WHITE PAPER

W I N T E R   C O R P O R A T I O N

Measuring the Performance of the Oracle® Exadata Storage Server

The Large Scale Data Management Experts

WinterCorp

SPONSORED RESEARCH PROGRAM

WINTER CORPORATION

MEASURING THE PERFORMANCE OF THE ORACLE® EXADATA STORAGE SERVER

RICHARD WINTER
Febrary 2009

WinterCorp

411 WAVERLEY OAKS ROAD, SUITE 328
WALTHAM, MA 02452
781-642-0300

visit us at www.wintercorp.com

Executive Summary

THE ORACLE® EXADATA STORAGE SERVER (Exadata) provides high performance, manageability and availability for database applications. Exadata employs an innovative architecture featuring scalable I/O bandwidth; intelligence integrated into the storage system; and, standard, commodity hardware.

This paper presents the results of the first independently validated tests of the performance of Exadata for data warehousing. WinterCorp, an industry expert in large scale data management, was retained by Oracle to review the design of the tests; audit the test process; analyze the results; and, provide an independent technical assessment of the product.

The tests involved running multiple concurrent data warehouse queries against a multi-billion row data warehouse schema with Oracle Database 11g Release 1 version 11.1.0.7. The queries were of moderate complexity and the database, though synthesized, was deliberately designed to reflect many of the challenges of real data warehouse query processing. The tests were run on a hardware configuration equivalent to that used in a single-rack HP Oracle Database Machine: 14 Exadata Storage Servers and eight Oracle Real Application Clusters (RAC) database servers.

The tests showed that the Oracle Exadata single rack configuration delivered data from storage at 14 GB/second—a rate that far exceeds what most Oracle customers have experienced in practice, even with dedicated high end, multi-rack enterprise arrays. In fact, only because of the intelligence built into the Exadata Storage Servers—and the consequent offloading of work from the database tier to the storage tier—could the eight RAC servers in the configuration drive database scans at this 14 GB/second rate.

Thus the tests served to validate three of the principal intended advantages of the Exadata architecture: high storage bandwidth; intelligent offload processing; and, reduced requirements for space, power and cooling. All of these advantages were realized in comparison to the storage solutions employed by most Oracle customers based on the shared array and SAN architectures in widespread use in the industry.

Through the process described in this report, WinterCorp was also able to observe the transparency and manageability of the Exadata Storage; its resilience to failure; its modular expandability; its integration with Automatic Storage Management, Oracle Enterprise Manager, and other Oracle capabilities; and its general usability.

In the opinion of WinterCorp, Oracle data warehouse users should give serious consideration to the Exadata product family when addressing data warehouse service level objectives or anticipating growing data warehouse requirements.

Table of Contents

1 *About This Report*

WINTERCORP

Founded in 1992 by Richard Winter, WinterCorp is an independent consultant dedicated exclusively to large scale data management. The company is expert in the architecture and engineering of large scale data warehouses and has helped users address some of the most demanding data warehouse requirements faced in the last fifteen years. WinterCorp is vendor and platform independent and has thus been able to provide the industry with expert, objective analysis and measurement of products, architectures and solutions. WinterCorp has frequently been retained by both users and vendors to design, conduct, manage, audit and analyze benchmarks and proofs-of-concept concerning data warehouse performance, scalability and availability.

INTENDED AUDIENCE

This report is written for the principal stakeholders in an enterprise using or considering Oracle as a data warehouse platform. The analysis, findings and conclusions presented here will be relevant to data warehouse executives, sponsors, architects and implementors.

METHODOLOGY

WinterCorp was retained by Oracle to participate in measuring and independently validating the performance of the Oracle Exadata Storage Server. WinterCorp's responsibililties included: review of the measurement plan, test design and actual test queries; review of all test inputs and outputs; and, independent assessment of results. WinterCorp wrote this report and maintains final editorial control over its content and presentation; and, is therefore solely responsible for the findings and conclusions presented here.

CONTENTS OF THIS REPORT

This report contains a brief description of the architecture and capabilities of the Oracle Exadata Storage Server; a description of the tests performed; the test results; and, WinterCorp's independent conclusions and findings from the tests. Publications are available from Oracle describing the Exadata Storage Server in more detail, including *A Technical Overview of the Oracle® Exadata Storage Server*, a White Paper written by Ron Weiss of Oracle.

