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September 22, 2005

Benchmarking dual-core AMD Opteron (AMD64) systems

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Abstract

We have tested AMD's dual-core Opteron and (single core) AMD Athlon 64 processors using various HEP and CMS specific applications as benchmarks. The results are presented in this note. We find the performance of AMD's dual-core Opteron processors impressive. The performance of the chips scales well as the number of copies of a given application is increased. They do not create much heat and consume very little power compared to the performance increase they provide. This kind of power draw will make these AMD dual-core processors a very attractive choice when running farms of high-performance machines.

second revised version

1 Introduction

In this note we follow up on the work presented in [1]. Dual-core CPU's are now available. They promise to nearly double the computing power while not increasing the infrastructure cost especially for cooling and electricity significantly compared to boxes equipped with single-core chips. We should also benefit from:

- lower space requirements and need for fewer racks.
- fewer console connections.
- fewer network connections although this might adversely affect the performance when one network interface is shared by 4 instead of 2 cpu-cores. Therefore having more processes competing for the same bandwidth. (the same is true for disk IO).
- nearly half the cooling and electricity cost for the same CPU power.

This makes these chips very attractive for running a cluster of high-performance machines. Nowadays the amount of computing power that can be provided is very often limited by the amount of cooling and electrical power that the computing center can provide. This report presents benchmark results obtained with dual-core Opteron machines and the results are compared to single-core machines that were tested previously (see [1] or for different benchmarks see [2]). We also tested an AMD Athlon 64 machine. While the Opteron processors target the server market the AMD Athlon 64 is intended for use in desktop machines. We were especially interested in two things:

- how does the performance of these processors scale when running up to 4 copies of various applications simultaneously.
- how much power do these chips consume (how hot do they run?).

For information about the architecture of the Opteron chip see [1], [7],[8].

2 Installation and Administration

As operating system we used Scientific Linux 3.04 which is available in 32 Bit and 64 Bit and comes with the 2.4.21 kernel. We had no problems installing this on the dual-core machines. We haven't tried to upgrade to a 2.6 kernel. In this note we only present results using the 64 Bit OS.

In principle the new platform behaves like any PC. Linux distributions exist and installation and booting the system just works as we are used to. We also successfully used the Rocks Cluster Distribution to install the OS.

With the new platform System management becomes a little bit more complex. When running with a 64 Bit OS in addition to the 64 Bit libraries also the 32 Bit Environment must be provided and maintained to allow applications to run in compatibility mode. Some of the tools (e.g. APT) are not multi platform aware and for other tools (YUM, RPM) the support for the new environment could be improved.

3 Benchmark Applications

We wanted to run benchmarks related to CMS physics. Porting and compiling all of the CMS OO (namely OSCAR and ORCA) ([3]) software for the new platform to run in **(64Bit/64Bit)** mode requires a lot of work and the recompilation of all the underlying libraries (e.g. POOL, SEAL....). Therefore we benchmarked this applications only in **(64Bit/32Bit)** mode. **(32Bit/32Bit)** results can be found on [1].

The CMS OO applications were installed using **DAR** ([4]) which provides a 'nearly' complete runtime environment for various CMS applications but doesn't allow for recompilation.

We also included several ROOT ([5]) based tests and also the Monte Carlo generator Pythia ([6]) in the test suite. CMS code and ROOT are dynamically linked C++ programs while PYTHIA is a statically linked FORTRAN program.

The Applications needed to be compiled in 64 Bit. For the recompilation we used the g++ (ROOT) and g77 (Pythia) compilers based on gcc version 3.2.3 that is provided with Scientific Linux 3.04.

