Taming Wild Threads

Tips and Pitfalls in Hybrid Programming

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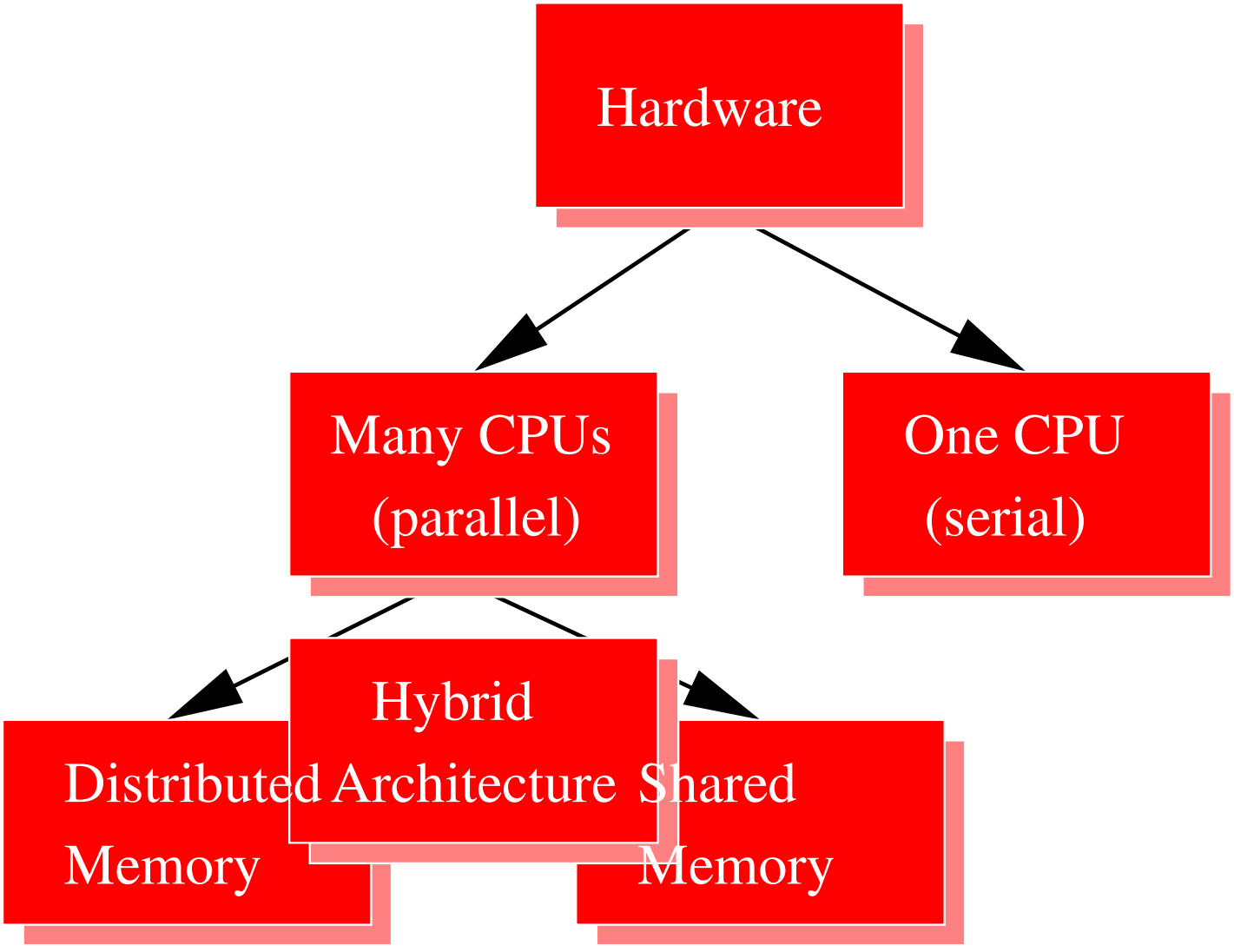
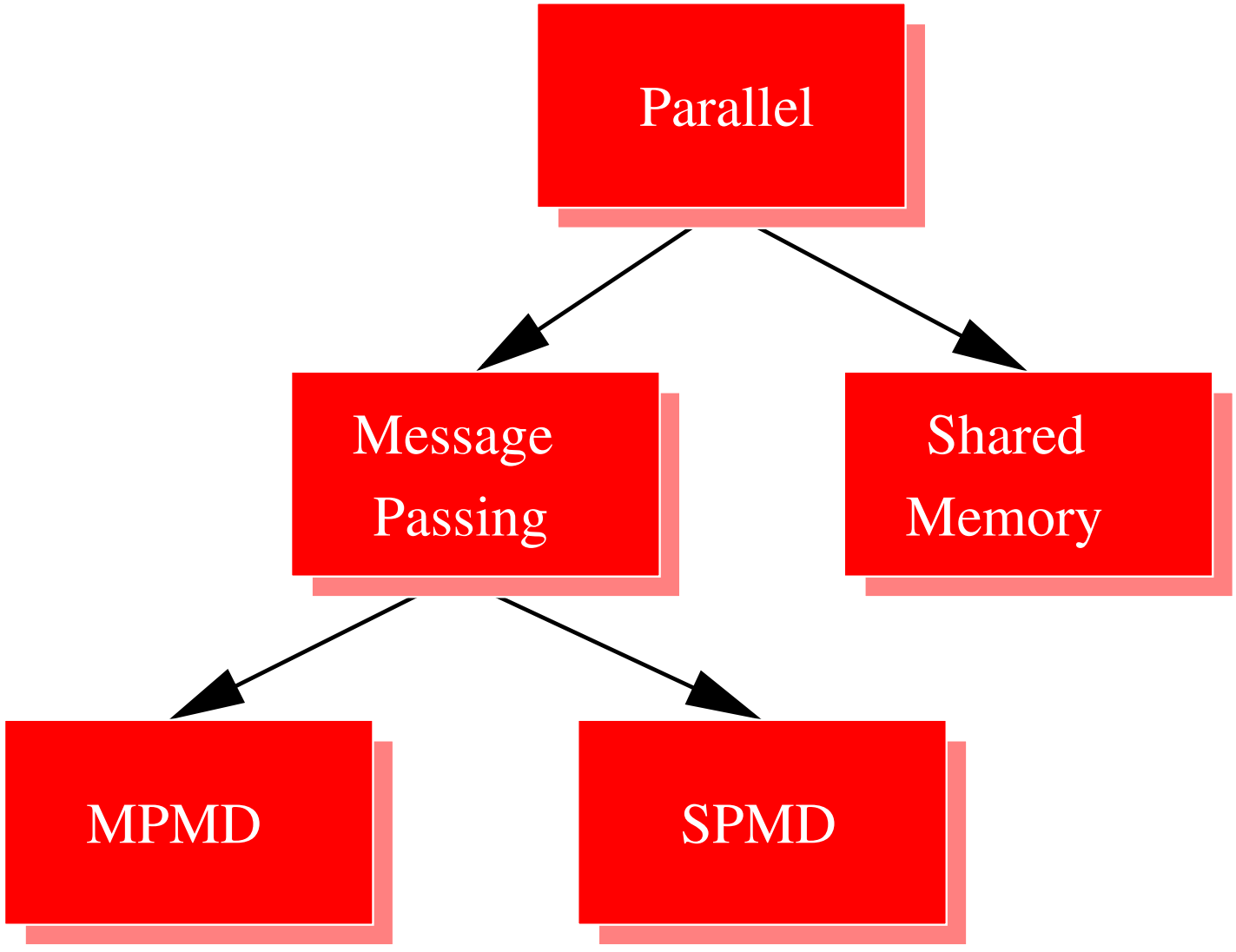
Parallel Computer Basics



