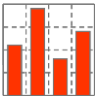


Performance Baseline of Hitachi Data Systems UCP for Oracle

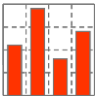
Part I: CPU Performance

Benchmark Performance Suite Release 8.5 (Build 131015)

October 2013



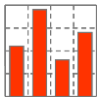
- 1 Introduction to CPU Performance Tests**
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Why measure CPU performance?

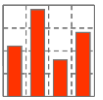
- CPU performance has a huge impact on
 - performance of most database operations
 - Oracle license (*core factor*) and maintenance cost - even with Unlimited License Agreement (ULA)

CPU Performance



What is measured?

- CPU performance from the Oracle point of view
 - Pure processor performance
 - Including level 1, 2, 3 cache
 - No memory access
 - No I/O operations
- Speed of single thread
 - Elapsed time [s] for algorithms
 - Operations per second [ops]
- Maximum throughput of system
 - Operations per second [ops]
- Scalability
 - Throughput per process for $n = \{1, 2, 4, 8, \dots, n\}$
- Efficiency of
 - Multi threading
 - Virtualization
 - Encryption

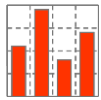


How is CPU performance measured?

- Following data types are most important for Oracle applications
 - PLS_INTEGER
 - NUMBER
 - VARCHAR2
 - DATE

- Benchware uses these Oracle data types in PL/SQL to measure the performance characteristics of a CPU
 - PL/SQL is the most powerful transaction programming language
 - Some important core applications are completely written in PL/SQL

CPU Performance



Overview of CPU performance tests with Benchware test codes

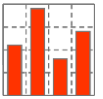
Oracle CPU Performance	Test Code for SIMPLE_INTEGER	Test Code for SIMPLE_FLOAT	Test Code for PLS_INTEGER	Test Code for NUMBER	Test Code for VARCHAR2
▪ Basic arithmetic operation	CPU-11	CPU-12	CPU-13	CPU-14	-

Oracle CPU Performance	Test Code for SIMPLE_INTEGER	Test Code for SIMPLE_FLOAT	Test Code for PLS_INTEGER	Test Code for NUMBER	Test Code for VARCHAR2
▪ Mixed operations and SQL built in functions	-	CPU-22	CPU-23	CPU-24	CPU-25

Oracle CPU Performance	Test Code for SIMPLE_INTEGER	Test Code for SIMPLE_FLOAT	Test Code for PLS_INTEGER	Test Code for NUMBER	Test Code for VARCHAR2
▪ Fibonacci numbers n = {39, 40, 41, 42}	-	-	-	CPU-34	-
▪ Prime numbers [2'000'000, 2'001'000]	-	-	-	CPU-44	-

Remarks:

- All CPU performance tests are using level 1, 2, 3 CPU cache and are therefore CPU bound.
- The Benchware Performance Suite uses optional encrypted tablespace to test the impact of encryption to performance.



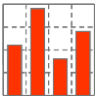
Remarks on other benchmark tools . . .

- SAP, TPC, Swingbench, Hammerora, ...
 - No specific CPU performance tests with Oracle data types

- SPEC, CPUbench, ...
 - No specific CPU performance tests with Oracle data types

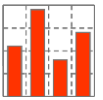
Remarks:

Application developers appreciate the very unique characteristics of the Oracle numeric data type NUMBER, therefore most Oracle applications use this data type as their standard numerical data type. The data type NUMBER uses a binary coded decimal implementation. This method can not be directly mapped to hardware data types and causes a lot of overhead. The performance of arithmetic operations with the data type NUMBER is therefore by factors slower than native data types like SIMPLE_INTEGER. Oracle implemented a specific software library for each processor architecture to handle numeric operations with the data type NUMBER. During our benchmarks, we experienced that the performance of the data type NUMBER does not correlate with industry standard SPEC benchmark results.



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CPU Performance



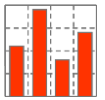
CPU Architecture

CPU	HDS UCP Large SMP	HDS UCP Small SMP
Type	Intel Xeon E7-8870	Intel Xeon E5-2690
Launch Date	2011	2012
Frequency [GHz]	2.4 – 2.8	2.9 – 3.8
#cores per socket	10	8
Multithreading	2-fold	2-fold
Performance numbers from other Benchmarks	HDS UCP Large SMP	HDS UCP Small SMP
SPECint_base2006 (speed)	36.4	55.4
Oracle CPU speed in sys.aux_stats\$	3'074	2'605

Remark:

Oracle has an internal estimation about CPU speed in sys.aux_stats\$, but none estimation about CPU throughput. The Oracle speed estimation does either correlate with SPECint_base2006 numbers nor with Benchware performance results in Oracle 11g Release 2.

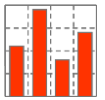
CPU Performance



Server Configuration

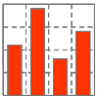
Server	HDS UCP Large SMP	HDS UCP Small SMP
CPU type	Intel Xeon E7-8870	Intel Xeon E5-2690
#sockets	4	2
#cores	40	16
#threads	80	32
#lcpu	-	-
Server Cost	-	-
Performance numbers from other Benchmarks	HDS UCP Large SMP	HDS UCP Small SMP
SPECint_rate_base2006 (throughput)	40 cores: 1'000	16 cores: 668
Software	HDS UCP Large SMP	HDS UCP Small SMP
Operating System	Oracle Linux 6.1	RedHat Linux 6.3
Oracle Database System	11.2.0.4	11.2.0.3
Benchware Performance Suite	8.5 Build 131015	8.4 Build 130731

CPU Performance



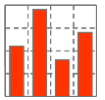
Oracle Licensing

Oracle Enterprise Edition	HDS UCP Large SMP	HDS UCP Small SMP
Oracle core license factor	x 0.5	x 0.5
Oracle license cost <small>(list price 25th of June 2013)</small>		
▪ Enterprise Edition (47'500)	950'000	380'000
▪ Partition Option (11'500)	230'000	92'000
▪ Diagnostic Pack (5'000)	100'000	40'000
▪ Tuning Pack (5'000)	100'000	40'000
Total Oracle license cost	1'380'000	552'000

