Parallel Computational Models

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6.173
Fall 2010
L02

Parallel Computational Models

Formally, a Computational Model is a Coherent collection of mechanisms for

- **communication**
- **synchronization**
- partitioning
- placement
- scheduling

Computational model defined at all levels of abstraction:

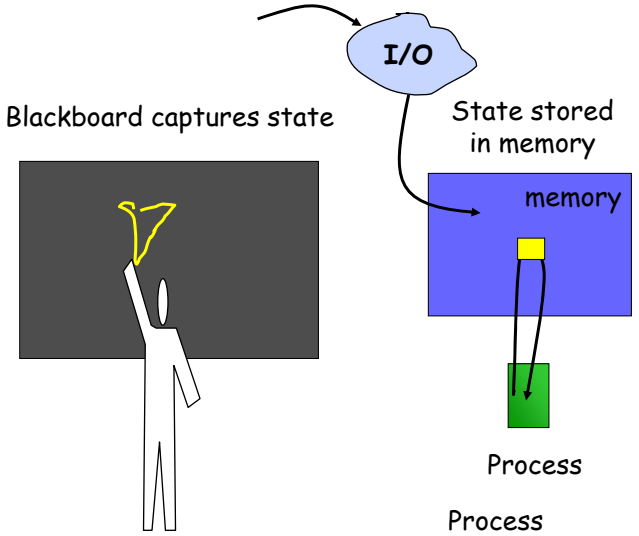
Machine hardware – e.g., a shared-memory machine

Language – e.g., a message passing language

Algorithm – e.g., a CREW (concurrent read, exclusive write) shared-memory algorithm

Let's review some examples to build intuition

For Reference: Sequential Programming Model



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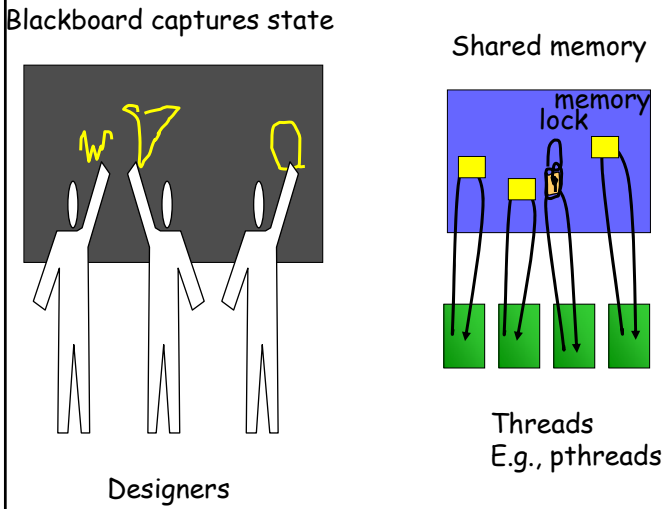
Shared Memory Parallel Programming Model



Communication: **via shared memory**
Synchronization: **shared memory locks**

Discuss:
What is it good for; not good for?
Shared memory programming models have many variants; we will revisit in a later lecture

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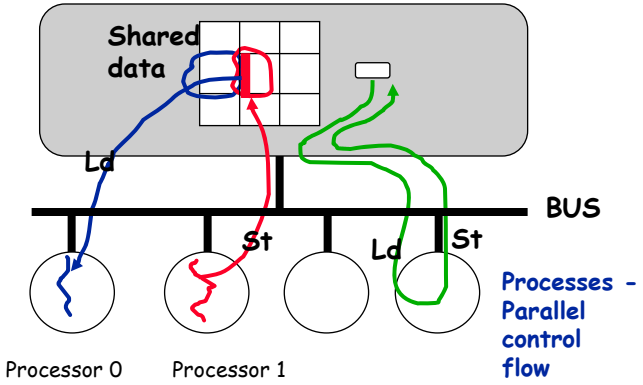
Shared Memory Machine Model

Uniform access shared memory (SRAM)



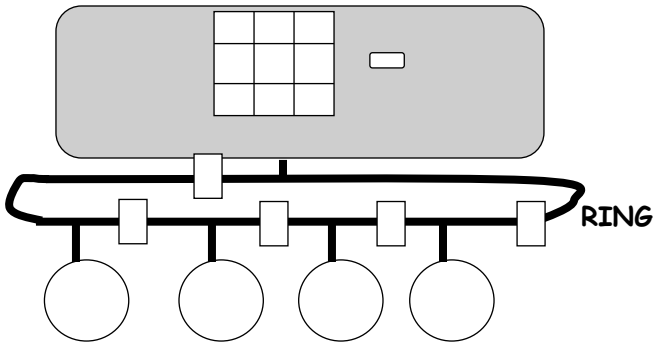
Communication: via shared memory
Synchronization: shared memory locks

