CERN openlab II

CPU-level
Performance Monitoring with perfmon/pfmon

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perfmon

- A powerful interface to the Performance Monitoring Units (PMUs) in the processor(s)
  - Very detailed information available
    - ~140 events / 5 counters available on Core2 based CPUs
    - ~120 events / 4 counters available on AMDs Barcelona
    - ~650 events / 12 counters available on Montecito (Itanium2)
    - ... the Cray X2 provides ~2000 events ...
  - Very little/no overhead for non-latency bound applications
  - Allows for counting or sampling (== non-intrusive profiling)
  - More info:
    - http://perfmon2.sourcefore.net
    - Overview: http://perfmon2.sourceforge.net/perfmon2-20080124.pdf

pfmon

- Allows for multiplexing – measuring a large number of performance counter events by switching between different sets – a large number of events can be measured at the same time if the application runs long enough

- Improvements submitted by Andrzej Nowak include
  - Proper correlation of symbols across dlopen()/dlclose() calls
  - Rewrite of symbol table parsing and management
  - And others ...

- Many more improvements ...

➔ Pfmon is now in a state that it can be used on HEP/CERN software ... we have a huge number of shared libs !!

- In connection with the HEPiX benchmark WG
- Running on 3GHz Woodcrests (Xeon 5160)
- Getting CPU level performance information for
  - SPEC2000
    - int and fp benchmarks together
    - All sub-benchmarks separately
  - SPEC2006
    - int and fp benchmarks together
    - All sub-benchmarks separately
    - All C++ sub-benchmarks together
  - In 32bit and 64bit mode (with CERN/HEP settings)
  - Running as single job and with 4 parallel jobs (# of cores)

Pfmon measurements cont.

- Monitoring the jobs running on lxbatch
  - Pfmon running in system-wide mode
  - overview over the application-mix on batch/worker nodes
  - "public" lxbatch nodes used (ATLAS/CMS a bit underrepresented)
  - Kernel and additional packages have to be "production ready" !!
    - Previous attempt for low level monitoring using "perfctr" resulted in very unstable machines ...
    - The kernel with perfmon patches has to be stable
    - Running pfmon should not introduce instabilities
    - openafs had to rebuild for the new kernel
    - Up to now no instabilities :-)

- Comparing the SPEC performance with and without pfmon

Test	SPECInt2006	SPECfp2006
std. SLC4.6 w/ std. Kernel	34.26	25.6
std. SLC4.6 w/ 2.6.24.2 Kernel & perfmon patches & pfmon *inactive*	38.16 (111%)	27.77 (108%)
std. SLC4.6 w/ 2.6.24.2 Kernel & perfmon patches & pfmon *active*	38.23 (112%)	27.78 (108%)

- The performance "impact" of pfmon is
  → The performance actually **increases** !!!
    - ... mainly due to the newer kernel ...
- Measurements by Alejandro Iribarren

Pfmon – What do we measure

- CPI (Cycles per instruction)
- Load / Store instructions
- x87 instructions
- computational SIMD instructions
- Branch instructions
- Mispredicted branches
- Level2 cache misses (rate)
- Bus utilisation
- Data bus utilisation

- "Bus Not Ready"
- Resource stalls
- Detailed look into the resource stalls:
  - ROB full (Re-Order Buffer full)
  - RS full (Reservation Station full)
  - LD / ST limits
  - Mispredicted branches
  - FP ctrl word

What do we measure – some details

- x87 and computational SIMD instructions
  - They are the "floating point" (FP) instructions
  - x87 instr. are default in 32bit mode
  - SIMD instr. are default in 64bit mode
- Mispredicted branches
  - Percentage of branches that were mispredicted
  - They carry a performance penalty (~14 cycles)!
- Level2 cache misses (rate)
  - Percentage of requests to the L2 cache that have to go to main memory
  - They carry a significant performance penalty (~250 cycles)!!!

What do we measure – some details II

- Bus utilisation
  - Percentage of bus cycles used to transfer bus transactions of any kind
- Data bus utilisation
  - Percentage of bus cycles used to transfer data
- Bus Not Ready
  - Percentage of bus cycles during which no new bus transactions can start.
  - A high value indicates a highly loaded and frequently overloaded/congested bus

Pfmon – The Results – SPECint2000

- SPECint2000 contains ~1% floating point!!

