Modernizing Oracle Database on IBM Power

Practical guidance on getting current!

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Overview

Challenge

Customers need to upgrade Oracle DB and IBM Power servers to assure continued support and manage costs.

Solution

This paper provides an overview of how to efficiently upgrade from Oracle 11gR2 to 19c, and from IBM Power8 to IBM Power10.

Executive overview

The objective of this white paper is to provide joint guidance for IBM® and Oracle customers on upgrading from IBM Power8® to IBM Power10, and from Oracle Database 11gR2 to Oracle Database 19c. For reasons of long-term support, cost of maintenance, security, and overall efficiency, it is important to assist customers in planning their move to the most current long-term support version of the IBM server and Oracle Database.

To prepare this paper, the test team selected two workloads that are representative of the variety that customers may use. Each workload was run on the Power8 processor-based server with Oracle 11gR2. Both the Oracle database and the Power8 processor-based server were configured as per best practices, including the application of current service to IBM AIX® and Oracle Database. The test team recommends that all the plans to upgrade Oracle Database, and the system it is running on, start with the IBM and Oracle software being upgraded to current levels.

Disclaimer

The results shown in this paper are for education purposes only. The results **do not** represent the full potential capability of IBM Power10 processor-based systems, Oracle Database 11g Release 2, Oracle Database 19c, and IBM FlashSystem® 9150. The results were derived from configurations that used default values, and generally accepted best practices, without any intense tuning on AIX, Oracle Database 11g Release 2, Oracle Database 19c, or the storage area network (SAN) server. The results would vary on different Power8 and Power10 processor-based systems and for different types of applications with differing workload characteristics.

Software

- Oracle 11gR2 and 19c
- IBM AIX 7.2

Hardware

- IBM Power E880
- IBM Power E870
- IBM Power E1080

Oracle Database and IBM Power configurations

Using Oracle 11gR2, each workload was driven to high system utilization on a Power8 logical partition (LPAR) sized to meet the required throughput objectives. The team then moved the workload to a Power10 LPAR that was sized to provide the capacity similar to Power8, based on rPerf ratings from the IBM Power® rPerf report found at: https://www.ibm.com/downloads/cas/K90RQOW8.

The database execution was stopped on the Power8 processor-based systems and restarted on the Power10 processor-based system after moving the shared storage system connection to the Power10 processor-based system. After the baseline execution of validation tests were completed on 11gR2, an upgrade to 19c was completed using the Oracle Database AutoUpgrade utility and workload execution was resumed.

When workload was again ramped up, the same high utilization was achieved, and the throughput was recorded.

The following table provides the hardware and software configuration (returned by using the `prtconf` command). This configuration was used for the sample Brokerage online transaction processing (OLTP) workload.

Configuration	Power8	Power10
System model	IBM, 9119-MME	IBM, 9080-HEX
Processor type	PowerPC_POWER8	PowerPC_POWER10
Number of cores	48	24
Clock speed	4.02GHz	3.6 to 4.16GHz
Memory	800 GB	800 GB
Firmware version	IBM, FW860.90 (SC860_226)	IBM, FW1010.00 (NH1010_047)
Nodes/Drawers	2	1
Chips per node	4	4
SMT (Default values used)	4	8
OS level	AIX 72 TL5 SP2	AIX 72 TL5 SP2
Oracle Grid Home Version	11.2.0.4+ PSU 31718723	11.2.0.4.201020/19.11
Oracle DB home version	11.2.0.4+ PSU 31718723	11.2.0.4.201020/19.11
Oracle one-off patch	32109594	32109594(11G)
Workload users	216	216

Table 1. Hardware and software configuration

Brokerage – OLTP workload

This workload simulated the transactions and database of a stock brokerage firm. The test team created a database size of approximately 1 TB using 50,000 customers. The team modified the transaction mix with a read/write ratio of approximately 90/10 so that more CPU operations can be performed.

For the Oracle 11gR2 baseline, the database was installed on an IBM Power E870 server (which is based on IBM Power8 architecture) with logical partition (LPAR) using 48 cores. The LPAR placement of the cores and memory in Power8 was done to provide better alignment. When the team performed the runs, it was observed that the CPU utilization reached approximately 100%.

Figure 1 shows the migration methodology that was followed for the Brokerage OLTP workload.