Locks can be done by holding the bus and performing back to back load-store

(Historical: MIMD – Multiple instruction multiple data)

Shared Memory Machine Model

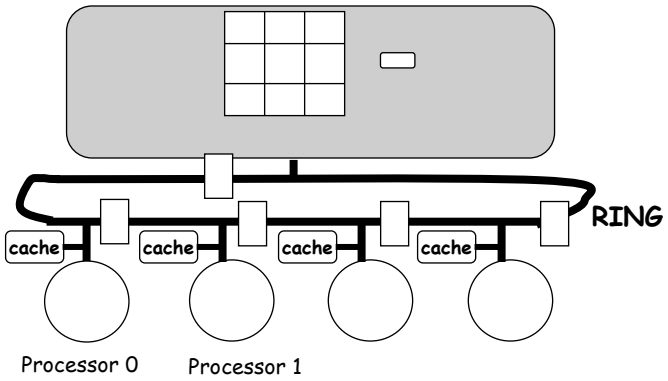
Non-uniform access shared memory (SRAM)



Can replace bus with a ring (Beehive), or mesh (Tile processor)

Beehive and Modern Manycores also have Per-Processor Caches

Non-uniform access shared memory (SRAM)

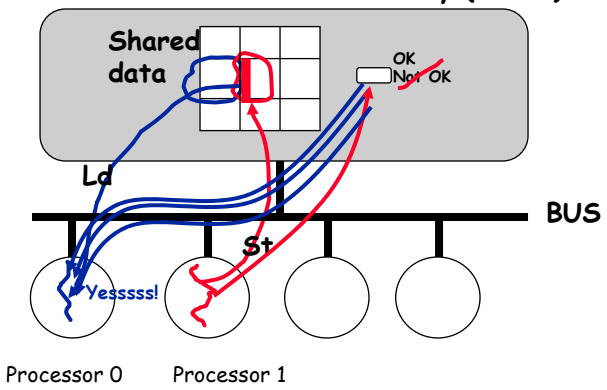


Caches introduces the cache coherence problem – we will study this in depth later in the course

Historical note: the cache coherence problem occupied computer architects for an entire decade in the 90's!

Need for Synchronization

Uniform access shared memory (SRAM)

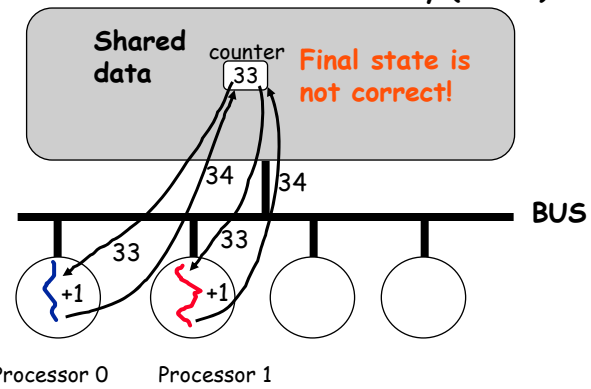


When should Processor 0 read the data being written by Processor 1?

Producer-Consumer synchronization

Need for Synchronization

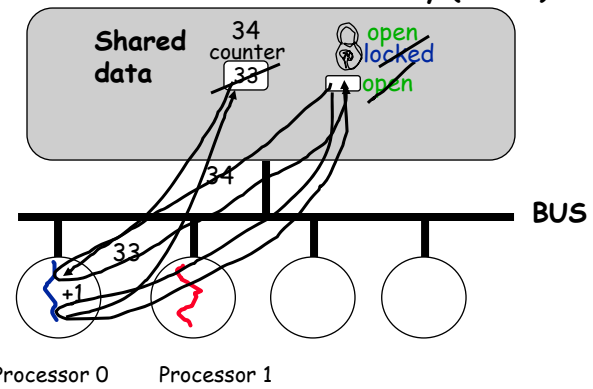
Uniform access shared memory (SRAM)



How to safely increment shared counter?

Need for Synchronization

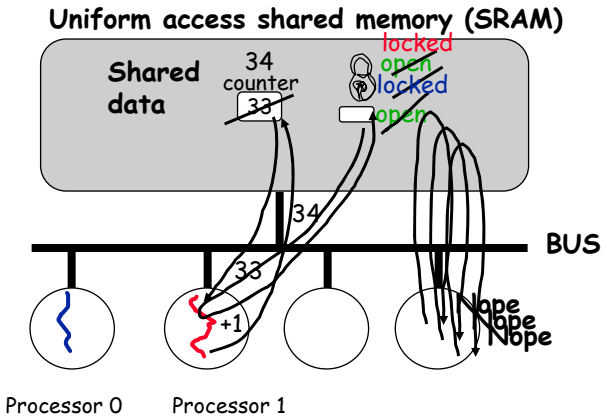
Uniform access shared memory (SRAM)



How to safely increment shared counter?

