

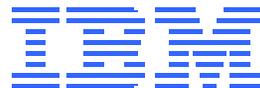
ACM SIGMOD International Conference on
Management of Data (SIGMOD'02),
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Tutorial: Application Servers and Associated Technologies

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These slides are available at http://www.almaden.ibm.com/u/mohan/AppServersTutorial_SIGMOD2002_Slides.pdf

About the Speaker



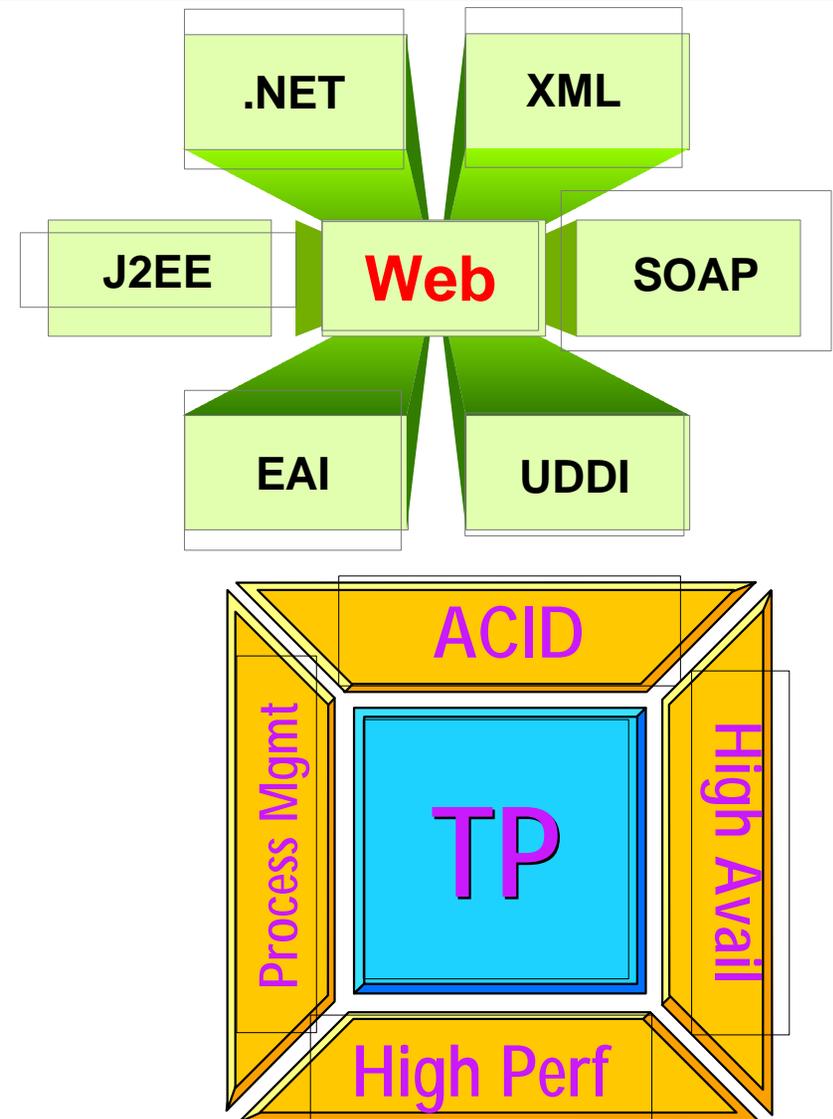
Dr. C. Mohan joined the IBM Almaden Research Center as a Research Staff Member in 1981. In 1997, he was named an IBM Fellow for being recognized worldwide as a leading innovator in transaction management. He received the ACM SIGMOD Innovations Award in 1996 in recognition of his innovative contributions to the development and use of database systems. At VLDB99, he was honored with the 10 Year Best Paper Award for the impact of his work on the ARIES family of algorithms. In 1992, he was elected to the IBM Academy of Technology. Mohan is a core member of IBM's Application Integration Middleware (AIM) Architecture Board. Currently, he is working on data caching and next generation messaging in the context of WebSphere and DB2. He was the founding leader of the Dominotes project which resulted in the enhancement of Domino/Notes's scalability by the introduction of transactional recovery in R5. Prior to that, Mohan led the Exotica project which was focussed on the workflow product FlowMark (now called MQSeries Workflow), the messaging product MQSeries and the groupware product Lotus Notes. Mohan was a designer/implementer of the R* distributed DBMS, the Starburst extensible DBMS and DB2. He is the primary inventor of the ARIES family of recovery and locking methods, and the Presumed Abort commit protocol. He has had major impact on numerous IBM and non-IBM prototypes and products. Mohan's research results and designs have been incorporated in the IBM products DB2, MQSeries, S/390 Parallel Sysplex Coupling Facility, ADSM (now called Tivoli Storage Manager), SQL/DS and VM Shared File System, in Microsoft's SQLServer, in the IBM prototypes R*, Starburst and QuickSilver, and in IBM's SNA LU6.2 and DRDA. Mohan is a consultant to IBM's database, transaction, messaging and workflow product groups.

Mohan is the recipient of several IBM awards: an IBM Corporate Award for his contributions to database support for the S/390 parallel sysplex; an IBM Outstanding Innovation Award (OIA) for his coinvention of the ARIES recovery method which is being used in numerous IBM and non-IBM products and prototypes; an OIA for his inventions (ARIES, ARIES/IM, Commit_LSN) and major contributions to performance, availability and concurrency in DB2/MVS V4; three OIAs for his algorithmic and hardware architectural coinventions for supporting the shared disks transaction environment in S/390 and DB2/MVS; an Outstanding Technical Achievement Award (OTAA) for enhancements to Lotus Domino to provide log-based recovery; an OIA for his coinvention of the Hybrid Join method which is implemented in DB2/MVS; an OIA for his coinvention of the Presumed Abort commit protocol which has been widely adopted in the industry and which is now part of the JTS, ISO-OSI, X/Open and DRDA distributed transaction processing standards; an IBM Research Division Award (RDA) for his work on transaction management in R*; an RDA for his contributions to WDSF/VM; 10th Plateau IBM Invention Achievement Award for his patent activities (30 issued and 3 pending). Mohan was named a leading software inventor of IBM for 1994 and 1995, and a Master Inventor in 1997.

Mohan was the Americas PC Chair for the 1996 International Conference on Very Large Data Bases, a PC Vice-Chair for the 1994 IEEE International Conference on Data Engineering and the PC Chair for the 1987 International Workshop on High Performance Transaction Systems. He is the Industrial PC Co-Chair for ICDE2003. He has been an Editor of the VLDB Journal, and Distributed and Parallel Databases - An International Journal. Mohan received a PhD in computer science from the University of Texas at Austin in 1981 and a BTech in chemical engineering from the Indian Institute of Technology, Madras in 1977.

Overview

- TP Monitors
- Business Shifts
- Java 2, Enterprise Edition (J2EE)
- Beans, Messaging
- Application Server Products
- Benchmarks
- Caching
- Business Process Management
- Summary and Outlook



Traditional TP Monitors

Provide infrastructure for **efficient** execution of transactional applications (CICS, IMS TM, Tuxedo, TopEnd, ACMS, ...)

Typical Characteristics

- ACID transactions: atomic, durable transactions
- Very large databases (VLDBs)
- **Scalable high performance:** throughput, response time (<1 sec), ...
- Data comm: large client nets, synchronous and asynchronous messaging (app-app comm)
- Legacy data, applications, hardware
- Workload management, accounting, ...
- **Industrial-strength software infrastructure** (RAS, ...)
- Online, batch, query access to data



Example apps: finance (banking, brokerage), insurance, healthcare, telecom, reservations (hotel, car, air), inventory control, retail/distribution, HR, ...

IBM's CICS Transaction Server

**30 billion transactions/day (> WWW)
\$100B/week (~ Nasdaq)**

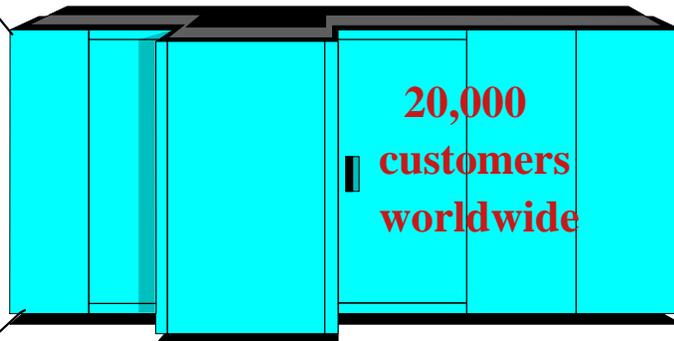
 **\$1 Trillion in apps (IDC)**

**32 years
invested in
applications**

**Used by 490 + of IBM's
top 500 customers**



**30 million
users**

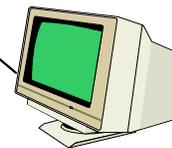


**950,000 programmers earn
their living from CICS**

**15 Million 3270
terminals waiting to
be replaced**



**5000 packages
from 2000 ISVs**



**5,000+ packages
from 2000 ISVs**

Up to 150,000 concurrent users/system on CICS

Up to 750,000 concurrent users/system on TPF

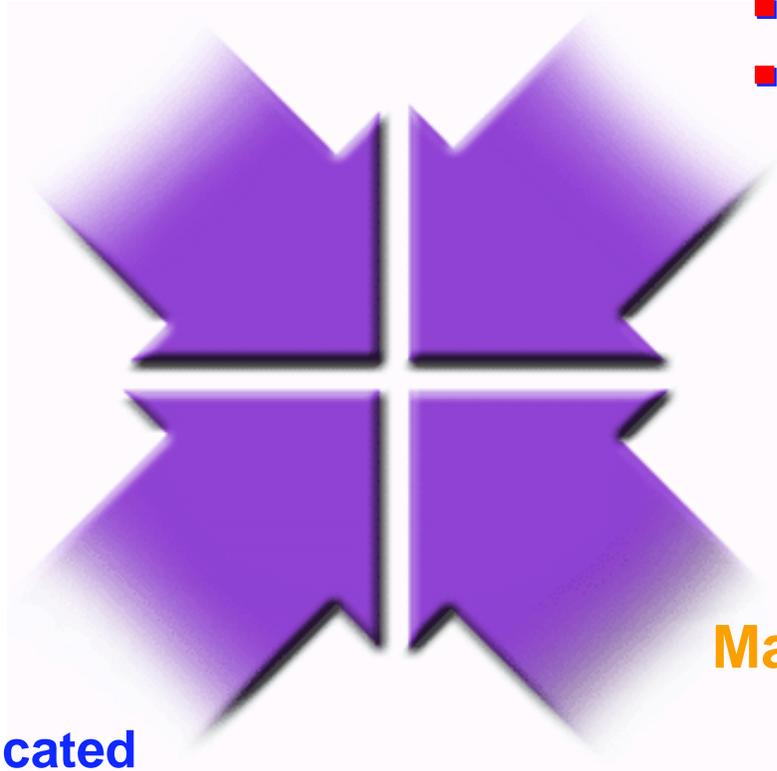
Business Shifts

Business

- Globalization
- Deregulation
- Competition

Technology

- Power of the Web
- Pervasive computing
- Information vs. data



Customers

- More sophisticated
Complex transactions
- More demanding
Standards, Performance, 24X7
Cost of Ownership

Markets

- Fragmented
- Mass customization

SIGMOD2001 App Server Panel Questions

- How are ASs different from decades-old TP monitors like CICS? Why are they needed?
- What is the market share of different products?
- Have ASs come into existence and acquired prominence because of standards like Java, JDBC, EJB, CORBA, XML, IIOP, etc.?
- How are legacy apps, and data sources like IMS and VSAM integrated into modern AS environments?
- How do AS products differ architecturally?
- What is the right place for the AS functionality in the software stack - in the OS, integrated with the DBMS or as a separate middleware component?

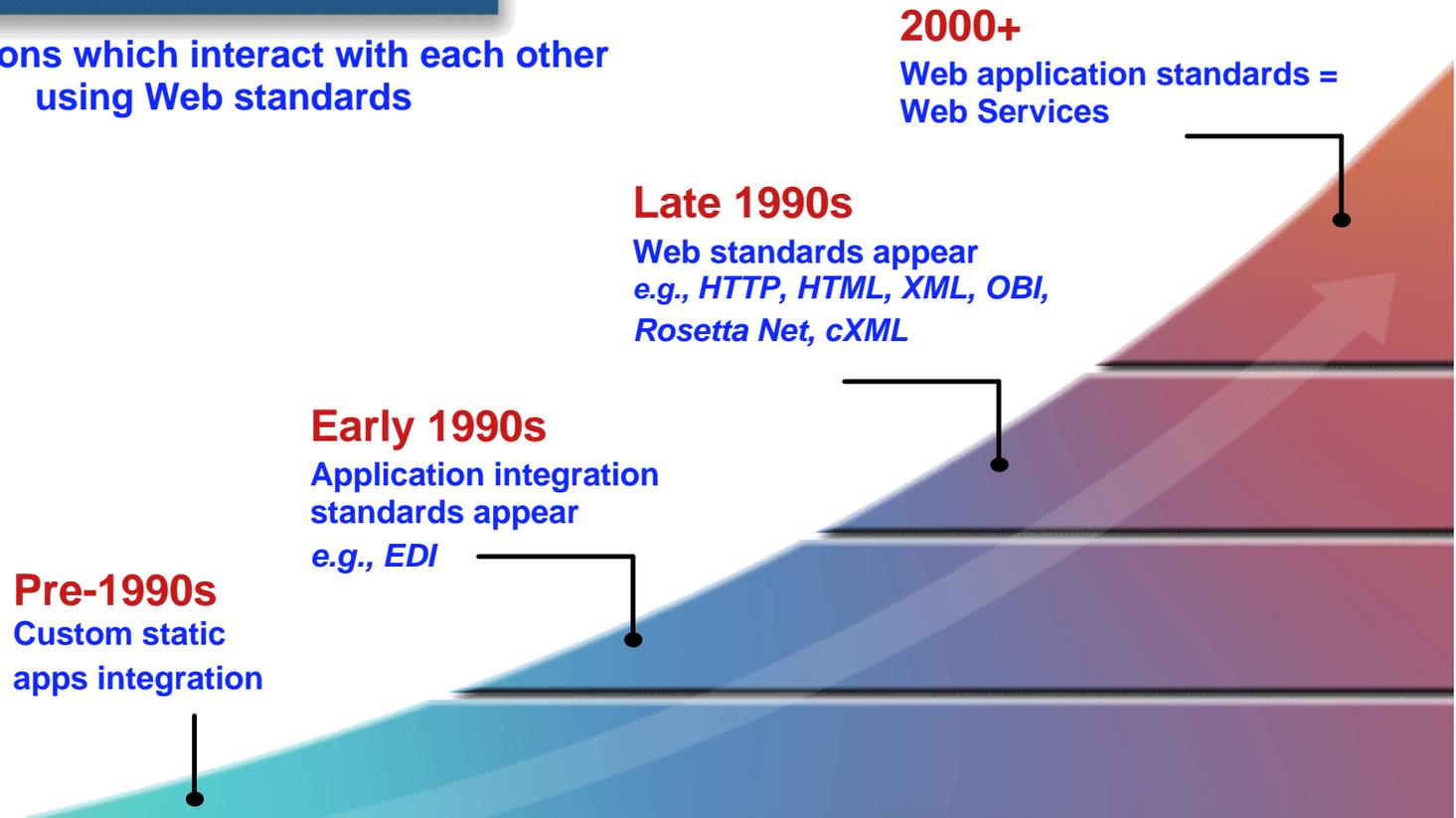
SIGMOD2001 App Server Panel Questions

- How much should ASs interact with/leverage DBMSs?
- Are ASs really needed when DBMS stored procedures, triggers and UDFs are usable for server-side logic?
- What role do integrated software development tools play in the successful deployment of ASs?
- How easy is to port apps across different ASs?
- What are the systems management issues?
- Who are the customers with ASs in production usage?
- What are some thorny issues to be solved by vendors?
- What AS problems should researchers address?

