Parallelization of GISS ModelE
MPI etc.

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Developers

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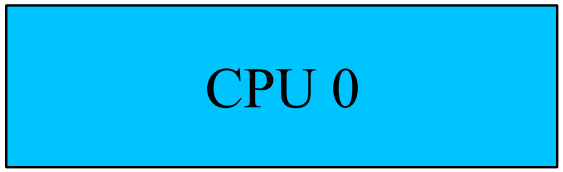
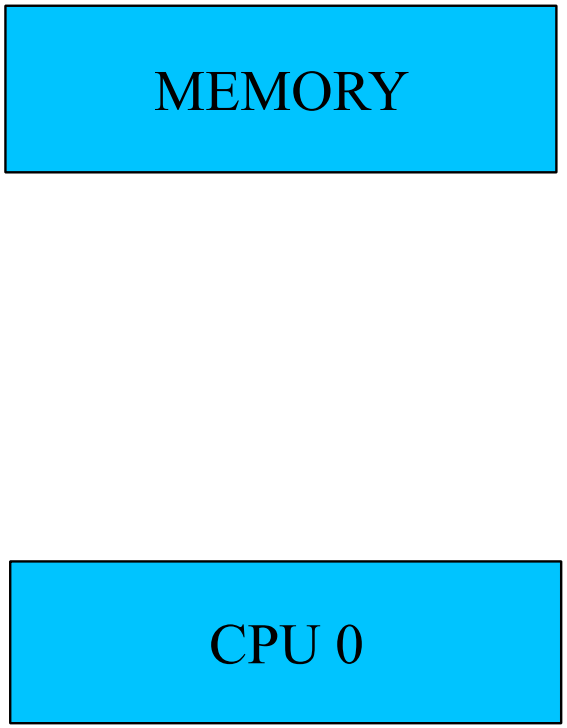
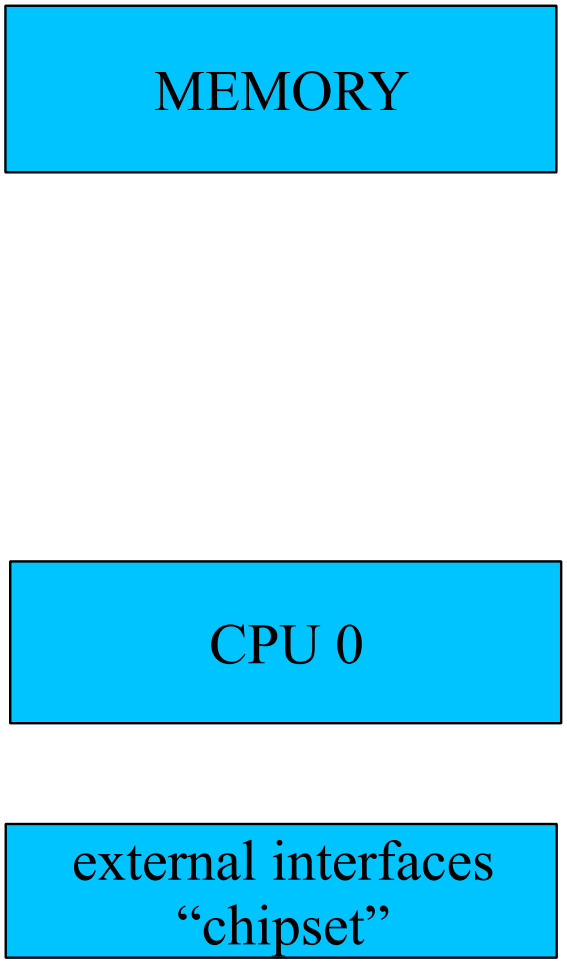
Hardware