- **ROOT:** We are using the 4.02/00 production version of ROOT and configured it for 64 Bit using the command: **configure linuxx8664gcc**
  ROOT provides various benchmarking routines testing various aspects with its distribution: Here we only use the stress benchmark which is a suite of programs that tests the essential parts of Root. In particular, there is an extensive test of the I/O system and Trees.
- **Pythia:** For the benchmark we run 100.000 super symmetry events at $\sqrt{s}$ =14 TeV (the Pythia main65.f example). The code is compiled with g77 with the O2 option:
  g77 -O2 -o main65 main65.f pythia6227.o
- **OSCAR_3_7_0:** The GEANT 4 based CMS detector simulation program. Here we simulate 300 single pion events of 50 GeV/c P_t.
- **ORCA_8_7_1:** The OSCAR output events are then digitized (writeAllDigis) and reconstructed (writeDST) with the corresponding ORCA applications:
  - **writeAllDigis**
  - **writeDST**

Table 3 shows the matrix of the different applications that we used to benchmark the performance and the different operation modes that we tested.

Application	**Operating mode:**	
	Compatibility (64Bit/32Bit)	64-bit (64Bit/64Bit)
ROOT: stress (up to 4 copies simultaneously)	Yes	Yes
Pythia (up to 4 copies simultaneously)	Yes	Yes
OSCAR (up to 4 copies simultaneously)	Yes	N/A
ORCA Digitization (up to 4 copies simultaneously)	Yes	N/A
ORCA Reconstruction (up to 4 copies simultaneously)	Yes	N/A

Table 1: *Matrix of various benchmarks run in the different operating modes.*

4 Hardware

The dual-core Opterons that we tested were the AMD Opteron 265 (1.8 Ghz) chip, the AMD Opteron 270 (2.0 GHz) and the AMD Opteron 275 (2.2 GHz) chips with 2 x 128k L1 Cache and 2 x 1 MB L2 Cache. The dual-core chips are based on the Italy Dual Core Architecture using 0.09 Micron technology. The chips are pin compatible with Opteron platforms of the last two years, therefore require nothing more than a BIOS update in order for most older motherboards to support this new architecture. For comparison we list results obtained previously (see [1] with an AMD Opteron 244 (1.8 GHz) 246 (2.0 GHz) chip and an AMD Opteron 248 (2.2 Ghz) with 128k L1 Cache and 1 MB L2 Cache which should be very similar in performance per core when compare to the dual core machines running at the same speed. The single-core chips are based on 0.13 Micron technology. We also tested an AMD Athlon 64 Processor 3500+ (2211MHz) with 512 KB cache. The last processor is intended for the use in desktop machines.

Processor	Speed	Architecture
Opteron 244	1.8 Ghz	AMD-64 (single-core)
Opteron 265	1.8 Ghz	AMD-64 (dual-core)
Opteron 246	2.0 Ghz	AMD-64 (single-core)
Opteron 270	2.0 Ghz	AMD-64 (dual-core)
AMD Athlon 64	2.2 Ghz	AMD-64 (single core))
Opteron 248	2.2 Ghz	AMD-64 (single-core)
Opteron 275	2.2 Ghz	AMD-64 (dual-core)

Table 2: *Processors tested.*

5 Benchmarking results

In this section we present the various benchmark results.

Pythia Benchmarking results								
	Operating mode:							
	Compatibility (64Bit/32Bit)				64-bit (64Bit/64Bit)			
CPU	single (Events/sec)	$\times$ 2 (av.) (Events/sec)	$\times$ 3 (av.) (Events/sec)	$\times$ 4 (av.) (Events/sec)	single (Events/sec)	$\times$ 2 (av.) (Events/sec)	$\times$ 3 (av.) (Events/sec)	$\times$ 4 (av.) (Events/sec)
244	90.3	90.4	-	-	110.1	110	-	-
265	91.98	92.11	92.1	92.03	110.9	110.91	110.8	110.38
246	100.9	101.1	-	-	121.2	121.5	-	-
270	102.36	102.44	102.35	102.31	122.95	122.95	123.02	123.07
AMD64	111.06	-	-	-	129.8		-	-
248	112.3	112.3	-	-	136.4	136.1	-	-
275	112.67	112.75	112.6	112.5	135.3	135.3	135.2	134.9

