Extract, Transform, Load (ETL)

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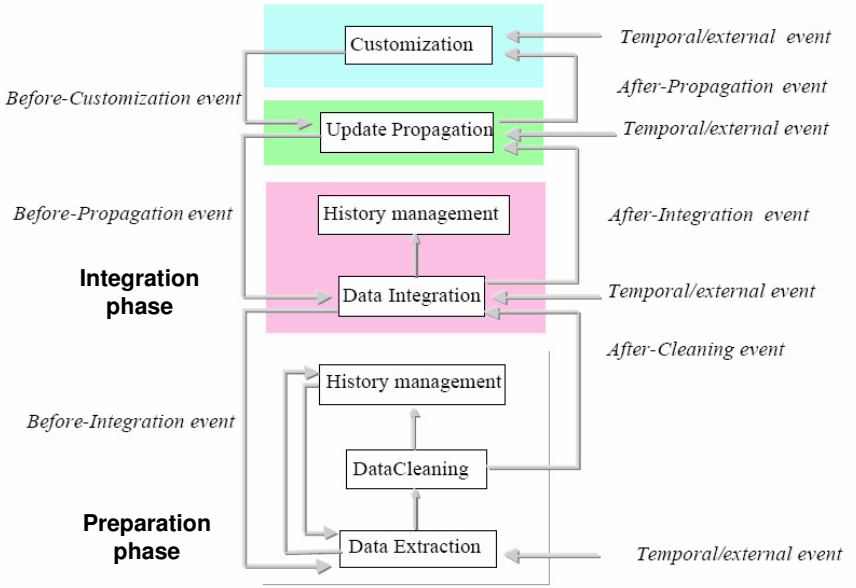
ETL Overview

- General ETL issues
  - ETL/DW refreshment process
  - Building dimensions
  - Building fact tables
  - Extract
  - Transformations/cleansing
  - Load
- MS Integration Services

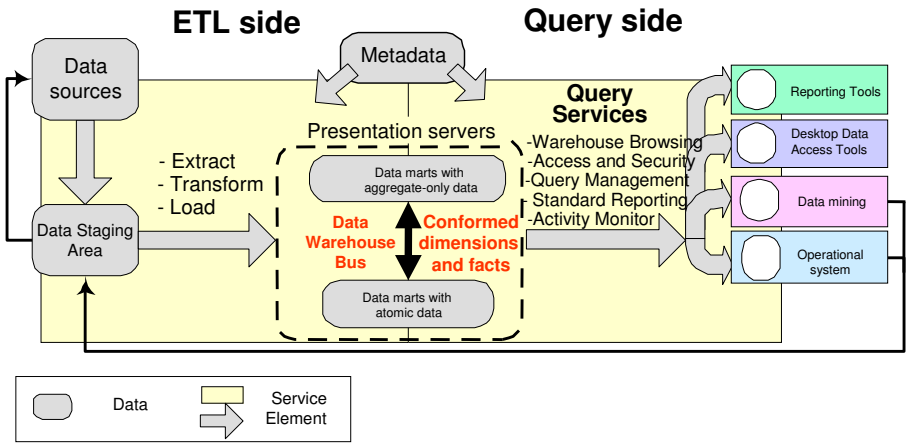
The ETL Process

- The **most underestimated** process in DW development
- The **most time-consuming** process in DW development
  - 80% of development time is spent on ETL!
- Extract
  - Extract relevant data
- Transform
  - Transform data to DW format
  - Build keys, etc.
  - Cleansing of data
- Load
  - Load data into DW
  - Build aggregates, etc.

Refreshment Workflow



ETL In The Architecture



Data Staging Area (DSA)

- Transit storage for data in the ETL process
  - Transformations/cleansing done here
- No user queries
- Sequential operations on large data volumes
  - Performed by central ETL logic
  - No need for locking, logging, etc.
  - RDBMS or flat files? (DBMS have become better at this)
- Finished dimensions copied from DSA to relevant marts
- Allows centralized backup/recovery
  - Often too time consuming to initial load all data marts by failure
  - Backup/recovery facilities needed
  - Better to do this centrally in DSA than in all data marts