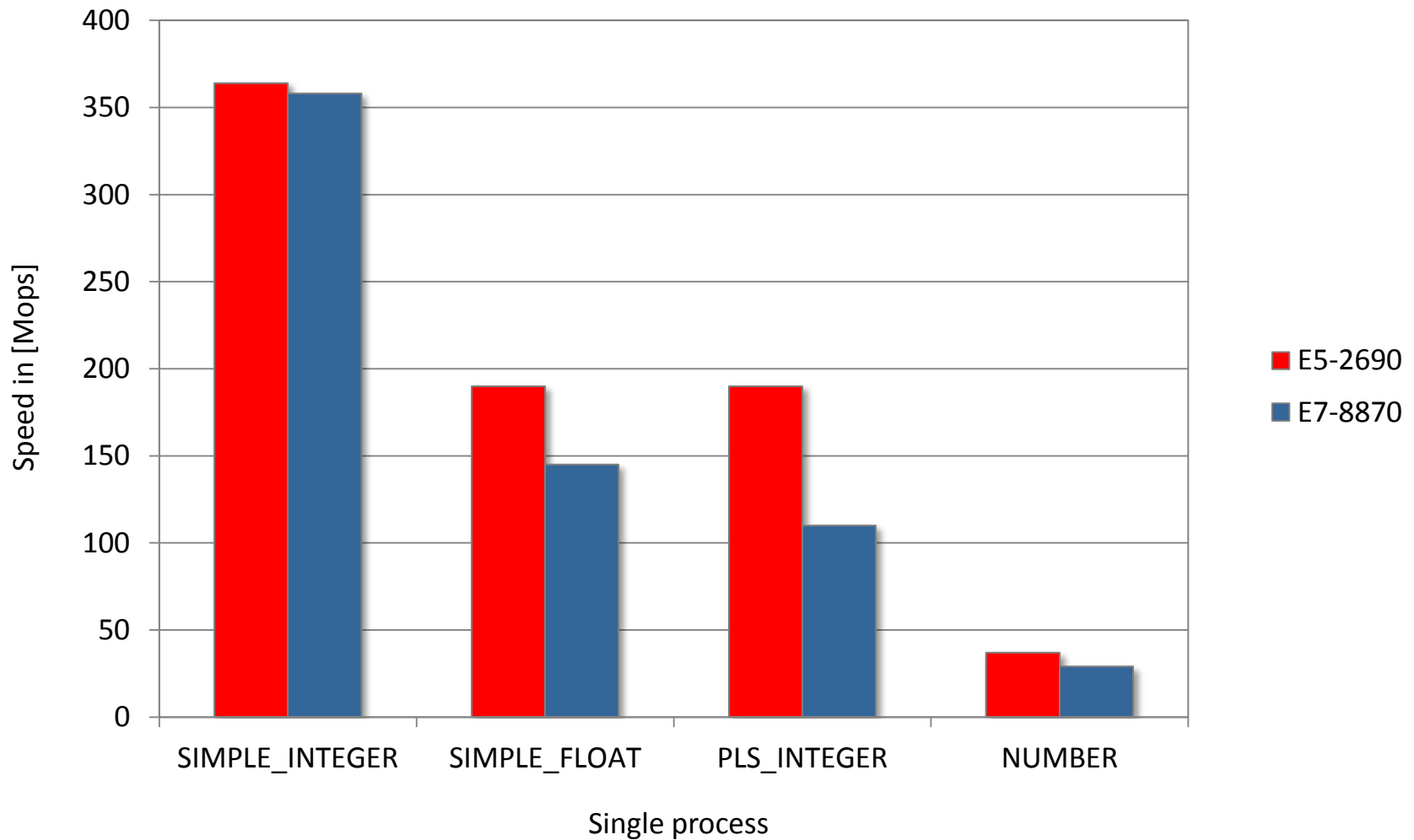


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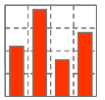
CPU Performance



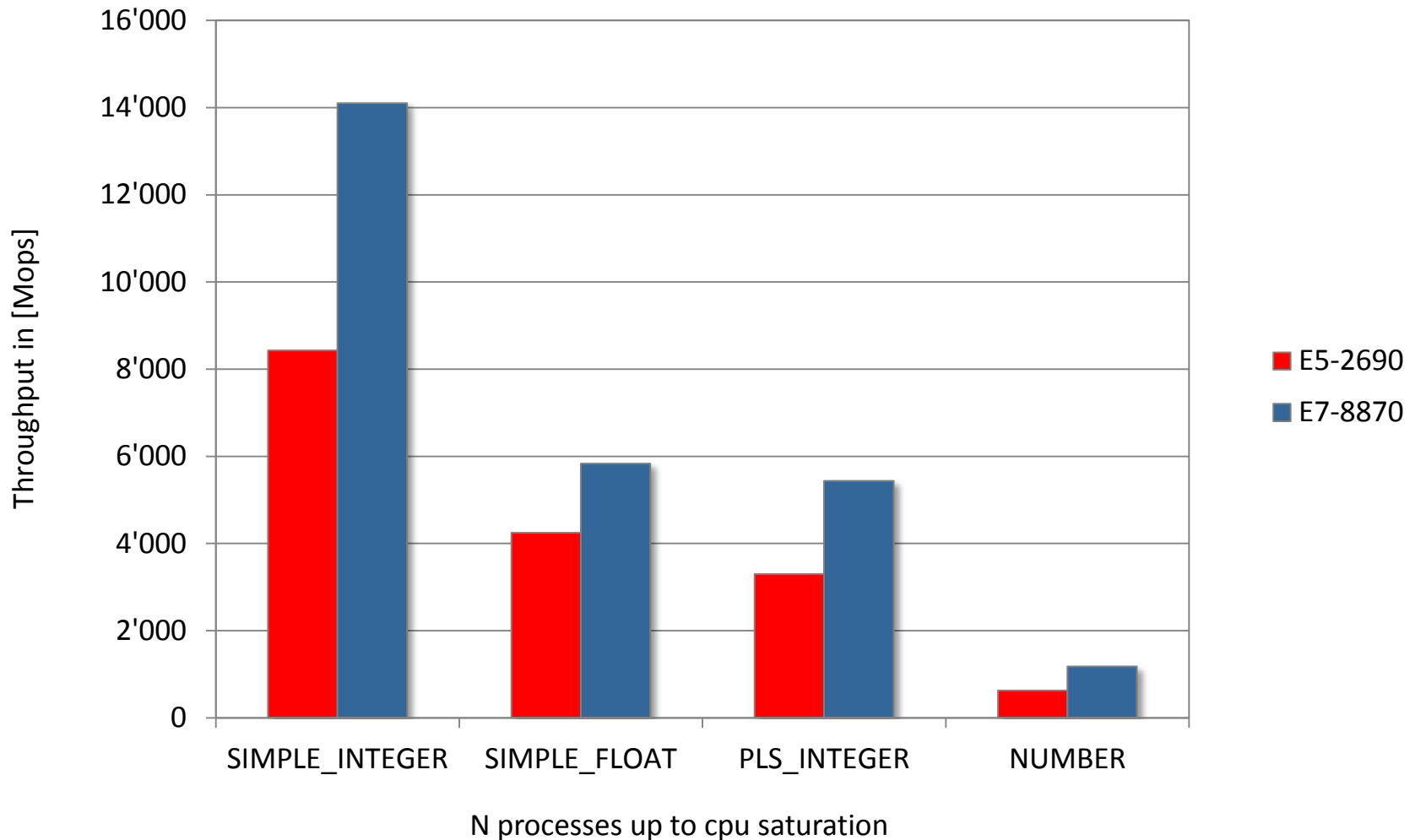
Single process speed, arithmetic ADD operation, different Oracle data types



