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# Enterprise Information Systems

## Chapter 1 - Motivation



# EIS – Main Focus Is On Integration

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- Data/Information Integration
  - integrated access to (heterogeneous) data originating from multiple sources
    - queries range over data from multiple DBs!
  - virtual integration: integrate on access/query (e.g., federated DBMS)
  - materialized integration: extract, transform, load data into a single materialized data warehouse in advance (e.g., data replication, data warehousing)
  - needs a strong foundation to overcome multiple kinds of heterogeneity
- Enterprise Application Integration
  - integration of (heterogeneous, coarse-grained) applications within an enterprise (vs. development of new application)
  - integration across different middleware platforms
- Business-to-business Integration
  - support interactions, integration of business processes among trading partners, across company boundaries
  - foundation for e-business, e-commerce



# Integration Challenges

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- Goal of Integration:  
*Provide a homogeneous, integrated view on multiple, distributed, autonomous and heterogeneous systems, components, or data sources.*
- Three fundamental challenges:
  - Distribution
  - Autonomy
  - Heterogeneity
- Orthogonal, but interrelated

*Let's look at the above challenges in the scope of data/information integration!*



# Distribution

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- Physical distribution
  - Data located on (geographically) separated systems
  - Challenges:
    - Addressing data across the globe (URLs)
    - Accessing data in different schemas (Multi-database languages, federated database systems)
    - Optimizing distributed queries (no topic of this lecture)
- Logical distribution
  - Several possible storage locations for a given data item
  - Caused by (partial) redundancy due to overlapping intension of schema elements
  - Challenges:
    - Maintaining consistency among redundant data
    - Provide metadata to enable data localization
    - Detect and resolve duplicates
    - Detect and resolve data inconsistencies and conflicts
- Physical and logical distribution are orthogonal:
  - Data can be logically distributed and physically on the same system (and vice versa)

} Data Cleaning



# Autonomy

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- Design Autonomy
  - Administrators of data sources can freely decide in which way they model data
  - Data model, formats, units, ...
  - Leads to heterogeneity among sources
- Interface Autonomy
  - Freedom to decide how technical access is provided
  - Protocols (HTTP, JDBC, SOAP, ...), supported query languages (SQL, XQuery, ...)
- Access Autonomy
  - Freedom to decide *whom* to allow access to *what* data
  - Mode of Authentication (Certificates, Username/Password)
  - Authorization (boolean, R/W, Access Control Lists, ...)
- Judicial Autonomy
  - Freedom to prohibit integration of data by others
  - Intellectual property (IP) issues

⇒ Autonomy is the major cause of integration problems



# Heterogeneity

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- Translated from [LeNa07]:  
*"Two information systems that do not provide the exact same methods, models and structures to access their data are called heterogeneous."*
- Causes for heterogeneity among IS:
  - Specific requirements
  - Independent development
  - Developer preferences
  - ...➔ All aspects result from autonomy
- Heterogeneity of metadata *and* data
- Two main approaches:
  - Try to resolve heterogeneity when needed
  - Enforce homogeneity/limit heterogeneity by establishing standards (not in this lecture)
    - No real solution to the problem
    - Only creates "spheres of homogeneity", any participants that have existing systems or requirements not conforming to the standards have to resolve heterogeneity locally



# Technical Heterogeneity

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- Refers to differences in the options to access data, e.g.
  - Communication protocols (HTTP, SOAP, ...)
  - Exchange formats (binary, text, XML, ...)
  - APIs (JDBC, ODBC, proprietary)
  - Query mechanism
    - Forms, canned queries
    - Query languages
  - Query language
    - SQL, XQuery, ...



# Data Model Heterogeneity

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- Caused by the use of different data models among data sources
  - hierarchical, relational, XML, ...
- Data models can have different expressiveness, e.g. support of
  - Inheritance
  - Types and degree of associations between entities/application concepts
  - Multi-valued attributes
  - Different atomic data types
- Mapping from semantically richer to poorer models in general results in a loss of information





# Syntactic Heterogeneity

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- Differences in the representation of identical facts
  - Binary representations (little/big endian, number formats)
  - Encodings (ASCII, ISO-8859-1, EBCDIC, Unicode, ...)
  - Separators (Tab-delimited vs. CSV)
  - Textual representation
- Not to be mixed up with semantic heterogeneity!
- Usually easy to resolve (if used consistently)
- Examples:
  - "20070201" vs. "Februar 1st, 2007" vs. "02-01-07" vs. "1.2.2007"
  - "123.45" vs. "1.2345x10<sup>2</sup>"
- ➔ *Data Fusion*



# Structural Heterogeneity

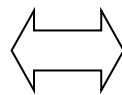
- Caused by **modeling identical application concepts differently** using the *same* elements in the same data model
- Example - denormalized relational schema

## Employee

<u>EmpNo</u>	Name	DoB	<u>DeptNo</u>
4711	Bob	1978-03-20	11
0815	Jane	1975-11-05	7
1234	Joe	1954-05-26	11

## Department

<u>DeptNo</u>	Name
7	Sales
11	Accounting



## EmpDept

<u>EmpNo</u>	Name	DoB	Deptname	DeptNo
4711	Bob	1978-03-20	Accounting	11
0815	Jane	1975-11-05	Sales	7
1234	Joe	1954-05-26	Accounting	11

- Easily resolved using relational operators:

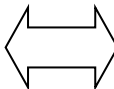
```
SELECT e.EmpNo, e.Name, e.DoB, d.name as deptname, d.deptno  
FROM Employee e, Department d WHERE e.deptno = d.deptno
```



# Structural Heterogeneity (cont.)

- Example: inverted hierarchy

```
<bib>
  <book title="a">
    <author name="x"/>
    <author name="y"/>
  </book>
  <book title="b">
    <author name="x"/>
  </book>
</bib>
```



```
<bib>
  <author name="y">
    <book title="a"/>
  </author>
  <author name="x">
    <book title="a"/>
    <book title="b"/>
  </author>
</bib>
```