ETL Construction Process

- Plan
  1) Make high-level diagram of source-destination flow
  2) Test, choose and implement ETL tool
  3) Outline complex transformations, key generation and job sequence for every destination table
- Construction of dimensions
  4) Construct and test building static dimension
  5) Construct and test change mechanisms for one dimension
  6) Construct and test remaining dimension builds
- Construction of fact tables and automation
  7) Construct and test initial fact table build
  8) Construct and test incremental update
  9) Construct and test aggregate build (**you** do this later)
  10) Design, construct, and test ETL automation

Building Dimensions

- Static dimension table
  - DW key assignment: production keys to DW keys using table
  - Combination of data sources: find common key?
  - Check one-one and one-many relationships using sorting
- Handling dimension changes
  - Described in last lecture
  - Find the newest DW key for a given production key
  - Table for mapping production keys to DW keys must be updated
- Load of dimensions
  - Small dimensions: replace
  - Large dimensions: load only changes

Building Fact Tables

- Two types of load
- Initial load
  - ETL for all data up till now
  - Done when DW is started the first time
  - Very heavy - large data volumes
- Incremental update
  - Move only changes since last load
  - Done periodically (e.g., month or week) after DW start
  - Less heavy - smaller data volumes
- Dimensions must be updated **before** facts
  - The relevant dimension rows for new facts must be in place
  - Special key considerations if initial load must be performed again

Types of Data Sources

- Non-cooperative sources
  - Snapshot sources – provides only full copy of source, e.g., files
  - Specific sources – each is different, e.g., legacy systems
  - Logged sources – writes change log, e.g., DB log
  - Queryable sources – provides query interface, e.g., RDBMS
- Cooperative sources
  - Replicated sources – publish/subscribe mechanism
  - Call back sources – calls external code (ETL) when changes occur
  - Internal action sources – only internal actions when changes occur
    - DB triggers is an example
- Extract strategy depends on the source types

Extract

- Goal: fast extract of relevant data
  - Extract from source systems can take **long** time
- Types of extracts:
  - Extract applications (SQL): co-existence with other applications
  - DB unload tools: faster than SQL-based extracts
- Extract applications the only solution in some scenarios
- **Too** time consuming to ETL all data at each load
  - Extraction can take days/weeks
  - Drain on the operational systems
  - Drain on DW systems
  - => Extract/ETL only changes since last load (delta)

Computing Deltas

- Delta = changes since last load
- Store sorted total extracts in DSA
  - Delta can easily be computed from current+last extract
  - + Always possible
  - + Handles deletions
  - - High extraction time
- Put update timestamp on all rows (in sources)
  - Updated by DB trigger
  - Extract only where “timestamp > time for last extract”
  - + Reduces extract time
  - - Cannot (alone) handle deletions
  - - Source system must be changed, operational overhead

Changed Data Capture

- Messages
  - Applications insert messages in a “queue” at updates
  - + Works for all types of updates and systems
  - - Operational applications must be changed+operational overhead
- DB triggers
  - Triggers execute actions on INSERT/UPDATE/DELETE
  - + Operational applications need **not** be changed
  - + Enables real-time update of DW
  - - Operational overhead
- Replication based on DB log
  - Find changes directly in DB log which is written anyway
  - + Operational applications need **not** be changed
  - + No operational overhead
  - - Not possible in some DBMS

Common Transformations

- Data type conversions
  - EBCDIC → ASCII/UniCode
  - String manipulations
  - Date/time format conversions
- Normalization/denormalization
  - To the desired DW format
  - Depending on source format
- Building keys
  - Table matches production keys to surrogate DW keys
  - Correct handling of history - especially for total reload

Data Quality

- Data almost **never** has decent quality
- Data in DW must be:
  - Precise
    - DW data must match known numbers - or explanation needed
  - Complete
    - DW has all relevant data and the users know
  - Consistent
    - No contradictory data: aggregates fit with detail data
  - Unique
    - The same things is called the same and has the same key (customers)
  - Timely
    - Data is updated ”frequently enough” and the users know when

Cleansing

- BI does not work on “raw” data
  - Pre-processing necessary for BI analysis
- Handle inconsistent data formats
  - Spellings, codings, …
- Remove unnecessary attributes
  - Production keys, comments,…
- Replace codes with text **(Why?)**
  - City name instead of ZIP code,…
- Combine data from multiple sources with common key
  - E.g., customer data from customer address, customer name, …

