Niagara(T1)
A CMT PROCESSOR

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Agenda:

- Why CMT Processors
- Highlights of Sun Niagara Processor
- Performance characteristics of T1
- Need for Virtualization
- CMT & Virtualization
- Sun Virtualization Solutions
- HW and Software Network Virtualization.
Case For CMT Processors
Tradional processor behavior

Single scalar processor

Processor optimized for ILP
Characteristics of Commercial Work Load

- High degree of thread level parallelism (TLP)
- Large working sets result in poor locality of reference leading to high cache miss rates
- There is significant data sharing among threads resulting in coherence misses
- There is low instruction level parallelism (ILP) due to high cache miss rates, difficult to predict branches etc...
- Performance is bottle necked by stalls on memory access
Sun Solution

NIAGARA

Chip Multi Threaded Processor
Niagara(T1)

- Uses CPU threads to exploit TLP
  - Memory and Pipeline stall times are hidden due to multiple threads
  - Shared L2 cache allows efficient data sharing between threads
- Memory system is designed for high throughput
  - High bandwidth interface to L2 cache for L1 misses
  - Highly associative L2 cache
  - High bandwidth interface to DRAM
Designed for Performance and Efficiency

Dedicated Integrated Memory Controllers

Integrated Internal Communications

On-Chip Simplicity Means No Wait Latency

Clean Sheet Design Delivers Highest Performance, Efficiency

BUS

Sun Proprietary Information
Niagara Specs

- Up to 32 threads, 8 cores
- Unique L1$ 16KB-I, 8KB-D per core
- Shared L2$ 3MB, 134GB/s, 12 way associative
- Radically changed cache coherency processing
- 4XDDR2 Mem on CHIP Controllers 23GB/sec
- Upto 128 GB memory
- SSL support - 7X the RSA throughput of Xeon
- Requires about 70 Watts
- Each thread requires just about 2.0 watts
- No Recompilation required
Thread Selection Policy

- CPU switches between available threads every cycle giving priority to least recently executed thread.
- Threads become unavailable due to:
  - Long latency ops: loads, branch, mul, div
  - Pipeline stalls such as cache misses, traps, and resource conflicts
- Loads are speculated as cache hits, and the thread is switched in with lower priority.
Multithreaded Process on Niagara

Larger number of Memory References outstanding from overlapping h/w threads leads to higher throughput
SWaP (Space, Watts and Perf)

Performance: 19,000 Users

Space: 2RU x Watts: 312

Performance/(Space*Watts) = SWaP Rating

Performance/(Space*Watts) = SWaP: 30.4

1. LotusR6iNotes
# Sun Fire T1000 Crushes Xeon and p5+

<table>
<thead>
<tr>
<th></th>
<th>Sun Fire T1000</th>
<th>Dell SC1425 SPECjbb2005</th>
<th>IBM p5+ 520 SPECjbb2005</th>
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<tr>
<td><strong>Performance</strong></td>
<td>2.1X</td>
<td>1.6X</td>
<td></td>
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<tr>
<td><strong>Power Usage</strong></td>
<td>1/2</td>
<td>1/2</td>
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<td><strong>Space</strong></td>
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<td><strong>SWaP</strong></td>
<td>4.4X</td>
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<td>14X</td>
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Niagara-2 (T2): True System on a Chip

- Better performance than Niagara-1
- Up to 8 Cores
- Up to 64 threads per CPU
- Same power envelope as T1
- On chip NIC's
- And much more that I can not state
Performance Characteristics of T1
Positive Characteristics

• If a strand is stalled, its cycles can be utilized by other threads
• Multiple threads running the same application benefit by sharing text and data in L2 cache
• These characteristics make CMT ideal for throughput computing.
Not so Positive Characteristics

- If one thread is thrashing the L1 instruction cache, data cache, or TLB's on a core, it can adversely affect other threads on that core.
- If all threads run on the same core they are only getting one-quarter of the CPU time.
- So CMT is not ideal for real time applications.
Scaling issues to be aware of

- Hot locks are the most common reason applications fail to scale on CMT processors
- Tuning Critical Sections
- Apply more threads as CMT is a thread rich environment.
Server Virtualization
Benefits of Virtualization

- Virtualization is masking and sharing of server resources
- Results in
  - Server Consolidation
  - Higher server utilization
  - Increased operational efficiency
  - Improved manageability
CMT and Virtualization

- CMT provides hooks for server virtualization
- Each Strand can be a Virtual CPU
- Niagara-2 also provides support for Network Virtualization
Solaris Virtualization Solutions

- Containers (BSD Jails)
- Logical Domains (Individual OS Instance per domain)
- Xen
Logical Domains + Zones

- Partitioning capability
  - Create virtual machines each with sub-set of resources
  - Protection & Isolation using HW+firmware combination
Network Virtualization
HW Based Network Virtualization

- Niagara-2 (T2) has on chip network interfaces
- Supports network virtualization/partitioning
  - Multiple Partitions can co-exist within a port
  - Only cable, MAC and RX FIFO's are shared.
- Virtualization/Partitioning can be Based on
  - VLANS – upto 4K per port
  - MAC address – upto 16 per port
  - Service addresses (IP addresses, TCP/UDP ports) - upto 256 per device
- Interrupts for flow are sent to a particular CPU
- Full register sets are provided to control RX Rings
NIU RX Classification Model

Incoming flows are classified at layer 2, 3, or 4 and put into RX DMA channel according to classification rules that matched the flow.
Software Based Network Virtualization

- Not All NIC's have HW support for Virtualization
- Software creates virtual stacks over 1Gb and 10Gb NIC's
- Virtual stacks are isolated from each other (for both resources and security purposes)
- Each Virtual stack can be tuned separately
Virtualized Networking

Specific To Containers:
- Global Zone
- Zone 1
- Zone 2

Shared Stack with Global Zone

Common To All Virtual Machines:
- Virtual NIC
- Flow Classifier
- NIC

Global Zone Mem area
Zone 1 Mem area
Zone n Mem area
Virtual Network with XEN
Future Work

- More work is needed to characterize different workloads on CMT processors and define best practices
- Open Interfaces are needed to implement Virtualization
- Network Bandwidth/Resource control support is needed in HW
References

- Various Sun internal and external documents and publications on Niagara
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