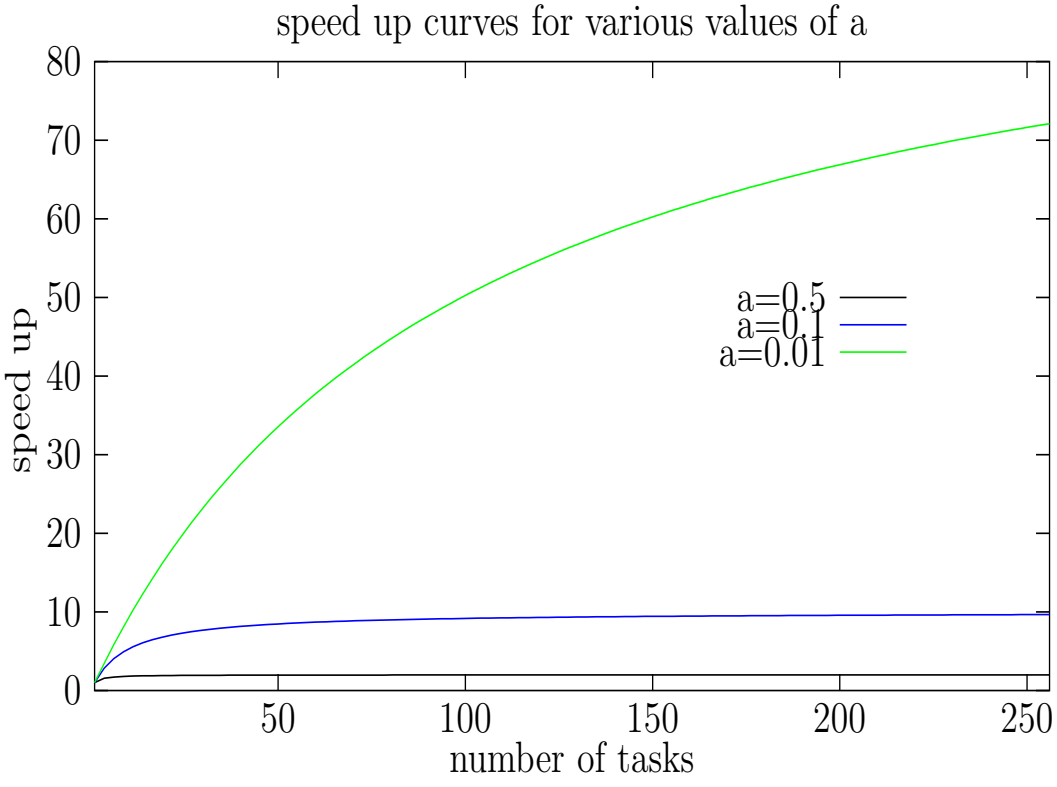
Basic Programming Paradigms



Amdahls Law

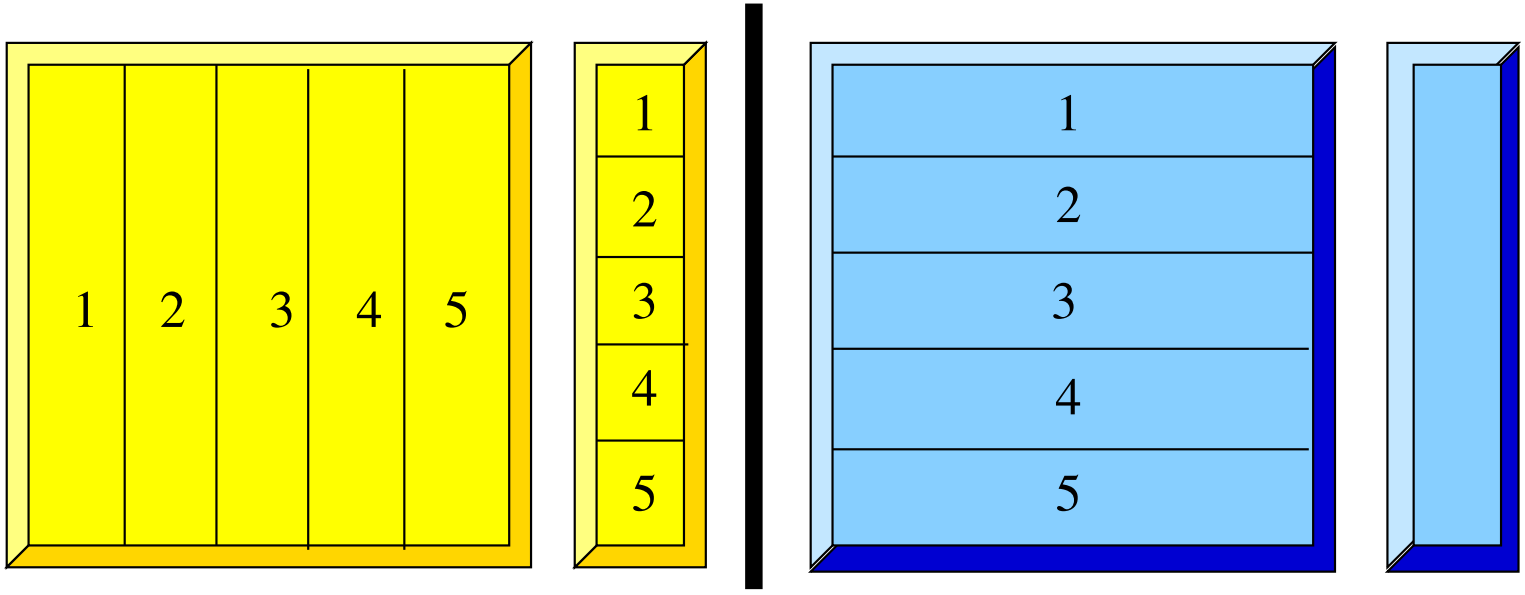
- $t(1) = t_{ser} + t_{par}$
- $t(p) = t_{ser} + t_{par}/p$
- $a = t_{ser}/t(1)$
- Speed up:

$$s = t(1)/t(p)$$
$$= 1/(a + \frac{1-a}{p})$$
$$= 1/a \quad p \to \infty$$



Choose Data Distribution

Matrix Vector Multiplication



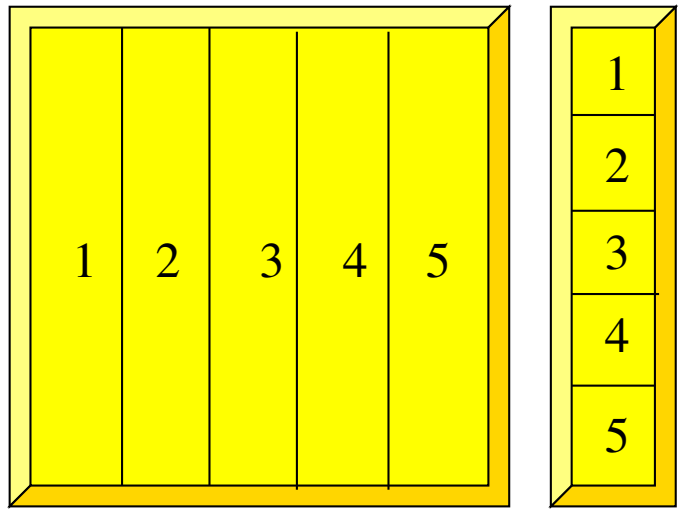
Stride 1 access

Access with large stride

Check Loop Boundaries

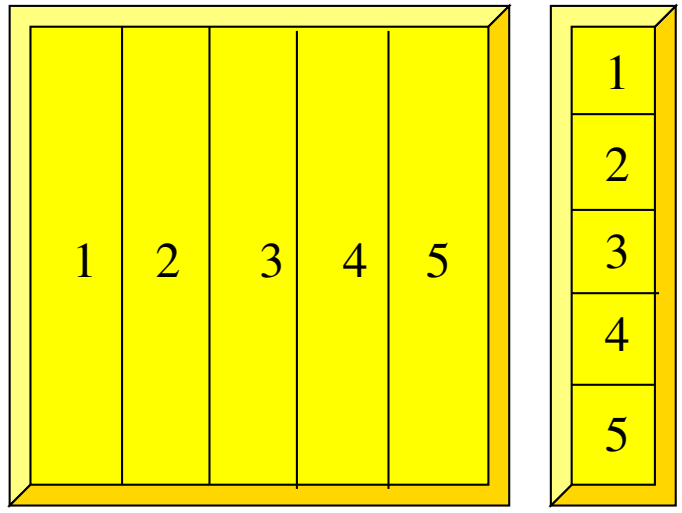
Do $j = 1, n\_loc$
  Do $i = 1, n$
    $c(i) = c(i) + a(i,j) * b(j)$
  end Do
end Do