- Only slightly faster in 64bit mode
  - Due to a few sub-benchmarks being extremely slowed down in 64bit mode!!
  - Significantly more L2 cache misses in 64bit mode
  - Slightly more mispredicted branches
  - BNR much higher in 64bit mode
  - Slightly more resource stalls in 64bit mode
  - ... but still significantly fewer actual instructions used !!

SPECint2000 – 32bit mode – 4 jobs	SPECint2000 – 64bit mode – 4 jobs
45201237332100 UNHALTED_CORE_CYCLES	44804927344019 UNHALTED_CORE_CYCLES
45837316931397 INSTRUCTIONS_RETIRED	379967583644997 INSTRUCTIONS_RETIRED
7497308624143 BRANCH_INSTRUCTIONS_RETIRED	6421199461762 BRANCH_INSTRUCTIONS_RETIRED
302799323740 MISPREDICTED_BRANCH_RETIRED	288149260964 MISPREDICTED_BRANCH_RETIRED
19296716652582 INST_RETIRED:LOADS	12159284443871 INST_RETIRED:LOADS
624928 SIMD_COMP_INST_RETIRED:PACKED_SINGLE	413103994039 SIMD_COMP_INST_RETIRED:PACKED_SINGLE
:SCALAR_SINGLE:PACKED_DOUBLE:SCALAR_DOUBLE	:SCALAR_SINGLE:PACKED_DOUBLE:SCALAR_DOUBLE
9323887361488 INST_RETIRED:STORES	5366523996464 INST_RETIRED:STORES
442567549137 X87_OPS_RETIRED:ANY	57678491535 X87_OPS_RETIRED:ANY
22143424590558 RESOURCE_STALLS:ANY	23933277888657 RESOURCE_STALLS:ANY
378414578559 BUS_TRANS_ANY:ALL_AGENTS	724554943704 BUS_TRANS_ANY:ALL_AGENTS
308895207467 BUS_DRDY_CLOCKS:ALL_AGENTS	574793437730 BUS_DRDY_CLOCKS:ALL_AGENTS
1741997649 BUS_BNR_DRV:ALL_AGENTS	7859133902 BUS_BNR_DRV:ALL_AGENTS
543636967874 LAST_LEVEL_CACHE_REFERENCES	618095730129 LAST_LEVEL_CACHE_REFERENCES
27980144496 LAST_LEVEL_CACHE_MISSES	54049684697 LAST_LEVEL_CACHE_MISSES
5035359994977 CPU_CLK_UNHALTED:BUS	4992386647432 CPU_CLK_UNHALTED:BUS
--	--
Ratios:	Ratios:
CPI: 0.9861	CPI: 1.1801
load instructions %: 42.098%	load instructions %: 32.025%
store instructions %: 20.341%	store instructions %: 14.134%
load and store instructions %: 62.440%	load and store instructions %: 46.160%
resource stalls % (of cycles): 48.989%	resource stalls % (of cycles): 53.417%
branch instructions %: 16.356%	branch instructions %: 16.912%
% of branch instr. mispredicted: 4.039%	% of branch instr. mispredicted: 4.487%
% of l2 loads missed: 5.147%	% of l2 loads missed: 8.745%
bus utilization %: 15.030%	bus utilization %: 29.026%
data bus utilization %: 6.135%	data bus utilization %: 11.513%
bus not ready %: 0.069%	bus not ready %: 0.315%
comp. SIMD inst. ('new FP') %: 0.000%	comp. SIMD inst. ('new FP') %: 1.088%
comp. x87 instr. ('old FP') %: 0.966%	comp. x87 instr. ('old FP') %: 0.152%

- SPECint2006 contains ~0.1% floating point ... negligible ...
- Only slightly faster in 64bit mode
  - Due to a few sub-benchmarks being extremely slowed down in 64bit mode!!
  - Slightly more L2 cache misses in 64bit mode, but very high miss rate in general
  - BNR much higher in 64bit mode
  - Slightly more resource stalls in 64bit mode
  - ... again, significantly fewer actual instructions in 64bit mode