Computer

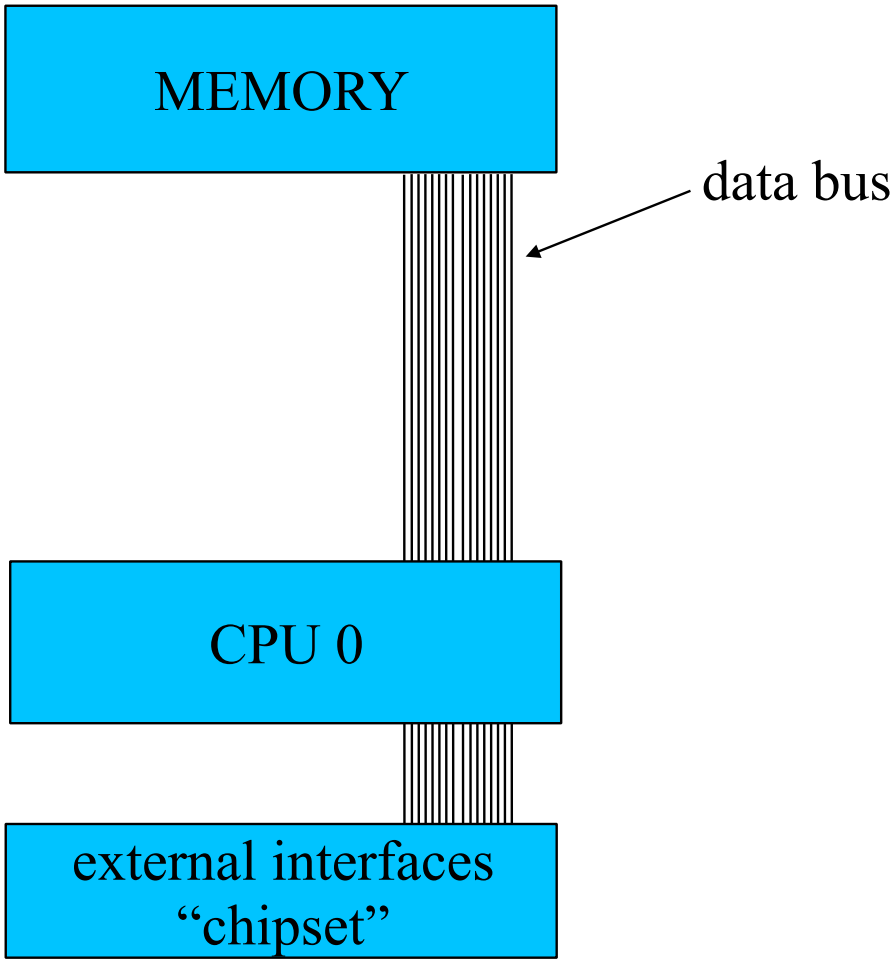



Computer
MEMORY
CPU 0

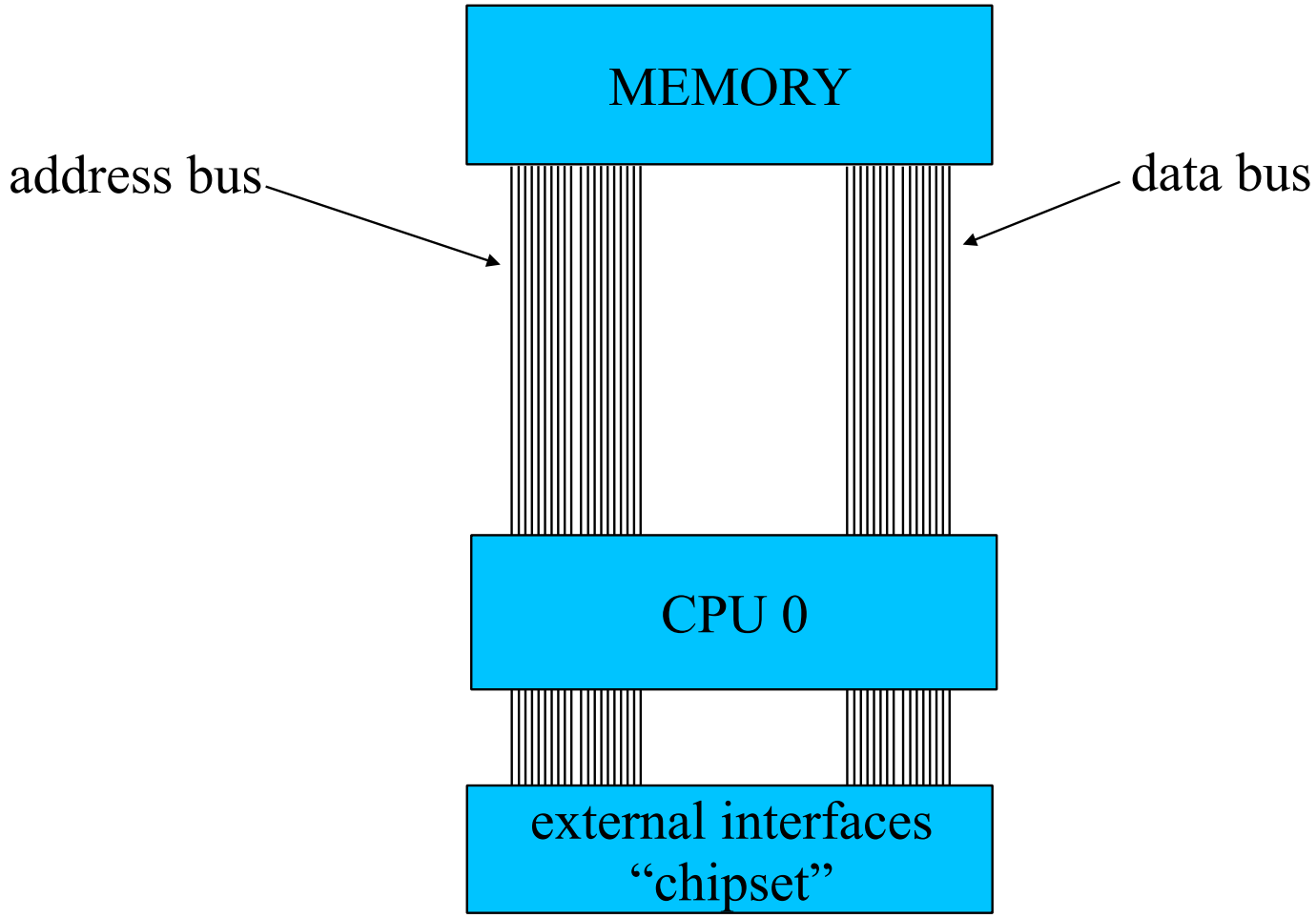
Computer



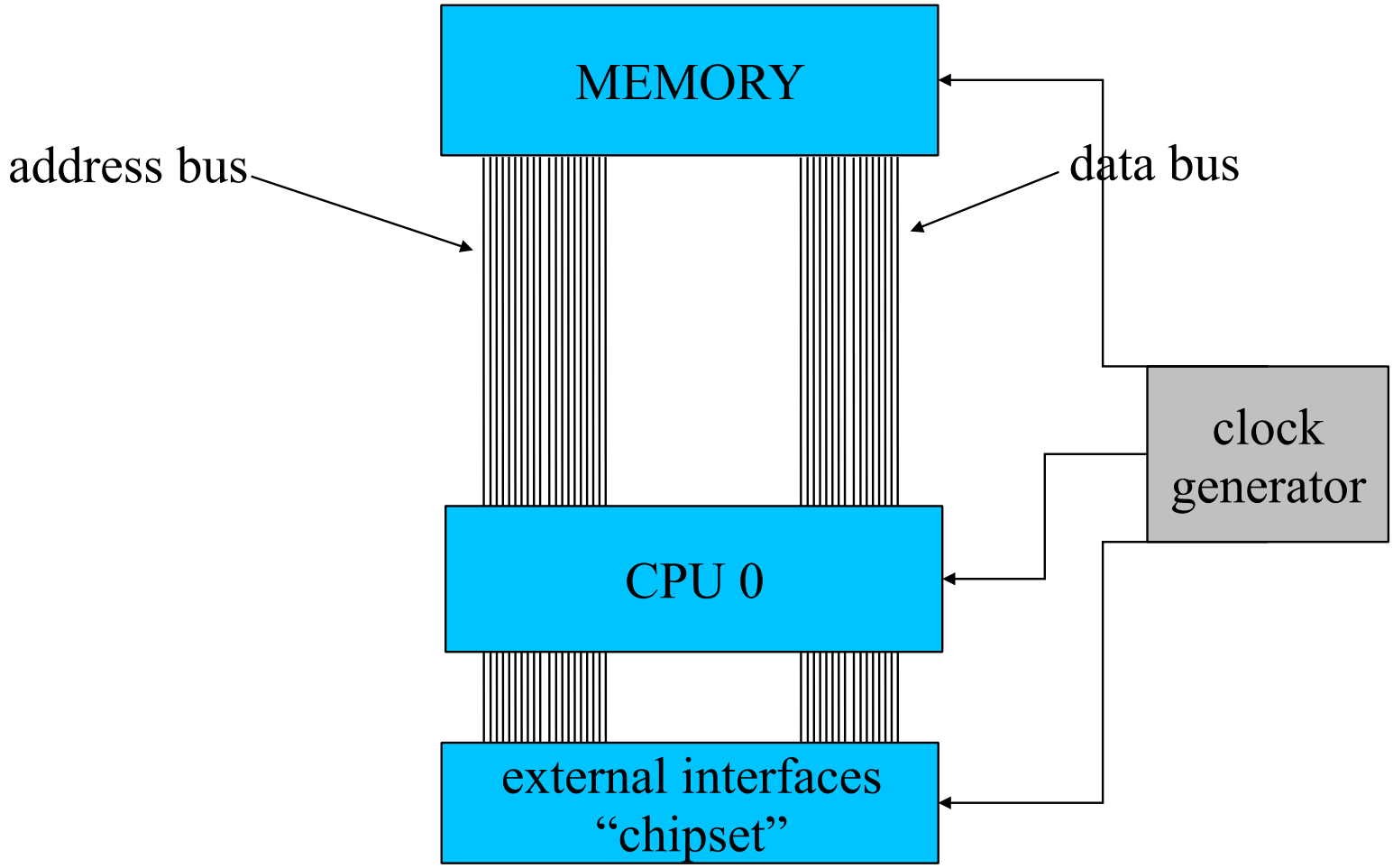
Computer



Computer


MEMORY
address bus
data bus
CPU 0
external interfaces
“chipset”

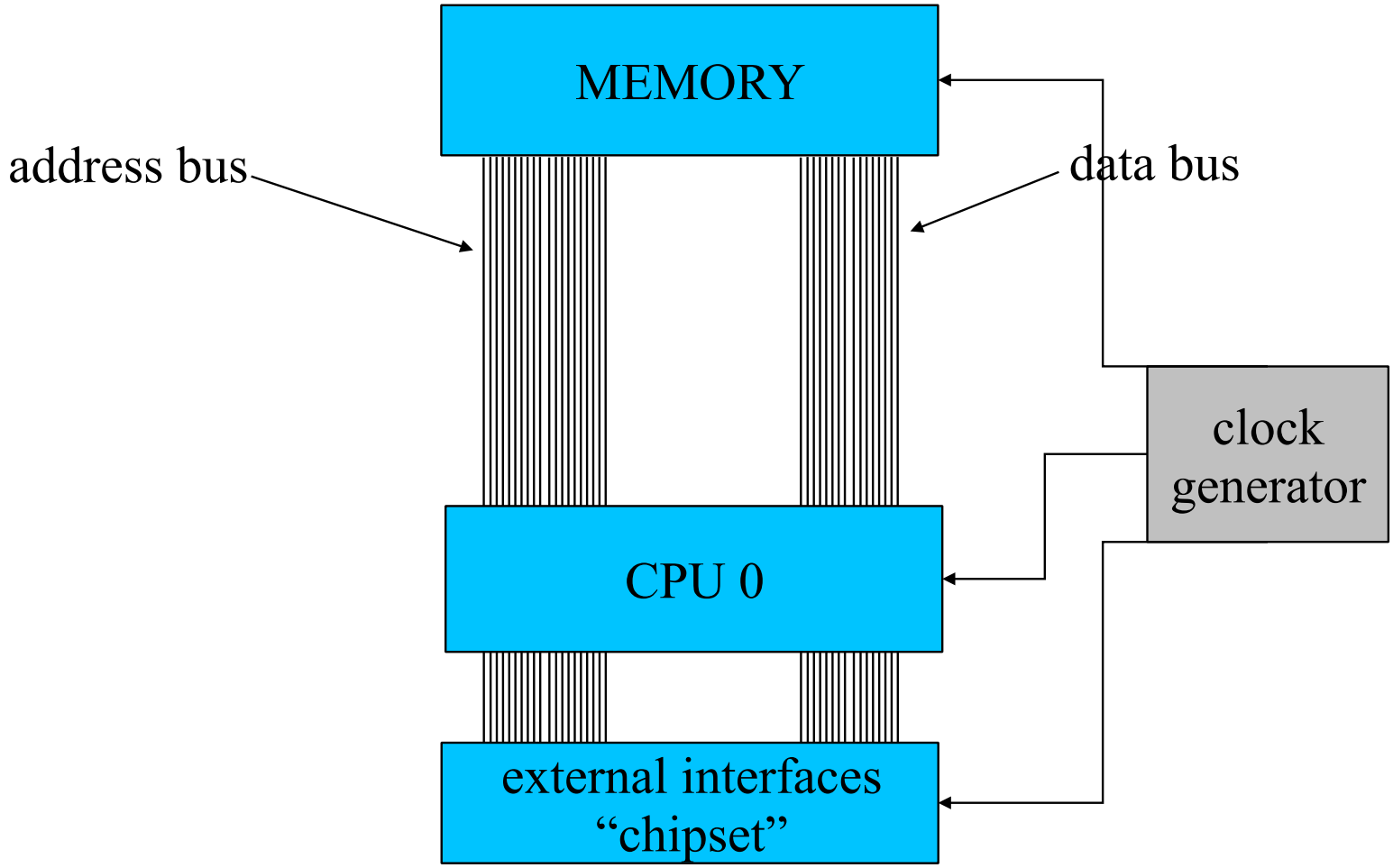
Computer


MEMORY
address bus
data bus
clock generator
CPU 0
external interfaces "chipset"

