Prof. Dr.-Ing. Stefan Deßloch
AG Heterogene Informationssysteme
Geb. 36, Raum 329
Tel. 0631/205 3275
dessloch@informatik.uni-kl.de

TECHNISCHE UNIVERSITÄT KAISERSLAUTERN

Enterprise Information Systems
Chapter 1 - Motivation

EIS – Main Focus Is On Integration

- Data/Information Integration
  - integrated access to (heterogeneous) data originating from multiple sources
    - queries range over date 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

- 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

- 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

    } Data Cleaning
- Physical and logical distribution are orthogonal:
  - Data can be logically distributed and physically on the same system (and vice versa)

Autonomy

- 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

- 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

- 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

- 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

- 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^{2}"
- ➡ *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

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

Department

DeptNo	Name
7	Sales
11	Accounting

⟺

EmpDept

EmpNo	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

categorical attribute

Person

ID	Name	Gender
1234	Bob	male
4567	Jane	female

⟺

Men

ID	Name
1234	Bob

Women

ID	Name
4567	Jane

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

Semantic Heterogeneity

- "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

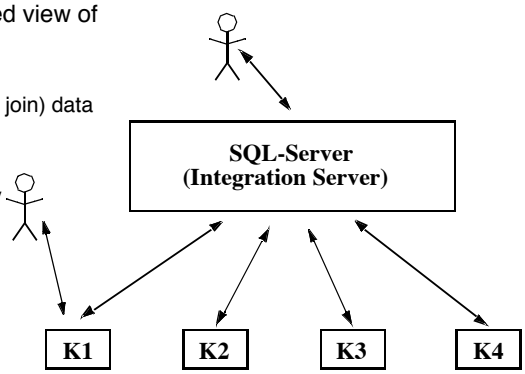
- Traditional Middleware
  - supports access to multiple data sources within the same application, transaction
    - directly (using DB-gateways)
    - indirectly (by invoking distributed application components)
  - but fails to provide data integration
    - no means to analyze/query data from multiple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

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

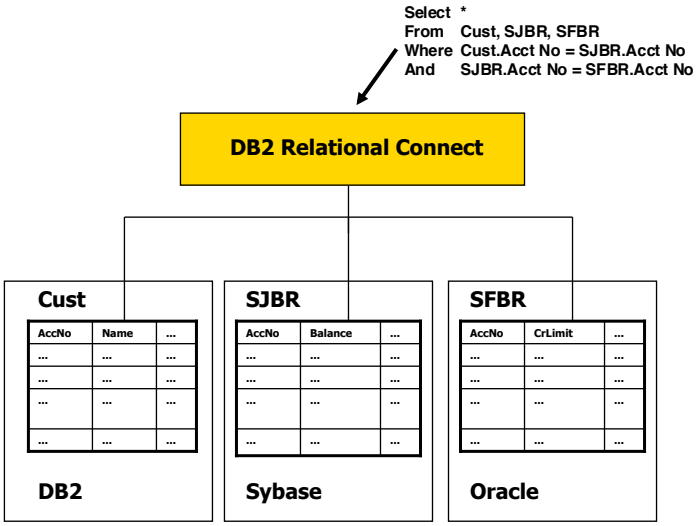
    - does not help to overcome data heterogeneity
- Two architectural approaches to achieve data integration
  - materialized integration: replication, data warehousing
  - virtual integration: federated DBMS, multi-database systems

