Treadmarks: Distributed Shared Memory on Standard Workstations and Operating Systems

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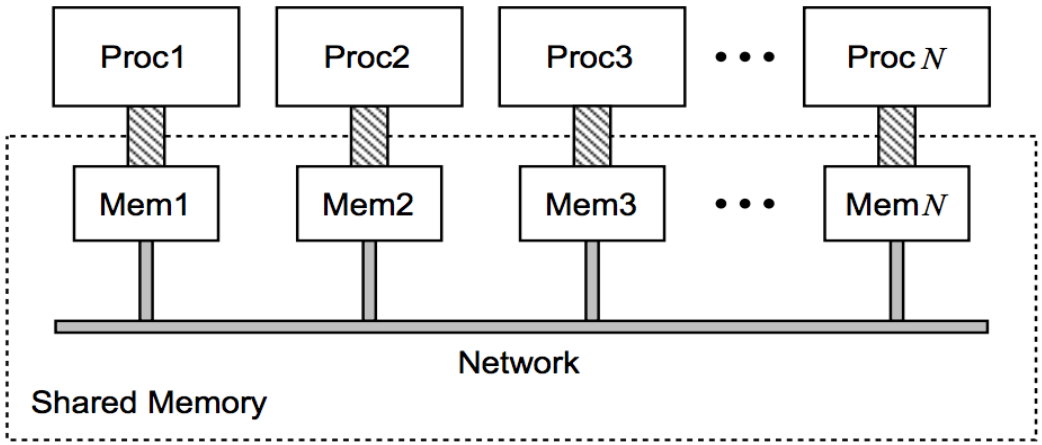
Distributed Shared Memory

- DMS is a form of memory architecture where the (physically separete) memories can be addressed as one (logically shared) address space
  - Easier to program than MPI
  - High cost of communication



Problems of DMS

- Lack of Portability
  - Hardware
    - In-house research platforms
  - Software
    - Kernell modifications
- Poor Performance
  - Communication overhead
  - False sharing

Problems of DMS

- Lack of Portability
  - Hardware
    - In-house research platforms -> **Standard Unix Systems Platforms**
  - Software
    - Kernell modifications -> **User-level implementation**
- Poor Performance
  - Communication overhead -> **Lazy Release Consistency**
  - False sharing -> **multiple writer protocols**

Release Consistency

- Release Consistency (RC) is a relaxed memory consistency model that permits a processor to delay making its changes to shared data visible to other processors until certain syncronization access occur

- Shared memory access
  - Ordinary
  - Synhonized Accesses
    - Acquire access
    - Release access

Release Consistency

P1:

a1: acq(L)

data access

r1: rel(L)

P2:

a2: acq(L)

data access

r2: rel(L)

If P1:r1 happened before P2:a2

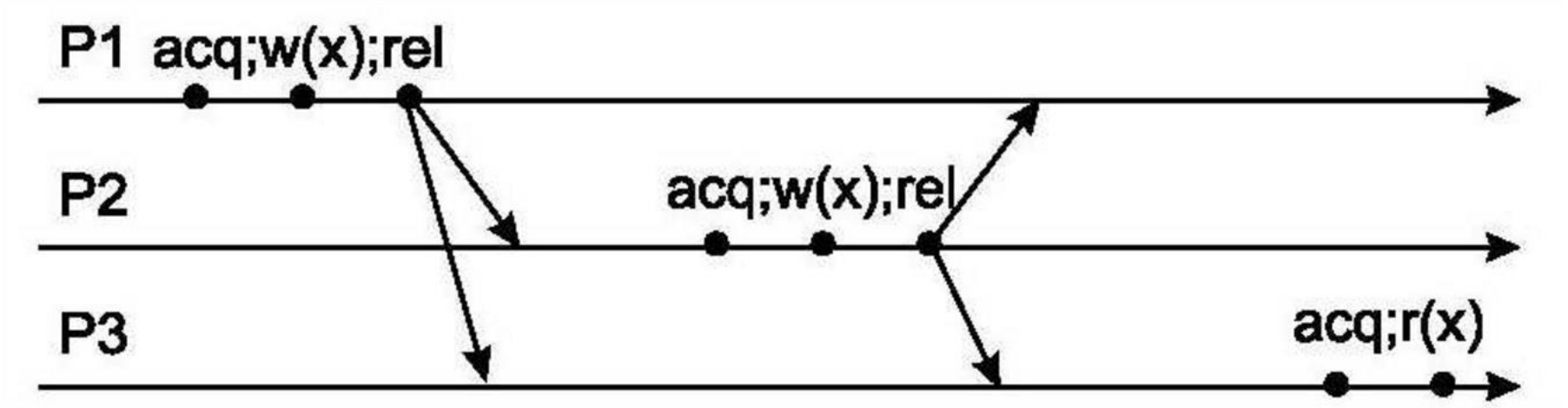
- All coherence actions prior to P1:r1 should be complete before P2:a2