SPECint2006 – 32bit mode – 4 jobs		SPECint2006 – 64bit mode – 4 jobs	
461179857748960	UNHALTED_CORE_CYCLES	453153422688509	UNHALTED_CORE_CYCLES
350589714455709	INSTRUCTIONS_RETIRED	303883044666778	INSTRUCTIONS_RETIRED
54906528688928	BRANCH_INSTRUCTIONS_RETIRED	48233916086552	BRANCH_INSTRUCTIONS_RETIRED
2903104696534	MISPREDICTED_BRANCH_RETIRED	2568377286745	MISPREDICTED_BRANCH_RETIRED
162881915117934	INST_RETIRED:LOADS	96299115605813	INST_RETIRED:LOADS
0	SIMD_COMP_INST_RETIRED:PACKED_SINGLE :SCALAR_SINGLE:PACKED_DOUBLE:SCALAR_DOUBLE	359749309739	SIMD_COMP_INST_RETIRED:PACKED_SINGLE :SCALAR_SINGLE:PACKED_DOUBLE:SCALAR_DOUBLE
58657311592597	INST_RETIRED:STORES	33169229301278	INST_RETIRED:STORES
399618515172	X87_OPS_RETIRED:ANY	132684652120	X87_OPS_RETIRED:ANY
265980169455834	RESOURCE_STALLS:ANY	283825996907464	RESOURCE_STALLS:ANY
9030113964523	BUS_TRANS_ANY:ALL_AGENTS	11197303950198	BUS_TRANS_ANY:ALL_AGENTS
7313830415240	BUS_DRDY_CLOCKS:ALL_AGENTS	9007337650460	BUS_DRDY_CLOCKS:ALL_AGENTS
82885334380	BUS_BNR_DRV:ALL_AGENTS	226487203141	BUS_BNR_DRV:ALL_AGENTS
3945120792043	LAST_LEVEL_CACHE_REFERENCES	4818080605870	LAST_LEVEL_CACHE_REFERENCES
478431290431	LAST_LEVEL_CACHE_MISSES	720453702717	LAST_LEVEL_CACHE_MISSES
51581290410280	CPU_CLK_UNHALTED:BUS	50797500445973	CPU_CLK_UNHALTED:BUS

```
--------------------------------------------------------     --------------------------------------------------------
Ratios:                                                      Ratios:
                              CPI: 1.3154                                                  CPI: 1.4912
               load instructions %: 46.459%                                  load instructions %: 31.690%
              store instructions %: 16.731%                                 store instructions %: 10.915%
     load and store instructions %: 63.190%                        load and store instructions %: 42.605%
     resource stalls % (of cycles): 57.674%                        resource stalls % (of cycles): 62.634%
             branch instructions %: 15.661%                                branch instructions %: 15.873%
% of branch instr. mispredicted: 5.287%                      % of branch instr. mispredicted: 5.325%
               % of l2 loads missed: 12.127%                                 % of l2 loads missed: 14.953%
                  bus utilization %: 35.013%                                    bus utilization %: 44.086%
             data bus utilization %: 14.179%                               data bus utilization %: 17.732%
                    bus not ready %: 0.321%                                     bus not ready %: 0.892%
   comp. SIMD inst. ('new FP') %: 0.000%                       comp. SIMD inst. ('new FP') %: 0.118%
    comp. x87 instr. ('old FP') %: 0.114%                       comp. x87 instr. ('old FP') %: 0.044%
```

- The SPEC2006 C++ benchmarks contain 10-14% floating point
- **Slower** in 64bit mode !!
  - Almost all C++ benchmarks are slowed down in 64bit mode!!
  - Slightly more L2 cache misses in 64bit mode, but very high miss rate in general
  - Slightly more mispredicted branches in 64bit mode
  - BNR higher in 64bit mode
  - ~10% more resource stalls in 64bit mode
  - ... again, fewer actual instructions in 64bit mode