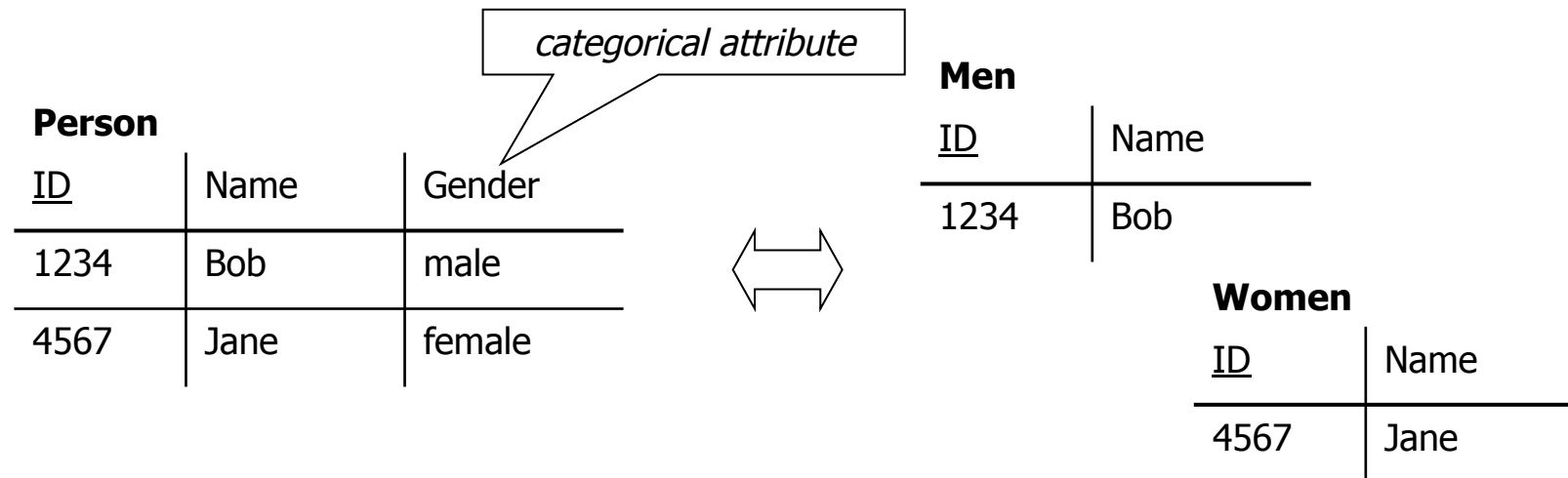
- Easily resolved using XQuery

```
<bib> {
  for $a in distinct-values(doc("BookAuthor.xml")//author/@name)
  return <author name="{ $a }"> {
    for $b in doc("BookAuthor.xml")//book
    where $b/author/@name = $a
    return <book title="{ $b/@title }"/>
  } </author>
} </bib>
```



# Schematic Heterogeneity

- Often considered a special case of structural heterogeneity
- Caused by modeling identical application concepts using *different data model concepts* of the same data model
- Example: *attribute value – relation name* conflict



- Problems of this kind cannot be resolved *generically* with SQL
  - How to handle an unknown/variable number of values for categorical attributes?

# Semantic Heterogeneity

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- “Semantics” = interpretation of data and metadata
- Different representation of identical application concepts, (e.g. synonyms)
- Identical representation of different application concepts (e.g. homonyms)
  - e.g. Lotus (the car) vs. Lotus (the flower)
- Ambiguities – unclear whether two elements refer to the same concept (are synonyms) or refer to broader/narrower terms (hypernyms)
  - hypernym or synonym?
    - car – (motor) vehicle
    - person – employee
    - product – item
  - decision depending on context
- Perhaps *the* biggest challenge in II
- Resolving semantic heterogeneity is a prerequisite for many integration tasks
- Many attempts to automate
  - ➔ *Schema Matching*



# Data Integration Middleware

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- Traditional Middleware

- supports access to multiple data sources within the same application, transaction
  - directly (using DB-gateways)
  - indirectly (by invoking distributed application components)
- but fails to provide data integration
  - no means to analyze/query data from multiple sources within the same statement

```
SELECT *  
FROM Source1-table T1, Source2-table T2  
WHERE T1.a1 = ...  
      AND  
      T1.a2 = T2.a1
```

- does not help to overcome data heterogeneity

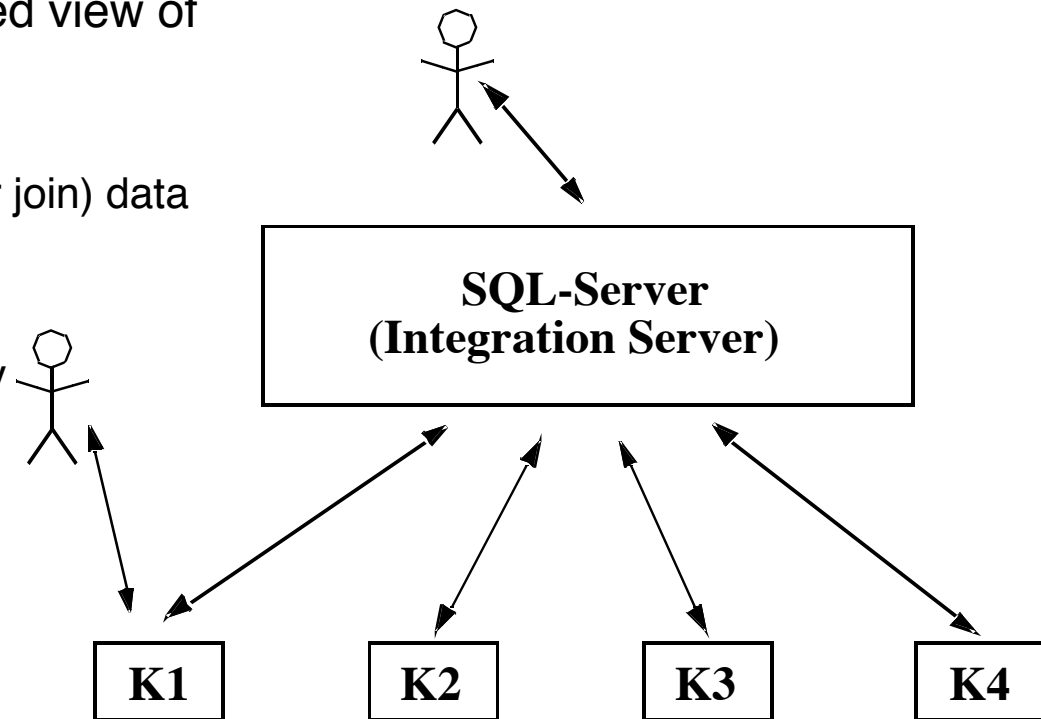
- Two architectural approaches to achieve data integration