Table 3: *Summary of Pythia Benchmarking results. We see basically no drop in performance when running up to 4 copies of Pythia simultaneously. Again as we observed in [1] there is a 20 % boost in performance when running in (64/64) bit mode compared to (64Bit/32Bit) compatibility mode.*

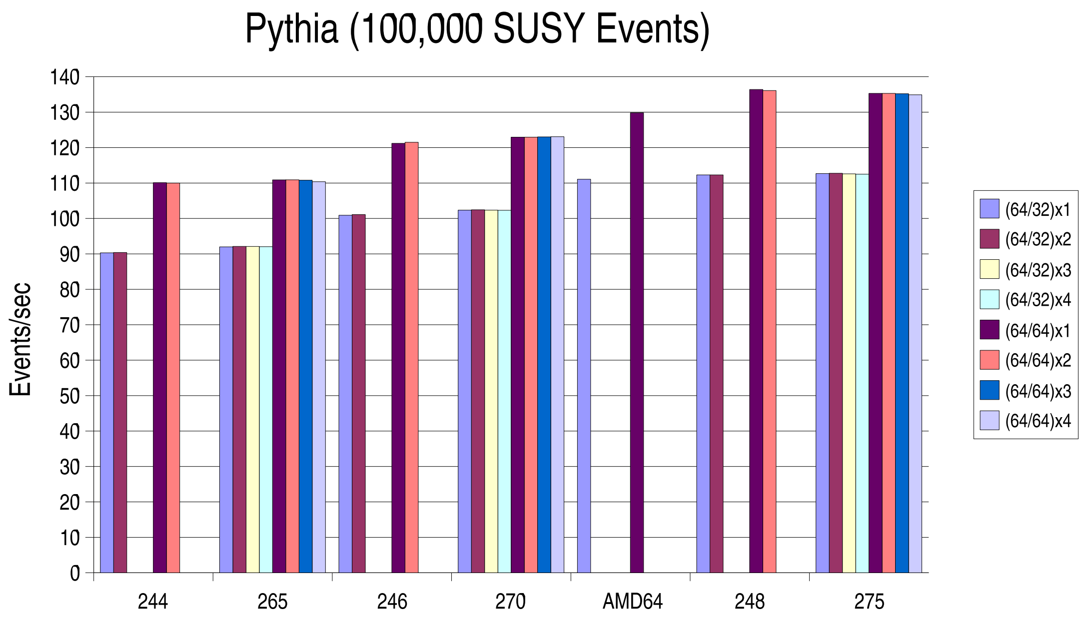

Figure 1: *Summary of Pythia Benchmarking results. We see basically no drop in performance when running up to 4 copies of Pythia simultaneously. Again as we observed in [1] there is a 20 % boost in performance when running in (64/64) bit mode compared to (64Bit/32Bit) compatibility mode.*

ROOT Stress								
	Operating mode:							
	Compatibility (64Bit/32Bit)				64-bit (64Bit/64Bit)			
CPU	single ROOTMks	× 2 (av.) ROOTMks	× 3 (av.) ROOTMks	× 4 (av.) ROOTMks	single ROOTMks	× 2 (av.) ROOTMks	× 3 (av.) ROOTMks	× 4 (av.) ROOTMks
244	672.5	373.3	-	-	1059.9	1050.75	-	-
265	719.3	718.7	719.6	715.65	1093.3	1085.35	1077.1	1075.9
246	751.6	748.25	-	-	1176.1	1165.65	-	-
270	827.3	819.3	819.77	819.33	1201.6	1201.75	1190.9	1182.8
AMD64	891.4	-	-	-	1295.9	-	-	-
248	834.7	835.75	-	-	1320.8	1305.95	-	-
275	910.2	907.1	904.2	903	1327.96	1335.1	1311.1	1306

Table 4: *Summary of Root Stress Benchmarking results. We observe that this application also scales very well. There is only a 1.6% performance drop when running 4 copies of stress simultaneously on the dual-cores.*