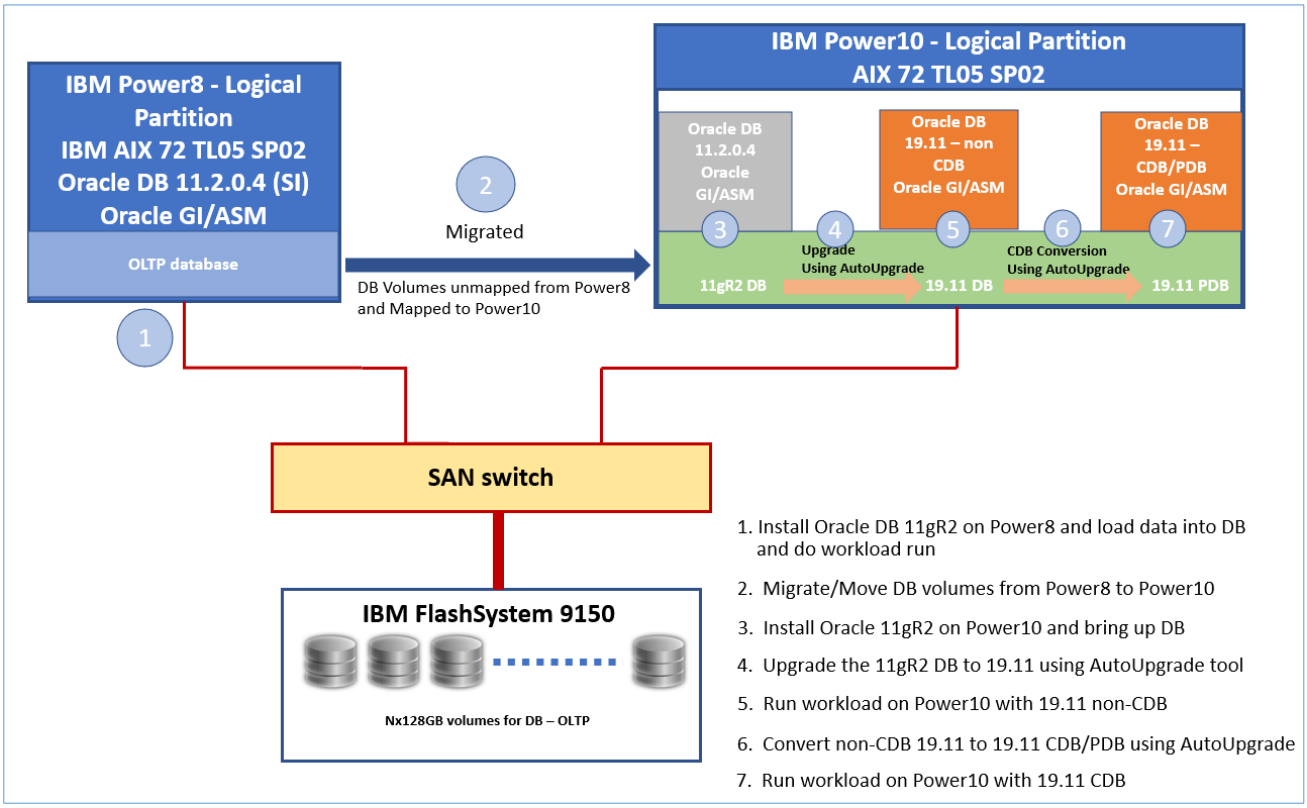

Figure 1. Flow diagram for the OLTP workload

Partition placement in Power servers for OLTP workload

The lssrad tool was used to get the partition placement details. On this Power8 processor-based system, the processors and memory spread across two system node enclosures as shown in Figure 2.

```
REF1    SRAD        MEM      CPU
0
           0    99546.25      0-23
           1    99351.00      24-47
           2    99351.00      48-71
           3    99351.00      72-95
1
           4    99351.00      96-119
           5    99516.94      120-143
           6    99344.00      144-167
           7    99536.00      168-191
```

Figure 2. Output of lssrad command on the LPAR in Power8

On the Power10 LPAR, the required capacity was estimated as 24 cores, and this resized LPAR was able to fit on a single system node enclosure as shown in Figure 3.

```
REF1    SRAD        MEM      CPU
0
           0   198908.19       0-47
           1   198869.44       48-95
           2   198695.00       96-143
           3   198871.00       144-191
```

Figure 3. Output of lssrad command on the LPAR in Power10

Capacity comparison of Power10 with Power8 running OLTP workload

The test team observed that the LPAR in a 24-cores Power10 processor-based system with the same number of workload users as in Power8 reached CPU utilization of approximately 100%.

The team recommends AIX 7.2 TL 5 SP3 for production use, which includes Power10 tunable options. Refer to the note in the “Appendix” section.