SPEC2006 C++ – 32bit mode – 4 jobs	SPEC2006 C++ – 64bit mode – 4 jobs
196604109151652 UNHALTED_CORE_CYCLES	215947712982588 UNHALTED_CORE_CYCLES
150762226596169 INSTRUCTIONS_RETIRED	119991871388997 INSTRUCTIONS_RETIRED
20597482426950 BRANCH_INSTRUCTIONS_RETIRED	18241941807980 BRANCH_INSTRUCTIONS_RETIRED
764119332313 MISPREDICTED_BRANCH_RETIRED	745321349045 MISPREDICTED_BRANCH_RETIRED
59343184864687 INST_RETIRED:LOADS	36586210736816 INST_RETIRED:LOADS
0 SIMD_COMP_INST_RETIRED:PACKED_SINGLE	16549768252572 SIMD_COMP_INST_RETIRED:PACKED_SINGLE
:SCALAR_SINGLE:PACKED_DOUBLE:SCALAR_DOUBLE	:SCALAR_SINGLE:PACKED_DOUBLE:SCALAR_DOUBLE
22653050918291 INST_RETIRED:STORES	11817242786897 INST_RETIRED:STORES
16499979718174 X87_OPS_RETIRED:ANY	17200520909 X87_OPS_RETIRED:ANY
121652777590140 RESOURCE_STALLS:ANY	150950098548670 RESOURCE_STALLS:ANY
4058630608266 BUS_TRANS_ANY:ALL_AGENTS	5005296800109 BUS_TRANS_ANY:ALL_AGENTS
3131296782062 BUS_DRDY_CLOCKS:ALL_AGENTS	3821979997184 BUS_DRDY_CLOCKS:ALL_AGENTS
30656103004 BUS_BNR_DRV:ALL_AGENTS	47675704094 BUS_BNR_DRV:ALL_AGENTS
2216257328615 LAST_LEVEL_CACHE_REFERENCES	2767263319645 LAST_LEVEL_CACHE_REFERENCES
307891738955 LAST_LEVEL_CACHE_MISSES	410542553241 LAST_LEVEL_CACHE_MISSES
22121483842719 CPU_CLK_UNHALTED:BUS	24255546086757 CPU_CLK_UNHALTED:BUS
---	---
Ratios:	Ratios:
CPI: 1.3041	CPI: 1.7997
load instructions %: 39.362%	load instructions %: 30.491%
store instructions %: 15.026%	store instructions %: 9.848%
load and store instructions %: 54.388%	load and store instructions %: 40.339%
resource stalls % (of cycles): 61.877%	resource stalls % (of cycles): 69.901%
branch instructions %: 13.662%	branch instructions %: 15.203%
% of branch instr. mispredicted: 3.710%	% of branch instr. mispredicted: 4.086%
% of l2 loads missed: 13.892%	% of l2 loads missed: 14.836%
bus utilization %: 36.694%	bus utilization %: 41.271%
data bus utilization %: 14.155%	data bus utilization %: 15.757%
bus not ready %: 0.277%	bus not ready %: 0.393%
comp. SIMD inst. ('new FP') %: 0.000%	comp. SIMD inst. ('new FP') %: 13.792%
comp. x87 instr. ('old FP') %: 10.944%	comp. x87 instr. ('old FP') %: 0.014%

SPEC2006 410.bwaves – 32 bit mode – 4 jobs	SPEC2006 410.bwaves – 64 bit mode – 4 jobs
66184607716621 UNHALTED_CORE_CYCLES	82646441371942 UNHALTED_CORE_CYCLES
32038993376478 INSTRUCTIONS_RETIRED	43269747823376 INSTRUCTIONS_RETIRED
1045662341511 BRANCH_INSTRUCTIONS_RETIRED	3377043818102 BRANCH_INSTRUCTIONS_RETIRED
5569854319 MISPREDICTED_BRANCH_RETIRED	146650527607 MISPREDICTED_BRANCH_RETIRED
19500786788306 INST_RETIRED:LOADS	14517944486917 INST_RETIRED:LOADS
0 SIMD_COMP_INST_RETIRED:PACKED_SINGLE	10476785264283 SIMD_COMP_INST_RETIRED:PACKED_SINGLE
:SCALAR_SINGLE:PACKED_DOUBLE:SCALAR_DOUBLE	:SCALAR_SINGLE:PACKED_DOUBLE:SCALAR_DOUBLE
4768056184869 INST_RETIRED:STORES	2998919112401 INST_RETIRED:STORES
6752053870705 X87_OPS_RETIRED:ANY	10959281897 X87_OPS_RETIRED:ANY
55650366867224 RESOURCE_STALLS:ANY	62157492993642 RESOURCE_STALLS:ANY
2795205261519 BUS_TRANS_ANY:ALL_AGENTS	2794173784751 BUS_TRANS_ANY:ALL_AGENTS
1975145132590 BUS_DRDY_CLOCKS:ALL_AGENTS	1974651943707 BUS_DRDY_CLOCKS:ALL_AGENTS
36173999054 BUS_BNR_DRV:ALL_AGENTS	35367284875 BUS_BNR_DRV:ALL_AGENTS
580148778988 LAST_LEVEL_CACHE_REFERENCES	550307895671 LAST_LEVEL_CACHE_REFERENCES
81972164145 LAST_LEVEL_CACHE_MISSES	112587229075 LAST_LEVEL_CACHE_MISSES
7369433865245 CPU_CLK_UNHALTED:BUS	9209403050219 CPU_CLK_UNHALTED:BUS
--	--
Ratios:	Ratios:
CPI: 2.0658	CPI: 1.9100
load instructions %: 60.866%	load instructions %: 33.552%
store instructions %: 14.882%	store instructions %: 6.931%
load and store instructions %: 75.748%	load and store instructions %: 40.483%
resource stalls % (of cycles): 84.084%	resource stalls % (of cycles): 75.209%
branch instructions %: 3.264%	branch instructions %: 7.805%
% of branch instr. mispredicted: 0.533%	% of branch instr. mispredicted: 4.343%
% of l2 loads missed: 14.130%	% of l2 loads missed: 20.459%
bus utilization %: 75.859%	bus utilization %: 60.681%
data bus utilization %: 26.802%	data bus utilization %: 21.442%
bus not ready %: 0.982%	bus not ready %: 0.768%
comp. SIMD inst. ('new FP') %: 0.000%	comp. SIMD inst. ('new FP') %: 24.213%
comp. x87 instr. ('old FP') %: 21.074%	comp. x87 instr. ('old FP') %: 0.025%