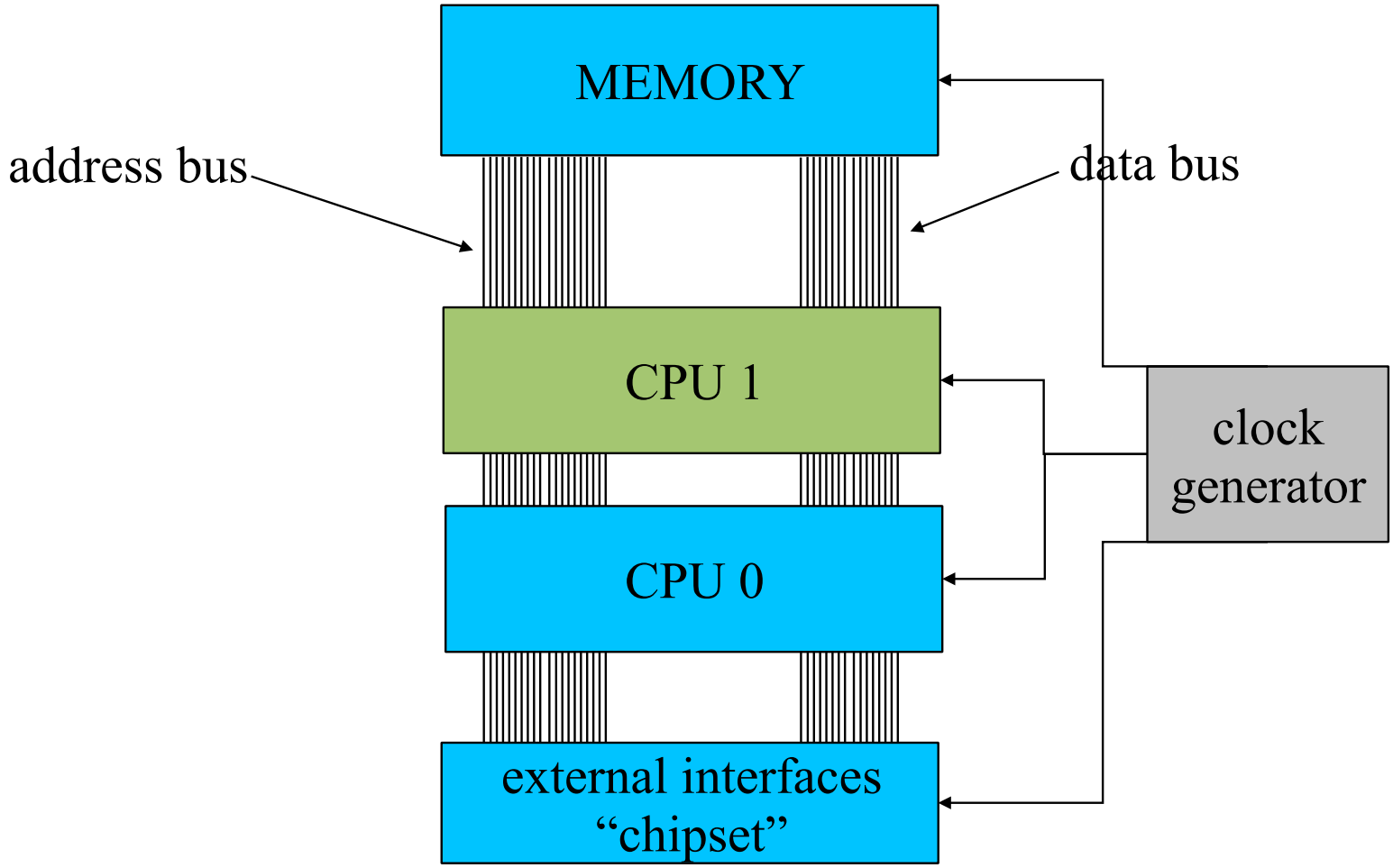
Computer

MEMORY
address bus
data bus
clock generator
CPU 0
external interfaces
“chipset”

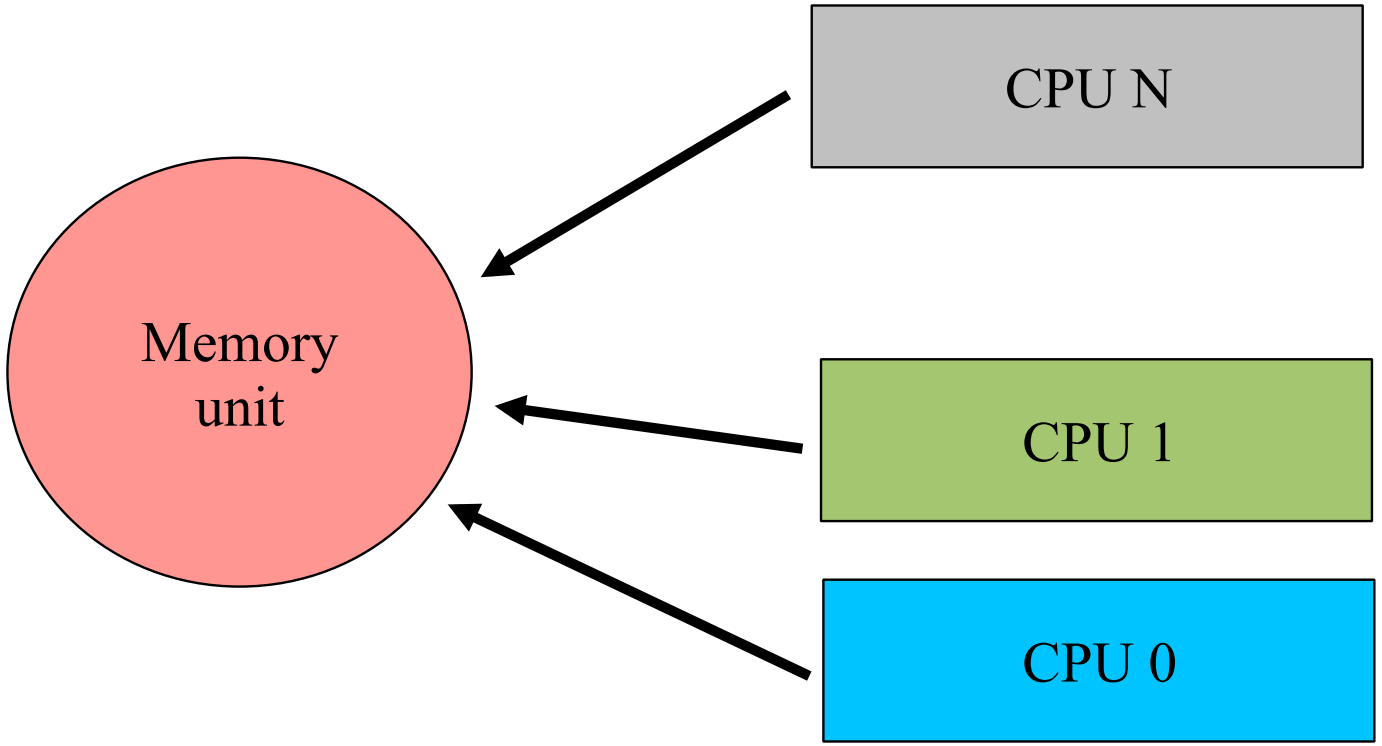
Computer


MEMORY
address bus
data bus
clock generator
CPU 0
external interfaces "chipset"

Computer


MEMORY
address bus
data bus
CPU 1
clock
generator
CPU 0
external interfaces
“chipset”