The following observations can be made from Figure 4:

- The execution plans for workload SQLs did not change when the test team moved the 11gR2 DB storage volumes from Power8 to Power10. The improvement in throughput were observed when the test team restarted execution of 11gR2 on the Power10 processor-based system.
- On Power10 partition, some of the workload SQLs changed their execution plans when the team upgraded the database from 11gR2 to 19c. But this did not substantially change the throughput.
- After the upgrade, when the test team changed the database `compatible` parameter to `19.0.0` from `11.2.0.4` and made no other configuration changes, the execution plans of the workload did not change.

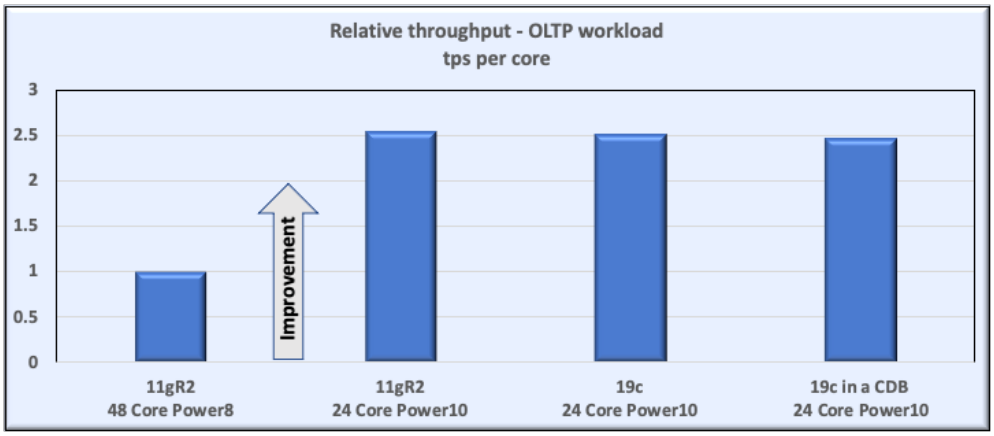

Figure 4. Throughput per core

It has been observed that the movement from Power8 to Power10 provided a benefit of 2.5 times more throughput (delivered by Power10) and improvements delivered in both database versions 11g and 19c. Generational improvements in the Power10 architecture increased the number of cores on a chip and improved per core throughput, allowing the partition to be placed on a single system node enclosure. This improved throughput and reduced the space and power requirements for the workload.

BIDAY analytical workload

BIDAY is an IBM developed analytical workload that models different types of analysis that businesses can use in their business intelligence (BI) workload. The workload has one terabyte (1 TB) of raw data representing retail sales tracking loaded into Oracle Database.

The BIDAY workload consist of a set of 26 queries with complexity ranging from simple to very complex queries. The workload can be scaled by executing 1, 2, 4, 8, and more concurrent users. The BIDAY schema has one of the tables, named **Sales_Fact**, as a fact table which is single Range-Hash partitioned and filled with nine billion rows.

During the test, the set of all 26 queries were run sequentially in the same strict order and the team presented each concurrent execution of this set as an additional user. For example, for two users two copies of each query set are run, and for eight users eight copies of each query set are run concurrently. The execution of the queries is serialized, and therefore, all the users are executing the same query set.

The configuration (returned by using the `prtconf` command) shown in Table 2 was used with an IBM AIX LPAR for evaluating the capacity of the Oracle Database on IBM Power servers.

Configuration	IBM Power8	IBM Power10
System model	IBM,9119-MHE	IBM, 9080-HEX
Processor type	PowerPC_POWER8	PowerPC_POWER10
Number of cores	48 (dedicated)	27 (dedicated)
Clock speed or WOF* range	4.35 GHz	3.60 GHz to 4.15 GHz
Memory	512 GB	512 GB
Firmware version	FW860.70 (SC860_205)	FW1010.00 (NH1010_047) Pre GA
Nodes/Drawers	2	1
Chips per node	4	4
SMT (default values used)	4	8
OS level	AIX 72 TL05 SP02	AIX 72 TL05 SP02
Oracle Grid Infrastructure	11.2.0.4 + PSU 31718723	11.2.0.4 + PSU 31718723, 19.11.0.0.0
Oracle Database	11.2.0.4 + PSU 31718723	11.2.0.4 + PSU 31718723, 19.11.0.0.0
Oracle one-off patch	32109594 (11.2.0.4)	32109594 (11.2.0.4)

Table 2. Configuration used with an IBM AIX LPAR

The BIDAY workload queries with high-level complexity are CPU-intensive and can saturate 48 dedicated cores in Power8 and 27 dedicated cores in Power10 easily with four or more users concurrently running the queries.