$n\_loc = ncols / nprocs$

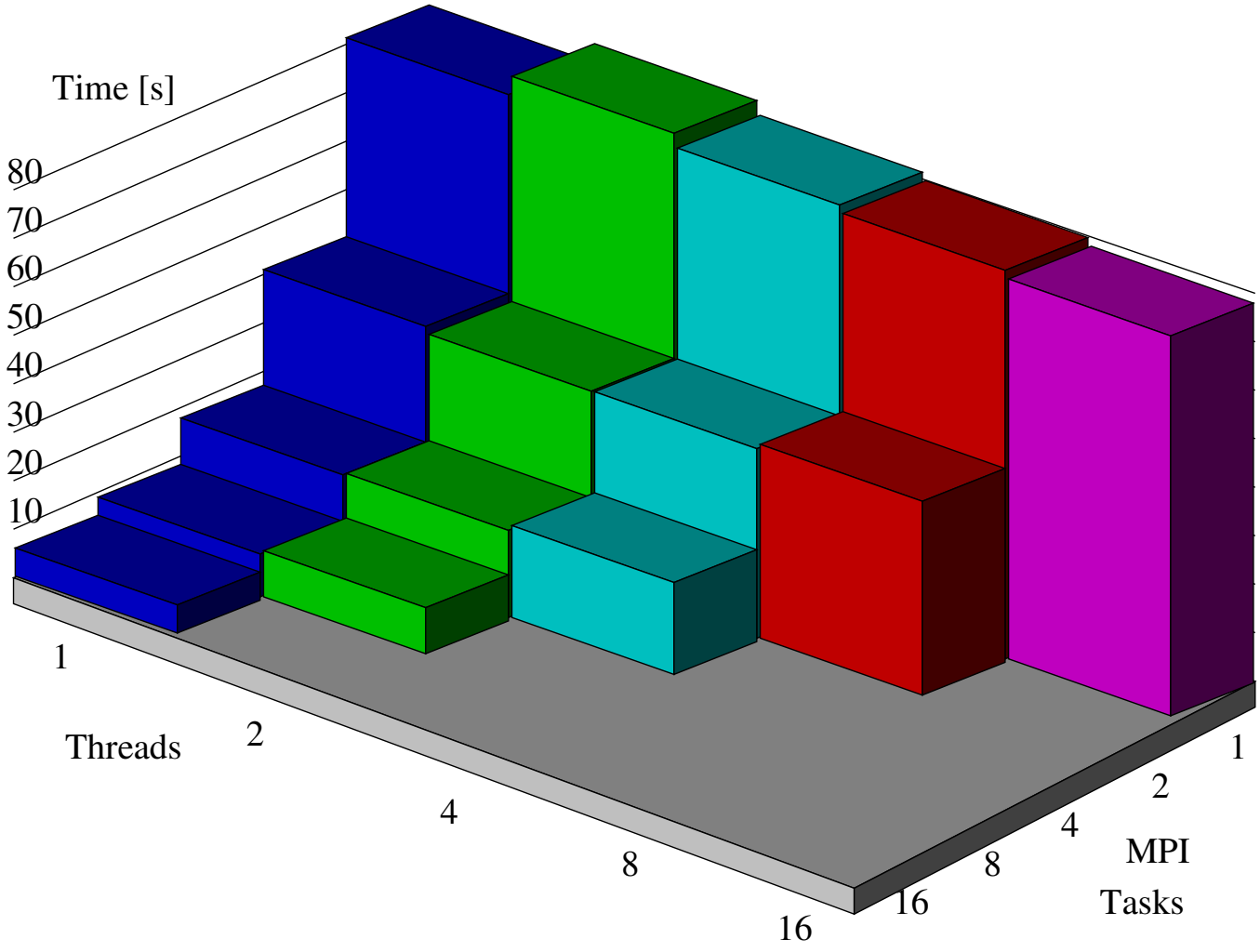


Set Up MPI Communication

Do $j = 1, n\_loc$
  Do $i = 1, n$
    $c(i) = c(i) + a(i,j) * b(j)$
  end Do
end Do
call mpi_reduce_scatter



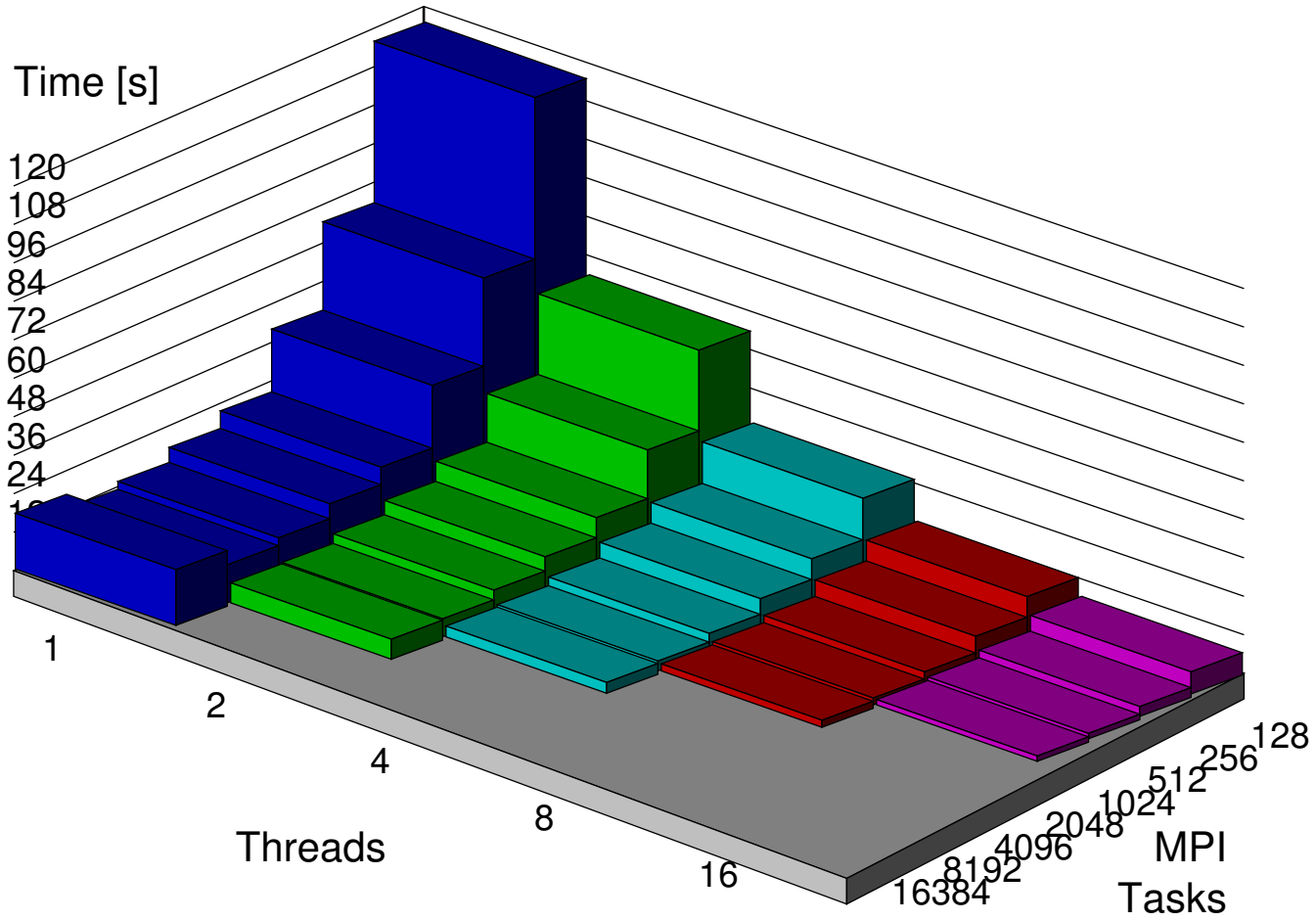
Timings on p690 (-qsmp=auto)



Conditions to make this happen

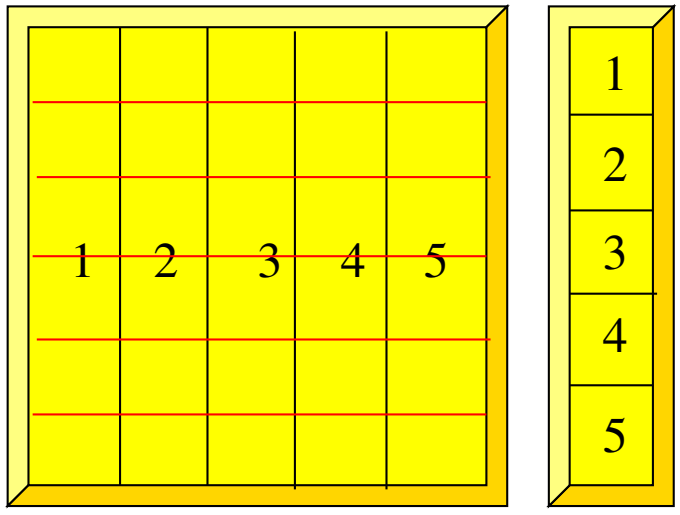
- Incomplete compiler options -
  - Use MPI wrapper for the compiler.
  - Forget to set the OpenMP option.
- OMP_NUM_THREADS not set. Possible defaults -
  - OMP_NUM_THREADS=1
  - OMP_NUM_THREADS="all node"
- OMP_NUM_THREADS only limits number of threads.