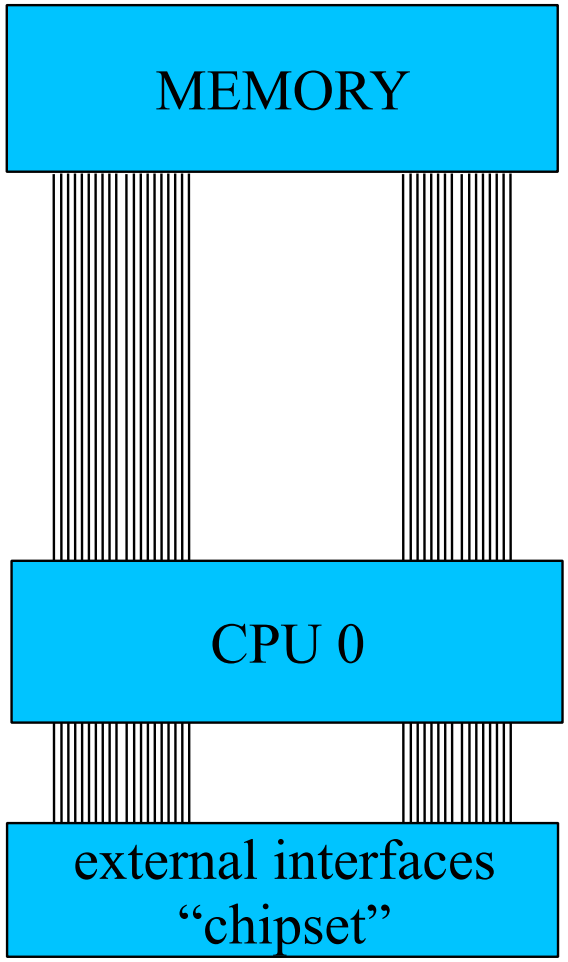
Shared memory architecture



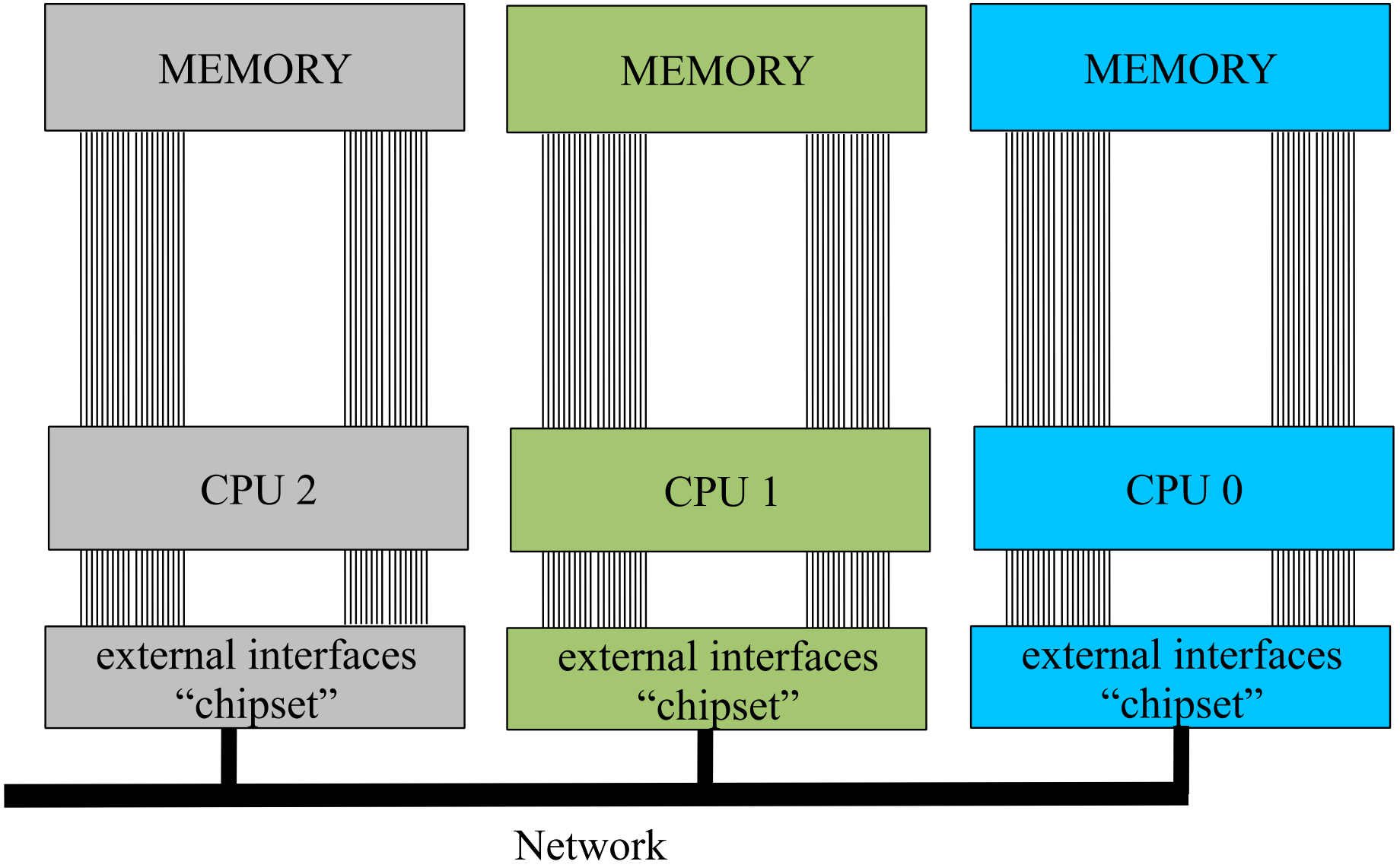
bus frequency = 800 MHz

distance = 300E6 / 800E6 = 0.37 m