- materialized integration: replication, data warehousing
- virtual integration: federated DBMS, multi-database systems



# Data Federation: Virtual Integration

- Goal: homogeneous, integrated view of data from multiple sources
  - a single (logical) database
  - a single query may collect (or join) data from multiple sources
- Data Federation requires
  - Wrapper/mediator technology
  - Data and schema integration mechanisms

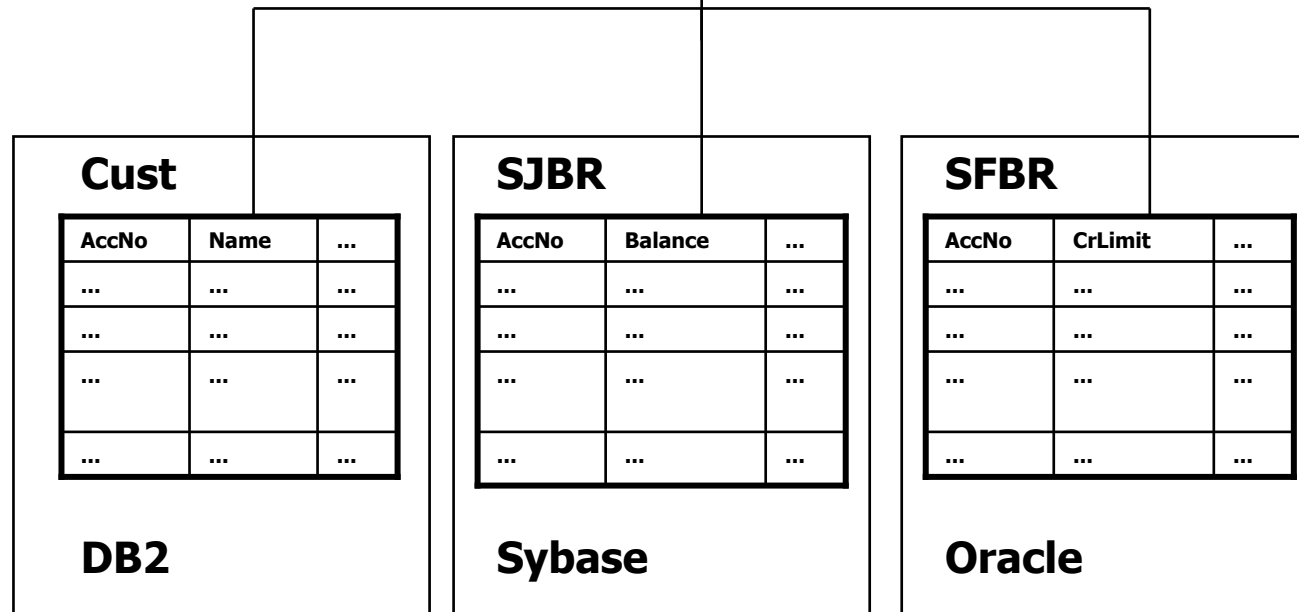


# Example - DB2 Relational Connect

```
Select *  
From Cust, SJBR, SFBR  
Where Cust.Acct No = SJBR.Acct No  
And SJBR.Acct No = SFBR.Acct No
```