BG/Q Timings (-qsmp=auto)



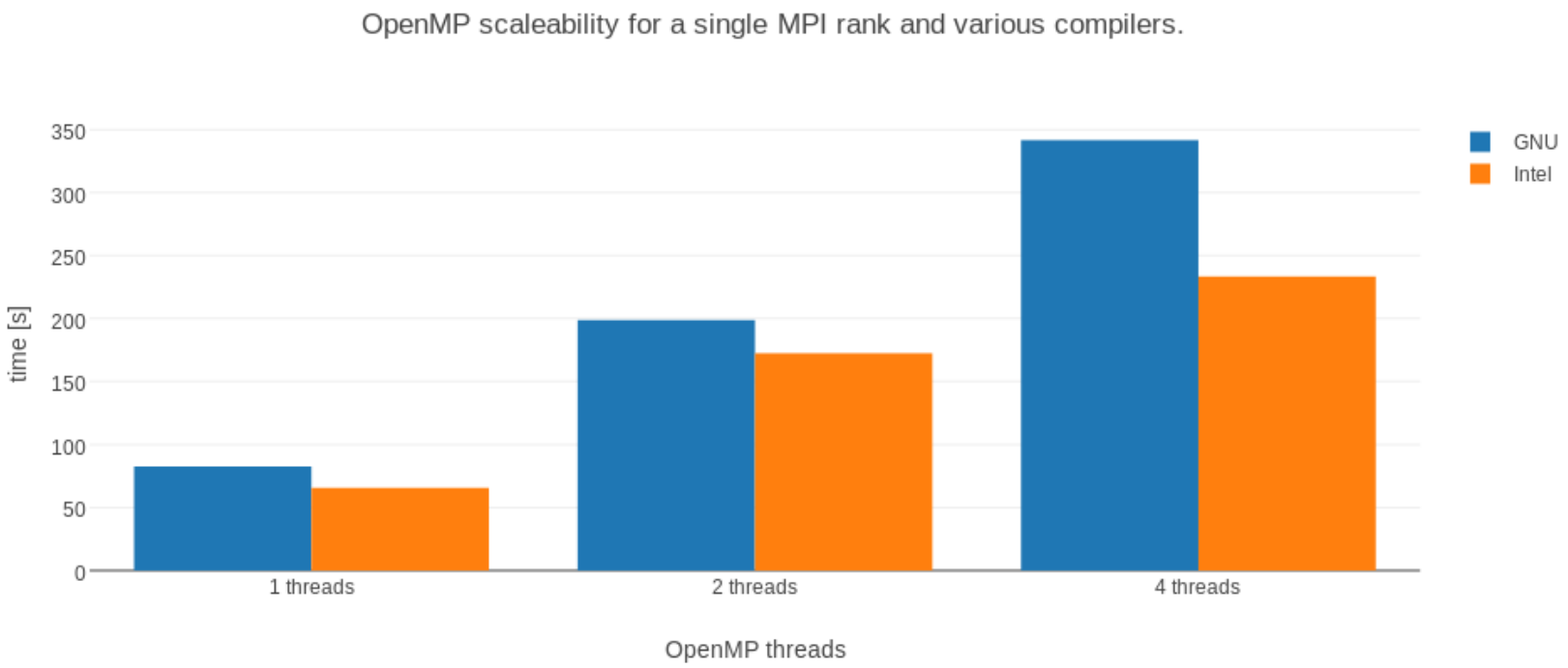
Choose OpenMP Work Distribution

```
Do j = 1, n_loc
$OMP do parallel reduction(+:c)
   Do i = 1,n
     c(i) = c(i) + a(i,j) * b(j)
   end Do
$OMP end do parallel
end Do
call mpi_reduce_scatter
```



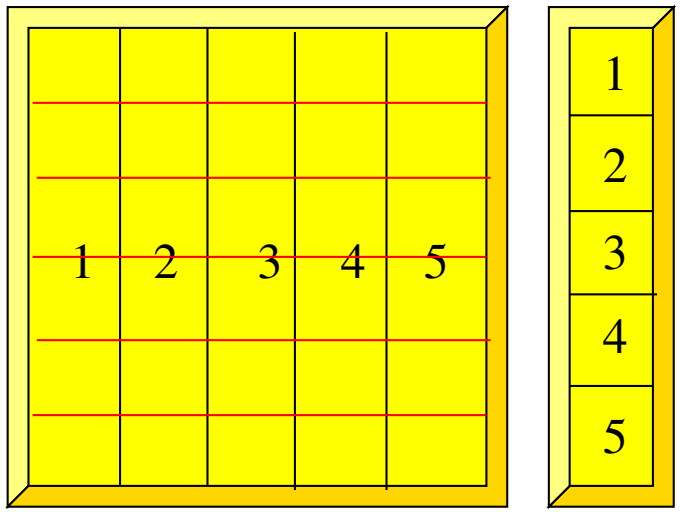
Overhead !!!