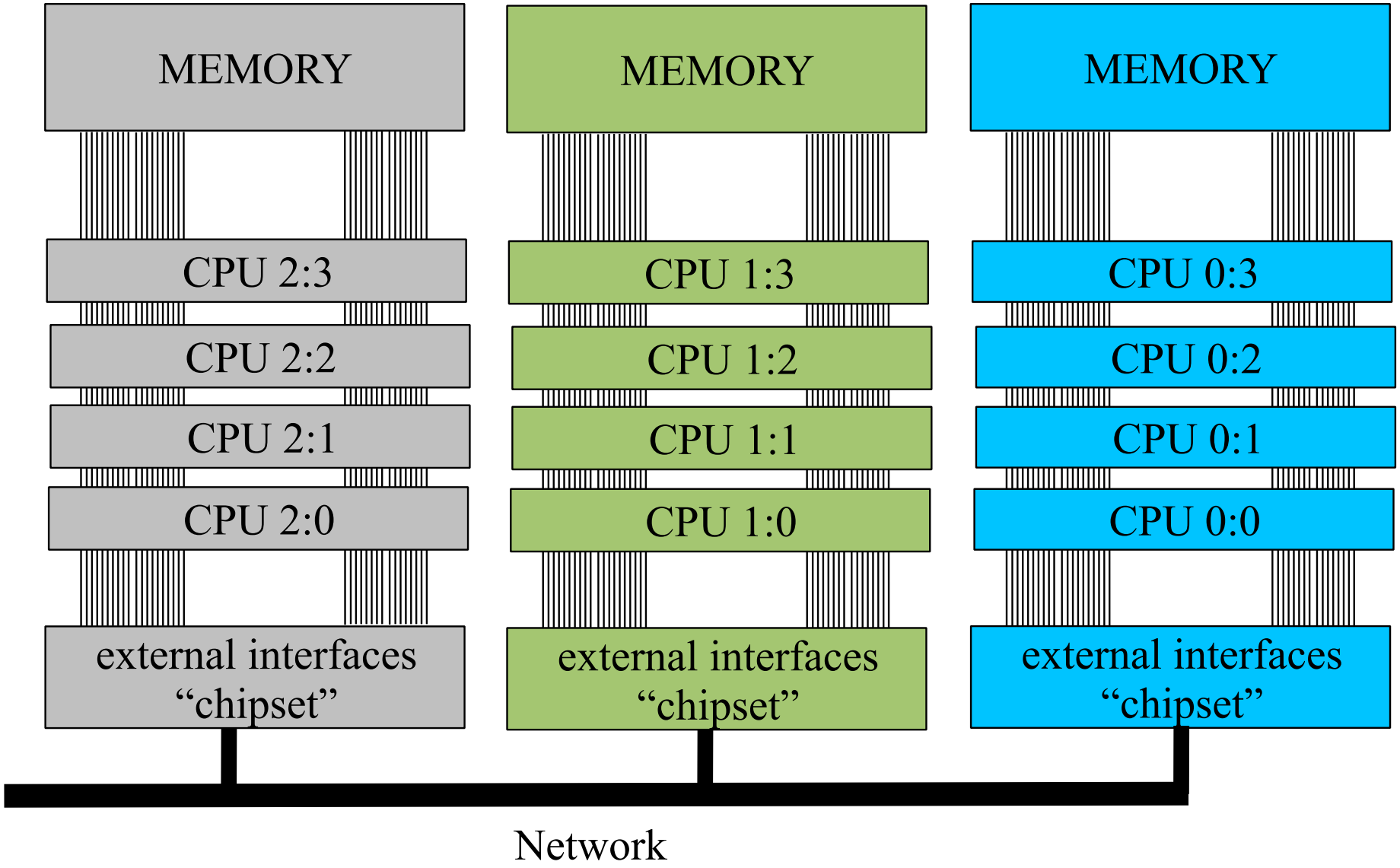
Distributed memory architecture



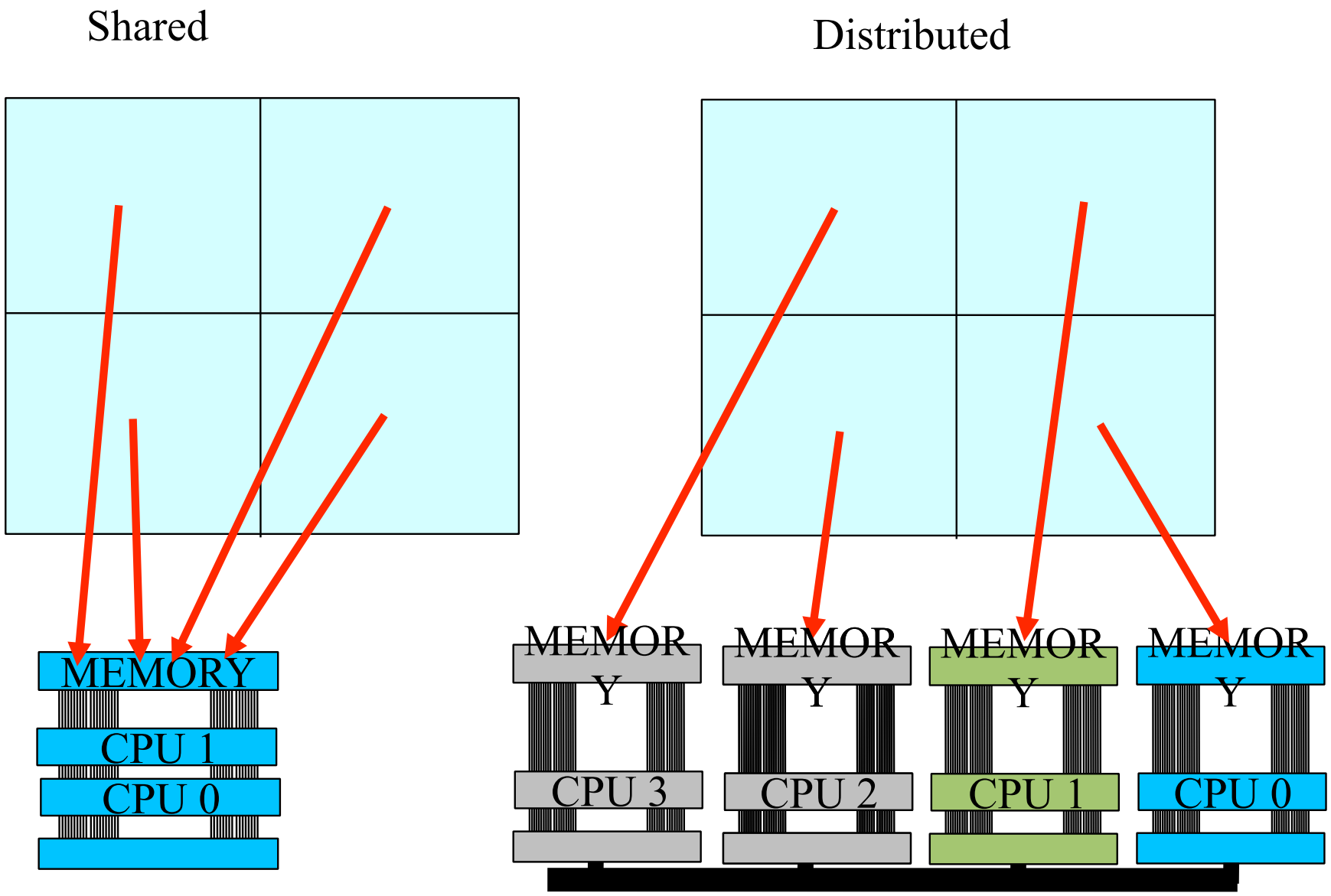
Distributed memory architecture

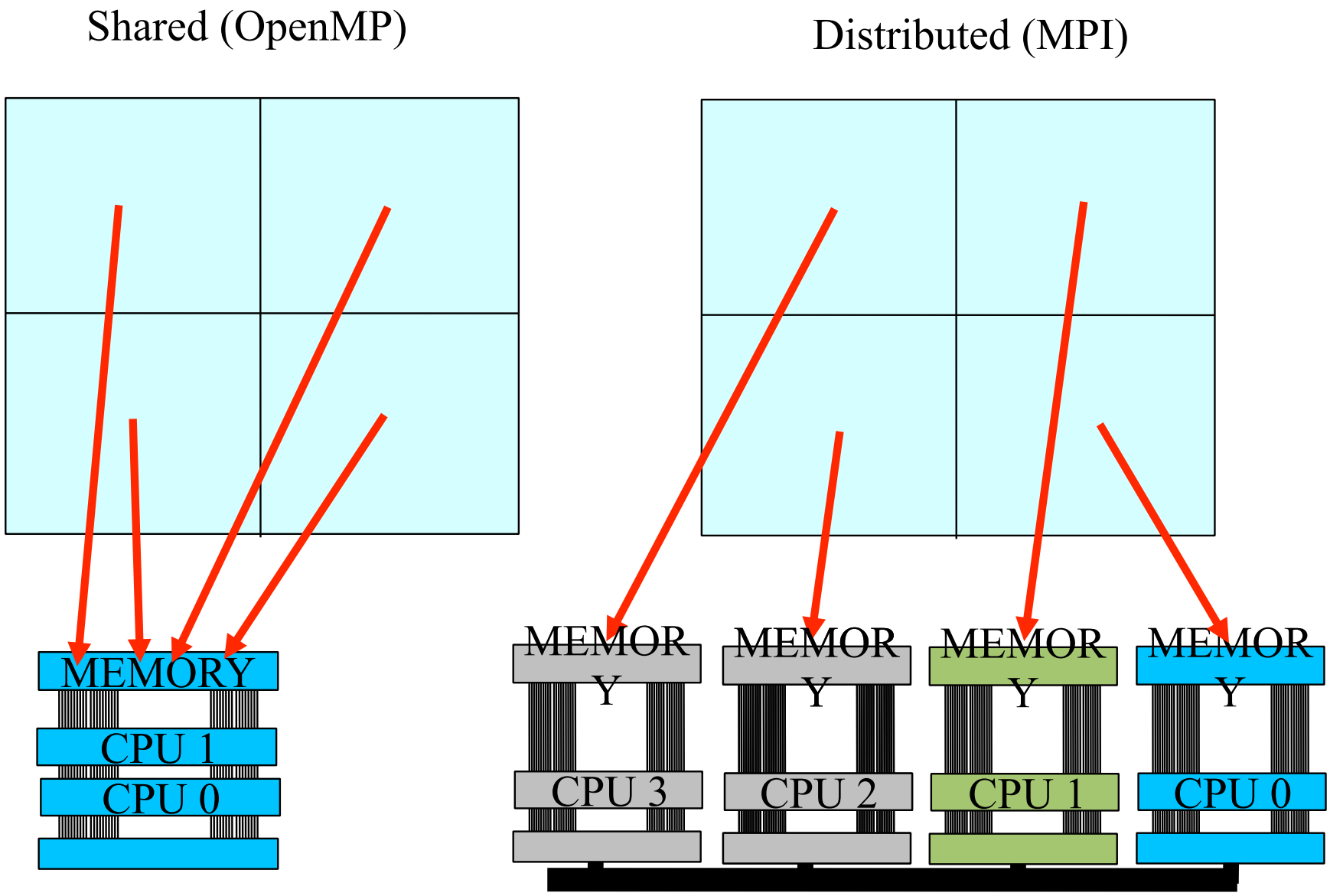


“Discover”