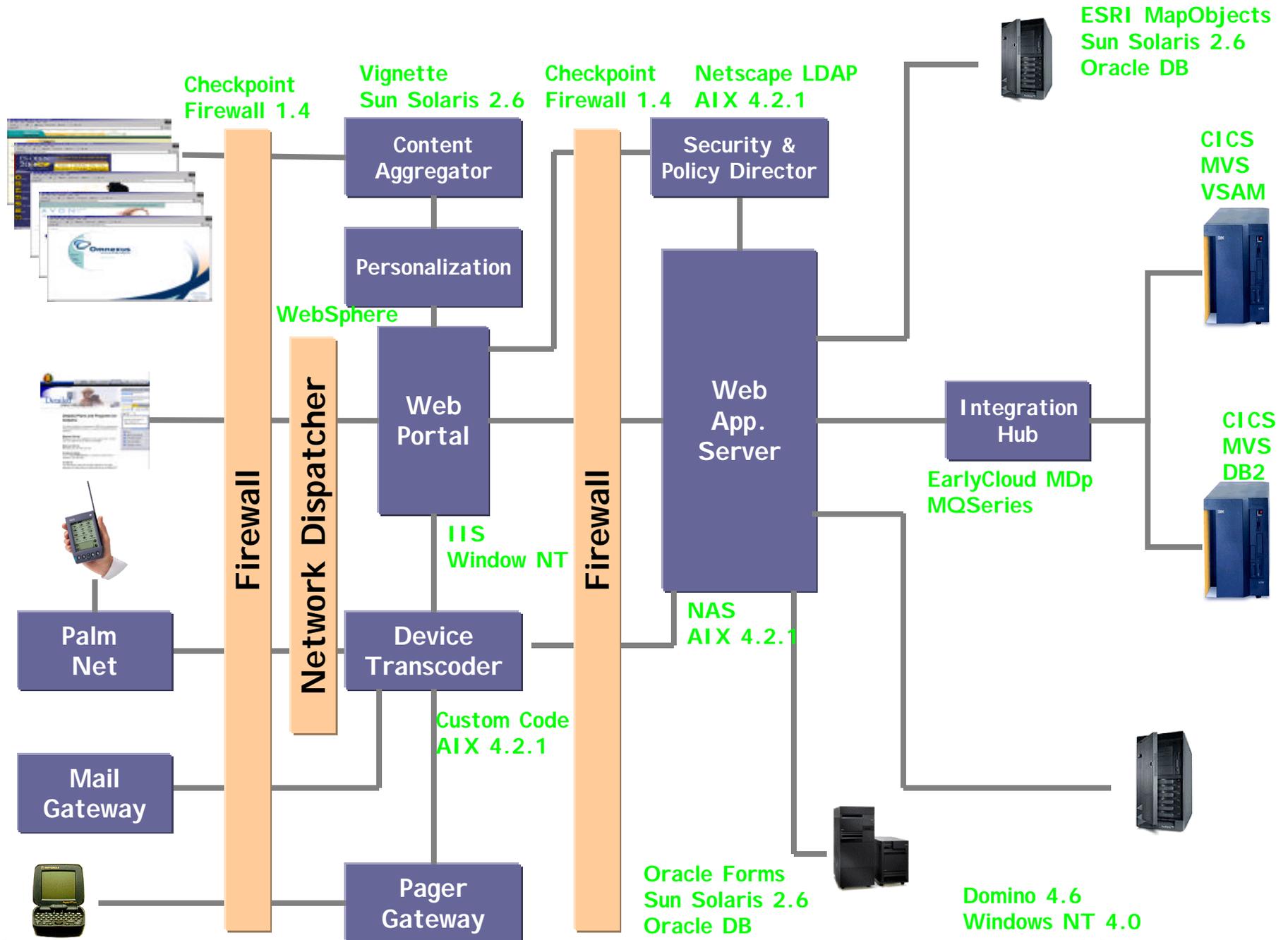
Web Application Integration Evolution



Applications which interact with each other using Web standards



A Sample Customer Environment

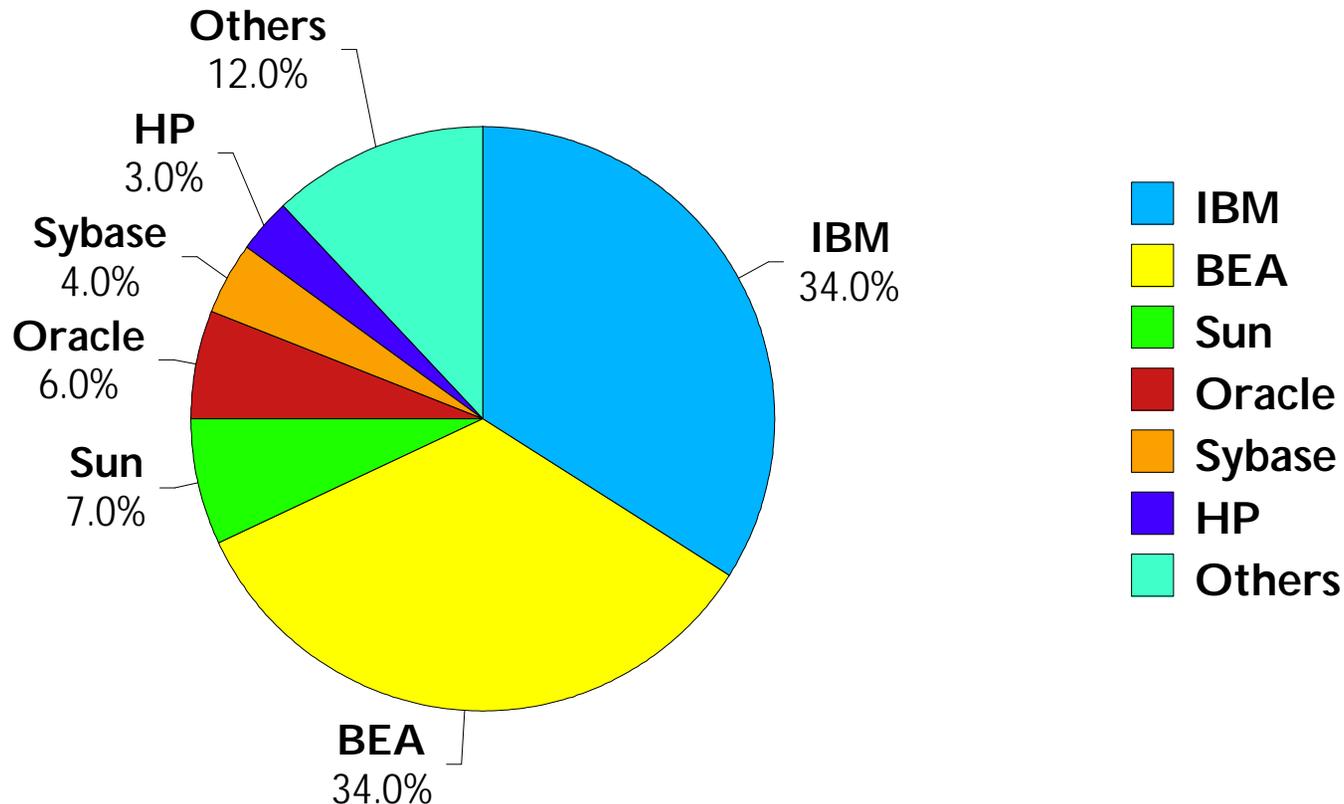


Application Servers

- Modern equivalents of traditional TP monitors
- Except Microsoft, all based on Java 2, Enterprise Edition (J2EE)
- **Commercial:** BEA WebLogic, IBM WebSphere, Oracle9i Application Server, Sun ONE (iPlanet), Sybase EAServer, HP, Iona, ATG, Allaire, SilverStream, Brokat, Borland, Pramati, Fujitsu Interstage, SAS, Macromedia, Trifork, Hitachi, NEC, Computer Associates, ..., Microsoft .NET
- **Open Source:** JBoss, JOnAS
- Some representative quotes:
 - "J2EE is to Java what SQL was to databases"
 - "Without J2EE, it is not an application server"
- Vendor differentiation based on scalability, high availability, reliability, ease of use, legacy data & app integration, complementary products (e.g., for personalization, commerce, workflow) and extensions

J2EE Application Server Market Share

Giga's Final Estimates for 2001



- **2001: \$2.19B (39% Y2Y growth)**
- **2001 (2000) market share: IBM 34% (31%), BEA 34% (36%), Sun 7% (9%), Oracle 6% (3%), Sybase 4%, HP 3%, Others 12%**



Market Share

■ IDC

- 2006: \$4.4 (est.), **2001: \$2.2B**; 2000: \$2B, 1999: \$987M
- 2001 (2000): BEA 24.8% (20%), IBM 23% (17%),
Oracle 12% (9%), Sun 7.9% (9%)

■ Gartner/Dataquest

Stand-alone application servers (excludes Oracle)

- 2001 (2000): BEA 34% (33%), IBM 31% (22%),
Sun 9% (10%), Iona 3%, Sybase 1%
- 2006: \$3.2B (22% CGR), **2001: \$1.18B** (20% Y2Y)
2000: \$990M (92% Y2Y)

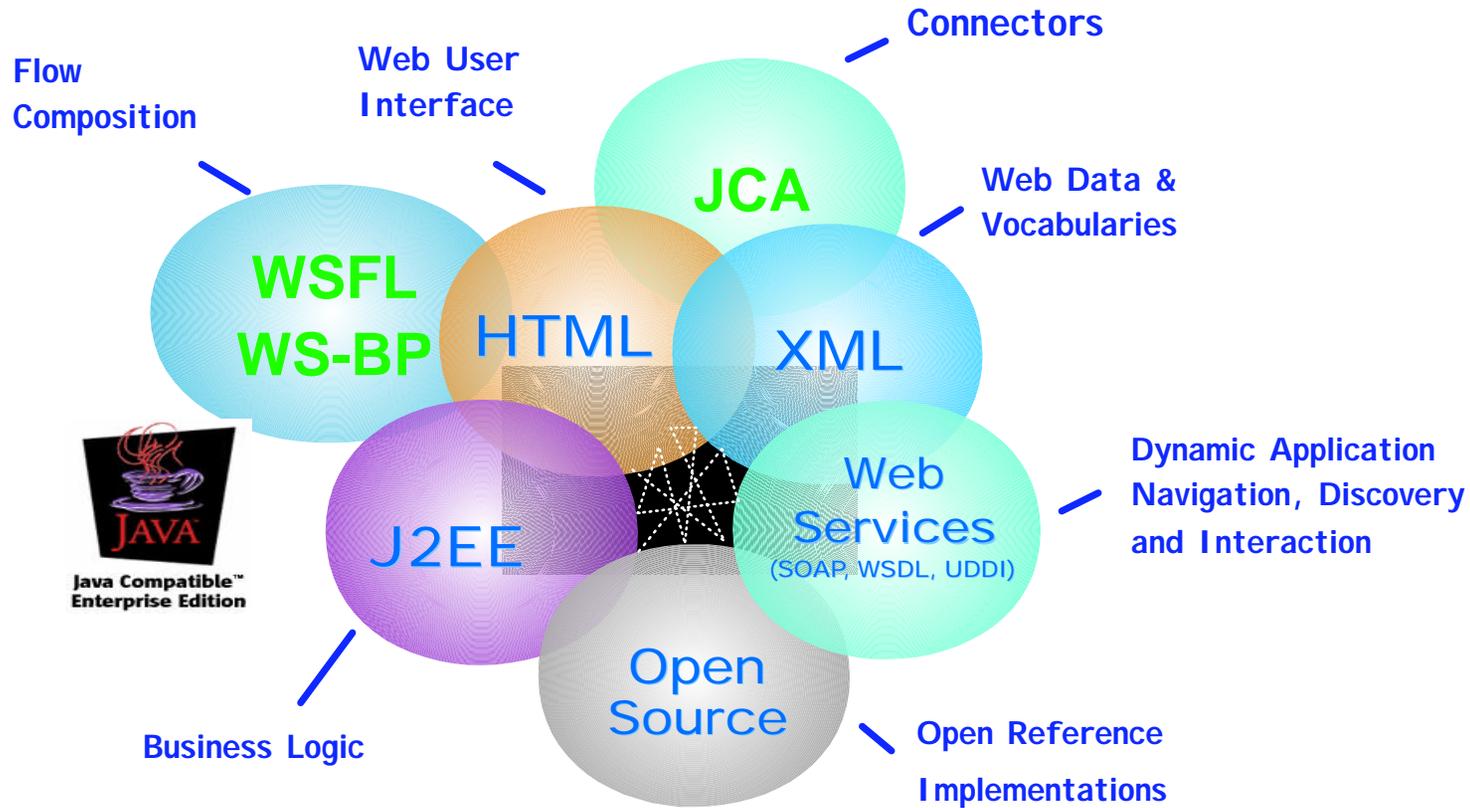
Bundled application servers

- 2001: IBM 33%, BEA 24%, Oracle 12%
- **2001: \$1.9B**

■ Meta Group

- 2004: J2EE 40%, .NET 30%

Open Standards



Trusted Internet Networking Services

Linux Windows AIX Solaris HP/UX OS/400 OS/390 zOS

Application Server Functionality

- Quality of Service: clustering, cloning, routing, failover, session persistence, session migration, load balancing
 - Java virtual machine (JVM)
 - Rules engine for personalization, commerce pricing, message transformations, ...
 - Caching: data, objects
 - Authentication, authorization, single sign-on
 - Web server plug-ins for caching, load balancing, failover
 - Messaging, development tooling
-
- ✓ **Component Container**
 - ✓ **Transaction Integration**
 - ✓ **Thread/Connection Pooling**
 - ✓ **Memory Management**
 - ✓ **Load Balancing/Failover**
 - ✓ **Session/State Mgmt**
- ✓ **Connections:**
 - ✓ **RDBMS**
 - ✓ **Transaction Systems**
 - ✓ **ERP Systems**
 - ✓ **Dynamic Page Generation**
 - ✓ **HTTP**

Java 2 Enterprise Edition (J2EE)



Application Server Platform for Java (latest 1.3, 7/2001)

- Java Servlets & Java Server Pages (JSP)
- Enterprise Java Beans (EJB)
- Java Transaction API (JTA)
- Java Transaction Service (JTS)
- Java API for XML Parsing (JAXP)
- Java Messaging Service (JMS)
- Message Driven Beans (MDB)
- Remote Method Invocation (RMI)
- Java Database Connection 2 (JDBC2)
- Java Connector Architecture (JCA)
- Java Naming and Directory Interface (JNDI)
- JavaBeans Activation Framework (JAF)

http://java.sun.com/j2ee/sdk_1.3/index.html

For excellent news, views, ..., visit <http://www.theserverside.com/>

Certification

J2EE Compatibility Test Suite (CTS)

- Helps ensure portability of apps

<http://java.sun.com/j2ee/compatibility.html>

J2EE Application Verification Kit (AVK)

- Tool for testing apps for correct use of J2EE APIs and portability across different J2EE app servers
- Pilot underway

