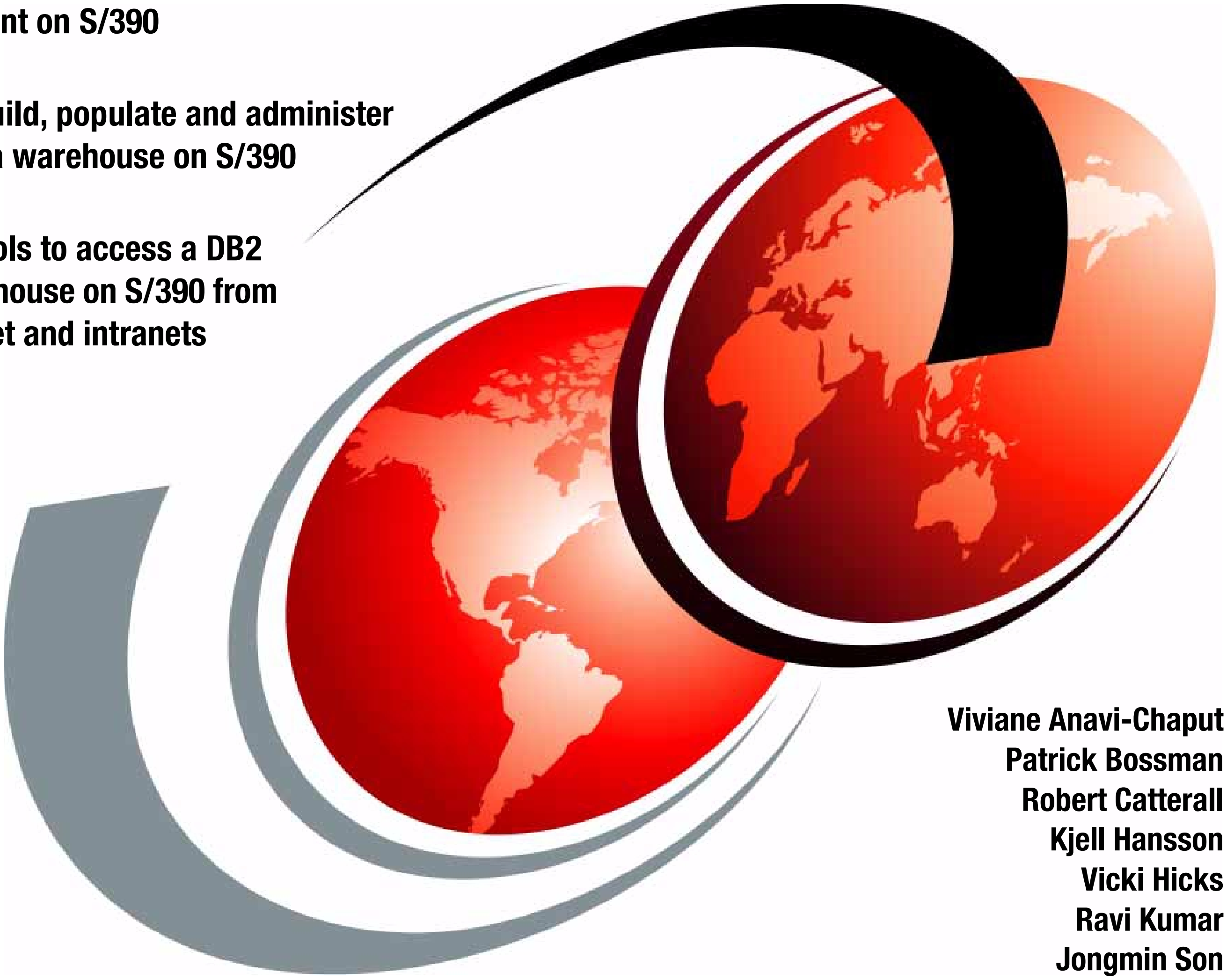
Business Intelligence Architecture on S/390

Presentation Guide

Design a business intelligence environment on S/390

Tools to build, populate and administer a DB2 data warehouse on S/390

BI-user tools to access a DB2 data warehouse on S/390 from the Internet and intranets



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Business Intelligence Architecture on S/390 Presentation Guide

July 2000

Take Note!

Before using this information and the product it supports, be sure to read the general information in Appendix A, “Special notices” on page 173.

First Edition (July 2000)

This edition applies to 5645-DB2, Database 2 Version 6, Database Management System for use with the Operating System OS/390 Version 2 Release 6.

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Contents

Preface

This IBM Redbook was derived from a presentation guide designed to give you a comprehensive overview of the building blocks of a business intelligence (BI) infrastructure on S/390. It describes how to configure, design, build, and administer the S/390 data warehouse (DW) as well as how to give users access to the DW using BI applications and front-end tools.

The book addresses three audiences: IBM field personnel, IBM business partners, and our customers. Any DW technical professional involved in building a BI environment on S/390 can use this material for presentation purposes. Because we are addressing several audiences, we do not expect all the graphics to be used for any one presentation.

The chapters are organized to correspond to a typical presentation that ITSO professionals have delivered worldwide:

1. Introduction to BI architecture on S/390

   This is a brief introduction to business intelligence on S/390. We discuss BI infrastructure requirements and the reasons why a S/390 DB2 shop would want to build BI solutions on the same platform where they run their traditional operations. We introduce the BI components; the following parts of the presentation expand on how DB2 on S/390 addresses those components.

2. Data warehouse architectures and configurations

   This chapter covers the DW architectures and the pros and cons of each solution. We also discuss the physical implementations of those architectures on the S/390 platform.

3. S/390 data warehouse database design

   This chapter discusses logical and physical database design issues applicable to a DB2 for OS/390 data warehouse solution.

4. Data warehouse data population design

   The data warehouse data population design section covers the ETL processes, including the initial loading of the data in the warehouse and its subsequent refreshes. It includes the design objectives, partitioning schemes, batch window optimization using parallel techniques to speed up the process of loading and refreshing the data in the warehouse.

5. Data warehouse administration tools

   In this chapter we discuss the tool categories of extract/cleansing, metadata and modeling, data movement and load, systems and database management.

6. Access enablers and Web user connectivity

   This is an overview of the interfaces and middleware services needed to connect end users and web users to the data warehouse.

7. BI user tools and applications on S/390

   This section includes a list of front-end tools that connect to the S/390 with 2 or 3-tier physical implementations.

8. BI workload management

   OS/390 Workload Manager (WLM) is discussed here as a workload management tool. We show WLM's capabilities for dynamically managing mixed BI workloads, BI and transactional, DW and Data Marts (DM) on the same S/390.

9. BI Scalability on S/390

   This chapter shows scalability examples for concurrent users, processors, data, and I/Os.

10. Summary

   This chapter summarizes the competitive edge of S/390 for BI.

The presentation foils are provided in a CD-ROM appended at the end of the book. You can also download the presentation script and foils from the IBM Redbooks home page at:

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The team that wrote this redbook

This redbook was produced by a team of specialists from around the world working at the International Technical Support Organization, Poughkeepsie Center.

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Comments welcome

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- Fax the evaluation form found in “IBM Redbooks review” on page 185 to the fax number shown on the form.
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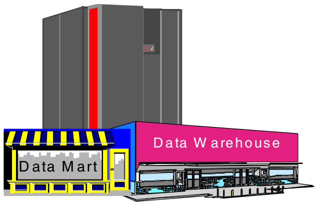
Chapter 1. Introduction to BI architecture on S/390

Introduction to Business Intelligence Architecture on S/390

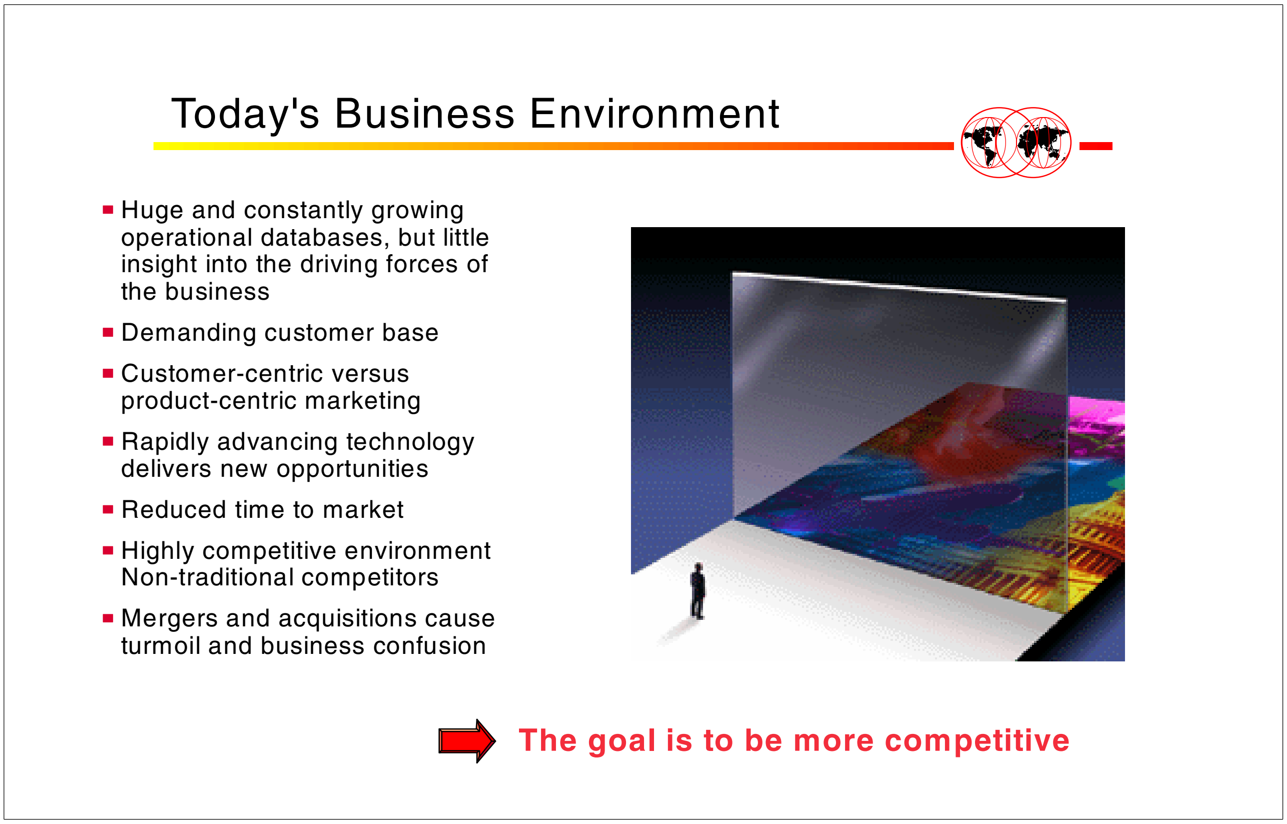


This chapter introduces business intelligence architecture on S/390.

It discusses today's market requirements in business intelligence (BI) and the reasons why a customer would want to build a BI infrastructure on the S/390 platform.

It then introduces business intelligence infrastructure components. This serves as the foundation for the following chapters, which expand on how those components are architected on S/390 and DB2.

1.1 Today’s business environment



Today's Business Environment

- Huge and constantly growing operational databases, but little insight into the driving forces of the business
- Demanding customer base
- Customer-centric versus product-centric marketing
- Rapidly advancing technology delivers new opportunities
- Reduced time to market
- Highly competitive environment Non-traditional competitors
- Mergers and acquisitions cause turmoil and business confusion

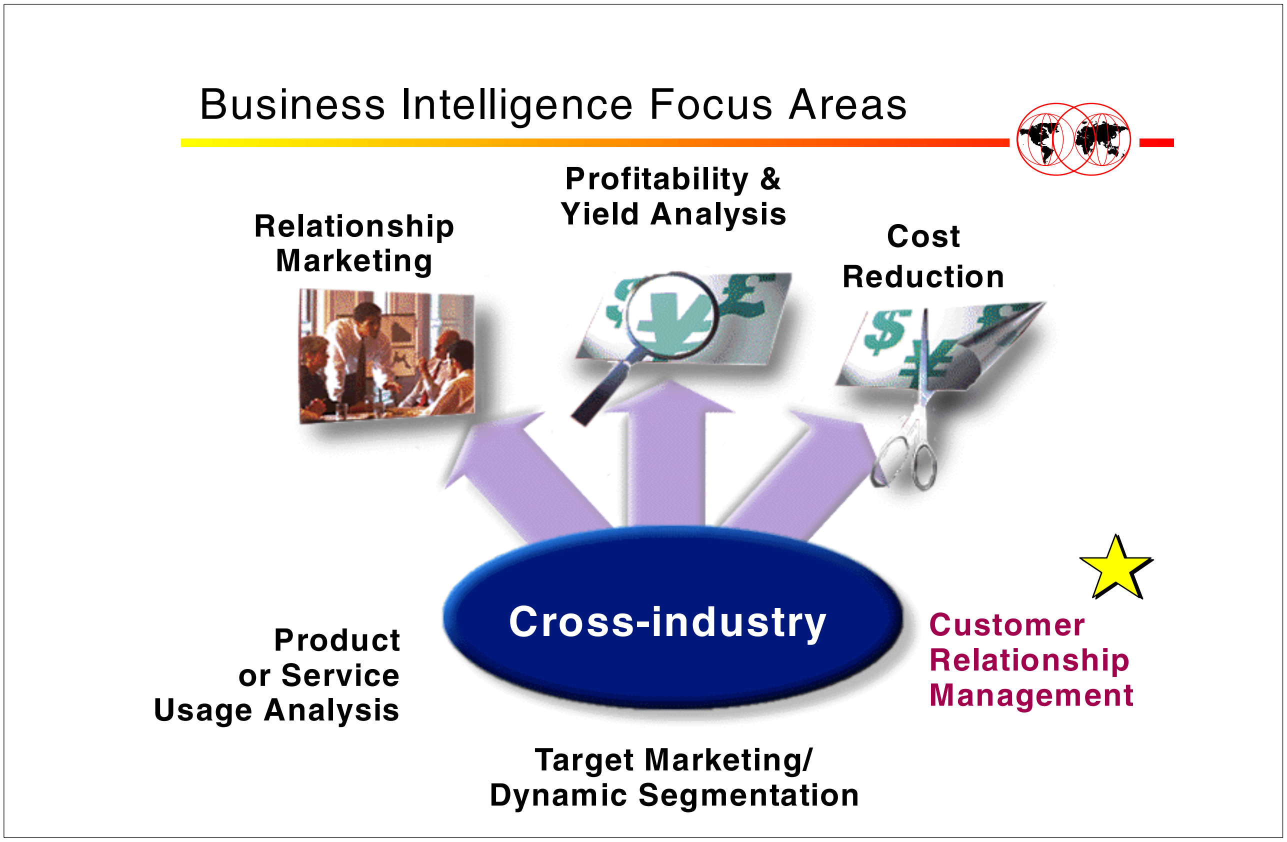
The goal is to be more competitive

Businesses today are faced with a highly competitive marketplace, where technology is moving at an unprecedented pace and customers’ demands are changing just as quickly.

Understanding customers, rather than markets, is recognized as the key to success. Industry leaders are quickly moving from a product-centric world into a customer-centric world.

Information technology is taking on a new level of importance due to its business intelligence application solutions.

1.2 Business intelligence focus areas



Business Intelligence Focus Areas

Relationship Marketing

Profitability & Yield Analysis

Cost Reduction

Cross-industry

Product or Service Usage Analysis

Customer Relationship Management

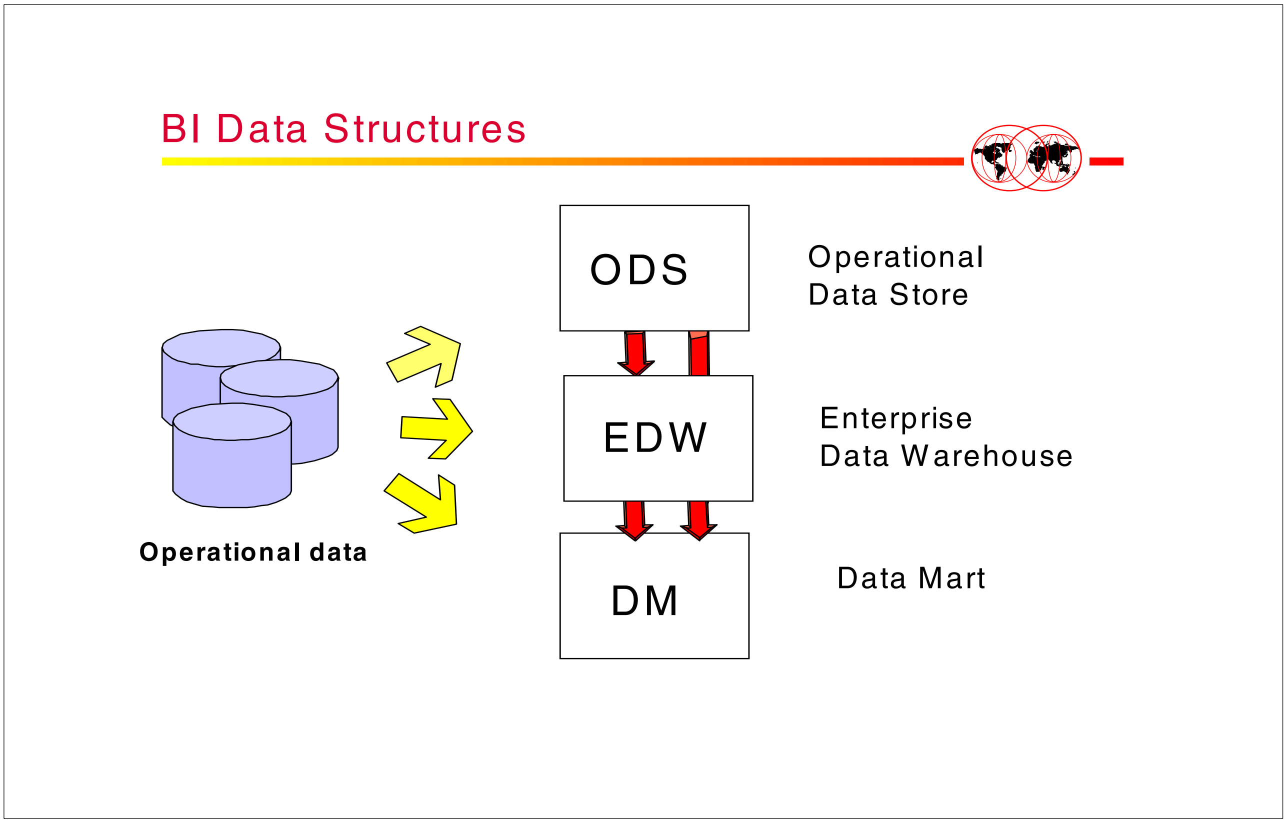
Target Marketing/ Dynamic Segmentation

To make their business more competitive, corporations are focusing their business intelligence activities on the following areas:

- Relationship marketing
- Profitability and yield analysis
- Cost reduction
- Product or service usage analysis
- Target marketing and dynamic segmentation
- Customer relationship management (CRM)

Customer relationship management is the area of greatest investment as corporations move to a customer-centric strategy. Customer loyalty is a growing challenge across industries. As companies move toward one-to-one marketing, it becomes critical to understand individual customer wants, needs, and behaviors. IBM Global Services has an entire practice built around CRM solutions.

1.3 BI data structures



BI Data Structures

ODS

Operational Data Store

EDW

Enterprise Data Warehouse

DM

Data Mart

Operational data

Companies have huge and constantly growing operational databases. But less than 10% of the data captured is used for decision-making purposes. While most companies collect their transactional data in large historical databases, the format of the data does not facilitate the sophisticated analysis that today's business environment demands. Many times, multiple operational systems may have different formats of data. Often, the transactional data does not provide a comprehensive view of the business environment and must be integrated with data from external sources such as industry reports, media data, and so forth. The solution to this problem is to build a data warehousing system that is tuned and formatted with high-quality, consistent data that can be transformed into useful information for business users. The structures most commonly used in BI architectures are:

- **Operational data store**

  An operational data store (ODS) presents a consistent picture of the current data stored and managed by transaction processing systems. As data is modified in the source system, a copy of the changed data is moved into the operational data store. Existing data in the operational data store is updated to reflect the current status of the source system. Typically, the data is stored in "real time" and used for day-to-day management of business operations.

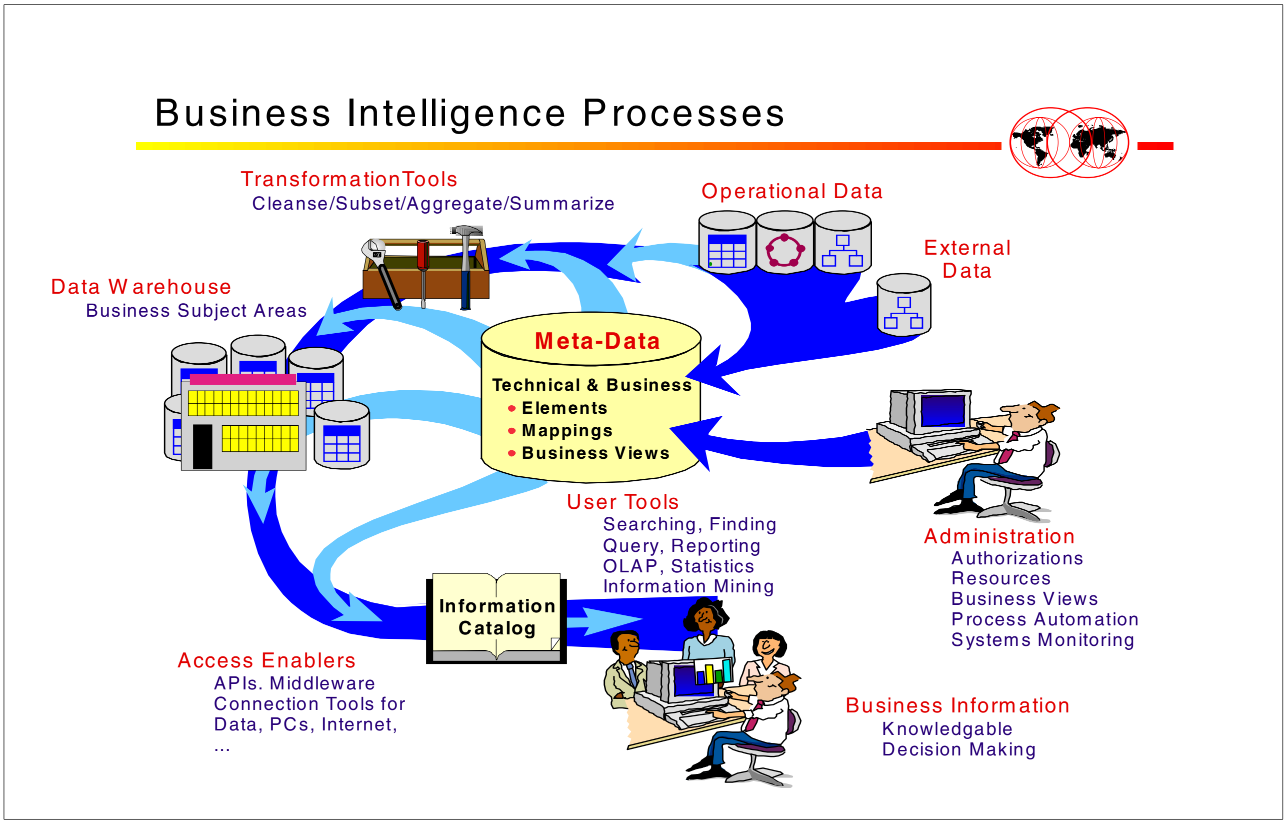
- **Data warehouse**

  A data warehouse (or an enterprise data warehouse) contains detailed and summarized data extracted from transaction processing systems and possibly other sources. The data is cleansed, transformed, integrated, and loaded into databases separate from the production databases. The data that flows into the data warehouse does not replace existing data, rather it is accumulated to maintain historical data over a period of time. The historical data facilitates detailed analysis of business trends and can be used for decision making in multiple business units.

- **Data mart**

  A data mart contains a subset of corporate data that is important to a particular business unit or a set of users. A data mart is usually defined by the functional scope of a given business problem within a business unit or set of users. It is created to help solve a particular business problem, such as customer attrition, loyalty, market share, issues with a retail catalog, or issues with suppliers. A data mart, however, does not facilitate analysis across multiple business units.

1.4 Business intelligence processes



Business Intelligence Processes

TransformationTools
Cleanse/Subset/Aggregate/Summarize

Operational Data

External Data

Data Warehouse
Business Subject Areas

Meta-Data

Technical & Business
- **Elements**
- **Mappings**
- **Business Views**

User Tools
Searching, Finding
Query, Reporting
OLAP, Statistics
Information Mining

Administration
Authorizations
Resources
Business Views
Process Automation
Systems Monitoring

Information Catalog

Access Enablers
APIs. Middleware
Connection Tools for
Data, PCs, Internet,
...

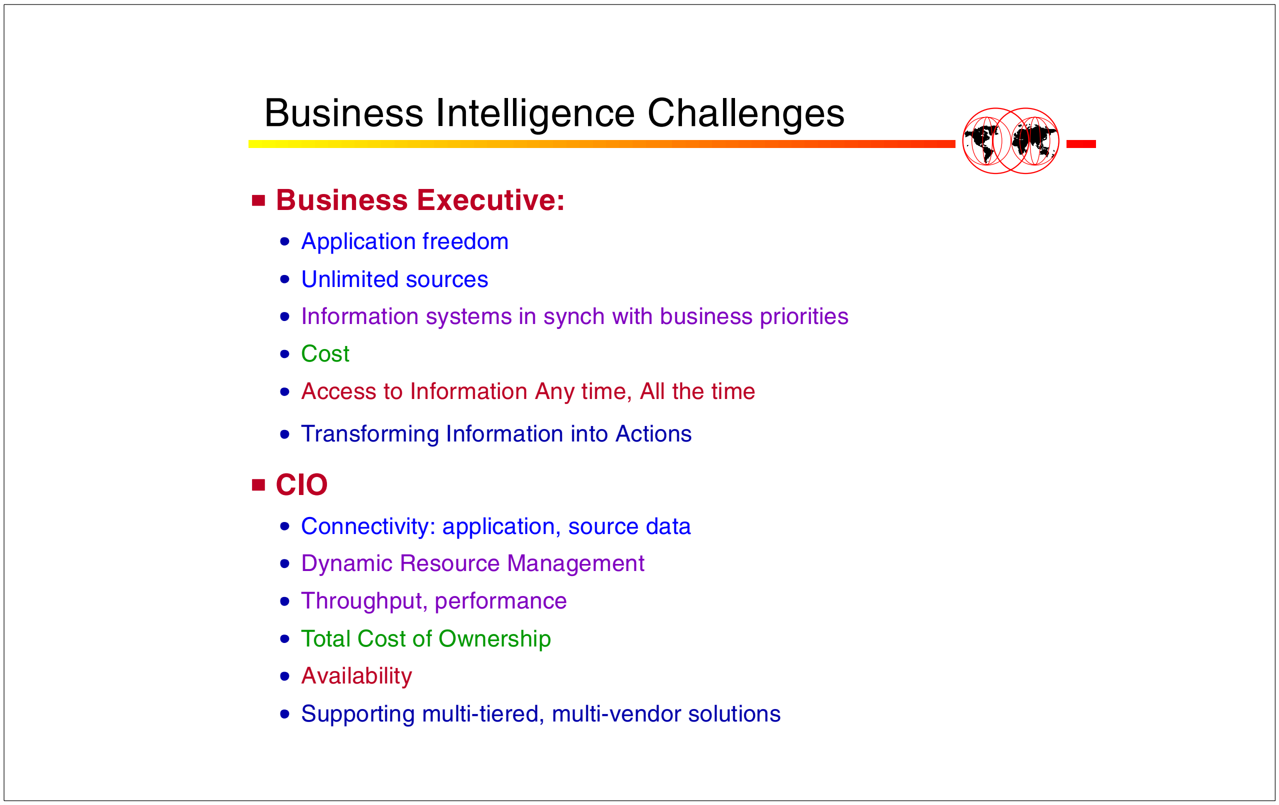
Business Information
Knowledgable
Decision Making

BI processes and tasks can be summarized as follows:

- Understand the business problem to be addressed
- Design the warehouse
- Learn how to extract source data and transform it for the warehouse
- Implement extract-transform-load (ETL) processes
- Load the warehouse, usually on a scheduled basis
- Connect users and provide them with tools
- Provide users a way to find the data of interest in the warehouse
- Leverage the data (use it) to provide information and business knowledge
- Administer all these processes
- Document all this information in meta-data

BI processes extract the appropriate data from operational systems. Data is then cleansed, transformed and structured for decision making. Then the data is loaded in a data warehouse and/or subsets are loaded into data mart(s) and made available to advanced analytical tools or applications for multidimentional analysis or data mining. Meta-data captures the detail about the transformation and origins of data and must be captured to ensure it is properly used in the decision-making process. It must be sourced and maintained across a heterogeneous environment and end users must have access to it.

1.5 Business intelligence challenges



Business Intelligence Challenges

- **Business Executive:**
  - Application freedom
  - Unlimited sources
  - Information systems in synch with business priorities
  - Cost
  - Access to Information Any time, All the time
  - Transforming Information into Actions
- **CIO**
  - Connectivity: application, source data
  - Dynamic Resource Management
  - Throughput, performance
  - Total Cost of Ownership
  - Availability
  - Supporting multi-tiered, multi-vendor solutions

The business executive views the challenges of implementing effective business intelligence solutions differently than does the CIO, who must build the infrastructure and support the technology.

The business executive wants :

- **Application freedom and unlimited access to data -** the flexibility and freedom to utilize any application or tool on the desktop, whether developed internally or purchased off the shelf, and access to any and all of the many sources of data that are required to feed the business process, such as operational data, text and html data from e-mail and the internet, flat files from industry consultants, audio and video from the media, without regard to the source or format of that data. And the executive wants that information accessible at all times.

The CIO’s challenge is:

- **Connectivity and heterogeneous data sources -** building an information infrastructure with a database technology that is accessible from all application servers and can integrate data from all data formats into a single transparent interface to those applications.

The business executive wants:

- **Information systems in synch with business processes -** information systems that can recognize his business priorities and adjust automatically when those priorities change.

The CIO challenge is:

- **Dynamic resource management/performance and throughput -** a system infrastructure that dynamically allocates system resources to guarantee that business priorities are met, ensuring that service level agreements are constantly honored and that the appropriate volume of work is consistently produced.

The business executive wants:

- **Low purchase cost.** Today's BI solutions are most often funded in large part or entirely by the business unit, and the focus at this level is on the cost of purchasing the solution and bringing it on line.

The CIO challenge is:

- **Total cost of ownership.** Skill shortages and rising cost of the workforce, along with incentives to come in under budget, drive the CIO to leverage the infrastructure and skill investments already made.

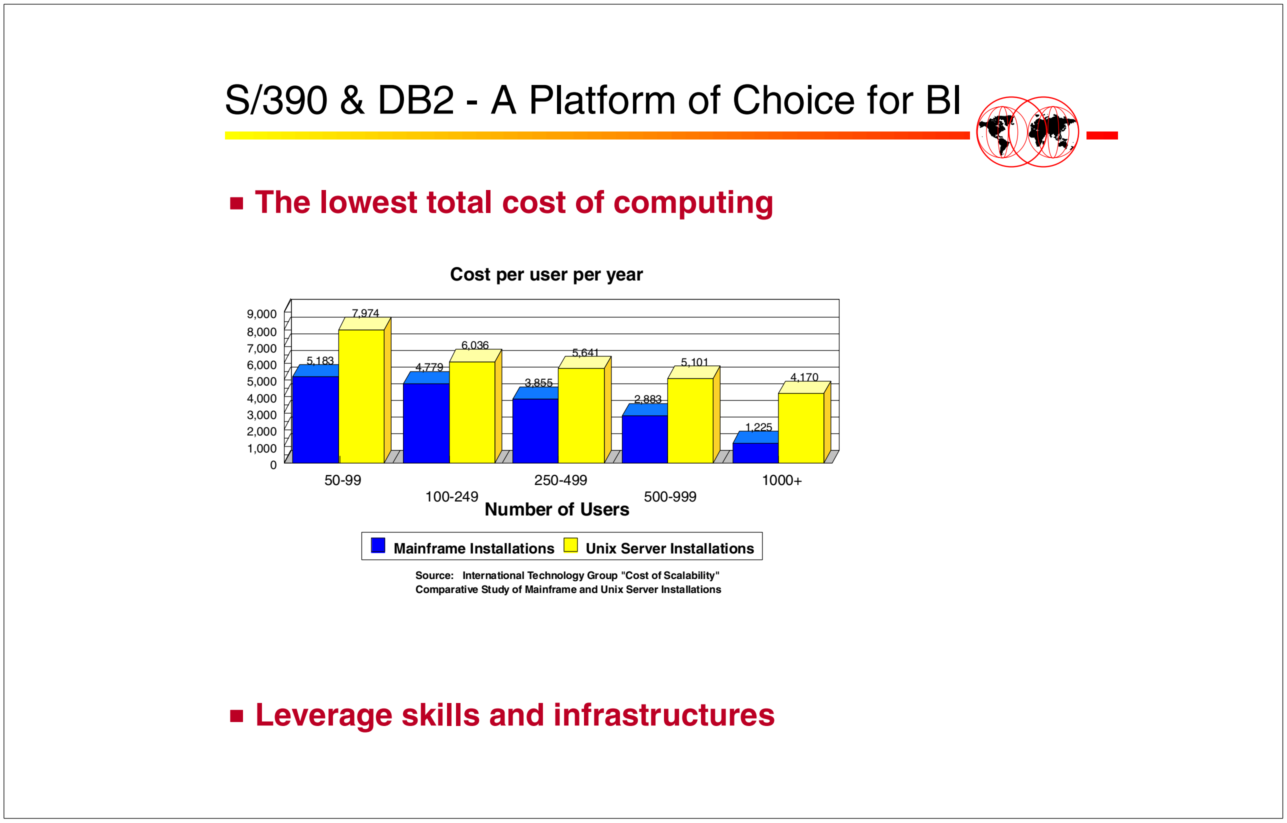
The business executive wants:

- **Access to all the data all the time/the ability to transform information into actions.** Most e-business companies operate across multiple time zones and multiple nations. With decision makers in headquarters and regional offices around the world, BI systems must be on line 24x365. Furthermore, the goal of integrating customer relationship management with real-time transactions makes currency of data in the decision support systems critical.

The CIO challenge is:

- **Availability/multi-tiered and multi-vendor solutions.** Reliability and integrity of the hardware and software technology for decision support systems are as critical as those for transaction systems. Growing in importance is the need to be able to do real-time updates to operational data stores and data warehouses, without interrupting access by the end users.

1.6 S/390 & DB2 - A platform of choice for BI



S/390 & DB2 - A Platform of Choice for BI

- The lowest total cost of computing

Cost per user per year

Source: International Technology Group "Cost of Scalability" Comparative Study of Mainframe and Unix Server Installations

- Leverage skills and infrastructures

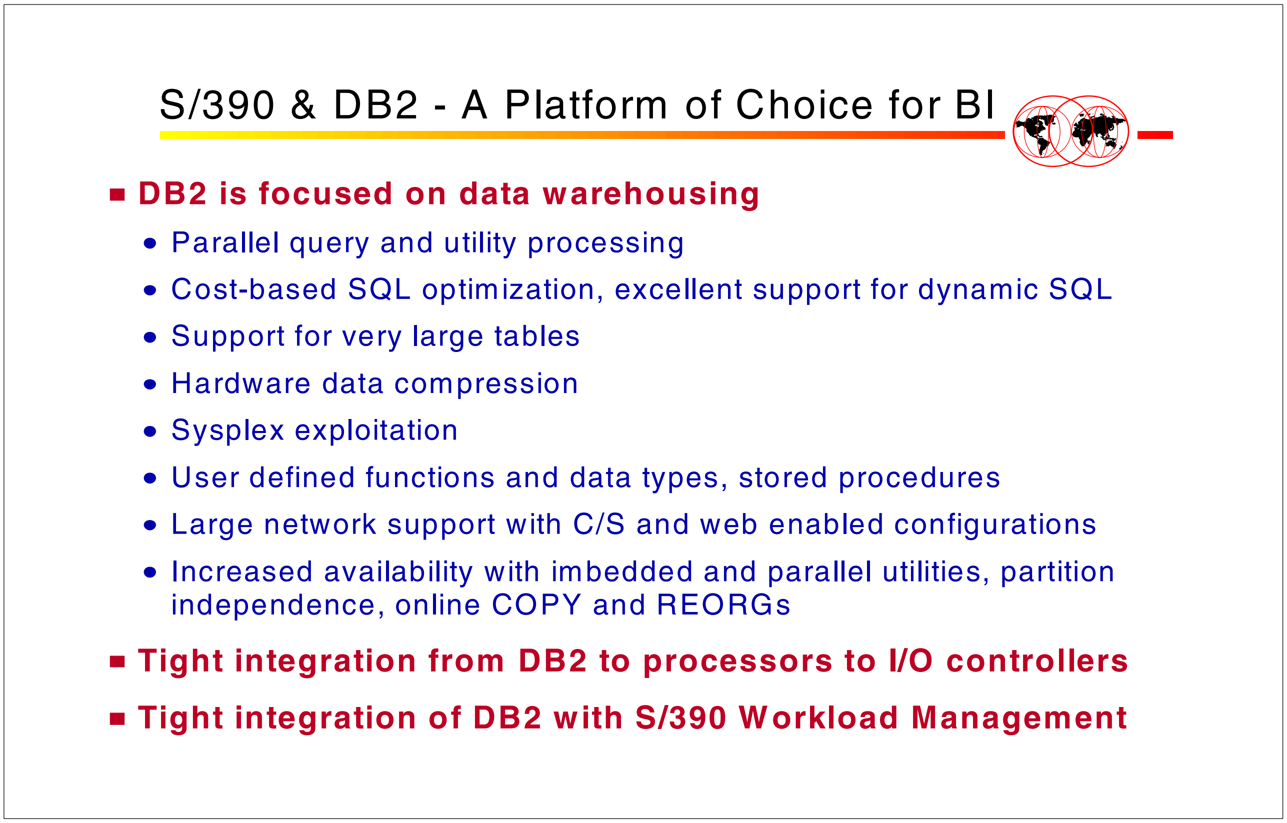
Considering the BI issues we have just identified, let's have a look at how S/390 and DB2 are satisfying such customer requirements.

- **The lowest total cost of computing**

  In addition to the hardware and software required to build a BI infrastructure, total cost of ownership involves additional factors such as systems management and training costs. For existing S/390 shops, given that they already have trained staff, and they already have established their systems management tools and infrastructures, the total cost of ownership for deploying a S/390 DB2 data warehousing system is lower when compared with other solutions. Furthermore, a study done by ITG shows that when you consider the total cost of ownership, as opposed to the initial purchase price, across the board, the cost per user is lower on the mainframe.

- **Leverage skills and infrastructures**

  Because of DB2's powerful data warehousing capabilities, there is no need for a S/390 DB2 shop to introduce another server technology for data warehousing. This produces very significant cost benefits, especially in the support area, where labor savings can be quite dramatic. Additionally, reducing the number of different technologies in the IT environment will result in faster and less costly implementations with fewer interfaces and incompatibilities to worry about. You can also reduce the number of project failures if you have better familiarity with your technology and its real capabilities.



S/390 & DB2 - A Platform of Choice for BI

- **DB2 is focused on data warehousing**
  - Parallel query and utility processing
  - Cost-based SQL optimization, excellent support for dynamic SQL
  - Support for very large tables
  - Hardware data compression
  - Sysplex exploitation
  - User defined functions and data types, stored procedures
  - Large network support with C/S and web enabled configurations
  - Increased availability with imbedded and parallel utilities, partition independence, online COPY and REORGs
- **Tight integration from DB2 to processors to I/O controllers**
- **Tight integration of DB2 with S/390 Workload Management**

- **DB2 is focused on data warehousing**

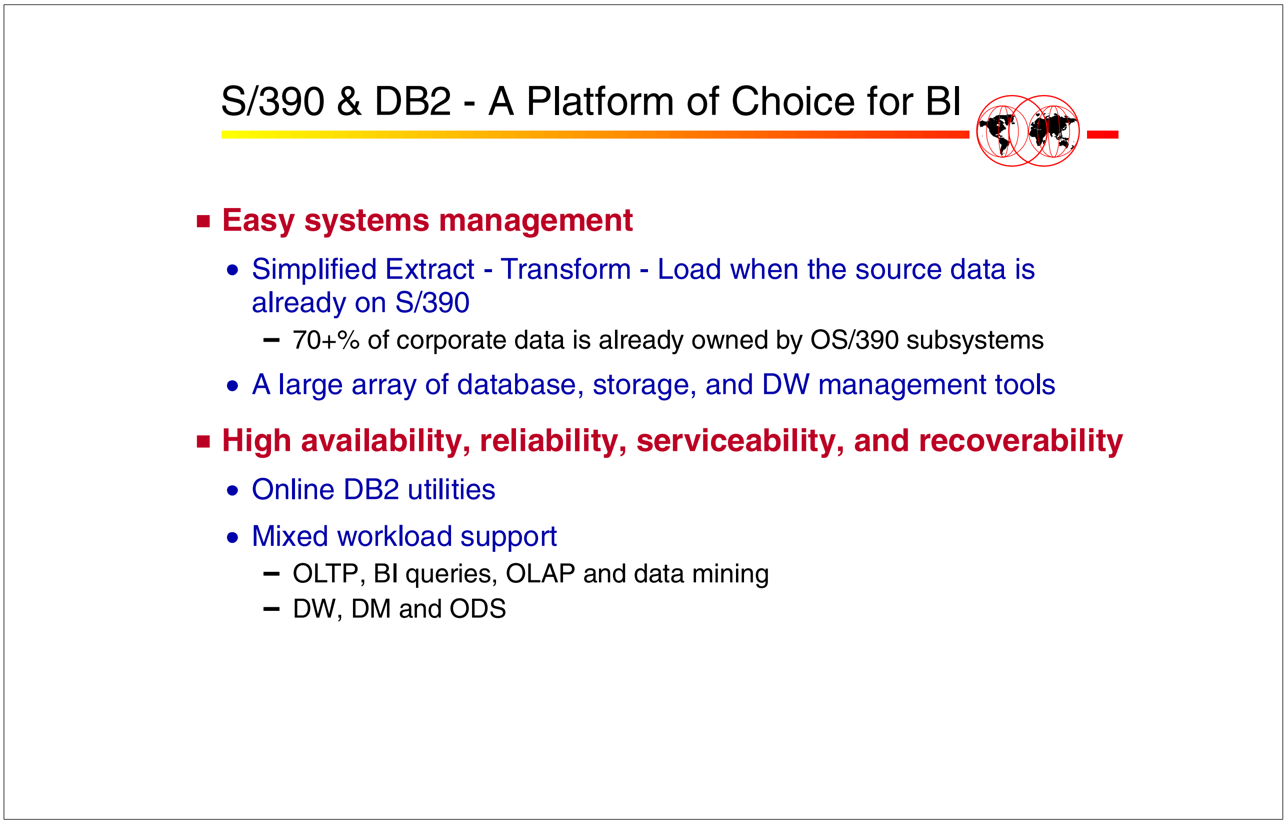
  DB2 is an aggressive contender for business intelligence, able to scale up to the very largest data warehouses. Significant technical developments over the years, such as I/O and CPU parallelism, Sysplex Query parallelism, data sharing, dynamic SQL caching, TCP/IP support, sequential caching support, buffer pool enhancements, lock avoidance, and uncommitted reads, have made DB2 for OS/390 a very powerful data warehousing product. DB2 is Web-enabled, supports large networks, and is universally accessible from any C/S structure using DRDA, ODBC, or Java connectivity interfaces.

- **Tight integration from DB2 to processors to I/O controllers**

  New disk controllers, such as ESS, help with the scanning of large databases often required in BI. DB2 parallelism is enhanced by the ESS device speeds, and by its ability to allow parallel acces of a logical volume by different hosts and different servers simultaneously. Simultaneous volume update and query capability enhance availability characteristics.

- **Tight integration of DB2 with S/390 workload management**

  The unpredictable nature of query workloads positions DB2 on OS/390 to get huge benefits from the unique capabilities of the OS/390 operating system to manage query volumes and throughput. This ensures that high priority work receives appropriate system resources and that short running, low resource consuming queries are not bottlenecked by resource-intensive queries.



S/390 & DB2 - A Platform of Choice for BI

- **Easy systems management**
  - Simplified Extract - Transform - Load when the source data is already on S/390
    - 70+% of corporate data is already owned by OS/390 subsystems
  - A large array of database, storage, and DW management tools
- **High availability, reliability, serviceability, and recoverability**
  - Online DB2 utilities
  - Mixed workload support
    - OLTP, BI queries, OLAP and data mining
    - DW, DM and ODS

- **Easy system management**

  The process of extracting, transforming, and loading data in the DW is the most complex task of data warehousing. This is one of the major reasons why a S/390 DB2 shop would want to keep the DW server on S/390. The transformation process is significantly simplified when the DW server is on the same platform as the source data extracted from the operational environment. The process is much simplified by avoiding distributed access and data transfers between different platforms.

  Data warehouse systems also require a set of tools for managing the data warehouse. The DB2 Warehouse Manager tools help in data extraction and transformation and metadata administration. They can also integrate metadata from third party tools such as ETI's EXTRACT and VALITY's INTEGRITY.

  DB2 has a complete set of utilities, which use parallel techniques to speed up maintenance processes and manage the database. DB2 also includes several optional features for managing DB2 databases, such as the DB2 Administration tool, DB2 Buffer Pool tool, DB2 Performance Monitor, and DB2 Estimator. DFSMS helps manage disk storage.

  Workload Management (WLM) is one of the most important management tools for OS/390. It allows administrators to control different workload executions based on business-oriented targets. WLM uses these targets to dynamically manage dispatching priorities, and use of memory and other resources, to achieve the target objective for each workload. It can be used to control mixed transaction and BI workloads such as basic queries, background complex queries, database loading, executive queries, specific workloads of a department, and so forth.

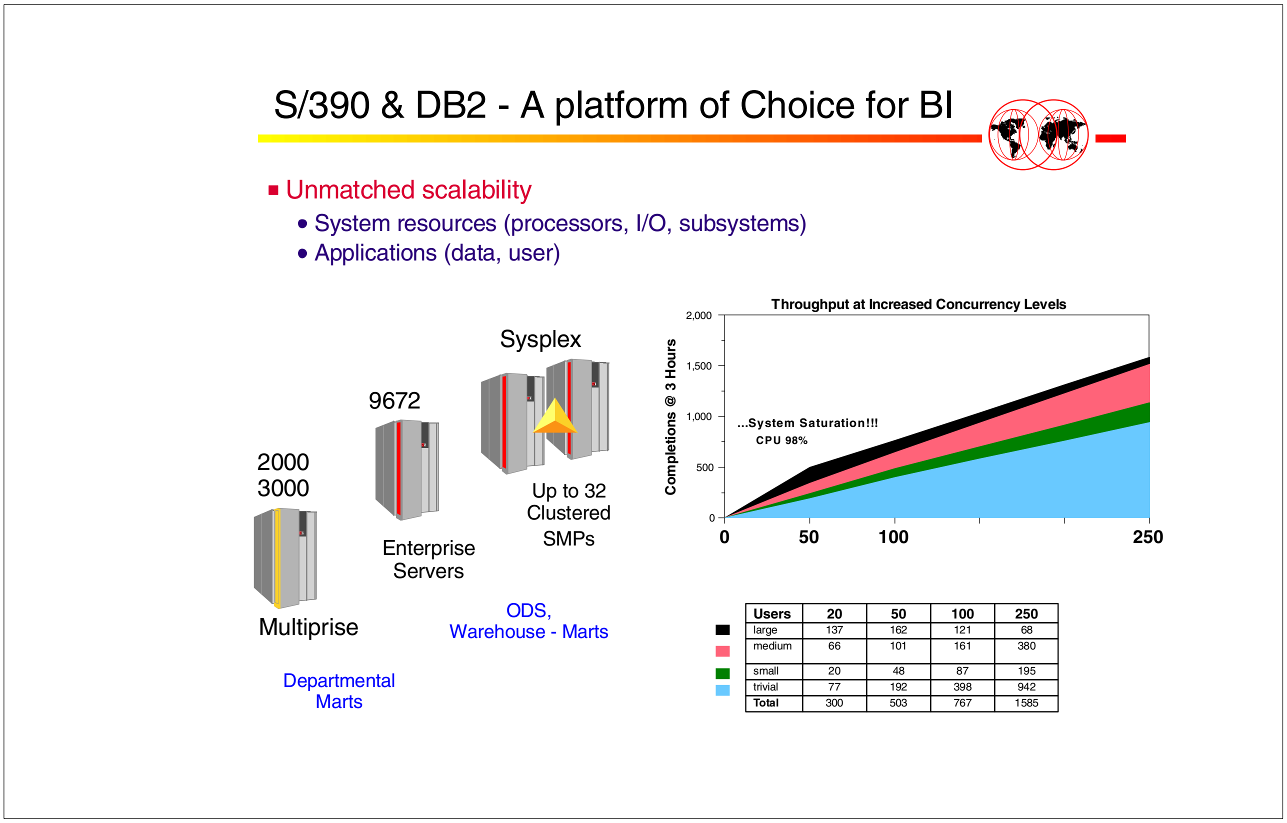
- **High availability, reliability, serviceability, and recoverability**

  A high aggregate quality of service in terms of availability and performance is achieved through the combination of S/390 hardware, OS/390, and DB2. This combination of high quality services results in a mature platform which supports a high performance, scalable and parallel processing environment. This platform is considered to be more robust and have higher availability than most other systems. As many organizations rely more and more on their data warehouse for business operations, high availability is becoming crucial for the data warehouse; this can be easily achieved on the S/390 together with OS/390 and DB2.

  Online Reorg and Copy capabilities, together with DB2's partition independence capability, allow concurrent query and data population to take place, thereby increasing the availability of the data warehouse to run user applications.

  There are also a lot of opportunities with WLM for OS/390 to balance mixed workloads to better use the processor capacity of the system. The ability to run mixed operational and BI workloads is exclusive to the S/390 platform. For example, running regular production batch jobs is easier when extra processor resources are available from the data warehouse after users go home, since we know most dedicated BI boxes are not fully utilized off prime shift. By the same token, an occasional huge data mining query run over a weekend can take advantage of extra OLTP processor resources, since weekend CPU utilization is typically low on most OLTP systems.

  The same rationale applies when DWs and DMs coexist on the same platform and the WLM manages the resources according to the performance objectives of the workloads.



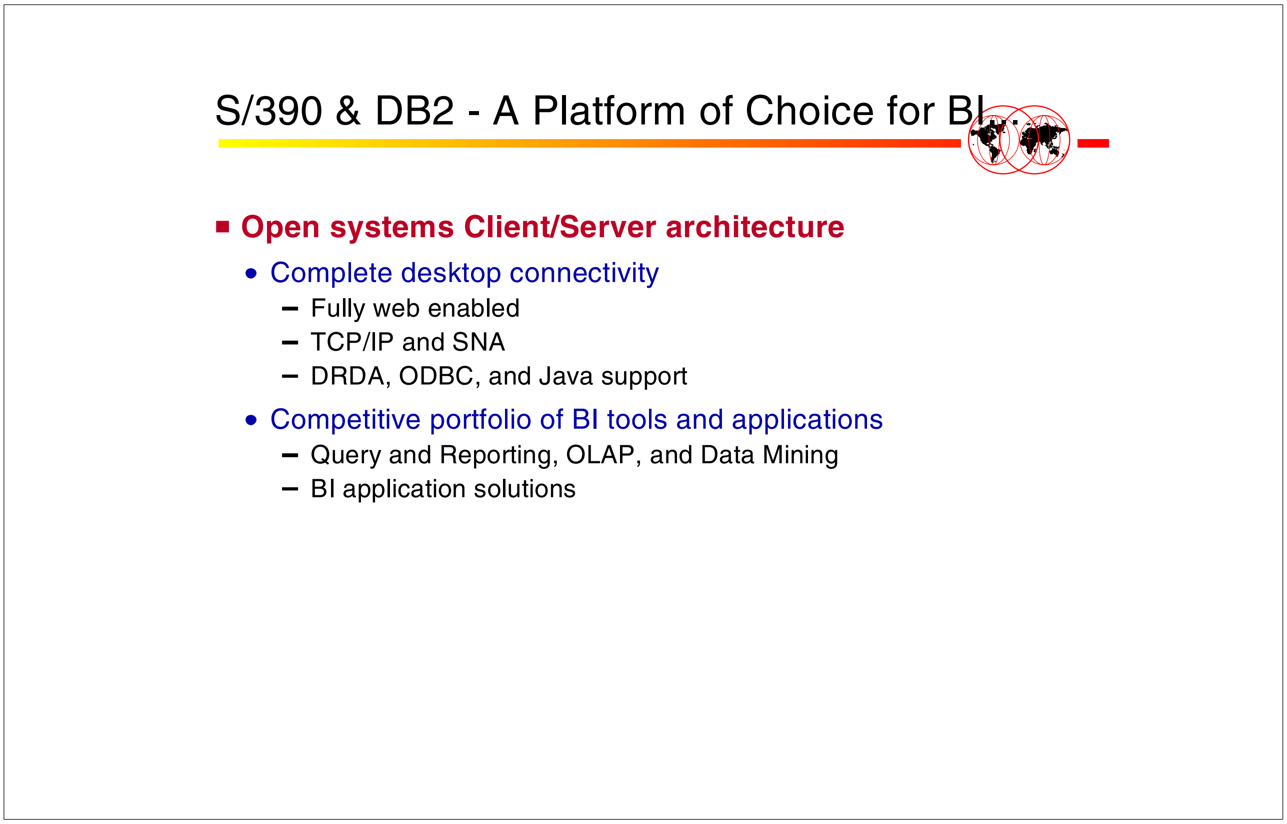
S/390 & DB2 - A platform of Choice for BI

- Unmatched scalability
  - System resources (processors, I/O, subsystems)
  - Applications (data, user)

	Users	20	50	100	250
■	large	137	162	121	68
🟥	medium	66	101	161	380
🟩	small	20	48	87	195
🟦	trivial	77	192	398	942
	Total	300	503	767	1585

- **Unmatched scalability**

  S/390 Parallel Sysplex allows an organization to add processors and/or disks to hardware configurations independently as the size of the data warehouse grows and the number of users increases. DB2 supports this scalability by allowing up to 384 processors and 64,000 active users to be employed in a DB2 configuration.



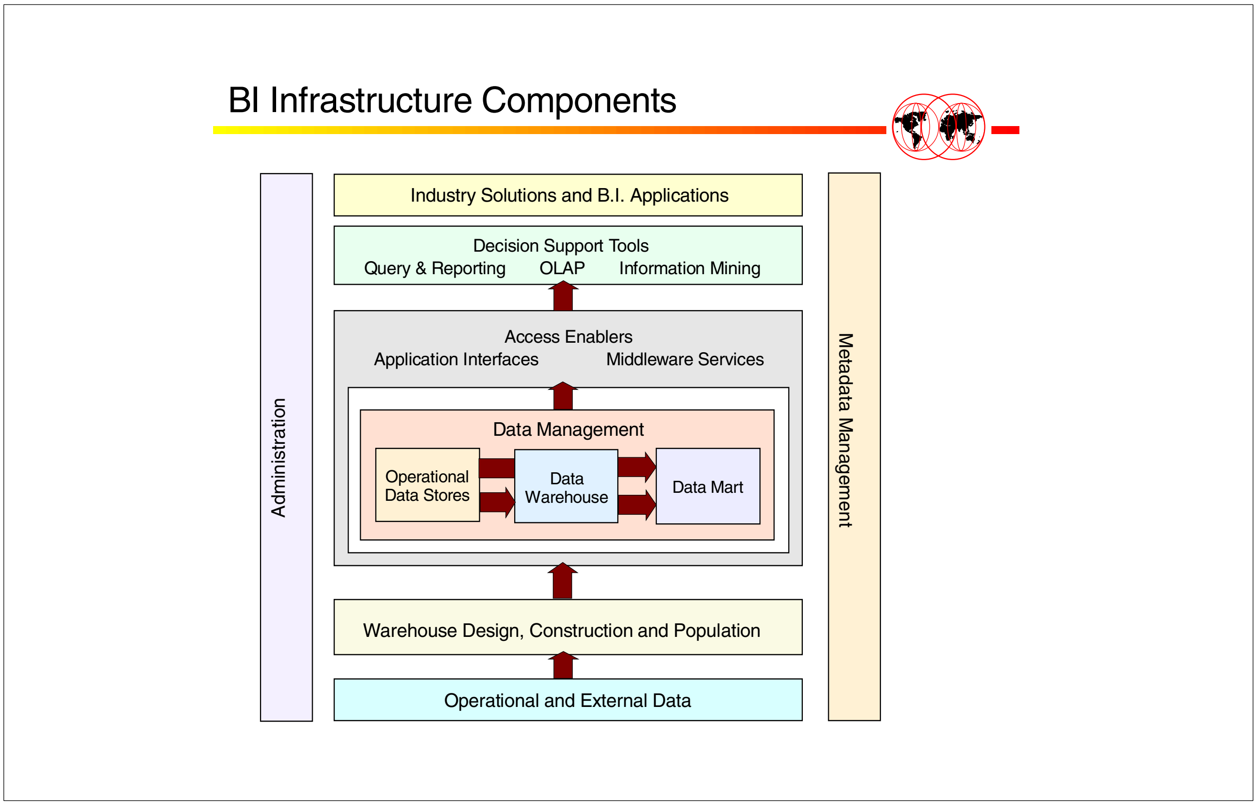
S/390 & DB2 - A Platform of Choice for BI

- **Open systems Client/Server architecture**
  - Complete desktop connectivity
    - Fully web enabled
    - TCP/IP and SNA
    - DRDA, ODBC, and Java support
  - Competitive portfolio of BI tools and applications
    - Query and Reporting, OLAP, and Data Mining
    - BI application solutions

- **Open systems Client/Server architecture**

  The connectivity issue today is to connect clients to servers, and for client applications to interoperate with server applications. Decision support users can access the S/390 DB2 data warehouse from any client desktop platform (Win, Mac, UNIX, OS/2, Web browser, thin client) using DRDA, ODBC, Java APIs, and Web middleware, through DB2 Connect and over native TCP/IP and/or SNA networks. DB2 can support up to 150,000 clients connected to a single SMP, and 4.8 million clients when connected to a S/390 Parallel Sysplex.

1.7 BI infrastructure components



BI Infrastructure Components

Administration

Industry Solutions and B.I. Applications

Decision Support Tools
Query & Reporting OLAP Information Mining

Access Enablers
Application Interfaces Middleware Services

Data Management
Operational Data Stores
Data Warehouse
Data Mart

Warehouse Design, Construction and Population

Operational and External Data

Metadata Management

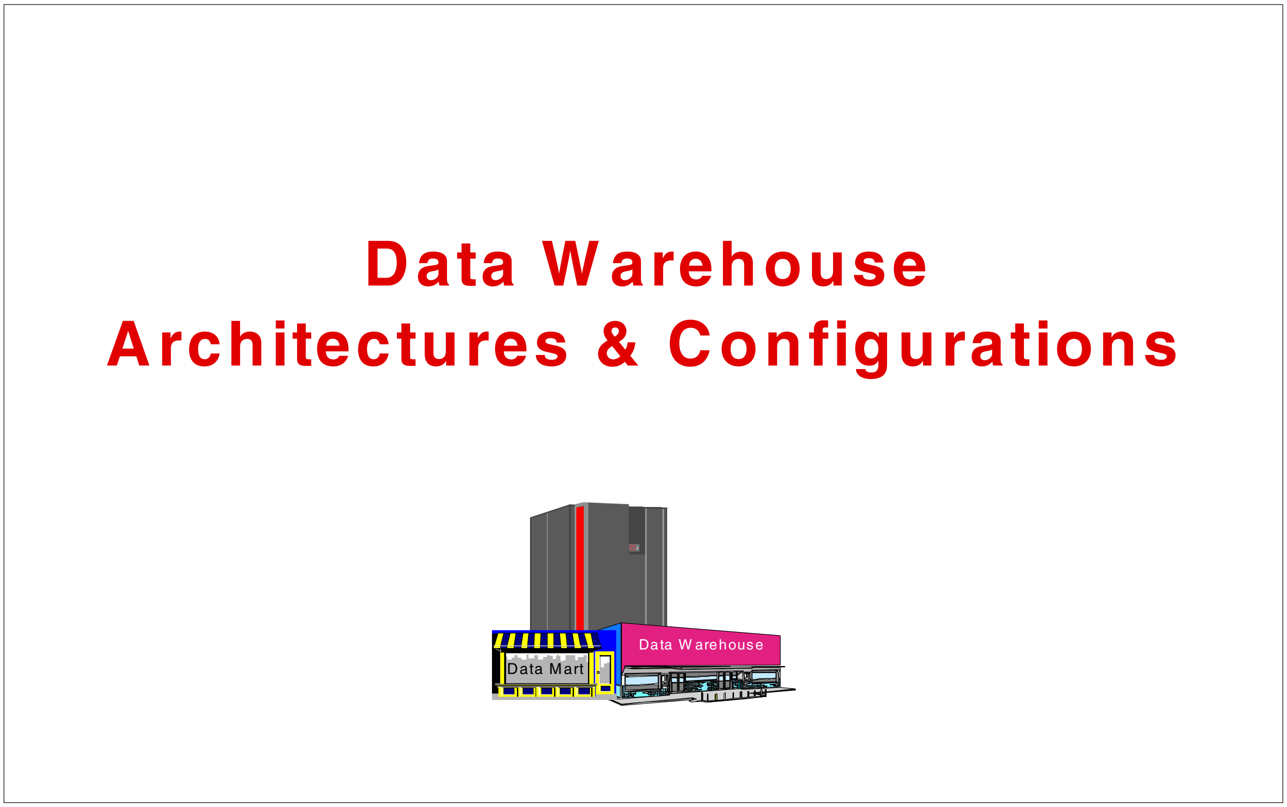
The main components of a BI infrastructure are shown here.

- The *operational and external data* component shows the source data used for building the data warehouse.
- The *warehouse design, construction and population* component provides:
  - DW architectures and configurations.
  - DW database design.
  - DW data population design, including extract-transform-load (ETL) processes which extract data from source files and databases, clean, transform, and load it into the DW databases.
- The *data management* component (or database engine) is used to access and maintain information stored in DW databases.
- The *access enablers* component provides the user interfaces and middleware services which connect the end users to the data warehouse.
- The *decision support tools* component employs GUI and Web-based BI tools and analytic applications to enable business end users to access and analyze data warehouse information across corporate intranets and extranets.
- The *industry solutions and BI applications* component provides complete business intelligence solution packages tailored by industry or area of application.

- The *metadata management* component manages DW metadata, which provides administrators and business users with information about the content and meaning of information stored in a data warehouse.
- The *data warehouse administration* component provides a set of tools and services for managing data warehouse operations.

The following chapters expand on how OS/390 and DB2 address these components—the products, tools and services they integrate to build a high performance and cost effective BI infrastructure on S/390.

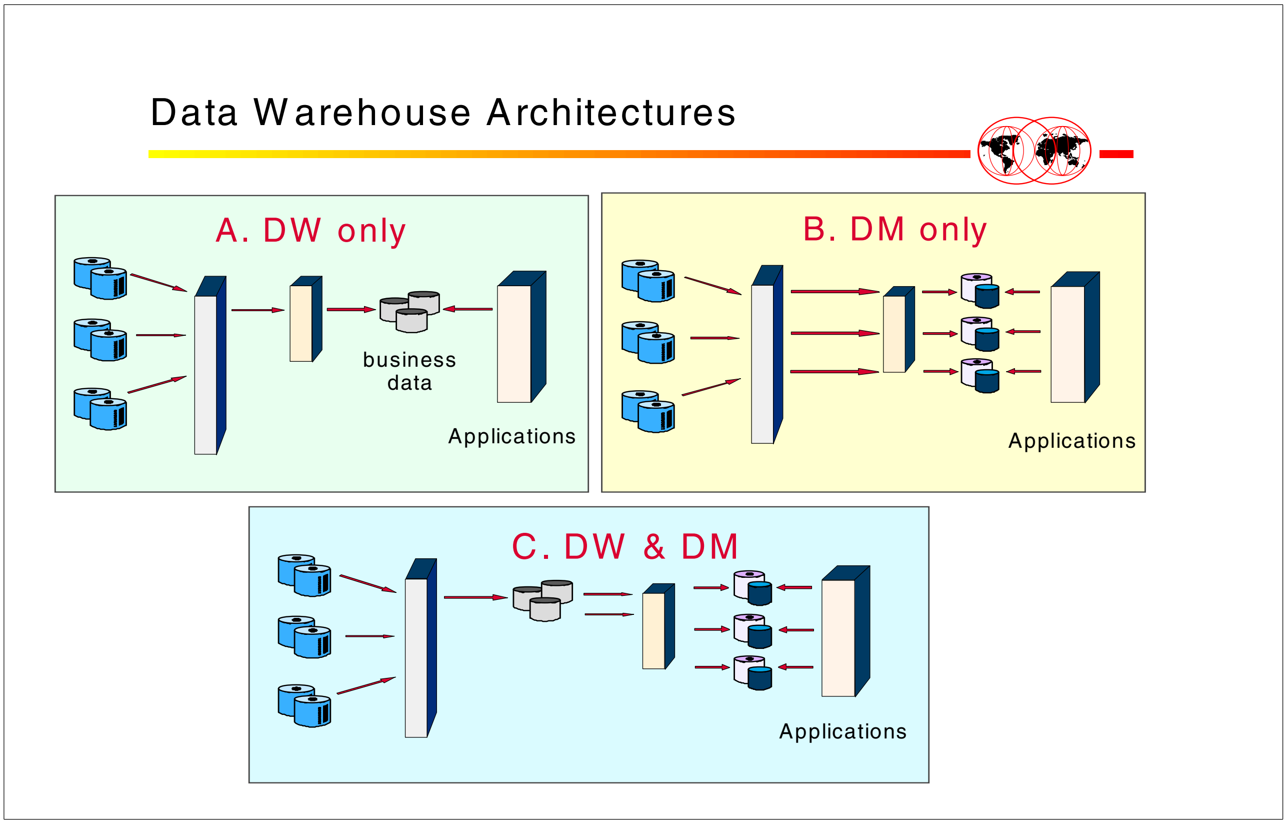
Chapter 2. Data warehouse architectures and configurations



Data Warehouse
Architectures & Configurations

This chapter describes various data warehouse architectures and the pros and cons of each solution. We also discuss how to configure those architectures on the S/390.