Release Consistency

- Two Types of RC
  - Eager Release Consistency (ERC)
  - Lazy Release Consistency (LRC)

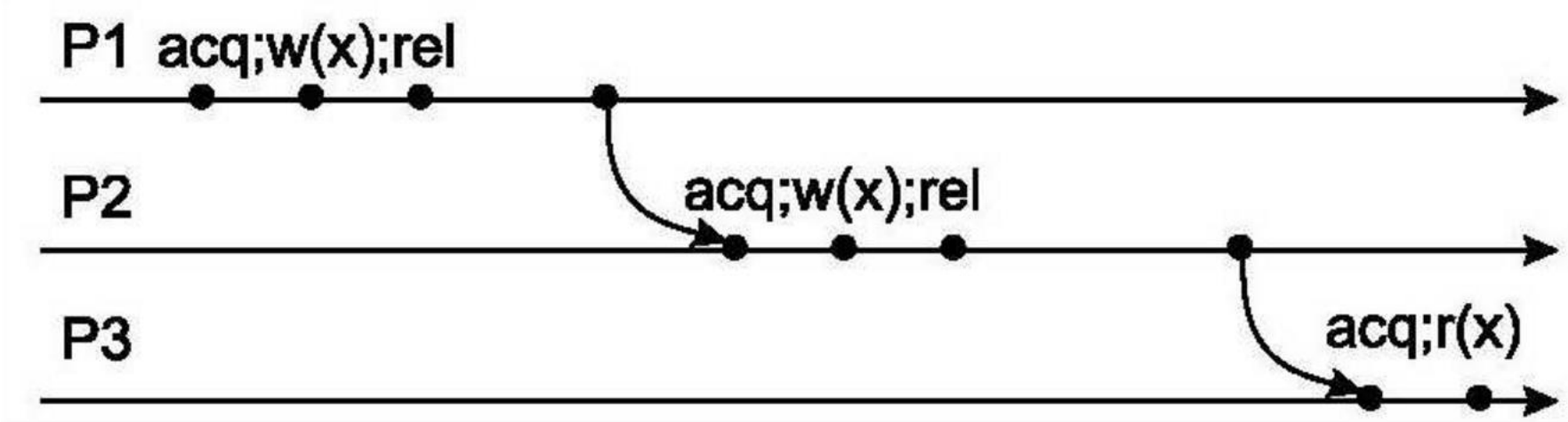
Eager Release Consistency

- Push Model



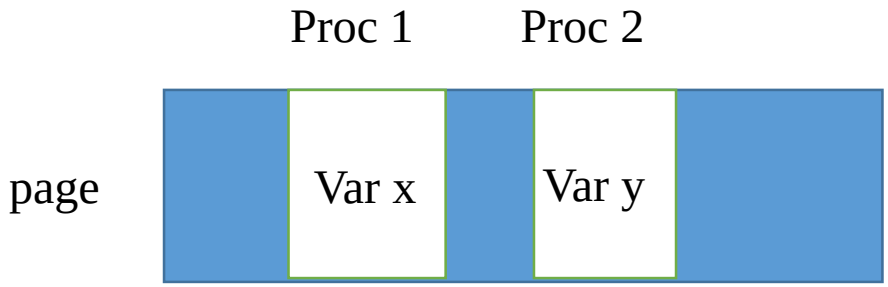
Lazy Release Consistency

- Pull Model



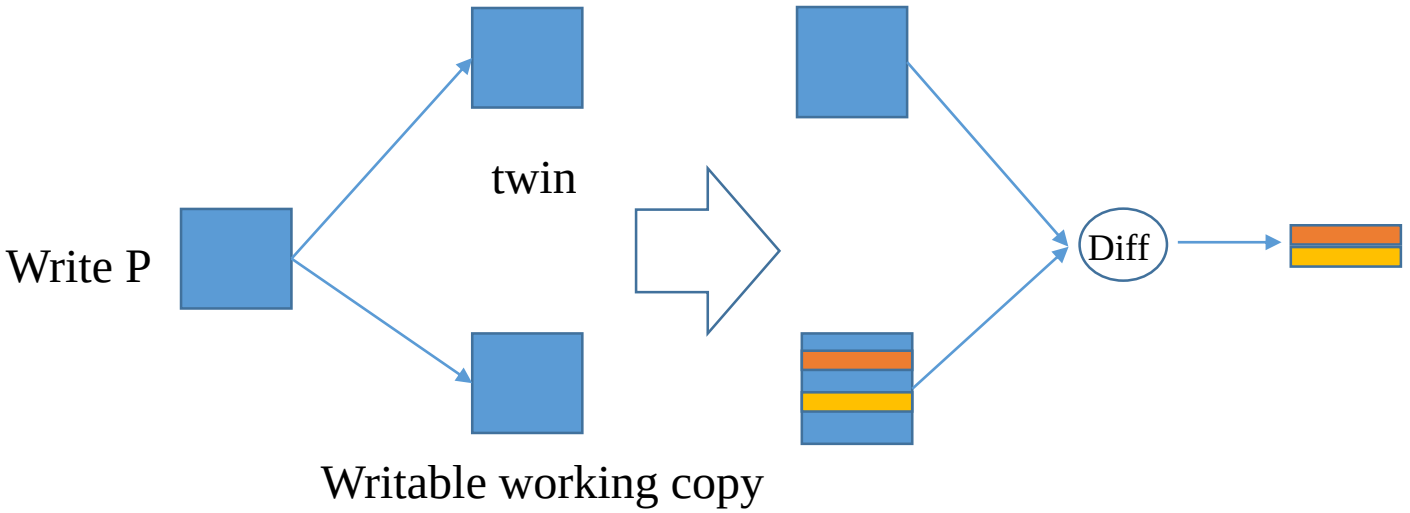
Multiple-Writer Protocol

- To solve False sharing Problem => Multiple writer protocol
  - Several processes make modifications to different variables at the same page



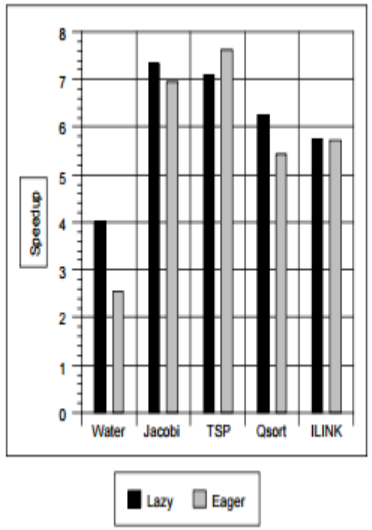
Multiple-Writer Protocol

- Two method
  - Twin
    - 1. Copy original page
    - 2. Compared original page and changed page
  - Diff
    - Difference between twin and copyset