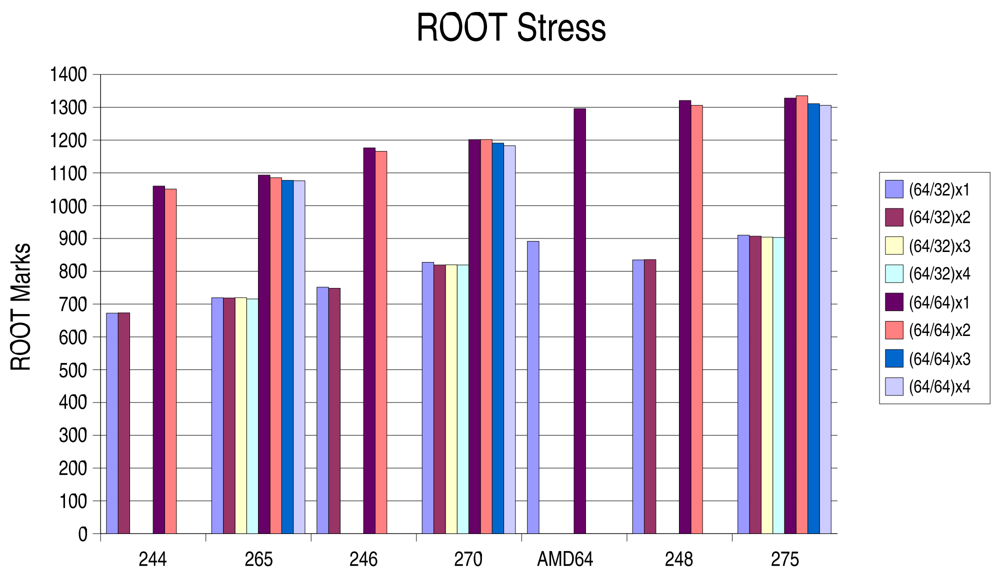

Figure 2: *Summary of Root Stress Benchmarking results. There is only a 1.6% performance drop when running 4 copies of stress simultaneously on the dual-cores.*

CMS OO Benchmarks				
	Operating mode: Compatibility (64Bit/32Bit)			
CPU	single (Evt./sec)	× 2 (av.) (Evt./sec)	× 3 (av.) (Evt./sec)	× 4 (av.) (Evt./sec)
	OSCAR 300 single 50GeV Pion Events			
Opteron 244	0.0866	0.0867	-	-
Opteron 265	0.0920	0.0918	0.0916	0.0912
Opteron 246	0.0956	0.0959	-	-
Opteron 270	0.1016	0.1012	0.0999	0.0994
AMD64	0.1076	-	-	-
Opteron 248	0.1067	0.1074	-	-
Opteron 275	0.1089	0.1088	0.1081	0.1073
	ORCA Digitization 300 single 50GeV Pion Events			
Opteron 244	0.0989	0.098	-	-
Opteron 265	0.1096	0.108	0.1092	0.1089
Opteron 246	0.1092	0.108	-	-
Opteron 270	0.1311	0.1290	0.1267	0.1268
AMD64	0.1421	-	-	-
Opteron 248	0.1210	0.1196	-	-
Opteron 275	0.142	0.140	0.140	0.138
	ORCA Reconstruction (DST) 300 single 50GeV Pion Events			
Opteron 244	0.809	0.806	-	-
Opteron 265	0.9263	0.9268	0.9058	0.9131
Opteron 246	0.901	0.895	-	-
Opteron 270	1.055	1.057	0.974	0.962
AMD64	1.118	-	-	-
Opteron 248	0.974	0.988	-	-
Opteron 275	1.106	1.089	0.946	0.864

Table 5: *Summary of CMS Benchmarking results. As the Applications become more IO intense we observe that the efficiency drop increases as the processes compete for disk IO bandwidth. We observe that OSCAR which is very CPU intensive and which requires a lot of memory but is not very IO intensive scales very well resulting in a performance drop of only 0.9 %/2.2 %/1.6 % on the 265/270/275 running 4 copies of OSCAR simultaneously. For the ORCA digitization the drop is 0.6 %/3.3 %/2.8 % on the 265/270/275 running 4 copies simultaneously. For the ORCA reconstruction (DST) application we observe a significant drop in performance of 1.4 %/8.8 %/21.8 % for the 265/270/275 respectively.*