2 *The Oracle Exadata Storage Server*

The Oracle Exadata Storage Server is a new type of database storage appliance, optimized for high performance in database query processing. The storage appliance is connected to one or more instances of Oracle Database in place of conventional storage arrays.

An Exadata Storage Server consists of one or more storage servers, where each storage server is an HP DL180 G5 server configured with two Intel 2.66 Ghz quad core processors, twelve disks, a smart storage array controller, 8 GB of memory and two Infiniband ports.

The disk array within an Exadata Storage Server can be populated with either 450GB Serial Attached SCSI (SAS) drives or 1 TB Serial Advanced Technology Attachment (SATA) drives.

A SAS populated Exadata Storage Server provides about 1.5 TB of uncompressed user data capacity and 1 GB/second of uncompressed data bandwidth.

A SATA populated Exadata Storage Server provides about 3 TB of uncompressed user data capacity and 750 MB/second of uncompressed data bandwidth.

With the use of Infiniband switches, an Oracle Exadata Storage Server is designed to scale modularly to hundreds of storage servers. Each storage server is connected redundantly to two switches. A standard 42U rack can accommodate up to 14 storage servers and eight Real Application Clusters servers. Oracle Exadata Storage Servers readily scale to multiple racks.

This hardware architecture provides the Exadata Storage Server with high bandwidth (that is, data can be transferred between the database and storage at a high sustained rate), which is helpful in a wide range of database operations. Scans, loads and backups are three common operations that can proceed more rapidly with the Exadata Storage Server than with conventional storage architectures, because of the higher underlying bandwidth of the storage system. For example, a single-rack Oracle Exadata Storage Server populated with SAS disks will deliver data at approximately 14 GB per second. Most data warehouse queries will be accelerated substantially by the increased bandwidth alone.

But, the intelligence built into the Exadata software is designed to add to the performance gain. Exadata Storage Server Software features Smart Scan technology, which offloads certain aspects of SQL processing from the database grid to storage—notably filtration (e.g., SQL WHERE predicate) and column projection. In addition, Exadata performs filtering of large tables that are joined with smaller tables, a common scenario in data warehouses employing the star schema. This is implemented using Bloom Filters, which are an efficient probabilistic method to determine whether a row is a member of the desired result set.

Data protection is also built in to the Exadata architecture. Disks are mirrored, each with a disk on a different storage server (thus, data is protected automatically against both single disk and single storage server failures). Because each storage server is connected via Infiniband to two switches, data is also protected against single switch failures.

The Exadata storage is transparent to the database application or end user and is supported by Oracle Automatic Storage Management (ASM) and Oracle Enterprise Manager.

The overall aim of the Exadata Storage Server design is to provide greatly improved performance, scalability, manageability, and availability for database applications.

3 *The Exadata Storage Server Performance Tests*

The performance tests were designed to quantify and validate the performance advantages of the Exadata Storage Server, demonstrating both the increased bandwidth and the value of embedding query processing intelligence within the storage system.

A business context was defined for the test as follows: the group responsible for bolstering club card and affinity credit card activity for Acme Inc has built a data mart with data from several sources, including the main corporate ERP and CRM systems; partner merchant ERP systems; and, outside syndicated data.

TEST SYSTEM

The system configured for this performance testing consisted of a fully-loaded single rack with eight RAC servers and 14 Exadata Storage Servers.

DATABASE

To obtain performance data for the Exadata Storage Server, the Affinity Card Test Database (ACTD) was created, along with four test queries of moderate complexity. The ACTD consists of 10 related tables, with row counts and sizes as shown in *Figure 1*.

Figure 1: Tables in the ACTD Database

Table Name	Row Count	Size (GB)
all_card_trans	172,546,198,628	13,458
partner_merchant_sales	5,161,772,800	281
customer_fact	25,808,864	23
our_sales	1,267,934,426	105
customer_service	5,053,661	16
our _stores	500	small
partner_merchants	450	small
zipcodes	43,191	small
zipregions	6	small
mcc	500	small

Note that the largest table, *all_card_trans*, contains over 172 billion rows and occupies 13.5 TB, uncompressed, on disk. Three tables have over a billion rows. Also, note that most of the tables are partitioned on different keys, forcing some non-partitionwise joins among large tables. In order to add additional real-world feel to the database, ISO 7812 Issuer Identifer values of 3333XX and 4777XX are assigned to the affinity credit cards for the ficticious company—Acme Inc. The *all_card_trans* table is partitioned by transaction date and the first number of the credit card.