Types Of Cleansing

- Conversion and normalization
  - Text coding, date formats, etc.
  - Most common type of cleansing
- Special-purpose cleansing
  - Normalize spellings of names, addresses, etc.
  - Remove duplicates, e.g., duplicate customers
- Domain-independent cleansing
  - Approximate, “fuzzy” joins on records from different sources
- Rule-based cleansing
  - User-specifed rules, if-then style
  - Automatic rules: use data mining to find patterns in data
    - Guess missing sales person based on customer and item

Cleansing

- Mark facts with Data Status dimension
  - Normal, abnormal, outside bounds, impossible,…
  - Facts can be taken in/out of analyses
- Uniform treatment of NULL
  - Use explicit NULL value rather than “special” value (0,-1,…)
  - Use NULLs only for measure values (estimates instead?)
  - Use special dimension keys for NULL dimension values
    - Avoid problems in joins, since NULL is not equal to NULL
- Mark facts with changed status
  - New customer, Customer about to cancel contract, ……

Improving Data Quality

- Appoint “data quality administrator”
  - Responsibility for data quality
  - Includes manual inspections and corrections!
- Source-controlled improvements
  - The optimal?
- Construct programs that check data quality
  - Are totals as expected?
  - Do results agree with alternative source?
  - Number of NULL values?
- Do not fix **all** problems with data quality
  - Allow management to see “weird” data in their reports?
  - Such data may be meaningful for them? (e.g., fraud detection)

Load

- Goal: fast loading into DW
  - Loading deltas is much faster than total load
- SQL-based update is **slow**
  - Large overhead (optimization, locking, etc.) for every SQL call
  - DB load tools are much faster
- Index on tables **slows** load a lot
  - Drop index and rebuild after load
  - Can be done per index partition
- Parallellization
  - Dimensions can be loaded concurrently
  - Fact tables can be loaded concurrently
  - Partitions can be loaded concurrently

Load

- Relationships in the data
  - Referential integrity and data consistency must be ensured **(Why?)**
  - Can be done by loader
- Aggregates
  - Can be built and loaded at the same time as the detail data
- Load tuning
  - Load without log
  - Sort load file first
  - Make only simple transformations in loader
  - Use loader facilities for building aggregates
- Should DW be on-line 24*7?
  - Use partitions or several sets of tables (like MS Analysis)

ETL Tools

- ETL tools from the big vendors
  - Oracle Warehouse Builder
  - IBM DB2 Warehouse Manager
  - Microsoft Integration Services
- Offers much functionality at a reasonable price
  - Data modeling
  - ETL code generation
  - Scheduling DW jobs
  - …
- The "best" tool does not exist
  - Choose based on your own needs
  - Check first if the "standard tools" from the big vendors are OK

Issues

- Pipes
  - Redirect output from one process to input of another process

```
ls | grep 'a' | sort –r
```

- Files versus streams/pipes
  - Streams/pipes: no disk overhead, fast throughput
  - Files: easier restart, often only possibility
- ETL tool or not
  - Code: easy start, co-existence with IT infrastructure
  - Tool: better productivity on subsequent projects
- Load frequency
  - ETL time dependent of data volumes
  - Daily load is much faster than monthly
  - Applies to all steps in the ETL process

MS Integration Services

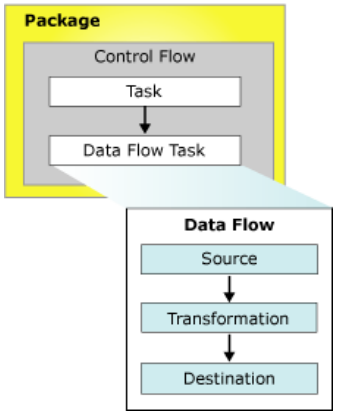
- A concrete ETL tool
- Example ETL flow
- Demo

Integration Services (IS)

- Microsoft's ETL tool
  - Part of SQL Server 2005
- Tools
  - Import/export wizard - simple transformations
  - BI Development Studio – advanced development
- Functionality available in several ways
  - Through GUI - basic functionality
  - Programming - advanced functionality