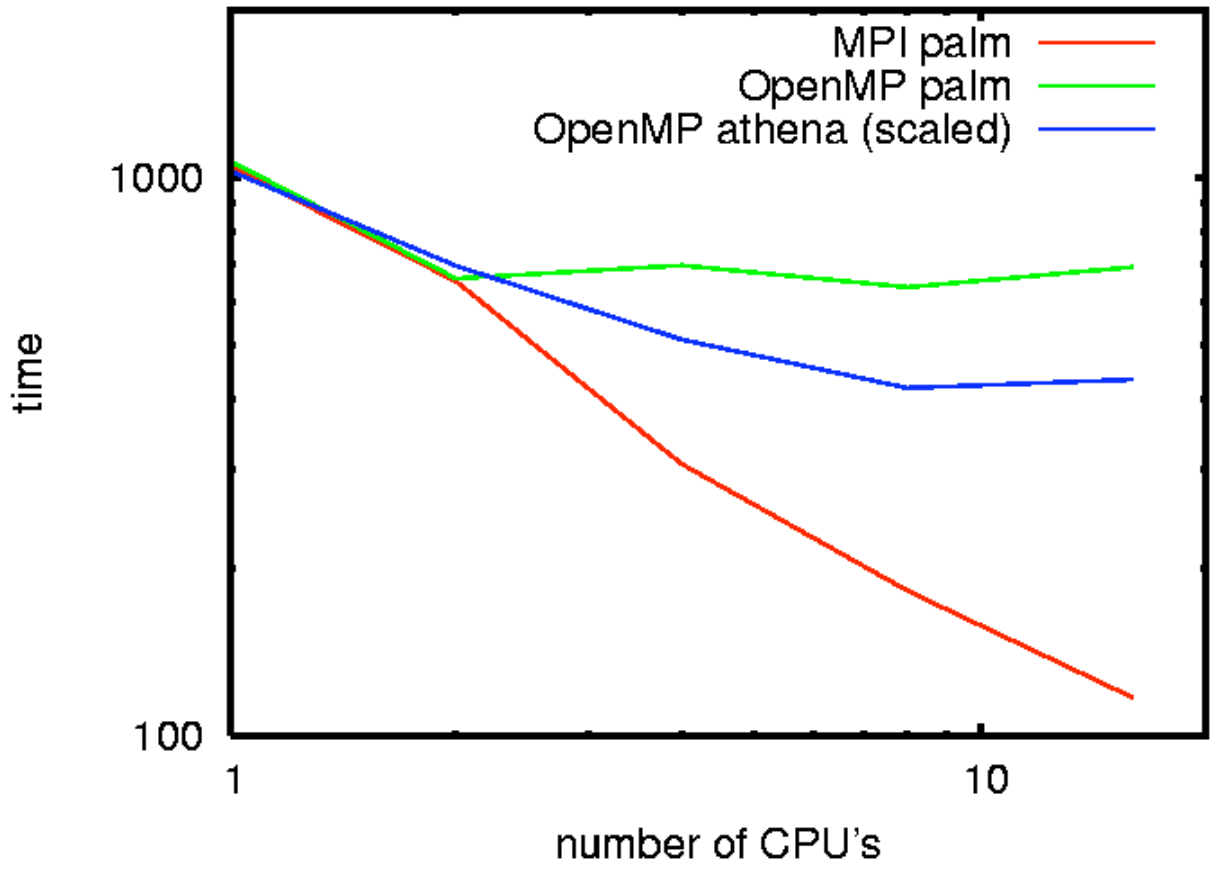

MEMORY
MEMORY
MEMORY
CPU 2:3
CPU 2:2
CPU 2:1
CPU 2:0
CPU 1:3
CPU 1:2
CPU 1:1
CPU 1:0
CPU 0:3
CPU 0:2
CPU 0:1
CPU 0:0
external interfaces “chipset”
external interfaces “chipset”
external interfaces “chipset”
Network

“Discover”

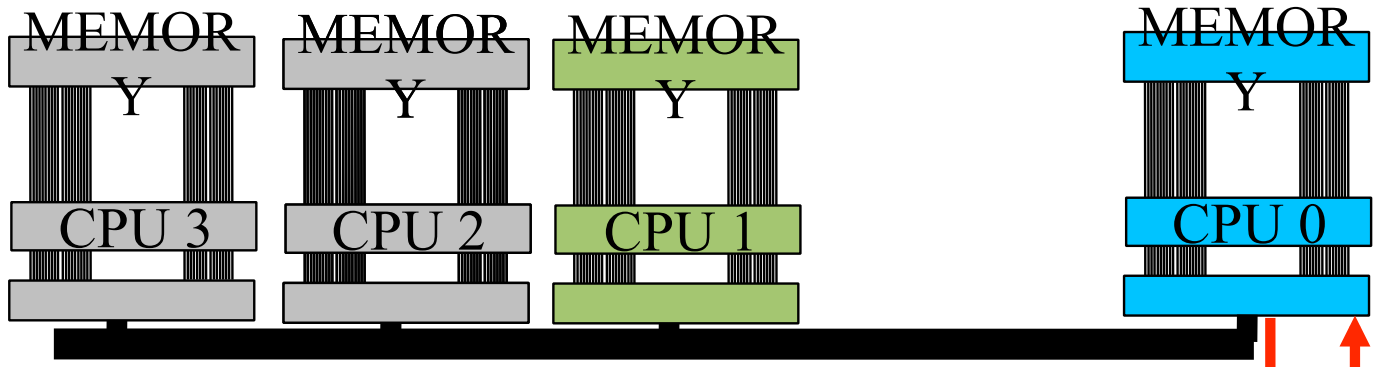

Shared
Distributed
MEMORY
CPU 1
CPU 0
MEMOR Y
MEMOR Y
MEMOR Y
MEMOR Y
CPU 3
CPU 2
CPU 1
CPU 0


Shared (OpenMP)
Distributed (MPI)
MEMORY
CPU 1
CPU 0
MEMOR Y
MEMOR Y
MEMOR Y
MEMOR Y
CPU 3
CPU 2
CPU 1
CPU 0

MPI vs OpenMP (E1M20)



Message Passing Interface (MPI)

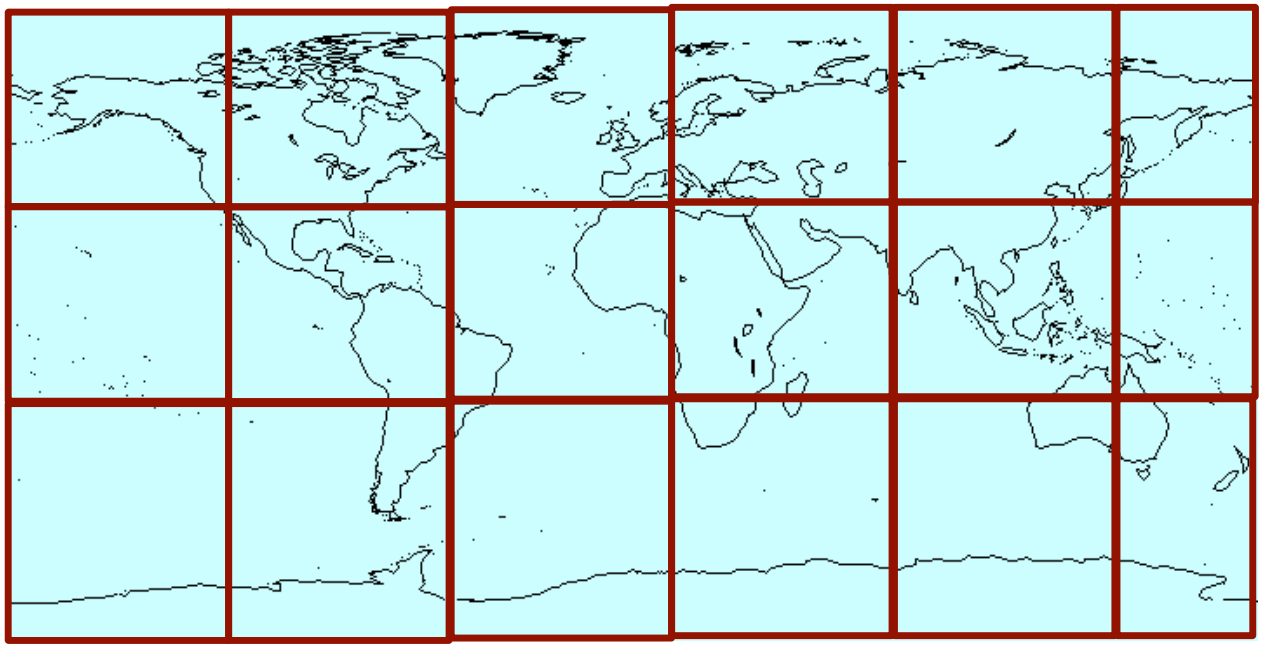


MPI_SEND(BUF, COUNT, DATATYPE, DEST,
TAG, COMM, IERR)

MPI_RECV(BUF, COUNT, DATATYPE, SOURCE,
TAG, COMM, STATUS, IERR)