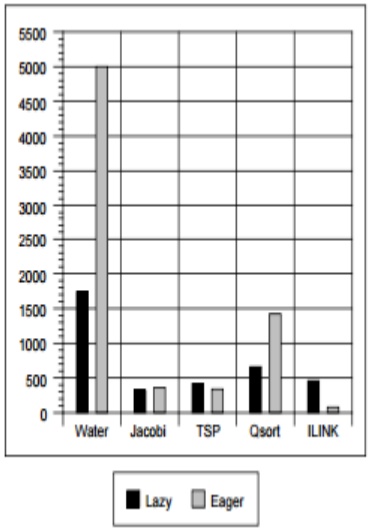


Lazy Diff Creation

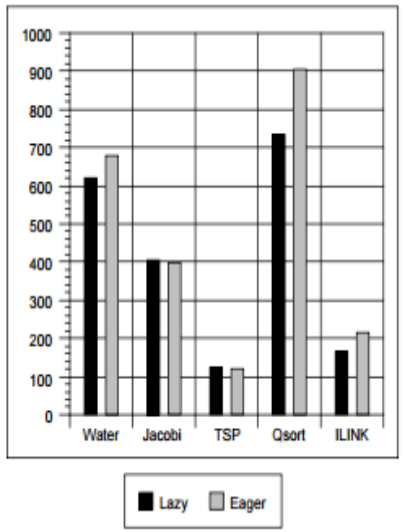
- In TreadMarks, Diff created
  - Modifications to a page
  - Write notice from another process
    - Different from Munin;s implementation
      - Diff creation postponed until the modification are requested
      - Reduce the number of diff created