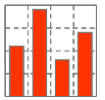
CPU Performance



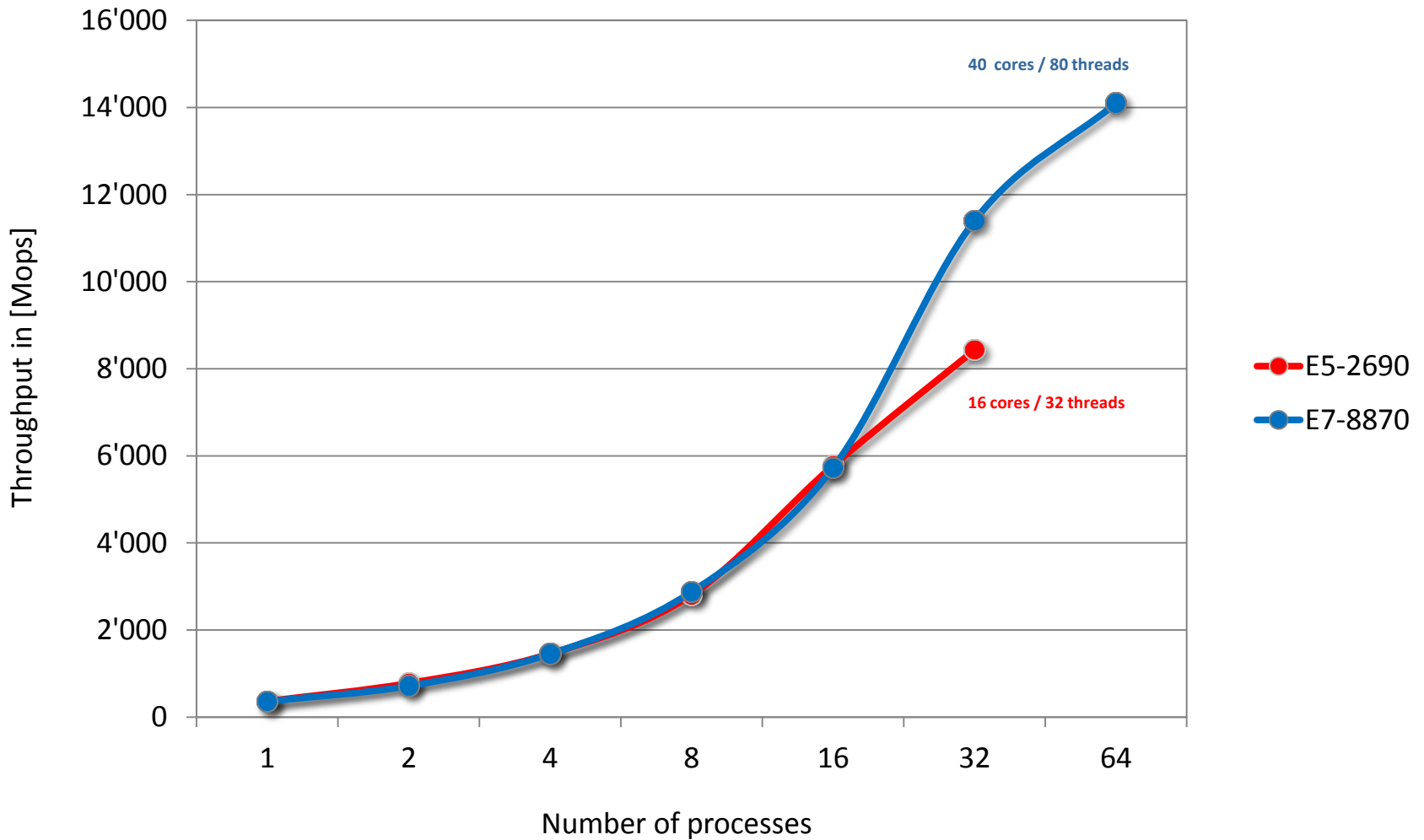
Maximum throughput, arithmetic ADD operation, different Oracle data types



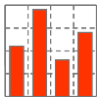
CPU Performance



Oracle CPU performance: arithmetic ADD, data type SIMPLE_INTEGER



CPU Performance



Oracle CPU performance: arithmetic ADD, data type SIMPLE_INTEGER

Intel Xeon
E5 2690 2.9 – 3.8 GHz

Run	Tst	Code	#N	#J	#T	CPU busy [%]	CPU user [%]	CPU sys [%]	CPU idle [%]	Throughput ops/sec [ops]	Elap time [s]
2	1	CPU-11	1	1	1	4	3	1	96	3.636E+08	121
	2	CPU-11	1	2	1	7	6	1	93	7.769E+08	121
	3	CPU-11	1	4	1	13	13	1	87	1.455E+09	121
	4	CPU-11	1	8	1	25	24	0	75	2.810E+09	126
	5	CPU-11	1	16	1	50	49	1	50	5.774E+09	124
	6	CPU-11	1	32	1	95	95	0	5	8.429E+09	126

Intel Xeon
E7 8870 2.4 – 2.8 GHz

Run	Tst	Code	#N	#J	#T	CPU busy [%]	CPU user [%]	CPU sys [%]	CPU idle [%]	Throughput ops/sec [ops]	Elap time [s]
12	1	CPU-11	1	1	1	2	1	0	98	3.588E+08	301
	2	CPU-11	1	2	1	3	3	0	97	7.152E+08	302
	3	CPU-11	1	4	1	5	5	0	95	1.449E+09	303
	4	CPU-11	1	8	1	10	10	0	90	2.875E+09	303
	5	CPU-11	1	16	1	20	20	0	80	5.723E+09	303
	6	CPU-11	1	32	1	40	40	0	60	1.140E+10	303
	7	CPU-11	1	64	1	79	79	0	21	1.410E+10	305
	8	CPU-11	1	128	1	99	98	0	1	1.388E+10	309

Legend:

#N number of RAC nodes

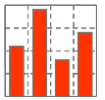
#J number of jobs

#T number of threads (PX)