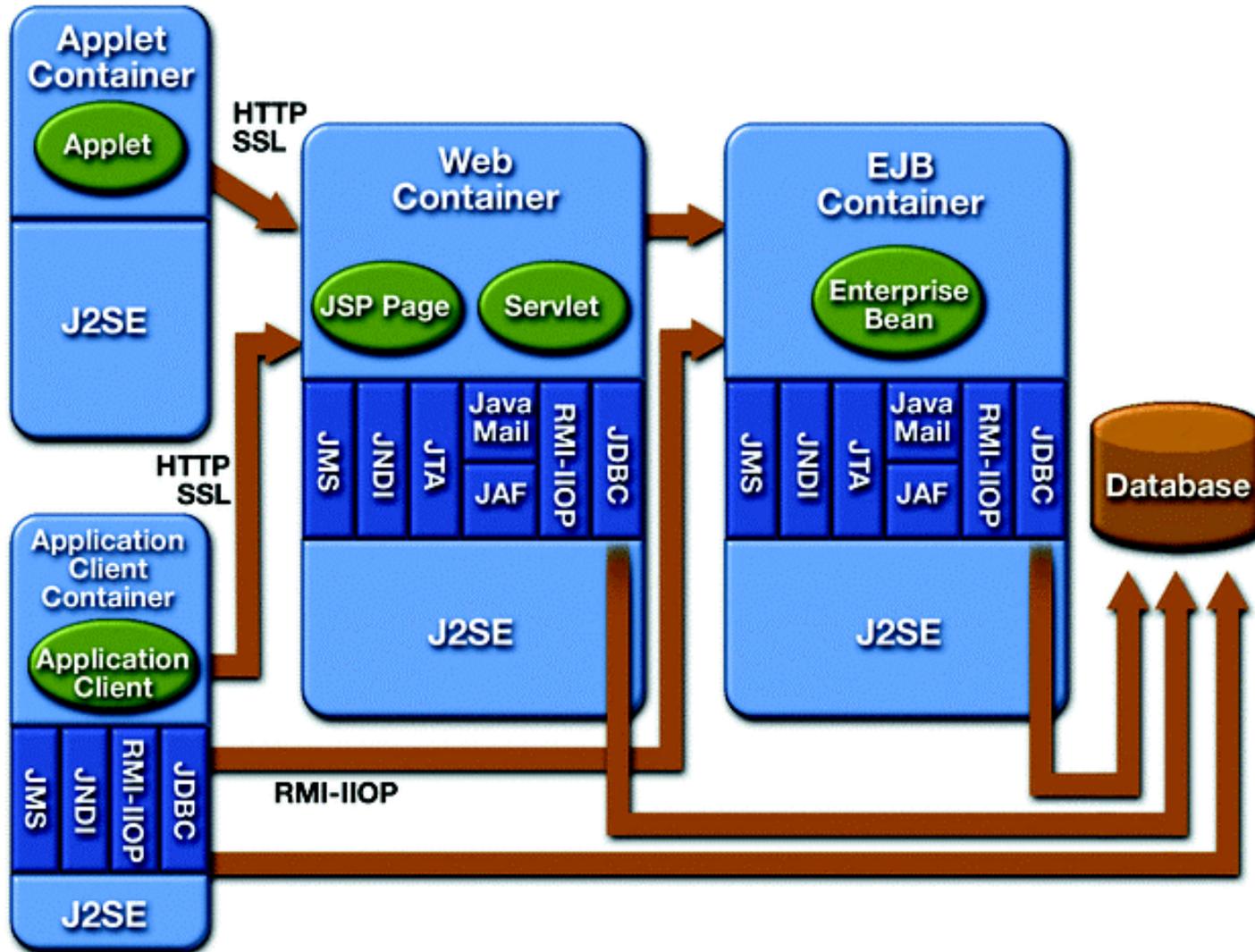
<http://java.sun.com/j2ee/avk/>

J2EE Licensees

- Ship products with J2EE branding

<http://java.sun.com/j2ee/licensees.html>

Multi-Tier J2EE-Based Architecture



A J2EE app with all its modules delivered in an Enterprise ARchive (EAR) file = WARs + JARs

Web Container and Components

Web Container: Provides request dispatching, security, concurrency and life-cycle management

- Web app = HTML/XML pages, JSPs, Servlets, Java classes, applets, images, multimedia and other files
- Web client packaged into a **Web Application Archive (WAR)** and deployed into a web container for execution

Servlets

- Java classes to dynamically process requests and construct responses
- **HttpServlet** class provides methods, such as **doGet** and **doPost**, for handling HTTP-specific services

JSPs

- Text-based documents that execute as servlets

- Server components execute within a component execution system (**container**)
- CORBA provides infrastructure for EJBs
- EJBs are the component model for CORBA and J2EE
- Support multi-tier apps by defining support for
 - Client-server distribution
 - Transactions
 - Scalable state management
 - Deployment
 - Security
- **Server Bean**: Implements business logic which executes synchronously with a client program
- Support transient and persistent objects
- Bean provider indicates several choices via **deployment descriptor**
- Latest: 2.0 (8/2001)

Types of Beans

Entity

- Represents a persistent business object
- Allows shared access, has primary key, and may participate in relationships with other entity beans
- Typically, each entity bean maps to a table and each instance of the bean corresponds to a row in that table
- Bean-managed persistence (**BMP**) and container-managed persistence (**CMP**)
- Transaction attributes in deployment descriptor

Session

- Represents a single client inside J2EE server, like an interactive session maintains conversational state
- **Stateful** and **stateless** session beans
- Not shared, not persistent, can be transaction aware
- Object-valued attributes associated with a session by name

EJB 2.0

- Declarative specification of relationships between EJBs
- Declarative query language based on abstract schema - DBMS-/vendor-independent way to find entity beans at run time, based on various search criteria
- *Local interfaces* for efficient invocation of EJBs in same container - call-by-reference parameter passing
- Inter-server application interoperability using RMI/IIOP
- No support for events, different isolation levels, many SQL operators (subqueries, Group By, ...) - for detailed critique, see <http://www.softwarereality.com/programming/ejb/index.jsp>
- Caching is fundamental to improve performance
- EJB 2.1 (4/2002) under JCP review:
Focus on web services, EJB QL enhancements

Container-Managed Persistence (CMP)

- **EJB Container** handles all database access of entity bean
- Bean not tied to specific persistent storage mechanism
- Bean's **abstract schema** defines bean's persistent fields and relationships; schema named in deployment descriptor
- Schema referred to in **EJB QL queries**, one of which is required for every **finder** method (except *findByPrimaryKey*)
- Typically, an entity bean maps to a table and the bean's persistent fields (identified by **getters/setters**) to columns
- **Relationship fields**, defined by **access** methods, are like foreign keys and they identify related beans
- Doesn't support inheritance

EJB Query Language

- Used to define queries for **finder** and **select** methods of CMP entity bean
- A **subset of SQL92**, but has extensions to allow navigation over relationships of bean's abstract schema
- EJB QL navigates via a **path expression** to related beans, whereas SQL joins tables
- Queries defined in bean's **deployment descriptor**
- Scope of query spans schemas of related beans packaged in same **JAR file**

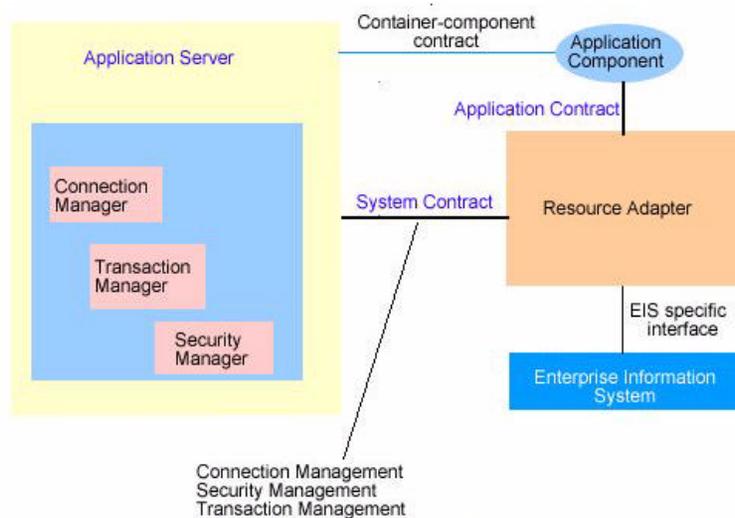
Java Transaction API & Service

- X/Open defined **XA** transaction standard
 - Supported by TP monitors and RDBMSs
 - **Presumed Abort** two-phase commit protocol
- OMG defined **OTS**: object version of XA + a few more features (e.g., nested transactions)
 - Supported by ORB/TP vendors
- JCP defined **JTS**: Java mapping of OTS with extensions
 - Interoperates with non-Java environments
- Transaction properties of EJBs defined during design or deployment via declarations in **deployment descriptor**
 - **TX_Required**, **TX_Mandatory**



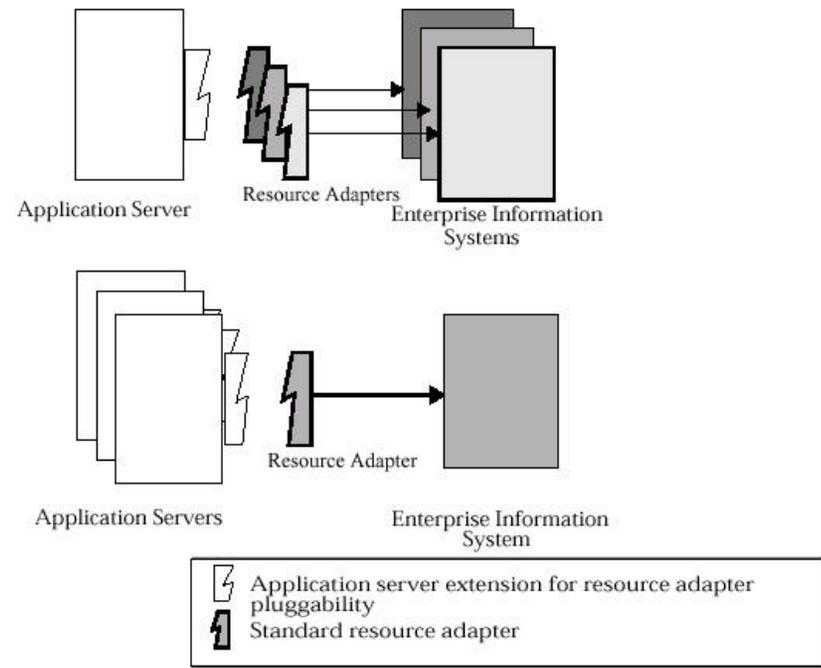
Java Connector Architecture (JCA)

- Allows tight integration of J2EE apps and legacy systems (EISs) via resource adaptors
- Pools connections to an underlying EIS
- Allows transactional access to EISs
- Secure access to an EIS



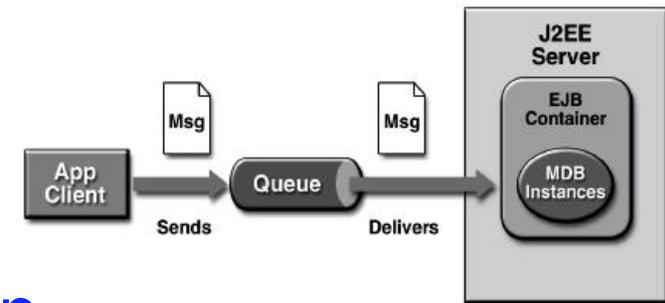
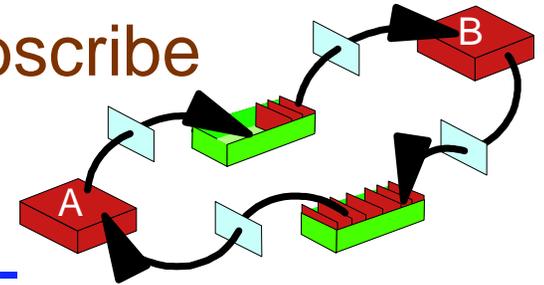
J2EE Connector Architecture Overview

System Level Pluggability between Application Servers and EISs



Java Messaging Service (JMS)

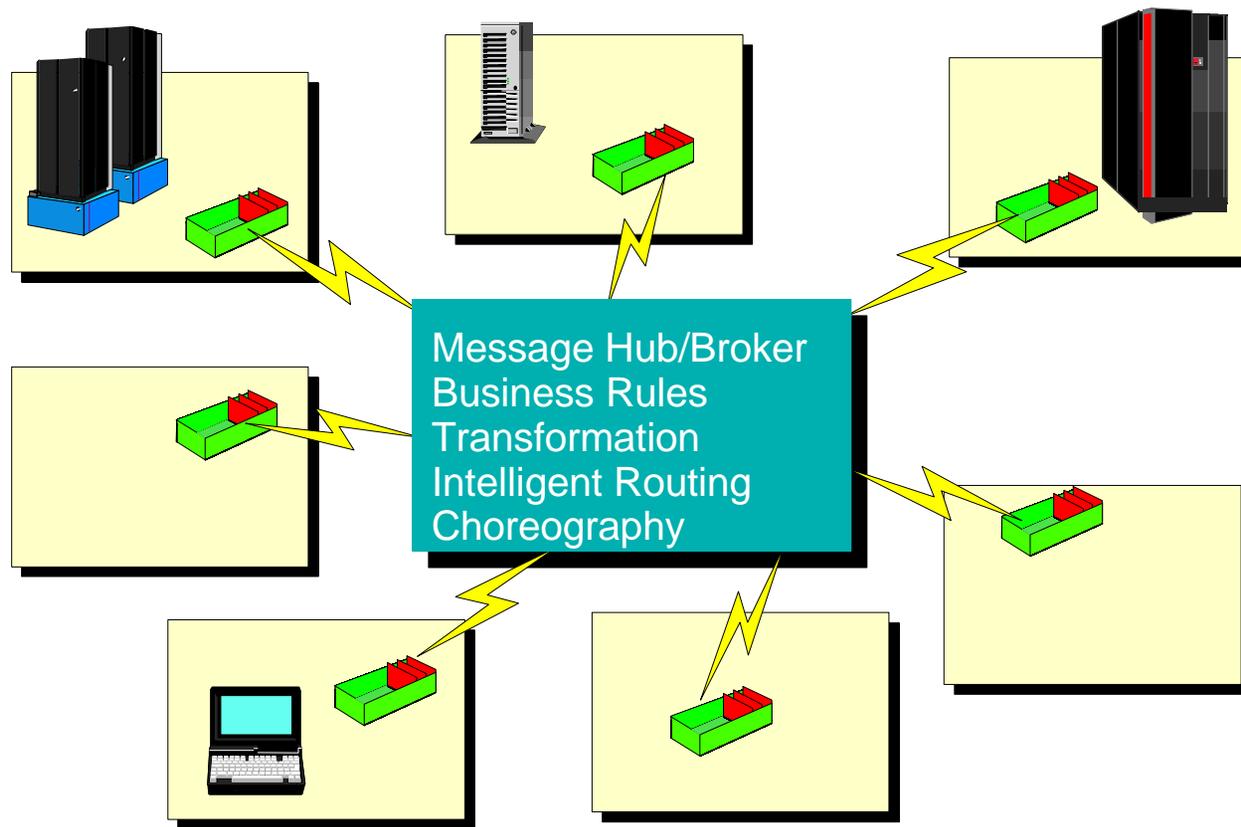
- Transactional, asynchronous messaging - APIs to create, send, receive, read messages
- Domains: Point-to-point (PTP), Publish/Subscribe
- Message Driven Beans (MDBs)
 - For **asynch** consumption of messages - acts as a JMS message listener
 - Don't have local/remote interfaces for client access
 - Resembles a stateless session bean
 - On receiving message satisfying message selector, container invokes *onMessage* method of MDB
- JMS and MDBs mandatory in J2EE 1.3
- Latest spec 1.1 (4/2002)



JMS Qualities of Service

- Delivery Mode - set by Sender/Publisher
 - Persistent
 - Non-persistent
- Subscription Durability - set by Subscriber
 - Non-durable
 - Durable
- Transactionality
 - Attribute of sending and/or receipt of messages
- Acknowledge Mode
 - Allows non-transactional receivers to specify how often acks should flow back to JMS server

MQSeries



MQSeries Workflow

End-to-end process management w/tracking and auditing, linking systems with people