For a complete list of tables and fields, see *Appendix A*.

QUERIES

For the performance tests, the queries were run one at a time and then concurrently. In English, the queries were:

- **Question 1** List our customers with Club Card points earned higher than 20,000 who purchased goods at partner merchant stores using our affinity credit card in the last 90 days.
- **Question 2** List our customers with Club Cards who purchased more than $1,000 worth of goods/services in the western retail region. Omit non-affinity card purchases and all restaurant, travel and gasoline purchases.
- **Question 3** List our Club Card members that have returned more than 10% of their purchased goods in the last three months while using our affinity card at non-partner retail merchants on goods and services totaling more than $1,000.
- **Question 4** List our Club Card members that have spent more than $1,000 at non-partner retail merchants in the last 180 days with our affinity credit card. Consider only non-partner merchants within 10 miles radius[1] of one of our stores.

See *Appendix B* for the SQL form of these queries used in the tests. Some of the query plans were tuned with Oracle SQL Tuning Advisor.

[1]Note: the proximity of merchants was calculated using syndicated US Postal zipcodes

4 *Test Environment*

The tests were run in December 2008 on Oracle Database 11g, Release 11.1.0.7. In these tests, a database grid consisting of eight RAC servers and a storage grid of 14 Exadata Storage Servers was used. Each RAC server was an HP DL-360 G5 with two Quad-Core Intel Xeon 5430 (2.66 GHz) processors with 32 GB of main memory. A unified, redundant Infiniband fabric was used for both storage and RAC interconnect. The Exadata Storage Server configuration attached to the database grid consisted of 14 Exadata Storage Servers populated with the SAS hard drive option. At the time of this testing, Exadata Storage Servers with the SAS option consisted of 12 300GB hard disk drives providing about 1.5 TB of uncompressed user data capacity and 1 GB/ second of uncompressed data bandwidth.

The disks were managed with Automatic Storage Management in normal redundancy disk groups for performance and data protection.

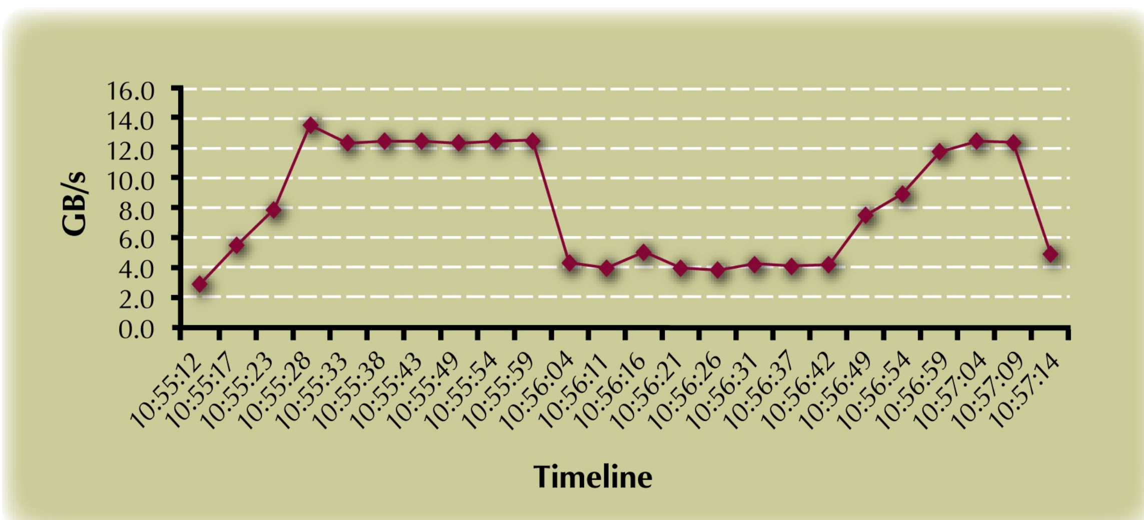
The hardware configuration for the December 2008 tests was equivalent to one of the standard single-rack configurations for the HP Oracle Database Machine.