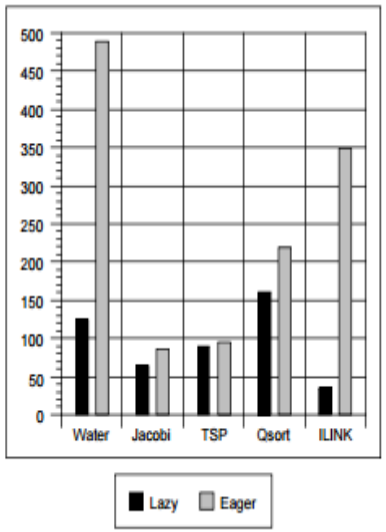
Speedup



Message Rate



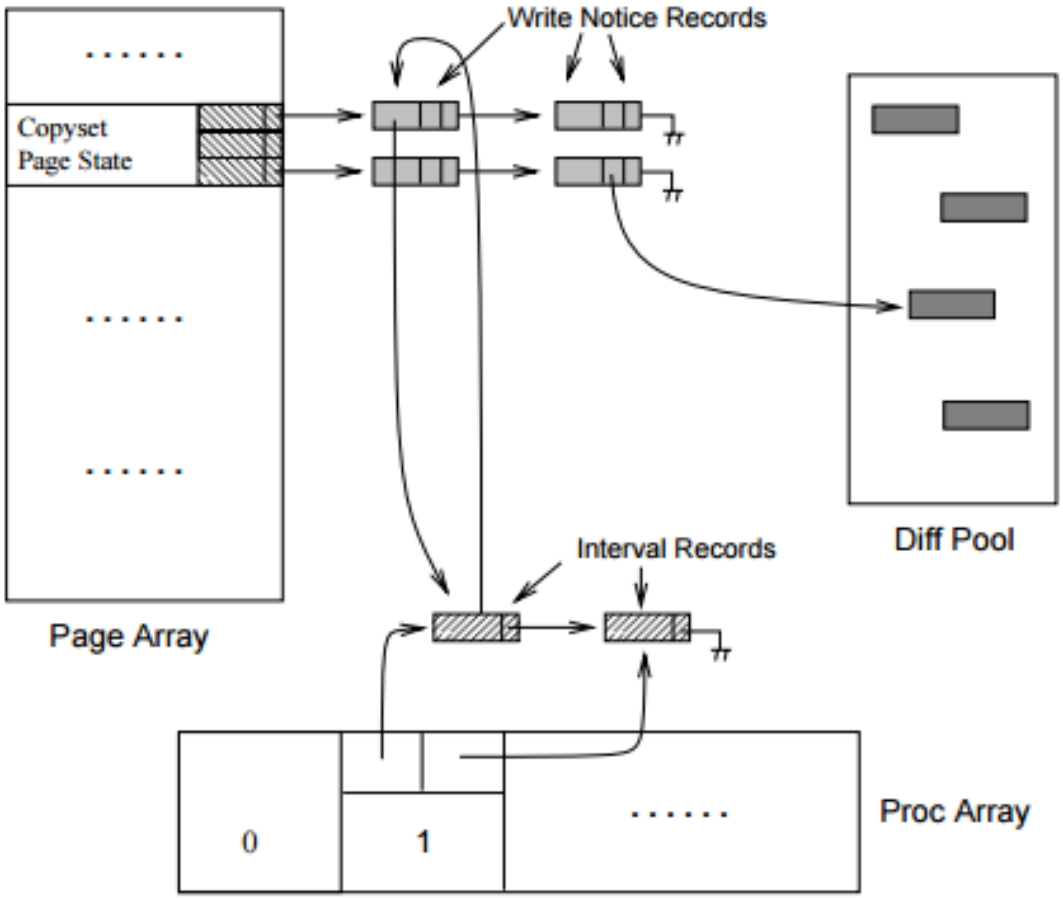
Data Rate



Diff Creation Rate

Data Structure

- Overview of Data Structure



Implementation

- Interval Creation
  - Logically
    - a new interval begins at each release and acquire
  - In practice
    - postponed until we communicate with another process
    - avoiding overhead

- Diff Creation
  - with lazy diff creation
    - Page writable until **diff request** or a **write notice arrives**
    - When **actual diff is created**, page **is read protected**, the twin is **discarded**

Implementation

- Lock and Barriers
  - Lock : Statically assigned manager
  - Assigned in a **round-robin** fashion among the processor
  - All the lock acquire requests are **directed to the manager**
  - When lock is released,
    - The releaser “informs ” the acquirer of all intervals
  - After receiving this messages
    - The acquirer “incorporates” this information into its data structures
    - 1. the acquirer appends an interval record to the interval record list for that processor
    - 2. for each write notice
      - 1) it prepends a write notice record to the page's write notice record list
      - 2) adds pointers from the write notice record to the interval record, and vice versa
  - Barriers : Centralized manager

Implementation

- Access Misses
  - without write notice
    - Initially setup that processor 0 has the page
  - with write notice
    - 1. Get the diffs from the write notice with small timestamp
    - 2. Create an actual diff which is correction of all diff related to the page
    - 3. The twin is discarded and the result is copied to copyset
- Garbage collection
  - Write notice records, Interval records, Diffs
  - It is triggered when the free space drops below a threshold
- Unix Aspects
  - TreadMarks relies on Unix standard libraries
    - Remote process creation, interprocessor communication, and memory management

Performance Evaluation

- Environment
  - 8 DECstation-5000/240
  - Connected to a 100-Mbps ATM LAN and a 10-Mbps Ethernet

- Applications
  - Water – molecular dynamics simulation , 343 molecules for 5 steps
  - Jacobi – Successive Over-Relaxation with a grid of 2000 by 1000 elements
  - TSP – branch & bound algorithm to solve the traveling salesman problem for a 19 cities
  - Quicksort – sorts an array of 256K integers. Using bubblesort to sort subarray of less than 1K element
  - ILINK – genetic linkage analysis