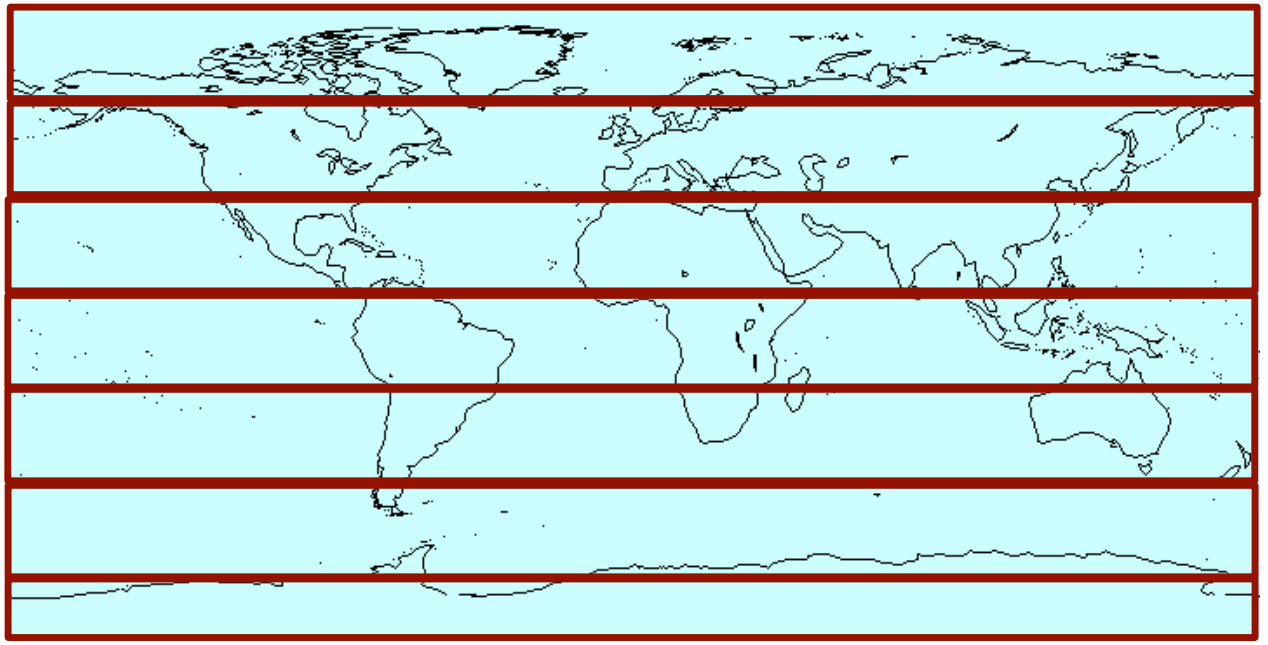
Domain Decomposition

2-Dimensional



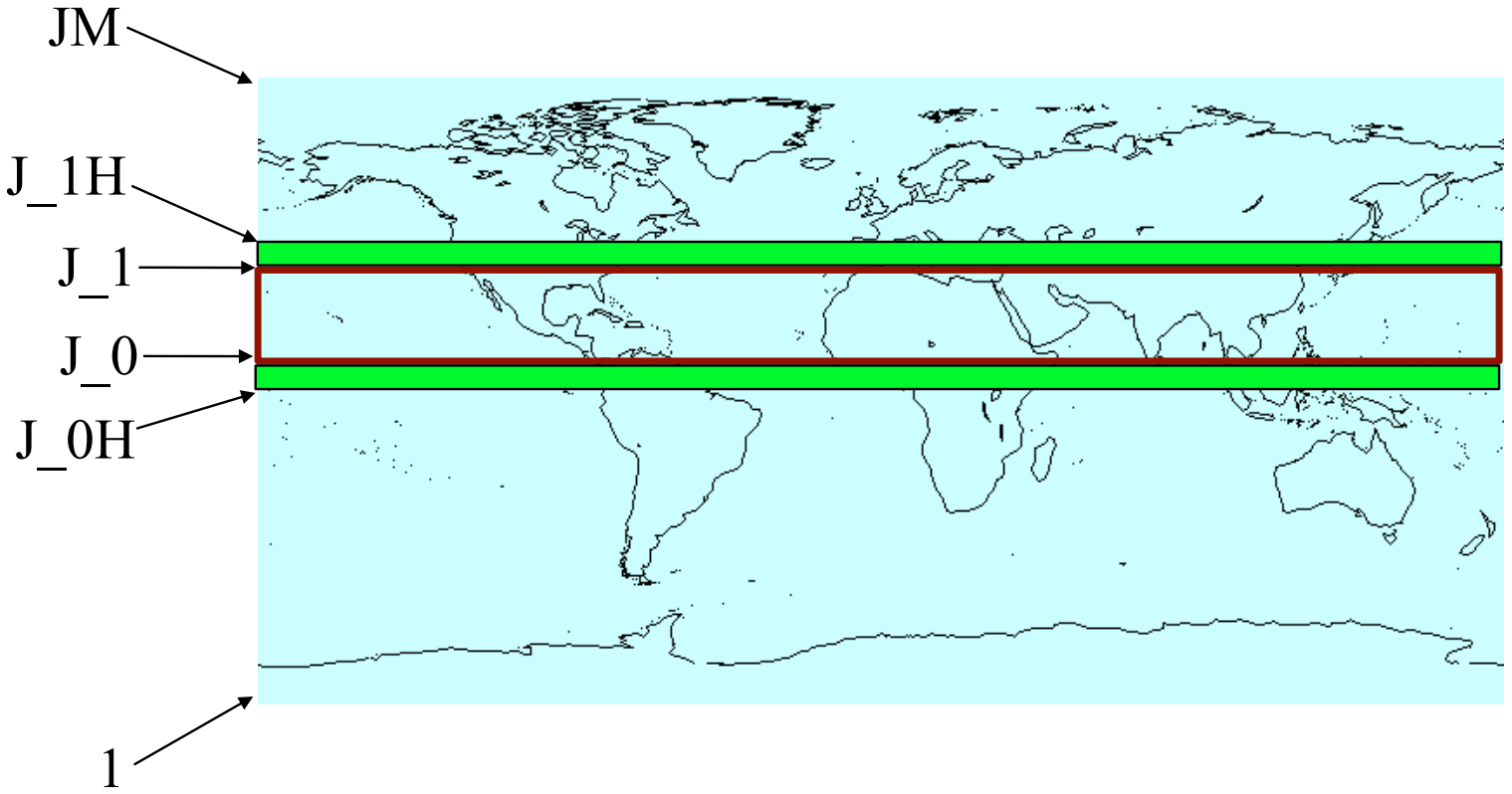
Domain Decomposition

1-Dimensional



Halos (Ghost Cells)

We use 1-cell halos : J_0H = J_0 – 1
J_1H = J_1 + 1

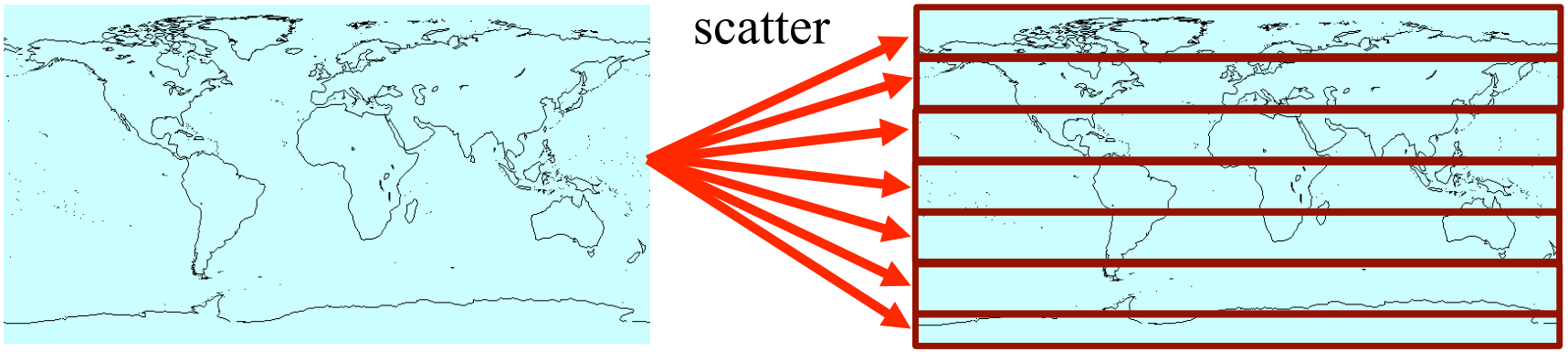


CALL HALO_UPDATE(grid, V, from=NORTH)

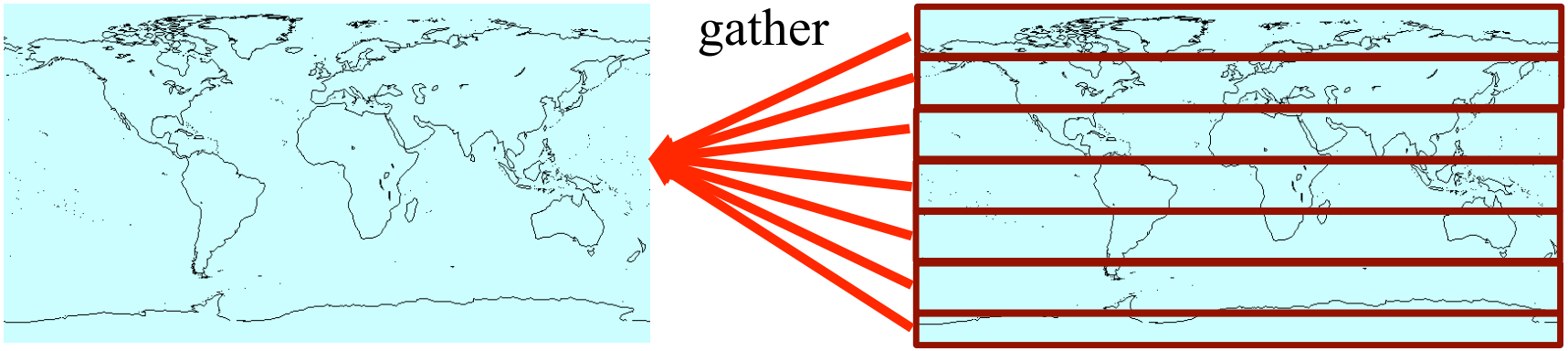
Gather/Scatter

I/O, diagnostics, coupling

computations



CALL UNPACK_DATA(grid, TEARTH_glob, TEARTH)



CALL PACK_DATA(grid, TEARTH, TEARTH_glob)