5 *Test Results*

SERIAL EXECUTION

The queries were first run one at a time. The overall completion time for the four queries was 126 seconds. Aggregate physical disk I/O throughput was averaged at 5-second intervals during the test. *Figure 2* shows a timeline with aggregate Exadata Storage Server physical I/O measured during the test.

Figure 2: Physical Disk I/O, Serially Executed Queries

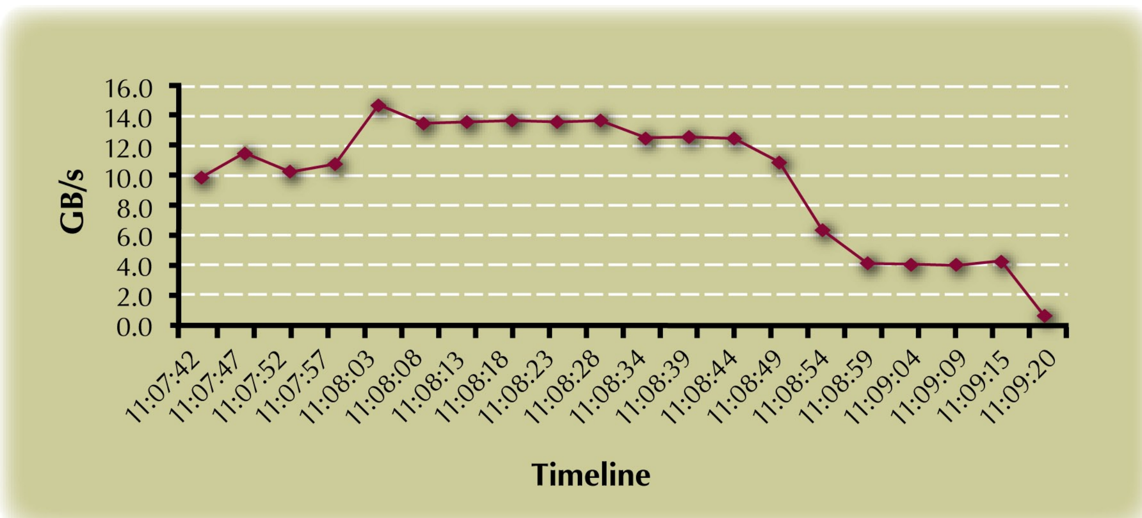


Complex queries exhibit varying demand placed upon storage as the query progresses from disk-intensive to cpu-intensive portions of the query plan (e.g., scan to join, sort, etc). During the most disk-intensive portions, the serially executed queries drove physical disk I/O to within 4% of the expected maximum I/O rate for a single-rack HP Oracle Database Machine, which is 14 Gigabytes per second. However there were significant portions of time when the database grid was stressed for cpu-intensive work while storage bandwidth was under-utilized as depicted in *Figure* 2. In order to achieve a more uniform I/O workload, the queries were next tested with concurrent execution. The query completion time for the four test queries was 126 seconds when executed serially.

CONCURRENT EXECUTION

The database server grid component of the HP Oracle Database Machine is capable of servicing concurrently executed parallel queries. The tests were next executed with all four queries started simultaneously. When executed concurrently, the overall completion time for the four queries was 99 seconds—an improvement of 21% over the serially executed test results. With Data Warehouse queries, inceased disk I/O throughput is expected to pay dividends in the form of reduced query processing time. When processing queries concurrently, there are more disk I/O intensive tasks in motion at any given time. As such, the timeline in *Figure 3* shows that during the concurrent processing of the four complex queries the HP Oracle Database Machine demonstrated maximum theoretical throughput at 11.08.03. Moreover, physical I/O averaged above 95% of maximum theoretical throughput for nearly half of the overall query processing window (11:08:03 through 11:08:44).

Figure 3: Physical Disk I/O, Concurrent Queries



It is significant to drive physical I/O at rates of 14 GB/second with a simple table scan, it is another thing entirely to do so with a concurrent mix of complex parallel queries.

