C-DAC Four Days Technology Workshop

ON

Hybrid Computing – Coprocessors/Accelerators
Power-Aware Computing – Performance of Applications Kernels

hyPACK-2013
(Mode-1:Multi-Core)

Lecture Topic:

Multi-Core Processors : Multi-Core Architecture Part-II : Memory Allocators

Venue : CMSD, UoHYD ; Date : October 15-18, 2013

An Overview of Memory Allocator for Multithreaded Application

Lecture Outline

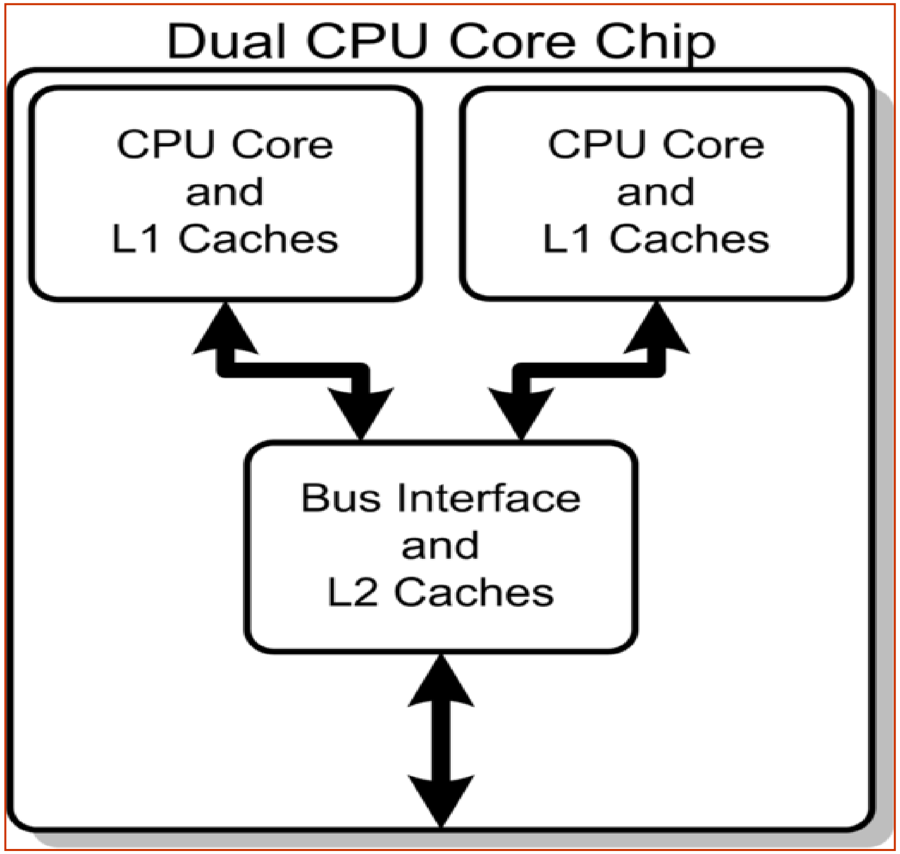
Following Topics will be discussed

- Introduction
- Understanding of Memory Allocation on Threads
- Case Studies & Examples

Dual Core Processor

Conceptual diagram of

- A dual-core CPU, with
- CPU-local Level 1 caches, and
- Shared, on-chip Level 2 caches



An Overview of Memory Allocator for Multithreaded Application

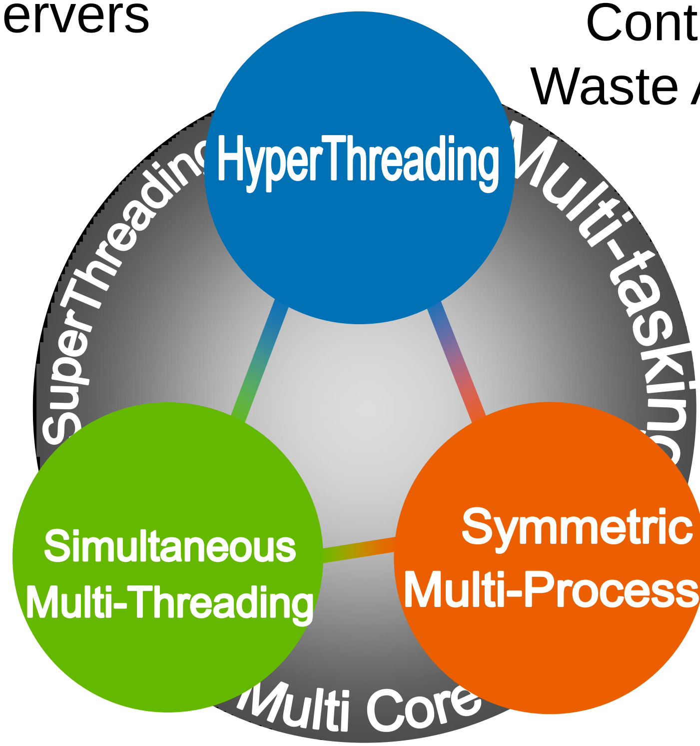
- Web Servers
- Data Base Managers
- news servers
- Parallel Scientific Applications
- Applications are written in C & C++
  - Shared Memory Multi-processors
  - **Make intensive use of Dynamic Memory Applications**