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

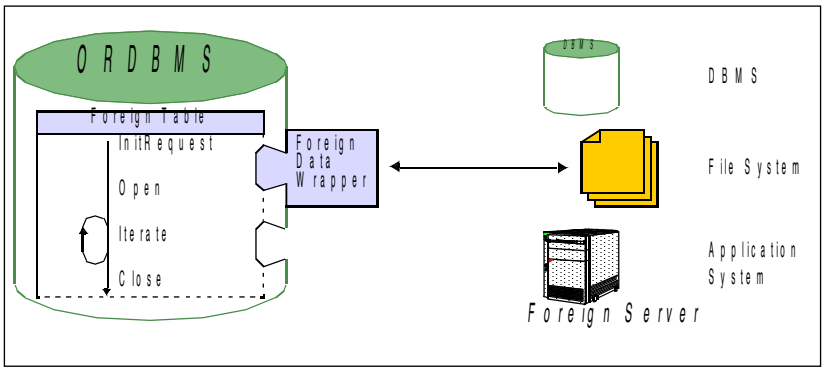


Example - DB2 Relational Connect

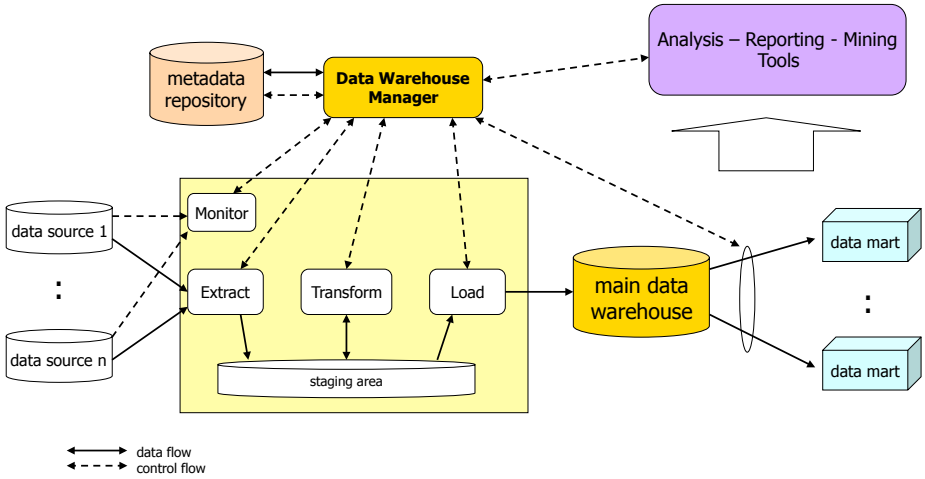


Standard – SQL/MED

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



Data Warehousing Architecture



Integration Process

- 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!**

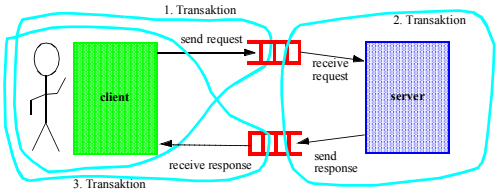
- Integration plan can then be "implemented" using middleware for virtual or materialized data integration

Enterprise Application Integration

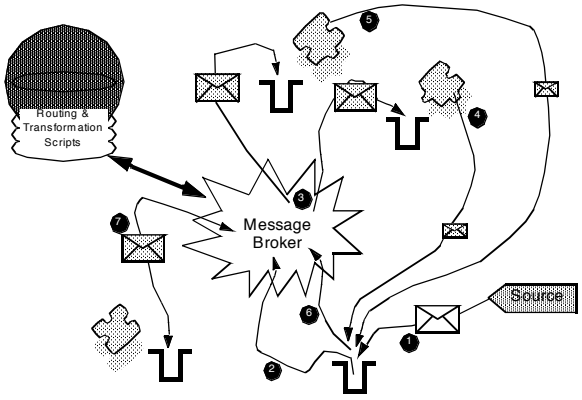
- Focus on application integration within an enterprise (vs. development of new application)
  - integration across different middleware platforms
  - major shift towards asynchronous interactions (**M**essage-**O**riented **M**iddleware)
- Message Brokers
  - based on MOM
  - hub-and-spoke (instead 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)

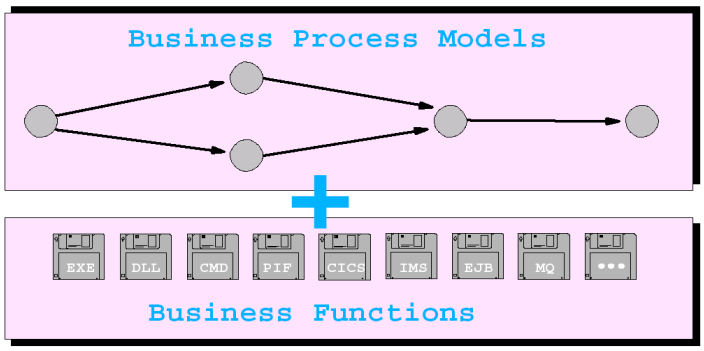
- Message-oriented interoperability
  - programming model: asynchronous message exchange
- Support for persistent, transactional message queues
  - asynchronous transactions
  - reliable messaging
- Optimizing throughput, not response time
- Loosely-coupled application components
  - "client" not blocked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