- A BAD example
- Much slower in 64bit mode
  - Using MORE instructions in 64bit mode
  - Much higher L2 cache miss rate in 64bit mode
  - More branches in 64bit mode
  - Significantly more mispredicted branches in 64bit mode
  - BNR and bus utilisation actually lower in 64bit mode

Pfmon – SPEC2006 example II

- A really GOOD example
- Much faster in 64bit mode
  - ~46% fewer "core cycles" !!!
  - Only ~12% fewer instructions

SPEC2006 435.gromacs – 32bit mode – 4 jobs	SPEC2006 435.gromacs – 64bit mode – 4 jobs
52545097029601 UNHALTED_CORE_CYCLES	28335415184402 UNHALTED_CORE_CYCLES
28239032175254 INSTRUCTIONS_RETIRED	24923444284898 INSTRUCTIONS_RETIRED
786718407198 BRANCH_INSTRUCTIONS_RETIRED	755991835848 BRANCH_INSTRUCTIONS_RETIRED
49833012629 MISPREDICTED_BRANCH_RETIRED	48309357560 MISPREDICTED_BRANCH_RETIRED
11318465152987 INST_RETIRED:LOADS	8722788997385 INST_RETIRED:LOADS
0 SIMD_COMP_INST_RETIRED:PACKED_SINGLE	9695772998672 SIMD_COMP_INST_RETIRED:PACKED_SINGLE
:SCALAR_SINGLE:PACKED_DOUBLE:SCALAR_DOUBLE	:SCALAR_SINGLE:PACKED_DOUBLE:SCALAR_DOUBLE
5018510676257 INST_RETIRED:STORES	3515929682894 INST_RETIRED:STORES
9717550976444 X87_OPS_RETIRED:ANY	169222816 X87_OPS_RETIRED:ANY
41735531957443 RESOURCE_STALLS:ANY	18613627304402 RESOURCE_STALLS:ANY
74104263298 BUS_TRANS_ANY:ALL_AGENTS	76000740916 BUS_TRANS_ANY:ALL_AGENTS
59386726849 BUS_DRDY_CLOCKS:ALL_AGENTS	61365932872 BUS_DRDY_CLOCKS:ALL_AGENTS
15596654 BUS_BNR_DRV:ALL_AGENTS	32145113 BUS_BNR_DRV:ALL_AGENTS
224259236583 LAST_LEVEL_CACHE_REFERENCES	227650501186 LAST_LEVEL_CACHE_REFERENCES
3380348570 LAST_LEVEL_CACHE_MISSES	3661361080 LAST_LEVEL_CACHE_MISSES
5842738075086 CPU_CLK_UNHALTED:BUS	3152227191304 CPU_CLK_UNHALTED:BUS
--	--
Ratios:	Ratios:
CPI: 1.8607	CPI: 1.1369
load instructions %: 40.081%	load instructions %: 34.998%
store instructions %: 17.772%	store instructions %: 14.107%
load and store instructions %: 57.852%	load and store instructions %: 49.105%
resource stalls % (of cycles): 79.428%	resource stalls % (of cycles): 65.690%
branch instructions %: 2.786%	branch instructions %: 3.033%
% of branch instr. mispredicted: 6.334%	% of branch instr. mispredicted: 6.390%
% of l2 loads missed: 1.507%	% of l2 loads missed: 1.608%
bus utilization %: 2.537%	bus utilization %: 4.822%
data bus utilization %: 1.016%	data bus utilization %: 1.947%
bus not ready %: 0.001%	bus not ready %: 0.002%
comp. SIMD inst. ('new FP') %: 0.000%	comp. SIMD inst. ('new FP') %: 38.902%
comp. x87 instr. ('old FP') %: 34.412%	comp. x87 instr. ('old FP') %: 0.001%