Mutual exclusion synchronization
(Atomic: if open, then lock, else retry)
Hold bus captive for read/write on lock

Need for Synchronization



How to safely increment shared counter?

Mutual exclusion synchronization
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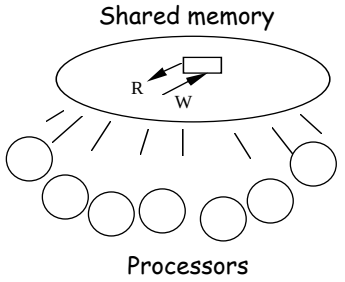
Shared Memory Algorithm Model

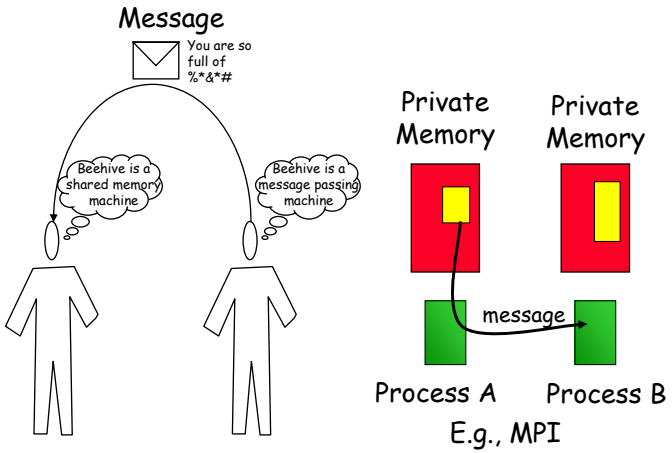
PRAM – Parallel Random Access Memory



Variants
Multiple simultaneous R,W -- CRCW PRAM
Exclusive writes only -- CREW PRAM
Exclusive R & W -- EREW PRAM
… may be realistic….. or not.

Summary: we just saw shared memory programming model, shared memory machine model, and shared memory algorithm model

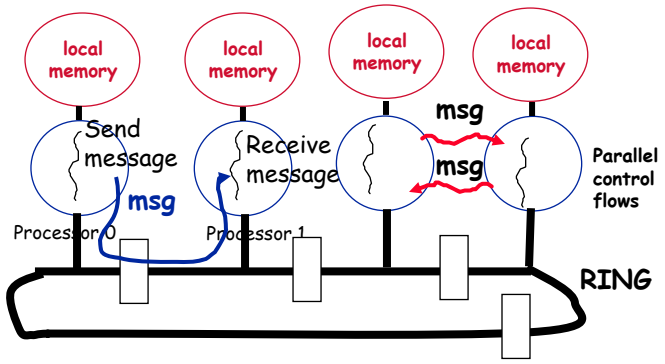
Message Passing Parallel Programming Model



Communication: via messages
Synchronization: via messages

Discuss:
What is it good for; not good for?
Inspired by object oriented programming model

Message Passing Parallel Machine Model



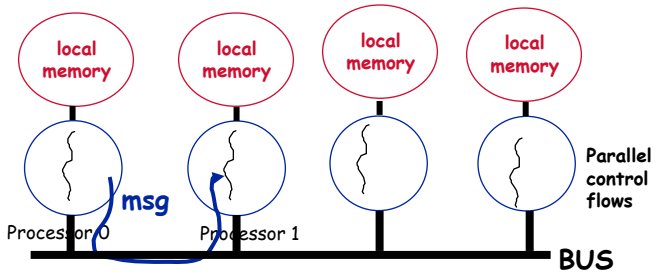
Communication
via messages.
Send/receive
msg are
new instructions

Synchronization
via messages

Message can achieve communication and synchronization in a single action

(Historical: MIMD – Multiple instruction multiple data)