27 dedicated cores in Power10 were estimated to provide the capacity of 48 (4.35 GHz) cores in Power8 based on the **rPerf** values of their Power servers. To know more about IBM Power rPerf, refer: https://www.ibm.com/downloads/cas/K90RQOW8

Partition placement in Power servers for BIDAY queries

The CPU cores and memory resources assigned to the LPAR were aligned to be placed in a single system node enclosure in the Power10 processor-based server and in two system node enclosures in a Power8 processor-based server. The assigned memory was almost equally shared to the cores. The output of the cores and memory assignment can be viewed using the following AIX command.

```
# lssrad -a -v
REF1   SRAD        MEM      CPU
0
          0   113275.12      0-47
          1   131954.00      48-103
          2   131968.25      104-159
          3   131947.00      160-215
```

Figure 5. LPAR cores and memory placement in Power10

* WOF refers to Workload Optimized Frequency. IBM Power9 and Power10 processor-based scale-out and scale-up servers implement Workload Optimized Frequency as a new feature of the energy management (EnergyScale) technology.

```
# lssrad -a -v
REF1   SRAD        MEM      CPU
0
          0   63722.25      0-23
          1   63495.00      24-47
          2   63495.00      48-71
          3   63728.00      72-95
1
          4   63744.00      96-119
          5   63740.94      120-143
          6   63728.00      144-167
          7   63488.00      168-191
```

Figure 6. LPAR cores and memory placement in Power8

The BIDAY workload queries ran on Oracle Database version 11.2.0.4 with 1, 2, 4, and 8 users with the `parallel_degree_limit` DB parameter set to a number which matched the number of logical processors available in the LPAR. The `parallel_degree_policy` parameter was set to AUTO. For example, the LPAR in the IBM Power8 processor-based system was set up with 48 dedicated cores with SMT4 enabled. In total, 192 logical processors are available to the Oracle Database for executing the queries with up to 192 parallel processes.

Next, the test team installed the same Oracle Grid Infrastructure and Database software version 11.2.0.4 on the LPAR on the IBM Power10 processor-based system and migrated the database volumes from the LPAR in Power8 to Power10. The team then started the LPAR in Power10 and the database using the migrated SAN volumes. The BIDAY queries were run with 1, 2, 4, and 8 users and the team collected the elapsed time of each of the users. Because Power10 executes in the SMT8 mode by default, we increased the `parallel_degree_limit` DB parameter to 216 which matched the logical processors available in the LPAR in the Power10 processor-based system. The `parallel_degree_policy` parameter remained to be set to AUTO.

The team installed Oracle Grid Infrastructure and Database 19c version 19.11.0.0.0 on another set of filesystems for an out-of-place upgrade from Oracle Database 11g (11.2.0.4) to 19.11.0.0.0. They used the Oracle Database AutoUpgrade tool with the latest *autoupgrade.jar* file. After successfully completing the database upgrade steps, the BIDAY workload queries were executed on the Oracle Database version 19.11.0.0.0 with the same values assigned to the database parameters, `parallel_degree_limit=216` and `parallel_degree_policy=AUTO`, and collected the total elapsed time from staring the set of queries to completion of them.

The flow diagram for migration and the Database upgrade is shown in a high level in the following diagram.