An Overview of threading

SMP and Cluster Platforms
based on Intel/AMD

Industry Standard Servers

Single Threaded CPU
Preemptive vs. co-operative
Multitasking
Context, process and Thread
Waste Associated with Threads
Time Slicing
I/O Threads



Implementing
Hyper-threading
- Replicated
- Partitioned
- Shared

Implementing
Hyper-threading
- Caching & SMT

Source : http://www.intel.com/

An Overview of Memory Allocator for Multithreaded Application

❖ **Memory Allocation is often a bottleneck that severely limits program scalability on multiprocessor systems**

- Existing Serial memory allocations do not scale well for multithreaded applications.
- Concurrent memory allocators do not provide one or more following features….
  - Speed (fast malloc & free)
  - Scalability
  - False Sharing avoidance (Cache line)
  - Low fragmentation (Poor Data Locality, Paging)
  - Still some execution block is utilized
- Blowup

Hoard : A Memory allocator

- **Achieve Scalable Memory Performance on Shared Memory Architectures**
  - Questions should be addresses on Multi Cores
    - Per Core "heap" & "global heap"
    - Transfer of "heap" from processors to global
  - False Sharing : It occurs when multiple processors share words in the same cache line without actually sharing data.
  - False sharing of heap objects
  - The Scheduling of multithreaded programs can cause them to require much more memory when run on multiple processors rather than single processor.

Source : http://www.hoard.org/

Hoard : A Memory allocator

- **Example :**
  - Threads in Producer–consumer relationship
    - Blow-up mechanism exists ….
    - Memory Consumption grows linearly
  - Producer thread repeatedly allocates a block of memory and it gives it to a consumer thread which frees it.
  - If the memory freed by the consumer is unavailable it the producer, the program consumes more and more memory as it runs…
  - Memory Consumption grows without bound while the memory required….

Hoard : A Memory allocator

- Each thread calls **x= malloc(S); …free(s)**.
  - If these threads are serialised the total memory required is **s**.
  - For serial – Memory requirement is **s**
  - For **p** threads – memory requirement is **ps**.

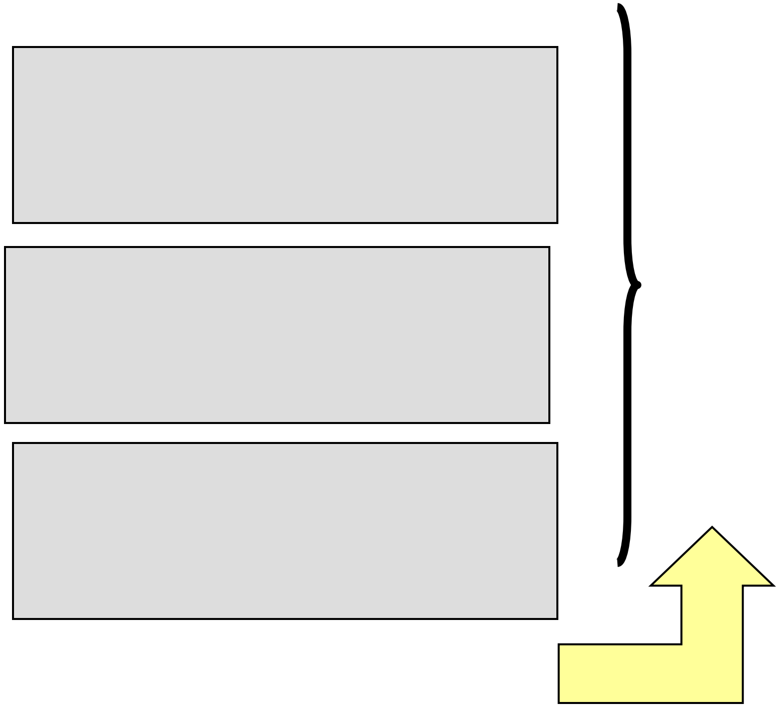
- If they execute on p processors, each call to malloc may run in parallel, increasing the memory requirement to **P*s.**

- Hoard can be viewed as an allocator that generally avoids false sharing & reduce synchronization costs..

- Each thread can access only its heap and global heap. Designation of heaps : 0 as global heap & heap 1 through p as the per-processor heaps.