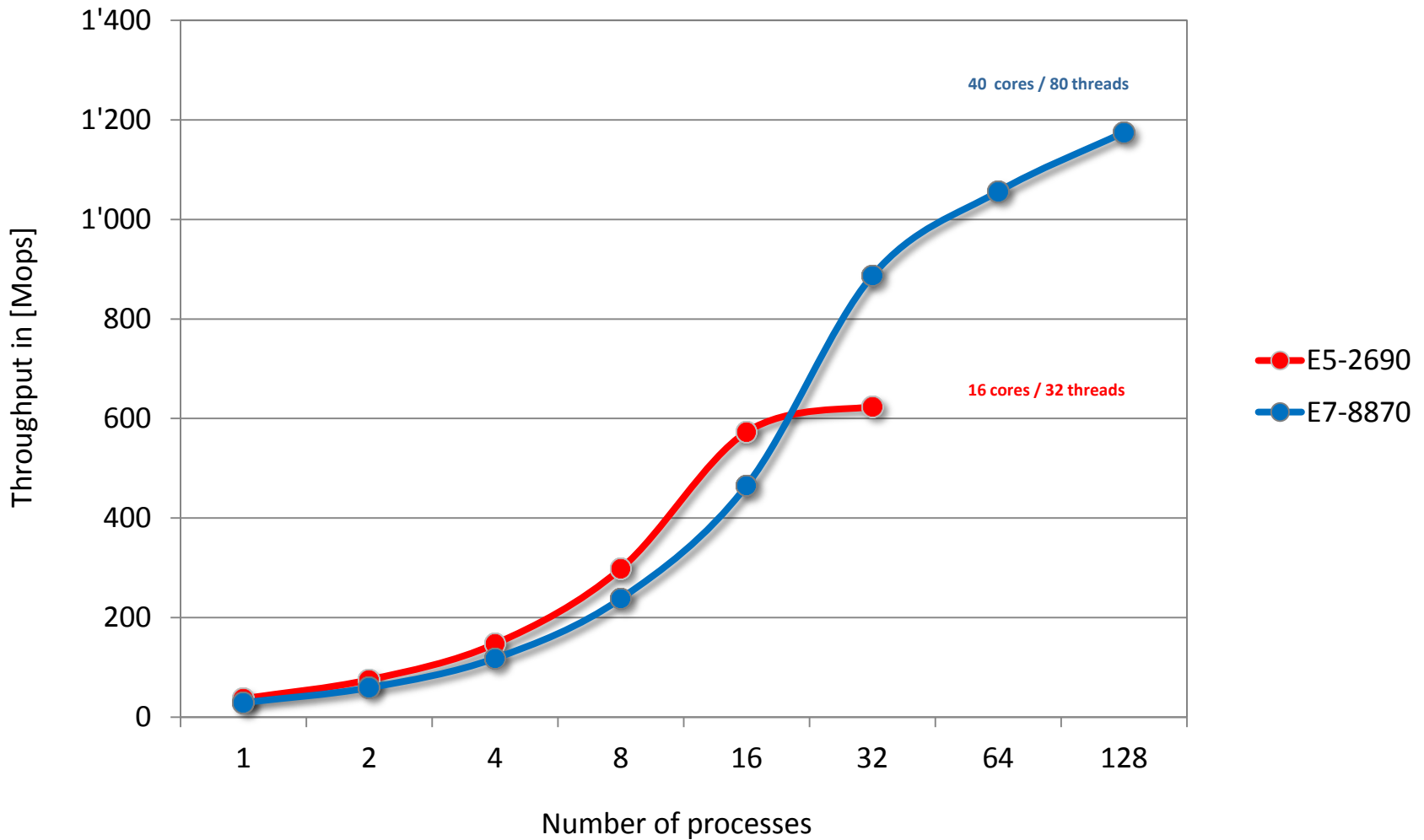
[ops] operations per second

[s] elapsed time in seconds

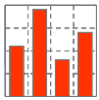
CPU Performance



Oracle CPU performance: arithmetic ADD, data type NUMBER



CPU Performance



Oracle CPU performance: arithmetic ADD, data type NUMBER

Intel Xeon
E5 2690 2.9 – 3.8 GHz

Run	Tst	Code	#N	#J	#T	CPU busy [%]	CPU user [%]	CPU sys [%]	CPU idle [%]	Throughput ops/sec [ops]	Elap time [s]
2	19	CPU-14	1	1	1	4	3	1	96	3.756E+07	123
	20	CPU-14	1	2	1	7	6	0	93	7.512E+07	123
	21	CPU-14	1	4	1	13	12	1	87	1.476E+08	123
	22	CPU-14	1	8	1	25	25	1	75	2.981E+08	124
	23	CPU-14	1	16	1	50	49	1	50	5.735E+08	124
	24	CPU-14	1	32	1	95	95	0	5	6.246E+08	126

Intel Xeon
E7 8870 2.4 – 2.8 GHz

Run	Tst	Code	#N	#J	#T	CPU busy [%]	CPU user [%]	CPU sys [%]	CPU idle [%]	Throughput ops/sec [ops]	Elap time [s]
12	25	CPU-14	1	1	1	2	1	0	98	2.981E+07	161
	26	CPU-14	1	2	1	3	3	0	97	5.963E+07	161
	27	CPU-14	1	4	1	5	5	0	95	1.185E+08	162
	28	CPU-14	1	8	1	10	10	0	90	2.385E+08	161
	29	CPU-14	1	16	1	20	20	0	80	4.655E+08	165
	30	CPU-14	1	32	1	38	38	0	62	8.879E+08	173
	31	CPU-14	1	64	1	69	68	0	31	1.056E+09	291
	32	CPU-14	1	128	1	98	98	0	2	1.175E+09	310

Legend:

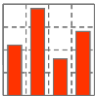
#N number of RAC nodes

#J number of jobs

#T number of threads (PX)