Pfmon – The results – lxbatch

- ## Pfmon in system-wide mode
  - ### Running on five batch nodes for one month
  - ### All "inefficiencies" like waiting for CASTOR are included !!
  - ### ~10% floating point content
    - ~70% is in 32bit mode
    - ~30% is in 64bit mode

```
83944504728489062 UNHALTED_CORE_CYCLES
73367226776016493 INSTRUCTIONS_RETIRED
10686337067594955 BRANCH_INSTRUCTIONS_RETIRED
  311480171783874 MISPREDICTED_BRANCH_RETIRED
24721876265962484 INST_RETIRED:LOADS
 2283757395310938 SIMD_COMP_INST_RETIRED:PACKED_SINGLE
          :SCALAR_SINGLE:PACKED_DOUBLE:SCALAR_DOUBLE
12290157485830441 INST_RETIRED:STORES
 5471569673512022 X87_OPS_RETIRED:ANY
32749455427271767 RESOURCE_STALLS:ANY
  879105305211474 BUS_TRANS_ANY:ALL_AGENTS
  669442811829209 BUS_DRDY_CLOCKS:ALL_AGENTS
   25343960918275 BUS_BNR_DRV:ALL_AGENTS
 1249350584406064 LAST_LEVEL_CACHE_REFERENCES
   32338430323044 LAST_LEVEL_CACHE_MISSES
10798222210620212 CPU_CLK_UNHALTED:BUS
-------------------------------------------------------
Ratios:
                        CPI: 1.1442
            load instructions %: 33.696%
           store instructions %: 16.752%
  load and store instructions %: 50.448%
  resource stalls % (of cycles): 39.013%
          branch instructions %: 14.566%
% of branch instr. mispredicted: 2.915%
          % of l2 loads missed: 2.588%
             bus utilization %: 16.282%
        data bus utilization %: 6.200%
              bus not ready %: 0.469%
  comp. SIMD inst. ('new FP') %: 3.113%
  comp. x87 instr. ('old FP') %: 7.458%
```

Pfmon – The results – lxbatch cont.