Results

Speedups Obtained on TreadMarks

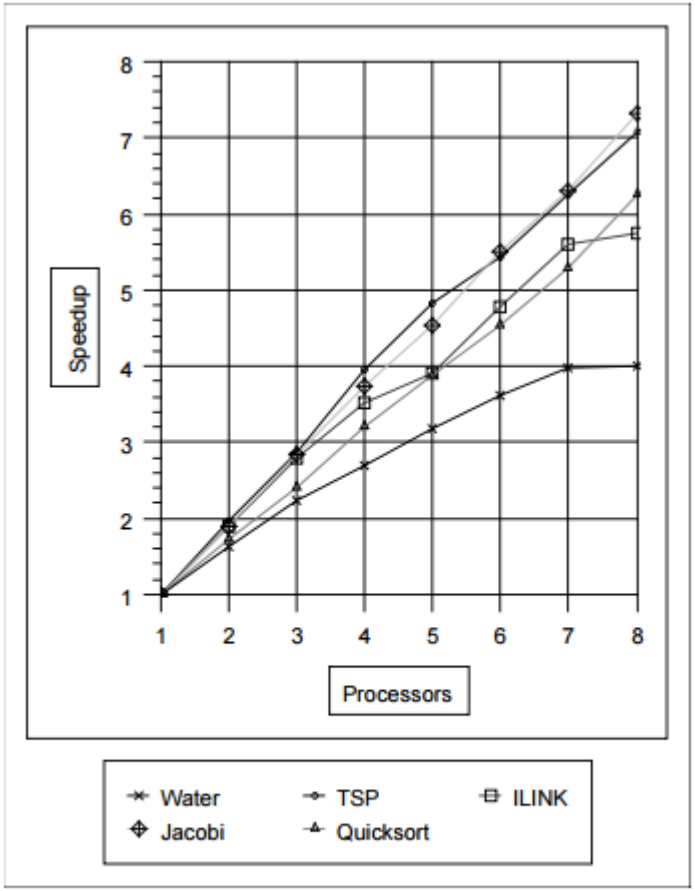


Figure 3 Speedups Obtained on TreadMarks

Execution Statistics
for an 8-processor run on TreadMarks

	Water	Jacobi	TSP	Quicksort	ILINK
Input	343 mols 5 steps	2000x1000 floats	19-city tour	256000 integers	CLP
Time (secs)	15.0	32.0	43.8	13.1	1113
Barriers/sec	2.5	6.3	0	0.4	0.4
Locks/sec	582.4	0	16.1	53.9	0
Msgs/sec	2238	334	404	703	456
Kbytes/sec	798	415	121	788	164