2.1 Data warehouse architectures



Data warehouses can be created in several ways.

DW only approach

Section A of this figure illustrates the option of a single, centralized location for query analysis. *Enterprise data warehouses* are established for the use of the entire organization; however, this means that the entire organization must accept the same definitions and transformations of data and that no data may be changed by anyone in order to satisfy unique needs. This type of data warehouse has the following strengths and weaknesses:

- Strengths:
  - Stores data only once.
  - Data duplication and storage requirements are minimized.
  - There are none of the data synchronization problems that would be associated with maintaining multiple copies of informational data.
  - Data is consolidated enterprise-wide, so there is a corporate view of business information.
- Weaknesses:
  - Data is not structured to support the individual informational needs of specific end users or groups.

DM only approach

In contrast, Section B shows a different situation, where each individual department needs its own smaller copy of the data in order to manipulate it or to provide quicker response to queries. Thus, the data mart was created. As an analogy, a data mart is to a data warehouse as a convenience store is to a supermarket. The data mart approach has the following strengths and weaknesses:

- Strengths:
  - The data marts can be deployed very rapidly.
  - They are specifically responsive to identified business problems.
  - The data is optimized for the needs of particular groups of users, which makes population of the DM easier and may also yield better performance.
- Weaknesses:
  - Data is stored multiple times in different data marts, leading to a large amount of data duplication, increased data storage requirements, and potential problems associated with data synchronization.
  - When many data sources are used to populate many targets, the result can be a complex data population “spider web.”
  - Data is not consolidated enterprise-wide and so there is no corporate view of business information. Creating multiple DMs without a model or view of the enterprise-wide data architecture is dangerous.

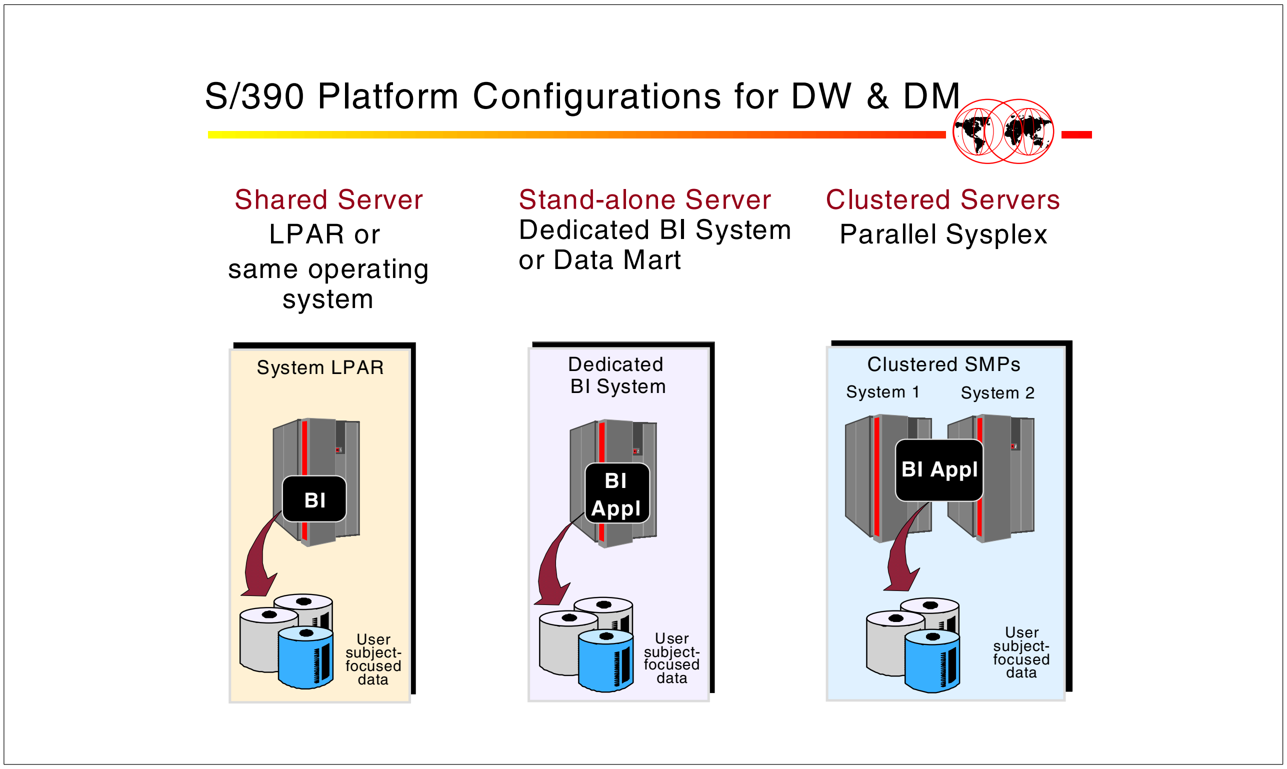
Combined DW and DM approach

Section C illustrates a combination of both data warehouse and data mart approaches. This is the enterprise data view. The data warehouse represents the entire universe of data. The data marts represent departmental slices of the data. End users can optionally drill through the data mart to the data warehouse to access data that is more detailed and/or broader in scope than found at the data mart level. This type of implementation has the following strengths and weaknesses:

- Strengths:
  - Data mart creation and population are simplified since the population occurs from a single, definitive, authoritative source of cleansed and normalized data.
  - DMs are in synch and compatible with the enterprise view. There is a reference data model and it is easier to expand the DW and add new DMs.
- Weaknesses:
  - There is some data duplication, leading to increased data storage requirements.
  - Agreement and concurrence to architecture is required from multiple areas with potentially differing objectives (for example, “speed to market” sometimes competes with “following an architected approach”).

No matter where your data warehouse begins, data structuring is of critical importance. Data warehouses must be consistent, with a single definition for each data element. Agreeing on these definitions is often a stumbling block and a topic of heated discussion. In the end, one organization-wide definition for each data element is a prerequisite if the data warehouse is to be valuable to all users.

2.2 S/390 platform configurations for DW and DM



S/390 Platform Configurations for DW & DM

Shared Server
LPAR or
same operating
system

Stand-alone Server
Dedicated BI System
or Data Mart

Clustered Servers
Parallel Sysplex

DB2 and OS/390 support all ODS, DW, and DM data structures in any type of architecture:

- Data warehouse only
- Data mart only
- Data warehouse and data mart

Interoperability and open connectivity give the flexibility for mixed solutions with S/390 in the various roles of ODS, DW or DM.

In the development of the data warehouse and data marts, a growth path is established. For most organizations, the initial implementation is on a logical partition (LPAR) of an existing system. As the data warehouse grows, it can be moved to its own system or to a Parallel Sysplex environment. A need for 24 X 7 availability for the data warehouse, due perhaps to world-wide operations or the need to access current business information in conjunction with historical data, necessitates migration to DB2 data sharing in a Parallel Sysplex environment. A Parallel Sysplex may also be required for increased capacity.

Shared server

Using an LPAR can be an inexpensive way of starting data warehousing. If there is unused processing capacity on a S/390 server, an LPAR can be created to tap that resource for data warehousing. By leveraging the current infrastructure, this approach:

- Minimizes costs by using available capacity.

- Takes advantage of existing connectivity.
- Incurs no added hardware or system software costs.
- Allows the system to run 98-100 percent busy without degrading user response times, provided there is lower priority work to preempt.

Stand-alone server

A stand-alone S/390 data warehouse server can be integrated into the current S/390 operating environment, with disk space added as needed. The primary advantage of this approach is data warehouse workload isolation, which might be a strong argument for certain customers when the service quality objectives for their BI applications are very strict. An alternative to the stand-alone server is the Parallel Sysplex, which also offers very high quality of service, with the additional advantage of increased flexibility that a stand-alone solution cannot achieve.

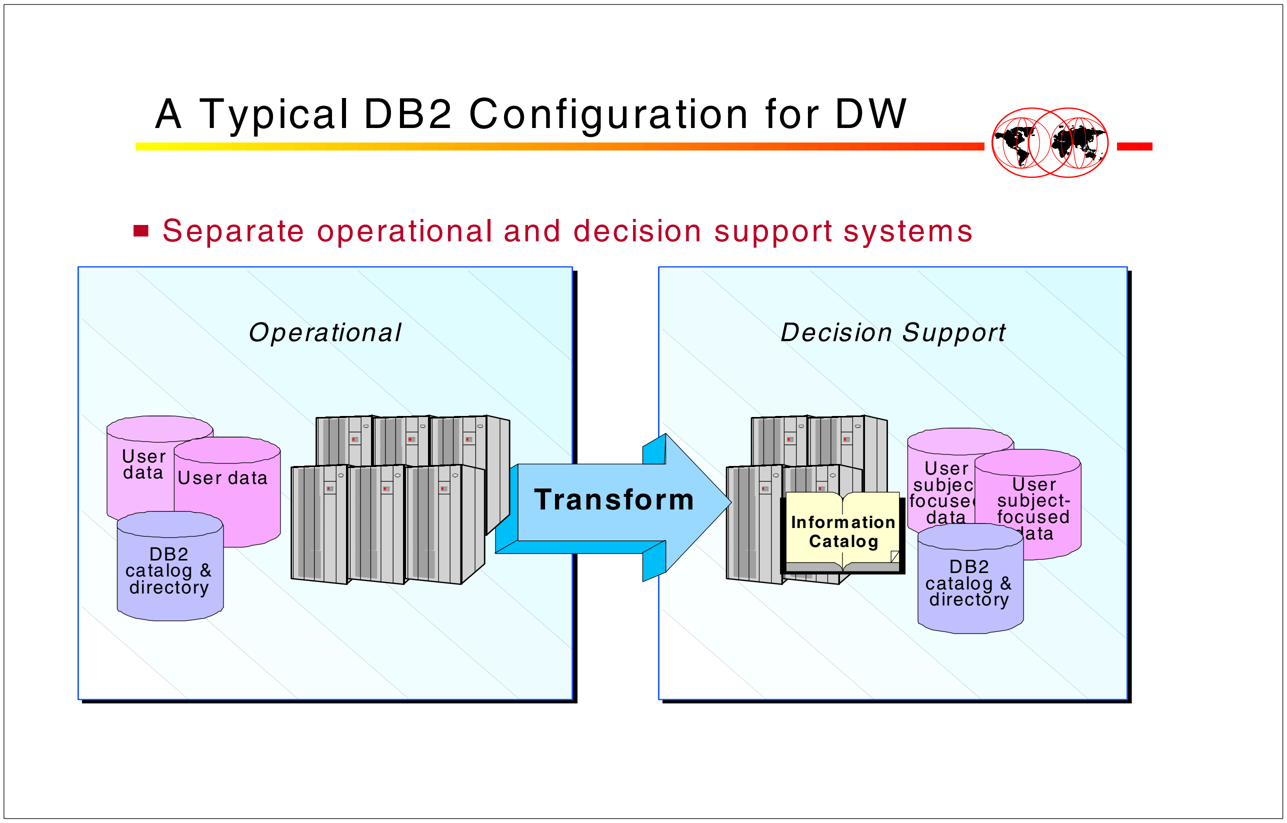
Clustered servers

A Parallel Sysplex environment offers the advantages of exceptional availability and capacity, including:

- Planned outages (due to software and/or hardware maintenance) can be virtually eliminated.
- Scope and impact of unplanned outages (loss of a S/390 server, failure of a DB2 subsystem, and so forth) can be greatly reduced relative to a single system implementation.
- Up to 32 S/390 servers can function together as one logical system in a Parallel Sysplex. The Sysplex query parallelism feature of DB2 for OS/390 (Version 5 and subsequent releases) enables the resources of multiple S/390 servers in a Parallel Sysplex to be brought to bear on a single query.

There are advantages to an all S/390 solution. Consolidating DW and DM on the same S/390 platform or Parallel Sysplex, you can take advantage of S/390 advanced resource sharing features, such as LPAR and WLM resource groups. You can also increase the system’s efficiency by co-sharing unused cycles between DW and DM workloads. These S/390-unique features can provide significant advantages over stand-alone implementations where each workload runs on separate dedicated servers. These capabilities are further described in 8.10, “Data warehouse and data mart coexistence” on page 157.

2.3 A typical DB2 configuration for DW



A Typical DB2 Configuration for DW

- Separate operational and decision support systems

Major implementations of data warehouses usually involve S/390 servers separate from those running operational applications. This physical separation of workloads may be needed (or appear to be needed) for additional processing power, due to security issues, or from fear that data warehouse processing might otherwise consume the entire system (a circumstance that can be prevented using Workload Manager).

Here we show a typical configuration for decision support.

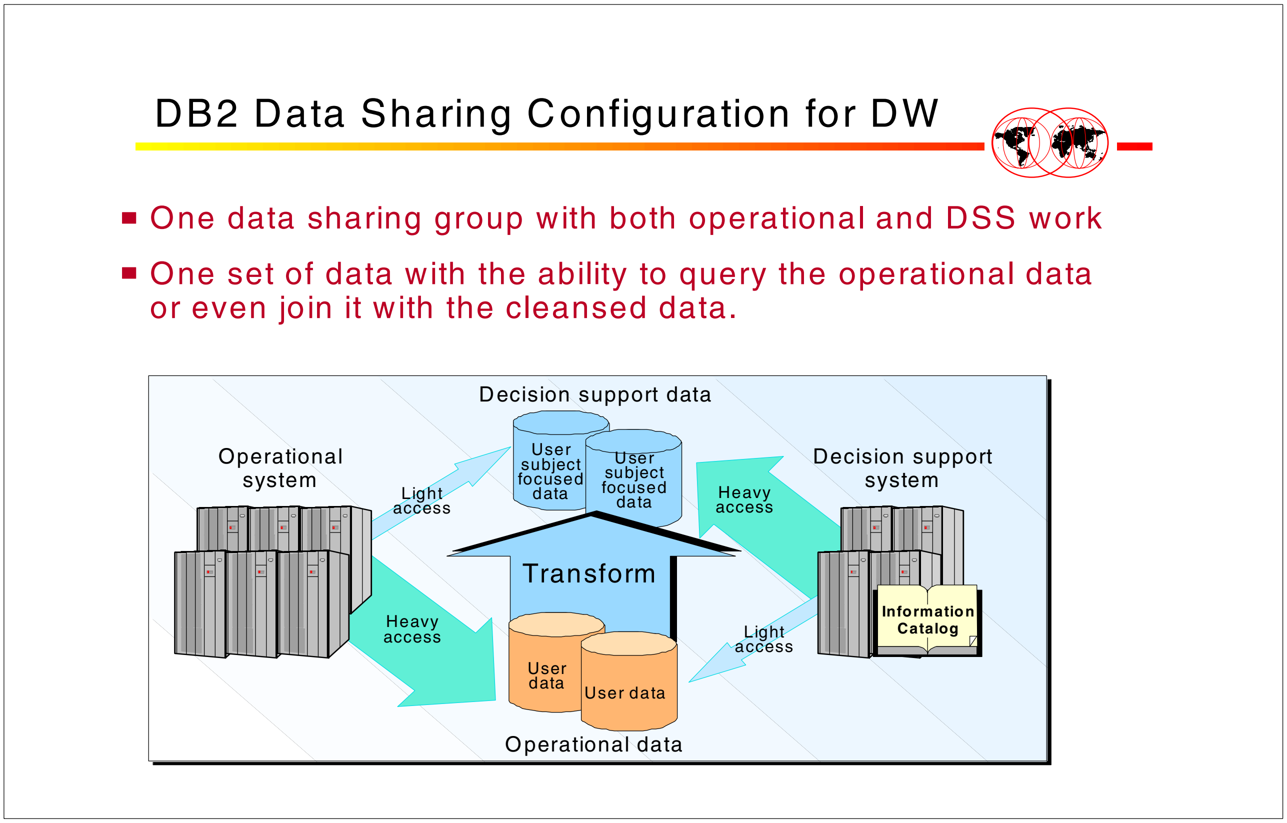
Operational data and decision support data are in separate environments—in either two different central processor complexes (CPCs) or LPARs, or two different data-sharing groups. In this case, you cannot access both sets of data in the same SQL statement. Additional middleware software, such as DB2 DataJoiner, is needed.

Some customers feel that they need to separate the workloads of their operational and decision support systems. This was the case for most early warehouses, because people were afraid of the impact on their revenue-producing applications should some runaway query take over the system.

Thanks to newer technology, such as the OS/390 Workload Manager and DB2 predictive governor, this is no longer a concern, and more and more customers can implement operational and decision support systems either on the same

S/390 server or on a server that is in the same sysplex with other systems running operational workloads.

2.4 DB2 data sharing configuration for DW



DB2 Data Sharing Configuration for DW

- One data sharing group with both operational and DSS work
- One set of data with the ability to query the operational data or even join it with the cleansed data.

Here we show a configuration consisting of one data sharing group with both operational and decision support data. Such an implementation offers several benefits, including:

- Simplified system operation and management compared with a separate system approach
- Easy access to operational DB2 data from decision support applications, and vice versa (subject to security restrictions)
- Flexible implementations
- More efficient use of system resources

A key decision to be made is whether the members of the group should be cloned or tailored to suit particular workload types. Quite often, individual members are tailored for DW workload for isolation, virtual storage, and local buffer pool tuning reasons.

The most significant advantages of the configuration shown are the following:

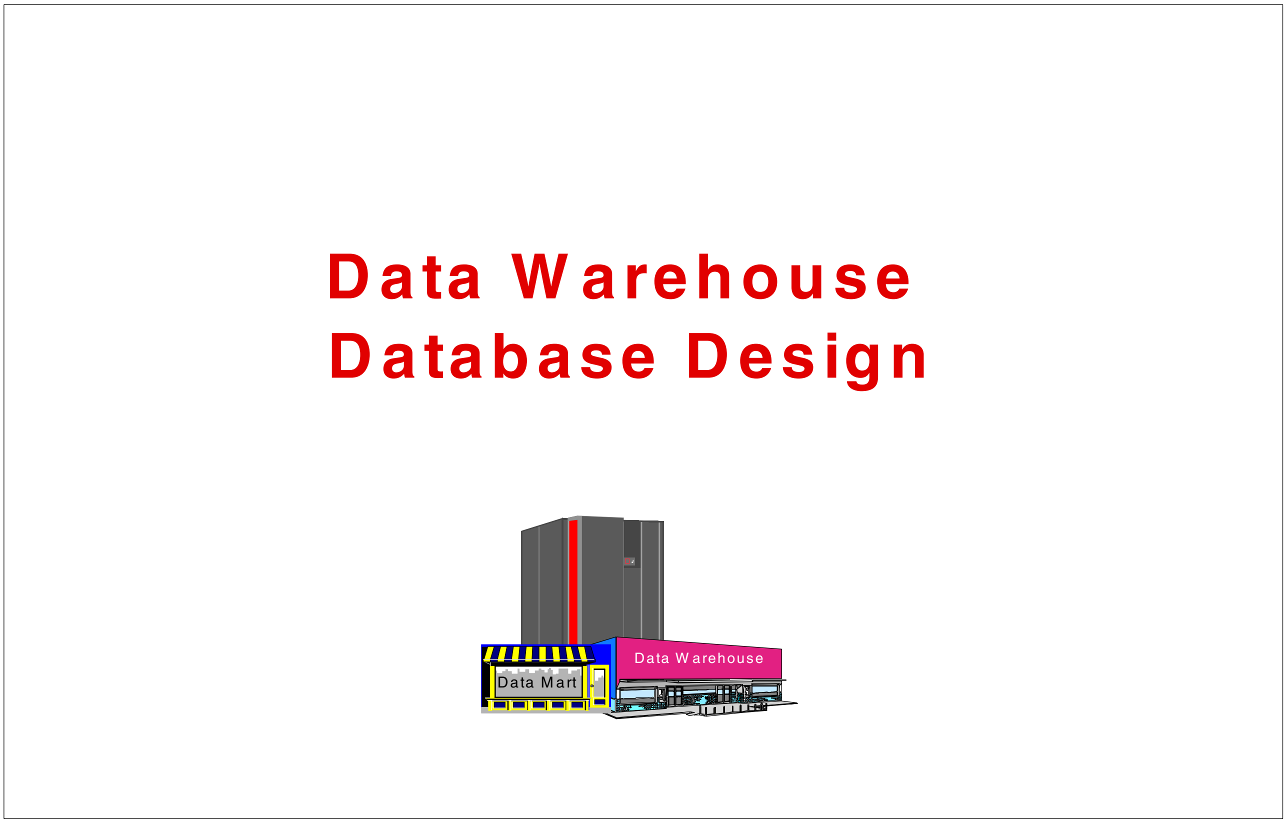
- A single database environment

  This allows DSS users to have heavy access to decision support data and occasional access to operational data. Conversely, production can have heavy access to operational data and occasional access to decision support data. Operational data can be joined with decision support data without requiring the use of middleware, such as DB2 DataJoiner. It is easier to operate in a single data sharing group environment, compared with having separate operational and decision support data sharing groups. This solution really supports advanced implementations that intermingle informational decision support data and processing with operational, transaction-oriented data.

- Workload Manager

  With WLM, more processing power can be dedicated to the operational environment on demand at peak times. Conversely, more processing power can be dedicated to the decision support environment after business hours to speed up heavy reporting activities. This can be done easily with resource switching from one environment to the other by dynamically changing the WLM policy with a VARY command. Thus, effective use is made of processing capacity that would otherwise be wasted.

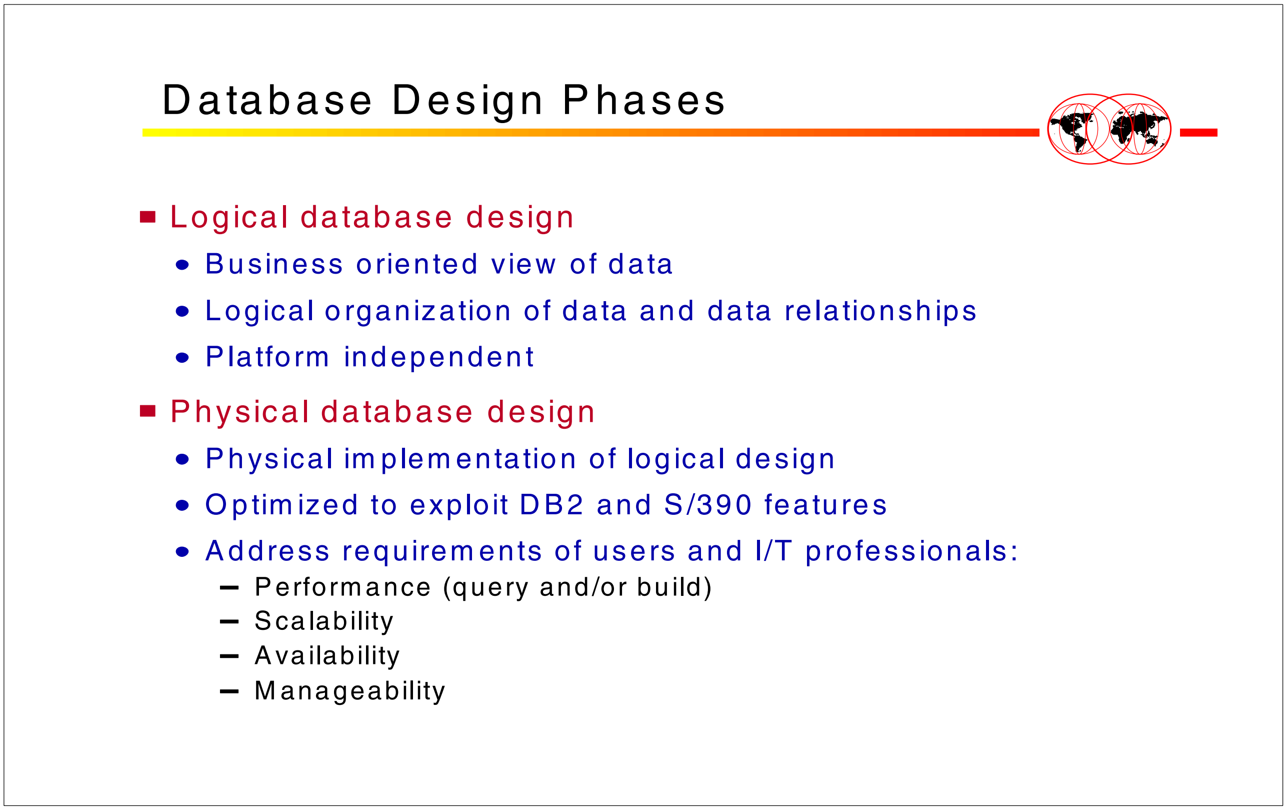
Chapter 3. Data warehouse database design



Data Warehouse Database Design

In this chapter we describe some database design concepts and facilities applicable to a DB2 for OS/390 data warehouse environment.

3.1 Database design phases



Database Design Phases

- Logical database design
  - Business oriented view of data
  - Logical organization of data and data relationships
  - Platform independent
- Physical database design
  - Physical implementation of logical design
  - Optimized to exploit DB2 and S/390 features
  - Address requirements of users and I/T professionals:
    - Performance (query and/or build)
    - Scalability
    - Availability
    - Manageability

There are two main phases when designing a database: logical design and physical design.

The logical design phase involves analyzing the data from a business perspective and organizing it to address business requirements. Logical design includes, among many others, the following features:

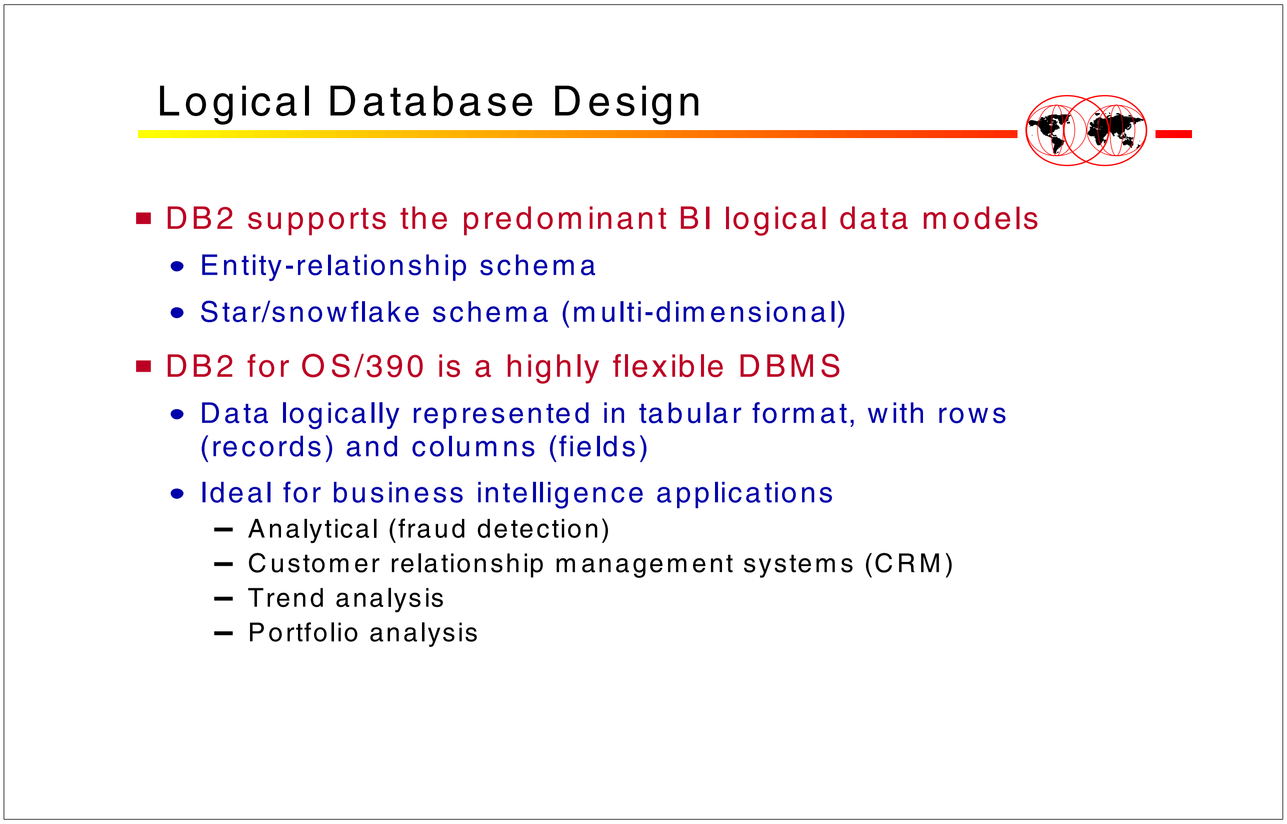
- Defining data elements (for example, is an element a character or numeric field? a code value? a key value?)
- Grouping related data elements into sets (such as customer data, sales data, employee data, abd so forth)
- Determining relationships between various sets of data elements

Logical database designs tend to be largely platform independent because the perspective is business-oriented, as opposed to being technology-oriented.

Physical database design is concerned with the physical implementation of the logical database design. A good physical database design should exploit the unique capabilities of the hardware/software platform. In this chapter we discuss the benefits that can be realized by taking advantage of the features of DB2 on a S/390 server.

The physical database design is an important factor in achieving the performance (for both query and database build processes), scalability, manageability, and availability objectives of a data warehouse implementation.

3.2 Logical database design



Logical Database Design

- DB2 supports the predominant BI logical data models
  - Entity-relationship schema
  - Star/snowflake schema (multi-dimensional)
- DB2 for OS/390 is a highly flexible DBMS
  - Data logically represented in tabular format, with rows (records) and columns (fields)
  - Ideal for business intelligence applications
    - Analytical (fraud detection)
    - Customer relationship management systems (CRM)
    - Trend analysis
    - Portfolio analysis

The two logical models that are predominant in data warehouse environments are the entity-relationship schema and the star schema (a variant of which is called the snowflake schema). On occasion, both models may be used—the entity-relationship model for the enterprise data warehouse and star schemas for data marts. Pictorial representations of these models follow.

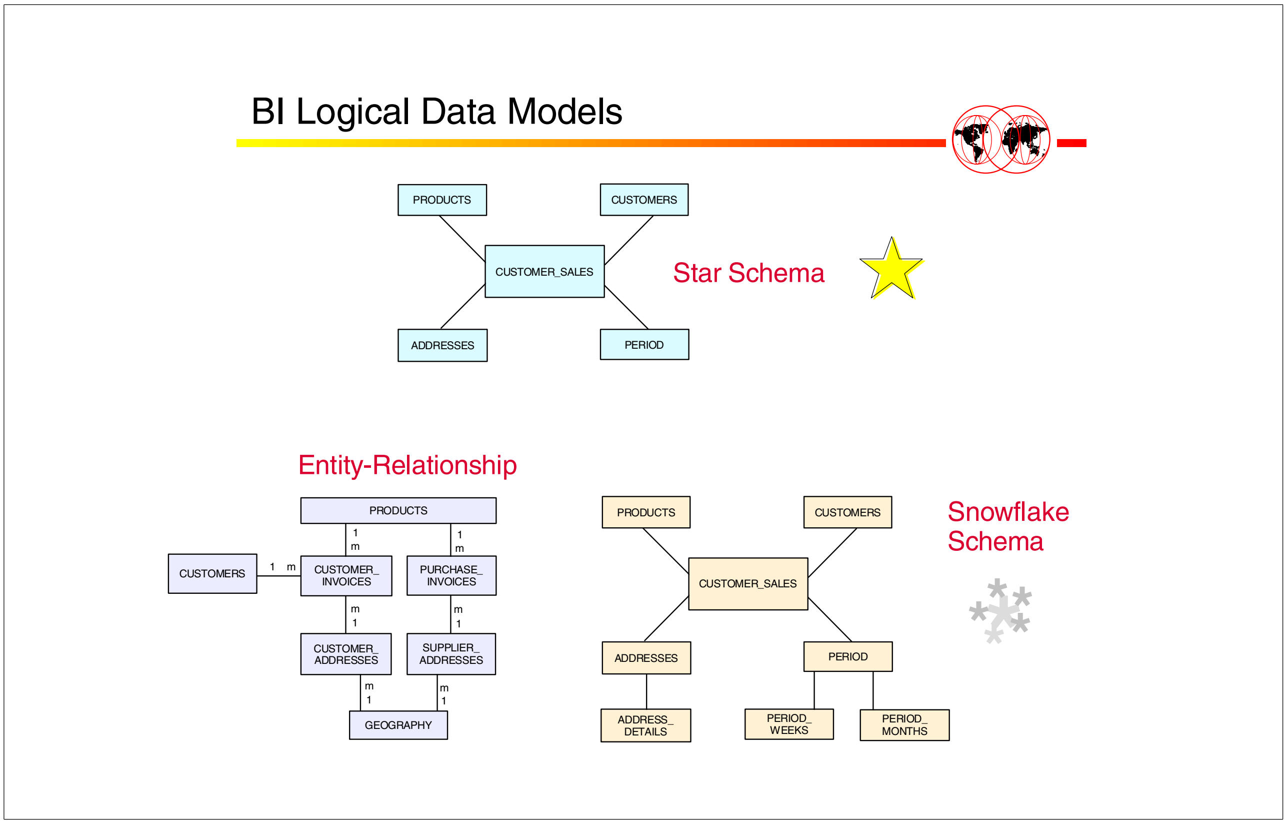
DB2 for OS/390 supports both the entity-relationship and star schema logical models.

DB2 is a highly flexible DBMS. Logically speaking, DB2 stores data in tables that consist of rows and columns (analogous to records and fields). The flexibility of DB2, together with the unparalleled scalability and availability of S/390, make it an ideal platform for business intelligence (BI) applications.

Examples of BI applications that have been implemented using DB2 and S/390 include:

- Analytical (fraud detection)
- Customer relationship management systems
- Trend analysis
- Portfolio analysis

3.2.1 BI logical data models



BI Logical Data Models

PRODUCTS
CUSTOMERS
CUSTOMER_SALES
ADDRESSES
PERIOD

Star Schema

Entity-Relationship

PRODUCTS
1
m
1
m
CUSTOMERS
1
m
CUSTOMER_ INVOICES
PURCHASE_ INVOICES
m
1
m
1
CUSTOMER_ ADDRESSES
SUPPLIER_ ADDRESSES
m
1
m
1
GEOGRAPHY

PRODUCTS
CUSTOMERS
CUSTOMER_SALES
ADDRESSES
PERIOD
ADDRESS_ DETAILS
PERIOD_ WEEKS
PERIOD_ MONTHS

Snowflake Schema

The BI logical data models are compared here.

Entity-relationship
An entity-relationship logical design is data-centric in nature. In other words, the database design reflects the nature of the data to be stored in the database, as opposed to reflecting the anticipated usage of that data. Because an entity-relationship design is not usage-specific, it can be used for a variety of application types: OLTP and batch, as well as business intelligence. This same usage flexibility makes an entity-relationship design appropriate for a data warehouse that must support a wide range of query types and business objectives.

Star schema
The star schema logical design, unlike the entity-relationship model, is specifically geared towards decision support applications. The design is intended to provide very efficient access to information in support of a predefined set of business requirements. A star schema is generally not suitable for general-purpose query applications.

A star schema consists of a central fact table surrounded by dimension tables, and is frequently referred to as a multidimensional model. Although the original concept was to have up to five dimensions as a star has five points, many stars today have more than five dimensions.

The information in the star usually meets the following guidelines:

- A fact table contains numerical elements.
- A dimension table contains textual elements.
- The primary key of each dimension table is a foreign key of the fact table.
- A column in one dimension table should not appear in any other dimension table.

Some tools and packaged application software products assume the use of a star schema database design.

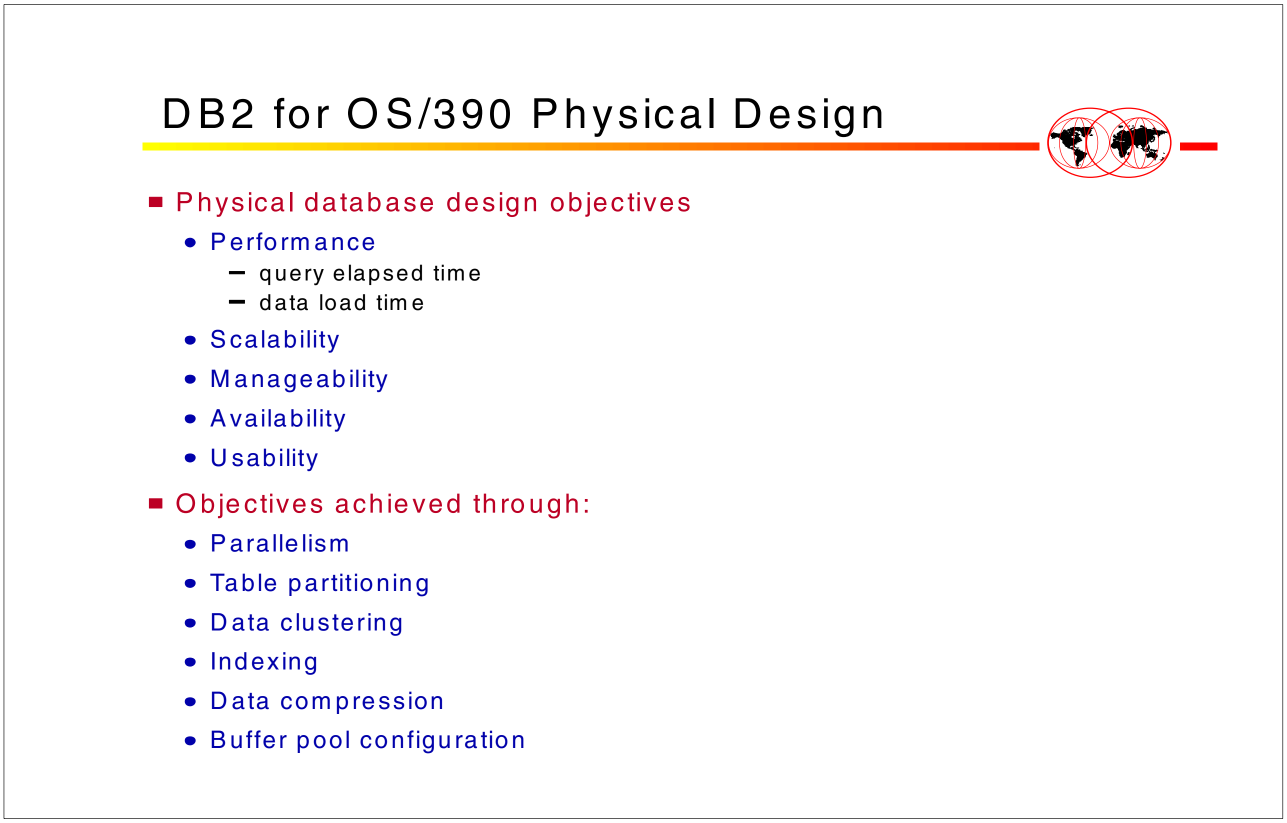
Snowflake schema

The snowflake model is a further normalized version of the star schema. When a dimension table contains data that is not always necessary for queries, too much data may be picked up each time a dimension table is accessed. To eliminate access to this data, it is kept in a separate table off the dimension, thereby making the star resemble a snowflake.

The key advantage of a snowflake design is improved query performance. This is achieved because less data is retrieved and joins involve smaller, normalized tables rather than larger, denormalized tables. The snowflake schema also increases flexibility because of normalization, and can possibly lower the granularity of the dimensions.

The disadvantage of a snowflake design is that it increases both the number of tables a user must deal with and the complexities of some queries. For this reason, many experts suggest refraining from using the snowflake schema. Having entity attributes in multiple tables, the same amount of information is available whether a single table or multiple tables are used.

3.3 Physical database design



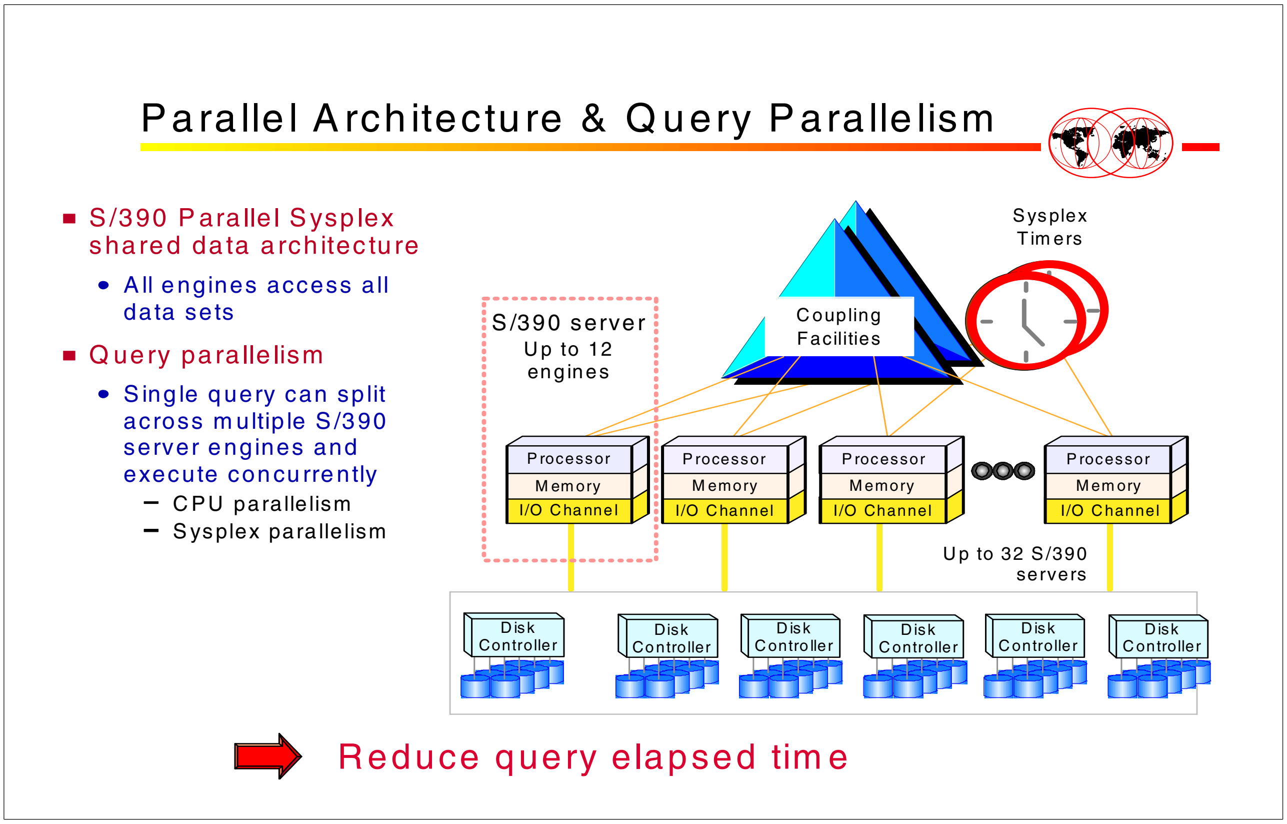
DB2 for OS/390 Physical Design

- Physical database design objectives
  - Performance
    - query elapsed time
    - data load time
  - Scalability
  - Manageability
  - Availability
  - Usability
- Objectives achieved through:
  - Parallelism
  - Table partitioning
  - Data clustering
  - Indexing
  - Data compression
  - Buffer pool configuration

As mentioned previously, physical database design has to do with enhancing data warehouse performance, scalability, manageability, availability, and usability. In this section we discuss how these physical design objectives are achieved with DB2 and S/390 through:

- Parallelism
- Table partitioning
- Data clustering
- Indexing
- Data compression
- Buffer pool configuration

3.3.1 S/390 and DB2 parallel architecture and query parallelism



Parallel Architecture & Query Parallelism

- S/390 Parallel Sysplex shared data architecture
  - All engines access all data sets
- Query parallelism
  - Single query can split across multiple S/390 server engines and execute concurrently
    - CPU parallelism
    - Sysplex parallelism

Reduce query elapsed time

Parallelism is a major requirement in data warehousing environments. Parallel processes can dramatically speed up the execution of heavy queries and the loading of large volumes of data.

S/390 Parallel Sysplex and shared data architecture

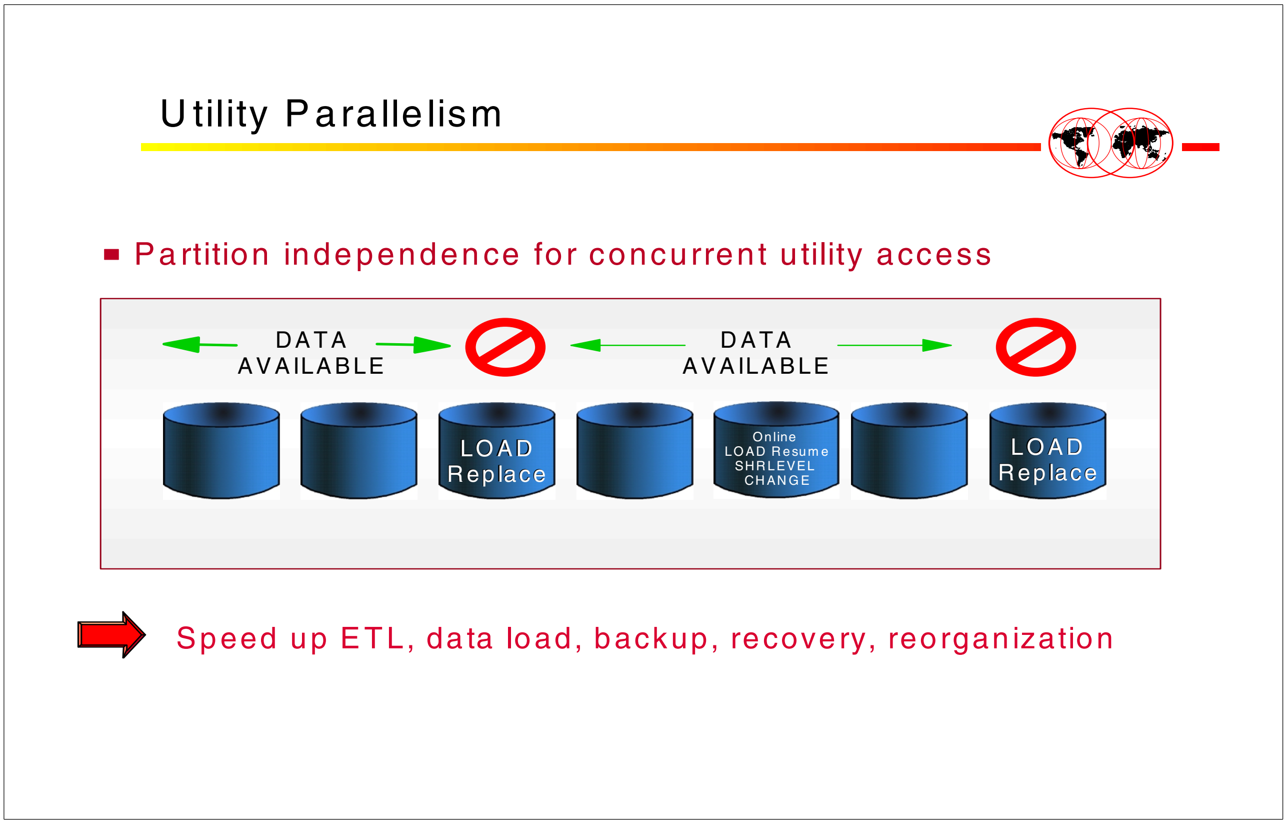
DB2 for OS/390 exploits the S/390 shared data architecture. Each S/390 server can have multiple engines. All S/390 servers in a Parallel Sysplex environment have access to all DB2 data sets. In other platforms, data sets may be available to one and only one server. Non-uniform access to data sets in other platforms can result in some servers being heavily utilized while others are idle. With DB2 for OS/390 all engines are able to access all data sets.

Query parallelism

A single query can be split across multiple engines in a single server, as well as across multiple servers in a Parallel Sysplex. Query parallelism is used to reduce the elapsed time for executing SQL statements. DB2 exploits two types of query parallelism:

- **CPU parallelism** - Allows a query to be split into multiple tasks that can execute in parallel on one S/390 server. There can be more parallel tasks than there are engines on the server.
- **Sysplex parallelism** - Allows a query to be split into multiple tasks that can execute in parallel on multiple S/390 servers in a Parallel Sysplex.

3.3.2 Utility parallelism



Utility Parallelism

- Partition independence for concurrent utility access

DATA AVAILABLE

DATA AVAILABLE

LOAD Replace

Online LOAD Resume SHRLEVEL CHANGE

LOAD Replace

Speed up ETL, data load, backup, recovery, reorganization

DB2 utilities can be run concurrently against multiple partitions of a partitioned table space. This can result in a linear reduction in elapsed time for utility processing windows. (For example, backup time for a table can be reduced 10-fold by having 10 partitions.) Utility parallelism is especially efficient when loading large volumes of data in the data warehouse.

SQL statements and utilities can also execute concurrently against different partitions of a partitioned table space. The data not used by the utilities is thus available for user access. Note that the Online Load Resume utility, recently announced in DB2 V7, allows loading of data concurrently with user transactions by introducing a new load option: SHRLEVEL CHANGE.

3.3.3 Table partitioning

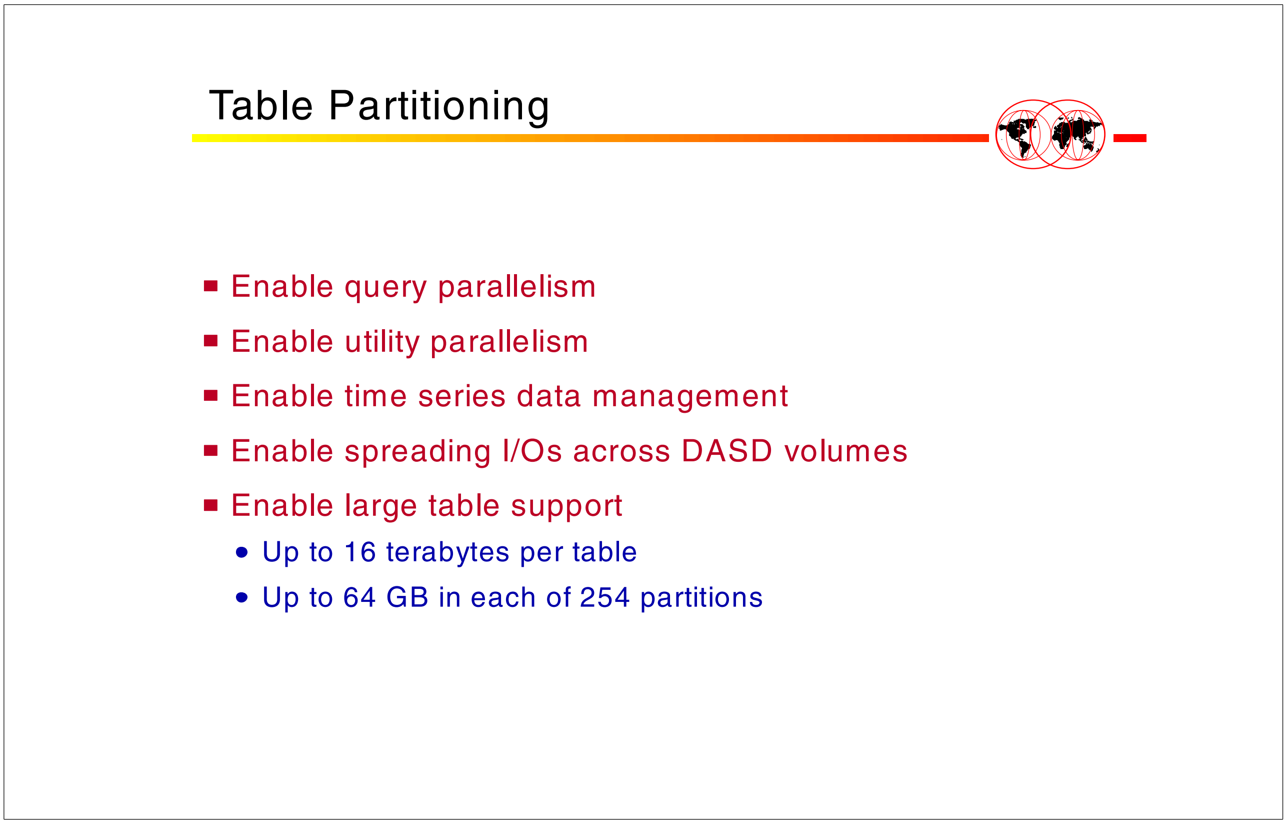


Table Partitioning

- Enable query parallelism
- Enable utility parallelism
- Enable time series data management
- Enable spreading I/Os across DASD volumes
- Enable large table support
  - Up to 16 terabytes per table
  - Up to 64 GB in each of 254 partitions

Table partitioning is an important physical database design issue. It enables query parallelism, utility parallelism, spreading I/Os across DASD volumes, and large table support.

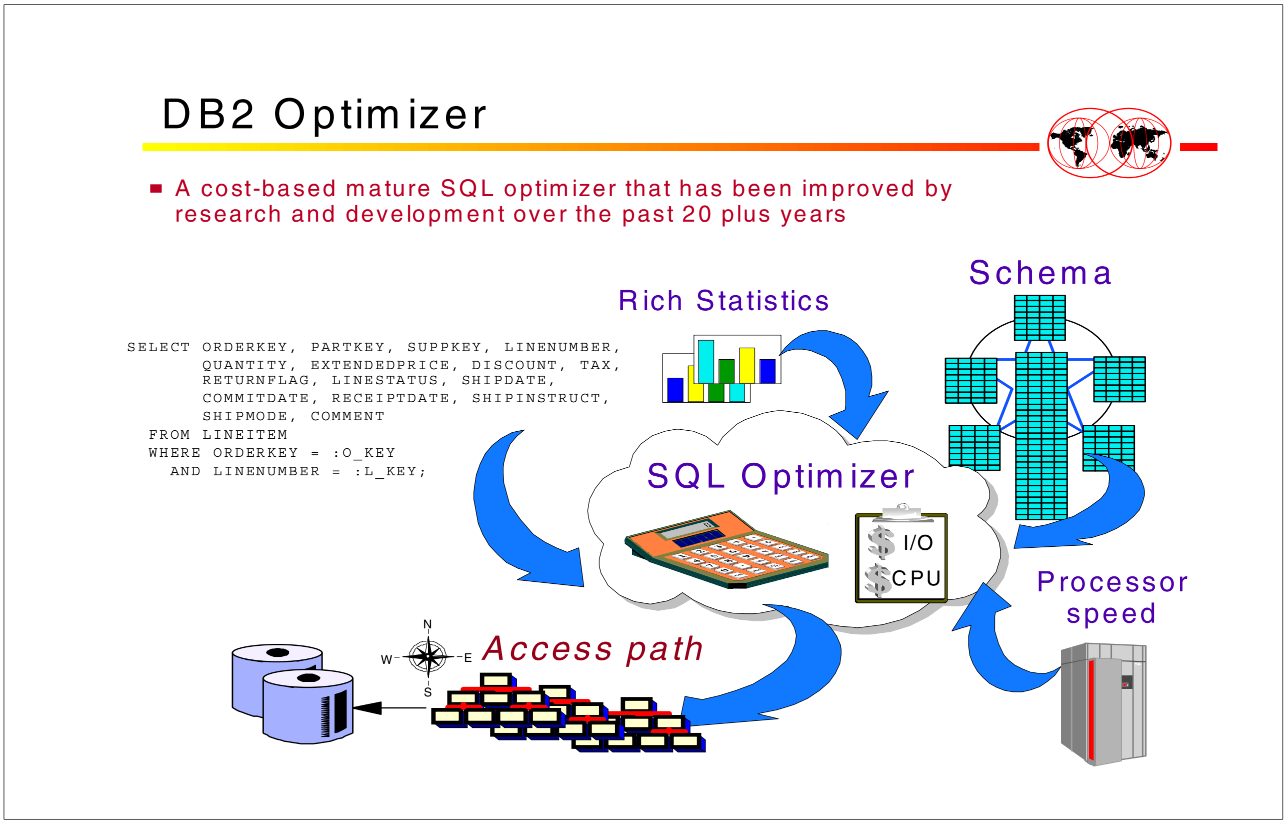
Partitioning enables query parallelism, which reduces the elapsed time for running heavy ad hoc queries. It also enables utility parallelism, which is important in data population processes to reduce the data load time.

Another big advantage of partitioning is that it enables time series data management. Load Replace Partition can be used to add new data and drop old data. This topic is further discussed in 4.3, “Table partitioning schemes” on page 60.

Partitioning can also be used to spread I/O for concurrently executing queries across multiple DASD volumes, avoiding disk access bottlenecks and resulting in improved query performance.

Partitioning within DB2 also enables large table support. DB2 can store 64 gigabytes of data in each of 254 partitions, for a total of up to 16 terabytes of compressed or uncompressed data per table.

3.3.4 DB2 optimizer



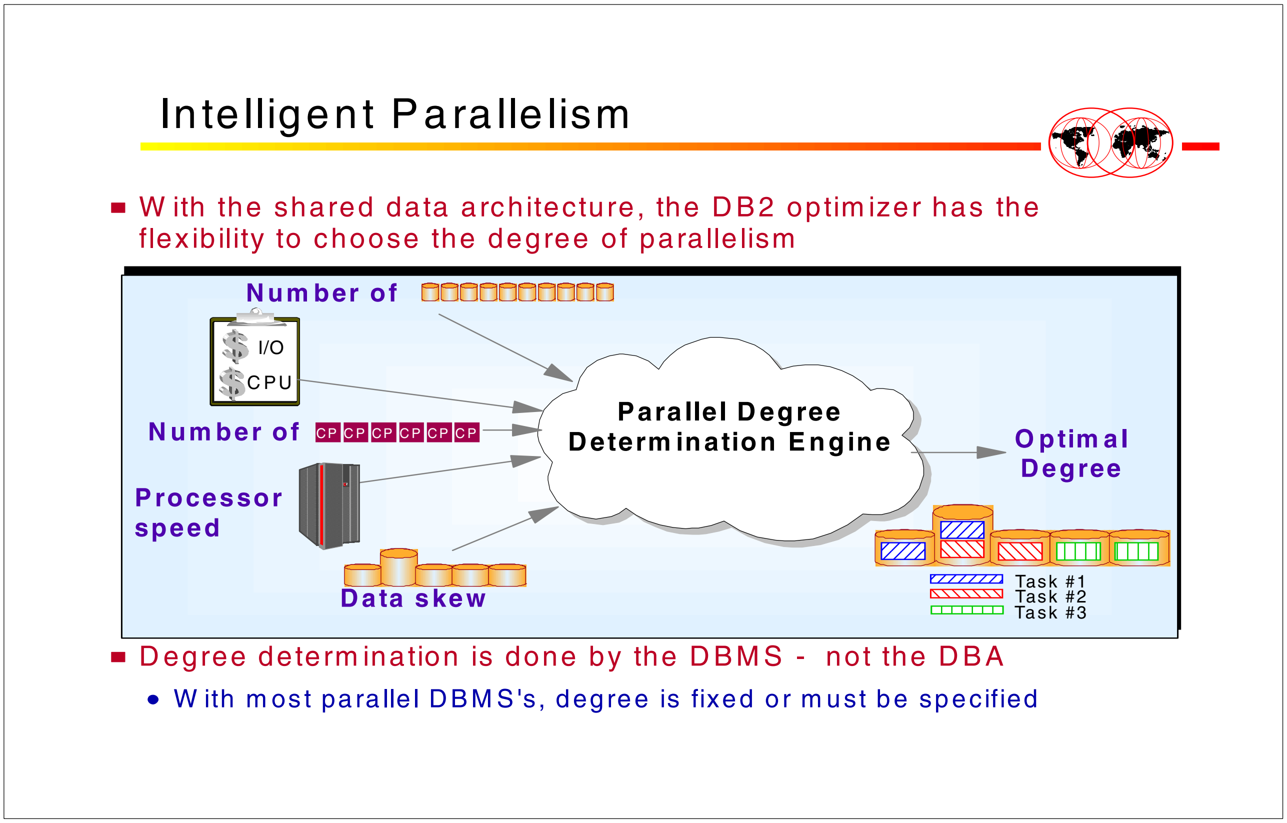
DB2 Optimizer

- A cost-based mature SQL optimizer that has been improved by research and development over the past 20 plus years

```
SELECT ORDERKEY, PARTKEY, SUPPKEY, LINENUMBER,
       QUANTITY, EXTENDEDPRICE, DISCOUNT, TAX,
       RETURNFLAG, LINESTATUS, SHIPDATE,
       COMMITDATE, RECEIPTDATE, SHIPINSTRUCT,
       SHIPMODE, COMMENT
  FROM LINEITEM
  WHERE ORDERKEY = :O_KEY
    AND LINENUMBER = :L_KEY;
```

Query performance in a DB2 for OS/390 data warehouse environment benefits from the advanced technology of the DB2 optimizer. The sophistication of the DB2 optimizer reflects 20 years of research and development effort.

When a query is to be executed by DB2, the optimizer uses the rich array of database statistics contained in the DB2 catalog, together with information about the available hardware resources (for example, processor speed and buffer storage space), to evaluate a range of possible data access paths for the query. The optimizer then chooses the best access path for the query—the path that minimizes elapsed time while making efficient use of the S/390 server resources. If, for example, a query accessing tables in a star schema database is submitted, the DB2 optimizer recognizes the star schema design and selects the star join access method to efficiently retrieve the requested data as quickly as possible. If a query accesses tables in an entity-relationship model, DB2 selects a different join technique, such as merge scan or nested loop join. The optimizer is also very efficient in selecting the access path of dynamic SQL, which is so popular with BI tools and data warehousing environments.



Intelligent Parallelism

- With the shared data architecture, the DB2 optimizer has the flexibility to choose the degree of parallelism

Number of

I/O

CPU

Number of CP CP CP CP CP CP

Processor speed

Data skew

Parallel Degree Determination Engine

Optimal Degree

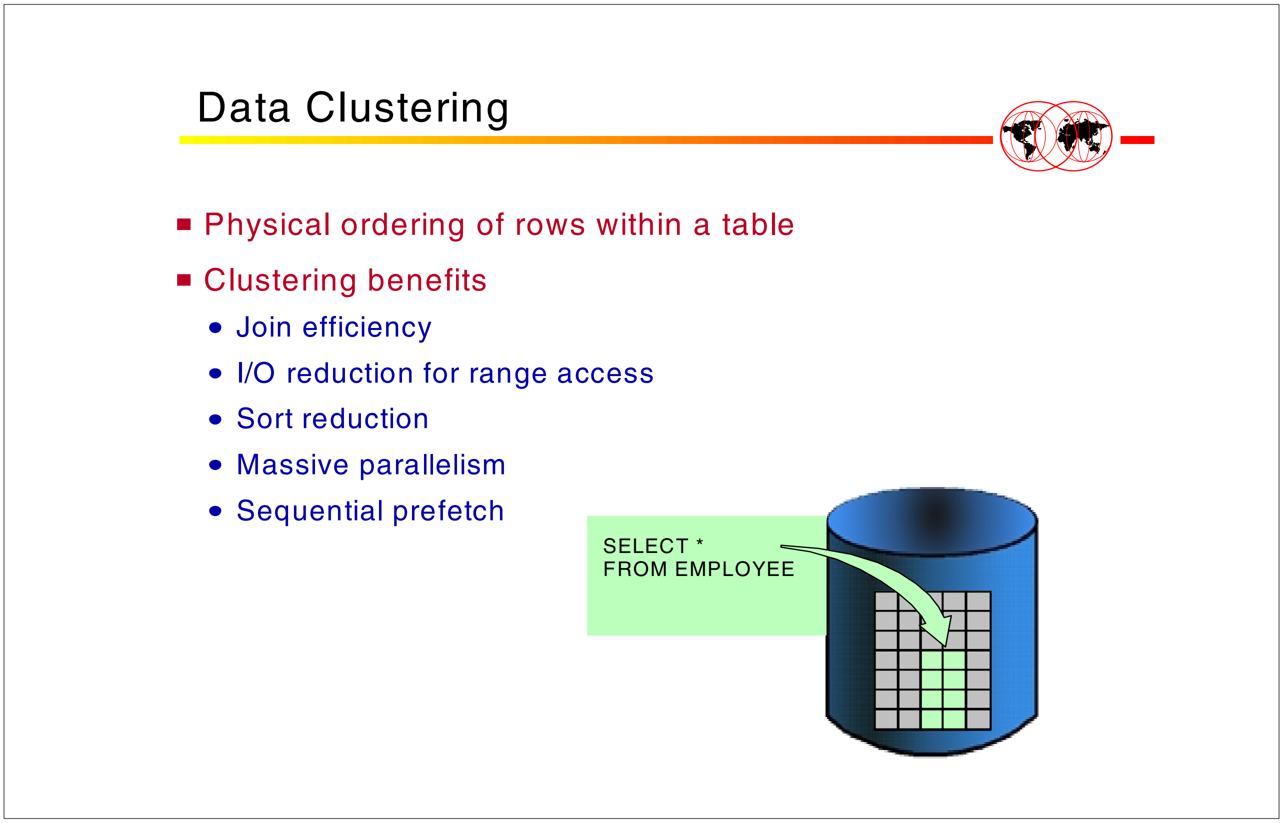
▨ Task #1
▨ Task #2
▥ Task #3

- Degree determination is done by the DBMS - not the DBA
  - With most parallel DBMS's, degree is fixed or must be specified

DB2 exploits the S/390 shared data architecture, which allows all server engines to access all partitions of a table or index. On most other data warehouse platforms, data is partitioned such that a partition is accessible from only one server engine, or from only a limited set of engines.

When a query accessing data in multiple partitions of a table is submitted, DB2 considers the speed of the server engines, the number of data partitions accessed, the distribution of data across partitions, the CPU and I/O costs of the access path, and the available buffer pool resource to determine the optimal degree of parallelism for execution of the query. The degree of parallelism chosen provides the best elapsed time with the least parallel processing overhead. Some other database management systems have a fixed degree of parallelism or require the DBA to specify a degree.