Source : http://www.hoard.org/

Hoard : A Memory allocator



Heap 0 : Global heap

Heap 1 Processor 1

Heap 2 Processor 2

Heap 3 Processor 3

Heap 4 Processor 4

Superblocks

Each superblock has some blocks (Empty/Partially filled /Fully Filled)

thread 'k' maps to heap 'k'

Source : http://www.hoard.org/

Hoard : A Memory allocator

- Allocation and freeing in Hoard Memory Allocator
- Hoard maintains usage statistics for each heap
  - The amount of memory allocated by Hoard from the operating system held in heap i.
  - The amount of memory is use ("Live") in heap "I"
- Hoard allocates memory from the system in chunks as well as **superblocks**
- Each superblock is an array of some number of blocks (objects) and contains a free list of its available blocks maintained in LIFO order to improve locality.
  - All the superblocks are of same size (S), a multiple of system page size.

Hoard : A Memory allocator

❖ Allocation and freeing in Hoard Memory Allocator

- Collision of heap segments to threads by hashing on the LWP id.

❖ The number of LWP's – No of Processors

❖ Initially global heap is empty

❖ Thread 'k' is mapped to heap 'k'

❖ Global heap is empty

❖ Heap 1 has two superblocks (one is partially full & one is empty)

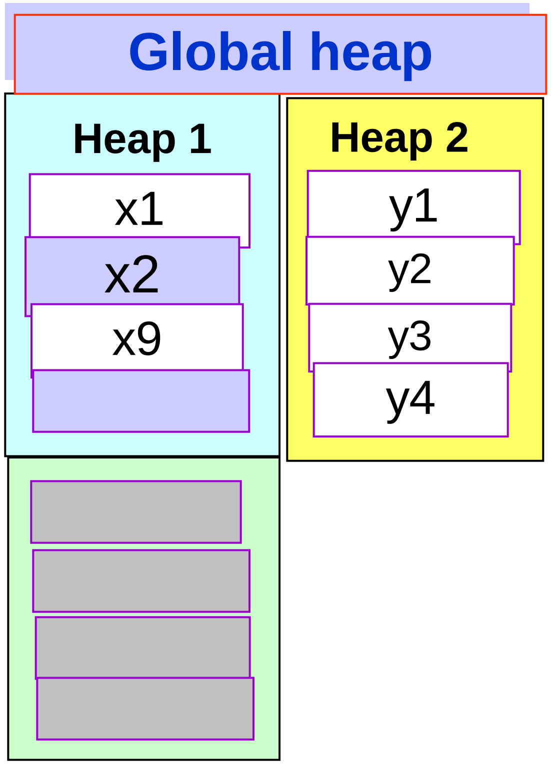
❖ Heap 2 has completely full superblock

❖ Superblock size = S

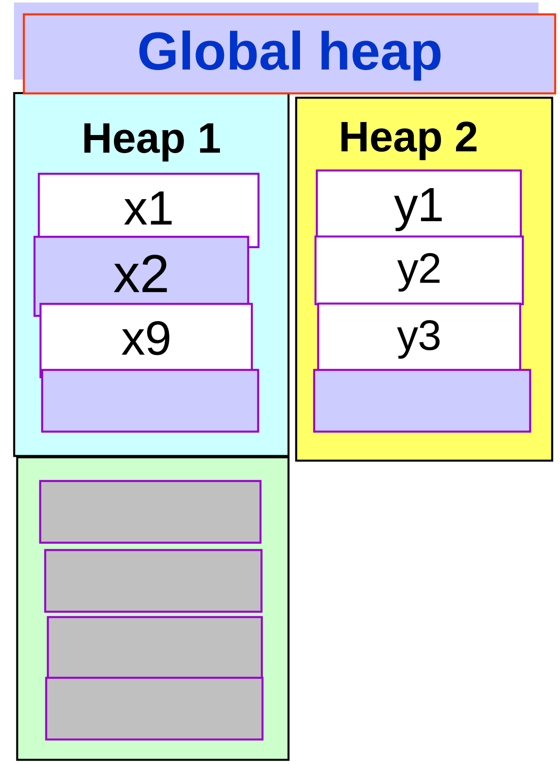
Hoard : A Memory allocator

- ❖ Allocation and freeing in Hoard Memory Allocator
    - ➢ Collision of heap segments to threads by hashing on the LWP id.
- ❖ The number of LWP's I set to No of Processors

t1: x9=malloc(s);

