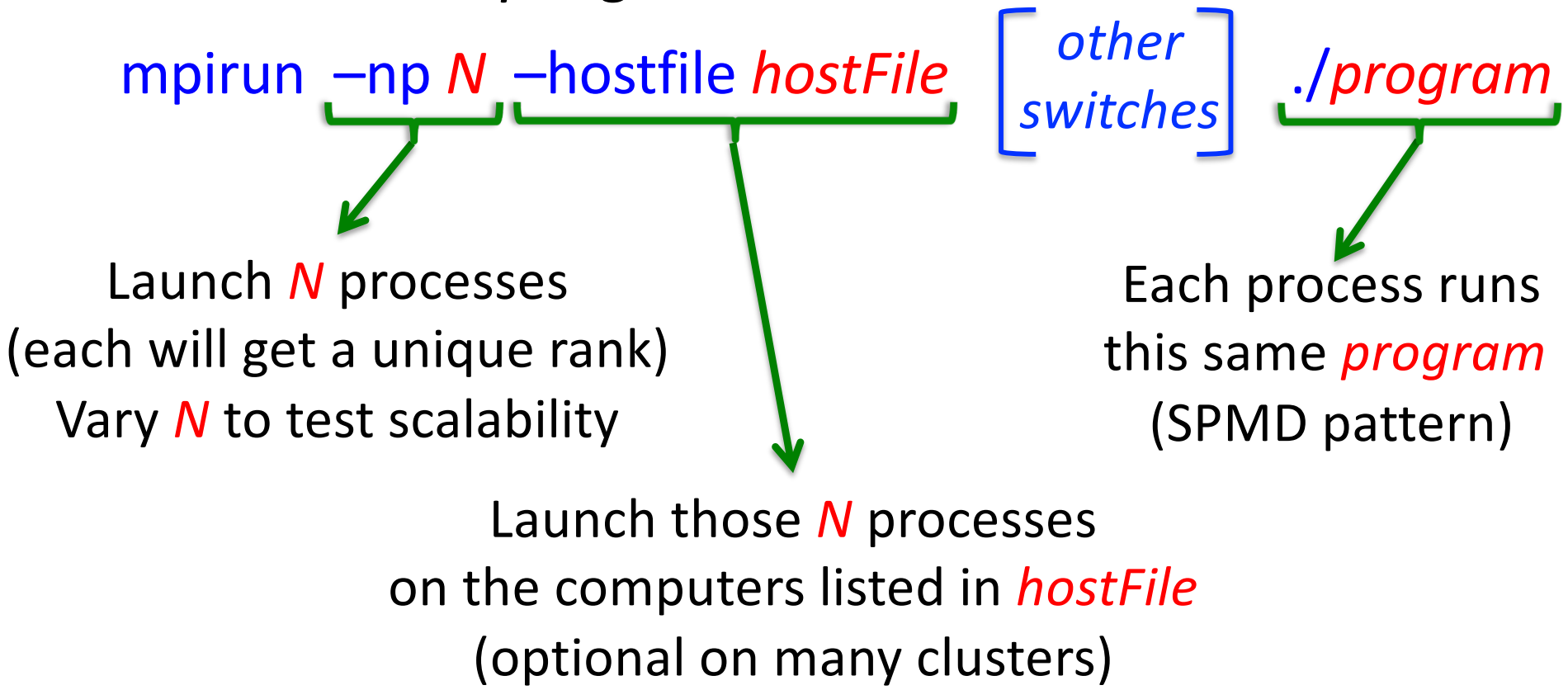
- The *Message Passing Interface*
- An industry-standard library for message passing parallel computing in C, C++, Fortran, with 3rd party bindings for Java, Python, R, …
- Designed by a large consortium:
  - 12 companies: *Cray, IBM, Intel, …*
  - 11 national labs: *ANL, LANL, LLNL, ORNL, Sandia, …*
  - representatives from 16 universities
- Useful on shared- or distributed-parallel systems

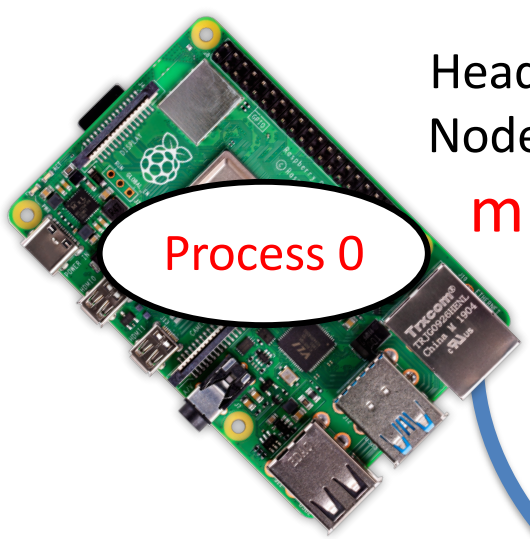
MPI Software: Multi*processing*

- Software *processes* run on each computer
- MPI lets these processes communicate by *sending-receiving messages* via the network.
- *Single Program Multiple Data* (SPMD) pattern
  - Each process runs the same program, but has different data values (e.g., a different process ID) as it runs