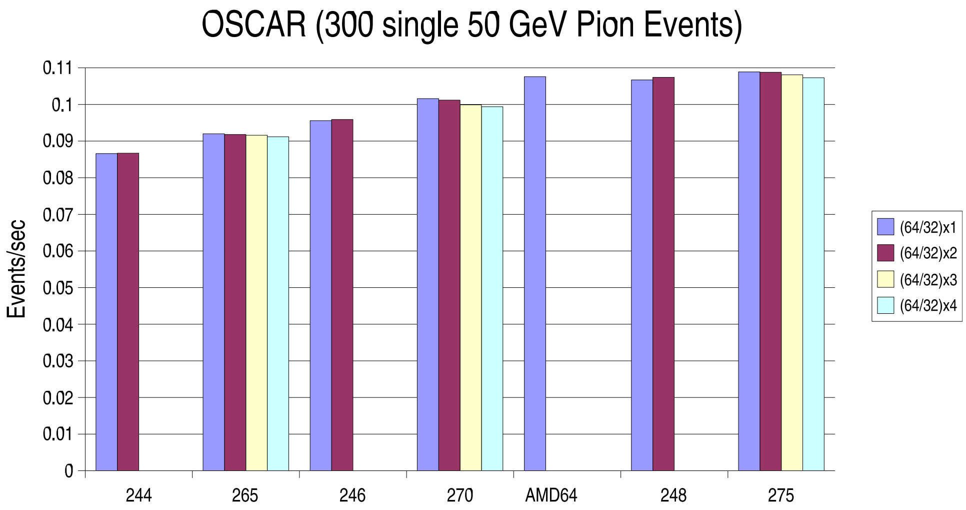

Figure 3: *Summary of OSCAR Benchmarking results. We observe that this application which is very CPU but not very IO intensive also scales very well. The performance drop is only 0.9 %/2.2 %/1.6 % on the 265/270/275 running 4 copies of OSCAR simultaneously.*

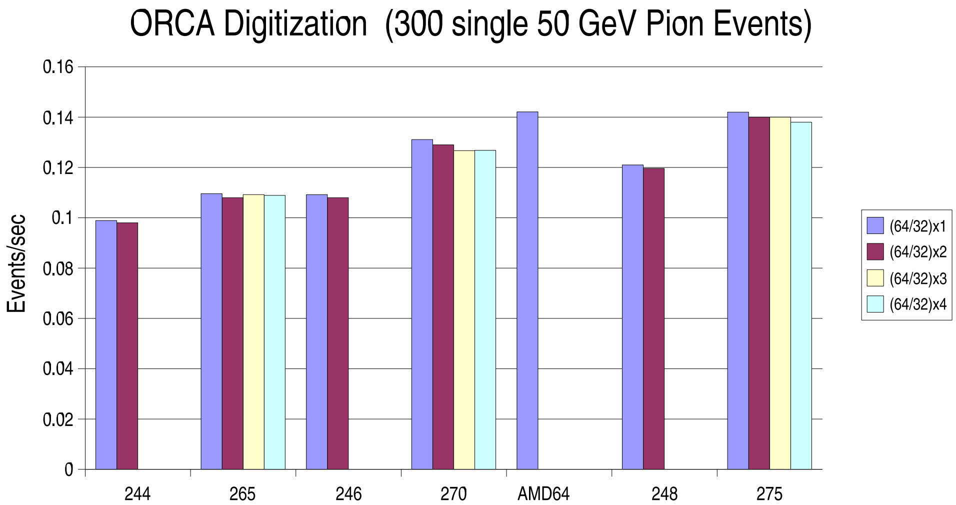

Figure 4: *Summary of ORCA Digitization Benchmarking results. The performance drop is .6 %/3.3 %/2.8 % on the 265/270/275 running 4 copies of the ORCA Digitization simultaneously.*