Figure 4 Execution Statistics for an 8-Processor Run on TreadMarks

Execution Time Breakdown

TreadMarks

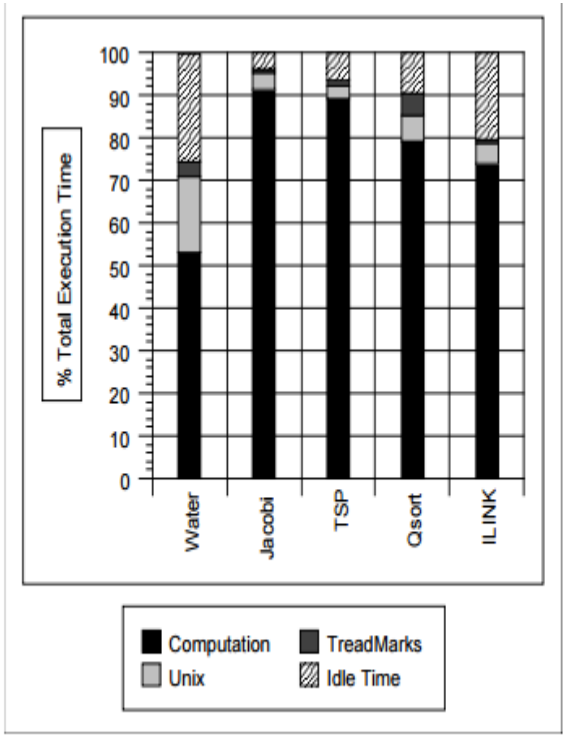


Figure 5 TreadMarks Execution Time Breakdown

Unix Overhead

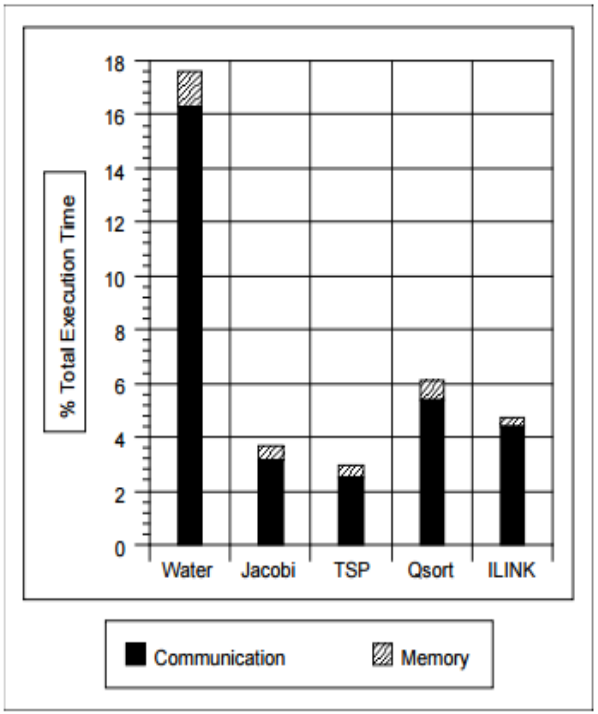


Figure 6 Unix Overhead Breakdown

TreadMarks Overhead

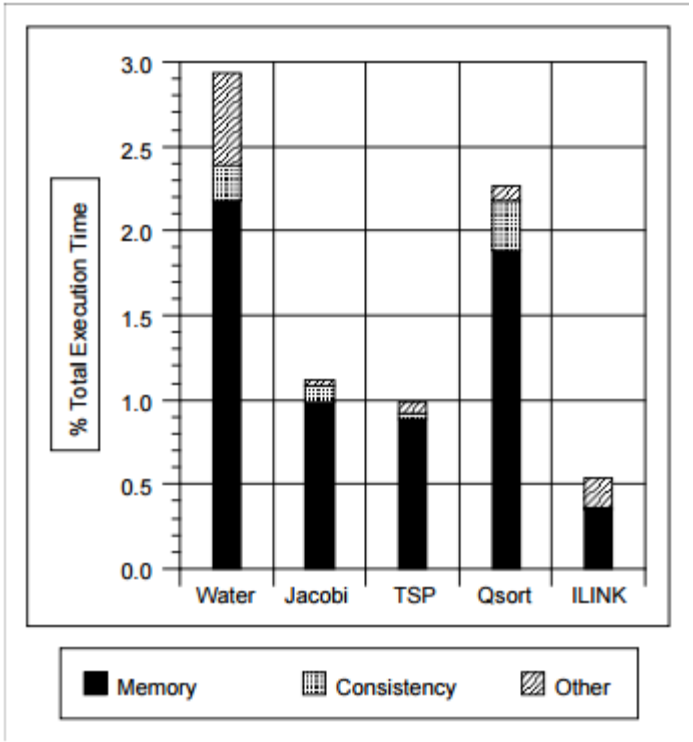


Figure 7 TreadMarks Overhead Breakdown

Conclusion

- Efforts on reducing the cost of communication
  - Lazy release consistency
  - Multiple-writer protocols
  - Lazy diff creation

- User-level DSM is a viable technique for parallel computation on clusters of workstations connected by suitable networking technology