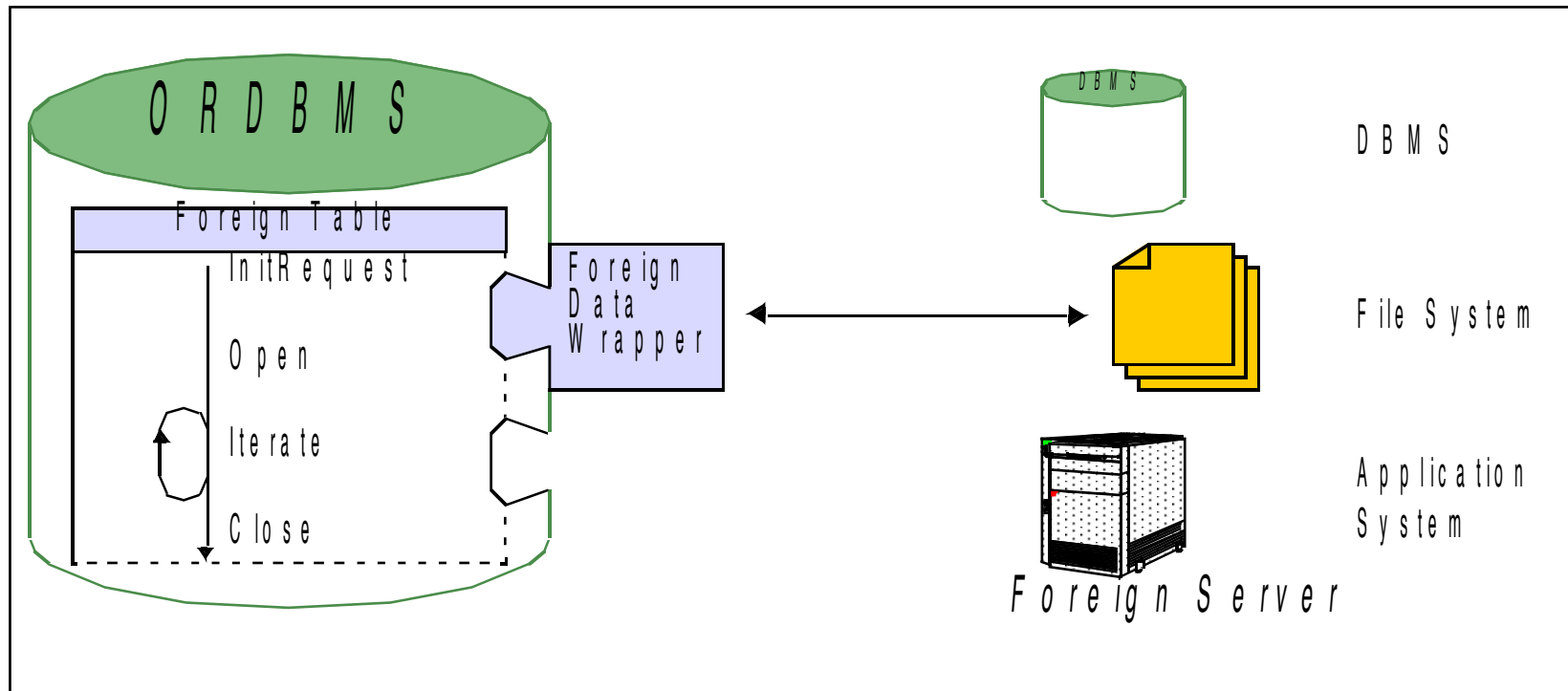
**DB2 Relational Connect**



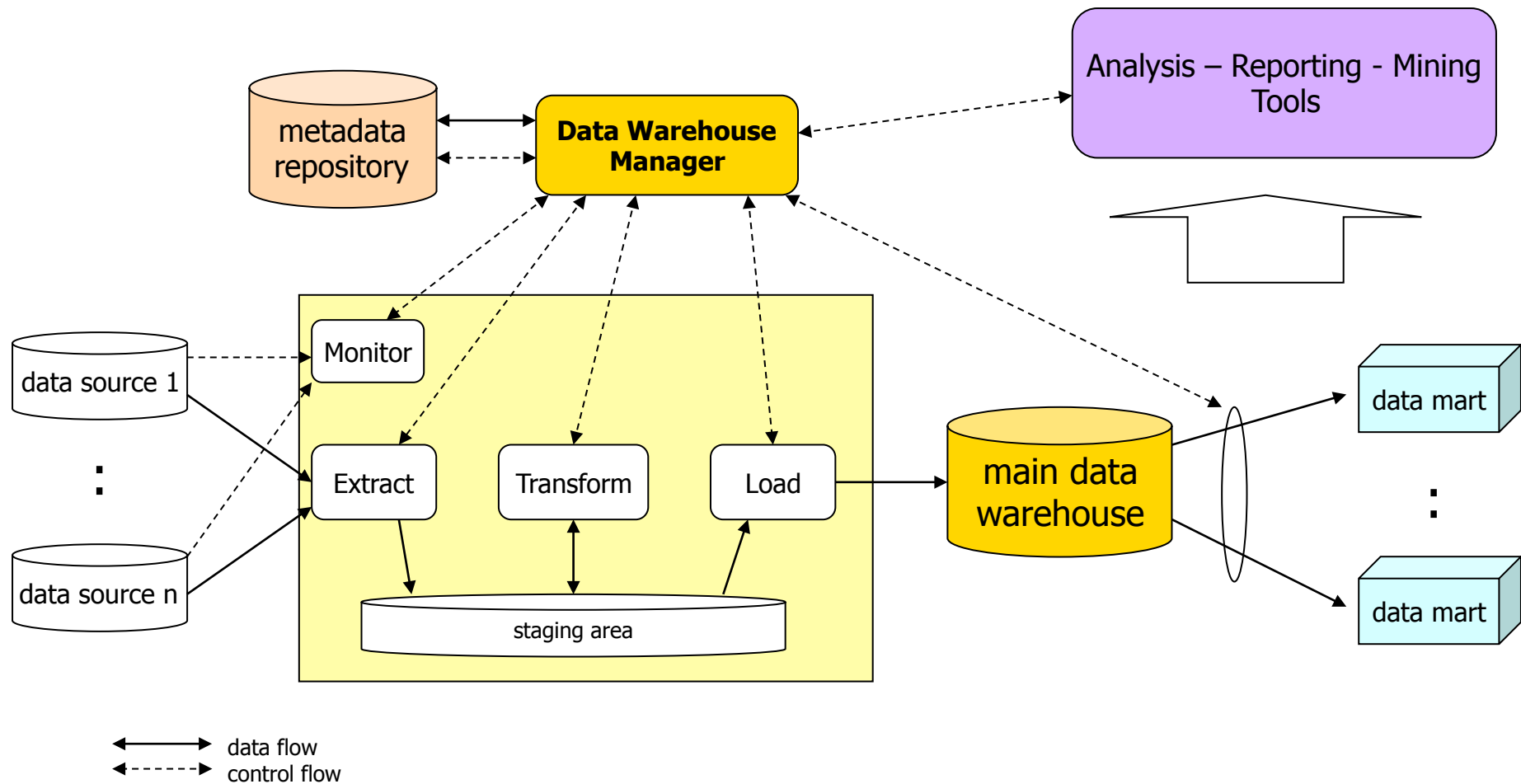


# Standard – SQL/MED

- 'Foreign Data Wrapper' in 'SQL/MED'