3.3.5 Data clustering



Data Clustering

- Physical ordering of rows within a table
- Clustering benefits
  - Join efficiency
  - I/O reduction for range access
  - Sort reduction
  - Massive parallelism
  - Sequential prefetch

SELECT *
FROM EMPLOYEE

With DB2 for OS/390, the user can influence the physical ordering of rows in a table by creating a clustering index. When new rows are inserted into the table, DB2 attempts to place the rows in the table so as to maintain the clustering sequence. The column or columns that comprise the clustering key are determined by the user. One example of a clustering key is a customer number for a customer data table. Alternatively, data could be clustered by a user-generated or system-generated random key.

Some of the benefits of clustering within DB2 are:

- Improved performance for queries that join tables.

  When a query joins two or more tables, query performance can be significantly improved if the tables are clustered on the join columns (join columns are common to the tables being joined, and are used to match rows from one table with rows from another).

- Improved performance for queries containing range-type search conditions.

  Examples of range-type search conditions would be:

  WHERE DATE_OF_BIRTH >’7/29/1999’

  WHERE INCOME BETWEEN 30000 AND 35000

  WHERE LAST_NAME LIKE’SMIT%’

  A query containing such a search condition would be expected to perform better if the rows in the target table were clustered by the column specified in the range-type search condition. The query would perform better because rows qualified by the search condition would be in close proximity to each other, resulting in fewer I/O operations.

- Improved performance for queries which aggregate (GROUP BY) or order rows (ORDER BY).

  If the data is clustered by the aggregating or ordering columns, the rows can be retrieved in the desired sequence without a sort.

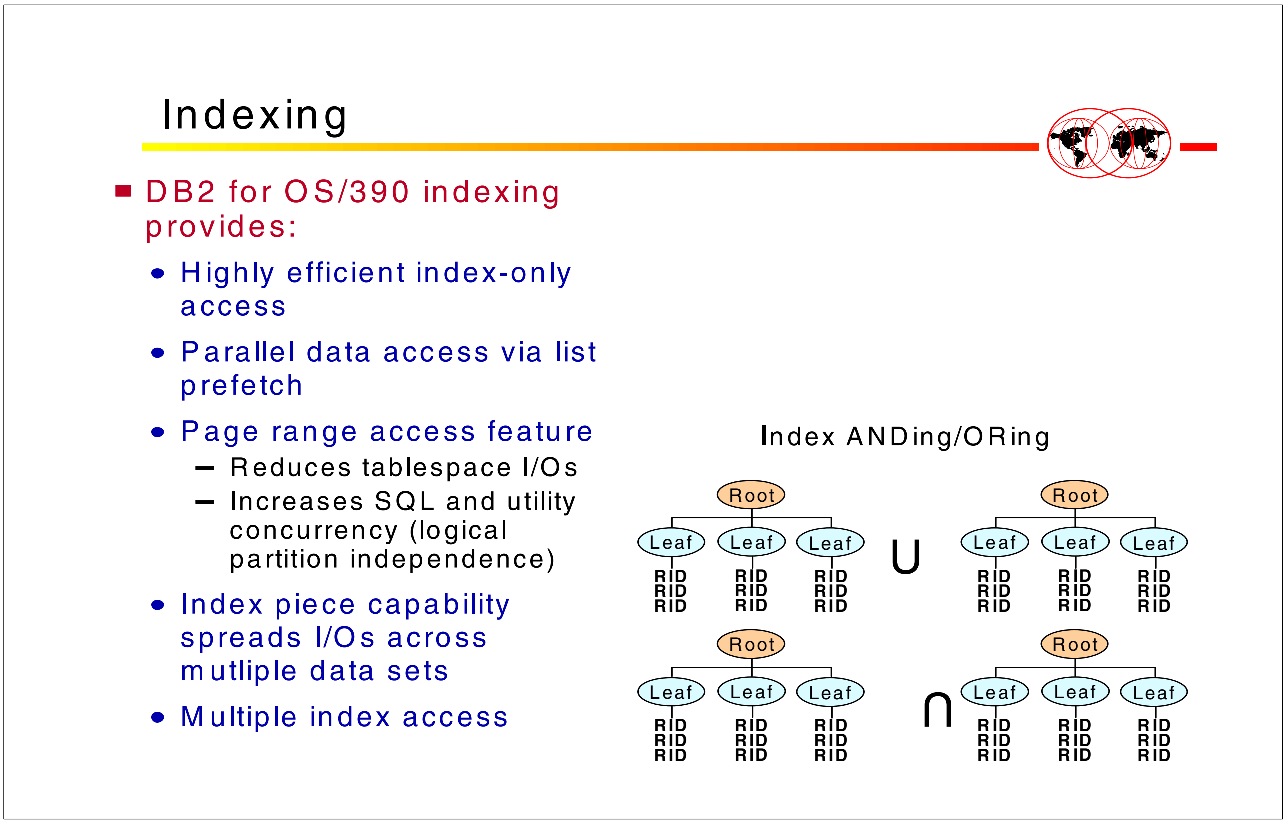
- Greater degree of query parallelism.

  This can be especially useful in reducing the elapsed time of CPU-intensive queries. Massive parallelism can be achieved by the use of a random clustering key that spreads rows to be retrieved across many partitions.

- Reduced elapsed time for queries accessing data sequentially.

  Data clustering can reduce query elapsed time through a DB2 for OS/390 capability called sequential prefetch. When rows are retrieved in a clustering sequence, sequential prefetch allows DB2 to retrieve pages from DASD before they've been requested by the query. This anticipatory read capability can significantly reduce query I/O wait time.

3.3.6 Indexing



Indexing

- DB2 for OS/390 indexing provides:
  - Highly efficient index-only access
  - Parallel data access via list prefetch
  - Page range access feature
    - Reduces tablespace I/Os
    - Increases SQL and utility concurrency (logical partition independence)
  - Index piece capability spreads I/Os across mutliple data sets
  - Multiple index access

Index ANDing/ORing
Root
Leaf
RID
∪
∩

Indexes can be used to significantly improve the performance of data warehouse queries in a DB2 for OS/390 environment. DB2 indexes provide a number of benefits:

- Highly efficient data retrieval via index-only access.

  If the data columns of interest are part of an index key, they can be identified and returned to the user at a very low cost in terms of S/390 processing resources.

- Parallel data access via list prefetch.

  When many rows are to be retrieved using a non-clustering index, data page access time can be significantly reduced through a DB2 capability called list prefetch. If the target table is partitioned, data pages in different partitions can be processed in parallel.

- Reduced query elapsed time and improved concurrency via page range access.

  When the target table is partitioned, and rows qualified by a query search condition are located in a subset of the table's partitions, page range access enables DB2 to avoid accessing the partitions that do not contain qualifying rows. The resulting reduction in I/O activity speeds query execution. Page range access also allows queries retrieving rows from some of a table's partitions to execute concurrently with utility jobs accessing other partitions of the same table.

- Improved DASD I/O performance via index pieces.

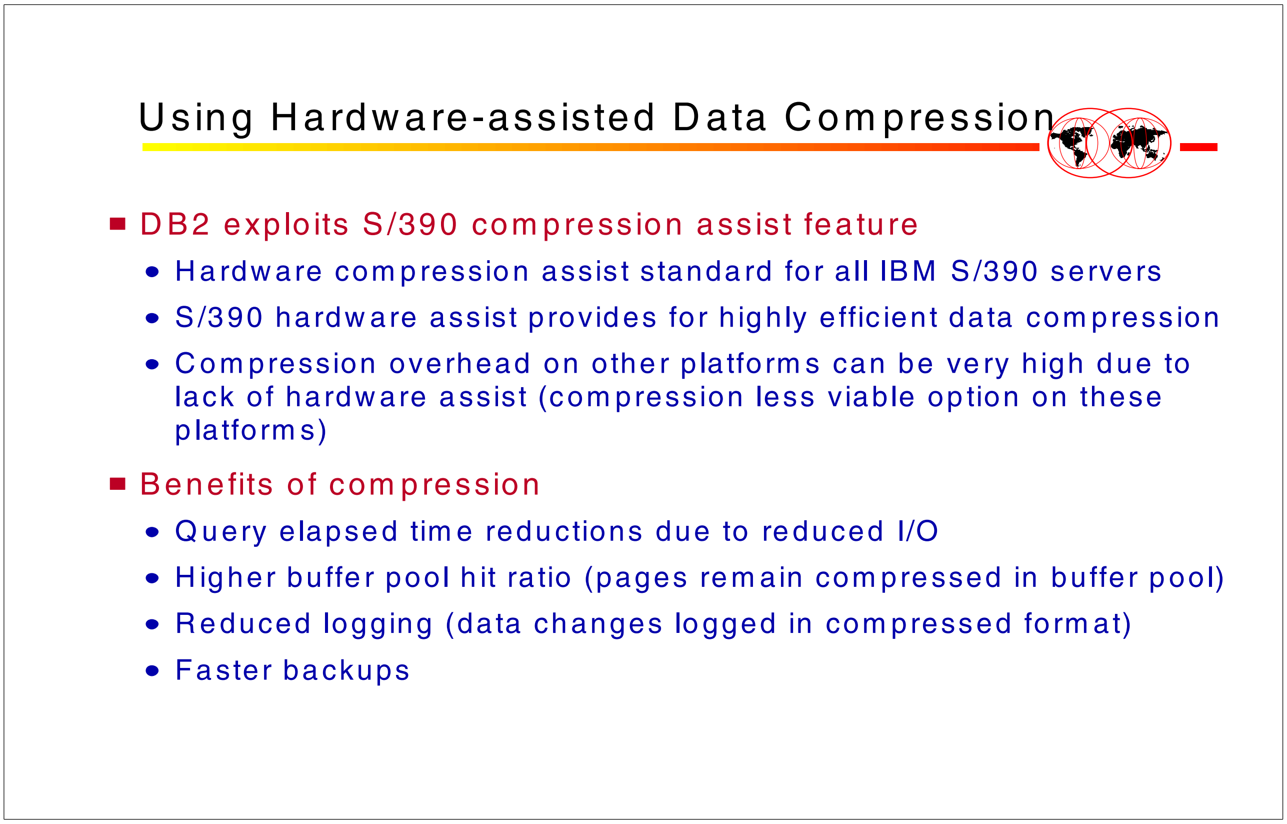
  The DB2 for OS/390 index piece capability allows a nonpartitioning index to be split across multiple data sets. These data sets can be spread across multiple DASD volumes to improve concurrent read performance.

- Improved data access efficiency via multi-index access.

  This feature allows DB2 for OS/390 to utilize multiple indexes in retrieving data from a single table. Suppose, for example, that a query has two ANDed search conditions: DEPT ='D01' AND JOB_CODE ='A12'. If there is an index on the DEPT column and another on the JOB_CODE column, DB2 can generate lists of qualifying rows using the two indexes and then intersect the lists to identify rows that satisfy both search conditions. Using a similar process, DB2 can union multiple row-identifying lists to retrieve data for a query with multiple ORed search conditions (e.g., DEPT ='D01' OR JOB_CODE ='A12').

A key benefit of DB2 for OS/390 is the sophisticated query optimizer. The user does not have to specify a particular index access option. Using the rich array of database statistics in the DB2 catalog, the optimizer considers all of the available options (those just described represent only a sampling of these options) and automatically selects the access path that provides the best performance for a particular query.

3.3.7 Using hardware-assisted data compression



Using Hardware-assisted Data Compression

- DB2 exploits S/390 compression assist feature
  - Hardware compression assist standard for all IBM S/390 servers
  - S/390 hardware assist provides for highly efficient data compression
  - Compression overhead on other platforms can be very high due to lack of hardware assist (compression less viable option on these platforms)
- Benefits of compression
  - Query elapsed time reductions due to reduced I/O
  - Higher buffer pool hit ratio (pages remain compressed in buffer pool)
  - Reduced logging (data changes logged in compressed format)
  - Faster backups

DB2 takes advantage of hardware-assisted compression, a standard feature of IBM S/390 servers, which provides a very CPU-efficient data compression capability. Other platforms utilize software compression techniques which can be excessively expensive due to high consuption of processor resources. This high overhead makes compression a less viable option on these platforms.

There are several benefits associated with the use of DB2 for OS/390 hardware-assisted compression:

- Reduced DASD costs.

  The cost of DASD can be reduced, on average, by 50% through the compression of raw data. Many customers realize even greater DASD savings, some as much as 80%, by combining S/390 processor compression capabilities with IBM RVA data compression. And future releases of DB2 on OS/390 will extend data compression to include compression of system space, such as indexes and work spaces.

- Opportunities for reduced query elapsed times, due to reduced I/O activity.

  DB2 compression can significantly increase the number of rows stored on a data page. As a result, each page read operation brings many more rows into the buffer pools than it would in the non-compressed scenario. More rows per page read can significantly reduce I/O activity, thereby improving query elapsed time. The greater the compression ratio, the greater the benefit to the read operation.

- Improved query performance due to improved buffer pool hit ratios.

  Data pages from compressed tables are stored in compressed format in the DB2 buffer pool. Because DB2 compression can significantly increase the number of rows per data page, more rows can be cached in the DB2 buffer pool. As a result, buffer pool hit ratios can go up and query elapsed times can go down.

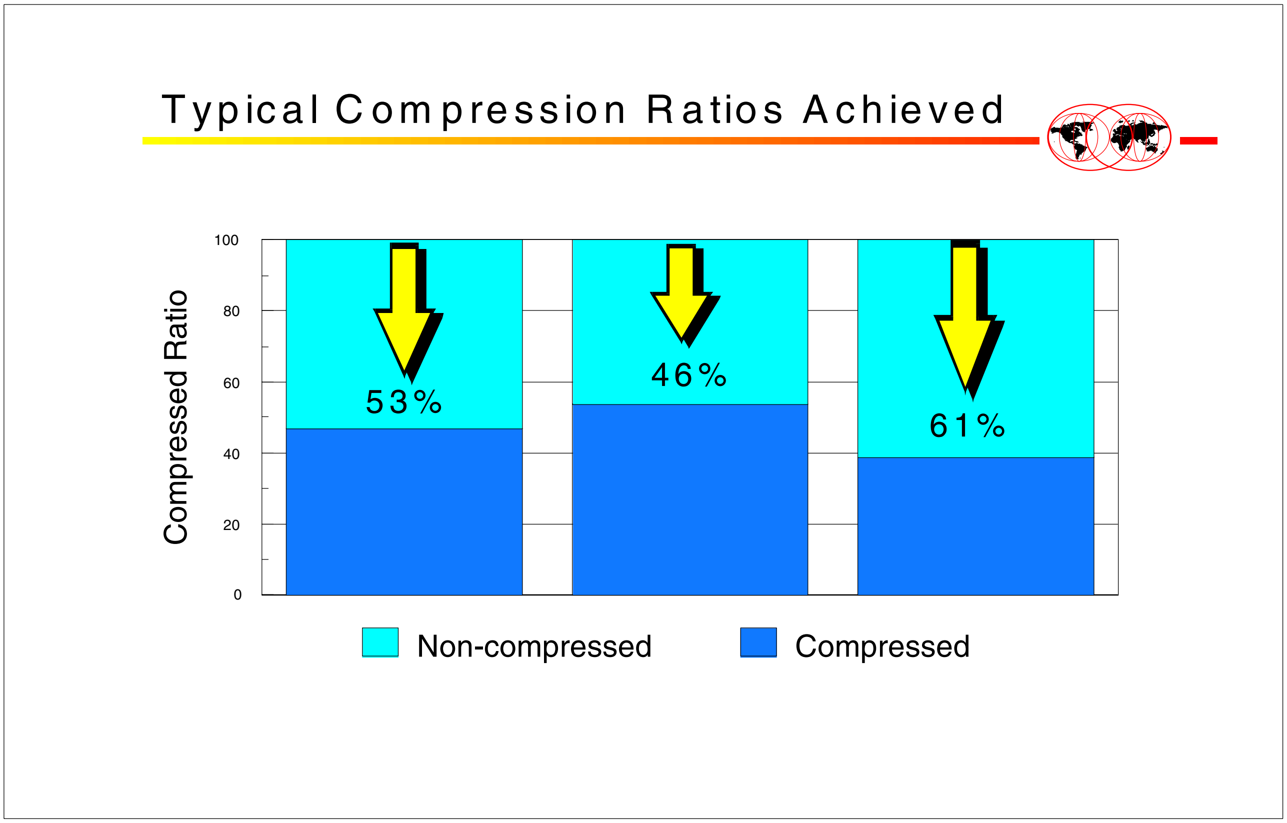
- Reduced logging volumes.

  Compression reduces DB2 log data volumes because changes to compressed tables are captured on the DB2 log in compressed format.

- Faster database backups.

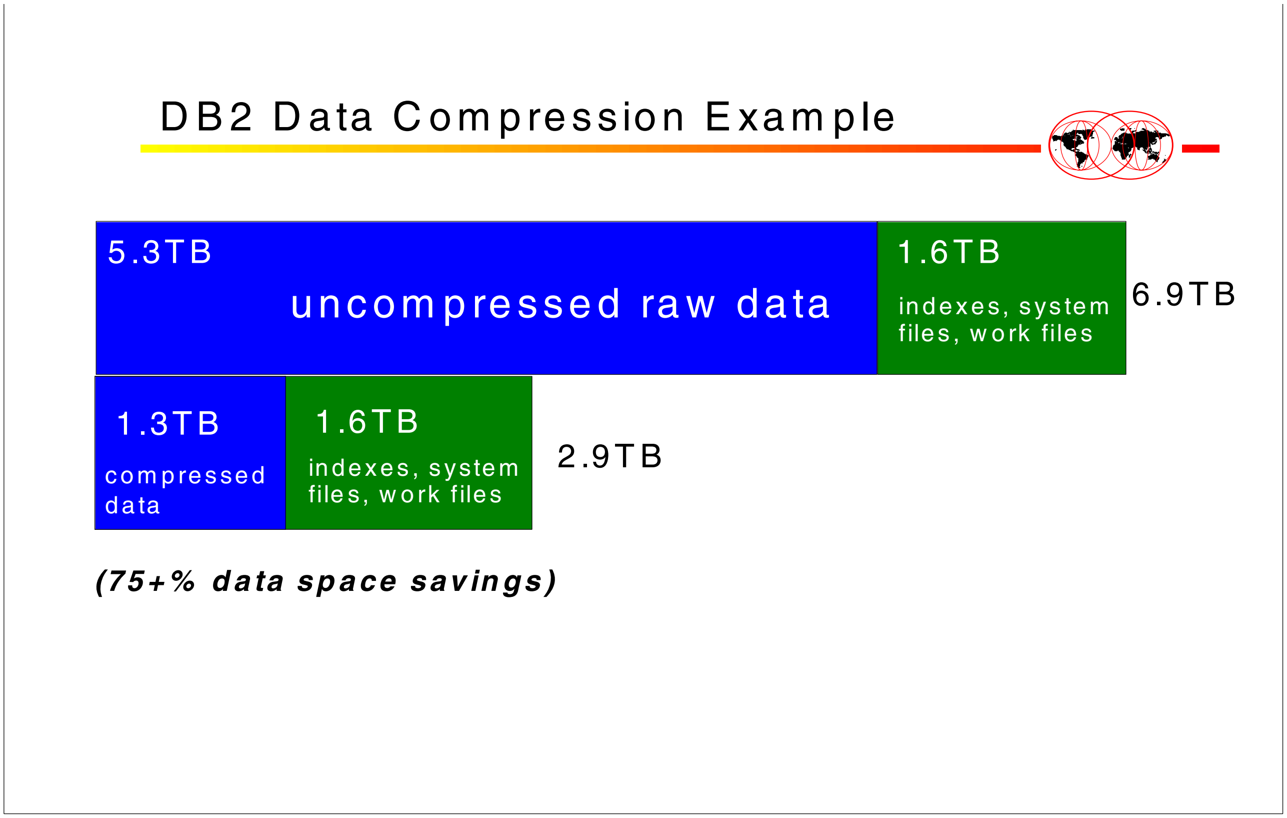
  Compressed tables are backed up in compressed format. As a result, the backup process generates fewer I/O operations, leading to improvements in elapsed and CPU time.

Note that DB2 hardware-assisted compression applies to tables. Indexes are not compressed. Indexes can, of course, be compressed at the DASD controller level. This form of compression, which complements DB2 for OS/390 hardware-assisted compression, is standard on current-generation DASD subsystems such as the IBM Enterprise Storage Server (ESS).



Typical Compression Ratios Achieved

The amount of space reduction achieved through the use of DB2 for OS/390 hardware-assisted compression varies from table to table. Compression ratio on average tends to be typically 50 to 60 percent, and in practice it ranges from 30 to 90 percent.



DB2 Data Compression Example

5.3TB

uncompressed raw data

1.6TB

indexes, system files, work files

6.9TB

1.3TB

compressed data

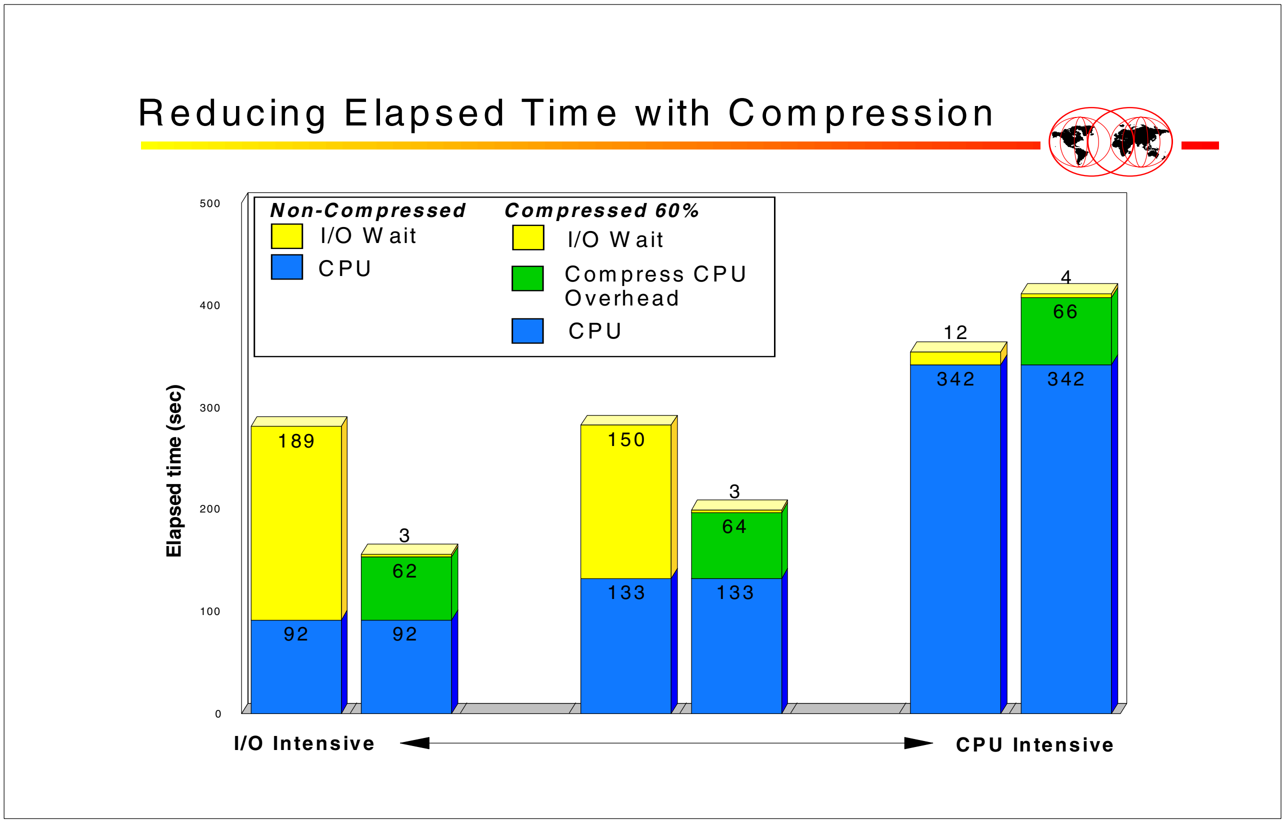
1.6TB

indexes, system files, work files

2.9TB

(75+% data space savings)

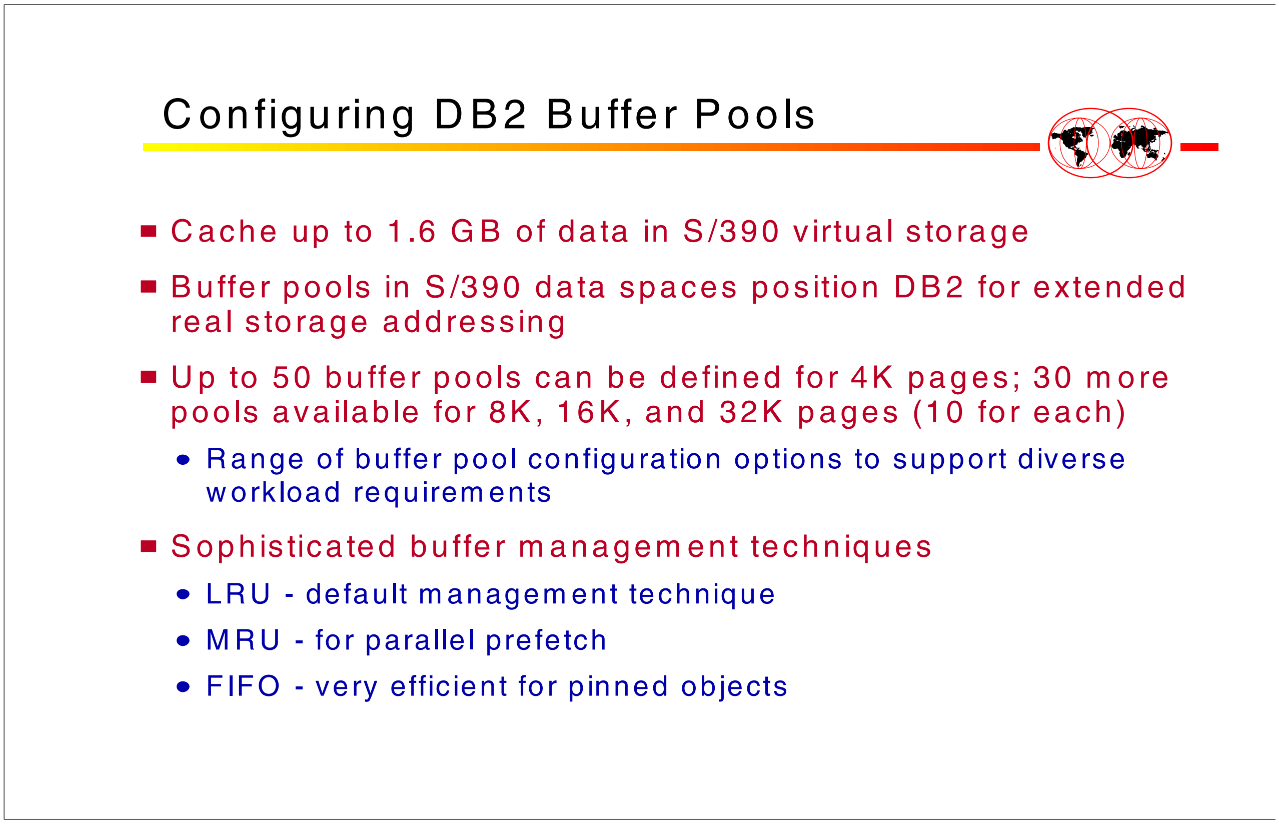
Here we see an example of the space savings achieved during a joint study conducted by the S/390 Teraplex center with a large banking customer. The high data compression ratio—75 percent—led to a 58 percent reduction in the overall space requirement for the database (from 6.9 terabytes to 2.9 terabytes).



Reducing Elapsed Time with Compression

Here we show how elapsed time for various query types can be affected by the use of DB2 for OS/390 compression. For queries that are relatively I/O intensive, data compression can significantly improve runtime by reducing I/O wait time (compression = more rows per page + more buffer hits = fewer I/Os). For CPU-intensive queries, compression can increase elapsed time by adding to overall CPU time, but the increase should be modest due to the efficiency of the hardware-assisted compression algorithm.

3.3.8 Configuring DB2 buffer pools



Configuring DB2 Buffer Pools

- Cache up to 1.6 GB of data in S/390 virtual storage
- Buffer pools in S/390 data spaces position DB2 for extended real storage addressing
- Up to 50 buffer pools can be defined for 4K pages; 30 more pools available for 8K, 16K, and 32K pages (10 for each)
  - Range of buffer pool configuration options to support diverse workload requirements
- Sophisticated buffer management techniques
  - LRU - default management technique
  - MRU - for parallel prefetch
  - FIFO - very efficient for pinned objects

Through its buffer pool, DB2 makes very effective use of S/390 storage to avoid I/O operations and improve query performance.

Up to 1.6 gigabytes of data and index pages can be cached in the DB2 virtual storage buffer pools. Access to data in these pools is extremely fast—perhaps a millionth of a second to access a data row.

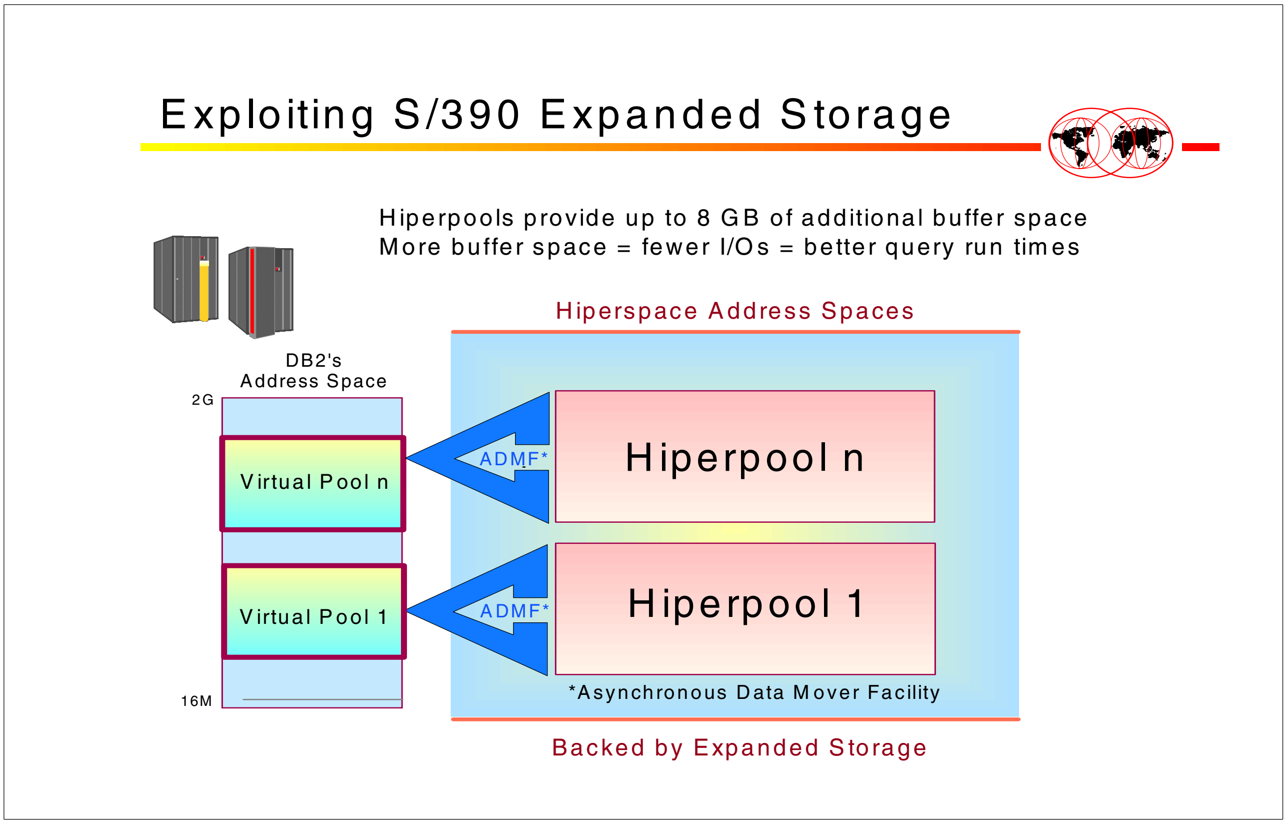
With DB2 for OS/390 Version 6, additional buffer space can be allocated in OS/390 virtual storage address spaces called *data spaces*. This capability positions DB2 to take advantage of S/390 extended 64 bit real storage addressing when it becomes available. Meanwhile, hyperpools remain the first option to consider when additional buffer space is required.

DB2 buffer space can be allocated in any of 50 different pools for 4K (that is, 4 kilobyte) pages, with an additional 10 pools available for 8K pages, 10 more for 16K pages, and 10 more for 32K pages (8K, 16K, and 32K pages are available to support tables with extra long rows). Individual pools can be customized in a number of ways, including size (number of buffers), objects (tables and indexes) assigned to the pool, thresholds affecting read and write operations, and page management algorithms.

DB2 uses sophisticated algorithms to effectively manage the buffer pool resource. The default page management technique for a buffer pool is *least recently used* (LRU). With LRU in effect, DB2 works to keep the most frequently referenced pages resident in the buffer pool. When a query splits, and the parallel tasks are concurrently scanning partitions of an index or table, DB2 automatically utilizes a *most recently used* (MRU) algorithm to manage the pages read by the parallel tasks. MRU makes the buffers occupied by these pages available for stealing as soon as the page has been read and released by the query task. In this way, DB2 keeps split queries from pushing pages needed by other queries from the buffer pool. The first in, first out (FIFO) buffer management technique, introduced with DB2 for OS/390 Version 6, is a very CPU-efficient algorithm that is well suited to pools used to “pin” database objects in S/390 storage (pinning refers to caching all pages of a table or index in a buffer pool).

The buffer pool configuration flexibility offered by DB2 for OS/390 allows a database administrator to tailor the DB2 buffer resource to suit the requirements of a particular data warehouse application.

3.3.9 Exploiting S/390 expanded storage



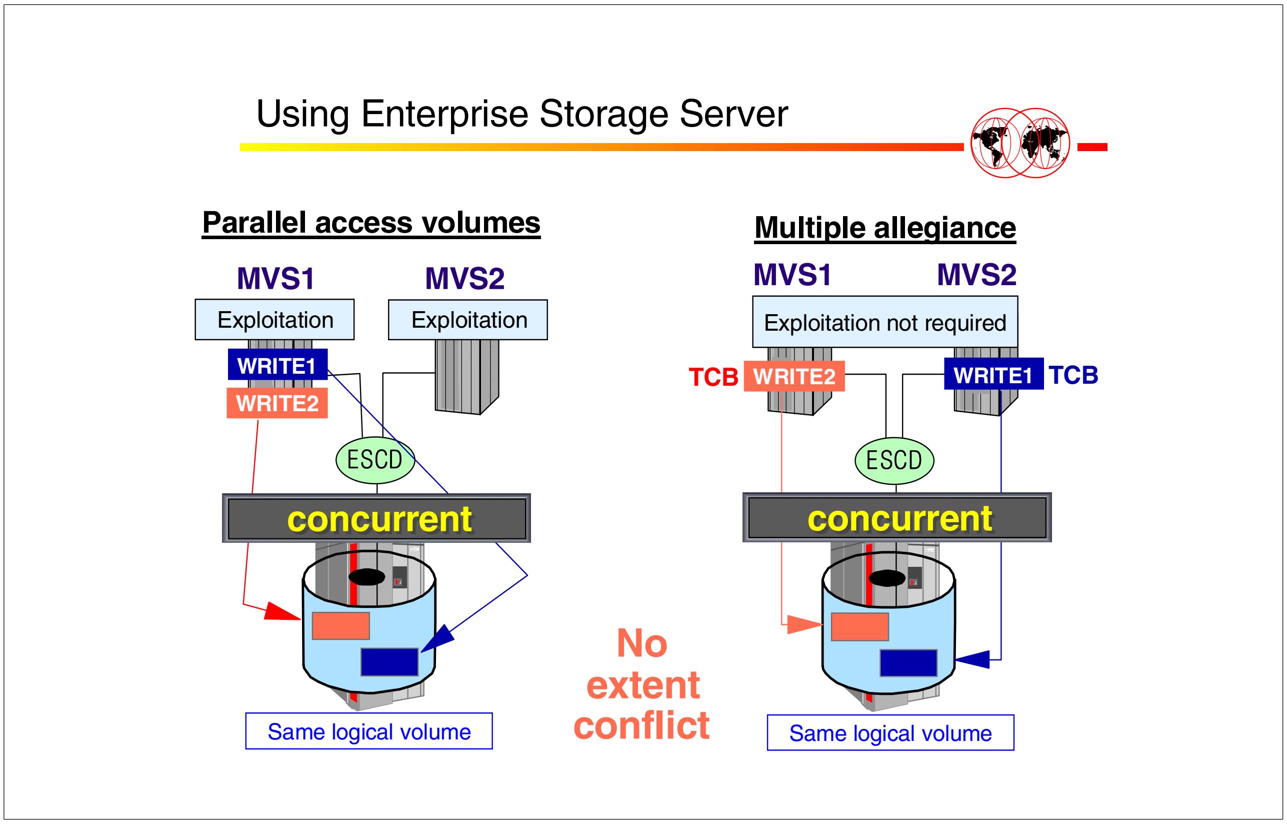
Exploiting S/390 Expanded Storage

Hiperpools provide up to 8 GB of additional buffer space
More buffer space = fewer I/Os = better query run times

Hiperspace Address Spaces
DB2's Address Space
2G
Virtual Pool n
ADMF*
Hiperpool n
Virtual Pool 1
ADMF*
Hiperpool 1
16M
*Asynchronous Data Mover Facility
Backed by Expanded Storage

DB2 exploits the expanded storage resource on S/390 servers through a facility called hiperpools. A hiperpool is allocated in S/390 expanded storage and is associated with a virtual storage buffer pool. A S/390 hardware feature called the asynchronous data mover function (ADMF) provides a very efficient means of transferring pages between hiperpools and virtual storage buffer pools. Hiperpools enable the caching of up to 8 GB of data beyond that cached in the virtual pools, in a level of storage that is almost as fast (in terms of data access time) as central storage and orders of magnitude faster than the DASD subsystem. More data buffering in the S/390 server means fewer DASD I/Os and improved query elapsed times.

3.3.10 Using Enterprise Storage Server



Using Enterprise Storage Server

S/390 and Enterprise Storage Server (ESS) are the ideal combination for DW and BI applications.

The ESS offers several benefits in the S/390 BI environment by enabling increased parallelism to access data in a DW or DM.

The parallel access volumes (PAV) capability of ESS allows multiple I/Os to the same volume, eliminating or drastically reducing the I/O system queuing (IOSQ) time, which is frequently the biggest component of response time.

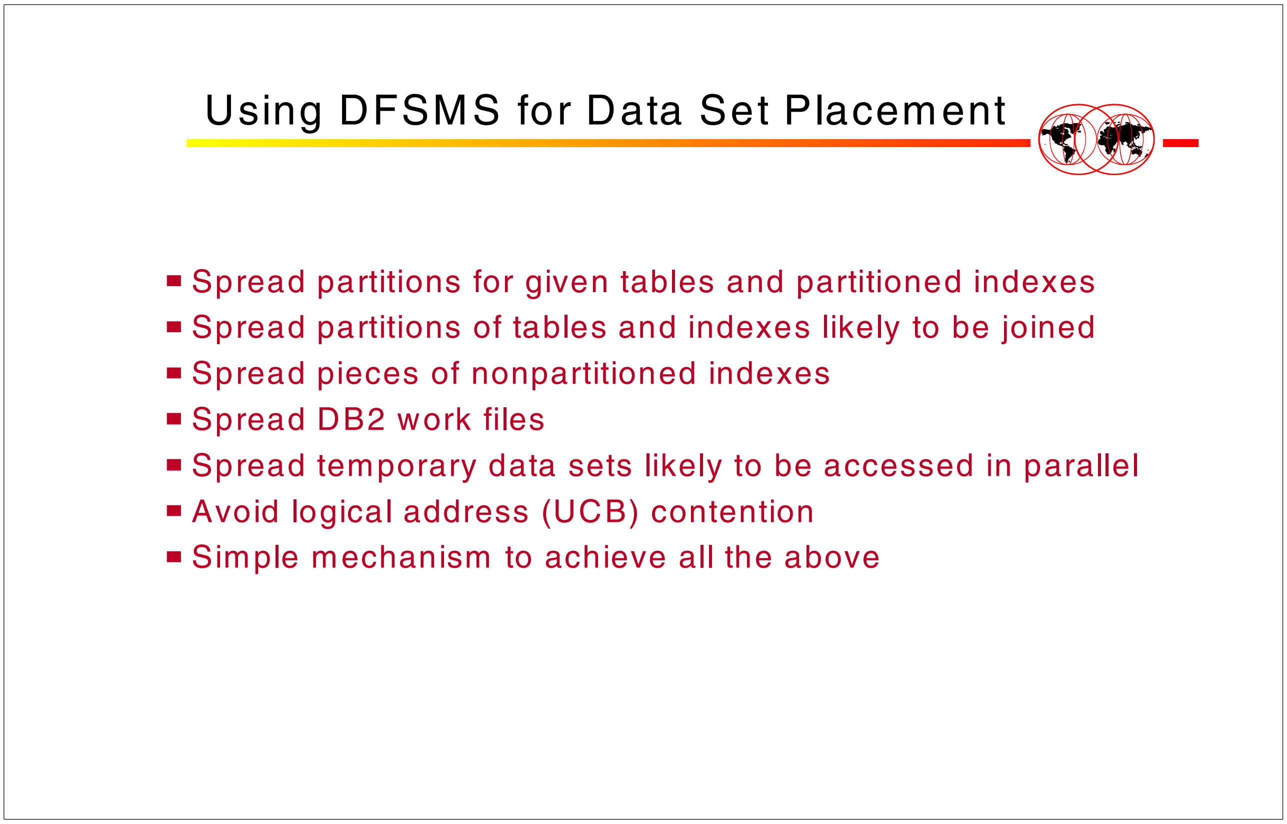
The multiple allegiance (MA) capability of ESS permits parallel I/Os to the same logical volume from multiple OS/390 images, eliminating or drastically reducing the wait for pending I/Os to complete.

ESS receives notification from the operating system as to which task has the highest priority, and that task is serviced first as against the normal FIFO basis. This enables, for example, query type I/Os to be processed faster than data mining I/Os.

ESS with its PAV and MA capabilities provides faster sequential bandwidth and reduces the requirement for hand placement of datasets.

The measurement results from the DB2 Development Laboratory show that the ESS supports a query single stream rate of approximately 11.5 MB/sec. Only two ESSs are required, compared to twenty-seven 3990 controllers, to achieve a total data rate of 270 MB/sec for a massive query. Elapsed times for DB2 utilities (such as Load and Copy) show a range of improvements from 40 to 50 percent on the ESS compared to the RVA X82. With ESS, the DB2 logging rate is almost 2.5 times faster than RAMAC 3 (8.4 MB/sec versus 3.4 MB/sec).

3.3.11 Using DFSMS for data set placement



Using DFSMS for Data Set Placement

- Spread partitions for given tables and partitioned indexes
- Spread partitions of tables and indexes likely to be joined
- Spread pieces of nonpartitioned indexes
- Spread DB2 work files
- Spread temporary data sets likely to be accessed in parallel
- Avoid logical address (UCB) contention
- Simple mechanism to achieve all the above

Should you hand place the data sets, or let Data Facility Systems Managed Storage (DFSMS) handle it? People can get pretty emotional about this. The performance-optimizing approach is probably intelligent hand placement to minimize I/O contention. The practical approach, increasingly popular, is SMS-managed data set placement.

The components of DFSMS automate and centralize storage management according to policies set up to reflect business priorities. The Interactive Storage Management Facility (ISMF) provides the user interface for defining and maintaining these policies, which SMS governs.

The data set services component of DFSMS could still place on the same volume two data sets that should be on two different volumes, but several factors combine to make this less of a concern now than in years past:

- DASD controller cache sizes are much larger these days (multiple GB), resulting in fewer reads from spinning disks.
- DASD pools are bigger, and with more volumes to work with, SMS is less likely to put on the same volume data sets that should be spread out.
- DB2 data warehouse databases are bigger (terabytes) and it is not easy to hand place thousands of data sets.
- With RVA DASD, data records are spread all over the subsystem, minimizing disk-level contention.

- If you do go with SMS-managed placement of DB2 data sets created using storage groups, you may not need more than one DB2 storage group.
- You can, of course, have multiple SMS storage groups, which introduces the following considerations:
  - You can use automated class selection (ACS) routines to direct DB2 data sets to different SMS storage groups based on data set name.
  - We recommend use of a few SMS storage groups with lots of volumes per group, rather than lots of SMS storage groups with few volumes per group. You may want to consider creating two primary SMS storage groups, one for table space data sets and one for index data sets, because this approach is:
    - Simple: the ACS routine just has to distinguish between table space name and index name.
    - Effective: you can reduce contention by keeping table space and index data sets on separate volumes.

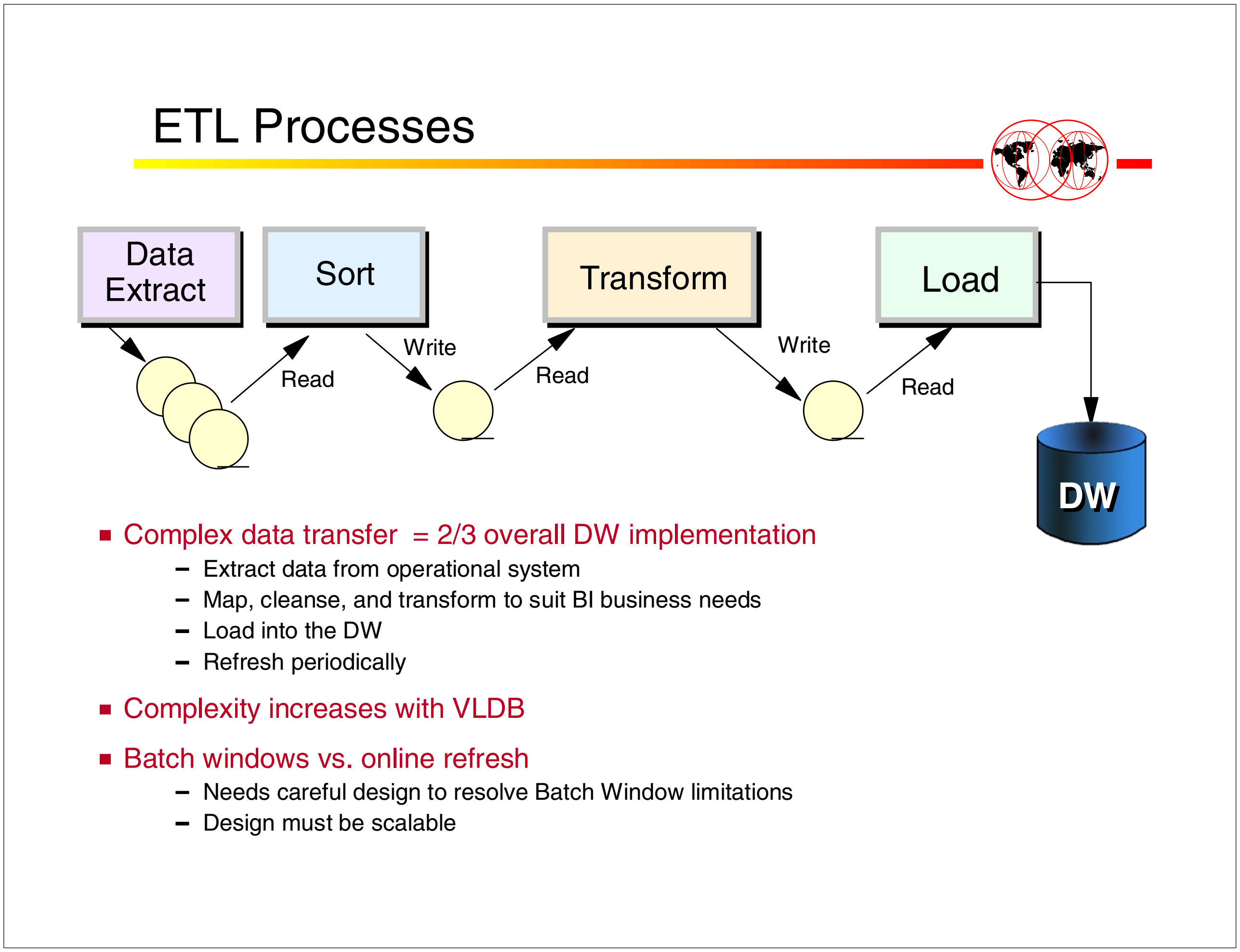
    You may want to have one or more additional SMS storage groups for DB2 data sets, one of which could be used for diagnostic purposes.
- With ESS, having data sets on the same volume is less of a concern because of the PAV capability, and there is no logical address or unit control block (UCB) contention.

Chapter 4. Data warehouse data population design

Data Warehouse
Data Population Design

This chapter discusses data warehouse data population design techniques on S/390. It describes the Extract-Transform-Load (ETL) processes and how to optimize them through parallel, piped, and online solutions.

4.1 ETL processes



ETL Processes

- Complex data transfer = 2/3 overall DW implementation
  - Extract data from operational system
  - Map, cleanse, and transform to suit BI business needs
  - Load into the DW
  - Refresh periodically
- Complexity increases with VLDB
- Batch windows vs. online refresh
  - Needs careful design to resolve Batch Window limitations
  - Design must be scalable

ETL processes in a data warehouse environment extract data from operational systems, transform the data in accordance with defined business rules, and load the data into the target tables in the data warehouse.

There are two different types of ETL processes:

- Initial load
- Refresh

The initial load is executed once and often handles data for multiple years. The refresh populates the warehouse with new data and can, for example, be executed once a month. The requirements on the initial load and the refresh may differ in terms of volumes, available batch window, and requirements on end user availability.

Extract

Extracting data from operational sources can be achieved in many different ways. Some examples are: total extract of the operational data, incremental extract of data (for instance, extract of all data that is changed after a certain point in time), and propagation of changed data using a propagation tool (such as DB2 DataPropagator). If the source data resides on a different platform than the data warehouse, it may be necessary to transfer the data, implying that bandwidth can be an issue.

Transform

The transform process can be very I/O intensive. It often implies at least one sort; in many cases the data has to be sorted more than once. This may be the case if the transform, from a logical point of view, must process the data sorted in a way that differs from the way the data is physically stored in DB2 (based on the clustering key). In this scenario you need to sort the data both before and after the transform.

In the transformation process table, lookups against reference tables are frequent. They are used to ensure consistency of captured data and to decode encoded values. These lookup tables are often small. In some cases, however, they can be large. A typical control you want to do in a transform program is, for example, to verify that the customer number in the captured data is valid. This implies a table lookup against the customer table for each input record processed (if the data is sorted in customer number order, the number of lookups can be reduced; if the customer table is clustered in customer number order, this improves performance drastically).

Load

To reduce elapsed time for DB2 loads, it is important to run them in parallel as much as possible. The load strategy to implement correlates highly to the way the data is partitioned: if data is partitioned using a time criteria you may, for example, be able to use load replace when refreshing data.

The initial load of the data warehouse normally implies that a large amount of data is loaded. Data originating from multiple years may be loaded into the data warehouse.The initial load must be carefully planned, especially in a very large database (VLDB) environment. In this context the key issue is to reduce elapsed time.

The design of refresh of data is also important. The key issues here are to understand how often the refresh should be done, and what batch window is available. If the batch window is short or no batch window at all is available, it may be necessary to design an online refresh solution.

In general, most data warehouses tend to have very large growth. In this sense, scalability of the solution is vital.

Data population is one of the biggest challenges in building a data warehouse. In this context, designing the architecture of the population process is a key activity. To design an effective population process, there are a number of issues you need to understand. Most of these involve detailed understanding of the user requirements and of existing OLTP systems.

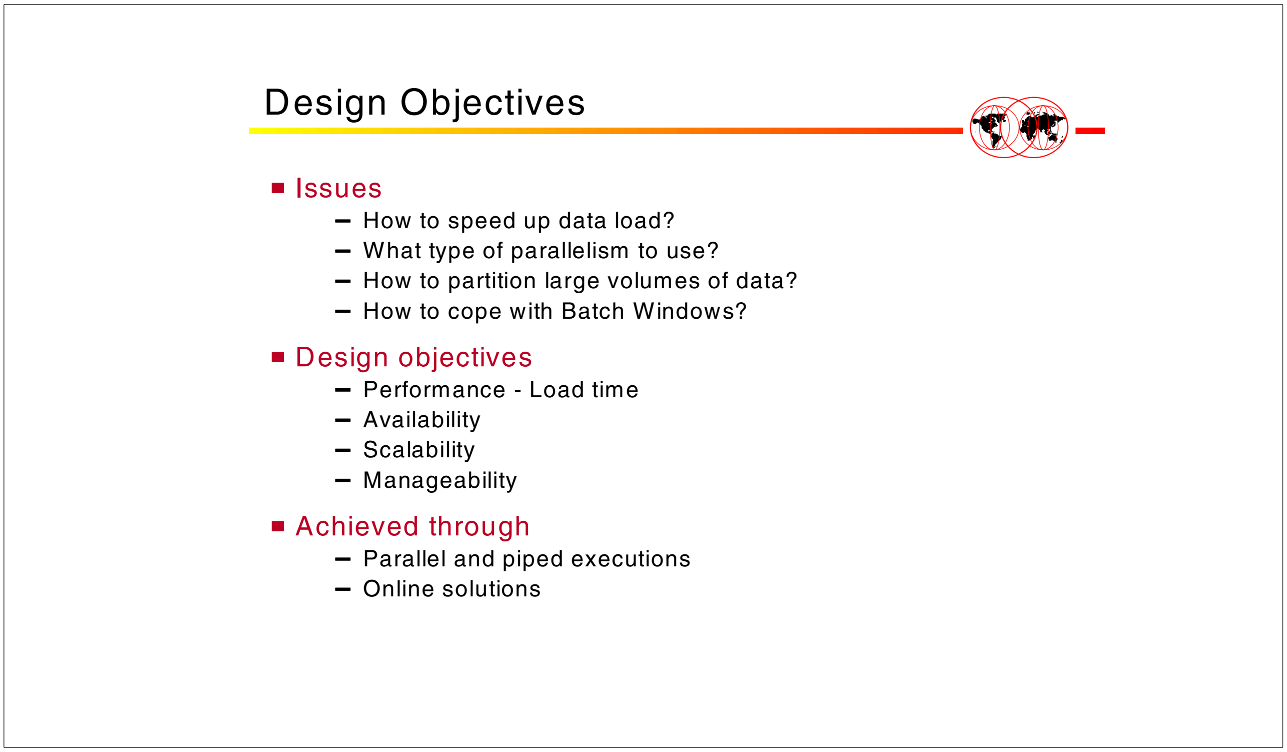
Some of the questions you need to address are:

- How large are the volumes to be expected for the initial load of the data?
- Where does the OLTP data reside? Is it necessary to transfer the data from the source platform to the target platform where the transformation takes place, and if so, is sufficient bandwidth available?

- What is your batch window for the initial load?
- For how long should the data be kept in the warehouse?
- When the data is removed from the warehouse, should it be archived in any way?
- Is it necessary to update any existing data in the data warehouse, or is the data warehouse read only?
- Should the data be refreshed periodically on a daily, weekly, or monthly basis?
- How is the data extracted from the operational sources? Is it possible to identify changed data or is it necessary to do a full refresh?
- What is your batch window for refreshing the data?
- What growth can be expected for the volume of the data?

For very large databases, the design of the data population process is vital. In a VLDB, parallelism plays a key role. All processes of the population phase must be able to run in parallel.

4.2 Design objectives



Design Objectives

- Issues
  - How to speed up data load?
  - What type of parallelism to use?
  - How to partition large volumes of data?
  - How to cope with Batch Windows?
- Design objectives
  - Performance - Load time
  - Availability
  - Scalability
  - Manageability
- Achieved through
  - Parallel and piped executions
  - Online solutions

The key issue when designing ETL processes is to speed up the data load. To accomplish this you need to understand the characteristics of the data and the user requirements. What data volumes can be expected, what is the batch window available for the load, what is the life cycle of the data?

To reduce ETL elapsed time, running the processes in parallel is key. There are two different types of parallelism:

- Piped executions
- Parallel executions

Piped executions allow dependant processes to overlap and execute concurrently. Batch Pipes, as it is implemented in SmartBatch (see 4.4.2, “Piped executions with SmartBatch” on page 66) falls into this category.

Parallel executions allow multiple occurrences of a process to execute at the same time and each occurrence processes different fragments of the data. DB2 utilities executing in parallel against different partitions fall into this category.

Deciding what type of parallelism to use is part of the design. You can also combine process overlap and symmetric processing. See 4.4.3, “Combined parallel and piped executions” on page 68.

Table partitioning drives parallelism and, thus, plays an important role for availability, performance, scalability, and manageability. In 4.3, “Table partitioning schemes” on page 60, different partitioning schemes are discussed.

4.3 Table partitioning schemes

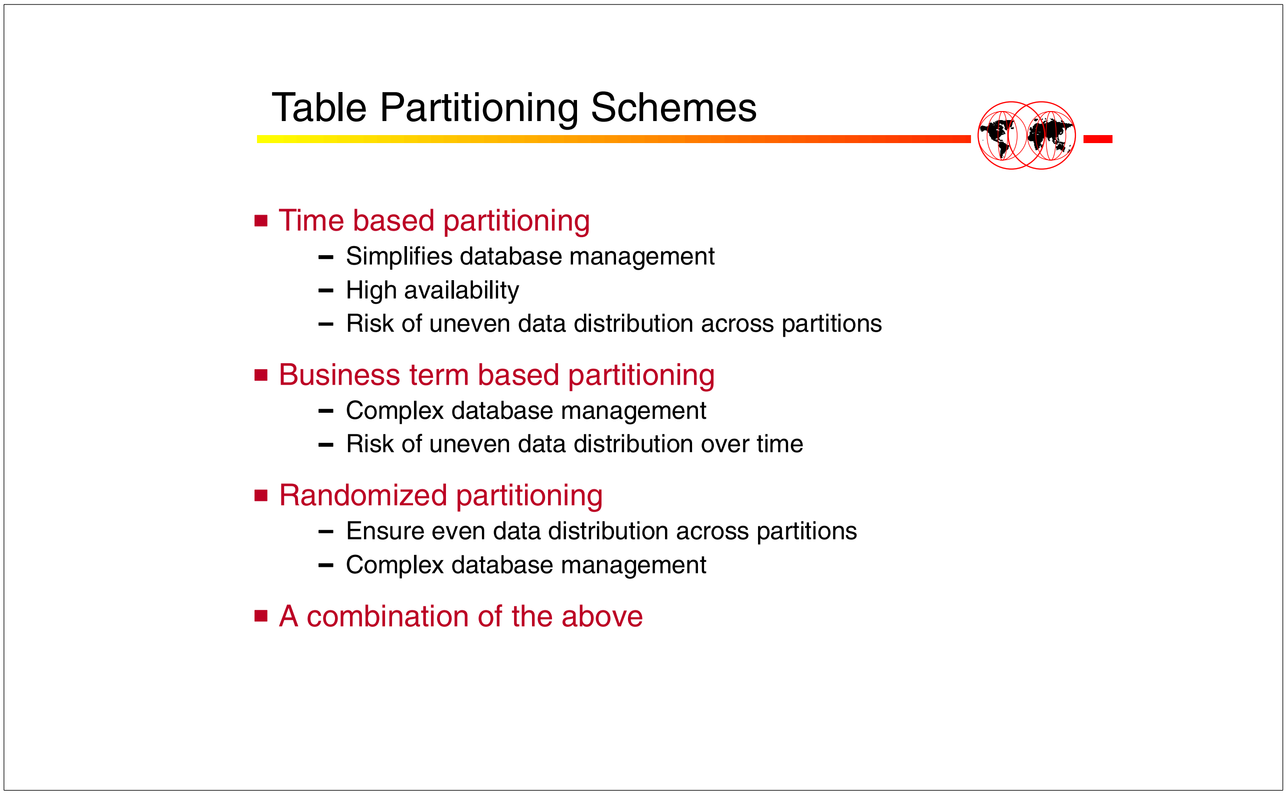


Table Partitioning Schemes

- Time based partitioning
  - Simplifies database management
  - High availability
  - Risk of uneven data distribution across partitions
- Business term based partitioning
  - Complex database management
  - Risk of uneven data distribution over time
- Randomized partitioning
  - Ensure even data distribution across partitions
  - Complex database management
- A combination of the above

There are a number of issues that need to be considered before deciding how to partition DB2 tables in a data warehouse. The partitioning scheme has a significant impact on database management, performance of the population process, end user availability, and query response time.

In DB2 for OS/390 partitioning is achieved by specifying a partitioning index. The partitioning index specifies the number of partitions for the table. It also specifies the columns and values to be used to determine in which partition a specific row should be stored. In most parallel DBMSs, data in a specific partition can only be accessed by one or a limited number of processors. In DB2 all processors can access all the partitions (in a Sysplex this includes all processors on all members within the Sysplex). DB2’s optimizer decides the degree of parallelism to minimize elapsed time. One important input to the optimizer is the distribution of data across partitions. DB2 may decrease the level of parallelism if the data is unevenly distributed.

There are a number of different approaches that can be used to partition the data.

Time-based partitioning

The most common way to partition DB2 tables in a data warehouse is to use time-based partitioning, in which the refresh period is a part of the partitioning key. A simple example of this approach is the scenario where a new period of data is added to the data warehouse every month and the data is partitioned on month number (1-12). At the end of the year the table contains twelve partitions, each partition with data from one month.

Time-based partitioning enables load replace on partition level. The refreshed data is loaded into a new partition or replaces data in an existing partition. This simplifies maintenance for the following reasons:

- Reorg table space is not necessary (as long as data is sorted in clustering key before load).
- The archive process is normally easier; the oldest partitions should be archived or deleted.
- Utilities such as Copy and Recover can be performed on partition level (only refreshed partitions).
- Inline utilities such as Copy and Runstats can be executed as part of the load.
- A limited number of load jobs are necessary when data is refreshed (one job for each refreshed partition).

One of the challenges in using a time-based approach is that data volumes tend to vary over time. If the difference between periods is large, it may affect the degree of parallelism.

Business term partitioning

In business term partitioning the data is partitioned using a business term, such as a customer number. Using this approach, it is likely that refreshed data needs to be loaded to all or most of the existing partitions. There is no correlation, or limited correlation, between the customer number and the new period. Business term partitioning normally adds more complexity to database management because of the following factors:

- With frequent reorganizations, data is added into existing partitions.
- Archiving is more complex: to archive or delete old data, all partitions must be accessed.
- One load resume job and one copy job per partition; all partitions must be loaded/copied.
- Inline utilities cannot be used.

To ensure an even size of the partitions, it is important to understand how data distribution fluctuates over time. Based on the allocation of the business term, the distribution may change significantly over time. The customer number may, for example, be an ever-increasing sequence number.

Randomized partitioning

Randomized partitioning ensures that data is evenly distributed across all partitions. Using this approach, the partitioning is based on a randomized value created by a randomizing algorithm (such as DB2 ROWID). Apart from this, the management concerns for this approach are the same as for business term partitioning.

Time and business term-based partitioning

DB2 supports partitioning using multiple criteria. This makes it possible to partition the data both on a period and a business term. We could, for example, partition a table on current month and customer number. This implies that data from each month is further partitioned based on customer number. Since each period has its own partitions, the characteristics of this solution are similar to the time-based one.

The advantage of using this approach, compared to the time-based one, is that we are able to further partition the table. Based on the volume of the data, this could lead to increased parallelism.

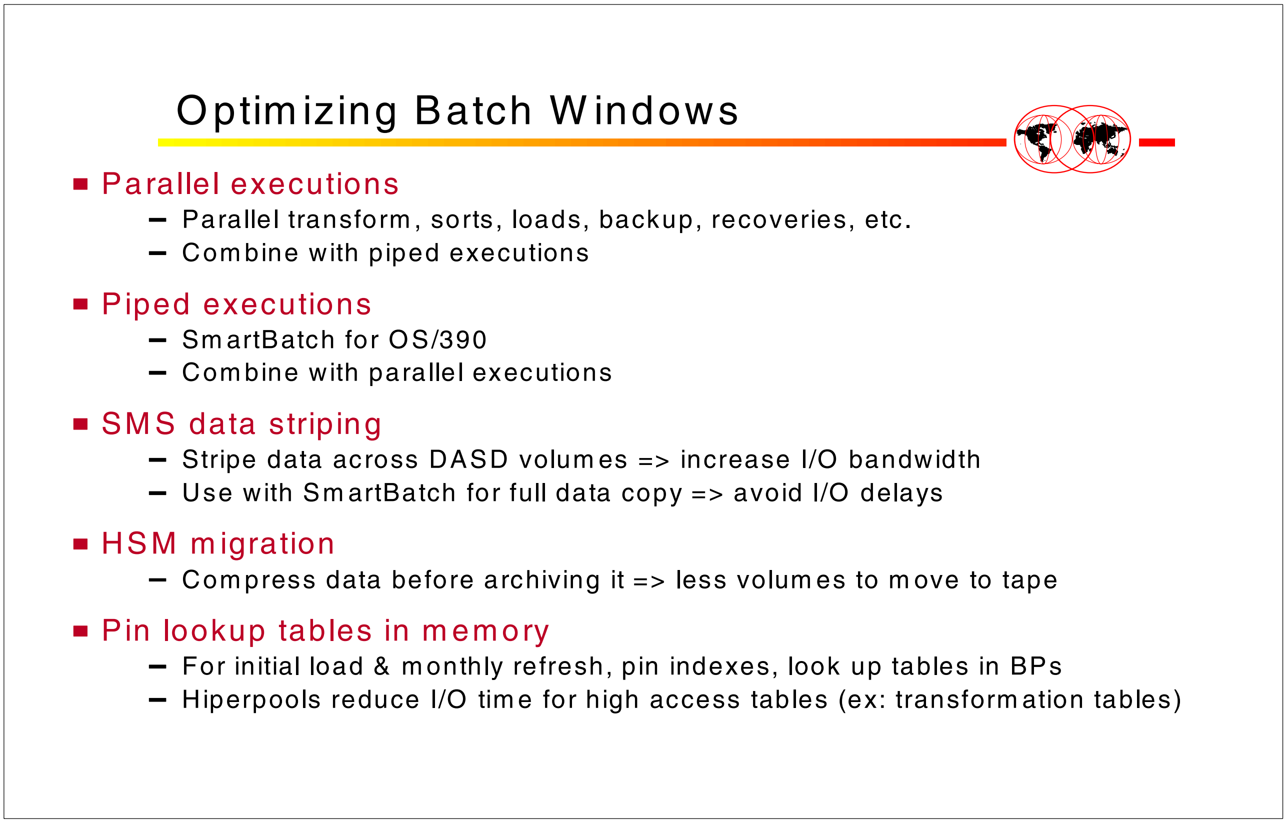
One factor that is important to understand in this approach is how the data normally is accessed by end user queries. If the normal usage is to only access data within a period, the time-based approach would not enable any query parallelism (only one partition is accessed at a time). This approach, on the other hand, would enable parallelism (multiple partitions are accessed, one for each customer number interval).