DOMAIN_DECOMP.f

```
TYPE DIST_GRID       ! - contains all info about domain decomposition
  TYPE (ESMF_Grid) :: ESMF_GRID
  ! Parameters for Global domain
  INTEGER :: IM_WORLD       ! Number of Longitudes
  INTEGER :: JM_WORLD       ! Number of latitudes
  ! Parameters for local domain
  INTEGER :: I_STRT         ! Begin local domain longitude index
  INTEGER :: I_STOP         ! End   local domain longitude index
  INTEGER :: J_STRT         ! Begin local domain latitude  index
  INTEGER :: J_STOP         ! End   local domain latitude  index
  INTEGER :: J_STRT_SKP     ! Begin local domain exclusive of S pole
  INTEGER :: J_STOP_SKP     ! End   local domain exclusive of N pole
  ! Parameters for halo of local domain
  INTEGER :: I_STRT_HALO    ! Begin halo longitude index
  INTEGER :: I_STOP_HALO    ! End   halo longitude index
  INTEGER :: J_STRT_HALO    ! Begin halo latitude  index
  INTEGER :: J_STOP_HALO    ! End   halo latitude  index
  ..........................................................................
END TYPE DIST_GRID
```

DOMAIN_DECOMP.f

Initialization routines:
INIT_APP, INIT_GRID, FINISH_APP, DESTROY_GRID

Scatter routines:
ESMF_BCAST, UNPACK_DATA, UNPACK_DATAj,
UNPACK_COLUMN, UNPACK_BLOCK, UNPACK_J

Gather routines:
PACK_DATA, PACK_DATAj, PACK_COLUMN, PACK_BLOCK,
PACK_J, GLOBALSUM, GLOBALMIN, GLOBALMAX

Halo routines:
HALO_UPDATE, HALO_UPDATE_COLUMN

I/O routines:
DREAD_PARALLEL, MREAD_PARALLEL, READT_PARALLEL,
READ_PARALLEL, WRITE_PARALLEL,WRITEI_PARALLEL

Polling routines:
GET, AM_I_ROOT

Main

```
PROGRAM GISS_MODELE
USE DOMAIN_DECOMP

CALL INIT_APP(GRID, IM, JM, LM)
CALL ALLOC_DRV(GRID)

CALL INIT_GRID(OGRID, IMO, JMO, LMO)
CALL ALLOC_OCEAN(OGRID)

! MAIN CODE
.....

CALL STOP_MODEL("OK", 13)

END
```

Memory Allocation

```
SUBROUTINE ALLOC_GHY_COM(GRID)
USE DOMAIN_DECOMP, ONLY : DIST_GRID, GET
IMPLICIT NONE
TYPE (DIST_GRID), INTENT(IN) :: GRID

INTEGER :: J_1H, J_0H
INTEGER :: IER

CALL GET(GRID, J_STRT_HALO=J_0H, J_STOP_HALO=J_1H)

ALLOCATE(      SNOWE(  IM,J_0H:J_1H),
*              TEARTH(    IM, J_0H:J_1H),
*              WEARTH(    IM, J_0H:J_1H),
*             AIEARTH(    IM, J_0H:J_1H),
*              SNOAGE(3, IM, J_0H:J_1H),
*         STAT=IER)
  .....................................
 END SUBROUTINE ALLOC_GHY_COM
```

“Single Column” code

```
SUBROUTINE A(GRID)
USE DOMAIN_DECOMP, ONLY : DIST_GRID, GET
IMPLICIT NONE
TYPE (DIST_GRID), INTENT(IN) :: GRID

INTEGER :: J_1, J_0

CALL GET(GRID, J_STRT=J_0, J_STOP=J_1)



DO J=J_0,J_1
  DO I=1,IM
    X(I,J) = Y(I,J) + Z(I,J)
   ENDDO
 ENDDO

 ..............................................
 END SUBROUTINE A
```

“Advection” code

```
SUBROUTINE B(GRID)
USE DOMAIN_DECOMP, ONLY : DIST_GRID, GET, NORTH
IMPLICIT NONE
TYPE (DIST_GRID), INTENT(IN) :: GRID

INTEGER :: J_1, J_0

CALL GET(GRID, J_STRT=J_0, J_STOP=J_1)
CALL HALO_UPDATE(GRID, Z, FROM=NORTH)

DO J=J_0,J_1
  DO I=1,IM
    X(I,J) = Y(I,J) + Z(I,J+1)
   ENDDO
 ENDDO

 .....
 END SUBROUTINE B
```

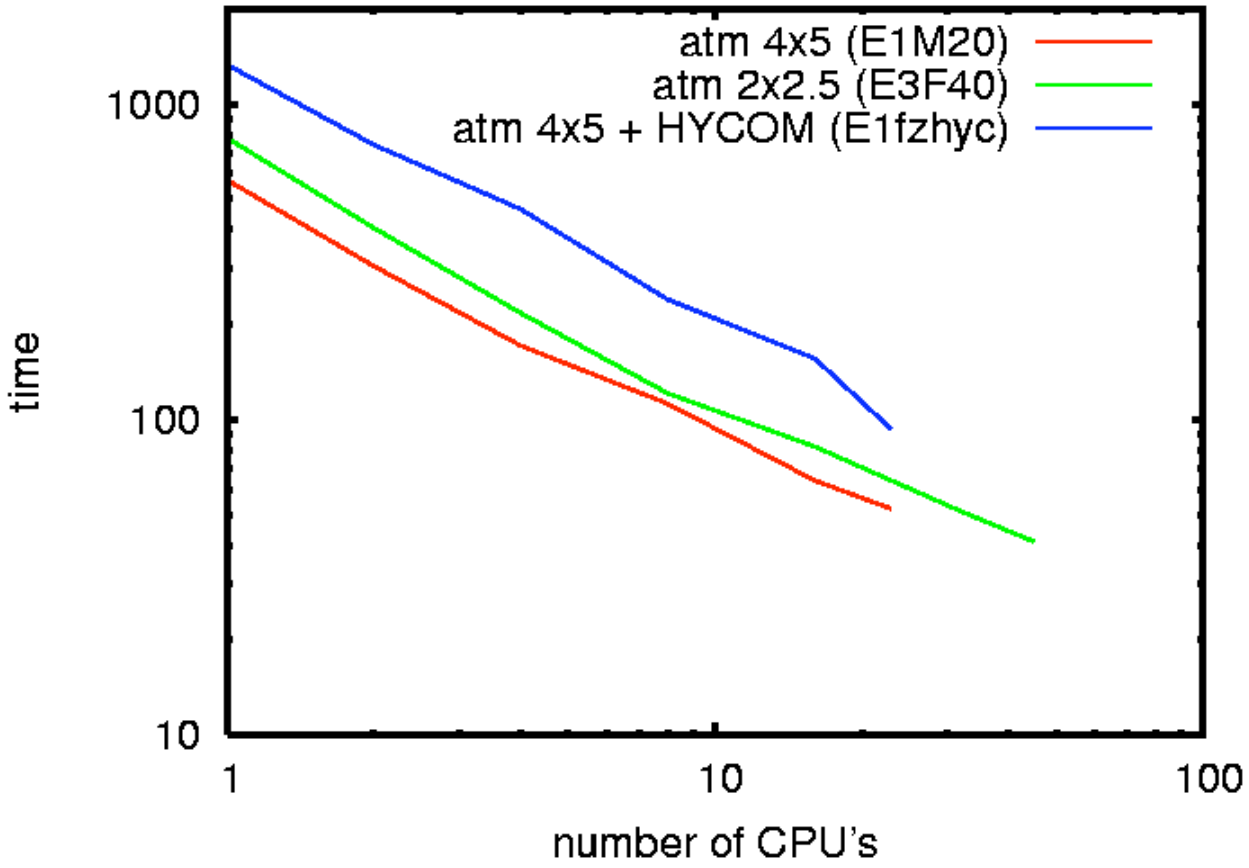
I/O

```
SUBROUTINE READ_SOMETHING(GRID)
USE SOME_MODULE, ONLY : TEARTH
USE DOMAIN_DECOMP, ONLY : DIST_GRID
IMPLICIT NONE
TYPE (DIST_GRID), INTENT(IN) :: GRID
REAL*8 TEARTH_glob(IM,JM)

 IF( AM_I_ROOT() ) THEN
  READ( KUNIT ) TEARTH_glob
 ENDIF

 CALL UNPACK_DATA( GRID, TEARTH_glob, TEARTH )
 ..........................................
 END SUBROUTINE READ_SOMETHING
```

Local arrays and arguments

```
SUBROUTINE C( GRID, X )
USE DOMAIN_DECOMP, ONLY : DIST_GRID, GET
IMPLICIT NONE
TYPE (DIST_GRID), INTENT(IN) :: GRID
REAL*8 X(:, GRID%J_STRT_HALO:)
REAL*8 Y(IM, GRID%J_STRT_HALO:GRID%J_STOP_HALO)

.....
END SUBROUTINE C
```

Current performance of the model



Some statistics (atmospheric part)

Times for a 10 day model run on 15 CPU's:

Global (excluding initialization):	97 s
MPI_SendRecv (i.e. halo updates):	12 s

The number of MPI_SendRecv called: ~23000/day

Conclusions

- OpenMP is ineffective on current architectures should be abandoned
- Current MPI implementation demonstrates decent scaling in all tests
- Though the model may profit from switching to 2D decomposition, there is no evidence that 1D decomposition is currently a bottleneck
- In any case, the model needs cleaner interfaces to domain decomposition library