# Data Warehousing Architecture



# Integration Process

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- Schema Matching
  - Find inter-schema correspondences
- Schema Mapping
  - Based on correspondences
  - Define how to "translate" one schema into another
    - implies data transformation
- Schema Integration
  - Based on correspondences (and mapping)
  - Define an integrated, global/federated schema

## → Integration Plan!

- Integration plan can then be "implemented" using middleware for virtual or materialized data integration



# Enterprise Application Integration

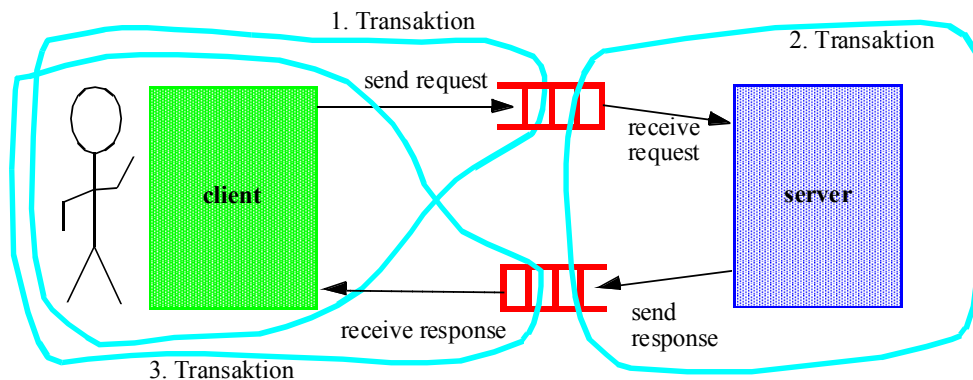
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- Focus on application integration within an enterprise (vs. development of new application)
  - integration across different middleware platforms
  - major shift towards asynchronous interactions (**M**essage-**O**riented **M**iddleware)
- Message Brokers
  - based on MOM
  - hub-and-spoke (instead of point-to-point)
  - publish and subscribe model to link applications together
- Business Process Modeling and Workflow Management Systems
  - make integration logic explicit, easy to modify/extend
  - "programming in the large"