In this approach, the distribution of customer number over time must be considered to enable optimal parallelism.

Time-based and randomized partitioning

In this approach a time period and a randomized key are used to partition the data. This solution has the same characteristics as the time- and business term-based partitioning except that it ensures that partitions are evenly sized within a period. This approach is ideal for maximizing parallelism for queries that access only one time period, since it optimizes the partition size within a period.

4.4 Optimizing batch windows



Optimizing Batch Windows

- **Parallel executions**
  - Parallel transform, sorts, loads, backup, recoveries, etc.
  - Combine with piped executions
- **Piped executions**
  - SmartBatch for OS/390
  - Combine with parallel executions
- **SMS data striping**
  - Stripe data across DASD volumes => increase I/O bandwidth
  - Use with SmartBatch for full data copy => avoid I/O delays
- **HSM migration**
  - Compress data before archiving it => less volumes to move to tape
- **Pin lookup tables in memory**
  - For initial load & monthly refresh, pin indexes, look up tables in BPs
  - Hiperpools reduce I/O time for high access tables (ex: transformation tables)

In most cases, optimizing the batch window is a key activity in a DW project. This is especially true for a VLDB DW.

DB2 allows you to run utilities in parallel, which can drastically reduce your elapsed time.

Piped executions make it possible to improve I/O utilization and make jobs and job steps run in parallel. For a detailed description, see 4.4.2, “Piped executions with SmartBatch” on page 66.

SMS data striping enables you to stripe data across multiple DASD volumes. This increases I/O bandwidth.

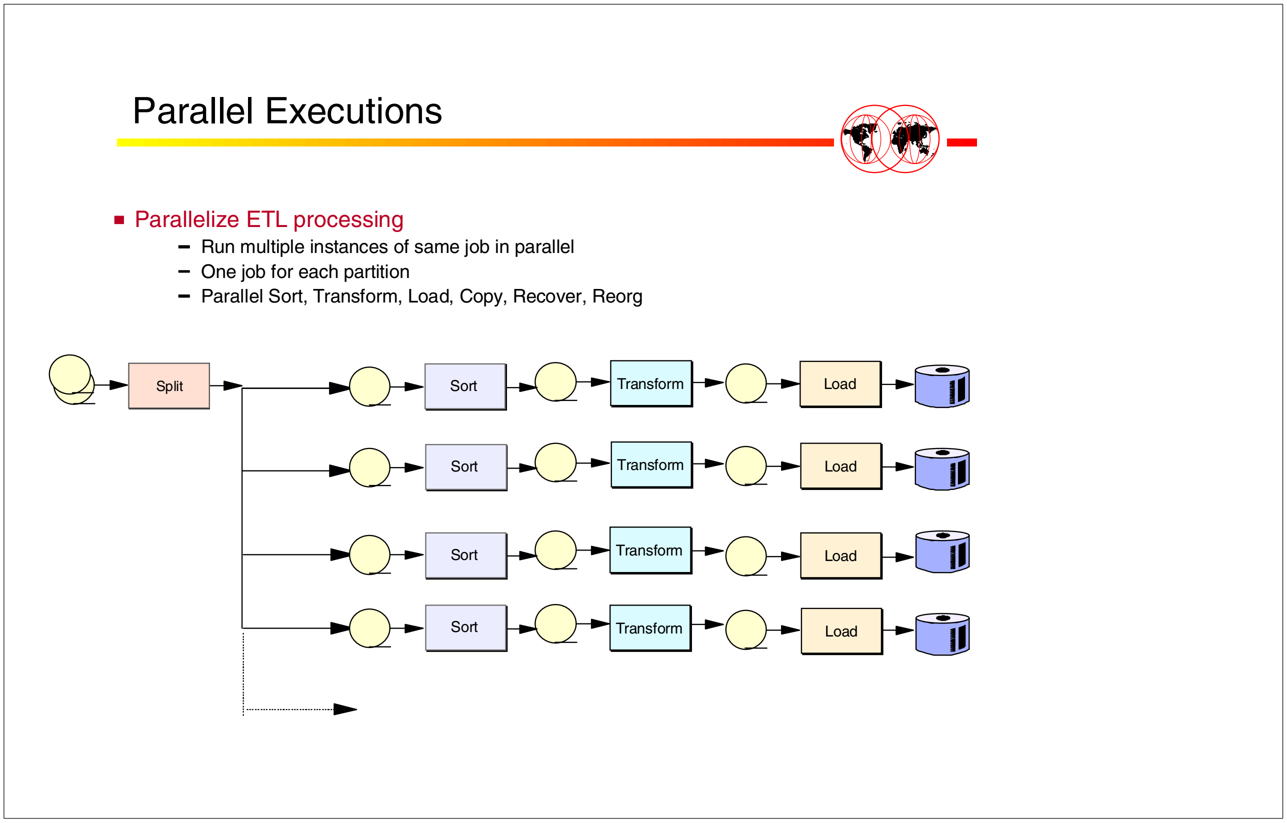
HSM compresses data very efficiently using software compression. This can be used to reduce the amount of data moved through the tape controller before archiving data to tape.

Transform programs often use lookup tables to verify the correctness of extracted data. To reduce elapsed time for these lookups, there are three levels of action that can be taken. What level to use depends on the size of the lookup table. The three choices are:

- Read the entire table into program memory and use program logic to retrieve the correct value. This should only be used for very small tables (<50 rows).

- Pin small tables into a buffer pool. Make sure that the buffer pool setup has a specific buffer pool for small tables and that this buffer pool is a little bigger than the sum of the npages or nleaves of the object you are putting in it.
- Larger lookup tables can be pinned using the hiperpool. Use this approach to store medium-sized, frequently-accessed, read-only table spaces or indexes.

4.4.1 Parallel executions



Parallel Executions

- Parallelize ETL processing
  - Run multiple instances of same job in parallel
  - One job for each partition
  - Parallel Sort, Transform, Load, Copy, Recover, Reorg

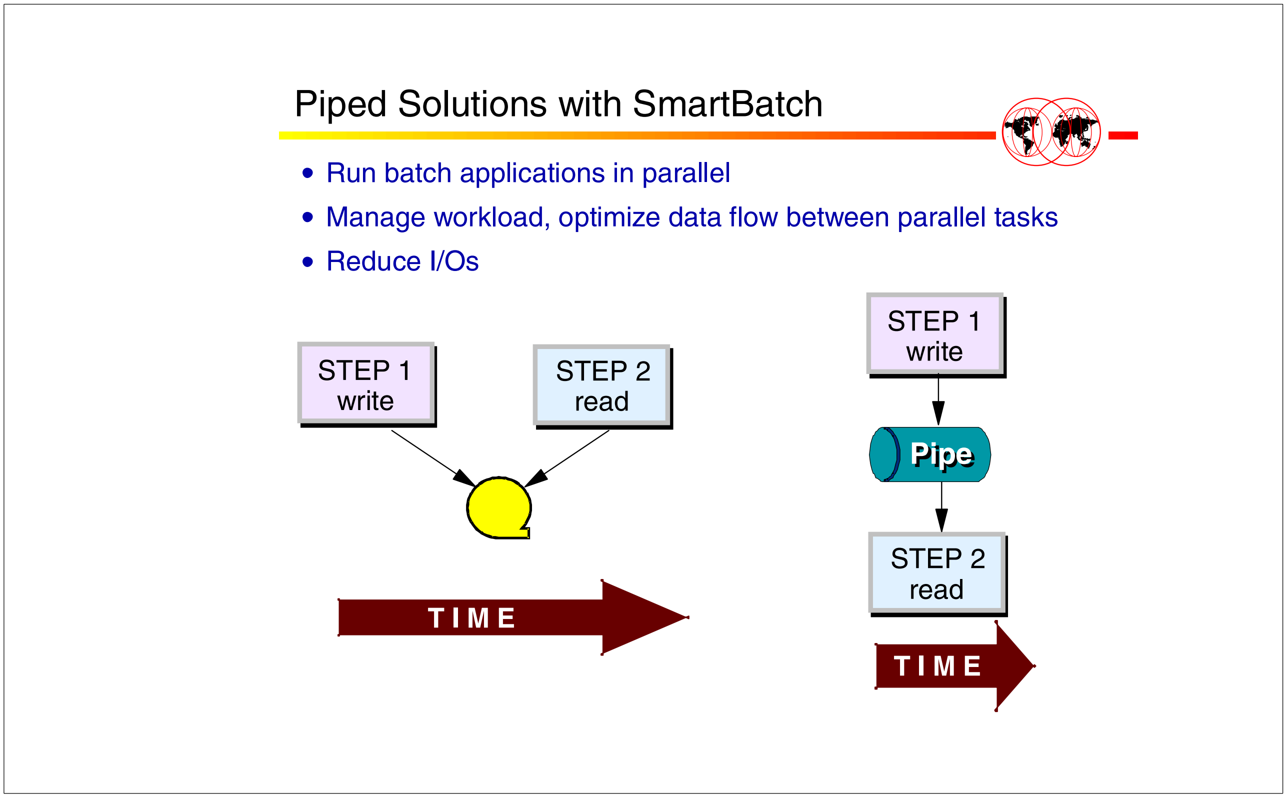
To reduce elapsed time as much as possible, ETL processes should be able to run in parallel. In this example, each process after the split can be executed in parallel; each process processes one partition.

In this example, source data is split based on partition limits. This makes it possible to have several flows, each flow processing one partition. In many cases, the most efficient way to split the data is to use a utility such as DFSORT. Use option COPY and the OUTFIL INCLUDE parameter to make DFSORT split the data (without sorting it).

In the example, we are sorting the data after the split. This sort could have been included in the split, but in this case it is more efficient to first make the split and then sort, enabling the more I/O-intensive sorts to run in parallel.

DB2 Load parallelism has been available in DB2 for years. DB2 allows concurrent loading of different partitions of a table by concurrently running one load job against each partition. The same type of parallelism is supported by other utilities such as Copy, Reorg and Recover.

4.4.2 Piped executions with SmartBatch



Piped Solutions with SmartBatch

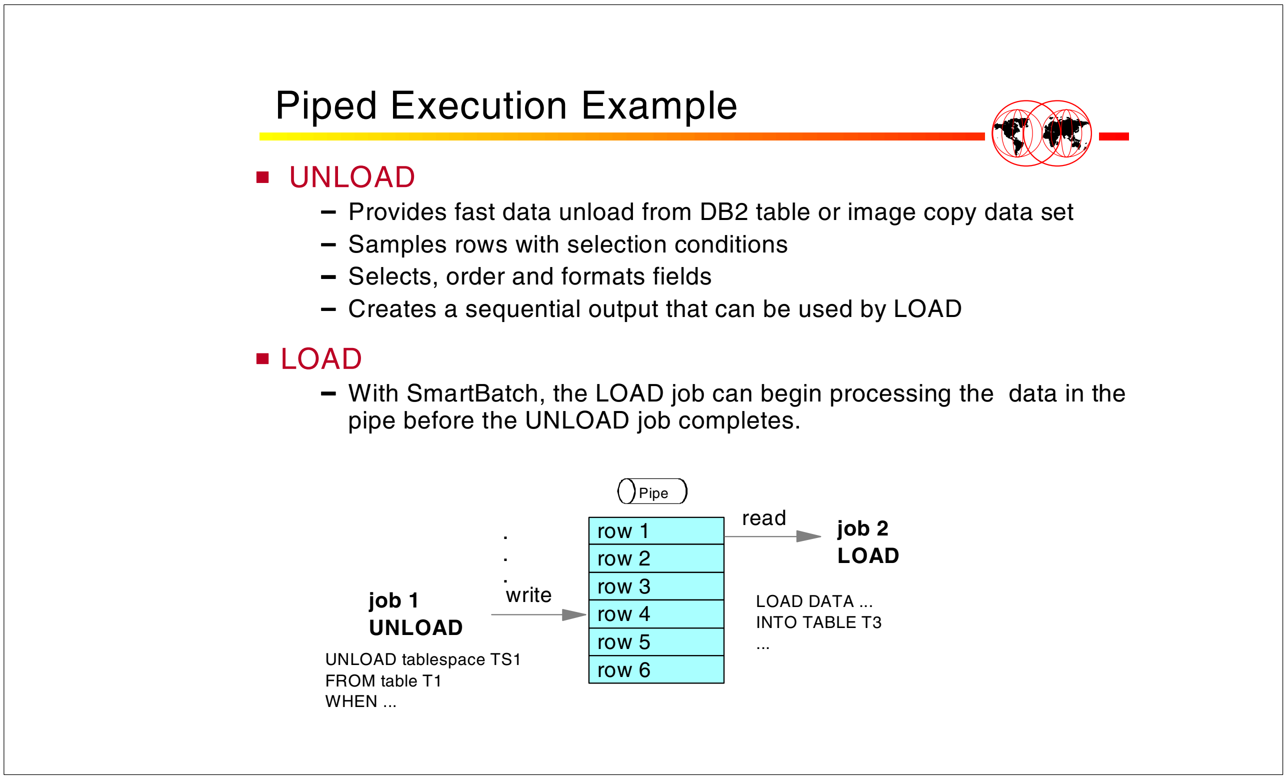
- Run batch applications in parallel
- Manage workload, optimize data flow between parallel tasks
- Reduce I/Os

IBM SmartBatch for OS/390 enables a piped execution for running batch jobs. Pipes increase parallelism and provide data in memory. They allow job steps to overlap and eliminate the I/Os incurred in passing data sets between them. Additionally, if a tape data set is replaced by a pipe, tape mounts can be eliminated.

The left part of our figure shows a traditional batch job, where job step 1 writes data to a sequential data set. When step 1 has completed, step 2 starts to read the data set from the beginning.

The right part of our figure shows the use of a batch pipe. Step 1 writes to a batch pipe which is written to memory and not to disk. The pipe processes a block of record at a time. Step 2 starts reading data from the pipe as soon as step 1 has written the first block of data. Step 2 does not need to wait until step 1 has finished. When pipe 2 has read the data from pipe 1, the data is removed from pipe 1. Using this approach, the total elapsed time of the two jobs can be reduced and the need for temporary disk or tape storage is removed.

IBM SmartBatch is able to automatically split normal sequential batch jobs into separate units of work. For an in-depth discussion of SmartBatch, refer to *System/390 MVS Parallel Sysplex Batch Performance*, SG24-2557.



Piped Execution Example

- UNLOAD
  - Provides fast data unload from DB2 table or image copy data set
  - Samples rows with selection conditions
  - Selects, order and formats fields
  - Creates a sequential output that can be used by LOAD
- LOAD
  - With SmartBatch, the LOAD job can begin processing the data in the pipe before the UNLOAD job completes.

Pipe

row 1
row 2
row 3
row 4
row 5
row 6

job 1
UNLOAD

```
UNLOAD tablespace TS1
FROM table T1
WHEN ...
```

write

read

job 2
LOAD

```
LOAD DATA ...
INTO TABLE T3
...
```

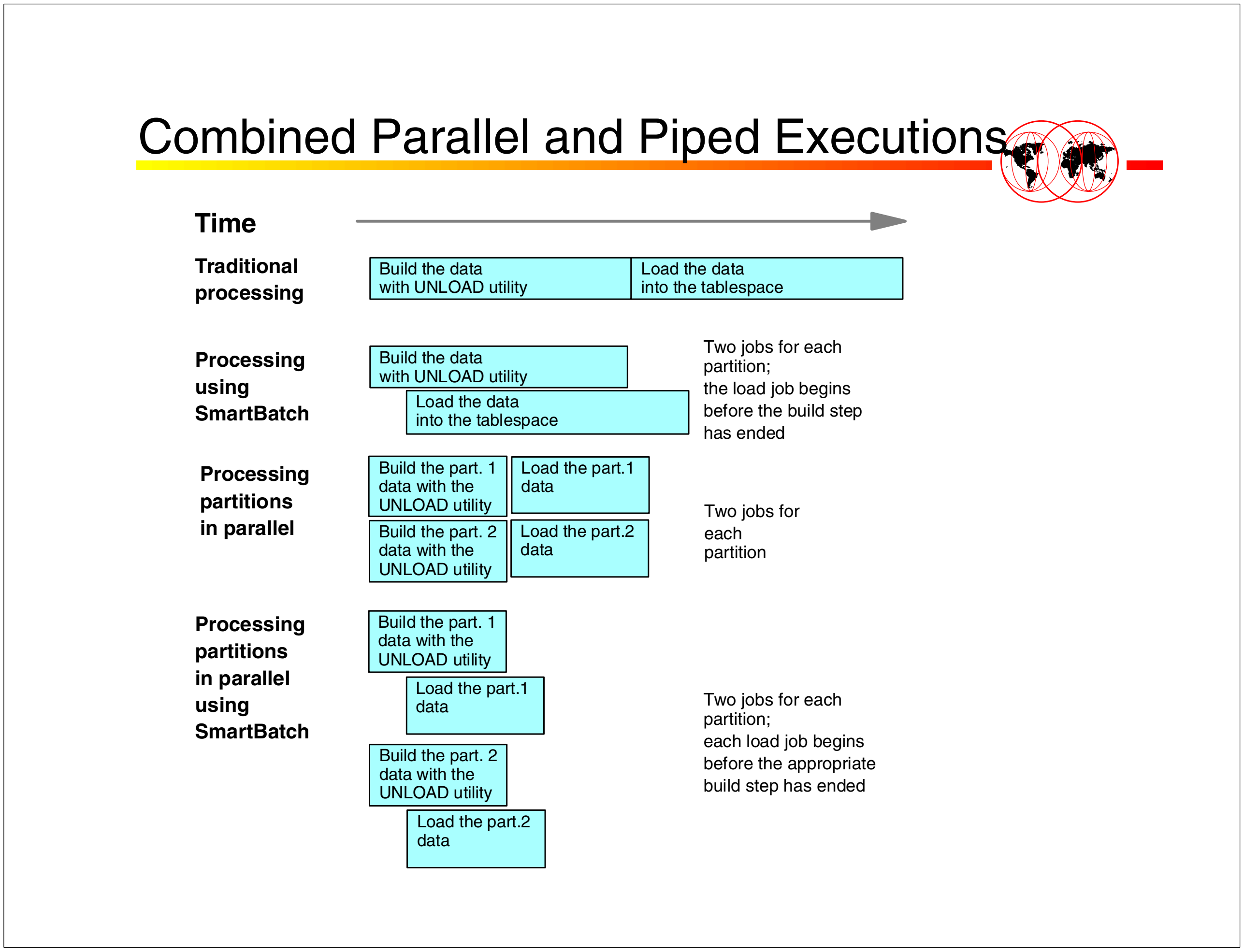
Here we show how SmartBatch can be used to parallelize the tasks of data extraction and loading data from a central data warehouse to a data mart, both residing on S/390.

The data is extracted from the data warehouse using the new UNLOAD utility introduced in DB2 V7. (The new unload utility is further discussed in 5.2, “DB2 utilities for DW population” on page 96.) The unload writes the unloaded records to a batch pipe. As soon as one block of records has been written to the pipe DB2 load utility can start to load data into the target table in the data mart. At the same time, the unload utility continues to unload the rest of the data from the source tables.

SmartBatch supports a Sysplex environment. This has two implications for our example:

- SmartBatch uses WLM to optimize how the jobs are physically executed, for example, which member in the Sysplex it will be executed on.
- It does not matter if the unloaded data and the data to be loaded are on two different DB2 subsystems on two different OS/390 images, as long as both images are part of the same Sysplex.

4.4.3 Combined parallel and piped executions



Combined Parallel and Piped Executions

Time

Traditional processing

Build the data with UNLOAD utility

Load the data into the tablespace

Processing using SmartBatch

Build the data with UNLOAD utility

Load the data into the tablespace

Two jobs for each partition; the load job begins before the build step has ended

Processing partitions in parallel

Build the part. 1 data with the UNLOAD utility

Load the part.1 data

Build the part. 2 data with the UNLOAD utility

Load the part.2 data

Two jobs for each partition

Processing partitions in parallel using SmartBatch

Build the part. 1 data with the UNLOAD utility

Load the part.1 data

Build the part. 2 data with the UNLOAD utility

Load the part.2 data

Two jobs for each partition; each load job begins before the appropriate build step has ended

Based on the characteristics of the population process, parallel and piped processing can be combined.

The first scenario shows the traditional solution. The first job step creates the extraction file and the second job step loads the extracted data into the target DB2 table.

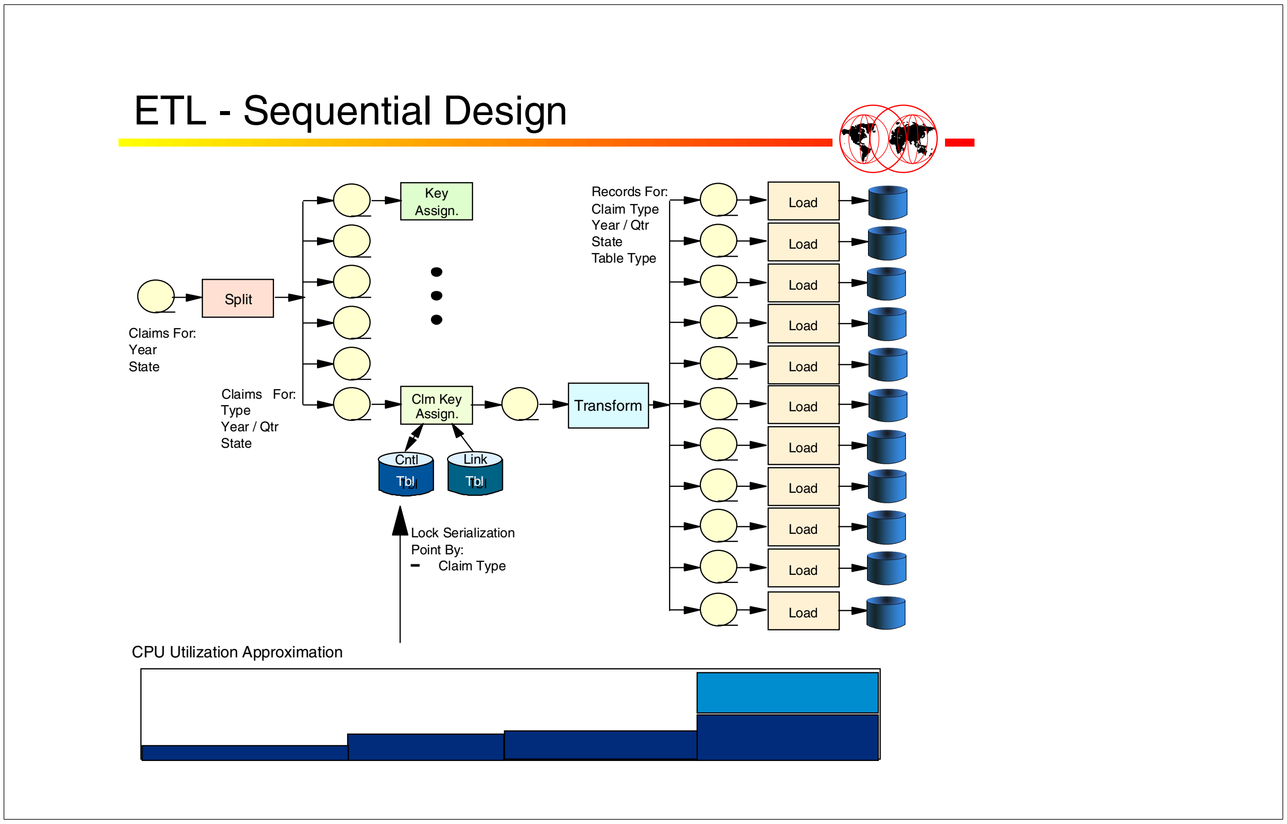
In the second scenario, SmartBatch considers those two jobs as two units of work executing in parallel. One unit of work reads from the DB2 source table and writes into the pipe, while the other unit of work reads from the pipe and loads the data into the target DB2 table.

In the third scenario, both the source and the target table have been partitioned. Each table has two partitions. Two jobs are created and both jobs contain two job steps. The first job step extracts data from a partition of the source table to a sequential file and the second job step loads the extracted sequential file into a partition of the target table. The first job does this for the first partition and the second job does this for the second partition.

In the fourth scenario, SmartBatch manages the jobs as four units of work:

- One performs unload of data from partition 1 to a pipe (pipe 1).
- One reads data from pipe 1 and loads it into the first partition of the target tables.
- One unloads data from the second partition and writes it to a pipe (pipe 2).
- One reads data from pipe 2 and loads it into the second partition of the target table.

4.5 ETL - Sequential design



ETL - Sequential Design

Claims For:
Year
State

Split

Claims For:
Type
Year / Qtr
State

Key Assign.

Clm Key Assign.

Cntl Tbl

Link Tbl

Lock Serialization Point By:
- Claim Type

Transform

Records For:
Claim Type
Year / Qtr
State
Table Type

Load

CPU Utilization Approximation

We show here an example of an initial load with a sequential design. In a sequential design the different phases of the process must complete before the next phase can start. The split must, for example, complete before the key assignment can start.

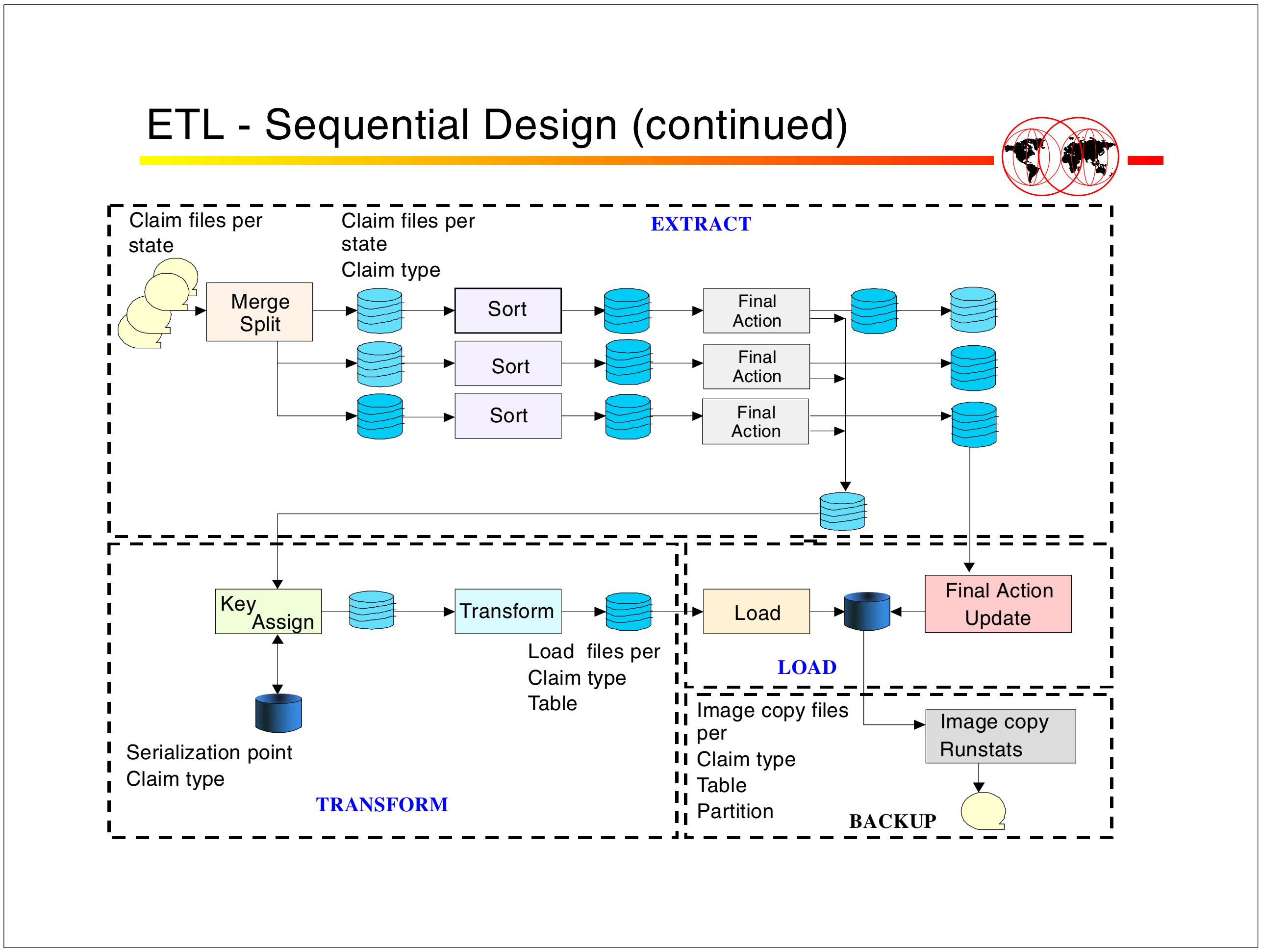
In this example of an insurance company, the input file is split by claim type, which is then updated to reflect the generated identifier, such as claim ID or individual ID. This data is sent to the transformation process, which splits the data for the load utilities. The load utilities are run in parallel, one for each partition. This process is repeated for every state for every year, a total of several hundred times.

As can be seen at the bottom of the chart, the CPU utilization is very low until the load utilities start running in parallel.

The advantage of the sequential design is that it is easy to implement and uses a traditional approach, which most developers are familiar with. This approach can be used for initial load of small to medium-sized data warehouses and refresh of data where a batch window is not an issue.

In a VLDB environment with large amounts of data a large number of scratch tapes are needed: one set for the split, one set for the key assignment, and one set for the transform. A large number of reads/writes for each record makes the elapsed time very long. If the data is in the multi-terabyte range, this process requires several days to complete through a single controller. Because of the number of input cartridges that are needed for this solution when loading a VLDB, media failure may be an issue. If we assume that 0.1 percent of the input cartridges fail on average, every 1000th cartridge fails.

This solution has a low degree of parallelism (only the loads are done in parallel), hence the inefficient usage of CPU and DASD. To cope with multi-terabyte data volumes, the solution must be able to run in parallel and the number of disk and tape I/Os must be kept to a minimum.



ETL - Sequential Design (continued)

EXTRACT

Claim files per state

Merge Split

Claim files per state Claim type

Sort

Sort

Sort

Final Action

Final Action

Final Action

TRANSFORM

Key Assign

Transform

Load files per Claim type Table

Serialization point Claim type

LOAD

Load

Final Action Update

BACKUP

Image copy files per Claim type Table Partition

Image copy Runstats

Here we show a design similar to the one in the previous figure. This design is based on a customer proof of concept conducted by the IBM Teraplex center in Poughkeepsie. The objectives for the test are to be able to run monthly refreshes within a weekend window.

As indicated here, DASD is used for storing the data, rather than tape. The reason for using this approach is to allow I/O parallelism using SMS data striping. This design is divided into four groups:

- Extract
- Transform
- Load
- Backup

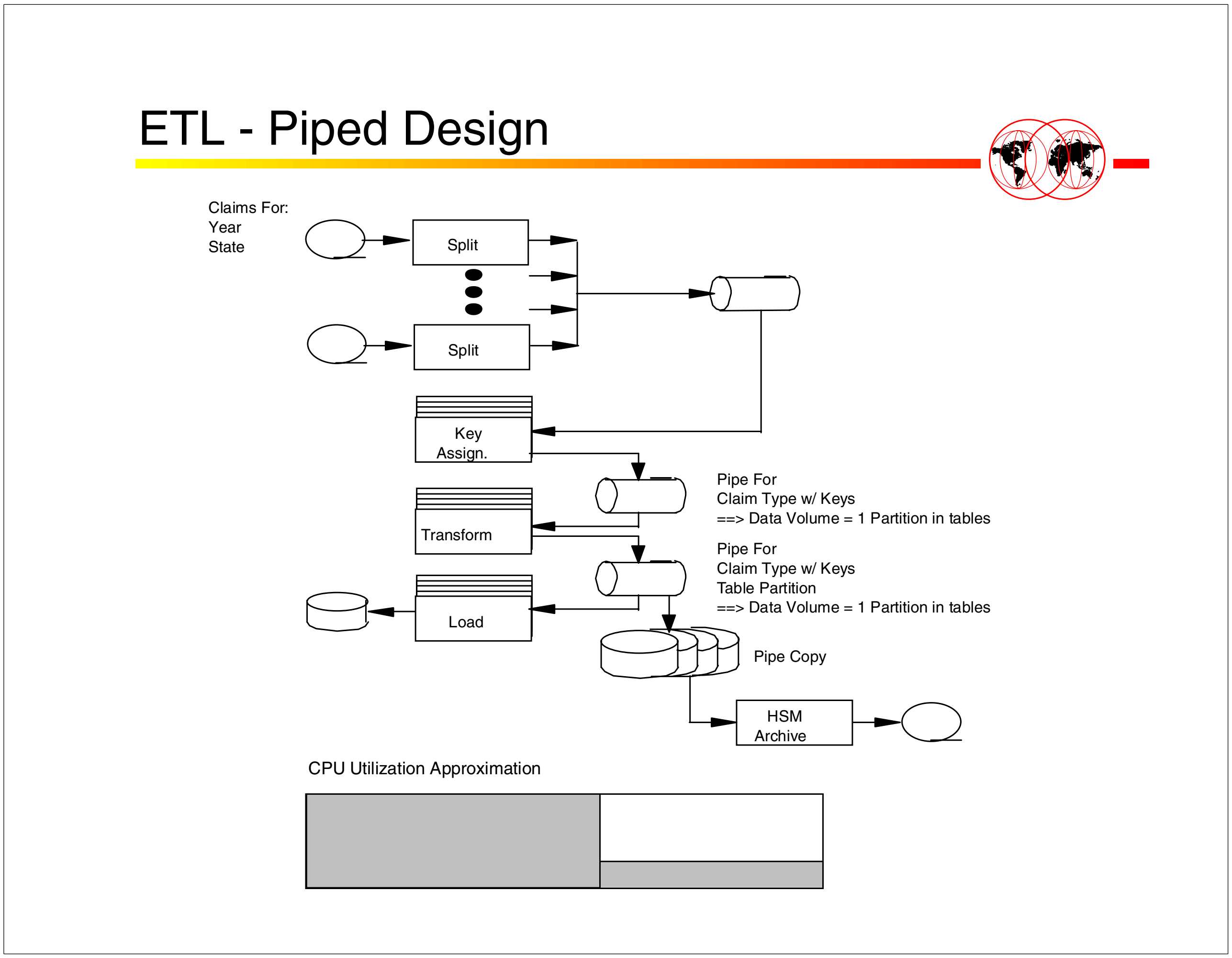
The extract, transform and backup can be executed while the database is online and available for end user queries, removing these processes from the critical path.

It is only during the load that the database is not available for end user queries. Also, Runstats and Copy can be executed outside the critical path. This leaves the copy pending flag on the table space. As long as the data is accessed in a read-only mode, this does not cause any problem.

Executing Runstats outside the maintenance window may have severe performance impacts when accessing new partitions. Whether Runstats should be included in the maintenance must be decided on a case-by-case basis. The decision should be based on the query activity and loading strategy. If this data is load replaced into a partition with similar data volumes, Runstats can probably be left outside the maintenance part (or even ignored).

Separating the maintenance part from the rest of the processing not only improves end-user availability, it also makes it possible to plan when to execute the non-critical paths based on available resources.

4.6 ETL - Piped design



ETL - Piped Design

The piped design shown here uses pipes to avoid externalizing temporary data sets throughout the process, thus avoiding I/O system-related delays (tape controller, tape mounts, and so forth) and potential I/O failures.

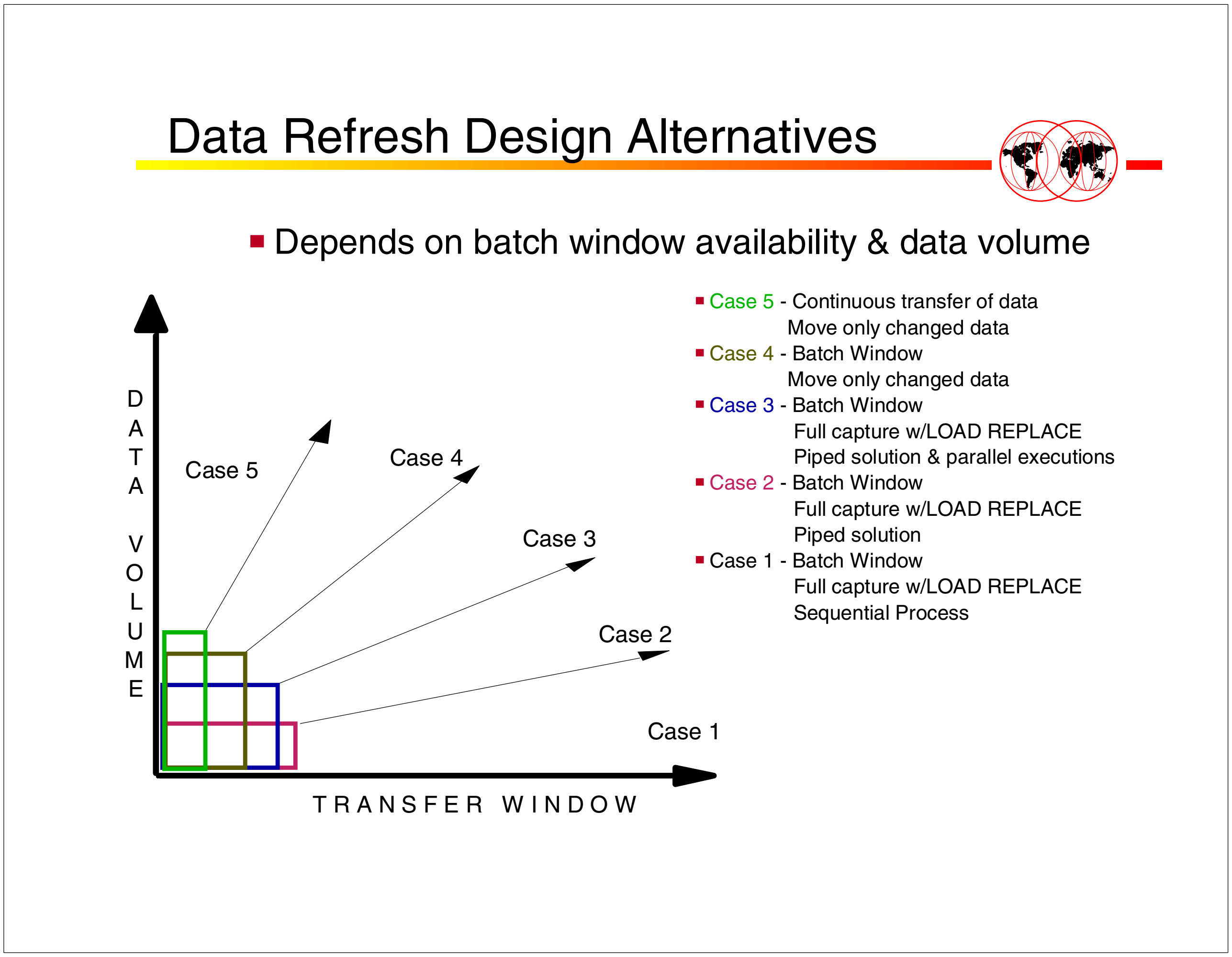
Data from the transform pipes are read by both the DB2 Load utility and the archive process. Since reading from a pipe is by nature asynchronous, these two processes do not need to wait for each other. That is, the Load utility can finish before the archive process has finished making DB2 tables available for end users.

This design enables parallelism—multiple input data sets are processed simultaneously. Using batch pipes, data can also be written and read from the pipe at the same time, reducing elapsed time.

The throughput in this design is much higher than in the sequential design. The number of disk and tape I/Os has been drastically reduced and replaced by memory accesses. The data is processed in parallel throughout all phases.

Since batch pipes concurrently process multiple processes, restart is more complicated than in sequential processing. If no actions are taken, a piped solution must be restarted from the beginning. If restartability is an important issue, the piped design must include points where data is externalized to disk and where a restart can be performed.

4.7 Data refresh design alternatives



Data Refresh Design Alternatives

- Depends on batch window availability & data volume

- Case 5 - Continuous transfer of data
  Move only changed data
- Case 4 - Batch Window
  Move only changed data
- Case 3 - Batch Window
  Full capture w/LOAD REPLACE
  Piped solution & parallel executions
- Case 2 - Batch Window
  Full capture w/LOAD REPLACE
  Piped solution
- Case 1 - Batch Window
  Full capture w/LOAD REPLACE
  Sequential Process

In a refresh situation the batch window is always limited. The solution for data refresh should be based on batch window availability, data volume, CPU and DASD capacity. The batch window consists of:

- Transfer window - the period of time where there is negligible database update occurring on the source data, and the target data is available for update.
- Reserve capacity - the amount of computing resource available for moving the data.

The figure shows a number of alternatives to design the data refresh.

Case 1: In this scenario sufficient capacity exists within the transfer window both on the source and on the target side. The batch window is not an issue. The recommendation is to use the most familiar solution.

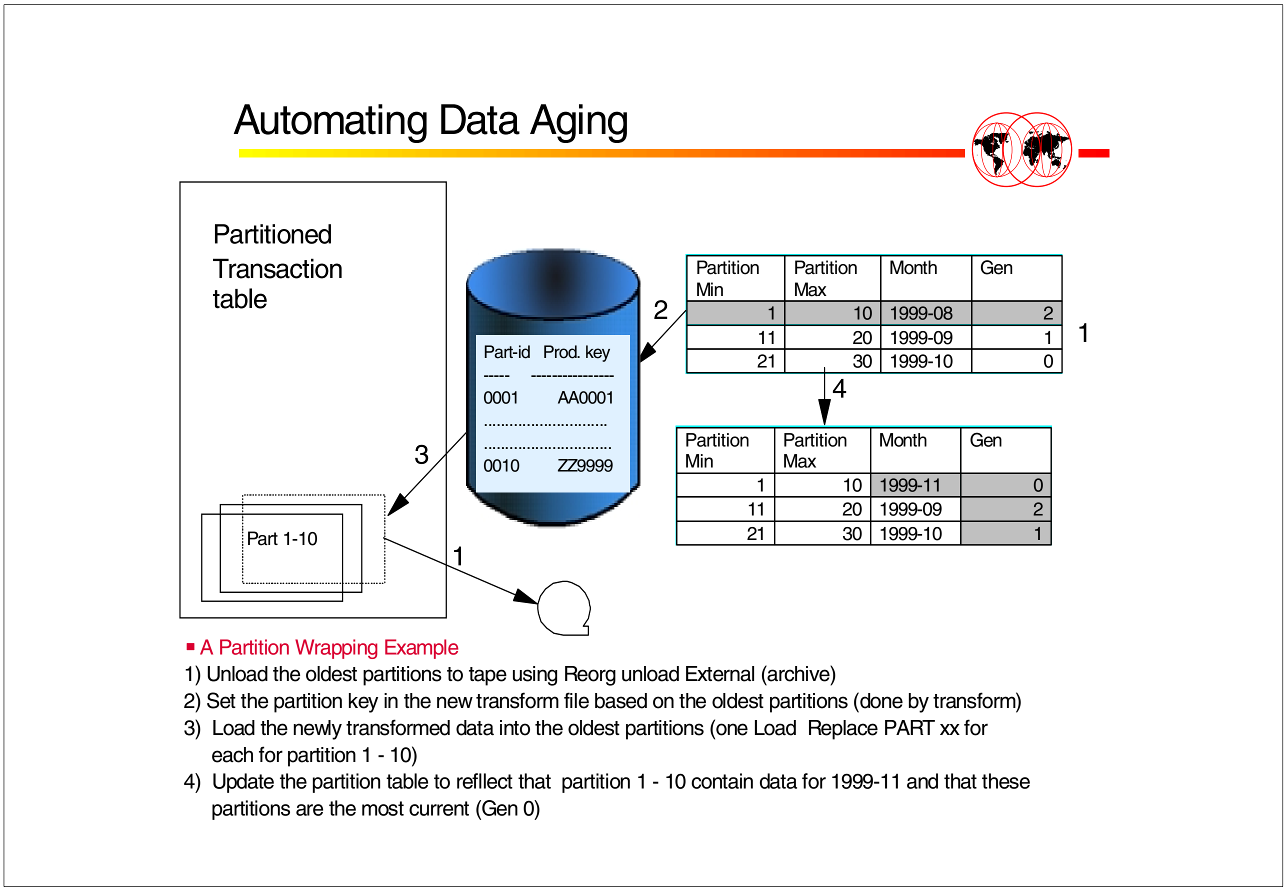
Case 2: In this scenario the transfer window is shrinking relative to the data volumes. Process overlap techniques (such as batch pipes) work well.

Case 3: If the transfer window is short compared to the data volume, and there is sufficient capacity available during the batch window, the symmetric processing technique works well (parallel processing, where each process processes a fragment of the data; for example, parallel load utilities for the load part).

Case 4: If the transfer window is very short compared to the volume of data to be moved, another strategy must be applied. One solution is to move only the changed data (delta changes). Tools such as DB2 DataPropagator and IMS DataPropagator can be used to support this approach. In this scenario it is probably sufficient if the changed data is applied to the target once a day or even less frequently.

Case 5: In this scenario the transfer window is essentially nonexistent. Continuous or very frequent data transfer (multiple times per day) may be necessary to keep the amount of data to be changed at a manageable level. The solution must be designed to avoid deadlocks between queries and the processes that apply the changes. Frequent commits and row-level locking may be considered.

4.8 Automating data aging



Automating Data Aging

Partition Min	Partition Max	Month	Gen
1	10	1999-08	2
11	20	1999-09	1
21	30	1999-10	0

Partition Min	Partition Max	Month	Gen
1	10	1999-11	0
11	20	1999-09	2
21	30	1999-10	1

- A Partition Wrapping Example

1) Unload the oldest partitions to tape using Reorg unload External (archive)
2) Set the partition key in the new transform file based on the oldest partitions (done by transform)
3) Load the newly transformed data into the oldest partitions (one Load Replace PART xx for each for partition 1 - 10)
4) Update the partition table to refllect that partition 1 - 10 contain data for 1999-11 and that these partitions are the most current (Gen 0)

Data aging is an important issue in most data warehouses. Data is considered active for a certain amount of time, but as it grows older it could be classified as non-active, stored in an aggregated format, archived, or deleted. It is important to keep the data aging routines manageable, and it should also be possible to automate them. Here we show an example of how automating data aging can be achieved using a technique called *partition wrapping*.

In this example the customer has decided that the data should be kept as active data for three months, during which the customer must be able to distinguish between the three different months. After three months the data should be archived to tape.

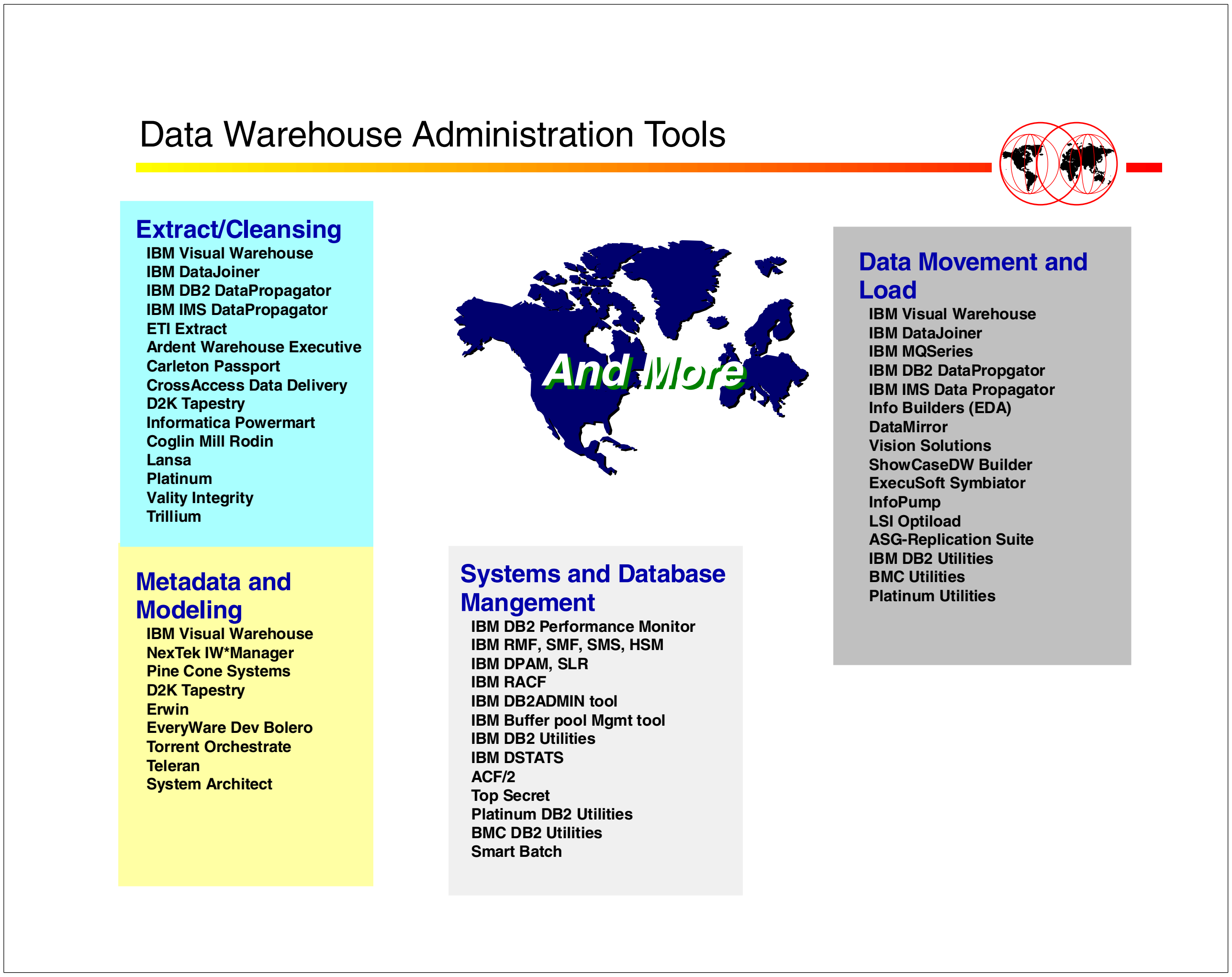
A partition table is used in this example. It is a very small table, containing only three rows, and is used as an indicator table throughout the process to distinguish between the different periods. As indicated, the process contains four steps:

1. To unload the data from the oldest partitions, the unload utility must know what partitions to unload. This information can be retrieved using SQL against the partition table. In our example ten parallel REORG UNLOAD EXTERNAL job steps are executed. Each unload job unloads a partition of the table to tape.

2. The transform program (actually ten instances of the transform program execute in parallel, each instance processing one partition of the table) reads the partition table to get the oldest range of partitions. The partition ID is stored as a part of the key in the output file from the transform (one file for each partition).
3. In order for the DB2 load to load the data into correct partitions, the load card must contain the right partition ID. This can be done in a similar way as for the unload, either by using a program or by using an SQL statement. The data is loaded into the oldest partitions using load replace on a specific partition (ten parallel loads are executed).
4. When the loads have completed, the partition table is updated to reflect that partitions 1-10 now contain data for November. This can be achieved by running an SQL using DSNTIAUL or DSNTEP2.

To simplify the end-user access against tables like these, views can be used. A current view can be created by joining the transaction table with the partition table using join criteria PARTITION_ID and specifying GEN = 0.

Chapter 5. Data warehouse administration tools



Data Warehouse Administration Tools

Extract/Cleansing

IBM Visual Warehouse
IBM DataJoiner
IBM DB2 DataPropagator
IBM IMS DataPropagator
ETI Extract
Ardent Warehouse Executive
Carleton Passport
CrossAccess Data Delivery
D2K Tapestry
Informatica Powermart
Coglin Mill Rodin
Lansa
Platinum
Vality Integrity
Trillium

Metadata and Modeling

IBM Visual Warehouse
NexTek IW*Manager
Pine Cone Systems
D2K Tapestry
Erwin
EveryWare Dev Bolero
Torrent Orchestrate
Teleran
System Architect

And More

Systems and Database Mangement

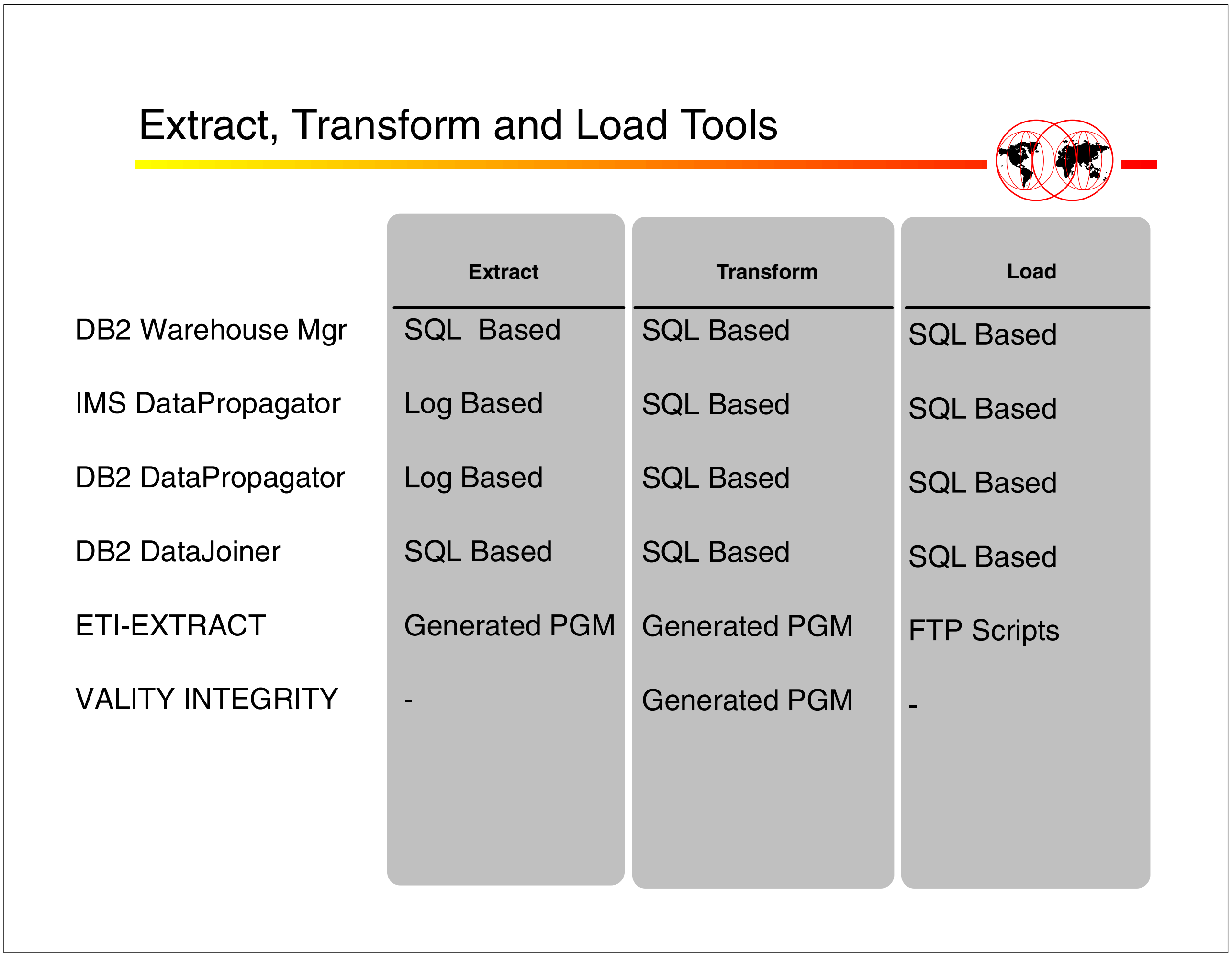
IBM DB2 Performance Monitor
IBM RMF, SMF, SMS, HSM
IBM DPAM, SLR
IBM RACF
IBM DB2ADMIN tool
IBM Buffer pool Mgmt tool
IBM DB2 Utilities
IBM DSTATS
ACF/2
Top Secret
Platinum DB2 Utilities
BMC DB2 Utilities
Smart Batch

Data Movement and Load

IBM Visual Warehouse
IBM DataJoiner
IBM MQSeries
IBM DB2 DataPropgator
IBM IMS Data Propagator
Info Builders (EDA)
DataMirror
Vision Solutions
ShowCaseDW Builder
ExecuSoft Symbiator
InfoPump
LSI Optiload
ASG-Replication Suite
IBM DB2 Utilities
BMC Utilities
Platinum Utilities

There are a large number of DW construction and database management tools available on the S/390. This chapter gives an introduction to some of these tools.

5.1 Extract, transform, and load tools



Extract, Transform and Load Tools

	Extract	Transform	Load
DB2 Warehouse Mgr	SQL Based	SQL Based	SQL Based
IMS DataPropagator	Log Based	SQL Based	SQL Based
DB2 DataPropagator	Log Based	SQL Based	SQL Based
DB2 DataJoiner	SQL Based	SQL Based	SQL Based
ETI-EXTRACT	Generated PGM	Generated PGM	FTP Scripts
VALITY INTEGRITY	-	Generated PGM	-

The extract, transform, and load (ETL) tools perform the following functions:

- Extract

  The extract tools support extraction of data from operational sources. There are two different types of extraction: extract of entire files/databases and extract of delta changes.

- Transform

  The transform tools (also referred to as cleansing tools) cleanse and reformat data in order for the data to be stored in a uniform way. The transformation process can often be very complex, and CPU- and I/O-intensive. It often implies several reference table lookups to verify that incoming data is correct.

- Load

  Load tools (also referred to as move or distribution tools) aggregate and summarize data as well as move the data from the source platform to the target platform.

Within each functional category (extract, transform, and load) the tools can be further categorized by the way that they work, as follows:

- Log capture tools

  Log capture tools, such as DB2 DataPropagator and IMS Data Propagator, asynchronously propagate delta changes from a source data store to a target data store. Since these tools use the standard log, there is no performance impact on the feeding application program. Use of the log also removes the need for locking in the feeding database system.

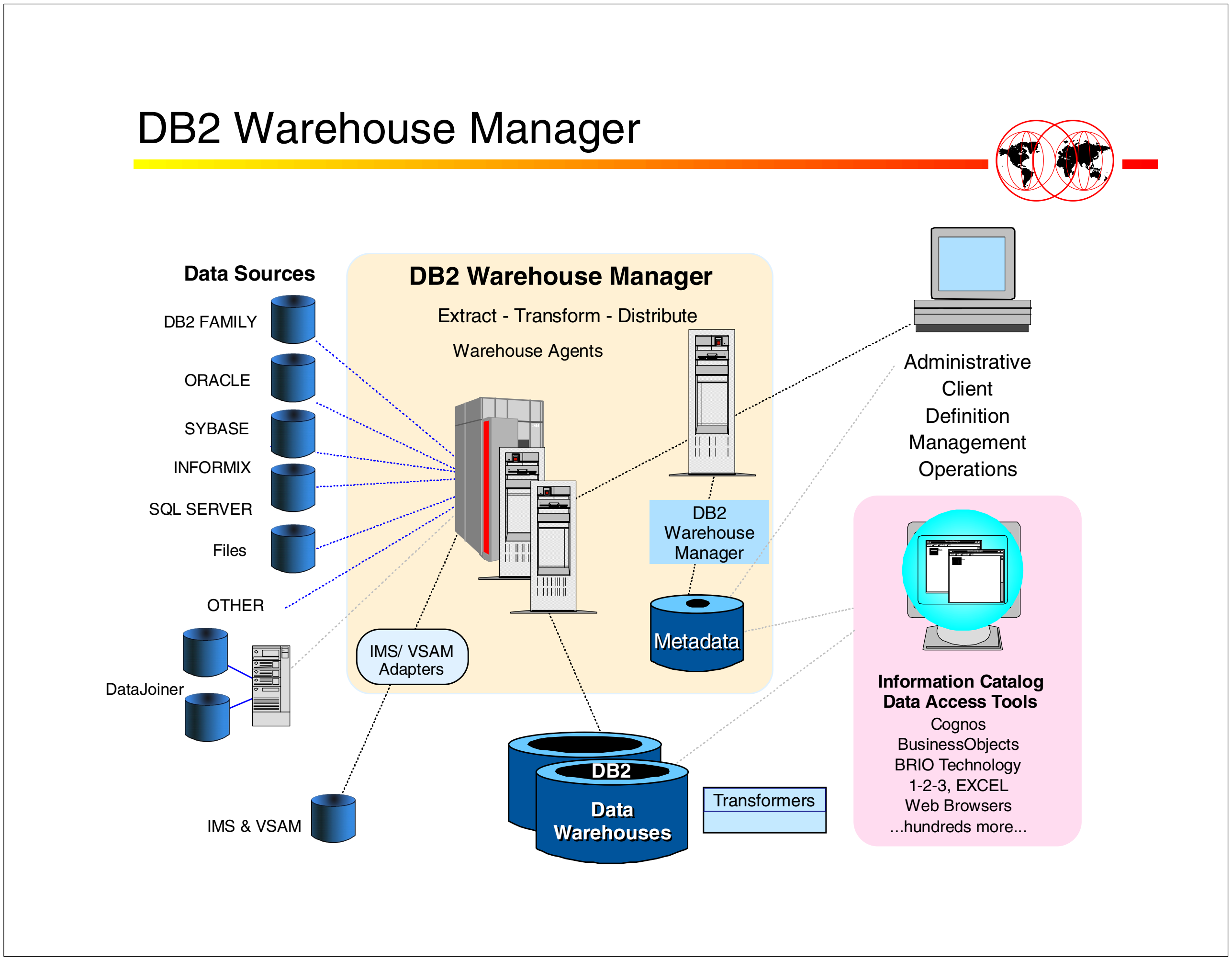
- SQL capture tools

  SQL capture tools, such as DB2 Warehouse Manager, use standard SQL to extract data from relational database systems; they can also use ODBC and middleware services to extract data from other sources. These tools are used to get a full refresh or an incremental update of data.

- Code generator tools

  Code generator tools, such as ETI, perform the extraction by using a graphical user interface (GUI). Most of these tools also have an integrated metadata store.

5.1.1 DB2 Warehouse Manager



DB2 Warehouse Manager

Data Sources

DB2 FAMILY

ORACLE

SYBASE

INFORMIX

SQL SERVER

Files

OTHER

DataJoiner

IMS & VSAM

DB2 Warehouse Manager

Extract - Transform - Distribute

Warehouse Agents

IMS/ VSAM Adapters

DB2 Warehouse Manager

Metadata

DB2 Data Warehouses

Transformers

Administrative Client
Definition
Management
Operations

Information Catalog
Data Access Tools
Cognos
BusinessObjects
BRIO Technology
1-2-3, EXCEL
Web Browsers
...hundreds more...

DB2 Warehouse Manager is IBM's integrated data warehouse tool. It speeds up warehouse prototyping, development, and deployment to production, executes and automates ETL processes, and monitors the warehouses.

5.1.1.1 DB2 Warehouse Manager overview

The DB2 Warehouse Manager server runs under Windows NT. The server is the warehouse hub that coordinates the different components in the warehouse including the DB2 Warehouse Manager agents. It offers a graphical control facility, fully integrated with DB2 Control Center. The DB2 Warehouse Manager allows:

- Registering and accessing data sources for your warehouse
- Defining data extraction and data transformation steps
- Directing the population of your data warehouses
- Automating and monitoring the warehouse management processes
- Managing your metadata using
- standards-based metadata interchange

5.1.1.2 The Information Catalog

The Information Catalog manages metadata. It helps end users to find, understand, and access information they need for making decisions. It acts as a metadata hub and stores all metadata in its control database. The metadata contains all relevant information describing the data, the mapping, and the transformation that takes place.

The Information Catalog does the following:

- Populates the catalog through metadata interchange with the DB2 Warehouse Manager and other tools, including QMF, Lotus 123, Brio, Business Objects, Cognos, Excel, Hyperion, and others. The metadata interchange makes it possible to use business-related data from the DB2 Warehouse Manager in other end-user tools.
- Allows your users to directly register shared information objects, including tables, queries, reports, spreadsheets, web pages, and others.
- Provides navigation and search across the objects to locate relevant information.
- Displays object metadata such as name, description, contact, currency, lineage, and tools for rendering the information.
- Can invoke the defined tool in order to render the information in the object for the end user.

5.1.1.3 DB2 Warehouse Manager Steps

Steps are the means by which DB2 Warehouse Manager automates ETL processes. Steps describe the ETL tasks to be performed within the DB2 Warehouse Manager, such as:

- Data conversions
  - Data filtering
  - Derived columns
  - Summaries
  - Aggregations
  - Editions
- Transformations

5.1.1.4 Agents and transformers

A DB2 Warehouse Manager agent performs ETL processes, such as extraction, transformation, and distribution of data on behalf of the DB2 Warehouse Manager Server. Agent executions are described in the steps. DB2 Warehouse Manager can trigger an unlimited number of steps to perform the extraction, transformation and distribution of data into the target database.

The warehouse agent for OS/390 executes OS/390-based processes on behalf of the DB2 Warehouse Manager. It permits data to be processed in your OS/390 environment without the need to export it to an intermediate platform environment, allowing you to take full advantage of the power, security, reliability, and availability of DB2 and OS/390.