Skylake 8168 Timings

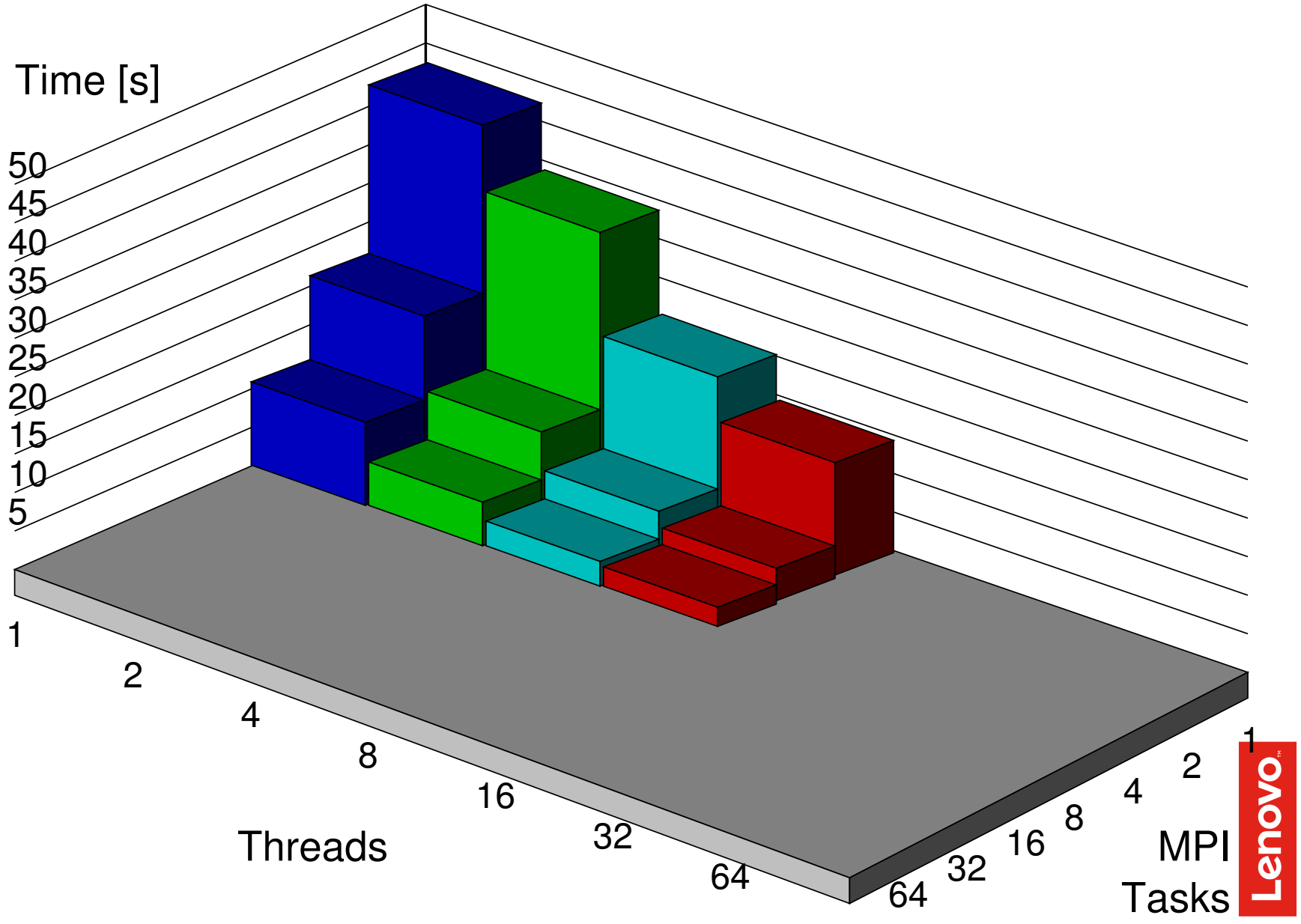


Do we need the Reduction Clause ?

```
$OMP parallel shared(c)
 c = 0
 Do j = 1,n_loc
$OMP do parallel
    Do i = 1,n
      c(i) = c(i) + a(i,j) * b(j)
    end Do
$OMP end do
 end Do
$OMP end parallel
 call mpi_reduce_scatter
```



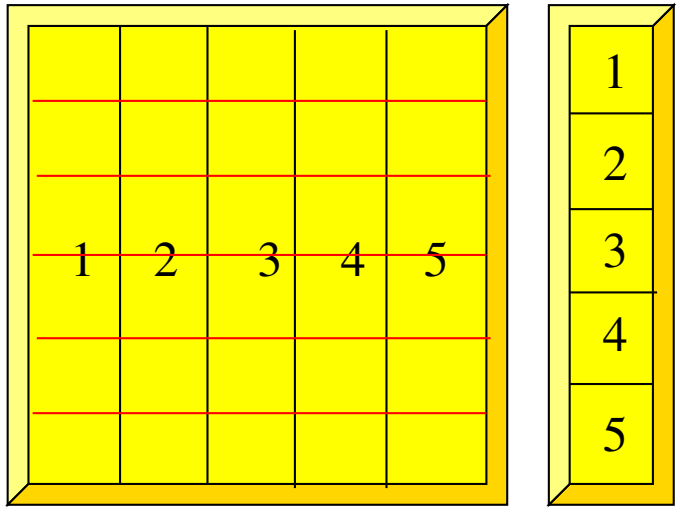
Skylake 8168 Timings for Intel Compiler



Enlarging parallel Region

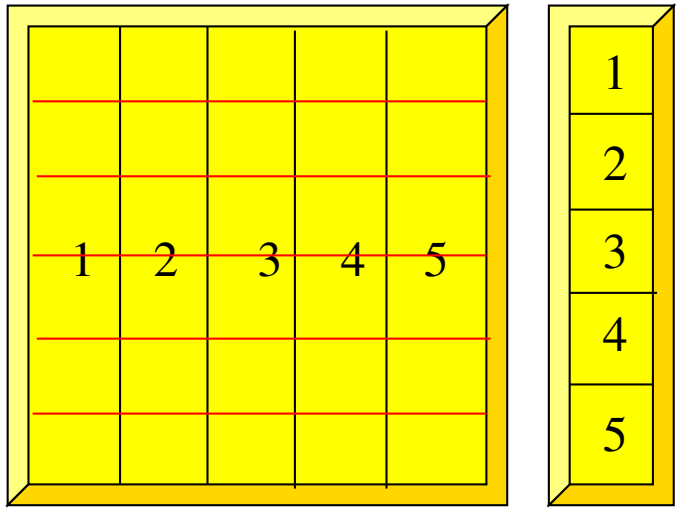
```
$OMP parallel reduction(+:c)
c = 0
Do j = 1,n_loc
$OMP do parallel
   Do i = 1,n
     c(i) = c(i) + a(i,j) * b(j)
   end Do
$OMP end do
end Do
$OMP end parallel
call mpi_reduce_scatter
```

Wrong results !!!