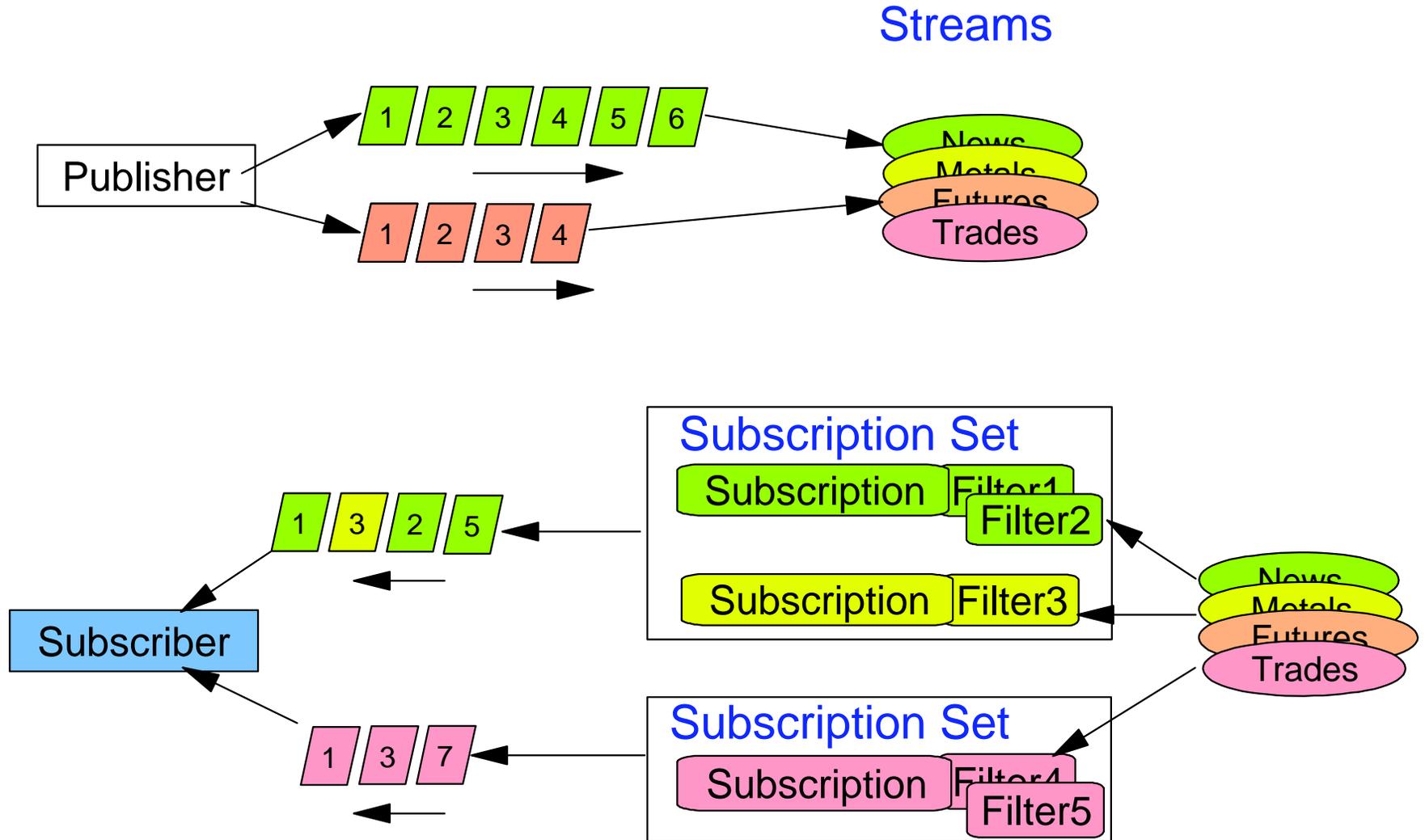
MQSeries Integrator

Business information manipulation, content publish/subscribe, XML

MQSeries

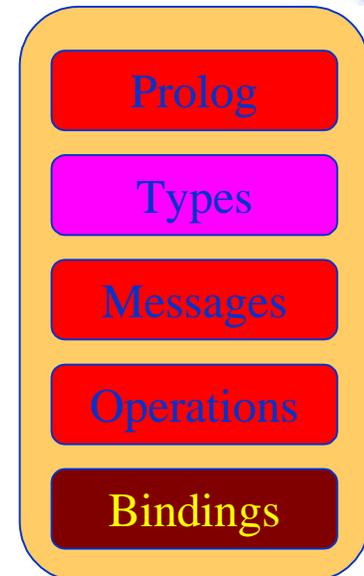
Messaging services with assured delivery

Publish/Subscribe



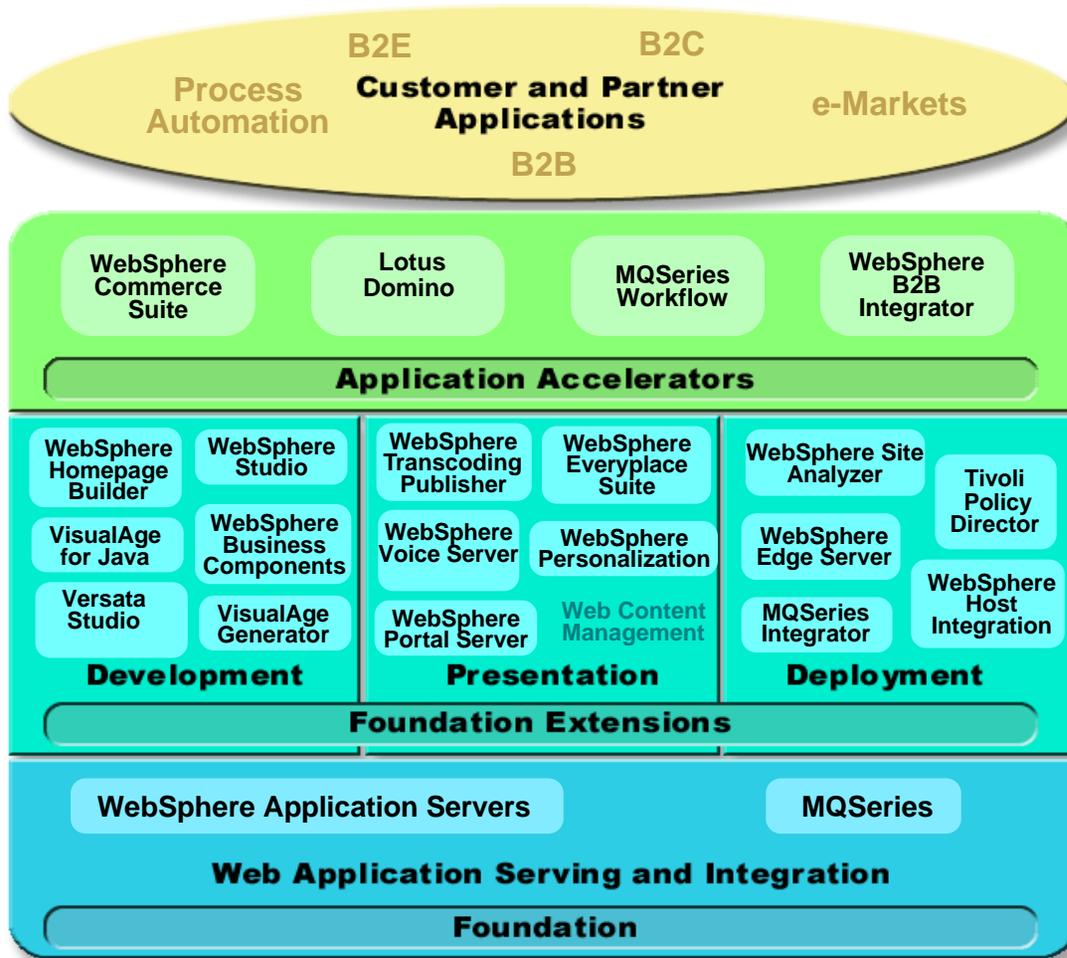
Web Services

- **UDDI** (Universal Description, Discovery and Integration) for discovering services
- **SOAP** (Simple Object Access Protocol) for using services
- **WSDL** (Web Services Description Language) for describing services
- A service = a set of port types
- Set of XML Schema definitions
- Set of message definitions
- Set of operations
- Bindings provide implementation or usage details for services, port types, etc.
- XML everywhere!
- App servers provide message handlers (for intercepting incoming and outgoing messages) and serializers (for mapping complex data types between Java and XML)

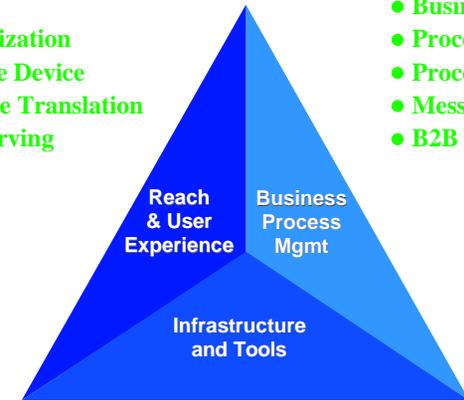


IBM WebSphere Platform

Enabling business transformation



- Portals
- Personalization
- Pervasive Device
- Language Translation
- Voice Serving



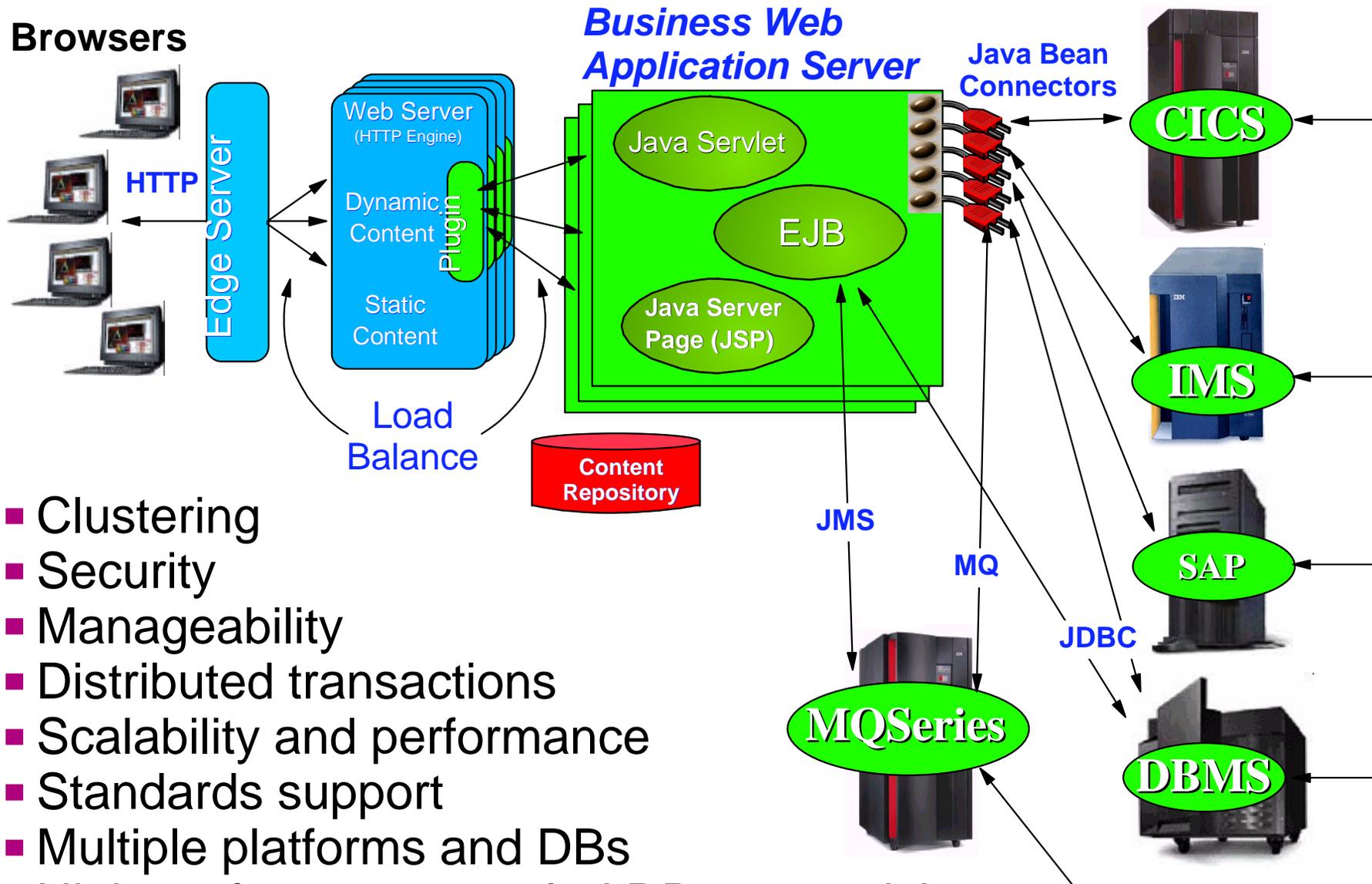
- Business Modeling
- Process Integration
- Process Automation
- Message Interaction
- B2B Integration

- Application Servers
- Messaging Middleware
- Development Tools
- Application & Data Access

Customers: eBay, Coca Cola, Deutsche Bank, Honda, Schwab, Allstate, 3M, SAS

V5 announced in 5/2002

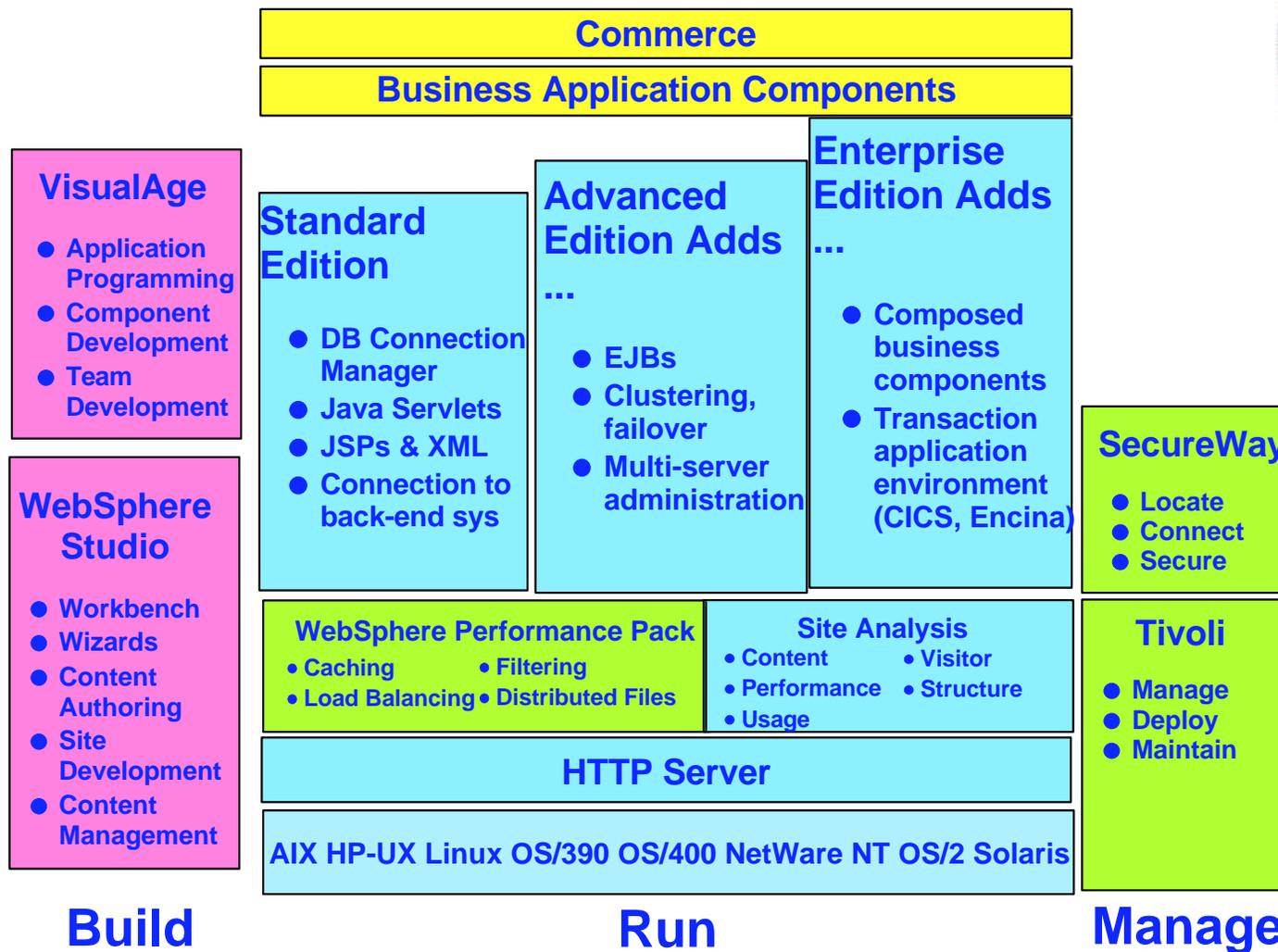
WebSphere App Server (WAS) Advanced Edition