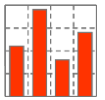
[ops] operations per second

[s] elapsed time in seconds

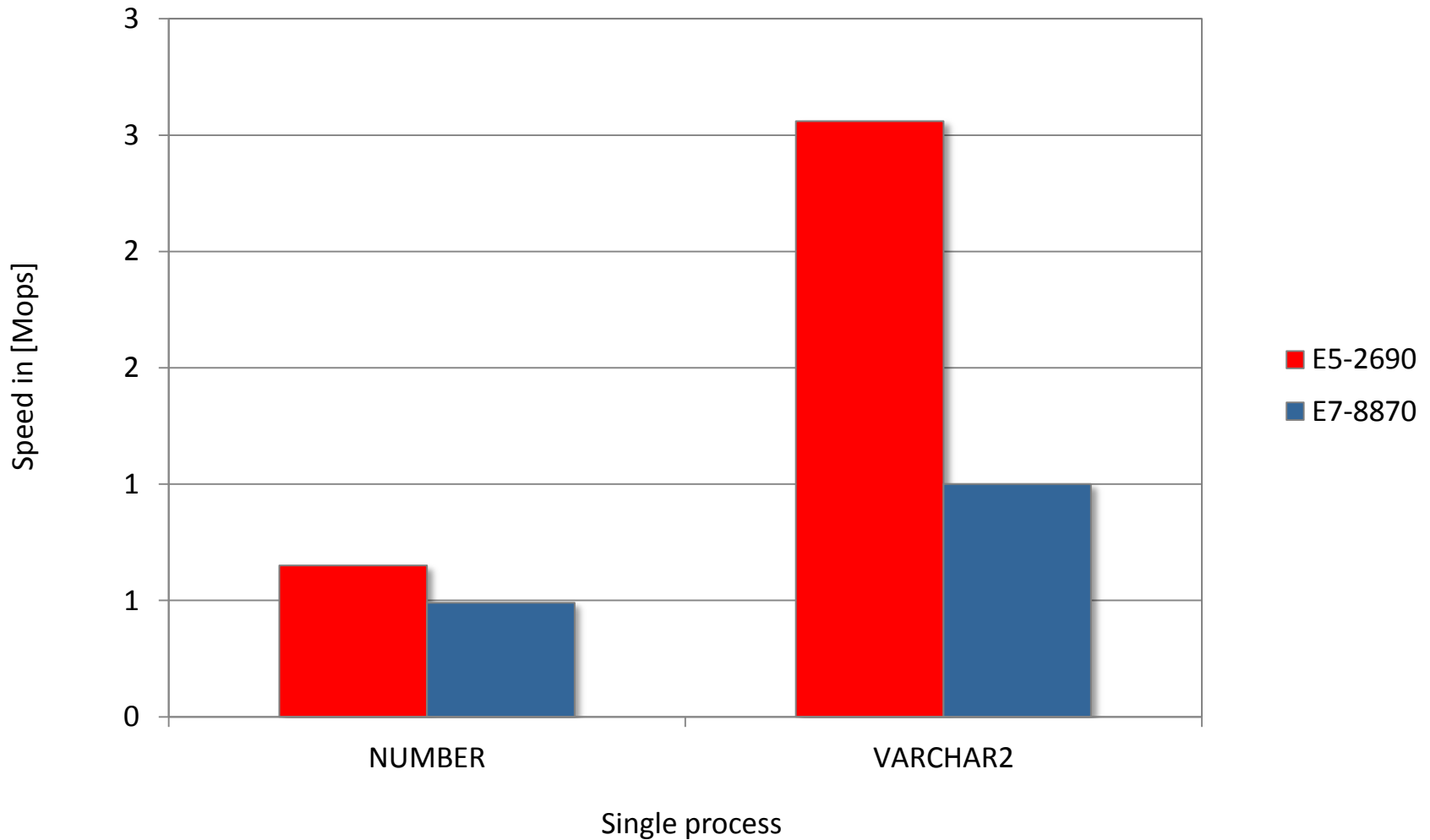


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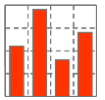
CPU Performance



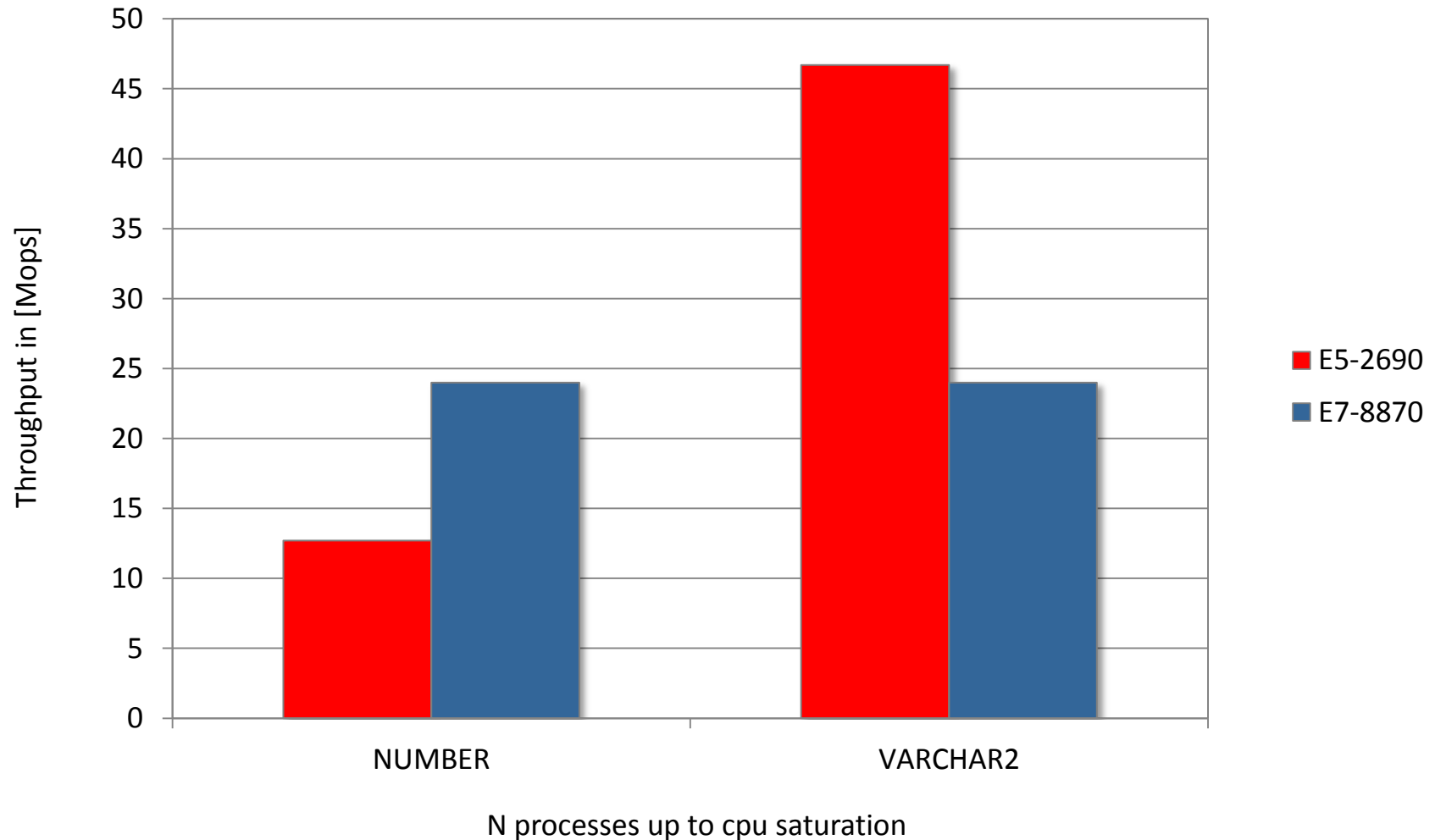
Single process speed, mixed SQL built-in functions, different Oracle data types