- ## Code seems relatively efficient – CPI of 1.17
- ## Few resource stalls
- ## Bus and data bus utilisations are very low
  - The *Bus Not Ready* percentage of 0.469% points to bus congestions under full load ... and "bursty" memory access patterns!!!!

```
  83944504728489062 UNHALTED_CORE_CYCLES
  73367226776016493 INSTRUCTIONS_RETIRED
  10686337067594955 BRANCH_INSTRUCTIONS_RETIRED
    311480171783874 MISPREDICTED_BRANCH_RETIRED
  24721876265962484 INST_RETIRED:LOADS
   2283757395310938 SIMD_COMP_INST_RETIRED:PACKED_SINGLE
              :SCALAR_SINGLE:PACKED_DOUBLE:SCALAR_DOUBLE
  12290157485830441 INST_RETIRED:STORES
   5471569673512022 X87_OPS_RETIRED:ANY
  32749455427271767 RESOURCE_STALLS:ANY
    879105305211474 BUS_TRANS_ANY:ALL_AGENTS
    669442811829209 BUS_DRDY_CLOCKS:ALL_AGENTS
     25343960918275 BUS_BNR_DRV:ALL_AGENTS
   1249350584406064 LAST_LEVEL_CACHE_REFERENCES
     32338430323044 LAST_LEVEL_CACHE_MISSES
  10798222210620212 CPU_CLK_UNHALTED:BUS
-------------------------------------------------------
Ratios:
                          CPI: 1.1442
            load instructions %: 33.696%
           store instructions %: 16.752%
  load and store instructions %: 50.448%
  resource stalls % (of cycles): 39.013%
         branch instructions %: 14.566%
% of branch instr. mispredicted: 2.915%
            % of l2 loads missed: 2.588%
               bus utilization %: 16.282%
          data bus utilization %: 6.200%
                bus not ready %: 0.469%
  comp. SIMD inst. ('new FP') %: 3.113%
  comp. x87 instr. ('old FP') %: 7.458%
```
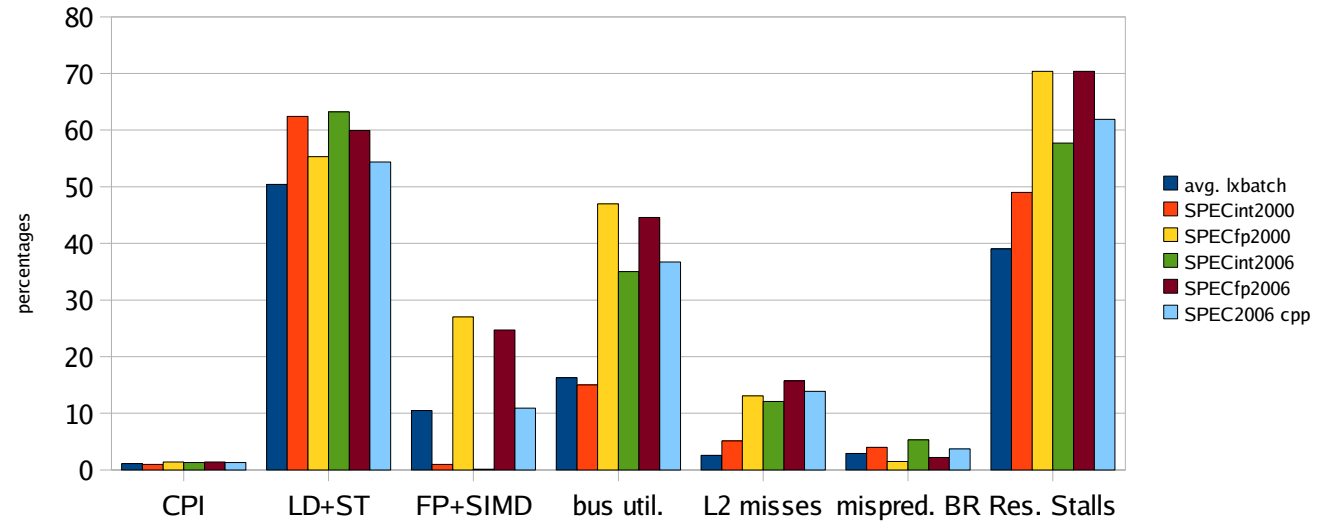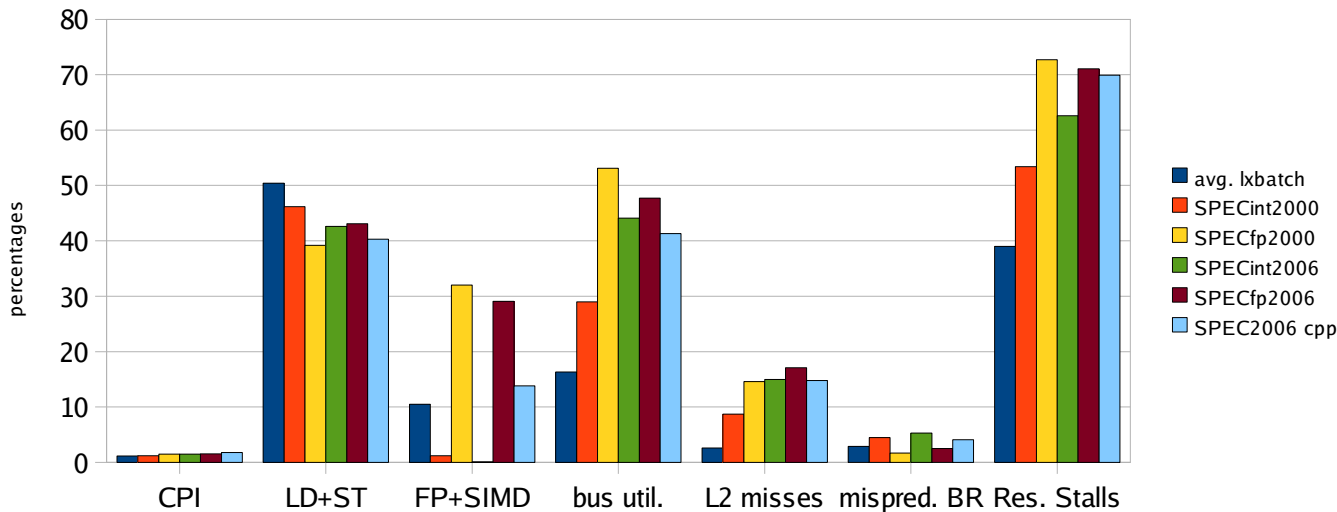
Lxbatch - everything	Lxbatch – under load (more than 87.5% of cycles used)
83944504728489062 UNHALTED_CORE_CYCLES	42144662725260216 UNHALTED_CORE_CYCLES
73367226776016493 INSTRUCTIONS_RETIRED	36103982787223754 INSTRUCTIONS_RETIRED
10686337067594955 BRANCH_INSTRUCTIONS_RETIRED	5360125638092404 BRANCH_INSTRUCTIONS_RETIRED
311480171783874 MISPREDICTED_BRANCH_RETIRED	152446109206656 MISPREDICTED_BRANCH_RETIRED
24721876265962484 INST_RETIRED:LOADS	12120993052849229 INST_RETIRED:LOADS
2283757395310938 SIMD_COMP_INST_RETIRED:PACKED_SINGLE	1121532429684894 SIMD_COMP_INST_RETIRED:PACKED_SINGLE
:SCALAR_SINGLE:PACKED_DOUBLE:SCALAR_DOUBLE	:SCALAR_SINGLE:PACKED_DOUBLE:SCALAR_DOUBLE
12290157485830441 INST_RETIRED:STORES	5970918951513077 INST_RETIRED:STORES