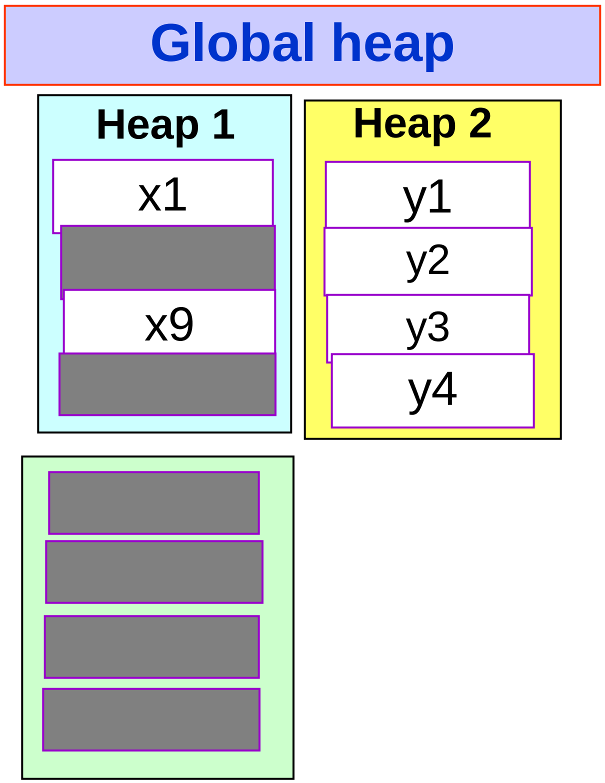


t1: free(y4);

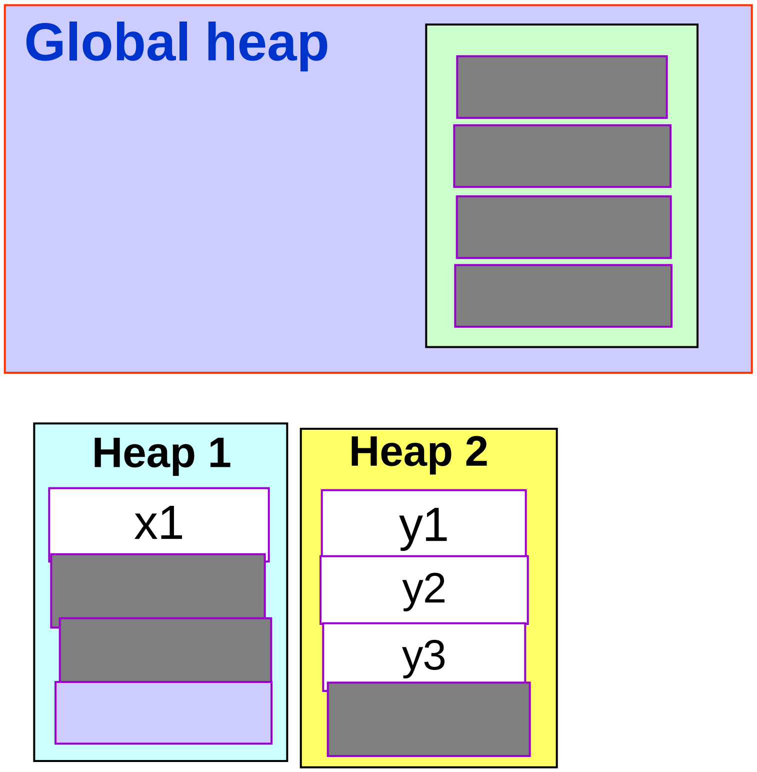


Hoard : A Memory allocator

t2: free(x2);



t2: free(x9);



Source : http://www.hoard.org/

Hoard : A Memory allocator

- ❖ Allocation and freeing in Hoard Memory Allocator
- ❖ Fragmentation Problems
  - ➢ Re-cycle completely empty superblocks for re-use.
- ❖ Avoid false Sharing
- ❖ Memory Allocation and De-allocation Algorithms

Hoard : A Memory allocator

- Single Threaded Applications
  - Each thread allocates one small object, writes on it a number of times and then **frees** it.
  - Overheads ignore
  - Superblock size = 1024*1024 Bytes.
  - Different classes & the number of classes
  - Avoid false Sharing

Hoard : A Memory allocator

- Multi-threaded Threaded Memory Benchmarks
  - **Shbench :** The large object size – randomly scattered in the super block
    - Represents real program
    - One Size Class per Superblock
    - Dynamic Storage Allocation
  - Larson Benchmark: Estimation of workload for server
  - Speedup, Scalability, and False Sharing avoidance

Hoard : A Memory allocator

❖ Taxonomy of Memory Allocated Algorithms

- **Serial Single heap**
- **Concurrent Single Heap**
- **Pure Private heaps**
- **Private heaps with ownership**
- **Private heaps with thresholds**

Hoard : A Memory allocator

Taxonomy of Memory Allocated Algorithms :Issues

- **Contention for the lock primitives**
- **Number of size Classes**
- **Freeing Blocks O(log C)**
- **Multiple heap Allocation**
- **Speed, Scalability, false Sharing avoidance and low fragmentation**

Conclusions

- An overview of Memory Allocation for Multi-threading Applications

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Thank You

Any questions ?