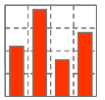
CPU Performance



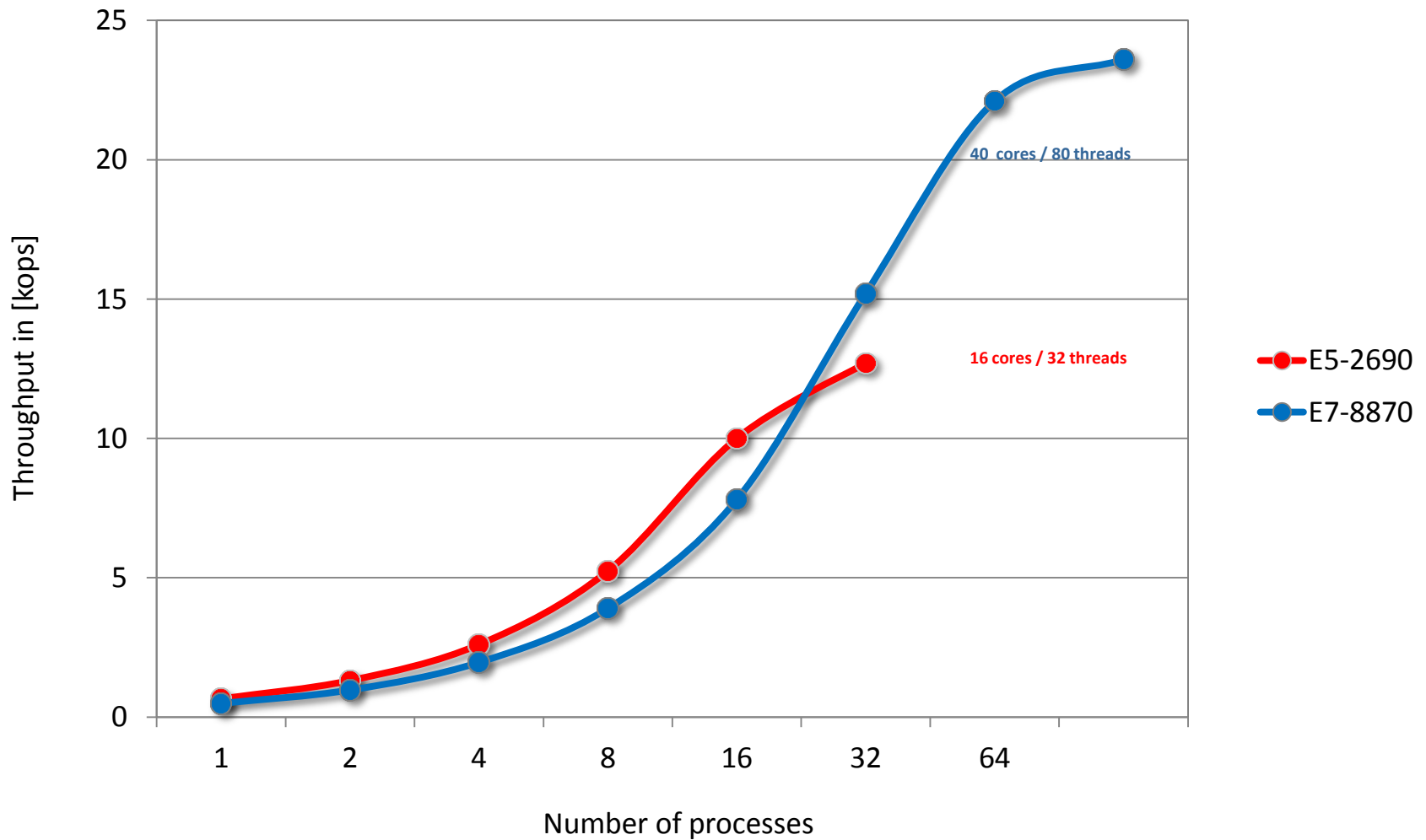
Maximum throughput, mixed SQL built-in functions, different Oracle data types



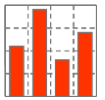
CPU Performance



Oracle CPU performance: mixed SQL built-in functions, data type NUMBER



CPU Performance



Oracle CPU performance: mixed SQL built-in functions , data type NUMBER

Intel Xeon
E5 2690 2.9 – 3.8 GHz

Run	Tst	Code	#N	#J	#T	CPU busy [%]	CPU user [%]	CPU sys [%]	CPU idle [%]	Throughput ops/sec [ops]	Elap time [s]
2	37	CPU-24	1	1	1	4	3	1	96	6.557E+05	122
	38	CPU-24	1	2	1	7	6	1	93	1.311E+06	122
	39	CPU-24	1	4	1	13	13	1	87	2.602E+06	123
	40	CPU-24	1	8	1	26	25	0	74	5.246E+06	122
	41	CPU-24	1	16	1	50	49	1	50	1.006E+07	126
	42	CPU-24	1	32	1	95	95	0	5	1.269E+07	128

Intel Xeon
E7 8870 2.4 – 2.8 GHz

Run	Tst	Code	#N	#J	#T	CPU busy [%]	CPU user [%]	CPU sys [%]	CPU idle [%]	Throughput ops/sec [ops]	Elap time [s]
12	49	CPU-24	1	1	1	2	1	0	98	4.918E+05	244
	50	CPU-24	1	2	1	3	3	0	97	9.756E+05	246
	51	CPU-24	1	4	1	5	5	0	95	1.967E+06	244
	52	CPU-24	1	8	1	10	10	0	90	3.902E+06	246
	53	CPU-24	1	16	1	20	20	0	80	7.805E+06	246
	54	CPU-24	1	32	1	39	39	0	61	1.524E+07	252
	55	CPU-24	1	64	1	79	79	0	21	2.209E+07	305
	56	CPU-24	1	128	1	99	99	0	1	2.357E+07	310

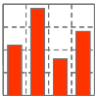
Legend:

#N number of RAC nodes
#J number of jobs

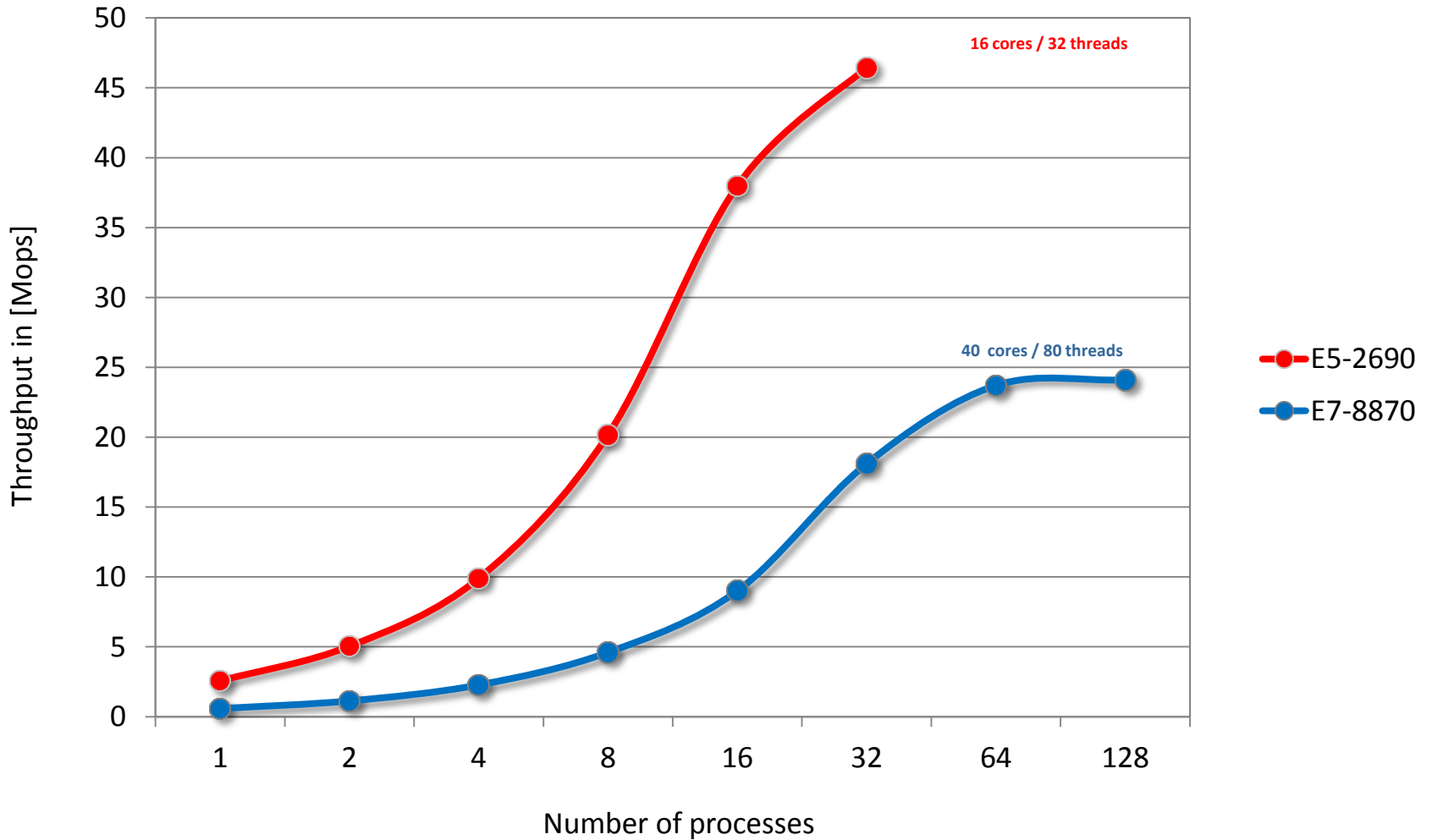
#T number of threads (PX)
[ops] operations per second