- Clustering
- Security
- Manageability
- Distributed transactions
- Scalability and performance
- Standards support
- Multiple platforms and DBs
- High-performance, pooled DB connectivity
- Integration with rest of WS Software Platform

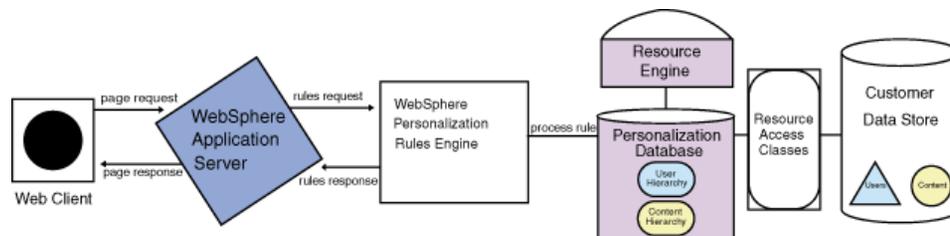
WebSphere Family

Family of Complementary, Integrated Products

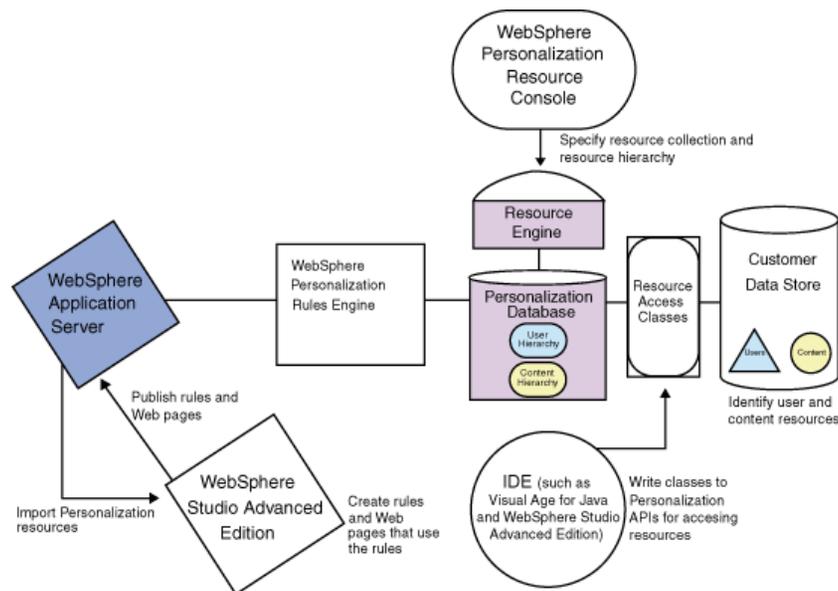


WebSphere Personalization

Runtime Environment

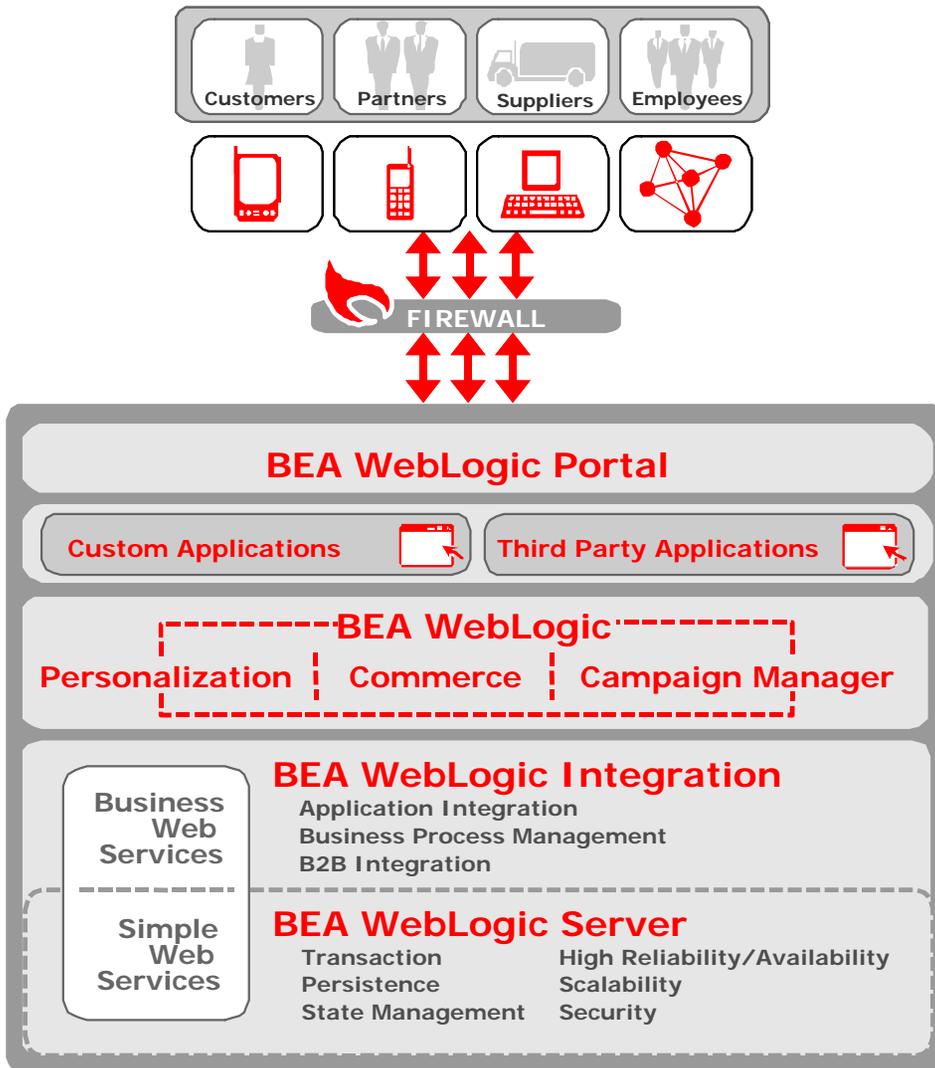


Development Environment



WAS + DB2 Synergy

- WAS uses DB2 for session persistence to allow failover
- WAS integrated performance wizard for DB2
- WAS does connection pooling for efficient DB2 access
- WAS does DB2 SQL prepared statement caching
- WAS uses DB2 as the administrative repository

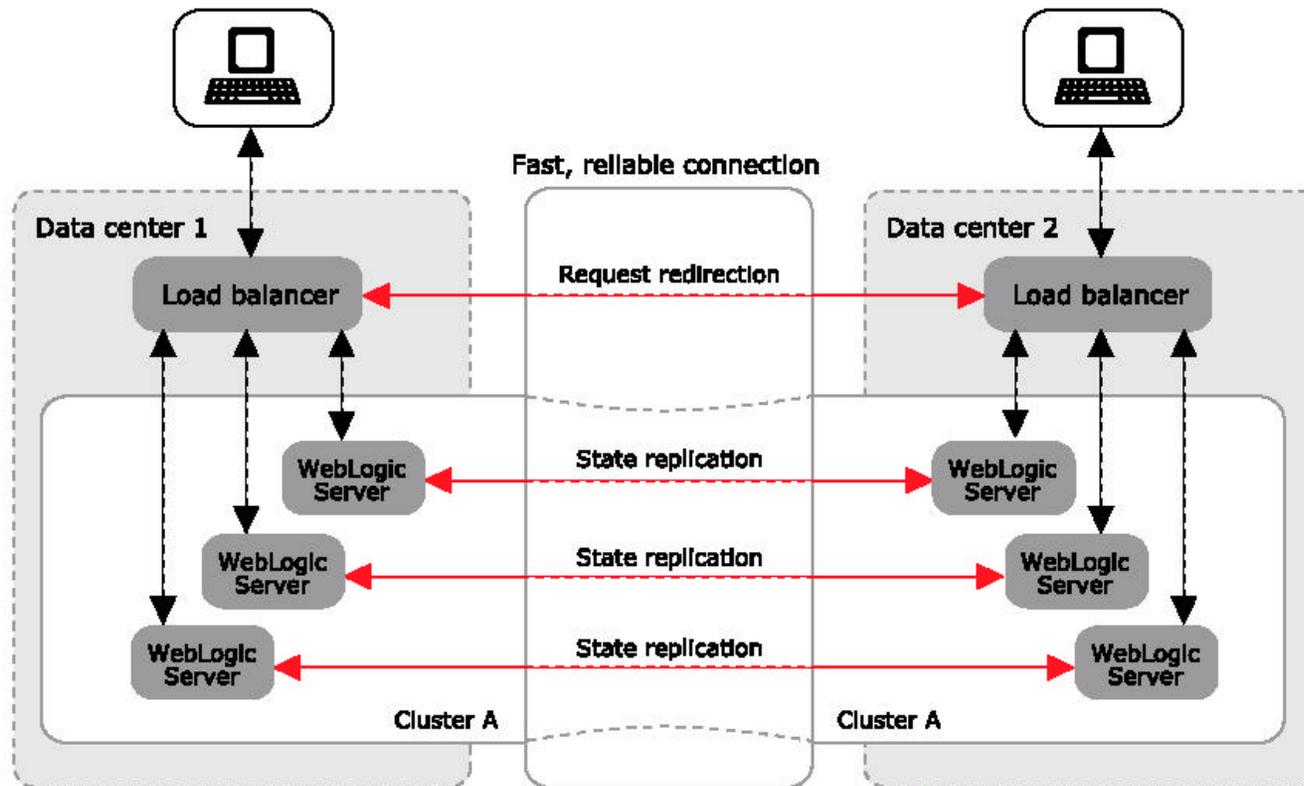


- Latest Release: 7.0
- In-memory servlet & EJB state replication, JCA support
- Clustered JMS failover
- WSDL 1.1, SOAP 1.1, 1.2
- Interoperability between J2EE objects and ActiveX components
- 2 new products: web developer tool called WebLogic Workshop; data middleware product, Liquid Data, for info extraction from multiple apps