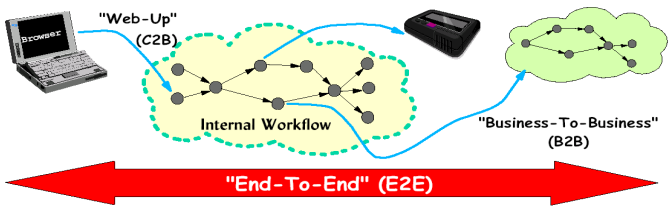
Message Brokering – Processing Model



Workflow-Based Applications: Structure

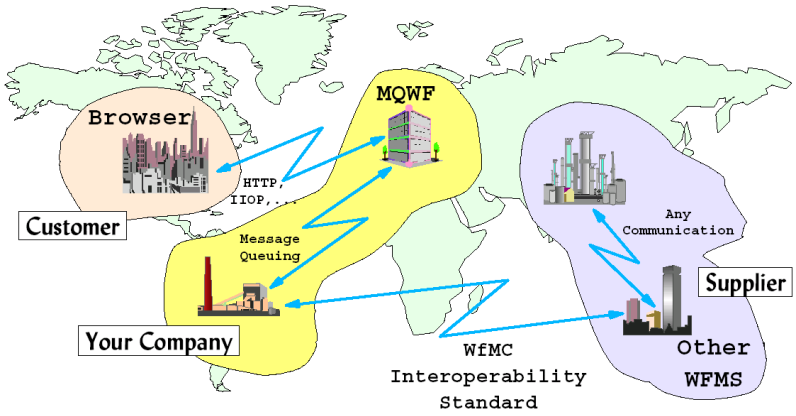


Workflows And External Communications



- 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 invokation 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

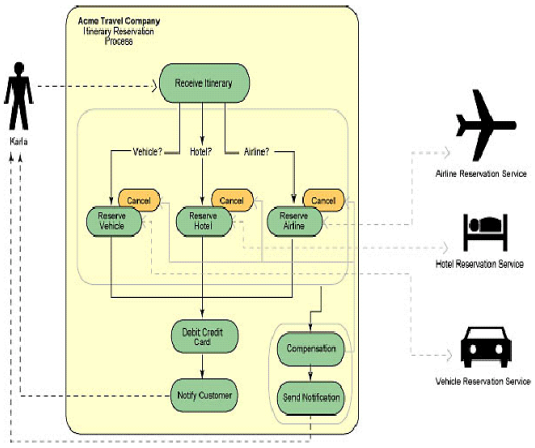


Business-To-Businesss (B2B) Integration

- 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!

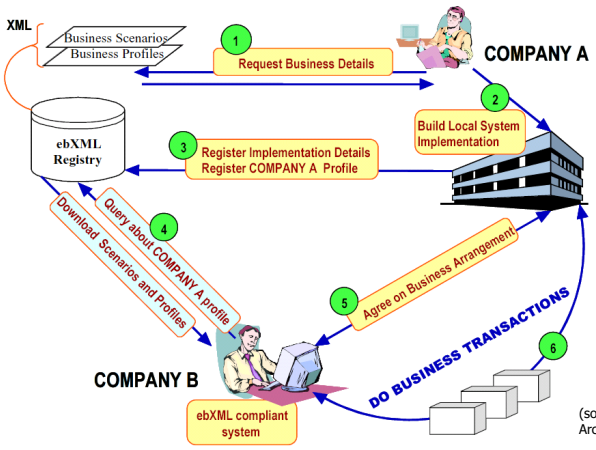
Web Services & Business Processes

- 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



(source: ebXML Technical Architecture Specification)

Summary

- 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)
  - 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