14 Gigabytes per second is a rate that can be achieved with some conventional storage arrays —only in dedicated large-scale enterprise arrays, that would require multiple full-height cabinets of hardware—and would therefore entail more space, power, and cooling than the HP Oracle Database Machine we tested here. Additionally, with established storage architectures, Oracle cannot offload any processing to the storage tier, therefore the database tier would require substantially more hardware to achieve a rate approaching 14 GB/second.

Yet more significant is this: the Exadata storage architecture is scalable with respect to all its hardware components: storage bandwidth, network bandwidth, memory bandwidth and processor capacity. Each storage server has its own dedicated paths to storage and is connected to the database tier via a scalable Infiniband network. The Exadata Storage Servers do not interact with one another. Each storage server has a hardware level bandwidth of one GB/second. If you want more bandwidth (up to some limit that has not yet been reached) you can simply add more storage servers.

Thus, the performance tests validate three of the basic elements of the Exadata Storage Server value proposition. They demonstrate: (a) even a modest configuration of eight Real Application Clusters servers with 14 Exadata Storage Servers readily scales to an impressive throughput of 14 GB/s; (b) the offload-processing benefit of Smart Scan™ renders sufficient bandwidth to execute concurrent, complex queries that drive sustained I/O at near maximum theoretical rates; and, (c) a single rack Exadata configuration delivers bandwidth and concurrent query throughput that could only be achieved in a standard industry array or SAN with multiple racks of enterprise storage and with several additional RAC servers. Thus, the Exadata architecture also offers advantages in hardware efficiency, space, power and cooling at both the database and storage tiers.

6 *Manageability*

Until the advent of the Exadata Storage Server, Oracle customers had to choose between two options, neither or which satisfy all of their needs.

Most users have been placing data warehouse data in the enterprise storage area network (SAN), storing it in large arrays, mixed with other types of data. This approach confers advantages in manageability, simplicity and uniformity from the enterprise storage management perspective. However, it typically compromises data warehouse performance because few customers are able to dedicate enough bandwidth to the data warehouse. The result is that storage bandwidth becomes the limiting factor on data warehouse performance. As the data warehouse matures and becomes more critical to the daily activities of the enterprise, limitations on its performance and throughput grow in significance to the business.

Some users have been choosing to solve the bandwidth problem by provisioning the Oracle data warehouse with many small arrays. But, as the configuration grows, this introduces complexity and reduces manageability. Multiple small, independent storage arrays are ultimately not a scalable approach for these reasons.

With the Exadata Storage Server, Oracle customers have one storage product that provides high performance for the data warehouse with scalability and manageability.

The manageability is present first because the Exadata Storage Server is integrated with Oracle's Automated Storage Management (ASM). Thus, none of the pre-existing capabilities of ASM are reduced or compromised.

Each disk in an Exadata Storage Server is mirrored with a disk on another storage server. Thus single disks and single storage servers can fail without interrupting database operations. Similarly, a storage server can be taken offline for maintenance without interrupting database operation.

Storage is also readily expanded via the addition of new storage servers. The database need not be taken offline when storage storage servers are added. And, repaired storage servers can be brought back online while the database continues to run.

The use of Exadata storage is transparent to database applications. No changes to applications are required and all features of Oracle database are supported. Exadata storage may be mixed with other types of storage in an instance of ASM, thus facilitating migration.

Oracle ASM supports storage virtualization on Exadata storage as well, thus enabling both the definition of logical volumes that differ from physical volumes and the ready management of hot and cold data areas. The creation of logical volumes, striping and other basic storage functions are automated by ASM and this automation applies equally to Exadata storage.

7 *Conclusions*

The tests described in this report demonstrate that the Oracle Exadata Storage Server delivers major advantages in storage bandwidth and system efficiency.

These gains are proven and quantified with illustrative data warehouse queries on a multi-billion row scale. The queries chosen are not simple scans, but combine scanning with joins, sorting, grouping and other complex database operations. They demonstrate that the Oracle tools routinely used to create and optimize queries successfully integrate the intelligence in Exadata storage with the existing performance capabilities of Oracle.

The tests show that even a modest 14 Exadata storage server system—housed in one standard 42U rack—will deliver higher throughput and system efficiency than Oracle using a dedicated multiple cabinet high-end enterprise class array—when processing data warehouse queries. As a result, the Oracle Exadata Storage Server, when properly configured for most data warehouse workloads, will also deliver savings in space, power, cooling when compared to a typical SAN based storage solution.