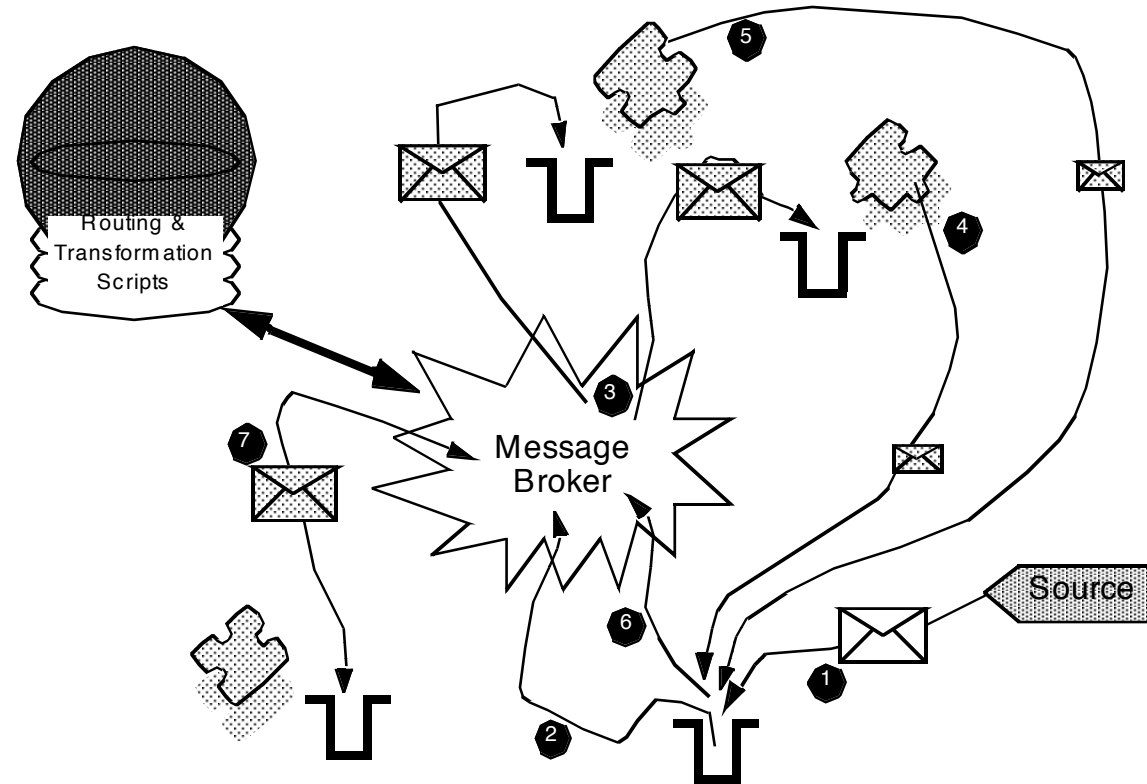


# Message-Oriented Middleware (MOM)

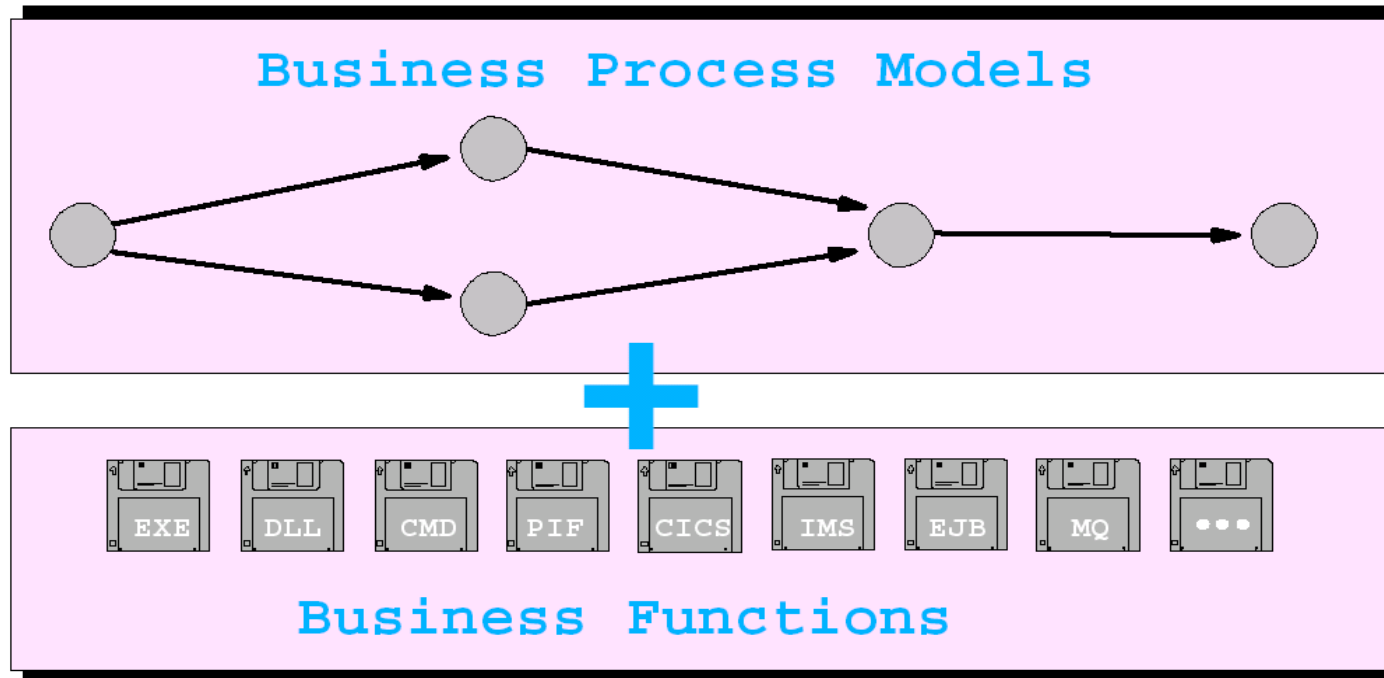
- Message-oriented interoperability
  - programming model: asynchronous message exchange
- Support for persistent, transactional message queues
  - asynchronous transactions
  - reliable messaging
- Optimizing throughput, not response time
- Loosely-coupled application components
  - "client" not blocked during request processing
  - "server" may chose request processing time more flexibly
    - may not even be available at request enqueue time