Warehouse transformers are stored procedures or user-defined functions that provide complex transformations commonly used in warehouse development, such as:

- Data manipulation
- Data cleaning
- Key generation

Transformers are planned to run on the OS/390 in the near future.

5.1.1.5 Scheduling facility

DB2 Warehouse Manager includes a scheduling facility that can trigger tasks based on either calendar scheduling or event scheduling. The DB2 Warehouse Manager provides a trigger program which initiates DB2 Warehouse Manager steps from OS/390 JCL. This capability allows a job scheduler such as OPC to handle the scheduling of DB2 Warehouse Manager steps.

5.1.1.6 Interoperability with other tools

The DB2 Warehouse Manager can extract data from different platforms and DBMSs. This data can be cleansed, transformed and then stored on different DBMSs. DB2 Warehouse Manager normally extracts data from operational sources using SQL. Integrated with the following tools, DB2 Warehouse Manager can broaden its ETL capabilities:

- DataJoiner

  Using DataJoiner, the DB2 Warehouse Manager can extract data from many vendor DBMSs. It can also control the population of data from the data warehouse to vendor data marts. When the mart is on a non-DB2 platform, DB2 Warehouse Manager uses DataJoiner to connect to the mart.

- DB2 DataPropagator

  You can control DB2 DataPropagator data propagation with DB2 Warehouse Manager steps.

- ETI-EXTRACT

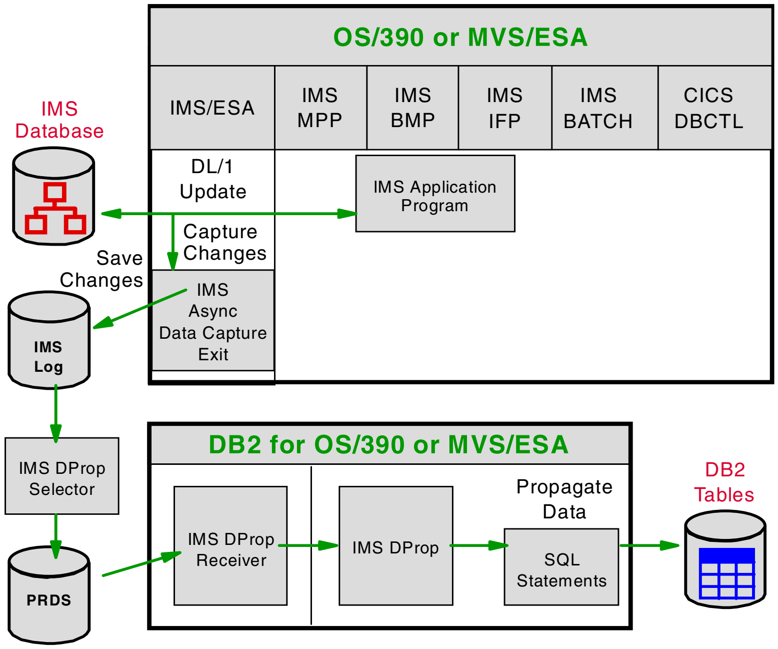
  DB2 Warehouse Manager steps can control the capture, transform and distribution logic created in ETI-EXTRACT.

- VALITY-INTEGRITY

  DB2 Warehouse Manager steps can invoke and control data transformation code created by VALITY- INTEGRITY.

5.1.2 IMS DataPropagator

IMS DataPropagator



OS/390 or MVS/ESA

IMS/ESA

IMS MPP

IMS BMP

IMS IFP

IMS BATCH

CICS DBCTL

DL/1 Update

Capture Changes

IMS Async Data Capture Exit

IMS Application Program

IMS Database

Save Changes

IMS Log

IMS DProp Selector

PRDS

DB2 for OS/390 or MVS/ESA

IMS DProp Receiver

IMS DProp

Propagate Data

SQL Statements

DB2 Tables

IMS DataPropagator enables continuous propagation of information from a source DL/I database to a DB2 target table. In a data warehouse environment this makes it possible to synchronize OLTP IMS databases with a data warehouse in DB2 on S/390.

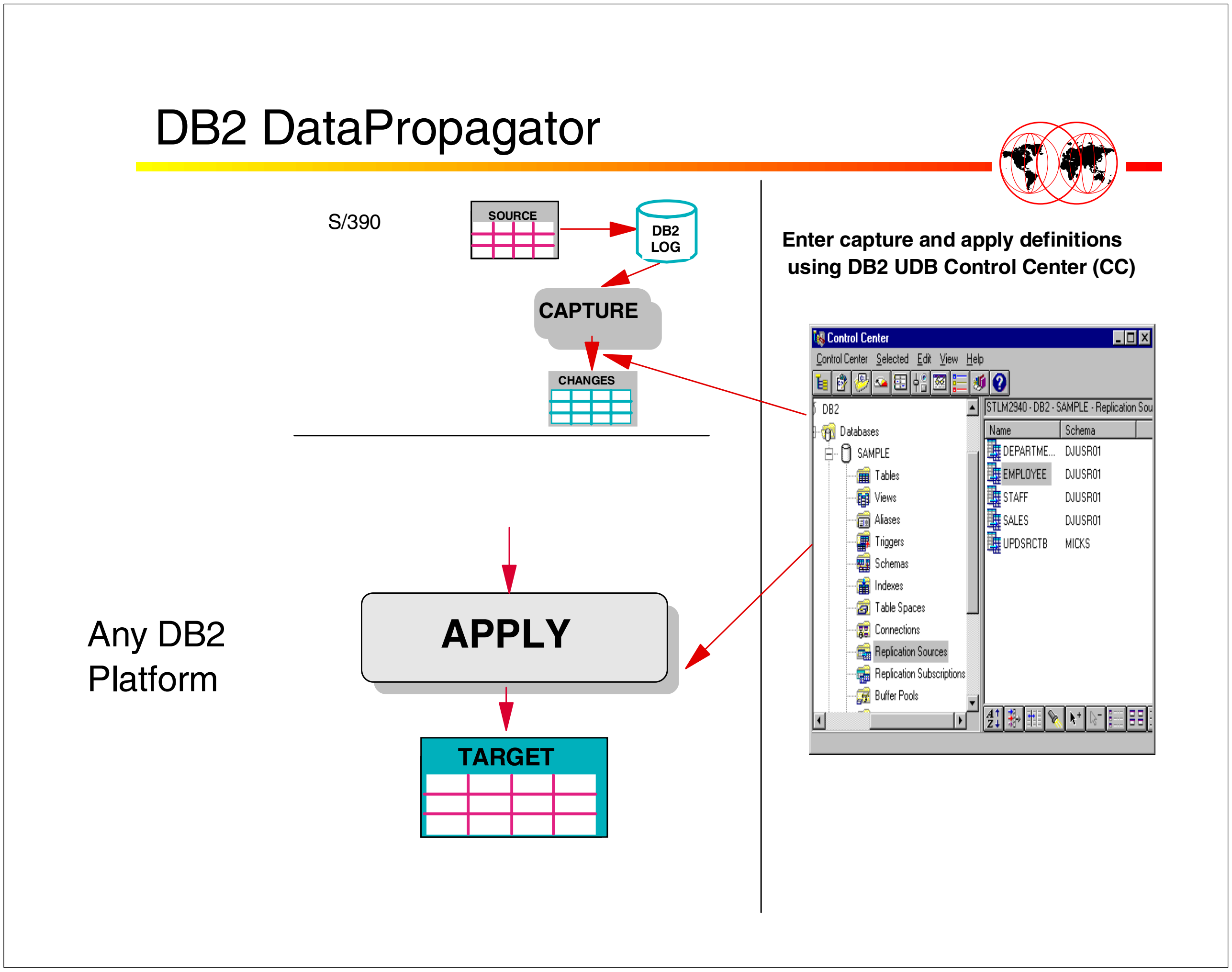
To capture changes from a DL/I database, the database descriptor (DBD) needs to be modified. After the modification, changes to the database create a specific type of log record. These records are intercepted by the selector part of IMS DataPropagator and the changed data is written to the Propagation Request Data Set (PRDS). The selector runs as a batch job and can be set to run at predefined intervals using a scheduling tool like OPC.

The receiver part of IMS DataPropagator is executed using static SQL. A specific receiver update module and a database request module (DBRM) are created when the receiver is defined. This module reads the PRDS data set and applies changes to the target DB2 table.

Before any propagation can take place, mapping between the DL/I segments and the DB2 table must be done. The mapping information is stored in the control data sets used by IMS DataPropagator.

5.1.3 DB2 DataPropagator

DB2 DataPropagator



Enter capture and apply definitions using DB2 UDB Control Center (CC)

Name	Schema
DEPARTME...	DJUSR01
EMPLOYEE	DJUSR01
STAFF	DJUSR01
SALES	DJUSR01
UPDSRCTB	MICKS

DB2 DataPropagator makes it possible to continuously propagate data from a source DB2 table to a target DB2 table. The capture process scans DB2 log records. If a log record contains changes to a column within a table that is specified as a capture source, the data from the log is inserted into a staging table.

The apply process connects to the staging table at predefined time intervals. If any data is found in the staging table that matches any apply criteria, the changes are propagated to the defined target tables. The apply process is a many-to-many process. An apply can have one or more staging tables as its source by using views. An apply can have one or more tables as its target.

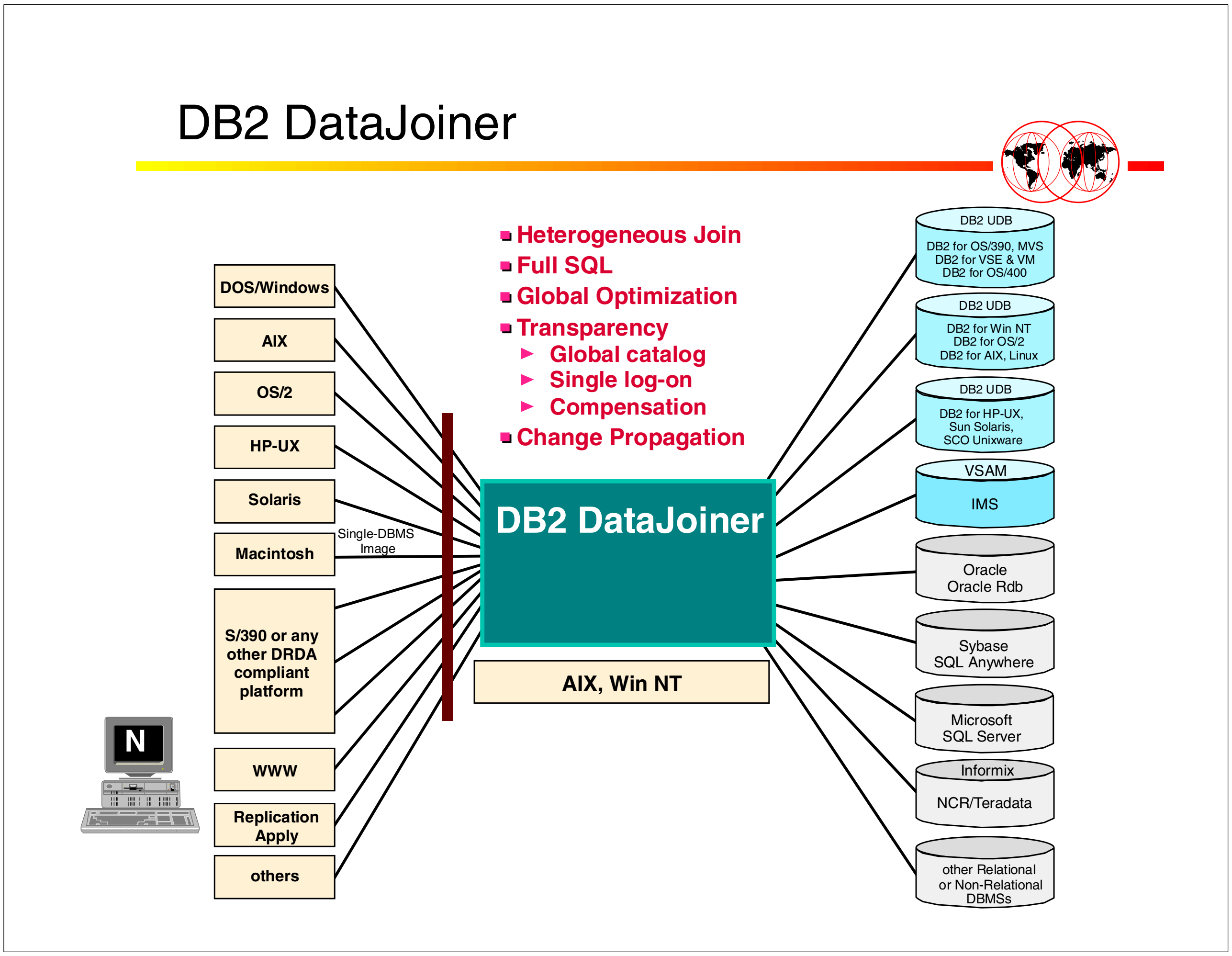
The apply process is entirely SQL based. There are three different types of tables involved in this process:

- Staging tables, populated by the capture process
- Control tables
- Target tables, populated by the apply process

If the target of the apply process is not within the same DB2 subsystem, DB2 DataPropagator uses Distributed Relational Database Architecture (DRDA) to connect to the target tables. This is true whether the target resides in another DB2 for S/390 subsystem or on DB2 on a non-S/390 platform.

For propagation to work, the source tables must be defined using the Data Capture Change option (Create table or Alter table statements). Without the Data Capture Change option, only the before/after values for the changed columns are written to the log. With the Data Capture Change option activated, the before/after for *all* columns of the table are written to the log. As a rule of thumb, the amount of data written to the log triples when Data Capture Change option is activated.

5.1.4 DB2 DataJoiner



DB2 DataJoiner

- Heterogeneous Join
- Full SQL
- Global Optimization
- Transparency
  - Global catalog
  - Single log-on
  - Compensation
- Change Propagation

DOS/Windows

AIX

OS/2

HP-UX

Solaris

Macintosh

S/390 or any other DRDA compliant platform

WWW

Replication Apply

others

Single-DBMS Image

DB2 DataJoiner

AIX, Win NT

DB2 UDB
DB2 for OS/390, MVS
DB2 for VSE & VM
DB2 for OS/400

DB2 UDB
DB2 for Win NT
DB2 for OS/2
DB2 for AIX, Linux

DB2 UDB
DB2 for HP-UX,
Sun Solaris,
SCO Unixware

VSAM
IMS

Oracle
Oracle Rdb

Sybase
SQL Anywhere

Microsoft
SQL Server

Informix
NCR/Teradata

other Relational
or Non-Relational
DBMSs

DB2 DataJoiner facilitates connection to a large number of platforms using a number of different DBMSs. In a data warehouse environment on S/390, DataJoiner can be used to extract data from a large number of DBMSs using standard SQL, and it can be used to join data from a number of DBMSs in the same SQL. It can also be used to distribute data from a central data warehouse on S/390 to data marts on other platforms using other DBMSs.

DB2 DataJoiner has its own optimizer. The optimizer optimizes the way data is accessed by considering factors such as:

- Type of join
- Data location
- I/O speed on local compared to server
- CPU speed on local compared to server

When you use DB2 DataJoiner, as much work as possible is done on the server, reducing network traffic.

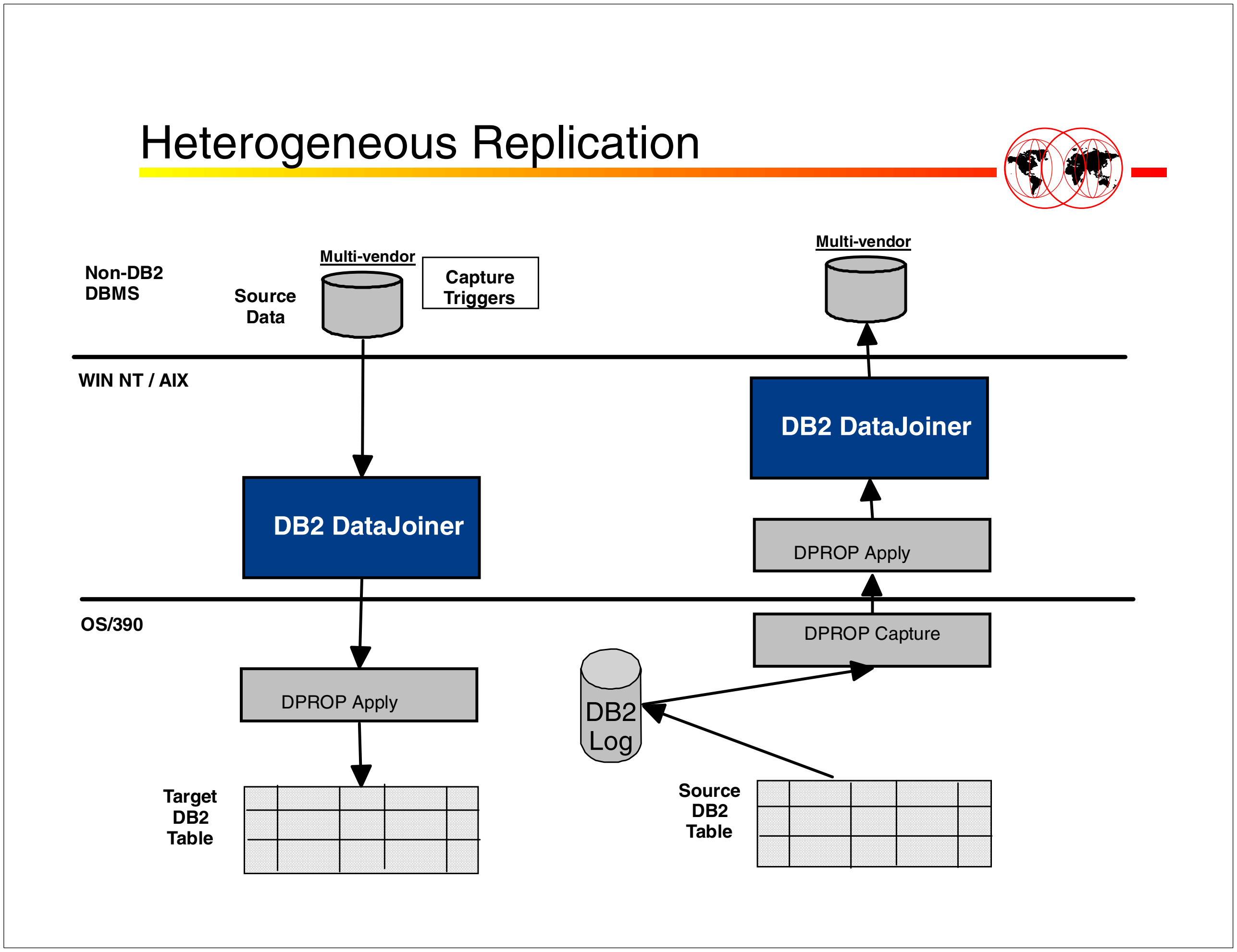
To join different platforms and different DBMSs, DataJoiner manages a number of administrative tasks, including:

- Data location resolution using nicknames
- SQL dialect translation
- Data type conversion
- Error code translation

A nickname is created in DataJoiner to access different DBMSs transparently. From a user perspective, the nickname looks like a normal DB2 table and is also accessed like one using standard SQL.

DataJoiner currently runs on AIX and NT. A DRDA connection is established between S/390 and DataJoiner. The S/390 is the application requester (AR) and DataJoiner is the application server (AS). From a S/390 perspective, connecting to DataJoiner is no different from connecting to a DB2 system running on NT or AIX.

5.1.5 Heterogeneous replication



Heterogeneous Replication

Non-DB2 DBMS

Source Data

Multi-vendor

Capture Triggers

Multi-vendor

WIN NT / AIX

DB2 DataJoiner

DB2 DataJoiner

DPROP Apply

OS/390

DPROP Capture

DPROP Apply

DB2 Log

Target DB2 Table

Source DB2 Table

Combining DB2 DataPropagator and DB2 DataJoiner makes it possible to achieve replication between different platforms and different DBMSs. In a data warehouse environment, data can be captured from a non-DB2 for OS/390 DBMS and propagated to DB2 on OS/390. It is also possible to continuously propagate data from a DB2 for OS/390 system to a non-DB2 for OS/390 DBMS, such as Oracle, Informix Dynamic Server, Sybase SQL Server, or Microsoft SQL Server. This approach can be used when you want to replicate data from a central data warehouse on the S/390 platform to a data mart that resides on a non-IBM relational DBMS.

When propagating data from a non-DB2 source database to a DB2 database, there is no capture component. The capture component is emulated by using triggers in the source DBMS. These triggers are generated by DataJoiner when the replication is defined. In this scenario the general recommendation is to place the Apply component on the target platform (in our case, DB2 on S/390).

To establish communication between the source DBMS and DataJoiner, some vendor DBMSs need additional database connectivity. When connecting to

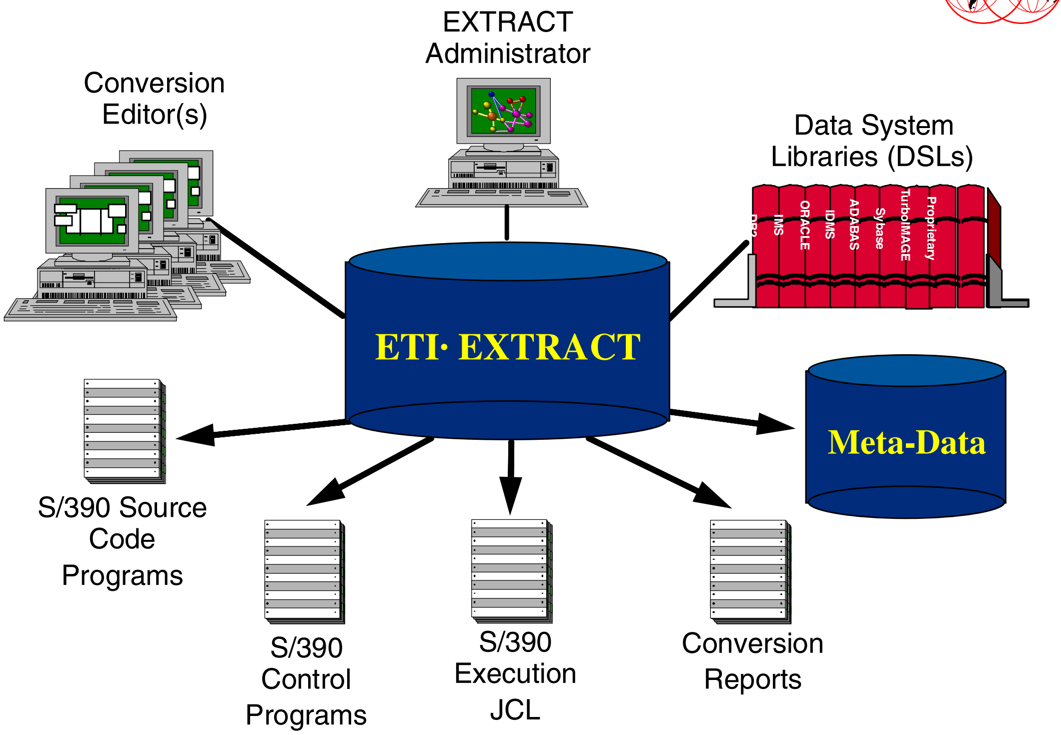
Oracle, for example, the Oracle component SQL*Net (Oracle Version 7) or Net8 (Oracle Version 8) must be installed and configured.

In the second scenario, propagating changes from DB2 on S/390 to a non-DB2 platform, the standard log capture function of DB2 DataPropagator is used. DB2 DataPropagator connects to the server where DataJoiner and the Apply component reside, using DRDA. The Apply component forwards the data to DataJoiner that connects to the target DBMS using the middleware specific for the target DBMS.

For a detailed discussion about multi-vendor cross-platform replication, refer to *My Mother Thinks I'm a DBA!, Cross-Platform, Multi-Vendor, Distributed Relational Data Replication with IBM DB2 DataPropagator and IBM DataJoiner Made Easy!*, SG24-5463-00.

5.1.6 ETI - EXTRACT

ETI - EXTRACT

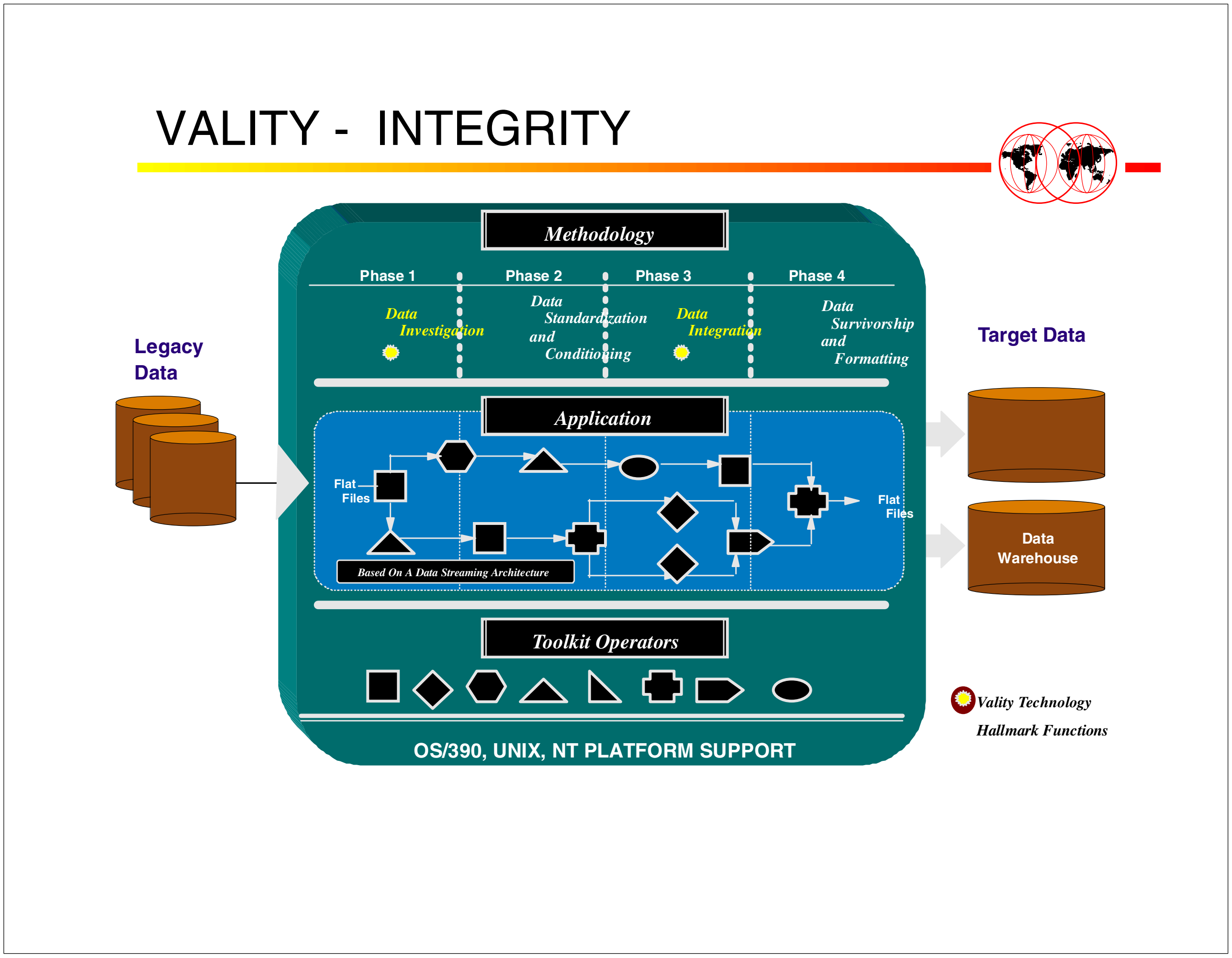


ETI-EXTRACT, from IBM business partner Evolutionary Technologies International (ETI), is a product that makes it possible to define extraction and transformation logic using a high-level natural language. Based on these definitions, effective code is generated for the target environment. At generation time the target platform and the target programming language are decided. The generation and preparation of the code takes place at the machine or the machines where the data sources and target reside. ETI-EXTRACT manages movement of program code, compile and generation. ETI-EXTRACT also analyzes and creates application process flows, including dependencies between different parts of the application (such as extract, transform, load, and distribution of data).

ETI-EXTRACT can import file and record layouts to facilitate mapping between source and target data. ETI-EXTRACT supports mapping for a large number of files and DBMSs.

ETI-EXTRACT has an integrated meta-data store, called MetaStore. MetaStore automatically captures information about conversions as they take place. Using this approach, the accuracy of the meta-data is guaranteed.

5.1.7 VALITY - INTEGRITY



VALITY - INTEGRITY

Methodology
Phase 1
Phase 2
Phase 3
Phase 4
Data Investigation
Data Standardization and Conditioning
Data Integration
Data Survivorship and Formatting
Legacy Data
Target Data
Application
Flat Files
Flat Files
Based On A Data Streaming Architecture
Data Warehouse
Toolkit Operators
Vality Technology Hallmark Functions
OS/390, UNIX, NT PLATFORM SUPPORT

INTEGRITY, from IBM business partner Vality, is a pattern-matching product that assists in finding hidden dependencies and inconsistencies in the source data. The product uses its Data Investigation component to understand the data content. Based on these dependencies, INTEGRITY creates data cleansing programs that can execute on the S/390 platform.

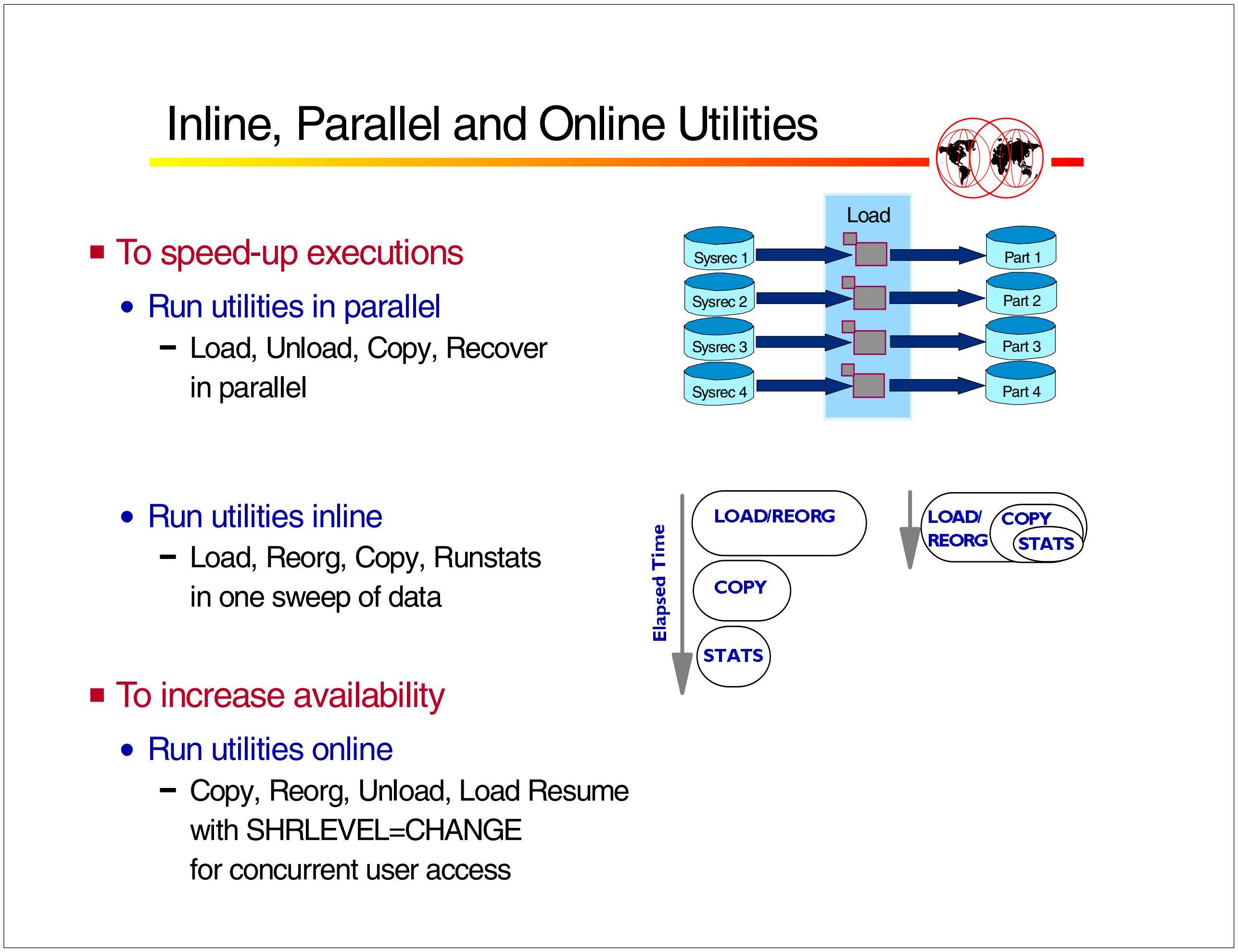
Assume, for example, that you have source data containing product information from two different applications. In some cases the same product has different part numbers in both systems. INTEGRITY makes it possible to identify these cases based on analysis of attributes connected to the product (part number description, for example). Based on this information, INTEGRITY links these part numbers, and also creates conversion routines to be used in data cleansing.

The analysis part of INTEGRITY runs on a Windows NT, Windows 95, or Windows 98 platform. The analysis creates a data reengineering application that can be executed on the S/390.

5.2 DB2 utilities for DW population

To establish a well-performing data warehouse population and maintenance, a strategy for execution of DB2 utilities must be designed.

5.2.1 Inline, parallel, and online utilities



Inline, Parallel and Online Utilities

- To speed-up executions
  - Run utilities in parallel
    - Load, Unload, Copy, Recover in parallel
  - Run utilities inline
    - Load, Reorg, Copy, Runstats in one sweep of data
- To increase availability
  - Run utilities online
    - Copy, Reorg, Unload, Load Resume with SHRLEVEL=CHANGE for concurrent user access

Utility executions for data warehouse population have an impact on the batch window and on the availability of data for user access. DB2 offers the possibility of running its utilities in parallel and inline to speed up utility executions, and online to increase availability of the data.

Parallel utilities

DB2 Version 6 allows the Copy and Recover utilities to execute in parallel. You can execute multiple copies and recoveries in parallel within a job step. This approach simplifies maintenance, since it avoids having a number of parallel jobs, each performing a copy or recover on different table spaces or indexes. Parallelism can be achieved within a single job step containing a list of table spaces or indexes to be copied or recovered.

DB2 Version 7 introduces the Load partition parallelism, which allows the partitions of a partitioned table space to be loaded in parallel within a single job. It also introduces the new Unload utility, which unloads data from multiple partitions in parallel.

Inline utilities

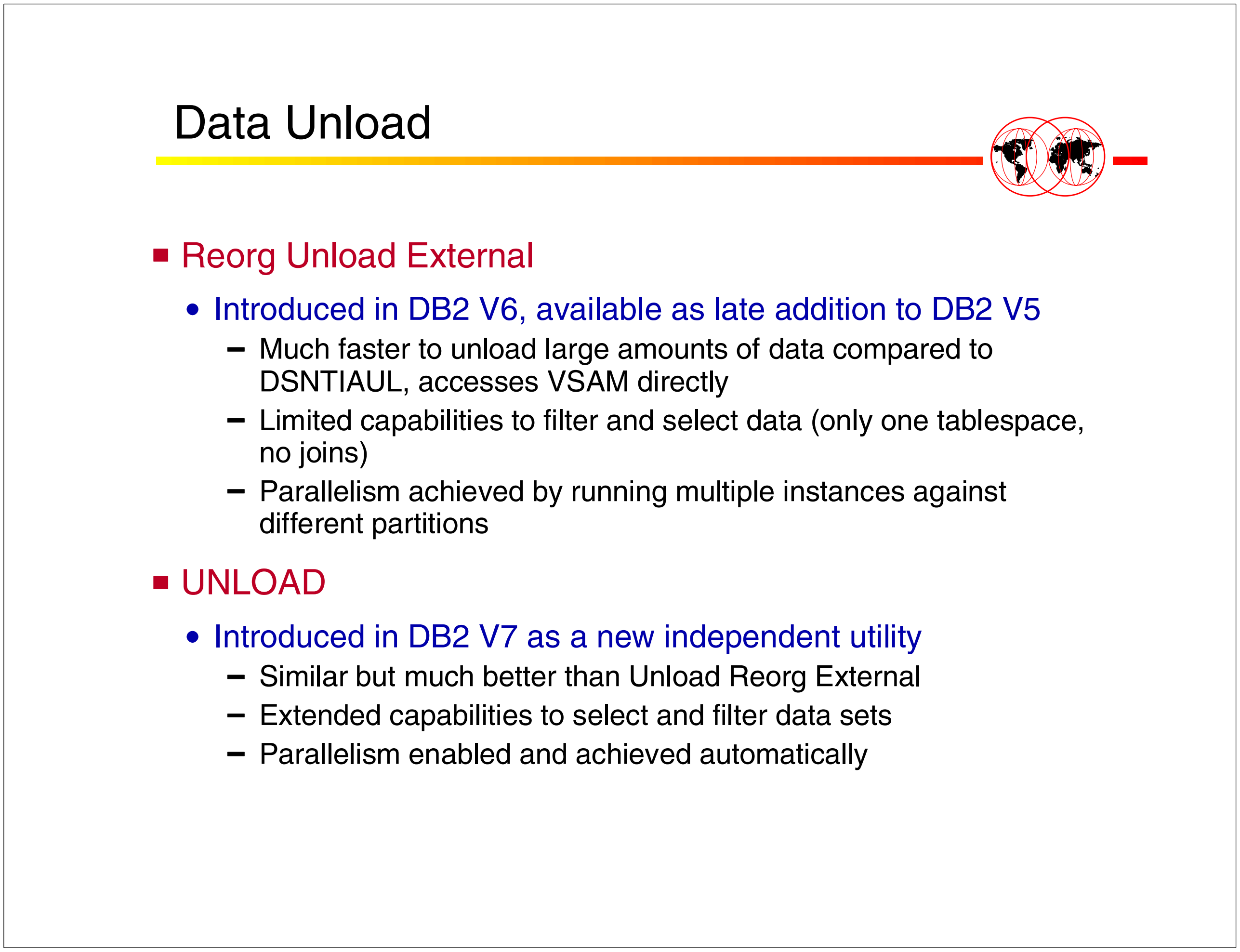
DB2 V5 introduced the inline Copy, which allowed the Load and Reorg utilities to create an image copy at the same time that the data was loaded. DB2 V6 introduced the inline statistics, making it possible to execute Runstats at the same time as Load or Reorg. These capabilities enable Load and Reorg to perform a Copy and a Runstats during the same pass of the data.

It is common to perform Runstats and Copy after the data has been loaded (especially with the NOLOG option). Running them inline reduces the total elapsed time of these utilities. Measurements have shown that elapsed time for Load and Reorg, including Copy and Runstats, is almost the same as running the Load or the Reorg in standalone (for more details refer to *DB2 UDB for OS/390 Version 6 Performance Topics*, SG24-5351).

Online utilities

Share-level change options in utility executions allow users to access the data in read and update mode concurrently with the utility executions. DB2 V6 supports this capability for Copy and Reorg. DB2 V7 extends this capability to Unload and Load Resume.

5.2.2 Data unload



Data Unload

- Reorg Unload External
  - Introduced in DB2 V6, available as late addition to DB2 V5
    - Much faster to unload large amounts of data compared to DSNTIAUL, accesses VSAM directly
    - Limited capabilities to filter and select data (only one tablespace, no joins)
    - Parallelism achieved by running multiple instances against different partitions
- UNLOAD
  - Introduced in DB2 V7 as a new independent utility
    - Similar but much better than Unload Reorg External
    - Extended capabilities to select and filter data sets
    - Parallelism enabled and achieved automatically

To unload data, use Reorg Unload External if you have DB2 V6; use Unload if you have DB2 V7.

Reorg Unload External

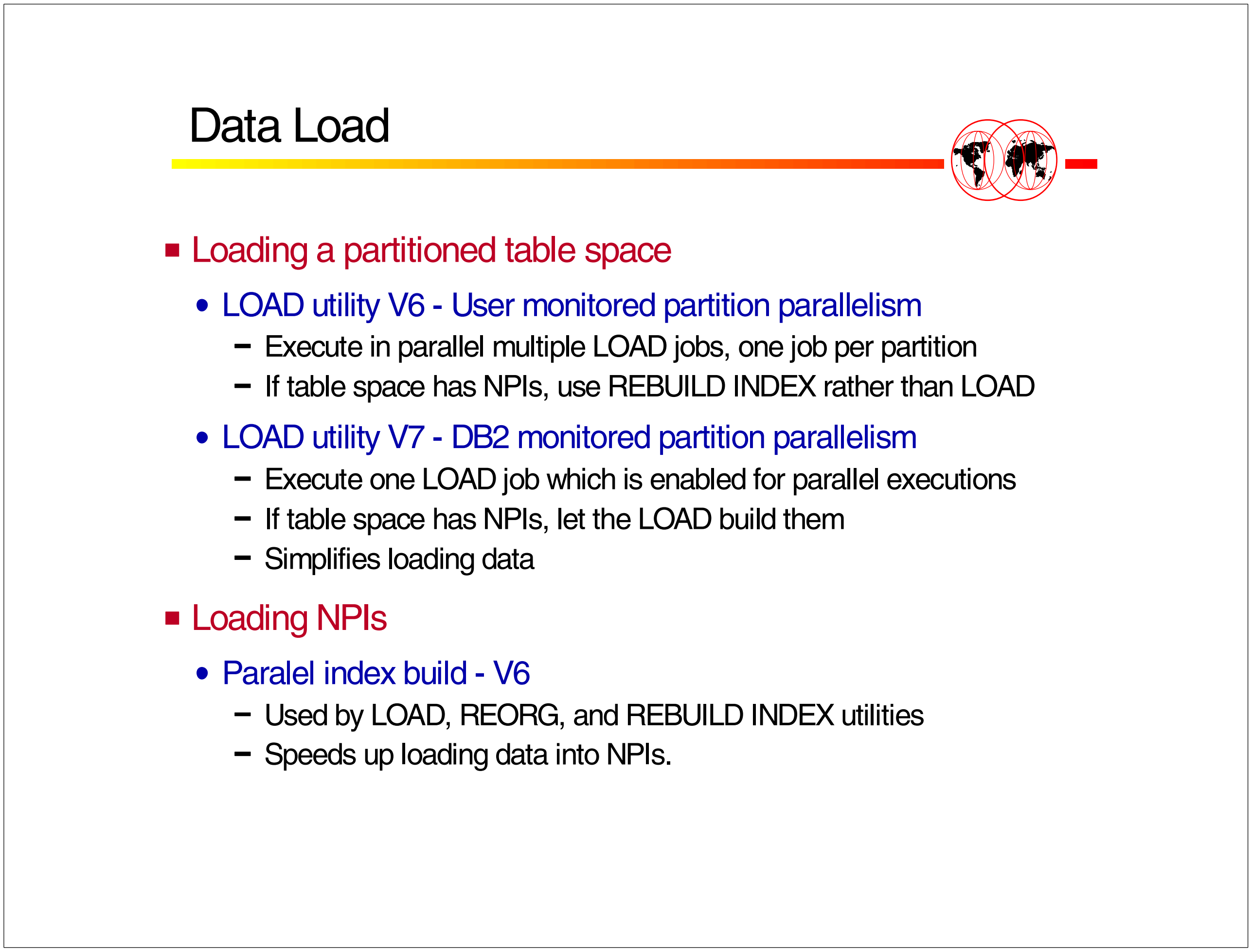
Reorg Unload External was introduced in DB2 V6, and was also a late addition to DB2 V5. In most cases it performs better than DSNTIAUL. Comparative measurements between DSNTIAUL and fast unload show elapsed time reductions between 65 and 85 percent and CPU time reductions between 76 and 89 percent.

Reorg Unload External can access only one table; it cannot perform any kind of joins, it cannot use any functions or calculations, and column-to-column comparison is not supported. Using fast unload, parallelism is manually specified. To unload more than one partition at a time, parallel jobs with one partition in each job must be set up. To get optimum performance, the number of parallel jobs should be set up based on the number of available central processors and the available I/O capacity. In this scenario each unload creates one unload data set. If it is necessary for further processing, the data sets must be merged after all the unloads have completed.

Unload

Introduced in DB2 V7, the UNLOAD utility is a new member of the DB2 Utilities family. It achieves faster unload than Reorg Unload External in certain cases. Unload can unload data from a list of DB2 table spaces with a single Unload statement. It can also unload from image copy data sets for a single table space. Unload has the capability of selecting the partitions to be unloaded and can sample the rows of a table to be unloaded by using WHEN specification clauses.

5.2.3 Data load



Data Load

- Loading a partitioned table space
  - LOAD utility V6 - User monitored partition parallelism
    - Execute in parallel multiple LOAD jobs, one job per partition
    - If table space has NPIs, use REBUILD INDEX rather than LOAD
  - LOAD utility V7 - DB2 monitored partition parallelism
    - Execute one LOAD job which is enabled for parallel executions
    - If table space has NPIs, let the LOAD build them
    - Simplifies loading data
- Loading NPIs
  - Paralel index build - V6
    - Used by LOAD, REORG, and REBUILD INDEX utilities
    - Speeds up loading data into NPIs.

DB2 has efficient utilities to load the large volumes of data that are typical of data warehousing environments.

Loading a partitioned table space

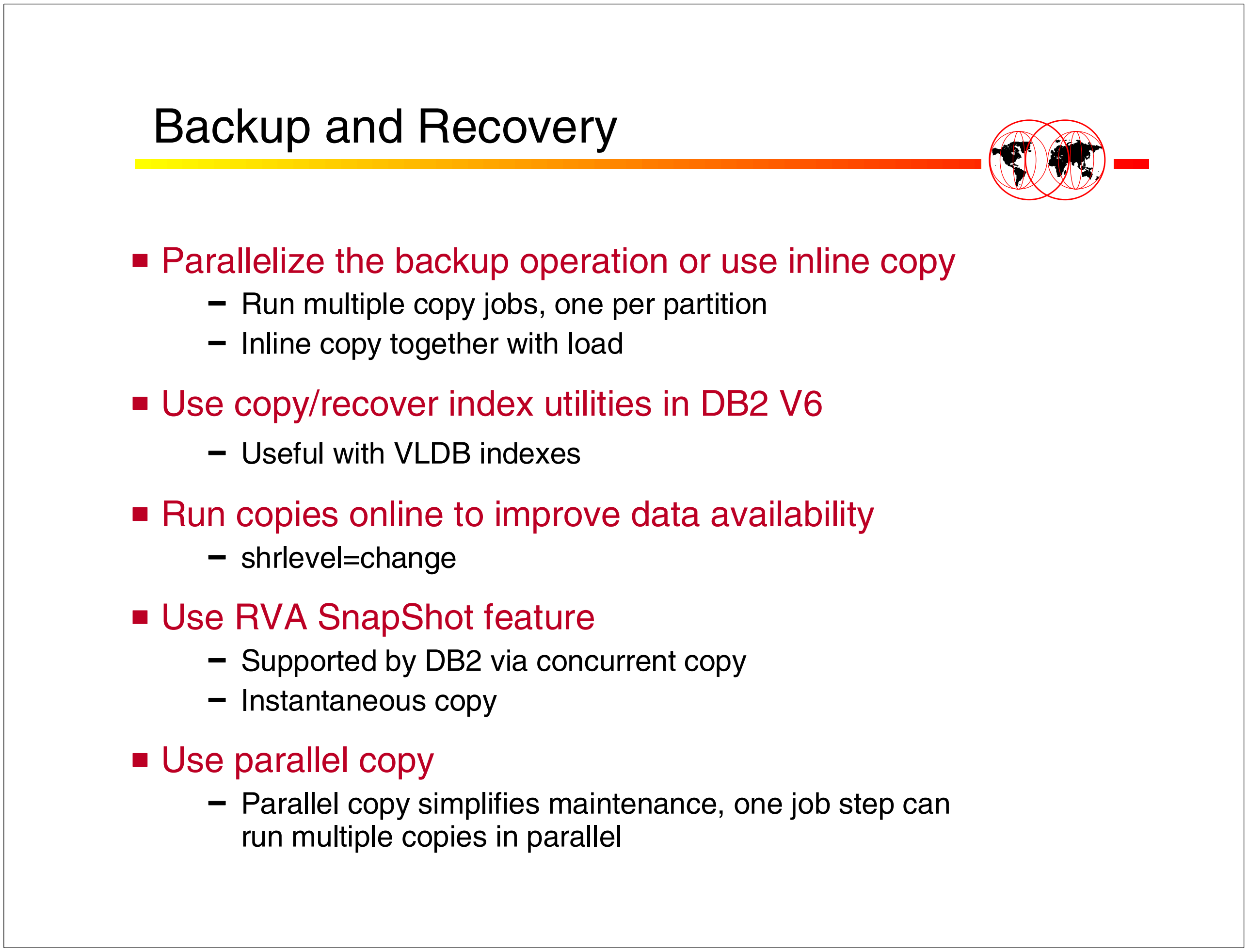
In DB2 V6, to load a partitioned table space, the database administrator (DBA) has to choose between submitting a single LOAD job that may run a very long time, or breaking up the input data into multiple data sets, one per partition, and submitting one LOAD job per partition. The latter approach involves more work on the DBA's part, but completes the load in a much shorter time, because some number of the load jobs (depending on resources, such as processor capacity, I/O configuration, and memory) can run in parallel. In addition, if the table space has non-partitioned indexes (NPIs), the DBA often builds them with a separate REBUILD INDEX job. Concurrent LOAD jobs can build NPIs, but there is significant contention on the index pages from the separate LOAD jobs. Because of this, running REBUILD INDEX after the data is loaded is often faster than building the NPIs while loading the data.

DB2 V7 introduces Load partition parallelism, which simplifies loading large amounts of data into partitioned table spaces. Partitions can be loaded in parallel with a single LOAD job. In this case the NPIs can also be built efficiently without resorting to a separate BUILD INDEX job. Index page contention is eliminated because a separate task is building each NPI.

Loading NPIs

DB2 V6 introduced a parallel sort and build index capability which reduces the elapsed time for rebuilding indexes, and Load and Reorg of table spaces, especially for table spaces with many NPIs. There is no specific keyword to invoke the parallel sort and build index. DB2 considers it when SORTKEYS is specified and when appropriate allocations for sort work and message data sets are made in the utility JCL. For details and for performance measurements refer to *DB2 for OS/390 Version 6 Performance Topics*, SG24-5351.

5.2.4 Backup and Recovery



Backup and Recovery

- Parallelize the backup operation or use inline copy
  - Run multiple copy jobs, one per partition
  - Inline copy together with load
- Use copy/recover index utilities in DB2 V6
  - Useful with VLDB indexes
- Run copies online to improve data availability
  - shrlevel=change
- Use RVA SnapShot feature
  - Supported by DB2 via concurrent copy
  - Instantaneous copy
- Use parallel copy
  - Parallel copy simplifies maintenance, one job step can run multiple copies in parallel

The general recommendation is to take an image copy after each refresh to ensure recoverability. For read-only data loaded with load replace, it can be an option to leave the table spaces nonrecoverable (do not take an image copy and leave the image copy pending flag). However, this approach may have some important implications:

- It is up to you to recover data and indexes through reload of the original file. You need to be absolutely sure where the load data set for each partition is kept. There are no automatic ways to recover the data.
- Recover index cannot be used (load always rebuilds the indexes).
- If the DB2 table space is compressed, the image copy is compressed. However, the initial load data set is not.

When data is loaded with load replace, using inline copy is a good solution in most cases. The copy has a small impact on the elapsed time (in most cases the elapsed time is close to the elapsed time of the standalone load).

If the time to recover NPIs after a failure is an issue, an image copy of NPIs should be considered. The possibility to image copy indexes was introduced in version 6 and allows indexes to be recovered using an image copy rather than being rebuilt based on the content of the table.

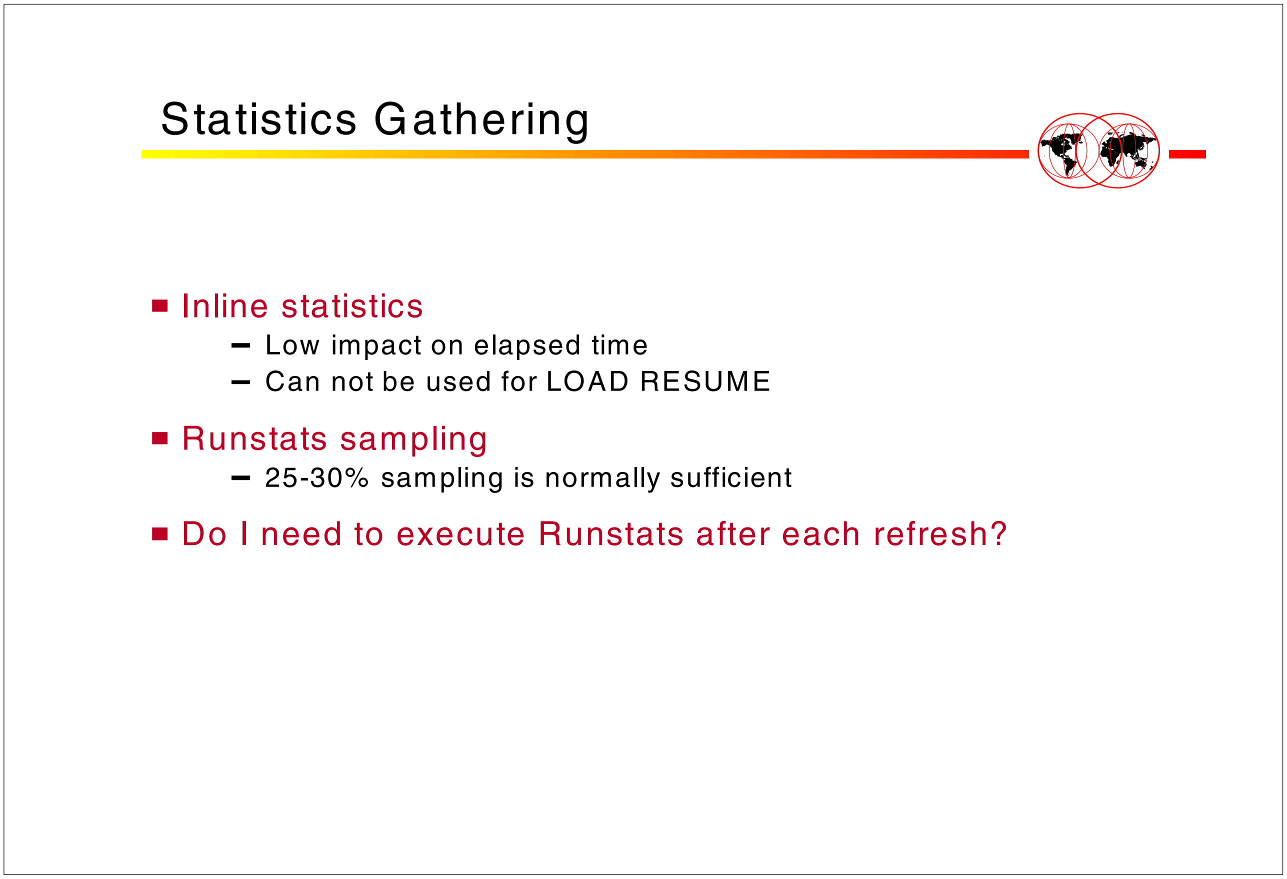
When you design data population, consider using shrlevel reference when taking image copies of your NPIs to allow load utilities to run against other partitions of the table at the same time as the image copy.

When backing up read/write table spaces in a data warehouse environment where availability is an important issue, using sharelevel change option should be considered. Shrlevel change allows user updates to the data during the image copy.

High availability can also be achieved using RVA SnapShots. They enable almost instant copying of data sets or volumes. The copies are created without moving any data. Measurements have proven that image copies of very large data sets using the SnapShot technique only take a few seconds. The redbook *Using RVA and SnapShot for BI with OS/390 and DB2*, SG24-5333, discusses this option in detail.

In DB2 Version 6 the parallel parameter has been added to the copy and recover utilities. Using the parallel parameter, the copy and recover utilities consider executing multiple copies in parallel within a job step. This approach simplifies maintenance, since it avoids having a number of parallel jobs, each performing copy or recover on different table spaces or indexes. Parallelism can be achieved within a single job step containing a list of table spaces or indexes to be copied or recovered.

5.2.5 Statistics gathering



Statistics Gathering

- Inline statistics
  - Low impact on elapsed time
  - Can not be used for LOAD RESUME
- Runstats sampling
  - 25-30% sampling is normally sufficient
- Do I need to execute Runstats after each refresh?

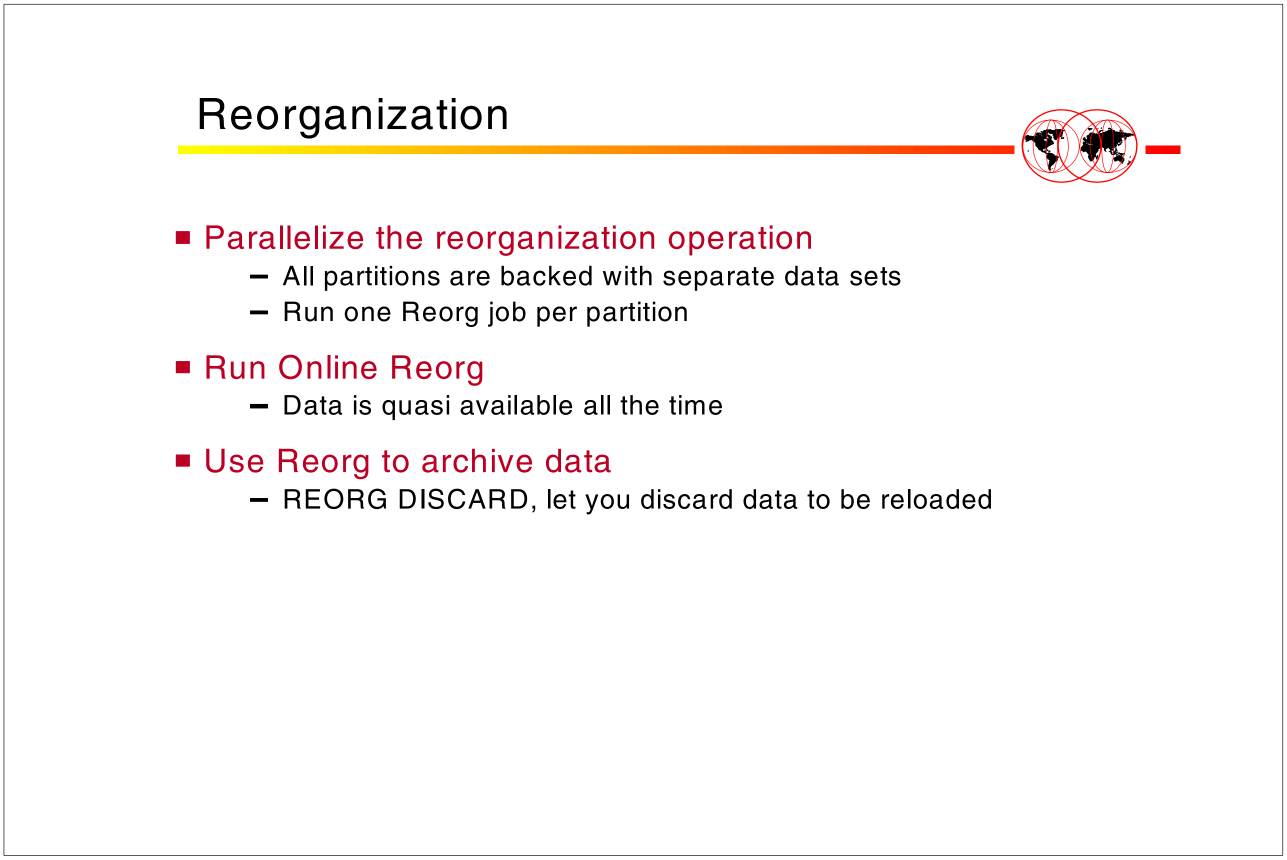
To ensure that DB2’s optimizer selects the best possible access paths, it is vital that the catalog statistics are as accurate as possible.

Inline statistics: DB2 Version 6 introduces inline statistics. These can be used with either Load or Reorg. Measurements have shown that the elapsed time of executing a load with inline statistics is not much longer than executing the load standalone. From an elapsed time perspective, using the inline statistics is normally the best solution. However, inline copy cannot be executed for load resume. Also note that inline statistics cannot perform Runstats on NPIs when using load replace on the partition level. In this case, the Runstats of the NPI must be executed as a separate job after the load.

Runstats sampling: When using Runstats sampling, the catalog statistics are only collected for a subset of the table rows. In general, sampling using 20-30 percent seems to be sufficient to create acceptable access paths. This reduces elapsed time by approximately 40 percent.

Based on your population design, it may not be necessary to execute Runstats after each refresh. If you are using load replace to replace existing data, you could consider executing Runstats only the first time, if data volumes and distribution are fairly even over time.

5.2.6 Reorganization



Reorganization

- Parallelize the reorganization operation
  - All partitions are backed with separate data sets
  - Run one Reorg job per partition
- Run Online Reorg
  - Data is quasi available all the time
- Use Reorg to archive data
  - REORG DISCARD, let you discard data to be reloaded

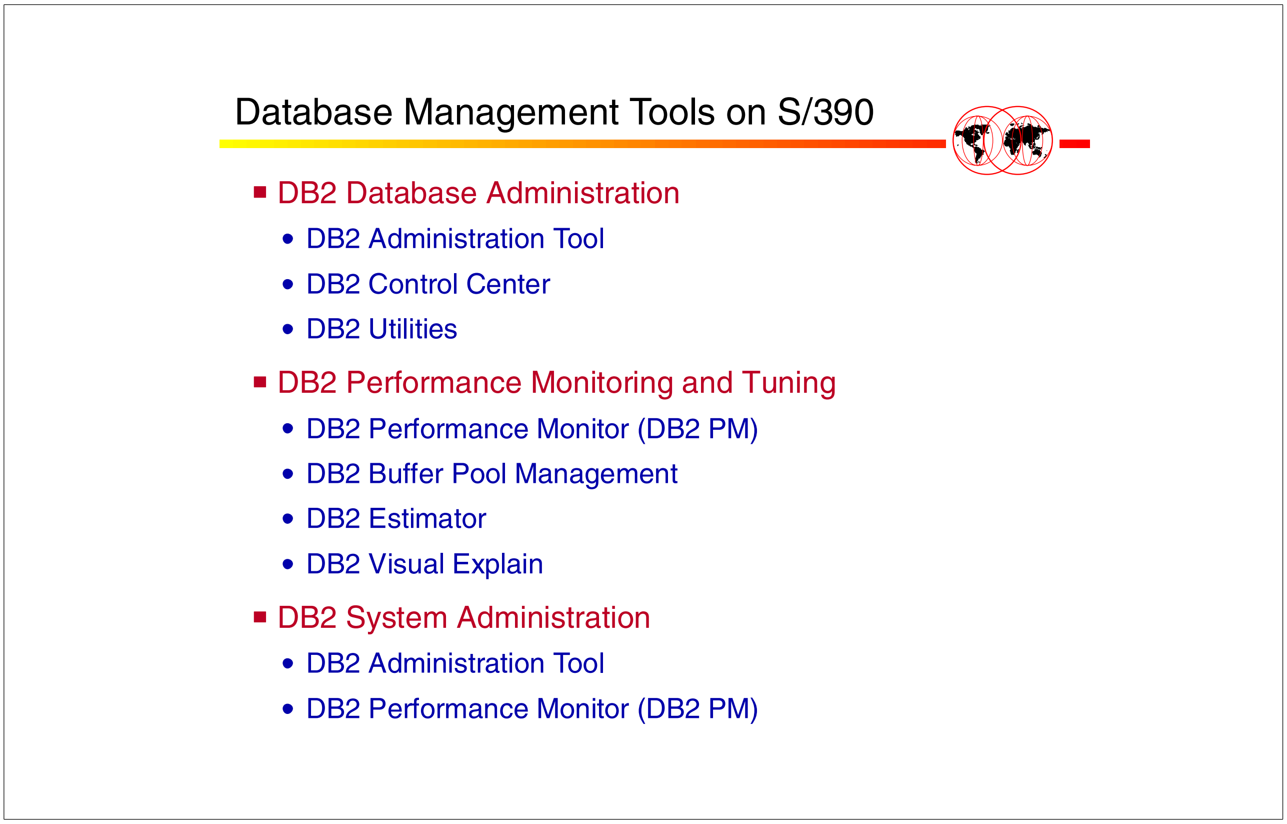
For tables that are loaded with load replace, there is no need to reorganize the table spaces as long as the load files are sorted based on the clustering index. However, when tables are load replaced by partition, it is likely that the NPIs need to be reorganized, since data from different partitions performs inserts and deletes against the NPIs regardless of partition. Online Reorg of index only is a good option in this case.

For data that is loaded with load resume, it is likely that both the table spaces and indexes (both partitioning and non-partitioning indexes) need to be reorganized, since load resume appends the data at the end of the table spaces. Online Reorg of tablespaces and indexes should be used, keeping in mind that frequent reorgs of indexes usually are more important.

Online Reorg provides high availability during reorganization of table spaces or indexes. Up to DB2 V6, the Online Reorg utility at the switch phase needs exclusive access to the data for a short period of time; if there are long-running queries accessing the data, there is a risk that the Reorg times out. DB2 V7 introduces enhancements which drastically reduce the switch phase of Online Reorg.

Reorg Discard (introduced in DB2 Version 6 and available as a late addition to DB2 Version 5) allows you to discard data during the unload phase (the data is not reloaded to the table). The discarded data can be written to a sequential data set in an external format. This technique can be used to archive data that no longer should be considered to be active. This approach is especially useful for tables that are updated within the data warehouse or tables that are loaded with load resume. The archive process can be accomplished at the same time the table spaces are reorganized.

5.3 Database management tools on S/390



Database Management Tools on S/390

- DB2 Database Administration
  - DB2 Administration Tool
  - DB2 Control Center
  - DB2 Utilities
- DB2 Performance Monitoring and Tuning
  - DB2 Performance Monitor (DB2 PM)
  - DB2 Buffer Pool Management
  - DB2 Estimator
  - DB2 Visual Explain
- DB2 System Administration
  - DB2 Administration Tool
  - DB2 Performance Monitor (DB2 PM)

Database administration is a key function in all data warehouse development and maintenance activities. Most of the tools that are used for normal database administration are also useful in a DW environment.