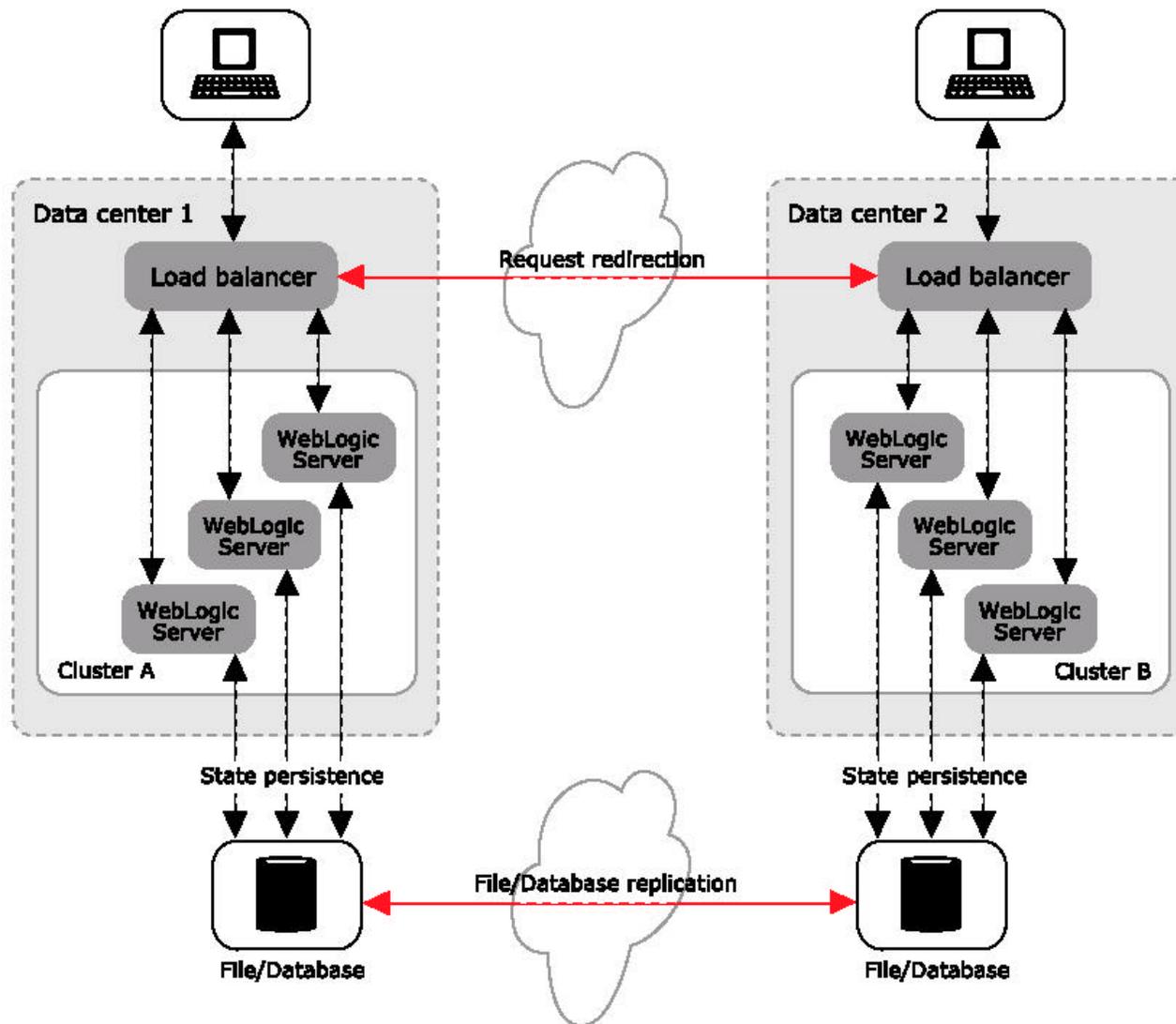
• Customers: Credit Suisse

WebLogic Express = JSPs + Servlets + JDBC

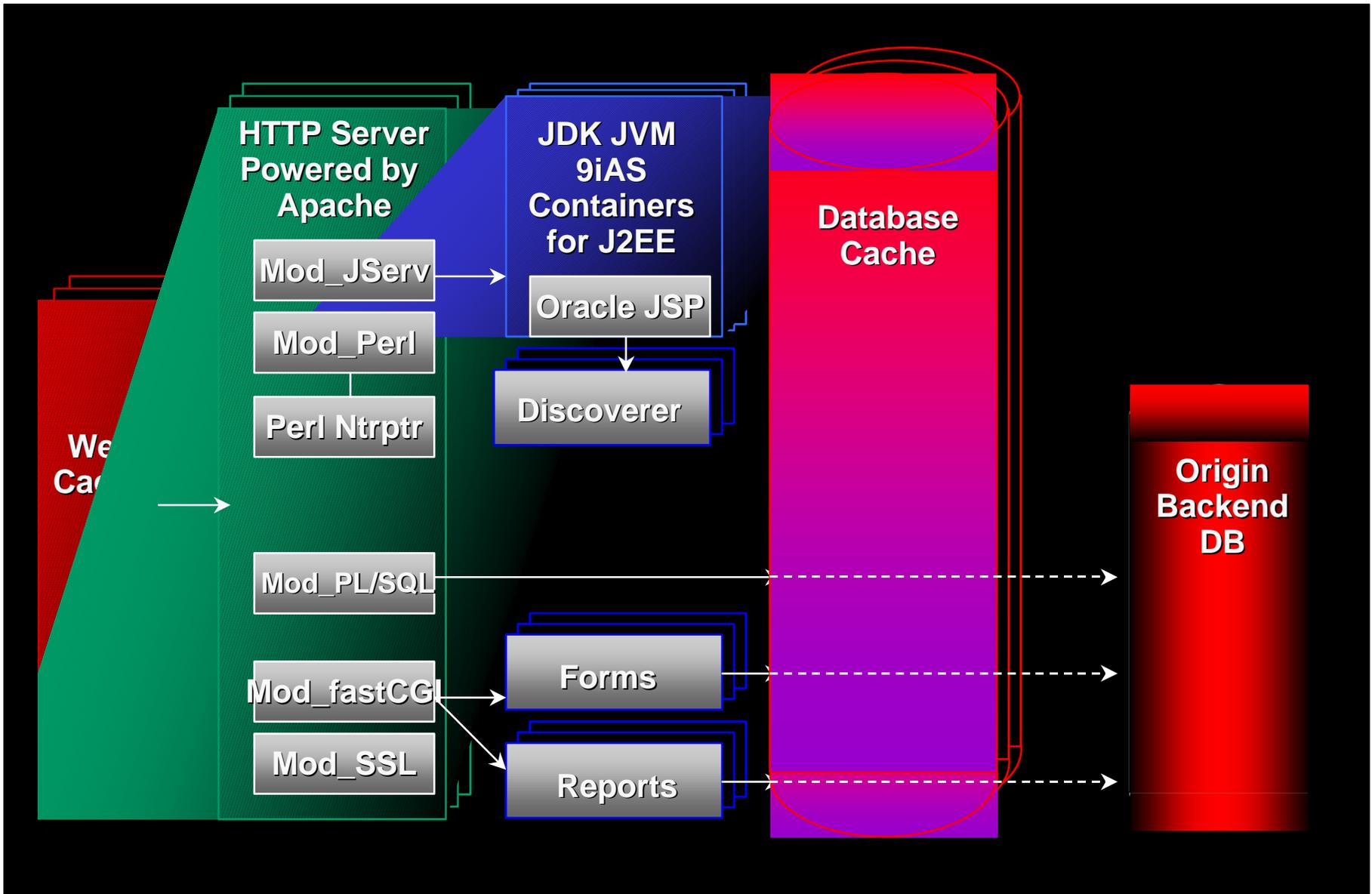
WAN Clustering with Reliable, High Throughput Connection



WAN Clustering with Unreliable Connection



Oracle9iAS: Architecture



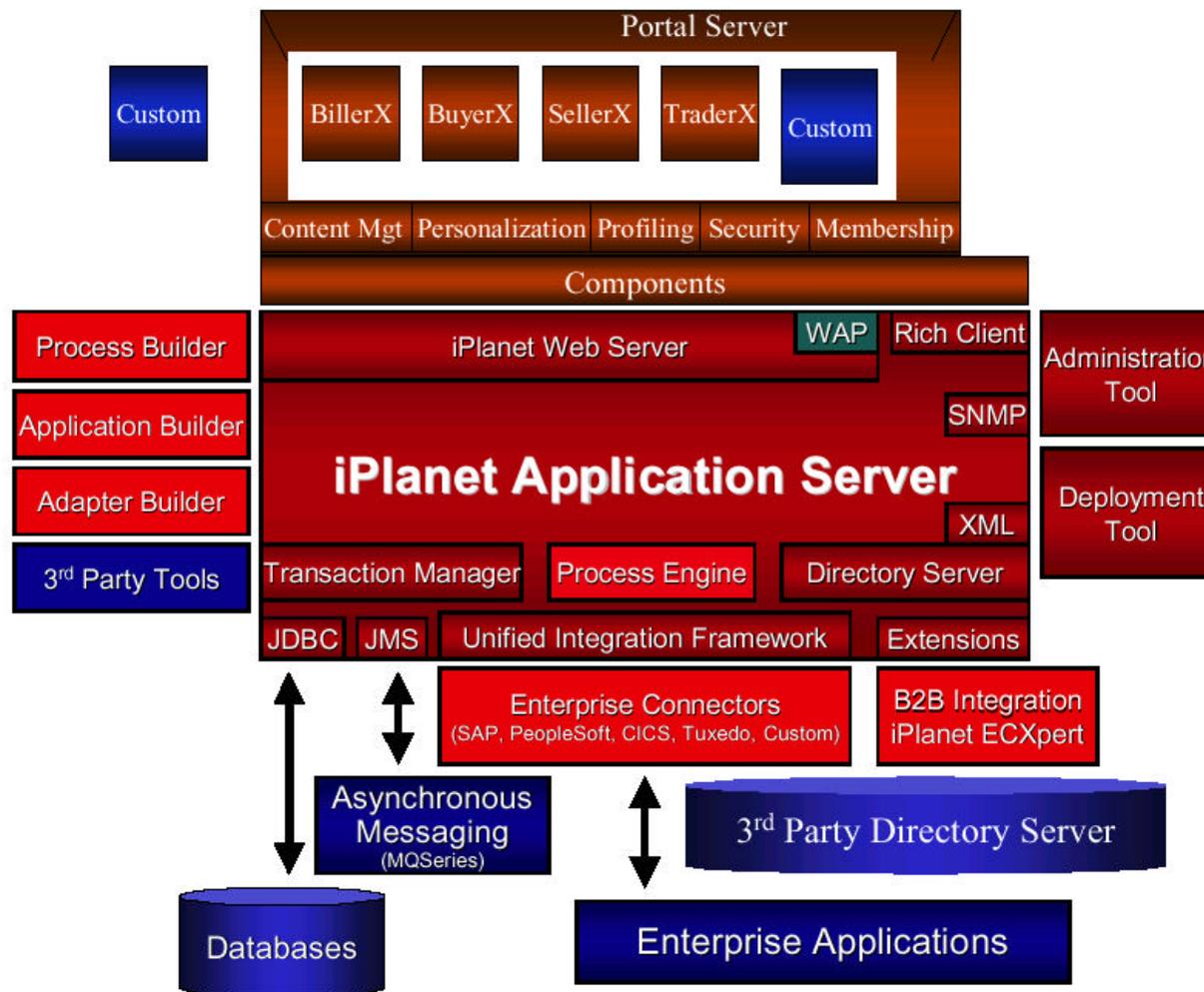
Customers: Sprint PCS, Rentals.com, Kids 123, US Army

Oracle9iAS

Latest: Release 2, J2EE 1.3 certified

- *Oracle9iAS Containers for J2EE* (OC4J) licensed from Swedish company Ironflare (**Orion** app server)
- Database cache in app server machine
- Advanced Queuing (AQ)
 - Functionality in Oracle DBMS
 - Message warehousing made simpler
 - Provides end-to-end message tracking
 - Avoids two-phase commit for transaction with SQL and messaging calls
- Oracle Internet File System (IFS) for content management
- Oracle Workflow

Sun ONE (iPlanet) Application Server



Derived from
Kiva (Netscape) &
NetDynamics (Sun)

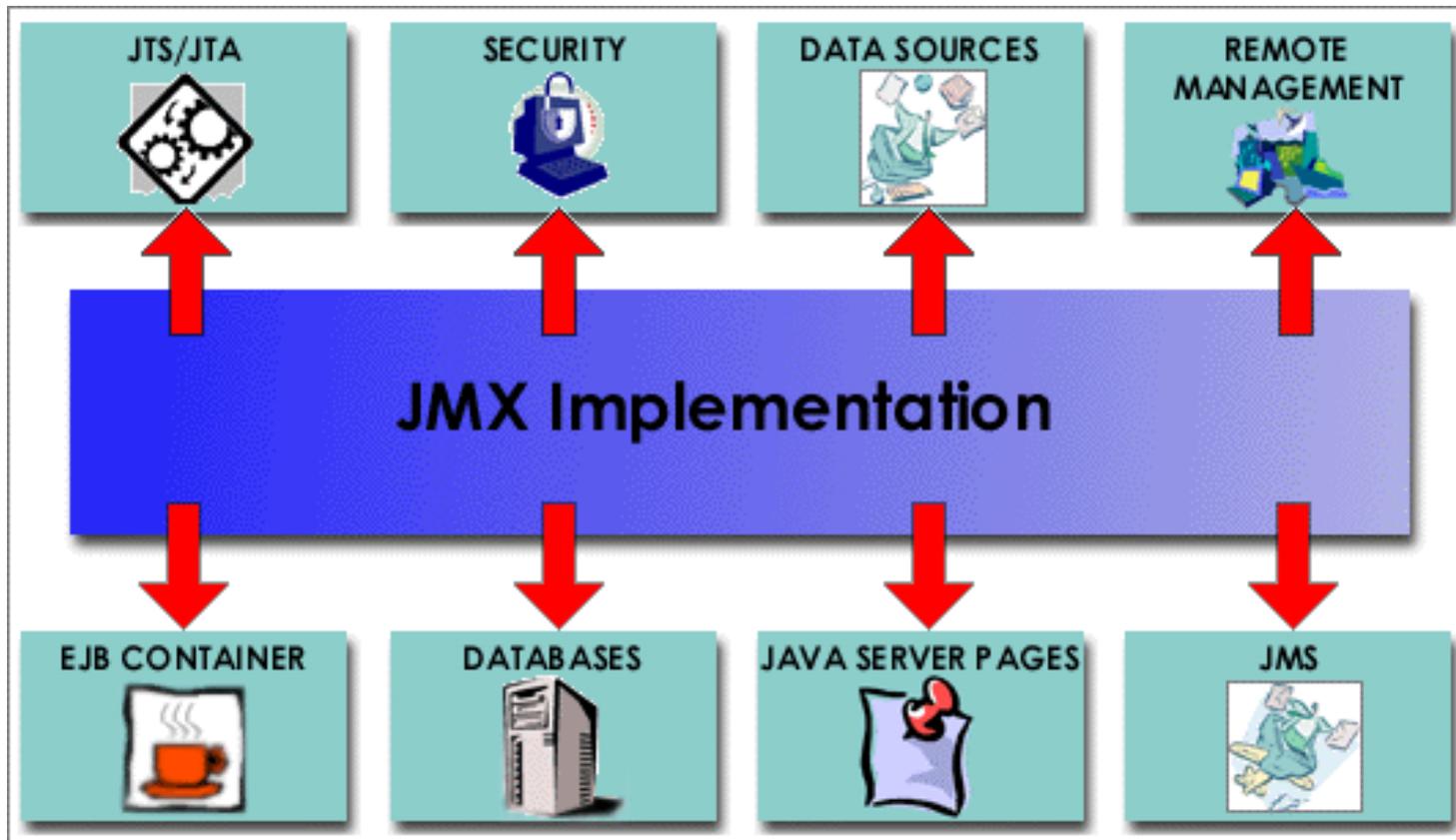
Latest Release: 6.5, Bundled with Solaris 9

Expose business processes as web services

Integration with Forte Java IDE, Sun ONE Message Queue

JBoss

- Open source application server
 - Exploits Java Management Extension (JMX) to configure and administer different plug-ins
 - Supports "hot-deploy" of server modules
- <http://www.jboss.org/>



JOnAS

- Open source, pure Java implementation of EJB 1.1 relying on JDK and JNDI
- Relies on open source JMS Joram (<http://www.objectweb.org/joram/>)
- Derived from an INRIA research project



<http://www.evidian.com/jonas/index.htm>

Microsoft's .NET

- Make resources, applications and information, available any time, any place and on any device
- Relies on UDDI, SOAP, WSDL and software-as-a-service model
- Emphasis on multiple languages and access devices
- Common Language Specification & Runtime (CLS & CLR)

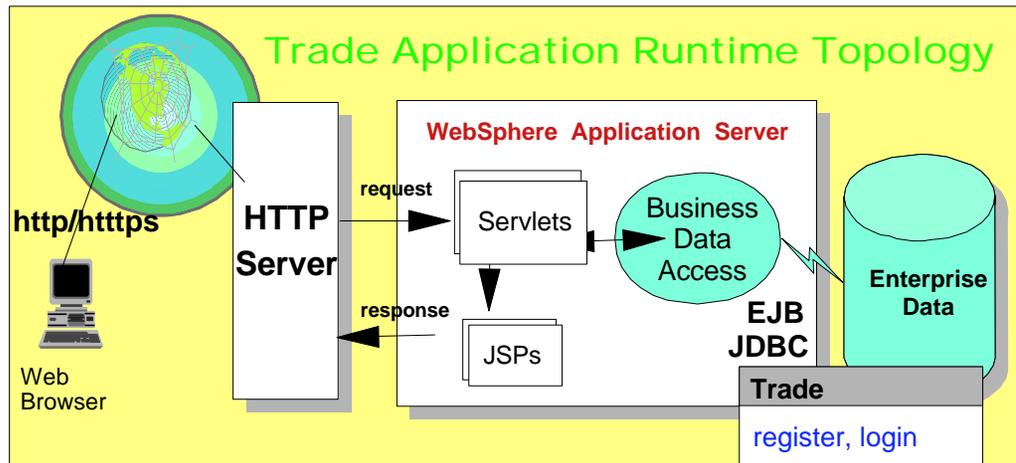


ECPerf Benchmark (JSR 131)

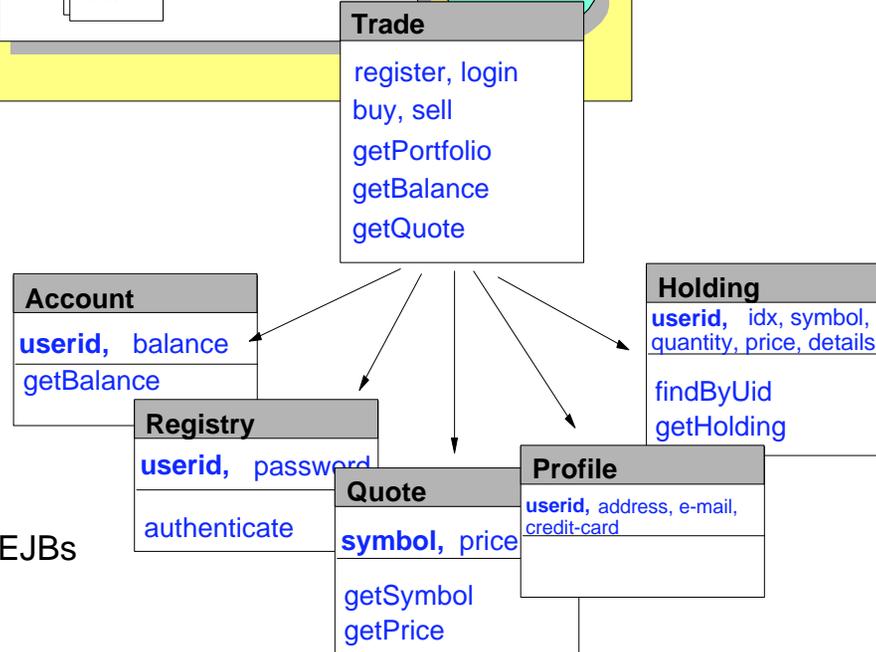
- EJB benchmark to measure scalability and performance of J2EE servers
- 4 ECperf domains: Manufacturing, Supplier & Service Provider, Customer, Corporate
- Stresses ability of EJB containers to handle complexities of memory management, connection pooling, passivation/activation, caching, etc.
- Version 1.1, 4/2002 - To be repackaged as SPECjAppServer2002 and administered by SPEC (<http://www.spec.org/osg/jAppServer/>)