[s] elapsed time in seconds

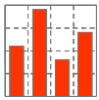
CPU Performance



Oracle CPU performance: mixed SQL built-in functions, data type VARCHAR2



CPU Performance



Oracle CPU performance: mixed SQL built-in functions, data type VARCHAR2

Intel Xeon
E5 2690 2.9 – 3.8 GHz

Run	Tst	Code	#N	#J	#T	CPU busy [%]	CPU user [%]	CPU sys [%]	CPU idle [%]	Throughput ops/sec [ops]	Elap time [s]
2	43	CPU-25	1	1	1	4	3	1	96	2.564E+06	117
	44	CPU-25	1	2	1	7	6	1	93	5.042E+06	119
	45	CPU-25	1	4	1	13	12	1	87	9.917E+06	121
	46	CPU-25	1	8	1	25	25	0	75	2.017E+07	119
	47	CPU-25	1	16	1	49	48	1	51	3.798E+07	126
	48	CPU-25	1	32	1	94	94	0	6	4.677E+07	127

Intel Xeon
E7 8870 2.4 – 2.8 GHz

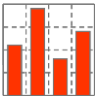
Run	Tst	Code	#N	#J	#T	CPU busy [%]	CPU user [%]	CPU sys [%]	CPU idle [%]	Throughput ops/sec [ops]	Elap time [s]
12	57	CPU-25	1	1	1	2	1	0	98	5.769E+05	312
	58	CPU-25	1	2	1	3	3	0	97	1.130E+06	312
	59	CPU-25	1	4	1	5	5	0	95	2.269E+06	314
	60	CPU-25	1	8	1	10	10	0	90	4.606E+06	311
	61	CPU-25	1	16	1	20	20	0	80	9.081E+06	313
	62	CPU-25	1	32	1	40	39	0	60	1.814E+07	313
	63	CPU-25	1	64	1	78	78	0	22	2.376E+07	315
	64	CPU-25	1	128	1	97	97	0	3	2.414E+07	324

Legend:

#N number of RAC nodes
#J number of jobs

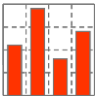
#T number of threads (PX)
[ops] operations per second

[s] elapsed time in seconds

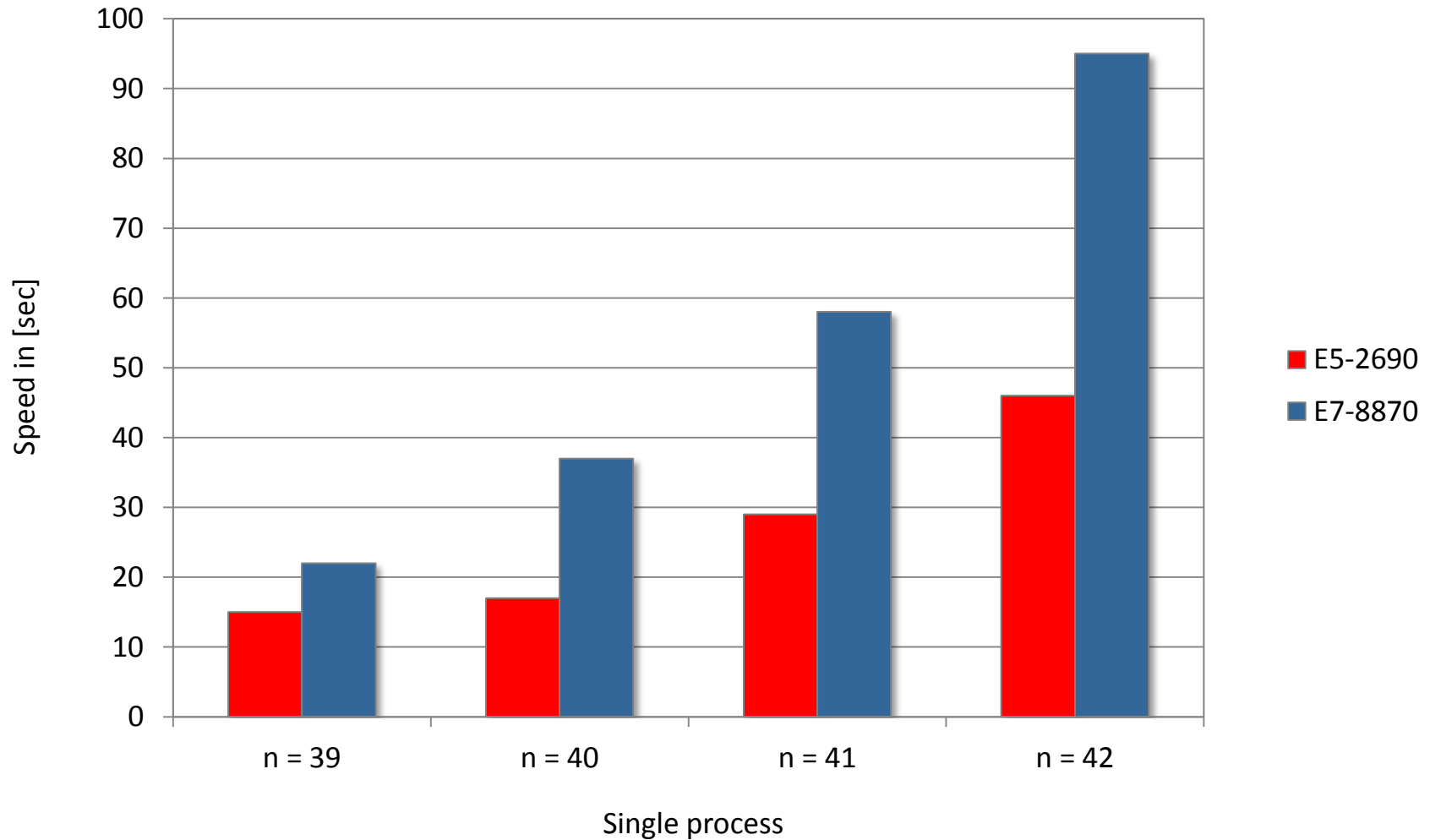


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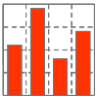
CPU Performance