5.3.1 DB2ADMIN

DB2ADMIN, the DB2 administration tool, contains a highly intuitive user interface that gives an instant picture of the content of the DB2 catalogue. DB2ADMIN provides the following features and functionality:

- Highly intuitive, panel-driven access to the DB2 catalogue.
- Instantly run any SQL (from any DB2ADMIN panel).
- Instantly run any DB2 command (from any DB2ADMIN panel).
- Manage SQLIDs.
- Results from SQL and DB2 commands are available in scrollable lists.
- Panel-driven DB2 utility creation (on single DB2 object or list of DB2 objects).
- SQL select prototyping.
- DDL and DCL creation from DB2 catalogue.
- Panel-driven support for changing resource limits (RLF), managing DDF tables, managing stored procedures, and managing buffer pools.

- Panel-driven support for system administration tasks like stopping DB2 and DDF, displaying and terminating distributed and non-distributed threads.
- User-developed table maintenance and list applications are easy to create.

5.3.2 DB2 Control Center

The DB2 Control Center (CC) provides a common interface for DB2 database management on different platforms. In DB2 Version 6, support for DB2 on S/390 is added. CC is written in Java and can be launched from a Java-enabled Internet browser. It can be set up as a 3-tier solution where a client can connect to a Web server. CC can also run on the Web server or it can run another server communicating with the Web server.

CC connects to S/390 using DB2 Connect. This approach enables an extremely thin client. The only software that is required on the client side is the Internet browser. CC supports both Netscape and Microsoft Internet Explorer. The functionality of CC includes:

- Navigating through DB2 objects in the system catalogue
- Invoking DB2 utilities such as Load, Reorg, Runstats, Copy
- Creating, altering, dropping DB2 objects
- Listing data from DB2 tables
- Displaying status of database objects

CC uses stored procedures to start DB2 utilities. The ability to invoke utilities from stored procedures was added in DB2 V6 and is now also available as a late addition to DB2 V5.

5.3.3 DB2 Performance Monitor

DB2 Performance Monitor (DB2 PM) is a comprehensive performance monitor that lets you display detailed monitoring information. DB2 PM can either be run from an ISPF user interface or from a workstation interface available on Windows NT, Windows 95, or OS/2. DB2 PM includes functions such as:

- Monitoring DB2 and DB2 applications online (both active and historical views)
- Monitoring individual data-sharing members or entire data-sharing groups
- Monitoring query parallelism in a Parallel Sysplex
- Activating alerts when problems occur based on threshold values
- Viewing DB2 subsystem status
- Obtaining tuning recommendations
- Recognizing trends and possible bottlenecks
- Analyzing SQL access paths (specific SQL statements, plans, packages, or QMF queries)

5.3.4 DB2 Buffer Pool management

Buffer pool sizing is a key activity for a DBA in a data warehouse environment. The DB2 Buffer Pool Tool uses the instrumentation facility interface (IFI) to collect the information. This guarantees a low overhead. The tool also provides “what if” analysis, making it possible to verify the buffer pool setup against an actual load.

DB2 Buffer Pool Tool provides a detailed statistical analysis of how the buffer pools are used. The statistical analysis includes:

- System and application hit ratios
- Get page, prefetch, and random access activity
- Read and write I/O activity
- Average and maximum I/O elapsed times
- Random page hiperpool retrieval
- Average page residency times
- Average number of pages per write

5.3.5 DB2 Estimator

DB2 Estimator is a PC-based tool that can be downloaded from the Web. It lets you simulate elapsed and CPU time for SQL statements and the execution of DB2 utilities. DB2 Estimator can be used for “what if” scenarios. You can, for example, simulate the effect of adding an index on a CPU, and elapsed times for a load. You can import DB2 statistics from the DB2 catalogue into DB2 Estimator so the estimator uses catalogue statistics.

5.3.6 DB2 Visual Explain

DB2 Visual Explain lets you graphically explain access paths for an SQL statement, a DB2 package, or a plan. Visual Explain runs on Windows NT or OS/2, which connects to S/390 using DB2 Connect.

5.4 Systems management tools on S/390

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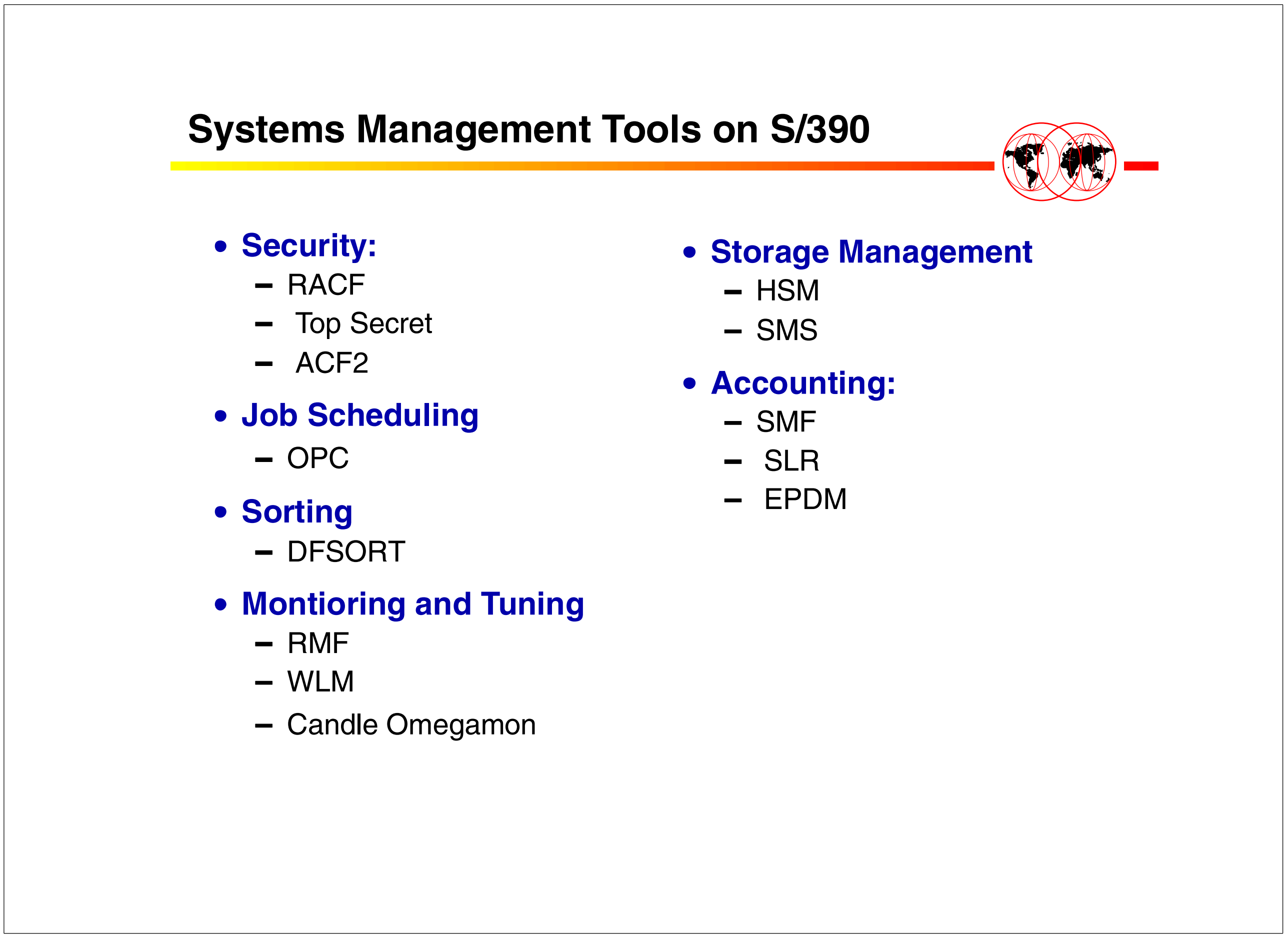


Systems Management Tools on S/390

- **Security:**
  - RACF
  - Top Secret
  - ACF2
- **Job Scheduling**
  - OPC
- **Sorting**
  - DFSORT
- **Montioring and Tuning**
  - RMF
  - WLM
  - Candle Omegamon
- **Storage Management**
  - HSM
  - SMS
- **Accounting:**
  - SMF
  - SLR
  - EPDM

Many of the tools and functions that are used in a normal OLTP OS/390 setup also play an important role in a S/390 data warehouse environment. Using these tools and functions makes it possible to use existing infrastructure and skills. Some of the tools and functions that are at least as important in a DW environment as in an OLTP environment are described in this section.

5.4.1 RACF

A well functioning access control is vital both for an OLTP and for a DW environment. Using the same access control system for both the OLTP and DW environments makes it possible to use the existing security administration.

DB2 V5 introduced Resource Access Control Facility (RACF) support for DB2 objects. Using this support makes it possible to control access to all DB2 objects, including tables and views, using RACF. This is especially useful in a DW environment with a large number of end users accessing data in the S/390 environment.

5.4.2 OPC

Normally, dependencies need to be set up between the application flow of the operational data and the DW application flow. The extract program of the operational data may, for example, not be started before the daily backups have been taken. Using the same job scheduler, such as Operations Planning and Control (OPC), both in the operational and the DW environment makes it very easy to create dependencies between jobs in the OLTP and DW environment. Job scheduling tools are also important within the warehouse. A warehouse setup often tends to contain a large number of jobs, often with complex dependencies. This is especially true when your data is heavily partitioned and each capture, transform, and load contains one job per partition.

5.4.3 DFSORT

Sorting is very important in a data warehouse environment. This is true both for sorts initiated using the standard SQL API (Order by, Group by, and so forth) and for SORT used by batch processes that extract, transform, and load data. In a warehouse DFSORT is not only used to do normal sorting of data, but also to split (OUTFIL INCLUDE), merge (OPTION MERGE), and summarize data (SUM).

5.4.4 RMF

Resource Measurement Facility (RMF) enables collection of historical performance data as well as on-line system monitoring. The performance information gathered by RMF helps you understand system behavior and detect potential system bottlenecks at an early stage. Understanding the performance of the system is a critical success factor both in an OLTP environment and in a DW environment.

5.4.5 WLM

Workload Manager (WLM) is a OS/390 component. It enables a proactive and dynamic approach to system and subsystem optimization. WLM manages workloads by assigning goal and work oriented priorities based on business requirements and priorities. For more details about WLM refer to Chapter 8, “BI workload management” on page 143.

5.4.6 HSM

Backup, restore, and archiving are as important in a DW environment as in an OLTP environment. Using Hierarchical Storage Manager (HSM) compression before archiving data can drastically reduce storage usage.

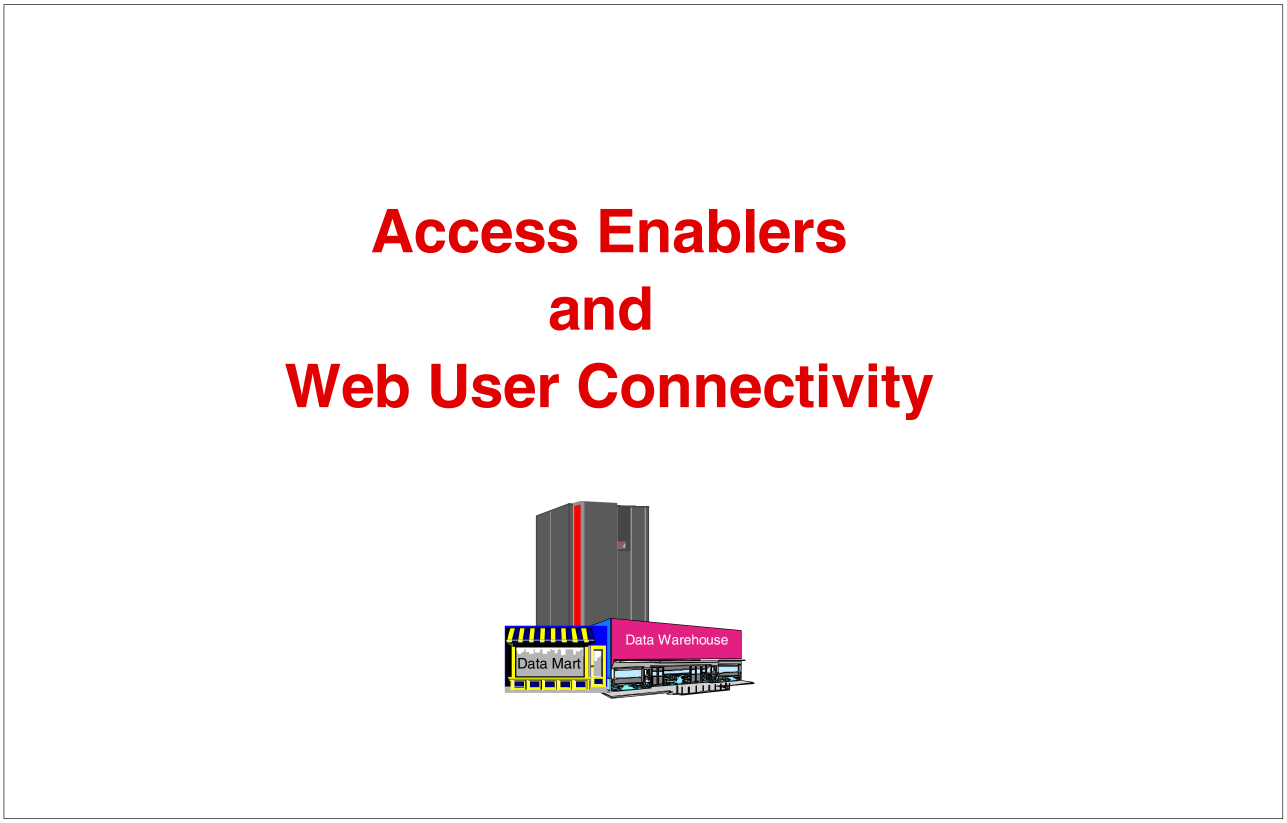
5.4.7 SMS

Data set placement is a key activity in getting good performance from the data warehouse. Using Storage Management Subsystem (SMS) drastically reduces the amount of administration work.

5.4.8 SLR / EPDM / SMF

Distribution of costs for computing is vital also in a DW environment, where it is necessary to be able to distribute the cost for populating the data warehouse as well as the cost for end-user queries. Service Level Reporter (SLR), Enterprise Performance Data Manager (EPDM), and System Management Facilities (SMF) can help in analyzing such costs.

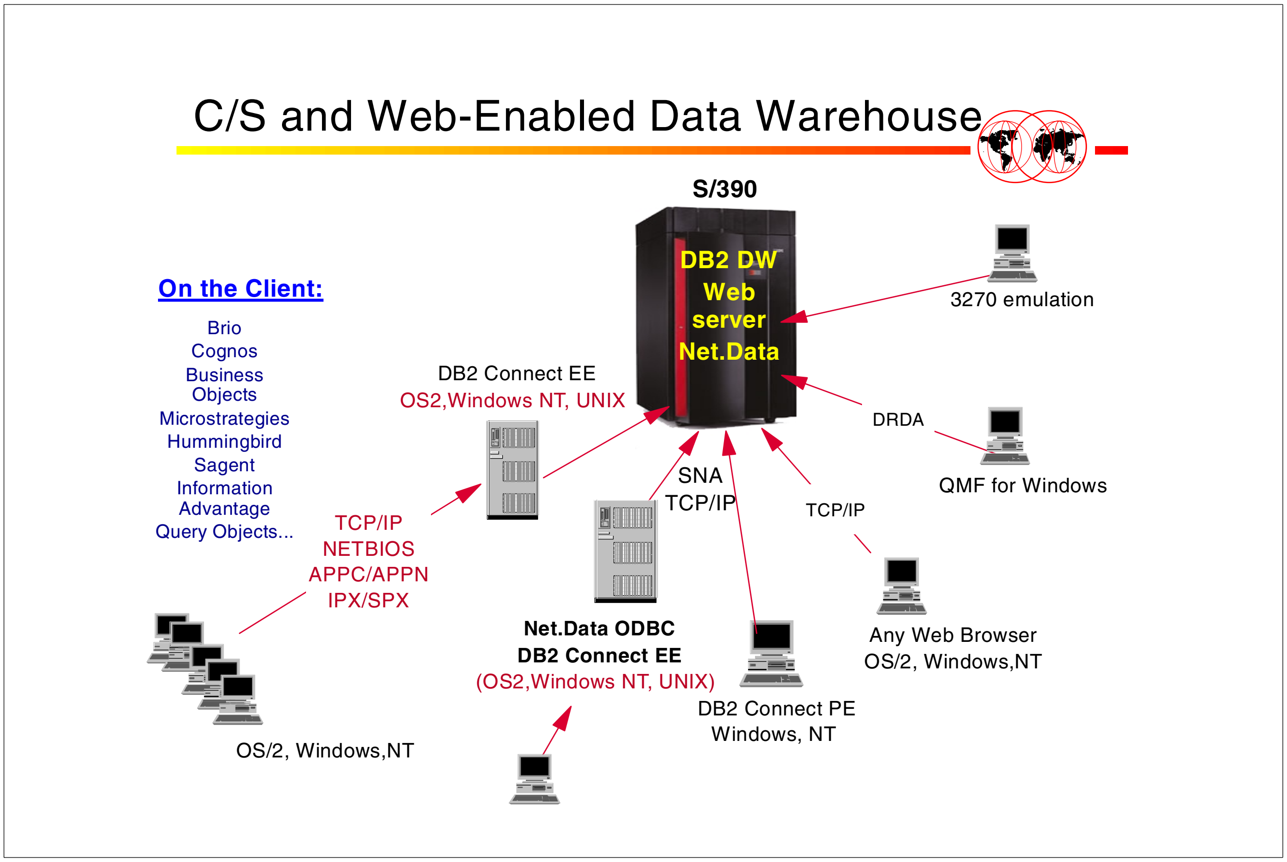
Chapter 6. Access enablers and Web user connectivity



Access Enablers
and
Web User Connectivity

This chapter describes the user interfaces and middleware services which connect the end users to the data warehouse.

6.1 Client/Server and Web-enabled data warehouse



DB2 data warehouse and data mart on S/390 can be accessed by any workstation and Web-based client. S/390 and DB2 support the middleware required for any type of client connection.

Workstation users access the DB2 data warehouse on S/390 through IBM's DB2 Connect. An alternative to DB2 Connect, meaning a tool-specific client/server application interface, can also be used.

Distributed Relational Database Architecture (DRDA) database connectivity protocols over TCP/IP or SNA networks are used by DB2 Connect to connect to the S/390.

Web clients access the DB2 data warehouse and marts on S/390 through a Web server. The Web server can be implemented on a S/390 or on another middle-tier UNIX, Intel or Linux server. Connection from the remote Web server to the data warehouse on S/390 requires DB2 Connect.

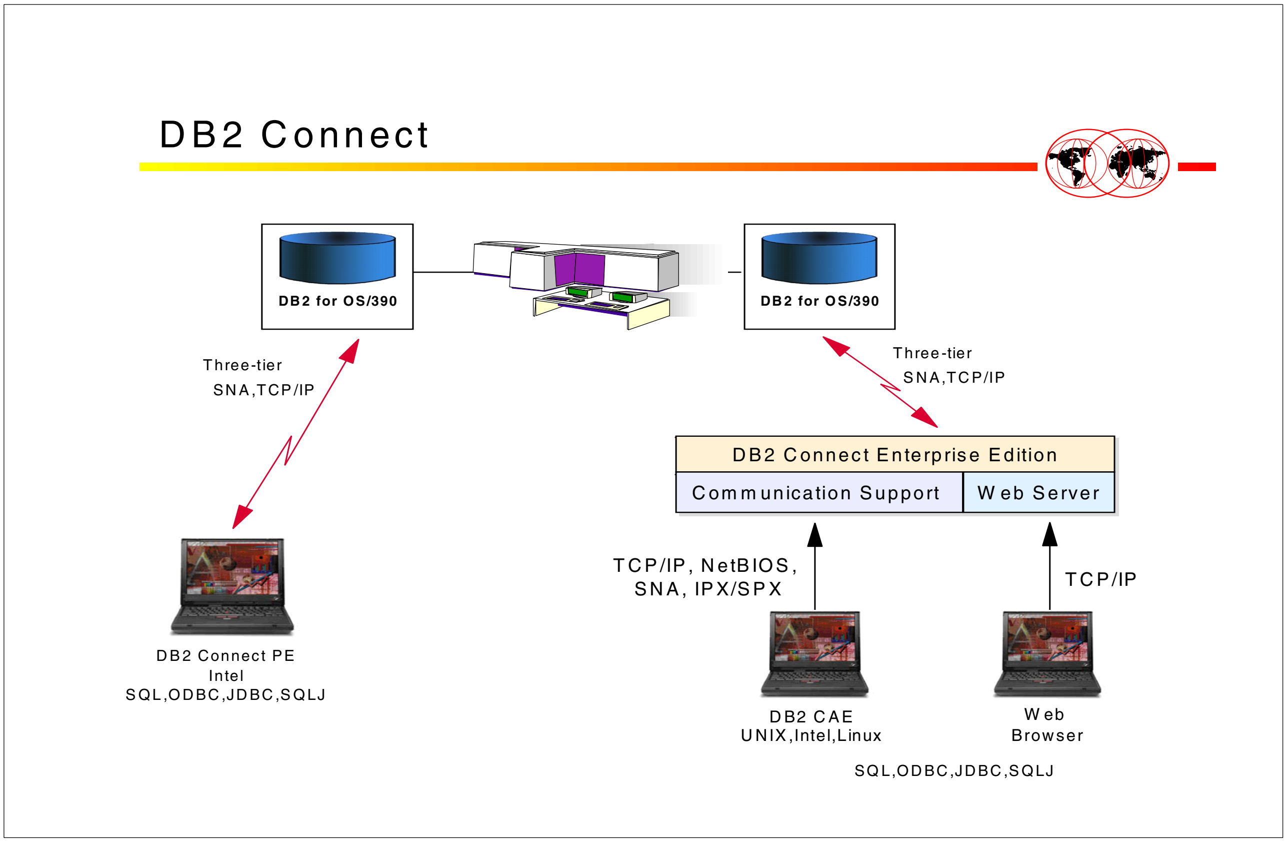
Net.Data middleware or Java programming interfaces, such as JDBC and SQLJ, are used to address database access requests coming from the Web in HTML format, to transform them into the SQL format required by DB2.

Some popular BI tools accessing the data warehouse on S/390 are:

- Query and reporting tools - QMF for Windows, MS Access, Lotus Approach, Brio Query, Cognos Impromptu
- OLAP multidimensional analysis tools - DB2 OLAP Server for OS/390, MicroStrategy DSS Agent, BusinessObjects
- Data mining tools - Intelligent Miner for Data for OS/390, Intelligent Miner for Text for OS/390
- Application solutions - DecisionEdge, Intelligent Miner for Relationship Marketing, Valex

Some of those tools are further described in Chapter 7, “BI user tools interoperating with S/390” on page 121.

6.2 DB2 Connect



DB2 Connect

DB2 Connect is IBM’s middleware to connect workstation users to the remote DB2 data warehouse on the S/390. Web clients have to connect to a Web server first—before they can connect to the DB2 data warehouse on S/390. If the Web server is on a middle tier, it requires DB2 Connect to connect to the S/390 data warehouse.

DB2 Connect uses DRDA database protocols over TCP/IP or SNA networks to connect to the DB2 data warehouse.

BI tools are typically workstation tools used by UNIX, Intel, Mac, and Linux-based clients. Most of the time those BI tools use DRDA-compliant ODBC drivers, or Java programming interfaces such as JDBC and SQLJ, which are all supported by DB2 Connect and allow access to the data warehouse on S/390.

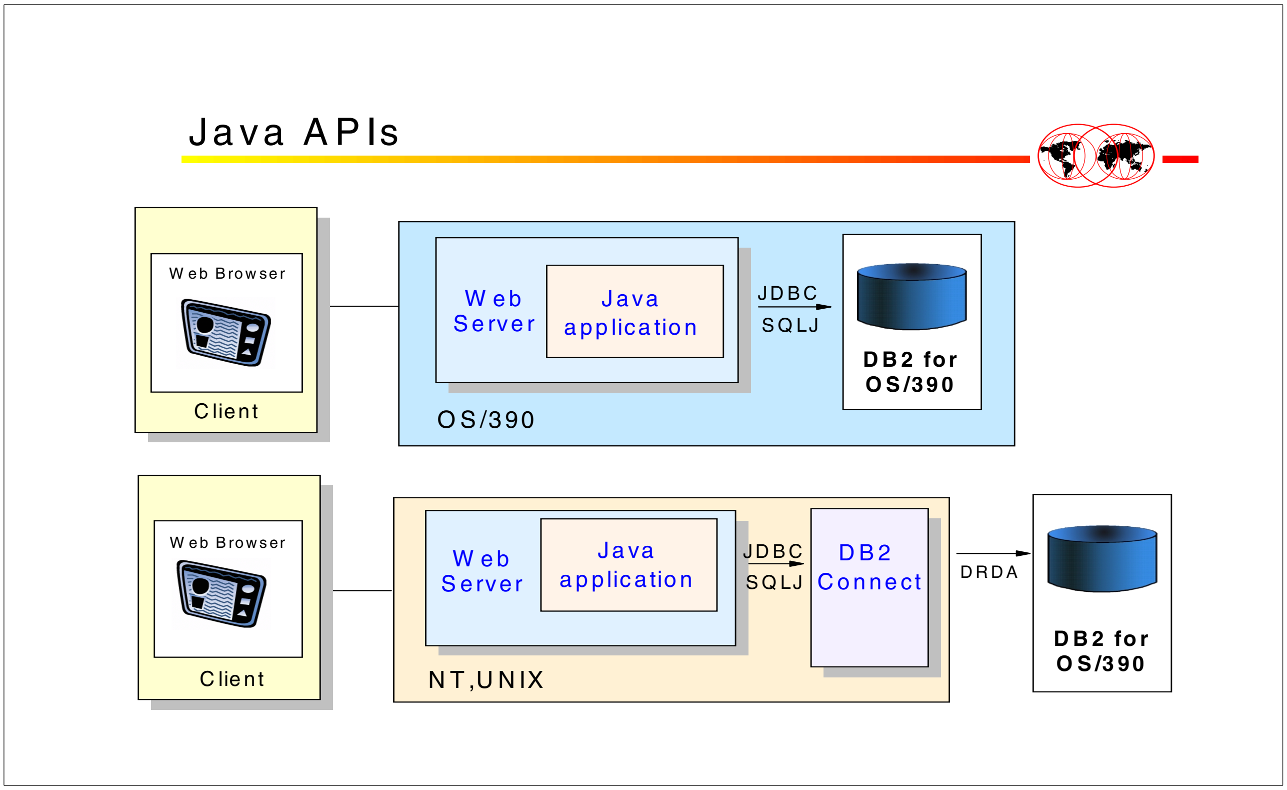
DB2 Connect Personal Edition

DB2 Connect Personal Edition is used in a 2-tier architecture to connect clients on OS/2, Windows, and Linux environments directly to the DB2 data warehouse on S/390. It is well suited for client environments with native TCP/IP support, where intermediate server support is not required.

DB2 Connect Enterprise Edition

DB2 Connect Enterprise Edition on OS/2, Windows NT, UNIX and Linux environments connects LAN-based BI user tools to the DB2 data warehouse on S/390. It is well suited for environments where applications are shared on a LAN by multiple users.

6.3 Java APIs



Java APIs

Web Browser

Client

Web Server

Java application

JDBC

SQLJ

DB2 for OS/390

OS/390

Web Browser

Client

Web Server

Java application

JDBC

SQLJ

DB2 Connect

DRDA

DB2 for OS/390

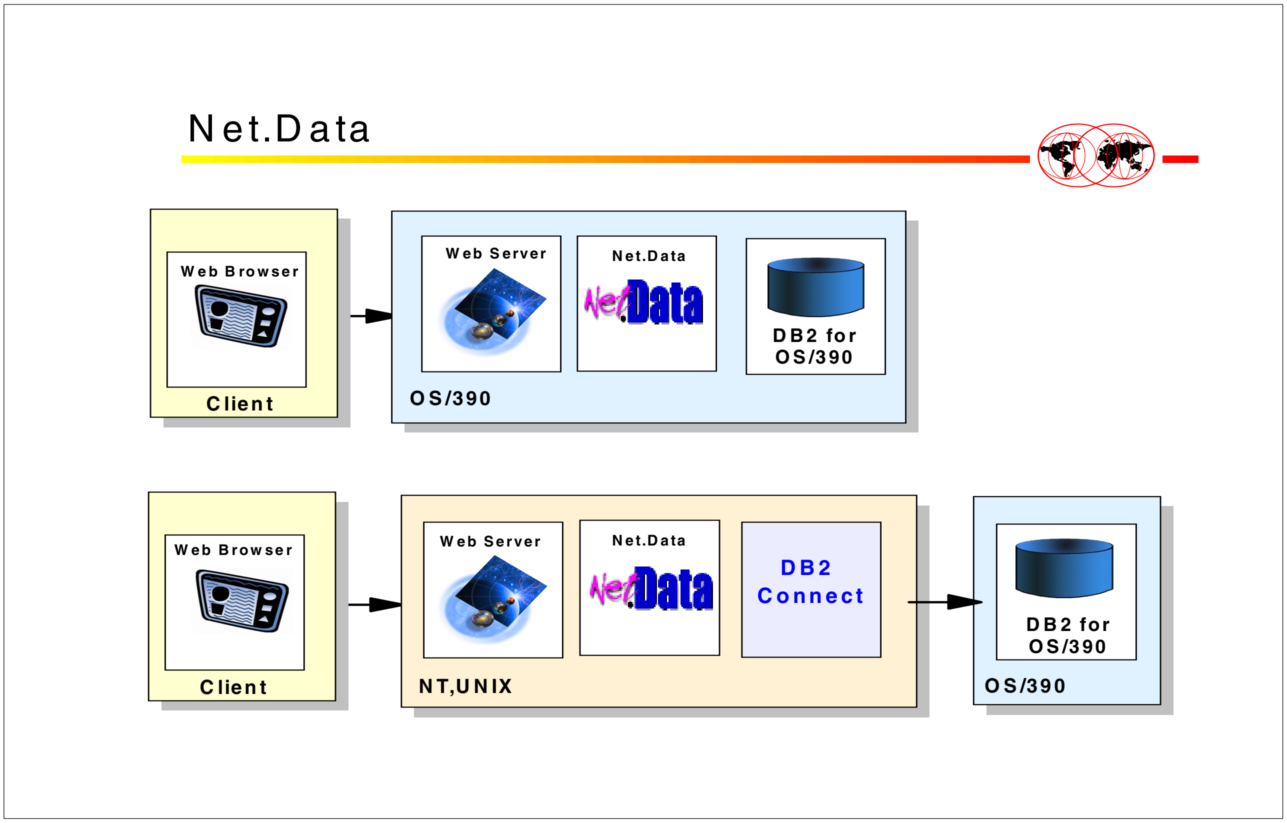
NT,UNIX

A client DB2 application written in Java can directly connect to the DB2 data warehouse on S/390 by using Java APIs such as JDBC and SQLJ.

JDBC is a Java application programming interface that supports dynamic SQL. All BI tools that comply with JDBC specifications can access DB2 data warehouses or data marts on S/390. JDBC is also used by WebSphere Application Server to access the DB2 data warehouse.

SQLJ extends JDBC functions and provides support for embedded static SQL. Because SQLJ includes JDBC, an application program using SQLJ can use both dynamic and static SQL in the program.

6.4 Net.Data



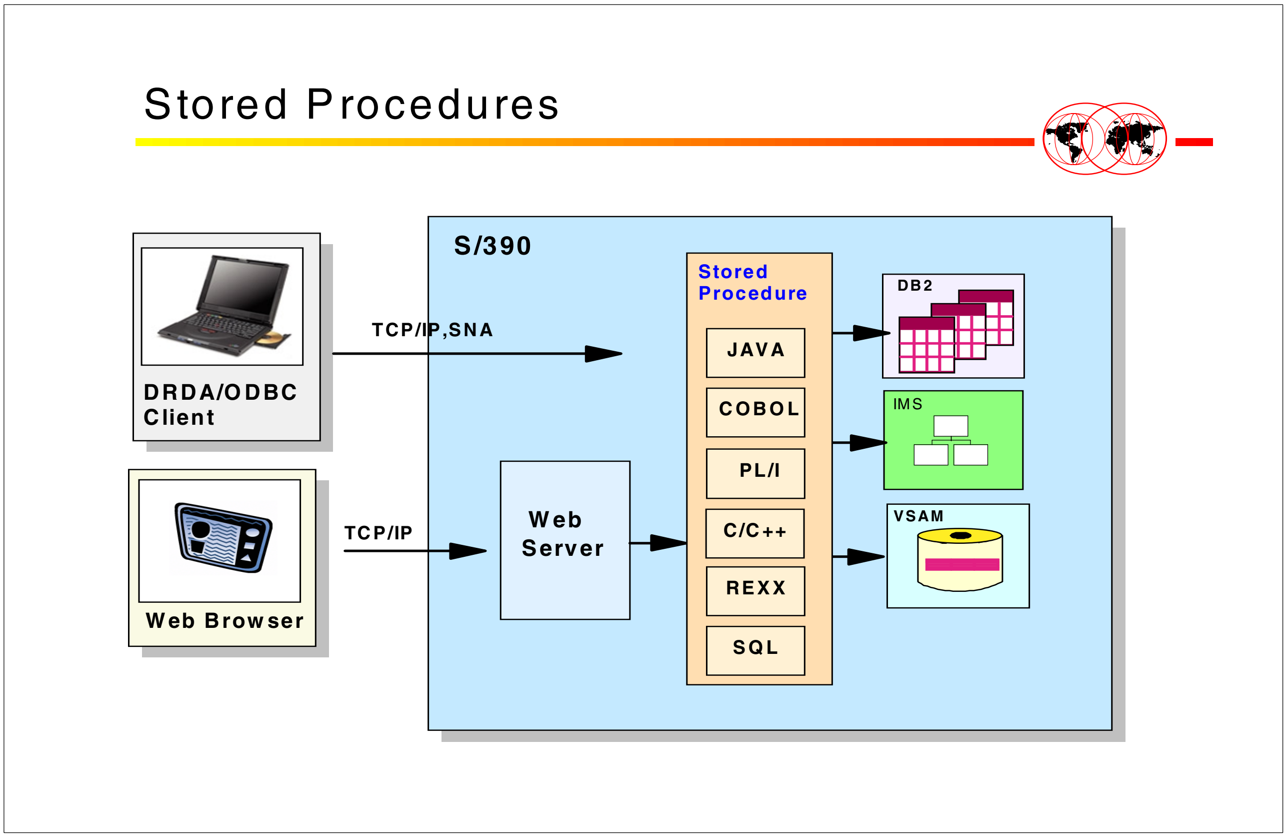
Net.Data is IBM's middleware, which extends to the Web data warehousing and BI applications. Net.Data can be used with RYO applications for static or ad hoc query via the Web. Net.Data with a webserver on S/390, or a second tier, can provide a very simple and expedient solution to a requirement for Web access to a DB2 database on S/390. Within a very short period of time, a simple EIS system can give travelling executives access to current reports, or mobile workers an ad hoc interface to the data warehouse.

Net.Data exploits the high performance APIs of the Web server interface and provides the connectors a Web client needs to connect to the DB2 data warehouse on S/390. It supports HTTP server API interfaces for Netscape, Microsoft, Internet Information Server, Lotus Domino Go Web server and IBM Internet Connection Server, as well as the CGI and FastCGI interfaces.

Net.Data is also a Web application development platform that supports client-side programming as well as Web server-side programming with Java, REXX, Perl and C/C++. Net.Data applications can be rapidly built using a macro language that includes conditional logic and built-in functions.

Net.Data is not sold separately, but is included with DB2 for OS/390, Domino Go Web server, and other packages. It can also be downloaded from the Web.

6.5 Stored procedures



Stored Procedures

The main goal of the stored procedure, a compiled program that is stored on a DB2 server, is a reduction of network message flow between the client, the application, and the DB2 data server. The stored procedure can be executed from C/S users as well as Web clients to access the DB2 data warehouse and data mart on S/390. In addition to supporting DB2 for OS/390, it also provides the ability to access data stored in traditional OS/390 systems like IMS and VSAM.

A stored procedure for DB2 for OS/390 can be written in COBOL, PL/I, C, C++, Fortran, or Java. A stored procedure written in Java executes Java programs containing SQLJ, JDBC, or both. More recently, DB2 for OS/390 offers new stored procedure programming languages such as REXX and SQL. SQL is based on an SQL standard known as SQL/Persistent Stored Modules (PSM). With SQL, users do not need to know programming languages. The stored procedure can be built entirely in SQL.

DB2 Stored Procedure Builder (SPB) is a GUI application environment that supports rapid development of stored procedures. SPB can be launched from VisualAge for Java, MS Visual Studio, or as a native tool under Windows.

Chapter 7. BI user tools interoperating with S/390

BI User Tools
Interoperating with S/390

This chapter describes the front-end BI user tools and applications which connect to the S/390 with 2- or 3-tier physical implementations.

BI User Tools Interoperating with S/390

Query/Reporting

IBM QMF Family
Lotus Approach
Showcase Analyzer
Business Objects
Brio Query
Cognos Impropmtu
Wired for OLAP
Andyne GQL
Forest & Trees
Seagate Crystal Info
SpeedWare Reporter
SPSS
MetaViewer
AlphaBlox
NexTek EI*Manager
EveryWare Dev Tango
IBI Focus
InfoSpace SpaceSQL
Scribe
SAS Client Tools
arcplan Inc. inSight
Aonix Front & Center
MathSoft
Microsoft Desktop Products

Applications

IBM DecisionEdge
Intelligent Miner for RM
IBM Fraud and Abuse
Management system
Viador Portal Suite
Platinum Risk Advisor
SAP Business Warehouse
Recognition Systems
Business Analysis Suite for
SAP
Show Business Cuber
VALEX

OLAP

IBM DB2 OLAP Server
Microstrategy
Hyperion Essbase
Business Objects
Cognos Powerplay
Brio Enterprise
Andyne PaBLo
Information Advantage
Pilot
Velocity
Olympic amis
Sillvon DataTracker
InfoManager/400
DI Atlantis
NGQ-IQ
Primos EIS Executive
Information System

Data Mining

IBM Intelligent Miner for
Data
IBM Intelligent Miner for
Text
Viador suite
SearchCafe
PolyAnalyst Data Mining

There are a large number of BI user tools in the marketplace. All the tools shown here, and many more, can access the DB2 data warehouse on S/390. These decision support tools can be broken down into three categories:

- Query/reporting
- Online analytical processing (OLAP)
- Data mining

In addition, tailored BI applications provide packaged solutions that can include hardware, software, BI user tools, and service offerings.

Query and reporting tools

Query and reporting analysis is the process of posing a question to be answered, retrieving relevant data from the data warehouse, transforming it into the appropriate context, and displaying it in a readable format. These powerful yet easy-to-use query and reporting analysis tools have proven themselves in many industries.

IBM's query and reporting tools on the S/390 platform are:

- Query Management Facility (QMF)
- QMF for Windows
- Lotus Approach
- Lotus 123

To increase the scope of its query and reporting offerings, IBM has also forged relationships with partners such as Business Objects, Brio Technology and Cognos, whose tools are optionally available with Visual Warehouse.

OLAP tools

OLAP tools extend the capabilities of query and reporting. Rather than submitting multiple queries, data is structured to enable fast and easy data access, viewed from several dimensions, to resolve typical business questions.

OLAP tools are user friendly since they use GUIs, give quick response, and provide interactive reporting and analysis capabilities, including drill-down and roll-up capabilities, which facilitate rapid understanding of key business issues and performances.

IBM's OLAP solution on the S/390 platform is the DB2 OLAP Server for OS/390.

Data mining tools

Data mining is a relatively new data analysis technique that helps you discover previously unknown, sometimes surprising, often counterintuitive insights into a large collection of data and documents, to give your business a competitive edge.

IBM's data mining solutions on the S/390 platform are:

- Intelligent Miner for Data
- Intelligent Miner for Text

These products can process data stored in DB2 and flat files on S/390 and any other relational databases supported by DataJoiner.

Application solutions

In competitive business, the need for new decision support applications arises quickly. When you don't have the time or resources to develop these applications in-house, and you want to shorten the time to market, you can consider complete application solutions offered by IBM and its partners.

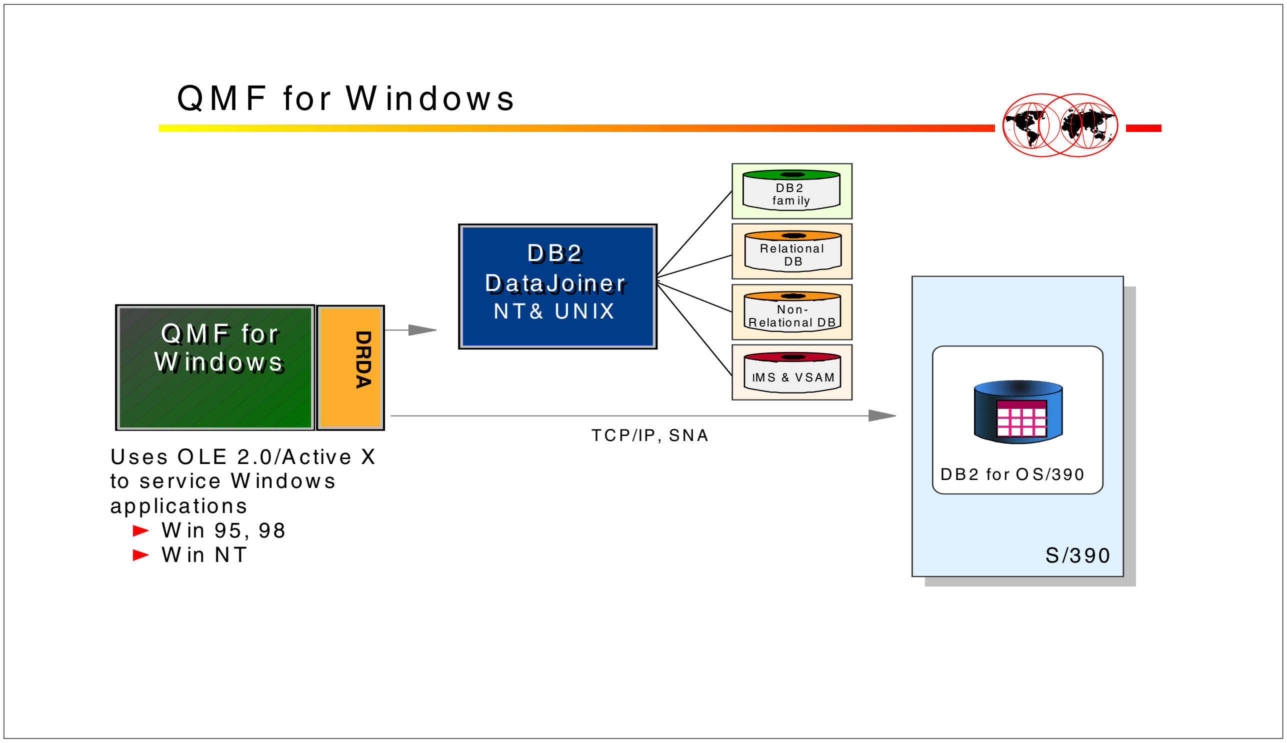
IBM's application solution on the S/390 platform is:

- Intelligent Miner for Relationship Marketing

7.1 Query and Reporting

IBM’s query and reporting tools on S/390 include the QMF Family, Lotus Approach and Lotus 123. We are showing here the examples of QMF for Windows and Lotus Approach.

7.1.1 QMF for Windows



QMF for Windows

Uses OLE 2.0/Active X to service Windows applications

- Win 95, 98
- Win NT

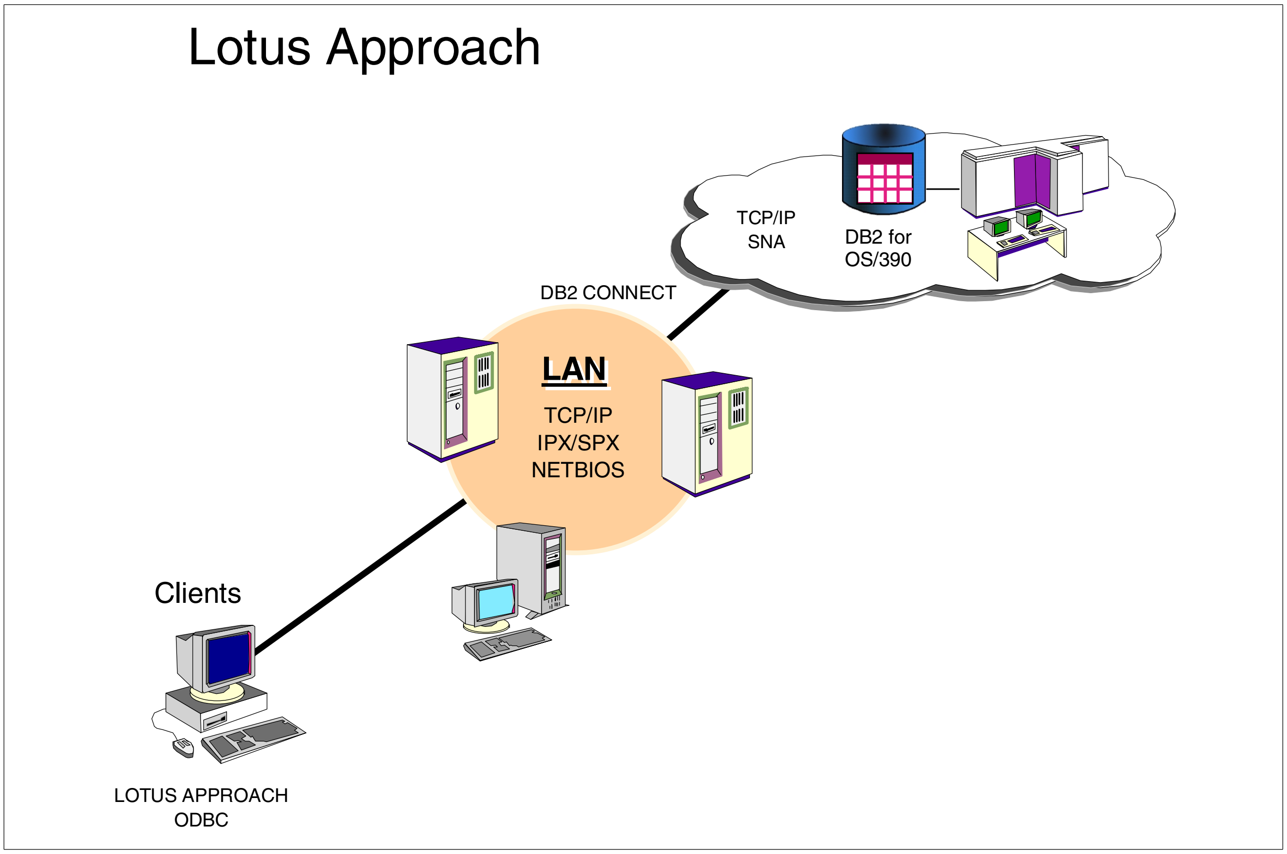
QMF on S/390 has been used for many years as a host-based query and reporting tool. More recently, IBM introduced a native Windows version of QMF that allows Windows clients to access the DB2 data warehouse on S/390.

QMF for Windows transparently integrates with other Windows applications. S/390 data warehouse data accessed through QMF for Windows can be passed to other Windows applications such as Lotus 1-2-3, Microsoft Excel, Lotus Approach, and many other desktop products using Windows Object Linking and Embedding (OLE).

QMF for Windows connects to the S/390 using native TCP/IP or SNA networks. QMF for Windows has built-in features that eliminate the need to install separate database gateways, middleware and ODBC drivers. For example, it does not require DB2 Connect because the DRDA connectivity capabilities are built into the product. QMF for Windows has a built-in Call Level Interface (CLI) driver to connect to the DB2 data warehouse on S/390.

QMF for Windows can also work with DataJoiner to access any relational and non-relational (IBM and non-IBM) databases and join their data with S/390 data warehouse data.

7.1.2 Lotus Approach

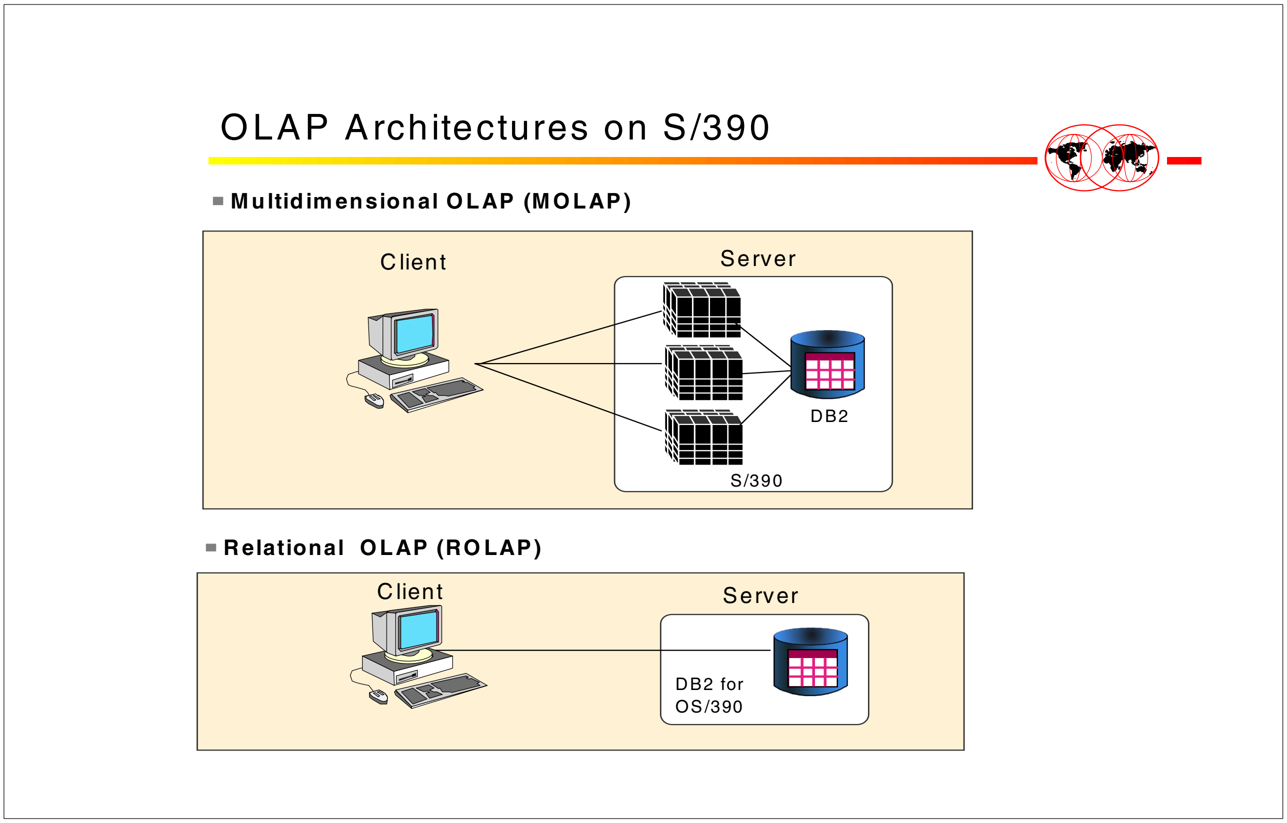


Lotus Approach is IBM’s desktop relational DBMS query tool, which has gained popularity due to its easy-to-use query and reporting capabilities. Lotus Approach can act as a client to a DB2 for OS/390 data server and its query and reporting capabilities can be used to query and process the DB2 data warehouse on S/390.

With Lotus Approach, you can pinpoint exactly what you want, quickly and easily. Queries are created in intuitive fashion by typing criteria into existing reports, forms, or worksheets. You can also organize and display a variety of summary calculations, including totals, counts, averages, minimums, variances and more.

The SQL Assistant guides you through the steps to define and store your SQL queries. You can execute your SQL against the DB2 for OS/390 and call existing SQL stored procedures located in DB2 on S/390.

7.2 OLAP architectures on S/390



OLAP Architectures on S/390

- Multidimensional OLAP (MOLAP)

- Relational OLAP (ROLAP)

There are two prominent architectures for OLAP systems: Multidimensional OLAP (MOLAP) and Relational OLAP (ROLAP). Both are supported by the S/390.

MOLAP

The main premise of MOLAP architecture is that data is presummarized, precalculated and stored in multidimensional file structures or relational tables. This precalculated and multidimensional structured data is often referred to as a “cube”. The precalculation process includes data aggregation, summarization, and index optimization to enable quick response time. When the data is updated, the calculations have to be redone and the cube should be recreated with the updated information. MOLAP architecture prefers a separate cube to be built for each OLAP application.The cube is not ready for analysis until the calculation process has completed. To achieve the highest performance, the cube should be precalculated, otherwise calculations will be done at data access time, which may result in slower response time.

The cube is external to the data warehouse. It is a subject-oriented extract or summarized data, where all business matrixes are precalculated and stored for multidimensional analysis, like a subject-oriented data mart. The source of the data may be any operational data store, data warehouse, spread sheets, or flat files.

MOLAP tools are designed for business analysts who need rapid response to complex data analysis with multidimensional calculations. These tools provide excellent support for high-speed multidimensional analysis.

DB2 OLAP Server is an example of MOLAP tools that run on S/390.

ROLAP

ROLAP architecture eliminates the need for multidimensional structures by accessing data directly from the relational tables of a data mart. The premise of ROLAP is that OLAP capabilities are best provided directly against the relational data mart. It provides a multidimensional view of the data that is stored in relational tables. End users submit multidimensional analyses to the ROLAP engine, which then dynamically transforms the requests into SQL execution plans. The SQL is submitted to the relational data mart for processing, the relational query results are cross-tabulated, and a multidimensional result set is returned to the end user.

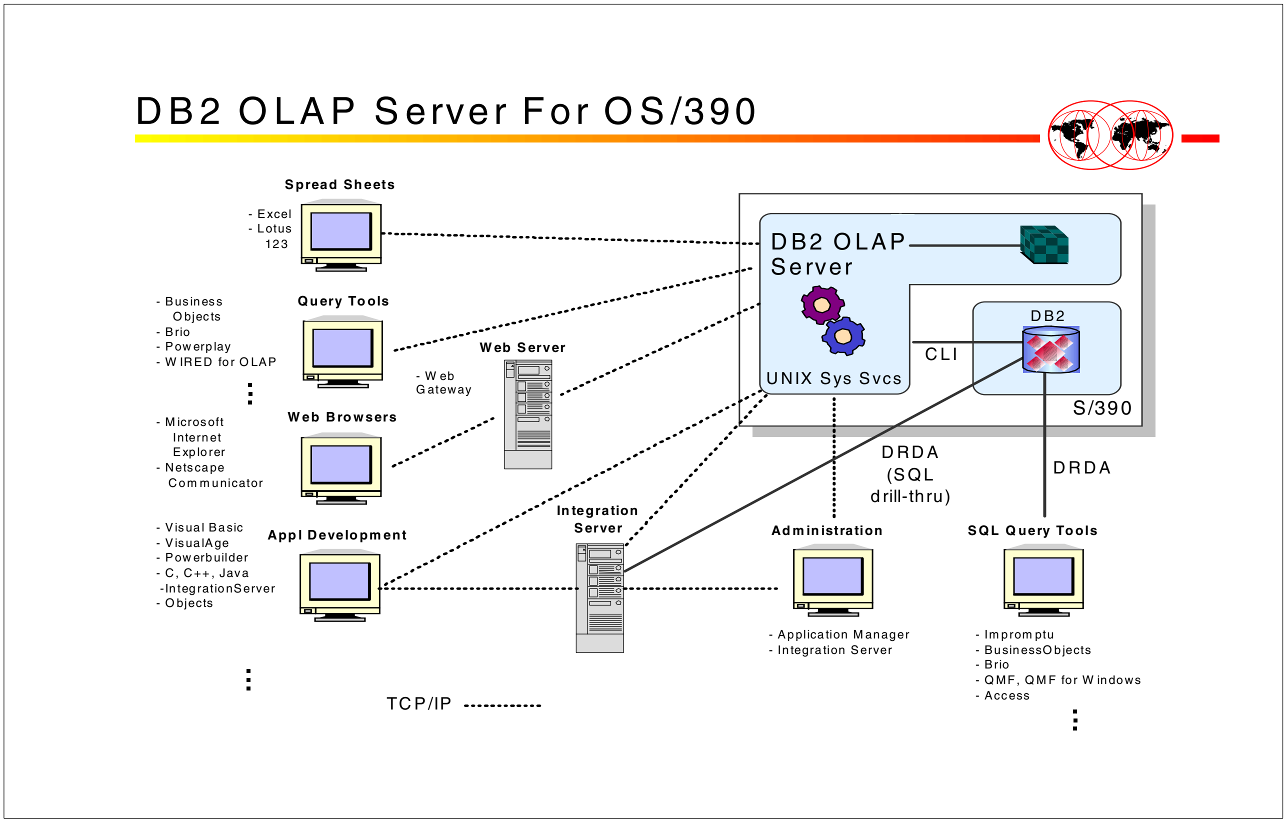
ROLAP tools are also very appropriate to support the complex and demanding requirements of business analysts.

IBM business partner Microstrategy's DSS Agent is an example of a ROLAP tool.

DOLAP

DOLAP stands for Desktop OLAP, which refers to desktop tools, such as Brio Enterprise from Brio Technology, and Business Objects from Business Objects. These tools require the result set of a query to be transmitted to the fat client platform on the desktop; all OLAP calculations are then performed on the client.

7.2.1 DB2 OLAP Server for OS/390


DB2 OLAP Server For OS/390

DB2 OLAP Server for OS/390 is a MOLAP tool. It is based on the market-leading Hyperion Essbase OLAP engine and can be used for a wide range of management, reporting, analysis, planning, and data warehousing applications.

DB2 OLAP Server for OS/390 employs the widely accepted Essbase OLAP technology and APIs supported by over 350 business partners and over 50 tools and applications.

DB2 OLAP Server for OS/390 runs on UNIX System Services of OS/390. The server for OS/390 offers the same functionality as the workstation product.

DB2 OLAP Server for OS/390 features the same functional capabilities and interfaces as Hyperion Essbase, including multi-user read and write access, large-scale data capacity, analytical calculations, flexible data navigation, and consistent and rapid response time in network computing environments.

DB2 OLAP Server for OS/390 offers two options to store data on the server:

- The Essbase proprietary database
- The DB2 relational database for SQL access and system management convenience

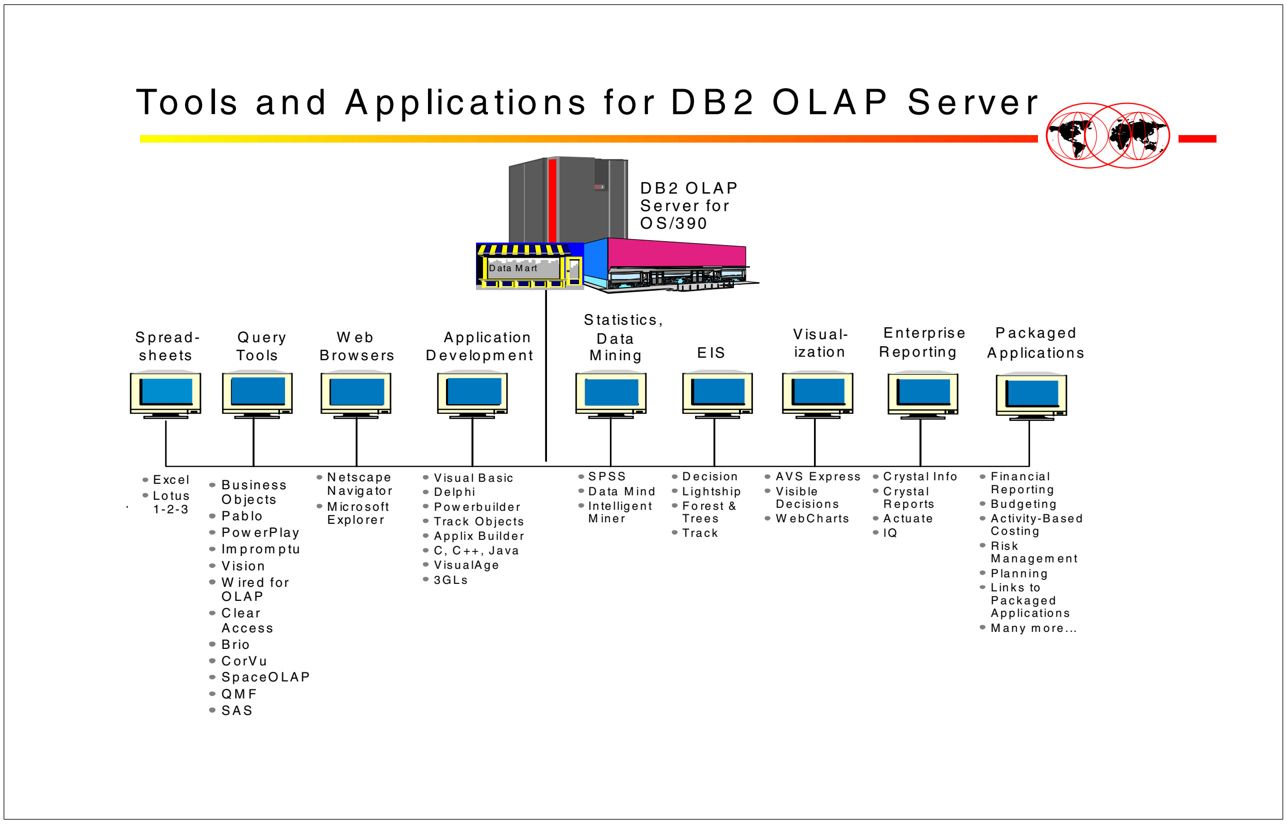
The storage manager of DB2 OLAP Server integrates the powerful DB2 relational technology and offers the following functional characteristics:

- Automatically designs, creates and maintains star schema.
- Populates star schema with calculated data.
- Does not require DBAs to create and populate star schema.
- Is optimal for attribute-based, value-based queries or analysis requiring joins.

With the OLAP data marts on S/390, you have the advantages of:

- Minimizing the cost and effort of moving data to other servers for analysis
- Ensuring high availability of your mission-critical OLAP applications
- Using WLM to dynamically and more effectively balance system resources between the data warehouse and your OLAP data marts (see 8.10, “Data warehouse and data mart coexistence” on page 157)
- Allowing connection of a large number of users to the OLAP data marts
- Using existing S/390 platform skills

7.2.2 Tools and applications for DB2 OLAP Server



Tools and Applications for DB2 OLAP Server

Spreadsheets
- Excel
- Lotus 1-2-3

Query Tools
- Business Objects
- Pablo
- PowerPlay
- Impromptu
- Vision
- Wired for OLAP
- Clear Access
- Brio
- CorVu
- SpaceOLAP
- QMF
- SAS

Web Browsers
- Netscape Navigator
- Microsoft Explorer

Application Development
- Visual Basic
- Delphi
- Powerbuilder
- Track Objects
- Applix Builder
- C, C++, Java
- VisualAge
- 3GLs

Statistics, Data Mining
- SPSS
- Data Mind
- Intelligent Miner

EIS
- Decision
- Lightship
- Forest & Trees
- Track

Visualization
- AVS Express
- Visible Decisions
- WebCharts

Enterprise Reporting
- Crystal Info
- Crystal Reports
- Actuate
- IQ

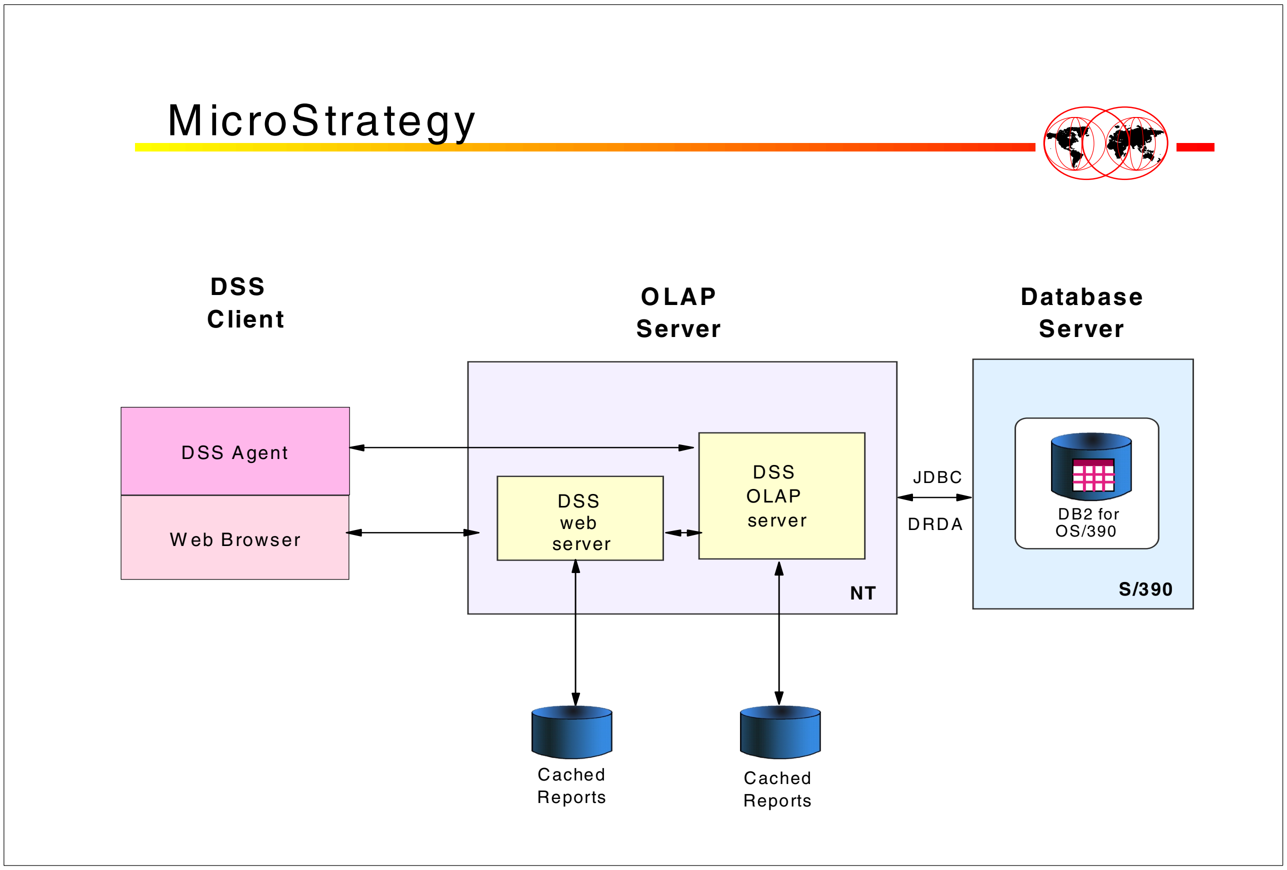
Packaged Applications
- Financial Reporting
- Budgeting
- Activity-Based Costing
- Risk Management
- Planning
- Links to Packaged Applications
- Many more...