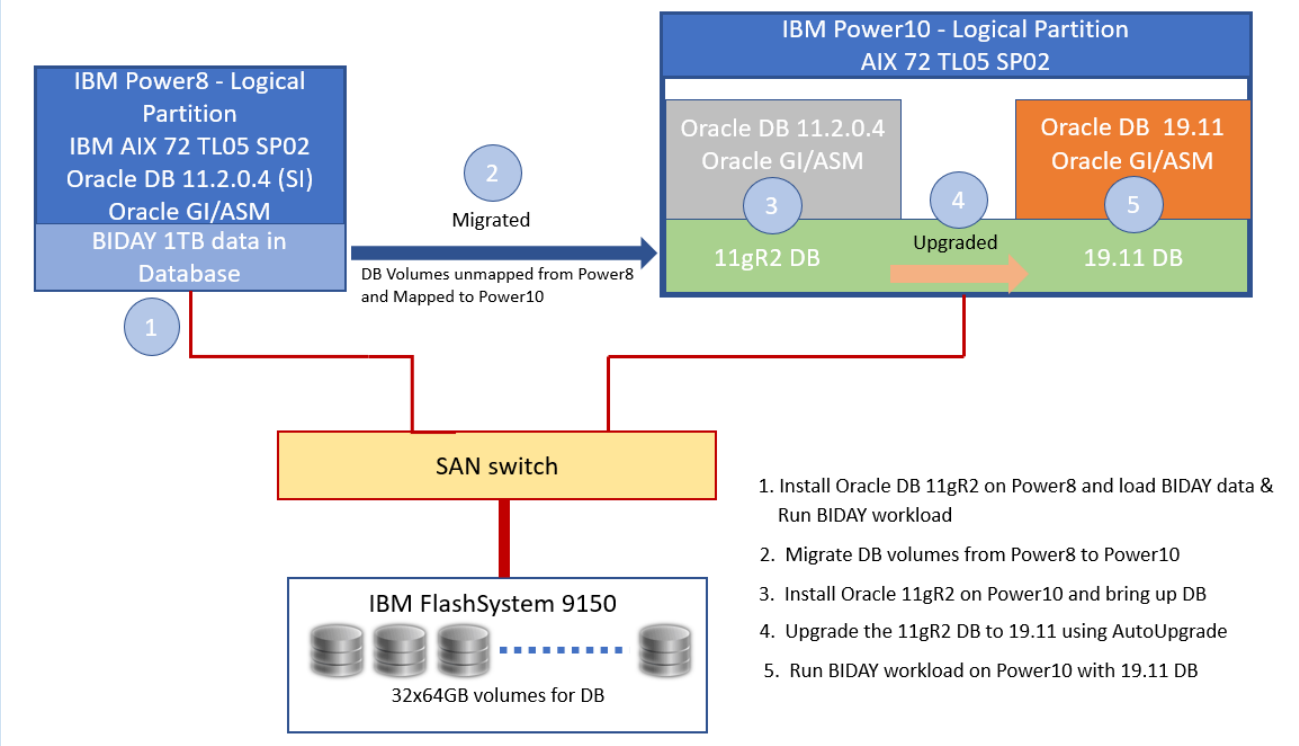

Figure 7. Flow diagram for Oracle DB migration and upgrade

Capacity comparison of Power10 with Power8 running BIDAY queries

The IBM Power10 processor-based system with 27 cores outperformed the Power8 processor-based system with 48 cores for running business analytics type of queries with the following results.

Capacity metrics	Power8 with 48 cores Oracle DB 11gR2 (11.2.0.4)	Power10 with 27 cores Oracle DB 11gR2 (11.2.0.4)	Power10 with 27 cores Oracle DB 19c (19.11)	Power10 with 27 cores Oracle DB 19c (19.11) In-Memory
Relative per core improvement factor	1.00x	2.48x	3.61x	146.28x
Relative query elapsed time improvement factor	1.00x	1.38x	2.03x	79.80x

Table 3. Capacity comparison of Power10 with Power8

CPU utilization and I/O throughput

The result shown in Table 3 was obtained for the BIDAY queries ran on row format data by eight users, and an average value of 96% and a maximum value of 100% CPU utilization was observed. I/O bottlenecks were not observed in the SAN volumes and adapters.

The SAN connectivity between the AIX LPAR and the IBM FlashStorage system had enough bandwidth to read the data for processing. The following I/O throughput (as shown in Table 4) was observed while executing the queries on row format data. The higher data rates (storage I/O) of Oracle Database 19.11 are reflected in the improved query time compared to Oracle Database 11g R2.

System	Number of LPAR cores	Database version	Storage I/O
Power8 processor-based	48	11g R2	2.6 GBps
Power10 processor-based	27	11g R2	3.6 GBps
Power10 processor-based	27	19.11	5.2 GBps

Table 4. I/O throughput

Oracle Database In-Memory feature for BIDAY queries

The BIDAY workload can leverage Oracle Database 19c In-Memory feature. With this option, it is also possible to run with native data types such as BINARY_FLOAT, which was used. When executed with the In-Memory feature, the schema loads the nine billion row table, named **Sales_Fact**, into the In-Memory area with *critical* priority and the default compression level. While the fact table was loaded into the In-Memory area, data was compressed with an average rate of 4.1 compression ratio. The entire Sales_Fact table with an original size of 726 GB was compressed to less than 200 GB. This means the real memory for the table, and some additional metadata was contained in the resized *SGA_TARGET* of 450 GB.