The Correct OpenMP Program

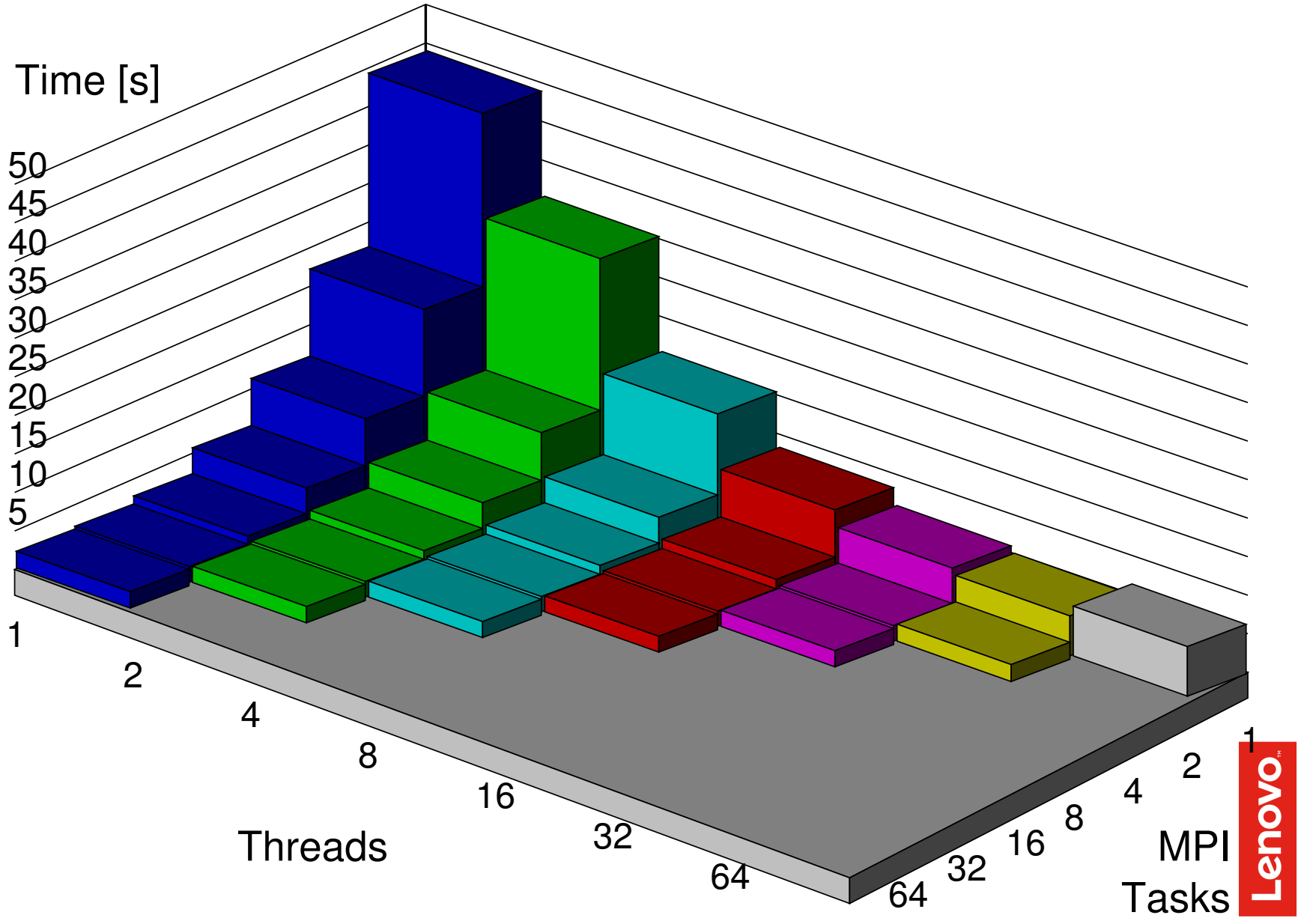
```
$OMP parallel reduction(+:c)
c = 0

c = 0
$OMP parallel reduction(+:c)
Do j = 1,n_loc
$OMP do parallel
   Do i = 1,n
     c(i) = c(i) + a(i,j) * b(j)
   end Do
$OMP end do
end Do
$OMP end parallel
call mpi_reduce_scatter
```



Initialization Move Explained

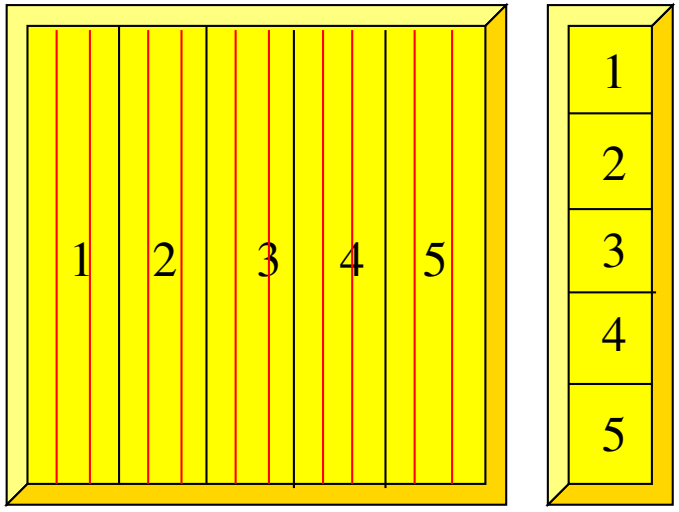
- Inside the parallel region the shared variable c is hidden behind private c's
- All private c's are initialized with 0
- All private c's are added to the shared c at the end of the parallel region
- Shared c needs initialization

