NATURAL ENVIRONMENT RESEARCH COUNCIL

EPSRC

Introduction to OpenMP

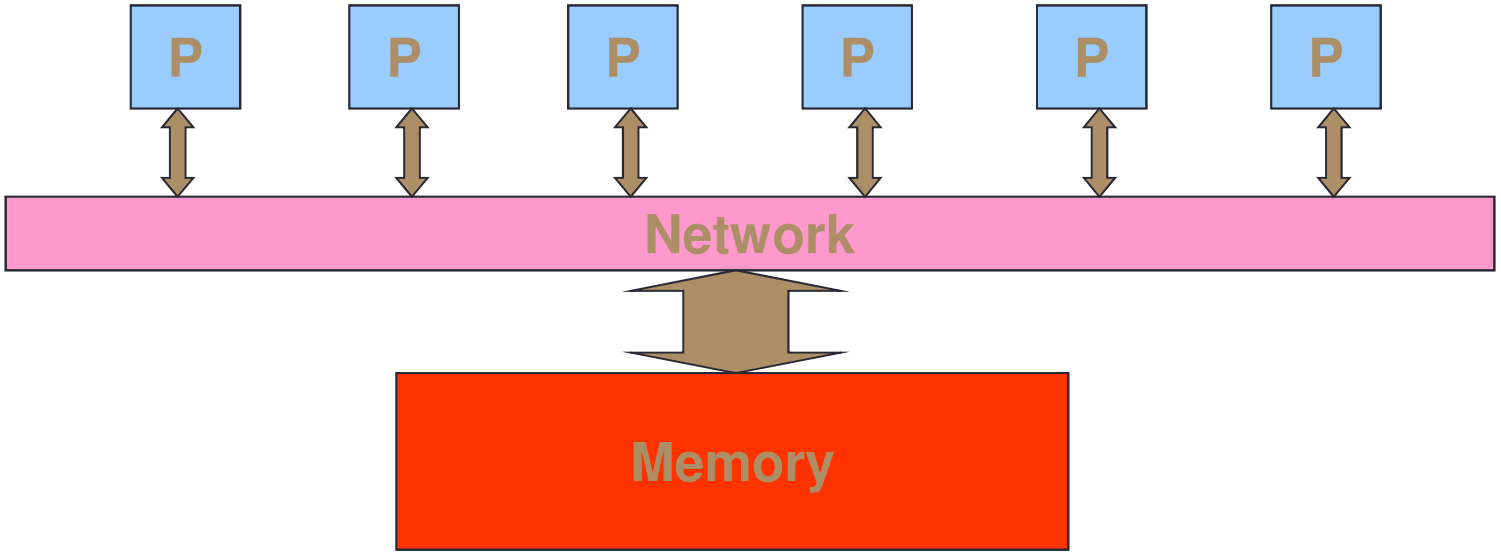
Lecture 12: Non-uniform memory access

epcc

Distributed shared memory

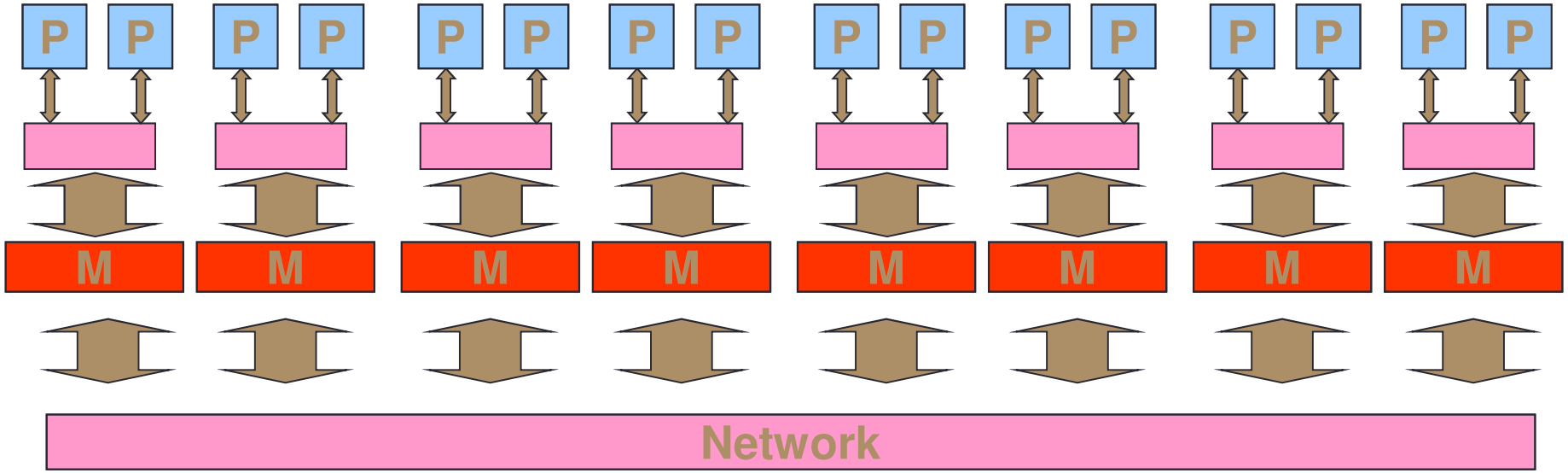
- Shared memory machines using buses and a single main memory do not scale to large numbers of processors
  - bus and memory become a bottleneck
- Distributed shared memory machines designed to:
  - scale to larger numbers of processors
  - retain a single address space
- Modest sized multi-socket systems connected with HyperTransport or QPI are, in fact, distributed shared memory
- Also true of recent multicore chips
  - multiple “dies” on a single chip (i.e. single socket)

True shared memory



Examples: Sun X4600, all multicore PCs, IBM p575, NEC SX8, Fujitsu PRIMEQUEST

Distributed shared memory



Directory based coherency

- For scalability, there is no bus, so snooping is not possible
- Instead use a directory structure
  - bit vector for every block
  - one bit per processor
  - stored in (distributed) memory
  - bit is set to 1 whenever the corresponding processor caches the block.
- Still some scalability issues:
  - directory takes up a lot of space for large machines
  - e.g. 128 byte cache block, 256 processors: directory is 20% of memory
  - some techniques to get round this

Implementation

- Node where memory (and directory entry) is located is called the home node.
- Basic principal is same as snoopy protocol
  - cache block has same 3 states (modified, shared, invalid)
  - directory entry has modifed, shared and uncached states.
- Cache misses go to the home node for data, and directory bits are set accordingly for read/write misses.
- Directory can:
  - invalidate a copy in a remote cache
  - fetch the data back from a remote cache
- Cache can write back to home node.

cc-NUMA

- We have described a distributed shared memory system where every memory address has a home node.
- This type of system is known a a cache-coherent non-uniform memory architecture (cc-NUMA).
- Main problem is that access to remote memories take longer than to local memory
  - difficult to determine which is the best node to allocate given page on
- OS is responsible for allocating pages
- Common policies are:
  - first touch: allocate on node which makes first access to the page
  - round robin: allocate cyclically

Migration and replication

- Possible for the OS to move pages between nodes as an application is running
- Pages can either be migrated or replicated.
- Migration involves the relocation of a page to a new home node.
- Replication involves the creation of a “shadow” of the page on another node.
  - read miss can go to the shadow page
- Cache coherency is still maintained by hardware on a cache block basis.