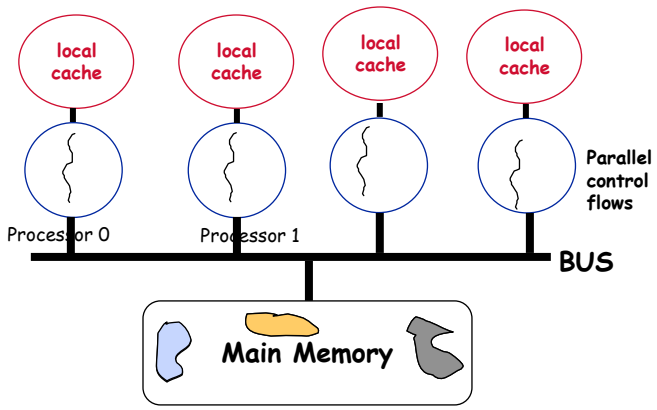
Message Passing Parallel Machine Model



Communication via messages

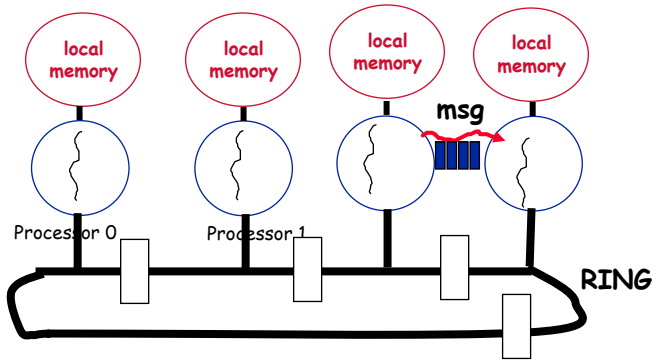
Can also use a bus or mesh (or other interconnect) for communication

Message Passing Parallel Machine Model



Can replace local memories with private caches (as in Beehive). Cache demand fetch data from main memory as needed. Since there is no shared data in the message passing model, there is no cache coherence problem.

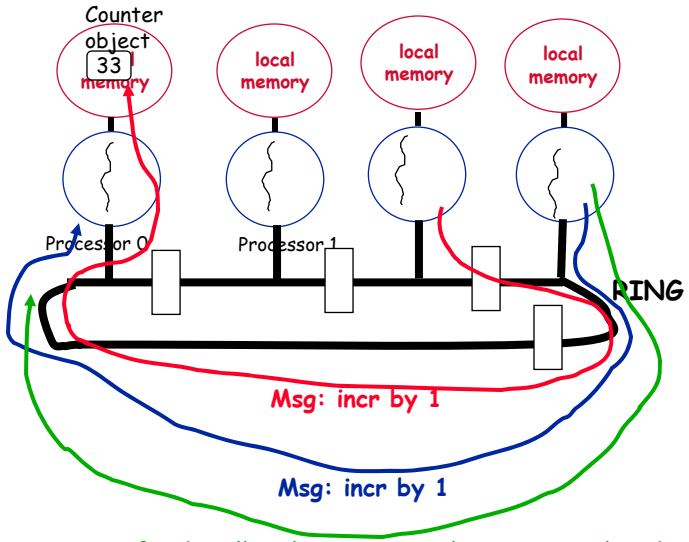
Producer Consumer Synchronization in Message Passing Model



Producer sends data when it is ready, so receiver can assume received data in message is good

Message can achieve communication and synchronization in a single action

Mutual Exclusion Synchronization in Message Passing Model



Msg: if *val* smaller than *count*, replace *count* with *val*

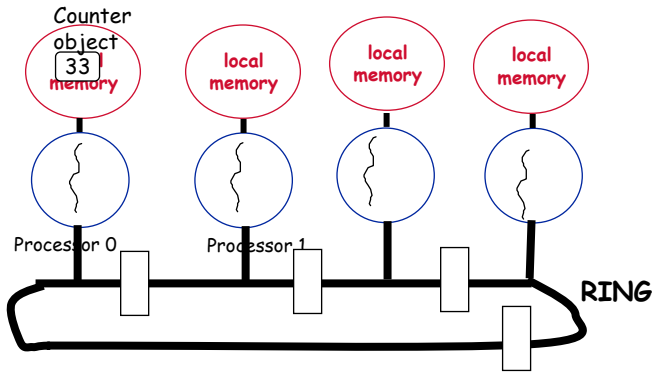
Processor 0 is in charge of counter object.
If you want to increment counter, send message to processor 0

Processor 0 serializes multiple requests.

Message can also contain a piece of code (or a pointer to code) that Processor 0 should run (variously called active message, future)

Message Passing Model

To Share or Not to Share



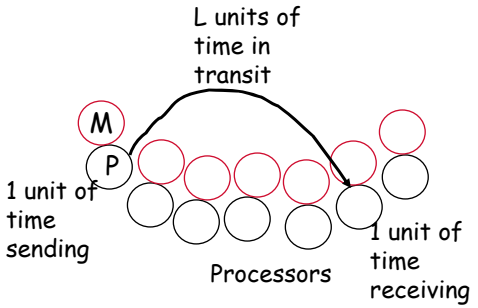
No sharing of data (almost).
Discuss: One thing is still shared, what is it? So, how do you share/bootstrap?

Message passing models often share immutable initial state, read-only data, etc.
This immutable shared data is often copied into all local memories at initialization

Message Passing Algorithm Model

Postal model for message passing

[SPAA 1992]



Summary: we just saw shared memory programming model, shared memory machine model, and shared memory algorithm model

Many More Computational Models Exist

Streaming model

Dataflow model

Data parallel model

Hybrid models

Invent a new one and get a phd…

Details in 6.846