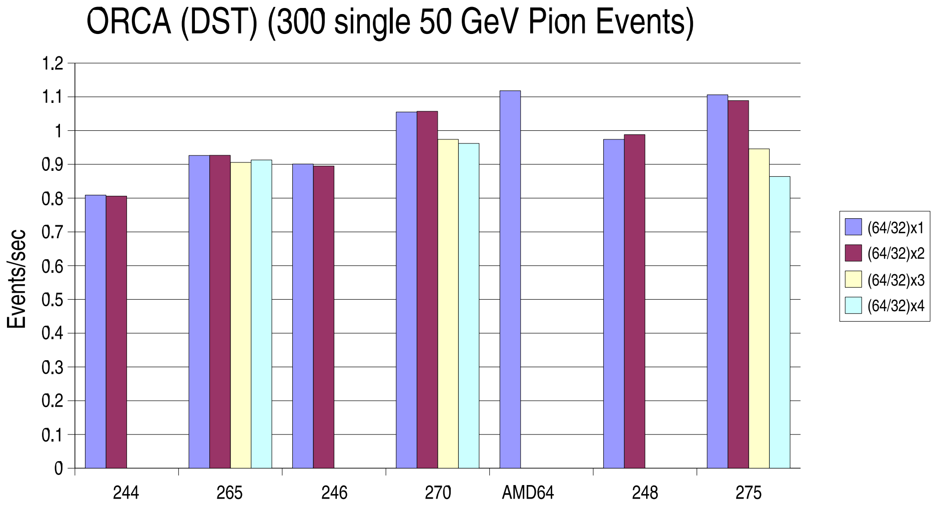

Figure 5: *Summary of ORCA DST (Reconstruction) Benchmarking results. For this application we observe the highest degradation in efficiency when ramping up the number of simultaneously running copies of this application. We observe a significant drop in performance of 1.4 %/8.8 %/21.8 % for the 265/270/275 respectively.*

6 Power consumption

Power Consumption		
CPU	Idle	Loaded
242	1.2A	1.4A
248	1.4A	1.6A
270	1.2A	1.7A

Table 6: *Summary of power consumption based on idle load running LTS 3.04 (64 Bit) and fully loaded CPUs using a calculation of π and running "dd"*

As shown in Table 6, the dual core CPUs use a very comparable amount of power as the single core CPUs. In fact, when idle, the dual core CPUs actually consume less power than some of the single core CPUs. This is because the dual-core chips are now equipped with AMD's Power Now! [9] technology that will reduce power consumption at idle with the proper OS and BIOS setup opening the possibility for significant power savings. It will be interesting to explore this in the future. This shows that we in fact get twice the performance using dual-core CPUs for the same cost in power and cooling. The loads were brought up by using a program to calculate π doing an infinite loop, and "dd".

Also, a big difference between the latest dual-core Opteron processors and Intel's Xeon lineup is reported in [10].

7 Conclusion

We have tested AMD's dual-core Opteron 265, 270 and 275 processors using various HEP and CMS specific applications as benchmarks. We find the performance of AMD's dual-core Opteron processors is very impressive. The performance of the chips scales very nicely as the number of copies of a given application is increased. We only observe a significant performance drop when running the Orca reconstruction program (DST). These processors do not create much heat and consume very little power compared to the performance increase they provide. This kind of power draw will make these AMD dual-core processors a very attractive choice when running farms of high-performance machines. For comparison we included results obtained previously with single core opterons. We also benchmarked (single core) AMD Athlon 64 which now are available for user desktop machines. for the HEP applications that were used here when running a single process per CPU core this processor provides the same performance as the Opteron processors running at the same speed for the HEP applications that were used here.

Acknowledgment

We would like to thank Justin Boggs from the AMD Developer Center for answering all of our questions. One of the dual-core machines we tested was provided by Koi Computers [11]. The Sun Fire V20z with the Opteron 275 was given on loan to CERN by SUN Microsystems, Switzerland [12].

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