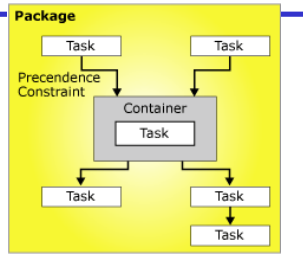
Packages

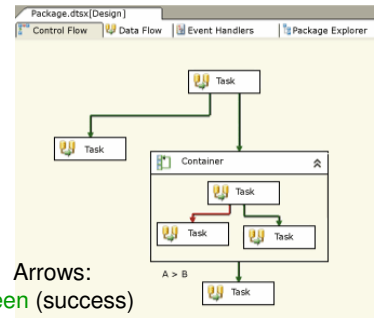
- The central concept in IS
- Package for:
  - Sources, Connections
  - Control flow
  - Tasks, Workflows
  - Transformations
  - Destinations
  - ……



Package Control Flow

- "Containers" provide
  - Structure to packages
  - Services to tasks
- Control flow
  - Foreach loop container
    - Repeat tasks by using an enumerator
  - For loop container
    - Repeat tasks by testing a condition
  - Sequence container
    - Groups tasks and containers into control flows that are subsets of the package control flow
- Task host container
  - Provides services to a single task

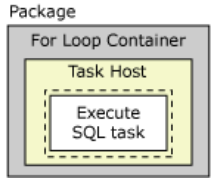




Arrows:
green (success)
red (failure)

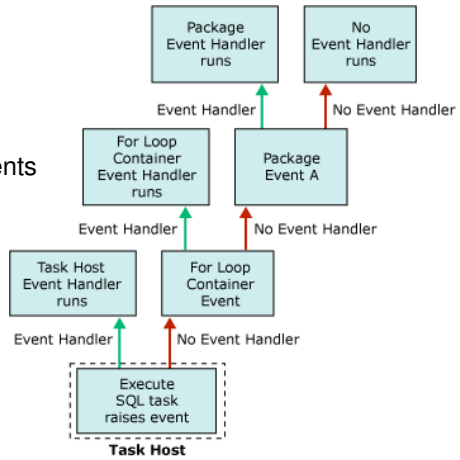
Tasks

- Data Flow – runs data flows
- Data Preparation Tasks
  - File System – operations on files
  - FTP – up/down-load data
- Workflow Tasks
  - Execute package – execute other IS packages, good for structure!
  - Execute Process – run external application/batch file
- SQL Servers Tasks
  - Bulk insert – fast load of data
  - Execute SQL – execute any SQL query
- Scripting Tasks
  - Script – execute VN .NET code
- Analysis Services Tasks
  - Analysis Services Processing – process dims, cubes, models
  - Analysis Services Execute DDL – create/drop/alter cubes, models
- Maintenance Tasks – DB maintenance



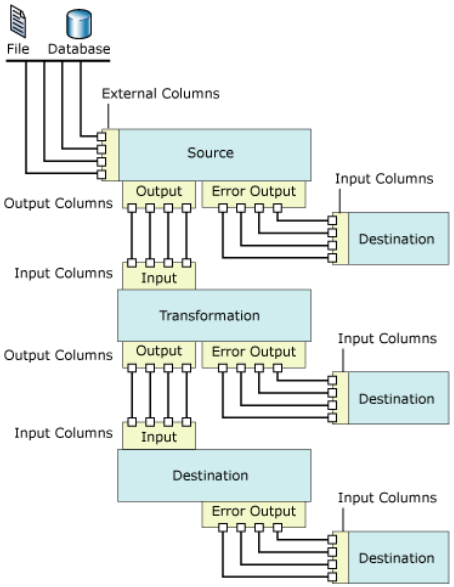
Event Handlers

- Executables (packages, containers) can raise events
- Event handlers manage the events
- Similar to those in languages JAVA, C#



Data Flow Elements

- Sources
  - Makes external data available
  - All ODBC/OLE DB data sources: RDBMS, Excel, Text files, ……
- Transformations
  - Update
  - Summarize
  - Cleanse
  - Merge
  - Distribute
- Destinations
  - Write data to specific store
  - Create in-memory data set
- Input, Output, Error output