Skylake 8168 Timings for GNU Compiler



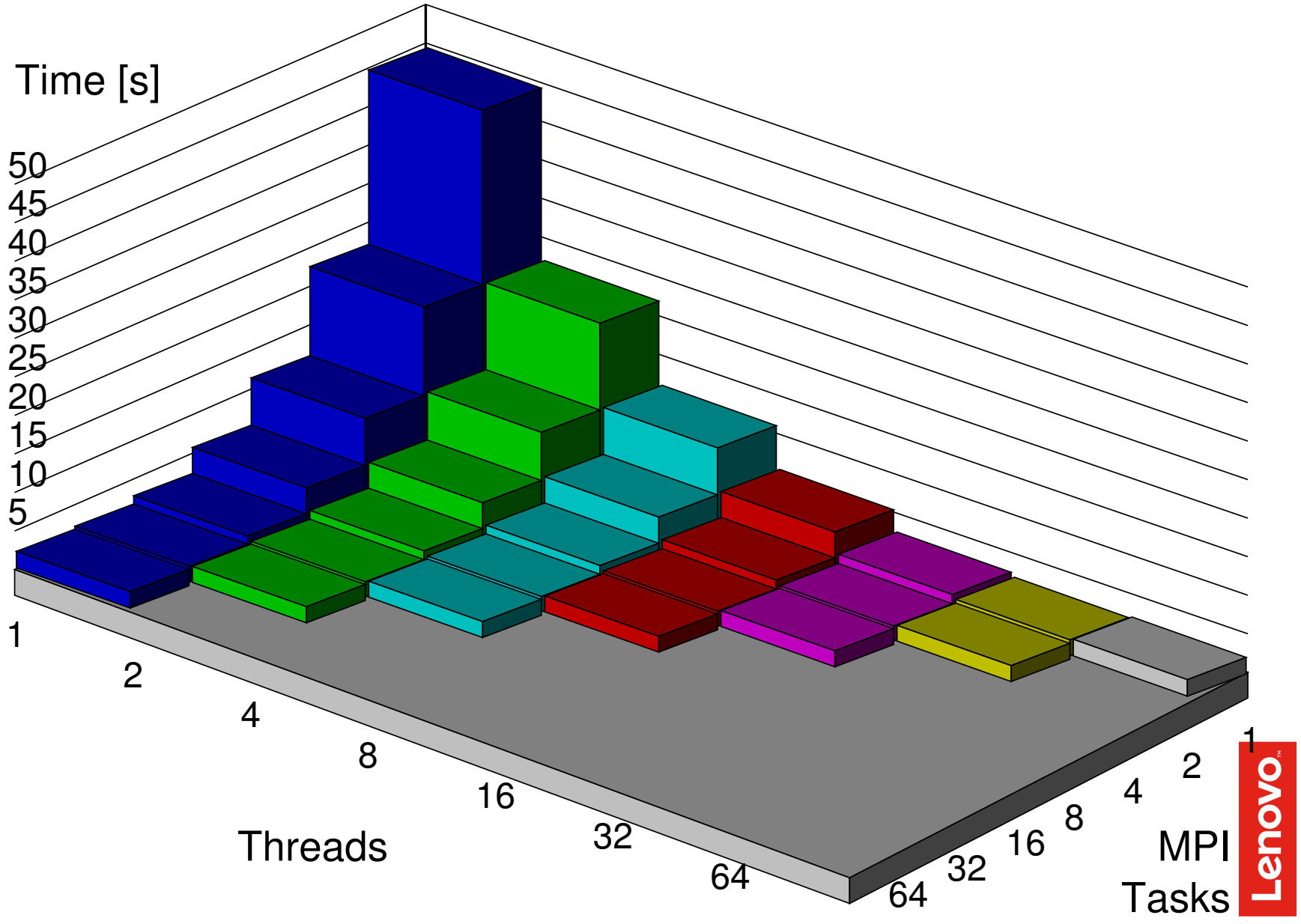
Redistribute OpenMP Work

```
$OMP do parallel
$OMP reduction(+:c)
 Do j = 1,n_loc
    Do i = 1,n
      c(i) = c(i) + a(i,j) * b(j)
    end Do
 end Do
$OMP end do parallel
 call mpi_reduce_scatter
```

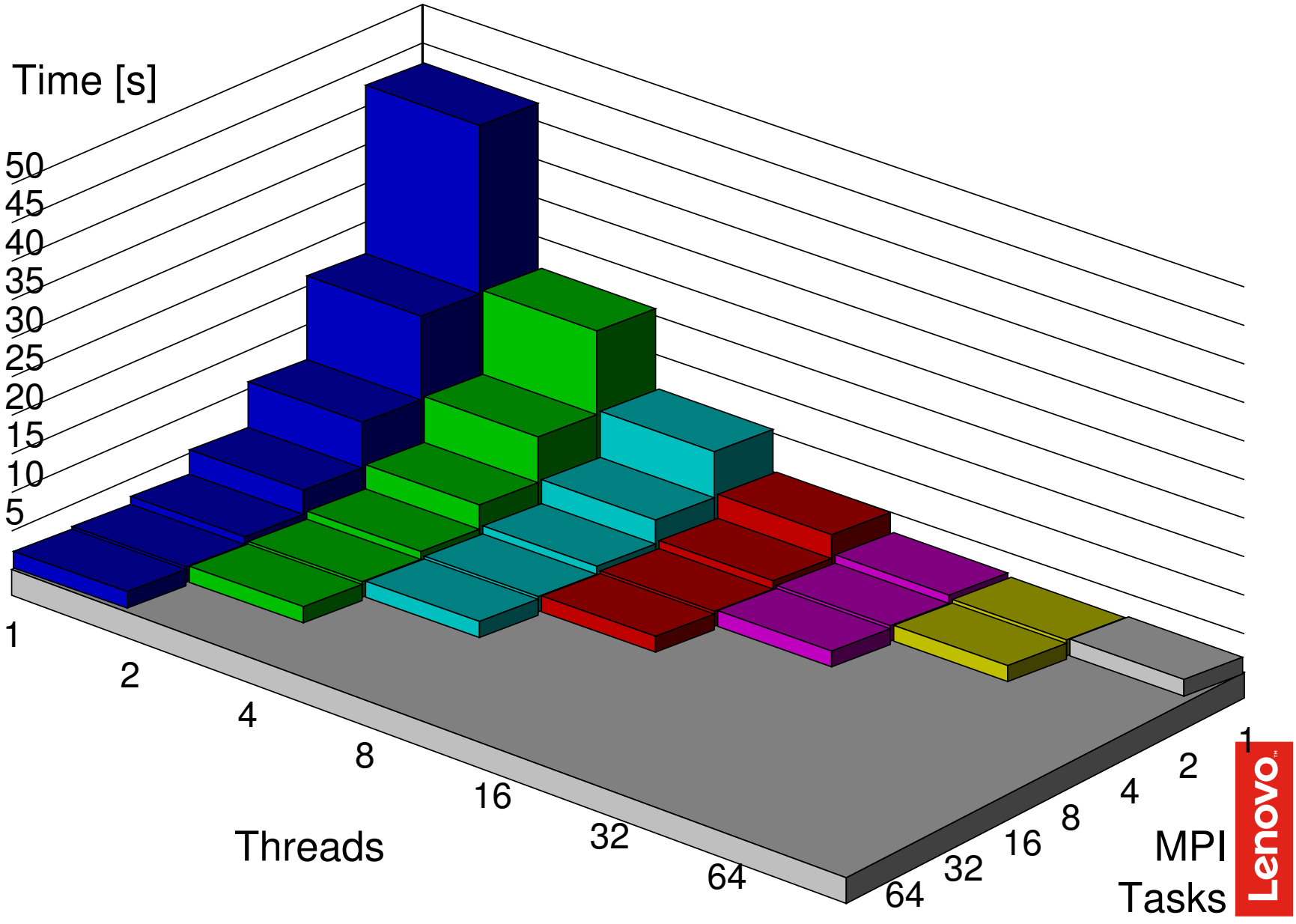


Choose the same loop for OpenMP and MPI

Skylake 8168 Timings for GNU Compiler



Skylake 8168 Timings for Intel Compiler



Conditions for Mixed Mode Programming

- Hybrid mode includes an MPI program
- SMP on each node has to pay off
  - Easy and effective SMP parallelization
  - MPI communication overhead explodes
  - Escape from Adapter bottle necks
  - Local dynamical load balancing

Hybrid mode does not invalidate or escape from Amdahls Law !