The tests also show that both of the key performance innovations in the Exadata Storage Server contribute significantly to data warehouse performance and scalability in two major ways.

First, the fundamental architecture of the Exadata Storage Server—a set of independent storage storage servers linked to the database tier by a scalable network built from standard components —contributes high storage bandwidth with modular scaling. Significantly, the Exadata storage storage server provides a much higher ratio of bandwidth to storage capacity than is economically available in enterprise class storage arrays.

Second, the intelligence built into the storage storage server—which performs filtering, projection and some joins within the storage tier—increases the effective storage bandwidth further. One can readily devise realistic examples in which the benefit from these operations would yield factors of 10, 100 or more in the efficiency of performing specific queries. Moving these database operations into the storage tier produces more than performance gains—it also reduces work for the database tier.

In the opinion of WinterCorp, Oracle data warehouse users can expect to see dramatic gains from the Oracle Exadata product family, combined with benefits in integration, storage management, economy and modular scalability. In addition, many customers will be attracted by the advantages in space, power and cooling offered by these products.

Therefore, WinterCorp recommends that Oracle data warehouse users consider the Oracle Exadata Storage Server whenever they evaluate how to better to address service level objectives, whether for current or new data warehouse requirements.

Appendix A: Test Data Warehouse Schema

Our Stores
store_id number(6),
city varchar2(40),
state char(2),
zip number(5)

Our Sales
custid number(12),
trans_id number(16),
trans_dt date,
trans_amt number(7),
store_code number(6),
club_points_earned number(7),
aff _cc_num varchar2(20),
non aff _cc_num varchar2(20)

Customer Service
custid number(12),
club_card_num varchar2(20),
return_dt date,
refund_amt number(7),
cc_number varchar2(20)

Zipcodes
zip number(5),
city varchar2(40),
state char(2),
longitude number(13,7),
latitude number(13,7),
tz number(2),
dst number(1)

Customer Facts
custid number(12),
gender char(7),
fnamechar(15),
mi char(3),
lnamechar(20),
address varchar2(60),
city varchar2(40),
state char(3),
zip number(6),
country_code char(8),
email varchar2(60),
phone varchar2(30),
security_word varchar2(30),
dob date,
cc_type char(20),
cc_number varchar2(20),
cc_cvc number(6),
cc_expiry date,
public_id varchar2(15),
ups_last_track varchar2(40),
custdetail1 varchar2(60),
custdetail2 varchar2(60),
custdetail3 varchar2(60),
club_card_num varchar2(20),
club_status number(2),
club_membership_ date,
club_card_expiry dt date,
club_card_points number(8),
aff _cc_num varchar2(20),
aff _cr_lim number(6),
aff _cr_high_bal number(6),
aff _cr_activity_score number(3),
hh_income number(7),
cust_fico number(4),
empindustry number(3),
cust_home_store number(6),
cust_shipto_detail1 varchar2(120),
cust_shipto_detail2 varchar2(120)

mcc (Merchant Categories)
mccnumber(6),
description varchar2(240),
misc varchar2(40),
mccgrouping varchar2(20)

All Card Transactions
card_no varchar2(20),
card_type char(20),
mccnumber(6),
purchase_amt number(6),
purchase dt date,
merchant_code number(7),
merchant_city varchar2(40),
merchant_state char(3),
merchant_zip number(6)

Partner Merchants
partner_id number(6),
merchant_code number(7),
merchant_type number(4),
store_name varchar2(40),
store_id number(6),
store_zip number(6)

Partner Merchant Sales
partner_id number(6),
store_id number(6),
cc_number varchar2(20),
product_id number(8),
mccnumber(6),
purchase dt date,
sales_price number(8),
promo_price number(8),
catalog_sale char(3)

Appendix B: Test Data Warehouse Queries

QUERY 1

List our customers with Club Card points earned higher than 20,000 who purchased goods at partner merchant stores using our affinity credit card in the last 90 days.

```
with gold_member_aff_cust as
(
        select custid, aff_cc_num from cust_fact
                where ( club_card_num not like '0%' and aff_cc_num not like '0%')
 and
                club_card_points > 20000
),
pm_affinity_activity_90 as (
        select cc_number from partner_merchant_sales
                where (cc_number like '4777%' or cc_number like '3333%')
                and
                purchase_dt > to_date('10-SEP-2008','dd-mon-yyyy')
)
select custid from gold_member_aff_cust where aff_cc_num in ( select cc_number from
pm_affinity_activity_90 );
```