System	BBops/ min@Std	Price/ BBops	J2EE Server	DBMS	Approval Date
Dell 4600	7539.90	\$7	WebLogic 7.0 Beta	Oracle 9.0.1.1	3/25/02
IBM x330 cluster	32581.47	\$11	WebSphere AE 4.03	DB2 7.2	4/22/02
IBM x330 cluster	25658.13	\$12	WebSphere AE 4.03	DB2 7.2	4/29/02
IBM x350 6RY	16634.40	\$13	WebSphere AE 4.03	DB2 7.2	3/11/02
Compaq DL-580	4018.0	\$14	Pramati 3.0 SP1	Oracle 8.1.6	3/25/02
HP LT6000r U3	16696.17	\$18	WebLogic 7.0 Beta	Oracle 8.1.7 (WebLogic JDriver)	2/25/02
HP LT6000r U3	15180.43	\$20	WebLogic 7.0 Beta	Oracle 8.1.7 (Oracle Driver)	2/19/02
Compaq DL-580	14467.97	\$22	Pramati 3.0 SP1	Oracle 8.1.6	4/29/02
IBM p640 B80	10316.13	\$27	WebSphere AE 4.02	DB2 7.2	1/7/02

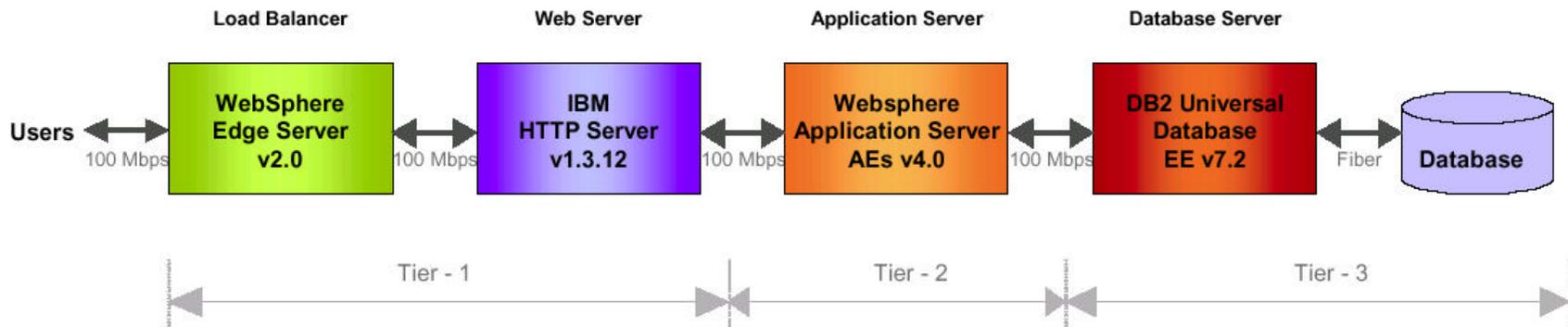
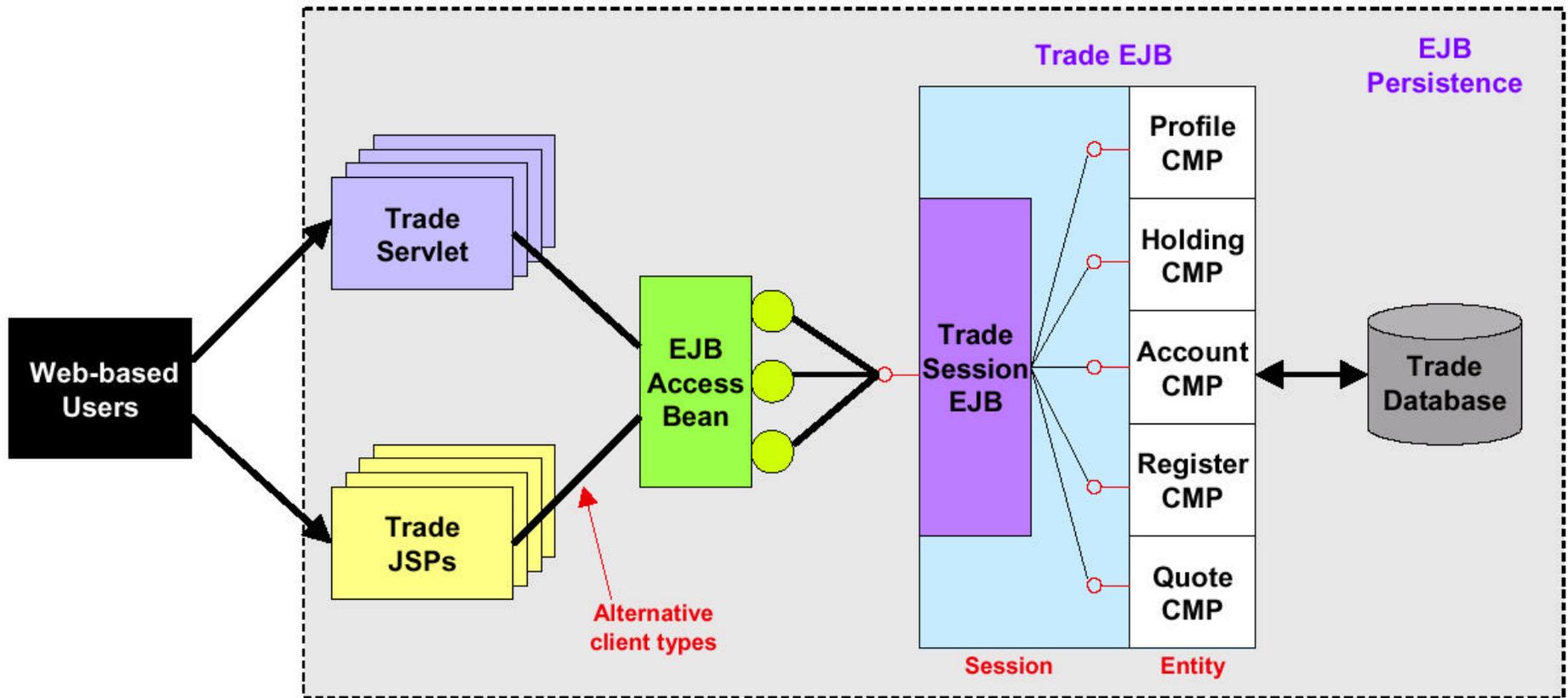
IBM's Trade2 Benchmark



- ▶ Trade JDBC
 - ▶ JSPs, Servlet,
 - ▶ HTTP Session,
 - ▶ DataBeans JDBC
- ▶ Trade EJB
 - ▶ JSP, Servlet,
 - ▶ HTTP Session,
 - ▶ SessionEJBs, EntityEJBs



Trade2



http://www.ibm.com/software/webservers/appserv/wpbs_download.html

Caching for Web Applications

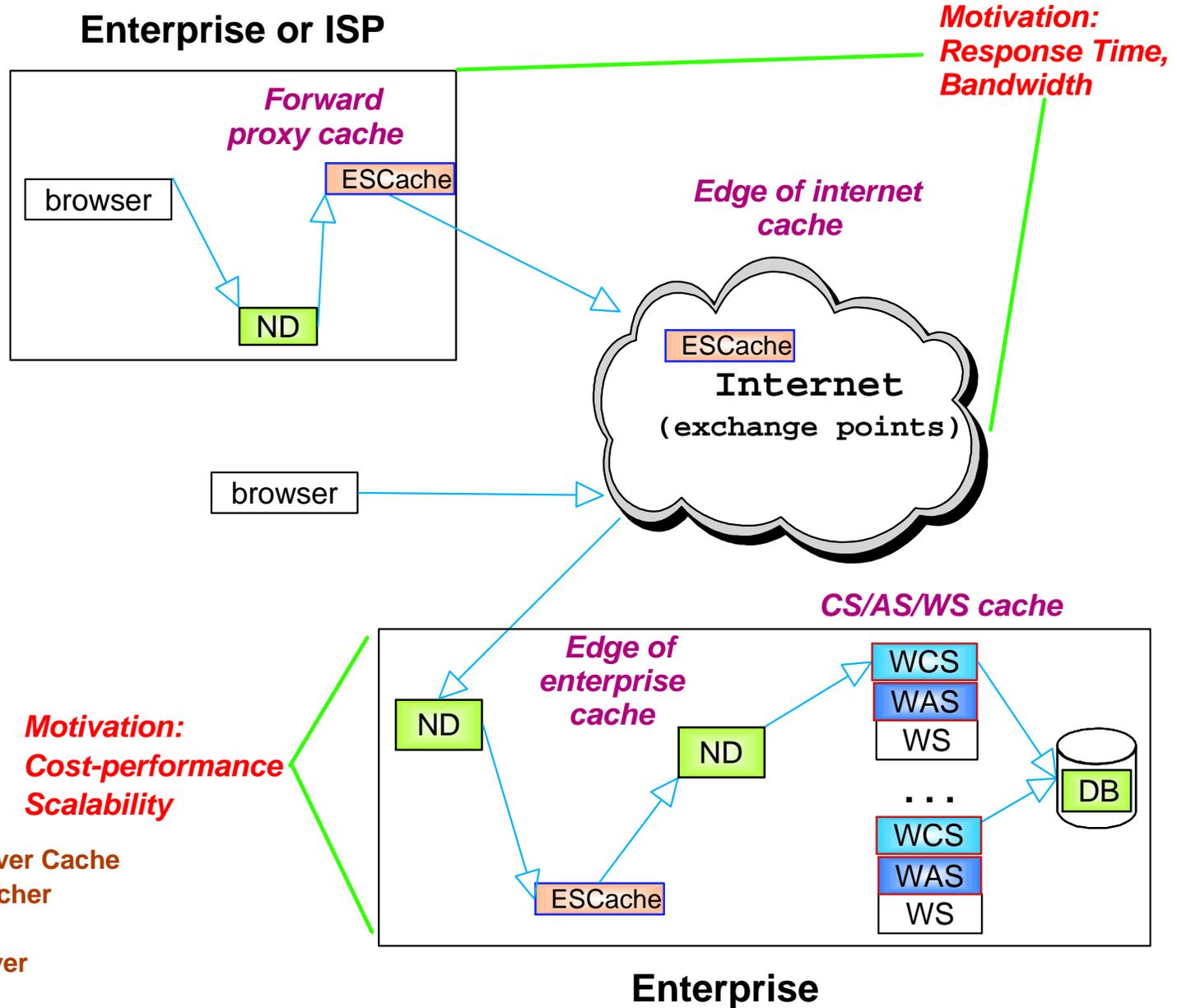
Considerations for caching in web context are:

- **What, when and where** to cache
- **Granularity of caching:** web pages, page fragments, servlet execution result, EJB state, SQL query result, tables, ...
- **Location of cache:** client, proxy, edge-of-net, internet service provider, edge-of-enterprise, app server, web server, DBMS
- **Caching and invalidation policies:** application transparency, push vs. pull, freshness maintenance, triggers, log sniffing
- **Enabling cache exploitation:** routing, failover, accounting, authentication, authorization, ...
- **Tools:** performance monitoring, analysis

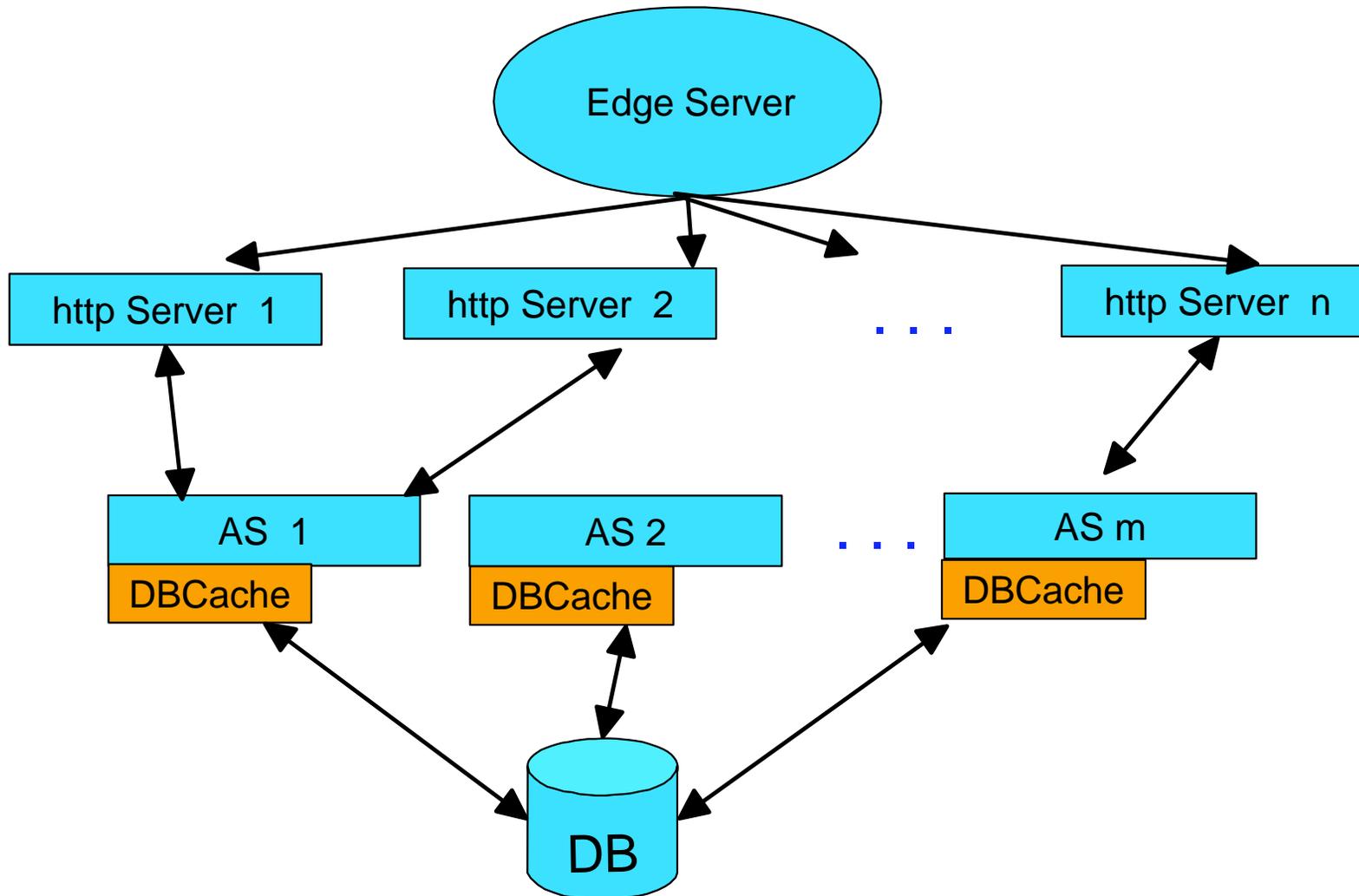
Related DB Technologies: replication, materialized views, mediator systems, client-server DBMSs, buffer management, main-memory DBMSs, query optimization, content mgmt, ...