DB2 OLAP Server for OS/390 uses the Essbase API, which is a comprehensive library of more than 300 Essbase OLAP functions. It is a platform for building applications used by many tools. All vendor products that support Essbase API can act as DB2 OLAP clients.

DB2 OLAP Server for OS/390 includes the spreadsheet client, which is desktop software that supports Lotus 1-2-3 and MS Excel. This enables seamless integration between DB2 OLAP Server for OS/390 and these spreadsheet tools.

Hyperion Wired for OLAP is an additional license product. It is an OLAP analysis tool that gives users point-and-click access to advanced OLAP features. It is built on a 3-tier client/server architecture and gives access to DB2 OLAP Server for OS/390 either from a Windows client or a Web client. It also supports 100 percent pure Java.

7.2.3 MicroStrategy



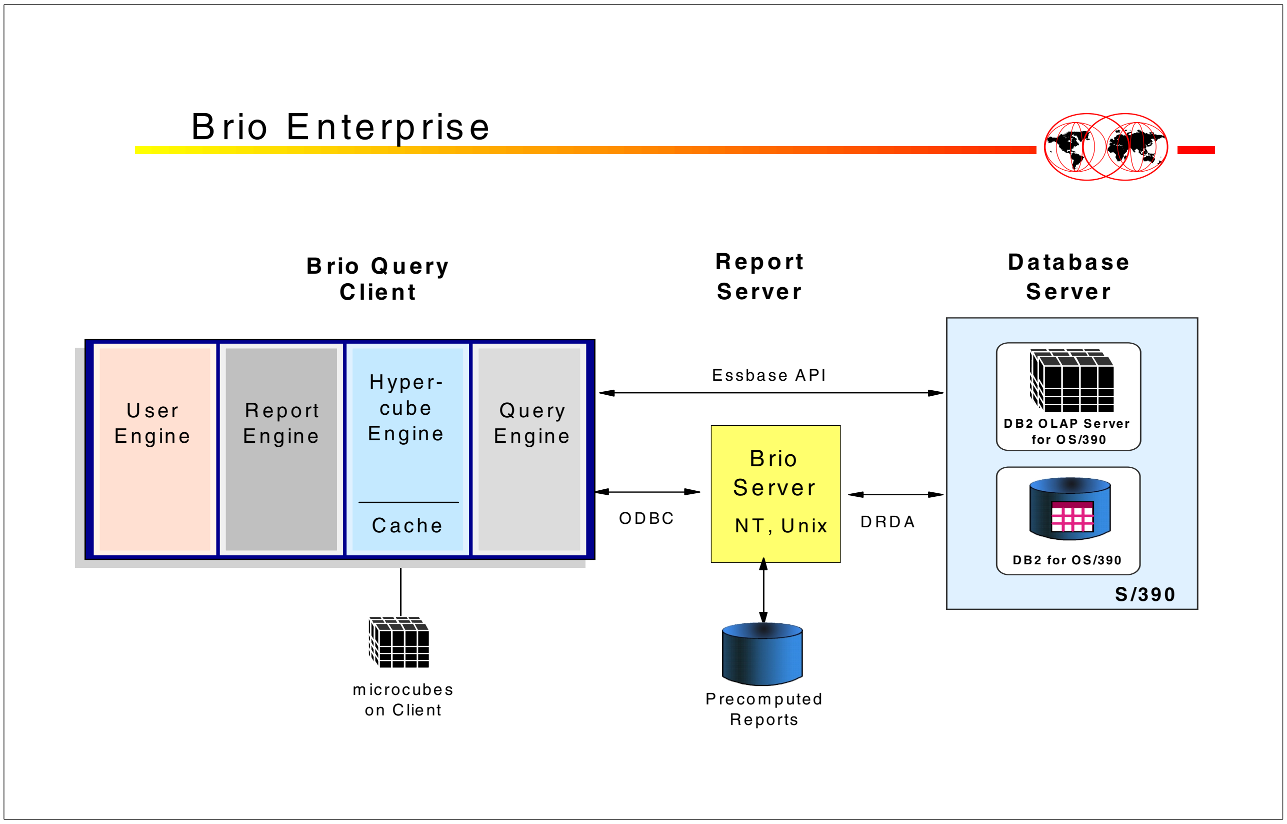
MicroStrategy DSS Agent is an ROLAP front-end tool. It offers some unique strengths when coupled with a DB2 for OS/390 database; it uses multi-pass SQL and temporary tables to solve complex OLAP problems, and it is aggregate aware.

DSS Agent, which is the client component of the product, runs in the Windows environments (Windows 3.1, Windows 95 or Windows NT). DSS Server, which is used to control the number of active threads to the database and to cache reports, runs on Windows NT servers.

The DSS Web server receives SQL from the browser (client) and passes the statements to the OLAP server through Remote Procedure Call (RPC), which then forwards them to DB2 for OS/390 for execution using ODBC/JDBC protocol. In addition, the actual metadata is housed in the same DB2 for OS/390.

To improve performance, report results may be cached in one of two places: on the Web server or the OLAP server. Some Web servers allow caching of predefined reports, ad hoc reports, and even drill reports, which are report results from drilling on a report. End users submit multidimensional analyses to the ROLAP engine, which then dynamically transforms the requests into SQL execution plans.

7.2.4 Brio Enterprise



Brio Enterprise

Brio Technology is one of IBM's key BI business partners.

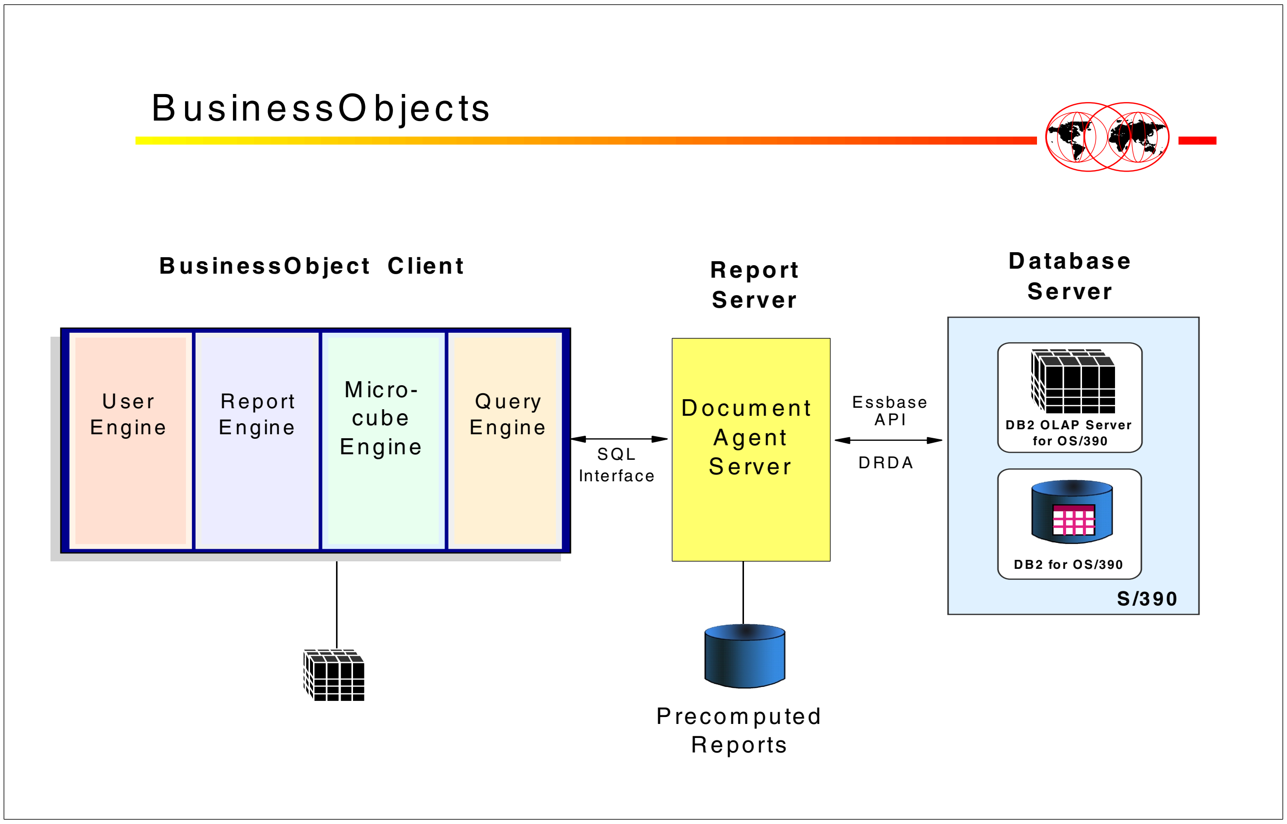
OLAP query

Brio provides an easy-to-use front end to the DB2 OLAP Server for OS/390. By fully exploiting the Essbase API, the OLAP query part of Brio displays the structure of the multidimensional database as a hierarchical tree.

Relational query

Relational query uses a visual view representing the DB2 data warehouse or data mart tables on S/390. Using DB2 Connect, the user can run ad hoc or predefined reports against data held in DB2 for OS/390. Relational query can be set up to run either as a 2-tier or 3-tier architecture. In a 3-tier architecture the middle server runs on NT or UNIX. Using a 3-tier solution, it is possible to store precomputed reports on the middle-tier server, which can be reused within a user community.

7.2.5 BusinessObjects



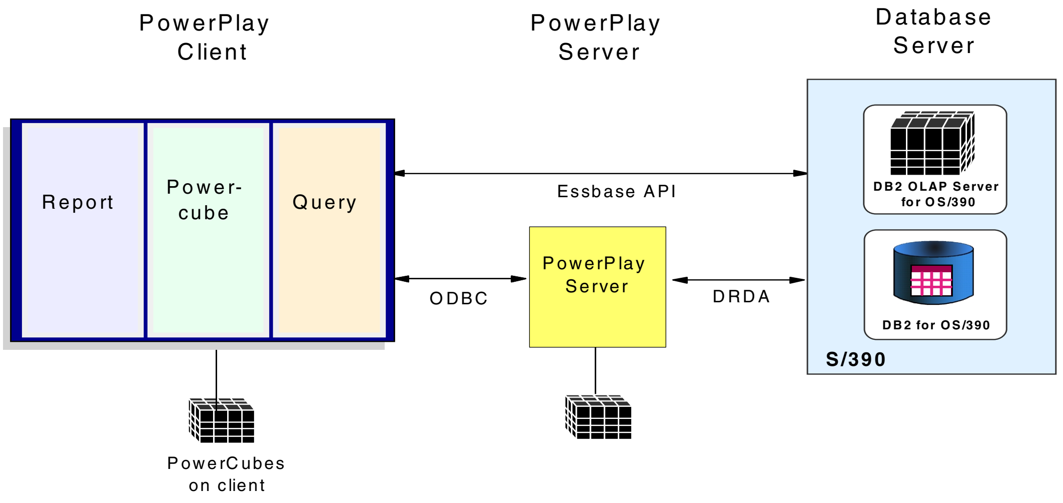
BusinessObjects is a key IBM business partner in the BI field. BusinessObjects DB2 OLAP access pack is a data provider that lets BusinessObjects users access DB2 OLAP server for OS/390.

BusinessObjects provides universe, which maps data in the database, so the users do not need to have any knowledge of the database because it has business terms that isolate the user from the technical issues of the database. Using DB2 Connect, BusinessObjects users can access DB2 for OS/390. On the LAN, BusinessObjects Documents, which consist of reports, can be saved on the Document server so these documents can be shared by other BusinessObjects users.

The structure that stores the data in the document is known as the microcube. One feature of the microcube is that it enables the user to display only the data the user wants to see in the report. Any non-displayed data is still present in the microcube, which means that the user can display only the data that is pertinent for the report.

7.2.6 PowerPlay

PowerPlay



Cognos PowerPlay is a multidimensional analysis tool from Cognos, a key IBM BI business partner. It includes the DB2 OLAP driver, which converts requests from PowerPlay into Essbase APIs to access the DB2 OLAP server for OS/390.

Powercubes can be populated from DB2 for OS/390 using DB2 Connect. Using PowerPlay’s transformation, these cubes can be built on the enterprise server that is running on NT or UNIX. With this middle-tier server, PowerPlay provides the rapid response for predictable queries directed to Powercubes.

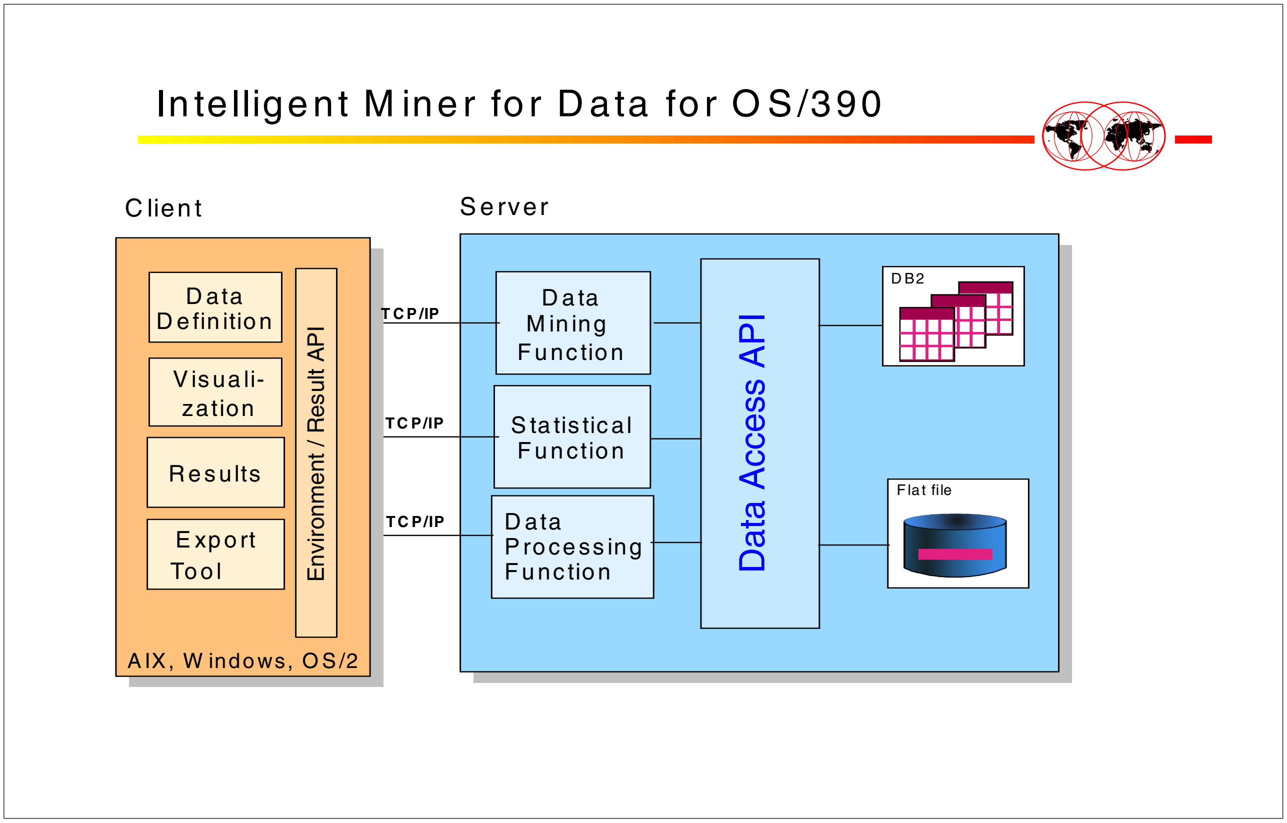
In addition, Powercubes can be stored on the client. They provide full access to Powercubes on the middle-tier server and the DB2 OLAP server for OS/390. The client can store and process OLAP cubes on the PC. When the client connects to the network, Powerplay automatically synchronizes the client’s cubes with the centrally managed cubes.

7.3 Data mining

IBM's data mining products for OS/390 are:

- Intelligent Miner for Data for OS/390
- Intelligent Miner for Text for OS/390

7.3.1 Intelligent Miner for Data for OS/390



Intelligent Miner for Data for OS/390 (IM) is IBM's data mining tool on S/390. It analyzes data stored in relational DB2 tables or flat files, searching for previously unknown, meaningful, and actionable information. Business analysts can use this information to make crucial business decisions.

IM supports an external API, allowing data mining results to be accessed by other application environments for further analysis, such as Intelligent Miner for Relationship Marketing and DecisionEdge.

IM is based on a client/server architecture and mines data directly from DB2 tables as well as from flat files on OS/390. The supported clients are Windows 95/98/NT, AIX and OS/2.

IM has the ability to handle large quantities of data, present results in an easy-to-understand fashion, and provide programming interfaces. Increasing numbers of mining applications that deploy mining results are being developed.

A user-friendly GUI enables users to visually design data mining operations using the data mining functions provided by IM.

Data mining functions

All data mining functions can be customized using two levels of expertise. Users who are not experts can accept the defaults and suppress advanced settings. Experienced users who want to fine-tune their application have the ability to customize all settings according to their requirements.

The algorithms for IM are categorized as follows:

- Associations
- Sequential patterns
- Clustering
- Classification
- Prediction
- Similar time sequences

Statistical functions

After transforming the data, statistical functions facilitate the analysis and preparation of data, as well as providing forecasting capabilities. Statistical functions included are:

- Factor analysis
- Linear regression
- Principal component analysis
- Univariate curve fitting
- Univariate and bivariate statistics

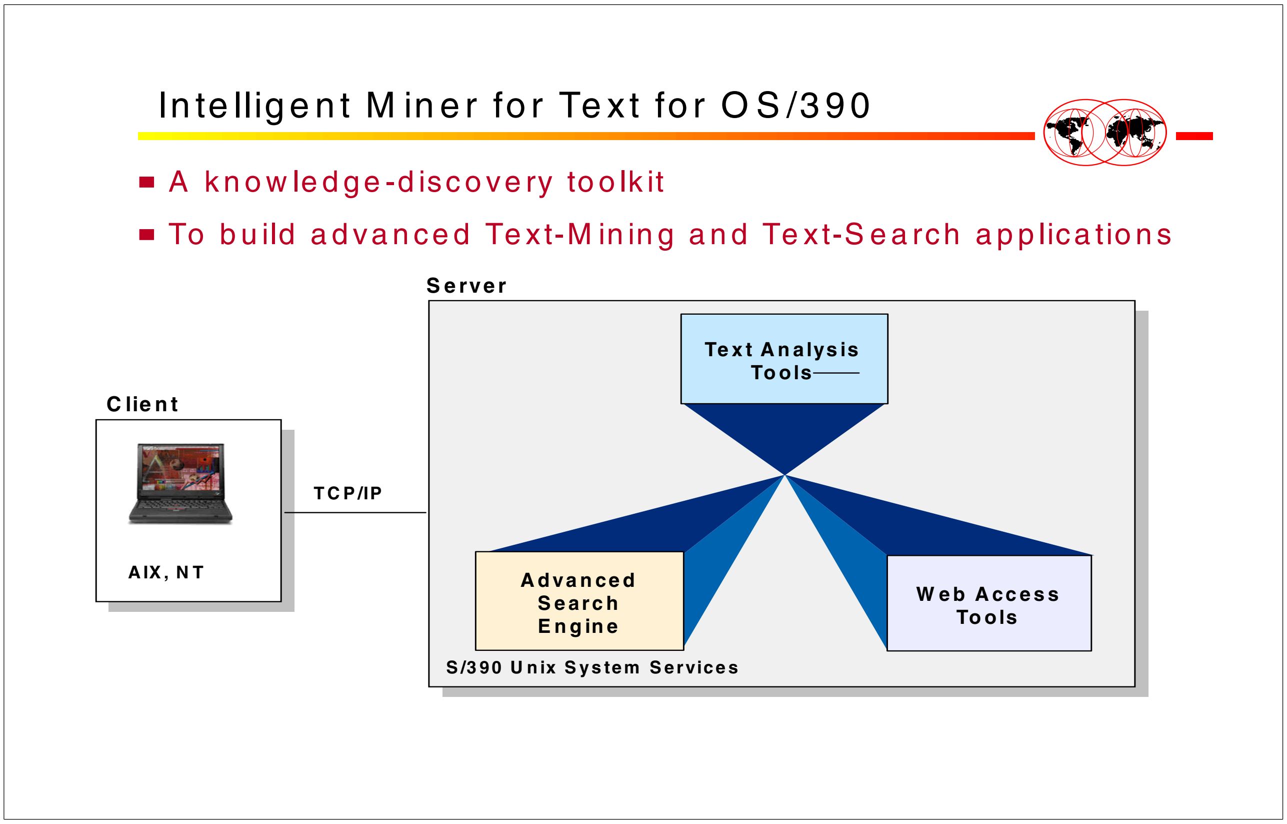
Data processing functions

Once the desired input data has been selected, it is usually necessary to perform certain transformations on the data. IM provides a wide range of data processing functions that help to quickly load and transform the data to be analyzed.

The following components are client components running on AIX, OS/2 and Windows.

- Data Definition is a feature that provides the ability to collect and prepare the data for data mining processing.
- Visualization is a client component that provides a rich set of visualization tools; other vendor visualization tools can be used.
- Mining Result is the result from running a mining or statistics function.
- Export Tool can export the mining result for use by visualization tools.

7.3.2 Intelligent Miner for Text for OS/390



Intelligent Miner for Text for OS/390

- A knowledge-discovery toolkit
- To build advanced Text-Mining and Text-Search applications

Intelligent Miner for Text is a knowledge discovery software development toolkit. It provides a wide range of sophisticated text analysis tools, an extended full-text search engine, and a Web Crawler to enrich business intelligence solutions.

Text analysis tools
Text analysis tools automatically identify the language of a document, create clusters as logical views, categorize and summarize documents, and extract relevant textual information, such as proper names and multi-word terms.

TextMiner
TextMiner is an advanced text search engine, which provides basic text search, enhanced with mining functionality and the capability to visualize results.

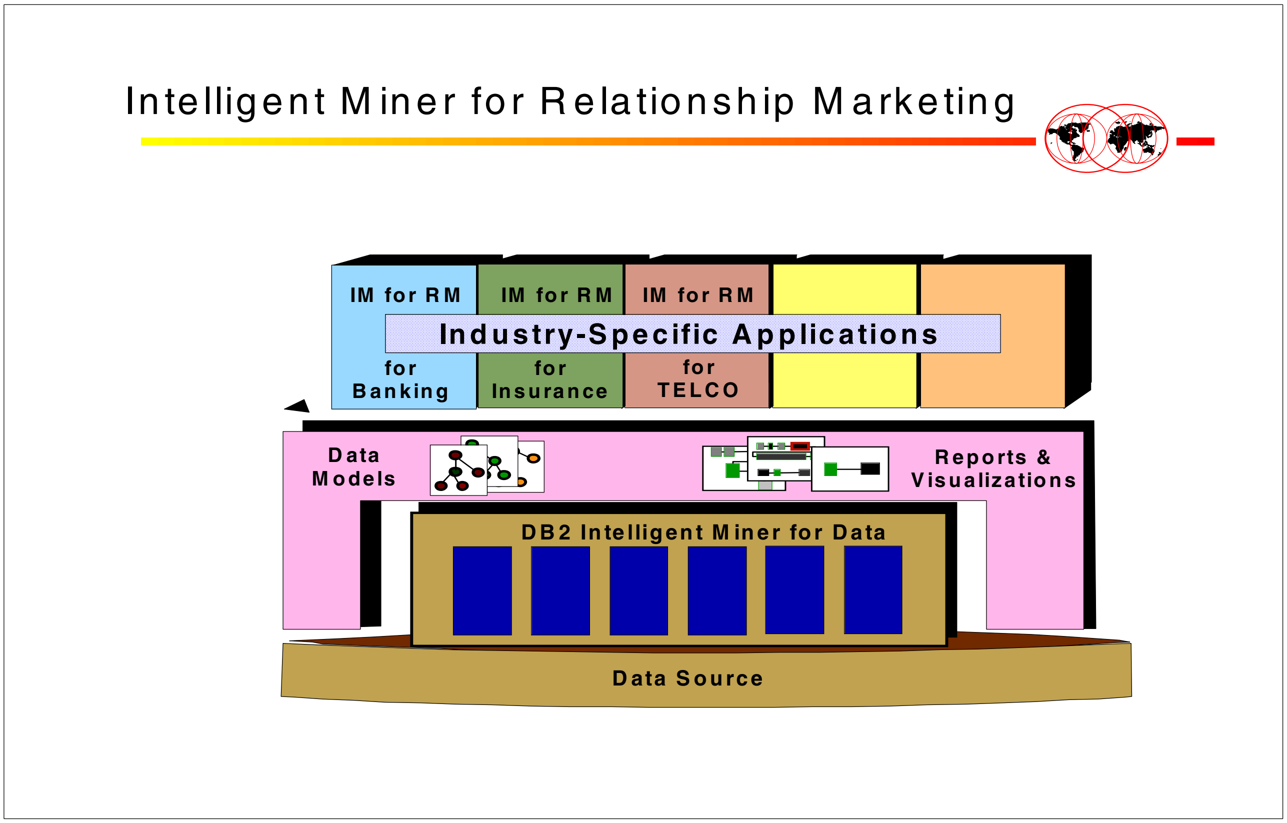
NetQuestion, Web Crawler, Web Crawler toolkit
These Web access tools complement the text analysis toolkit. They help develop text mining and knowledge management solutions for the Inter/intranet Web environments. These tools contain leading-edge algorithms developed at IBM Research and in cooperation with customer projects.

7.4 Application solutions

IBM has complete packaged application solutions including hardware, software, and services to build customer-specific BI solutions. Intelligent Miner for Relationship Marketing is IBM's application solution on S/390.

There are also ERP warehouse application solutions which run on S/390, such as SAP Business Warehouse (BW), and PeopleSoft Enterprise Performance Management (EPM). This section describes these applications.

7.4.1 Intelligent Miner for Relationship Marketing



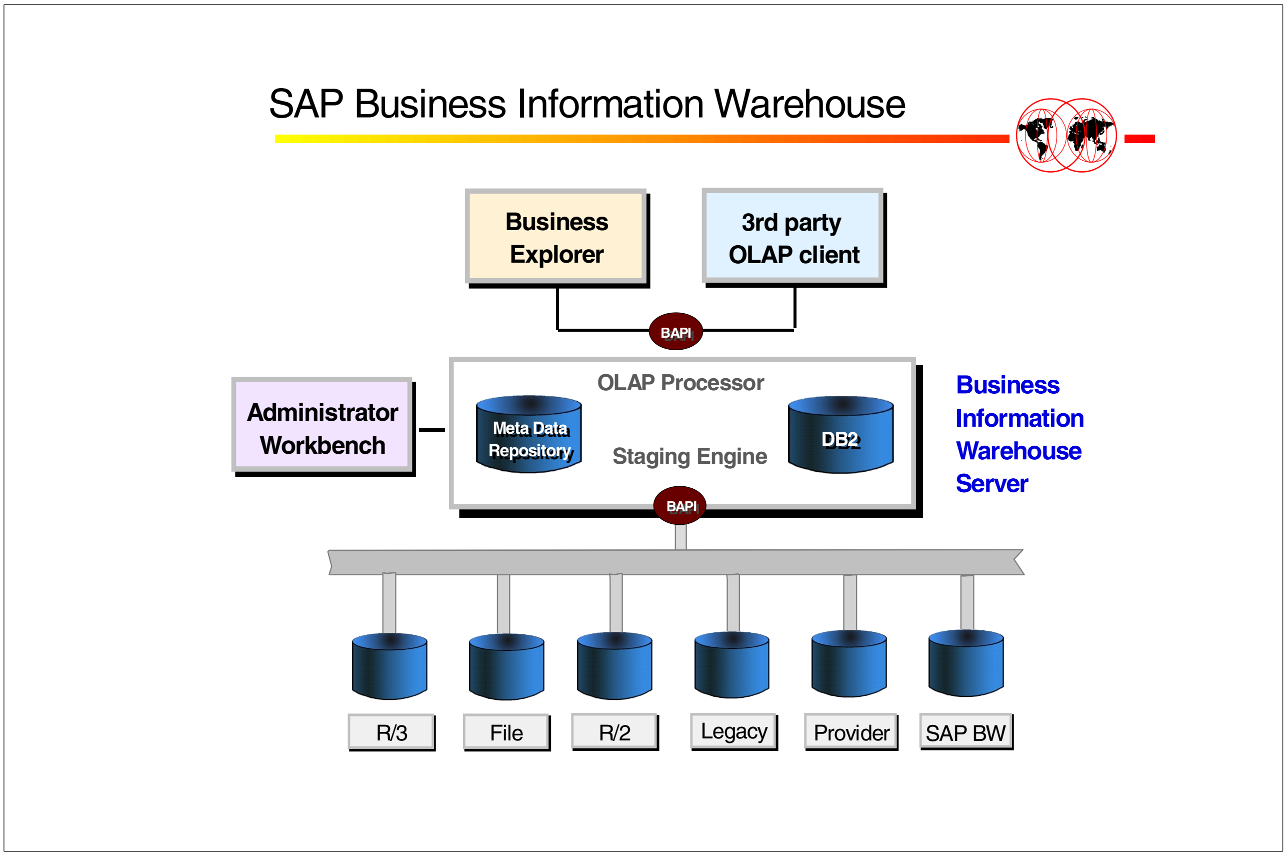
Intelligent Miner for Relationship Marketing (IMRM) is a complete, end-to-end data mining solution featuring IBM's Intelligent Miner for Data. It includes a suite of industry- and task-specific customer relationship marketing applications, and an easy-to-use interface designed for marketing professionals.

IMRM enables the business professional to improve the value, longevity, and profitability of customer relationships through highly effective, precisely-targeted marketing campaigns. With IMRM, marketing professionals discover insights into their customers by analyzing customer data to reveal hidden trends and patterns in customer characteristics and behavior that often go undetected with the use of traditional statistics and OLAP techniques.

IMRM applications address four key customer relationship challenges for the Banking, Telecommunications and Insurance industries:

- Customer acquisition - Indentifying and capturing the most desirable prospects
- Attrition - Identifying those customers at greatest risk of defecting
- Cross-selling - Determining those customers who are most likely to buy multiple products or services from the same source
- Win-back - Regaining desirable customers who have previously defected

7.4.2 SAP Business Information Warehouse



SAP Business Information Warehouse is a relational and OLAP-based data warehousing solution, which gathers and refines information from internal SAP and external non-SAP sources.

On S/390, SAP applications used to run on 3-tier physical implementations where the application server was on a UNIX platform and the database server was on S/390.

The trend today is to port the SAP applications to S/390 and run the solutions in 2-tier physical implementations. SAP-R3 (OLTP application) is already ported to S/390. SAP-BW is also expected to be ported to S/390 in the near future.

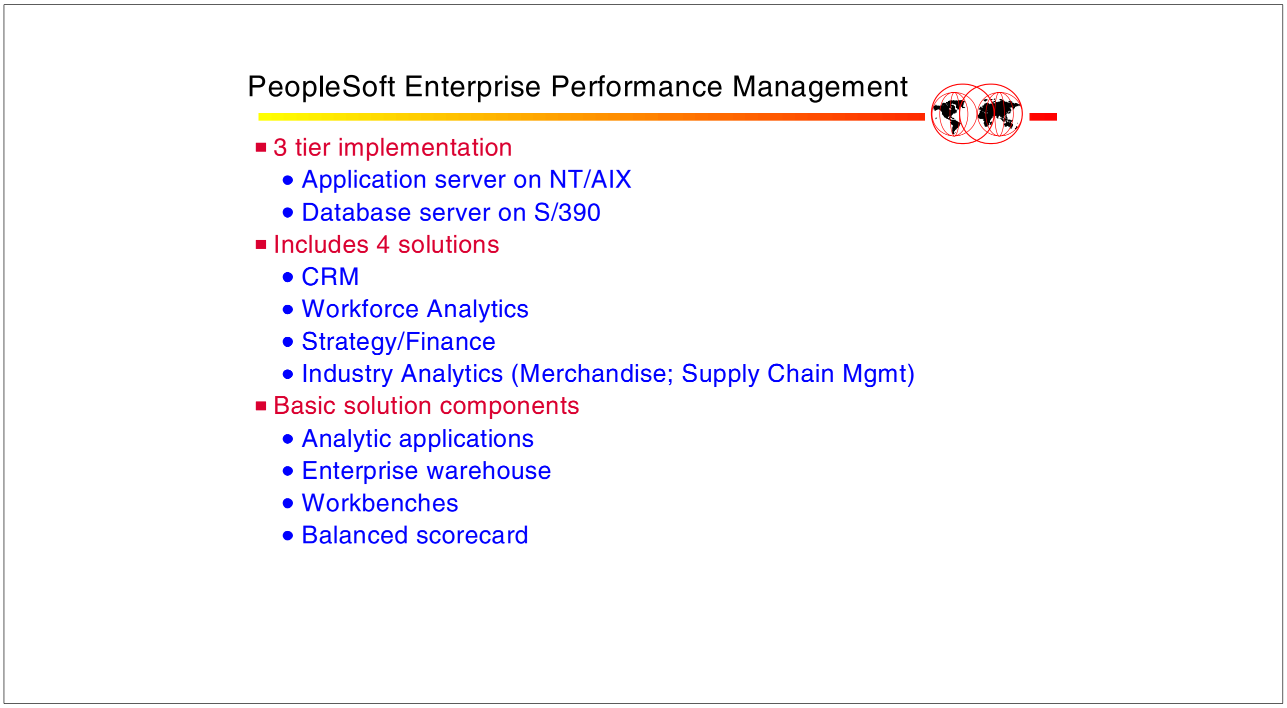
SAP Business Information Warehouse includes the following components:

- Business Content - includes a broad range of predefined reporting templates geared to the specific needs of particular user types, such as production planners, financial controllers, key account managers, product managers human resources directors, and others.
- Business Explorer - includes a wide variety of prefabricated information models (InfoCubes), reports, and analytical capabilities. These elements are tailored to the specific needs of individual knowledge workers in your industry.
- Business Explorer Analyzer - The Analyzer lets you define the information and key figures to be analyzed within any InfoCube. Then, it automatically creates

the appropriate layout for your report and gathers information from the InfoCube's entire dataset.

- Administrator Workbench - ensures user-friendly GUI-based data warehouse management.

7.4.3 PeopleSoft Enterprise Performance Management



PeopleSoft Enterprise Performance Management

- 3 tier implementation
  - Application server on NT/AIX
  - Database server on S/390
- Includes 4 solutions
  - CRM
  - Workforce Analytics
  - Strategy/Finance
  - Industry Analytics (Merchandise; Supply Chain Mgmt)
- Basic solution components
  - Analytic applications
  - Enterprise warehouse
  - Workbenches
  - Balanced scorecard

PeopleSoft Enterprise Performance Management (EPM) integrates information from outside and inside your organization to help measure and analyze your performance.

The application runs in a 3-tier physical implementation where the application server is on NT or AIX and the database server is on S/390 DB2.

PeopleSoft EPM includes the following solutions:

- Customer Relationship Management - provides in-depth analysis of essential customer insights: customer profitability, buying patterns, pre- and post-sales behavior, and retention factors.
- Workforce Analytics - aligns the workforce with organizational objectives.
- Strategy/Finance - Measures, analyzes, and communicates strategic and financial objectives.
- Industry Analytics - Focuses on processes that deliver a key strategic advantage within specific industries. For instance, it enables organizations to analyze supply chain structures, including inventory and procurement, to determine current efficiencies and to design optimal structures.

The basic components of those solutions are:

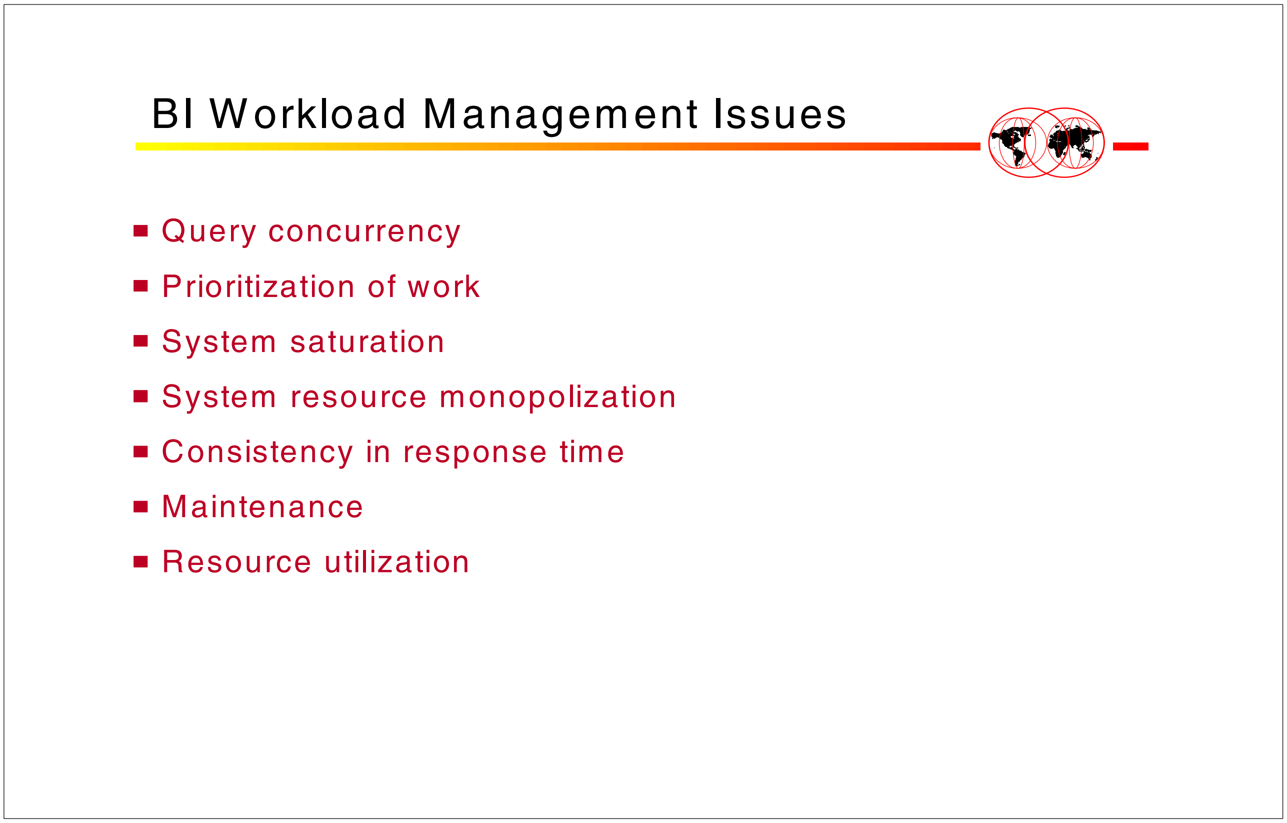
- Analytic applications
- Enterprise warehouse
- Workbenches
- Balanced scorecard

Chapter 8. BI workload management

BI Workload Management

This chapter discusses the need for a workload manager to manage BI workloads. We discuss OS/390 WLM capabilities for dynamically managing BI mixed workloads, BI and transactional workloads, and DW and DM workloads on the same S/390.

8.1 BI workload management issues



BI Workload Management Issues

- Query concurrency
- Prioritization of work
- System saturation
- System resource monopolization
- Consistency in response time
- Maintenance
- Resource utilization

Installations today process different types of work with different completion and resource requirements. Every installation wants to make the best use of its resources, maintain the highest possible throughput, and achieve the best possible system response.

In an Enterprise Data Warehouse (EDW) environment with medium to large and very large databases, where queries of different complexities run in parallel and resource consumption continuously fluctuates, managing the workload becomes extremely important. There are a number of situations that make managing difficult, all of which should be addressed to achieve end-to-end workload management. Among the issues to consider are the following:

- Query concurrency

  When large volumes of concurrent queries are executing, the system must be flexible enough to handle throughput. The amount of concurrency is not always known at a point in time, so the system should be able to deal with the throughput without having to reconfigure system parameters.

- Prioritization of work

  High priority work has to be able to complete in a timely fashion without totally impeding other users. That is, the system should be able to accept new work and shift resources to accommodate the new workload. If not, high priority jobs may run far too long or not at all.

- System saturation

  System saturation can be reached quickly if a large number of users suddenly inundate system resources. However, the system must be able to maintain throughput with reasonable response times. This is especially important in an EDW environment where the number of users may vary considerably.

- System resource monopolization

  If "killer" queries enter your system without proper resource management controls in place, they can quickly consume system resources and cause drastic consequences for the performance of other work in the system. Not only is time wasted by administrative personnel to cancel the "killer" query, but these queries result in excessive waste of system resources. You should consider using the predictive governor in DB2 for OS/390 Version 6 if you want to prevent the execution of such a query.

- Consistency in response time

  Performance is key to any EDW environment. Data throughput and response time must always remain as consistent as possible regardless of the workload. Queries that are favored because of a business need should not be impacted by an influx of concurrent users. The system should be able to balance the work load to ensure that the critical work gets done in a timely fashion.

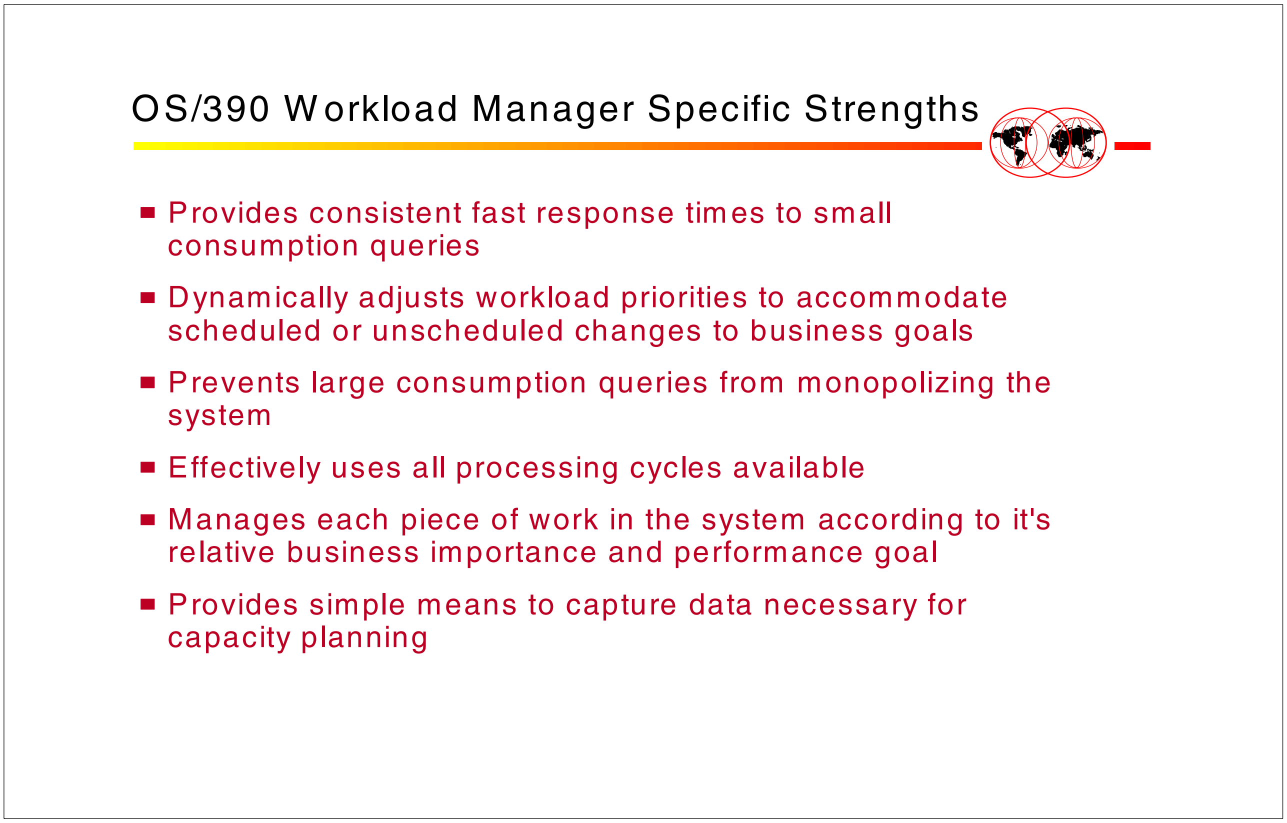
- Maintenance

  Refreshes and/or updates must occur regularly, yet end users need the data to be available as much as possible. Therefore, it is important to be able to run online utilities that do not have a negative impact. The ability to favor one workload over the other should be available, especially at times when a refresh may be more important than query work.

- Resource utilization

  It is important to utilize the full capacity of the system as efficiently as possible, reducing idle time to a minimum. The system should be able to respond to dynamic changes to address immediate business needs. OS/390 has the unique capability to guarantee the allocation of resources based on business priorities.

8.2 OS/390 Workload Manager specific strengths



OS/390 Workload Manager Specific Strengths

- Provides consistent fast response times to small consumption queries
- Dynamically adjusts workload priorities to accommodate scheduled or unscheduled changes to business goals
- Prevents large consumption queries from monopolizing the system
- Effectively uses all processing cycles available
- Manages each piece of work in the system according to it's relative business importance and performance goal
- Provides simple means to capture data necessary for capacity planning

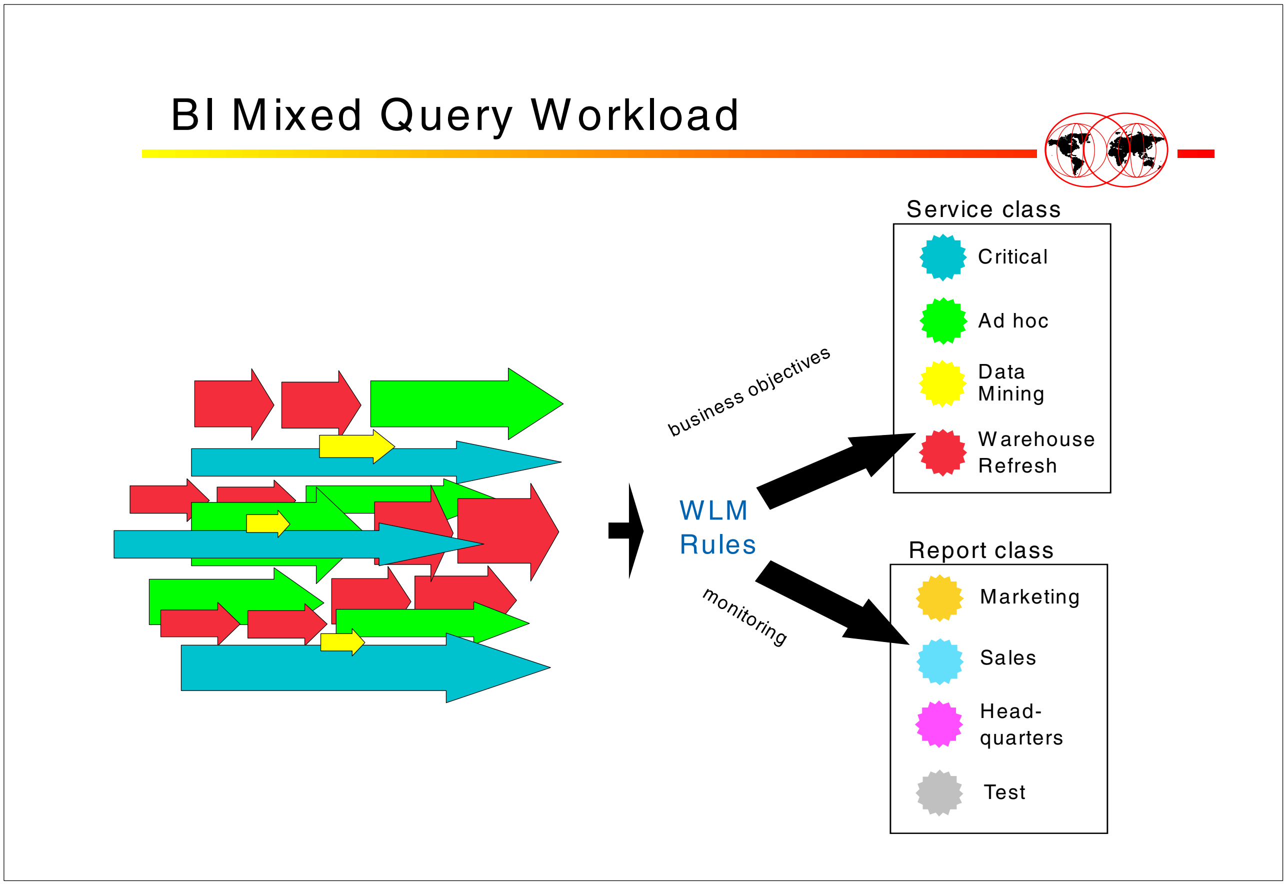
WLM, which is an OS/390 component, provides exceptional workload management capabilities.

WLM achieves the needs of workloads (response time) by appropriately distributing resources such that all resources are fully utilized. Equally important, WLM maximizes system use (throughput) to deliver maximum benefit from the installed hardware and software.

WLM introduces a new approach to system management. Before WLM, the main focus was on resource allocation, not work management. WLM changed that perspective by introducing controls that are goal-oriented, work-related, and dynamic.

These features help you align your data warehouse goals with your business objectives.

8.3 BI mixed query workload



BI Mixed Query Workload

business objectives

WLM Rules

monitoring

Service class

- Critical
- Ad hoc
- Data Mining
- Warehouse Refresh

Report class

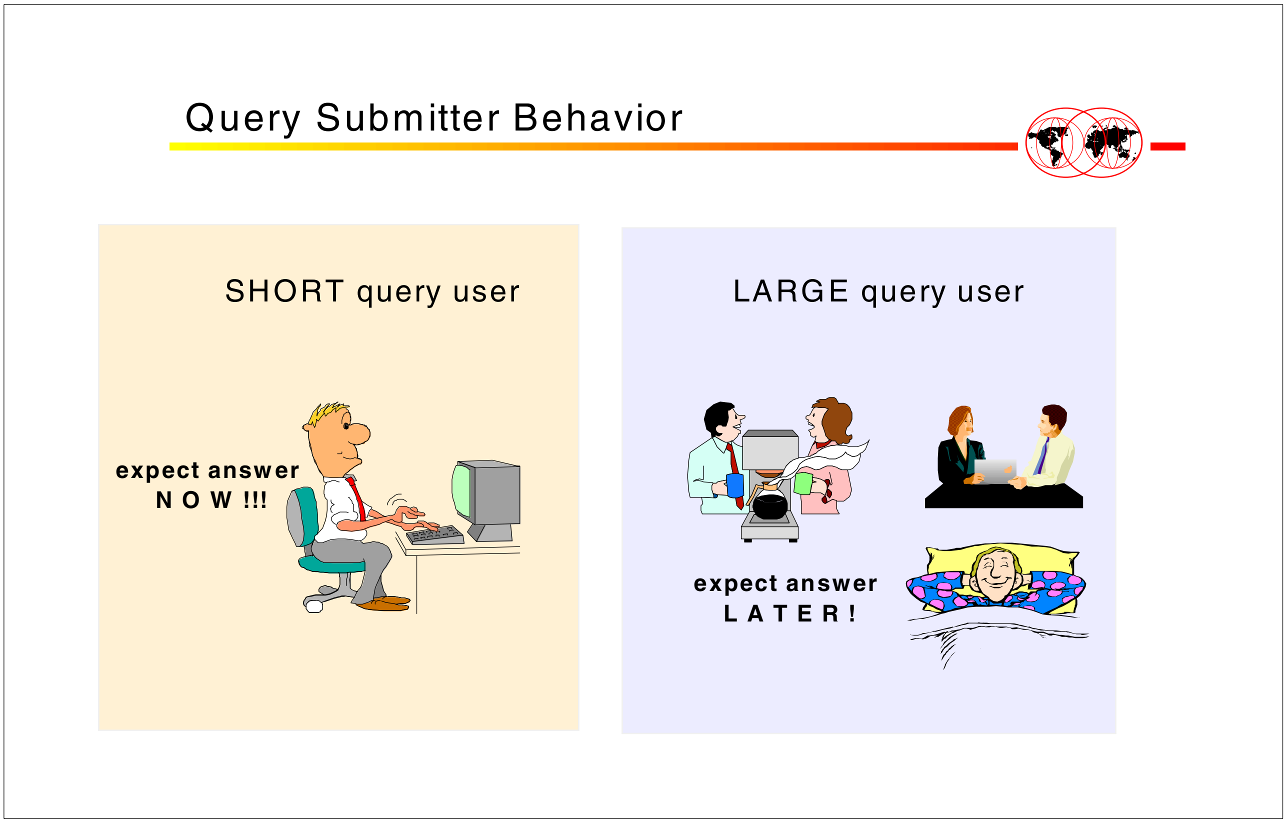
- Marketing
- Sales
- Head-quarters
- Test

BI workloads are heterogeneous in nature, including several kinds of queries:

- *Short queries* are typically those that support real-time decision making. They run in seconds or milliseconds; some examples are call center or internet applications interacting directly with customers.
- *Medium queries* run for minutes, generally less than an hour; they support same day decision making, for example credit approvals being done by a loan officer.
- *Long-running reporting and complex analytical queries*, such as data mining and multi-phase drill-down analysis used for profiling, market segmentation and trend analysis, are the queries that support strategic decision making.

If resources were unlimited, all of the queries would run in subsecond timeframes and there would be no need for prioritization. In reality, system resources are finite and must be shared. Without controls, a query that processes a lot of data and does complex calculations will consume as many resources as become available, eventually shutting out other work until it completes. This is a real problem in UNIX systems, and requires distinct isolation of these workloads on separate systems, or on separate shifts. However, these workloads can run harmoniously on DB2 for OS/390. OS/390's unique workload management function uses business priorities to manage the sharing of system resources based on business needs. Business users establish the priorities of their processes and IT sets OS/390's Workload Manager parameters to dynamically allocate resources to meet changing business needs. So, the call center will continue to get subsecond response times, even when a resource-intensive analytical query is running.

8.4 Query submitter behavior



Query Submitter Behavior

SHORT query user

expect answer
NOW !!!

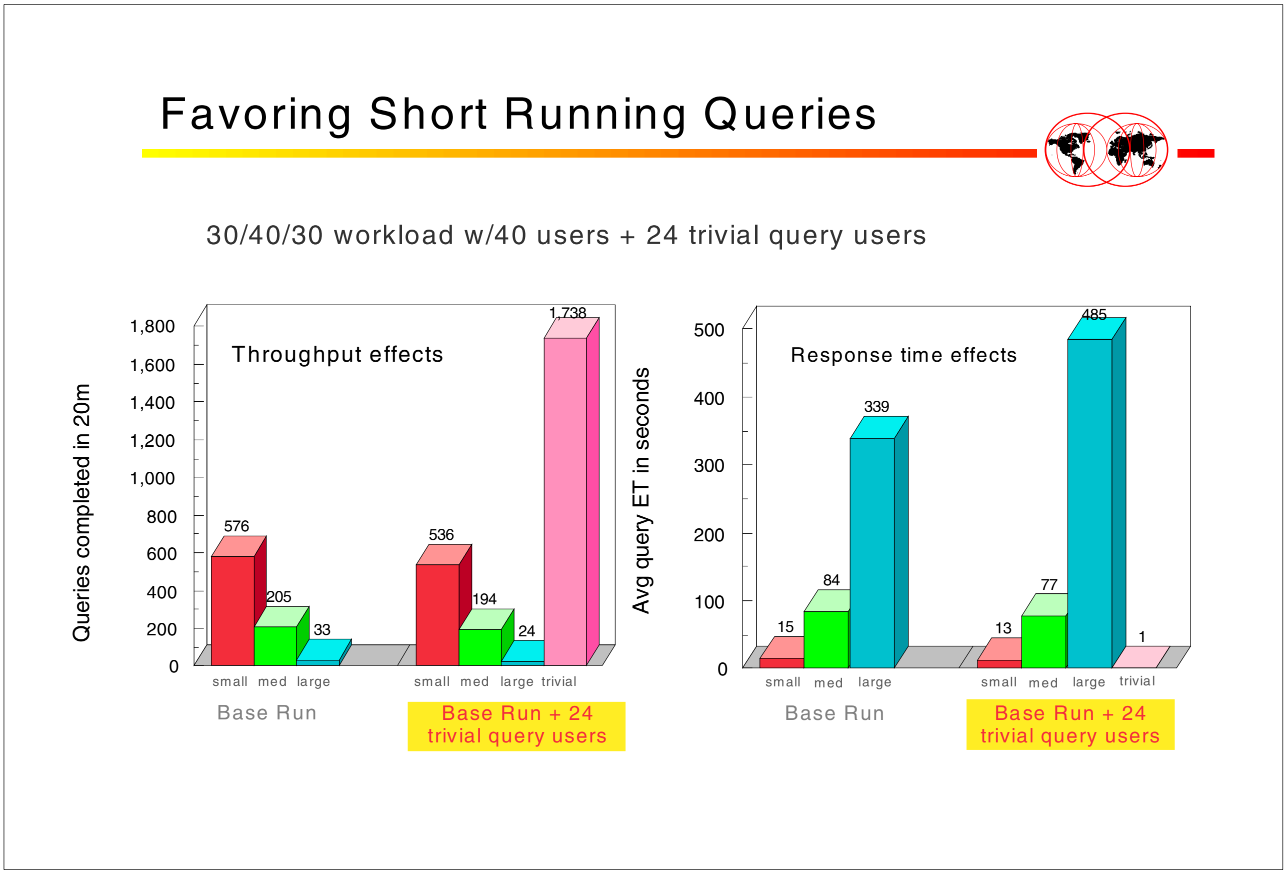
LARGE query user

expect answer
LATER!

Short-running queries can be likened to an end user who waits at a workstation for the response, while long-running queries can be likened to an end user who checks query results at a later time (perhaps later in the day or even the next day).

The submitters of trivial and small queries expect a response immediately. Delays in response times are most noticeable to them. The submitters of queries that are expected to take some time are less likely to notice an increase in response time.

8.5 Favoring short running queries



Favoring Short Running Queries

30/40/30 workload w/40 users + 24 trivial query users

Certainly, in most installations, very short running queries need to execute with longer running queries.

How do you manage response time when queries with such diverse processing characteristics compete for system resources at the same time? And how do you prevent significant elongation of short queries for end users who are waiting at their workstations for responses, when large queries are competing for the same resources?

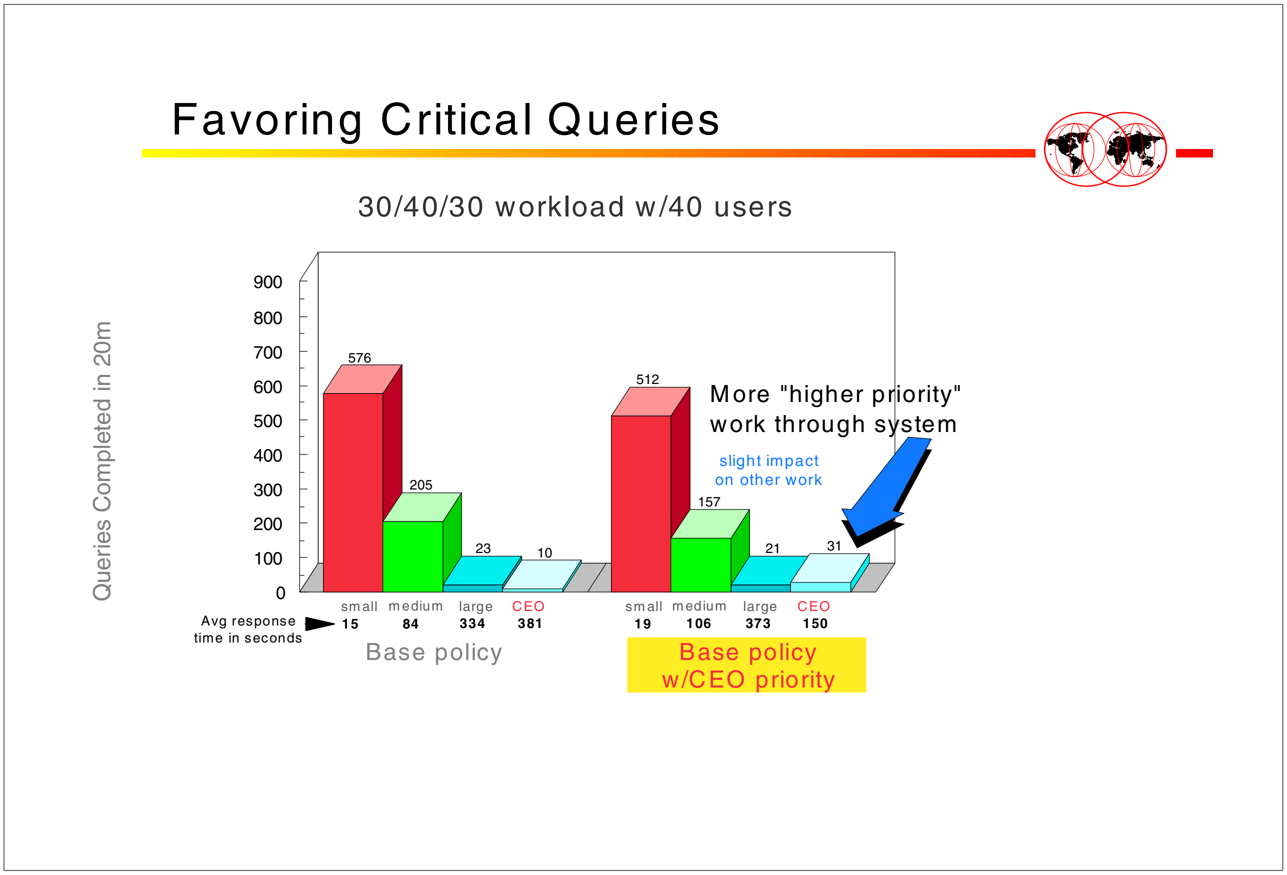
By favoring the short queries over the longer, you can maintain a consistent expectancy level across user groups, depending on the type and volume of work competing for system resources.

OS/390 WLM takes a sophisticated and accurate approach to this kind of problem with the *period aging* method.

As queries consume additional resources, period aging is used to step down the priority of resource allocations. The concept is that all work entering the system begins execution in the highest priority performance period. When it exceeds the duration of the first period, its priority is stepped down. At this point the query still receives resources, but at lower priority than when it started in the first period. The definition of a period is flexible: the duration and number of periods established are totally at the discretion of the system administrator. Through the establishment of multiple periods, priority is naturally established for shorter running work without the need to identify short and long running queries. Implementation of period aging does not in any way prevent or cap full use of system resources when only a single query is present in the system. These controls only have effect when multiple concurrent queries execute.

Here we examine the effects of bringing in an additional workload on top of a workload already running in the system. The bar charts show the effective throughput and response times. The workload consists of 40 users running 30 small, 40 medium, and 30 large queries. We use prioritization and period aging with the WLM. In 20 minutes 576 small, 205 medium and 33 large queries are completed. The response times for the small, medium, and large queries are 15 seconds, 84 seconds and 339 seconds, respectively. We then add 24 trivial query users to this workload. Results show that 1738 trivial queries are completed in 20 minutes with a 1-second response time requirement satisfied, without any appreciable impact on the throughput and response times of small, medium and large queries.

