多核心架構的混合式快取記憶體之能源及效能改善

Energy and performance improvement for multicore system with hybrid cache

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開發工具：Gem5
測試環境：Linux Ubuntu 12.04

一、簡介：

近年來,自旋轉移力矩隨機存取記憶體(STT-RAM)、相變隨機存取記憶體(PCRAM)等非揮發性記憶體(NVM)，因為其低耗能及高密度的特色而受到相當大的重視。但是，NVM同時也有著寫入時間長、有限的寫入次數等問題存在（由下列表格所示）。因此，許多SRAM混合NVM的快取記憶體架構(hybrid cache)被提出，配合上適當的快取寫入管理方針來降低非揮發性記憶體的寫入壓力。

	SRAM	STT-RAM	PRAM
Density	1X	4X	16X
Read time	Very fast	Fast	Slow
Write time	Very fast	Slow	Very Slow
Read energy	Low	Low	Medium
Write energy	Low	Highe	High
Leakage energy	High	Low	Low
Endurance	10^{16}	4×10^{12}	10^{9}

而在此架構下,我使用了一些方式去改善快取記憶體的存取及更有效地利用其他的存取記憶體,首先利用了Migration 之方式,先使用 LRU 演算法找出近期最少使用的 Banks 並在之後將其 Banks 併入其他有在運作並且需要此 Banks 之核心中,此方式不僅提高使用率,也加速了記憶體的存取。而除了Migration 之外,我還搭配了 Data inverting 的技術,此方式是在寫入資料之前,先檢查所需要輸入之資料和原本資料各 bit 之異同,若超過某一個數字,則將所有資料內容 invert,即 1 變 0 或 0 變 1 在進行寫入之動作,如此一來便可以節省寫入資料之時間。以上兩種方式的結合便是我所使用的方式,以用來改善混合形快取記憶體之能源以及效能。

二、測試結果：

```
system.physmem.bytes_read::cpu0.inst      52661/0/6       # Number of bytes read from this memory
system.physmem.bytes_read::cpu0.data      92117539        # Number of bytes read from this memory
system.physmem.bytes_read::tsunami.ide    1608            # Number of bytes read from this memory
system.physmem.bytes_read::cpu1.inst      537406600       # Number of bytes read from this memory
system.physmem.bytes_read::cpu1.data      95584539        # Number of bytes read from this memory
system.physmem.bytes_read::cpu2.inst      599435332       # Number of bytes read from this memory
system.physmem.bytes_read::cpu2.data      123743454       # Number of bytes read from this memory
system.physmem.bytes_read::cpu3.inst      564104088       # Number of bytes read from this memory
system.physmem.bytes_read::cpu3.data      101990219       # Number of bytes read from this memory
system.physmem.bytes_read::total          2641000455      # Number of bytes read from this memory
system.physmem.bytes_inst_read::cpu0.inst 526617076        # Number of instructions bytes read from this memory
system.physmem.bytes_inst_read::cpu1.inst 537406600        # Number of instructions bytes read from this memory
system.physmem.bytes_inst_read::cpu2.inst 599435332        # Number of instructions bytes read from this memory
system.physmem.bytes_inst_read::cpu3.inst 564104088        # Number of instructions bytes read from this memory
system.physmem.bytes_inst_read::total     2227563096       # Number of instructions bytes read from this memory
system.physmem.bytes_written::cpu0.data   14181908         # Number of bytes written to this memory
system.physmem.bytes_written::tsunami.ide 4567040          # Number of bytes written to this memory
system.physmem.bytes_written::cpu1.data   15977095        # Number of bytes written to this memory
system.physmem.bytes_written::cpu2.data   43880892        # Number of bytes written to this memory
system.physmem.bytes_written::cpu3.data   18508834        # Number of bytes written to this memory
system.physmem.bytes_written::total       97115769        # Number of bytes written to this memory
system.physmem.num_reads::cpu0.inst       131654269       # Number of read requests responded to by this memory
system.physmem.num_reads::cpu0.data       23824112        # Number of read requests responded to by this memory
system.physmem.num_reads::tsunami.ide     201             # Number of read requests responded to by this memory
system.physmem.num_reads::cpu1.inst       134351650       # Number of read requests responded to by this memory
system.physmem.num_reads::cpu1.data       24437824        # Number of read requests responded to by this memory
system.physmem.num_reads::cpu2.inst       149858833       # Number of read requests responded to by this memory
system.physmem.num_reads::cpu2.data       26950645        # Number of read requests responded to by this memory
system.physmem.num_reads::cpu3.inst       141026022       # Number of read requests responded to by this memory
system.physmem.num_reads::cpu3.data       25764946        # Number of read requests responded to by this memory
system.physmem.num_reads::total           657868502       # Number of read requests responded to by this memory
system.physmem.num_writes::cpu0.data      3573911         # Number of write requests responded to by this memory
system.physmem.num_writes::tsunami.ide    71360           # Number of write requests responded to by this memory
system.physmem.num_writes::cpu1.data      3820295         # Number of write requests responded to by this memory
system.physmem.num_writes::cpu2.data      7925739         # Number of write requests responded to by this memory
system.physmem.num_writes::cpu3.data      4390258         # Number of write requests responded to by this memory
system.physmem.num_writes::total          19781563        # Number of write requests responded to by this memory
system.physmem.bw_read::cpu0.inst         5301268524      # Total read bandwidth from this memory (bytes/s)
system.physmem.bw_read::cpu0.data         927314803       # Total read bandwidth from this memory (bytes/s)
system.physmem.bw_read::tsunami.ide       16187           # Total read bandwidth from this memory (bytes/s)
system.physmem.bw_read::cpu1.inst         5409882860      # Total read bandwidth from this memory (bytes/s)
system.physmem.bw_read::cpu1.data         962215870       # Total read bandwidth from this memory (bytes/s)
system.physmem.bw_read::cpu2.inst         6034304246      # Total read bandwidth from this memory (bytes/s)
system.physmem.bw_read::cpu2.data         1245681744      # Total read bandwidth from this memory (bytes/s)
system.physmem.bw_read::cpu3.inst         5678637063      # Total read bandwidth from this memory (bytes/s)
system.physmem.bw_read::cpu3.data         1026699593      # Total read bandwidth from this memory (bytes/s)
system.physmem.bw_read::total             26586020890     # Total read bandwidth from this memory (bytes/s)
```