5471569673512022 X87_OPS_RETIRED:ANY	2539982276037386 X87_OPS_RETIRED:ANY
32749455427271767 RESOURCE_STALLS:ANY	16566025785506481 RESOURCE_STALLS:ANY
879105305211474 BUS_TRANS_ANY:ALL_AGENTS	474022962607770 BUS_TRANS_ANY:ALL_AGENTS
669442811829209 BUS_DRDY_CLOCKS:ALL_AGENTS	359724451168553 BUS_DRDY_CLOCKS:ALL_AGENTS
25343960918275 BUS_BNR_DRV:ALL_AGENTS	13925551815460 BUS_BNR_DRV:ALL_AGENTS
1249350584406064 LAST_LEVEL_CACHE_REFERENCES	618434008358344 LAST_LEVEL_CACHE_REFERENCES
32338430323044 LAST_LEVEL_CACHE_MISSES	17859525620786 LAST_LEVEL_CACHE_MISSES
10798222210620212 CPU_CLK_UNHALTED:BUS	5293924072201402 CPU_CLK_UNHALTED:BUS
---	---
Ratios:	Ratios:
CPI: 1.1442	CPI: 1.1673
load instructions %: 33.696%	load instructions %: 33.572%
store instructions %: 16.752%	store instructions %: 16.538%
load and store instructions %: 50.448%	load and store instructions %: 50.111%
resource stalls % (of cycles): 39.013%	resource stalls % (of cycles): 39.308%
branch instructions %: 14.566%	branch instructions %: 14.846%
% of branch instr. mispredicted: 2.915%	% of branch instr. mispredicted: 2.844%
% of l2 loads missed: 2.588%	% of l2 loads missed: 2.888%
bus utilization %: 16.282%	bus utilization %: 17.908%
data bus utilization %: 6.200%	data bus utilization %: 6.795%
bus not ready %: 0.469%	bus not ready %: 0.526%
comp. SIMD inst. ('new FP') %: 3.113%	comp. SIMD inst. ('new FP') %: 3.106%
comp. x87 instr. ('old FP') %: 7.458%	comp. x87 instr. ('old FP') %: 7.035%

Comparison 32bit

Comparison 64bit

- None of the benchmarks looks like a perfect match to the results from lxbatch ...

- ... but ... all C++ benchmarks from SPEC2006 are a pretty good match for
  - Floating Point content
  - Loads and stores
  - Mispredicted branches

- Very low bus utilisation on batch nodes
  - ... but ... *BNR* is quite high, pointing to a very uneven memory access pattern and congestion

- Batch machines running 2.6.24.x & pfmon are stable !!!!! ... and are actually ~10% faster ;-)

- New machines will go into production soon
  - Using the latest perfmon/pfmon
  - 50 boxes will be set up to run pfmon in system-wide mode
  - Statistics will significantly increase
  - Include the special queues for CMS and ATLAS
- Using pfmon to take a closer look at software from the experiments
- More measurements
  - with different compilers
  - On different systems (i.e. Harpertowns)
- Paper is being prepared