8.6 Favoring critical queries



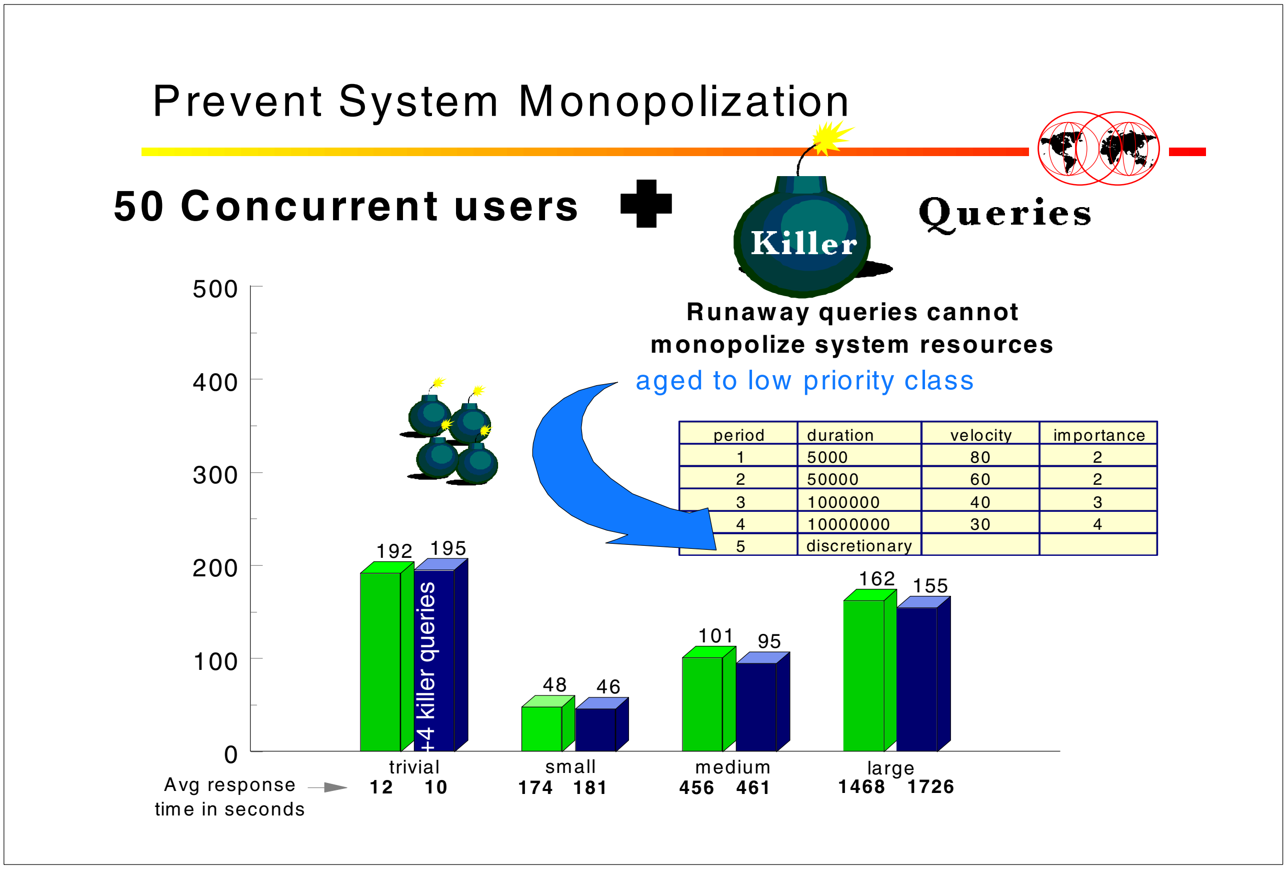
Favoring Critical Queries

30/40/30 workload w/40 users

WLM offers you the ability to favor critical queries. To demonstrate this, a subset of the large queries is reclassified and designated as the “CEO” queries. The CEO queries are first run with no specific priority over the other work in the system. They are run again classified as the highest priority work in the system. Three times as many CEO queries run to completion, as a result of the prioritization change, demonstrating WLM’s ability to favor particular pieces of work.

WLM policy changes can be made dynamically through a simpler ALTER command. These changes are immediate and are applicable to all new work as well as *currently executing work***.** There is no need to suspend, cancel or restart existing work to make changes to priority. While prioritization of specific work is not unique to OS/390, the ability to dynamically change priority of work already in flight is. Business needs may dictate shifts in priority at various times of the day/week/month and as crises arise. WLM allows you to make changes “on the fly” in an unplanned situation, or automatically, based on the predictable processing needs of different times of the day.

8.7 Prevent system monopolization



Prevent System Monopolization

50 Concurrent users + Killer Queries

Runaway queries cannot monopolize system resources

aged to low priority class

period	duration	velocity	importance
1	5000	80	2
2	50000	60	2
3	1000000	40	3
4	10000000	30	4
5	discretionary		

We previously mentioned the importance of preventing queries that require large amounts of resources to monopolize the system. While there is legitimate work using lots of resources that must get through the system, there is also the danger of “killer” queries that may enter the system either intentionally or unwittingly. Such queries, without proper resource management controls, can have drastic consequences on the performance of other work in the system and, even worse, result in excessive waste of system resources.

These queries may have such a severe impact on the workload that a predictive governor would be required to identify them. Once they are identified, they could be placed in a batch queue for later execution when more critical work would not be affected. In spite of these precautions, however, such queries could still slip through the cracks and get into the system.

Work would literally come to a standstill as these queries monopolize all available system resources. Once the condition is identified, the offending query would then need to be cancelled from the system before normal activity is resumed. In such a situation, a good many system resources are lost because of the cancellation of such queries. Additionally, an administrator's time is required to identify and remove these queries from the system.

WLM prevents occurrences of such situations. Killer queries are not even a threat to your system when using WLM because of WLM's ability to quickly move such queries into a discretionary performance period. Quickly aging such queries into a discretionary or low priority period allows them to still consume system resources but only when higher priority work does not require use of these resources.

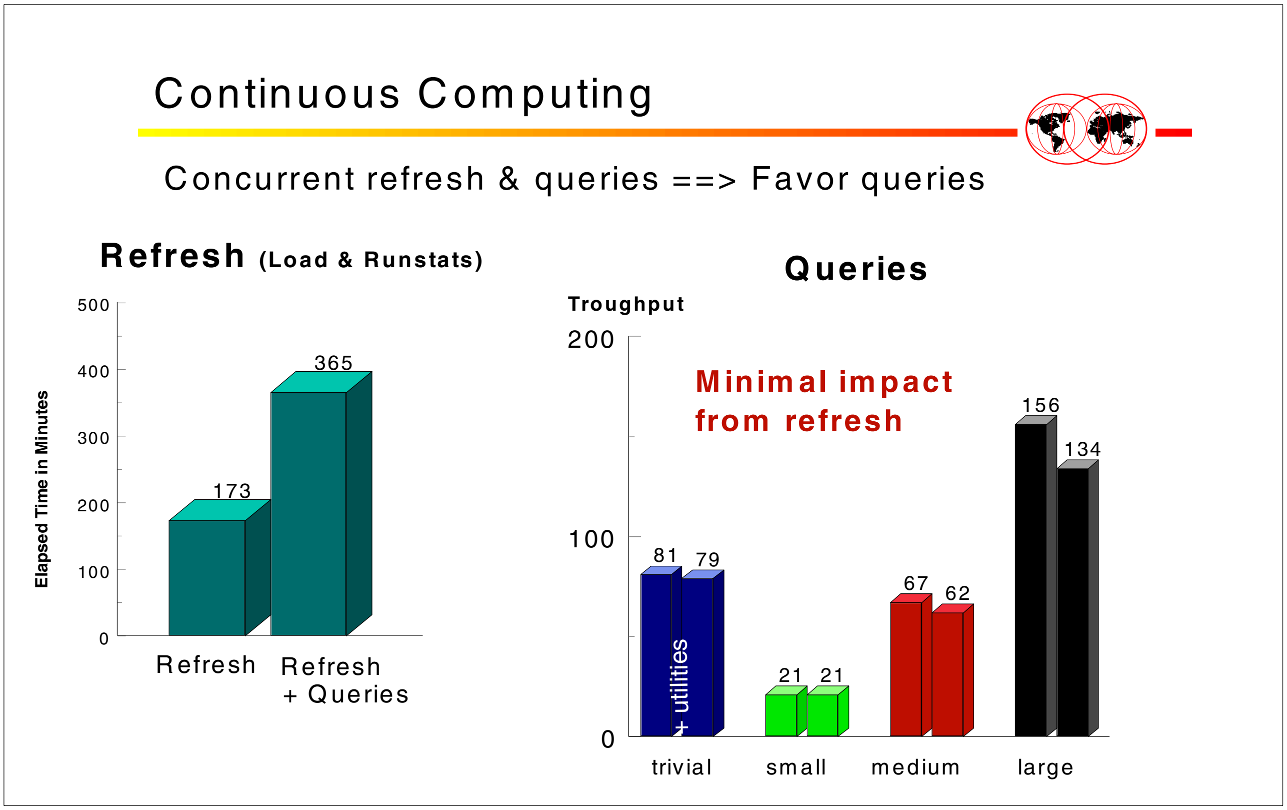
The figure on the previous page shows how WLM provides monopolization protection. We show, by adding killer queries to a workload in progress, how they quickly move to the discretionary period and have virtually no effect on the base high priority workload.

The table in our figure shows a WLM policy. In this case, velocity as well as period aging and importance are used. Velocity is the rate at which you expect work to be processed. The smaller the number, the longer the work must wait for available resources. Therefore, as work ages, its velocity decreases. The longer a query is in the system, the further it drops down in the periods. In period 5 it becomes discretionary, that is, it only receives resources when there is no other work using them. Killer queries quickly drop to this period, rendering them essentially "harmless." WLM period aging and prioritization keep resources flowing to the normal workload, and keep the resource consumers under control. System monopolization is prevented and the killer query is essentially neutralized.

We can summarize the significance of such a resource management scheme as follows:

- Killer queries can get into the system, but cannot impact the more critical work.
- There is no need to batch queue these killer queries for later execution. In fact, allowing such queries into the system would allow them to more fully utilize the processing resources of the system as these queries would be able to soak up any processing resources not used by the critical query work. As a result, idle cycle time is minimized and the use of the system's capacity is maximized.
- Fewer system cycles would be lost due to the need to immediately cancel such queries. End users, instead of administrators, can decide whether or when queries should be canceled.

8.8 Concurrent refresh and queries: favor queries



Continuous Computing

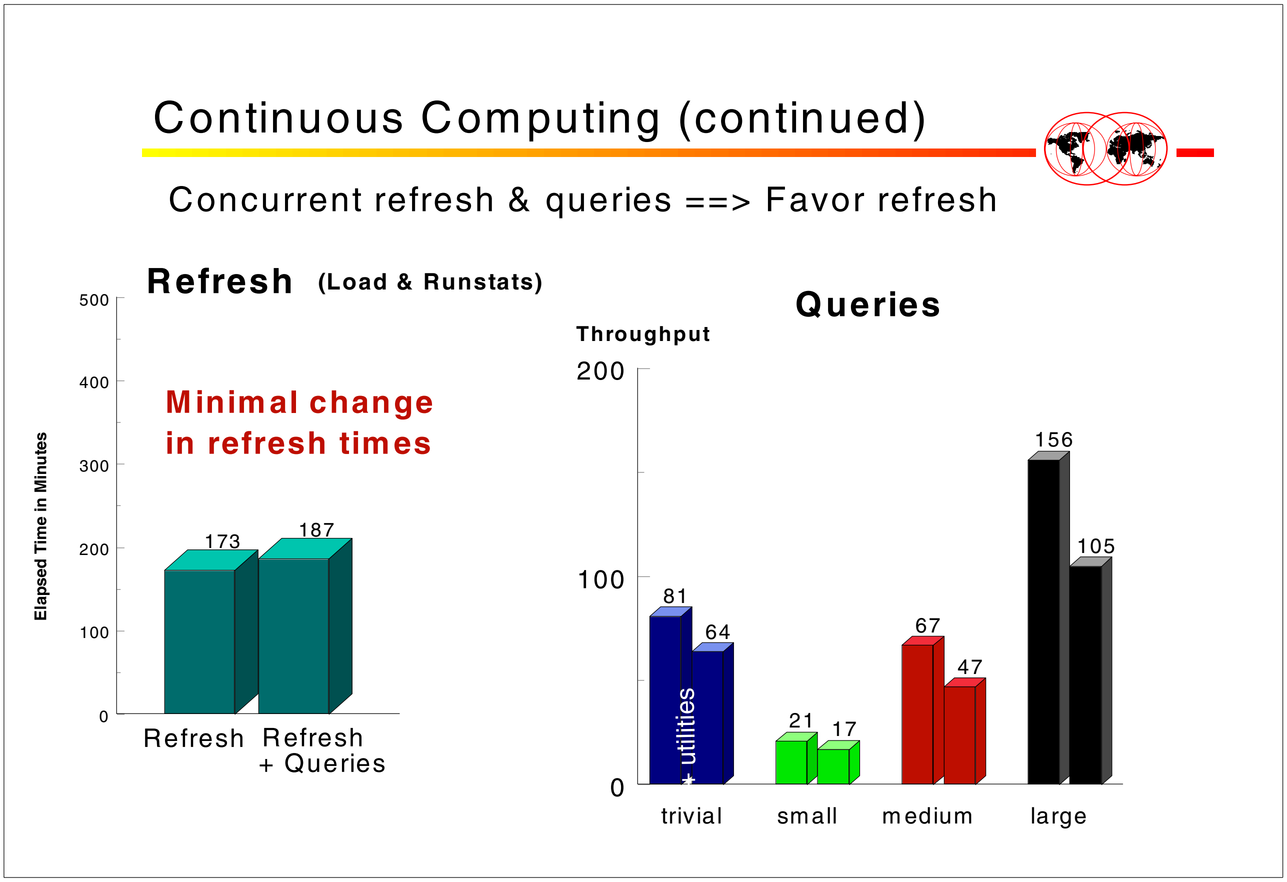
Concurrent refresh & queries ==> Favor queries

Today, very few companies operate in a single time zone, and with the growth of the international business community and web-based commerce, there is a growing demand for business intelligence systems to be available across 24 time zones. In addition, as CRM applications are integrated into mission-critical processes, the demand will increase for current data on decision support systems that do not go down for maintenance. WLM plays a key role in deploying a data warehouse solution that successfully meets the requirements for continuous computing. WLM manages all aspects of data warehouse processes including batch and query workloads. Batch processes must be able to run concurrently with queries without adversely affecting the system. Such batch processes include database refreshes and other types of maintenance. WLM is able to manage these workloads such that there is always a continuous flow of work executing concurrently.

Another important factor to continuous computing is WLM’s ability to favor one workload over the other. This is accomplished by dynamically switching policies. For instance, query work may be favored over a database refresh so that online end users are not impacted.

Our tests indicate that by favoring queries run concurrently with database refresh (of course, the queries do not run on the same partitions as the database refresh), there is more than a twofold increase in elapsed time for database refresh compared to database refresh only. More importantly, the impact from database refresh is minimal on the query elapsed times.

8.9 Concurrent refresh and queries: favor refresh



Continuous Computing (continued)

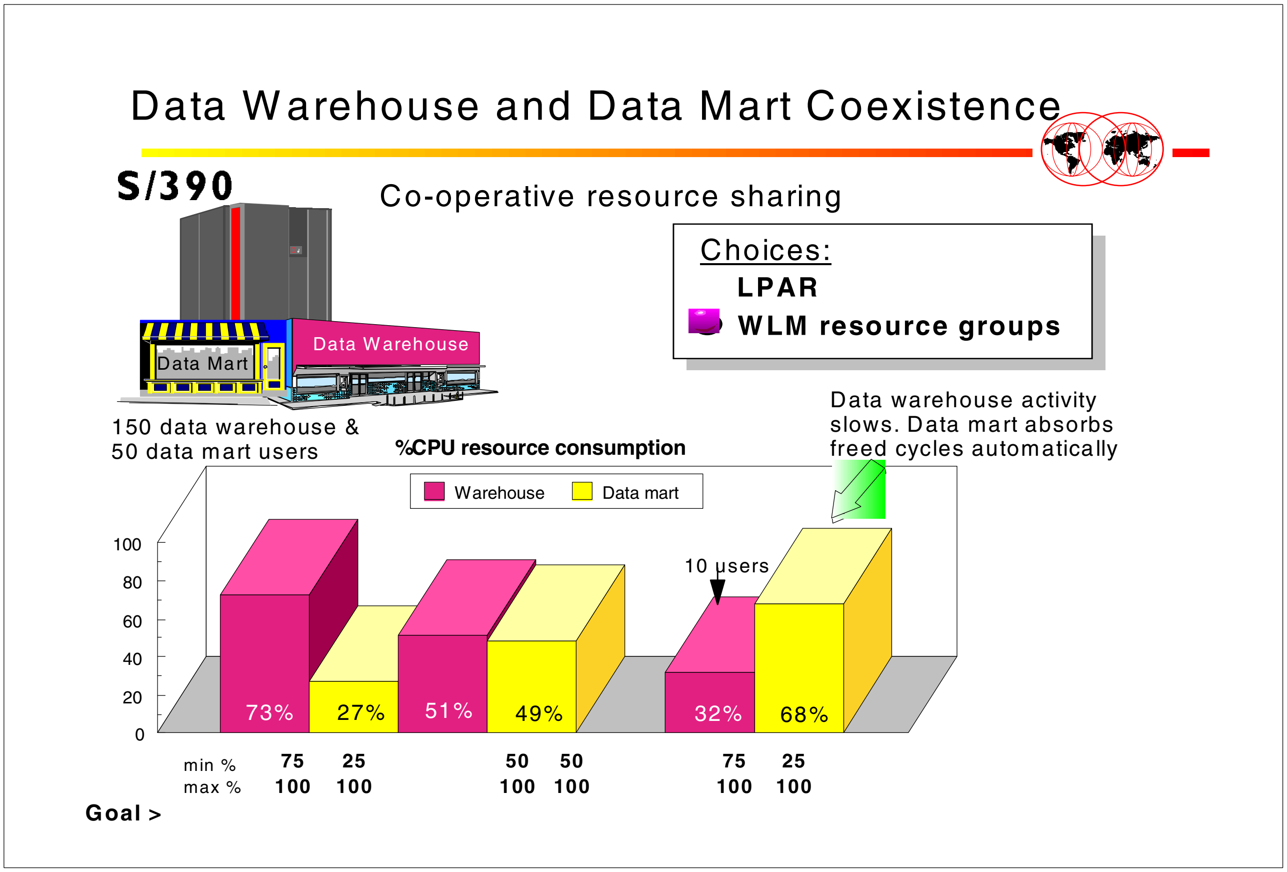
Concurrent refresh & queries ==> Favor refresh

Minimal change in refresh times

There may be times when a database refresh needs to be placed at a higher priority, such as when end users require up-to-the-minute data or the refresh needs to finish within a specified window. These ad hoc change requests can easily be fulfilled with WLM.

Our test indicates that by favoring database refresh executed concurrently with queries (of course, the queries do not run on the same partitions as the database refresh), there is a slight increase in elapsed time for database refresh compared to database refresh only. The impact from database refresh on queries is that fewer queries run to completion during this period.

8.10 Data warehouse and data mart coexistence



Data Warehouse and Data Mart Coexistence

S/390

Co-operative resource sharing

Choices:

LPAR

WLM resource groups

150 data warehouse &
50 data mart users

%CPU resource consumption

Data warehouse activity
slows. Data mart absorbs
freed cycles automatically

Many customers today, struggling with the proliferation of dedicated servers for every business unit, are looking for an efficient means of consolidating their data marts and data warehouse on one system while guaranteeing capacity allocations for the individual business units (workloads). To perform this successfully, system resources must be shared such that work done on the data mart does not impact work done on the data warehouse. This resource sharing can be accomplished using advanced sharing features of S/390, such as LPAR and WLM resource groups.

Using these advanced resource sharing features of S/390, multiple or diverse workloads are able to coexist on the same system. These features can provide significant advantages over implementations where each workload runs on separate dedicated servers. Foremost, these features provide the same ability to dedicate capacity to each business group (workload) that dedicated servers provide, without the complexity and cost associated with managing common software components across dedicated servers.

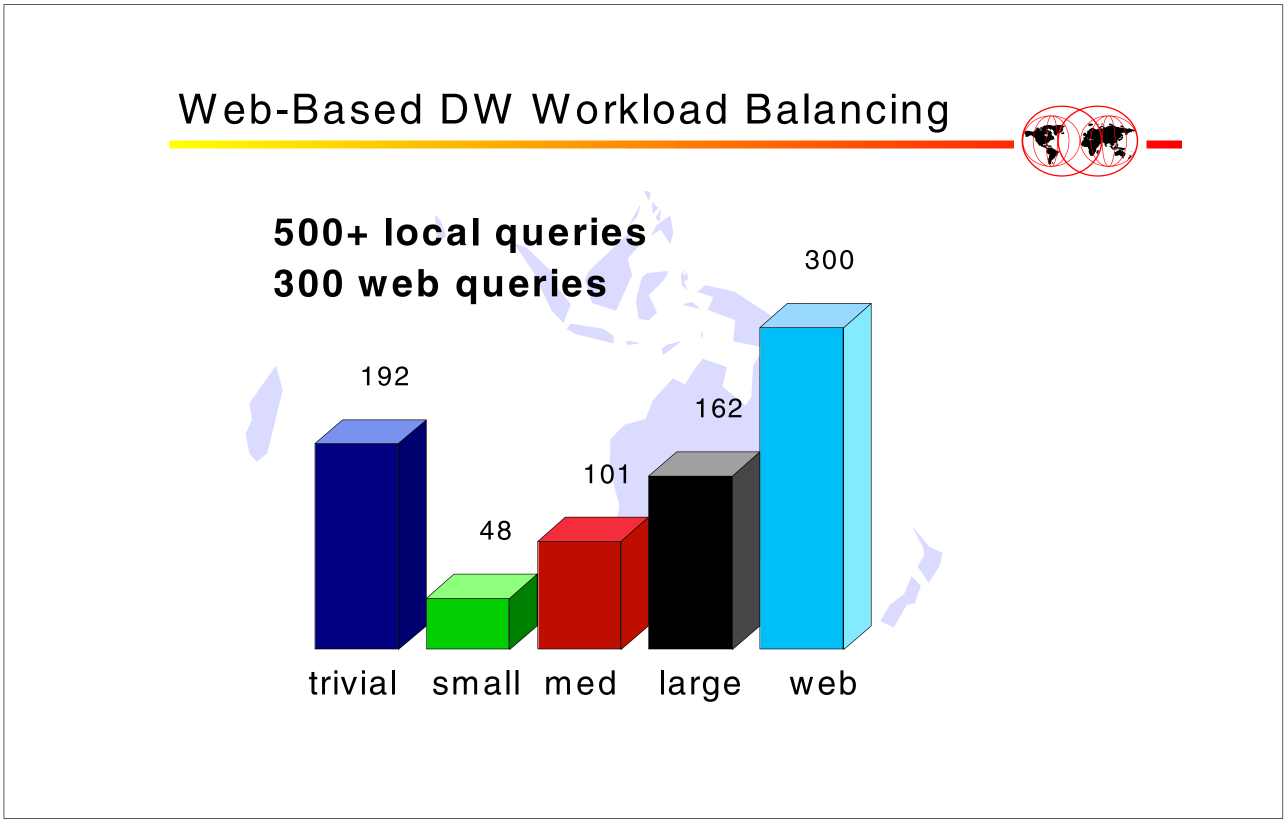
Another significant advantage stems from the “idle cycle phenomenon” that can exist, where dedicated servers are deployed for each workload. Inevitably, there are periods in the day where the capacity of these dedicated servers is not fully utilized, hence “idle cycles.” A dedicated server for each workload strategy provides no means for other active workloads to tap or “co-share” the unused resources. These unused cycles are in effect wasted and generally go unaccounted for when factoring overall cost of ownership. Features such as LPAR and WLM resource groups can be used to virtually eliminate the idle cycle phenomenon by allowing the co-sharing of these unused cycles across business units (workloads) automatically, without the need to manually reconfigure hardware or system parameters. The business value derived from minimizing idle cycles is maximization of your dollar investment (goal = zero idle cycles = maximum return on investment).

Another advantage is that not only can capacity be guaranteed to individual business units (workloads), but there is the potential to take advantage of additional cycles unused by other business units. The result is a guarantee to each business unit of x MIPs with a potential for x+MIPs (who could refuse?) bonus MIPs, if you will, that come from the sophisticated resource management features available on S/390.

To demonstrate that LPAR and WLM resource groups distribute system resources effectively when a data warehouse and a data mart coexist on the same S/390 LPAR, a validation test was performed. Our figure shows the highlights of the results. Two WLM resource groups were established, one for the data mart and one for the data warehouse. Each resource group was assigned specific minimum and maximum capacity allocations. 150 data warehouse users ran concurrently with 50 data mart users. In the first test, 75 percent of system capacity was available to the data warehouse and 25 percent to the data mart. Results indicate a capacity distribution very close to the desired distribution.

In the second test, the capacity allocations were dynamically altered a number of times, with little effect on the existing workload. Again the capacity stayed close to the desired 50/50 distribution. Another test demonstrated the ability of one workload to absorb unused capacity in the data warehouse. The idle cycles were absorbed by the data mart, accelerating the processing while maintaining constant use of all available resources.

8.11 Web-based DW workload balancing



Web-Based DW Workload Balancing

500+ local queries
300 web queries

With WLM, you can manage Web-based DW work together with other DW work running on the system and, if necessary, prioritize one or the other.

Once you enable the data warehouse to the Web, you introduce a new type of users into the system. You need to isolate the resource requirements for DW work associated with these users to manage them properly. With WLM, you can easily accomplish this by creating a service policy specifically for Web users. A very powerful feature of WLM is that it not only balances loads within a single server, but also Web requests across multiple servers in a sysplex.

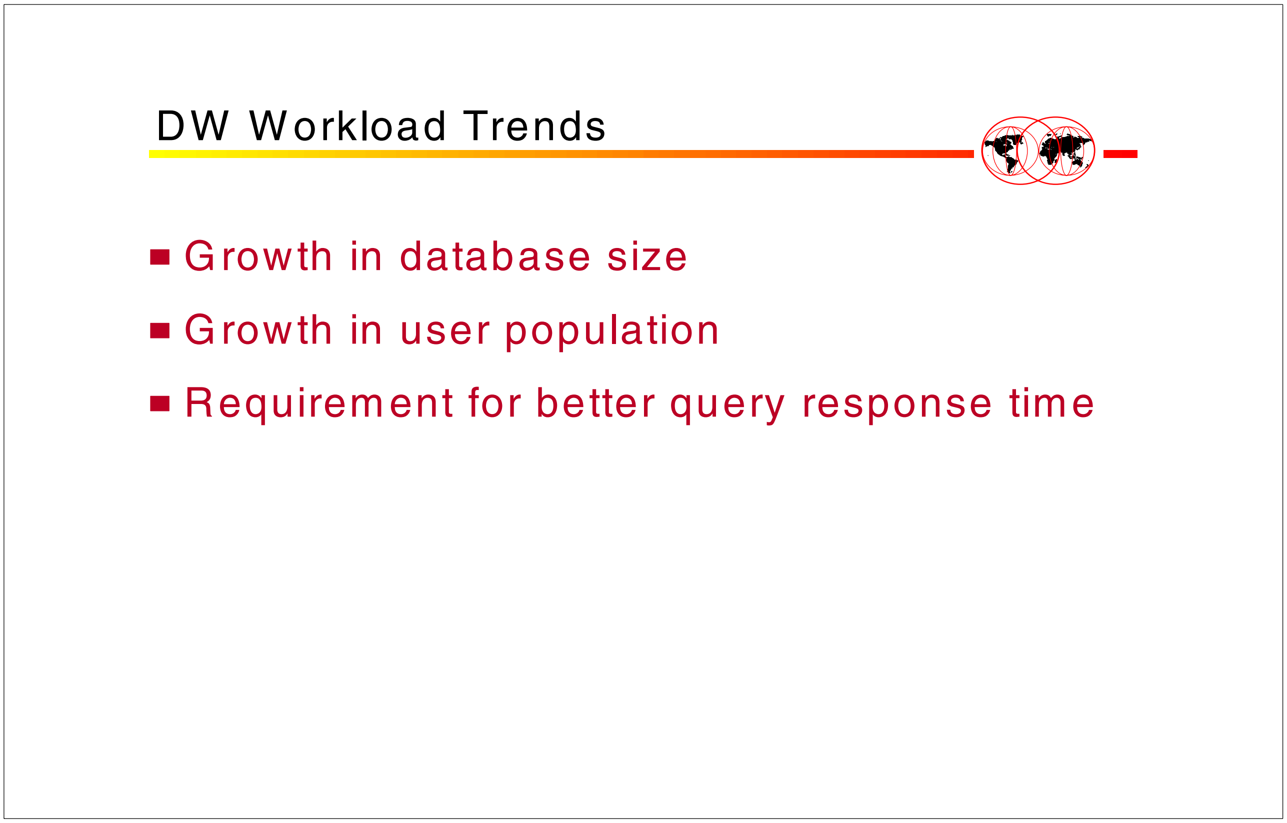
Here we show throughput of over 500 local queries and 300 Web queries made to a S/390 data warehouse in a 3-hour period.

Chapter 9. BI scalability on S/390

BI Scalability on S/390

This chapter presents scalability examples for concurrent users, processors, data, and I/O.

9.1 Data warehouse workload trends



DW Workload Trends

- Growth in database size
- Growth in user population
- Requirement for better query response time

Recently published technology industry reports show three typical workload trends in the data warehouse area:

- Growth in database size

  The first trend is database growth. Many organizations foresee an annual growth rate in database sizes ranging from 8 to over 200 percent.

- Growth in user population

  The second trend is significant growth in user population. For example, the number of BI users in one organization is expected to triple, while another organization anticipates an increase from 200 to more than 2000 users within 18 months. Many organizations have started offering access to their data warehouses to their suppliers, business partners, contractors, and even the general public, via Web connections.

- Requirement for better query response time

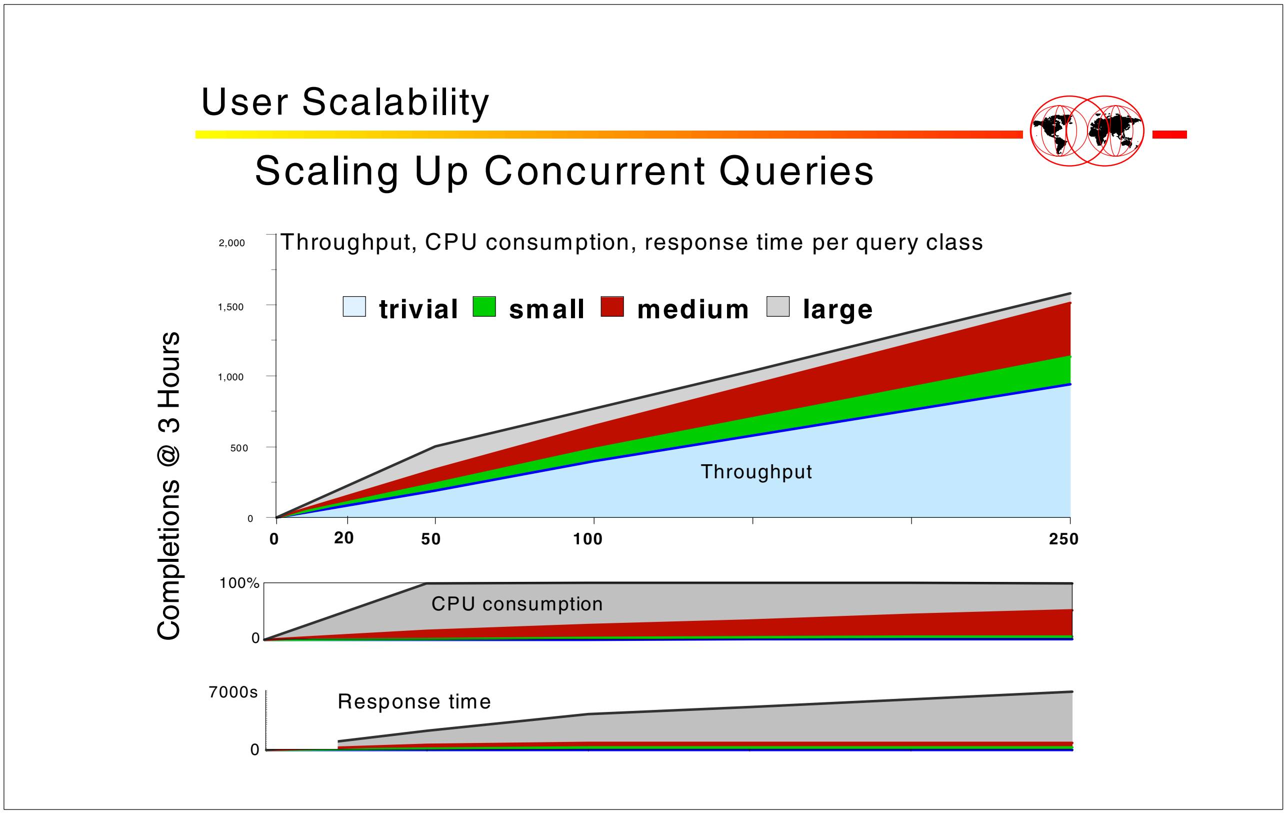
  The third trend is the pressure to improve query response time with increased workloads. Because of the growth in the number of BI users, volume of data, and complexity of processing, the building of BI solutions requires not only careful planning and administration, but also the implementation of scalable hardware and software products that can deal with the growth.

The following questions need to be addressed in a BI environment:

- What happens to the query response time and throughput when the number of users increases?
- Is the degradation in the query response time disproportionate to the growth in data volumes?
- Do the query response time and throughput improve if processing power is enhanced, and is it also possible to support more end users?
- Is it possible to scale up the existing platform on which the data warehouse is built to meet the growth?
- Is the I/O bandwidth adequate to move large amounts of data within a given time period?
- Is the increase in time to load the data linear to the growth in data volumes?
- Is it possible to update or refresh a data warehouse or data mart within a given batch window when there is growth in data volumes?
- Can normal maintenance, such as backup and reorganization, occur during the batch window when there is growth in data volumes?

Scalability is the answer to all these questions. Scalability represents how much work can be accomplished on a system when there is an increase in the number of users, data volumes and processing capacity.

9.2 User scalability


User Scalability

Scaling Up Concurrent Queries

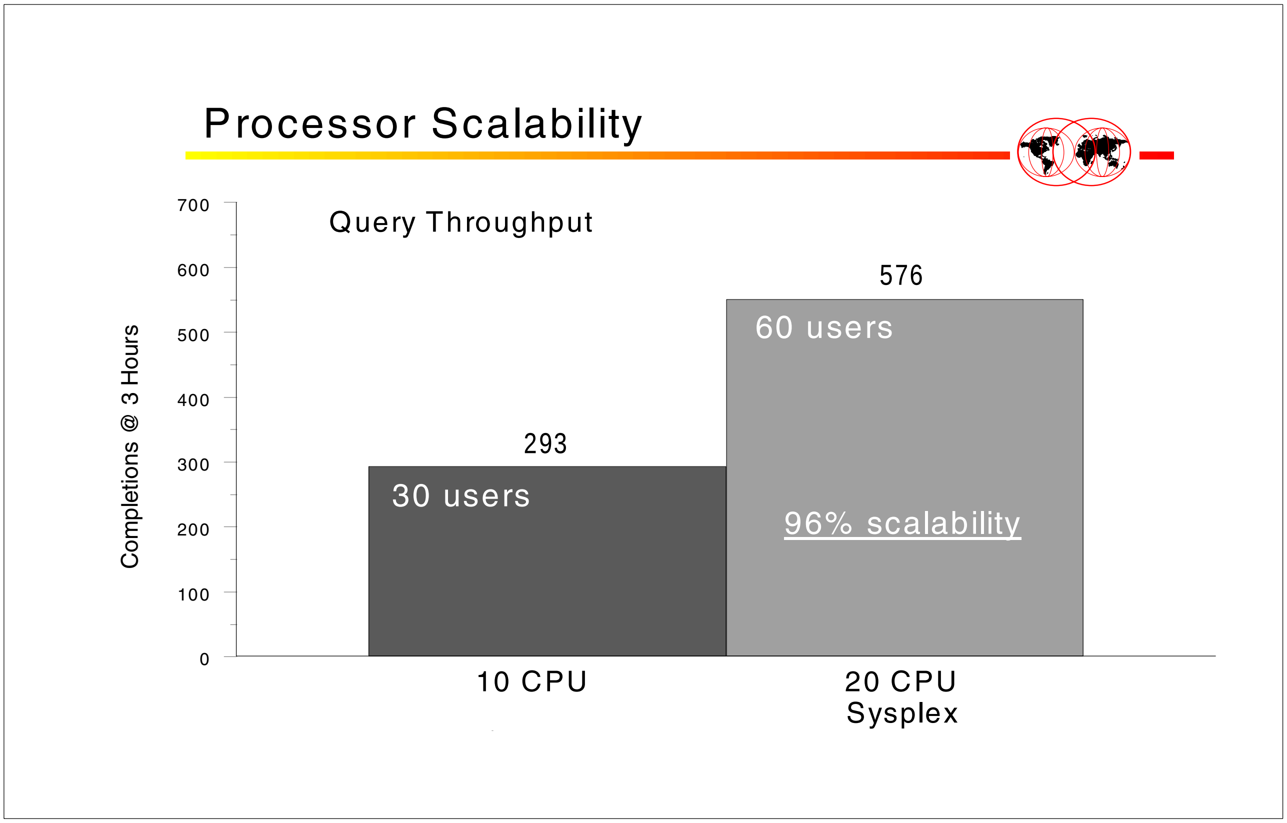
User scalability ensures that response time scales proportionally as the number of active concurrent users goes up. That is, as the number of concurrent users goes up, a scalable BI system should maintain consistent system throughput while individual query response time increases proportionally. Data warehouse access through Web connection makes this scalability even more essential.

It is also desirable to provide optimal performance at both low and high levels of concurrency without having to alter the hardware configuration and system parameters, or to reserve capacity to handle the expected level of concurrency. This sophistication is supported by S/390 and DB2. The DB2 optimizer determines the degree of parallelism and the WLM provides for intelligent use of system resources.

Based on the measurements done, our figure shows how a mixed query workload scales while the number of concurrent users goes up. The x-axis shows the number of concurrent queries. The y-axis shows the number of queries completed within 3 hours. The CPU consumption goes up for large queries, but becomes flat when the saturation point (in this case 50 concurrent queries) is reached. Notice that when the level of concurrency is increased after the saturation point is reached, WLM ensures proportionate growth of overall system throughput. The response time for trivial, small, and medium queries increases less than linearly after the saturation point, while for large queries it is much less linear.

S/390 keeps query response times consistent for small queries with the WLM period aging method, which prevents large queries from monopolizing the system. Our figure shows the overall effect of period aging and prioritization of response times. The large queries are the most affected, while the other queries are minimally affected. This behavior is consistent with the expectations of users initiating those queries.

9.3 Processor scalability: query throughput

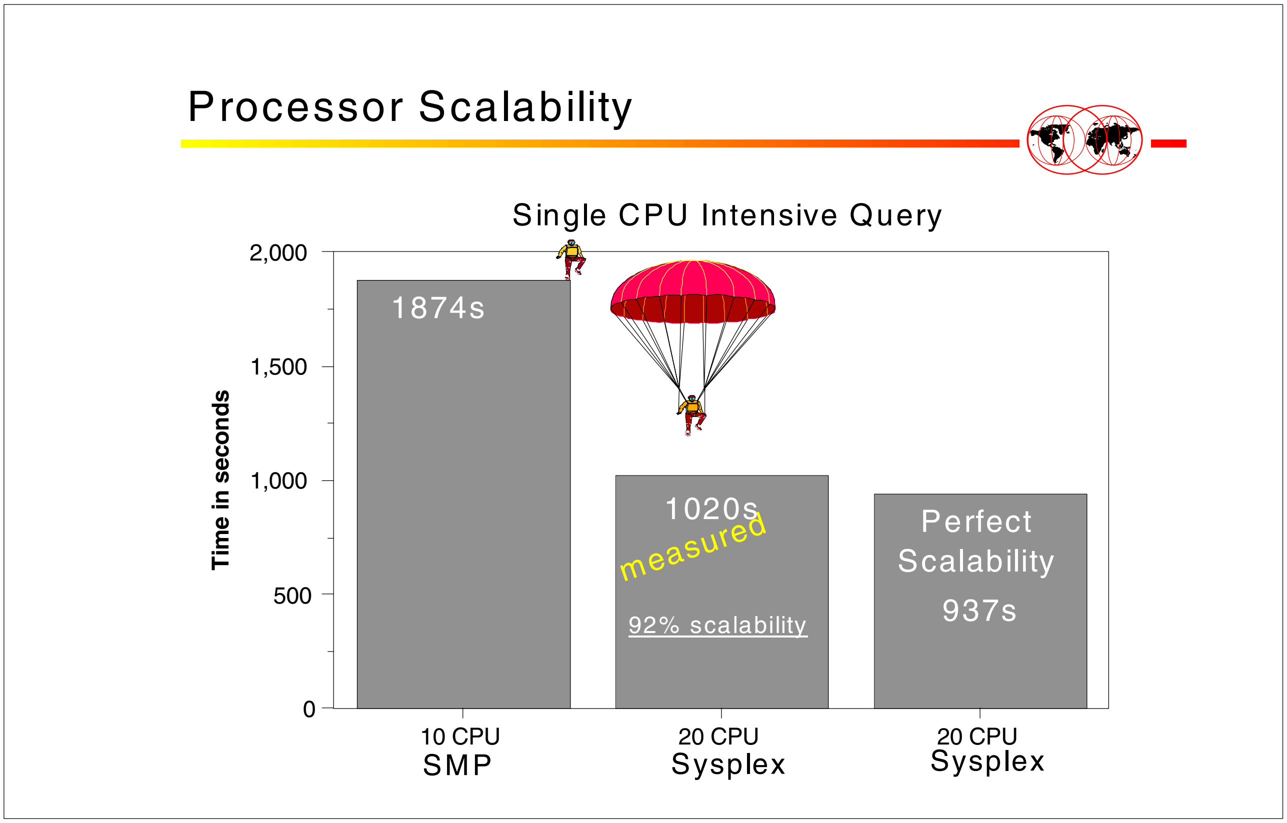


Processor Scalability

Processor scalability is the ability of a workload to fully exploit the capacity within a single SMP node, as well as the ability to utilize the capacity beyond a single SMP node. The sysplex configuration is able to achieve a near two-fold increase in system throughput by adding another server to the configuration. That is, when more processing power is added to the sysplex, more end user queries can be processed with a constant response time, more query throughput can be achieved, and the response time of a CPU-intensive query decreases in a linear fashion. A sysplex configuration can have up to a maximum of 32 nodes, with each node having up to a maximum of 12 processors.

Here we show the test results when twice the number of users run queries on a sysplex with two members, doubling the available number of processors. The measurements show 96 percent throughput scalability during a 3-hour period.

9.4 Processor scalability: single CPU-intensive query

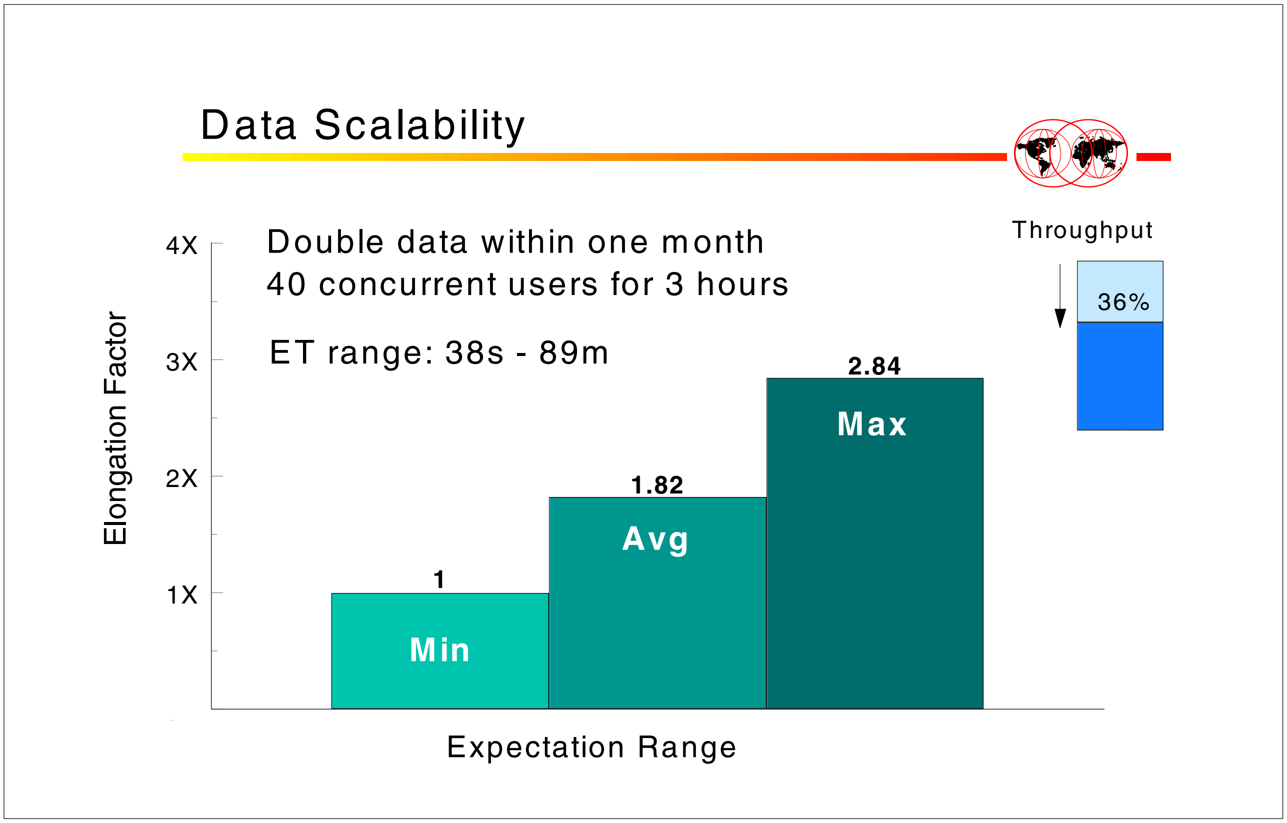


Processor Scalability

How much faster does a CPU-intensive query run if more processing power is available?

This graph displays results of a test scenario done as part of a study conducted jointly by S/390 Teraplex Integration Center and a customer. It demonstrates that when S/390 processors were added with no change to the amount of data, the response time for a single query was reduced proportionately to the increase in processing resource, achieving near perfect scalability

9.5 Data scalability



Data Scalability

Double data within one month
40 concurrent users for 3 hours

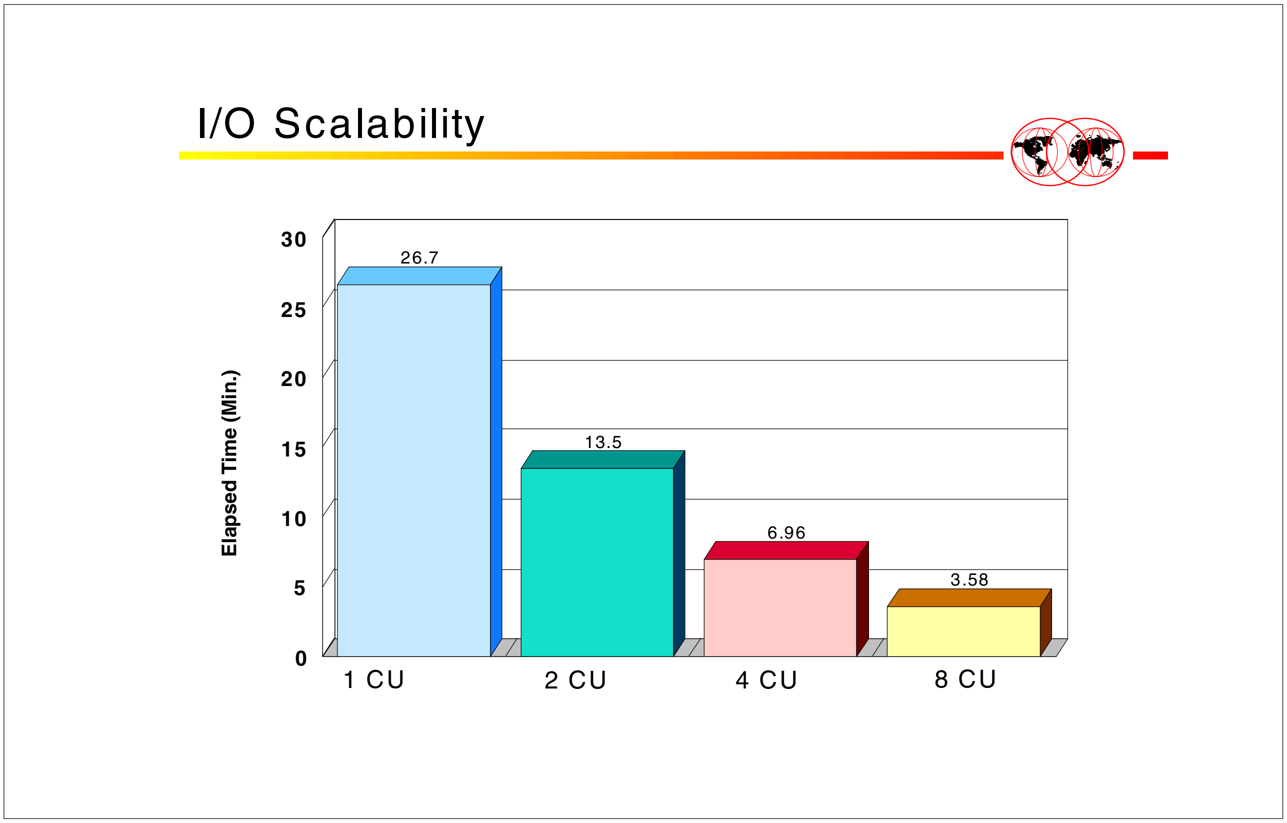
ET range: 38s - 89m

Data scalability is the ability of a system to maintain expected performance in query response time and data loading time as the database size increases.

In this joint study test case, we doubled the amount of data being accessed by a mixed set of queries, while maintaining a constant concurrent user population and without increasing the amount of processing power. The average impact to query response time was less than twice the response time achieved with half the amount of data, better than linear scalability. Some queries were not impacted at all, while one query experienced a 2.8x increase in response time. This was influenced by the sort on a large number of rows, sort not being a linear function.

What is important to note on this chart is that the overall throughput was decreased only by 36%, far less than the 50% reduction that would have been expected. This was the result of WLM effectively managing resource allocation favoring high priority work, in this case short queries.

9.6 I/O scalability


I/O Scalability

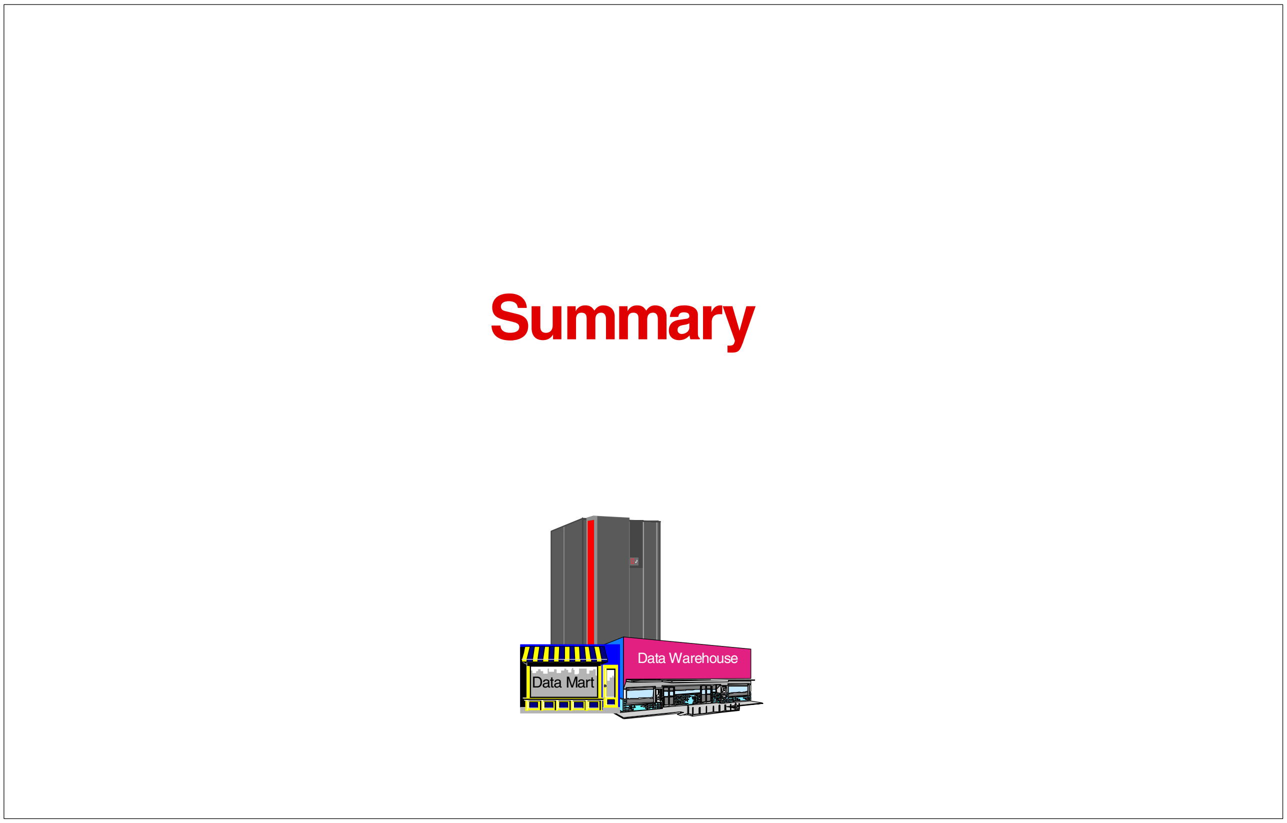
I/O scalability is the S/390 I/O capability to scale as the database size grows in a data warehouse environment. If the server platform and database cannot provide adequate I/O bandwidth, progressively more time is spent to move data, resulting in degraded response time.

This figure graphically displays the scalability characteristics of the I/O subsystem on an I/O-intensive query. As we increased the number of control units (CU) from one to eight, with a constant volume of data, there was a proportionate reduction in elapsed time of I/O-intensive queries. The predictable behavior of a data warehouse system is key to accurate capacity planning for predictable growth, and in understanding the effects of unpredictable growth within a budget cycle.

Many data warehouses now exceed one terabyte, with rapid annual growth rates in database size. User populations are also increasing, as user communities are expanded to include such groups as marketers, sales people, financial analysts and customer service staff internally, as well as suppliers, business partners, and customers through Web connections externally.

Scalability in conjunction with workload management is the key for any data warehouse platform. S/390 WLM and DB2 are well positioned for establishing and maintaining large data warehouses.

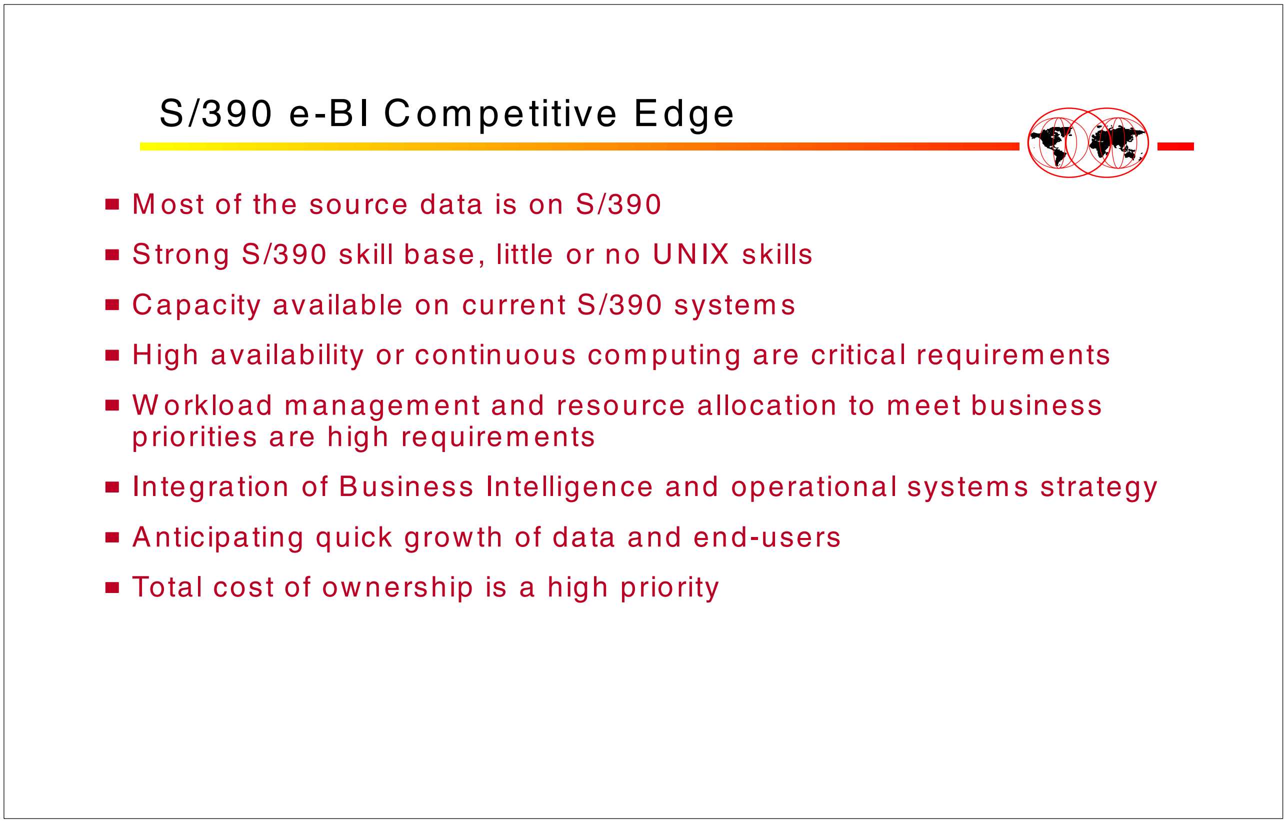
Chapter 10. Summary



Summary

This chapter summarizes the competitive advantages of using S/390 for business intelligence applications.

10.1 S/390 e-BI competitive edge



S/390 e-BI Competitive Edge

- Most of the source data is on S/390
- Strong S/390 skill base, little or no UNIX skills
- Capacity available on current S/390 systems
- High availability or continuous computing are critical requirements
- Workload management and resource allocation to meet business priorities are high requirements
- Integration of Business Intelligence and operational systems strategy
- Anticipating quick growth of data and end-users
- Total cost of ownership is a high priority

When customers have a strong S/390 skill base, when most of their source data is already on S/390, and additional capacity is available on the current systems, S/390 becomes the best choice as a data warehouse server for e-BI applications.

S/390 has a low total cost of ownership, is highly available and scalable, and can integrate BI and operational workloads in the same system. The unique capabilities of the OS/390 Workload Manager automatically govern business priorities and respond to a dynamic business environment.

S/390 can achieve high return on investment, with rapid start-up and easy deployment of e-BI applications.

Appendix A. Special notices

This publication is intended to help IBM field personnel, IBM business partners, and customers involved in building a business intelligence environment on S/390. The information in this publication is not intended as the specification of any programming interfaces that are provided by the BI products mentioned in this document. See the PUBLICATIONS section of the IBM Programming Announcement for those products for more information about what publications are considered to be product documentation.

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Appendix B. Related publications

The publications listed in this section are considered particularly suitable for a more detailed discussion of the topics covered in this redbook.

B.1 IBM Redbooks publications

For information on ordering these publications see "How to get IBM Redbooks" on page 179.

- *The Role of S/390 in Business Intelligence,* SG24-5625
- *Getting Started with DB2 OLAP Server on OS/390,* SG24-5665
- *Building VLDB for BI Applications on OS/390: Case Study Experiences,* SG24-5609
- *Data Warehousing with DB2 for OS/390*, SG24-2249
- *Getting Started with Data Warehouse and Business Intelligence*, SG24-5415
- *My Mother Thinks I'm a DBA! Cross-Platform, Multi-Vendor, Distributed Relational Data Replication with IBM DB2 DataPropagator and IBM DataJoiner Made Easy!,* SG24-5463
- *From Multiplatform Operational Data To Data Warehousing and Business Intelligence,* SG24-5174
- *Data Modeling Techniques for Data Warehousing*, SG24-2238
- *Managing Multidimensional Data Marts with Visual Warehouse and DB2 OLAP Server*, SG24-5270
- *Intelligent Miner for Data: Enhance Your Business Intelligence*, SG24-5422
- *Intelligent Miner for Data Application Guide,* SG24-5252
- *IBM Enterprise Storage Server,* SG24-5465
- *Implementing SnapShot*, SG24-2241
- *Using RVA and SnapShot for BI with OS/390 and DB2,* SG24-5333
- *DB2 for OS/390 and Data Compression*, SG24-5261
- *OS/390 Workload Manager Implementation and Exploitation,* SG24-5326
- *DB2 UDB for OS/390 Version 6 Performance Topics,* SG24-5351
- *DB2 Server for OS/390 Version 5 Recent Enhancements - Reference Guide*, SG24-5421
- *DB2 for OS/390 Application Design Guidelines for High Performance,* SG24-2233
- *Accessing DB2 for OS/390 data from the World Wide Web*, SG24-5273
- *The Universal Connectivity Guide to DB2*, SG24-4894
- *System/390 MVS Parallel Sysplex Batch Performance*, SG24-2557

B.2 IBM Redbooks collections

Redbooks are also available on the following CD-ROMs. Click the CD-ROMs button at http://www.redbooks.ibm.com/ for information about all the CD-ROMs offered, updates and formats.

CD-ROM Title	Collection Kit Number
System/390 Redbooks Collection	SK2T-2177
Networking and Systems Management Redbooks Collection	SK2T-6022
Transaction Processing and Data Management Redbooks Collection	SK2T-8038
Lotus Redbooks Collection	SK2T-8039
Tivoli Redbooks Collection	SK2T-8044
AS/400 Redbooks Collection	SK2T-2849
Netfinity Hardware and Software Redbooks Collection	SK2T-8046
RS/6000 Redbooks Collection (BkMgr Format)	SK2T-8040
RS/6000 Redbooks Collection (PDF Format)	SK2T-8043
Application Development Redbooks Collection	SK2T-8037
IBM Enterprise Storage and Systems Management Solutions	SK3T-3694

B.3 Other resources

These publications are also relevant as further information sources:

- Yevich, Richard, "Why to Warehouse on the Mainframe"*, DB2 Magazine,* Spring 1998
- *Domino Go Webserver Release 5.0 for OS/390 Web Master's Guide,* SC31-8691
- *Installing and Managing QMF for Windows,* GC26-9583
- *IBM SmartBatch for OS/390 Overview,* GC28-1627
- *DB2 for OS/390 V6 What's New?,* GC26-9017
- *DB2 for OS/390 V6 Release Planning Guide,* SC26-9013
- *DB2 for OS/390 V6 Release Utilities Guide and Reference*, SC26-9015

B.4 Referenced Web sites

These web sites are also relevant as further information sources:

- META Group, "1999 Data Warehouse Marketing Trends/Opportunities", 1999, go to the META Group Website and visit “Data Warehouse and ERM”.

  http://www.metagroup.com/

- S/390 Business Intelligence web page:

  http://www.ibm.com/solutions/businessintelligence/s390

- IBM Software Division, DB2 Information page:

  http://w3.software.ibm.com/sales/data/db2info

- IBM Global Business Intelligence page:

  http://www-3.ibm.com/solutions/businessintelligence/

- DB2 for OS/390:

  http://www.software.ibm.com/data/db2/os390/

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List of Abbreviations

ACS	Automated Class Selection
ADM	Asynchronous Data Mover
ADMF	Asynchronous Data Mover Function
AIX	Advanced Interactive Executive (IBM’s flavor of UNIX)
API	Application Programming Interface
ASCII	American Standard Code for Information Interchange
BI	Business Intelligence
CD	Compact Disk
CD-ROM	Compact Disk - Read Only Memory
CLI	Call Level Interface
CPU	Central Processing Unit
C/S	Client/Server
DASD	Direct Access Storage Device
DB2	Database 2
DBA	Database Administrator
DBMS	Database Management System
DDF	Distributed Data Facility (DB2)
DFSMS	Data Facility Storage Management Subsystem
DM	Data Mart
DOLAP	Desktop OLAP
DRDA	Distributed Relational Database Architecture
DW	Data Warehouse
EPDM	Enterprise Performance Data Manager
ERP	Enterprise Resource Planning
ESS	Enterprise Storage Server
ETL	Extract Transform Load
FIFO	Frst In First Out
GB	Gigabyte
GUI	Graphical User Interface
HSM	Hierarchical Storage Manager
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
IBM	International Business Machines Corporation
IIOP	Internet Inter-ORB Protocol
ISMF	Integrated Storage Management Facility
IP	Internet Protocol
ISV	Independent Software Vendor
ITSO	International Technical Support Organization
JDBC	Java Database Connectivity
JDK	Java Development Kit
LPAR	Logically Partitioned mode
LRU	Last Recently Used
MB	Megabyte
MOLAP	Multidimentional OLAP
MRU	Most Recently Used
MVS	Multiple Virtual Storage - OS/390
ODBC	Open Database Connectivity
ODS	Operational Data Store
OLAP	Online Analytical Processing
OMVS	Open MVS
OPC	Operations Planning and Control
OS	Operating System
OS/390	Operating System for the IBM S/390
PRDS	Propagation Request Data Set
ROLAP	Relational OLAP
RPC	Remote Procedure Calls
RYO	Roll Your Own
PAV	Parallel Access Volumes
RACF	Resource Access Control Facility
RAID	Redundant Array of Independent Disks
RAMAC	Raid Architecture with Multilevel Adaptive Cache
RAS	Reliability, Availability, and Serviceability
RMF	Resource Measurement Facility

RVA	RAMAC Virtual Array
S/390	IBM System 390
SQL	Structured Query Language
SQLJ	*SQL Java*
SLR	Service Level Reporter
SMF	System Management Facilities
SMS	Storage Management Subsystem
SNA	Systems Network Architecture
SNAP/SHOT	System Network Analysis Program/Simulation Host Overview Technique
SSL	Secure Socket Layer
TCP/IP	Transmission Control Protocol based on IP
UCB	Unit Control Block
URL	Uniform Resource Locator
VLDB	Very Large Databa
WLM	Workload Manager
WWW	Worl Wide Web

Index

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Tools to build, populate and administer a DB2 data warehouse on S/390

BI-user tools to access a DB2 data warehouse on S/390 from the Internet and intranets

This IBM Redbook presents a comprehensive overview of the building blocks of a business intelligence infrastructure on S/390. It describes how to architect and configure a S/390 data warehouse, and explains the issues behind separating the data warehouse from or integrating it with your operational environment.

This book also discusses physical database design issues to help you achieve high performance in query processing. It shows you how to design and optimize the extract/transformation/load (ETL) processes that populate and refresh data in the warehouse. Tools and techniques for simple, flexible, and efficient development, maintenance, and administration of your data warehouse are described.

The book includes an overview of the interfaces and middleware services needed to connect end users, including Web users, to the data warehouse. It also describes a number of end-user BI tools that interoperate with S/390, including query and reporting tools, OLAP tools, tools for data mining, and complete packaged application solutions.

A discussion of workload management issues, including the capability of the OS/390 Workload Manager to respond to complex business requirements, is included. Data warehouse workload trends are described, along with an explanation of the scalability factors of the S/390 that make it an ideal platform on which to build your business intelligence applications.

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