While executing the queries with the In-Memory feature enabled, no significant SAN I/O throughput was observed. The speed up in query execution was calculated as follows:

- Speed up Power10 and 11gR2 = (elapsed time from 11gR2 in Power8 / elapsed time from 11gR2 in Power10)
- Speed Up Power10 and 19.11 = (elapsed time from 11gR2 in Power8 / elapsed time from 19.11 in Power10)

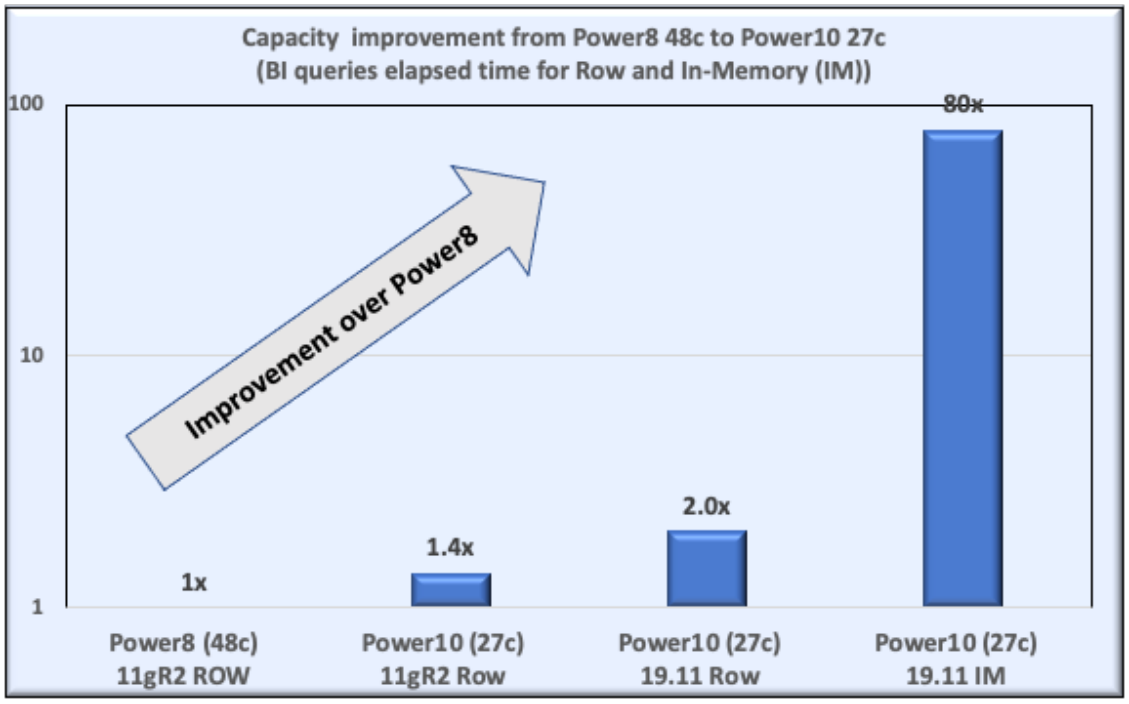

Figure 8. BI queries elapsed time improvement from Oracle DB 11gR2 to 19.11 with IBM Power8 and Power10

While comparing the effective capacity of the scenarios, a metric which takes into account the improvement in core capacity as well as improvements in query elapsed time is required. For this purpose, the test team used a metric computed as *(cores x queries elapsed time in seconds) / users*.
The LPAR in Power10 was used only with 27 dedicated cores and the LPAR in Power8 was used with 48 dedicated cores. The Power10 processor-based system was observed to improve the BIDAY queries up to 2.48 times with the Oracle 11gR2 database and 3.61 times with the Oracle 19.11 database when normalized to a per core basis.