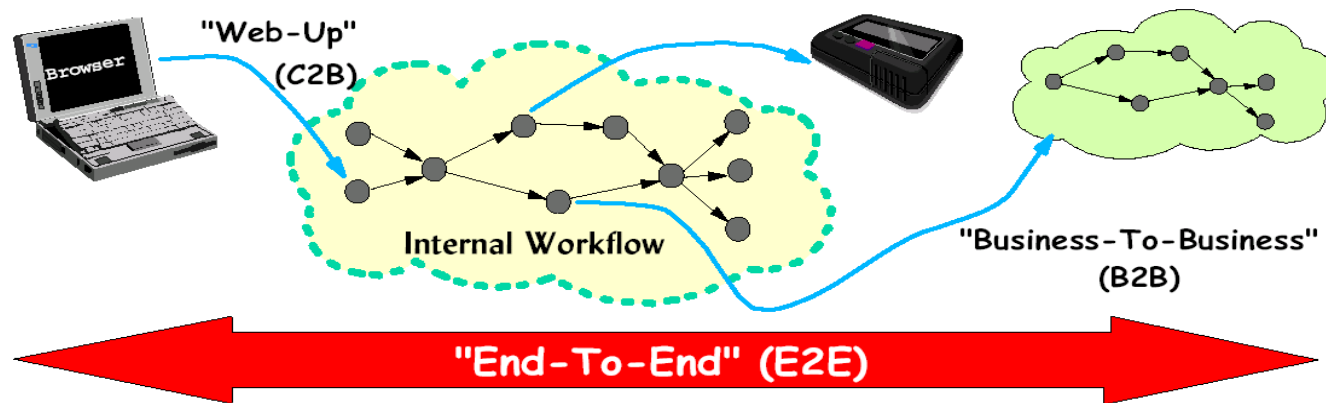
# Message Brokering – Processing Model



# Workflow-Based Applications: Structure



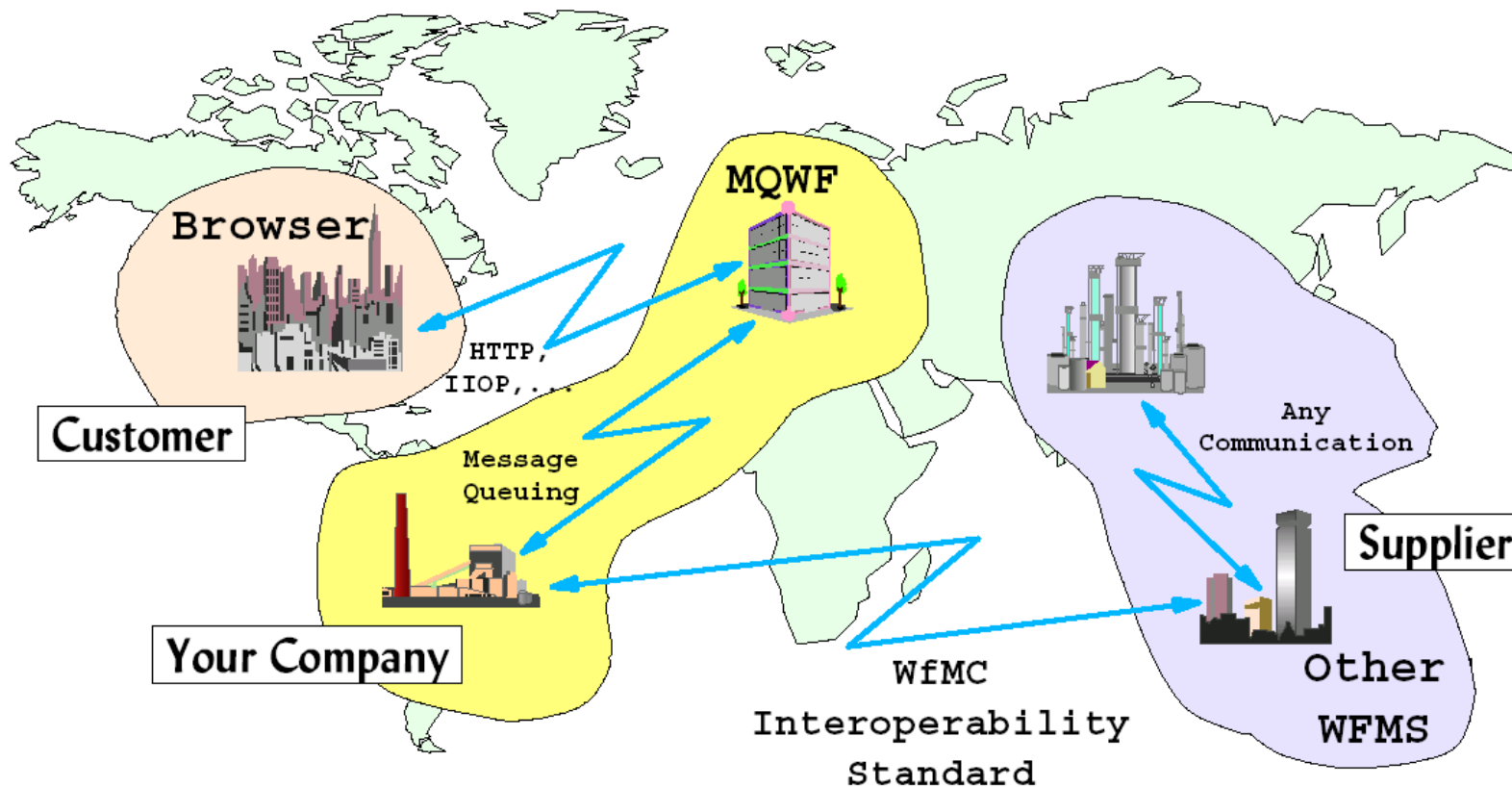
# Workflows And External Communications



- Customers invoke company's applications to perform certain steps of the business process
  - E.g. place on order, inquire status,...
  - Company's applications must get a browser-based front-end for that purpose ("web-up")
- Workflow activities may directly communicate with the outside
  - Send e-mail, faxes, messages,...
- Workflow activities may trigger actions in another company
  - Simple invocation of program or start of another workflow ("subprocess" from invokers point-of-view)
  - Such "business-to-business" scenarios are the base for realizing sophisticated "supply chains"



# Virtual Enterprise: Scenario



# Business-To-Business (B2B) Integration

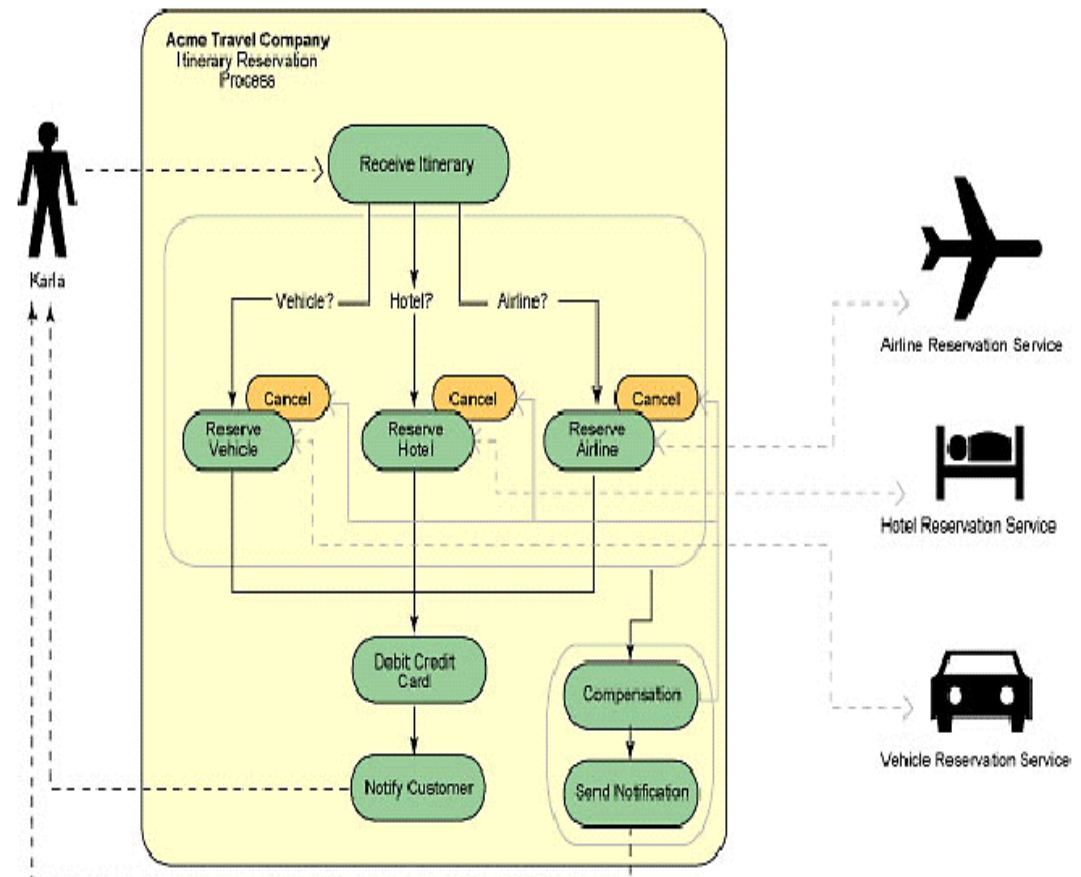
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- Goal: facilitate interaction among trading partners, across companies
  - Establish relation between processes of different enterprises
  - Predominant are relation to suppliers, and customer relations to other enterprises like industrial consumers, retailers, banks
- Traditional B2B has focused on well-defined, standard message formats and protocols (e.g., RosettaNet, cXML)
  - Ad hoc B2B occurs today via XML over HTTP
- How to publish business functions to customers, partners and suppliers?
  - E.g. access to reservation systems, quote systems
  - Programmatic access to a service, independent of underlying implementation and client software
- Web services, service-oriented architectures play a dominant role!