http://www.almaden.ibm.com/u/mohan/Caching_VLDB2001.pdf

Points of Non-Database Caching



Web Setup with Data Caching

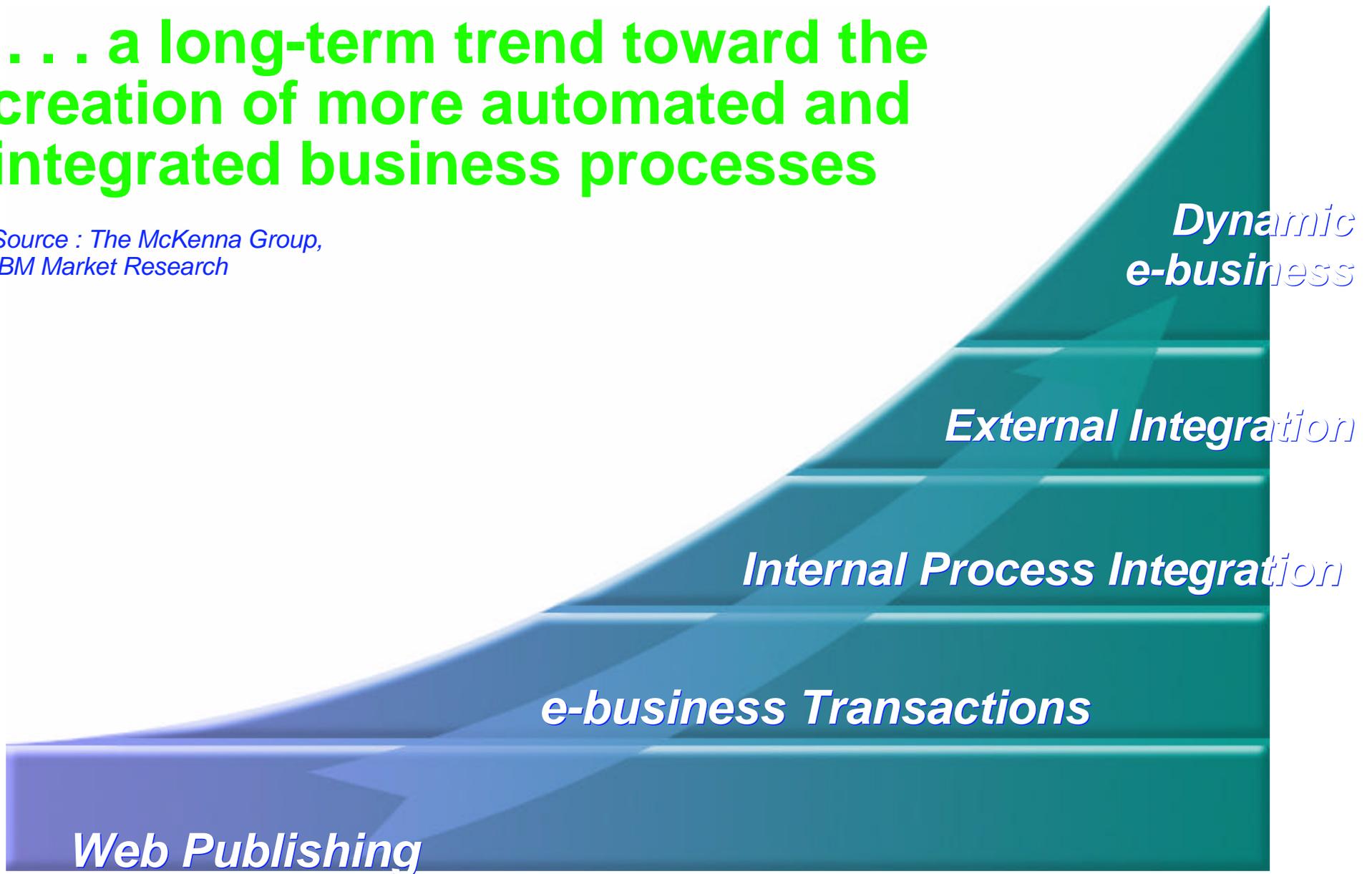


Goal: Help improve scalability and performance of e-business apps

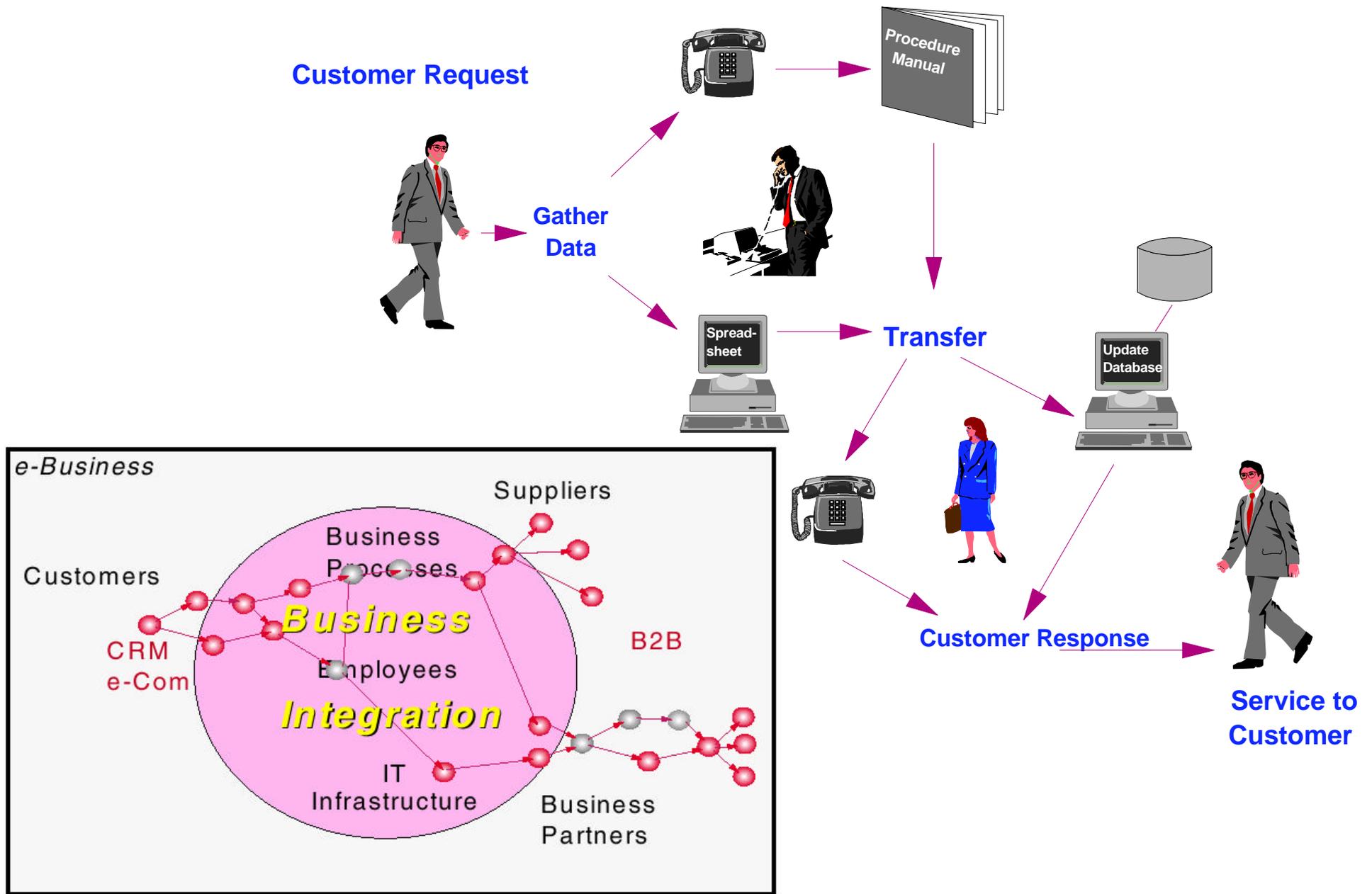
Dynamic e-Business

... a long-term trend toward the creation of more automated and integrated business processes

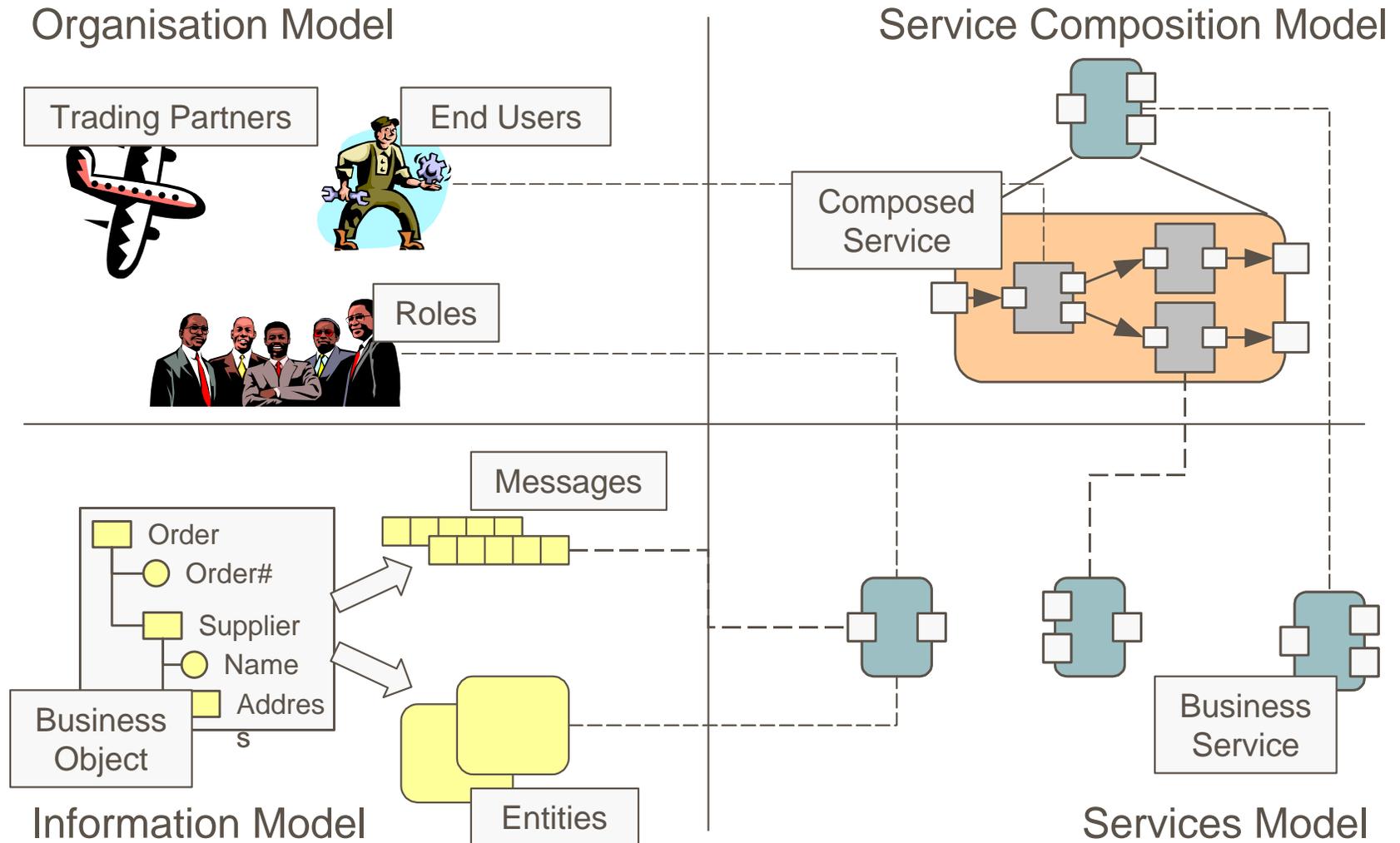
Source : The McKenna Group,
IBM Market Research



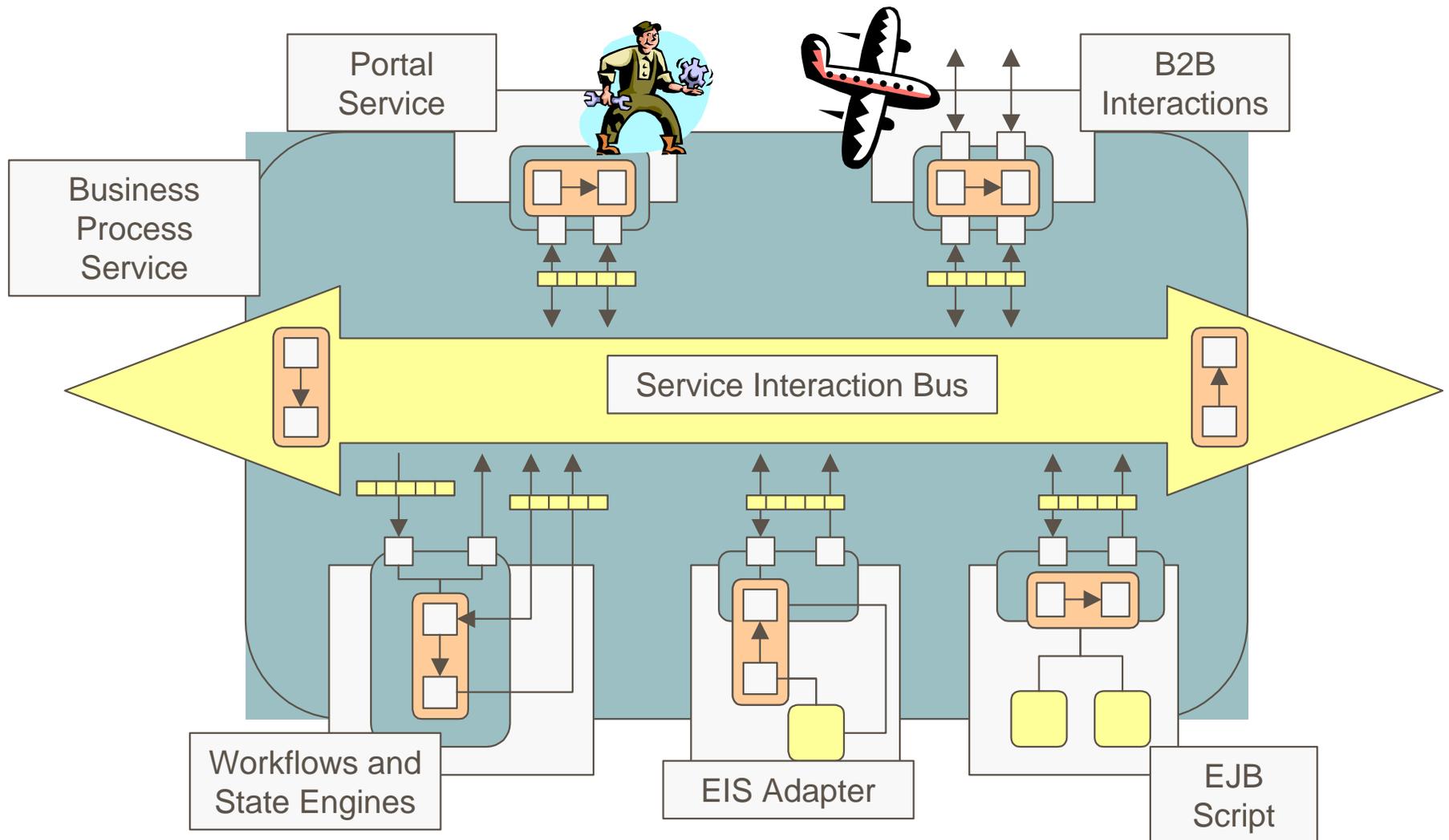
Workflow/Business Processes



A Common Programming Model



Services-Oriented Architecture



Workflow Developments

- B2B commerce has popularized inter-organizational workflows
- Web Services Flow Language (WSFL) spec published
- Microsoft releases BizTalk Server with support for transaction compensation
- IBM buys CrossWorlds Software for B2B collaboration

Summary and Outlook



- J2EE has become wildly successful
- Microsoft attempting to fight with .NET
- Revival of object to relational database mapping
- XML parsing overhead too high
- Standardized benchmarks beginning to take off
- EJBs yet to expose full spectrum of database functionality
- Web services becoming popular, even for intranet usage - being extended with transactions, business processes, ...
- Compensating transaction support begins to appear finally
- Research needed on self-tuning/adapting systems
- Caching appears everywhere

Summary and Outlook



- Identity management is crucial
- Embedded systems are the wave of the future
- ISVs will be forced to give up proprietary application server-like infrastructure
- J2EE 1.4 expected in early 2003
- Sun agrees to allow open source Java spec implementations
- There will be vendor consolidation - smaller vendors dropping their app servers
- **DBMS researchers and practitioners should pay more attention and influence work in app server area!**

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