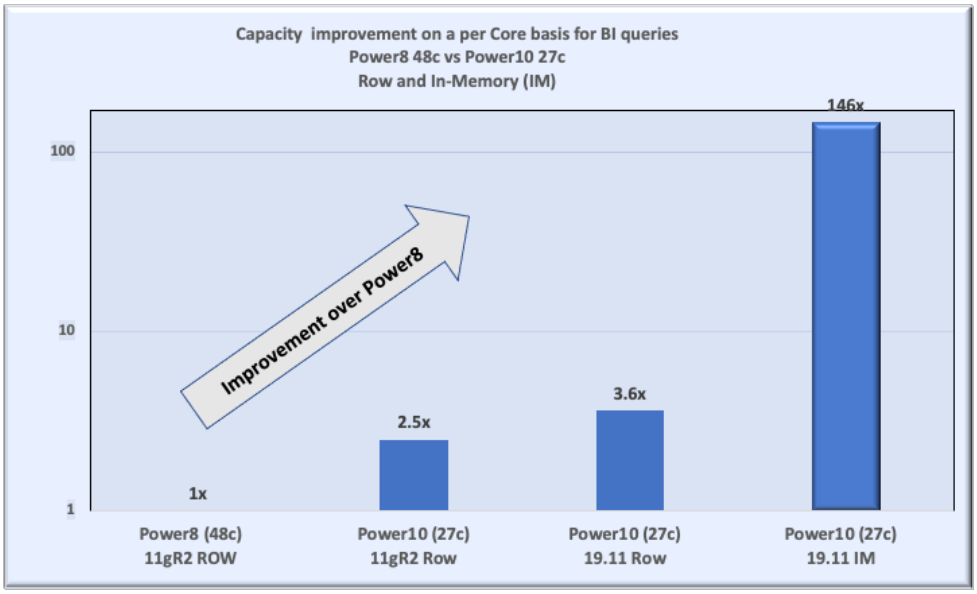

Figure 9. BI queries capacity change on a per core basis from IBM Power8 to Power10

Oracle Database and AIX tuning parameters for BIDAY

The Oracle Database server instance was not tuned for the best possible capacity. Most of the parameters hold the database default values except the following parameters:

```
PARALLEL_DEGREE_LIMIT = <number of logical threads available in the LPAR>
PARALLEL_DEGREE_POLICY = AUTO
SGA_TARGET=250G
```

In-Memory only:

```
SGA_TARGET=450G
INMEMORY_SIZE=260G
INMEMORY_OPTIMIZED_ARITHMETIC=ENABLE
```

The team recommends AIX 7.2 TL 5 SP3 for production use, which includes Power10 tunable options (refer to the note in the “Appendix” section.

For more detailed information about DB parameters and their values, refer to the “Appendix” section.

BIDAY workload summary

The BI workload (BIDAY) queries running with Oracle Database version 19.11 on the newly introduced IBM Power10 processor-based systems shows 3.61 times more speed on a per core basis for row type data, and 146.28 times improvement with In-Memory data compared with the result of row type queries on IBM Power8 processor-based systems for the equal number of Power server's rPerf values.

The BIDAY queries' total elapsed time on Oracle Database version 19.11 was improved up to 2.03 times for queries that ran on row type data and improved up to 79.8 times with In-Memory columnar type data on Power10 processor-based systems compared with Power8 processor-based systems with Oracle Database version 11.2.0.4.

Summary

This paper explained how proper planning can help users of earlier Oracle database versions to update to the current version on the new IBM Power10 processor-based server with minimal disruption. The steps to accomplish includes:

- Updating the Oracle release to the current patch set.
- Using Oracle tools that provide compatibility, including AutoUpgrade.
- Updating the AIX operating system, firmware, and VIOS to the current levels.
- Adding Oracle 19c features including Container Database and Database In-Memory incrementally

Appendix

Oracle Database parameters used for BIDAY workload

The parameter values for Oracle Database 11gR2 and 19.11 are same.

```
_ash_size=524288000
sga_target=268435456000
diagnostic_dest=/u01/11gr2/base
audit_file_dest=/u01/11gr2/base/admin/biday10/adump
db_create_file_dest="+BIDAY_P10"
compatible=11.2.0.4.0
parallel_min_servers=512
open_cursors=400
deferred_segment_creation=FALSE
undo_tablespace=UNDOTBS2
commit_wait=NOWAIT
processes=5120
pga_aggregate_target=67108864000
dispatchers="(PROTOCOL=TCP) (SERVICE=orclXDB)"
parallel_degree_policy=AUTO
parallel_threads_per_cpu=1
commit_logging=BATCH
parallel_max_servers=3526
db_block_size=8192
parallel_degree_limit=216
star_transformation_enabled=TRUE
#optimizer_adaptive_reporting_only=TRUE
sga_max_size=268435456000
control_files='+BIDAY_P10/biday10/controlfile/current.269.1077915501'
audit_trail=DB
db_name="biday10"
db_domain=""
remote_login_passwordfile=EXCLUSIVE
db_unique_name="biday10"
optimizer_dynamic_sampling=0
recyclebin=OFF
```