QUERY 2

List our customers with Club Cards who purchased more than $1,000 worth of goods/services in the western retail region. Omit non-affinity card purchases and all restaurant, travel and gasoline purchases.

```
with act
as
(
select act.card_no, act.purchase_amt
from all_card_trans act ,mcc m, zipcodes z
where (act.card_no like '4777%' or
 act.card_no like '3333%') and
 act.mcc = m.mcc and
 m.misc not like 'rest%trav%gas%' and
 act.merchant_zip = z.zip and
 z.state in ('CA', 'OR', 'WA')
)
select
 cf.custid,
 sum (act.purchase_amt) sales
from act ,cust_fact cf
where
 act.card_no = cf.aff_cc_num and
 cf.club_card_num not like '0%'
group by cf.custid
having sum (act.purchase_amt) > 1000;
```

QUERY 3

List our Club Card members that have returned more than 10% of their purchased goods in the last 3 months while using our affinity card at non-partner retail merchants on goods and services totaling more than $1,000.

```
with club_member_returns as (
        select custid, sum(refund_amt) returns
        from cust_service cs
        where return_dt > to_date('10-SEP-2008','dd-mon-yyyy')
        and
        (
        cs.club_card_num not like '0%'
        )
        group by custid
),
club_aff_10_90_returns as (
        select cmr.custid, cf.aff_cc_num, cmr.returns, sum(os.trans_amt)
        from club_member_returns cmr, cust_fact cf, our_sales os
        where cf.custid = cmr.custid and cf.custid = os.custid
                        and
                        os.club_points_earned > 0
        and
        (
        (cf.aff_cc_num like '4777%' or cf.aff_cc_num like '3333%')
                and
        cf.club_card_num not like '0%'
        )
                and
                        os.trans_dt > to_date('10-SEP-2008','dd-mon-yyyy')
        group by cmr.custid, cf.aff_cc_num, cmr.returns
        having (returns / sum(os.trans_amt) * 100) > 10
)
select card_no, sum(purchase_amt) sales
 from all_card_trans act
 where ( card_no like '4777%' or card_no like '3333%' )
 and
 act.purchase_dt > to_date('10-SEP-2008','dd-mon-yyyy')
                and
                card_no in ( select aff_cc_num from club_aff_10_90_returns)
 and act.merchant_code not in ( select merchant_code from partner_merchants)
 group by card_no
 having sum(purchase_amt) > 1000;
```

QUERY 4

List our Club Card members that have spent more than $1,000 at non-partner retail merchants in the last 180 days with our affinity credit card. Consider only non-partner merchants within 10 miles radius (same zipcode) of one of our stores.

```
select cf.custid, sum(act.purchase_amt) sales
        from all_card_trans act, cust_fact cf
        where
                ( act.card_no like '4777%' or act.card_no like '3333%' )
                        and
                act.card_no = cf.aff_cc_num
                        and
                cf.club_card_num not like '0%'
                        and
                act.purchase_dt > to_date('10-JUN-2008','dd-mon-yyyy')
                        and
                act.merchant_zip in ( select distinct(zip) from our_stores)
                        and
                act.merchant_code not in (select merchant_code from partner_
merchants)
        group by custid
        having sum(act.purchase_amt) > 1000 ;
```

WinterCorp is an independent consulting firm that specializes in the performance and scalability of terabyte- and petabyte-scale data management systems throughout their lifecycle.

Since our inception in 1992, we have architected many of the world's largest and most challenging databases in production today. Our consulting services help organizations define business-critical database solutions, select their platforms, engineer their implementations, and manage their growth to optimize business value.

With decades of experience in large-scale database implementations and in-depth knowledge of database products, we deliver unmatched insight into the issues that impede performance and the technologies that enable success.

WinterCorp

411 WAVERLEY OAKS ROAD, SUITE 328
WALTHAM, MA 02452
781-642-0300

visit us at www.wintercorp.com