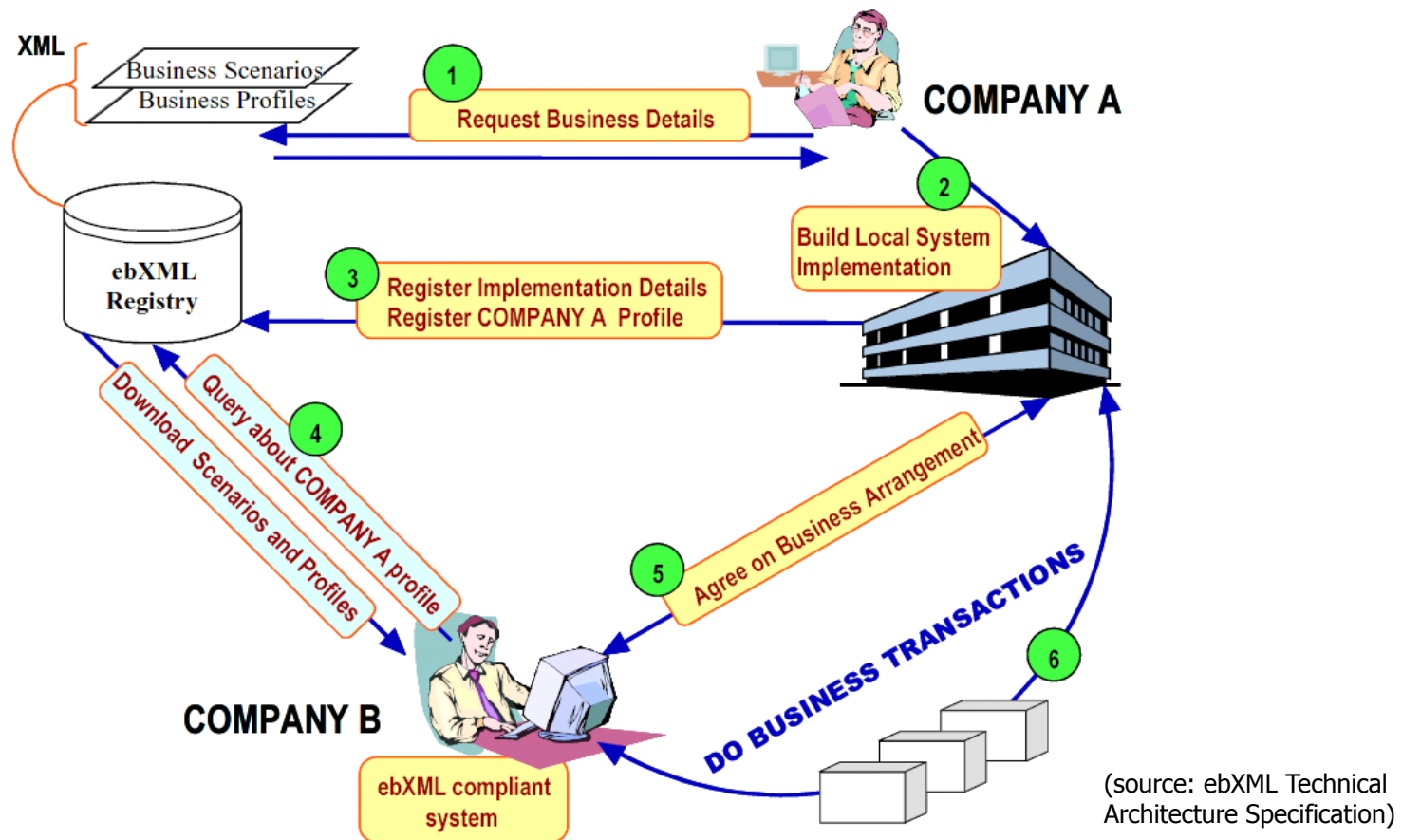
# Web Services & Business Processes

- Business process making use of web services
- Business process externalized as a web service
- Long-running transactions
- Compensation
- Correlation
- Dynamic Binding of business partners and web services



# e-Business Collaboration

- Example: ebXML



# Summary

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- Middleware
  - supports the development, deployment, and execution of complex information systems
  - facilitates **interaction** between and **integration** of applications **across multiple distributed, heterogeneous platforms and data sources**
- Major challenges: distribution, autonomy, heterogeneity
  - different forms of (data) heterogeneity
- Data/Information Integration
  - integrated access to (heterogeneous) data originating from multiple sources
- Enterprise Application Integration
  - integration of (heterogeneous, coarse-grained) applications within an enterprise (vs. development of new application)
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- Business-to-business Integration
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