The Database In-Memory parameters for the Oracle Database 19c version 19.11.0.0.0

```
_always_vector_transformation=TRUE
_ash_size=524288000
sga_target=450G
sga_max_size=450G
diagnostic_dest=/u01/11gr2/base
audit_file_dest=/u01/11gr2/base/admin/biday10/adump
db_create_file_dest="+BIDAY_P10"
compatible=19.0.0
parallel_min_servers=512
open_cursors=400
deferred_segment_creation=FALSE
undo_tablespace=UNDOTBS2
commit_wait=NOWAIT
processes=5120
pga_aggregate_target=67108864000
dispatchers="(PROTOCOL=TCP) (SERVICE=orclXDB)"
parallel_degree_policy=AUTO
parallel_threads_per_cpu=1
commit_logging=BATCH
parallel_max_servers=3526
db_block_size=8192
parallel_degree_limit=216
star_transformation_enabled=TRUE
control_files='+BIDAY_P10/biday10/controlfile/current.269.1077915501'
audit_trail=DB
db_name="biday10"
db_domain=""
remote_login_passwordfile=EXCLUSIVE
db_unique_name="biday10"
optimizer_dynamic_sampling=0
recyclebin=OFF
optimizer_inmemory_aware=TRUE
inmemory_optimized_arithmetic=ENABLE
inmemory_max_populate_servers=128
inmemory_size=260g
```

Note: The `commit_wait=nowait` and `commit_logging=batch` parameters were used to make these tests run more consistently, and these shall not be used for production workloads. For more details on the correct usage, and risks, of using these advanced parameters see sections 1.48 and 1.46 of the Oracle Database, Database Reference, 19c, E96196-16 dated October 2021 at: https://docs.oracle.com/en/database/oracle/oracle-database/19/refrn/index.html

Note: When using AIX 7.2 TL5 SP2 the team changed the `enhanced_affinity_private` parameter setting to 90 (the default value is 40 in the current OS level). This is not required with SP3 as the value of 90 becomes the default on Power10.

```
vmo -o enhanced_affinity_private=90
```

The purpose of this tuning is to specify the percentage of process private memory allocations that are affinitized by default. At the time of writing this paper the default percentage is 40. It is recommended to set to 90 for Power10. This tunable parameter limits the default amount of affinitized memory allocated for process private memory. Affinitizing private memory may improve process throughput. The result may vary for different types of queries.

For more details on this AIX parameter, refer to the following IBM Redbooks® “Power Systems Enterprise Servers with PowerVM Virtualization and RAS” at https://www.redbooks.ibm.com/redbooks/pdfs/sg247965.pdf

Oracle Database parameters used for Brokerage OTLP workload

The parameter values for Oracle Database 11gR2 and 19.11 are the same except that for 11gR2 the `compatible` parameter is set to `11.2.0.4.0`.

```
*._ash_size=536870912
*.audit_file_dest='/u01/base/admin/tpce/adump'
*.audit_trail='db'
*.commit_logging='BATCH'
*.compatible='19.0.0'
*.control_files='+DATA/tpce/controlfile/current.289.1079231875'#Restore Controlfile
*.db_block_size=8192
*.db_create_file_dest='+DATA'
*.db_domain=''
*.db_name='tpce'
*.diagnostic_dest='/u01/base'
*.dispatchers='(PROTOCOL=TCP) (SERVICE=tpceXDB)'
*.local_listener=LISTENER_TPCE
*.open_cursors=300
*.parallel_max_servers=600
*.pga_aggregate_target=30g
*.processes=5000
*.remote_login_passwordfile='EXCLUSIVE'
*.resource_manager_plan=''
*.sessions=5505
*.sga_target=450g
*.undo_tablespace='UNDOTBS1'
```

Note: The `commit_logging=batch` parameter was used to make these tests run more consistently, and this shall not be used for production workloads. For more details on the correct usage, and risks, of using this advanced parameter see sections 1.46 of the Oracle Database, Database Reference, 19c, E96196-16 dated October 2021 at: https://docs.oracle.com/en/database/oracle/oracle-database/19/refrn/index.html

Note: When using AIX 7.2 TL5 SP2, the team changed the `enhanced_affinity_private` parameter setting to 90 (the default value is 40 in the current OS level). This is not required with SP3 as the value of 90 becomes the default on Power10.

```
vmo -o enhanced_affinity_private=90
```

Get more information

For more information on using Oracle Database on IBM Systems, you can contact ibmoracle@us.ibm.com

For more information on using Oracle AutoUpgrade, refer to the following websites:

- Learn how to use AutoUpgrade to simplify your upgrade tasks https://docs.oracle.com/en/database/oracle/oracle-database/19/upgrd/using-autoupgrade-oracle-database-upgrades.html

- Database upgrade guide https://docs.oracle.com/en/database/oracle/oracle-database/19/upgrd/index.html

Acknowledgments

IBM acknowledges Oracle engineering staff who provided guidance on the development and review of the white paper.

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