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 separate) 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
    - Kernel modifications

- Poor Performance
  - Communication overhead
  - False sharing
Problems of DMS

- Lack of Portability
  - Hardware
    - In-house research platforms -> Standard Unix Systems Platforms
  - Software
    - Kernel 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 synchronization access occur.

- Shared memory access
  - Ordinary
  - Synchonized 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

Write P

Writable working copy
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
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
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

Execution Statistics for an 8-processor run on TreadMarks

![Graph showing speedups on TreadMarks](image)

![Table showing execution statistics for 8-processor run on TreadMarks](image)

**Figure 3** Speedups Obtained on TreadMarks

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

**Figure 5**  TreadMarks Execution Time Breakdown

**Figure 6**  Unix Overhead Breakdown

**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