MPI Runtime

- To run an MPI *program* from the command line:

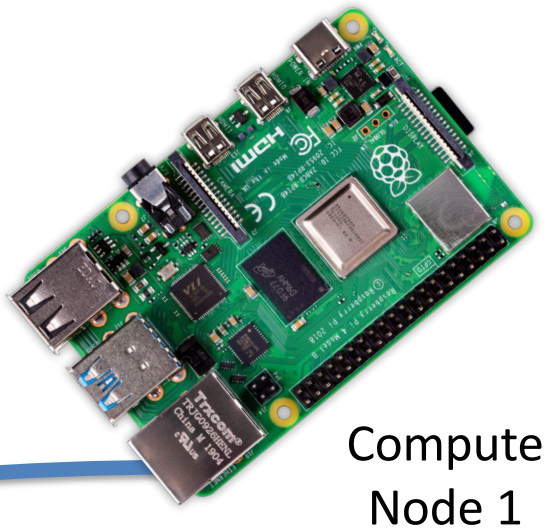




Head
Node

mpirun –np 1 …

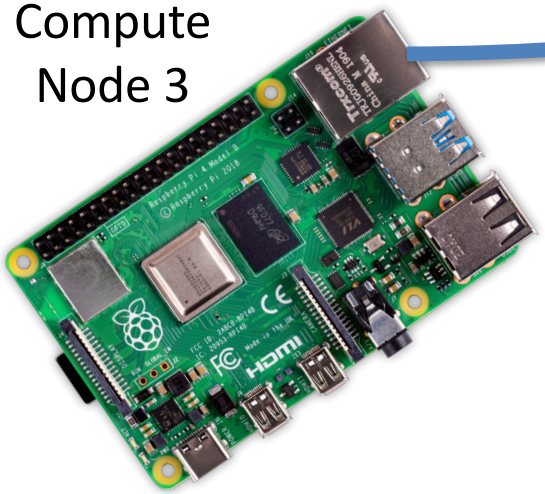
Process 0

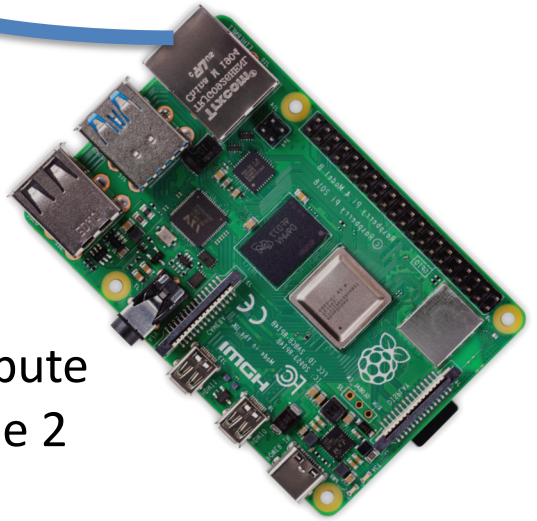


Compute
Node 1

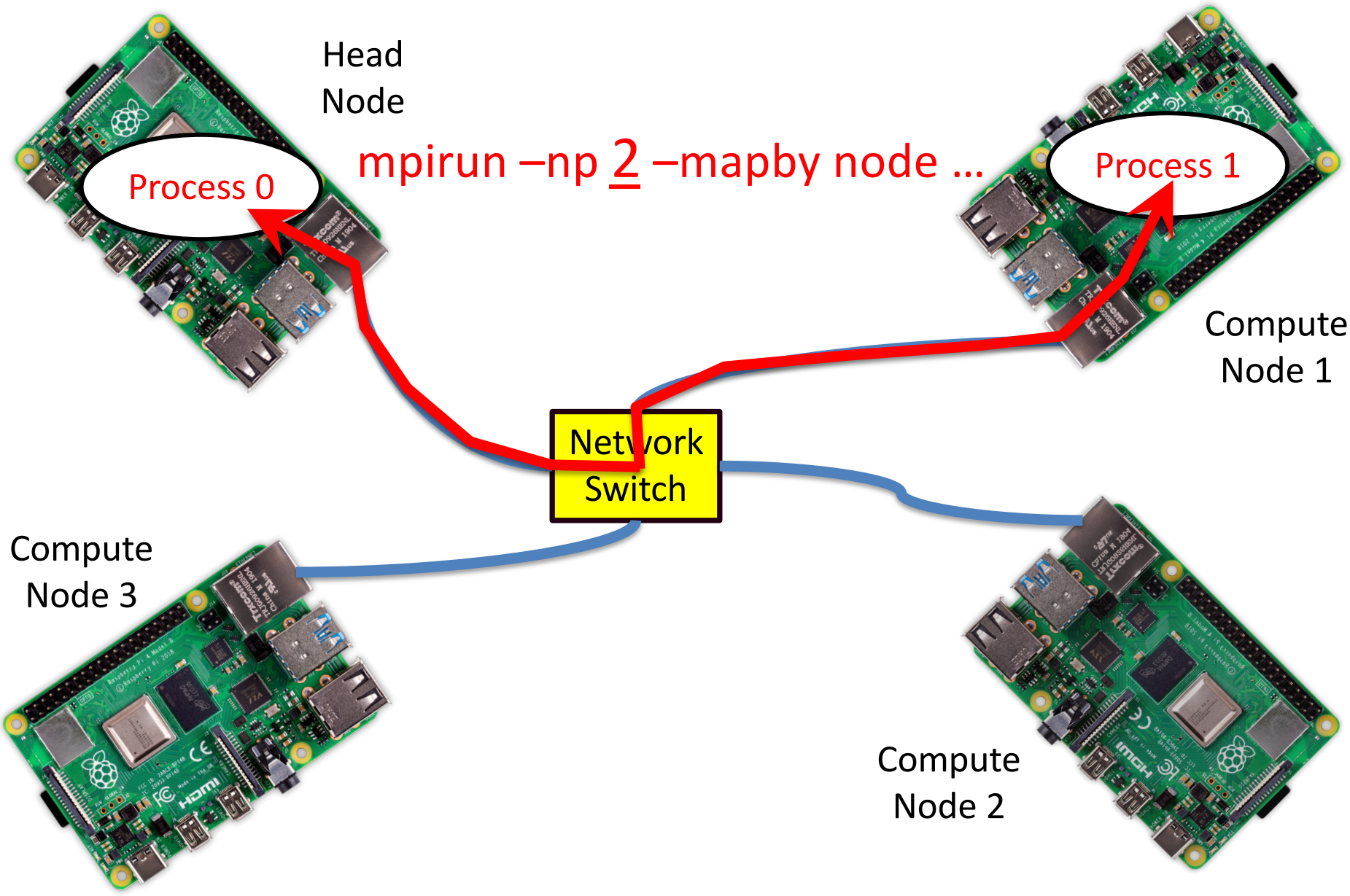
Network
Switch

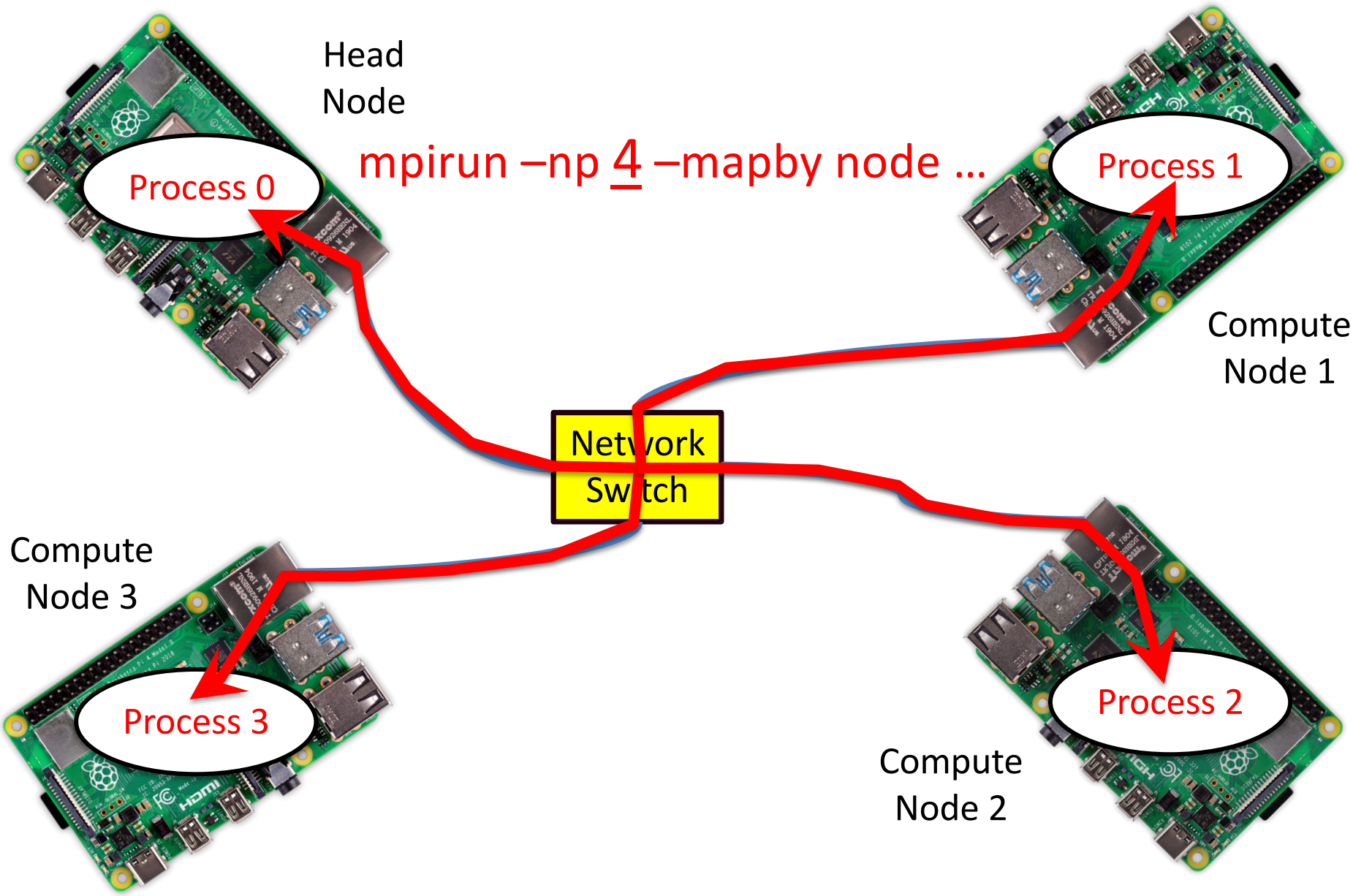
Compute
Node 3





Compute
Node 2


Head
Node
mpirun –np 2 –mapby node …
Process 0
Process 1
Compute
Node 1
Network
Switch
Compute
Node 3
Compute
Node 2


Head
Node
mpirun –np 4 –mapby node …
Process 0
Process 1
Compute
Node 1
Network
Switch
Compute
Node 3
Process 3
Process 2
Compute
Node 2

Parallel Problem Solving

Two common parallel algorithmic strategies:

- *Data decomposition*: process a dataset of size N by dividing the data among the P processes
  - Each process does N/P of the work, in parallel
  - Can scale well for large datasets
- *Task decomposition*: Divide a process into its functional steps (aka *tasks*); perform any independent tasks in parallel
  - Scalability bounded by the number of tasks

Data Decomposition (1 Process)

process 0

Data Decomposition (2 Processes)

Process 0

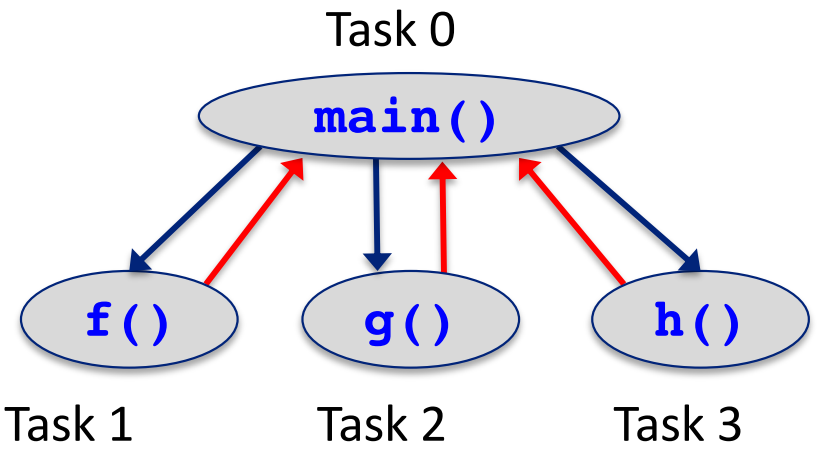
Process 1

Data Decomposition (4 Processes)

Task Decomposition

The independent steps in a sequential computation can be “parallelized”:

```
int main() {
    x = f();
    y = g();
    z = h();
    w = x + y + z;
}
```



Patternlets…

are minimalist, scalable, and complete programs, each illustrating one or more parallel patterns:

- *Minimalist* to help students understand the pattern by eliminating non-essential details
- *Scalable* so that students can vary the number of processes and see the pattern's behavior change
- *Complete* for flexible use:
  - Instructors can use them in a 'live coding' lecture
  - Students can explore them in a hands-on exercise, and use them as models for their own programs.

Exemplars…

are programs that use parallel patterns to solve a 'real world' problem.

Exemplars let students see how a pattern can be useful in a meaningful context.

A *patternlet* is useful for *introducing* students to a pattern; an *exemplar* is useful for helping students see how and why a pattern is *relevant*.