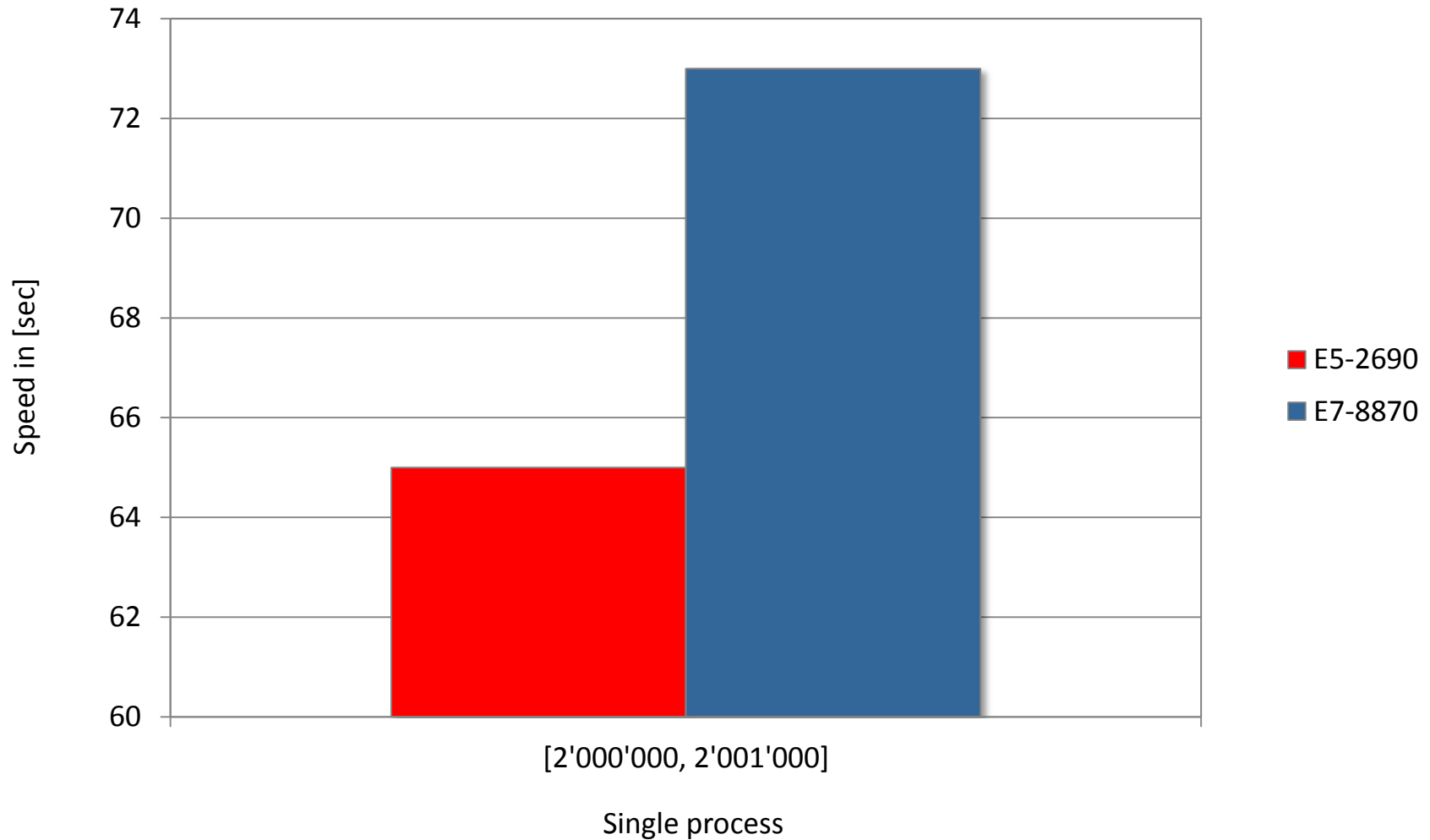
Oracle CPU performance: calculation of fibonacci numbers (recursive)

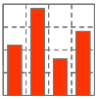


CPU Performance



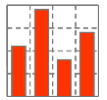
Oracle CPU performance: calculation of prime numbers (recursive)





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Benchmark Results



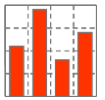
Summary CPU Performance

	Metric	HDS UCP Large SMP	HDS UCP Small SMP
#cores		40	16
#threads		80	32
Basic arithmetic ADD operation	Metric	HDS UCP Large SMP	HDS UCP Small SMP
Single thread speed			
▪ SIMPLE_INTEGER	[Mops]	358	363
▪ SIMPLE_FLOAT	[Mops]	145	190
▪ PLS_INTEGER	[Mops]	110	190
▪ NUMBER	[Mops]	30	37
Throughput			
▪ SIMPLE_INTEGER	[Mops]	14'100	8'429
▪ SIMPLE_FLOAT	[Mops]	5'831	4'246
▪ PLS_INTEGER	[Mops]	5'436	3'294
▪ NUMBER	[Mops]	1'175	624

Legend:

[Mops] million operations per second

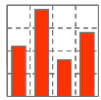
Benchmark Results



Summary CPU Performance

	Metric	HDS UCP Large SMP	HDS UCP Small SMP
#cores		40	16
#threads		80	32
Mixed arithmetic operations	Metric	HDS UCP Large SMP	HDS UCP Small SMP
Speed			
▪ SIMPLE_FLOAT	[Mops]	3.5	8.5
▪ PLS_INTEGER	[Mops]	0.5	0.6
▪ NUMBER	[Mops]	0.5	0.6
Throughput			
▪ SIMPLE_FLOAT	[Mops]	158	163
▪ PLS_INTEGER	[Mops]	23	13
▪ NUMBER	[Mops]	23	13
Mixed string operation	Metric	HDS UCP Large SMP	HDS UCP Small SMP
Speed			
▪ VARCHAR2	[Mops]	0.6	2.6
Throughput			
▪ VARCHAR2	[Mops]	24	46

Benchmark Results



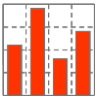
Summary CPU Performance

	Metric	HDS UCP Large SMP	HDS UCP Small SMP
#cores		40	16
#threads		80	32
Algorithms	Metric	HDS UCP Large SMP	HDS UCP Small SMP
Speed, calculate fibonacci numbers			
▪ N = 39	[s]	22	15
▪ N = 40	[s]	37	17
▪ N = 41	[s]	58	29
▪ N = 42	[s]	95	46
Speed, calculate prime numbers			
▪ Interval [2'000'000, 2'001'000]	[s]	73	65

Legend:

[s] elapsed time in seconds

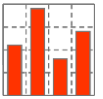
Benchmark Results



Reviewing CPU Performance

- HDS offers its x86 servers with different Intel processors
- This benchmark compares the Oracle CPU performance on a smaller 2 socket server versus a larger 8 socket server

Benchmark Results



Reviewing CPU Performance

- The smaller SMP server with E5-2690 processor
 - Less Oracle license cost (factor 2.5)
 - More speed
 - Less throughput, but not factor 2.5

- Final conclusion
 - The smaller SMP provides better price/performance ratio

- The larger SMP Server with E7-8870 processor
 - Abnormal weak VARCHAR2 processing performance
 - Eventually PL/SQL bug in Oracle 11.2.0.4?

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