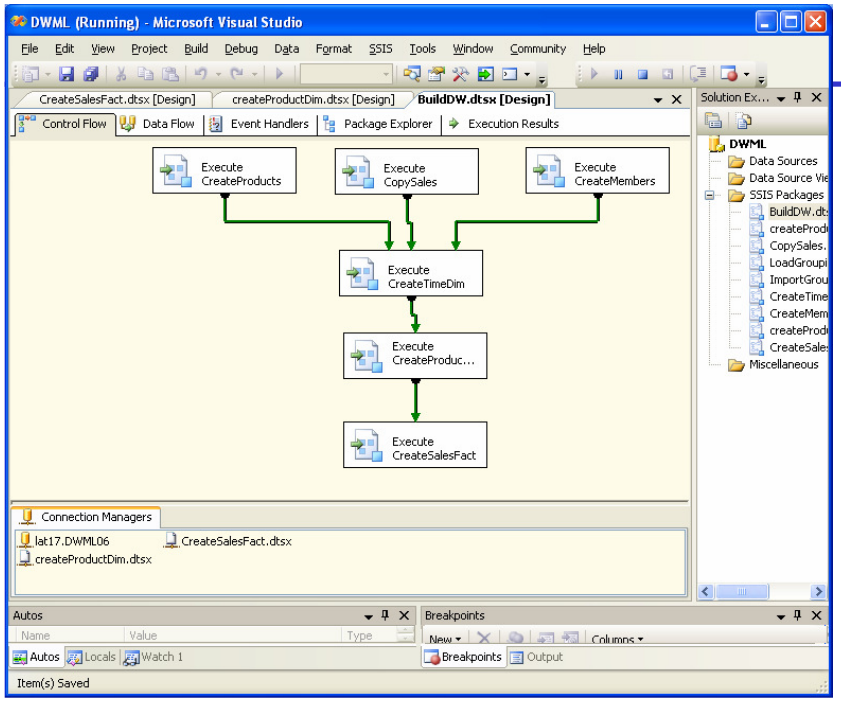


Transformations

- Business intelligence transformations
  - Term Extraction - extract terms from text
  - Term Lookup – look up terms and find term counts
- Row Transformations
  - Character Map - applies string functions to character data
  - Derived Column – populates columns using expressions
- Rowset Transformations (*rowset = tabular data*)
  - Aggregate - performs aggregations
  - Sort - sorts data
  - Percentage Sampling - creates sample data set by setting %
- Split and Join Transformations
  - Conditional Split - routes data rows to different outputs
  - Merge - merges two sorted data sets
  - Lookup Transformation - looks up ref values by exact match
- Other Transformations
  - Export Column - inserts data from a data flow into a file
  - Import Column - reads data from a file and adds it to a data flow
  - Slowly Changing Dimension - configures update of a SCD

A Simple IS Case

- Use BI Dev Studio/Import Wizard to copy TREO tables
- Save in
  - SQL Server
  - File system
- Look at package structure
  - Available from mini-project web page
- Look at package parts
  - DROP, CREATE, source, transformation, destination
- Execute package
  - Error messages?
- Steps execute in parallel
  - But dependencies can be set up



ETL Demo

- Load data into the Product dimension table
  - Construct the DW key for the table by using “IDENTITY”
  - Copy data to the Product dimension table
- Load data into the Sales fact table
  - Join “raw” sales table with other tables to get DW keys for each sales record
  - Output of the query written into the fact table

ETL Part of Mini Project

- *Core:*
  - Build an ETL flow using MS DTS that can do an initial (first-time) load of the data warehouse
  - Include logic for generating special DW surrogate integer keys for the tables
  - Discuss and implement basic transformations/data cleansing
- *Extensions:*
  - Extend the ETL flow to handle incremental loads, i.e., updates to the DW, both for dimensions and facts
  - Extend the DW design and the ETL logic to handle slowly changing dimensions of Type 2
  - Implement more advanced transformations/data cleansing
  - Perform error handling in the ETL flow

A Few Hints on ETL Design

- **Don’t** implement all transformations in one step!
  - Build first step and check that result is as expected
  - Add second step and execute both, check result
  - Add third step…
- Test SQL before putting into IS
- Do **one** thing at the time
  - Copy source data one-one to DSA
  - Compute deltas
    - Only if doing incremental load
  - Handle versions and DW keys
    - Versions only if handling slowly changing dimensions
  - Implement complex transformations
  - Load dimensions
  - Load facts

Summary

- General ETL issues
  - The ETL process
  - Building dimensions
  - Building fact tables
  - Extract
  - Transformations/cleansing
  - Load
- MS Integration Services